THE SUPERCONDUCTING CW-LINAC-DEMONSTRATOR AT GSI

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Abstract

The GSI applied for a new superconducting (sc) cw-LINAC in parallel to the existing UNILAC (Universal Linear Accelerator). Such a machine is highly desirable with respect to the needs in the field of Superheavy Elements (SHE) for example. The GSI UNILAC is limited in providing a proper beam for SHE and in fulfilling the requirements for FAIR (Facility for Antiproton and Ion Research) simultaneously.

A sc Crossbar-H (CH) structure is the key component of the proposed compact LINAC. In first vertical rf-tests at the Institute of Applied Physics (IAP) maximum gradients of up to 7 MV/m were achieved. The cw-LINAC should be operated at 217 MHz with cavities providing gradients of 5.1 MV/m at a total length of minimum 0.6 m.

In a first step a prototype of such a sc cw-LINAC as a demonstrator is financed by the Helmholtz Institute Mainz (HIM). The demonstrator is the first section of the proposed cw-LINAC comprising a sc CH-cavity embedded by two sc solenoids. The aim is a full performance test of the demonstrator with beam at the GSI high charge injector (HLI) in 2013. Presently the tendering of the solenoids, the cavity, the cryostat and the rf-amplifier is in progress.

INTRODUCTION

In June 2009 the Helmholtz-Institute Mainz (HIM) was founded. The research activities of HIM are supported by the integrated department of accelerator physics and integrated detectors (ACID) [1]. Within the scope of ACID a collaboration of the IAP, the Institute for Nuclear Physics (KPH) at the University Mainz, and the GSI acceleration department is established. Its mission is the technical design of a cw-LINAC in parallel to the existing UNILAC at GSI (fig. 1) and the realisation of a corresponding demonstrator (fig. 2).

Such a machine is highly desirable with respect to the needs in the field of SHE, because the UNILAC at GSI is limited in providing a proper beam for SHE and in fulfilling the requirements for FAIR simultaneously [2]. An upgrade programme of the HLI was initialized to keep the SHE research at GSI competitive on a high level [3, 4]. Complete cw-capabilities and higher beam intensities as well are intended.

CW-LINAC

A conceptual layout of a sc cw-LINAC was worked out [5], which allows the acceleration of highly charged ions with a charge to mass ratio of 1 to 6 at 1.4 MeV/u from the upgraded HLI. Nine superconducting CH-cavities operated at 217 MHz accelerate the ions to energies variable between 3.5 MeV/u and 7.5 MeV/u, since the energy spread should be kept smaller than ±3keV. As beam focusing elements seven superconducting solenoids are applied (tab. 1).

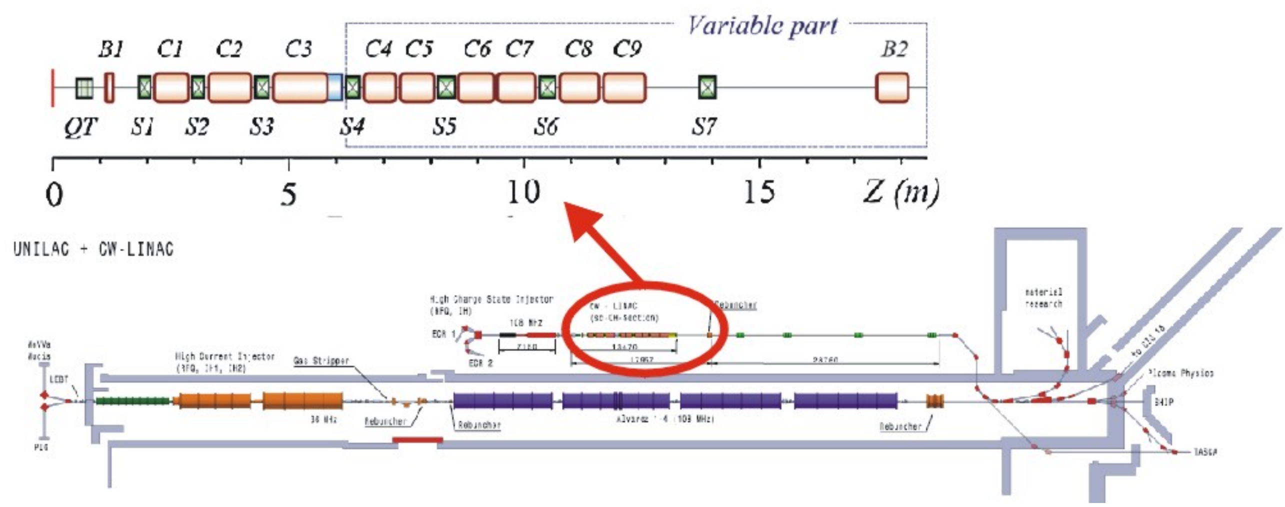

Figure 1: The future layout of the GSI accelerator facility with the integrated cw-LINAC in parallel to the existing UNILAC (Ci = Cavity, Bi = (Re-)Buncher, Si = Solenoid, QT = Quadrupole-Triplet). The cw-LINAC should provide SHE-experiments like SHIP and TASCA with beam.

Table 1: General Parameters of the cw-LINAC

Mass/Charge		1/6
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

CW-LINAC-DEMONSTRATOR

The Cryostat

The demonstrator is the first section of the proposed cw-LINAC comprising a superconducting CH-cavity embedded by two superconducting solenoids (fig. 2).

The components should be mounted in a cryogen environment operating at temperatures of 4.4 Kelvin. The cryostat itself has a cylindric shape with caps to both sides. For reasons of assembling and servicing the caps should be able to open. The cold-warm-transition which are mounted at these caps are connected to the cold beam pipe with an aperture of 50 mm. The inner surface of the cryostat is coated with a µ-metal layer to suppress

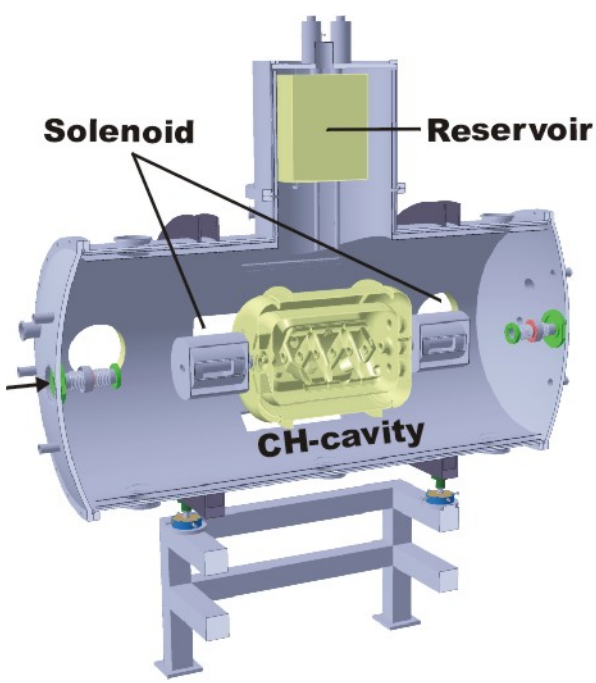

Figure 2: A scheme of the cw-LINAC Demonstrator shows the CH-cavity in its centre embedded by two sc solenoids. On the top a reservoir for liquid helium as well as nitrogen is integrated.

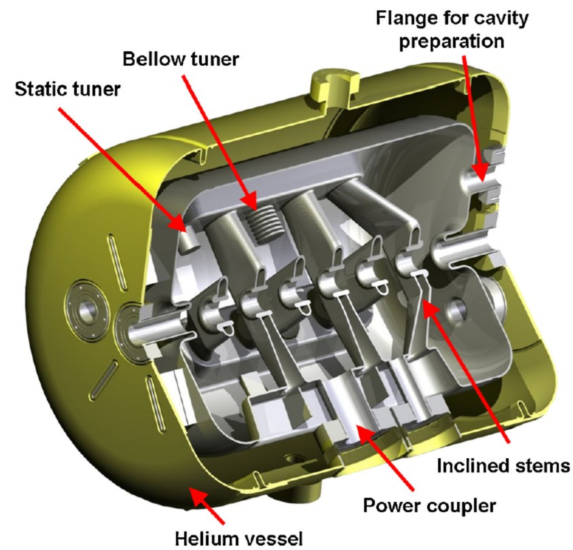

Figure 3: IAP - design of a sc 325 MHz CH-cavity.

external magnetic fields, e.g. the terrestrial magnetic field. The thermal isolation is assured by evacuating the cryostat in combination with a pipe-shaped nitrogen shield. Layers of superisolation on the outer side of the shield additionally should keep the static thermal losses smaller than 15 Watt. A reservoir (50-100 ltr.) of liquid nitrogen for the thermal shield and a liquid helium reservoir supplying the cryogenic bath of the cavity and the solenoids are integrated on the top of the cryostat tank. This inter-reservoir itself is supplied by an external reservoir. The evaporated helium is leaded to a storage balloon outside the cryostat.

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	613
Gap length	mm	40.8
Aperture	mm	20
Effective gap voltage	kV	225
Voltage gain	MV	3.13
Accelerating gradient	MV/m	5.1

The sc CH-Cavity

The sc CH-structure is the key component (fig. 3). 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 were achieved. The fabrication of another 326 MHz sc CH-cavity (β=0.16, 7 gaps) is currently in progress [6].

The cavities designed for the cw-LINAC are operated at 217 MHz. The cavities provide gradients of 5.1 MV/m at a total length of minimum 0.6 m. The general parameters are listed in table 2.

The sc Solenoids

The solenoids provide maximum fields of 9 T at an effective length of 350 mm and a free aperture of 30 mm. The fringe fields has to reduced from the maximum field to 50 mT at the entrance of the neighbouring cavity within 200 mm. First simulations shows, that proper gradients can be achieved by using anti-windings [7].

Full Performance Tests at GSI HLI

For full performance tests with beam a test environment at the HLI injection line is favoured. The goal is to connect the demonstrator straight ahead to the HLI (fig.4). Two existing experiments at the HLI has to move since the space is needed for the demonstrator test environment including a new radiation protection cave.

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

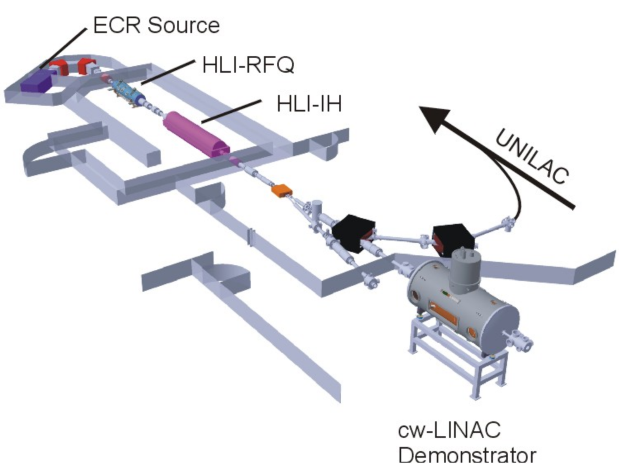

Figure 4: The HLI should be used as an injector for the cw-LINAC demonstrator. The demonstrator is mounted straight ahead to the HLI.

Status

Presently the tendering of the solenoids, the cavity and the cryostat is in progress. The technical design of the cryostat is a challenging task regarding to the cold-warm-transition, the support-system and the high requirements of thermal and magnetic shielding. Additionally a strategy for inserting the components has to be worked out including their alignment with beam in a cold environment. Therefore a feasibility study was ordered. First results are expected in October 2010, which influence the final design of the cavity and the solenoids.

The conceptual design of the cavity and the solenoid is almost worked out and a 7.5 kW rf-amplifier already ordered. The ordering of the 3000 l LHe-reservoir and the 12 m^3 storage balloon for helium gas has started (tab. 3).

OUTLOOK

The main components of the demonstrator, like the cavity, the solenoid and the cryostat, are expected to be ordered in 2010. The assembly of the components under cleanroom conditions to a well-working system should follow in winter 2011/2012. First horizontal rf-tests of the system shall take place at IAP in 2012 then. Thus full performance tests at GSI HLI are expected in spring 2013 at earliest.

Successful full performance tests with beam would be a major milestone towards a sc cw-LINAC at GSI. Independent from the financing a realisation of the proposed cw-LINAC is estimated in 2017.

Table 3: Time Schedule

	cw-LINAC -Demonstrator
2010	Ordering of the cryostat & Solenoids. the cavity the rf-amplifier, and the LHe-supply
2011-2012	Delivery of the components 1st tests (warm + cold)
2013	Full performance test at GSI HLI
2017	commissioning "sc cw-LINAC"

REFERENCES

[1] Stöcker H., Krausch G., Maas F., Proposal for the Establishment of a Helmholtz Institute (2009)
[2] S. Hofmann et al., Heavy Element Research at GSI-SHIP, EXON 2004, p. 157, Peterhof, Russia (2004)
[3] W. Barth et al., Unilac-upgrade programme for the heavy element research at gsi-ship, Proceedings of EPAC 2006, Edinburgh, Scotland, TUPLS034, 04 Hadron Accelerators, A08 Linear Accelerators, p.1565, (2006)
[4] P. Gerhard et al., Status of the unilac–upgrade programme for the heavy element research at gsi–ship, Proceedings of EPAC08, Genoa, Italy, THPP021, 04 Hadron Accelerators, A08 Linear Accelerators, p.3416, (2008)
[5] Minaev S. et al., Superconducting, energy variable heavy ion linac with constant β, multicell cavities of CH-Type, Phys. Rev. ST Accel. Beams 12, 120101 (2009)
[6] Dziuba F. et al., Development of superconducting crossbar-H-mode cavities for proton and ion accelerators. Phys. Rev. ST Accel. Beams 13, 041302 (2010)
[7] Puerschl J., Podlech H., internal note (2010)