ECOS 2012

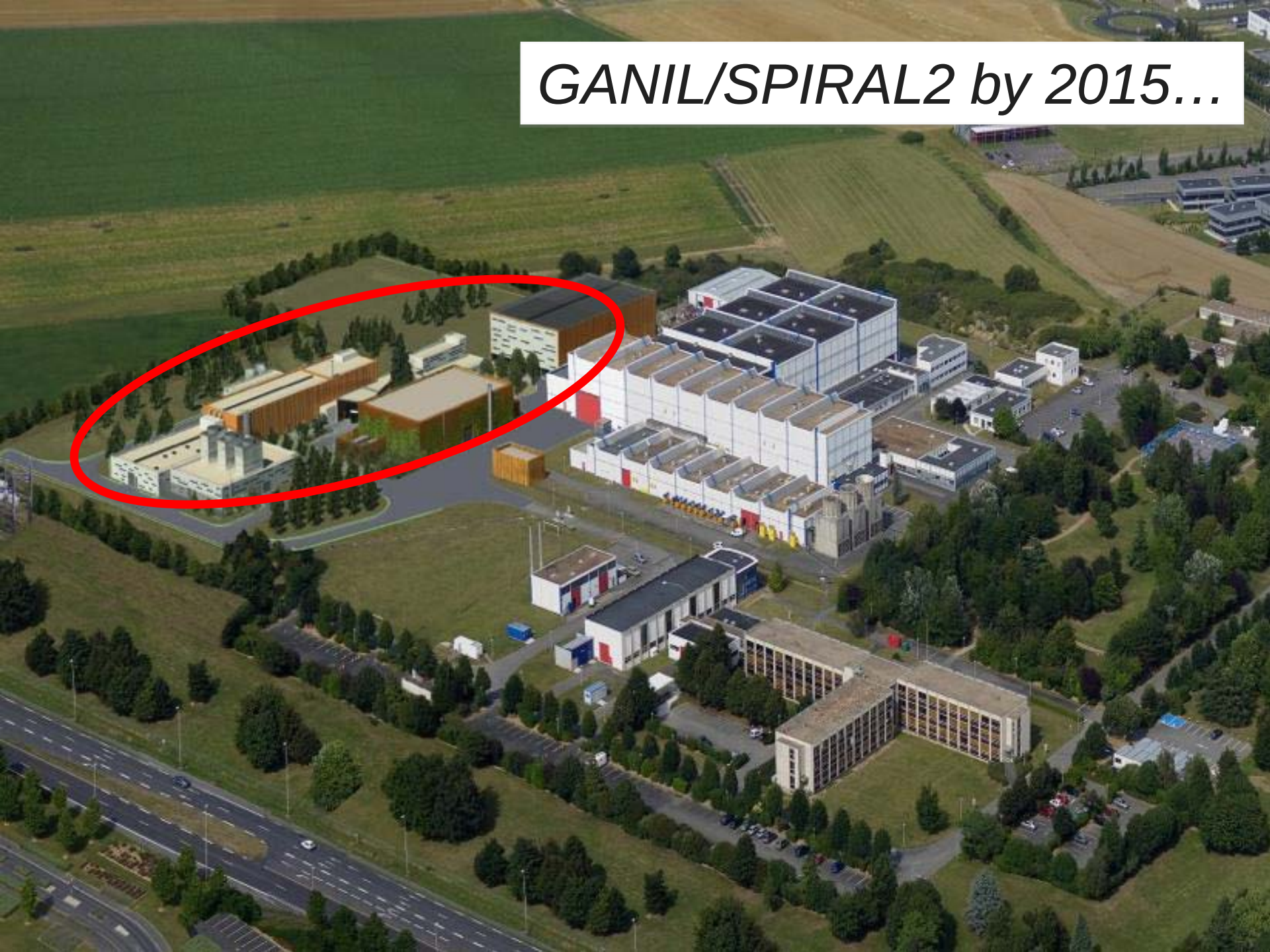
18-21 June 2012

Villa Vigoni (Como Lake), Italy

Status and Challenges of the SPIRAL2 driver accelerator

Patrick Bertrand

On behalf of the SPIRAL2 accelerator team


GANIL/SPIRAL2 by 2015…

Construction of SPIRAL2 Phase 1 building

Preparation of the site in November 2010

Construction of Phase 1 building

Photo JM Enguerrand – 19 mai 2011

Excavations ready
May 2011

Construction of Phase 1 building

The same view in May 2012…

82 Letters of Intend (>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

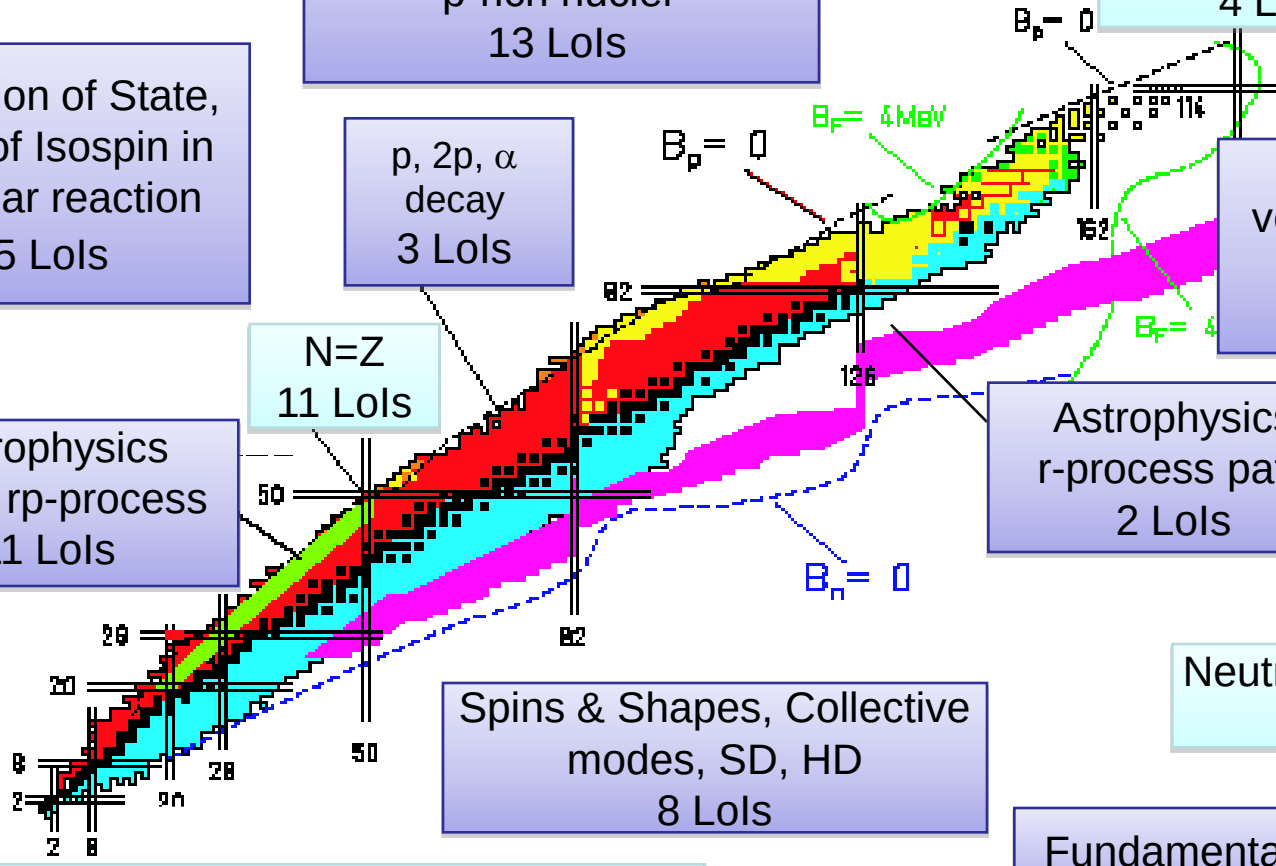
p, 2p, α
decay
3 LoIs

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



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

Neutrons for science
13 LoIs

Fundamental Interactions – 2 LoIs

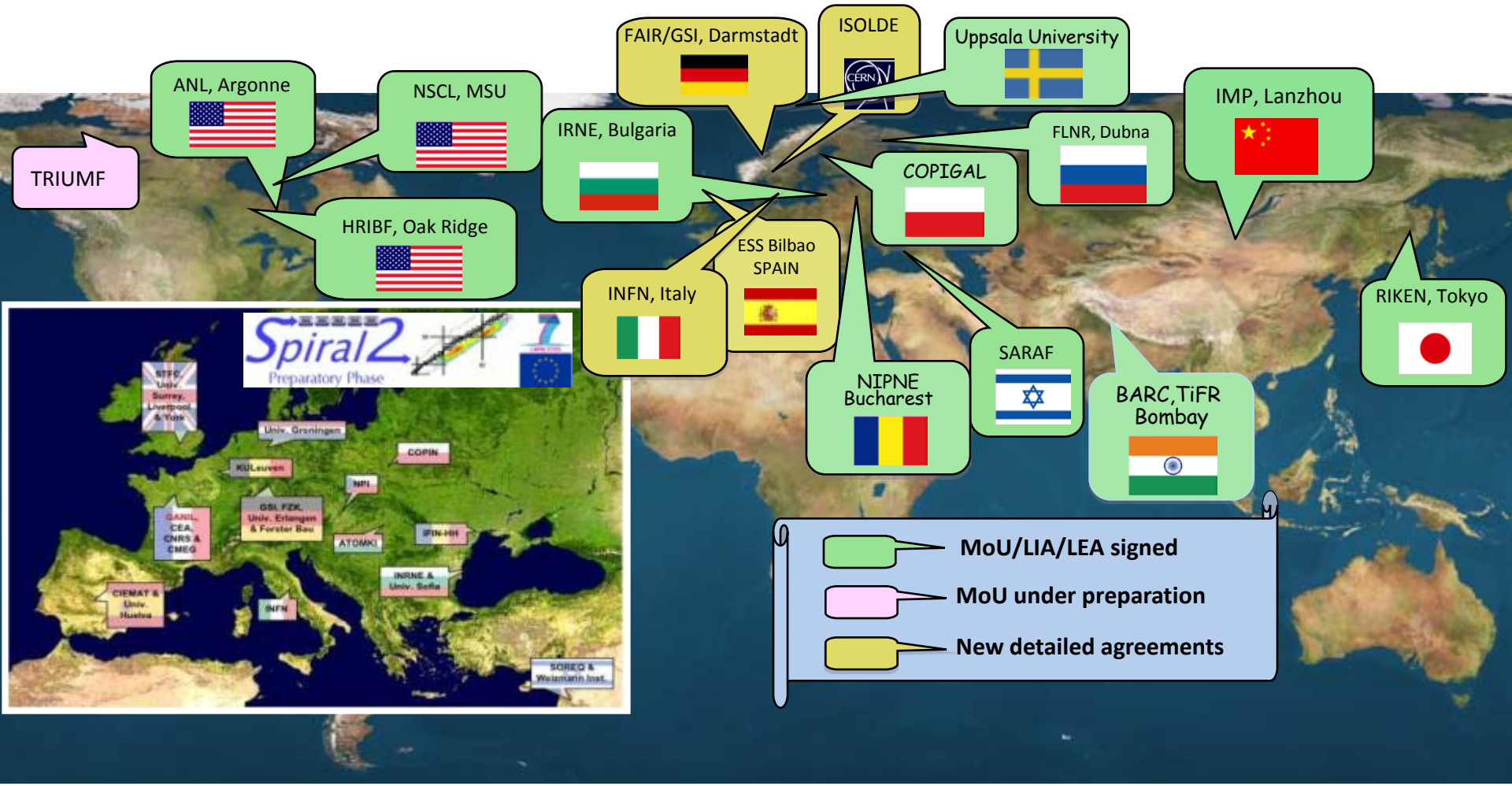
29 LoIs Phase 1 (16 for S3, 13 for NFS)

53 LoIs Phase 2 (21 for DESIR)

Atomic physics 1 LoI

(from M. Lewitowicz)

International Collaborations



For accelerator, production, physics and detectors…

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)

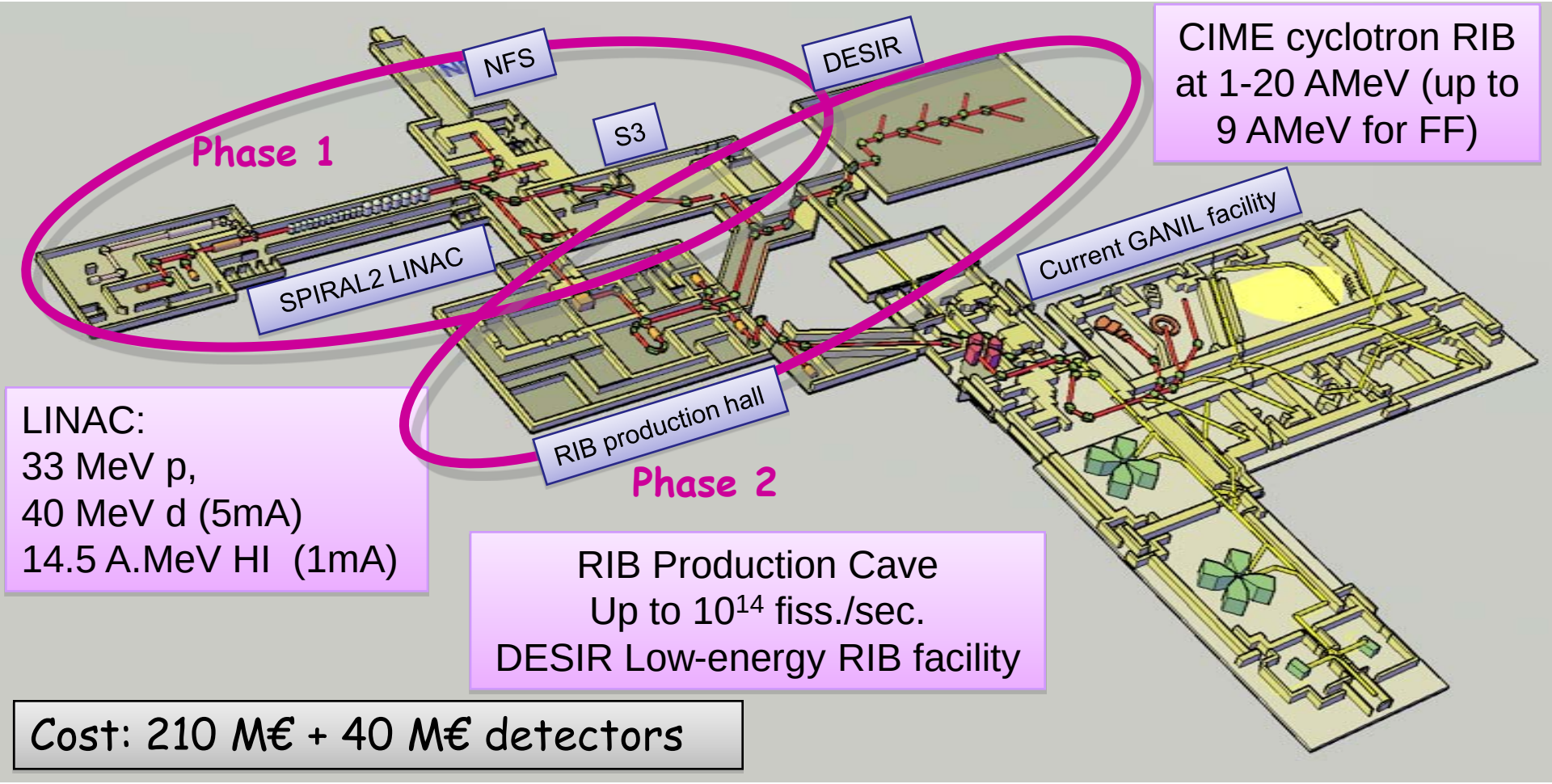
Foreign laboratories

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

GANIL-SPIRAL1-SPIRAL2 Layout

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

Phase 2: RIB Production + post-accelerated RIBs + DESIR



CIME cyclotron RIB at 1-20 AMeV (up to 9 AMeV for FF)

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

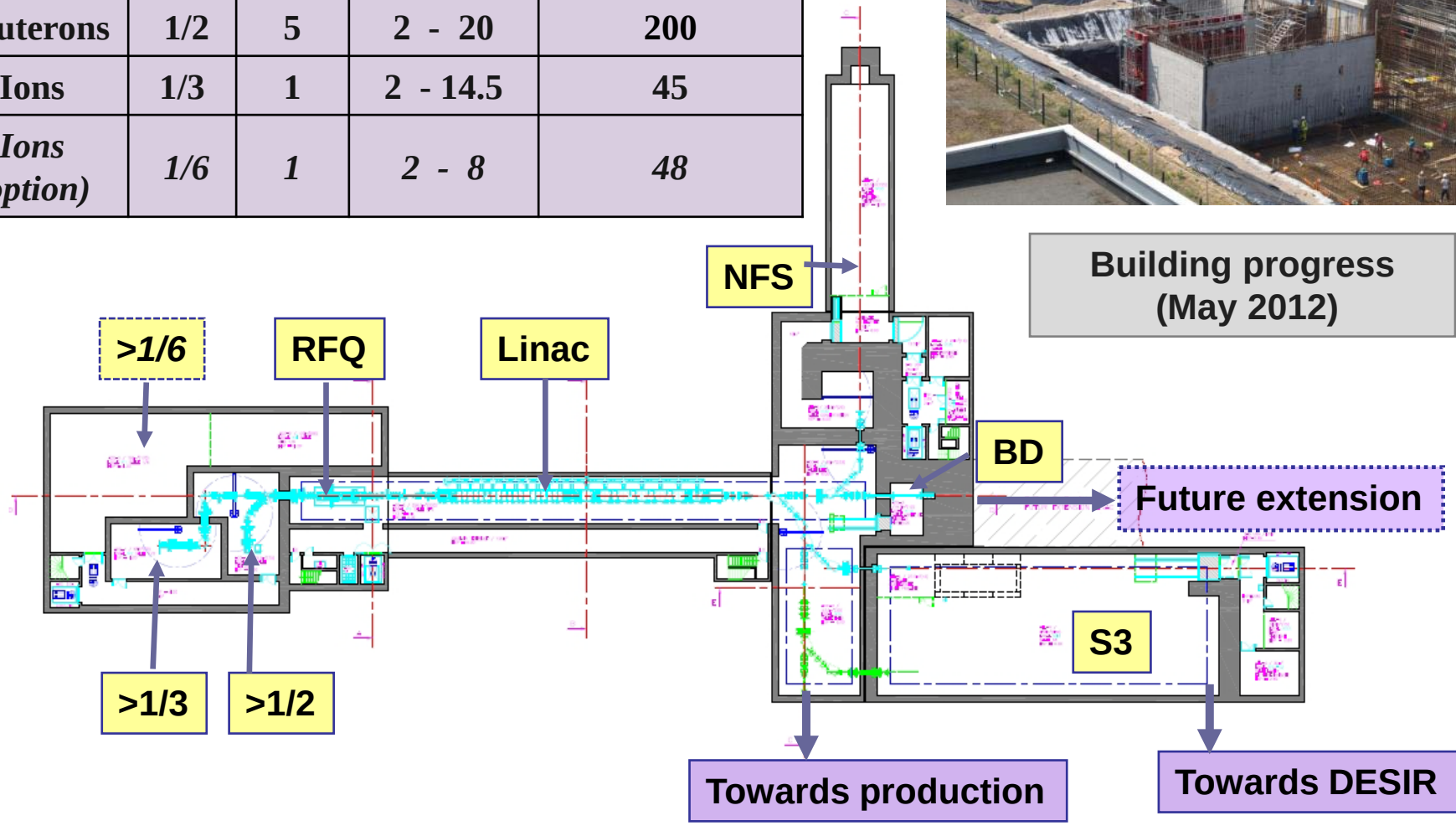
RIB Production Cave
Up to 10^{14} fiss./sec.
DESIR Low-energy RIB facility

Cost: 210 M€ + 40 M€ detectors

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***

Building progress (May 2012)



Some Challenges of the SPIRAL2 …

- Huge variety of beams → Double Challenge !
  - Simulations for design → Find compromises (Frequency, apertures...)
  - Beam Intensity → Space Charge (or not), diagnostics, vacuum…
  - Beam power → Machine protection, Beam dump, activation…
  - Energy range → The design itself, multiple tunings…
- Components of the accelerator
  - Heavy Ion ECR source → 1mA Ar^{12+}… and metallic ions…
  - Transfer lines → complexity, depends of many laboratories…
  - RFQ design/construction → mechanical tolerances, seals…
  - Cryomodules and couplers → 6.5 MV/m in operation, clean integration process…
  - Main Beam Dump → 200 kW, surveillance, water circuit…
- Security, safety, radioprotection and protection of the machine
  - Beam losses (< 1W/m) → Machine protection system, activation…
  - Nuclear Ventilation, activation of Beam dump water…
  - Safety report, earth quake consequences…
- Anticipate future extensions → Injector for Q/A=1/6 ions, Building implantation…

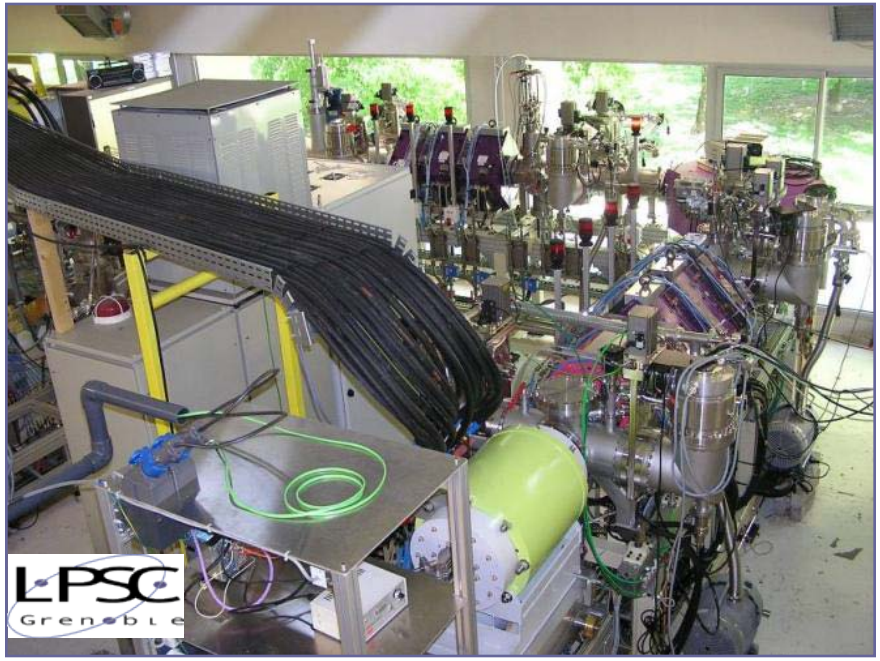
Our optimisation strategy for the construction of the Spiral2 accelerator

- 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

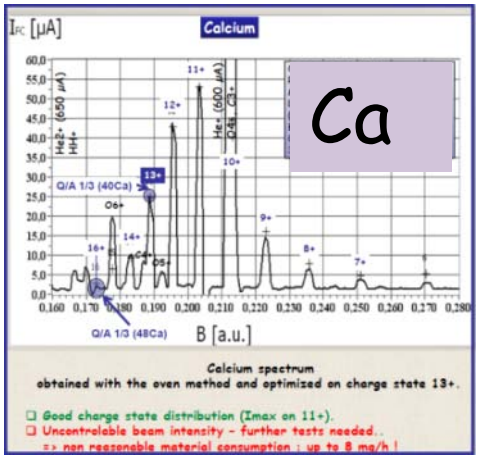
  . Collaboration between teams
  . Validation of the Design et the beam dynamics
  . Gain time for the installation/tests at GANIL/SPIRAL2 site

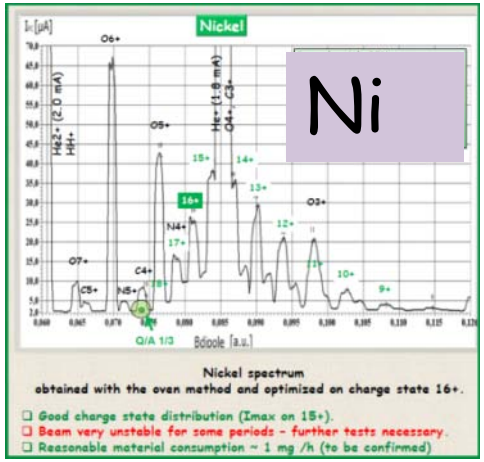
- Optimise the interweaving between the building planning and the accelerator planning

Phoenix-V2+LEBT1 beam tests (LPSC Grenoble)



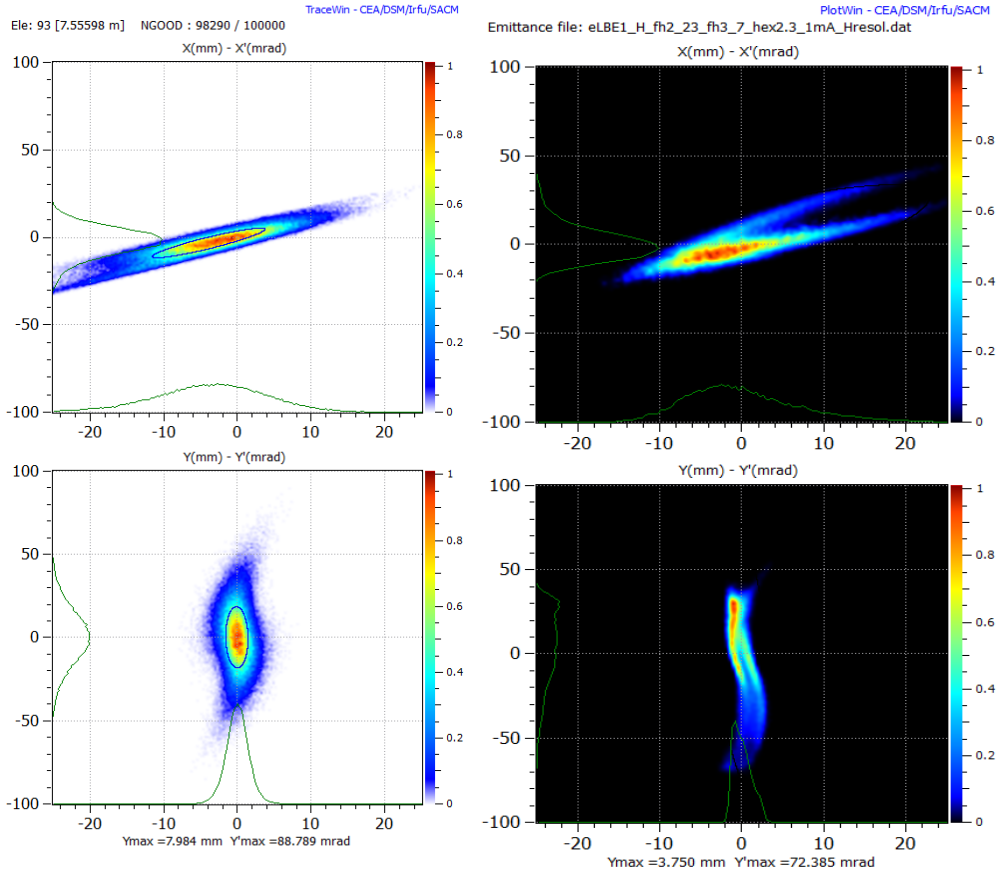
RESULTS FOR GASES		
	I max for Q optimum	**I max for Q/A 1/3**
4He	> 2 mA ¦ 2+ non opt.	> 2 mA ¦ 2+ non opt.
16O	1.3 mA ¦ 6+	**1.3 mA ¦ 6+**
40Ar	450 µA ¦ 9+ 350 µA ¦ 11+	175 µA ¦ 12+ Isotope 36 --- 70 µA ¦ 13+ Isotope 40 --- 22 µA ¦ 14+ Isotope 40
86Kr	110 µA ¦ 17+	non measurable





20 µAe Ni 19+ obtained !!!

Phoenix-V2+LEBT1 beam tests (LPSC Grenoble)



Simulation

Beam test

stable 62 kV reached !

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

Source Voltage : 53.33 kV

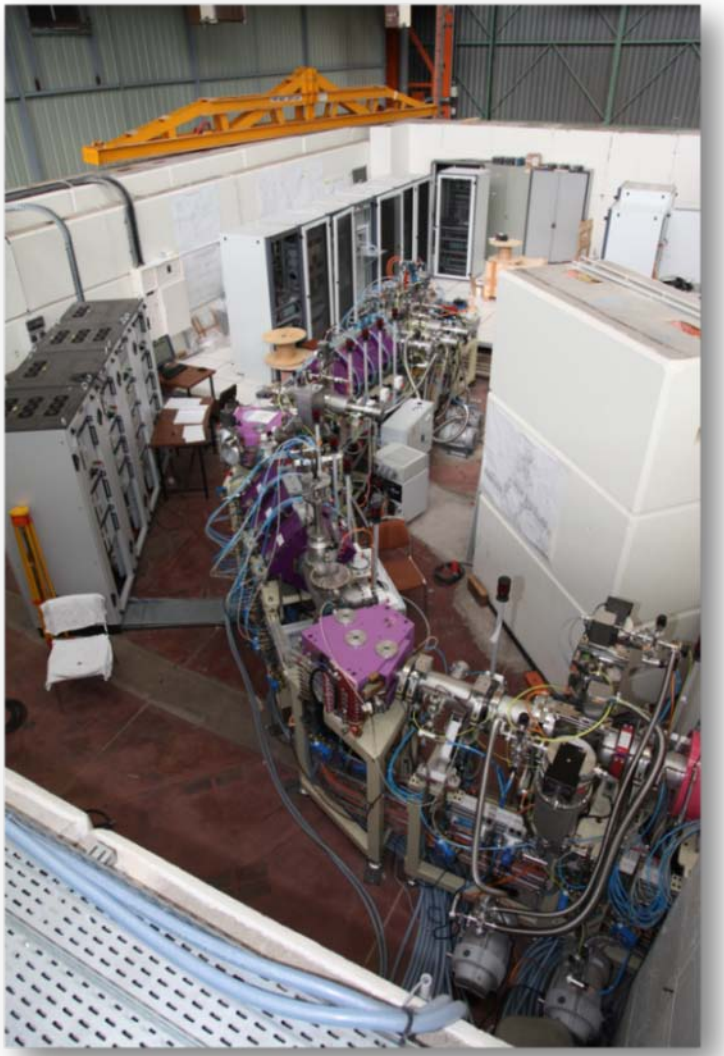
Q/m : 1/2.66

Beam Intensity : 1.3 mA

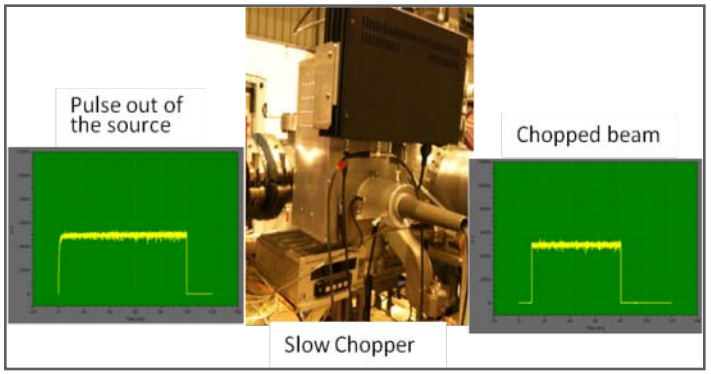
Measured emittances
(π.mm.mrad norm. RMS)

Horizontal : 0.25
Vertical : 0.14

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

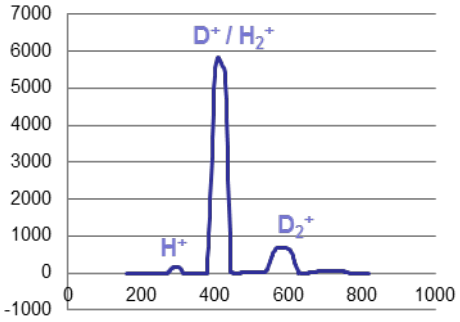


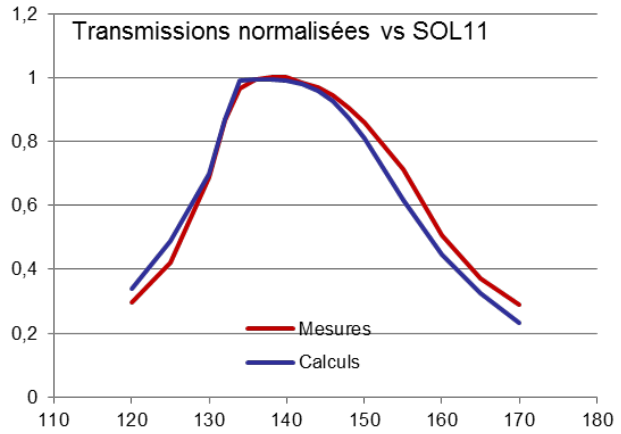
- LBEC beam line added in 2011 with all instrumentation and Interlocks. (up to RFQ entrance)
- More than 5 mA proton or Deuteron beam conducted to end LBEC in September 2011
- Slow chopper tested with success . *(developed by Catania)*

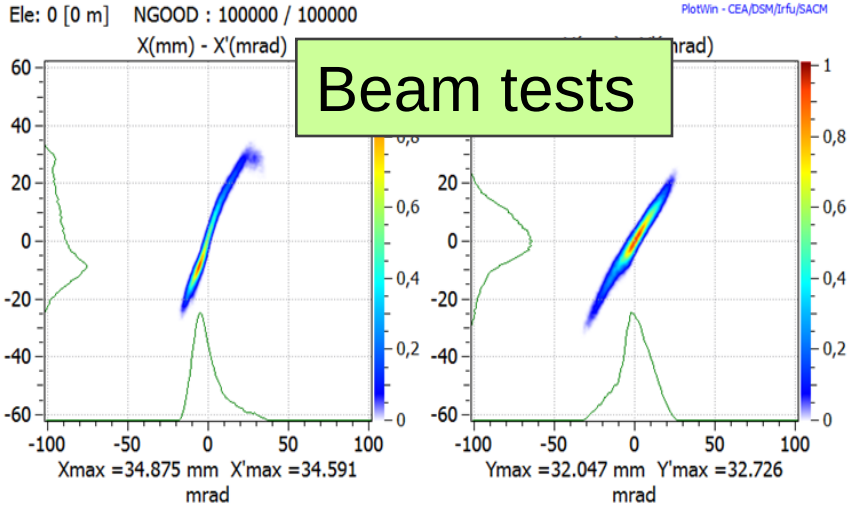


Beam tests results for Deuterons (IRFU – Saclay)

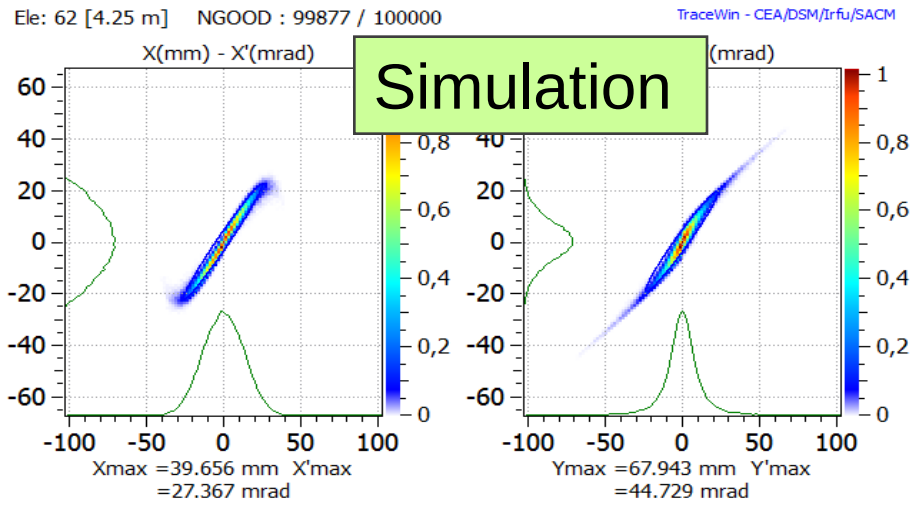
Ion	Proportion	Courant
Ions	100 %	6.9 mA
H^+	2.1 %	0,15 mA
H_2^+	0,5 %	0.035 mA
D^+	83 %	5.8 mA
D_2^+	9.7 %	0.68 mA
D_3^+	0 %	0 mA
Ions lourds	3.5 %	0.25 mA







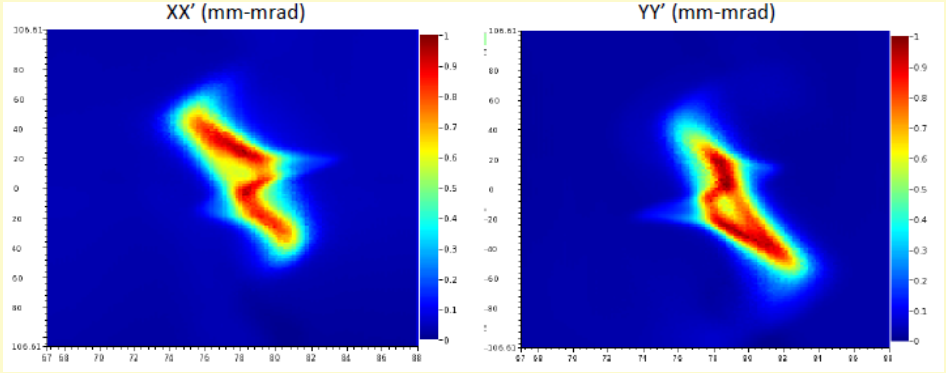
Beam tests



Simulation

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

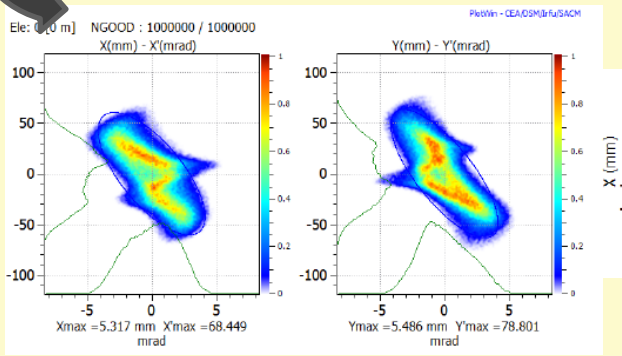
Beam tests results for Deuterons *(D. Uriot, IRFU – Saclay)*



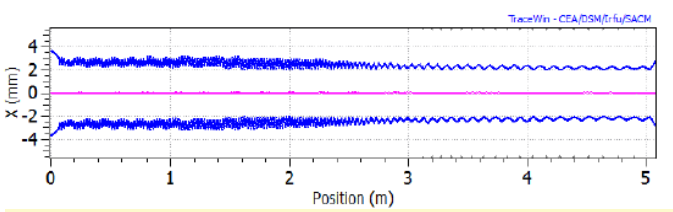
Real beam matched at RFQ entrance,
Measured with the emittancemeter

$\varepsilon_{xx'}$	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

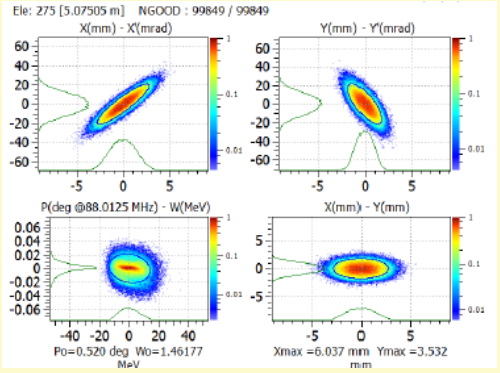
Emittance measured
at RFQ entrance



Generation of particles
with TRACEWIN code…

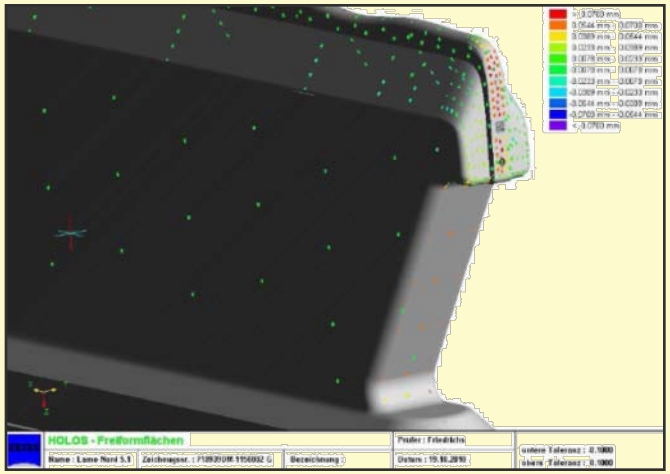


Sent into the RFQ…
accelerated and bunched

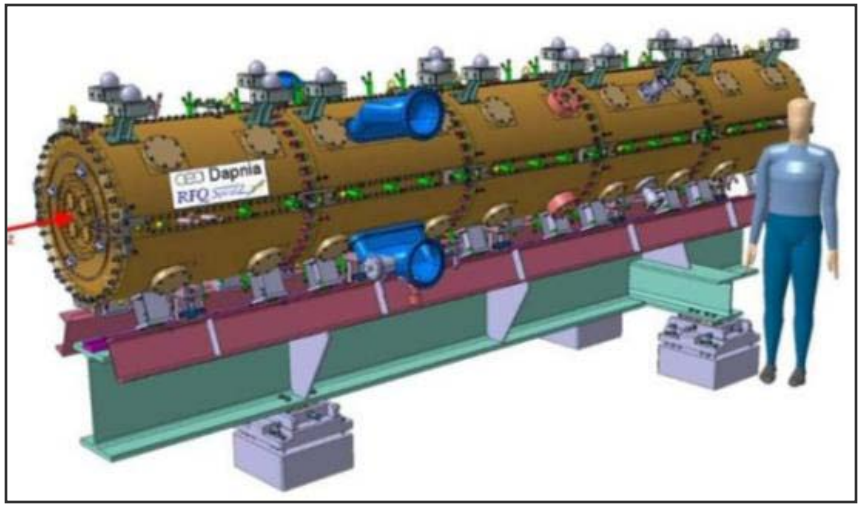


Emittance obtained
at RFQ exit

RFQ Status (IRFU – Saclay)



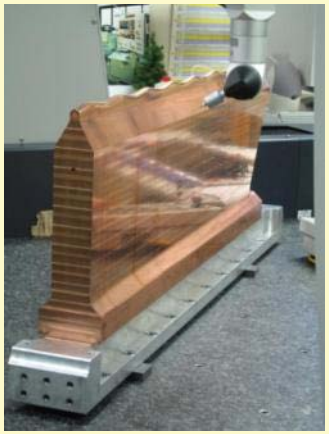
T5 segment - 3D measurements



- 88.05 MHz, 4-vanes, 5 meters long
  more than 97% transmission
- Segment T5 manufactered and accepted
  (but revealed vacuum gasket problems..)
- T1 .. T4 tubes achieved
- 3D measurements of segment T4 last week
- *Planning to be followed strictly…*

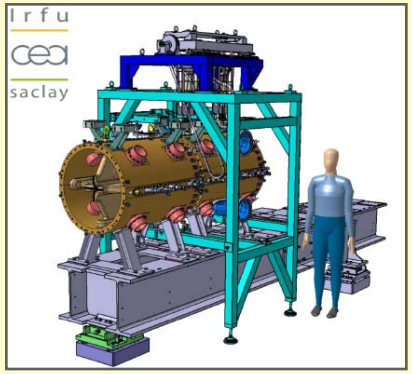
RFQ Status (IRFU – Saclay)

All tubes machined



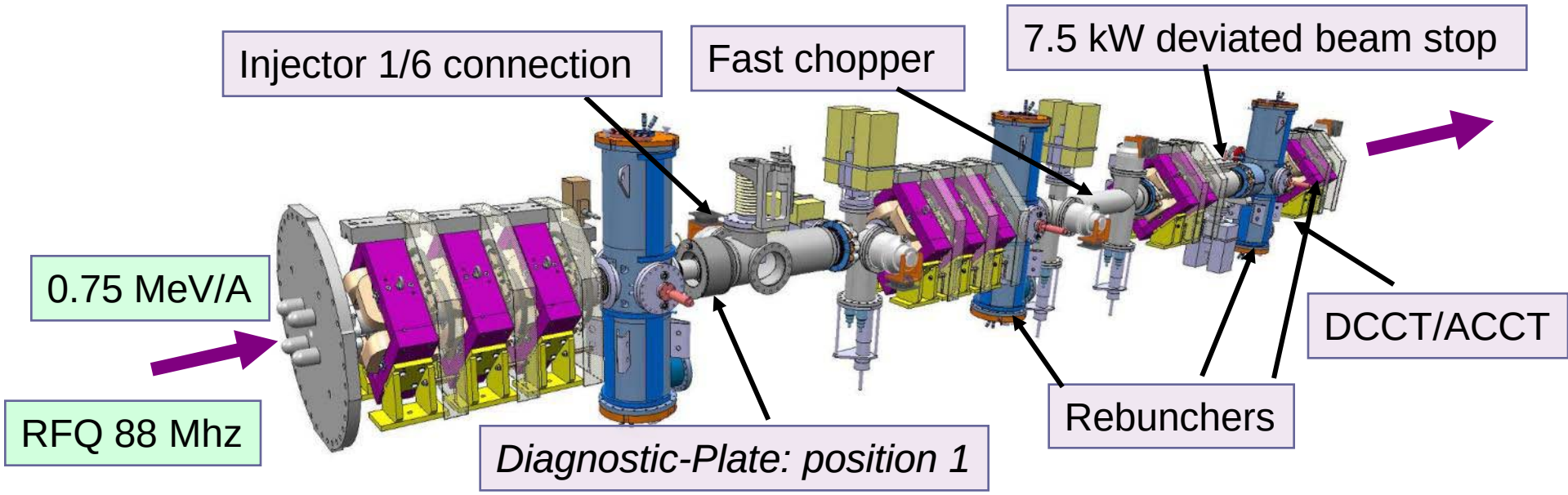
All electrodes pre-machined, some measured

Tube T4 measured (last week)

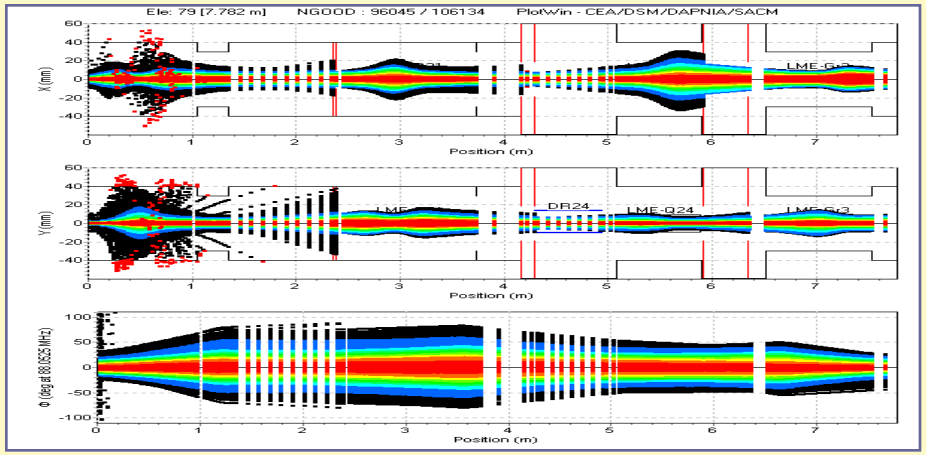


Assembly system ready (T4+T5 assembly at Saclay ASAP)

The MEBT Challenge…

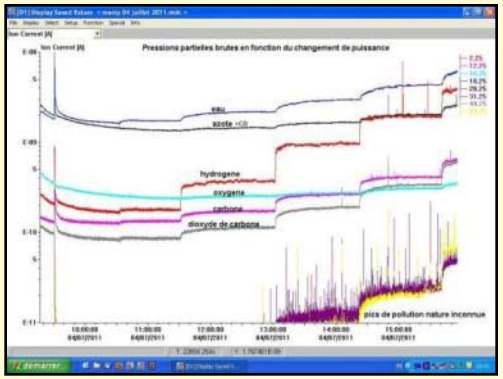


- Accept future 1/6 beams Injector
- Fast chopper and deviated beam stop.
- Protect the linac against halo
  → *3 sets of H-V slits*
- Match all types of beams to linac
- Measurement of beam intensity at Linac Entrance

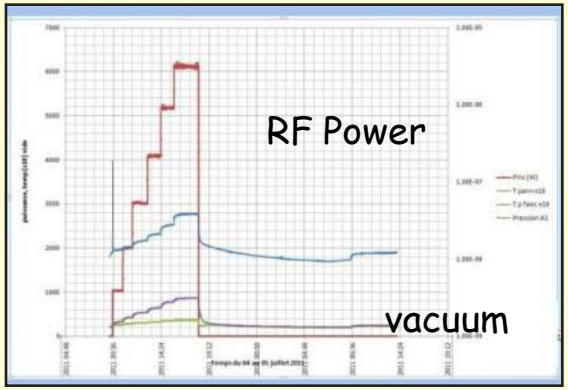


MEBT: First rebuncher Tested at GANIL

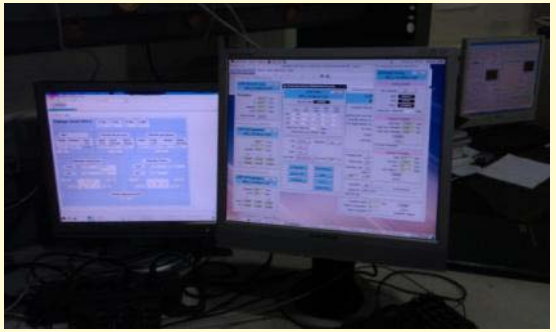
The first rebuncher



Vacuum analysis (2011)



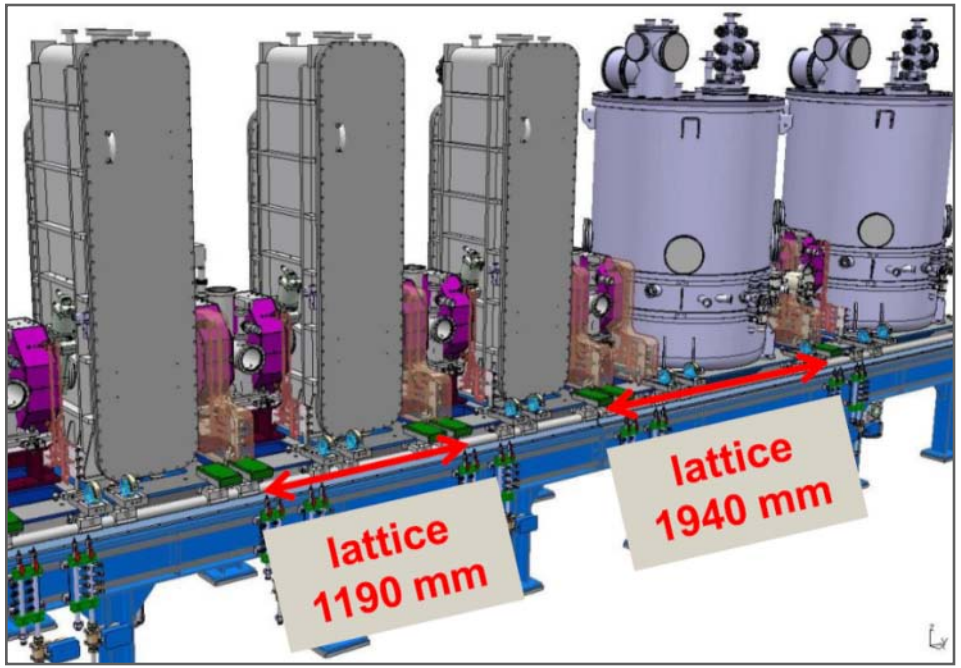
RF long duration tests at 6 kW (2011)



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

Superconducting LINAC with independently phased QWR cavities and short cryomodules…

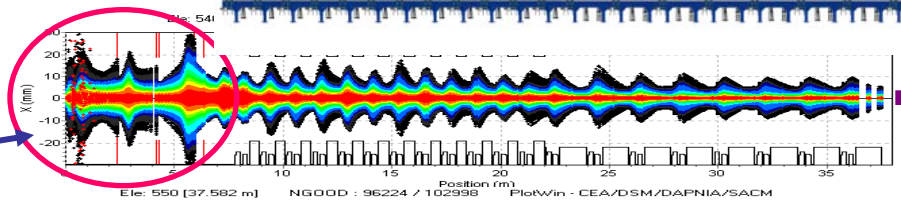
12 low beta cryomodules (0.07) and 7 high beta cryomodules (0.12)
L≈35 m



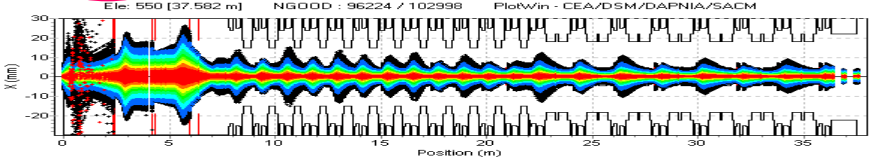
Assembly test
Cryo A + Warm section

Design of the 88 Mhz Linac using Tracewin code…

MEBT

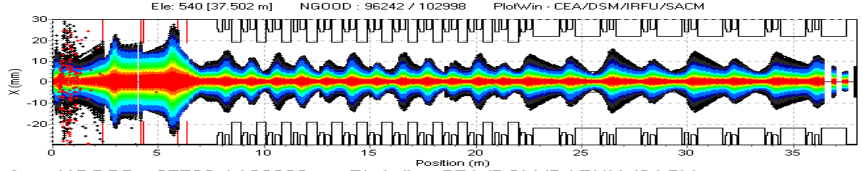


Deuterons 5 mA , 40 MeV

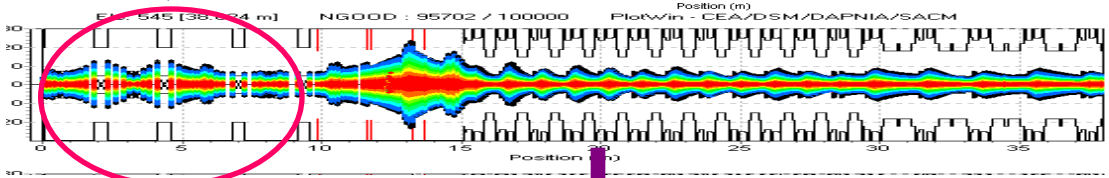


q/A=1/3,1 mA , 14.5 MeV/A

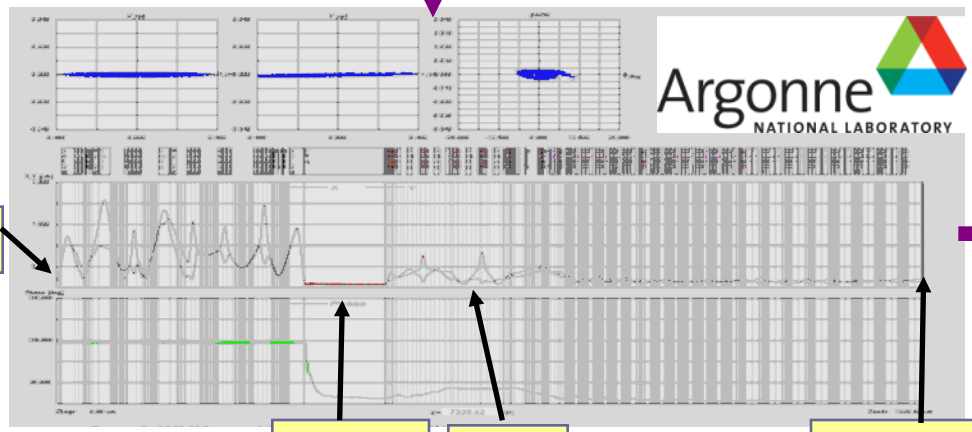
1/6 MEBT



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

LINAC Warm Sections activities…

All Boxes ready

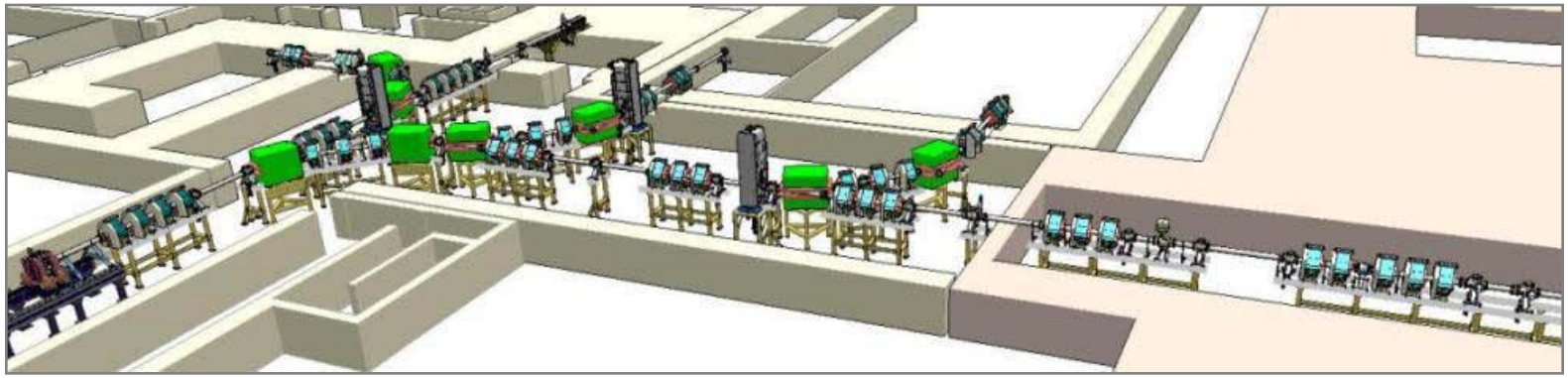
Quadrupole assembly

Magnetic measurements

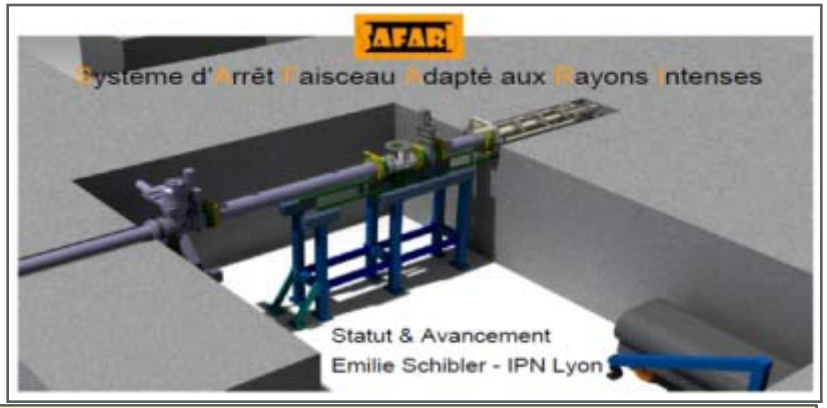
Box + quads…

Insertion of one BPM

HEBT Lines
(IPNO, IPNL, Ciemat (Spain), GANIL



HEBT dipoles
under construction



- Dipoles under construction
  - *1st one received,*
  - *measurement running at GANIL…*
- Quadripoles and steerers under construction

Cryogenic system (IPN Orsay)

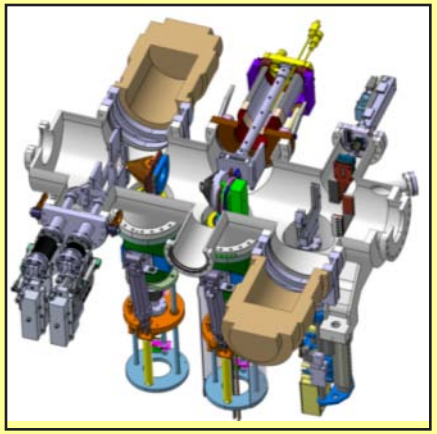
Helium gas buffer ready

Cold Box to be tested this week

Valve boxes ready

Diagnostics...(GANIL, IPNO, NIPNE, IPHC, SARAF)

Beam tests with SPIRAL2 BPM (IPNO) installed at SARAF (Israel)

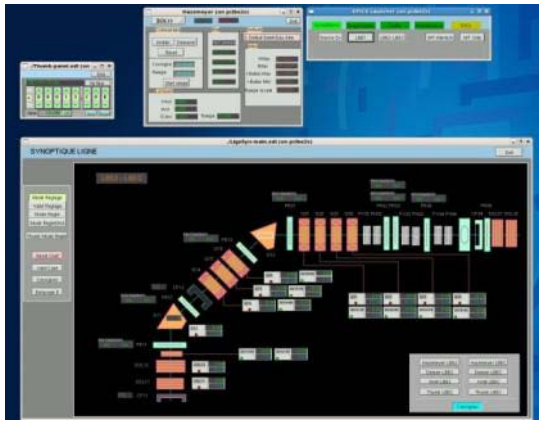


MEBT Diag-Plate (IPHC Strasbourg)

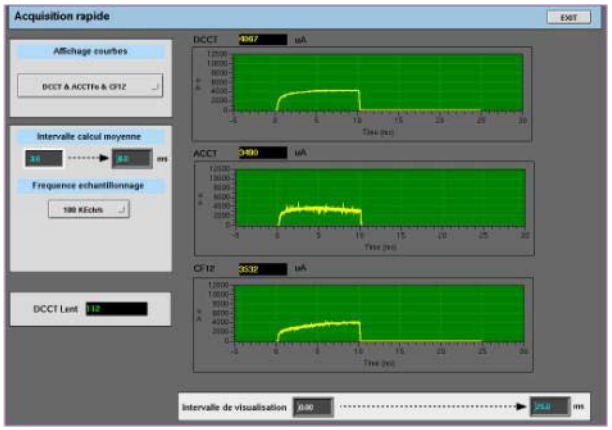
Electronics for profilers (Ganil development)

Beam Loss Monitors development (IFIN-HH Romania)

Command/control

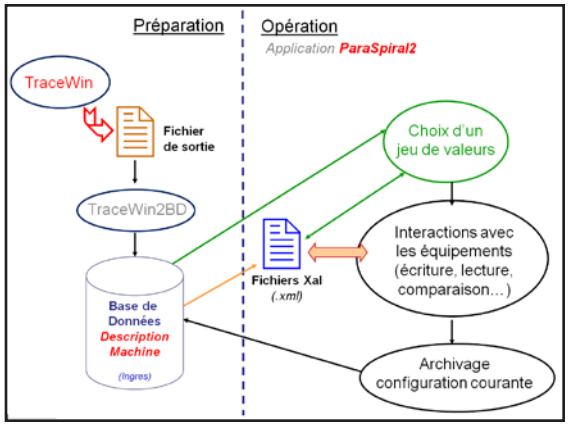


EPICS LEBT2 + LEBC interface



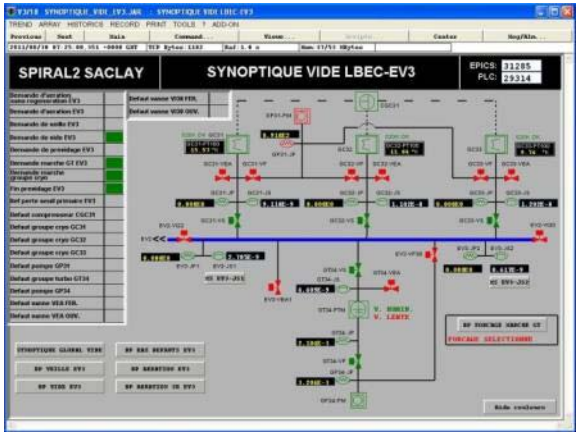
Fast acquisition (FC/ACCT/DCCT)

Beam alignment (Xal application)



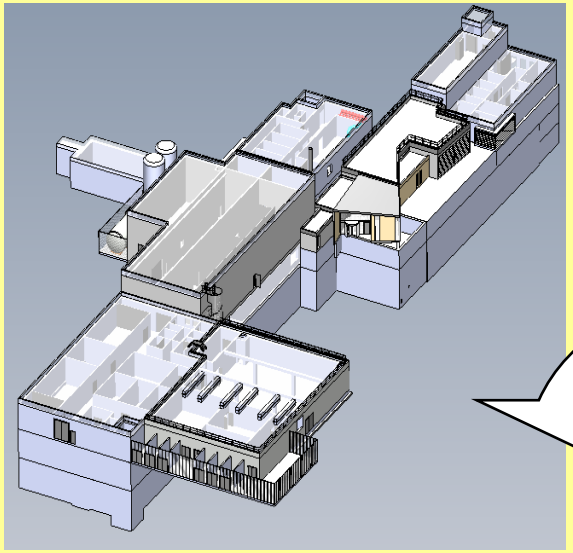
Management of Parameters

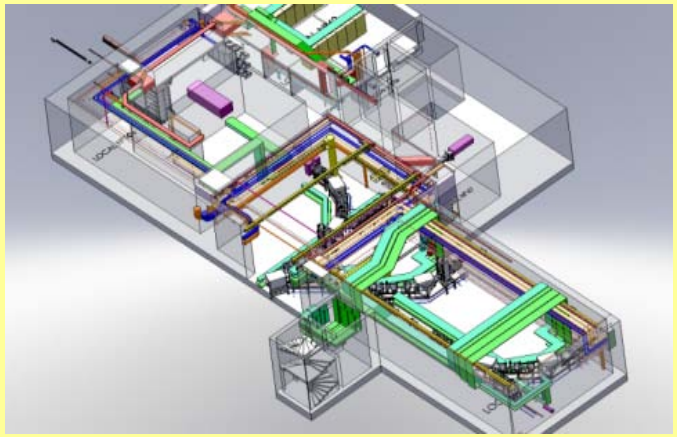
- EPICS based system
- Many tools developped and already used in operation on LEBT lines
- Many tools and programs under development

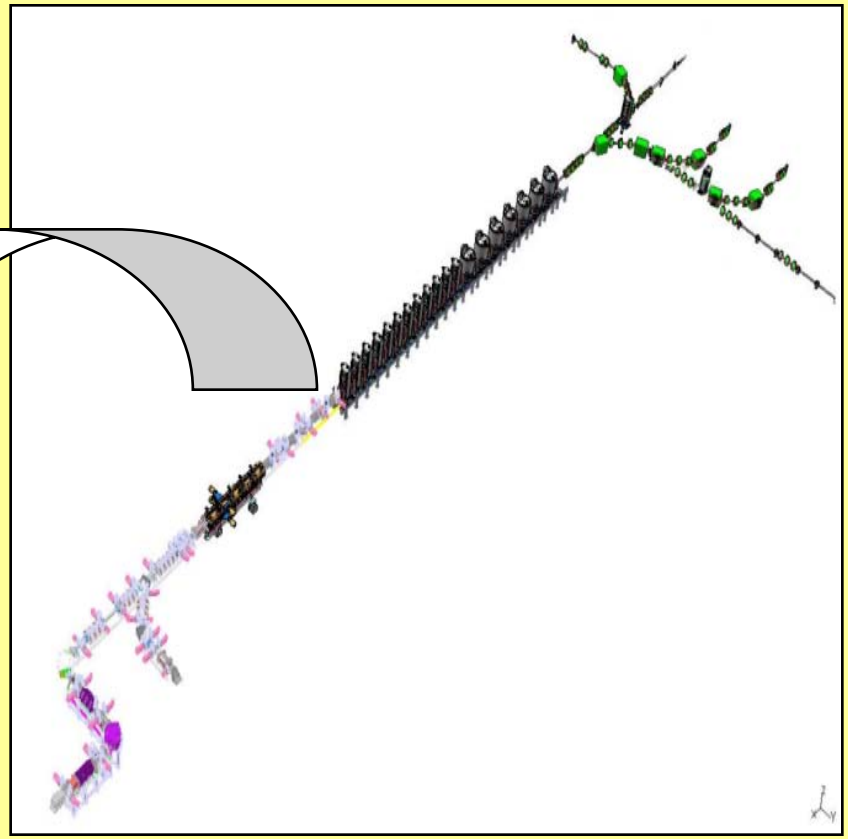


Vacuum LBEC synoptic

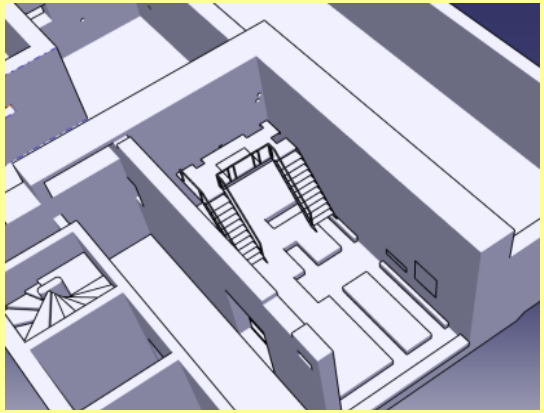
Another challenge: Synthesis between the accelerator and the building

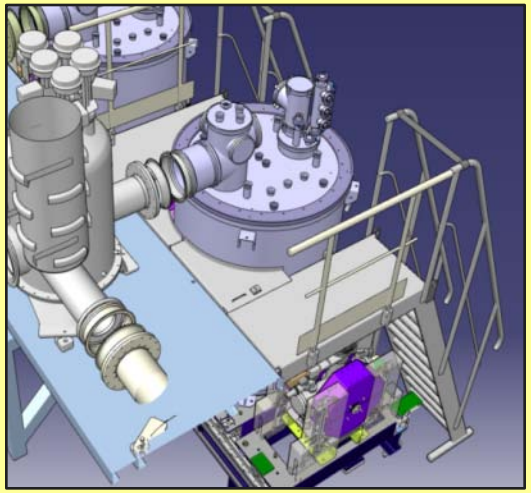




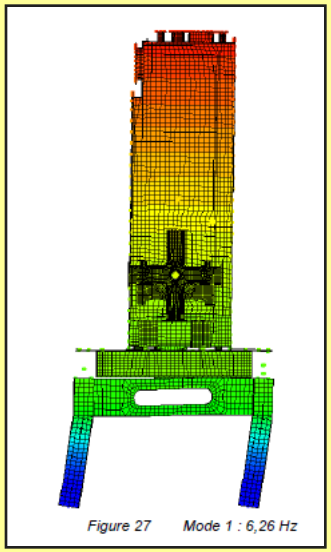


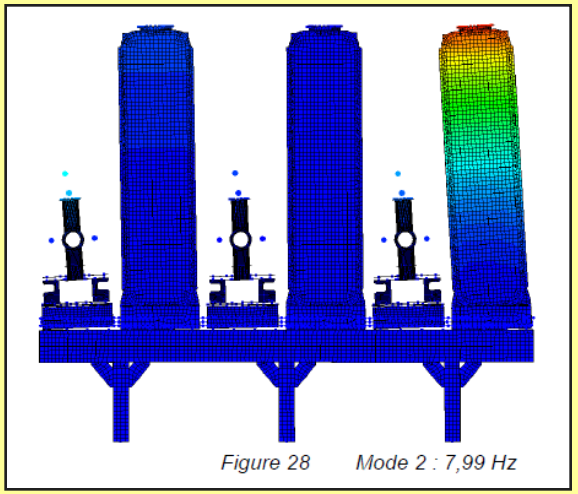
Last but not least…





Accessibility, footbridges and security of workers…





Effect of an earthquake on the building integrity…

CONCLUSION

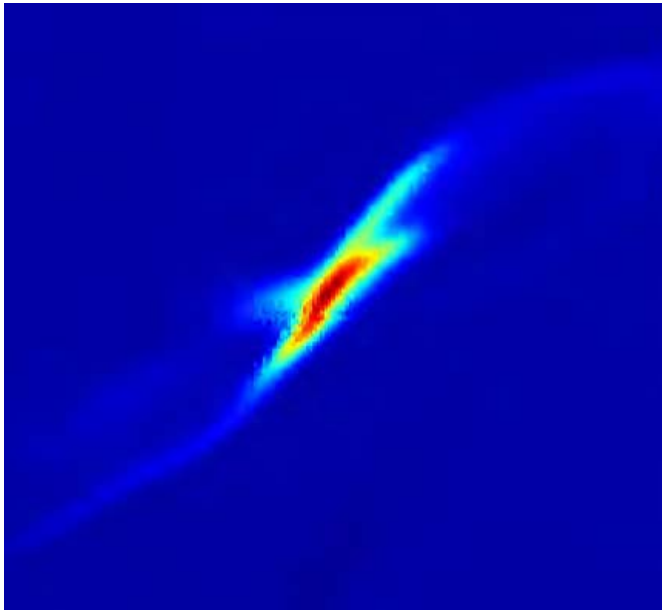
➢ **Good beam tests performed at Saclay and Grenoble:**

- Allowed us to check the design of transfer lines
- Good emittances, separation, vacuum, beam profiles
- Behaviour of slow chopper and associated deviated beam stop
- Development of metallic beams
- Validation of 60 kV for 1/3 ions ECR source

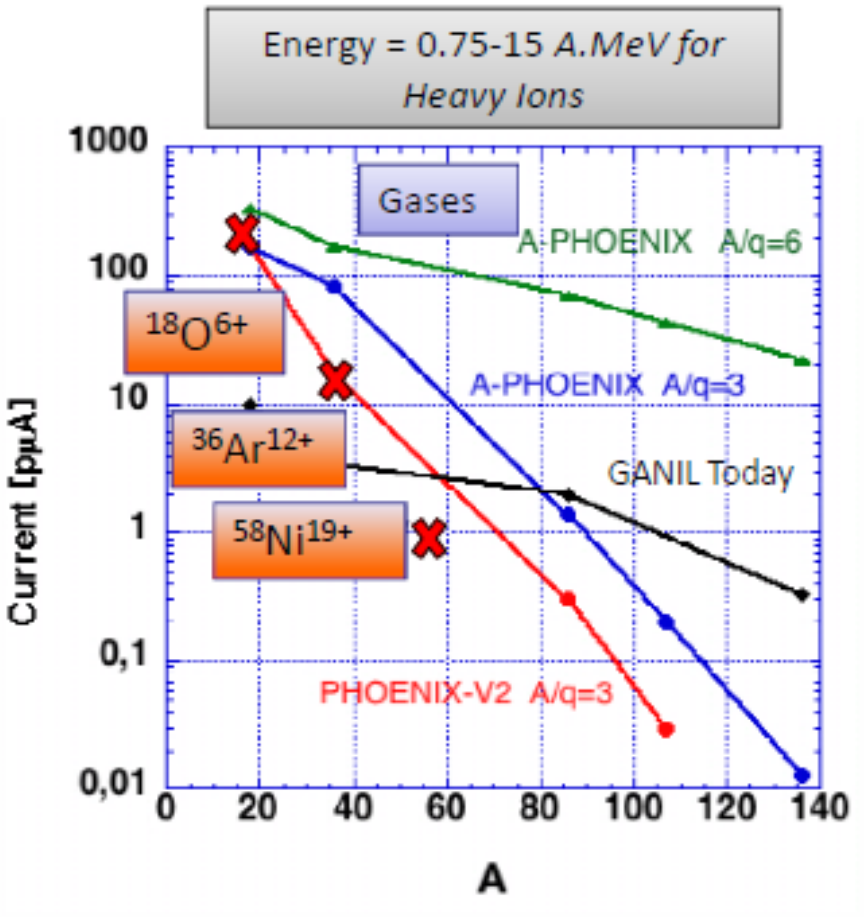
➢ **Big contracts remain to be launched in 2012:**

- ECR 18 GHz Emittor
- Mechanic supports and vacuum tubes (MEBT + HEBT)
- Set of diagnostics to complete
- RFQ cooling system
- Vacuum pumps and rapid vanes (EIS) (MEBT+LINAC+HEBT)
- HEBT Commutation grid (EIS)
- Main Beam Dump (HEBT)
- Development of MPS system…

THANK YOU !



Day 1 SPIRAL2 LINAC beams



Ion(s)	Energy Range (MeV/nucleon)	Maximum Intensity (pμA)	Remarks
$^{1}H^{1+}$	20-33	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{2}H^{1+}$	10-20	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{4}He^{2+}$	10-20	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{12}C^{4+}$	5-7	≥10 **)	S3 beam line
$^{18}O^{6+}$	5-7	≥10 **)	S3 beam line
$^{22}Ne^{8+}$	5-7	≥10 **)	S3 beam
$^{40}Ar^{14+}$	4-5	≥10 **)	S3
$^{32-36}S^{12+}$	5-7	≥10 **)	m line
$^{40}Ca^{14+}$	5-7	≥10	S3 beam line
$^{48}Ca^{16+}$	5-7	≥10	S3 beam line
$^{58}Ni^{18+}$	4-14	≥1 **)	S3 beam line

Beam Intensity Reached

- ✓Starting source for commissioning and first experiments => Phoenix V2
- ✓Upgrade of Phoenix V2 => V3 Large plasma chamber and new oven Ø20 mm