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CAVITY DESIGNS FOR THE CH3 TO CH11 OF THE SUPERCONDUCTING HEAVY ION ACCELERATOR HELIAC

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Abstract

In collaboration of GSI, HIM and the Goethe University Frankfurt, the superconducting linear accelerator Helmholtz Linear Accelerator (HELIAC) is being built at GSI in Darmstadt. The cw-mode operated linac with a final energy of 7.3 MeV/u at a mass-to-charge ratio of $A/q = 6$ and a frequency of 216.816 MHz is intended for various experiments, especially with heavy ions at energies close to the Coulomb barrier for the research of superheavy elements. The entire planned linac consists of four cryostats, four superconducting buncher, four solenoids and twelve superconducting CH-cavities. After successful beam tests with CH0 and successful high frequency tests with CH1 and CH2, CH3 to CH11 will be designed. Based on previous experience and successful test results, individual optimizations of the cavity design will be performed. Among other things, attention has been paid to reducing production costs by designing as many components as possible, such as spokes or the tank caps with the same geometries. Despite this cost reduction, it was possible to improve the theoretical performance in the simulations.

INTRODUCTION

The HELIAC is a cw-operated superconducting linear accelerator to be built at GSI in collaboration between IAP, GSI and HIM. It will replace UNILAC, which is currently under reconstruction as part of the FAIR project, in the experiments on the synthesis of superheavy elements (SHE) [1]. Within the demonstrator project, a sc CH cavity (CH0) has already been successfully tested with beam in a prototype cryostat with two superconducting solenoids [2]. While the demonstrator project was still in progress, work began on designing and building the identical CH1 and CH2 cavities. These two cavities were successfully realized and tested under cold conditions [3]. The entire sc accelerator will consist of four cryomodules (CM), each with three sc CH cavities, two solenoids (S) and a buncher (B) (see Fig. 1).

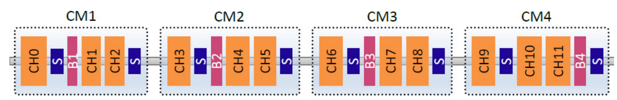

Figure 1: Layout of sc HELIAC.

In Summer 2018 the design of nine 216.816 MHz sc CH-cavities (CH3 to CH11) for the cw-mode operated HELIAC at GSI in Darmstadt has started [4]. The design for these cavities is based on the design of the previously successfully tested CH1 and CH2 [3]. During the design progress several new optimizations and modifications were done. A new design for the dynamic bellow tuner has been developed, which has been examined for its influence on the frequency and for its mechanical properties. This new design of the dynamic tuner was compared with the design of the tuner of the CH1 and CH2 cavities [5]. In addition, the new designs focused on reducing peak electric and magnetic fields within the cavity.

CAVITY DESIGN

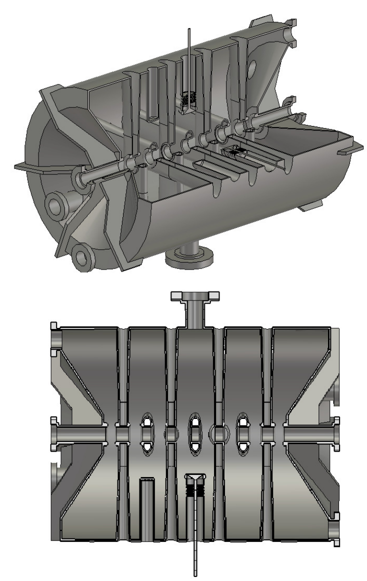

Figure 2: Layout of the 216.816 MHz sc CH-cavity CH3 with new bellow tuner design. The basic design of all cavities from CH3 to CH11 is the same except for the number of gaps, the gap lengths, the radius and the length. Here CH3 is shown as an example.

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Due to the increasing beta from cavity CH3 to CH11 (see Fig. 2), the gap lengths also increase. To compensate for the change in frequency caused by the resulting decrease in capacity on the beam line, the radius increases from cavity to cavity. Even though the gap lengths increase steadily, the total length of the cavities varies only minimally, because the accelerator was designed so as to reduce the number of gaps in the later cavities(see Fig. 3) [6, 7].

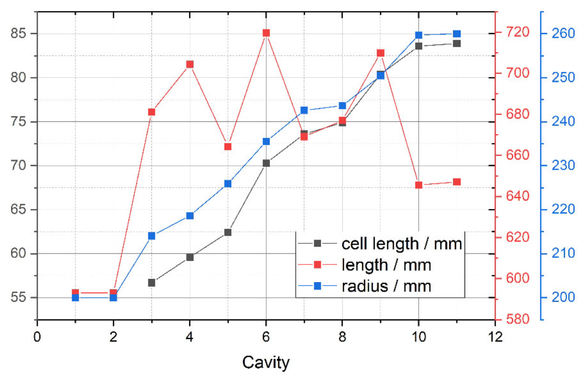

Figure 3: Geometric differences between CH3 to CH11.

The designs of all nine cavities (CH3 to CH11) were designed to produce as many components as possible with the same geometric dimensions, despite the changing gap length, radii and lengths. Both the spokes and the conically running deep lids were designed with identical geometric dimensions (see Fig. 4). Only the length of the spokes varies, which can be cut to the respective radius of the cavity. Likewise, only the outer cover, which can also be cut to size, varies for the lids. This consistent design of the components can significantly reduce both manufacturing costs and production time.

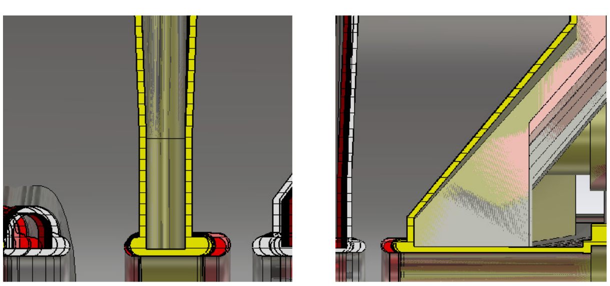

Figure 4: Here, all nine cavities were colored in different shades. They were placed on top of each other in such a way that the first spokes of each cavity are on top of each other (left) and that all lids are on top of each other (right).

Despite these design constraints, the cavities could be optimized with respect to peak electric and magnetic fields. This was achieved by adapting the length and thickness of the extended drift tubes outside the actual spokes to the respective geometries. The variance of the capacitances on the beamline not only increased the acceleration field E_a, but also reduced the electric peak fields E_{peak}. By adjusting the radii of the cavities, this compensated for changes in frequency that occurred and reduced the magnetic peak fields B_{peak}. Even if an adjustment of the spokes or the lids would probably allow a further optimization in the performance, a good compromise between performance and cost could be found here, so that in the current simulations of the cavities CH3 to CH11 it can be seen that the perfomance with regard to the limiting peak fields could be improved for most of the cavities and the construction costs and constrution time could be reduced in direct comparison to the two predecessor cavities CH1 and CH2 (see Fig. 5).

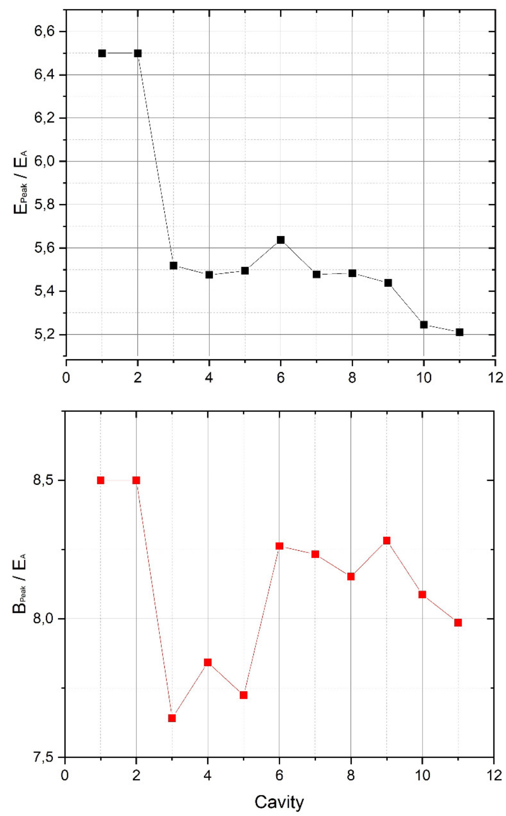

Figure 5: The ratio of the peak electric (top) and magnetic (bottom) fields versus the accelerating field of all cavities CH3 to CH11 presented here compared to the two predecessor cavities CH1 and CH2 [3].

Another factor in lowering the electric peak fields was adjusting the design of the dynamic bellow tuner (see Fig. 6). In cavities CH1 and CH2, the design was a compromise between functionality and lack of space between the spokes due to the short gap length [3]. The biggest change is the rounded head of the tuner, which offers less surface area for the electric field. Thus, the ratio E_{peak}/E_A could be further reduced. In addition, it was possible to simplify the geometry and thus reduce welding work, which in turn lowers production costs. Two dynamic tuner are installed in each cavity, but their heads are positioned differently close to the beam line. In the previous cavities, the two tuner were at

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the same height. Due to this difference in distance from the beam line, the tuner have a different frequency deviation, so that it is also possible to react to possible lower fluctuations in the resonant frequency, since the tuner further away has a smaller deviation and therefore allows significantly finer corrections to the resonant frequency per mm of displacement (see Fig. 7).

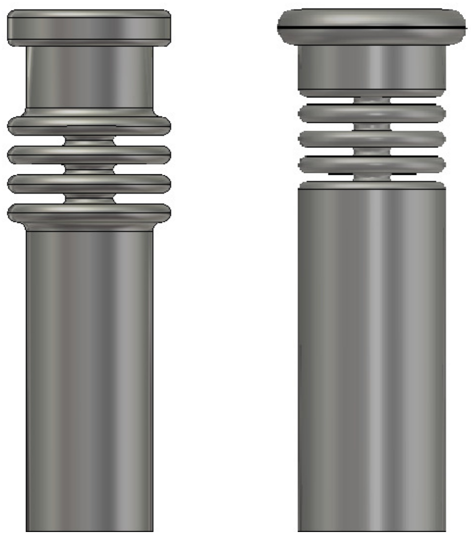

Figure 6: On the left, the design of the dynamic bellows tuner of cavities CH1 and CH2, on the right, the design from cavities CH3 to CH11.

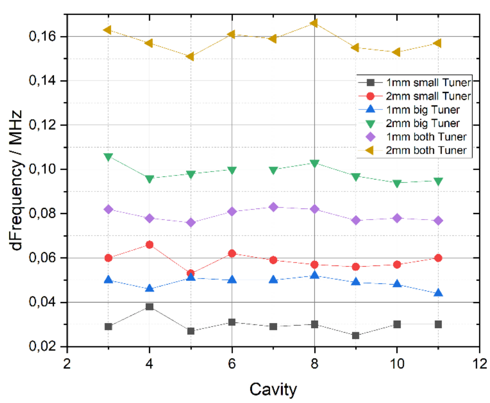

Figure 7: Tuner stroke of all dynamic bellows tuner with new design. 'small' is the tuner that is further away from the beam line, while 'big' is closer to the beam line. Shown is the frequency change at ±0.5 mm and ±1 mm displacement of both tuner individually and both tuner simultaneously.

OUTLOOK

Currently, the multipacting and secondary electron behavior of the cavities of CH0 and CH1 are being investigated. During cold tests of the CH1 and CH2 cavities, one with and the other without the helium tank attached, it was noticed that the multipacting conditioning at low field levels was significantly more time consuming and difficult than for CH0. The aim of the current investigations is to find out where this difference originates and, if necessary, to adapt the designs of CH3 to CH11 so that they exhibit similarly few problems during conditioning and commissioning as CH0. After these possible adjustments to the design, the design phase is finished and the tender can begin.

CONCLUSION

A new design of the additional cavities for the HELIAC superconducting accelerator at GSI could be created. These designs represent a compromise between performance improvement as well as cost and manufacturing time reduction. Components such as the spokes and the tapered lids were designed to be geometrically identical without reducing the functionality of the cavities. A new design of the dynamic bellow tuner enabled both the reduction of peak electrical fields and increased flexibility for operators during accelerator operation.

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