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STUDY ON THE MULTIPACTOR BARRIERS OF THE SARAF-PHASE 2 LOW-BETA AND HIGH-BETA SUPERCONDUCTING CAVITIES*

Guillaume Ferrand†, Matthieu Baudrier, Luc Maurice, Nicolas Pichoff
Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA-Irfu) Institut de Recherche sur les lois Fondamentales de l'Univers, Gif-sur-Yvette, France

Abstract

CEA is committed to delivering a Medium Energy Beam Transfer line and a superconducting linac (SCL) for SARAF accelerator in order to accelerate 5 mA beam of either protons from 1.3 MeV to 35 MeV or deuterons from 2.6 MeV to 40 MeV. The SCL contains 13 half-wave resonator (HWR) low beta cavities (beta= 0.09) at 176 MHz and 14 HWR high-beta cavities (beta = 0.18) at 176 MHz. The low-beta and high-beta series were qualified in 2021 and 2022 respectively. This contribution will focus on the observation of the multipactor barriers for all cavities. It will present series of data obtained during the conditioning of these cavities.

INTRODUCTION

In 2014, CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives, Saclay, France) was committed to delivering a Medium Energy Beam Transfer line and a superconducting linac (SCL) for SNRC (Soreq Nuclear Research Center, Soreq, Israel), on the SARAF (Soreq Applied Research Accelerator Facility) site [1].

This new accelerator, called Saraf-Phase II, was designed to accelerate 5 mA beam of either protons from 1.3 MeV to 35 MeV or deuterons from 2.6 MeV to 40 MeV. CEA planned the end of the commissioning of the last cryomodule for 2023.

The SARAF-Phase II accelerator contains 13 superconducting cavities with $\beta_{opt} = 0.09$, called low-beta (LB) cavities, and 14 superconducting cavities for $\beta = 0.18$, called high-beta (HB) cavities [2]. A detailed presentation of the results for LB series can be found in Ref. [3].

In 2022, the last HB series cavities were tested successfully. These 29 tests produced a lot of data concerning the multipactor (MP) conditioning. The purpose of this paper is to present some of these data and discuss them. It shows that the duration of the conditioning of these cavities is inversely proportional to the power accepted by the cavity.

DESIGN

The design of both cavity kinds began in 2016 and was described in Ref. [4]. The frequency for the superconducting LINAC is 176 MHz, in order to keep the RFQ [5]. Table 1 presents the performances for these accelerating fields as mentioned in Ref. [6].

Table 1: Performances According to Final RF Simulations

Parameter	Low β cav.	High β cav.
β_{opt}	0.091	0.181
E_{acc}(MV/m)	7	8.1
E_{pk}(MV/m)	34.5	35.8
B_{pk}(mT)	65.6	65.3
$Q_{0,max}$@4.45 K	$8{\cdot}10^8$	$1.2{\cdot}10^9$
R/Q@β_{opt}(Ω)	189	280
Stored Energy (J)	5.7	16.8
RF losses @ Q_0 (W)	7.9	15.5

Figure 1 (left) presents the final design of the LB cavity with its helium tank. Both inner and outer conductors are cylindrical. Figure 1 (right) presents the final design of the HB cavity with its helium tank. Contrary to the LB cavity, the inner conductor is conical. See Ref. [3] for more information.

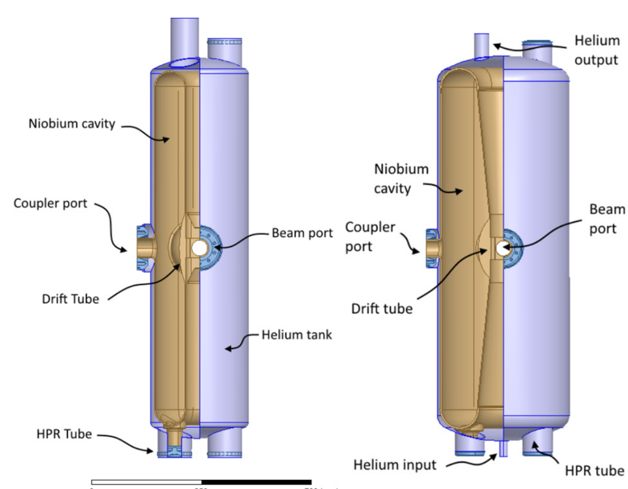

Figure 1: LB (left) HB (right) SARAF cavity.

SIMULATION OF MULTIPACTOR

Before launching the manufacturing of the cavities, we tried to simulate potential MP regions using the Musicc3D software [7]. A few MP regions were found at low field, from 30 kV/m to 100 kV/m as shown in Figure 2. We were not able to find MP barriers at higher field, even if the experience showed that they exist for both cavities.

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† Guillaume.ferrand@cea.fr

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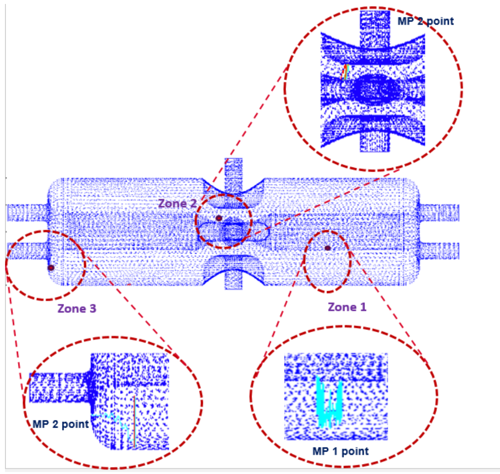

Figure 2: LB cavity MP barriers according to Musicc3D.

VERY LOW FIELD MP BARRIERS

All tests were done with the cavity fully immerged in liquid helium at 4.2 K (diphasic He at 1 atm.).

We observed MP barriers at very low field between 30 and 40 kV/m for both cavities. When the cavity is stuck at this field, conditioning is not effective, even after hours.

If the cavity is first launched with an injected power higher than 100 mW, these barriers are not visible. However, after a few ten minutes of tests at higher field (higher than 2 MV/m), launching the cavity with 100 mW blocks it in the barrier. The minimal required power to relaunch the cavity is around 500 mW (with approximately 50% chance to pass the barrier). Sometimes, after a few hours without RF, the very low-field barrier is easier to pass. These barriers tend to reinforce with time of testing.

We did not see any significant difference between LB and HB cavities for very low-field barriers.

MEDIUM FIELD MP BARRIERS

Medium field barriers were found from 1.8 to 3.5 MV/m for LB cavities and 1.6 to 2.7 MV/m for HB cavities. These barriers have been successfully conditioned for all cavities. However, time to condition them was variable from one cavity to another one.

For LB cavities, it took only 20 minutes for cavity called SLN103, and 1 hour for cavity SLN101, with a majority of cavities between 30 and 40 minutes. Figure 3 shows the evolution of the MP barrier in time for the three first series cavities, SLN101 to SLN103. Most of the other cavities behaved similarly to SLN102. After the end of the conditioning, we tested of the cavity on the full range to verify that barriers were well conditioned. A second conditioning was necessary for none of the LB cavities.

Figure 3 shows that the evolution is not linear. Figure 4 shows the conditioning for two cavities with approximately the same conditioning duration. We observed two very close MP barriers. When the first barrier ends, at 2.7 MV/m, the second barrier begins. Curves are close to a parabolic function. For the first barrier, the field seems to be exactly the same for both cavities, but the field of the second barrier seems different. It appeared that all cavities show these 2 separate barriers, with variations of 0.1 to 0.2 MV/m from one cavity to another one.

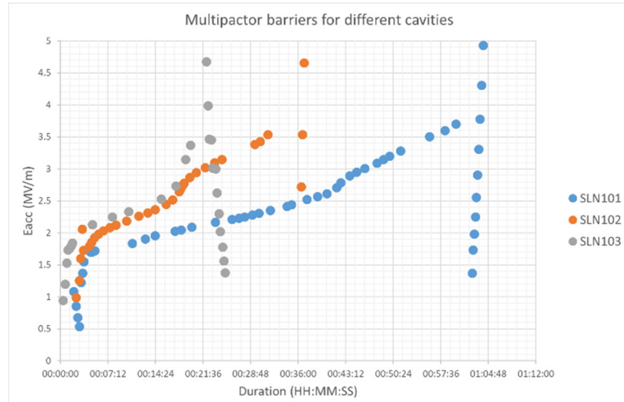

Figure 3: Time to condition the multipactor barriers for 3 LB cavities.

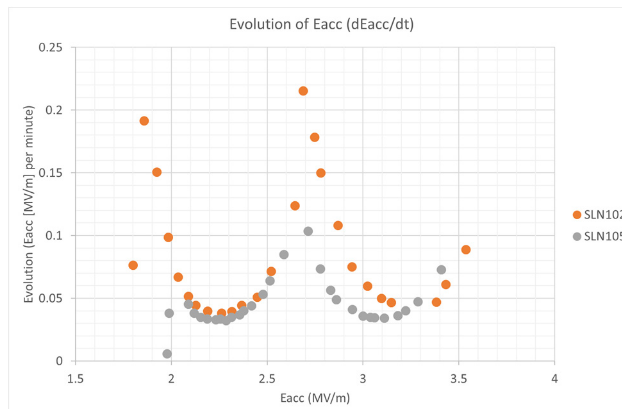

Figure 4: Evolution of Eacc in time for two LB cavities: SLN102 and SLN105.

We observed the effect of the injected power on the evolution of the MP barrier. Cavity SLN111 was conditioned with two different input powers: 5.8 and 3.0 W (4.7 and 2.7 W accepted powers). Figure 5 shows that the conditioning is faster if the injected power is higher. The grey line represents the curve at 3.0 W multiplied by the ratio of the accepted powers. The conditioning speed is almost proportional to the accepted power.

The same analysis was done for HB cavities. The evolution varies from one cavity to another one. Figure 6 shows two different HB cavities. For comparison, the conditioning time was divided by the injected power, as we used about twice more power for SLN126 than for SLN127. For SLN127, conditioning lasted 30 minutes with 4.5 W accepted power. For SLN126, conditioning lasted 2 hours and 45 minutes with 8.5 W accepted power. At some points, SLN126 was 20 times "slower" than SLN127. We tried to correlate the difficulty to condition the cavity to the performance, but found no evidence of any correlation. At the nominal field (8.1 MV/m), the Q_0 for SLN126 and SLN127 was $2.37 \cdot 10^9$ and $2.54 \cdot 10^9$ respectively. This 7% difference is close to the accuracy of the measurement.

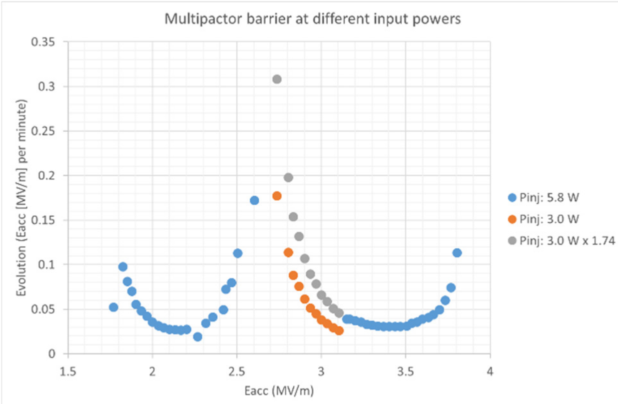

Figure 5: Evolution of the MP barrier for SLN111 with 2 different injected powers.

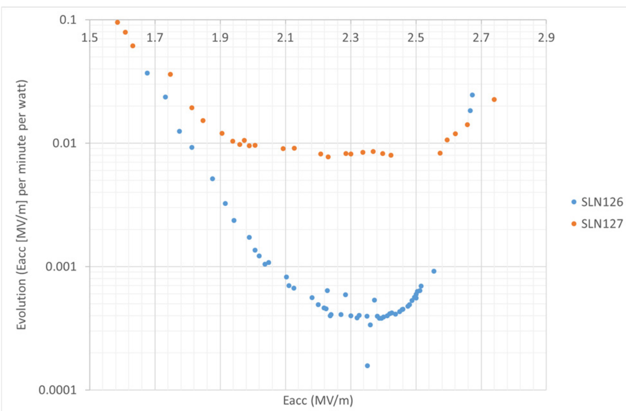

Figure 6: Evolution of the MP conditioning for SLN126 and SLN127.

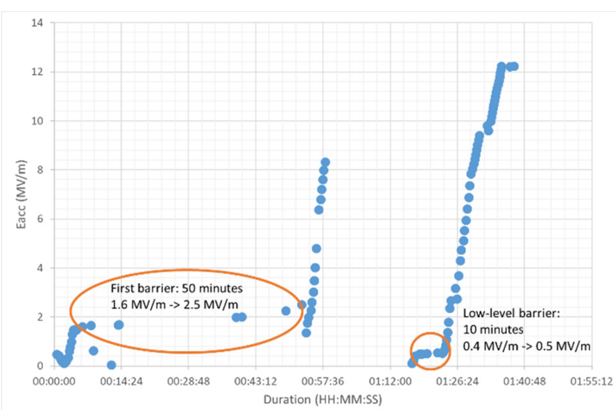

Figure 7: Multipactor barriers for cavity SLN122. The small barrier at 0.4 MV/m is visible.

LOW FIELD MP BARRIER

Only with the HB cavities, we saw a very small MP barrier at low field, only after conditioning of the medium field MP barrier. This barrier, between 0.4 and 0.5 MV/m was always conditioned in a few minutes. For most of the HB cavities we did not have time to record it before the barrier was conditioned. Cavity SLN122 was the one where this barrier was the most visible (Figure 7). As for other barriers, after conditioning, it was never seen again.

CONCLUSION

In this paper, we showed a few simulations of MP barriers with Musicc3D. We did not succeed to simulate barriers at medium field, only the very low-field barriers.

During the test, three types of barriers were seen. Very low-field barriers appeared for all cavities, but only after a few ten minutes. These barriers cannot be conditioned but were not critical for tests.

Medium barriers were the most common. Two barriers were seen from 1.8 to 3.5 MV/m for LB cavities, and one barrier from 1.6 to 2.7 MV/m for HB cavities. The evolution speed of these barriers was variable from one cavity to another one. For HB cavities, it could vary by a factor 20. We did not correlate this speed to the final performance of the cavity. We observed a very good stability from one cavity to another one for barrier beginning and ending fields, even when the conditioning time was varying a lot.

A low-field barrier that can be conditioned in a few minutes was found only on HB cavities.

REFERENCES

[1] N. Pichoff *et al.*, "The SARAF-LINAC Project 2019 Status," in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 4352-4355. doi:10.18429/JACoW-IPAC2019-THPTS116

[2] J. Dumas, P. Nghiem, N. Pichoff and D. Uriot, "Beam Dynamics Studies for the Saraf MEBT and SC Linac," in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 655-658. doi:10.18429/JACoW-IPAC2017-MOPIK058

[3] G. Ferrand *et al.*, "SARAF-Phase 2 Low-Beta and High-Beta Superconducting Cavities Qualification," presented at the 20th Int. Conf. on RF Superconductivity (SRF'21) , East Lansing, MI, USA, Jun.-Jul. 2021, paper WEOCAV06

[4] G. Ferrand *et al.*, "Final Design of the Fully Equipped HWR Cavities for SARAF," in *Proc. LINAC'16*, East Lansing, MI, USA, Sep. 2016, pp. 123-125. doi:10.18429/JACoW-LINAC2016-MOPRC025

[5] A. Perry, Y. Ben Aliz, A. Kaizer, A. Kreisel, J. Rodnizki and L. Weissman, "Status of Saraf Superconducting Acceleration Module," in *Proc. SRF'11*, Chicago, IL, USA, Jul. 2011, paper MOPO011, pp. 69-73.

[6] G. Ferrand *et al.*, "Results of CEA Tests of Saraf Cavities Prototypes," in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 4356-4358. doi:10.18429/JACoW-IPAC2019-THPTS117

[7] T. Hamelin, J. Coacolo, M. Chabot, J. Lesrel and G. Martinet, "Musicc3D: A Code for Modeling the Multipacting," in *Proc. SRF'13*, Paris, France, Sep. 2013, paper TUP092, pp. 683-685.