ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

COMMISSIONING OF A CLEANROOM FOR SRF ACTIVITIES AT THE HELMHOLTZ INSTITUTE MAINZ

T. Kürzeder[1,2†], K. Aulenbacher[1,2,3], W. Barth[1,2], C. Burandt[1,2], J. Conrad[4], F. Dziuba[1,2,3], V. Gettmann[1,2], R. Heine[1,2,3], F. Hug[3], S. Lauber[1,2], J. List[1,2], M. Miski-Oglu[1,2], T. Stengler[3], S. Yaramyshev[2]
[1]HIM, Helmholtz Institute Mainz, Mainz, Germany
[2]GSI, Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
[3]JGU, Johannes Gutenberg-Universität Mainz, Mainz, Germany
[4]Technische Universität Darmstadt, Darmstadt, Germany

Abstract

A newly built cleanroom is under commissioning at the Helmholtz-Institute Mainz (HIM). In its ISO-class 6 area vacuum components and cavities can be cleaned in different ultrasonic baths and in a dedicated conductance rinsing bath. In the ISO-class 4 area a large vacuum oven offers the possibility for comprehensive drying. A high pressure rinsing cabinet (HPR) has been installed between the two cleanroom areas to be loaded and unloaded from both sides. Complete cold-strings have to be mounted in the ISO-class 4 area and to be rolled out of the cleanroom on a rail system installed on the floor. All installations and tools have been integrated to treat and assemble superconducting 217 MHz multigap crossbar cavities for the Helmholtz Linear Accelerator (HELIAC), which is under development by HIM and GSI. Those crossbar H-mode (CH) cavities have a diameter of 650 mm and a weight of up to 100 kg. The cleanroom will be also used for the Mainz Energy-Recovering Superconducting Accelerator (MESA) project, processing the TESLA/XFEL type 9-cell cavities and other beamline components. This paper introduces the cleanroom and its installations and presents some particle measurements at rest and from tools during operation.

INTRODUCTION

On the campus of the Johannes Gutenberg University in Mainz (JGU) a new building of the Helmholtz Institute Mainz (HIM) started its regular operation in January 2017. It comprises a cleanroom (CR) [1], which is foreseen as part of the infrastructure for the SRF projects at GSI in Darmstadt and JGU in Mainz. The HElmholtz LInear ACcelerator (HELIAC) [2-5] will use 217 MHz superconducting crossbar H-mode (CH) cavities [6-9] and is currently under development at HIM and GSI. The GSI UNILAC, recently upgraded for FAIR short pulse operation with high intense heavy ion [10-13] and proton beams [14,15] does not satisfy the requirements for the SHE- and other high duty factor user-programs [16,17] anymore. Therefore HELIAC will be an additional stand-alone Linac fulfilling those needs. Its first cavity was already successfully tested, accelerating different mass to charge ratio ion beams in 2017 [18]. The Mainz Energy-Recovering Superconducting Accelerator (MESA) uses 1.3 GHz TESLA/XFEL type 9-cell cavities. Its 2 cryo-modules each equipped with two of those cavities are currently tested at HIM for acceptance on site [19, 20]. The dimensions of the cleanroom and its installations and tools were chosen to serve both projects.

CLEANROOM LAYOUT

The cleanroom is divided in an ISO-class 6 (CR 1) and an ISO-class 4 (CR 2) area. Pictures of both rooms can be seen in Figs. 1 and 2. Together with its greyroom and air locks, the cleanroom covers an area of 155 m^2. A facility for ultrahigh purity water is located at the basement of the HIM building. It produces, when needed, up to 2.5 m^3 deionized (DI) water per hour with a conductivity of less than 1 µS/cm. 5200 l of this DI water are stored in a buffer tank. For all applications performed in the cleanroom an additional purification process lowers the conductivity down to 0.056 µS/cm, a 0.2 µm particle filter ensures for sufficiently high quality of the water.

Figure 1: Fisheye perspective of CR 1 (ISO-6). In the middle part the US and C-rinse baths are shown, on the left: Personnel air lock, roll-up door and part of the HPR.

Figure 2: Photo of CR 2 (ISO-4): the HPR with its lever for the movable wand (on top) is shown. The door of the vacuum oven and a lift trolley is shown as well.

All rooms and locks of the cleanroom together with data of their ISO-class, size, overpressure and changes of their air per hour are listed in Table 1. Figure 3 shows a sketch of the cleanroom with its major installations. The typical

† t.kuerzeder@gsi.de

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

transfer paths for objects are illustrated. The personnel enter CR 1 room through an air lock, where cleanroom clothes have to be put on. Objects, such as RF-cavities, will be brought in by a different air lock via the grey room. In this air lock wet pre-cleaning with a high pressure DI water cleaner (car wash) is possible. To enter CR 2 every person has to go through the next air lock including an air shower.

In CR 1 components and tools will be prepared and cleaned before they get transferred to CR 2. Therefore, the main feature inside the ISO-6 zone is a large ultrasonic bath (USB) and a conductance rinse bath (C-rinse). The USB has an immersion depth of approximately 1.4 m and a usable width of 750 mm × 750 mm. Ultrahigh purity water can be used together with a soapy detergent to remove any grease. During the process the water can be heated up to 80°C, while the liquid is pumped in a cycle through a particle filter removing all residual (pollute) particles, e.g. metal shavings. A lifter unit, capable for a load of 300 kg allows to move objects to the C-rinse of the same size, and after that to an unload/load position. After cleaning, objects can be brought through a lock into CR 2 for drying. RF-cavities can be loaded from CR 1 into a high pressure rinsing cabinet and can be unloaded in CR 2 (ISO 4) side after the rinsing process. Thus the HPR serves also as an air lock between the two cleanrooms. Inside the cabinet the cavity is fixed on a rotating table, while the HPR wand is moving up and down spraying ultrahigh purity water at 100 bar on the inner surfaces. Cavities of up to 1.3 m in length (and even longer if using a shorter table) and up to 1.3 m in diameter can be treated. Wet objects are left in the laminar flow of the ISO-class 4 for drying, alternatively a large vacuum oven in CR 2 can be used to perform an efficient drying procedure of the surfaces. Its usable inner dimensions are 0.9 × 0.9 × 1.5 m^3, applying oil free vacuum pumps and filtered nitrogen for ventilation. During a 120°C bake out the cavity and furnace volume can be pumped separately on demand.

Table 1: Different Cleanroom Sections with Main Parameters as ISO-class, Size, Overpressure and the Changes of Air per Hour (φ). Their Purposes and Features are also listed. The Greyrooms fulfill ISO 8 Margins in Terms of Particle Concentrations at Rest.

Room	ISO	A [m^2]	$(P - P_0)$[Pa]	φ [1/h]	Main purpose / features
Greyroom 1	(8)	18	10	-	Access to car wash, power supplies (USB)
Personnel air lock	6	4.3	30	100	Locker room, CR-clothes, hand-disinfection
Material air lock	6	3.2	30	60	High pressure DI water cleaner (car wash)
Cleanroom 1	6	42	45	60	Cleaning, preparation / large USB and C-rinse
Personnel air lock	4	1.3	45-75	-	Air shower before entering CR 2
Material lock	6	2.1	75	300	Roll-up door + curtain between CR 1 and CR 2
Cleanroom 2	4	43	75	300	cold-string assembly / 160°C CR vacuum oven
HPR cabinet	4	1.9	≥ 75	-	Accessible from CR 1 and CR 2
Greyroom 2	(8)	18	10	-	Infrastructure (Oven and HPR), power supplies

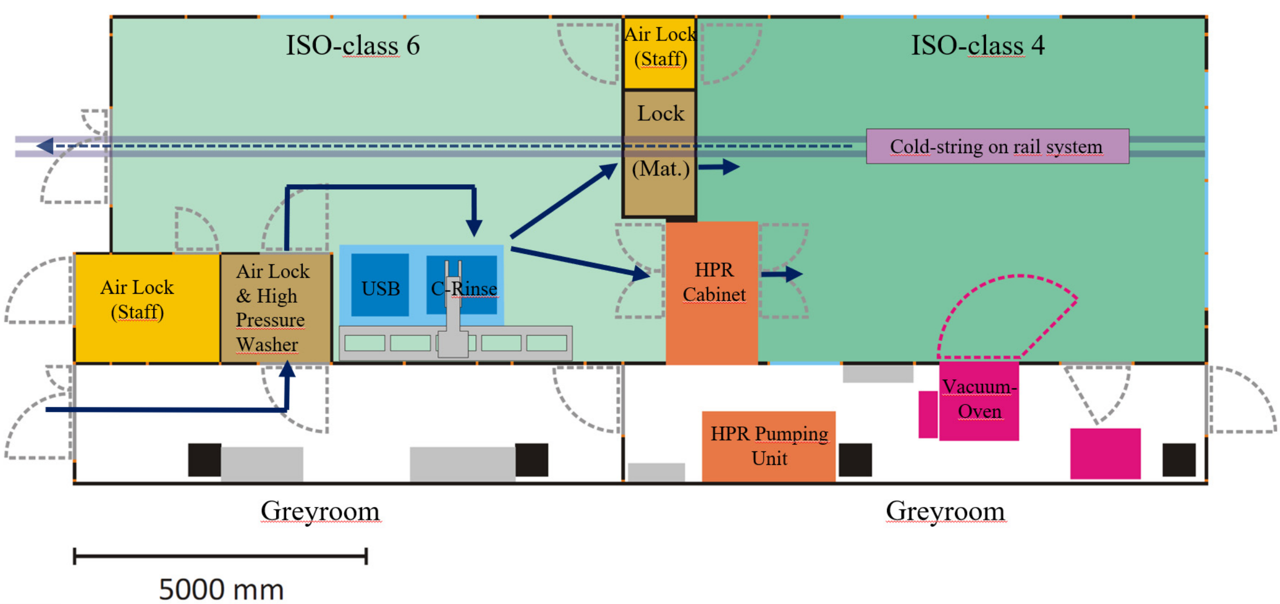

Figure 3: Sketch of the HIM-cleanroom. The ISO-class 6, -class 4 and greyroom areas are shown, as well as the different features such as air locks for personnel and objects, large ultrasonic (USB) and conductance rinsing (C-Rinse) baths with their crane, a high pressure rinsing (HPR) cabinet, vacuum oven and mounting rail for cold-string assembly and transportation. Typical transfer paths for objects and material (blue arrows) are depicted.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

The final assembly of cold strings has to be executed in CR 2. All parts of the cold-string will be mounted on support tables, which are sitting on a rail system in the cleanroom floor. Once the beam vacuum is closed, the entire string can be rolled back in CR 1 and at last outside of cleanroom. Prior to this, leak tests can be performed in the CR 1 or 2.

PARTICLE MEASUREMENTS

The cleanroom without equipment and machines was already put into operation in November 2015. In summer 2017 the CR was shut down, several walls and part of its roof and ceiling were opened to bring in the large USB, the C-rinse together with its lever system, the HPR cabinet and its 100 bar water pumping unit and the large vacuum oven with its accessory. Bringing in all new devices, the reconstruction of the cleanroom walls, additional feed-throughs and attachments generated a lot of additional contaminations. After this and before recommissioning of the cleanroom, the vendor provided for major cleaning of all surfaces. Following this, the cleanroom was re-classified by the same vendor in 2018. It was observed, that the particle concentrations were higher compared to the first commissioning in 2015. While CR 2 met the ISO-4 criteria, CR 1 was not ISO-class 6 conform to new ISO 14644-1:2015 norm anymore. The upper limit for particles/m^3 (≥ 5 µm) has been significantly exceeded at one single measuring point. For cleanroom classifications the particle counters are placed on evenly spread positions. Exemplary, Fig. 4 shows a comparison of particle concentrations in CR 1 (ISO 6). It compares the results at the points of measurements with the highest particle concentration per cubic meter. As shown (2019 measurement) the particle concentration went down significantly, since all rooms were regularly cleaned. To the best of our present knowledge a weekly cleaning of the floors and working surfaces and a monthly cleaning including walls, ceilings and other hard reachable places is sufficient to keep the particle concentration low (even if this is not industry standard for ISO-class 6 and 4). Once per year also the ground underneath the double floor has to be cleaned.

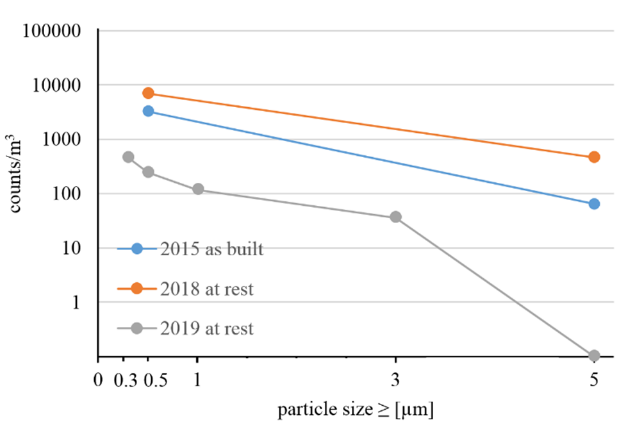

Figure 4: Particle concentrations at the “worst” spot of CR 1 during classification measurements after the CR was built (2015), altered (2018) and today (2019).

Roll-up Door

Due to limited space, the access door for material between cleanroom 1 and 2 is not built as an air lock. Instead of this, a roll-up door serves as a barrier to the ISO 6 and vertical blinds to the ISO 4 CR enclosing an area of just 2.1 m^2 as a lock (see Figs. 1 and 2). For this, if the roll-up door is opened, the pressures of both rooms are instantly equalized. In any case this causes a turbulences, when the air from the ISO 4 is streaming over, also the vertical blinds are flapping. For further investigations of particle concentrations in the CR the door was opened and closed every two minutes (the door was open for 15 seconds). While counting particles the probe was 65 cm above the floor* (see Fig. 5). One measuring point was just in front of the door in CR 1 (ISO 6) and the other was on the inside of the lock (ISO 4). The results are depicted in Fig. 6. Even in operation the inside of the lock meets the ISO-class 4 criteria. In comparison to a measurement at rest the particle concentration on the ISO 6 side (CR 1) is much higher, but still within the norm margins.

Figure 5: Closed (left) and opened (right) rool-up door with the particle counter placed in front of it in CR 1.

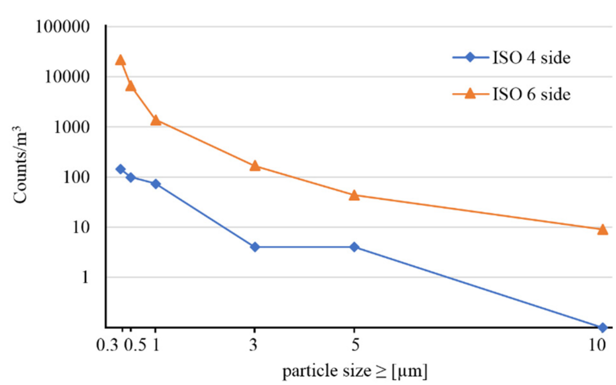

Figure 6: Measured particle concentrations during roll-up door operation inside the lock (ISO 4) and on ISO 6 side.

Cleanroom Lift Trolleys

Each room is equipped with a dedicated cleanroom lifter to transport cavities and other heavy objects. In Fig. 7 the lifter is shown; all surfaces are built from stainless steel or transparent plastic with rounded edges for eased wiping.

*Particle counter: AeroTrak® Modell 9310

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

The motor is covered at the top, driving the mechanism which rolls up or off a washable polyester belt. This allows to move a rotatable along its pole carrying objects of up to 200 kg. It was designed to hand over cavities to the crane of the ultrasonic bath, the HPR and the vacuum oven vertically and to place them horizontally for cold-string assembly. Most of the particles which are produced by the roll-up mechanism are guided by the covers along the pole down to the floor.

Figure 7: The photo on the left shows the trolley, while on the right the lift trolley during testing of the cleanroom infrastructure with a 3 GHz cavity [21] from TU Darmstadt is depicted; handing over a cavity in its frame to the lifter system of the ultrasonic bath.

For a first investigation the probe of a particle counter was placed just beneath the pole. During the measurement the fork was moved up and down with maximum speed but without any object on it. More than 8000 particles ≥ 0.3 µm were counted per square foot. Therefore, we disassembled all cover sheets from the trolley and wiped all surfaces and the belt again. Those measures ensured a dramatic improvement (see Table 2). The lift trolley has proven itself to be a perfect tool for the handling of SRF cavities inside the HIM cleanrooms.

Table 2: Particle Measurement with CR Lift Trolley During Constant Operation. The probe was placed just beneath the pole. Slower Movement of the Fork Improves the Particle Concentrations

	Particles / ft^3 ≥ x µm				
	0.3	**0.5**	**1**	**5**	**10**
First test	8195	1500	364	3	1
After cleaning	62	9	2	0	0
Slow movement	30	3	0	0	0

HPR AT HIM-CLEANROOM

The HPR is accessible from two sides so it acts as an air lock for cavities which are brought in after ultrasonic cleaning and conductance rinse from the ISO-class 6 cleanroom (see Fig. 1). After HPR unloading is possible from the ISO-class 4 CR (see Fig. 2). The HPR wand is not fixed. It moves up and down during a rinsing program, moved by a lever on top of the cabinet in the ISO-class 4 (CR 2) room, entering it through a little hole. To avoid particles moving through that hole into the cabinet, two additional FFUs on top of the cabinet provide an overpressure on its inside. While the wand is moving up and down, the cavity is rotated on a table. This design was chosen in order to rinse CH-cavities off axis. Due to its complex geometrical structure, not all surfaces in a CH structure (see Fig. 8), can be polished reliably when only spraying along the beam axis.

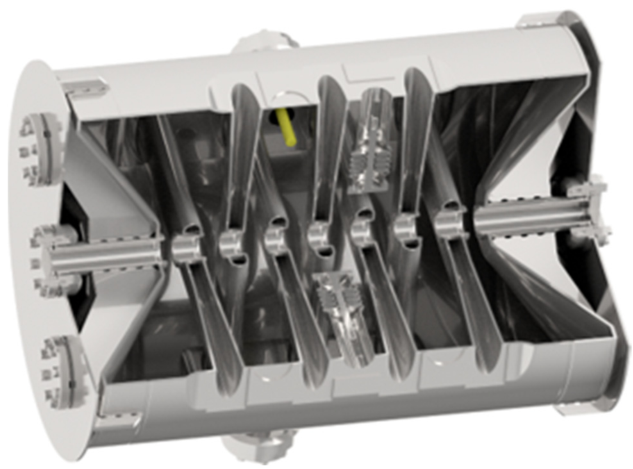

Figure 8: Sectional view of a 217 MHz CH cavity [22] for HELIAC; 10 cm off beam axis two openings from each side for additional rinsing of the four sector quadrants are available.

Typically, CH-cavities are equipped with two openings from each side (10 cm off beam axis) to rinse all four sector quadrants (Fig. 8). As a consequence for advanced off axis rinsing the cavity needs to be put 10 cm off centre on the rotating table. Thus the axis of rotation is fixed at the centre of the favoured quadrant, while the high pressure nozzle moves up and down. In Fig. 9 the rotation process is shown schematically: For rinsing of each quadrant, the cavity has to be relocated on the table and once it has to be turned around. Through the openings on the opposite side the water can flow out during the rinsing process. So far, only rinsing along beam axis has been performed on CH-cavities and led to a significant performance improvement [6]. In the future it is envisaged that all CH-cavities will be rinsed along beam axis and in each of their four sector quadrants. The effect on the cavity performance after those treatments is part of further investigations.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

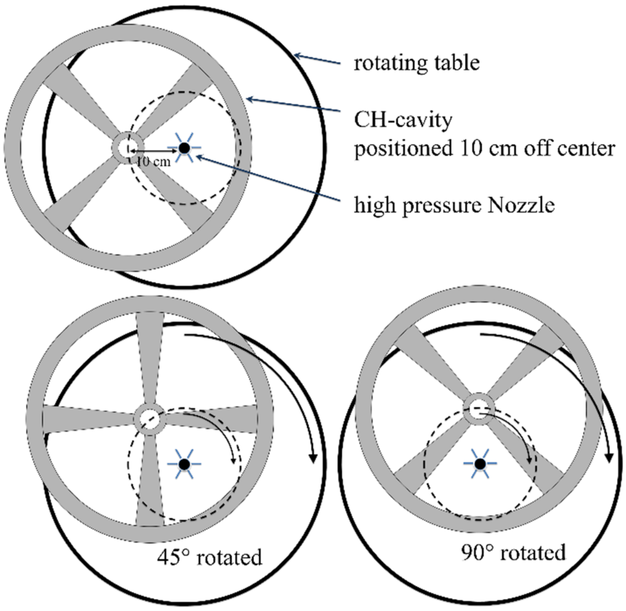

Figure 9: Schematic illustration of the high pressure rinsing process at one sector quadrant of a CH-cavity.

Figure 10: Photo of HPR cabinet with open doors taken from CR 1. A particle counter is placed on the rotating table.

Measurements with a particle counter (see Fig. 10) on the HPR table while rotating and its wand moving up and down (without spraying water) so far never counted more than 4 particles ≤ 0.5 µm per m^3. In a different measurement, the cabinet doors to the ISO-class 6 CR were opened, implicating that effectively the air above the HPR is sucked into the cabinet. Due to this only four particles were counted. Leaving the door open for a longer time did not cause additional particles. Therefore, the cabinet for itself seems to work excellent with respect to particle contaminations. In the future the particle production of the loading and unloading process of a cavity with a cleanroom lift trolley needs to be investigated and optimized as well.

RF TESTING AT HIM-LAB

Next to the cleanroom, in the same hall, a concrete shielded area for RF testing of superconducting cavities is located. Its inner dimensions of 4 × 13 m^2 offers adequate space for cryo-modules and further instrumentation. Liquid helium is supplied by a cryogenic transfer line from the liquefier of the JGU Institute for Nuclear Physics [23]. While HELIAC cavities will be operated at 4 Kelvin, a sub atmospheric compressor station can be used to lower the pressure of the helium bath down to 16 mbar in order to lower the temperature down to 1.8 K. At the moment, two cryo-modules with 1.3 GHz cavities for the MESA project are tested there [20]. After this testing the next two CH-cavities for HELIAC will be tested in a short horizontal test cryo-module, the demonstrator module which has been used for the first beam testing at GSI in Darmstadt. The shielded area is also allocated for future RF testing of the fully mounted HELIAC cryo-modules before they will be transported to the new HELIAC-bunker at GSI.

CONCLUSION

After installation of large ultrasonic bath and a conductance rinse bath, a HPR cabinet and a large vacuum oven the SRF cleanroom at HIM has been successfully re-classified. It could be shown, that particle concentrations went down due to regularly cleaning. The particle production of different tools in operation has been carefully investigated. So far, the results are very promising - further investigations have to be conducted in order to reduce all sources of particle contamination down to a minimum.

In the next months ahead, additional devices will be constructed and tested in order to prepare the cleanroom and its tools for the next cavity treatments. Assembly procedures have to be investigated as well.

REFERENCES

[1] F. Schlander *et al.*, “A New Cleanroom with Facilities for Cleaning and Assembly of Superconducting Cavities at Helmholtz-Institut Mainz”, in *Proc. 17th Int. Conf. RF Superconductivity (SRF'15)*, Whistler, Canada, Sep. 2015, pp. 575-577.

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

[3] W. Barth *et al.*, “First heavy ion beam test with a superconducting multigap CH cavity”, *Phys. Rev. ST Accel. Beams*, vol. 21, p. 020102, Feb. 2018.

[4] M. Schwarz *et al.*, "Beam Dynamics Simulations for the New Superconducting CW Heavy Ion LINAC at GSI", *J. Phys.: Conf. Ser.* 1067, p. 052006, 2018.

[5] S. Yaramyshev *et al.*, "Advanced Approach for Beam Matching along the Multi-Cavity SC CW Linac at GSI", *J. Phys.: Conf. Ser.* 1067, p. 052005, 2018.

[6] 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,

[7] H. Podlech *et al.*, "Superconducting CH structure", *Phys. Rev. ST Accel. Beams*, vol. 10, 080101, 2007.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP101

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

[9] K. Taletskiy *et al.*, "Comparative study of low beta multi-gap superconducting bunchers", *J. Phys.: Conf. Ser.* 1067 082006, 2018.

[10] W. Barth *et al.*, "U28+ intensity record applying a H2 gas-stripper cell", *Phys. Rev. ST Accel. Beams*, vol. 18,p. 040101, 2015.

[11] W. Barth *et al*., "Upgrade program of the high current heavy ion UNILAC as injector for FAIR", *Nucl. Instrum. Methods Phys. Res.,* Sect. A, vol. 577, no. 211, 2007.

[12] S. Yaramyshev *et al*., "Virtual charge state separator as an advanced tool coupling measurements and simulations", *Phys. Rev. ST Accel. Beams,* vol. 18, 050103, 2015.

[13] W. Barth *et al*., "High brilliance uranium beams for the GSI FAIR", *Phys. Rev. ST Accel. Beams*, vol. 20, 050101, 2017.

[14] A. Adonin *et al*., "Production of high current proton beams using complex H-rich molecules at GSI*", Rev. Sci. Instrum.* 87, 02B709, 2016.

[15] W. Barth *et al*., "Heavy ion linac as a high current proton beam injector", *Phys. Rev. ST Accel. Beams*, vol. 18, 050102, 2015.

[16] J. Khuyagbaatar *et al*., "48Ca + 249Bk Fusion Reaction Leading to Element Z=117: Long-Lived α-Decaying 270Db and Discovery of 266Lr", *Phys. Rev. Lett.* 112, 172501, 2014.

[17] M. Block *et al*., "Direct mass measurements above uranium bridge the gap to the island of stability", *Nature*, vol. 463, pp. 785–788, 2010.

[18] W. Barth *et al*., "Superconducting CH-Cavity Heavy Ion Beam Testing at GSI", *J. Phys.: Conf. Ser.* 1067 052007, 2018

[19] T. Stengler, K. Aulenbacher, F. Hug, D. Simon, and T. Kuerzeder, "Cryomodule Fabrication and Modification for High Current Operation at the Mainz Energy Recovering Superconducting Accelerator MESA", in *Proc. 18th Int. Conf. RF Superconductivity (SRF'17)*, Lanzhou, China, Jul. 2017, pp. 297-300.

[20] T. Stengler *et. al.*, "SRF testing for Mainz Energy Recovering Superconducting Accelerator MESA", presented at the 19th Int. Conf. on RF Superconductivity (SRF'19), Dresden, Germany, July 2019, paper TUP041, this conference.

[21] J. Conrad *et al.*, "Soft Chemical Polishing and Surface Analysis of Niobium Samples", *J. Phys. Conf. Ser.,* 1067, p. 082009, 2018.

[22] M. Basten *et. al.,* "Cryogenic tests of the superconducting beta=0.069 CH-cavities for the HELIAC-project" *LINAC´18,* ", Beijing, China, 2018.

[23] F. Hug *et. al.,* "Cryogenic Installations for Module Tests at Mainz", presented at the 19th Int. Conf. on RF Superconductivity (SRF'19), Dresden, Germany, July 2019, paper THP054, this conference.