

OVERVIEW ON SC CH-CAVITY DEVELOPMENT*

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Abstract

During the last decades an enormous effort has been put into the development of low beta structures for hadron acceleration worldwide. Since hadrons exhibit a very inert velocity gain due to their high mass this change in speed has to be taken into account when utilizing low beta cavities. At the Institute of Applied Physics (IAP), Frankfurt, Germany, five multi-cell CH-cavities (Crossbar H-Mode) have been developed and tested for different kind of applications so far. In addition to the successfully tested original 360 MHz prototype further structures envisaged for beam operation have been fabricated and tested. Overview, status and outlook of this cavity technology is topic of this contribution.

OVERVIEW AND STATUS

360 MHz CH-cavity Prototype

The first milestone in the development of superconducting CH-cavities was the successful design and test of the 360 MHz, 19-cell, $\beta_{\text{geom.}} = 0.1$ CH-cavity [1]. After several chemical and HPR (High Pressure Pure Water Rinsing) treatments this resonator reached an accelerating gradient of 7 MV/m (see Fig. 1), accordingly 5.6 MV of voltage in total. It was the first tested, low-beta, multi-cell cavity with

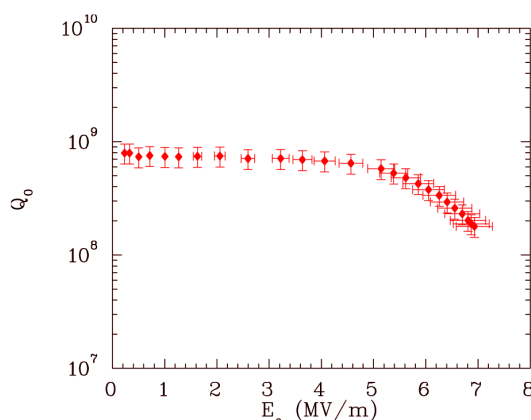


Figure 1: Q_0 - E_a -curve of the 360 MHz CH-prototype [2].

an unrivaled voltage gain worldwide. Meanwhile the cavity has been reactivated to serve for investigations regarding

advanced surface processing schemes like mild baking concepts or plasma discharge cleaning.

Compact 325 MHz CH-cavity

The next step was the design of a compact, 7-cell, 325 MHz CH-cavity at $\beta_{\text{geom.}} = 0.16$ and a new kind of tuning system to adjust the frequency dynamically both slowly and fast during beam operation [3–5]. The novel tuner consists of a bellow type geometry which is put inside the cavity and connected to the outside by a rod and can be operated by a piezo and a stepping motor drive, respectively. Four additional flanges for surface preparation enable an improved cavity performance after HPR. Another aspect providing a compact geometry was the implementation of inclined stems at the first and last drift tube. Consequently, this cavity achieved an accelerating gradient of 8.5 MV/m at 4 K resulting in a voltage of 4.2 MV. Furthermore, tests at 2 K yielded a gradient of 14.1 MV/m (see Fig. 2) and a voltage of 7 MV, respectively [6, 7].

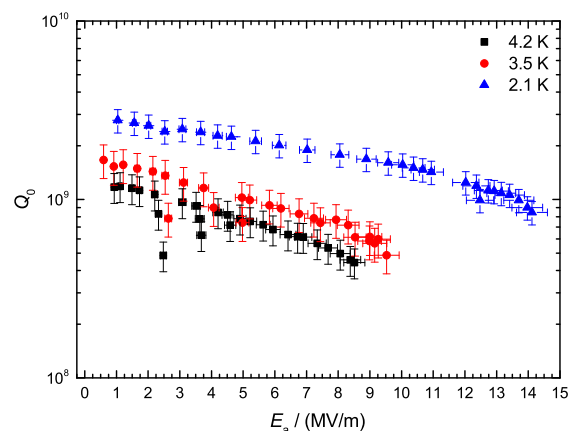


Figure 2: Q_0 - E_a -curve of the 325 MHz CH-cavity [7].

217 MHz Demonstrator Cavity (CH0) for HELIAC

With the very promising results from the previous two cavities it was decided to elaborate a newly planned, dedicated, energy-variable, superconducting, cw heavy ion linac: HELIAC (HELMholtz LINEar ACcelerator) at GSI, Darmstadt, in collaboration with HIM Mainz and GU Frankfurt based upon the aforementioned novel type of multi-cell resonators with EQUUS (EQUidistant mUltigap Structure) beam dynamics concept [8–10]. As a first step towards

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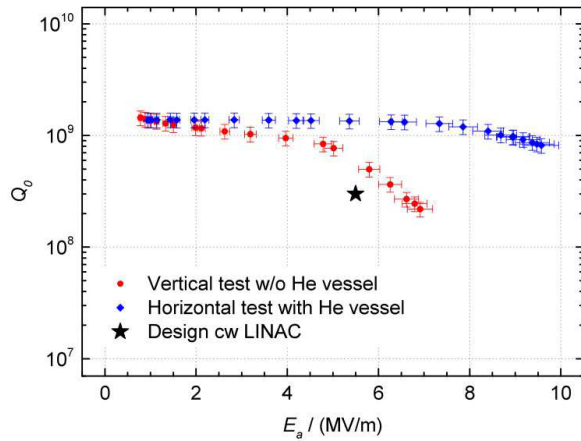


Figure 3: Q_0 - E_a -curve of the 217 MHz CH0 cavity for the HELIAC project [11].

the whole linac a so-called demonstrator cryomodule comprising two sc 9.3 T solenoids and a novel sc 217 MHz CH-cavity (CH0) with 15 equidistant accelerating gaps has been developed [12–15]. The geometry of CH0 is even more complex and challenging than the structure of the 325 MHz CH-cavity due to the higher amount of accelerating gaps and tuners and the lower β (thus, providing less space). After final surface preparation (BCP (**B**uffered **C**hemical **P**olishing + **H**PR)) the cavity was delivered to IAP for tests in a vertical cryostat surpassing the demanded design gradient and quality factor despite field emission (see Fig. 3, red circles) [16]. Returning to Research Instruments (RI, manufacturer) for the final assembly of the helium vessel and further HPR preparation the cavity has been tested at GSI inside a horizontal cryostat. Due to an HPR treatment utilizing the additional preparation flanges the performance of the cavity could significantly be improved. An accelerating gradient of 9.6 MV/m at $Q_0 = 8.14 \times 10^8$ has been achieved (see Fig. 3, blue rhombs) [11, 17]. Furthermore, cavity CH0 has successfully been installed at GSI inside the demonstrator cryomodule (together with the two sc solenoids) and accelerated heavy ion beams from the HLI (High Charge State Injector) with various mass-to-charge ratios [18, 19]. Also the tuning system based on bellow tuners could successfully be operated during the beam tests with a stepper motor [20].

CH1/2 for the HELIAC Project

Another step further leading to HELIAC was realized within the development of the Advanced Demonstrator concept [21–23]. For this cryomodule scheme two structurally identical CH-cavities (CH1 and CH2 in the HELIAC pattern) have been developed at IAP [24]. After fabrication and surface processing of CH1 this cavity reached a gradient of 9 MV/m (at $Q_0 = 2.4 \times 10^8$) in a first vertical test setup in Frankfurt (see Fig. 4) [25]. By now this cavity has been returned to RI for further surface cleaning processes. Meanwhile CH2 is prepared for first cold tests inside the vertical cryostat at Frankfurt.

MC7: Accelerator Technology

T07 Superconducting RF

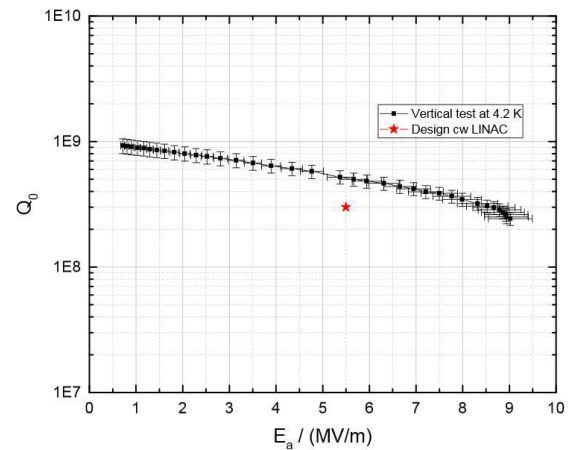


Figure 4: Q_0 - E_a -curve of the 217 MHz CH1 cavity for the HELIAC project [25].

CONCLUSION AND OUTLOOK

CH-cavities have proven to deliver high real estate gradients and in this context also high voltage gains enabling compact, energy-variable Linacs with a minimum number of resonators and concurrently preserving beam quality [26]. As a follow up of CH0, CH1 and CH2 the next HELIAC cavities are under design investigation with a main focus of attention to geometry and tuner design. Figure 5 shows the present simulation status. All cavities described in the previous chapters are depicted in Fig. 6 and their rf parameters are summarized in Table 1.

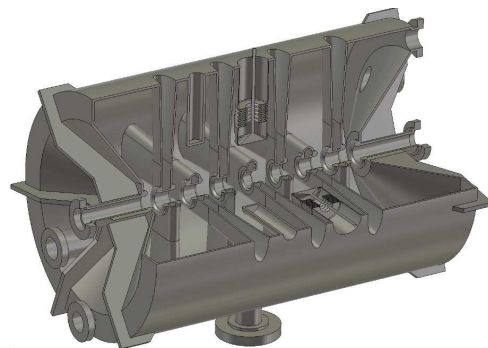


Figure 5: Design status of 217 MHz CH3 cavity for the HELIAC project.

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Figure 6: From left to right: 360 MHz CH-cavity prototype, 325 MHz CH-cavity, 217 MHz CH0 and CH1/2 from the HELIAC project.

Table 1: Main RF Parameters of the CH-Cavities

Parameter and Unit	360 MHz CH	325 MHz CH	217 MHz CH0	217 MHz CH1
f in MHz	360	325	217	217
No. of cells	19	7	15	8
β	0.1	0.16	0.059	0.069
Length ($\beta\lambda$ -def.) in mm	810	505	612	382
Diameter in mm	274	347	409	400
E_a in MV/m (at 2 K)	7	8.5 (14.1)	9.6	9
E_p/E_a	5.6	5	6.3	6
B_p/E_a in mT/(MV/m)	5.7	13	5.7	<10
G in Ω	56	66	52	50
R_a/Q_0	3180	1260	3240	1070

REFERENCES

[1] H. Podlech *et al.*, “Superconducting CH structure”, *Phys. Rev. ST Accel. Beams*, vol. 10, 080101, 2007. doi:10.1103/PhysRevSTAB.10.080101

[2] H. Podlech *et al.*, “New Cavity Shape Developments for Low Beta Applications”, in *Proc. 14th Int. Conf. RF Superconductivity (SRF’09)*, Berlin, Germany, Sep. 2009, paper THOAAU06, pp. 473–478.

[3] M. Busch, M. Amberg, W. A. Barth, F.D. Dziuba, H. Podlech, and U. Ratzinger, “Superconducting CH-cavity Development”, in *Proc. 1st Int. Particle Accelerator Conf. (IPAC’10)*, Kyoto, Japan, May 2010, paper MOPD032, pp. 753–755.

[4] M. Busch *et al.*, “Status of the 325 MHz SC CH-cavity at IAP Frankfurt”, in *Proc. 2nd Int. Particle Accelerator Conf. (IPAC’11)*, San Sebastian, Spain, Sep. 2011, paper MOPC082, pp. 265–267.

[5] M. Amberg *et al.*, “Structural Mechanics of Superconducting CH Cavities”, in *Proc. 2nd Int. Particle Accelerator Conf. (IPAC’11)*, San Sebastian, Spain, Sep. 2011, paper MOPC083, pp. 268–270.

[6] M. Busch, M. Amberg, F.D. Dziuba, H. Podlech, and U. Ratzinger, “Cold Power Tests of the SC 325 MHz CH-cavity”, in *Proc. 27th Linear Accelerator Conf. (LINAC’14)*, Geneva, Switzerland, Aug.-Sep. 2014, paper THPP068, pp. 1007–1009.

[7] M. Busch, M. Amberg, M. Basten, F.D. Dziuba, H. Podlech, and U. Ratzinger, “Recent Measurements on the SC 325 MHz CH-cavity”, in *Proc. 17th Int. Conf. RF Superconductivity (SRF’15)*, Whistler, Canada, Sep. 2015, paper MOPB065, pp. 255–257.

[8] S. Minaev, U. Ratzinger, H. Podlech, M. Busch, and W. Barth, “Superconducting, energy variable heavy ion linac with con-

[9] W. Barth *et al.*, “A superconducting cw-linac for heavy ion acceleration at GSI”, *EPJ Web Conf.*, vol. 138, p. 01 026, 2017. doi:10.1051/epjconf/201713801026

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

[11] F.D. Dziuba *et al.*, “First Cold Tests of the Superconducting cw Demonstrator at GSI”, in *Proc. 25th Russian Particle Accelerator Conf. (RuPAC’16)*, Saint Petersburg, Russia, Nov. 2016, pp. 84–86. doi:10.18429/JACoW-RUPAC2016-WECEMH01

[12] F.D. Dziuba *et al.*, “Development of Superconducting CH Cavities”, in *Proc. 15th Int. Conf. RF Superconductivity (SRF’11)*, Chicago, IL, USA, Jul. 2011, paper MOPO037, pp. 169–171.

[13] F.D. Dziuba *et al.*, “Status of the Superconducting CW Demonstrator for GSI”, in *Proc. 26th Linear Accelerator Conf. (LINAC’12)*, Tel Aviv, Israel, Sep. 2012, paper TUPB072, pp. 639–641.

[14] V. Gettmann *et al.*, “Status of the SC CW-Linac Demonstrator”, in *Proc. 16th Int. Conf. RF Superconductivity (SRF’13)*, Paris, France, Sep. 2013, paper MOP006, pp. 80–82.

[15] F.D. Dziuba *et al.*, “A Superconducting 217 MHz CH Cavity for the CW Demonstrator at GSI”, in *Proc. 16th Int. Conf. RF Superconductivity (SRF’13)*, Paris, France, Sep. 2013, paper THP006, pp. 906–908.

[16] F.D. Dziuba *et al.*, “First Performance Test on the Superconducting 217 MHz CH Cavity at 4.2 K”, in *Proc.*

- 28th Linear Accelerator Conf. (LINAC'16), East Lansing, MI, USA, Sep. 2016, pp. 953–955. doi:10.18429/JACoW-LINAC2016-THPLR044
- [17] F.D. Dziuba *et al.*, “Performance Tests of the Superconducting 217 MHz CH Cavity for the CW Demonstrator”, in *Proc. 18th Int. Conf. RF Superconductivity (SRF'17)*, Lanzhou, China, Jul. 2017, pp. 440–443. doi:10.18429/JACoW-SRF2017-TUPB024
- [18] W. Barth *et al.*, “First heavy ion beam tests with a superconducting multi-gap CH cavity”, *Phys. Rev. Accel. Beams*, 21 020102, 2018. doi:10.1103/PhysRevAccelBeams.21.020102
- [19] W. Barth *et al.*, “Superconducting CH-Cavity Heavy Ion Beam Testing at GSI”, *J. Phys.: Conf. Ser.*, vol. 1067, 052007, 2018. doi:10.1088/1742-6596/1067/5/052007
- [20] F.D. Dziuba *et al.*, “Further RF Measurements on the Superconducting 217 Mhz CH Demonstrator Cavity for a cw Linac at GSI”, presented at the 10th International Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May. 2019, paper WEPRB014, this conference.
- [21] W.A. Barth *et al.*, “Further Investigations for a Superconducting cw-LINAC at GSI”, in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 2197–2200. doi:10.18429/JACoW-IPAC2017-TUPVA055
- [22] M. Miski-Oglu *et al.*, “Steps Towards Superconducting CW-LINAC for Heavy Ions at GSI”, in *Proc. 17th Int. Conf. RF Superconductivity (SRF'15)*, Whistler, Canada, Sep. 2015, paper MOPB067, pp. 262–264.
- [23] W.A. Barth *et al.*, “Further Layout Investigations for a Superconducting CW-linac for Heavy Ions at GSI”, in *Proc. 18th Int. Conf. RF Superconductivity (SRF'17)*, Lanzhou, China, Jul. 2017, pp. 108–111. doi:10.18429/JACoW-SRF2017-MOPB023
- [24] M. Basten *et al.*, “Development of a 217 MHz Superconducting CH Structure”, in *Proc. 27th Linear Accelerator Conf. (LINAC'14)*, Geneva, Switzerland, Aug.-Sep. 2014, paper TUPP060, pp. 563–565.
- [25] M. Basten *et al.*, “Cryogenic Tests of the Superconducting beta=0.069 CH-cavities for the HELIAC-project”, in *Proc. 29th Linear Accelerator Conf. (LINAC'18)*, Beijing, China, Sep. 2018, pp. 855–858. doi:10.18429/JACoW-LINAC2018-THP0072
- [26] M. Schwarz *et al.*, “Advanced Beam Dynamics Design for the Superconducting Heavy Ion Accelerator HELIAC”, presented at the 10th International Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May. 2019, paper MOPTS034, this conference.