STATUS OF THE BEAM DYNAMICS DESIGN OF THE NEW POST-STRIPPER DTL FOR GSI - FAIR

A.Rubin†, D. Daehn, X. Du, L. Groening, M.S. Kaiser, S. Mickat, GSI, Darmstadt, Germany

Abstract

The GSI UNILAC has served as injector for all ion species since 40 years. Its 108 MHz Alvarez DTL providing acceleration from 1.4 MeV/u to 11.4 MeV/u has suffered from material fatigue and has to be replaced by a new section [1]. The design of the new post-stripper DTL is now under development in GSI. An optimized drift tube shape increases the shunt impedance and varying stem orientations mitigate parasitic rf-modes [2]. This contribution is on the beam dynamics layout.

INTRODUCTION

The existing UNIversal Linear ACcelerator UNILAC at GSI (Fig. 1) serves as injector for the Facility for Antiproton and Ion Research (FAIR), which is under constructing now at GSI [3]. The UNILAC will provide all primary ions but protons.

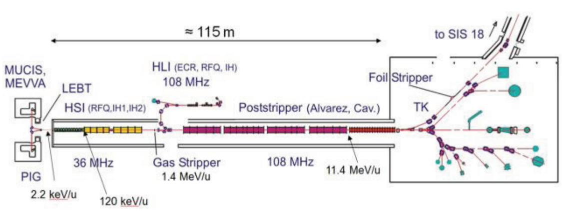

Figure 1: The UNIversal Linear ACcelerator (UNILAC) at GSI.

Due to the FAIR [4] requirements the UNILAC needs a considerable upgrade in nearest future. The existing post-stripper DTL suffered considerably from material fatigue during the last four decades and the amount of resources required for its maintenance increases continuously [5]. Replacement by a completely new DTL is due. The beam design parameters of the upgraded UNILAC are listed in Tab. 1.

Table 1: Parameters of the Upgraded UNILAC

Ion A/q	≤ 8.5
Beam Current	1.76 A/q mA
Input Beam Energy	1.4 MeV/u
Output Beam Energy	3-11.7 MeV/u
Beam Pulse Length	200µs
Beam Repetition Rate	10 Hz
Rf Frequency	108.408 MHz

BEAM DYNAMICS SIMULATIONS FOR THE 1ST ALVAREZ TANK

Beam dynamics simulations for the new post-stripper DTL were done for $^{238}U^{28+}$ using the TraceWin code [6]. The behaviour of the beam in the proposed structure was investigated for different zero current phase advances, as without current, as for the current of 15 mA. Input rms emittances were chosen as E_x=E_y=0.175mm·mrad (norm.), E_z=16.57deg·MeV. Periodic solutions were found for each case. The smallest transverse emittance growth along the 1st tank A1 (15mA) was obtained for a zero current phase advance k_0 of 55°-90°. It confirms results of the measurements in frame of the HIPPI experiments [7,8]. The initial zero current phase advances k_0 of 65°-90° also correspond to the stability areas of the Hofmann stability chart (Fig. 2).

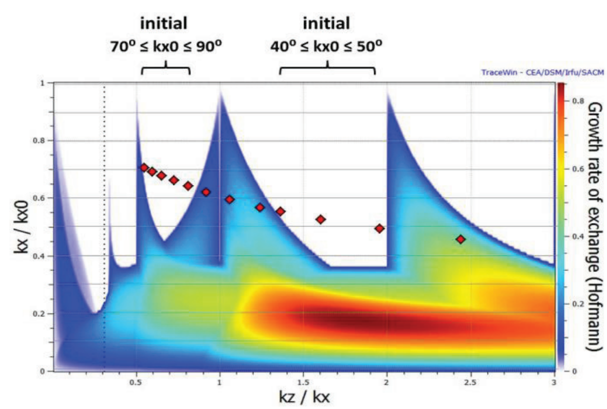

Figure 2: Initial zero current phase advances at Hofmann stability chart for the 1st tank of the new Alvarez-DTL.

Concerning the electric and magnetic field models the following cases for tank A1 were studied:

- "hard edge" model for E-field and B-field with identical quadrupoles in each drift tube (effective length of 96mm);
- 3D field maps for E-field, analytical field model for B-field with identical quadrupoles;
- 3D field maps for E-field and B-field with identical quadrupoles;
- "hard edge" model for E-field and B-field with three groups of quadrupoles (effective lengths 96 mm, 122 mm and 140 mm);
- 3D field maps for E-field, analytical field model for B-field with three groups of quadrupoles as above.

† a.rubin@gsi.de

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Beam dynamics simulations were done for $k_0 = 65^0$ and for I=15 mA. The results of simulations of all cases are basically identical (Fig. 3-4). The transverse rms emittance growth for A1 is up to 3%, longitudinally it is about 2% (Fig. 5).

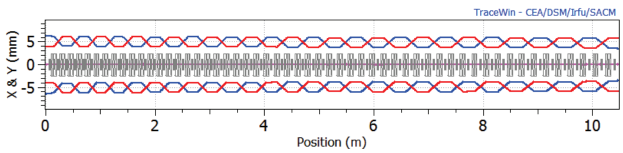

Figure 3: Transverse envelopes along A1.

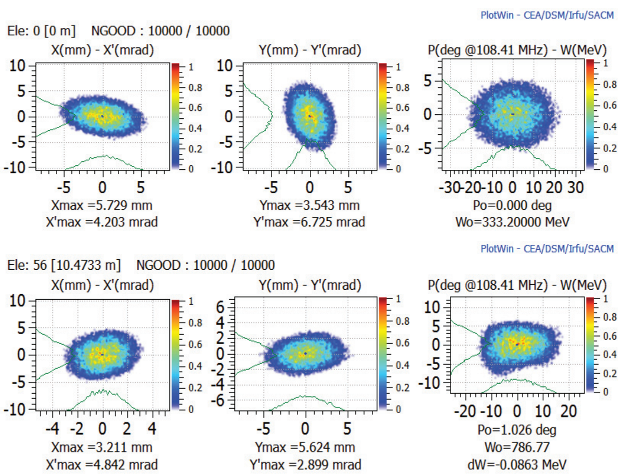

Figure 4: Input (top) and output (bottom) particle distributions for A1.

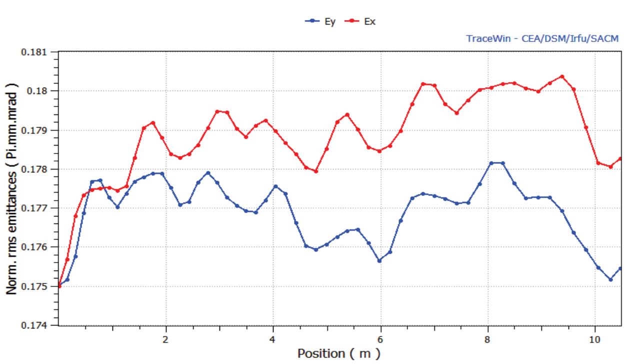

Figure 5: Transverse rms emittance along new tank A1.

GENERAL MODEL OF THE INTERTANK SECTION

The intertank sections for the presented design consist of quadrupoles, a phase probe, a current transformer, a valve, a profile grid, and a buncher. The layout is not finalized yet but the installation length is close to 1m. The recent design is shown in Fig. 6. The three quadrupoles, two of an effective length of 96 mm are assigned to the half drift tubes (Q1,3), are positioned to keep strict periodicity. The middle one (Q2) should have approximately 25% more of effective length. The distances between the quadrupole centers are about 50 cm. A re-buncher with 0.4-0.7MV is placed behind the 2nd quadrupole.

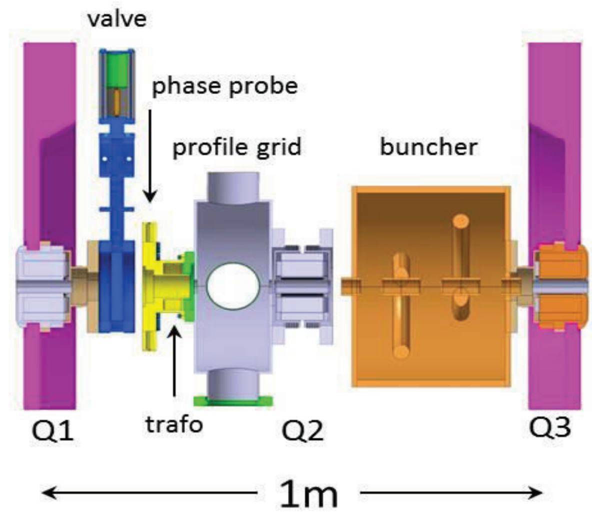

Figure 6: Design of the 1st intertank section.

BEAM DYNAMICS SIMULATIONS FOR THE COMPLETE ALVAREZ DTL

Beam dynamics simulation along the complete Alvarez DTL was done for the transverse zero current phase advance k_0 of 65^0 for each tank. The intertank sections allow for a matched transition. The layout is basically the same for all intertank sections, except the total length.

Regarding the periodic solution the following settings are proposed for the DTL: A1 - 55 cells, A2 - 45 cells, A3 - 37 cells, A4 - 33 cells, A5 - 18 cells. The rebuncher voltage is fixed at 0.5 MV for all intertank sections. The intertank quadrupole gradients were found separately. The gradients of the 1st and the 3rd quadrupole-in each intertank section vary from 31 T/m to 45 T/m, the 2nd ones are about 65 T/m. The transverse and longitudinal envelopes along the whole Alvarez DTL are shown on Fig. 7.

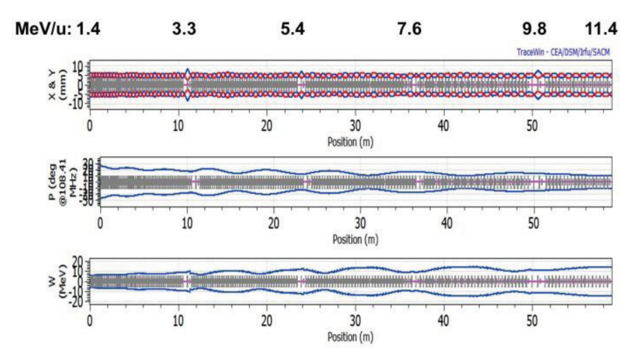

Figure 7: Transverse and longitudinal envelopes along the complete Alvarez DTL.

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Output particle distributions are compact (Fig. 8) and can be easily matched to the following structures. The tranverse emittance growth is about 4%, longitudinal - it is about 1.5% along the whole DTL (Fig. 9).

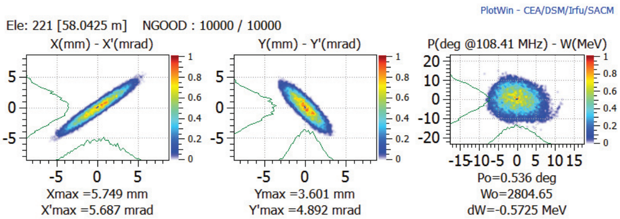

Figure 8: Output particle distribution behind the complete DTL.

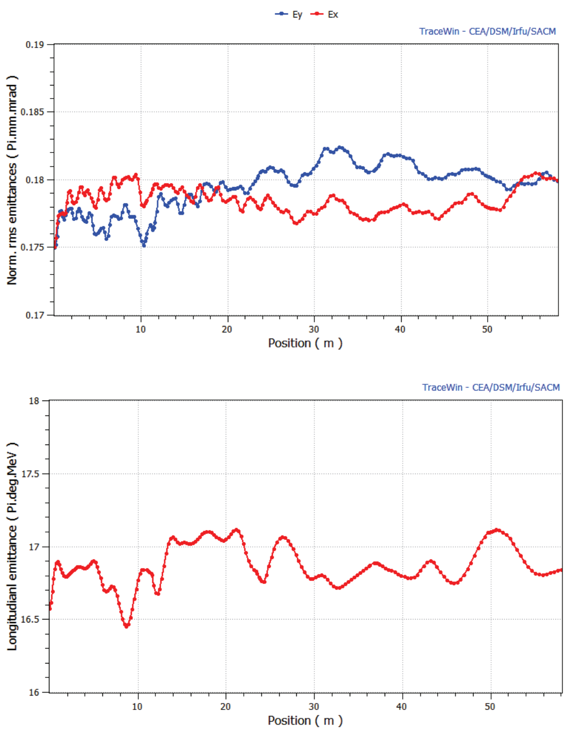

Figure 9: Transverse (top) and longitudinal (bottom) emittance along the new Alvarez DTL.

ALVAREZ DTL FOR TRANSPORT OF LOW ENERGY BEAMS

Simultaneously to the FAIR injector function, the UNILAC serves established GSI experiments requiring beam energies (nuclear-, biophxsics, material research) close to the Coulomb barrier, i.e. it provides energies in the range from about 3.0 MeV/u up to 11.7 MeV/u. For the low energy operation the rf-power of the downstream tanks is switched off starting from behind. The intertank bunchers are used then to maintain a reasonable bunch length up to the DTL exit. In comparison to the FAIR requirements the established UNILAC experiments require lower beam current but higher duty cycles.

Figure 10 illustrates the scenario with rf-power off for A2-A5. Low energy / low current beams are delivered to the exit of the DTL preserving short bunch length. Only 2.5% of the particles are outside ±45° behind the DTL. Shortening the 2[nd] tank will reduce this amount to zero. The bunchers' voltage range from 0.4 MV to 0.7 MV.

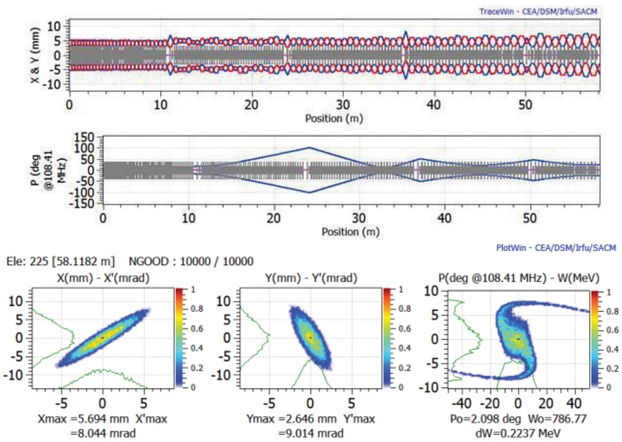

Figure 10: Transverse and longitudinal envelopes along the whole Alvarez DTL (top) and output particle distribution (bottom); rf-power is off for A2 - A5.

With the switched-off rf-power for A3-A5 the beam reaches the energy of 5.4 MeV/u. There are no particles outside ±15° behind the DTL (Fig. 11).

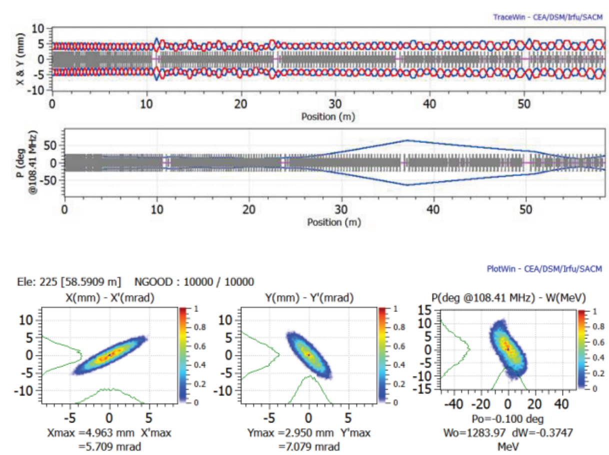

Figure 11: Transverse and longitudinal envelopes along the whole Alvarez DTL (top) and output particle distribution (bottom); rf-power is off for A3 - A5.

OUTLOOK

A conceptual beam dynamics design of the whole DTL was worked out and promising with respect to FAIR requirements in intensity and quality. Also the design considers the established UNILAC experiments. For the next iteration the optimization of the longitudinal beam parameters concerning lowest beam energies is planned. In parallel the mechanical design is detailed.

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