SUPERCONDUCTING CW HEAVY ION LINAC AT GSI

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Abstract

An upgrade program has to be realized in the next years, such that enhanced primary beam intensities at the experiment target are available. For this a new sc 28 GHz full performance ECR ion source is under development. Via a new low energy beam line an already installed new RFQ and an IH-DTL will provide for cw-heavy ion beams with high average beam intensity. It is planned to build a new cw-heavy ion-linac behind this high charge state injector. In preparation an R&D program is still ongoing: The first linac section comprising a sc CH-cavity embedded by two sc solenoids (financed by HIM and partly by HGF-ARD-initiative) as a demonstrator will be tested with beam at the GSI High Charge Injector (HLI). The new linac should feed the GSI flagship experiments SHIP and TASCA, as well as material research, biophysics and plasma physics experiments in the MeV/u-area. The linac will be integrated in the GSI-UNILAC-environment; it is housed by the existing constructions. Different layout scenarios of a multipurpose high intensity heavy ion facility will be presented as well as the schedule for preparation and integration of the new cw-linac.

INTRODUCTION

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 HLI in combination with the Universal Linear Accelerator (UNILAC) is a powerful high duty factor (25%) accelerator to provide heavy ion beams for the ambitious SHE-research program at GSI. 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 [1,2]. 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 best. Significant higher beam intensities will be provided and lead to an increase of the SHE production rate.

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 [3] of a sc cw-LINAC was worked out, 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. Nine superconducting CH-cavities [4] operated at 217 MHz accelerate the ions to energies between 3.5 MeV/u and 7.3 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.

CW-LINAC-DEMONSTRATOR

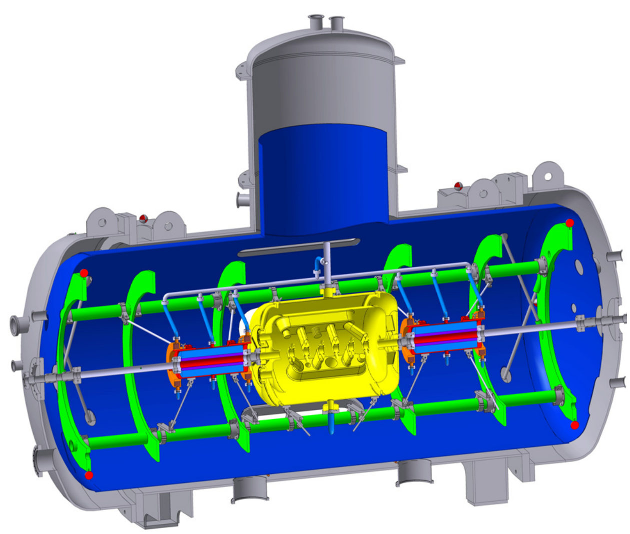

Figure 1: Scheme of the cw-LINAC Demonstrator; CH-cavity (yellow) in its centre embedded by two sc solenoids (red-orange).

The first section of the cw-LINAC comprising a sc CH-cavity embedded by two sc solenoids (financed by HIM and ARD) as a demonstrator (see fig. 1) will be tested with beam at the HLI (see fig. 2).

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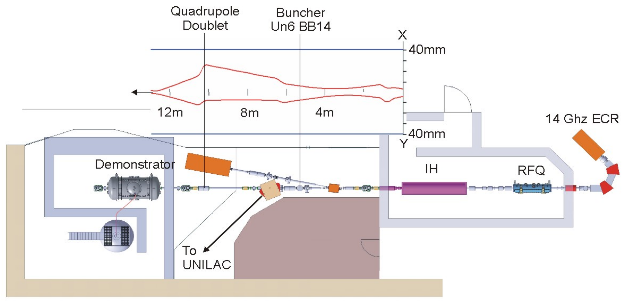

Figure 2: Existing HLI serves as an injector for the cw-LINAC demonstrator. A re-buncher as well as a quadrupole doublet provide for matching to the demonstrator.

A study has been worked out which provides a concept to assemble the cryostat [5] with the solenoids and the cavity as well as to align the three components to the beam axis. An sc CH-structure was chosen as key component for the whole linac. In a prototype test of a 360 MHz sc CH-cavity (β=0.16, 19 gaps) at the IAP maximum gradients of up to 7 MV/m at Q_0-values between 10^8 and 10^9 were achieved in a vertical cryostat. The rf-cavities have an operating frequency of 217 MHz and provide gradients of 5.1 MV/m at a total length of minimum 0.6 m [6]. The CH-prototype cavity [7, 8] is surrounded by two sc-solenoids with maximum design fields of 9.3 T at an effective length of 290 mm and a free beam aperture of 30 mm. The fringe fields are 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 [9].

The favoured location to set up the Demonstrator is in straightforward direction of the GSI-HLI (fig. 2 and 3). 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 longitudinal matching of the beam from the HLI to the demonstrator an existing re-buncher can be used, while for transverse focusing an additional quadrupole doublet is foreseen. Additional beam diagnostic elements (profile grids, emittance meter) have to be integrated in the beam line in front of and behind the cryostat. Beam energy measurements by time of flight method (TOF) have to be performed with phase probes.

In 2012 the new test area was cleared completely. After this the radiation shielding bunker was built; assembly of the matching line is now completed and an emittance meter is in place of the demonstrator. First beam measurements were successfully accomplished to check the capabilities of the matching beam line. In autumn a dedicated beam test with a full performance argon beam is scheduled to verify the assumed beam parameters at the entrance of the demonstrator.

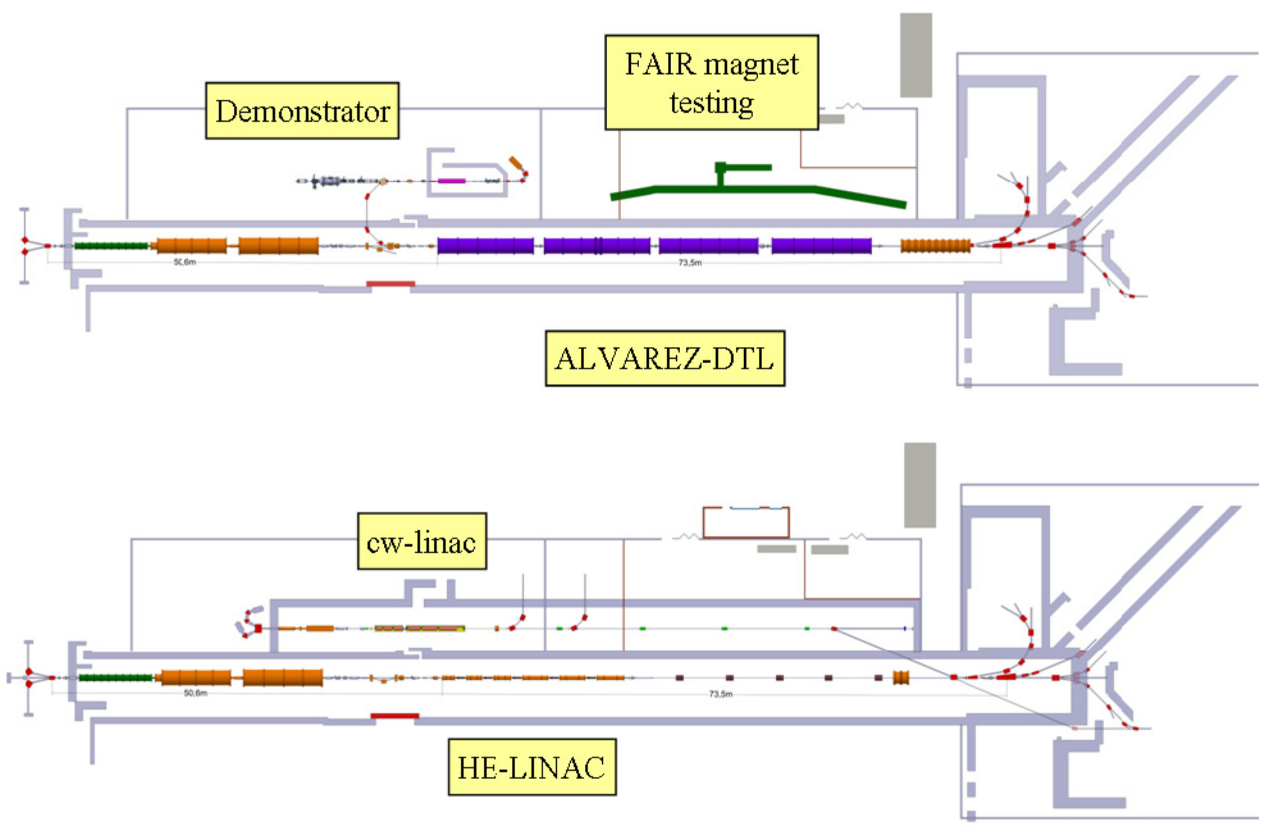

Figure 3: Complete GSI-injector environment; with demonstrator in place as scheduled for 2014 (top), after completion with HE-linac and cw-LINAC in place (bottom).

MULTIPURPOSE HIGH INTENSITY HEAVY ION LINAC

Successful R&D at the cw-CH-linac demonstrator is a milestone for the realization of the sc-cw-linac-project [10, 11]. This new injector linac could be an integrated part of a revised multipurpose heavy ion linac at GSI. A proposal for this advanced GSI-injector environment including all beam transfer lines was elaborated in 2011 [12]. Beam could be delivered by the cw-linear accelerator for highly charged ions and by the synchrotron injector (HE-linac) on a pulse to pulse basis (fig. 3). Additional beam lines would be required in order to avoid restrictions on beam operation during construction times of the different linac systems. Then the warm cw-linac (HLI) in combination with the HE-linac could also serve as a synchrotron injector for rare isotopes delivered by the ECR-ion sources. Optionally heavy ions, mainly uranium ions, from the HSI would be transferable to the cw-linac (cold), where a high duty factor ion beam could be accelerated for UNILAC experiments (e.g. for the material research cave). Additionally a high intensity proton beam from the new FAIR-p-linac will serve the synchrotron only. A maintenance program dedicated to the complete UNILAC will be performed in the next years. During this time the High Current Injector will be upgraded as a high intensity heavy ion FAIR-injector. The FAIR p-linac should be mounted until 2017. After completion of the technical design in the next three years, the HE-linac is gradually built up until the end of this decade.

STATUS & OUTLOOK

Table 2: Time Schedule

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

The mechanical assembly of the demonstrator at GSI-HLI is still in preparation. Components like the 3000 ltr LHe-tank, the 25 m^3 recovery balloon and the compressor are in house. The order of the CH-cavity is placed to Research Instruments (RI) at Bergisch Gladbach, Germany, the 5 kW rf-amplifier was delivered in may 2010. The cryostat, the two sc-solenoids and the support system were ordered at Cryogenic (London, U.K.). Cryogenic will also provide for the integration, alignment in cryogenic environment of the cryostat.

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