What do we measure, and how do we measure it ?

- Production of transactinides
- Isolation of nuclei of interest
- Instrumentation and measurements

K. Hauschild

Production of Transactinides

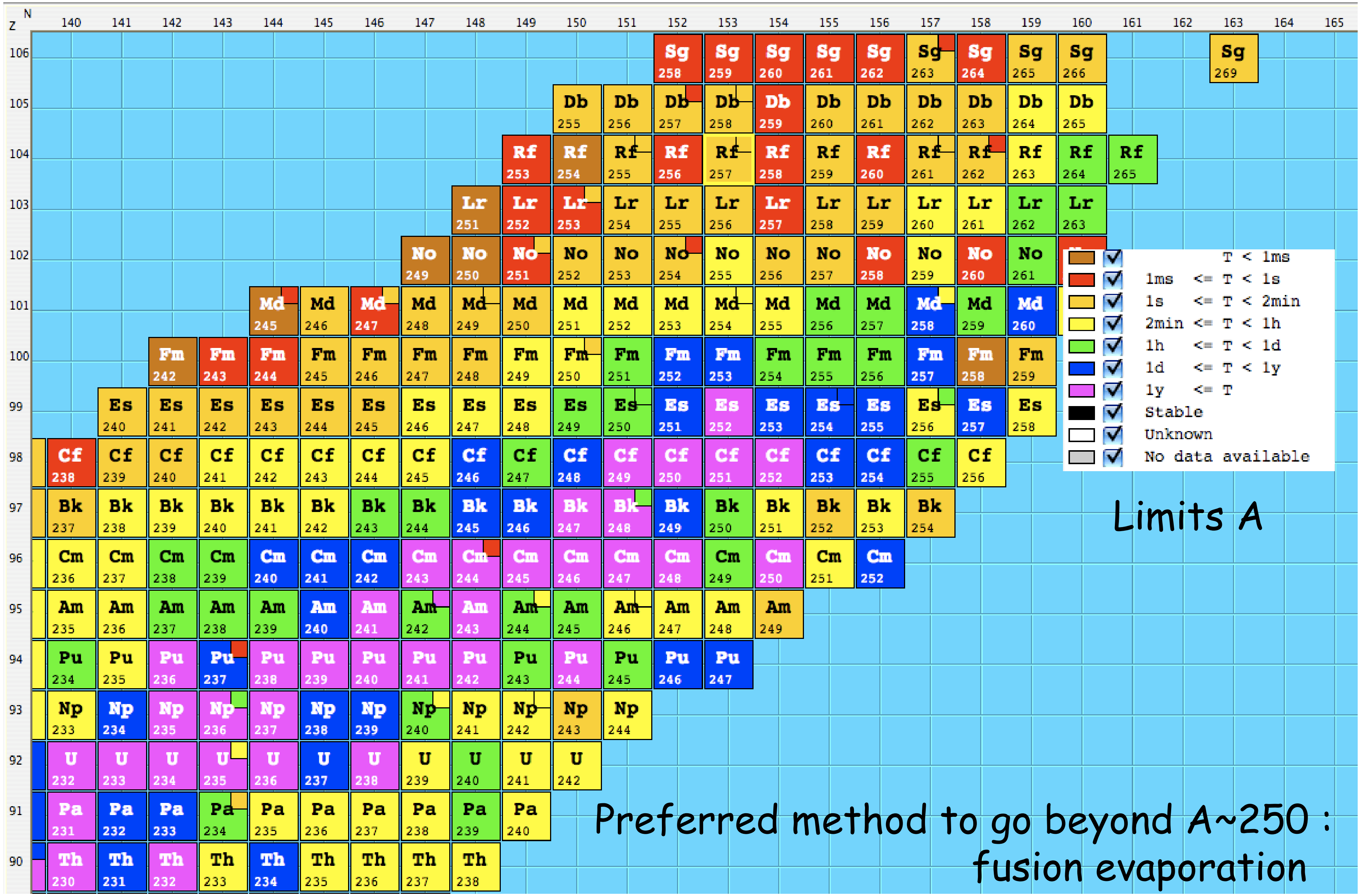
N-capture + β-decay
(reactor production eg 252Cf -> 255Es)

Transfer reactions : (d,p), (p,d), (t,p), (α,t)
(heaviest 254Es(t,p)256Es -> 256Fm*)

Multinucleon transfer

Require long Lived targets

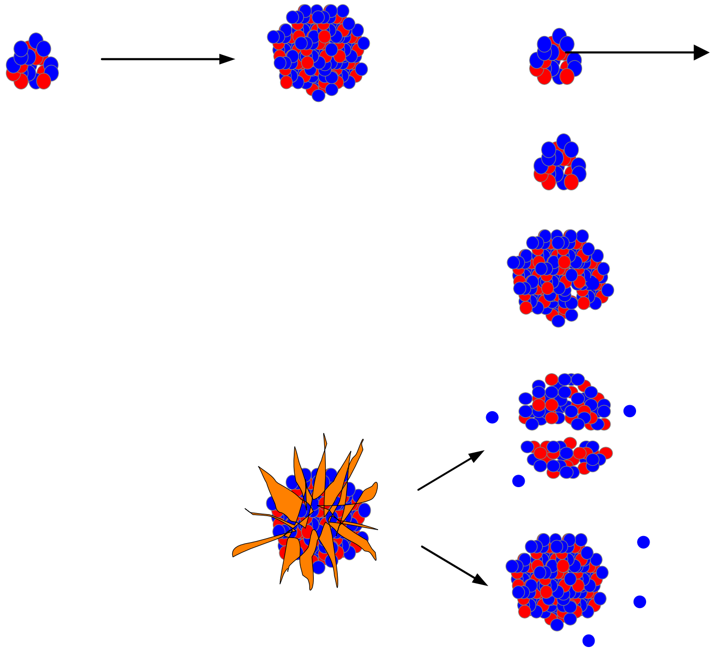
Production of Transactinides



Limits A

Preferred method to go beyond A~250 :
fusion evaporation

Production : Heavy ion fusion evaporation



Unreacted beam
Scattered beam

(**1 pμA : 6x10^{12} pps**)

Transfer : beamlike

Transfer : targetlike
Coulex

σ > 1 barn

Fusion - Fission

Survival of nucleus of interest : **σ ~ 100 nb**

For , I_{BEAM} = 1 pμA, σ = 100 nb, A_{target} ~ 200
=> < 2 ER/s per mg/cm^2

Want to select the needle in the hay stack !

Selection techniques
conditions experimental set up

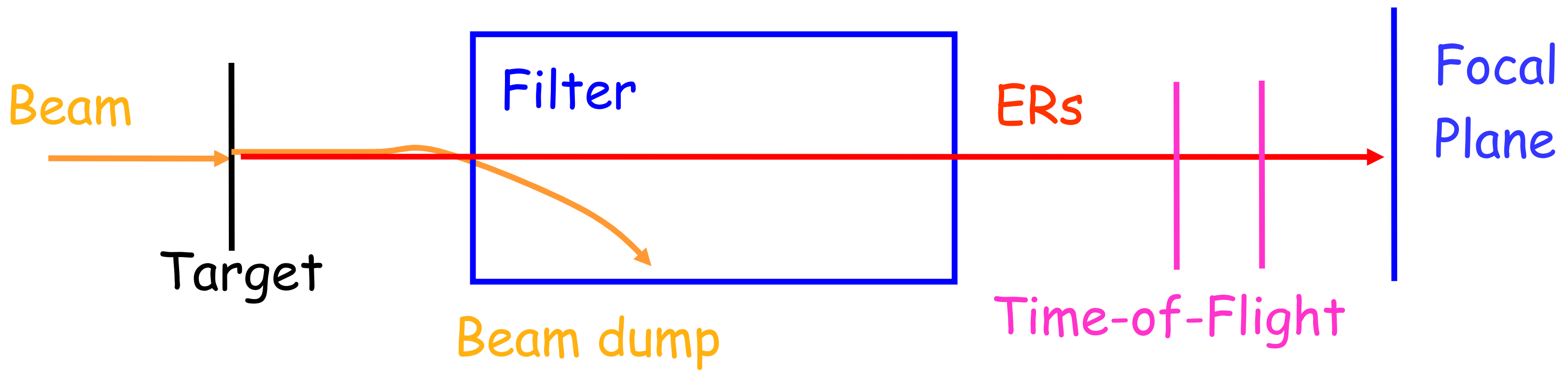
- Thick target and chemistry
- Thin targets :
- Catcher foils(chemistry or rotating wheel)
- Gas jet transport :
  - rotating wheels
  - couple to on-line mass separator (ISOL)

In-flight separators (most of us here)

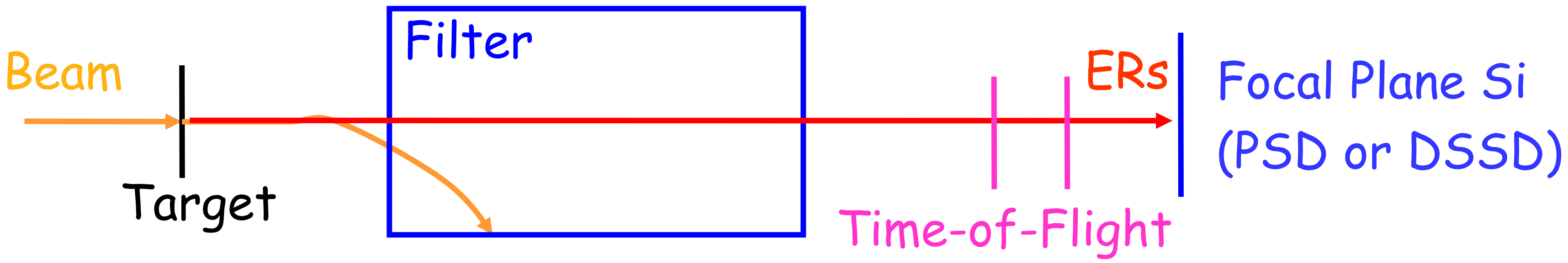
In flight separators

some examples :
Wein filter (crossed ED and MD) : SHIP, LISE
Electrostatic deflectors + MD : VASSILISSA
Electromagnetic mass analyser : FMA, CAMEL
Gas filled : RITU, DGFS, BGS
Hybrid : VAMOS (Wein + Magnetic spectrometer)

Aim is to remove beam (~ 1 μpA) from the detection system and to separate the recoils from the scattered beam and reaction products

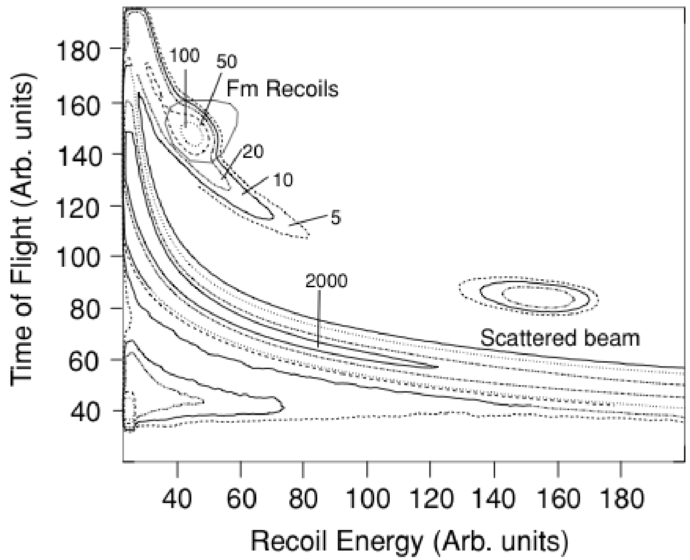


Identification of Recoils



1) Energy of transported ion is detected in focal plane Si

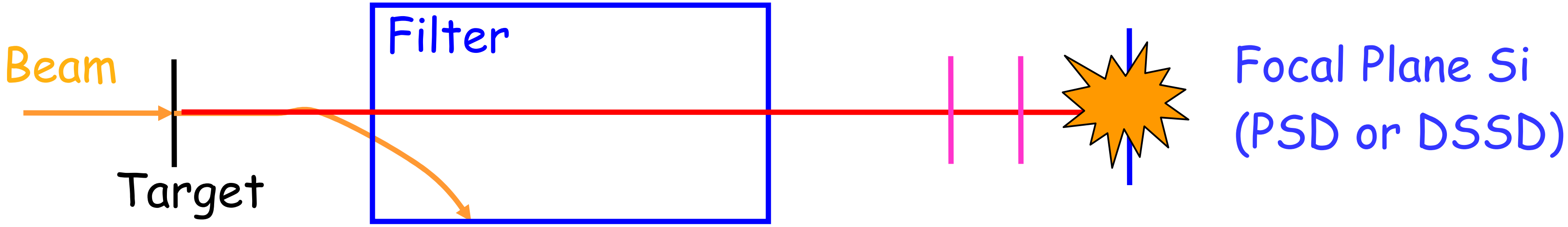
2) During transversal of separator - Time of flight measurement :
emissive foils or MultiWire Proportial Counter - DSSD
|_ dE also measured
(entrance windows+gas : asymmetric reactions)



(1) + (2) E-dE, E-ToF, (X-Y in ToF)

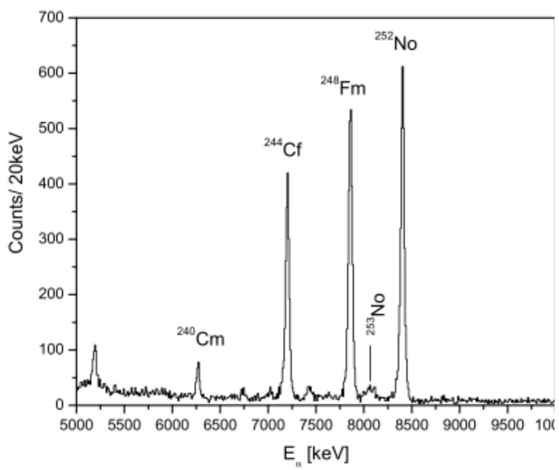
J.E. Bastin et al PRC 73 (2006) 024308

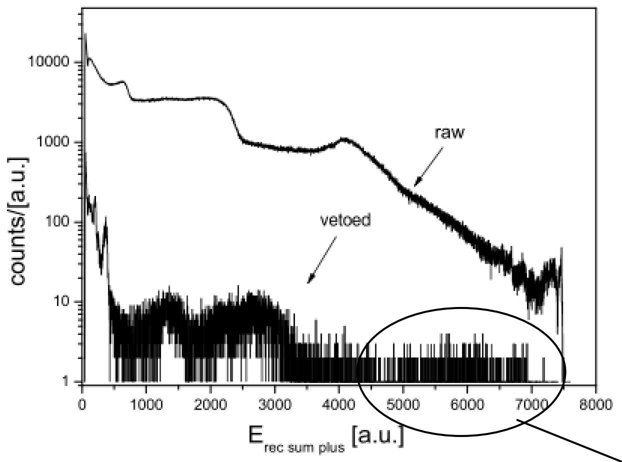
Identification of Alphas/Fission



Something detected in Si without coincident Time-of-Flight signal

FWHM ~15-25 keV



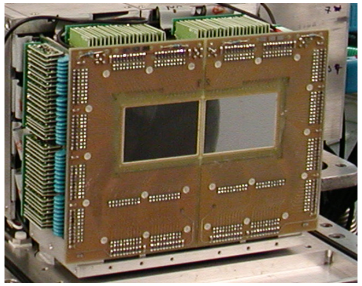


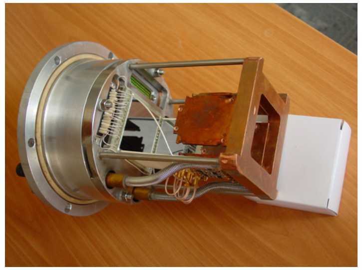
A.-P. Leppanen EPJA 28 (2006) 301

Recoil-Alpha Correlations

R(E1,T1, POS1), x, x, x, x, x, x, Alpha(E2,T2,POS2)

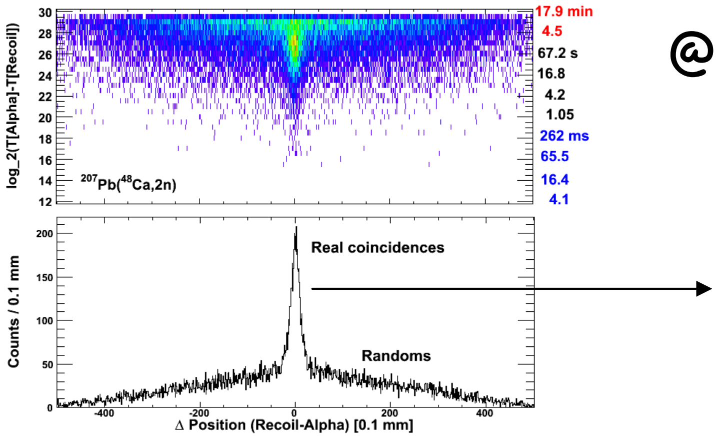
Key component : the position at which the events are detected
(Double Sided Strip Detector or Position Sensitive Strip Detector)



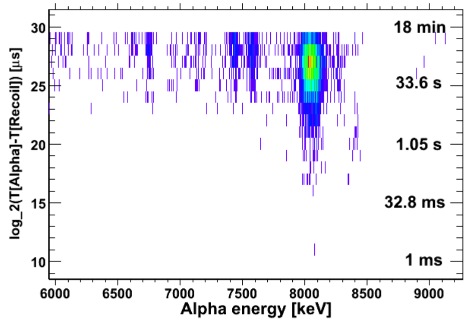


Position = StripX,StripY

Position = StripX, PosY



@ large dT random ↑



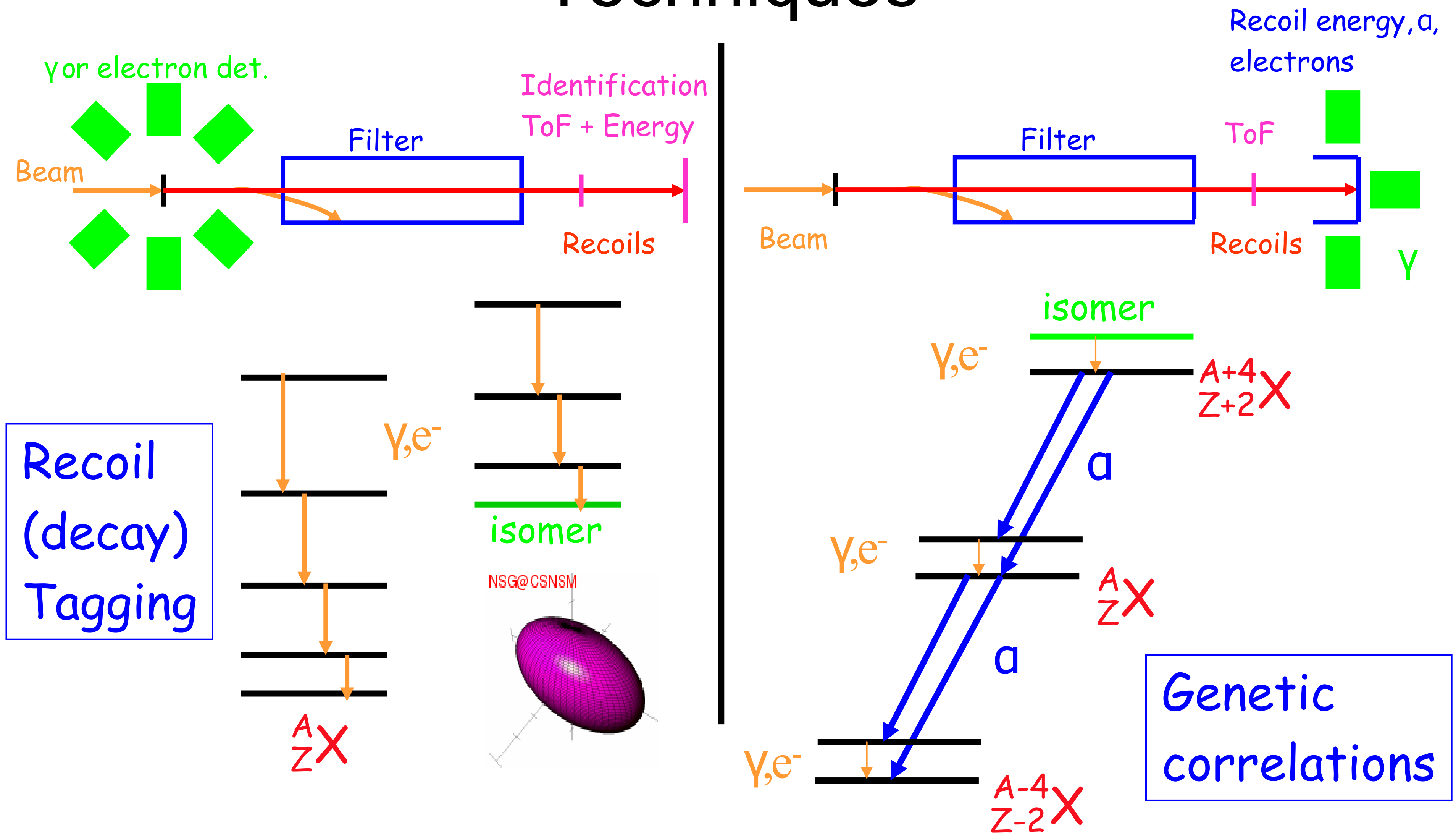
Alpha correlated recoils
- E(alpha), T1/2
- if fine-structure
  - I(a) -> HF (Ch. T)
- alpha emitting isomers

2 posibilities :

Prompt spectroscopy

Decay spectroscopy

Techniques



(taken from ToF)

Analysis techniques : individual time-stamped ADCs written to disk

1) Fine structure α-decay : α is the trigger and search for data of interest written later

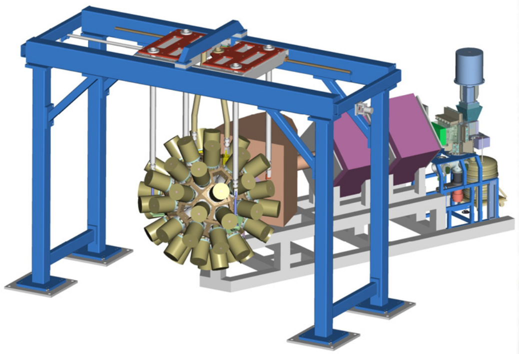
2) Recoil tagging : ToF v E(Recoil) is good, search for data of interest (γ, ce) earlier (prompt decay @ target, or, later (isomers in recoil

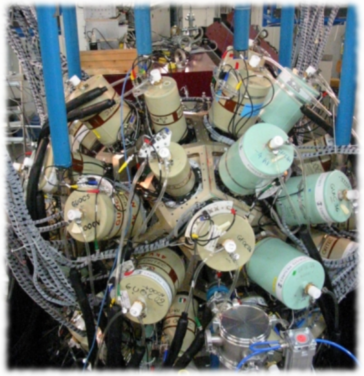
3) Recoil decay tagging : use the decay characteristics (τ, E(α)) and Si strip position sensitivity to search for position and time correlated Recoil-α events (and similarly recoil-fission or alpha - alpha)

Example set-ups : prompt spectroscopy

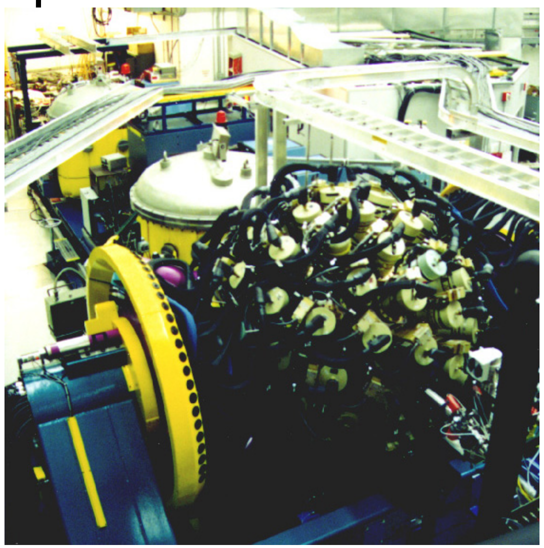
2 options : detect either Gamma-rays or Conversion electrons

Jurogam + RITU

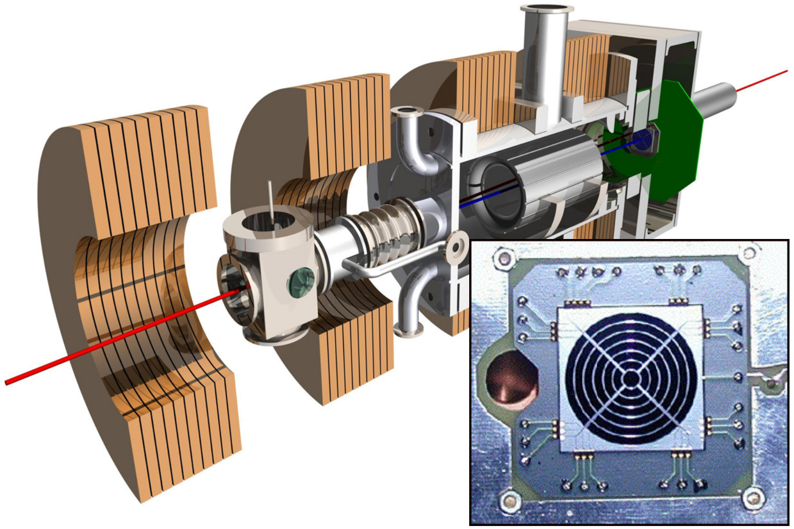




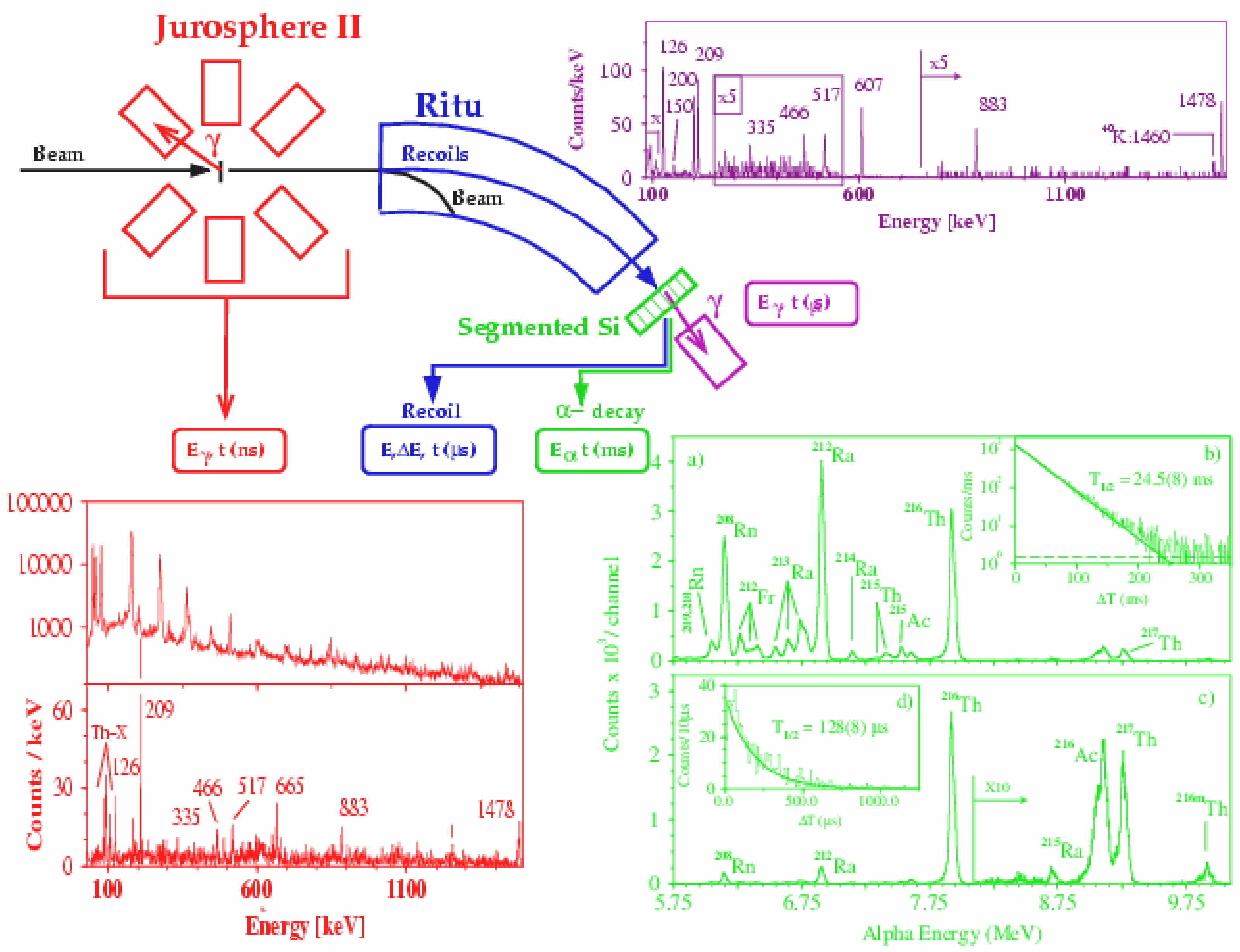
Gammasphere
+ FMA



SACRED + RITU

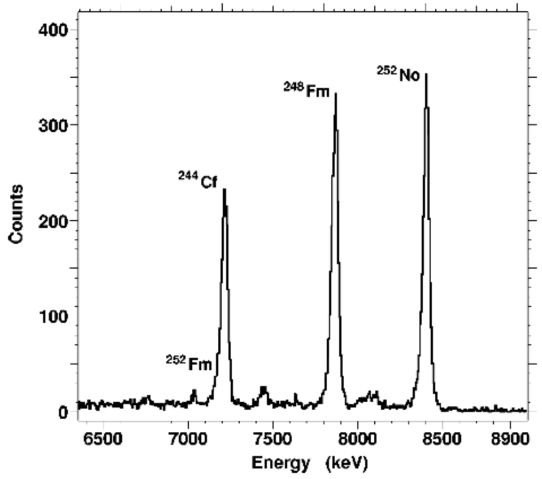


^{216}Th : Recoil [Alpha] Decay Tagging @ JYFL

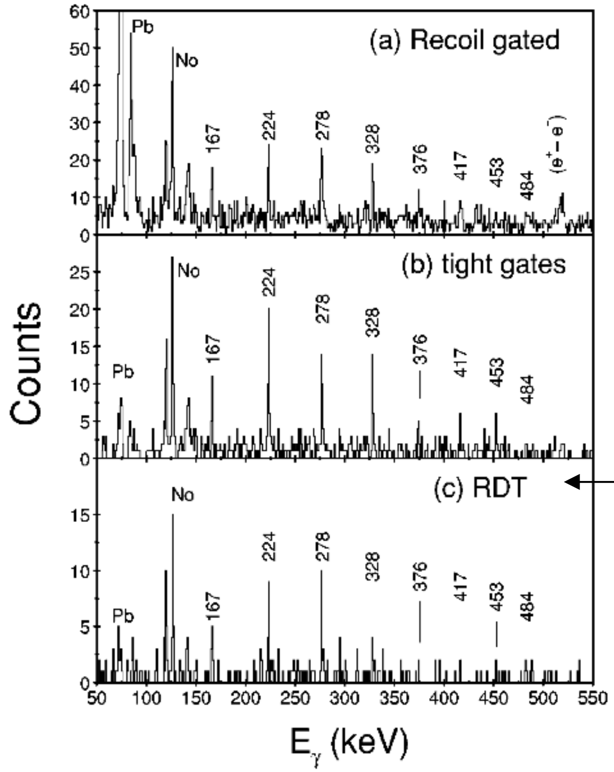


Prompt spectroscopy II

Example : 206Pb(48Ca, 2n)252No (fission branch ~25%)



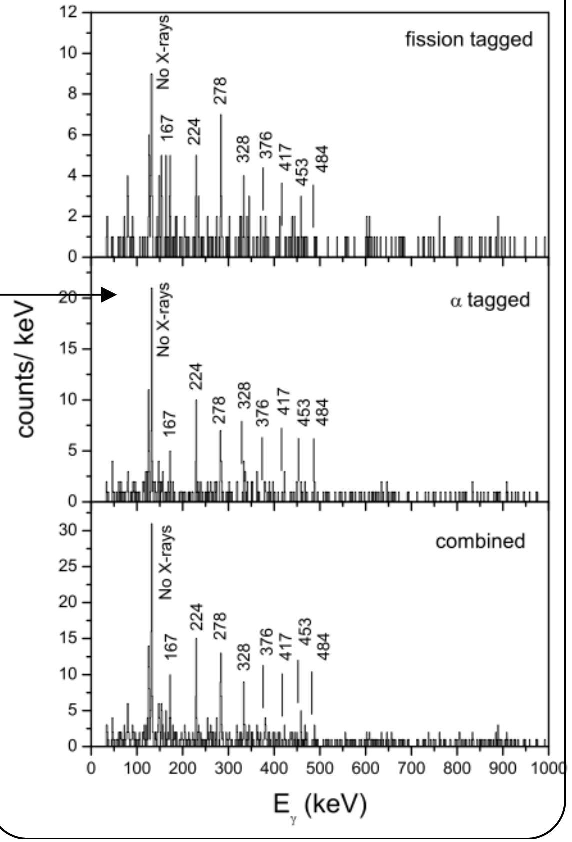
Alpha spectrum is very clean
=> try recoil gating only



R.-D. Herzberg et al,
PRC65 (2002) 014303

Alpha-correlated recoils
used as confirmation

A.-P. Leppanen et al,
EPJA28 (2006) 301



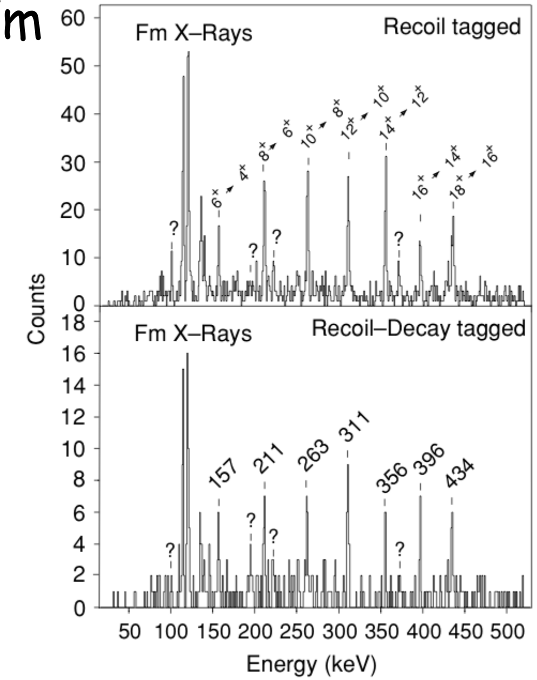
Recoil - fission tagging extends method

(FWHM ~1.25-2.0 keV)

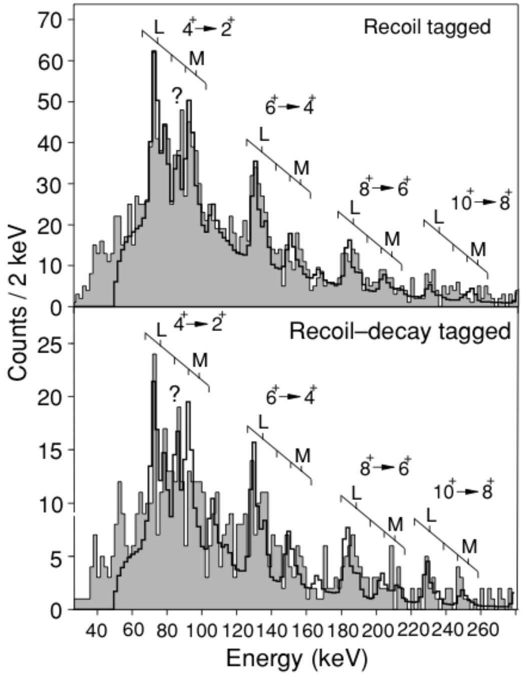
Prompt spectroscopy III

250Fm

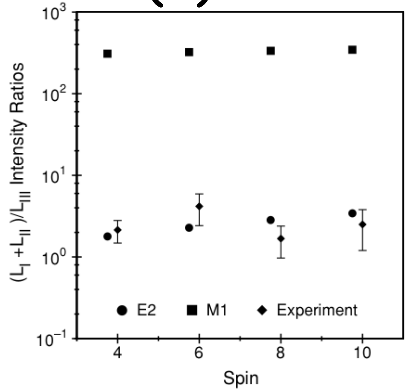
Jurosphere IV

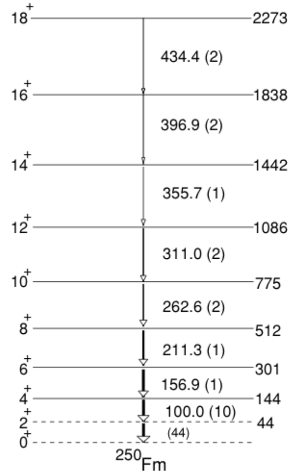


SACRED



I(e) -> ICC





$$J^{(1)} = (2I-1)h^2/[E_\gamma(I)] = J_0 + J_1\omega^2$$
$$J^{(2)} = 4h^2/[E_\gamma(I)-E_\gamma(I-2)] = J_0 + 3J_1\omega^2$$
} Harris

with $h\omega = E_\gamma/2$ and $I = J_0\omega + J_1\omega^3 + 1/2$

=> Estimate of E*(2+) -> B(E2:2+->0+) -> β_2 = 0.28(2)

J.E. Bastin et al., PRC73 (2006) 024308

Prompt spectroscopy IV

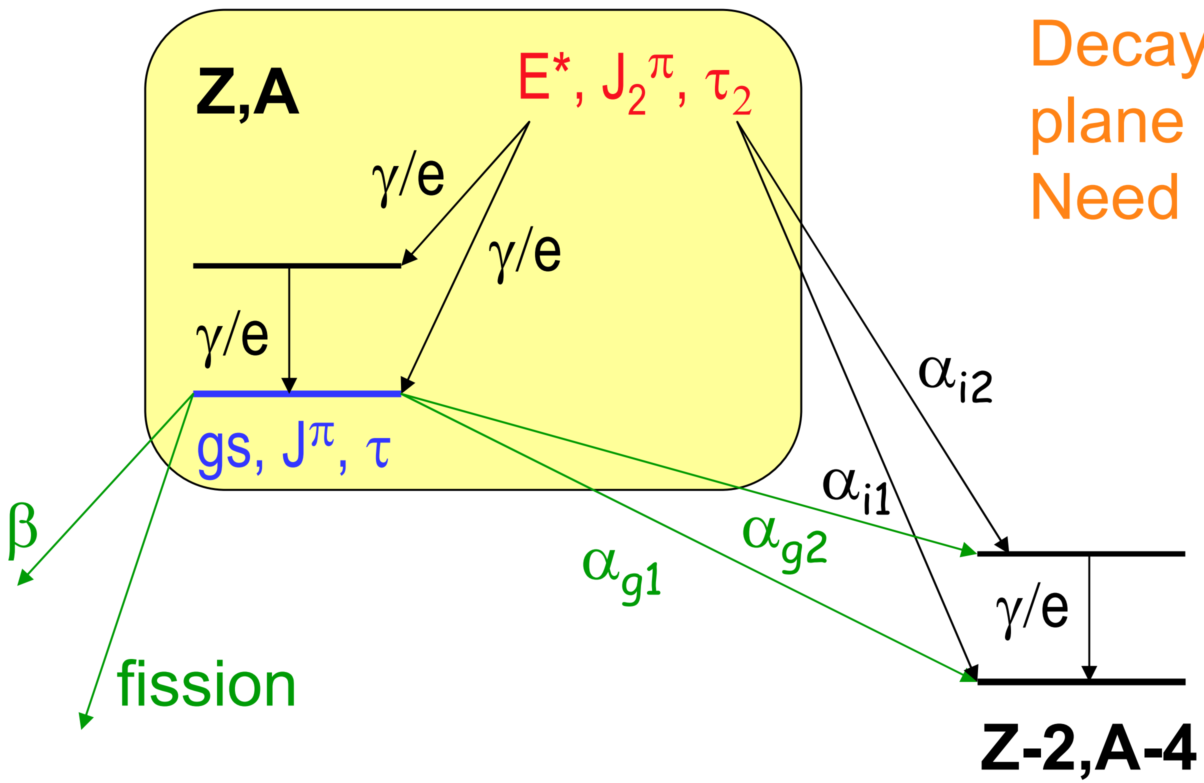
Access : rotational band -> J2's and deformation in even-even
structure of odd-A [B(M1)/B(E2)]
fission barrier heights

Limited ….. Mostly to singles (very few g-g coincidences)
Makes interpretating odd-A spectra very difficult
Also problems with excited bands in even-even

Future : Jurogam-II + digital electronics (factor >5)
AGATA
SAGE (perform ICE spectroscopy with Jurogam)
[Bonn -> Saclay mini-oranges with Jurogam ?]

More from Rauno later

Focal plane spectroscopy



Decay types determine focal plane set-up

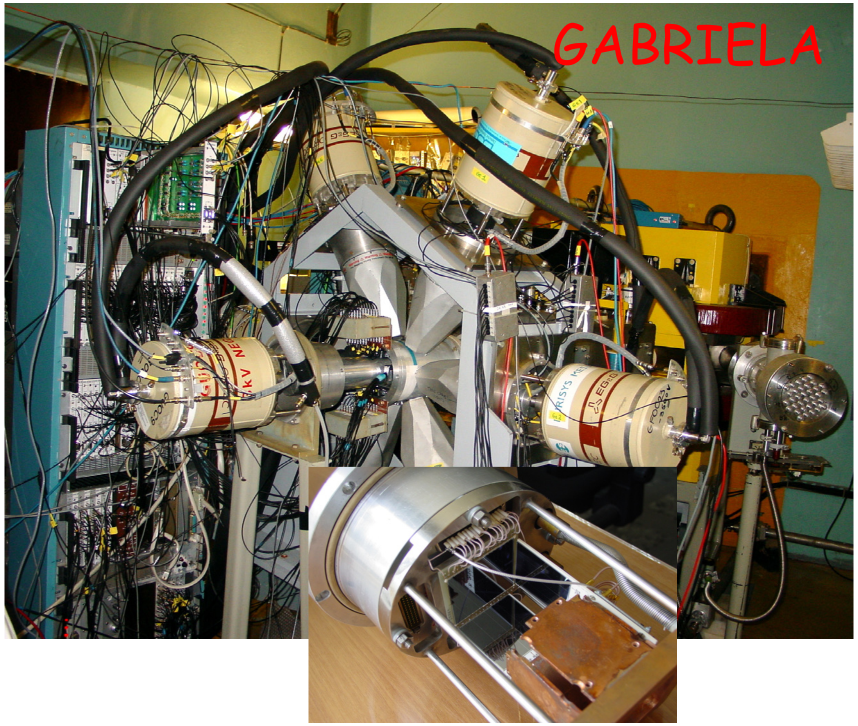
Need : DSSD/PSD

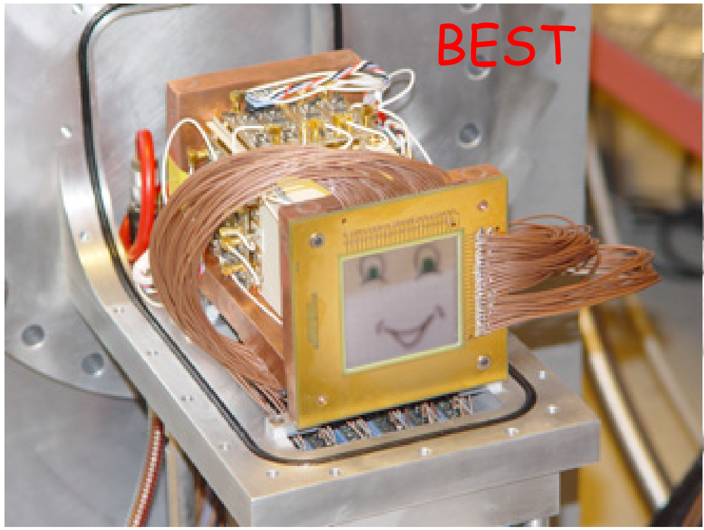
Ge's

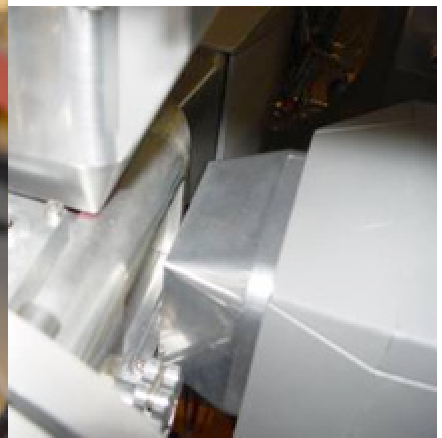
Si tunnel

Size of focal plane is pulled in opposite directions :
detection of transmitted recoil vs compactness for gamma/e- spectroscopy

Example focal plane set-ups :





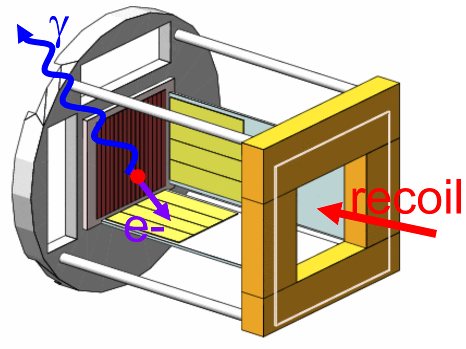


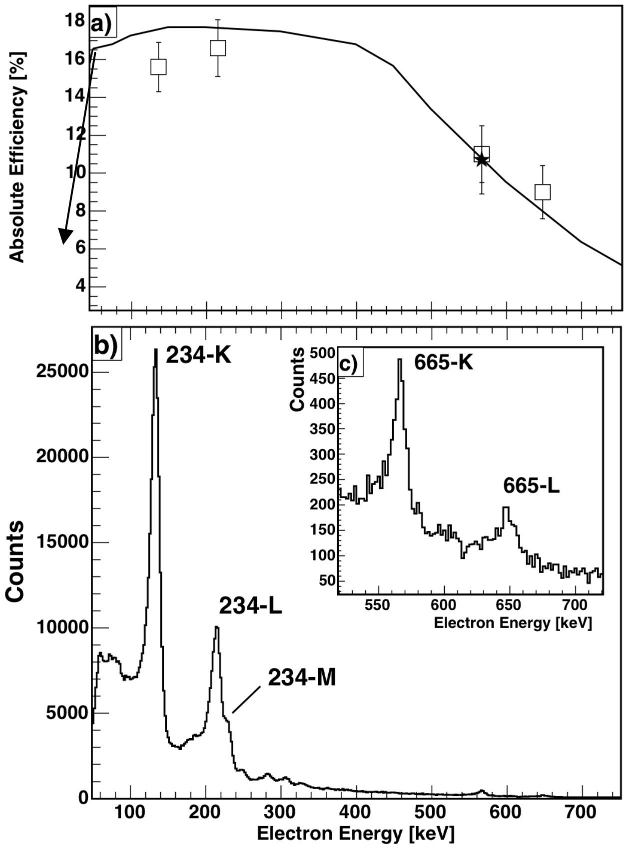
GSI photos ?
Fritz follows !

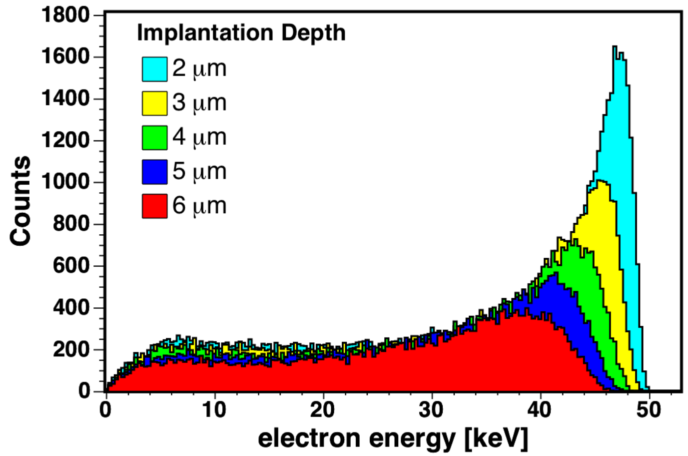
Focal plane spectroscopy

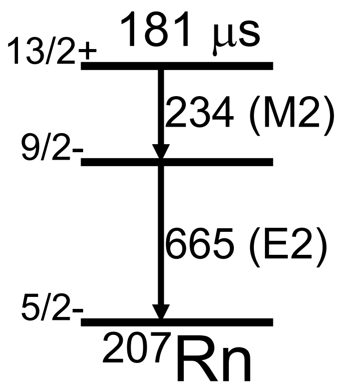
Most set-ups can perform coincident α-e, α-γ, γ-e
However, conversion electrons can be a pain !

For GABRIELA we have compared efficiencies measured in-beam with Geant4 simulations for the tunnel detectors



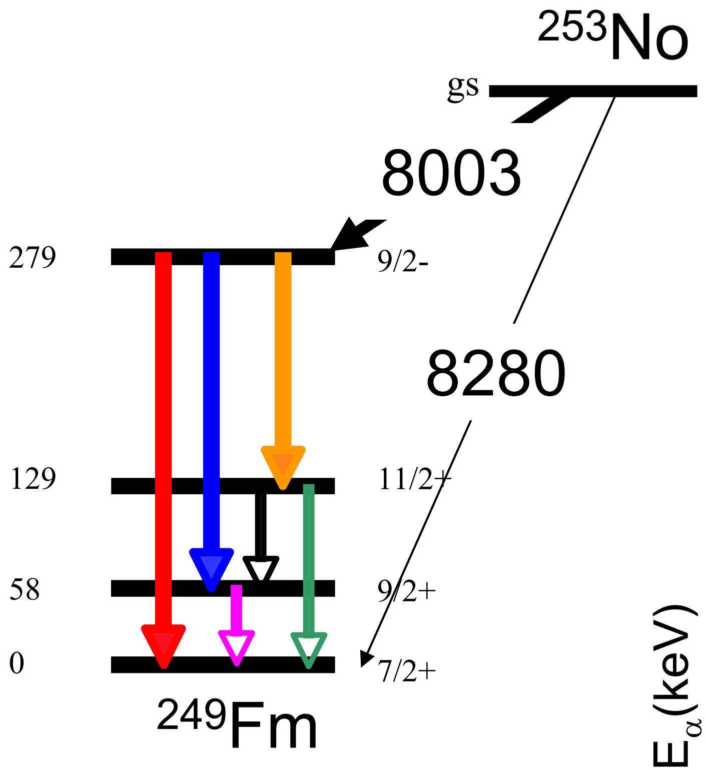


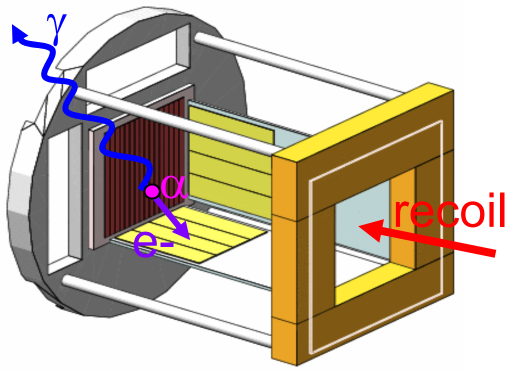


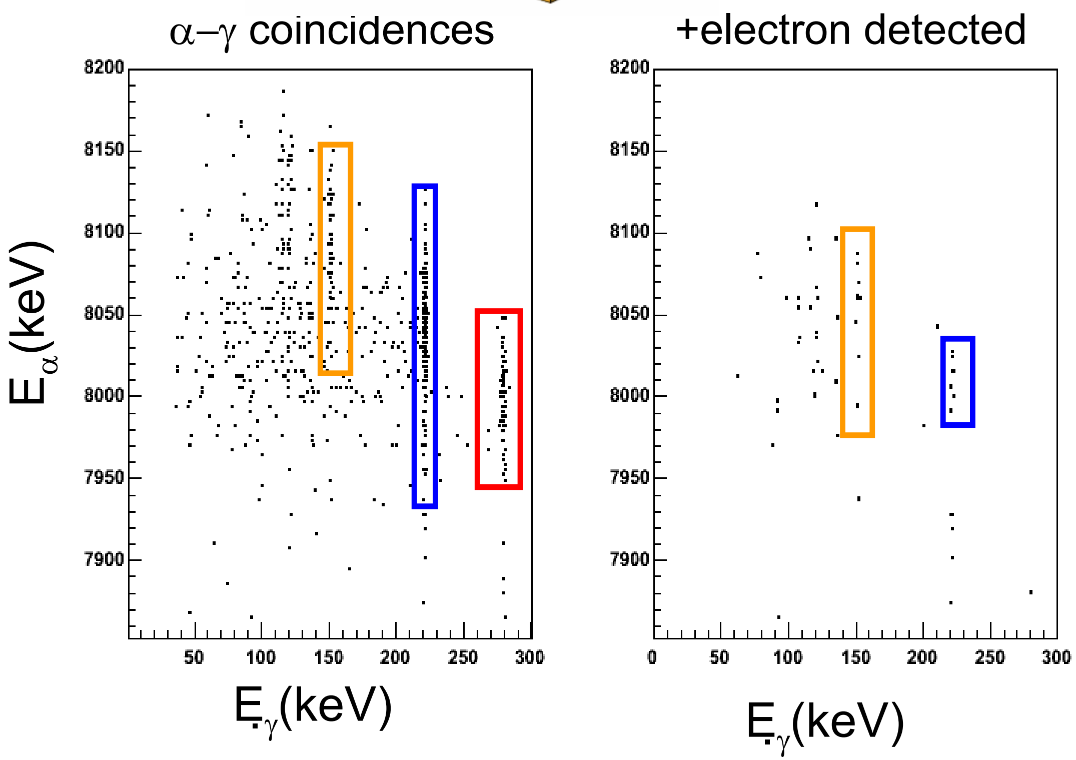


Low energy electrons do not escape implantation detector
=> Summing with coincident α
=> Summing of e- cascades

Consequences of summing I





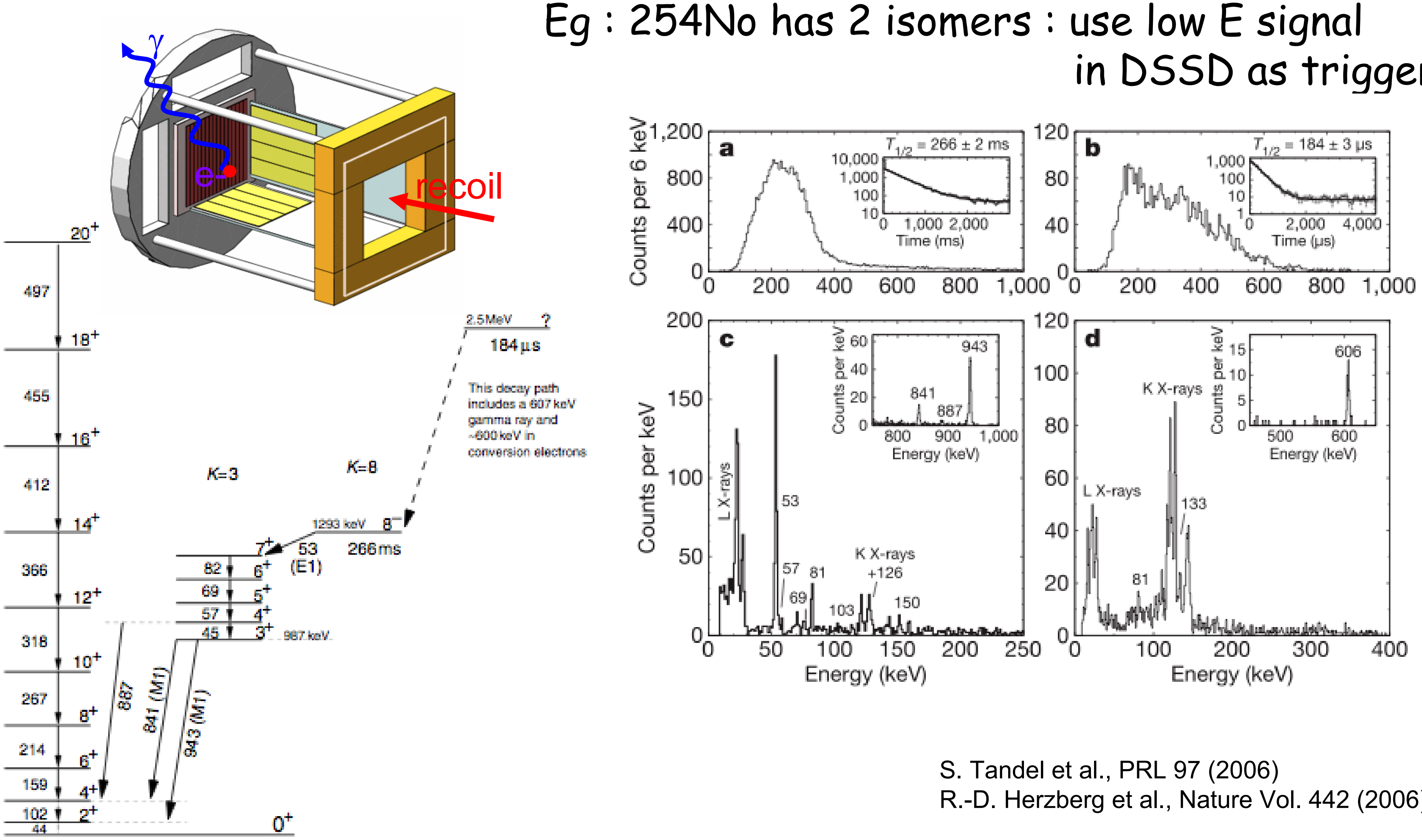


Christophe will be discussing this in more detail

Consequences of summing II

an electron cascade from an isomer summed in the implantation detector
=> G.D. Jones method : NIM A488 (2002) 471

Eg : 254No has 2 isomers : use low E signal in DSSD as trigger



S. Tandel et al., PRL 97 (2006)
R.-D. Herzberg et al., Nature Vol. 442 (2006)