FURTHER UPGRADE MEASURES AT NEW GSI CW-LINAC DEMONSTRATOR SETUP

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Abstract

A new continuous wave (cw) linac is required to deliver high intensity heavy ion beams for future Super Heavy Element (SHE) experiments at GSI Darmstadt, Germany [1]. The presented upgrade measures are dedicated to improve the performance of the cw demonstrator setup. The key component is a cryomodule comprising a superconducting (sc) 217 MHz Crossbar-H-mode (CH) cavity [2, 3] surrounded by two sc 9.3 T solenoids with compensation coils. The solenoid coil is made of a Nb_3Sn wire, while and the compensation coils at both ends of the solenoid comprise NbTi wires. The distance between solenoid lense and CH cavity has to be optimized for ideal beam matching as well as for a minimum rest field inside the cavity well below the critical magnetic field. The GSI High Charge State (HLI) injector has to deliver a heavy ion beam with an energy of 1.4 MeV/u. Longitudinal matching to the demonstrator is provided by two 108.4 MHz cw room temperature $\lambda/4$ re-buncher cavities installed behind the HLI [4]. In this paper electromagnetic simulations of the field optimization for the solenoids and the re-buncher cavities will be presented as well as first beam experiments at the beam transport line to the demonstrator cavity.

INTRODUCTION

The sc cw-linac demonstrator for the SHE project at GSI (Fig. 1) is under constructions and the first test beam operation will start in spring 2016. The test operation comprises the construction of the beam line to the cryostat including the rt 108 MHz re-buncher for longitudinal focusing and the horizontal cryostat-module with the 217 MHz CH-cavity demostrator surrounded by two sc 9.3 T solenoids with beam. The 217 MHz CH-cavity demostrator with 15 accelerating cells and a design gradient of 5.1 MV/m was finished in spring 2015 and accelerates highly charged ions with a mass-to-charge ratio of up to 6. The following cryomodule comprises two short CH-cavities and one solenoid. The entire cw-linac will accelerate the highly charged ions from HLI energy of 1.4 MeV/u up to 3.5 - 7.3 MeV/u for the SHE program.

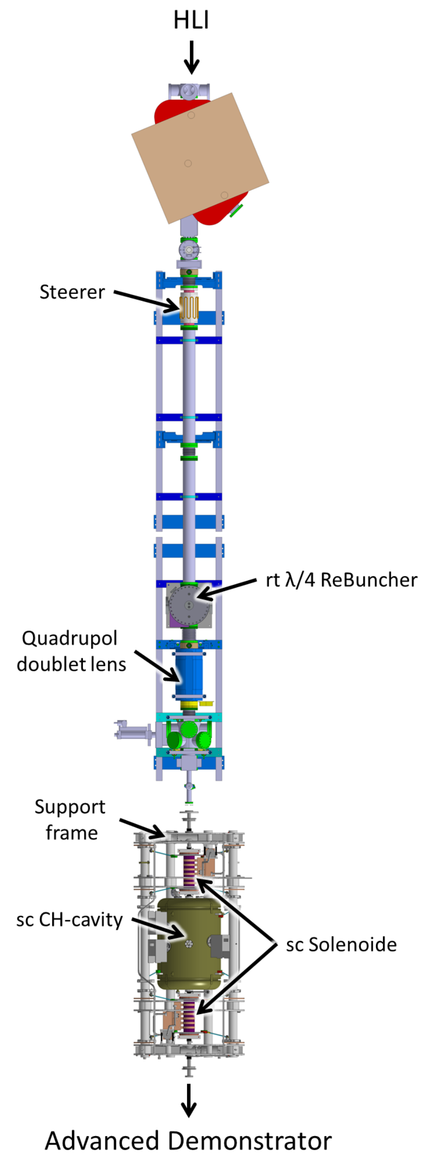

Figure 1: Top view of the construction layout of the cw-LINAC demonstrator section comprising rt $\lambda/4$ re-buncher cavity and the cryostat; the sc CH-cavity is surrounded by two sc solenoids on a support frame (cryostat is not shown).

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λ/4 RE-BUNCHER

The λ/4 re-buncher [4, 5] has drift tubes looking like in a Interdigital-H mode (IH) cavity including the non-concentric bulges (Fig. 2, Table 1). Two stems build a large inner conductor with two drift tubes. The stem on the opposite side has one drift tube. This coaxial-type structure and has a compact length along the beam axis for low velocities in heavy-ion linacs. The RF amplifier enables for independent phase adjustment of the cavity. At synchronous phase of -90° the re-buncher serves for longitudinal matching into the cw-demonstrator.

The frequency tuning is based on the diameter of the inner conductor and the dynamic frequency tuner [6]. A change of the diameter of the inner conductor can be used for a large frequency range. The upgraded inner conductor has a cone-shaped geometry for multipacting decrease. The dynamic tuner is located on the height of the beam axis and is a capacitive tuner against the drift tube stem. The dynamic tuner has a frequency deviation of ± 375 kHz at a middle insertion depth (Fig. 3). The thermal losses on the tank surfaces (especially on the inner conductor) have no major effect on the frequency fluctuation during operation, as the cooling concept is according to the losses. The voltage distribution for the operation frequency of 108.4 MHz along the beam axis is shown in Fig. 4. The dynamic tuner has only a minimal effect on the voltage distribution on the beam axis and has therefore the best position. The parasitic frequency mode is observed at a small tuner distance to the beam axis.

Table 1: Parameters of the CW λ/4-re-buncher

Parameter	Unit	Value
Frequency	MHz	108.408
max. A/q		6
max. Current	mA	1.0
Synchronous Phase	deg.	-90
Energy	MeV/u	1.4
Gaps		4
Gap length	mm	38.0
Drift tubes		3
Drift tube length	mm	37.75
Aperture	mm	30.0
Tank diameter	mm	298.7
Tank height	mm	690.0
Thermal losses	kW	2
Q - Factor		11190

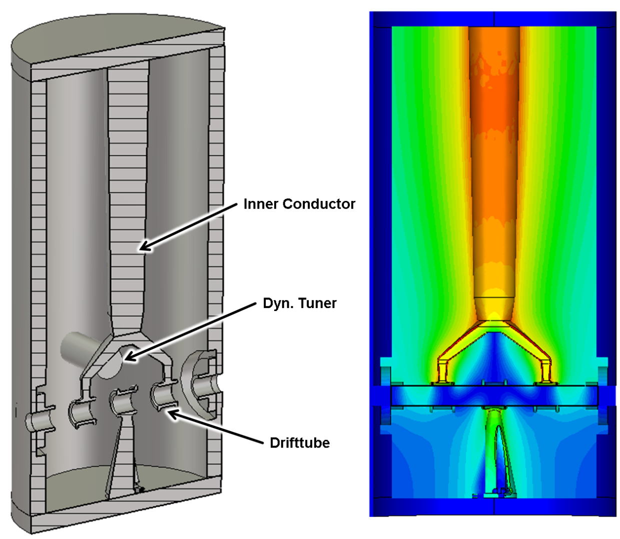

Figure 2: Cross sectional view (left) and magnetic field distribution (right) of the four gap λ/4-re-buncher; the dynamical plunger is shown in the background; the drift tubes are equipped with bulges to reduce the dipole effect.

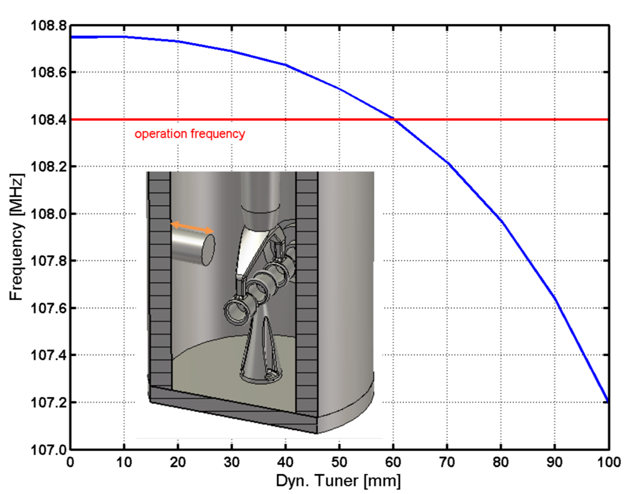

Figure 3: Simulated frequency range of the λ/4 rebuncher depending on the position of the dynamical plunger. The plunger (radius: 25 mm) has a length of 60 mm in operation.

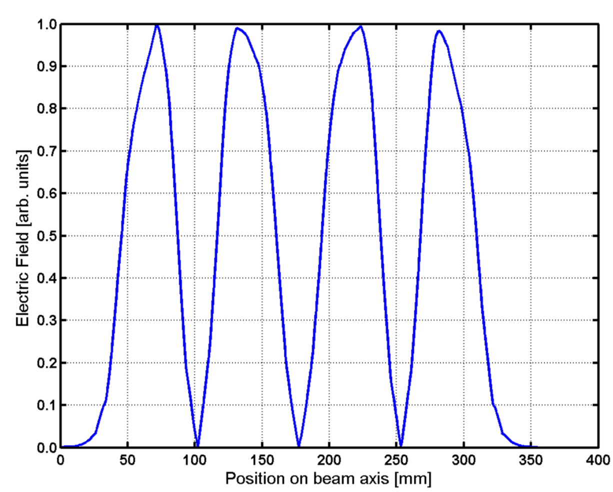

Figure 4: Simulated electrical field distribution on beam axis at 108.4 MHz for the λ/4 rebuncher.

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SOLENOID

The magnet has a 9.3 T sc solenoid as the main coil and two compensation coils at both ends of the solenoid coil (Fig. 5) [7, 8]. The magnetic field lines of the solenoid have a large expansion (along the beam axis) and the compensation coils are important to minimise the rest field inside the neighbouring CH-cavity. The minimum distance z of the solenoid lense to the CH-cavity is choosen to keep the rest field inside the cavity, below to a critical magnetic field of 50 mT.

Table 2: Parameters of the SC Solenoid

Parameter	Unit	Value
Turns		20650
Wire material		Nb_3Sn
Magnetic flux density	T	9.3
Eff. Length	mm	298.0
Mechanical Length	mm	380.0
$\varnothing_i$	mm	16.5
$\varnothing_a$	mm	49.0
Aperture	mm	30.0
max. Current	A	110.0
Homogeneity		0.001

Table 3: Parameters of the SC Compensation Coils

Parameter	Unit	Value
Turns		718
Wire material		NbTi
Magnetic flux density	T	9.3
Length	mm	24.0
$\varnothing_i$	mm	77.0
$\varnothing_a$	mm	85.4
max. Current	A	110.0

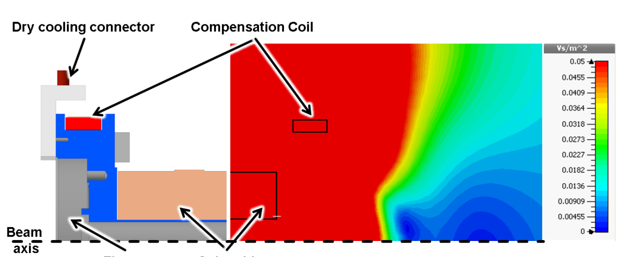

Figure 5: Cross sectional view (left) and a typical example of the magnetic field distribution of the solenoid with compensation coils (right).

Cryogenic Ltd. (UK) [9] has been cooled down the sc solenoid to a temperature level of LHe and field profiles were measured after removal the solenoid from the LHe bath. The simulation [6] and the measurement of the magnetic field match very well (Fig. 6). The axial field map of the solenoid

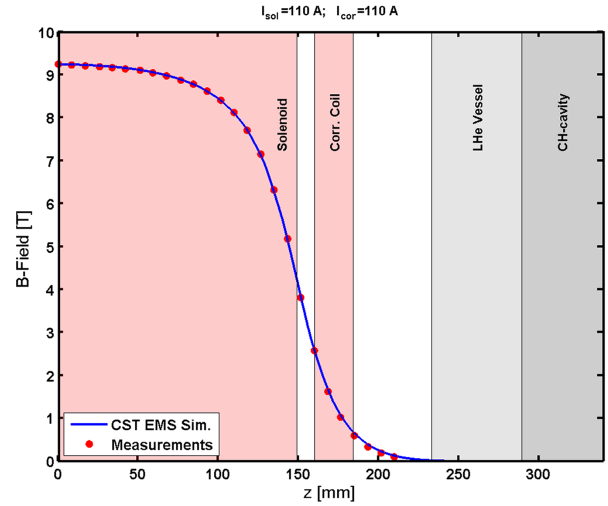

Figure 6: Simulated and measured magnetic field in the cavity region of the sc solenoid with compensation coils.

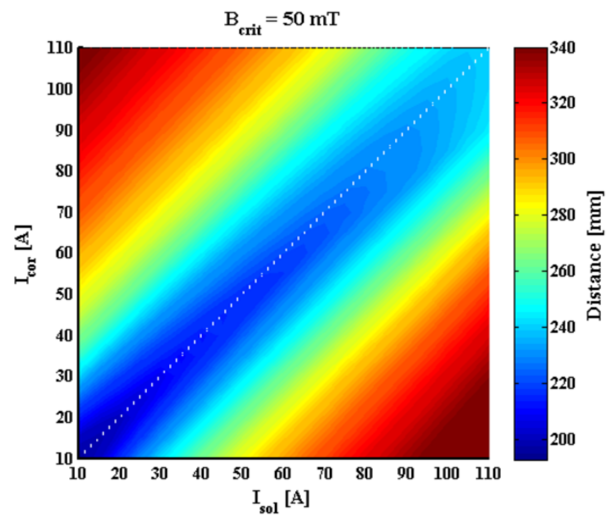

Figure 7: Minimum Distance z (color) at B_{crit} = 50 mT for all current combinations of the solenoid (I_{sol}) and the compensation coils (I_{cor}).

is shown, with the fringe field strength is highlighted. The map indicates that the fringe field inside the CH-cavity is less than 50 mT (Fig. 7).

OUTLOOK

The first beam test with the presented cw-linac demonstrator setup will take place in 2016. The component delivery of an additional new cryomodule comprising two short sc CH-cavities [10] and a sc solenoid is expected for 2017.

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