FROM RESEARCH TO INDUSTRY

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IRFU SCIENTIFIC COMMITTEE

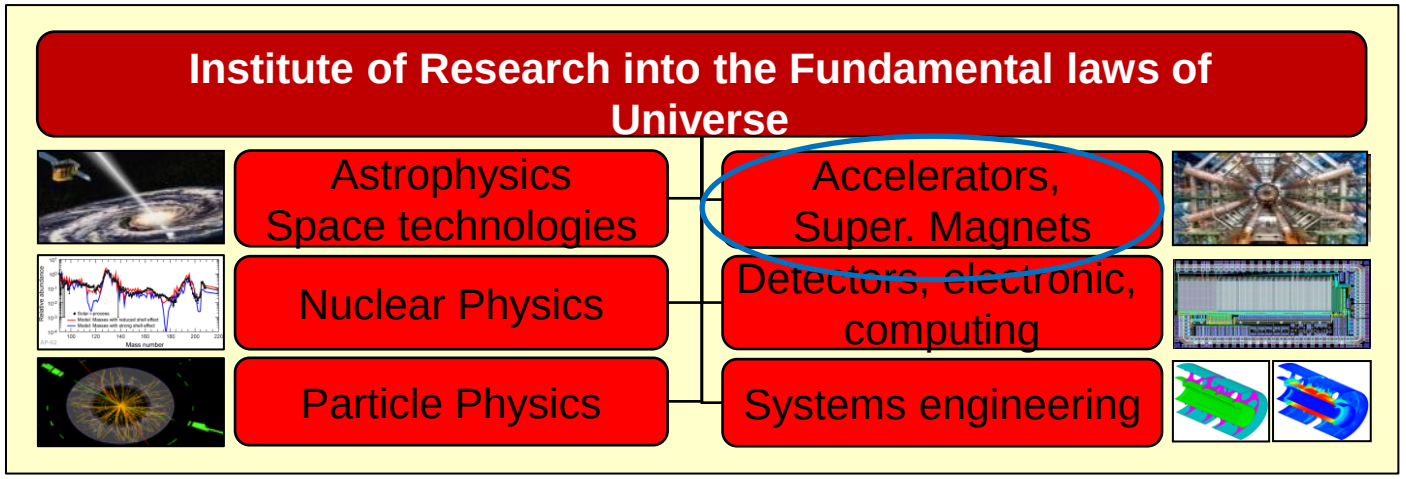
ACCELERATORS, CRYOGENICS & MAGNETISM DIVISION

Pierre VEDRINE
Head of SACM

14th of January 2015

ORGANISATION

IRFU ACTIVITIES (~800 FTE)
FONDAMENTAL PHYSICS AND HIGH TECHNOLOGIES



- Irfu/SACM is developing and realizing particle accelerators, cryogenic systems and superconducting magnets for the scientific programs of Irfu and more widely of CEA.
- Iru/SACM develops R&D activities to support theses programs.

- Irfu/SACM is also involved in large scale projects in Europe and Japan
- These projects are managed within the Irfu project organisation

- These projects rely on the skills and activities of SACM, SIS and SEDI.
- In December 2014 , 81 engineers and 44 technicians, CEA staff, belong to the Irfu/SACM division.

SACM is organized in 5 laboratories

Direction : P. Védrine
Deputies : P. Brédy, O. Napoly


CSTS : Président M. Durante

LEAS
JM. Rifflet, A. Payn

Superconducting Magnets


LEDA
J. Schwindling, R. Gobin

Particle Accelerators


LCSE
P. Brédy, C. Mayri

Cryogenics & Test Facilities

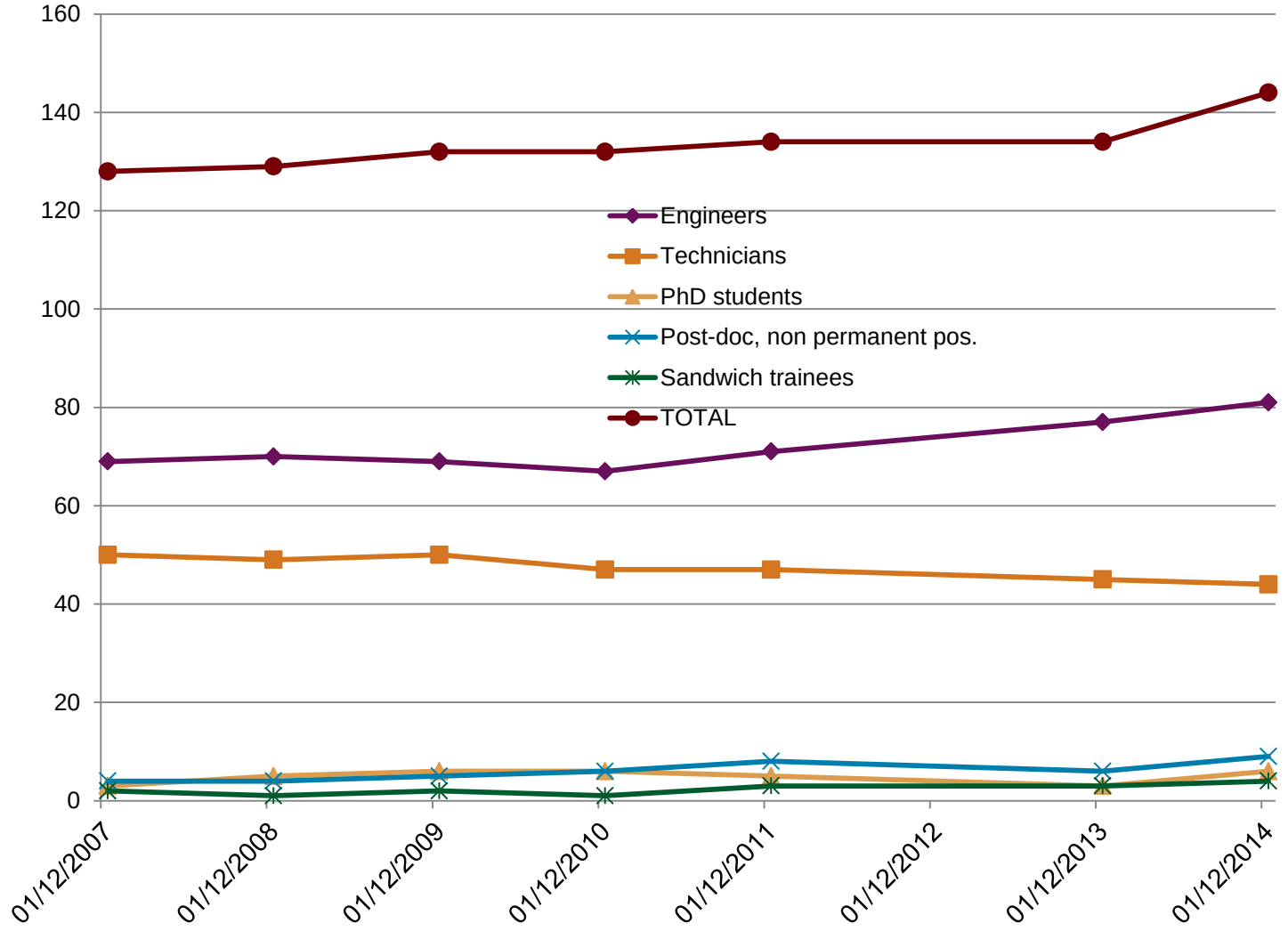

LISAH
C. Marchand, G. Devanz

Accelerating & Radiofrequency Systems


LIDC2
C. Madec, J.P. Charrier

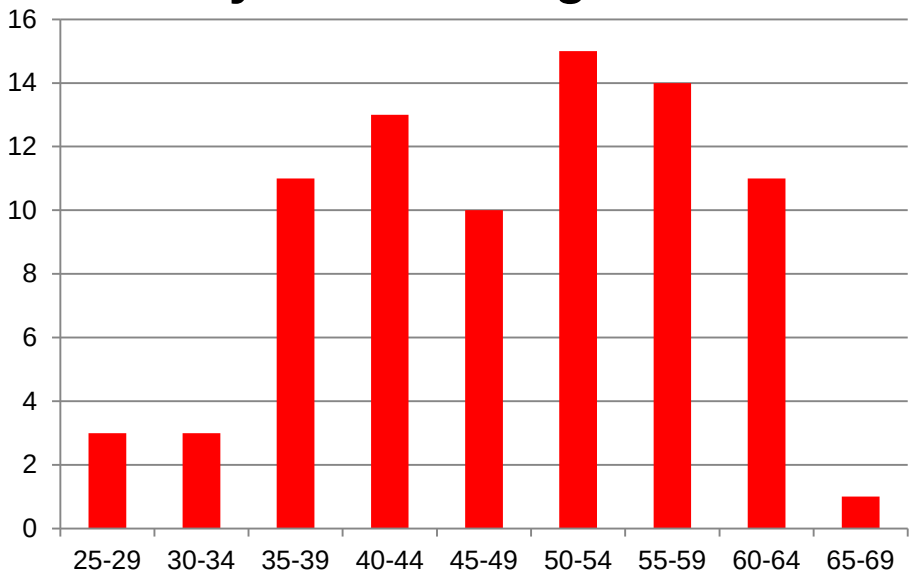
Superconducting cavities & Cryomodules


POSITIVE MANPOWER EVOLUTION (2007-2014)



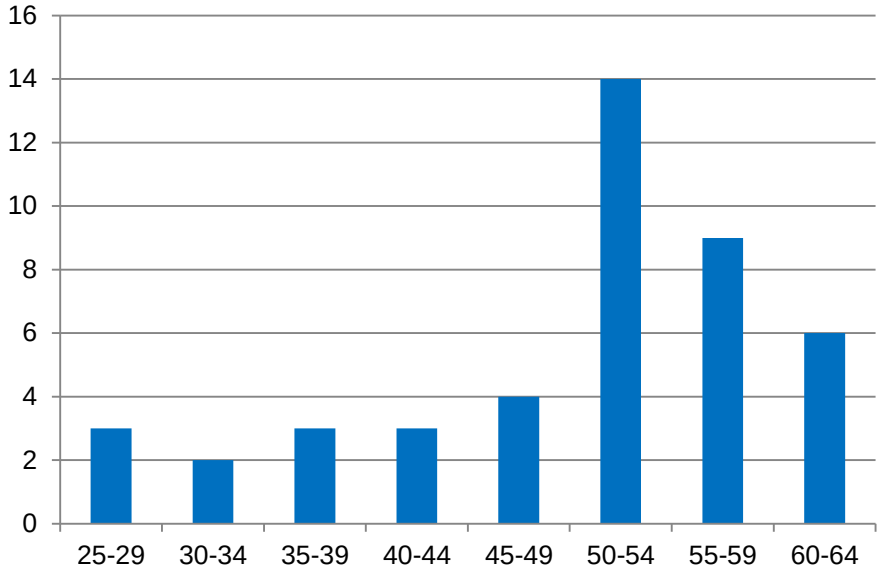
AGE DISTRIBUTIONS

Physicists & engineers



81 A1 Mean age: 48 years

Technicians



44 A2 Mean age: 49 years

In the next five years, at least 10 retirements are expected
(4 engineers and 6 technicians)

Risk of loss of skills and strong technical supports

Opportunity for a thematic reconfiguration and/or shift towards R&D

SACM MANPOWER SITUATION IN 2015

High workload on multiple projects and R&D activities

4 new permanent positions, 7 new non-permanent positions and 4 new PhD students in 2014.

5 retirements are expected in 2015.

Start of several major projects: ESS, SARAF, ...

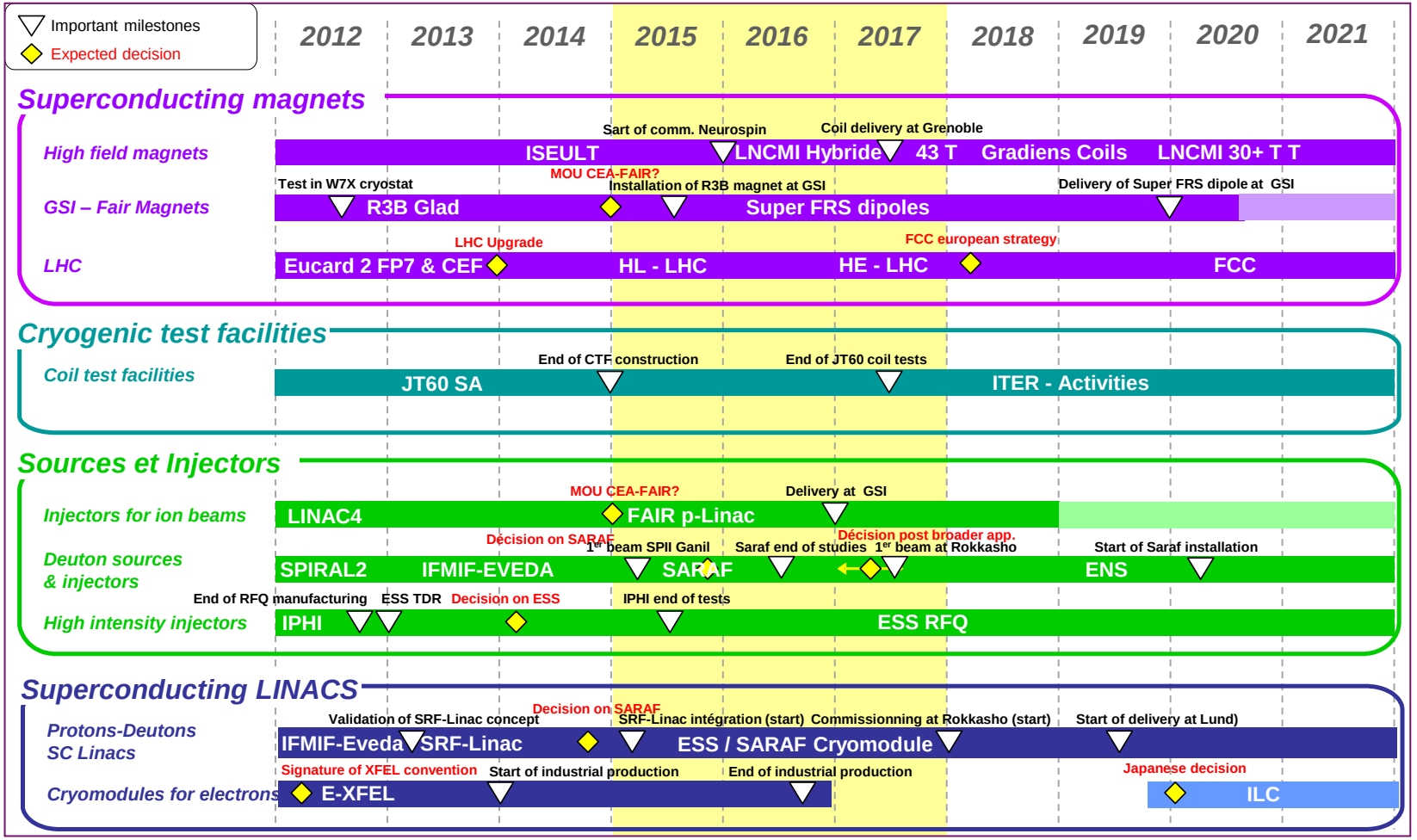
6 permanent positions opened in 2015

Opening of more than 16 non-permanent positions in 2015

Recruitment for the next 4 years : **9 technicians and 3 engineers**

The goals are to keep and to **develop the key skills** of the division (engineers, technicians) and to **increase the availability of HR for R&D**;

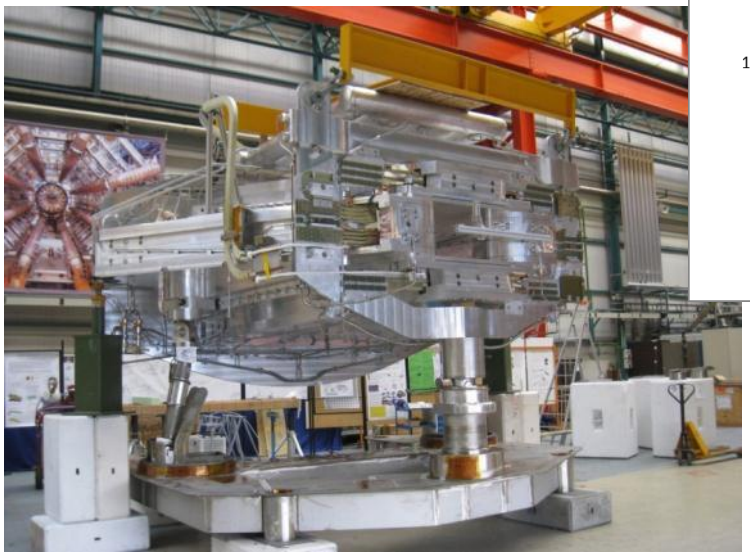
CLEAR ROADMAP FOR 2020



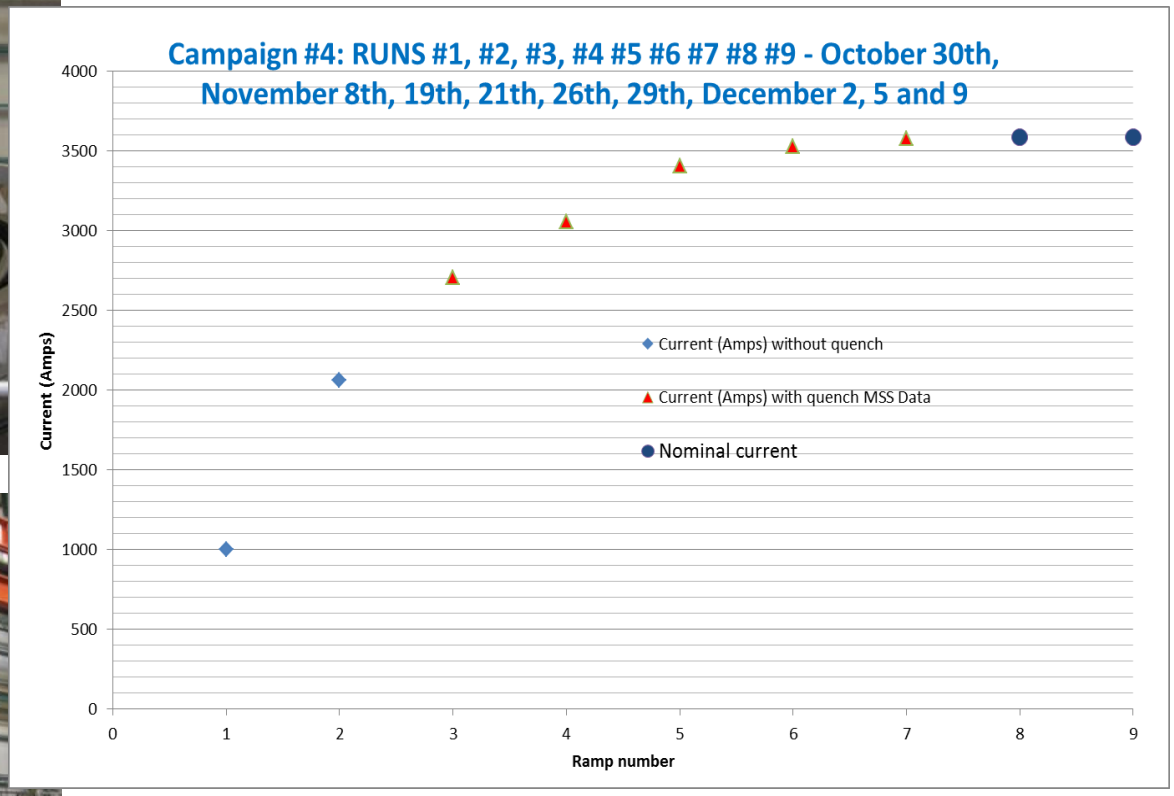
Theme
CRYOGENICS & MAGNETISM

SUPERCONDUCTING MAGNETS

R3B-GLAD : LARGE ACCEPTANCE DIPOLE FOR GSI



Nominal field achieved end of 2013 !



R3B-GLAD INTEGRATION

Integration of the cold mass in 2014

Delivery at GSI mid 2015

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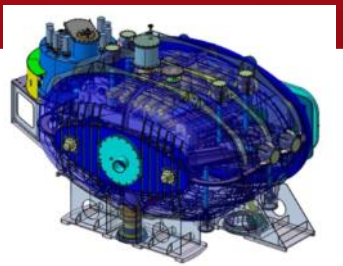
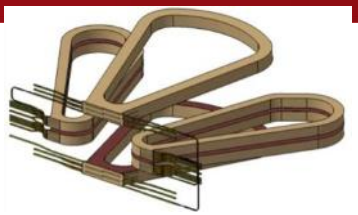




FAIR SUPER-FRS DIPOLE

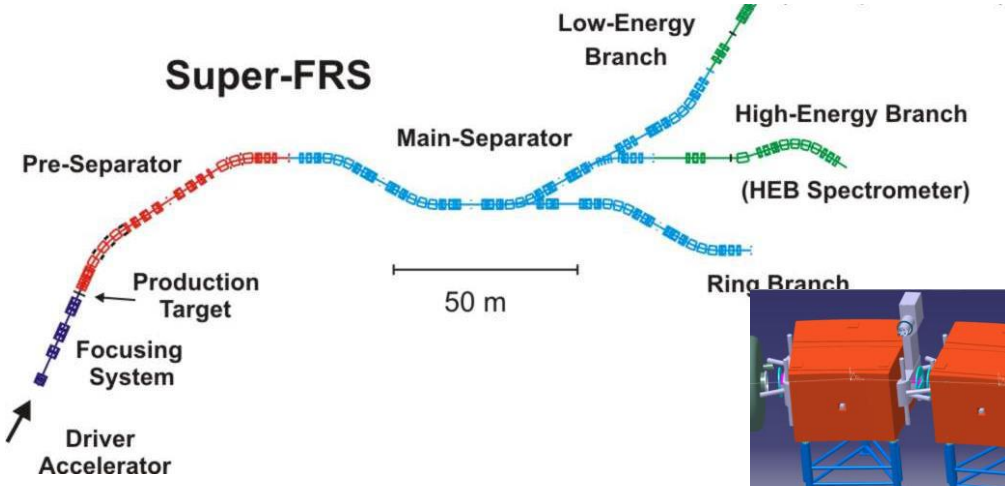
24 superferric dipoles for FAIR (GSI Darmstadt)

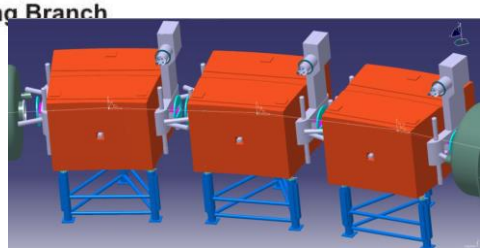
- Call for tender for the conductor is launched

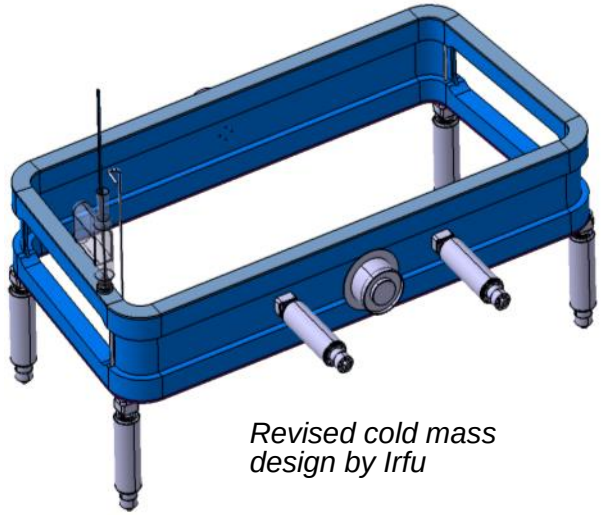
- Magnet detailed design and specification are ongoing

- Call for tender for magnet manufacturing mid 2015

Prototype IMP Lanzhou







Revised cold mass design by Irfu

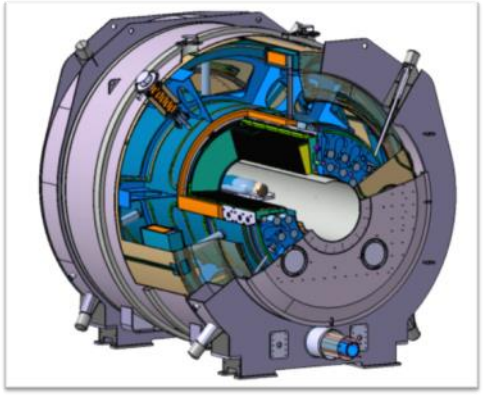
ISEULT (WHOLE BODY MRI MAGNET AT 11.75 T)

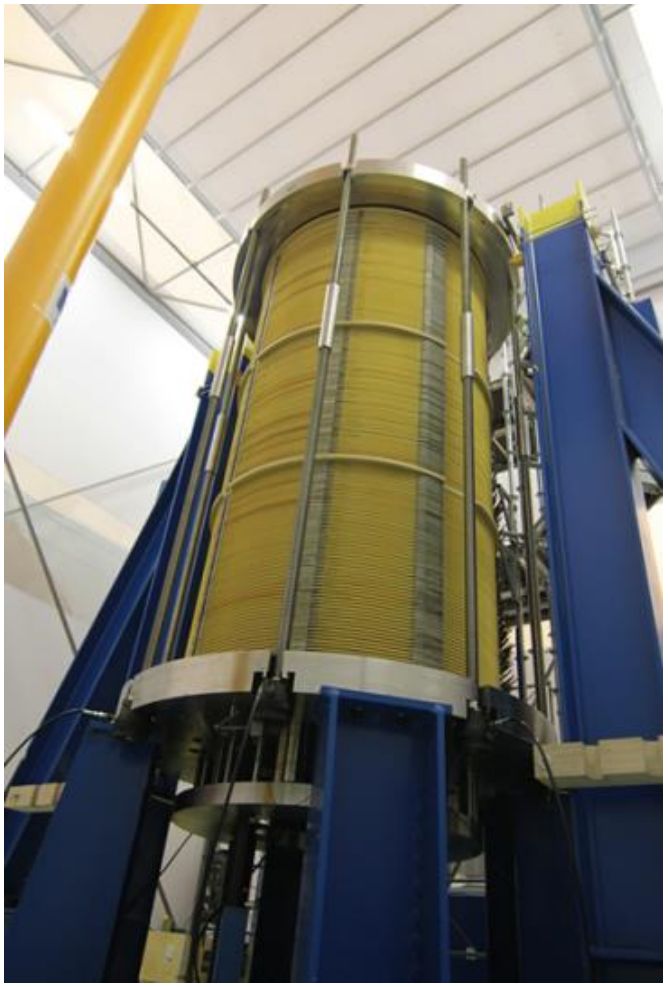
Double pancakes stacked in June 2014.
Connections are finished
Polymerization of the main coil next month

Shielding coils completed and assembled on the mechanical structure

Review 19-20 January

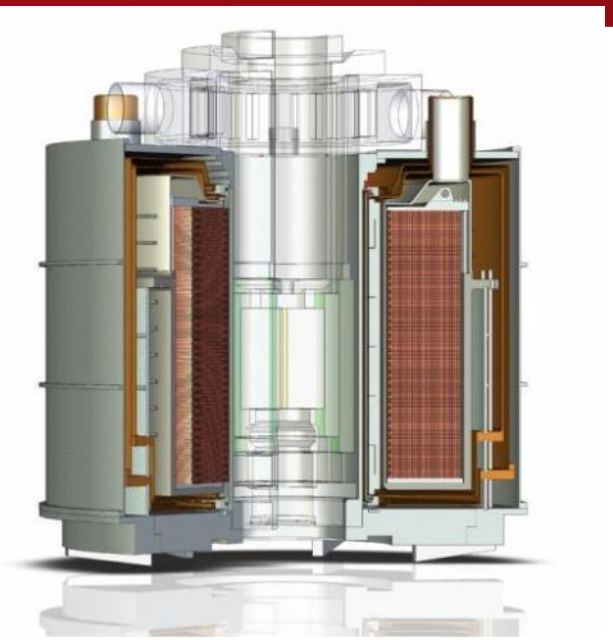
Estimated delivery end 2015





HIGH FIELD HYBRID MAGNET FOR LNCMI

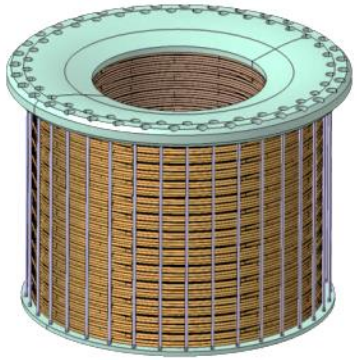
8.5 T solenoid, ϕ1100 mm,
around a 35 T resistive copper magnet

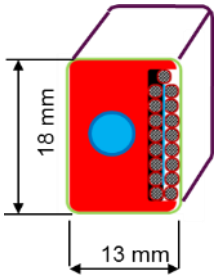


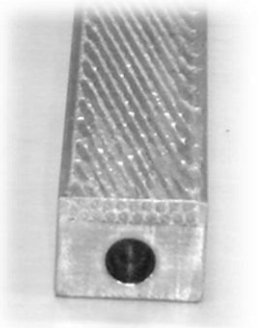
NbTi Conductor is made by LNCMI.

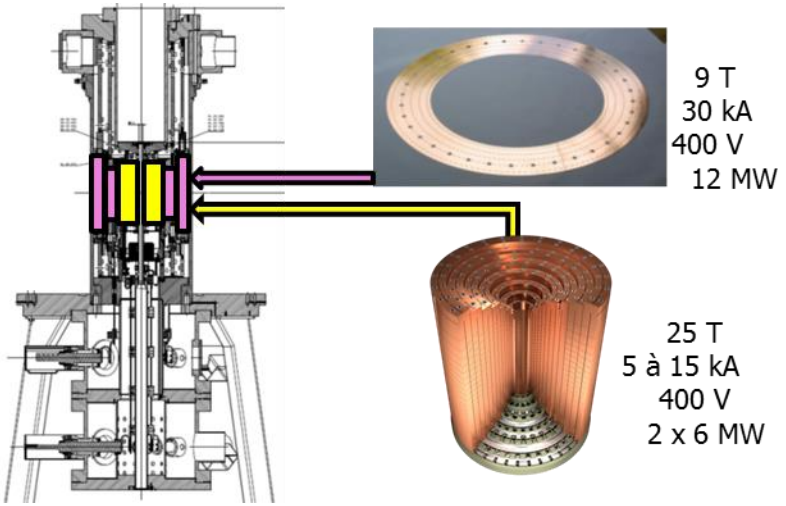
Call for tender for the coil will be launched in 2015

End of the project in 2017





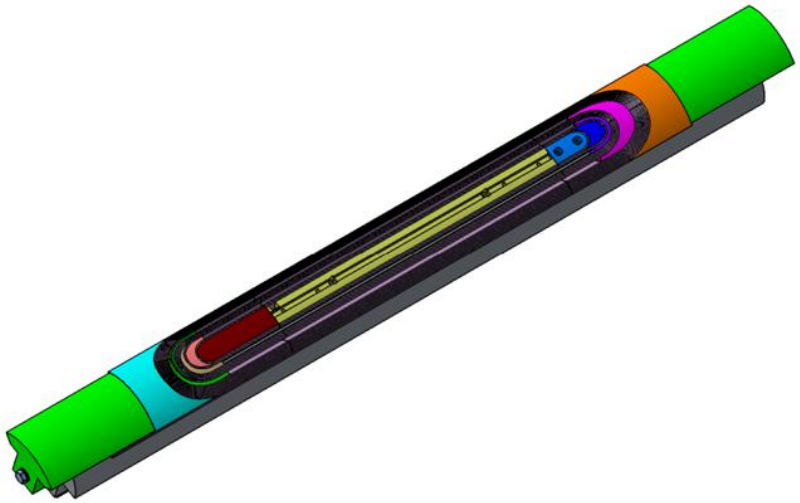


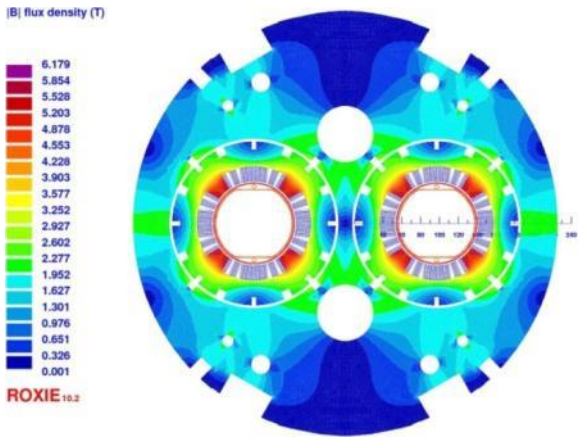


LHC - UPGRADE IN LUMINOSITY - HILUMI

Irfu/SACM is in charge of the NbTi large aperture quadrupole Q4 design through EU program « Hi-Lumi » and of prototyping through the new CERN-CEA collaboration agreement signed in July 2014.

Very precise prototype windings has to be realized.





Design finalization.

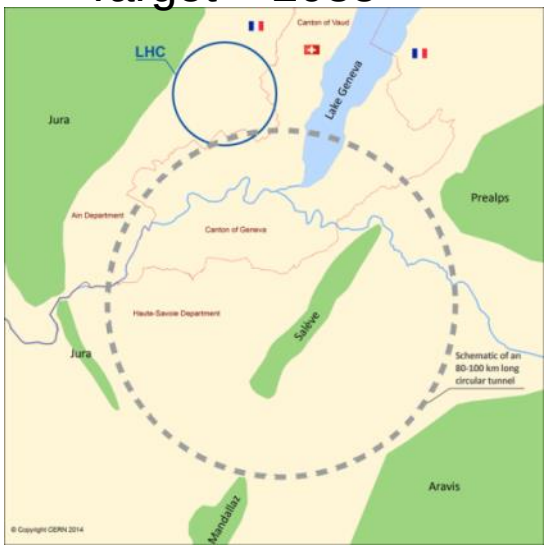
First winding tests: beginning of 2015

Realization and test of a short model: end of 2016

UPGRADE IN ENERGY – FUTURE CIRCULAR COLLIDER

Future Circular Collider: 100 TeV
16 T in 100 km ← Nb3Sn
20 T in 80 km ← Nb3Sn + HTS

Target ~2035

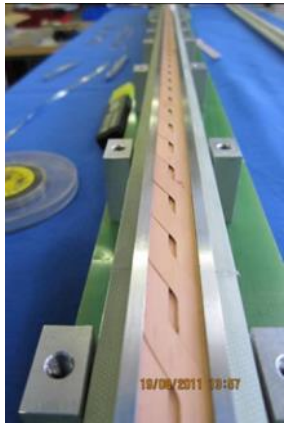


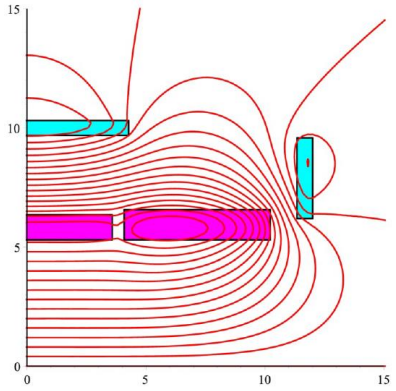
- EuCARD : FRESCA2 Nb3Sn 13 T dipole: first tests end of 2015 ; design and manufacturing of a 6 T HTS dipole

- EuCARD2 : Design and manufacturing of a 5 T HTS dipole, 40 mm aperture, accelerator field quality : to demonstrate the feasability
  Choice between Bi2212 et YBaCuO
  (Collaboration CERN et LARP (US))

- H2020 Design Study EurCirCol: Complete the EuCARD and EuCARD2 activities to design a 16 T Nb3Sn dipole magnet

- FCC Detector magnets





HTS MAGNET R&D

High Fields

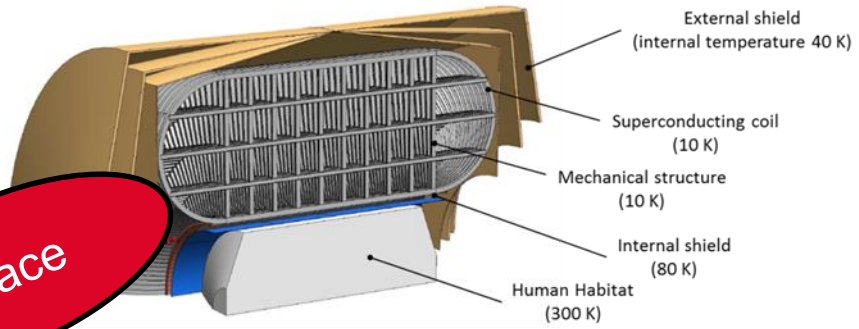
ANR NOUGAT HTS insert - LNCMI Grenoble

10 T, ϕ170 mm, HTS insert in a 20 T resistive coil.
Long term objective : 30 T fully superconducting High Field Magnet

TASUM (H2020 DS) : 10 T HTS superconducting magnet in external field of 20 T → answer in 2015

Space

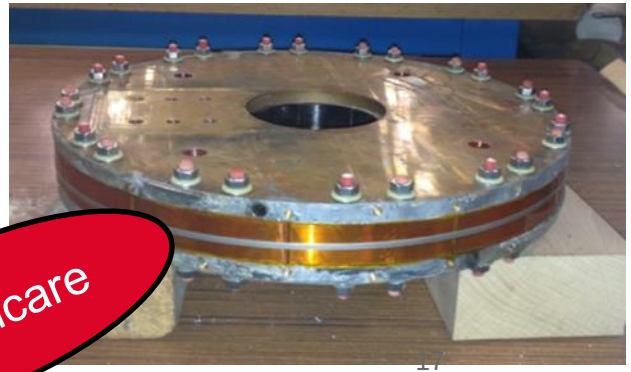
SR2S : Space Radiation Superconducting Shield for Interplanetary Travel



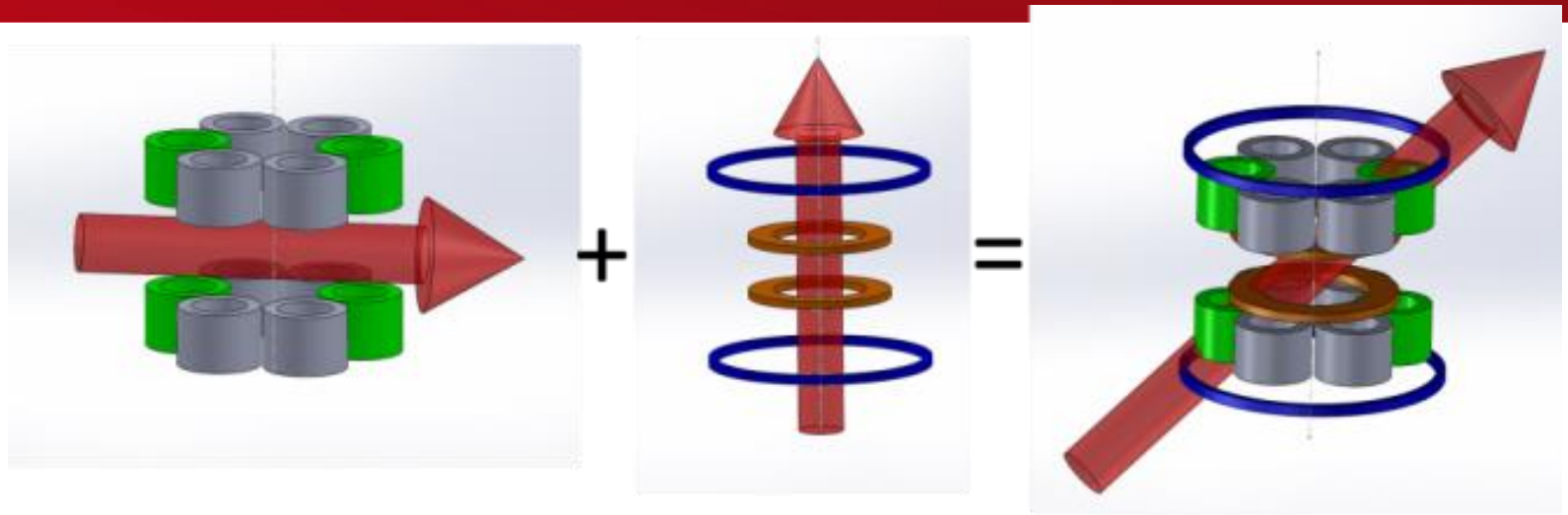
Healthcare

MgB2: Lotus + project:

Integrated system producing radionuclides and PET tracers, using, in a medium term, MgB2 magnets



NEW CONCEPT OF VECTOR MAGNETS : WAVE

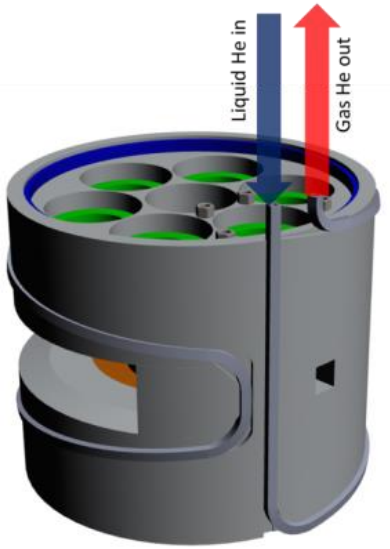


Generate 1T in all the directions (IRAMIS/LLB) ;
for neutron diffraction experiment)

Detailled studies ongoing

Call for tender for coil manufacturing in 2015

Same needs for Soleil beamlines (but in a different environment)



Theme
CRYOGENICS & MAGNETISM

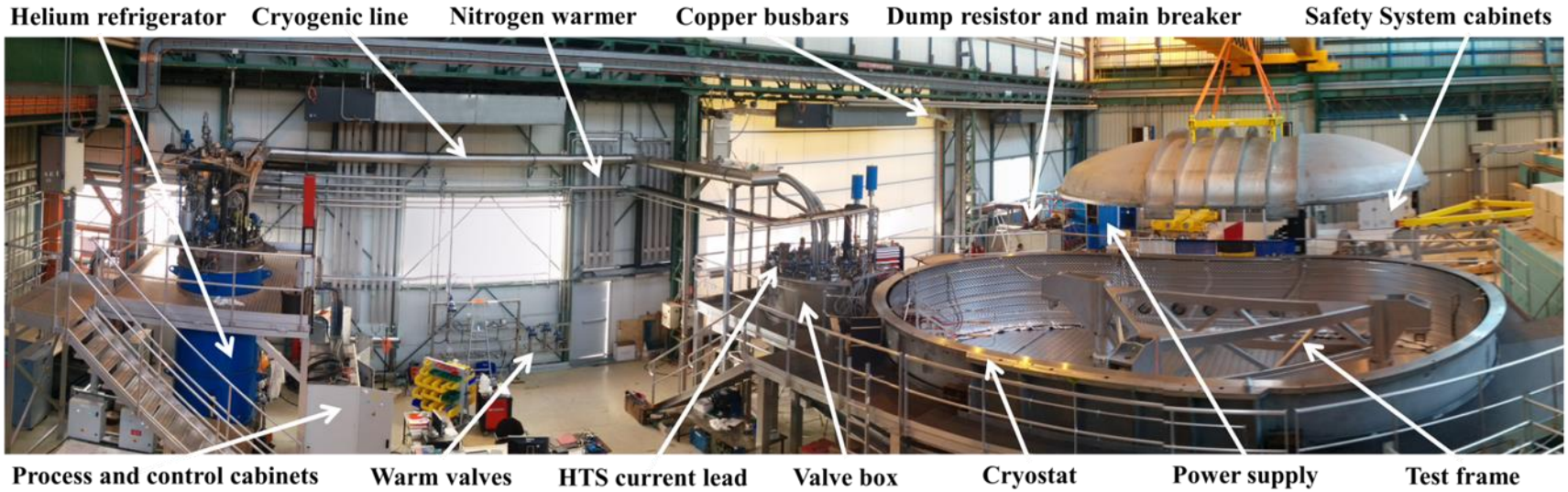
CRYOGENICS AND TEST FACILITIES

JT60-SA Cold Test Facility

- Reception tests of the **cryostat** (under vacuum and LN2)
- External **infrastructure** installation (platform, integration area…)
- **Satellite** and cryogenic internal equipment installation
- Refrigerator connection (first tests and **restart of the refrigerator**, transfer lines…)
- Installation of the **electrical circuit (**« W7X »power supply, external lines, bus bars …)

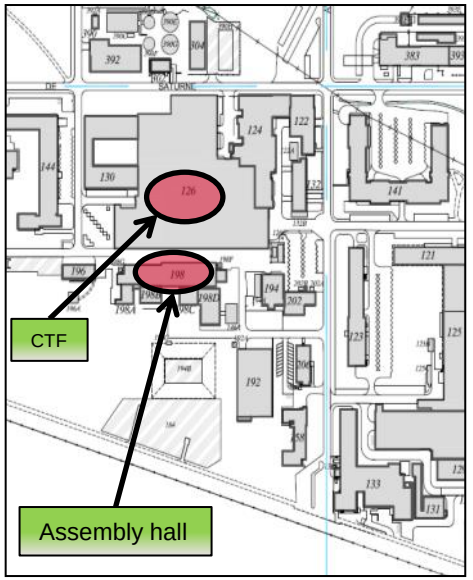
- CTF global commissioning: February 2015

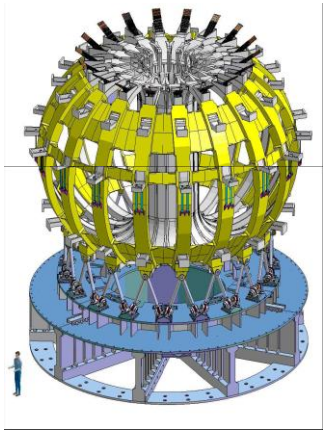
- CTF ready for JT-60SA TF coils tests: May 2015



JT60-SA OIS INTEGRATION

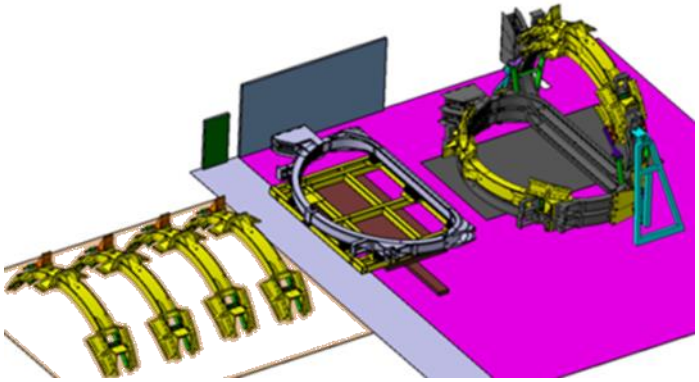
- **Procurement arrangement** signed with F4E
- Choice of the configuration for the integration in the **building 198**
- Technical specifications for **equipment & tooling**
- Operations to be synchronized **in the middle of 2015** with the cold tests



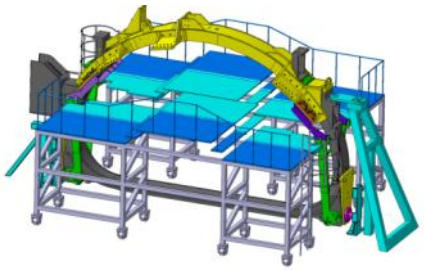


Tokamak JT60SA

OIS + Toroidal coil



Integration chain



Control and assembly platform

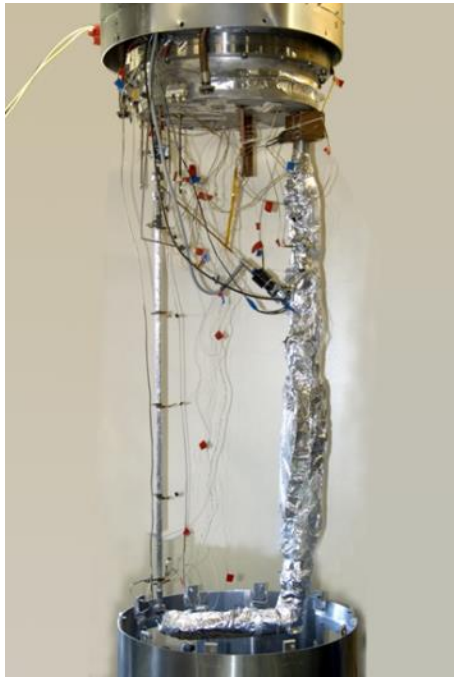
Cooling solutions and Superfluid helium heat transfer studies

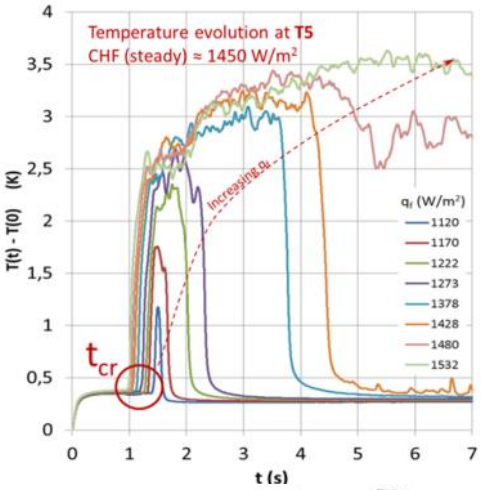
Thermosiphon studies in permanent and transient modes

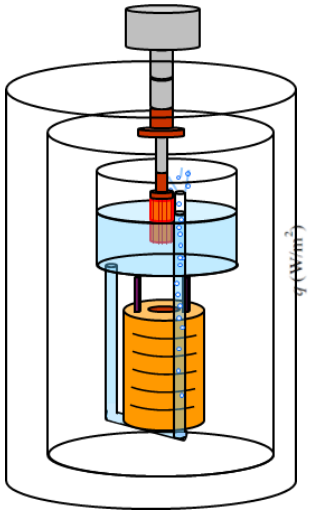
Development of an autonomous conducting loop : ThermAutonome (closed-loop)

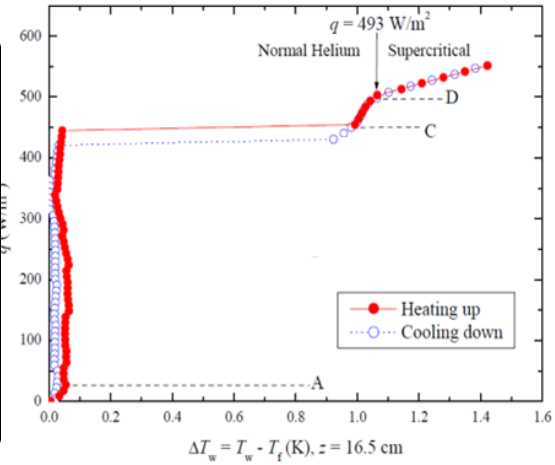
Pulsating heat pipe developments

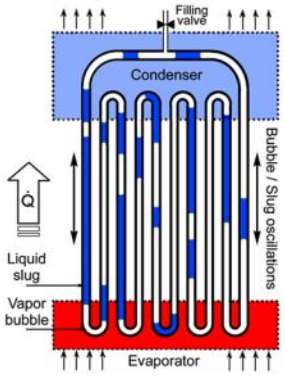
Heat transfer studies in superfluid helium

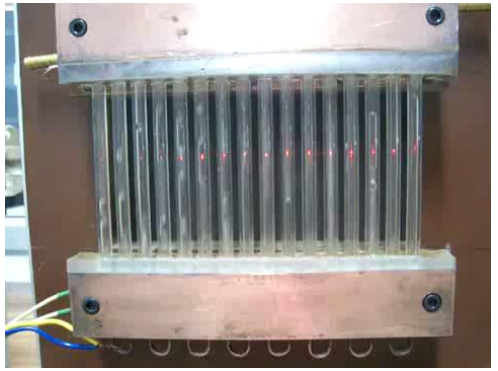




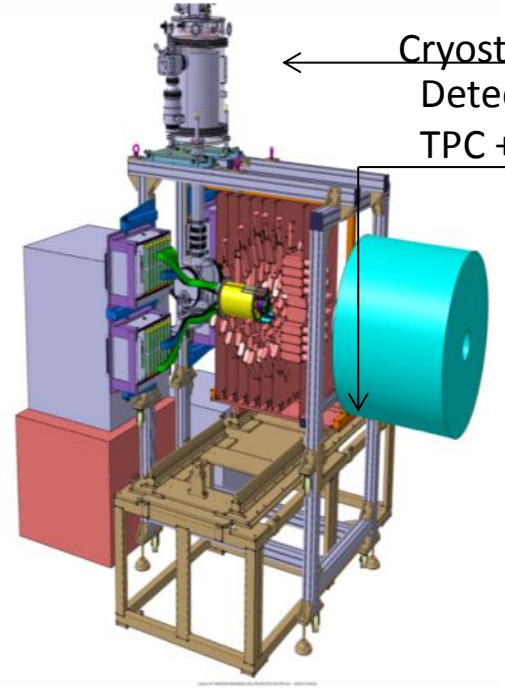






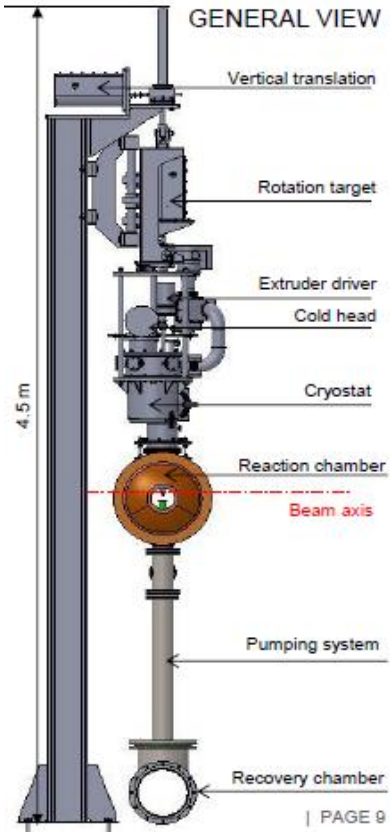


HYDROGEN TARGETS



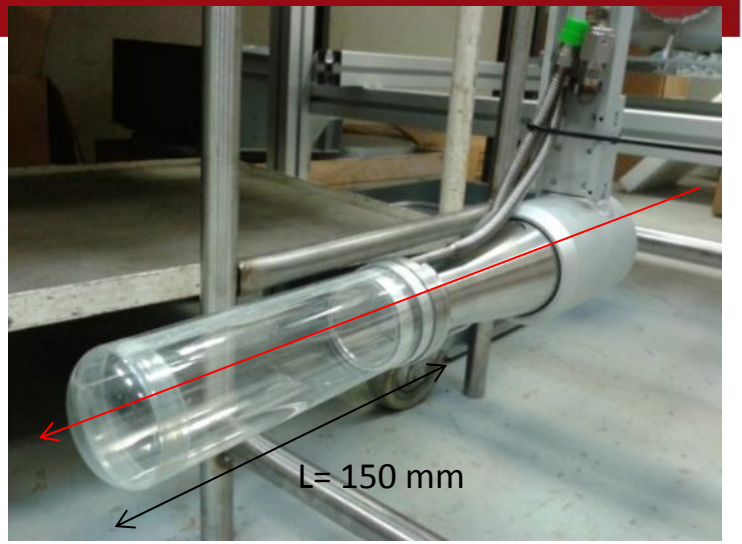
Cryostat **Minos**
Detecteur Mins
TPC + LH_2 Target

6 weeks of experiment at RIKEN in 2014

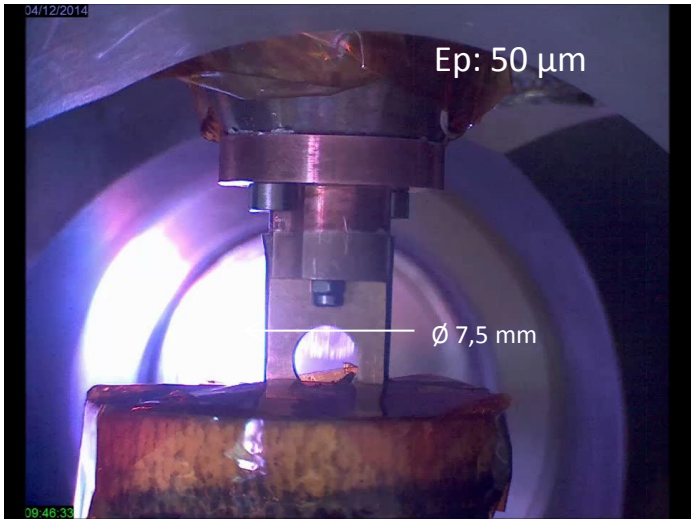


CHyMENE : quasi-solid hydrogen ribbon target (10 mm wide, 50 µm thick),

Collaboration Pelin laboratory, IPN Orsay, IRFU for Spiral 2.



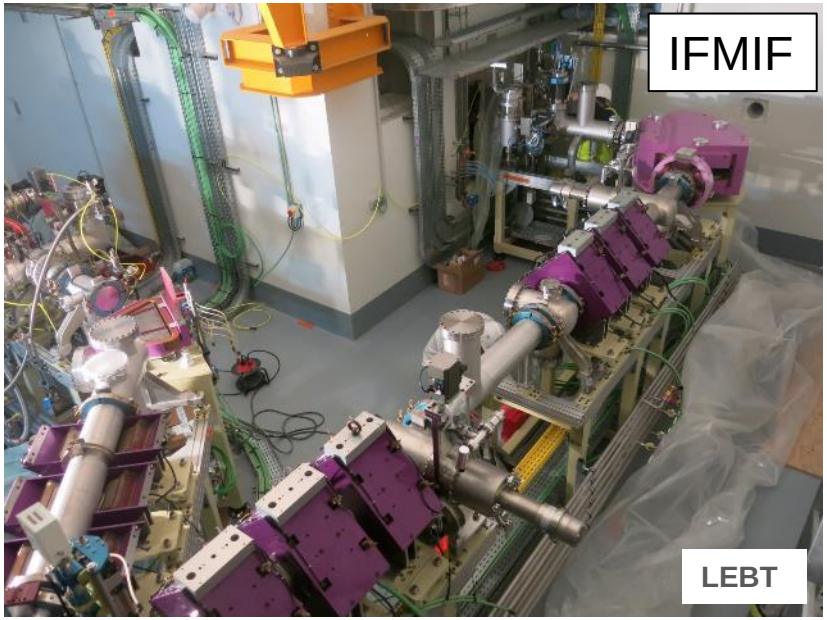
Ø eff (fenetre d'entrée) :39 mm
Epaisseur Mylar 125 µm

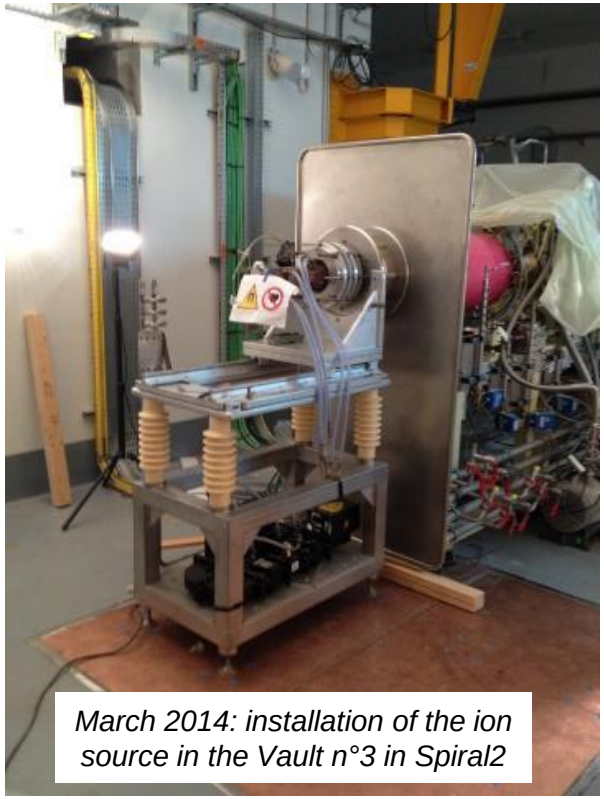


SOURCES & INJECTORS

INJECTORS for IFMIF and SPIRAL2

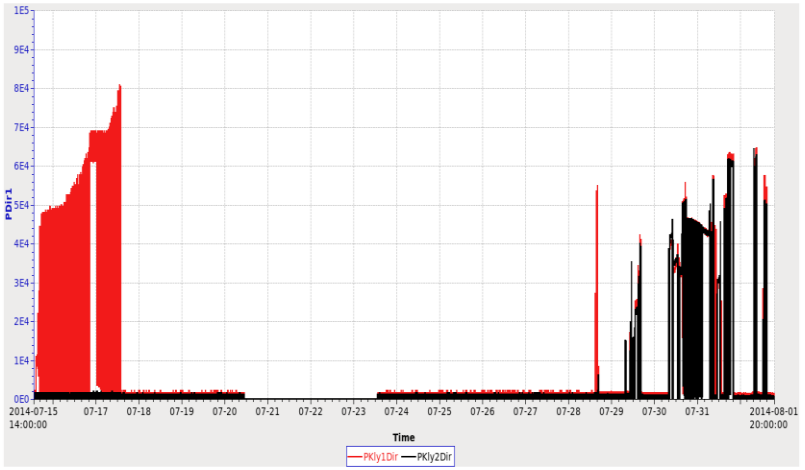
- Irfu has recently started the commissioning of the IFMIF and Spiral2 injectors.
- 1st H+ beam *105mA @100keV* at Rokkasho (Japan) in November 2014
- 1st H+ beam *3,5mA @20kV* 18th of December at Caen (Normandy)
- Final commissioning in 2015





March 2014: installation of the ion source in the Vault n°3 in Spiral2

IPHI : A HIGH INTENSITY INJECTOR WITH A 6m RFQ



RF tests July 2014

The RFQ is installed, vacuum tests are OK.
1st RF testing up to 100kW, @1% duty cycle in July 2014.

2015 objectives:
Completing the installation (cooling system, control-command)
Conditioning, first beam and tests for ESS

RFQ FOR SPIRAL 2 AND ESS

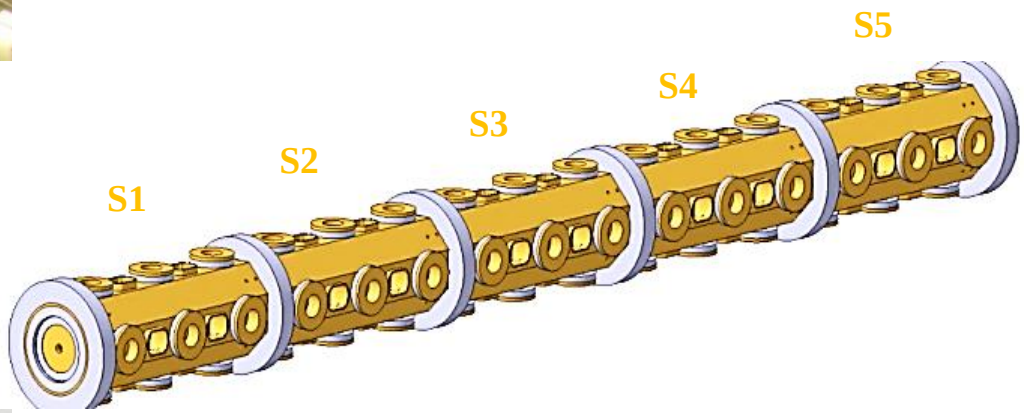
September to December 2014: assembly and adjustment of the 5 sections of Spiral 2 RFQ

View of the Spiral RFQ

- Installion and starting of the subsystems (Skid cooling, vacuum systems, LLRF) in March 2015.
- Start of conditioning in April 2015

ESS RFQ design is finalized

- 5 Sections for a total length = 4.58m
- RFQ in Cuc2 and flanges in stainless steel



Schematic view of the ESS RFQ

- Critical Design Review 18 November 2014:
- ESS agreement to launch the supply of copper

SYNERGIUM – NEW 352 MHz RF PLATFORM

2014

New 352 MHz RF platform funded by Synergium

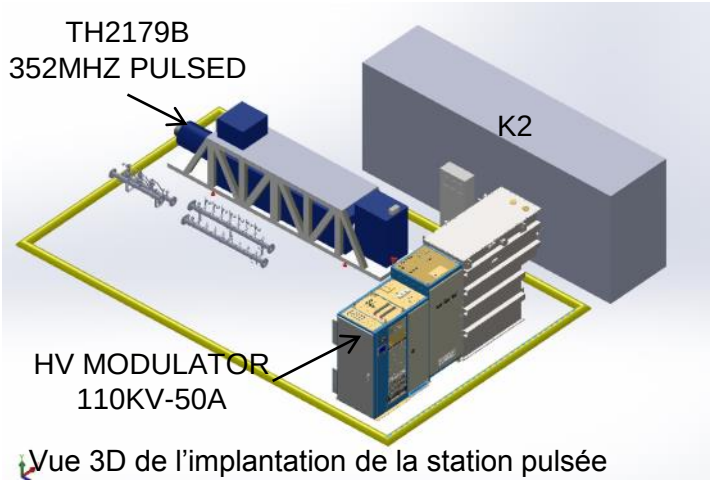
- Order of **two new CW klystrons** THALES TH2189B for IPHI
- Order of one **pulsed klystron** THALES TH2179 et one modulator DTI for the conditionning of the des coupleurs Spoke couplers and ESS injector

Ligne actuelle RF CW à 352MHz connectée à IPHI

2015

Installation of the klystrons and modulator

Installation of a new RF line to power the ESS bunker



Vue 3D de l'implantation de la station pulsée 352MHz

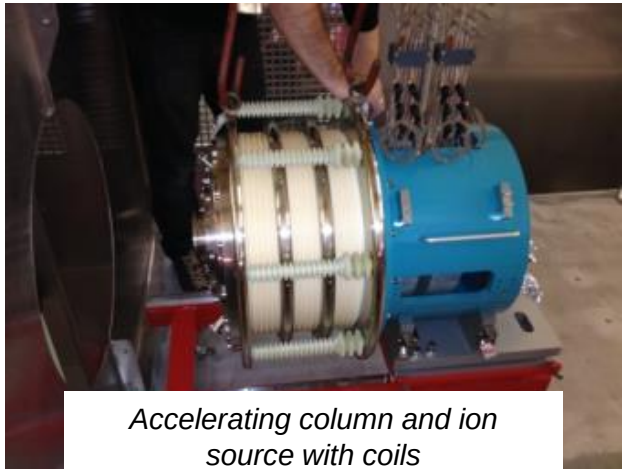
FAIR : INJECTOR INSTALLED AT SACLAY

- Ions source, RF chain and accelerating column installed on HV platform
- LEBT positioned and aligned

H^+ beam,
100 keV
100 mA total
70 mA after cone
PULSED ONLY

FAIR LEBT

Accelerating column



Accelerating column and ion source with coils

Source and RF chain on plateform

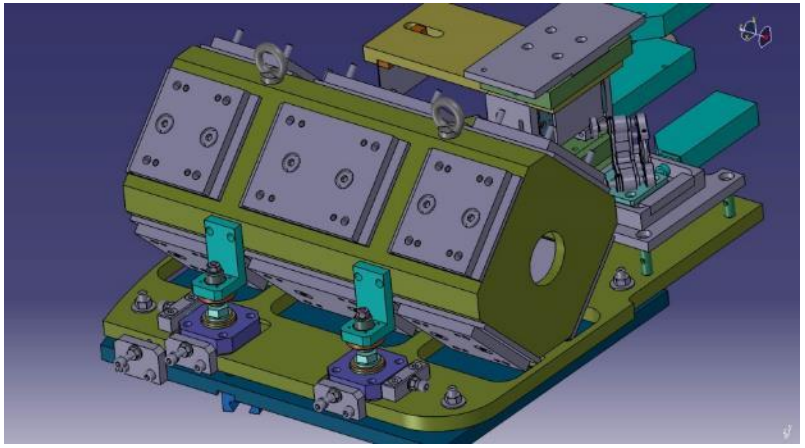
2015 GOAL : Start and commissioning proton beams in the first semester

LASER-PLASMA: CILEX, DACTOMUS, EUPRAXIA, ICAN-P

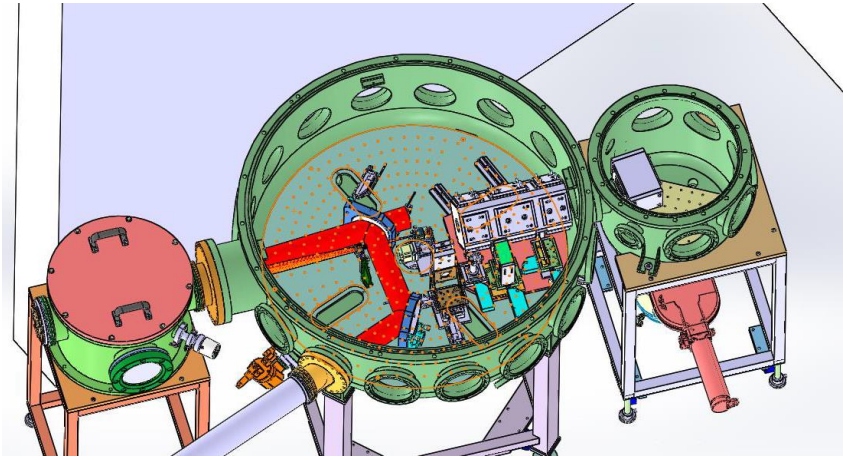
- SACM is involved in the production and acceleration of electrons by laser plasma interaction (multi-stages) in collaboration with LLR, LAL, IRAMIS, LPGP, LULI.
- SACM is in charge of the transport and characterisation of a 50 MeV±5 MeV, 10 µm beam with high quality quadrupole and dipole permanent magnet.

- R & D DACTOMUS for CILEX: Realisation of a beam transport line and characterization of electrons from a laser source - plasma is in progress
- H2020 Design study Eupraxia for the study of laser-plasma multistage accelerator
- Application for a FET-Open funding ICAN-P possible applications for the accelerators of beams produced from a multi-fiber laser beam

2015 Objectives:
Reception and magnetic measurements of Dactomus magnets
UHI100 installation and testing
Eupraxia? ICAN-P?



Permanent quadrupole magnet triplet for Dactomus



Cilex : Implantation of the Dactomus magnet in UHI 100 experiment

R&D 12 GHz KLYSTRON

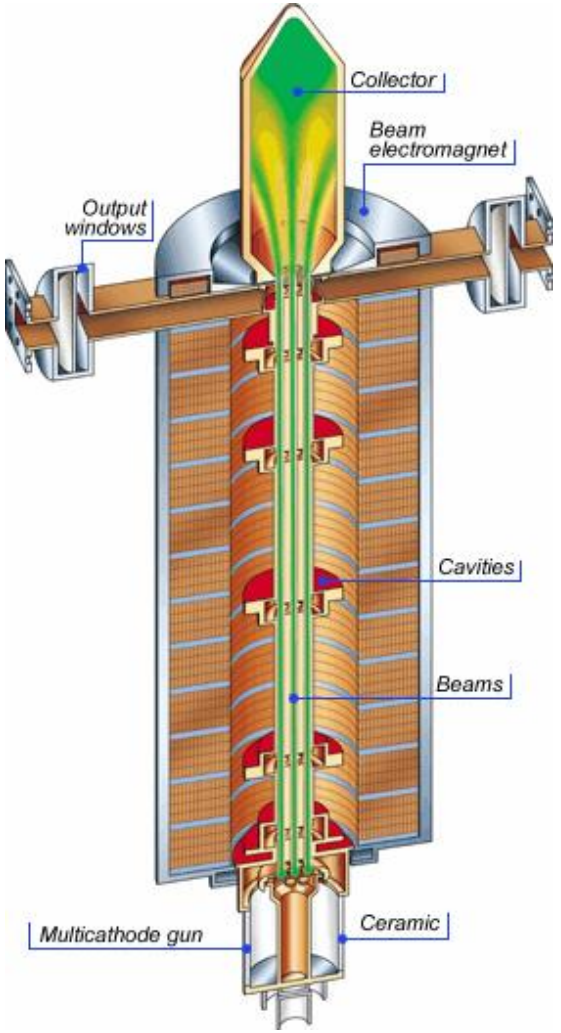
2014

Signature of a research contract with THALES ED:

PhD student to develop a high efficiency 12 GHz klystron by increasing the number of cavities and perform an adiabatic bunching (“RFQ like” bunching)

2015

Demonstrate the feasability of the new concept with a 4.9 GHz klystron prototype based on an existing “cheap” THALES klystron.

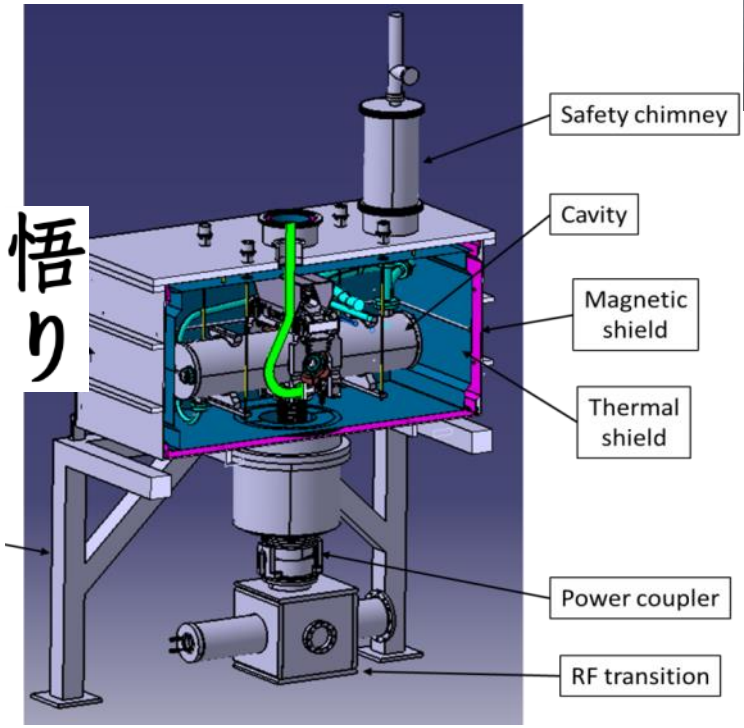


SUPERCONDUCTING CAVITIES & CRYOMODULES

IFMIF SRF LINAC

- Assembly of a mock-up (one cavity + coupler)
- Design of a new cryostat for the test of the cavity with its coupler SaTHoRI,
- Conditioning at CIEMAT of two prototype couplers.
- Important activities on the licensing of the cavities
- Start of the manufacturing of critical components (cavities, couplers ...)

Mock-up of one cavity + coupler



2 prototype coupleurs on the test bench at INDRA (Madrid). Photo : CIEMAT

SPIRAL2 CRYOMODULES (CMA)

2014

Assembly of 2 cryomodules in the new ESS clean room and qualification on Supratech

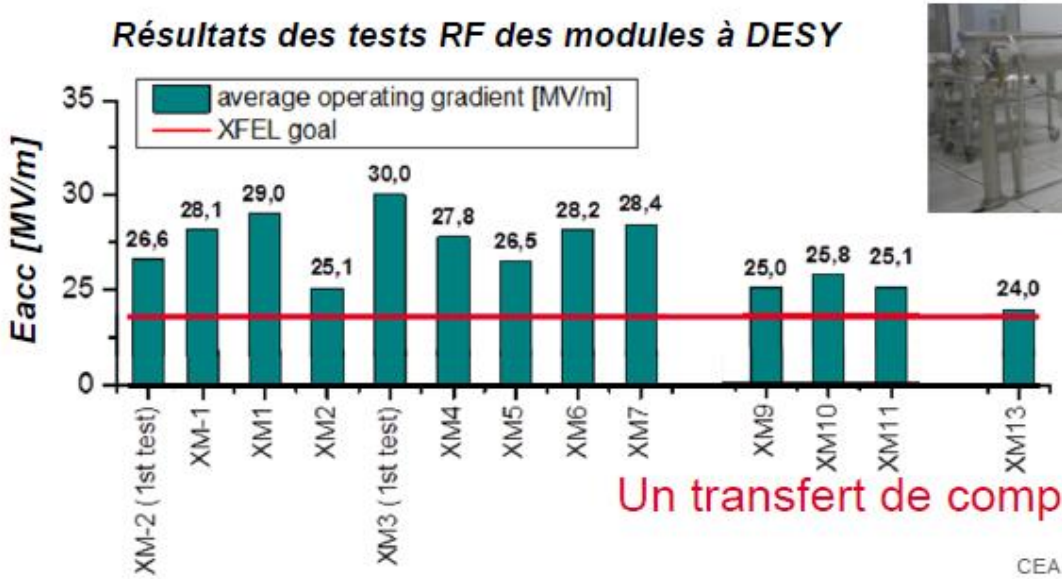
Transport of 4 CMA to Ganil

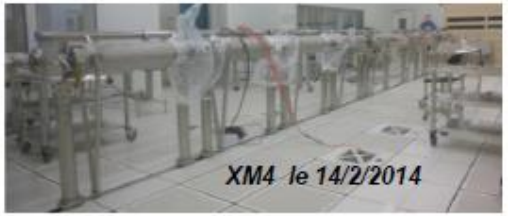
2015

Test of the LLRF during the qualification test of the CMA n° 11 in Supratech

Assembly and qualification of the two last CMAs, **Delivery in May 2015** and installation of the 2 first CMA on the LINAC

XFEL : 1 CRYOMODULE PER WEEK

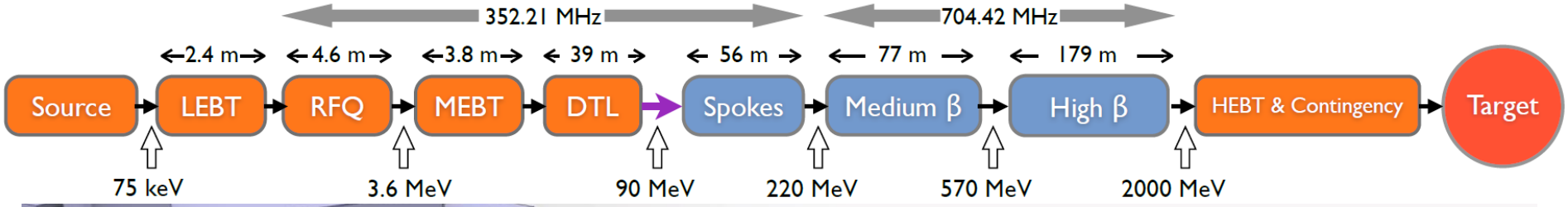


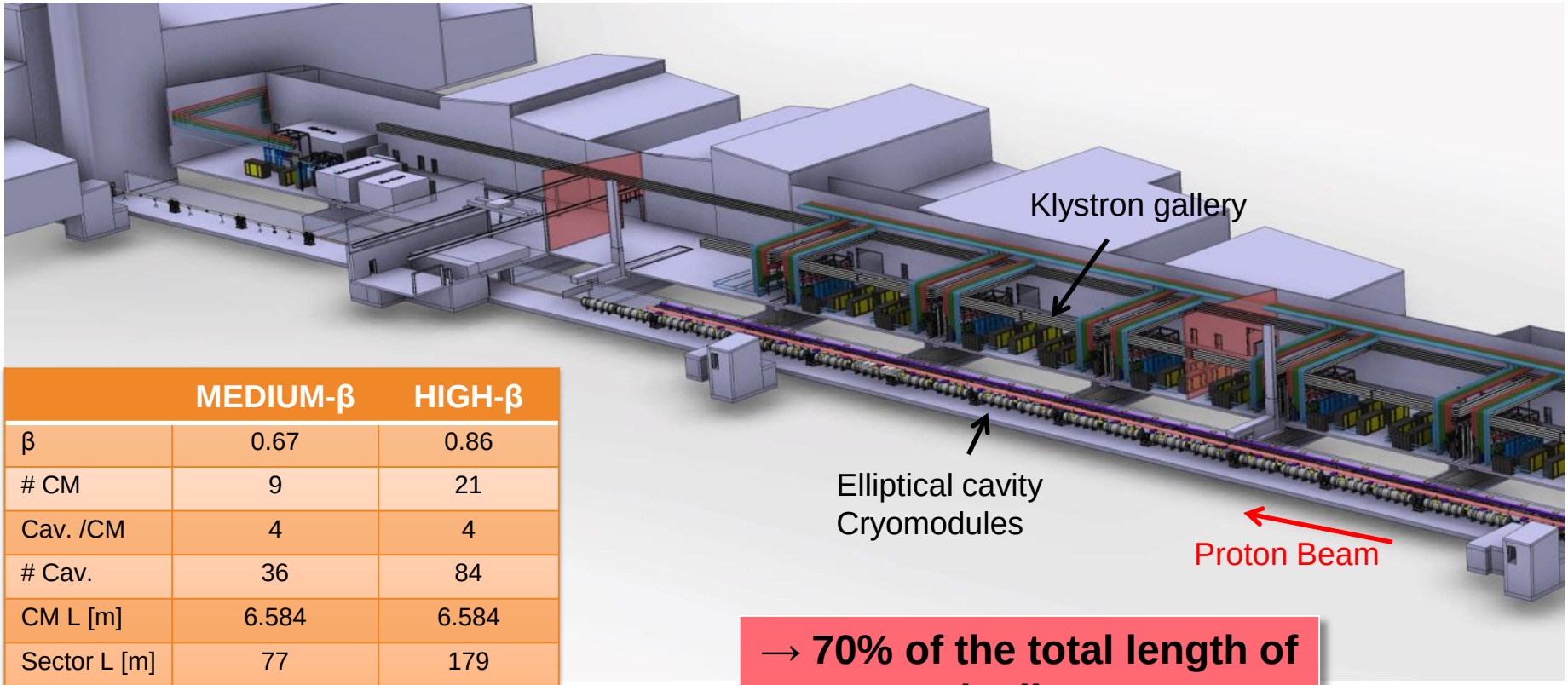


2015 Objectives:
1 CM every 4 days
XM82 at the end of 2015

Un transfert de compétence réussi

ESS SUPERCONDUCTING LINAC





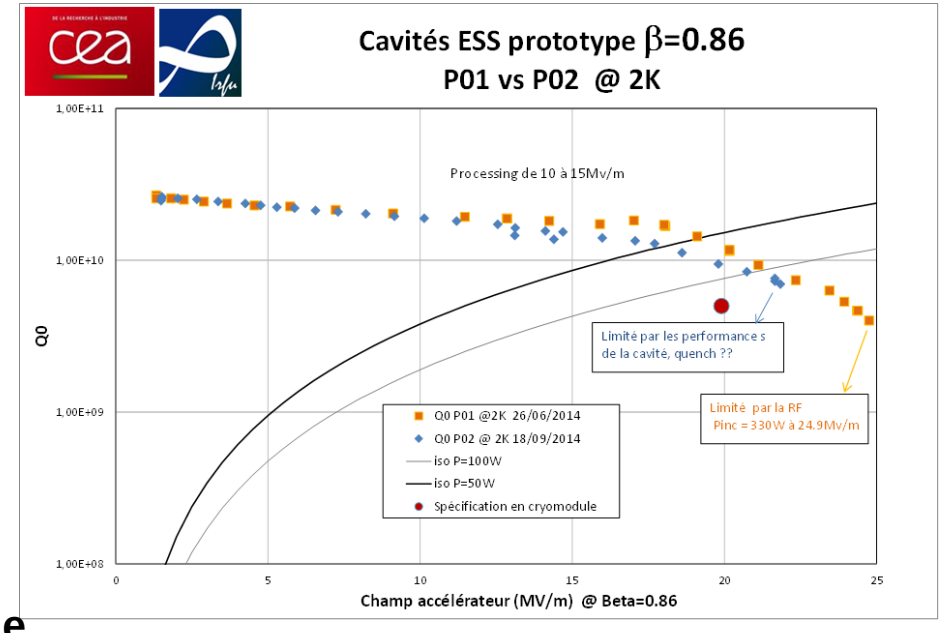
	MEDIUM-β	HIGH-β
β	0.67	0.86
# CM	9	21
Cav. /CM	4	4
# Cav.	36	84
CM L [m]	6.584	6.584
Sector L [m]	77	179

→ 70% of the total length of the linac

ESS CAVITIES AND CRYOMODULES

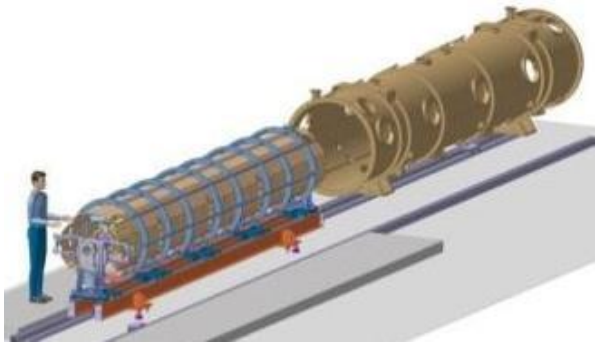
2014

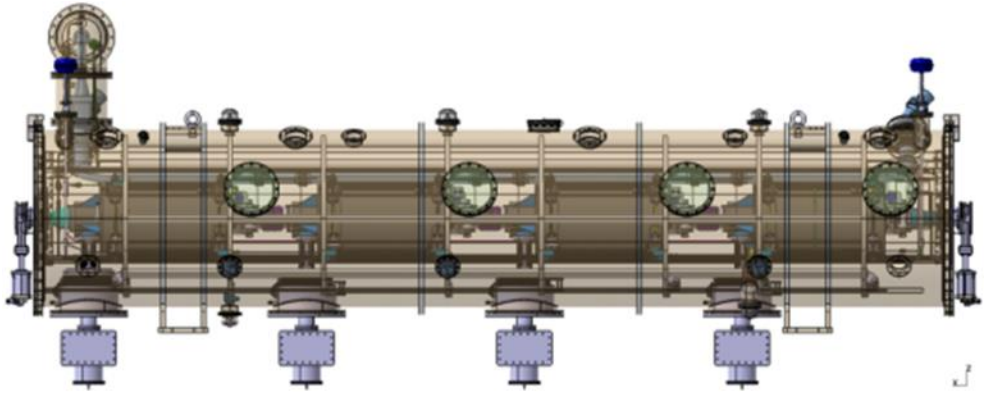
Positive RF tests in vertical cryostat of two prototypes of high beta cavities (Zanon and RI)



Design of the M-ECCTD prototype cryomodule (in collaboration with IPN Orsay)

Design of the assembly tooling





NEW CLEAN ROOM FOR ESS

Cleanroom funded under the Swedish-French agreement on ESS was inaugurated on May 13

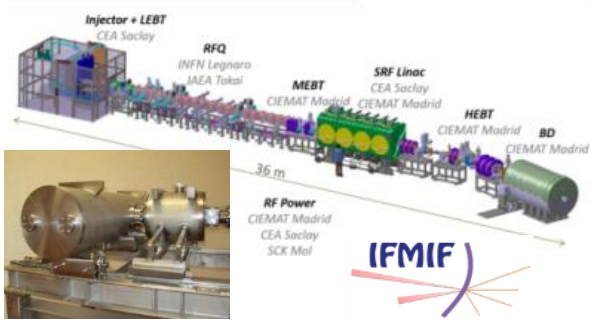
- SPIRAL2 : Cavities and cryomodule assembly
- IFMIF: Preparation and assembly of series cavities
- ESS : Preparation of cavities, coupleurs and assembly of two cryomodules prototyp:
  - **MECCTD : medium beta**
  - **HECCTD : high beta**
- R&D activities: High Pressure Rinsing

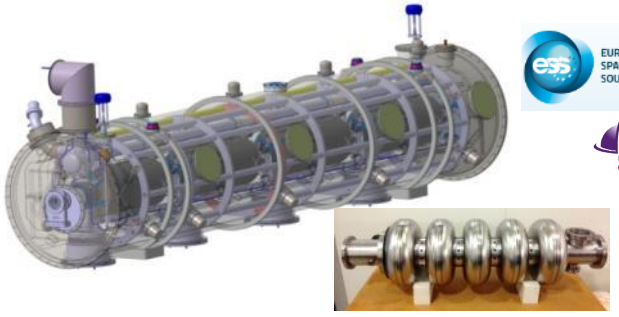
Salle ISO7 : 27m²

Salle ISO5 : 53m²

HPR

Mats LINDROOS, Gabriele FIONI & Philippe CHOMAZ





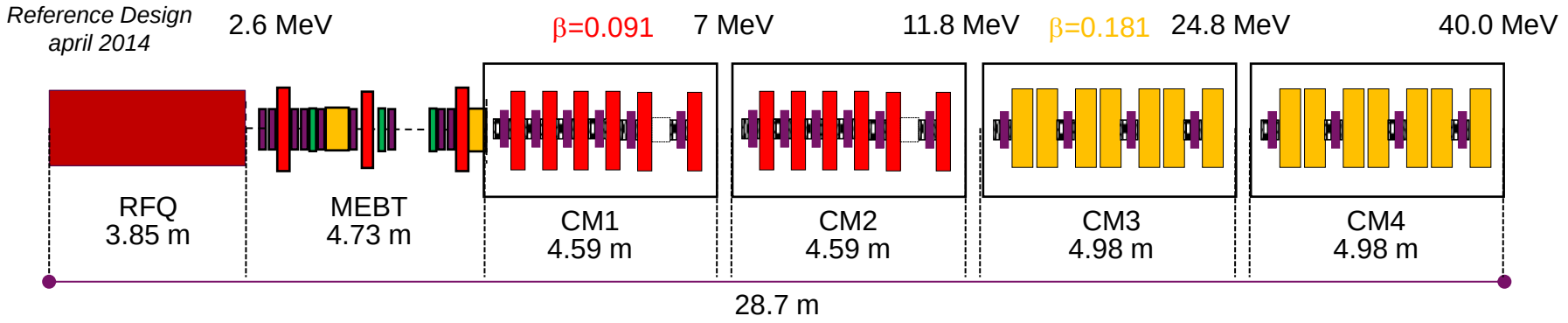
SARAF : NEW INJECTOR FOR SOREQ

SARAF Top Level Requirements :

- Beam:
  - Deutons/protons,
  - pulsed/cw,
  - 0.04 - 5 mA,
  - 2.6-40 MeV (protons 35 MeV).

- **Low losses:**
  - <150 nA/m @ <5 MeV,
  - <40 nA/m @ <10 MeV,
  - <5 nA/m @ <20 MeV,
  - <1 nA/m @ <40 MeV.

- 6000 h/yr, **90% availability**.



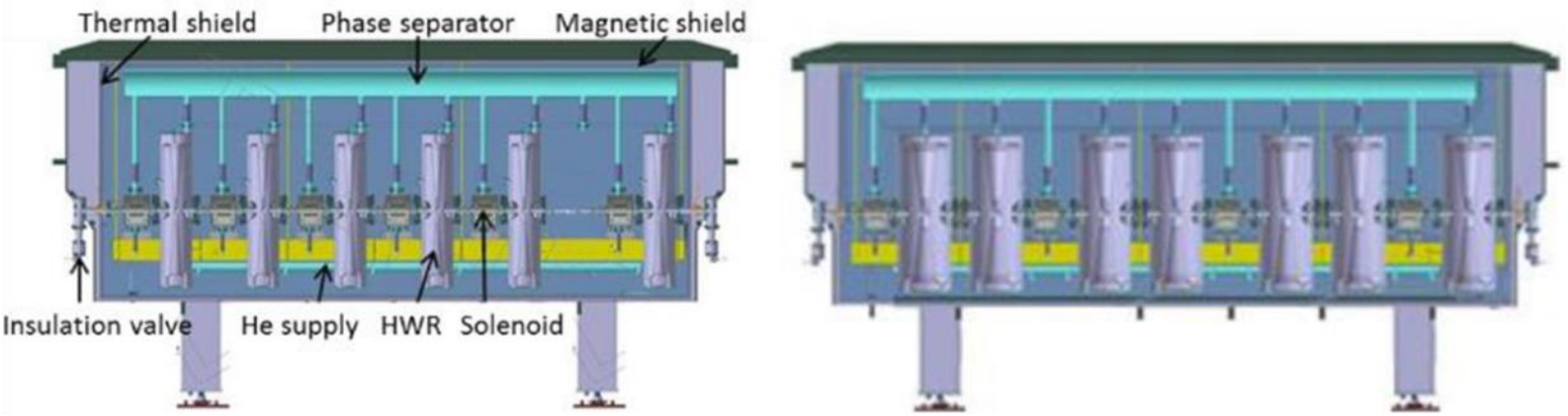
26 October 2014
Bridging activities contract signed

October 2015 subsystem PDRs

26-27 January 2015
Kick-off meeting at Saclay

December 2015 Go-NoGo decision

SARAF CRYOMODULES



2015

Pre-validation studies for low and medium cavities beta:
Target performance of 6.5 MV/m and 7.5 MV/m, respectively

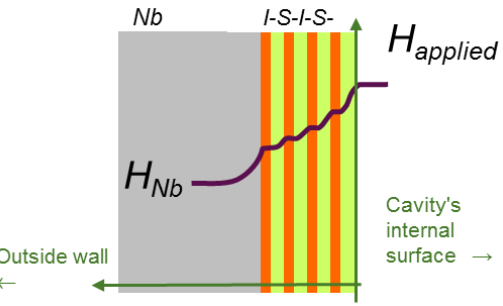
Pre-validation studies for couplers

Determination of the optimal beta

Cryomodule PDR

CDR of critical components (cavities, couplers, tuners)

R&D NANOCOMPOSITE MULTILAYERS



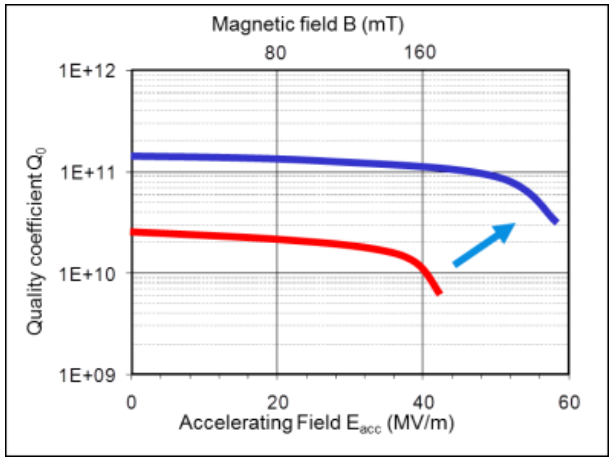
Multilayers: Nb / insulator/ superconductor / insulator /superconductor… :

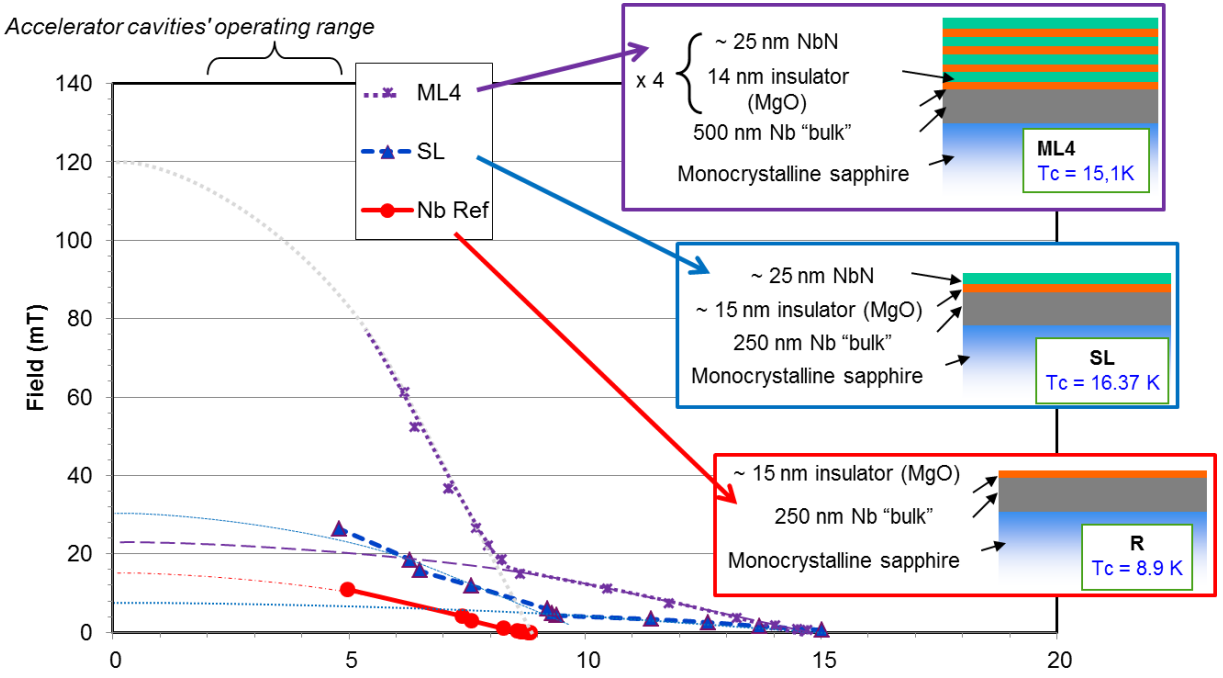
Surface screening and low Rs

- Thin SC films. d< λ => artificial enhancement of H_{C1}^{*}
- The thin layers stand high fields without vortex nucleation
- Niobium surface screening: allows higher field in the cavity
- $R_s^{NbN} \approx \frac{1}{10} R_s^{Nb}$ => $Q_0^{multi} >> Q_0^{Nb}$

$$H_{Nb} = H_{appl}\, e^{-\frac{Nd}{\lambda}} \; **$$

** In theory 20 nm NbN : H_{C1} x ~200*
*** Simplified model from Gurevich*





AERES REPORT - SUMMARY FOR SACM

The report is excellent on the activities of the Institute in general and in particular for our division.

The Committee underlines the strength of our world-class expertise in the field of superconducting magnets and accelerators, our excellent organization in connection with other IRFU technical divisions, the availability of large technological platforms and strong collaboration with industry and European R&D

Some points of improvements have been highlighted by the Committee. SACM should allow a rejuvenation of the technical staff and enough efforts on R&D to prepare for the long-term future. An increase in the number of PhD students and postdocs could also help in this perspective.
The business / service provider model and continuous and aggressive acquisition strategy require a robust QA and risk management plan, in which a clear understanding of who carries the cost and schedule risk is necessary.

R&D PROSPECTIVE

A prospective on R&D is launched based on the AERES report and the Executive report of the "accelerators" working group of the IN_2P_3/IRFU Prospective Days

The action will be coordinated with the members of the CSTS together with in 6 senior engineers,

1- Identification of ongoing activities and allocated resources

2. Evaluation of the R&D results over the last decade

3- Prospective on future activities, proposition and prioritization of research areas.

Delivery of the report: June 2015

CONCLUSION

A clear roadmap for 2020

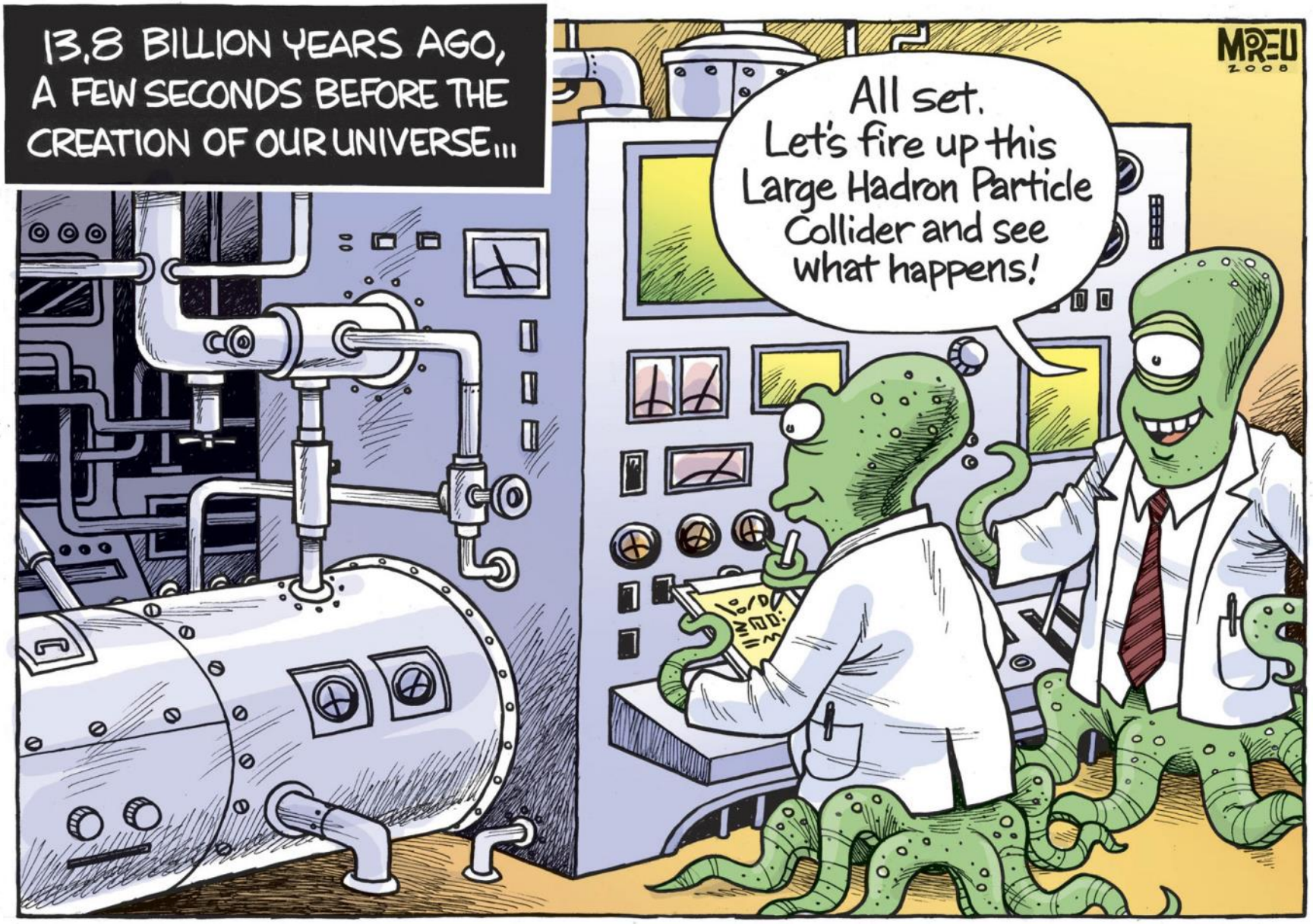
- To finish large projects (IFMIF, Iseult, IPHI, XFEL, LNCMI, ..)
- To start new projects (ESS, SARAF, LHC updgrades, …)
- To reinforce the R&D programs
- To explore new projects beyond 2016

We have an **positive increase of HR** to support these programs and a consolidation of the technological platforms.

We contribute to the future of major large accelerator and superconducting magnet projects world wide…

….and we are preparing together with SPP, SPhN, SIS and SEDI the future discoveries in Nuclear and Particle Physics

...ORIGIN OF THE UNIVERSE



MANPOWER EVOLUTION (2007-2014)

	31/12/07	31/12/08	31/12/09	01/12/10	01/12/11	01/12/13	01/12/14
Engineers	69	70	69	67	71	77	81
Technicians	50	49	50	47	47	45	44
PhD students	3	5	6	6	5	3	6
Post-doc, non permanent pos.	4	4	5	6	8	6	9
Sandwich trainees	2	1	2	1	3	3	4
TOTAL	128	129	132	132	134	134	144

M.O Globale plan de charge 2014