ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP004

LATEST CRYOGENIC TEST RESULTS OF THE SUPERCONDUCTING BETA=0.069 CH-CAVITIES FOR THE HELIAC-PROJECT*

M. Basten[1,†], K. Aulenbacher[2,3,4], W. Barth[2,3], C. Burandt[2,3], M. Busch[1], T. Conrad[1], F. Dziuba[2,3,4], V. Gettmann[2,3], M. Heilmann[2], T. Kürzeder[2,3], S. Lauber[2,3,4], J. List[2,3,4], M. Miski-Oglu[2,3], H. Podlech[1], J. Salvatore[2], A. Schnase[2], M. Schwarz[1], S. Yaramyshev[2]

[1]IAP University of Frankfurt, 60438 Frankfurt am Main, Germany
[2]GSI Helmholtz-Centre, 64291 Darmstadt, Germany
[3]HIM Helmholtz-Institute Mainz, 55099 Mainz, Germany
[4]KPH Johannes Gutenberg University Mainz, 55128 Mainz, Germany

Abstract

The upcoming FAIR (Facility for Antiproton and Ion Research) project at GSI will use the existing UNILAC (UNIversal Linear Accelerator) as an injector, reducing the beam time for the ambitious Super Heavy Element (SHE) program. To keep the UNILAC user program competitive a new superconducting (sc) continuous wave (cw) high intensity heavy ion LINAC should provide ion beams with max. duty factor above the coulomb barrier [1]. The fundamental sc LINAC design comprises a low energy beam transport (LEBT)-section followed by a sc Drift Tube Linac (DTL) consisting of sc Crossbar-H-mode (CH) structures for acceleration up to 7.3 MeV/u [2,3]. The latest milestones towards the new cw LINAC HELIAC (HELmholtz LInear ACcelerator) have been the successful tests and commissioning of the first demonstrator section with heavy ion beam in 2017 and 218 [4] as well as the successful test under cryogenic conditions of the second CH-cavity in 2018 [5]. Now the third CH-cavity has been tested at cryogenic temperatures of 4 Kelvin at the Institute for Applied Physics (IAP) at Goethe University Frankfurt (GUF). The results of these measurements as well as the status of the HELIAC-project will be presented.

INTRODUCTION

The HELIAC-project will comprise four cryomodules each equipped with three CH-cavities (CH), two superconducting solenoids with $B < 9\,\mathrm{T}$ (S) and a two-gap buncher (B) [6]. Sufficient beam diagnostic devices (D) will be installed in the warm intersections between each cryomodule (see Fig. 1). The next milestone after the successful commissioning of the first two CH-cavities (CH 0 and CH 1) is to be reached with the cryogenic test of the third CH-cavity (CH 2) followed by the commissioning of the fully equipped first cryomodule. The first cryomodule will provide beams with energies up to the coulomb barrier (at medium mass over charge ratio) for first experiments at the GSI facility. The second and third cavity are structurally identical with a geometric beta profile of $\beta = 0.069$ and a design gradient of $5.5\,\mathrm{MV\,m^{-1}}$ (see Table 1).

Table 1: Main Parameters Of CH-cavity CH 1 And CH 2

Parameter	Unit	Value
β		0.069
Frequency	MHz	216.816
Accelerating cells		8
Length ($\beta\lambda$-definition)	mm	381.6
Cavity diameter (inner)	mm	400
Cell length	mm	47.7
Aperture diameter	mm	30
Dynamic bellow tuner		2
Wall thickness	mm	3-4
Design Accelerating gradient	MV/m	5.5
Design Accelerating voltage	MV	2.1
E_p/E_a		6,5
B_p/E_a	mT/(MV/m)	<10
G	Ω	51
R_a/Q_0	Ω	1050

EXPERIMENTAL SETUP

After the delivery of CH2 to IAP at the beginning of 2019, eight temperature probes and 60 Thermo-Luminescence-Dosimeters (TLD's) have been installed for first testing at 4.2 K. Due to design faults the power coupler as well as the pickup for CH2 have been manufactured without ventilation holes so that the volume inside of each coupler could only be evacuated via their screw thread. Due to the virtual leaks of the couplers under warm conditions only 1×10^{-7} mbar after more than one week of active evacuation could be reached. Although the vacuum pressure inside the cavity was more than one order of magnitude higher as for CH1 we started the cooldown to 4.2 K. Any residuals inside the couplers should freeze out as soon as the cavity reaches 4.2 K resulting in much lower vacuum pressure inside the cavity. During the cooldown the vacuum inside the cavity was maintained by a ion getter pump.

* Work supported by BMBF Contr. No. 05P18RFRB1, EU Framework Programme H2020 662186 (MYRTE) and HIC for FAIR
† Basten@iap.uni-frankfurt.de

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP004

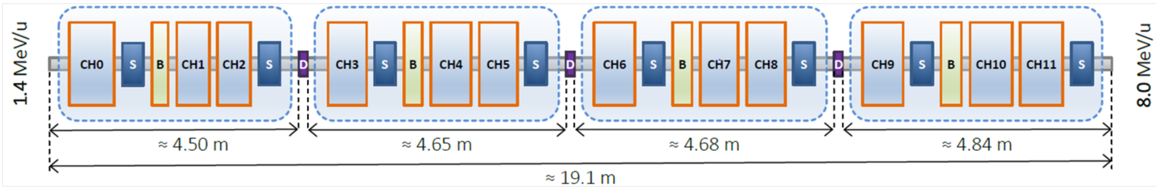

Figure 1: Layout of the upcoming HELIAC with four cryomodules each comprising three CH-cavities (CH), two solenoids (S) and a two-gap-buncher [7].

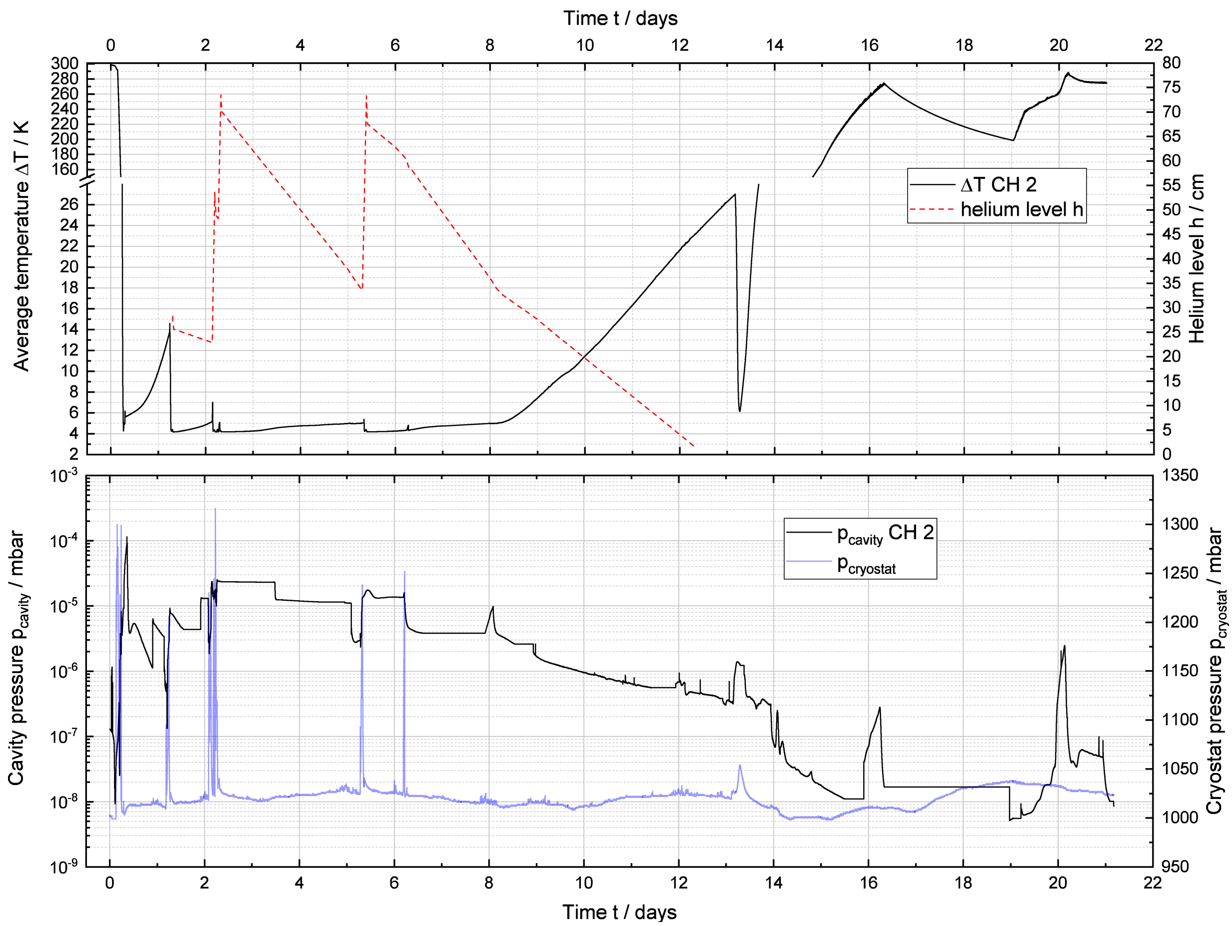

Figure 2: Long term recording of the pressure p_{cavity} (down) and average temperature ΔT (top) of CH2 as well as the helium level (top) and pressure p_{cryostat} inside the cryostat (down).

COOLDOWN OF CH2

The cavity was mounted to the cryostat top in a frame of aluminum rings fastened with stainless steel rods. After the assembly of the cavity string inside the vertical cryostat the liquid nitrogen shield was filled directly followed by a rapid cooldown of the cavity with liquid helium. Avoiding hydrogen related Q-disease in the temperature region in the temperature region $150\,\text{K} > T > 60\,\text{K}$ the temperature change was in the range of $2\,\text{K}\,\text{min}^{-1}$. The vacuum pressure inside the cavity dropped down to $p_{\text{cavity}} = 1 \times 10^{-8}$ mbar during rapid cooldown for a short period of time due to cryosorption effects (see Fig. 2). As soon as the helium level started to build up inside the cryostat, p_{cavity} rose up several orders of magnitude up to 1×10^{-4} mbar. The ion getter pump was not sufficient to handle the rapid increase of pressure so that an additional turbomolecular pump has been installed to reduce p_{cavity} again. During the following days the pressure got worse with increasing helium level and could not be reduced over time. For this reason a cold leak had to be considered. Measurements with a helium gas detector delivered helium leakage rates of about $5 \times 10^{-4}\,\text{mbar}\,\text{l}\,\text{s}^{-1}$ substantiating the assumption of a vakuum leak and resulting in the abortion of the cold test. As soon as the helium level dropped down to zero we used a heating unit to raise the temperature inside the cryostat up to room temperature. The cavity pressure dropped with increasing cavity temperature also indicating a vakuum leak which appears only under cold conditions.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP004

MEASURED RESULTS

We could still obtain some results although the cold test had to be canceled before low level conditioning and high power measurements were started. The measured frequency at 4.2 K was $f_{CH2} \approx 216.8268$ MHz which is approximately 10.8 kHz above the design frequency due to the last BCP-treatment resulting in an unexpected frequency jump. The pressure sensitivity $\Delta f/p$ of both cavities was measured at room temperature before and at 4.2 K during the final cold test (FM) and has been compared with the results from the intermediate measurements (IM) during the construction phase [8] (see Table 2). Both cavities have undergone several BCP-treatments between the intermediate and final measurements resulting in different pressure sensitivities. Normalization of the increase of $\Delta f/p$ on the BCP erosion of each cavity results in approximately 50 mHz mbar^{-1} µm^{-1}.

Table 2: Measured Pressure Sensitivity Of CH 1 And CH 2 During The Construction Phase, Under Warm Conditions Before And At 4.2 K During The Final Cold Test

	Unit	CH 1	CH 2
IM at room temperature	Hz mbar^{-1}	-10.2	-8.9
FM at room temperature	Hz mbar^{-1}	-12.7	-15.1
FM at 4.2 K	Hz mbar^{-1}	-4.5	-8.2

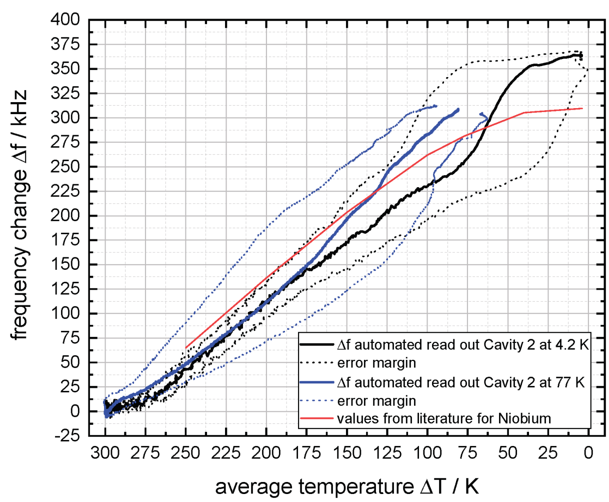

Figure 3: Frequency change Δf depending on the average temperature ΔT of CH 2 during the cold test at 4.2 K compared to the preliminary cold test at 77 K during the construction phase of CH 2.

The frequency change Δf depending on the average temperature ΔT during the cold test at 4.2 K of the second cavity is shown in Fig. 3. All data have been evaluated once per second by automated software routines resulting in high amounts of data so that error margins instead of single error bars have been used. The total frequency change at 4.2 K was $\Delta f \approx 364$ kHz while the measured frequency change during a preliminary cold test with liquid nitrogen conducted by the manufacturer (also shown in Fig. 3) suggested a frequency change of $\Delta f \approx 344$ kHz. The same estimation with liquid nitrogen has been performed for the first CH-cavity resulting in similar results (about 20 kHz below the actual Δf at 4.2 K). This method is proofed as sufficient and is proposed to be considered for the development of the following CH-structures of the HELIAC.

SUMMARY & OUTLOOK

After the successful power test of the first CH-cavity in 2018, the second cavity has been completed and delivered to IAP in 2019. As soon as all preparations could be completed the cavity was cooled down to 4.2 K for the first time although the pressure inside the cavity was in the range of 1×10^{-7} mbar only due to missing ventilation holes inside the coupler and pickup. With increasing helium level inside the cryostat the pressure inside the cavity became worse; an additional turbomolecular pump has been used to improve the vacuum pressure again. Measurements with a helium gas detector delivered helium leakage rates in the range of 5×10^{-4} mbar l s^{-1} indicating a vakuum leak inside the cavity under cold conditions. The next consecutive step has to be a in-depth search for the position of the vacuum leak under warm conditions. This proceeding is potentially challenging and time consuming in particular when the leak appears under cold conditions only. As soon as the leak has been found and removed we can restart cold testing and determine the RF performance of CH 2 and compare it with the results from CH 1.

ACKNOWLEDGEMENT

This work has been supported by Helmholtz-Institute Mainz (HIM), Gesellschaft für Schwerionenforschung (GSI) and HIC for FAIR. This work was financially supported by BMBF Contr. No. 05P18RFRB1, the EU Framework Programme H2020 662186 (MYRTE) and HIC for FAIR.

REFERENCES

[1] W. Barth *et al.*, "High brilliance uranium beams for the GSI FAIR", *Phys. Rev. ST Accel. Beams*, vol. 20, 050101, 2017. DOI:10.1103/PhysRevAccelBeams.20.050101

[2] W. Barth *et al.*, "A superconducting CW-LINAC for heavy ion acceleration at GSI", *EPJ Web Conf.*, vol. 138, 01026, 2017. DOI: 10.1051/epjconf/201713801026

[3] H. Podlech *et al.*, "Superconducting CH structure", *Phys. Rev. ST Accel. Beams*, vol. 10, 080101, Aug. 2007. DOI: 10.1103/PhysRevSTAB.10.080101

[4] W. Barth *et al.*, "First heavy ion beam tests with a superconducting multi gap CH-cavity", *Phys. Rev. ST Accel. Beams*, vol. 21, p. 020102, 2018. DOI: 10.1103/PhysRevAccelBeams.21.020102

[5] M. Basten *et al.*, "Cryogenig Tests of the Superconducting $\beta = 0.069$ CH-cavities for the HELIAC-project", in *Proc. LINAC'18*, Beijing, China, Sep. 2018, pp. 855-858. DOI: 10.18429/JACoW-LINAC2018-THPO072

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP004

[6] M. Gusarova *et al.*, "Design of the two-gap superconducting re-buncher", *J. Phys.: Conf. Ser.* 1067 082005, 2018. DOI:10.1088/1742-6596/1067/8/082005

[7] M. Schwarz *et al.*, "Beam Dynamics Simulations for the New Superconducting CW Heavy Ion LINAC at GSI", *J. Phys.: Conf. Ser.* 1067 052006, 2018. DOI:10.1088/1742-6596/1067/5/052006

[8] M. Basten *et al.*, "Final Factory-side measurements of the next sc CH-cavities for the HELIAC-project", in *Proc. IPAC'18*, Vancouver, Canada, April. 2018, pp. 943-945. DOI:10.18429/JACOW-IPAC2018-TUPAF088