STEPS TOWARDS SUPERCONDUCTING CW-LINAC FOR HEAVY IONS AT GSI

M. Miski-Oglu*, M. Amberg, V. Gettmann HIM, Mainz, Germany
W. Barth, GSI, Darmstadt; HIM, Mainz, Germany
K. Aulenbacher HIM Mainz, IKP Mainz, Germany
M. Heilmann, S. Mickat, S. Yaramyshev, GSI, Darmstadt, Germany
M. Basten, D. Bänsch, F. Dziuba, H. Podlech, U. Ratzinger,
IAP Frankfurt University, Frankfurt, Germany

Abstract

Providing heavy ion beams for the ambitious experiment program at GSI, the Universal Linear Accelerator (UNILAC) serves as a powerful high duty factor (25%) accelerator. Beam time availability for SHE-research will be decreased due to the limitation of the UNILAC providing a proper beam for FAIR simultaneously. To keep the GSI-SHE program competitive on a high level, a standalone sc cw-LINAC in combination with the upgraded GSI High Charge State injector is planned to build. In preparation for this the first linac section (financed by HIM and partly by HGF-ARD-initiative) will be tested in 2015 as a demonstrator. After successful testing the construction of an extended cryomodule comprising two further, but shorter CH cavities is foreseen to test until end of 2017. In this contribution the measurement of the beam parameters at the entrance of cw-demonstrator, the preliminary simulation of beam dynamics for the first stage of advanced demonstrator will be presented. As a final R&D step towards an entire linac an advanced cryo modules comprising up to five CH cavities is envisaged for 2019 serving for first user experiments at the coulomb barrier.

DEMONSTRATOR ENVIRONMENT AT GSI

The commissioning of the cw-demonstrator [1] consisting of 2 superconducting (**sc**) solenoids and the superconducting CH-cavity is scheduled for the first quarter of 2016. Figure 1 shows the demonstrator environment at GSI.

The beam with an energy of $1.4\,\mathrm{MeV/u}$ from existing high charge state injector (HLI) operating at $108\,\mathrm{MHz}$ is transported through the line comprising of quadrupole lenses for transversal matching and two rebuncher cavities for longitudinal matching to the demonstrator sc CH-cavity [2, 3]. The liquid He cryostat maintains the cooling of the cavity and two sc solenoids [4, 5] is placed within the radiation protection shelter.

EMITTANCE MEASUREMENT OF HLI BEAM

Within the preparations to commissioning of cw-demonstrator, during a beam time in 2015 the transverse emittance of the Ar^{7+} and Ar^{10+} beams from HLI injector was measured. The measurements was done by a slit-grid device [6]. Two stepping motor driven slits of $0.2\,\mathrm{mm}$ width, one in vertical and another in horizontal plane are installed in the vacuum chamber at the position of the cw-

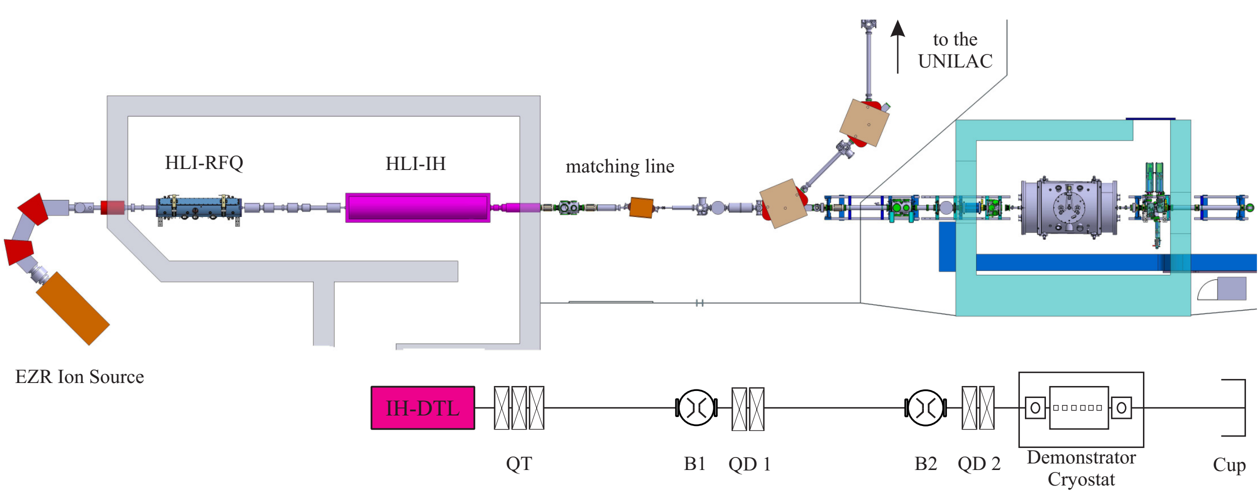

Figure 1: Top: footprint of the demonstrator test environment at GSI. Bottom: scheme of the beam line. The main elements of the beam line: quadrupole triplet QT, quadrupole doublets QD1 and QD2 and two buncher cavities B1, B2.

* m.miskioglu@gsi.de

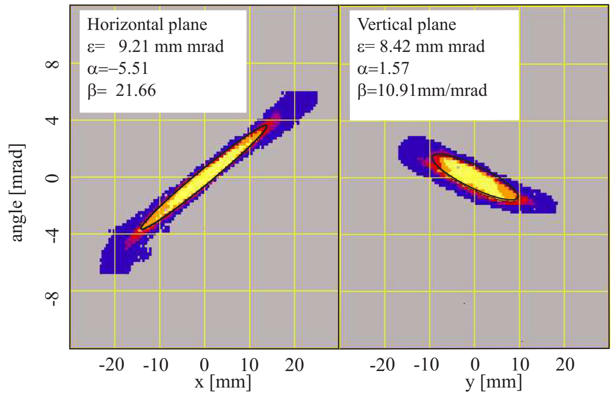

Figure 2: Example of measured emittance for Ar^{10+}. The black curves show $4 \cdot \epsilon_{rms}$ phase space ellipses.

demonstrator entrance. Two stepping motor driven SEM profile grids one for measurements vertical and another one in horizontal planes are installed in separate vacuum chamber downstream the beam line. The each grids contain 31 wires with 1mm interval. The distance between slit and grid for each plane is 1000 mm, which yields an angular resolution of 1 mrad. The slit and grid was moved in 0.5 mm steps in parallel with 4 intermediate grid steps, which increases the angular resolution up to 0.2 mrad.

Figure 2 shows the example of the transverse emittance measurement for an Ar^{10+} beam. In order to increase the significance of the measurement the emittance was measured for four different settings of quadrupole gradients (for Ar^{10+} beam) and three settings for (Ar^{7+} beam). The

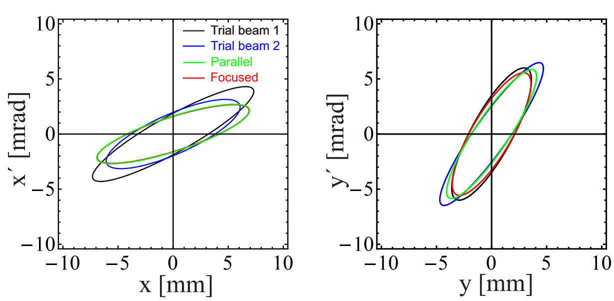

Figure 3: Backwards calculated phase space ellipses to the output of IH-DTL for four different sets of gradients for Ar^{10+} beam.

measured emittance was used to make backwards calculations to the output of the IH-DTL. For this purpose prior to the beam time the positions of quadrupoles was measured as well as the values of excitation currents was gauged with dedicated DC current transformer. The calculations has been done by the matrix code "TRACE 3-D" [7]. Figure 3 shows the calculated phase space ellipses backwards to the output of the IH-DTL for four different sets of quadrupole gradients for Ar^{10+} beam. The phase space ellipses for different settings deviate slightly due to 2% accuracy for measurement of excitation current of quadrupoles .

Figure 4 shows the comparison of averaged phase space ellipses for Ar^{10+} and Ar^{7+} beams. The deviations in

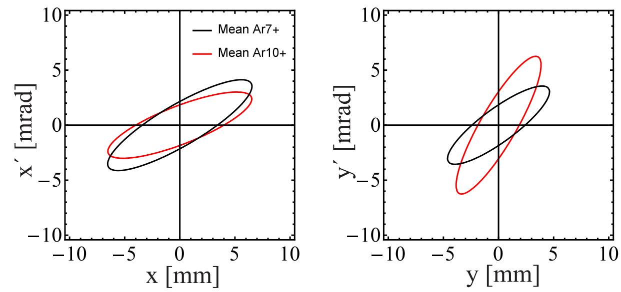

Figure 4: Comparison of averaged phase space ellipses for Ar^{10+} and Ar^{7+} beams.

$x - x'$ plane are of the same extent as that for individual measurements and can be explained by accuracy of current an position measurements of quadrupoles. However, the deviations in $y - y'$ are bigger due to the different settings of vertical steering magnets between RFQ and IH-DTL. Qualitatively the measurement results are in agreement with the design value of the HLI injector [8].

PRELIMINARY LAYOUT FOR FIRST STAGE OF ADVANCED DEMONSTRATOR

The first beam of the advanced demonstrator linac [9] containing up to nine superconducting cavities is scheduled for end of 2019.Figure 5 (top) shows the preliminary schematic layout of the first stage of the advanced demonstrator linac containing 3 sc CH-cavities operating at 217 MHz. The first cavity C1 is demonstrator cavity [2] consisting of 15 equidistant accelerating gaps for heavy ions with a synchronous velocity of $\beta = 0.059$. The cavities C2,C3 are so called short cavities [10] consisting of only 8 equidistant accelerating gaps for heavy ions with a synchronous velocity up to $\beta = 0.069$. The bottom panel of Fig. 5 shows the transversal and longitudinal beam envelopes calculated by LORASR code.

The input distributions fpr this calculations was determined from a measured phase space ellipses in transversal plane; design IH output distribution [8] in longitudinal plane. The beam with a mass to charge ratio equal to 6 at 1.4 MeV/u behind HLI is accelerated by three cavities up to 2.2 MeV/u. The cavity C1 produces a strongly convergent beam in both transversal and the longitudinal planes. Therefore the cavities C1 and C2 are placed in the same cryostat to minimize the distance between them. The beam focusing is maintained by superconducting solenoids S1-S3 providing the maximum fields of 9.3T at overall length of 380 mm and a free beam aperture of 30 mm. The design of solenoids is based on the 9 T sc solenoid for the ISAC-II cryo module [11]. The coil configuration with two main coils and two bucking coils was assumed to meet the demands at best. A fringe field of less then 40 mT in the cavity region can be achieved by using anti-windings. The delivery of two short cavities and the new cryostat for two cavities is scheduled to the third quarter of 2017, the first

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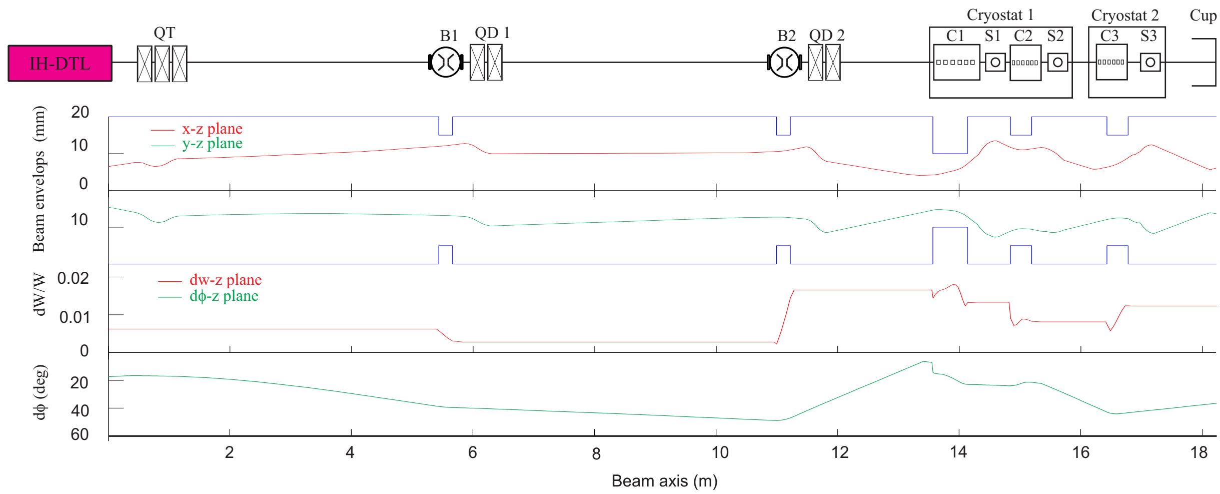

Figure 5: Top: preliminary layout of the first stage of the advanced demonstrator. Bottom: calculated transverse and longitudinal beam envelopes.

with the beam are planed on the end of 2017.

CONCLUSION

The design of the cw LINAC based on shorter sc CH-cavities could minimize the overall technical risk and costs. Applying short CH-cavities an optimized operation of the whole LINAC with respect to the beam quality could be achieved. A multistage approach of R&D is envisaged for fixing an optimized heavy ion cw-LINAC design.

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