SPIRAL 2 Commissioning Status

Jean-Michel Lagniel (GANIL) for the SPIRAL 2 Team

With thanks to the SPIRAL 2 team

Menu

1- SPIRAL 2 facility (Phase 1) presentation

2- Injector commisionning (Sources and **RFQ**)

3- SC linac status

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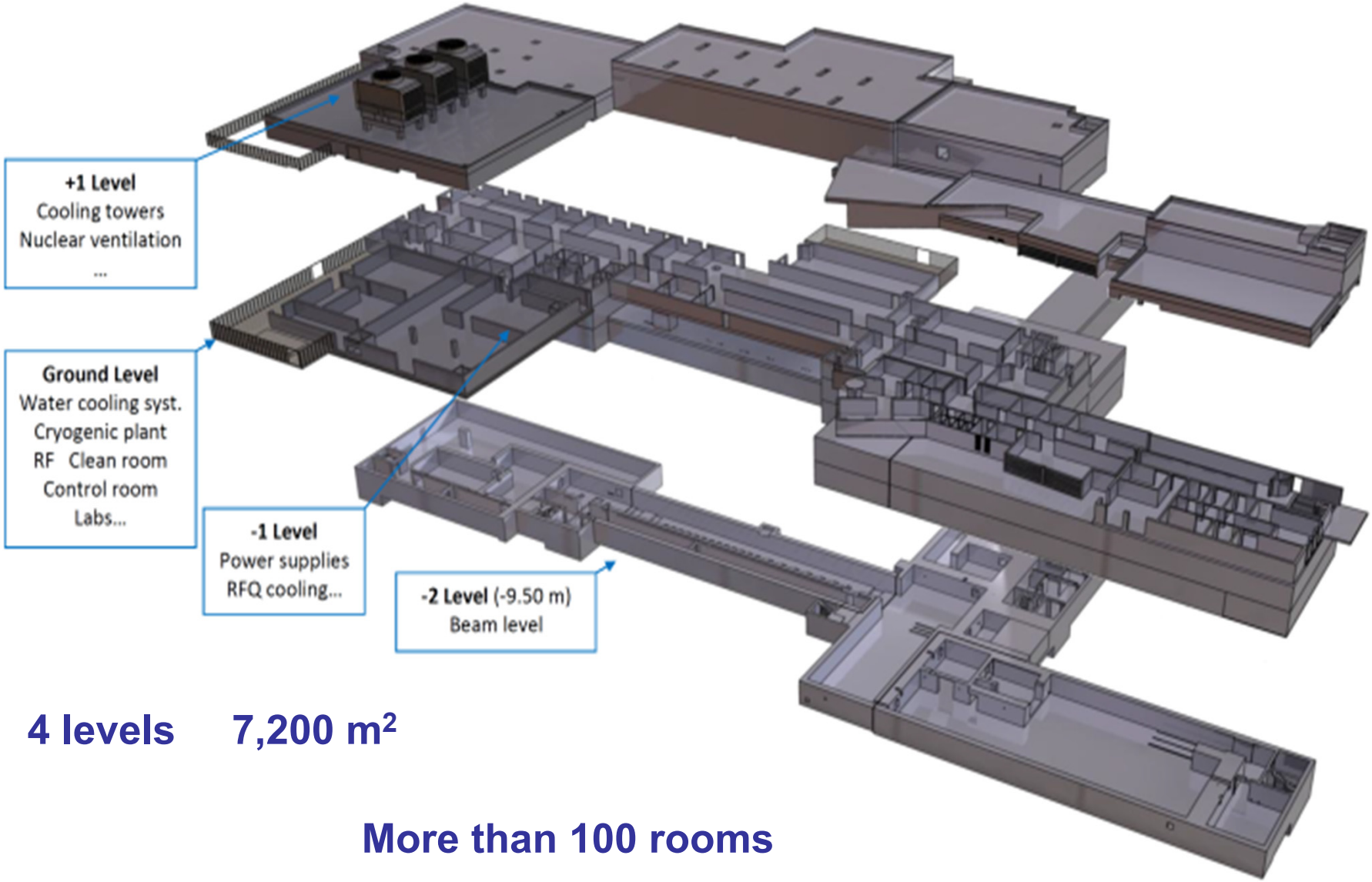
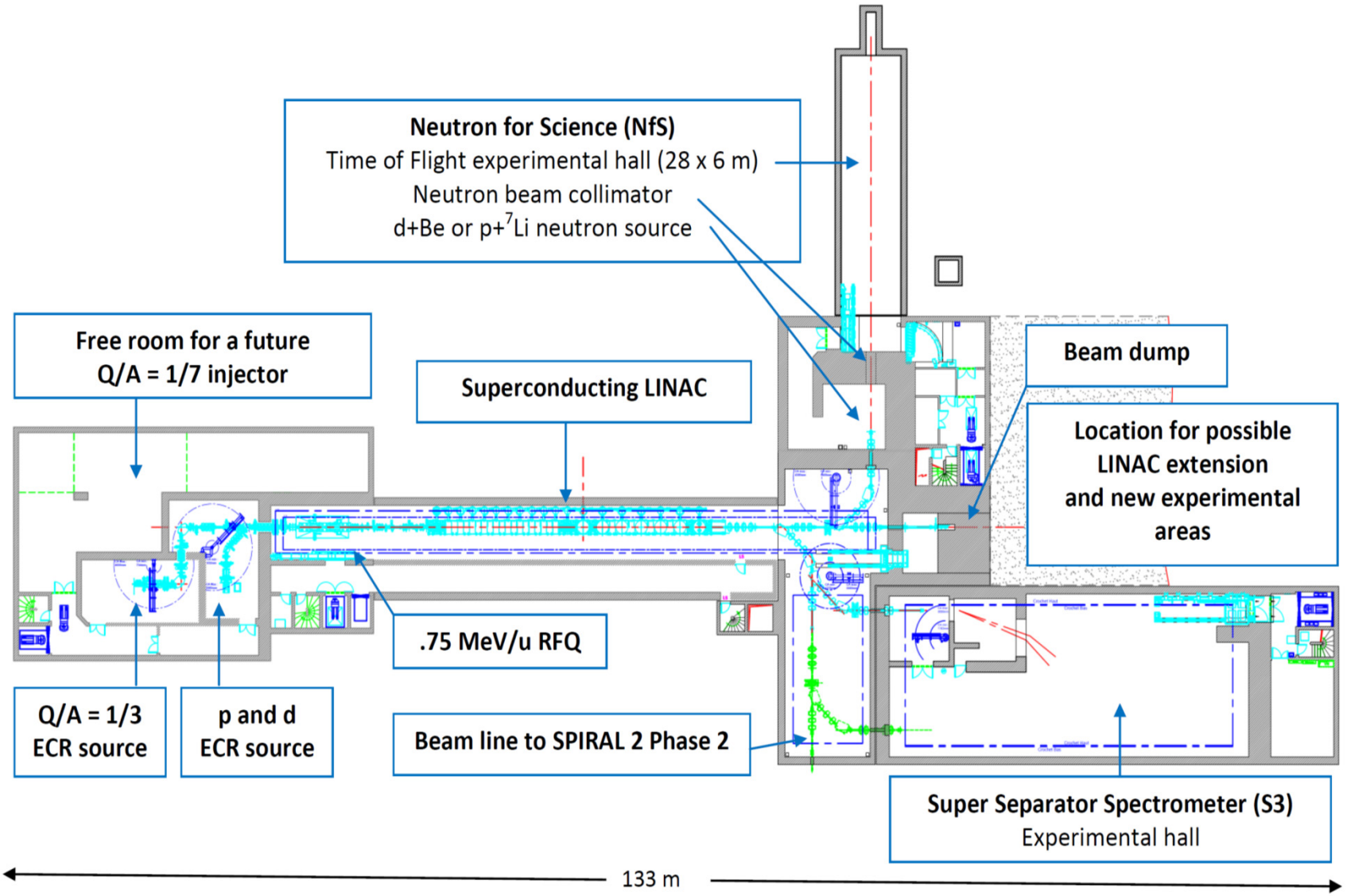
-1- SPIRAL 2 Facility



4 levels **7,200 m²**

More than 100 rooms

-1- SPIRAL 2 Facility - 9.50 m (beam level)



-1- SPIRAL 2 Construction

SPIRAL 2 building site preparation January 2011

-1- SPIRAL 2 construction

2011 +3.5 years : September, 2014

-2- SPIRAL 2 injector commissioning

18 GHz 60 kV
LPSC Grenoble

Free space for the future A/Q = 7 injector connection

RFQ
1 < A/Q < 3

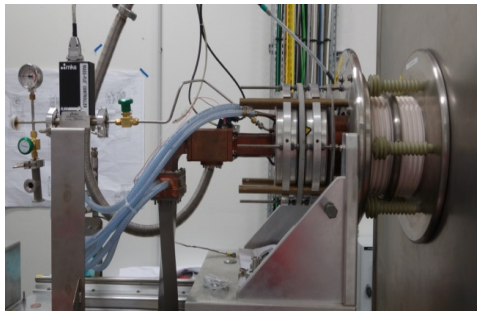
Re-bunchers

Medium Energy
Beam Transfer Line

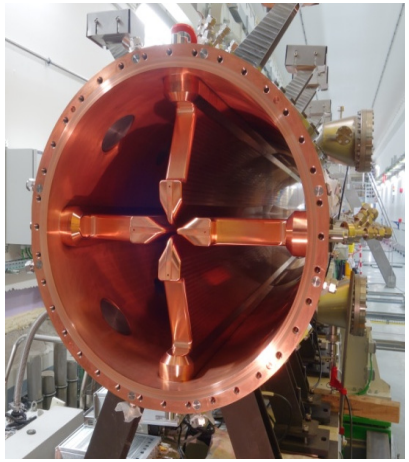
Fast shopper (Bunch selector)

ECR Ion Source
D^+, p

ECR Ion Source
(Heavy ions, q/A=1/3)

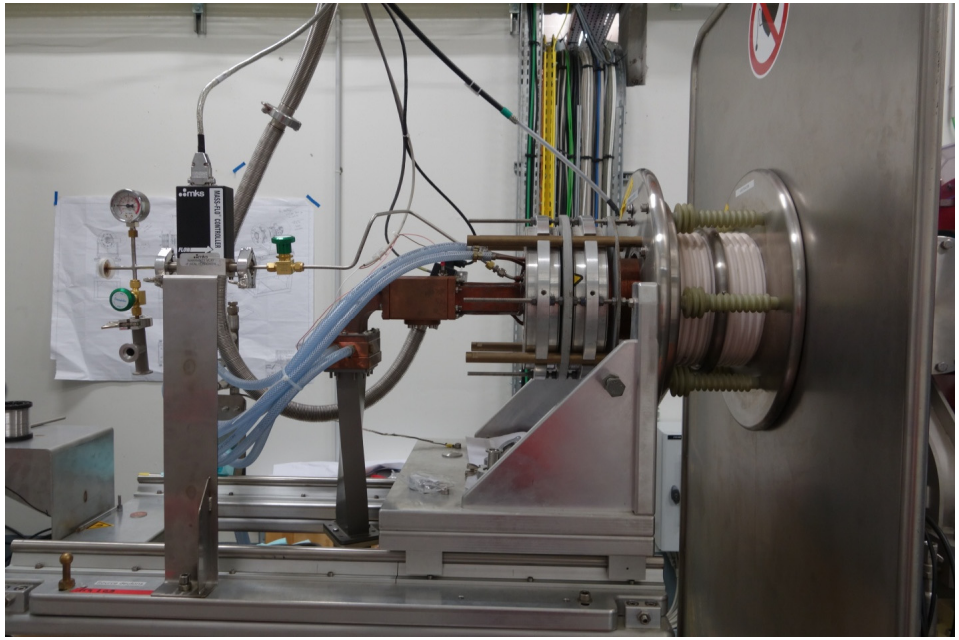


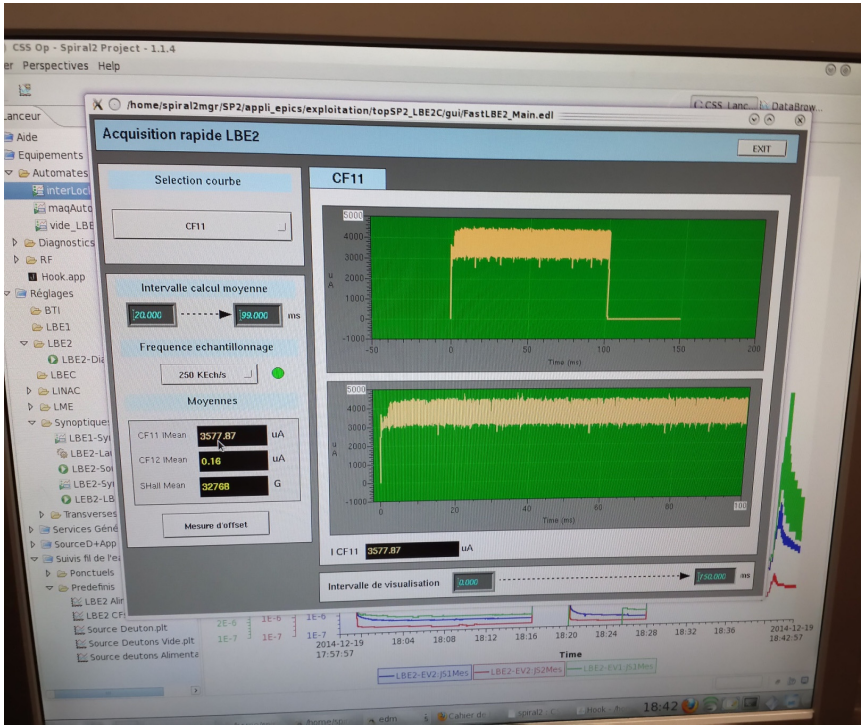
2.45 GHz 40 kV IRFU Saclay



0.75 MeV/u RFQ

First beam at GANIL
December 19, 2014

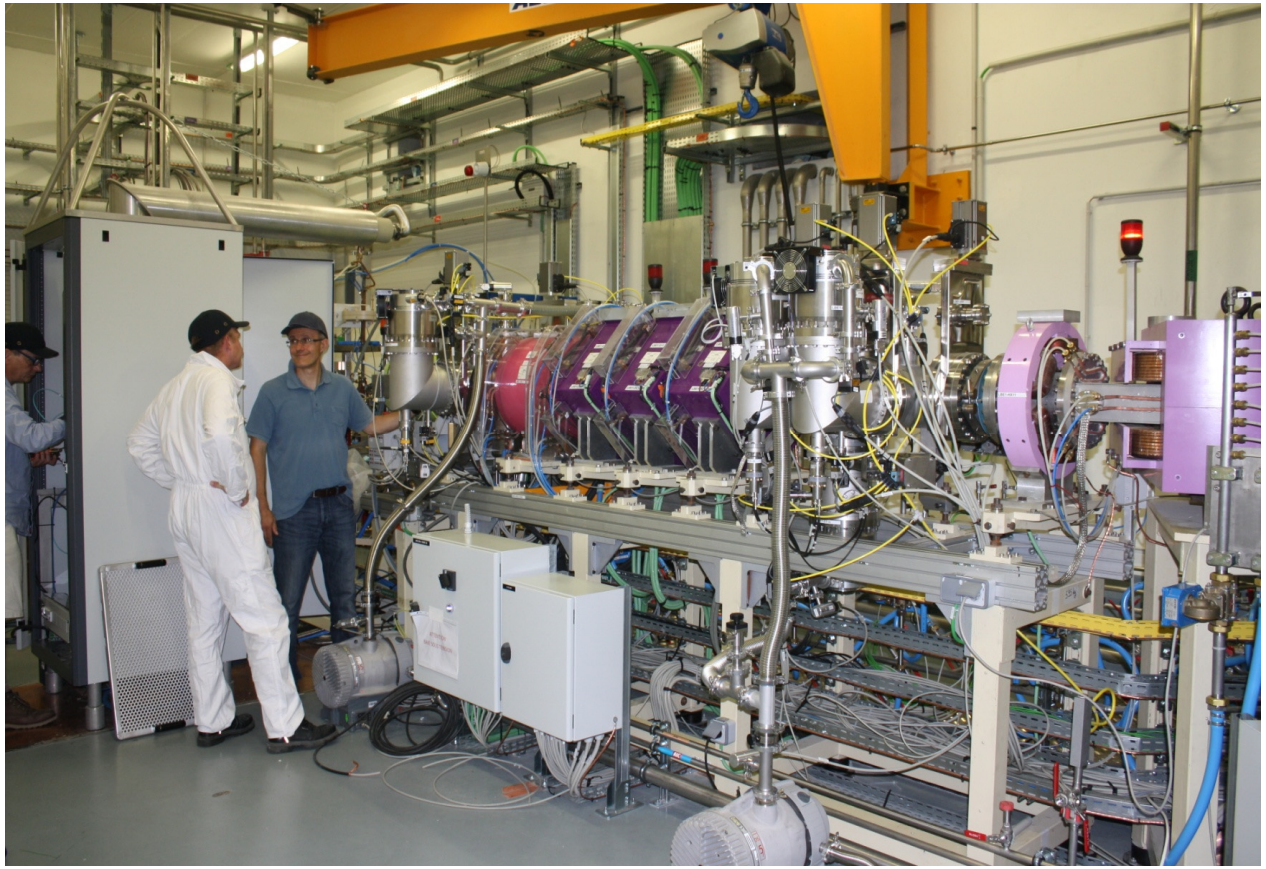


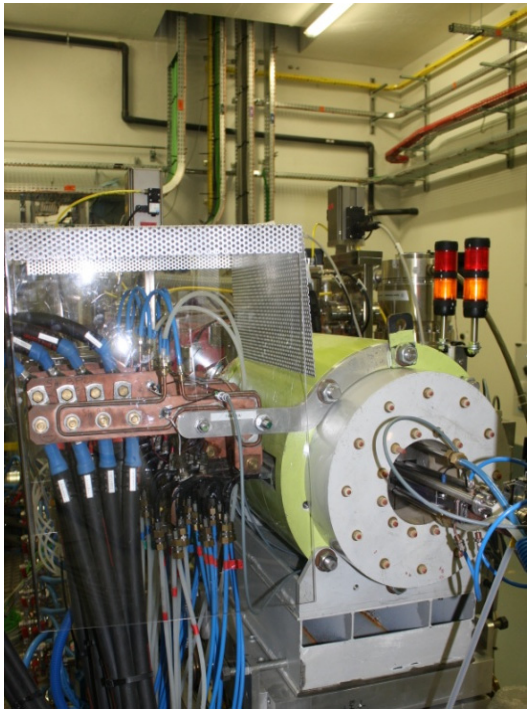


Protons

Issue = noise (emittance growth)

First beam (230 µA Argon 9+) July 10, 2015

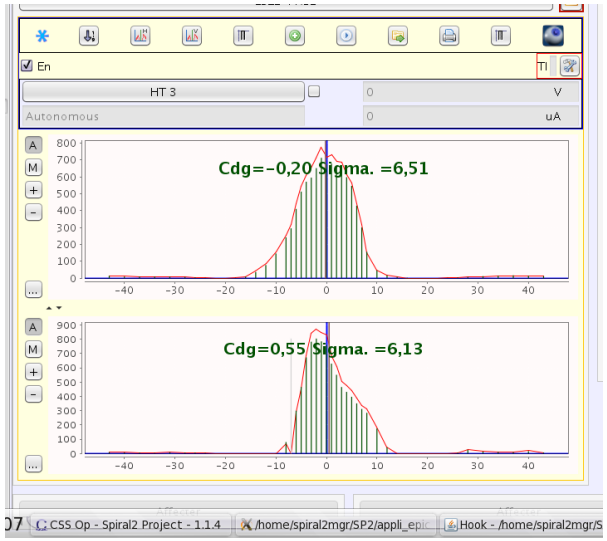


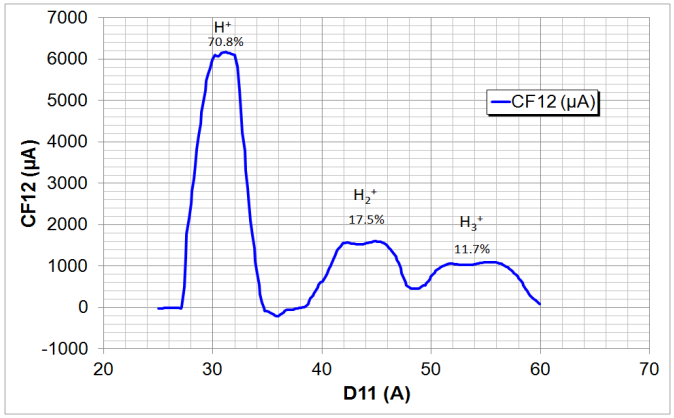


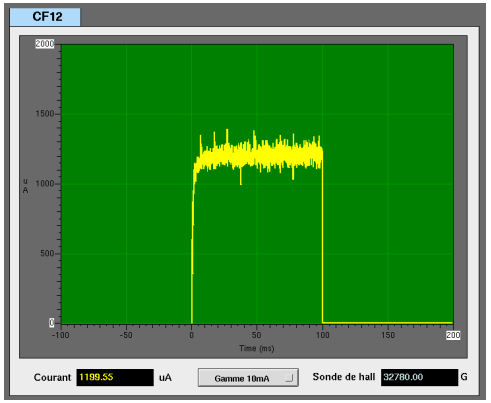
Test
He 4 2+ A/Q = 2

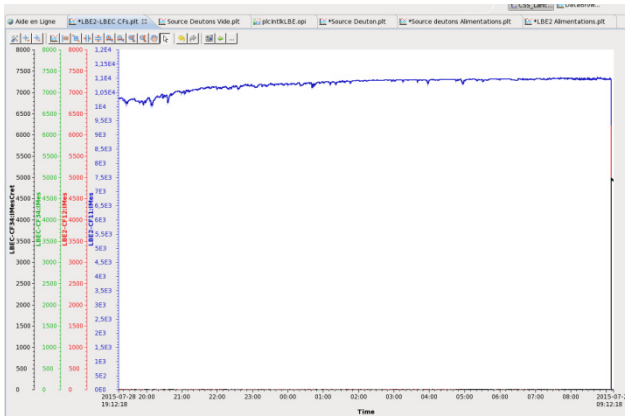
D beam forbidden !

-2- SPIRAL 2 p/d and HI source commissioning

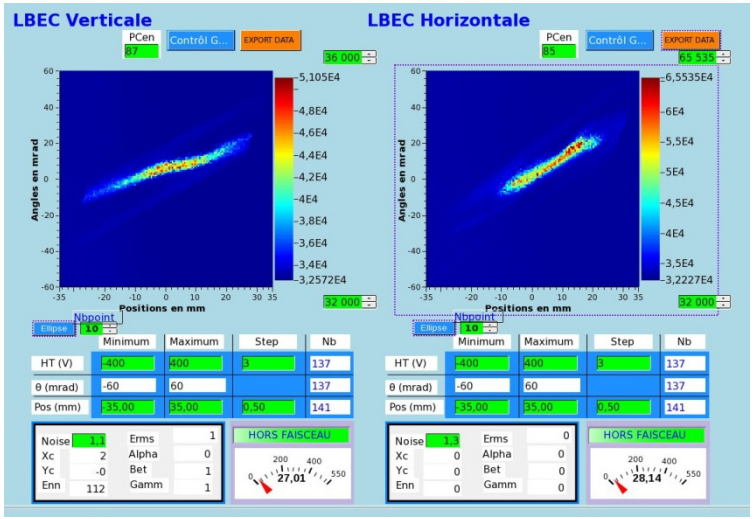








0.2 π mm mrd
rms norm.



Long period stability (6 mA CW)

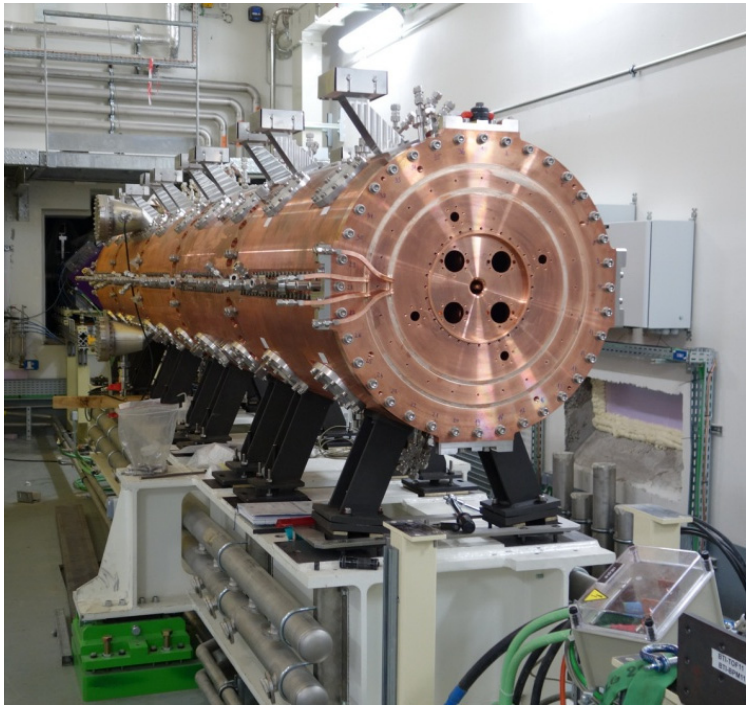
Emittance measurements f(I) July + August + Sept

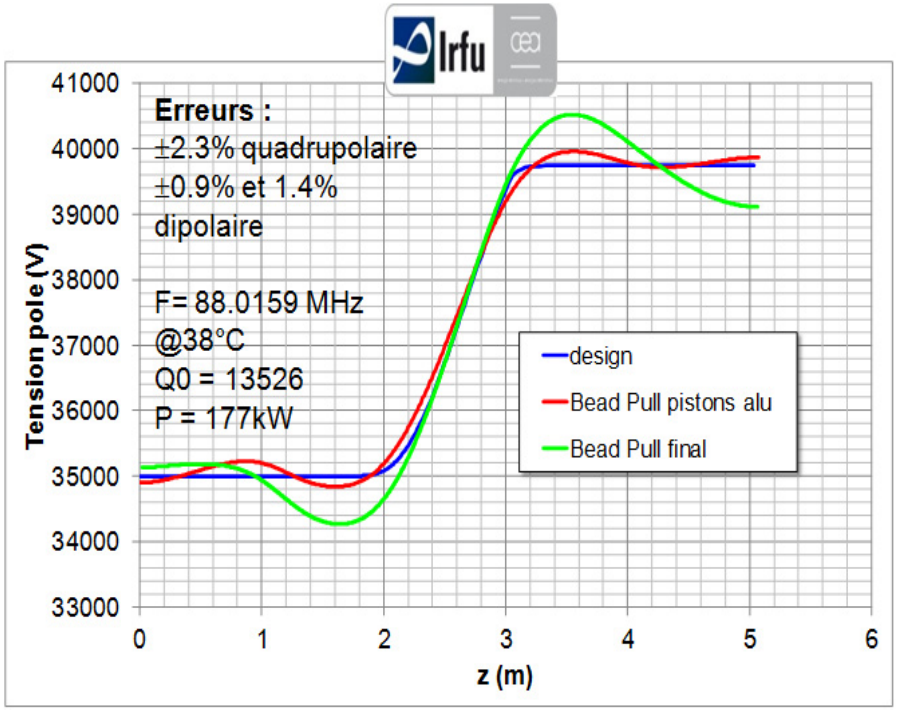
Ability to extract 11 mA CW from the p source => 6 mA proton beam

Beam intensity and emittance control using 6 H and 6 V slit systems

CEA-Saclay-IRFU responsibility + GANIL Team

Installation / alignment / vacuum tests Nov. 2014 to Feb. 2015





Voltage law (bead-pull) measurements + adjustments (40 plungers) OK March 2015

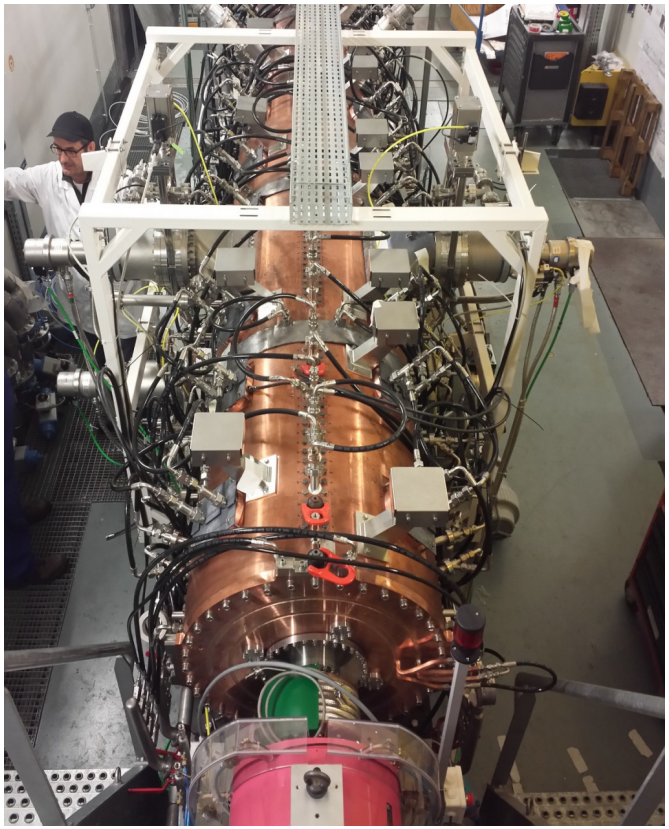
Max error = 2.3 % on the quadrupolar mode (+3 % longitudinal emittance increase)

Expected transmission = 99.7 %

-2- SPIRAL 2 RFQ equipment

RFQ cabling
Cooling / tuning system tests

rf amplifiers tests / load



4 x 60 kW rf amplifiers (tubes / 4 x 3 kW solid state preamplifier)

DB electronica (Padova, Italy)

First campaign mid October 2015 (~ 2 weeks)

Pulsed mode, multipactor issues at low level

Procedure adjustments / adjustment of the feedback loop coefficients

Second campaign November 2015 (~ 3 weeks) with 3 amplifiers

rf power ramp-up up to CW, November 6 : 38 kV CW (2 amplifiers)

November 23 : A/Q = 2 field = 75 kV CW (89 kW)

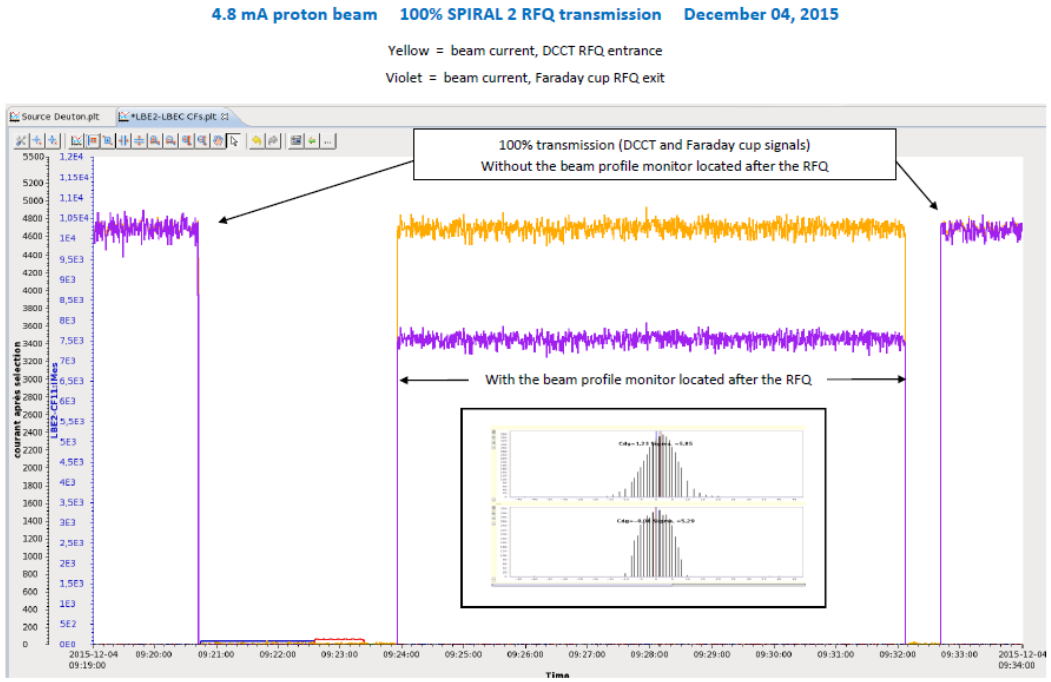
End November : 85 kV CW (with 3 amp / 4)

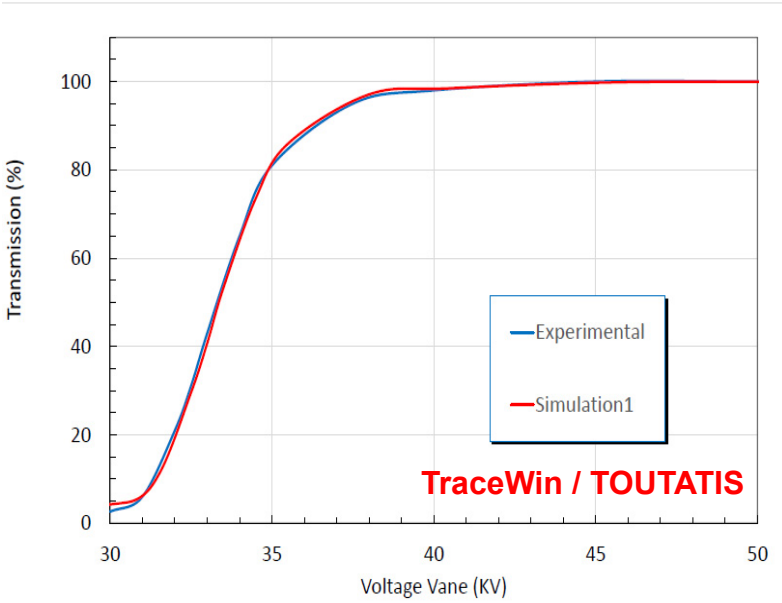
4 amplifiers needed for the A/Q = 3 field = 113 kV (180 kW => 4 x 45 kW)

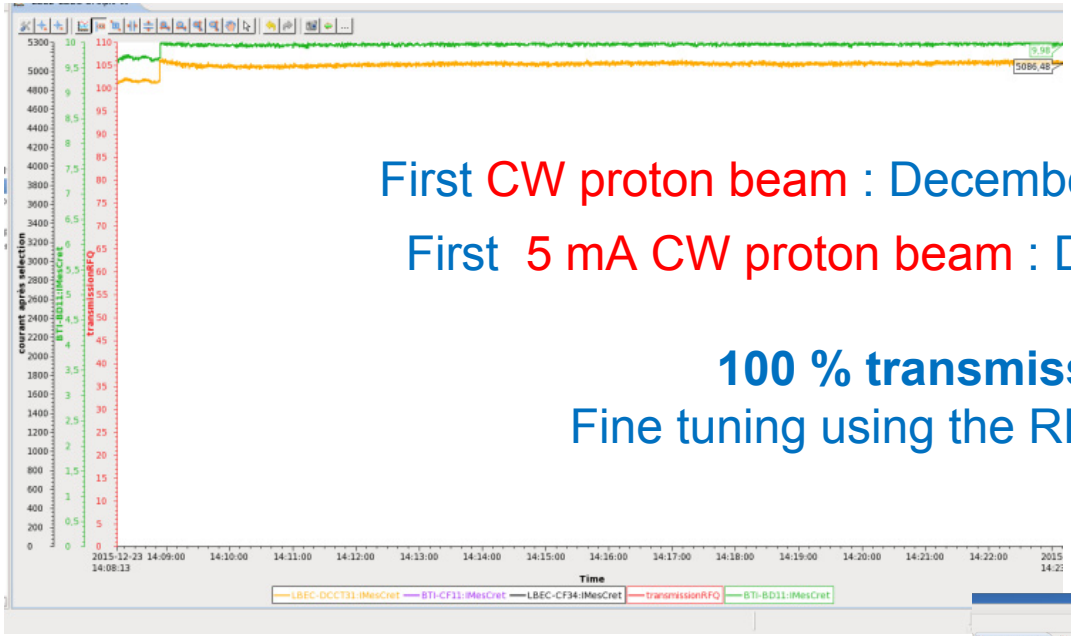
2015, December 03, 9h26 : First RFQ beams (Protons)

RFQ in CW rf operation (up to 50 kV) Pulsed beam 200 µA, 200 µs, 2 Hz

5 mA with 100% transmission at the end of the working day
(SPIRAL 2 nominal beam current)







First CW proton beam : December 18, 2015 : 2.3 mA

First 5 mA CW proton beam : December 23, 2015

100 % transmission

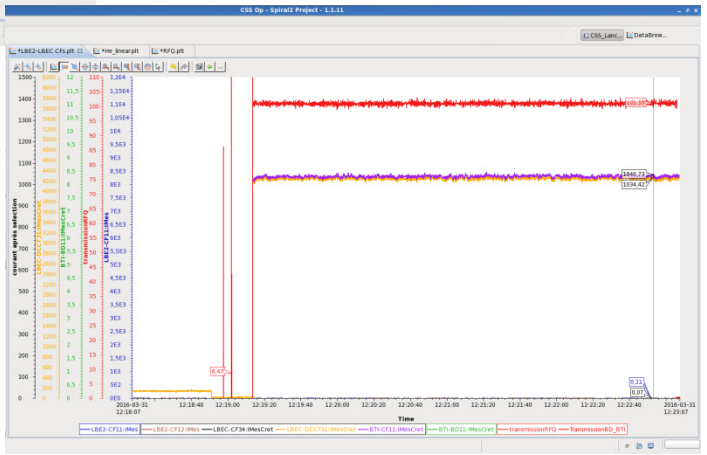
Fine tuning using the RFQ vacuum

A/Q = 2 beam up to 1.5 mA $^4He^{2+}$

February 25, 2016 : First pulsed beam, 250 µA

First CW beam : June 04, 2016 ~ 1 mA

Transmission > 99 %



Proton & A/Q = 2 : RFQ always operated CW from the rf point of view

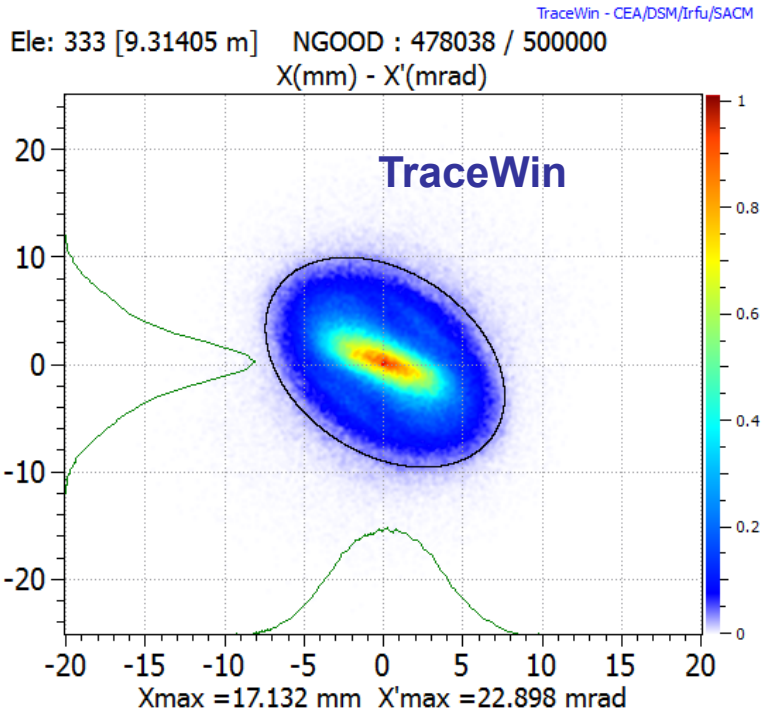
rf operation stable and reliable (with 3/4 amps, up to 80 kV)

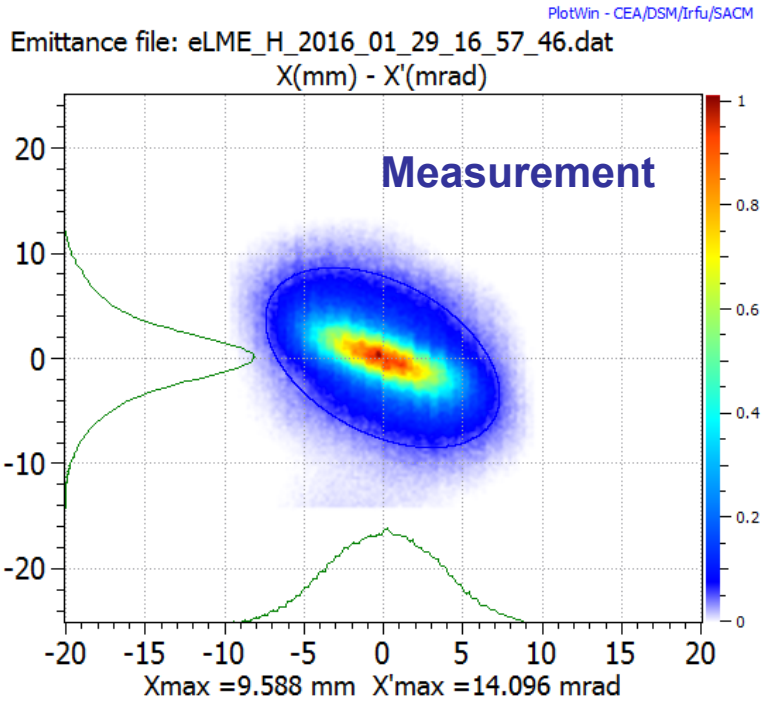
3 main objectives for the commissioning

1 = Measure the RFQ beam characteristics,
including the longitudinal emittances using a rebuncher + FFC & BEM

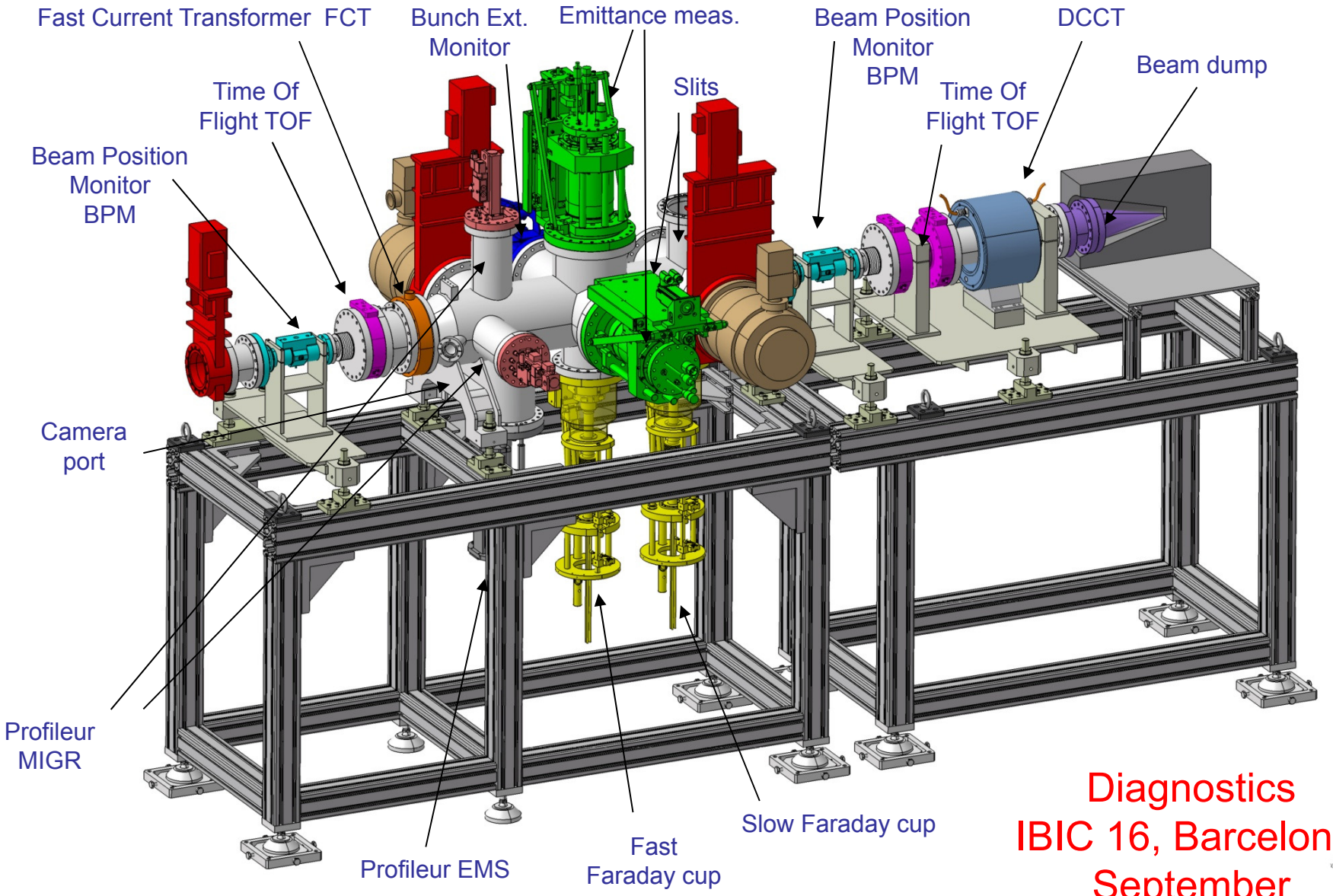
2 = Debug / measure the performances of the diagnostics (BTI)

3 = Prepare the Superconducting LINAC commissioning
measuring the beam characteristics for the different commissioning phases (low current)



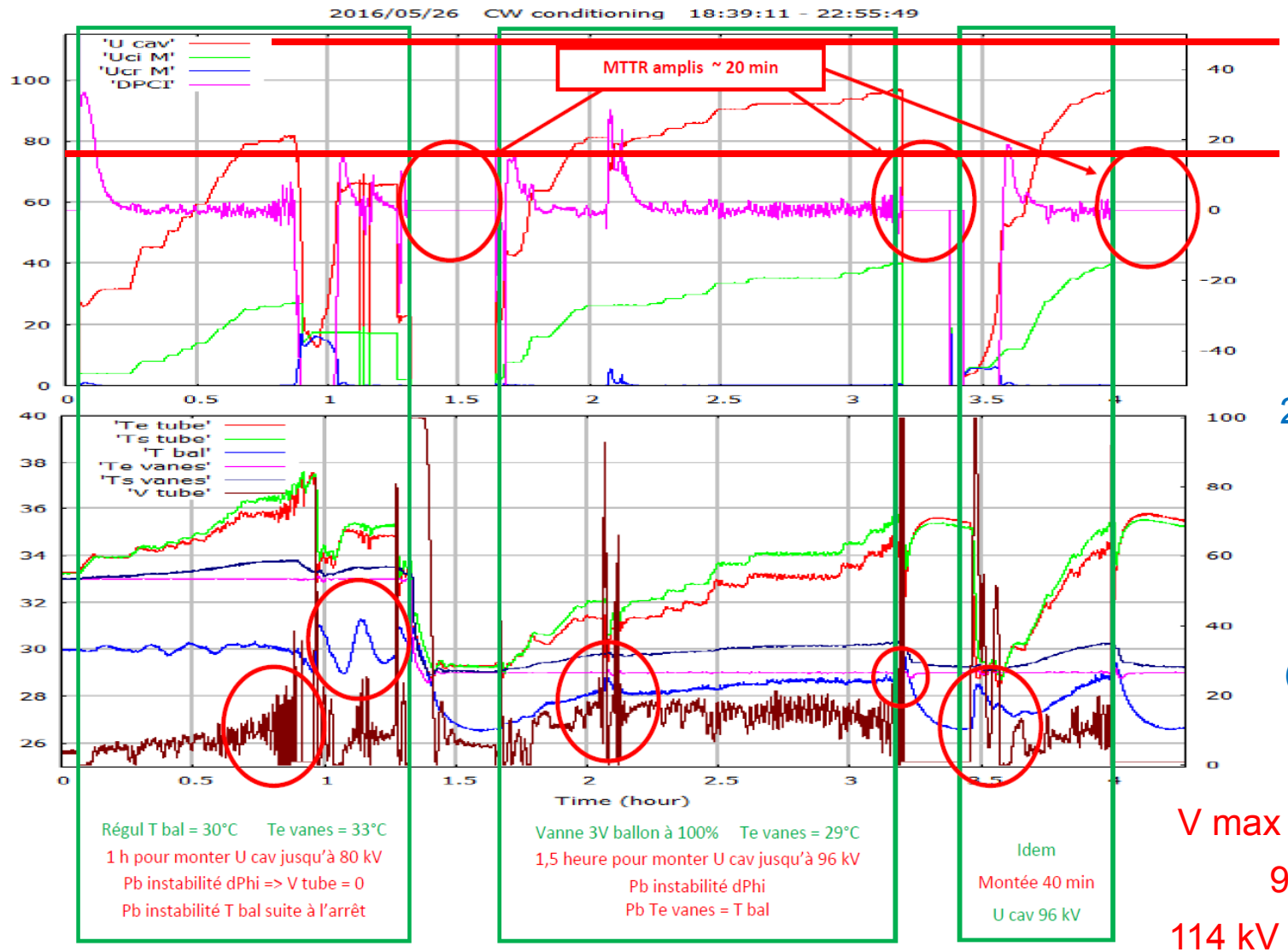


-2- SPIRAL 2 Injector Test Bench (BTI)



Diagnostics
IBIC 16, Barcelona, September

-2- SPIRAL 2 RFQ A/Q > 2 rf conditioning



MTTR

Amplifiers :
20 min to restart
(delays)

+

Field ramp up :
40 to 90 min
(slow feedback)

V max achieved today

96 kV CW

114 kV 15% duty cycle

Issue # 1 = rf amplifiers reliability / availability

Availability : one short period with 4 amps, 3/4 amps most of the time, 2/4 today

MTBF too short (over protections ?) MTT Repair / Restart too longs (spares / shorter delays ?)

Issue # 2 = LLRF

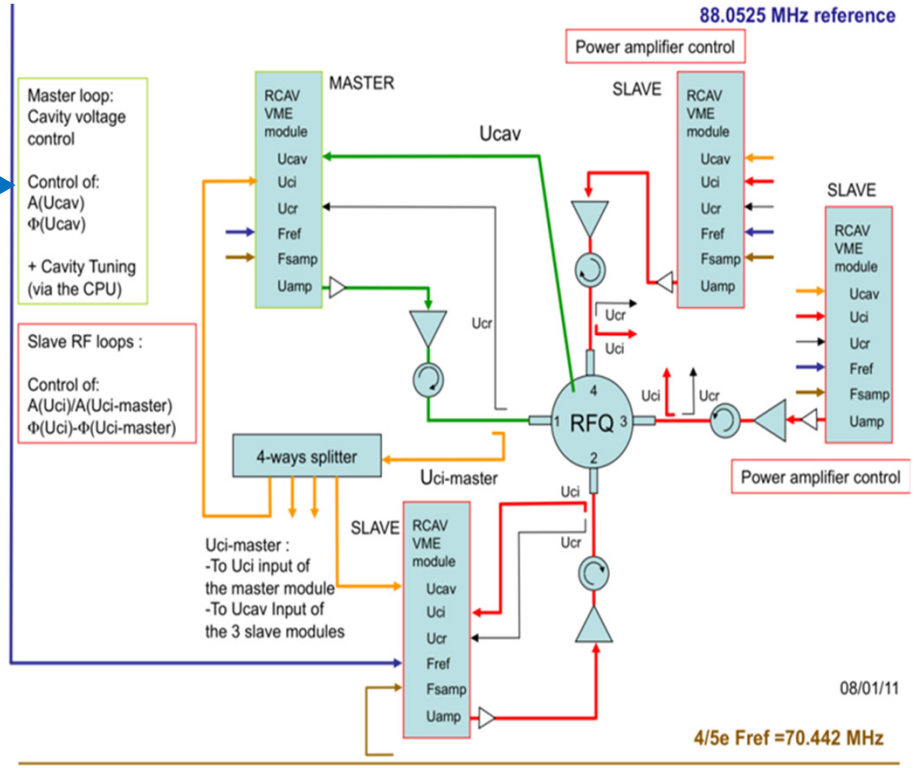
LLRF : amplitude and phase control of 4 amps coupled to one RFQ cavity

Variable frequency mode unavailable

Variable frequency mode implemented based on internal I/Q vector rotations of the 4 signals

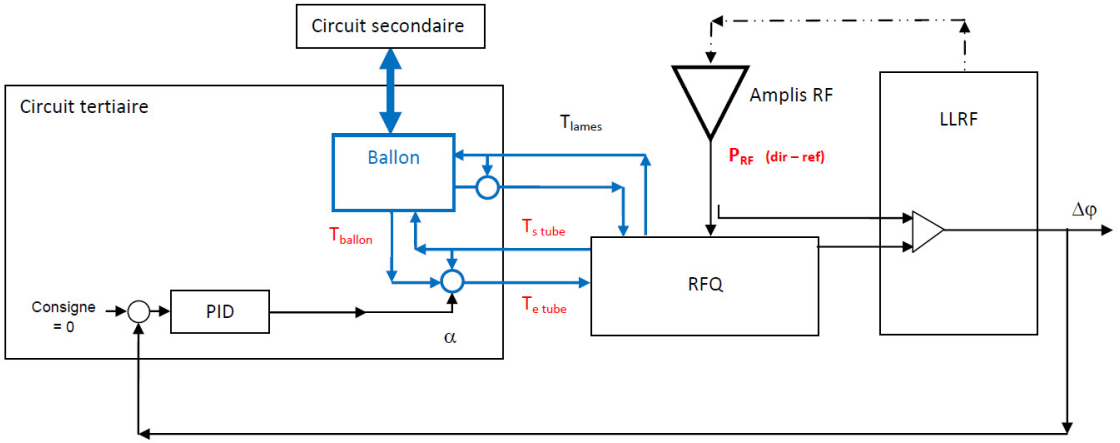
Amplifier issue ? (differences between the 4 amps, delayed response, nonlinearities…)

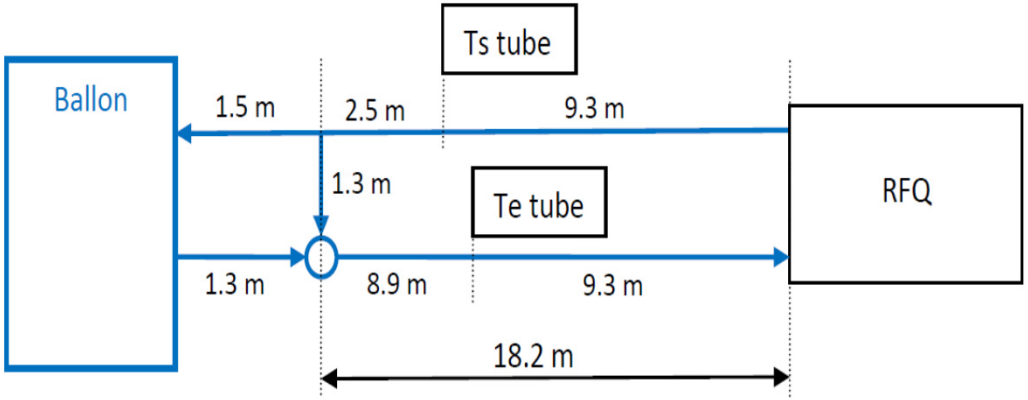
LLRF issue ?



Issue # 3 = RFQ cavity tuning loop

Very difficult to tune at high power … Too slow … Unstable





Long water lines

⇩

3-Way valve response time = 30 s
Long delay

⇩

Stability = Long time constant (> 2 D)

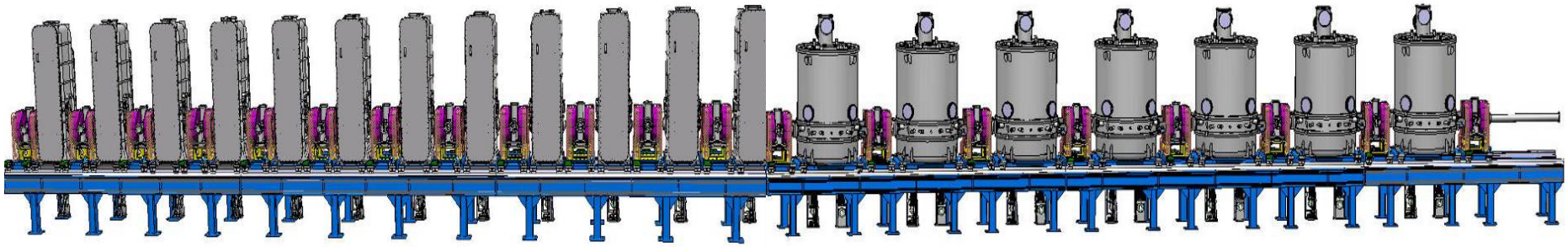
⇩

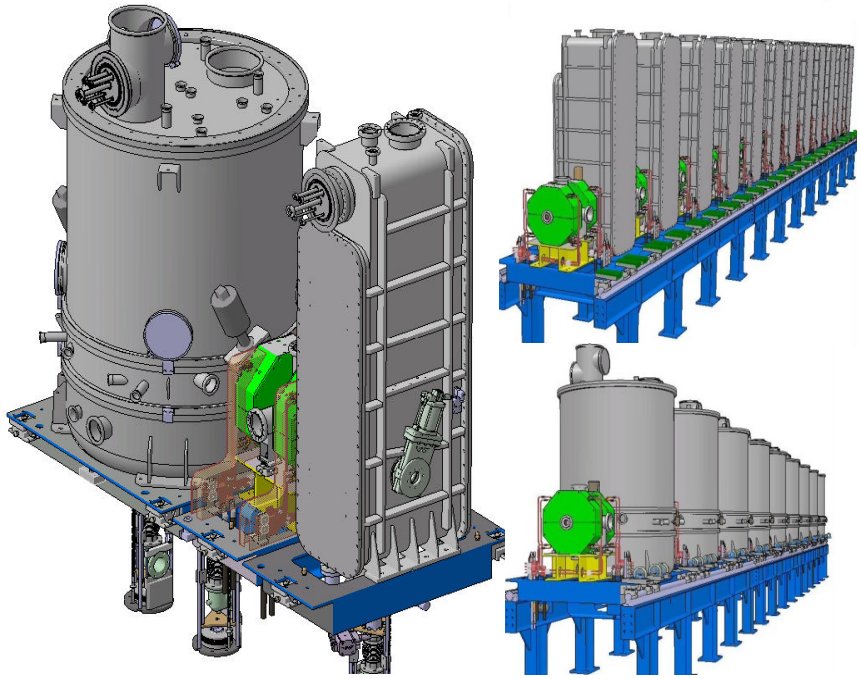
Slow response of the cavity tuning loop

⇩

Slow rf power ramp-up

88 MHz QWR 12 x 1 = 12 β = 0.07 cavities 7 x 2 = 14 β = 0.12 cavities

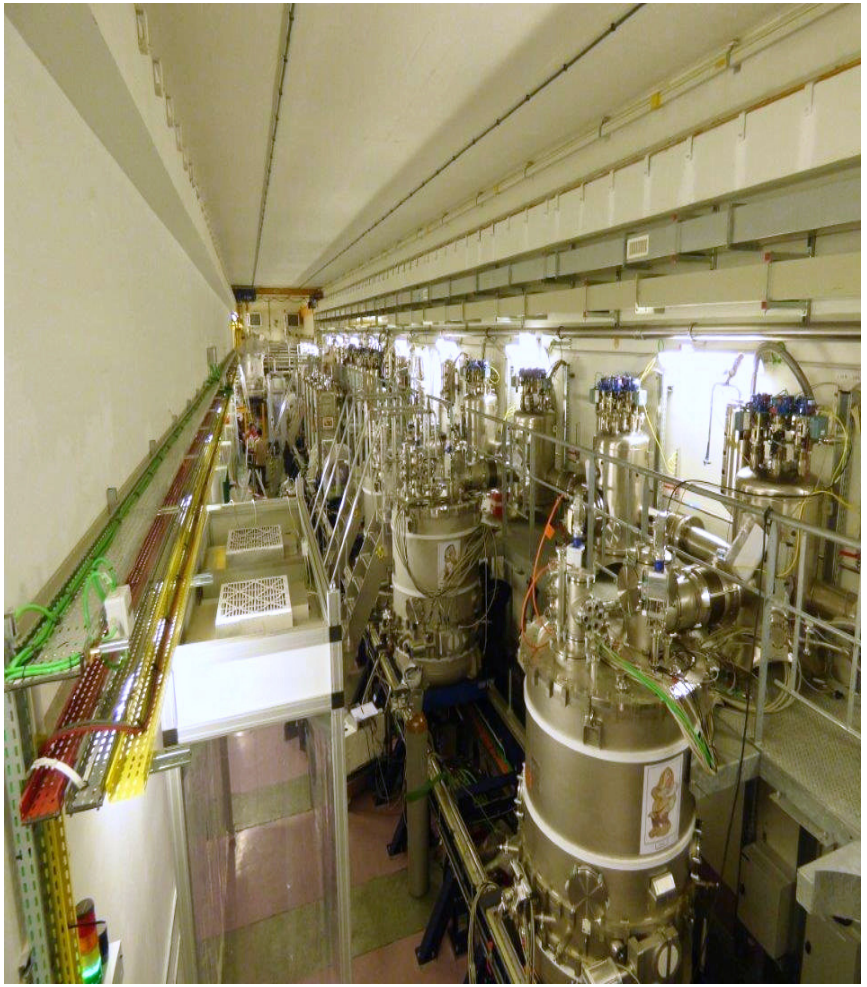




	Q/A	I max (mA)	Energy (MeV/n)	CW max beam power (kW)
P	1/1	5	2 - 33	165
D	1/2	5	2 - 20	200
Ions	1/3	1	2 - 14.5	45
	1/7	*1*	*2 - 8*	*48*

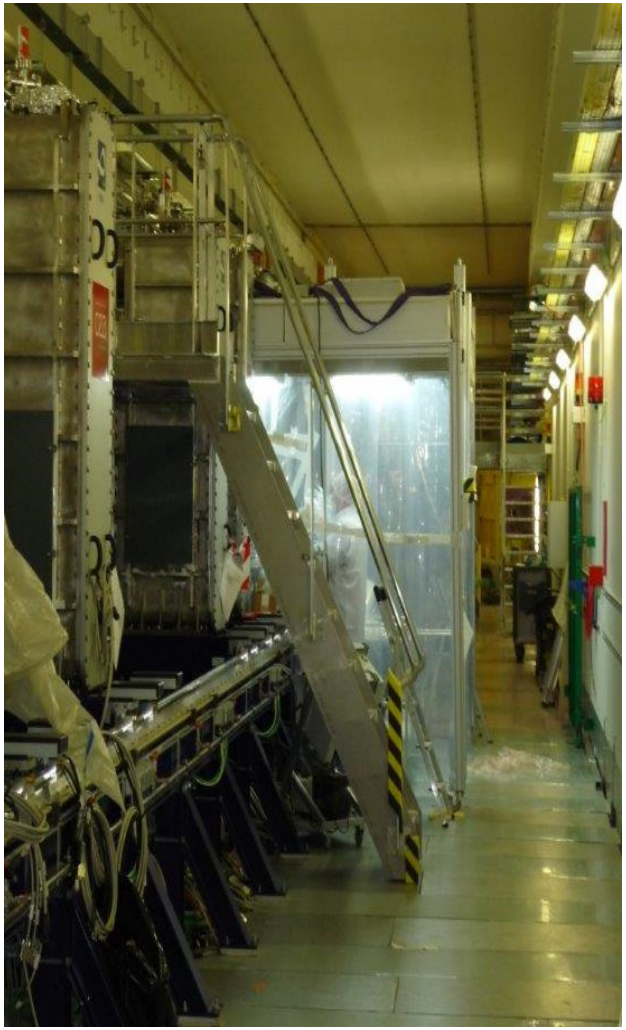
Wide range of particles, intensities, energies, duty-cycles (CW up to single bunch)

-2- SPIRAL 2 LINAC cryomodules

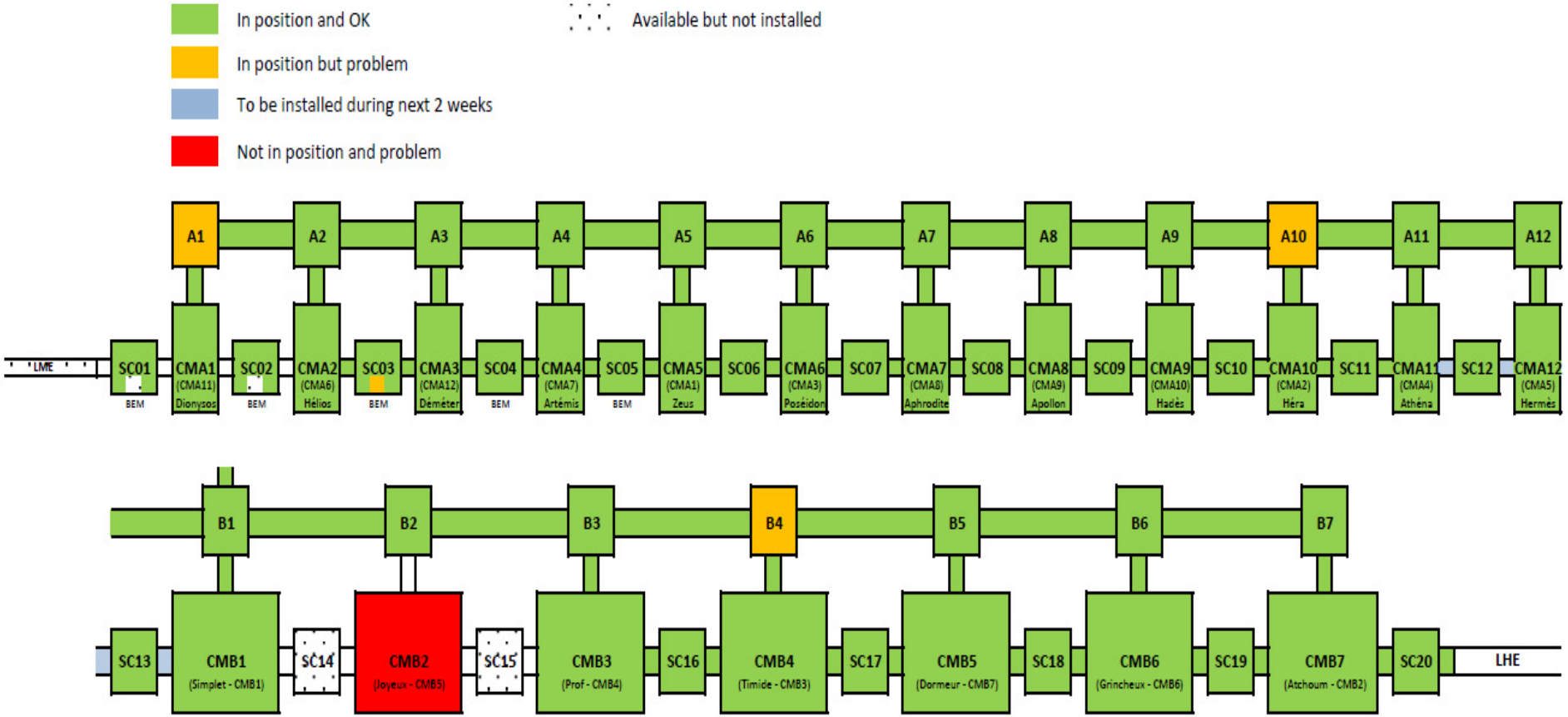


Today : 12 /12 CM-A + 6 /7 CM-B aligned and connected to their valve boxes

18 / 20 hot-section installed



All the valve-boxes have been “re-fabricated” (mechanical errors, cryo. leaks…)



A1 Pb de sonde de température nécessitant de démonter la boite à vannes
A10 Pb de sonde de traversée étanche ne nécessitant a priori pas de démonter la boite à vannes
B4 Pb de sonde de température ne nécessitant a priori pas de démonter la boite à vannes

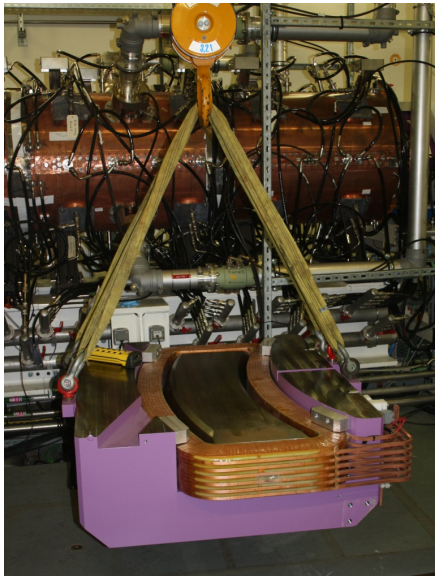
2 cryomodules with cryogenic leaks

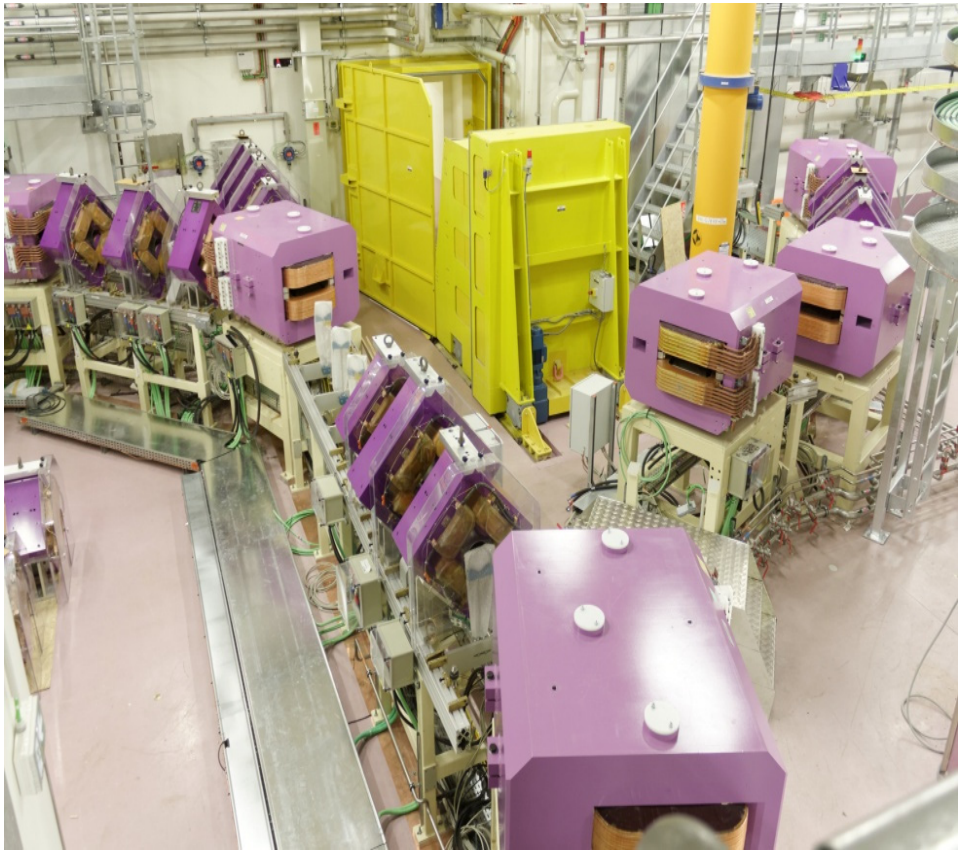
Cryogenic system (1,300 W equivalent 4.5 K) installed, first liquid helium in July 2015

One solid state amplifier / cavity
Up to 20 kW

Amplifiers, feeders, circulators, LLRF and interlock PLC have been tested independently, installed in the building and interconnected

-2- SPIRAL 2 HEBT line installation





-5- Summary

Good advances of the SPIRAL 2 project since January 2011 !!!

- Both light and heavy ion sources working very well

- RFQ working well with protons and A/Q = 2 ions (He and O)

- RFQ conditioned up to 96 kV CW ➢ A/Q = 2.4 ions

- RFQ improvements
-rf amplifiers (reliability) LLRF (variable freq. loop) Tuning system (faster and stable)

- **Superconducting linac : first cooling down this week**
(cooling down of all the valve-boxes + 2 cryomodules)

- The installation and commissioning progresses are limited by the availability of the GANIL team
Operation of the GANIL “cyclotron facility” in //

- **First linac beam beginning 2017**