STATUS AND FUTURE PERSPECTIVES OF THE HIE-ISOLDE PROJECT AT CERN

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Abstract

The High Intensity and Energy (HIE)-ISOLDE project aims at several important upgrades of the present ISOLDE radioactive beam facility at CERN. The main focus lies in the energy upgrade of the post-accelerated radionuclide beams from 3 MeV/u up to 10 MeV/u through the addition of superconducting cavities. This will open the possibility of many new types of experiments including transfer reactions throughout the nuclear chart. The first stage of this upgrade involves the design, construction, installation and commissioning of two high-β cryomodules downstream of REX-ISOLDE, the existing post-accelerator. Each cryomodule houses five high-β superconducting cavities and one superconducting solenoid. Prototypes of the Nb-sputtered Quarter Wave Resonators (QWRs) cavities for the new superconducting linear accelerator have been manufactured and are undergoing RF cold tests.

The project also includes a design study of improved production targets to accommodate to the future increase of proton intensity delivered by the new LINAC4 proton driver. This improvement combined with the recently installed solid state lasers of the RILIS laser ion source and the radiofrequency quadrupole cooler and buncher ISCOOL will lead to an increase of the radioactive beam intensities of up to an order of magnitude. The project has been approved by CERN and its implementation started in January 2010. An overview of the project and the timeline will be given here.

INTRODUCTION

The HIE-ISOLDE project is a major upgrade of the existing ISOLDE and REX-ISOLDE facilities with the objective of increasing the energy and the intensity of the delivered radioactive ion beam (RIB) [1]. This project aims at filling the request for more energetic post-accelerated beams by means of a new superconducting (SC) linac based on QWRs. A research and development programme looking at all the different aspects of the SC linac started in 2008 and continued throughout 2011. In particular the R&D effort has focused on the development of the high β cavity (β = 10.3%), for which it has been decided to adopt the Nb sputtered on Cu substrate technology. Other R&D activities are related to the beam dynamics studies [2] which seek to define a very compact accelerating lattice and consequently the shortest possible machine, a design of compact SC solenoids with limited fringe fields, and the study of the cryomodule concept. The superconducting linac is designed to provide a total accelerating voltage of at least 39.6 MV with an average synchronous phase φ_s of - 20 deg. This is the minimum voltage required in order to achieve a final energy of at least 10 MeV/u with A/q=4.5.

The required infrastructure has been determined and the integration of the SC linac and High-Energy Bean Transfer Lines (HEBT) inside the existing ISOLDE experimental hall has been finalised.

The project also aims at improving the target and front-end part of ISOLDE to fully benefit from potential upgrades of the existing CERN proton injectors e.g LINAC4 and upgrade in energy of the PS Booster. The beam emittance will be improved with an RFQ cooler implemented after a pre-separator but before a new High-Resolution Separator. The new HRS, based on the latest magnet technology, will have sufficient mass resolution to permit isobaric separation. The RFQ cooler will also permit a tailoring of the time structure of the beam, removing the dependence on the proton beam time structure and diffusion-effusion properties of the target and ion source units. Highly charged ions will be provided for REX and other users through an improved low energy stage of REX-ISOLDE and a possible installation of an upgraded EBIS charge breeder.

PHYSICS MOTIVATION

The current REX energy of 2.8 MeV/u for A/q=4.5 largely restricts the physics program to measurements of collective degrees of freedom through single-step Coulomb excitation and probing single-particle degrees of freedom of light nuclei through direct nuclear reactions. The provision of exotic beams with energies up to 10 MeV/u will greatly expand the application of these methods to all ISOLDE beams [3]. Complete measurements of low-lying collective structure will be possible and, for particle states, unambiguous physical quantities can be extracted. The versatility of the accelerator, with variable energy down to 0.45 MeV/u, will facilitate measurements of rates of reactions that are building blocks of nucleo-synthesis chains, while the higher energy beams from the new linac will also allow prototype studies of new collective modes using electromagnetic probes and studies of exotic proton-rich and neutron-rich nuclei using fusion and highly-damped binary collisions.

The 34 letters of intent submitted in 2010 for experiments at HIE-ISOLDE include 284 participants. The demand for the upgrade of the REX-ISOLDE linac is reflected in 88% of the letters requesting higher beam energies that will be provided by the HIE upgrade.

HIGH BETA CAVITIES

The development of the superconducting cavities started in 2008 and focussed on the high-beta cavity design, which will be installed first. The cavities are based on the Nb sputtered on Cu technology pioneered at LNL-Legnaro. They are specified to reach a nominal accelerating field of 6 MV/m on axis over an active length of 300 mm. A Q-value of 5.10^8 is necessary to reach this field with a power dissipation of 7 W. In recent years much effort has been put in the design of a coating facility and the optimisation of the coating process. The latest test have showed a Q-values of 1.5 $.10^8$ at 6 MV/m close to the design goal. Further details can be found in [4].

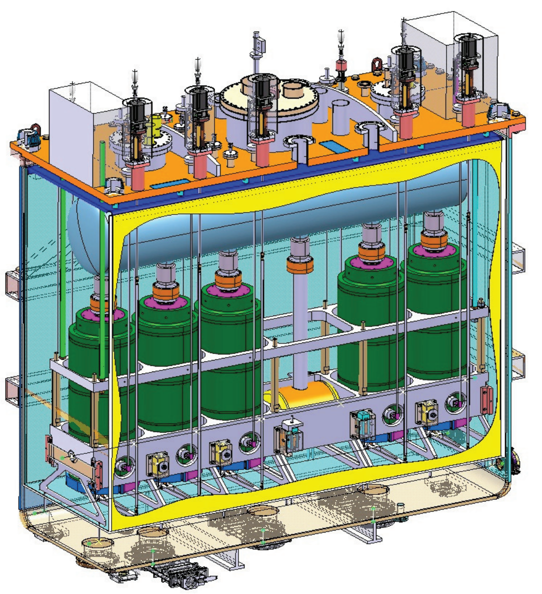

Figure 1: 3D model of the high-beta cryomodule.

CRYOMODULE DESIGN

The cavities will be grouped in common cryomodules with six cavities and two focussing solenoids for the low-beta cryomodules, and five cavities and one focussing solenoid for the high-beta cryomodules. Figure 1 shows a 3D model of the high-beta cryomodule. In order to minimise the drift length between cavities and the overall length of the machine a common vacuum was chosen for the beam and cryogenic insulation. The solenoids need to be aligned with stringent precision (±0.15 mm, ±1σ tolerance) and a system of independent adjustment under vacuum for the cavity and solenoid assembly is foreseen. A position monitoring system based on CCD cameras is also under development. The active components will be cooled to 4.5 K in two stages using gaseous and liquid He. Insulation will be guaranteed by a heat screen at 75K. A vacuum of 10^{-8} mbar after cryopumping is necessary for optimal operation. A detailed description of the high-beta cryomodule design can be found in [5].

INTEGRATION AND LAYOUT

The new HIE-ISOLDE superconducting linear accelerator will require a major increase of equipment to the existing facility's infrastructure. Two new surface buildings will be constructed in order to house the helium compressor station and the helium refrigerator cold box (Figure 2). Ground breaking has started at the end of last summer (2011) with the preparation of the site and the construction of a new lock to allow access of personnel and material to the experimental hall while HIE ISOLDE construction work is on-going.

Presently civil engineering works are in progress for the construction of the new buildings adjacent to the existing ISOLDE experimental hall. The construction works should be completed by the third quarter of 2012 after which the installation of the electrical systems and main services will take over.

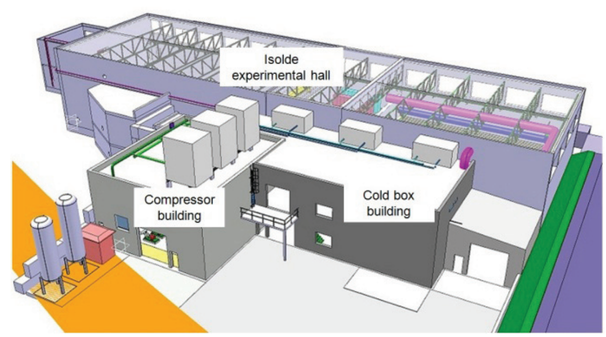

Figure 2: New HIE-ISOLDE buildings.

The cryogenic station installation will start in the second quarter of 2013. The LHe liquefier will be installed in a separate light construction building as close as possible to the linac in order to minimize the length of the LHe distribution line. This will enable an easier and more stable operation of the cryogenic system.

The cryogenic system to be supplied includes one cryogenic transfer line, which will link the cold box and the different interconnecting ("jumper") boxes feeding from the top, the six cryomodules of the new SC linac. The shielding tunnel will be installed for the full linac, whereas the installation of the cryogenic transfer line, of the linac as well as the high-energy beam transfer lines will take place in stages (Figure 3) [6].

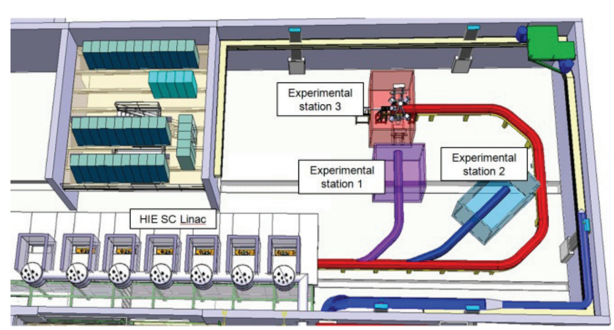

Figure 3: Layout of the HIE-ISOLDE facility.

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In a first stage only the first two high-beta cryomodules will be installed in the tunnel. Downstream the existing REX linac, they will boost the radioactive ion beam energy to 5.5MeV per nucleon and deliver the beam to two experimental stations via the first stage of the HEBT.

PLANNING AND OPERATION

If the very tight and carefully planned schedule is respected, the various experiments currently receiving beams from ISOLDE will not suffer from the upgrade works; see Fig. 4. Civil engineering work and installation of the main services such as power, ventilation and cooling will take place while the ISOLDE facility is running for the experiments. To guarantee a minimum of perturbation to the operation of the facility, the main services will be connected and the existing services modified only during the CERN Long Shutdown (December 2012 till April 2014). Civil engineering work inside the experimental hall, such as the construction of the new tunnel, as well as the move of the existing Miniball experiment to its new position will also be carried out during this period of shutdown.

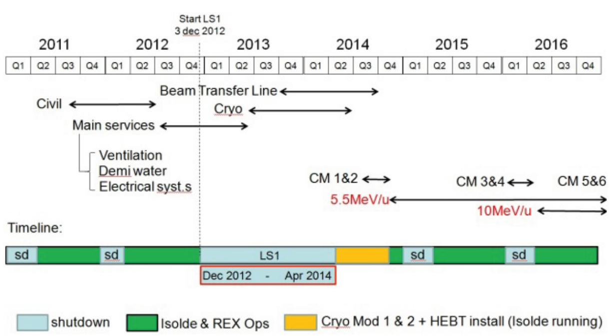

Figure 4: A simplified presentation of the HIE-ISOLDE planning.

Start-up of the low energy (60keV/u) part of the ISOLDE facility excluding the REX post-accelerator is foreseen for April 2014 as normal. However at that moment the HIE-ISOLDE Linac and high-energy beam transfer line will still be under construction with the installation of the first two high-beta cryomodules and the beam transfer line elements into the summer of 2014. Beam commissioning at 5.5MeV/u is planned for the end of the 2014 run and physics at 5.5MeV/u for the start of 2015.

The remaining two high-beta cryomodules will be installed in a second stage in 2016, increasing the beam energy to 10MeV per nucleon, together with an additional bend to the high energy beam transfer line providing the users with a third experimental station (and possible connection of a storage ring at the back of the hall). A chopper line and the two low-beta cryo-modules completing the HIE-ISOLDE linac are foreseen for a later stage after 2017.

OUTLOOK

The main technological options of the linac are now fixed and most components are in their final design or prototyping phase. The high-energy beam transfer lines designs have been finalised and the components are now in the specification or prototyping phase. The infrastructure installation is under way and should be completed by mid 2013. The cryogenic lines and first phase of the linac and transfer lines installation is planned for 2014. The linac commissioning at 5.5 MeV/u is foreseen for late 2014 and the first physics should take place in early 2015.

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