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STRAIGHT INJECTION OF AN INTENSE URANIUM BEAM INTO THE GSI HIGH CURRENT RFQ

H. Vormann, S. Yaramyshev, A. Adonin, W. Barth, L. Dahl, P. Gerhard, L. Groening, R. Hollinger,
M. Maier, S. Mickat, A. Orzhekhovskaya, C. Xiao, GSI, Darmstadt, Germany

Abstract

A dedicated high current uranium ion source and LEBT will be built at the GSI High Current Injector (HSI), to fulfil the intensity requirements for FAIR (Facility for Antiproton and Ion Research at Darmstadt) [1, 2]. This new injection line will be integrated into the existing complex which already comprises two branches (Figure 1). The new LEBT is designed as a straight injection line without dipole magnet, i.e. without dispersive charge state separation. All uranium charge states, coming from the ion source, are transported to the heavy ion high current GSI-HSI-RFQ. Only the design charge state U^{4+} is accelerated to the final RFQ energy. The new LEBT design is based on beam emittance and current measurements behind the existing ion source. Beam dynamics simulations have been performed with the codes TRACE-3D (envelopes), DYNAMION, BEAMPATH and TRACK (multiparticle). The recent layout of the LEBT, as well as the results of beam dynamics studies are presented.

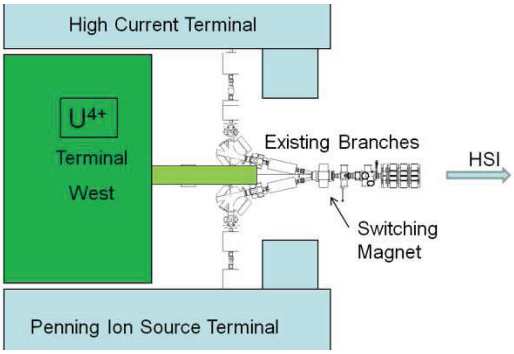

Figure 1: Location of the Compact-LEBT.

DESIGN OF THE NEW BEAM BRANCH

For the design of the new branch measurement data of uranium beam were required. Therefore direct uranium measurements have been performed in autumn 2013 at the existing high current ion source terminal (North Terminal) with the VARIS ion source [3]. Emittance measurements behind the first triplet of the beam line were made with the GSI standard mobile emittance device (horizontal and vertical, Figure 2). To measure the large beam directly behind the terminal, the special emittance measurement device from the high current test injector HOSTI (*german: HOch Strom Test Injektor*) was used (large grid size). Also tantalum beam was measured, to allow a comparison of the measurement results from HOSTI [4] and from North Terminal.

Measurements

The measurement campaign lasted from in June to October 2013, after installing the mobile emittance device in the existing high current beam line, downstream of the quadrupole triplet behind the ion source terminal. The high total uranium beam current of at least 55 mA behind the ion source (U^{4+} and U^{3+}) was reached as in the previous years.

In October the HOSTI emittance measurement device was installed instead of the triplet. The measurements confirmed the results of earlier measurements behind the triplet. This design allows matching of a beam with large emittance to the subsequent RFQ, with nearly 100% transmission of U^{4+} through the LEBT, U^{3+} can be scraped off with collimators. Remaining U^{3+} ions are not accelerated in the RFQ, and will be lost at low energies without damage of the machine.

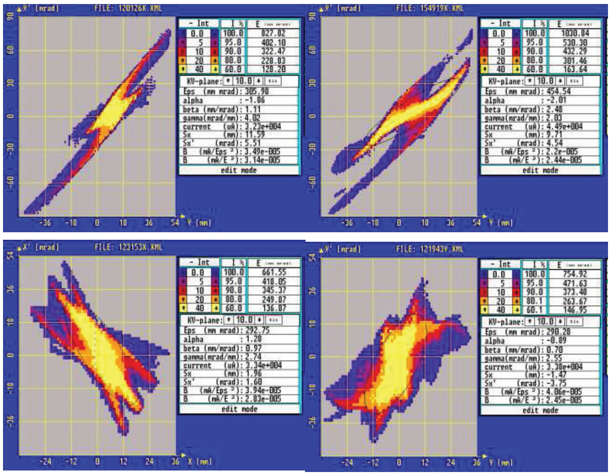

Figure 2: Measured emittances behind ion source post acceleration gap (top, horizontally 35 mA and 55 mA), and behind triplet (lower, horizontally and vertically).

Simulations

From the measurement data particle distributions were produced and tracked backwards through the triplet (Figure 3). A special analysis method "virtual charge state separator" allowed to quantify the partitions of the 3+ and 4+ charge states to 35% resp. 65%, in accordance with operation data with an analysing dipole magnet [5].

Based on these measurements, simulations for an optimised design have been performed, providing a versatile solution for matching to the downstream accelerator chain. This solution takes account for the two existing source branches for other ion species.

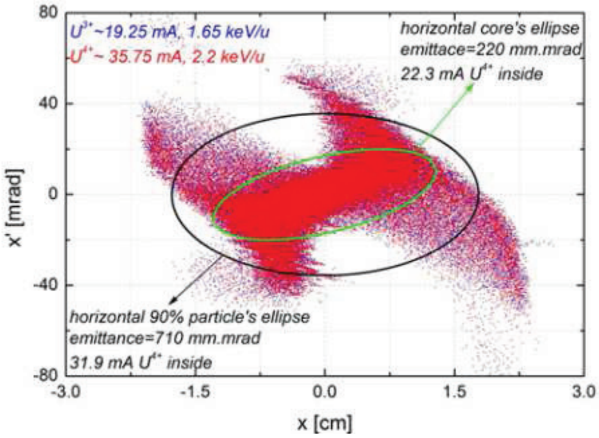

Figure 3: Particle distribution generated from high current measurement data (55 mA total, transformed backward).

The design consists of a quadrupole quartet QQ1directly behind the new ion source terminal, a new quadrupole triplet QT between the existing beam branches, to focus the beam through the switching magnet, and a second quadrupole quartet QQ2 for matching to the RFQ (Figure 4) [3]. QQ1 is newly built with large aperture (150 mm), QQ2 is in routine operation since 1999 (aperture 100 mm).

This proposed version (9.7 m long) allows matching of the U^{4+} beam (65% of 35 mA resp. 55 mA) to the RFQ, with high current RFQ transmission up to approx. 85%.

The measurement setup is shown in Figure 5.

In order to investigate the most compact LEBT, the particle distributions generated from the measurement data (Figure 3) were used also for simulations of a very short beam line with two solenoids as focusing elements, ignoring the existing LEBT environment. It was shown that within a dedicated emittance ellipse of 220 mm mrad 22.3 mA are included (see Figure 3). This is nominally less than required for FAIR (table 1), but one should consider that the development work with the HOSTI is aiming to optimise these beam current values. Furthermore, precise simulations have shown that the acceptance of the RFQ depends on the individual beam properties and allows acceleration of sufficient beam current.

Special care was taken for scraping off parasitic U^{3+} particles with a collimation aperture (Figure 6, Figure 7): In the long version of the LEBT at the RFQ entrance remain after collimation 16 mA U^{4+} out of the input distibution (see Figure 3), but only 4 mA of U^{3+}.

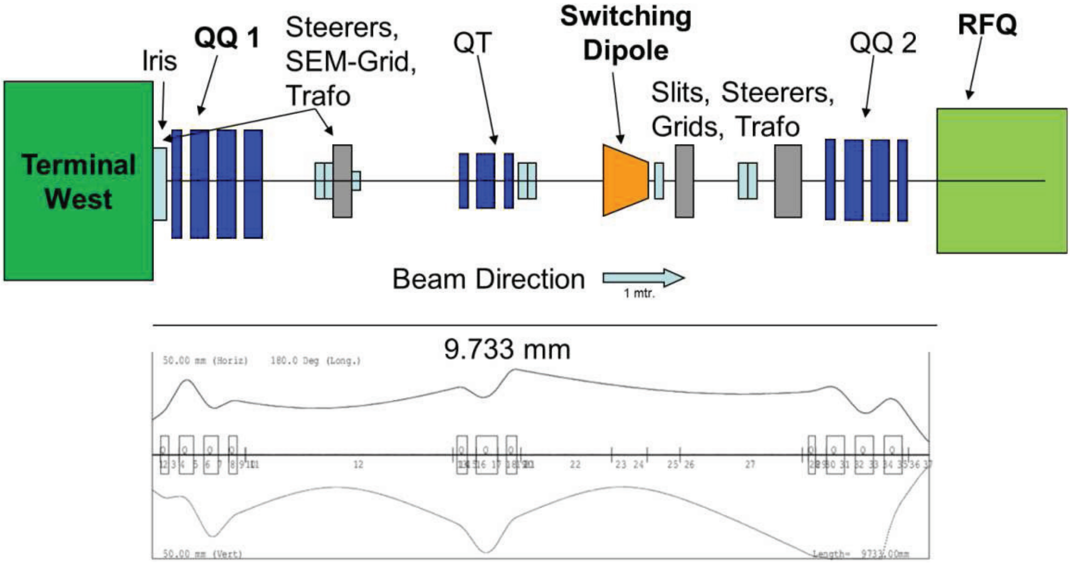

Figure 4: Layout of the new straight injection line.

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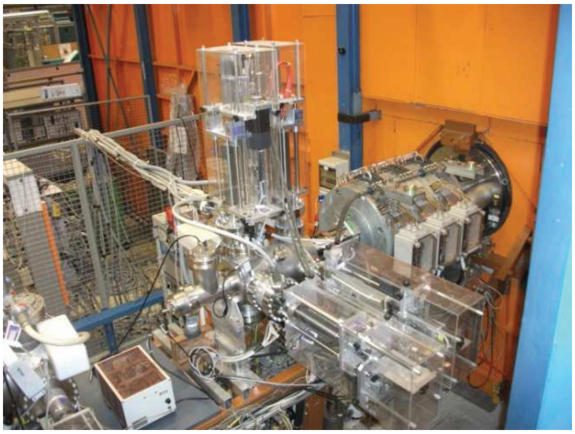

Figure 5: Emittance measurement device behind the quadrupole triplet.

Table 1: Required Uranium Beam Currents for FAIR

Position	Ion Beam Current	Within norm. Emittance, approx
RFQ input	25 mA	< 0.3
RFQ output	20 mA	< 0.5
HSI output (U4+)	18 mA	< 0.5
Alv. Input (U28+)	15 mA	< 0.75
Alvarez output	15 mA	< 0. 8(h)/2.5(v)

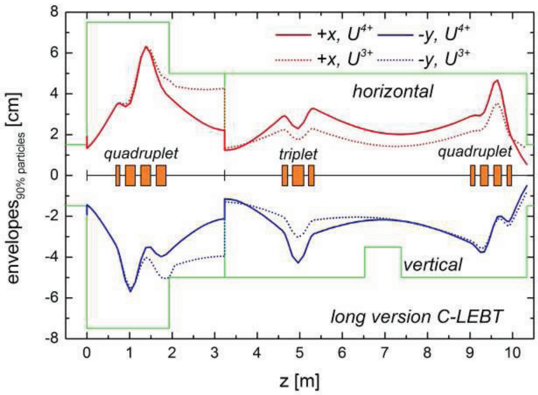

Figure 6: Beam envelopes (long version, space charge compensation 98%).

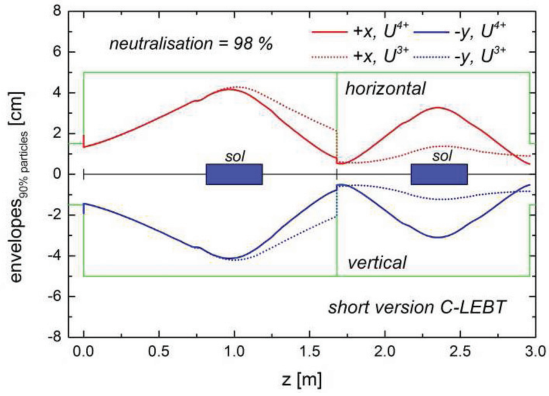

Figure 7: Beam envelopes (short version).

Simulations of the existing LEBT branches (Figure 1) are still ongoing. Special attention is paid to the influence of the 77.5 degree analysing dipole magnet, where the reason for a relatively large beam loss is expected.

STATUS OF MACHINE COMPONENTS

While beam diagnostics components with larger apertures in the existing straight part of the LEBT are already in operation since 2012, the new quadrupole quartet with enlarged aperture (150 mm diam., Figure 8) is not yet installed. After its delivery in 2012, precise field mapping has been done. A new switching magnet and steerers with larger aperture for the existing straight part of the LEBT are under design, the quadrupole triplet will be designed similar to the two already existing triplets.

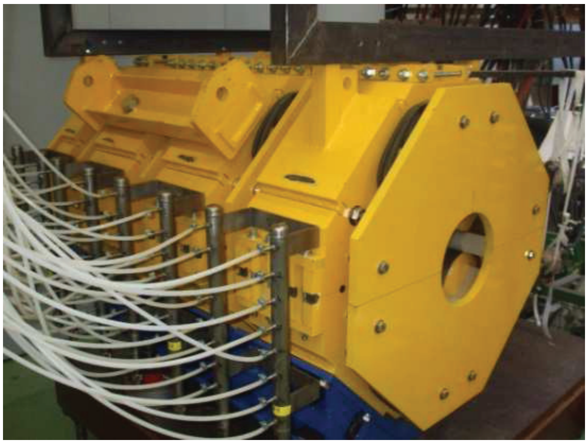

Figure 8: The new quadrupole quartet.

The general layout for the new compact uranium terminal (Terminal West) [6] contains a closed underpressure system, and all other sections like a high voltage area with power supplies, transformers, a working platform (closed electrical working area), and a service area with glove box (radiation protection controlled area).

REFERENCES

[1] L. Dahl, W. Barth et al., “Development of the Intensity and Quality of the Heavy Ion Beams at GSI”, proc. HIAT ,12, Chicago, USA (2012).

[2] L. Dahl et al., “A New LEBT and RFQ Radial Matcher for the UNILAC Front End“, proc. LINAC ’06, Knoxville, USA (2006).

[3] S. Yaramyshev et al., “Beam measurements at North Terminal”, GSI scientific report (2013).

[4] A. Adonin et al., “HOSTI measurements”, GSI scientific report (2013).

[5] S. Yaramyshev et al., “A virtual charge state separator”, *these proceedings*, THPME007, IPAC'14, Dresden, Germany (2014).

[6] H. Vormann et al., “Status of the Compact-lEBT”, GSI scientific report (2013).