RECENT DEVELOPMENTS ON SUPERCONDUCTING β035 AND β015 SPOKE CAVITIES AT IPN FOR LOW AND MEDIUM ENERGY SECTIONS OF PROTON LINEAR ACCELERATORS

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Abstract

Spoke cavities studies leaded by IPN-Orsay, for both PDS/XADS and EURISOL projects, are fully integrated within the 5th and 6th European Framework Programs.

During 2003, first tests performed on the β035, 2-gap spoke cavity have demonstrated the great potential of this type of cavity in terms of RF performances (Eacc max=12.5 MV/m at T=4.2 K) and mechanical behavior (very low sensitivity to errors fabrication, good stiffness, accelerating field flatness…). In 2004, we have been able to test the cavity into super-fluid Helium thanks to the upgrade of our cryogenic facility. Last results at 4.2 K and 2 K are presented.

In parallel, the fabrication of the new spoke cavity (2-gap, 352 MHz, β015) has begun in January. While keeping the same geometry than the β035 cavity, we carried out significant changes on coupler port localization and stiffening system designs.

Finally, we will present the preliminary thought on modular spoke-type cryomodule which are based on the "short" cryomodule concept used for the Quarter Wave Resonators in the SPIRAL-2 project.

TEST AT 2 K ON BETA 0.35 SPOKE CAVITY

The recent upgrade of the IPN cryogenic facility allowed us to test the cavity at 2 K. The power capacity of the facility is 35 W. About 1500 litres of liquid helium have been used during the 3-day test. Classical preparation was done on 100-class room: a "light" BCP chemistry (~10 µm), followed by a HPR cleaning with ultra–pure water.

For this test, we used a movable coupler with a displacement range of 12 mm (Fig. 1) and a 200-Watt RF amplifier. Q_0 values expected were 8.8 10^9 at 2 K and 1.9 10^9 at 4.2 K.

Test at T=4.2 K

We started by a classical series of tests at 4.2 K (See results of the 4 measurements for 4 different positions of the antenna in Fig. 2). A maximum accelerating gradient of 10 MV/m has been reached after helium processing (red curve). In each case, we were limited by the RF power available and we never detected a quench. One can note that a "little" multipacting barrier was observed around 1.5 MV/m during the second measurement (pink curve) and has been easily processed.

Lorentz forces measurements are presented in following subsection.

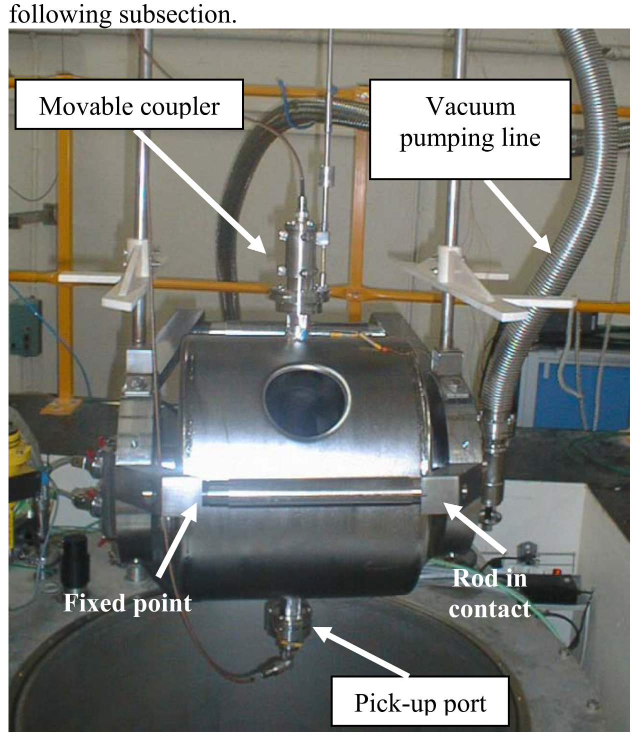

Figure 1: β0.35 spoke cavity fixed on its insert.

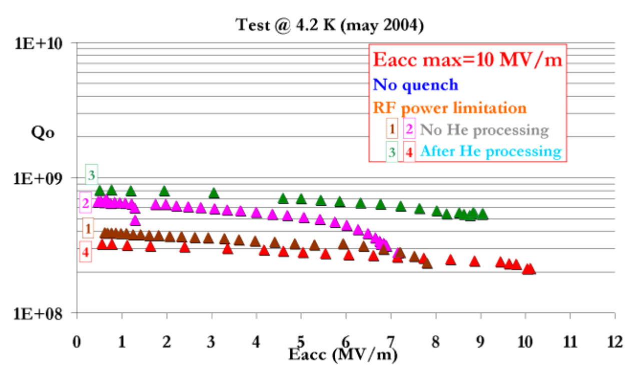

Figure 2: Q_0 vs. Eacc curves at 4.2 K.

Test at T=2 K

Cool down of the cavity from 4.2 K to 2 K last for 6 hours without problem (no He leak detected). The total frequency shift observed during the cool down was +205 kHz.

First test (not plotted on Fig. 3) showed a strong electronic activity starting from 9 MV/m (Q_0 dropped from 2.5 10^9 to 1.2 10^9). After a RF processing, accelerating gradient was pushed up to 13.5 MV/m (until RF amplifier limit). Then, we performed He processing during 2 hours (blue and red curves in Fig.3) to finally reach an accelerating gradient of 16.2 MV/m with Q_0=1.5 10^9. It corresponds to a peak electric field of 49.5 MV/m and a peak magnetic field of 134 mT. Because of losses due to magnetic field on the antenna (see [1] and subsection above), the cavity was under coupled (β_i=0.21) and most of the power was reflected. At 16.2 MV/m, for a 122-Watt incident power, 75% was directly reflected, leaving only 30 W into the cavity. One can note that the cavity did not show electronic activity until 11 MV/m.

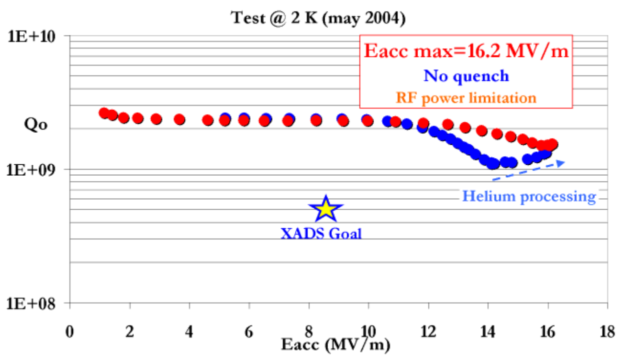

Figure 3: Q_0 vs. Eacc curves at T=2 K.

Lorentz forces detuning

The Lorentz forces detuning factor (in Hz/(MV/m)²) measured at 4.2 K are in good agreement with those measured in previous tests (i.e. -5.72, -6.94, -6.36 and -6.68 in 2004 as compared to -5.6 and -7.3 in 2003). In addition to the measurement accuracy, the discrepancy between values in 2004 and 2003 may be due to the pre-stress we applied on the cavity which was not exactly the same.

Detuning factor value at 2 K was very different: K=-8.9 Hz/(MV/m)². As the cavity is pre-stressed in extension by the meaning of 3 rods only in contact at one cavity side (See Fig.1), the cavity becomes "free" at 2 K when the Helium bath pressure decreases. We can notice that this value remains reasonable.

BETA 0.15 SPOKE CAVITY ACTIVITIES

To keep going with the spoke cavities development for PDS/XADS and EURISOL European accelerator projects, we launched the fabrication (by Framatome-anp/CERCA) of a 2-gap, β0.15 cavity in January 2004. Its delivery is expected in August and first test in vertical cryostat is planned to the beginning of 2005. As shown in Fig. 4, the cavity will be equipped of a Stainless Steel helium tank. Thanks to our experience with the β0.35 spoke cavity, we have defined a new location of the RF coupler port in order to avoid "extra" losses and we have also designed a new stiffening system to sustain 1 bar while leaving the cavity beam tubes "free".

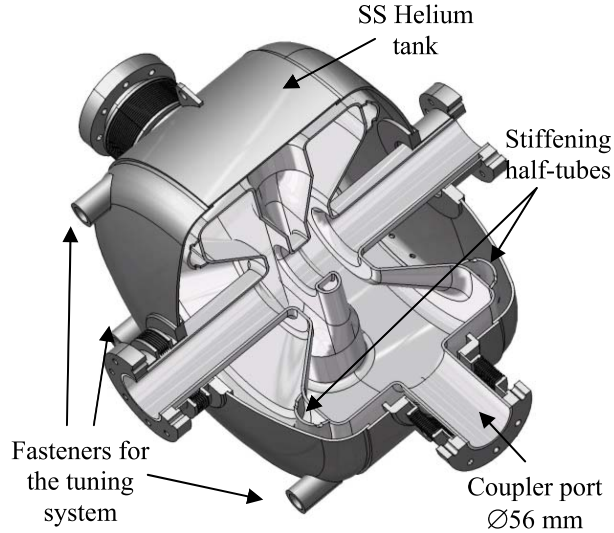

Figure 4: β0.15 spoke cavity 3D drawing, equipped with its Helium tank and coupler port.

RF calculations

Results of RF simulations have been presented in 2002 [2] with the "old" coupler port. Table 1 summarizes the parameters calculated with MAFIA with the new coupler port dimensions located at 90° with respect to the spoke bar. One can note that Ep/Eacc and Bp/Eacc ratios are given for both "American" ([b]) and "European" ([c]) definitions.

Table 1: RF parameters of β0.15 spoke cavity

Q_0[a]	1.4 E+09
G [Ω]	67
Ep/Eacc	3.97[b] 5.92[c]
Bp/Eacc [mT/MV/m]	7.95[b] 11.86[c]
Voltage gain @ 30 MV/m [MeV]	0.63
Optimal beta	0.18

[a] Assuming a residual resistance of 10 nΩ
[b] Lacc=iris-to-iris length
[c] Lacc=βλ length

New power coupler location

During our tests, we have measured Qo values 3 times lower than those expected. We have already demonstrated, using MAFIA, that these "extra" losses came from high magnetic field surrounding the antenna tip inside the RF port [1]. As both β0.35 and β0.15 are based on the same RF design, calculations to determine the new coupler position have been performed for the β0.35 spoke cavity and, then, applied to the β0.15 one [3]. This study, performed with HFSS software, shows that optimal position is 90° with respect to the spoke bar (See Fig. 5).

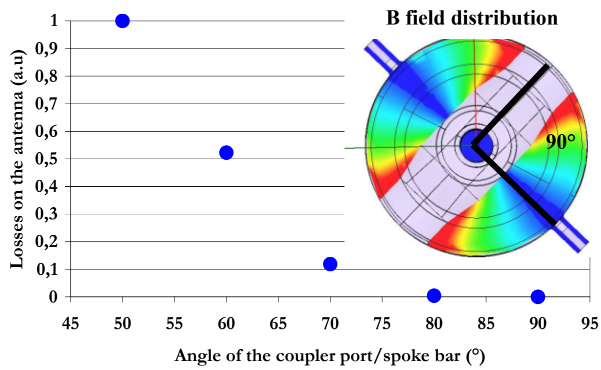

Figure 5: Losses on the antenna (in arbitrary units) vs. coupler port position.

Studies on different coupler windows

To fit the PDS/XADS and EURISOL requirements of their respective linac design, we started to study a CW, 352 MHz coupler for both β0.15 and β0.35 spoke cavities. It will be designed to reach at least 20 kW (for a 14-kW nominal power). We are finishing the comparative study between both disc (with and without chokes) and cylindrical windows. Choice will be made soon in order to launch the fabrication at the end of 2004.

TEST BENCH FABRICATION

The mechanical measurements [1] done on the β0.35 spoke prototype, have been performed using several set-up as a "rough" test bench (which was previously dedicated to elliptical cavity tuning) and the tensile machine from LAL. To have an "all-in-one" test bench, we have launched the fabrication of a specific test bench for all cavities developed by IPN (5-cell elliptical cavity, spoke and QWR). Fig. 6 shows how the β0.15 spoke cavity should be installed on the bench. The useful length between both arms is 1200 mm (including the 200-mm loading sensor).

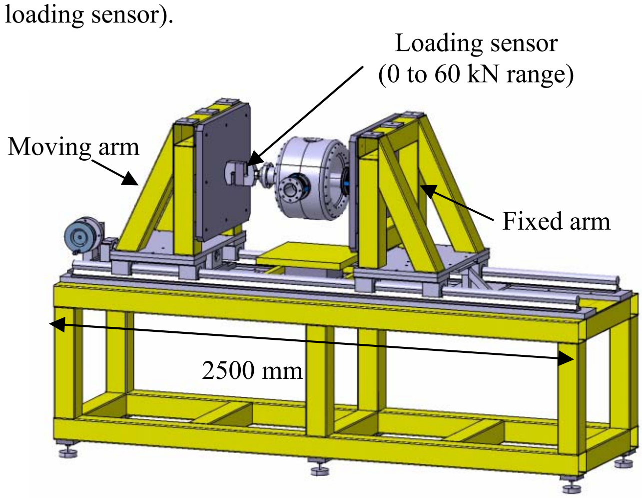

Figure 6: Test bench for mechanical measurements.

For the first tests, it will be equipped with a loading sensor fixed on one cavity flanges in order to have a direct measurement of the force applied to determine the cavity stiffness. We will use at least 3 displacement sensors (range: 2.5 mm with a resolution of 1 µm) to measure the real cavity displacement (one on the cavity flanges and one behind each arm). Fabrication is under progress and the first tests will start on November 2004 with the SPIRAL-2 β0.12 QWR [4].

SPOKE-TYPE CRYOMODULE

Based on the "short" cryomodule concept developed for the SPIRAL-2 linac [4], we started the study of a modular spoke-type cryomodule (see Fig. 7). There is 1 cavity per cryomodule and warm focussing devices should be used. To fit the focussing lattice length, it could be possible to put together 2 cryomodules. Thank to its little dimensions we can fix the tuning system outside to make its design and integration easier.

We plan to build a prototype, in the frame of the EURISOL project, during the year 2006. Integration will be done at IPN and the possibility to perform a preliminary test with a low current beam, issued from the IPN Orsay tandem accelerator, has to be studied.

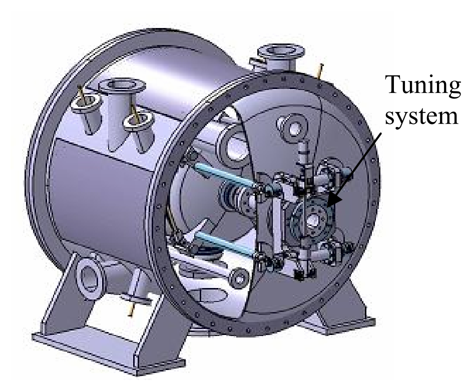

Figure 7: 3D cryomodule drawing integrating 1 cavity.

ACKNOWLEDGMENTS

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