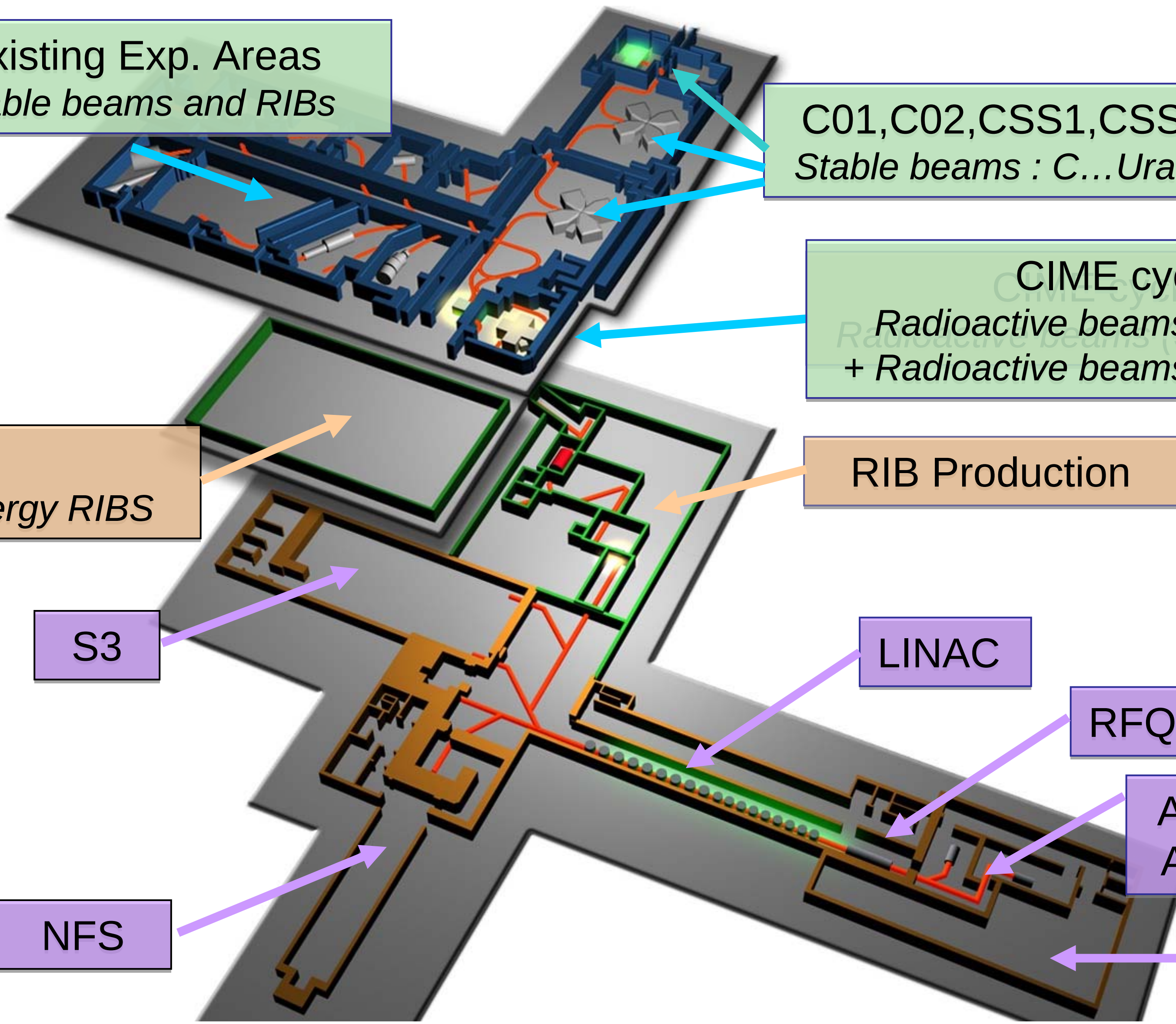
CYCLOTRON 2010
Lanzhou

Post-acceleration of high intensity RIB through the CIME cyclotron in the frame of the SPIRAL2 project at GANIL

Patrick BERTRAND
Alain SAVALLE
on behalf of SPIRAL2 and GANIL teams

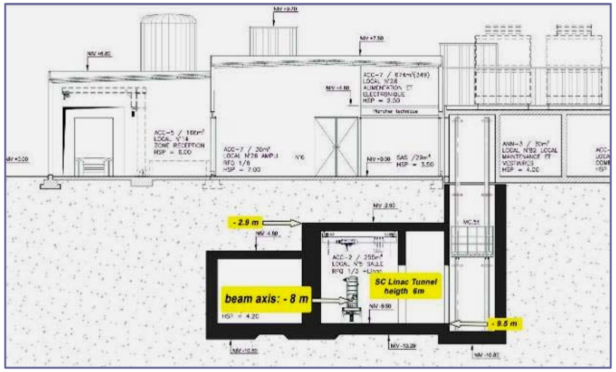
GANIL - France

GANIL-SPIRAL1-SPIRAL2 facility layout

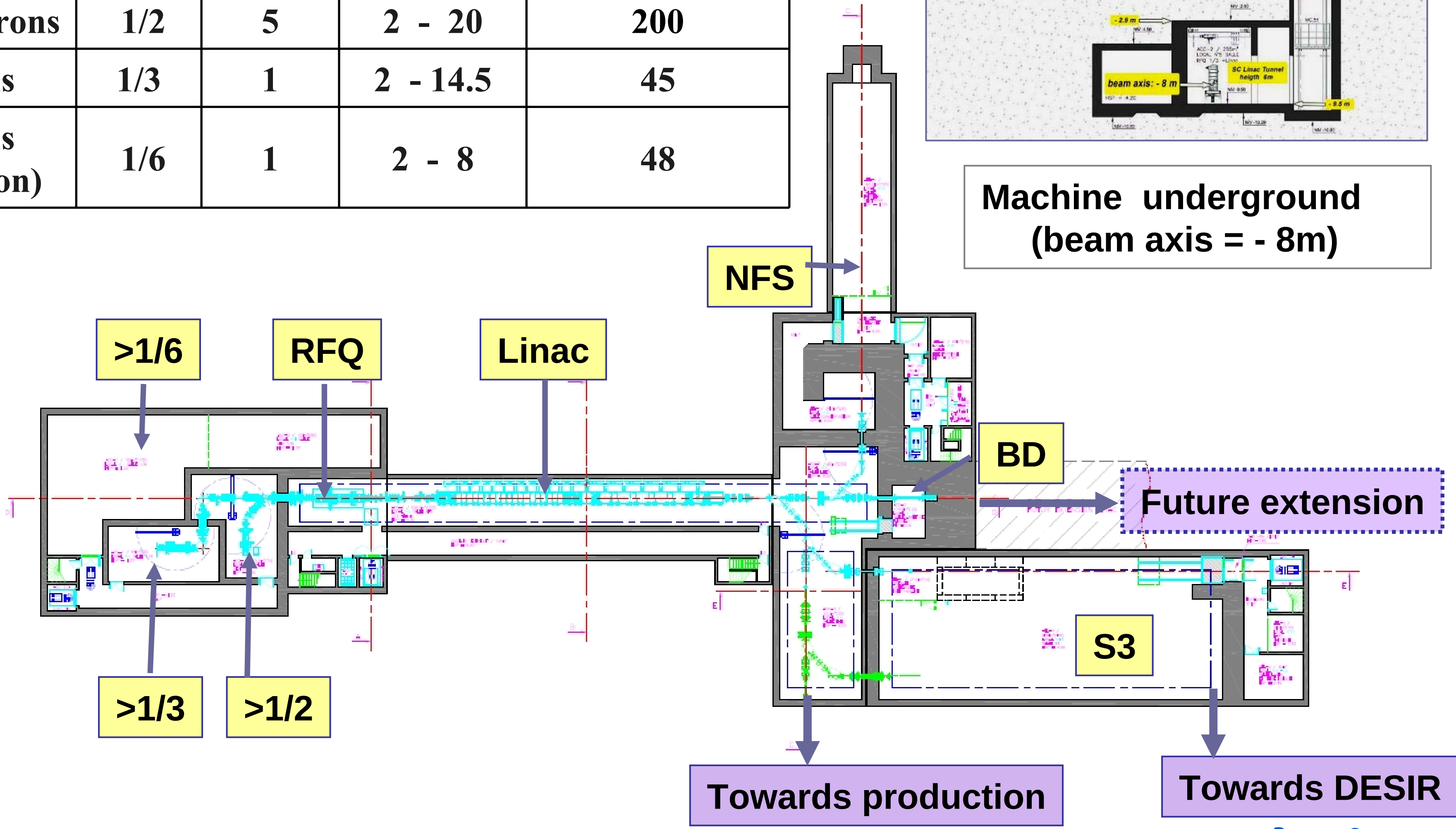


SPIRAL2 Driver Beam Characteristics

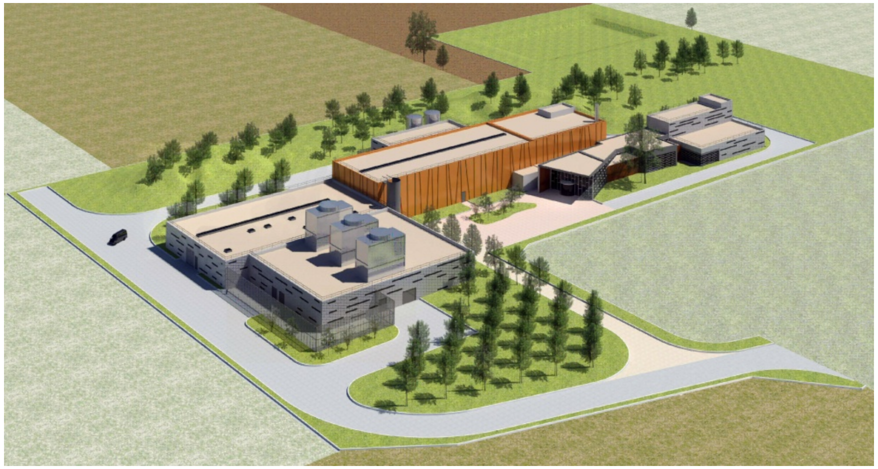
	Q/A	I (mA)	Energy (Mev/u)	CW max beam Power (KW)
Protons	1/1	5	2 - 33	165
Deuterons	1/2	5	2 - 20	200
Ions	1/3	1	2 - 14.5	45
Ions (option)	1/6	1	2 - 8	48



Machine underground
(beam axis = - 8m)

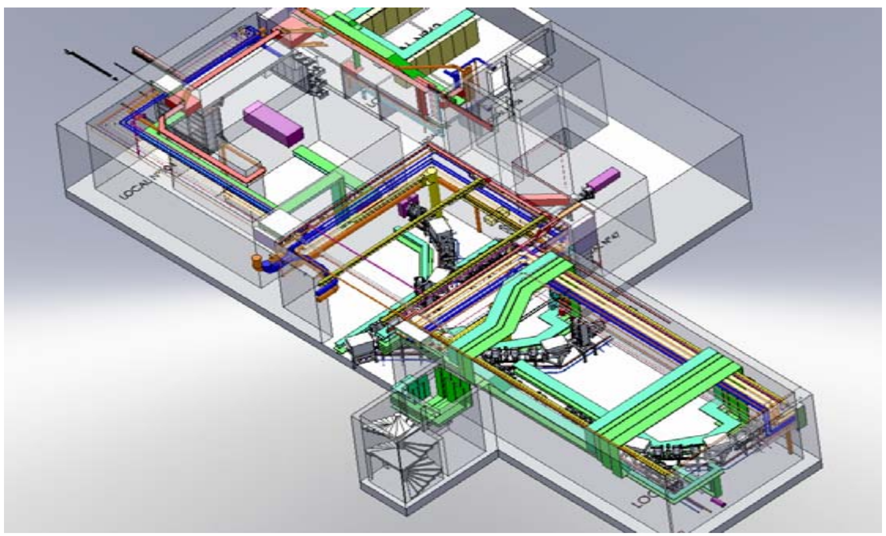


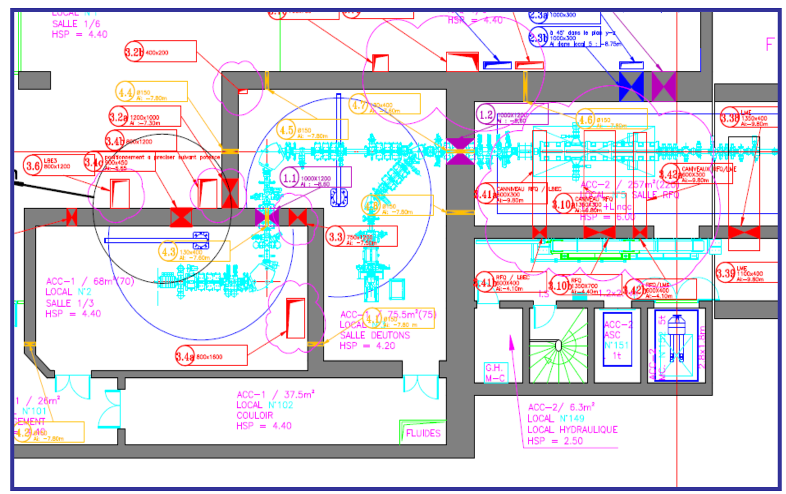
Spiral2 Accelerator Building Integration



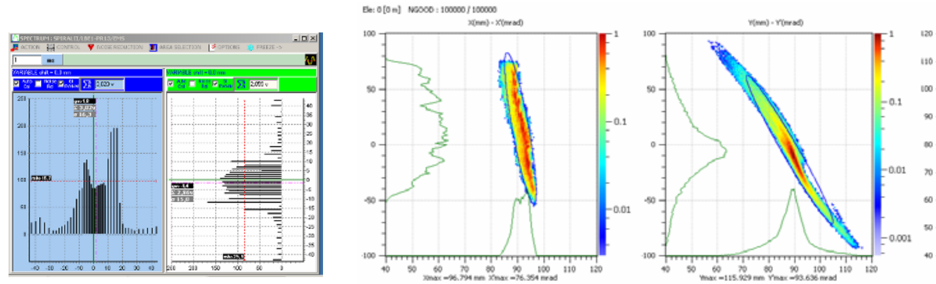
- Public inquiry started (conclusion in Oct.)
- Construction permit expected by December
- Effective Construction in 2011
- Safety authorization in 2012

- Accelerator construction done in parallel
- Technical and beam tests distributed in various laboratories

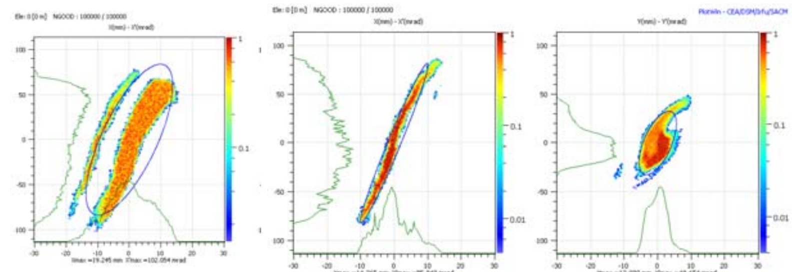




PhoenixV2 + LEBT1 Beam Tests (LPSC Grenoble)



Beam profiles and emittance
(O16 6+, March 2010)



Xe132 25+
O16 3+

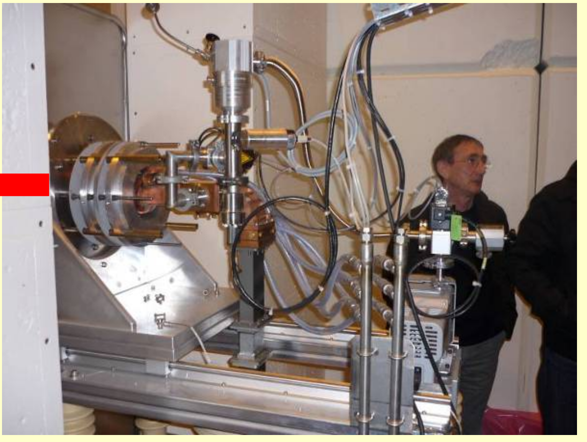
Xe132 25+
Separation using slits

Up to 98%transmission !!!

LCO oven (metallics)

- <u>**Technical & beam Commissioning 2010 :**</u>
  - **Automats, C/C (Epics) , Vacuum…**
  - **Faraday cups, profilers**
  - **Emittance-meters, slits**
  - **PHOENIX V2 @ 18 GHz**
    - **Extraction at 47 kV**
    - **Ar, O, Xe, Ca…**
  - **feedback with TRACEWIN transport code**
- **Next steps : increase voltage 47→ 60 kV**

Deuteron/proton source + LEBT2 +LEBTC (CEA/IRFU Saclay)

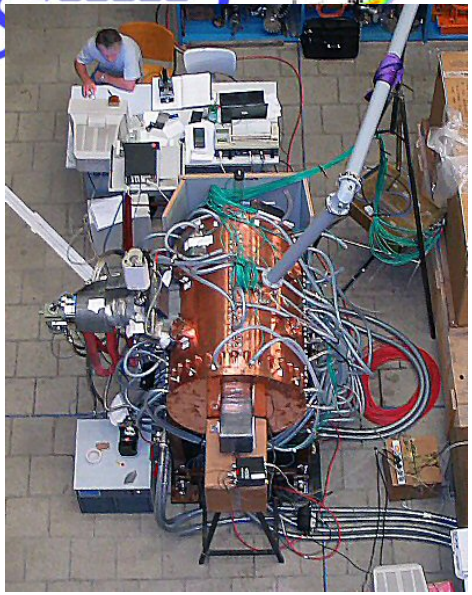


Deuteron 2.45 Ghz ECR source tested successfully in March 2010

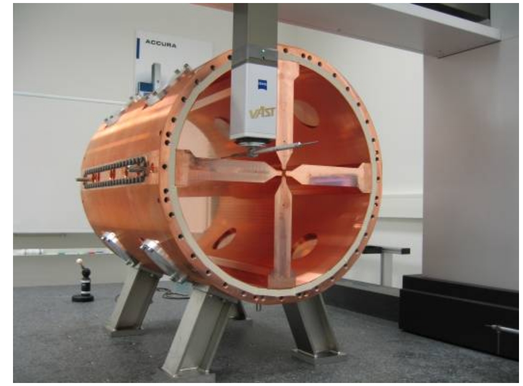
LEBT2 ready for beam tests
LEBC installation in progress

First proton beam observed last week on beam stop after first bending magnet !!

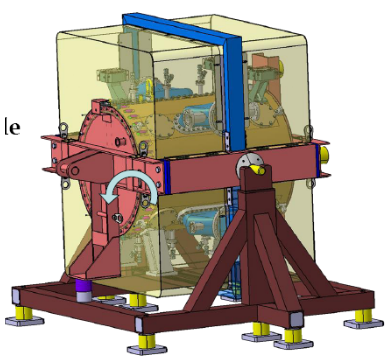
4-vane 88 MHz RFQ (CEA/SACLAY)



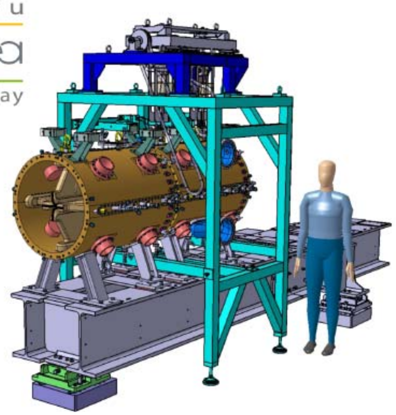
Automated test bank for RF tests is operational (was used on prototype…)



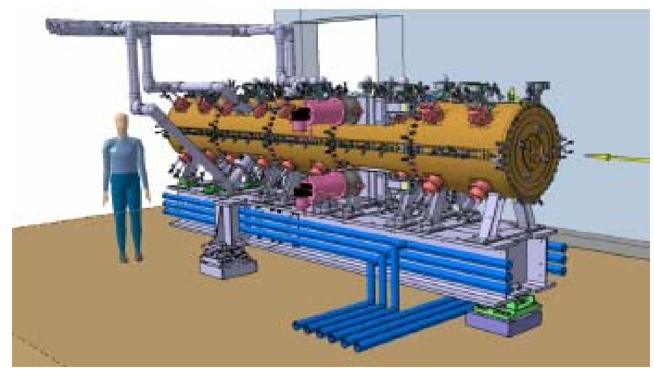
Construction of RFQ: first segment finished in a few days !



Safe segment rotation (storage and transport)

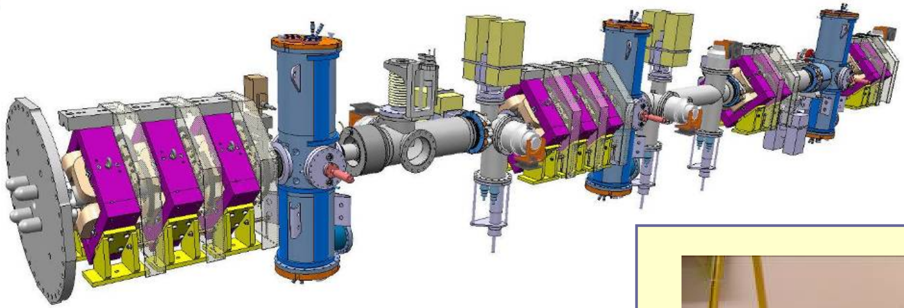


System for RFQ assembly



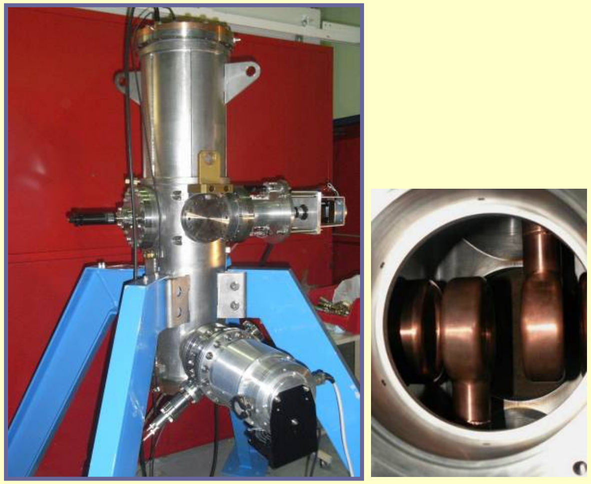
Implantation study into tunnel…

Some objects of the MEBT…

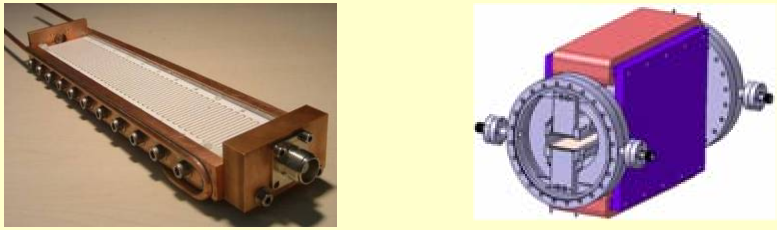


Slits (elimination of Halo…)

Quadrupole measurements



Rebuncher under test at Ganil



Fast Chopper
(for NFS experiments)

SC-LINAC collaboration

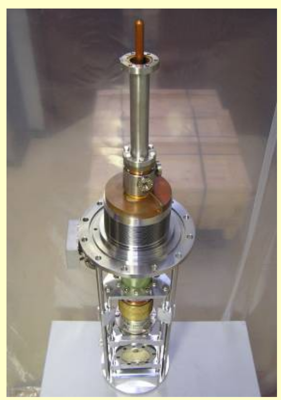
Cavities and cryomodules A

IRFU/Saclay

Amplifiers

GANIL/Caen

Couplers



LPSC/Grenoble

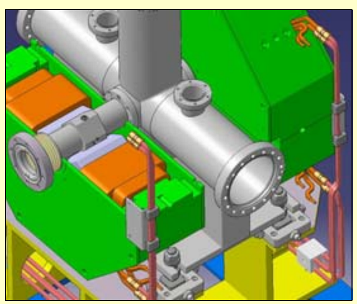
Cavities and cryomodules B

IPNO/Orsay

Some objects of the LINAC warm Sections

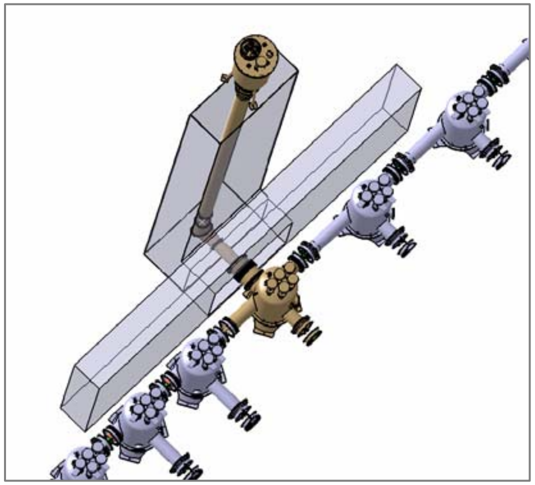
LINAC Support structure

Magnetic Measurements of Linac warm Quadrupoles



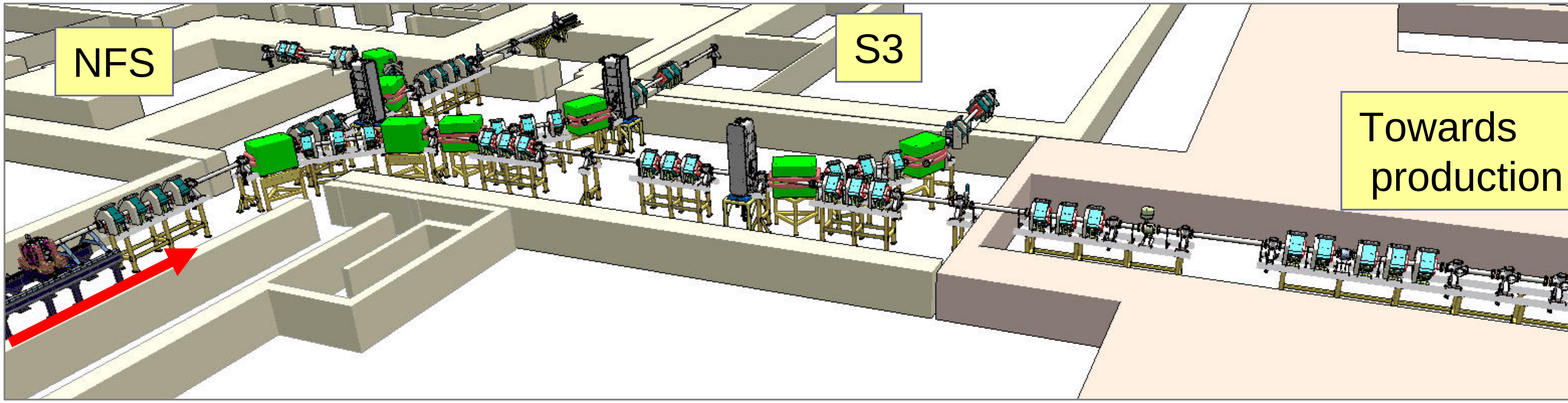
BPM prototype (Orsay)

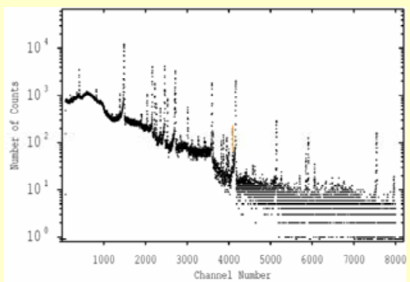
Cryogenic Transfer Lines (IPN Orsay)



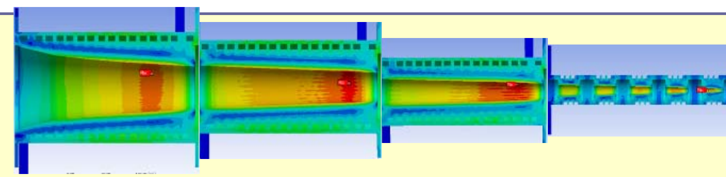
- ✓ 2 prototype valve boxes connected to Cryomodules A and B at Orsay and Saclay
- ✓ 6 valve boxes already delivered and OK
- ✓ 16 valves boxes in fabrication

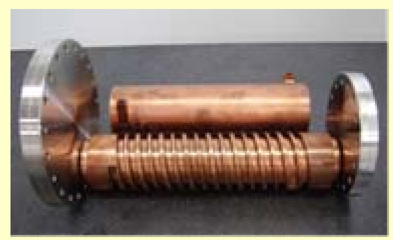
HEBT Lines… (modularity…)





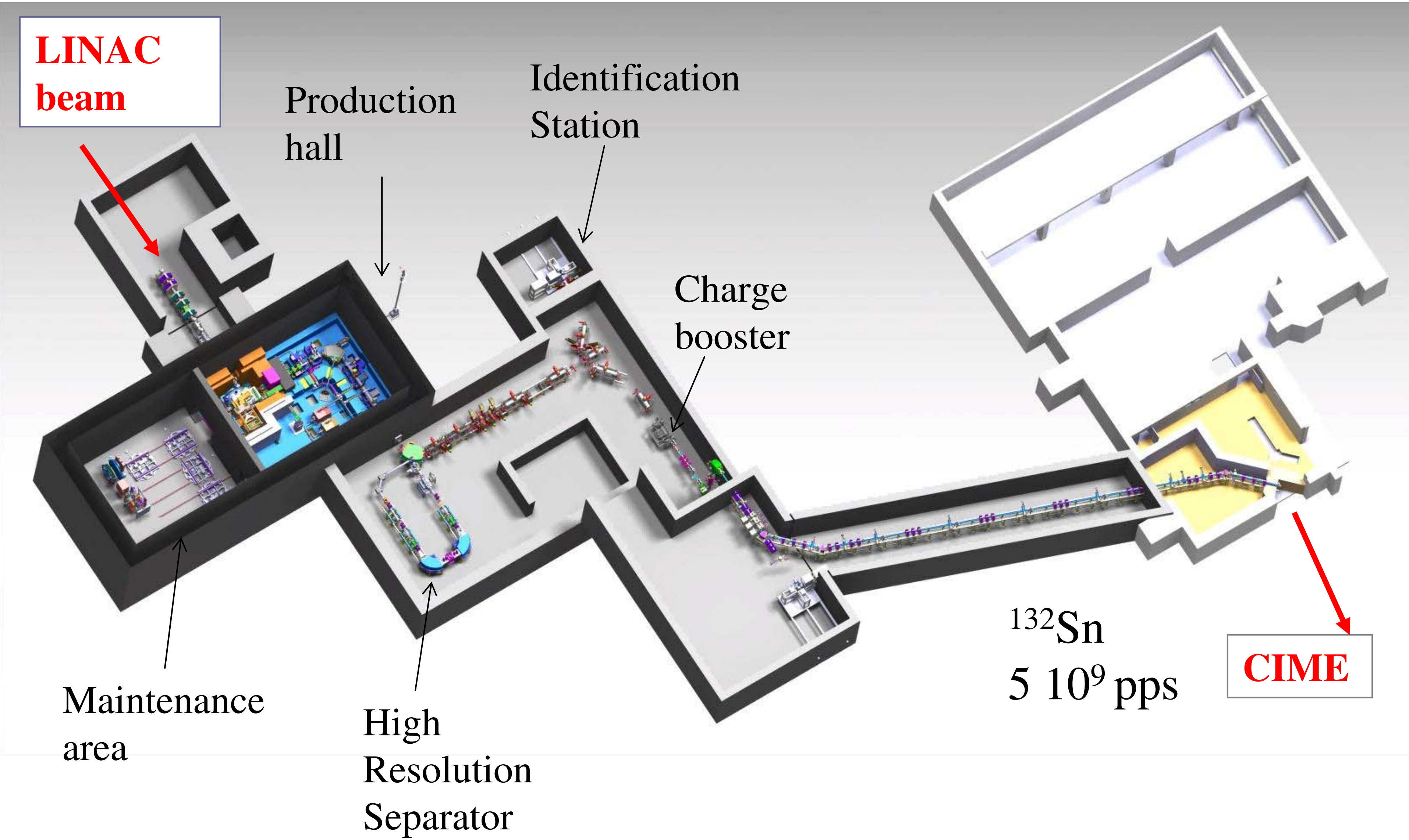
Activation of various materials
(Romania)



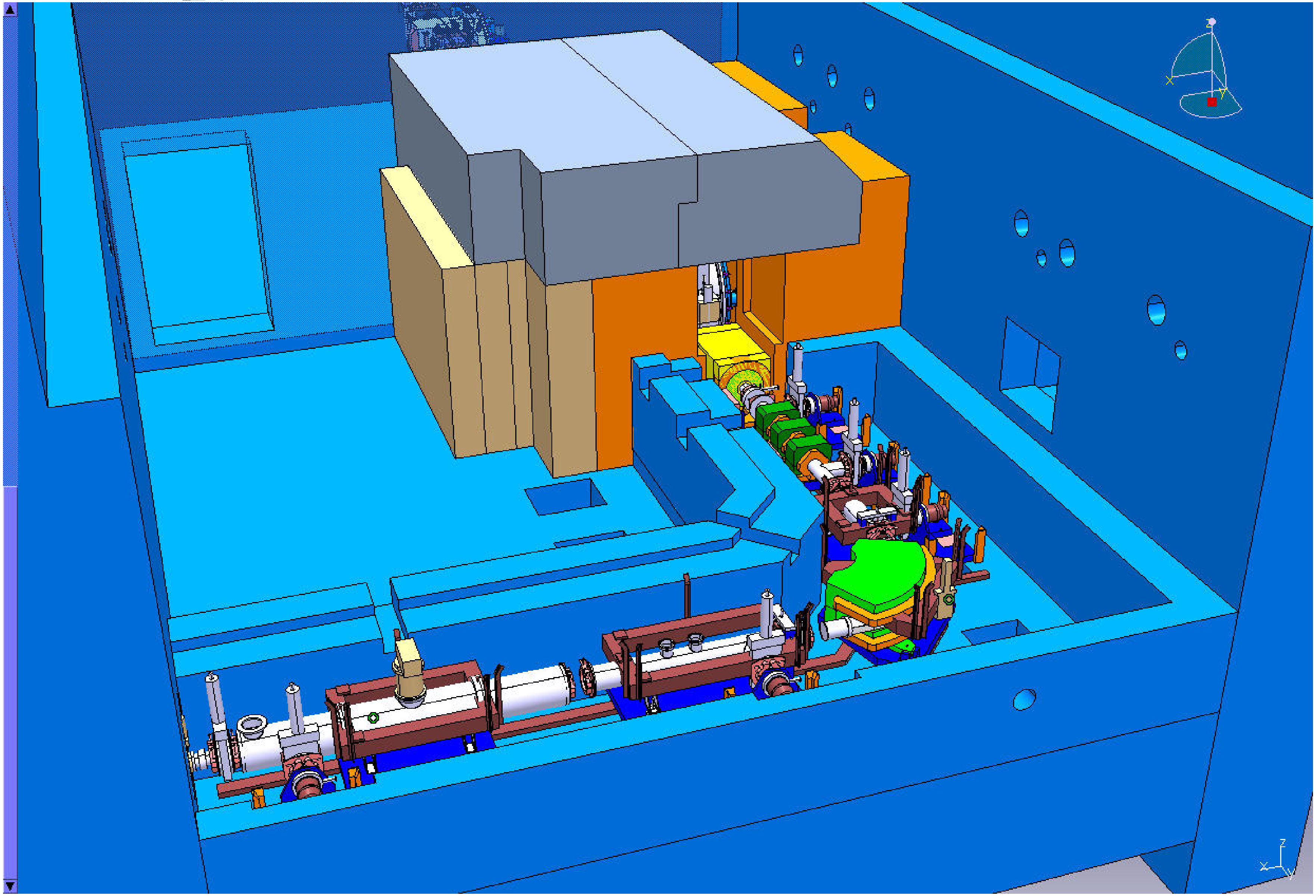


Studies of the Main Beam Dump
And first segments (IPN-Lyon + Spain)

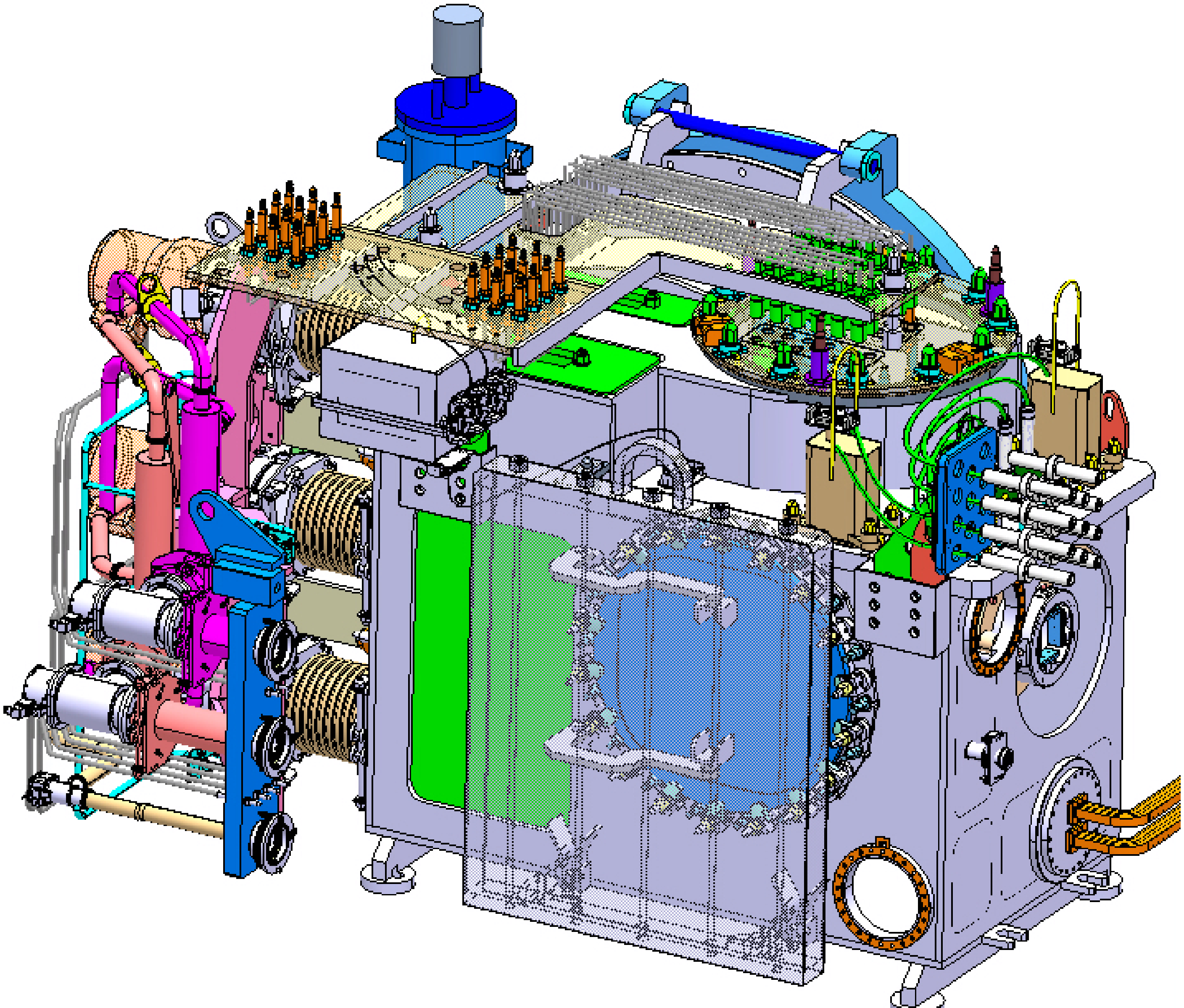
RIB Production



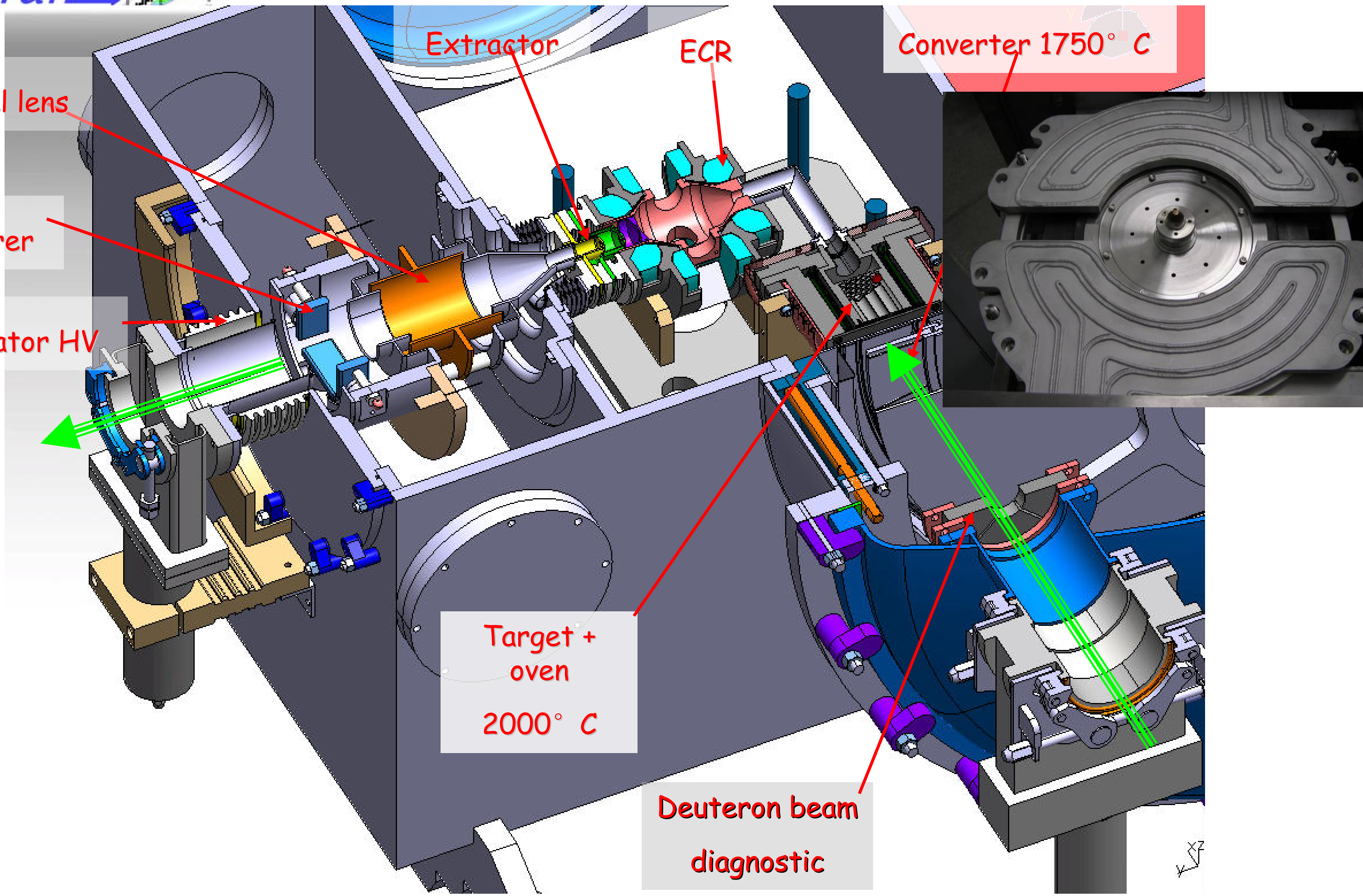
Production area (hot cell)



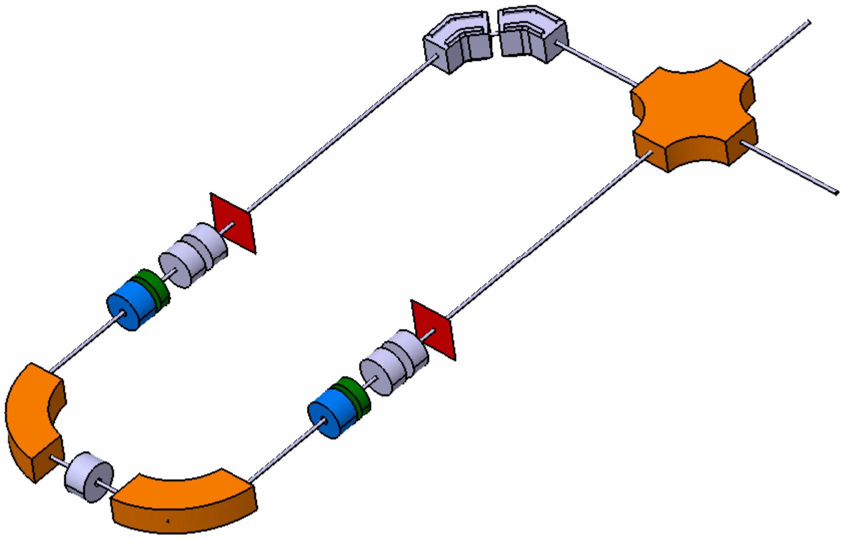
Production module



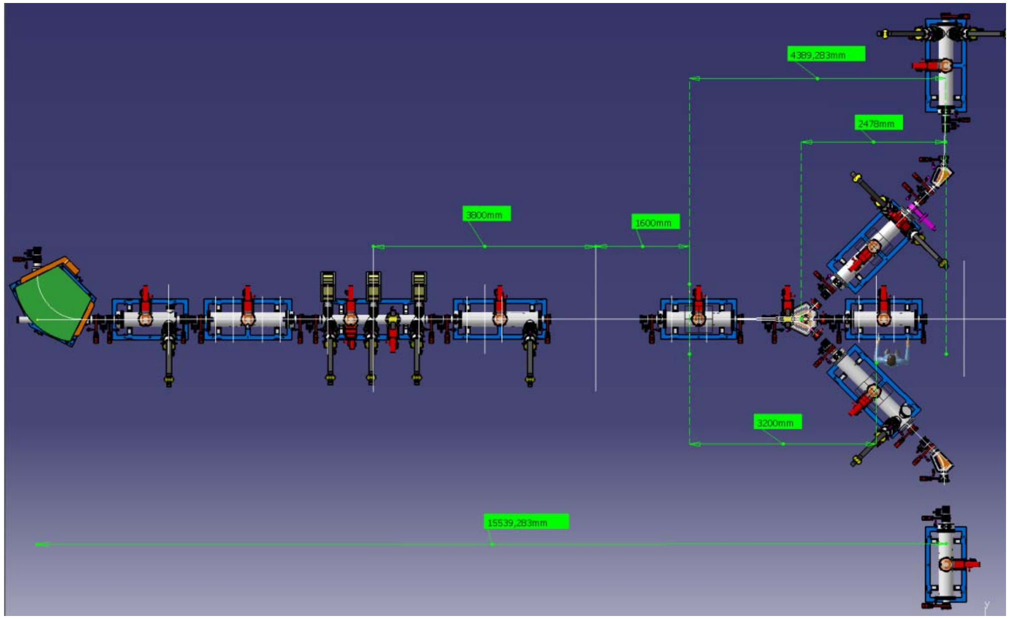
Production Module (inside)



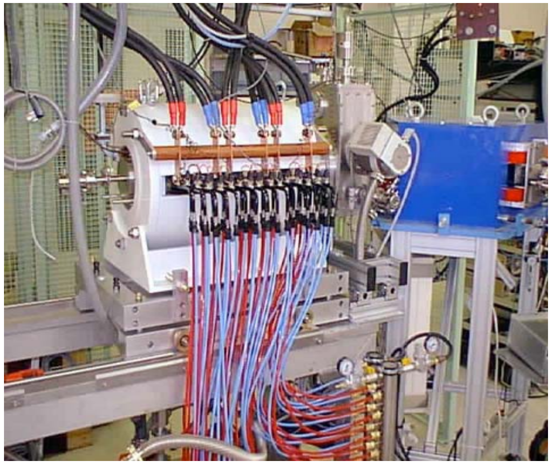
Beam transport systems



High Resolution Separator
(CENBG)
(1/20 000 with RFQ-cooler)

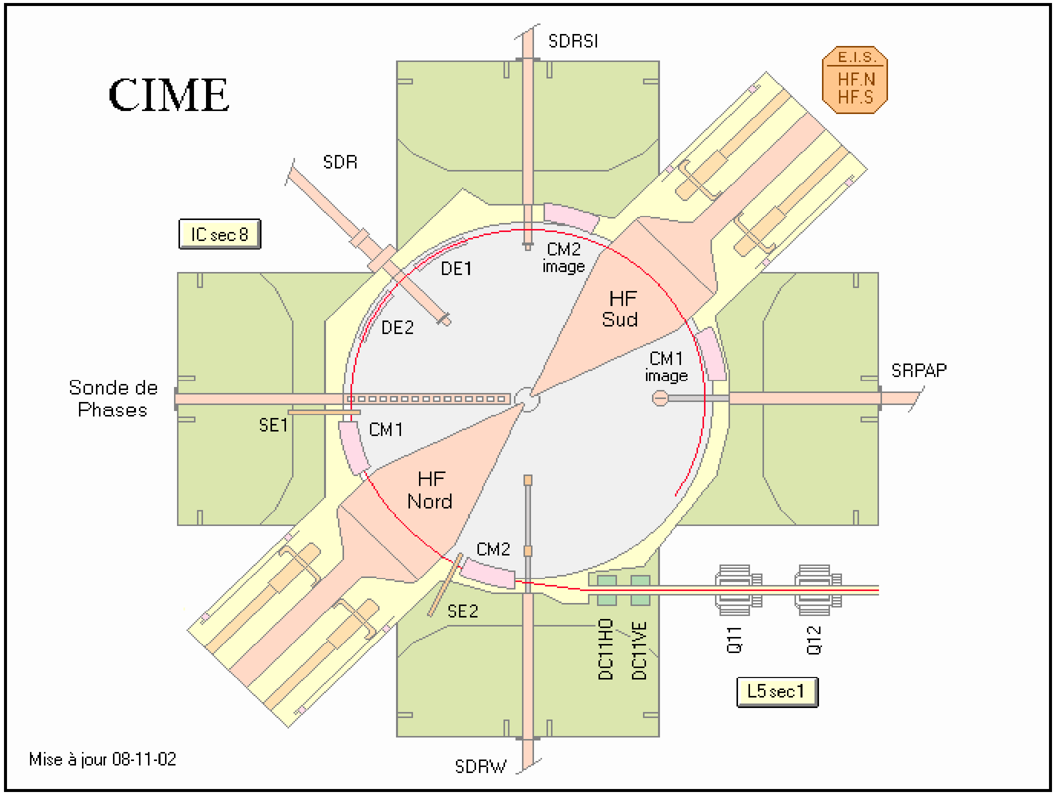


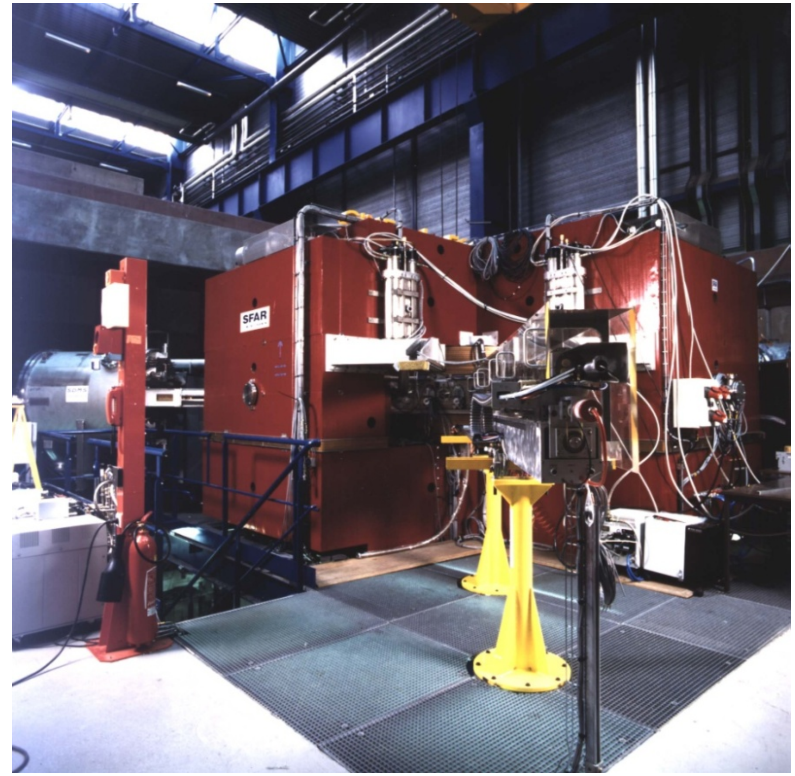
1+ beam line (IPHC)



n+ source:
Phoenix booster
(from LPSC)

CIME Cyclotron





Compact cyclotron with Axial injection

100-300 turns 2 RF (9.6-14.4 Mhz) cavities

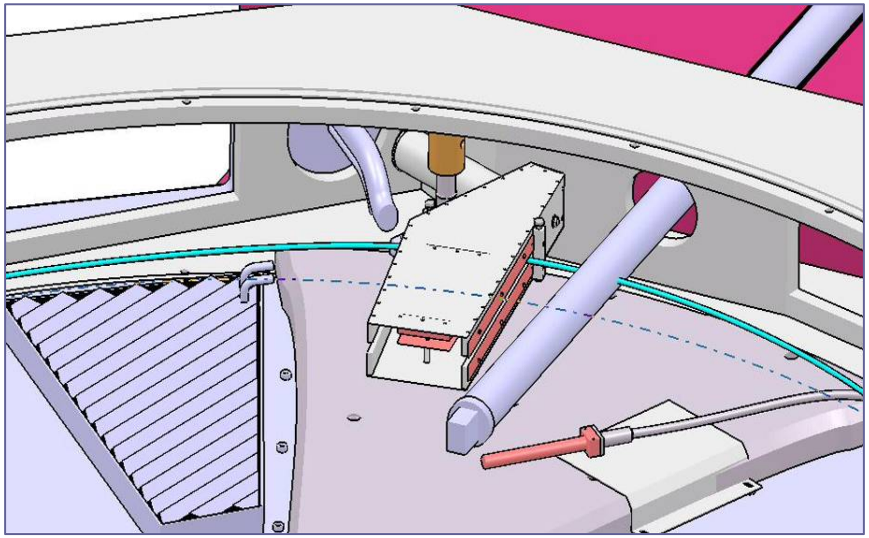
Ejection with 2 Electrostatic deflectors and 2 Magnetic channels

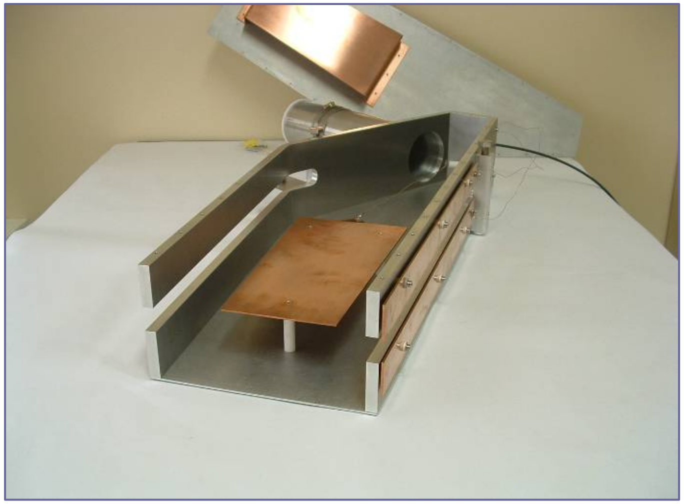
Energy range :
1.2 MeV.A - 24 MeV.A
(q/A)<1/8 (q/A) >1/3

CIME cyclotron : improvement of the mass separation

(P. Bertrand et al., Cyclo'04, ECPM 09)

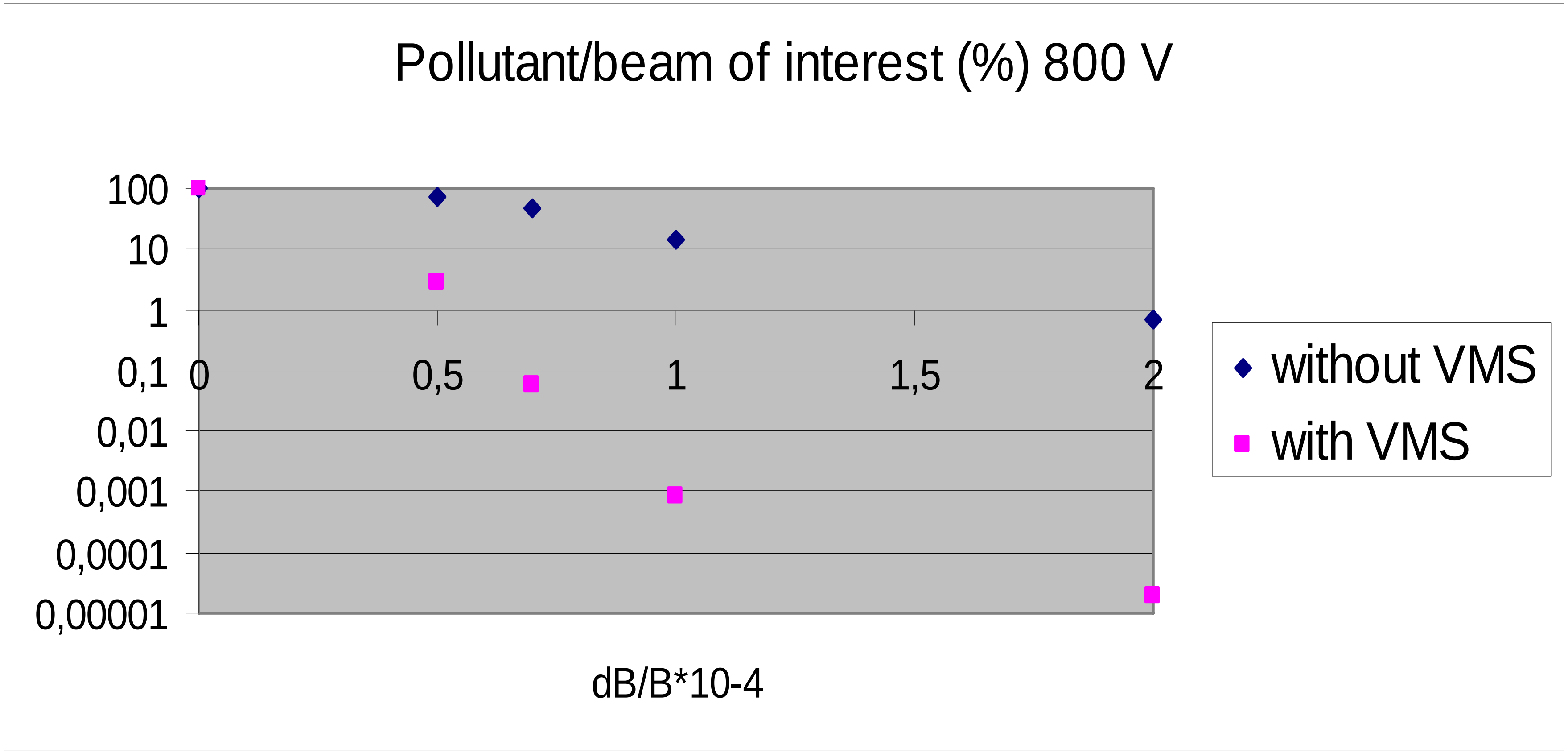
beam	Possible pollutant	d(q/m)/(q/m)	Phase shift at ejection (φ)
$^{15}O^{4+}$	$^{15}N^{4+}$	1.9 10^{-4}	48°
$^{132}Sn^{20+}$	$^{132}Xe^{20+}$	1.0 10^{-4}	35°
$^{140}Cs^{21+}$	$^{140}Ba^{21+}$	4.8 10^{-5}	16°





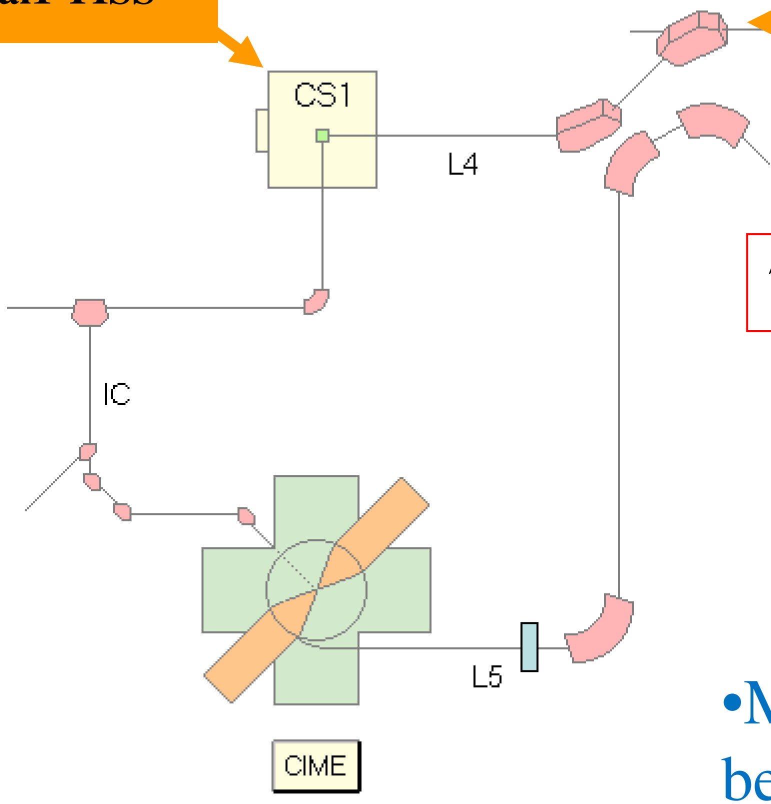
$$V(t) = V_{\max}\sin\left(\frac{v}{h}\omega_{hf}t\right)\sin(2\omega_{hf}t)$$

Vertical Mass Separator : results



Radiological aspects : Measurements

Spiral1 TISS



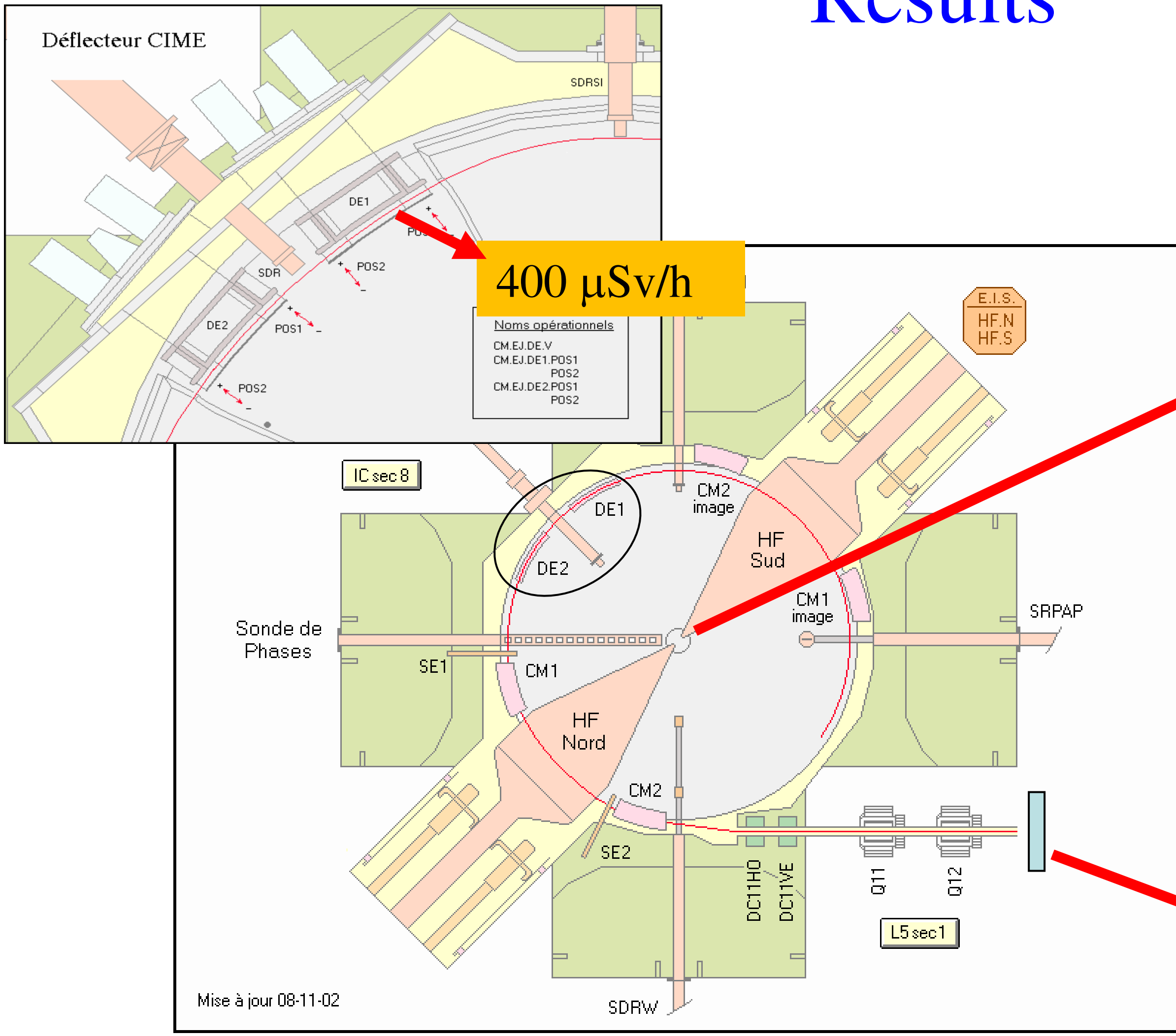
^{78}Kr 70 MeV.A

76Kr or 77Kr beams 10^7 pps

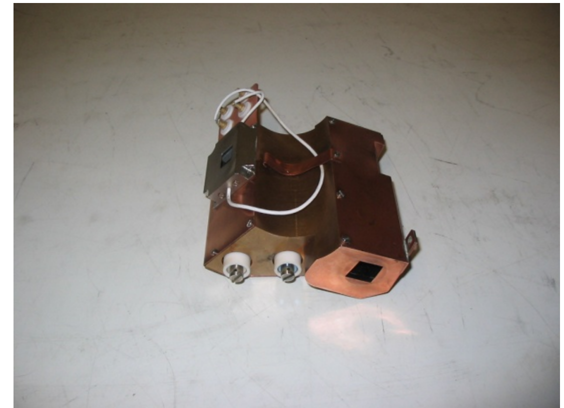
76Kr(14.8h)→ 76Br(16.2h) → 76Se
77Kr(1.23h)→ 77Br(57.0h) → 77Se

- Measurement of radioactivity in beam lines and inside the cyclotron
- Measurement of contamination of cryogenic pumps

Results



400 µSv/h



1 mSv/h at contact

Superficial contamination

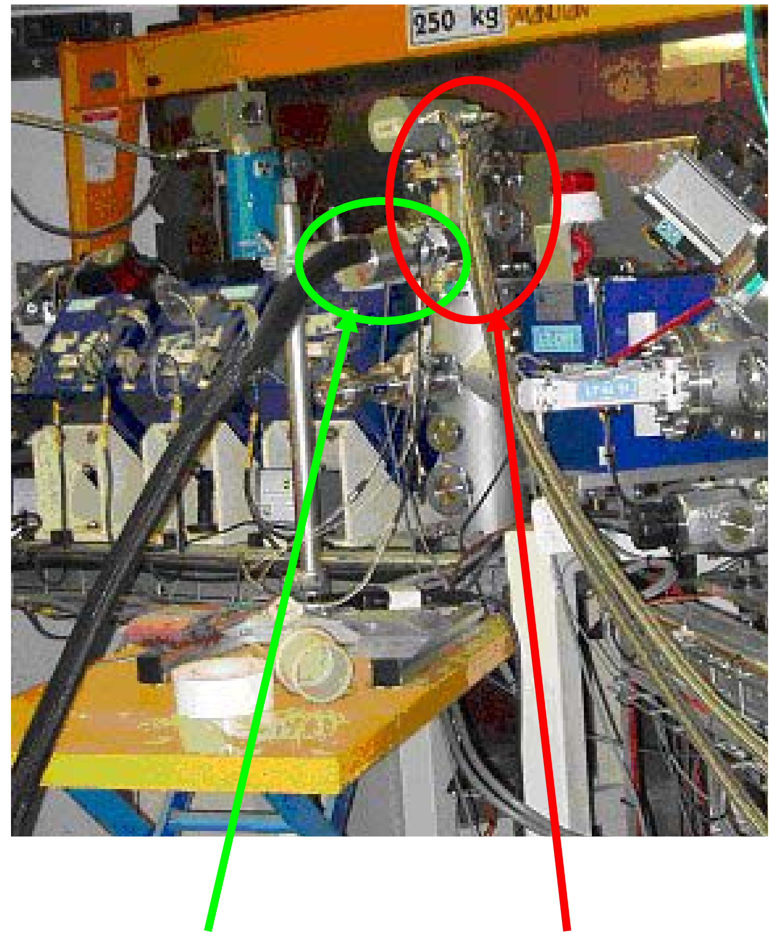
9 000 Bq ^{76}Br / 900 Bq 76Kr

- Plate : 1 mSv/h (contact)
- No contamination

Contamination of cryogenic pumps

- Before acceleration :
  10-20% gases are released and pumped

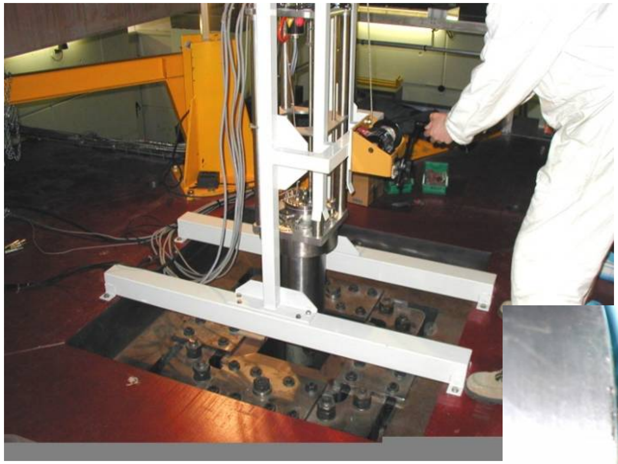
- After acceleration :
  <1% released

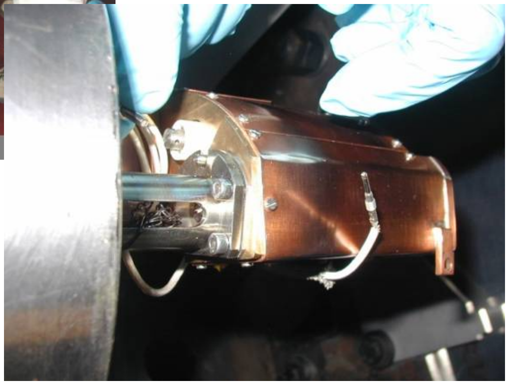


Spectroscopy Cryogenic trap

Maintenance

View of people working during a CIME maintenance operation





Dismounting of CIME inflector

CIME deflector extracted

Estimated annual collective dose :10 man.mSv. Operation is possible with some optimisations, including use of spares for inflectors, deflectors, and improvement of mechanics in order to reduce the operation time

Safety

- MODIFICATIONS OF THE CIME HALL

  Taking into account an accidental contamination during operation maintenance, static (walls) and dynamic (nuclear ventilation) confinement will be necessary

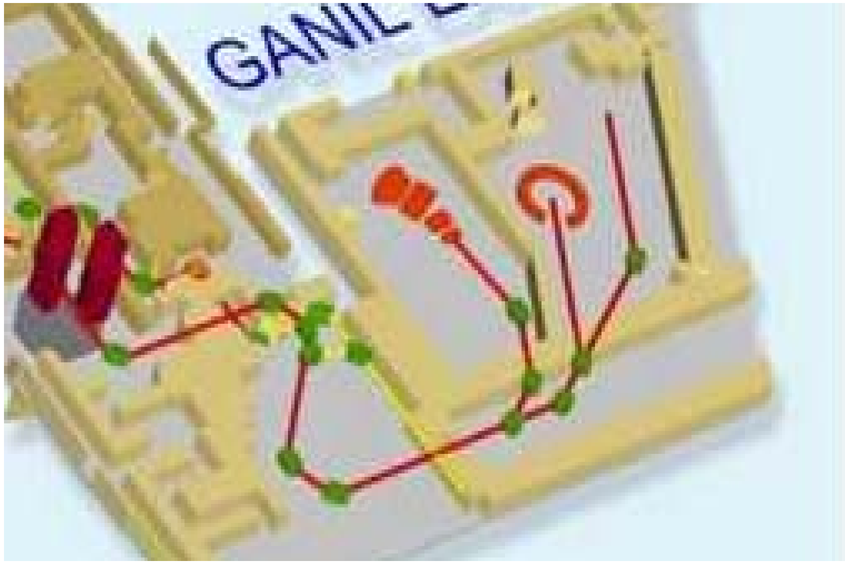
  The modifications are quite important (preliminary cost ~2 M€).

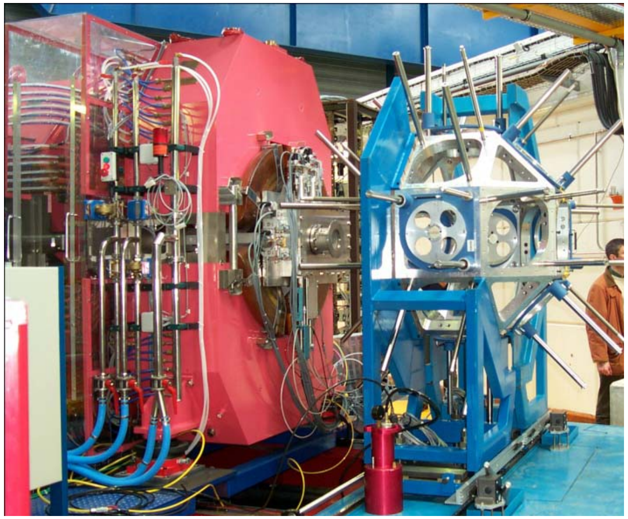
- VACUUM SYSTEM

  Up to the CIME cyclotron, the contamination of the pumps justifies the storage of gases.

  After CIME ejection, contamination of the "vacuum" gases is reduced. Storage is not necessary but gases must be analyzed before release.

Experimental areas





- Challenge : high activity (up to 10^{10} Bq) close to a gamma detector.
- The incident beam has to be stopped away from the detector with a shielding.
- Interactions of the incident beam with residual gas resulting to halo and other causes of losses.
- Rutherford scattering on target.

CONCLUSION

-SPIRAL2 accelerator components are in technical tests and/or construction. Accelerator building is completely defined.

-The detailed design solution of the RIB process equipments and the production building, compatible with the safety constraints, is underway.

-The necessary modifications of the existing GANIL facility have been identified, but are still to be fully validated.

At the beginning of SPIRAL2 operation with the cyclotron CIME, the beam intensity will probably be reduced to check the hypothesis in terms of radioprotections, safety, and detection.

THANK YOU !

SPIRAL2 is a collaboration between many laboratories:

CEA/IRFU/SACM,SIS

CEA/DPTA

CNRS/IN2P3/IPNO, IPHC, LPC Caen, LPSC, CENBG, CSNSM

GANIL-CEA/CNRS,

Gatchina, Legnaro, Bucarest

international MoU :

Bucarest (Romania)

Spain

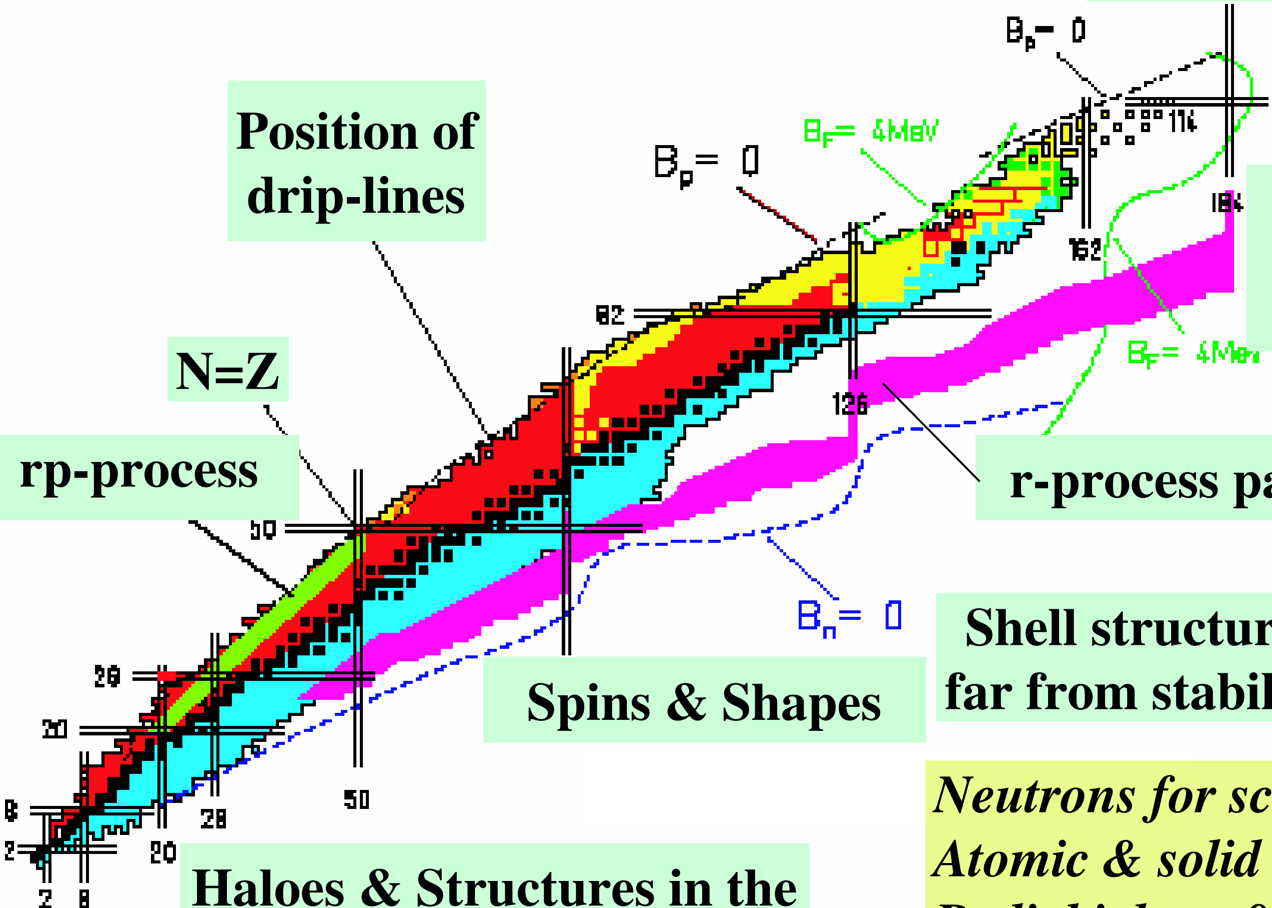
Argonne lab. USA

Triumf (Canada)

Soreq/Saraf (Israel)

And many physics collaborations (detectors…)

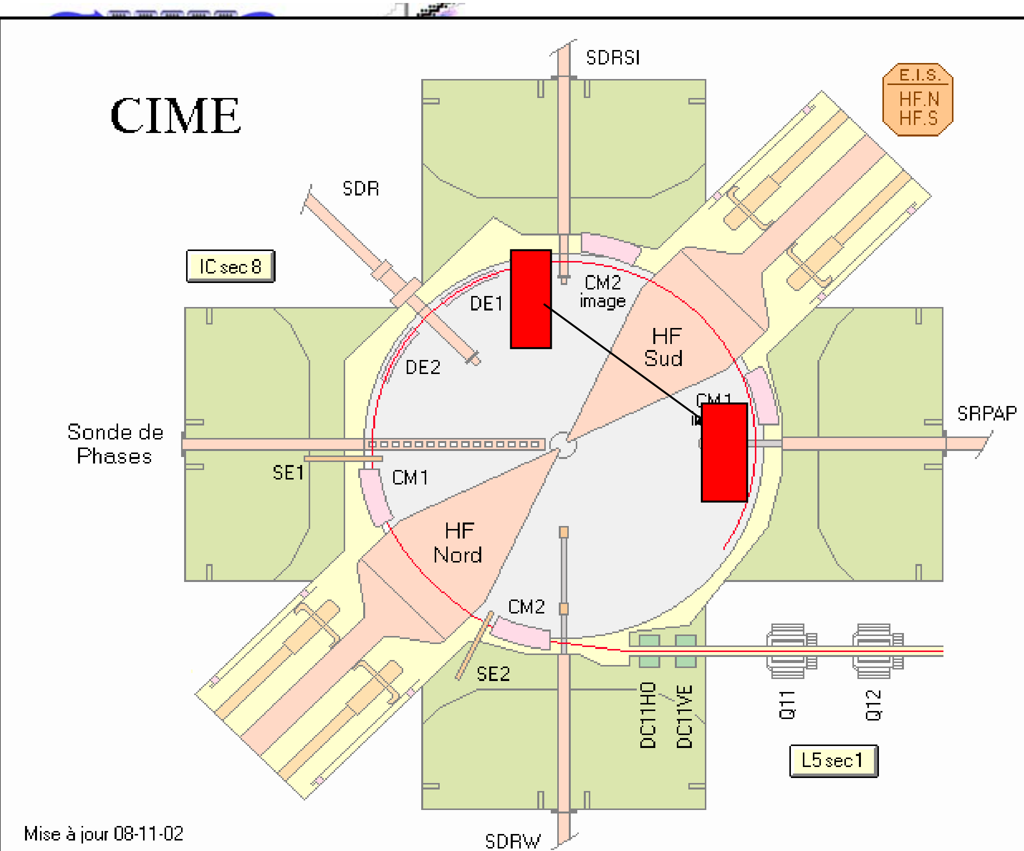
The scientific case of SPIRAL 2

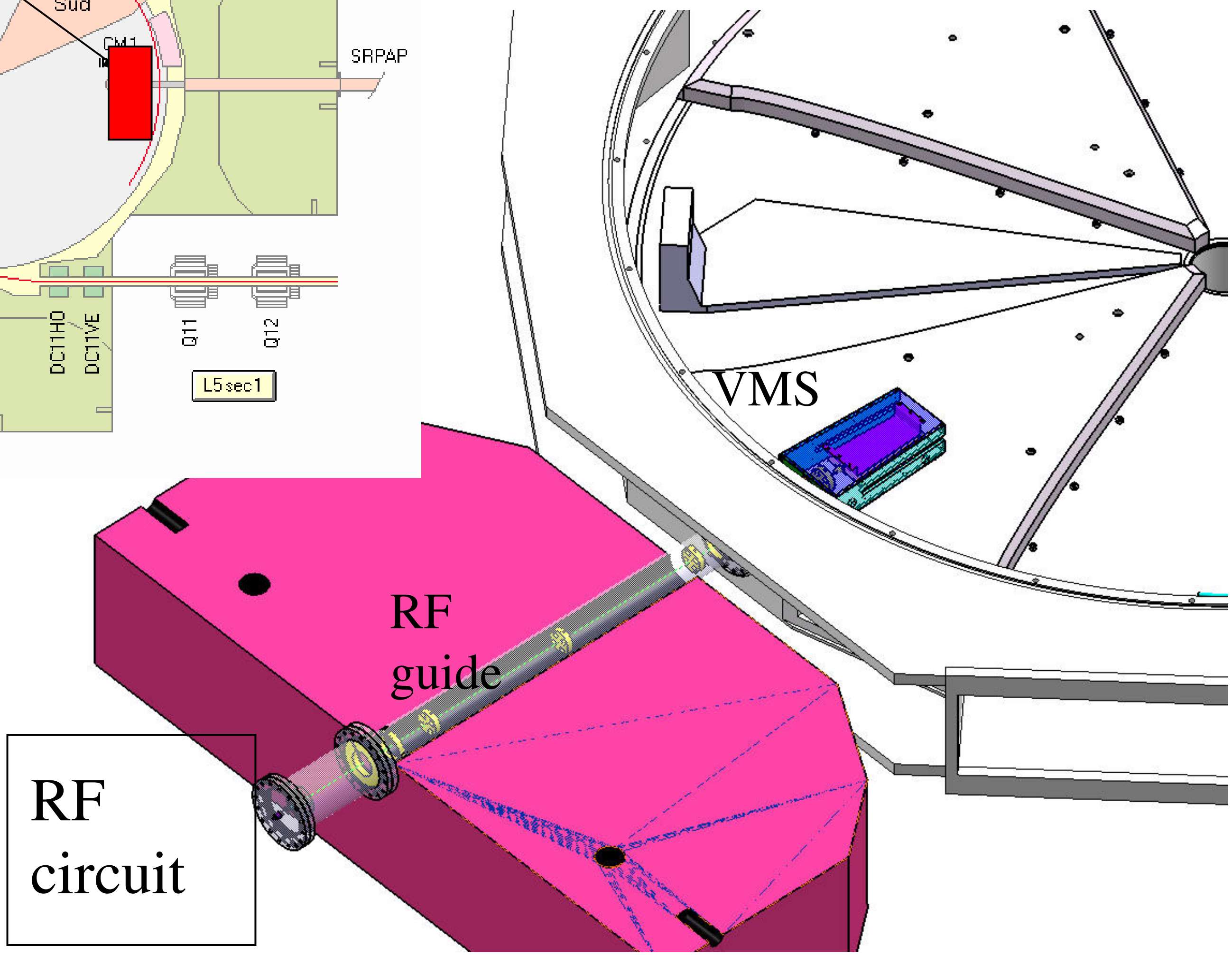


Neutrons for science
Atomic & solid state physics
Radiobiology & Isotope production

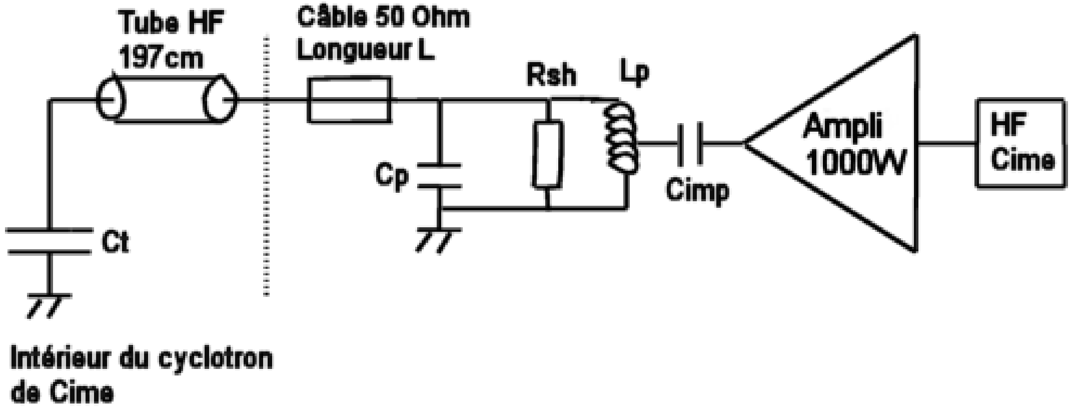
SPIRAL 2 White Book: www.ganil.fr

The new vertical separator device





RF circuit



Cimp : Condensateur variable pour adapter le circuit à 50 Ohm

Lp : Self fixe du circuit RLC

Cp : Condensateur variable du circuit RLC

Rsh : Résistance d'environ 200Ohm d'une puissance de 1500 Watts

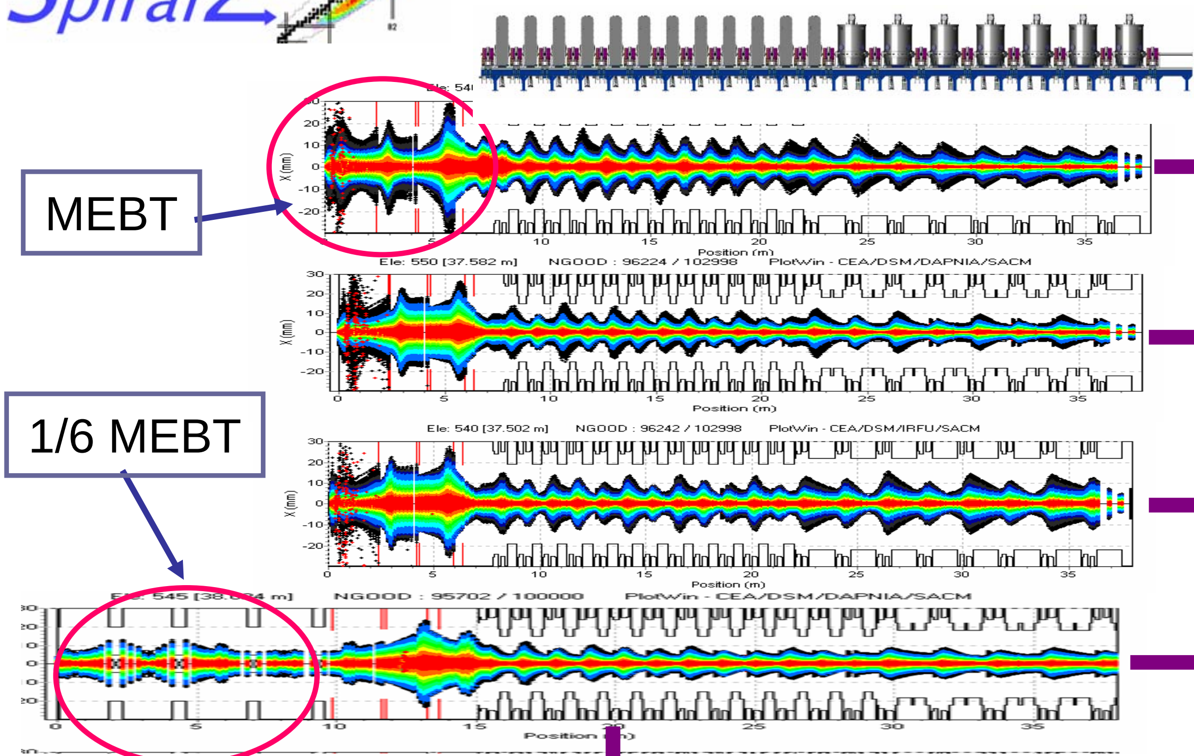
Câble de 50 Ohm sa longueur varie suivant la fréquence de travail

Le tube H.F mesure 1970mm pour un diamètre de 80mm.

Ct : C'est la capacité équivalente du Trieur Vertical, environ 33pF

Le signal entrant sur l'amplificateur provient de la cavité de cime, la fréquence de ce signal est multipliée par 2, avant d'être mixée par un signal BF. Pour produire la modulation d'amplitude (AM)

88 MHz SC-LINAC

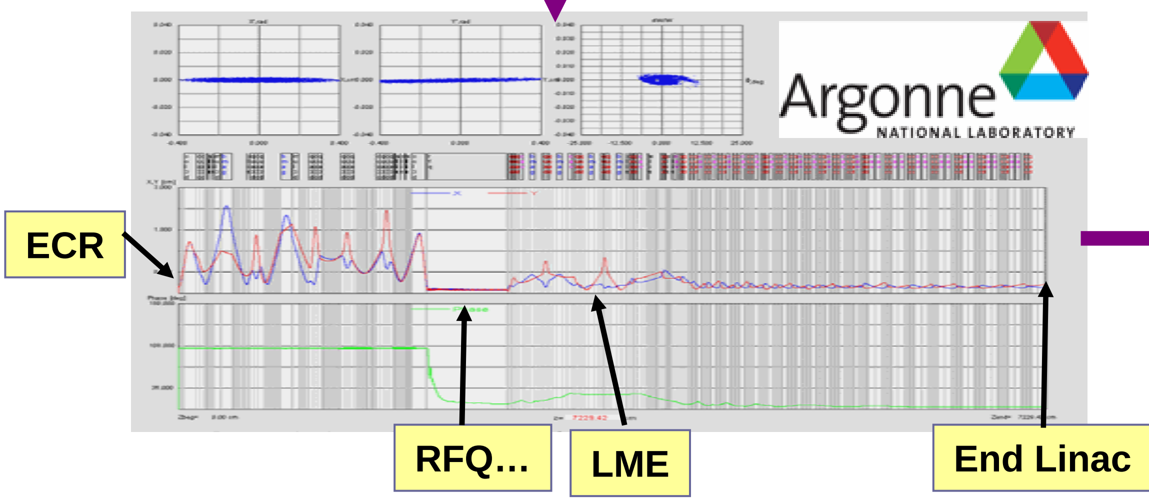


Deuterons 5 mA , 40 MeV

q/A=1/3,1 mA , 14.5 MeV/A

q/A=1/3 1 mA , 2 MeV/A

q/A=1/6 1 mA , 2 MeV/A



Track code (P. Ostroumov)
End-to-end for 0.5 mA
q/A=1/6 1 mA , 8.5 MeV/A