DEVELOPMENT OF SPOKE CAVITIES FOR THE EURISOL AND EUROTRANS PROJECTS

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IPN Orsay is strongly involved within the EURISOL and EUROTRANS projects, especially collaborating to the overall design of the linac. Since a few years, main part of the work is dedicated to the development of superconducting spoke cavities and their associated components (RF coupler, tuning system...). The results of the recent tests of both beta 0.15 and beta 0.35, 352 MHz, spoke cavities are presented. We will also describe the study realized on the future horizontal cryomodule for spoke cavities tests and, also the first design of the power coupler. Then, an overview of the latest beam dynamics calculations performed in order to design a linac using spoke cavities will be presented.

SPOKE 0.35

Electromagnetic parameters

MAFIA calculations

Qo[a](@ 4.2K) (@ 2 K)	1.9 E+09 8.8 E+09
r/Q [Ω]	220
G [Ω]	101
Ep/Eacc	3.06[b] 4.56[c] 5.42[d]
Bp/Eacc [mT/MV/m]	8.28[b] 12.33[c] 14.65[d]
Voltage gain [MV]	1.96 @ Ep=30 MV/m
Optimal beta	0.36

[a] *assuming a 10 nOhm residual resistance*
[b] *Lacc=iris-to-iris length=0.2 m*
[c] *Lacc=beta.lambda=0.297 m*
[d] *Lacc=cavity length=0.354 m*

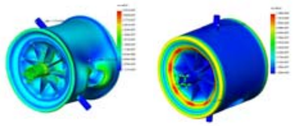
- 2-gap structure
- Niobium: RRR250, 3-mm thick
- No Helium tank
- 8 stiffeners/end-cup
- Capacitive coupling by Ø30 mm port (use of both movable and fixed antenna)

Mechanical calculations

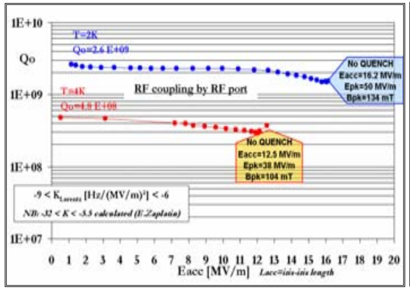
Maximum stress @ 1 bar > 120 MPa with "free" boundarie conditions:

► Cavity beam tubes were both fixed during mechanical tests @ 300 K under vacuum

► Addition of an external stiffening system for cold tests



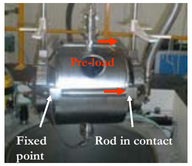
BC: both beam tubes fixed — BC: 1 beam tube fixed



Results

- Eacc max=16.2 MV/m (corresp. Epk=50 MV/m & Bpk=134 mT)
- Extra-losses on the antenna due to B field ⇒ rotation of the RF port of 45° for the 2nd prototype
- No quenches, very flat Qo vs. Eacc curves, no X-ray emission below 12 MV/m @ 2K
- Static Lorentz forces detuning coefficients measurements are in good agreement with simulation

Lorentz forces detuning measurements



@ 4.2 K

Test #1 (March 03): -5.6

Test #2 (July 03): -7.3

Test #3 (May 04): -6.94 < K_L < -5.72

► Discrepancies come from the ≠ manual pre-loads before each test

@ 2 K

Test #3 (May 04) : -8.9

► Higher value ⇔ cavity is less constrained due to the Helium bath pressure decrease between 4.2 K and 2 K

SPOKE 0.15

Electromagnetic parameters

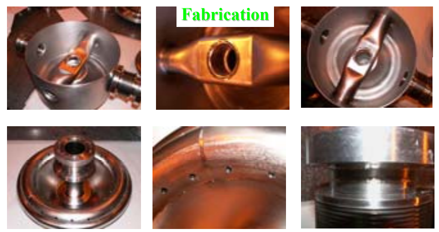
MAFIA calculations

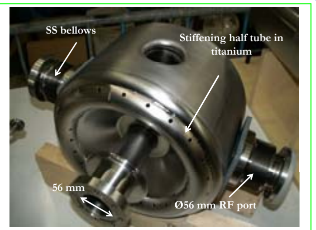
Qo[a](@ 4.2K) (@ 2 K)	1.3 E+09 6.2 E+09
r/Q [Ω]	88
G [Ω]	67
Ep/Eacc	3.32[b] 6.74[c] 8.57[d]
Bp/Eacc [mT/MV/m]	7.14[b] 14.48[c] 18.45[d]
Voltage gain [MV]	0.63 @ Ep=30 MV/m
Optimal beta	0.2

[a] *assuming a 10 nOhm residual resistance*
[b] *Lacc=iris-to-iris length=0.084 m*
[c] *Lacc=beta.lambda=0.17 m*
[d] *Lacc=cavity length=0.217 m*

- 2-gap structure
- Niobium: RRR250, 3-mm thick
- Stainless Steel bellows already welded for the Helium vessel (TIG welding scheduled in October)
- New stiffeners for external pressure sustaining: ½ tube in Titanium on the top part of each end-cup
- RF coupling by Ø56 mm port located at 90° w/r to the spoke bar
- Capacitive coupling with a fixed antenna

Fabrication

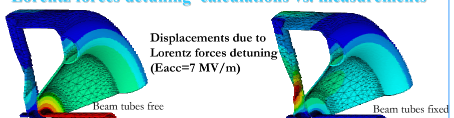


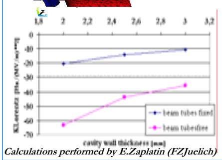


Delivered in December 2004

~ one year of fabrication (done by CERCA)

Lorentz forces detuning calculations vs. measurements





Calculations performed by E.Zaplatin (FZJuelich)

➢ The cavity was maintained (but not fixed) during cold tests ⇒ wide spread in Lorentz forces detuning coefficient measurements: from -55 to -28 Hz/(MV/m)²

➢ Good correlation with MWS simulations taking into account the reduction of the thickness down to 2-mm (see thickness measurements).

First tests @ 300K

❑ Frequency check after delivery: OK, discrepancy of only 300 kHz (NB: ~450 kHz for the β0.35 1st prototype).

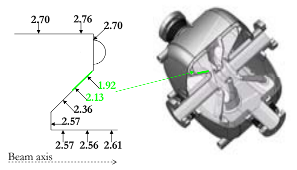
❑ Frequency shift due to Ø8 mm antenna into RF coupler: 7 MHz !!! (confirmed by simulations)

❑ Cavity tested under vacuum: OK, no leak detected & stiffening Titanium tubes are sufficient.

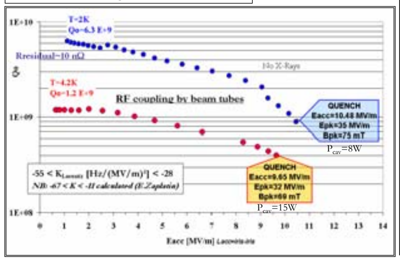
❑ Displacement of the beam tubes under vacuum: 0.17 mm (experiment), 0.18 mm (simulations) ⇒ Good agreement with calculations

For 1 bar pressure	beam tubes fixed		beam tubes free		beam tubes free
	ANSYS (E.Zaplatin)	COSMOS	ANSYS (E.Zaplatin)	COSMOS	Measurements @ 300K
Max displacement (mm)	0,09	0,11	0,14	0,18	0,17
Max Von Mises stress (MPa)	55,3	46,7	43,8	38,7	N/A
Frequency shift (kHz)	-442,3	N/A	-378,7	N/A	-440

❑ Measurements of the thickness: Not homogenous, i.e down to 2-mm on some end-cup areas !!! ⇒ big effect on static Lorentz forces detuning coefficient (see cold test)



Average thickness in mm on end-cup (after 140 µm of BCP removal)



Results

➢ Preparation of the cavity: BCP chemistry (etching of ~140µm) and 2-hour HPR processing through all ports.

➢ Test @ 4K: QUENCH at Eacc= 9.6 MV/m

- ❑ 2 hours of conditioning to reach 9.6 MV/m
- ❑ 2 MP barriers observed at 1.5 MV/m and 7-8 MV/m (processed in a few minutes), X-rays emission starting from 4 MV/m (1st test) then nothing (2nd and 3rd tests)

➢ Test @ 2K: QUENCH at Eacc= 10.5 MV/m

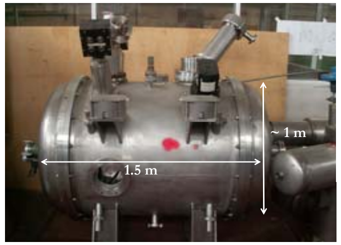
- ❑ 1 MP barrier observed around 8 MV/m, no X-rays emission

⇒ Quenches occured at the same Bpk field level ~70mT!

Horizontal Cryomodule

CM0 horizontal cryomodule collected from CEA/Saclay in June

Main goal ⇒ Integrate our β0.15 spoke cavity and its associated RF coupler in order to test them at the required levels of power (i.e. up to 20 kW in CW regime) for the EUROTRANS and EURISOL projects



Time schedule

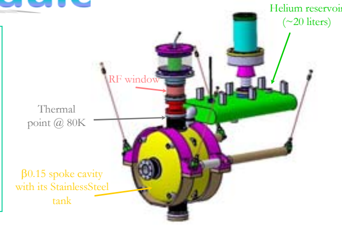
❑ Detail study completed in May 2005

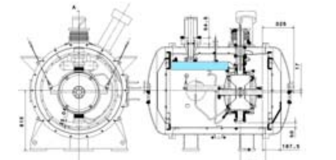
❑ Modifications of the cryomodule structure to fit the cavity but especially, the coupler window dimensions: between september and december 2005

❑ First tests at 4K and low power (i.e. 600W) *with the cavity only*: beginning of 2006

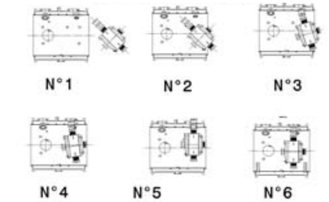
❑ Test with the cavity *and* the coupler: foreseen in June 2006

❑ Test at higher power level (i.e. at least 5 kW): beginning of 2007

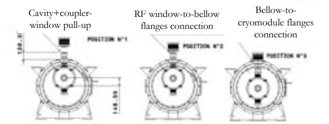




2D drawings of the spoke cavity and cryomodule assembly



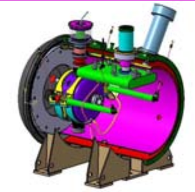
Cavity+coupler-window assembly steps inside the cryomodule

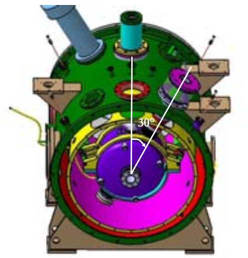


- The spoke cavity *and* the RF window block will be first fully assemble into class-10 clean room when slide inside the cryomodule
- The main difficulty comes from the overall height of this cavity+RF window block ⇒ need to tilt it during the assembly

OPTION #1: Cavity on the left side

- 2 possibilities of assembly: 0° or ±30°
- keep the support structure as it is
- … but need the change of all CF flanges on the cryomodule

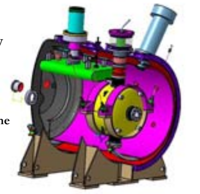


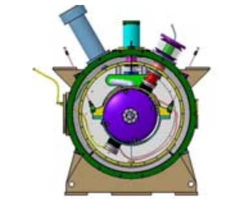


❖ Option #1 is preferred even if it is the most expensive ⇒ possible problems coming from Helium bubbling in the spoke bar (when horizontal) could be studied and compared with results obtained when spoke cavity is rotated by 30°. Not possible if choosing option#2

OPTION #2: Cavity on the right side

- Only 1 possibility of assembly: 0°
- keep the CF flange on the cryomodule as it is
- … but need the change of the support structure

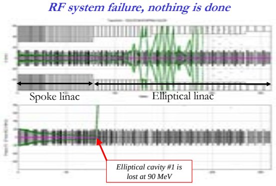




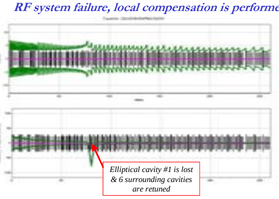
Beam Dynamics

Analysis of the fault-tolerance capability of SC linacs for ADS application (EUROTRANS project, see also Biarrotte ThP35)

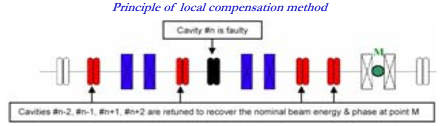
RF system failure, nothing is done



RF system failure, local compensation is performed



Principle of local compensation method



Conclusions of the study

1/ In every case, **with an appropriate retuning, the beam can be transported up to the high-energy end without any beam loss** (100 % transmission, small emittance growth), and within the nominal target parameters

2/ Need of at least **30% margins** on RF power and accelerating fields

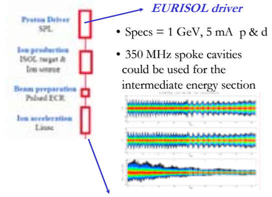
GOAL = BEAM INTERRUPTION << 1sec

3/ Need of a **fast retuning procedure (ms range) of the neighbouring cavities**, that implies the use of adequat diagnostics and of a fast digital LLRF control system using pre-tabulated setpoints

4/ Then, need of a slower retuning procedure to achieve perfect transport, acting on the failed cavity tuning system and on a few quadrupoles if needed

This analysis is presently starting: expected results in 2007/ 2008

Spoke cavities for EURISOL



EURISOL driver

- Specs = 1 GeV, 5 mA p & d
- 350 MHz spoke cavities could be used for the intermediate energy section

EURISOL post-accelerator

- Specs = 100 MeV/u heavy-ions, up to A/q=10
- 260 MHz or 350 MHz 2-gap spoke cavities could be used for the high-energy section

$^{132}Sn^{25+}$	Section 1	Section 2	Section 3	Section 4	TOTAL
Cavity Freq.	88.05 MHz	88.05 MHz	176.1 MHz	264.15 MHz	-
Cavity β	0.07	0.12	0.24	0.38	-
# cav./ lattice	1	3	6	9	-
# cavities	12 cav	27 cav	60 cav	126 cav	225 cav
Length	13.3 m	21.6 m	41.7 m	84.7 m	161.3 m
Beam energy	0.67 MeV/u 2.8 MeV/u	2.8 MeV/u 14.3 MeV/u	14.3 MeV/u 39.2 MeV/u	39.2 MeV/u 100.1 MeV/u	0.67 MeV/u 100.1 MeV/u