ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP005

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

T. Conrad*, M. Basten, M. Busch, H. Podlech, M. Schwarz,
IAP, Goethe University Frankfurt, Frankfurt am Main, Germany
K. Aulenbacher[1], W. Barth[2], F. Dziuba, V. Gettmann, T. Kürzeder, S. Lauber, J. List, M. Miski-Oglu,
Helmholtz-Institute Mainz, Mainz, Germany
[1]also at Johannes Gutenberg University, Mainz, Germany
M. Heilmann, A. Rubin, A. Schnase, S. Yaramyshev,
[2]GSI Helmholzzentrum, Darmstadt, Germany

Abstract

In collaboration of GSI, Helmholtz-Institute Mainz and Goethe University Frankfurt new designs for the superconducting (sc) crossbar H-Mode drift tube linear accelerator (CH-DTL) cavities of the proposed Helmholtz Linear Accelerator (HELIAC) are developed. The continuous wave (cw) mode operated linac with a final energy of 7.3 MeV/u is intended for various experiments, especially with heavy ions at energies near the coulomb barrier for super-heavy element research. Currently twelve superconducting (sc) CH-cavities are considered which will be split into four different cryostats. Each cavity will be equipped with dynamic bellow tuners. After successful beam tests with CH0 as well as last surface preparations and ongoing rf tests with CH1 and CH2, CH3 to CH11 will be designed. Based on the experience gained so far and successful test results, individual optimizations are carried out on the cavity design. Furthermore, attention was paid to reduce production costs, e.g. by keeping the cavity diameter in each cryostat constant despite varying particle velocities and gap numbers. In addition to reaching the resonance frequency of 216.816 MHz and the influence of the bellow tuners on the frequency, the mechanical stability of the bellow tuners, the thermal effects on the cavity and the measures to mitigate secondary electron emission are investigated.

INTRODUCTION

In August 2018 the design of nine 216.816 MHz sc CH-cavities (CH3 to CH11) for the cw-mode operated HELIAC has started [1]. The design for these cavities is based on the design of the previously successfully tested CH1 and CH2 [2, 3]. During the current design phase several new optimizations and modifications are done. Two new designs for the dynamic bellow tuners have currently been developed, which have been examined both for their influence on the frequency and for their mechanical properties. Due to the short gap length between the spokes of the identical CH1 and CH2, a solution between functionality, mechanical and secondary electron emission characteristics had to be found for the bellows tuners [2]. For the following cavities CH3 to CH11, this compromise can be dispensed with, as the increasing gap lengths leave more scope for designs that focus on functionality. Figure 1 shows exemplarily CH3 with one of the two new tuner designs as well as an cross section trough the cavitiy.

* conrad@iap.uni-frankfurt.de

CAVITY DESIGN

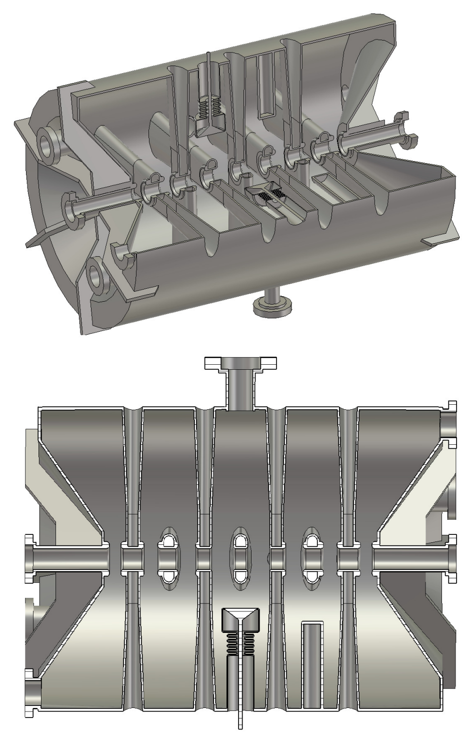

Figure 1: Layout of the 216.816 MHz sc CH-cavity CH3 with bellow tuner design 1.

In order to keep costs and construction costs as low as possible, the design of all subsequent cavities is based on the successfully implemented and tested design of the CH1 and CH2. As the beta increases as the accelerator progresses, the gap length must increase, but the accelerator has been designed to decrease the number of gaps in the subsequent cavities so that the length of the cavities does not change drastically (see Fig. 2) [4,5]. In order to save further costs, the cavities within a cryostat are designed so that they all have an equal outer radius. This allows all spokes within a cryostat to be manufactured with the same mechanical tools. However, this means a greater design effort, since the

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capacity decreases due to the declining number of gaps and the larger gap length, thus the frequency increases. In order to keep the resonance frequency of all cavities constant, the tuners and the drift tubes must compensate more. The design of all nine cavities is optimized individually. The single geometries within the cavities are adapted so that the E_{peak}/E_A ratio is kept as low as possible by reducing the electrical peak fields. However, since radius and spokedesign are constant within a cryostat, these optimizations can only be done by tuners, bellow tuners and drift tubes. Figures 2 and 3 show the geometric and physical differences between the individual cavities.

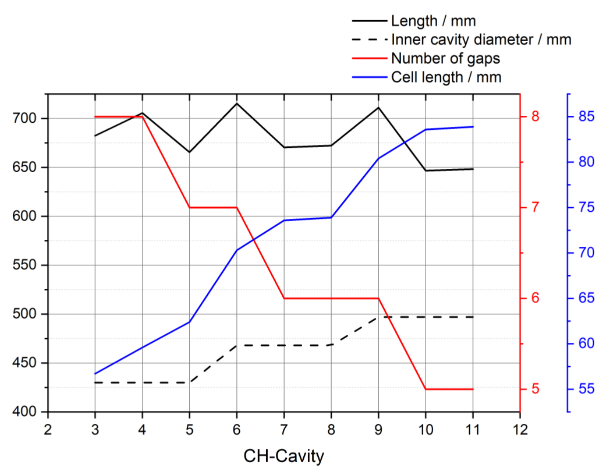

Figure 2: Geometric differences between CH3 to CH11.

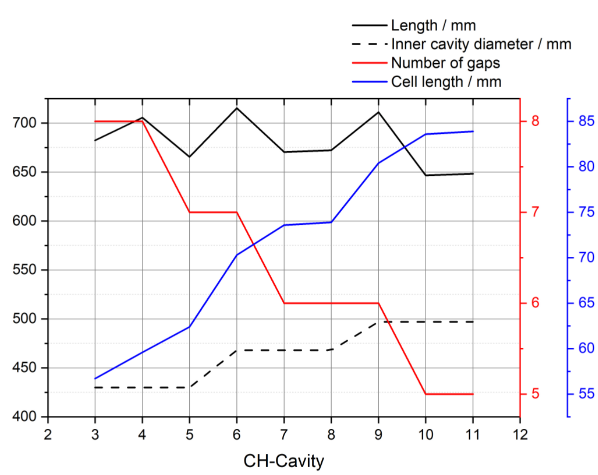

Figure 3: Differences in accelerator properties from CH3 to CH11.

BELLOW TUNER DESIGN

To improve the functionality of the built-in bellow tuners, three different designs are currently being tested. The original design of the bellow tuners from CH1 and CH2 as well as two others. Figure 4 shows the different design proposals.

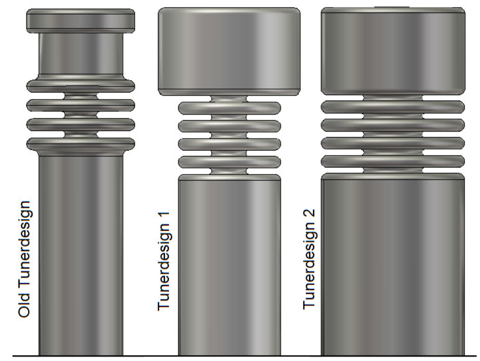

Figure 4: The three different tunerdesigns currently under investigation.

A serious difference to the bellow tuners in CH1 and CH2 is the positioning of the bellow tuners within the cavities. In the two cavities already built, the two bellow tuners, which are rotated by 90 degrees to each other, are at the same height so that they are at the same distance from the beam axis. This means that both tuners have the same frequency change at a maximum deflection of 1 mm. In the current design, the bellow tuners have a small offset to each other, so one bellow tuner is closer to the beam axis than the other. Thus, the two dynamic tuners show a different frequency change at a maximum deflection of 1 mm. The tuner which is closer to the beam axis has a frequency shift of about 75 kHz, the tuner which is further away from the beam axis has a frequency shift of 25 kHz, so that the total possible shift is about 100 kHz (see Fig. 5). Figure 6 shows the frequency change against the mechanical deflection of the tuner. The total deflection of 1 mm is achieved by pulling the bellows tuners 0.5 mm in one direction and pushing 0.5 mm them into the other. This range of frequency change is therefore large enough to compensate for possible fluctuations within the resonant frequency that may occur due to mechanical or thermal influences.

In addition to the influence on the resonance frequency of the cavity, the force required to steer the bellow tuners out is of interest. The so-called Von-Mises-Stress is connected to this deflection force. This indicates how much internal tension a material can withstand before it gives way and tears. Since the different tuner designs in Fig. 4 also have different lamella geometries, the forces on the tuners are different. Figures 7 and 8 show these differences graphically. The material used in this accelerator is niobium. The critical limit for the Von-Mises-Stress of niobium is temperature dependent. In the cold state this critical limit is 0.49 GPa (black line in Fig. 8) [6].

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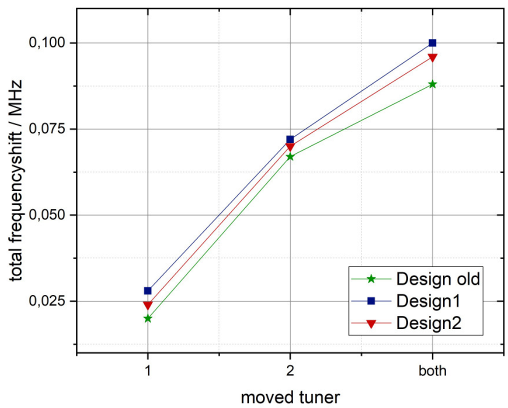

Figure 5: Frequency deviation at maximum excursion of 1 mm for tuner 1 (further away from the beam axis), tuner 2 (closer to the beam axis) and both tuners.

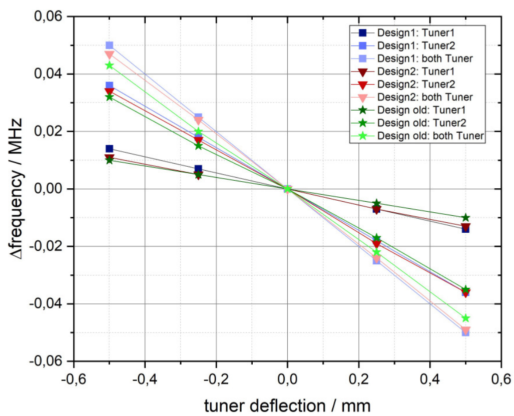

Figure 6: Frequency change versus deflection of the tuner for all simulated designs and tuners.

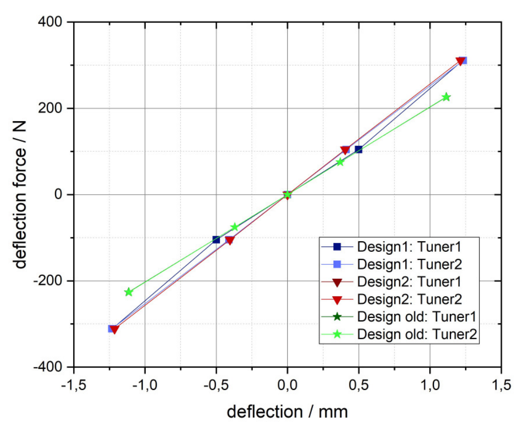

Figure 7: Required deflection force versus corresponding tuner deflection.

SUMMARY OUTLOOK

It was shown that changes and optimizations were made to the already existing cavity design of CH1 and CH2. There are currently three different tuner designs, among which a final design has to be selected or created

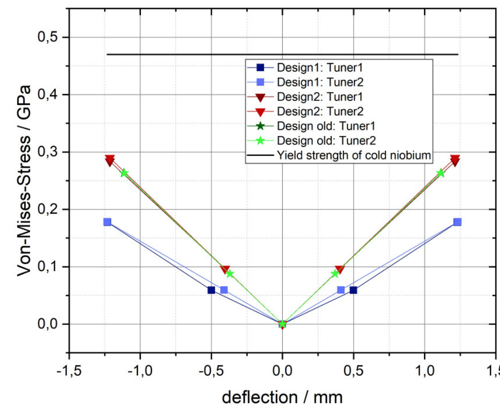

Figure 8: Von-Mises-Stress within the tuner versus deflection.

after further investigations, especially with regard to secondary electron emission and multipacting. In addition, initial models and simulations concerning CH3 to CH11 have already been carried out and compared with the existing beam dynamics. The slit stresses and geometries previously assumed were confirmed. In the next steps, the design for CH3 is completed so that it is ready for construction. Then the designs for CH4 and CH5 will also be completed so that Cryomodule 2 can be realized.

ACKNOWLEDGEMENTS

This work is supported by the BMBF Contr. NO. 05P18RFRB1 and HIC for FAIR.

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