Development of a coupled CH-power cavity from 11.7 MeV to 24.3 MeV

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Abstract

This report adds the last results to CARE-Report-2008-014-HIPPI. It describes the development of a full scale, 12.6 MV cavity to be tested at a nominal rf power of 1.35 MW. Based on cavity simulations and on investigations with a 1 to 2 scaled cold rf model the geometry of the 27 cell, coupled CH- cavity is fixed step by step. The design of the power cavity has progressed and the cavity wall structure has been ordered already.

Introduction

During the funding period of CARE-HIPPI it was investigated, whether CH-cavities can be attractive for proton acceleration.
In a first step, a 8 cell CH-prototype was built, to investigate welding techniques and the galvanic copper plating process at this specific geometry. [1] This cavity was also operated under UHV conditions and with an time averaged rf-power up to 2kW. No pulsed high power rf source was available to perform high voltage tests as well.
In a second step a rf model was built to investigate coupled CH-cavities.

Meanwhile GSI decided to base the FAIR-proton injector on this new concept. A CH-DTL development from 3 - 70 MeV was started.
This report concentrates on the present status of the prototype cavity which is under construction. This cavity corresponds to the second coupled cavity of the actual FAIR proton linac layout. A 2.5 MW 325 MHz power klystron was already delivered to GSI and a test stand will be installed to test the CH-prototype with nominal rf power. The tests will start end of 2010 / early 2011. In HIPPI report 2008 [2] the main characteristics of this cavity and investigations on a 1:2 scaled model cavity were explained already.
This report tells some latest developments on the cavity geometry and the concept of technical realization.

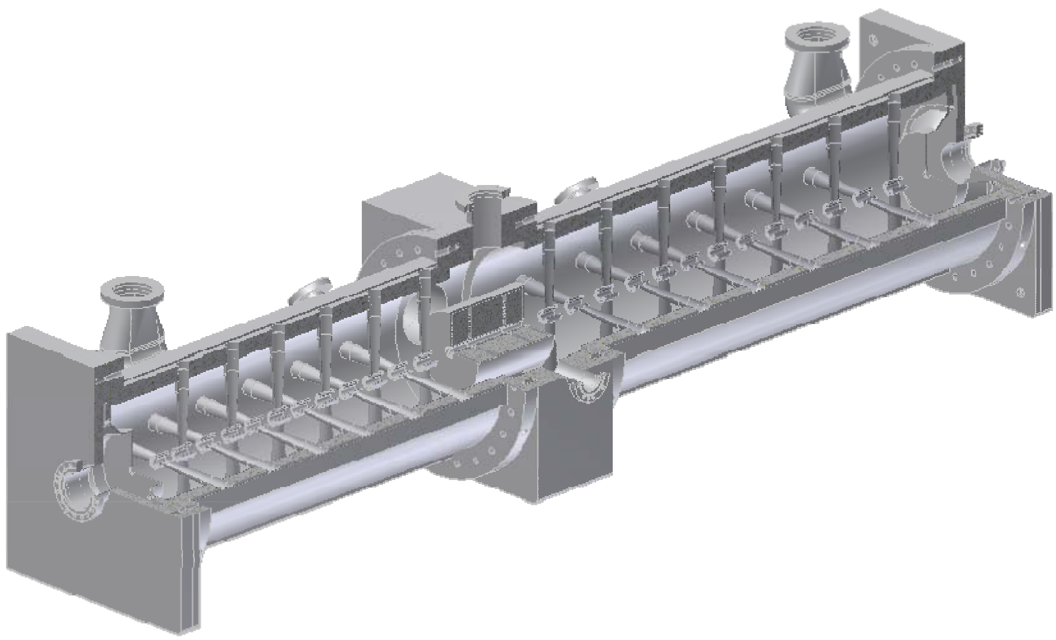


Fig. 1: 3d view into the coupled cavity no. 2 to be built as a prototype cavity

The 70 MeV FAIR proton injector

The linac is mechanically grouped in two tanks, each having a length of about 10m. Fig.1 shows the 35 MeV section. In between both sections there will be a diagnostics section affording two lenses and one rebuncher to get a safe beam transport.

While it is clear that the low energy section has to apply the coupled cavity concept to exploit the full power of one klystron into one cavity the beam dynamics would allow three simple, long cavities in the high energy section, alternatively. The final decision will depend on the difference in beam quality and in construction costs.

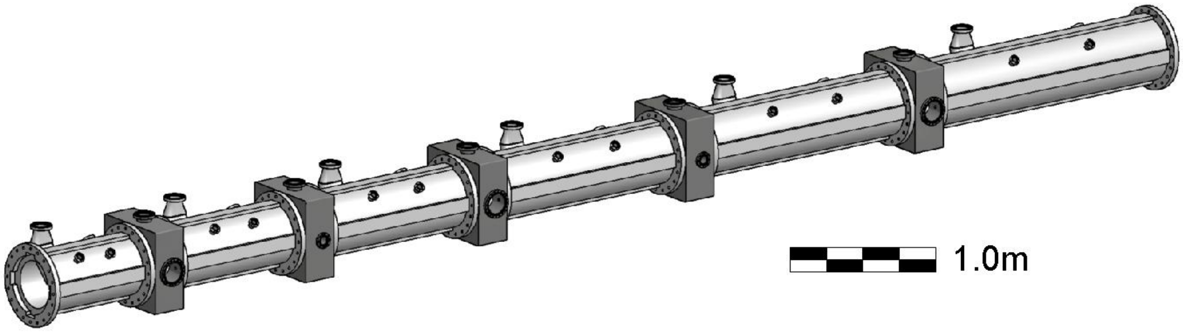


Fig. 2: View on the 35 MeV low power section of the proton linac, consisting of coupled CH-cavities no. 1, 2, 3.

Design of the coupled prototype cavity No. 2

The low energy section consists of 13 gaps, followed by the coupling cell and by the 14 gap high energy section. The whole cavity has an inner length of about 2.8m.

The coupling cell has a length of $2\beta\lambda$ and contains the focusing triplet lens within one drift tube.

Table 1 lists the main cavity parameters.

Fig. 3 shows a sectional vertical view along the beam axis. Every second stem is crossed against the neighbours by 90 deg, as shown by Fig. 4.

Table 1: Main parameters of coupled cavity no. 2

No. of gaps	27 (13+14)
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
Effective Shunt Impedance [MΩ/m]	60
Average E_0T [MV/m]	6.4 - 5.8
Kilpatrick Factor	2.0
Coupling Constant [%]	0.3
No. of Plungers	11 (4+1+6)
Beam Aperture [mm]	20
Total Length [mm]	3000

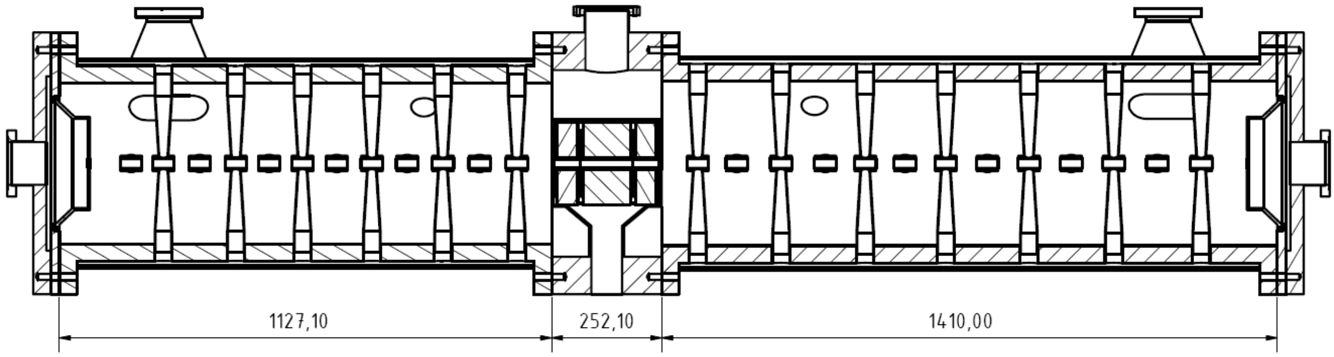


Fig. 3 Cross sectional view of coupled cavity no. 2

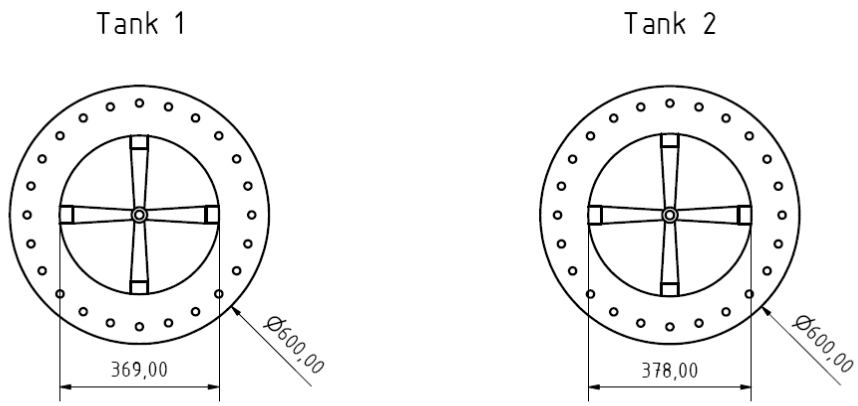


Fig. 4: Cross sectional view of the two acceleration structures of coupled cavity no. 2

Beam dynamics

The 99% beam envelope at 45mA and with included parameter errors are plotted in Fig.5. The foreseen aperture seems sufficient in the FAIR injector linac case as the duty factor will stay below $3 \cdot 10^{-4}$.

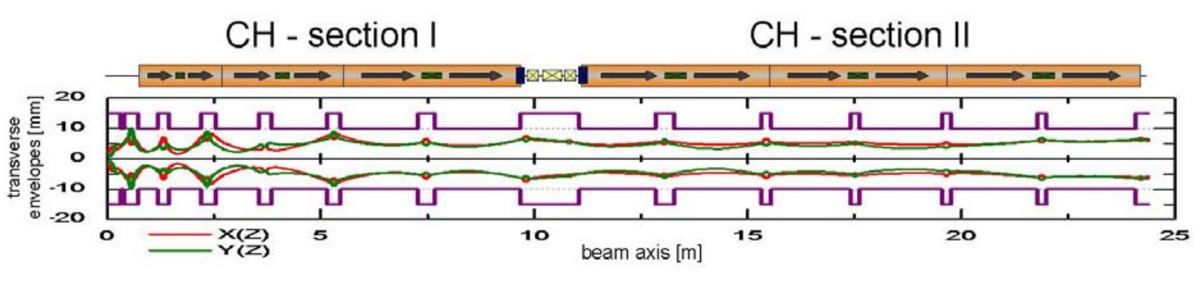


Fig. 5: 99% beam envelopes at 45mA of the whole 70 MeV DTL

RF-Properties

The coupling cell with a length of $2\beta\lambda$ houses the triplet lens. The corresponding drift tube ist charged oppositely at the ends in the mode of operation. This means that it acts like an Alvarez-type drift tube. The coupling between an acceleration section and the coupling cell is accomplished by HF-field around the coupling drift tube as well as by the gap capacity. The couplin factor is around 0.3%. The spacing between the 0 - mode and the $\pi/2$ - mode ia about 1.3MHz, which seems sufficient. Possibilities for an increased ode separation are actually investigated at the rf model.

Concepts for fine tuning of the voltage distribution already during cavity fabrication are studied as well and seem promising.

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

Mechanical Design

As printed out before three cavities will mechanically form one tank of about 10m. The prototype cavity probes the second cavity of the low energy section.

This concept leads to tight tolerances with respect to the plane orientation of the and flanges as well as with respect to their transverse positioning against the beam axis. To avoid mechanical deformation by gravity the linac will be placed on a rail system with flexible supports - as applied on the GSI Unilac. Alternatively, each tank could be mounted on a robust support and then be aligned via a 3-point adjusting device with respect to the beam axis.

The neighboured cavities will be connected by an intertank unit (Fig.6). It consists of a quadrupole triplet housed in a drift tube and mounted into a rectangular flange which at the same time provides the endwalls for the neighboured cavities. No bellow connection along the beam line is needed by that concept.

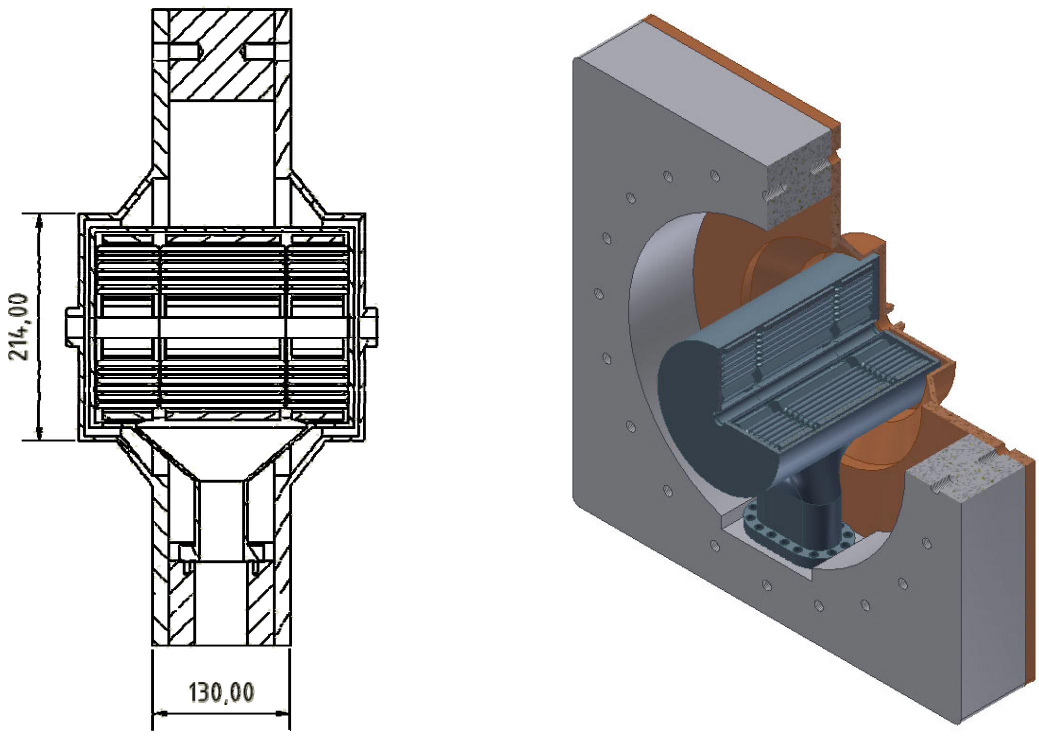
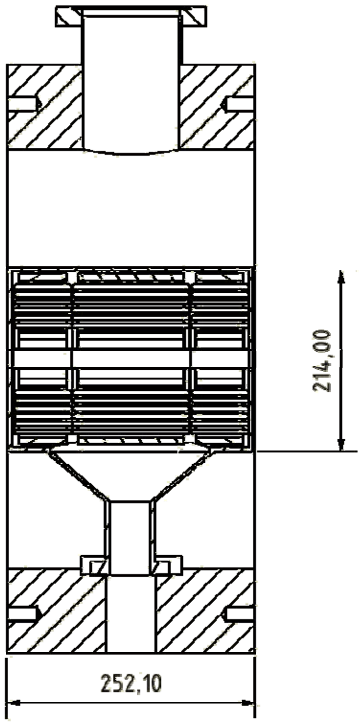


Fig. 6: Intertank unit between coupled cavities 1, 2, 3 in section no. 1)

Coupling Cell

The cross sectional view as well as a view in direction of the beam axis on the coupling cell are shown in Fig. 7. It is investigated, whether a capacitive 4-knob-probe could be integrated into the drift tube containing the quadrupole triplet. The technology of cavity internal lenses can be transfered from IH-cavities as built many times successfully.
the flanges of the coupling tank will be covered by:

- incoupling loop
- vacuum pump
- plunger
- quadrupole lens



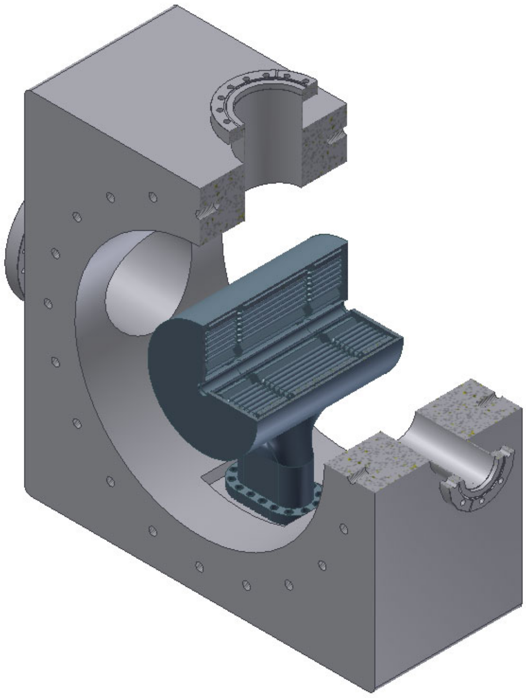


Fig. 7: Views of the coupling cell with internal quadrupole triplet

Drift tube sections

As was demonstrated successfully by the prototype the drift tube stems can be welded into the tank wall at the inner surface. Special techniques were developed to integrate long drift tubes with modest transverse stem diameters. Additionally care must be taken to limit longitudinal stress along the stem caused by temperature differences between tank wall and drift tube structure.

Figs. 8 & 9 show the cooling concepts of the stems and drift tubes.

Fig. 10 shows the integration of the stems into the cylindrical tank with cooling channels.

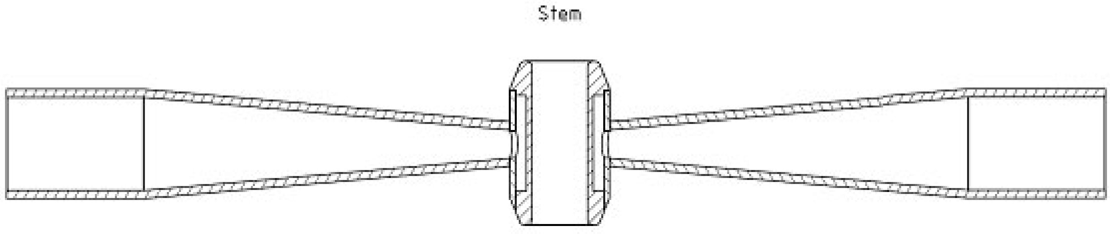


Fig. 8: Cross sectional view of a watercooled stem with drift tube

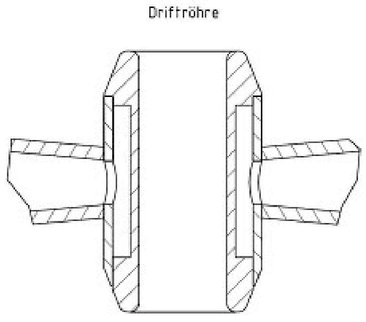


Fig. 9: - Detail of a water cooled drift tube

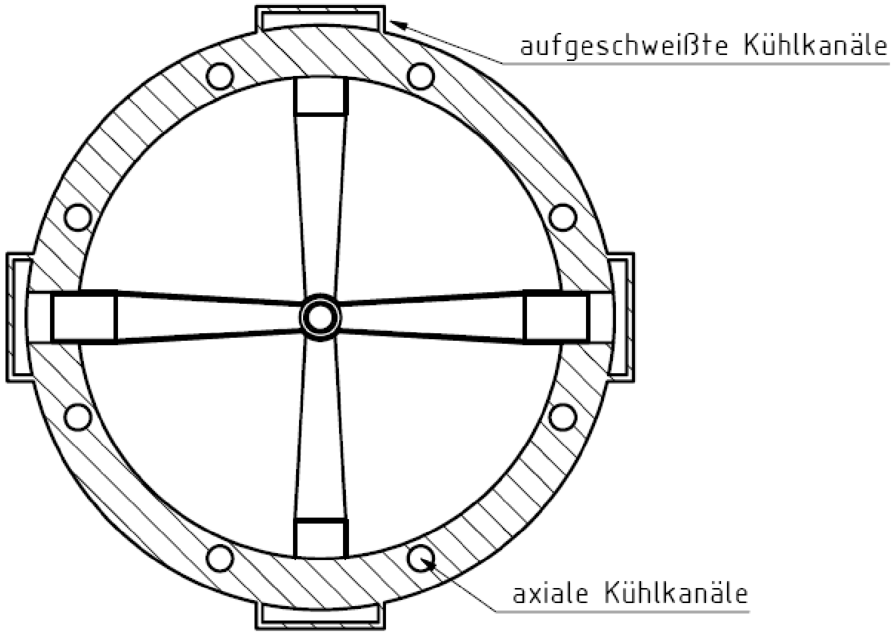


Fig. 10: Cooling channels in a cross sectional view

Conclusions

During the 5 year period of HIPPI the idea of a proton linac based on CH cavities was intensively investigated at IAP and with strong support and encouragement by GSI and by the HIPPI community. The prototype cavity under construction has to demonstrate finally the feasibility and efficiency of this new concept.

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395)

4. References

[1] Status of the 70MeV, 70mA CH Proton DTL for FAIR
G. Clemente, H. Podlech, R. Tiede, U. Ratzinger
Proceedings of the EPAC06, p. 1283

[2] HIPPI-Relevant Activities at IAP-Frankfurt on the Development of the Room Temperature CH-DTL
G. Clemente, H. Podlech, U. Ratzinger, R. Tiede, S. Minaev
CARE-Report-2008-014-HIPPI