VERTICAL TEST RESULTS ON ESS MEDIUM AND HIGH BETA ELLIPTICAL CAVITY PROTOTYPES EQUIPPED WITH HELIUM TANK

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Abstract
The ESS elliptical superconducting Linac consists of two types of 704.42 MHz cavities, medium and high beta, to accelerate the beam from 216 MeV (spoke cavity Linac) up to the final energy at 2 GeV. The last Linac optimization, called Optimus+[1], has been carried out taking into account the limitations of SRF cavity performance (field emission). The medium and high-beta parts of the Linac are composed of 36 and 84 elliptical cavities, with geometrical beta values of 0.67 and 0.86 respectively [2]. This work presents the latest vertical test results on ESS medium and high beta elliptical cavity prototypes equipped with helium tank. We describe the cavity preparation procedure from buffer chemical polishing to vertical test.

INTRODUCTION

CEA-Saclay is in charge to develop and manufacture 6 medium beta elliptical cavities for the superconducting section of ESS Linac. Three of this cavities are now installed in cryomodule demonstrator [3]. In the next future 5 high beta cavities will also be manufactured and installed (4 of them) into a cryomodule for testing.
At this moment all 6 medium beta cavities has been manufactured, 4 were tested and integrated with helium tank. Figure 1 shows a section of a medium beta cavity equipped with the helium tank.
The remaining 2 cavities will be used to improve preparation procedures.

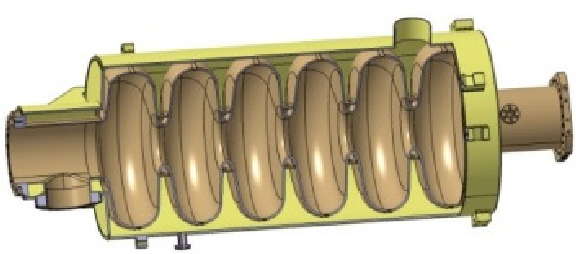

Figure 1: Medium beta elliptical cavity with helium tank, section view.

In Table 1 are shown all the relevant parameters concerning medium beta cavities design and working conditions.

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Table 1: Medium and High Beta Cavity Design Parameters

Parameter	Medium beta	High beta
Frequency [MHz]	704.42	
Accelerating length [mm]	0.855	0.915
# cells	6	5
Operating temperature	2K	
Beta	0.67	0.86
Nominal E_{acc} [MV/m]	16.7	19.9
Q_0 at nominal E_{acc}	$>5x10^9$	
E_{pk}/ E_{acc}	2.36	2.2
B_{pk}/ E_{acc} mT/(MV/m)	4.79	4.3
E_{pk} at nominal E_{acc} [MV/m]	39.4	43.8
G [Ω]	196.63	241
Cell to cell coupling	1.2%	1.8%

CAVITY PREPARATION AND TESTING

All cavities were prepared with the same recipe:
1. 200µm removed by BCP (Bulk removal)
2. Heat treatment (600°C for 10 hours)
3. Helium Tank integration
4. 20µm removed by BCP (with cooling water in the helium tank)

As a result we were able to systematically obtain a residual surface resistance lower than 6nΩ, as shown in figure 2 and summarized in table 2.

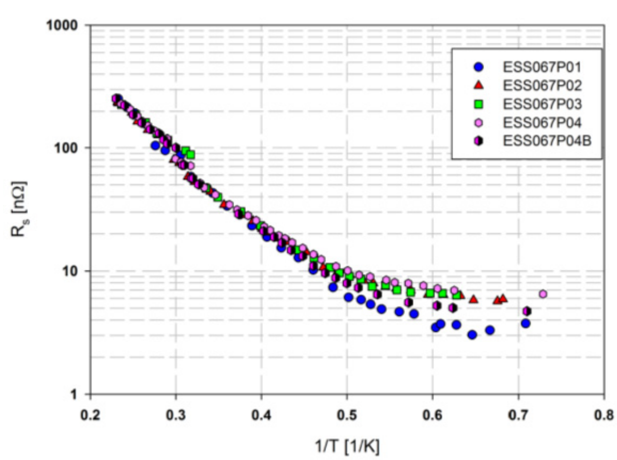

Figure 2: Surface resistance measurements at 1MV/m with respect to temperature.

Table 2: Residual Surface Resistance Measured at 1MV/m During Vertical Test

Cavity serial number	Residual resistance (R_0)[nΩ]	Q0 at 1MV/m@2K
MP01	3.14	$3.2x10^{10}$
MP02	6.09	$2.2x10^{10}$
MP03	6.06	$2.1x10^{10}$
MP04	7.09	$1.9x10^{10}$
MP04 (b)	4.85	$2.5x10^{10}$

A second measurement was performed on the fourth cavity (ESS067P04), this time the stainless steel blank flanges mounted on the beam tubes were substituted by extensions, this was done in order to reduce the electromagnetic field amplitude on the stainless steel and hence the ohmic losses. As a result the measured surface resistance at 2K dropped from 10 to 8 nΩ (figure 2). In table 2 are displayed residual surface resistance for each test, the data were fitted with formula (1), using A, B and R_0 as free parameters.

$$\boldsymbol{R_S = \frac{A}{T} e^{-\frac{B}{T}} + R_0} \qquad (1)$$

The vertical cryostat is also equipped with compensation solenoid that allow us to minimize the magnetic field vertical component in the cavity region, on average its amplitude is about 0.1µT, while the radial part is between 1 and 2µT. [4]

VERTICAL TEST RESULTS IN CONTINUOUS WAVE (CW) MODE FOR MEDIUM BETA CAVITIES

Unloaded Quality Factor Versus Accelerating Field (Q_0-E)

Each cavity was tested in the vertical cryostat once they were equipped with the helium tank. Cavities MP01 and MP02 exceeded performance requirements despite the occurrence of field emission. During MP03 testing we were able to detect x-ray only during multipactor processing, typically between 8 and 12MV/m, after the processing the x-ray dose was within the background (~0.1-0.2µSv/h). It is worth mentioning that x-ray dose probe was installed only on the top flange of the cryostat.

In figure 3 are shown the results for each cavity of unloaded quality factor with respect to accelerating filed. It is required to have a Q_0 bigger than $5x10^9$ at 16.9MV/m for the accelerating field (E_{acc}). It could be notice that, both MP03 and MP04 had similar Q-drop, despite x-ray were detected only during MP04 tests. A detailed analysis is ongoing and results will be presented in a future publication. Even with tube extension we observed a Q drop starting at 10MV/m (47.9mT), the MP04B curve has an upward offset with respect to MP04.

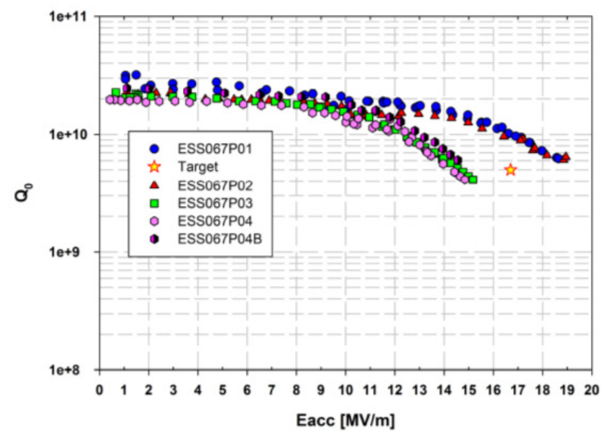

Figure 3: Q-E curves for medium beta cavities equipped with helium tank, test is performed in vertical cryostat.

X-Ray Measures

A radiation dose rate monitor was installed on the vertical cryostat top plate. The detector, a Berthold micro-gamma LB112, was connected to the software used for cavity measures in order to correlate each measuring point to a radiation dose rate in case field emission occurs. In figure 4 are shown the measures obtained during the unloaded Q measure shown in figure 3. Despite strong field emission cavity MP01 and MP02 are above specification concerning the unloaded Q, cavity MP03 did not show any radiation despite during the multipacting barrier between 8MV/m and 12MV/m. During the MP04 second test some processing occurred and the radiation dose rate was slightly reduced.

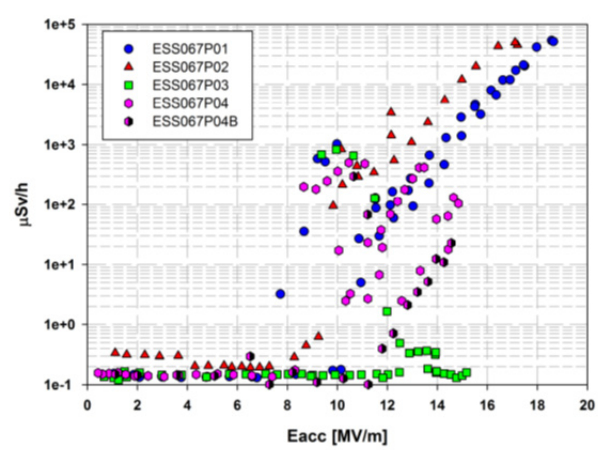

Figure 4: X-ray dose rate measured on the vertical cryostat top plate during cavity vertical tests.

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The radiation dose background in the experimental hall (SupraTech) is between 0.1 and 0.2µSv/h. In table 3 are shown the dose level measured on the top flange of the vertical cryostat when the cavity was in π-mode with an accelerating field about 15MV/m.

Table 3: X-ray Dose Rate During Vertical Tests

Cavity serial number	X-ray dose rate at ~15MV/m (π-mode) [mSv/h]
MP01	2.8
MP02	18.6
MP03	0.0002 (background)
MP04	0.1
MP04 (b)	0.022

We dedicate most of our effort to understand and optimize all the process involving the first prototype (P01)

HEAT TREATMENTS AND LOW TEMPERATURE BAKING

Q-Disease "Vaccination"

One vertical test on medium beta was dedicated to verify the effect of keeping the cavity at 100K for hours (about 5). This was done in order to verify if the cavity was properly "vaccinated" against Q-disease by the heat treatment at 600°C. In figure 5 are shown two Q-E curve obtained before and after the 100K "parking". No change in the cavity performance was observed and hence the heat treatment proved to be effective.

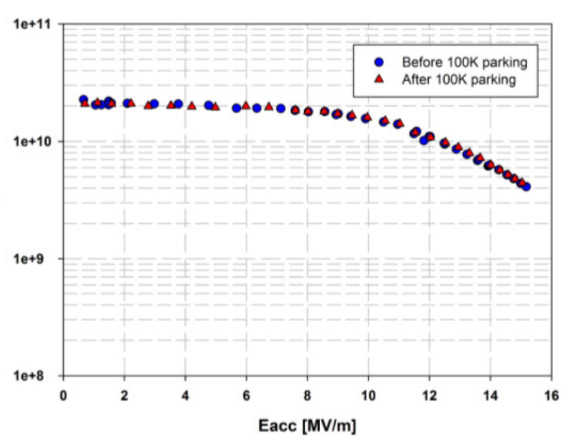

Figure 5: Q-E curves for a medium beta cavity before and after 100K parking for several hours.

Low Temperature Baking On High Beta Cavity

During high beta cavities prototyping we also started to qualify the oven to perform low temperature baking (120°C for 48hours). The residual resistance measurement was performed before and after the baking, in figure 6 are shown the results. The BCS contribution at 4.2K is dropped by 60% while the residual resistance is increased by 35%.

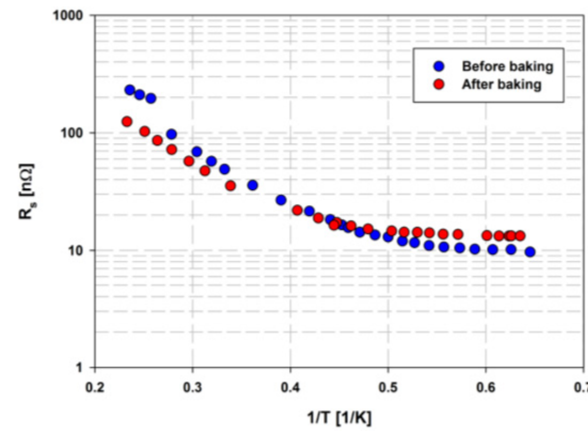

Figure 6: Surface resistance for a high beta cavity before and after low temperature baking (120°C for 48hours).

SUMMARY

Six medium beta cavities have been manufactured for the Elliptical Cavities Cryomodule Technology Demonstrator (ECCTD). Four of them are now equipped with helium tank and three of these are now installed in the cryomodule demonstrator. We have performed power test in the vertical cryostat with all the cavities, two of them have performance that exceed specification even with field emission, other two have a Q-drop that is under investigation. All the cavities have dangerous higher order modes (HOMs) frequency away from the machine line more than 5MHz, as designed and compliant with requirements.

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