THE SUPERCONDUCTING CW LINAC DEMONSTRATOR FOR GSI*

F. Dziuba†,1, M. Amberg[3], K. Aulenbacher[3,4], W. Barth[2,3], M. Busch[1],
S. Mickat[2,3], H. Podlech[1], U. Ratzinger[1]

[1]IAP Frankfurt University, 60438 Frankfurt am Main, Germany
[2]GSI Helmholtzzentrum, 64291 Darmstadt, Germany
[3]Helmholtz-Institut Mainz (HIM), 55099 Mainz, Germany
[4]KPH Mainz University, 55128 Mainz, Germany

Abstract

At GSI a new, superconducting (sc) continuous wave (cw) LINAC is under design in cooperation with the Institute for Applied Physics (IAP) of Frankfurt University and the Helmholtz Institut Mainz (HIM). This proposed LINAC is highly requested by a broad community of future users to fulfill the requirements of nuclear chemistry, nuclear physics, and especially in the research field of Super Heavy Elements (SHE). In this context the preliminary layout of the LINAC has been carried out by IAP. The main acceleration of up to 7.3 AMeV will be provided by nine sc Crossbar-H-mode (CH) cavities operated at 217 MHz. Currently, a prototype of the cw LINAC as a demonstrator is under development. The demonstrator comprises a sc CH-cavity embedded between two sc solenoids mounted in a horizontal cryomodule. A full performance test of the demonstrator in 2013/14 by injecting and accelerating a beam from the GSI High Charge Injector (HLI) is one important milestone of the project. The status of the demonstrator is presented.

MOTIVATION

Since in the future the existing UNILAC (Universal Linear Accelerator) at GSI will be used as an injector for FAIR (Facility for Antiproton and Ion Research), beam time availability for the production of SHE (Super Heavy Elements) will be very limited. For this reason, an upgrade of the HLI was initialized to keep the SHE program at GSI competitive on a high level [1]. A long term cost-benefit analysis showed that a new standalone sc cw LINAC in combination with the upgraded HLI is needed to fit the requirements of SHE production at best [2]. The proposed heavy ion LINAC will provide higher beam intensities and increases the SHE production rate significantly. For the production of element 120 a beam time on target of ten weeks for one event is estimated at minimum with the existing UNILAC. By operating the new sc cw LINAC it is expected that the beam time will be reduced by a factor of 20 to 4 days.

* Work supported by HIM, GSI, BMBF Contr. No. 06FY9089I
† dziuba@iap.uni-frankfurt.de

THE SUPERCONDUCTING CW LINAC

A collaboration of GSI, the IAP, and HIM is assigned to realize the proposed sc cw LINAC in parallel to the existing UNILAC. The layout of the cw LINAC (see Fig. 1) was worked out at the IAP of Frankfurt University [3]. Highly charged ions with a mass to charge ratio (A/q) of 6 will be accelerated at 1.4 AMeV from the upgraded HLI up to 7.3 AMeV, while the energy spread should be kept smaller than ± 3 AkeV. Above an energy of 3.5 AMeV the linac is fully energy variable. The main acceleration of approximately 35 MV will be provided by nine sc multi-gap CH-cavities [4] operated at 217 MHz. For beam focusing, seven sc solenoids are foreseen. The main parameters of the sc cw LINAC are summarized in Table 1.

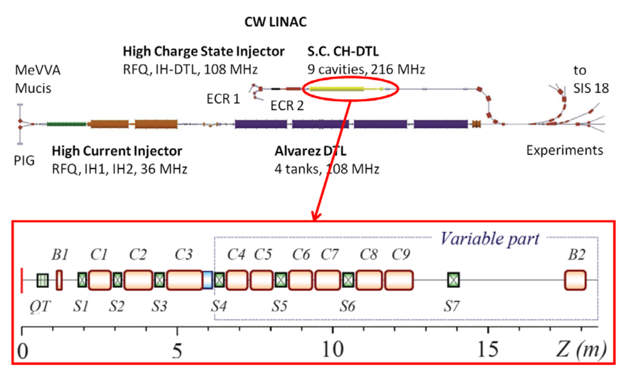

Figure 1: Future layout of the new sc cw LINAC in parallel to the existing GSI UNILAC (Ci = Cavity, Bi = (Re-)Buncher, Si = Solenoid, QT = Quadrupole-Triplet).

Table 1: Design parameters of the cw LINAC

A/q		6
Frequency	MHz	217
Max. beam current	mA	1
Injection energy	AMeV	1.4
Output energy	AMeV	3.5 - 7.5
Output energy spread	AkeV	± 3
Length of acceleration	m	12.7
Sc CH-cavities		9
Sc solenoids		7

CW LINAC DEMONSTRATOR

In a first step, a prototype of the described cw LINAC is under development as a demonstrator, which is mainly financed by HIM. The demonstrator consists of a sc CH-cavity embedded between two sc solenoids mounted in a horizontal cryomodule (see Fig. 2). A concept study has been worked out regarding assembling as well as aligning the cavity, the solenoids, and the cryostat to the beam axis, especially after cooling down the three components [5]. The most important design criteria for the new cryostat are:

- modular design, universally usable - option to test various types of solenoids and CH-cavities with different lengths and diameters
- movable compound coils along the solenoids
- various flanges for assembling options, power couplers, tuners, and the cryo supply
- a dome for electrical supplies with a reservoir for cryogenic liquids
- a measuring system to control the positions of the cold masses on the beam axis

The design parameters of the new cryostat are shown in Table 2.

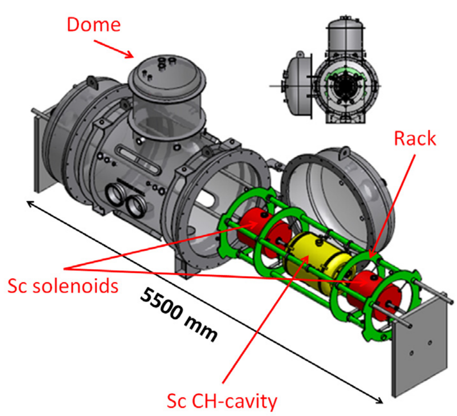

Figure 2: Layout of the cw LINAC demonstrator close to the final design. In the center of the mounting rack the cavity (yellow) is embedded by two sc solenoids (red).

At present the sc CH-cavity for the demonstrator is under development. Furthermore, the tendering of the cryostat and the solenoids is in progress. In order to demonstrate the cavity capabilities it is planned to run a full performance test by injecting and accelerating a beam from the existing 1.4 AMeV GSI HLI in 2013/14. Therefore, the cw LINAC demonstrator will be set up straight ahead the HLI, as shown in Figure 3.

A new liquid helium (LHe) supply with a 3000 ltr tank as well as a helium recovery system have arrived at GSI already. The consumed helium will be collected in a 25 m^3 balloon, bottled by a compressor, reprocessed by a condensor, and brought back to the helium reservoir. During the full performance test a consumption of 20 ltr LHe per hour is predicted.

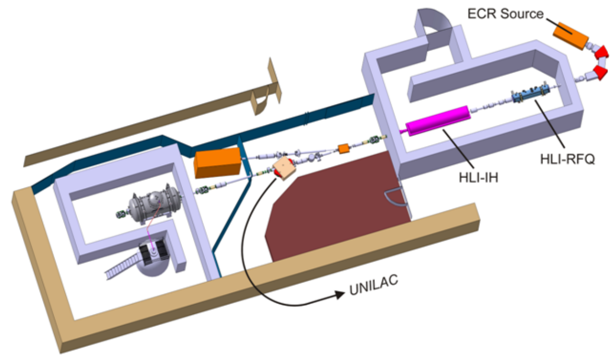

Figure 3: Future test stand at GSI using the existing HLI as an injector for the cw LINAC demonstrator [5].

Table 2: Design parameters of the cryostat

Inner length	mm	2200
Inner diameter	mm	1120
Material tank		Stainless steel
Insulating vacuum	mbar	$< 1 \cdot 10^{-5}$
Max. system pressure	bar	< 0.5
Operating temperature	K	4.4
Temperature thermal shield	K	77
Max. static losses (stand by)	W	< 10

THE SUPERCONDUCTING CH-CAVITY

The sc 217 MHz CH-cavity [6] (see Fig. 4 top) for the cw LINAC demonstrator has a design gradient of 5.1 $\mathrm{MV/m}$ and consists of 15 accelerating cells at a total length of 690 mm. It will be operated with the special EQUUS (EQUidistant mUlti-gap Structure) beam dynamics [3].

By using inclined end stems inside of the cavity and by adjusting the gap-to-cell-length ratio (g/l), a homogeneous field distribution along the beam axis can be reached. Because of the inclined stems inductance is increased in the end cell region which allows a very compact longitudinal design of the cavity as an extended end cell is not needed for field flattening anymore. Since a flat field distribution results in an efficient acceleration and reduces the peak fields an improved beam acceptance is caused by that design as well, which is essential to avoid beam losses and activation of accelerator components. Figure 4 (bottom) shows the simulated field distribution of the 217 MHz cavity before and after the optimization.

Matching the design frequency during the fabrication process of a sc CH-cavity is a serious challenge. Regarding this, the tuning of the cavity will be done by capacitive tuners positioned between the stems: For the coarse

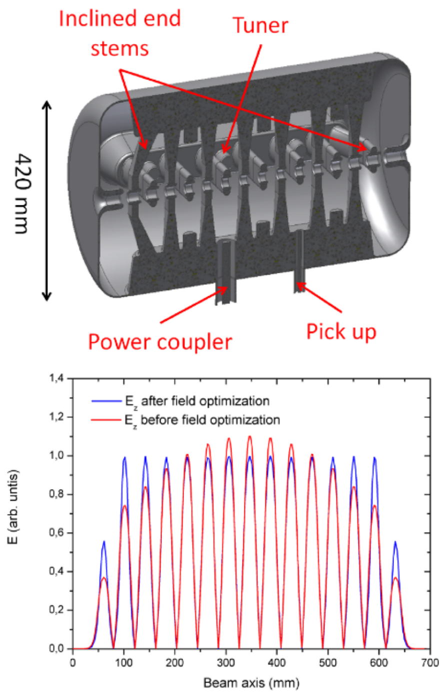

Figure 4: Side view of the sc 217 MHz CH-cavity for the new cw LINAC at GSI (top) and E_z along the beam axis before and after the field optimization (bottom).

tuning nine static tuners will be adapted accordingly during the fabrication to hit the design frequency. In order to calculate the frequency shift of the static tuners, several rf simulations have been performed. A maximum height of 63 mm for the static tuners is foreseen, which results in a frequency shift range of ± 2 MHz. Additionally, three bellow tuners, driven by stepping motors should control the frequency of the cavity during operation. These slow tuners will readjust frequency changes and pressure effects at 4.2 K. Furthermore, two of them are connected to fast reacting piezo elements. They will be driven by a signal bandwidth of up to several hundred Hz to compensate limitations like microphonics and Lorentz-Force-Detuning. To provide an sufficient safety margin for the fast tuning during beam operation a frequency shift of ± 150 Hz/μm is required. Further rf, mechanical and multipacting simulations are in progress at the moment to determine the final geometry of the dynamic bellow tuners.

SUMMARY & OUTLOOK

First preparations have been started already to set up the cw LINAC demonstrator at the GSI HLI. The 3000 ltr LHe-tank as well as the helium recovery system have arrived at GSI.

The rf design of the sc 217 MHz CH-cavity is completed. Further rf, mechanical and multipacting simulations concerning the cavity tuning are in progress at the moment. The fabrication process of the cavity will start within this year at RI (Research Instruments GmbH, Bergisch Gladbach, Germany). Furthermore, a 5 kW rf-amplifier was delivered in May 2010. At present, the call for tender of the cryostat and the sc solenoids is in progress.

The delivery of the main components is expected in 2012/13. After assembling of the CH-cavity and the solenoids under clean room conditions and first rf test at the IAP, a full performance test with beam at the HLI is foreseen in 2013/14. Successful beam tests of the demonstrator are a fundamental step on the way to the proposed sc cw LINAC, which realization is estimated in 2019 earliest.

Table 3: Main parameters of the 217 MHz CH-cavity

β		0.059
Frequency	MHz	217
Accelerating cells		15
Total length	mm	690
Cavity diameter	mm	420
Cell length	mm	40.8
Accelerating gradient	MV/m	5.1
Effective gap voltage	kV	225
Voltage gain	MV	3.13
E_p/E_a		6.5
B_p/E_a	mT/(MV/m)	5.9
R_a/Q_0	Ω	3540

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