STATUS OF THE 70 MEV FAIR PROTON INJECTOR*

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Abstract

The FAIR anti-proton research program required a dedicated 70 MeV proton injector. This 325 MHz linac is currently under design and construction at GSI. The accelerator comprises an ECR source, a 3 MeV RFQ, and a DTL based on CH-cavities. The first prototype cavity has been built and the preliminary low level RF investigations were successfully performed. The status as well as the perspectives of the project are given and discussed.

INTRODUCTION

The FAIR proton linac [1] has to inject a 70 MeV proton beam into the SIS 18 with a repetition rate of 4 Hz. The multiturn injection scheme requires a beam current from 35 to 70 mA within an RF pulse of 250 μs. The conceptual scheme of the linac is showed in Fig.1. An ECR ion source provides up to 100 mA proton which are then accelerated into an RFQ up to 3 MeV. The DTL section consists of three coupled CH cavities up to 36 MeV followed by three CH-DTL's. A dedicated diagnostics section is foreseen between the two DTL sections. Due to the high shunt impedance of the CH cavities [2], the total length of the accelerator is around 25 meters.

Table 1: Main Parameters of the FAIR proton linac

Output Energy (MeV)	70
Frequency (MHz)	325.224
Pulse Current (mA)	35-70
RF Pulse (μs)	250
Repetition Rate (Hz)	4

STATUS OF THE PROJECT

In the frame of the FAIR project, the proton linac is based on an German-French inkind collaboration. between CEA, GSI and the University of Frankfurt.

LEBT

The ECR source is part of the French inkind contribution for the FAIR project. The ion source is specified to deliver up to 100 mA protons within a normalized transverse rms emittance of 0.3 mm mrad. The extraction voltage has been fixed at 95 kV. The entire design has been based on the IPHI deuteron injector. Particular care was taken in the self-consistent simulation of the space and time dependence of the space charge compensation along the LEBT [3].

The construction, including the LEBT set-up, is well advanced and the first beam test at CEA is foreseen for September 2013. After the commissioning phase in France, all components will be transferred and reassembled at the FAIR site.

RFQ

The first choice for the RFQ was the 4-rod type developed at the Frankfurt University [4]. This choice was motivated by the advantages of the 4-rod structure in terms of mechanical construction and lower fabrication costs. Nevertheless, the operational frequency of 325 MHz would be the highest ever used for those kind of structure. For that reason, a short model was built at IAP, Frankfurt (see Fig.2) to test the main RF properties and the tuning procedure. Low level RF measurements were in good agreement with simulations and, at the moment, the cavity is being tested under high power condition at IAP.

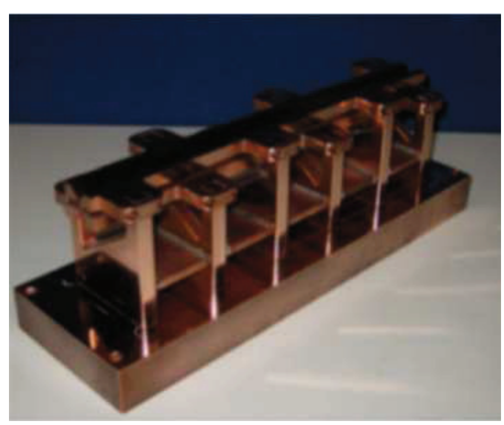

Figure 2: The four-rod model of the FAIR proton linac RFQ.

Recently, IAP and GSI agreed on the possibility to in-

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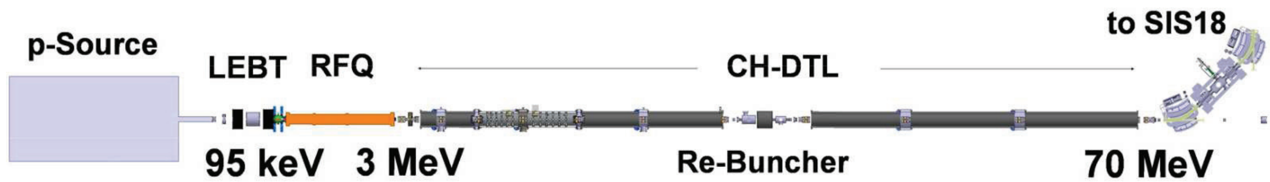

Figure 1: The schematic layout of the FAIR proton linac.

vestigate alternative solutions to the four-rod cavity. At the moment, a ladder RFQ [6] and a four vane cavity are under investigation at the Frankfurt University. The aim of this investigation is to compare all major characteristics of the structures such us, for example, fabrication costs, tuning procedure, dipole components suppression and mechanical constructions.

For all structure the power consumption is expected to be lower than 1 MW, although it is foreseen to feed the structure with a 3.0 MW-class klystron

The final decision is expected to be taken within 2013.

Bunchers

The proton linac contains three buncher cavities, one placed in the matching section between the RFQ and the DTL, one installed in the diagnostics section between the two DTL sections, and the last one inserted into the transfer channel to the SIS18. At present, the halfwave 3MeV buncher is been already simulated with CST Microwave Studio. A model of the simulations is shown in Fig.3. Each buncher will be fed by a 50 kW solid state amplifier and the RF simulations indicates that the power needs are well below this value.

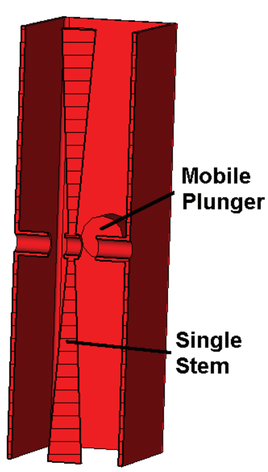

Figure 3: The 3 MeV rebuncher.

CH DTL

H-mode cavities offer outstanding shunt impedances at low beam energies and enable the acceleration of intense protons and ion beams. Crossed-bar H-cavities extend these properties to energies even beyond 100 MeV. Thus, the design of the proton linac is based on those kind of cavities. As usual for H-mode structures, the beam dynamics lattice is defined according to the KONUS lattice.

Three coupled CH-DTL perform the first stage of acceleration to the energy of 36 MeV where a 1.6 meter long dedicated diagnostic section is installed.

At that energy, space charge effects are reduced and the KONUS offers the possibility to build long lens free sections. For that reason, the high energy section is based on standard lens free CH cavities with slightly larger beam aperture at each cavity ends.

The first coupled CH has been fabricated [7] and tuned with respect to the frequency and field flatness [8] as one can see from Figs.4-5.

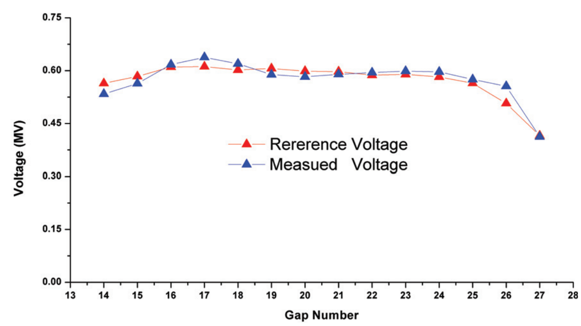

Figure 4: The field distribution in the first CH section.

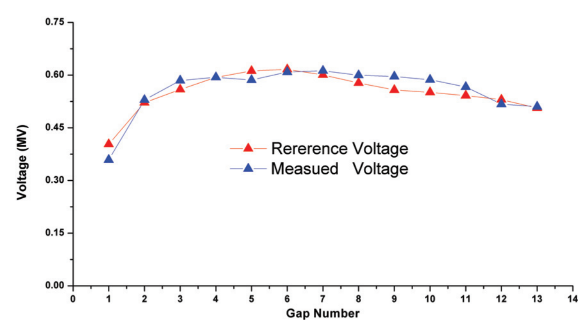

Figure 5: The field distribution in the second CH section.

This first prototype was built with dummy stems and drift tubes to perform the tuning operations. At the moment, the dummy components have been replaced and the welding operation of the stainless steel component is in progress at IAP. A detail of the cavity and of the camera assisted welding operations are showed in Figs.6-7.

Figure 6: The stainless stems welded into the outer cylinder.

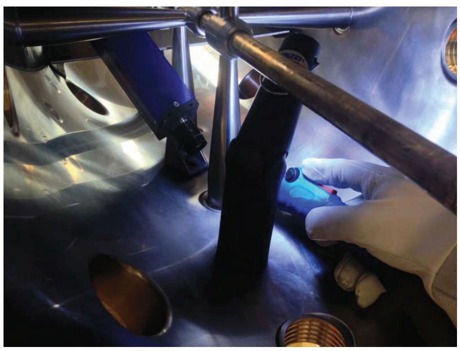

Figure 7: The camera assisted welding operations.

The welding operations for both CH sections are expected to be concluded within summer 2013. At that point, all components will be transferred at GSI for the galvanic operations. A dedicated high power RF test bench has been built at GSI, all necessary waveguides, water load and the first 3 MW klystron have been delivered. The geometry of the high power coupling loop has also been defined [9]. The cavity will undergo high power RF test in 2014. The same test bench will be used for all Site Acceptance Tests of all proton linac DTL and RFQ cavities.

In parallel, the RF simulations of the lens free CH cavities are ongoing. An example of the simulated model of the first simple CH-DTL, is shown in Fig.8. Those cavities will consist of two outer cylinder flanged together. In fact, the total length of each cavities exceed the dimensions of the galvanic bath at GSI. To facilitate the welding operation close to the flanges, the central stems are inclined.

RF Power Source

All DTL cavities and the RFQ will be powered by one klystron each. The klystrons are specified to deliver up to 2.7 MW in their linear range and they will be fed by an individual modulator. A first TOSHIBA klystron has been delivered and its modulator is expected this year. This klystron will be used for the test bench. All the other klystrons will be delivered by Thalys and are financed through the French inkind contribution of FAIR.

Specification of three 50 kW solid state amplifiers for

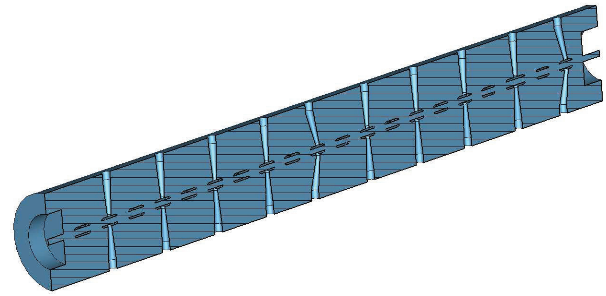

Figure 8: The simulations model of the first CH-DTL after the diagnostics section.

the bunchers are also defined. The RFQ will require about 800 kW of rf- power. CNRS/Orsay will provide for the procurement of the rf-chain of the proton linac. A considerable amount of equipment for the rf-test has been already delivered as llrf-components, waveguides, scopes etc.

SCHEDULE

The parameters of all devices are frozen and the technical specification including mechanical integration is in progress. Major efforts are currently made to finalize the civil construction planning, i.e. provision of load data, cabling lists, specification of rooms, etc. The general design of the building including shielding and location of the RF system has been completed. Additional shielding material had to be located close to the transfer channel to reduce the radiation level coming from the SIS18.

Recent planning assumes the building to be ready in summer of 2016. Commissioning of the linac will be section-wise up to the full design current of 70 mA. After each cavity a mobile diagnostic bench allowing for energy, current, and emittance measurement will be installed. We expect commissioning to full performance to last about two years.

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