STATUS OF THE FAIR pLINAC

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Abstract

This paper describes the progress in the development of the 68 MeV, 70 mA proton injector for the FAIR facility. The injector comprises an ECR-type high current proton source followed by a ladder 4-rod RFQ and six normal conduction CH-DTL accelerator cavities. This unique design allows for a compact structure by using many not yet established accelerator technologies. The design of the cavities has been completed by our collaboration partners at IAP Frankfurt. The design of the buncher cavities, the mechanical integration as well as beam diagnostic devices are currently under development. The construction of a new modulator for the pLinac RF-system has been started on site. The proton source and the LEBT as well as the subsequent chopper are currently setup at CEA/Saclay. The commissioning phase of the proton source at Saclay started at the beginning of 2017. An overview of the pLinac main parameters and design choices is given, and the overall status is reported.

INTRODUCTION

In order to generate the required intensity of antiproton beams for the FAIR Panda experiment, a dedicated proton linac for the FAIR accelerator chain is required [1]. The FAIR proton injector [2] has to provide at least 35 mA with a repetition rate of 4 Hz to fill the SIS18 synchrotron up to the space-charge limit. 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 solenoid magnetic lenses enclosing a diagnostics chamber. The diagnostic chamber will house an iris, an Alison scanner, a secondary emission grid (SEM), a Wien filter and a beam stopper. A ladder 4-Rod RFQ will be connected to the LEBT, which is followed by a chopper and a beam dump in front of the RFQ entrance. Six normal conducting crossbar cavities of CCH and CH type aranged in two sections accelerate the beam to the final energy of 68 MeV.

pLINAC DESIGN ADJUSTMENT

The matching of power requirements of the CCH and CH cavities for using identical klystron amplifiers was improved and adjusted for safe and robust operation [3]. For the same reason, the the final energy of the pLinac has recently slightly been decreased to a value of 68 MeV.

The design of the MEBT section at 3 MeV between the RFQ and the CCH section was extended in length to allow for the assembly of the necessary components for beam matching, vacuum, and diagnostic. The diagnostic line between the CCH and the CH section with a newly designed 4-gap 1,6 MV CH type rebuncher has been reduced in length and will operate at a sligthly reduced energy of 33 MeV. The adjusted main parameters of the pLinac are summarized in Table 1.

Table 1: pLinac Main Parameters

Ion source	95 keV
MEBT energy	3 MeV
CCH section	33 MeV
Final energy	68 MeV
Pulse current	70 mA
Protons per pulse	$5 \cdot 10^{12}$
RF-frequency	325.224 MHz

pLINAC BUILDING

In order to enable beam tests using the new developped ladder RFQ at an early stage it was decided to set up the building for the pLinac much earlier than originally scheduled. Figure 1 illustrates the current state of planning. Comprehensive studies examined the effects on the cost of construction of the building including media supply as well as of the influence on the shutdown and planned beam times of the GSI accelerator facility anf confirmed the changed schedule to be beneficial. The anticipated availability of the proton injector during the reconstruction phase of the GSI Unilac and the permanent availability of the RF test bench are further advantages.

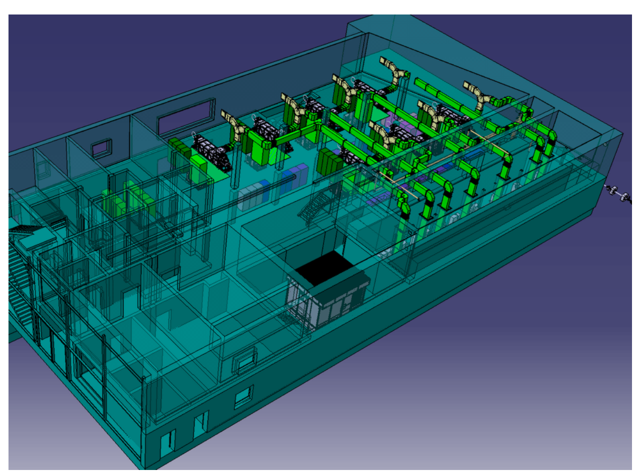

Figure 1: 3D view of the pLinac building including the RF support structures and the accelerator tunnel.

To allow for an early erection of the pLinac building the construction of the radiation safety wall alongside the existing TK tunnel as well as the beam dump for the pLinac will start as early as this year during the shutdown of the GSI accelerators.

ION SOURCE AND LEBT

First plasma operation of the ECR proton ion source [4] took place at the end of 2015 at CEA/Saclay. The commissioning of the source started at beginning of 2017. The commissioning is expected to be completed within four dedicated phases. Factory acceptance tests for several power supplies will be prepared, too. Figure 2 shows a photo of the ion source terminal, and figure 3 confirms the first plasma measurement.

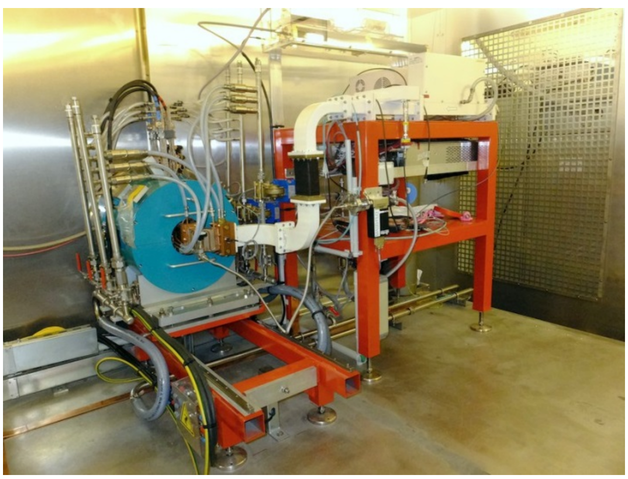

Figure 2: Proton ECR source at CEA/Saclay.

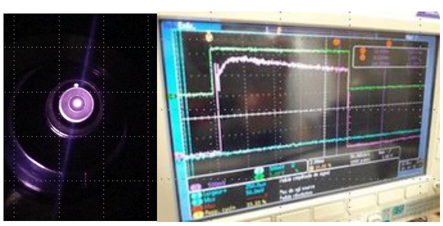

Figure 3: First plasma observed.

LADDER-RFQ

The decision for using a ladder RFQ was taken following the successful high power RF performance tests [5] of the prototype ladder RFQ at the RF test bench of GSI. These test shows an excellent performance of the cavity under high RF power load. The final RFQ beam dynamic design could be improved by increasing the nominal electrode voltage [6]. A full-sized RFQ will be constructed at IAP Frankfurt and transported to GSI for initial high power RF tests at the RF test bench and later on also for beam tests at the final installation place in the pLinac building. A 3D-view of the mechanical construction is shown in figure 4. Copper plating of the tank vacuum chamber is planned to be carried out at GSI's galvanic workshop. Particular important is the matching of the schedules to the refurbishment of the galvanic workshop in the upcoming time.

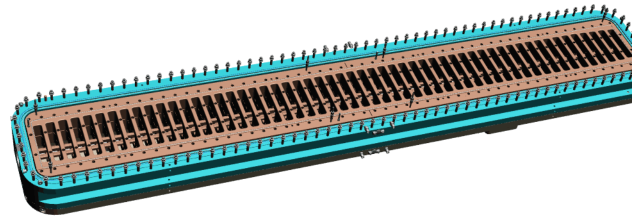

Figure 4: 3D model of the ladder RFQ illustrating the ladder structure with electrodes.

CH-CAVITIES

The last iteration of the redesign of the CCH cavities was recently finished. A special shape at the cavity ends is needed to increase the effective voltage for the end gaps and to improve the effective shunt impedance [7].

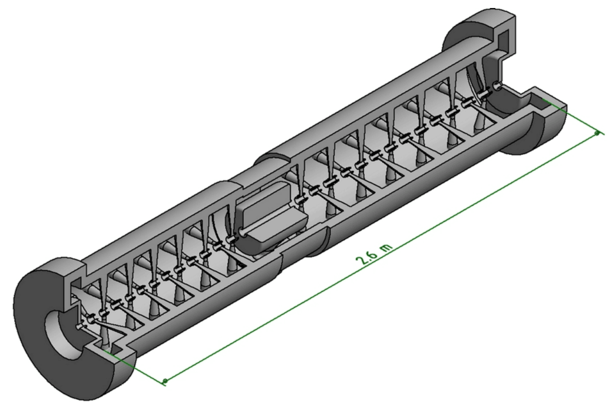

Figure 5: Final RF design of the 2nd coupled cavity CCH2.

Numerous beam dynamic simulations and error studies [3] has been performed just prior to fix relevant design parameters and determine the manufacturing and alignment tolerances.

FOCUSING MAGNETS

The redesign of the cavities and the diagnostic sections mutually made it necessary to change the design of the focussing quadrupoles. All quadrupoles used in the accelerator sections are now arranged as triplets. The lenses are either integrated inside the cavities or placed externally. Figure 6 show an integrated triplet lens with RF housing.

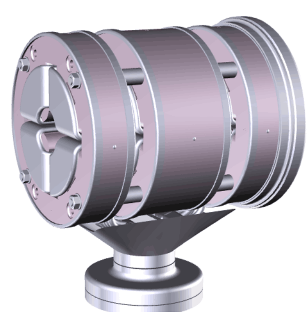

Figure 6: Magnetic triplet. RF housing only partly shown.

The approved geometry of the CCH cavities is a necessary step not to delay the manufacturing process of the triplets further.

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BEAM DIAGNOSTIC

Standard devices like cup, ACCT, SEM-Grid, Slit are conceptionally designed but some details are still lacking. Partly new technologies used e.g. SEM-Grid digitalization are conceptually proven.

Mechanical interfaces are not fixed on every place due to the delay in the finalization of the cavity design.

The Work on the new developments for BPM readout (digital ampl. & phase determination) is making progress. The design of the intermediate test bench used for the commissiong phase inside the pLinac building has to be finished.

RF & POWER SUPPLIES

All klystrons are expected to be delivered at GSI during the current year. Factory acceptance tests with participation of the GSI are already ongoing.

The first of series of the modulator is currently being constructed at GSI. A 3D rack view of the modulator together with the pulse transformer is shown in figure 7.

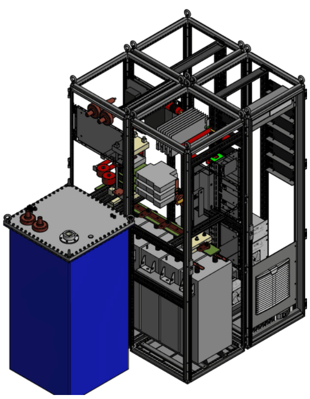

Figure 7: Model of the modulator.

With the expected completion of the first of series of the modulators during next year high ower RF tests at the test bench can be continued again.

MECHANICAL INTGEGRATION

The mechanical integration of all accelerator components is a major effort due to the confined spaces for focusing elements due to the requirements of the konus beam dynamic. The re-design of the first rebuncher is in progress.

CONCLUSION AND OUTLOOK

The overview of the current status of the pLinac project shows that the project's progress is considerable. The design of all major components has been finished by now. Recent efforts are currently being made to finalize the civil construction planning, i.e. provision of load data, cabling lists and the detailed room planning. The main effort for the next year will be the mechanical layout and construction of the cavity tanks. The technical specification as well as mechanical integration is on the path.

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. Tiede *et al.,* "Improved Beam Dynamics and Cavity RF Design for the FAIR Proton Injector", in *Proc. LINAC2016*, East-Lansing, MI, USA, 2016.

[4] C. Ullmann, R. Berezov *et. al.,* "The Proton Injector for the Accelerator Facility of Antiproton and Ion Research (FAIR)", *Rev. Sci. Instrum*. vol. 85, p. 02A952, 2014.

[5] M. Schuett, U. Ratzinger, R. Brodhage, Development of a 325MHz Ladder-RFQ of the 4-ROD Type, *Proc. of IPAC2015*, Richmond, USA, p. 3745 (2015).

[6] M. Schuett *et al.,* "Status of the modulated 3 MeV 325 MHz Ladder-RFQ", IPAC2017, Copenhagen Denmark, May 2017, paper TUPVA074, this conference.

[7] A. Almomani *et al.,* "Updated Cavities Design for the FAIR P-LINAC", IPAC2017, Copenhagen, Denmark, May 2017, paper TUPVA064, this conference.