PROGRESS IN SUPERCONDUCTING CH-CAVITY DEVELOPMENT

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Abstract

The superconducting CH-Cavity (Crossbar H-Mode) is the first multi-cell drift tube cavity for the low and medium energy range of proton and ion linacs. A 19 cell, β = 0.1, f = 360 MHz prototype cavity has been developed, fabricated and tested successfully with a voltage of 5.6 MV corresponding to gradients of 7 MV/m. Two new, optimised CH-cavities are currently under development at IAP. One cavity (f=325.224 MHz, β=0.15, 7 cells) is foreseen as an upgrade for the GSI Unilac. The other one (f=216.96 MHz, β=0.059, 15 cells) is planned for the cw operated heavy ion linac also at GSI. The construction of the 325 MHz 7-gap CH-cavity has started. The new cavity has an optimized geometry regarding tuning possibilities, high power RF coupling, minimized end cell lengths and possibilities for surface preparation. After low power tests it is planned to test this cavity with a 10 mA, 11.4 MeV/u beam delivered by the Unilac at GSI. For preliminary tests a copper model has been fabricated and tested in order to check the properties of the new geometry.

THE 325 MHz CH-CAVITY

Large international projects with high requirements regarding beam power and quality (e.g. IFMIF (**I**nternational **F**usion **M**aterial **I**rradiation **F**acility) [1, 2] / EUROTRANS (**EURO**pean Research Programme for the **TRANS**mutation of High Level Nuclear Waste in an Accelerator Driven System) [2]) ask for new linac developments. The superconducting CH-cavity is an excellent candidate for those requirements because it reduces the number of drift spaces between cavities significantly compared to conventional low-β ion linacs [3]. Along with KONUS beam dynamics, which decreases the transverse rf defocusing and allows the development of long lens free sections, this leads to high real estate gradients with moderate both electric and magnetic peak fields. A 19-cell, superconducting 360 MHz CH-prototype (see Figure 1) has been developed and successfully tested in the past years. Gradients of up to 7 MV/m, corresponding to an effective voltage gain of 5.6 MV could be reached [4]. These promising results led to a new design proposal for high power applications (see Figure 2). The new cavity is operated at 325 MHz, consists of 7 cells, β = 0.1545 and has an effective length of 505 mm.

The most important changes in comparison to the CH-prototype are:

- inclined end stems

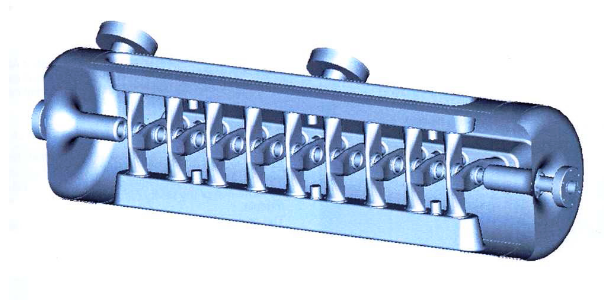

Figure 1: Sideview of the 19-cell, β = 0.1, 360 MHz CH-Prototype.

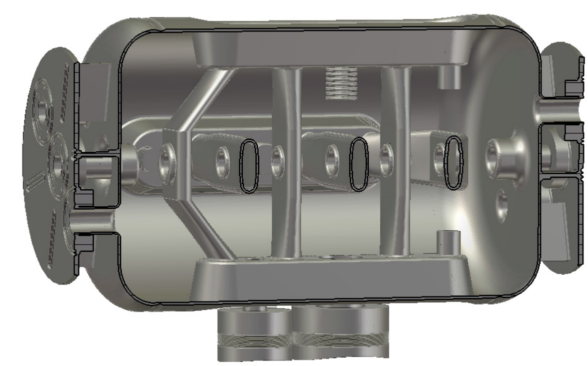

Figure 2: Design of the superconducting 7-cell CH-Cavity (325 MHz, β = 0.15)[6].

- additional flanges at the tank caps for cleaning procedures
- two membrane tuner inside the cavity
- two ports for larger power couplers due to changed stem geometry

These elements can be seen in Figure 2.

Inclined end stems lead to a more homogeneous field distribution along the beam axis (see Figure 3) compared with straight stems because the volume for the magnetic field in this area and therefor the inductance is increased. At the same time the longitudinal dimensions of the cavity can be reduced by about 20%-25% since an extended end cell is not needed for field flattening. Flanges at the tank caps provide a pleasant way to process the cavity surface with BCP (**B**uffered **C**hemical **P**olishing) and HPR (**H**igh **P**ressure **R**insing). In Table 1 the main parameters of the new cavity are summarized.

For the tuning of the cavity three types of tuners are foreseen: There will be 4 static tuners with a diameter of 30 mm and a height between 0 and 60 mm to adjust the frequency

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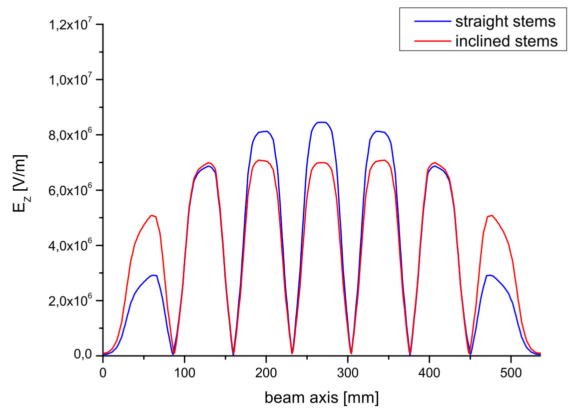

Figure 3: Field distribution for different stem / girder geometries.

Table 1: Specifications of the 325 MHz CH-cavity

β	0.1545
frequency [MHz]	325.224
no. of cells	7
length ($\beta\lambda$-def.) [mm]	505
diameter [mm]	352.6
E_a [MV/m]	5
E_p/E_a	5.1
B_p/E_a [mT/(MV/m)]	13
G [Ω]	64
R_a/Q_0	1248
R_aR_s [Ω^2]	80000

after fabrication. They are positioned between the stems and the height is fixed after adjustment. The frequency range is plotted in Figure 4. Furthermore a new way to tune

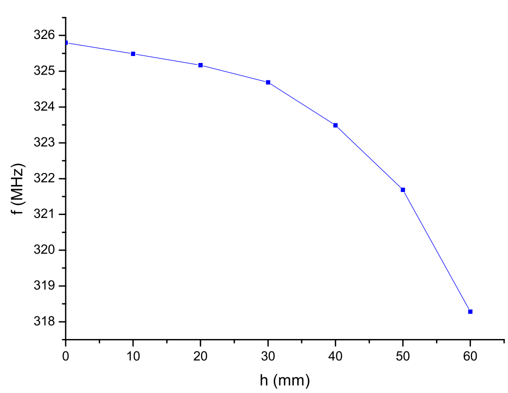

Figure 4: Tuning range of the static tuners.

the frequency during beam operation will be tested. While the CH-prototype was tuned by pushing the tank caps and varying the end cell of the resonator, the new cavity will use two membrane tuners (a fast and a slow one) inside the cavity. They will be placed on the girder between the stems and driven by a piezo. The slow tuner adjusts the frequency after cooling the cavity down, while the fast one regulates the frequency during beam operation. A prototype of the membrane tuner (see Figure 5) has already been tested at room temperature. Further tests at 4 K and with piezos are planned within the next weeks.

To calculate the influence of the membrane tuners rf simulations have been performed. The height of the static tuners was kept constant while increasing continuosly the height of the fast membrane tuner. Figure 5 shows that at a point of approximately 50 mm tuner height a shift of 150 kHz/mm is achievable, which is sufficient for fast tuning during beam operation.

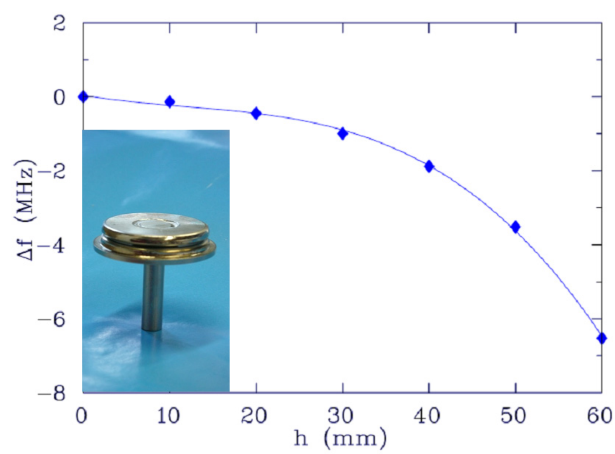

Figure 5: Tuning range of the fast membrane tuner.

It is planned to test the cavity with beam at the GSI Unilac at the exit energy of 11.4 MeV. The frequency of 325 MHz is the third harmonic of the Unilac.

THE 217 MHz CH-CAVITY

At GSI the design effort for a cw operated heavy ion linac has started. The linac will be used for the production of super heavy elements. It has to provide ion beams with a A/q of up to 6 and energies up to 7.3 AMeV. Above an energy of 3.5 AMeV the linac is fully energy variable. Due to the required cw operation the main linac will be superconducting. The front end is the existing high charge injector (108.48 MHz, 1.4 AMeV) which is presently being upgraded for the required duty cycle. The main acceleration of approximately 35 MV will be provided by a superconducting linac consisting of 9 CH-cavities operated at 217 MHz (see Figure 6). The first superconducting CH-cavity (cavity no. 5, see Figure 7) is currently under design and it is planned to test it with beam in 2012. The geometrical properties are adapted to the 325 MHz CH-cavity and first rf simualtion results could be achieved (see Table 2).

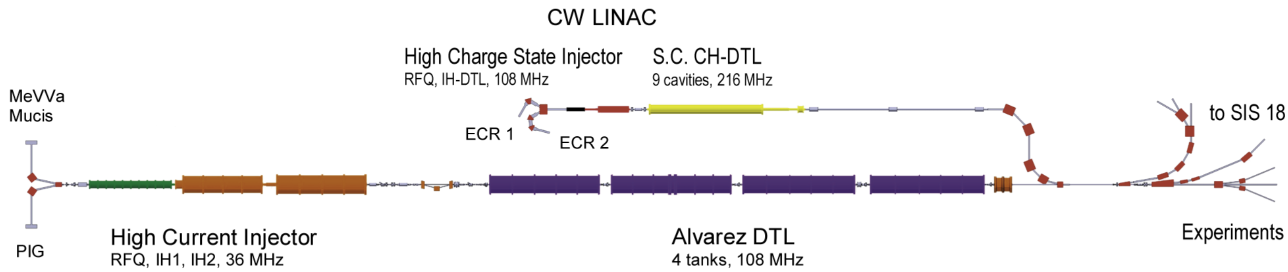

Figure 6: Schematic overview of the cw heavy ion linac.

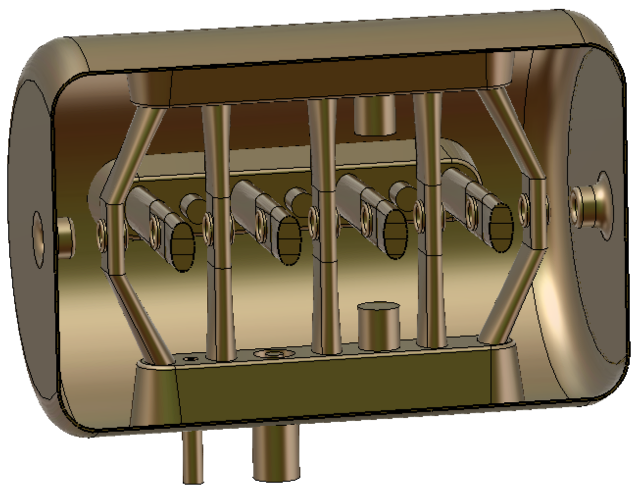

Figure 7: First design layout for the cw heavy ion linac.

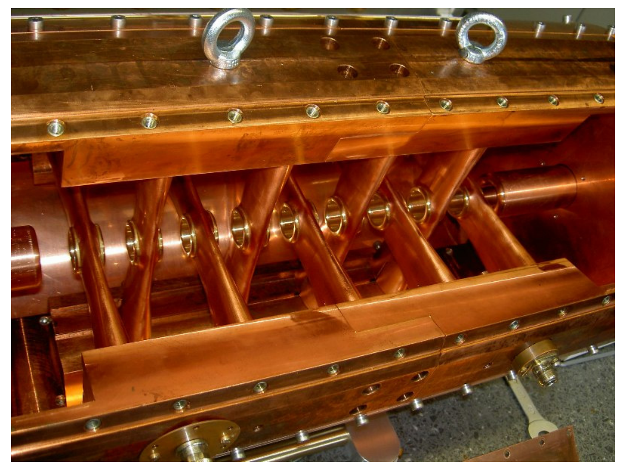

Figure 8: Photograph of the r.t. copper model.

Table 2: Parameter of the Fifth s.c. CH-cavity of the cw Linac

β	0.092
Frequency [MHz]	217.96
No. of cells	10
Length (βλ-def.) [mm]	642
Diameter [mm]	470
E_a [MV/m]	5.1

THE COPPER MODEL

A room temperature copper model has been built to validate the electromagnetic simulations and for preliminary results in the run-up to the fabrication of the superconducting CH-structure (see Figure 8) [5]. The design is very modular in order to modify the geometry for future purposes [7]. Possible modifications include:

- cell number
- cell length
- cavity length
- coupler size /position
- stem shape
- tuner position
- tuner size and shape

Bead pull measurements with an applied β-profile show an unflat field distribution at a constant gap to cell length ratio of 0.5 (see Figure 9).

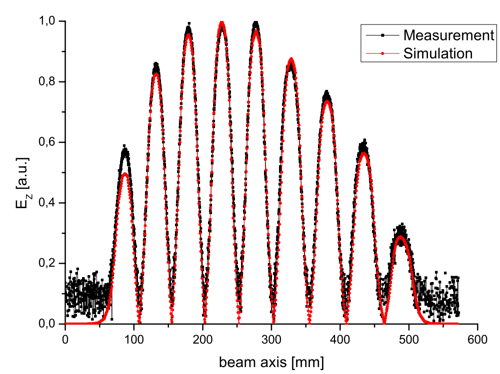

Figure 9: Longitudinal electric field distribution with β-profile.

By adjusting the gap to cell-length ratios, i.e. varying the drift tube lengths, the field distribution can be flattened (see Figure 10).

The measurement of a geometry with straight end stems and on the other hand with inclined end stems yields a slightly better field flatness in the case of inclined end stems (see Figures 11 and 12).

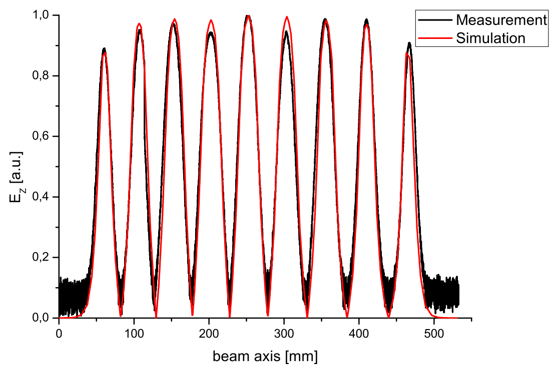

Figure 10: Longitudinal electric field distribution with flattened β-profile by variation of the gap to cell length ratio.

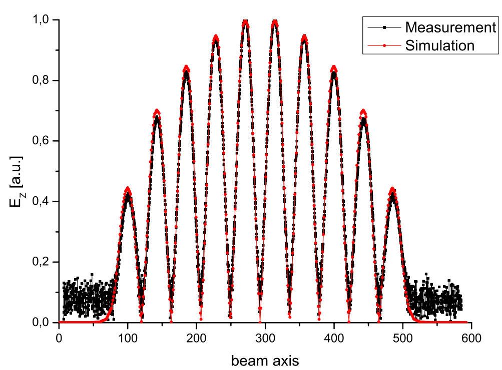

Figure 11: Longitudinal electric field distribution with a const. β.

A better result could be achieved by adjusting the girder length and the end cell area of the cavity to the geometry of the inclined stems.

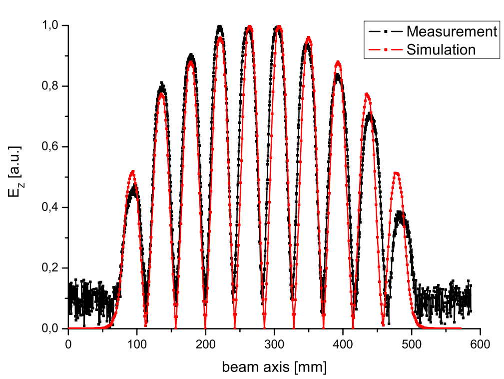

Figure 12: Longitudinal electric field distribution with inclined end stems.

SUMMARY & OUTLOOK

The rf simulations of the 325 MHz sc CH-cavity for the GSI Unilac are completed and the fabrication process is about to begin at Research Instruments. Additional thermal and mechanical simulations have yet to be performed to ensure smooth operation after cool down and during beam time. First simulations of the 217 MHz CH-cavity for the cw heavy ion linac at GSI have been started. Measurements of the copper model showed good accordance with the simulations and further modifications of the geometry will be performed for the optimisation of future s.c. CH-cavities.

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