SPIRAL2 Cryomodule Production Results and Analysis

P.-E. Bernaudin (GANIL)

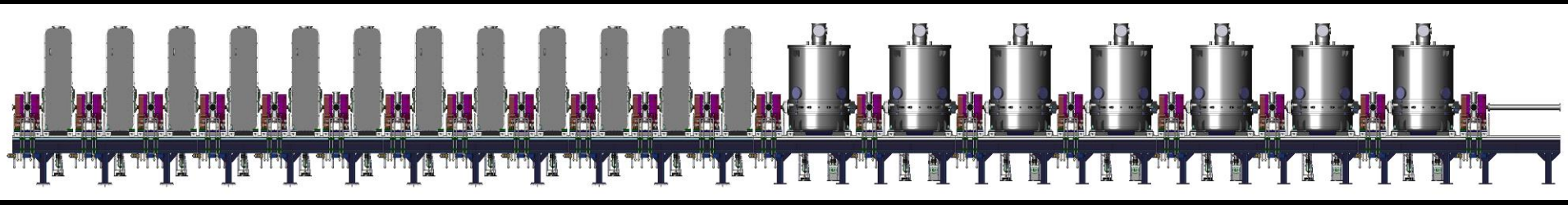
On behalf of the GANIL, IPNO, Irfu and LPSC teams

Talk outline

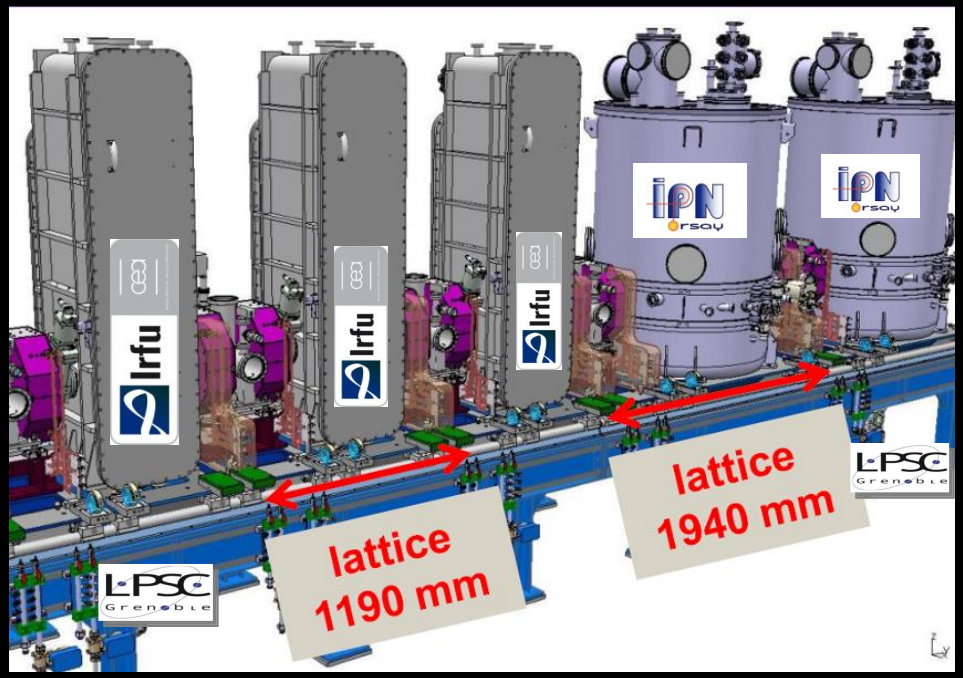
1. The SPIRAL2 superconducting Linac
2. Cryomodules production
3. Achieved performances
4. Conclusions & perspectives

1. The SPIRAL2 superconducting linac

The SPIRAL2 superconducting accelerator



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

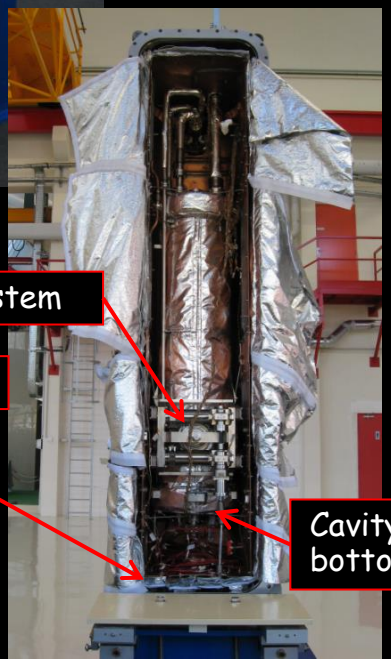


Particles	p^+	D^+	Ions	
Q/A	1	1/2	1/3	1/6
I (mA) max.	5	5	1	1
W_O min. (Mev/A)	2	2	2	2
W_O max. (Mev/A)	33	20	14.5	8.5
CW max. beam power (KW)	165	200	44	48

Cryomodules general design

Common features:

- QWR cavities, 88 MHz
- Bulk niobium
- 4.5K operation
- Same power coupler
- Separate vacuum
- BCP treatment

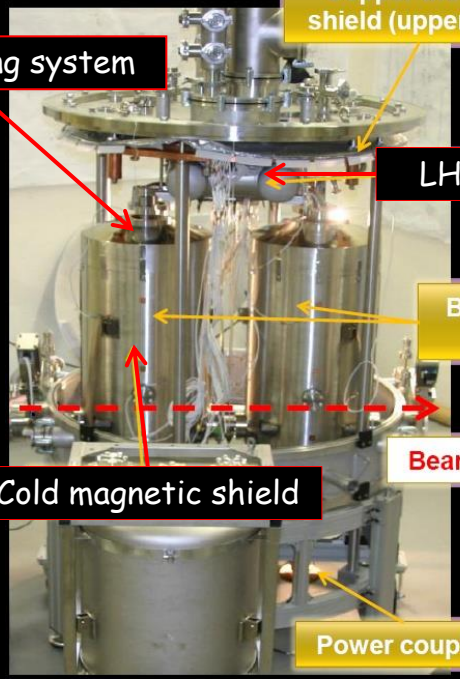


Mechanical tuning system

RT magnetic shield

No HPR after vertical cryostat test

Cavity removable bottom



Copper thermal shield (upper part)

Plunger tuning system

LHe buffer

Beta 0.12 QWR

Beam axis

Cold magnetic shield

Cavity baking

Power coupler

2. Cryomodules production

Production strategy

Prototyping stage	Pre-series stage	Production stage
Cavities prototypes →	**Cryomodules prototypes**, featuring pre-series cavities and couplers (≠ prototypes) →	**Series components** *(including upgraded prototype cryomodules)*
Coupler prototypes →		

All three stages:

	Design	Manufacturing	Assembling	Testing
Low beta	Irfu	Industry	Irfu	Irfu
Power coupler	LPSC Grenoble	Industry	LPSC Grenoble	LPSC Grenoble
High beta	IPN Orsay	Industry	IPN Orsay	IPN Orsay

→ Three independent teams.

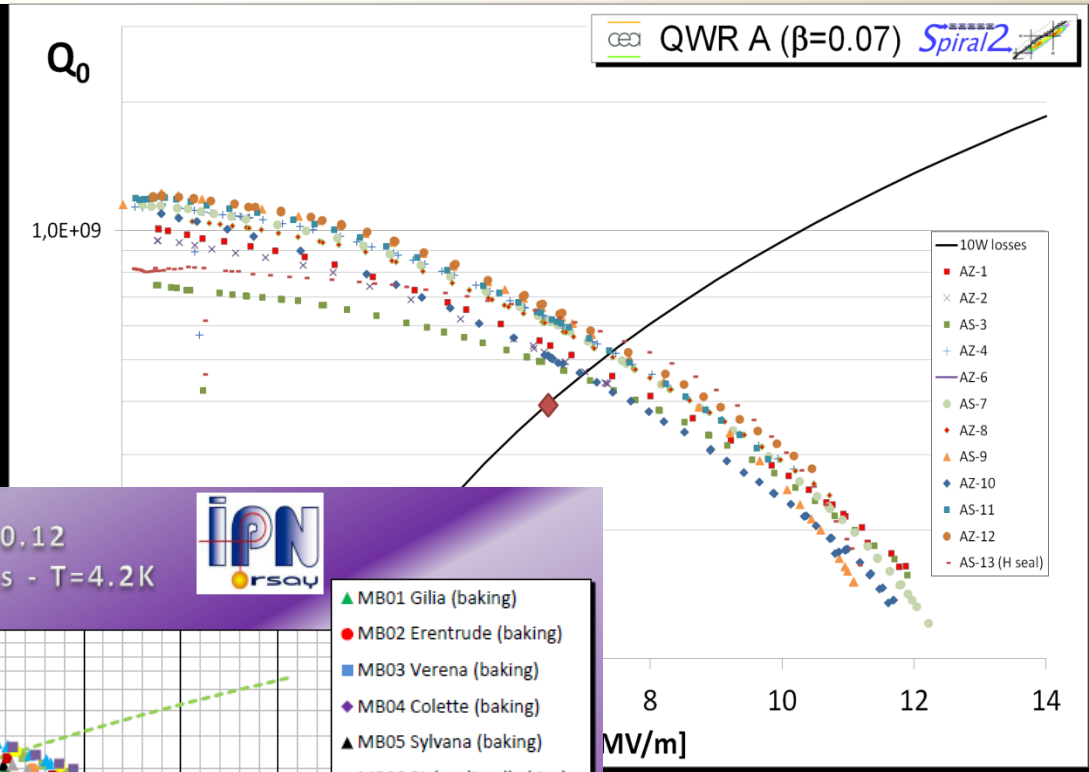
Implementation

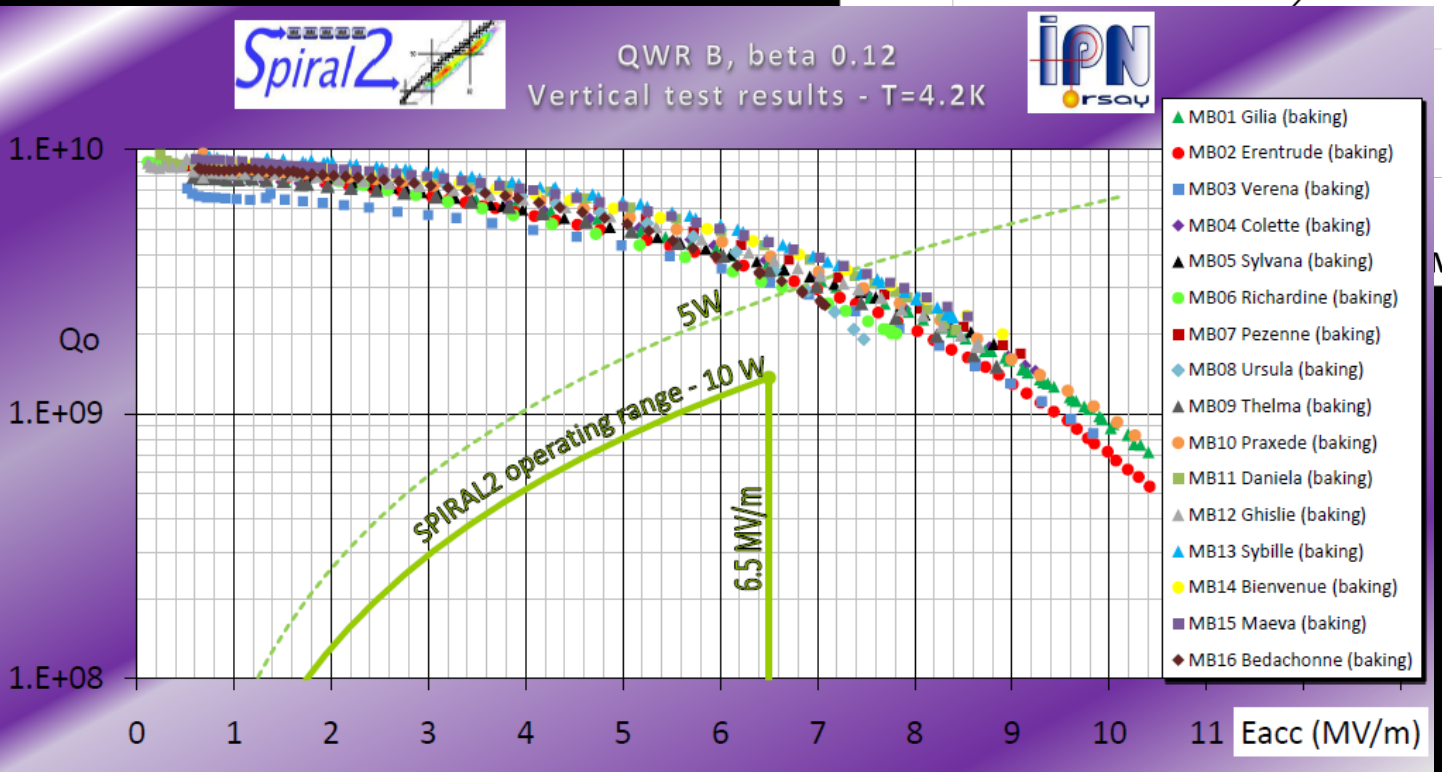
8 low beta and 5 high beta cryomodules qualified in a row
Other cryomodules in assembly phase

3. Achieved performances

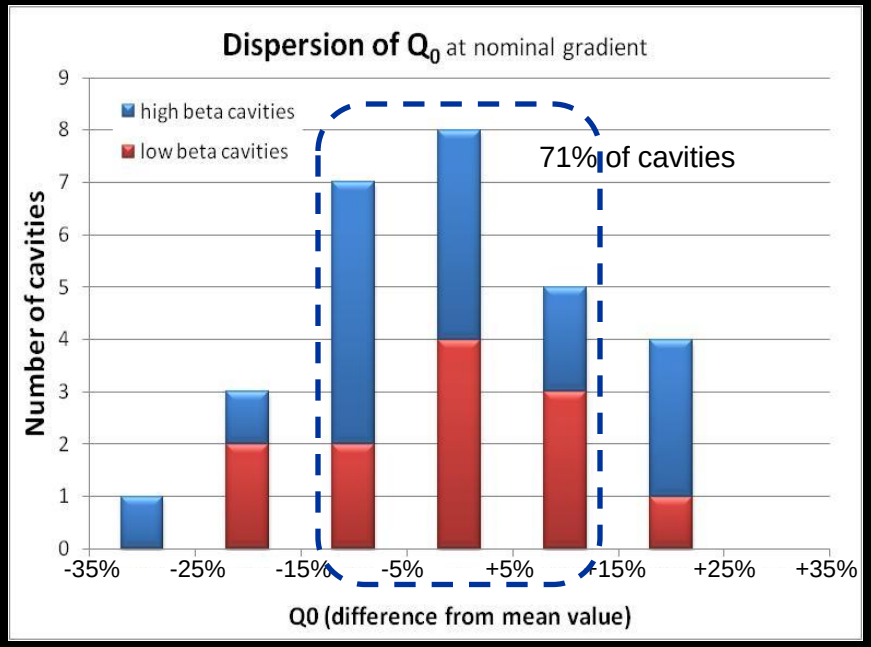
Cavities performances in vertical cryostat

Very homogeneous results

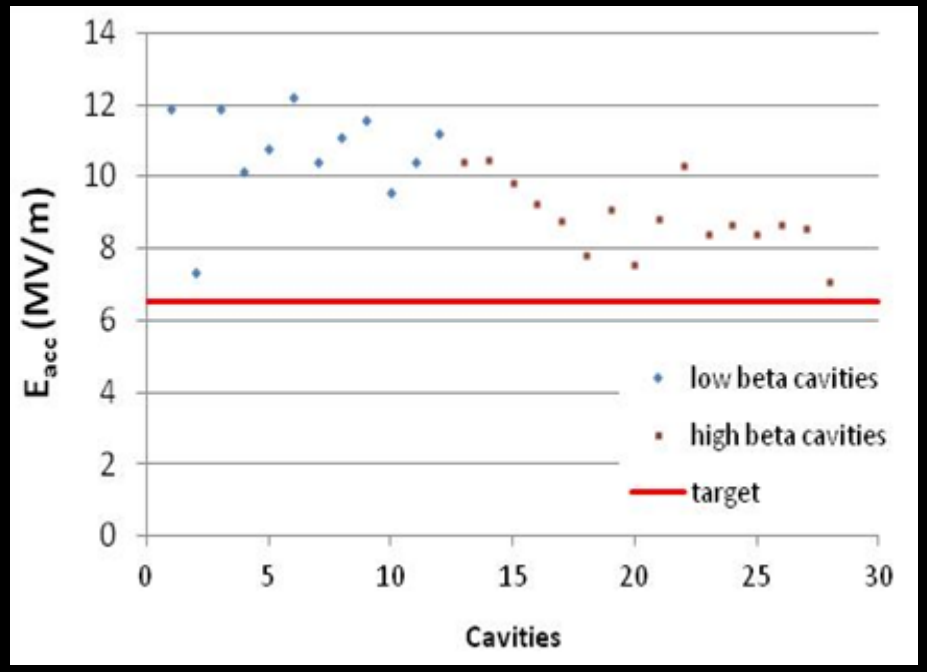




Cavities performances in vertical cryostat



Maximum gradient reached



		low beta	high beta
target (10 W limit)		4,0E+08	1,4E+09
Computed (simulation codes)		7,6E+08	2,7E+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

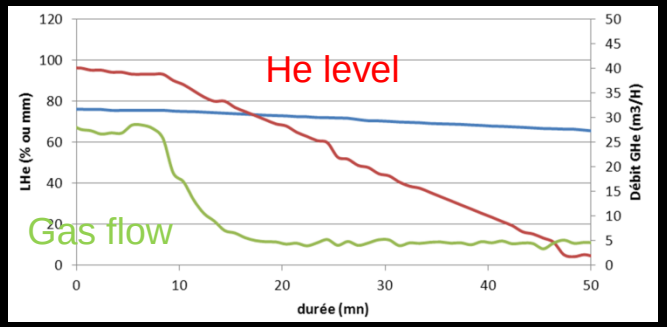
		low beta	high beta
Nominal gradient		6,5	6,5
max gradient reached in vertical cryostat	min	7,4	7,1
	max	12,2	10,5
	mean	10,7	8,9

Cavities performances in cryomodules

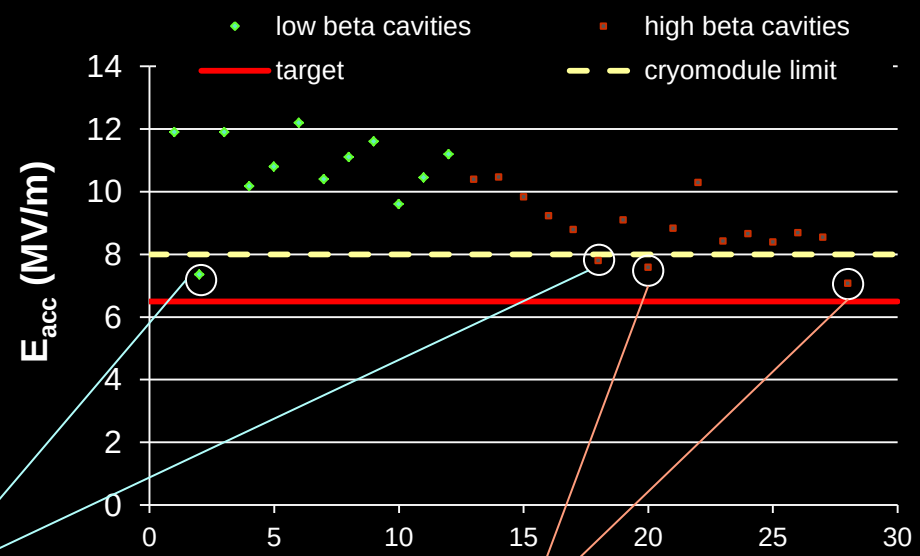
		low beta	high beta
target (10 W limit)		4,0E+08	1,4E+09
Computed (simulation codes)		7,6E+08	2,7E+09
achieved in vertical cryostat, at nominal gradient	min	4,8E+08	2,6E+09
	max	7,0E+08	4,6E+09
	mean	5,9E+08	3,7E+09
achieved in cryomodule, at nominal gradient	min	2,8E+08	2,0E+09
	max	5,5E+08	3,9E+09
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

-38%

Q_0 in cryomodules: calorimetric measurements (lower accuracy)



Maximum gradient reached

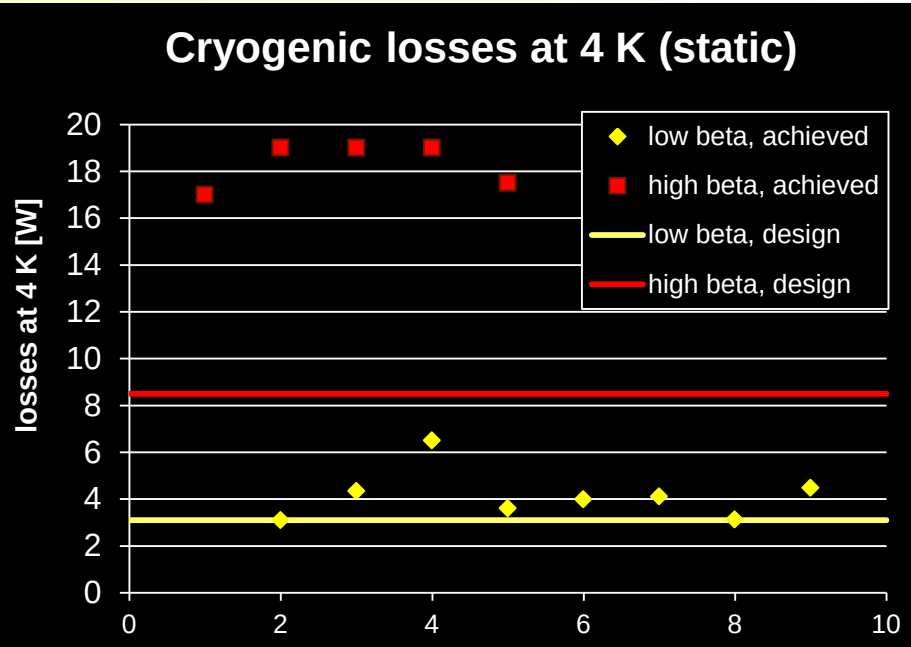


Max gradient in cryomodules: administrative limit (avoid quench)

Not yet tested in cryomodule

Spare cavities

Cryomodules cryogenic performances

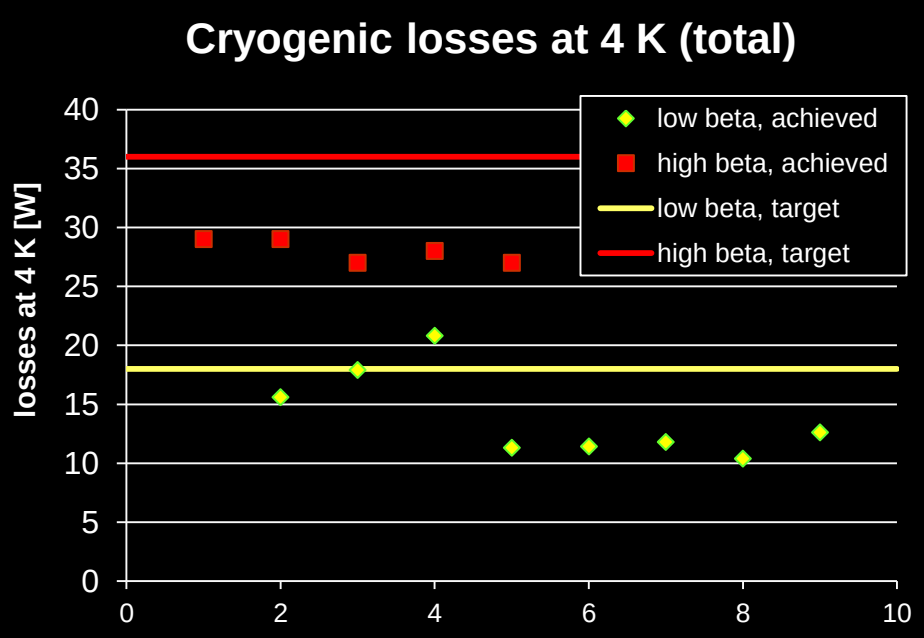


Measurement methods:

- 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



Other cryomodules performances

- Tuning systems
  - ✓ Effective tuning range
    - low beta: 13 kHz (restricted to protect the cavity)
    - High beta: 10 kHz
  - ✓ Reliability: low beta system heavily 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)

4. Conclusions & perspectives

SPIRAL2 cryomodules performances

SPIRAL2 cryomodules tests results:

- Achieved gradients and Q_0
- Dispersion of performances
- Decrease of performance VC -> cryomodule
- Achievable performances for short and compact cryomodules
- Etc.

But:

- New low β cavity designs, new cavities treatment (EP): *enhanced performances*
- SPIRAL2 cryomodules not yet operated on-line and with beam: *we can expect some decrease of performances – how much?*

Installation tests

Cryomodules to warm sections beam line connections :

No Q_0 loss, no maximum gradient loss, same field emission

Transportation test:

	Before	after
X-rays dose rate at nominal gradient (μSv)	730	9
Total losses at 4K and nominal gradient (W)	15.4	13.2

Thank you for your attention !…

GANIL spiral2