DEVELOPMENT AND MEASUREMENTS ON A COUPLED CH PROTON LINAC FOR FAIR

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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. Each cavity will be powered by a 3 MW klystron. For the second acceleration unit from 11.7 to 24.3 MeV a 1:2 scaled model of a coupled CH-cavity has been built. Low level RF measurements have been performed to determine the main parameters and to prove the concept of coupled CH-cavities. Technical and mechanical investigations have been done in 2009 to prepare a complete technical concept for manufacturing. Recently, the construction of the prototype has started. The main components of this second cavity will be ready for measurements in summer 2010. At that time the cavity will be tested with dummy stems (made from aluminum) wich will allow precise frequency and field tuning. This paper reports on recent developments and measurements of the prototype model. It will outline the main fabrication steps towards that novel type of proton DTL.

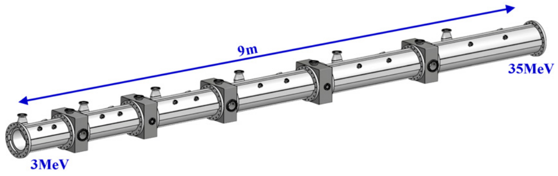

Figure 1: 3D-View of tank 1

INTRODUCTION

The proton linac for FAIR is mechanically grouped in two tanks, each having a length of about 10m. Based on the actual design the first tank will consist of 3 coupled CH-cavities. Between both tanks there will be a diagnostics section with an additional rebuncher inside.
Further investigations have shown that a simplified layout of the 2nd section of the proton linac will be an improvement. In that case, three simple CH cavities without a coupling cell will be used, reducing the triplet lens number by three and simplifying the cavity layout a lot.

THE COUPLED PROTOTYPE CAVITY

The prototype cavity corresponds to the second coupled cavity of the first tank. 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 2.8m and an inner diameter of about 375mm.
The coupling cell has a length of $2\beta\lambda$ and hosts the focusing triplet lens within one large drift tube. The intertank sections will also house triplet lenses as well as beam diagnostics. They mechanically connect 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 [MΩ/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]	179 / 210 / 182

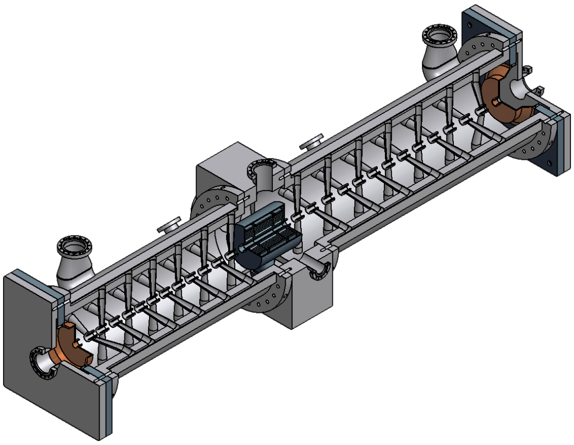

Figure 2: 3D-View of the coupled prototype cavity

MECHANICAL DESIGN

Intertank unit

The concept based on two 10m long tanks leads to very tight tolerances with respect to the surface finishing of the tank flanges as well as with respect to the transverse alignment against the beam axis. To control mechanical deformations by gravity or stress the linac will be mounted on a rail system - as practiced at the GSI Unilac. Alternatively, each tank could be mounted precisely on a robust support and then be aligned via a 3-point adjusting device with respect to the beam axis.

The neighbored cavities will be connected by an intertank unit. It consists of a quadrupole triplet housed in a drift tube and mounted into a rectangular massive frame which provides the end flanges for the neighbored cavities at the same time. No bellow connection along the beam line is foreseen in that concept within each 10m section.

Drift tube sections

It has been demonstrated successfully by a 8-cell prototype cavity [4] that the drift tube stems can be welded into the tank wall at the inner surface. To avoid large holes in the outer tank, special techniques were developed to integrate long drift tubes with modest transverse stem diameters. Additional care must be taken to limit longitudinal stress along the stem caused by temperature differences between tank wall and drift tube structure.

Whith respect to the cooling system a stem and drift tube geometry was developed which allows to produce the stems in four single parts.

New camera assisted welding techniques make it possible to weld the stems with very high precission.

Cooling system

Because of the low duty cycle, investigations on the cooling system showed that it is possible to keep the whole cavity at moderate temperature with only eight cooling channels (20mm diameter) along the cavity wall and at a wall thickness of 5mm along the stems.

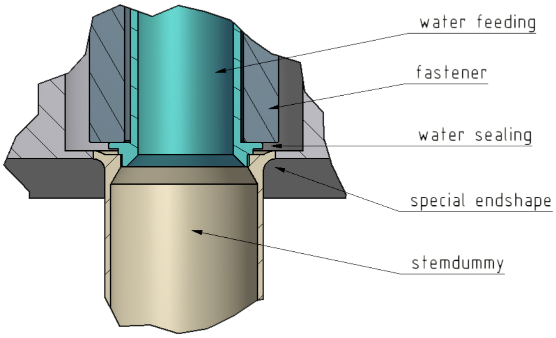

Figure 3: Cross sectional view of deatiled stem tank connection

Assembling techniques

During the design period of the prototype cavity, several investigations on the welding process have been performed, to proof not only the reliability but also to mark the frontiers of conventional inert gas welding.

A special stem and tank geometry was developed, that makes it possible to insert full length stems longitudinally into the tanks and put it into an upright posture at the final position. This assembling method makes it possible to weld the stems directly to the inner tank surface in a way, that is acceptable for the following galvanic copper plating.

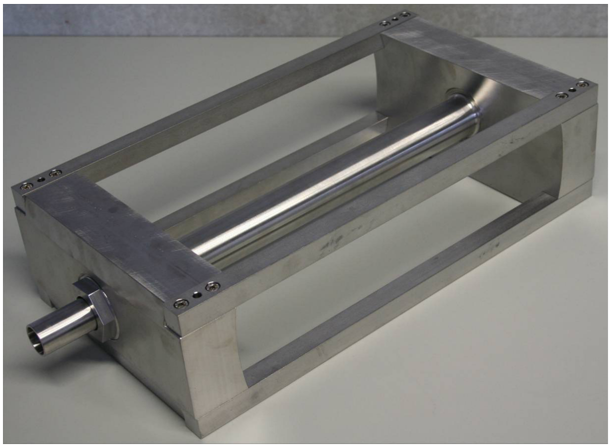

Figure 4: Stem dummy used for welding and cooling tests

Status of manufacturing

Due to technical standardisation, that has to be complied by the manufacturing process, a short delay came up, which stalled the start of the manufacturing by some weeks.

At present, the main parts are in production and assemblage of the main parts is expected in summer 2010.

RF PROPERTIES AND TUNING

Tuning concept

The coupling between an acceleration section and the coupling cell is accomplished by RF-fields around the coupling drift tube as well as by the gap capacity. The corresponding drift tube inside the coupling cell is charged oppositely at the ends in the mode of operation. This means, that it acts like an Alvarez type drift tube.

The coupling factor is around 0.3%. This means, the spacing between the 0-mode and the $\pi/2$-mode is about 1.3MHz, which seems to be sufficient. Possibilities for an increased mode separation are actually investigated at the rf model.

Concepts for fine tuning of the voltage distribution already during cavity fabrication with static tuners are studied. The results seem very promising.

The acceleration sections of the cavity contain no screwed connections. Therefore a Q-value within 5% of the theoretical value is expected. This was demonstrated successfully by the 8-cell prototype. [4]

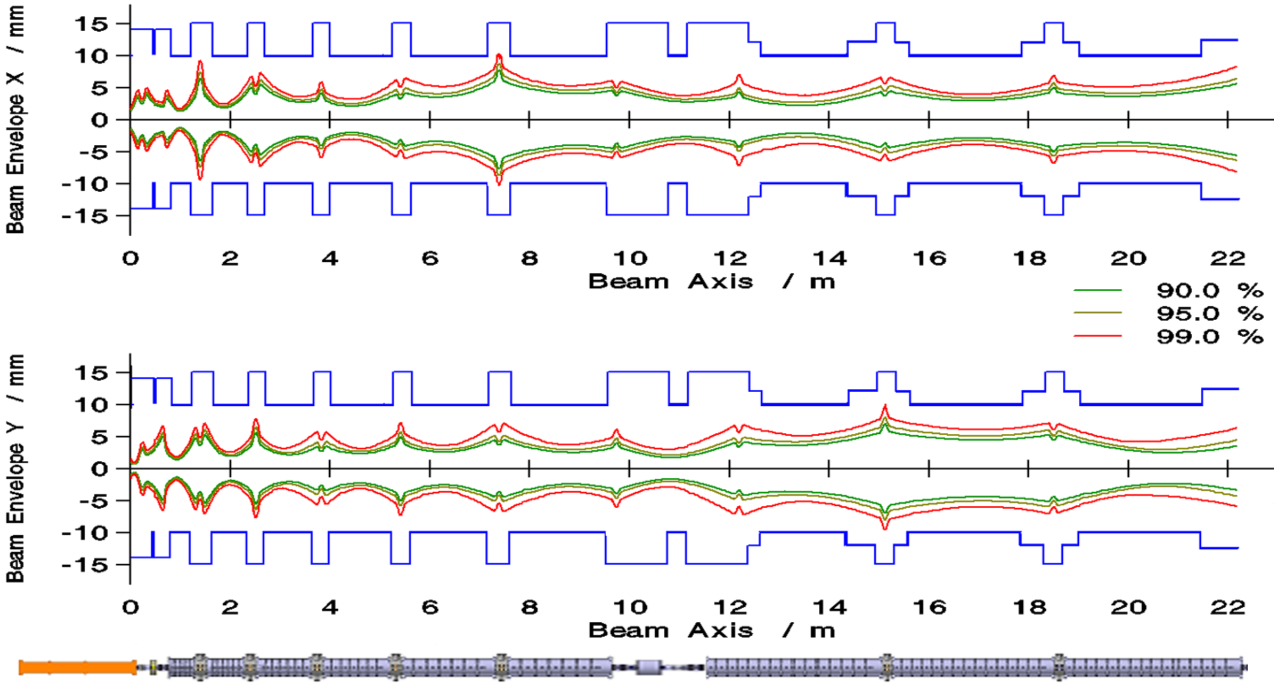

Figure 5: Schematic view of the proton linac with beam envelopes at 80mA, 100% transmission

Measurements

Fig. 6 shows all permanently installed tuners on the scaled model. All tuners except tuner no. 5 have a counterpart 180 around the cavity at the same z position.

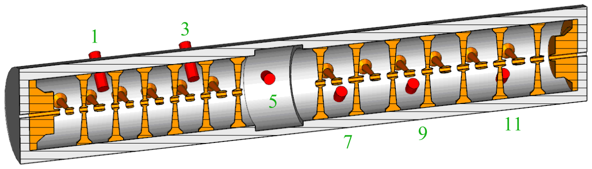

Figure 6: Cross sectional view of the 2:1 scaled model with cylindrical tuners, 30mm diameter

During the measurements on the coupled CH model, a major point was to investigate the dynamic tuning system, which is responsible for frequency regulation during operation.
Fig. 7 shows the possible tuning range of tuner no. 5. Inserting the plunger by a length of 35mm causes a frequency shift of about 1MHz for the 0 Mode and 1.3MHz for the π Mode, that has no major effect on the voltage distribution.

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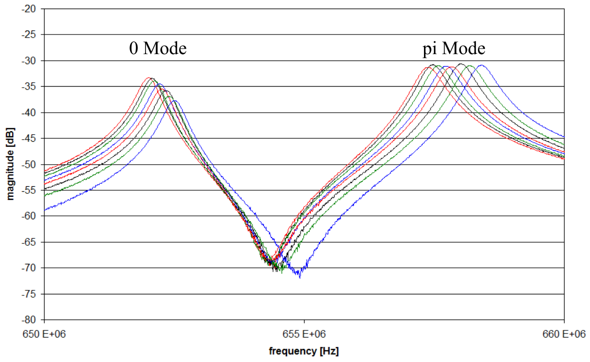

Figure 7: Mode spectrum to show the tuning range of tuner no. 5

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