Delivery of the 704 MHz HIPPI cavity

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Abstract

The so-called Cavity B of the CARE/HIPPI program is a 5-cells 704.4 MHz elliptical cavity with a beta=0.47. This cavity was fabricated by ACCEL and delivered on March 27th 2007 at Saclay. This report documents the cavity delivery and the first measurements.

Introduction

The so-called Cavity B of the CARE/HIPPI program is a 5-cells 704.4 MHz elliptical cavity with a beta=0.47. As the coupling port should host a 100 mm diameter power coupler, the beam tube has been widen on the coupler side to a 130 mm diameter in order to reach Qex values below 10^6. Optimization of the geometry led to a symmetric design (130 mm diameter beam tubes ending by 80 mm flanges) which limits the number of modes excited by a modulation frequency of the Lorentz forces. Moreover, using two series of stiffening rings greatly improves the mechanical behaviour of the cavity while maintaining a wide tuning range. Their respective radii have been optimized in one hand for lowering the static Lorentz force coefficient (K_L) of low frequency mechanical modes, and in the other hand for limiting the cavity stress to acceptable values (40 MPa).

This cavity was fabricated by ACCEL and delivered on March 27th 2007 at Saclay.

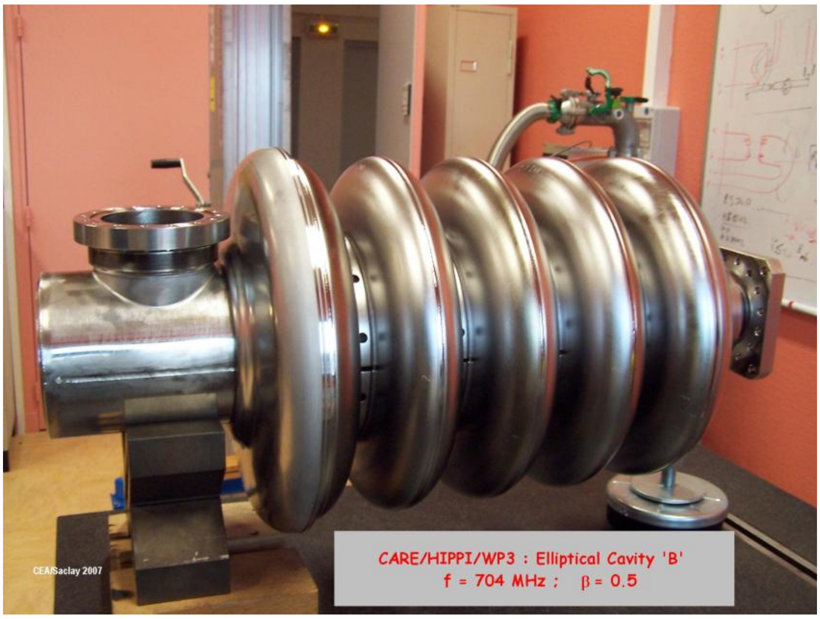

Figure 1: Cavity B ready for surface preparation and qualification test in vertical cryostat

First mechanical measurements

The cavity was mounted on the tuning bench for mechanical and RF measurements. The cavity has been internally inspected using an endoscope to check the quality of the electron beam welds of all irises and equators. All the welds are visually soft and of even width.

The total length, cavity unconstrained is 831.6 mm instead of 832.6 mm.

Cells outer diameter

Only outer dimensions can be measured. Due to the presence of the weld at the equators, it is uneasy to measure the cells outer diameter. The measurement at the weld position is however giving some insight on what could be the value of the inner diameter. The measurements have been made at the center of the weld, which is its larger dimension.
From now on, the cell numbering begins by the cell close to the power coupler port, which is labeled 1.

Cell #	1	2	3	4	5
Outer diameter at weld center (mm)	380.60	380.62	380.57	380.72	380.52

Stiffening rings

Outer stiffening rings are labeled 1-2, 2-3, 3-4 and 4-5 according to their adjacent cell labels.
Their outer diameter has been measured using two methods (this dimension should be 228.4 mm).

	1-2	2-3	3-4	4-5
Diameter method 1 vertical measurement (mm)	227.81	228.14	227.99	228.64
Diameter method 2 vertical measurement (mm)	227.86	228.14	227.86	228.62
Diameter method 2 horizontal measurement (mm)	228.1	227.74	227.70	227.82

One obvious difference from the prescribed dimension is the diameters of the holes in the stiffening rings, 10 mm instead of 8 mm for the outer rings and 4 instead of 8 for the inner ones. This issue prevents the cavity tuning bench from being used without modifications, and delays the operation of field flatness and frequency adjustment, while parts are being reworked.

RF measurements at room temperature

The fundamental passband was measured by ACCEL and communicated to us, so was the field profile measurement of the pi mode. The main concerns are a shift of the frequencies towards lower values by approximately 4 MHz, an uneven field profile on the pi mode : a factor of 4 exists between the field amplitude in the highest field and lowest field cells

These measurements have been repeated upon arrival of the cavity at Saclay. These new measurements exhibit very similar results owing to the fact that temperature may have been different for the two different series of data. Table 1 displays the fundamental passband frequencies.

mode	Measured frequency @300K @ Saclay [MHz]	Measured Q0 @300K @ Saclay	Measured frequency @300K @ Accel [MHz]
Pi/5	691.450000	7350	691.450000
2 Pi/5	693.495312	7460	693.484
3 Pi/5	696.007813	7480	696.001
4 Pi/5	698.182812	9700	698.156
Pi	**699.770313**	7290	699.752

Table 1: fundamental passband mode frequencies

The corresponding theoretical frequencies are recalled in the next table. The first column corresponds to the standard operating conditions.

mode	Freq. @ 2K after 200 μm etching [MHz]	Freq. @ 300K after 200 μm etching [MHz]	Freq. @ 300K, air, after 200 μm etching [MHz]	Freq. @ 300K, air, as delivered [MHz]
Pi/5	696.061	695.045	694.836	695.975
2 Pi/5	698.580	697.560	697.351	697.785
3 Pi/5	701.486	700.462	700.252	701.053
4 Pi/5	703.669	702.642	703.458	703.181
Pi	**704.472**	703.443	704.261	**703.941**

Table2: fundamental band mode theoretical frequencies

The coefficients needed for different temperature and preparation stages are:
the thermal shrinkage of Nb from 300K to 2K which is 0.146%
the effect of changing the dielectric from vacuum to air is taken into account by multiplying the frequency by 0.9997, which produces a change by about -200 kHz
the effect of the chemical etching is mode dependent, but always tends to decrease the resonant frequency
no pressure effects are taken into account in this table

The main conclusion is that the pi mode frequency is 4.171 MHz below its nominal value of 703.941 MHz when measured at room temperature, in air. This discrepancy cannot be explained by the difference in cavity length, which would (for an even distribution of the pi mode) account for a difference of only 300 kHz.

The measured quality factor of the cavity on the pi mode is 7290 at room temperature (theoretical Q is 7420 for $\rho_{Nb} = 15\ 10^{-8}\ \Omega.m$)

Field distribution on the Pi mode

A bead-pull measurement has been carried out to obtain the electric field distribution in the cavity. The setup is represented in figure 2. The perturbing object is a metallic cylinder, which is 5 mm in length, 2 mm in diameter.

Figure 2: bead-pull setup on the cavity tuning bench

The field measurement is shown in figure 3. The field distribution is uneven, the ratio between the field in the first and forth cell is 3.5.

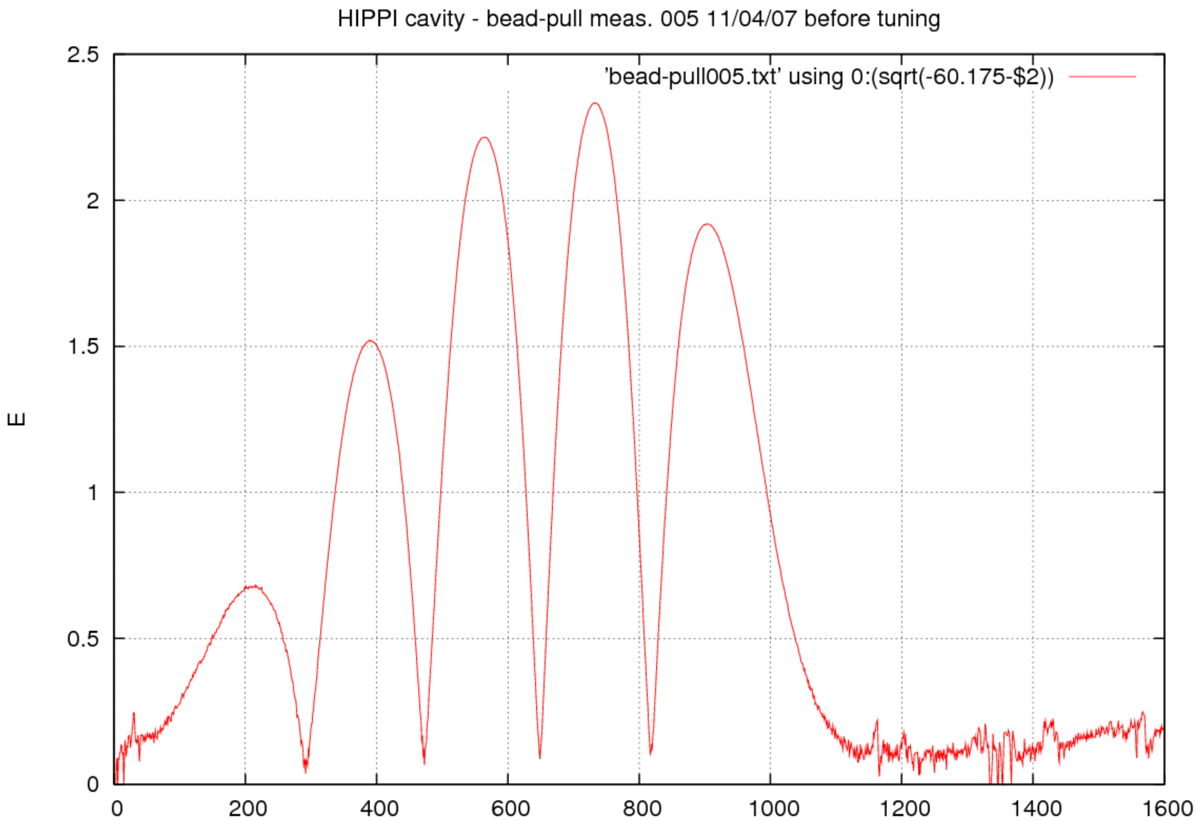

Figure 3 : Measured electric field distribution in the cavity

Next measurements

The tuning of the cavity will start in May 07, upon arrival of the new parts of the tuning bench compatible with the 10mm holes of the stiffening rings.

Once the field flatness and cavity frequency are correctly tuned, 150 microns of the cavity inner face will be removed by chemical polishing with FNP 1-1-2 acid mixture. Then the cavity is rinsed with ultra-pure water and heat-treated at 650 °C for 24 hours (June 07).

New RF measurements have to be done in order to insure that no degradation occurred during the previous preparation steps. After the field profile and the mode frequencies of the fundamental band have been checked, the cavity will go through the last preparation steps : 20 microns chemical polishing and high pressure rinsing.

The cavity is then ready to be equipped with RF antennas in clean room and to be tested at cryogenic temperature in vertical cryostat (summer 07).

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