THE SC CW-LINAC-DEMONSTRATOR – SRF TECHNOLOGY FINDS THE WAY TO GSI

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Abstract

A new superconducting (sc) continous wave (cw) LINAC at GSI is desired by a broad community of future users. Especially the Super Heavy Elements (SHE) program at GSI and at the Helmholtz Institute Mainz (HIM) benefits highly from such a dedicated machine [1]. A conceptual layout of an sc cw-LINAC was worked out at the Institute for Applied Physics (IAP) at Frankfurt University [2]. Here the key component, an sc Crossbar-H (CH) cavity, was developed recently [3]. The multi-gap cavity is operated at 217 MHz and provides gradients of 5.1 MV/m at a total length of 0.69 m [4]. The first section of the proposed cw-LINAC comprising a sc CH-cavity embedded by two sc solenoids is financed by HIM as a demonstrator. One important milestone of the project is a full performance test with beam of the demonstrator in 2013/14 at the GSI High Charge Injector (HLI). With the demonstrator the srf-technology finds the way to GSI. The tests would be the first of an sc multi-gap structure with heavy ions being an important milestone towards the proposed cw-LINAC.

MOTIVATION

Since 1981 six new elements, from element 107 to element 112, were discovered at GSI. An important milestone for the successful SHE program at GSI was the commissioning of the High Charge Injector (HLI) in the early nineties. Nevertheless the HLI in combination with the Universal Linear Accelerator (UNILAC) is not a dedicated machine to the SHE-research. In future the UNILAC is designated as an injector for FAIR (Facility for Antiproton and Ion Research). Beam time availability for SHE-research will be decreased due to the limitation of the UNILAC in providing a proper beam for SHE and in fulfilling the requirements for FAIR simultaneously. To keep the SHE program at GSI competitive on a high level, an upgrade program of the HLI was initialized comprising a new 28 GHz ECR source and a new cw capable RFQ [5, 6].

As a result of a long term cost-benefit analysis a standalone sc cw-LINAC in combination with the upgraded HLI is assumed to fit the requirements of SHE at best [1]. Significant higher beam intensities will be provided and lead to an increase of the SHE production rate: The production cross section of element 120 is assumed to be smaller than 0.1 pbarn for instance. With the existing UNILAC a beam time on target of ten weeks for one event is estimated at minimum by experience [7]. The proposed sc cw-LINAC is expected to reduce the beam time by a factor of 20 to 4 days.

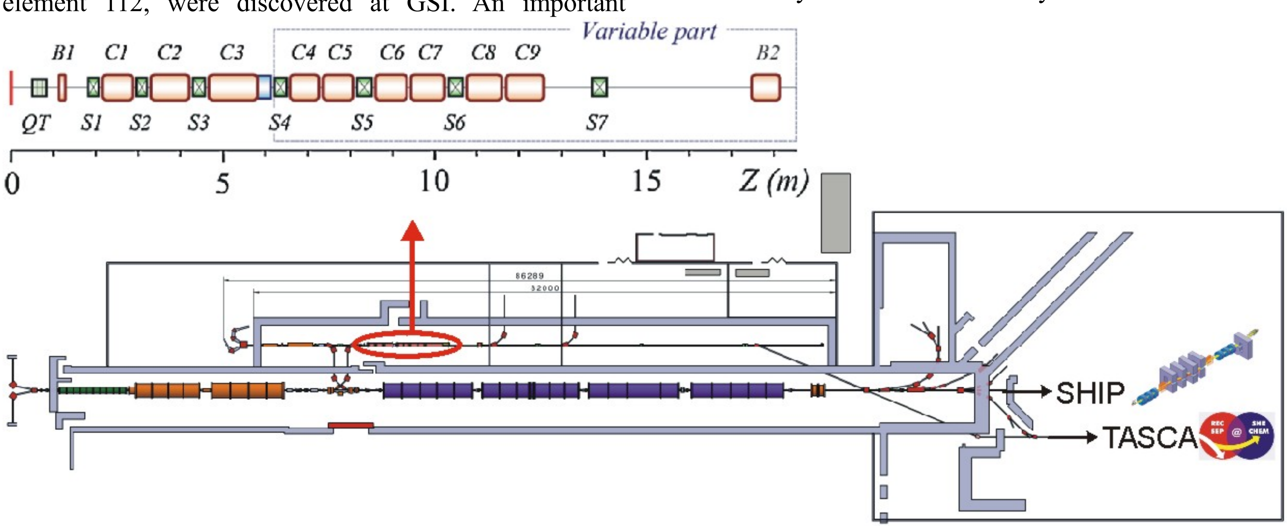

Figure 1: Draft layout of the future GSI accelerator facility with the integrated cw-LINAC in parallel to the existing UNILAC (Ci = Cavity, Bi = (Re-)Buncher, Si = Solenoid, QT = Quadrupole-Triplet). The cw-LINAC should provide SHE-experiments like SHIP (Separator for Heavy Ion reaction Products) and TASCA (TransActinide Separator and Chemistry Apparatus) with beam.

SC CW-LINAC

Table 1: Design parameters of the cw-LINAC

Mass/Charge		6
Frequency	MHz	217
Max. beam current	mA	1
Injection Energy	MeV/u	1.4
Output energy	MeV/u	3.5 – 7.5
Output energy spread	keV/u	+- 3
Length of acceleration	m	12.7
Sc CH-cavities		9
Sc solenoids		7

The technical design and the realisation of such a sc cw-LINAC in parallel to the existing UNILAC at GSI is assigned to a collaboration of GSI, the IAP, and the Helmholtz-Institute Mainz (HIM), which was founded in 2009.

A conceptual layout of a sc cw-LINAC was worked out [2], which allows the acceleration of highly charged ions with a mass to charge ratio of 6 at 1.4 MeV/u from the upgraded HLI (Fig. 1). Nine superconducting CH-cavities operated at 217 MHz accelerate the ions to energies between 3.5 MeV/u and 7.5 MeV/u, while the energy spread should be kept smaller than ±3keV/u. As beam focusing elements seven superconducting solenoids are applied. The general parameters are listed in Table 1.

The commissioning of the cw-LINAC is scheduled in 2019 at earliest. A first proposal was submitted in 2009, which was evaluated excellent by the Helmholtz Gemeinschaft Deutscher Forschungszentren (HGF). The financing of the future project depends strongly on the results of the demonstrator project described below.

Presently beam dynamical investigations are performed to fit the cw-LINAC design to the technical and on-site conditions as well as to the requirements of the future user community.

CW-LINAC-DEMONSTRATOR

The Cryostat

The demonstrator is financed by HIM mainly. It is the realisation of the first section of the proposed cw-LINAC comprising a superconducting CH-cavity embedded by two superconducting solenoids (Fig. 2). A study has been worked out which provided a concept to assemble the cryostat with the solenoids and the cavity as well as to align the three components to the beam axis [8].

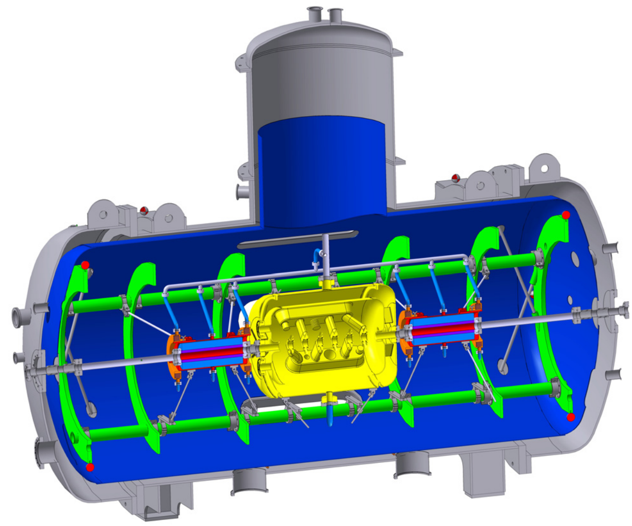

Figure 2: A scheme of the cw-LINAC Demonstrator shows the CH-cavity (yellow) in its centre embedded by two sc solenoids (red-orange). On the top space for a reservoir of liquid helium as well as of liquid nitrogen is reserved.

The SC CH-cavity

The sc CH-structure is the key component and offers a variety of research and development [9, 10]. A first prototype of a 360 MHz sc CH-cavity (β=0.16, 19 gaps) was tested at the IAP successfully. In vertical rf-tests maximum gradients of up to 7 MV/m at Q_0-values between 10^8 and 10^9 were achieved. The fabrication of another 325 MHz sc CH-cavity (β=0.16, 7 gaps) is currently in progress. The cavities designed for the cw-LINAC are operated at 217 MHz and provide gradients of 5.1 MV/m at a total length of 0.69 m. The general parameters are listed in Table 2.

Table 2: General parameters of the sc CH-Cavity designed for the cw-LINAC demonstrator.

β		0.059
Frequency	MHz	217
Gap number		15
Total length	mm	690
Gap length	mm	40.8
Aperture	mm	20
Effective gap voltage	kV	225
Voltage gain	MV	3.13
Accelerating gradient	MV/m	5.1

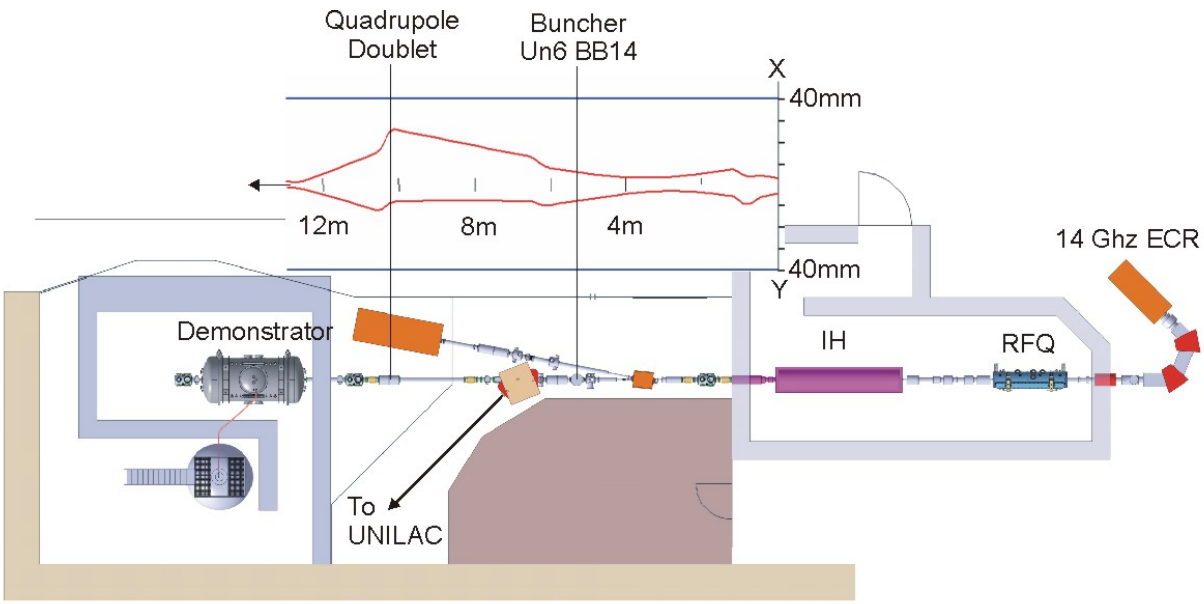

Figure 4: The existing HLI should be used as an injector for the cw-LINAC demonstrator. In longitudinal plane the existing buncher UN6BB, in transverse plane an additional quadrupole doublet should be used to match the beam to the demonstrator.

The SC Solenoids

The solenoids provide maximum fields of 9.3 T at an effective length of 290 mm and a free beam aperture of 30 mm. The fringe fields have to be reduced from the maximum field to 50 mT at the inner NbTi-surface of the neighbouring cavity. Based on the 9T solenoid design for the ISAC-II cryomodule [11] a coil configuration with two main coils and two bucking coils was assumed to fit the requirements at best (Fig. 3). The calculations show that proper gradients can be achieved by using anti-windings [12]. The general parameters of the solenoids are listed in Table 3.

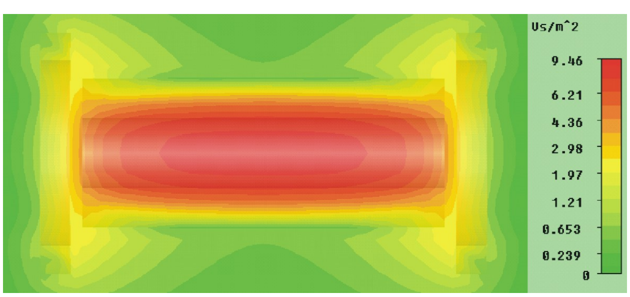

Figure 3: The solenoid field of the chosen coil configuration is calculated. Within the requirements the fringe field is shielded by the compensation coils.

Full Performance Tests at GSI HLI

The favoured location to setup the Demonstrator is in straightforward direction of the HLI at GSI (fig. 4). Two existing experiments at the HLI have to move since the space is needed for the demonstrator test environment including a new radiation protection cave.

The liquid helium (LHe) supply is covered by a 3000 ltr tank. The consumed helium is collected in a 25 m^3 recovery balloon and bottled by a compressor. In operation a consumption of 20 ltr LHe per hour is predicted.

For matching the beam from the HLI to the demonstrator the existing buncher UN6 BB14 can be used longitudinally. For transverse focusing an additional doublet is needed.

Moreover beam diagnostics like profile grids and emittance measurements stations has to be integrated in the beam line in front of and behind the demonstrator as well as phase probes for time of flight (TOF) measurements.

Table 3: General parameters of the sc solenoids designed for the cw-LINAC Demonstrator.

max. field	T	9.3
B*l	Tm	2.635
effective Length	mm	290
Beam aperture	mm	30

OUTLOOK

The mechanical assembly of the demonstrator at GSI-HLI is in preparation already. Components like the 3000 ltr LHe-tank, the 25 m^3 recovery balloon and the compressor are in house already. The order of the CH-cavity is placed to Research Instruments (RI) in Bergisch

Gladbach, Germany, recently while a 5 kW rf-amplifier was delivered in May 2010. Presently the tendering of the cryostat and the solenoids is in progress.

In 2012/13 the delivery of the main components is expected. The assembly of the CH-cavity and the solenoids under cleanroom conditions to a well-working system will be done at the IAP afterwards. Here first horizontal rf-tests of the system should take place. Thus full performance tests at GSI HLI are expected in 2013/14 at earliest.

Successful full performance tests with beam of the sc cw-LINAC would be a major milestone towards a sc cw-LINAC at GSI. Assuming favorable conditions with respect to financing a realisation of the proposed cw-LINAC is estimated in 2019 at earliest.

SCHEDULING

Table 4: Time Schedule

	cw-LINAC – and Demonstrator-Project
2005	HLI-upgrade program comprising new sc ECR-source, new LEBT, and new cw-capable RFQ was defined
2009	Proposal of a new sc cw LINAC Foundation of HIM
2010	"excellent" - evaluation of the sc cw-LINAC-project Successful commissioning of the cw capable RFQ Tendering of the demonstrator components
2011	Delivery of the LHe-supply and the rf-amplifier Ordering of the cavity, the solenoids, and the cryostat Beginning of assembling the test facility at GSI HLI
2012-2013	Delivery of the cavity, the solenoid and the cryostat 1st tests (warm + cold) at IAP
2013/14	Full performance test at GSI HLI
>2019	Commissioning "sc cw-LINAC"

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