DEVELOPMENT OF BETA 0.12, 88 MHZ, QUARTER-WAVE RESONATOR AND ITS CRYOMODULE FOR THE SPIRAL2 PROJECT

G. Olry, J-L. Biarrotte, S. Blivet, S. Bousson, C. Commeaux, C. Joly, T. Junquera, J. Lesrel, E. Roy, H. Saugnac, P.Szott, B. Legoff * CNRS/IN2P3/IPNO, Orsay, France

SPIRAL2 is a radioactive beams facility, composed of a superconducting linac driver, delivering deuterons with an energy up to 40 MeV (5 mA) and heavy ions with an energy of 14.5 MeV/u (1 mA). This facility is now fully approved by the French government.

The first prototype of beta 0.12 quarter-wave resonator has been recently fabricated by Zanon company and tested at IPN Orsay. The details on its fabrication and the results of the RF and mechanical tests at 4K will be presented. Then, we will show the design of the cryomodule-B, dedicated to the high energy section of the linac, which is now ready to be ordered. Finally, the last studies of the R&D program, such as the last optimizations of the geometry, the new developments of the tuning system or the design of the helium vessel, are described..

QUARTER-WAVE RESONATOR

RF design

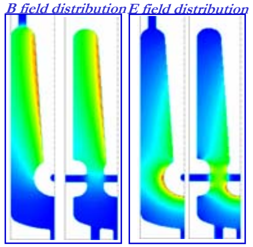
GOAL: Eacc=6.5 MV/m ⇔ Epeak=36 MV/m & Bpeak=66 mT for Pdissipated<10 W

MAFIA calculations

Qo* (@ 4.2K	3.0 E+09
r/Q [Ω]	518
G [Ω]	38
Ep/Eacc	3.53ᵝ 5.56ᶜ
Bp/Eacc [mT/MV/m]	6.47ᵝ 10.18ᶜ
Voltage gain @ Ep=36 MV/m [MV]	2.65
Dissipated power @ Ep=36 MV/m [W]	4.5

* assuming a 10 nOhm residual resistance
ᵝ Lacc=iris-to-iris length=0.26 m
ᶜ Lacc=beta.lambda=0.41 m

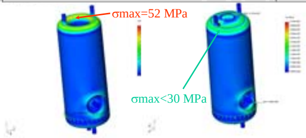
B field distribution *E field distribution*



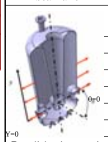
MECHANICAL design

COSMOS & MICAV calculations

Maximum stress on cavity @ 1 bar [MPa]	<30
Maximum displacement of the stem [mm]	0.16
Tuning sensitivity using the cavity body [kHz/mm]	1.4
Tuning sensitivity using one Ø30 plunger [kHz/mm]	1.2
Static tuning range [kHz]	<70

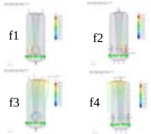


Von Misses stresses [MPa]
a/ without stiffening plate b/ with stiffening plate



	Y mm	Df Hz/mm	K N/mm
Perpendicular to beam axis	0	7800	8500
	118	3000	6100
	237	1400	5100
	382	1900	4800
Parallel to beam axis	0	31600	8500
	148	13000	6100
	267	5900	5100
	385	3700	4800

First modes of vibration	
f1 [Hz]	55
f2 [Hz]	62
f3 [Hz]	173
f4 [Hz]	197



	Mod a	Mod b	Measures on mod b
Vac.sensitivity kHz/bar	-5.5	-4.5	-15
Temp. Sensitivity kHz @ 4K	150	150	165
Stem displacement	0.5	0.16	0.28
Buckling pressure	1.7	1.7	

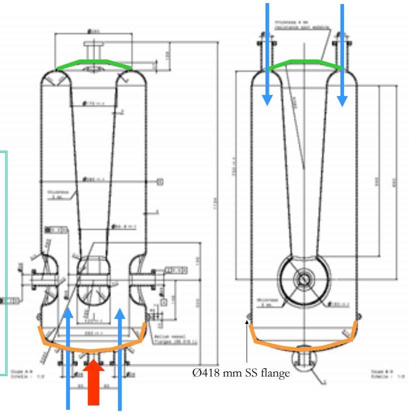
FABRICATION *by Zanon SpA (Italy)*

Cavity during "warm" tuning process

Accelerating gap area

Stiffening plate (Nb 4-mm thick)

- Welded bottom plate (no joint)
- Niobium thickness: 4 mm (except for the stem: 3 mm)
- Beam tubes & all ports aperture: Ø36 mm
- Capacitive RF coupling
- Stiffening plate on top-torus
- 4 ports for HPR process
- No He tank for the first tests (but Ø418 mm SS flange brazed on cavity bottom allows to weld an He tank for further developments)



Ø418 mm SS flange

TEST @ 4.2 K

TEST #1

$Q_o=1.0\ 10^{10}$ ⇔ Residual resistance=1.5 nΩ

No quench up to **11 MV/m** (i.e. Vacc=4.4 MV) and P=36 W

TEST #2

"100 K effect" (5 days between 70 K and 130 K): $Qo=8.2\ 10^8$ ⇔ Residual resistance=43 nΩ

Quench @ 8 MV/m

TEST #3

With 1 plunger in Niobium (Ø30 mm and L=154 mm): $Qo=6.8\ 10^9$ ⇔ Residual resistance=3 nΩ ⇒ losses in the SS CF40 flange (~20%)

Quench @ 8.2 MV/m

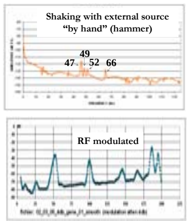
Detuning: -**66.9 kHz** meas. (68 kHz calc.)

TEST #4

With 1 plunger in Niobium (Ø20 mm and L=142 mm): $Qo=1.0\ 10^{10}$ ⇔ Residual resistance=1 nΩ ⇒ no losses

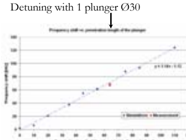
No quench up to **11 MV/m** (i.e. Vacc=4.4 MV) and P=25 W

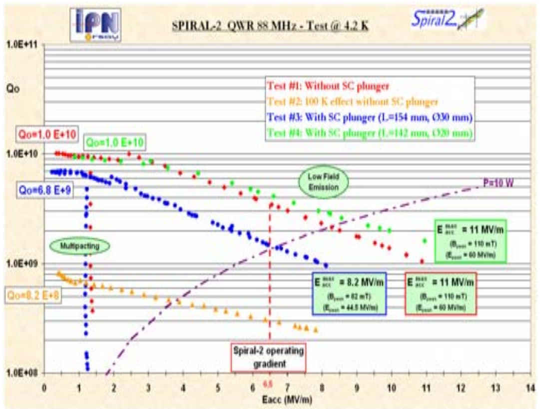
Detuning: -**18.2 kHz** meas. (N/A calc.)



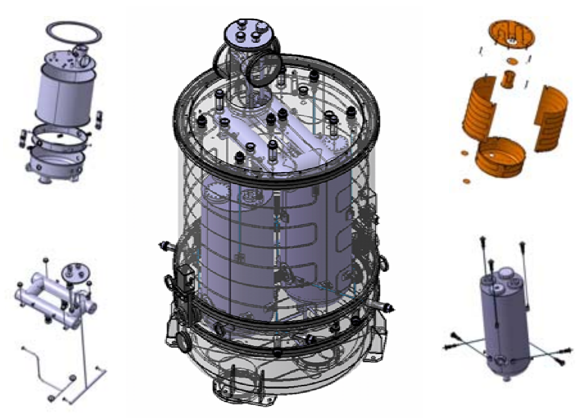
Microphonics measurements

Detuning with 1 plunger Ø30



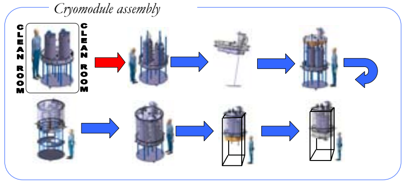


CRYOMODULE

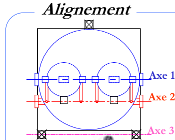


- Cryostat insulation vacuum & cavity vacuum separated
- Cryogenic static losses (evaluated) < 10 W @ 4K & < 65 W @ 60K
- Cavity tank helium feeding by thermosiphon from a buffer vessel placed inside the cryomodule
- Thermal shield @ 60-80K with GHe
- Cavity kept in position by mean of antagonist rods

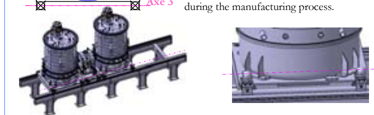
Cryomodule assembly



Alignement



Axe 2 materialized by « robson & halley » mires represents the cavity axis (Axe 1). It is adjusted during the manufacturing process.



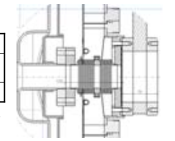
Axe 3 of each cryomodule are then adjusted between us on the accelerator support bench.

Axe 3 is adjusted to Axe 2 by means of optical windows placed on the cryostat vacuum vessel.

300k/4k Transition

	Q 80K	Q 4K
Thermal Radiation	< 1 W	< 0.1 W
Solid conduction	< 2 W	< 0.15 W

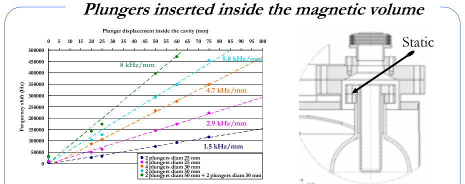
300 K / 4 K transition Thermal losses



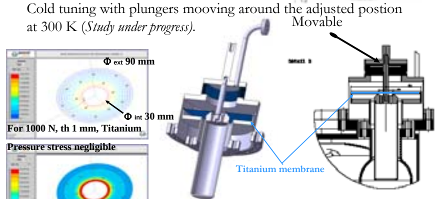
Cold tuning system

Two solutions are under study

Plungers inserted inside the magnetic volume



Cold tuning with plungers mooving around the adjusted postion at 300 K (*Study under progress*).



Tuning range around 2 kHz for one plunger.

To be optimized

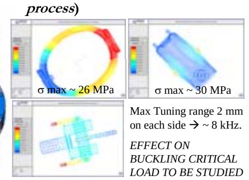
Mechanical deformation of the RF walls

WARM TUNING

Adjustment of the gap distance (range +/- 2 mm) during the manufacturing. Sensitivity ~ 100 kHz/mm (for each gap)

COLD TUNING (*study under process*)

- Motoreductor ~ 80000 µsteps/turn
- Ball screw 2.5 mm/tr
- Lever arm ratio ~10



Max Tuning range 2 mm on each side → ~ 8 kHz.

EFFECT ON BUCKLING CRITICAL LOAD TO BE STUDIED

Df/dx (Hz/mm)	Kcav (N/mm)	Kanneau (N/mm)	kCTS (N/mm)	A	Mechanical resolution (nm)	Frequency resolution (Hz)
~4 kHz	~5000	~ 18400	>50000	0.73	1.14	0.004

- Manufacturing of the first cryostat cryomodule : from beginning 2006
- CTS manufacturing (either plungers either wall deformation) : from beginning 2006
- Tests on cryomodule prototype : Vibrations and microphonies, Mounting procedure, cryogenic qualification …: from end 2006
- Tests of the complete cryomodule with HF power, power couplers, CTS… : from beginning 2007