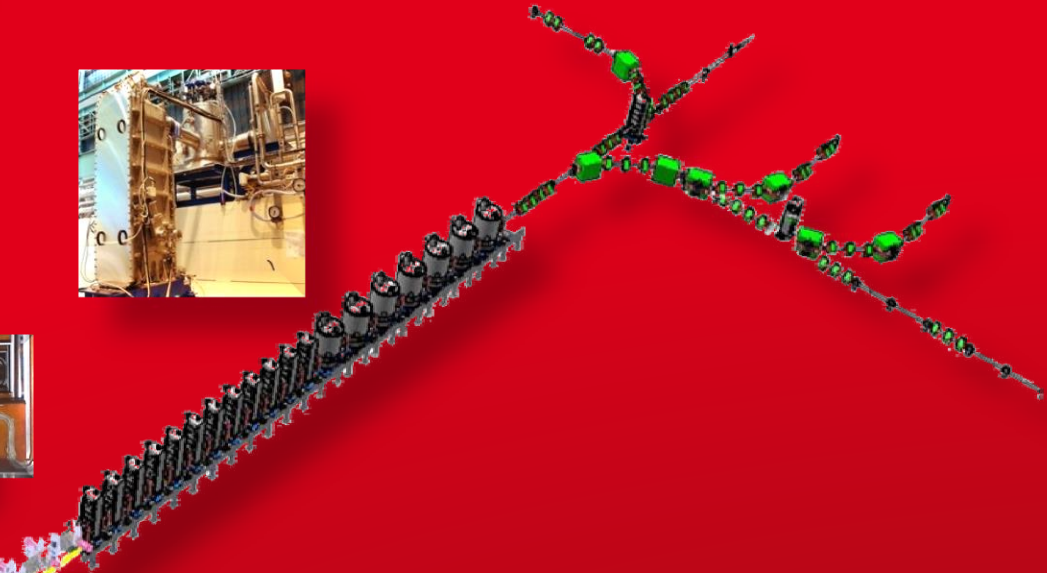
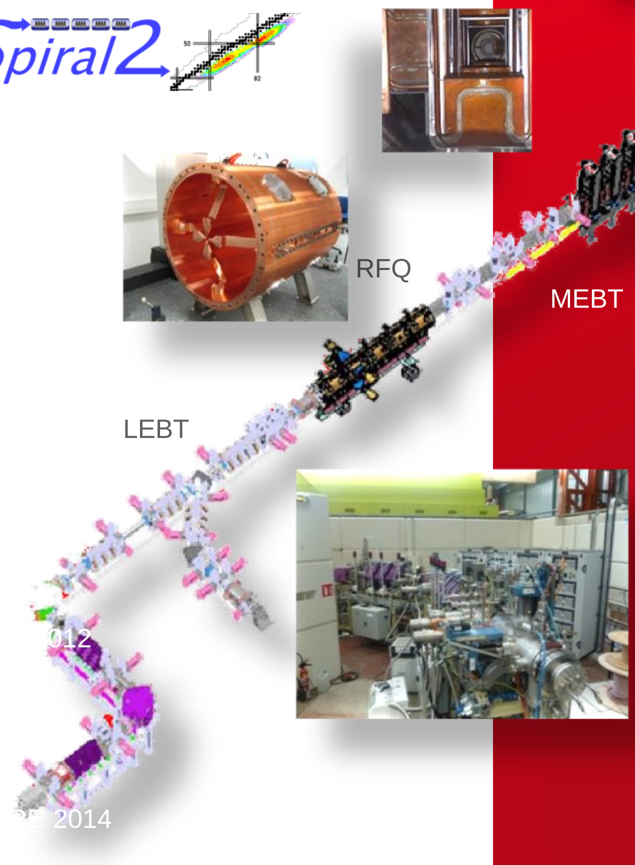


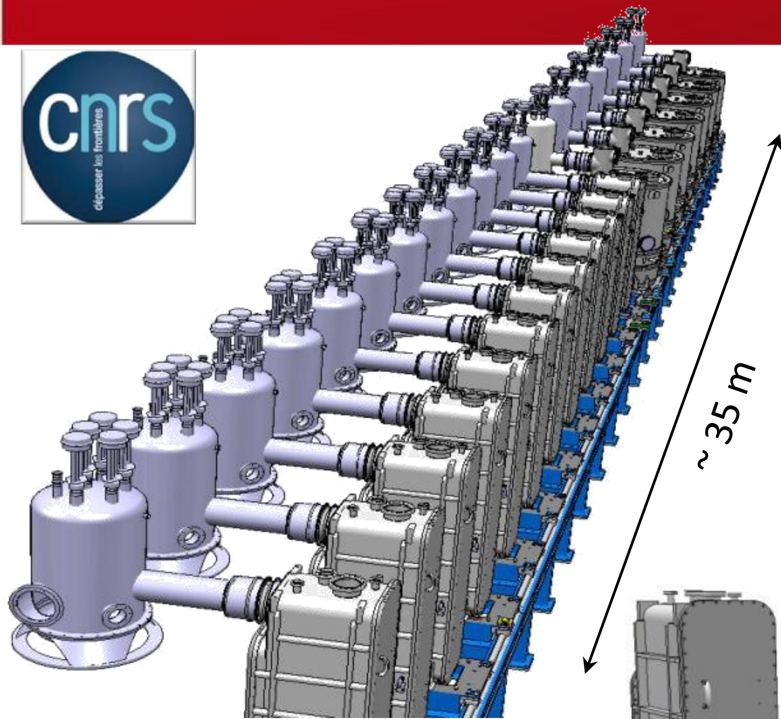


SPIRAL 2 CRYOMODULE TESTS

G. DEVANZ
CEA-Irfu,Saclay

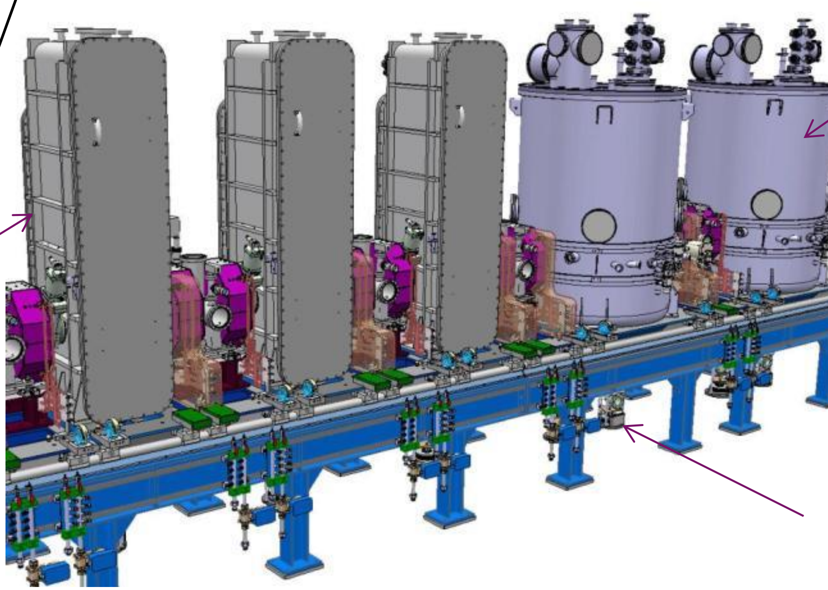
On behalf of CNRS and CEA teams

SPIRAL 2 - SRF LINAC



RIB facility installed in GANIL Caen

- Deuterons (5 mA) and ions up to q/A=1/6
- Temperature: 4.5 K
- Frequency : 88 MHz
- E_{acc} max : 6.5 MV/m



7 high beta CMs

14 β = 0.12 QWR

IPN Orsay

12 Low beta CMs

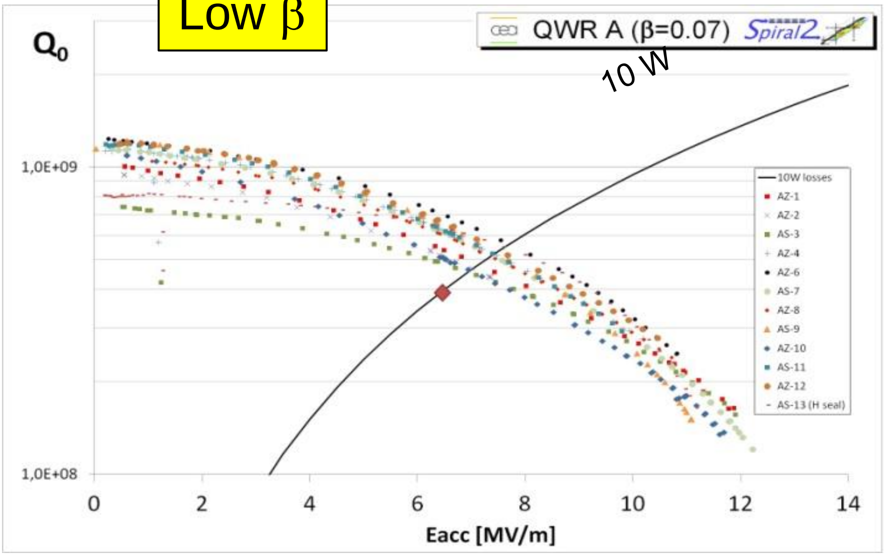
12 β = 0.07 QWR

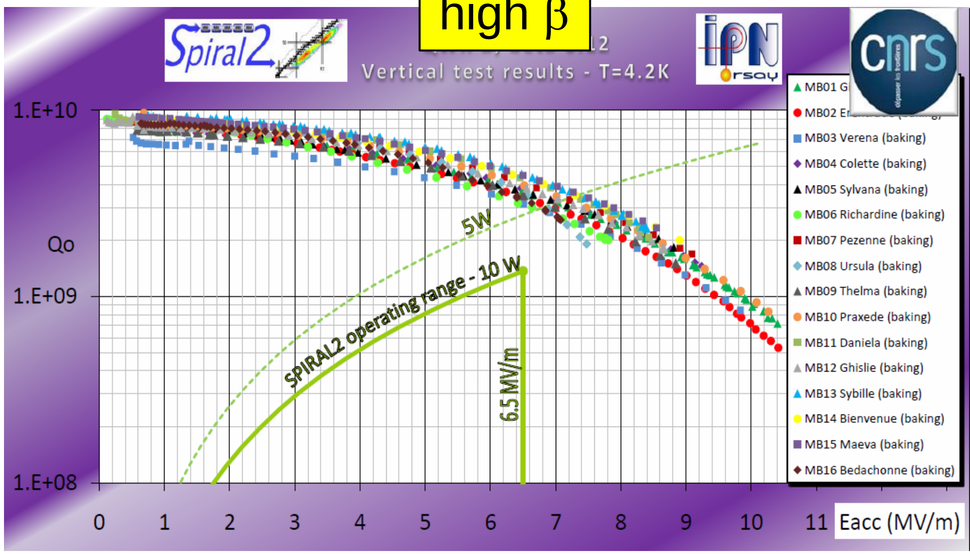
CEA-IRFU Saclay

28 power couplers

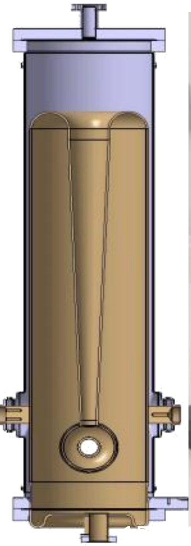
LPSC Grenoble

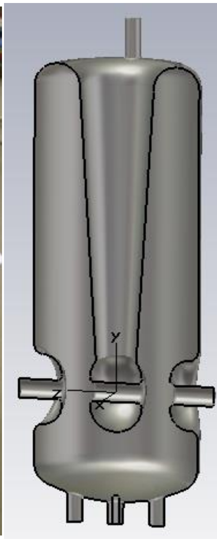
QWR PERFORMANCE



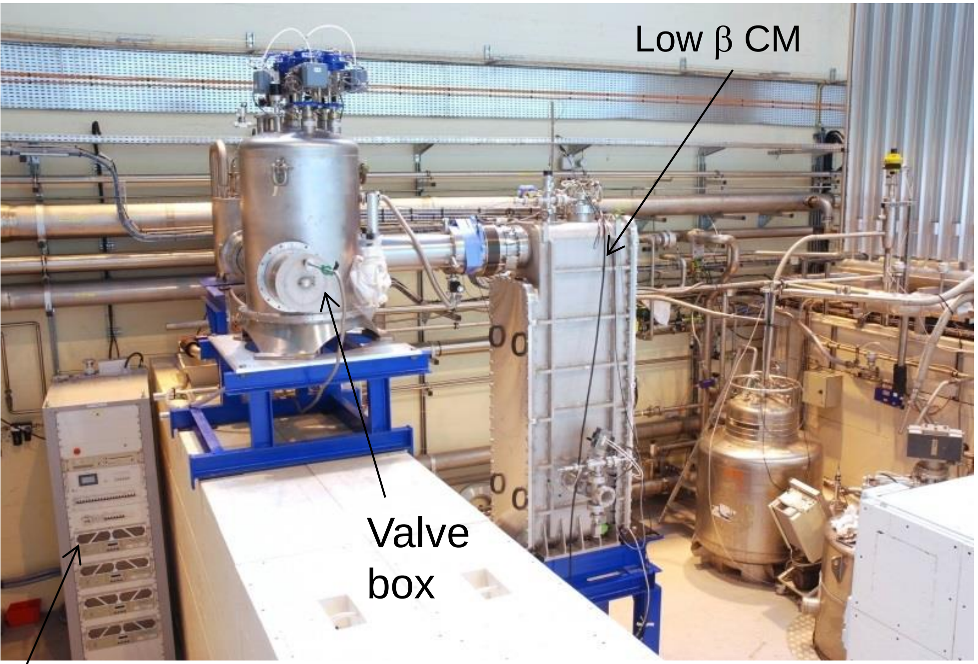


All cavities above specifications

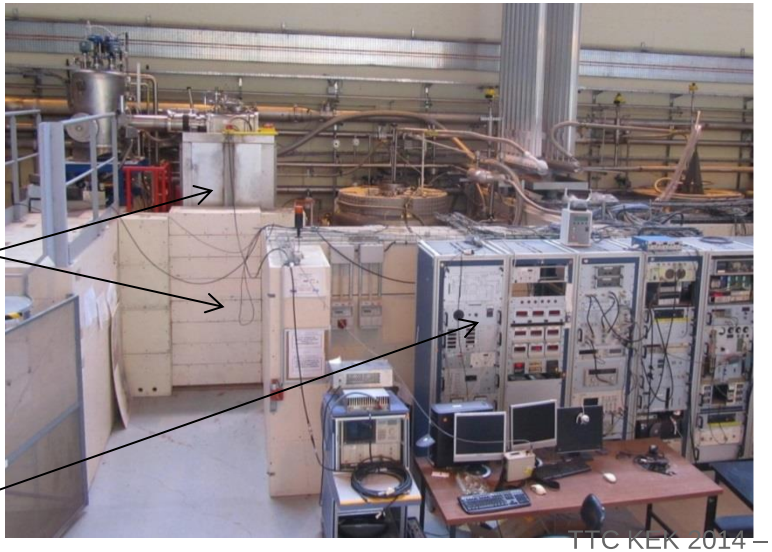




SPIRAL-2 TEST AREA AT SACLAY AND ORSAY



10 kW solid-state amplifier



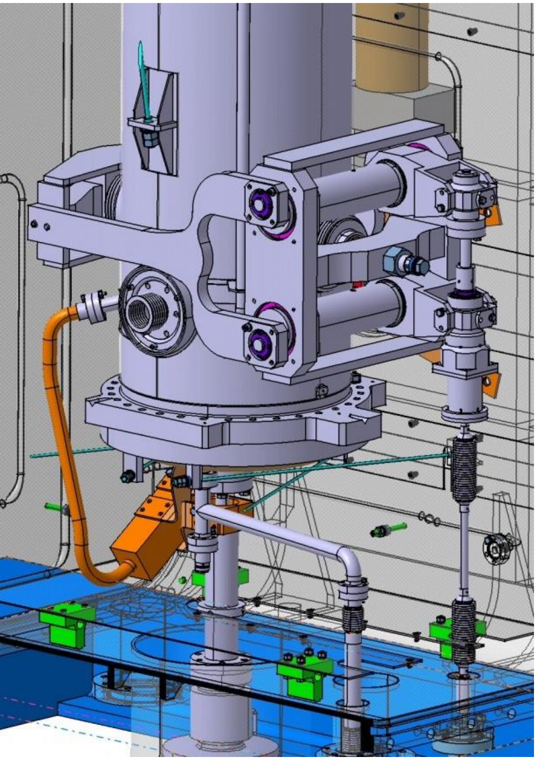
Radiation shields (lead + concrete)

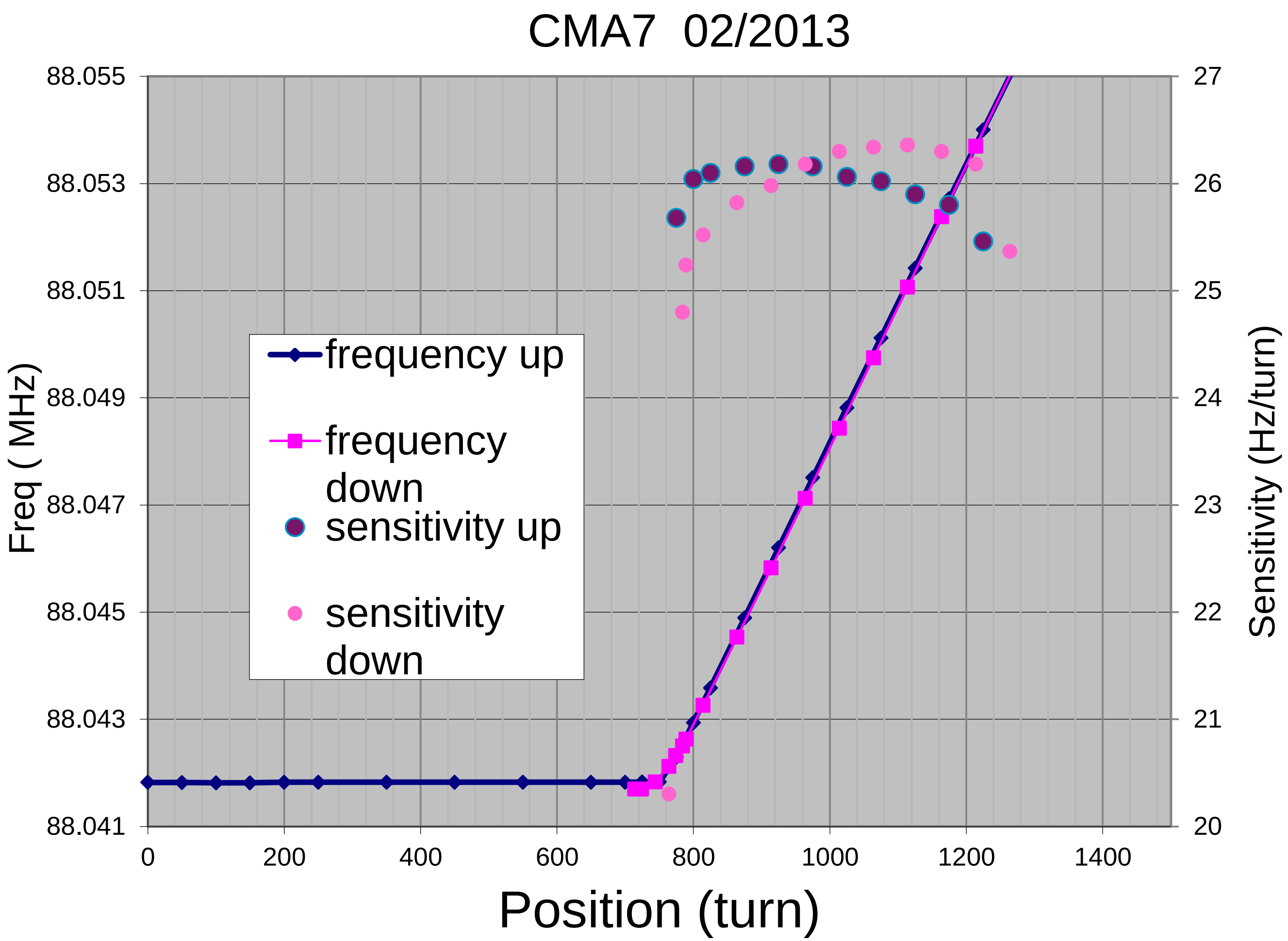
Control systems

MAIN CRYOMODULE TEST STEPS

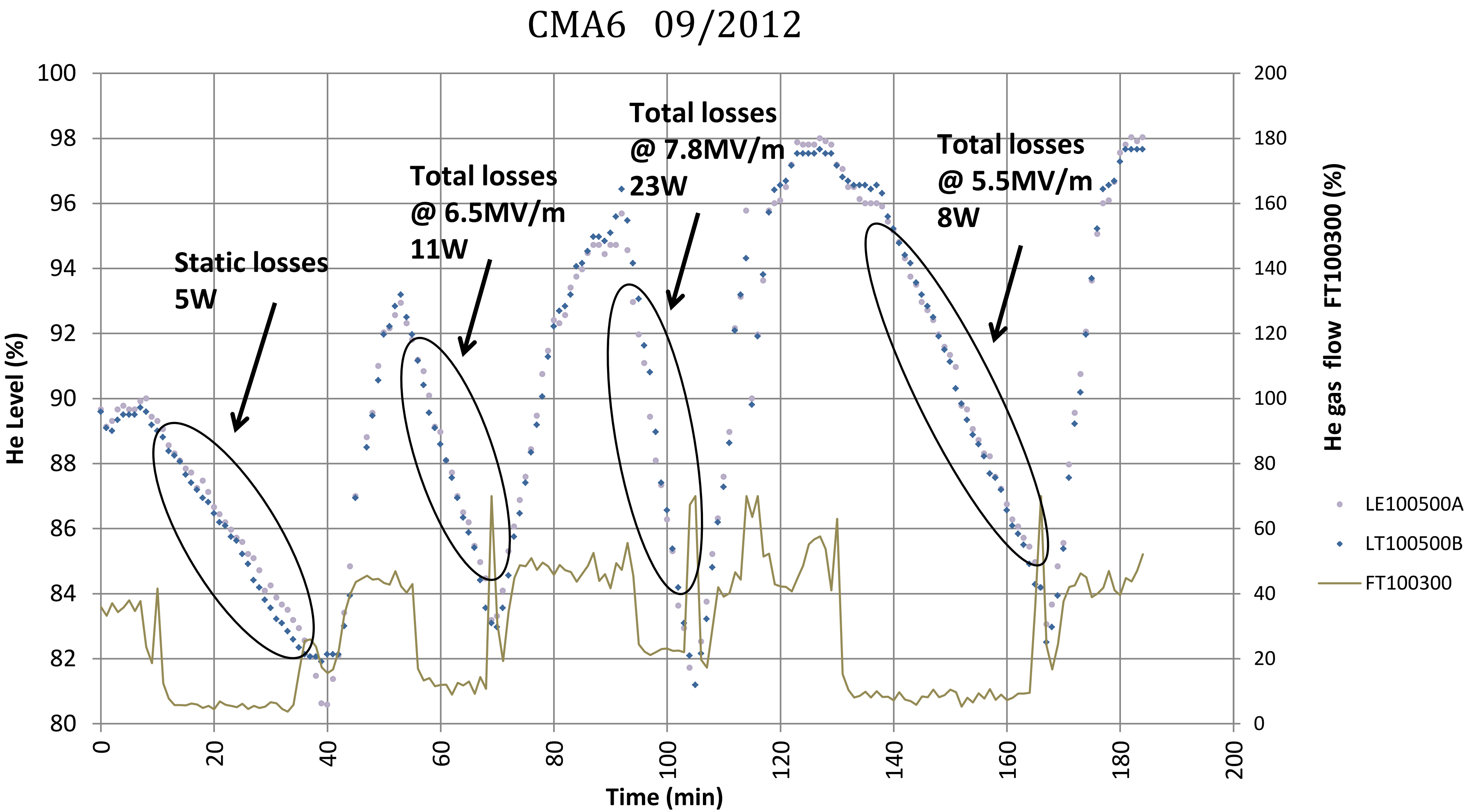
- Tuner calibration and hysteresis measurement
- Power coupler processing
- Static heat load measurement
- Cavity processing
- Radiation measurement
- Dynamic heat load measurement

TUNER TEST IN CM





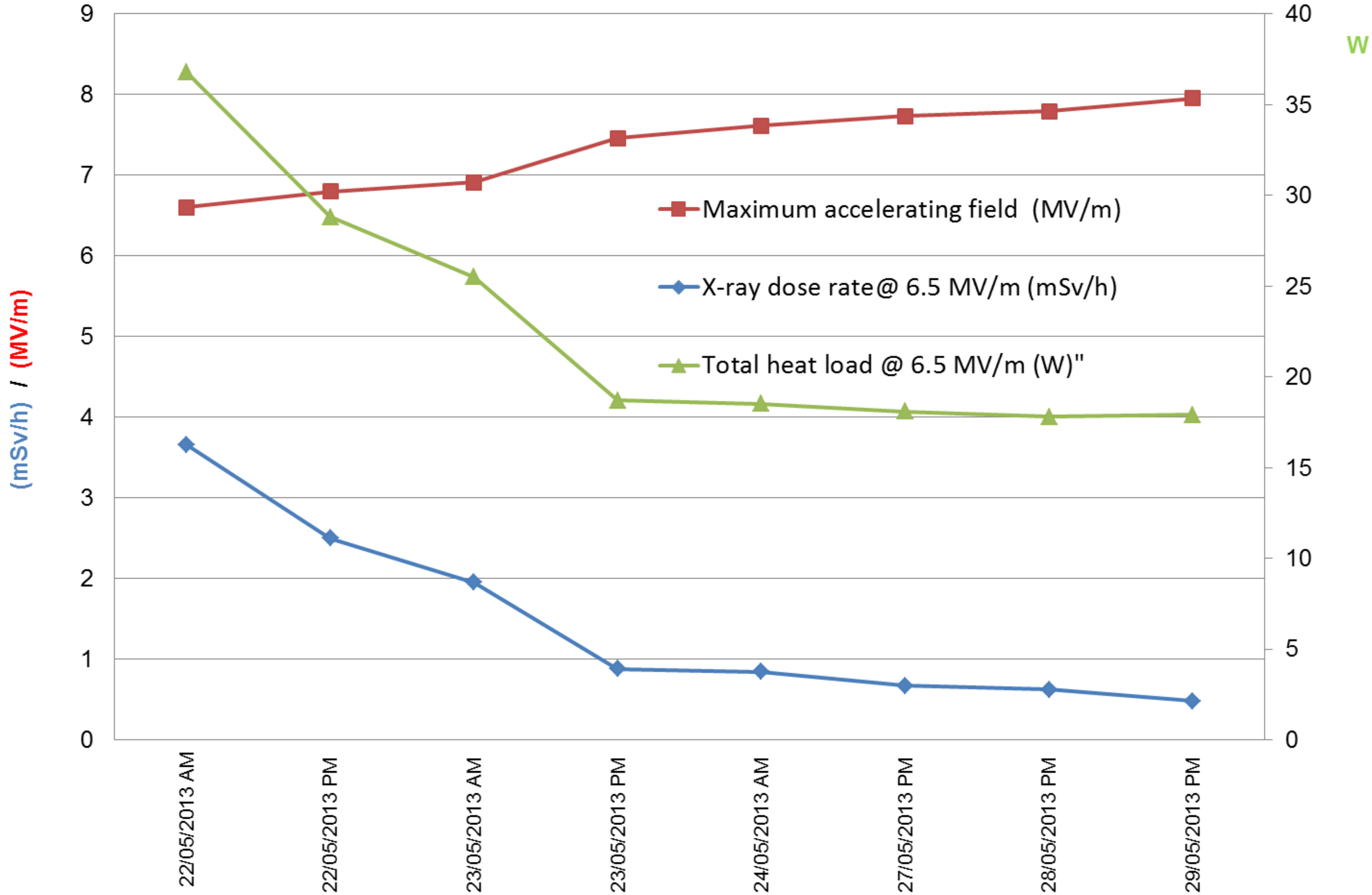
HEAT LOAD MEASUREMENT



Using Lhe level gauge rate of change in the upper part of cylindrical He jacket/phase separator (Boil-off)

HEAT LOAD / RADIATION LEVEL

Conditionning a CMA up to 8 MV/m



CRYOMODULE PERFORMANCE SUMMARY TABLE

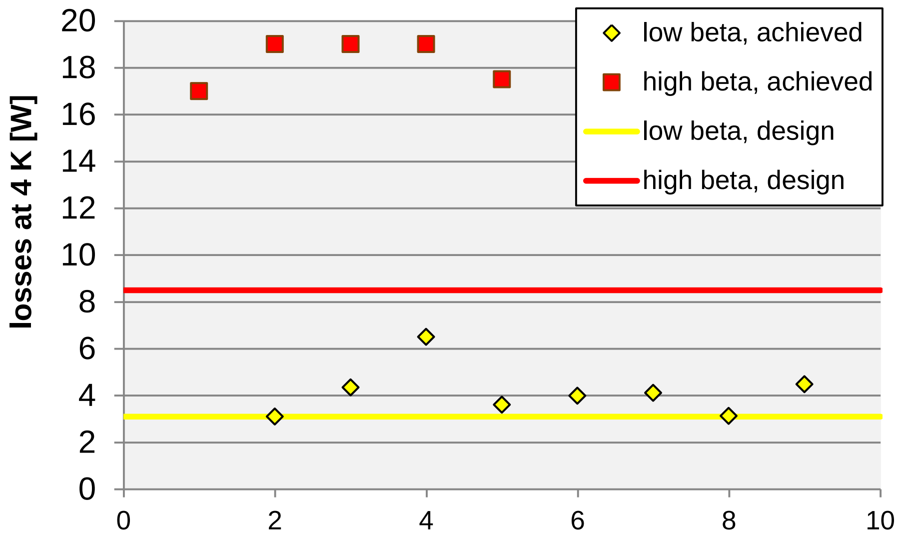
	Spec	CMA4	CMA6	CMA7	CMA2	CMA3	CMA5	CMA9	CMA8	CMA10
Qi	$4,0.10^5 < X < 7,5.10^5$	$1,02.10^6$	$8,27.10^5$	$7,4.10^5$	$7,43.10^5$	$6,66.10^5$	$7,2.10^5$	$6,8.10^5$	$7,45.10^5$	$7,6.10^5$
Max accelerating field (MV/m)	> 6.5	8.85	8.34	9	9.1	7.95	9.1	8.44	9	9.11
Total losses @ 6.5MV/m and 4K (W)	< 20.5	20.8	11.41	11.8	13.35	17.9	11.3	12.6	10.38	10.41
Total losses @ 7.8MV/m and 4K (W)				21	24.4	40.82	18.9	36.7	18.88	16.31
Static losses @4K (W)		6.5	3.98	4.1	3.2	4.34	3.6	4.47	3.12	3.96
Pressure sensitivity (Hz/mbar)	< 5 Hz/mbar	-1.58	-1.32	-1.45	-1.21	-1.08	-1.22	-1.24	-1.66	-1.38
Beam vacuum (mbar)	$< 5.10^{-7}$ mbar	1.10^{-7}	2.10^{-8}	$1,1.10^{-8}$	4.10^{-8}	$1,4.10^{-8}$	$3,3.10^{-8}$	$1,7.10^{-8}$	3.10^{-8}	$3,8.10^{-8}$
X rays @6.5MV/m		560	91	14.3	10	494	1.4	677	32	3
Sensitivity of tuning system (Hz/turn)	20< X < 35	24.96	24.86	26.1	26.1	25.99	25.75	25.7	26.35	27.4

	Unit	Specs	CMB1		CMB2		CMB3		CMB4		CMB5		CMB6	
Max. acc. Gradient	MV/m	> 6.5	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	>8.0	6.3
Total losses @4K, 6.5MV/m	W	< 36.0	29.5		30		27		31		27.5		33	
Static losses @4K	W	<12.5	17		19		19		19		17.5		20	
Pressure sensitivity	Hz/mbar	< 8.0	5.3	5	5.4	5.8	5.2	4.5	4.9	5.2	5.9	7.3	10	20
CTS Hysteresis	Hz	<20	15	16	5	20	20	40	25	10	20	50	6.2	5.8
X-ray dose @6.5 MV/m	µSv/h		22000	0	160	0	0	0	70	0	0	0	0	0
Cavity alignment	mm	◎ 1.2	0.16	0.34	0.62	0.32	0.24	0.38	0.14	0.36	0.38	0.56	0.24	0.46

- 9/12 low β CMs tested. First module produced before preparation and assembly procedure optimisation
- 6/7 high β CMs tested. Downstream QWR of CMB6 quenches slightly below specs , will be set to 5.5 MV/m in the linac. Makeup gain provided by neighbouring cavity

CRYOMODULE CRYOGENIC PERFORMANCES

Cryogenic losses at 4 K (static)



Analysis from P. E. Bernaudin, THIOB02, LINAC'14

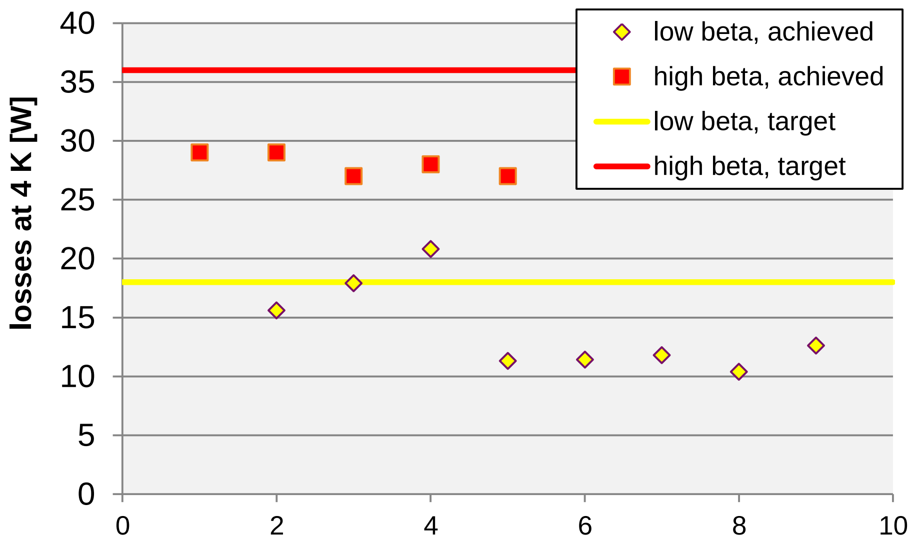
Measurement methods:

- helium gas flow meter, *and/or*
- helium level decrease in buffer (better accuracy)

All cryomodules (but 1) to specs:

- *Low beta:* static performances compensate for dynamic losses
- *High beta:* cavity low dynamic losses compensate for underestimated static losses

Cryogenic losses at 4 K (total)



QWR PERFORMANCE DEGRADATION

		low beta	high beta
target (10 W limit)		4,0E+08	1,4E+09
achieved in vertical cryostat, at nominal gradient	min	4,8E+08	2,6E+09
	max	7,0E+08	4,6E+09
	mean	5,9E+08	3,7E+09
achieved in cryomodule, at nominal gradient	min	2,8E+08	2,0E+09
	max	5,5E+08	3,9E+09
	mean	4,4E+08	3,0E+09

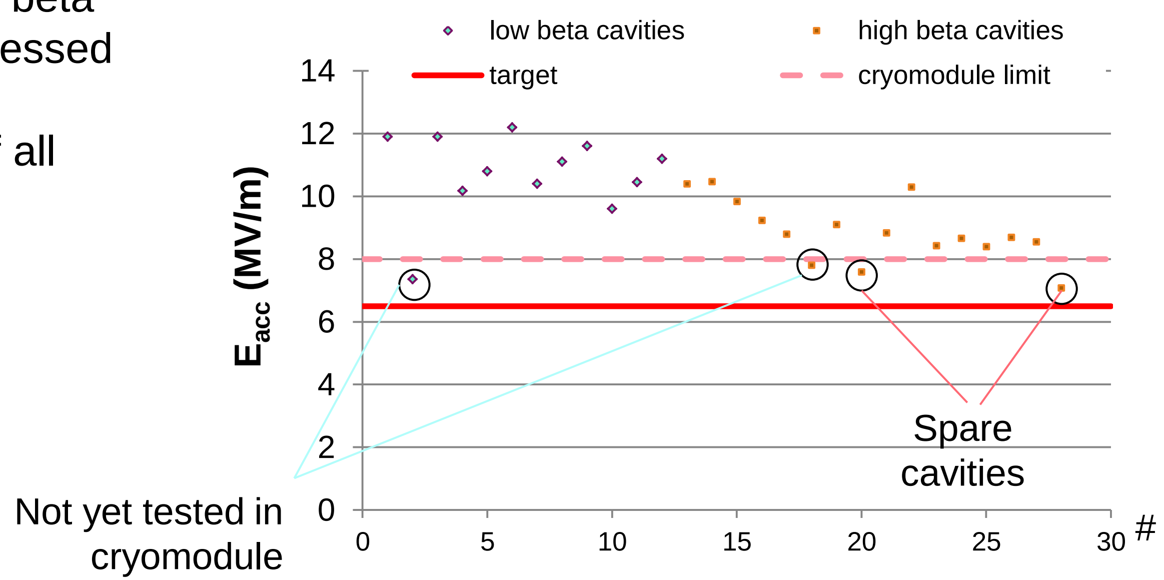
Analysis from P. E. Bernaudin, THIOB02, LINAC'14

Qo measurements before and after assembly in CM:

- Show a reduction of 33% for both beta famillies (if the non-standard processed low beta is ingnored)
- Show a global reduction of 38% if all cavities are considered

Max gradient in cryomodules: administrative limit set at 8 MV/m (avoid quench)
→ *no direct VT/CM comparison available*

Maximum gradient reached in VT



OTHER CRYOMODULES PERFORMANCES

Analysis from P. E. Bernaudin, THIOB02, LINAC'14

- Tuning systems
  - ✓ Effective tuning range
    - low beta: 13 kHz (restricted to protect the cavity)
    - High beta: 10 kHz
  - ✓ Reliability: low beta system cycled
  - ✓ Hysteresis
    - low beta: up to 4 Hz (cavity bandwidth is 130 Hz)
    - High beta: ~20 Hz (cavity bandwidth is 80 Hz)
- Cavities sensitivity to pressure (He bath)
  - ✓ Dependant on chemical etching intensity
  - ✓ Always better than specifications (< 8 Hz/mbar)
  - ✓ Simulations proved reliable
- X-Rays emission by cryomodules
  - ✓ Diagnostics sensitive to X-rays (BEM, BLM)
  - ✓ Low beta cavities emission homogeneous (usually a few μSv/h)
  - ✓ High beta cavities emission: nil or strong (~20 mSv/h)
- CM performance after transport
  - ✓ No change after Saclay-Ganil-Saclay round-trip (total 500 km)

SRF LINAC INSTALLATION HAS STARTED AT GANIL

Thank you for your attention

Thanks to
P. –E. BERNAUDIN
G. OLRY
O. PIQUET
for providing data

Irfu
Institut de recherche sur les lois fondamentales de l'Univers

Additionnal slides

SPECIFICS OF LOW AND HIGH BETA CM

Specific to low beta HWRs:
→ normal conducting OFHC copper « bottom plate » with FPC port
→ room temperature mu-metal magnetic shield
→ compression tuner

Specific to high beta HWRs:
→ Nb « bottom plate » with FPC port
→ actively cooled cryoperm/A4K magnetic shield
→ superconducting plunger tuner
→ have been processed with HPR between VT and CM assembly