FIRST COUPLED CH POWER CAVITY FOR THE FAIR PROTON INJECTOR

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Abstract

For the research program with cooled antiprotons at FAIR a dedicated 70 MeV, 70 mA proton injector is required. [1] 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 2.5 MW Klystron. For the second acceleration unit from 11.5 MeV to 24.2 MeV a 1:2 scaled model has been built. [2] Low level RF measurements have been performed to determine the main parameters and to prove the concept of coupled CH cavities. For this second tank technical and mechanical investigations have been performed in 2010 to develop a complete technical concept for the manufacturing. In Spring 2011, the construction of the first power prototype has started. The main components of this cavity will be ready for measurements in summer 2011. At that time, the cavity will be tested with a preliminary aluminum drift tube structure, which will allow precise frequency and field tuning. This paper will report on the recent technical development and achievements. It will outline the main fabrication steps towards that novel type of proton DTL. Also first low level RF measurements are expected.

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.

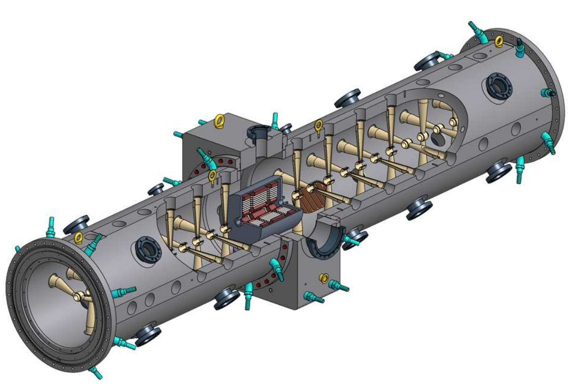

Figure 1: 3D-View of the coupled prototype cavity

THE COUPLED PROTOTYPE CAVITY

Figure 1 shows the prototype cavity which corresponds to the second coupled cavity. 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 360mm.

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, as shown in Fig. 2. 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]	180 / 217 / 182

MECHANICAL DESIGN

Intertank Unit and Cavity End Cell

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.

Within the intertank units space is narrow. Therefore a special cavity end cell geometry was developed, that allows

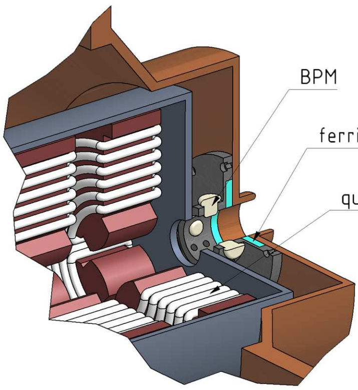

Figure 2: Cross sectional view of a detail of the intertank section with beam position monitors

to mount diagnostics, such as beam position monitors, next to the quadrupol lense inside the RF free region.

To make this kind of layout possible several changes of the mechanical and RF design had to be performed. Of capital importance were the inclined stems as well as a special end shape of the cavity wall to shield the RF free region against the accelerating 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. Figure 3 shows the curved stem ends, which were design for stress release.

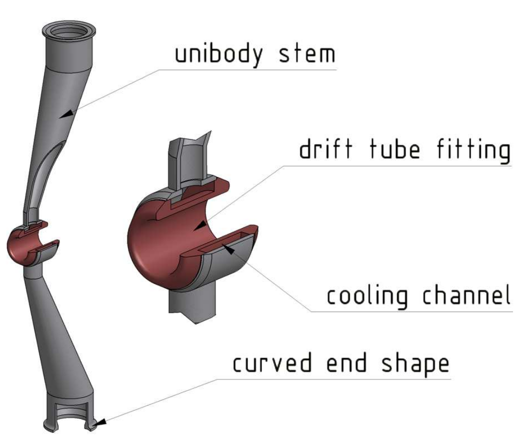

Figure 3: Cross sectional view of an inclined stem with a detail of the drift tube

With respect to the cooling system a stem and drift tube geometry was developed which allows to produce the stems in two single parts. The stems are produced hollow as a unibody piece in which only the drift tube has to be inserted. This technique makes it possible to stick to the very tight tolerances for the stems alignment.

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

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.

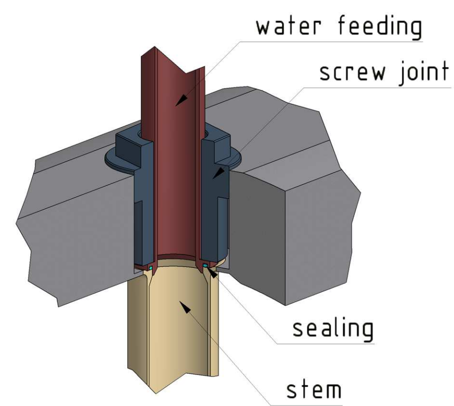

Figure 4: Cross sectional view of deatiled stem tank connection

As shown in Fig. 4, the water feeding of every stem is removable by a large screw and therefore makes it possible to examine the welding area and the inside of the stems. This is not only facilitating the maintenance work but also gives the possibility to precisely adjust the stems before welding.

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.

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 time.

At present, the main parts are in production and assemblage of the main parts is expected this year.

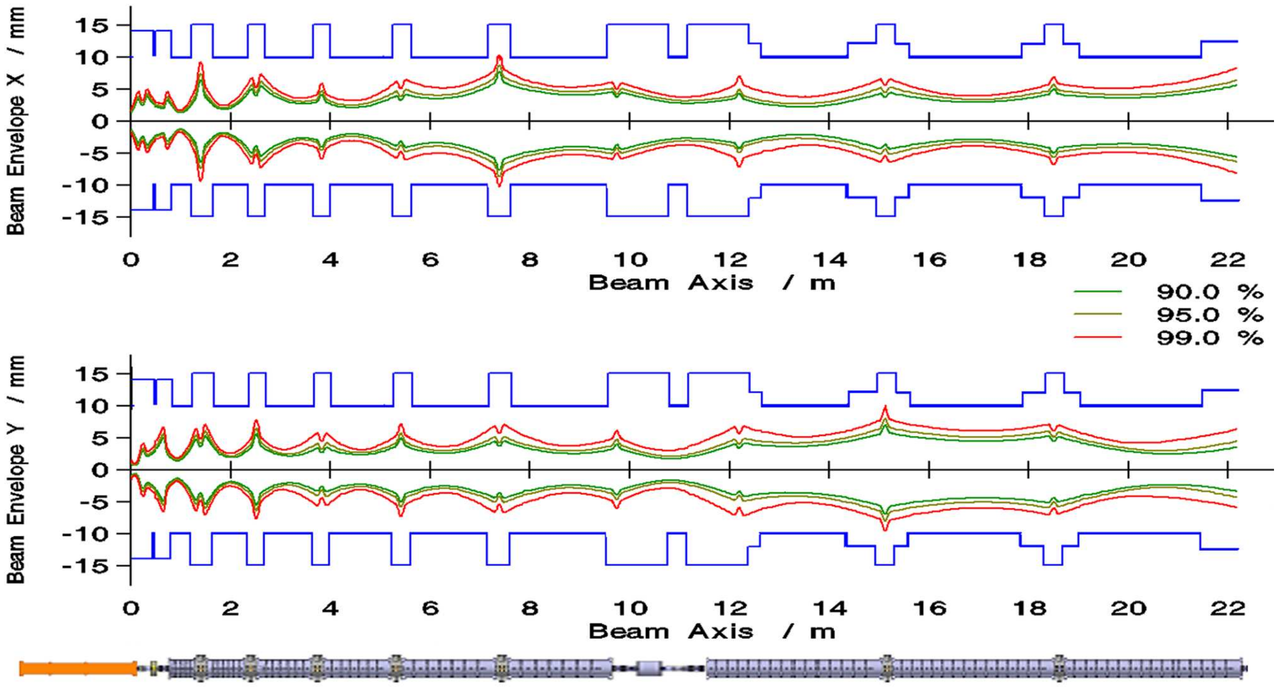

Figure 5: Schematic view of the proton linac with beam envelopes at 80mA, 100% transmission

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. [3]

Measurements

During the measurements on the 1:2 scaled model, a major point was to investigate the dynamic tuning system, which is responsible for frequency regulation during operation.

Figure 6 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.

Figure 5 shows the beam envelopes for the whole proton injector.

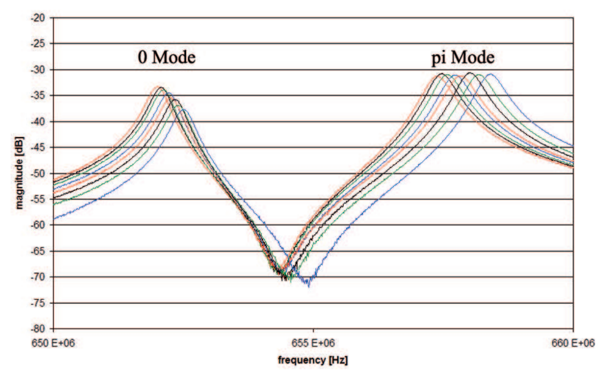

Figure 6: Mode spectrum to show the tuning range of tuner no. 5

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