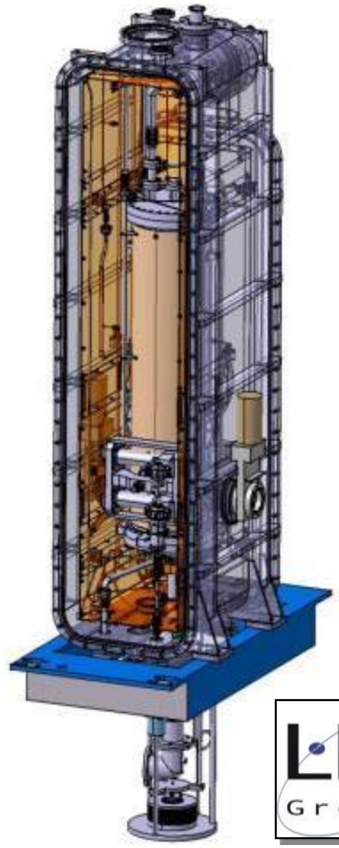
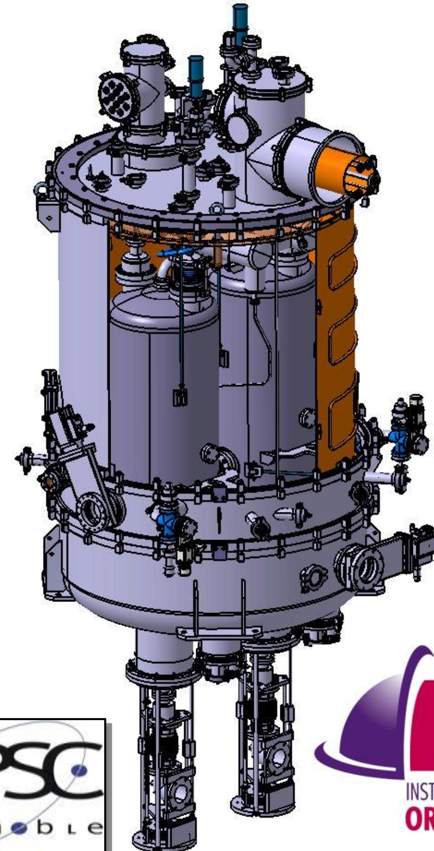
DE LA RECHERCHE À L'INDUSTRIE





PERFORMANCES OF SPIRAL2 LOW AND HIGH BETA CRYOMODULES

C. Marchand (CEA/IRFU)

On behalf of GANIL, IPNO, Irfu and LPSC teams

laboratoire commun CEA/DSM CNRS/IN2P3

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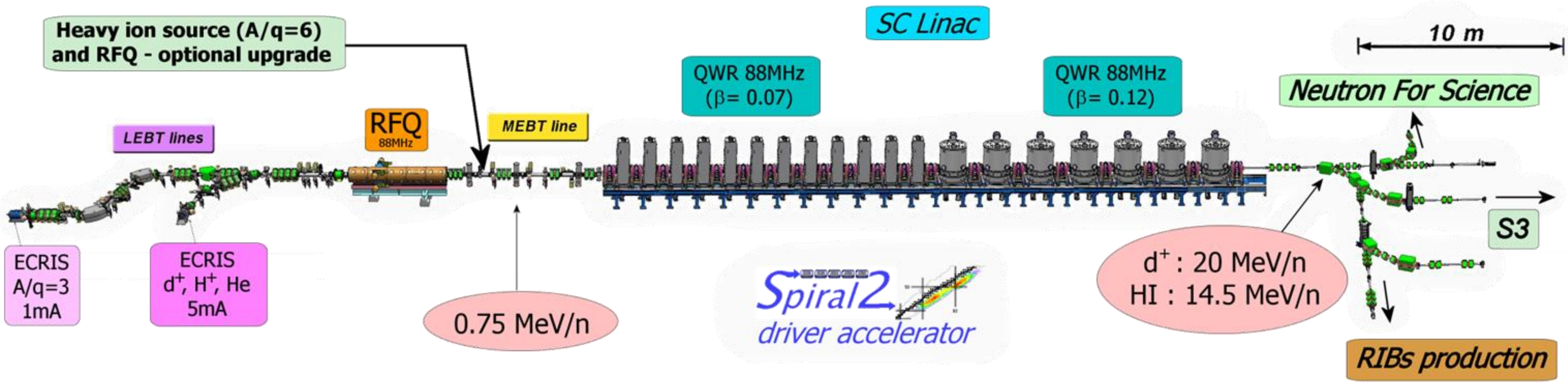
TALK OUTLINE

1. The SPIRAL2 superconducting accelerator
2. Low and High β Cavities and Cryomodules:

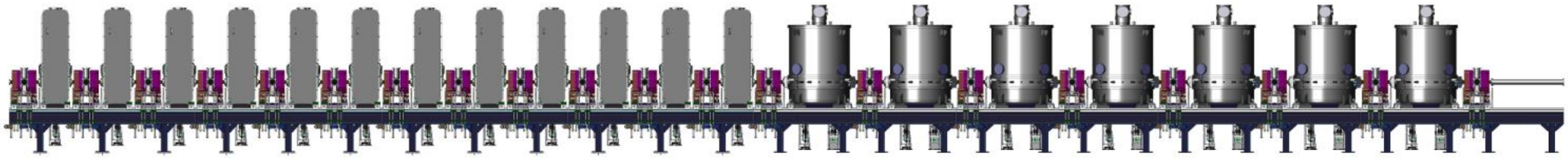
   Similarities and Differences
3. Cavity preparation and Cryomodule assembly
4. Cavities and Cryomodules performances
5. Status of Installation



Total length: 65 m
Slow (LEBT) and Fast Chopper (MEBT) RFQ (1/1, 1/2, 1/3) & 3 re-bunchers
12 QWR beta 0.07 (12 cryomodules) 14 QWR beta 0.12 (7 cryomodules) 1.1 kW helium liquefier (4.5 K) Ambient temperature Qpoles Solid state RF amplifiers (10 & 20 KW) 6.5 MV/m cavity gradient

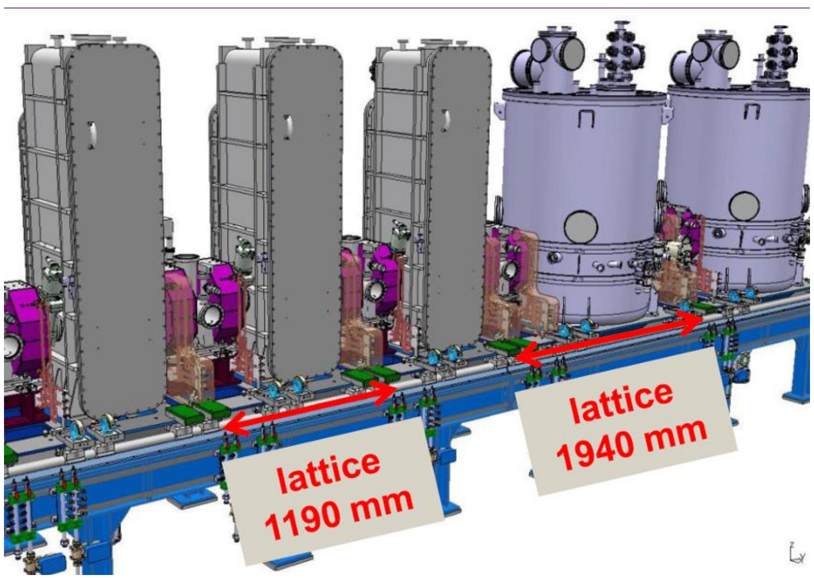
Particles	H^+	$^3He^{2+}$	D^+	Ions	
Q/A	1	2/3	1/2	1/3	1/6 (opt.)
I (mA) max.	5	5	5	1	1
W_O max. (MeV/A)	33	24	20	15	9
CW max. beam power (KW)	165	180	200	44	48

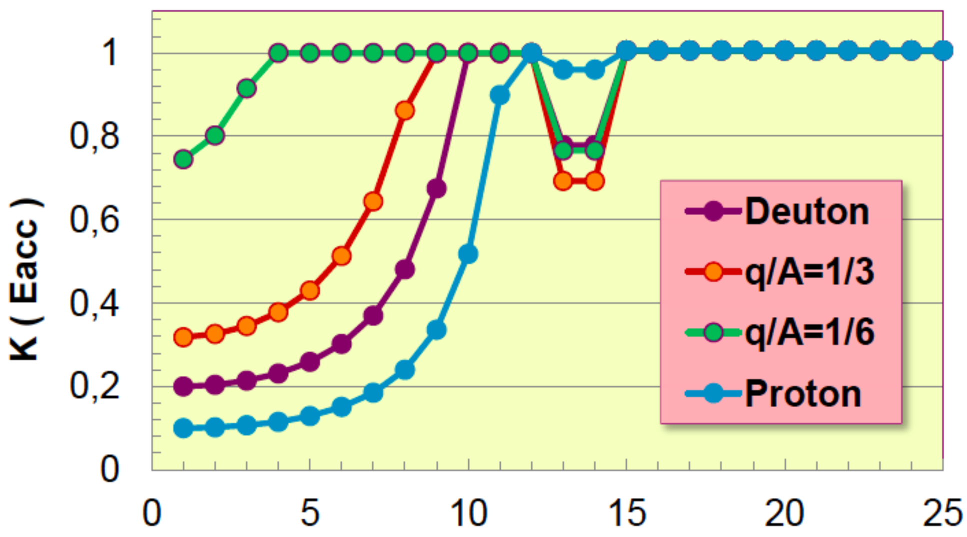
SPIRAL2 SC LINAC



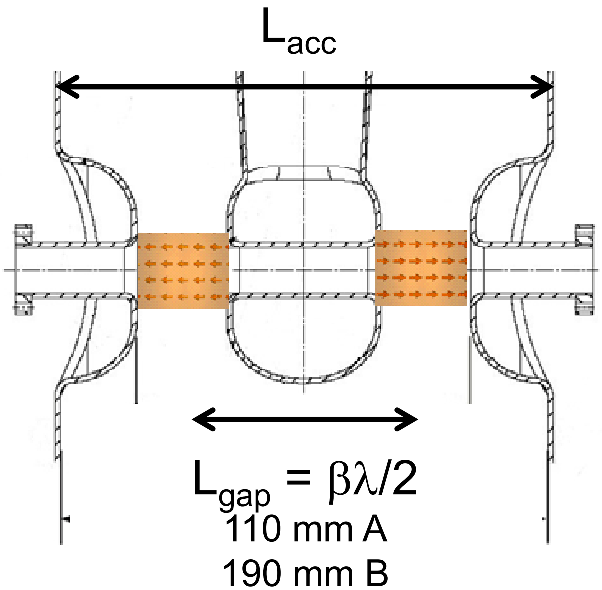
12 β_0=0.07 cavities   L≈32 m   14 β_0=0.12 cavities

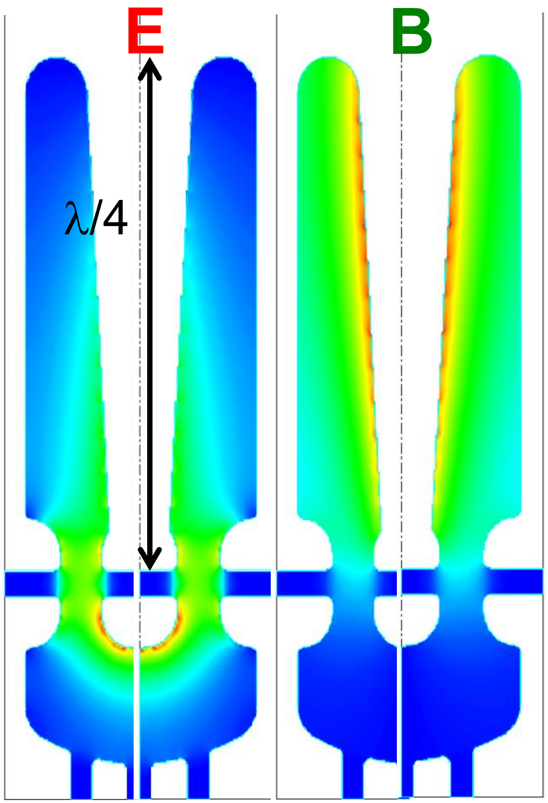
- Large energy range ➔ independently phased cavities
- High intensity ➔short cryomodules, periodic structure





CAVITIES DESIGN



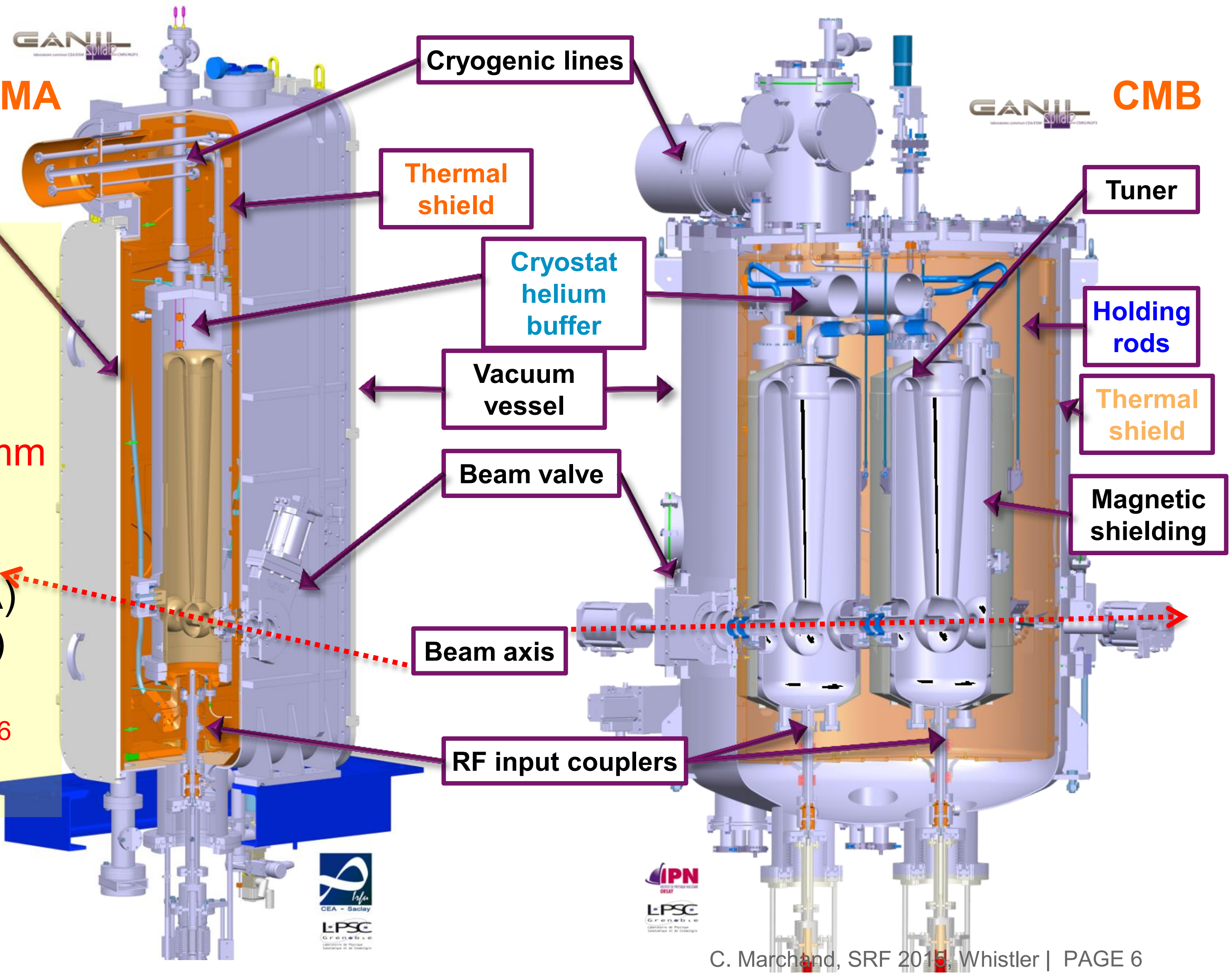


Cavities	A	B
# cavities	**12**	**14**
∅ cavity [mm]	238	380
∅ Beam tube [mm]	38	44
f [MHz]	**88.05**	**88.05**
β_{opt}	**0.07**	**0.12**
Epk/Ea	5.36	4.76
B_{pk}/E_{acc} [mT/MV/m]	8.70	9.35
L_{acc} [m]	0.24	0.40
V_{acc} **@ 6.5 MV/m** [MV]	**1.55**	**2.66**
G [Ω]	22	37
r/Q [Ω]	600	515
Q_0 **@ 6.5 MV/m** (10W)	**3.5 10^8**	**1,4 10^9**

CRYOMODULES LAYOUT

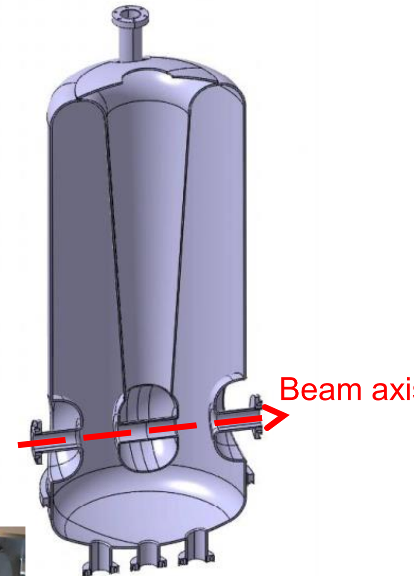
Specifications:

- E_{acc} : 6.5 MV/m
- Alignment.: ~1 mm
- Thermal losses:
  < 20.5 W (CMA)
  < 36 W (CMB)
- Coupling: Q_i~10^6



SIMILARITIES

- **Pure Niobium**
- **QWR design**
- **88.0525 MHz frequency**
- **4,2 K liquid helium cooling**
- **Capacitive coupler 12 kW**



Cavity B

Cavity A

Poster THPB106

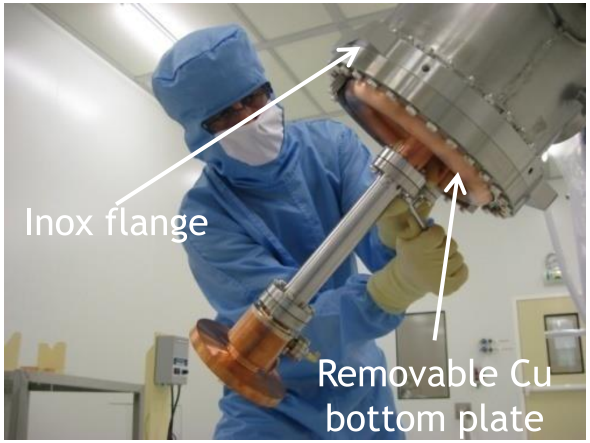
Coupler installation on cavity in clean room

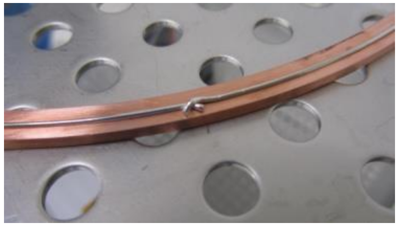
DIFFERENCES [1]: TANK & CAVITY BOTTOM

- **Helium tank:** **A:** *Inox*, **B:** *Titane*

- **Bottom:**
  A: *removable Cu bottom plate*
  ➔easier HPR
  B: *fully welded Nb*
  ➔minimize surface resistance

Cavity A

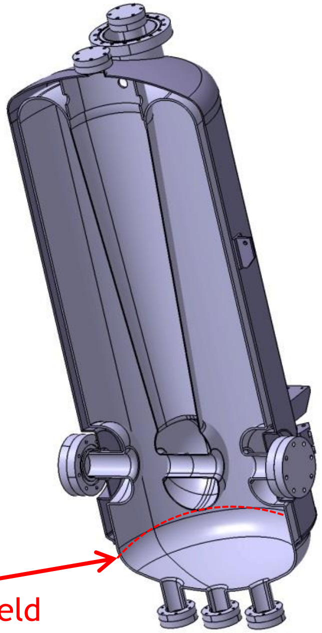




Indium seal

Cavity B

Tank Titane



Circular closing weld

DIFFERENCES [2]: TUNING SYSTEM

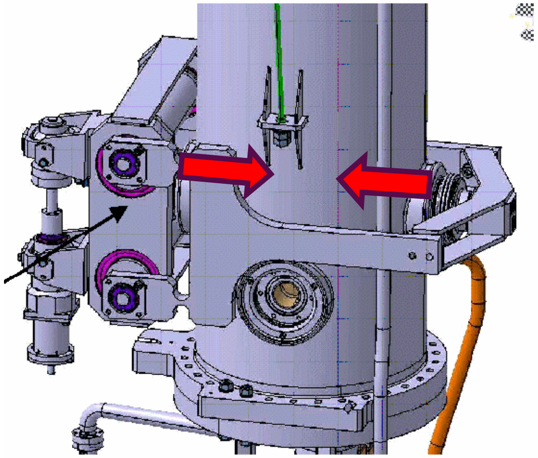
<u>Frequency tuning :</u>

→ Change cavity volume to tune frequency

- *To compensate for slow cyclic helium bath pressure variations*
- *To compensate possible faster vibrations…*

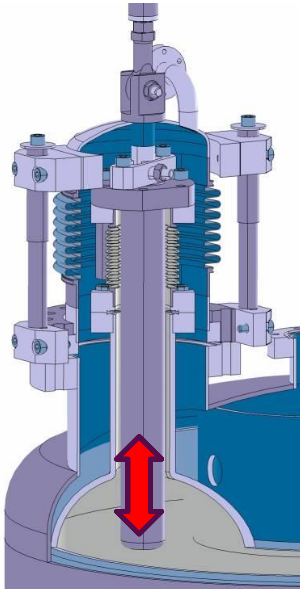
- **Cavity A: mechanical system to deform cavity inside elastic limits**
  - *Tuning range: 13 kHz*

- **Cavity B: supraconductor plunger**
  - *Tuning range: 10 kHz*



Cavity A

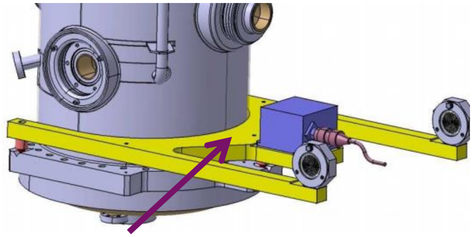
Paparella talk
FRAA01



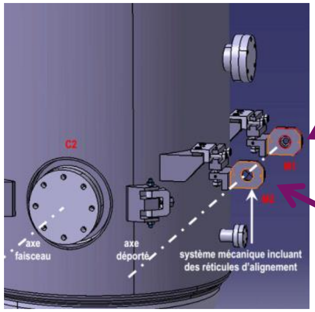
Cavity B

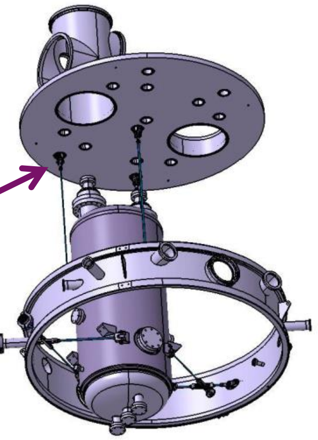
DIFFERENCES [3]: CAVITY ALIGNMENT

- **Cavity A**
  - *Alignment inside warm CM during assembly using special fork*
  - *Axis report on outside of CM for alignment on LINAC*



- **Cavity B**
  - *Axis report by 3 targets remaining on cavity*
  - *Alignment of cavity/CM when cold through CM windows*

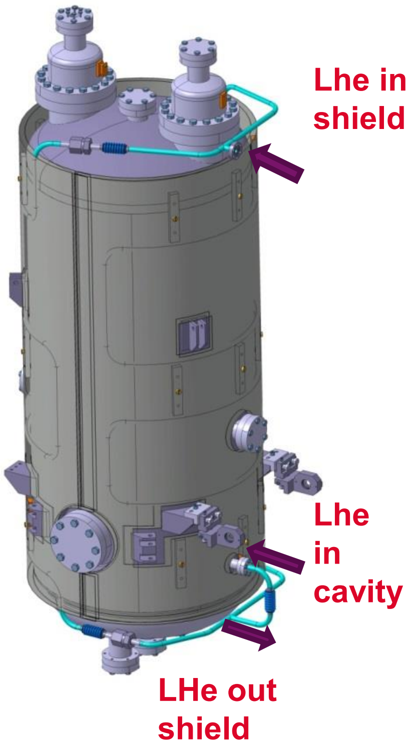




DIFFERENCES [4]: MAGNETIC SHIELD

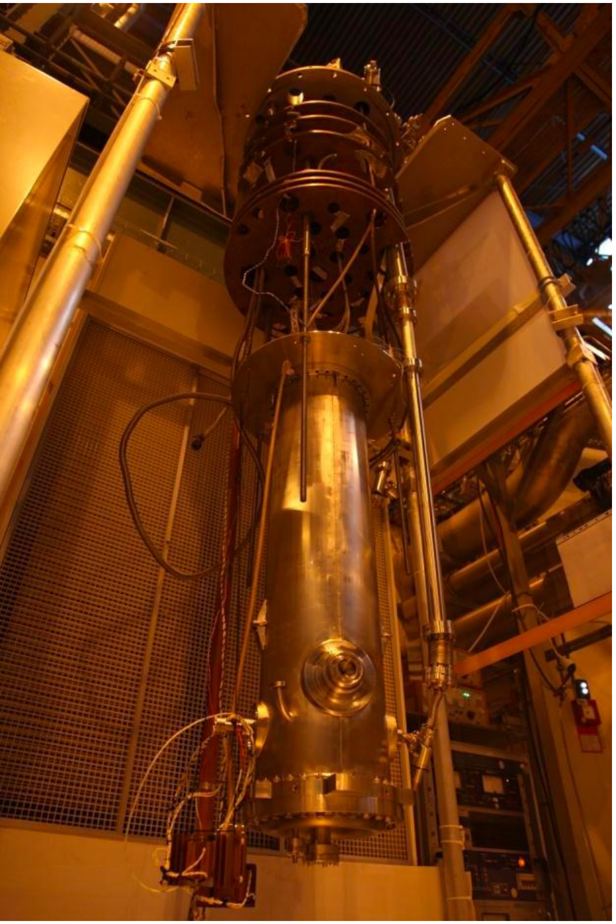
→ *Attenuate by a factor ~50 V & H components of earth field*

- **CMA: « warm » Mu-metal, 1 layer, inside vacuum vessel**



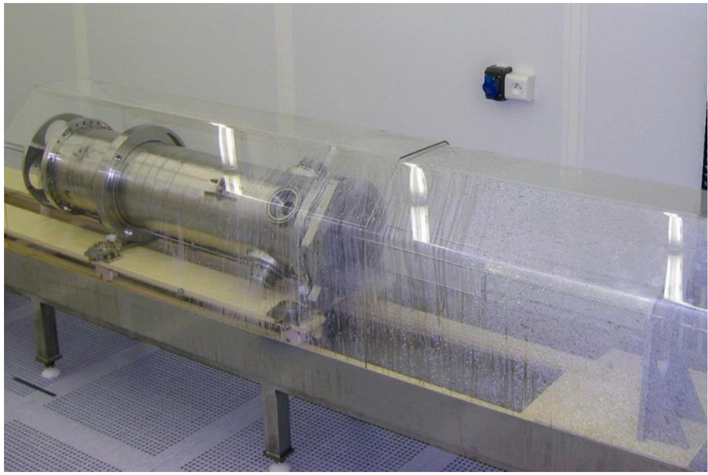
- **CMB: « cold » Cryoperm, 2 layers, outside cavity, cooled with LHe**

CAVITIES PREPARATION BEFORE TESTS IN VC



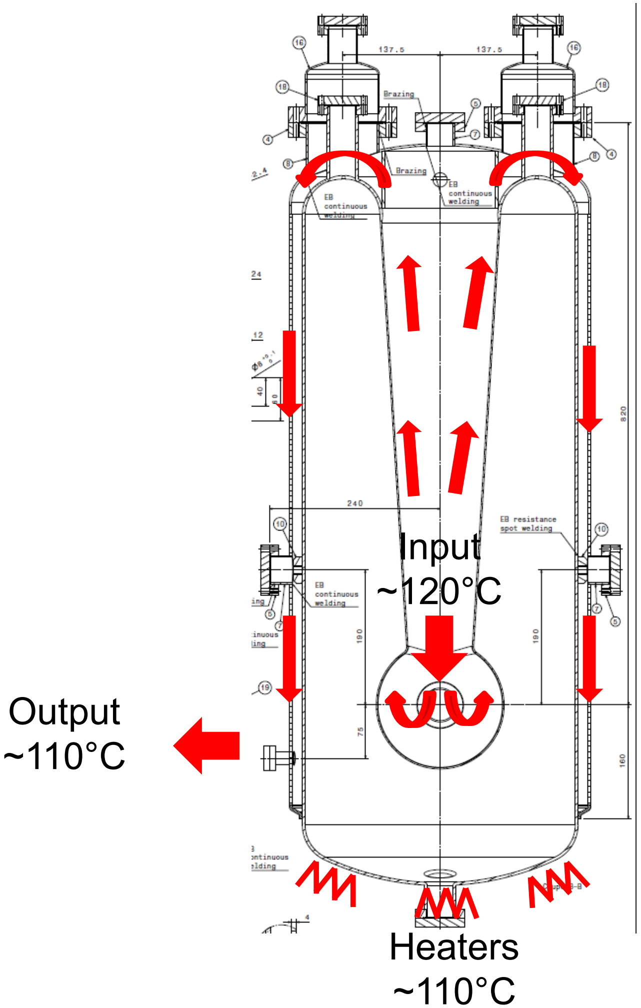
- **Cavities A&B**
  - Standard BCP etching HF,HNO_3,H_3PO_4: 1/1/2 (~150 µm)

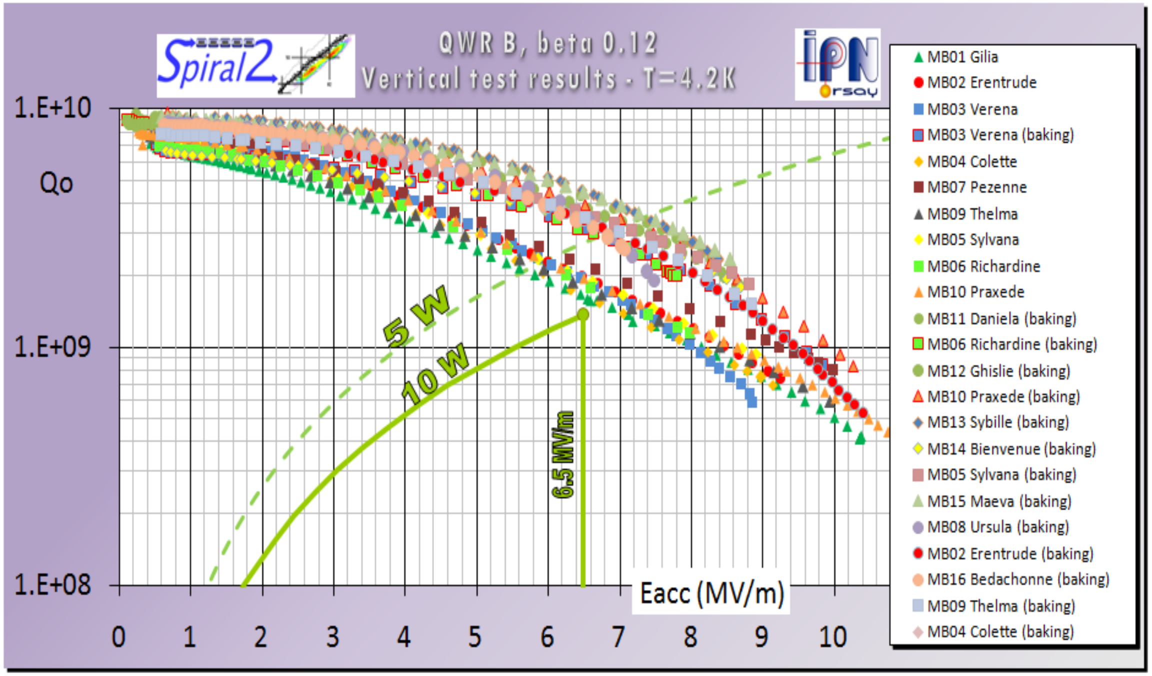
  - 100 bars HPR in ISO4 clean room



  - No 100K healing

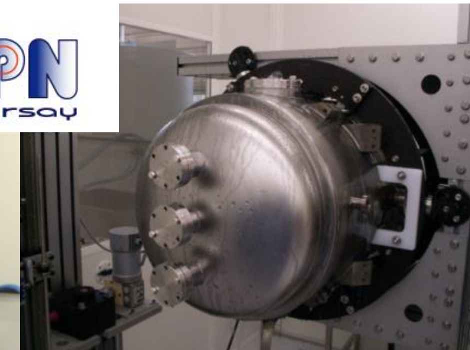
- **Cavities B**
  - 48 hours 120 C baking





After baking: losses divided by ~2 @ Eacc=6.5 MV/m

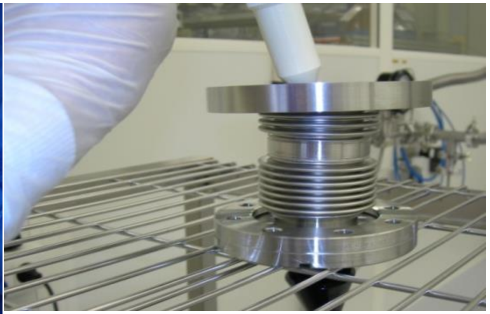
CRYOMODULES ASSEMBLY (CLEAN ROOM)



Systematic particle count of all parts assembled in clean room

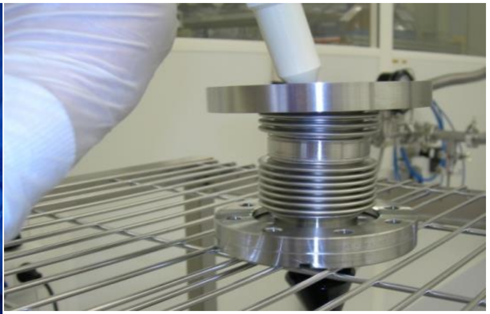
Cryomodules A: no HPR on cavities before CM assembly (slow venting to AP using filtered N2)

CRYOMODULES ASSEMBLY (CLEAN ROOM)



Systematic particle count of all parts assembled in clean room

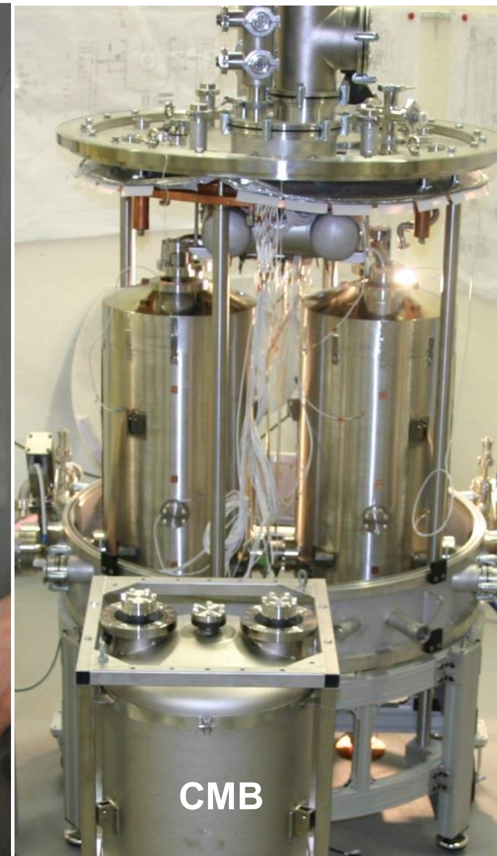
CRYOMODULES ASSEMBLY (CLEAN ROOM)



Systematic particle count of all parts assembled in clean room

Cryomodules A: no HPR on cavities before CM assembly (slow venting to AP using filtered N2)

CRYOMODULES ASSEMBLY (OUTSIDE)

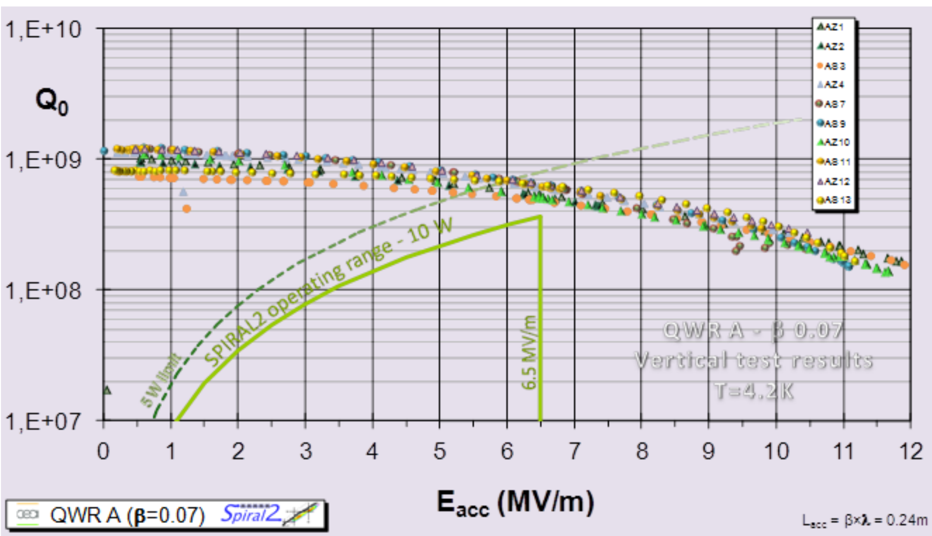


End of cryomodule assembly outside clean room

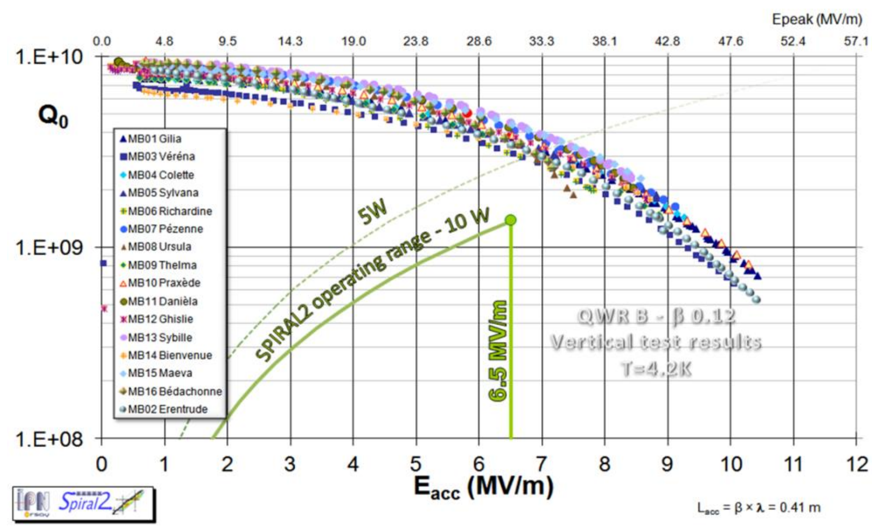
CAVITIES PERFORMANCES: Q_0/E_{ACC}

All cavities are above specifications with remarkably similar behavior after tests in vertical cryostat (preamble before assembly in cryomodules)

CAVITIES A



CAVITIES B

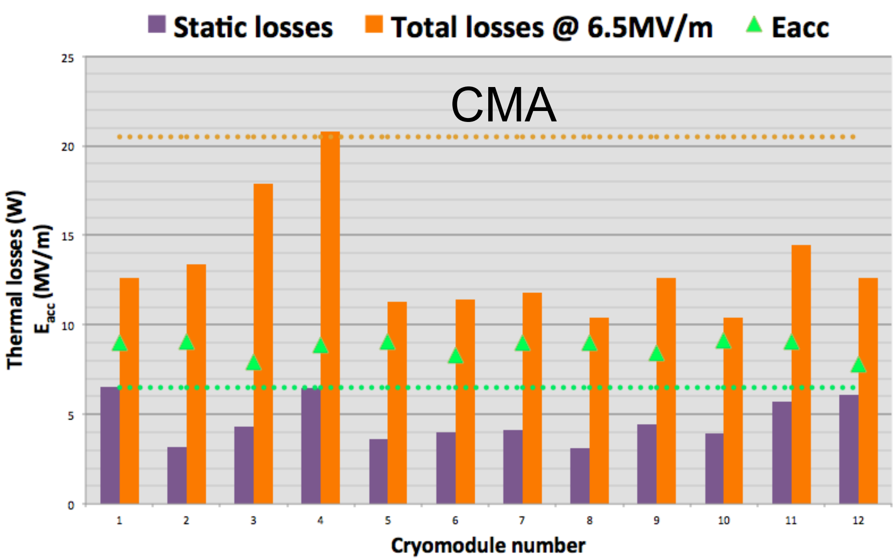


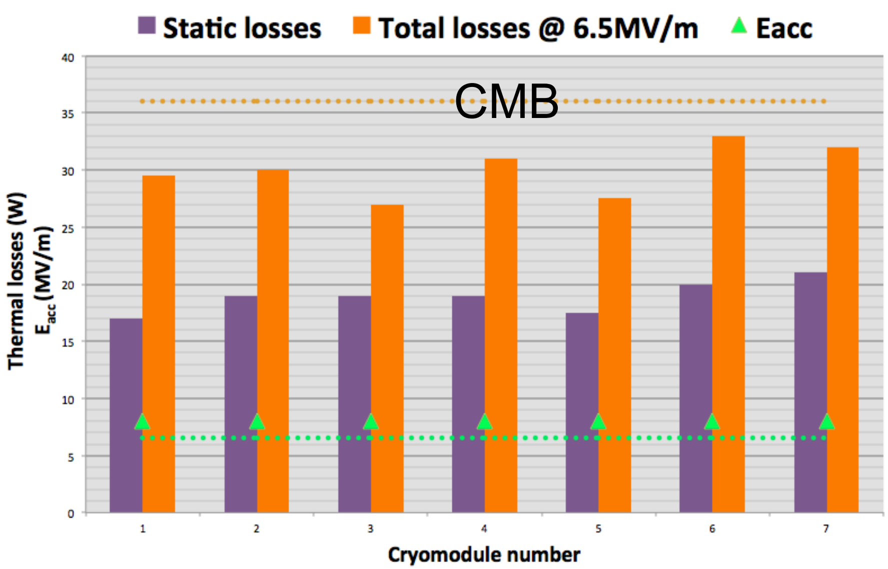
$$Q_0 = \frac{V_{acc}^2}{(r/Q) P_{CAV}}$$

- Vertical cryostat: $P_{cav} = P_{RF}$
- Cryomodule: $P_{cav} = P_{tot} - P_{stat}$

measured via thermal losses @ 4K (A: He level decrease; B: gas flow)

Q_0		CMA	CMB
Specifications (10 W limit)		4,0E+08	1,4E+09
Computed (simulation codes)		7,6E+08	2,7E+09
Tests in VC @ 6.5 MV/m Deduced from RF losses	mean	**5,8E+08**	**3,7E+09**
Tests in CM @ 6.5 MV/m Deduced from therm. losses	mean	**5,0E+08**	**3,0E+09**





CRYOMODULES PERFORMANCES

- **Frequency sensitivity to He bath pressure:**
  - ✓ Dependant on chemical etching intensity
  - ✓ Matches specifications (< 8 Hz/mbar)
  - ✓ Close to simulated values

Data	Value		CMA	CMB
Pressure sensitivity [Hz/mbar]	Specifications		>8.0	>8.0
	computed		-2,5	-7,0
	achieved in cryomodule	min	-2,9	-7,3
		max	-1,1	-4,5
		mean	-1,5	-5,4

- **Tuning systems**
  - ✓ Effective tuning range:
    Low beta: 13 kHz; High beta: 10 kHz
  - ✓ Hysteresis
    Low beta: < 4 Hz (cavity bandwidth is 130 Hz)
    High beta: ~20 Hz (cavity bandwidth is 80 Hz)

Parameters (units) (specs)	CMA	CMB
Range (MHz) (88.049-88.055)	In spec	In spec
Sensitivity (kHZ/mm)	26.9±1.5	1.1
Hysteresis (Hz) (<20)	< 4	20±12

CRYOMODULES PERFORMANCES

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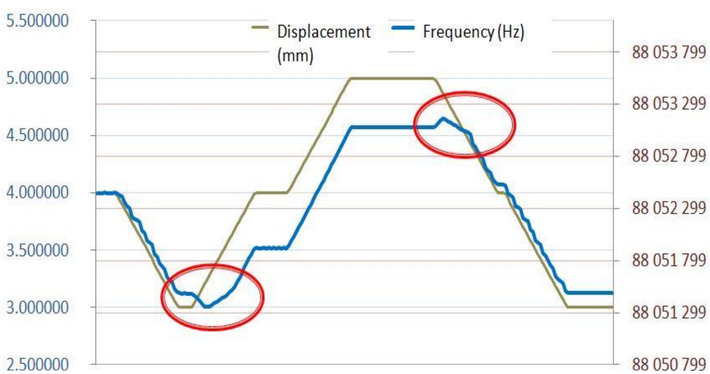
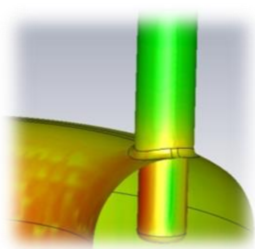
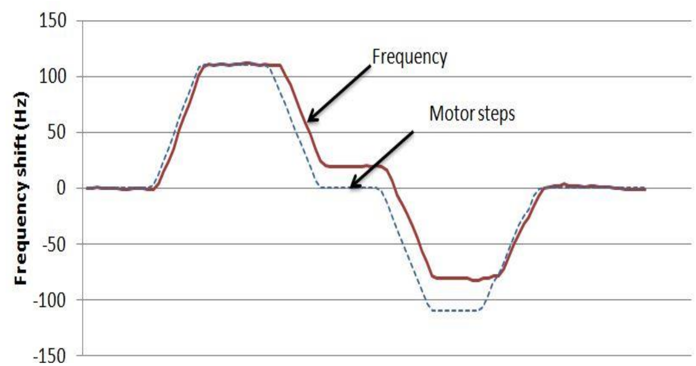


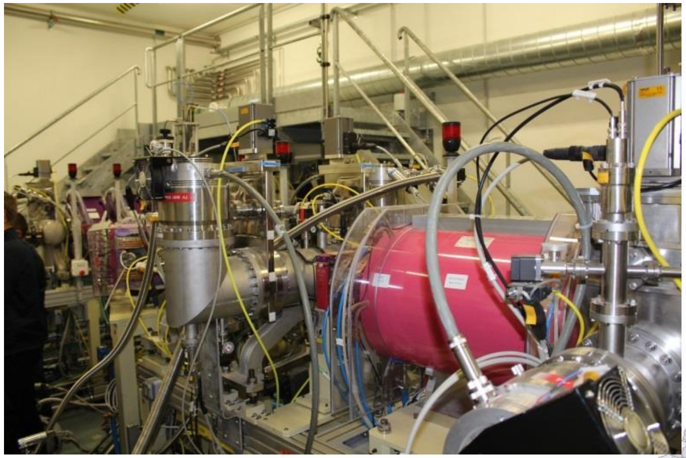
Hysteresis and « negative » backslash of the plunger before improvements



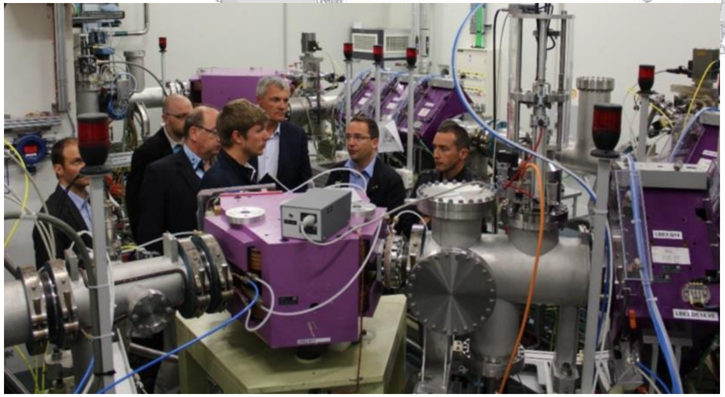


Hysteresis and « negative » backslash of the plunger after improvements

INSTALLATION STATUS: LBE + RFQ



Proton beam commissioned out of LBE



- RFQ fully installed and water cooled
- RF conditionning & proton beam out of RFQ: November 2015

INSTALLATION STATUS: SC LINAC

INSTALLATION STATUS: SC LINAC

❖ **CMA:**

- 6/12 at GANIL
- 3/12 fully installed on LINAC
- One succesfull clean connection of one warm section to 2 successive CM

❖ **CMB:**

- 7/7 at GANIL
- 4/7 fully installed on LINAC

SUMMARY

- **All 12 low β and 7 high β cryomodules assembled and RF and cryogenic performances measured**

- **Cryomodules and warm sections installation ongoing on LINAC**

- **First beam out of RFQ : ~ November 2015**

Job opportunities at CEA/Saclay for Postdocs in SRF

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THANKS FOR YOUR ATTENTION

And thanks to:

P.-E. Bernaudin
G. Olry
P. Bosland

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