Results of SC proton cavity tests (B = 1 and B = 0.65)

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19 June 2014

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project EuCARD, grant agreement no. 227579.

This work is part of EuCARD Work Package **10: SC RF technology for higher intensity proton accelerators and higher energy electron linacs**.

Grant Agreement No: 227579

EuCARD

European Coordination for Accelerator Research and Development

Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures,
Combination of Collaborative Project and Coordination and Support Action

DELIVERABLE REPORT

RESULTS OF SC PROTON CAVITY TESTS (BETA=1 AND BETA=0.65)

DELIVERABLE: D10.2.1

Document identifier:	EuCARD-Del-D10-2-1.docx
Due date of deliverable:	End of Month 52 (July 2013)
Report release date:	08/10/2013
Work package:	WP10: Superconducting RF technologies for higher intensity proton accelerators & higher energy electron linacs
Lead beneficiary:	CEA
Document status:	Final

Abstract:

The two superconducting cavities were carefully designed for challenging performance. They were fabricated in industry with intermediate tests and specialized processing in CEA and CNRS. The results are promising, except for a degradation of the field flatness of the low velocity cavity, after electron-beam welding. This might reduce the accelerating gradient. Due to delays in manufacturing, the final performance tests will be carried out in the coming months.

The European Coordination for Accelerator Research and Development (EuCARD) is a project co-funded by the European Commission in its 7th Framework Programme under the Grant Agreement no 227579. EuCARD began in April 2009 and will run for 4 years.

Delivery Slip

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Executive Summary

This workpackage consists in the development of two superconducting elliptical cavities compatible with the high energy section of the SPL R&D project at CERN.

The first cavity (704 MHz, 5 cells, beta=1) has been designed by CEA Saclay and fabricated by Zanon in Italy. CEA participated closely in the manufacturing follow up with the objective to obtain the correct resonant frequency and accelerating field profile. The cavity has been delivered to CEA where the fine tuning and the inner surface preparation have been performed. The RF tuning of the cavity has been successfully achieved. The electropolishing process which allows reaching very smooth surface has been applied for the first time for this kind of cavity. Due to the large volume of the cavity, a problem of hydrogen gas accumulation in the acid circuit has been discovered on the first electropolishing experiment, leading to a 2 months delay for the test of the cavity. After readjusting the electropolishing process parameters, the problem seems to be partially solved. The cavity will then be assembled in clean room and tested at CEA at cold temperature in the next three weeks.

The second cavity (704 MHz, 5 cells, beta=0.65) has been designed by IPN Orsay and fabricated by RI in Germany. IPN also worked closely with RI to reach the target resonant frequency during the cavity fabrication. When received at IPN Orsay, the field profile of the cavity has been very well improved after few iterations of tuning. Standard BCP chemical etching has been carried out at IPN in order to obtain a smooth inner surface. The cavity has been sent back to RI for helium vessel welding and final acceptance. Additional measurements after delivery at IPN showed a degradation of the electric field profile. This is probably due to overheating of some cavity parts during the helium vessel welding operation. The next operation will be the clean room assembly and the test in vertical cryostat at CEA right after with the beta=1 SPL cavity test.

1. PART I MANUFACTURING FOLLOW-UP AND SURFACE PREPARATION OF A 704 MHZ BETA=1 SPL-TYPE SUPERCONDUCTING ELLIPTICAL CAVITY AT CEA SACLAY

2. INTRODUCTION

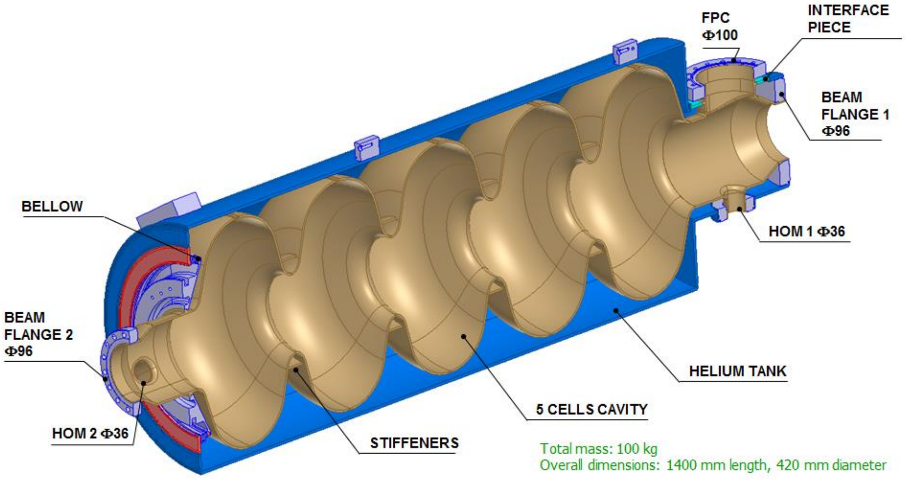
In the frame of the European EUCARD project, CEA Saclay is developing a high gradient 704 MHz superconducting prototype cavity. This project follows up from previous development at CEA at this frequency [1,2] and prepares for future R&D for the ESS project where two families of elliptical cavities are foreseen in large quantities [3,4,5]

This cavity aims at reaching a challenging accelerating gradient of 25 MV/m. Its design is compatible with the $\beta = 1$ section of the SPL project at CERN. The cavity has 5 elliptical cells made in bulk niobium of 4.3 mm thickness and is scaled from the TESLA/DESY 1.3 GHz cavity. It is equipped with a fundamental mode coupler port and two HOM ports. The beam tubes have conical taper shape allowing the use of similar XFEL type flanges and sealing configurations. The liquid helium vessel is made of titanium. It is an alternative design to the SPL cavity developed by CERN where stainless steel is adopted [6]. The main characteristics and a 3D cut-view of the cavity are given in Table 1 and Figure 1.

More details about the RF and mechanical design of the cavity are also given in [7].

Table 1: SPL-Eucard cavity specifications

Parameters	**Value**	**Units**
Frequency	704.42	MHz
Number of gaps (Ngaps)	5	-
Beta	1	-
Eacc	25	MV/m
Epeak/Eacc	1.99	-
Bpeak/Eacc	4.20	mT/(MV/m)
Lacc (Ngaps.βλ/2)	1.0647	m
r/Q	566	Ohms
G	270	Ohms
Operation temperature	2	K
Q_0 at 2K (R_{BCS}=3.2nΩ)	$8.4.10^{10}$	-
Lorentz force detuning K_L	1	Hz/(MV/m)²



Total mass: 100 kg
Overall dimensions: 1400 mm length, 420 mm diameter

Figure 1: Eucard SPL-type 704 MHz cavity

3. FREQUENCY TUNING DURING FABRICATION

The fabrication contract has been awarded to E. Zanon in February 2012. Intermediate RF measurement campaigns have been organized during the manufacturing of the cavity. These measurements have been performed on half-cells before iris welding and on dumbbells and end group cells before equator welding.

1.1. RF FREQUENCY MEASUREMENT TOOLING

The principle of the frequency measurement system proposed by E. Zanon is based on the INFN tooling developed for the Trasco cavity. As shown in Figure 2, the tooling is composed of two disks that close the cavity volume. On the equator side, the disk is maintained by a ring and pressed manually by 12 screws. To ensure good electrical contacts, thin slices are machined at the disk extremities. Two coaxial antennas are placed at the center of each plate. To minimize the perturbation of the resonant frequency, the antenna lengths are adjusted to reduce as much as possible the coupling factor. An amplifier is used to increase to signal to noise ratio. The frequency is measured when the quality factor Q_0 reaches 6000 or above.

Five configurations of disks have been experimented with different thickness, flatness and material (Niobium and Copper). The frequency precision measurement has been improved from 1.4 MHz to less than 100 kHz.

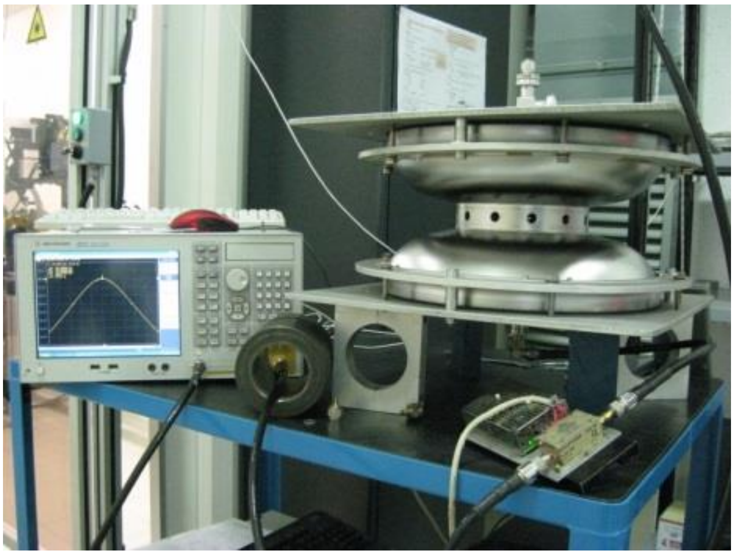


Figure 2: RF measurement set-up of cavity dumbbell

1.2. RF TRIMMING

After deep drawing, extra-lengths of about 2 mm are left intentionally at the equator of each element. It allows a fine adjustment of the resonant frequency by successive machining operations (trimming). Two trimming steps have been performed with removed thickness of about 0.5 mm for each pass. As shown in Figure 3, one of the four dumbbells and the two end cells have reached the target frequency of 703.04 MHz. The frequency of the three other dumbells is lower than expected (702.2 MHz) which stays within the specifications. This is due to the cell deformation during the turning operation which cannot be controlled perfectly.

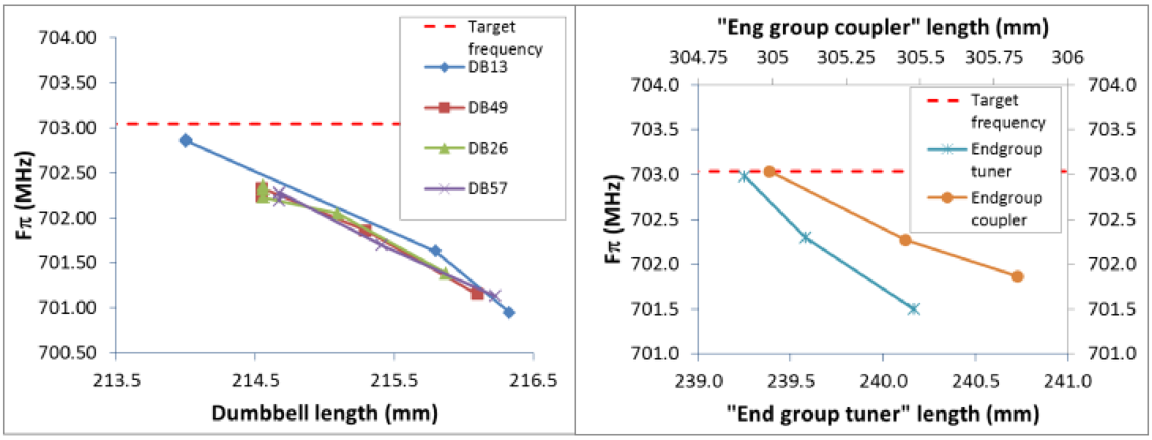


Figure 3: Resonant frequency of each cavity element measured after trimming steps

4. QUALITY CONTROL AND FINAL WELDING

1.3. DIMENSIONAL CONTROL

3D measurements of the inner profile have been carried out on one dumbbell and one end group cell. As shown in Figure 4, the measured shape is well in agreement with the specification. The largest deviation is observed in the iris region and is about 0.5 mm maximum.

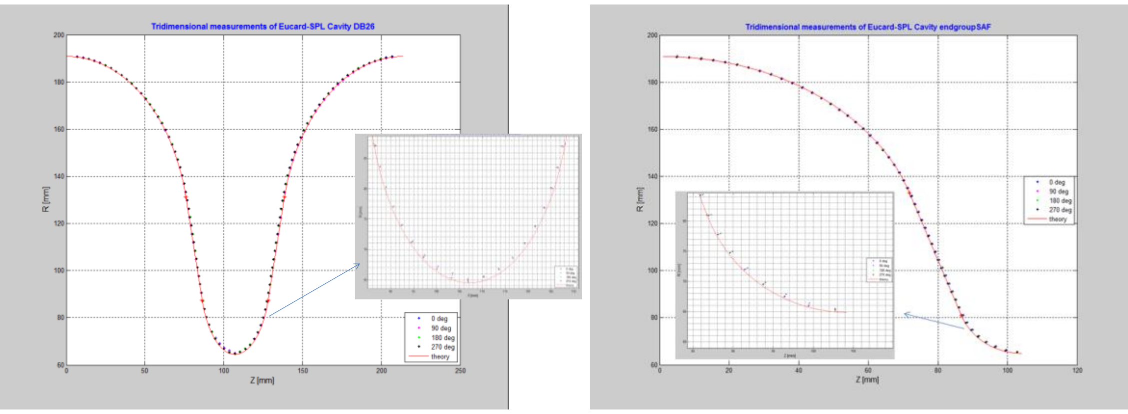


Figure 4: Dimensional control of the inner cavity shape

1.4. EB WELDING AND FIELD PROFILE BEFORE TUNING

The final welding of the cavity has been successfully completed in May 2013. The iris and equator weldings have been carefully inspected. As shown in Figure 5, the welding area is regular and is typically 6 mm width. The full cavity has been delivered at CEA and is shown in Figure 6.

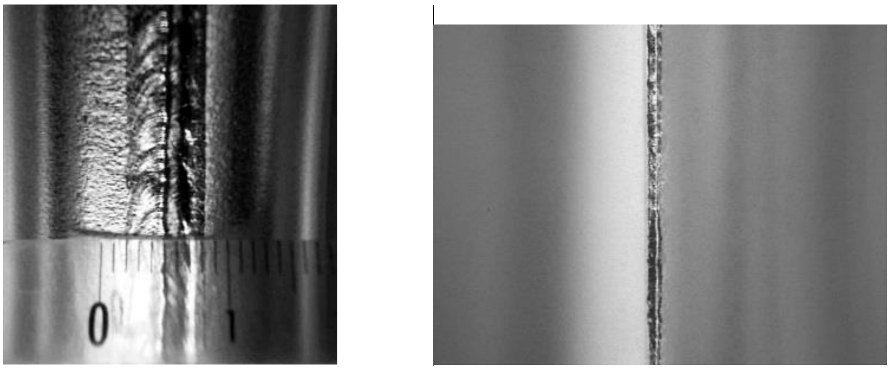


Figure 5: Typical pictures of an iris (left) and equator (right) welding (inner side of the cavity)

Figure 6: Picture of the full cavity after final welding

5. FIELD FLATNESS AND FREQUENCY SPECTRUM

Before final welding, several RF simulations were performed using different longitudinal positions of the dumbbells. The measured frequency of each element is taken into account in the model, as well as the equator welding shrinkage (0.4 mm on each part of the joint). The best combination predicts a field flatness ratio of 89% when assembled. Figure 7 illustrates that the measured on-axis field after the equator welding and before tuning looks similar to the calculated one. The field is lower in the 4th cell and corresponds to the higher frequency dumbbell DB1-3. The measured field flatness ratio is 80 % before tuning which is already quite satisfactory.

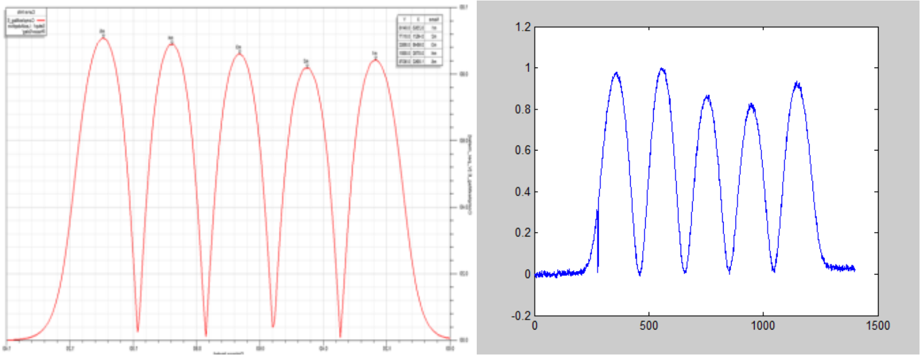


Figure 7: Calculated (left) and measured (right) on-axis E field profile before tuning (arbitrary units in horizontal and vertical axis)

1.5. FREQUENCY SPECTRUM

To obtain an accelerating mode frequency of 704.4 MHz at 2 K and assuming 200 µm chemical removals, the target frequency at 293 K after fabrication is 703.837 MHz.

The measured first band-pass is given in Table 2. The π-mode frequency is 703.707 MHz which is 130 kHz below the target frequency. The measured frequency spectrum is compared with the calculated one using the same model employed to predict the on-axis field profile. The difference is smaller than 0.2 MHz for the π-mode and stays below 0.5 MHz for the full spectrum.

Table 2: Frequency spectrum of the Eucard cavity before field flatness tuning

Mode	F (MHz) Modeled	F (MHz) Measured	ΔF (MHz)
p/5	691.705	691.281	0.424
2p/5	694.925	694.695	0.23
3p/5	698.995	698.836	0.159
4p/5	702.265	702.411	-0.146
π	**703.53**	**703.707**	**-0.177**

1.6. FIELD FLATNESS TUNING

The cavity has been installed on the newly developed tuning system in order to improve the field flatness along the cavity.

After few iterations, the field flatness ratio has been improved from 80% to 92%. The π-mode frequency is now 703.755 MHz. The final field profile before any chemical treatment is shown in Figure 8.

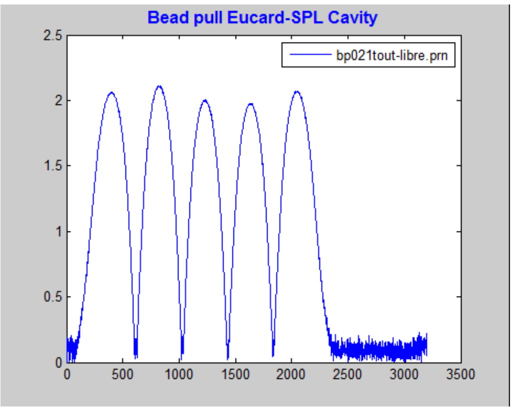


Figure 8: Electric field profile after tuning (arbitrary units in horizontal and vertical axis)

6. ELECTROPOLISHING

The vertical electropolishing (VEP) process has been chosen for both bulk removal and final polishing. This critical operation benefits from previous R&D performed on single cell and 9-cell ILC type cavities [8,9]. An aluminum cathode with a constant diameter of 70 mm along the cavity has been chosen. The electrolyte is composed of a H_2SO_4 (95%) – HF (40%) mix with a 9:1 proportion. The applied voltage has been set to 7.5 V which corresponds to the start of the diffusion region. At this potential value, the current varies from 170 to 190 A depending on the acid temperature in the cavity (14° to 16°C).

A picture of the cavity installed in the VEP set-up is shown in Figure 9.

Figure 9: 704 MHz 5-cell cavity installed in the vertical electropolishing set-up

Three passes of electropolishing have been performed with average removed thickness of respectively 10, 60 and 40 µm. Between each step, the quality surface, the field profile and the niobium thickness have been controlled. The second electropolishing step of 60 µm during 7 hours revealed a quality surface problem at the top of the cavity (tuner side). The surface roughness was clearly deteriorated in small areas and the removal rate was locally 5 times higher than the average rate in the cavity. This could be explained by a difficult evacuation of the Hydrogen gas produced at the cathode during the reaction. Some retention areas in the acid circuit were also discovered after the treatment. To solve this problem, the third electropolishing of 40 µm have performed with successive ON/OFF cycles on the applied voltage while keeping the acid circulation in the cavity. During this 3rd EPV, the cavity has also been drained four times in order to facilitate the evacuation of the Hydrogen remaining gas. Figure 10 shows the amount of Niobium removed after each step of electropolishing along the cavity wall. The total Niobium removed (red curve) is 115 µm and varies between 80 µm and 250 µm.

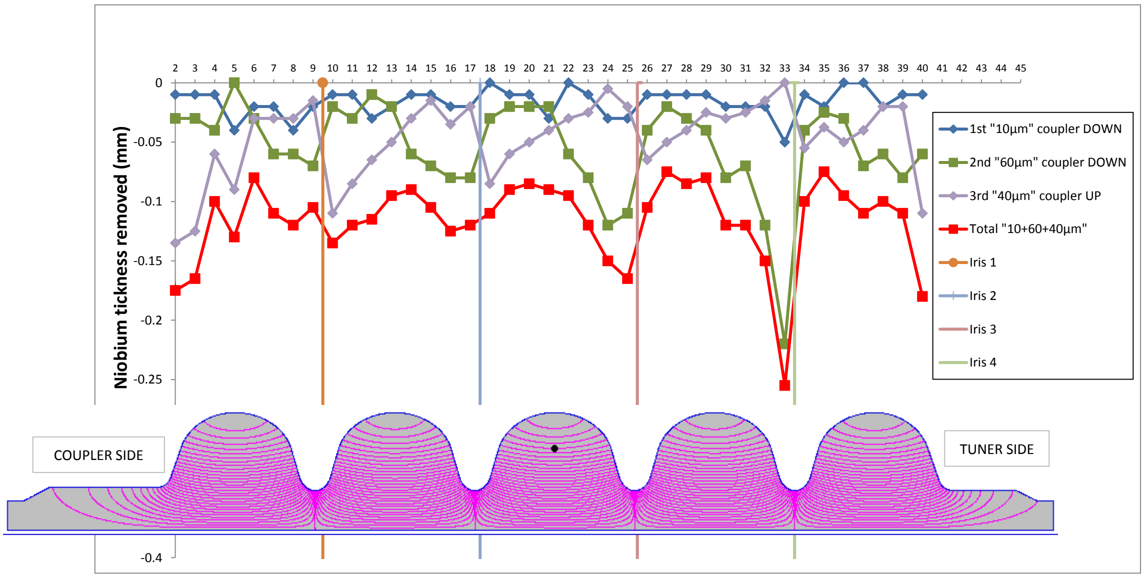


Figure 10: Measurement of Niobium thickness removed after successive electropolishing passes

7. CONCLUSION AND OUTLOOK

To conclude, this project allowed us to improve significantly the technical follow-up and in particular the RF tuning procedure of 704 MHz elliptical cavities during manufacturing. The electropolishing process has also been applied for the first time with very promising preliminary results. A final chemical treatment coupled to a clean room assembly with High Pressure Rinsing will be performed in the next two weeks. As shown in Figure 11, the cavity will then be mounted in a vertical cryostat at CEA Saclay to measure the accelerating gradient limit and the quality factor Q_0 at 4K and 2K. A detailed schedule of the remaining actions is presented in Figure 12.

Since this SPL type cavity is a scaled model of the FLASH/XFEL cavity and is very similar to the future ESS elliptical cavity design, a direct comparison of the performances will be possible. Further developments could be considered in the near future for elliptical bulk niobium cavities with more collaboration between ESS, CERN, DESY and European industrial partners. The objective would be to push further the accelerating gradient limit and to optimize the manufacturing cost and delay.

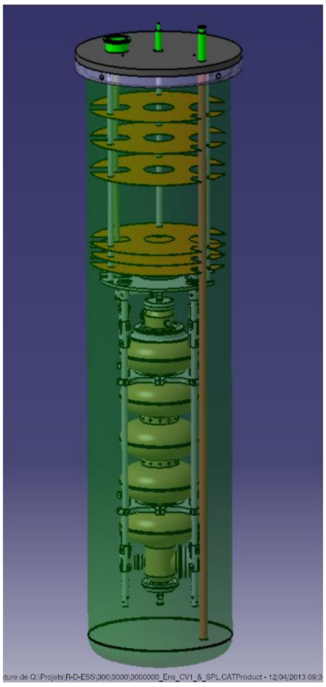


Figure 11: Set-up of the vertical test of the Eucard/SPL cavity

		October 2013				
		W40	W41	W42	W43	W44
1	4rd chemical treatment (40 um, coupler port UP)	🟦				
2	Clean room assembly with High Pressure Rinsing		🟦			
3	Mounting of the cavity on the vertical insert and leak test			🟦		
4	Preparation of the cool down process			🟦		
5	High gradient test of the cavity at 2K				🟦	
6	Test report					▲

Figure 12: Detailed schedule for the test of the SPL cavity

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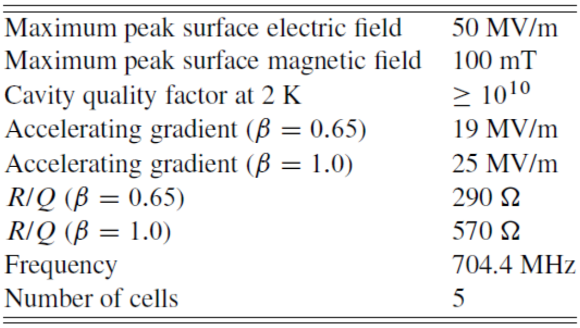
9. PART II DEVELOPMENT OF A BETA 0.65, 704 MHZ, 5-CELL ELLIPTICAL CAVITY FOR SPL

10. INTRODUCTION

Within the framework of EuCARD, IPN Orsay has designed a beta 0.65, 704 MHz, 5-cell elliptical cavity for the SPL project at CERN. The RF and mechanical simulations of the cavity were carried out in order to fulfill the requirements of the SPL linac, listed in Table 1. After the completion of these studies, IPN Orsay had followed-up the fabrication of the assembly “cavity + helium vessel” and started recently, the preparation of the cavity for the purpose of the test at 2K in vertical cryostat.

Table 1: SPL superconducting linac design parameters [1]



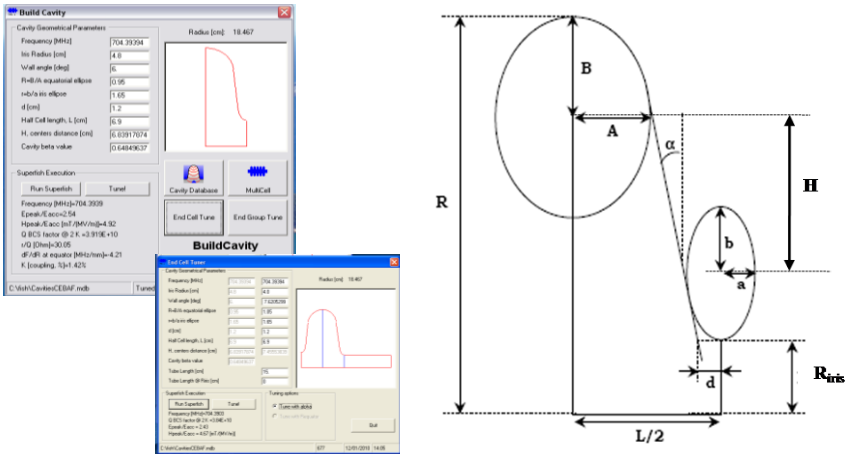
Maximum peak surface electric field	50 MV/m
Maximum peak surface magnetic field	100 mT
Cavity quality factor at 2 K	$\geq 10^{10}$
Accelerating gradient ($\beta = 0.65$)	19 MV/m
Accelerating gradient ($\beta = 1.0$)	25 MV/m
R/Q ($\beta = 0.65$)	290 Ω
R/Q ($\beta = 1.0$)	570 Ω
Frequency	704.4 MHz
Number of cells	5

11. CAVITY DESIGN

1.7. RF STUDIES

In Table 1, by taking into account the values of peak surface fields and the challenging accelerating gradient of 19 MV/m, one can deduce the Epk/Eacc and Bpk/Eacc ratios: respectively, 2.6 and 5.2 mT/(MV/m). Because of the high accelerating gradient, both peak surface fields might be rather high if one does not take care of the design. Then, the RF design of the cavity has been carried out by using 2D and also 3D codes (Superfish and Build cavity [2] and Microwave Studio [3]).

We first optimized the shape of the cells with the Superfish and Build Cavity 2D codes (see Figure 1). At this stage of the study, the cavity did not include any RF coupler nor HOM and Pick-up ports.



Build Cavity

Cavity Geometrical Parameters

Frequency [MHz]: 704.39394
Iris Radius [cm]: 4.8
Wall angle [deg]: 6.
R=B/A equatorial ellipse: 0.95
r=b/a iris ellipse: 1.65
d [cm]: 1.2
Half Cell length, L [cm]: 6.9
H, centers distance [cm]: 6.83917874
Cavity beta value: 0.64849637

Radius [cm]: 18.467

Superfish Execution

Frequency [MHz]=704.3939
Epeak/Eacc=2.54
Hpeak/Eacc [mT/(MV/m)]=4.92
Q BCS factor @ 2 K =3.919E+10
r/Q [Ohm]=30.05
dF/dR at equator [MHz/mm]=4.21
K [coupling, %]=1.42%

C:\Vish\CavitiesCEBAF.mdb

Figure 1: Build Cavity user interface (left) and all parameters used for optimization (right)

After several runs, we obtained good RF parameters (see Table 2) and very good field flatness (Figure 2).

Table 2: RF parameters after 2D optimization

Epk/Eacc	2.5
Bpk/Eacc (mT/MV/m)	4.9
R/Q @beta=0.65 (Ohm)	299
Frequency (MHz)	704.407
Qo @2K with $R_{residual}$=2 nΩ	3.9 10^{10}

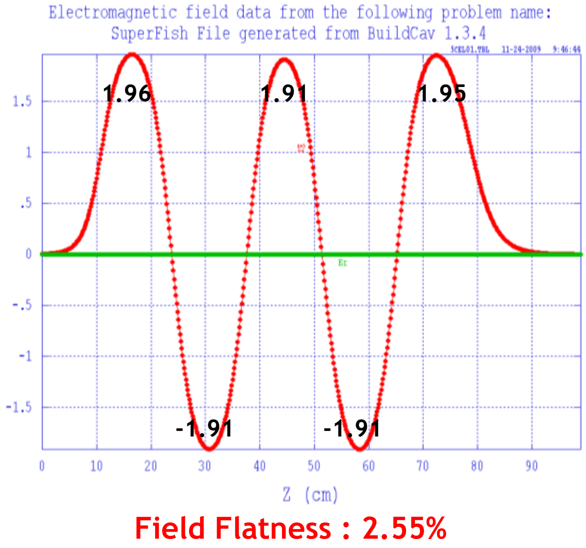
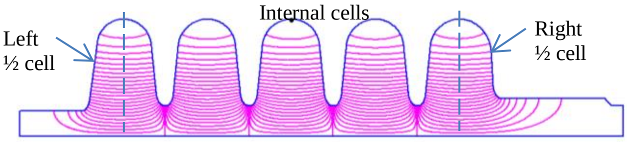


Figure 2: Field flatness of the electrical field along beam axis with the optimized parameters in Table 3.

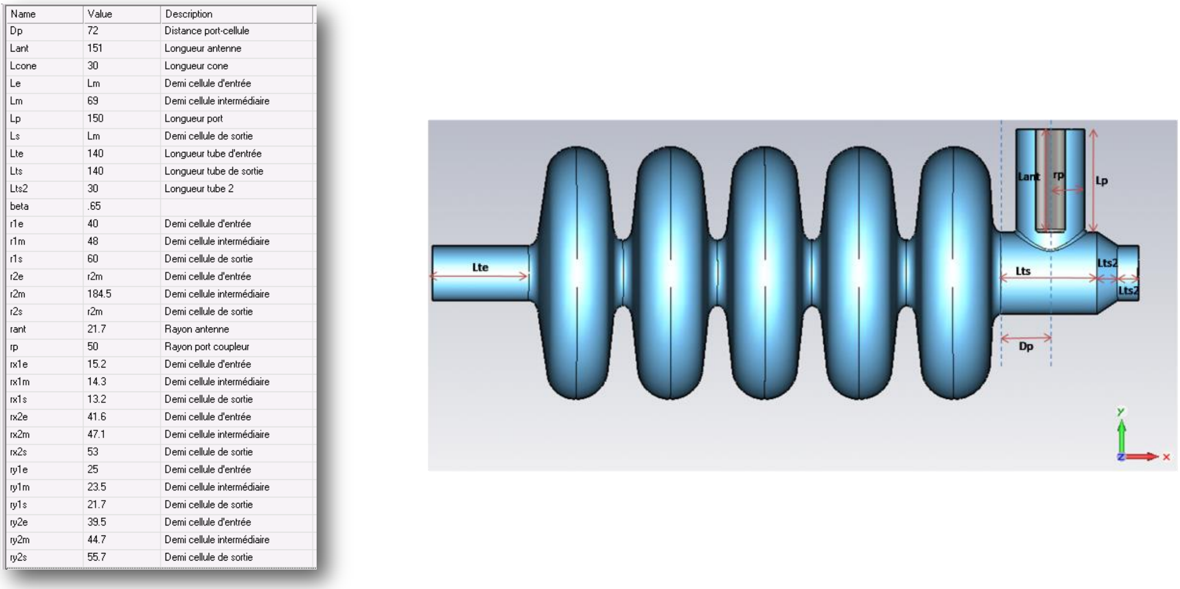
After completion of the 2D optimization (see final parameters in Table 3), we started the second step of the study by integrating the RF coupler port and the HOM and pick-up ports. We used Microwave Studio module of the 3D CST Studio Suite code.

Table 3: Final optimized parameters with 2D codes


Left
½ cell
Internal cells
Right
½ cell

Parameters (mm)	Left ½ Cell	Internal cells	Right ½ cell
R	184.67	184.67	184.67
L	69	69	69
Riris	40	48	60
A	41.62	47.10	53.02
B	39.53	44.75	55.67
a	15.15	14.26	13.17
b	25	23.53	21.73
L_tube	150		170

More than 30 parameters have been used (Figure 3) to carry out the last optimizations of the cavity geometry. Integration of the RF coupler port has been done in order to get the right external coupling factor $Q_{ext}=10^6$ (corresponding to a 4-mm antenna penetration). Such integration perturbed the frequency and the electrical field profile. So, in order to get the expected Q_{ext} value, a cell-to-cell coupling around 1.5% and a good field flatness, we needed to modify again the left and right ½ cells and the beam tubes aperture. Finally, the optimization of the geometry gave good RF parameters which are summarized in Table 4.



Name	Value	Description
Dp	72	Distance port-cellule
Lant	151	Longueur antenne
Lcone	30	Longueur cone
Le	Lm	Demi cellule d'entrée
Lm	69	Demi cellule intermédiaire
Lp	150	Longueur port
Ls	Lm	Demi cellule de sortie
Lte	140	Longueur tube d'entrée
Lts	140	Longueur tube de sortie
Lts2	30	Longueur tube 2
beta	.65	
r1e	40	Demi cellule d'entrée
r1m	48	Demi cellule intermédiaire
r1s	60	Demi cellule de sortie
r2e	r2m	Demi cellule d'entrée
r2m	184.5	Demi cellule intermédiaire
r2s	r2m	Demi cellule de sortie
rant	21.7	Rayon antenne
rp	50	Rayon port coupleur
rx1e	15.2	Demi cellule d'entrée
rx1m	14.3	Demi cellule intermédiaire
rx1s	13.2	Demi cellule de sortie
rx2e	41.6	Demi cellule d'entrée
rx2m	47.1	Demi cellule intermédiaire
rx2s	53	Demi cellule de sortie
ry1e	25	Demi cellule d'entrée
ry1m	23.5	Demi cellule intermédiaire
ry1s	21.7	Demi cellule de sortie
ry2e	39.5	Demi cellule d'entrée
ry2m	44.7	Demi cellule intermédiaire
ry2s	55.7	Demi cellule de sortie

Figure 3: (Table on the left) all parameters list and (Cavity model on the right) parameters used for RF coupler port integration.

Table 4: Final RF parameters after 3D optimization

Epk/Eacc	2.63
Bpk/Eacc (mT/MV/m)	5.12
Vacc @beta=0.65 & 1 Joule	1.11
Cell-to-cell coupling (%)	1.45
G (Ohm)	197
R/Q @beta=0.65 (Ohm)	275
Frequency (MHz)	704.4

Qo @2K with $R_{residual}$=2 nΩ	3.9 10^{10}

1.8. MECHANICAL STUDIES

In parallel to the RF studies, exhaustive simulations have been performed to optimize the mechanical behavior of the cavity under static vacuum load and to minimize its Lorentz forces detuning factor. It has been shown (see Figure 4) that cavity stresses for a 1.5 bar external load, remained below 50 MPa (=Yield strength limit of the Niobium @300K) with 4-mm thick walls and that, only one ring between each cell (localized at 94 mm from the axis) was necessary to get a Lorentz forces detuning factor around -1.6 Hz/(MV/m)².

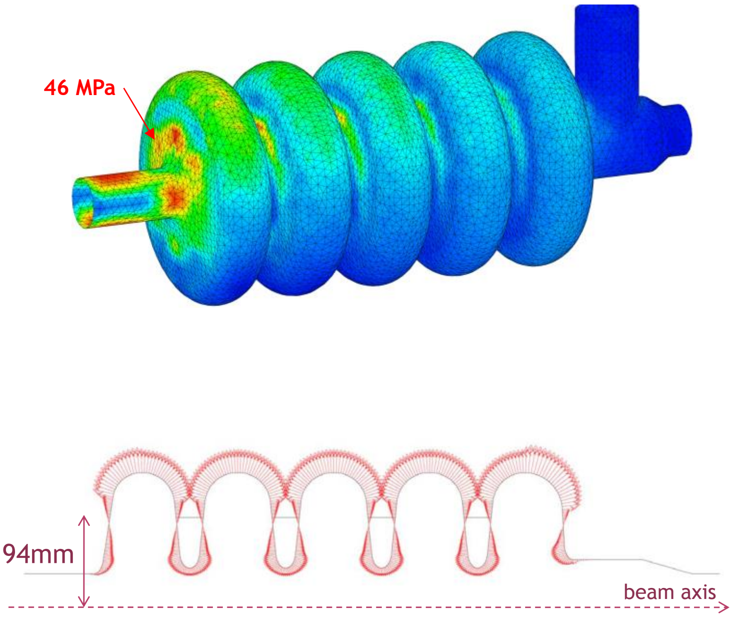


Figure 4: (Upper) Von Misses stresses for 1.5 bar and (Lower) cavity walls deformation due to Lorentz forces

We have also calculated two other important values:

1/ Frequency shift due to thermal contraction between 300K and 2K: +1 MHz

2/ Frequency shift due to chemical etching: -0.4 MHz for 100µm

1.9. FINAL CAVITY DESIGN

Finally, in collaboration with CEA/Saclay, we studied the integration of the helium vessel (made of Titanium) and the main interfaces: the “XFEL-type” Nb/Ti flanges of the beam tubes, the Stainless Steel flange of the RF coupler port and the Titanium flange of the tuning system. Figure 5 shows the final design of the assembly “cavity + helium vessel”.

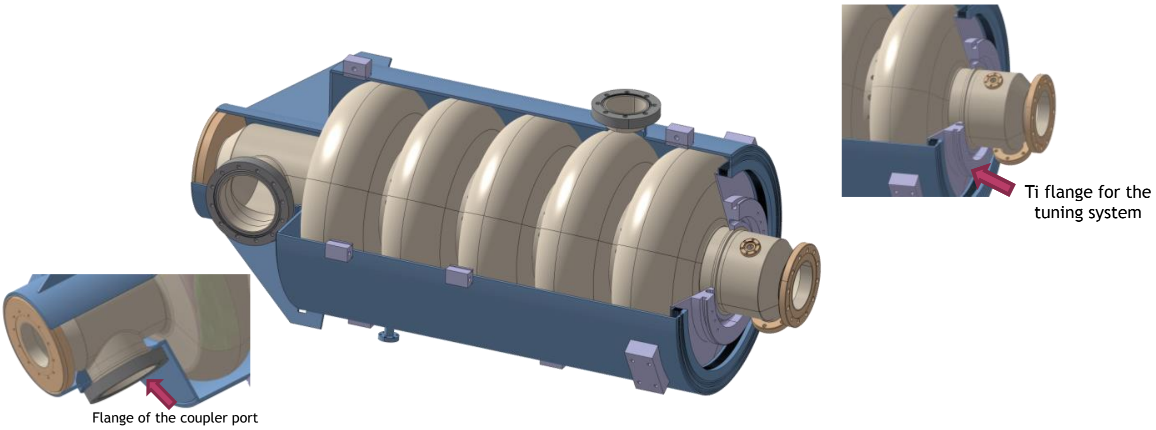


Figure 5: 3D model of the cavity equipped with its helium vessel

12. CAVITY FABRICATION

1.10. NIOBIUM

We ordered the following material list to Tokyodenkai (all Niobium pieces with high RRR specifications):

1/ Sheets: 4.2-mm thick for the cells, 3.2-mm for the end-groups and 2-mm for the HOM/pick-up ports

2/ Two thick rings for the Niobium-to-Titanium transitions of the RF coupler and tuning system flanges (Figure 6).

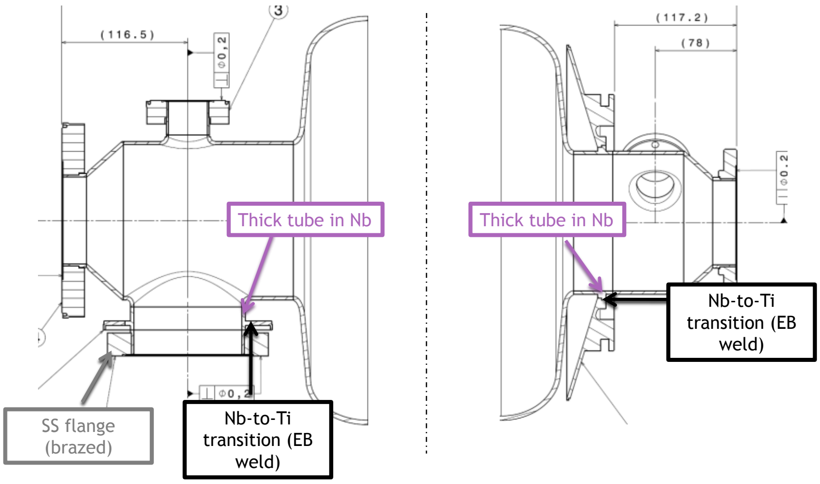


Figure 6: Sketches of the end-groups with the Nb-to-Ti transitions

1.11. FABRICATION

Research Instruments (RI) has been awarded in October 2011 of the fabrication contract. After technical discussions, IPN Orsay approved the manufacturing file officially in March 2012. The lead time was foreseen not to be more than 13 months from the contract signature (i.e. delivery of the complete "cavity + helium vessel" assembly in November 2012) but, because of many reasons, mainly linked to underestimation of the design work and high work load of the manufacturer's workshop, the cavity equipped with its helium vessel was delivered June 18, 2013!

1.12. DIMENSIONAL CONTROL

One key point (with the RF tuning by trimming, see next §) was the 3D dimensional control of each half-cell after spinning and each dumb-bell after welding. More than 200 points were measured for each half cell and deviations from the tolerances were measured on 4 profiles for each dumb-bell (see Figure 7). Most of the dumb-bells satisfied the required tolerance: +/- 0.5 mm from the theoretical profile.

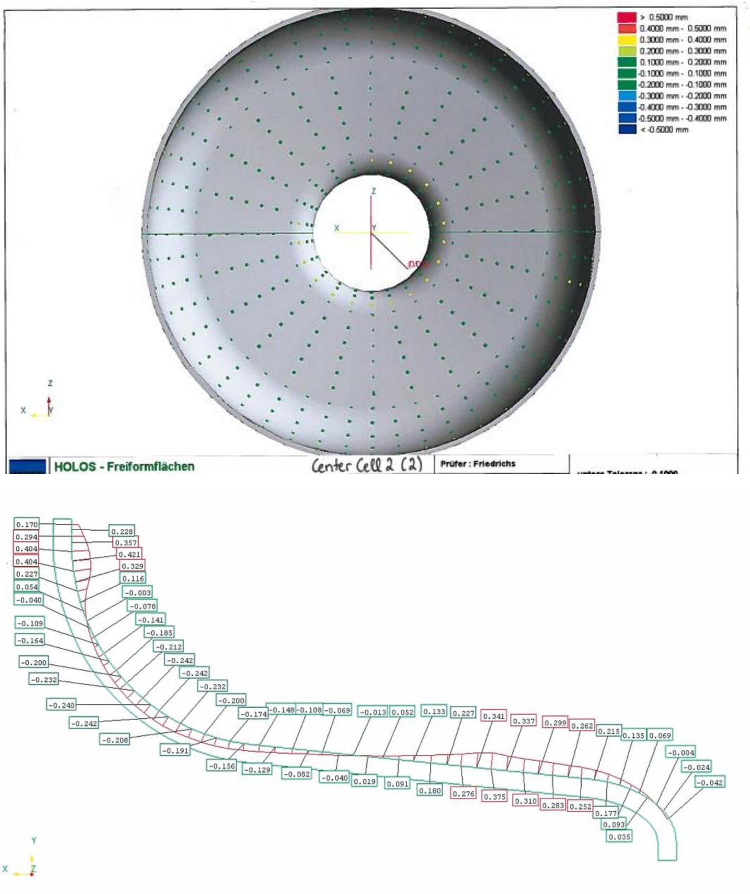


Figure 7: (upper) 3D control of one half-cell and (lower) profile measurement of a dumb-bell.

1.13. RF TUNING BY TRIMMING

As for the beta=1 cavity, a frequency control of each dumb-bells and the 2 end-groups has been done after the welding steps, followed by a trimming process in order to match the frequency at 300K: 703.591 MHz. RI used a fully automated RF frequency measurement bench, developed for the XFEL cavities. Three trimming passes were needed to get the right frequency. This fabrication step was not an issue.

1.14. FINAL WELDING OF THE BARE CAVITY

After the final welding of the 2 end-groups and a leak tightness test, the cavity (without its helium vessel) was delivered to IPN Orsay in March 2013 (Figure 7) for chemistry etching and field flatness tuning. After these two operations, the cavity was sent back to RI for the last step: the welding of the Titanium helium vessel.

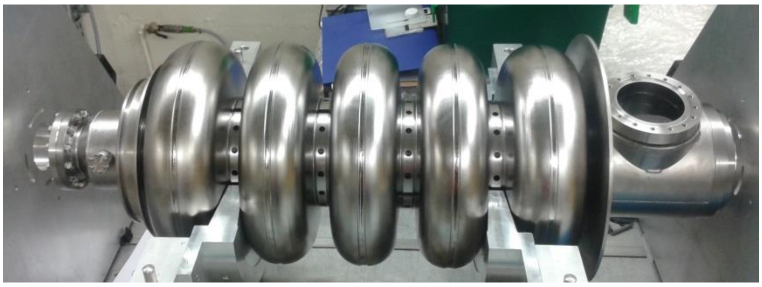


Figure 8: Bare cavity delivered at IPN Orsay (March 2013)

13. CAVITY PREPARATION

After the delivery, we controlled the frequency and the leak tightness of the cavity in order to check if any damages could have been done during the transport. We found the same values as RI before shipment.

1.15. CHEMICAL ETCHING

Therefore, the cavity was prepared for BCP chemistry. The goal was to remove 200 µm. As illustrated in figure 9, the chemistry process was done in two passes by rotating the cavity after 200 minutes (based on a 0.5 µm/min rate) in order to obtain a homogenous etching of the surface. We measured the thickness on 1 point on each half-cell close to the equator to control the removed material (Table 5). NB: thickness of the welding seam of the equator was measured between 1.8 and 2 mm before etching.

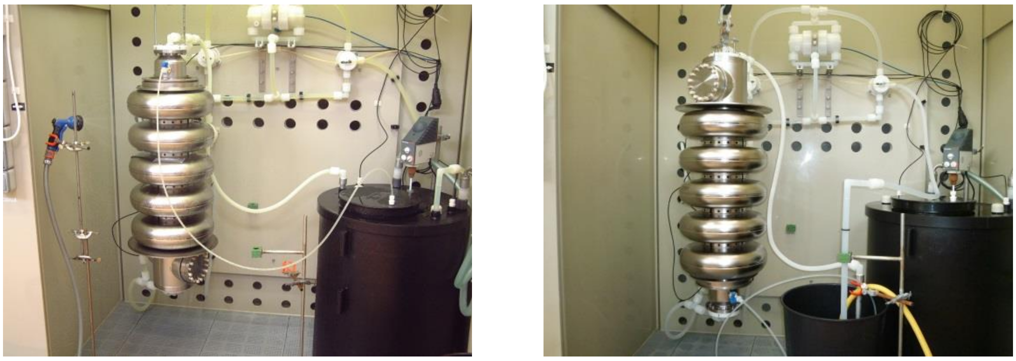


Figure 9: (left) First chemistry process and (right) second one after 180° rotation of the cavity

Table 5: Thickness measurements during the chemistry process

	Half-Cell n°	**Before etching**	**After 1st pass**		**After 2nd pass**		
		Thickness (mm)	**Thickness (mm)**	**Removal (µm)**	**Thickness (mm)**	**Removal (µm)**	**Total removal (µm)**
	1	3.914	3.816	-98	3.746	-70	-168
	2	3.865	3.790	-75	3.720	-70	-145
	3	3.858	3.777	-81	3.728	-49	-130
	4	3.824	3.780	-44	3.675	-105	-149
	5	3.970	3.850	-120	3.818	-32	-152
	6	3.720	3.664	-56	3.600	-64	-120
	7	3.770	3.714	-56	3.605	-109	-165
	8	3.680	3.540	-140	3.510	-30	-170
	9	3.540	3.460	-80	3.380	-80	-160
	10	3.610	3.500	-110	3.460	-40	-150

After 2 times 200 minutes, an average value of 150 µm was removed (variation between 120 and 170 µm) at the equator region. It corresponds to an etching rate of 0.375 µm/min. The removed Niobium of the total inner surface was deduced by weight difference before and after etching. We found that 2.648 kg was removed, corresponding to an average value of 207 µm. This value and the data from the Niobium removed at the equator region indicate that the Niobium removed from the iris and the beam tubes surfaces must be higher than 200µm.

After the rinsing and the drying of the cavity, we measured the frequency of the fundamental mode in order to compare it with the predicted value. We calculated -0.4 MHz for 100µm removed from the surface. From the measurements of thicknesses, the frequency shift should have varied from -600 kHz (corresponding to 150 µm) to -820 kHz (corresponding to 207 µm). We measured -696 kHz.

1.16. FIELD FLATNESS TUNING PROCESS

After the chemistry process, the cavity has been installed on a refurbished tuning bench from CEA (Figure 10) in order to improve the field flatness along the cavity axis. First measurement showed a field flatness of about 48% (Figure 11). The main field distortion was located on the RF coupler port end-group side. The field flatness is defined as: $N \cdot \frac{E_{cellmax} - E_{cellmin}}{\sum_N E_{cell}} \cdot 100$. So, 0% means perfect field flatness. Our goal was to get better than 5%.

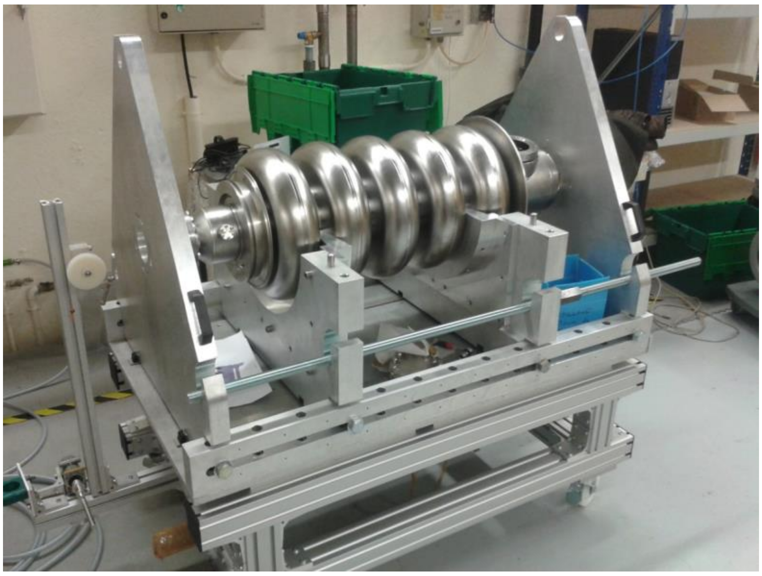


Figure 10: Bare cavity installed on the tuning test bench.

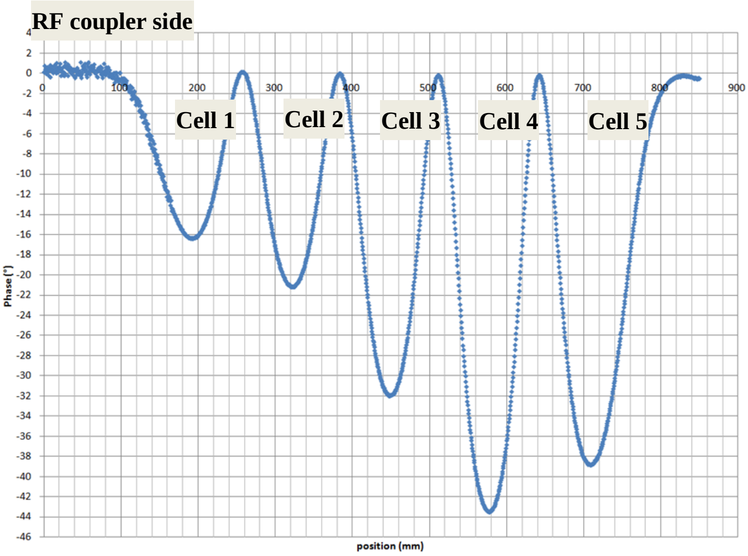


Figure 11: Electrical field profile along beam axis of $TM_{010\text{-}\pi}$ mode after etching and before tuning.

We only deformed 3 cells in order to improve the field flatness to 5.7% (Figure 12). Cell 1 and 2 have been stretched of about, respectively, 2.5 mm and 1.5 mm, whereas cell 4 has been squeezed of about 1.5 mm.

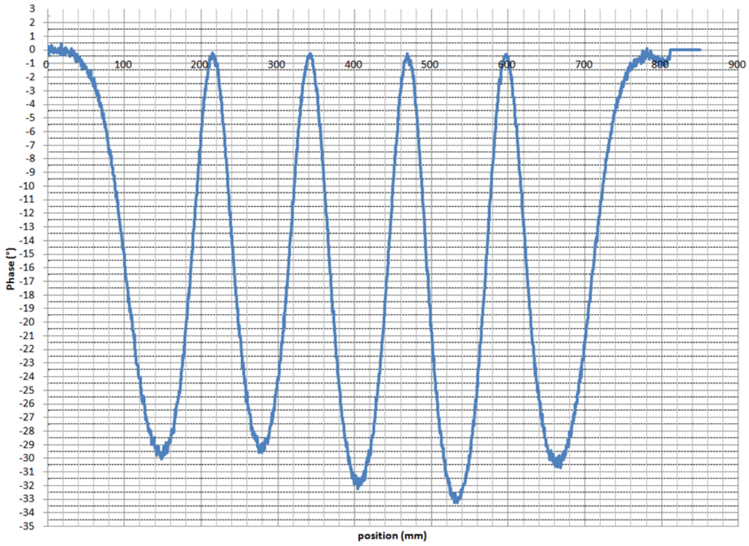


Figure 12: Electrical field profile along beam axis of TM$_{010-\pi}$ mode after tuning

After the field flatness process, the cavity has been sent back to RI for the welding of the Titanium helium vessel. Final delivery of the "cavity + helium vessel" was done end of June 2013. We measured again the field flatness and we observed a severe degradation of the field flatness around 38%. We suspected that the heat load during the EB welding of the helium vessel parts has released the stresses located inside the Niobium cells (due to spinning). Because the helium vessel is welded around the cavity, we decided not to do any new deformation on the cavity.

14. OUTLOOK FOR PART II

The cavity is now ready for clean room preparation (High Pressure Rinsing, antenna and valve assembly) but, because of increasing activity overload inside the clean room, we are still waiting for. Nevertheless, the plan is to prepare the cavity in time to be tested in the vertical cryostat of the CEA/Saclay after the test of the beta=1.

15. REFERENCES

[1] F. Gerick, Conceptual design of the SPL II, CERN-2006-006

[2] Poisson Superfish 2D code (http://laacg1.lanl.gov/laacg/services/download_sf.phtml) and Build Cavity code (http://wwwsrf.mi.infn.it/Members/pierini/resolveuid/6bbdb0733fa6052304784fa9c3102ad8)

[3] CST Studio Suite, www.cst.com