Overview of Accelerator Activities in France

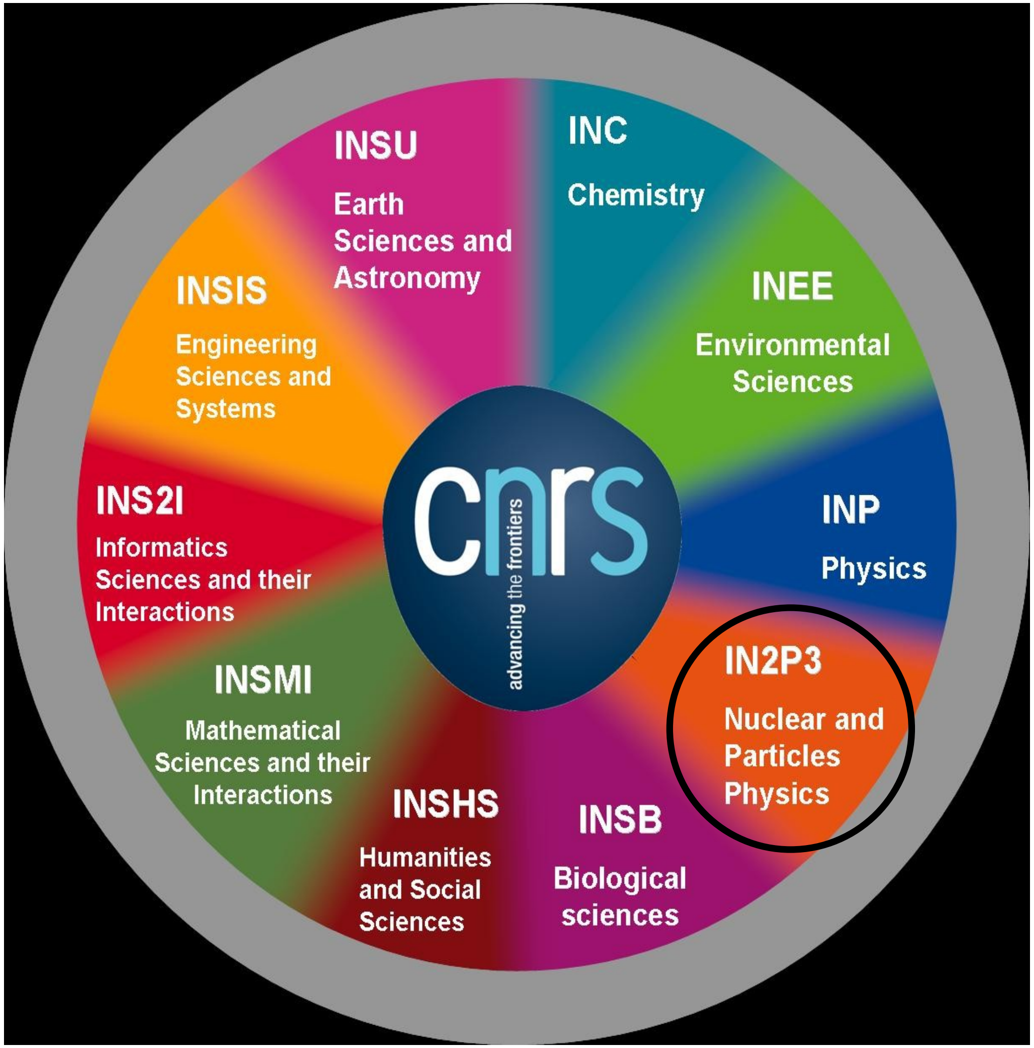
B. Launé and A. Daël
CEA/CNRS Pôle Accélérateurs

CNRS/IN2P3

National
Scientific
Research
Center

32 000 persons

14 000 Technical staff

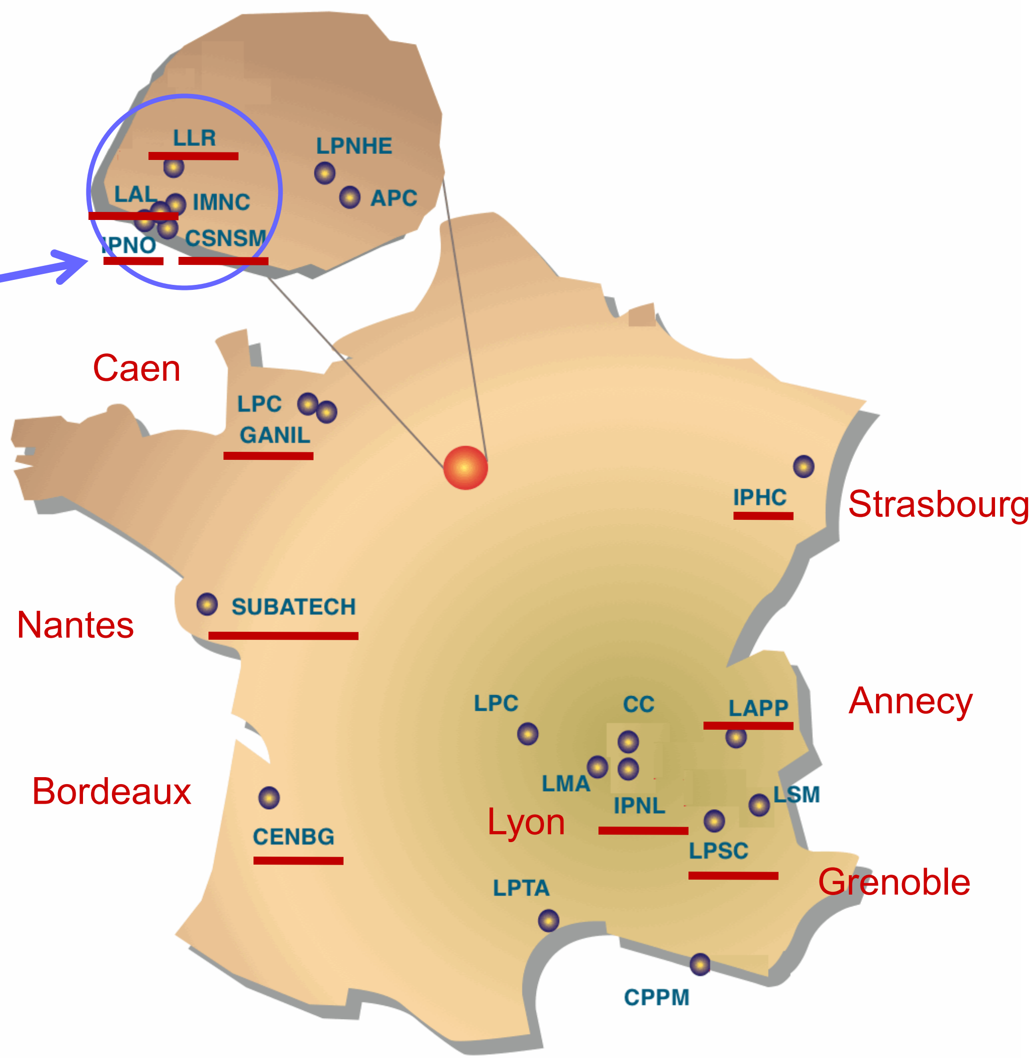


IN2P3 : Institut de Physique Nucléaire et des Particules

Orsay/Saclay

- 2 400 persons
- 1 500 Technical staff
- 20 laboratories

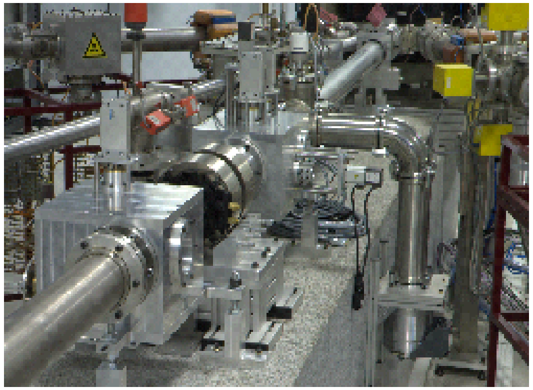
Laboratories involved in Accelerators for 250 FTE



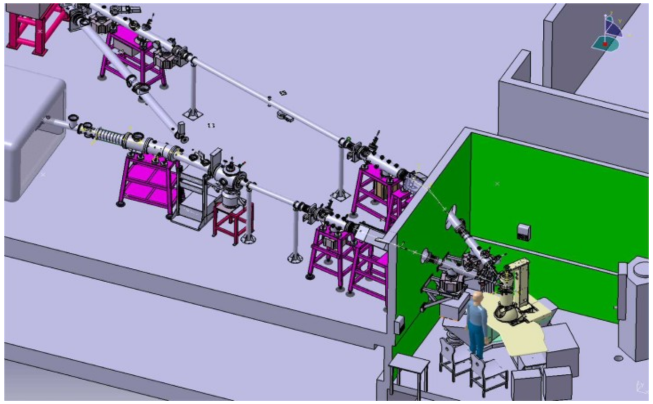
IN2P3 Platforms for research and applications

ANAFIRE Lyon

AIFIRA Bordeaux



JANNUS CSNSM Orsay



ARRONAX Nantes

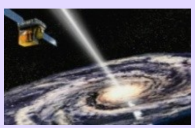
CEA/IRFU
The largest institute of CEA : Research and Technology

CEA
~15 000

Defense | Technology | Research | Nuclear Energy

Irfu
~ 800

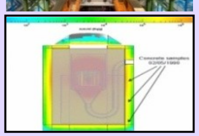
Institute of Research into the Fundamental laws of Universe



Astrophysics
Space technologies

Nuclear Physics

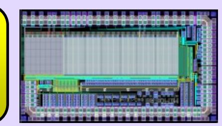
Particle Physics



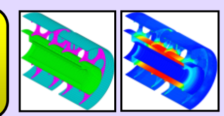
Nuclear expertise

Accelerators,
Supra. Magnets

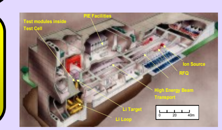
Detectors, electronic,
computing



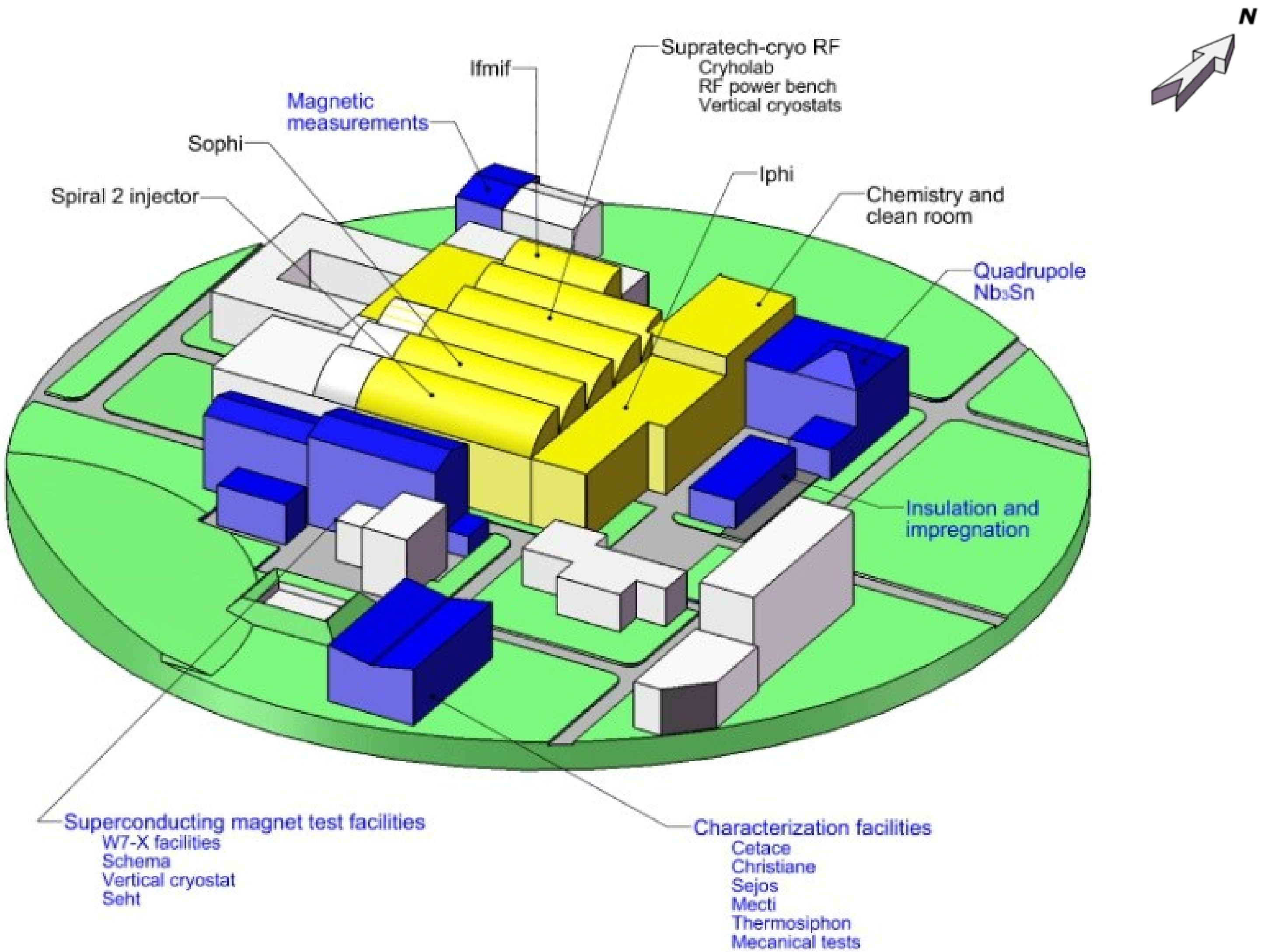
Systems engineering

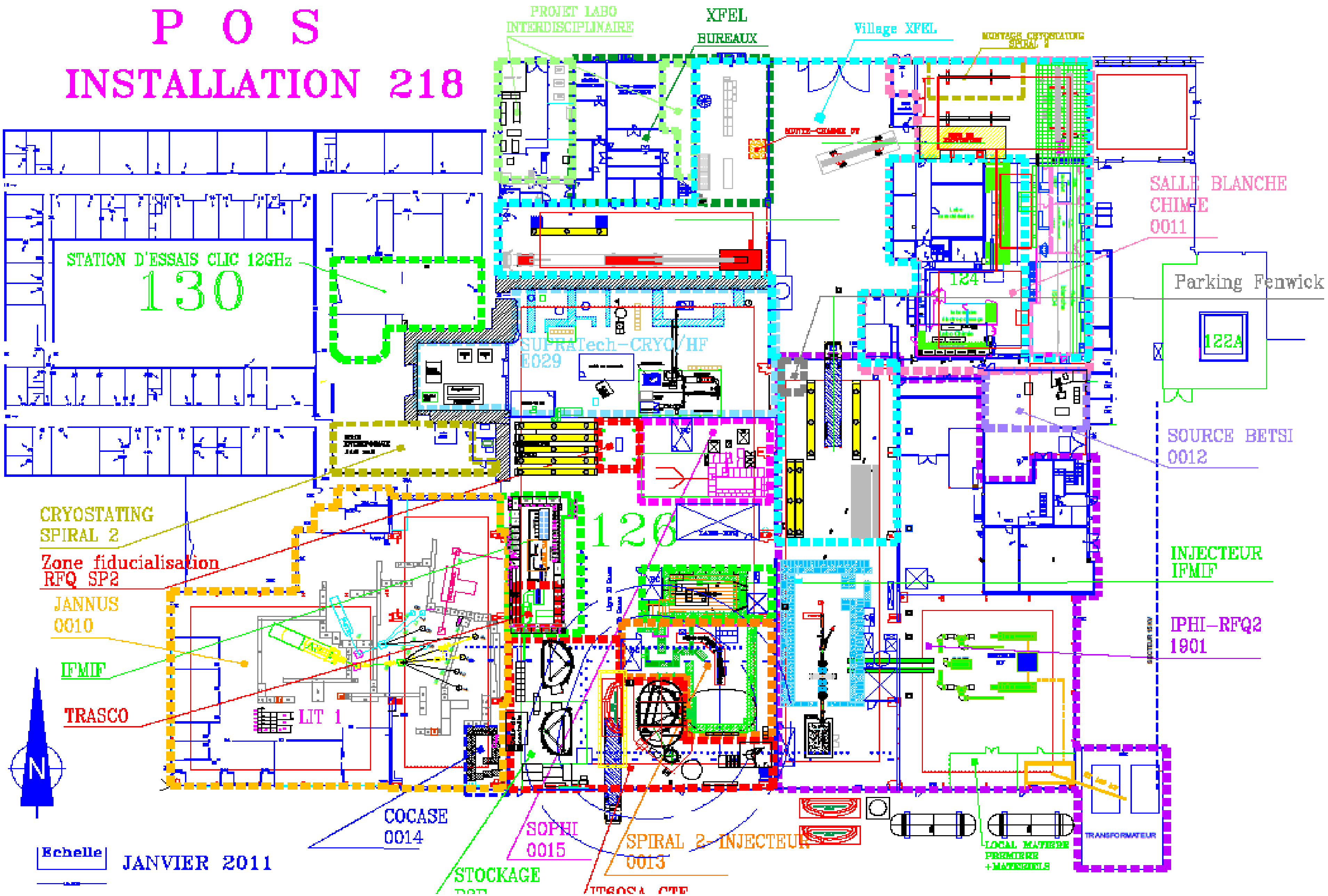


IFMIF EVEDA

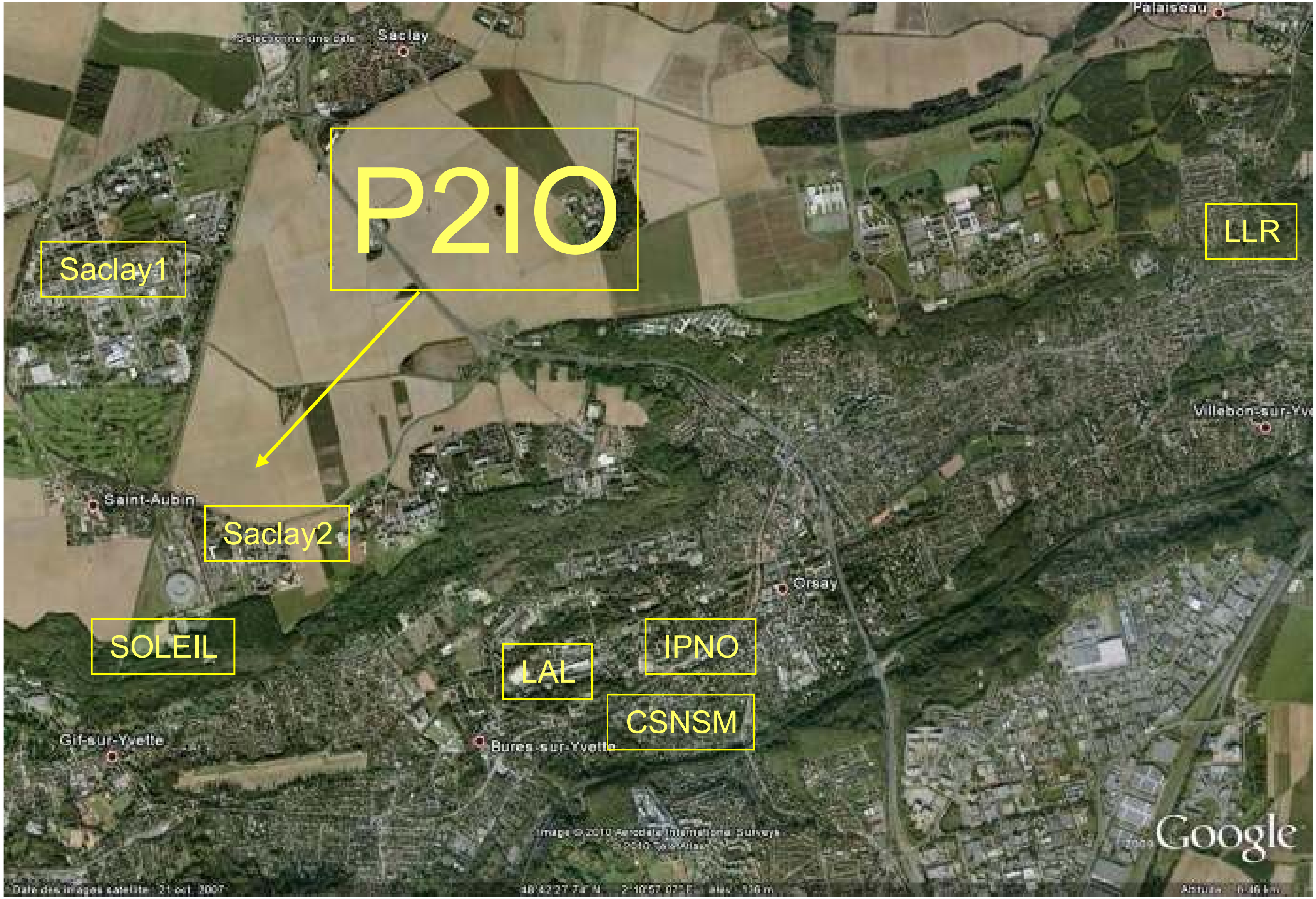


IRFU Accelerator Installations@Saclay




P O S
INSTALLATION 218
PROJET LABO INTERDISCIPLINAIRE
XFEL
BUREAUX
Village XFEL
STATION D'ESSAIS CLIC 12GHz
130
SALLE BLANCHE CHIMIE
0011
124
Parking Fenwick
122A
SUPRATech-CRYO/HF
E029
SOURCE BETSI
0012
126
CRYOSTATING SPIRAL 2
Zone fiducialisation RFQ SP2
JANNUS
0010
IFMIF
TRASCO
LIT 1
INJECTEUR IFMIF
IPHI-RFQ2
1901
COCASE
0014
SOPHI
0015
SPIRAL 2 INJECTEUR
0013
STOCKAGE
TRANSFORMATEUR
LOCAL MATIERE PREMIERE +MATERIELS
N
Echelle
JANVIER 2011

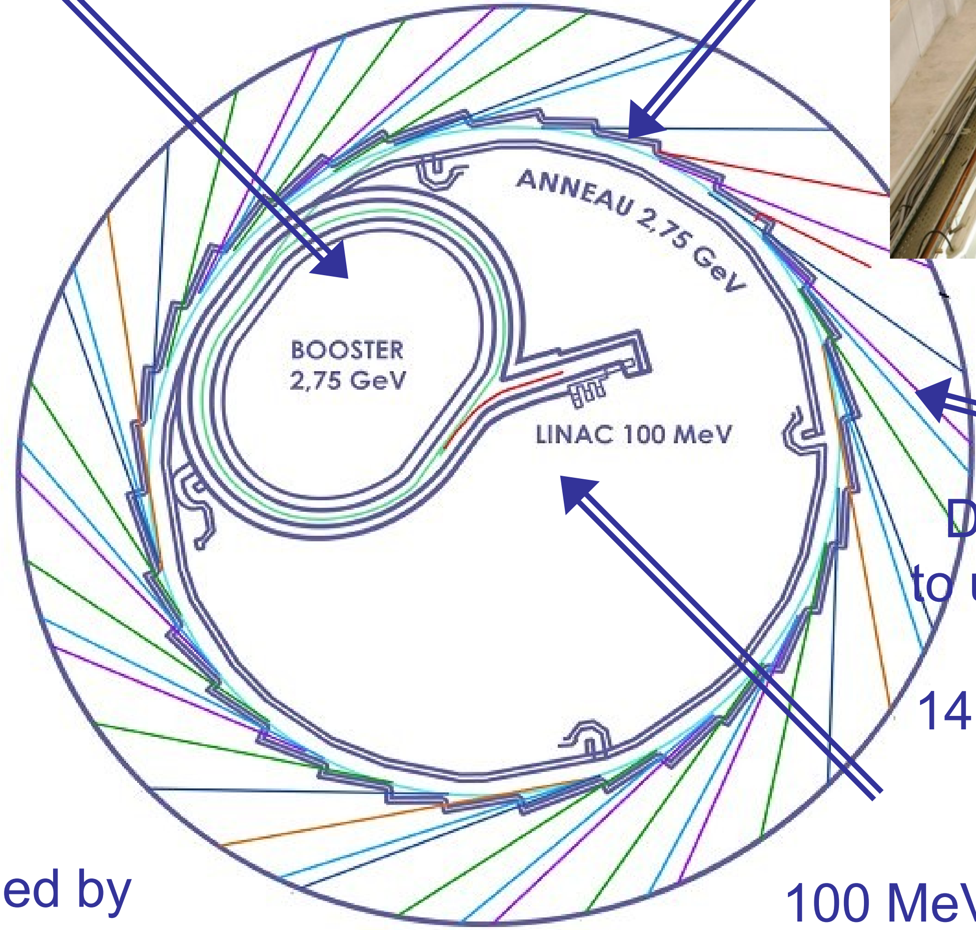
Plateau de Saclay



3 Accelerators at SOLEIL

A **Storage Ring**
2,75 GeV, 354 m

A **Booster synchrotron**
100 MeV => 2,75 GeV, 157 m, 3 Hz,



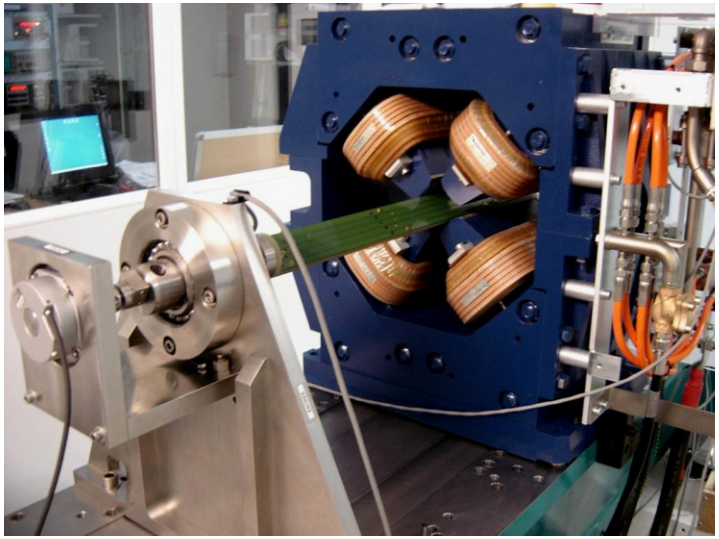
Delivering X-ray beam to up to 35 **Beamlines** :
21 on insertions
14 on bending magnets

An **e- Linac** :
100 MeV, 16,5 m, 3 Hz, 8 nC

All designed by SOLEIL

Accelerator R&D infrastructure

Magnetic measurement lab equipped with 4 benches and one clean room



Vacuum lab equipped with cleaning facility and NEG coating bench

RF and power supplies labs equipped with test stands

Metrology lab and mechanical workshops

SOLEIL R&D activities

Free electron lasers, seeding
(Collaboration with SPARC (Italy), with Japan, LUNEX5 project..)

Ultra short pulse (fs)
Slicing,..

Compton back scattering compact X-Ray source
(collaboration with LAL)

Development of new RF solid state amplifiers.

Development of new types of undulators

Development of innovative power supplies

Development of innovative kicker system (for Cryring/FAIR) with SIGMAPHI

CEA/CNRS Collaboration on Accelerators

- Establishment of the « Pôle accélérateurs » in 2005
- Common entity to coordinate actions on accelerators

Expert Comittee : Accelerator Scientific Comittee

Executive Comittee : A. Daël (CEA/IRFU) and B. Launé (CNRS/IN2P3)

Regular meetings, negociation in common for the Contribution to CERN or to FAIR

Driving Forces

- Higher energy
- Higher intensity/luminosity
- Higher efficiency
- Higher reliability
- Make accelerator technologies available to society

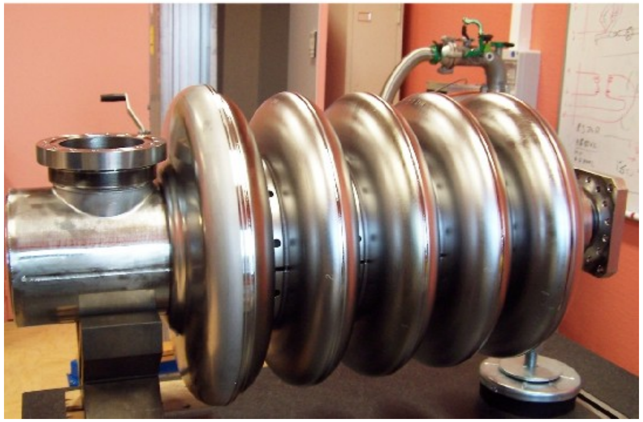
How

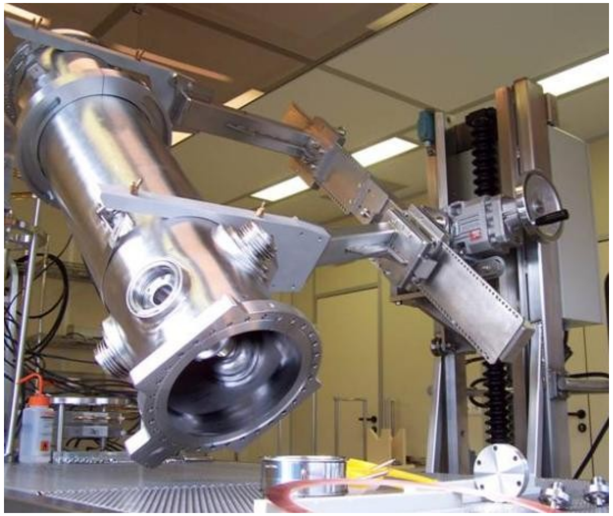
- Sustain R&D program
- Develop technological platforms
- Participate in European R&D programs
- Participate to world class accelerator development (SPIRAL2, ESS, XFEL…)
- Develop partnerships with CERN, DESY…
- Propose innovative accelerators for applications

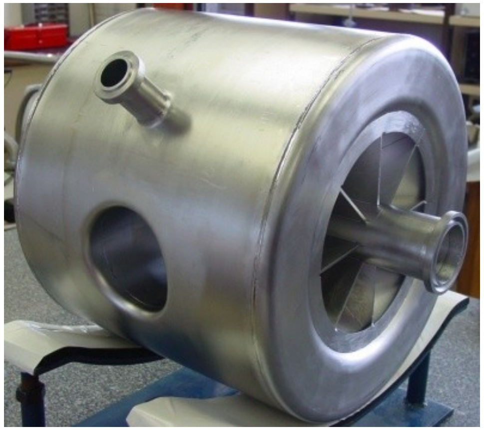
Quest for high gradient

- Superconducting RF Technology
- CLIC/CTF3 accelerating structures
- Laser/plasma acceleration

SRF developments







EuCARD WP10

Example of technological platform: SUPRATech@Orsay

French participation to XFEL

- CEA/IRFU : Integration of 83 cryomodules
- CNRS/IN2P3/LAL : delivery of over 600 Couplers

CEA/IRFU : XFEL Cryomodules

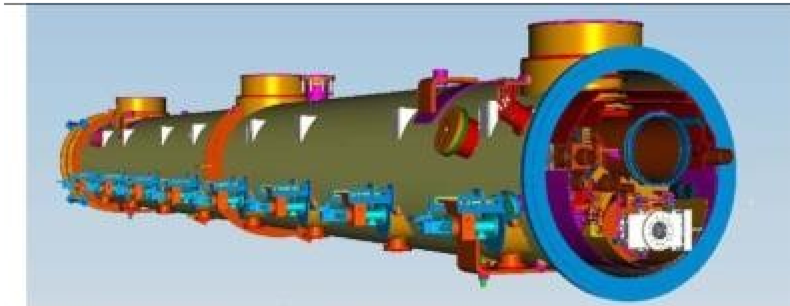
- The 83 cryomodules of the XFEL LINAC will be integrated at CEA Saclay in a new dedicated facility

- The CEA contribution covers :

▪ Assembly in the clean room of 83 cavity strings (each with 8 cavities, 8 RF couplers , one quadrupole, one BPM and two vacuum valves)

▪ Assembly of 83 Cold Masses in their vacuum vessel

- The series operation will be sub contracted to an industrial operator



XFEL Module Assembly at Saclay

The 83 (103) XFEL cryomodules of the XFEL 14 (20) GeV Cold Linac will be assembled at Irfu-Saclay.

Prototyping: roll-in of cavity string in IS04 Area Clean Room

XFEL Module Assembly at Saclay

Transfer of cryomodule in Clean Room roll-out Area

XFEL Module Assembly at Saclay

Transfer of cryomodule in RF Coupler assembly area

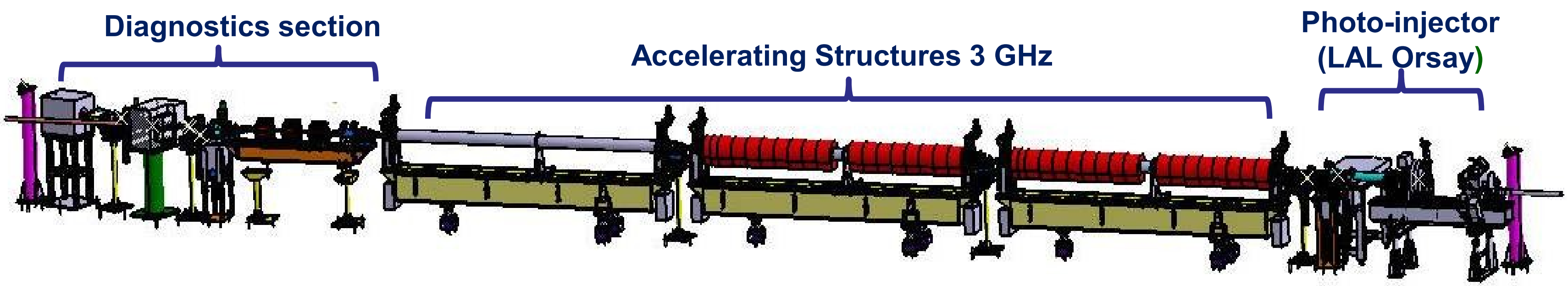
CNRS/IN2P3/LAL : XFEL couplers' industrialisation

- Delivery of all the power couplers (more than 600) for the XFEL project in DESY Hamburg.
- The contract has already been attributed to a Thales / RI consortium
- LAL will host all the conditionning process. The couplers will be received, prepared, conditionned and then send to Saclay to be integrated in the CryoModule

The CLIC-CTF3 R&D Program

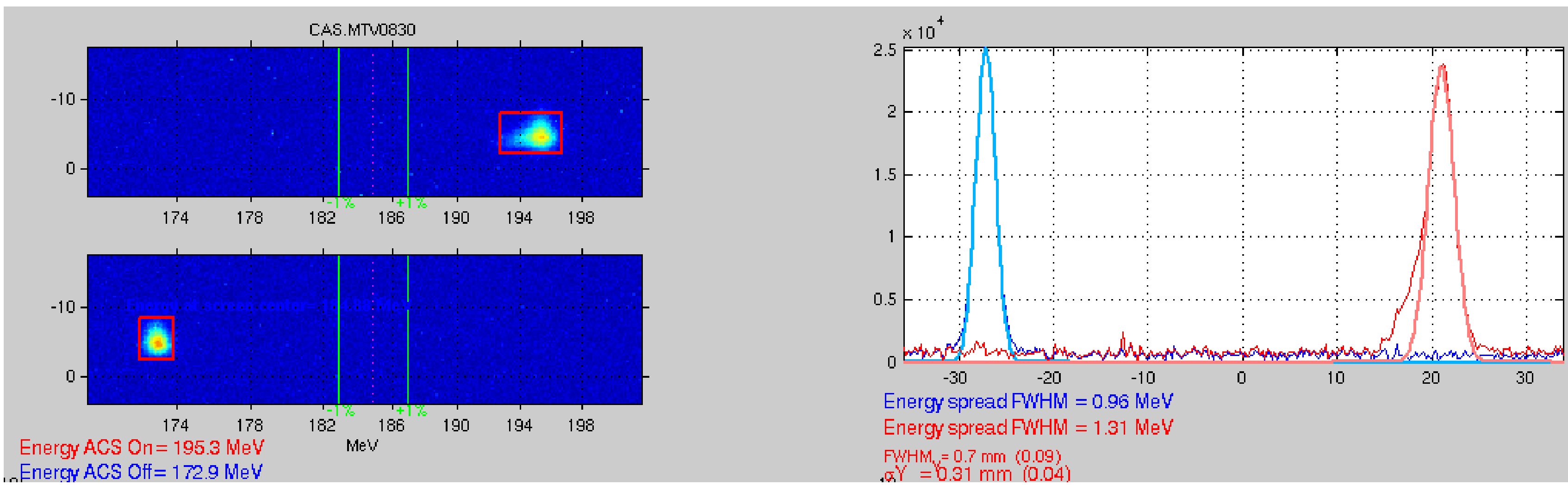
In collaboration with IRFU, IN2P3/LAL and CERN, the probe beam linac Califes is in operation since 2009 to test CLIC high gradient structures.

Parameters	Specified	Tested
Energy	200 MeV	185 MeV
Norm. rms emittance	< 20 π mm.mrad	8 π mm.mrad
Energy spread	< ± 2 %	± 0.5 %
Bunch charge	0.6 nC	0.65 nC
Number of bunches	1-32-226	from 1 to 300



First Accelerating Gradient Result at CERN

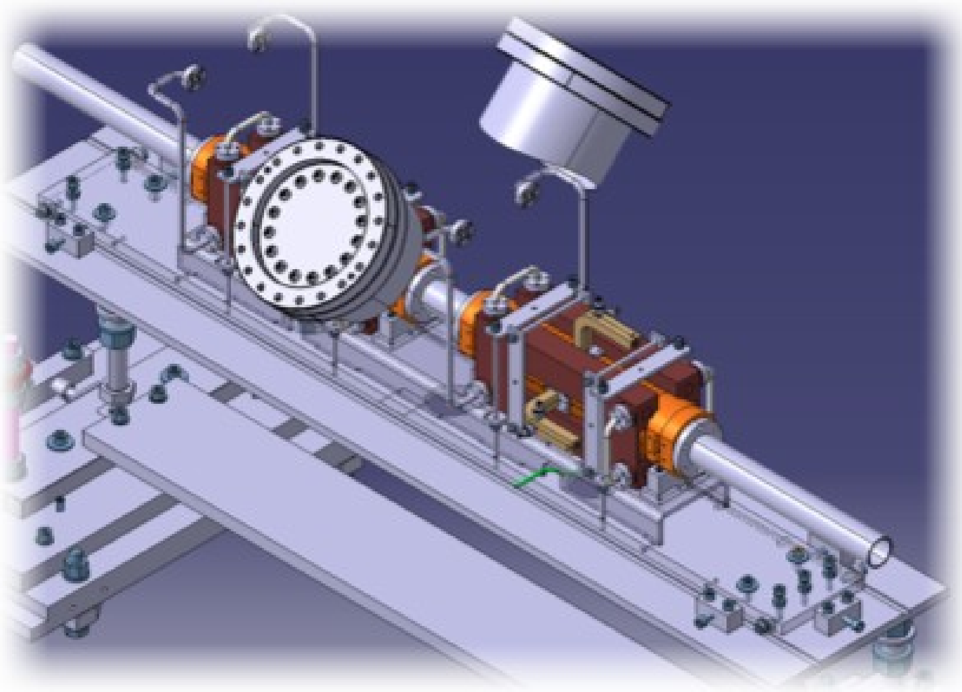
The first beam test at CERN (end of 2010) have reached an accelerating gradient of **112 MV/m** with a good energy spread in a reproducible manner.



CTF3, including Califes, started up again in February 2011.

New CLIC Accelerating Structures

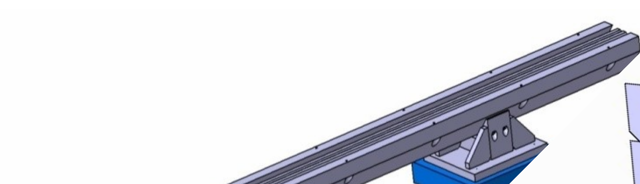
- IRFU is studying new structures fabricated by Mecachrome (25 nm surface rugosity).
- The partnership has trained the industrial producer to a new machining technology.
- The structures will be tested in the coming year at CTF3.

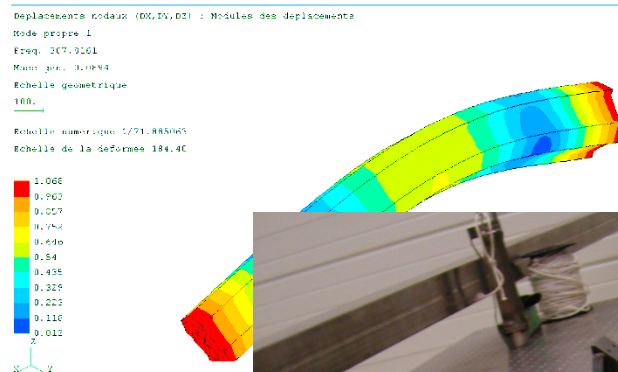


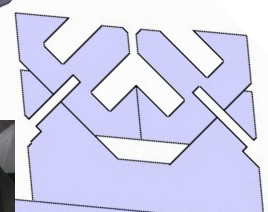
CLIC cell with wake field damping.

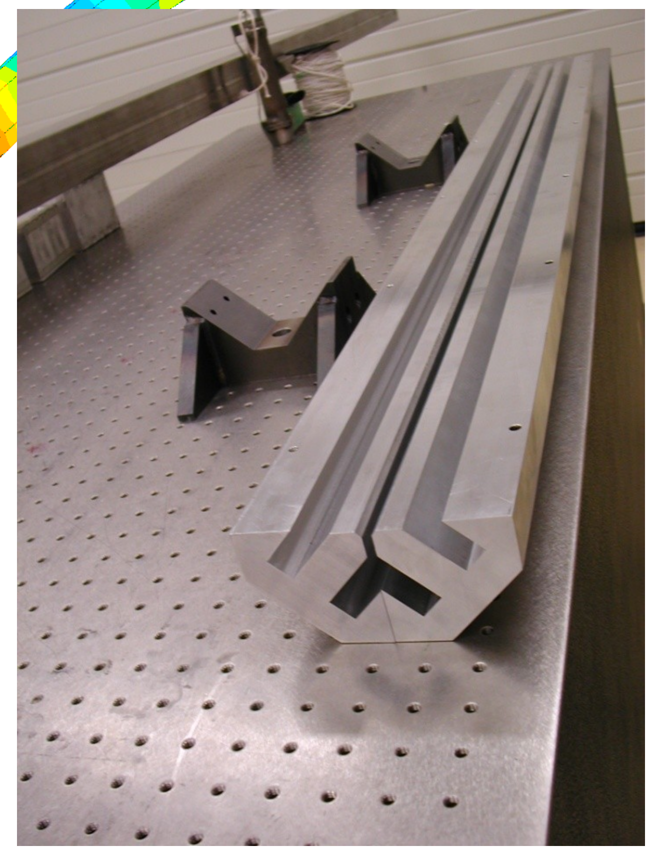
CLIC : IN2P3/LAPP

- Final focus optical elements stabilization
- Tests on a model : vibration calculations

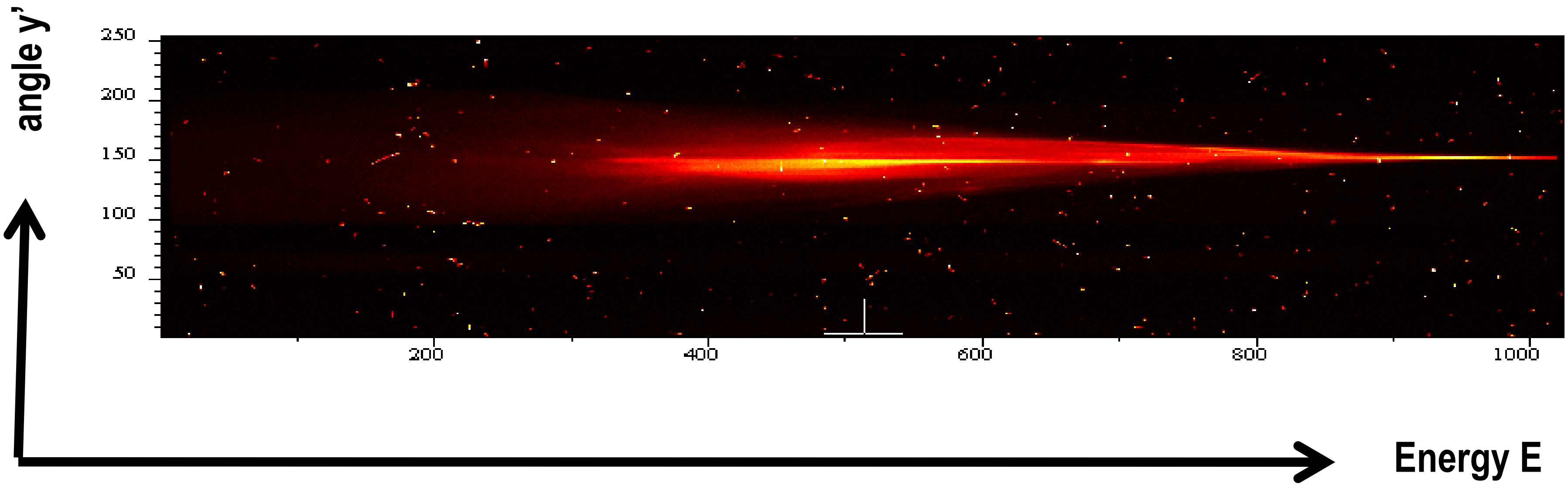








Laser/Plasma Acceleration

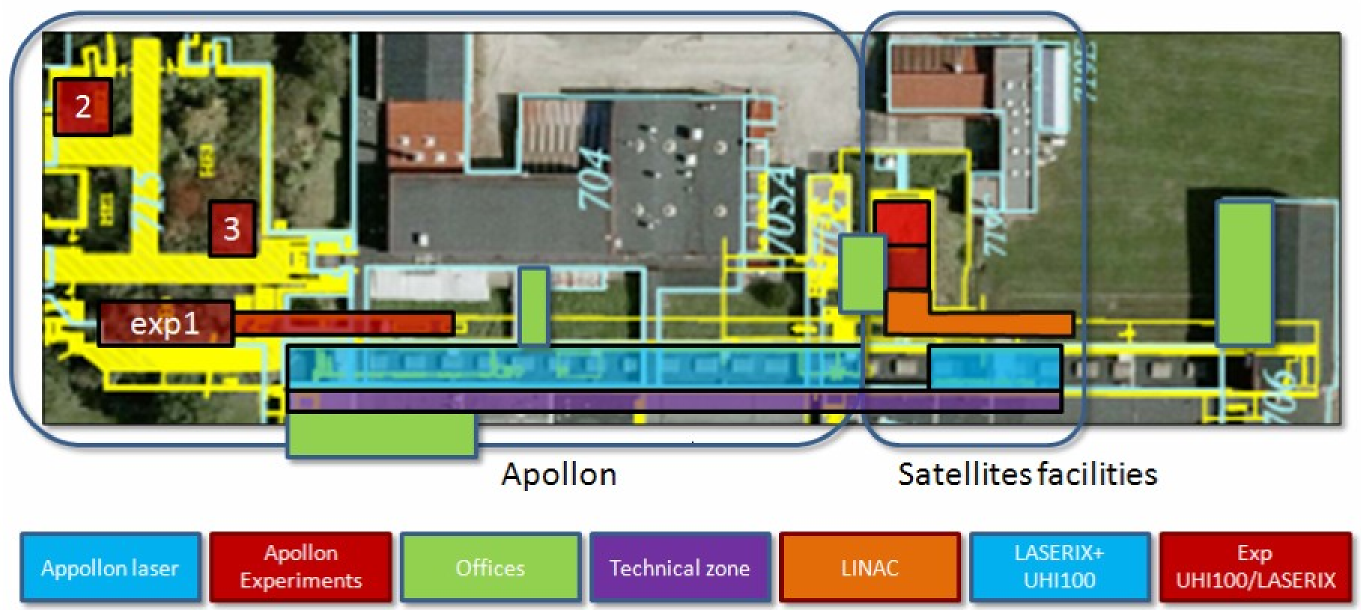


Bridgelab Symposium for Laser Acceleration
ROUTE TOWARD REALITY
Saclay, February 14th, 2011

New WP in EuCARD

Laser/plasma

- ILE : Institut de la Lumière Extrême, 3 instruments
  - Laser APOLLON, 10 PW -> construction 2015 @CEA (Orme)
  - Laser LUIRE (LOA) 500 TW, 2012
  - Laser ELFIE (LULI) OPCPA -> upgrade 100 TW



CILEX : LLR, SOLEIL, LAL, CEA/IRFU, CEA/IRAMIS

APOLLON : EQUIPEX « Equipement d'Excellence »

Dedicated area for laser acceleration, funded through EQUIPEX

- Transport and diagnostics e^- beam line (LLR)
  - low E (~200MeV–2GeV): high precision, tunable
  - high E (~2GeV–20GeV): low precision, fixed
- Magnetic wiggler and associated radiation diagnostics (SOLEIL)

  (U18 cryogenic undulator, period 18mm, B=1.55T, L=2m)
- Photogun injector + RF LINAC (LAL)

  (50-200 pC, 100 fs)

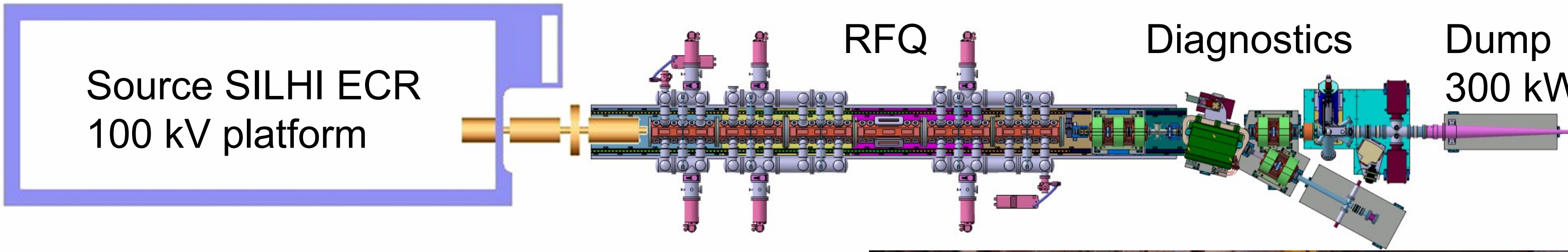
EuCARD WP11

CNRS, CNRS/IN2P3/LAL-LLR , UParisSud, CEA/Iramis/Irfu, SOLEIL

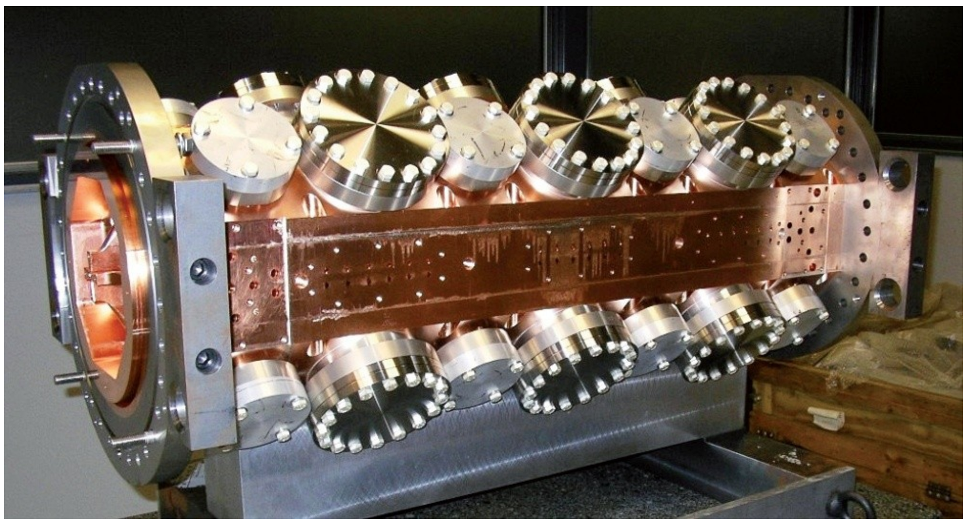
Quest for higher intensities

- Sources/front end : next talks (IPHI/SILHI and LPSC ion sources developments)
- IPHI
- SPIRAL2 : LINAC+ RIB
- IFMIF/EVEDA
- FAIR
- ESS

IPHI (High Intensity Proton Injector)



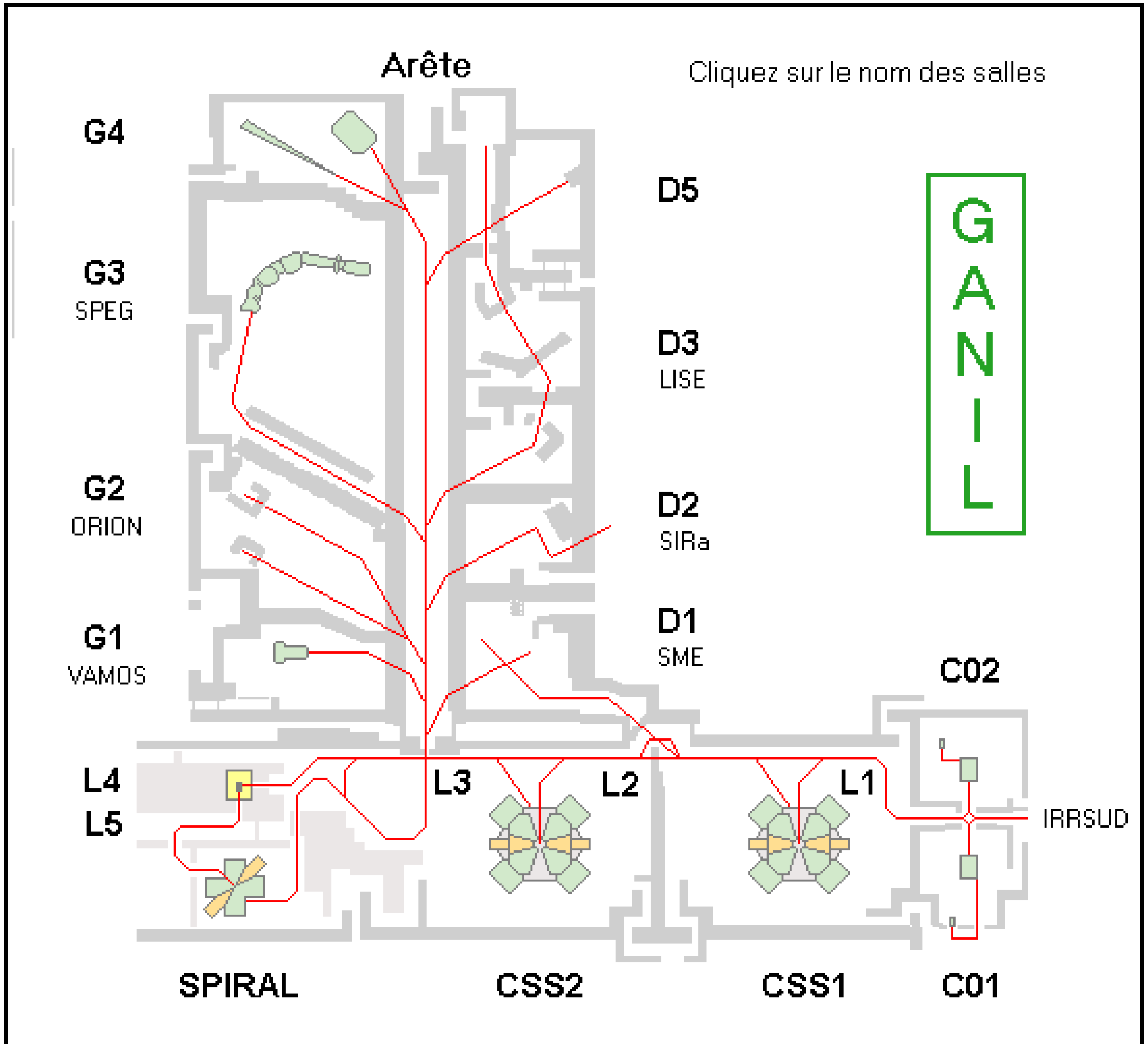
One RFQ sector (1m)



IPHI is a front-end demonstrator for future applications:

- Waste Transmutation (ADS)
- Spallation Neutrons Sources (ESS)
- Neutrino Factories (NuFact)
- Material Irradation (IFMIF)

GANIL


Arête
Cliquez sur le nom des salles
G4
G3
SPEG
G2
ORION
G1
VAMOS
D5
D3
LISE
D2
SIRa
D1
SME
C02
GANIL
L4
L5
L3
L2
L1
IRRSUD
SPIRAL
CSS2
CSS1
C01

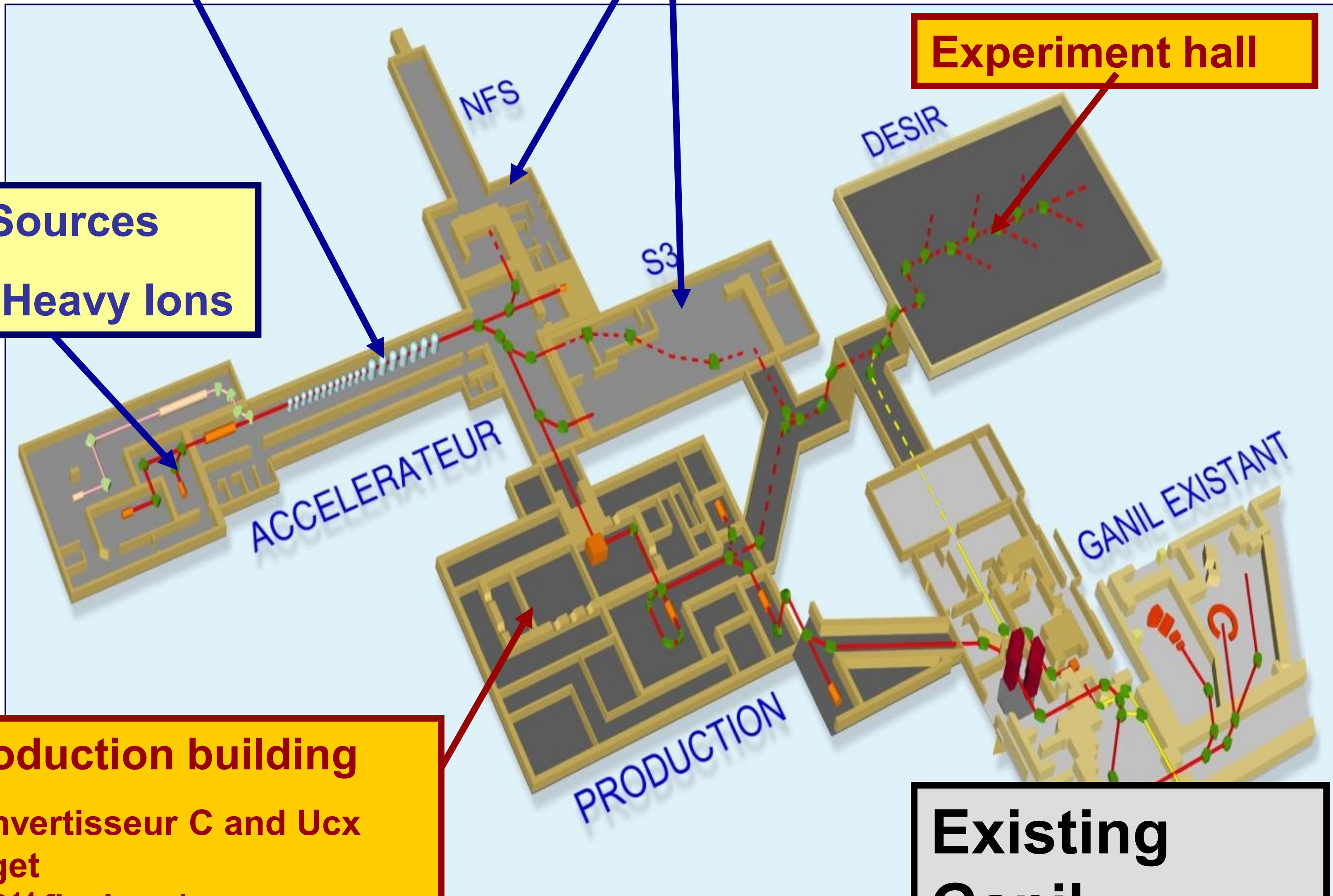
SPIRAL2

Superconducting LINAC
40 MeV d, 5 mA , 14 MeV/n
Heavy Ions

Experimental halls

Ion Sources

D+ / Heavy Ions



Experiment hall

Production building

Convertisseur C and Ucx target
≤ 10^{14} fissions/s

Existing Ganil

SPIRAL2 : a shared Project

In France

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE — IN2P3

- Bordeaux
- Caen
- Grenoble
- Lyon
- Orsay
- Paris
- Strasbourg

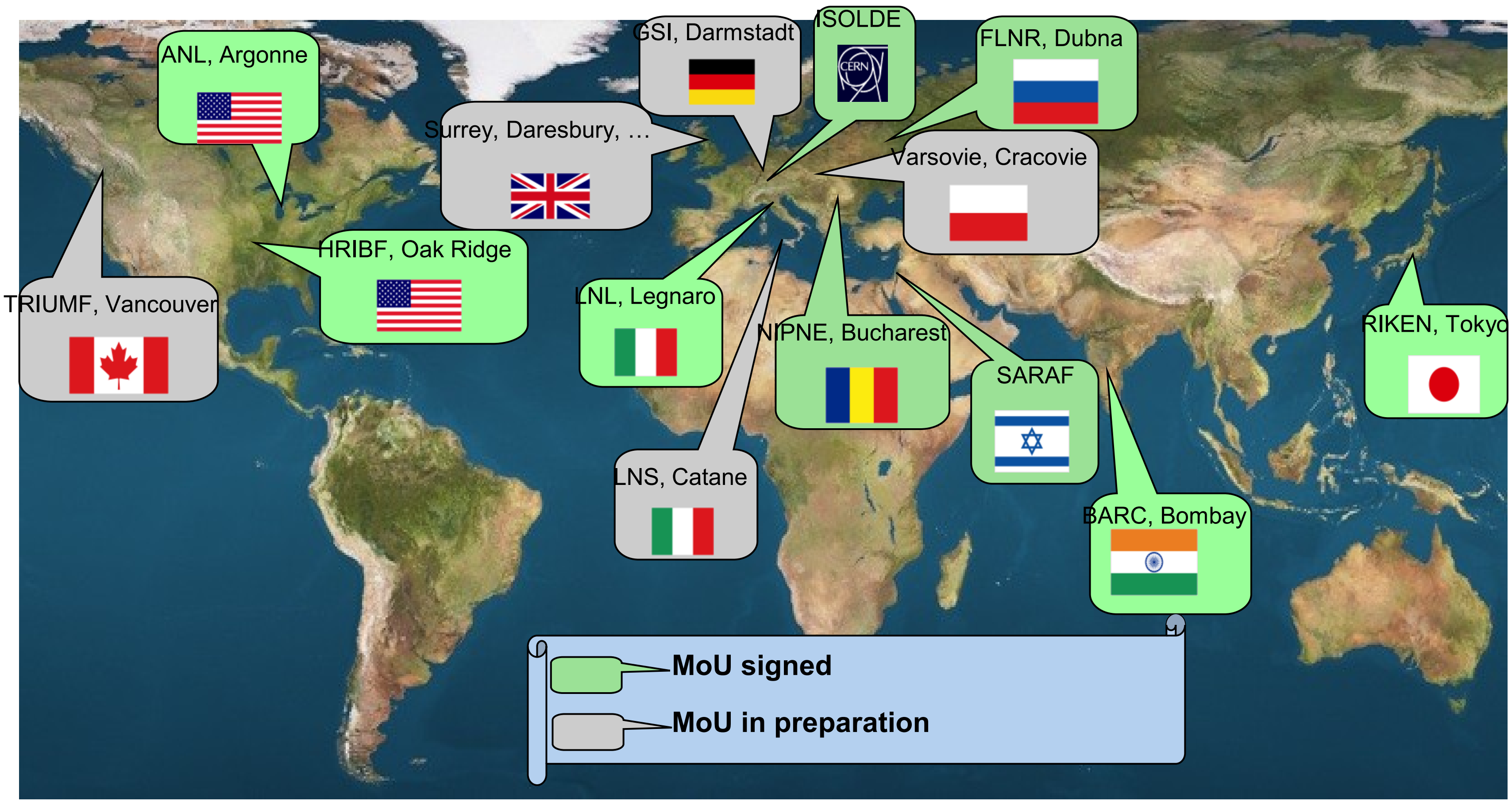
cea

- Bruyères le Chatel
- Cadarache
- Fontenay aux Roses
- Saclay (3 départements)

Grand Accélérateur National d'Ions Lourds
GANIL
Laboratoire commun CEA / DSM - CNRS / IN2P3

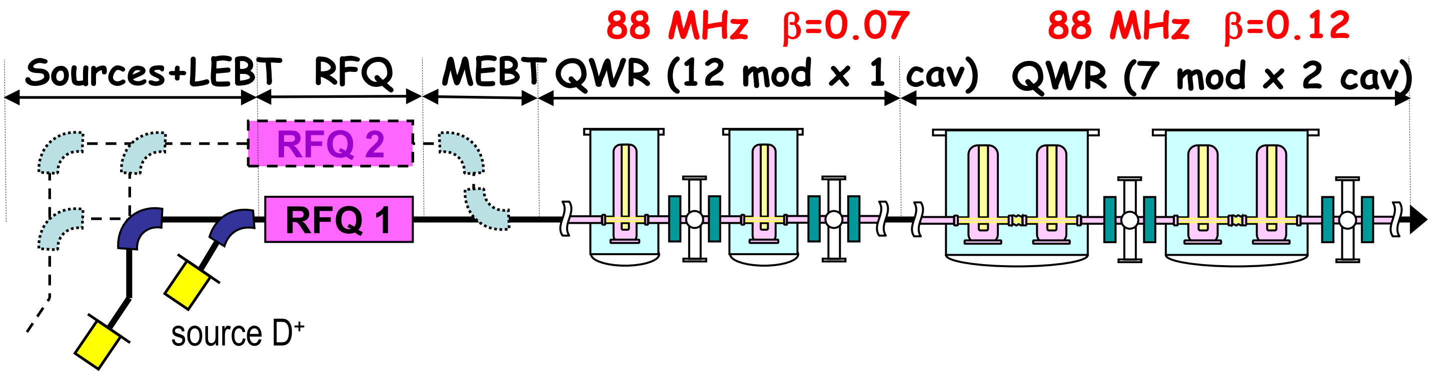
SPIRAL2 : A shared Project

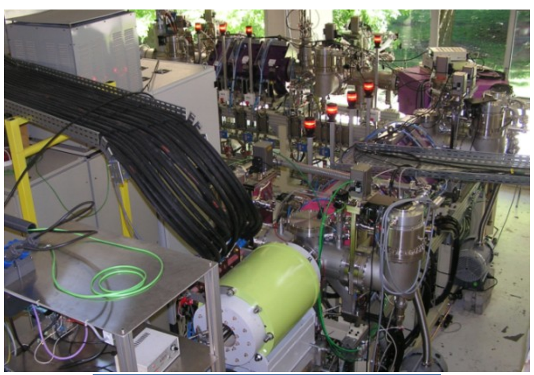
In the world



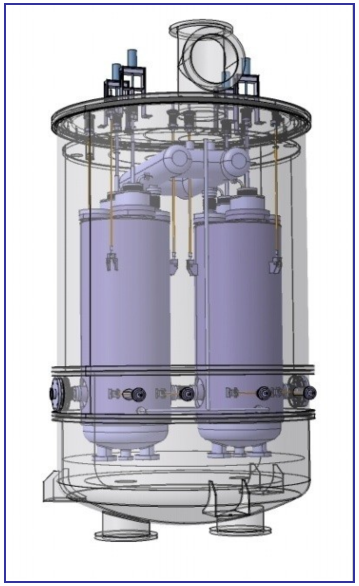
Phase 1 (LINAC) : construction started

SPIRAL2 LINAC





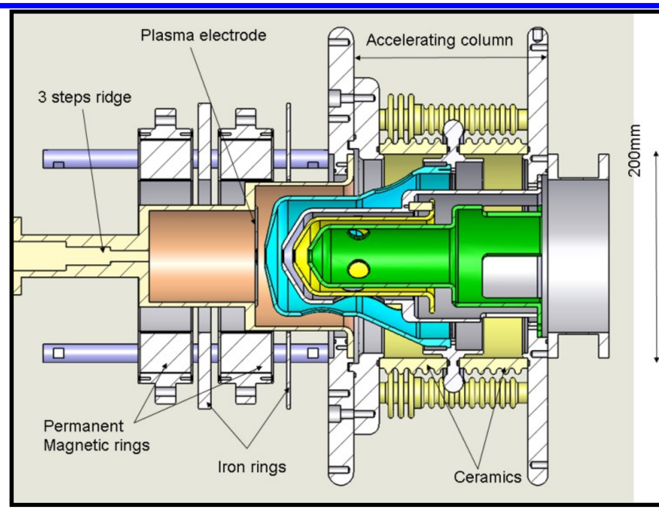
Low Energy Beam Line Spiral2



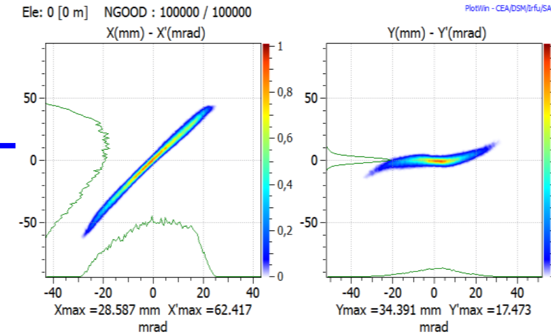
See T. Lamy's presentation

Spiral2 D+ injector at Saclay

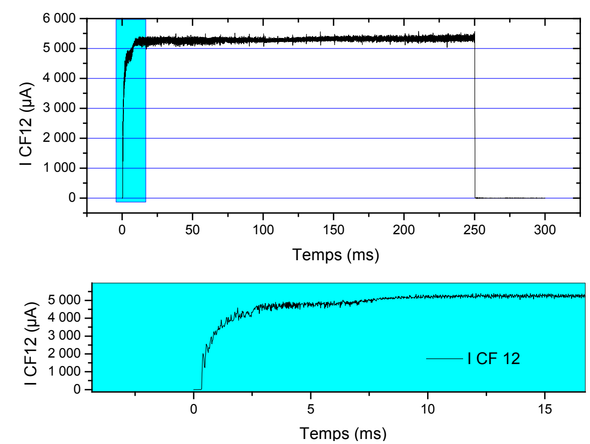
Injector in CEA Saclay. Blue arrow symbolises the beam orientation

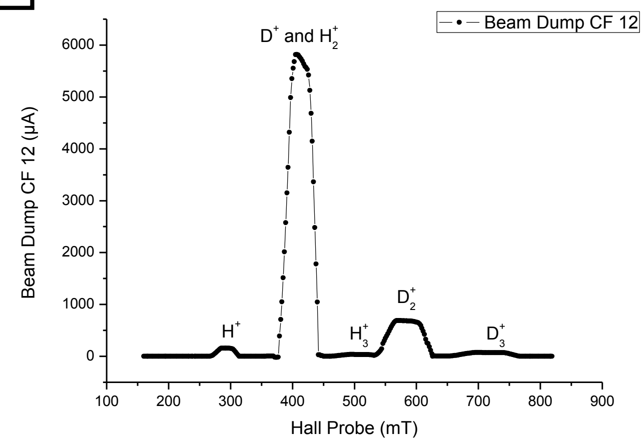


Permanent magnet source



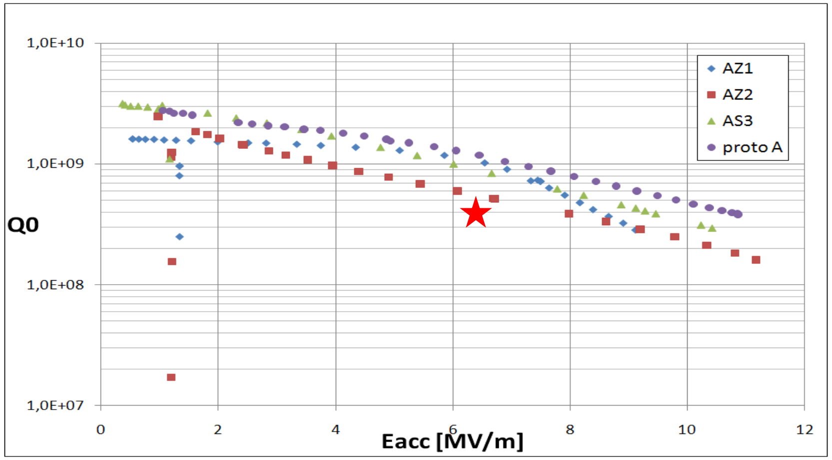
Horizontal and vertical measurements with the IPHC Strasbourg emittance measurement unit with a 5mA CW D+ at 40keV . Emit = 0.17 mm.mrad

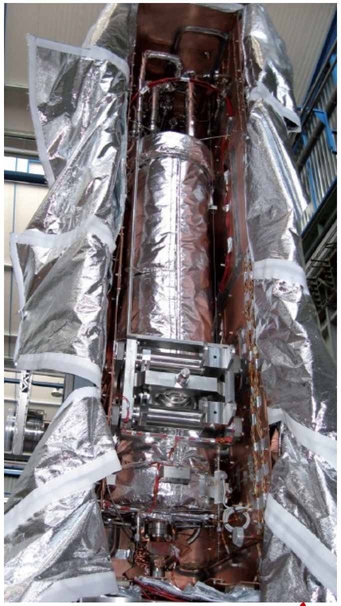




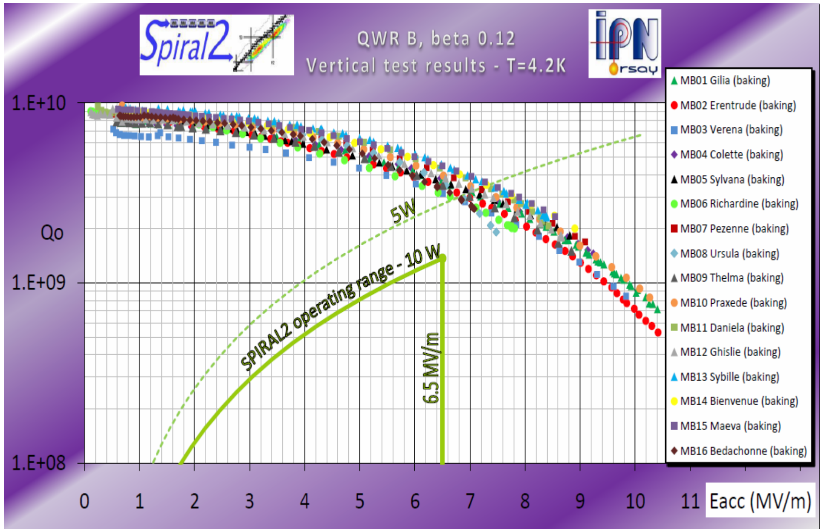
Mass spectrum after the first dipole D11. Some Proton particles are also detected. D+ proportion is are around 80%.

SPIRAL2 Cavities/Cryomodules





CEA/IRFU/SACM

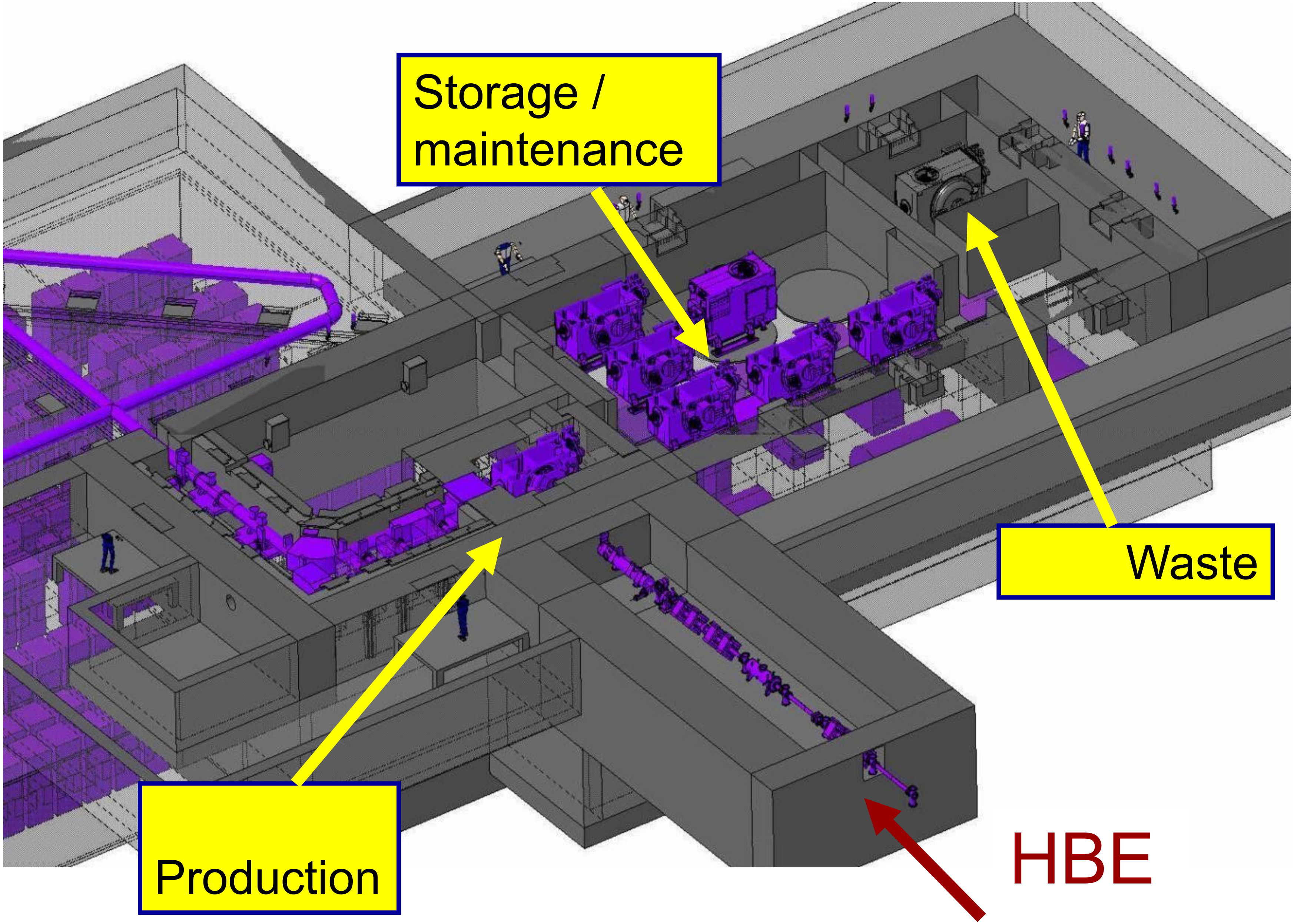


Long Road

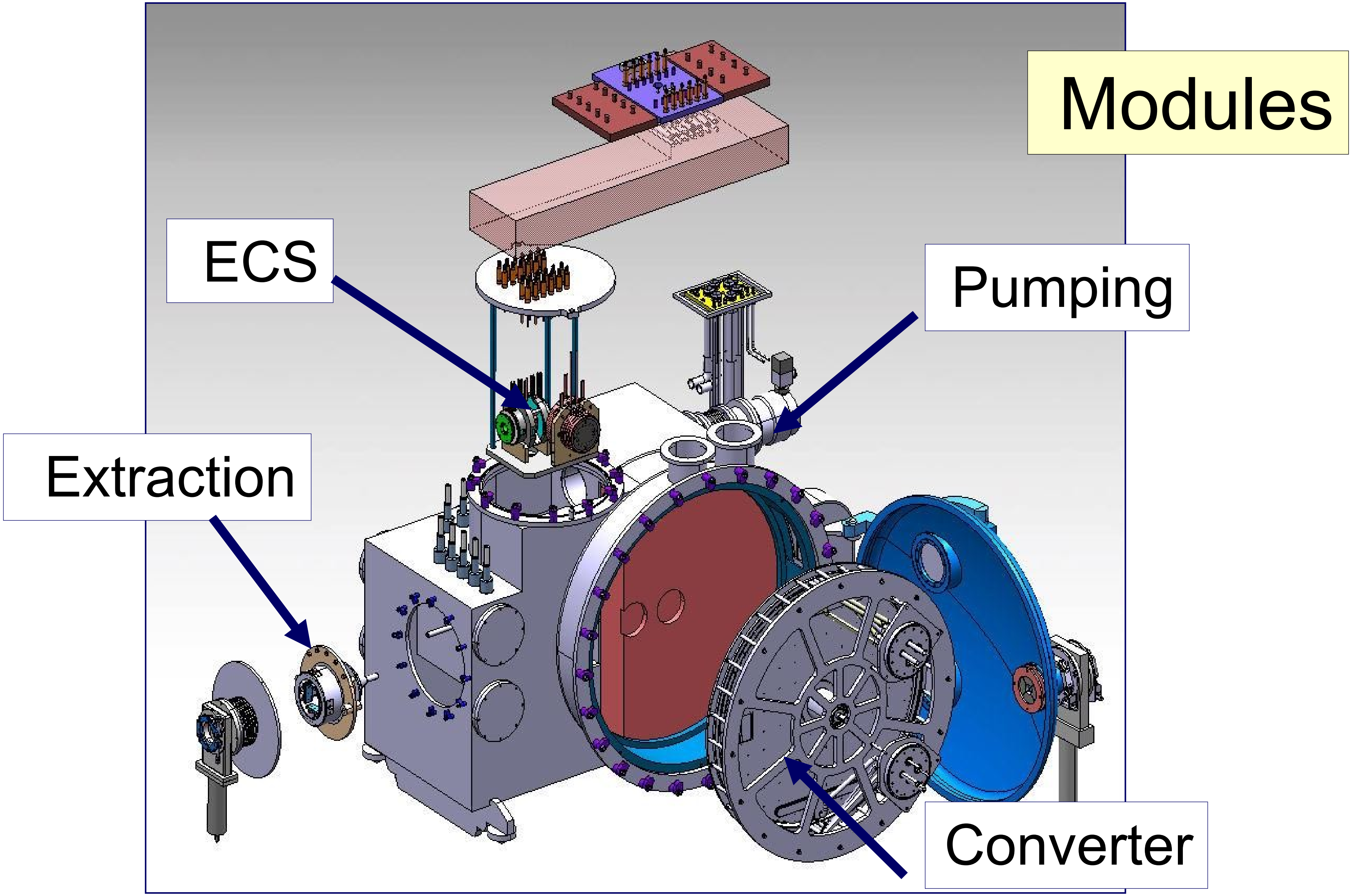
CNRS/IN2P3/IPNO

Phase 2 : RIB production

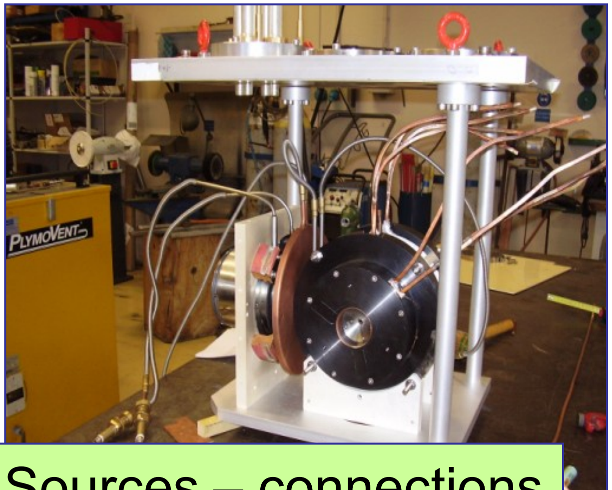
Production building



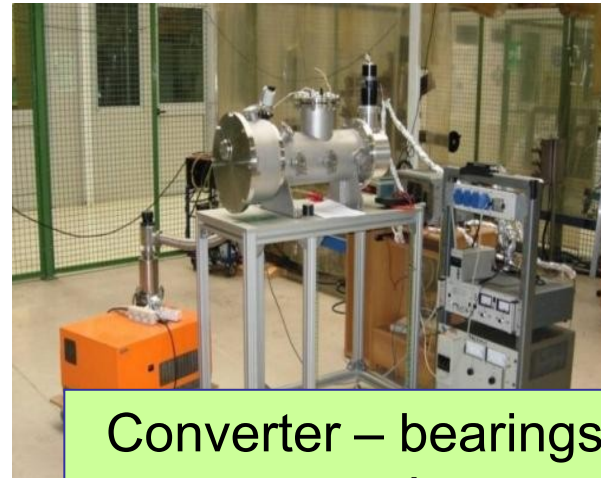
Production building : production module



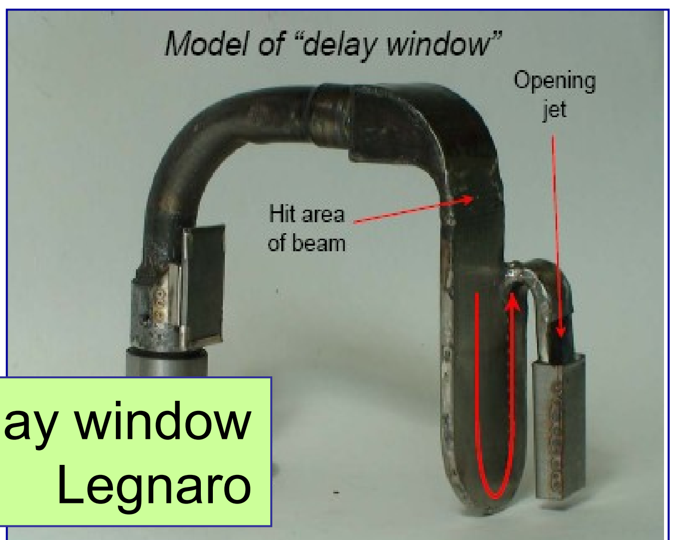
Production building : technological developments



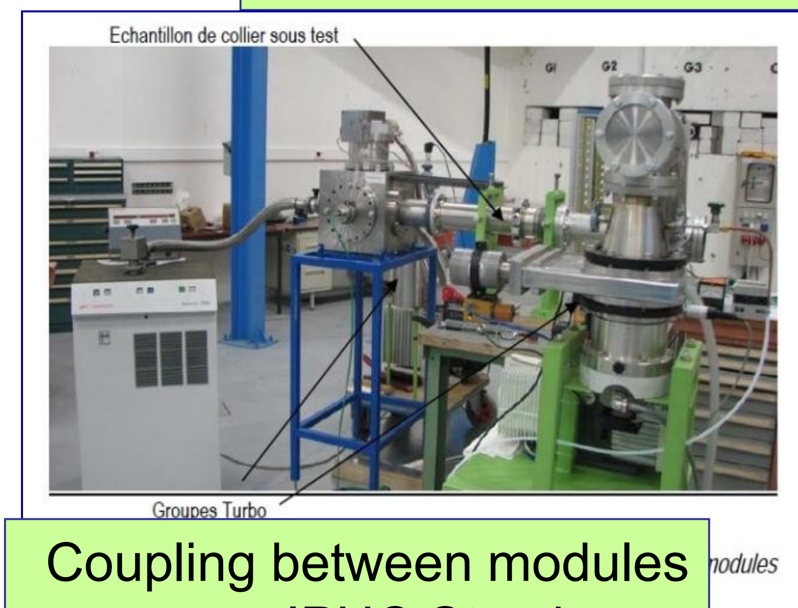
Sources – connections
Ganil



Converter – bearings
Legnaro

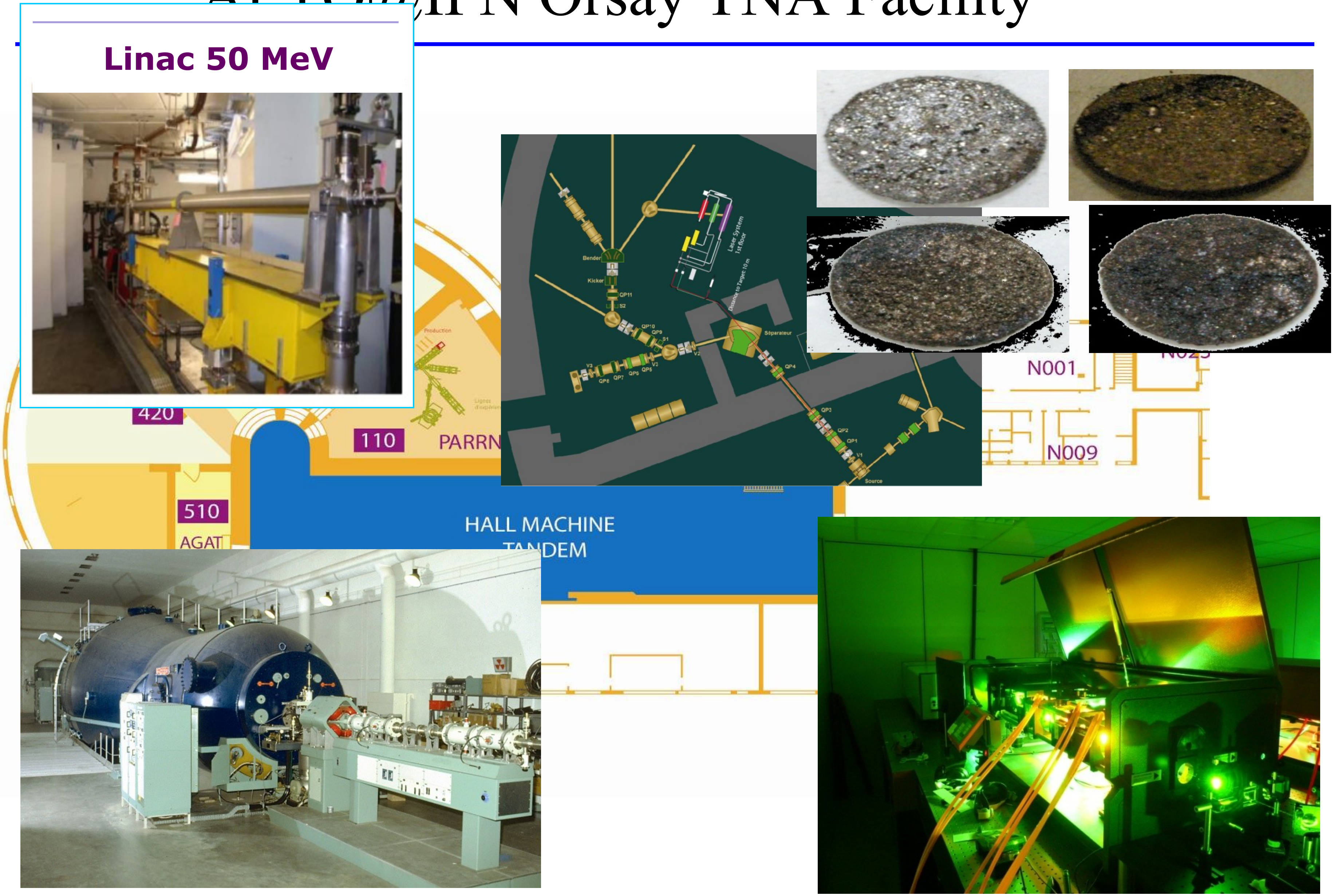


Delay window
Legnaro



Coupling between modules
IPHC Strasbourg

ALTO@IPN Orsay TNA Facility



IFMIF/EVEDA

IRFU is in charge of the construction of :

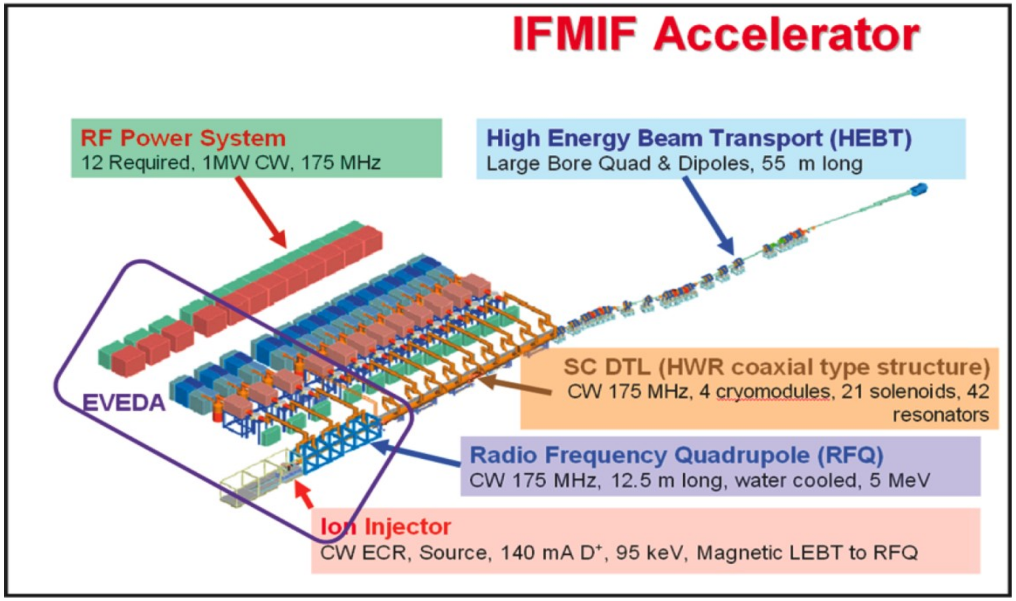
a) overall accelerator coordination, including beam dynamics

b) the ion injector (125 mA D+)

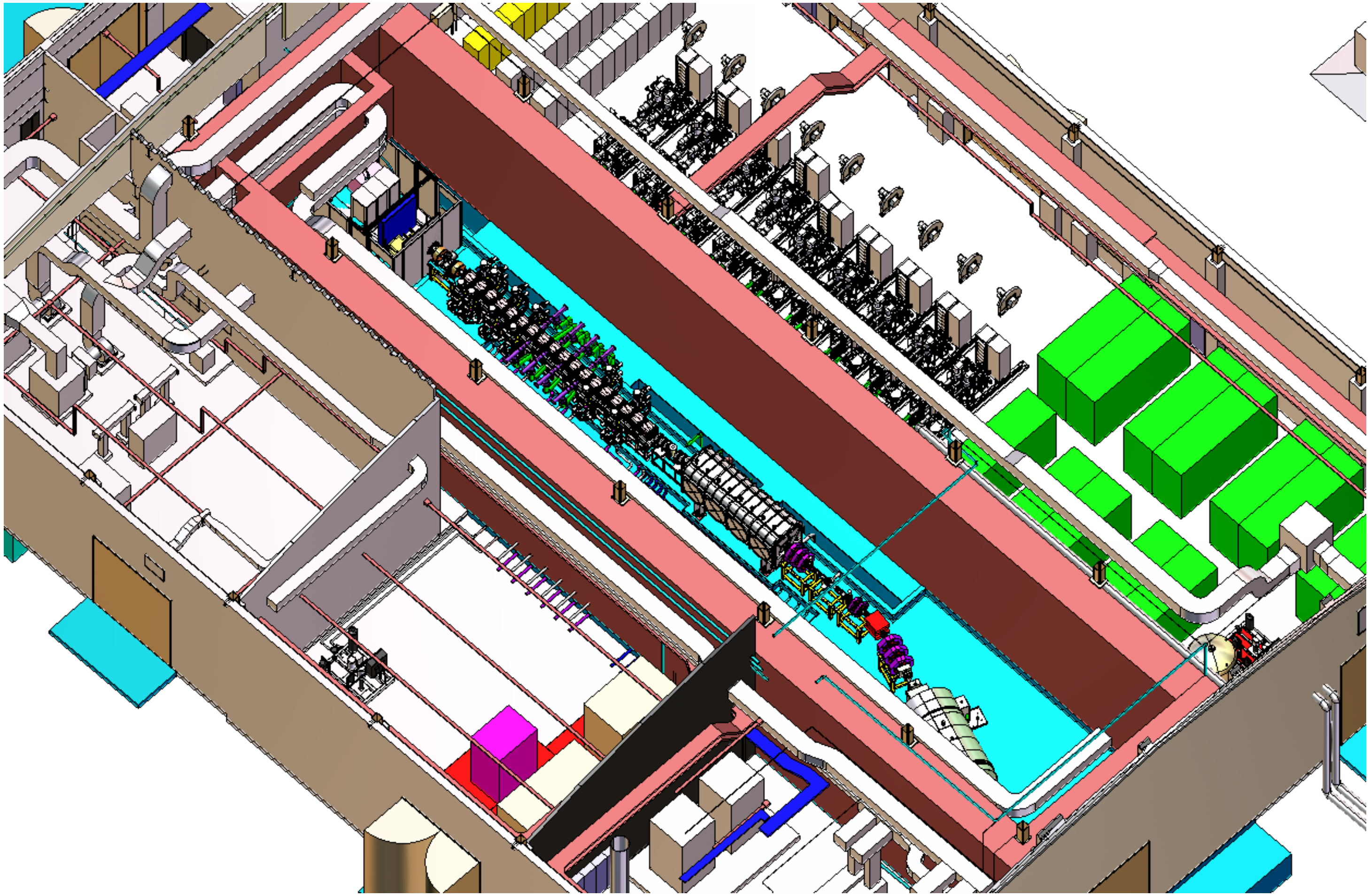
c) the high power RF tests

d) the superconducting linac module,

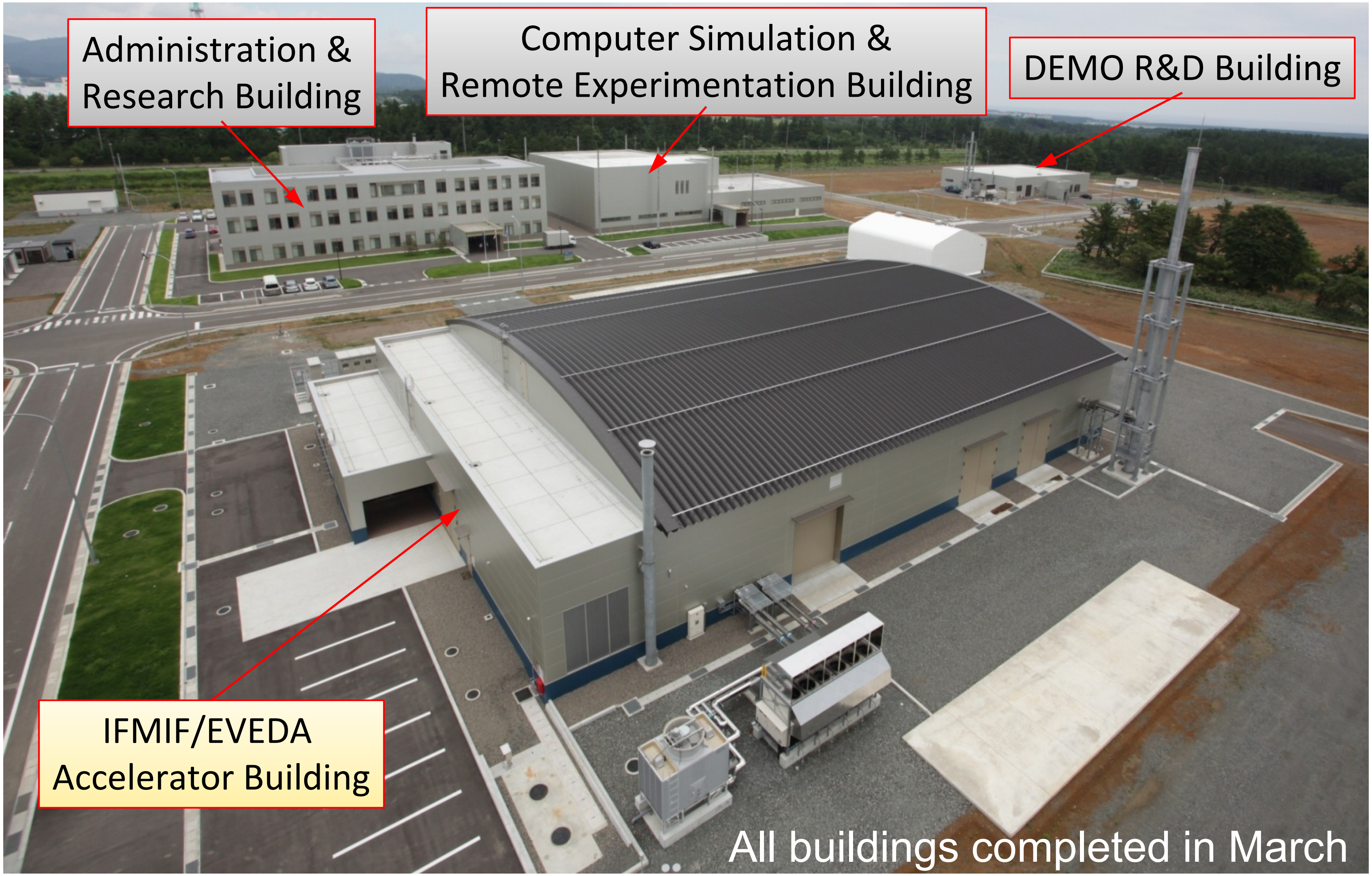
e) the linac control-command



IFMIF EVEDA : 125mA Deuterons 9 MeV

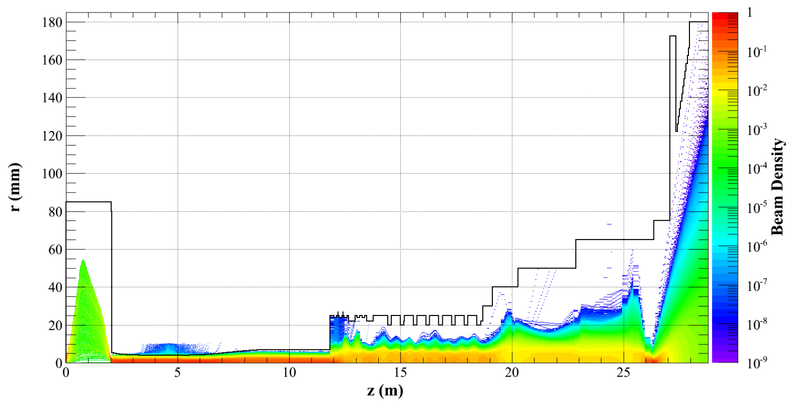


International Fusion Energy Research Centre

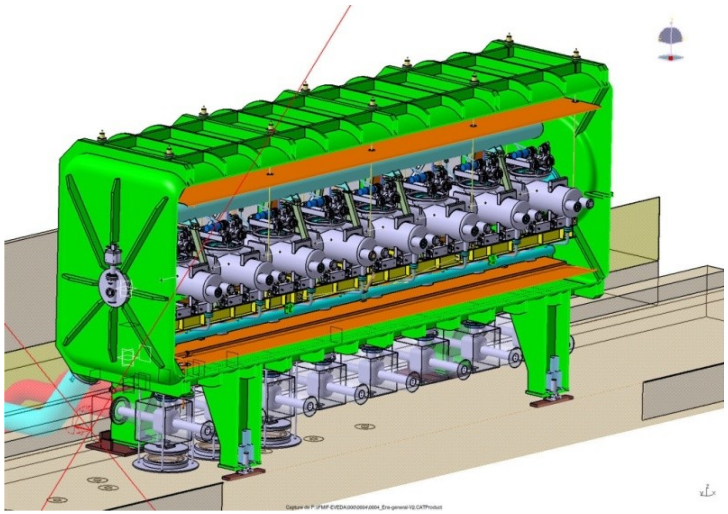


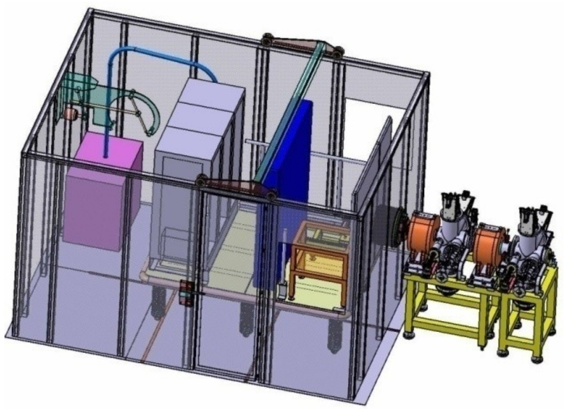
IFMIF-EVEDA Project : a beam of 1 MW

Beam Dynamics: start-to-end simulations with space charge



Cryomodule

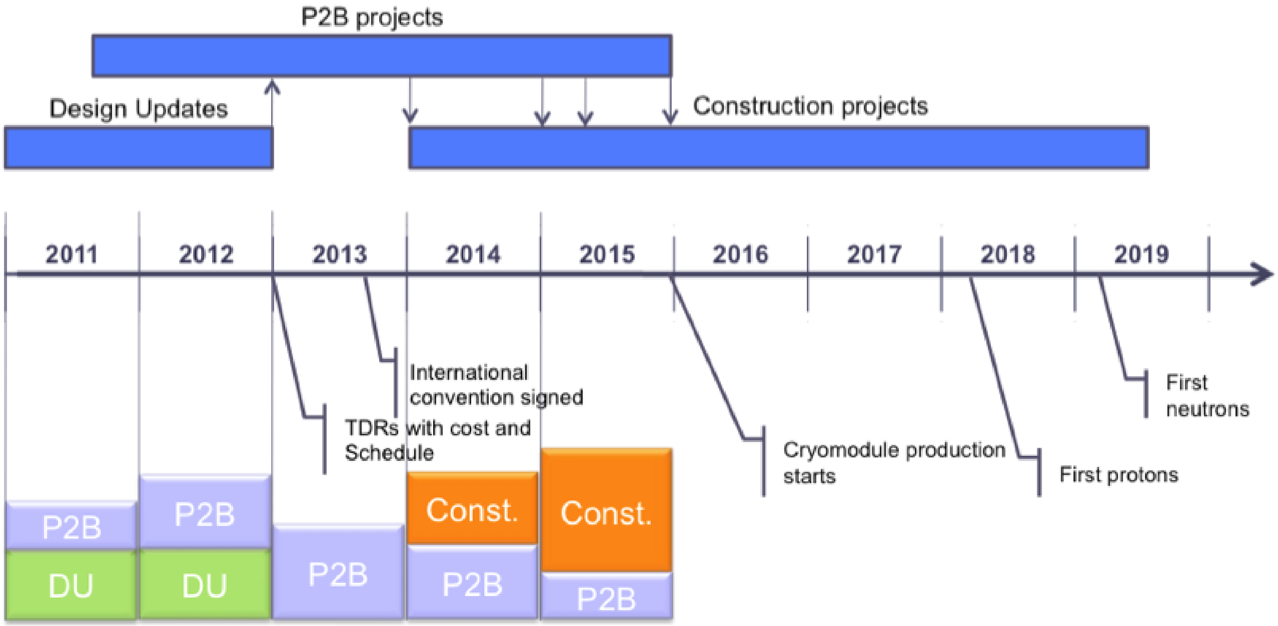




D+ injector

First cavity prototype under RF measurments

ESS : European Spallation Source



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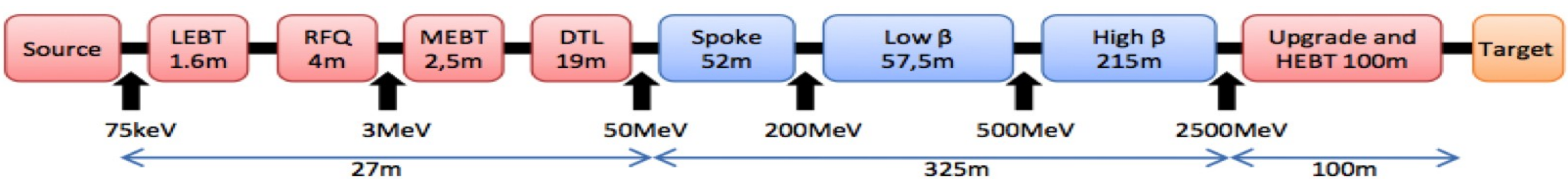
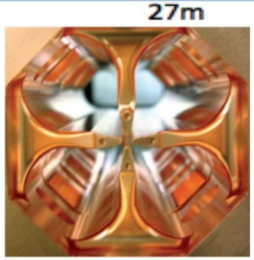


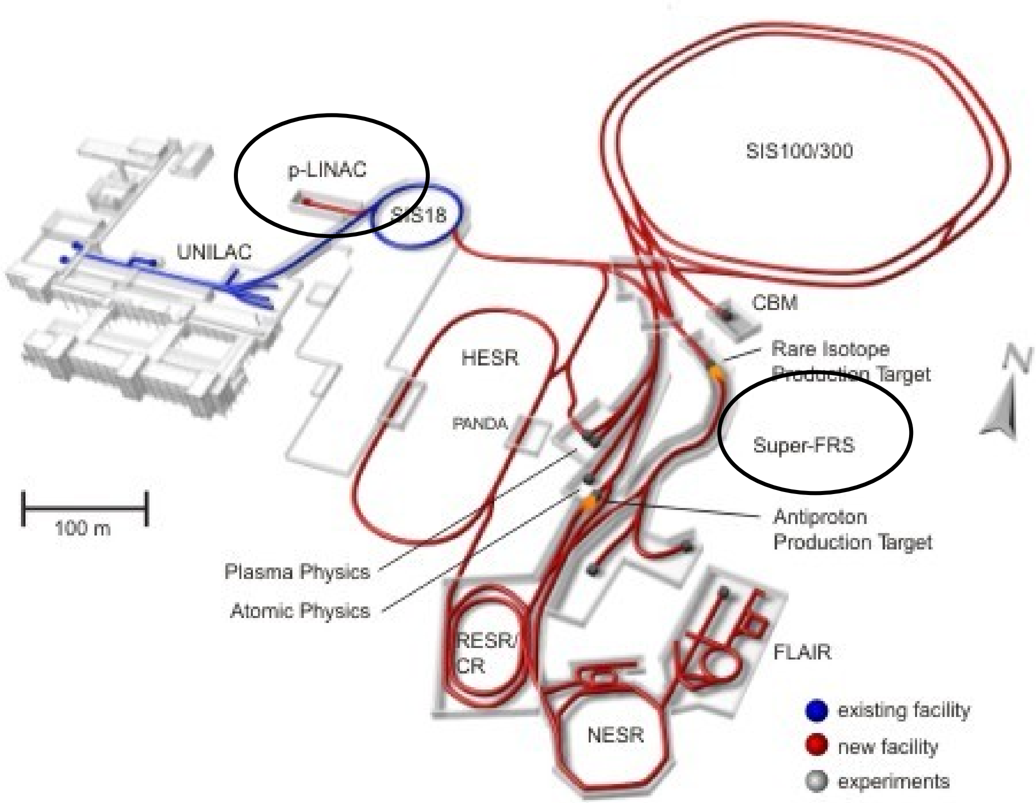


ESS : France Involvement

Dec 13th, 2010 : France/Sweden Agreement for the Accelerator Design Update and prototyping phases 2011-16 :

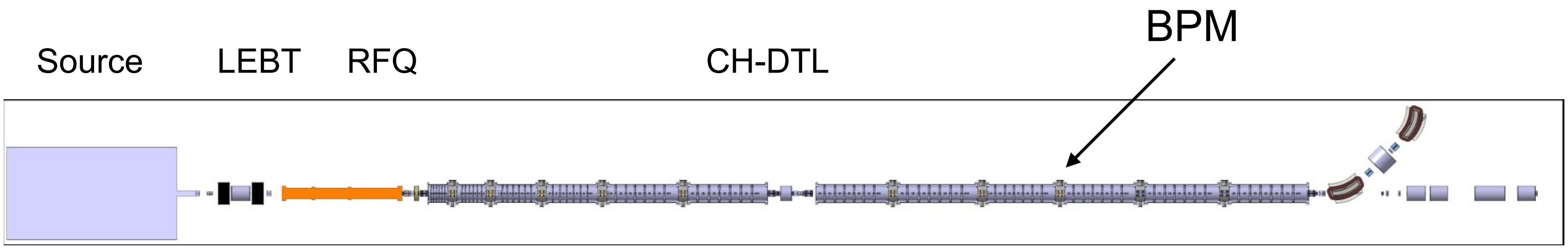
- CEA and CNRS lead WPs dedicated to the linac SC sections,
- Realization of :
  - 352 MHz test facility (CEA)
  - 2 Spoke cavities (CNRS)
  - 1 spoke cryomodule and its power coupler (CNRS)
  - 8 elliptical cavities with their 8 power couplers (CEA)
  - Beam test with IPHI (CEA)
- Several TDR contributions :
  - CEA: RFQ, SC quadrupoles, high beta elliptical cavity, power coupler
  - CNRS: Spoke cavity, its cryomodule and power coupler

FAIR

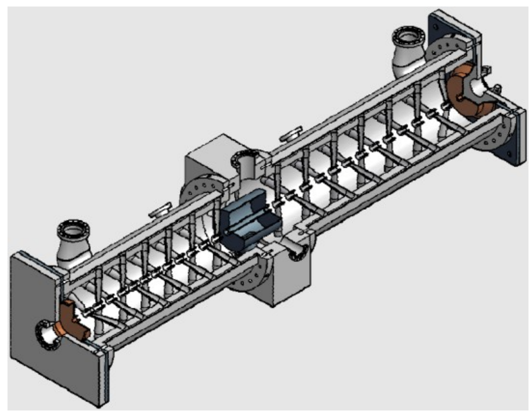


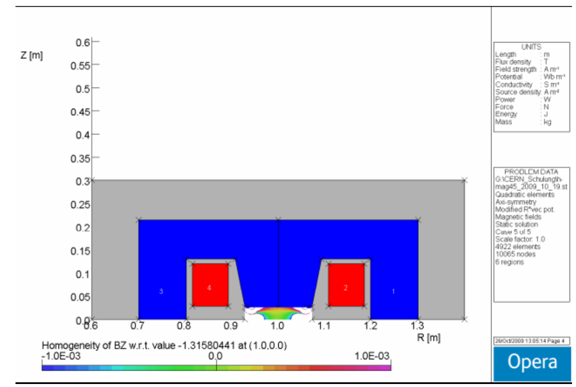
p-LINAC
SIS18
UNILAC
SIS100/300
CBM
Rare Isotope
Production Target
HESR
PANDA
Super-FRS
100 m
Antiproton
Production Target
Plasma Physics
Atomic Physics
RESR/
CR
FLAIR
NESR
existing facility
new facility
experiments

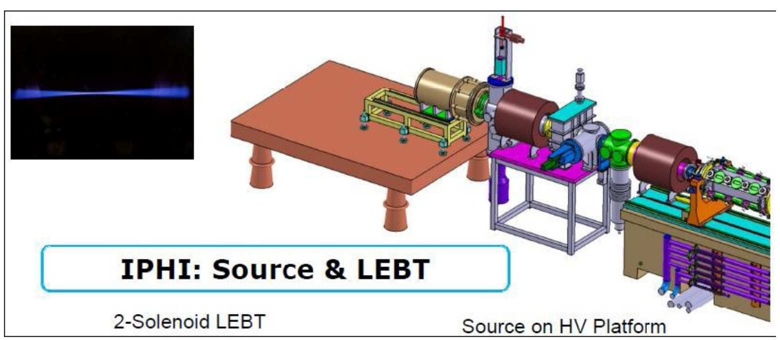
FAIR Proton Linac

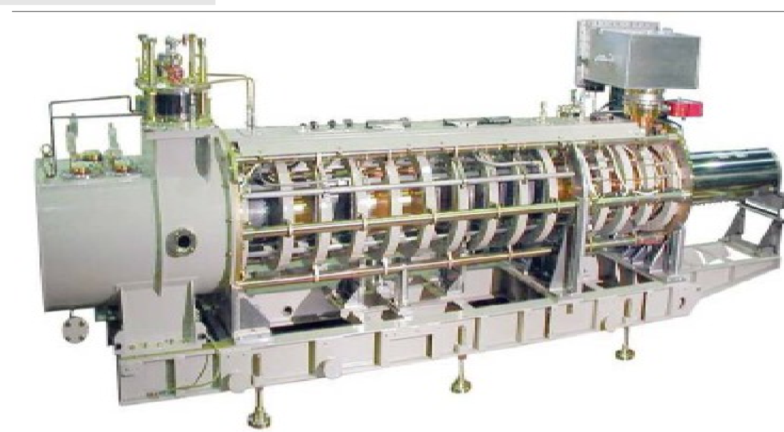


95 keV 3 MeV







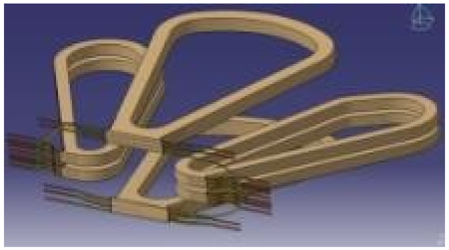


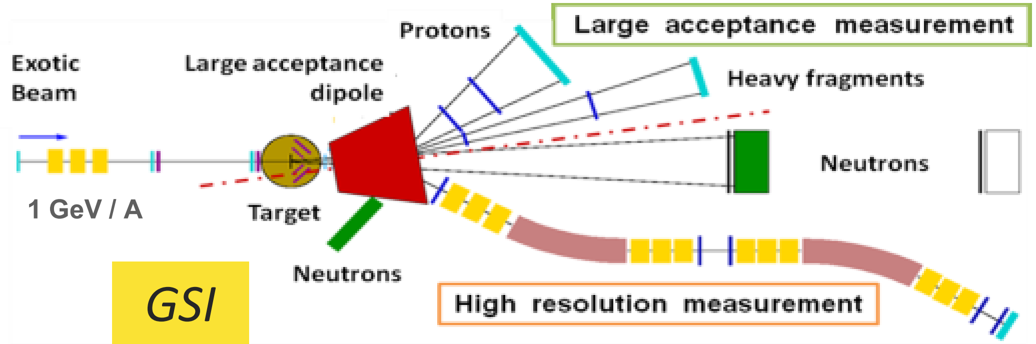
FAIR SFRS Dipole

Parameters

- **Design superferric H-type, straight**
- **Max. dipole field: 1.6 T**
- **Min. dipole field: 0.15 T**
- **Bending angle: 15°**
- **Pole face angles (entrance / exit): 0°**
- **Curvature radius, R =8.125 m**
- **Effective path length, L =2.126 m**
- **Useable horizontal aperture: ±190 mm**
- **Sagitta: 70 mm**
- **Total horizontal good field area: ±225 mm**
- **Useable vertical gap: ±70 mm**
- **Vertical pole gap height: ±85 mm**

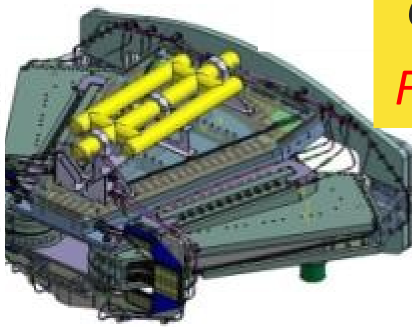
R3B-GLAD : Large Acceptance Dipole pour GSI Darmstadt



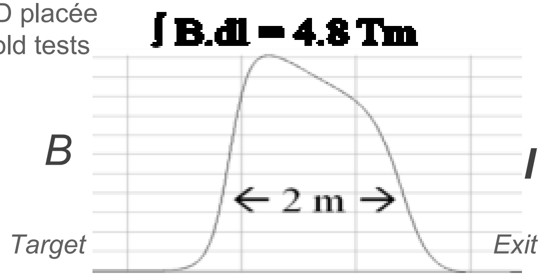


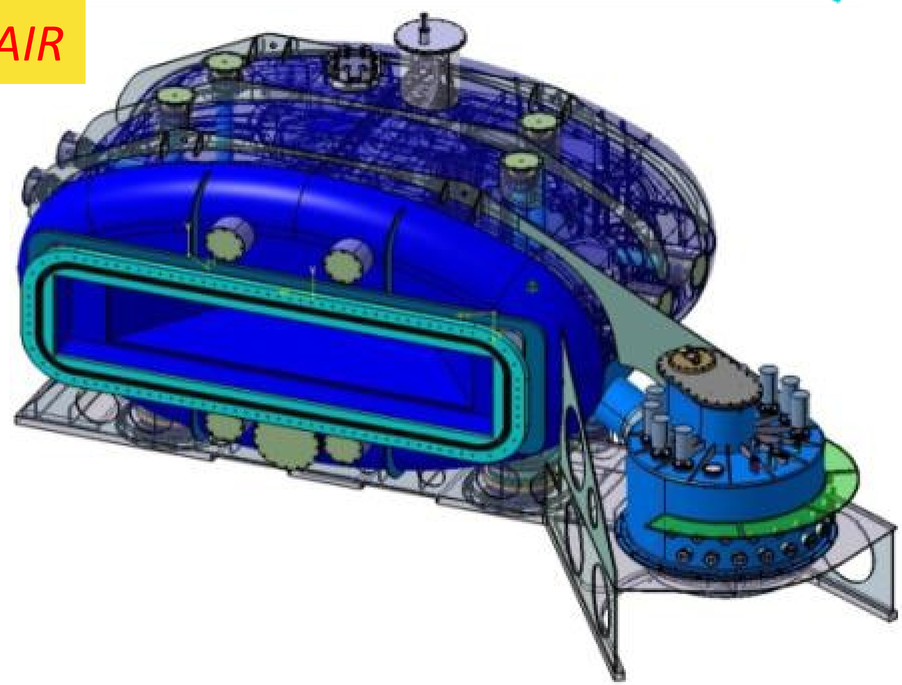
GSI

FAIR



Cold mass R3B-GLAD placée inside the W7X for cold tests





Cable : Rutherford Cu–NbTi, 17 km, 5.2 tons

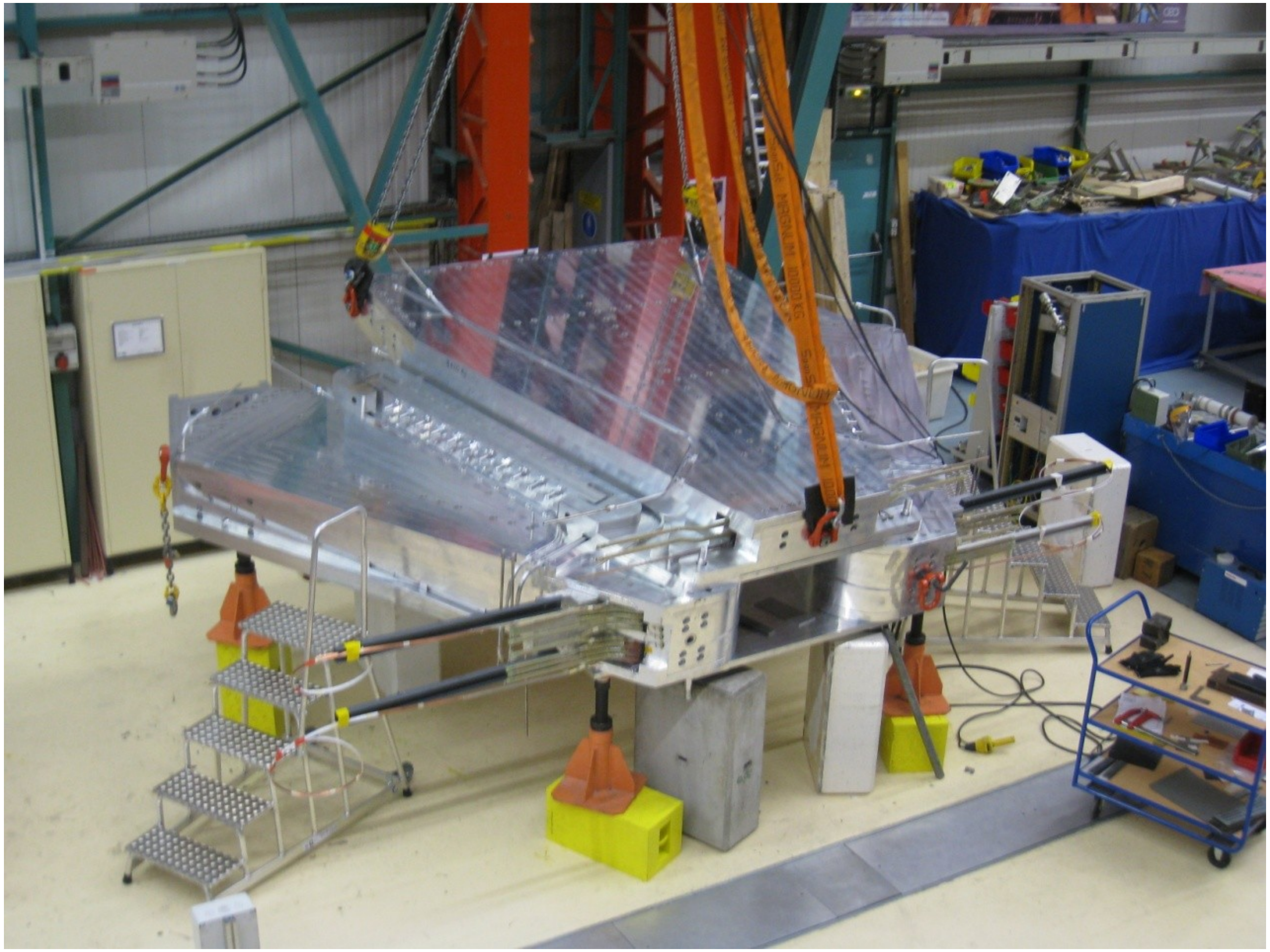
Cold mass : Al 5083, 22 tons

Thermosiphon : Liq-Helium 4.6 K

Magnet : 50 t

Active shielding : Target area < 20 mT

R3B-GLAD Spectrometer



Extra France Contribution to CERN

Agreement for LHC construction CERN/CEA/CNRS 1996-2005, CEA/DAPNIA and CNRS/IN2P3/IPNO:

- Quadrupole
- Short Straight Section
- Thermometer Calibration

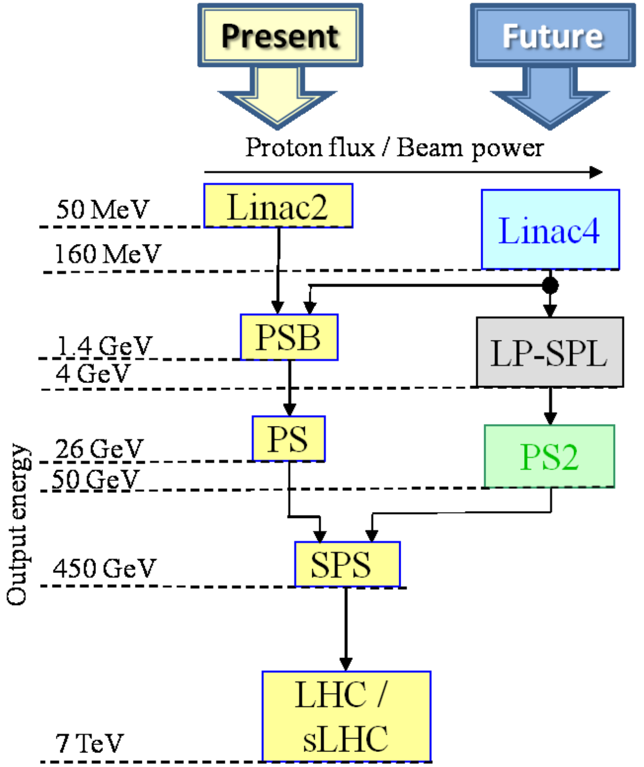
New agreement 2008-2012

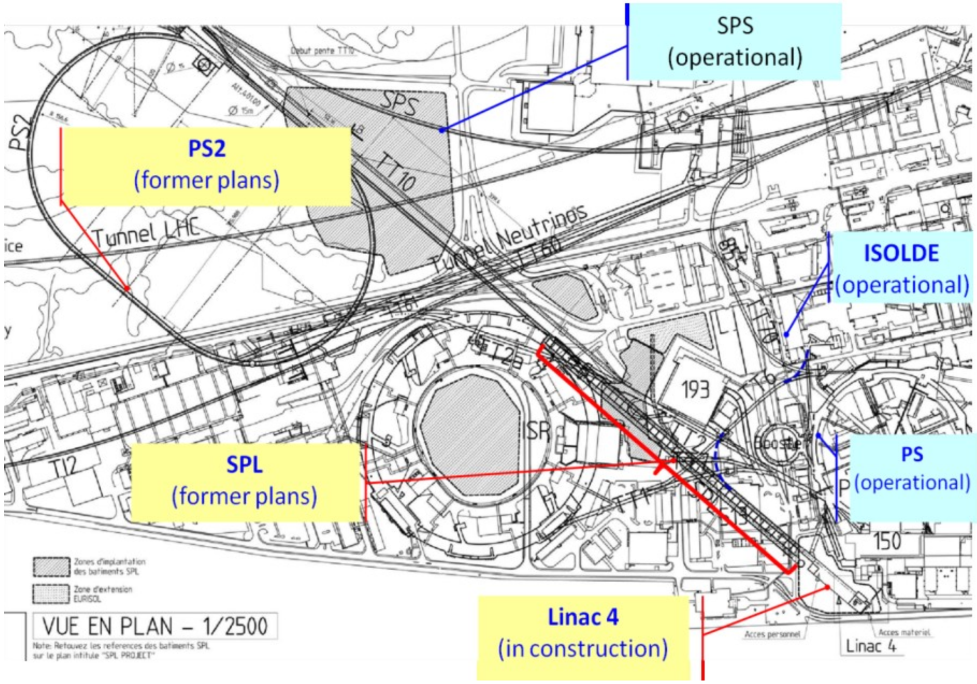
- LINAC4
- SPL
- Superconducting magnets
- CLIC
- PS2 Studies, PS windings, LHC vacuum vessel, connection cryostat

11.2 M€ 471 person.month

IRFU + LAL, IPNO,LAPP, LPSC

CERN Roadmap



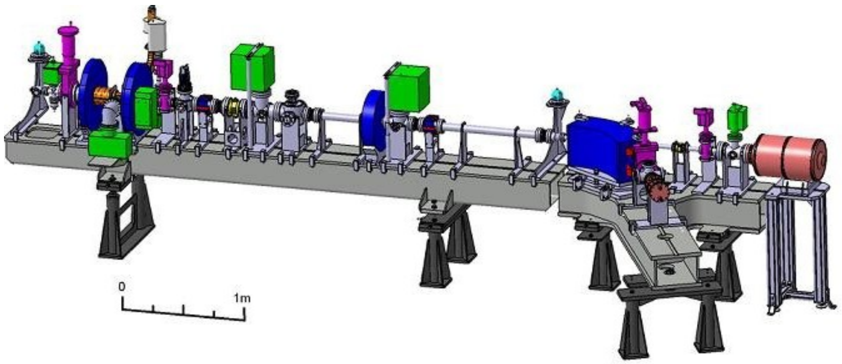


LP-SPL: **Low Power**-Superconducting Proton Linac (4 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
sLHC: "Super-luminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
HP-SPL: **High Power**-Superconducting Proton Linac (5 GeV, 5 MW) for neutrino factories

Examples of R&D

- PHIL LAL platform
- Thin layers technology

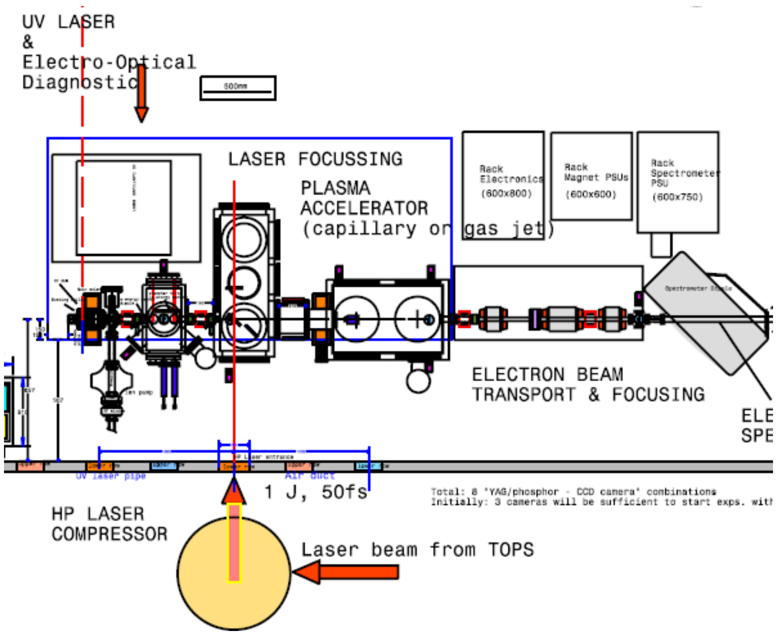
PHIL @ LAL



Test bench for high brillance Photo Guns
Experiments at low energy
Test for other installation (ThomX…)
Student and personnel training

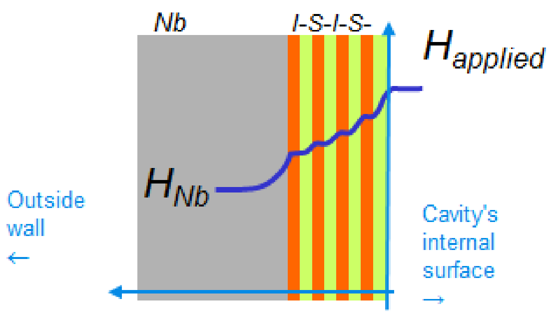
Beam in 2010,
Beam characterisation underway

Now different upgradings are ongoing to increase the reliability of the machine.

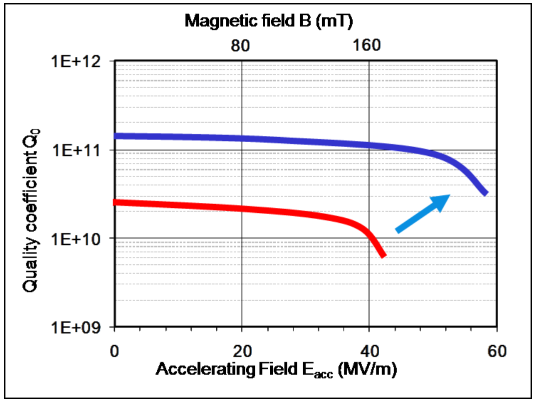


Thin layers

- **Nanometric layers I/S/I/ on Nb : field screening with high H_{C1} nanometric layers**
  - Structure proposed by A. Gurevich in 2006 to overcome bulk Nb monopoly in SRF applications
  - Nb surface screening => normal state transition delayed => **higher accelerating gradient.**
  - Layers with higher T_C=> **higher Q_0**

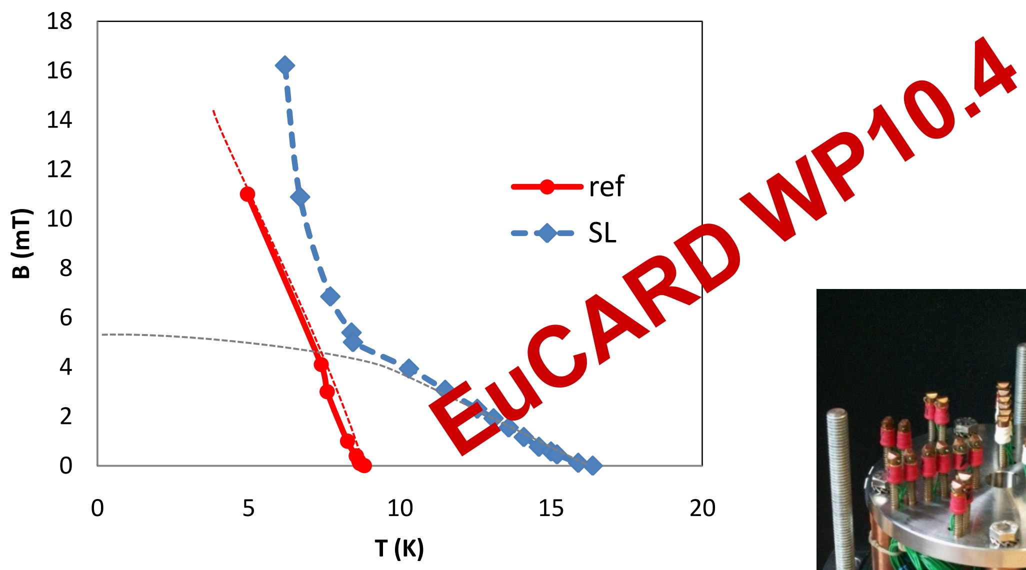


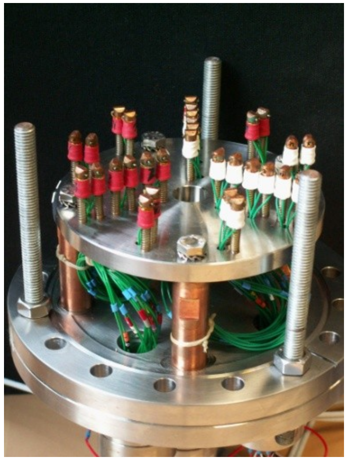
$$H_{Nb} = H_{appl}\, e^{-\frac{Nd}{\lambda}}$$



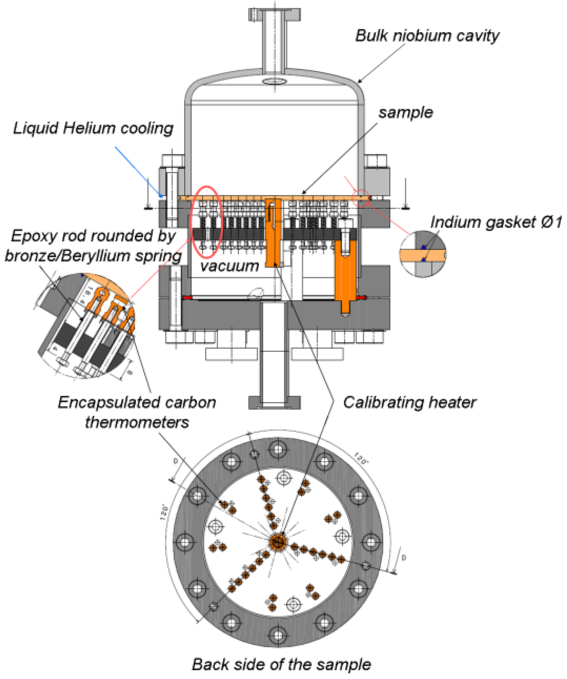
Thin layers

- **Screening effect** experimentally demonstrated for the **1rst time** on a model sample
  - 8.90 K < Tp° < 16K : behavior ~ NbN alone
  - Tp° < 8.90K, i.e. when Nb substrate is SC ,
    => $B_{C1}^{SL} >> B_{C1}^{Nb}$





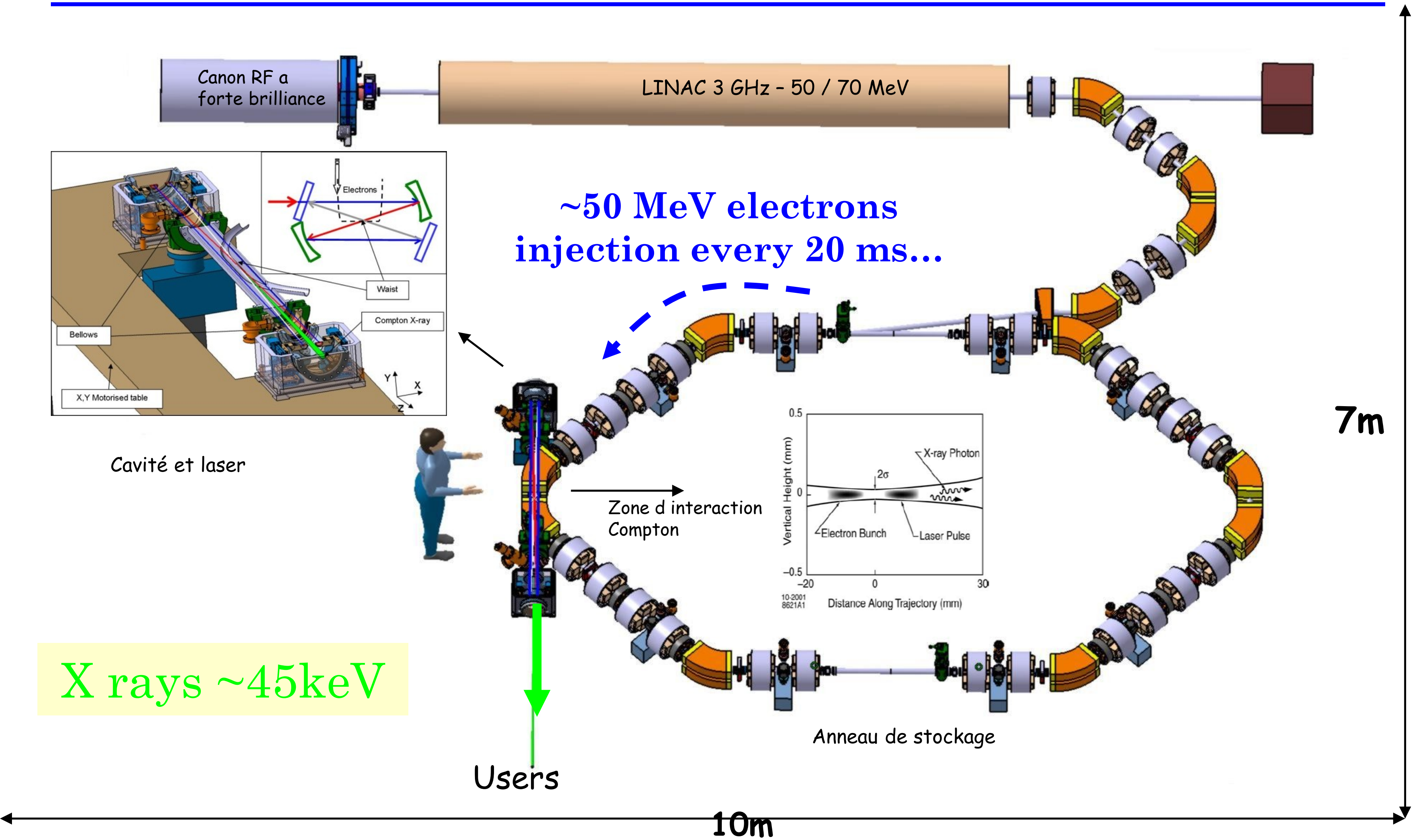
Caraterisation platform
Ex @IPNO



Applications

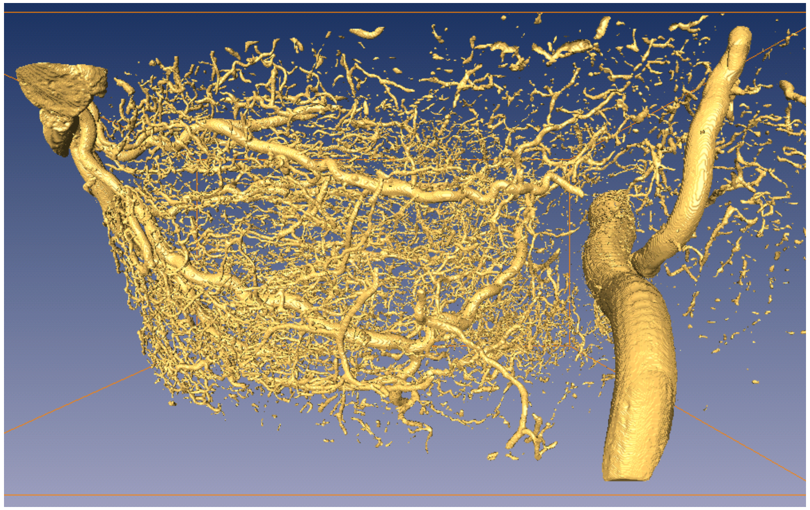
- ThomX
- SOFI
- ADS
- NMR : ISEULT
- High fields : CNRS/LNCMI
- Fusion : JT60, ITER

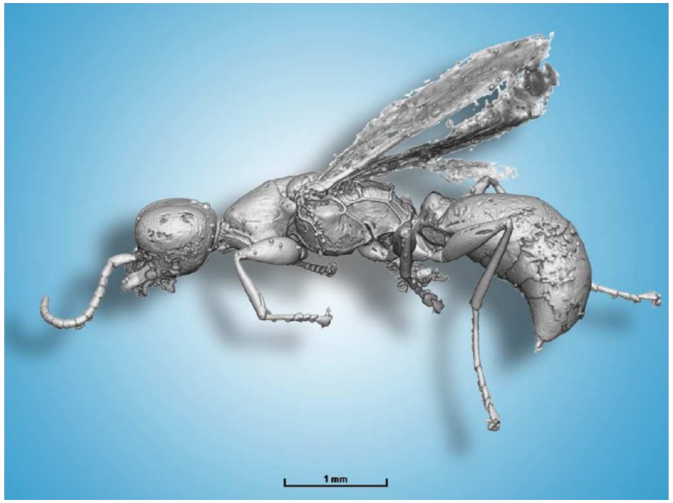
ThomX : compact X-Ray Source for imaging



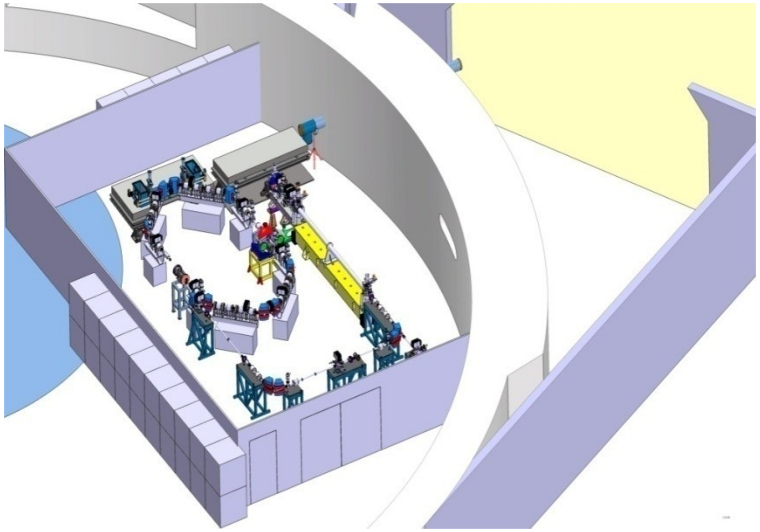
ThomX

- Many applications : museum, medicine…
- Industrialisation
- R&D machine : laser and accelerator technology





ThomX : A very compact machine which can be installed in a hospital or museum



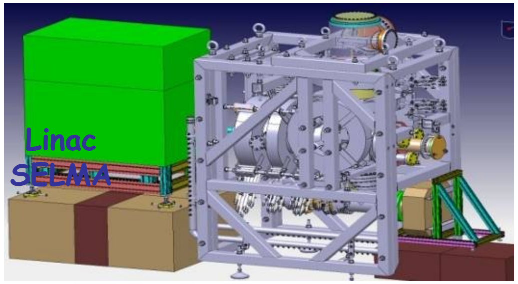
- Collaboration between UPSud, LAL IN2P3, Soleil, Celia, Thalès, Inst.Neel, ESRF, CNRS C2rmf, Inserm Grenoble
- CDR published, TDR Phase, has been financed via EQUIPEX, project team being gathered

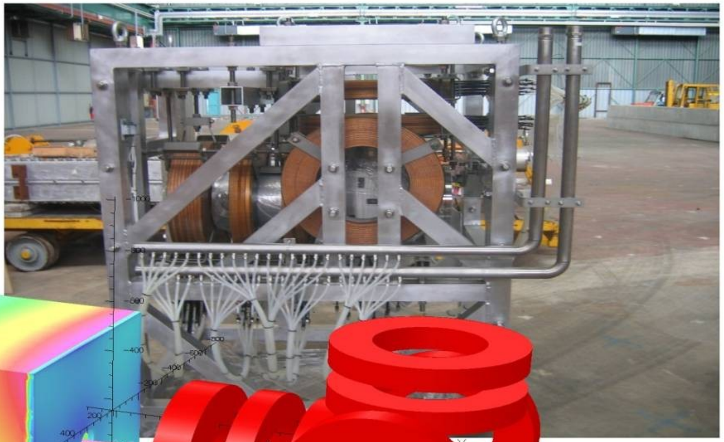
SOPHI : High intensity positron source

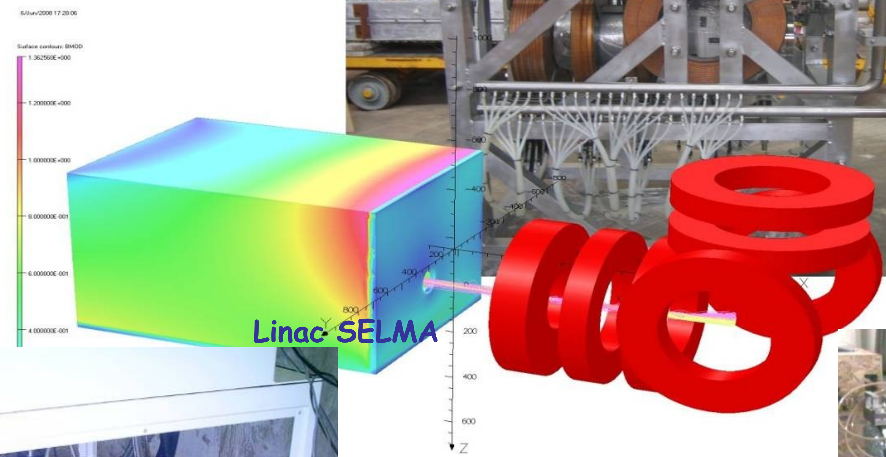
Démonstrator based on a electron accelerator

Application IRFU :

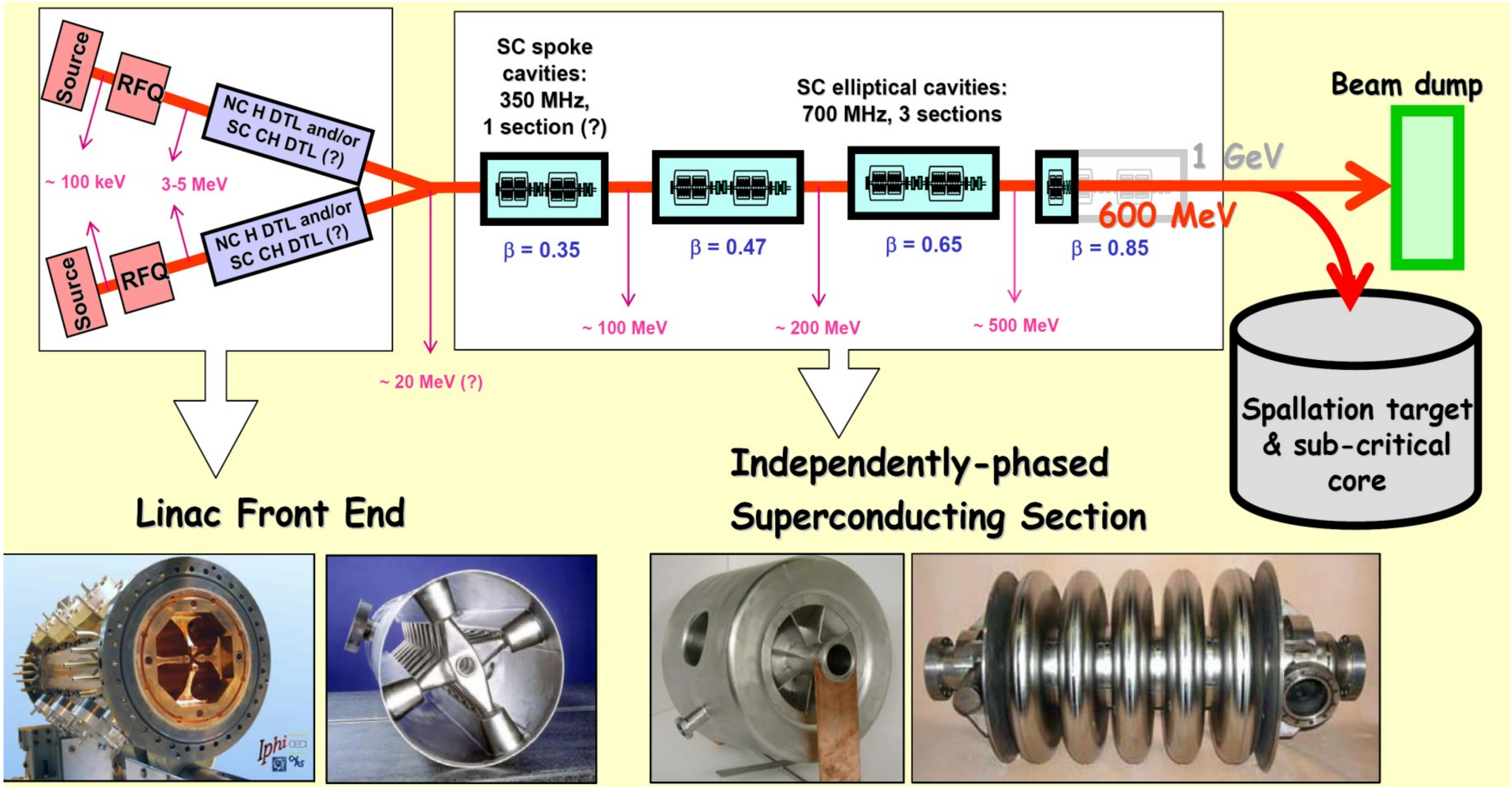
- ***Anti hydrogene production***



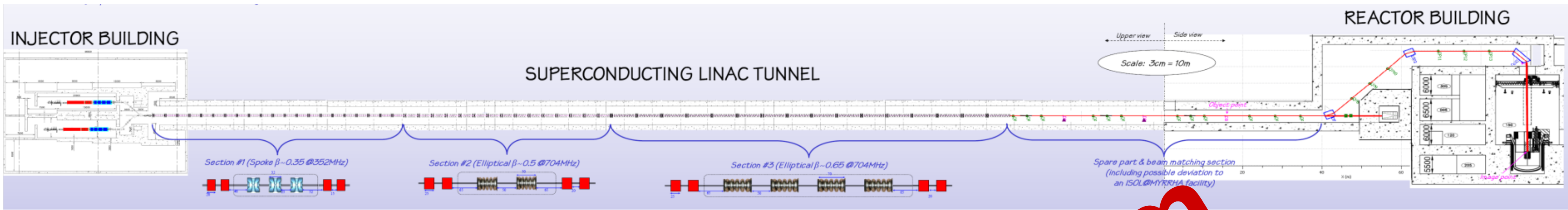




Accelerator Driven Systems



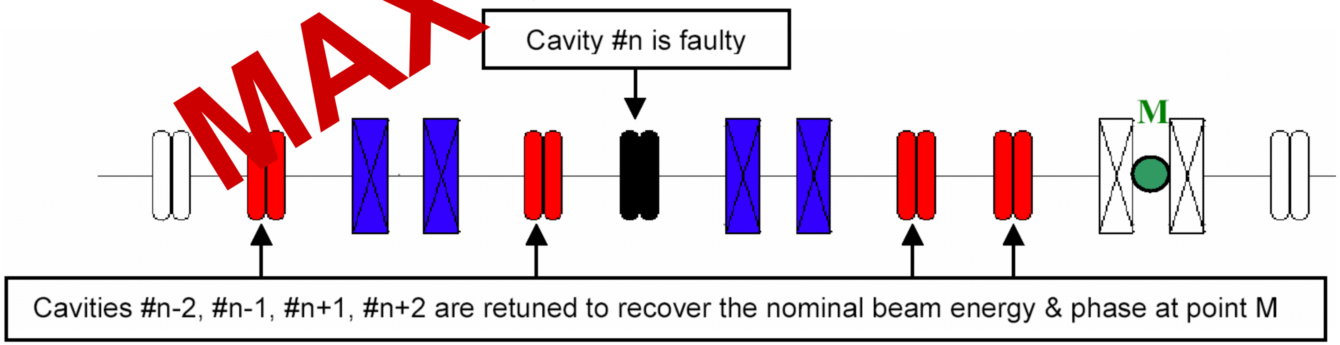
MYRRHA@Mol SCK•CEN



Less than 10 beam trips > 3 s during a 3-month shift :
main accelerator challenge

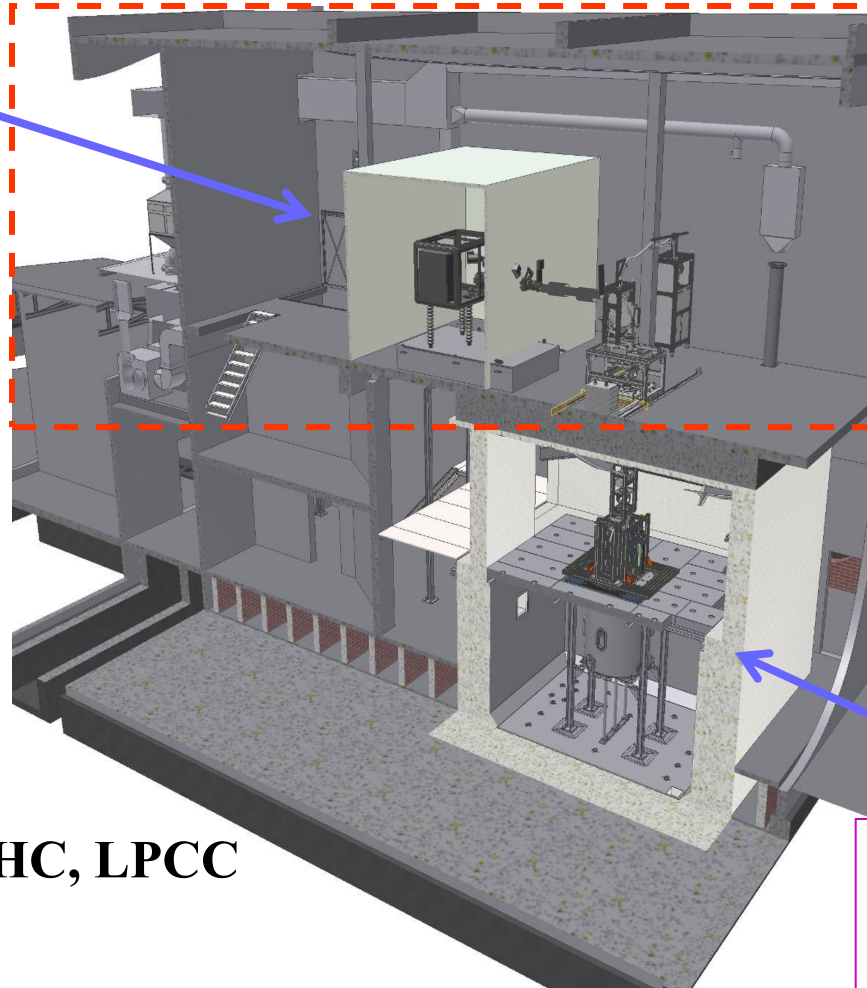
Constraints on the accelerator design
Overdesign, redundancy, fault tolerant design…

MAX FP7 Program



GUINEVERE

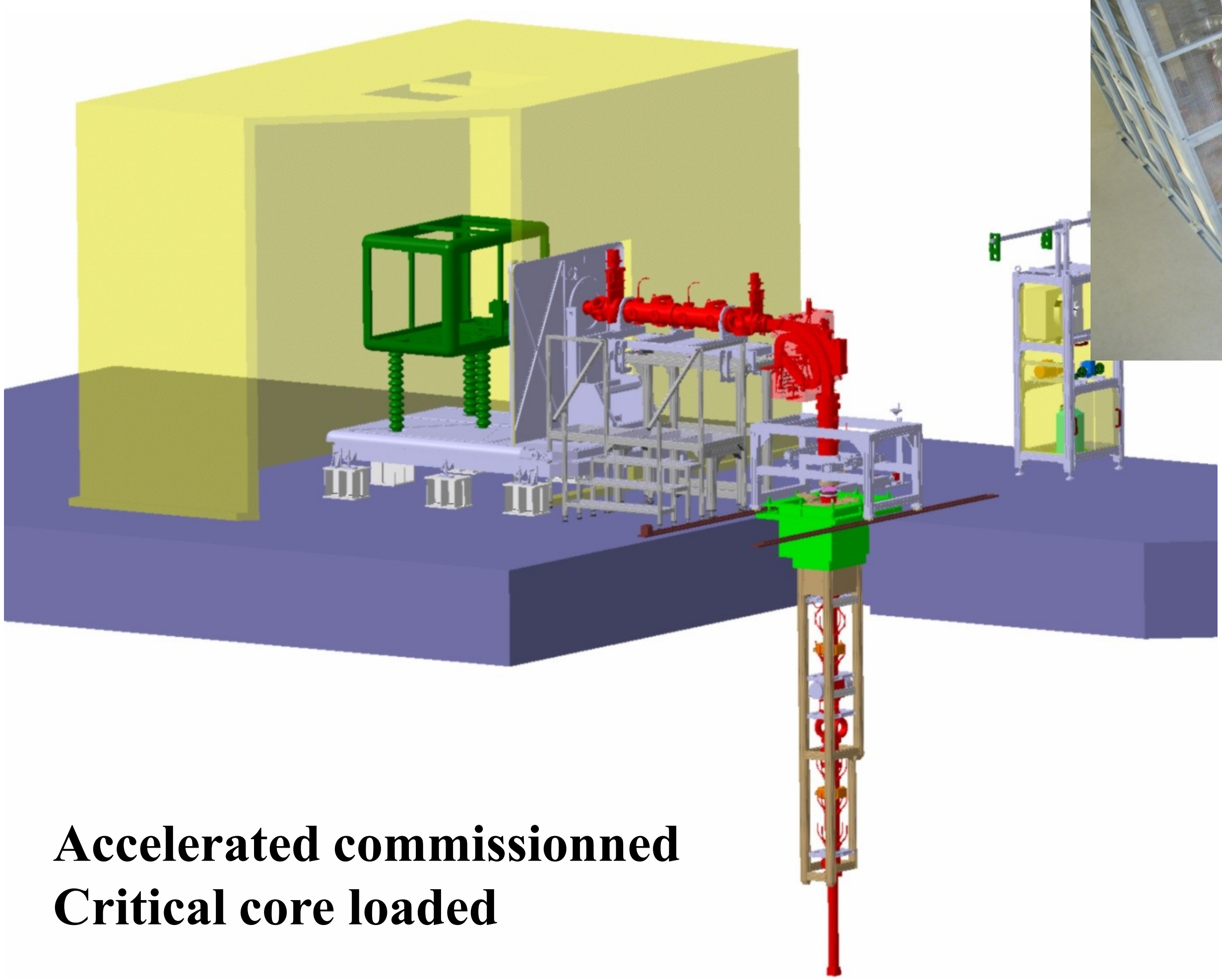
D^+ accelerator
GENEPI-3C

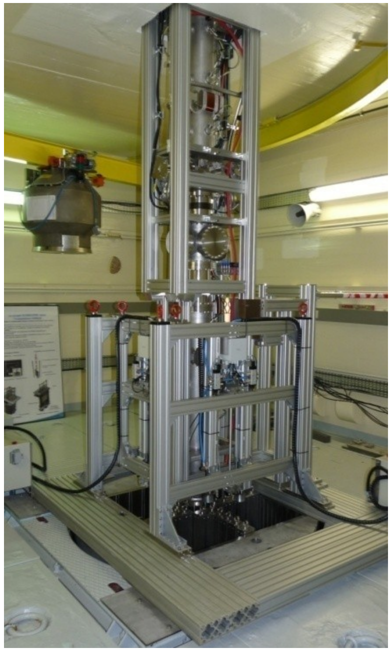


LPSC, IPNO, IPHC, LPCC
collaboration

Mol SCK-CEN
VENUS-F reactor
U enriched at 30%
+ solid lead

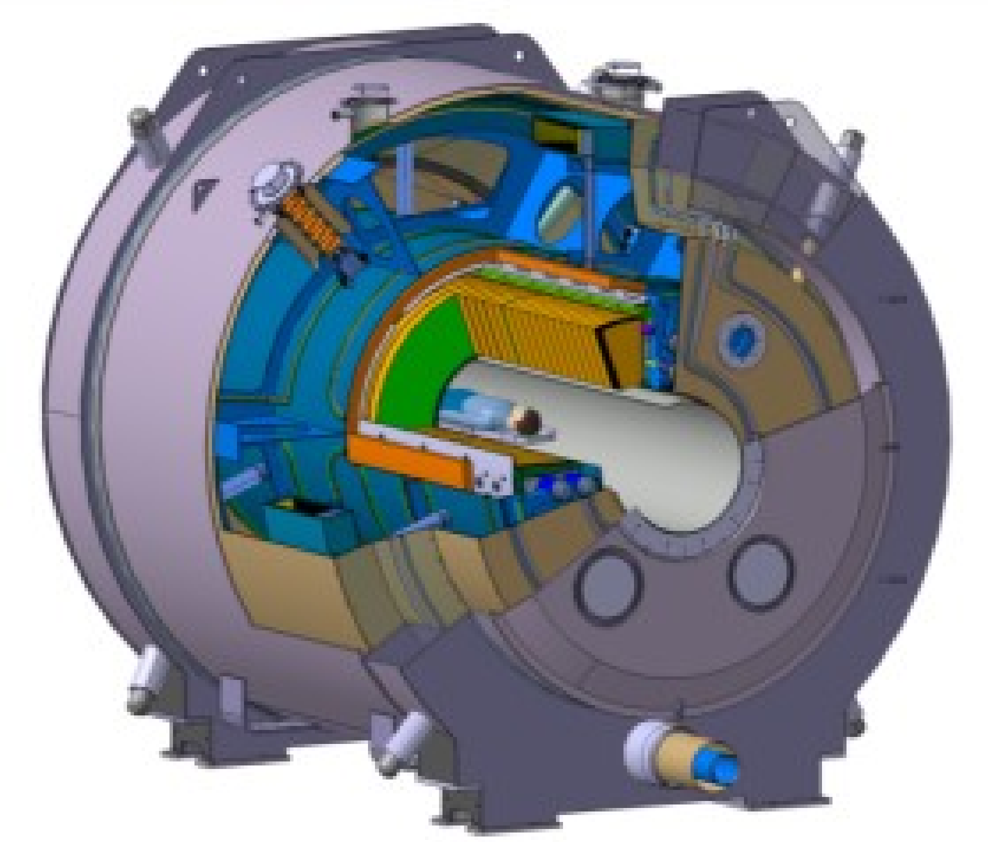
GUINEVERE

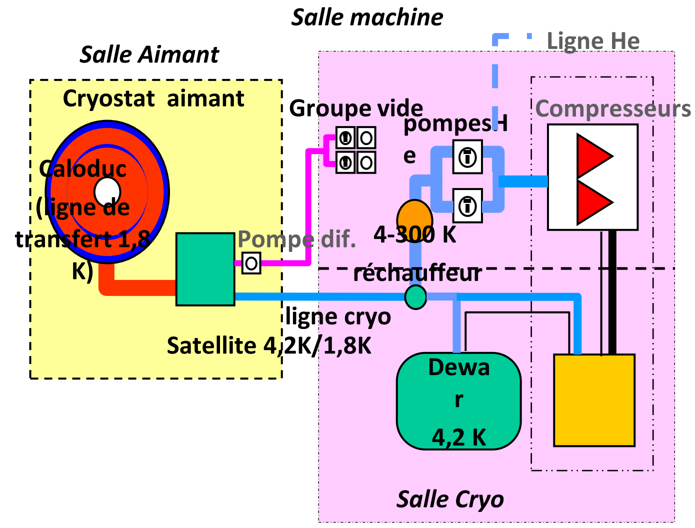




Accelerated commissionned
Critical core loaded

ISEULT (Whole body MRI magnet at 11.75 T)





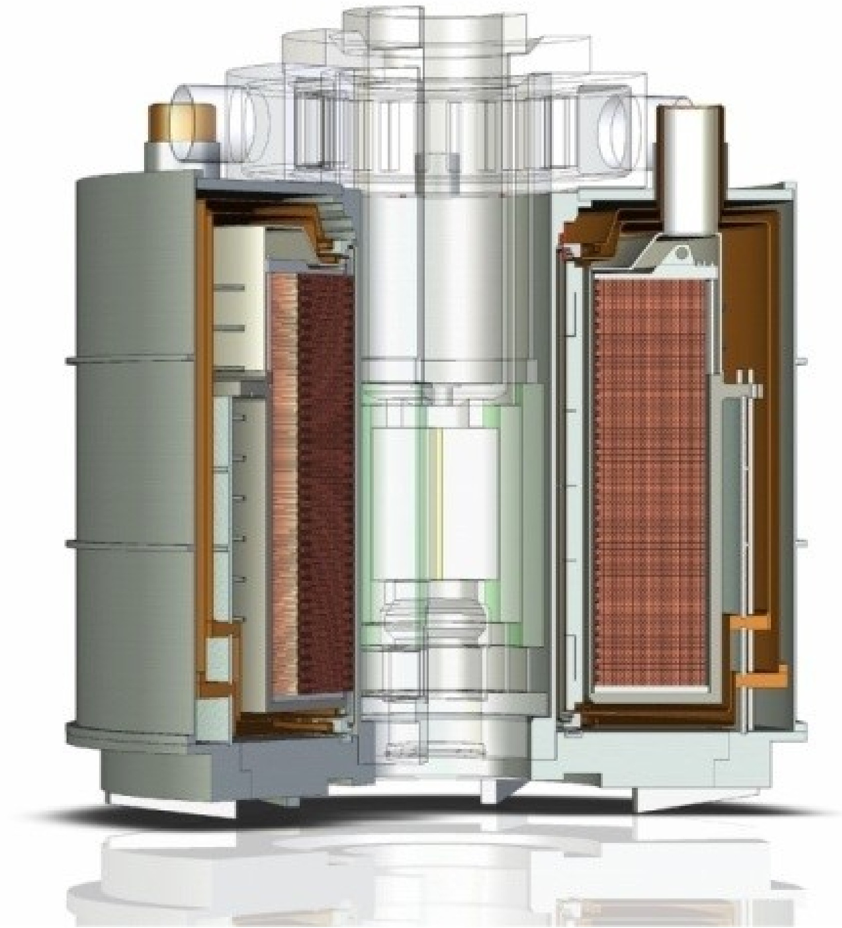
B=11.75 T

Stored Energy :338 MJ

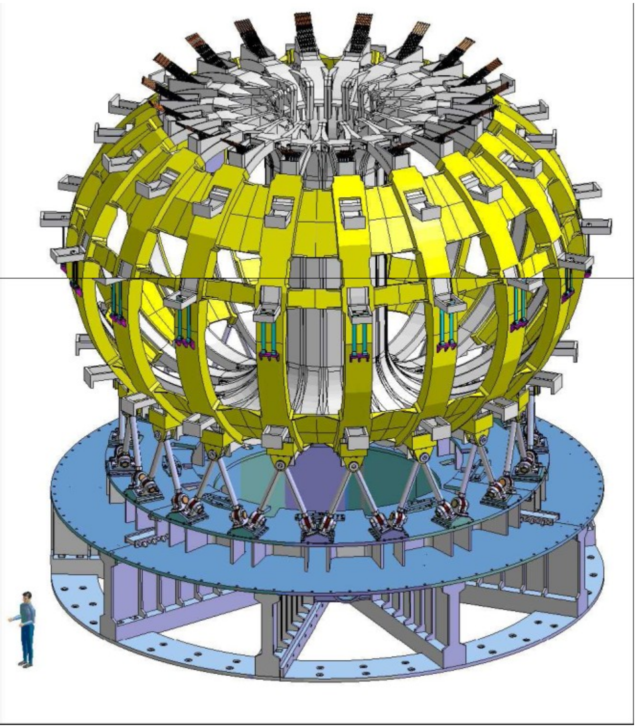
170 double pancakes

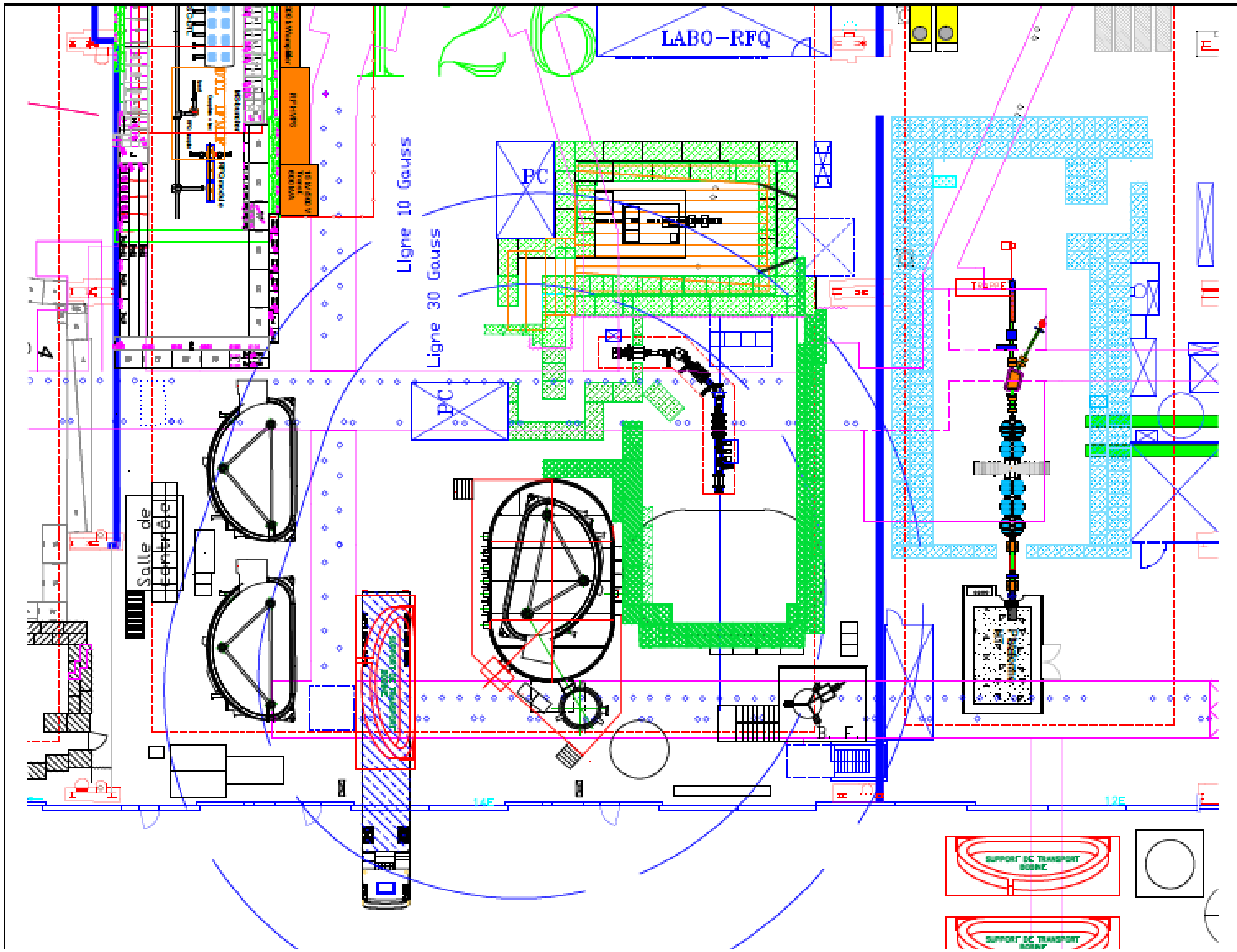
Construction of the SC outsert of 8.5 T for the CNRS/LNCMI

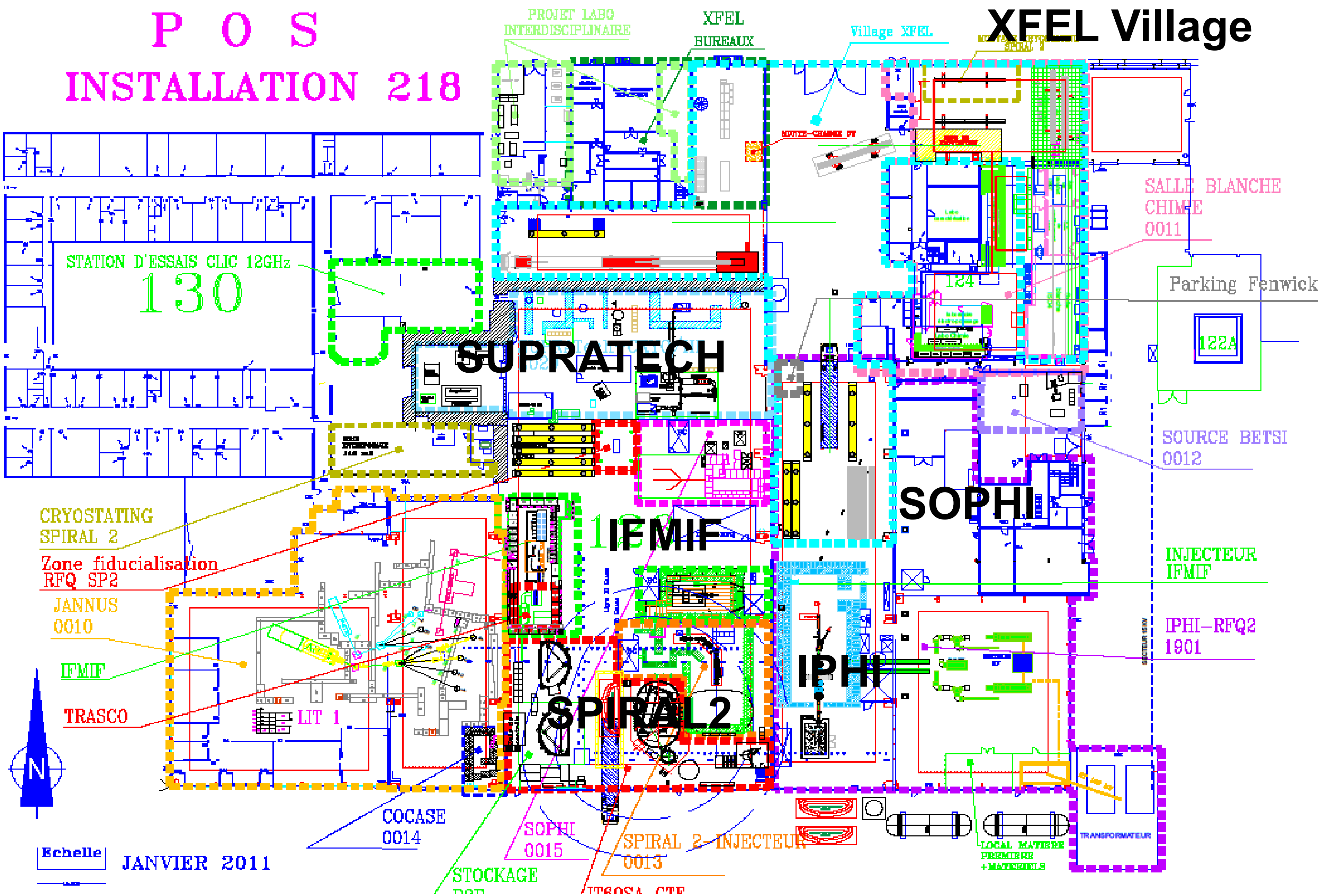
- A new concept of conductor is developed .
- The Rutherford cable is inserted in a channel
- The channel is a hollow OFHC copper allowing the cooling by super fluid helium.
- The winding pack is vacuum impregnated



JT60SA Test facility






P O S
INSTALLATION 218
XFEL Village
PROJET LABO INTERDISCIPLINAIRE
XFEL BUREAUX
Village XFEL
STATION D'ESSAIS CLIC 12GHz
130
SUPRATECH
SALLE BLANCHE CHIMIE 0011
Parking Fenwick
122A
124
SOURCE BETSI 0012
SOPHI
IFMIF
INJECTEUR IFMIF
IPHI-RFQ2 1901
IPHI
SPIRAL2
CRYOSTATING SPIRAL 2
Zone fiducialisation RFQ SP2
JANNUS 0010
IFMIF
TRASCO
LIT 1
N
COCASE 0014
SOPHI 0015
SPIRAL 2 INJECTEUR 0013
STOCKAGE
LOCAL MATIERE PREMIERE +MATERIELS
TRANSFORMATEUR
Echelle
JANVIER 2011

Conclusions

- Clear Roadmap
- Major challenges ahead : XFEL, SPIRAL2, IPHI, IFMIF, ESS …
- European programs are a vital part