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Paul Scherrer Institut
5232 Villigen PSI
Switzerland
Tel. +41 (0)56 310 21 11
Fax +41 (0)56 310 21 99
www.psi.ch

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Neutronic and Nuclear Post-Test Analysis of MEGAPIE

L.Zanini, H. U. Aebersold, K. Berg, J. Eikenberg, U. Filges, F. Gröschel,
M. Lüthy, M. Rüthi, S. Scazzi, L. Tobler, W. Wagner, B. Wernli
Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

S. Panebianco, J.-C. David, D. Doré, S. Lemaire, S. Leray, A. Letourneau,
F. Michel-Sendis, A. Prevost, D. Ridikas, G. Stankunas
CEA, Centre de Saclay, IRFU/Service de Physique Nucléaire, F-91191 Gif-sur-Yvette, France

J.-C. Toussaint
CEA, Centre de Saclay, IRFU/Service d'Ingénierie des Systèmes, F-91191 Gif-sur-Yvette, France

M. Eid
CEA, Centre de Saclay, DEN/DM2S/SERMA, F- 91191 Gif-sur-Yvette, France

C. Latgé
CEA, Centre de Cadarache, DEN/DTN/DIR, F-13108 Saint Paul Lez Durance, France

A. Yu. Konobeyev, U. Fischer
Institut für Reaktorsichereit, Forschungszentrum Karlsruhe Gmbh, 76021, Karlsruhe, Germany

N. Thiolliere, A. Guertin
SUBATECH laboratory, CNRS/IN2P3-EMN-University, F-44307 Nantes, France

T. Buchillier, C. Bailat
Institut universitaire de radiophysique appliquée (IRA)
Rue du Grand-Pré 1 CH - 1007 Lausanne, Switzerland

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EXECUTIVE SUMMARY

Scope of the work

The spallation target is one of the most delicate and technically challenging components of an Accelerator-Driven System (ADS)[*]. The MEGAPIE experiment has been very important since it consisted in the first experiment to design, manufacture, test, commission and operate a liquid metal spallation target at the MW beam power level.

The design phase of the project was supported by a R&D work divided in several areas, and performed by specialists from the corresponding research fields, studying problems related to thermal-hydraulics, structural mechanics, materials issues, neutronic and nuclear assessment. Concerning the latter topics, in the design phase a comprehensive study was performed on neutronic benchmark, target performance, power deposition, radiation damage to structural materials, target activation, gas production, and shielding. A lot of the work performed needed a validation in the irradiation phase, where neutronic and nuclear measurements, and corresponding calculations, could be performed.

The goals of the work presented in this report were many: *i*) characterize the SINQ facility with the MEGAPIE target from the neutronic point of view, by measuring neutron fluxes at various points of the facility; *ii*) measure the flux inside the spallation neutron source; *iii*) compare the neutronic performance of MEGAPIE with the ones of the solid targets used routinely at SINQ; *iv*) measure the delayed neutrons; *v*) measure the gas release from the target following irradiation; *vi*) complement each measurement with Monte Carlo calculations, for the purpose of validating the codes used during the design and measurement phases of the project, and if necessary improve the previous calculations; *vii*) perform target activation calculations of interest to the target disposal and the post-irradiation experiment.

Such an ambitious group of tasks could be performed thanks to the deep involvement of experts from many of the institutions part of the MEGAPIE collaboration.

Neutronic performance

The spallation neutron source of an ADS must provide the additional neutrons needed to drive a subcritical core. The spallation source must be highly efficient given the constraints of the beam current and of the subcritical core. While it is outside the scope of the MEGAPIE experiment to measure the neutron yield of a spallation target, by measuring the neutron fluxes at several points of the target and of the surrounding facility it is possible to characterize the neutronic behavior of the spallation source. Basic measurements consist in monitoring the neutron fluxes at the normal measurement points of the facility. This offers several advantages: standard and very reliable measurement techniques can be used; Monte Carlo codes used for the neutronic simulations can be validated; the neutronic performance of the liquid metal target can be directly compared with more traditional types of spallation targets, such as the solid rod types used at SINQ.

However, these measurements have one disadvantage: the measured neutron spectra are mostly thermalized, due to the presence of the large heavy water moderator surrounding the SINQ facility. The traditional flux measurements were therefore complemented with flux measurements inside the spallation target. These challenging measurements were accomplished using micrometric fission chambers inserted in the central rod of the MEGAPIE target.

The results presented in this report are of great interest:

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[*] A list of acronyms is given in Annex E.

- The experimentally observed relative increase of the thermal neutron flux of a factor 1.76 using MEGAPIE, with respect to the solid target used before, is reproduced by calculations. These results are complemented by measurements of epithermal and fast neutrons, discussed in the report.
- We are able to reproduce by calculations, with discrepancies within 2 standard deviations, most of the thermal fluxes outside the target.
- For the measurements outside the target, the highest discrepancy is found at the NAA, which is the closest measurement point, with calculations overestimating the measurements by 30%.
- The discrepancy between measurements and calculations is higher in the central rod, where the calculated values are higher than the measured ones by factors from 2 to 3. The fission chamber measurements are in very good agreement with results from monitor foils inserted in close proximity.

The experimental work was accompanied by a high-quality simulation program where the spallation targets and the surrounding SINQ facility were described in great detail, using two state-of-the-art particle transport codes such as FLUKA and MCNPX. The fact that the experimental absolute fluxes at the exit of the target block are correctly simulated indicates that overall, the absolute neutronic performances of the targets are correctly calculated. However, discrepancies are found in close proximity to the beam interaction zone, i.e., in a region where the neutron flux is high, it has a high gradient, and a mixed thermal-epithermal-fast spectrum. It is clearly a great challenge to measure the flux close to the interaction point, and it will be important for future investigations on high power liquid metal targets, to understand the origin of these discrepancies. A factor 2-3 between measurements and calculations can be very important in that part of the target, since it is the most subject to radiation damage and to power deposition, with related thermal-hydraulics and structural mechanics issues.

Delayed neutrons

Another aspect of the neutron flux study that needs to be considered is the delayed neutron flux. DNs are obviously important in reactors, but they can also constitute a safety issue in high-power liquid metal targets. The reason is that, while in the spallation zone the DN flux is negligible compared to the prompt neutron flux, in other areas of the target loop, where the prompt neutrons are shielded, their contribution might be dominant, both in terms of absolute flux and of energy spectrum. That can be important for instance for ancillary components, which must be qualified also to withstand potentially high DN fluxes.

The results from the measurements performed during the MEGAPIE start up indeed confirm that at the top of the MEGAPIE target, the absolute DN flux is comparable to the prompt neutron flux.

Gas production

The production and release of volatile elements during irradiation is a key safety issue in an accelerator-driven system. One of the main disadvantages of an ADS with respect to a fast reactor system is in the amount of volatile elements ending in the cover gas system (CGS), due to the fact that the coolant is directly irradiated by a proton beam, and a large amount of gas is generated by spallation reactions. This requires special care and makes the handling of the gas more complicated. A large program of calculations and experiments was performed in the frame of the MEGAPIE project to assess the volatility of key elements such as noble gases, mercury, and polonium in the MEGAPIE configuration. In the irradiation phase, absolute amounts of released noble gases and of Hg and Au isotopes were determined by the γ spectroscopy measurements from the fresh gas sampling made after 2 days of operation. We found that only a fraction of the noble gases produced in the LBE was released into the expansion volume after 2 days of operation. The amount is about 1% of the total, calculated amount. This fraction is nearly the same for Ar, Kr and Xe isotopes, indicating a similar release mechanism for all the noble gas elements. We know from previous measurements at ISOLDE that noble gases diffuse slowly in LBE targets and the diffusion time decreases as the temperature increases. As expected, also the release of Hg was a small fraction of the total, while only traces of Po isotopes were detected from the gas samples, coming presumably from decay of the parent At isotopes. A comparison was performed also with expected release rates during the regular gas samplings. In this case the amount of calculated radioisotopes are within a factor of 3 to the experimental values, indicating, as expected, that the noble gas release is more complete after one month of operation or more.

Unfortunately it was not possible to measure directly hydrogen and helium isotopes. Only indirect measurements, from the pressure in the cover gas, were performed and the calculated pressures compared fairly well with the measured ones.

Target activation

A large amount of nuclear calculations has been performed since the beginning of the MEGAPIE project, and even though they are not part of the post irradiation analysis, they are presented here. The main need for activation calculations in the post-test analysis phase was to determine the activation of the LBE and of the structural materials, for the target decommissioning after irradiation. The main tools were the codes FLUKA, MCNPX, and associated evolution codes, and the SNT code.

A large validation and development work has been performed in recent years for these codes. The results from the different calculations were compared for the LBE and structural material activation, showing an overall good agreement for the LBE, with the exception of specific isotopes: isomers, more difficult to calculated, and tritium, emitted or not according to the spallation model used and more or less in good agreement with the few available experimental data. The results for the activation of the target lower structure show some more important differences between FLUKA and MCNPX, presumably coming from the thermal and epithermal region.

Introduction

The MEGAwatt PIlot Experiment (MEGAPIE) project[1] was started in 2000 to design, build and operate a liquid metal spallation neutron target at the power level of 1 MW. The project is an important step in the roadmap towards the demonstration of the Accelerator-Driven System (ADS) concept[2], and for high power molten metal targets in general.

In an accelerator-driven system the spallation target is placed inside a sub-critical reactor core (Figure 1). The role of the spallation target is to provide the extra neutrons needed by the subcritical core to keep the reactor working. Since an ADS is a fast neutron system, there is no moderation and the spallation neutron spectrum is therefore a typical fast spectrum.

For a subcritical core with k_{eff}=0.95, a strong neutron source is needed, and in the roadmap an accelerator current higher than 10 mA is indicated as baseline parameter for the experimental ADS. The choice of the accelerator current and energy depends primarily on the number of neutrons that need to be generated, and that are eventually used to drive the reactor.

With the 590 MeV cyclotron delivering a continuous beam on target with a current up to 1.8 mA, SINQ is the most powerful spallation neutron source in the world, with a proton beam power on target that can reach 1 MW. With this accelerator performance, the SINQ facility was the ideal choice for the MEGAPIE experiment. The SINQ facility has operated steadily since 1997, with a neutronic performance constantly increasing, thanks to the accelerator upgrades and to several improvements of the spallation targets; up to MEGAPIE all targets were based on the same concept of a bundle of heavy material rods, cooled by a flow of heavy water[3]. During the years, different types of rods were used (e.g. full zircaloy, steel rods filled with Pb, zircaloy rods filled with Pb).

The MEGAPIE target was installed at SINQ at the end of 2005 and irradiated for four months, from August to December 2006.

In the MEGAPIE target a loop of about 82 liters of lead-bismuth eutectic (LBE) circulates enclosed by a steel structure. The target is about 5 m long and the LBE is made circulating by means of a main electromagnetic pump, while a bypass pump is used for a second loop to cool the window.

The MEGAPIE experiment was conceived to study all the issues involved in a high-power liquid metal target for an ADS, such as target cooling, operation of the loop, window resistance, and target behavior during operation and during transients.

Since the primary objective of an ADS target is to generate neutrons, it is very important to study the neutronic behavior of such a target. The most obvious quantity related to the spallation target is its neutronic performance. The neutron yield (number of neutrons per incoming proton) is the balance between the number of neutrons generated by the reaction and the number of neutrons lost in the interactions with the structural materials and the target itself.

Ideally one should be able to measure the neutron yield, the number of generated neutrons per incident proton, in a high power liquid metal target. The neutron yield cannot be directly measured; but the neutronic performance can be deduced from a series of flux measurements done in the facility, at different positions and distances from the spallation target.

It must be noted that the presence of the heavy water moderator in the SINQ facility will change the spectrum, from a fast one to a prevalently thermal one, in most of the measurement points (with the exception of measurements performed near the center of the target). With respect to an ADS, there is therefore an additional challenge of measuring and calculating mixed thermal/fast fluxes.

The study of the neutronic performance is of great interest also for the SINQ users. In fact, while the main motivation for the MEGAPIE experiment was related to ADS applications, the possibility to use a liquid target for routine production of neutrons in a research facility is of great interest, in view of its good neutronic performance and in the potentially higher current densities that can be accepted. For this purpose it is important to compare the neutronic performance of a liquid target with the standard solid targets used in SINQ. Detailed neutronic studies started during the design phase of MEGAPIE[4]. Besides measuring the neutron flux increase using a liquid metal target, it is important to measure the energy spectrum to see if the epithermal and fast neutron flux increase by the same amount of the thermal flux. Since the liquid and the solid target differ in the fact that the neutrons are already partially moderated in a SINQ type solid target, in principle differences in the spectral distributions can be expected.

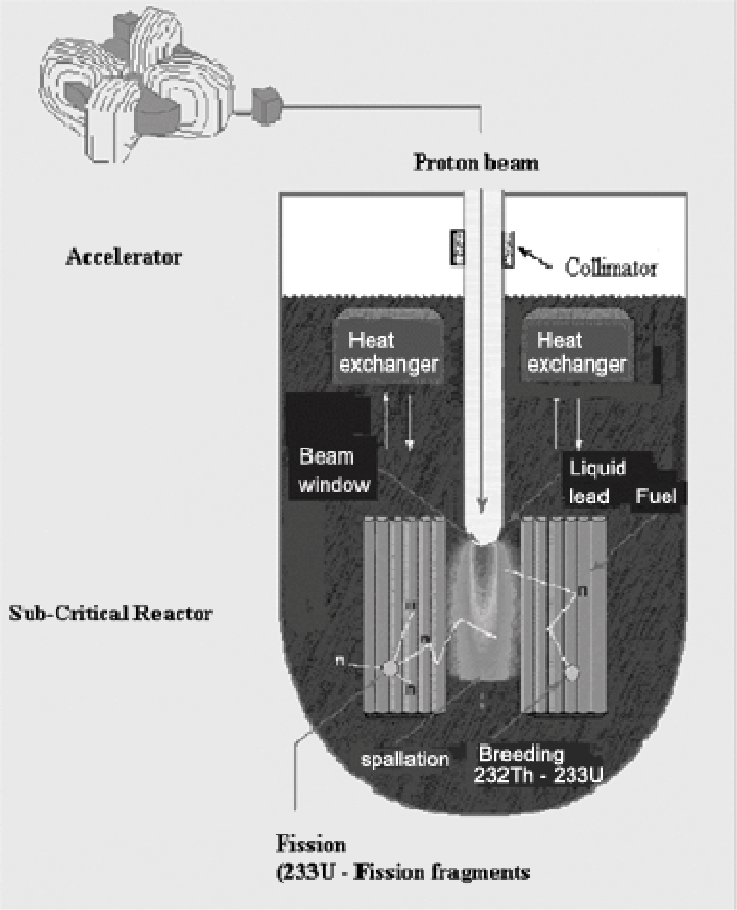


Figure 1. Schematic diagram of an ADS.

There are different ways to measure the neutron flux from the target. One innovation introduced in the MEGAPIE experiment is the measurement of the neutron flux in the close proximity of the spallation zone, by means of innovative micro fission chambers that, because of the high local neutron fluxes (up to 10^{15} n/cm^2/s/mA), work in current mode giving a current proportional to the neutron yield. We have coupled these innovative measurements with more conventional flux measurements at the beam lines.

Although spallation physics models are nowadays considered reliable and well benchmarked against a large set of experimental nuclear data, a spallation target such as MEGAPIE and the surrounding SINQ facility is a complex system and it is not a trivial task to perform precise flux calculations. Furthermore, a precise neutronic characterization is crucial for future ADS development. These are the reasons why we have designed and built a neutron detector to measure “in situ” and to characterize the inner neutron flux of the target under irradiation. Coupled with very detailed Monte Carlo simulations, these integral measurements should provide the scientific community with accurate data on the neutron generation of such a system to constrain commonly used neutron production models including neutron transport phenomena. Moreover, other effects as the influence of spallation residues accumulation on the neutron balance or the temperature on the neutron energy spectrum could be assessed.

The realization of a spallation neutron source with nominal beam power of the order of 1 MW based on liquid metal technology introduces some new radioprotection issues that must be addressed. Radioactive nuclides produced in liquid metal targets are transported into hot cells, pumps or close to electronics with radiation sensitive components. Besides the considerable amount of decay γ activity in the irradiated liquid metal, a significant amount of the Delayed Neutron (DN) precursor activity can be accumulated in the target fluid. The transit time from the front of a liquid metal target into areas where DNs may be important, can be as short as a few seconds, i.e. well within one half-life of many DN precursors. Therefore, it seems very important to evaluate the DN flux as a function of position and determine if DNs may contribute significantly to the activation and dose rates.

Delayed neutrons are important not only in reactor systems, but also in a spallation system, especially with a liquid metal loop. All the spallation sources of new generation, such as the now operating SNS, or the proposed ESS and EURISOL[68] are based on liquid metal target technology, with a loop that extends considerably beyond the neutron production region. Delayed neutrons in such a system can cause significant radiation protection issues, as they are emitted in regions of the facility which are less shielded than the spallation region. A measurement of delayed neutrons in a representative spallation target system such as MEGAPIE may help in the design of future target systems for ADS or for neutron facilities in general.

Finally, from the point of view of safety, the most important aspect discussed in this work is the problem of gas production and release in an ADS target. The production and release of volatile elements during irradiation is a key safety issue in an accelerator-driven system. Since in an ADS the coolant is directly irradiated by a proton beam generating a large amount of gas by spallation reactions, this issue is comparatively more important in an ADS than in a fast reactor. Additionally, a large amount of Po isotopes are produced in the LBE, which must be carefully studied as polonium can be volatile at relatively high temperatures. The problem can be separated in gas production, diffusion and release, and a great deal of information can be obtained from gas sampling and pressure measurements during irradiation.

We have structured this report in two parts. The first part is dedicated to the neutronic and gas measurements performed during the irradiation campaign. Each chapter treats a specific measurement, and the Monte Carlo calculations performed to validate the neutron transport codes used in the MEGAPIE experiment. The second part is dedicated to activity calculations, mainly of relevance to the target conditioning and disposal after irradiation, but also, from a more general point of view, on a basic study of the nuclear aspects of a spallation target (LBE and structural materials). Several tables with the results are in the annexes. The general conclusions are at the end of the report.

Part I: MEGAPIE neutronic and nuclear post-test analysis

1. MEGAPIE DESCRIPTION, OPERATION AND MEASUREMENT PROGRAM

1.1 Target description

The MEGAPIE target consists of a loop of LBE inside a structure arranged vertically over a length of about 5 meters [5,6]. A schematic view of the main components of the MEGAPIE target is shown in Fig. 1.1, while a more detailed drawing is shown in Fig. 1.2. A detailed drawing of the bottom part of the target is shown in Fig. 1.3.

In order to operate the loop, several components are needed. In fact, nine separate components were built separately and then assembled. From bottom to top they are the following:

1. the lower liquid metal container, made of T91 steel. The bottom part is the 1.5 mm-thick hemispherical beam window;
2. the lower target enclosure, a double walled, D_2O cooled hull made of $AlMg_3$;
3. the main flow guide tube (316L), representing the barrier between the rising and down coming LBE flow;
4. the central rod, inserted in the LBE, close to the proton interaction zone, containing the neutron detectors for flux measurements;
5. the upper target enclosure;
6. the heat exchanger;
7. the electromagnetic pumps for the main and bypass flow systems;
8. the target top shielding;
9. the target head, the upper component of MEGAPIE through which instrumentation lines are fed through the target head.

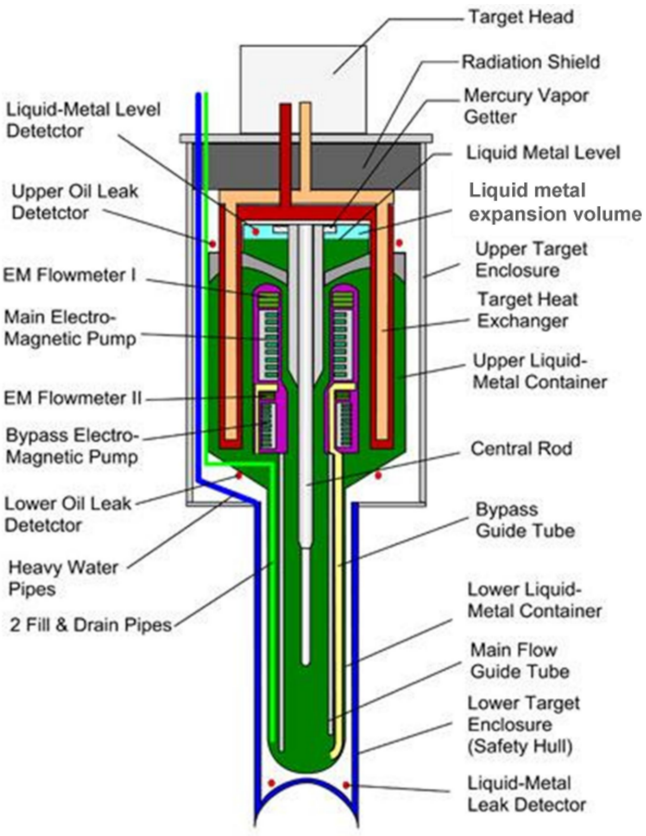


Figure 1.1. Schematic view of the MEGAPIE target assembly.

The proton beam penetrates the target from below via two windows. Both the LBE and the structural materials (in particular the beam windows) need to be cooled. The double-walled enclosure hull (lower target enclosure) is cooled by a forced convection heavy water flow. The inner beam window is cooled by the LBE flow. The lower target enclosure and the beam window are separated by an insulating gap intended to be filled with 0.5 bar helium.

The LBE flow is provided by two electromagnetic pumps: an axis-symmetric main flow down an annulus (placed between the main flow guide tube and the lower liquid metal container) and an additional flow via a by-pass tube. Due to the large height of the target the character of the flow is mixed convection. The combination of main flow and by-pass flow ensures the cooling of the beam window.

The spallation heat which is produced in the LBE in the lower part of the main flow guide tube (in the region up to 30 cm above the beam window), is removed via heat exchanger pins to an intermediate cooling loop and finally to an existing secondary cooling system. The fluid of the secondary system is light water.

In the centre of the main flow guide tube an instrumentation pin (central rod) is inserted which holds instrumentation for the measurement of the neutron flux density and thermo-hydraulic data. The main operation parameters of the target are indicated in Table 1.1.

Table 1.1. Main parameters of the MEGAPIE target and of the proton beam.

Main specifications	
Length	5.35 m
Diameter lower part	10.6 cm
Diameter upper part	20 cm
LBE volume	About 82 liters
Structural Materials	
Lower liquid metal container	T91 steel
Upper container	316L steel
Lower target enclosure	$AlMg_3$
Operation parameters	
LBE temperature range	240-380 °C
Max LBE flow velocity	1.2 m/s
Window temperature range	330-380 °C
Beam characteristics	
Proton beam energy	575 MeV
Repetition Rate	51 MHz
Maximum proton current	1.375 mA[a]

[a]maximum value during MEGAPIE operation

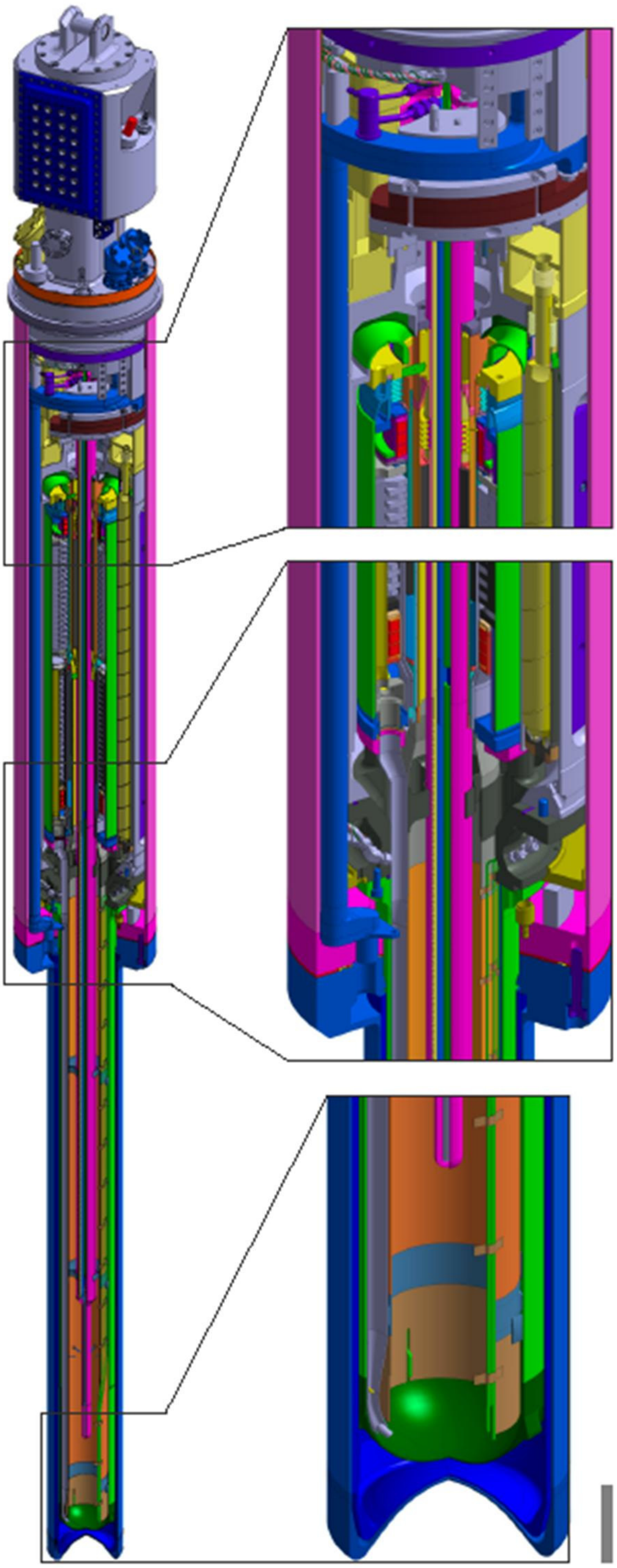


Figure 1.2. The MEGAPIE target. View of the entire target, of the lower part (proton interaction zone) and of the upper parts of the heat exchanger-EM pump area.

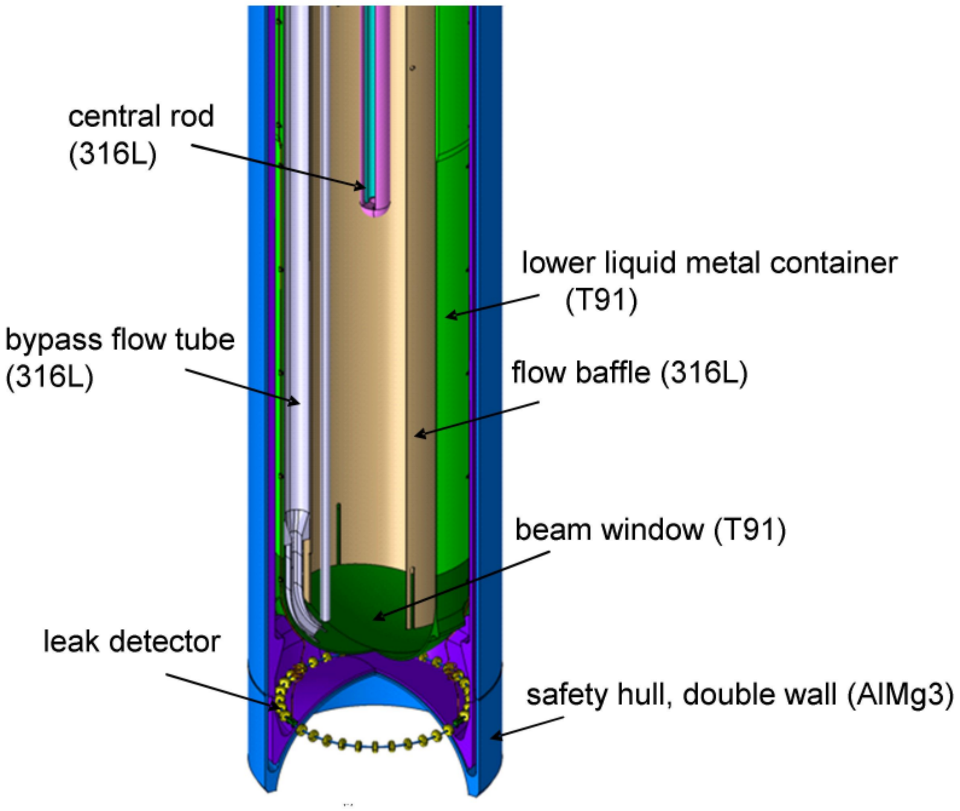


Figure 1.3. Drawing of the bottom part of the MEGAPIE target.

1.2 SINQ facility

The SINQ facility is part of the PSI accelerator complex, (Fig. 1.4), which consists of a series of three units: a Cockroft-Walton pre-accelerator (860 keV), the Injector Cyclotron 2 (72 MeV), and the 590 MeV main ring proton cyclotron, currently delivering a current up to 1.8-2.0 mA. The cyclotrons operate at a radiofrequency of 51 MHz, making in practice SINQ a continuous neutron source. The proton beam is directed to the SINQ target after having interacted with a 4 cm thick graphite target (called “target E”), reducing the current to SINQ to about 1.3 mA, the energy to 575 MeV, and enlarging the beam profile. The proton beam line is first bent downwards through a sloping drift tube into the basement of the SINQ-facility so that it hits the target from the bottom (Fig. 1.5).

The goal of the facility is to provide thermal and cold neutrons to the users for various applications (mainly related to material science). For this purpose, the spallation target is inserted in a moderator tank of about 2 m diameter. A cold (25 Kelvin) liquid deuterium source provides cold neutrons to some of the beam lines. A system of inserts is placed in the moderator tank (Fig. 1.6) with the purpose to extract neutrons for the beam lines. The inserts are at different longitudinal levels (indicated in the figure).

The target-moderator system is surrounded by a shielding block, consisting essentially of iron, with an external layer of borated concrete (Fig. 1.5).

Outside the target block several thermal and cold beam lines serve a variety of instruments (Fig. 1.4), mainly dedicated to material science studies.

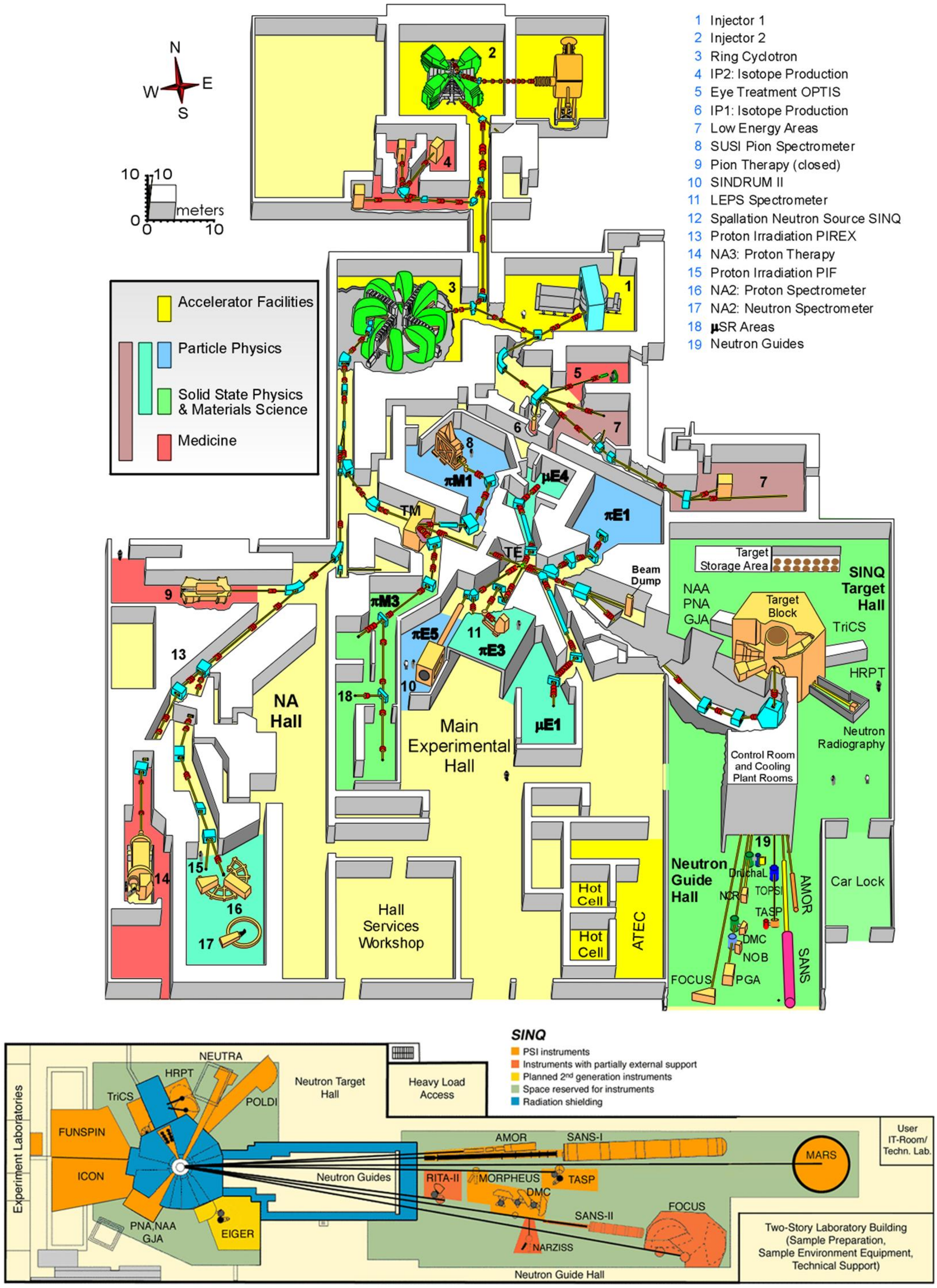


Figure 1.4. *Top*: the PSI accelerator complex. *Bottom*: detail of the SINQ instrument hall.

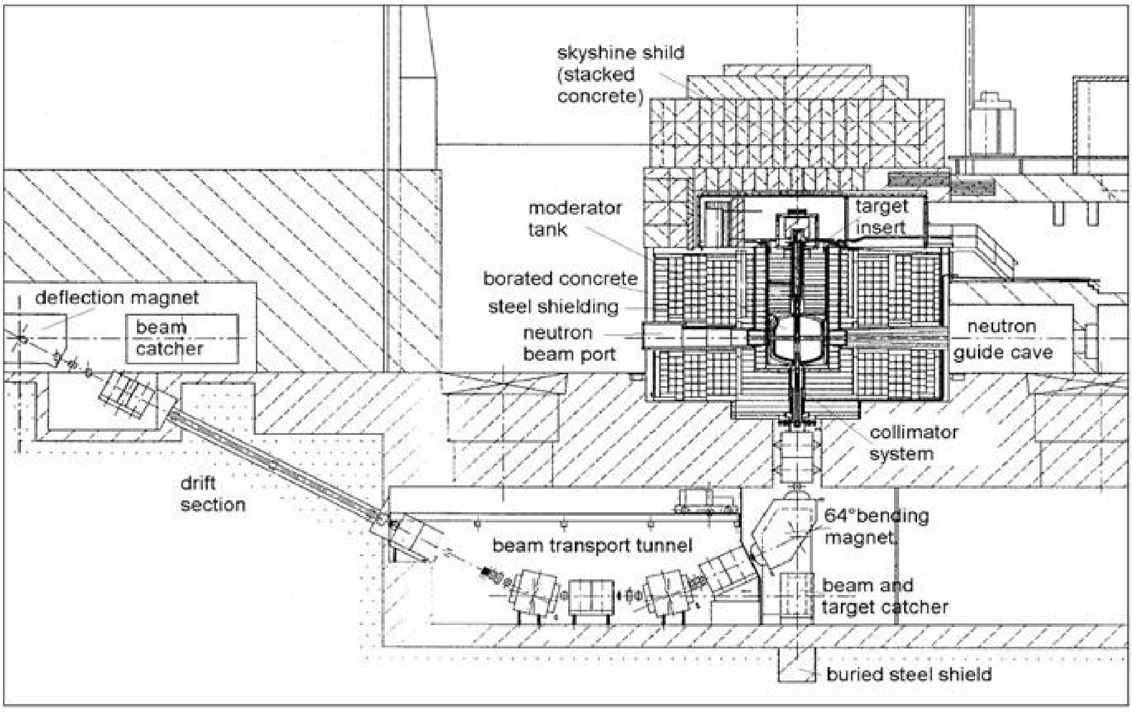


Figure 1.5. Vertical view of the SINQ facility showing the proton beam line.

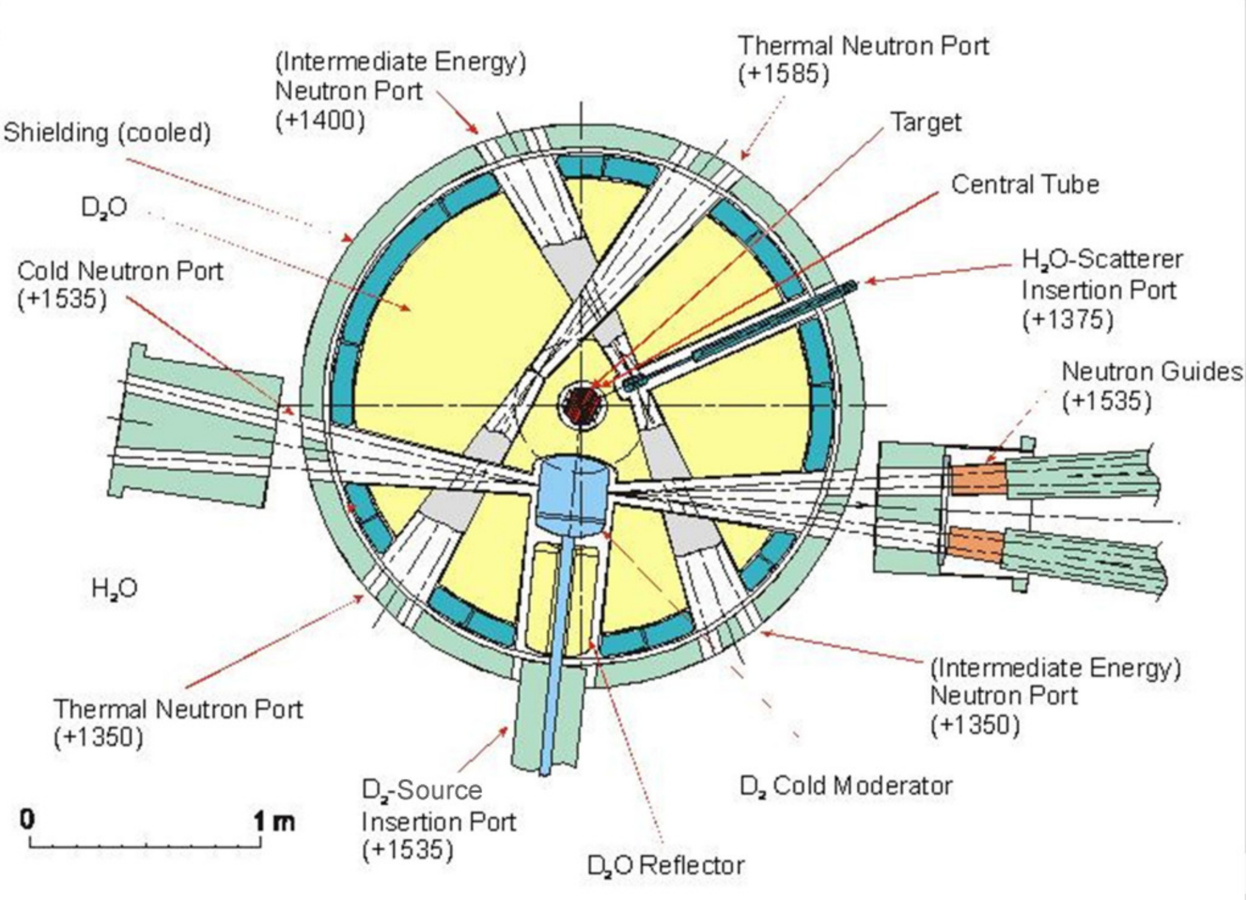


Figure 1.6. Schematic view of the SINQ moderator tank with the beam line inserts. The numbers (units in mm) indicate the different longitudinal positions of the beam lines.

1.3 MEGAPIE irradiation history

The irradiation of the MEGAPIE target started on August 14, 2006. A start up phase at low proton currents (Fig. 1.7), lasting a few days, was followed by the irradiation phase at full power (Fig 1.8).

A large number of measurements and monitoring operations were performed during start up. An illustration of the planned start up operations is shown in Figs. 1.9 and 1.10. The start up operation was divided in three phases.

- In phase 1 (August 14) a proton current of 40 μA was sent for about 1.5 hours on target. During this phase, the first neutrons were measured on instruments at the beam lines; the beam interrupt system was tested; a check of the response of some target systems, like the LBE leak detectors and the neutron detector inside the central rod was done. A first mapping of the dose rate distribution in the TKE was done, and the delayed neutron measurements were started.
- In phase 2 (August 15), the beam current was ramped in 50 μA steps up to 250 μA. With the higher beam power, a temperature rise was observed in the target, and the heat removal system started to operate. At the end of the second phase, gas samples of only slightly decayed gas from the expansion volume were taken and analyzed. Additional dose rate measurements were performed in the TKE.
- In phase 3, the proton current was ramped in 100-150 μA steps up to 0.9 mA. A further increase up to almost 1.2 mA triggered a large amount of beam trips caused by beam instability. Transients were studied in this phase. During this period, measurements of the neutron flux meters in the central rod and of the VIMOS beam monitoring system were made. Radiation mapping around the SINQ target block and in the neutron guide hall was performed.

Following the success of the three initial phases, the target was operated at a 1.25 mA peak current for several days, and finally the peak maximum was reached by maintaining stable beam operation. The summary of the irradiation parameters is reported in Table 1.2.

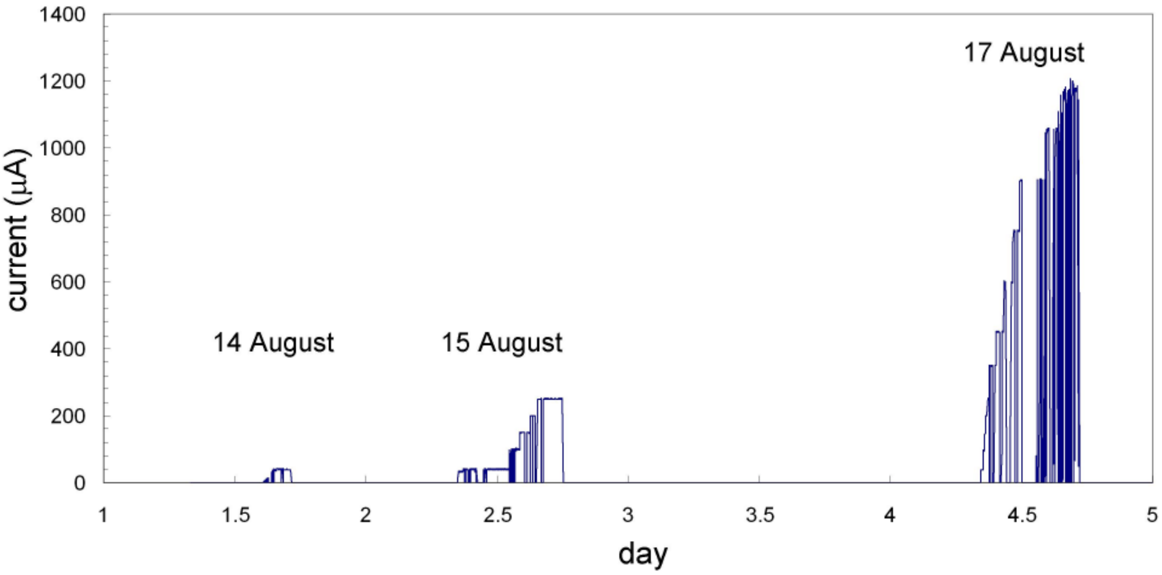


Figure 1.7. Beam irradiation history (beam current vs. day of irradiation) at the start up of MEGAPIE (day 1 is 14 August 2006).

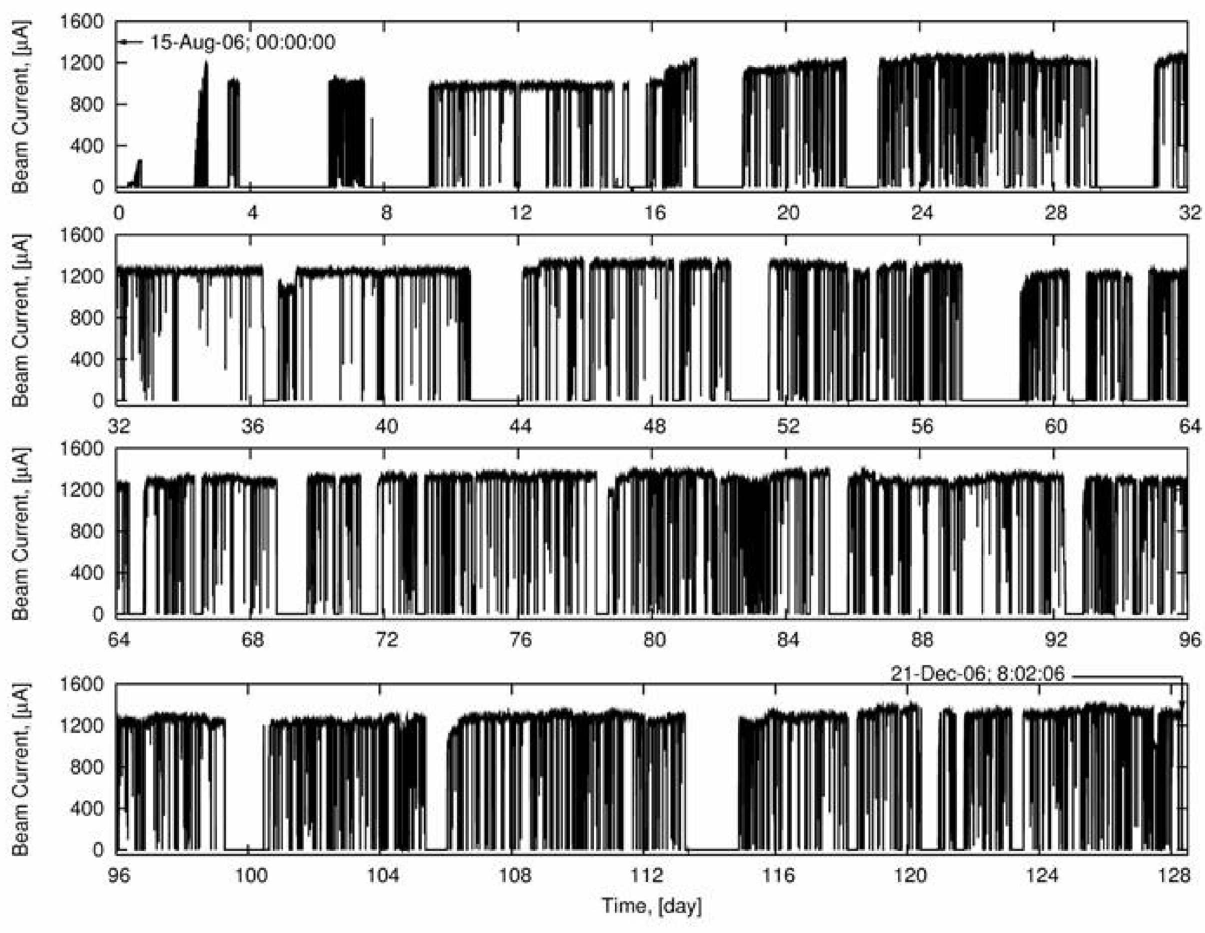


Figure 1.8. Beam irradiation history (beam current vs. day of irradiation) from 15 August 2006 until 21 December 2006.

In Fig. 1.8 the proton beam current from 15 August to 21 December 2006 is shown. The peak current reached during operation was 1375 µA corresponding to a beam power of 0.79 MW. The target irradiation continued and neutrons were delivered to the SINQ users until December 21, with weekly interruptions for routine maintenance operations, but without major problems. The accumulated charge on target for the whole MEGAPIE operation was close to 3 A·h.

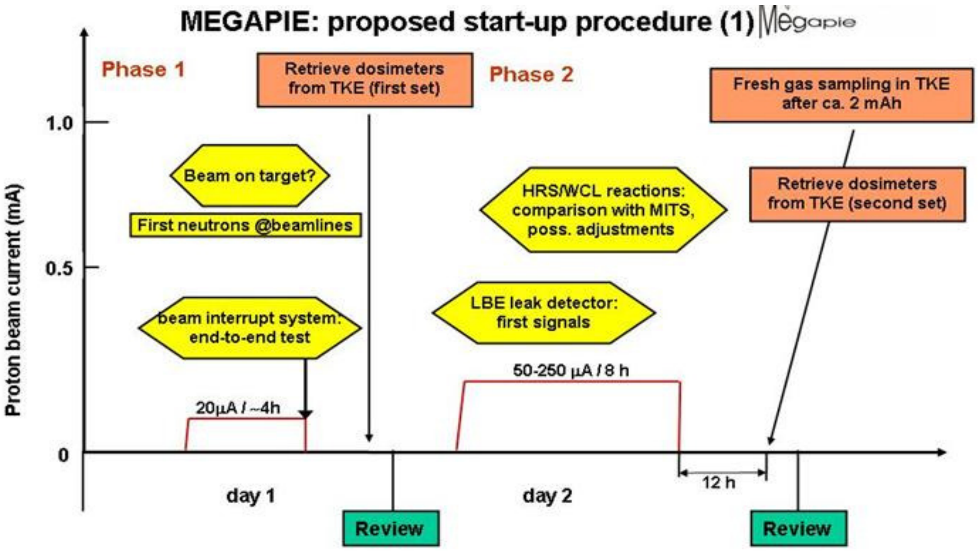
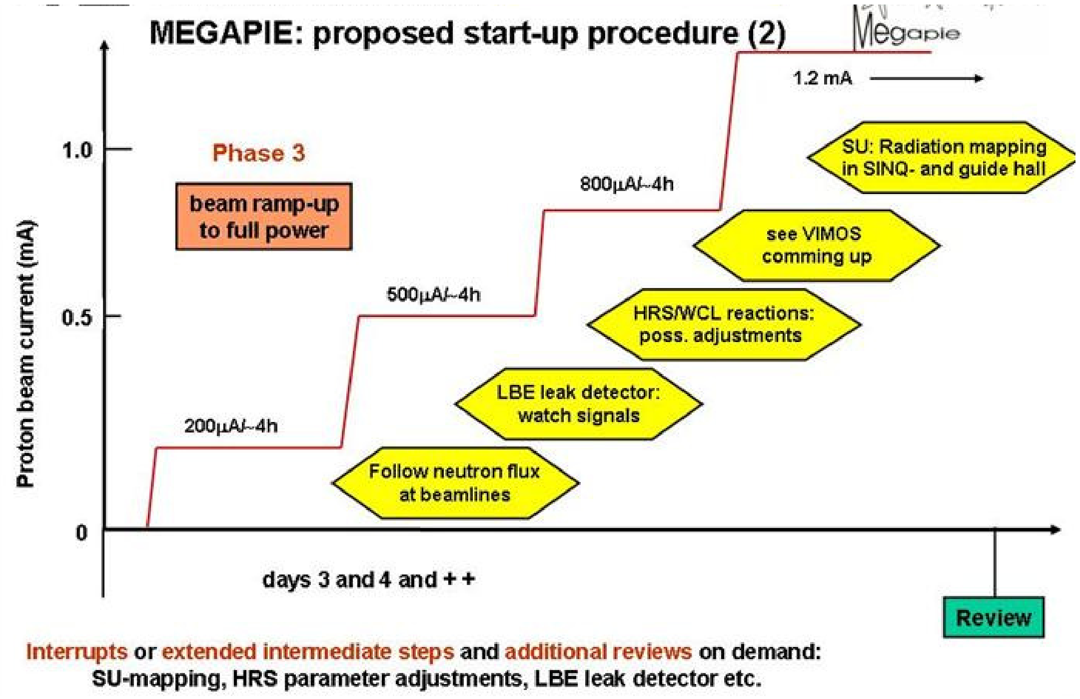


Figure 1.9. The MEGAPIE start up procedure with indicated measurements for the first two days of operation.



Interrupts or extended intermediate steps and additional reviews on demand:
SU-mapping, HRS parameter adjustments, LBE leak detector etc.

Figure 1.10. The MEGAPIE start up procedure for the third and fourth day of operation.

Table 1.2. Irradiation parameters during commissioning and normal operation of MEGAPIE.

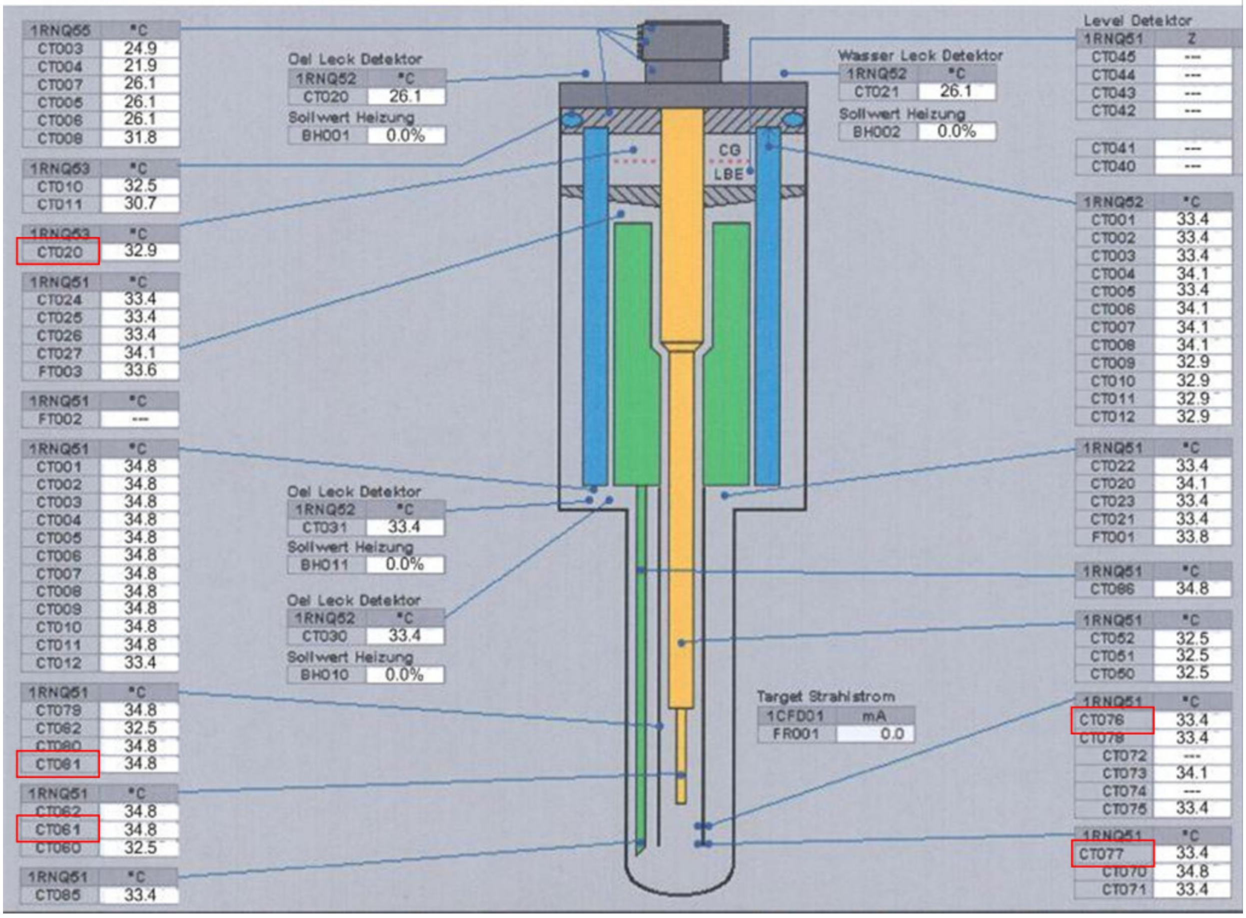
START UP	
Start	14 August 2006
End	17 August 2006
Initial current	40 µA
Maximum current	1.2 mA
NORMAL OPERATION	
Start of irradiation	21 August 2006
End of irradiation	21 December 2006
Maximum current	1.375 mA
Total charge of current*	2.79582 A·h
Average current	0.947 mA

* includes start up phase

1.4 Operating conditions

During the MEGAPIE irradiation, several measurements were performed to monitor the target operational parameters, such as temperature, level detection, flow rates and pressure measurements. For the analysis of the neutronic and nuclear data we are interested in the temperature measurements in the target (particularly in the LBE and in the expansion volume) and in the pressure measurements of the MEGAPIE expansion volume. The positions of the thermocouples are shown schematically in Fig. 1.11. The temperatures of some of these thermocouples (including the one in the expansion volume) during operation are shown in Figs. 1.12 and 1.13.

The temperature of the cover gas expansion volume was on the average about 230 °C. During operation also the temperature at the bottom of the central rod (about 40 cm above the beam window) was measured, giving a value on the average of 350 °C. For the data analysis it is also of interest to know the temperature of the LBE free surface. This temperature can only be estimated indirectly from the thermocouple measurements at the inlet of the heat exchanger, at a position about 5 cm below the free surface. Such temperature was on the average 320 °C during operation. It is estimated that the temperature at the LBE free surface was of about 280-285 °C.



1RNQ55	°C
CT003	24.9
CT004	21.9
CT007	26.1
CT005	26.1
CT006	26.1
CT008	31.8

1RNQ53	°C
CT010	32.5
CT011	30.7

1RNQ53	°C
CT020	32.9

1RNQ51	°C
CT024	33.4
CT025	33.4
CT026	33.4
CT027	34.1
FT003	33.6

1RNQ51	°C
FT002	---

1RNQ51	°C
CT001	34.8
CT002	34.8
CT003	34.8
CT004	34.8
CT005	34.8
CT006	34.8
CT007	34.8
CT008	34.8
CT009	34.8
CT010	34.8
CT011	34.8
CT012	33.4

1RNQ51	°C
CT079	34.8
CT082	32.5
CT080	34.8
CT081	34.8

1RNQ51	°C
CT062	34.8
CT061	34.8
CT060	32.5

1RNQ51	°C
CT085	33.4

Oel Leck Detektor

1RNQ52	°C
CT020	26.1

Sollwert Heizung

BH001	0.0%

Oel Leck Detektor

1RNQ52	°C
CT031	33.4

Sollwert Heizung

BH011	0.0%

Oel Leck Detektor

1RNQ52	°C
CT030	33.4

Sollwert Heizung

BH010	0.0%

Wasser Leck Detektor

1RNQ52	°C
CT021	26.1

Sollwert Heizung

BH002	0.0%

Target Strahlstrom

1CFD01	mA
FR001	0.0

Level Detektor

1RNQ51	Z
CT045	---
CT044	---
CT043	---
CT042	---
CT041	---
CT040	---

1RNQ52	°C
CT001	33.4
CT002	33.4
CT003	33.4
CT004	34.1
CT005	33.4
CT006	34.1
CT007	34.1
CT008	34.1
CT009	32.9
CT010	32.9
CT011	32.9
CT012	32.9

1RNQ51	°C
CT022	33.4
CT020	34.1
CT023	33.4
CT021	33.4
FT001	33.8

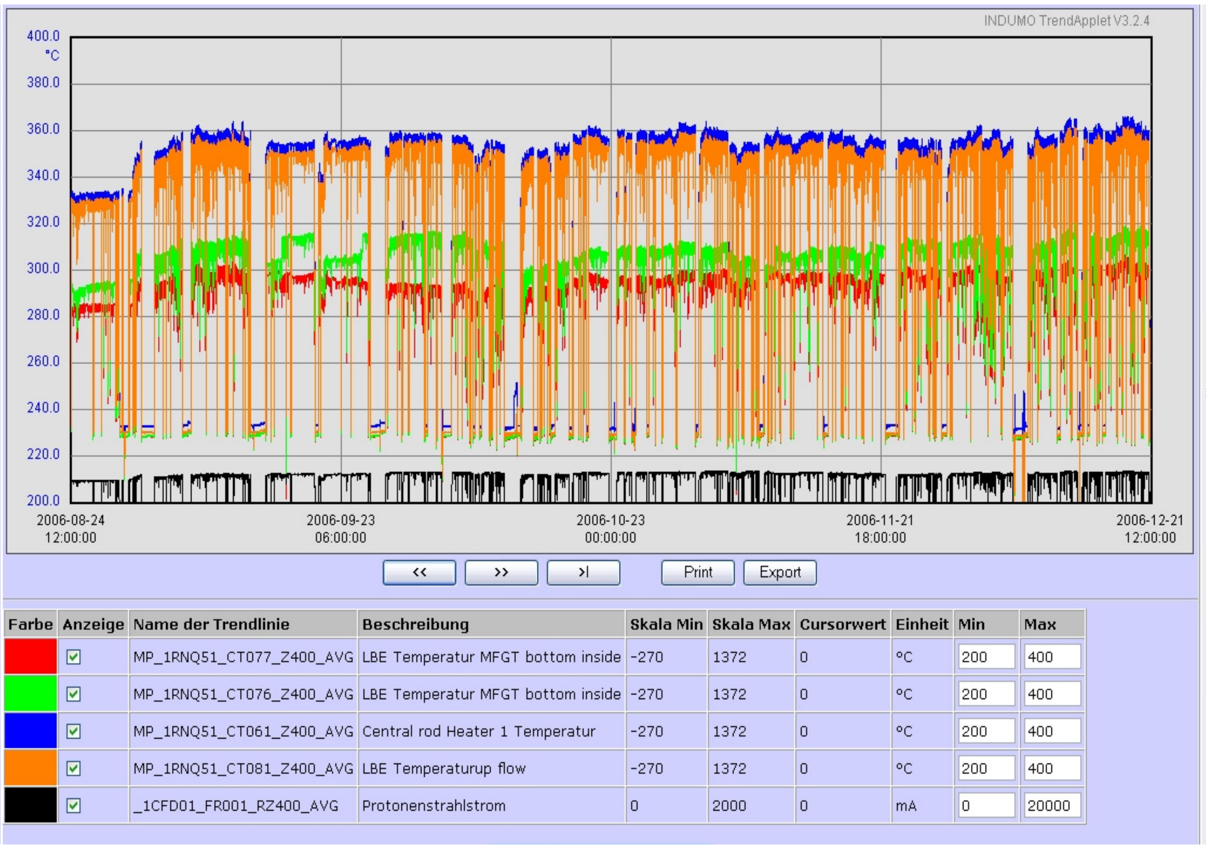
1RNQ51	°C
CT086	34.8

1RNQ51	°C
CT052	32.5
CT051	32.5
CT050	32.5

1RNQ51	°C
CT076	33.4
CT078	33.4
CT072	---
CT073	34.1
CT074	---
CT075	33.4

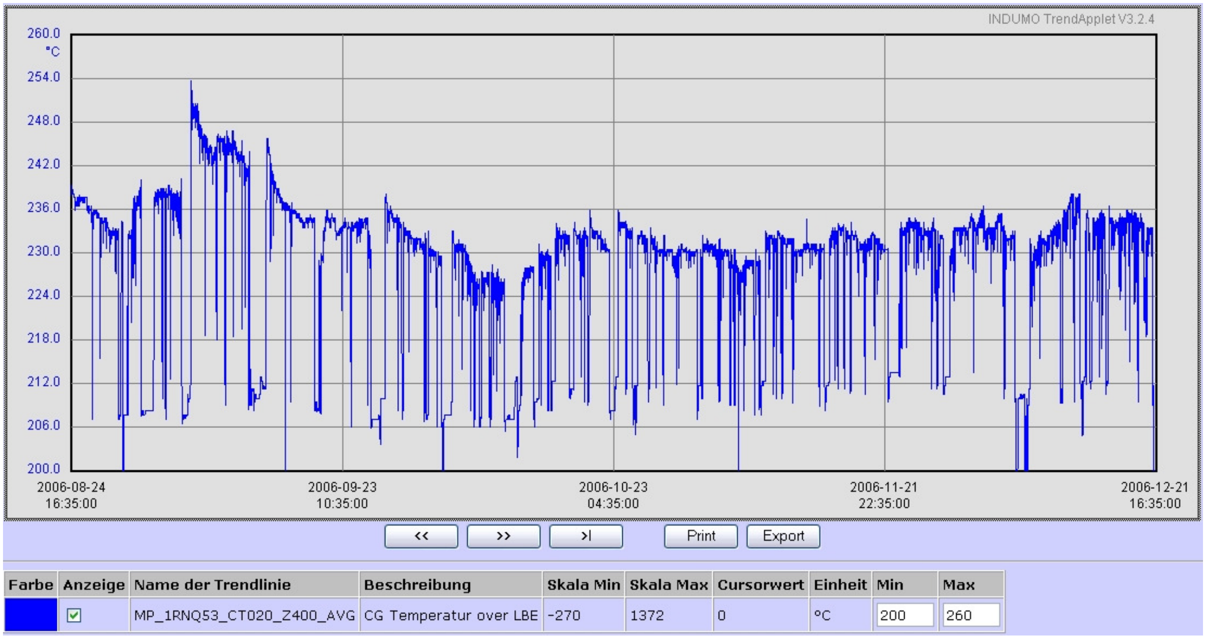
1RNQ51	°C
CT077	33.4
CT070	34.8
CT071	33.4

Figure 1.11. Screen shot of the MEGAPIE control panel with the position of the thermocouples (target in cold conditions). Five thermocouples (four in the bottom of the target, and one in the expansion volume), whose values during irradiations are plotted in the next two figures, are highlighted.



Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
🟥	☑	MP_1RNQ51_CT077_Z400_AVG	LBE Temperatur MFGT bottom inside	-270	1372	0	°C	200	400
🟩	☑	MP_1RNQ51_CT076_Z400_AVG	LBE Temperatur MFGT bottom inside	-270	1372	0	°C	200	400
🟦	☑	MP_1RNQ51_CT061_Z400_AVG	Central rod Heater 1 Temperatur	-270	1372	0	°C	200	400
🟧	☑	MP_1RNQ51_CT081_Z400_AVG	LBE Temperaturup flow	-270	1372	0	°C	200	400
⬛	☑	_1CFD01_FR001_RZ400_AVG	Protonenstrahlstrom	0	2000	0	mA	0	20000

Figure 1.12. Temperature measurements in the target during irradiation. Readings from four thermocouples labelled CT077, CT076, CT061 and CT081 are indicated. The positions of the thermocouples are shown in Fig. 1.11. In black (on a different scale) is the proton current.



Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
🟦	☑	MP_1RNQ53_CT020_Z400_AVG	CG Temperatur over LBE	-270	1372	0	°C	200	260

Figure 1.13. Screen shot of the expansion volume temperature measurement panel during MEGAPIE operation, after Ref. [7]. The position of the thermocouple CT020 is shown in Fig. 1.11.

1.5 Neutronic and nuclear measurement program

The neutronic and nuclear measurement program consisted in the study of the neutron flux and of the gas production in the facility. The general goal was to characterize SINQ by performing a mapping of the neutron flux at different points of the facility, from the center of the target to the beam lines. Another goal was to benchmark the Monte Carlo codes (FLUKA and MCNPX) used during the design of the target.

Additionally, the nuclide production was studied by sampling the gas produced during the commissioning of the target, and accumulated in the expansion volume above the free surface of the Pb/Bi eutectic (LBE). Because of experimental constraints, some of the measurements could be performed only at the beginning of the irradiation.

The measurement program was structured in the following way (Fig. 1.14): a set of measurements was performed during the start up phase, where the beam current was low. Part of these measurements could only be performed during this phase, as measurements with the nominal current would lead for instance to a saturation of the detectors. Other measurements were performed both in the start up phase and at nominal power, to study the behavior of the measurement quantities at different irradiation conditions.

Table 1.3. Summary table of the detector main characteristics. Details can be found further in the report.

Experiment	Location	Detector type	Characteristics	Operating conditions	Peculiarities
DN measurement	[a]TKE floor	^{3}He counter	Length: 45 cm Pressure: 8 bar	Irradiation followed by beam stop; beam intensity from 40 μA to 900 μA	CH_2 box for n moderation, Gd foil for background n suppression
Inner flux measurement	Central rod	Micro fission chambers	Length: 23 mm Diameter: 4 mm Ioniz. Gas: Ar	Continuous data taking and on-line monitoring	3 ^{235}U stages (1 with Gd shielding) + 2 minor actinides deposits
Neutron spectrum measurement	ICON line	Bonner spheres	^{3}He detector and 11 polyethylene spheres of different diameter.	Continuous during start up phase	
Fresh gas sampling	TKE	HPGe detector	2 samples taken	Sampling taken 15 hours after beam stop in the second day	
Flux measurements	EIGER, ICON, NEUTRA beam lines and NAA station	Au, Co activation foils, threshold detectors	Au and Co foils also covered with Cd	At various times during irradiation	

[a]Target head enclosure

The following measurements were planned (see Table 1.3):

1. Delayed neutron measurements were performed on day 1 and 2 of operation, at low operating currents, given the count rate limitations of the DN detector.
2. Flux measurements in the central rod with the micro fission chambers were performed from the start to the end of the irradiation program.
3. A set of neutron spectral distribution measurements at the ICON beam line was done on the first day of irradiation using Bonner spheres.
4. Fresh gas sampling at the target was performed after two days of operation.
5. Activation measurements at the NAA to determine thermal, epithermal and fast flux were done both at the start of irradiation and in nominal operating conditions.

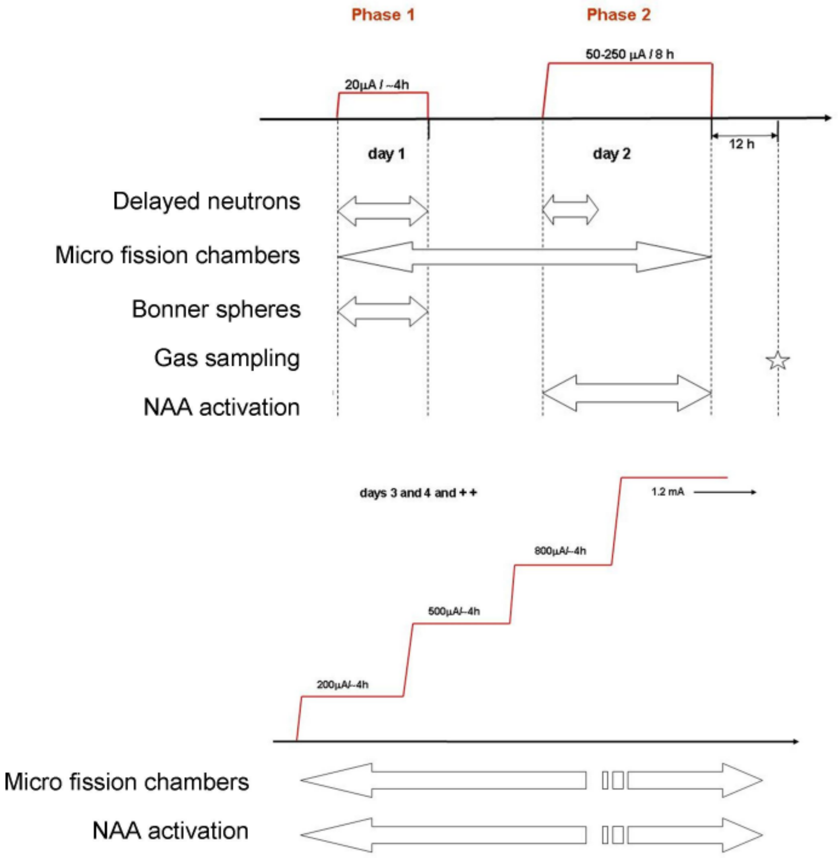


Figure 1.14. Time line of the neutronic and nuclear measurements.*Top*: start up days 1 and 2. *Bottom*: start up day 3 and following.

2. MODELING

Monte Carlo calculations were an essential tool during the neutronic design phase of MEGAPIE, with important contributions relevant to the design and to the safe operation of the target. The bulk of the Monte Carlo calculations provided an overall characterization of the neutronic and nuclear behavior of the target prior to operation[4]. During the irradiation phase of the project, several neutronic and nuclear measurements were done. In correspondence to each of these measurements, additional calculations were then performed to validate the codes used.

The codes used in the design phase were the comprehensive FLUKA and MCNPX particle transport codes. These two codes were also the main ones used in the post-test analysis.

2.1 Modeling tools and procedure

Neutronic and nuclear calculations in the post-test analysis were made using FLUKA 2006.3b and MCNPX 2.5.0. Additional activation calculations were performed with the SNT code, as described in Chapter 7. Even though the various models used in the design phase were very detailed, a refined model of the SINQ facility with the MEGAPIE target was needed before the measurement phase. The main improvements consisted in the refinements of details of the SINQ facility around the target. Additionally, two more models were prepared, with the two solid targets used before and after MEGAPIE (target 6 and target 7); an accurate geometrical description of the latest two solid targets and of MEGAPIE was performed; the surrounding SINQ facility was the same in the three models. As the absolute neutron fluxes need to be calculated at the beam lines, which are up to about 7-8 m away from the target center, the entire SINQ target block was modeled, and the beam lines collimators were included in an attempt to calculate precisely the fluxes. A view of the geometry of the model with the MEGAPIE target is represented in Fig. 2.1 using the MCNPX viewer. Three dimensional views of the geometry are shown in Fig. 2.2 and 2.3.

The modeling procedure consists of several steps:

1. geometry definition. To ensure consistency between the calculations, the geometry was modeled in FLUKA, and then converted into MCNPX by means of a conversion program[8];
2. material definition;
3. source definition;
4. physics parameters;
5. tallies;
6. evolution codes.

2.2 Geometry definition

The geometry definition must include the spallation target and the surrounding SINQ facility. In the case of MEGAPIE, the bottom of the target, where the spallation reactions take place, contains several structural components. It is important to model correctly the structural materials surrounding the spallation zone, as they contribute significantly to the neutron balance. This is true especially for the steels T91 and 316L, due to the relatively high neutron capture cross section of Fe and Cr. Details of the loop, also above the spallation region were modeled with care, since this was required for the analysis of the delayed neutrons experiment, for activation calculations and for future calculations for the Post Irradiation Experiment (PIE).

During operation the MEGAPIE target has a thermal expansion, resulting in a vertical shift of the bottom part of the target. The shift is estimated to be of 1 cm for the target, and of 1.4 cm for the central rod, with respect to “cold” conditions. Such shifts were taken into account in the models.

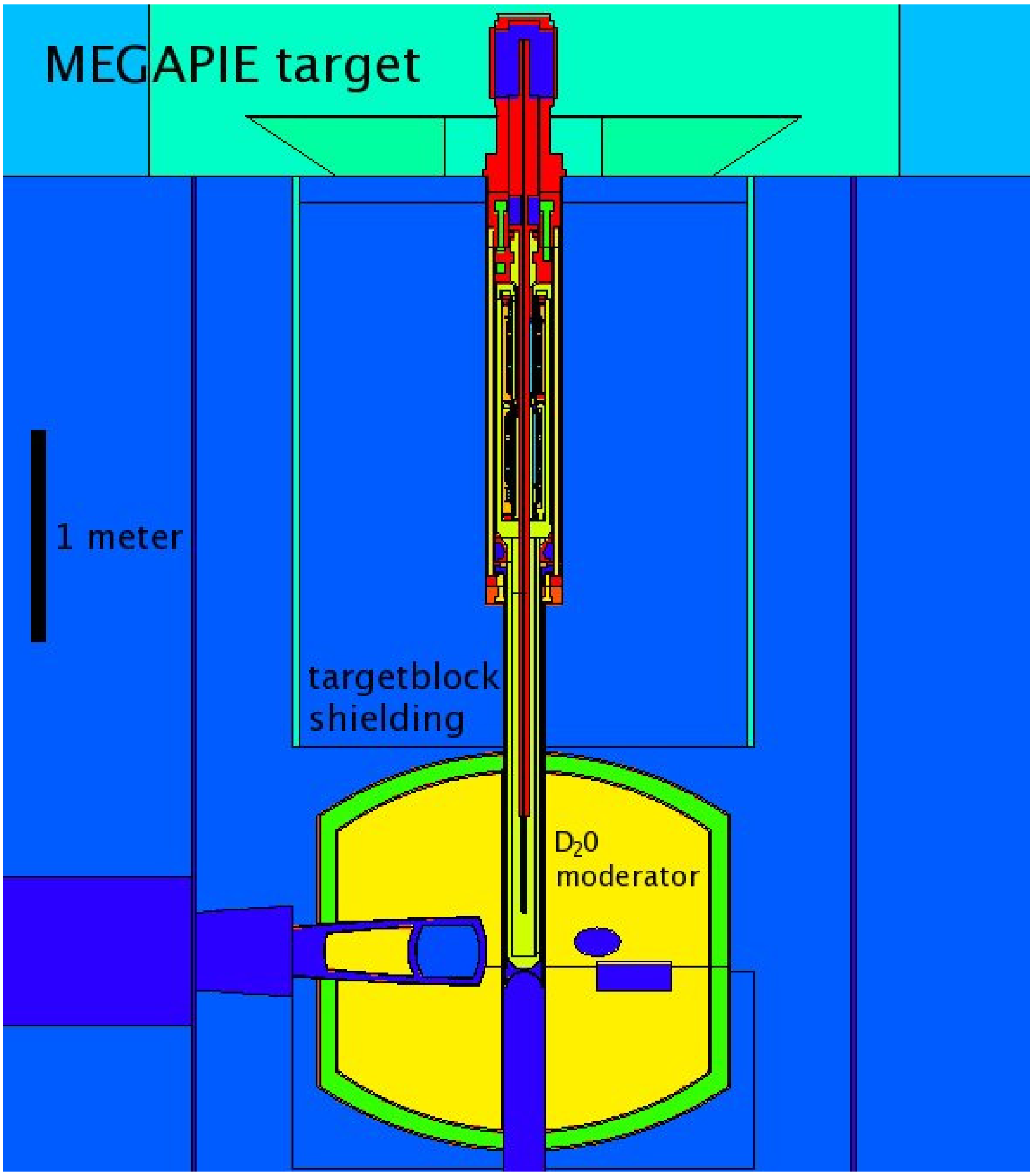


Figure 2.1. MCNPX two-dimensional visualization of the simulated system composed by the SINQ facility combined with the MEGAPIE target.

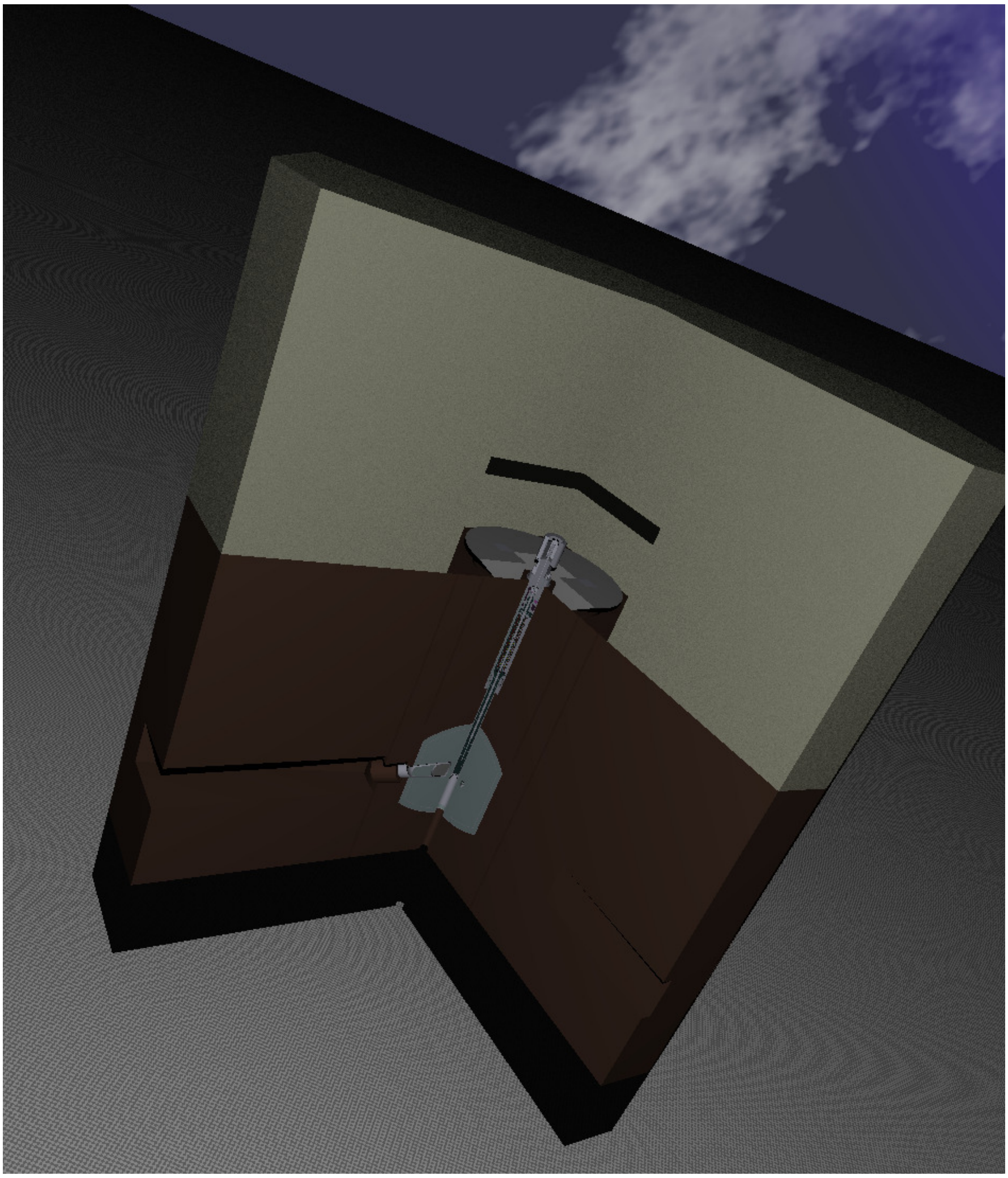


Figure 2.2. Global 3D povray[9] view of the model of the SINQ target block with the MEGAPIE target.

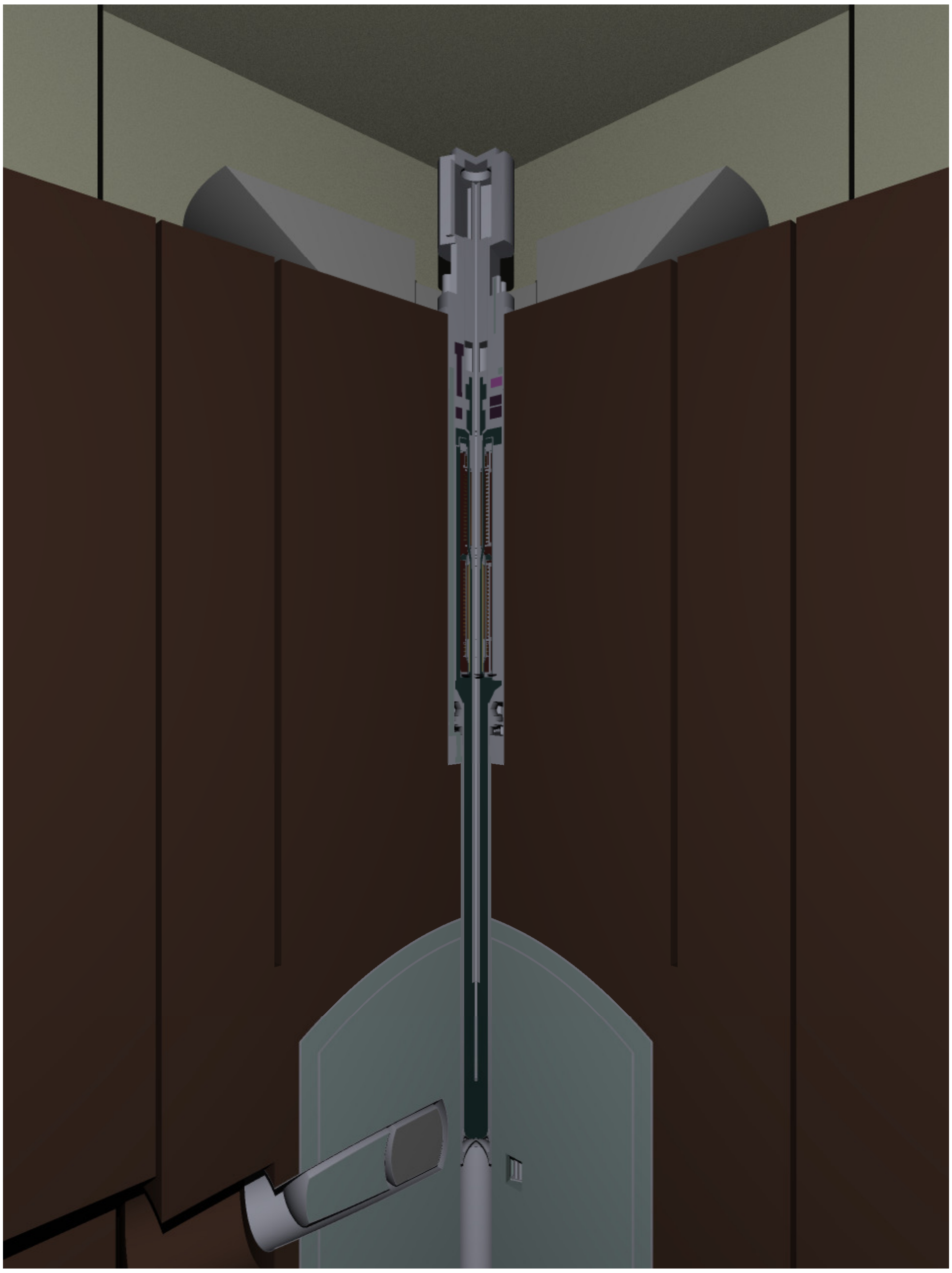


Figure 2.3. Global 3D povray view of the model of the SINQ target block with the MEGAPIE target.

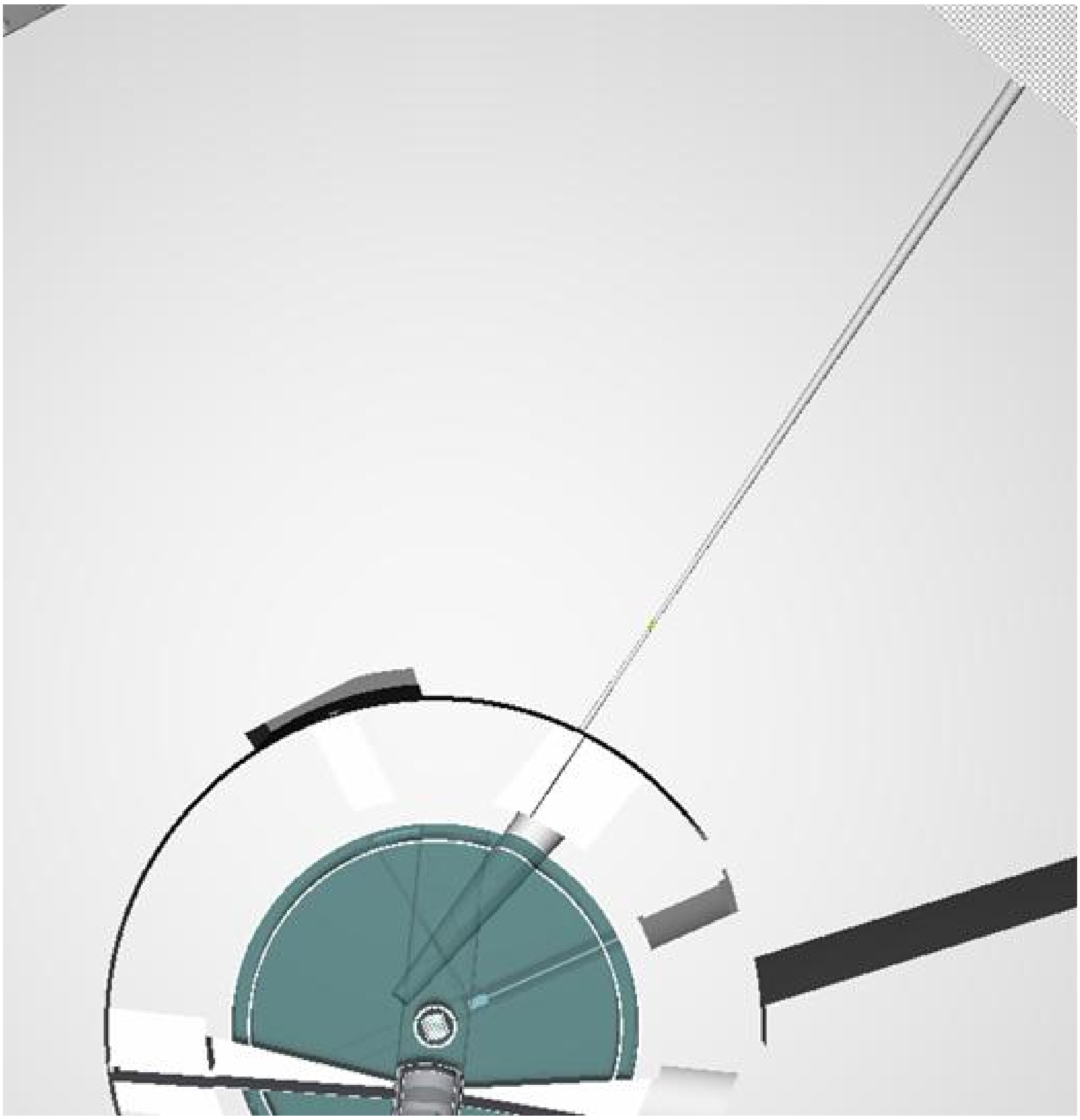


Figure 2.4. Horizontal cut of the MCNPX model of the SINQ facility, showing also the collimation system of the NEUTRA beam line.

For the simulations of the solid targets irradiated in 2004-2005 (target 6) and in 2007 (target 7), the same model of the SINQ facility was used, where the solid rod targets replaced the MEGAPIE target. A view of the geometry with also the NEUTRA collimator is shown in Fig. 2.4. More detailed views of the solid target are shown in Figs. 2.5, 2.6 and 2.7.

Target 6 consisted of a bundle of rods arranged in layers of 9 and 10 rods each, for a total of 37 rows and 351 rods. Each rod consists of a cylinder with radius of 0.54 cm and 13.6 cm length. There are different types of rods: 1) the majority consists of Pb rods inside steel 316L cladding, the volume of the cladding being filled to 90% with Pb; 2) the lowest row of 9 rods consists of $AlMg_3$ cylinders which are open (therefore allowing the D_2O to circulate), for cooling purpose during operation; 3) for the rods at the sides of the bundle, zircaloy replaces the steel; 4) several rods filled with specimens for the STIP[10,11] program (mostly steel specimens) occupy some of the central positions in the target.

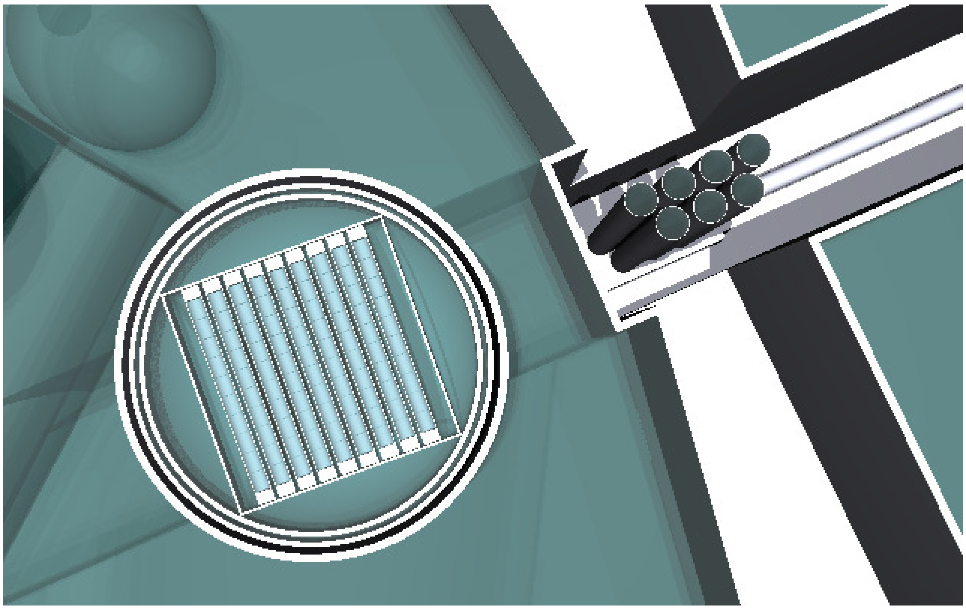


Figure 2.5. Horizontal cut of the MCNPX model of the SINQ solid target with the water scatterer.

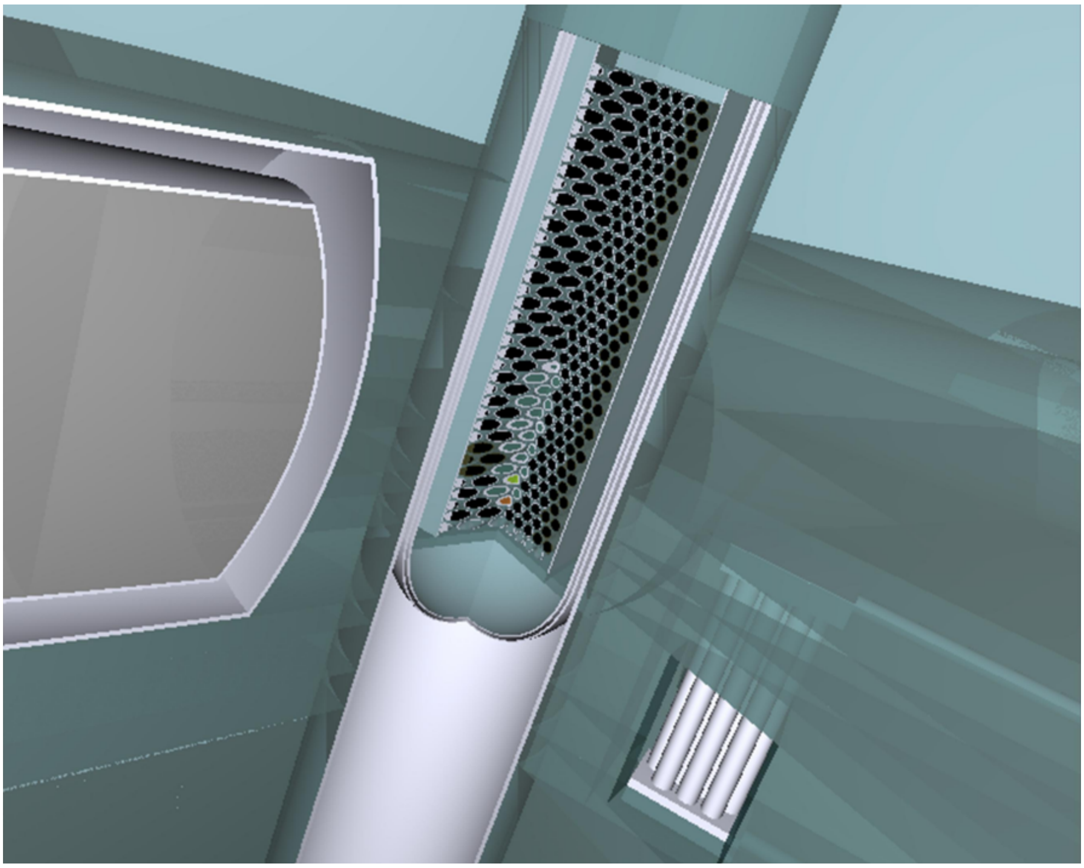


Figure 2.6. Perspective view of a section of the solid target 6, of the water scatterer (on the right) and the D_2 moderator (on the left).

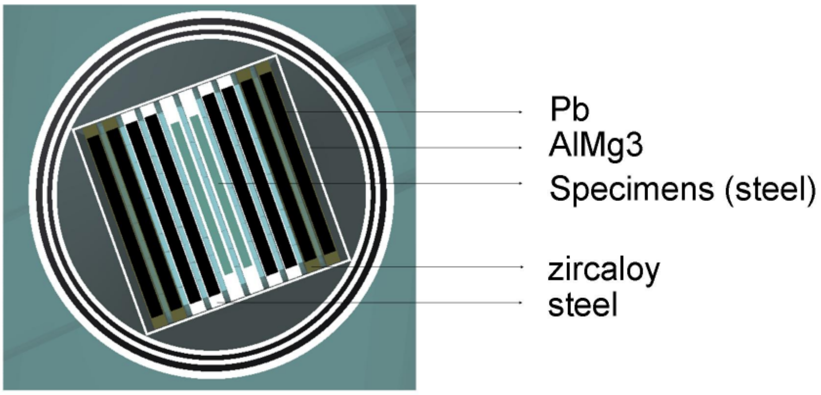


Figure 2.7. View of a modelled row of target 6, showing the different types of rods.

The target 7, which was inserted in the SINQ facility after the end of the MEGAPIE irradiation program, is very similar to target 6. The difference consists in the cladding (only zircaloy is used) and in a different arrangement of the STIP samples in the target.

2.3 Materials definition

The material definition is very important for flux calculations, as the presence of neutron capturing materials (such as steel, or possibly impurities in the LBE) will affect the target performance. Additionally, the presence of impurities may affect the radionuclide inventory in the target.

Precise compositions for the T91 and 316L steels, and for the $AlMg_3$ were known. A chemical analysis of a non irradiated sample of LBE (from the stock that was used in MEGAPIE) was performed, and a list of impurities extracted. The material compositions used in the simulations of MEGAPIE are listed in Table 2.1. For LBE, steel T91 and $AlMg_3$, new chemical analyses were carried out at PSI on existing samples. In the last row the densities of the materials are indicated (for LBE, the density at 300 °C is indicated).

Similarly, for the calculations involving the solid target the materials were precisely defined.

Table 2.1. Target materials specifications. Element composition (weight ppm). References: [1]PSI chemical analysis, S. Köchli 4.6.2007; [2,4]PSI chemical analysis, S. Köchli 14.9.2004; [3]F. Atchison, PSI report AN-96-01-16; [5]M. Dubs, private communication, 2004.

Element	LBE[1]	T91[2]	316L[3]	$AlMg_3$[4]	Densimet[5]
Ag	6.6		2		
Al		79	153	973000	
B	1.7				
Bi	555000				
C			230		
Ca	0.39		27	12.2	
Cd	0.6				
Co		159	1094	1.4	
Cr	0.4	95400	172000	292	
Cs			13		
Cu	2.1	1250	3163	826	40000
Fe	0.2	874000	656041	2690	
In	28				
K			1	2	
Mg	0.2		3	32040	
Mn		4090	15610	3270	
Mo		9250	24533	17.4	
Na			27		
Nb		668			
Ni	2.4	1320	120666	31	60000
P		140	190		
Pb	455000			22.5	
Rb			3		
S		67	133		
Si		1600	4483	300	
Sn	113	120	56		
Ta		26.8			
Ti		10.2	551	200	
V		2250		36.4	
W	2.7	9			900000
Zn		0.9	24	463	
ρ (g/cm^3)	10.3	7.76	7.96	2.66	19.3

2.4 Source definition

A detailed knowledge of the beam profile is important for precise Monte Carlo calculations of fluxes, nuclide production, and beam power deposition. However, the actual beam profile on the MEGAPIE target was not precisely known; two approaches are used to determine it, one from calculations and one from old measurements.

The reference beam profile comes from calculations[12], where the effects of the interaction with the “target E” (see Fig 1.4), and of the collimation system are taken into account, giving a two-dimensional profile which is roughly a double Gaussian. The profile is shown in Fig. 2.8. The implementation of this beam profile in MCNPX and FLUKA is shown in Fig. 2.10. As shown in the figure, the two axes of the profile are rotated with respect to the *X*-axis in order to coincide with the diagonal of the target box.

The experimental beam profile comes from γ mapping measurements of the beam calotte, performed after irradiation and after target extraction. The latest available measurement is from the SINQ target 6 (Fig. 2.9). A comparison between projection on the *X* and *Y* axis for the two distributions is shown in Fig. 2.11. We note that, even though the second distribution is experimental, it is not necessarily more correct than the calculated one, as it refers to a particular period of operation (before MEGAPIE), and it represents the average distribution over the whole irradiation period.

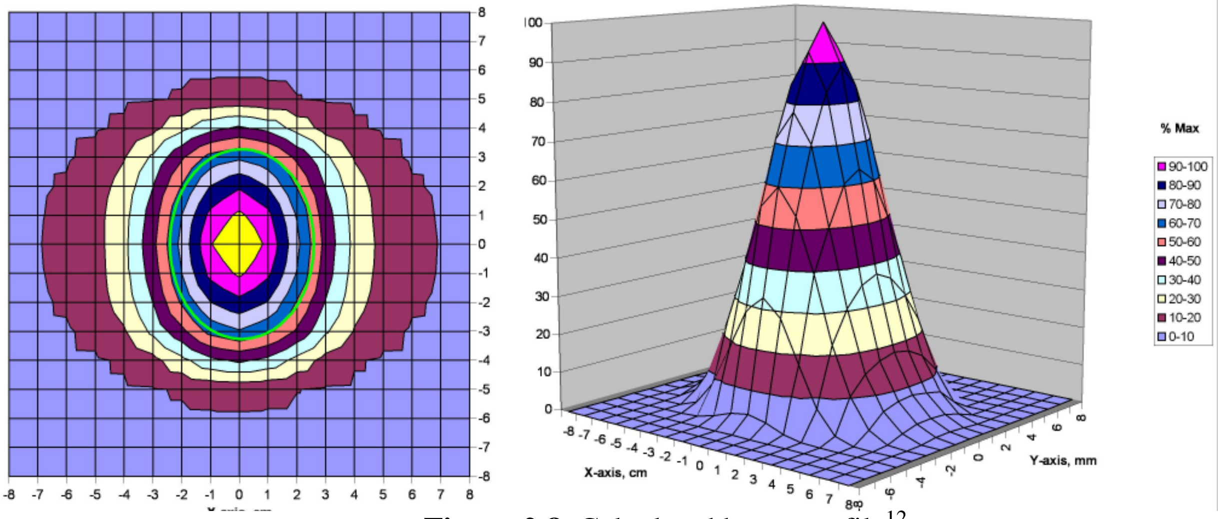


Figure 2.8. Calculated beam profile[12].

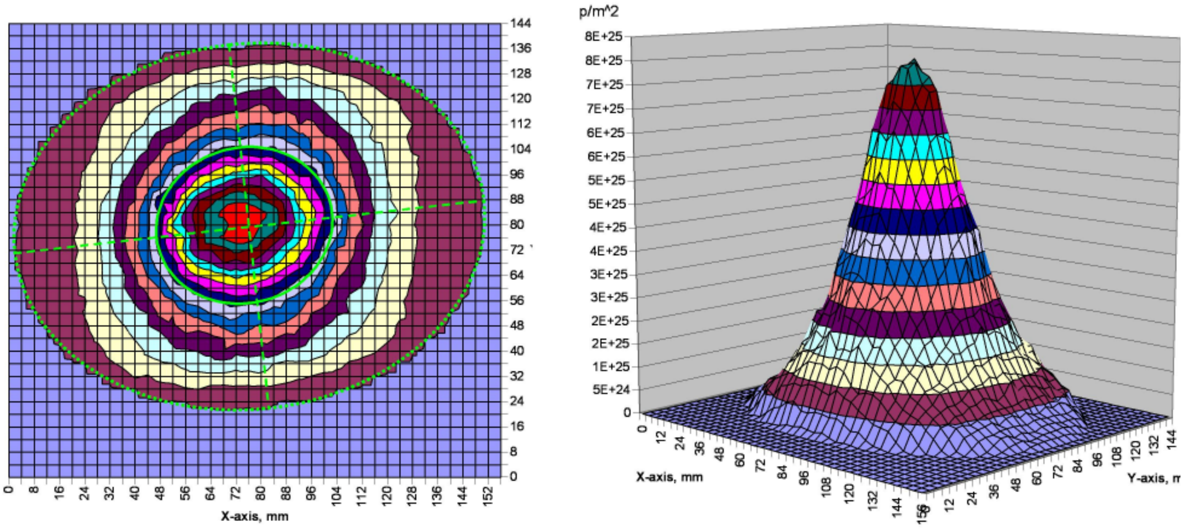


Figure 2.9. Beam profile obtained from γ mapping of the SINQ target 6 calotte[13].

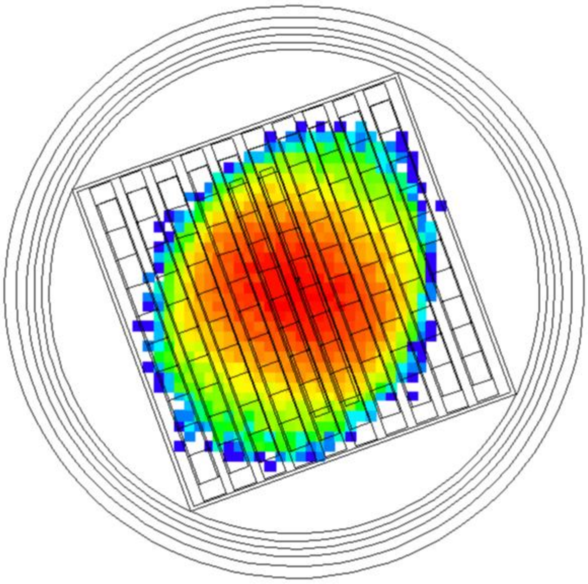


Figure 2.10. Calculated[12] beam footprint in the solid target.

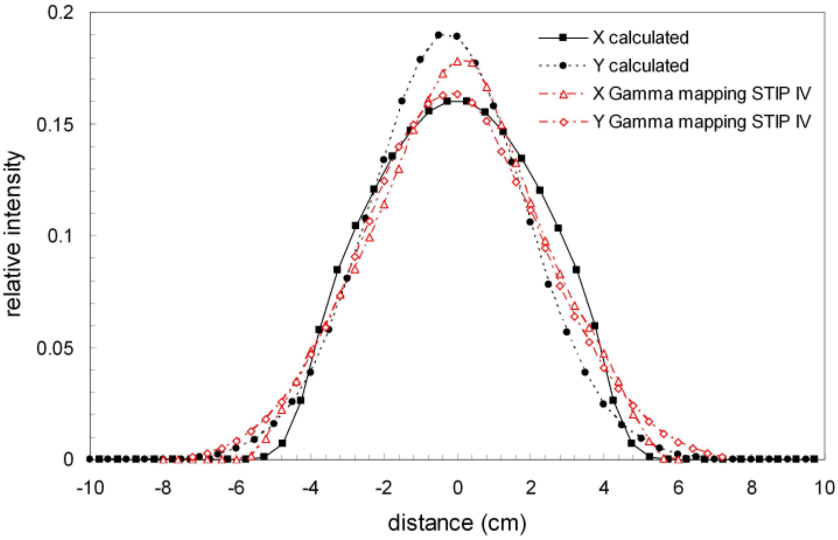


Figure 2.11. Comparison between calculated profile[12] and profile from the γ mapping[13] (for target 6).

2.5 Physics parameters

In a spallation neutron source, the nuclear reactions are started by high-energy particles (such as 0.6 GeV protons in the case of SINQ), and the end “products” are often thermal neutrons. The simulation of particle reactions and transport down to thermal energies spans about 12 orders of magnitude in energy. This gives an idea of the complexity of the problems Monte Carlo codes must handle. Reaction models are used at all energies for all the particles, with the exception of neutrons, for which cross section data are used from thermal energy up to a threshold energy between 20 MeV and 150 MeV.

2.5.1 FLUKA

In the present report, FLUKA was used for nuclide production calculations. FLUKA is a multi-particle transport code which is able, when coupled with the DPMJET-3 code[14] to treat transport and interactions of hadrons and heavy ion beams up to 10000 TeV/n. The spallation reactions in FLUKA are handled by the PEANUT (PreEquilibrium Approach to Nuclear

Thermalization) algorithm, which treats the particle interactions from 4-5 GeV down to threshold, with the exception of neutrons for which reactions down to 20 MeV are modeled. The nucleon-nucleus reactions are described as a sequence of stages: generalized intranuclear cascade (GINC), preequilibrium emission, evaporation/fragmentation/fission, and nucleus deexcitation.

The transport of neutrons with energy below 20 MeV is performed by a multigroup algorithm. For low-energy neutron reactions, FLUKA uses a set of cross section data tables, mostly at room temperature, from the ENDF/B-VI and JEF-2.2 databases. The energy structure is divided into 72 groups from 0 to 20 MeV. The thermal region is represented by only one group (from 0 to 0.41 eV); because of this limitation, we chose not to calculate fluxes with FLUKA.

It is important to select the correct input options as recommended in the FLUKA manual, to ensure that the appropriate evaporation and nucleon-nucleus interaction models are chosen, and that the transport of secondary particles is taken into account. The set of cards used in the FLUKA calculations is indicated in Table 2.2.

Table 2.2. List of relevant cards in the FLUKA input. The complete definition of the source is performed by an external routine.

```
DEFAULTS                                                              EET/TRAN
BEAM         -0.575                                               1.0 PROTON
BEAMPOS         0.0       0.0     -19.0       0.0       0.0
SOURCE          -19.
EMF
PHYSICS    3.0                                                        EVAPORAT
PHYSICS    1.0                                                        COALESCE
PHYSICS                           0.05                                DPMTHRESH
PHYSICS                                             0.05              QMDTHRESH
EVENTYPE                            2.                                DPMJET
```

2.5.2 MCNPX

MCNPX was used extensively for flux and activation calculations. MCNPX is a general purpose Monte Carlo radiation transport code that tracks nearly all particles at nearly all energies.

The types of particles transported are specified using the MODE card. PHYS is the physics energy cutoff card, which allows to specify the particle maximum energy. For neutrons (PHYS:N) it is possible to specify a threshold energy to separate the low-energy region, where cross section tables are used, from the high-energy part, where physics models are used. If no threshold is specified the default option is the so-called “mix&match”, which uses data tables up to their energy limit (different for each table), and models above the energy limit.

Different physics models for spallation and evaporation can be specified. The most common spallation models (intranuclear cascade) are the Bertini and INCL4. They are usually coupled with the Dresner and ABLA evaporation models, respectively. More details are given in Chapter 7.

For flux calculations, f4 and f5 tallies were used; in the case of NAA (see Chapter 4) both f4 and f5 tallies were computed, with an agreement better than 1 % found between the two calculations.

2.6 Evolution codes

In activation calculations one must be able to calculate the nuclide inventory and any time during or after the irradiation,. This can be done in some cases by the Monte Carlo itself, but most often it is necessary to couple the transport codes with evolution codes.

The change in the concentration of nuclides in irradiated materials is defined by a set of coupled differential equations known as *Bateman equations*:

$$\frac{dN_i}{dt} = \sum_{k \neq i} (\lambda_{ik}^r + \lambda_{ik}^d) \cdot N_k(t) - (\lambda_i^r + \lambda_i^d) \cdot N_i(t), \tag{1}$$

where

- N_i is the concentration of i^{th} nuclide at the time t;
- λ_{ik}^r is the rate of the nuclear reaction resulting in the transformation of k^{th} nuclide into the i^{th} nuclide;
- λ_{ik}^d is the corresponding radioactive decay rate;
- λ_i^r is the transmutation (disappearance) rate of i^{th} nuclide due to nuclear reactions;
- λ_i^d is the radioactive decay rate of the nuclide.

The term λ_{ik}^r includes also the contributions from the reactions following the proton interaction, leading to the k^{th} nuclide.

The nuclear reaction rates λ_{ik}^r and λ_i^r are equal to

$$\lambda_{ik}^r = \sum_j \int \sigma_{ik}^{(j)}(E) \cdot \varphi^{(j)}(E) dE, \tag{2}$$

$$\lambda_i^r = \sum_j \int \sigma_{abs,i}^{(j)}(E) \cdot \varphi^{(j)}(E) dE, \tag{3}$$

where $\varphi^{(j)}(E)$ is the energy distribution of particles of j-type; $\sigma_{ik}^{(j)}$ is the cross section for the production of i^{th} nuclide due to interactions of k^{th} nuclide with particles of j^{th} type; $\sigma_{abs,i}^{(j)}$ is the "absorption" cross section equal to the difference between the total reaction cross section and the inelastic scattering cross section for the j^{th} particles interacting with the i^{th} nuclide.

The coupling with the evolution codes is different for FLUKA and MCNPX. In the case of FLUKA, production rates of residual nuclei are calculated at all energies. In the case of MCNPX, production rates for residual nuclei are given only when nuclear models are used: residual nuclei are not calculated with data tables. For this reason, for activation calculations, where the MCNPX output is coupled with CINDER'90, the threshold in the PHYS:n card must be set at 20 MeV. In fact, CINDER calculates the activation only up to 20 MeV of neutron energy. By setting the threshold at 20 MeV, we assure that nuclide production is calculated in the entire neutron energy region.

Table 2.3. The three calculation schemes for isotope production calculations and the codes used for the two neutron energy regions, and for the time evolution.

	Production rate (E_n<20 MeV)	Production rate (E_n>20 MeV)	Evolution
1	FLUKA	FLUKA	ORIHET 3
2	CINDER'90	MCNPX	CINDER'90
3	SNT	SNT	SNT

2.6.1 ORIHET 3

The ORIHET 3 code[74] allows the study of the buildup and decay of activity in any system for which the nuclide production rates are known. The code solves the Bateman equations for the concentration of nuclides. It must be noted that the term λ_i^r in eq. (1), that takes into account the transmutation rate of the i^{th} nuclide is not considered, because ORIHET 3 does not compute reactions in the produced nuclides, and the initial material composition is kept for the entire evolution calculation. The effect of this in the final calculations is negligible for the MEGAPIE target in the actual irradiation conditions.

2.6.2 CINDER'90

CINDER'90 is a FORTRAN code with a data library used to calculate the inventory of nuclides in an irradiated material. Like ORIHET 3, a set of Bateman equations is solved, in this case using the Markov method which reduces the initial set of coupled differential equations to a set of independent, linear differential equations. One important difference with respect to ORIHET 3 is that the evolution of the irradiated material is calculated, and for this purpose the neutron and proton fluxes in the irradiated material, as well as the volume of the cell, must be provided.

3. INNER NEUTRON FLUX MEASUREMENTS

This chapter and the following two are dedicated to neutron flux measurements and calculations with MEGAPIE. The experimental program included the flux measurement in close proximity of the neutron production region, where a flux of the order of 10^{14} n/cm^2/s/mA is expected, and additional measurements at various points in the facility, with thermal fluxes ranging from 10^8 n/cm^2/s/mA to 10^{13} n/cm^2/s/mA. A complete characterization of the neutronic performance of the SINQ facility with the MEGAPIE target, spanning six orders of magnitude, is therefore expected. This set of data is of great value for the benchmarking of the Monte Carlo codes. Part of the results have been published[15,16].

Before proceeding, in order to avoid confusion, we remind the definition of neutron flux[17], as there is some time ambiguity in its use. For monoenergetic neutrons of velocity v (m/s), and of density n (neutrons/m^3), the neutron flux is defined as $\phi=vn$. The fluence is the integral of the flux over a certain period of time (NB: the International Commission for Radiological Units, ICRU, has banned the term 'flux' and replaced it by 'fluence rate'; however, 'flux' is still currently and widely used). The flux quantity should not be confused with the rate of particles crossing a surface element, which is a current and depends on the orientation of the surface with respect to the direction of the particles. The results can be completely different: for an isotropic source, the fluence is a factor 2 higher than the current; for a monodirectional beam perpendicular to a surface, fluence and current are numerically the same, while for a surface parallel to a monodirectional beam, the fluence value is still the same, while the current is zero.

3.1 Neutron detector description

We have designed and developed an innovative detector to measure the absolute inner neutron flux of the target with accuracy better than 5% and to follow the time and spatial evolutions of the flux over a large neutron intensity range. It should be noted that a 1 MW liquid Pb-Bi spallation target like MEGAPIE constitutes a very constraining environment due to:

- *high temperature*: around 420 °C with beam-on and 230 °C with beam-off;
- *high level of radiation*: more than 10^{13} n/cm^2/s and almost the same level of γ rays coming from spallation reactions and activation of structural materials;
- *electromagnetic perturbations* due to the electromagnetic pumps.

Moreover, the overall dimensions of the central rod where the detector was located were very small (20 mm in diameter) and its access impossible during the whole irradiation period.

The neutron detector, built in 2005, contains eight micrometric fission chambers already employed in the framework of the Mini-INCA project[18]. These fission chambers, developed by CEA Saclay IRFU/SPhN laboratory, were adapted for the MEGAPIE specific environment, with dedicated cables, electronics and acquisition system. Each chamber is a CFUT/C3 type, characterized by a diameter of 4 mm, a total length of 23 mm and an anode cathode gap of 500 µm. Anode and cathode are made of stainless steel and nuclear quality titanium respectively. The ionizing gas is pure argon. The chambers are realized by Photonis and assembled by the CEA Cadarache DEN/DER/SPEX laboratory.

The whole detector is 4.7 m long with a 12 mm diameter in its lower part and 22 mm in the upper part. The detector is made of three sections. The first section is made by a stainless steel tube 49.5 cm high and with a diameter of 12 mm. It contains the eight fission chambers and is inserted in the central rod in order to be as close as possible to the proton-beam interaction zone in the LBE (Fig. 3.1).

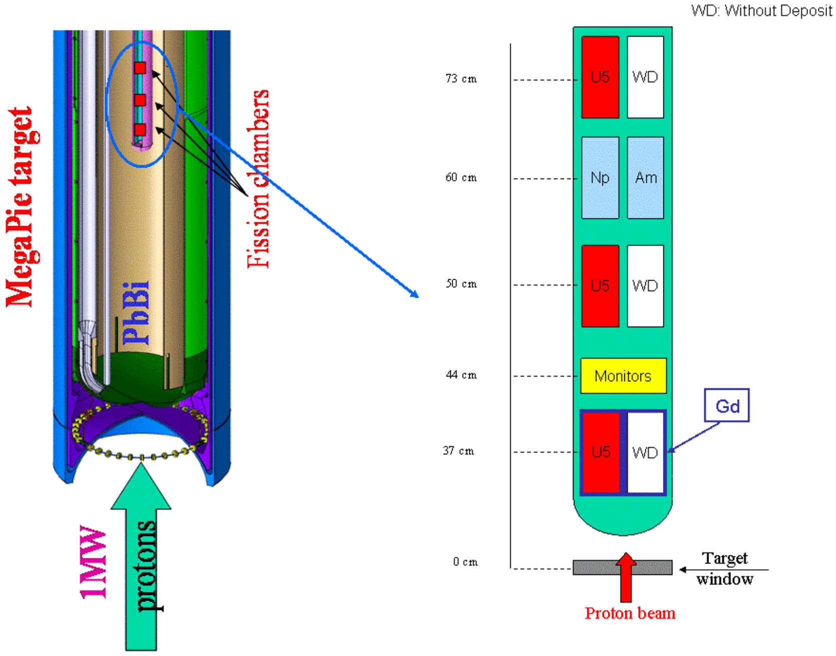


Figure 3.1. Schematic view of the bottom part of the MEGAPIE target (left) and neutron detector layout (right).

The signals from the fission chambers are transported by 1 mm thick mineral cables inside the detector and connected to triaxial organic cables outside the detector to avoid electromagnetic perturbations. Fission chambers are imbedded in pairs along the axis of the detector over a 50 cm length. Each pair, except one, is made by a chamber containing a ^{235}U deposit and a chamber without deposit to compensate the fission signal from leakage currents or from currents induced by radiation fields. The cables were chosen to prevent leakage currents higher than few nA at 500 °C temperature. The bottom pair is shielded with natural metallic Gd filter (200 μm thickness) to absorb thermal neutrons and be more sensitive to epithermal neutrons. Finally, one pair is constituted by a chamber with ^{241}Am and the other one with ^{237}Np to probe their incineration. These different configurations are chosen to provide an overall characterization of the inside neutron flux, in terms of its intensity but also its energy distribution. Fission chambers have been developed by a CEA-PHOTONIS collaboration and they have been tested and calibrated at the High Flux Reactor at ILL (Grenoble).

To increase the accuracy on the energy spectrum determination, nine activation neutron flux monitors were put inside the detector, between the first and the second chamber pairs, in a small titanium box (1.4 cm long and 6.5 mm in diameter). These nine monitors are made by ultrapure metal disks or powder. They provide an integral measurement of the thermal and epithermal flux by capture and threshold reactions.

The first stage is equipped with three K-type thermocouples made of Chromel-Alumel assembly. Their operating range extends between -200°C and 1200°C. They have been used to monitor temperature fluctuations inside the detector in order to estimate and subtract the thermal noise on fission chamber signals.

The second stage of the neutron detector is made by a stainless steel tube with a diameter of 12.7 mm and a length of 3.2 m. Its structure integrates a radiation shielding extending along 2.7 m. The shielding is made of stainless steel full cylinders rotated by 22.5% one with respect to the other. This prevents any neutron leakage by stopping the particles moving vertically towards the target head. The shielding is surrounded by silica in order to ensure electrical insulation.

Finally, the third stage of the detector is made by a 100.6 cm long steel tube, with a diameter of 2.2 cm. It contains an electric box hosting the connections between coaxial mineral cables to coaxial organic cable. Mineral cables, which transport the chamber signal, are radiation hard but very sensitive to torsion and must be manipulated with care. In order to avoid any structural problem with cables, mostly in the target head where a lot of cables are present, we preferred to use organic cable, more resistant, in the last stage of the detector where radiation level is not very high. The very top of the neutron detector is equipped with spacers made to absorb thermal dilatations of the whole detector and, at the same time, ensure a correct grounding of the detector structure.

3.2 Systematic errors reduction

The reduction of systematic uncertainties is one of the challenges for this kind of measurements. Indeed, fission chambers are usually used in relative measurements where the sensitivity of the detector is an effective observable calibrated with respect to a reference. In our case, relative calibration was not feasible in absence of the neutron flux. Thus, a deep validation and calibration campaign of all the detector pieces, the electronics and the acquisition, were performed at the ILL reactor in a well known neutron flux[19]. The sensitivity of the detectors was measured and the dispersion of the results was evaluated to be less than 3%. Then, all the masses of the ^{235}U deposits, which constitute one of the main sources of uncertainty, were checked by γ spectroscopy and mass-spectrometry resulting in an absolute error less than 1% (Table 3.1).

Table 3.1. Mass of ^{235}U deposits. Expected current, fission rate and burn up calculated by Monte Carlo simulation for 4 months of irradiation at 1.4 mA beam current.

Chamber number	^{235}U mass (μg)	Expected current (μA)	Expected fission rate (s^{-1})	Burn up (%)
1	134.8 ± 0.87	6.81	2.22×10^{8}	0.8
3	38.99 ± 0.25	34.97	1.14×10^{9}	13.23
5	138.69 ± 0.9	138.69	1.19×10^{9}	4.1

The mechanical resistance of the actinide deposit in a high temperature environment was also tested by SEM (Scanning Electron Microscopy) analysis. Finally, we performed a comprehensive study of all the physical processes involved in the functioning of such detectors[20,21]. In particular, all the processes which can degrade the response of the detector, as space charge effects, have been modeled in detail, providing a simulation tool able to calculate the delivered current as a function of the applied voltage. All these developments allow limiting the global uncertainty on the neutron flux measurement to less than 3%.

3.3 Modelling of the target

MEGAPIE is the first experiment demonstrating the operational feasibility of a spallation target based on liquid metal technology. Since the beginning of the project, a big effort was put in providing the maximum of neutronic information in order to design, operate and qualify such a complex system. The MEGAPIE target is a complex system that has been simulated using Monte Carlo transport codes such as FLUKA and MCNPX. The first set of simulations[22] was performed in the target R&D phase in order to define the key parameters of the experiment (neutron flux intensity, mass of the deposit in the fission chambers, thermal/fast neutrons ratio, activation, etc…). The simulation work has been constantly improved, taking into account more and more detailed description of the whole SINQ geometry, including the target head, the TKE environment and the neutron guides. The simulated neutron energy distributions are shown on Fig. 3.2. We can clearly see the effect of the Gd shielding on the lowest chambers where the thermal part of the spectrum is completely suppressed.

Since fission chambers are placed very close to the beam interaction point, they are very sensitive to the neutron flux distribution, both in position and energy. Thus it is very important to study the influence of the simulation parameters and physics models on the neutron flux properties. In particular, we performed a set of simulations using the MCNPX transport code to study the influence of the neutron detector geometry, the composition of the LBE, the beam profile and different spallation models on the neutron flux.

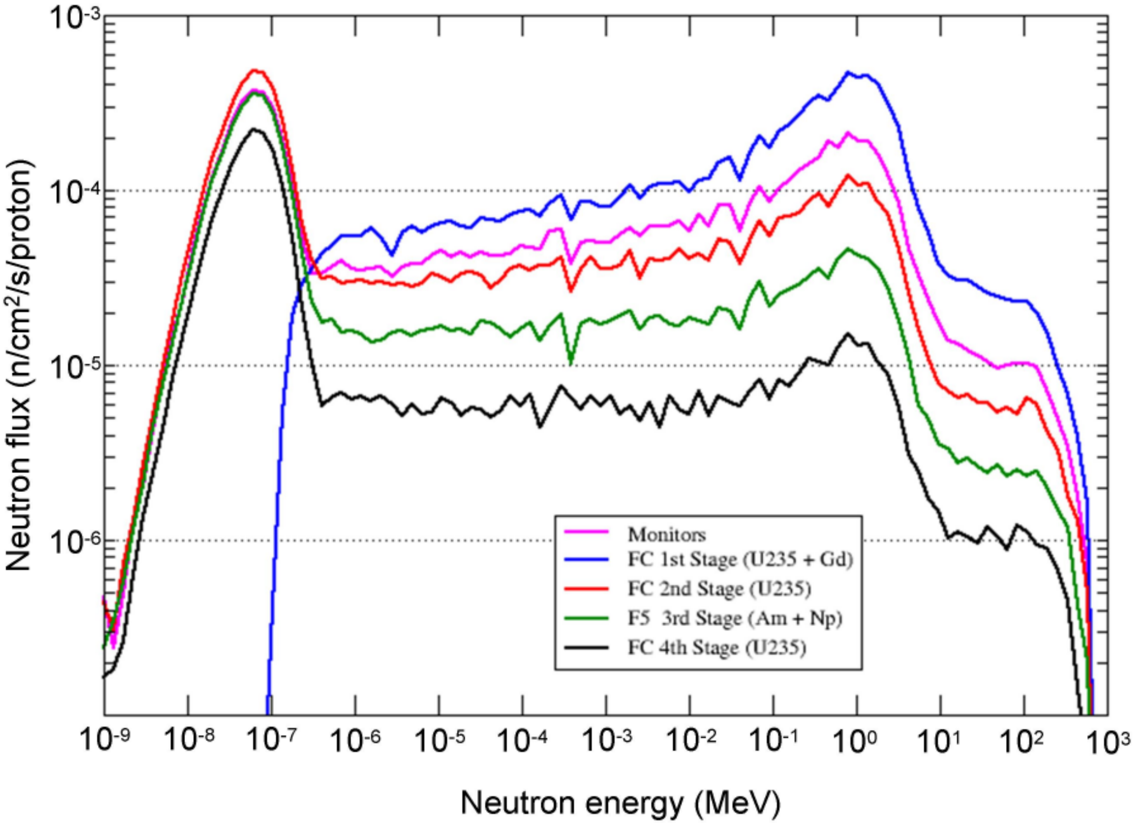


Figure 3.2. Simulated neutron fluxes as "seen" by fission chambers, along the beam axis.

First of all, our simulation shows that a very precise description of the neutron detector, which takes into account the presence of titanium pieces, filling gas and activation foils near the fission chambers, affects the neutron flux on the fission chambers not more than 1% when compared to a calculation where these structural components are not present.

The composition of the LBE is a very important topic because the presence of neutron absorbers (like boron, gadolinium or cadmium) can modify significantly the energy distribution of the neutron flux and its absolute values. In order to compare the simulation to the quantity measured by the fission chambers, we present in Table 3.2 the simulated fission rate ($\sigma\phi$), which depends on the neutron flux and the effective fission cross section of the fissile isotope for the four positions along the neutron detector and for different concentrations of boron in the LBE. The fission rate is calculated taking the neutron flux distribution given by the MCNPX transport code and the fission cross sections from the ENDFB-VI library. We call "Std boron" the boron concentration which has been effectively measured from a sample of MEGAPIE LBE (see Table 2.1). This "real" composition is compared to the one without boron and two others with the "Std boron" concentration multiplied respectively by 10 and 100. The comparison shows that the presence of some ppm of boron in the LBE affects the neutron flux mostly in the thermal region, as expected. In the lowest position, where the Gd shielding cuts away the thermal part of the spectrum, the effect of B is around 3% and does not exceed 20% when the boron concentration reaches a few per mil. On the contrary, looking at the upper position, which is characterized by an almost fully moderated spectrum, the presence of some per mil of boron changes the fission rate by a factor of 3.

Table 3.2. Simulated fission rates (fissions s^{-1} mA^{-1}) for different boron concentrations in LBE. The Bertini spallation model was used is MCNPX.

Position (isotope)	1 (^{235}U + Gd)	3 (^{235}U)	4 (^{241}Am)	5 (^{235}U)
No boron	6.74×10^{-10}	8.63×10^{-9}	3.92×10^{-11}	3.08×10^{-9}
Std boron	6.63×10^{-10}	8.48×10^{-9}	3.99×10^{-11}	3.07×10^{-9}
Std x 10	6.43×10^{-10}	7.28×10^{-9}	3.66×10^{-11}	2.83×10^{-9}
Std x 100	5.44×10^{-10}	2.93×10^{-9}	1.63×10^{-11}	1.02×10^{-9}

Another important parameter that can influence the neutron flux is the beam profile. In particular, since the fission chambers are placed in the beam axis and close to the impact point, the size and shape of the beam footprint can have a large impact on the measured flux. There exist different parameterizations of the beam footprint coming either from calculations or γ activity measurements (see Chapter 2). Our study shows that the largest influence of the beam profile on the fission rate (around 14%) concerns mostly the lowest chambers, which are closer to the beam impact point. On the contrary, this effect does not exceed 4% for the upper chambers.

The last important item concerning the simulation of neutron flux is the evaluation of the influence of spallation models in the neutron production. The code MCNPX allows the user to choose between different intranuclear cascade and fission-evaporation model combinations among ISABEL, BERTINI and INCL4 for cascade and DRESNER and ABLA for de-excitation. The latest possibility with MCNPX is to use the package CEM2k (cascade and de-excitation). For both ISABEL and BERTINI models, the pre-equilibrium option has been used. Table 3.3 shows the simulated fission rate for different model combinations. From the simulated values we can see that the effect is not large, below 9%, but it should be looked at with care when one wants to perform precise studies on the neutron production. Finally, it should be stressed that our present simulation does not take into account the actual temperature of LBE and D_2O moderator, which might have a non negligible influence.

Table 3.3. Simulated fission rates (fissions s^{-1} mA^{-1}) for different physics models within MCNPX. The simulation is performed with “std boron” concentration.

Position (isotope)	1 (^{235}U + Gd)	3 (^{235}U)	4 (^{241}Am)	5 (^{235}U)
Bertini-Dresner	6.63×10^{-10}	8.48×10^{-9}	3.99×10^{-11}	3.07×10^{-9}
INCL4-ABLA	7.01×10^{-10}	8.29×10^{-9}	3.83×10^{-11}	3.07×10^{-9}
ISABEL-ABLA	6.74×10^{-10}	8.30×10^{-9}	4.19×10^{-11}	3.11×10^{-9}
CEM2k	5.79×10^{-10}	8.42×10^{-9}	4.20×10^{-11}	3.29×10^{-9}

3.4 Experimental results

The MEGAPIE has stand for four months under a proton beam power close to 700 kW. The neutron detector has functioned reliably for all this time at a temperature around 400 °C with frequent beam interruptions. During the whole irradiation phase the currents of the 8 fission chambers have been recorded every 2 s (Fig. 3.3). The beam current intensity was also recorded to study the neutron production of the target normalized to one incident proton, which is one of the fundamental parameters in the economy of a neutron source (Fig. 3.4). In order to constantly check the good functioning of the chambers, calibration curves were acquired every day during irradiation (Fig. 3.5).

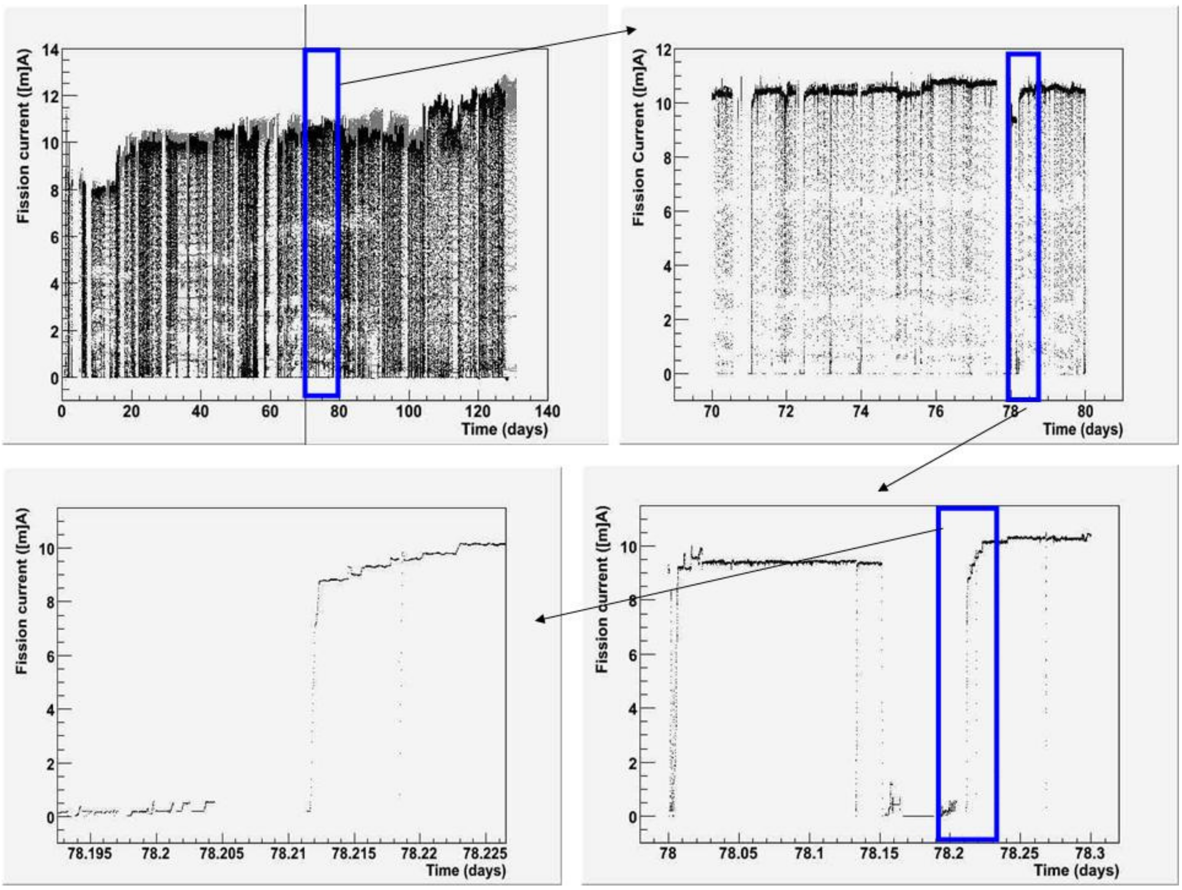


Figure 3.3. Online display of ^{235}U fission chamber current (in μA).

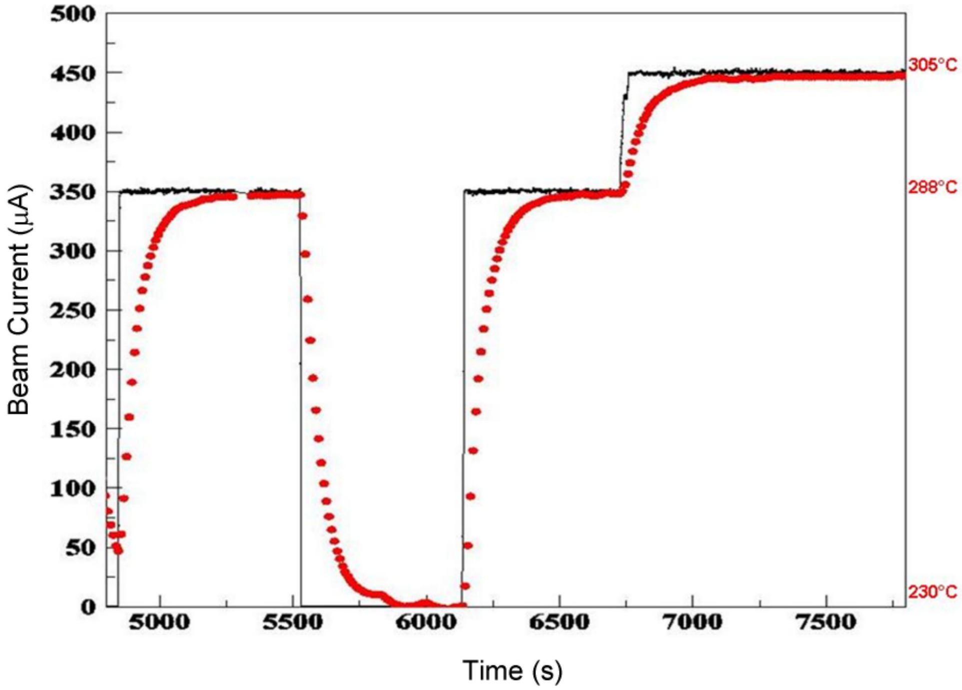


Figure 3.4. Online display of the proton beam intensity (black) and temperature inside neutron detector (red).

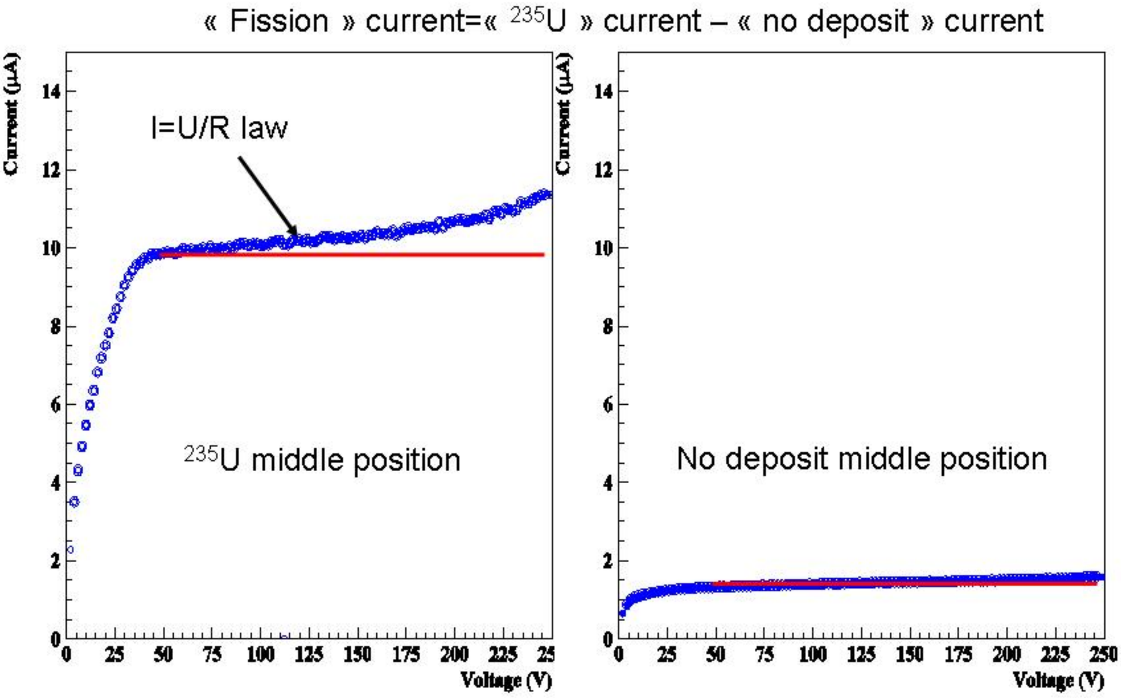


Figure 3.5. Calibration curves of ^{235}U and "no deposit" chambers.

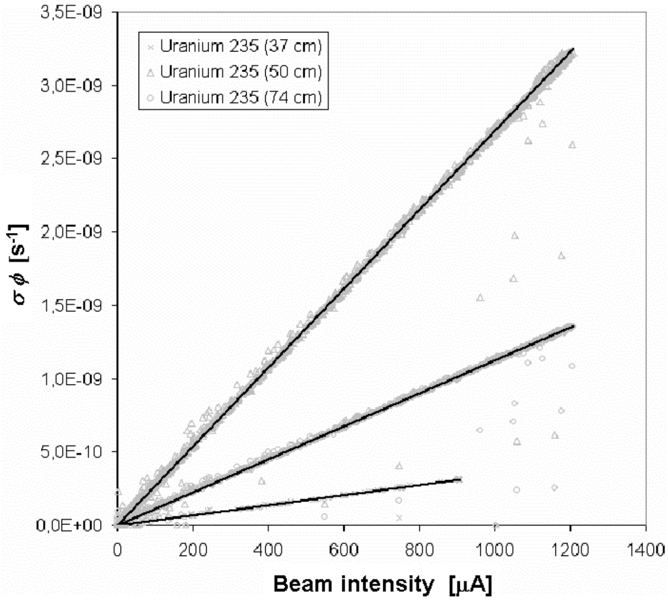


Figure 3.6. Correlation between the fission rate and the proton beam intensity.

The current measured by the fission chambers is proportional to the fission rate ($\sigma\phi$) which depends on the neutron flux and the effective fission cross section of the fissile isotope. The extraction of the neutron flux is therefore not straightforward and requires a good characterization of the neutron energy distribution, which is calculated with simulation codes. However, if the epithermal/thermal ratio does not evolve over time or with the beam intensity, the fission rate is a good estimate of the relative variations of the neutron flux. The evolution of the fission rate as a function of the proton beam intensity is shown on Fig. 3.6, where we see a good correlation for the three uranium chambers, as expected. This validates the correct functioning of the detectors. In Fig. 3.7 the evolution of the fission rate normalized to the proton beam intensity is plotted, as a function of time, for the middle and the upper chambers. We can see a small decrease of the fission currents due to the burn up of the uranium deposit, reaching an estimated 5.5% and 6.5% depletion for the upper and middle fission chambers respectively at the end of the 123 day irradiation period.

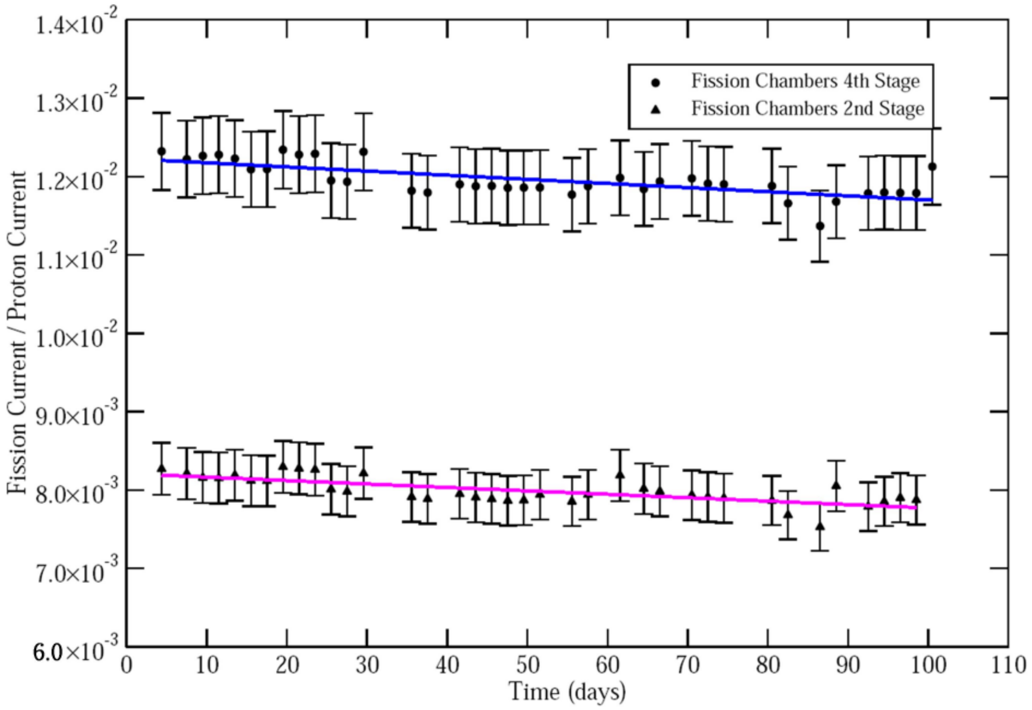


Figure 3.7. Time evolution of two ^{235}U fission chamber signals, normalised to the proton beam current.

Figure 3.8 shows the evolution of ^{241}Am and ^{237}Np currents as a function of time. We clearly see the increase of Am current due to the transmutation of ^{241}Am into the long-lived fissionable metastable state of ^{242}Am. From these data it should be possible to extract a fission cross section for ^{242m}Am into a moderated flux. The incineration of the ^{237}Np is much more difficult to see due to the 2 days half-life fissile isotope ^{238}Np which decays before absorbing neutrons to fission, thus leading to a constant current during all the irradiation.

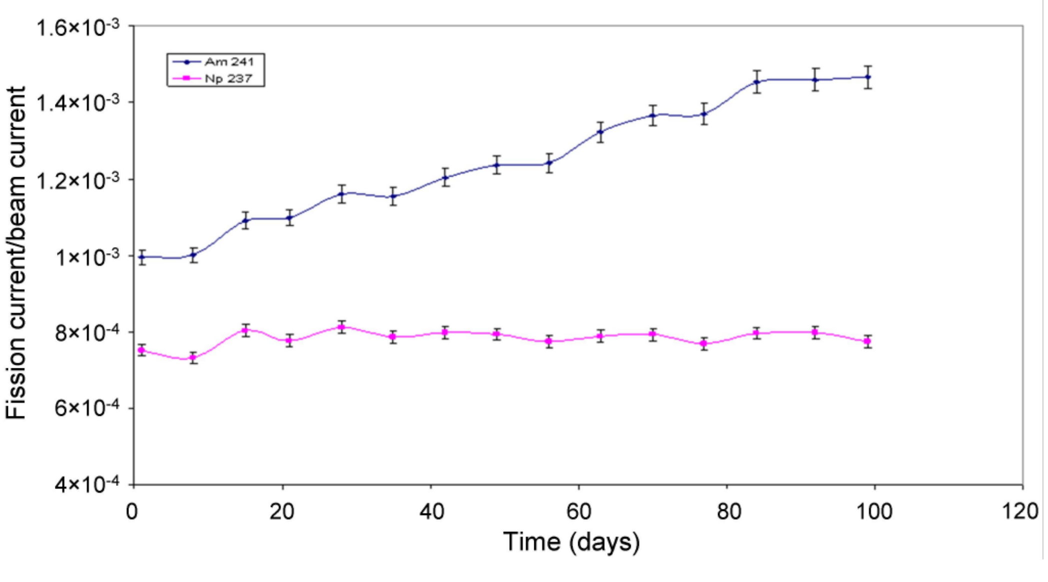


Figure 3.8. Time evolution of the ^{241}Am and ^{237}Np fission chamber signals, normalised to the proton beam current.

Taking into account all improvements and studies of the target system description and modelling, as described in the previous section, we can finally compare the measured fission rates to the simulated ones (Table 3.4). The fission rate normalization is actually extracted from the measured fission current taking into account the chamber sensitivity which has been previously measured at ILL with a precision of 3%. This constitutes de main dominant source of uncertainty since the precision of the fission current measurement is around 1‰.

Table 3.4. Comparison of simulated fission rates (fissions s^{-1} mA^{-1}) with the measured ones for different fission chambers.

Position (isotope)	1 (^{235}U + Gd)	3 (^{235}U)	4 (^{241}Am)	5 (^{235}U)
Measured $\sigma\phi$	3.70×10^{-10} (3%)	2.85×10^{-9} (3%)	1.37×10^{-11} (3%)	1.19×10^{-9} (3%)
Simulated $\sigma\phi$	6.63×10^{-10}	8.48×10^{-9}	3.99×10^{-11}	3.07×10^{-9}

From this comparison we can see that there is a systematic over-prediction of the measured values by a factor of 2-3, which cannot be explained for the moment. In order to validate the fission chambers measurement, we could extract and measure the flux monitors.

3.5 Flux monitors analysis

Neutron flux monitors were inserted together with the fission chambers in the MEGAPIE central rod, to provide absolute measurements of the neutron fluence. Nine monitors were chosen for the sensitivity of the reactions to the neutron energy to scan the neutron flux distribution. The monitors were placed at 42 cm from the target window. They consisted of ultra-pure metal discs, with the exception of magnesium which was a powder sealed inside a Ti box. The discs were all 6 mm in diameter except for Al-Co which was 5 mm in diameter. The latter was sealed inside a Ti box to prevent from losses in case of fusion due to high temperature. The characteristics of the monitors are given in table 3.5.

Table 3.5. Characteristics of the monitors. Errors on mass measurements are lower than 1 μg.

N	Element	Mass (mg)	Impurities (ppm)
1	Al-0,1%Co 99.999%	5.576	not communicated
2	iron > 99.99%	9.889	Ag 1, Al 2, Ca 3, Cr 1, Cu 2, Mg 2 Mn 1, Ni 1, Si 3
3	gadolinium > 99.9 %	39.753	not communicated
4	nickel 99.999 %	11.565	Al 2, Ca 2, Cu 1, Mg 1, Fe 2, Si 1
5	niobium 99.9 %	59.083	B 10, Cu 5, Fe 30, Mo 10, Ni 5, Si 100, Ta 500, Ti 10, W 100, Zr 10, C 25, H 10, N 20, O 100
6	rhodium 99.9 %	8.236	Al 10, Ca 10, Cu 5, Fe 40, In 100, Na 50, Ni 5, Pd 5, Pt 5, Ru 40, Si 45
7	titanium 99.999%	14.7	Al 3, Ca 2, Cr 6, Cu 10, Fe 10, Mg 1, Mn 1, Nb 5, Ni 3, S 1, Si 5, V 3, Zn 1, Zr 3
8	yttrium > 99.9 %	15.776	not communicated
9	manganese 98.5 %	20.4138	not communicated

The reference reactions are indicated in Table 3.6 with the reaction neutron energy thresholds. The most important γ rays are indicated with their absolute intensities. Global errors take into account only the errors on intensities and on reaction cross sections.

Table 3.6. Reference reactions and most important γ rays for all the monitors.

N	Reaction of interest	Half-life (days)	Reaction threshold (MeV)	γ Energies (keV)	γ Intensities (%)
1	$^{59}Co(n,\gamma)^{60}Co$	1925.1 (5)	Thermal	1173.237 1332.501	99.85 (3) 99.9826 (6)
2	$^{54}Fe(n,p)^{54}Mn$	312.10	0.7	834.85	99.976 (1)
3	$^{152}Gd(n,\gamma)^{153}Gd$	241.6 (2)	Burn-up Gd shielding	103.1812	21.11 (23)
	$^{159}Gd(n,\gamma)^{160}Tb$	72.3	Burn-up Gd shielding	298.58 879.383 966.171	26.13 (18) 30.10 (6) 25.10 (12)
4	$^{58}Ni(n,p)^{58}Co$	70.82 (3)	0.5	810.76	99.450 (10)
	$^{58}Ni(n,2n)^{57}Co$	271.79 (9)	15-20	122.06	85.60 (17)
5	$^{93}Nb(n,\gamma)^{94}Nb$	7300000	Thermal + epithermal	702.62 871.09	97.9 (20) 99.9 (20)
6	$^{103}Rh(n,2n)^{102}Rh$	207 (3)	10-20	475.10 556.4	38.4 (25) 96 (10)
	$^{103}Rh(n,2n)^{102m}Rh$	1058	10-20	475.10 631.28 697.5	95 (4) 56 (2) 44 (2)
	$^{103}Rh(n,3n)^{101}Rh$	1204 (100)		127.226 (9) 325.23 (3)	68.0 (7) 11.83 (11)
7	$^{46}Ti(n,p)^{46}Sc$	83.81	2.5	889.28 1120.55	99.984 (1) 99.987 (1)
8	$^{89}Y(n,2n)^{88}Y$	106.61	10	898.04 1836.06	93.7 (3) 99.2 (3)
9	$^{55}Mn(n,2n)^{54}Mn$	312.10	10	834.85	99.976 (10)

The flux monitors were extracted from the neutron detector at the PSI Hotlab in February 2008. During the cutting phase, prior to opening the container box, a dark powder inside the detector container was found. This powder was identified as gadolinium. Pure metallic gadolinium was in fact used not only as neutronic shielding for fission chambers' first stage but also as a metallic disk monitor.

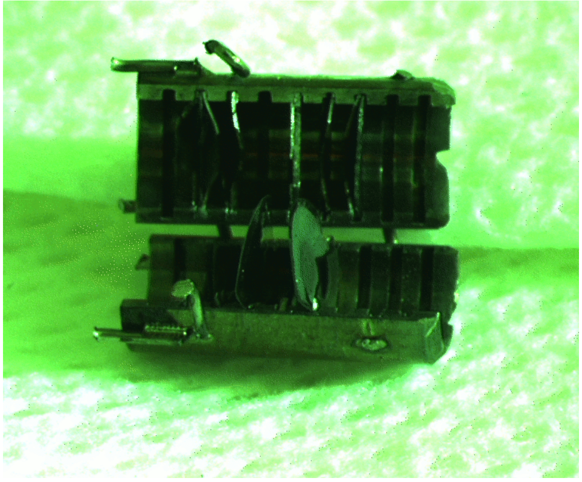


Figure 3.9. The monitor box after opening, showing some of the monitor's discs still inside.

The finding of Gd powder set clear reasons to question the physical integrity of the other metallic monitors inside the box. As a precaution, it was therefore decided to make a first γ spectroscopy analysis on the entire, unopened box: previous simulations of the expected γ-spectra seen by a Ge detector had shown that in the worst case, the thermal flux could still be resolved out of the ^{60}Co γ lines.

After opening the box, four monitors were retrieved that appeared to be in integral condition (Fig. 3.9). The remaining five were reduced to fragments and powder. All of the monitors and retrieved fragments were collected, labelled, their mass measured and their γ spectra measured before being stored in case further analysis will be needed. The measurement of the mass (see Table 3.7) gives, to a few percent, the initial masses of recovered monitors; their physical integrity is likely to be intact.

Table 3.7. Recovered monitors' initial masses and measured masses after retrieval. Note that the AlCo monitor is encapsulated in a titanium capsule whose mass was not precisely measured, hence the difference presented here.

monitor	ND No	measured mass (mg)	orig. monitor mass (mg)	mass ratio
AlCo	1	31.88000	5.576*	*
Fe	2	9.98000	9.889	1,009
Ni	5	12.04000	11.565	1,041
Rh	6	8.44000	8.236	1,025

We present here the results of the analysis on the AlCo and Ni monitors. The half-lives of the γ-emitters involved are all several orders of magnitude greater than the duration of the proton beam trips and/or beam stops. Therefore our analysis considers an average proton current value of 0.96 mA, as it has been precisely calculated from the proton beam data.

A comparison with more precise calculation that takes into account the actual proton beam history is presented in Fig 3.10 for the ^{59}Fe case, which is one of the shortest-lived gamma emitters considered in this study. In the figure is plotted the gamma activity of the ^{59}Fe daughter produced by ^{58}Fe(n,γ)^{59}Fe reaction in the iron monitor. The time evolution is performed by taking the calculated average neutron fluence rate at the iron monitor position. The two curves correspond to the gamma activity as a function of time calculated considering only an average proton current and the actual proton beam history respectively. An uncertainty of 5% is added to this second curve representing the uncertainty with which is known the instantaneous proton current. Fig 3.11 is a close-up at the end of the cooling period, when the actual activity of the monitor was measured. A discrepancy with the measured activity of a factor 1.6 is observed.

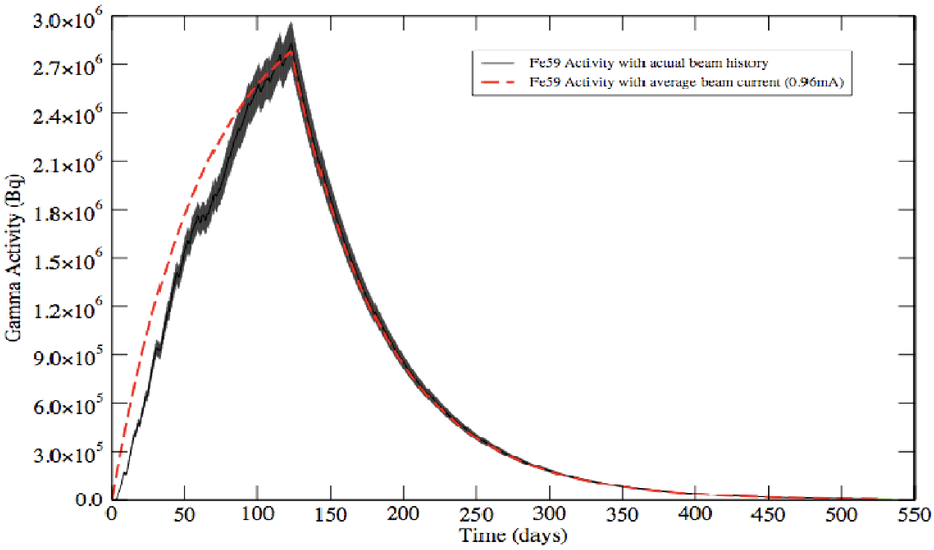


Figure 3.10. Time evolution of the gamma activity of the iron monitor calculated using an average proton current and the actual beam history.

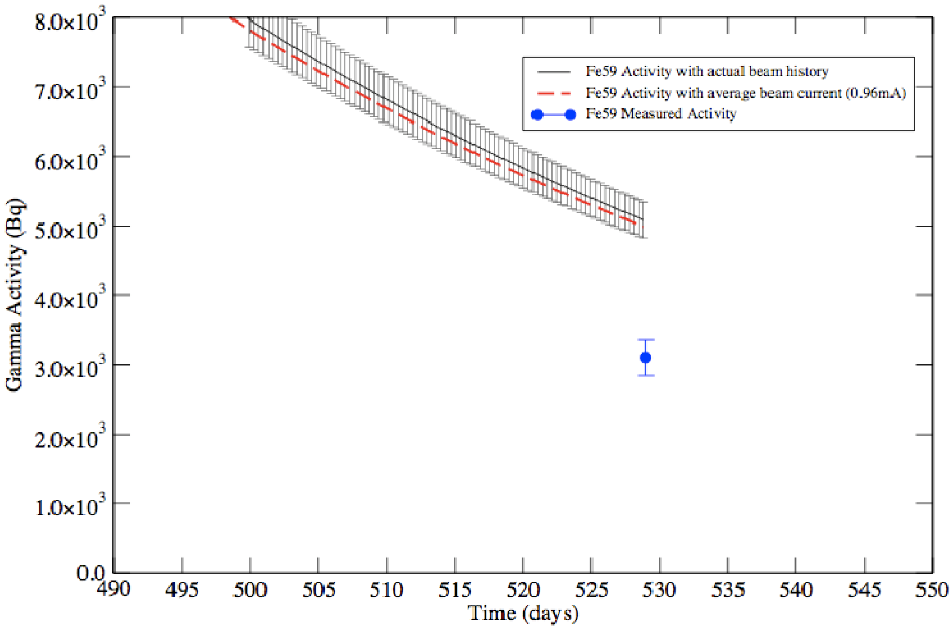


Figure 3.11. Close-up of the end of the time evolution of the gamma activity of the iron monitor calculated using an average proton current and the actual beam history.

A first approach can be taken in order to verify that the activities measured are compatible with the fission rates observed in the fission chambers: first, one simply interpolates linearly the expected average neutron flux value to the monitor's position, located in between the first and second chambers; depending on the Monte Carlo model used to estimate the fission cross sections, this interpolated flux value in the monitor position should be of about 2.0 x10^{13} n/cm²/s/mA. Then, analytical resolution of the simple Bateman equation leading to the formation of ^{60}Co (in the case of the AlCo monitor) or to ^{58}Co (in the case of the Ni monitor) is straightforward. Table 3.8 presents the activities of the monitors calculated analytically using this method of "interpolated" average flux (deduced from measures) and the average cross-section calculated with the reference MCNPX model.

From the results presented, we can clearly see from the "Bateman" column that the AlCo and Ni monitor activation measurements are in good agreement with the average flux extracted from the fission chambers measurement, provided that the calculated average cross sections are correct. It is important to note that the two γ emitter monitors are concerned by different energy ranges: thermal and epithermal for ^{60}Co, fast for ^{58}Co.

On the contrary, if we take the total average neutron flux simulated with the reference MCNPX model and we perform the evolution with the CINDER or the MURE code, the calculated activity does not agree with fission chamber measurements. This overestimation of the fission rates calculated with MCNPX using the MEGAPIE input reference geometry confirms the discrepancy presented in Section 3.4. This overestimation factor is not constant since it ranges from 2 to 3 depending on the z coordinate along the central rod.

Table 3.8. Activities measured and calculated: "Bateman" column gives the analytical value calculated with the corresponding cross section estimated with MCNPX and an interpolated total average neutron flux value deduced from measurements. The "CINDER" and "MURE" values are given by these codes using different cross sections and fluxes (63-group for CINDER, continuous for MURE), normalized to 0.947 mA of proton current.

Isotope	*A* measured (Bq)	*A* "Bateman"	*A* "CINDER"	*A* "MURE"
^{60}Co	4.41×10^5	4.51×10^5	8.48×10^5	8.90×10^5
^{58}Co	3.78×10^5	3.58×10^5	7.90×10^5	-

It is worth mentioning that the reaction rates measured with fission chambers were taken on the first week of the target operation and therefore reflect the initial conditions of the neutron spectrum, i.e. they are not sensitive to the evolution of (or the accumulation of spallation residues in) the LBE composition throughout the more than four months of irradiation. These are the conditions that have been simulated.

The observed discrepancies between the simulation and the measurements have pointed towards two other working hypotheses which have been investigated. The first is to quantify by an independent calculation the sensitivity of the neutron flux to the geometrical model used. The second is to address an eventual angular distribution of the proton beam source which could modify the actual proton intensity seen by the target.

3.6 A simplified model of the target

We developed a simplified model of the MEGAPIE target in order to test the impact of the "complexity" of the model on the simulated flux. In this simplified model, the geometrical description of the neutron detector, fission chambers and monitors is the same than in the complex one. Major simplifications have been done however: the fine level of detail in the upper part of the target (TKE description, EM pumps, etc.) has been removed, replaced by simple stainless steel (L316). The neutron beam lines are not reproduced and the entire volume of the moderator tank is filled with D_2O. Figure 3.12 shows a centered and vertical cut of the MEGAPIE target as simulated in our simplified MCNPX model and in the complex reference model.

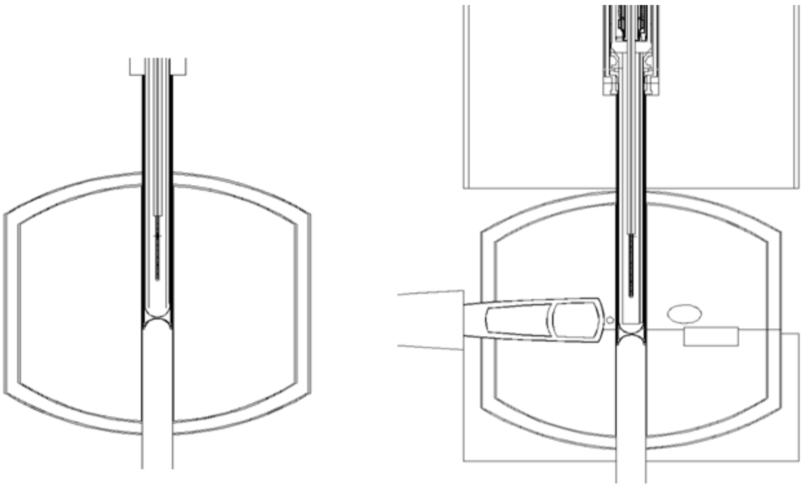


Figure 3.12. Comparison of the MCNPX models of the MEGAPIE target: simplified (left) and reference model (right).

Figure 3.13 illustrates the ratio between the neutron flux values calculated from the simplified model with respect to the reference one at the different fission chamber and monitor positions inside the detector. From the lowest fission chamber (at around 37 cm from the window) to the highest one we can see the agreement between both models deteriorates. Replacing the highly detailed geometry and consequently the materials considered does modify the neutron absorptions and reflections and this is seen by the fission chambers. The three points clustered at around *z* = 43 cm correspond to the AlCo, Fe and Ni monitors. The shadowing effect of the Gd monitor, closest to the iron monitor can be seen. The remaining points correspond to the four fission chamber positions along the *z* axis.

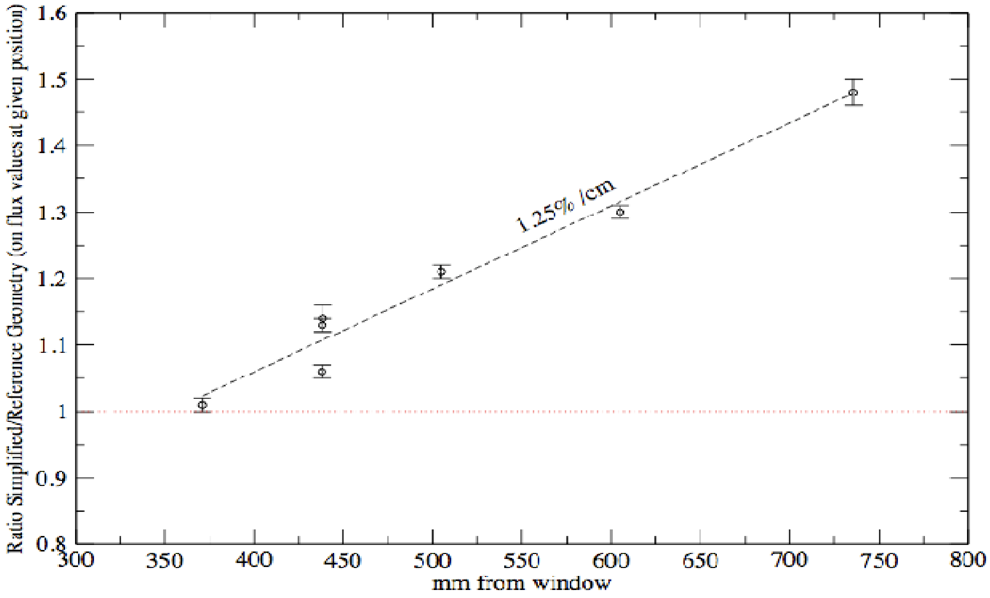


Figure 3.13. Ratios (simplified/complex) of the average neutron fluxes calculated by MCNPX with the two geometrical models of the target.

3.7 A modified source description

We investigated the sensitivity of a possible proton beam divergence on the simulated neutron flux in the central rod. In MEGAPIE the proton beam optics has been set in order to better focus the beam below the target window so as to diminish hot spots on the window and prevent local damages. This can create an angular distribution on the proton beam that reaches the LBE: this angular distribution is actually unknown and the study presented here is meant to evaluate the effect of the beam divergence.

The detailed proton source implemented in the MCNPX calculations used so far does not consider any angular distribution of the impinging protons: they are all parallel to the beam axis. We have considered several angular distributions of the source where the emitted protons have a uniform distribution along a revolving cone of a given maximum angular aperture, θ. A different entry angle of the source protons on the LBE determines the maximum possible length of the generated cascade in the LBE and has a direct effect on neutron production. We have considered different values for the parameter θ, from 0 to 35 degrees in steps of 5 degrees.

Fig. 3.14 shows the effect of this parameter on the average neutron flux calculated by MCNPX, and represents the ratio of the neutron flux simulated value to the actual measured one. The simulation is performed using the complex reference model and with the proton source (focal point) set at 10 cm below the target window. We can see that the simulation reproduces the measured flux value at NAA for a value of $\theta = 20°$. At this value, the discrepancies observed for the other locations are reduced, but still remain important. Also, for any given value of θ, the discrepancy observed always increases along the *Z* axis (the curves do not cross); leading to conclude that independently from the parameter θ, missing absorptions along the *Z* axis must play a role.

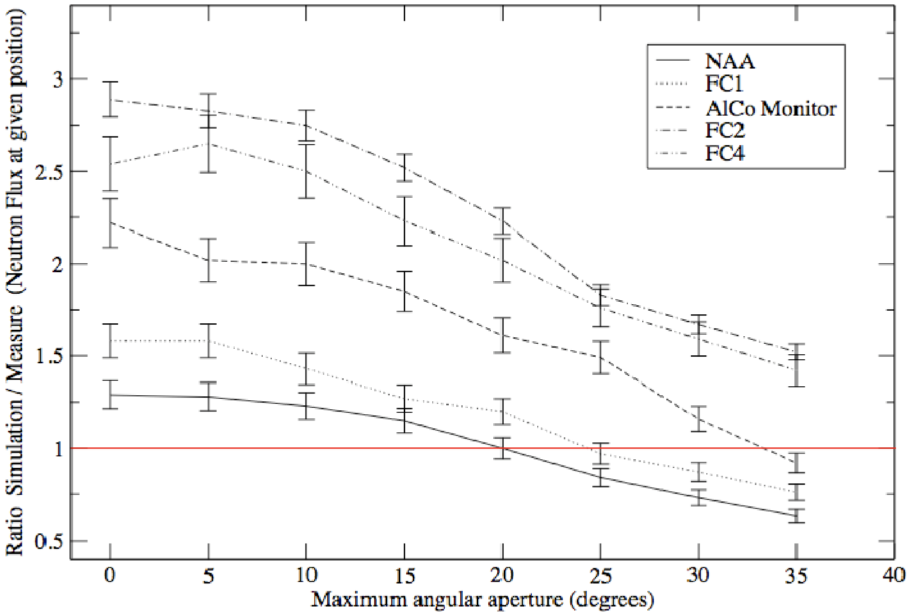


Figure 3.14. Ratios between calculated and measured neutron fluxes as a function of the the proton source angular aperture.

3.8 Conclusions

We presented a set of studies on the neutronics of the MEGAPIE spallation target, based on the measurement of the inner neutron flux and the simulation of the system. All the simulation studies show the importance of the insertion of the neutron detector inside the target to study macroscopic effects that could greatly modify estimated quantities such as, for example, activation residues.

From the experimental point of view, the data analysis shows a big discrepancy with respect to the calculations. On the other hand, flux monitors γ spectroscopy shows that the measured activities are compatible with the fission rates measured by the fission chambers. This good agreement between the data is present in case of thermal but also epithermal spectrum, meaning that the neutron energy distribution is correctly simulated. This means that the discrepancy comes probably from a missing normalization factor in the simulations which should be investigated further. Since it was shown on this chapter that the neutron production is not very sensitive to spallation models, we think that this missing factor does not come from the physics model used. Rather, the reason for the non correct reproduction of the experimental data may come from the intrinsic difficulty of calculating the fluxes in that particular position, in the central rod of MEGAPIE, where there is a high flux gradient with a mixed thermal/epithermal spectrum, and still an important contribution from fast neutrons. We will see in the following chapter that, at similar distances from the spallation target, but in the nearly completely thermalized spectrum, inside the heavy water tank, calculations and data are in better agreement.

4. OUTER NEUTRON FLUX MEASUREMENTS

4.1 Introduction

While in the previous chapter we have described neutron flux measurements inside the MEGAPIE target, in proximity to the proton interaction area, in this chapter flux measurements performed in several points of the SINQ facility, outside the spallation target, are treated. Several of these measurements were already performed in previous years, prior to MEGAPIE operation, with the solid spallation targets. Some of the measurements were repeated in 2007 when another solid target ("target 7") replaced MEGAPIE in SINQ. There is therefore the possibility to compare the performance of MEGAPIE with the conventional solid targets used until 2005, and in 2007 after MEGAPIE operation. Such information is obviously of great interest to SINQ, and to the spallation neutron source community in general, as the neutronic performance of a typical solid target can be compared with the innovative liquid metal target. In the general framework of the neutronic study and Monte Carlo code validation, these investigations are important also for ADS research.

Activation foils for thermal and epithermal neutron determination were irradiated at three beam lines of the SINQ facility: ICON, NEUTRA and EIGER; additionally, measurements were performed at the NAA irradiation station located inside the moderator tank. The measurement positions are shown in Fig. 4.1. Of the three beam lines, NEUTRA and EIGER are thermal neutrons lines, while ICON is a beam line for cold neutrons from a D_2 moderator placed inside the heavy water tank. The integral fluxes vary from about 10^{13} n/cm^2/s/mA at the NAA to about 10^8 n/cm^2/s/mA at the beam lines. Before describing the measurements and the results, some general considerations on the neutron flux in the SINQ facility, based on Monte Carlo simulations, are discussed.

4.2 The neutron flux in SINQ

The neutron spectral distribution in a moderated environment can be divided into three energy regions: below 1 eV is the region of the thermalized neutrons, in thermodynamic equilibrium with the thermal motion of the moderator atoms; between 1 eV and about 100 keV, there is the epithermal region or partially moderated neutrons, being slowed down by elastic collisions with the nuclei of the moderator substance; above these energies, there is the fast neutron component, which can be more or less important, depending on the target-moderator configuration. For the SINQ geometry, the latter component at the beam lines is generally at the per cent level.

The calculated radial distribution in the SINQ heavy water tank, of the neutrons with energy lower than 1 eV is shown in Fig. 4.2, for MEGAPIE and the target 6. These calculations have been performed with a model in which there are no beam inserts in the heavy water tank (we refer to the obtained fluxes as "unperturbed"). This figure is very interesting as it shows not only that the liquid metal target is more performing than the solid one, but also that the maxima in the distributions are reached at different radial distances from the target center. The maximum in the case of MEGAPIE is at about 20-22 cm, while in the case of the solid target is at about 17 cm. The liquid metal target is therefore advantageous in the SINQ facility, as most of the beam inserts are at about 20 cm from the center of the target. This is not an accidental result, as the SINQ facility was originally conceived as a facility with a liquid metal target[23]. Another interesting observation is that with MEGAPIE the thermal flux drops significantly at small radial distances, while in the case of the solid target a higher fraction of thermal neutrons is present close to the target center. Both effects are due to the presence, in the case of the solid target, of heavy water inside the spallation target.

Another interesting quantity to look at is the fraction of non-thermal neutrons as a function of the radial distance (Fig. 4.3). The distances of greatest interest are about 20 cm and 30-40 cm, corresponding to the positions of the thermal beam ports, and of the cold moderator, respectively. At 20 cm distance the fraction of non-thermal neutrons is quite high, between 20 and 30 %, with a slightly higher fraction in the case of MEGAPIE. At 40 cm distance this fraction is reduced to about 6% for both targets.

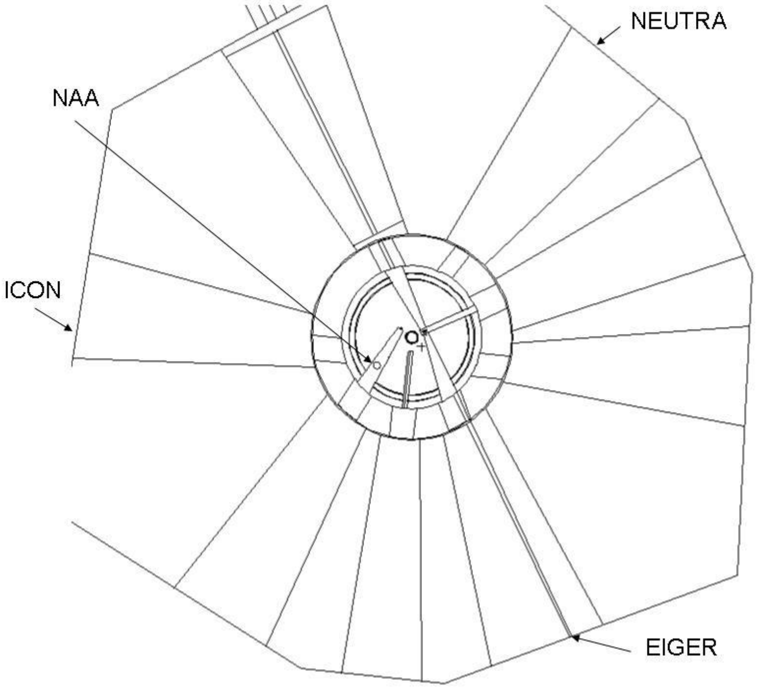


Figure 4.1. Schematic view from the FLUKA/MCNPX model of the measurement positions for ICON, EIGER and NEUTRA beam lines, and for the NAA station.

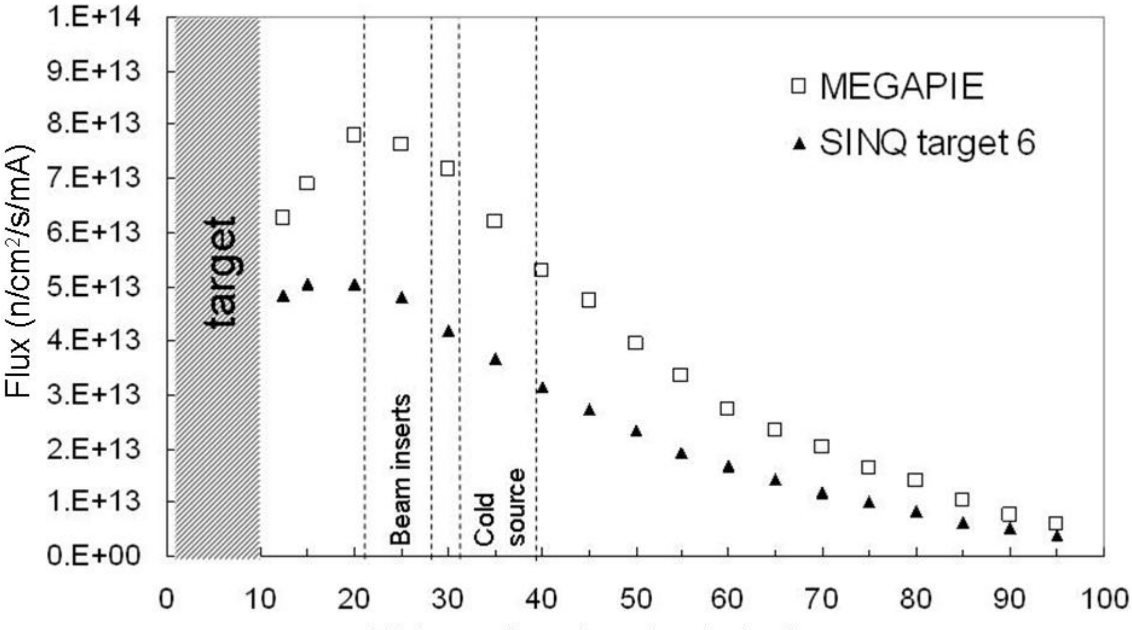


Figure 4.2. Calculated radial distribution of the integral thermal (*E*<1 eV) neutrons fluxes for MEGAPIE and solid target (target 6), for an unperturbed case.

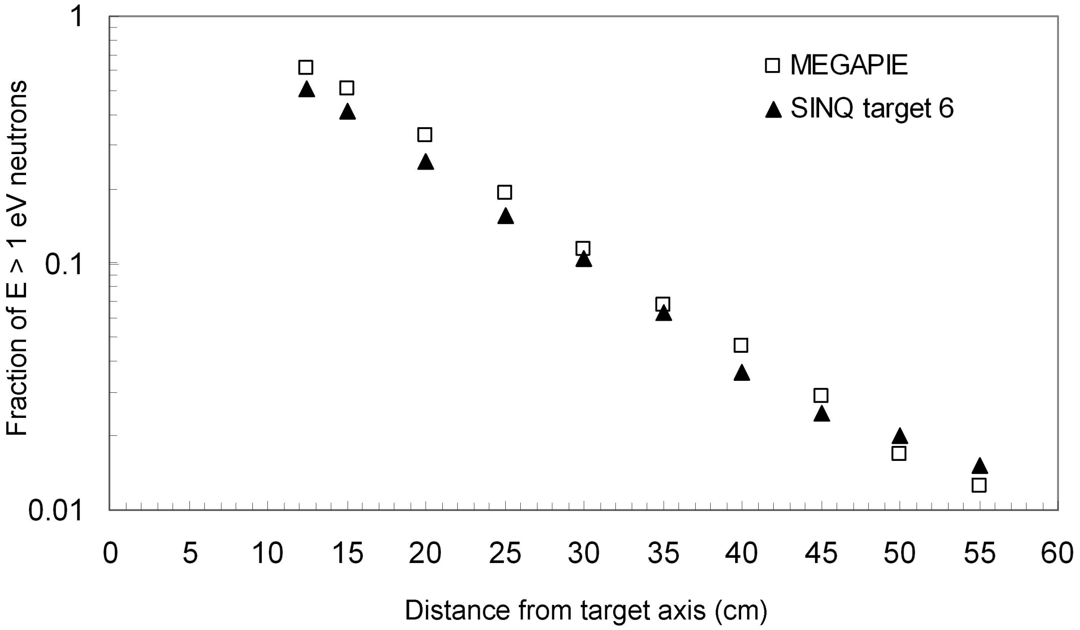


Figure 4.3. Calculated radial distribution of the fraction of non-thermal (E >1 eV) neutrons for MEGAPIE and solid target, for the unperturbed case.

The calculated neutron spectra at the exit points of the NEUTRA, ICON and EIGER beam lines and at NAA are shown in Fig. 4.4 with MEGAPIE. In the following four figures (Fig. 4.5 to 4.8), the calculated spectra with MEGAPIE and the two solid targets are shown. Spectra are shown per unit lethargy, where the lethargy u is defined as $u=ln(E_Q/E)$, with E_Q an arbitrary energy (typically it is chosen as the maximum possible neutron energy); to obtain the flux in these units, the calculated MCNPX values for an energy bin (in n/cm^2) are divided by the bin width, and multiplied by the mid energy value of each bin.

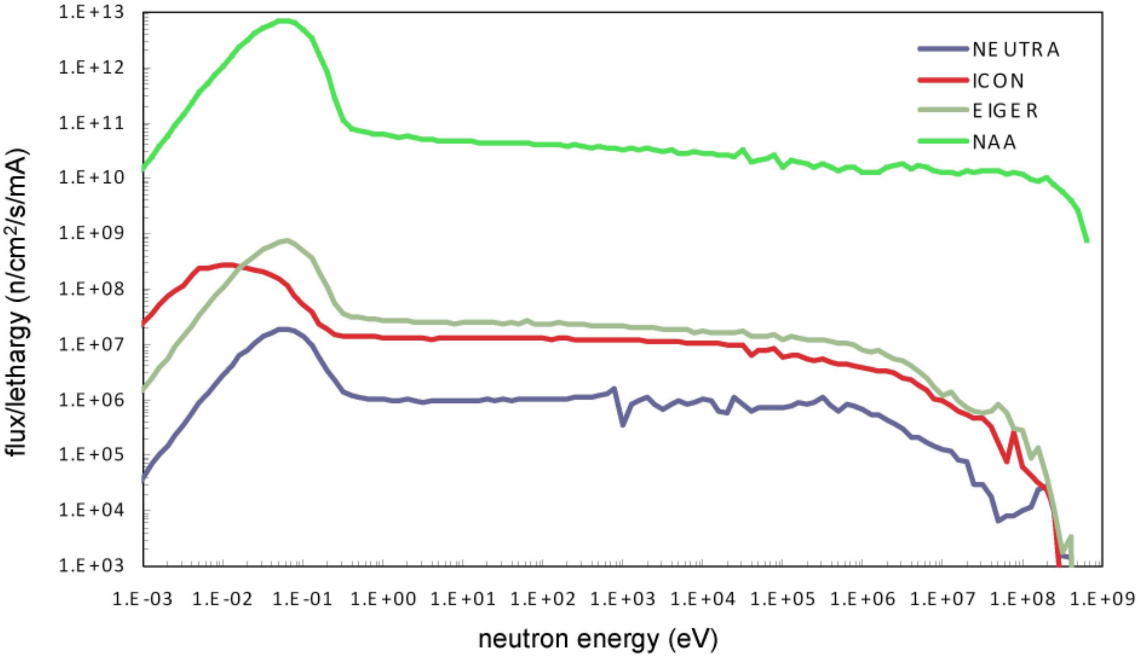


Figure 4.4. Calculated fluxes per unit lethargy at NEUTRA, ICON and EIGER with the MEGAPIE target.

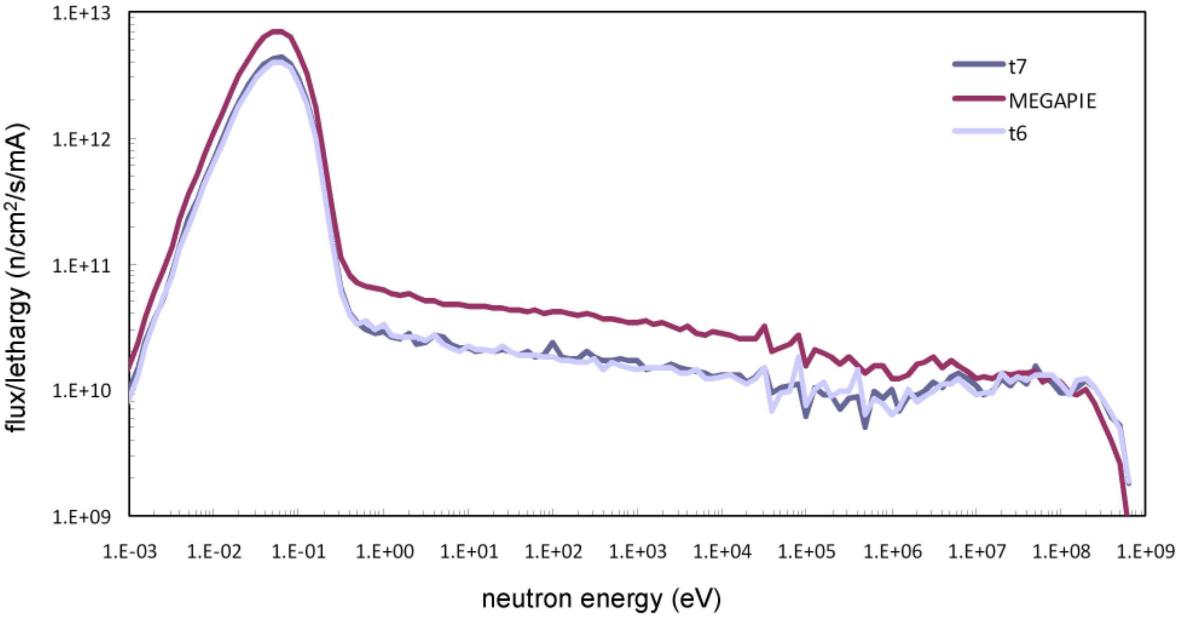


Figure 4.5. Calculated fluxes per unit lethargy at NAA with the MEGAPIE target and the two solid targets.

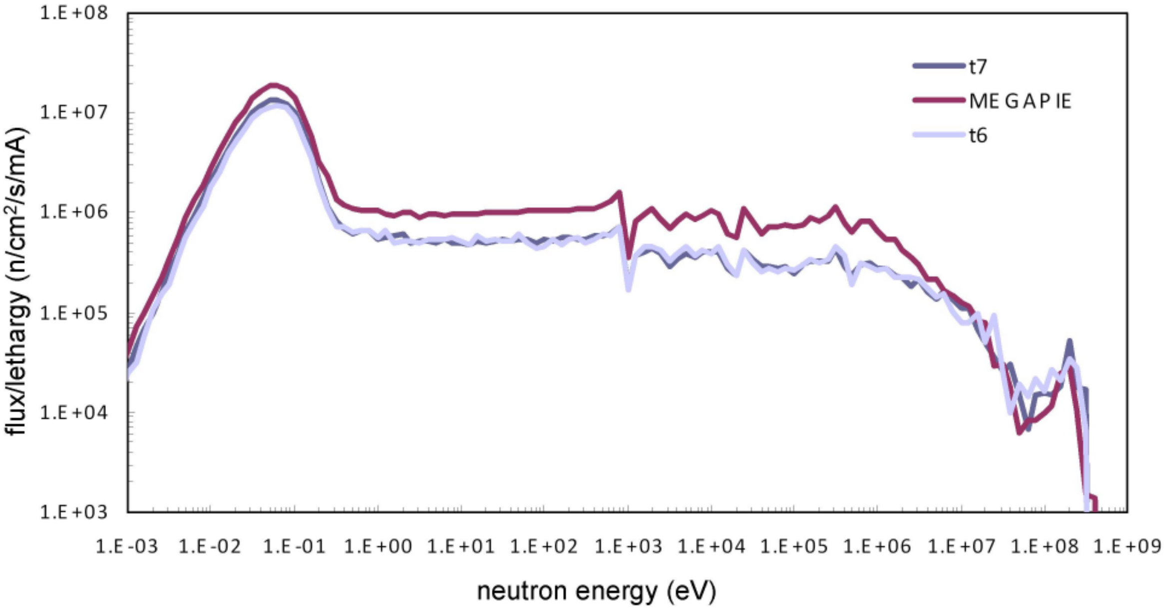


Figure 4.6. Calculated fluxes per unit lethargy at NEUTRA with the MEGAPIE target and the two solid targets.

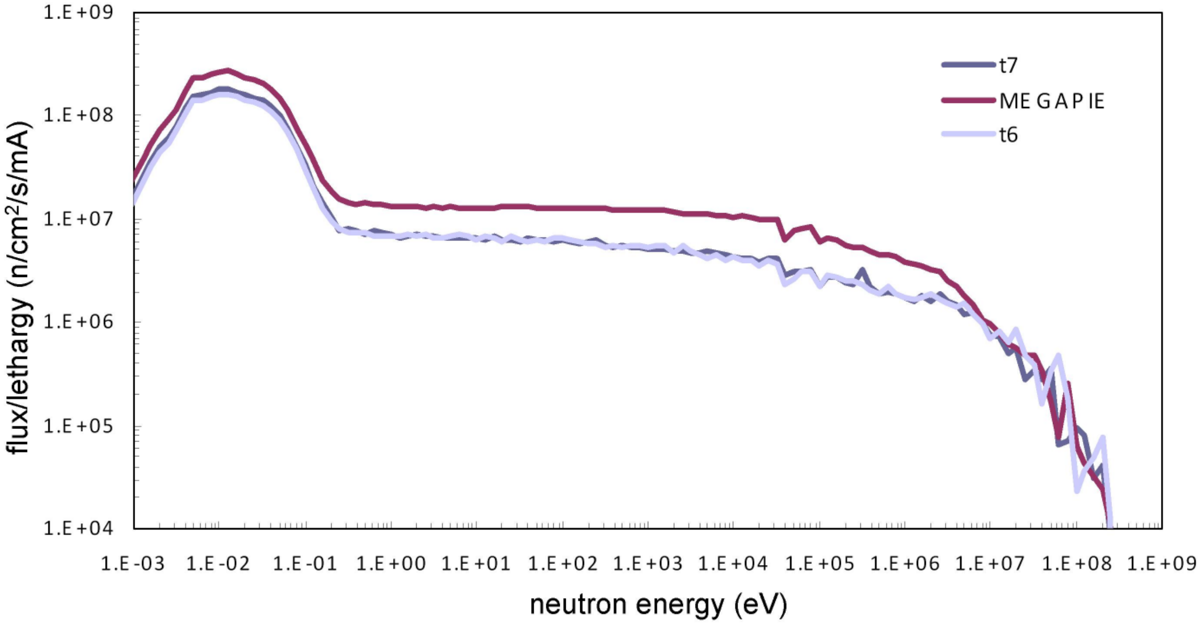


Figure 4.7. Calculated fluxes per unit lethargy at ICON with the MEGAPIE target and the two solid targets.

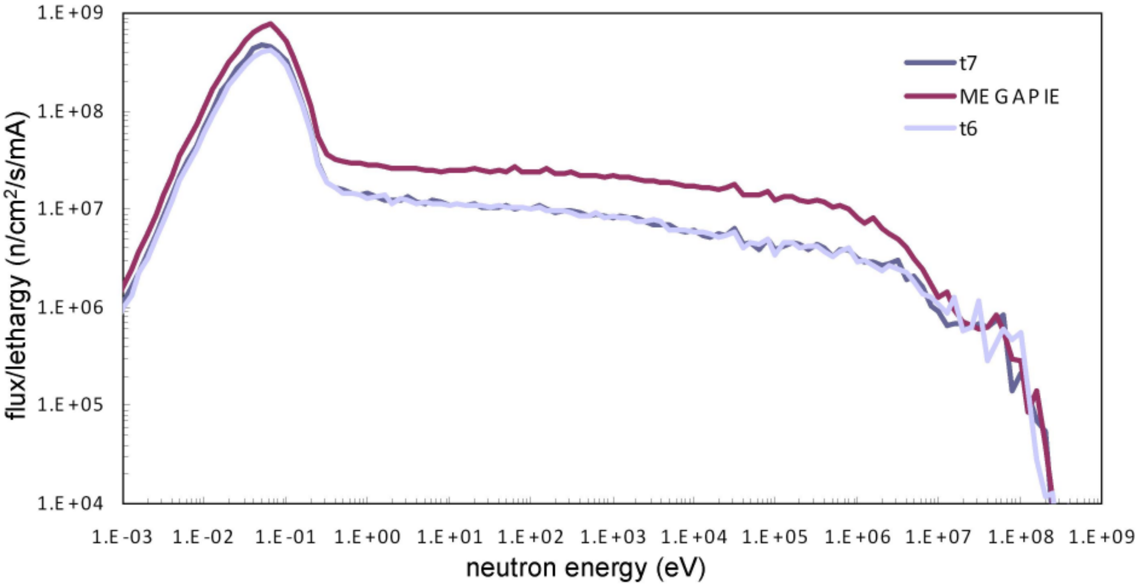


Figure 4.8. Calculated fluxes per unit lethargy at EIGER with the MEGAPIE target and the two solid targets.

4.3 The activation method

The activation method consists in the determination of the neutron flux from the measurement of the activity of irradiated samples of a suitable material. Two common materials used are gold and cobalt; these two elements are monoisotopic in the natural state, they have a well known capture cross sections in the thermal and resonance energy regions, they have a single resonance dominating the epithermal cross section (at 4.9 eV and 132 eV for Au and Co, respectively), and precisely known resonance integrals, thus allowing also an estimation of the epithermal flux.

Following the neutron irradiation, the activation *C* is defined as the number of radioactive atoms formed by neutron reaction per second and cm^2 of probe area. *C* depends on the thickness

d of the activation foil, on the incoming neutron flux ϕ and on the average macroscopic activation cross section:

$$C\left[\frac{atoms}{cm^2 s}\right] = \overline{\Sigma}_{act}\, \phi\, d\,, \tag{4}$$

where the macroscopic cross section is expressed as the product of the microscopic cross section by the number of target atoms per cm^3 , N_t:

$$\Sigma_{act}(E) = N_t \sigma_{act}(E)\,. \tag{5}$$

We recall that the macroscopic cross section (dimensions of cm^{-1}) is the inverse of the mean free path. The total activation *B(t)* is the number of radioactive atoms present per cm^2 of probe area. The total activation at a decay time t_d, following an irradiation time t_{irr} is

$$B(t_d)\left[\frac{atoms}{cm^2}\right] = \frac{C}{\lambda}\left(1 - e^{-\lambda t_{irr}}\right)e^{-\lambda t_d}\ , \tag{6}$$

the activity *A(t)* is given by

$$A(t_d)\left[\frac{1}{s}\right] = B(t_d)\lambda S = \lambda N(t_d), \tag{7}$$

where *S* is the foil surface area in cm^2.

From the above equations, the flux is given by:

$$\phi\left[\frac{n}{cm^2\ s\,mA}\right] = \frac{A(t_d)\lambda\, e^{\lambda t_d}}{\overline{\Sigma}_{act}\, d\lambda S\left(1 - e^{-\lambda t_{irr}}\right)I_p} = \frac{A(t_d)e^{\lambda t_d}}{(N_{AV}\ m/A)\overline{\sigma}_{act}\left(1 - e^{-\lambda t_{irr}}\right)I_p}, \tag{8}$$

since $N_t = \dfrac{N_{Av}\,[mol^{-1}]m[g]}{A[g/mol]\ V[cm^3]}$.

The flux defined in this way is in units of n/cm^2/s/mA. The quantity that is directly measured is the reaction rate *R* defined by:

$$R\ \left[s^{-1}\ mA^{-1}\right] = \phi\,\overline{\sigma}_{act} = \frac{A(t_d)\, e^{\lambda t_d}}{(1 - e^{-\lambda t_{irr}})\,(N_{AV}\ m/A)\,I_p}, \tag{9}$$

where *A*(*t*) is the activity after decay time *t* determined experimentally by means of γ spectroscopy. The reaction rate is normalized to the number of atoms in the sample, and to the proton current.

The thermal neutron flux is determined by subtracting the flux of a sample irradiated with the Cd cover from the flux of a sample made of the same material and irradiated without Cd cover; in this way the epithermal and fast component from the total spectrum are subtracted obtaining the thermal part. The flux of each sample is evaluated from Eq. 10:

$$\phi_{TH} = \frac{1}{(N_{AV}/A)\overline{\sigma}_{th}\, I_p}\left(\frac{A_{bare}(t_d)e^{\lambda t_d}}{m_{bare}(1 - e^{-\lambda t_{irr}})} - \frac{A_{Cd}(t_{d1})e^{\lambda t_{d1}}}{m_{Cd}(1 - e^{-\lambda t_{irr1}})}\right) \tag{10}$$

$$\phi_{EPI} = \frac{1}{(N_{AV}/A) I_{RES} I_p} \frac{A_{Cd}(t_{d1}) e^{\lambda t_{d1}}}{m_{Cd}(1 - e^{-\lambda t_{irr1}})} \quad , \tag{11}$$

with the second equation being a good approximation of the epithermal flux.

The resonance integral I_{RES} is defined assuming that the neutron spectrum above the cadmium threshold has a $1/E$ dependence, by the following equation:

$$I_{RES} = \int_{E_{CUT}}^{E_{MAX}} \frac{\sigma(E)}{E} dE, \tag{12}$$

where E_{CUT} is the cadmium threshold. It must be noted (as pointed out in Ref. [24]) that with this definition of I_{RES}, the obtained epithermal flux is the flux per unit logarithmic energy interval, or unit lethargy $u=ln(E_Q/E)$. The epithermal flux in lethargy units is constant; the epithermal integral flux, integrated between E_{CUT} and E_{MAX}, is given by

$$\Phi = \phi_{EPI} \Delta u = \phi_{EPI} \ln\left(\frac{E_{MAX}}{E_{CUT}}\right) = \phi_{EPI} \times 13.8, \tag{13}$$

where the factor 13.8 is obtained with E_Q=E_{MAX}=1 MeV (for SINQ) and E_{CUT}=1 eV. Because of the somewhat arbitrary threshold energies, the epithermal integral fluxes obtained in this way are only indicative.

4.4 NAA measurement

The Neutron Activation Analysis (NAA) station is an irradiation station located inside the heavy water tank, at about 80 cm from the center of the SINQ target (Fig. 4.9). At the NAA station, samples are placed inside polyethylene capsules, and sent to two irradiation positions by means of a pneumatic system. Gold and cobalt foils were irradiated to measure the thermal neutron flux. Some measurements were performed with the samples placed inside Cd capsules for thermal neutron absorption and correction for the activation due to non thermal neutrons as explained above.

Additionally, a set of threshold detectors was irradiated to measure reaction rates induced by neutrons with energy greater than 1 MeV. Measurements were performed in 2006 (MEGAPIE target) and 2007 (SINQ solid target). Foils of Al, Ti, Mn, Fe, Ni, and Cu were used. Reaction rates were obtained from γ spectroscopy measurements (see Fig. 4.9). Results from previous measurements existed and were compared.

The lists of activation measurements performed with the MEGAPIE target and with target 7 are shown in Table 4.1 and Table 4.2, respectively. For the threshold detectors, irradiation times up to 1 hour were applied, with proton beam currents of about 1 mA. After irradiation, the activities in the foils were measured using an HPGe detector previously calibrated. A typical γ spectrum is shown in Fig. 4.10. The analysis of the γ spectra was performed using the GENIE software[25].

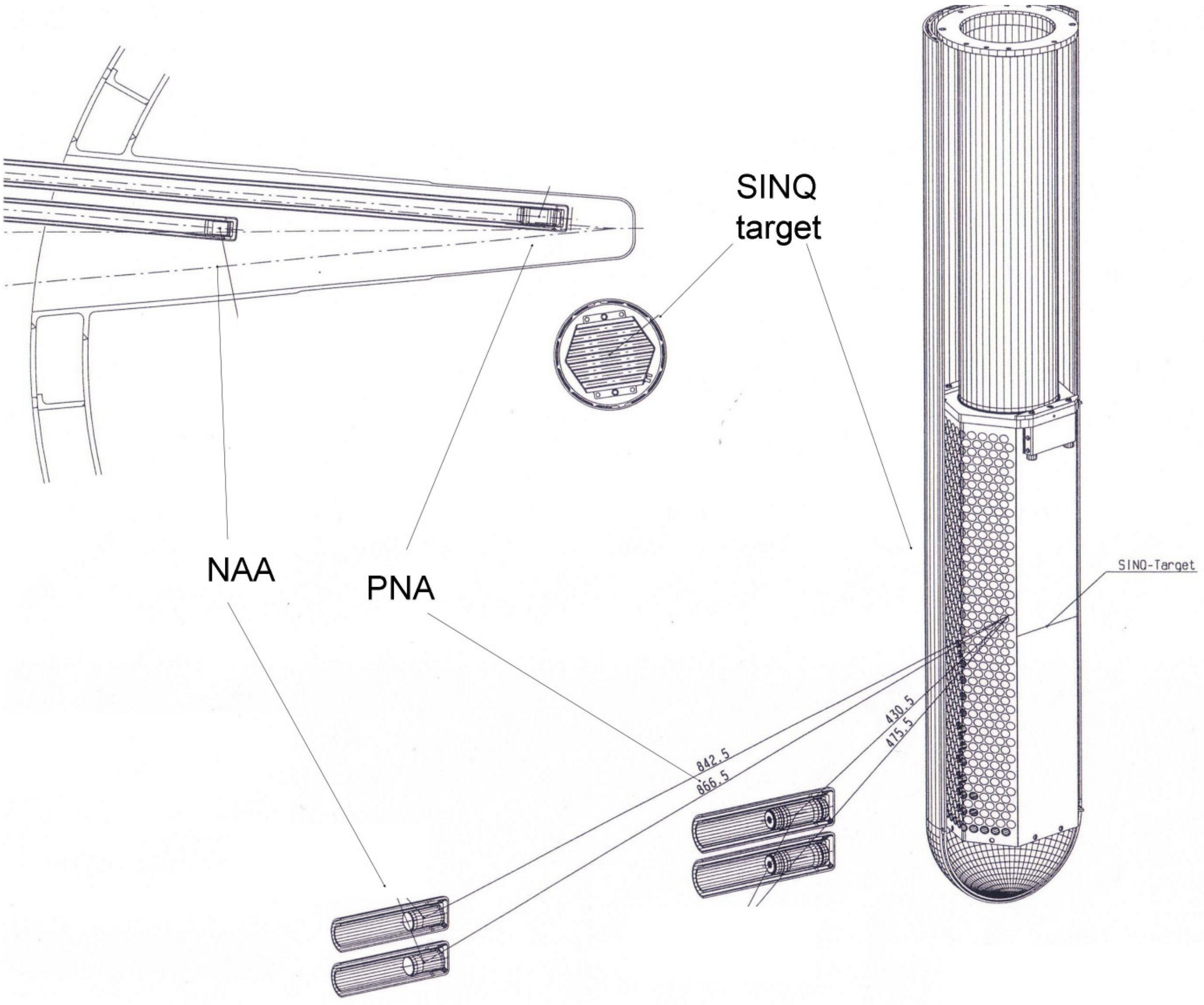


Figure 4.9. The NAA and PNA stations at SINQ.

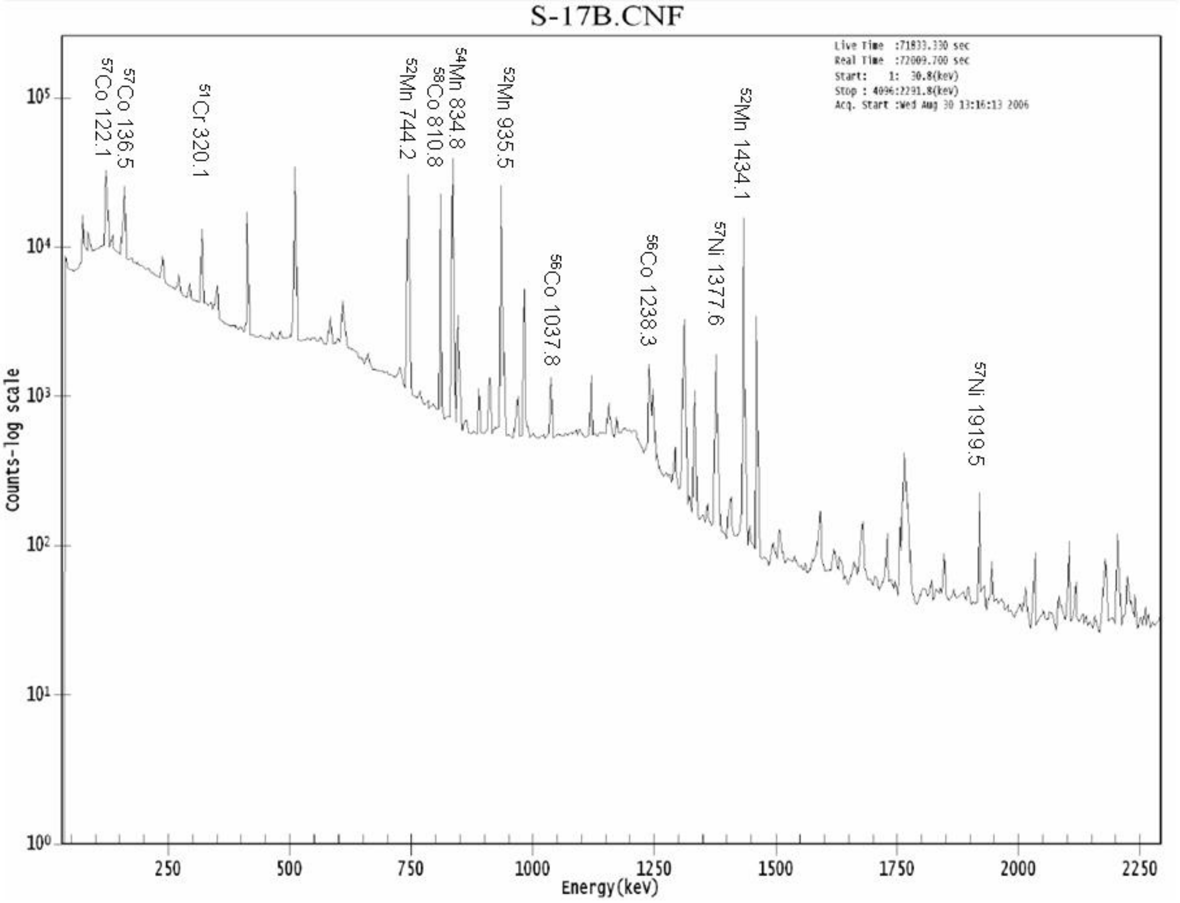


Figure 4.10. Gamma spectrum from irradiated Mn sample measured with the MEGAPIE target. γ line energies (in keV) of identified isotopes are indicated.

Precise chemical composition was available for most of the foils used for threshold detectors, with the exception of Cu and Co. The Mn sample consisted in fact 89.8 % of Mn and 10.1% of Ni. The only significant impurity in the other foils was 0.23 w% of Fe present in the Al foil.

Table 4.1: Foil activation list at NAA in 2006 (MEGAPIE target). Note that the current from the NAA monitor was not correct, and the one directly coming from the SINQ monitor system was used.

Element	Sample	Mass (mg)	Cd cover	Irradiation time (s)	Current (μA) NAA monitor	Current (μA) from SINQ	End irr. time
DAY 1		14.08.2006					
Au	33	11.69	No	10	42	39.5	16:39:08
Au	7	34.81	Yes	300	42	39.2	16:56:30
DAY 2		15.08.2006					
Au	34	12.29	No	10	167.9	200	15:13:54
Co	29	53	No	60	185.7	199.9	15:26:24
Co	30	56.09	Yes	60	234.7	250	16:00:51
Au	8	43.24	Yes	900	237.9	163.1	15:50:00
DAY 3		24.08.2006					
Au	35	9.14	No	60	876.3	960.4	10:36:41
Co	31	53.5	No	60	669.6	956.8	10:46:06
Au	2	43.68	Yes	3660	693.6	753.1	12:14:27
Au	1	36.17	Yes	3660	693.6	753.1	12:14:27
Au	9	39.60	Yes	3660	693.6	753.1	12:14:27
Mn	17	94.66	Yes	3660	693.6	753.1	12:14:27
Ti	24	488.06	Yes	3660	693.6	753.1	12:14:27
Cu	14	1014	Yes	3660	693.6	753.1	12:14:27
Co	32	56.84	Yes	3600	825.2	897.9	14:51:46
Al	10	152.2	Yes	3600	825.2	897.9	14:51:46
Ni	20	907.9	Yes	3600	825.2	897.9	14:51:46
Ti	25	55.96	Yes	3600	825.2	897.9	14:51:46
Ti	26	56.42	Yes	3600	825.2	897.9	14:51:46
DAY 4		13.10.2006					
Fe	A	121.5	Yes	900	1060.3	1207.2	14:50:00
Fe	B	118.3	Yes	2700	1065.2	1205.8	15:39:00
Au	3	36.13	No	60	1034.1	1207.7	14:16:00
Au	4	37.7	Yes	120	1065.1	1203	14:28:00

Table 4.2: Foil activation list at NAA in 2007 (target 7). All measurements were performed at full power, with beam currents close to 1.3 mA.

Element	Sample	Mass (mg)	Cd cover	Irradiation time (s)	Date	End irr. time
Au	3	36.13	No	60	04.05.2007	10:34:00
Au	4	37.7	Yes	60	04.05.2007	10:44:00
Co	42	49.79	No	60	04.05.2007	10:50:00
Co	43	50.66	Yes	60	04.05.2007	10:58:00
Au	7	34.81	No	60	04.05.2007	14:48:00
Au	8	43.24	Yes	60	04.05.2007	14:52:00
Ti	A	143.5	Yes	3600	08.05.2007	16:33:00
Al	13	75.33	Yes	3600	08.05.2007	16:33:00
Fe	D	118.5	Yes	3600	09.05.2007	10:10:00
Co	I	61.3	Yes	60	09.05.2007	10:31:00
Co	H	63.8	Yes	60	09.05.2007	10:37:00
Ni	A	283.5	Yes	3600	09.05.2007	11:47:00
Cu	E	148	Yes	3600	09.05.2007	11:47:00
Mn	1	64.16	Yes	3600	09.05.2007	11:47:00
Au	1	36.17	Yes	60	24.05.2007	9:44:00
Au	2	43.68	No	60	24.05.2007	9:48:00
Au	33	11.69	Yes	60	24.05.2007	9:53:00
Au	34	12.29	No	60	24.05.2007	9:57:00
Ni	B	282.8	Yes	1800	24.05.2007	10:32:00
Cu	F	147.5	Yes	1800	24.05.2007	10:32:00
Mn	8	95.71	Yes	1200	24.05.2007	11:49:00
Co	J	61.5	Yes	60	19.06.2007	13:38:00

4.5. Measurements at the beam lines

Measurements were performed at the ICON, NEUTRA and EIGER beam lines, right at the exit of the SINQ target block (see Fig. 4.1). ICON is one of the cold neutron beam lines with direct view to the cold source. NEUTRA and EIGER are thermal neutron beam lines.

Gold foils were placed at the exit of the beam lines. At ICON and EIGER some gold foils were covered with Cd in order to correct for the epithermal component.

Such measurements were performed since 2000 at the NEUTRA beam exit, and in 2005, 2006 and 2007 at ICON and EIGER. We discuss in the following the detailed analysis for each beam line. Flux values presented in Tables 4.3 to 4.7 are uncorrected values. The final, corrected values are the ones reported in Tables 4.10 and 4.11.

4.5.1 NEUTRA

In 2005 and 2006 two sets of measurements were performed; for each set, three foils were irradiated. The foils were circular, with 1 cm diameter, and the vertical distance between the center of the foils was 2.5 cm. Results from the measurements performed in 2005, 2006 and 2007 are shown in Table 4.3.

The values at the different vertical positions are very close, indicating that the beam profile is uniform in the considered area, and we can take the average between the measurements. We note however a systematic difference between the 2005 measurements performed in June and July, of about 13 %. The difference in 2006 is lower, about 5 %. The reason for this discrepancy is not clear, as the samples were placed always in a reference with a precision better than a few per cent. One reason for the discrepancy could be related to a non perfect calibration of the beam monitors (the two 2005 measurements were performed at different currents, 0.5 mA and 1.1 mA, respectively). The average of the six measurements was taken, and a larger systematic uncertainty was considered.

Table 4.3. Flux measurement at NEUTRA.

Date	Mass (mg)	Uncorrected flux ($n/cm^2/s/mA$)
Target 6		
15.06.2005	27.31	2.83E+07
15.06.2005	28.51	2.79E+07
15.06.2005	25.33	2.78E+07
05.07.2005	23.23	2.35E+07
05.07.2005	27.1	2.45E+07
05.07.2005	3.37	2.61E+07
MEGAPIE		
31.08.2006	3.44	5.02E+07
31.08.2006	3.44	5.04E+07
31.08.2006	3.18	5.07E+07
16.11.2006	4.81	4.88E+07
16.11.2006	3.43	4.82E+07
16.11.2006	3.2	4.66E+07
Target 7		
29.05.2007	23.62	2.80E+07
29.05.2007	27.15	2.71E+07
29.05.2007	3.37	2.96E+07

4.5.2 ICON

The first measurements at ICON were performed in 2005. Five irradiation foils were placed next to each other forming a square (with one foil in the center). Measurements were performed with and without Cd cover. Measurements in 2006 and 2007 were performed using a sample holder in which 6 samples at the time could be placed (Fig. 4.11). A 1 mm thick layer of Cd was placed in front of the samples in position 4, 5, and 6. Results are shown in Table 4.4 (2005 measurements) and 4.5 (2006 and 2007 measurements). As shown in Table 4.5, foils in positions 3 give flux values 10 to 15% lower than the average values from positions 1 and 2. The same is observed for the position 6 with respect to positions 4 and 5. Clearly the flux is lower at those positions; we consequently considered the average from positions 1 and 2 for thermal (4 and 5 for epithermal). A similar effect is found for the 2005 measurements (Table 4.4) and also in this case the three measurements with higher flux were considered.

Table 4.4. Flux measurement at ICON in 2005.

Date	Mass (mg)	Uncorrected flux ($n/cm^2/s/mA$)
05.07.2005	169.8	4.25E+08
05.07.2005	194.2	4.93E+08
05.07.2005	177.4	4.73E+08
05.07.2005	173	4.21E+08
05.07.2005	190.9	4.93E+08
05.08.2005	143*	1.77E+07
05.08.2005	146.3*	2.05E+07
05.08.2005	138*	2.00E+07
05.08.2005	124.6*	1.88E+07
05.08.2005	142.2*	2.05E+07

*foil covered by 0.5 mm Cd layer

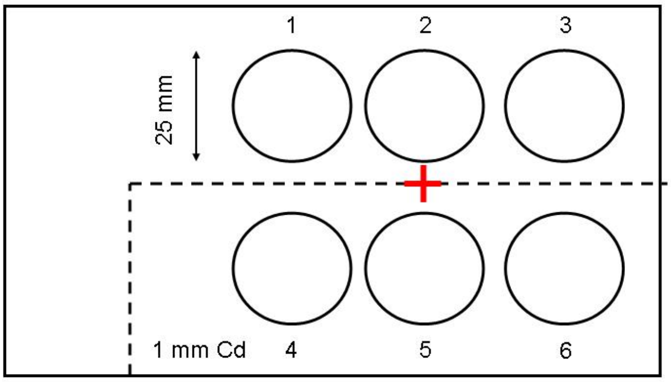


Figure 4.11. Sample holder used in 2006 and 2007 measurements at ICON. The cross represents the center of the beam collimation system.

Table 4.5. Flux measurement at ICON in 2006 and 2007. For sample position see Fig. 4.11.

Date	Sample nr	Mass (mg)	position	Uncorrected flux ($n/cm^2/s/mA$)
MEGAPIE				
31.08.2006	81	174.9	1	8.94E+08
31.08.2006	82	174.0	2	9.07E+08
31.08.2006	83	189.4	3	8.10E+08
31.08.2006	84	178.3*	4	5.72E+07
31.08.2006	85	172.2*	5	5.84E+07
31.08.2006	86	177*	6	5.06E+07
Target 7				
19.04.2007	200	251.9	1	5.37E+08
19.04.2007	201	236.6	2	5.15E+08
19.04.2007	202	262.5	3	4.58E+08
19.04.2007	204	261.4*	4	1.77E+07
19.04.2007	205	257.3*	5	1.60E+07
19.04.2007	206	238.7*	6	1.48E+07

*foil covered by 0.5 mm Cd layer.

4.5.3 EIGER

The EIGER beam line has three special characteristics:

- the beam line looks to the water scatterer placed nearby the target;
- the collimation is coated by supermirrors;
- a sapphire filter to reduce the epithermal component of the neutron flux is situated in front of the supermirror guide.

To observe the expected vertical neutron flux distribution at the guide exit, several gold foils were positioned along the vertical beam center. The diameter of each foil was 10 mm. In 2005 and 2006 only seven and five vertical measurement positions were used, respectively (see Fig. 4.12). To get a more detailed vertical flux distribution the number of positions was increased to 11 in 2007 (Fig. 4.13). The foils were distributed over a vertical length of 13 cm. Furthermore, the positioning was done with a previous beam image measurement using image plates. In this way the gold foils could be precisely positioned.

The measurements made are reported in Tables 4.6 and 4.7.

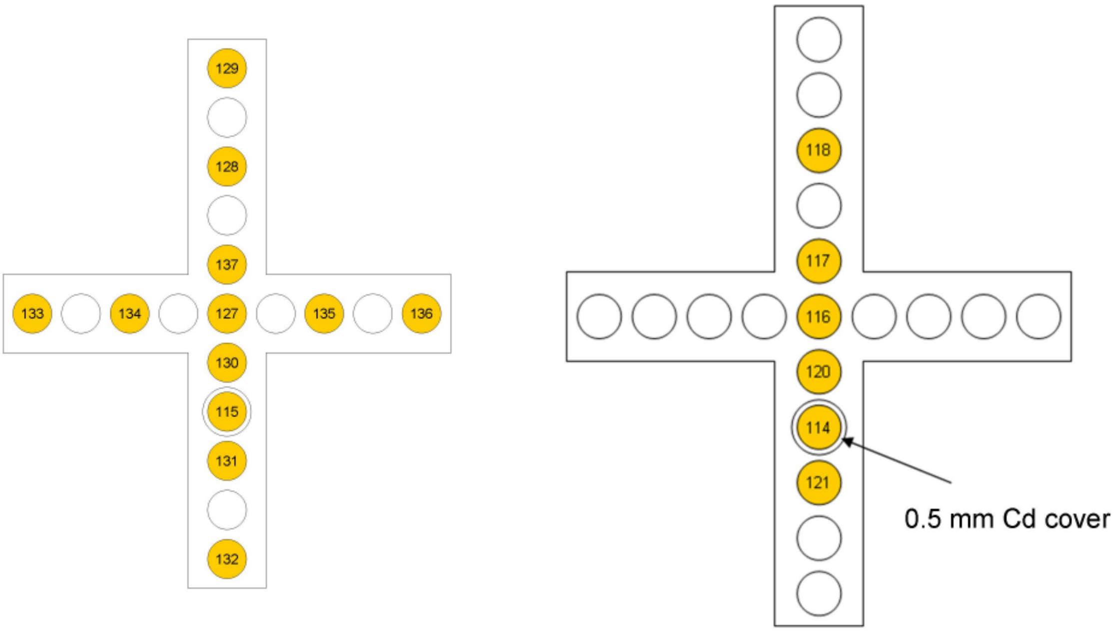


Figure 4.12. The arrangement of gold foils during the EIGER flux measurement in 2005 (left) and 2006 (right).

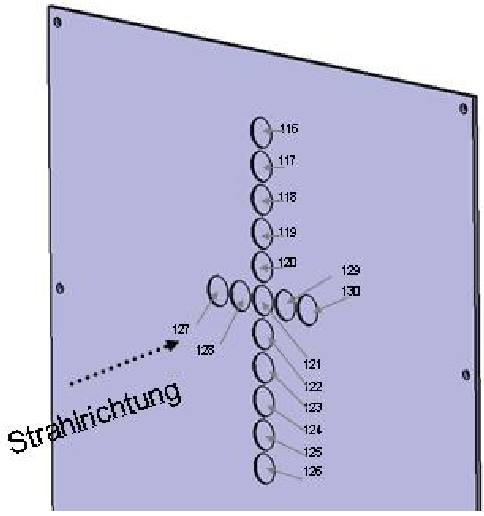


Figure 4.13. The arrangement of gold foils during the EIGER flux measurement in 2007.

In 2007 an extensive study of the beam profile at EIGER was performed by simulations and experiments. The goal was to get a good knowledge of the beam line in order to build there a highly sophisticated Triple-Axes spectrometer. The effects due to the supermirrors were investigated in detail because of their influence on the beam profile.

The measurements made are reported in Table 4.7. The comparison of absolute neutron fluxes for simulated and measured values is shown in Fig. 4.14. The simulations were performed by a coupled MCNPX and McStas model. In Fig. 4.14 (left side) the agreement looks satisfactory for the central part of the profile. At the edges we can observe small differences which can be explained by the simplified model (no vertical flux distribution was considered for the water scatterer) or by uncertainties of the measurements. In fact each simulated data point represents exactly the size of a gold foil. To compare the beam profile more precisely, a second simulation was done where the number of data points was increased to 200. Afterwards the simulation was compared with the image plate measurement which delivers a high resolution beam profile on relative scale. The results are shown in Fig. 4.14 (right side). Now the simulated and measured vertical beam profiles are showing a nearly perfect agreement. Only the effect of the inhomogeneous flux distribution at the water scatterer surface results in the small differences on one side of the beam profile.

Table 4.6. Gold foil measurements at EIGER in 2005 and 2006. See foil positions in Fig. 4.12.

Date	Foil number	Horizontal position (cm)	Vertical position (cm)	Mass	Uncorrected flux (n/cm^2/s/mA)
Target 6					
15.06.2005	84			178.3	5.78E+08
15.06.2005	85			172.1	5.37E+08
15.06.2005	86			177	5.33E+08
15.06.2005	87			173.5	5.34E+08
10.08.2005	129	0	12.5	2.78	8.77E+05
10.08.2005	128	0	7.5	3.58	3.83E+07
10.08.2005	137	0	2.5	3.25	5.53E+08
10.08.2005	127	0	0	3.07	5.31E+08
10.08.2005	130	0	-2.5	4.82	5.38E+08
10.08.2005	115*	0	-5.0	27.1	4.36E+06
10.08.2005	131	0	-7.5	3.13	5.26E+08
10.08.2005	132	0	-12.5	3.99	9.17E+05
10.08.2005	133	-6	0	4.24	1.62E+06
10.08.2005	134	-3	0	3.43	4.71E+06
10.08.2005	135	3	0	3.43	2.80E+07
10.08.2005	136	6	0	3.2	2.00E+06
MEGAPIE					
16.11.2006			7.5	2.93	1.57E+07
16.11.2006	117		2.5	3.37	8.85E+08
16.11.2006	116		0	2.95	8.40E+08
16.11.2006	120		-2.5	2.75	8.35E+08
16.11.2006	114		-5	23.2*	9.29E+06
16.11.2006	121		-7.5	3.77	9.44E+08

*foil covered by 0.5 mm Cd layer

Table 4.7 Flux measurement at EIGER in 2007. See foil position in Fig. 4.13.

Date	Sample	Horizontal position (cm)	Vertical position (cm)	Mass (mg)	Uncorrected flux (n/cm^2/s/mA)
13.06.2007	116	0	6	39.41	5.53E+08
13.06.2007	117	0	4.8	39.2	5.28E+08
13.06.2007	118	0	3.6	40.82	4.96E+08
13.06.2007	119	0	2.4	39.46	4.86E+08
13.06.2007	120	0	1.2	39.9	4.78E+08
13.06.2007	121	0	0	39.98	4.68E+08
13.06.2007	122	0	-1.2	40.68	4.74E+08
13.06.2007	123	0	-2.4	40.56	4.75E+08
13.06.2007	124	0	-3.6	41.41	4.79E+08
13.06.2007	125	0	-4.8	41.16	5.00E+08
13.06.2007	126	0	-6	41.05	5.20E+08
13.06.2007	127	-2.4	0	41	7.70E+06
13.06.2007	128	-1.2	0	41.29	3.88E+08
13.06.2007	129	1.2	0	42.1	1.11E+08
13.06.2007	130	2.4	0	42.55	2.56E+06

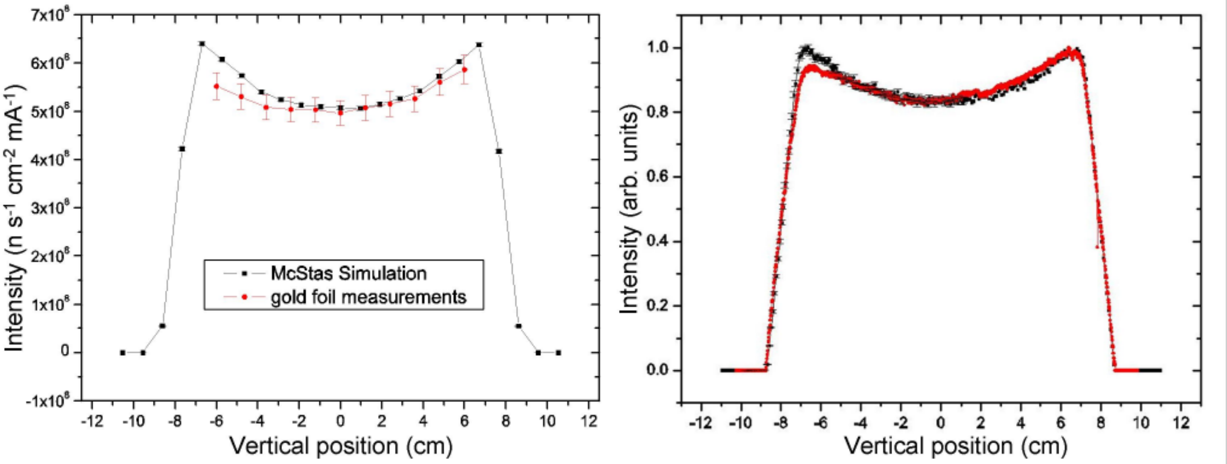


Figure 4.14. *Left*. Vertical distribution of the absolute thermal neutron flux at the guide exit of the EIGER beam line. Comparison between gold foil measurements and McStas simulation. *Right*. Vertical distribution of the thermal neutron flux on a relative scale taken at the guide exit of the EIGER beam line. Comparison between image plate measurement and McStas simulation. 2007 measurements.

4.6 Results

4.6.1 Systematic corrections

There are a number of effects that can systematically affect the measurement of the neutron flux using activation foils[26]. The most important are the following.

Self shielding: even if thin foils are used in the measurements, the finite thickness implies that as the neutrons cross the foil, the neutron flux is diminished due to neutron absorption, and this will induce a lower activation in the foil.

Elastic scattering: a neutron crossing the foil might be scattered without being captured. In practice, in the thermal energy region the capture cross section strongly dominates, however this is not necessarily the case in the epithermal region. The two physical processes, scattering and absorption, can combine to give a total self-shielding factor. The total self-shielding factors $G(t)$ as a function of the foil thickness have a different behaviour, whether the material has a high capture cross section of a high scattering cross section. In the first case, $G(t)$ is always lower than 1; in the second case, G(t) can be higher than 1 for some foil thicknesses, because neutrons with energies equal to the resonance energy can have one or more scattering interactions in the foil, before being captured at a lower energy (and higher cross section). Typical examples are gold (high absorption cross section) and manganese (high scattering cross section).

Foil perturbation: introducing a probe to measure the neutron flux will affect the flux itself, in presence of backscattering. In fact, neutrons that are absorbed in the probe are absent in the backscattered flux. This correction might be non negligible at the NAA, which is placed inside the heavy water tank.

Self-shielding corrections are very different for thermal and resonance neutrons. Thermal neutrons are absorbed in gold foils with an average capture cross section of about 100 barn. In first approximation, one can use the formula for the attenuation law; the fraction of absorbed neutrons for a foil of thickness d is $1-exp(-\Sigma d)$, which gives a 1% attenuation for foils of 20 μm thickness. In reality the correction is slightly higher than that, and we have assumed a 2% systematic correction for gold foils of that thickness, for the NEUTRA and EIGER measurements. In the case of ICON and NAA we took a correction factor of 4%, because in the case of ICON the lower average neutron energy implies a capture rate approximately double, while in the case of NAA, which is in the middle of the water tank, neutrons coming from all directions will travel on average a larger distance in the foil.

For epithermal neutrons the self-shielding correction can be very large. In the case of gold, the resonance integral is strongly dominated by the 4.9-eV resonance, with a cross section of about 1550 barn. Epithermal neutron resonance self-shielding factors have been measured and calculated in several works (see for instance Ref. [27] and references therein). As shown in Fig. 4.15 an epithermal self-shielding factor of about 0.4-0.6 is expected for a gold foil of 10 µm thickness. The effect is higher for isotropic beams, as in this case the distance traveled by the neutrons in the foils is larger. While for the measurements at ICON, EIGER and NEUTRA we can assume that the beam is well collimated and hitting the foil perpendicularly, at the NEUTRA station we are closer to the isotropic situation, as the station is placed inside the heavy water tank. It is however not a fully isotropic situation as the neutron flux at the station is dominated by neutrons coming from the target. We have considered in this case a self-shielding factor as the average between the collimated an isotropic case. Self-shielding factors extracted from Fig. 4.15 are listed in Table 4.8.

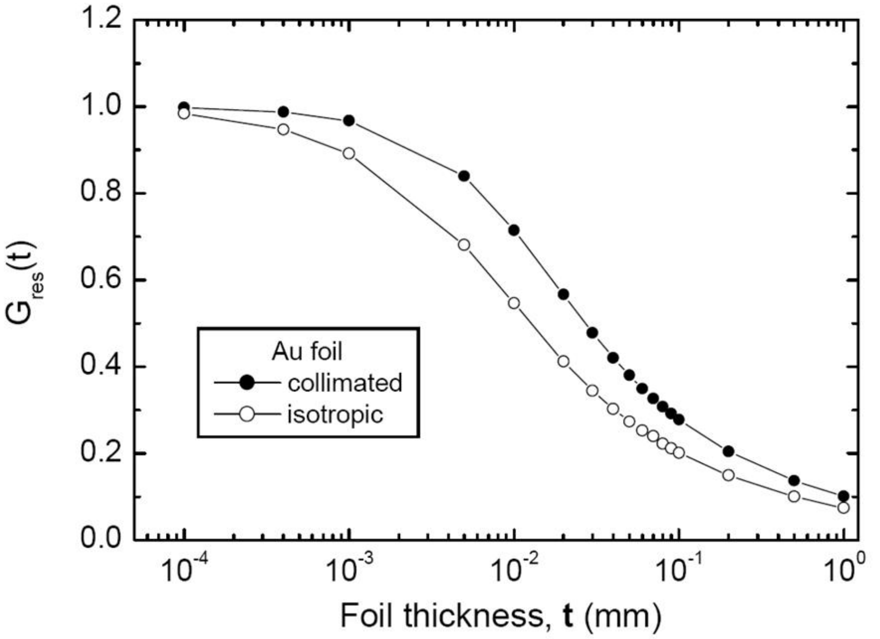


Figure 4.15. Calculated resonance self-shielding factors of gold foils of different thickness, for isotropic and collimated beam, after Ref. [27].

Table 4.8. Epithermal self-shielding factors extracted from Fig. 4.15 for different foil thicknesses *t*, and for the collimated and isotropic case.

t (µm)	Collimated	Isotropic
0.1	.989	.948
1	.968	.895
5	.840	.681
10	.716	.546
20	.567	.413
25	.521	.379
30	.480	.344
40	.397	.303

4.6.2 Uncertainties

We have estimated the uncertainties for the thermal measurements at the four measuring points.

NEUTRA. As indicated above, in 2005 and 2006 two different sets of measurements were carried out, each set having three gold foils irradiated. While the agreements between the results obtained within one set were better then a few %, in 2005 the average values between the two sets are of 13 %. The difference in 2006 is much lower. We therefore have a source of random error of the order of 10%.

EIGER. The measurements at EIGER have smaller random error, thanks to the precise profile measurements of the integrated fluxes at the beam exits described above. A systematic uncertainty better than 5% for the 2007 measurements and of about 7 % for the 2006 measurement was estimated.

ICON. For ICON the precision in the positioning can be estimated from the measurement history since 2001. We conservatively give an uncertainty of 10 % to these measurements.

NAA. At NAA the systematic uncertainties are better than 5 % given the precision of the sample positioning system. A systematic uncertainty slightly better than 5 % was found in previous years measurements.

4.6.3 Thermal neutron fluxes

In order to extract the absolute thermal and epithermal neutron fluxes, thin gold foils were irradiated without and with cadmium covers, respectively.

Time-of-flight measurements performed in the past (see Ref. [28] and references therein) as well as MCNPX calculations indicate that the thermal peak values are higher than the nominal value of 0.025 eV for the thermal beam lines. For the ICON cold neutron beam line, the peak flux is of course at a lower energy, due to the presence of the D_2 moderator. Therefore effective, averaged neutron capture cross sections between 0 and E_{cut} of gold and cobalt were calculated from the actual flux distributions:

$$\sigma_{EFF} = \frac{\int_0^{Ecut} \phi(E)\sigma(E)dE}{\int_0^{Ecut} \phi(E)dE}. \tag{14}$$

The cadmium threshold energy E_{cut} is usually around 0.5 eV. A threshold value of 1 eV was determined in Ref. [28] by Monte Carlo simulations: it was chosen so that the difference of the gold foil activation without and with the cadmium shielding equals the activation due to neutrons with energy lower than the threshold value.

As shown in Table 4.9, the effective thermal cross sections differ significantly from the nominal gold thermal neutron capture cross section of 98.7 barn. In the table, calculated cross sections for MEGAPIE are shown. Values for target 6 and target 7 are very close to the indicated cross sections. In the case of the ICON and NEUTRA beam lines experimental time-of-flight measurements of the neutron spectra were available. In this case the difference with the calculated values is at most of 7%. In these cases the experimental values were used in the data analysis.

In the NEUTRA measurements there was not the possibility to place Cd layers in front of the foils, thus the correction for the epithermal flux was applied during the data analysis by extrapolating the epithermal contribution from the data at the other beam lines. In particular, a systematic correction was applied to determine the thermal flux, assuming that the fraction of epithermal neutrons is the same as for the ICON beam line.

Table 4.9. Calculated and experimental effective thermal cross sections.

	Exp. [barn]	MEGAPIE [barn]
ICON	158.3	170
NEUTRA	80	82.6
EIGER		82.8
NAA		86.1

Results from integrated thermal and epithermal neutron measurements are shown in Table 4.10 for the target 6, MEGAPIE and target 7. MCNPX values are the integrated fluxes up to 1 eV neutron energy, while experimental values are from the measurements where the contribution from epithermal neutrons is subtracted, and the flux is obtained by dividing for the effective cross section between 0 and 1 eV. Experimental and calculated values are therefore directly comparable.

In the case of EIGER, it must be considered that the MCNPX simulation did not take into account the supermirrors in the collimator, responsible for the vertical distribution of the flux shown in Fig. 4.14, as well as the sapphire filter. The supermirrors increase by about 10-20% the thermal fluxes, depending on the measured position[29], while the sapphire filter reduces the thermal component by a similar amount, while cutting by about a factor of 10 the epithermal component.

Table 4.10. Summary of experimental and calculated integral thermal and epithermal fluxes. Thermal fluxes are integrated between 0 and 1 eV. Experimental uncertainties in the thermal fluxes (in per cent) are indicated in parenthesis. Epithermal fluxes are per logarithmic energy unit. Statistical uncertainties on calculated values are lower than 1 %. See comments in the text concerning the EIGER epithermal flux.

	Thermal			Epithermal		
	Experimental [n/cm^{2}s/mA]	Self-shielding factor	MCNPX [n/cm^{2}s/mA]	Experimental [n/cm^{2}s/mA]	Self-shielding factor	MCNPX [n/cm^{2}s/mA]
Target 6						
ICON	4.19×10^{8} (10)	0.96	4.92×10^{8}	5.70×10^{6}	0.57	6.73×10^{6}
NEUTRA	2.47×10^{7} (10)	0.98	2.40×10^{7}	-	-	5.38×10^{5}
EIGER	6.73×10^{8} (7)	0.98	7.98×10^{8}	1.22×10^{6}	0.57	1.19×10^{7}
NAA	-	-	7.34×10^{12}	-	-	2.32×10^{10}
MEGAPIE						
ICON	7.45×10^{8} (10)	0.96	8.12×10^{8}	1.62×10^{7}	0.57	1.30×10^{7}
NEUTRA	4.48×10^{7} (10)	0.98	3.77×10^{7}	-	-	9.73×10^{5}
EIGER	1.14×10^{9} (7)	0.98	1.40×10^{9}	2.61×10^{6}	0.57	2.48×10^{7}
NAA	1.04×10^{13} (5)	0.96	1.30×10^{13}	4.43×10^{10}	0.49	4.73×10^{10}
Target 7						
ICON	4.61×10^{8} (10)	0.96	5.42×10^{8}	4.53×10^{6}	0.57	6.56×10^{6}
NEUTRA	2.83×10^{7} (10)	0.98	2.68×10^{7}	-	-	5.04×10^{5}
EIGER	7.45×10^{8} (7)	0.98	8.65×10^{8}	-	-	1.12×10^{7}
NAA	6.20×10^{12} (5)	0.96	8.02×10^{12}	1.97×10^{10}	0.49	2.61×10^{10}

The experimental and calculated thermal fluxes are plotted in Fig. 4.16. On the average from the four measurement points, MEGAPIE has a neutronic performance higher than target 6 of a factor 1.74 ± 0.12, (calculated value 1.69) and of a factor of 1.62 ± 0.08 (calculated value 1.54) with respect to target 7. The calculated and experimental increases of the thermal neutron flux using MEGAPIE are therefore in good agreement. The calculated increase is higher than the previously estimated[4] factor of about 1.4. Investigations during the post-test analysis have shown that the difference is due to a non perfect modeling of the solid target in the old calculations; in particular, the STIP samples, which decrease the flux by about 10% were not included, as well as other minor details such as the small gaps inside the lead filled steel rods.

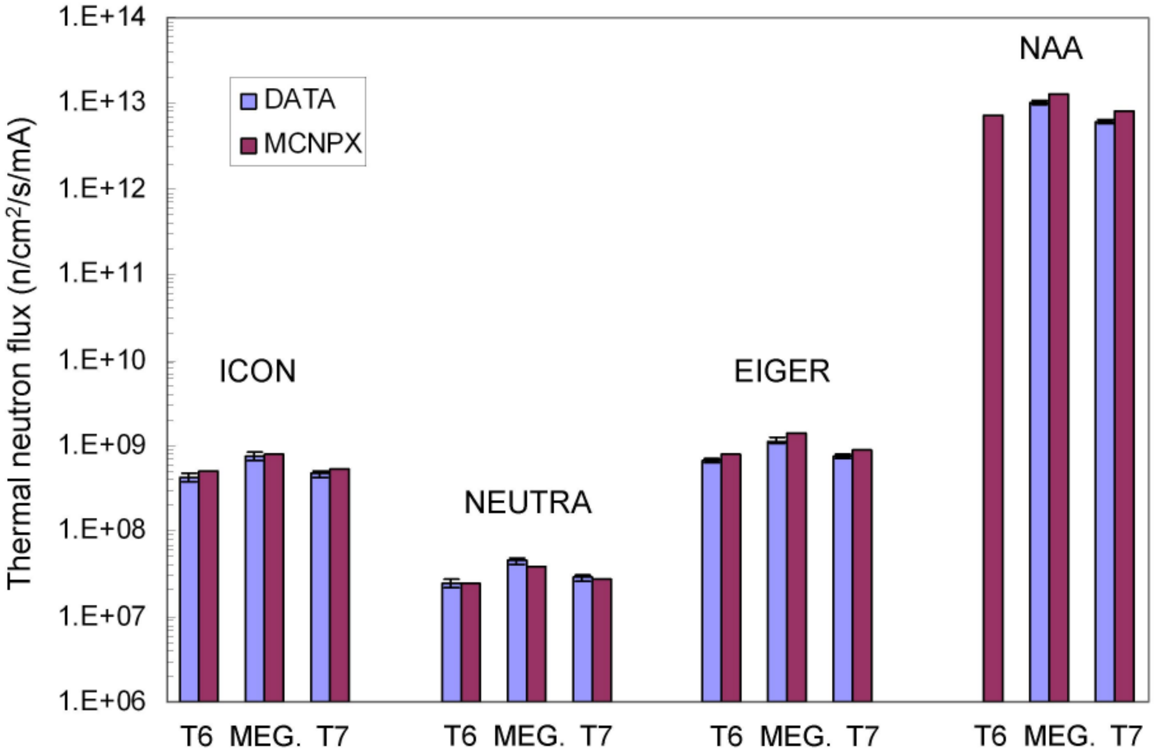


Figure 4.16. Experimental and calculated absolute thermal (E < 1 eV) neutron fluxes at ICON, NEUTRA and EIGER beam lines and NAA station, with target 6, MEGAPIE and target 7.

4.6.4 Epithermal neutron fluxes

Some of the activation foil measurements were performed with and without Cd layers. From these measurements, besides the pure thermal flux, it is possible to have an indication of the epithermal flux.

The resonance integral of gold is strongly dominated by the single isolated resonance at 4.9 eV. The proper experimental technique for the extraction of the epithermal flux at the resonance point would require (at the beam lines) more sophisticated measurements such as the double foil technique. Therefore the extracted epithermal fluxes ϕ_{EPI} are only indicative.

The obtained epithermal fluxes are given in Table 4.10. As shown, results are available for the EIGER, ICON and NAA measurements. An absolute comparison with calculations can be performed only for the ICON and NAA measurements, as for EIGER the presence of the sapphire filter strongly reduces the epithermal component (and partially the thermal component). In the EIGER case, it is still possible to make a relative comparison between the different targets.

The epithermal flux was obtained under the assumption that the flux above the Cd threshold has a *1/E* dependence, that is constant in lethargy units. As shown in Fig. 4.4, the flux is almost constant in lethargy units from 1 eV to 1 MeV. The epithermal flux obtained from the reaction rate is the flux per logarithmic energy unit. The total epithermal flux can be estimated by multiplying the epithermal flux per logarithmic energy bin by an appropriate factor. We evaluated this factor as the ratio between the calculated integral flux above 1 eV, and the calculated epithermal flux at 5 eV:

$$f = \frac{\Phi_{CALC}\left[1\ eV - 600\ MeV\right]}{\varphi_{CALC}\left(5\ eV\right)} . \qquad (15)$$

The obtained value (averaged over the values for NAA and ICON, for the different targets) is 10.9, relatively close to the value $ln(10^6/1)=13.8$ given in section 4.3.

Results are summarized in Table 4.11. In the second column the experimental fraction

Φepi / (Φepi+ Φth) is shown, where Φepi is the integrated epithermal flux, obtained multiplying the flux per logarithmic energy unit from table 4.10 by the constant 10.9. Similarly, the corresponding calculated fraction is shown in the third column.

Despite the coarse epithermal flux measurements, we can draw some interesting conclusions from these results. As we have seen before, calculations predict a higher fraction of flux of neutrons with $E > 1$ eV with the MEGAPIE target. For ICON, the calculated fraction is 0.13 with target 6, 0.15 with MEGAPIE, and 0.12 for target 7. The experimental results indicate a fraction of 0.13 for target 6, 0.19 for MEGAPIE and 0.10 for target 7. For NAA, the calculated fraction is 0.038 with MEGAPIE, 0.034 for target 7. The experimental results indicate a fraction of 0.045 for MEGAPIE and 0.034 for target 7.

Table 4.11. Experimental and calculated fraction of epithermal neutrons. See explanation in the text.

	Φepi / (Φepi+ Φth) exp	Φepi / (Φepi+ Φth) calc
ICON		
T6	0.13	0.13
MEGAPIE	0.19	0.15
T7	0.10	0.12
NAA		
MEGAPIE	0.045	0.038
T7	0.034	0.034

It is therefore confirmed that the epithermal component with MEGAPIE is larger than with the solid targets. The experimental value seems some 20-25% higher than the predicted one, but this could be due to the lack of precision of these measurements.

4.6.5 Fast neutrons

Reaction rates were measured at NAA for several foils with threshold reactions from 1 MeV up. Results are reported in Table 4.12. Some interesting information can be extracted from these data. First of all, we can compare with the reaction rates measured with the different targets to have an idea of the changes of the fast neutron flux at the NAA position. From the results in Table 4.12 we see that the reaction rates taken with MEGAPIE and target 7 are on average close. This seems to indicate that the fast neutron flux with MEGAPIE is about the same as with the solid targets, that is, the fast flux does not increase as the thermal and epithermal one, in agreement with the calculated spectra of Fig. 4.5. This interesting result could be explained by the different structures of the two spallation targets, with an influence of the heavy water inside the solid targets on the fast spectrum at the measured position, or with possible leaks of scattered fast neutrons in the spaces between the layers of rods of the solid targets.

Table 4.12. Measured reaction rates per atom [s^{-1} mA^{-1}] for MEGAPIE and SINQ target 7. Statistical uncertainties in % are indicated in parenthesis.

Nuclide	MEGAPIE	Target 7
	Mn sample	
^{48}V	-	$4.81\ 10^{-17}$ (1.3)
^{51}Cr	$4.91\ 10^{-16}$ (3.0)	$4.51\ 10^{-16}$ (3.1)
^{52}Mn	$1.99\ 10^{-16}$ (0.6)	$1.85\ 10^{-16}$ (1.4)
^{54}Mn	$6.60\ 10^{-15}$ (0.8)	$5.29\ 10^{-15}$ (0.7)
^{56}Co	$1.33\ 10^{-16}$ (1.8)[a]	$1.31\ 10^{-16}$ (1.3)
^{57}Co	$5.92\ 10^{-16}$ (4.1) [a]	$5.13\ 10^{-16}$ (3.6)
^{57}Ni	$6.57\ 10^{-17}$ (2.4)	-
^{58}Co	$8.27\ 10^{-16}$ (1.0)	$5.75\ 10^{-16}$ (0.9)
^{60}Co	-	$2.30\ 10^{-16}$ (5.9)
	Ni sample	
^{48}V	-	$2.21\ 10^{-17}$ (0.6)
^{51}Cr	-	$1.79\ 10^{-16}$ (2.8)
^{52}Mn	$1.16\ 10^{-16}$ (1.0)	$1.08\ 10^{-16}$ (0.6)
^{54}Mn	-	$3.64\ 10^{-16}$ (0.8)
^{55}Co	$1.15\ 10^{-16}$ (0.6)	-
^{56}Co	$1.04\ 10^{-15}$ (1.9)	$9.62\ 10^{-16}$ (0.4) [a]
^{57}Co	$4.48\ 10^{-15}$ (3.3)	$5.63\ 10^{-15}$ (3.1)
^{58}Co	$6.61\ 10^{-15}$ (0.8)	$5.55\ 10^{-15}$ (0.8)
^{56}Ni	$2.07\ 10^{-17}$ (3.5)	$2.26\ 10^{-17}$ (2.2)
^{57}Ni	$5.75\ 10^{-16}$ (1.3)	-
^{59}Fe	-	$1.84\ 10^{-17}$ (2.2)
	Al sample	
^{22}Na	$1.77\ 10^{-16}$ (5.0)	-
^{24}Na	$9.58\ 10^{-16}$ (1.3)	$7.69\ 10^{-16}$ (0.5)

[a] corrected for parent decay

Table 4.12. Continued.

Nuclide	MEGAPIE	Target 7
Ti sample		
^{44}Sc	$2.57\ 10^{-16}$ (1.2) [a]	$2.09\ 10^{-16}$ (0.4)
^{44m}Sc	$1.36\ 10^{-16}$ (2.5)	$1.09\ 10^{-16}$ (2.3)
^{46}Sc	$1.76\ 10^{-15}$ (2.3)	$1.36\ 10^{-15}$ (0.5)
^{47}Sc	$2.00\ 10^{-15}$ (1.8)	$1.53\ 10^{-15}$ (0.5)
^{48}Sc	$5.85\ 10^{-16}$ (0.3)	$4.32\ 10^{-16}$ (0.3)
Cu sample		
^{48}V	$1.24\ 10^{-18}$ (2.9)	$1.32\ 10^{-18}$ (7.4)
^{52}Mn	$4.83\ 10^{-18}$ (0.8)	$5.82\ 10^{-18}$ (1.9)
^{54}Mn	$5.26\ 10^{-17}$ (2.4)	$5.19\ 10^{-17}$ (0.2)
^{56}Co	$3.44\ 10^{-17}$ (1.3)	$3.54\ 10^{-17}$ (0.8)
^{57}Co	$2.26\ 10^{-16}$ (3.4)	$2.17\ 10^{-16}$ (3.8)
^{58}Co	$5.47\ 10^{-16}$ (0.9)	$4.74\ 10^{-16}$ (0.9)
^{60}Co	$5.54\ 10^{-16}$ (1.1)	$4.81\ 10^{-16}$ (1.3)
^{57}Ni	$2.42\ 10^{-18}$ (3.3)	-
^{59}Fe	$3.72\ 10^{-17}$ (1.7)	$3.19\ 10^{-17}$ (2.1)
Fe sample		
^{48}V	-	$5.03\ 10^{-17}$ (1.0)
^{51}Cr	$4.03\ 10^{-16}$ (9.0)	$5.61\ 10^{-16}$ (2.6)
^{52}Mn	$9.84\ 10^{-17}$ (1.0)	$1.57\ 10^{-16}$ (0.5)
^{54}Mn	$1.47\ 10^{-15}$ (2.7)	$2.10\ 10^{-15}$ (0.7)

[a] corrected for parent decay

4.6.6 Calculation of radionuclide production rates at NAA

The calculation of reaction rates has been done using SNT (see Section 7.2.2) starting from the neutron spectra calculated with MCNPX 2.5.0. Results for MEGAPIE and SINQ target 7 are shown in Table 4.13 and in Figs. 4.17-4.21.

Tables 4.14 and 4.15 show the contributions of various parts of the neutron spectrum to the nuclide production rates for different targets. The results for MEGAPIE and SINQ target 7 are close. Tables show also the origin of data used in the reaction rate calculations with the SNT code.

It is seen that in most of the cases neutrons with energy from 20 to 150 MeV give the main contribution to the radionuclide production for the considered materials. ^{58}Co (Ni sample), ^{60}Co

(Cu sample), and ^{24}Na (Al sample) are formed mainly from neutrons with energies below 20 MeV. ^{44}Sc (Cu sample) is originated from neutron reactions at energies above 150 MeV.

The reactions responsible for the formations of the nuclides are *(n,xnp)* inelastic reactions. A given nuclide can be formed either by a direct reaction, or by the formation of parent nuclides and subsequent beta decay, in which case we consider also the cumulative cross sections. Cumulative and direct cross section data sets were prepared for the SNT calculations. Cumulative cross sections are shown in the Annex C (Figs. C13-C18). Direct cross sections coincide with the cumulative ones in most of the cases, with the exception of a few nuclides where the parent contribution to the cumulative cross section is of about 10%.

Table 4.13. Measured and calculated reaction rates per atom (s^{-1} mA^{-1}) for MEGAPIE and SINQ target 7. Calculations were performed for neutrons with energy above 1 MeV.

Nuclide	MEGAPIE		Target 7	
	Measured	Calculated (SNT)	Measured	Calculated (SNT)
Mn sample (89.8% Mn, 10.1% Ni)				
^{51}Cr	$4.91\ 10^{-16}$ (3.0)	$1.08\ 10^{-15}$	$4.51\ 10^{-16}$ (3.1)	$9.01\ 10^{-16}$
^{52}Mn	$1.99\ 10^{-16}$ (0.6)	$1.86\ 10^{-16}$	$1.85\ 10^{-16}$ (1.4)	$1.72\ 10^{-16}$
^{54}Mn	$6.60\ 10^{-15}$ (0.8)	$8.59\ 10^{-15}$	$5.29\ 10^{-15}$ (0.7)	$6.32\ 10^{-15}$
Ni sample				
^{48}V	-	-	$2.21\ 10^{-17}$ (0.6)	$3.80\ 10^{-17}$
^{51}Cr	-	-	$1.79\ 10^{-16}$ (2.8)	$2.59\ 10^{-16}$
^{52}Mn	$1.16\ 10^{-16}$ (1.0)	$1.93\ 10^{-16}$	$1.08\ 10^{-16}$ (0.6)	$1.74\ 10^{-16}$
^{54}Mn	-	-	$3.64\ 10^{-16}$ (0.8)	$3.48\ 10^{-16}$
^{56}Co	$1.04\ 10^{-15}$ (1.9)	$2.47\ 10^{-15}$	$9.62\ 10^{-16}$ (0.4)	$2.21\ 10^{-15}$
^{57}Co	$4.48\ 10^{-15}$ (3.3)	$6.36\ 10^{-15}$	$5.63\ 10^{-15}$ (3.0)	$4.85\ 10^{-15}$
^{58}Co	$6.61\ 10^{-15}$ (0.8)	$9.38\ 10^{-15}$	$5.55\ 10^{-15}$ (0.8)	$7.01\ 10^{-15}$
^{56}Ni	$2.07\ 10^{-17}$ (3.5)	$1.46\ 10^{-16}$	$2.26\ 10^{-17}$ (2.2)	$1.36\ 10^{-16}$
Al sample (99.77% Al, 0.23% Fe)				
^{22}Na	$1.77\ 10^{-16}$ (5.0)	$2.09\ 10^{-16}$	-	$1.92\ 10^{-16}$
^{24}Na	$9.58\ 10^{-16}$ (1.3)	$1.13\ 10^{-15}$	$7.69\ 10^{-16}$ (0.5)	$8.80\ 10^{-16}$
Ti sample				
^{44}Sc	$2.57\ 10^{-16}$ (1.2)	$3.34\ 10^{-16}$	$2.09\ 10^{-16}$ (0.4)	$2.97\ 10^{-16}$
^{44m}Sc	$1.36\ 10^{-16}$ (2.5)	$2.46\ 10^{-16}$	$1.09\ 10^{-16}$ (2.3)	$2.06\ 10^{-16}$
^{46}Sc	$1.76\ 10^{-15}$ (2.3)	$1.60\ 10^{-15}$	$1.36\ 10^{-15}$ (0.5)	$1.39\ 10^{-15}$
^{47}Sc	$2.00\ 10^{-15}$ (1.8)	$2.05\ 10^{-15}$	$1.53\ 10^{-15}$ (0.5)	$1.73\ 10^{-15}$
^{48}Sc	$5.85\ 10^{-16}$ (0.3)	$8.93\ 10^{-16}$	$4.32\ 10^{-16}$ (0.3)	$7.30\ 10^{-16}$
Cu sample				
^{52}Mn	$4.83\ 10^{-18}$ (0.8)	$4.17\ 10^{-17}$	$5.82\ 10^{-18}$ (1.9)	$3.97\ 10^{-17}$
^{54}Mn	$5.26\ 10^{-17}$ (2.4)	$8.04\ 10^{-17}$	$5.19\ 10^{-17}$ (0.2)	$6.90\ 10^{-17}$
^{57}Co	$2.26\ 10^{-16}$ (3.4)	$4.16\ 10^{-16}$	$2.17\ 10^{-16}$ (3.8)	$3.68\ 10^{-16}$
^{58}Co	$5.47\ 10^{-16}$ (0.9)	$5.72\ 10^{-16}$	$4.74\ 10^{-16}$ (0.9)	$5.17\ 10^{-16}$
^{60}Co	$5.54\ 10^{-16}$ (1.1)	$4.02\ 10^{-16}$	$4.81\ 10^{-16}$ (1.3)	$3.30\ 10^{-16}$
^{59}Fe	$3.72\ 10^{-17}$ (1.7)	$1.18\ 10^{-17}$	$3.19\ 10^{-17}$ (2.1)	$1.05\ 10^{-17}$
Fe sample				
^{51}Cr	$4.03\ 10^{-16}$ (9.0)	$5.92\ 10^{-16}$	$5.61\ 10^{-16}$ (2.6)	$5.39\ 10^{-16}$
^{52}Mn	$9.84\ 10^{-17}$ (1.0)	$2.52\ 10^{-16}$	$1.57\ 10^{-16}$ (0.5)	$2.26\ 10^{-16}$
^{54}Mn	$1.47\ 10^{-15}$ (2.7)	$2.02\ 10^{-15}$	$2.10\ 10^{-15}$ (0.7)	$1.74\ 10^{-15}$

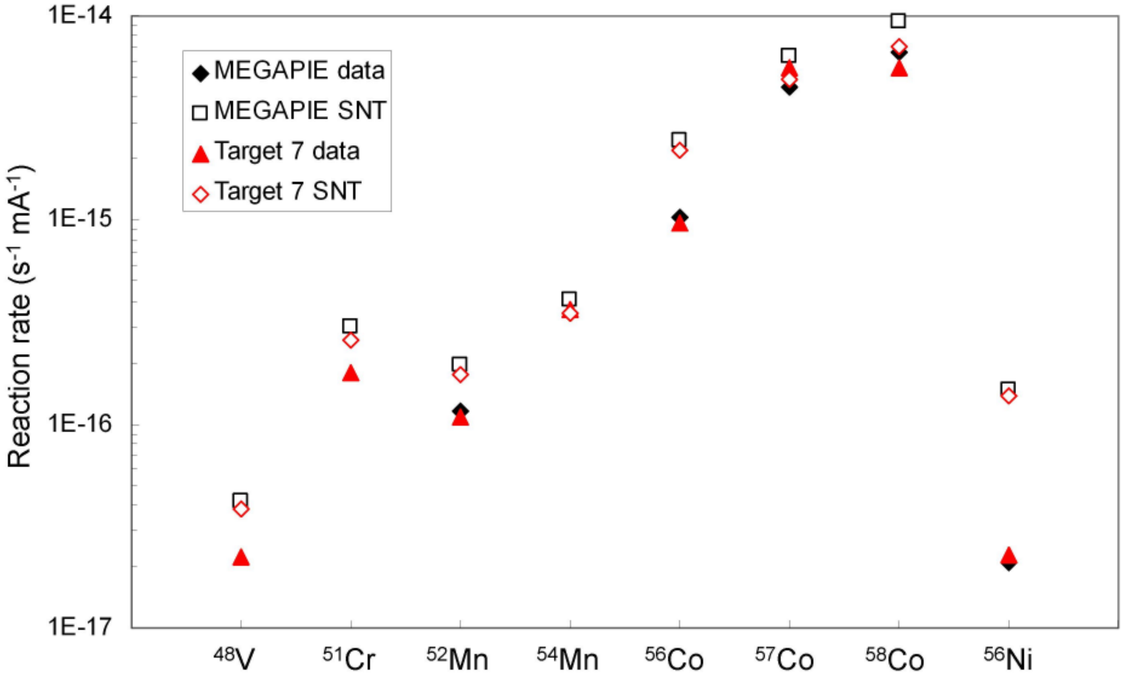


Figure 4.17. Measured and calculated reaction rates with Ni sample, with MEGAPIE and target 7.

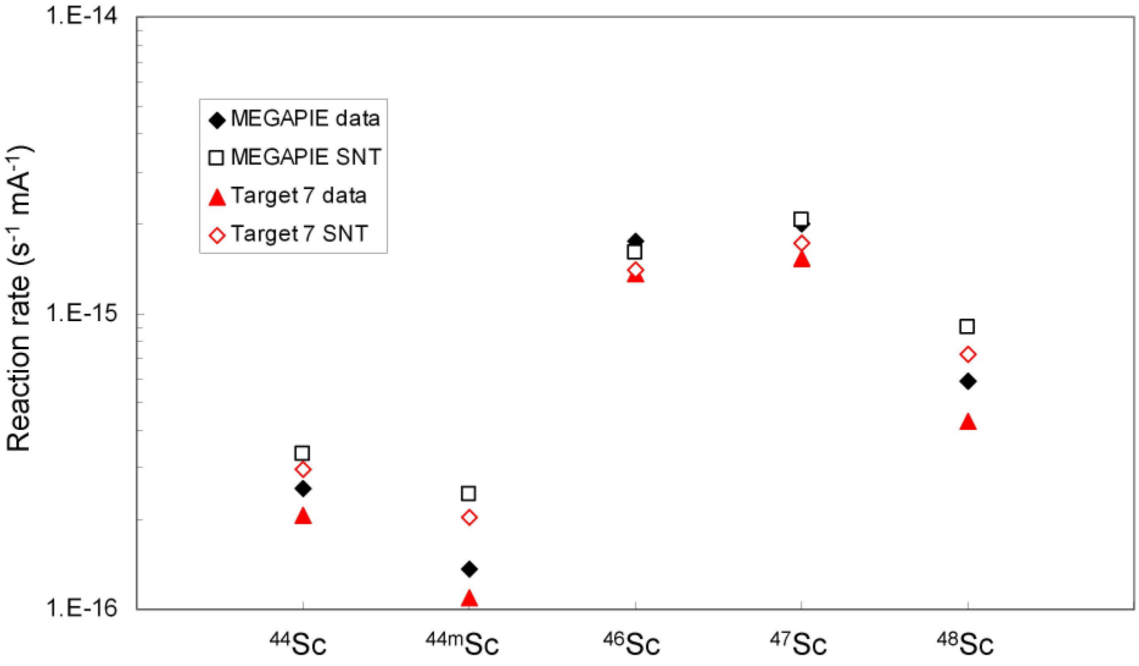


Figure 4.18. Measured and calculated reaction rates with Ti sample, with MEGAPIE and target 7.

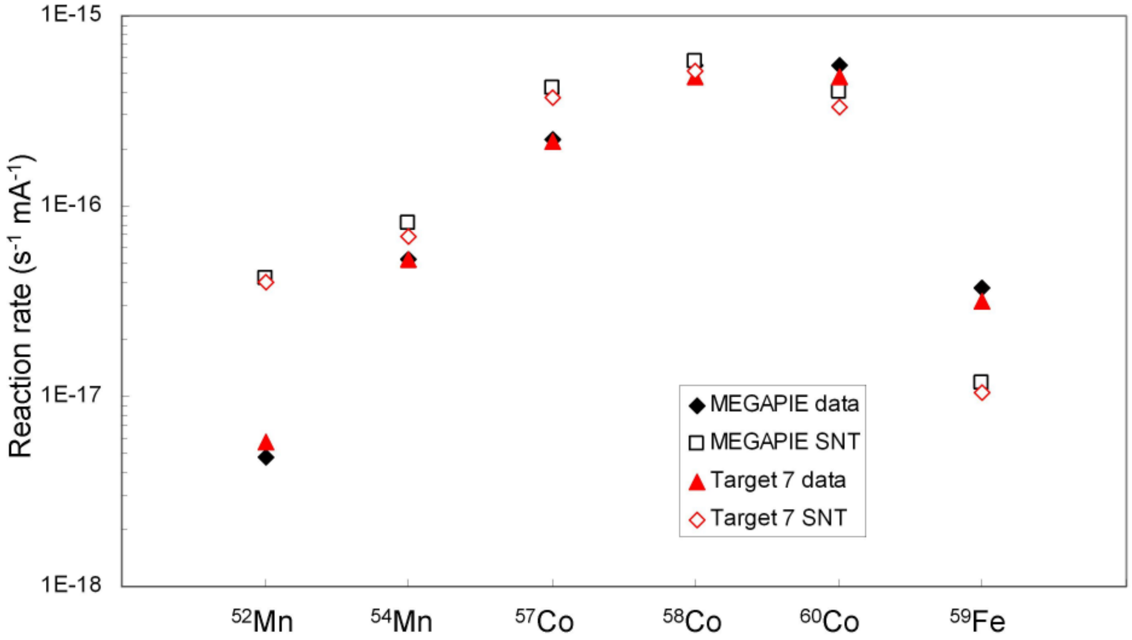


Figure 4.19. Measured and calculated reaction rates with Cu sample, with MEGAPIE and target 7.

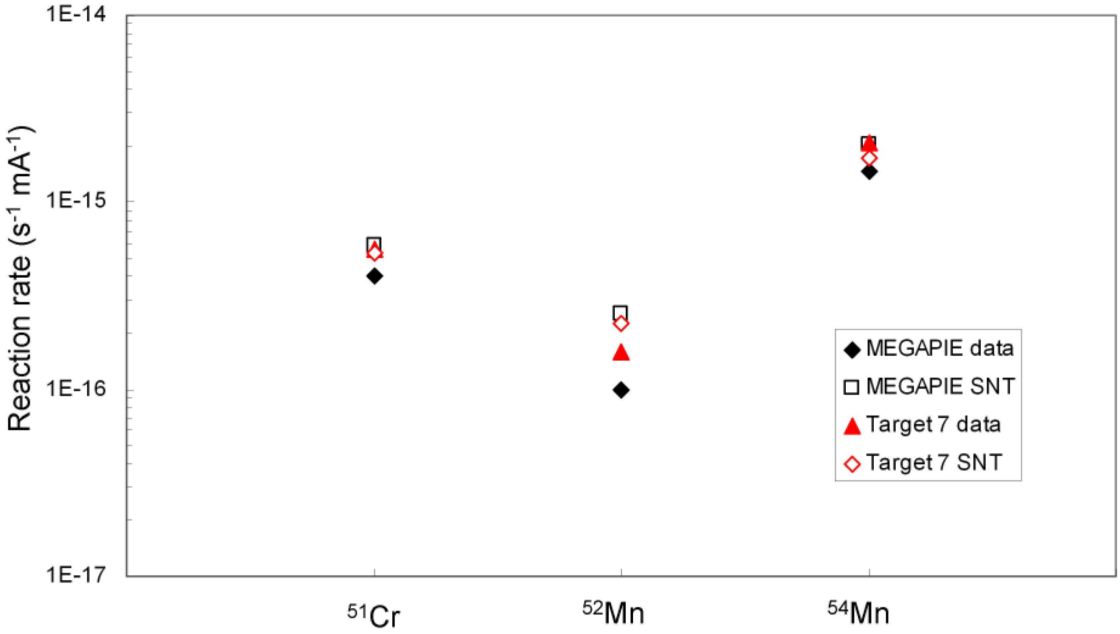


Figure 4.20. Measured and calculated reaction rates with Fe sample, with MEGAPIE and target 7.

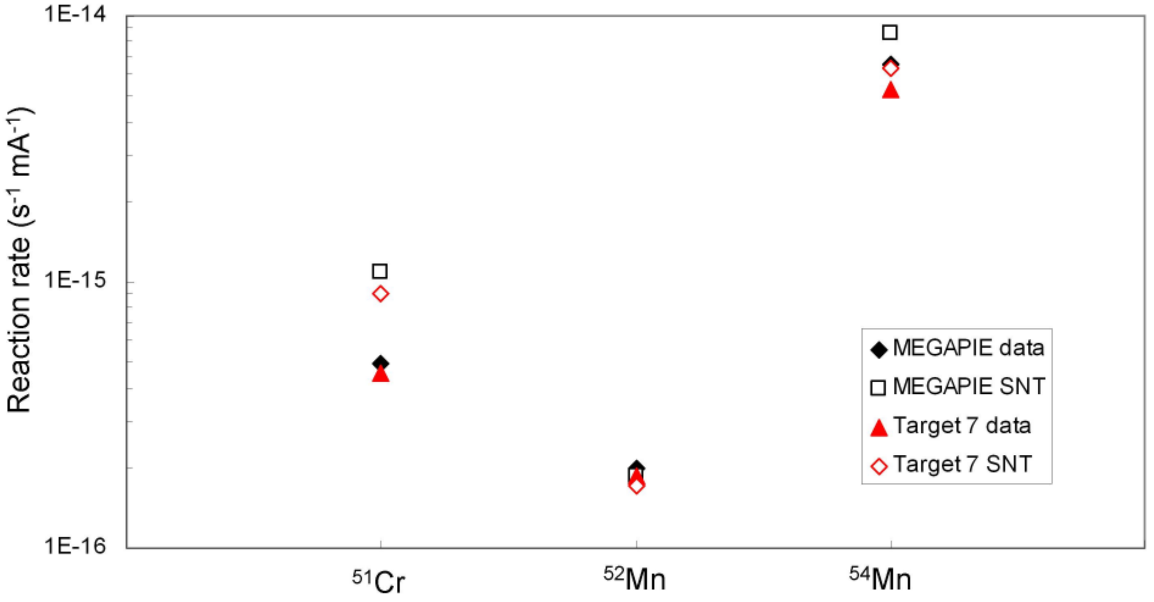


Figure 4.21. Measured and calculated reaction rates with Mn sample, with MEGAPIE and target 7.

The observed difference between calculated and measured reaction rates (Table 4.13) and data from Tables 4.14 and 4.15 can be used for the further improvement of evaluated data from JEFF-3.1A, IEAF-2001, and IEAF-2007.

Table 4.14. The contribution of different parts of the neutron spectrum to the calculated nuclide production rates (%) with the MEGAPIE target.

Nuclide	Rate, s^{-1} mA^{-1}	Neutrons < 20 MeV (JEFF-3.1A)	Neutrons 20-150 MeV (IEAF-2001)	Neutrons >150 MeV (IEAF-2007)
		Mn sample	(89.8% Mn, 10.1% Ni)	
Cr 51	1.08e-15	<0.001	96.2	3.8
Mn 52	1.86e-16	0	90.3	9.7
Mn 54	8.59e-15	51.5	48.0	0.5
		Ni sample		
V 48	4.15e-17	0	84.6	15.4
Cr 51	3.00e-16	0.008	92.4	7.6
Mn 52	1.93e-16	0	90.7	9.3
Mn 54	4.05e-16	6.9	87.3	5.8
Co 56	2.47e-15	<0.001	98.5	1.5
Co 57	6.36e-15	43.0	56.1	0.9
Co 58	9.38e-15	84.9	14.9	0.2
Ni 56	1.46e-16	0	98.4	1.6
		Al sample	(99.77% Al, 0.23% Fe)	
Na 22	2.09e-16	0	93.6	6.4
Na 24	1.13e-15	83.9	15.4	0.6
		Ti sample		
Sc 44	3.34e-16	1.2	90.7	8.1
Sc 44m	2.46e-16	0.2	99.8	0
Sc 46	1.60e-15	20.5	77.2	2.3
Sc 47	2.05e-15	19.7	78.5	1.8
Sc 48	8.93e-16	38.7	60.6	0.7
		Cu sample		
Mn 52	4.17e-17	0	82.2	17.8
Mn 54	8.04e-17	0	94.3	5.7
Co 57	4.16e-16	0	92.2	7.8
Co 58	5.72e-16	0	96.1	3.9
Co 60	4.02e-16	62.8	35.7	1.5
Fe 59	1.18e-17	0	94.4	5.6
		Fe sample		
Cr 51	5.92e-16	7.5	86.2	6.4
Mn 52	2.52e-16	0.05	91.8	8.1
Mn 54	2.02e-15	27.8	69.9	2.3

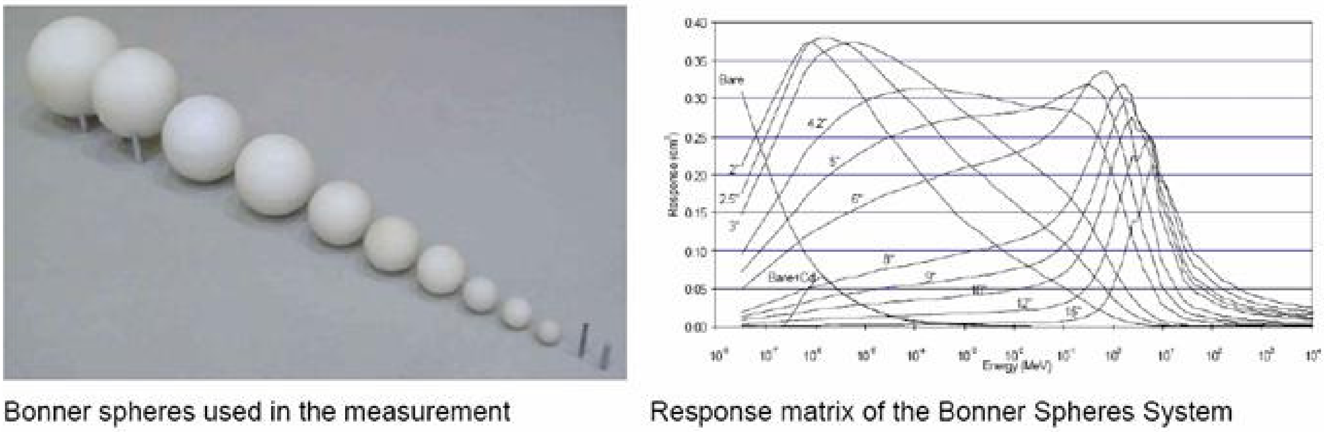
Table 4.15. The contribution of different parts of the neutron spectrum to the calculated nuclide production rates (%) with the SINQ target 7.

Nuclide	Rate, s^{-1} mA^{-1}	Neutrons < 20 MeV (JEFF-3.1A)	Neutrons 20-150 MeV (IEAF-2001)	Neutrons >150 MeV (IEAF-2007)
Mn sample (89.8% Mn, 10.1% Ni)				
Cr 51	9.01e-16	<0.001	93.7	6.3
Mn 52	1.72e-16	0	85.6	14.4
Mn 54	6.32e-15	44.1	54.9	1.0
Ni sample				
V 48	3.80e-17	0	77.9	22.1
Cr 51	2.59e-16	0.007	88.0	12.0
Mn 52	1.74e-16	0	86.0	14.0
Mn 54	3.48e-16	5.1	85.6	9.3
Co 56	2.21e-15	<0.001	97.6	2.4
Co 57	4.85e-15	35.6	62.8	1.6
Co 58	7.01e-15	82.0	17.7	0.3
Ni 56	1.36e-16	0	97.6	2.4
Al sample (99.77% Al, 0.23% Fe)				
Na 22	1.92e-16	0	90.4	9.6
Na 24	8.80e-16	82.0	16.9	1.1
Ti sample				
Sc 44	2.97e-16	0.9	86.5	12.5
Sc 44m	2.06e-16	0.2	99.8	0
Sc 46	1.39e-15	17.3	79.1	3.6
Sc 47	1.73e-15	15.5	81.5	3.0
Sc 48	7.30e-16	34.0	64.9	1.1
Cu sample				
Mn 52	3.97e-17	0	75.4	24.6
Mn 54	6.90e-17	0	91.0	9.0
Co 57	3.68e-16	0	87.8	12.2
Co 58	5.17e-16	0	94.0	6.0
Co 60	3.30e-16	58.5	39.1	2.4
Fe 59	1.05e-17	0	91.6	8.4
Fe sample				
Cr 51	5.39e-16	6.0	84.4	9.6
Mn 52	2.26e-16	0.03	87.6	12.4
Mn 54	1.74e-15	23.4	73.0	3.6

4.7 Neutron spectrum measurement with a Bonner Sphere System

At the ICON beam line (about 16 m from the SINQ target) a neutron spectrum measurement was performed using a Bonner Sphere System consisting of a ^{3}He neutron detector and a set of 11 polyethylene spheres of diameters from 2 to 15 inches. Each sphere has a different response function, as shown in Fig. 4.22. In order to perform a good measurement (low background and no dead time correction) it was necessary to shield the thermal neutron flux around the Bonner sphere system. This was realized using a 1 cm thick Cadmium wall. The expected energy cutoff in the measured spectrum at around 1 eV is also shown in figure 4.23.

The data analysis was performed using the response functions to unfold the neutron spectrum in the energy range between 100 meV and 20 MeV. Results are shown in Fig. 4.23 and a relative comparison (normalized to 1 at 1eV) with a calculated spectrum is performed. The agreement is excellent.



Bonner spheres used in the measurement

Response matrix of the Bonner Spheres System

Figure 4.22. Bonner Sphere System used in the experiment and the according response matrix.

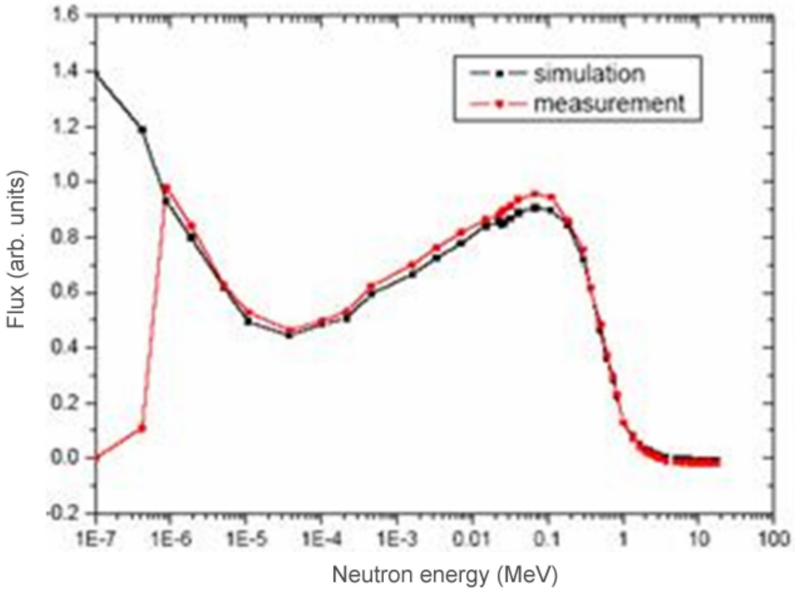


Figure 4.23. Comparison between calculated and measured spectrum. Both spectra are normalized to 1 at 1 eV.

4.8 Conclusions

The goals of the study of the neutron flux at various points of the SINQ facility were the following:

- study of the absolute neutronic performance of the MEGAPIE target;
- comparison of MEGAPIE with the solid targets used regularly at SINQ;
- validation of the Monte Carlo codes used in the simulations.

Overall, we succeeded in characterizing the neutron flux in the SINQ facility. Some discrepancies are found and point at intrinsic difficulties of this task. However, it is less difficult than the fission chambers measurements, because we measure in a region strongly dominated by thermal neutrons.

The present set of data and calculations provides a good understanding of the neutronic performance of the SINQ facility with different targets. Absolute thermal and epithermal fluxes, ranging from 10^{13} n/cm^2/s/mA to 10^7 n/cm^2/s/mA, have been measured. The Monte Carlo model of the facility, with the different targets, has proven to be successful in correctly reproducing the experimental results. More in detail, we found that for the thermal measurements, most of the experimental results are within 2 standard deviation from the calculated values. The value at NAA is an exception. In this case, the calculated flux is about 30% higher than measured. However, with a quoted experimental uncertainty of 5%, the discrepancy is of several standard deviations, with the calculated values higher than the experimental ones. This discrepancy goes in the same direction as the ones observed in the measurements inside the central rod.

5. DELAYED NEUTRONS MEASUREMENTS

5.1 Introduction and objectives

Since 2003, different authors started calculations of the delayed neutrons (DNs) flux in heavy liquid metal based systems[30,32], where the importance of this issue for design and radioprotection was outlined. One important conclusion was that absolute estimates on DNs are very much model-dependent and no experimental data were available for DN yields from high energy fission-spallation reactions on Pb and Bi targets. This initiated an experimental campaign devoted to characterize the DN production in high energy fission-spallation reactions with Pb and Bi targets[31]. As a natural conclusion of this campaign, the measurement of DNs flux at the MEGAPIE target was proposed to validate the estimations made by Monte Carlo simulations.

5.2 Estimation of the DN flux

The LBE loop in the MEGAPIE spallation target, as in most of the high-power spallation targets based on liquid metal technologies, extends much further compared to the primary proton interaction zone. As shown in Fig. 5.1, the activated LBE reaches as high as 400 cm arriving to the heat exchanger, from where it returns to its initial position. It takes about 20 s for the entire 82 liters of LBE to make a "round trip" at a flow rate of about 4 liters/s. It is clear that a big part of the DN precursors, created in the interaction region via high-energy fission-spallation, will not have enough time to decay completely even at the very top location of the circulating liquid metal. The main concern is about the DNs flux contributing to the total neutron flux at the very top position of the heat exchanger.

5.2.1 A simplified geometrical model

To estimate the DN flux we employed the multi-particle transport code MCNPX combined with the material evolution program CINDER'90, as detailed in Ref. [32]. The DN data (emission probabilities and decay constants) were based on the ENDF/B-VI evaluations[33]. For the MEGAPIE target characteristics we used the design values, i.e. a 575 MeV proton beam with 1.4 mA intensity. The 3D geometry of the target has been modeled in detail and all the materials used in the target have been taken into account (see Chapter 2)[34,35]. The estimation of the DN parameters for MEGAPIE was performed in steps according to the following procedure:

1. calculation of independent fission fragment and spallation product distributions with MCNPX;
2. calculation of cumulative fission fragment and spallation product yields with CINDER'90;
3. identification of all known DN precursors and construction of the 6-group DN table.

After having built the DN table we developed a generalized geometrical model to estimate the DN flux at any position *x* of the MEGAPIE target loop as presented in Fig. 5.1.

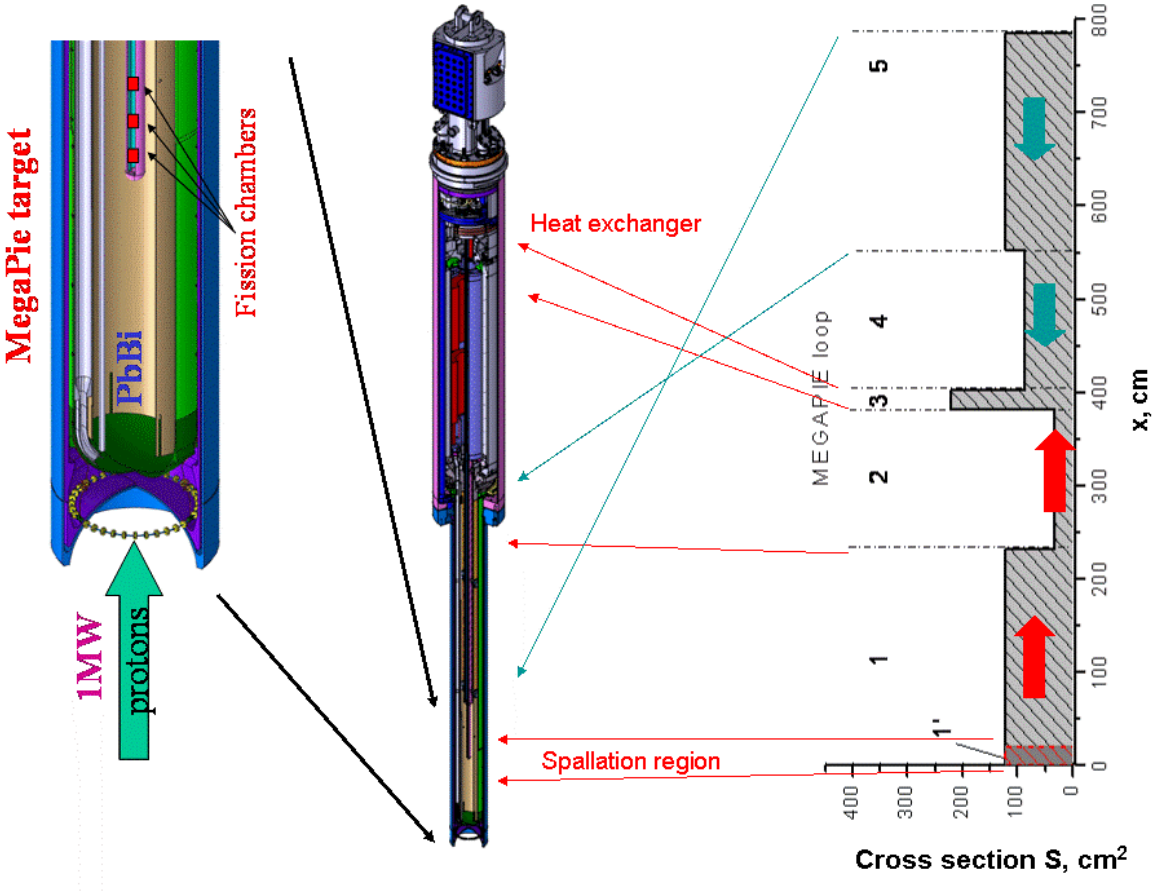


Figure 5.1. *Center and left:* schematic view of the full MEGAPIE target with details of the lowest part, the proton-LBE interaction zone. *Right*: cross sectional view of the liquid LBE loop as a function of the geometrical position *x* (cm).

From the figure one can notice that the LBE cross section changes in the loop, implying that the transit time of a given LBE volume element depends on its position. In particular, the permanence time of an LBE volume under irradiation, in the spallation region is very short (~0.5 s) compared to the total circulation time (~20 s). Within this model the DN flux at position *x* can be expressed as:

$$a(x) = \sum_{i=1}^{n} a_i(x) = \sum_{i=1}^{n} a_i^a \frac{1-\exp(-\lambda_i \tau_a)}{1-\exp(-\lambda_i T)} \exp(-\lambda_i \tau_d(x)), \tag{16}$$

where τ_a is the activation time of the LBE under irradiation, T represents the total circulation period of the LBE; τ_d is the transit (decay) time to reach the point *x;* λ_i is the decay constant of the DN precursor *i* while a_i is the density of DNs due to the precursor *i.*

By using the above equation and the 6-group DN table[32] we found that at the very top position of the LBE loop (400 cm level above the target window) the DN flux is of the order of 2×10^5 n/(cm^2 s). This intermediate result allowed us to recalculate the neutron flux at the level of the heat exchanger inserting the volumetric DN source as a function of *x* provided in Fig. 5.1. It was found that the neutron flux at this position due to DNs and prompt spallation neutrons is of the same order of magnitude, both equal to a few 10^6 n/(cm^2 s). It should be pointed out that this estimation relies on the hypothesis that 3 averaged time parameters are sufficient to describe a simplified liquid metal loop dynamics. These time constants, estimated from the target characteristics (LBE volume and main pump speed) are: τ_a=0.5 s, T=20 s and τ_d (at the heat exchanger) = 10 s (see eq. (16)).

In addition, the prompt neutron energy spectrum at the heat exchanger position has a strong thermal component (because the MEGAPIE spallation target is surrounded by a heavy water moderator-reflector) while the DN energy spectrum at this level is not "perturbed" yet, i.e. with an average energy of the order of 400-600 keV. These fast neutrons will have considerably higher penetration power compared to the thermal ones. This result clearly points out that activation and dose rates due to DNs should not be neglected.

On the other hand, the 6-group DN parameters, i. e. yields and time spectra of DNs, which were extracted from MCNPX simulations based on different physics models (namely INCL4+ABLA and CEM2k), are model-dependent nearly by two orders of magnitude[32]. This analysis showed that DN yields and time spectra from high energy fission-spallation reactions needed to be measured since no data of this type were available.

5.3 Measurement of the DN flux

5.3.1 Experimental setup and method

In order to verify the estimations of DN flux at MEGAPIE we proposed a measure at the top of the target head. We decided to make use of a simple setup, based on a ^{3}He counter.

The neutron detection was performed by a 45 cm long ^{3}He (8 bar) tube counter installed in a polyethylene box (47x20x10 cm^3). The CH_2 box ensured the moderation of neutrons in order to increase the neutron detector efficiency. The CH_2 box was surrounded by a 1 mm thick ^{nat}Cd foil to avoid the background due to the thermal neutrons. The detector was placed on the floor of the target head enclosure chamber, the so called TKE, at around 3 m from the target head (Fig. 5.2).

The detector was set up and tested in the TKE before irradiation at the end of June 2006. During this phase we performed a complete characterization of the detection system by using an Am-Be neutron source placed in different positions on the polyethylene box. The results of these tests have been compared to a simple MCNP simulation of the detector in order to estimate the neutron detection efficiency. This simulation, which did not take into account the whole geometry of the TKE and was performed by taking a point-like source, showed a good agreement between the measured counting rate and the calculation.

The DN data taking took place during the first week of the target irradiation. During this start-up phase, the beam power was increased in long steps, each step being followed by a beam stop. This procedure gave us the possibility to acquire data starting at each beam stop, corresponding to different beam powers.

The measured counting rate as a function of time, normalized to the beam intensity, is presented in Fig. 5.3 for different beam powers. One can notice that during the irradiation the neutron detector saturates, due to the high neutron flux, i.e. the detector gives a counting rate independent from the beam power. When the beam stops, we start counting DNs but some seconds are needed before the counting rate becomes proportional to the beam intensity. Since we know that the detector electronics needs ~50 ms after saturation to become operational again, we can argue that the DN flux during the first seconds after the beam stop is still quite high (as we have seen before, calculations predict a DN flux of the same order of the PN flux) and that the detector is still in saturation.

It is important to note that the background is also given by the decay of short-lived nuclides coming from the water loops (from the moderation and target enclosure cooling systems), in particular the neutron emitters ^{16}C ($t_{1/2}$= 0.75 s) and ^{17}N ($t_{1/2}$= 4.17 s), and neutrons coming from (γ,n) reactions of the 5.3-MeV γ of ^{15}C ($t_{1/2}$= 2.45 s) and of the 6.13-MeV γ of ^{16}N ($t_{1/2}$= 7.13 s) (see Fig. 5.2 and Ref.[36]). Such background is expected to add significantly to the prompt neutron radiation coming from the target. A dosimetry mapping was performed[37] at the beginning of irradiation. Data shown in Fig. 5.2 indicate also the fast neutron flux level at various positions in the TKE; the indicated fluxes are for an average current of phase I and II of irradiation of 0.09 mA. This corresponds to fast fluxes at the level of 10^6 n/cm^2/s/mA in the TKE, and of about 5×10^5 n/cm^2/s/mA in the position of the DN detector (position 8 in the figure). It is worth noting that estimations from old measurements with the SINQ solid targets gave fast neutron fluxes in the TKE approximately a factor 10 higher, which is believed to come mainly from the water activation[36]. In fact, the greatest component comes from the solid target water cooling loop, which was not operating during MEGAPIE.

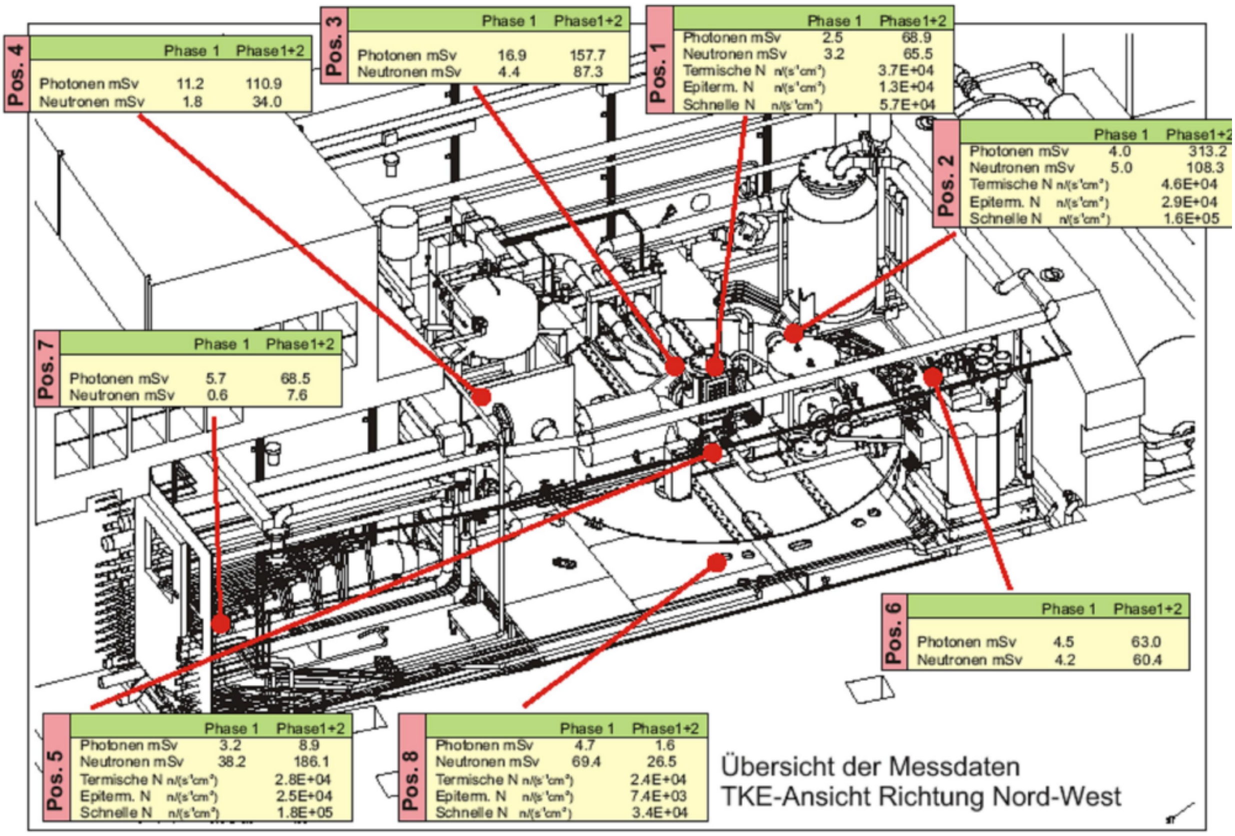


Figure 5.2. Scheme of the TKE where dosimetry measurements have been performed after the first day (phase 1) and after the second day (phase 1+2) of irradiation in 8 positions. The DN detector was placed in position 8. Figure from Ref. [37].

As soon as the DN flux lowers, the counting rate becomes proportional to the beam intensity: as expected, at equilibrium the DN precursor production rates are proportional to the beam power. Thanks to this proportionality, we can sum the decay curves taken at different beam currents to increase the statistics.

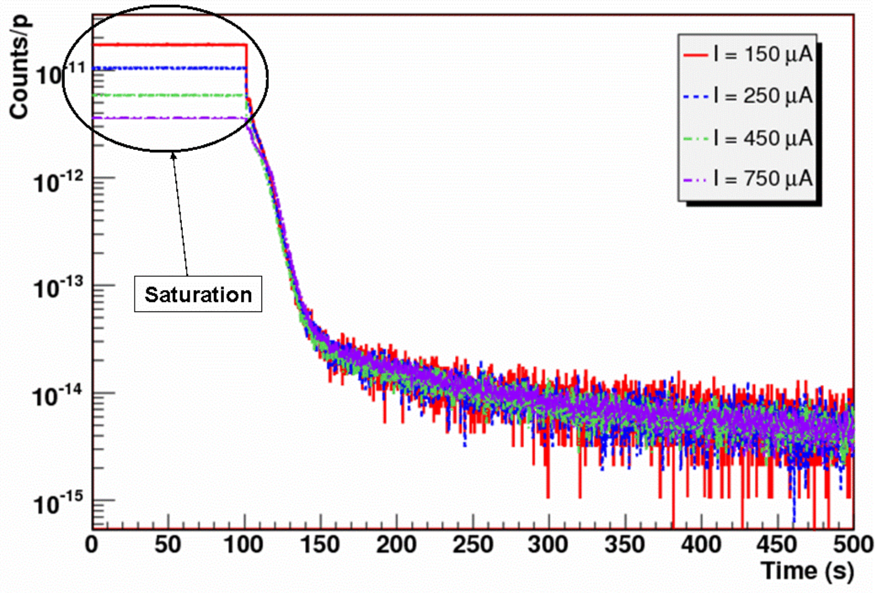


Figure 5.3. The DN decay curves normalized to the beam intensity (counts/proton); data were taken at different beam powers.

5.3.2 Efficiency measurement and calculation

The measurement of the detector efficiency is necessary in order to extract absolute values from the DN spectra. The characterization of the ^{3}He counter was performed using an Am-Be source. The measured counting rates have been compared with a Monte Carlo simulation of the full detector. The geometrical model of the detector and the neutron energy spectrum of the Am-Be source used in the simulations are presented in Figs. 5.4 and 5.5, respectively.

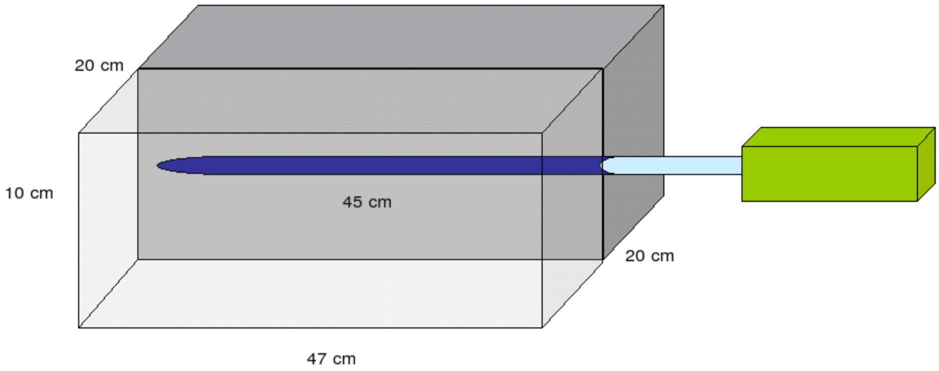


Figure 5.4. Geometrical model of the DN detector used in the efficiency calculations. The ^{3}He tube is represented in blue (the green box is the pre-amplifier) while the grey box corresponds to the CH_2.

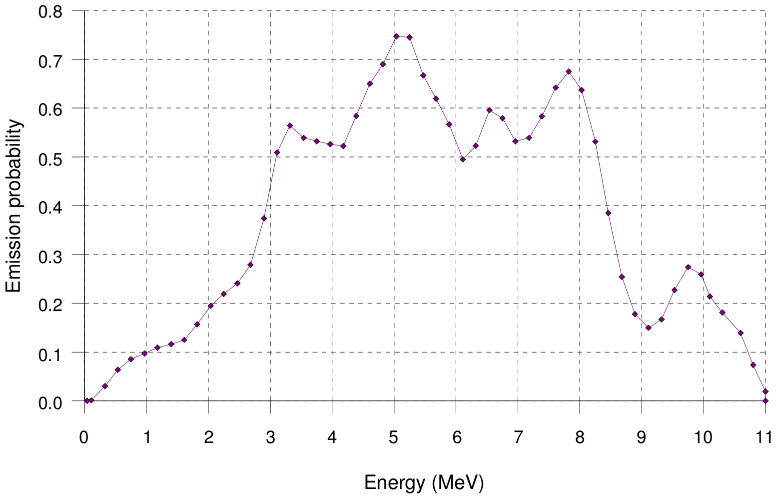


Figure 5.5. Neutron energy distribution of the Am-Be source used in the efficiency calculations.

The efficiency measurement was performed by placing the Am-Be neutron source with a 2.29×10^5 Bq activity in several positions around the detector and on the polyethylene box (see Fig. 5.6).

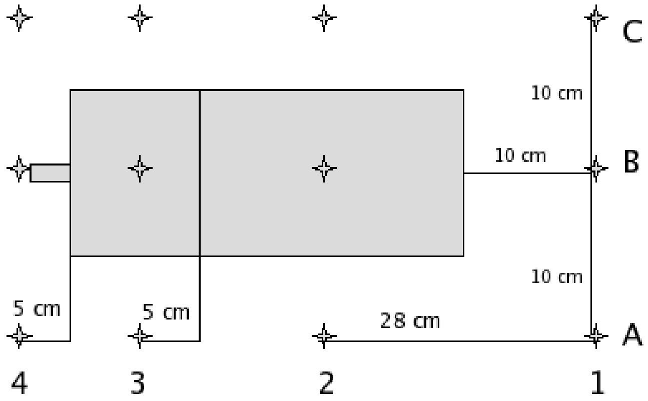


Figure 5.6. Schematic view of the source positions where efficiency measurements were performed.

The global efficiency (E_{gl}) of the ^{3}He detector is described as the number of detected neutrons in the ^{3}He tube per emitted neutron by the Am-Be source:

$$E_{gl} = \frac{N_{He-3}}{N_{Am-Be} \cdot \varepsilon}, \tag{17}$$

where $N_{\text{He-3}}$ is the number of neutrons detected in the detector, $N_{\text{Am-Be}}$ the total number of produced neutrons by the Am-Be source and ε corresponds to the efficiency of the detector.

The efficiency was then calculated with Monte Carlo simulations using MCNPX by taking a point like source. The comparison of the measurement with the calculation (Table 5.1) shows a good systematic agreement for all positions, not exceeding 30%, meaning that the detector geometry is correctly simulated.

Table 5.1. Comparison of the measured and simulated counting rates (CR in counts/s) using the Am-Be source.

Source position	Measured CR	Simulated CR	Sim./meas.
1A	270	357	1.32
1B	282	376	1.33
1C	285	360	1.26
2A	1570	1654	1.05
2B	1639	1899	1.16
2C	1465	1657	1.13
3A	1113	1114	1.00
3B	1180	1290	1.09
3C	1036	1138	1.10
4A	589	541	0.92
4B	619	599	0.97
4C	560	528	0.94

In order to estimate the DN efficiency for the neutrons coming from all over the target the most detailed and complete 3D geometry model of MEGAPIE target was used, by taking into account all materials, densities and compositions used in the design, in particular in the upper part on the SINQ facility, where the detector is placed. Since the main delayed neutron emitter is ^{17}N, as it will be shown in the next section, we take for simplicity for our calculations a source description characterized by the neutron energy distribution showed in Table 5.2.

Table 5.2. Delayed neutrons from ^{17}N (Ref. [33]).

Nuclide	Half life [s]	Neutron energy [MeV]	Intensity (%)
^{17}N	4.16 ± 0.01	0.40	47
		1.22	47
		1.79	6

Since the LBE transport is very complicated due to the MEGAPIE target geometry, it is difficult a priori to have information about the contribution to the total DN emission coming from the LBE in a particular target zone. Thus we examined the whole target geometry and estimated the LBE loop as it showed in Fig. 5.1.

It is clear that a big part of the DN precursors, created in the spallation region via high energy fission-spallation reactions, will not have enough time to decay completely even at the very top location of the loop. The main concern is about the DN flux contributing to the total neutron flux at the very top position of the heat exchanger. Thus the calculation was made by considering the upper 1.5 meters of the LBE loop, divided into 8 intervals according to the target structure. By this procedure, the calculation includes the following regions of the target:

i) liquid metal expansion volume (380-366 cm);
ii) upper part of liquid metal loop (366-357 cm);
iii) heat exchanger (upper part of main flow pump, 357-335 cm);
iv) heat exchanger (lower part of main flow pump, 335-310 cm);
v) heat exchanger (upper part of bypass flow pump, 310-285 cm);
vi) heat exchanger (middle part of bypass flow pump, 285-260 cm);
vii) heat exchanger (lower part of bypass main flow pump, 260-240 cm) and
viii) liquid metal displacement position (240-226 cm).

To realize such distribution in MCNPX we used a set of cylindrical sources, coaxial to the vertical axis of the target, with top and bottom boundaries as described in the previous paragraph. In each slice we defined the radius of the cylinder such that it would cover all the LBE volumes in that particular region of the target structure. Also, we limited our source definition to start each neutron transport history only from the LBE.

Using this method, we were able to calculate the efficiency of our DN detector from neutrons coming from the exact location of the MEGAPIE target and to estimate the contribution of the different loop regions to the total DN flux.

The neutron flux in ^{3}He volume was calculated. The counting rates were then calculated from equation (16) and taking DN precursors previously measured with a solid lead target (see next section). The results are presented in Table 5.3 for different *x* intervals of the MEGAPIE target with the modelled ^{3}He detector placed at about 3.5 m from the target head. The reconstructed energy spectrum of DNs transported from different loop zones to the ^{3}He detector position is shown in figure 5.6. One can clearly see both thermal and fast contributions, and also pronounced elastic scattering effects probably due to Fe/Ni shield (above 10 keV).

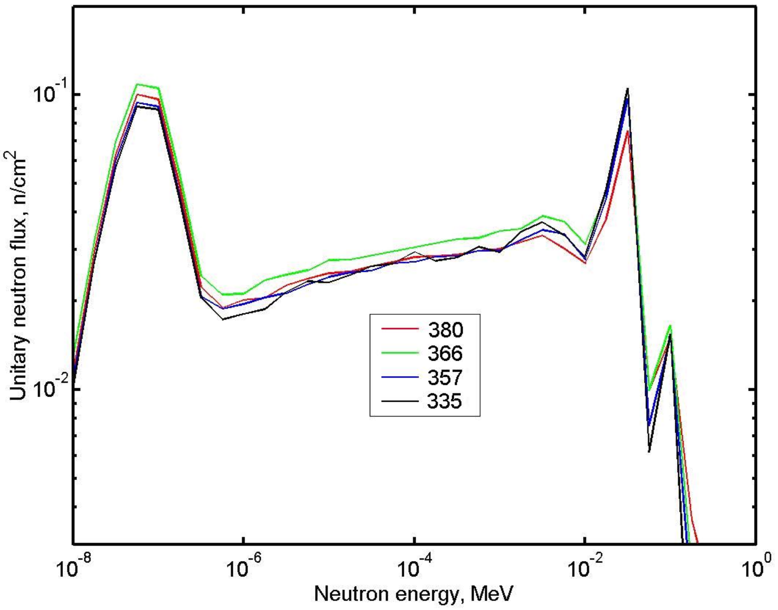


Figure 5.7. Reconstructed energy spectrum of DNs transported from different LBE zones to the ^{3}He detector position.

Table 5.3. Results of the full MEGAPIE simulation for the counting rate in the DN detector coming from neutrons emitted along the LBE loop.

Interval x, [cm]	Response [#/n]	Time t_{up}, [s]	Time t_{down}, [s]	Volume V_{up}, [l]	Volume V_{down}, [l]	DN flux a_{up}, [n/cm^2/s]	DN flux a_{down}, [n/cm^2/s]	Counting rate CR/Vo	Counting rate CR/Vo/I, [#/s]	Contribution %
380-366	6,01E-07	8,70	8,90	0,8	0,8	1,44E+10	1,39E+10	6,80E+03	1,09E-12	15,1
366-357	5,62E-07	8,50	9,70	1,6	3,2	1,48E+10	1,22E+10	1,77E+04	2,83E-12	39,1
357-335	3,84E-07	8,10	10,48	1,1	3,1	1,58E+10	1,08E+10	9,77E+03	1,56E-12	21,6
335-310	2,05E-07	7,83	11,35	1,2	3,5	1,66E+10	9,39E+09	5,41E+03	8,66E-13	12.0
310-285	9,89E-08	7,53	12,25	2,1	3,6	1,74E+10	8,14E+09	3,25E+03	5,20E-13	7,20
285-260	4,20E-08	7,00	13,15	1,4	3,6	1,89E+10	7,06E+09	1,09E+03	1,74E-13	2,41
260-240	2,09E-08	6,65	13,88	1,1	2,9	2,00E+10	6,29E+09	4,21E+02	6,74E-14	0,93
240-226	1,68E-08	6,38	14,73	3,4	3,4	2,09E+10	5,51E+09	7,53E+02	1,21E-13	1,67
						TOT	4,400E+04	**7,23E-12**		

As expected, the main contribution to the total neutron flux comes from the upper regions of the LBE loop. The percentage distribution of delayed neutrons from the upper part of the target is showed in Fig. 5.8.

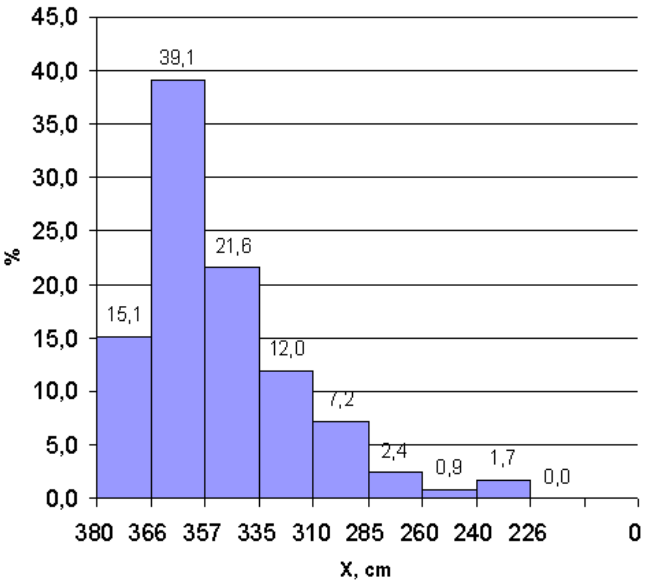


Figure 5.8. Distribution of the contributions to the DN flux, coming from the different regions of the LBE loop at distance *x* from the target bottom.

5.3.3 Interpretation of the data

The interpretation of the data is non trivial since we do not know *a priori* which precursors are contributing to the DN flux. On the other hand, DNs were measured using 1 GeV protons interacting with massive Pb and Bi targets of variable thicknesses at PNPI Gatchina (Russia)[31]. During this experiment it was found that, contrary to the conventional six-group approach, DN decay curves could be described by four exponential terms corresponding to four dominant isotopes. In particular, up to 10-20 s, major DN contributors come from light mass products, resulting from the spallation process, as ^{9}Li and ^{17}N, rather than fission products as in the case of actinide fission. For longer decay times, from 50 to 100 s, the DN activity is dominated by usual fission products as ^{88}Br and ^{87}Br. This result has been a starting point for the MEGAPIE data interpretation.

Using the normalized decay time spectra shown in Fig. 5.3, summed up to increase the statistics, and taking the DN precursor half-lives extracted from the experiment at PNPI[31], we fitted the experimental decay curve using eq. 16. From the fit (Fig. 5.9) we extracted the DN densities a_i (normalised to unity) of the identified precursors, together with the LBE transit times τ_a and T.

Table 5.4 summarizes the results obtained from the fit. We add that, as for the Gatchina experiment, it was impossible to extract DN density for ^{9}Li due to its short half-life, which is comparable with the acquisition channel width Δt_{ch} = 200 ms.

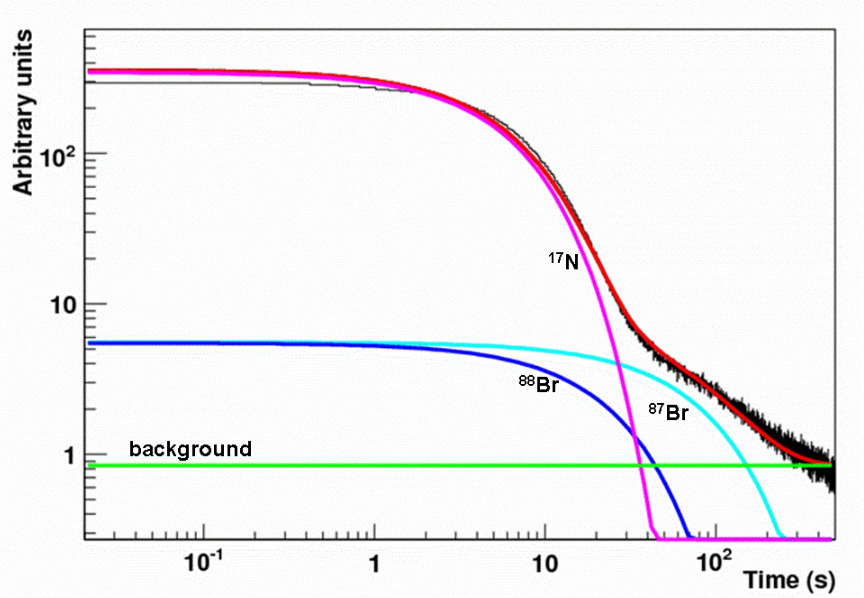


Figure 5.9. Fit of the experimental DN decay curve obtained from eq. 16. The relative contributions from individual precursors are also shown.

Table 5.4. Normalized DN densities a_i of the three identified contributors extracted from the experimental fit.

Group	Precursor	Half-life (s)	a_i, %
1	^{87}Br	55.6	4.3
2	^{88}Br	16.3	3.3
3	^{17}N	4.16	92.4

The DN densities are fairly compatible with the ones of the Gatchina experiment, meaning that in the LBE loop the precursors involved are the same as in the solid target experiment. Moreover, the LBE transit times from the fit (τ_a=0.49 s, T=19.6 s) are in very good agreement with the values estimated from the loop technical characteristics. This means that the LBE loop can be well approximated by the three averaged time parameters, which validates the simplified approach developed above.

We can now compare (Fig. 5.10) the measured absolute counting rate of the ^{3}He detector (counts/s) normalized to 1 mA primary proton beam current (in red) to the calculated one. The black curve of the same figure shows the equivalent theoretical calculation, which combines DN yields and decay parameters extracted from the PNPI experiment, MCNPX simulations for DN transport from different PbBi locations to the ^{3}He detector position and also calculated ^{3}He detector efficiency (see previous section). The theoretical curve underestimates the experimental data by a factor of 2. The blue curve presents a slightly different scenario, in which one assumes that the LBE was irradiated longer at the proton–LBE interaction point, namely for about 1 s instead of the nominal 0.5 s. In this case, the data are perfectly reproduced. Indeed, Dury[25] showed that in the interaction zone, close to the target window, average LBE speed is somewhat decreased by vortex formation and the irradiation time can be longer than 0.5 s.

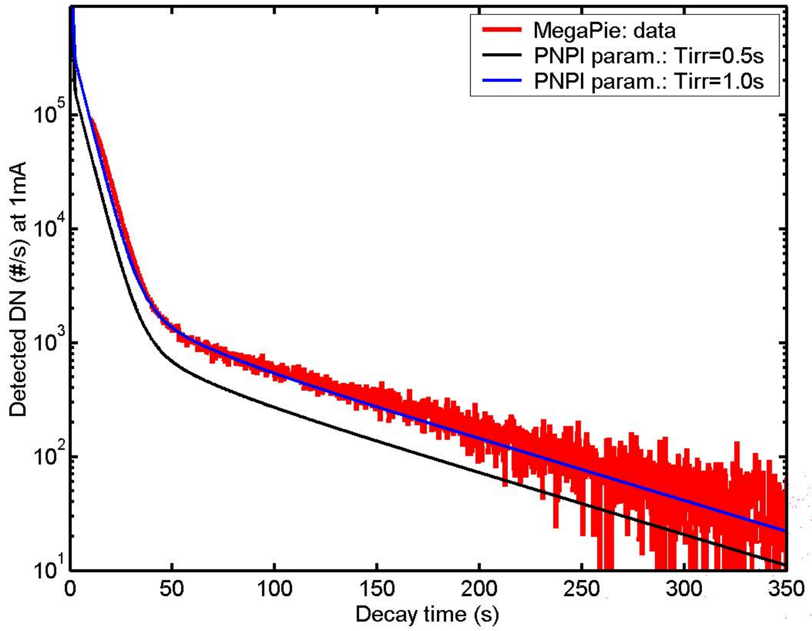


Figure 5.10. Comparison of measured DN spectrum with two calculations, performed with different transit times of the LBE in the proton irradiation zone.

Finally in Figure 5.11 the reconstructed DN flux at the location of the ^{3}He counter is presented. Both experimental data (corrected for the ^{3}He detector efficiency) and theoretical calculations (with t_{irr}=1s) are shown. In summary, at the DN detector location the delayed neutron flux is at the level of 2×10^4 n/(s cm^2) for the primary beam intensity of 1 mA. After the beam is switched off, this DN flux decreases sharply due to the decrease of the dominant contribution by ^{17}N ($t_{1/2}$=4.2 s), while later follows the decay pattern of ^{87}Br ($t_{1/2}$=55.6 s).

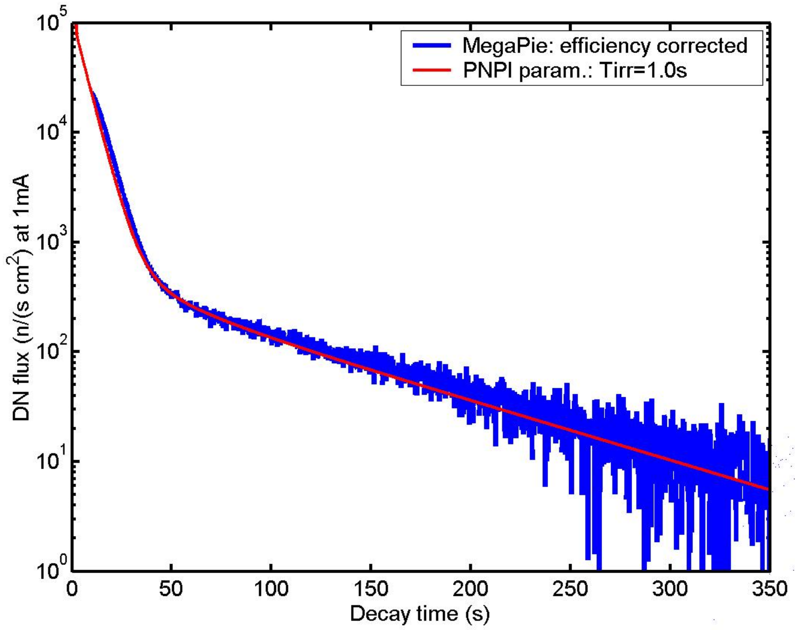


Figure 5.11. Delayed neutron flux evolution at the ^{3}He detector position, from data analysis and calculations.

5.4 Conclusions

We reported on the study of the delayed neutron flux for the MEGAPIE spallation target, based on simulations, modeling and measurements. A detailed comparison between the DN decay curve measured at MEGAPIE and the results of a geometrical model involving three averaged liquid metal transit times and the DN precursor parameters was presented.

The main results are the following:

- The fit of the DN decay curve measured at MEGAPIE was performed using the results of the model and the DN densities extracted are in fair agreement with DN parameters previously measured at similar energy but with solid targets in a simple geometrical configuration.
- We could extract the total delayed neutron flux, corrected for the ^{3}He detector efficiency, at the top of the target. The analysis procedure used to reconstruct the flux from the measured counting rates showed an agreement with the calculation within a factor of two, which has to be considered as a very satisfactory result, taking into account the great difficulty of both the DN measurement and simulation.

6. GAS PRODUCTION AND RELEASE

6.1 Introduction

The production and release of volatile elements during irradiation is a key safety issue in an accelerator-driven system. One of the main disadvantages of an ADS with respect to a fast reactor system is in the amount of volatile elements ending in the cover gas system (CGS), due to the fact that the coolant is directly irradiated by a proton beam generating a large amount of gas by spallation reactions. It is estimated that the activity in the CGS may be up to 10^5 times than in the CGS of fast reactors under normal conditions operating with LBE [38]. This requires special shielding for the CGS and makes the handling of the gas more complicated, and implies higher risks in case of an accident. Additionally, in case of evaporation of Po isotopes, the CGS inventory will also include highly radiotoxic α-emitting radionuclides, in particular ^{208,209,210}Po.

In the design and licensing phase of MEGAPIE a considerable effort was devoted to the problem of gas production and release. The project had to answer several questions from which depended the licensing of the target, such as: total amount produced, pressure in the expansion volume, amount of Hg and Po release in the expansion volume, total inventory of Po. The problem must be separated in gas production, diffusion and release.

Gas production. The amount of gas that is released depends in the first place on the amount produced inside the LBE. Nuclides are produced as a consequence of the interaction of the proton beam with the target. The spallation is a reaction where a fast particle, such as a high-energy proton, interacts with a heavy nucleus, producing neutrons and other particles. Given the high energy of the incident particle, first the proton interacts with the single nucleons of the nucleus, leading to the ejection of nucleons and pions, which still have enough energy to induce a cascade reaction (called intranuclear cascade). After this phase, the nucleus is left in a highly excited state and nucleons (mostly neutrons) are evaporated. Fragmentation or fission of the nucleus may occur, as well as inelastic neutron reactions. This sequence of processes leads to the production of isotopes, with a mass range spanning the entire chart of nuclides.

Today, the knowledge on the nuclide production comes from experiments (mainly thin target experiments) and theoretical models. In the last few years a great deal of information has been collected, as discussed in Chapter 7. The uncertainties of the predicted production rates are relatively low for nuclides close in mass to the target nuclei (such as for instance Hg and Po), while they increase in the fission region, where the various theoretical models give quite different predictions, and become large in the tails of these distributions (Ar isotopes) where experimental data to support the models are lacking. According to these calculations, in the case of MEGAPIE, long lived (i.e. present after one month from the end of irradiation) volatile products constitute at least 2 % of the total produced radioactive inventory in MEGAPIE, if only noble gases and mercury are considered as volatile.

Gas production in MEGAPIE was calculated using Monte Carlo codes. Predictions rely on theoretical models for spallation and fission induced by high-energy protons, and calculations were performed using the latest available models, validated with experimental data on thin targets. It is the case for FLUKA, and for recent spallation and evaporation models used in MCNPX, such as the INCL4 and ABLA models. Additional calculations were performed using the SNT code.

Gas diffusion and release. Once the nuclides are produced in the target, the volatile ones diffuse and are eventually at least partially released from the target. This process is very complex[39]. In the first stage, the nuclear products will be present as dissolved impurities within the LBE. Subsequently, they are transported within the target system by both diffusion and convection. During this process they can undergo different chemical reactions such as oxide formation with the oxygen dissolved in the LBE, reactions with construction material surfaces, and deposition at cold surfaces. In the case they reach the liquid metal surface in the expansion volume, they will be partially transferred to the gas phase.

In a complex system such as MEGAPIE it is very difficult to quantify to which extent each of these processes will progress. This problem was addressed from two points of view:

Release studies, accompanied by theoretical calculations of gas release, were performed for the most important components of the MEGAPIE inventory[39,40,41]. Theoretical studies predicted the behaviors of the volatile elements, divided in groups according to their chemical and physical properties[39]: noble gases and hydrogen; elements that evaporate from the LBE without chemical reactions (Cd, Hg, Tl and Pb); alkaline metals (Rb and Cs); polonium; halogens (Br and I). For each of these elements, the fraction present in the expansion volume was estimated, with the exception of hydrogen and noble gases, for which a complete release in the expansion volume was assumed. Among all the other elements, the only element for which a relatively high release was estimated was mercury, for which a fractional release of 1.6×10^{-6} was predicted. To reduce the release of mercury, a cold trap (at about 40 ºC) was placed between the expansion volume and the cover gas system.

In addition, an experimental program was carried out to perform at the same time measurements of basic production rates, and studies of release properties of the LBE. Such program is the IS419 experiment performed at CERN and reported in Refs. [42,43,44].

In the MEGAPIE irradiation phase, the goal of the gas measurement was to determine the stable and radioactive gas release by the LBE following irradiation of the target, in an attempt to check the predictions from both the gas production codes and the release models. The measurements were performed by sampling the gas in the expansion volume. In order to minimize the dose rates, a first sampling was performed in the start up phase, with only a small amount of charge on target. Additional measurements were performed at later times, but only sampling decayed gas inside the decay tank of the cover gas system.

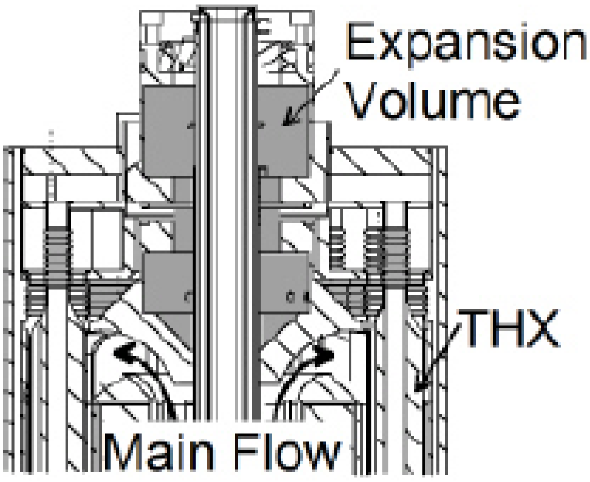


Figure 6.1. MEGAPIE target expansion volume for gas storage. The expansion volume is located right above the heat exchanger (THX) inlets.

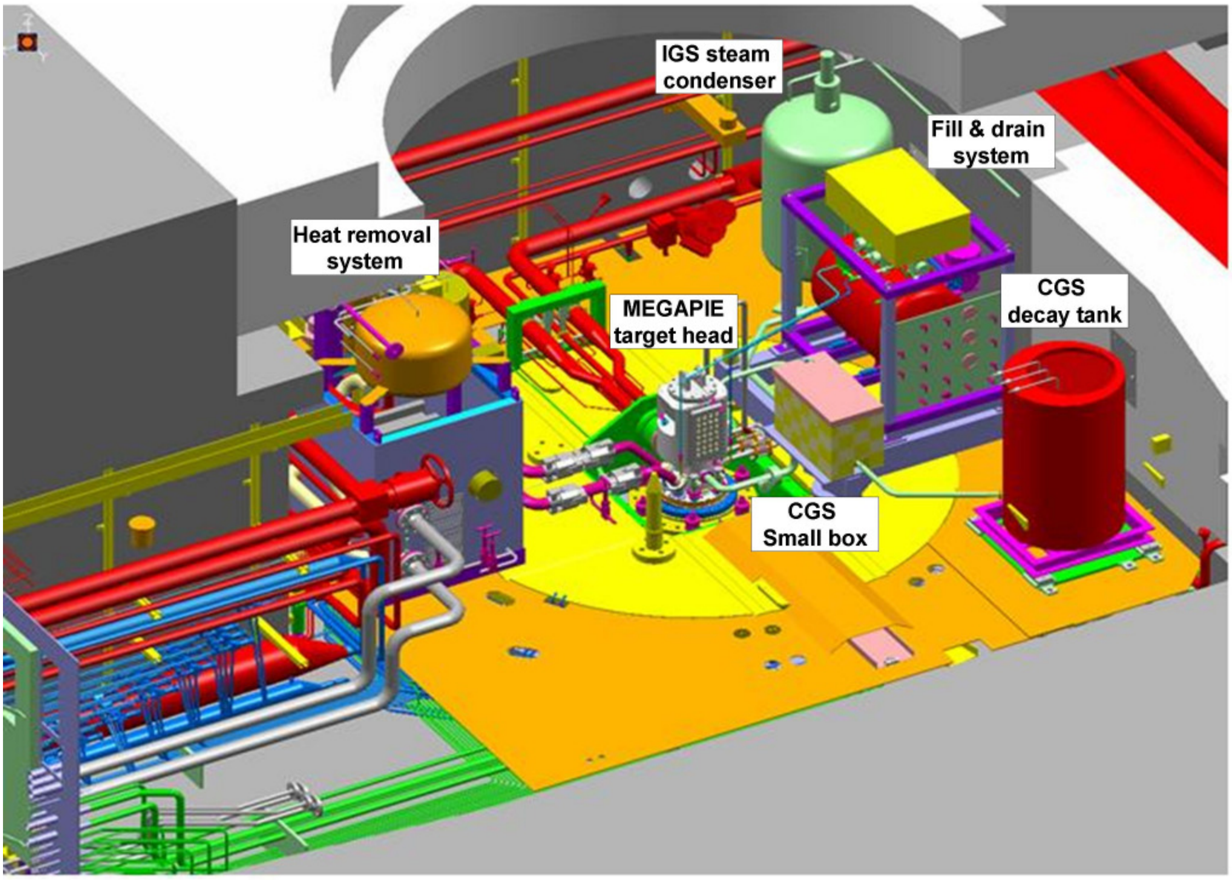


Figure 6.2. Representation of the MEGAPIE ancillary systems in the TKE.

6.2 MEGAPIE Cover gas system

During the MEGAPIE experiment volatile elements are produced, diffused through the LBE and collected in an expansion volume of about two liters placed at the top of the target, above the LBE free surface (Fig. 6.1).

A drawing of the ancillary systems in the TKE is shown in Fig. 6.2. The cover gas system consists essentially of the following components: a tube system connecting the expansion volume of MEGAPIE to the CGS; a Pb shielded box containing valves for the operations and pressure transducers (the so-called “small box”); a larger shielded volume where a 13 liters decay tank, and other components of the CGS system, are placed. The entire system is contained in a secondary loop. During sample taking, a small sampling unit could be connected to the system, as explained in detail below.

Operation of the CGS was performed by opening and closing pneumatic actuated valves which allowed the transfer of the gas collected in the expansion volume, and of additionally inflated argon. The operation of the produced gas was required for three reasons: 1) handling and control of the radioactive gas, 2) handling and control of the pressure in the expansion volume above the LBE free surface, and 3) analysis of the gas produced during irradiation. Gas sampling was performed by manually inserting gas sampling units in the system, and operating the relevant valves remotely.

More in detail, the cover gas system was designed and built with the purpose to perform the following tasks:

1. deflate the cover gas plenum of the target expansion tank into a decay tank, down to the initial plenum pressure;
2. sample the gas of the target expansion tank before or during deflation;

3. sample the gas of the decay tank before venting;
4. deflate the decay tank to the controlled exhaust system;
5. after the end of the MEGAPIE experiment, empty the target cover gas into the decay tank; successively disconnect the pipes at the outlet of the target expansion volume.

There were five pressure transducers present in the system: CP001 and CP002 were placed inside the small box; since there was no valve between the small box and the target expansion volume, these two transducers gave the pressure in the expansion volume. The transducers CP003 and CP004 were placed inside the decay tank, while CP005 gave the pressure inside the dilution volume BB002.

The values of the level detectors during operation allowed to cross check the expansion volume at the top of the target. The volume is different during hot standby and during irradiation, giving values of 1900 ± 100 cm^3 and 1400 ± 100 cm^3, respectively. These values are in agreement with the pressure changes observed during the experiment in correspondence to hot standby situations.

6.3 CGS operation

A summary of the operation history of the CGS is given in Table 6.1. The most important operations were the following:

1. After the start of irradiation on August 14, the fresh gas sampling (FGS) was performed on August 16.
2. The first venting to the decay tank (VDT) was performed right after the FGS operation, and consisted in filling the DT mainly with Ar, up to about 0.66 bars, to clean the gas lines from radioactive gas.
3. The first exhaust of the gas content of the decay tank was performed on 20 September 2006 (in this case, very little radioactive gas was present in the decay tank). This operation was followed on the same day by the venting of the content of the expansion volume to the decay tank.
4. On September 27, the first decayed gas sampling (DGS) was performed. The amount of gas vented to the decay tank one week earlier, corresponding to the irradiation from 16 August to 20 September, was sampled.
5. A venting to the exhaust system was performed on December 7, followed by a venting to the decay tank.
6. A second decayed gas sampling of the gas inventory generated from 20 September to 7 December 2006 was performed on 24 January 2007. Following the sampling, a venting to the exhaust was performed on January 25.
7. A third decayed gas sampling was performed on 30 January 2007, sampling the amount of gas that was left after the previous venting of the decayed tank, corresponding to the gas inventory created from December 7 to December 21.

The goal of the FGS was to measure also radionuclides of relatively short half life. Because of the high activity, such measurement required taking the samples only a few hours after the end of operation. Therefore the FGS had to be performed at the beginning of irradiation. Later on in the irradiation campaign only samples of gas from the CGS decay tank, that had decayed at least one week could be taken. The complete list of the samples taken is given in Table 6.2.

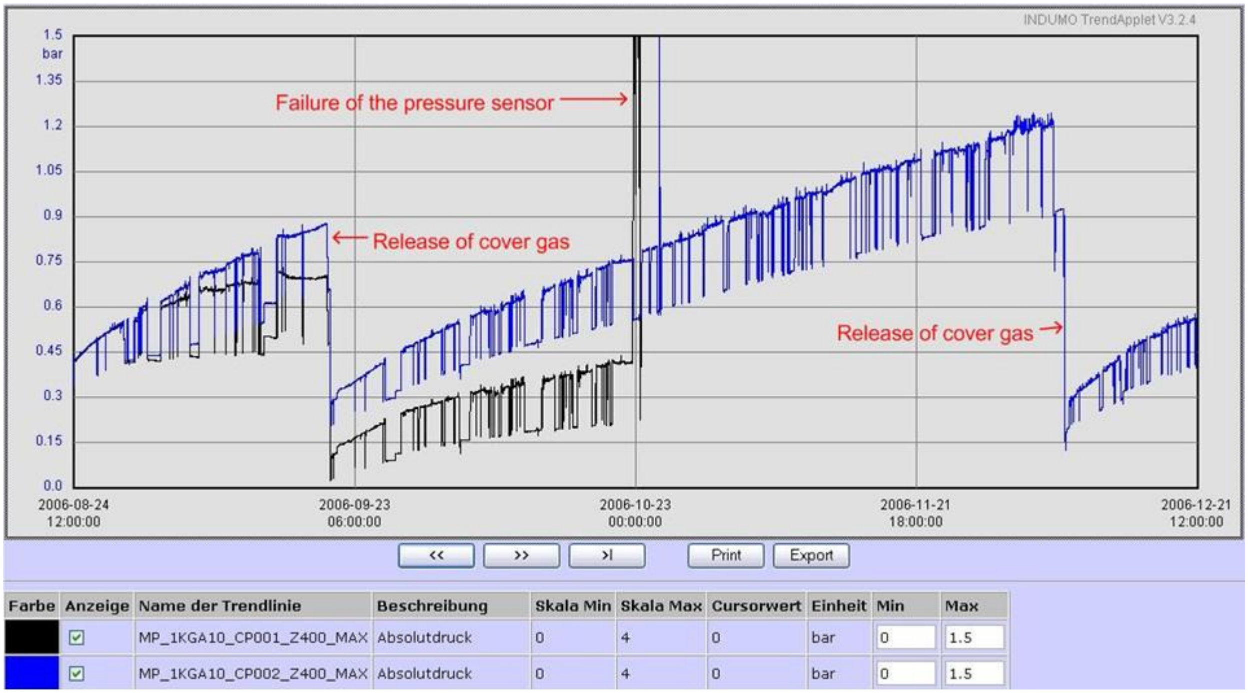
The pressure measurement in the expansion volume for most of the MEGAPIE operation period is shown in Fig. 6.3. Soon after the start of irradiation, one of the two transducers started to show a lower pressure than the other one, and it stopped working at the end of October. The pressure value from the other transducer is considered more reliable. We think however that also the latter was damaged, even though less severely, since pressure indications at the end of the operation were not consistent with the expectations. Nevertheless we considered only the CP002 value as the reference. From about day 40, also the two sensors inside the decay tank (CP003 and CP004) started drifting apart. Both sensors indicated a pressure slightly decreasing with time, a sign either of malfunctioning, or of leak in the decay tank. The failure of the pressure sensors will be a subject of investigation during the post irradiation experiment.

Table 6.1. Date and time of CGS operations. Sampling operations are indicated in bold. For each date the corresponding total proton charge on target is indicated. Additionally, the accumulated proton charge corresponding to each sample taken is given.

Date	Time	CGS operation	Total charge on target (mA·h)	Total charge for sample (mA·h)	Irradiation period sampled
14 August 2006	15:30	Start irradiation	0		
16 August 2006	8:50	**Fresh gas sampling**	1.003	1.003	14-16 August
16 August 2006	8:55	Venting to decay tank	1.003		
20 September 2006	10:40	Exhaust	607.6		
20 September 2006	16:35	Venting to decay tank	607.6		
27 September 2006	9:25	**Decayed gas sampling**	769.9	606.6	16 August-20 September
7 December 2006	10:55	Exhaust	2448.1		
7 December 2006	11:20	Venting to decay tank	2448.1		
21 December 2006	8:00	End irradiation	2796.6		
24 January 2007	15:00	**Decayed gas sampling**	2796.6	1840.5	20 September – 7 December
25 January 2007	1:35	Exhaust	2796.6		
30 January 2007	10:00	**Decayed gas sampling**	2796.6	348.5	7 December – 21 December

Table 6.2. CGS samples details. For each sample is indicated the date and time it was taken, the type of sampling, and the measurement performed (γ or mass spectroscopy).

Type of sampling	Sample label	date	Time	γ spectroscopy	Mass spectroscopy
FGS	cgm-160806-01	16/8/2006	9:00	X	X
FGS	cgm-160806-02	16/8/2006	9:00	X	X
DGS	cgm-270906-01	27/9/2006	9:25	X	X
DGS	cgm-250107-01	24/1/2007	15:00		X
DGS	cgm-250107-02	24/1/2007	15:00	X	X
DGS	cgm-300107-01	30/1/2007	10:00		X
DGS	cgm-300107-02	30/1/2007	10:00	X	X



Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
■	☑	MP_1KGA10_CP001_Z400_MAX	Absolutdruck	0	4	0	bar	0	1.5
🟦	☑	MP_1KGA10_CP002_Z400_MAX	Absolutdruck	0	4	0	bar	0	1.5

Figure 6.3. Values of the pressure sensors in the expansion volume during irradiation.

6.4 Fresh gas sampling

The fresh gas sampling was performed at the end of the second day of operation. In the first two days of irradiation a beam with a current gradually increasing from 40 µA to 250 µA was delivered to the target (Fig. 6.4). An approximated (but sufficiently detailed for the calculations) irradiation history of the first two days of operation is given in Table 6.4.

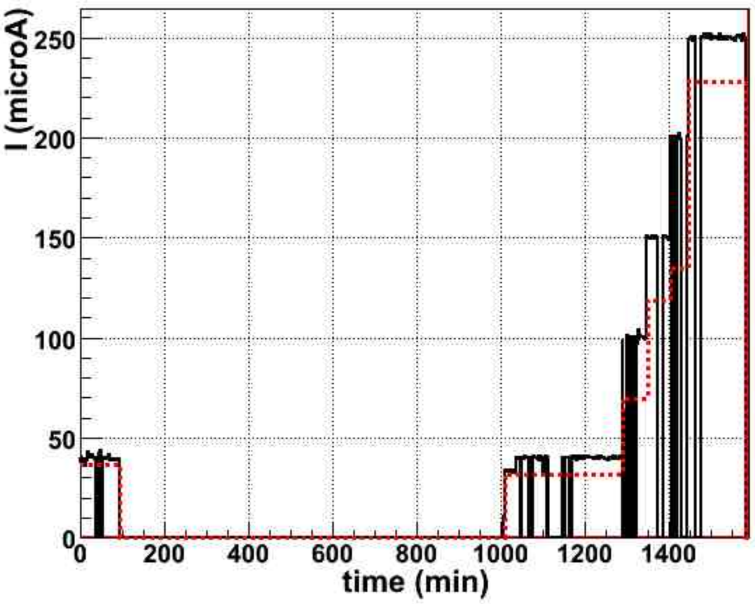


Figure 6.4. Irradiation at the start up of MEGAPIE; with dashed lines the approximated irradiation history used in the calculations (Table 6.3) is shown.

Table 6.3. Approximate irradiation history between MEGAPIE start up (14 August 2006 at 15:37) and first gas sample extraction (16 August 2006 at 9:01).

Start		Stop		Δt (s)	Intensity (µA)	Integrated charge (mA·h)
14. August	15:37	14. August	17:09	5520	36.88	0.06
14. August	17:09	15. August	8:23	54840	0	0.06
15. August	8:23	15. August	13:05	16980	31.56	0.21
15. August	13:05	15. August	14:04	3540	69.49	0.27
15. August	14:04	15. August	15:01	3420	118.47	0.39
15. August	15:01	15. August	15:44	2580	134.95	0.48
15. August	15:44	15. August	18:01	8220	227.99	1.00
15. August	18:01	16. August	09:01	54000	0	1.00

At the end of the second day of operation, about 1 mA·h of charge had been accumulated on target. Two gas samples were taken after the second day of operation, 15 hours after the end of irradiation. Details on the sampling procedure and on the variation of the pressure in the system during operation are given below.

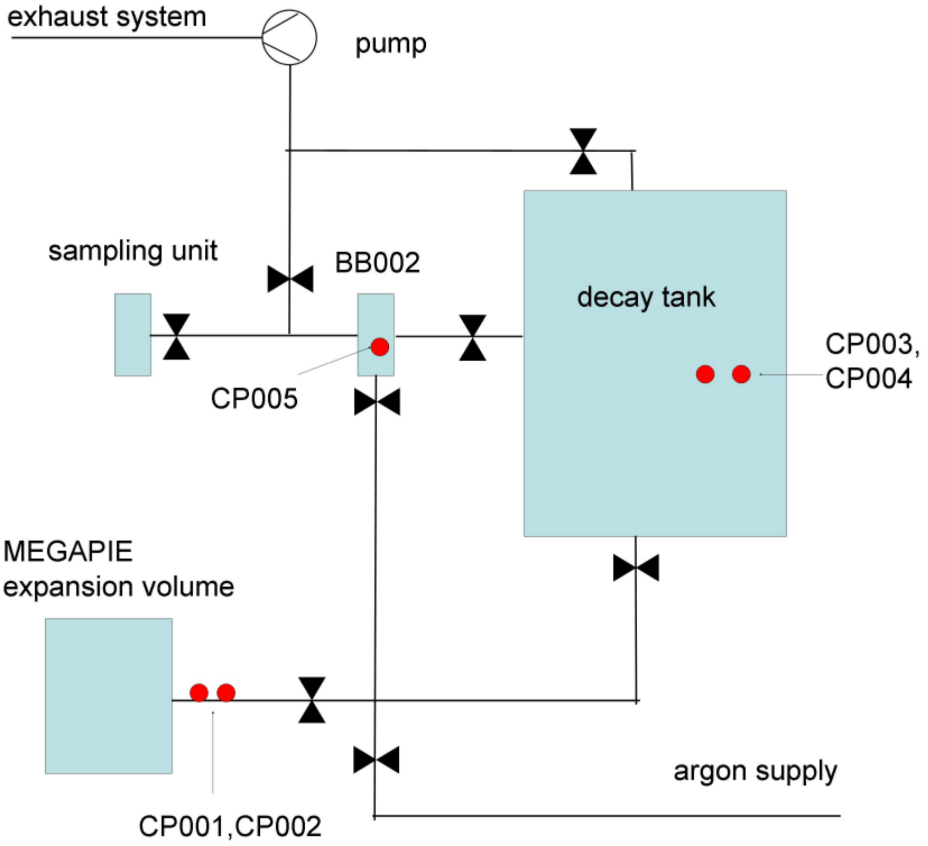


Figure 6.5. Schematic representation of the cover gas system operational components. The positions of the five pressure transducers (CP001/CP005) are indicated.

To understand the FGS procedure, we refer to Fig. 6.5 and Fig. 6.6. The FGS consisted of a series of operations, indicated below. The measured pressure values during the operation are shown in Fig. 6.7:

1. filling of the volume BB002 and of the sampling unit, giving a slight decrease of the CP001 value, and an increase of CP005 from 0 to about 0.2 bar;
2. venting of the content of BB002 and sampling unit to the decay tank, which brings a decrease of the pressure in BB002 to nearly 0 bar (due to the volume difference), and a negligible increase of the pressure in the decay tank;
3. flushing of the lines and of the decay tank, with Ar, giving an increase of the pressures in the decay tank to about 0.66 bar;
4. the first sample is taken, and a new sampling unit is placed;
5. exhaust the remaining content of the small volume and of the line to the sample;
6. filling of the small volume and the sampling unit from the decay tank to about 0.65 bar;
7. taking of the second sample, and insert a new sampling unit (for future samplings);
8. pump the remaining content of the small volume, which brings the pressure in the sampling unit down to 0 bar.

The pressure values during the fresh gas sampling operation are shown in Fig. 6.7. The initial pressure in the MEGAPIE expansion volume was of about 0.22 bar, as indicated by the CP001 sensor.

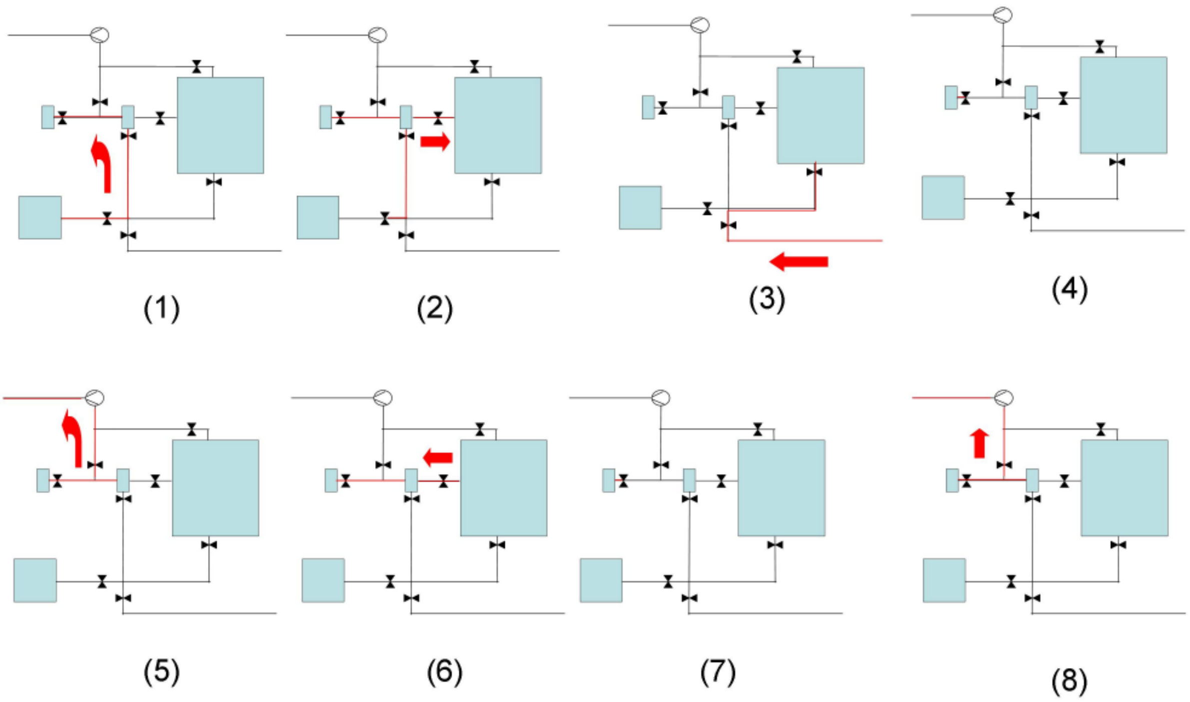


Figure 6.6. Fresh gas sampling procedure. See explanation in the text.

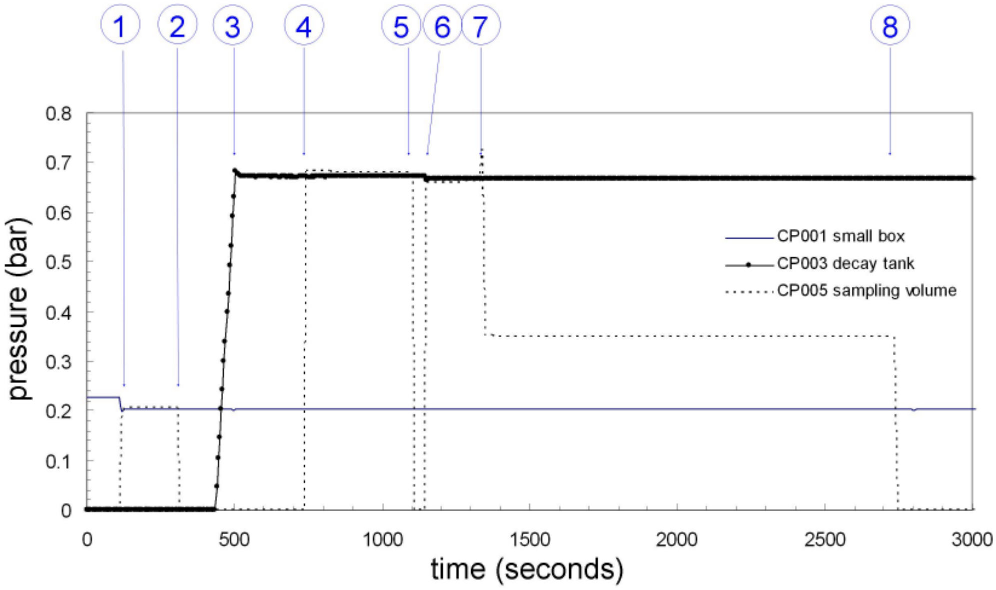


Figure 6.7. Pressure sensor values in the cover gas system during the fresh gas sampling operation. See explanation in the text. The various steps of the sampling operation detailed in the text and in Fig. 6.6 are indicated.

6.4.1 Sampling factor

The sampling factor *f* is the fraction of gas present in the cover gas system that enters in the sampling unit. It depends on the volume of the various components of the CGS (expansion volume, decay tank, tubes, sampling unit), on the temperatures of the expansion volume and of the CGS, and on the sampling procedure. Since the sampling procedures for the fresh gas sampling and the decayed sampling are different, two sampling factors are determined. The values are 3×10^{-4} and 1.5×10^{-3} for the FGS and DGS, respectively.

These sampling factors are calculated assuming that there is uniform distribution of the gas inside the volumes during the sampling operations. However, there are potential sources of uncertainties related to this sampling procedure. The first sampling was taken with the small volume BB002 almost empty, and the pressure inside the volume was below the sensitivity of the corresponding pressure sensor. Furthermore, due to the very low gas pressure, the transfer occurs very likely with a molecular flow, and the amount of gas in the sampling unit might depend on how long the procedure lasted. It is worth noting that the activities in the two samples taken during the fresh gas sampling differ on average by about 40%, while according to the calculated sampling factor should be the same (see Table 6.4). As shown below, this sampling factor applies only to noble gases.

Table 6.4. Calculation of sampling factors in the fresh gas sampling procedure.

	Expansion volume	Mixing volume BB002	Pipe small box to mixing volume	Decay tank	Pipe to sampling unit	Sampling unit
Volumes (cm^3)	1900	35	14.61	13000	1.46	50
Step 0: initial mass in ET	1	0	0	0	0	0
Step 1 (fillin of BB002+ sample volume)	9.21E-01	2.78E-02	1.16E-02	0.00E+00	1.16E-03	3.97E-02
Step 2 (relief in DT)	9.20E-01	2.14E-04	8.94E-05	7.96E-02	8.94E-06	3.06E-04
Step 3 (flush DT)	9.20E-01	2.14E-04	8.94E-05	7.96E-02	8.94E-06	3.06E-04
Step 4 (take first sample)	9.20E-01	2.14E-04	8.94E-05	7.96E-02	8.94E-06	**3.06E-04**
Step 5 (evacuate small volume+sampling unit)	9.20E-01	0	8.94E-05	7.96E-02	0	0
Step 6 (fill BB002+ second s.u.)	9.20E-01	2.13E-04	8.94E-05	7.91E-02	8.89E-06	3.04E-04
Step 7 (take second sample)	9.20E-01	2.13E-04	8.94E-05	7.91E-02	8.89E-06	**3.04E-04**

6.5 Decayed gas sampling

As previously discussed, the goal of the decayed gas samplings was limited to the assessment of the radioactivity level in the decay tank prior to further operations such as exhaust of the decay tank content. Since samples of decayed (at least 1 week) gas were taken, the information from the γ spectroscopy measurements is limited. The results are briefly discussed in the next section.

6.6 Gamma spectroscopy measurement and analysis

6.6.1 Fresh gas sampling

Most of the samples were analyzed by both γ and mass spectroscopy. The γ spectra from the two samples taken during the fresh gas sampling are shown in Fig. 6.8 and 6.9. The γ spectroscopy results are shown in Table 6.5. The indicated activities are the measured ones, extrapolated at the time of the sampling (16 August at 9:01), and refer to the sampling unit; therefore, to obtain the total activity in the expansion volume these values have to be divided by the sampling factor. The part of the γ spectrum up to 700 keV is shown in Fig. 6.9, with some γ lines of interest indicated. We note the following:

1. the absolute amount of noble gases in the first sampling is about 40% greater than in the second sample;
2. in the first sample Hg and Au isotopes (coming from Hg isotope decay) were observed, while they were not seen in the second sample.

The first result gives an indication of the systematic uncertainty of the measurements. The sampling factor in the two samplings is the same (see Table 6.4) and therefore the activities should be the same.

It is not obvious to interpret the non-observation in the second sample of Hg and Au isotopes. One reason could be related to these heavy elements sticking to the walls of the CGS (at about 40 °C, much lower than the temperature of the expansion volume) during the sampling operation. This however does not seem to be likely, because of the low concentrations of these elements. Following operation (1) (Fig. 6.6) Hg vapor was transferred to the small volume BB002. It is possible that after operation (2), or even during operation (1), the heavy elements transferred to the decay tank were absorbed. In this case there would be no flow of Hg and Au back to the small volume during operation (6) and subsequent sampling. As a consequence, the sampling factor for Hg and Au isotopes is not correct.

The amount of a given volatile m_{SU} in the sampling unit, is a fraction of the amount in the LBE m_{LBE},

$$m_{SU} = f \times r \times m_{LBE}\,, \tag{18}$$

where r is the fraction or gas produced which is released to the expansion volume, $r=m_{EV}/m_{LBE}$, and f is the sampling factor, $f=m_{SU}/m_{EV}$. The quantity of interest is the release fraction r. However, the measured quantity is the product $f{\times}r$ (if we have confidence on the theoretical estimates in the LBE), and the release factor must be deduced from the estimation of the sampling factor f, and from the calculated amount of gas produced in the LBE, m_{LBE}. It is reasonable to conclude that the sampling factor for noble gases is close to the calculated one of $3{\times}10^{-4}$. However, for mercury it is certainly different, since Hg was observed in only one of the two FGS samples taken, indicating a more complex path of the mercury molecules in the CGS during the sampling operation. In fact, there are three possible scenarios of Hg release path leading to different sampling factors:

1. transfer to the sampling unit, without further dilution in the decay tank: heavy elements stick inside the sampling unit, without dilution in the decay tank; the sampling factor is in this case $f = 4{\times}10^{-2}$:

$$m_{SU} = \frac{V_{SU}\,T_{EV}}{V_{EV}\,T_{SU}} m_{EV} = 4\times10^{-2}\; m_{EV}\,; \tag{19}$$

2. transfer in the sampling unit, without further dilution in the decay tank as in the previous case, but with Hg partially sticking to the walls of the gas lines between the expansion volume and the sampling unit, which gives $0 \le f \le 4{\times}10^{-2}$.
3. correct sampling, as for the noble gases, with $f = 3{\times}10^{-4}$.

We can therefore only give an upper limit for the mercury sampling factor: $0 \le f \le 4{\times}10^{-2}$.

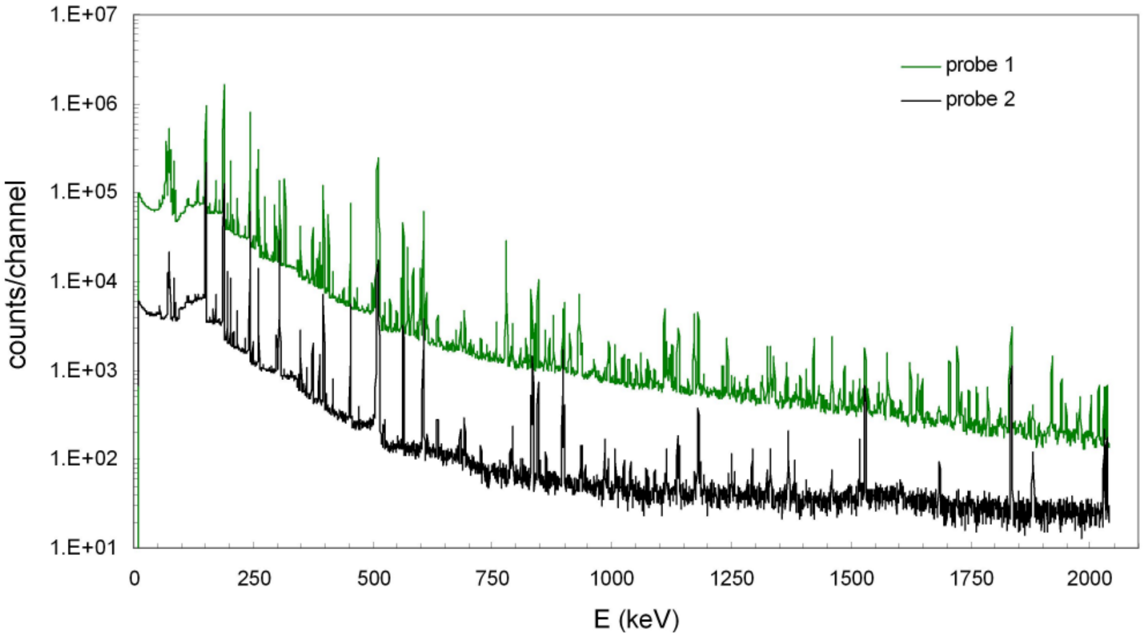


Figure 6.8. Gamma spectra from the two FGS probes.

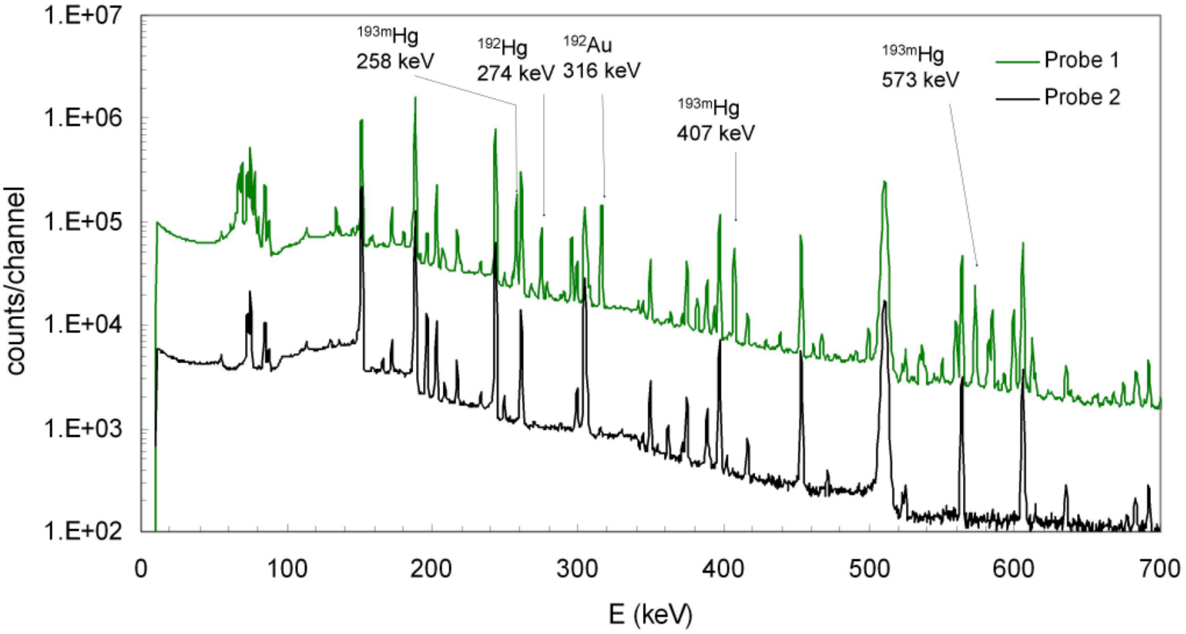


Figure 6.9. Part of the two γ spectra of Fig. 6.8 below 700 keV, with identified γ lines from heavy nuclides observed only in the first probe.

It is interesting to note that the amount of gold observed is higher than the expected amount from mercury decay. A simple verification comes from the comparison of ^{192}Hg and ^{192}Au activities (for the other isotopes the comparison is more difficult due to the presence of metastable states). The expected ^{192}Au activity A_2 of the time of the sampling, calculated extrapolating from the ^{192}Hg activity A_1 at the time of the sampling from the following formula for the growth of the daughter activities

$$A_2(t) = N_0 \frac{\lambda_2 \lambda_1}{\lambda_2 - \lambda_1}(e^{-\lambda_1 t} - e^{-\lambda_2 t}), \tag{20}$$

is between 5×10^3 Bq and 1×10^4 Bq, depending whether we consider the time 0 the end of the irradiation (15 August 8 PM) or the beginning (15 August 8 AM). The amount observed is at least 3-4 times higher, which can indicate that the mercury is absorbed more quickly than gold in the system, as it is unrealistic to assume that the gold isotopes are released directly from the LBE.

Gamma lines from the decay of ^{195}Hg were also observed. This nuclide is also fed by the decay of its metastable state; knowing precisely the release conditions one could correct for the metastable decay; however, because of the mentioned uncertainties on the release process, we preferred not to quote the ^{195}Hg value as the uncertainties would have been too high.

Table 6.5. Measured activities from the fresh gas sampling of the MEGAPIE expansion volume, performed on 16 August 2006. The indicated activities are extrapolated at the time of the sampling (16 August at 9:01). Heavy radionuclides were not observed in the second sample.

Nuclide	Half life	Probe 1 (Bq)	Probe 2 (Bq)
^{41}Ar	1.83 h	3.2×10^{2} (20%)	2.4×10^{2} (20%)
^{79}Kr	34.9 h	4.5×10^{4} (5%)	3.14×10^{4} (5%)
^{85m}Kr	4.48 h	1.5×10^{5} (5%)	1.08×10^{5} (5%)
^{88}Kr	2.84 h	2.65×10^{4} (5%)	1.92×10^{4} (5%)
^{122}Xe	20.1 h	1.38×10^{4} (10%)	9.3×10^{3} (5%)
^{125}Xe	16.9 h	9.5×10^{4} (5%)	6.47×10^{4} (5%)
^{127}Xe	36.4 d	5×10^{3} (5%)	3.6×10^{3}(5%)
^{129m}Xe	8.89 d	7.6×10^{3} (5%)	3.9×10^{3} (50%)
^{135}Xe	9.1 h	5.7×10^{2} (10%)	3.6×10^{2} (5%)
^{192}Au	5.0 h	3.41×10^{4} (5%)	
^{193}Au	17.65 h	1.18×10^{4} (10%)	
^{195}Au	186.1 d	1.2×10^{2} (15%)	
^{192}Hg	4.9 h	1.79×10^{4} (5%)	
^{193m}Hg	11.1 h	1.24×10^{4} (5%)	
^{195m}Hg	40 h	2.9×10^{3} (5%)	
^{197}Hg	64.1 h	2.12×10^{4} (5%)	
^{197m}Hg	23.8 h	3.6×10^{3} (5%)	
^{203}Hg	46.59 d	5×10^{1} (5%)	

6.6.2 Decayed gas sampling

The first decayed gas sampling was performed on September 27, after about 600 mA·h of charge had been accumulated on target. The final samplings were taken after the end of the irradiation. Results of the γ spectroscopy from these samples are shown in Table 6.6. FLUKA calculations of expected activities are also shown in the table, for the first two samplings (for the third sampling the expansion volume is not known, as the sampling was done after the target cooling took place). Even if these measurements are coarse, the results indicate a higher noble gas release in the expansion volume when the samples are taken weeks or months after the beginning of irradiation, with respect to the fresh gas sampling, as expected.

Table 6.6. Gamma-spectroscopy results from samples taken on 27 September 2006 (decayed gas sampling), 25 January 2007 (last sample taken from the decay tank) and 30 January 2007 (sample taken from the expansion volume at the end of irradiation), and comparison with FLUKA calculations. Volumes of the sampling units are also indicated.

Nuclide	Activity in the probe (Bq)	Error (%)	FLUKA
27 September 2006 (50 ml)			
^{127}Xe	2×10^9	20	6.3×10^8
25 January 2007 (0.63 ml)			
^{85}Kr	3.3×10^6	10	3.6×10^6
^{127}Xe	1.04×10^7	5	1.9×10^7
^{129m}Xe	2.0×10^5	15	-
30 January 2007 (0.63 ml)			
^{85}Kr	2.1×10^6	10	
^{127}Xe	9.4×10^6	10	
^{129m}Xe	9.4×10^5	15	

6.7 Mass spectroscopy

In addition to the γ spectroscopy measurements, the content of the probes was measured by mass spectroscopy. The main goal of the mass spectroscopy was to measure the amount of light nuclides, and in particular ^{4}He, since elements with higher mass were expected to be below detection limits. All samples indicated in Table 6.2 were analyzed. Unfortunately, several problems were encountered in the measurement process and consequently in the data analysis. Despite all the precautions taken, air was still observed in the samples. For relatively clean samples, several nuclide peaks were observed; however, the relative amounts were inconsistent with results from γ spectroscopy, as well as with calculations, indicating that this measurement technique was not apt for quantitative measurements. One example is shown in Fig. 6.10, where the mass spectroscopy from the last CGS sample (taken on 30 January) is shown. The identified ions (isotopes or molecules) are listed in Table 6.7. The spectrum shows several peaks from background, but also the presence of radioactive Kr isotopes, and even traces of Xe isotopes. The relative amounts are inconsistent with the γ spectroscopy results and with the calculations. Therefore no quantitative results were extracted from these data.

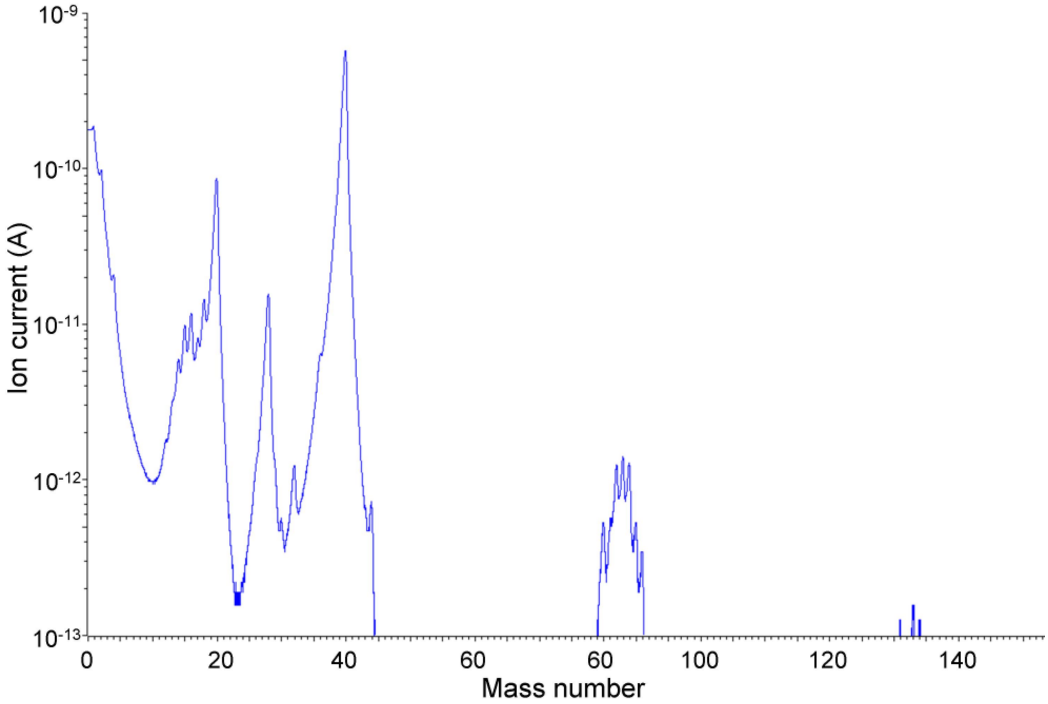


Figure 6.10. Mass spectroscopy measurement of a CGS sample taken on 30 January 2007.

6.8 Calculations

Gas production calculations were performed with different codes. In order to compare calculated and experimental values, one has to apply the following hypothesis on the behavior of the generated gas:

- spallation products are distributed homogeneously in the target: this assumption is justified by the fact that the LBE loop time in the target (~20 seconds) is very small compared to the time before sampling (two days), and the isotopes produced in principle have the time to be uniformly distributed in the LBE volume prior to sampling. This fact allows us to calculate spallation nuclei production in the whole target rather than extract production as a function of the position.

- The generated amount of spallation products is very small compared to the amount of LBE. That implies that spallation nuclei production comes purely from nuclear reactions in the LBE and spallation reactions on generated nuclides are negligible. As a consequence, the residue calculations have to be done only once, using the initial composition of the LBE.

Table 6.7. List of identified nuclides and molecules from the mass spectroscopy of a CGS sample taken on 30 January 2007.

Mass number	Ion
1	H^+
2	H_2^+ (He^{++})
4	He^+
12	C^+
13	CH^+
14	N^+
15	CH_3^+, NH^+
16	O^+, CH_4^+, NH_2^+
18	H_2O^+
20	$^{40}Ar^{++}$
28	N_2^+
32	O_2^+
36	$^{36}Ar^+$
40	$^{40}Ar^+$
44	CO_2^+
80	$^{80}Kr^+$
82	$^{82}Kr^+$
83	$^{83}Kr^+$
84	$^{84}Kr^+$
85	$^{85}Kr^+$
86	$^{86}Kr^+$

Volatiles can be released in case of a containment failure, and then their activity and volume must be known. The mechanisms producing these volatile elements are different. H and He come mainly from evaporation, Kr, Xe and I are fission products, Ne isotopes originate from a combination of these two mechanisms, Hg is obtained mainly after the first stage of the spallation process, the intranuclear cascade, and Po is the result either of Bi activation by low energy neutrons or spallation. The models used in the Monte Carlo codes must be able to reproduce the experimental results in the different mass ranges. As an example, Fig. 6.11 shows the calculated amounts in liters of hydrogen and noble gases, using MCNPX with two model combinations. Detailed calculations are shown below.

The calculations were performed using the irradiation history of Table 6.3. It is important to reproduce with the calculations the detailed irradiation history, including the final decay time of 15 hours from the end of the irradiation to the taking of the samples. In fact, during both irradiation and decay times the amount of a given nuclide is influenced not only by its direct production from the spallation reactions, but also by the decay from the parents. Thus for instance, the amount of some Hg isotopes depends also on the decay of the thallium isobars, also after the end of the irradiation.

The calculation of decay products of volatile elements, that are non volatile (like for example Au from Hg) must be treated differently. In this case only the decay from volatile elements in the expansion volume must be considered, and this clearly depends on the release characteristics of the parent nuclides. If the gas release in the expansion volume was instantaneous and complete then the amount of decay products would be precisely calculated by performing an evolution calculation following the irradiation history of Table 6.3, by putting to 0 the production rate of these decay products. E.g., one would have to put to 0 the production rate of ^{192}Au, and obtain the amount in the expansion volume by simply following evolution of the system with the irradiation history. This will give the theoretical amount of ^{192}Au due to the decay of ^{192}Hg only.

However, in reality the diffusion is slow and, as we will see below, it is not complete, but only a small fraction of the produced amount.

With MCNPX we used different models to describe the intranuclear cascade and evaporation processes. Calculations with Bertini/Dresner[45,46], INCL4/ABLA[47,48], ISABEL/ABLA[49,48] and CEM [50] codes were performed. For each models, a MCNPX numerical computation generates input files for the evolution code CINDER'90. The irradiation profile until the gas sample extraction is included in the input file for CINDER'90.

FLUKA 2006.3b was used in conjunction with ORIHET 3. SNT calculations were performed following the procedure outlined in the next chapter.

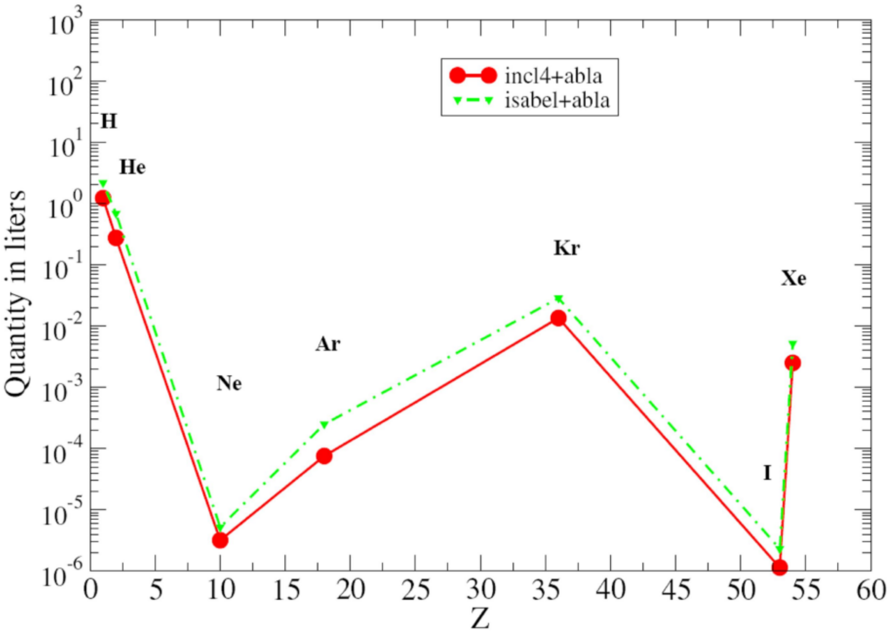


Figure 6.11. MCNPX calculated quantity of volatiles (up to Xe) produced in the LBE target after 123 days of irradiation with 575 MeV protons at 0.947 mA using two spallation models.

In order to evaluate the statistical error associated to the calculated activities, we used the following method: two additional CINDER'90 calculations were carried out, with isotopic production rates (used in the Bateman equations) increased or reduced by their statistical uncertainties (given by MCNPX), thus obtaining uncertainty bars on the final production rates. Statistical uncertainty sources in the Bateman equation come from neutron flux and spallation production rate. Error on neutron flux is lower than 0.04% while spallation uncertainty is generally at the per-cent level or higher.

The results from the calculations are shown in Table 6.8. Metastable states were calculated only with two MCNPX models, and with SNT. The calculated values are the expected activities in the 50 ml sampling unit, assuming complete release of the gas from the LBE to the expansion volume. That is, they are the calculated activities in the LBE, multiplied by the sampling factor f=3×10^{-4}. It is obvious that the calculations are much higher than the measured values. Assuming that the calculations give overall correct results, we can conclude that the release to the LBE is only partial.

The mass distribution of the measured and calculated amounts is shown in Fig. 6.12. From the values in Table 6.8, the points relative to the metastable states of isotopes have been removed. The calculations are consistently higher than the experimental values. To better understand the difference between calculations and data, we plot in Fig. 6.13 the ratio $r=m_{SU}/f/m_{LBE}$ for each nuclide, as a function of the mass number. The average ratio for noble gases is 1.5×10^{-2}. We can only put a lower limit on Hg release of 2.1×10^{-7} (assuming $f \leq 4\times10^{-2}$).

In Fig. 6.14 the same ratios are plotted as a function of the nuclide half lives. The ratios are practically independent of the half lives for both noble gases and heavy elements. This result could be explained by the fact that most of the irradiation took place in the last four hours of the commissioning phase. Assuming that the dilution of the noble gases during the sampling was correct, we can say that the ratio of 1.5×10^{-2} coincides with the noble gas release fraction in these irradiation conditions.

One notable discrepancy is found with SNT for the calculated yield of ^{41}Ar, which is much lower than the value obtained with the other codes. This value results from the use of the improved Fong model [51,52] used in the CASCADE/ASF calculation. The model predicts the sharp decrease of the fission yields for lead and bismuth isotopes with decrease of the fragment mass for $A < 43$. Probably the data obtained for MEGAPIE can be applied for further model improvement.

Table 6.8: Activities measured (Probe 1) and calculated with MCNPX (with different model combinations), FLUKA and SNT. Activity values in Bq. Calculated values are activities in LBE multiplied by the sampling factor f=3×10^{-4}. Statistical uncertainties for the Bertini/Dresner MCNPX calculation are indicated.

Nuclide	Probe 1	MCNPX				FLUKA	SNT
		Bertini/Dresner	INCL4/ ABLA	ISABEL/ ABLA	CEM		
^{41}Ar	3.2×10^{2}	3.71×10^{4} (15 %)	1.40×10^{4}	3.10×10^{4}	2.30×10^{4}	2.6×10^{4}	2.7×10^{2}
^{79}Kr	4.5×10^{4}	5.28×10^{6} (5 %)	2.54×10^{6}	6.00×10^{6}	1.80×10^{6}	2.0×10^{6}	5.2×10^{6}
^{85m}Kr	1.5×10^{5}	1.06×10^{7} (4 %)	1.48×10^{7}	-	-	-	5.3×10^{6}
^{88}Kr	2.7×10^{4}	2.65×10^{6} (4 %)	1.92×10^{6}	2.30×10^{6}	1.50×10^{6}	1.8×10^{6}	1.3×10^{6}
^{122}Xe	1.4×10^{4}	2.39×10^{6} (7 %)	1.20×10^{6}	3.50×10^{6}	2.00×10^{6}	5.7×10^{5}	2.6×10^{6}
^{125}Xe	9.5×10^{4}	6.55×10^{6} (5 %)	5.34×10^{6}	9.60×10^{6}	3.40×10^{6}	3.8×10^{6}	8.2×10^{6}
^{127}Xe	5.0×10^{3}	3.25×10^{5} (5 %)	2.86×10^{5}	4.90×10^{5}	1.80×10^{5}	3.2×10^{5}	4.0×10^{5}
^{129m}Xe	7.6×10^{3}	9.48×10^{4} (4 %)	1.76×10^{5}	-	-	-	1.2×10^{-2}
^{135}Xe	5.7×10^{2}	2.09×10^{6} (12 %)	2.51×10^{5}	1.20×10^{5}	1.70×10^{6}	1.6×10^{5}	7.2×10^{4}
^{192}Au	3.4×10^{4}	8.47×10^{8} (0.5 %)	9.59×10^{8}	1.30×10^{9}	1.50×10^{9}	1.1×10^{9}	1.4×10^{9}
^{193}Au	1.2×10^{4}	8.00×10^{8} (0.5 %)	8.67×10^{8}	1.20×10^{9}	1.40×10^{9}	9.9×10^{8}	1.2×10^{9}
^{195}Au	1.2×10^{2}	5.26×10^{6} (0.5 %)	5.70×10^{6}	7.80×10^{6}	8.40×10^{6}	7.0×10^{6}	7.1×10^{6}
^{192}Hg	1.8×10^{4}	3.46×10^{8} (0.6 %)	3.94×10^{8}	5.20×10^{8}	6.10×10^{8}	4.4×10^{8}	5.3×10^{8}
^{193m}Hg	1.2×10^{4}	1.71×10^{8} (0.4 %)	1.31×10^{8}	-	-	-	5.0×10^{7}
^{195m}Hg	2.9×10^{3}	5.82×10^{7} (0.4 %)	4.64×10^{7}	-	-	-	2.7×10^{7}
^{197}Hg	2.1×10^{4}	6.30×10^{8} (0.4 %)	6.49×10^{8}	8.10×10^{8}	8.10×10^{8}	8.3×10^{8}	7.2×10^{8}
^{197m}Hg	3.6×10^{3}	6.72×10^{7} (0.4 %)	6.68×10^{7}	-	-	-	5.7×10^{7}
^{203}Hg	5.0×10^{1}	2.26×10^{6} (0.4 %)	2.51×10^{6}	1.20×10^{6}	1.30×10^{6}	9.3×10^{5}	1.4×10^{6}

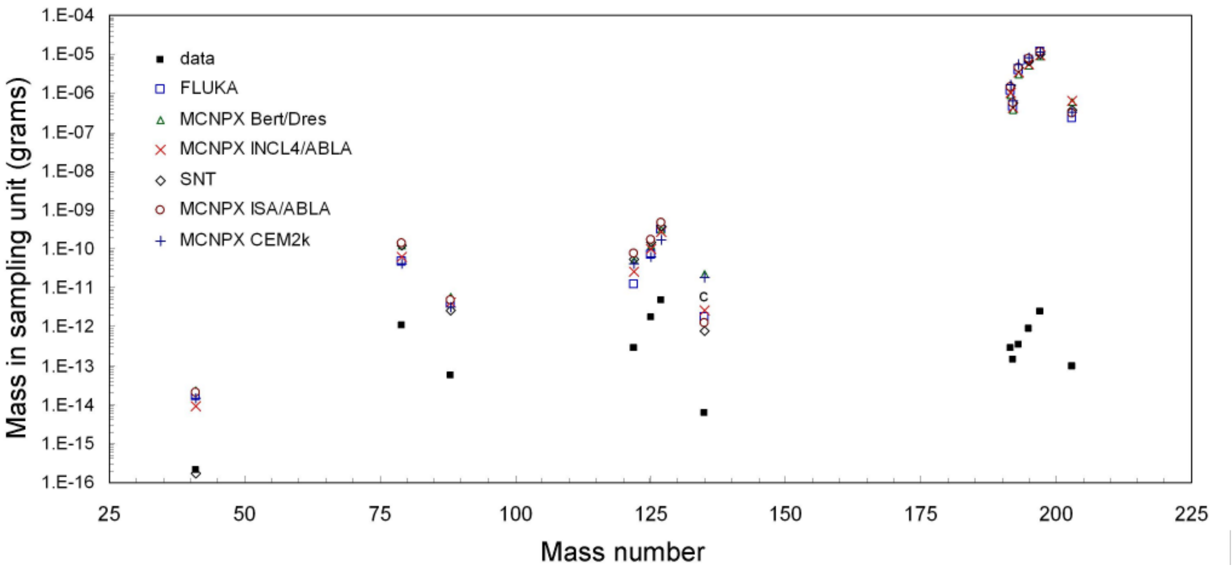


Figure 6.12. Comparison between the measured amounts (grams) in the sampling unit, and the maximum expected values from calculations, assuming f=3×10^{-4} for noble gases and $f \leq 4\times10^{-2}$ for mercury and its decay product gold. The calculated values shown for heavy elements (A>180) are therefore upper limits.

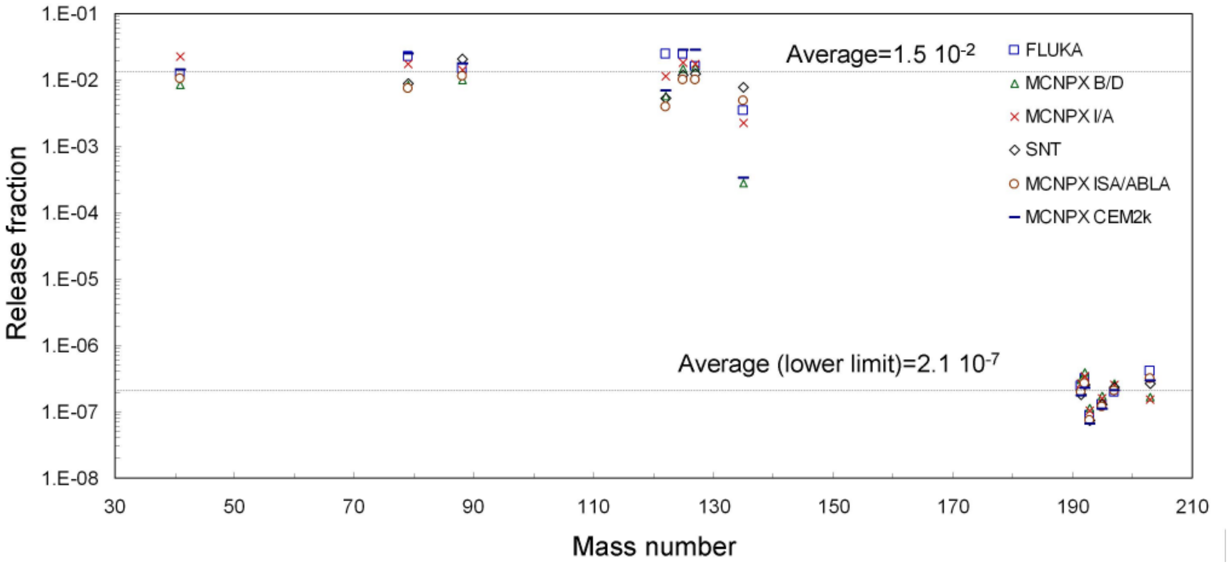


Figure 6.13. Estimated fractional release r for noble gases and heavy elements. The quantity plotted is $r=m_{SU}/f/m_{LBE}$, assuming $f = 3\times10^{-4}$ for noble gases and $f \leq 4\times10^{-2}$ for mercury and its decay product gold. The calculated values shown for heavy elements (A>180) are therefore lower limits of the fractional release.

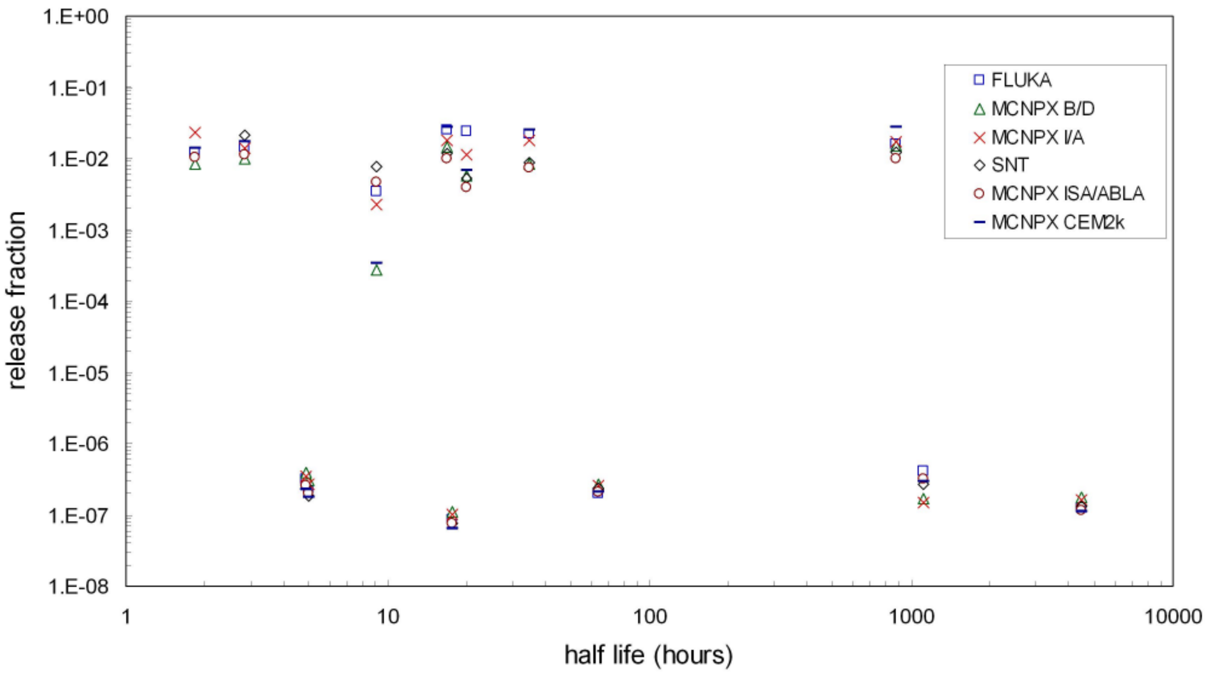


Figure 6.14. Ratio between calculated and measured activities as a function of nuclide half life.

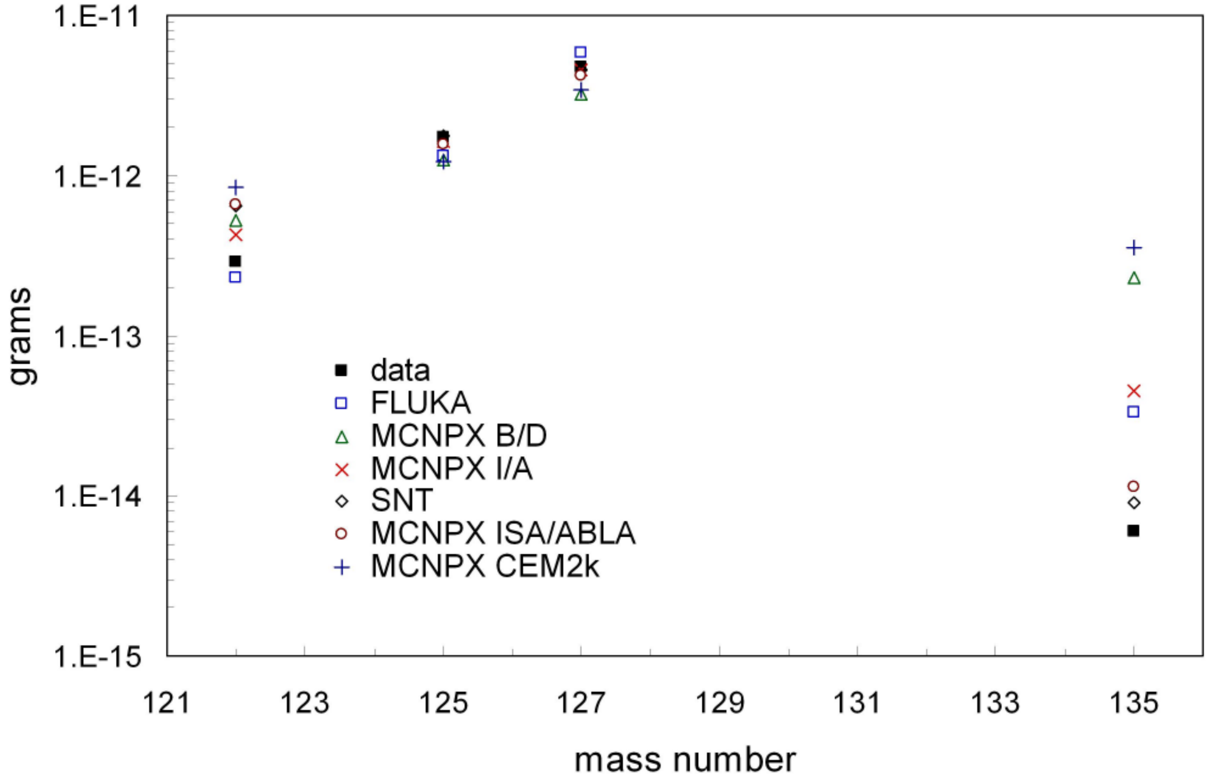


Figure 6.15. Measured and calculated amounts (in grams) of Xe isotopes. Calculations are normalized to the data (see text).

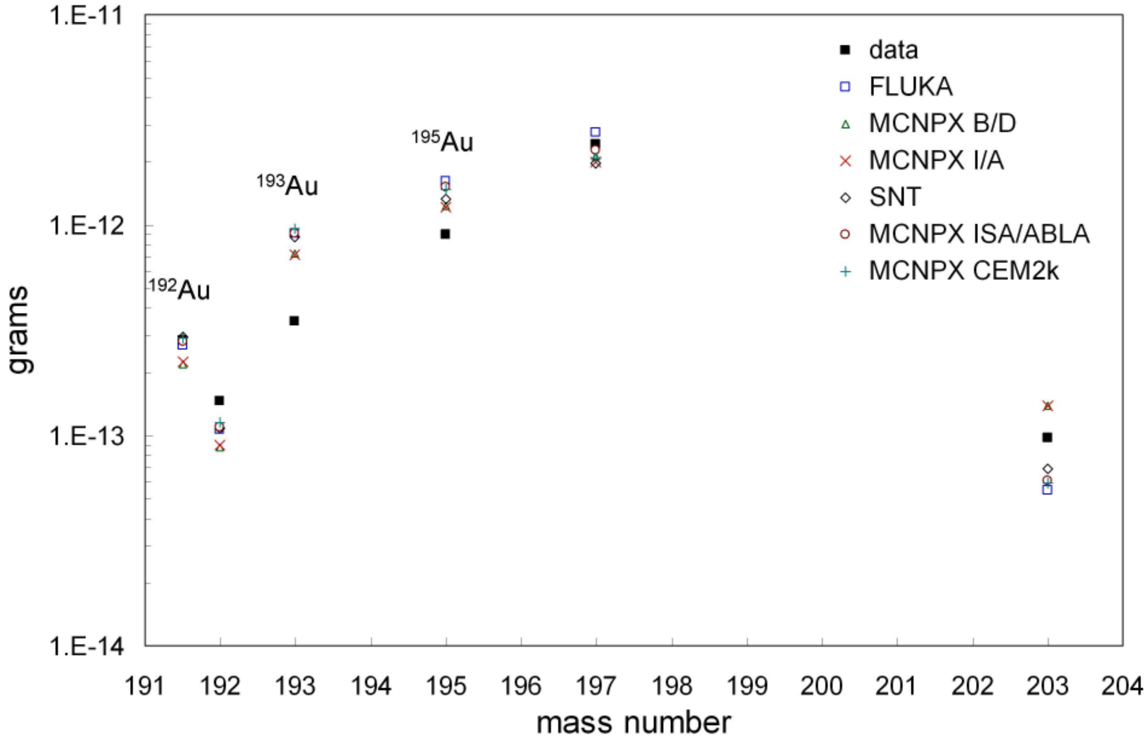


Figure 6.16. Measured and calculated amounts (in grams) of Hg and Au isotopes. Gold isotopes are indicated in the figure. Calculations are normalized to the data.

It is interesting to plot the mass distribution of calculated and measured amounts of elements for which several isotopes were measured, namely xenon (Fig 6.15) and mercury and gold (Fig. 6.16). In these two figures the calculated masses are normalized to the experimental one using the normalization factor

$$\frac{1}{N}\sum_{i=1}^{N}\frac{m_{i,data}}{m_{i,calc}}, \tag{21}$$

where the sum is over all the isotopes N of a given element.

As it was shown in Fig. 6.13, no corrections are needed for partial decay of short-lived nuclides, usually placed on the tails of the mass distributions. From Fig. 6.15, one can see that there are some discrepancies between experimental results and some calculations at the tails of the distributions; in particular for ^{135}Xe for the MCNPX calculations with Bertini/Dresner and with CEM2k, which give results much higher than the data. From Fig. 6.16, the set of calculations is overall more consistent with the data, especially for the Hg isotopes. As discussed above, the release path of gold isotopes, coming only from the decay of the corresponding parent Hg isotopes is much more difficult to simulate.

6.9 Light nuclei

A quantitative measurement of the light nuclei production (hydrogen and helium isotopes) was not possible in MEGAPIE, due to the lack of quantitative information from the mass spectroscopy measurements. It is however of great importance to determine the production rates of these nuclides, for several reasons such as pressure increase in the cover gas system and tritium production; in the case of structural materials, radiation damage can be induced by hydrogen and helium production, and eventually estimates must be done also for the materials.

6.9.1 SNT calculations

The evaluation of proton, deuteron, triton, ^{3}He, and alpha-particle production cross sections has been performed using available experimental data from EXFOR and Refs. [53,54,55,56,57,58], cross section obtained from systematic [59], and results of model calculations. Experimental proton production cross sections from Ref. [54] were corrected to include the whole energy range for emitted protons. Calculations have been carried out using the nuclear models implemented in the TALYS code [60], the ALICE/ASH code [61], the DISCA-C code [62], and the CASCADE code [63,64]. All models mentioned above include the possibility for the simulation of the non-equilibrium emission of clusters from excited nuclei.

Examples of calculations and the evaluated data are given in Annex C (Figs. C2-C12).

Table 6.9 shows evaluated rates for the production of hydrogen and helium isotopes in lead-bismuth eutectic. The relative contribution of protons and neutrons are also shown. Averaged production cross sections are presented in Table 6.10.

Table 6.9. SNT calculated production rates of hydrogen and helium isotopes (atoms per incident protons) in LBE and the relative contribution from proton and neutron irradiation.

Particle produced	Atoms/ proton	Relative contribution, %	
		Protons	Neutrons
proton	1.27 ± 0.17	86.1	13.9
deuteron	0.210 ± 0.020	78.8	21.2
triton	0.057 ± 0.012	81.5	18.5
^{3}He+^{4}He	0.133 ± 0.025	84.1	15.9

Table 6.10. Cross sections for hydrogen and helium isotopes production averaged using the energy distributions of neutrons and protons in the LBE.

Particle produced	Averaged cross section (mb)	
	Proton irradiation	Neutron irradiation
proton	2160	18.4
deuteron	325	4.65
triton	90.8	1.09
^{3}He+^{4}He	220	2.21

6.9.2 MCNPX and FLUKA calculations

MCNPX calculations with four model combinations were performed, while for FLUKA the physics options described in Section 2.5.1 were used. Results are shown in Table 6.11. We have excluded from the table the results on deuteron and triton production from INCL4/ABLA and ISABEL/ABLA, which are known to be not correct in the MCNPX version used.

In general, the results on proton production are rather consistent between the different models. For deuteron production, SNT and FLUKA agree well, Bertini/Dresner is lower and CEM2k is higher.

For triton, CEM2k is much higher than the other values. For He, values range from 0.12 atoms/proton (FLUKA) to 0.30 atoms/proton (CEM2k).

Table 6.11. Calculated production rates (atoms/source proton) in LBE of hydrogen and helium isotopes.

Particle	MCNPX 2.5.0				SNT	FLUKA 2006.3b
	INCL4/ ABLA	Bertini/ Dresner	ISABEL/ ABLA	CEM2k		
proton	1.57	1.83	1.43	1.28	1.27	1.15
deuteron	-	0.089	-	0.36	0.210	0.22
triton	-	0.048	-	0.12	0.057	0.073
helium isotopes	0.173	0.203	0.300	0.192 (^{4}He) 0.031 (^{3}He)	0.133	0.108 (^{4}He) 0.0063 (^{3}He)

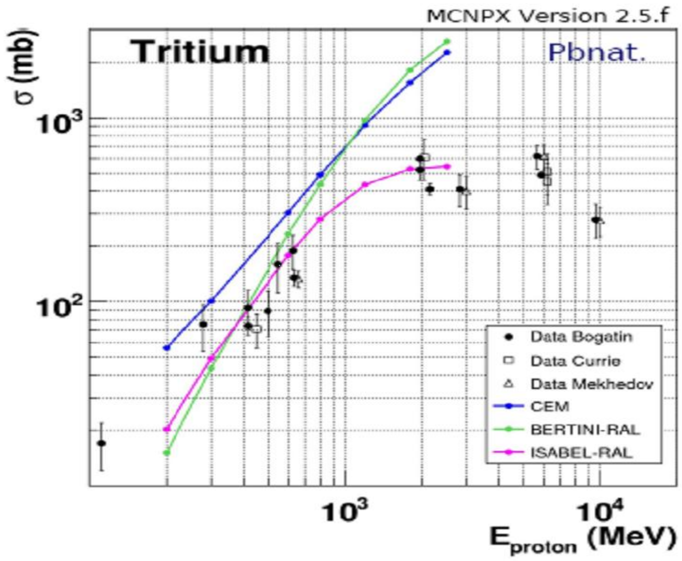


Figure 6.17. Tritium production cross section from $p(E_p)$+Pb: data are compared with MCNPX code predictions. After Ref. [65].

In Fig. 6.17 a benchmark comparison of tritium calculations using MCNPX with different models is shown. Results are compared with experimental data on $p(E_p)$+Pb at different proton energies. We see that at the energy range of the MEGAPIE proton beam (575 MeV), the data are well reproduced using the Bertini-RAL model combination (RAL is the fission model associated in MCNPX to the Dresner evaporation model).

During MEGAPIE operation a large amount of tritium was found in the dyphil oil, exceeding the calculations by several orders of magnitude. The calculations assumed production of tritium only by spallation in the oil loop, which starts at a level about 2 m above the beam window, and therefore led to very small expected amounts. Such discrepancy can only be explained by leak of tritium from the LBE to the oil loop. A special procedure had to be developed to handle the dyphil after irradiation.

6.9.3 Pressure build up calculations

The pressure in the MEGAPIE expansion volume was measured continuously during operation with the two pressure transducers CP001 and CP002 placed in the small box (Fig. 6.5). The pressure increase was calculated and compared with the experimental values. For this purpose, we considered the time between the beginning of irradiation (14th August 2006) until the first venting to the decay tank (20th September 2006). The evolution calculation is performed in this time interval according to the current profiles showed in Fig. 6.18.

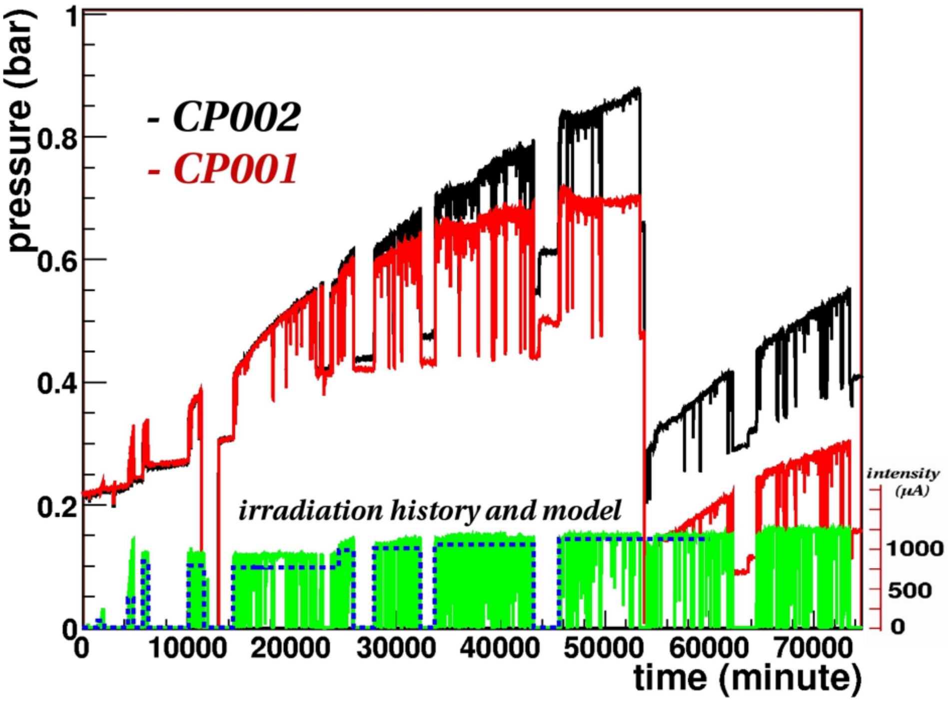


Figure 6.18. Gas pressure measured in the expansion volume by tranducers CP001 and CP002 from the beginning of irradiation (14th August 2006) for about 50 days of operation. The actual irradiation history (green line) and the approximated one used in the calculations (dotted line) are shown.

Since the transducer CP001 failed after about two months of irradiation, we use as reference for comparison with the simulations only the value of the transducer CP002. For the pressure build-up the MCNPX calculated production rates (with the Bertini/Dresner intranuclear cascade/evaporation model) from Table 6.11 were used.

The pressure calculation in the expansion tank is based on the following considerations:

1. the gases behave as perfect gas;
2. the pressure build-up is mainly due to hydrogen and helium. The contribution from the other volatile elements is about three orders of magnitude smaller;
3. hydrogen isotopes combine instantaneously in the expansion volume forming H_2 molecules;
4. the temperature of the gas is given by the CT020 thermocouple response (see Fig. 1.11 on page 27);
5. the dimension of the expansion volume depends of LBE volume, which depends on its temperature, and it is different in hot standby and operating conditions.

Following those assumptions, the pressure is given by:

$$P(t) = \frac{1}{V}\left(V_0 P_0 + \tau \frac{R T(t) n(t)}{Na} \right) \tag{22}$$

Where $P(t)$ and P_0 represent pressure at time t and at t=0. V_0 is the initial expansion tank volume. V is the expansion volume depending on the irradiation conditions. During beam irradiation at maximum power, V is equal to 1.4 liters while $V=V_0$=1.9 liters during a beam stop. Na is the Avogadro constant and $T(t)$ represents the temperature of the free surface. R = 8.31 J mol^{-1} K^{-1} is the gas constant. The initial pressure is $P_0 = 0.22\times10^5$ Pascal, given by Figure 6.18 at the initial time.

The amount $n(t)$ of the considered chemical compounds released in the expansion tank is given by:

$$n(t)=\left(\tau_1\frac{n_H(t)+n_D(t)+n_T(t)}{2}+\tau_2\, n_{He}(t)\right) \tag{23}$$

Where $n_H(t)$,$n_D(t)$,$n_T(t)$ and $n_{He}(t)$ are the nuclei number of hydrogen, deuterium, tritium and helium given by CINDER calculation. τ_1 and τ_2 are the release factors for hydrogen and helium. We choose here to simplify $\tau_1=\tau_2=\tau$. In order to take into account in the model possible gas leaks, one would have to consider that leaks must be proportional to the pressure. Thus, the leak corrected pressure is $P_c(t) = P(t) - a\cdot P(t)$ and the leak term a appears as a global factor. The corrected pressure is thus given by:

$$P(t) = \frac{(1-a)}{V}\left(V_0 P_0 + \tau\frac{RT(t)n(t)}{Na}\right) \tag{24}$$

Figure 6.19 compares the pressure calculation with the experimental one (with τ=1 and a=0).

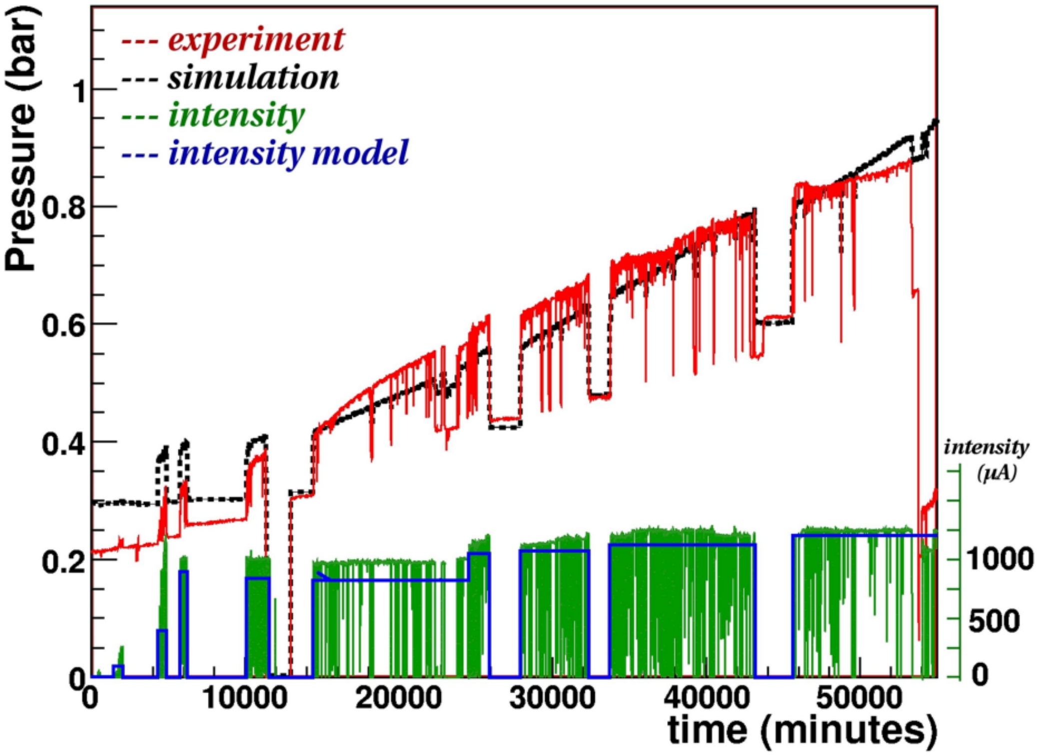


Figure 6.19. Gas pressure measured and calculated (dotted line) in the expansion volume by transducers CP002 from beginning of irradiation (14th August 2006) until the first exhaust (20th September 2006). The simplified irradiation history is showed in blue.

6.10 Interpretation of the results

6.10.1 Gas sampling

Absolute amounts of released noble gases and of Hg and Au isotopes were determined by the γ spectroscopy measurements from the fresh gas sampling made after 2 days of operation. We found the following results:

1. only a fraction of the noble gases produced in the LBE was released and found in the expansion volume after 2 days of operation. The amount is about 1% of the total, calculated amount. This fraction is nearly the same for Ar, Kr and Xe isotopes, indicating a similar release mechanism for all the noble gas elements. We know from previous measurements at ISOLDE, that noble gases diffuse slowly in LBE targets, and the diffusion time decreases as the temperature increases. To have a complete, or near complete release, even in a small target, one should heat the free surface up to about 600 °C. At the temperature of the MEGAPIE free surface, about 250 °C, the release is strongly suppressed: $r=(1.5\pm0.5)\times10^{-2}$ (see Fig. 6.13).

2. Most of the models used in the calculations seem to reproduce fairly well the mass distribution of the measured radionuclides; there is however a large spreading of the results in the tails of the distributions (Figs. 6.15, 6.16).

3. As expected, also the release of Hg was a small fraction of the total. It is however difficult to estimate the fraction of Hg released in the expansion volume, and as previously discussed we can only give a lower limit on the mercury release: $r \geq (2.1\pm0.2)\times10^{-7}$ (see Fig. 6.13). We remind that the expected release fraction is of about 10^{-6} (Ref. [39]).

4. A comparison was performed also with expected release rates during the regular gas samplings. In this case the amount of calculated ^{85}Kr and ^{127}Xe are within a factor of 3 to the experimental values, indicating, as expected, that the noble gas release is more complete after one month of operation or more.

6.10.2 Pressure build-up

The pressure increase in the expansion volume depends mostly on the release of light elements, hydrogen and helium. The contribution from the other noble gases or mercury in terms of pressure is negligible. Production rates were calculated with different codes and model combinations. The calculated pressures compare fairly well with the measured ones (Fig. 6.19). However, the calculated pressure is lower than the measured one at the beginning of the irradiation, while after about 25 days of operation it becomes higher. The measured pressure shows a trend that seems to indicate either a gas leak, or a partial failure of the pressure transducers. Both effects are possible, as in fact leaks were observed (some ^{127}Xe was detected in the insulation gas), as well as pressure transducer failure (one of the two pressure transducers in the small box started to malfunction after a few days of operation, until eventually it stopped working). Leaks could be in the opposite direction too (from the insulation gas into the expansion volume) and that could explain the higher pressure observed at the beginning of operation.

PART II: ACTIVITY CALCULATIONS

7. CALCULATIONS OF TARGET ACTIVATION

7.1 Introduction

In the previous chapter we have discussed the problem of stable and radioactive volatile elements production and release during the operation of MEGAPIE. The creation and accumulation of radionuclides during irradiation of the MEGAPIE target is an important topic: besides all the issues related to the gas production, knowledge of the activation of the target is important for licensing, study of accident cases, target handling and disposal after irradiation, waste conditioning. Important scientific information can be obtained in the post irradiation experiment, by the analysis of samples of LBE and structural materials.

Following the spallation reaction, isotopes spanning the entire chart of nuclides (up to $Z = 85$ in the case of an LBE target) are created. The target activation can be calculated using Monte Carlo codes. FLUKA and MCNPX are at present two of the codes with the highest reliability for activation calculations following spallation reactions. In the following, after a short discussion of the various options used in the codes, we show a code comparison, and discuss the status of the code validation work, showing the ability in reproducing the experimental data and what still needs to be improved. The code versions used in the present work utilize models and cross section data tables able to reproduce the most recent experimental results of production cross section over large mass regions, measured in thin target experiments[66,67]. Both codes have been benchmarked using basic data obtained within the HINDAS program[66] and the EURISOL-DS project[68].

These codes must be used in conjunction with evolution codes such as CINDER'90 and ORIHET 3, which were described in Chapter 2. Additionally, neutron and proton spectra can be used in conjunction with other programs, such as SNT, for activation calculations.

Additionally, the codes have been benchmarked with data on production rates of volatile elements in a proton-irradiated molten lead-bismuth target and the codes have been able to reproduce with good precision production rates of nuclides from Z=2 to Z=80 [69].

A large amount of nuclear calculations has been performed since the beginning of the MEGAPIE project, as reported in Ref. [4]. Calculations were needed for several topics such as target design, radioprotection issues, and study of accident cases. Additional calculation work was done in the post-test analysis phase. This work was required for two reasons:

1) considerable progress has been achieved in the MCNPX and FLUKA codes capabilities to calculated nuclide production in the last 2-3 years. It was therefore important to compute the activation products with the latest available models, better benchmarked against experimental data.

2) In the post-test analysis phase, activation calculations could be performed with the actual irradiation history.

Because of these reasons, calculations in support of target handling, conditioning and disposal after irradiation were repeated. Additionally, calculations in support of the post irradiation experiment (PIE) were performed, even though they are not reported here.

After the section on code validation, the results on activation calculations of the LBE and of the target structure are discussed. Finally, some important topics, such as decay heat and dose rates, and effect of the impurities in the LBE, are treated. Part of the results presented here has been published before[70,71].

The general conclusions for this chapter are at the end of Chapter 8.

7.2 Calculation methods

7.2.1 FLUKA and MCNPX

Activation calculations were performed with the FLUKA code[72], version 2006.3b, and with MCNPX[73], version 2.5.0. Both codes are particle physics Monte Carlo simulation packages that calculate the particle transport and interaction with matter. They have a wide range of applications including medium and high-energy physics and engineering, shielding, dosimetry, and medical.

For the calculations of the activation of the lower half of the MEGAPIE target, the full simulations starting from the interaction of the proton beam with the target was performed. As mentioned above, protons with energy of 575 MeV were distributed according to the SINQ calculated beam profile. The obtained results were then normalized to a proton current of 0.947 mA.

FLUKA allows calculating the residual nuclei production rates (atoms/proton) for any volume of the geometry of the problem. The production rates were then used as input to the ORIHET 3 program[74] to calculate the activity build up and decay at times specified by the user. The build up calculation was performed up to 123 days of irradiation, while decay calculations were performed at different times, up to 100 years after end of irradiation.

For MCNPX, the contribution of the high energy residues to the activities and concentration of nuclear elements has been extracted using HTAPE3X from MCNPX2.5.0 and given to the evolution code CINDER'90 for subsequent decay and activation by low-energy neutrons (below 20 MeV). In this report, different models have been considered to calculate the elementary cross sections:

- Bertini[45]-Dresner[46],
- INCL4-ABLA[47],
- Isabel[75]-ABLA,
- CEM2k[76].

7.2.2 SNT

Activation calculations were also done using the SNT code[77,78,79,80,81]. The SNT code was specially designed for the modeling of material transmutations and dose calculations under the irradiation with low, intermediate and high energy particles. Input data can be presented using various formats including ENDF/B, EAF and others. The code has been improved and corrected at FZK.

Energy distributions of neutrons and protons in the LBE have been calculated with MCNPX.

Calculations were performed using evaluated data from the various sources listed below. The data are the results of evaluations performed by different authors considering all the experimental data available at the time for incident neutrons and protons at energies from 0.01 meV up to 600 MeV.

The data sets, with energy ranges and numbers of target nuclei used in the calculation of nuclide composition are shown below for neutrons and protons.

Neutrons:

- JEFF-3.1A[82], $E_n < 20$ MeV, 691 nuclei;
- JEFF-3.1 (general purpose file), $20 < E_n < 150$ MeV, 31 nuclei;
- IEAF-2001[83], $20 < E_n < 150$ MeV, 641 nuclei;
- IEAF-2007[84], $150 < E_n < 575$ MeV, 669 nuclei.

Protons:

- PADF[85], $E_p < 150$ MeV, 2322 nuclei;
- PADF-600[86], 150 MeV $< E_p <$ 575 MeV, 23 nuclei;

- YIELDX[87], 150 MeV < E_p< 575 MeV, 725 nuclei.

The tritium production cross section at incident nucleon energies above 150 MeV was evaluated according to a semi-empirical approach[88] and using available measured data. Yields of heavy clusters were estimated with the help of the so-called nuclear forces break down model[89]. Parameters of the model have been specified in Refs. [81,90]. Knock-out cross sections were obtained for 69 residual nuclei from ^{7}Be to ^{28}Na produced in the irradiation of heavy nuclei with nucleons of intermediate energy.

Radioactive decay properties of nuclei were taken from JEFF3.1.1[82], which is the latest version of the JEFF radioactive data set.

7.3 Code validation

As mentioned before, the recent advances in FLUKA and MCNPX allow for a precision in the numerical calculations of nuclide production that was not achievable a few years ago. The most recent versions of FLUKA and MCNPX have been recently compared with experimental data in the frame of the EURISOL-DS study[68]. As shown in Figs. 7.1 and 7.2, FLUKA and MCNPX (the latter using both INCL4-ABLA and Bertini-Dresner model combinations) have been compared with Pb+p data at 1 GeV initial energy, taken in inverse kinematics. From these results we can draw the following conclusions:

- in general, for spallation products with mass close to the mass of the target element, all models reproduce satisfactorily the data;
- for the fission region, FLUKA and MCNPX (INCL4-ABLA) are better than Bertini-Dresner;
- none of models is satisfactory in the evaporation region far from the target.

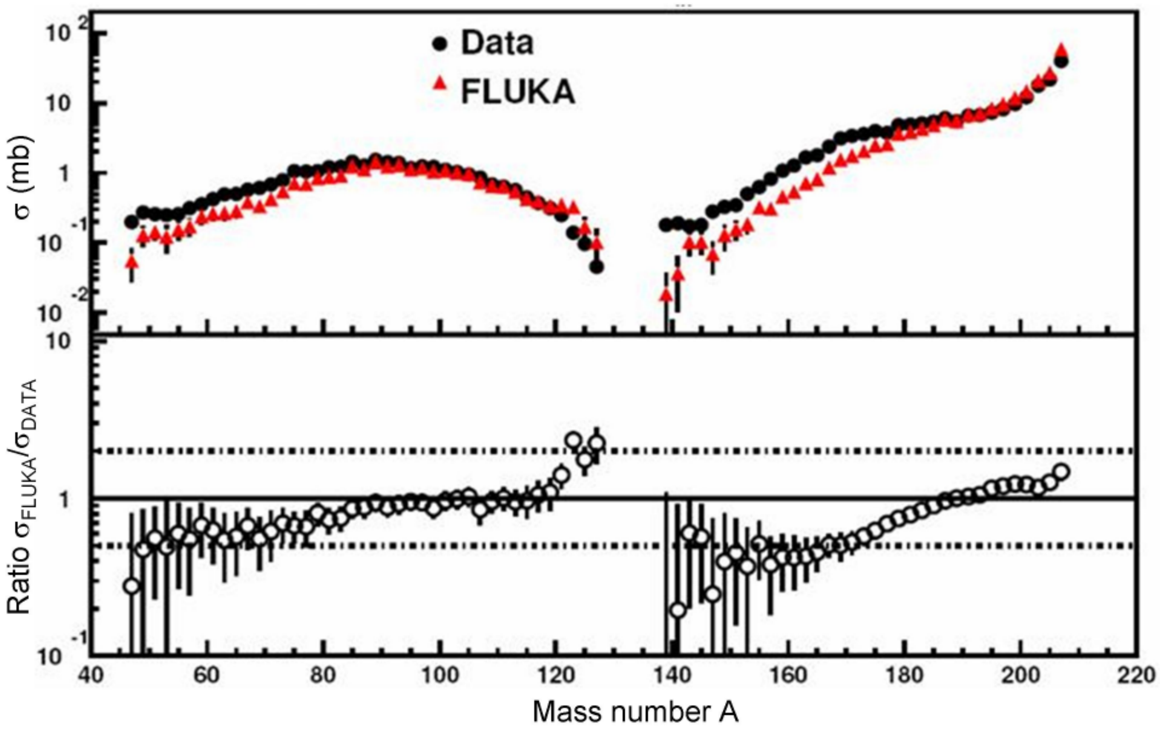


Figure 7.1. Comparison between experimental and FLUKA calculated production cross sections, after Ref. [91]. The plotted cross sections are not the total, but the average values over the number of isobars for which both calculations and data were available.

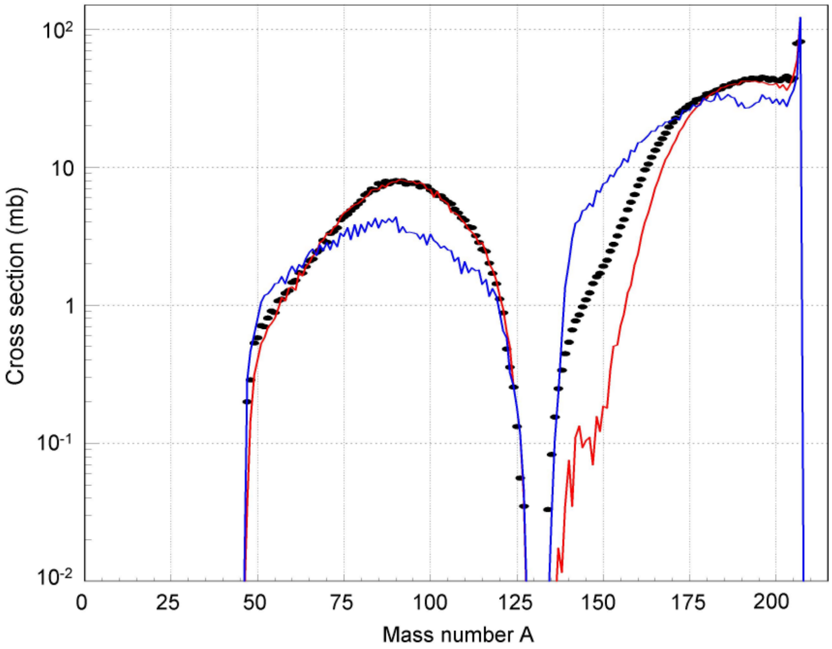


Figure 7.2. Comparison between elementary experimental data[66] and MCNPX INCL4-ABLA (red), Bertini-Dresner (blue) calculated production cross sections.

Data at 500 MeV, therefore at energies closer to the MEGAPIE case, exist. Fig. 7.3 shows the *Z*-dependence of radionuclide yields for p+^{208}Pb interactions at the proton energy of 500 MeV, obtained experimentally[92, 93], and calculated using INCL4/ABLA, CEM03, and CASCADE/ASF (SNT) models. Calculations with CASCADE/ASF and available experimental data at the initial proton energy from 150 MeV to 600 MeV have been used to get evaluated data included in PADF-600 file. This file was applied together with other libraries for the calculation of reaction rates. The calculated and measured *Z*-dependence of yields of residuals shown in Figs.7.3 is obtained using the same number of nuclides.

Experimental data[94,95] present the most detailed available information about the yields of fission and evaporation residues in nuclear interactions of 500 MeV protons with ^{208}Pb. However, the total fission reaction cross section for ^{208}Pb obtained by summing up the individual isotopic cross sections in Ref. [94] was found noticeably higher than all other experimental data[96]. In this experiment, only a small part of the fission fragments is transmitted through the fragment separator because of its limited angular acceptance, requiring large correction factors. This has led the GSI collaboration to perform a new experiment in which a full-acceptance set-up was used to determine the total fission cross sections with higher precision. Preliminary results[97] indicate that the cross-sections obtained at 500 MeV in Ref. [94] are very likely overestimated.

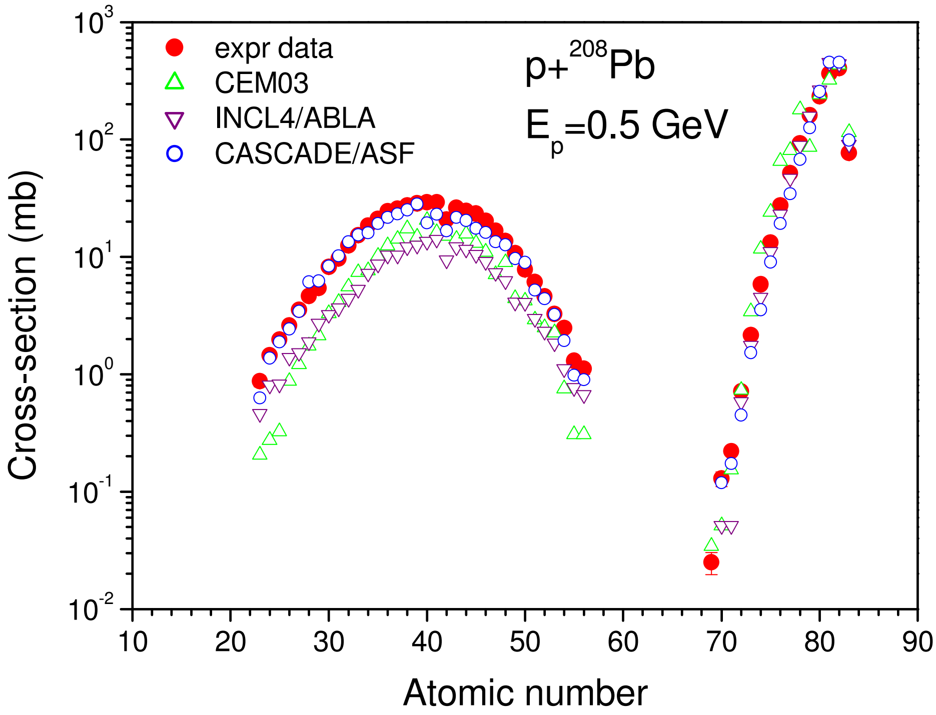


Figure 7.3. Cross sections measured in Refs. [92,93] and calculated using INCL4/ABLA, CEM03, and CASCADE/ASF models depending on atomic numbers of nuclides.

Tables C4-C6, and Fig. C1 in Annex C show values of statistical factors[98] corresponding to the description of available experimental cross sections for proton interactions with lead isotopes and ^{209}Bi using Bertini/Dresner, CEM03, INCL4/ABLA, and CASCADE/ASF models.

By calculating the production yields (atoms/proton) using these codes in the MEGAPIE case, differences will therefore be observed, especially in some mass regions. One example of direct comparison of the mass distribution of the production rates can be done between FLUKA and SNT (see Fig. 7.4). A general good agreement is found, with the exception of some mass regions (around *A*=30 and *A*=150) which are the regions where experimental data are scarce or not available. More details are shown in the following sections.

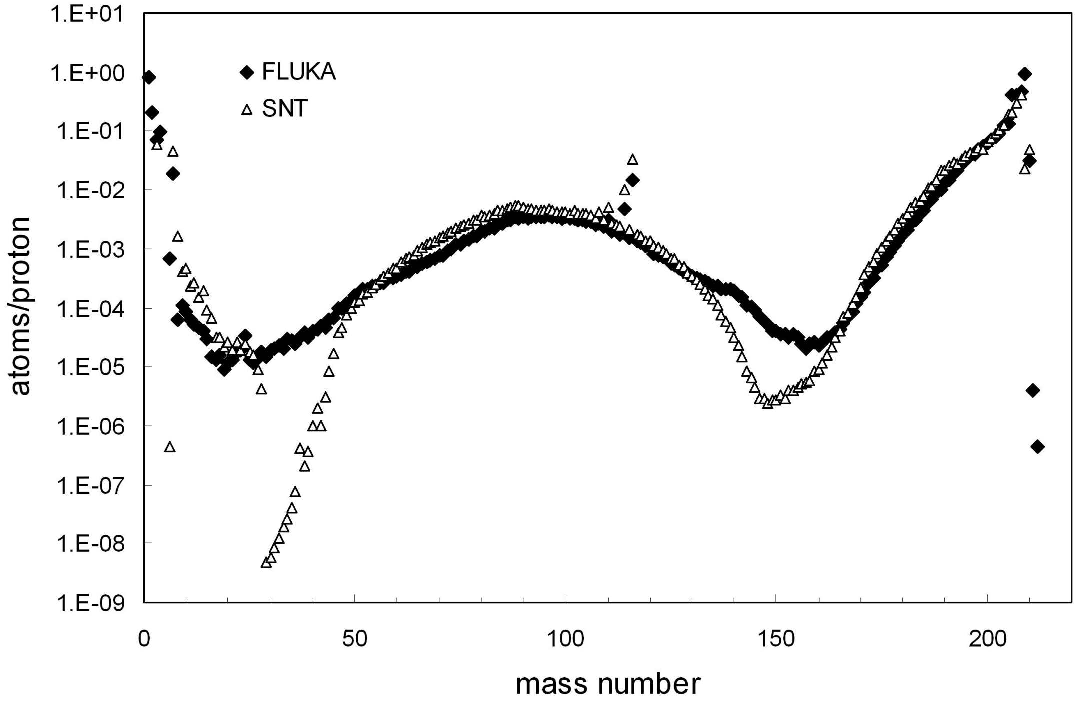


Figure 7.4. Comparison between calculated yields (atoms/proton) in the LBE of MEGAPIE, with FLUKA and SNT codes.

7.4 Activation of LBE and of the lower structure

7.4.1 FLUKA and MCNPX

In this section we report the results of the LBE and lower structure activation calculated with FLUKA and MCNPX. While detailed results are shown in the tables in the Annex A and B (Tables A1, A2, B1, and B2), a comparison between the results of the two codes is given in the following.

It is of interest to look at several quantities which help to understand the problem of the target activation, and to assess the validity and coherence of the results:

1. direct comparison of activities of the most relevant nuclides calculated with different codes;
2. contribution to activation coming from models and from $E < 20$ MeV neutrons;
3. total activities of LBE and target structure calculated with different models;
4. main contributors to the total activity.

1) *Direct comparison of activities of the most relevant nuclides calculated with different codes.* Detailed comparisons between calculations from FLUKA 2006.3b and MCNPX 2.5.0 (INCL4-ABLA) are shown in Table D1 in Annex D (page 248), for a comprehensive list of all the nuclides of interest for the waste specification[99]. The activity values after 1 year of cooling time are shown for the entire lower half target structure, and for the LBE. The agreement between individual activity values is good, but some discrepancies exist between the two codes. For the LBE, the ratios between FLUKA and MCNPX calculations are between 0.5 and 1.5 for 58 % of the nuclides, and between 0.2 and 5 for 78% of the nuclides. For the structure, the discrepancies are higher, with ratios lower than 0.2 or higher than 5 for nearly 50% of the nuclides. For the nuclides with higher activities the agreement is better, and as a consequence the total activities are very close.

A comparison between the 25 nuclides with higher activities, for both structure and LBE, is given in Table 7.1. This selection corresponds to almost all the activity for the target structure, and to more than 99% of the LBE activity. For LBE the results from the different codes are in good agreement. For the target structure, large differences are found for some nuclides (for instance ^{57}Co and ^{22}Na), and in general the discrepancies are much larger than for the LBE, showing that the calculation of the activation induced by thermal capture is still not satisfactory. However, it is worth noting that most of the activity after 1 year (84 % for FLUKA, 94 % for MCNPX) is due to only two nuclides for which FLUKA and MCNPX agree within 30%.

Table 7.1. Extract from Table D1 in Annex D. List of the 25 nuclides with higher activities after one year of cooling for the target lower structure (left part of the table) and the LBE (right part). MCNPX values calculated with INCL4-ABLA models.

Nuclide	**Target structure**			**Nuclide**	**LBE**		
	FLUKA	MCNPX	ratio		FLUKA	MCNPX	SNT
^{55}Fe	1.65E+13	1.94E+13	0.85	^{210}Po	2.19E+13	2.07E+13	1.45E+13
^{54}Mn	3.54E+12	2.77E+12	1.28	^{195}Au	1.9E+13	1.76E+13	2.05E+13
^{60}Co	1.33E+12	4.74E+11	2.81	^{3}H	7.72E+12	-	6.12E+12
^{49}V	1.05E+12	8.07E+11	1.30	^{207}Bi	4.26E+12	5.05E+12	5.11E+12
^{57}Co	4.03E+11	9.52E+09	42.3	^{204}Tl	2.7E+12	4.38E+12	3.84E+12
^{22}Na	3.16E+11	1.29E+09	245	^{208}Po	2.18E+12	9.43E+11	1.59E+12
^{3}H	2.37E+11	-	-	^{185}Os	1.12E+12	1.99E+12	1.93E+12
^{58}Co	1.56E+11	3.39E+09	46.0	^{179}Ta	6.82E+11	1.05E+12	1.40E+12
^{63}Ni	8.18E+10	3.05E+09	26.8	^{193}Pt	6.57E+11	6.57E+11	7.89E+11
^{182}Ta	5.12E+10	1.25E+10	4.10	^{106}Ru	6.17E+11	4.67E+11	4.57E+11
^{56}Co	4.26E+10	7.87E+09	5.41	^{183}Re	3.59E+11	5.71E+11	6.88E+11
^{46}Sc	3.82E+10	2.03E+10	1.88	^{119m}Sn	3.01E+11	2.39E+09	2.08E+11
^{45}Ca	2.14E+10	1.36E+10	1.57	^{88}Y	2.46E+11	1.95E+11	6.11E+11
^{88}Y	1.61E+10	4.93E+09	3.27	^{102}Rh	2.14E+11	1.56E+11	1.92E+11
^{35}S	6.02E+09	2.04E+09	2.95	^{173}Lu	1.85E+11	2.07E+11	3.48E+11
^{88}Zr	3.42E+09	1.22E+09	2.80	^{95}Zr	1.32E+11	1.35E+11	1.14E+11
^{83}Rb	1.5E+09	3.33E+08	4.50	^{109}Cd	1.3E+11	1.54E+11	4.47E+11
^{44}Ti	1.14E+09	2.01E+09	0.57	^{172}Hf	1.28E+11	1.14E+11	2.39E+11
^{85}Sr	8.63E+08	2.9E+08	2.98	^{85}Kr	1.17E+11	1.19E+11	1.59E+11
^{59}Ni	6.4E+08	2.52E+07	25.4	^{194}Hg	9.33E+10	7.12E+10	1.04E+11
^{113}Sn	5.13E+08	1.15E+08	4.46	^{83}Rb	8.82E+10	8.93E+10	3.22E+11
^{75}Se	4.73E+08	6.04E+08	0.78	^{101}Rh	7.67E+10	8.5E+10	1.73E+11
^{65}Zn	3.71E+08	1.1E+09	0.34	^{90}Sr	7.27E+10	7.17E+10	6.81E+10
^{39}Ar	2.7E+08	1.51E+08	1.79	^{139}Ce	7.13E+10	6.45E+10	1.44E+10
^{125}Sb	2.64E+08	8.13E+09	0.03	^{175}Hf	6.21E+10	7.56E+10	1.20E+11

The comparison between the LBE results (right half of Table 7.1) is much better with only two nuclides showing large discrepancies: the metastable state ^{119m}Sn, and tritium. The tritium is obviously more important, and it is known that the tritium calculation using the INCL4-ABLA model is not correct, and therefore not reported in the table. On the contrary, the amount of tritium calculated with the Bertini-Dresner model combination is close to the FLUKA value (see Table 6.11). In Fig. 7.5 the activities in the LBE calculated with FLUKA 2006.3b, MCNPX (INCL4-ABLA) and SNT are compared.

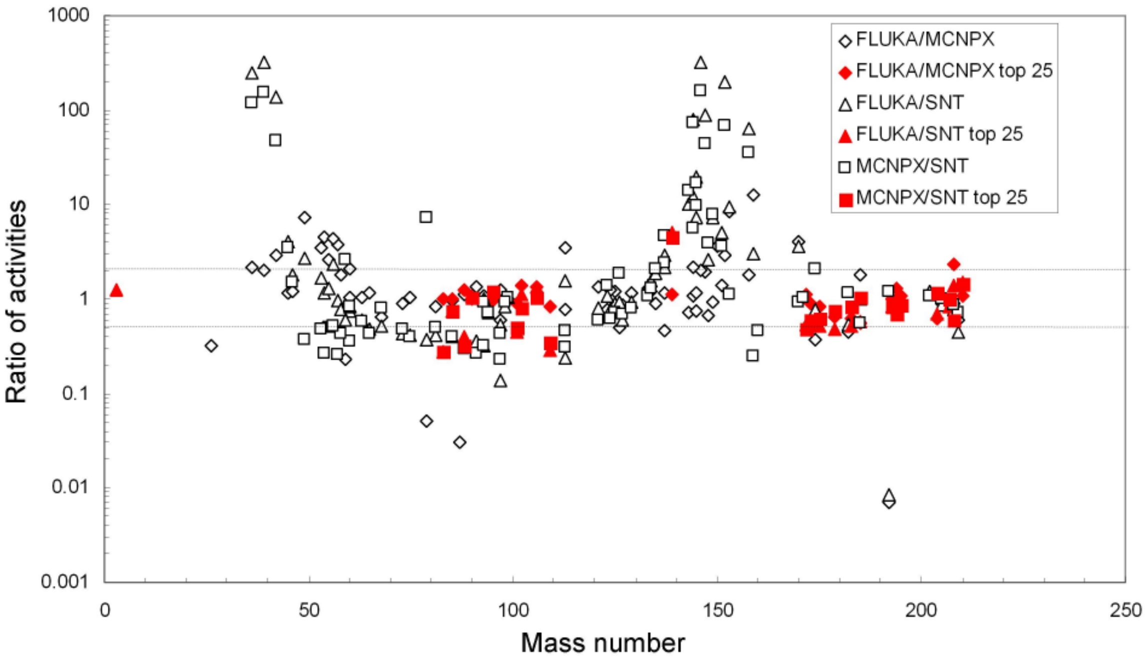


Figure 7.5. Comparison between activities in the LBE (data from Table D1 in Annex D) after 1 year of cooling, calculated with FLUKA 2006.3b, MCNPX (INCL4-ABLA) and SNT. The points in red correspond to the 25 nuclides with highest activity (Table 7.1). For reference, the lines corresponding to a ratio of 0.5 and 2 are drawn.

Some differences between FLUKA 2006.3b and MCNPX are also found for the calculations of the metastable states production. The calculations for metastable states by these codes are still problematic. In general, MCNPX/CINDER calculates a higher number of metastable states in the neutron rich region. As these radionuclides are generally short lived, they are usually not relevant to the target disposal issue. In FLUKA only ground states for residual nuclei were calculated, and the metastable states are obtained by parent decay during the ORIHET 3 calculation and also low-energy neutron reaction in CINDER'90. FLUKA values of the production rates of metastable states in the present report are therefore underestimated.

In SNT, the data files with cross sections, which are used for activation calculations, contain the information about yields of nuclei in metastable states and cross sections for reactions with metastable targets.

2) *Contribution to activation coming from models.* The MCNPX calculated total activities of the LBE and of the target structure as a function of the cooling time up to 10^5 years is shown in Fig. 7.6. The activities due to models are shown with dashed lines. These results indicate that the LBE is mainly activated by high-energy particles whereas the container activation is mainly due to low-energy neutrons. It is worth noting that at about 5 years of cooling, the activity of the container is very close to the one of the LBE.

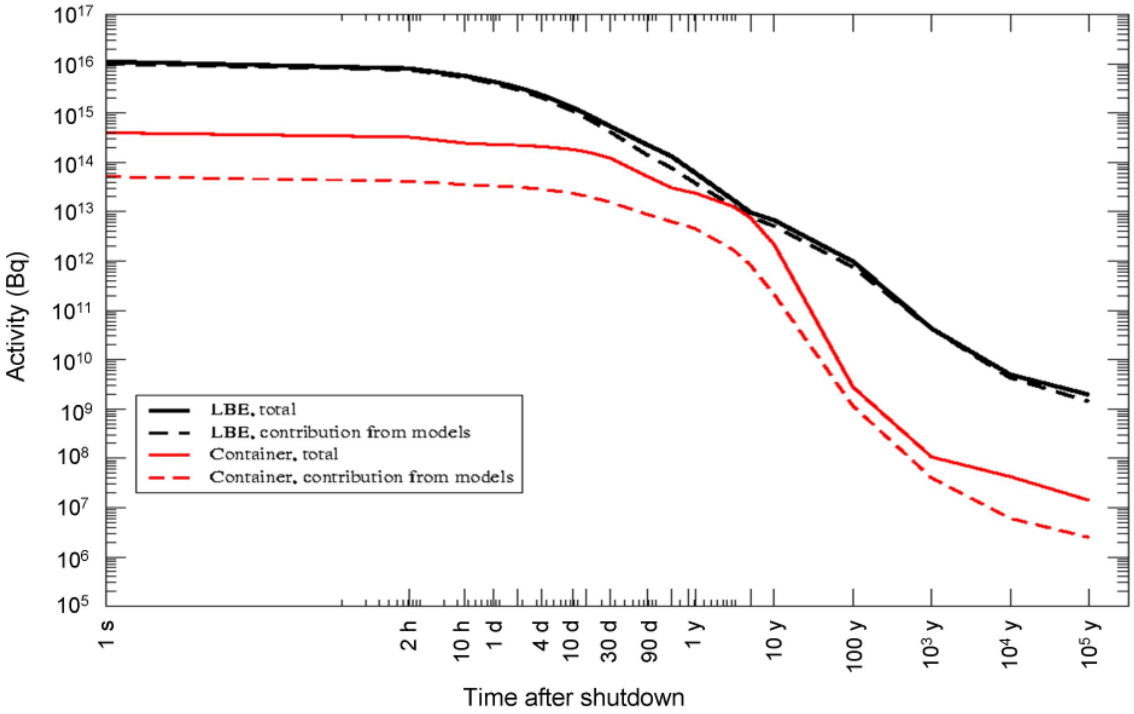


Figure 7.6. Activity of the LBE and container (window included) due to high-energy reactions, calculated by models, (dashed lines) and total, adding the activation by low-energy neutrons (full lines). The calculation is done using INCL4-ABLA in MCNPX.

3) *Total activities of LBE and target structure calculated with different models*. Differences between spallation models available in MCNPX have also been studied. For the LBE target the total calculated activities are very similar, except in the region lying between 5 and 10 years of cooling time (Fig. 7.7). The difference is due to the fact that the tritium is not calculated correctly with the ABLA de-excitation model, since this model does not allow for evaporation of tritium, contrary to Dresner and CEM2k. Since the tritium contribution is very important between 5 and 10 years of cooling time (see Table C2 on page 217, calculated with SNT, which indicated a contribution of about 35% to the total activity at these cooling times), the results obtained with ABLA give a significantly lower total activity at these times.

4) *Main contributors to the total activity*. In Fig. 7.8 we see that numerous nuclides are responsible of the total activity after the shutdown (28 nuclides contribute between 1 and 5 %). All these nuclides are close in mass to Pb and Bi. Concerning the target structure, the situation is different. The total activity is mainly due to very few nuclei produced mainly by low-energy neutron activation, like ^{51}Cr ($t_{1/2}$= 27.7 days) and ^{56}Mn ($t_{1/2}$= 2.6 hours) after shut down (Fig. 7.9).

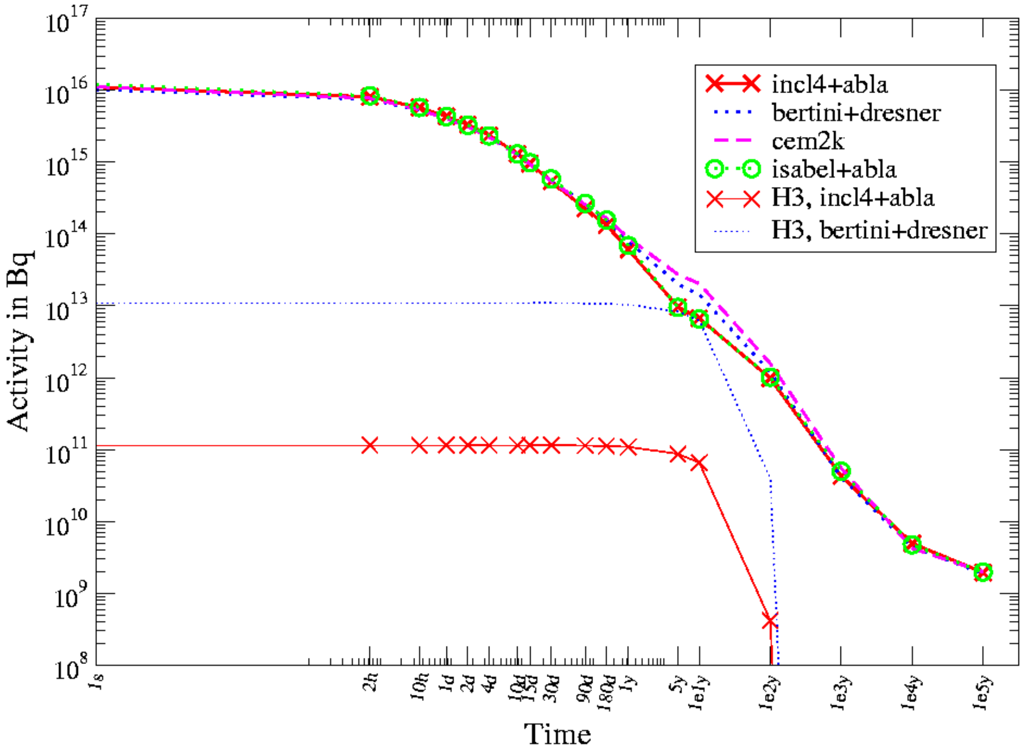


Figure 7.7. Total activity of the LBE as a function of cooling time after 123 days of irradiation with 575 MeV protons at 0.947 mA using MCNPX and different models.

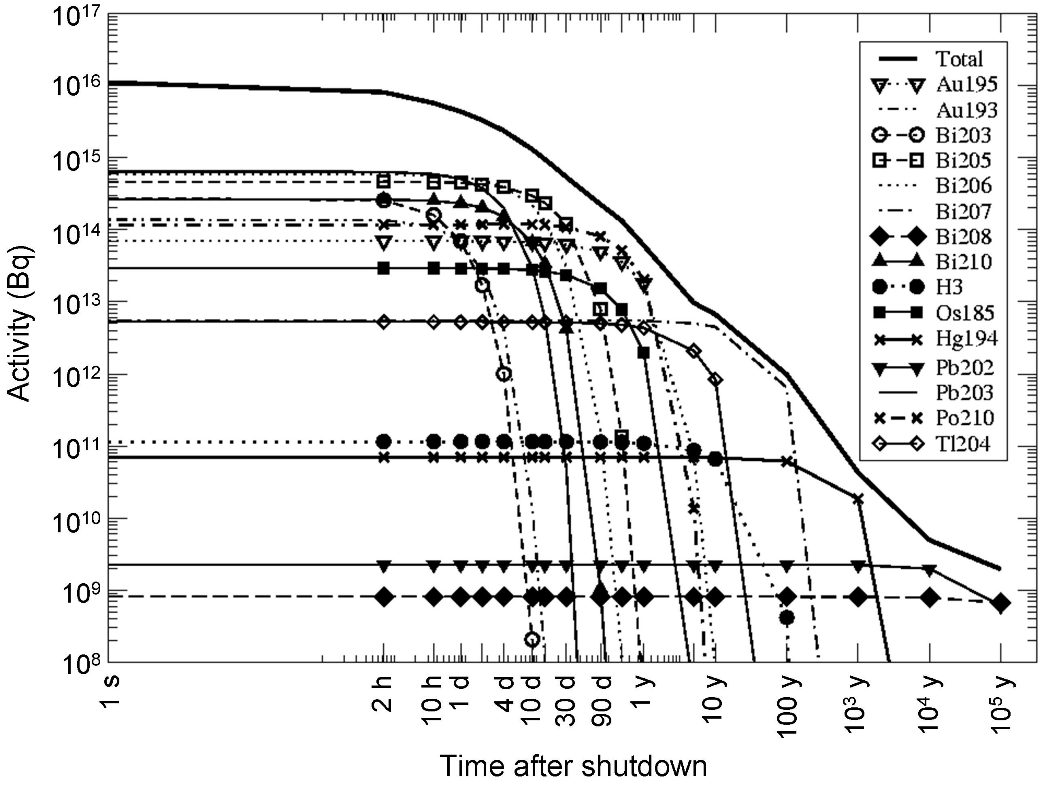


Figure 7.8. Main contributors to the activity (in Bq) of the LBE as a function of cooling time after 123 days of irradiation with 575 MeV protons at 0.947 mA using INCL4-ABLA models.

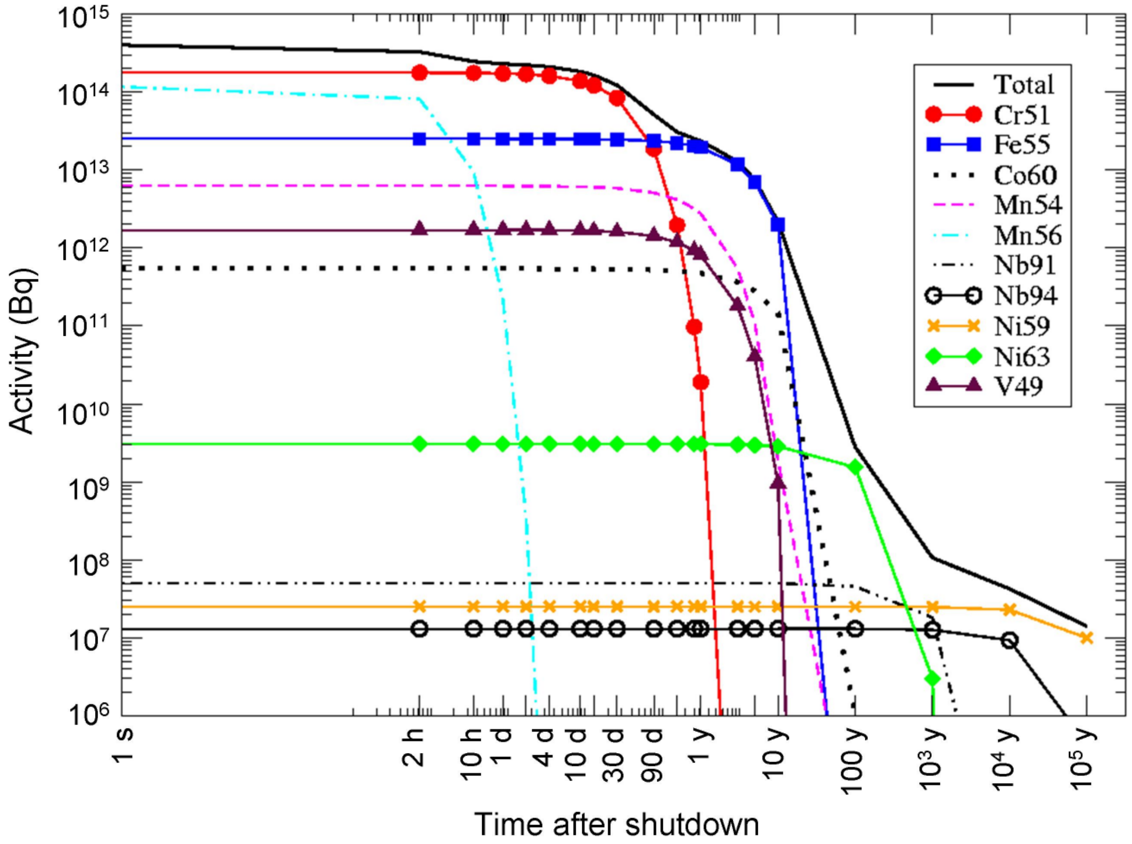


Figure 7.9. Same as figure 7.8 for the container.

In Fig. 7.10 the activity due to volatile elements is plotted. Activity from volatiles is small compared to the total activity in the LBE target. Nevertheless, because of emission during operation and in case of containment failure this released activity must be known for safety issues, as discussed in the previous chapter. The roles played by tritium (not shown in the figure since INCL4-ABLA fails to produce it) and by some metastable states point out the difficulties to get a reliable assessment for some nuclides.

In Fig. 7.11 the modification of the chemical composition of the LBE after 123 days of irradiation at 0.947 mA. A similar figure, but for the container, is shown in Fig. 7.12. Dots indicate the initial compositions.

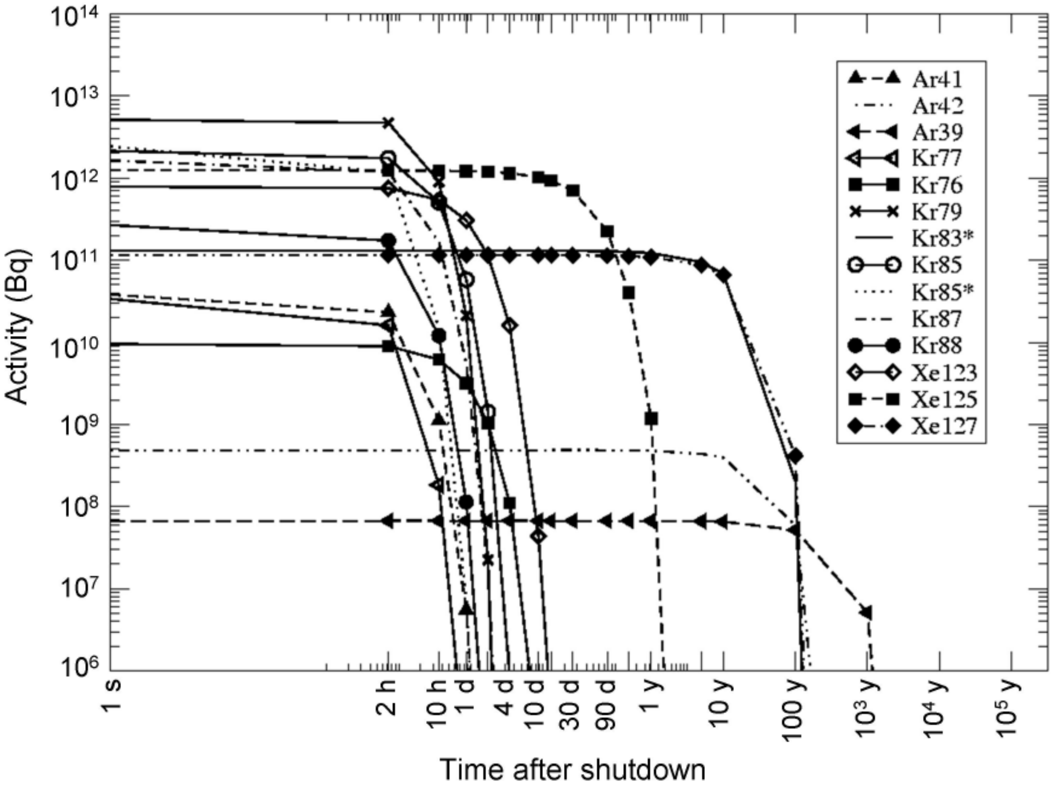
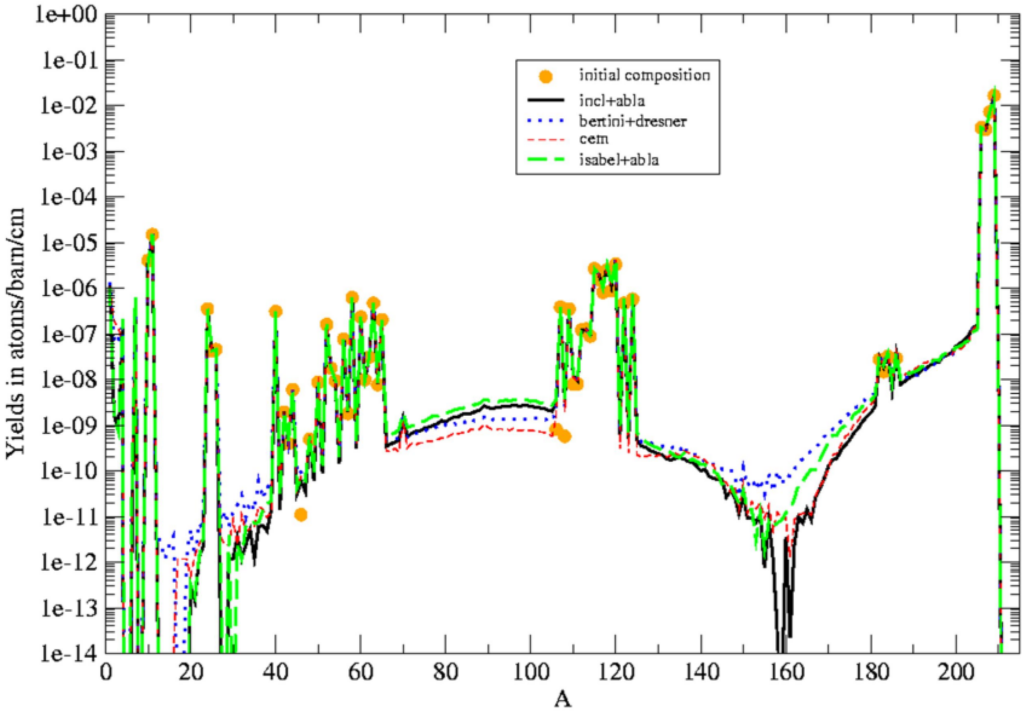


Figure 7.10. Main contributors to the activity in LBE (in Bq) coming from volatile elements as a function of cooling time after 123 days of irradiation with 575 MeV protons at 0.947 mA. Calculations with MCNPX using INCL4-ABLA.



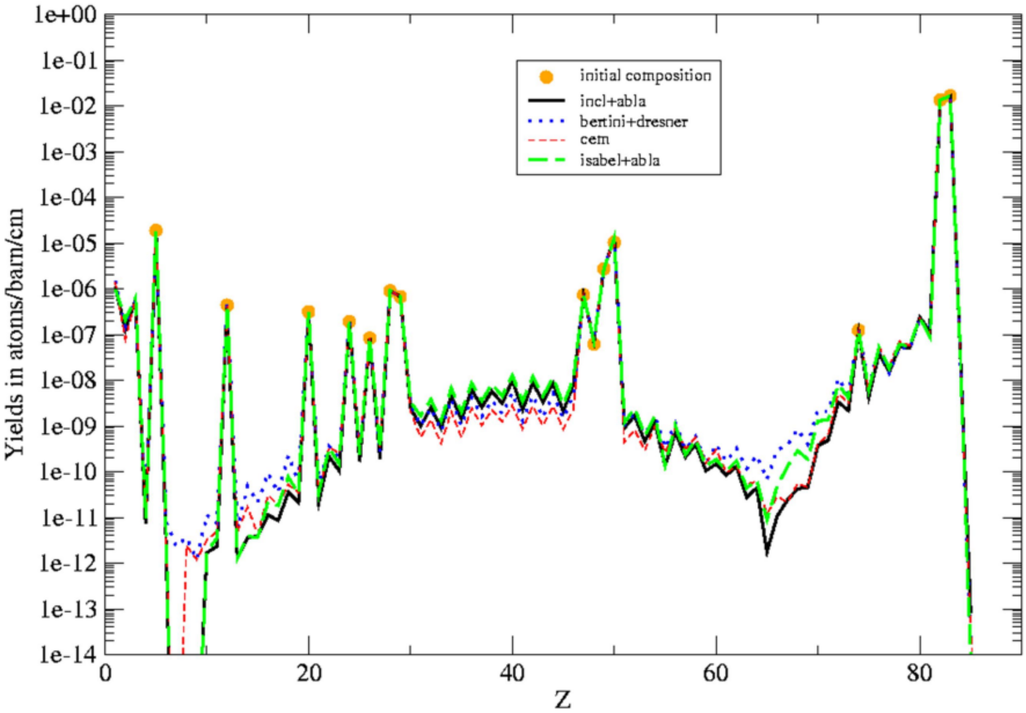


Figure 7.11. Concentration of elements in the LBE after 123 days of irradiation by 575 MeV protons at 0.947 mA (mass distribution (*top*) and charge distribution (*bottom*)). The initial composition of the target is represented as full orange dots. Results obtained are shown using different spallation models: INCL4-ABLA (thick full line), Bertini-Dresner (dotted line), CEM2k (thin dashed line), ISABEL-ABLA (thick dashed line).

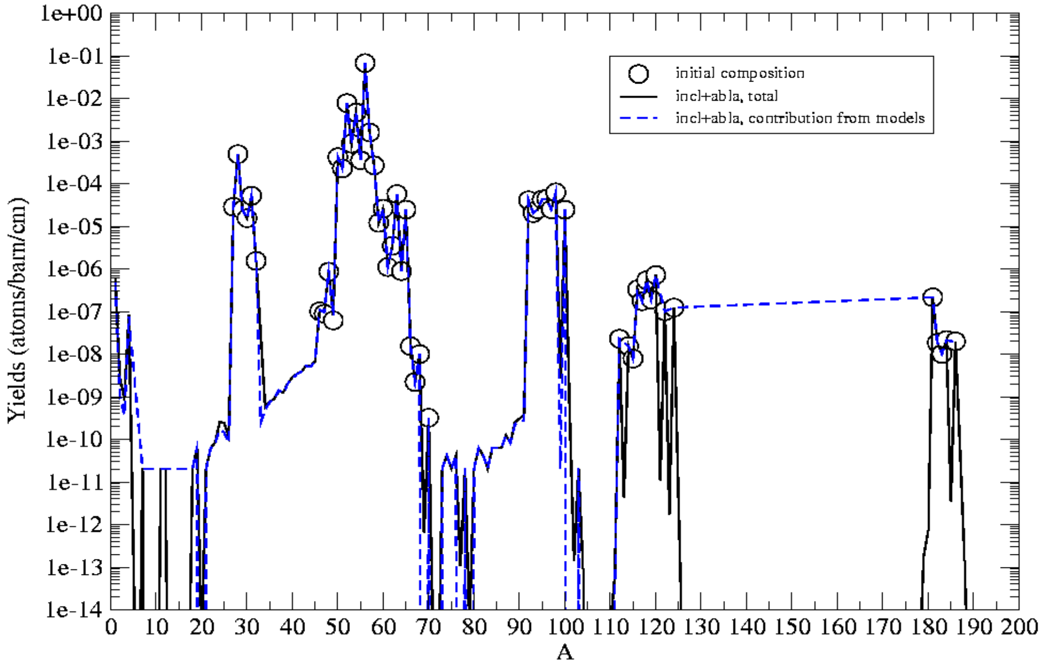


Figure 7.12. Chemical composition of the container (window included) as a function of nuclide mass using INCL4-ABLA model and assuming 123 days of irradiation at 0.947 mA by 575 MeV protons. Circles represent the initial composition and dotted lines the contribution to the total yields coming from models.

7.4.2 SNT

The analysis of the activation of the LBE was performed also with the SNT code. In this case we had a more in depth look at the following two topics:

1. contribution to the activity by the different nuclides;
2. origin of nuclides produced under irradiation.

The calculated total activity is shown in Fig. 7.13. The activity is compared with the calculated activity from FLUKA and MCNPX (INCL4-ABLA). Overall the curves are in excellent agreement. There are, however, differences of about 40% around the average value (SNT) at about 5 years cooling time. As previously discussed, the lower value of MCNPX at these cooling times is due to the incorrect calculation of tritium using the INCL4-ABLA option.

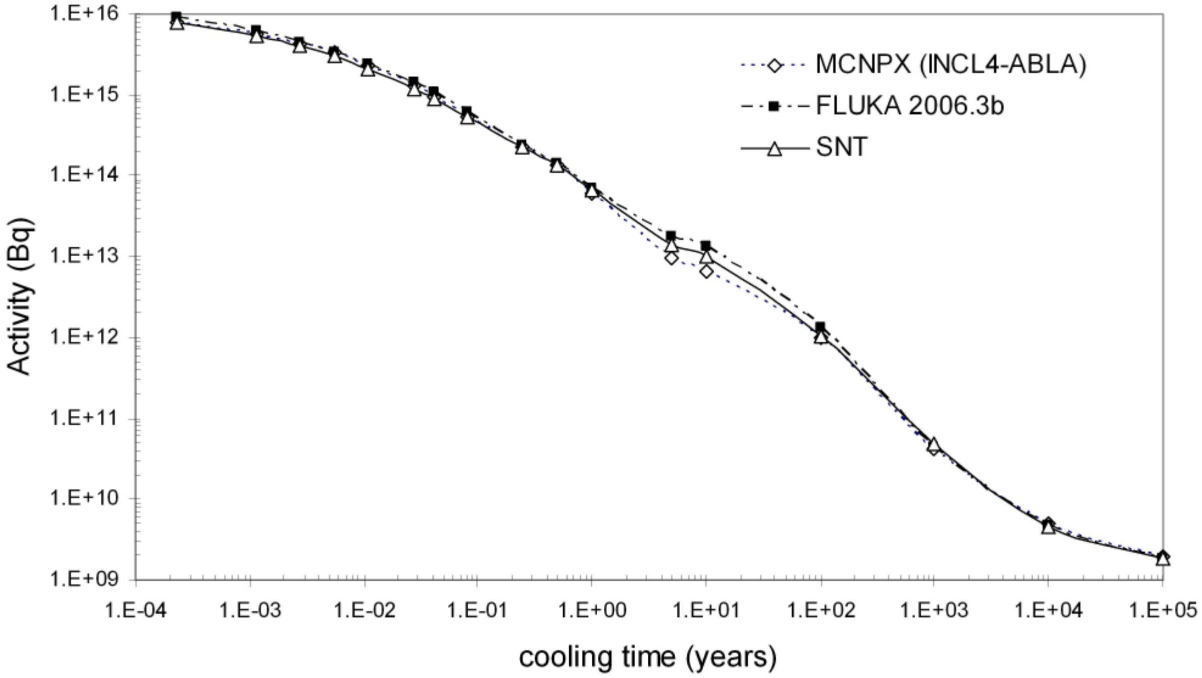


Figure 7.13. Calculated total activity of the LBE in MEGAPIE with MCNPX 2.5.0 (INCL4-ABLA), FLUKA2006.3b, and SNT, as a function of the cooling time.

1) *Contribution to the activity by the different nuclides*

Table 7.2 shows the list of the main radionuclides, with the highest contribution to the total activity at different times after the irradiation. The initial composition includes the impurities in the LBE. Fig. 7.14 presents the relative contribution of some important nuclides to the total activity at the time of cooling from several minutes up to 5×10^7 years.

Fig. 7.15 shows the relative parts of activities produced by nuclides with different atomic numbers. The activity of radionuclides with *Z* from 70 to 84 dominates at all cooling times.

Table C2 in the Annex shows the list of radionuclides, for which the relative contribution to the total activity exceeds one percent at least one time during the cooling time from several minutes up to 5×10^7 years. Data are shown at various times after the irradiation.

Table 7.2. The contribution of various nuclides to the total activity of the LBE. The five nuclides giving the highest contribution to the total activity (*R*,%) at various times after the irradiation are shown.

Time of cooling (days)	Total activity (Bq)	Nuclide, *R*(%)		Nuclide, *R*(%)		Nuclide, *R*(%)		Nuclide, *R*(%)		Nuclide, *R*(%)	
0.00E+00	1.23E+16	Pb 203	4.23	Bi 206	3.79	Tl 201	3.50	Tl 200	3.05	Pb 201	2.84
1.16E-04	1.23E+16	Pb 203	4.24	Bi 206	3.79	Tl 201	3.50	Tl 200	3.06	Pb 201	2.84
2.31E-04	1.22E+16	Pb 203	4.26	Bi 206	3.81	Tl 201	3.52	Tl 200	3.07	Pb 201	2.86
3.47E-04	1.22E+16	Pb 203	4.28	Bi 206	3.83	Tl 201	3.53	Tl 200	3.09	Pb 201	2.87
6.94E-04	1.20E+16	Pb 203	4.33	Bi 206	3.87	Tl 201	3.57	Tl 200	3.12	Pb 201	2.90
1.39E-03	1.18E+16	Pb 203	4.42	Bi 206	3.95	Tl 201	3.65	Tl 200	3.19	Pb 201	2.96
3.47E-03	1.13E+16	Pb 203	4.60	Bi 206	4.12	Tl 201	3.80	Tl 200	3.32	Pb 201	3.08
6.94E-03	1.08E+16	Pb 203	4.83	Bi 206	4.32	Tl 201	3.99	Tl 200	3.48	Pb 201	3.22
1.39E-02	1.01E+16	Pb 203	5.14	Bi 206	4.60	Tl 201	4.25	Tl 200	3.71	Pb 201	3.40
2.08E-02	9.68E+15	Pb 203	5.37	Bi 206	4.81	Tl 201	4.45	Tl 200	3.88	Pb 201	3.52
4.17E-02	8.83E+15	Pb 203	5.86	Bi 206	5.26	Tl 201	4.87	Tl 200	4.24	Pb 201	3.75
8.33E-02	7.88E+15	Pb 203	6.51	Bi 206	5.88	Tl 201	5.45	Tl 200	4.72	Bi 205	4.04
2.08E-01	6.49E+15	Pb 203	7.68	Bi 206	7.04	Tl 201	6.54	Tl 200	5.61	Bi 205	4.88
4.17E-01	5.39E+15	Pb 203	8.81	Bi 206	8.30	Tl 201	7.70	Tl 200	6.46	Bi 205	5.83
1.00E+00	4.03E+15	Bi 206	10.5	Pb 203	10.1	Tl 201	9.36	Bi 205	7.61	Tl 200	7.28
2.00E+00	3.06E+15	Bi 206	12.5	Tl 201	10.0	Pb 203	10.0	Bi 205	9.65	Tl 200	6.50
5.00E+00	1.90E+15	Bi 206	14.9	Bi 205	13.8	Tl 201	8.19	Pb 203	6.30	Ir 189	5.05
1.00E+01	1.20E+15	Bi 205	18.0	Bi 206	14.4	Po 210	6.99	Au 195	6.38	Ir 189	6.26
3.00E+01	5.32E+14	Bi 205	18.7	Po 210	14.6	Au 195	13.4	Ir 189	5.36	Bi 206	4.91
6.00E+01	3.08E+14	Po 210	21.7	Au 195	20.7	Bi 205	10.1	Os 185	5.97	Re 183	4.57
9.00E+01	2.29E+14	Po 210	25.2	Au 195	24.9	Os 185	6.45	Re 183	4.58	Bi 205	4.23
1.80E+02	1.35E+14	Au 195	30.2	Po 210	27.2	Os 185	5.62	H 3	4.66	Bi 207	3.83
2.70E+02	9.16E+13	Au 195	31.8	Po 210	25.5	H 3	6.77	Bi 207	5.61	Tl 204	4.39
3.65E+02	6.52E+13	Au 195	31.4	Po 210	22.3	H 3	9.38	Bi 207	7.84	Tl 204	5.89
5.48E+02	3.94E+13	Au 195	26.3	H 3	15.1	Po 210	14.8	Bi 207	12.8	Tl 204	8.93
7.30E+02	2.79E+13	H 3	20.8	Au 195	18.9	Bi 207	17.9	Tl 204	11.5	Po 210	8.37
1.82E+03	1.43E+13	H 3	34.2	Bi 207	32.8	Tl 204	13.2	Pt 193	5.24	Po 208	4.33
2.74E+03	1.17E+13	Bi 207	37.7	H 3	36.1	Tl 204	10.3	Pt 193	6.14	Po 208	2.91
3.65E+03	1.01E+13	Bi 207	41.4	H 3	36.4	Tl 204	7.67	Pt 193	6.87	Po 208	1.87
5.48E+03	8.02E+12	Bi 207	46.9	H 3	34.7	Pt 193	8.10	Tl 204	3.99	Hg 194	1.27
7.30E+03	6.63E+12	Bi 207	51.0	H 3	31.7	Pt 193	9.16	Tl 204	1.99	Hg 194	1.52
1.82E+04	2.82E+12	Bi 207	62.2	Pt 193	14.2	H 3	13.8	Hg 194	3.41	Au 194	3.41
2.74E+04	1.64E+12	Bi 207	62.2	Pt 193	17.3	H 3	5.83	Hg 194	5.66	Au 194	5.66
3.65E+04	1.03E+12	Bi 207	57.2	Pt 193	19.4	Hg 194	8.64	Au 194	8.64	H 3	2.27
5.48E+04	4.89E+11	Bi 207	40.5	Pt 193	20.5	Hg 194	16.8	Au 194	16.8	Po 209	2.30
7.30E+04	2.87E+11	Hg 194	26.6	Au 194	26.6	Bi 207	23.2	Pt 193	17.5	Po 209	2.80
1.82E+05	1.04E+11	Hg 194	46.1	Au 194	46.1	Pb 202	1.82	Tl 202	1.82	Po 209	1.02
2.74E+05	7.06E+10	Hg 194	45.8	Au 194	45.8	Pb 202	2.66	Tl 202	2.66	Bi 208	1.28
3.65E+05	4.94E+10	Hg 194	44.3	Au 194	44.3	Pb 202	3.79	Tl 202	3.79	Bi 208	1.84
5.48E+05	2.54E+10	Hg 194	39.5	Au 194	39.5	Pb 202	7.32	Tl 202	7.32	Bi 208	3.57
7.30E+05	1.44E+10	Hg 194	32.0	Au 194	32.0	Pb 202	12.8	Tl 202	12.8	Bi 208	6.30
1.82E+06	4.86E+09	Pb 202	36.5	Tl 202	36.5	Bi 208	18.5	Nb 94	1.69	Nb 93m	1.48
2.74E+06	4.60E+09	Pb 202	37.4	Tl 202	37.4	Bi 208	19.5	Nb 94	1.64	Nb 93m	1.09
3.65E+06	4.44E+09	Pb 202	37.5	Tl 202	37.5	Bi 208	20.1	Nb 94	1.56	Nb 93m	0.79
5.48E+06	4.17E+09	Pb 202	37.4	Tl 202	37.4	Bi 208	21.2	Nb 94	1.40	Tc 99	0.47
7.30E+06	3.93E+09	Pb 202	37.1	Tl 202	37.1	Bi 208	22.2	Nb 94	1.25	Tc 99	0.49
1.82E+07	2.88E+09	Pb 202	34.2	Tl 202	34.2	Bi 208	28.7	Tc 99	0.60	Nb 94	0.60
2.74E+07	2.28E+09	Bi 208	34.5	Pb 202	31.1	Tl 202	31.1	Pb 205	0.72	Tc 99	0.70
3.65E+07	1.84E+09	Bi 208	40.8	Pb 202	27.8	Tl 202	27.8	Pb 205	0.89	Tc 99	0.80
5.48E+07	1.28E+09	Bi 208	53.6	Pb 202	20.9	Tl 202	20.9	Pb 205	1.28	Tc 99	0.99
7.30E+07	9.56E+08	Bi 208	65.2	Pb 202	14.5	Tl 202	14.5	Pb 205	1.71	Tc 99	1.12
1.82E+08	4.02E+08	Bi 208	88.0	Pb 205	4.01	Bi 210m	1.53	Tl 206	1.53	Tc 99	1.01
2.74E+08	2.59E+08	Bi 208	85.5	Pb 205	6.17	Bi 210m	2.25	Tl 206	2.25	Tc 99	0.70
3.65E+08	1.72E+08	Bi 208	80.4	Pb 205	9.16	Bi 210m	3.19	Tl 206	3.19	Nb 93m	0.93
5.48E+08	8.39E+07	Bi 208	64.3	Pb 205	18.4	Bi 210m	5.82	Tl 206	5.82	Nb 93m	1.53
7.30E+08	4.85E+07	Bi 208	43.4	Pb 205	31.1	Bi 210m	8.98	Tl 206	8.98	Nb 93m	2.12
1.82E+09	1.88E+07	Pb 205	69.8	Bi 210m	11.5	Tl 206	11.5	Pd 107	1.56	Nb 93m	1.45
2.74E+09	1.48E+07	Pb 205	79.2	Bi 210m	8.24	Tl 206	8.24	Pd 107	1.52	Nb 93m	0.61
3.65E+09	1.22E+07	Pb 205	85.7	Bi 210m	5.61	Tl 206	5.61	Pd 107	1.41	Tc 98	0.44
5.47E+09	8.97E+06	Pb 205	93.3	Bi 210m	2.41	Tl 206	2.41	Pd 107	1.13	Tc 98	0.26
7.30E+09	6.91E+06	Pb 205	96.6	Bi 210m	0.99	Tl 206	0.99	Pd 107	0.86	Nb 92	0.30
1.83E+10	1.73E+06	Pb 205	99.1	Nb 92	0.66	Pd 107	0.14	I 129	0.07	Sm 146	<0.01

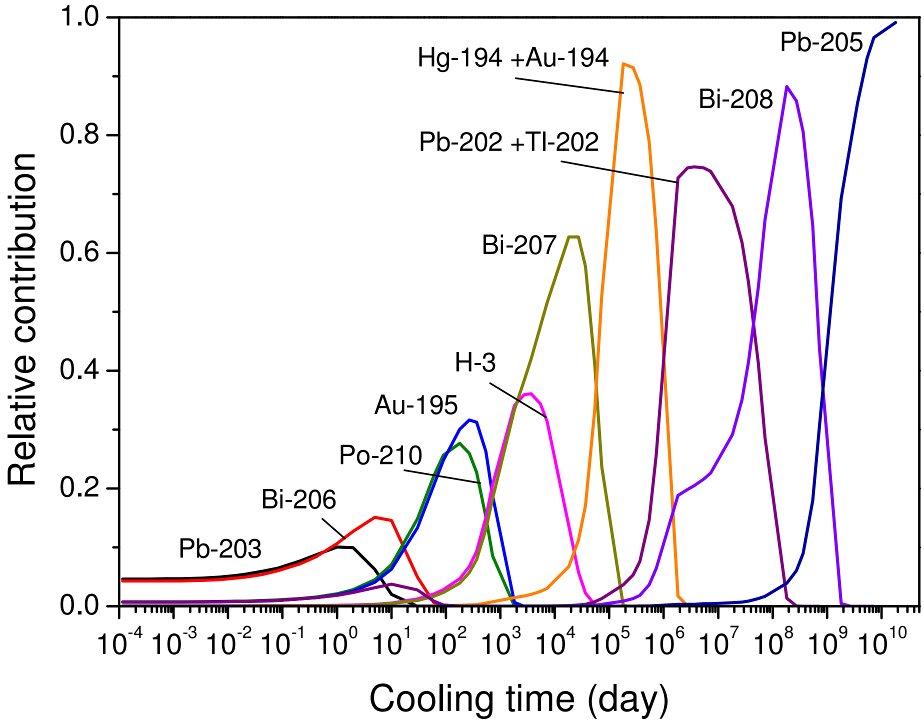


Figure 7.14. The relative contribution of nuclides providing most of the activity of the LBE after 123 days of irradiation, as a function of the cooling time.

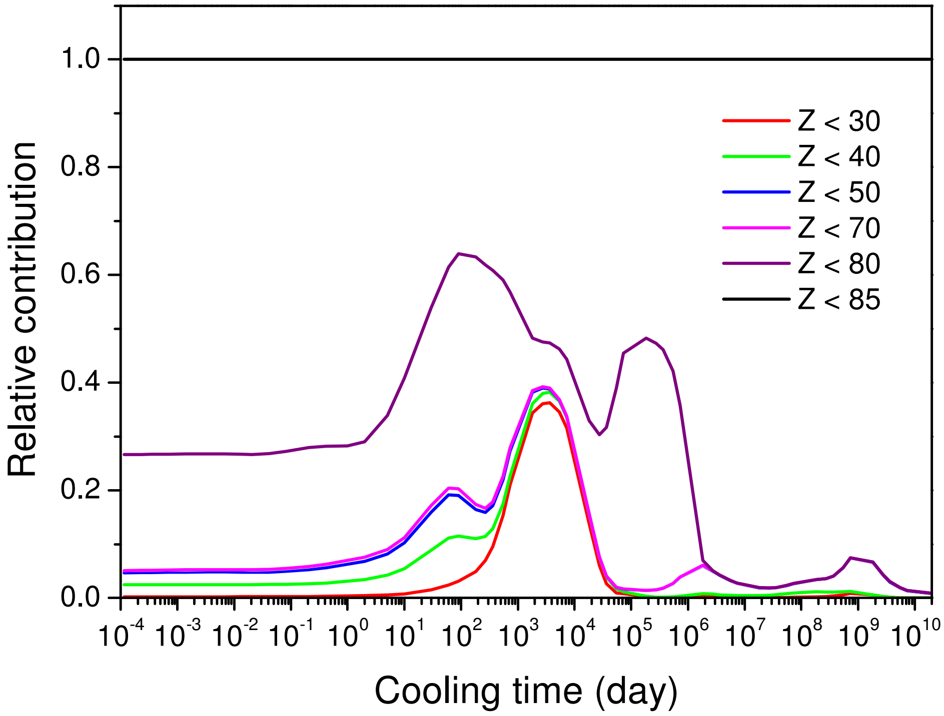


Figure 7.15. The relative contribution of nuclides with various atomic numbers to the total activity of irradiated LBE, as a function of the cooling time. The black line ($Z < 85$) corresponds to all nuclides.

2) *The origin of nuclides produced under irradiation*

The contribution of various energy ranges of neutrons and protons to the nuclide production was examined. This information is important to determine or modify the priority list for the evaluation of cross sections for radionuclide yields in the LBE of an accelerator-driven system.

The contributions to the nuclide production of different parts of particle spectra are considered:

- the neutron energy range below 20 MeV;
- neutron energies between 20 and 150 MeV;
- neutrons with energy above 150 MeV;
- protons with energy below 150 MeV;
- proton energies above 150 MeV.

Fig. 7.16 shows the contribution of radionuclides production from neutrons and protons with different energies to the total activity, as a function of the cooling time.

Detailed results are given in Table C1 on page 205, where the contribution of different energy ranges of neutrons and protons to the production of all radionuclides in the LBE are presented.

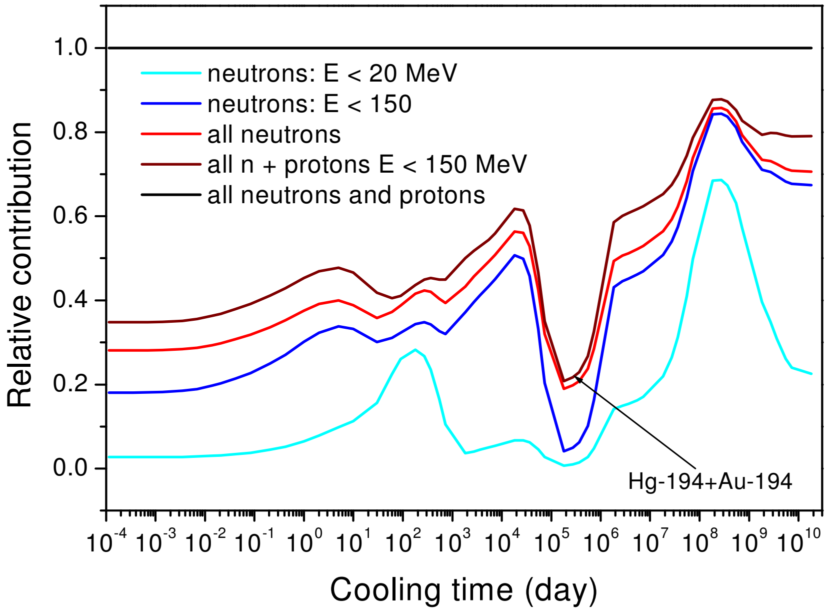


Figure 7.16. Contribution of radionuclides production from neutrons and protons of different energy ranges to the total activity of the LBE. The indicated peak at about 10^5 years of cooling corresponds to ^{194}Hg and ^{194}Au, which are mainly produced by high-energy protons.

Fig. 7.17 shows the relative contribution of all protons to the total activity of LBE after the irradiation. Peaks in the distribution are observed at cooling times where the contribution by protons is stronger (for instance for ^{194}Hg and ^{194}Au at about 10^5 years of cooling).

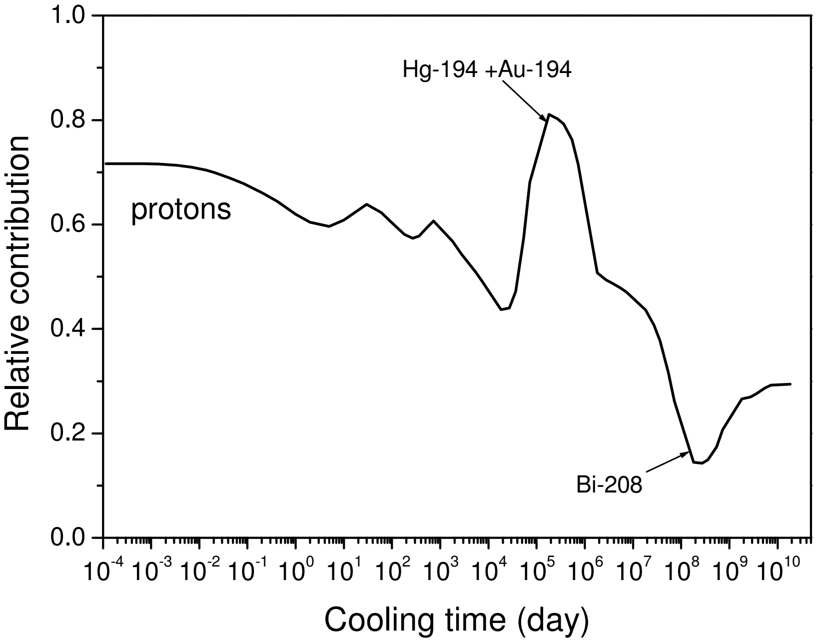


Figure 7.17. The contribution of protons to the total activity of LBE as a function of the cooling time.

7.4.3 Uncertainties in the calculations

As an indication of the statistical uncertainties, in Fig. 7.18 the uncertainties on the FLUKA calculated production rates as a function of the production rates values are shown for the LBE and the structural materials. The uncertainties are determined from the analysis of 5 statistically independent runs with 2 millions histories each. For lower production rates the uncertainties approach 100%. We note that the fraction of production rates with uncertainties higher than 50% is quite high, between 15% and 35% of the total. However, it concerns mainly nuclides with short half lives, therefore less relevant for the problem of the waste disposal.

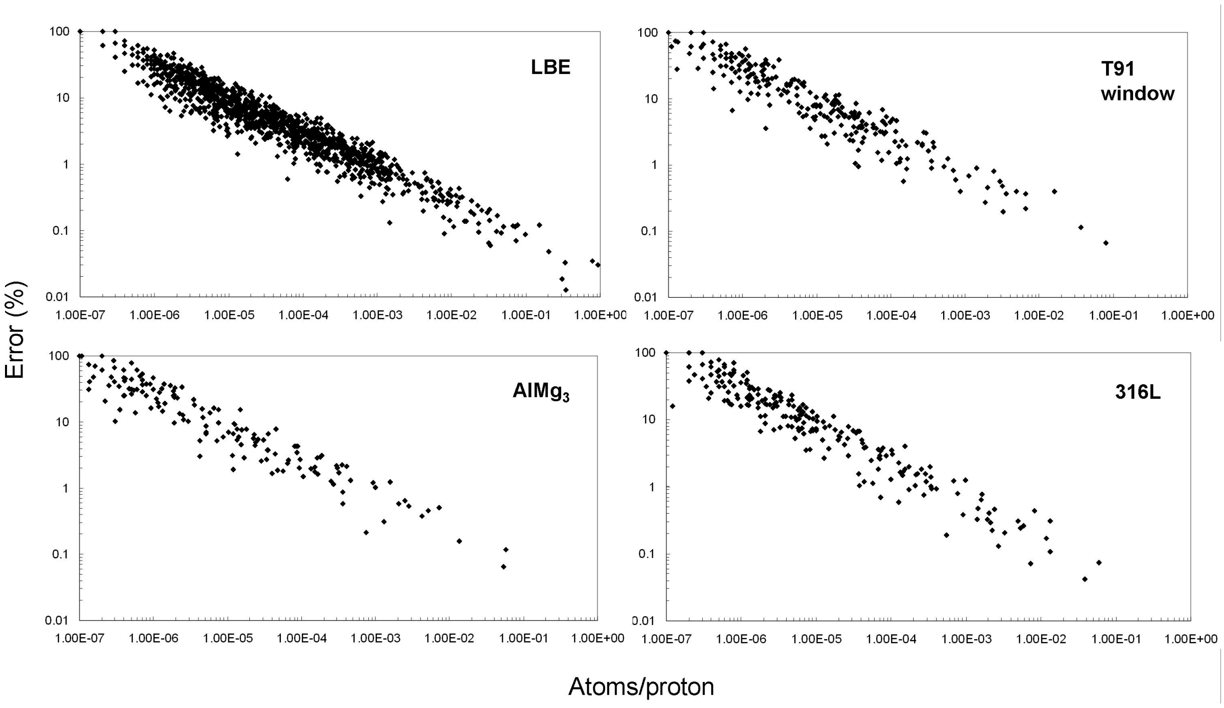


Figure 7.18. Uncertainties in calculated (FLUKA) production rates (atoms/proton) in the LBE and structural materials.

7.5 Decay heat in LBE and dose rates

Calculations of the decay heat were performed using FLUKA/ORIHET 3 and MCNPX/CINDER'90. Results are shown in Table 7.3 for selected cooling times. The agreement between the three calculations is satisfactory. In Fig. 7.19 the data in the table are displayed. Information on the decay heat was important for the freezing procedure of the target and for the target storage.

Table 7.3. Calculated decay heat (Watt) of the LBE, at different cooling times, after 123 days of irradiation at 0.947 mA.

Cooling time	FLUKA-ORIHET 3	MCNPX-CINDER'90	
		Bertini+Dresner	INCL4+ABLA
Initial	2730	2435.3	2651.9
1 month	187	162.3	163.4
6 months	55	54.3	51.3
1 year	24.2	23.0	21.4
2 years	7.0	6.0	5.3
3 years	3.92	3.1	2.5
10 years	2.06	1.6	1.3
100 years	0.279	0.2	0.2

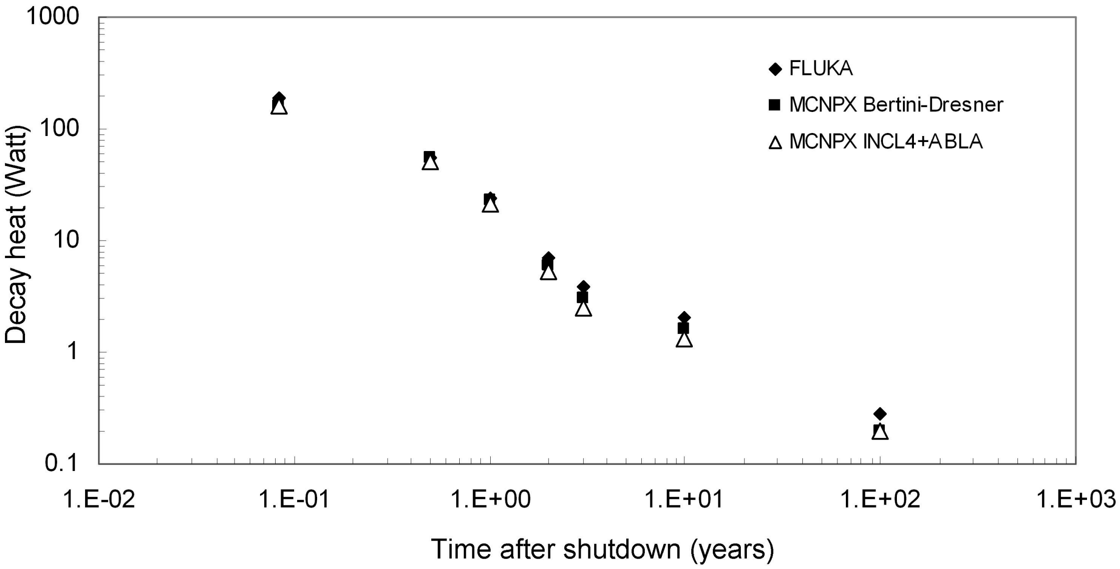


Figure 7.19. Calculated LBE decay heat as a function of the cooling time.

7.6 Effect of impurities in the LBE

As previously said, the LBE used in MEGAPIE contained impurities (Table 2.1 on page 38). The impact of the impurities on the radionuclide inventory was investigated: the presence of impurities in the LBE, such as In (28 ppm) and Sn (113 ppm), or elements with large thermal cross sections like boron (2 ppm) can affect the overall inventory.

7.6.1 FLUKA

FLUKA results are shown in Figs. 7.20 and 7.21, where the *A* and *Z* distributions of atoms produced in the LBE, with and without impurities, are shown. The only significant differences are for lithium ($Z=3$), cadmium and indium (Z=48, 49). The nuclides showing larger production rate in the LBE with impurities are ^{7}Li (from (n,α) reaction on the ^{10}B impurity), ^{116}In (capture in ^{115}In) and ^{114}Cd (inelastic reactions in In and Sn impurities). It is worth noting that the (n,α) reaction on ^{10}B brings also a relative increase of about 17% in the α production.

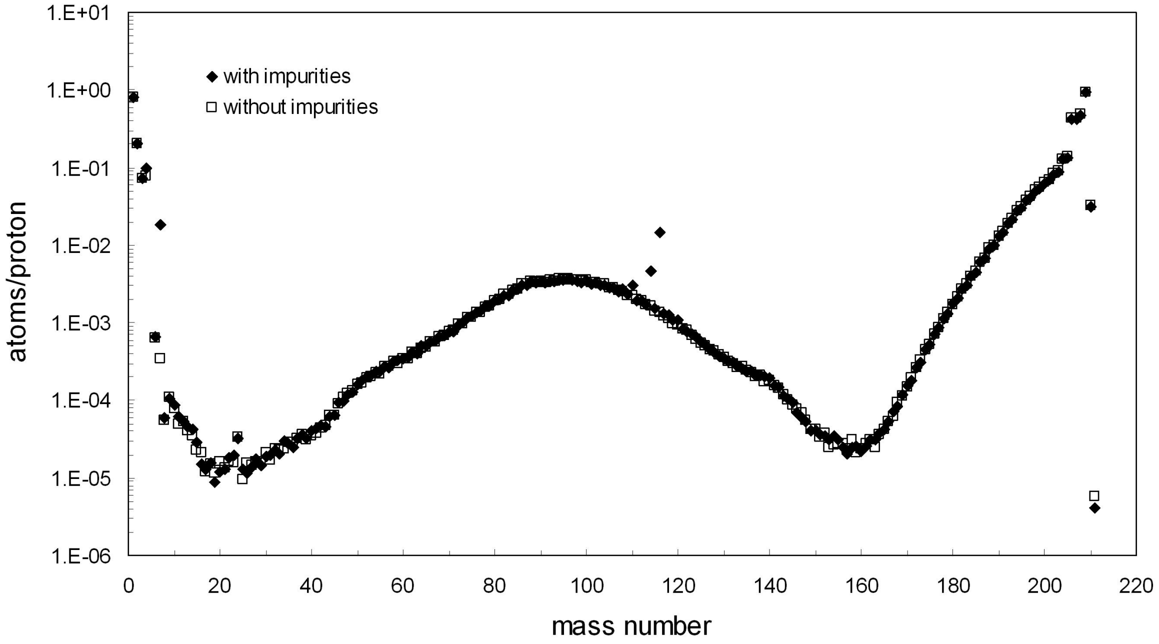


Figure 7.20. Calculated (FLUKA 2006.3b) mass distribution of nuclide production in a portion of the LBE, with and without impurities.

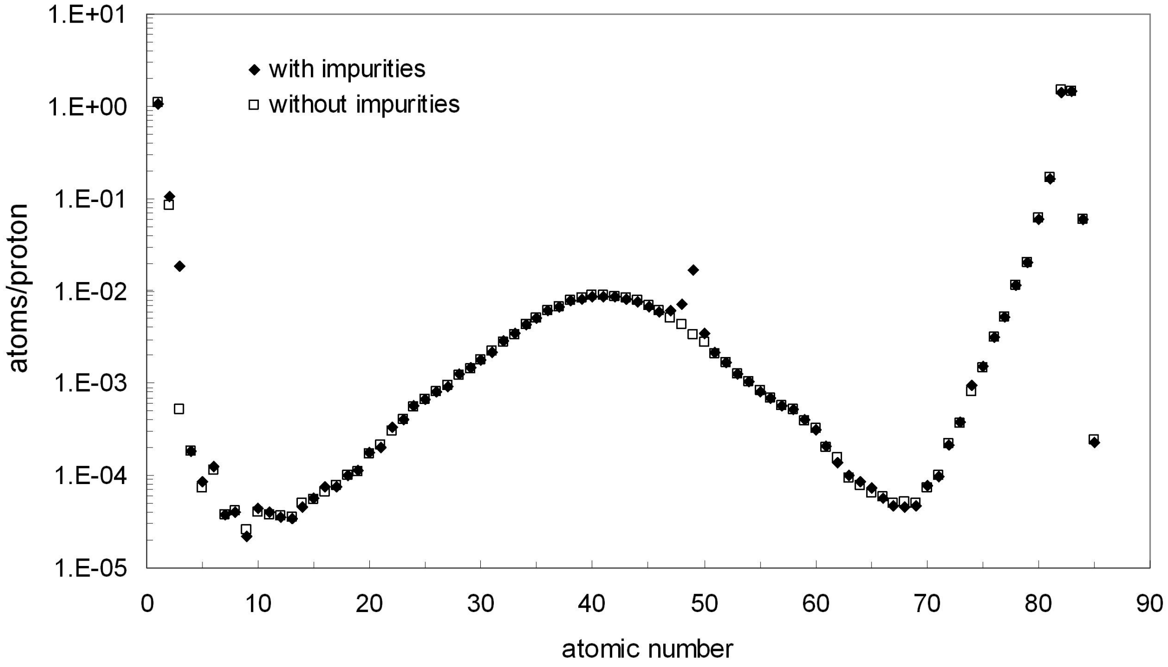


Figure 7.21. Calculated (FLUKA 2006.3b) *Z* distribution of nuclide production in a portion of the LBE, with and without impurities.

7.6.2 MCNPX

Also MCNPX2.5.0 (INCL4-ABLA) shows that the impurities have no effect on the total activity, since the main contributors come from reactions on Pb and Bi. As shown in Figs. 7.22-7.24, the differences in the concentrations and in the activities between two sets of calculations, performed with and without impurities, are minimal. Some differences are observed after 1 year of cooling, but concern nuclides with low activity.

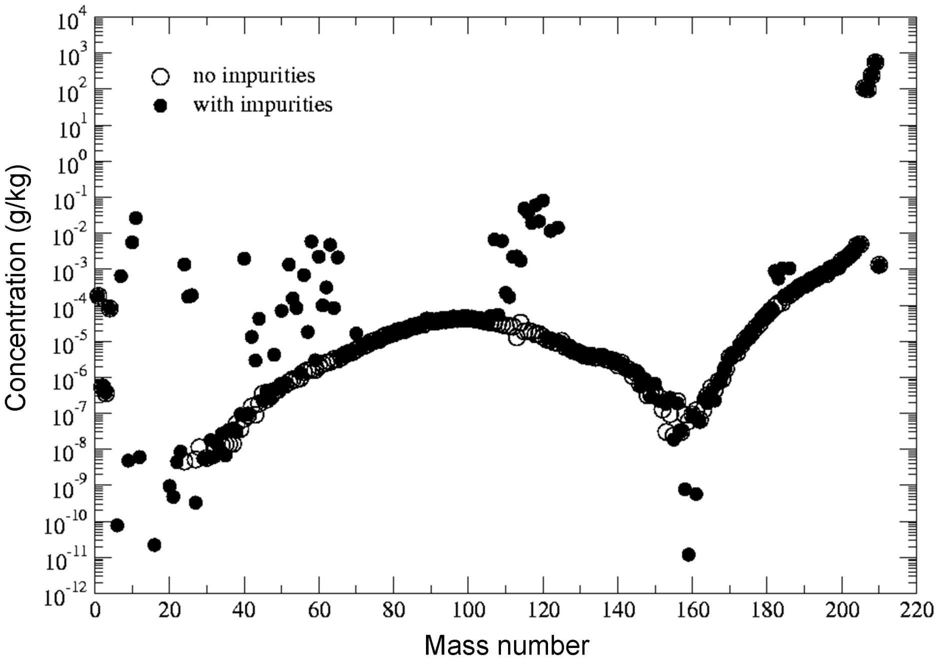


Figure 7.22. The concentration of all nuclides contained in the irradiated LBE after 123 day-irradiation with 575 MeV protons at 0.947 mA using INCL4-ABLA, as a function of the mass number. Calculations were performed for the pure LBE (open circles) and for the real LBE composition (black circles).

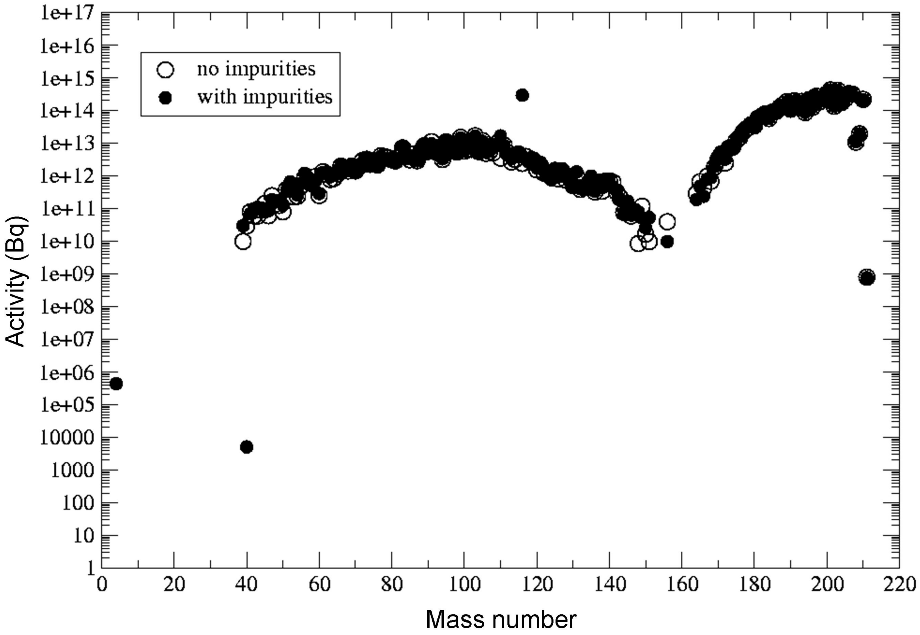


Figure 7.23. The activity of radionuclides contained in the LBE after 123 day-irradiation with 575 MeV protons at 0.947 mA as a function of the mass number. Calculations with MCNPX 2.5.0 using INCL4-ABLA.

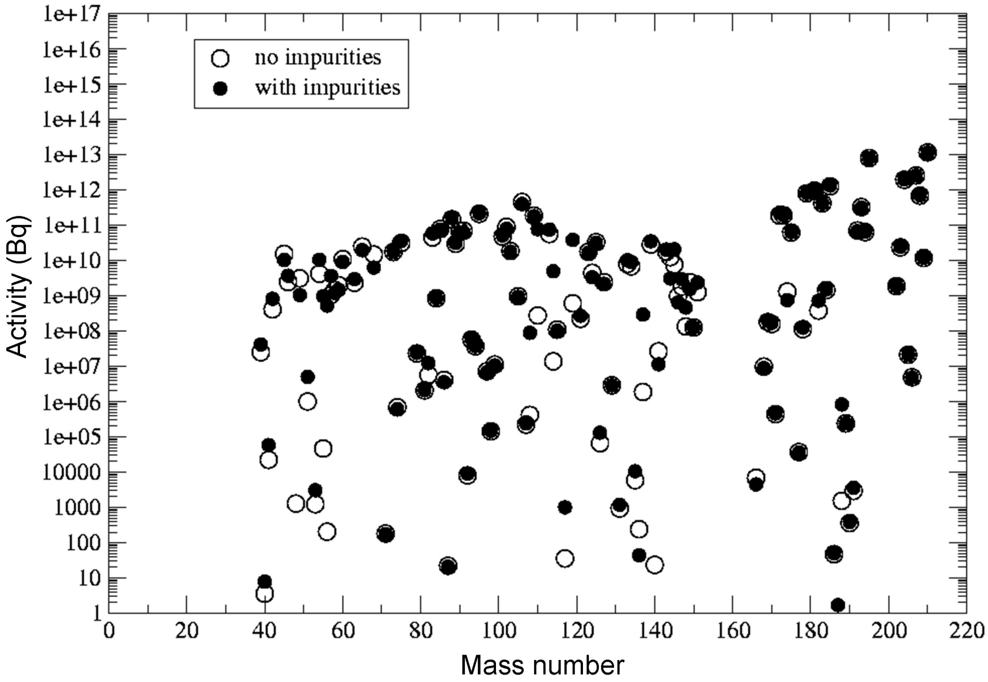


Figure 7.24. The activity of radionuclides contained in the LBE after 123 day-irradiation with 575 MeV protons at 0.947 mA and 1 year of cooling, as a function of the mass number. Calculations with MCNPX 2.5.0 using INCL4-ABLA.

7.6.3 SNT

The dependence of reaction rates upon the atomic mass number and atomic number calculated for LBE with and without impurities are shown in Fig. 7.25 and Fig. 7.26.

The mass dependence of the concentration of all nuclides contained in the LBE after the 123-day irradiation period is shown in Fig. 7.27.

Fig. 7.28 presents the *A*-dependence of the concentration of unstable nuclides calculated for pure LBE and for the LBE with impurities. The activity of radionuclides after 123 days of irradiation is shown in Fig. 7.29 and 7.30 at $T = 0$ and $T = 1$ year of cooling, depending on the mass number of radionuclides. Results are consistent with the FLUKA and MCNPX results. After one year of cooling, there are only a few nuclides with activity greater than 10^9 Bq, which show a significantly higher activity with the impurities: ^{114}In and ^{114m}In (factor 270 increase) and ^{110m}Ag (factor 210 increase). These nuclides come from thermal neutron capture in the In and Ag impurities.

The difference in the total activity of the radionuclides calculated for the pure LBE and for the real LBE composition does not exceed 2 % at any time after the end of the irradiation.

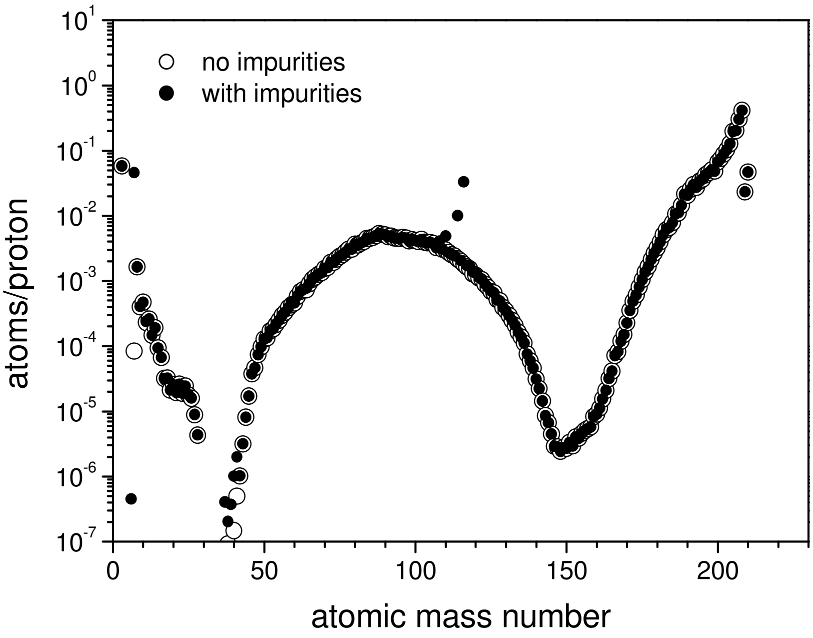


Figure 7.25. SNT calculated production rates in the LBE depending on the mass number of nuclides. Calculations were performed for the pure LBE (open circles) and for the real LBE composition (black circles).

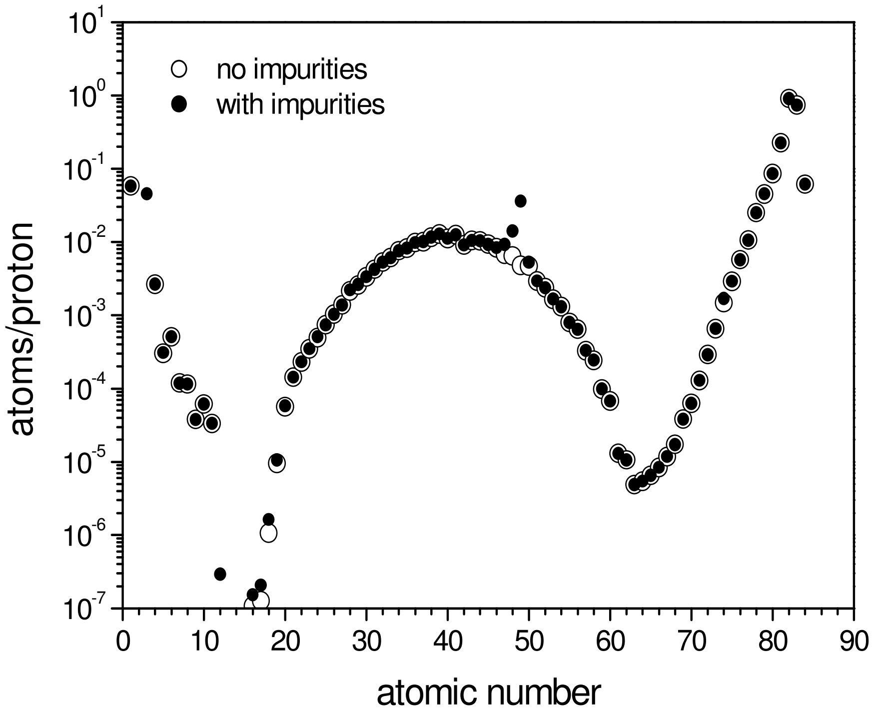


Figure 7.26. SNT calculated production rates in the LBE depending on the atomic number of nuclides. Calculations were performed for the pure LBE (open circles) and for the real LBE composition (black circles).

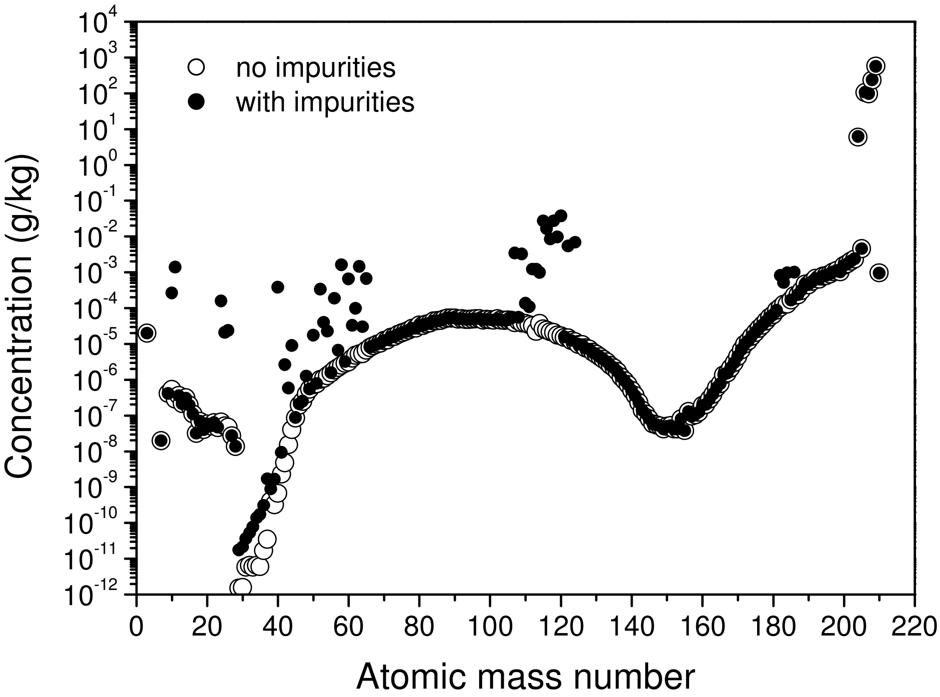


Figure 7.27. The concentration of all nuclides contained in the irradiated LBE after 123 day-irradiation depending on the mass number of nuclides, calculated with SNT. Calculations were performed for the pure LBE (open circles) and for the real LBE composition (black circles).

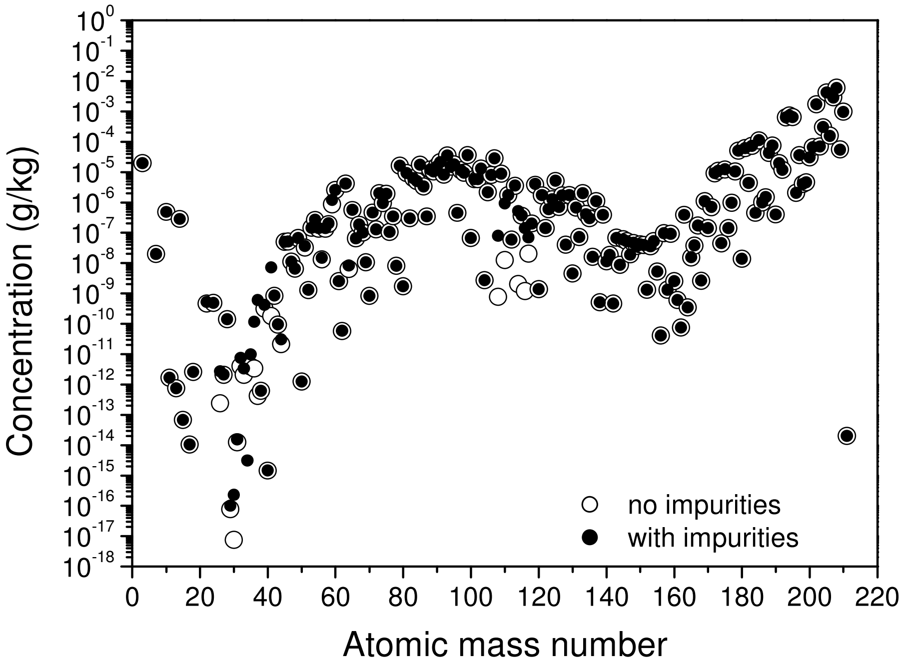


Figure 7.28. The concentration of unstable nuclides produced in the LBE after 123 day-irradiation depending on the mass number of nuclides, calculated with SNT.

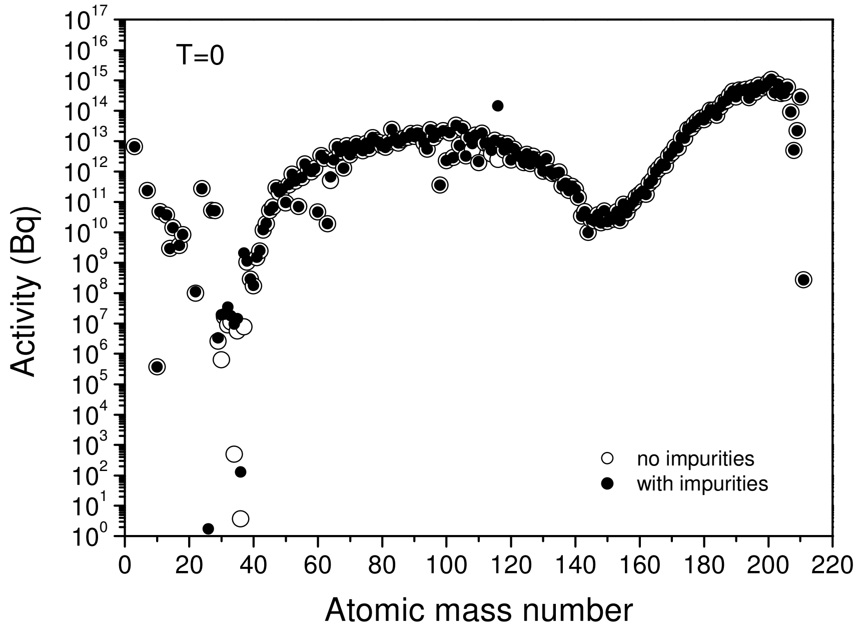


Figure 7.29. The activity of radionuclides produced in the LBE after 123 day-irradiation depending on the mass number of nuclides, calculated with SNT.

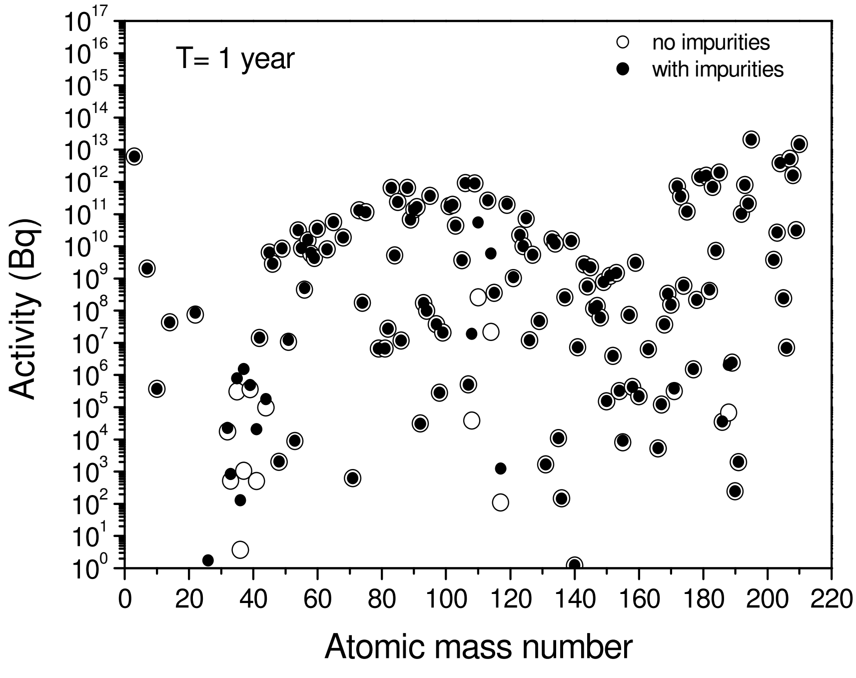


Figure 7.30. The activity of radionuclides contained in the LBE after 123 day-irradiation and 1 year cooling depending on the mass number of nuclides, calculated with SNT.

8. CONCLUSIONS AND RECOMMENDATIONS

A comprehensive set of flux and gas release measurements was performed during the irradiation phase of MEGAPIE in 2006, in parallel to a calculation program. As discussed in the introduction these investigations are of great relevance for ADS and for the SINQ facility. As the results of relevance to SINQ are obvious (see Chapter 4), we concentrate the discussion in this conclusive chapter on the relevance of these results in the framework of ADS. For each of the topics, neutronic performance, delayed neutrons, gas production and activation, we discuss the main results, give recommendations to ADS technology, and discuss the points needing further analysis.

8.1 Neutronic performance

8.1.1 Main results

A big effort was devoted to the study of the neutron fluxes in the MEGAPIE target and in the surrounding SINQ facility. The most relevant results are the following:

- **Absolute fluxes.** Absolute fluxes have been determined at different points in the facility, and results have been compared with calculations, obtaining in general an agreement within 20% for thermal fluxes. Epithermal flux measurements at two measurement points confirmed that the "background" of neutrons with $E > 1$ MeV is bigger with the liquid metal target. Fast neutron ($E > 1$ MeV) fluxes were measured at the NAA station, and results compare well with calculations.
- **Neutron flux inside MEGAPIE**. For the first time, the measurement of the neutron flux inside a liquid metal target was performed. Such a system is very important as an online monitor, and also for offline determination of the absolute fluxes close to the proton interaction point. A disagreement with calculations of a factor 2-3 (depending on the chamber position) exists. We think that the measurements are correct, since they agree with the results from the flux monitors placed in the same positions. It is likely that the calculations of the fission rates in that particular position are not correct, due to the inherent difficulty of reproducing the mixed neutron spectrum, with strong thermal, epithermal and fast components at the detector locations.
- **Code validation**. Most of the experimental data and calculations at the exits of the SINQ target block agree within two standard deviations, indicating that the neutron creation, moderation and transport to the beam lines are correctly modeled. Calculations at NAA are about 30% higher than the data, but out of about 5 standard deviations, due to the high precision of the measurements. Calculations inside the central rod are 2-3 times higher than measurements. This trend indicates that close to the proton interaction region is more difficult to reproduce correctly the shape of the neutron spectrum or the absolute flux value.
- **Relative comparison between different targets**. The flux measurement performed in different years at various points of the SINQ facility allowed for a relative comparison of the neutronic performance of the different targets. On the average from four measurement points, MEGAPIE has a neutronic performance higher than target 6 of a factor of 1.74 ± 0.12. The performance changes between the two different solid targets and MEGAPIE has been correctly reproduced.

8.1.2 Recommendations and points requiring further analysis

The knowledge of the neutronic performance of an ADS system is a very important parameter, which depends on the spallation target used. From the experience gained in the MEGAPIE work, we learned that this knowledge can be difficult to achieve for the following reasons:

- **Correct definition of the model and influence of structural material**. Throughout this work it was found that significant changes in the results were usually obtained with each progressive refinement of the geometry, of the materials and of the source definition. In particular, in an attempt to reproduce the experimental results on flux calculations we have progressively refined the description of the geometry of the structural materials in the target and in the SINQ facility. The target and the collimation systems, as well as the structure at measurement points such as the NAA or the fission chambers are relatively complex and are therefore a challenge for the correct modeling of the facility. The correct definition of the structural materials, as well as the precise geometrical definition, is essential in the code validation process.
- **Influence of boundary conditions**. The real profile of the proton beam impinging on the target was not known and we have observed a dependence of the results on the different beam profile used in the simulations, at least for the flux calculations close to the target interaction point. It is important to have a precise knowledge for a realistic calculation. Additional indications may come after the beam footprint will be measured during the PIE.

Despite the efforts made, we have not achieved a full agreement between our sets of data and calculations. We therefore recommend that for future studies more efforts are devoted to this problem, with the following directives:

- more precise activation foil measurements: uncertainties better than 10% for the individual measurement points should be achieved;
- additional measurements, to complement the FC measurements, in the spallation region; alternatively, one could perform FC measurements in regions of the facility where the flux is better known, such as at NAA at SINQ;
- additional MC simulations, with more sensitivity studies for instance on different cross section data sets, and with different codes;
- more precise spectral measurements. While the spectral measurement with the Bonner spheres system was successful and gave a good agreement with the calculations, we think that a more precise measurement close to the spallation region would yield important information, and could possibly solve the discrepancy observed between experiment and calculations in the central rod.

8.2 Delayed neutrons

8.2.1 Main results

Important results were obtained on the delayed neutrons:

- we presented a detailed comparison between the DN curve measured at MEGAPIE and the results of a geometrical model involving three averaged liquid metal transit times and the DN precursor parameters;
- the fit of the DN decay curve measured at MEGAPIE was performed using the results of the model and the DN densities extracted are in fair agreement with DN parameters previously measured at similar energies but for solid targets;

- the DN absolute fluxes were extracted and are in fair agreement (within a factor of 2) with calculations, a result totally acceptable given the difficulty of the measurements, with the detector located in a complex area, very difficult to simulate.

8.2.2 Recommendations and points requiring further analysis

We think that our studies have confirmed the importance of the DN issues in an ADS, and in liquid metal targets in general. Equipment should be qualified to withstand fast DN fluxes at the level of 10^6 n/cm^2/s/mA or higher.

8.3 Gas production

8.3.1 Main results

Gas production measurements by γ spectroscopy led to very important information on the gas release in an ADS target. We can summarize the main results:

- noble gas release is a slow process: the release rates of noble gases in the MEGAPIE system are at the % level after 1-2 days of operation, while the release becomes almost complete weeks after the beginning of operation;
- the fractional amounts of the released noble gases are the same for all the elements.
- the mass distributions of the released nuclides can be well reproduced by calculations;
- the release of mercury elements is presumably much lower than the noble gas release, although only a lower limit could be given with our measurement procedure;
- traces of Po and I isotopes were detected from the gas samples. The quantity of Po observed is compatible with production from the decay of parent astatine isotopes, which have higher volatility than polonium;
- pressure increase in the cover gas could be fairly well (within a factor of 2) reproduced with calculations. Given the leaks detected, and the fact that the pressure transducers did not function well during the whole irradiation period, it is a satisfactory result.

8.3.2 Recommendations and points requiring further analysis

The amount of data and calculations gathered in this work is important and overall is in agreement with findings from the experimental and calculation work of recent years. The cover gas system is one of the most important parts of an ADS target, which must handle quantities of stable and radioactive gas which are orders of magnitude higher than the quantities released by a reactor.

There are some important recommendations for an ADS:

- the sampling should be performed in a more accurate way, especially to observe the heaviest elements that can be trapped by the system and only partially released. Gas sampling is not a simple operation, and if possible it should be performed remotely; the potential deposition in the CGS pipes of heavy radioisotopes such as Hg might increase the dose rates near the CGS.
- It is important to develop a reliable measurement system for the stable noble gases.
- Leaks of radioactive Xe isotopes produced in the LBE were detected in the insulation gas system, corresponding roughly to 1 % of the amount of the total inventory in the CGS. The issue of leaks between target components should be carefully studied in future ADS designs.

8.4 Target activation calculations

8.4.1 Main results

A large set of Monte Carlo calculations was performed during the MEGAPIE project, and in this report we have presented the work on activation of the LBE and of the structural materials. The results are of interest for several reasons: code validation; comparison of results of LBE activation; comparison of results of structure activation; study of the origin of nuclides produced during irradiation; study of contributions from neutrons and protons to the activation; effect of impurities in the LBE.

Overall, the results between FLUKA 2006.3b, MCNPX 2.5.0 and SNT are consistent. The comparison was performed for the LBE and for the structure of the target. For the LBE the results compare well, with only a few discrepancies (neglecting the radionuclides with lower activity). Discrepancies for the structural materials are bigger. The reason is related to the different origin of the activation: residual nuclei in LBE are mainly due to spallation reactions, while target structure activation is mainly due to low-energy neutron capture. The latter is sensitive to the simulated thermalization process and to the capture cross sections data used.

The effect of the impurities in the radionuclide inventory of the LBE, using the actual chemical composition of the LBE used in MEGAPIE, is minimal.

8.4.2 Recommendations and points requiring further analysis

Comparison of results of structure activation should be made with other codes. In the present work FLUKA/ORIHET 3 and MCNPX/CINDER'90 were used for the structure activation. Additional work will be done for the Post Irradiation Experiment.

Annex A. FLUKA results

Total activity decay of the target lower part (without LBE)

Table A1. Radionuclide inventory of the target lower part (without LBE) : decay following 123 days of irradiation at 0.947 mA (2.79582 A·h). Calculations performed with FLUKA2006.3b and ORIHET 3. Activities in Bq. Number of proton histories: 10 millions.

Time unit=Years

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
H 3	2.51E+11	2.50E+11	2.44E+11	2.37E+11	2.24E+11	2.12E+11	1.43E+11	9.07E+08
Be 7	1.15E+12	7.78E+11	1.07E+11	9.97E+09	8.62E+07	7.45E+05	2.69E-09	0.00E+00
Be 10	9.98E+04	9.98E+04	9.98E+04	9.98E+04	9.98E+04	9.98E+04	9.98E+04	9.98E+04
C 14	2.38E+07	2.38E+07	2.38E+07	2.38E+07	2.38E+07	2.38E+07	2.38E+07	2.35E+07
Na 22	4.12E+11	4.03E+11	3.61E+11	3.16E+11	2.42E+11	1.85E+11	2.87E+10	1.11E+00
Al 26	7.83E+06	7.83E+06	7.83E+06	7.83E+06	7.83E+06	7.83E+06	7.83E+06	7.83E+06
Si 32	2.51E+07	2.51E+07	2.50E+07	2.50E+07	2.48E+07	2.47E+07	2.38E+07	1.49E+07
P 32	2.29E+11	5.25E+10	5.70E+07	2.50E+07	2.49E+07	2.47E+07	2.38E+07	1.49E+07
P 33	1.31E+11	5.71E+10	8.85E+08	5.99E+06	2.74E+02	1.26E-02	0.00E+00	0.00E+00
S 35	1.09E+11	8.54E+10	2.56E+10	6.02E+09	3.33E+08	1.85E+07	2.96E-02	0.00E+00
Cl 36	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05
Ar 37	3.97E+11	2.18E+11	1.07E+10	2.89E+08	2.11E+05	1.53E+02	0.00E+00	0.00E+00
Ar 39	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.69E+08	2.68E+08	2.63E+08	2.09E+08
Ar 42	3.35E+07	3.34E+07	3.31E+07	3.28E+07	3.21E+07	3.14E+07	2.71E+07	4.07E+06
K 40	1.42E+02	1.42E+02	1.42E+02	1.42E+02	1.42E+02	1.42E+02	1.42E+02	1.42E+02
K 42	2.58E+11	3.34E+07	3.31E+07	3.28E+07	3.21E+07	3.14E+07	2.71E+07	4.07E+06
K 43	1.05E+11	1.58E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ca 41	1.72E+06	1.72E+06	1.72E+06	1.72E+06	1.72E+06	1.72E+06	1.72E+06	1.72E+06
Ca 45	1.01E+11	8.91E+10	4.66E+10	2.14E+10	4.51E+09	9.51E+08	1.77E+04	0.00E+00
Ca 47	1.30E+10	1.27E+08	9.87E-03	7.49E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 44	1.47E+12	1.15E+09	1.15E+09	1.14E+09	1.13E+09	1.11E+09	1.02E+09	3.57E+08
Sc 45m	1.93E+06	1.69E+06	8.85E+05	4.06E+05	8.57E+04	1.81E+04	3.35E-01	0.00E+00
Sc 46	7.84E+11	6.10E+11	1.73E+11	3.82E+10	1.86E+09	9.08E+07	5.92E-02	0.00E+00
Sc 47	6.39E+11	1.59E+09	3.77E-02	2.86E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 48	1.46E+11	1.41E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 44	1.15E+09	1.15E+09	1.15E+09	1.14E+09	1.13E+09	1.11E+09	1.02E+09	3.57E+08
V 48	4.43E+12	1.19E+12	1.61E+09	5.83E+05	7.63E-02	9.99E-09	0.00E+00	0.00E+00
V 49	2.27E+12	2.13E+12	1.55E+12	1.05E+12	4.90E+11	2.27E+11	1.06E+09	0.00E+00
Cr 48	2.19E+11	1.52E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 51	1.75E+14	8.21E+13	1.82E+12	1.88E+10	2.02E+06	2.17E+02	0.00E+00	0.00E+00
Mn 52	7.23E+12	1.69E+11	1.06E+03	1.56E-07	3.63E-27	0.00E+00	0.00E+00	0.00E+00
Mn 53	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06
Mn 54	7.96E+12	7.44E+12	5.30E+12	3.54E+12	1.57E+12	6.99E+11	2.40E+09	0.00E+00
Fe 55	2.13E+13	2.08E+13	1.87E+13	1.65E+13	1.28E+13	9.93E+12	1.68E+12	2.00E+02
Fe 59	5.19E+12	3.23E+12	3.02E+11	1.75E+10	5.94E+07	2.01E+05	1.02E-12	0.00E+00
Fe 60	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02
Co 56	1.12E+12	8.60E+11	2.19E+11	4.26E+10	1.61E+09	6.08E+07	6.65E-03	0.00E+00
Co 57	1.02E+12	9.48E+11	6.43E+11	4.03E+11	1.59E+11	6.26E+10	9.20E+07	0.00E+00
Co 58	5.56E+12	4.14E+12	9.32E+11	1.56E+11	4.38E+09	1.23E+08	1.69E-03	0.00E+00
Co 60	1.52E+12	1.50E+12	1.42E+12	1.33E+12	1.17E+12	1.02E+12	4.07E+11	2.95E+06
Co 60m	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02	6.45E+02
Ni 56	5.32E+10	1.51E+09	2.56E+01	1.23E-08	2.29E-27	0.00E+00	0.00E+00	0.00E+00
Ni 57	7.71E+11	5.43E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 59	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.39E+08
Ni 63	8.24E+10	8.23E+10	8.21E+10	8.18E+10	8.12E+10	8.07E+10	7.69E+10	4.12E+10
Cu 67	1.18E+09	3.39E+05	5.40E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 65	1.04E+09	9.59E+08	6.22E+08	3.71E+08	1.32E+08	4.67E+07	3.30E+04	0.00E+00
Ga 67	2.36E+09	3.77E+06	3.29E-08	4.57E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 68	1.50E+09	2.95E+08	2.00E+08	1.25E+08	4.92E+07	1.93E+07	2.78E+04	0.00E+00
Ge 68	3.19E+08	2.95E+08	2.00E+08	1.25E+08	4.91E+07	1.93E+07	2.78E+04	0.00E+00
Ge 69	1.18E+09	2.91E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 71	4.27E+09	8.25E+08	8.05E+04	1.25E+00	2.99E-10	7.19E-20	0.00E+00	0.00E+00
Ge 71m	1.17E+08	5.16E+04	7.18E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 73m	4.69E+09	3.63E+09	9.74E+08	2.01E+08	8.60E+06	3.68E+05	9.56E-05	0.00E+00
As 71	2.96E+09	1.31E+06	1.82E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 72	4.74E+09	1.11E+08	3.87E+02	1.10E-04	8.97E-18	0.00E+00	0.00E+00	0.00E+00
As 73	4.69E+09	3.63E+09	9.74E+08	2.01E+08	8.60E+06	3.68E+05	9.56E-05	0.00E+00

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
As 74	1.17E+09	3.59E+08	9.44E+05	7.61E+02	4.94E-04	3.21E-10	0.00E+00	0.00E+00
As 75m	1.96E+09	1.64E+09	6.81E+08	2.37E+08	2.86E+07	3.45E+06	1.30E+00	0.00E+00
As 76	1.18E+09	4.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 72	1.18E+09	9.67E+07	3.37E+02	9.60E-05	7.81E-18	0.00E+00	0.00E+00	0.00E+00
Se 75	3.92E+09	3.29E+09	1.36E+09	4.73E+08	5.72E+07	6.91E+06	2.59E+00	0.00E+00
Br 77	1.24E+10	1.80E+06	9.18E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 79	1.66E+10	9.35E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 81	2.22E+04	2.23E+04	2.23E+04	2.23E+04	2.23E+04	2.23E+04	2.23E+04	2.23E+04
Kr 83m	2.18E+10	1.65E+10	4.85E+09	1.12E+09	5.92E+07	3.14E+06	3.70E-03	0.00E+00
Kr 85	5.51E+06	5.49E+06	5.35E+06	5.18E+06	4.86E+06	4.55E+06	2.90E+06	8.78E+03
Rb 82	3.41E+10	8.78E+09	1.41E+08	9.94E+05	4.94E+01	2.46E-03	0.00E+00	0.00E+00
Rb 83	2.78E+10	2.22E+10	6.51E+09	1.50E+09	7.95E+07	4.22E+06	4.97E-03	0.00E+00
Rb 83m	1.57E+10	2.74E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 84	5.47E+09	2.88E+09	1.15E+08	2.41E+06	1.07E+03	4.70E-01	0.00E+00	0.00E+00
Rb 86	2.93E+09	9.47E+08	3.28E+06	3.68E+03	4.62E-03	5.80E-09	0.00E+00	0.00E+00
Sr 82	2.00E+10	8.78E+09	1.41E+08	9.94E+05	4.94E+01	2.46E-03	0.00E+00	0.00E+00
Sr 83	3.13E+10	5.47E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 85	4.28E+10	3.10E+10	6.08E+09	8.63E+08	1.74E+07	3.50E+05	4.72E-07	0.00E+00
Sr 89	1.92E+09	1.27E+09	1.57E+08	1.28E+07	8.55E+04	5.70E+02	3.34E-13	0.00E+00
Sr 90	1.91E+07	1.90E+07	1.89E+07	1.86E+07	1.82E+07	1.78E+07	1.50E+07	1.72E+06
Y 87	1.04E+11	2.06E+08	3.34E-06	9.77E-23	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 88	4.95E+10	5.18E+10	3.70E+10	1.61E+10	2.05E+09	2.18E+08	1.49E+01	0.00E+00
Y 89m	1.70E+11	2.76E+08	1.57E+04	1.28E+03	8.56E+00	5.70E-02	3.34E-17	0.00E+00
Y 90	1.01E+10	2.29E+07	1.89E+07	1.86E+07	1.82E+07	1.78E+07	1.50E+07	1.73E+06
Y 91	2.27E+09	1.58E+09	2.61E+08	3.00E+07	3.96E+05	5.22E+03	3.66E-10	0.00E+00
Zr 88	7.12E+10	5.53E+10	1.56E+10	3.42E+09	1.64E+08	7.89E+06	4.66E-03	0.00E+00
Zr 89	1.70E+11	2.76E+08	2.55E-06	3.80E-23	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 93	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03
Zr 95	6.07E+09	4.37E+09	8.41E+08	1.16E+08	2.23E+06	4.28E+04	4.06E-08	0.00E+00
Nb 91	1.35E+08	1.35E+08	1.35E+08	1.35E+08	1.35E+08	1.35E+08	1.34E+08	1.22E+08
Nb 91m	2.40E+07	1.70E+07	3.00E+06	3.74E+05	5.84E+03	9.12E+01	2.06E-11	0.00E+00
Nb 92	1.33E+03	1.33E+03	1.33E+03	1.33E+03	1.33E+03	1.33E+03	1.33E+03	1.33E+03
Nb 93m	3.31E+05	4.76E+05	1.20E+06	2.05E+06	3.70E+06	5.28E+06	1.46E+07	4.01E+07
Nb 94	1.59E+07	1.59E+07	1.59E+07	1.59E+07	1.59E+07	1.59E+07	1.59E+07	1.59E+07
Nb 95	8.46E+10	4.87E+10	3.76E+09	3.07E+08	5.11E+06	9.73E+04	8.95E-08	0.00E+00
Nb 95m	6.71E+07	5.24E+07	1.01E+07	1.39E+06	2.67E+04	5.12E+02	4.86E-10	0.00E+00
Nb 96	5.26E+10	2.19E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 93	4.68E+07	4.68E+07	4.68E+07	4.68E+07	4.68E+07	4.68E+07	4.68E+07	4.60E+07
Mo 99	3.80E+12	1.81E+09	3.72E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 96	1.18E+10	8.70E+07	1.69E-03	2.41E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 97	9.57E+02	9.57E+02	9.57E+02	9.57E+02	9.57E+02	9.57E+02	9.57E+02	9.57E+02
Tc 98	3.95E+02	3.95E+02	3.95E+02	3.95E+02	3.95E+02	3.95E+02	3.95E+02	3.95E+02
Tc 99	4.16E+06	4.31E+06	4.31E+06	4.31E+06	4.31E+06	4.31E+06	4.31E+06	4.31E+06
Tc 99m	3.33E+12	1.75E+09	3.59E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh105	2.19E+09	1.50E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd107	4.24E+01	4.24E+01	4.24E+01	4.24E+01	4.24E+01	4.24E+01	4.24E+01	4.24E+01
Ag109m	4.01E+08	3.84E+08	3.06E+08	2.33E+08	1.35E+08	7.79E+07	1.69E+06	6.86E-16
Cd109	4.01E+08	3.84E+08	3.06E+08	2.33E+08	1.35E+08	7.79E+07	1.69E+06	6.86E-16
Cd111m	2.37E+05	1.34E+02	6.00E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In111	2.37E+09	1.32E+06	5.93E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In113m	4.63E+09	3.86E+09	1.54E+09	5.14E+08	5.69E+07	6.31E+06	1.30E+00	0.00E+00
Sn113	4.63E+09	3.86E+09	1.54E+09	5.13E+08	5.69E+07	6.31E+06	1.29E+00	0.00E+00
Sn117m	4.01E+06	8.57E+05	3.64E+02	3.30E-02	2.72E-10	2.24E-18	0.00E+00	0.00E+00
Sn121	1.18E+10	9.51E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn123	5.70E+08	4.85E+08	2.14E+08	8.04E+07	1.13E+07	1.60E+06	1.76E+00	0.00E+00
Sn125	4.14E+09	4.68E+08	8.20E+03	1.62E-02	6.38E-14	2.51E-25	0.00E+00	0.00E+00
Sb125	2.99E+08	3.27E+08	2.99E+08	2.64E+08	2.05E+08	1.59E+08	2.75E+07	4.13E-03
Te125m	3.12E+07	4.42E+07	6.73E+07	6.38E+07	5.02E+07	3.90E+07	6.72E+06	1.01E-03
Yb169	1.14E+09	6.19E+08	2.29E+07	4.40E+05	1.62E+02	5.98E-02	0.00E+00	0.00E+00
Yb169m	1.61E+08	5.99E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu169	1.18E+09	4.38E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta179	2.84E+08	2.76E+08	2.35E+08	1.94E+08	1.33E+08	9.07E+07	6.31E+06	8.19E-09
Ta182	4.68E+11	3.90E+11	1.55E+11	5.12E+10	5.61E+09	6.13E+08	1.15E+02	0.00E+00
W185	1.61E+09	1.21E+09	2.98E+08	5.52E+07	1.90E+06	6.51E+04	3.67E-06	0.00E+00
W187	7.89E+10	4.61E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl200	1.18E+09	2.68E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl201	1.18E+09	1.34E+06	1.09E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0total	**1.33E+15**	**1.28E+14**	**3.22E+13**	**2.38E+13**	**1.68E+13**	**1.24E+13**	**2.34E+12**	**4.40E+10**

Total activity decay of the LBE

Table A2. Radionuclide inventory of the LBE: decay following 123 days of irradiation at 0.947 mA. Calculations performed with FLUKA2006.3b and ORIHET 3. Activities in Bq. Only nuclides having activities higher than 1 Bq after 1 month of decay are listed. Number of proton histories: 10 millions.

Time unit=Yrs

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
H 3	8.17E+12	8.13E+12	7.94E+12	7.72E+12	7.30E+12	6.90E+12	4.65E+12	2.95E+10
Be 7	2.50E+10	1.68E+10	2.32E+09	2.16E+08	1.87E+06	1.61E+04	5.82E-11	0.00E+00
Be 10	6.57E+04	6.57E+04	6.57E+04	6.57E+04	6.57E+04	6.57E+04	6.57E+04	6.57E+04
C 14	7.51E+06	7.51E+06	7.51E+06	7.51E+06	7.51E+06	7.51E+06	7.50E+06	7.42E+06
Na 22	1.01E+09	9.90E+08	8.86E+08	7.76E+08	5.94E+08	4.55E+08	7.05E+07	2.73E-03
Mg 28	4.27E+10	1.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al 26	1.30E+03	1.30E+03	1.30E+03	1.30E+03	1.30E+03	1.30E+03	1.30E+03	1.30E+03
Al 28	7.52E+10	1.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Si 32	1.34E+08	1.34E+08	1.34E+08	1.33E+08	1.33E+08	1.32E+08	1.27E+08	7.94E+07
P 32	4.37E+10	1.01E+10	1.40E+08	1.34E+08	1.33E+08	1.32E+08	1.27E+08	7.94E+07
P 33	1.13E+11	4.94E+10	7.66E+08	5.18E+06	2.37E+02	1.09E-02	0.00E+00	0.00E+00
S 35	9.51E+10	7.48E+10	2.24E+10	5.27E+09	2.92E+08	1.62E+07	2.59E-02	0.00E+00
Cl 36	3.25E+04	3.25E+04	3.25E+04	3.25E+04	3.25E+04	3.25E+04	3.25E+04	3.25E+04
Ar 37	1.46E+10	7.99E+09	3.93E+08	1.06E+07	7.71E+03	5.62E+00	0.00E+00	0.00E+00
Ar 39	1.53E+08	1.53E+08	1.53E+08	1.53E+08	1.52E+08	1.52E+08	1.49E+08	1.18E+08
Ar 42	1.02E+09	1.02E+09	1.01E+09	9.96E+08	9.76E+08	9.55E+08	8.24E+08	1.24E+08
K 40	6.80E+00	6.80E+00	6.80E+00	6.80E+00	6.80E+00	6.80E+00	6.80E+00	6.80E+00
K 42	1.10E+11	1.02E+09	1.01E+09	9.96E+08	9.76E+08	9.55E+08	8.24E+08	1.24E+08
K 43	2.00E+11	3.03E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ca 41	4.27E+04	4.27E+04	4.27E+04	4.27E+04	4.27E+04	4.27E+04	4.27E+04	4.27E+04
Ca 45	1.21E+11	1.06E+11	5.55E+10	2.55E+10	5.37E+09	1.13E+09	2.10E+04	0.00E+00
Ca 47	1.87E+11	1.82E+09	1.42E-01	1.08E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 44	3.67E+10	3.03E+07	3.02E+07	3.00E+07	2.96E+07	2.93E+07	2.70E+07	9.41E+06
Sc 45m	2.30E+06	2.02E+06	1.05E+06	4.84E+05	1.02E+05	2.15E+04	4.00E-01	0.00E+00
Sc 46	1.06E+11	8.26E+10	2.34E+10	5.17E+09	2.52E+08	1.23E+07	8.01E-03	0.00E+00
Sc 47	4.32E+11	6.43E+09	5.43E-01	4.12E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 48	2.30E+11	2.22E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 44	3.03E+07	3.03E+07	3.02E+07	3.00E+07	2.96E+07	2.93E+07	2.70E+07	9.41E+06
V 48	9.29E+10	2.52E+10	3.41E+07	1.23E+04	1.62E-03	2.11E-10	0.00E+00	0.00E+00
V 49	4.93E+10	4.63E+10	3.36E+10	2.29E+10	1.06E+10	4.94E+09	2.30E+07	0.00E+00
Cr 48	1.53E+10	1.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 51	2.37E+11	1.11E+11	2.45E+09	2.54E+07	2.73E+03	2.93E-01	0.00E+00	0.00E+00
Mn 52	9.29E+10	2.17E+09	1.37E+01	2.01E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 53	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04
Mn 54	8.27E+10	7.73E+10	5.52E+10	3.68E+10	1.63E+10	7.27E+09	2.49E+07	0.00E+00
Fe 55	1.46E+10	1.43E+10	1.29E+10	1.14E+10	8.81E+09	6.83E+09	1.16E+09	1.38E-01
Fe 59	1.05E+12	6.54E+11	6.10E+10	3.55E+09	1.20E+07	4.06E+04	2.06E-13	0.00E+00
Fe 60	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05
Co 56	3.04E+10	2.33E+10	5.94E+09	1.15E+09	4.36E+07	1.65E+06	1.80E-04	0.00E+00
Co 57	3.88E+10	3.60E+10	2.44E+10	1.53E+10	6.04E+09	2.38E+09	3.50E+06	0.00E+00
Co 58	1.72E+11	1.27E+11	2.87E+10	4.82E+09	1.35E+08	3.80E+06	5.22E-05	0.00E+00
Co 60	3.00E+10	2.97E+10	2.81E+10	2.63E+10	2.31E+10	2.02E+10	8.05E+09	2.34E+05
Co 60m	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05	1.76E+05
Ni 56	2.36E+09	6.70E+07	1.14E+00	5.46E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 57	1.12E+10	7.89E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 59	7.31E+05	7.31E+05	7.31E+05	7.31E+05	7.31E+05	7.31E+05	7.31E+05	7.30E+05
Ni 63	4.75E+09	4.75E+09	4.74E+09	4.72E+09	4.69E+09	4.65E+09	4.43E+09	2.38E+09
Ni 66	1.29E+12	1.26E+08	8.84E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 66	2.56E+12	1.26E+08	8.85E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 67	2.31E+12	6.64E+08	1.06E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 65	7.63E+10	7.00E+10	4.54E+10	2.71E+10	9.60E+09	3.40E+09	2.41E+06	0.00E+00
Zn 72	1.30E+12	2.53E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 67	2.40E+11	3.82E+08	3.33E-06	4.62E-23	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 68	5.65E+11	1.12E+10	7.60E+09	4.76E+09	1.87E+09	7.35E+08	1.06E+06	0.00E+00
Ga 72	3.20E+12	3.63E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 72m	1.30E+12	2.53E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 68	1.21E+10	1.12E+10	7.60E+09	4.76E+09	1.87E+09	7.34E+08	1.06E+06	0.00E+00
Ge 69	1.25E+11	3.07E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 71	1.05E+12	1.72E+11	1.68E+07	2.60E+02	6.25E-08	1.50E-17	0.00E+00	0.00E+00

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
Ge 71m	3.88E+09	1.71E+06	2.38E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 73m	3.53E+12	5.08E+11	1.36E+11	2.82E+10	1.20E+09	5.15E+07	1.34E-02	0.00E+00
As 71	9.82E+10	4.33E+07	6.03E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 72	2.52E+11	1.33E+09	4.63E+03	1.32E-03	1.08E-16	0.00E+00	0.00E+00	0.00E+00
As 73	6.59E+11	5.08E+11	1.36E+11	2.82E+10	1.20E+09	5.15E+07	1.34E-02	0.00E+00
As 74	1.52E+12	4.65E+11	1.22E+09	9.86E+05	6.40E-01	4.16E-07	0.00E+00	0.00E+00
As 75m	1.98E+11	1.66E+11	6.89E+10	2.40E+10	2.89E+09	3.50E+08	1.31E+02	0.00E+00
As 76	2.96E+12	1.01E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 77	5.73E+12	1.44E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 72	1.42E+10	1.16E+09	4.04E+03	1.15E-03	9.37E-17	0.00E+00	0.00E+00	0.00E+00
Se 75	3.97E+11	3.33E+11	1.38E+11	4.79E+10	5.79E+09	7.00E+08	2.63E+02	0.00E+00
Se 77m	1.83E+10	4.61E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 79	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06
Br 77	6.99E+11	1.01E+08	5.15E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 82	4.88E+12	3.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 79	4.47E+11	2.51E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 81	2.77E+06	2.77E+06	2.77E+06	2.77E+06	2.77E+06	2.77E+06	2.77E+06	2.77E+06
Kr 83m	7.93E+12	9.70E+11	2.85E+11	6.57E+10	3.48E+09	1.85E+08	2.17E-01	0.00E+00
Kr 85	1.25E+11	1.24E+11	1.21E+11	1.17E+11	1.10E+11	1.03E+11	6.56E+10	1.99E+08
Rb 82	8.84E+11	2.86E+10	4.59E+08	3.23E+06	1.61E+02	8.00E-03	0.00E+00	0.00E+00
Rb 83	1.66E+12	1.30E+12	3.83E+11	8.82E+10	4.68E+09	2.48E+08	2.92E-01	0.00E+00
Rb 83m	1.07E+11	1.87E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 84	3.55E+12	1.87E+12	7.46E+10	1.57E+09	6.92E+05	3.05E+02	0.00E+00	0.00E+00
Rb 86	7.57E+12	2.45E+12	8.48E+09	9.47E+06	1.19E+01	1.49E-05	0.00E+00	0.00E+00
Rb 87	5.52E+01	5.52E+01	5.52E+01	5.52E+01	5.52E+01	5.52E+01	5.52E+01	5.52E+01
Sr 82	6.51E+10	2.86E+10	4.59E+08	3.23E+06	1.61E+02	8.00E-03	0.00E+00	0.00E+00
Sr 83	2.14E+11	3.73E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 85	1.49E+12	1.08E+12	2.12E+11	3.01E+10	6.07E+08	1.22E+07	1.65E-05	0.00E+00
Sr 89	9.14E+12	6.03E+12	7.47E+11	6.10E+10	4.07E+08	2.71E+06	1.59E-09	0.00E+00
Sr 90	7.44E+10	7.43E+10	7.35E+10	7.27E+10	7.09E+10	6.93E+10	5.85E+10	6.73E+09
Y 87	1.85E+12	3.36E+09	5.47E-05	1.60E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 88	2.15E+12	1.81E+12	7.44E+11	2.46E+11	2.51E+10	2.45E+09	1.55E+02	0.00E+00
Y 89m	1.27E+12	2.66E+09	7.47E+07	6.10E+06	4.07E+04	2.71E+02	1.59E-13	0.00E+00
Y 90	7.30E+12	7.71E+10	7.36E+10	7.27E+10	7.10E+10	6.93E+10	5.85E+10	6.73E+09
Y 91	1.10E+13	7.69E+12	1.27E+12	1.45E+11	1.92E+09	2.54E+07	1.78E-06	0.00E+00
Zr 88	2.83E+11	2.20E+11	6.21E+10	1.36E+10	6.54E+08	3.14E+07	1.86E-02	0.00E+00
Zr 89	1.27E+12	2.06E+09	1.90E-05	2.84E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 93	2.49E+06	2.50E+06	2.50E+06	2.50E+06	2.50E+06	2.50E+06	2.50E+06	2.50E+06
Zr 95	6.91E+12	4.97E+12	9.56E+11	1.32E+11	2.54E+09	4.86E+07	4.62E-05	0.00E+00
Nb 91	4.44E+08	4.44E+08	4.43E+08	4.43E+08	4.43E+08	4.42E+08	4.39E+08	4.01E+08
Nb 91m	4.95E+06	3.50E+06	6.18E+05	7.72E+04	1.21E+03	1.88E+01	4.24E-12	0.00E+00
Nb 92	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04
Nb 93m	4.08E+05	5.63E+05	1.34E+06	2.24E+06	4.00E+06	5.68E+06	1.56E+07	4.29E+07
Nb 94	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.11E+07
Nb 95	1.33E+13	9.89E+12	2.05E+12	2.90E+11	5.77E+09	1.11E+08	1.02E-04	0.00E+00
Nb 95m	7.64E+10	5.95E+10	1.14E+10	1.58E+09	3.04E+07	5.82E+05	5.53E-07	0.00E+00
Nb 96	8.25E+12	3.44E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 93	4.73E+07	4.73E+07	4.73E+07	4.73E+07	4.72E+07	4.72E+07	4.72E+07	4.64E+07
Mo 99	1.18E+13	5.62E+09	1.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 95	5.15E+11	9.95E+06	1.76E+06	2.21E+05	3.49E+03	5.50E+01	1.33E-11	0.00E+00
Tc 95m	3.57E+08	2.53E+08	4.48E+07	5.63E+06	8.87E+04	1.40E+03	3.37E-10	0.00E+00
Tc 96	1.17E+12	8.66E+09	1.68E-01	2.40E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 97	2.95E+05	2.96E+05	2.96E+05	2.96E+05	2.96E+05	2.96E+05	2.96E+05	2.96E+05
Tc 97m	7.98E+07	6.64E+07	2.06E+07	5.05E+06	3.04E+05	1.83E+04	5.25E-05	0.00E+00
Tc 98	2.32E+05	2.32E+05	2.32E+05	2.32E+05	2.32E+05	2.32E+05	2.32E+05	2.32E+05
Tc 99	2.08E+07	2.13E+07	2.13E+07	2.13E+07	2.13E+07	2.13E+07	2.13E+07	2.13E+07
Tc 99m	1.03E+13	5.42E+09	1.11E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 97	3.02E+11	2.15E+08	3.33E-08	4.67E-27	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru103	1.26E+13	7.39E+12	5.02E+11	2.00E+10	3.16E+07	5.00E+04	1.24E-15	0.00E+00
Ru106	1.21E+12	1.15E+12	8.66E+11	6.17E+11	3.13E+11	1.59E+11	1.38E+09	0.00E+00
Rh 99	1.61E+11	4.36E+10	6.21E+07	2.39E+04	3.54E-03	5.25E-10	0.00E+00	0.00E+00
Rh100	4.54E+11	9.49E+07	2.22E-05	1.59E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh101	9.46E+10	9.30E+10	8.52E+10	7.67E+10	6.22E+10	5.04E+10	1.16E+10	7.14E+01
Rh101m	9.35E+10	8.04E+08	2.19E-02	4.71E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh102	7.31E+11	6.60E+11	3.95E+11	2.14E+11	6.26E+10	1.83E+10	3.36E+06	0.00E+00
Rh103m	1.29E+13	7.43E+12	4.97E+11	1.98E+10	3.13E+07	4.95E+04	1.23E-15	0.00E+00
Rh105	1.39E+13	9.49E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh106	7.11E+12	1.15E+12	8.66E+11	6.17E+11	3.13E+11	1.59E+11	1.38E+09	0.00E+00
Pd100	2.36E+10	7.22E+07	1.69E-05	1.21E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
Pd103	7.96E+11	2.31E+11	4.63E+08	2.69E+05	9.09E-02	3.07E-08	0.00E+00	0.00E+00
Pd107	5.07E+05	5.07E+05	5.07E+05	5.07E+05	5.07E+05	5.07E+05	5.07E+05	5.07E+05
Pd112	2.50E+12	9.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag105	4.33E+11	2.60E+11	2.02E+10	9.41E+08	2.05E+06	4.45E+03	1.02E-15	0.00E+00
Ag109m	8.57E+12	2.15E+11	1.71E+11	1.30E+11	7.52E+10	4.35E+10	9.44E+08	3.83E-13
Ag111	8.81E+12	5.25E+11	3.68E+05	1.54E-02	2.68E-17	0.00E+00	0.00E+00	0.00E+00
Ag112	6.19E+12	1.13E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd109	2.25E+11	2.15E+11	1.71E+11	1.30E+11	7.52E+10	4.35E+10	9.44E+08	3.83E-13
Cd111m	1.20E+10	5.30E+04	2.38E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd113m	1.30E+09	1.30E+09	1.27E+09	1.24E+09	1.18E+09	1.13E+09	7.99E+08	9.57E+06
Cd115	3.88E+12	3.11E+08	8.12E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd115m	5.99E+10	3.74E+10	3.51E+09	2.05E+08	7.03E+05	2.41E+03	1.33E-14	0.00E+00
In111	9.38E+11	5.23E+08	2.35E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In113m	2.82E+11	2.35E+11	9.38E+10	3.12E+10	3.46E+09	3.84E+08	7.88E+01	0.00E+00
In115m	3.88E+12	3.42E+08	2.47E+05	1.44E+04	4.94E+01	1.69E-01	9.37E-19	0.00E+00
Sn113	2.82E+11	2.35E+11	9.37E+10	3.12E+10	3.46E+09	3.83E+08	7.87E+01	0.00E+00
Sn117m	5.49E+11	1.18E+11	5.02E+07	4.55E+03	3.75E-05	3.08E-13	0.00E+00	0.00E+00
Sn119m	7.07E+11	6.66E+11	4.64E+11	3.01E+11	1.27E+11	5.36E+10	1.27E+08	0.00E+00
Sn121	1.65E+12	1.81E+08	1.80E+08	1.79E+08	1.76E+08	1.74E+08	1.59E+08	5.13E+07
Sn121m	2.33E+08	2.33E+08	2.32E+08	2.30E+08	2.27E+08	2.24E+08	2.05E+08	6.61E+07
Sn123	1.72E+11	1.46E+11	6.45E+10	2.42E+10	3.41E+09	4.81E+08	5.31E+02	0.00E+00
Sn125	1.31E+11	1.49E+10	2.60E+05	5.16E-01	2.03E-12	7.96E-24	0.00E+00	0.00E+00
Sn126	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04
Sb118	1.53E+12	9.95E+09	2.27E+02	1.56E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb119	2.61E+12	1.16E+07	1.07E-03	2.15E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb122	1.43E+12	6.40E+08	9.39E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb124	5.15E+11	3.64E+11	6.29E+10	7.69E+09	1.15E+08	1.71E+06	2.80E-07	0.00E+00
Sb125	5.22E+10	5.22E+10	4.71E+10	4.16E+10	3.23E+10	2.52E+10	4.33E+09	6.51E-01
Sb126	1.91E+11	3.54E+10	7.41E+06	5.05E+03	4.76E+03	4.76E+03	4.76E+03	4.76E+03
Sb126m	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04	3.40E+04
Sb126n	2.37E+04	2.37E+04	2.37E+04	2.37E+04	2.37E+04	2.37E+04	2.37E+04	2.37E+04
Sb127	1.24E+11	5.29E+08	6.52E-04	3.43E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te118	3.30E+11	9.94E+09	2.27E+02	1.56E-07	7.33E-26	0.00E+00	0.00E+00	0.00E+00
Te119	5.61E+11	3.76E+02	6.60E-08	1.33E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te119m	3.52E+08	4.03E+06	7.08E-04	1.42E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te121	1.35E+12	4.99E+11	3.54E+10	1.48E+10	2.85E+09	5.51E+08	5.54E+03	0.00E+00
Te121m	7.52E+10	6.57E+10	3.31E+10	1.46E+10	2.81E+09	5.43E+08	5.46E+03	0.00E+00
Te125m	4.32E+11	4.97E+11	2.49E+11	5.91E+10	9.12E+09	6.18E+09	1.06E+09	1.59E-01
Te127	4.74E+11	9.97E+09	3.60E+09	1.13E+09	1.11E+08	1.08E+07	9.41E-01	0.00E+00
Te127m	1.10E+10	9.68E+09	3.68E+09	1.15E+09	1.13E+08	1.11E+07	9.60E-01	0.00E+00
Te129	1.10E+11	1.27E+09	5.48E+07	1.27E+06	6.76E+02	3.61E-01	0.00E+00	0.00E+00
Te129m	3.73E+09	2.01E+09	8.68E+07	2.01E+06	1.07E+03	5.72E-01	0.00E+00	0.00E+00
Te131	9.36E+09	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te131m	8.79E+07	4.46E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te132	5.32E+09	7.57E+06	3.71E-08	2.58E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I122	6.08E+11	1.23E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I124	9.64E+11	6.29E+09	6.59E-02	4.51E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I125	1.51E+12	1.07E+12	1.80E+11	2.14E+10	3.02E+08	4.26E+06	4.72E-07	0.00E+00
I126	1.05E+12	2.11E+11	6.70E+07	4.29E+03	1.76E-05	7.23E-14	0.00E+00	0.00E+00
I129	9.20E+03	9.21E+03	9.22E+03	9.22E+03	9.22E+03	9.22E+03	9.22E+03	9.22E+03
I131	1.52E+11	1.10E+10	2.12E+04	2.97E-03	5.80E-17	0.00E+00	0.00E+00	0.00E+00
I132	4.13E+10	7.81E+06	3.82E-08	2.83E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe122	9.63E+10	1.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe127	1.20E+12	6.73E+11	3.70E+10	1.14E+09	1.09E+06	1.04E+03	7.45E-19	0.00E+00
Xe129m	1.04E+12	1.15E+11	7.88E+05	5.08E-01	2.11E-13	8.77E-26	0.00E+00	0.00E+00
Xe131m	1.77E+09	6.60E+08	1.24E+05	2.84E+00	1.47E-09	7.59E-19	0.00E+00	0.00E+00
Xe133	1.22E+11	2.34E+09	4.20E+00	1.37E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe133m	8.01E+08	9.02E+04	1.04E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs128	6.53E+11	2.79E+07	3.78E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs129	1.02E+12	1.54E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs131	1.45E+12	3.64E+11	6.44E+07	1.15E+03	3.20E-07	8.80E-17	0.00E+00	0.00E+00
Cs132	5.39E+11	2.10E+10	1.76E+03	5.77E-06	6.17E-23	0.00E+00	0.00E+00	0.00E+00
Cs134	2.61E+10	2.54E+10	2.21E+10	1.87E+10	1.34E+10	9.55E+09	9.11E+08	6.88E-05
Cs135	2.01E+04	2.01E+04	2.01E+04	2.01E+04	2.01E+04	2.01E+04	2.01E+04	2.01E+04
Cs136	4.84E+10	9.80E+09	3.22E+06	2.14E+02	9.44E-07	4.17E-15	0.00E+00	0.00E+00
Cs137	2.84E+08	2.83E+08	2.80E+08	2.77E+08	2.71E+08	2.65E+08	2.25E+08	2.83E+07
Ba128	1.59E+11	2.79E+07	3.78E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba131	6.67E+11	1.07E+11	1.11E+07	1.84E+02	5.04E-08	1.39E-17	0.00E+00	0.00E+00
Ba133	2.39E+10	2.38E+10	2.32E+10	2.24E+10	2.10E+10	1.97E+10	1.24E+10	3.28E+07

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
Ba135m	1.01E+04	1.01E+04	1.01E+04	1.01E+04	1.01E+04	1.01E+04	1.01E+04	1.01E+04
Ba136m	5.33E+09	1.08E+09	3.54E+05	2.35E+01	1.04E-07	4.59E-16	0.00E+00	0.00E+00
Ba137m	2.68E+08	2.67E+08	2.65E+08	2.62E+08	2.56E+08	2.50E+08	2.13E+08	2.67E+07
Ba140	1.42E+10	2.73E+09	6.92E+05	3.38E+01	8.07E-08	1.92E-16	0.00E+00	0.00E+00
La134	6.79E+11	2.99E+08	9.25E-07	3.02E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La135	9.89E+11	2.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La137	4.41E+06	4.42E+06	4.42E+06	4.42E+06	4.42E+06	4.42E+06	4.42E+06	4.42E+06
La140	8.08E+10	3.14E+09	7.97E+05	3.89E+01	9.29E-08	2.22E-16	0.00E+00	0.00E+00
Ce134	2.30E+11	2.98E+08	9.23E-07	3.70E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce139	4.48E+11	3.85E+11	1.79E+11	7.13E+10	1.13E+10	1.80E+09	4.61E+03	0.00E+00
Ce141	1.75E+11	9.20E+10	3.57E+09	7.27E+07	3.01E+04	1.25E+01	0.00E+00	0.00E+00
Ce143	4.91E+10	1.15E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce144	5.48E+09	5.09E+09	3.52E+09	2.26E+09	9.27E+08	3.81E+08	7.58E+05	0.00E+00
Pr140	6.62E+11	5.96E+08	1.48E-05	7.19E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr143	2.32E+11	5.06E+10	2.11E+07	1.88E+03	1.48E-05	1.17E-13	0.00E+00	0.00E+00
Pr144	9.88E+10	5.09E+09	3.52E+09	2.26E+09	9.27E+08	3.81E+08	7.58E+05	0.00E+00
Pr144m	5.37E+07	4.99E+07	3.45E+07	2.21E+07	9.09E+06	3.74E+06	7.43E+03	0.00E+00
Nd140	3.04E+11	5.95E+08	1.48E-05	7.18E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd147	6.08E+10	8.97E+09	5.99E+05	5.89E+00	5.71E-10	5.53E-20	0.00E+00	0.00E+00
Pm143	7.09E+10	6.55E+10	4.40E+10	2.73E+10	1.05E+10	4.04E+09	5.02E+06	0.00E+00
Pm144	2.90E+10	2.74E+10	2.05E+10	1.44E+10	7.19E+09	3.58E+09	2.71E+07	0.00E+00
Pm145	2.54E+09	2.63E+09	3.00E+09	3.29E+09	3.57E+09	3.62E+09	2.89E+09	8.52E+07
Pm146	5.97E+09	5.91E+09	5.61E+09	5.27E+09	4.65E+09	4.10E+09	1.71E+09	2.15E+04
Pm147	1.49E+10	1.52E+10	1.37E+10	1.20E+10	9.22E+09	7.08E+09	1.11E+09	5.24E-02
Pm148	6.32E+10	1.26E+09	3.66E+00	2.12E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm149	5.68E+10	4.29E+06	7.97E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm151	1.24E+10	2.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm145	3.06E+10	2.94E+10	2.16E+10	1.49E+10	7.07E+09	3.36E+09	1.83E+07	0.00E+00
Sm146	4.07E+02	4.18E+02	4.32E+02	4.39E+02	4.51E+02	4.61E+02	5.04E+02	5.35E+02
Sm151	1.22E+08	1.23E+08	1.22E+08	1.22E+08	1.21E+08	1.20E+08	1.14E+08	5.68E+07
Sm153	1.36E+10	2.52E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu145	4.00E+10	1.16E+09	2.15E+01	1.15E-08	3.43E-27	0.00E+00	0.00E+00	0.00E+00
Eu146	5.18E+10	7.53E+09	7.97E+08	5.79E+07	3.05E+05	1.61E+03	1.83E-13	0.00E+00
Eu147	8.47E+10	3.60E+10	4.50E+08	2.36E+06	6.46E+01	1.77E-03	0.00E+00	0.00E+00
Eu148	4.95E+10	3.37E+10	4.85E+09	4.76E+08	4.57E+06	4.39E+04	3.31E-10	0.00E+00
Eu149	8.00E+10	6.74E+10	2.19E+10	5.61E+09	3.70E+08	2.44E+07	1.32E-01	0.00E+00
Eu150	4.75E+08	4.74E+08	4.70E+08	4.66E+08	4.57E+08	4.49E+08	3.93E+08	7.25E+07
Eu152	8.20E+08	8.16E+08	7.99E+08	7.79E+08	7.40E+08	7.03E+08	4.91E+08	4.90E+06
Eu154	5.54E+08	5.50E+08	5.32E+08	5.11E+08	4.71E+08	4.35E+08	2.47E+08	1.74E+05
Eu155	1.11E+09	1.09E+09	1.03E+09	9.56E+08	8.27E+08	7.15E+08	2.58E+08	5.26E+02
Eu156	9.99E+09	2.52E+09	2.42E+06	5.81E+02	3.35E-05	1.94E-12	0.00E+00	0.00E+00
Gd146	9.93E+09	6.42E+09	7.21E+08	5.24E+07	2.76E+05	1.46E+03	1.65E-13	0.00E+00
Gd147	1.95E+10	3.45E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd148	1.21E+08	1.21E+08	1.20E+08	1.20E+08	1.18E+08	1.17E+08	1.10E+08	4.77E+07
Gd149	4.70E+10	4.90E+09	5.61E+04	6.69E-02	9.48E-14	1.34E-25	0.00E+00	0.00E+00
Gd150	1.27E+04	1.27E+04	1.27E+04	1.27E+04	1.27E+04	1.27E+04	1.27E+04	1.27E+04
Gd151	4.69E+10	3.98E+10	1.70E+10	6.11E+09	7.93E+08	1.03E+08	6.39E+01	0.00E+00
Gd153	3.88E+10	3.63E+10	2.34E+10	1.38E+10	4.82E+09	1.68E+09	1.06E+06	0.00E+00
Tb153	7.68E+10	1.01E+07	2.57E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb154	3.85E+10	2.58E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb155	1.06E+11	2.14E+09	5.14E+00	2.38E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb156	3.96E+10	7.80E+08	2.10E+00	1.11E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb157	4.35E+08	4.35E+08	4.34E+08	4.32E+08	4.27E+08	4.23E+08	3.95E+08	1.64E+08
Tb158	2.68E+07	2.68E+07	2.68E+07	2.67E+07	2.66E+07	2.65E+07	2.58E+07	1.83E+07
Tb160	6.96E+09	5.21E+09	1.21E+09	2.10E+08	6.33E+06	1.91E+05	4.32E-06	0.00E+00
Tb161	1.00E+10	4.74E+08	1.03E+02	1.05E-06	1.09E-22	0.00E+00	0.00E+00	0.00E+00
Dy154	3.22E+03	3.22E+03	3.22E+03	3.22E+03	3.22E+03	3.22E+03	3.22E+03	3.22E+03
Dy159	5.41E+10	4.68E+10	2.25E+10	9.37E+09	1.62E+09	2.81E+08	1.31E+03	0.00E+00
Dy166	1.18E+09	2.44E+06	7.99E-08	5.41E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H0160	8.39E+10	1.36E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H0160m	7.81E+10	2.06E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H0163	8.62E+06	8.63E+06	8.63E+06	8.63E+06	8.63E+06	8.63E+06	8.62E+06	8.50E+06
H0166	6.50E+09	3.64E+06	1.19E-07	8.07E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er160	7.81E+10	1.70E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er165	2.53E+11	1.91E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er167m	3.85E+11	3.98E+10	4.40E+05	5.02E-01	6.51E-13	0.00E+00	0.00E+00	0.00E+00
Er169	2.95E+09	3.16E+08	4.18E+03	5.93E-03	1.19E-14	2.38E-26	0.00E+00	0.00E+00
Er172	1.18E+09	4.26E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm165	2.40E+11	1.25E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
Tm166	3.27E+11	4.84E+07	1.90E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm166m	3.05E+11	4.19E+07	1.64E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm167	3.91E+11	4.05E+10	4.48E+05	5.10E-01	6.62E-13	8.59E-25	0.00E+00	0.00E+00
Tm168	7.44E+09	5.94E+09	1.91E+09	4.90E+08	3.23E+07	2.13E+06	1.15E-02	0.00E+00
Tm170	4.00E+09	3.40E+09	1.49E+09	5.58E+08	7.80E+07	1.09E+07	1.13E+01	0.00E+00
Tm171	6.78E+08	6.59E+08	5.66E+08	4.73E+08	3.30E+08	2.30E+08	1.84E+07	1.42E-07
Tm172	2.36E+09	2.17E+06	1.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb166	3.05E+11	4.19E+07	1.64E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb169	6.26E+11	3.40E+11	1.26E+10	2.42E+08	8.91E+04	3.28E+01	0.00E+00	0.00E+00
Yb169m	8.61E+10	3.21E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb171m	1.08E+12	8.99E+10	2.45E+05	5.22E-02	2.37E-15	0.00E+00	0.00E+00	0.00E+00
Yb175	4.73E+09	3.12E+07	3.46E-04	2.52E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu169	6.29E+11	2.34E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu170	8.80E+11	3.79E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu171	1.17E+12	9.69E+10	2.64E+05	5.62E-02	2.55E-15	0.00E+00	0.00E+00	0.00E+00
Lu172	1.86E+11	1.81E+11	1.54E+11	1.28E+11	8.82E+10	6.09E+10	4.55E+09	1.49E-05
Lu172m	1.85E+11	1.79E+11	1.54E+11	1.28E+11	8.82E+10	6.09E+10	4.55E+09	1.48E-05
Lu173	3.02E+11	2.94E+11	2.38E+11	1.85E+11	1.11E+11	6.72E+10	1.95E+09	3.26E-11
Lu174	4.84E+08	4.76E+08	4.36E+08	3.92E+08	3.18E+08	2.58E+08	5.96E+07	3.89E-01
Lu177	2.36E+09	1.04E+08	1.62E+01	1.11E-07	5.21E-24	0.00E+00	0.00E+00	0.00E+00
Hf172	1.85E+11	1.79E+11	1.54E+11	1.28E+11	8.82E+10	6.09E+10	4.55E+09	1.48E-05
Hf173	1.85E+12	1.12E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf175	2.29E+12	1.71E+12	3.79E+11	6.21E+10	1.67E+09	4.48E+07	4.53E-04	0.00E+00
Hf181	1.02E+09	6.23E+08	5.16E+07	2.60E+06	6.64E+03	1.69E+01	1.18E-17	0.00E+00
Ta177	5.14E+12	7.22E+08	2.53E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta178	6.72E+12	2.53E+12	1.91E+10	5.45E+07	4.43E+02	3.60E-03	0.00E+00	0.00E+00
Ta179	9.98E+11	9.68E+11	8.26E+11	6.82E+11	4.66E+11	3.19E+11	2.22E+10	2.88E-05
Ta182	2.18E+09	1.81E+09	7.20E+08	2.38E+08	2.61E+07	2.85E+06	5.36E-01	0.00E+00
Ta183	2.36E+09	3.83E+07	3.92E-02	2.73E-06	2.73E-06	2.73E-06	2.73E-06	2.73E-06
W178	6.70E+12	2.53E+12	1.91E+10	5.45E+07	4.43E+02	3.60E-03	0.00E+00	0.00E+00
W181	6.81E+12	5.80E+12	2.43E+12	8.55E+11	1.06E+11	1.31E+10	5.85E+03	0.00E+00
W183m	6.62E+12	4.95E+12	1.10E+12	1.80E+11	4.83E+09	1.30E+08	1.31E-03	1.36E-07
W185	2.37E+10	1.79E+10	4.39E+09	8.13E+08	2.79E+07	9.60E+05	5.41E-05	0.00E+00
W187	4.83E+11	2.82E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W188	8.35E+08	6.17E+08	1.35E+08	2.17E+07	5.66E+05	1.47E+04	1.20E-07	0.00E+00
Re181	1.31E+13	1.36E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re182	1.19E+11	4.51E+07	2.89E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re182m	1.63E+13	4.75E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re183	1.32E+13	9.91E+12	2.19E+12	3.59E+11	9.66E+09	2.60E+08	2.62E-03	0.00E+00
Re184	2.11E+10	1.21E+10	7.54E+08	2.70E+07	3.43E+04	4.38E+01	2.44E-19	0.00E+00
Re186	3.55E+09	1.25E+07	5.82E-06	9.54E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re187	2.70E+00	2.73E+00	2.73E+00	2.73E+00	2.73E+00	2.73E+00	2.73E+00	2.73E+00
Re188	2.02E+09	6.23E+08	1.36E+08	2.20E+07	5.72E+05	1.49E+04	1.21E-07	0.00E+00
Os182	1.63E+13	2.02E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os185	1.66E+13	1.34E+13	4.34E+12	1.12E+12	7.51E+10	5.02E+09	3.01E+01	0.00E+00
Os189m	4.54E+12	9.73E+11	3.27E+08	2.24E+04	1.05E-04	4.90E-13	0.00E+00	0.00E+00
Os191	2.95E+09	7.53E+08	7.99E+05	2.15E+02	1.56E-05	1.13E-12	0.00E+00	0.00E+00
Os193	3.55E+09	2.34E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir188	5.55E+13	8.29E+12	2.65E+08	1.08E+03	1.79E-08	2.98E-19	0.00E+00	0.00E+00
Ir189	6.07E+13	1.28E+13	4.30E+09	2.94E+05	1.38E-03	6.45E-12	0.00E+00	0.00E+00
Ir190	1.24E+11	2.08E+10	2.67E+06	5.75E+01	2.67E-08	1.24E-17	0.00E+00	0.00E+00
Ir191m	2.95E+09	7.53E+08	7.99E+05	2.15E+02	1.56E-05	1.13E-12	0.00E+00	0.00E+00
Ir192	2.67E+10	2.01E+10	4.80E+09	8.65E+08	2.80E+07	9.09E+05	3.42E-05	0.00E+00
Ir193m	1.16E+07	1.78E+06	7.88E+01	4.74E-04	1.71E-14	6.20E-25	0.00E+00	0.00E+00
Pt188	5.40E+13	6.88E+12	2.20E+08	8.97E+02	1.49E-08	2.48E-19	0.00E+00	0.00E+00
Pt190	2.85E+01	2.86E+01	2.86E+01	2.86E+01	2.86E+01	2.86E+01	2.86E+01	2.86E+01
Pt191	9.19E+13	5.41E+10	2.34E-06	5.56E-26	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt193	6.60E+11	6.66E+11	6.62E+11	6.57E+11	6.48E+11	6.39E+11	5.80E+11	1.67E+11
Pt193m	8.26E+07	7.30E+05	1.88E-05	3.78E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt202	5.32E+09	5.60E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au193	1.37E+14	6.90E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au194	3.51E+12	9.35E+10	9.34E+10	9.33E+10	9.32E+10	9.30E+10	9.20E+10	7.99E+10
Au195	7.35E+13	6.60E+13	3.75E+13	1.90E+13	4.87E+12	1.25E+12	9.13E+07	0.00E+00
Au196	1.92E+12	6.40E+10	2.46E+03	3.16E-06	5.20E-24	0.00E+00	0.00E+00	0.00E+00
Au198	1.15E+12	4.73E+08	4.60E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au199	1.06E+12	1.32E+09	3.26E-06	9.99E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au202	2.46E+11	5.60E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg194	9.35E+10	9.35E+10	9.34E+10	9.33E+10	9.32E+10	9.30E+10	9.20E+10	7.99E+10
Hg197	2.70E+14	1.09E+11	7.61E-07	2.53E-27	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Initial	**8.30E-02**	**5.00E-01**	**1.00E+00**	**2.00E+00**	**3.00E+00**	**1.00E+01**	**1.00E+02**
Hg203	3.96E+12	2.52E+12	2.62E+11	1.73E+10	7.58E+07	3.32E+05	1.02E-11	0.00E+00
Tl200	4.36E+14	8.76E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl201	4.88E+14	5.50E+11	4.45E-04	3.57E-22	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl202	7.18E+13	1.29E+13	4.57E+09	2.27E+09	2.27E+09	2.27E+09	2.27E+09	2.26E+09
Tl204	3.25E+12	3.20E+12	2.96E+12	2.70E+12	2.25E+12	1.87E+12	5.19E+11	3.53E+04
Tl206	4.94E+13	5.71E+06	4.08E-03	4.40E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb200	3.70E+14	2.43E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb202	2.29E+09	2.29E+09	2.29E+09	2.29E+09	2.29E+09	2.29E+09	2.29E+09	2.29E+09
Pb203	5.84E+14	4.01E+10	2.45E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb205	1.31E+07	1.40E+07	1.42E+07	1.42E+07	1.42E+07	1.42E+07	1.42E+07	1.43E+07
Pb205m	4.03E+14	1.02E+14	1.04E+11	2.67E+07	1.76E+00	1.16E-07	0.00E+00	0.00E+00
Pb207m	4.37E+12	4.34E+12	4.30E+12	4.26E+12	4.16E+12	4.07E+12	3.49E+12	4.84E+11
Bi205	4.03E+14	1.02E+14	1.04E+11	2.67E+07	1.76E+00	1.16E-07	0.00E+00	0.00E+00
Bi206	4.30E+14	2.62E+13	1.13E+08	6.35E+01	2.03E-11	6.51E-24	0.00E+00	0.00E+00
Bi207	4.35E+12	4.34E+12	4.30E+12	4.26E+12	4.16E+12	4.07E+12	3.49E+12	4.84E+11
Bi208	6.91E+08	6.91E+08	6.91E+08	6.91E+08	6.91E+08	6.91E+08	6.91E+08	6.91E+08
Bi210	2.86E+14	4.33E+12	3.09E+03	3.33E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po206	6.09E+13	5.60E+12	3.45E+07	1.95E+01	6.25E-12	2.00E-24	0.00E+00	0.00E+00
Po208	2.77E+12	2.71E+12	2.45E+12	2.18E+12	1.71E+12	1.35E+12	2.53E+11	1.13E+02
Po209	1.38E+10	1.38E+10	1.37E+10	1.37E+10	1.36E+10	1.35E+10	1.29E+10	6.99E+09
Po210	1.26E+14	1.17E+14	5.47E+13	2.19E+13	3.52E+12	5.65E+11	1.55E+06	0.00E+00
0total	**1.33E+16**	**6.04E+14**	**1.41E+14**	**7.10E+13**	**3.15E+13**	**2.24E+13**	**1.35E+13**	**1.35E+12**

Annex B. MCNPX results

Total activity decay of the target lower part (without LBE)

Table B1. Radionuclide inventory of the target lower part (without LBE) : decay following 123 days of irradiation at 0.947 mA (2.79582 A·h). Calculations performed with MCNPX 2.5.0 and CINDER90. Activities in Bq. Number of proton histories: 600000.

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
H	3	7.62e+09	7.58e+09	7.41e+09	7.20e+09	6.81e+09	6.43e+09	4.34e+09	2.76e+07
He	6	1.83e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Li	8	1.88e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Be	10	2.05e-08	2.05e-08	2.05e-08	2.05e-08	2.05e-08	2.05e-08	2.05e-08	2.05e-08
Be	11	1.92e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
C	14	9.95e-02	9.95e-02	9.95e-02	9.95e-02	9.95e-02	9.95e-02	9.94e-02	9.83e-02
C	15	1.46e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
N	16	1.24e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
N	17	8.16e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
N	18	8.49e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
O	19	4.87e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
O	20	2.45e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
O	21	2.43e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	17	9.25e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	18	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	20	6.22e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	21	1.04e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	22	3.23e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	23	1.05e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	19	1.59e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	23	4.27e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	24	6.51e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	25	3.14e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	21	1.20e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	22	1.68e+09	1.64e+09	1.47e+09	1.29e+09	9.85e+08	7.55e+08	1.17e+08	4.53e-03
Na	24	1.31e+10	1.51e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	24*	8.86e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	25	5.54e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	26	2.53e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	28	6.56e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	23	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	27	1.58e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	28	1.79e+07	6.01e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	29	2.05e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	25	1.17e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	26	1.08e+04	1.08e+04	1.08e+04	1.08e+04	1.08e+04	1.08e+04	1.08e+04	1.08e+04
Al	26*	1.05e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	28	3.37e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	29	4.95e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	30	1.09e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	31	1.79e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	32	1.02e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	27	3.08e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	31	1.31e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	32	1.74e+02	1.74e+02	1.73e+02	1.73e+02	1.72e+02	1.72e+02	1.67e+02	1.16e+02
Si	33	1.14e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	34	7.77e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	35	3.68e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	29	1.08e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	30	3.04e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	32	3.21e+11	7.36e+10	4.48e+07	6.43e+03	1.72e+02	1.72e+02	1.67e+02	1.16e+02
P	33	3.39e+07	1.48e+07	2.32e+05	1.59e+03	7.47e-02	3.50e-06	1.76e-36	0.00e+00
P	34	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	35	9.35e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	36	1.06e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	31	8.36e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	35	3.68e+10	2.89e+10	8.66e+09	2.04e+09	1.13e+08	6.25e+06	1.00e-02	0.00e+00
S	37	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	38	1.07e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	39	1.18e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	40	2.37e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	41	3.45e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	33	4.40e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	34	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	34*	9.53e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Cl	36	1.91e+05	1.91e+05	1.91e+05	1.91e+05	1.91e+05	1.91e+05	1.91e+05	1.91e+05
Cl	38	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	38*	1.26e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	39	1.56e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	40	4.24e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	41	3.97e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	42	5.63e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	35	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	37	4.72e+11	2.59e+11	1.27e+10	3.44e+08	2.50e+05	1.82e+02	0.00e+00	0.00e+00
Ar	39	1.51e+08	1.51e+08	1.51e+08	1.51e+08	1.51e+08	1.50e+08	1.48e+08	1.17e+08
Ar	41	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	42	6.96e+07	6.95e+07	6.89e+07	6.82e+07	6.68e+07	6.54e+07	5.64e+07	8.47e+06
Ar	43	7.64e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	44	1.15e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	45	3.90e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	46	8.62e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	37	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	38	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	38*	4.54e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	40	1.40e+02	1.40e+02	1.40e+02	1.40e+02	1.40e+02	1.40e+02	1.40e+02	1.40e+02
K	42	1.97e+11	6.95e+07	6.89e+07	6.82e+07	6.68e+07	6.54e+07	5.64e+07	8.47e+06
K	43	2.95e+10	4.03e+00	1.09e-49	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	44	2.09e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	45	8.39e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	46	5.92e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	47	1.06e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ca	39	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ca	41	2.43e+06	2.43e+06	2.43e+06	2.43e+06	2.43e+06	2.43e+06	2.43e+06	2.43e+06
Ca	45	6.40e+10	5.63e+10	2.95e+10	1.36e+10	2.91e+09	6.20e+08	1.24e+04	0.00e+00
Ca	47	3.24e+06	3.16e+04	2.46e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ca	49	9.55e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	41	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	42	2.95e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	42*	1.23e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	43	1.58e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	44	1.69e+12	2.03e+09	2.02e+09	2.01e+09	1.98e+09	1.95e+09	1.76e+09	4.70e+08
Sc	44*	1.89e+06	3.46e+02	5.81e-17	1.79e-39	1.69e-84	0.00e+00	0.00e+00	0.00e+00
Sc	45*	7.28e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	46	4.17e+11	3.24e+11	9.20e+10	2.03e+10	9.91e+08	4.83e+07	3.17e-02	0.00e+00
Sc	46*	1.79e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	47	2.59e+11	4.85e+08	9.54e-06	3.51e-22	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	48	9.19e+10	8.95e+05	5.91e-20	3.80e-50	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	49	1.32e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	50	1.47e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	50*	8.53e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	43	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	44	2.04e+09	2.03e+09	2.02e+09	2.01e+09	1.98e+09	1.95e+09	1.76e+09	4.70e+08
Ti	45	1.63e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	51	9.93e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	52	1.24e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	53	8.31e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	45	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	46	3.94e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	47	1.86e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	48	4.32e+12	1.17e+12	1.58e+09	5.70e+05	7.47e-02	9.79e-09	0.00e+00	0.00e+00
V	49	1.71e+12	1.60e+12	1.17e+12	8.07e+11	3.82e+11	1.80e+11	9.53e+08	5.05e-21
V	50	7.08e-06	7.08e-06	7.08e-06	7.08e-06	7.08e-06	7.08e-06	7.08e-06	7.08e-06
V	52	3.00e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	53	2.00e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	54	2.25e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	48	5.02e+11	3.49e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	49	2.55e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	51	1.77e+14	8.30e+13	1.84e+12	1.90e+10	2.05e+06	2.20e+02	0.00e+00	0.00e+00
Cr	55	2.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	56	4.85e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	57	2.36e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	58	1.14e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	49	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	50	2.36e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	51	2.21e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	52	7.70e+12	1.80e+11	1.14e+03	1.68e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	52*	3.08e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	53	1.21e+06	1.21e+06	1.21e+06	1.21e+06	1.21e+06	1.21e+06	1.21e+06	1.21e+06
Mn	54	6.23e+12	5.82e+12	4.15e+12	2.77e+12	1.23e+12	5.46e+11	1.87e+09	0.00e+00
Mn	56	1.40e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	57	1.56e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	58	1.09e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	58*	2.37e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Mn	59	1.08e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	60	3.34e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	52	4.43e+11	1.51e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	52*	2.85e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	53	3.28e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	53*	2.38e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	55	2.51e+13	2.45e+13	2.21e+13	1.94e+13	1.51e+13	1.17e+13	1.98e+12	2.36e+02
Fe	59	5.28e+12	3.29e+12	3.07e+11	1.78e+10	6.04e+07	2.04e+05	1.03e-12	0.00e+00
Fe	60	3.59e+01	3.59e+01	3.59e+01	3.59e+01	3.59e+01	3.59e+01	3.59e+01	3.59e+01
Fe	61	4.11e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	62	2.05e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	63	1.30e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	54	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	54*	1.53e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	55	1.67e+11	5.46e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	56	1.95e+11	1.50e+11	3.93e+10	7.87e+09	3.16e+08	1.27e+07	2.15e-03	0.00e+00
Co	57	2.40e+10	2.24e+10	1.52e+10	9.52e+09	3.75e+09	1.48e+09	2.18e+06	8.55e-31
Co	58	1.17e+11	8.76e+10	1.98e+10	3.32e+09	9.34e+07	2.63e+06	3.69e-05	0.00e+00
Co	58*	1.26e+11	1.45e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	60	5.41e+11	5.35e+11	5.06e+11	4.74e+11	4.16e+11	3.64e+11	1.45e+11	1.05e+06
Co	60*	6.90e+12	0.00e+00	0.00e+00	3.59e+01	3.59e+01	3.59e+01	3.59e+01	3.59e+01
Co	61	1.71e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	62	4.38e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	62*	8.83e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	63	8.41e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	64	4.27e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	65	6.73e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	66	3.66e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	55	8.94e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	56	9.85e+09	3.14e+08	9.58e+00	9.31e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	57	3.20e+10	2.30e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	59	2.52e+07	2.52e+07	2.52e+07	2.52e+07	2.52e+07	2.52e+07	2.52e+07	2.51e+07
Ni	63	3.07e+09	3.07e+09	3.06e+09	3.05e+09	3.03e+09	3.01e+09	2.87e+09	1.54e+09
Ni	65	3.46e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	66	1.52e+03	1.48e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	67	7.83e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	68	6.80e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	61	1.00e+10	5.53e-55	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	62	7.01e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	64	6.88e+12	3.93e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	66	1.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	67	4.98e+05	1.44e+02	2.34e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	67*	4.30e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	68	2.49e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	68*	1.63e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	69	4.29e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	70	1.02e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	70*	1.44e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	62	7.12e+04	1.60e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	63	2.56e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	65	3.11e+09	2.85e+09	1.85e+09	1.10e+09	3.89e+08	1.38e+08	9.64e+04	0.00e+00
Zn	69	3.09e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	69*	2.26e+07	2.74e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	71	7.58e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	71*	8.17e+04	2.11e-51	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	72	8.04e+00	1.57e-04	3.40e-28	1.44e-56	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	65	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	67	2.76e+01	4.40e-02	3.83e-16	5.31e-33	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	68	5.19e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	70	4.15e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	72	9.05e+01	2.65e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	73	3.29e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	74	2.76e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	74*	1.24e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	75	1.60e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	69	4.81e-01	1.19e-06	7.94e-35	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	71	1.37e+03	2.17e+02	2.13e-02	3.31e-07	8.04e-17	0.00e+00	0.00e+00	0.00e+00
Ge	73*	2.04e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	75	1.77e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	75*	2.25e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	70	8.91e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	71	3.91e+00	1.73e-03	2.40e-20	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	72	7.53e+03	2.84e-05	1.35e-47	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	73	6.43e+09	4.95e+09	1.33e+09	2.75e+08	1.17e+07	5.02e+05	1.31e-04	0.00e+00
As	74	5.37e+06	1.65e+06	4.35e+03	3.52e+00	2.30e-06	1.51e-12	0.00e+00	0.00e+00
As	76	1.35e+06	6.44e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	77	3.47e+01	7.95e-05	3.66e-33	3.85e-67	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	72	5.27e+02	4.32e+01	1.51e-04	4.33e-11	3.57e-24	2.93e-37	0.00e+00	0.00e+00

		Initial	30 d	183d	1y	2y	3y	10 y	100 y
Se	73	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	73*	8.48e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	75	5.00e+09	4.20e+09	1.74e+09	6.04e+08	7.29e+07	8.81e+06	3.30e+00	7.92e-83
Se	77*	3.01e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	79	1.35e-04	1.35e-04	1.35e-04	1.35e-04	1.35e-04	1.35e-04	1.35e-04	1.35e-04
Se	79*	1.29e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	81	4.49e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	81*	1.34e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	82	3.21e-21	3.21e-21	3.21e-21	3.21e-21	3.21e-21	3.21e-21	3.21e-21	3.21e-21
Se	84	3.58e-21	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	85	2.44e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	74	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	75	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	76	9.85e+09	2.95e-04	3.33e-72	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	76*	9.90e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	77	1.72e+05	2.48e+01	1.27e-18	9.33e-42	5.07e-88	0.00e+00	0.00e+00	0.00e+00
Br	77*	1.03e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	78	1.50e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	79*	3.28e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	80	7.14e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	80*	1.04e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	82	4.58e+02	2.86e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	82*	4.41e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	83	5.04e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	84	5.75e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	84*	5.75e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	85	2.18e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	86	1.22e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	87	1.84e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	88	5.95e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	76	1.90e+02	3.06e-13	1.46e-87	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	77	4.72e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	79	3.64e+06	2.05e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	79*	1.13e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	81	3.25e+04	3.25e+04	3.25e+04	3.25e+04	3.25e+04	3.25e+04	3.25e+04	3.25e+04
Kr	81*	3.53e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	83*	2.61e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	85	3.94e+01	3.91e+01	3.81e+01	3.69e+01	3.46e+01	3.24e+01	2.06e+01	6.12e-02
Kr	85*	4.38e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	87	1.62e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	88	1.29e-03	9.84e-81	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	89	1.49e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	91	3.25e-21	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	80	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	81	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	81*	1.38e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	82	1.93e+10	4.17e+09	6.71e+07	4.73e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	82*	7.32e+03	1.06e-30	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	83	6.12e+09	4.92e+09	1.45e+09	3.33e+08	1.77e+07	9.37e+05	1.11e-03	0.00e+00
Rb	83*	4.05e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	84	1.08e+07	5.70e+06	2.30e+05	4.88e+03	2.21e+00	9.97e-04	3.84e-27	0.00e+00
Rb	84*	5.85e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	86	7.69e+05	2.49e+05	8.62e+02	9.65e-01	1.21e-06	1.52e-12	0.00e+00	0.00e+00
Rb	86*	1.26e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	87	2.06e-08	2.06e-08	2.06e-08	2.06e-08	2.06e-08	2.06e-08	2.06e-08	2.06e-08
Rb	88	2.33e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	89	3.80e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	90	1.66e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	90*	4.04e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	91	1.58e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	92	3.68e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	81	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	82	9.50e+09	4.17e+09	6.71e+07	4.73e+05	2.36e+01	1.18e-03	0.00e+00	0.00e+00
Sr	83	9.85e+09	1.72e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	83*	5.85e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	85	1.44e+10	1.04e+10	2.04e+09	2.90e+08	5.84e+06	1.18e+05	1.59e-07	0.00e+00
Sr	85*	1.96e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	87*	1.60e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	89	5.06e+06	3.34e+06	4.13e+05	3.38e+04	2.26e+02	1.51e+00	8.98e-16	0.00e+00
Sr	90	1.21e+00	1.21e+00	1.20e+00	1.18e+00	1.15e+00	1.13e+00	9.48e-01	1.03e-01
Sr	91	9.07e+02	8.95e-21	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	92	5.03e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	93	1.05e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	94	1.57e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	95	3.17e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	96	5.10e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	84	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	85	1.97e+10	3.88e-72	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Y	85*	1.48e+02	1.30e-43	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	86	1.97e+10	4.81e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	86*	1.19e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	87	4.92e+10	9.23e+07	1.83e-06	6.81e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	87*	4.29e+05	4.37e-12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	88	9.03e+09	1.14e+10	1.06e+10	4.93e+09	6.55e+08	7.04e+07	4.24e+00	0.00e+00
Y	88*	3.29e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	89*	1.11e+11	1.78e+08	3.84e+01	3.14e+00	2.10e-02	0.00e+00	0.00e+00	0.00e+00
Y	90	1.00e+10	3.84e+06	2.62e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	90*	6.75e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	91	7.56e+09	5.28e+09	8.69e+08	9.99e+07	1.32e+06	1.74e+04	1.22e-09	0.00e+00
Y	91*	4.68e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	92	2.06e+07	2.78e-55	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	93	7.49e+03	1.55e-18	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	93*	4.89e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	94	1.28e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	95	7.83e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96	5.87e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96*	7.61e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96#	2.09e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	97	1.61e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	97*	2.40e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	86	9.85e+09	5.24e-04	1.07e-70	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	87	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	87*	5.62e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	88	2.53e+10	1.97e+10	5.55e+09	1.22e+09	5.84e+07	2.81e+06	1.66e-03	0.00e+00
Zr	89	1.10e+11	1.78e+08	1.66e-06	2.51e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	89*	3.17e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	90*	3.96e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	93	2.55e+02	2.55e+02	2.55e+02	2.55e+02	2.55e+02	2.55e+02	2.55e+02	2.55e+02
Zr	95	2.59e+08	1.86e+08	3.58e+07	4.96e+06	9.51e+04	1.82e+03	1.73e-09	0.00e+00
Zr	97	7.83e+07	8.59e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	98	2.82e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	99	5.60e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	88	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	89	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	89*	6.27e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	90	8.92e+10	8.90e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	90*	4.17e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	91	5.03e+07	5.04e+07	5.05e+07	5.05e+07	5.04e+07	5.04e+07	5.00e+07	4.57e+07
Nb	91*	1.02e+09	7.24e+08	1.32e+08	1.71e+07	2.88e+05	4.86e+03	1.88e-09	0.00e+00
Nb	92	6.36e+02	6.36e+02	6.36e+02	6.36e+02	6.36e+02	6.36e+02	6.36e+02	6.36e+02
Nb	92*	1.01e+10	1.28e+09	3.89e+04	1.49e-01	2.19e-12	0.00e+00	0.00e+00	0.00e+00
Nb	93*	1.16e+09	1.16e+09	1.14e+09	1.11e+09	1.07e+09	1.02e+09	7.61e+08	3.21e+07
Nb	94	1.31e+07	1.31e+07	1.31e+07	1.31e+07	1.31e+07	1.31e+07	1.31e+07	1.31e+07
Nb	94*	6.51e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	95	6.61e+10	3.64e+10	1.84e+09	5.80e+07	2.43e+05	4.04e+03	3.96e-19	0.00e+00
Nb	95*	5.92e+08	3.94e+06	4.22e+05	5.84e+04	1.12e+03	2.14e+01	0.00e+00	0.00e+00
Nb	96	3.07e+10	1.28e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	97	2.05e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	97*	2.40e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	98	1.66e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	98*	1.51e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	99	1.39e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	99*	3.46e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	100	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	100*	3.47e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	89	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	90	1.03e+10	2.42e-29	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	91	5.87e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	91*	7.32e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	93	2.04e+07	2.04e+07	2.04e+07	2.04e+07	2.04e+07	2.04e+07	2.04e+07	2.00e+07
Mo	93*	1.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	99	1.30e+12	6.20e+08	1.27e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	101	3.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	94	1.30e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	94*	1.95e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	95	7.54e+02	8.44e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	95*	1.38e+02	9.80e+01	1.74e+01	2.18e+00	3.43e-02	5.41e-04	1.30e-16	0.00e+00
Tc	96	9.85e+09	7.26e+07	1.41e-03	2.02e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	96*	9.15e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	97	9.70e-02	1.01e-01	1.11e-01	1.14e-01	1.15e-01	1.15e-01	1.15e-01	1.15e-01
Tc	97*	1.90e+05	1.51e+05	4.70e+04	1.16e+04	7.07e+02	4.31e+01	1.35e-07	0.00e+00
Tc	98	9.11e-02	9.11e-02	9.11e-02	9.11e-02	9.11e-02	9.11e-02	9.11e-02	9.11e-02
Tc	99	1.39e+06	1.43e+06	1.43e+06	1.43e+06	1.43e+06	1.43e+06	1.43e+06	1.43e+06
Tc	99*	1.14e+12	6.00e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	100	2.29e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	101	3.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Tc	102	1.50e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	102*	2.45e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	97	8.34e+00	5.95e-03	9.22e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	103	1.16e+02	6.82e+01	4.63e+00	1.84e-01	2.92e-04	4.62e-07	1.15e-26	0.00e+00
Rh	100	5.77e-02	1.72e-12	2.22e-65	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	100*	8.98e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	101	2.99e+01	2.94e+01	2.69e+01	2.42e+01	1.96e+01	1.59e+01	3.65e+00	2.20e-08
Rh	101*	1.73e+03	1.37e+01	3.74e-10	8.06e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	102	1.77e+02	1.74e+02	1.61e+02	1.45e+02	1.16e+02	9.16e+01	1.72e+01	7.70e-09
Rh	102*	9.30e+02	8.40e+02	5.04e+02	2.74e+02	8.06e+01	2.37e+01	4.54e-03	0.00e+00
Rh	103*	9.78e+09	2.84e+09	5.70e+06	3.31e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	104	9.25e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	104*	6.88e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	101	5.30e+01	7.32e-25	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	103	9.78e+09	2.84e+09	5.69e+06	3.31e+03	1.12e-03	3.78e-10	0.00e+00	0.00e+00
Pd	107	2.43e-10	2.43e-10	2.43e-10	2.43e-10	2.43e-10	2.43e-10	2.43e-10	2.43e-10
Pd	107*	1.78e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	109	1.05e-03	1.08e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	109*	9.54e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	111	4.90e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	111*	5.03e-05	7.59e-45	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	112	4.90e-04	1.92e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	113	1.48e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	113*	3.48e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	114	1.62e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	106	8.42e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	106*	7.66e-06	6.39e-07	2.43e-12	7.74e-19	7.83e-32	0.00e+00	0.00e+00	0.00e+00
Ag	107*	2.83e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	108	1.79e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	108*	1.72e-05	1.72e-05	1.72e-05	1.71e-05	1.70e-05	1.69e-05	1.63e-05	9.97e-06
Ag	109*	4.98e+04	4.76e+04	3.79e+04	2.88e+04	1.67e+04	9.64e+03	2.09e+02	0.00e+00
Ag	110	3.36e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	110*	2.43e-01	2.23e-01	1.46e-01	8.81e-02	3.20e-02	1.16e-02	9.62e-06	2.31e-45
Ag	111	7.49e-01	4.46e-02	3.13e-08	1.31e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	111*	1.24e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	112	3.18e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	113	1.34e-02	2.20e-43	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	113*	5.42e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	114	2.46e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	114*	2.00e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	115	4.33e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	115*	1.29e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	107	2.97e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	109	4.98e+04	4.76e+04	3.79e+04	2.88e+04	1.67e+04	9.64e+03	2.09e+02	8.51e-20
Cd	111*	1.53e+07	9.22e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	113	1.06e-11	1.06e-11	1.06e-11	1.06e-11	1.06e-11	1.06e-11	1.06e-11	1.06e-11
Cd	113*	5.58e+03	5.56e+03	5.45e+03	5.31e+03	5.06e+03	4.82e+03	3.41e+03	4.09e+01
Cd	115	7.99e+05	6.40e+01	1.67e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	115*	2.21e+05	1.38e+05	1.29e+04	7.57e+02	2.59e+00	8.89e-03	4.92e-20	0.00e+00
Cd	116*	2.86e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	117	6.35e+05	6.99e-83	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	117*	5.02e+05	3.29e-60	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	118	2.15e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	119	3.49e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	119*	2.74e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	120	1.91e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	121	1.16e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	121*	1.16e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	122	1.60e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	123	1.26e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	124	3.80e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109	2.48e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109*	7.74e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109#	5.00e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	110	1.88e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	110*	4.84e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	111	3.06e+07	1.82e+04	1.15e-12	4.31e-32	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	111*	1.23e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	112	4.08e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	112*	1.73e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	113*	1.04e+09	8.64e+08	3.45e+08	1.15e+08	1.27e+07	1.41e+06	0.00e+00	0.00e+00
In	114	1.50e+06	4.72e+05	5.60e+04	4.34e+03	2.61e+01	0.00e+00	0.00e+00	0.00e+00
In	114*	7.55e+05	4.94e+05	5.85e+04	4.54e+03	2.73e+01	1.64e-01	4.68e-17	0.00e+00
In	115	3.89e-09	3.92e-09	3.95e-09	3.96e-09	3.96e-09	3.96e-09	3.96e-09	3.96e-09
In	115*	2.11e+06	1.52e+01	1.43e+00	8.37e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	116	2.21e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	116*	5.97e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	116#	1.43e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
In	117	8.12e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	117*	2.38e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118	5.55e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118*	2.04e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118#	3.55e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	119	9.32e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	119*	4.94e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120	1.02e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120*	5.71e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120#	3.22e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	121	2.95e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	121*	1.01e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122	1.12e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122*	1.57e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122#	4.47e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	123	4.76e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	123*	1.19e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	124	1.07e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	124*	1.07e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	125	7.27e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	125*	7.27e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	110	1.85e+06	9.82e-48	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	111	2.46e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	113	1.04e+09	8.64e+08	3.45e+08	1.15e+08	1.27e+07	1.41e+06	2.90e-01	0.00e+00
Sn	113*	5.95e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	117*	1.28e+09	2.74e+08	1.16e+05	1.06e+01	8.69e-08	7.15e-16	0.00e+00	0.00e+00
Sn	119*	1.29e+09	1.20e+09	8.34e+08	5.42e+08	2.28e+08	9.62e+07	2.27e+05	0.00e+00
Sn	120*	3.61e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	121	7.32e+09	1.62e+07	1.61e+07	1.60e+07	1.58e+07	1.56e+07	1.43e+07	4.59e+06
Sn	121*	2.08e+07	2.08e+07	2.07e+07	2.06e+07	2.03e+07	2.01e+07	1.84e+07	5.91e+06
Sn	123	2.34e+09	1.99e+09	8.78e+08	3.30e+08	4.65e+07	6.55e+06	7.23e+00	0.00e+00
Sn	123*	4.69e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	125	4.14e+09	4.68e+08	8.20e+03	1.63e-02	6.40e-14	2.52e-25	0.00e+00	0.00e+00
Sn	125*	1.24e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	126	9.56e-02	9.56e-02	9.56e-02	9.56e-02	9.56e-02	9.56e-02	9.56e-02	9.55e-02
Sb	119	3.73e+03	6.67e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	120	1.12e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	120*	4.13e+03	1.07e+02	1.18e-06	3.38e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	121*	2.26e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	122	6.69e+06	2.79e+03	2.92e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	122*	1.06e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	124	1.17e+07	8.25e+06	1.43e+06	1.74e+05	2.60e+03	3.88e+01	6.37e-12	0.00e+00
Sb	124*	6.25e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	124#	2.03e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	125	1.04e+10	1.03e+10	9.23e+09	8.13e+09	6.30e+09	4.89e+09	8.27e+08	9.85e-02
Sb	126	4.42e+06	8.13e+05	1.63e+02	6.02e-03	8.18e-12	1.11e-20	0.00e+00	0.00e+00
Sb	126*	1.33e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	126#	7.66e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	127	3.11e+02	1.33e+00	1.64e-12	8.60e-27	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	123	6.79e-12	6.79e-12	6.79e-12	8.44e-12	8.44e-12	8.44e-12	8.44e-12	8.44e-12
Te	123*	2.75e+02	2.31e+02	9.56e+01	3.32e+01	4.01e+00	4.83e-01	1.80e-07	0.00e+00
Te	125*	1.15e+09	1.53e+09	2.09e+09	1.97e+09	1.54e+09	1.19e+09	2.02e+08	2.41e-02
Tm	173	1.19e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	174	6.18e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	175	9.43e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	176	1.29e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	175	2.03e-03	1.35e-05	1.54e-16	1.16e-29	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	176*	2.41e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	177	2.76e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	177*	8.72e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	178	1.63e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	179	3.33e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	180	8.13e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	174	9.51e-08	9.35e-08	8.57e-08	7.72e-08	6.26e-08	5.08e-08	1.17e-08	7.73e-17
Lu	174*	6.93e-07	5.97e-07	2.84e-07	1.17e-07	1.96e-08	3.30e-09	1.25e-14	0.00e+00
Lu	176	1.13e-12	1.13e-12	1.13e-12	1.13e-12	1.13e-12	1.13e-12	1.13e-12	1.13e-12
Lu	176*	1.46e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	177	2.75e+05	1.30e+04	5.68e+02	2.59e+02	5.36e+01	1.11e+01	0.00e+00	0.00e+00
Lu	177*	5.70e+03	5.00e+03	2.59e+03	1.18e+03	2.45e+02	5.07e+01	8.34e-04	0.00e+00
Lu	178	4.76e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	178*	1.02e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	179	3.76e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	180	5.28e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	181	1.67e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	182	1.40e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	175	1.01e-01	7.46e-02	1.65e-02	2.71e-03	7.28e-05	1.96e-06	1.98e-17	0.00e+00
Hf	177*	3.13e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	177#	1.78e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Hf	178*	8.05e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	178#	1.03e-01	1.03e-01	1.02e-01	1.00e-01	9.83e-02	9.61e-02	8.22e-02	1.10e-02
Hf	179*	1.61e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	179#	4.51e+02	1.95e+02	2.92e+00	1.89e-02	7.92e-07	3.32e-11	7.54e-42	0.00e+00
Hf	180*	3.57e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	181	7.35e+05	4.48e+05	3.71e+04	1.88e+03	4.79e+00	1.22e-02	0.00e+00	0.00e+00
Hf	182	1.47e-04	1.47e-04	1.47e-04	1.47e-04	1.47e-04	1.47e-04	1.47e-04	1.47e-04
Hf	182*	2.02e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	183	2.91e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	184	1.27e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	185	6.87e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	186	7.56e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	187	1.90e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	177	7.72e+01	1.04e-02	3.81e-22	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	178	1.97e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	178*	1.97e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	179	1.04e+07	1.01e+07	8.59e+06	7.10e+06	4.85e+06	3.32e+06	2.31e+05	3.02e-10
Ta	180	1.59e+08	2.17e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	180*	3.31e-08	3.31e-08	3.31e-08	3.31e-08	3.31e-08	3.31e-08	3.31e-08	3.31e-08
Ta	182	1.13e+11	9.40e+10	3.75e+10	1.25e+10	1.38e+09	1.53e+08	3.10e+01	0.00e+00
Ta	182*	1.04e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	182#	1.60e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	183	1.26e+11	2.05e+09	2.09e+00	3.48e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	184	2.13e+07	1.43e-18	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	185	8.65e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	186	7.25e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	187	3.56e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	188	8.84e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	178	1.26e+01	4.77e+00	3.63e-02	1.05e-04	8.71e-10	7.25e-15	0.00e+00	0.00e+00
W	179	2.17e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	179*	2.58e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	181	1.52e+07	1.28e+07	5.37e+06	1.89e+06	2.34e+05	2.90e+04	1.29e-02	0.00e+00
W	183*	1.60e+10	1.02e+08	1.05e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	185	1.09e+09	8.26e+08	2.03e+08	3.76e+07	1.29e+06	4.43e+04	2.50e-06	0.00e+00
W	185*	1.04e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	187	2.77e+10	1.90e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	188	7.91e+05	5.84e+05	1.28e+05	2.06e+04	5.39e+02	1.41e+01	1.16e-10	0.00e+00
W	189	2.18e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	183	9.84e+01	7.29e+01	1.61e+01	2.65e+00	7.12e-02	1.92e-03	1.95e-14	0.00e+00
Re	184	6.16e+02	3.54e+02	2.20e+01	7.83e-01	9.94e-04	1.26e-06	6.73e-27	0.00e+00
Re	184*	4.54e+01	4.00e+01	2.11e+01	9.84e+00	2.13e+00	4.62e-01	1.03e-05	1.69e-65
Re	186	6.32e+06	2.42e+04	1.76e-08	4.87e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	186*	1.67e-02	1.67e-02	1.67e-02	1.67e-02	1.67e-02	1.67e-02	1.67e-02	1.67e-02
Re	187	1.28e-01	1.29e-01	1.29e-01	1.29e-01	1.29e-01	1.29e-01	1.29e-01	1.29e-01
Re	188	1.33e+08	5.90e+05	1.29e+05	2.08e+04	5.44e+02	0.00e+00	0.00e+00	0.00e+00
Re	188*	4.76e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	189	8.18e+02	7.94e-07	4.14e-52	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	185	1.00e+00	8.00e-01	2.59e-01	6.71e-02	4.49e-03	3.01e-04	1.81e-12	0.00e+00
Os	186	2.54e-10	2.86e-10	2.86e-10	2.86e-10	2.86e-10	2.86e-10	2.86e-10	2.86e-10
Os	189*	2.79e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Total		**4.42e+14**	**1.21e+14**	**3.04e+13**	**2.36e+13**	**1.72e+13**	**1.28e+13**	**2.14e+12**	**2.79e+09**

Total activity decay of the LBE

Table B2. Radionuclide inventory of the LBE: decay following 123 days of irradiation at 0.947 mA. Calculations performed with MCNPX and CINDER90. Activities in Bq. Number of proton histories: 600000.

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
H	3	2.50e+11	2.49e+11	2.43e+11	2.36e+11	2.23e+11	2.11e+11	1.43e+11	9.05e+08
H	4	5.74e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
He	5	5.31e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
He	6	2.20e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
He	7	5.22e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Li	5	5.78e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Li	8	1.70e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Li	9	8.46e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Li	10	4.39e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Be	7	2.62e+00	1.76e+00	2.43e-01	2.26e-02	1.96e-04	1.70e-06	0.00e+00	0.00e+00
Be	8	1.14e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Be	10	7.36e+03	7.36e+03	7.36e+03	7.36e+03	7.36e+03	7.36e+03	7.36e+03	7.36e+03
Be	11	9.01e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
B	9	1.00e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
B	12	1.79e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
C	14	1.60e-01	1.60e-01	1.60e-01	1.60e-01	1.60e-01	1.60e-01	1.60e-01	1.58e-01
C	15	1.58e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
N	13	2.49e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
N	16	5.68e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
O	19	4.36e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	20	1.97e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	21	1.99e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	22	4.98e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
F	23	3.03e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	23	1.41e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	24	1.40e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ne	25	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	21	7.17e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	22	2.15e+03	2.10e+03	1.88e+03	1.64e+03	1.26e+03	9.65e+02	1.50e+02	5.79e-09
Na	24	9.73e+09	1.11e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	24*	2.89e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	25	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	26	7.95e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Na	28	3.96e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	23	2.51e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	27	1.52e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	28	2.82e+06	9.47e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	29	3.74e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mg	30	2.52e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	25	1.66e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	26	4.00e+03	4.00e+03	4.00e+03	4.00e+03	4.00e+03	4.00e+03	4.00e+03	4.00e+03
Al	26*	3.47e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	28	2.60e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	29	7.70e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	30	1.61e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	31	1.41e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Al	32	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	27	1.92e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	31	4.30e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	32	1.34e+07	1.34e+07	1.33e+07	1.33e+07	1.32e+07	1.32e+07	1.28e+07	8.93e+06
Si	33	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	34	9.96e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Si	35	6.05e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	29	2.04e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	30	7.97e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	32	1.14e+07	1.29e+07	1.33e+07	1.33e+07	1.33e+07	1.32e+07	1.28e+07	8.93e+06
P	33	2.85e+10	1.25e+10	1.95e+08	1.34e+06	6.28e+01	2.95e-03	1.48e-33	0.00e+00
P	34	1.18e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	35	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
P	36	8.02e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	31	5.83e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	35	1.23e+10	9.65e+09	2.89e+09	6.79e+08	3.76e+07	2.08e+06	3.34e-03	0.00e+00
S	37	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	38	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	39	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	40	4.68e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
S	41	6.91e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	33	1.23e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	34	5.64e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	34*	2.76e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	36	1.53e+04	1.53e+04	1.53e+04	1.53e+04	1.53e+04	1.53e+04	1.53e+04	1.53e+04

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Cl	38	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	38*	2.09e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	39	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	40	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	41	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl	42	1.09e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	35	2.86e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	37	2.31e+06	1.27e+06	6.24e+04	1.68e+03	1.23e+00	8.93e-04	0.00e+00	0.00e+00
Ar	39	7.50e+07	7.50e+07	7.49e+07	7.48e+07	7.46e+07	7.44e+07	7.31e+07	5.80e+07
Ar	41	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	42	3.48e+08	3.48e+08	3.45e+08	3.41e+08	3.34e+08	3.27e+08	2.82e+08	4.23e+07
Ar	43	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	44	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	45	3.70e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ar	46	5.46e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	38	1.48e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	40	1.80e+00	1.80e+00	1.80e+00	1.80e+00	1.80e+00	1.80e+00	1.80e+00	1.80e+00
K	42	5.95e+10	3.48e+08	3.45e+08	3.41e+08	3.34e+08	3.27e+08	2.82e+08	4.23e+07
K	43	9.85e+10	1.34e+01	3.65e-49	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	44	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	45	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	46	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	47	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
K	48	1.05e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ca	41	5.23e-02	5.23e-02	5.23e-02	5.23e-02	5.23e-02	5.23e-02	5.23e-02	5.22e-02
Ca	45	1.04e+11	9.14e+10	4.80e+10	2.21e+10	4.72e+09	1.01e+09	2.01e+04	0.00e+00
Ca	47	1.77e+11	1.73e+09	1.35e-01	1.02e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ca	49	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	42	9.02e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	43	3.79e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	44	9.85e+09	1.66e-46	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	44*	1.31e+05	2.39e+01	4.02e-18	1.24e-40	1.17e-85	0.00e+00	0.00e+00	0.00e+00
Sc	45*	2.04e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	46	8.81e+10	6.86e+10	1.95e+10	4.30e+09	2.10e+08	1.02e+07	6.70e-03	0.00e+00
Sc	46*	1.29e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	47	3.55e+11	5.97e+09	1.17e-04	4.32e-21	5.83e-54	0.00e+00	0.00e+00	0.00e+00
Sc	48	2.27e+11	2.21e+06	1.46e-19	2.75e-55	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	49	2.76e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	50	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	50*	3.39e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	51	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sc	52	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	43	1.76e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	44	8.47e-02	8.46e-02	8.41e-02	8.35e-02	8.22e-02	8.10e-02	7.31e-02	1.96e-02
Ti	45	5.82e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	51	3.75e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	52	3.55e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	53	1.18e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ti	54	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	47	3.33e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	48	1.96e+10	5.26e+09	7.10e+06	2.57e+03	3.36e-04	4.41e-11	0.00e+00	0.00e+00
V	49	6.68e+09	6.27e+09	4.59e+09	3.16e+09	1.49e+09	7.06e+08	3.73e+06	1.97e-23
V	50	3.00e-07	3.00e-07	3.00e-07	3.00e-07	3.00e-07	3.00e-07	3.00e-07	3.00e-07
V	52	1.12e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	53	5.42e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	54	4.33e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	55	3.25e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
V	59	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	48	3.73e+04	2.59e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	49	2.51e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	51	1.23e+11	5.74e+10	1.27e+09	1.32e+07	1.42e+03	1.52e-01	2.48e-37	0.00e+00
Cr	55	9.18e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	56	5.22e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	57	3.84e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	58	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	59	1.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cr	60	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	51	6.80e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	52	9.85e+09	2.30e+08	1.45e+00	2.14e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	52*	9.57e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	53	4.34e+03	4.34e+03	4.34e+03	4.34e+03	4.34e+03	4.34e+03	4.34e+03	4.34e+03
Mn	54	1.85e+10	1.73e+10	1.23e+10	8.23e+09	3.66e+09	1.62e+09	5.56e+06	5.26e-39
Mn	56	2.11e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	57	7.58e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	58	7.39e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	58*	9.57e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	59	6.50e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	60	3.55e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Mn	61	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mn	62	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	52	2.52e+04	4.62e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	52*	5.32e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	53	3.51e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	53*	6.63e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	55	5.66e+09	5.54e+09	4.98e+09	4.39e+09	3.40e+09	2.64e+09	4.47e+08	5.32e-02
Fe	59	1.09e+12	6.81e+11	6.35e+10	3.69e+09	1.25e+07	4.22e+04	2.13e-13	0.00e+00
Fe	60	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05
Fe	61	8.18e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	62	6.20e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	63	2.46e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	64	2.56e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	65	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	66	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Fe	67	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	54	1.11e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	54*	5.36e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	55	5.11e+04	1.67e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	56	6.54e+09	5.01e+09	1.31e+09	2.63e+08	1.06e+07	4.24e+05	7.17e-05	0.00e+00
Co	57	1.03e+10	9.57e+09	6.49e+09	4.07e+09	1.60e+09	6.32e+08	9.32e+05	3.66e-31
Co	58	9.49e+10	7.07e+10	1.60e+10	2.68e+09	7.54e+07	2.12e+06	2.98e-05	0.00e+00
Co	58*	3.62e+10	4.20e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	60	1.43e+10	1.41e+10	1.34e+10	1.25e+10	1.10e+10	9.62e+09	3.83e+09	1.99e+05
Co	60*	3.22e+09	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05	1.72e+05
Co	61	1.43e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	62	1.34e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	62*	3.37e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	63	1.01e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	64	8.86e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	65	4.73e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	66	2.36e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	67	1.18e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	68	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	69	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Co	70	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	55	1.67e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	56	4.74e+04	1.51e+03	4.61e-05	4.48e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	57	7.26e+08	5.22e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	59	3.15e+06	3.15e+06	3.15e+06	3.15e+06	3.15e+06	3.15e+06	3.14e+06	3.14e+06
Ni	63	4.64e+09	4.63e+09	4.62e+09	4.60e+09	4.57e+09	4.54e+09	4.33e+09	2.32e+09
Ni	65	1.65e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	66	1.21e+12	1.18e+08	8.30e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	67	1.02e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	68	4.83e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	69	1.97e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	70	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ni	71	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	61	1.98e+10	1.09e-54	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	62	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	64	1.68e+12	9.61e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	66	2.57e+12	1.18e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	67	2.34e+12	6.75e+08	1.10e-09	5.17e-31	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	67*	2.76e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	68	1.77e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	68*	2.28e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	69	9.06e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	70	7.53e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	70*	4.43e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	71	4.23e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	72	1.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	73	9.85e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cu	74	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	62	9.85e+09	2.21e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	63	4.69e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	65	6.67e+10	6.12e+10	3.97e+10	2.36e+10	8.36e+09	2.96e+09	2.07e+06	0.00e+00
Zn	69	2.74e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	69*	3.81e+07	4.61e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	71	1.87e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	71*	2.94e+06	7.59e-50	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	72	1.09e+12	2.13e+07	4.63e-17	1.96e-45	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	73	6.30e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	74	2.76e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	75	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	76	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zn	78	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	65	4.58e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	66	5.91e+10	5.21e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Ga	67	1.58e+11	2.51e+08	2.18e-06	3.03e-23	5.82e-57	0.00e+00	0.00e+00	0.00e+00
Ga	68	4.42e+11	1.72e+10	1.17e+10	7.31e+09	2.87e+09	1.13e+09	1.62e+06	0.00e+00
Ga	70	1.37e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	72	3.04e+12	3.06e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	73	2.62e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	74	1.66e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	74*	2.07e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	75	9.85e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	76	7.49e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	77	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	78	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ga	79	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	66	1.48e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	67	9.35e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	68	1.86e+10	1.72e+10	1.17e+10	7.31e+09	2.87e+09	1.13e+09	1.62e+06	4.70e-31
Ge	69	2.07e+11	5.10e+05	3.42e-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	71	1.12e+12	1.85e+11	1.81e+07	2.82e+02	6.85e-08	1.66e-17	0.00e+00	0.00e+00
Ge	73*	2.59e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	75	3.17e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	75*	4.74e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	77	1.43e+12	5.95e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	77*	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	78	8.47e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	79	5.31e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	79*	1.02e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	80	1.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	81	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ge	84	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	69	1.24e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	70	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	71	1.28e+11	5.65e+07	7.86e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	72	3.05e+11	2.78e+09	9.73e+03	1.75e-47	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	73	7.27e+11	5.60e+11	1.50e+11	3.11e+10	1.33e+09	5.68e+07	1.48e-02	0.00e+00
As	74	1.44e+12	4.40e+11	1.16e+09	9.41e+05	6.16e-01	4.03e-07	0.00e+00	0.00e+00
As	76	2.66e+12	1.27e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	77	4.77e+12	1.23e+07	5.64e-22	5.93e-56	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	78	3.55e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	79	2.78e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	80	1.68e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	81	9.75e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	82	4.04e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	82*	1.65e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	83	1.29e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	84	4.87e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	85	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
As	86	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	71	3.57e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	72	2.95e+10	2.42e+09	8.47e+03	2.43e-03	2.00e-16	1.65e-29	0.00e+00	0.00e+00
Se	73	1.97e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	73*	1.87e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	75	3.78e+11	3.17e+11	1.31e+11	4.56e+10	5.51e+09	6.66e+08	2.50e+02	5.98e-81
Se	77*	2.62e+10	3.92e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	79	4.87e+07	4.87e+07	4.87e+07	4.87e+07	4.87e+07	4.87e+07	4.87e+07	4.86e+07
Se	79*	2.75e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	81	4.23e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	81*	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	82	4.01e-09	4.01e-09	4.01e-09	4.01e-09	4.01e-09	4.01e-09	4.01e-09	4.01e-09
Se	83	1.40e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	83*	9.00e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	84	6.66e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	85	2.89e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	86	3.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Se	87	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	75	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	76	2.46e+11	1.03e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	76*	1.62e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	77	7.68e+11	1.11e+08	5.66e-12	4.18e-35	2.27e-81	0.00e+00	0.00e+00	0.00e+00
Br	77*	5.16e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	78	1.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	79*	1.70e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	80	3.68e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	80*	1.18e+09	1.16e-62	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	82	4.61e+12	2.88e+06	2.41e-36	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	82*	4.23e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	83	5.28e+12	3.06e-79	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	84	3.29e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	84*	3.22e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	85	2.07e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Br	86	1.26e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	87	5.51e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	88	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	89	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Br	90	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	76	9.85e+09	1.59e-05	7.58e-80	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	77	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	79	6.01e+11	3.37e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	79*	1.74e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	81	3.28e+06	3.28e+06	3.28e+06	3.28e+06	3.28e+06	3.28e+06	3.28e+06	3.28e+06
Kr	81*	2.59e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	83*	5.30e+12	1.29e-78	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	85	1.27e+11	1.26e+11	1.23e+11	1.19e+11	1.11e+11	1.04e+11	6.63e+10	1.97e+08
Kr	85*	2.07e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	87	3.13e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	88	1.80e+12	1.37e-65	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	89	8.09e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	90	1.75e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	91	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Kr	92	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	79	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	80	2.46e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	81	5.71e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	81*	6.20e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	82	1.21e+12	5.01e+10	8.05e+08	5.68e+06	2.83e+02	0.00e+00	0.00e+00	0.00e+00
Rb	82*	6.43e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	83	1.68e+12	1.32e+12	3.88e+11	8.93e+10	4.73e+09	2.51e+08	2.96e-01	0.00e+00
Rb	83*	4.35e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	84	3.47e+12	1.83e+12	7.39e+10	1.57e+09	7.10e+05	3.21e+02	1.24e-21	0.00e+00
Rb	84*	4.45e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	86	6.11e+12	1.98e+12	6.85e+09	7.67e+06	9.62e+00	1.21e-05	1.36e-55	0.00e+00
Rb	86*	6.94e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	87	1.84e+03	1.84e+03	1.84e+03	1.84e+03	1.84e+03	1.84e+03	1.84e+03	1.84e+03
Rb	88	7.04e+12	1.53e-65	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	89	4.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	90	2.49e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	90*	2.10e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	91	1.37e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	92	6.60e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	93	2.27e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	94	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rb	95	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	81	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	82	1.14e+11	5.01e+10	8.04e+08	5.68e+06	2.83e+02	1.41e-02	0.00e+00	0.00e+00
Sr	83	3.64e+11	6.37e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	83*	1.17e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	85	1.53e+12	1.10e+12	2.17e+11	3.08e+10	6.20e+08	1.25e+07	1.69e-05	0.00e+00
Sr	85*	1.31e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	87*	7.45e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	89	9.16e+12	6.04e+12	7.49e+11	6.12e+10	4.09e+08	2.73e+06	1.63e-09	0.00e+00
Sr	90	7.35e+10	7.34e+10	7.26e+10	7.17e+10	7.00e+10	6.83e+10	5.75e+10	6.26e+09
Sr	91	6.03e+12	5.95e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	92	3.80e+12	5.72e-80	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	93	2.21e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	94	8.53e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	95	3.44e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	96	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	97	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sr	98	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	83	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	84	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	85	2.17e+11	4.27e-71	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	85*	2.18e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	86	7.78e+11	1.06e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	86*	1.68e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	87	1.86e+12	3.49e+09	6.92e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	87*	4.04e+07	4.11e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	88	1.64e+12	1.39e+12	5.81e+11	1.95e+11	2.01e+10	1.97e+09	1.19e+02	0.00e+00
Y	88*	1.96e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	89*	1.33e+12	2.70e+09	6.96e+07	5.69e+06	3.80e+04	2.54e+02	0.00e+00	0.00e+00
Y	90	6.59e+12	7.59e+10	7.26e+10	7.17e+10	7.00e+10	6.83e+10	5.75e+10	6.27e+09
Y	90*	2.65e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	91	1.01e+13	7.05e+12	1.16e+12	1.33e+11	1.76e+09	2.33e+07	1.63e-06	0.00e+00
Y	91*	3.50e+12	3.78e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	92	1.09e+13	1.48e-49	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	93	7.87e+12	1.63e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	93*	7.64e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	94	5.32e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	30 d	183d	1y	2y	3y	10 y	100 y
Y	95	2.79e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96	1.46e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96*	1.96e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	96#	5.40e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	97	8.12e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	97*	5.91e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	98	2.26e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Y	99	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	85	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	86	1.97e+10	1.05e-03	2.15e-70	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	87	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	87*	2.13e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	88	2.58e+11	2.01e+11	5.66e+10	1.24e+10	5.97e+08	2.87e+07	1.69e-02	0.00e+00
Zr	89	1.33e+12	2.14e+09	2.01e-05	3.02e-22	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	89*	6.25e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	90*	5.29e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	93	2.33e+06	2.34e+06	2.34e+06	2.34e+06	2.34e+06	2.34e+06	2.34e+06	2.34e+06
Zr	95	7.04e+12	5.07e+12	9.74e+11	1.35e+11	2.59e+09	4.96e+07	4.71e-05	0.00e+00
Zr	97	3.84e+12	4.22e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	98	2.11e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	99	8.06e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	100	4.53e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zr	101	1.58e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	87	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	88	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	89	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	89*	1.02e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	90	3.94e+11	3.93e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	90*	4.74e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	91	3.30e+08	3.30e+08	3.30e+08	3.29e+08	3.29e+08	3.29e+08	3.26e+08	2.98e+08
Nb	91*	1.59e+07	1.13e+07	2.06e+06	2.67e+05	4.51e+03	7.59e+01	2.93e-11	0.00e+00
Nb	92	1.46e+04	1.46e+04	1.46e+04	1.46e+04	1.46e+04	1.46e+04	1.46e+04	1.46e+04
Nb	92*	3.44e+08	4.34e+07	1.32e+03	5.06e-03	7.45e-14	0.00e+00	0.00e+00	0.00e+00
Nb	93*	2.98e+07	2.99e+07	3.01e+07	3.03e+07	3.08e+07	3.13e+07	3.40e+07	4.09e+07
Nb	94	7.03e+07	7.03e+07	7.03e+07	7.03e+07	7.03e+07	7.03e+07	7.03e+07	7.01e+07
Nb	94*	9.60e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	95	1.12e+13	8.79e+12	2.03e+12	2.94e+11	5.70e+09	1.09e+08	1.07e-14	0.00e+00
Nb	95*	7.70e+10	5.96e+10	1.15e+10	1.59e+09	3.04e+07	5.83e+05	0.00e+00	0.00e+00
Nb	96	7.85e+12	3.28e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	97	1.13e+13	4.54e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	97*	3.64e+12	4.00e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	98	7.55e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	98*	3.47e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	99	3.98e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	99*	2.90e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	100	2.88e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	100*	1.02e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	101	1.34e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	102	6.50e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	103	1.97e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	104	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nb	105	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	90	9.85e+09	2.30e-29	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	91	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	91*	4.13e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	93	4.80e+07	4.80e+07	4.80e+07	4.80e+07	4.80e+07	4.80e+07	4.79e+07	4.70e+07
Mo	93*	2.06e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	99	1.21e+13	5.77e+09	1.18e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	101	5.67e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	102	3.67e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	103	1.71e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	104	7.98e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	105	4.33e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	106	1.18e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	107	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Mo	109	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	93	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	93*	1.41e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	94	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	94*	3.10e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	95	5.22e+11	1.26e+04	2.23e+03	2.80e+02	4.40e+00	0.00e+00	0.00e+00	0.00e+00
Tc	95*	4.37e+05	3.10e+05	5.49e+04	6.89e+03	1.09e+02	1.71e+00	4.12e-13	0.00e+00
Tc	96	1.26e+12	9.30e+09	1.80e-01	2.58e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	96*	2.70e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	97	2.37e+05	2.38e+05	2.38e+05	2.38e+05	2.38e+05	2.38e+05	2.38e+05	2.38e+05
Tc	97*	1.34e+08	1.09e+08	3.39e+07	8.38e+06	5.11e+05	3.12e+04	9.76e-05	0.00e+00
Tc	98	2.59e+05	2.59e+05	2.59e+05	2.59e+05	2.59e+05	2.59e+05	2.59e+05	2.59e+05
Tc	99	2.08e+07	2.13e+07	2.13e+07	2.13e+07	2.13e+07	2.13e+07	2.13e+07	2.13e+07

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Tc	99*	1.06e+13	5.59e+09	1.14e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	100	8.15e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	101	1.28e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	102	9.86e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	102*	1.32e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	103	5.87e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	104	4.07e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	105	2.51e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	106	1.03e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	107	5.61e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	108	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	109	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tc	110	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	94	3.72e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	95	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	97	3.05e+11	2.18e+08	3.37e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	103	1.10e+13	6.46e+12	4.39e+11	1.75e+10	2.77e+07	4.38e+04	1.09e-15	0.00e+00
Ru	105	7.34e+12	3.47e-37	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	106	9.23e+11	8.72e+11	6.56e+11	4.67e+11	2.36e+11	1.20e+11	1.01e+09	2.38e-18
Ru	107	2.77e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	108	1.43e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	109	6.30e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	109*	2.51e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	110	3.15e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	111	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ru	112	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	97	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	97*	5.29e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	98	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	98*	1.90e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	99	2.84e+11	7.70e+10	1.09e+08	4.21e+04	6.23e-03	9.24e-10	0.00e+00	0.00e+00
Rh	99*	3.06e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	100	6.40e+11	1.20e+08	7.78e-71	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	100*	9.64e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	101	1.05e+11	1.03e+11	9.44e+10	8.50e+10	6.89e+10	5.58e+10	1.28e+10	7.70e+01
Rh	101*	1.54e+08	1.21e+06	3.32e-05	3.37e-26	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	102	1.98e+11	1.94e+11	1.76e+11	1.56e+11	1.23e+11	9.68e+10	1.81e+10	8.13e+00
Rh	102*	3.49e+08	3.15e+08	1.89e+08	1.03e+08	3.02e+07	8.90e+06	1.70e+03	0.00e+00
Rh	103*	1.19e+13	6.72e+12	4.39e+11	1.74e+10	2.76e+07	4.37e+04	0.00e+00	0.00e+00
Rh	104	5.67e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	104*	1.62e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	105	1.31e+13	9.05e+06	6.90e-25	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	105*	2.08e+12	9.82e-38	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	106	6.74e+12	8.72e+11	6.56e+11	4.67e+11	2.36e+11	1.20e+11	1.01e+09	2.38e-18
Rh	106*	1.05e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	107	7.56e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	108	4.97e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	108*	1.05e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	109	3.08e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	109*	3.15e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	110	1.53e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	110*	3.15e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	111	8.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	112	4.92e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	113	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Rh	114	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	99	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	100	2.95e+10	9.11e+07	2.21e-05	1.65e-20	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	101	1.97e+11	2.72e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	103	9.09e+11	2.64e+11	5.29e+08	3.07e+05	1.04e-01	3.51e-08	0.00e+00	0.00e+00
Pd	105*	9.16e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	107	4.70e+05	4.71e+05	4.71e+05	4.71e+05	4.71e+05	4.71e+05	4.71e+05	4.71e+05
Pd	107*	9.10e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	109	7.37e+12	7.60e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	109*	5.78e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	111	3.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	111*	2.55e+07	1.10e-35	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	112	1.95e+12	7.64e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	113	1.07e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	113*	1.26e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	114	7.58e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	115	2.56e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	116	9.85e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	117	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pd	118	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	101	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	102	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	103	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	30 d	183d	1y	2y	3y	10 y	100 y
Ag	103*	5.46e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	104	1.77e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	104*	1.11e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	105	5.75e+11	3.46e+11	2.68e+10	1.25e+09	2.71e+06	5.89e+03	1.34e-15	0.00e+00
Ag	105*	5.56e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	106	1.30e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	106*	5.26e+09	4.39e+08	1.67e+03	5.32e-04	5.38e-17	1.08e-35	0.00e+00	0.00e+00
Ag	107*	7.11e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	108	9.00e+12	1.11e+07	1.10e+07	1.10e+07	1.09e+07	1.09e+07	1.05e+07	6.41e+06
Ag	108*	1.27e+08	1.27e+08	1.27e+08	1.26e+08	1.26e+08	1.25e+08	1.20e+08	7.37e+07
Ag	109*	7.75e+12	2.54e+11	2.02e+11	1.54e+11	8.91e+10	5.15e+10	1.12e+09	4.55e-13
Ag	110	2.35e+13	4.00e+09	2.62e+09	1.58e+09	5.74e+08	2.08e+08	1.73e+05	0.00e+00
Ag	110*	3.20e+11	2.94e+11	1.93e+11	1.16e+11	4.22e+10	1.53e+10	1.27e+07	3.04e-33
Ag	111	7.26e+12	4.33e+11	3.04e+05	1.27e-02	2.21e-17	0.00e+00	0.00e+00	0.00e+00
Ag	111*	3.39e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	112	5.25e+12	8.98e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	113	3.49e+12	5.72e-29	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	113*	1.99e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	114	2.50e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	114*	1.74e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	115	1.28e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	115*	6.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	116	6.50e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	116*	2.46e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	117	3.35e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	117*	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	118	5.62e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	118*	4.92e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	119	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ag	120	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	104	5.93e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	105	7.78e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	107	5.91e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	109	2.66e+11	2.54e+11	2.02e+11	1.54e+11	8.91e+10	5.15e+10	1.12e+09	4.55e-13
Cd	111*	4.74e+11	2.85e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	113	6.04e-05	6.07e-05	6.07e-05	6.07e-05	6.07e-05	6.07e-05	6.07e-05	6.07e-05
Cd	113*	3.74e+08	3.75e+08	3.67e+08	3.58e+08	3.41e+08	3.25e+08	2.30e+08	2.76e+06
Cd	115	3.35e+12	2.68e+08	7.02e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	115*	6.21e+10	3.88e+10	3.64e+09	2.13e+08	7.30e+05	2.50e+03	1.38e-14	0.00e+00
Cd	116*	1.24e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	117	1.43e+12	1.57e-76	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	117*	4.83e+10	3.86e-61	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	118	6.40e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	119	3.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	119*	6.50e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	120	2.56e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	121	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	121*	6.74e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	122	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	123	7.90e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	124	5.57e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cd	125	7.96e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	106	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	107	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	108	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109*	1.90e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	109#	1.47e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	110	6.40e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	110*	3.45e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	111	9.45e+11	5.64e+08	3.55e-08	1.33e-27	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	111*	6.62e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	112	1.79e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	112*	1.66e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	113*	3.67e+11	3.06e+11	1.22e+11	4.08e+10	4.52e+09	5.01e+08	1.03e+02	0.00e+00
In	114	2.34e+12	1.16e+09	1.38e+08	1.07e+07	6.42e+04	3.86e+02	0.00e+00	0.00e+00
In	114*	1.85e+09	1.21e+09	1.44e+08	1.11e+07	6.71e+04	4.03e+02	1.15e-13	0.00e+00
In	115	3.07e-03	3.12e-03	3.13e-03	3.13e-03	3.13e-03	3.13e-03	3.13e-03	3.13e-03
In	115*	3.35e+12	2.97e+08	4.02e+05	2.35e+04	8.06e+01	2.76e-01	0.00e+00	0.00e+00
In	116	2.28e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	116*	1.52e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	116#	8.17e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	117	2.95e+12	4.53e-76	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	117*	1.30e+12	6.50e-76	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118	2.10e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118*	7.98e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	118#	1.37e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	119	1.10e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
In	119*	3.04e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120	8.96e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120*	6.33e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	120#	5.23e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	121	3.65e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	121*	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122	2.36e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122*	9.38e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	122#	2.67e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	123	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	123*	6.98e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	124	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	124*	6.20e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	125	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	125*	3.01e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	126	1.98e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
In	126*	4.41e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	108	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	109	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	110	3.94e+10	2.09e-43	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	111	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	113	3.67e+11	3.06e+11	1.22e+11	4.07e+10	4.51e+09	5.00e+08	1.03e+02	0.00e+00
Sn	113*	1.21e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	117*	1.37e+10	2.92e+09	1.24e+06	1.13e+02	9.26e-07	7.62e-15	0.00e+00	0.00e+00
Sn	119*	5.66e+09	5.27e+09	3.68e+09	2.39e+09	1.01e+09	4.24e+08	1.00e+06	2.31e-35
Sn	120*	4.49e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	121	1.39e+12	1.37e+08	1.36e+08	1.35e+08	1.34e+08	1.32e+08	1.21e+08	3.89e+07
Sn	121*	1.77e+08	1.76e+08	1.75e+08	1.74e+08	1.72e+08	1.70e+08	1.56e+08	5.01e+07
Sn	123	2.25e+11	1.91e+11	8.45e+10	3.17e+10	4.47e+09	6.30e+08	6.95e+02	1.79e-74
Sn	123*	7.76e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	125	1.10e+11	1.24e+10	2.17e+05	4.31e-01	1.69e-12	1.58e-30	0.00e+00	0.00e+00
Sn	125*	1.20e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	126	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.89e+04
Sn	127	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	127*	3.17e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	128	2.77e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	128*	9.52e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	129	2.06e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	129*	2.12e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	130	4.18e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	130*	1.42e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sn	131	2.96e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	111	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	112	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	113	9.85e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	114	2.66e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	115	4.83e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	116	7.98e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	116*	2.01e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	117	1.34e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	117*	1.28e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	118	1.88e+12	1.25e+10	2.85e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	118*	1.23e+05	1.93e-39	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	119	2.46e+12	6.47e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	120	1.54e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	120*	3.54e+07	9.21e+05	1.01e-02	2.90e-12	2.37e-31	0.00e+00	0.00e+00	0.00e+00
Sb	121*	2.75e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	122	1.23e+12	5.12e+08	5.35e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	122*	6.34e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	124	4.18e+11	2.95e+11	5.10e+10	6.23e+09	9.30e+07	1.39e+06	2.28e-07	0.00e+00
Sb	124*	5.00e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	124#	1.25e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	125	4.29e+10	4.29e+10	3.87e+10	3.41e+10	2.65e+10	2.05e+10	3.47e+09	4.13e-01
Sb	126	1.87e+11	3.43e+10	6.90e+06	9.91e+03	9.66e+03	9.66e+03	9.65e+03	9.65e+03
Sb	126*	9.66e+07	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.90e+04	6.89e+04
Sb	126#	5.54e+07	4.62e+04	4.62e+04	4.62e+04	4.62e+04	4.62e+04	4.62e+04	4.62e+04
Sb	127	1.38e+11	5.88e+08	7.25e-04	3.82e-18	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	128	5.91e+10	2.91e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	128*	5.39e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	129	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	129*	3.89e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	130	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	130*	6.82e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	131	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	131*	2.00e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	132	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sb	132*	1.16e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	114	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Te	115	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	116	8.86e+10	8.91e-78	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	117	2.95e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	117*	1.27e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	118	4.14e+11	1.25e+10	2.85e+02	1.96e-07	9.27e-26	0.00e+00	0.00e+00	0.00e+00
Te	119	1.20e+12	2.72e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	119*	2.87e+07	3.24e+05	5.36e-05	1.00e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	121	1.73e+12	4.95e+11	9.47e+08	1.36e+07	2.54e+06	4.91e+05	0.00e+00	0.00e+00
Te	121*	6.85e+07	5.97e+07	3.01e+07	1.32e+07	2.56e+06	4.94e+05	4.97e+00	0.00e+00
Te	123	4.47e-02	4.48e-02	4.48e-02	4.48e-02	4.48e-02	4.48e-02	4.48e-02	4.48e-02
Te	123*	2.62e+08	2.20e+08	9.09e+07	3.16e+07	3.81e+06	4.60e+05	1.71e-01	0.00e+00
Te	125*	4.78e+09	6.34e+09	8.78e+09	8.25e+09	6.46e+09	5.01e+09	8.48e+08	1.01e-01
Te	127	5.30e+11	1.15e+10	4.16e+09	1.30e+09	1.28e+08	1.25e+07	0.00e+00	0.00e+00
Te	127*	1.27e+10	1.12e+10	4.25e+09	1.33e+09	1.30e+08	1.28e+07	1.11e+00	0.00e+00
Te	128*	1.77e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	129	1.27e+11	1.12e+09	4.84e+07	1.12e+06	5.97e+02	0.00e+00	0.00e+00	0.00e+00
Te	129*	3.26e+09	1.75e+09	7.54e+07	1.74e+06	9.31e+02	4.98e-01	6.18e-24	0.00e+00
Te	130*	1.92e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	131	4.87e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	131*	6.70e+08	3.35e+01	7.03e-36	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	132	9.85e+09	1.56e+07	1.32e-07	1.78e-24	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	133	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	133*	2.77e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	134	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Te	135	1.97e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	116	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	117	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	118	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	119	3.35e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	120	3.64e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	121	7.09e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	122	8.17e+11	2.42e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	123	1.23e+12	3.10e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	124	9.16e+11	6.01e+09	6.48e-02	4.59e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	125	1.33e+12	9.49e+11	1.64e+11	2.00e+10	2.97e+08	4.41e+06	7.03e-07	0.00e+00
I	126	8.02e+11	1.60e+11	4.81e+07	2.88e+03	1.03e-05	3.72e-14	2.86e-73	0.00e+00
I	128	4.85e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	129	7.88e+03	7.89e+03	7.89e+03	7.90e+03	7.90e+03	7.90e+03	7.90e+03	7.90e+03
I	130	1.49e+11	2.84e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	130*	9.20e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	131	2.07e+11	1.52e+10	3.01e+04	4.37e-03	9.24e-17	9.29e-31	0.00e+00	0.00e+00
I	132	1.08e+11	1.61e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	132*	3.08e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	133	2.95e+10	8.73e-01	1.09e-53	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	133*	2.84e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	134	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	134*	3.62e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	135	3.30e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	136	5.60e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
I	136*	7.56e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	119	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	120	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	121	1.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	122	1.87e+11	2.41e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	123	3.64e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	125	9.06e+11	9.94e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	125*	3.34e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	127	1.03e+12	5.79e+11	3.19e+10	9.84e+08	9.39e+05	8.95e+02	6.43e-19	0.00e+00
Xe	127*	1.33e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	129*	3.49e+08	3.28e+07	2.28e+02	1.50e-04	2.76e-17	0.00e+00	0.00e+00	0.00e+00
Xe	131*	2.37e+09	8.63e+08	1.69e+05	4.05e+00	2.34e-09	1.35e-18	1.36e-83	0.00e+00
Xe	133	1.18e+11	2.27e+09	4.08e+00	1.34e-10	1.43e-31	1.53e-52	0.00e+00	0.00e+00
Xe	133*	8.56e+08	9.62e+04	1.12e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	134*	3.38e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	135	3.27e+10	3.56e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	135*	3.28e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	137	1.04e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	138	3.97e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Xe	139	1.13e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	120	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	121	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	122	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	123	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	124	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	125	2.66e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	126	3.84e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	127	5.71e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	128	5.91e+11	3.64e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Cs	129	9.55e+11	1.41e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	130	4.43e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	131	1.09e+12	3.16e+11	7.22e+07	1.69e+03	7.59e-09	3.42e-20	0.00e+00	0.00e+00
Cs	132	2.66e+11	1.04e+10	8.61e+02	2.79e-06	2.91e-23	3.05e-40	0.00e+00	0.00e+00
Cs	134	2.21e+10	2.15e+10	1.87e+10	1.58e+10	1.13e+10	8.06e+09	7.66e+08	5.56e-05
Cs	134*	1.40e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	135	2.25e+04	2.26e+04	2.26e+04	2.26e+04	2.26e+04	2.26e+04	2.26e+04	2.26e+04
Cs	135*	8.92e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	136	5.92e+10	1.20e+10	3.93e+06	2.61e+02	1.15e-06	5.10e-15	0.00e+00	0.00e+00
Cs	136*	3.21e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	137	6.11e+08	6.10e+08	6.04e+08	5.97e+08	5.83e+08	5.70e+08	4.85e+08	6.06e+07
Cs	138	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	138*	4.07e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	139	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cs	140	4.92e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	125	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	126	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	127	1.77e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	128	2.07e+11	3.64e+07	4.99e-12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	129	4.43e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	129*	8.21e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	131	6.30e+11	1.06e+11	1.38e+07	3.03e+02	1.46e-07	7.02e-17	4.18e-82	0.00e+00
Ba	131*	1.43e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	133	1.84e+10	1.83e+10	1.78e+10	1.72e+10	1.61e+10	1.51e+10	9.52e+09	2.53e+07
Ba	133*	1.69e+08	3.95e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	135*	9.13e+07	2.13e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	136*	6.67e+09	1.34e+09	4.41e+05	2.93e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	137*	5.92e+08	5.76e+08	5.70e+08	5.64e+08	5.51e+08	5.38e+08	4.58e+08	5.72e+07
Ba	139	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	140	9.84e+09	1.89e+09	4.81e+05	2.35e+01	5.61e-08	1.34e-16	0.00e+00	0.00e+00
Ba	141	3.08e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	142	2.63e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ba	143	8.67e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	126	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	127	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	128	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	129	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	130	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	131	1.97e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	132	3.35e+11	6.31e-35	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	132*	6.13e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	133	4.04e+11	1.17e-33	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	134	6.80e+11	4.85e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	135	5.71e+11	1.97e+01	7.32e-56	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	136	3.84e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	136*	6.41e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	137	3.79e+06	3.80e+06	3.80e+06	3.80e+06	3.80e+06	3.80e+06	3.80e+06	3.80e+06
La	138	3.81e-01	3.81e-01	3.81e-01	3.81e-01	3.81e-01	3.81e-01	3.81e-01	3.81e-01
La	140	2.98e+10	2.18e+09	5.54e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	141	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	142	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	143	3.46e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	144	2.87e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
La	146	4.84e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	129	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	130	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	131	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	132	8.86e+10	2.35e-52	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	133	1.48e+11	2.35e-34	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	133*	2.65e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	134	3.74e+11	4.84e+08	1.50e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	135	3.05e+11	1.28e-01	8.32e-64	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	135*	1.33e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	136*	3.64e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	137	7.39e+11	3.42e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	137*	4.88e+07	2.09e+01	2.10e-31	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	139	4.06e+11	3.49e+11	1.62e+11	6.45e+10	1.03e+10	1.63e+09	4.17e+03	0.00e+00
Ce	139*	5.22e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	141	1.10e+11	5.74e+10	2.23e+09	4.54e+07	1.88e+04	7.78e+00	1.62e-23	0.00e+00
Ce	142	1.84e-07	1.84e-07	1.84e-07	1.84e-07	1.84e-07	1.84e-07	1.84e-07	1.84e-07
Ce	143	4.92e+10	1.14e+04	5.14e-30	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	144	2.55e+09	2.37e+09	1.63e+09	1.05e+09	4.31e+08	1.77e+08	3.52e+05	6.51e-30
Ce	145	9.38e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	146	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	147	1.96e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ce	148	4.76e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	130	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	132	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Pr	133	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	134	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	135	7.88e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	136	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	137	2.66e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	138	3.45e+11	4.89e-33	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	138*	2.27e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	139	5.91e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	140	6.30e+11	6.57e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	142	6.04e+10	2.12e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	142*	3.54e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	143	7.85e+10	1.79e+10	7.47e+06	6.64e+02	5.24e-06	4.14e-14	0.00e+00	0.00e+00
Pr	144	1.25e+10	2.37e+09	1.63e+09	1.05e+09	4.31e+08	1.77e+08	3.52e+05	0.00e+00
Pr	144*	1.12e+08	3.31e+07	2.29e+07	1.47e+07	6.03e+06	2.48e+06	4.93e+03	0.00e+00
Pr	145	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	146	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	147	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	148	7.46e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	148*	3.57e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	149	1.56e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pr	150	4.22e-12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	134	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	135	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	136	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	137	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	138	1.77e+11	4.87e-33	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	139	2.86e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	139*	7.60e+04	1.15e-35	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	140	3.35e+11	6.56e+08	1.64e-05	8.00e-22	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	140*	1.05e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	141	6.20e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	141*	8.51e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	144	1.31e-05	1.39e-05	1.72e-05	2.01e-05	2.35e-05	2.52e-05	2.68e-05	2.68e-05
Nd	145	2.82e-07	2.84e-07	2.95e-07	3.10e-07	3.47e-07	3.86e-07	6.44e-07	1.45e-06
Nd	147	2.95e+10	4.35e+09	2.91e+05	2.86e+00	2.77e-10	2.69e-20	0.00e+00	0.00e+00
Nd	149	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	151	4.79e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Nd	152	1.84e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	136	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	138	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	139	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	140	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	141	2.27e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	142	3.74e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	143	1.00e+11	9.25e+10	6.21e+10	3.85e+10	1.48e+10	5.70e+09	7.12e+06	0.00e+00
Pm	144	2.68e+10	2.53e+10	1.89e+10	1.33e+10	6.64e+09	3.31e+09	2.52e+07	0.00e+00
Pm	145	1.82e+09	1.94e+09	2.47e+09	2.89e+09	3.32e+09	3.45e+09	2.81e+09	8.29e+07
Pm	146	3.00e+09	2.97e+09	2.82e+09	2.65e+09	2.33e+09	2.06e+09	8.56e+08	1.08e+04
Pm	147	7.68e+09	7.79e+09	7.03e+09	6.16e+09	4.73e+09	3.63e+09	5.71e+08	2.69e-02
Pm	148	1.15e+10	2.41e+08	8.45e+05	3.94e+04	8.56e+01	2.87e-19	0.00e+00	0.00e+00
Pm	148*	3.43e+08	2.06e+08	1.60e+07	7.45e+05	1.62e+03	3.52e+00	8.07e-19	0.00e+00
Pm	149	2.03e+10	1.52e+06	2.83e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	149*	2.98e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	150	6.74e+07	6.86e-75	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	151	5.26e+03	1.02e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	152	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	152*	1.07e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	152#	9.22e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	153	7.91e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	154	7.57e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	154*	7.57e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	155	1.02e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pm	156	1.01e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	141	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	142	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	143	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	143*	3.91e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	145	4.06e+10	3.97e+10	2.91e+10	2.01e+10	9.52e+09	4.52e+09	2.47e+07	0.00e+00
Sm	146	3.03e+02	3.21e+02	3.44e+02	3.50e+02	3.55e+02	3.60e+02	3.82e+02	3.98e+02
Sm	147	3.98e-01	4.41e-01	4.88e-01	5.10e-01	5.45e-01	5.72e-01	6.48e-01	6.62e-01
Sm	148	2.19e-06	2.44e-06	2.87e-06	2.93e-06	2.94e-06	2.94e-06	2.94e-06	2.94e-06
Sm	149	2.66e-06	4.98e-06	1.13e-05	1.35e-05	1.42e-05	1.43e-05	1.43e-05	1.43e-05
Sm	151	7.33e+05	7.33e+05	7.30e+05	7.28e+05	7.22e+05	7.16e+05	6.79e+05	3.39e+05
Sm	153	6.45e+08	1.19e+04	1.97e-20	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	155	2.96e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	156	2.92e-02	1.46e-25	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Sm	157	8.38e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	142	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Eu	143	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	144	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	145	9.19e+10	2.65e+09	4.86e+01	2.57e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	146	7.47e+10	1.80e+10	1.97e+09	1.43e+08	7.54e+05	3.98e+03	0.00e+00	0.00e+00
Eu	147	1.06e+11	4.45e+10	5.42e+08	2.75e+06	7.09e+01	1.83e-03	0.00e+00	0.00e+00
Eu	148	3.85e+10	2.62e+10	3.78e+09	3.70e+08	3.56e+06	3.43e+04	2.61e-10	0.00e+00
Eu	149	8.33e+10	7.23e+10	2.35e+10	6.04e+09	3.98e+08	2.62e+07	1.40e-01	0.00e+00
Eu	150	1.30e+08	1.30e+08	1.29e+08	1.28e+08	1.25e+08	1.23e+08	1.07e+08	1.88e+07
Eu	150*	2.10e+08	9.26e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	152	2.84e+08	2.83e+08	2.77e+08	2.70e+08	2.56e+08	2.43e+08	1.69e+08	1.57e+06
Eu	152*	5.64e+09	1.79e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	152#	7.25e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	154	1.27e+07	1.26e+07	1.22e+07	1.17e+07	1.08e+07	9.96e+06	5.66e+06	3.98e+03
Eu	154*	1.28e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	155	1.25e+06	1.24e+06	1.17e+06	1.08e+06	9.33e+05	8.05e+05	2.85e+05	4.64e-01
Eu	156	8.00e+06	2.01e+06	1.92e+03	4.62e-01	2.67e-08	1.54e-15	0.00e+00	0.00e+00
Eu	157	6.90e+04	2.57e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	158	4.66e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	159	3.74e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Eu	160	2.69e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	144	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	145	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	145*	7.31e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	146	2.45e+10	1.58e+10	1.78e+09	1.29e+08	6.82e+05	3.60e+03	4.11e-13	0.00e+00
Gd	147	1.10e+10	1.96e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	148	1.84e+08	1.84e+08	1.84e+08	1.83e+08	1.81e+08	1.79e+08	1.68e+08	7.28e+07
Gd	149	7.55e+10	8.03e+09	1.03e+05	1.41e-01	2.65e-13	0.00e+00	0.00e+00	0.00e+00
Gd	150	8.80e+03	8.80e+03	8.80e+03	8.80e+03	8.80e+03	8.80e+03	8.80e+03	8.80e+03
Gd	151	3.33e+10	2.83e+10	1.21e+10	4.35e+09	5.64e+08	7.32e+07	4.52e+01	0.00e+00
Gd	152	1.11e-04	1.12e-04	1.12e-04	1.12e-04	1.12e-04	1.13e-04	1.15e-04	1.21e-04
Gd	153	4.34e+09	4.33e+09	2.80e+09	1.66e+09	5.81e+08	2.04e+08	1.33e+05	0.00e+00
Gd	155*	8.14e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	159	1.68e+02	2.65e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	161	1.79e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	162	5.11e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	163	6.75e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Gd	164	3.90e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	148	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	149	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	150	2.96e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	150*	2.15e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	151	3.83e+10	1.40e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	151*	2.39e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	152	2.95e+10	9.00e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	152*	7.96e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	153	3.92e+10	4.94e+06	1.27e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	154	9.87e+09	6.42e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	154*	1.84e+08	8.51e-17	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	154#	5.87e+07	1.31e-02	4.29e-51	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	155	1.99e+10	4.18e+08	1.02e+00	4.83e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	156	5.51e+07	1.08e+06	2.88e-03	1.51e-13	4.14e-34	0.00e+00	0.00e+00	0.00e+00
Tb	156*	1.18e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	156#	3.96e+07	4.35e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	157	1.70e+03	1.70e+03	1.70e+03	1.69e+03	1.69e+03	1.68e+03	1.63e+03	1.07e+03
Tb	158	1.50e+07	1.50e+07	1.49e+07	1.49e+07	1.48e+07	1.48e+07	1.43e+07	9.43e+06
Tb	158*	3.05e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	160	3.35e+06	2.51e+06	5.82e+05	1.01e+05	3.05e+03	9.18e+01	2.08e-09	0.00e+00
Tb	161	1.16e+05	5.51e+03	1.25e-03	1.35e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	162	1.55e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	163	1.66e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	164	8.64e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tb	165	5.10e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	151	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	152	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	153	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	154	3.05e+03	3.05e+03	3.05e+03	3.05e+03	3.05e+03	3.05e+03	3.05e+03	3.05e+03
Dy	155	2.00e+10	2.51e-12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	156	3.78e-12	3.78e-12	3.78e-12	3.78e-12	3.78e-12	3.78e-12	3.78e-12	3.78e-12
Dy	157	2.46e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	159	4.35e+09	3.76e+09	1.81e+09	7.53e+08	1.30e+08	2.26e+07	1.06e+02	0.00e+00
Dy	165	9.28e+07	1.35e-86	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	165*	5.94e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	166	2.99e+04	6.19e+01	2.03e-12	1.37e-28	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	167	3.33e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Dy	168	1.18e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	153	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	154	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	155	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Ho	158	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	158*	3.85e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	158#	1.21e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	159	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	159*	3.82e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	160	8.15e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	160*	6.10e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	160#	1.23e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	161	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	161*	5.10e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	162	6.89e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	162*	4.18e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	163	5.00e+06	5.00e+06	5.00e+06	5.00e+06	5.00e+06	5.00e+06	5.00e+06	4.93e+06
Ho	163*	3.92e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	164	1.12e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	164*	4.26e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	166	1.10e+09	7.40e+00	9.94e-42	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	166*	5.28e+03	5.28e+03	5.28e+03	5.28e+03	5.28e+03	5.27e+03	5.25e+03	4.99e+03
Ho	167	2.98e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	168	3.01e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	169	1.66e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	170	4.53e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ho	170*	4.53e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	155	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	159	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	160	8.21e+04	1.79e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	161	1.97e+10	1.23e-58	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	163	9.87e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	165	1.19e+11	9.42e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	167*	4.15e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	169	2.40e+06	2.50e+05	2.94e+00	3.61e-06	5.43e-18	0.00e+00	0.00e+00	0.00e+00
Er	171	2.37e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	172	1.38e+01	4.99e-04	2.41e-26	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	173	1.20e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Er	174	5.46e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	159	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	161	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	162	3.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	163	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	164	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	164*	8.60e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	165	1.19e+11	6.17e+03	1.54e-33	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	166	1.38e+11	2.19e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	167	1.87e+11	1.92e+10	2.10e+05	2.36e-01	2.97e-13	0.00e+00	0.00e+00	0.00e+00
Tm	168	1.14e+08	9.12e+07	2.93e+07	7.53e+06	4.97e+05	3.27e+04	1.77e-04	0.00e+00
Tm	170	1.00e+09	8.50e+08	3.74e+08	1.40e+08	1.95e+07	2.73e+06	2.82e+00	3.19e-77
Tm	171	5.31e+05	5.16e+05	4.44e+05	3.70e+05	2.58e+05	1.80e+05	1.44e+04	1.12e-10
Tm	172	4.88e+04	1.76e+01	8.85e-17	1.60e-37	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	173	7.02e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	174	1.59e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	175	8.50e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tm	176	4.93e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	158	5.32e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	161	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	162	2.96e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	163	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	164	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	165	1.19e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	166	1.38e+11	1.89e+07	7.37e-13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	167	1.87e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	169	4.43e+11	2.40e+11	8.87e+09	1.70e+08	6.25e+04	2.30e+01	2.08e-23	0.00e+00
Yb	169*	2.48e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	175	3.33e+06	2.21e+04	2.52e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	175*	3.02e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	176*	1.62e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	177	6.71e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	177*	1.94e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	178	2.75e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	179	4.70e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Yb	180	1.24e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	162	1.98e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	163	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	165	1.09e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	166	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	167	1.77e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	168	3.84e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	168*	8.43e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	169	4.33e+11	1.61e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Lu	169*	3.93e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	170	8.91e+11	3.66e+07	4.63e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	170*	1.91e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	171	1.44e+12	1.20e+11	3.27e+05	6.98e-02	3.18e-15	0.00e+00	0.00e+00	0.00e+00
Lu	171*	8.44e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	172	1.83e+11	1.62e+11	1.38e+11	1.15e+11	7.94e+10	5.48e+10	4.09e+09	1.32e-05
Lu	172*	5.10e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	173	3.40e+11	3.30e+11	2.67e+11	2.07e+11	1.25e+11	7.53e+10	2.18e+09	3.52e-11
Lu	174	1.10e+09	1.11e+09	1.11e+09	1.04e+09	8.71e+08	7.11e+08	1.64e+08	1.08e+00
Lu	174*	1.74e+09	1.50e+09	7.14e+08	2.93e+08	4.92e+07	8.28e+06	3.15e+01	0.00e+00
Lu	176	6.81e-03	6.81e-03	6.81e-03	6.81e-03	6.81e-03	6.81e-03	6.81e-03	6.81e-03
Lu	176*	5.75e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	177	2.95e+08	1.29e+07	1.62e+04	7.36e+03	1.53e+03	3.16e+02	0.00e+00	0.00e+00
Lu	177*	1.62e+05	1.42e+05	7.38e+04	3.36e+04	6.96e+03	1.44e+03	2.37e-02	0.00e+00
Lu	178	3.86e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	178*	1.50e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	179	2.18e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	180	1.80e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	181	7.90e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lu	182	1.96e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	162	5.91e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	163	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	165	6.01e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	166	7.87e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	167	1.38e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	168	3.05e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	169	3.94e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	170	8.62e+11	1.77e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	171	1.42e+12	1.20e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	172	1.65e+11	1.60e+11	1.37e+11	1.14e+11	7.86e+10	5.43e+10	4.05e+09	1.31e-05
Hf	173	2.20e+12	1.66e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	174	3.47e-04	3.47e-04	3.47e-04	3.47e-04	3.47e-04	3.47e-04	3.47e-04	3.47e-04
Hf	175	2.79e+12	2.08e+12	4.61e+11	7.56e+10	2.03e+09	5.46e+07	5.53e-04	0.00e+00
Hf	177*	6.36e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	177#	2.76e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	178*	1.43e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	178#	5.84e+02	5.83e+02	5.77e+02	5.71e+02	5.58e+02	5.46e+02	4.67e+02	6.24e+01
Hf	179*	1.05e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	179#	1.52e+08	6.57e+07	9.83e+05	6.36e+03	2.67e-01	1.12e-05	2.54e-36	0.00e+00
Hf	180*	4.99e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	181	3.24e+07	1.97e+07	1.64e+06	8.26e+04	2.11e+02	5.38e-01	2.72e-27	0.00e+00
Hf	182	4.14e-04	4.14e-04	4.14e-04	4.14e-04	4.14e-04	4.14e-04	4.14e-04	4.14e-04
Hf	182*	8.05e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	183	4.82e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	184	1.73e+01	1.10e-59	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	185	8.30e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	186	2.02e-02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hf	187	7.36e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	165	4.04e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	166	1.96e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	167	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	168	1.58e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	169	2.17e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	170	7.63e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	171	1.26e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	172	1.33e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	173	2.08e+12	1.08e-59	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	174	3.00e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	175	3.91e+12	5.72e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	176	5.65e+12	4.59e-15	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	177	7.87e+12	1.07e+09	3.91e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	178	9.29e+12	3.49e+12	2.66e+10	7.66e+07	6.37e+02	0.00e+00	0.00e+00	0.00e+00
Ta	178*	5.32e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	179	1.54e+12	1.49e+12	1.27e+12	1.05e+12	7.19e+11	4.91e+11	3.42e+10	4.48e-05
Ta	180	1.00e+11	1.36e-16	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	180*	3.55e-06	3.55e-06	3.55e-06	3.55e-06	3.55e-06	3.55e-06	3.55e-06	3.55e-06
Ta	182	4.75e+09	3.96e+09	1.58e+09	5.25e+08	5.81e+07	6.43e+06	1.31e+00	0.00e+00
Ta	182*	1.02e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	182#	1.58e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	183	5.57e+09	9.05e+07	9.27e-02	1.54e-12	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	184	1.31e+06	8.74e-20	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	185	2.00e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	186	1.18e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	187	2.58e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ta	188	3.41e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	166	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	167	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	168	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
W	169	5.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	170	5.07e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	171	8.90e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	172	9.26e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	173	1.74e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	174	2.71e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	175	3.59e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	176	5.42e+12	1.54e-84	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	177	7.73e+12	4.11e-86	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	178	9.20e+12	3.49e+12	2.66e+10	7.66e+07	6.37e+02	5.30e-03	0.00e+00	0.00e+00
W	179	1.28e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	179*	2.09e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	181	1.10e+13	9.34e+12	3.91e+12	1.38e+12	1.70e+11	2.11e+10	9.42e+03	1.21e-87
W	183*	4.33e+10	4.53e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	185	1.34e+10	1.01e+10	2.48e+09	4.59e+08	1.58e+07	5.42e+05	3.06e-05	0.00e+00
W	185*	1.63e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	187	1.92e+08	1.32e-01	1.20e-47	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	188	6.96e+09	5.14e+09	1.12e+09	1.82e+08	4.74e+06	1.24e+05	1.02e-06	0.00e+00
W	189	2.75e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	190	2.17e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	191	2.92e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
W	192	6.49e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	169	3.05e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	170	2.02e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	171	5.06e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	172	2.66e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	173	9.88e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	174	1.64e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	175	2.61e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	176	4.58e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	177	7.02e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	178	8.77e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	179	1.24e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	180	1.54e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	181	2.17e+13	2.45e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	182	2.48e+13	1.43e+10	9.14e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	182*	1.29e+09	7.21e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	183	2.10e+13	1.57e+13	3.48e+12	5.71e+11	1.54e+10	4.13e+08	4.22e-03	0.00e+00
Re	184	2.56e+11	1.48e+11	1.07e+10	1.11e+09	1.71e+08	3.70e+07	8.28e+02	0.00e+00
Re	184*	3.76e+09	3.31e+09	1.75e+09	8.14e+08	1.76e+08	3.82e+07	8.55e+02	1.40e-57
Re	186	3.62e+11	1.39e+09	1.01e-03	0.00e+00	4.45e+01	7.19e+01	7.19e+01	7.18e+01
Re	186*	7.19e+01	7.19e+01	7.19e+01	7.19e+01	7.19e+01	7.19e+01	7.19e+01	7.19e+01
Re	187	9.24e-02	9.24e-02	9.24e-02	9.24e-02	9.24e-02	9.24e-02	9.24e-02	9.24e-02
Re	188	2.68e+10	5.20e+09	1.14e+09	1.84e+08	4.79e+06	1.25e+05	0.00e+00	0.00e+00
Re	188*	1.44e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	189	9.86e+09	9.57e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	190	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	190*	1.16e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	191	8.16e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	192	1.01e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	193	6.72e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	194	2.73e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Re	195	7.03e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	172	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	173	3.25e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	174	7.32e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	175	1.17e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	176	2.72e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	177	4.68e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	178	6.71e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	179	1.08e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	180	1.41e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	181	2.08e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	181*	2.30e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	182	2.41e+13	3.03e+03	5.21e-47	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	183	2.95e+13	4.22e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	183*	3.43e+08	2.44e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	185	2.94e+13	2.37e+13	7.69e+12	1.99e+12	1.33e+11	8.92e+09	5.38e+01	0.00e+00
Os	186	6.55e-03	6.61e-03	6.61e-03	6.61e-03	6.61e-03	6.61e-03	6.61e-03	6.61e-03
Os	189*	5.82e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	190*	1.70e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	191	7.94e+10	2.03e+10	2.14e+07	5.79e+03	4.22e-04	3.08e-11	0.00e+00	0.00e+00
Os	191*	1.66e+09	3.17e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	192*	1.08e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	193	9.88e+09	6.51e+02	5.45e-34	3.01e-77	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	194	1.65e+04	1.63e+04	1.56e+04	1.47e+04	1.31e+04	1.17e+04	5.19e+03	1.58e-01
Os	195	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	196	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Os	197	2.09e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	198	1.34e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Os	199	2.62e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	173	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	174	1.72e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	175	3.39e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	176	8.81e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	177	2.02e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	178	3.62e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	179	6.65e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	180	9.92e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	181	1.68e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	182	2.07e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	183	2.70e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	184	3.51e+13	8.62e-61	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	185	4.33e+13	7.40e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	186	5.28e+13	4.10e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	186*	1.66e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	187	6.43e+13	9.04e-08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	188	7.57e+13	1.12e+13	3.52e+08	1.41e+03	3.67e-61	0.00e+00	0.00e+00	0.00e+00
Ir	189	8.82e+13	1.86e+13	6.23e+09	4.25e+05	1.97e-03	9.17e-12	4.28e-70	0.00e+00
Ir	190	1.12e+12	1.88e+11	2.42e+07	5.22e+02	2.44e-07	1.13e-16	5.42e-82	0.00e+00
Ir	190*	1.77e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	190#	7.34e+08	2.01e-60	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	191*	4.94e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	191#	3.58e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	192	3.77e+12	2.83e+12	6.78e+11	1.22e+11	4.17e+09	3.38e+08	2.06e+08	1.59e+08
Ir	192*	5.96e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	192#	2.12e+08	2.12e+08	2.11e+08	2.11e+08	2.11e+08	2.10e+08	2.06e+08	1.59e+08
Ir	193*	1.79e+11	2.47e+10	1.17e+06	7.64e+00	3.26e-10	0.00e+00	0.00e+00	0.00e+00
Ir	194	2.34e+11	1.62e+04	1.54e+04	1.47e+04	1.31e+04	1.17e+04	5.19e+03	0.00e+00
Ir	194*	3.47e+08	3.07e+08	1.66e+08	7.92e+07	1.81e+07	4.12e+06	1.33e+02	0.00e+00
Ir	195	1.08e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	195*	1.19e+08	3.35e-50	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	196	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	196*	3.53e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	197	6.89e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	197*	3.59e+04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	198	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	199	7.23e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ir	200	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	176	8.34e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	177	4.16e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	178	9.33e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	179	2.41e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	180	4.29e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	181	9.43e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	182	1.29e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	183	1.96e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	184	2.80e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	185	3.71e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	186	4.77e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	187	6.03e+13	2.17e-81	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	188	7.29e+13	9.27e+12	2.92e+08	1.17e+03	1.88e-08	3.01e-19	0.00e+00	0.00e+00
Pt	189	8.64e+13	6.98e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	190	3.84e+01	3.84e+01	3.84e+01	3.84e+01	3.84e+01	3.84e+01	3.84e+01	3.84e+01
Pt	191	1.13e+14	8.14e+10	1.34e-05	1.60e-24	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	193	6.61e+11	6.66e+11	6.62e+11	6.57e+11	6.48e+11	6.39e+11	5.80e+11	1.67e+11
Pt	193*	3.17e+10	2.47e+08	6.33e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	195*	2.69e+09	1.44e+07	5.67e-05	7.62e-19	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	197	6.31e+11	6.85e-01	5.31e-61	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	197*	6.38e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	199	3.45e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	199*	2.18e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	200	2.36e+11	7.12e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	201	1.77e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pt	202	6.89e+10	5.87e+05	1.98e-20	1.76e-72	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	177	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	178	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	179	2.86e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	180	6.26e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	181	2.98e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	182	4.43e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	183	8.56e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	184	1.46e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	185	2.31e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	186	3.34e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	187	4.72e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Au	188	6.15e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	189	7.77e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	190	9.23e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	191	1.06e+14	1.25e-57	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	191*	1.85e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	192	1.26e+14	2.71e-29	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	192*	9.01e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	193	1.40e+14	5.44e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	193*	3.62e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	194	1.21e+13	7.13e+10	7.12e+10	7.12e+10	7.11e+10	7.10e+10	7.03e+10	6.24e+10
Au	194*	4.87e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	194#	4.28e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	195	6.81e+13	6.12e+13	3.47e+13	1.76e+13	4.51e+12	1.16e+12	8.46e+07	0.00e+00
Au	195*	1.08e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	196	7.96e+12	2.66e+11	1.02e+04	1.31e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	196*	2.19e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	196#	1.83e+09	4.69e-14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	197*	1.85e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	198	7.38e+12	3.07e+09	3.02e-08	1.23e-28	2.02e-69	0.00e+00	0.00e+00	0.00e+00
Au	198*	1.34e+10	1.44e+06	1.68e-14	2.11e-38	3.31e-86	0.00e+00	0.00e+00	0.00e+00
Au	199	4.41e+12	5.46e+09	1.35e-05	4.15e-23	3.90e-58	0.00e+00	0.00e+00	0.00e+00
Au	200	2.91e+12	7.61e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	200*	2.82e+07	5.44e-05	7.50e-64	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	201	2.13e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	202	1.45e+12	5.87e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	203	9.85e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Au	204	5.71e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	180	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	181	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	182	6.01e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	183	1.49e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	184	3.40e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	185	8.45e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	186	1.46e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	187	2.41e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	188	3.69e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	189	5.37e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	190	6.90e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	191	8.51e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	192	1.08e+14	9.78e-32	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	193	1.24e+14	2.74e-45	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	193*	8.49e+08	2.38e-10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	194	7.12e+10	7.12e+10	7.12e+10	7.12e+10	7.11e+10	7.10e+10	7.03e+10	6.24e+10
Hg	195	1.77e+14	4.09e+05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	195*	1.04e+11	5.76e+05	2.25e-21	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	197	2.74e+14	1.06e+11	7.21e-07	1.88e-27	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	197*	2.66e+12	1.67e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	199*	1.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	203	1.24e+13	7.91e+12	8.21e+11	5.43e+10	2.38e+08	1.04e+06	3.21e-11	0.00e+00
Hg	205	1.04e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	206	3.24e+12	1.94e+00	1.92e+00	1.89e+00	1.83e+00	1.78e+00	1.43e+00	8.71e-02
Hg	207	6.80e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	208	7.25e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Hg	209	4.73e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	183	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	184	2.86e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	185	9.55e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	186	2.47e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	187	5.90e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	188	1.16e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	189	2.25e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	190	3.29e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	191	4.69e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	192	6.71e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	193	8.46e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	194	1.20e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	195	1.41e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	196	1.70e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	197	2.02e+14	7.40e-65	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	197*	2.91e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	198	2.42e+14	7.15e-28	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	198*	5.06e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	199	2.89e+14	1.47e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	200	3.52e+14	6.61e+06	4.77e-36	1.41e-86	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	201	4.32e+14	4.79e+11	3.88e-04	3.11e-22	2.00e-58	0.00e+00	0.00e+00	0.00e+00
Tl	202	8.14e+13	1.46e+13	4.62e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09
Tl	204	5.26e+12	5.18e+12	4.80e+12	4.38e+12	3.65e+12	3.04e+12	8.41e+11	5.73e+04
Tl	206	9.18e+13	1.41e+07	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Tl	206*	7.99e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	207	7.95e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	207*	3.72e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	208	2.03e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	209	9.58e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tl	210	2.63e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	185	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	186	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	187	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	188	8.27e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	189	2.44e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	190	6.51e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	191	1.16e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	192	2.30e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	193	3.14e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	194	5.81e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	195	7.42e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	196	9.96e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	197	1.28e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	198	1.62e+14	3.48e-78	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	199	2.09e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	199*	1.52e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	200	2.72e+14	1.79e+04	1.18e-47	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	201	3.51e+14	1.18e-09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	201*	2.80e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	202	2.02e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09	2.02e+09
Pb	202*	4.02e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	203	5.82e+14	3.89e+10	2.38e-11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	203*	1.03e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	203#	4.02e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	204	1.58e-03	1.59e-03	1.60e-03	1.61e-03	1.63e-03	1.65e-03	1.72e-03	1.75e-03
Pb	204*	9.36e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	205	1.50e+07	1.58e+07	1.61e+07	1.61e+07	1.61e+07	1.61e+07	1.61e+07	1.61e+07
Pb	207*	4.83e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	209	3.81e+13	1.79e-54	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Pb	210	1.03e+08	1.02e+08	1.01e+08	9.95e+07	9.64e+07	9.35e+07	7.52e+07	4.59e+06
Pb	211	4.54e+03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	189	1.97e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	190	1.48e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	191	5.32e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	192	1.68e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	193	4.21e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	194	9.43e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	195	1.64e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	196	2.65e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	197	3.90e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	198	5.04e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	199	7.33e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	200	1.03e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	201	1.39e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	202	1.77e+14	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	203	2.27e+14	5.44e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	204	2.96e+14	9.02e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	205	3.92e+14	9.93e+13	1.01e+11	2.59e+07	1.71e+00	1.13e-07	0.00e+00	0.00e+00
Bi	206	5.22e+14	2.18e+13	3.74e+07	5.84e-02	1.43e-19	0.00e+00	0.00e+00	0.00e+00
Bi	206*	2.87e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	207	5.16e+12	5.15e+12	5.10e+12	5.05e+12	4.94e+12	4.83e+12	4.16e+12	5.99e+11
Bi	207*	2.16e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Bi	208	7.83e+08	7.83e+08	7.83e+08	7.83e+08	7.83e+08	7.83e+08	7.83e+08	7.83e+08
Bi	209	3.19e+00	3.19e+00	3.19e+00	3.19e+00	3.19e+00	3.19e+00	3.19e+00	3.19e+00
Bi	210	2.70e+14	4.08e+12	1.01e+08	9.95e+07	9.65e+07	9.35e+07	7.53e+07	4.59e+06
Bi	210*	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06	8.73e+06
Bi	211	8.48e+08	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	192	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	193	2.95e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	194	1.58e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	195	4.43e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	196	1.38e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	197	3.17e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	198	5.97e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	199	9.02e+12	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	200	1.23e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	201	1.58e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	202	1.79e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	203	1.87e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	204	1.98e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	205	2.01e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	206	2.00e+13	1.83e+12	1.12e+07	6.33e+00	2.00e-12	6.35e-25	0.00e+00	0.00e+00

		Initial	**30 d**	**183d**	**1y**	**2y**	**3y**	**10 y**	**100 y**
Po	207	2.07e+13	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	207*	6.54e+07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	208	1.20e+12	1.17e+12	1.06e+12	9.43e+11	7.42e+11	5.85e+11	1.10e+11	4.91e+01
Po	209	2.26e+10	2.26e+10	2.25e+10	2.25e+10	2.23e+10	2.22e+10	2.11e+10	1.15e+10
Po	210	1.19e+14	1.11e+14	5.17e+13	2.07e+13	3.32e+12	5.33e+11	7.80e+07	4.67e+06
Po	211	6.21e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Po	211*	7.68e+06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	197	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	198	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	199	3.94e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	200	4.92e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	201	5.91e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	202	1.28e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	203	2.46e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	204	2.95e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	205	2.36e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	206	3.25e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	207	1.67e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	208	1.97e+11	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	209	8.86e+10	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
At	211	9.85e+09	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Total		**1.15e+16**	**4.97e+14**	**1.29e+14**	**5.88e+13**	**2.09e+13**	**1.27e+13**	**6.29e+12**	**9.24e+11**

Annex C. SNT results

Table C1. The contribution of different parts of the neutron and proton spectra to the nuclide production in irradiated LBE (%).

Nuclide[†]	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Po 210	1.384+02	99.96	0.03	0	0.007	<0.001
Po 209	3.726+04	0.004	<0.001	0	11.8	88.2
Po 208	1.070+03	<0.001	<0.001	0	66.6	33.4
Po 207	2.417-01	<0.001	<0.001	0	41.8	58.2
Po 206	8.800+00	<0.001	<0.001	0	56.5	43.5
Po 205	6.917-02	<0.001	<0.001	0	51.9	48.1
Po 204	1.471-01	<0.001	<0.001	0	65.0	35.0
Po 203	2.549-02	0	<0.001	0	45.3	54.7
Po 202	3.104-02	0	<0.001	0	44.5	55.5
Po 201	1.062-02	0	<0.001	0	19.1	80.9
Po 201m	6.181-03	0	<0.001	0	33.2	66.8
Po 200	7.986-03	0	<0.001	0	17.8	82.2
Bi 210	5.012+00	99.97	0.03	0	0	0
Bi 210m	1.096+09	99.92	0.08	0	0	0
Bi 208	1.344+08	73.1	15.2	1.3	1.8	8.6
Bi 207	1.160+04	10.6	66.9	2.0	7.5	13.0
Bi 206	6.243+00	<0.001	62.7	2.6	11.6	23.1
Bi 205	1.531+01	<0.001	48.4	3.7	17.6	30.2
Bi 204	4.675-01	<0.001	41.8	4.7	22.6	31.0
Bi 203	4.900-01	<0.001	30.8	5.3	20.0	43.9
Bi 202	7.167-02	<0.001	20.6	5.5	18.2	55.7
Bi 201	7.500-02	<0.001	23.4	10.8	15.4	50.5
Bi 201m	4.104-02	<0.001	3.3	0	12.5	84.2
Bi 200	2.528-02	0	8.8	8.9	12.0	70.3
Bi 200m	2.153-02	0	9.4	0	5.5	85.1
Bi 199	1.875-02	0	12.5	15.0	15.0	57.5
Bi 199m	1.715-02	0	0.6	0	2.0	97.4
Bi 198	7.153-03	0	2.2	21.4	18.5	57.9
Bi 198m	8.056-03	0	10.8	0	<0.001	89.2
Bi 197	6.458-03	0	5.0	21.3	14.0	59.8
Pb 209	1.355-01	38.2	59.3	2.4	0	0
Pb 205	5.588+09	24.6	45.7	3.2	7.9	18.6
Pb 204m	4.688-02	4.2	37.7	1.2	5.7	51.3
Pb 203	2.162+00	2.0	46.5	6.5	12.6	32.4
Pb 202	1.936+07	0.05	35.5	7.6	12.2	44.6
Pb 202m	1.488-01	0.01	56.1	0	<0.001	43.9
Pb 201	3.917-01	<0.001	28.5	9.0	10.8	51.7
Pb 200	8.958-01	<0.001	21.8	10.7	8.9	58.5
Pb 199	6.250-02	<0.001	13.5	15.3	8.6	62.7
Pb 199m	8.472-03	<0.001	28.9	5.7	5.7	59.8
Pb 198	1.000-01	<0.001	14.7	15.3	6.5	63.4
Pb 197	5.556-03	0	9.5	23.5	4.8	62.2
Pb 197m	2.986-02	0	4.2	8.7	7.6	79.5
Pb 196	2.569-02	0	5.3	17.1	4.0	73.6

[†] for all nuclides shown in the table contributions of different particle energy ranges can be approximately considered as additive values.

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Pb 195	1.042-02	0	3.2	29.6	2.5	64.8
Pb 195m	1.042-02	0	0.3	6.3	3.3	90.1
Pb 194	8.333-03	0	0.8	18.7	1.6	78.9
Tl 204	1.384+03	0.03	53.0	9.1	1.6	36.2
Tl 202	1.224+01	0.002	44.8	10.6	1.4	43.1
Tl 201	3.041+00	<0.001	28.7	9.4	9.0	52.8
Tl 200	1.088+00	<0.001	22.4	10.8	7.9	58.9
Tl 199	3.092-01	<0.001	16.3	15.5	7.1	61.2
Tl 198	2.208-01	<0.001	14.2	16.4	5.6	63.8
Tl 198m	7.792-02	<0.001	21.3	0	1.4	77.2
Tl 197	1.183-01	<0.001	8.2	16.9	4.4	70.5
Tl 196	7.667-02	0	4.4	19.4	3.4	72.8
Tl 196m	5.875-02	0	12.8	0	2.3	85.0
Tl 195	4.833-02	0	2.7	17.8	2.3	77.1
Tl 194	2.292-02	0	1.6	21.3	1.8	75.3
Tl 194m	2.278-02	0	0.03	0	<0.001	99.97
Tl 193	1.514-02	0	0.4	18.9	0.8	79.9
Tl 192	6.667-03	0	0.2	24.1	0.5	75.2
Tl 192m	7.500-03	0	0.2	0	<0.001	99.8
Tl 191	1.389-02	0	0.010	31.1	0.05	68.9
Hg 206	5.660-03	0.1	20.4	25.0	0.1	54.3
Hg 203	4.660+01	1.5	30.5	14.1	0.1	53.8
Hg 199m	2.924-02	<0.001	30.0	0	0.4	69.6
Hg 197	2.692+00	<0.001	8.6	16.3	4.1	71.0
Hg 197m	9.958-01	<0.001	20.7	0	0.5	78.8
Hg 195	4.125-01	<0.001	3.1	17.3	2.1	77.5
Hg 195m	1.733+00	<0.001	12.5	0	1.5	86.0
Hg 194	1.622+05	<0.001	2.0	15.7	1.3	80.9
Hg 193	1.583-01	<0.001	0.6	17.6	0.7	81.0
Hg 193m	4.917-01	<0.001	4.8	<0.001	0.9	94.3
Hg 192	2.021-01	<0.001	0.7	14.7	0.4	84.2
Hg 191	3.403-02	0	0.07	26.6	0.2	73.2
Hg 191m	3.528-02	0	0.4	0.1	0.1	99.3
Hg 190	1.389-02	0	0.1	13.0	0.03	86.8
Hg 189	5.278-03	0	0.001	25.5	0.01	74.5
Hg 189m	5.972-03	0	0.04	0.07	0.003	99.9
Au 201	1.806-02	<0.001	22.1	10.7	0.008	67.2
Au 200	3.361-02	<0.001	21.6	13.8	0.02	64.6
Au 200m	7.792-01	<0.001	15.5	0	<0.001	84.5
Au 199	3.139+00	<0.001	13.5	9.1	0.03	77.4
Au 198m	2.300+00	<0.001	0.001	0	<0.001	~100.
Au 196	6.183+00	<0.001	5.6	5.7	0.1	88.7
Au 196m2	4.000-01	<0.001	0.004	0	<0.001	~100.
Au 195	1.861+02	<0.001	3.4	16.6	2.1	78.0
Au 194	1.584+00	<0.001	3.6	4.7	0.2	91.5
Au 193	7.354-01	<0.001	1.1	15.6	0.7	82.6
Au 192	2.058-01	<0.001	0.7	12.4	0.3	86.6
Au 191	1.325-01	0	0.2	12.1	0.1	87.5
Au 190	2.972-02	0	0.1	11.9	0.05	87.9
Au 189	1.993-02	0	0.009	21.2	0.02	78.8
Au 188	6.139-03	0	0.005	10.9	0.006	89.0
Au 187	5.833-03	0	<0.001	11.7	0.002	88.3
Au 186	7.431-03	0	<0.001	10.1	<0.001	89.9
Au 175	7.000+01	0	0	0	<0.001	100.
Pt 202	1.833+00	<0.001	0.05	<0.001	<0.001	99.95
Pt 200	5.208-01	<0.001	3.6	7.1	<0.001	89.3
Pt 199	2.139-02	<0.001	15.9	6.0	<0.001	78.1
Pt 197	8.288-01	<0.001	13.8	7.1	0.002	79.2
Pt 197m	6.618-02	<0.001	20.2	0	0.002	79.8
Pt 195m	4.100+00	<0.001	14.2	0	0.02	85.8

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Pt 193	1.826+04	<0.001	1.1	15.6	0.7	82.6
Pt 193m	4.340+00	<0.001	5.8	0.02	0.07	94.1
Pt 191	2.802+00	<0.001	0.3	12.0	0.1	87.6
Pt 189	4.529-01	0	0.04	9.1	0.02	90.8
Pt 188	1.020+01	0	0.02	10.4	0.008	89.5
Pt 187	9.792-02	0	0.007	11.1	0.002	88.9
Pt 186	8.667-02	0	0.002	8.7	<0.001	91.3
Pt 185	4.924-02	0	<0.001	10.1	<0.001	89.9
Pt 185m	2.292-02	0	<0.001	8.1	<0.001	91.9
Pt 184	1.201-02	0	<0.001	9.1	<0.001	90.9
Pt 183	4.514-03	0	<0.001	9.9	<0.001	90.1
Ir 197m	6.181-03	<0.001	0.08	0	<0.001	99.92
Ir 196m	5.833-02	<0.001	0.04	0	<0.001	99.96
Ir 195	1.042-01	<0.001	0.4	6.3	<0.001	93.3
Ir 195m	1.583-01	<0.001	1.2	0	<0.001	98.8
Ir 194	8.042-01	<0.001	1.9	5.2	<0.001	92.9
Ir 194m2	1.710+02	0	0	0	<0.001	100.
Ir 192m2	8.802+04	<0.001	1.1	0	0.003	98.9
Ir 190m2	1.286-01	0	0.9	0	<0.001	99.1
Ir 189	1.320+01	<0.001	0.04	9.1	0.02	90.9
Ir 188	1.729+00	0	0.02	10.3	0.008	89.6
Ir 187	4.375-01	0	0.008	10.9	0.002	89.1
Ir 186	6.933-01	0	0.004	8.3	0.001	91.7
Ir 186m	8.000-02	0	0.002	8.6	<0.001	91.4
Ir 185	6.000-01	0	<0.001	8.3	<0.001	91.7
Ir 184	1.288-01	0	<0.001	8.3	<0.001	91.7
Ir 183	4.028-02	0	<0.001	6.9	<0.001	93.1
Ir 182	1.042-02	0	<0.001	6.6	<0.001	93.4
Os 196	2.424-02	<0.001	<0.001	<0.001	<0.001	~100.
Os 195	4.514-03	<0.001	0.02	<0.001	<0.001	99.98
Os 194	2.191+03	<0.001	0.7	<0.001	<0.001	99.3
Os 193	1.255+00	<0.001	0.2	<0.001	<0.001	99.8
Os 191	1.530+01	<0.001	0.8	0.002	<0.001	99.2
Os 191m	5.458-01	<0.001	0.04	0	<0.001	99.96
Os 190m	6.875-03	<0.001	0.9	0	<0.001	99.1
Os 189m	2.421-01	<0.001	0.04	9.0	0.02	90.9
Os 185	9.380+01	0	<0.001	8.3	<0.001	91.7
Os 183	5.417-01	0	<0.001	6.9	<0.001	93.1
Os 183m	4.125-01	0	<0.001	6.7	<0.001	93.3
Os 182	9.208-01	0	<0.001	6.3	<0.001	93.7
Os 181	7.292-02	0	<0.001	8.3	<0.001	91.7
Os 180	1.493-02	0	<0.001	6.4	<0.001	93.6
Os 179	4.514-03	0	<0.001	6.3	<0.001	93.7
Re 191	6.736-03	<0.001	0.5	0.002	0.004	99.5
Re 190m	1.333-01	<0.001	0.2	0	<0.001	99.8
Re 189	1.012+00	<0.001	0.1	0.008	<0.001	99.9
Re 188	7.075-01	0	0.1	0.03	<0.001	99.8
Re 188m	1.291-02	0	0.08	0	<0.001	99.92
Re 186m	6.940+07	0	0.01	0	<0.001	99.99
Re 183	7.000+01	0	<0.001	6.8	<0.001	93.2
Re 182	2.667+00	0	<0.001	6.3	<0.001	93.7
Re 182m	5.292-01	0	<0.001	0	<0.001	~100.
Re 181	8.292-01	0	<0.001	7.8	<0.001	92.2
Re 179	1.354-02	0	<0.001	6.0	<0.001	94.0
Re 178	9.167-03	0	<0.001	5.8	<0.001	94.2
Re 177	9.722-03	0	<0.001	5.9	<0.001	94.1
W 190	2.083-02	<0.001	0.002	<0.001	<0.001	~100.
W 189	7.431-03	0	<0.001	<0.001	<0.001	~100.
W 185	7.510+01	0	0.06	0.01	<0.001	99.93
W 181	1.210+02	0	<0.001	7.8	<0.001	92.2

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
W 179	2.573-02	0	<0.001	6.0	<0.001	94.0
W 179m	4.444-03	0	<0.001	5.9	<0.001	94.1
W 178	2.160+01	0	<0.001	5.8	<0.001	94.2
W 177	9.167-02	0	<0.001	5.9	<0.001	94.1
W 176	1.042-01	0	<0.001	5.5	<0.001	94.5
W 175	2.444-02	0	<0.001	5.8	<0.001	94.2
W 174	2.306-02	0	<0.001	6.0	<0.001	94.0
W 173	5.278-03	0	<0.001	6.5	<0.001	93.5
W 172	4.583-03	0	<0.001	6.5	<0.001	93.5
W 167	2.303-04	0	0	0	0	100.
Ta 179	5.880+02	0	<0.001	6.0	<0.001	94.0
Ta 178	6.451-03	0	<0.001	5.8	<0.001	94.2
Ta 178m	9.833-02	0	<0.001	0	<0.001	100.
Ta 177	2.350+00	0	<0.001	5.9	<0.001	94.1
Ta 176	3.371-01	0	<0.001	5.5	<0.001	94.5
Ta 175	4.375-01	0	<0.001	5.7	<0.001	94.3
Ta 174	4.750-02	0	<0.001	5.9	<0.001	94.1
Ta 173	1.308-01	0	<0.001	6.3	<0.001	93.7
Ta 172	2.556-02	0	<0.001	6.0	<0.001	94.0
Ta 171	1.618-02	0	<0.001	6.6	<0.001	93.4
Ta 170	4.694-03	0	<0.001	7.6	<0.001	92.4
Hf 177m	1.250-05	0	0	0	0	100.
Hf 177m2	3.569-02	0	<0.001	0	<0.001	100.
Hf 175	7.000+01	0	<0.001	5.8	<0.001	94.2
Hf 173	9.958-01	0	<0.001	6.4	<0.001	93.6
Hf 172	6.830+02	0	<0.001	6.1	<0.001	93.9
Hf 171	5.042-01	0	<0.001	6.8	<0.001	93.2
Hf 170	6.671-01	0	<0.001	7.7	<0.001	92.3
Hf 168	1.802-02	0	<0.001	9.7	<0.001	90.3
Hf 166	4.701-03	0	<0.001	15.4	<0.001	84.6
Lu 177m	1.603+02	0	<0.001	0	<0.001	~100.
Lu 177m2	4.861-03	0	0	0	<0.001	100.
Lu 173	4.880+02	0	<0.001	6.4	<0.001	93.6
Lu 172	6.700+00	0	<0.001	6.1	<0.001	93.9
Lu 171	8.250+00	0	<0.001	6.9	<0.001	93.1
Lu 170	2.012+00	0	<0.001	7.9	<0.001	92.1
Lu 169	1.419+00	0	<0.001	9.4	<0.001	90.6
Lu 168m	4.653-03	0	<0.001	9.2	<0.001	90.8
Lu 167	3.576-02	0	<0.001	12.6	<0.001	87.4
Lu 165	7.458-03	0	<0.001	15.2	<0.001	84.8
Yb 169	3.202+01	0	<0.001	9.7	<0.001	90.3
Yb 167	1.215-02	0	<0.001	12.1	<0.001	87.9
Yb 166	2.362+00	0	<0.001	15.0	<0.001	85.0
Yb 165	6.875-03	0	<0.001	16.1	<0.001	83.9
Yb 164	5.264-02	0	<0.001	20.0	<0.001	80.0
Yb 163	7.674-03	0	<0.001	25.8	<0.001	74.2
Yb 162	1.310-02	0	<0.001	33.5	<0.001	66.5
Tm 167	9.246+00	0	<0.001	12.0	<0.001	88.0
Tm 166	3.208-01	0	<0.001	13.6	<0.001	86.4
Tm 166m	3.935-06	0	0	15.4	0	84.6
Tm 165	1.252+00	0	<0.001	16.8	<0.001	83.2
Tm 163	7.542-02	0	<0.001	26.4	<0.001	73.6
Tm 162	1.507-02	0	<0.001	35.7	<0.001	64.3
Tm 161	2.097-02	0	<0.001	47.9	<0.001	52.1
Tm 160	6.528-03	0	<0.001	50.8	<0.001	49.2
Tm 159	6.340-03	0	<0.001	48.2	<0.001	51.8
Er 165	4.317-01	0	<0.001	16.8	<0.001	83.2
Er 163	5.208-02	0	<0.001	28.4	<0.001	71.6
Er 161	1.337-01	0	<0.001	49.9	<0.001	50.1
Er 160	1.191+00	0	<0.001	55.2	<0.001	44.8

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Er 159	2.500-02	0	<0.001	56.4	<0.001	43.6
Er 158	9.542-02	0	<0.001	70.7	<0.001	29.3
Er 157	1.295-02	0	<0.001	85.5	<0.001	14.5
Er 156	1.354-02	0	<0.001	88.3	<0.001	11.7
Ho 163	1.669+06	0	<0.001	28.4	<0.001	71.6
Ho 162	1.042-02	0	<0.001	0.2	<0.001	99.8
Ho 161	1.033-01	0	<0.001	49.0	<0.001	51.0
Ho 160	1.757-02	0	<0.001	57.3	<0.001	42.7
Ho 160m	2.083-01	0	<0.001	55.2	<0.001	44.8
Ho 159	2.295-02	0	<0.001	56.7	<0.001	43.3
Ho 158	7.847-03	0	<0.001	74.3	<0.001	25.7
Ho 158m	1.944-02	0	<0.001	70.7	<0.001	29.3
Ho 157	8.750-03	0	<0.001	84.4	<0.001	15.6
Ho 156	3.889-02	0	<0.001	86.8	<0.001	13.2
Ho 155	3.333-02	0	<0.001	87.3	<0.001	12.7
Ho 154	8.167-03	0	<0.001	96.9	<0.001	3.1
Dy 157	3.392-01	0	<0.001	85.8	<0.001	14.2
Dy 155	4.125-01	0	<0.001	89.2	<0.001	10.8
Dy 154	1.096+09	0	<0.001	96.7	<0.001	3.3
Dy 153	2.667-01	0	<0.001	99.1	<0.001	0.9
Dy 152	9.917-02	0	<0.001	97.4	<0.001	2.6
Dy 151	1.243-02	0	<0.001	99.5	<0.001	0.5
Dy 150	4.979-03	0	<0.001	99.8	<0.001	0.2
Tb 157	3.616+04	0	<0.001	86.0	<0.001	14.0
Tb 155	5.320+00	0	<0.001	89.3	<0.001	10.7
Tb 154	8.958-01	0	<0.001	98.0	<0.001	2.0
Tb 153	2.340+00	0	<0.001	95.1	<0.001	4.9
Tb 152	7.292-01	0	<0.001	97.3	<0.001	2.7
Tb 151	7.337-01	0	<0.001	99.6	<0.001	0.4
Tb 150	1.450-01	0	<0.001	99.6	<0.001	0.4
Tb 149	1.716-01	0	<0.001	98.3	<0.001	1.7
Tb 148	4.167-02	0	<0.001	99.5	<0.001	0.5
Tb 147	7.083-02	0	<0.001	99.9	<0.001	0.1
Tb 145	1.389-02	0	<0.001	99.6	<0.001	0.4
Gd 151	1.240+02	0	<0.001	99.7	<0.001	0.3
Gd 150	6.648+08	0	<0.001	99.8	<0.001	0.2
Gd 149	9.280+00	0	<0.001	98.8	<0.001	1.2
Gd 148	2.725+04	0	<0.001	99.6	<0.001	0.4
Gd 147	1.586+00	0	<0.001	99.8	<0.001	0.2
Gd 146	4.827+01	0	<0.001	99.8	<0.001	0.2
Gd 145	1.597-02	0	<0.001	99.8	<0.001	0.2
Eu 149	9.310+01	0	<0.001	97.6	<0.001	2.4
Eu 148	5.450+01	0	<0.001	66.6	<0.001	33.4
Eu 147	2.400+01	0	<0.001	99.8	<0.001	0.2
Eu 146	4.590+00	0	<0.001	95.5	<0.001	4.5
Eu 145	5.930+00	0	<0.001	91.9	<0.001	8.1
Sm 146	3.652+10	0	<0.001	79.1	<0.001	20.9
Sm 145	3.400+02	0	<0.001	73.6	<0.001	26.4
Sm 143	6.076-03	0	<0.001	45.7	<0.001	54.3
Sm 142	5.034-02	0	<0.001	42.6	<0.001	57.4
Sm 141	7.083-03	0	<0.001	46.8	<0.001	53.2
Sm 141m	1.569-02	0	<0.001	98.6	<0.001	1.4
Sm 140	1.029-02	0	<0.001	43.4	<0.001	56.6
Pm 149	2.212+00	0	<0.001	<0.001	<0.001	~100.
Pm 148	5.368+00	0	<0.001	<0.001	<0.001	~100.
Pm 147	9.582+02	0	<0.001	<0.001	<0.001	~100.
Pm 145	6.465+03	0	<0.001	34.1	<0.001	65.9
Pm 144	3.630+02	0	<0.001	<0.001	<0.001	~100.
Pm 143	2.660+02	0	<0.001	28.1	<0.001	71.9
Pm 141	1.451-02	0	<0.001	29.9	<0.001	70.1

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20–150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Nd 149	7.200-02	0	<0.001	<0.001	0	~100.
Nd 147	1.098+01	0	<0.001	<0.001	<0.001	100.
Nd 141	1.038-01	0	<0.001	8.8	<0.001	91.2
Nd 140	3.370+00	0	<0.001	8.8	<0.001	91.2
Nd 139	2.062-02	0	<0.001	9.5	<0.001	90.5
Nd 138	2.100-01	0	<0.001	5.2	<0.001	94.8
Nd 137	2.674-02	0	<0.001	8.1	<0.001	91.9
Nd 136	3.517-02	0	<0.001	2.9	<0.001	97.1
Nd 135	8.611-03	0	<0.001	0.07	<0.001	99.93
Nd 134	5.903-03	0	<0.001	<0.001	<0.001	~100.
Pr 147	9.306-03	0	<0.001	<0.001	0	100.
Pr 146	1.677-02	0	<0.001	<0.001	0	100.
Pr 145	2.493-01	0	<0.001	<0.001	<0.001	100.
Pr 144	1.200-02	0	<0.001	<0.001	0	100.
Pr 143	1.356+01	0	<0.001	<0.001	<0.001	100.
Pr 142	7.967-01	0	<0.001	<0.001	<0.001	100.
Pr 139	1.838-01	0	<0.001	5.3	<0.001	94.7
Pr 137	5.333-02	0	<0.001	2.4	<0.001	97.6
Pr 136	9.097-03	0	<0.001	0.9	<0.001	99.1
Pr 135	1.667-02	0	<0.001	0.5	<0.001	99.5
Pr 134	1.181-02	0	<0.001	0.03	<0.001	99.97
Pr 133	4.514-03	0	<0.001	<0.001	<0.001	~100.
Ce 146	9.389-03	0	0	<0.001	0	100.
Ce 144	2.850+02	0	<0.001	<0.001	<0.001	100.
Ce 143	1.377+00	0	<0.001	<0.001	<0.001	100.
Ce 141	3.250+01	0	<0.001	<0.001	<0.001	100.
Ce 139	1.376+02	0	<0.001	3.7	<0.001	96.3
Ce 137	3.750-01	0	<0.001	1.1	<0.001	98.9
Ce 135	7.375-01	0	<0.001	1.0	<0.001	99.0
Ce 134	3.160+00	0	<0.001	1.4	<0.001	98.6
Ce 133	6.736-02	0	<0.001	0.3	<0.001	99.7
Ce 132	1.462-01	0	<0.001	0.1	<0.001	99.9
Ce 131	7.083-03	0	0	<0.001	<0.001	~100.
Ce 130	1.590-02	0	0	<0.001	<0.001	~100.
La 143	9.819-03	0	0	<0.001	0	100.
La 142	6.326-02	0	0	<0.001	0	100.
La 141	1.633-01	0	<0.001	<0.001	0	100.
La 140	1.679+00	0	<0.001	<0.001	0	100.
La 137	2.192+07	0	<0.001	0.7	<0.001	99.3
La 136	6.854-03	0	<0.001	<0.001	0	100.
La 135	8.125-01	0	<0.001	0.6	<0.001	99.4
La 134	4.479-03	0	<0.001	0.8	<0.001	99.2
La 133	1.630-01	0	<0.001	0.8	<0.001	99.2
La 132	2.000-01	0	<0.001	1.1	<0.001	98.9
La 131	4.097-02	0	<0.001	1.8	<0.001	98.2
La 130	6.042-03	0	0	1.1	<0.001	98.9
La 129	8.056-03	0	0	0.03	<0.001	99.97
Ba 142	7.361-03	0	0	<0.001	0	100.
Ba 141	1.269-02	0	0	<0.001	0	100.
Ba 140	1.277+01	0	0	<0.001	0	100.
Ba 139	5.768-02	0	0	<0.001	0	100.
Ba 133	3.850+03	0	<0.001	1.0	<0.001	99.0
Ba 131	1.155+01	0	<0.001	1.7	<0.001	98.3
Ba 129	9.917-02	0	0	1.5	<0.001	98.5
Ba 129m	8.917-02	0	0	0.03	<0.001	99.97
Ba 128	2.430+00	0	<0.001	1.0	<0.001	99.0
Ba 127	8.819-03	0	0	1.2	0	98.8
Ba 126	6.944-02	0	0	0.01	0	99.99
Ba 124	7.639-03	0	0	<0.001	0	~100.
Cs 139	6.438-03	0	0	<0.001	0	100.

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Cs 138	2.320-02	0	0	<0.001	0	100.
Cs 137	1.097+04	0	0	<0.001	0	100.
Cs 136	1.303+01	0	0	<0.001	0	100.
Cs 135	8.401+08	0	<0.001	<0.001	0	100.
Cs 134	7.543+02	0	<0.001	<0.001	0	100.
Cs 132	6.530+00	0	<0.001	<0.001	0	100.
Cs 131	9.690+00	0	<0.001	1.0	<0.001	99.0
Cs 130	2.028-02	0	0	1.4	0	98.6
Cs 129	1.342+00	0	<0.001	1.8	<0.001	98.2
Cs 127	2.604-01	0	0	2.0	<0.001	98.0
Cs 125	3.243-02	0	0	2.1	0	97.9
Xe 138	9.778-03	0	0	0	0	100.
Xe 135m	1.062-02	0	0	<0.001	0	100.
Xe 133	5.244+00	0	0	<0.001	0	100.
Xe 133m	2.188+00	0	0	<0.001	0	100.
Xe 131m	1.193+01	0	0	<0.001	0	100.
Xe 127	3.640+01	0	<0.001	2.0	<0.001	98.0
Xe 125	7.042-01	0	0	1.7	<0.001	98.3
Xe 123	8.667-02	0	0	1.1	0	98.9
Xe 122	8.375-01	0	0	1.1	0	98.9
Xe 121	2.785-02	0	0	1.5	0	98.5
Xe 120	2.778-02	0	0	<0.001	0	~100.
I 135	2.738-01	0	0	<0.001	0	100.
I 134	3.646-02	0	0	<0.001	0	100.
I 133	8.667-01	0	0	<0.001	0	100.
I 132	9.562-02	0	0	<0.001	0	100.
I 131	8.023+00	0	0	<0.001	0	100.
I 130	5.150-01	0	0	<0.001	0	100.
I 129	5.880+09	0	0	<0.001	0	100.
I 128	1.735-02	0	0	<0.001	0	100.
I 126	1.298+01	0	0	1.0	0	99.0
I 125	5.941+01	0	0	1.9	<0.001	98.1
I 124	4.176+00	0	0	2.1	0	97.9
I 123	5.510-01	0	0	2.1	0	97.9
I 121	8.833-02	0	0	2.2	0	97.8
I 120	5.667-02	0	0	1.8	0	98.2
I 119	1.326-02	0	0	2.1	0	97.9
I 118	9.514-03	0	0	2.3	0	97.7
Te 134	2.903-02	0	0	<0.001	0	100.
Te 133	8.646-03	0	0	<0.001	0	100.
Te 132	3.204+00	0	0	<0.001	0	100.
Te 131	1.736-02	0	0	<0.001	0	100.
Te 131m	1.250+00	0	0	<0.001	0	100.
Te 129	4.833-02	0	0	<0.001	0	100.
Te 129m	3.360+01	0	0	<0.001	0	100.
Te 127	3.896-01	0	0	<0.001	0	100.
Te 127m	1.090+02	0	0	<0.001	0	100.
Te 125m	5.740+01	0	0	<0.001	0	100.
Te 121	1.916+01	0	0	2.0	0	98.0
Te 121m	1.540+02	0	0	2.2	0	97.8
Te 119	6.688-01	0	0	1.7	0	98.3
Te 119m	4.700+00	0	0	2.1	0	97.9
Te 118	6.000+00	0	0	1.3	0	98.7
Te 117	4.306-02	0	0	1.2	0	98.8
Te 116	1.038-01	0	0	1.2	0	98.8
Te 115m	4.653-03	0	0	<0.001	0	~100.
Te 114	1.056-02	0	0	<0.001	0	~100.
Sb 131	1.599-02	0	0	<0.001	0	100.
Sb 130	2.743-02	0	0	<0.001	0	100.
Sb 130m	4.375-03	0	0	0	0	100.

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Sb 129	1.817-01	0	0	<0.001	0	100.
Sb 128	3.754-01	0	0	<0.001	0	100.
Sb 127	3.850+00	0	0	<0.001	0	100.
Sb 126	1.240+01	0	0	<0.001	0	100.
Sb 125	1.008+03	0	0	<0.001	0	100.
Sb 124	6.020+01	0	0	<0.001	0	100.
Sb 122	2.700+00	0	0	0.6	0	99.4
Sb 120	1.104-02	0	0	2.1	0	97.9
Sb 119	1.596+00	0	0	2.3	0	97.7
Sb 118	2.500-03	0	0	2.3	0	97.7
Sb 117	1.167-01	0	0	2.5	0	97.5
Sb 116	1.097-02	0	0	2.4	0	97.6
Sb 115	2.229-02	0	0	2.2	0	97.8
Sb 113	4.632-03	0	0	2.7	0	97.3
Sn 128	4.102-02	0	0	<0.001	0	100.
Sn 127	8.750-02	0	0	<0.001	0	100.
Sn 126	8.401+07	0	0	<0.001	0	100.
Sn 125	9.640+00	0	0	<0.001	0	100.
Sn 125m	6.611-03	0	0	<0.001	0	100.
Sn 123	1.292+02	0	0	<0.001	0	100.
Sn 123m	2.782-02	0	0	<0.001	0	100.
Sn 121	1.126+00	0	0	<0.001	0	100.
Sn 121m	2.009+04	0	0	<0.001	0	100.
Sn 119m	2.930+02	0	0	<0.001	0	100.
Sn 117m	1.360+01	0	0	0.4	0	99.6
Sn 113	1.151+02	0	0	1.4	0	98.6
Sn 113m	1.451-02	0	0	2.7	0	97.3
Sn 111	2.451-02	0	0	0.9	0	99.1
Sn 110	1.708-01	0	0	1.0	0	99.0
Sn 109	1.250-02	0	0	1.9	0	98.1
Sn 108	7.153-03	0	0	3.3	0	96.7
In 119m	1.250-02	0	0	<0.001	0	100.
In 117	3.000-02	0	0	0.4	0	99.6
In 117m	8.069-02	0	0	<0.001	0	100.
In 115m	1.869-01	0	0	0.6	0	99.4
In 113m	6.908-02	0	0	1.4	0	98.6
In 112	1.021-02	0	0	2.8	0	97.2
In 111	2.805+00	0	0	2.4	0	97.6
In 111m	5.486-03	0	0	0.9	0	99.1
In 110	2.042-01	0	0	2.6	0	97.4
In 110m	4.799-02	0	0	1.0	0	99.0
In 109	1.750-01	0	0	2.3	0	97.7
In 108	4.028-02	0	0	1.9	0	98.1
In 108m	2.750-02	0	0	3.3	0	96.7
In 107	2.250-02	0	0	2.5	0	97.5
In 106	4.306-03	0	0	4.0	0	96.0
Cd 118	3.493-02	0	0	<0.001	0	100.
Cd 117	1.038-01	0	0	<0.001	0	100.
Cd 117m	1.400-01	0	0	<0.001	0	100.
Cd 115	2.228+00	0	0	0.6	0	99.4
Cd 115m	4.460+01	0	0	<0.001	0	100.
Cd 109	4.626+02	0	0	1.7	0	98.3
Cd 107	2.717-01	0	0	1.2	0	98.8
Cd 105	3.854-02	0	0	1.0	0	99.0
Cd 104	4.007-02	0	0	1.4	0	98.6
Cd 103	5.069-03	0	0	0.06	0	99.94
Ag 115	1.389-02	0	0	<0.001	0	100.
Ag 113	2.237-01	0	0	<0.001	0	100.
Ag 112	1.304-01	0	0	0.3	0	99.7
Ag 111	7.450+00	0	0	0.6	0	99.4

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Ag 106	1.667-02	0	0	3.0	0	97.0
Ag 105	4.130+01	0	0	2.5	0	97.5
Ag 105m	5.021-03	0	0	1.0	0	99.0
Ag 104	4.806-02	0	0	2.2	0	97.8
Ag 104m	2.326-02	0	0	1.4	0	98.6
Ag 103	4.562-02	0	0	2.1	0	97.9
Ag 102	8.958-03	0	0	2.8	0	97.2
Ag 102m	5.347-03	0	0	<0.001	0	~100.
Ag 101	7.708-03	0	0	4.7	0	95.3
Pd 112	8.458-01	0	0	<0.001	0	100.
Pd 111	1.625-02	0	0	<0.001	0	100.
Pd 109	5.709-01	0	0	0.6	0	99.4
Pd 107	2.374+09	0	0	1.1	0	98.9
Pd 103	1.698+01	0	0	1.6	0	98.4
Pd 101	3.529-01	0	0	1.0	0	99.0
Pd 100	3.630+00	0	0	0.9	0	99.1
Pd 99	1.486-02	0	0	1.7	0	98.3
Pd 98	1.229-02	0	0	<0.001	0	~100.
Rh 107	1.507-02	0	0	0.3	0	99.7
Rh 105	1.473+00	0	0	0.8	0	99.2
Rh 103m	3.897-02	0	0	0.9	0	99.1
Rh 102	1.060+03	0	0	3.9	0	96.1
Rh 101	1.169+03	0	0	3.4	0	96.6
Rh 101m	4.340+00	0	0	1.0	0	99.0
Rh 100	8.667-01	0	0	2.7	0	97.3
Rh 99	1.610+01	0	0	2.7	0	97.3
Rh 99m	1.958-01	0	0	1.7	0	98.3
Rh 98	6.056-03	0	0	2.3	0	97.7
Rh 97	2.132-02	0	0	2.3	0	97.7
Rh 97m	3.208-02	0	0	<0.001	0	~100.
Rh 96	6.875-03	0	0	4.3	0	95.7
Ru 106	3.726+02	0	0	0.1	0	99.9
Ru 105	1.850-01	0	0	0.3	0	99.7
Ru 103	3.926+01	0	0	0.7	0	99.3
Ru 97	2.900+00	0	0	1.1	0	98.9
Ru 95	6.846-02	0	0	0.8	0	99.2
Ru 94	3.597-02	0	0	0.2	0	99.8
Tc 105	5.278-03	0	0	<0.001	0	100.
Tc 104	1.271-02	0	0	<0.001	0	100.
Tc 101	9.861-03	0	0	0.4	0	99.6
Tc 99	7.816+07	0	0	1.2	0	98.8
Tc 99m	2.504-01	0	0	0.5	0	99.5
Tc 98	1.534+09	0	0	3.3	0	96.7
Tc 97	9.497+08	0	0	2.9	0	97.1
Tc 96	4.280+00	0	0	4.7	0	95.3
Tc 95	8.333-01	0	0	3.3	0	96.7
Tc 95m	6.100+01	0	0	0.8	0	99.2
Tc 94	2.035-01	0	0	3.1	0	96.9
Tc 94m	3.611-02	0	0	0.2	0	99.8
Tc 93	1.146-01	0	0	2.6	0	97.4
Mo 102	7.847-03	0	0	<0.001	0	100.
Mo 101	1.015-02	0	0	<0.001	0	100.
Mo 99	2.748+00	0	0	0.5	0	99.5
Mo 93	1.461+06	0	0	1.7	0	98.3
Mo 91	1.076-02	0	0	1.3	0	98.7
Mo 90	2.317-01	0	0	0.02	0	99.98
Mo 88	5.556-03	0	0	<0.001	0	~100.
Nb 97	5.007-02	0	0	0.1	0	99.9
Nb 96	9.729-01	0	0	0.4	0	99.6
Nb 95	3.499+01	0	0	0.8	0	99.2

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Nb 95m	3.608+00	0	0	0.3	0	99.7
Nb 94	7.300+06	0	0	1.9	0	98.1
Nb 92	1.278+10	0	0	3.4	0	96.6
Nb 91	2.484+05	0	0	3.6	0	96.4
Nb 90	6.083-01	0	0	4.2	0	95.8
Nb 89	8.458-02	0	0	4.7	0	95.3
Nb 88	1.007-02	0	0	4.5	0	95.5
Nb 88m	5.417-03	0	0	<0.001	0	~100.
Zr 97	6.977-01	0	0	<0.001	0	100.
Zr 95	6.403+01	0	0	0.3	0	99.7
Zr 93	5.588+08	0	0	0.8	0	99.2
Zr 90m	9.366-06	0	0	0.02	0	99.98
Zr 89	3.267+00	0	0	2.1	0	97.9
Zr 88	8.300+01	0	0	1.7	0	98.3
Zr 87	7.000-02	0	0	1.6	0	98.4
Zr 86	6.875-01	0	0	1.3	0	98.7
Zr 85	5.458-03	0	0	<0.001	0	~100.
Zr 84	1.799-02	0	0	<0.001	0	~100.
Y 95	7.153-03	0	0	<0.001	0	100.
Y 94	1.299-02	0	0	<0.001	0	100.
Y 93	4.242-01	0	0	<0.001	0	100.
Y 92	1.475-01	0	0	0.1	0	99.9
Y 91	5.851+01	0	0	0.4	0	99.6
Y 91m	3.452-02	0	0	0.1	0	99.9
Y 90	2.671+00	0	0	1.0	0	99.0
Y 89m	1.813-04	0	0	4.7	0	95.3
Y 88	1.066+02	0	0	2.2	0	97.8
Y 87	3.325+00	0	0	2.9	0	97.1
Y 87m	5.571-01	0	0	1.6	0	98.4
Y 86	6.142-01	0	0	2.9	0	97.1
Y 86m	3.333-02	0	0	1.3	0	98.7
Y 85	1.117-01	0	0	3.1	0	96.9
Y 83	4.917-03	0	0	0.04	0	99.96
Sr 93	5.155-03	0	0	<0.001	0	100.
Sr 92	1.129-01	0	0	<0.001	0	100.
Sr 91	4.012-01	0	0	0.1	0	99.9
Sr 90	1.052+04	0	0	0.3	0	99.7
Sr 89	5.057+01	0	0	0.6	0	99.4
Sr 87m	1.173-01	0	0	2.9	0	97.1
Sr 85	6.485+01	0	0	2.0	0	98.0
Sr 85m	4.695-02	0	0	3.1	0	96.9
Sr 83	1.350+00	0	0	1.0	0	99.0
Sr 82	2.555+01	0	0	0.7	0	99.3
Sr 81	1.549-02	0	0	<0.001	0	~100.
Sr 80	7.382-02	0	0	<0.001	0	~100.
Rb 89	1.069-02	0	0	<0.001	0	100.
Rb 88	1.236-02	0	0	<0.001	0	100.
Rb 86	1.864+01	0	0	0.9	0	99.1
Rb 84	3.350+01	0	0	2.0	0	98.0
Rb 83	8.620+01	0	0	2.5	0	97.5
Rb 81	1.907-01	0	0	2.3	0	97.7
Rb 79	1.590-02	0	0	4.5	0	95.5
Rb 78	1.226-02	0	0	<0.001	0	~100.
Kr 88	1.183-01	0	0	<0.001	0	100.
Kr 87	5.299-02	0	0	<0.001	0	100.
Kr 85	3.927+03	0	0	0.6	0	99.4
Kr 85m	1.867-01	0	0	<0.001	0	100.
Kr 83m	7.625-02	0	0	0.8	0	99.2
Kr 81	7.670+07	0	0	2.1	0	97.9
Kr 79	1.460+00	0	0	1.3	0	98.7

Nuclide		$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Kr	77	5.167-02	0	0	1.6	0	98.4
Kr	76	6.167-01	0	0	<0.001	0	~100.
Br	84	2.208-02	0	0	<0.001	0	100.
Br	83	1.000-01	0	0	0.2	0	99.8
Br	82	1.472+00	0	0	0.7	0	99.3
Br	80	1.222-02	0	0	1.6	0	98.4
Br	78	4.486-03	0	0	2.2	0	97.8
Br	77	2.377+00	0	0	2.6	0	97.4
Br	76	6.750-01	0	0	2.2	0	97.8
Br	75	6.715-02	0	0	3.6	0	96.4
Br	74	1.764-02	0	0	1.4	0	98.6
Se	83	1.549-02	0	0	<0.001	0	100.
Se	81	1.277-02	0	0	0.3	0	99.7
Se	81m	3.978-02	0	0	<0.001	0	100.
Se	79	1.377+08	0	0	0.8	0	99.2
Se	75	1.196+02	0	0	1.4	0	98.6
Se	73	2.979-01	0	0	1.2	0	98.8
Se	73m	2.764-02	0	0	0.003	0	~100.
Se	72	8.400+00	0	0	1.2	0	98.8
Se	70	2.854-02	0	0	0.002	0	~100.
As	79	6.257-03	0	0	<0.001	0	100.
As	78	6.299-02	0	0	0.2	0	99.8
As	77	1.618+00	0	0	0.5	0	99.5
As	76	1.092+00	0	0	1.1	0	98.9
As	74	1.778+01	0	0	2.4	0	97.6
As	73	8.030+01	0	0	2.5	0	97.5
As	72	1.083+00	0	0	2.2	0	97.8
As	71	2.720+00	0	0	2.2	0	97.8
As	70	3.653-02	0	0	5.7	0	94.3
As	69	1.058-02	0	0	<0.001	0	~100.
Ge	78	6.111-02	0	0	<0.001	0	100.
Ge	77	4.708-01	0	0	<0.001	0	100.
Ge	75	5.749-02	0	0	0.6	0	99.4
Ge	73m	5.787-06	0	0	1.2	0	98.8
Ge	71	1.143+01	0	0	1.8	0	98.2
Ge	69	1.627+00	0	0	1.0	0	99.0
Ge	68	2.710+02	0	0	1.1	0	98.9
Ge	67	1.312-02	0	0	<0.001	0	~100.
Ge	66	9.417-02	0	0	<0.001	0	~100.
Ga	74	5.639-03	0	0	<0.001	0	100.
Ga	73	2.025-01	0	0	0.2	0	99.8
Ga	72	5.875-01	0	0	0.4	0	99.6
Ga	70	1.468-02	0	0	1.6	0	98.4
Ga	68	4.698-02	0	0	2.3	0	97.7
Ga	67	3.261+00	0	0	2.4	0	97.6
Ga	66	3.954-01	0	0	3.0	0	97.0
Ga	65	1.056-02	0	0	12.3	0	87.7
Zn	72	1.938+00	0	0	<0.001	0	100.
Zn	69	3.917-02	0	0	0.8	0	99.2
Zn	65	2.442+02	0	0	1.1	0	98.9
Zn	63	2.667-02	0	0	0.6	0	99.4
Zn	62	3.858-01	0	0	<0.001	0	~100.
Cu	67	2.579+00	0	0	0.5	0	99.5
Cu	64	5.292-01	0	0	3.5	0	96.5
Cu	62	6.771-03	0	0	2.4	0	97.6
Cu	61	1.389-01	0	0	4.4	0	95.6
Cu	60	1.646-02	0	0	10.7	0	89.3
Ni	66	2.267+00	0	0	0.2	0	99.8
Ni	65	1.050-01	0	0	0.5	0	99.5
Ni	63	3.674+04	0	0	0.8	0	99.2

Nuclide	$T_{1/2}$ (day)	neutrons < 20 MeV	neutrons 20-150 MeV	neutrons >150 MeV	protons <150 MeV	protons >150 MeV
Ni 59	2.776+07	0	0	1.2	0	98.8
Ni 57	1.496+00	0	0	<0.001	0	~100.
Ni 56	6.075+00	0	0	<0.001	0	~100.
Co 61	6.875-02	0	0	0.6	0	99.4
Co 60	1.925+03	0	0	1.7	0	98.3
Co 58	7.086+01	0	0	2.2	0	97.8
Co 57	2.718+02	0	0	2.2	0	97.8
Co 56	7.731+01	0	0	7.1	0	92.9
Co 55	7.304-01	0	0	0.3	0	99.7
Fe 60	5.479+08	0	0	0.4	0	99.6
Fe 59	4.450+01	0	0	0.6	0	99.4
Fe 55	9.989+02	0	0	1.0	0	99.0
Fe 53	5.910-03	0	0	<0.001	0	~100.
Fe 52	3.448-01	0	0	0.008	0	~100.
Mn 56	1.076-01	0	0	0.4	0	99.6
Mn 54	3.121+02	0	0	1.8	0	98.2
Mn 53	1.344+09	0	0	2.1	0	97.9
Mn 52	5.595+00	0	0	4.6	0	95.4
Mn 51	3.208-02	0	0	<0.001	0	~100.
Cr 51	2.770+01	0	0	1.4	0	98.6
Cr 49	2.910-02	0	0	<0.001	0	~100.
V 49	3.300+02	0	0	1.9	0	98.1
V 48	1.597+01	0	0	4.6	0	95.4
V 47	2.264-02	0	0	<0.001	0	~100.
Ti 45	1.283-01	0	0	<0.001	0	~100.
Ti 44	2.191+04	0	0	<0.001	0	~100.
Sc 49	3.972-02	0	0	<0.001	0	100.
Sc 48	1.820+00	0	0	<0.001	0	100.
Sc 47	3.351+00	0	0	0.4	0	99.6
Sc 46	8.379+01	0	0	1.1	0	98.9
Sc 44	1.654-01	0	0	7.1	0	92.9
Sc 43	1.621-01	0	0	<0.001	0	~100.
Ca 49	6.056-03	0	0	<0.001	0	100.
Ca 47	4.538+00	0	0	<0.001	0	100.
Ca 45	1.630+02	0	0	0.8	0	99.2
Ca 41	3.762+07	0	0	<0.001	0	~100.
K 45	1.201-02	0	0	<0.001	0	100.
K 44	1.537-02	0	0	<0.001	0	100.
K 43	9.250-01	0	0	<0.001	0	~100.
K 42	5.150-01	0	0	0.1	0	99.9
Ar 44	8.243-03	0	0	<0.001	0	100.
Ar 42	1.205+04	0	0	<0.001	0	~100.
Ar 41	7.611-02	0	0	<0.001	0	~100.
Ar 39	9.825+04	0	0	<0.001	0	~100.
Cl 39	3.861-02	0	0	<0.001	0	~100.
Cl 38	2.583-02	0	0	<0.001	0	~100.
S 38	1.183-01	0	0	<0.001	0	100.
Mg 28	8.708-01	0	0	7.5	0	92.5
Mg 27	6.568-03	0	0	5.5	0	94.5
Na 24	6.232-01	0	0	5.1	0	94.9
F 18	7.620-02	0	0	4.7	0	95.3
N 13	6.922-03	0	0	4.3	0	95.7
C 14	2.082+06	0	0	6.1	0	93.9
C 11	1.415-02	0	0	5.3	0	94.7
Be 10	5.844+08	0	0	7.2	0	92.8
H 3	4.500+03	0.005	12.5	8.4	2.8	76.3

Table C2. Radionuclides for which the contribution to the total activity of irradiated LBE is greater or equal than 1 % of the total activity, for cooling times up to 5×10^7 years. Relative values of contributions (%) at various times after the irradiation are shown.

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Po 210	0.68	14.6	27.2	22.3	8.37	0.07	<0.001	<0.001
Po 209	<0.001	0.006	0.02	0.05	0.11	0.21	0.29	1.53
Po 208	0.02	0.37	1.33	2.44	4.51	4.33	1.87	<0.001
Po 206[‡]	0.35	0.88	<0.001	<0.001	<0.001	0.0	0.0	0.0
Bi 210	1.54	0.56	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bi 210m	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bi 208	<0.001	<0.001	<0.001	0.001	0.003	0.006	0.009	0.09
Bi 207	0.04	0.98	3.83	7.84	17.9	32.8	41.4	57.2
Bi 206	3.79	4.91	<0.001	<0.001	<0.001	0.0	0.0	0.0
Bi 205	2.59	18.7	0.22	<0.001	<0.001	0.0	0.0	0.0
Bi 204	1.96	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Bi 203	1.51	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Bi 202	1.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb 205	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Pb 203	4.23	0.007	<0.001	0.0	0.0	0.0	0.0	0.0
Pb 202	<0.001	<0.001	0.001	0.003	0.007	0.01	0.02	0.18
Pb 201	2.84	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Pb 201m	1.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb 200	2.41	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Pb 199	1.63	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb 198	1.62	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb 196	1.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 206	0.57	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tl 204	0.04	0.85	3.12	5.89	11.5	13.3	7.67	<0.001
Tl 202	0.66	2.81	0.004	0.003	0.007	0.01	0.02	0.18
Tl 201	3.49	0.10	<0.001	0.0	0.0	0.0	0.0	0.0
Tl 200	3.05	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Tl 199	2.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 198	2.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 197	1.88	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 196	1.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 195	1.49	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tl 194	1.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg 197	2.30	0.03	<0.001	0.0	0.0	0.0	0.0	0.0
Hg 195	1.63	0.002	<0.001	0.0	0.0	0.0	0.0	0.0
Hg 194	<0.001	0.02	0.08	0.16	0.37	0.72	1.01	8.64
Hg 193	1.16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg 192	1.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Au 195	0.64	13.4	30.2	31.4	18.9	0.62	<0.001	0.0
Au 194	0.06	0.02	0.08	0.16	0.37	0.72	1.01	8.64
Au 193	1.39	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Au 192	1.43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Au 191	1.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Au 190	0.96	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pt 193	0.006	0.15	0.59	1.21	2.79	5.24	6.87	19.4
Pt 191	1.23	0.02	<0.001	0.0	0.0	0.0	0.0	0.0
Pt 189	1.03	<0.001	0.0	0.0	0.0	0.0	0.0	0.0
Pt 188	0.69	2.07	<0.001	<0.001	<0.001	0.0	0.0	0.0
Ir 189	0.96	5.36	0.01	<0.001	<0.001	0.0	0.0	0.0
Ir 188	0.69	2.49	<0.001	<0.001	<0.001	0.0	0.0	0.0
Os 185	0.23	4.32	5.62	2.96	0.47	<0.001	<0.001	0.0
Re 183	0.20	3.57	3.19	1.06	0.07	<0.001	<0.001	0.0
W 181	0.10	1.99	3.31	2.38	0.69	0.003	<0.001	0.0
Ta 179	0.02	0.39	1.29	2.14	3.26	1.75	0.29	<0.001
In 116m	1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pd 107	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rh 103m	0.13	1.59	0.41	0.03	<0.001	<0.001	0.0	0.0
Ru 103	0.10	1.40	0.40	0.03	<0.001	<0.001	0.0	0.0
Tc 99	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Mo 93	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.01
Nb 95	0.11	1.81	1.36	0.38	0.02	<0.001	<0.001	0.0
Nb 94	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.009
Nb 93m	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Nb 91	<0.001	<0.001	<0.001	0.002	0.004	0.009	0.01	0.11
Zr 93	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Y 91	0.10	1.62	1.08	0.25	0.008	<0.001	<0.001	0.0
Y 88	0.04	0.81	1.36	0.94	0.23	<0.001	<0.001	0.0
Sr 89	0.08	1.25	0.63	0.10	0.002	<0.001	<0.001	0.0
H 3	0.05	1.21	4.66	9.38	20.8	34.3	36.4	2.27

[‡] For this and other nuclides with all relative values below 1 % shown in Table A1 the maximal contribution will exceed 1 % at other cooling times other than the ones shown in the table.

Table C3. Calculated activity (Bq) of radionuclides with $t_{1/2} \geq 1$ min produced in lead-bismuth irradiated during 123 days at various times after the irradiation.

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Fr 212	4.00E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fr 211	1.24E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fr 210	2.50E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 212	3.45E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 211	1.78E-05	2.98E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 210	4.13E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 209	1.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 208	2.99E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 207	5.29E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 206	5.11E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 205	5.87E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn 204	5.07E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 211	1.92E+04	6.34E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 210	1.58E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 209	4.14E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 208	5.98E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 207	5.67E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 206	5.72E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 205	2.29E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 204	3.87E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 203	1.04E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 202	1.28E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 202m	4.48E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
At 201	9.80E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 210	8.32E+13	7.76E+13	3.67E+13	1.45E+13	2.33E+12	9.68E+09	1.10E+06	3.77E+03
Po 209	3.11E+10	3.11E+10	3.10E+10	3.09E+10	3.07E+10	3.01E+10	2.91E+10	1.58E+10
Po 208	2.01E+12	1.97E+12	1.79E+12	1.59E+12	1.25E+12	6.18E+11	1.89E+11	1.09E+02
Po 207	4.72E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 206	4.35E+13	4.66E+12	6.55E+07	6.81E+01	1.07E-10	0.00E+00	0.00E+00	0.00E+00
Po 205	5.18E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 204	1.89E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 203	3.29E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 202	2.45E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 201	1.84E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 201m	8.15E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 200	1.80E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 199	8.23E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 199m	7.27E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po 198	6.36E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 212	2.63E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 212m	7.18E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 212m2	1.07E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 211	2.72E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 210	1.89E+14	2.99E+12	8.60E+04	8.18E+04	7.92E+04	7.22E+04	6.17E+04	3.70E+03
Bi 210m	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06
Bi 208	9.08E+08	9.08E+08	9.08E+08	9.08E+08	9.08E+08	9.08E+08	9.08E+08	9.08E+08
Bi 207	5.22E+12	5.21E+12	5.17E+12	5.11E+12	5.00E+12	4.68E+12	4.20E+12	5.90E+11
Bi 206	4.67E+14	2.61E+13	2.00E+08	2.07E+02	3.24E-10	0.00E+00	0.00E+00	0.00E+00
Bi 205	3.19E+14	9.95E+13	2.93E+11	2.22E+08	1.54E+02	0.00E+00	0.00E+00	0.00E+00
Bi 204	2.42E+14	6.75E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 203	1.86E+14	3.38E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 202	1.95E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 201	5.53E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 201m	3.18E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 200	1.06E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 200m	5.24E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 199	3.29E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 199m	3.64E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 198	3.41E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 198m	3.38E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 197	2.94E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 197m	1.01E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 196	1.79E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Bi 196m2	6.74E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 195	1.00E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 195m	4.54E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 194	4.02E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 194m	2.73E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 194m2	2.72E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi 193	1.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 211	1.72E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 210	8.43E+04	8.41E+04	8.30E+04	8.17E+04	7.92E+04	7.21E+04	6.17E+04	3.70E+03
Pb 209	2.19E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 205	1.53E+07	1.60E+07	1.63E+07	1.63E+07	1.63E+07	1.63E+07	1.63E+07	1.64E+07
Pb 204m	9.66E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 203	5.22E+14	3.97E+10	5.17E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 202	1.89E+09	1.90E+09	1.90E+09	1.90E+09	1.89E+09	1.89E+09	1.89E+09	1.89E+09
Pb 202m	8.86E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 201	3.50E+14	3.41E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 201m	1.75E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 200	2.96E+14	2.50E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 199	2.00E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 199m	7.03E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 198	1.99E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 197	9.48E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 197m	2.92E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 196	1.47E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 195	5.63E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 195m	2.48E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 194	8.31E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 193	2.41E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 193m	1.63E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 192	3.32E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 191	9.05E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 191m	5.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 190	9.66E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb 189m	6.25E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 210	1.42E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 209	2.48E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 208	3.03E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 207	3.75E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 206	6.99E+13	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06	6.91E+06
Tl 206m	1.05E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 204	4.59E+12	4.52E+12	4.20E+12	3.84E+12	3.22E+12	1.89E+12	7.77E+11	8.95E+04
Tl 202	8.16E+13	1.49E+13	4.95E+09	1.90E+09	1.89E+09	1.89E+09	1.89E+09	1.89E+09
Tl 201	4.31E+14	5.22E+11	7.38E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 200	3.76E+14	8.73E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 199	2.65E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 198	2.48E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 198m	2.29E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 197	2.32E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 196	1.89E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 196m	3.19E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 195	1.83E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 194	1.30E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 194m	3.24E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 193	1.21E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 193m	2.45E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 192	7.17E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 192m	2.75E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 191	4.40E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 191m	2.83E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 190	3.45E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 190m	1.75E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 189	2.02E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 189m	9.97E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 188	9.20E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl 188m	8.08E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 208	8.33E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 207	5.44E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 206	5.77E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Hg 205	2.83E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 203	6.16E+12	3.94E+12	4.23E+11	2.70E+10	1.18E+08	1.00E+01	1.63E-11	0.00E+00
Hg 199m	7.64E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 197	2.83E+14	1.34E+11	2.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 197m	1.16E+13	5.95E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 195	2.01E+14	1.23E+10	9.35E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 195m	7.13E+12	1.07E+10	8.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 194	1.04E+11	1.04E+11	1.04E+11	1.04E+11	1.04E+11	1.03E+11	1.02E+11	8.91E+10
Hg 193	1.43E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 193m	7.93E+12	2.26E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 192	1.44E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 191	6.49E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 191m	2.56E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 190	1.01E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 189	3.99E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 189m	2.64E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 188	5.52E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 187	2.01E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 187m	1.19E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg 186	2.49E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 201	7.46E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 200	7.91E+11	2.70E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 200m	3.79E+11	1.19E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 199	1.79E+12	2.38E+09	9.81E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 198	3.92E+12	3.46E+09	7.10E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 198m	9.01E+11	1.07E+08	2.49E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 196	4.00E+12	1.80E+11	3.01E+04	1.32E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 196m2	1.20E+12	3.17E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 195	7.91E+13	7.13E+13	4.08E+13	2.05E+13	5.25E+12	8.90E+10	9.93E+07	0.00E+00
Au 194	7.98E+12	1.04E+11	1.04E+11	1.04E+11	1.04E+11	1.03E+11	1.02E+11	8.91E+10
Au 193	1.71E+14	1.02E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 192	1.76E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 191	1.49E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 190	1.18E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 189	5.37E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 189m	3.90E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 188	7.71E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 187	5.62E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 186	4.54E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 185	2.00E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Au 175	5.47E+05	4.06E+05	9.20E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Pt 202	6.32E+09	7.49E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 201	2.17E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 200	5.52E+10	2.53E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 199	9.38E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 197	1.97E+11	2.61E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 197m	9.58E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 195m	2.76E+11	1.73E+09	1.68E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 193	7.92E+11	8.00E+11	7.95E+11	7.89E+11	7.78E+11	7.47E+11	6.97E+11	2.00E+11
Pt 193m	6.14E+11	5.10E+09	2.01E-01	2.96E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 191	1.51E+14	1.03E+11	1.16E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 189	1.27E+14	1.51E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 188	8.46E+13	1.10E+13	4.12E+08	1.43E+03	2.42E-08	0.00E+00	0.00E+00	0.00E+00
Pt 187	6.33E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 186	5.99E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 185	1.45E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 185m	2.59E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 184	3.26E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 183	2.13E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pt 182	1.87E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 197	3.63E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 197m	3.59E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 196m	7.14E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 195	1.91E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 195m	1.08E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 194	3.92E+10	9.22E+07	8.80E+07	8.30E+07	7.39E+07	5.23E+07	2.94E+07	9.02E+02
Ir 194m2	6.32E+09	5.60E+09	3.05E+09	1.44E+09	3.28E+08	3.87E+06	2.37E+03	0.00E+00
Ir 193m	7.37E+10	1.03E+10	5.33E+05	2.77E+00	1.04E-10	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Ir 192	2.66E+12	2.03E+12	5.31E+11	1.02E+11	3.94E+09	4.34E+07	4.25E+07	3.28E+07
Ir 192m	5.07E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 192m2	4.37E+07	4.37E+07	4.37E+07	4.36E+07	4.35E+07	4.31E+07	4.25E+07	3.28E+07
Ir 190	3.52E+11	6.23E+10	1.08E+07	2.46E+02	1.72E-07	0.00E+00	0.00E+00	0.00E+00
Ir 190m	1.71E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 190m2	1.23E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 189	1.18E+14	2.85E+13	1.95E+10	2.44E+06	4.86E-02	0.00E+00	0.00E+00	0.00E+00
Ir 188	8.55E+13	1.33E+13	4.96E+08	1.72E+03	2.91E-08	0.00E+00	0.00E+00	0.00E+00
Ir 187	6.51E+13	1.93E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 186	1.66E+13	1.56E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 186m	4.59E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 185	4.44E+13	4.17E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 184	3.78E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 183	2.31E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 182	2.72E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 181	1.04E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 180	1.35E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ir 179	9.79E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 196	2.13E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 195	4.98E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 194	9.31E+07	9.22E+07	8.79E+07	8.29E+07	7.39E+07	5.23E+07	2.93E+07	9.02E+02
Os 193	2.90E+09	1.94E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 191	1.49E+10	3.89E+09	4.35E+06	9.96E+02	6.56E-05	0.00E+00	0.00E+00	0.00E+00
Os 191m	7.48E+09	2.13E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 190m	1.37E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 189m	9.61E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 185	2.84E+13	2.30E+13	7.58E+12	1.93E+12	1.30E+11	3.99E+07	5.54E+01	0.00E+00
Os 183	1.57E+13	3.33E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 183m	2.02E+13	5.83E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 182	2.98E+13	4.69E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 181	1.21E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 181m	1.19E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 180	1.79E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 179	1.43E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 178	1.01E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 177	7.12E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 176	4.32E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Os 175	2.63E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 191	6.33E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 190	4.26E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 190m	1.58E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 189	1.31E+09	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 188	5.14E+09	2.86E+07	6.45E+06	1.03E+06	2.73E+04	5.16E-01	6.91E-09	0.00E+00
Re 188m	1.34E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 186	1.36E+11	7.80E+08	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04
Re 186m	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04	1.77E+04
Re 184	8.91E+10	5.55E+10	9.76E+09	3.99E+09	1.26E+09	4.30E+07	1.54E+05	0.00E+00
Re 184m	9.99E+09	9.10E+09	5.73E+09	3.24E+09	1.05E+09	3.58E+07	1.28E+05	0.00E+00
Re 183	2.53E+13	1.90E+13	4.30E+12	6.88E+11	1.85E+10	3.62E+05	5.14E-03	0.00E+00
Re 182	2.99E+13	1.88E+10	2.19E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 182m	1.48E+11	1.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 181	2.46E+13	3.32E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 180	1.88E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 179	1.19E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 178	1.22E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 177	9.33E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 176	7.03E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 175	4.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 174	3.20E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Re 173	1.83E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 190	1.24E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 189	1.62E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 188	3.81E+07	2.83E+07	6.38E+06	1.02E+06	2.70E+04	5.11E-01	6.84E-09	0.00E+00
W 187	6.45E+11	5.27E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 185	2.36E+10	1.79E+10	4.49E+09	8.14E+08	2.80E+07	1.14E+03	5.53E-05	0.00E+00
W 185m	1.03E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 181	1.24E+13	1.06E+13	4.47E+12	1.55E+12	1.91E+11	3.61E+08	1.04E+04	0.00E+00
W 179	1.59E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
W 179m	3.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 178	1.23E+13	4.69E+12	3.81E+10	1.01E+08	8.24E+02	4.52E-13	0.00E+00	0.00E+00
W 177	9.89E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 176	7.90E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 175	5.99E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 174	4.51E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 173	3.09E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 172	2.19E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 171	1.30E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 170	4.74E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 169	2.38E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W 167	1.41E-10	4.06E+05	9.20E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Ta 187	2.49E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 186	2.79E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 185	1.48E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 184	2.08E+08	2.58E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 183	3.54E+09	6.84E+07	1.84E-01	4.97E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 182	4.04E+09	3.37E+09	1.36E+09	4.45E+08	4.90E+07	6.55E+04	4.55E+00	3.48E+00
Ta 182m	2.69E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 182m2	2.76E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 180	6.54E+10	7.02E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 179	2.14E+12	2.07E+12	1.74E+12	1.40E+12	9.08E+11	2.50E+11	2.90E+10	4.42E-07
Ta 178	1.23E+13	4.69E+12	3.81E+10	1.01E+08	8.24E+02	4.52E-13	0.00E+00	0.00E+00
Ta 178m	2.07E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 177	9.96E+12	1.50E+09	9.12E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 176	8.02E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 175	6.20E+12	1.51E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 174	4.84E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 173	3.55E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 172	2.82E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 171	9.32E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 170	1.03E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 169	5.55E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 168	3.29E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ta 167	1.48E+11	4.06E+05	9.20E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Hf 186	4.19E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 185	5.23E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 184	4.43E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 183	1.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 182	3.48E+00	3.48E+00	3.48E+00	3.48E+00	3.48E+00	3.48E+00	3.48E+00	3.48E+00
Hf 182m	1.60E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 181	3.79E+07	2.32E+07	2.00E+06	9.68E+04	2.47E+02	4.12E-06	4.49E-19	0.00E+00
Hf 180m	4.29E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 179m2	1.90E+08	8.29E+07	1.32E+06	7.96E+03	3.34E-01	2.46E-14	0.00E+00	0.00E+00
Hf 178m2	7.67E+06	7.65E+06	7.58E+06	7.50E+06	7.33E+06	6.86E+06	6.13E+06	8.21E+05
Hf 177m	2.20E-10	2.34E+06	1.42E+06	7.64E+05	2.25E+05	5.77E+03	1.28E+01	0.00E+00
Hf 177m2	2.66E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 175	4.41E+12	3.31E+12	7.49E+11	1.20E+11	3.23E+09	6.32E+04	8.96E-04	0.00E+00
Hf 173	3.64E+12	3.59E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 172	3.46E+11	3.36E+11	2.88E+11	2.39E+11	1.65E+11	5.44E+10	8.53E+09	2.83E-05
Hf 171	2.06E+12	2.60E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 170	1.27E+12	3.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 169	7.71E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 168	5.69E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 167	1.64E+11	4.06E+05	9.20E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Hf 166	1.38E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 165	8.80E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf 164	4.97E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 182	4.37E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 181	1.30E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 180	4.42E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 179	1.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 178	3.82E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 178m	1.06E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 177	1.54E+08	6.75E+06	1.09E+00	4.55E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 177m	2.59E+06	2.34E+06	1.42E+06	7.64E+05	2.25E+05	5.77E+03	1.28E+01	0.00E+00
Lu 177m2	2.64E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 176m	4.76E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Lu 174	5.51E+08	5.50E+08	5.35E+08	4.99E+08	4.19E+08	2.35E+08	8.87E+07	2.19E+00
Lu 174m	5.72E+08	4.95E+08	2.39E+08	9.74E+07	1.66E+07	8.15E+04	1.16E+01	0.00E+00
Lu 173	5.76E+11	5.60E+11	4.52E+11	3.48E+11	2.07E+11	4.37E+10	3.27E+09	1.78E-11
Lu 172	3.37E+11	3.39E+11	2.91E+11	2.41E+11	1.67E+11	5.49E+10	8.61E+09	2.86E-05
Lu 172m	3.51E+11	3.36E+11	2.88E+11	2.39E+11	1.65E+11	5.44E+10	8.53E+09	2.83E-05
Lu 171	2.10E+12	1.80E+11	6.05E+05	1.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 171m	1.57E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 170	1.33E+12	6.37E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 169	7.59E+11	2.42E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 169m	4.94E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 168	1.09E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 168m	5.69E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 167	3.34E+11	4.07E+05	9.21E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Lu 167m	9.39E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 166	1.47E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 166m	1.00E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 166m2	7.37E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 165	1.83E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 164	1.15E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 163	6.26E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 162	2.71E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 162m	2.39E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 162m2	2.39E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lu 161	1.47E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 181	4.41E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 180	1.26E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 179	3.45E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 178	1.26E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 177	7.18E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 175	5.48E+06	3.81E+04	6.19E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 169	8.62E+11	4.72E+11	1.83E+10	3.34E+08	1.24E+05	6.27E-06	0.00E+00	0.00E+00
Yb 167	4.88E+11	4.07E+05	9.21E+04	1.47E+04	3.97E+02	7.76E-03	1.10E-10	0.00E+00
Yb 166	3.65E+11	5.50E+07	4.24E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 165	2.25E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 164	1.67E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 163	9.38E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 162	6.28E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 161	3.53E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 160	2.40E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 159	1.64E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Yb 158	6.70E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 177	1.29E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 176	1.41E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 175	4.69E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 174	1.94E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 173	1.16E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 172	9.60E+05	4.43E+02	4.12E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 171	5.20E+05	5.05E+05	4.35E+05	3.62E+05	2.52E+05	8.53E+04	1.40E+04	1.05E-10
Tm 170	1.09E+09	9.29E+08	4.14E+08	1.53E+08	2.14E+07	5.91E+04	3.20E+00	0.00E+00
Tm 168	6.23E+08	4.94E+08	1.56E+08	3.75E+07	2.25E+06	4.90E+02	3.86E-04	0.00E+00
Tm 167	4.82E+11	5.30E+10	9.46E+05	1.70E+04	4.59E+02	8.97E-03	1.27E-10	0.00E+00
Tm 166	4.26E+11	6.36E+07	4.91E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 166m	8.67E-08	5.50E+07	4.24E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 165	2.43E+11	1.51E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 164	1.85E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 164m	1.39E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 163	1.19E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 162	8.04E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 161	3.75E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 161m	1.76E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 160	3.75E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 160m	1.11E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 159	3.07E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 158	1.60E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 157	1.18E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tm 156	8.58E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 175	4.82E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 174	1.06E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Er 173	2.29E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 172	5.60E+04	2.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 171	1.95E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 169	3.03E+06	3.32E+05	5.22E+00	6.21E-06	1.27E-17	0.00E+00	0.00E+00	0.00E+00
Er 167m	1.46E-08	5.30E+10	9.46E+05	1.70E+04	4.59E+02	8.97E-03	1.27E-10	0.00E+00
Er 165	2.43E+11	2.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 163	1.25E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 161	4.79E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 160	4.90E+10	1.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 159	3.24E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 158	2.62E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 157	1.84E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 156	1.82E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 155	1.19E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Er 154	7.62E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 170	1.66E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 169	3.82E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 168	9.87E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 168m	4.73E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 167	5.09E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 166	1.09E+09	1.67E+02	8.38E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 166m	5.32E+03	5.32E+03	5.32E+03	5.31E+03	5.31E+03	5.30E+03	5.29E+03	5.02E+03
Ho 164	4.47E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 164m	7.20E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 163	6.35E+06	6.36E+06	6.36E+06	6.36E+06	6.36E+06	6.36E+06	6.35E+06	6.27E+06
Ho 162	2.04E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 162m	6.89E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 161	6.65E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 160	3.63E+10	1.78E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 160m	3.19E+10	1.76E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 159	4.90E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 158	2.77E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 158m	2.12E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 158m2	1.31E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 157	1.36E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 156	1.65E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 156m	9.86E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 156m2	7.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 155	2.08E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 154	1.27E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 154m	3.40E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 153	8.79E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 153m	3.26E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 152	4.14E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ho 150	5.46E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 168	6.52E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 167	1.42E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 166	4.80E+04	1.06E+02	5.63E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 165	2.50E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 165m	1.55E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 159	1.76E+10	1.53E+10	7.43E+09	3.06E+09	5.30E+08	2.76E+06	4.33E+02	0.00E+00
Dy 157	3.20E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 155	2.58E+10	3.55E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 154	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
Dy 153	1.51E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 152	9.10E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 151	7.00E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 150	6.19E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 149	1.09E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dy 148	6.32E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 165	4.90E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 164	1.60E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 163	8.40E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 162	5.84E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 161	2.83E+05	1.38E+04	3.87E-03	3.20E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 160	7.27E+06	5.45E+06	1.29E+06	2.20E+05	6.64E+03	1.83E-01	4.61E-09	0.00E+00
Tb 158	4.25E+05	4.25E+05	4.25E+05	4.24E+05	4.23E+05	4.19E+05	4.12E+05	3.09E+05
Tb 157	7.38E+07	7.41E+07	7.39E+07	7.36E+07	7.31E+07	7.16E+07	6.91E+07	3.68E+07

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Tb 156	4.90E+07	8.96E+05	1.65E-03	2.80E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 156m	1.18E+06	1.54E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 156m2	1.86E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 155	2.60E+10	5.69E+08	1.85E+00	6.30E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 154	3.73E+09	3.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 154m	3.80E+07	3.69E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 154m2	1.00E+06	4.22E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 153	2.00E+10	3.04E+06	1.53E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 152	1.33E+10	6.07E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 152m	5.93E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 151	1.51E+10	7.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 150	1.09E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 150m	2.22E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 149	1.24E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 149m	2.07E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 148	1.14E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 148m	1.23E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 147	5.69E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 147m	1.74E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tb 145	2.34E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 163	8.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 162	2.04E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 161	4.39E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 159	5.01E+04	9.35E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 153	4.03E+09	3.90E+09	2.53E+09	1.48E+09	5.18E+08	2.20E+07	1.14E+05	0.00E+00
Gd 151	9.18E+09	7.84E+09	3.39E+09	1.20E+09	1.57E+08	3.44E+05	1.28E+01	0.00E+00
Gd 150	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Gd 149	1.71E+10	1.84E+09	2.51E+04	2.50E-02	3.62E-14	0.00E+00	0.00E+00	0.00E+00
Gd 148	4.70E+07	4.69E+07	4.68E+07	4.65E+07	4.61E+07	4.48E+07	4.28E+07	1.86E+07
Gd 147	1.32E+10	2.72E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 146	8.96E+09	5.82E+09	6.76E+08	4.74E+07	2.51E+05	3.72E-02	1.55E-13	0.00E+00
Gd 145	3.76E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 145m	3.13E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 144	3.70E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 143m	8.52E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gd 142	1.06E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 159	1.49E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 158	3.59E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 157	1.04E+04	5.48E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 156	4.28E+04	1.09E+04	1.16E+01	2.50E-03	1.46E-10	0.00E+00	0.00E+00	0.00E+00
Eu 155	1.04E+04	1.02E+04	9.65E+03	8.97E+03	7.75E+03	5.00E+03	2.42E+03	4.86E-03
Eu 154	3.45E+05	3.42E+05	3.31E+05	3.18E+05	2.93E+05	2.30E+05	1.54E+05	1.09E+02
Eu 154m	5.91E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 152	4.05E+06	4.04E+06	3.98E+06	3.91E+06	3.76E+06	3.37E+06	2.80E+06	1.01E+05
Eu 152m	3.78E+08	5.66E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 152m2	9.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 150	1.54E+05	1.54E+05	1.53E+05	1.52E+05	1.49E+05	1.40E+05	1.28E+05	2.30E+04
Eu 150m	2.54E+07	3.19E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 149	9.71E+09	9.10E+09	3.04E+09	7.68E+08	5.07E+07	1.46E+04	1.83E-02	0.00E+00
Eu 148	1.51E+09	1.03E+09	1.53E+08	1.46E+07	1.40E+05	1.26E-01	1.05E-11	0.00E+00
Eu 147	1.59E+10	7.09E+09	9.32E+07	4.46E+05	1.18E+01	2.17E-13	0.00E+00	0.00E+00
Eu 146	1.28E+10	6.47E+09	7.47E+08	5.24E+07	2.77E+05	4.11E-02	1.71E-13	0.00E+00
Eu 145	1.19E+10	3.57E+08	8.67E+00	3.52E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 143	5.69E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu 142m	1.11E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 158	6.77E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 157	1.53E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 156	3.41E+03	2.99E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 155	7.84E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 153	8.55E+05	1.77E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 151	1.03E+04	1.03E+04	1.02E+04	1.02E+04	1.01E+04	9.88E+03	9.51E+03	4.76E+03
Sm 146	2.81E+01	3.30E+01	4.05E+01	4.15E+01	4.15E+01	4.15E+01	4.15E+01	4.15E+01
Sm 145	4.06E+09	4.01E+09	2.96E+09	2.03E+09	9.63E+08	1.03E+08	2.50E+06	0.00E+00
Sm 143	1.58E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 143m	6.95E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 142	1.44E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 141	7.73E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 141m	3.40E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Sm 140	5.87E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 139	1.96E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm 138	2.34E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 154	3.68E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 154m	7.11E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 153	8.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 152	1.70E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 152m	5.70E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 152m2	2.49E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 151	3.66E+04	8.54E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 150	1.55E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 149	2.55E+08	2.11E+04	8.08E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 148	6.08E+08	1.26E+07	4.89E-02	2.07E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 148m	5.11E+06	3.16E+06	2.85E+05	1.46E+04	4.20E+01	9.88E-07	1.91E-19	0.00E+00
Pm 147	1.70E+08	1.74E+08	1.58E+08	1.38E+08	1.06E+08	4.79E+07	1.28E+07	6.12E-04
Pm 146	1.81E+07	1.80E+07	1.74E+07	1.66E+07	1.53E+07	1.20E+07	7.90E+06	4.64E+03
Pm 145	5.64E+07	6.94E+07	1.23E+08	1.69E+08	2.18E+08	2.35E+08	1.98E+08	5.85E+06
Pm 144	3.68E+08	3.48E+08	2.61E+08	1.83E+08	9.13E+07	1.13E+07	3.46E+05	0.00E+00
Pm 143	7.04E+09	6.51E+09	4.40E+09	2.72E+09	1.05E+09	6.06E+07	5.21E+05	0.00E+00
Pm 141	2.30E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 140m	2.80E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 139	1.23E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 138m	2.34E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 137	1.42E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 137m	1.23E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm 136	1.66E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 152	1.05E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 151	2.33E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 149	3.81E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 147	8.64E+08	1.30E+08	1.00E+04	8.51E-02	8.37E-12	0.00E+00	0.00E+00	0.00E+00
Nd 141	7.81E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 141m	3.83E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 140	9.59E+10	2.01E+08	8.01E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 139	7.75E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 139m	1.00E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 138	7.67E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 137	3.11E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 136	2.42E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 135	1.78E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 135m	2.85E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 134	3.16E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 133	1.16E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 133m	2.20E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd 132	9.66E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 149	5.50E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 148	4.54E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 148m	7.94E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 147	4.87E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 146	1.61E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 145	5.84E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 144	5.16E+09	4.19E+08	2.92E+08	1.88E+08	7.82E+07	5.65E+06	7.10E+04	0.00E+00
Pr 144m	1.32E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 143	1.46E+10	3.22E+09	1.51E+06	1.18E+02	9.30E-07	0.00E+00	0.00E+00	0.00E+00
Pr 142	1.69E+10	7.86E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 142m	2.36E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 140	1.38E+11	2.01E+08	8.01E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 139	1.38E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 138	1.53E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 138m	1.49E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 137	1.19E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 136	1.09E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 135	8.32E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 134	4.25E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 134m	2.20E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 133	3.58E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 132	1.15E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr 131	8.70E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 146	7.22E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Ce 145	5.86E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 144	4.50E+08	4.19E+08	2.92E+08	1.88E+08	7.82E+07	5.65E+06	7.10E+04	0.00E+00
Ce 143	2.71E+09	7.49E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 141	1.73E+10	9.15E+09	3.73E+08	7.22E+06	3.00E+03	2.16E-07	0.00E+00	0.00E+00
Ce 139	9.06E+10	7.80E+10	3.67E+10	1.44E+10	2.30E+09	9.26E+06	9.44E+02	0.00E+00
Ce 137	2.58E+11	1.66E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 137m	2.20E+07	1.23E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 135	3.08E+11	1.76E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 134	2.96E+11	4.10E+08	2.11E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 133	1.79E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 133m	3.47E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 132	1.65E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 131	6.66E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 131m	8.70E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 130	3.21E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 129	6.05E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce 128	1.21E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 143	1.60E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 142	2.11E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 141	1.07E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 140	1.75E+10	5.26E+07	1.52E+04	6.61E-01	1.63E-09	0.00E+00	0.00E+00	0.00E+00
La 137	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06	1.55E+06
La 136	1.59E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 135	5.22E+11	2.57E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 134	5.29E+11	4.11E+08	2.11E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 133	4.57E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 132	4.06E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 132m	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 131	2.57E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 130	2.01E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 129	9.42E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 128	3.87E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 128m	1.21E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 127	1.26E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 127m	1.78E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La 125	1.44E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 142	3.64E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 141	2.25E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 140	2.33E+08	4.56E+07	1.32E+04	5.75E-01	1.42E-09	0.00E+00	0.00E+00	0.00E+00
Ba 139	2.20E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 137m	1.31E+08	1.30E+08	1.29E+08	1.27E+08	1.24E+08	1.17E+08	1.05E+08	1.47E+07
Ba 135m	3.49E+07	9.80E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 133	1.72E+10	1.72E+10	1.67E+10	1.62E+10	1.51E+10	1.24E+10	8.95E+09	2.42E+07
Ba 133m	5.73E+07	1.22E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 131	7.61E+11	1.26E+11	1.55E+07	2.34E+02	7.17E-08	0.00E+00	0.00E+00	0.00E+00
Ba 131m	1.01E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 129	4.57E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 129m	7.53E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 128	5.48E+11	1.05E+08	2.76E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 127	2.21E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 126	1.46E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 125	4.47E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 124	1.33E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 123	7.04E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba 122	2.12E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 140	1.40E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 139	5.45E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 138	1.96E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 138m	1.38E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 137	1.30E+08	1.30E+08	1.29E+08	1.27E+08	1.24E+08	1.17E+08	1.05E+08	1.47E+07
Cs 136	3.93E+10	7.96E+09	2.73E+06	1.45E+02	5.36E-07	0.00E+00	0.00E+00	0.00E+00
Cs 135	1.08E+04	1.08E+04	1.08E+04	1.08E+04	1.08E+04	1.08E+04	1.08E+04	1.08E+04
Cs 135m	4.01E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 134	1.68E+10	1.64E+10	1.42E+10	1.20E+10	8.59E+09	3.14E+09	5.87E+08	4.55E-05
Cs 134m	9.79E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 132	3.39E+11	1.48E+10	2.40E+03	1.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 131	1.31E+12	3.82E+11	8.75E+07	1.44E+03	4.45E-07	0.00E+00	0.00E+00	0.00E+00
Cs 130	5.14E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Cs 130m	9.96E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 129	1.11E+12	2.13E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 128	1.13E+12	1.05E+08	2.76E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 127	7.11E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 126	5.75E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 125	3.15E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 123	5.56E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 122m	8.78E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 121	4.12E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 121m	4.76E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs 120	6.32E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 138	1.98E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 137	1.16E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 135	6.99E+09	2.88E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 135m	2.51E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 133	1.21E+11	2.41E+09	5.90E+00	1.42E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 133m	8.16E+08	6.09E+04	1.40E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 131m	2.27E+09	3.97E+08	6.51E+04	1.40E+00	8.62E-10	0.00E+00	0.00E+00	0.00E+00
Xe 129m	9.53E+07	9.16E+06	7.53E+01	4.03E-05	1.71E-17	0.00E+00	0.00E+00	0.00E+00
Xe 127	1.53E+12	8.67E+11	4.98E+10	1.47E+09	1.41E+06	1.24E-03	0.00E+00	0.00E+00
Xe 127m	1.05E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 125	1.33E+12	2.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 123	7.22E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 122	4.42E+11	7.29E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 121	1.78E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 120	8.28E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 119	2.24E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 118	5.18E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe 117	2.05E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 136	3.59E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 135	1.28E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 134	5.93E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 134m	3.76E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 133	2.78E+10	2.09E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 132	6.80E+10	8.29E+06	6.69E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 132m	2.82E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 131	1.99E+11	1.54E+10	4.16E+04	5.67E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 130	2.75E+11	8.02E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 130m	5.14E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 129	9.95E+03	9.96E+03	9.97E+03	9.98E+03	9.98E+03	9.98E+03	9.98E+03	9.98E+03
I 128	5.89E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 126	6.85E+11	2.78E+11	3.06E+09	1.17E+07	2.01E+02	1.02E-12	0.00E+00	0.00E+00
I 125	1.87E+12	1.33E+12	2.30E+11	2.66E+10	3.76E+08	1.06E+03	6.01E-07	0.00E+00
I 124	1.25E+12	8.58E+09	1.32E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 123	1.86E+12	8.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 122	1.31E+12	7.31E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 121	9.28E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 120	4.95E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 120m	2.31E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 119	2.53E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 118	1.06E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 118m	2.01E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 117	9.86E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 115	1.95E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 134	7.02E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 133	1.13E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 133m	2.31E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 132	5.30E+09	8.04E+06	6.49E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 131	2.14E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 131m	1.71E+08	3.36E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 129	1.33E+11	1.83E+09	2.61E+08	2.36E+07	2.05E+05	1.35E-01	6.77E-12	0.00E+00
Te 129m	2.70E+09	1.83E+09	2.60E+08	2.35E+07	2.05E+05	1.35E-01	6.76E-12	0.00E+00
Te 127	4.50E+11	1.80E+10	6.17E+09	1.96E+09	2.03E+08	2.27E+05	2.74E+00	0.00E+00
Te 127m	1.88E+10	1.56E+10	6.15E+09	1.95E+09	2.03E+08	2.26E+05	2.73E+00	0.00E+00
Te 125m	7.95E+09	5.54E+09	9.05E+08	9.69E+07	1.18E+06	2.13E+00	5.73E-10	0.00E+00
Te 123m	2.24E+08	1.88E+08	7.87E+07	2.69E+07	3.24E+06	5.65E+03	1.43E-01	0.00E+00
Te 121	2.86E+12	9.67E+11	4.81E+09	2.72E+08	6.22E+07	7.85E+05	5.38E+02	0.00E+00
Te 121m	1.02E+09	9.05E+08	4.97E+08	2.38E+08	5.53E+07	6.98E+05	4.78E+02	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Te 119	1.56E+12	4.91E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 119m	2.45E+09	2.93E+07	7.24E-03	1.02E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 118	1.25E+12	3.89E+10	1.16E+03	6.07E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 117	4.94E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 116	2.60E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 115	5.69E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 115m	1.95E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 114	1.01E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 113	3.52E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te 112	9.23E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 133	1.06E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 132	4.10E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 132m	6.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 131	2.49E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 130	3.94E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 130m	3.26E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 129	2.34E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 129m	1.80E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 128	7.28E+10	6.44E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 128m	1.78E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 127	1.97E+11	2.17E+09	3.47E-01	2.88E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 126	3.81E+11	7.12E+10	1.62E+07	5.24E+02	7.22E-07	0.00E+00	0.00E+00	0.00E+00
Sb 126m	6.42E+07	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04
Sb 125	5.69E+10	5.65E+10	5.22E+10	4.73E+10	3.89E+10	2.17E+10	8.18E+09	1.97E+02
Sb 124	6.72E+11	4.75E+11	8.45E+10	1.00E+10	1.50E+08	5.02E+02	3.76E-07	0.00E+00
Sb 124m	7.39E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 124m2	2.82E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 122	1.71E+12	9.42E+08	4.84E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 122m	4.78E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 120	1.83E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 120m	1.78E+07	4.82E+05	6.98E-03	1.50E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 119	3.71E+12	5.50E+07	1.10E-02	1.55E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 118	2.99E+12	3.89E+10	1.16E+03	6.07E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 118m	9.83E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 117	2.16E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 116	1.25E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 116m	1.85E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 115	7.57E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 114	3.31E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 113	1.05E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb 111	4.76E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 130	3.24E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 130m	8.69E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 129	2.52E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 129m	4.21E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 128	3.41E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 127	9.10E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 127m	1.15E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 126	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04	3.69E+04
Sn 125	7.70E+10	8.91E+09	1.84E+05	3.08E-01	1.23E-12	0.00E+00	0.00E+00	0.00E+00
Sn 125m	8.23E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 123	1.59E+11	1.35E+11	6.05E+10	2.24E+10	3.16E+09	8.89E+06	4.97E+02	0.00E+00
Sn 123m	1.80E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 121	1.58E+12	2.94E+08	2.93E+08	2.91E+08	2.88E+08	2.80E+08	2.67E+08	1.11E+08
Sn 121m	2.94E+08	2.94E+08	2.93E+08	2.91E+08	2.88E+08	2.80E+08	2.67E+08	1.11E+08
Sn 119m	4.92E+11	4.59E+11	3.22E+11	2.08E+11	8.75E+10	6.56E+09	8.75E+07	0.00E+00
Sn 117m	1.49E+11	3.22E+10	1.54E+07	1.24E+03	1.03E-05	0.00E+00	0.00E+00	0.00E+00
Sn 113	1.20E+12	1.00E+12	4.06E+11	1.33E+11	1.48E+10	2.03E+07	3.42E+02	0.00E+00
Sn 113m	5.50E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 111	7.32E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 110	4.16E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 109	7.98E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 108	2.37E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 107	2.48E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn 106	2.50E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 121m	3.22E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 119	1.79E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 119m	1.69E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
In 118m	8.42E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 117	3.78E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 117m	5.45E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 116m	1.42E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 115m	3.89E+12	3.79E+08	2.03E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 114	3.74E+12	2.63E+11	3.54E+10	2.98E+09	2.26E+07	9.81E+00	2.45E-10	0.00E+00
In 114m	3.93E+11	2.63E+11	3.54E+10	2.98E+09	2.26E+07	9.81E+00	2.45E-10	0.00E+00
In 113m	1.22E+12	1.00E+12	4.07E+11	1.33E+11	1.48E+10	2.03E+07	3.42E+02	0.00E+00
In 112	1.35E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 112m	1.68E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 111	2.74E+12	1.66E+09	1.32E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 111m	9.49E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 110	1.13E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 110m	4.21E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 109	8.76E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 109m	3.71E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 108	3.53E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 108m	2.47E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 107	1.45E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 106	3.20E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 106m	3.41E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 105	6.84E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 104	3.74E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
In 103	3.53E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 119	1.77E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 119m	2.28E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 118	6.78E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 117	1.02E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 117m	8.42E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 115	3.90E+12	3.45E+08	1.85E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 115m	1.04E+11	6.51E+10	6.33E+09	3.57E+08	1.23E+06	5.01E-02	2.42E-14	0.00E+00
Cd 113m	8.24E+08	8.20E+08	8.04E+08	7.84E+08	7.47E+08	6.44E+08	5.04E+08	6.10E+06
Cd 111m	4.83E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 109	7.72E+11	7.39E+11	5.90E+11	4.47E+11	2.59E+11	5.02E+10	3.26E+09	1.37E-12
Cd 107	1.66E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 105	3.12E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 104	1.42E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 103	1.48E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 102	4.42E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd 101	4.02E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 117	4.07E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 116	9.13E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 115	1.93E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 113	4.74E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 113m	5.04E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 112	5.41E+12	4.64E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 111	8.44E+12	5.18E+11	4.50E+05	1.51E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 111m	3.11E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 110m	1.48E+11	1.37E+11	9.05E+10	5.46E+10	2.01E+10	1.00E+09	6.79E+06	0.00E+00
Ag 108	6.52E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 108m	1.89E+07	1.89E+07	1.89E+07	1.89E+07	1.89E+07	1.88E+07	1.87E+07	1.63E+07
Ag 106	2.28E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 106m	6.77E+09	5.79E+08	2.66E+03	6.96E-04	7.16E-17	0.00E+00	0.00E+00	0.00E+00
Ag 105	1.67E+12	1.01E+12	8.12E+10	3.64E+09	7.96E+06	8.30E-02	0.00E+00	0.00E+00
Ag 105m	3.15E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 104	7.87E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 104m	1.43E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 103	3.96E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 102	1.10E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 102m	2.34E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 101	2.32E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 100	3.13E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 100m	2.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag 99	2.66E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 114	4.52E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 113	7.85E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 112	1.86E+12	3.92E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 111	3.12E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Pd 111m	2.11E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 109	8.81E+12	1.36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 109m	2.58E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 107	5.02E+05	5.02E+05	5.02E+05	5.02E+05	5.02E+05	5.02E+05	5.02E+05	5.02E+05
Pd 103	3.26E+12	9.57E+11	2.10E+09	1.11E+06	3.75E-01	0.00E+00	0.00E+00	0.00E+00
Pd 101	8.30E+11	2.51E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 100	3.55E+11	1.15E+09	4.20E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 99	9.33E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 98	1.63E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 97	3.77E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd 96	2.06E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 109	2.58E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 108m	1.86E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 107	9.08E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 106m	1.30E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 105	1.50E+13	1.19E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 104m	1.11E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 103m	1.59E+13	8.43E+12	5.48E+11	2.17E+10	3.72E+07	1.88E-01	0.00E+00	0.00E+00
Rh 102	2.43E+11	2.39E+11	2.16E+11	1.92E+11	1.51E+11	7.37E+10	2.24E+10	1.05E+01
Rh 102m	7.11E+08	6.60E+08	4.54E+08	2.86E+08	1.15E+08	7.43E+06	7.76E+04	0.00E+00
Rh 101	2.15E+11	2.12E+11	1.94E+11	1.73E+11	1.40E+11	7.29E+10	2.47E+10	8.55E+01
Rh 101m	7.69E+11	9.92E+09	2.32E+00	3.08E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 100	1.94E+12	1.52E+09	5.52E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 100m	6.50E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 99	8.45E+11	2.32E+11	3.64E+08	1.26E+05	1.90E-02	0.00E+00	0.00E+00	0.00E+00
Rh 99m	9.34E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 98	3.43E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 98m	1.50E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 97	1.13E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 97m	8.14E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 96	2.09E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 96m	1.26E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 95	1.73E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 95m	2.07E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh 94	3.78E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 108	1.31E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 107	2.23E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 106	9.01E+11	8.52E+11	6.44E+11	4.57E+11	2.32E+11	3.02E+10	1.01E+09	0.00E+00
Ru 105	4.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 103	1.26E+13	7.47E+12	5.46E+11	2.16E+10	3.72E+07	1.88E-01	0.00E+00	0.00E+00
Ru 97	2.04E+12	1.57E+09	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 95	2.98E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 94	6.52E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru 92	8.01E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 105	3.57E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 104	5.39E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 102m	6.22E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 101	1.32E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 99	2.00E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07
Tc 99m	1.05E+13	1.45E+10	4.89E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 98	2.80E+05	2.80E+05	2.80E+05	2.80E+05	2.80E+05	2.80E+05	2.80E+05	2.80E+05
Tc 97	5.53E+05	5.60E+05	5.60E+05	5.60E+05	5.60E+05	5.60E+05	5.60E+05	5.60E+05
Tc 97m	6.11E+08	4.86E+08	1.53E+08	3.70E+07	2.24E+06	4.96E+02	4.03E-04	0.00E+00
Tc 96	2.43E+12	1.88E+10	5.31E-01	5.16E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 96m	7.69E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 95	1.86E+12	2.74E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 95m	5.78E+09	4.17E+09	8.10E+08	1.07E+08	1.99E+06	1.28E+01	2.81E-08	0.00E+00
Tc 94	6.47E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 94m	6.52E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 93	2.47E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 93m	5.92E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 92	1.73E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 91	3.26E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 91m	3.36E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 104	6.92E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 103	1.05E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 102	2.49E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 101	3.75E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Mo 99	1.05E+13	1.33E+10	4.50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 93	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.48E+08	1.48E+08	1.46E+08
Mo 93m	3.41E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 91	2.41E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 91m	5.28E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 90	3.17E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 89	9.77E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 88	2.94E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 99m	1.89E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 98m	3.23E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 97	1.31E+13	1.35E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 96	1.04E+13	5.45E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 95	1.36E+13	9.62E+12	1.83E+12	2.49E+11	4.97E+09	4.02E+04	1.31E-04	0.00E+00
Nb 95m	5.75E+10	2.50E+08	3.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 94	9.79E+07	9.79E+07	9.79E+07	9.79E+07	9.79E+07	9.79E+07	9.79E+07	9.76E+07
Nb 94m	7.35E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 93m	1.29E+07	1.34E+07	1.58E+07	1.87E+07	2.43E+07	3.96E+07	6.11E+07	1.48E+08
Nb 92	3.08E+04	3.08E+04	3.08E+04	3.08E+04	3.08E+04	3.08E+04	3.08E+04	3.08E+04
Nb 92m	8.83E+08	1.14E+08	4.05E+03	1.32E-02	1.98E-13	0.00E+00	0.00E+00	0.00E+00
Nb 91	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.21E+09	1.21E+09	1.10E+09
Nb 91m	1.11E+08	7.94E+07	1.50E+07	1.92E+06	3.33E+04	1.74E-01	2.73E-10	0.00E+00
Nb 90	9.00E+11	2.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 89	1.83E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 89m	4.33E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 88	3.52E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 88m	2.94E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 87	1.14E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 87m	9.44E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 86	1.80E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 97	2.53E+12	1.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 95	5.67E+12	4.11E+12	8.25E+11	1.14E+11	2.28E+09	1.85E+04	6.02E-05	0.00E+00
Zr 93	2.48E+06	2.49E+06	2.49E+06	2.49E+06	2.49E+06	2.49E+06	2.49E+06	2.49E+06
Zr 90m	2.68E-06	2.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 89	3.80E+12	6.60E+09	1.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 89m	2.37E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 88	8.73E+11	6.79E+11	1.94E+11	4.14E+10	1.96E+09	2.10E+05	5.05E-02	0.00E+00
Zr 87	2.68E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 86	3.71E+10	1.00E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 85	5.51E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr 84	1.01E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 95	2.18E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 94	4.22E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 93	7.82E+12	4.01E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 92	1.13E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 91	1.23E+13	8.63E+12	1.46E+12	1.63E+11	2.16E+09	5.02E+03	2.05E-06	0.00E+00
Y 91m	2.78E+12	1.68E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 90	1.16E+13	7.44E+10	6.90E+10	6.81E+10	6.65E+10	6.19E+10	5.49E+10	6.29E+09
Y 90m	4.41E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 89m	8.41E-08	6.60E+09	1.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 88	5.05E+12	4.29E+12	1.84E+12	6.11E+11	6.36E+10	5.64E+07	4.02E+02	0.00E+00
Y 87	5.02E+12	9.77E+09	2.57E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 87m	2.64E+11	3.34E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 86	1.67E+12	1.81E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 86m	3.69E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 85	4.59E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 85m	1.99E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 84m	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 83	1.62E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 83m	7.28E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 81	2.24E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 94	4.15E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 93	7.15E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 92	2.70E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 91	2.78E+12	1.59E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 90	6.98E+10	6.96E+10	6.89E+10	6.81E+10	6.65E+10	6.19E+10	5.48E+10	6.29E+09
Sr 89	1.00E+13	6.64E+12	8.50E+11	6.73E+10	4.53E+08	1.37E+02	1.89E-09	0.00E+00
Sr 87m	5.01E+12	1.01E+10	2.66E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 85	3.78E+12	2.74E+12	5.52E+11	7.64E+10	1.54E+09	1.28E+04	4.31E-05	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Sr 85m	3.98E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 83	7.00E+11	1.44E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 82	2.69E+11	1.19E+11	2.04E+09	1.35E+07	6.75E+02	8.48E-11	0.00E+00	0.00E+00
Sr 81	2.06E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 80	1.34E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 79	7.24E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr 78	4.45E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 90	1.61E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 90m	4.81E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 89	3.64E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 88	6.20E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 86	9.20E+12	3.01E+12	1.14E+10	1.17E+07	1.50E+01	0.00E+00	0.00E+00	0.00E+00
Rb 86m	1.76E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 84	7.68E+12	4.21E+12	2.09E+11	5.14E+09	3.43E+06	1.03E-03	0.00E+00	0.00E+00
Rb 84m	9.32E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 83	2.90E+12	2.43E+12	9.83E+11	3.22E+11	3.56E+10	4.83E+07	8.02E+02	0.00E+00
Rb 82	2.59E+12	1.19E+11	2.04E+09	1.35E+07	6.75E+02	8.48E-11	0.00E+00	0.00E+00
Rb 82m	3.78E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 81	9.87E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 81m	4.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 79	3.51E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 78	2.37E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 78m	3.36E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb 77	3.47E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 89	3.38E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 88	1.15E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 87	2.17E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 85	1.70E+11	1.69E+11	1.64E+11	1.59E+11	1.49E+11	1.23E+11	8.91E+10	2.70E+08
Kr 85m	1.65E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 83m	1.12E+13	2.43E+12	9.84E+11	3.22E+11	3.57E+10	4.83E+07	8.02E+02	0.00E+00
Kr 81	6.62E+06	6.62E+06	6.62E+06	6.62E+06	6.62E+06	6.62E+06	6.62E+06	6.62E+06
Kr 79	1.18E+12	7.70E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 77	8.09E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 76	6.77E+09	1.53E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 75	4.47E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr 74	2.15E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 85	2.10E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 84	4.00E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 84m	4.83E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 83	8.23E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 82	6.36E+12	4.64E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 82m	4.03E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 80	7.01E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 80m	1.56E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 78	3.29E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 77	1.64E+12	2.60E+08	2.60E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 77m	4.06E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 76	4.16E+11	2.02E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 75	7.99E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 74	3.84E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 74m	7.22E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 73	7.90E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br 72	4.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 84	3.56E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 83	1.12E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 83m	2.43E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 81	5.23E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 81m	3.47E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 79	6.65E+06	6.65E+06	6.65E+06	6.65E+06	6.65E+06	6.65E+06	6.65E+06	6.64E+06
Se 79m	3.91E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 75	9.49E+11	7.98E+11	3.35E+11	1.15E+11	1.38E+10	2.43E+07	6.22E+02	0.00E+00
Se 73	1.44E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 73m	6.31E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 72	2.34E+10	1.97E+09	8.29E+03	1.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 71	1.36E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se 70	1.68E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 79	3.91E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 78	5.75E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
As 77	9.21E+12	2.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 76	5.29E+12	2.86E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 74	2.11E+12	9.75E+11	2.05E+10	1.76E+08	1.47E+04	8.53E-09	0.00E+00	0.00E+00
As 73	1.53E+12	1.18E+12	3.23E+11	6.53E+10	2.80E+09	2.20E+05	3.16E-02	0.00E+00
As 72	8.38E+11	2.26E+09	9.52E+03	2.23E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 71	2.60E+11	1.24E+08	3.12E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 70	1.95E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 69	1.53E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
As 68	2.22E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 78	1.27E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 77	1.93E+12	1.27E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 75	5.91E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 73m	1.00E-07	1.18E+12	3.23E+11	6.53E+10	2.80E+09	2.20E+05	3.16E-02	0.00E+00
Ge 71	2.45E+12	4.11E+11	4.60E+07	6.18E+02	1.51E-07	0.00E+00	0.00E+00	0.00E+00
Ge 69	2.91E+11	8.20E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 68	2.36E+10	2.19E+10	1.49E+10	9.28E+09	3.65E+09	2.22E+08	2.08E+06	0.00E+00
Ge 67	5.06E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 66	1.33E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ge 64	7.88E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 75	1.53E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 74	2.42E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 73	4.71E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 72	5.53E+12	7.80E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 70	3.46E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 68	1.25E+12	2.19E+10	1.49E+10	9.28E+09	3.65E+09	2.22E+08	2.08E+06	0.00E+00
Ga 67	5.30E+11	9.02E+08	1.29E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 66	8.09E+10	1.17E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 65	6.10E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ga 64	6.63E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 74	3.67E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 72	1.77E+12	5.51E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 71	2.39E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 71m	3.18E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 69	4.87E+12	1.01E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 69m	5.00E+07	9.45E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 65	1.57E+11	1.45E+11	9.45E+10	5.59E+10	1.98E+10	8.86E+08	4.98E+06	0.00E+00
Zn 63	1.11E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 62	2.46E+08	9.67E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 61	2.79E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn 60	4.77E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 69	1.81E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 68m	6.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 67	4.00E+12	1.26E+09	3.92E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 66	4.54E+12	1.96E+08	2.35E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 64	6.59E+11	2.56E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 62	2.47E+11	9.84E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 61	4.88E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 60	4.84E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 59	1.77E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 66	1.88E+12	1.95E+08	2.34E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 65	2.22E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 63	8.09E+09	8.09E+09	8.06E+09	8.04E+09	7.98E+09	7.82E+09	7.55E+09	4.06E+09
Ni 59	1.22E+06	1.22E+06	1.22E+06	1.22E+06	1.22E+06	1.22E+06	1.22E+06	1.22E+06
Ni 57	1.40E+09	1.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni 56	2.82E+08	9.22E+06	3.40E-01	2.31E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 62	1.88E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 62m	1.60E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 61	2.51E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 60	3.98E+10	3.94E+10	3.73E+10	3.49E+10	3.06E+10	2.07E+10	1.07E+10	2.88E+05
Co 60m	2.11E+09	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05
Co 58	2.18E+11	1.63E+11	3.75E+10	6.14E+09	1.73E+08	3.85E+03	6.81E-05	0.00E+00
Co 58m	7.87E+09	3.49E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 57	4.02E+10	3.72E+10	2.54E+10	1.58E+10	6.24E+09	3.82E+08	3.64E+06	0.00E+00
Co 56	1.32E+10	1.01E+10	2.63E+09	5.02E+08	1.90E+07	1.04E+03	8.11E-05	0.00E+00
Co 55	1.56E+09	6.74E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co 54m	1.48E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 62	5.67E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 61	7.88E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Fe 60	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05
Fe 59	1.26E+12	7.92E+11	7.66E+10	4.29E+09	1.46E+07	5.69E-01	2.56E-13	0.00E+00
Fe 55	1.13E+10	1.11E+10	1.00E+10	8.81E+09	6.84E+09	3.20E+09	9.02E+08	1.14E-01
Fe 53	7.32E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 53m	8.60E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 52	1.50E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 51	3.89E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 58	7.66E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 57	1.11E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 56	1.26E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 54	7.06E+10	6.61E+10	4.74E+10	3.14E+10	1.40E+10	1.23E+09	2.13E+07	0.00E+00
Mn 53	9.03E+03	9.03E+03	9.03E+03	9.03E+03	9.03E+03	9.03E+03	9.03E+03	9.03E+03
Mn 52	1.97E+10	4.79E+08	4.07E+00	4.53E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 52m	1.76E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 51	8.85E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 50m	5.46E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 56	4.97E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 55	6.13E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 51	1.12E+11	5.31E+10	1.24E+09	1.22E+07	1.31E+03	1.66E-09	0.00E+00	0.00E+00
Cr 49	6.30E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 48	1.66E+07	1.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 53	4.84E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 52	6.08E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V 49	1.82E+10	1.71E+10	1.25E+10	8.46E+09	3.93E+09	3.94E+08	8.53E+06	0.00E+00
V 48	1.56E+10	4.24E+09	6.32E+06	2.06E+03	2.73E-04	0.00E+00	0.00E+00	0.00E+00
V 47	1.61E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 52	1.87E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 51	2.58E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 45	5.40E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti 44	8.98E+04	8.98E+04	8.93E+04	8.88E+04	8.78E+04	8.48E+04	8.01E+04	2.83E+04
Sc 50	9.35E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 49	2.33E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 48	1.93E+11	2.10E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 47	2.20E+11	2.62E+09	3.04E-01	1.62E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 46	5.86E+10	4.57E+10	1.32E+10	2.86E+09	1.40E+08	1.62E+04	4.51E-03	0.00E+00
Sc 44	5.10E+09	9.21E+04	8.93E+04	8.88E+04	8.78E+04	8.48E+04	8.01E+04	2.83E+04
Sc 44m	9.89E+06	2.20E+03	1.19E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 43	1.83E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sc 42m	2.30E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ca 49	9.72E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ca 47	6.93E+10	7.09E+08	7.95E-02	4.25E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ca 45	3.01E+10	2.65E+10	1.40E+10	6.38E+09	1.35E+09	1.28E+07	5.48E+03	0.00E+00
Ca 41	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04
K 46	9.69E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K 45	2.11E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K 44	1.26E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K 43	1.06E+10	1.83E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K 42	2.51E+09	7.31E+06	7.25E+06	7.17E+06	7.02E+06	6.60E+06	5.94E+06	8.98E+05
K 38	1.39E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ar 44	1.82E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ar 43	1.28E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ar 42	7.32E+06	7.31E+06	7.25E+06	7.17E+06	7.02E+06	6.60E+06	5.94E+06	8.98E+05
Ar 41	1.50E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ar 39	4.84E+05	4.84E+05	4.83E+05	4.82E+05	4.81E+05	4.78E+05	4.71E+05	3.74E+05
Ar 37	2.07E+09	1.14E+09	5.89E+07	1.52E+06	1.11E+03	4.34E-07	0.00E+00	0.00E+00
Cl 40	1.77E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl 39	2.87E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl 38	5.30E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl 36	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02
Cl 34m	9.51E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 38	4.80E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 37	6.98E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 35	1.43E+07	1.13E+07	3.43E+06	7.89E+05	4.35E+04	7.31E+00	3.73E-06	0.00E+00
P 33	1.78E+07	7.84E+06	1.30E+05	8.34E+02	3.91E-02	4.04E-15	0.00E+00	0.00E+00
P 32	3.45E+07	8.05E+06	1.68E+04	1.13E+04	1.12E+04	1.11E+04	1.08E+04	6.72E+03
P 30	1.93E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Si 32	1.14E+04	1.14E+04	1.13E+04	1.13E+04	1.12E+04	1.11E+04	1.08E+04	6.72E+03
Si 31	2.04E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Initial	30.0 d	180.0 d	1.0 y	2.0 y	5.0 y	10.0 y	100.0 y
Al 29	3.36E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al 28	2.55E+10	1.09E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al 26	1.75E+00	1.75E+00	1.75E+00	1.75E+00	1.75E+00	1.75E+00	1.75E+00	1.75E+00
Mg 28	2.55E+10	1.09E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mg 27	5.25E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na 24	1.43E+11	4.63E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na 22	1.11E+08	1.08E+08	9.71E+07	8.49E+07	6.50E+07	2.93E+07	7.73E+06	3.06E-04
Ne 24	1.25E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F 18	8.41E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F 17	3.69E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O 15	1.41E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O 14	2.84E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N 13	3.68E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C 14	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.24E+07
C 11	4.77E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Be 10	3.66E+05	3.66E+05	3.66E+05	3.66E+05	3.66E+05	3.66E+05	3.66E+05	3.66E+05
Be 7	2.35E+11	1.59E+11	2.25E+10	2.03E+09	1.75E+07	1.12E+01	5.32E-10	0.00E+00
H 3	6.47E+12	6.44E+12	6.29E+12	6.12E+12	5.78E+12	4.88E+12	3.69E+12	2.34E+10
Total	1.23E+16	5.32E+14	1.35E+14	6.52E+13	2.79E+13	1.43E+13	1.01E+13	1.03E+12

Table C4. Values of deviation factors§ obtained using (*p,x*) reaction cross sections calculated by various nuclear models for ^{208}Pb irradiated with 0.5 GeV protons and experimental fission yields ($Z < 60$). Best results are underlined.

Factors	Bertini/MPM/ Dresner	INCL4/ABLA	CEM03	CASCADE/ASF
H	5.49	4.07	4.74	2.93
D	0.677	0.567	0.588	0.327
R	0.430	0.454	0.560	0.933
F	4.09	2.68	3.32	1.77
L	1.35	1.23	0.902	0.411
$P_{1.3}$	0.0852	0.0330	0.140	0.516
$P_{2.0}$	0.261	0.299	0.418	0.838
$P_{10.0}$	0.962	0.992	0.948	0.995
Number of points	364	364	364	364

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§ $$H = \left(N^{-1} \sum_{i=1}^{N} [(\sigma_i^{\exp} - \sigma_i^{calc}) / \Delta\sigma_i^{\exp}]^2 \right)^{1/2}, \qquad D = N^{-1} \sum_{i=1}^{N} \left| \sigma_i^{\exp} - \sigma_i^{calc} \right| / \sigma_i^{\exp},$$

$$R = N^{-1} \sum_{i=1}^{N} \sigma_i^{calc} / \sigma_i^{\exp}, \qquad \mathrm{F} = 10^{\left(\mathrm{N}^{-1} \sum_{\mathrm{i}=1}^{\mathrm{N}} [\log(\sigma_{\mathrm{i}}^{\exp}) - \log(\sigma_{\mathrm{i}}^{\mathrm{calc}})]^2 \right)^{1/2}}$$

$$L = \left[\sum_{i=1}^{N} (\sigma_i^{calc} / \Delta\sigma_i^{\exp})^2 \, [(\sigma_i^{calc} - \sigma_i^{\exp}) / \sigma_i^{calc}]^2 \bigg/ \sum_{i=1}^{N} (\sigma_i^{calc} / \Delta\sigma_i^{\exp})^2 \right]^{1/2}, \qquad P_x = N_x/N,$$

where $\sigma_{\mathrm{i}}^{\exp}$ and $\Delta\sigma_{\mathrm{i}}^{\exp}$ are the measured cross section and its uncertainty, $\sigma_{\mathrm{i}}^{\mathrm{calc}}$ is the calculated or evaluated cross section, *N* is the number of experimental points, N_x is the number of points with the ratio

$$1/x < \sigma_{\mathrm{i}}^{\mathrm{calc}} / \sigma_{\mathrm{i}}^{\exp} < x.$$

Table C5. Values of deviation factors obtained using (*p,x*) reaction cross sections calculated by various nuclear models for ^{208}Pb irradiated with 0.5 GeV protons and experimental spallation yields ($Z > 60$). Best results are underlined.

Factors	Bertini/MPM/ Dresner	INCL4/ABLA	CEM03	CASCADE/ASF
H	15.30	5.74	6.72	4.011
D	1.21	0.487	0.644	0.359
R	1.85	1.25	1.33	0.906
F	3.30	1.76	2.15	2.21
L	0.748	0.473	0.559	0.471
$P_{1.3}$	0.337	0.4802	0.361	0.4802
$P_{2.0}$	0.525	0.817	0.708	0.777
$P_{10.0}$	0.951	0.995	0.990	0.975
Number of points	202	202	202	202

Table C6. Values of deviation factors obtained using *(p,x)* reaction cross sections calculated using various models for Pb and Bi isotopes irradiated with protons with incident energies from 150 to 600 MeV. Experimental data from 1960 up to present time are applied.

Factors	Bertini/MPM/ Dresner	INCL4/ABLA	CEM03	CASCADE/ ASF
H	9.68	4.64	5.29	5.63
D	0.842	0.533	0.575	0.405
R	0.995	0.798	0.913	1.028
F	3.55	2.27	2.65	1.92
L	0.791	0.546	0.589	0.509
$P_{1.3}$	0.176	0.204	0.279	0.482
$P_{2.0}$	0.390	0.520	0.585	0.785
$P_{10.0}$	0.966	0.993	0.971	0.992
Number of points	716	716	716	716

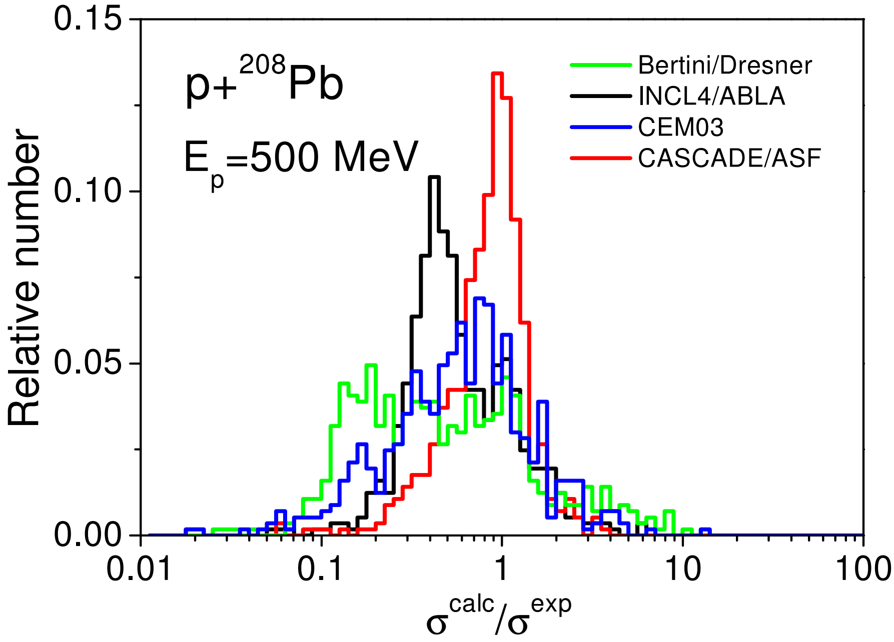

Figure C1. Histogram of ratios of cross sections calculated by various models to measured cross sections[94,95]. See Section 7.3 for details.

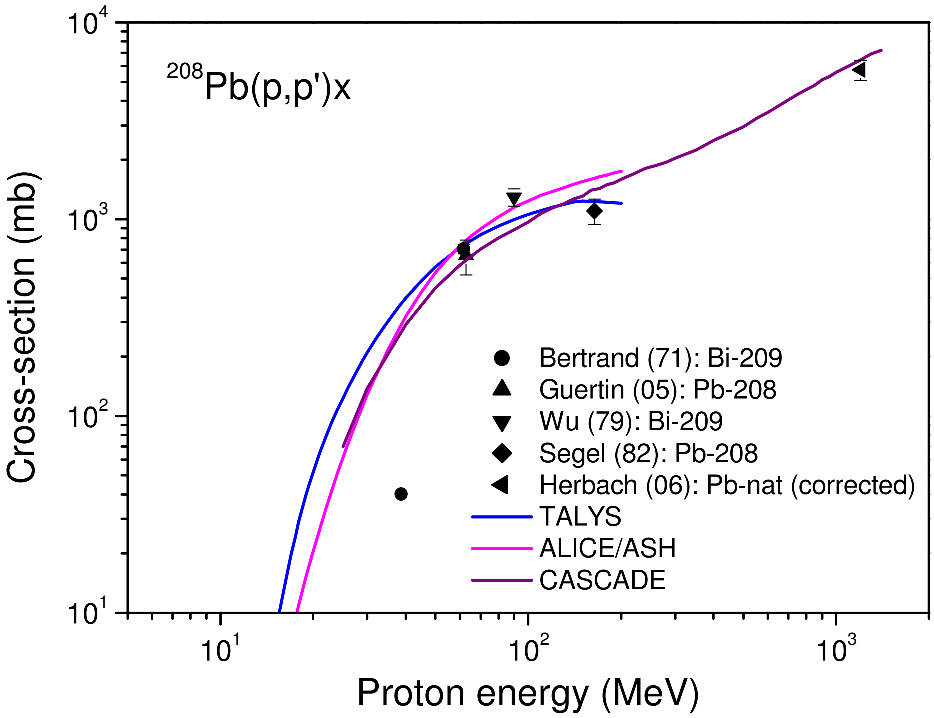

Figure C2. Proton production cross section for p+^{208}Pb interactions calculated using TALYS, ALICE/ASH, and CASCADE.

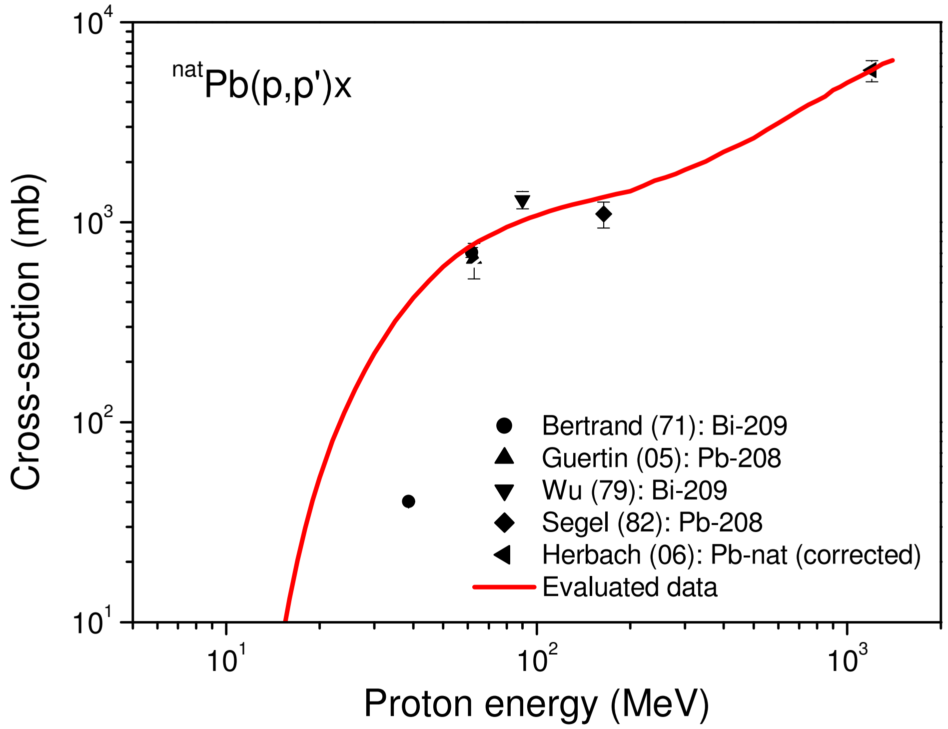

Figure C3. Evaluated proton production cross section for p+^{nat}Pb interactions.

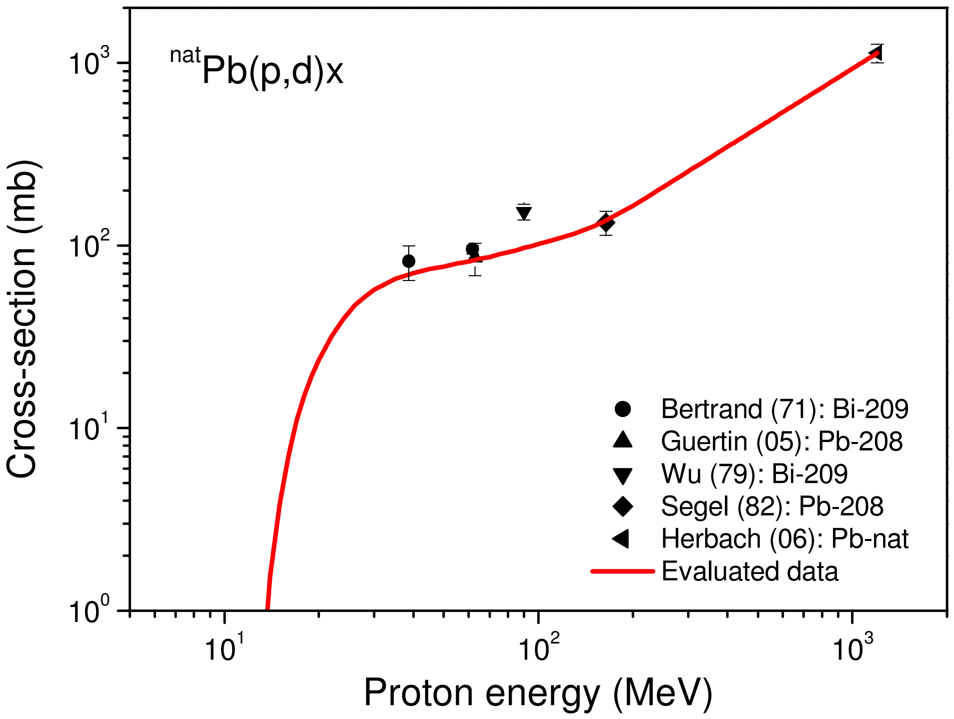

Figure C4. Evaluated deuteron production cross section for p+^{nat}Pb interactions.

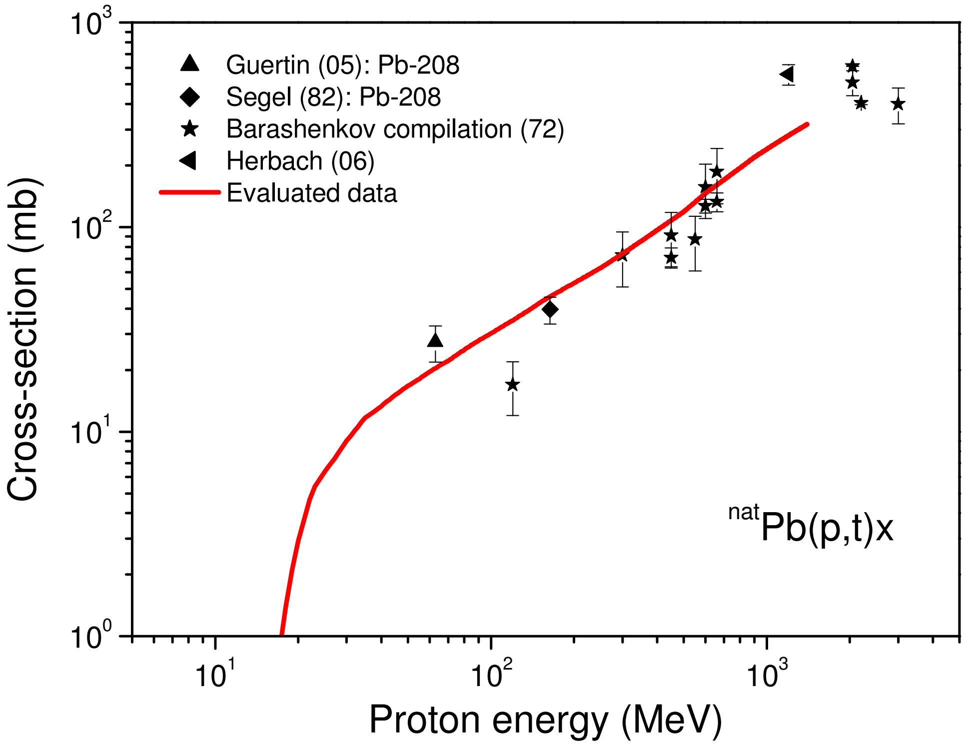

Figure C5. Evaluated triton production cross section for p+^{nat}Pb interactions.

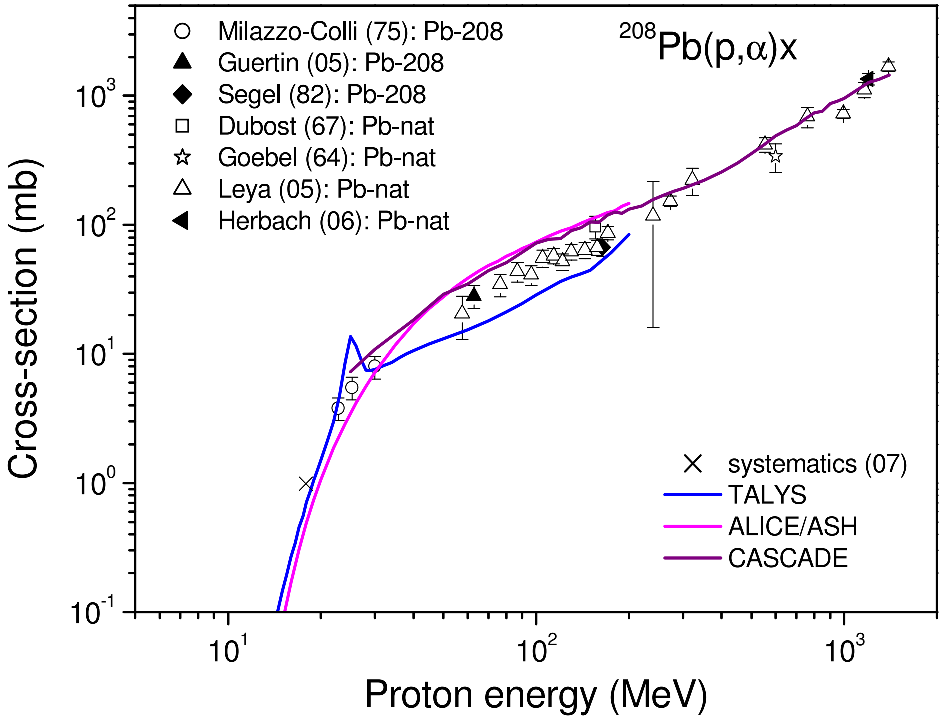

Figure C6. Alpha particle production cross section for p+^{208}Pb interactions calculated using TALYS, ALICE/ASH, and CASCADE.

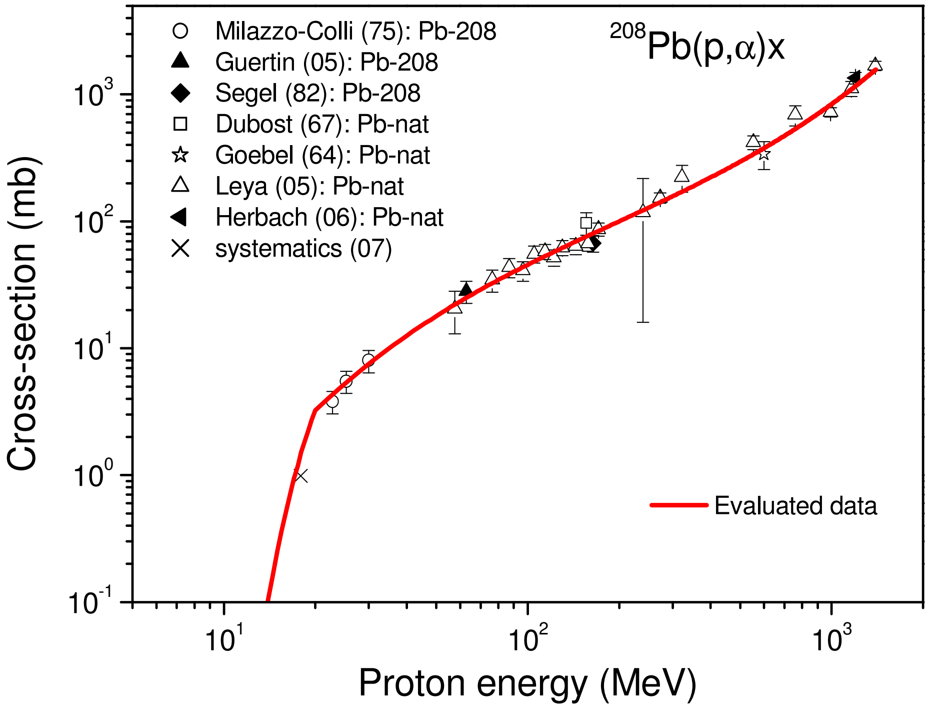

Figure C7. Evaluated α production cross section for p+^{208}Pb interactions.

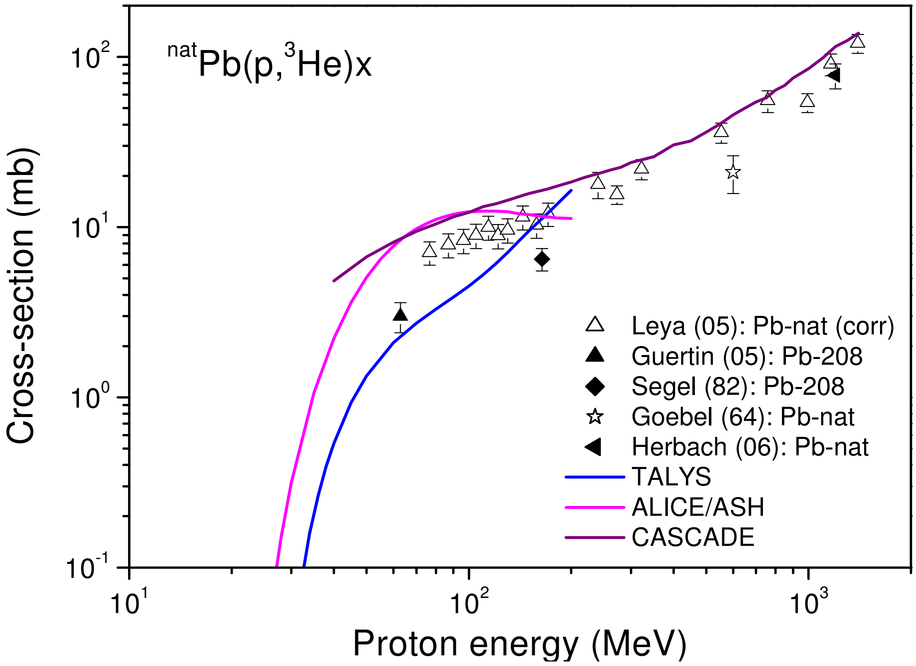

Figure C8. ^{3}He- production cross section for p+^{nat}Pb interactions calculated using TALYS, ALICE/ASH, and CASCADE.

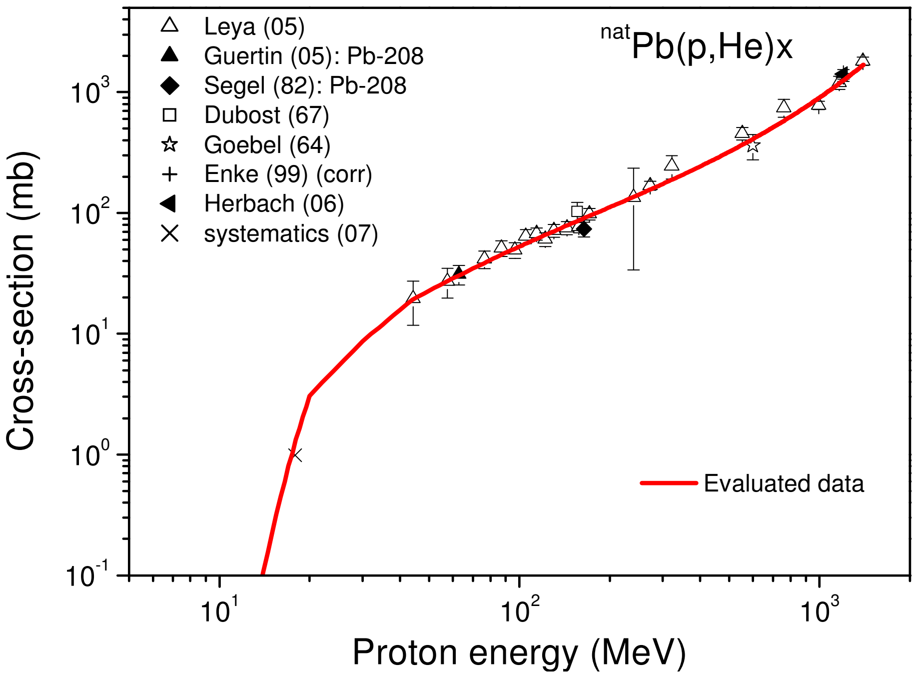

Figure C9. Evaluated helium production cross section for p+^{nat}Pb interactions (the sum of cross-sections for the ^{3}He- and ^{4}He- formation).

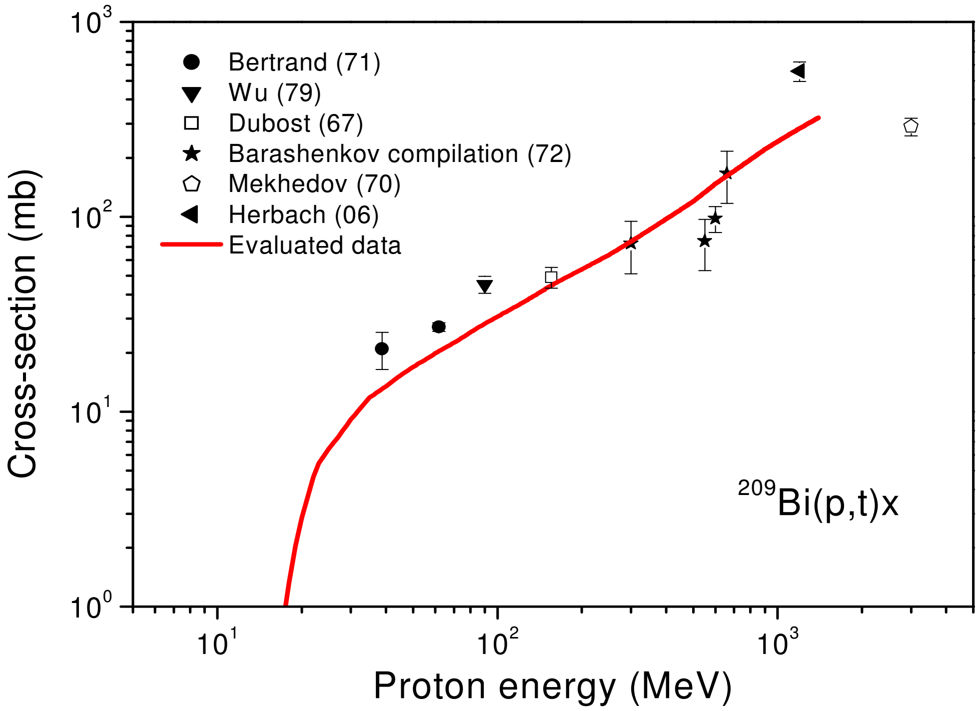

Figure C10. Evaluated triton production cross section for p+^{209}Bi interactions.

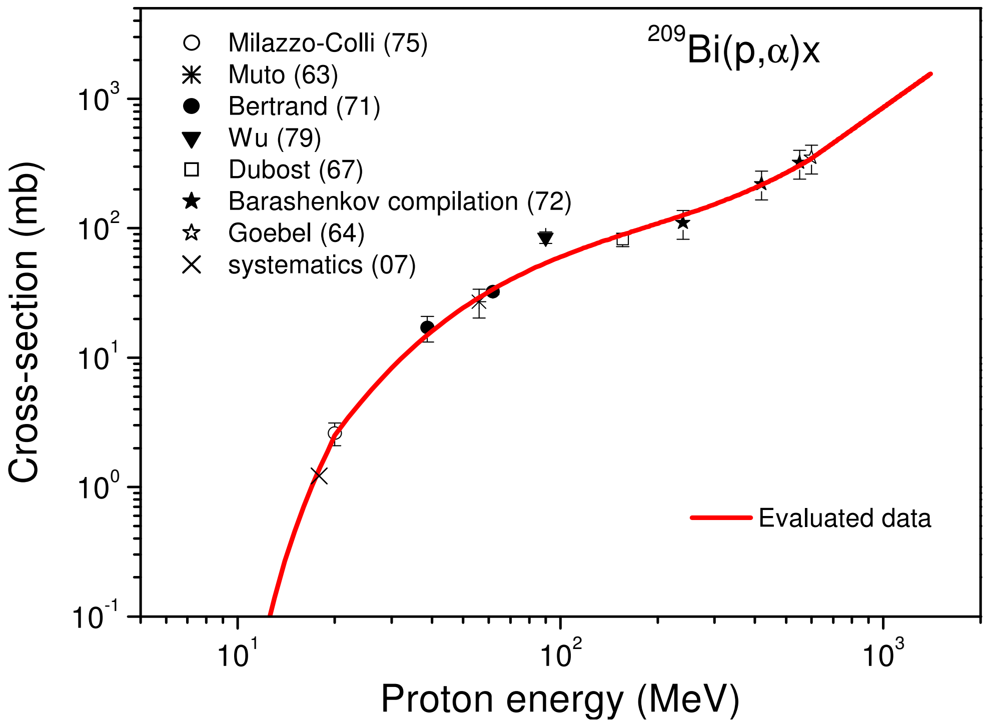

Figure C11. Evaluated alpha-particle production cross section for p+^{209}Bi interactions.

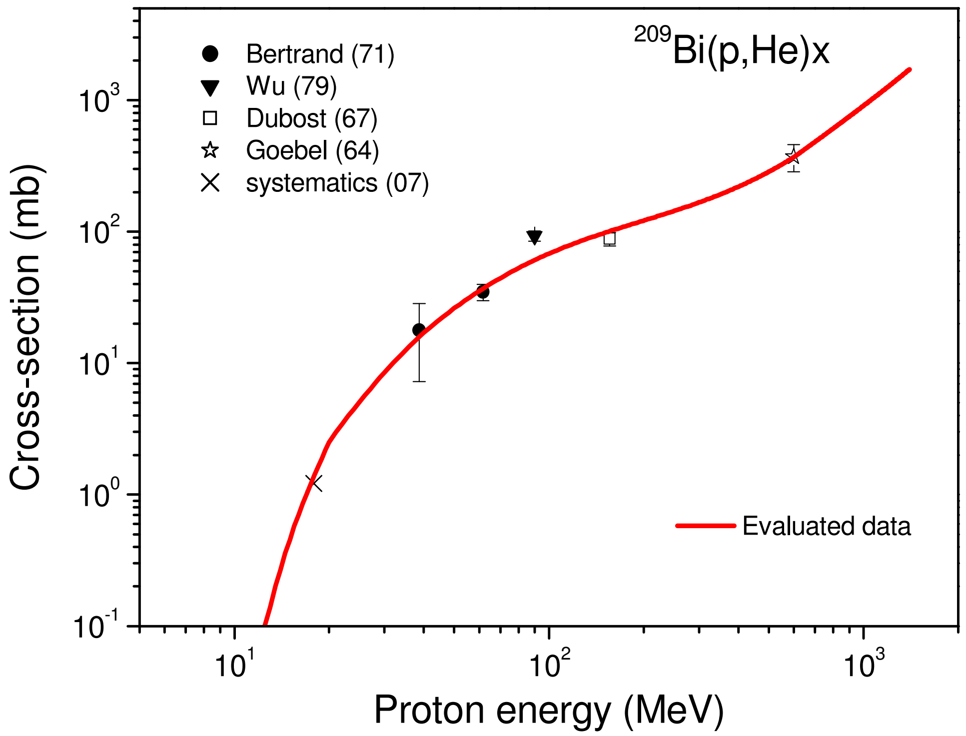

Figure C12. Evaluated helium production cross section for p+^{209}Bi interactions (the sum of cross-sections for the ^{3}He- and ^{4}He- formation).

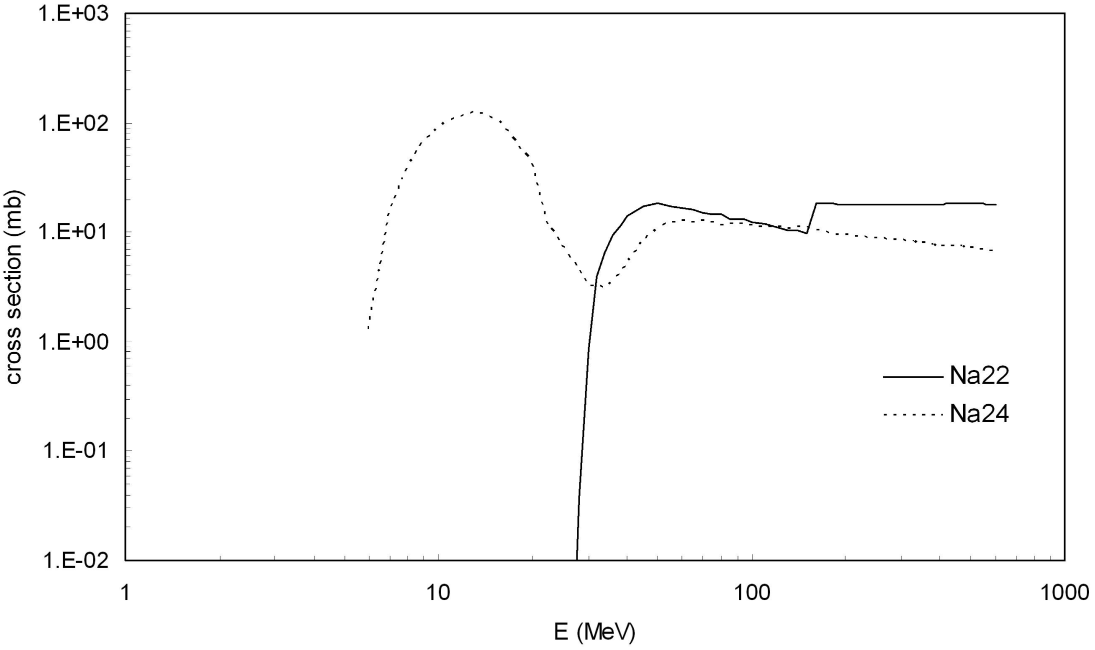

Figure C13. Cumulative neutron cross sections for indicated nuclides on a pure Al target.

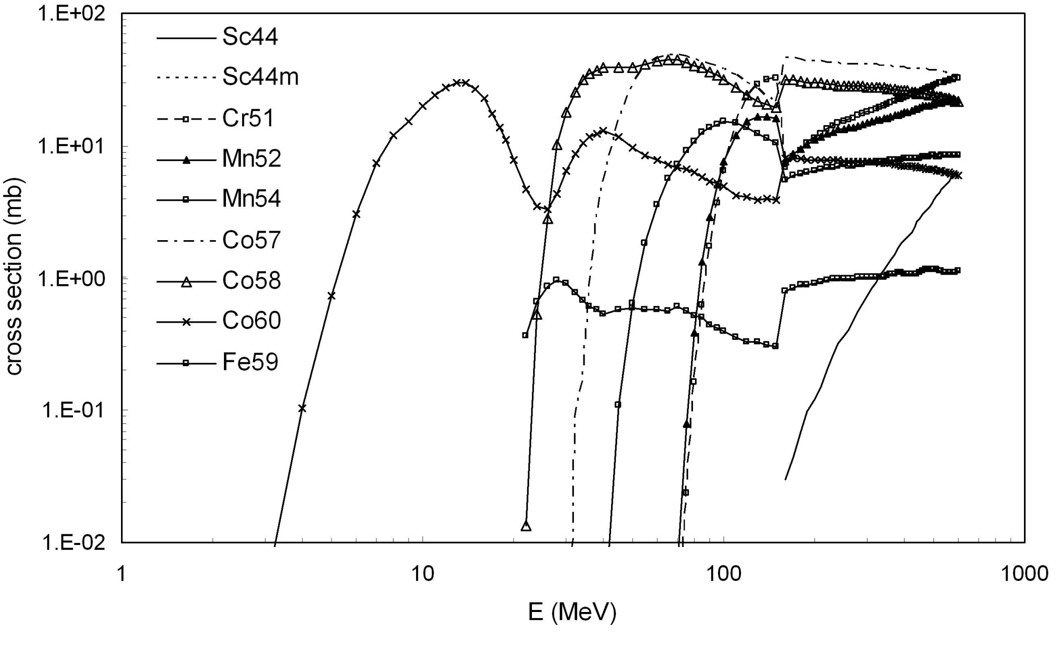

Figure C14. Cumulative neutron cross sections for indicated nuclides on a pure Cu target.

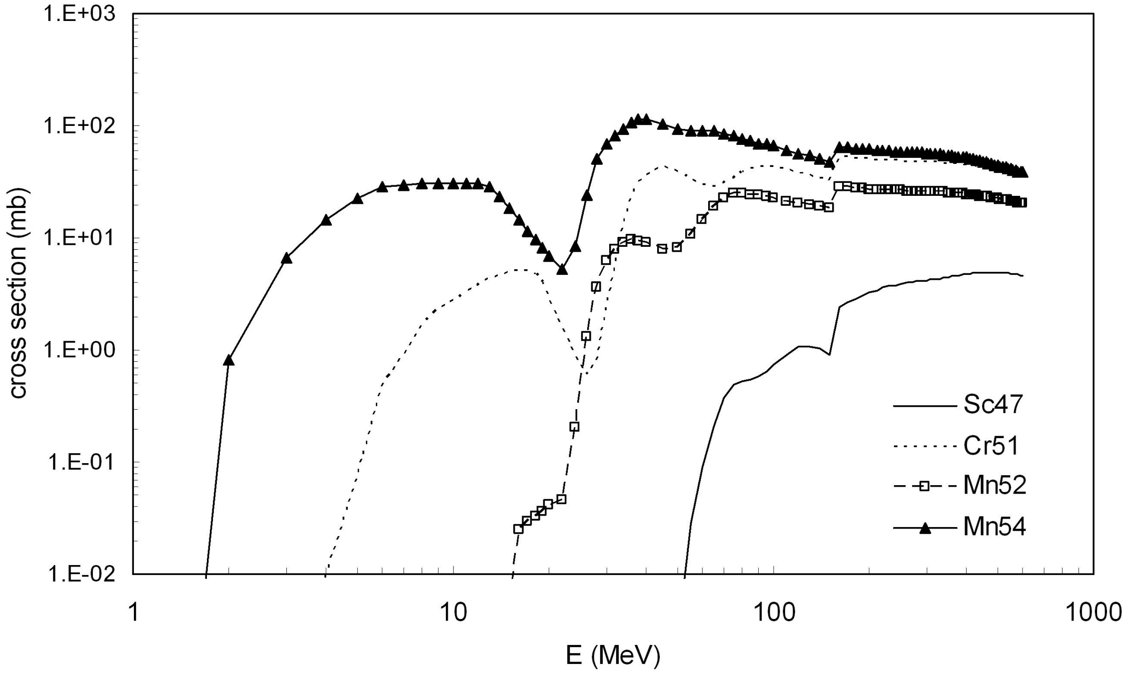

Figure C15. Cumulative neutron cross sections for indicated nuclides on a pure Fe target.

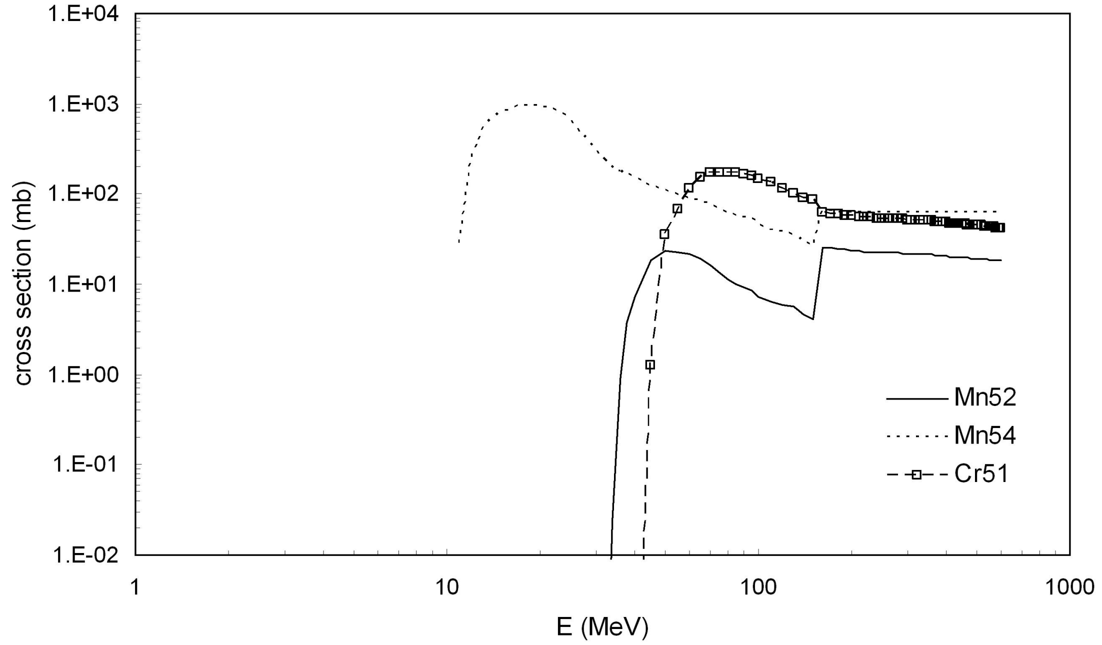

Figure C16. Cumulative neutron cross sections for indicated nuclides on a pure Mn target.

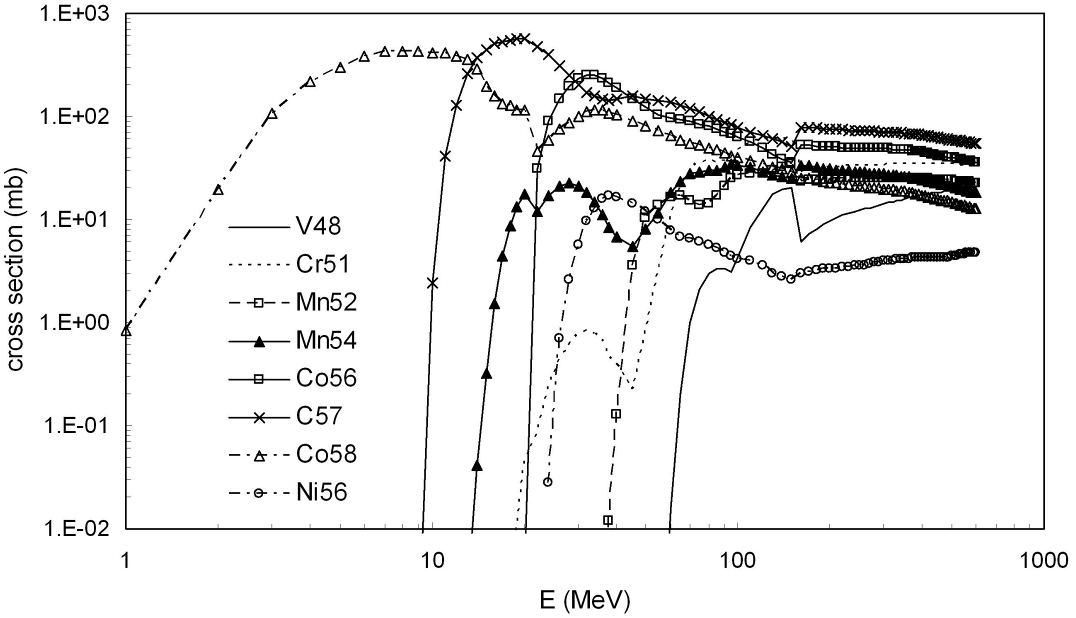

Figure C17. Cumulative neutron cross sections for indicated nuclides on a pure Ni target.

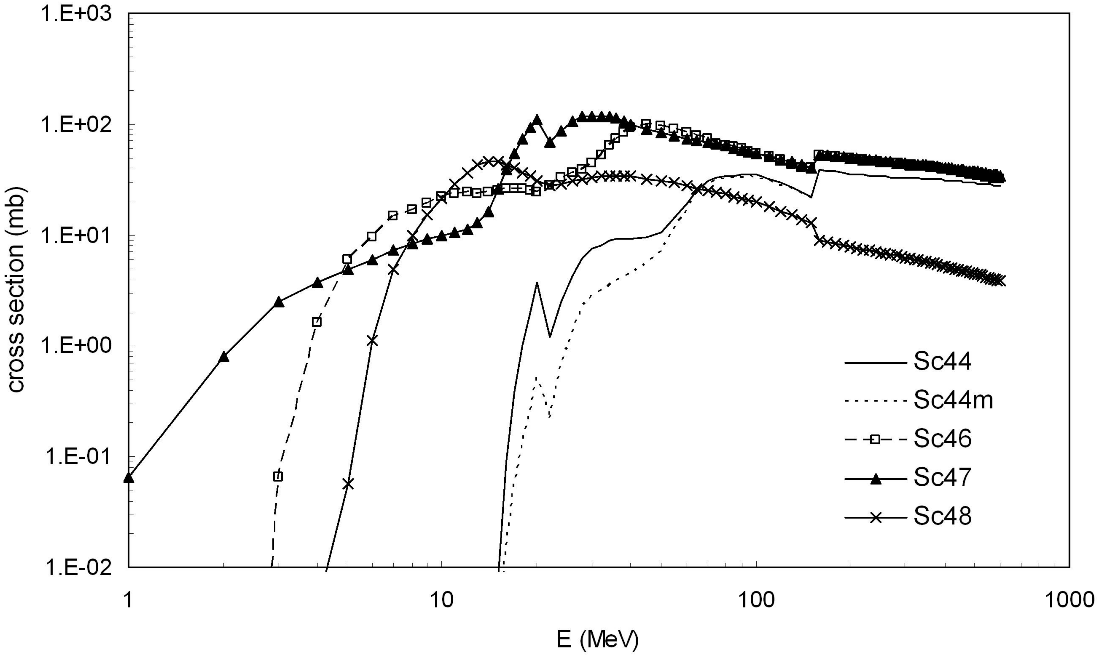

Figure C18. Cumulative neutron cross sections for indicated nuclides on a pure Ti target.

Annex D. Code comparison

Table D1. Comparison between activities (in Bq) after one year of cooling for nuclides relevant for safety. Calculations are shown with FLUKA 2006.3b and MCNPX 2.5.0 (INCL4-ABLA), for the target structure (lower half) and for the LBE. For the LBE also SNT results are given. The list for relevant nuclides is from Ref. [99].

Nuclide	**Target structure**			**LBE**		
	FLUKA	MCNPX	ratio	FLUKA	MCNPX	SNT
H 3	2.37E+11	7.20E+09	3.29E+01	7.72E+12	2.36E+11	6.12E+12
Be 10	9.98E+04			6.57E+04	2.26E-02	3.66E+05
C 14	2.38E+07			7.51E+06	1.60E-01	4.29E+07
Na 22	3.16E+11	1.29E+09	2.45E+02	7.76E+08	1.64E+03	8.49E+07
Al 26	7.83E+06	1.08E+04	7.25E+02	1.30E+03	4.00E+03	1.75E+00
Si 32	2.50E+07	1.73E+02	1.45E+05	1.33E+08	1.33E+07	1.13E+04
S 35	6.02E+09	2.04E+09	2.95E+00	5.27E+09	6.79E+08	7.89E+05
Cl 36	3.88E+05	1.91E+05	2.03E+00	3.25E+04	1.53E+04	1.29E+02
Ar 39	2.70E+08	1.51E+08	1.79E+00	1.53E+08	7.48E+07	4.82E+05
Ar 42	3.28E+07	6.89E+07	4.76E-01	9.96E+08	3.41E+08	7.17E+06
Ca 41	1.72E+06	2.43E+06	7.08E-01	4.27E+04	5.23E-02	2.05E+04
Ca 45	2.14E+10	1.36E+10	1.57E+00	2.55E+10	2.21E+10	6.38E+09
Sc 46	3.82E+10	2.03E+10	1.88E+00	5.17E+09	4.30E+09	2.86E+09
Ti 44	1.14E+09	2.01E+09	5.67E-01	3.00E+07	8.35E-02	8.88E+04
V 49	1.05E+12	8.07E+11	1.30E+00	2.29E+10	3.16E+09	8.46E+09
Mn 53	1.55E+06	1.21E+06	1.28E+00	1.49E+04	4.34E+03	9.03E+03
Mn 54	3.54E+12	2.77E+12	1.28E+00	3.68E+10	8.23E+09	3.14E+10
Fe 55	1.65E+13	1.94E+13	8.51E-01	1.14E+10	4.39E+09	8.81E+09
Fe 60	6.45E+02	3.59E+01	1.80E+01	1.76E+05	1.72E+05	2.10E+05
Co 56	4.26E+10	7.87E+09	5.41E+00	1.15E+09	2.63E+08	5.02E+08
Co 57	4.03E+11	9.52E+09	4.23E+01	1.53E+10	4.07E+09	1.58E+10
Co 58	1.56E+11	3.39E+09	4.60E+01	4.82E+09	2.68E+09	6.14E+09
Co 60	1.33E+12	4.74E+11	2.81E+00	2.63E+10	1.25E+10	3.49E+10
Ni 59	6.40E+08	2.52E+07	2.54E+01	7.31E+05	3.15E+06	1.22E+06
Ni 63	8.18E+10	3.05E+09	2.68E+01	4.72E+09	4.60E+09	8.04E+09
Zn 65	3.71E+08	1.10E+09	3.37E-01	2.71E+10	2.36E+10	5.59E+10
Ge 68	1.25E+08			4.76E+09	7.31E+09	9.28E+09
As 73	2.01E+08	2.75E+08	7.31E-01	2.82E+10	3.11E+10	6.53E+10
Se 75	4.73E+08	6.04E+08	7.83E-01	4.79E+10	4.56E+10	1.15E+11
Se 79		1.35E-04		2.48E+06	4.87E+07	6.65E+06
Kr 81	2.23E+04	3.25E+04	6.86E-01	2.77E+06	3.28E+06	6.62E+06
Kr 85	5.18E+06	3.69E+01	1.40E+05	1.17E+11	1.19E+11	1.59E+11
Rb 83	1.50E+09	3.33E+08	4.50E+00	8.82E+10	8.93E+10	3.22E+11
Rb 87				5.52E+01	1.84E+03	
Sr 85	8.63E+08	2.90E+08	2.98E+00	3.01E+10	3.08E+10	7.64E+10
Sr 90	1.86E+07	1.18E+00	1.58E+07	7.27E+10	7.17E+10	6.81E+10
Y 88	1.61E+10	4.93E+09	3.27E+00	2.46E+11	1.95E+11	6.11E+11
Zr 88	3.42E+09	1.22E+09	2.80E+00	1.36E+10	1.24E+10	4.14E+10
Zr 93	2.16E+03	2.55E+02	8.47E+00	2.50E+06	2.34E+06	2.49E+06
Zr 95	1.16E+08	4.96E+06	2.34E+01	1.32E+11	1.35E+11	1.14E+11
Nb 91	1.35E+08	5.05E+07	2.67E+00	4.43E+08	3.29E+08	1.22E+09
Nb 94	1.59E+07	1.31E+07	1.21E+00	7.13E+07	7.03E+07	9.79E+07
Mo 93	4.68E+07	2.04E+07	2.29E+00	4.73E+07	4.80E+07	1.49E+08
Tc 95m		2.18E+00		5.63E+06	6.89E+03	1.07E+08
Tc 97	9.57E+02	1.00E-01	9.57E+03	2.96E+05	2.38E+05	5.60E+05
Tc 97m		1.16E+04		5.05E+06	8.38E+06	3.70E+07
Tc 98	3.95E+02	9.00E-02	4.39E+03	2.32E+05	2.59E+05	2.80E+05

Table D1. Continued.

Nuclide	**Target structure**			**LBE**		
	FLUKA	MCNPX	ratio	FLUKA	MCNPX	SNT
Tc 99	4.31E+06	1.43E+06	3.01E+00	2.13E+07	2.13E+07	2.05E+07
Ru 106		0.00E+00		6.17E+11	4.67E+11	4.57E+11
Rh 101		2.42E+01		7.67E+10	8.50E+10	1.73E+11
Rh 102		1.45E+02		2.14E+11	1.56E+11	1.92E+11
Cd 109	2.33E+08	2.88E+04	8.09E+03	1.30E+11	1.54E+11	4.47E+11
Cd 113						
Cd 113m		5.31E+03		1.24E+09	3.58E+08	7.84E+08
In 115						
Sn 113	5.13E+08	1.15E+08	4.46E+00	3.12E+10	4.07E+10	1.33E+11
Sn 119m		5.42E+08		3.01E+11	2.39E+09	2.08E+11
Sn 121m		2.06E+07		2.30E+08	1.74E+08	2.91E+08
Sn 123	8.04E+07	3.30E+08	2.44E-01	2.42E+10	3.17E+10	2.24E+10
Sn 126				3.40E+04	6.90E+04	3.69E+04
Sb 124		1.74E+05		7.69E+09	6.23E+09	1.00E+10
Sb 125	2.64E+08	8.13E+09	3.25E-02	4.16E+10	3.41E+10	4.73E+10
Te 121m				1.46E+10	1.32E+07	2.38E+08
Te 127m				1.15E+09	1.33E+09	1.95E+09
I 129				9.22E+03	7.90E+03	9.98E+03
Cs 134				1.87E+10	1.58E+10	1.20E+10
Cs 135				2.01E+04	2.26E+04	1.08E+04
Cs 137				2.77E+08	5.97E+08	1.27E+08
Ba 133				2.24E+10	1.72E+10	1.62E+10
La 137				4.42E+06	3.80E+06	1.55E+06
Ce 139				7.13E+10	6.45E+10	1.44E+10
Ce 144				2.26E+09	1.05E+09	1.88E+08
Pm 143				2.73E+10	3.85E+10	2.72E+09
Pm 144				1.44E+10	1.33E+10	1.83E+08
Pm 145				3.29E+09	2.89E+09	1.69E+08
Pm 146				5.27E+09	2.65E+09	1.66E+07
Pm 147				1.20E+10	6.16E+09	1.38E+08
Sm 145				1.49E+10	2.01E+10	2.03E+09
Eu 149				5.61E+09	6.04E+09	7.68E+08
Eu 150				4.66E+08	1.28E+08	1.52E+05
Eu 152				7.79E+08	2.70E+08	3.91E+06
Eu 154				5.11E+08	1.17E+07	3.18E+05
Eu 155				9.56E+08	1.08E+06	8.97E+03
Gd 148				1.20E+08	1.83E+08	4.65E+07
Gd 151				6.11E+09	4.35E+09	1.20E+09
Gd 153				1.38E+10	1.66E+09	1.48E+09
Tb 158				2.67E+07	1.49E+07	4.24E+05
Tb 160				2.10E+08	1.01E+05	2.20E+05
Dy 159				9.37E+09	7.53E+08	3.06E+09
Tm 170				5.58E+08	1.40E+08	1.53E+08
Tm 171				4.73E+08	3.70E+05	3.62E+05
Lu 173				1.85E+11	2.07E+11	3.48E+11
Lu 174				3.92E+08	1.04E+09	4.99E+08
Hf 172				1.28E+11	1.14E+11	2.39E+11
Hf 174						
Hf 175				6.21E+10	7.56E+10	1.20E+11
Hf 182		1.88E+03				3.48E+00
Ta 179	1.94E+08	7.10E+06	2.73E+01	6.82E+11	1.05E+12	1.40E+12
Ta 182	5.12E+10	1.25E+10	4.10E+00	2.38E+08	5.25E+08	4.45E+08

Table D1. Continued.

Nuclide	Target structure			LBE		
	FLUKA	MCNPX	ratio	FLUKA	MCNPX	SNT
W 185	5.52E+07	3.76E+07	1.47E+00	8.13E+08	4.59E+08	8.14E+08
Re 183		2.65E+00		3.59E+11	5.71E+11	6.88E+11
Re 187				2.73E+00	9.24E-02	
Os 185				1.12E+12	1.99E+12	1.93E+12
Os 194					1.47E+04	8.29E+07
Ir 192				8.65E+08	1.22E+11	1.02E+11
Pt 193				6.57E+11	6.57E+11	7.89E+11
Au 195				1.90E+13	1.76E+13	2.05E+13
Hg 194				9.33E+10	7.12E+10	1.04E+11
Tl 204				2.70E+12	4.38E+12	3.84E+12
Pb 202				2.29E+09	2.02E+09	1.90E+09
Pb 205				1.42E+07	1.61E+07	1.63E+07
Bi 207				4.26E+12	5.05E+12	5.11E+12
Bi 208				6.91E+08	7.83E+08	9.08E+08
Po 208				2.18E+12	9.43E+11	1.59E+12
Po 209				1.37E+10	2.25E+10	3.09E+10
Po 210				2.19E+13	2.07E+13	1.45E+13
total	**2.38E+13**	**2.36E+13**	**1.01**	**6.37E+13**	**5.58E+13**	**6.09E+13**

Annex E. Acronyms

ADS	Accelerator-Driven System
CEA	Commissariat à l'Énergie Atomique
CEM	Cascade Exciton Model
CERN	European Organization for Nuclear Research
CGS	Cover Gas System
DGS	Decayed Gas Sampling
DN	Delayed Neutron
EIGER	Enhance Intensity and Greater Energy Range thermal neutron triple-axis spectrometer
ENDF/B	Evaluated Nuclear Data File version B
ESS	European Spallation Source
EURISOL	EURopean ISOL radioactive ion beam facility
EXFOR	EXchange FORmat
FC	Fission Chamber
FGS	Fresh Gas Sampling
FLUKA	FLUctuating KAskades Monte Carlo code
FZK	Forschungszentrum Karlsruhe
GSI	Gesellschaft für Schwerionenforschung mbH, Darmstadt, Germany
HINDAS	High and Intermediate energy Nuclear Data for Accelerator-driven Systems
ICON	Instrument for COld Neutron radiography at SINQ
ICRU	International Commission for Radiological Units
ILL	Institute Laue-Langevin
INCL4	IntraNuclear Cascade Liège (version #4)
JEFF	Joint Evaluated Fission and Fusion file
LBE	Lead-Bismuth Eutectic
MEGAPIE	MEGAWatt Pilot Experiment
MCNPX	Monte Carlo N-Particle eXtended radiation transport code
MURE	MCNP Utility for Reactor Evolution
NAA	Neutron Activation Analysis (irradiation facility at SINQ)
NEUTRA	NEUtron TRAnsmission radiography station at SINQ
PIE	Post Irradiation Experiment
PNA	Präparative Neutronenaktivierung (irradiation facility at SINQ)
PSI	Paul Scherrer Institut
SEM	Scanning Electron Microscopy
SINQ	Swiss spallation neutron source (Spallation Neutronen Quelle)
SNS	Spallation Neutron Source (USA)
STIP	SINQ Target Irradiation Program
THX	Target Heat eXchanger
TKE	Target Head Enclosure

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REFERENCES

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1. G. S. Bauer, M. Salvatores, G. Heusener, *J. Nucl. Mat 296, 17 (2001).*
2. The European technical working roup on ADS, *A European roadmap for developing ADS for nuclear waste incineration*, 2001.
3. G. S. Bauer, Y. Dai and W. Wagner, *SINQ layout, operation, applications and R&D to high power*, J. Phys. IV France 12 (2002).
4. L. Zanini *et al., Summary Report for MEGAPIE R&D Task Group X9*, PSI Bericht Nr. 05-12, 2005.
5. T. Kirchner *et al.*, *MEGAPIE Target design and dimensioning*, in Proceedings of the 4th MEGAPIE Technical Review Meeting, edited by C. Fazio, J. U. Knebel, F. Gröschel, p. 5, Paris, France, March 18-19, 2003.
6. C. Fazio *et al.*, Nucl. Eng. Des. 238, 1471 (2008).
7. S. Dementjev *et al.*, *MEGAPIE-SINQ experiment. Operational experience, components behaviour*, MPS-SINQ-DS34-102/0.
8. V. Vlachoudis, private communication, 2005.
9. Persistence of vision raytracer, www.povray.org.
10. Y. Dai and G.S. Bauer, *Status of the first SINQ Irradiation Experiment, STIP-I,* Journal of Nuclear Materials **296** (2001) 43.
11. Y. Dai et al., *The Second SINQ Target Irradiation Program, STIP-II,* J. Nucl. Mater. 343 (2005) 33.
12. U. Rohrer, *p-Strahlbreiten unp Profil-Formen beim SINQ-Target mit und ohne Target E (4 cm graphit)*, PSI internal report (2001).
13. Y. Dai, private communication, 2007.
14. S. Roesler, R. Engel, J. Ranft, *The Monte Carlo event generator DPMJET*-III, Proceedings of the Monte Carlo 2000 conference, A. Kling, F. Barao and F. Nakagawa eds., Springer-Verlag, 1033 (2001).
15. L. Zanini *et al.*, *Neutronic Performance of the MEGAPIE target*, Eighth International Topical Meeting on Nuclear Applications and Utilization of Accelerators, ACCAPP'07, American Nuclear Society, LaGrange Park, Illinois 60526, p. 493 (2007).
16. S. Panebianco *et al.*, *Neutronic Characterization of the MEGAPIE target*, Eighth International Topical Meeting on Nuclear Applications and Utilization of Accelerators, ACCAPP'07, American Nuclear Society, LaGrange Park, Illinois 60526, p. 485 (2007).
17. *The TARC experiment (PS211): Neutron-Driven Nuclear Transmutation by Adiabatic Resonance Crossing*, editor J. P. Revol, CERN 99-11, 15 December 1999.
18. A. Letourneau *et al.*, *Proceedings of the 3rd International Workshop Fission 2005*, Cadarache France, May 2005, published in AIP Conf. Proc. **798,** 277 (2005).
19. S. Chabod *et al.*, Nucl. Instrum. And Meth. A **562**, (2006) 618-620.
20. S. Chabod *et al.*, Nucl. Instrum. And Meth. A **566**, (2006) 633.
21. S. Chabod, Ph.D. thesis, University of Paris XI, 2006.
22. A. Letourneau *et al.*, in *Summary Report for MEGAPIE R&D Task Group X9*, PSI Bericht Nr. 05-12, 2005.
23. F. Atchison, *A guide to the SINQ design*, PSI internal report, 1987.
24. G. Erdtmann, *Neutron Activation Tables*, Verlag Chemie, 1976.
25. *Genie 2000 3.0 Operations Manual*, Canberra Industries, Inc., 2004.
26. K. H. Beckurts, K. Wirtz, *Neutron physics,* Springer-Verlag, 1964.
27. I. F. Gonçalves *et al.*, Applied Radiation and Isotopes 56 (2002), 945.
28. R. Hassanein, *Correction Methods for the quantitative evaluation of thermal neutron tomography*, Ph.D. thesis, ETH, 2007.
29. U. Filges, private communication, 2007.

---

30. P. D. Ferguson *et al.,* in *Proceedings of the XVI Meeting of the Int. Collaboration on Advanced Neutron Sources*, 12-15 May 2003, Neuss, Germany.
31. D. Ridikas *et al.*, *Europ. Phys. Journ. A* **32** (2007) 1-4.
32. D. Ridikas *et al.,* in *Proceedings of the 3rd International Workshop Fission 2005*, May 2005, Cadarache, France, published in AIP Conf. Proc. **798** (2005) 277.
33. W.B. Wilson *et al.*, Progress in Nucl. Energy **41**, (2002) 71-107.
34. T.V. Dury, Journ. Nucl. Science and Tech. **41**, (2003) 285-295.
35. Y. Foucher, M. Vatré, L. Zanini, MEGAPIE Input Model, private communication, 2006.
36. C. Perret, *Safety Report about the MEGAPIE Experiment with a liquid lead-bismuth eutectic target in the SINQ neutron source of PSI-West*, PSI report, 2002.
37. N. Frey, O. Morath, *SU-Mapping während der MEGAPIE Inbetriebnahme*, report PSI internal report AN-96-06-44, 2006.
38. *Accelerator-driven Systems (ADS) and Fast Reactors (FR) in Advanced Nuclear Fuel Cycle*s, OECD NEA Report, ISBN 92-64-18482-1, 2002.
39. J. Neuhausen, *Gas phase concentrations of volatile nuclear reaction products in the MEGAPIE expansion tank*, PSI report MPR-3-NJ18-002/0, 2005.
40. J. Neuhausen *et al.*, Radiochim. Acta 92, 917 (2004).
41. J. Neuhausen *et al.*, Radiochim. Acta 93, 155 (2005).
42. L. Zanini *et al., Volatile Elements Production Rates in a 1.4 GeV Proton-Irradiated Molten Lead-Bismuth Target,* CERN-PH-EP/2004-060.
43. Y. Tall *et al.*, *Volatile elements production rates in a proton-irradiated molten lead-bismuth target,* Proceedings of the International Conference on Nuclear Data for Science and Technology, Nice, 2007.
44. Y. Tall, Ph.D. thesis, 2008.
45. H. W. Bertini, Phys. Rev. 188(1969), p 1711.
46. L. W. Dresner, Report ORNL-TM-196 (Oak Ridge National Laboratory, Oak Ridge, TN) (1962).
47. A. Boudard *et al.*, Phys. Rev. C 66 (2002) 044615.
48. A. Junghans *et al.*, Nucl. Phys. A 629 (1998) 635.
49. Y. Yariv, Z. Fraenkel. Phys. Rev. C, 20 (1979), p 2227.
50. S. G. Masnik, V.D. Toneev. *MODEX – The program for calculation of the energy spectra of particles emitted in the reaction of pre-equilibrium and equilibrium statistical decays, Communication JINR P4-8417*, Dubna, 1974.
51. P. Fong, *Fission Dynamics and the Statistical Theory, Phys. Rev.* **135B** (1964) 1338.
52. A. Yu. Konobeyev, Yu. A. Korovin, M. Vecchi, *Fission Product Yields in Nuclear Reactions Induced by Intermediate Energy Particles*, *Kerntechnik*, **64** (1999) 216.
53. A. Guertin *et al.*, *Eur. Phys. J.A* (2005) 1; DOI 10.1140/ epja/i2004-10073-1.
54. C.-M.Herbach *et al.*, *Nucl. Phys.* **A765** (2006) 426.
55. V.S. Barashenkov, V.D. Toneev, Interaction of High Energy Particles and Atomic Nuclei with Nuclei, Atomizdat, Moscow, 1972.
56. L. Milazzo-Colli, G. M. Braga-Marcazzan, *Nuovo Cimento* **30A** (1975) 632.
57. H. Dubost, B. Gatty, M. Lefort, J. Peter, X. Tarrago, *J. de Physique* **28** (1967) 257.
58. K. Goebel, H. Schultes, J. Zähringer, *Production Cross Sections of Tritium and Rare Gases in Various Target Elements*, Report CERN 64-12 (1964).
59. C.H.M. Broeders, A.Yu. Konobeyev, Systematics of (p,α) (p,nα), and (p,np) Reaction Cross-Sections, *Appl. Rad. Isot.* **65** (2007) 1249.
60. A. Koning, S. Hilaire, M. Duijvestijn, TALYS-0.72, http://www.talys.eu/.
61. C.H.M. Broeders, A.Yu. Konobeyev, A.Yu. Korovin, V.P. Lunev, M. Blann, ALICE/ASH - *Pre-Compound and Evaporation Model Code System for Calculation of Excitation*

Functions, Energy and Angular Distributions of Emitted Particles in Nuclear Reactions at Intermediate Energies, FZKA 7183 (2006).

62. C.H.M. Broeders, A.Yu. Konobeyev, Yu.A. Korovin, V.N. Sosnin, DISCA - *Advanced Intranuclear Cascade Cluster Evaporation Model Code System for Calculation of Particle Distributions and Cross Sections at Emitted Particles in Nuclear Reactions at Intermediate Energies*, Forschungs-zentrum Karlsruhe, FZKA 7221, (2006).
63. C.H.M.Broeders, A.Yu.Konobeyev, *J. Nucl. Sci. Technol.*42 (2005) 897.
64. C.H.M. Broeders, A.Yu. Konobeyev, *Nucl. Instr.Meth. Phys. Res.*, A550 (2005) 241.
65. D. Ridikas and A. Herrera-Martinez, *Radiation safety with high power operation of EURISOL*, Proceedings of the conference on Accelerator Application AccApp07, Pocatello, ID, USA, 2007, in press.
66. W. Wlazlo *et al.,* Phys. Rev. Lett. 84 (2000) 5736; T. Enqvist *et al.,* Nucl. Phys. A 686 (2001) 481-524 .
67. C. Villagrasa Canton *et al*., Phys. Rev. C 75 (2007) 044603.
68. M. Felcini, A. Ferrari, EURISOL-DS/Task 5/TN-06-01, 2005; B. Rapp *et al.*, CEA Saclay EURISOL DS/Task5/TN-06-04, 2006; J.-C. David *et al.*, CEA Saclay Internal report: DAPNIA-07-04 EURISOL DS/Task11, 2007; J.-C. David *et al.*, CEA Saclay Internal report: DAPNIA-07-59 EURISOL DS/Task11, 2007.
69. L. Zanini *et al.*, *Volatile elements production rates in a 1.4-GeV proton-irradiated molten lead-bismuth target*, in International Conference on Nuclear Data for Science and Technology, R. C. Haight *et al*., eds. Merville, New York, 2005, p. 1525.
70. S. Lemaire, J.-C. David and S. Leray, Proceedings of the International Conference on Nuclear Data for Science and Technology, Nice, 2007.
71. L. Zanini, S. Lemaire, *Update on Monte Carlo calculations of activation of the MEGAPIE target*, PSI internal report TM-34-07-09, 2007.
72. A. Fassó *et al., FLUKA: a multi-particle transport code*, CERN-2005-10, INFN/TC_05/11, SLAC-R-773 (2005).
73. *MCNPX User's Manual, Version 2.5.0*, April 2005, LA-CP-0500369 (Denise B. Pelowitz, editor).
74. F. Atchison and H. Schaal, *Orihet 3 – Version 1.12, A guide for users*, March 2001.
75. Y. Yariv and Z. Fraenkel, Phys. Rev. C, 20 (1979) 2227; Y. Yariv and Z. Fraenkel, Phys. Rev. C, 24 (1981) 488.
76. S. G. Mashnik and A. J. Sierk, *Recent Developments of the Cascade-Exciton Model of Nuclear Reactions*, Los Alamos National Laboratory Report LA-UR-01-5390, Los Alamos (2001).
77. Yu.A.Korovin, A.Yu.Konobeyev, P.E.Pereslavtsev, The Code for Calculation of Isotope Concentration and Induced Activity of Irradiated Materials, *Voprosy Atomnoi Nauki i Techniki (Problems of Nuclear Science and Technology), Series: Nuclear Data*, 3-4 (1992) 117.
78. Yu. A. Korovin, V.V.Artisjuk, A.Yu.Konobeyev, P.E.Pereslavtsev, *Target and Structural Materials Activation Study for Accelerator-Based Transmutation Installations*, in Proc. Int. Conference and Technology Exposition. Future Nuclear Systems (GLOBAL), Sept. 1993, Seattle, USA, p. 760.
79. Yu.N.Shubin, A.V.Ignatyuk, A.Yu.Konobeyev, V.P.Lunev, *The Analyses of Long-Lived Radi -oactivity in Lead and Lead-Bismuth Targets*, in Proc. International Conference on Evaluation of Emerging Nuclear Fuel Cycle Systems (GLOBAL), Versailles, France, September 1995, p. 1522.
80. A. Yu. Konobeyev, Yu. A. Korovin, V. N. Sosnin, *Kerntechnik*, **64** (1999) 284.
81. A. Yu. Konobeyev, Yu. A. Korovin, M. Vecchi, *J. Nucl. Sci. Technol.*, Supplement **2**, (2002) p.1256.

---

82. http://www.nea.fr/html/dbdata/JEFF/.
83. U. Fischer *et al.*, *Intermediate Energy Activation File 2001 (IEAF-2001)*, FZK report, Interner Bericht, IRS-Nr.10/01-Fusion-Nr.179, August 2001.
84. Yu. Korovin *et al.*, *Evaluation of Activation Nuclear Data in the Energy Region 150 MeV to 1 GeV*, Proc. Int. Conf. for Nuclear Data for Science and Technology, Nice, April 22-27, 2007.
85. C.H.M. Broeders, U. Fischer, A.Yu. Konobeyev, L. Mercatali, S.P. Simakov, *J. Nucl. Sci. Technol.* **44** (2007), 933.
86. A. Yu. Konobeyev, U.Fischer, *Evaluated Data to Study Activation and Transmutation of Lead and Bismuth Irradiated with Protons at Energies up to 0.6 GeV*, 4th Workshop on Neutron Measurements, Evaluations and Applications - Nuclear data needs for Generation IV and accelerator driven systems (NEMEA), October 16-18, 2007 Prague.
87. R. Silberberg, C.H. Tsao, A.F. Barghouty, *Astrophys. J.*, **501** (1998) 911.
88. A. Yu. Konobeyev, Yu. A. Korovin, *Nucl. Instr. Meth. Phys. Res.*, **B82** (1993) 103.
89. F.P.Denisov, V.N.Mekhedov, *Nuclear Reactions at High Energies*, Moscow, Atomizdat, 1972.
90. A. Yu. Konobeyev, M. Vecchi, *Nuclide Composition of Pb-Bi Heat Transfer Irradiated in 80 MW Sub-Critical Reactor*, in Proc. Workshop on Spallation Module, October 18th, 1999, ENEA, Bologna, Report ENEA GRX-TM-00001, p. 70.
91. M. Felcini, A. Ferrari, EURISOL-DS/Task 5/TN-06-01, 2005.
92. B. Fernández-Domínguez *et al.*, *Nucl. Phys.* **A747** (2005) 227.
93. L. Audouin *et al.*, *Nucl. Phys.* **A768** (2006) 1.
94. B. Fernández-Domínguez *et al.*, *Nucl. Phys.* **A747** (2005) 227.
95. L. Audouin *et al.*, *Nucl. Phys.* **A768** (2006) 1.
96. Experimental Nuclear Reaction Data, http://www-nds.iaea.org/exfor/exfor00.htm.
97. K. H. Schmidt, ND-2007 International Conference on Nuclear Data for Science and Technology, April 22-27, 2007, Nice (France).
98. A. Yu. Konobeyev et al., Proc. Int. Conf. Nuclear Data for Science and Technology, Nice, April, 2007, N352.
99. S. Teichmann, private communication, 2007.

PAUL SCHERRER INSTITUT

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
Tel. +41 (0)56 310 21 11, Fax +41 (0)56 310 21 99
www.psi.ch