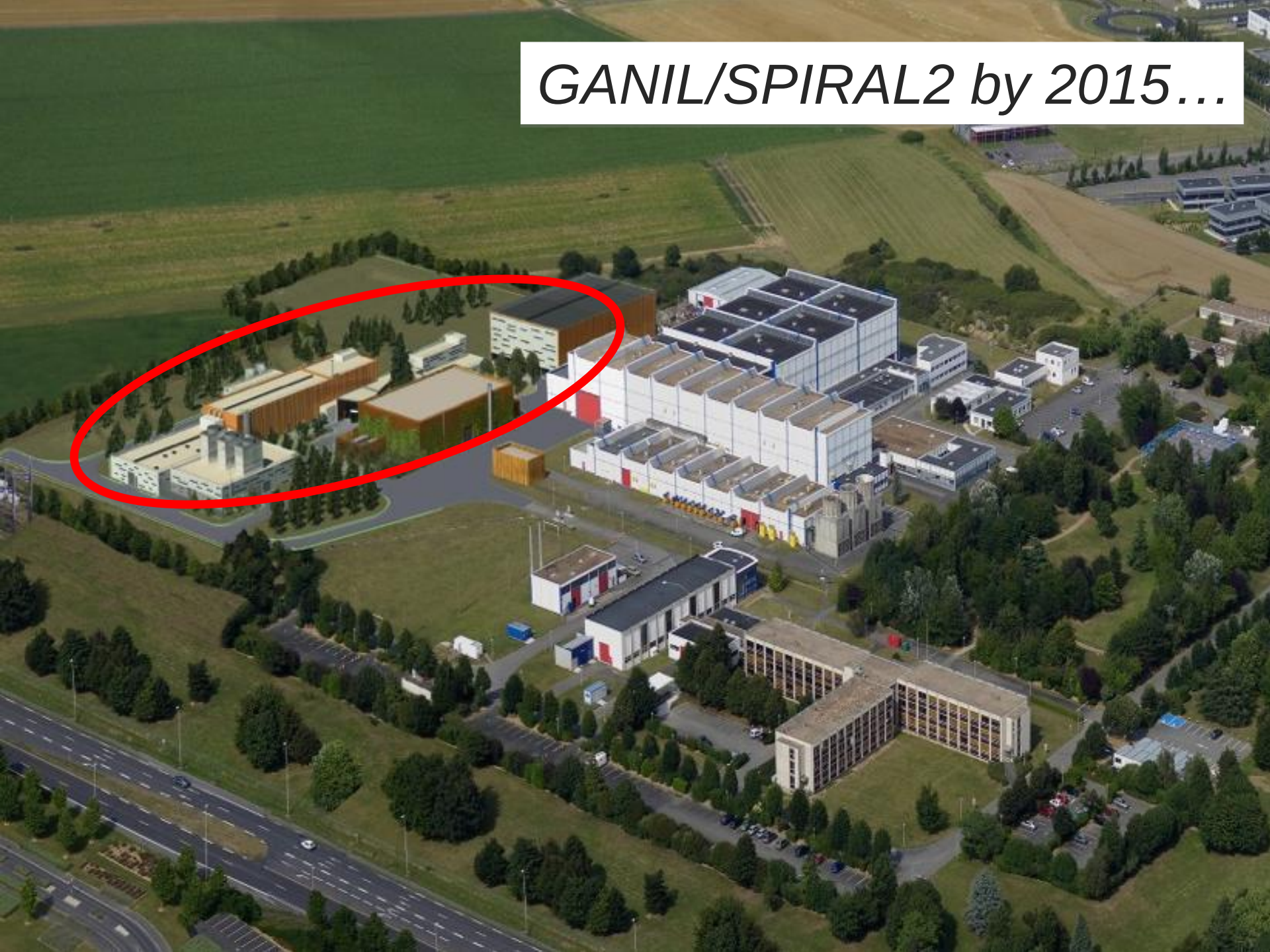
SPIRAL2 accelerator
Construction progress

Patrick Bertrand

On behalf of the SPIRAL2 Project Group


GANIL/SPIRAL2 by 2015…

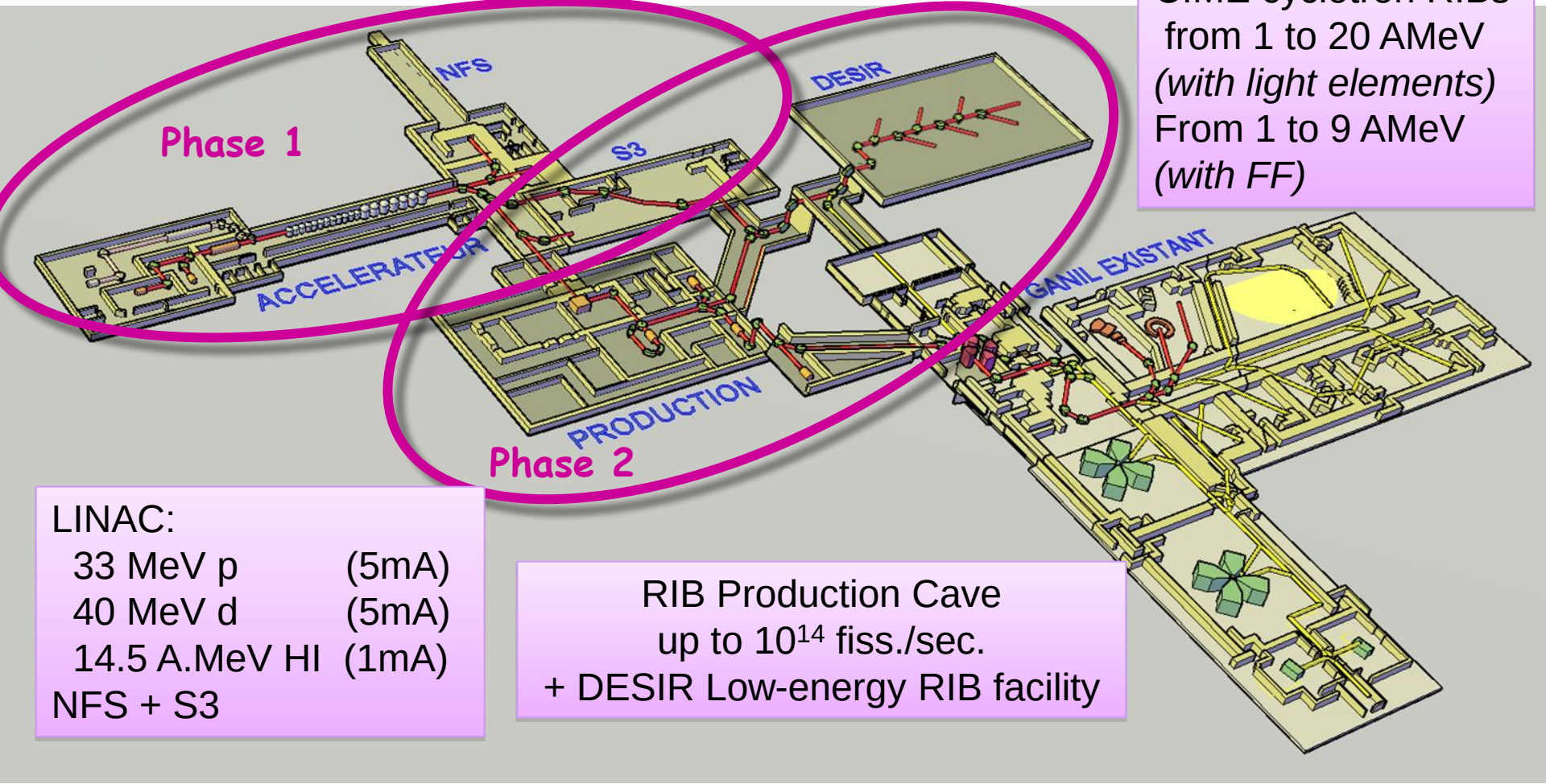
SPIRAL2-GANIL Layout

SPIRAL2 under construction:

Phase 1: High intensity stable beams in 2014 + Experimental rooms (S^3 + NFS)

Phase 2: High intensity Radioactive Ion Beams (RIBs)

CIME cyclotron RIBs
from 1 to 20 AMeV
(with light elements)
From 1 to 9 AMeV
(with FF)



LINAC:
33 MeV p (5mA)
40 MeV d (5mA)
14.5 A.MeV HI (1mA)
NFS + S3

RIB Production Cave
up to 10^{14} fiss./sec.
+ DESIR Low-energy RIB facility

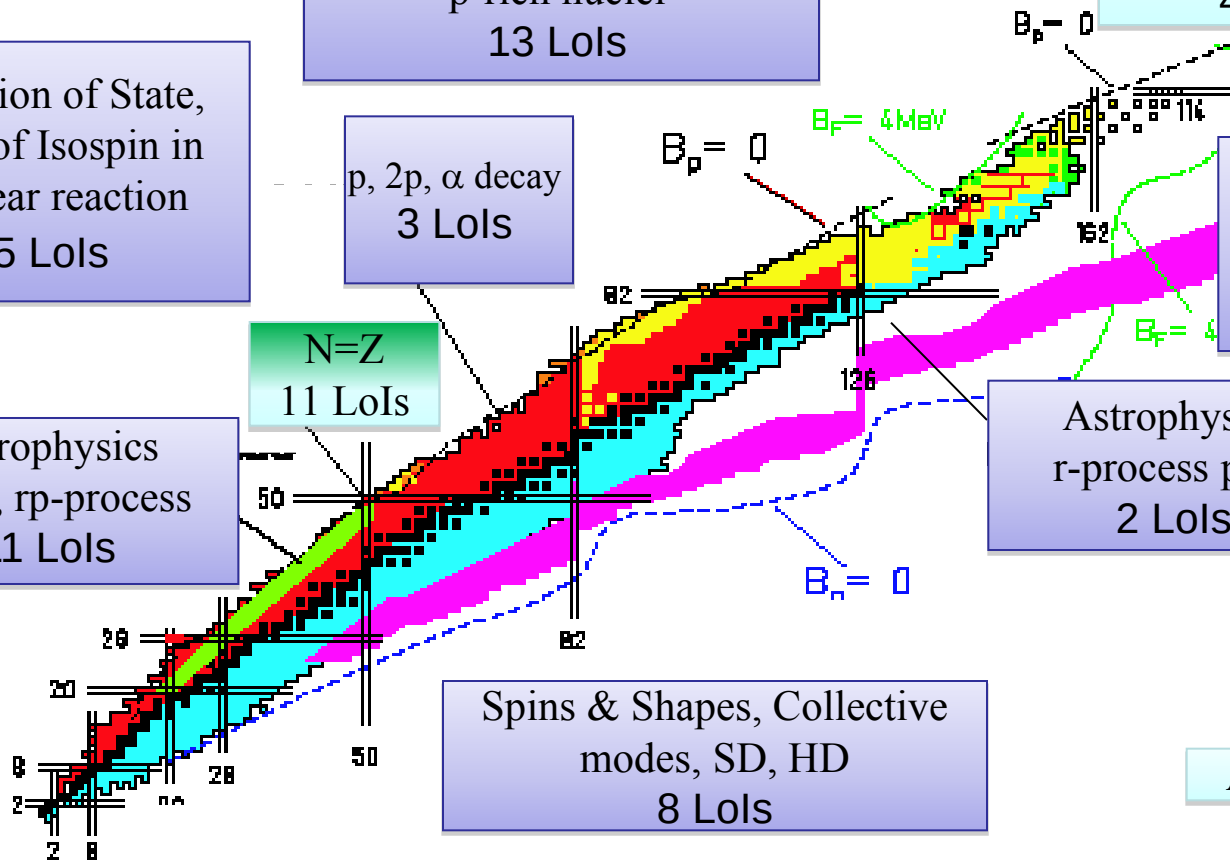
82 Letters of Intent (>1000 authors) for the Day 1 experiments at SPIRAL2

Shell structure
very far from stability in
p-rich nuclei
13 LoIs

Heavy and Super
Heavy Elements
4 LoIs

Equation of State,
Role of Isospin in
nuclear reaction
5 LoIs

p, 2p, α decay
3 LoIs



Shell structure
very far from stability in
n-rich nuclei
22 LoIs

N=Z
11 LoIs

Astrophysics
CNO, rp-process
11 LoIs

Astrophysics
r-process path
2 LoIs

Neutrons for science
13 LoIs

Spins & Shapes, Collective
modes, SD, HD
8 LoIs

Atomic physics 1 LoI

PHASE 2: 53 LoIs

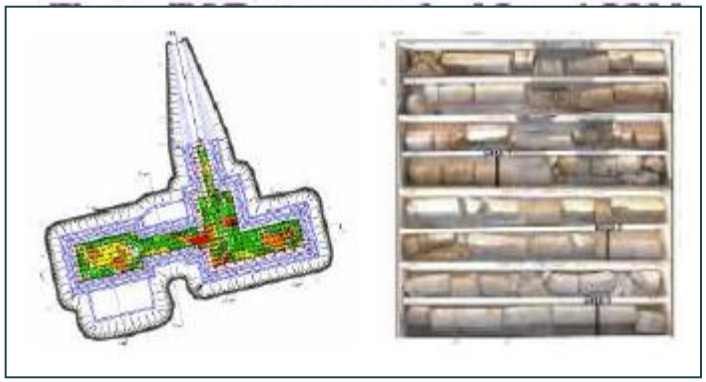
PHASE 1: 29 LoIs

Construction of SPIRAL2 Phase 1 building

Preparation of the site in November 2010

Construction of SPIRAL2 Phase 1 building

Excavations ready May 2011



Detection of anomalies by micro-gravimetry and core drilling...

Construction of SPIRAL2 Phase 1 building

The same view in May 2012…

Construction of SPIRAL2 Phase 1 building

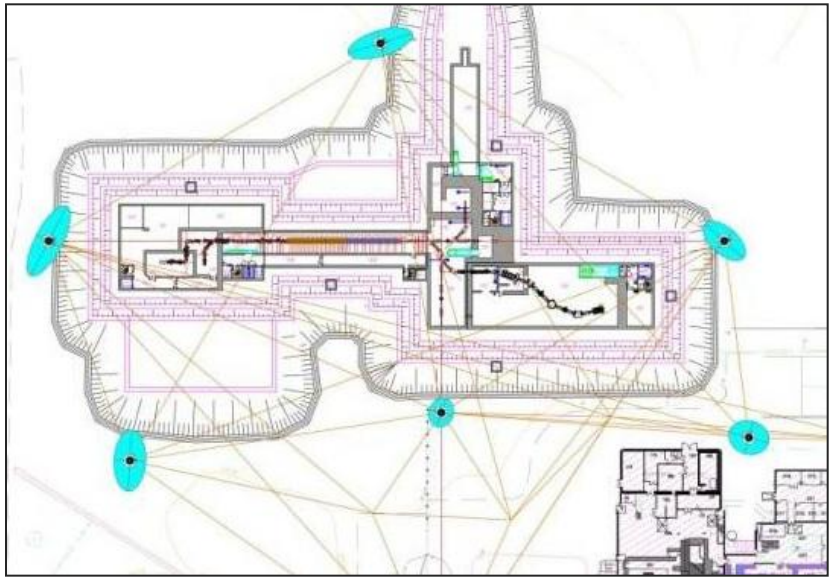
1/3 room ready to receive
the ECR source and LEBT1

Linac tunnel preparation

S3 experimental hall

NFS experimental hall

"Let no one ignorant of geometry enter…" (Plato)



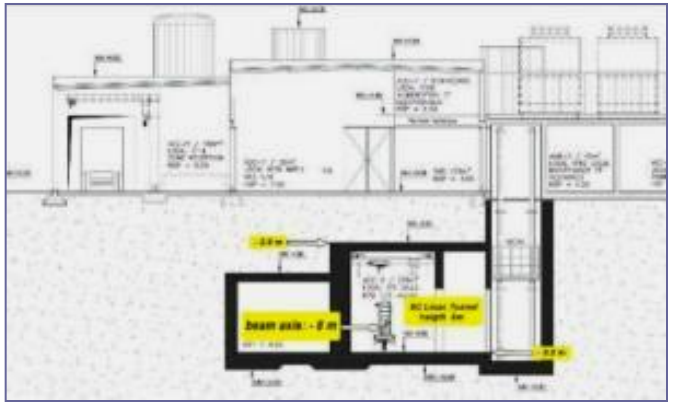
Preparation after excavation …

…and underground preparation of the **alignement** process...

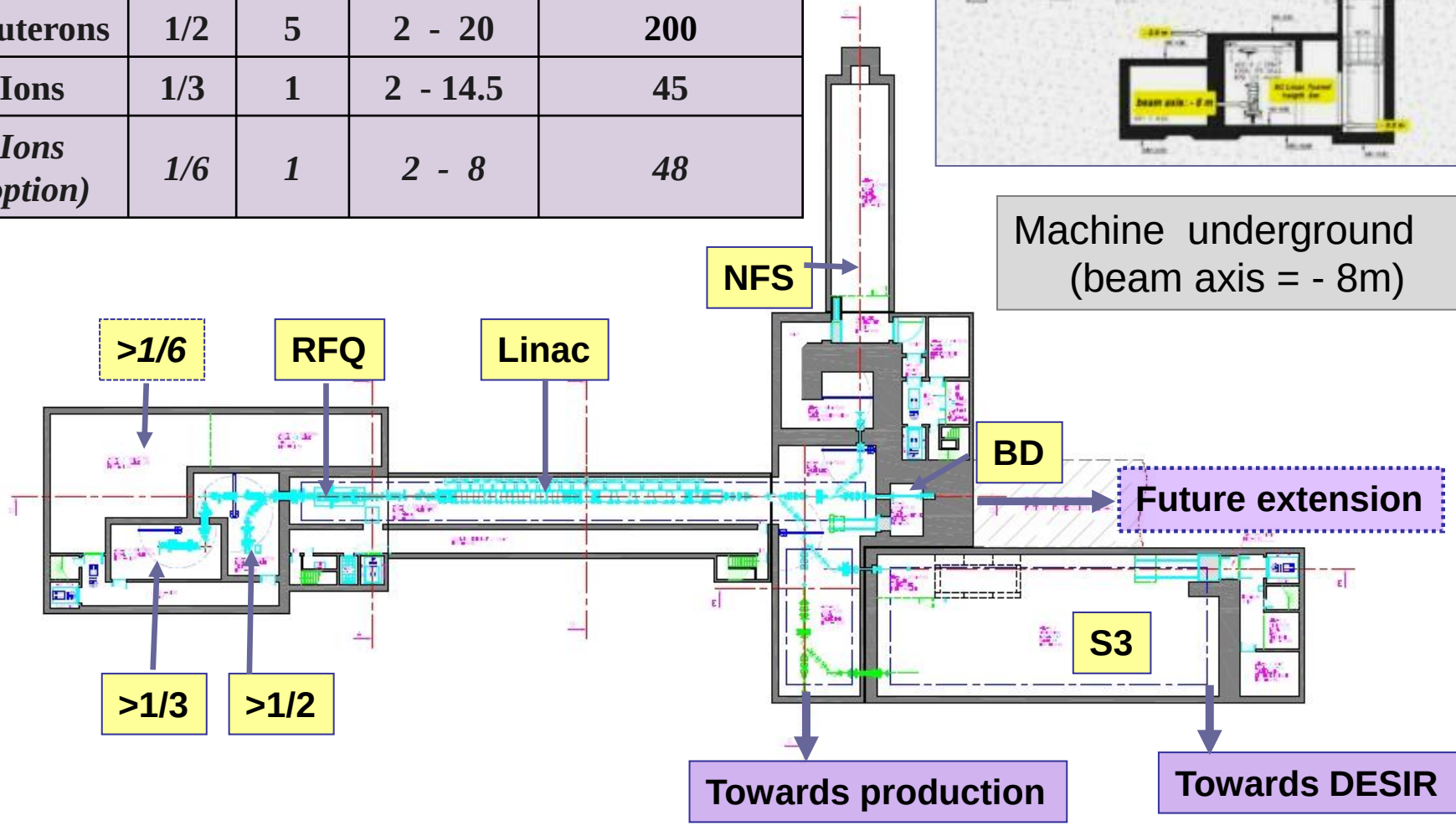
R. Beunard et al.
"…SPIRAL2 Geodetic Network…"
IWAA2012, Batavia, Sept. 2012.

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)



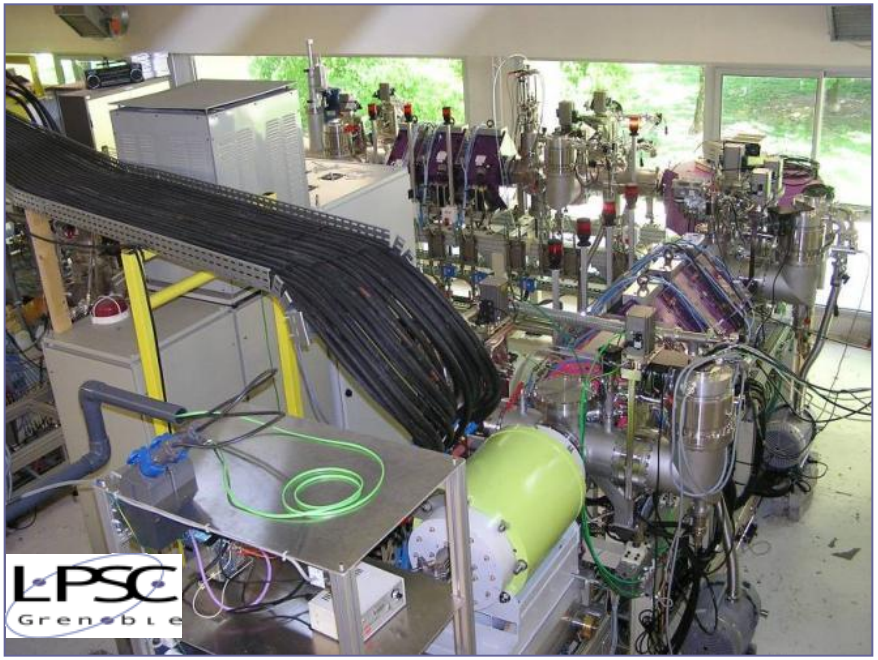
Our optimisation strategy for the construction of the Spiral2 accelerator

- **Build prototypes** when possible (RFQ, cavities, amplifiers, LLRF…)
- Run a maximum of **technical and assembly tests** in laboratories and/or with companies
- Run **beam tests** at LPSC/Grenoble and IRFU/Saclay

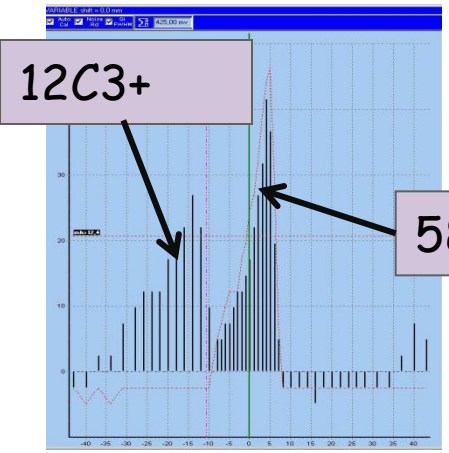
  . Collaboration between teams
  . Validation of the Design et the beam dynamics
  . Gain time for the installation/tests at GANIL/SPIRAL2 site

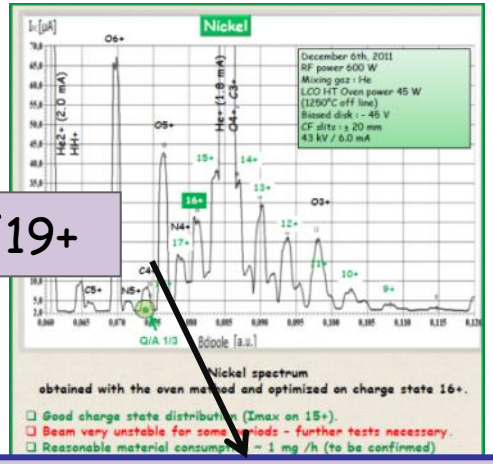
- Optimise the interweaving between the **building planning** and the **accelerator planning**

Phoenix-V2+LEBT1 beam tests (LPSC Grenoble)



RESULTS FOR GASES		
	I max for Q optimum	**I max for Q/A 1/3**
4He	> 2 mA ¦ 2+ non opt.	> 2 mA ¦ 2+ non opt.
16O	1.3 mA ¦ 6+	**1.3 mA ¦ 6+**
40Ar	450 µA ¦ 9+ 350 µA ¦ 11+	175 µA ¦ 12+ Isotope 36 --- 70 µA ¦ 13+ Isotope 40 --- 22 µA ¦ 14+ Isotope 40
86Kr	110 µA ¦ 17+	non measurable

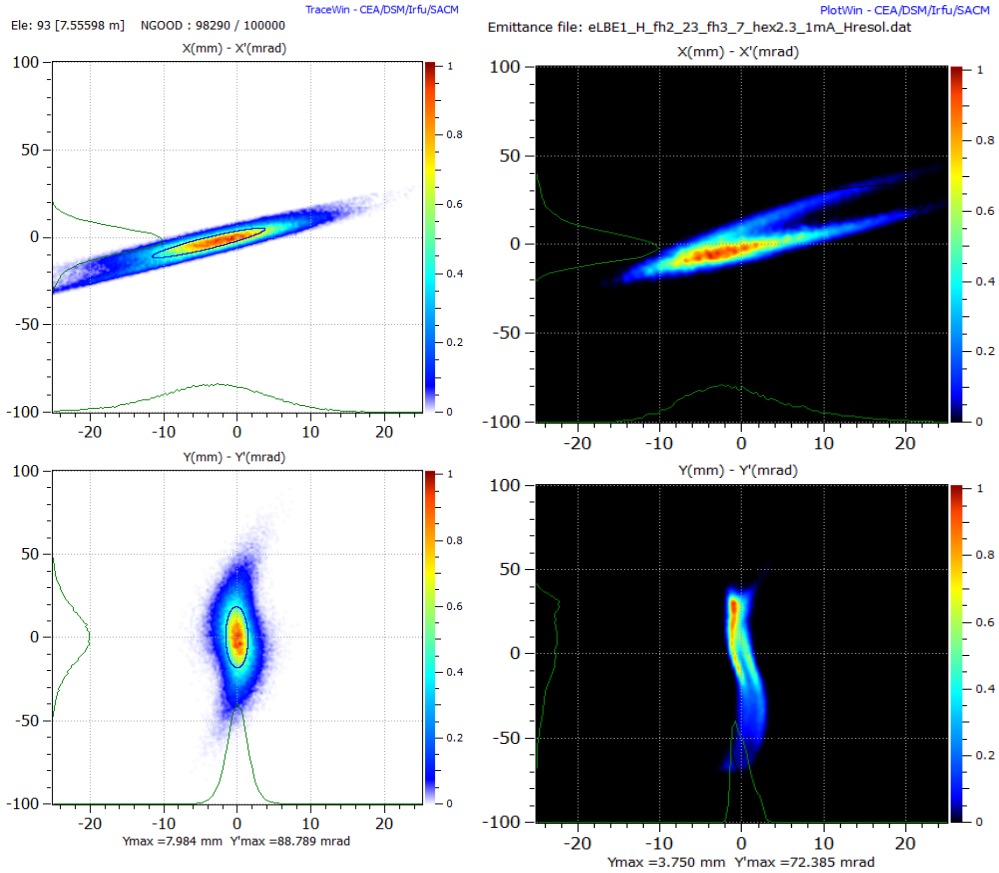




58Ni19+

20 µAe Ni 19+ obtained

Phoenix-V2+LEBT1: Technical and beam tests



Simulation

Beam test

$^{16}O^{6+}$ at 53.33.kV

Source Voltage : 53.33 kV

Q/m : 1/2.66

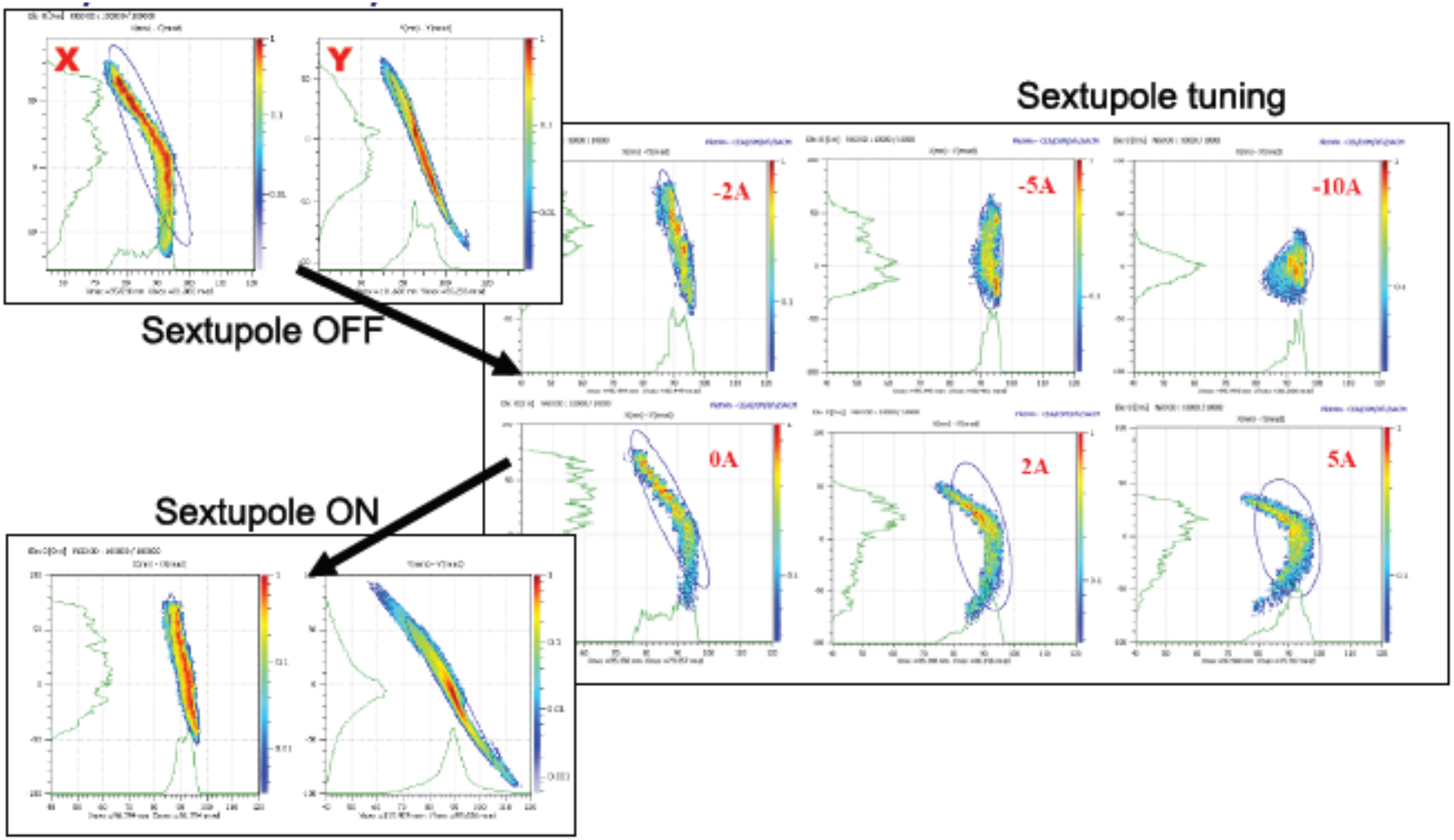
Beam Intensity : 1.3 mA

Measured emittances
(π.mm.mrad norm.rms)

Horizontal : 0.25
Vertical : 0.14

stable 62 kV reached

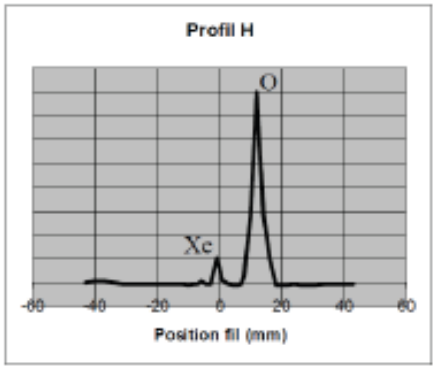
Phoenix-V2 + LEBT1: Optimisation of emittances

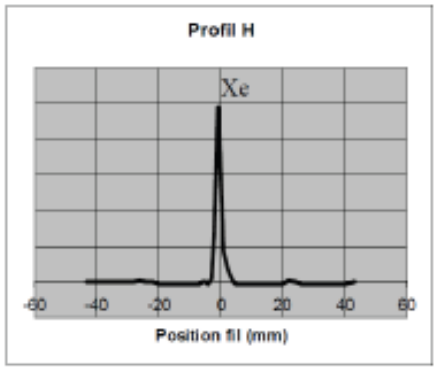


Phoenix-V2 + LEBT1: Purification of the beam

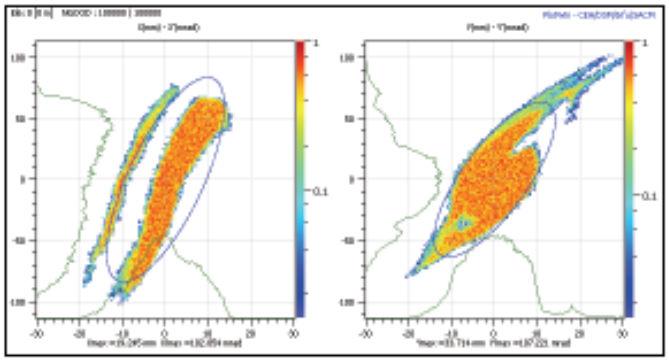
Milestone « Separation 100 » → OK

Experimental validation of the line separation power (> 100 in q/A), using a Xenon beam and **separating $^{132}Xe^{25+}$ (~10uA) from « pollutant » $^{16}O^{3+}$ (~300uA)**

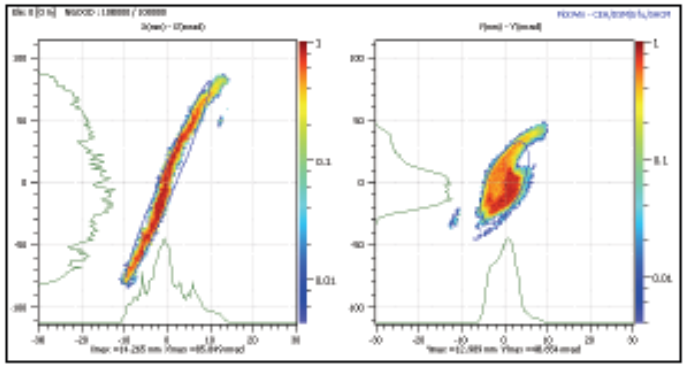




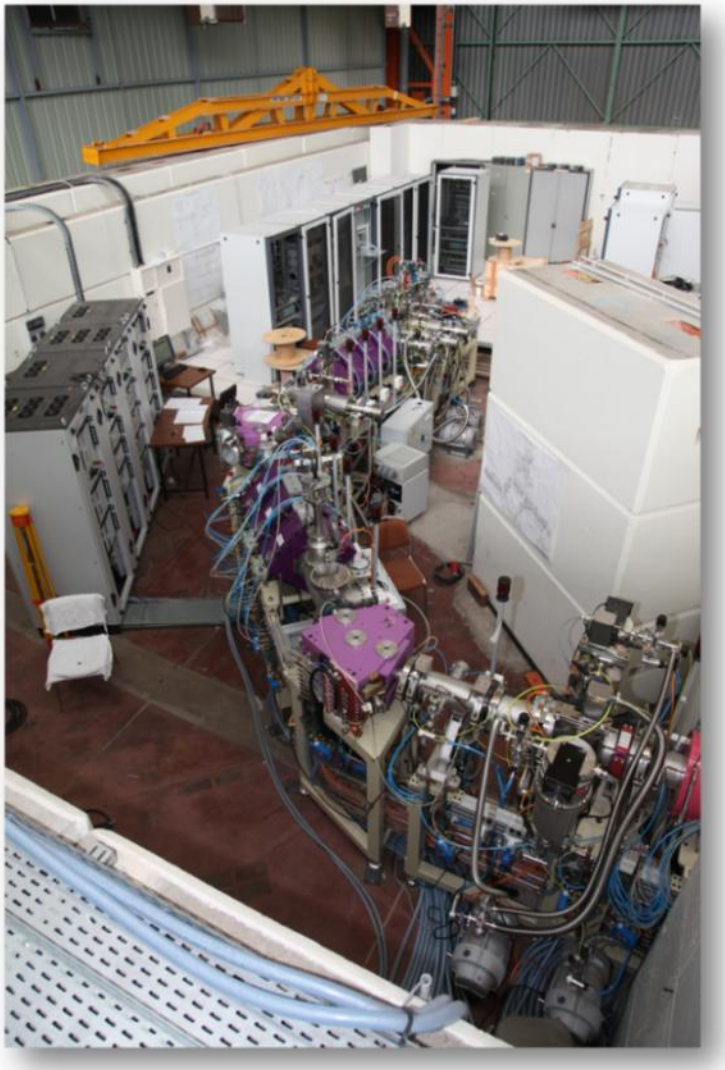
Separation slits opened



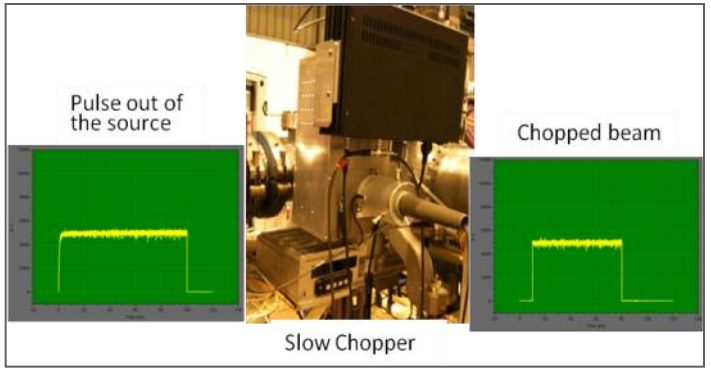
Separation slits closed (+/-5mm)



Deuteron/proton ECR + LBE2+LBEC beam tests (IRFU – Saclay)

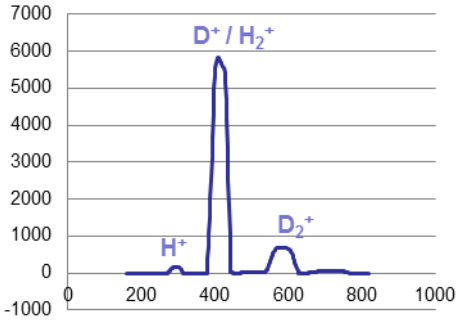


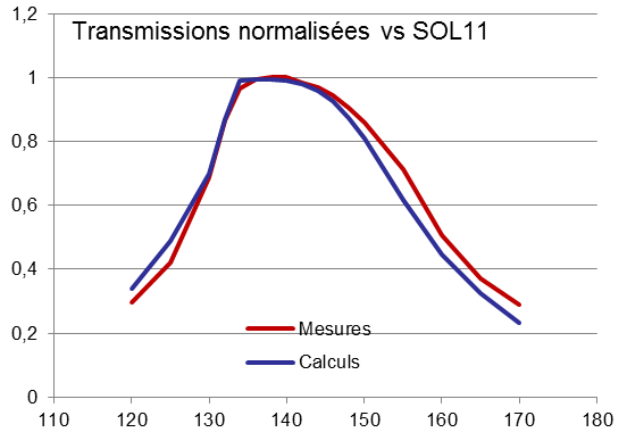
- LBEC beam line added in 2011 with all instrumentation and Interlocks. **(up to RFQ entrance)**
- **More than 5 mA proton or Deuteron** beam conducted to **end LBEC** in September 2011
- Slow chopper tested with success . *(developed by Catania)*

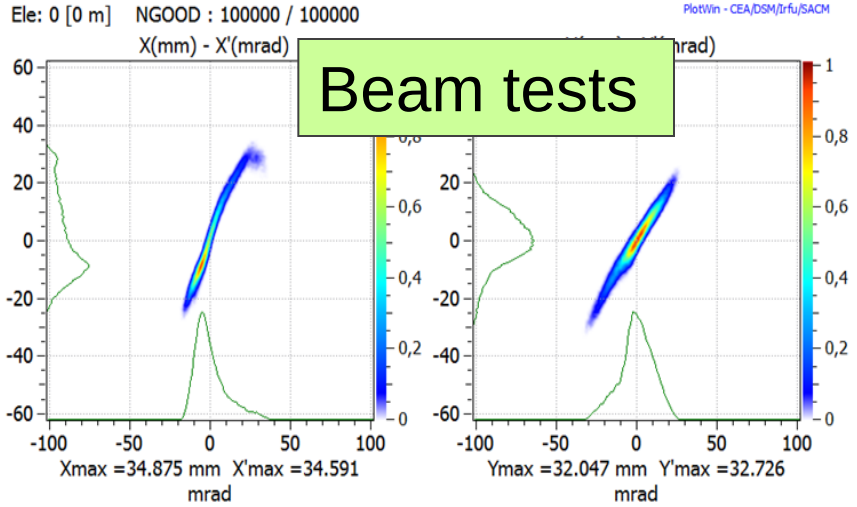


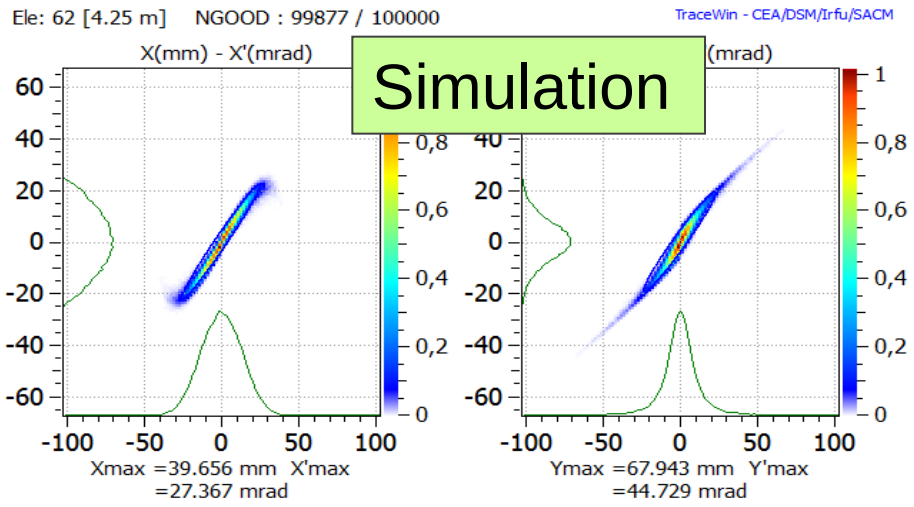
Beam tests results for Deuterons

Ion	Proportion	Courant
Ions	100 %	6.9 mA
H^+	2.1 %	0,15 mA
H_2^+	0,5 %	0.035 mA
D^+	83 %	5.8 mA
D_2^+	9.7 %	0.68 mA
D_3^+	0 %	0 mA
Ions lourds	3.5 %	0.25 mA



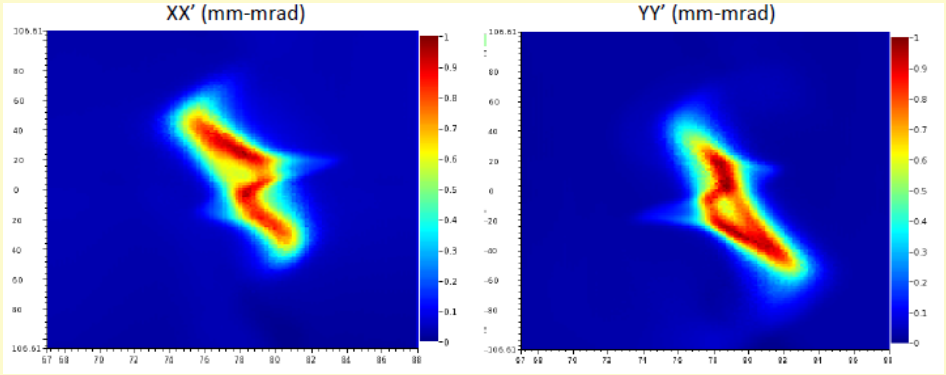






Nominal emittance : ~0.18 π.mm.mrad rms norm
Emittance = key parameter for the Linac !!

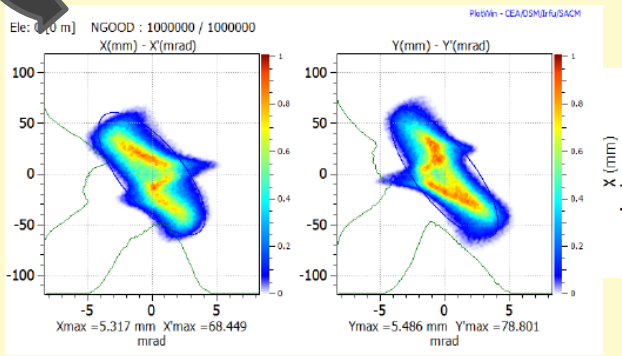
Beam tests results for Deuterons



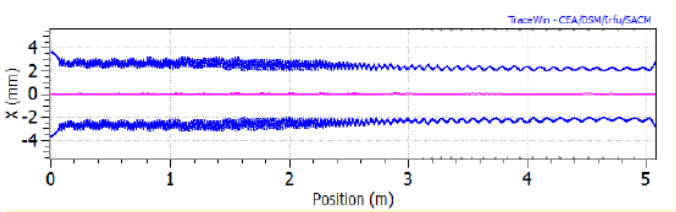
Real beam matched at RFQ entrance,
Measured with the emittancemeter

$\varepsilon_{xx'}$	0.23 π.mm.mrad
$\beta_{xx'}$	0.095 π.mm/mrad
$\alpha_{xx'}$	0.99
$\varepsilon_{yy'}$	0.22 π.mm.mrad
$\beta_{yy'}$	0.10 π.mm/mrad
$\alpha_{yy'}$	1.17

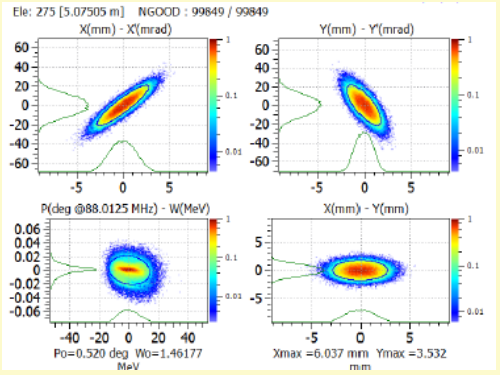
Emittance measured
at RFQ entrance



Generation of particles
with TRACEWIN code…

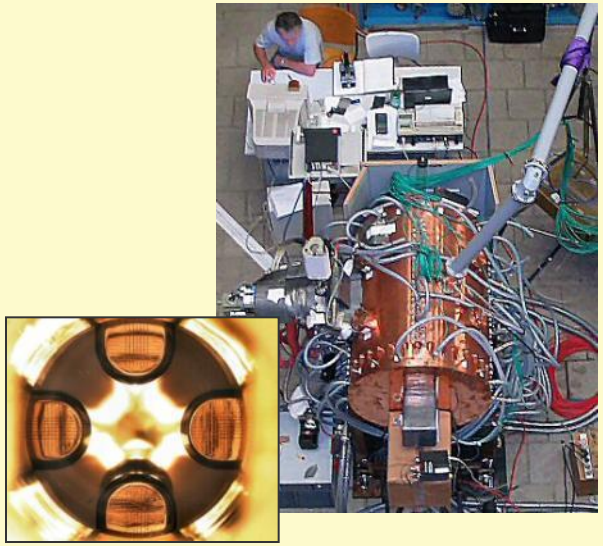


Sent into the RFQ…
accelerated and bunched

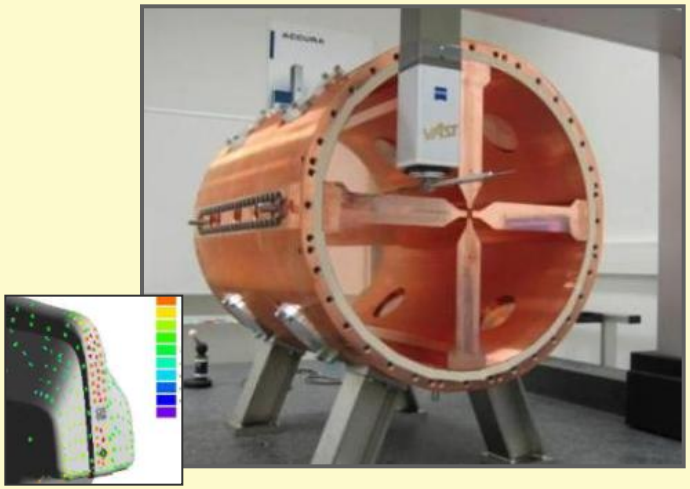


Emittance obtained
at RFQ exit

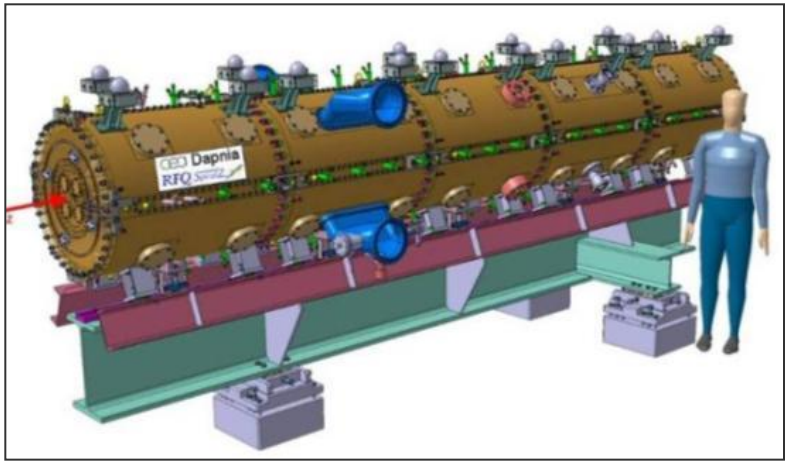
RFQ Status (IRFUSaclay design)



Prototype tested at full power



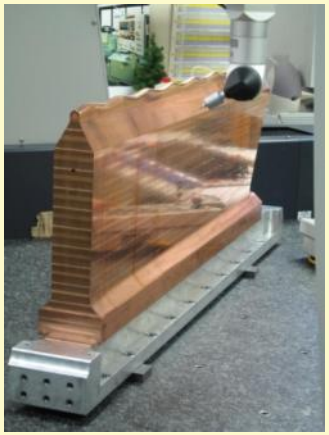
T5 segment - 3D measurements



- 88.05 MHz, 4-vanes, 5 meters long
  more than 97% transmission
- Segment T5 fabricated and accepted
  (but revealed vacuum gasket problems..)
- T1 .. T4 tubes achieved
- All vanes pre-machined (500 µm) and assembled into tubes
- *RFQ segments should be ready by end 2012*

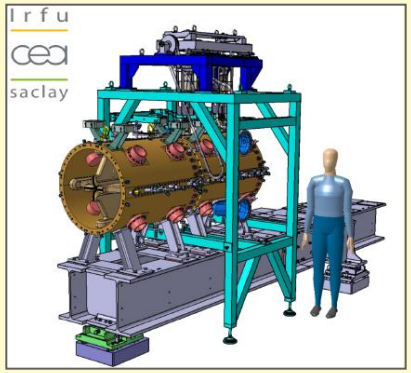
RFQ Status (IRFU – Saclay)

Tubes T1..T4 machined



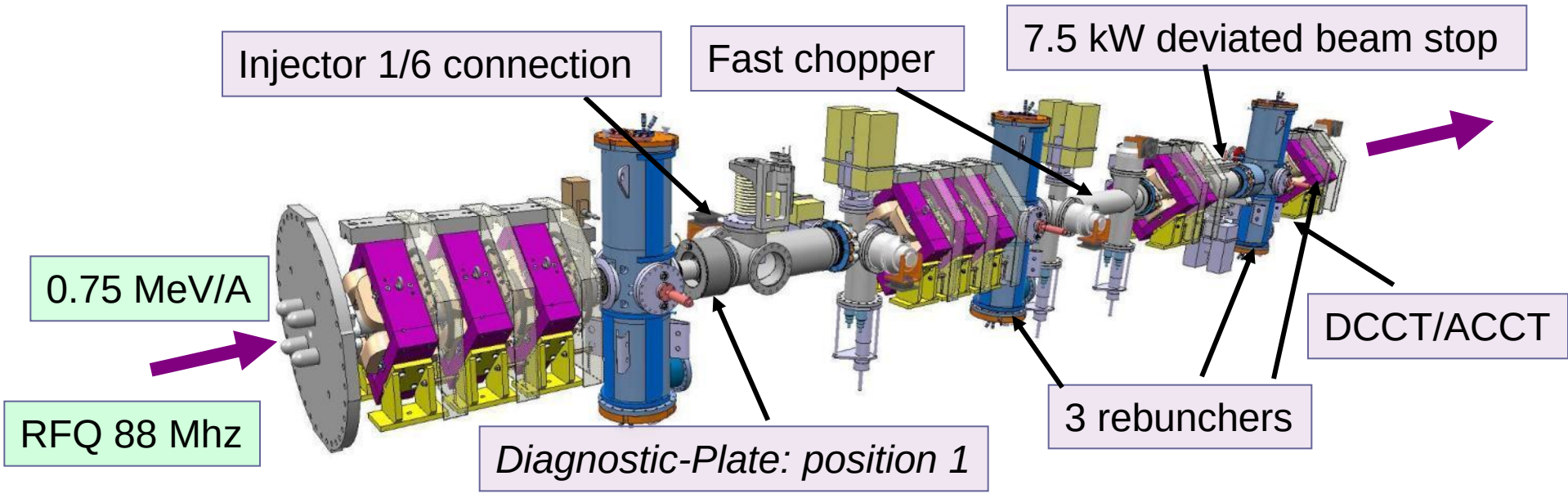
Machining and 3D measurement of the vanes

3D Measurement of tubes T1..T4

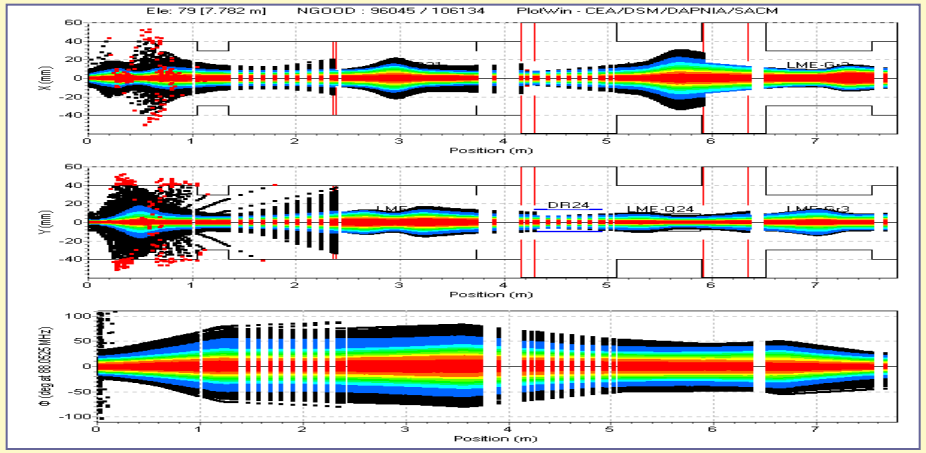


Assembly system ready
(T4+T5 assembled at Saclay ASAP)

The MEBT Challenge…



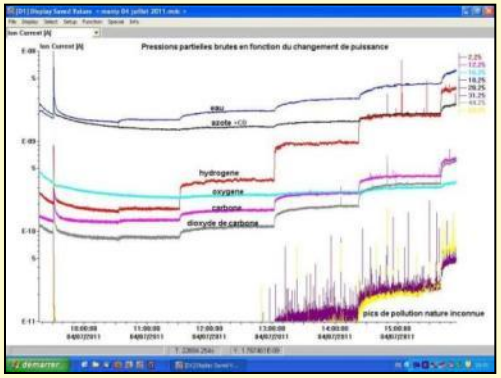
- Accepts **future 1/6 beams** Injector
- **Fast chopper** and deviated beam stop.
- Protect the linac against **halo**
  → *3 sets of H-V slits*
- **Match all types of beams** to linac
- Non interceptive **measurement of beam intensity** at Linac Entrance



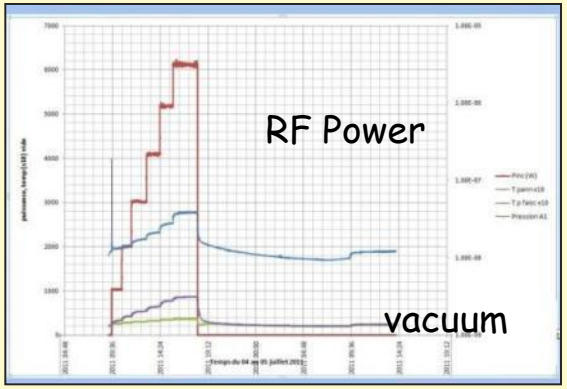
MEBT: First rebuncher Tested at GANIL



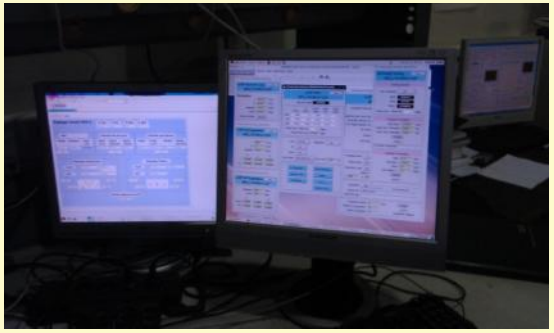
The first 3-gap rebuncher



Vacuum analysis (2011)

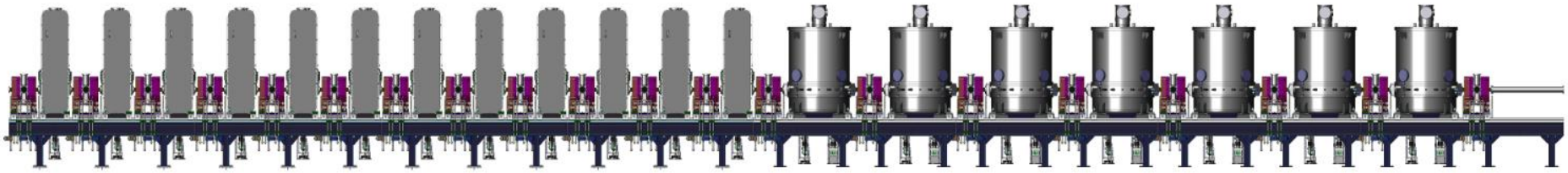


RF long duration tests at 6 kW (2011)



Tests of new LLRF + C/C (GANIL+IRFU, June 2012)

SC LINAC: 88 MHz QWR cavities with short cryomodules, and warm focusing sections…



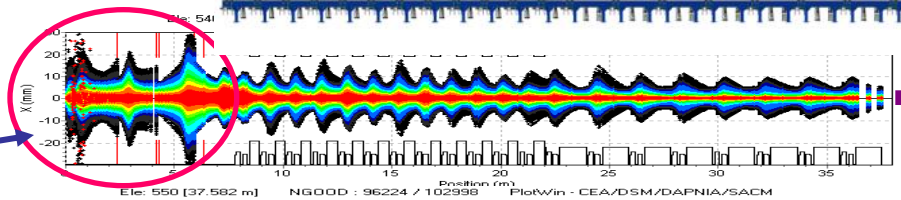
12 low beta cryomodules (0.07) and 7 high beta cryomodules (0.12)
L≈35 m

Assembly test
Cryo A + Warm section

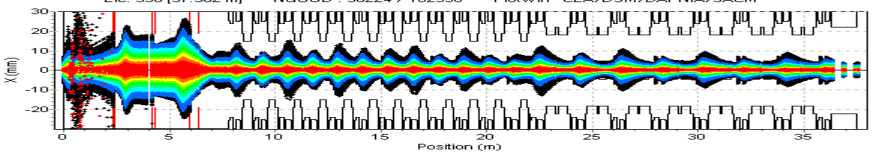
Cryomodule	A	B
Valve-to-valve length [mm]	610	1360
# cavities	12	14
f [MHz]	88.05	88.05
β_{opt}	0.07	0.12
Epk/Ea	5.36	4.76
Bpk/Ea [mT/MV/m]	8.70	9.35
r/Q [Ω]	599	515
Vacc @ 6.5 MV/m & β_{opt}	1.55	2.66
Lacc [m]	0.24	0.41
Beam tube ∅ [mm]	38	44

Design of the 88 MHz Linac using Tracewin code…

MEBT

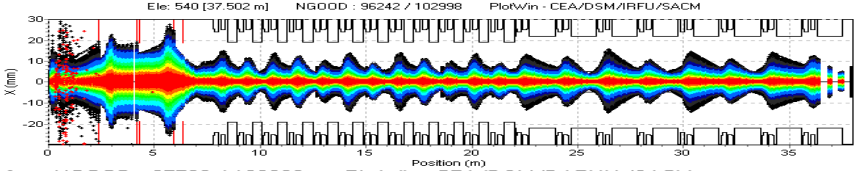


Deuterons 5 mA , 40 MeV

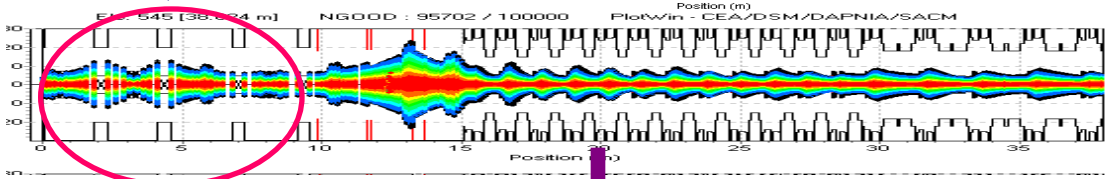


q/A=1/3,1 mA , 14.5 MeV/A

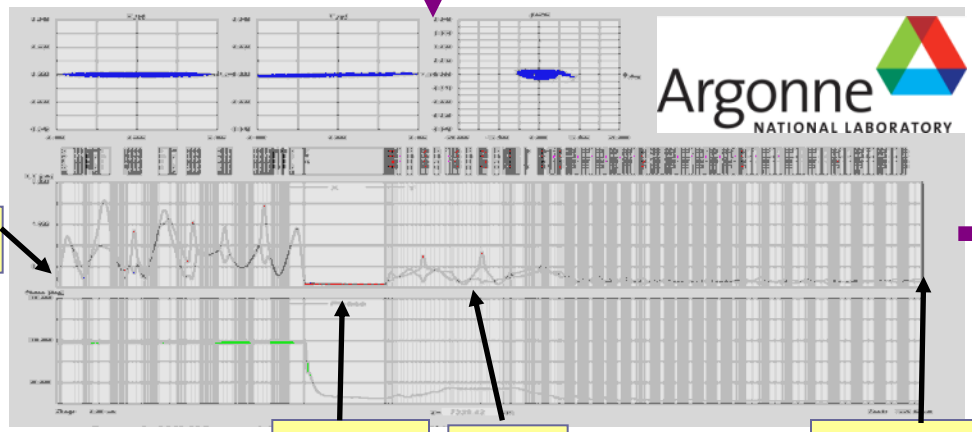
1/6 MEBT



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



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



ECR

RFQ…

LME

End Linac

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

LINAC cryomodules, couplers and amplifiers…

A

IRFU/Saclay

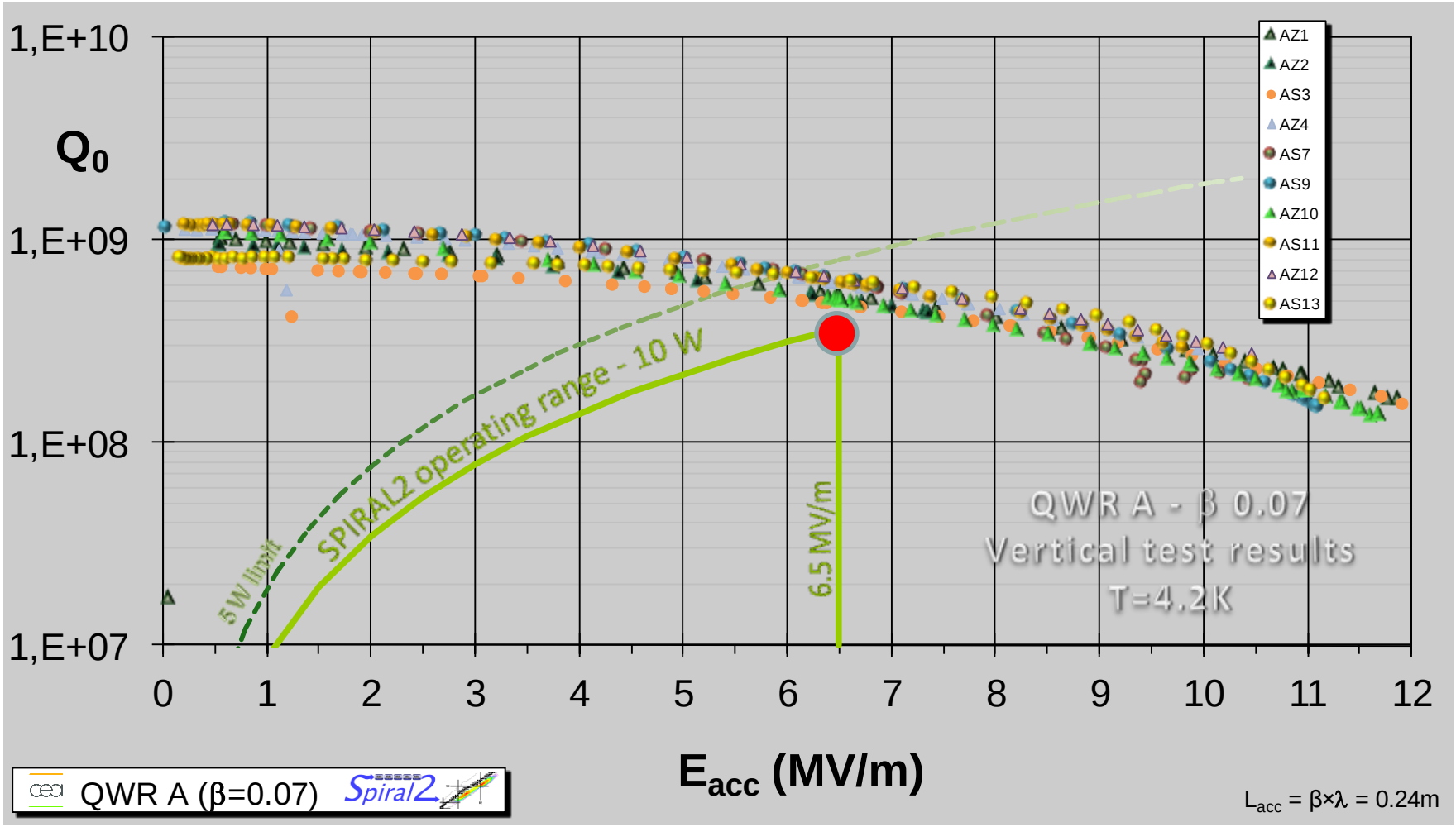
GANIL/Caen

LPSC/Grenoble

B

IPNO/Orsay

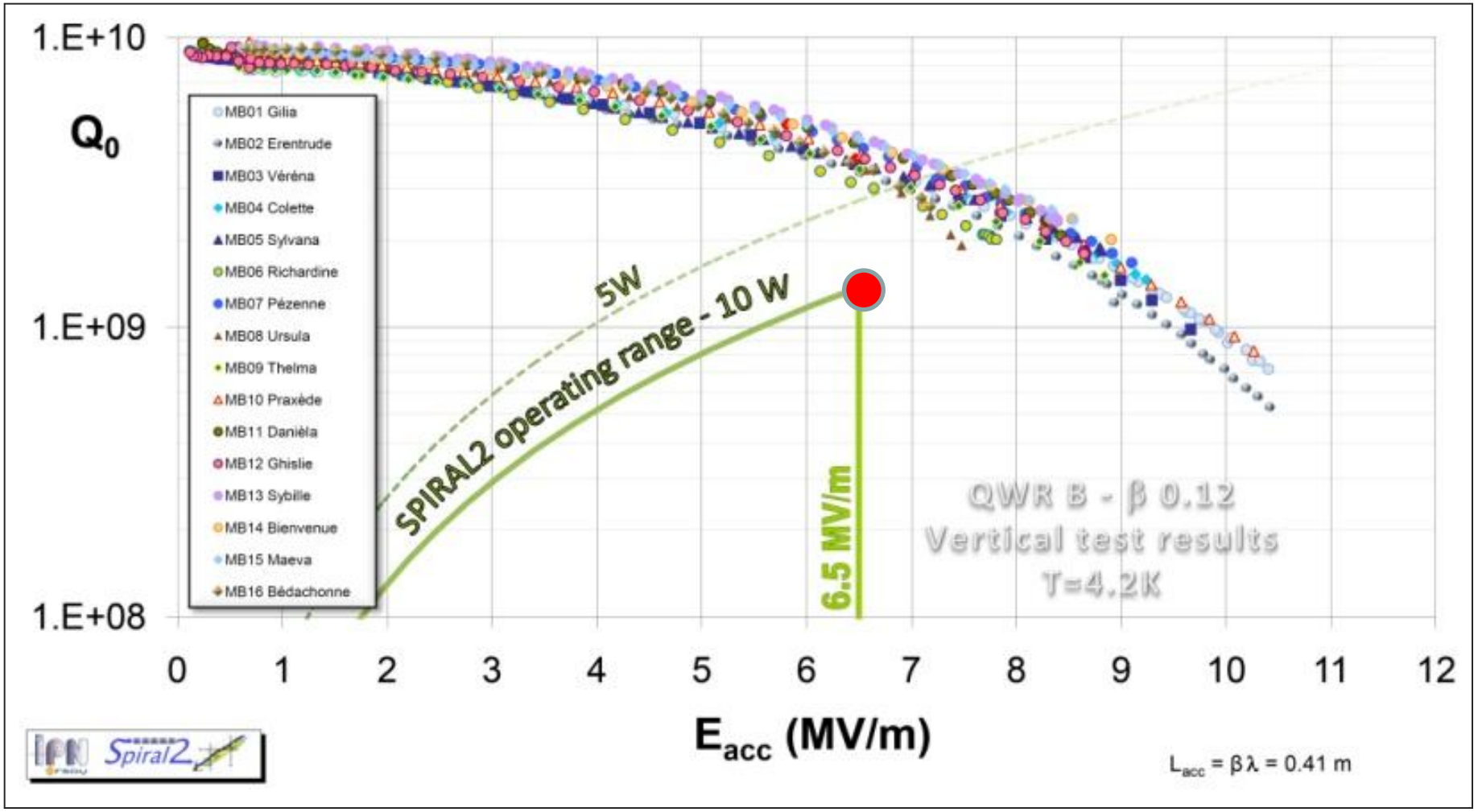
Performance of beta=0.07 cavities (VC)



« Low beta » Status

- **Cavities :**
  - All cavities qualified (in VC, last one in July 2012)
  - One spare cavity being repaired by manufacturer
- **Cryostats :**
  - Three cryomodules tested
  - One cryomodule fully qualified *without* Full Power Coupler
  - **One cryomodule conditioned and qualified with FPC**
  - Cryomodules assembling is started
  - All CMA to be delivered to GANIL **before end 2013**

Performance of beta=0.12 cavities (VC)



« High beta » Status

- **Cavities :** *(16 series cavities for 14 needed)*
  - All cavities tested and qualified (in VC, 2010)
  - One cavity needs repair at IPNO/orsay

  (too high Frequency…)

- **Cryostats :**
  - All manufactured
  - Cryomodules assembling is started
  - All CMA to be delivered to GANIL **before end 2013**

For both families of cryomodules…

➢ **Major difficulty**: high RF dissipations in cavities, due to electron field emission.

• The pollution sources are now understood:

- unexpected dirty parts from vendors,
- partly inadequate cryomodule assembly procedures,
- inappropriate venting procedure,
- power coupler surface cleanliness (probably)

→ Qualification of all cryomodules subcomponents and the power coupler preparations were **entirely reviewed**, and **now it works !**

We also take care of **the warm section vacuum pipes,** preparing them in clean room

And LINAC Warm Sections..

All vacuum boxes fabricated

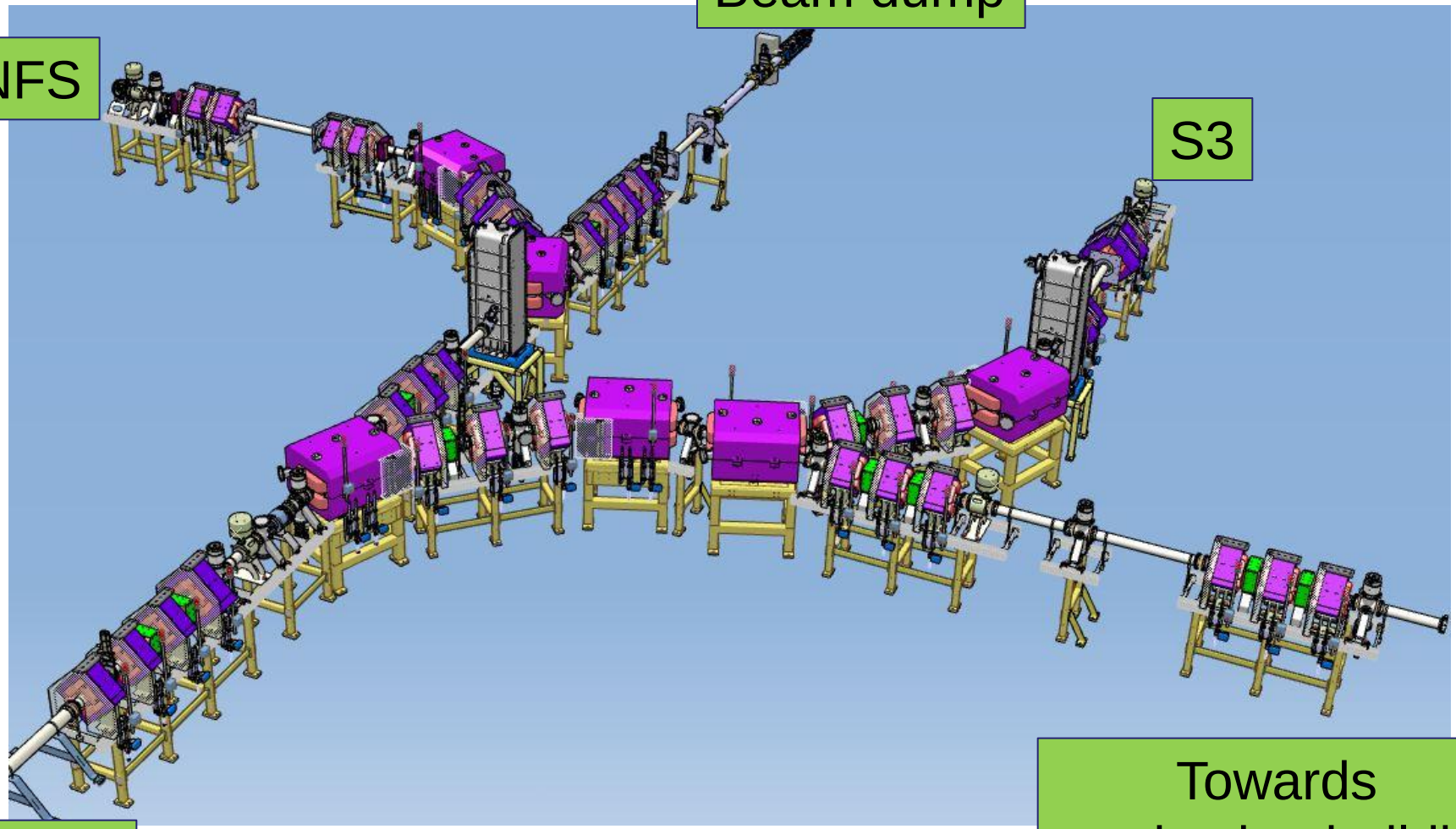
Quadrupole assembly

Box + qpole assembly…

Magnetic measurements

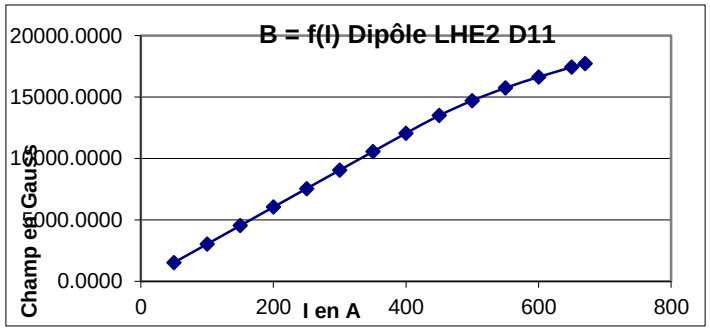
Insertion of one BPM

HEBT Lines



HEBT Magnets

- Dipoles all constructed
  - *All Dipoles received at GANIL*
  - *Magnetic measurement ongoing…*
- Quadripoles and steerers under fabrication



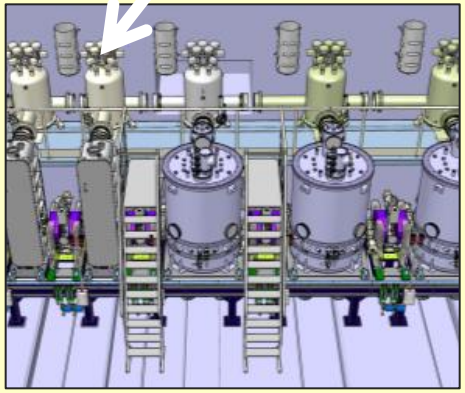
DIPOLES
Deviation angle 45°
Mass 6250 Kg
Imax 675 A
R = 105 mΩ
Q = 26 l/mn

- 21 Hall probes, every 1 cm in a thermostated box (35°)
- Mesh magnetic measurement : 5mm

Cryogenic system (IPN Orsay)

Helium gas buffer ready

Cold Box
Tested
last June

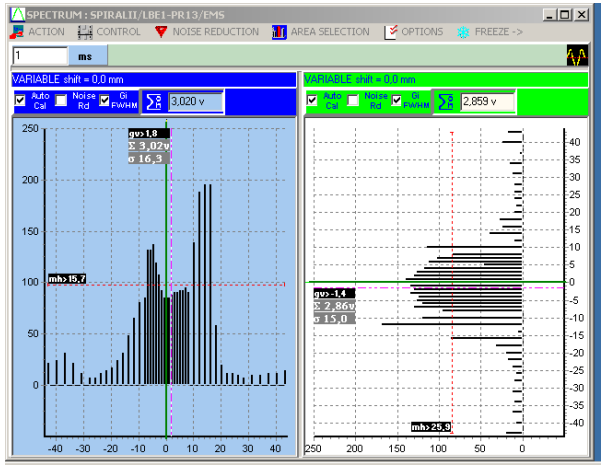


Valve boxes ready

Diagnostics: Secondary Emission Monitors

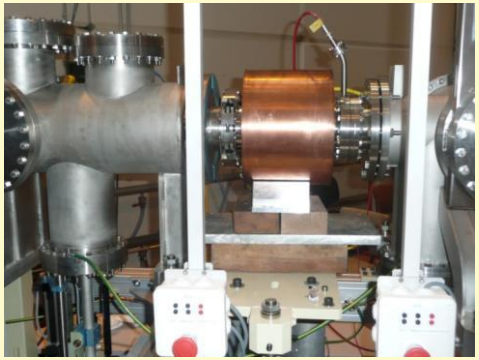
- 47 wires per monitor
- Fixed steps (0.5 mm, 1 mm)
- Variables steps (3mm..2mm..1mm)
- Wire diameter : 150 µ (70 µ for HEBT)

Diagnostics: Secondary Emission Monitors

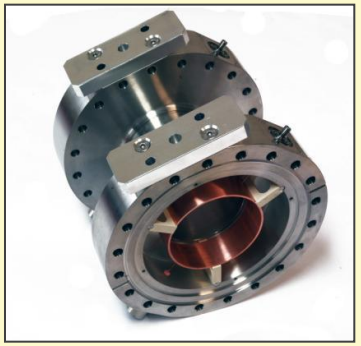


- 47 wires per monitor
- Fixed steps (0.5 mm, 1 mm)
- Variables steps (3mm..2mm..1mm)
- Wire diameter : 150 µ (70 µ for HEBT)

Diagnostics: Beam Intensity and Energy



ACCT/DCCT
tested at Saclay



Part of TOF device
(exit of the linac)

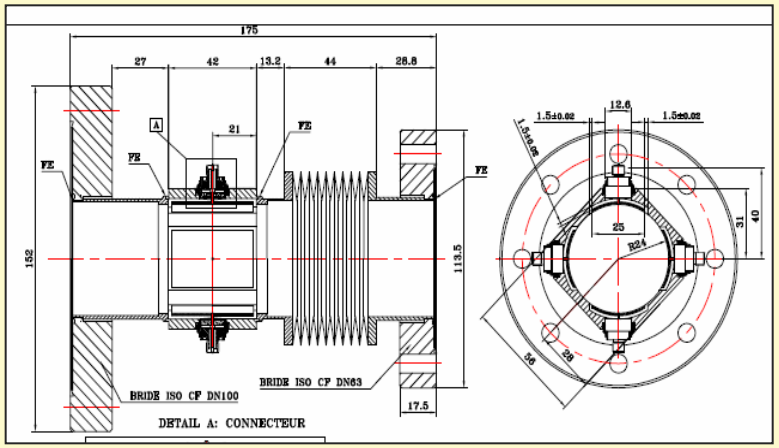
Please, see tupb029

Faraday Cup

Beam Loss Monitors development
(IFIN-HH Romania)

Spiral2 PP : BPM tests at SARAF

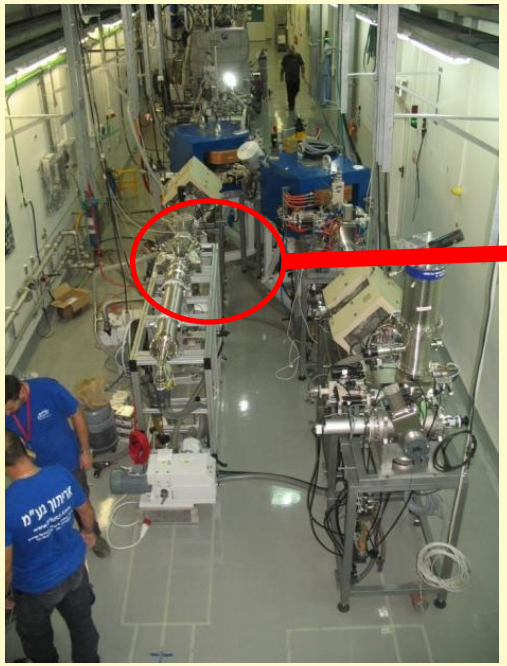
Design of the BPM prototype for a specific position at SARAF



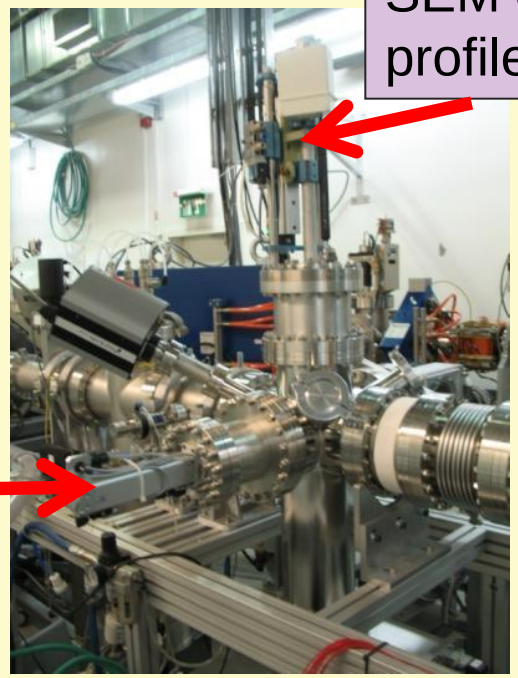
BPM Installation

First beam tests with GANIL BPM installed at SARAF

Spiral2 PP : IPM and SEM tests at SARAF



Ionization Profile Monitor

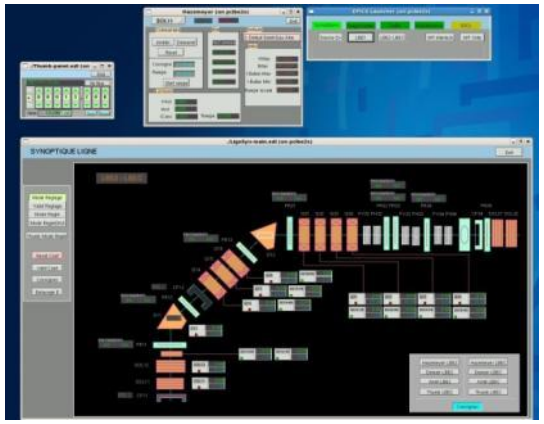


SEM grid profiler

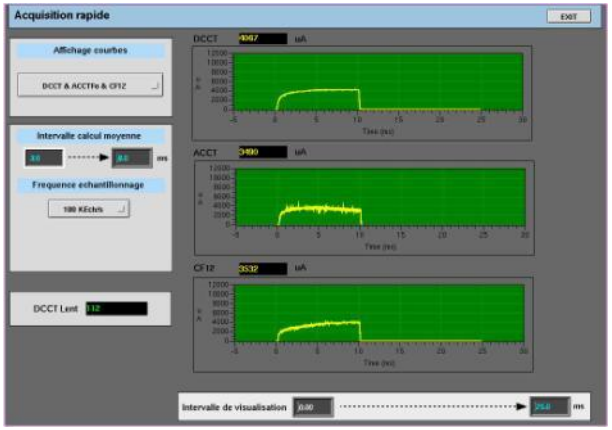
- Spiral2 profilers test is scheduled in November 2012 on the SARAF accelerator (FP7 SPIRAL PP framework collaboration).
- Grid profiler will be tested with the high intensity 3.3 proton beam.

IPM = Ionization Profile Monitor (non interveptive)
SEM = Secondary Emission Monitor

Command/control

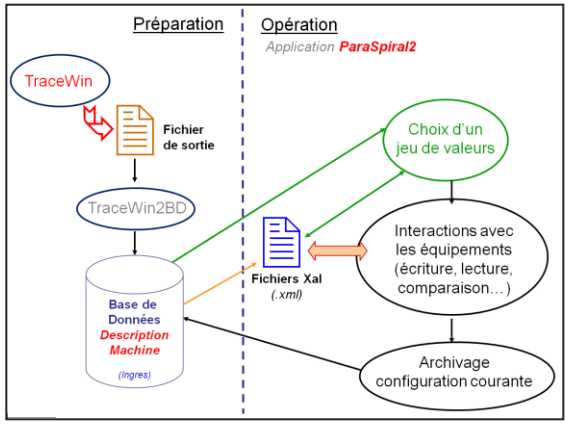


EPICS LEBT2 + LEBC interface



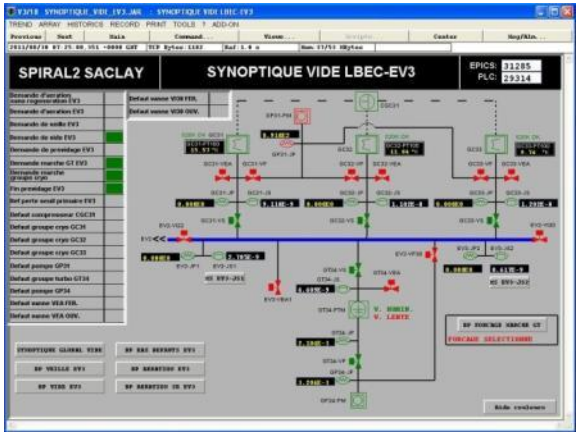
Fast acquisition (FC/ACCT/DCCT)

Beam alignment (**Xal** application)



Management of Parameters

- EPICS based system
- Many tools developped and **already used in operation** on LEBT lines
- Many tools and programs under development



Vacuum LBEC synoptic

Partners for the SPIRAL2 ACCELERATOR

CEA/DSM

Unités du centre Saclay…

IRFU/SACM	(Saclay)
IRFU/SIS	(Saclay)
IRFU/SPHN/LENAC	(Saclay)
DAM/ DP2I	
DAM/DPTA…	

CNRS/IN2P3

IPNO	(Orsay)
IPNL	(Lyon)
IPHC	(Strasbourg)
LPSC	(Grenoble)
LAL	(Orsay)

Foreign laboratories

SOREQ	(Israël)	IFIN-HH	(Bucarest)	ARGONNE	(USA)
CIEMAT	(Spain)	Huelva	(Spain)	BARC	(India)
INFN	(Italy)				

And many others for production, physics and detectors !!

CONCLUSION

- We enter now in the **phase of installation** of the accelerator into the building (first components underground this week !)
- **Decree signed** and published by Prime Minister 8th May 2012
- Documents for “mise en service” under preparation
- We expect first **low energy beam mid 2013** (with intermediate authorisation from Safety authorities)
- And beam for **physics** first months of **2014** (NFS)

THANK YOU !

THANK YOU !

“Si vous avez les idées claires,
c’est que vous êtes mal informés”
(H.S. Truman)

RIBs with SPIRAL2 *(and SPIRAL1 update)*

N=Z Isol + In-flight
(fusion-evaporation)

SHE
In-flight S3

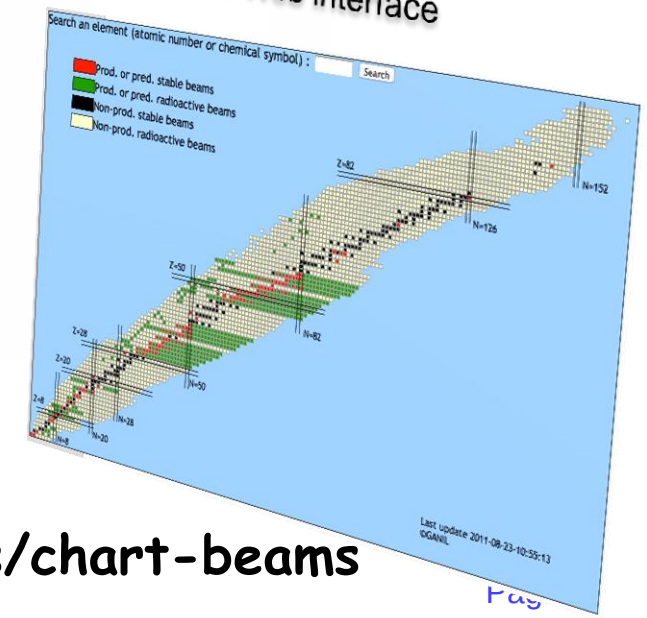
In-flight S3

+ SPIRAL1 update, with new RIBs !

ISOL RIB Fission Products

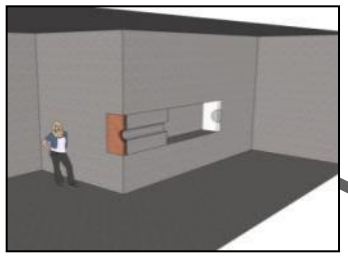
ISOL & in-flight RIB from transfer and deep inelastic Reactions

GANIL/SPIRAL1/SPIRAL2 Beams
New Web interface

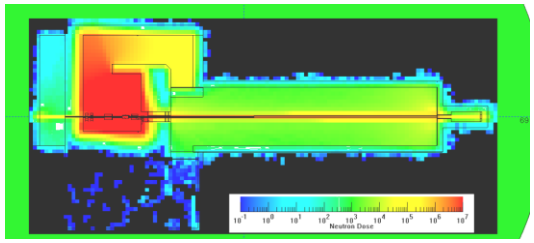


pro.ganil-spiral2.eu/users-guide/accelerators/chart-beams

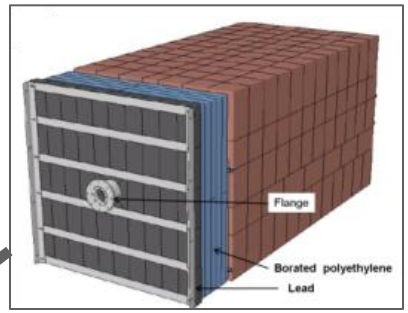
Neutron For Science facility (NFS)



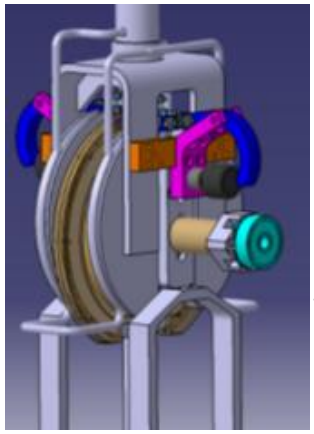
Neutron beam dump



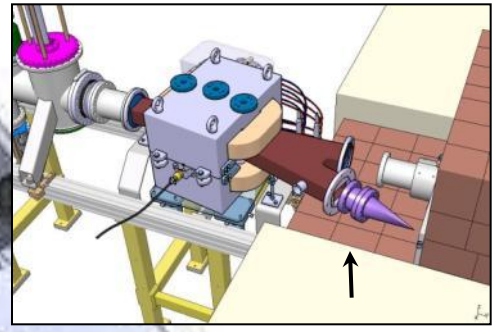
Safety calculations



Collimator



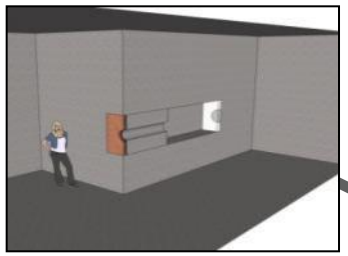
Converter system *(and material also other system for material irradiation)*



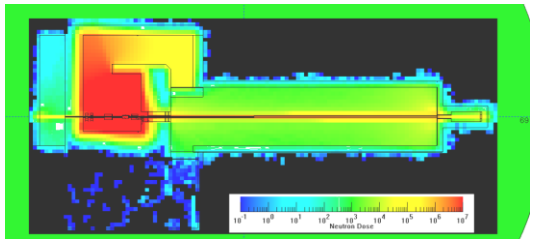
Magnet + Deuteron and proton beam dump

Neutron For Science facility (NFS)

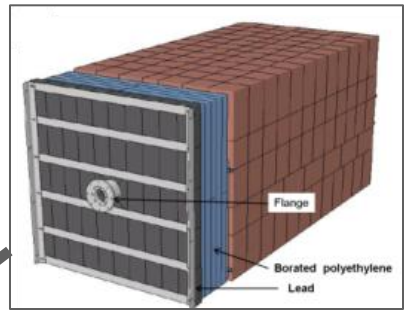
➔ ***First experiments in 2014***



Neutron beam dump

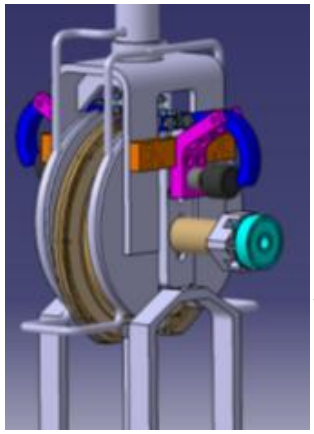


Safety calculations

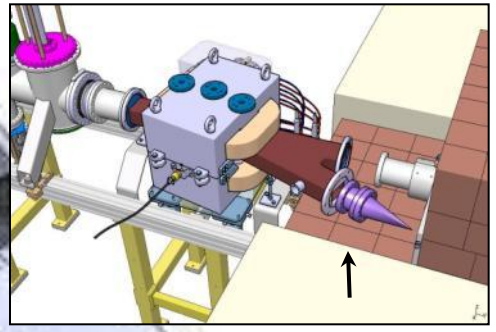


Collimator

Time-of-flight area



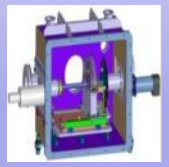
Converter system *(and material also other system for material irradiation)*



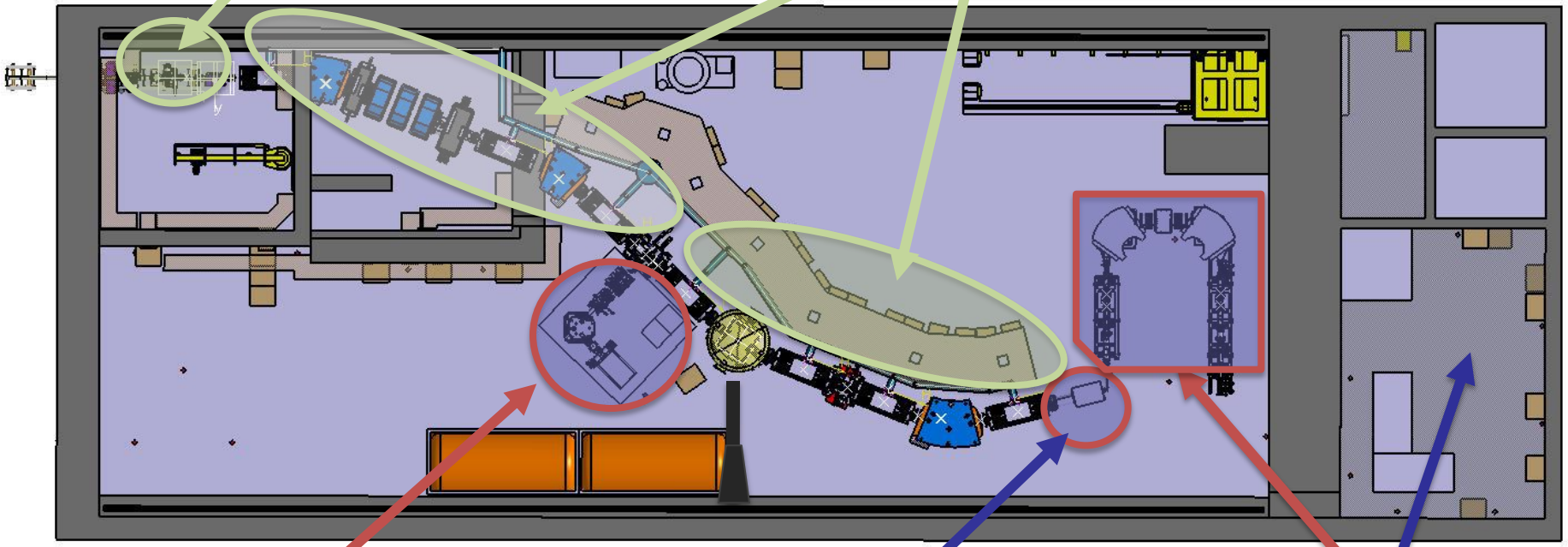
Magnet + Deuteron and proton beam dump

Super Spectrometer S3

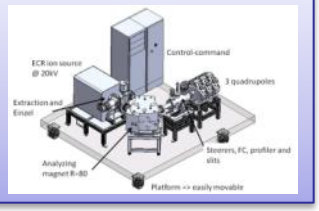
Target systems
For High Intensity



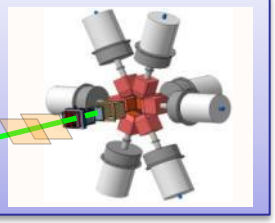
Momentum Achromat & Mass separator



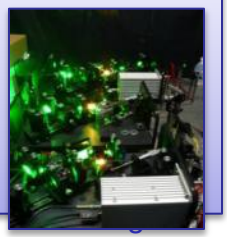
FISIC setup
Fast Ion Slow Ion Collisions



Implantation-decay station at the mass dispersive plan



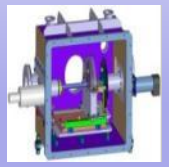
Low Energy Branch (LISOL)



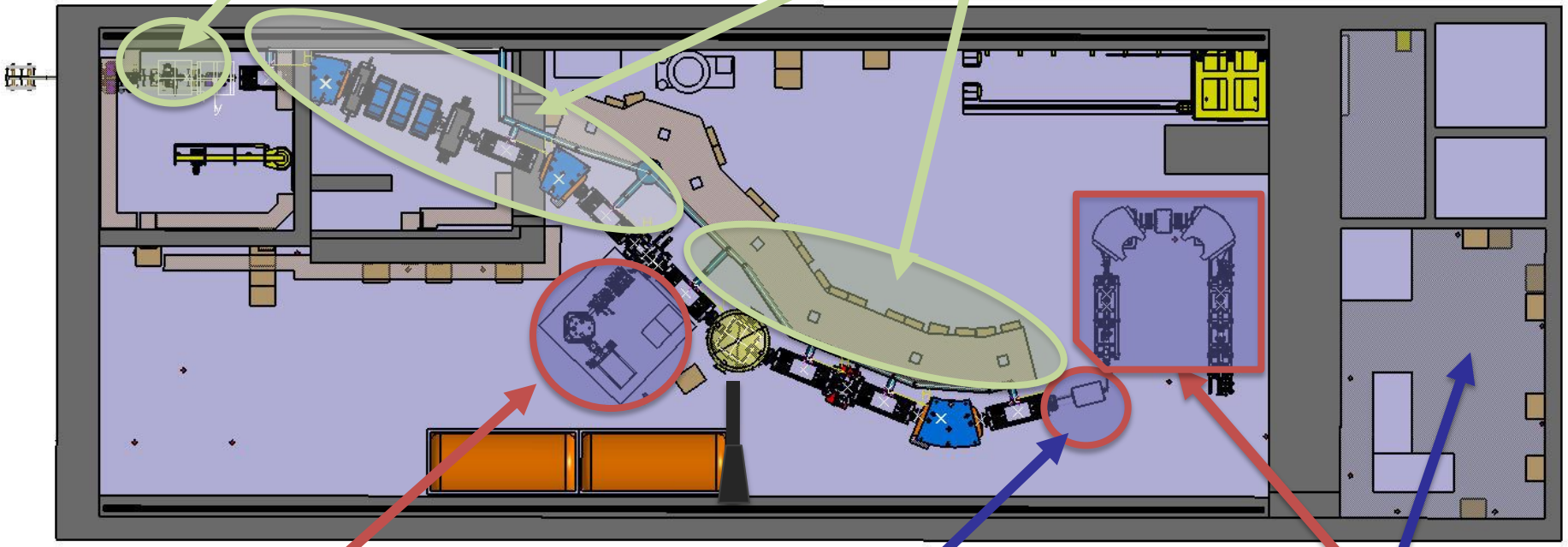
Super Spectrometer S3

➔ ***Commissioning - First experiment in 2015***

Target systems
For High Intensity



Momentum Achromat & Mass separator



FISIC setup
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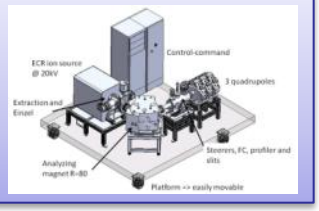
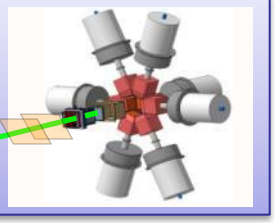


Implantation-decay station at the mass dispersive plan



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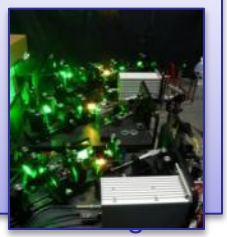
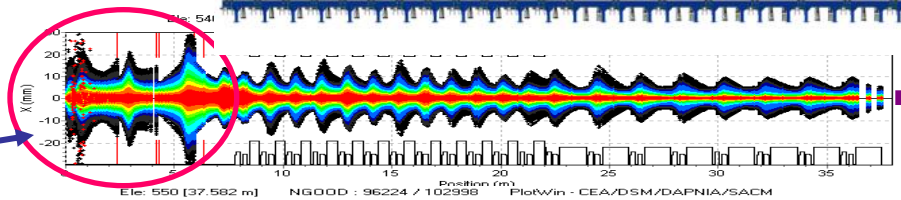
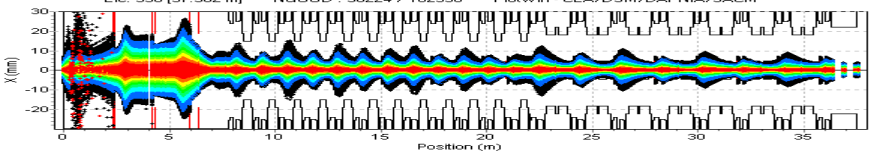


Design of the 88 Mhz Linac using Tracewin code…

MEBT

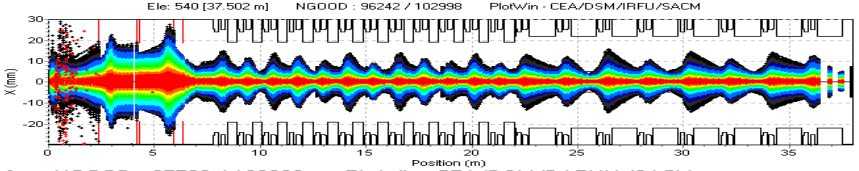


Deuterons 5 mA , 40 MeV

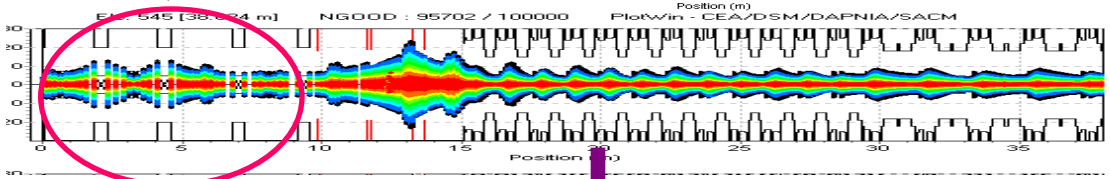


q/A=1/3,1 mA , 14.5 MeV/A

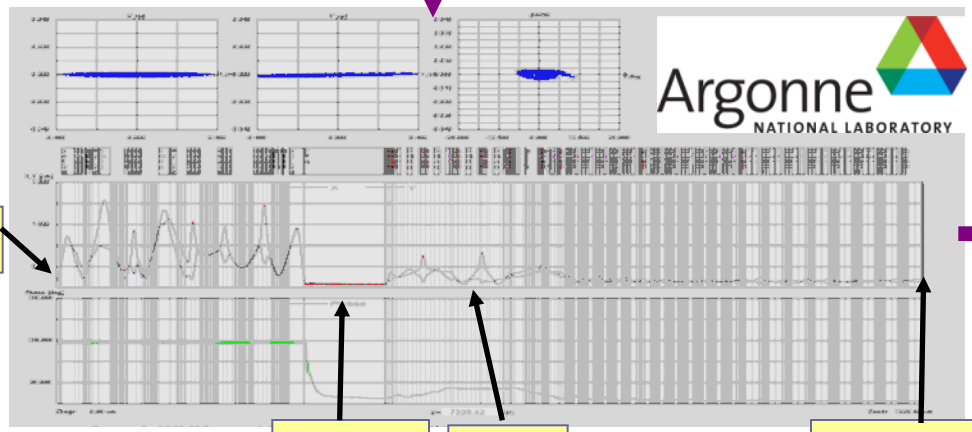
1/6 MEBT



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



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



ECR

RFQ…

LME

End Linac

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