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STATUS OF THE FAIR PROTON LINAC

C. Kleffner, S. Appel, R. Berezov, J. Fils, P. Forck, M. Kaiser, K. Knie, C. Muehle, S. Puetz, A. Schnase,G. Schreiber, A. Seibel, T. Sieber, V. Srinivasan, J. Trueller, W. Vinzenz, C. Will, GSI, Darmstadt
A. M. Almomani, H. Hähnel, U. Ratzinger, M. Schuett, M. Syha, IAP, Frankfurt am Main, Germany

Abstract

As part of the accelerator chain for antiproton production of the FAIR facility, a special high-intensity short pulsed 325 MHz Proton Linac is being developed [1], [2]. The Proton Linac is designed to deliver a beam current of 70 mA with an energy of 68 MeV. A 2.45 GHz ECR source designed for the generation of 100 mA beams with an energy of 95 keV is currently being tested at CEA/Saclay. The production of the structure of the IAP ladder RFQ is nearly completed. All parts of the RFQ vacuum chambers have been successfully copperplated at the GSI. Seven Thales Klystrons have been delivered to GSI at the beginning of 2018 and are nearly ready for use. The completion of the setup of the HV modulator is expected mid of the year 2019. The state of procurement and development of further accelerator components will be presented.

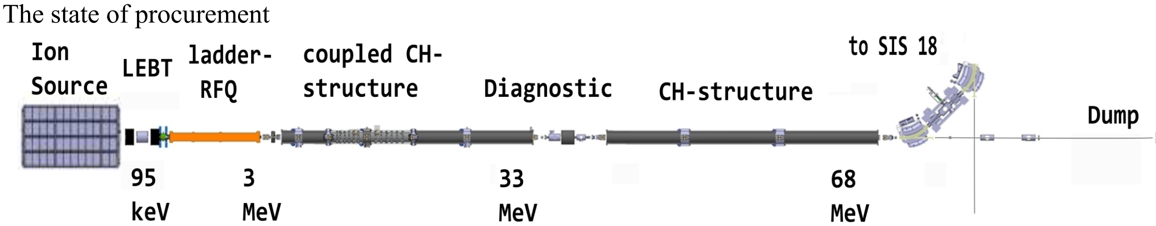

Figure 1: Layout of the FAIR Proton Linac.

OVERVIEW

Figure. 1 and Table 1. shows main properties and the structure of the Proton Linac. A 2.45 GHz ECR source generating 100 mA of 95 keV protons is followed by a Low-Energy Beam Transport line (LEBT) based on two sole-noid magnetic lenses enclosing a diagnostics chamber. A ladder 4-Rod RFQ will be built behind the LEBT, which is followed by a chopper and a beam conus in front of the RFQ entrance. Six normal conducting crossbar cavities of CCH and CH type arranged in two sections accelerate the beam to the final energy of 68 MeV.

The construction work on the Proton Linac beam dump and the eight meter thick radiation safety wall as seen in fig. 2 has been build up alongside the existing TK tunnel. This work has been executed as part of the GAF project in the first quarter of 2018.

PROTON LINAC BUILDING

After submission of the building application for the Proton Linac building in October 2017 the execution planning of the technical infrastructure started.

Figure 2: Proton Linac Interface Wall with the construction area for the Proton Linac in front.

ION SOURCE AND LEBT

The commissioning of the Proton source takes place at CEA, Saclay [3]. The 100 kV/150 mA high voltage power supply of the source has been commissioned successfully. By means of AC current transformer, fast current transformer FC, Wien filter (beam proportion) and Alison Scanner (emittance measurements) the extracted Proton beam has been characterized, see fig.3.

Table 1: Proton Linac Main Parameters

Particle	Proton (H^{+})
Ion source	95 keV
MEBT energy	3 MeV
CCH section	33 MeV
Final energy	68 MeV
Pulse current	70 mA
RF-frequency	325.224 MHz
Rep. rate	2,7 Hz

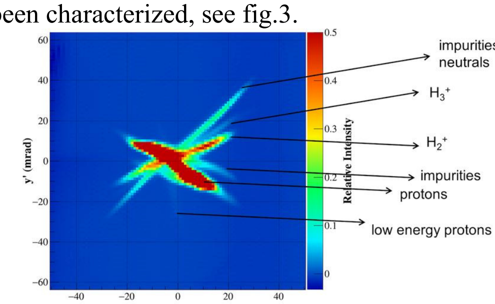

Figure 3: Typical emittance measurement taken at the diagnostic section within the LEBT.

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A current of 92 mA (80 mA H^+) with a RMS emittance of 0.3 π mm mrad behind the first solenoid has been produced.

LADDER RFQ

The ladder RFQ is under construction and will be delivered by IAP Frankfurt [4]. The production of the vacuum chambers as well as the ladder structure and the RFQ electrodes has been completed. All parts of the vacuum chambers have been successfully copperplated at the GSI galvanic workshop (fig. 4). After the first assembly of the RFQ first low level measurements show excellent consistency with the RF-simulations. This as well as well as details of the beam dynamic calculations are presented at this conference [6] [7].

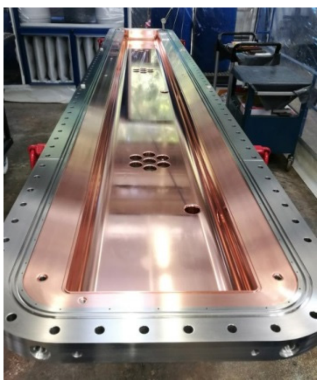

Figure 4: Copperplated RFQ half shelve at the GSI galvanic workshop.

CH-DTL LAYOUT

The final design for the entire CH-DTL was completed by IAP [5] at the beginning of the year. The current focus of the work is on the mechanical integration of all components.

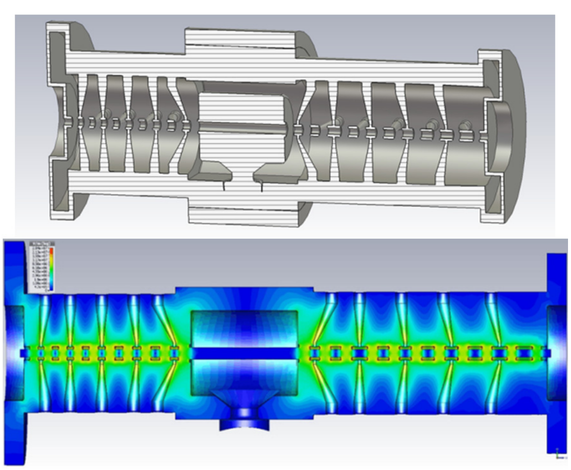

Figure 5: Layout of the first CCH-type cavity CCH1 and corresponding CST Microwave Studio calculations.

Another CH dummy prototype (fig. 6) with realistic stem geometries will be produced and copper-plated in the near future. For the first time the new additive planned for the GSI galvanic workshop will be used for this purpose.

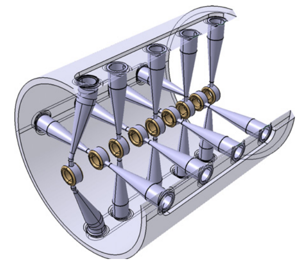

Figure 6: Model of the CCH1 dummy segment for welding and galvanic testing purposes.

In order to decrease welding and postprocessing time and to increase the welding quality all joints will be designed to be compatible with orbital electron beam welding. Extensive tests for the welding procedure are planned within this year.

RF & POWER SUPPLIES

Seven klystrons have been delivered beginning of this year and are stored on-site, see fig. 7. The eight klystron was ordered by the collaboration partner CNRS and will be availble mid of next year. With some interlock modifications the klystrons are ready for use.

Figure 7: Three of the delivered klystrons stored on-site.

The construction of a HV modulator is indispesible for further rf tests on site. The work on the HV modulators are ongoing. Two sets of racks as well as full set of capacitors were delivered. The tender process on the HV switches and the purchase of the transformers and charger power supply are ongoing.

ERROR STUDIES CH-DTL

After creation of a cooperation of GSI with IAP concerning beam dynamics calculations an advanced error analysis study was initiated for the CH-DTL section with the LORASR code [8], [9] and has been redone this year with the final CH-DTL design. Parameters that enter into beam dynamics simulations are subject to errors following a Gaussian distribution. Many runs were made with different assumptions on errors in quadrupole alignments (±0.1 mm) as well as in RF-amplitudes & -phases (±1%, ±1°). A resulting beam loss scenario is plotted in fig. 8 including beam envelopes along the CH-DTL section. In blue the beam envelope in vertical as well as in horizonal of the nominal run is shown together with the overlap of all envelopes in red. The studies include corrections by steerers,

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marked with the black arrows. It turned out as in the previous studies that the losses are dominated by quadrupole translations.

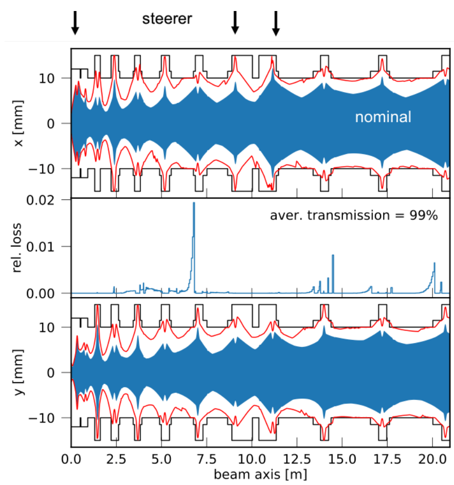

Figure 8: Simulated horizontal (upper) and vertical (lower) beam envelopes along the whole DTL section for a simulated current of 70 mA. In blue the nominal case, in red the overlap of all envelopes form all errors runs. Related loss (middle) along the DTL resulting from systematic error studies.

OPTIMIZATION OF THE MULTI-TURN INJECTION

For the multiturn injection (MTI) into the SIS18 synchroton emittance should be in a reachable value frame for the injector linac. On the other hand, if the available horizontal SIS18 acceptance is almost occupied, increasing of the so called multiplication factor lead to an increasing of injection loss. The MTI performance depends on various machine parameters and strongly on the injector beam parameters since a smaller emittance translates directly into better MTI performance [10].

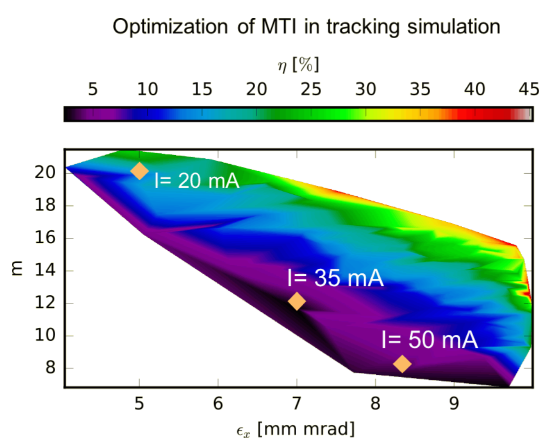

Figure 9: Proton linac MTI performance plot for the SIS18 synchrotron.

A new approach to solve such difficult but realistic problems is the use of genetic algorithms (GA) [11]. The outcome of GA optimization of simulation of injection loss, multiplication factor and beam emittance of injector is shown in fig. 9.

Three case with brilliance of 4, 5 and 6 mA/(mm mrad) has been marked in the figure. The simulations and heuristic optimization of the MTI demonstrate, that a low-loss injection to fill SIS18 up to the space charge limit for several emittance over many turns could be achieved for various proton puls currents. The optimal settings of the proton pulse current is expected to between 35 and 50 mA.

CONCLUSION AND OUTLOOK

The overview of the current status of the pLinac project shows the progress of the project. The design of all major components has been finished by now. One of the most important tasks in the near future will be the the creation of specifications for the CH-DTL cavity tanks.

REFERENCES

[1] U. Ratzinger, *et al.,* "A 70 MeV Proton Linac for the FAIR Facility Based on CH Cavities", in *Proc. LINAC 06,* paper TH1004, 2006.

[2] Technical Design Report (2008), Proton Linac, www.edms.cern.ch/document/994418/1.

[3] R. Berezov *et. al.,* "High intensity proton injector for the FAIR P-LINAC", *ICIS 2017*, CERN – CICG, Geneva.

[4] M. Schuett, U. Ratzinger, R. Brodhage, Development of a 325MHz Ladder-RFQ of the 4-ROD Type, *Proc. of IPAC'15*, Richmond, USA, p. 3745. (2015)

[5] U. Ratzinger, "Calculations of the CH- and CCH-Cavities for the FAIR proton linac", 2018, IAP Frankfurt, Final Report

[6] M. Schuett *et al.,* "First RF Measurements of the 325 MHz Ladder RFQ", presented at LINAC'18, Beijing, China, Sep. 2018, paper THPO060, unpublished.

[7] M. Syha *et al.*, "Beam Dynamics for the FAIR-p-linac-rfq", presented at LINAC'18, Beijing, China, Sep. 2018, paper TUPO083, unpublished.

[8] G. Clement, "Beam Dynamics Layout of the FAIR Proton Injector", in Proc. of the ICFA HB2008 Workshop, Nashville, U.S.A., 2008.

[9] R. Tiede, A. Almomani, M. Busch, F. Dziuba und U. Ratzinger, "Improved Beam Dynamics and Cavity RF Design for the FAIR Proton Injector", in *Proc. LINAC'16*, East Lansing, MI, USA, Sep. 2016, pp. 111-113, doi:10.18429/JACoW-LINAC16-MOPRC018

[10] S. Appel, Y. E. Hayek, M. Maier, C. Xiao und L. Groening, "Injection optimization through generation of flat ion beams", *Nucl. Instr. Meth.* A 866, 2017.

[11] S. Appel, O. Boine-Frankenheim und F. Petrov, "Injection optimization in a heavy-ion synchrotron using genetic algorithms", NIM A 852, 2017.