ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-THPF013

UNILAC PROTON INJECTOR OPERATION FOR FAIR

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Abstract

The pbar physics program at the Facility for Antiproton and Ion Research (FAIR) requires a high number of cooled pbars per hour [1]. The FAIR proton injector with coupled CH-cavities will provide for a high intensity (35 mA) pulsed 70 MeV proton beam at a repetition rate of 4 Hz [2, 3]. The recent heavy ion UNIversal Linear ACcelerator (UNILAC) at GSI is able to deliver proton as well as heavy ion beams for injection into the FAIR-synchrotrons. Recently GSI UNILAC could provide for a two orders of magnitude higher proton beam current in routine operation. A hydrocarbon beam (CH_3) from the MUCIS ion source [4] was accelerated inside the High Current Injector (HSI) and cracked in a supersonic nitrogen gas jet [5] into stripped protons and carbon ions. A new proton beam intensities record (3 mA) could be achieved during machine experiments in October 2014. Potentially up to 25% of the FAIR proton beam performance is achievable at a maximum UNILAC beam energy of 20 MeV and a maximum repetition rate of 2.7 Hz. The UNILAC can be used as a high performance proton injector for initial FAIR-commissioning and as a redundant option for the first FAIR-experiments [6].

INTRODUCTION

Two ion source terminals (PIG, MUCIS and MEVVA) deliver beam to a 36 MHz IH-RFQ and two IH-DTLs (up to 1.4 MeV/u). After acceleration the gas stripper and charge state separation four Alvarez DTL provide for end energies of 11.4 MeV/u; the eight installed Single Gap Resonators [7] could be used for energy fine adjustment. In the transfer line (TK) to the synchrotron SIS 18 [8, 9] a foil stripper and a second charge separator can be used.

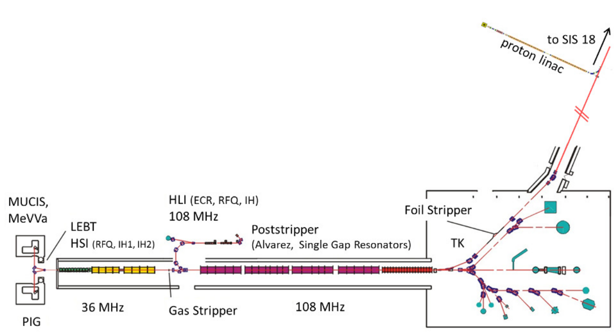

Figure 1: Schematic overview of the GSI UNILAC and FAIR proton linac.

The new FAIR proton linac delivers a high intensity proton beam with an energy of 70 MeV and a pulse current of up to 70 mA for injection into the SIS 18. The p-LINAC comprises of three new coupled CH-cavities with a compact and efficient design. The p-LINAC is connected to the TK (Fig. 1) by two 45 degree dipole magnets.

The first part of this machine experiment with the optimized mass spectrum (MUCIS), the gas stripper spectrum (HSI), emittance measurements and brillance for CH_3^+-operation are presented in [6].

RF CONTROL OPTIMIZATION

The proton acceleration with the current UNILAC implicates an optimization of the RF power control settings. The handling of low signal levels and in particular of the low level RF part (amplitude and phase control) is outside the predicable range of 100 kW up to 2 MW. The output power for the Alvarez tank (A3) is approximately 21 kW. The cavity voltage optimisation of a constant gap voltage (flat top) for the A3 (Fig. 2) was ensured with an adjustment of the rise time settings. While the beam pulse is passing the cavity, a flat top of the cavity voltage is required. The loop gain into to cavity has been optimized to increase up to a non-risky level.

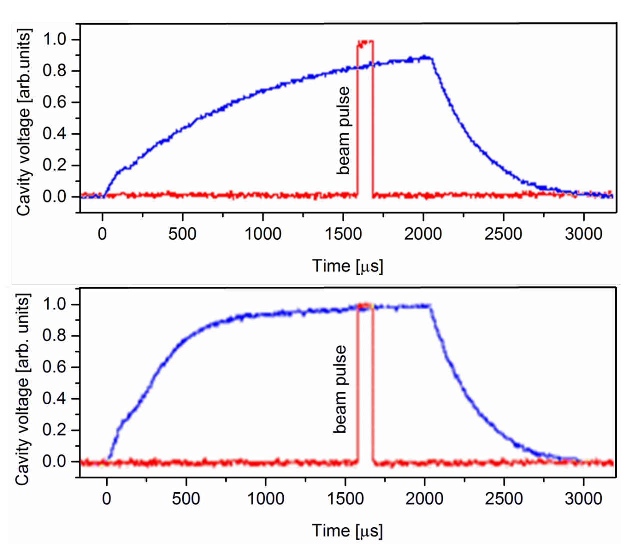

Figure 2: Shape of the cavity voltage before (top) and after (bottom) optimisation.

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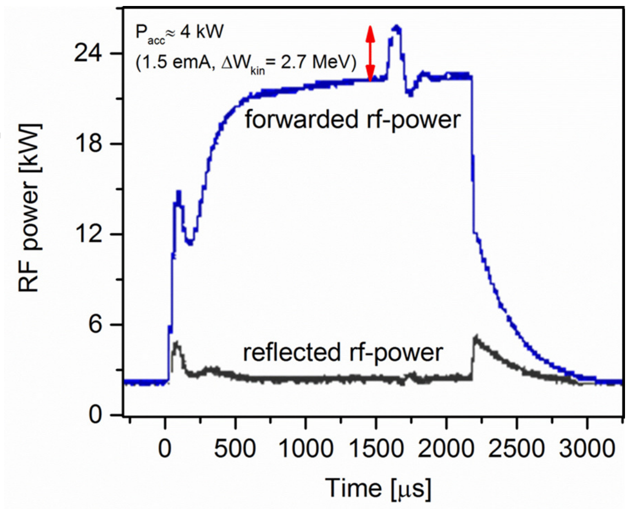

Figure 3: Forwarded and reflected RF power by the influence of the beam on the control system.

The influence of proton beam load is compensated by the control system. When the beam is entering the cavity the impedance decreases. The low level system controls the RF amplifier to a higher forwarded RF power; approximately 4 kW additional to the RF loss of 21 kW (Fig. 3). After the beam leaves the cavity the RF settings are recontrolled.

20 MeV PROTON BEAM

Behind the UNILAC Alvarez section eight single-gap resonators (SGR) can be used. The Alvarez DTL accelerates the ion beam to a maximum beam energy of 11.4 MeV/u. This beam energy was measured with the Time of Flight method TOF (Fig. 4). The adjunct eight single-gap resonators (SGR) with a maximum gap voltage of up to 1 MV (each) could accelerate the proton energy to 20 MeV/u (Fig. 5). This energy corresponds to 28.5% of the SIS-design energies for FAIR proton operation.

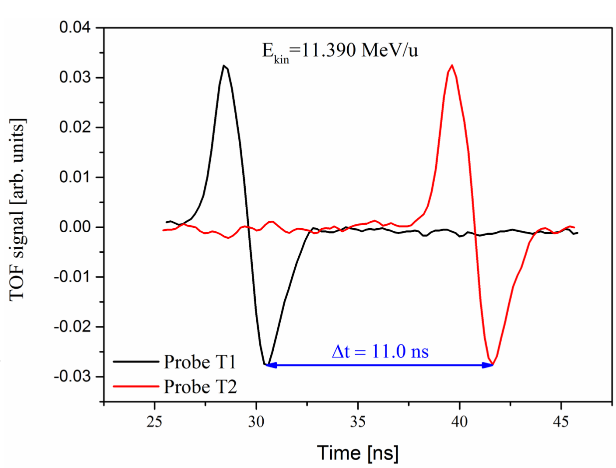

Figure 4: UNILAC proton beam energy measured with the Time of Flight method (phase probe, l=518.5 mm, 11 ns).

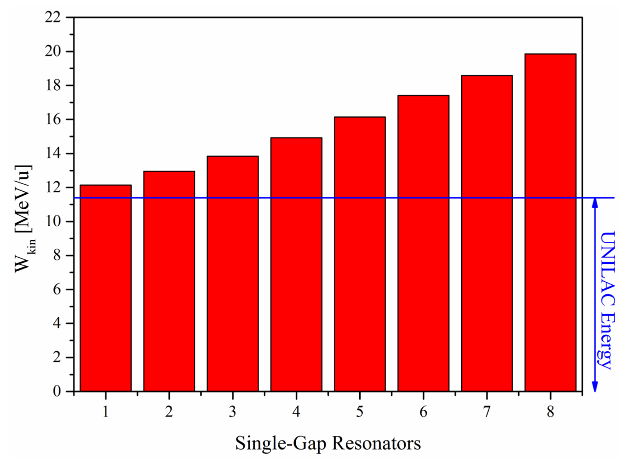

Figure 5: Proton beam energy of 20 MeV using eight single gap resonators.

HIGH CURRENT PROTON

The MUCIS ion source could provide for a hydrocarbon beam (CH_3). Due to particle losses in the matching section to the RFQ caused by an intrinsic high emittance the overall HSI-transmission is to limited 45%. The beam is cracked into stripped protons and carbon ions in a supersonic nitrogen gas jet. Behind the stripping section a triple proton output from each CH_3^+ molecule allows a beam poststripper operation close to the design limit (Fig. 6). During machine experiments (October 2014) the proton beam intensity was further increased. A new proton beam intensities record (3 mA) was reached behind the gas stripper. In general the overall transmission was limited by the aperture of a bending dipole in the transfer line.

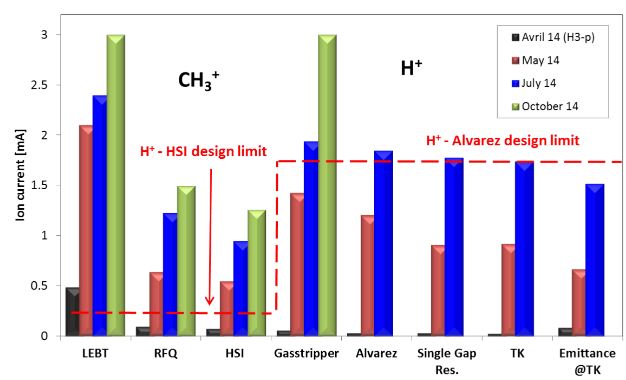

Figure 6: Beam current measurements at UNILAC and transfer line section; after stripping the proton beam operation is above the design limit.

COUPLED CH-DTL

The new FAIR proton injector (Fig. 8) comprises coupled Crossed-bar H-cavities (CH) to deliver a 70 MeV proton beam for high intensity (70 mA) and a repetition rate of 4 Hz.

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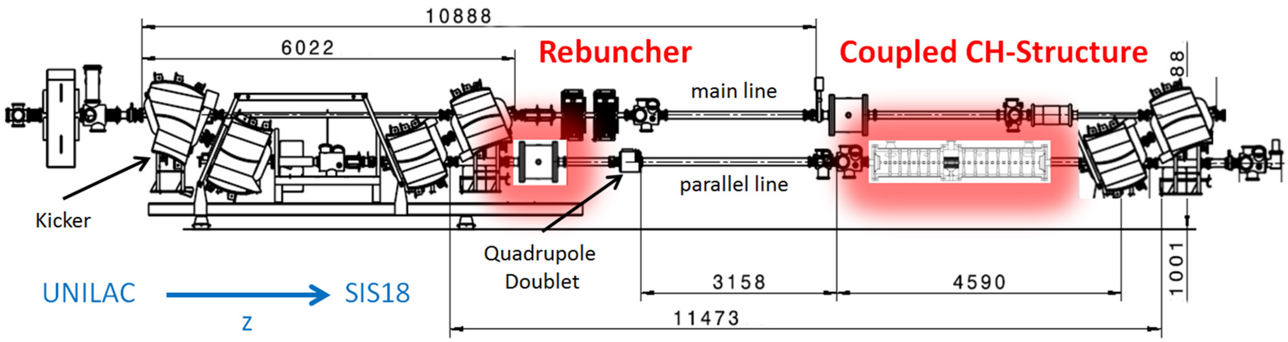

Figure 7: Proposal for first beam tests of high current proton beam operation with coupled CH-cavity in the transfer line.

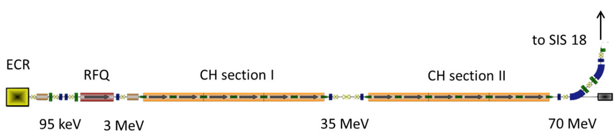

Figure 8: Schematic layout of the FAIR proton linac [3].

The new kind of roomtemperature 325.2 MHz CH-cavities (Fig. 9) are coupled via an intertank unit. The proton injector comprises six coupled CH-cavities, the intertank section is equipped with a magnetic triplet lens, and different beam diagnostics. For first testing a prototype was built; the measured normalized voltage distribution fits very well to the simulation (LORASR) [3]. The prototype is the second coupled CH-cavity of the p-LINAC with a total length of 2.8 m and 27 gaps. The proton beam input energy is 11.7 MeV, the output energy is 24.2 MeV. After copper plating the frequency tuning and the measurements of the voltage distribution have been repeated. It is proposed to

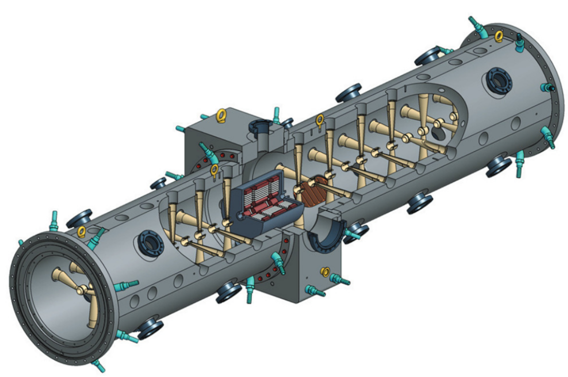

Figure 9: 3D-view (CAD) of the second coupled CH-cavity (section I) [3].

perform first beam tests with the prototype CH-cavity in a parallel line next to the transfer line (Fig. 7). This parallel beam line section is routinely used for additional beam diagnostics before injection into SIS 18. A rebuncher cavity for longitudinal focussing and a dipole chicane to bend the proton beam back to the transfer line is additionally required.

OUTLOOK

With the CH-prototype the UNILAC will be able to accelerate protons up to 24.4 MeV/u with a beam current up to 3 mA. This high performance proton injector can be particularly used for commissioning of the FAIR pbar chain. Besides UNILAC can operate as a redundant FAIR-proton injector.

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