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STATUS OF THE FAIR PROTON LINAC

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Abstract

For the research program with cooled antiprotons at FAIR a dedicated 70 MeV, 70 mA proton injector is required. The main acceleration of this room temperature linac will be provided by six CH cavities operated at 325 MHz. Within the last years, the assembly and tuning of the first power prototype was finished. The cavity was tested with a preliminary aluminum drift tube structure, which was used for precise frequency and field tuning. Afterwards, the final drift tube structure has been welded inside the main tanks and the galvanic copper plating has taken place at GSI workshops. This paper will report on the recent advances with the prototype as well as on the current status of the overall p-Linac project.

INTRODUCTION

The proton linac for FAIR is mechanically grouped in two sections, each having a length of about 9 m. Based on the actual design the first section will consist of 3 coupled CH-cavities. Between both sections there will be a diagnostics area with a rebuncher for longitudinal beam matching. Investigations have shown that a simplified layout of the 2nd section of the proton linac will be an improvement. Therefore, three simple CH cavities without a coupling cell will be used, reducing the triplet lens number by three and simplifying the layout and tuning of the cavities a lot.

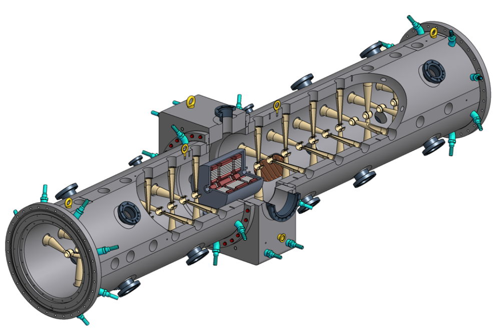

Figure 1: 3D-view of the coupled prototype cavity.

THE COUPLED PROTOTYPE CAVITY

Figure 1 shows the prototype cavity which corresponds to the second coupled cavity within the first section. The low energy part consists of 13 gaps, followed by the coupling cell and by the 14 gap high energy part. The whole cavity has an inner length of about 2.8 m and the cylindrical tanks have an inner diameter of about 360 mm. The coupling cell has a length of about $2\beta\lambda$ and hosts the focusing triplet lens within one large drift tube. The inter cavity tanks will also house triplet lenses and some beam diagnostics additionally (4 knob phase probes). They mechanically connect and support the neighbored cavities.

Table 1: Parameters of the Coupled CH Prototype Cavity

No. of gaps	13 + 14 = 27
Frequency [MHz]	325.2
Energy range [MeV]	11.7 - 24.3
Beam loading [kW]	882.6
Heat loss [MW]	1.35
Total power [MW]	2.2
Q_0-value	15300
Eff. shunt impedance [$M\Omega/m$]	60
Average $E_0T[MV/m]$	6.4 - 5.8
Kilpatrick factor	2.0
Coupling constant [%]	0.3
Aperture [mm]	20
Total inner length [mm]	2800
Inner diameter [mm]	360 / 434 / 364

Table 1 shows the main parameters of the prototype cavity. The prototype arrived at GSI in late 2013 and was prepared for galvanic copper plating. Unfortunately the plating process on long cavities with a complex inner structure is not trivial. Therefore lots of tests and investigations have been performed to realize a suitable copper layer. Figure 2 shows the final result after gavanic plating and polishing.

Figure 2: Picture of the copper plated inner surface of CH 3

This cavity is presently at the p-Linac RF test stand and is assembled with all tuners and the triplet lens. The first low level measurements were already performed and show a good accordance with theory and previous results. Copper plating and welding have not effected the performance and tolerances of the prototype. Further investigations and perturbation measurements of the field distribution will be performed within the next weeks.

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ION SOURCE, LEBT & CHOPPER

The p-Linac frontend will be equipped with an ECR ion source and a short LEBT consisting of two solenoids enclosing a diagnostics chamber which will house i.a. an allison scanner, a faraday cup and a wien filter.

Table 2: Main Parameters of the ECR Source

Beam Intensity [mA]	100
Beam Energy [keV]	95
Proton Fraction [%]	> 85

Subsequently to the second solenoid, there will be an electrical chopper. Two parallel copper plates will be loaded with a bipolar voltage of ±15 kV. By passing this electric field, the proton beam will be deflected to a tungsten plated copper cone. Using intensive water cooling, this cone is able to absorb the protons at most of the time. With a maximum repetition rate of 5 Hz, the chopper is switched off to produce short beam pulses with a length corresponding to the multiturn injection time of the synchrotron. Figure 3 shows a 3D view of the complete LEBT together with the ion source and the chopper. All parts except for the chopper are ready and and assembled at CEA, Saclay, Paris. The Chopper is currently under production and is expected to be integrated in the LEBT in late 2015.

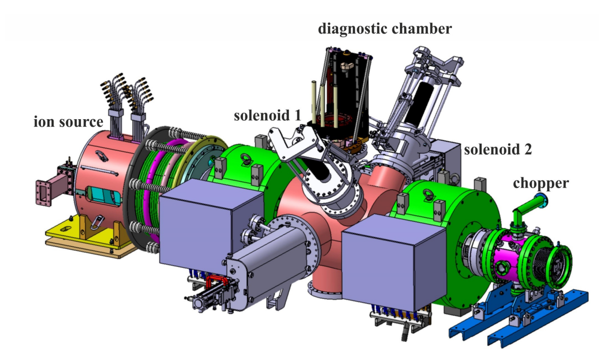

Figure 3: 3-D view of the ion soucre, LEBT and chopper

4-VANE RFQ

An RFQ will be directly connected to the LEBT. Given the high operating frequency of the p-Linac, the decision to build a 4-vane type RFQ seems obvious. Nevertheless two other possibilities came into question and are still under investigation by the Univ. of Frankfurt. It has been demonstrated that a 4-rod or even a ladder RFQ are powerful enough to be considered in the p-Linac. The decision to focus on a 4-vane RFQ was made together with international experts in mid 2014. Since then the beam dynamics and different vane shapes have been studied and a collaboration with INFN, Legnaro is under preparation for production and assembling this RFQ. Figure 4 shows a 3D view of the most recent RFQ simulation. Presuming a quick progression with the collaboration and no unexpected design difficulties the 4-vane RFQ can be ready until 2018.

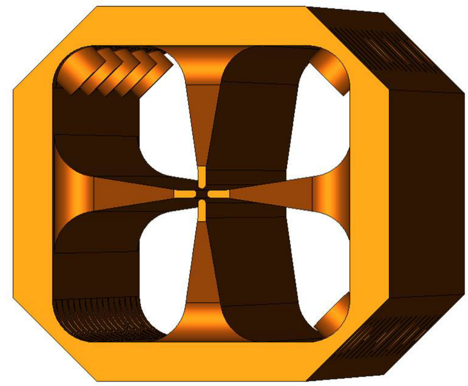

Figure 4: 3-D view of the latest RFQ simulations

BUNCHER

The longitudinal beam matching before the RFQ at 95 keV and at the diagnostics area at 35 MeV and also behind the complete p-Linac at 70 MeV is realised by three individual buncher cavities. Each cavity has its own requirements mainly caused by the varying beam energy. This results in three different lengths, so much that the the bunchers have two, four and six gaps respectively. The beam dynamics layout of a dedicated buncher is straight forward and was finalized together with the CH-cavities' beam dynamics. Mechanically the bunchers are not completely designed. A final technical layout can be acquired with modest resources. Figure 5 shows a first design study used for digital mock-up analysis. This gives an idea of the simplicity of such bunchers. The realization is planned for next year and will not take longer than 12 months.

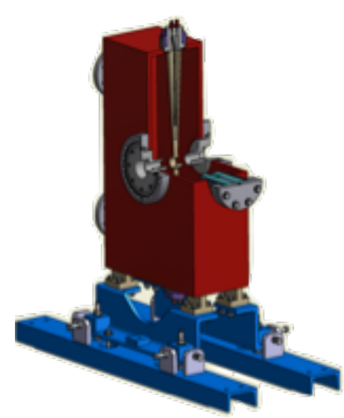

Figure 5: 3-D view of a general 2-gap buncher layout

CH-CAVITIES

The main acceleration from 3 MeV up to 70 MeV will be realized with six CH-cavities grouped into two sections,

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which are separated by a dedicated diagnostics area at 35 MeV. The first section will consist of three coupled CH each housing a quadrupole triplet within the vacuum and RF penetrated area. These coupled cavities are not trivial to be build, but as the prototype CH has shown it can be done, if an intense follow up is realised. The second section will consist of three up to 3.5 m long common CH-cavities. These cavities have only quadrupole triplets in between and the RF design is much more straightforward.

Beam dynamics investigations have finally been concluded. It could be shown, that the diagnostics area and the LEBT between RFQ and first CH can be realized more simple than initially expected. The next step is to implement the latest changes into the RF simulations and to validate the overall design. It is foreseen, that all parameters are defined shortly and tendering of the cavity production can start within this year. After the contractor is chosen it is planed to have the first cavity on campus after two years, meaning that the production will be finished in 2018.

FOCUSING MAGNETS

Induced by the revised beam dynamics simulations some modifications on the quadrupole triplets have been decided. The new layout of the magnets is simplified and unified for the whole p-Linac. Only one kind of joke profile is used and only to different lengths of triplets are used. All of these Triplets will be housed in a general squared vacuum tank which also supports the adjacent cavities. Tendering of the triplets took place in late 2014 and the contract with the company Danfysik was signed early 2015. This results in delivery of all magnets until 2017.

RF & POWER SUPPLIES

The main p-Linac components, such as the RFQ and the CH cavities will be powered by seven 325 MHz klystrons. Benefiting from recent developments, under the participating of CNRS, the klystrons will be delivered by the company Thales. The first klystron is already at GSI and is currently under commissioning at the RF test stand. Full operability is foreseen for late summer in this year. The CH prototype will also be ready by then and used as a resonant load for further testing of the klystron and the cavity itself. The power supply for the klystron is at the moment realized with a lease modulator. This device will be returned to CERN by the end of this year. In the meantime an optimized version of the modulator is under specification and will be ordered as soon as possible, and will be used for all p-Linac klystrons. In addition three solid state drivers with 45 kW power will be used to operate the buncher cavities. The 45 kW amplifiers are on site since late 2014. Recently they have been tested with a small 4-Rod RFQ model used as a resonant load. This tests could be performed with great success and the buncher amplifiers are therefore operational.

BEAM DIAGNOSTICS

All along the p-Linac a variety of beam diagnostic devices will be installed. Many of which are part of foreign contributions. Beam position monitors for example will originate from CEA, Saclay, Paris. Figure 6 shows the BPM prototype which will later on be mounted to the exit of the quadrupole triplets.

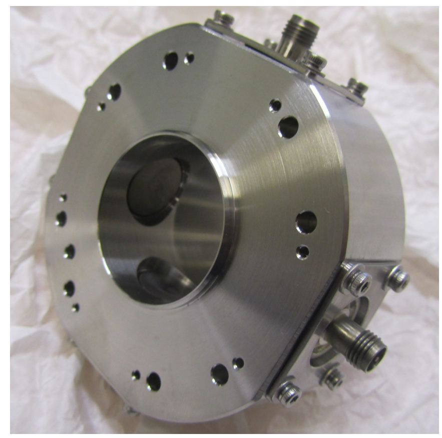

Figure 6: Picture of the BPM prototype with housing

CONCLUSION

This paper showed the current status of the p-Linac. The design of all major components is done and only minor changes in specifications are expected. Tendering of the missing parts may have started until early 2016.

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