CH-CAVITY DEVELOPMENT FOR THE 17 MeV EUROTRANS INJECTOR*

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Abstract

Recent international cw operated high-current applications with ambitious requirements regarding beam power and quality ask for new linear accelerator developments. In this context the CH-structure (**C**rossbar-**H**-mode) has been developed at the Institute for Applied Physics (IAP) of Frankfurt University. It is a multi-cell drift tube cavity for the low and medium energy range operated in the H_{21}-mode and can be used for superconducting as well as for room temperature applications. Because of the large energy gain per cavity, which leads to high real estate gradients, the CH-cavity is an excellent candidate for the efficient acceleration in high power proton and ion accelerators with fixed velocity profiles. One possible application for this kind of cavity is the **EURO**pean research programme for the **TRANS**mutation (EUROTRANS) of high level nuclear waste in an accelerator driven system (ADS), which requires an efficient high-current cw-linac (600 MeV, 4 mA, protons, 352 MHz). The paper describes the status of the CH-cavity development and the actual beam dynamics results for the reference design of the 17 MeV EUROTRANS injector.

INTRODUCTION

EUROTRANS is a European approach for high level nuclear waste transmutation using an accelerator driven system (ADS) with an efficient high-current cw-linac [1]. Such an accelerator system requires extremely high reliability and fault tolerance to reduce the number of unwanted beam trips and to avoid activation of the machine. In the first phase the EUROTRANS linac will deliver a 600 MeV proton beam with a beam current of 2.5–4 mA depending on the burning process of the fuel. The beam is transported to a spallation target consisting of liquid metal with a beam power of 1.5–2.4 MW, controlled by the beam current.

Taking advantage of the special KONUS (combined zero degree structure) beam dynamics, which decreases the transverse rf defocusing and enables long lens free acceleration sections, the superconducting CH-cavity is an excellent candidate for the front end of the EUROTRANS driver linac because it reduces the number of cavities significantly compared to conventional low-β linacs [2]. A 19-cell, 360 MHz superconducting CH-prototype cavity has been developed and successfully tested at the IAP. High gradients up to 7 MV/m were reached [3].

In this context the design of the 17 MeV EUROTRANS injector has been intensively studied by the IAP [4]. To achieve the extremely high reliability of operation (less than 3–10 beam trips with $t > 1$ s per year), the proposed front end consists of two identical, redundantly designed injectors up to 17 MeV operated at 352 MHz. A 50 keV proton beam provided by an electron cyclotron resonance ion source will be bunched and pre-accelerated up to 3 MeV by a 4-vane RFQ. Subsequently, the acceleration will be continuing by a CH-DTL which mainly consists of two room temperature (rt) CH-cavities up to 5 MeV and four superconducting (sc) CH-cavities up to 17 MeV (see Fig. 1).

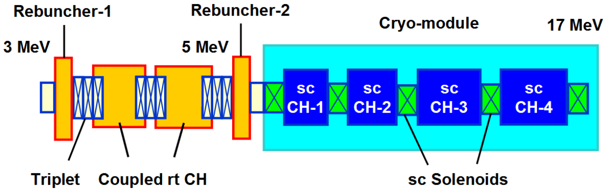

Figure 1: Reference layout of the 3–17 MeV CH-DTL.

RECENT SIMULATION RESULTS

Based on the preliminary beam dynamics design [4] the rt and sc CH-cavities of the 17 MeV EUROTRANS injector have been simulated. All cavities are provided with a well designed β-profile. In order to accomplish the requirements of high power applications, the cavities have been optimized with respect to their rf properties [5]. Figure 2 shows the first rt (top) and sc (bottom) EUROTRANS CH-cavities after the rf optimization. The major improvements of the sc CH-cavities for EUROTRANS in comparison to the prototype cavity are:

- optimized girder and stem geometry
- inclined end stems
- adjusted gap-to-cell-length ratio for field flattening
- new tuning system

Via the integration of inclined stems the end cell length and unwanted drift sections could be reduced significantly while the electric field distribution on the beam axis becomes more homogeneous, as an extended end drift tube is not longer needed for field flattening. The minimization of unnecessary drift sections decreases the total length of the cavities by approximately 20%. Furthermore, electric field flatness along the beam axis minimizes the peak field. This is essential to ensure a reliable operation of the

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cavities particularly of the sc ones. The electric field distribution on the beam axis was optimized by adjusting the gap-to-cell-length ratio (g/l) of the cavities while the gap-center distances given by the beam dynamics design were kept constant. Figure 3 shows the simulated field distribution of the first sc EUROTRANS CH-cavity before (red) and after (blue) the rf optimization as an example.

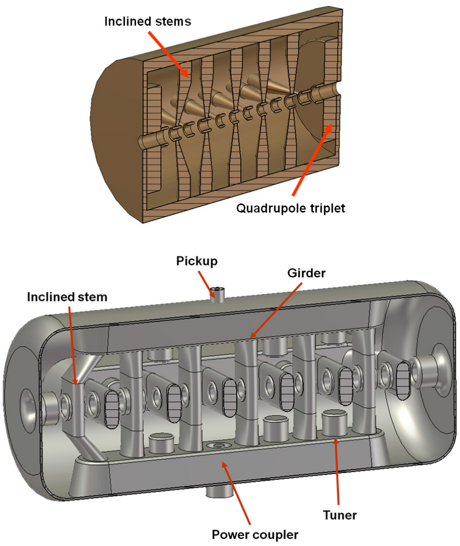

Figure 2: Recent design of the first rt (top) and sc (bottom) CH-cavity for the 17 MeV EUROTRANS injector linac.

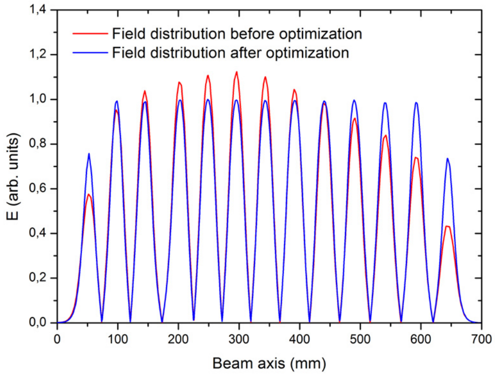

Figure 3: Electric field distribution before (red) and after (blue) the g/l-adjustment [5].

The tuning of the sc cavities will be done by seven capacitive tuners welded into the girders to reach the design frequency during the fabrication. Additionally, one fast bellow tuner is foreseen to act against limitations like microphonics or Lorentz force detuning and two slow bellow tuners to readjust the frequency at 4.2 K. The slow bellow tuners are provided with a tuning range of several hundred kHz and the fast bellow with a range of several hundred Hz. A simulation of the frequency as a function of the tuner height for the first sc cavity is shown in Figure 4. Ten identical cylindrical tuners with a diameter of 40 mm were used for this simulation.

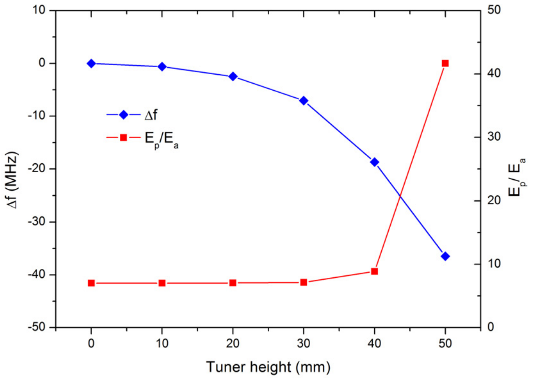

Figure 4: Tuning range of ten tuners with respect to the electrical peak fields of the first sc CH-cavity [5].

Because of the mentioned geometrical accommodations, the effective gap voltage along the CH-DTL has been redistributed while the total effective voltage U_a was kept constant. As an example, the new effective voltage profile of the first sc CH-cavity is shown by Figure 5 in comparison to the previous distribution. Table 1 summarizes the main parameters of the optimized EUROTRANS CH-cavities. The rf losses P_c are calculated using the simulated Q_0 values with safety margins.

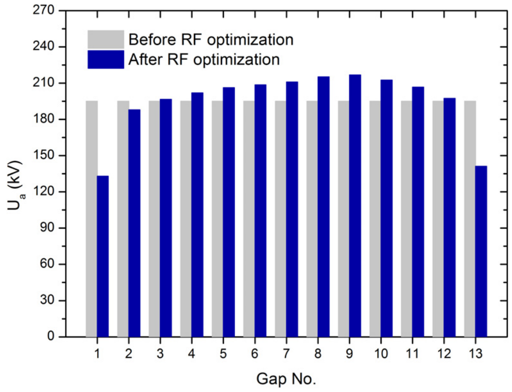

Figure 5: Effective voltage profiles along the beam axis before and after the rf optimization of the first sc CH-cavity.

Fitting for the new voltage profile along the CH-DTL, the beam dynamics design has been adjusted for the 5 mA case firstly [6]. Figure 6 shows the 100% transverse beam envelopes before and after the rf optimization along the 3–17 MeV CH-DTL, where the previous and new designs are represented by red and green curves, respectively. It is seen that the beam envelopes are almost identical to each other in both directions. In addition, at the exit of the CH-DTL, the differences in emittance growth for the transverse and longitudinal planes are only 1%, 2% and 8% (see Fig. 7). Therefore, the beam performance is still staying good after the redesign study.

Table 1: Main Parameters of the Optimized EUROTRANS CH-cavities

Parameter	**Unit**	**RT-1**	**RT-2**	**SC-1**	**SC-2**	**SC-3**	**SC-4**
$\overline{\beta}$ (mean value)		0.087	0.099	0.117	0.138	0.159	0.178
Frequency	MHz	352	352	352	352	352	352
Energy range	MeV	3–4.1	4.1–5.3	5–7.4	7.4–10.4	10.4–13.9	13.9–17.4
Total length	mm	491.5	588.5	696.6	862.9	1014.0	1124.3
Cavity diameter	mm	289.0	291.8	286.1	300.8	316.3	332.5
Aperture diameter	mm	18–20	20	25–30	30	40	40
Accelerating cells		11	12	13	14	14	14
G	Ω	60	59	56	58	60	63
R_a/Q_0	Ω	3164	3737	1775	2143	1831	1999
Q_0 (operation goal)		1.1×10^4	1.1×10^4	2×10^8	2×10^8	2×10^8	2×10^8
E_a ($\beta\lambda$-definition)	MV/m	2.9	2.6	3.9	3.9	3.9	3.6
E_p/E_a		6.9	5.3	6.8	7.2	7.3	7.6
B_p/E_a	mT/(MV/m)	7.2	8.0	10.2	9.2	11.6	10
U_a	MV	1.2	1.3	2.5	3.2	3.7	3.8
P_c (for operation goal Q_0)	W	41375	41112	18	24	37	36

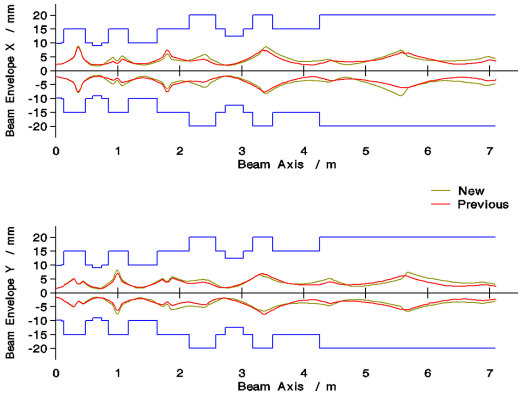

Figure 6: 100% transverse beam envelopes [6].

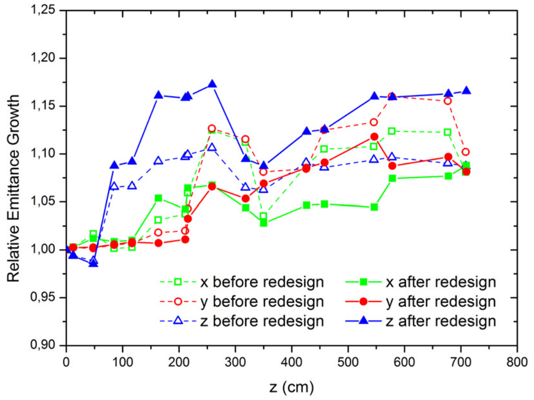

Figure 7: Relative rms emittance growth.

SUMMARY AND OUTLOOK

Intensive studies on the 3–17 MeV EUROTRANS CH-DTL with respect to rf cavity optimization and beam dynamics have been performed. The results show that a compact layout and a good beam quality are still achievable after the adjustments of the cavities in case of 5 mA. For the final design further beam dynamics as well as rf simulations will be performed. In addition, it is planned to study the upgradability of the CH-DTL for a 30 mA beam current.

ACKNOWLEDGEMENTS

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