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SPES, the LNL exotic beam ISOL facility

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Summary. — A new facility is being constructed at the Legnaro National Laboratory of INFN, devoted to the production of exotic beams (RIBs), mostly neutron-rich, through the production of fission fragments (10^{13} fiss/s) by an intense proton beam (200 μA) on a direct UCx target. However, a larger beam typology will be available, developing and using several other targets. Therefore, in the forthcoming years forefront research in nuclear structure and dynamics will be carried on, studying the *Terra Incognita* in the chart of nuclides, far from the β-stability valley. Characterized by high intensities, high quality and maximum available energies (up to 11 MeV/n for A$\simeq$130) of beams, through a coordinated effort dedicated to the developments and upgrading of both the accelerator complex and of up-to-date experimental set-ups, SPES will be operated as a modern and high performing facility.

1. – Introduction

The construction of more powerful radioactive beam facilities is needed to reach regions of the nuclear chart farther and farther away from the β-stabilty valley, studying more and more exotic nuclei, getting information on their structure and on nuclear matter properties at the extremes of the drip lines. SPES, the INFN RIB infrastructure, which is under construction at the Legnaro National Laboratory in Italy [1], pursues these aims. The layout of the facility is shown in figure 1. The project was born few years ago with the intent of building up a multipurpose facility, with four different phases: α-phase - construction of the main building and installation and commissionig of a proton driver based on a high intensity (up to 750 μA) 70 MeV commercial cyclotron, produced by the BEST company [3]; β-phase - construction of a RIB facility with a low energy area (non reaccelerated beams) and a post-acceleration beam facility, by upgrading the ALPI

(*) The SPES Collaboration: `https://web.infn.it/spes`

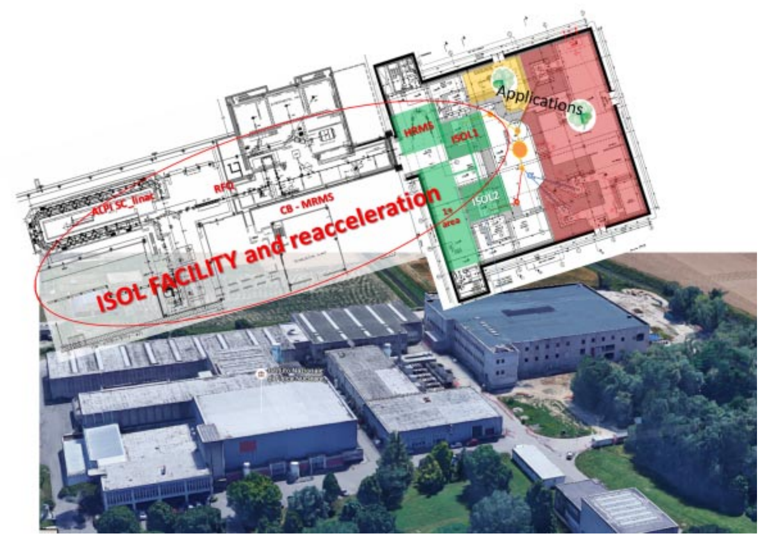

Fig. 1. – Upper part: layout of the SPES facility. Lower part: view of the new SPES building (on the right) and of the TANDEM-ALPI complex (on the left).

Linac of LNL; γ-phase - related to the development of two areas: on one side the RI-LAB activity, with a dedicated bunker, for research on new radio-isotopes: cross section measurements, high power new target tests, radioisotope production and connected tests on radio-pharmaceuticals will be performed; on the other end, a production facility in collaboration with a private company is under definition; this last will be operated in the RIFAC bunker and related pharmaceutical laboratories in order to produce radio-isotopes for medical diagnosis and therapy; δ-phase - neutron beam production by interaction of protons with heavy and light targets for either continuum spectra production (SEE: Single Event Effect study) or quasi mono-energetic spectra: applications of the neutron source go from nuclear astrophysics to test of electronics in space and characterization of nuclear waste.

2. – The SPES β-project

The construction of a Radioactive Ion Beam (RIB) facility is the major aim of the project. In particular, neutron-rich elements will be produced through the ISOL method by means of proton induced fission on uranium: a sliced UCx target has been designed to substain an intense proton beam (200 μA), with the final aim to produce up to 10^{13} fiss/s [2]. At the moment, the proton driver can deliver two beams simultaneously with the same energy but modulating different intensities at the two ports; an upgrade is undergoing to deliver the two beams even with different energies. The B70 cyclotron, which is shown in figure 2, has been installed and commissioned and it is ready to operate. A training period for the personnel has been performed and will continue in the forthcoming period. The machine has demonstrated to be stable and reliable and a proton beam of 70 MeV with a current up to 500 μA has been sent onto a high power beam dump (35 kW).

The Target-Ion Source (TIS) system [4], which is designed to substain up to 8 kW

Fig. 2. – Views from the SPES building area where the C70 BEST cyclotron is installed.

of power on the target, is the core of the project. It is integrated in the so-called Front End (FE), which is installed inside the production bunker. The FE couples the cyclotron (proton entrance channel) to the TIS itself and, downstream, it consists of a first selection stadium (Wien Filter) of the produced Radiactive Beams. The proton beam enters the TIS with an angle of 90° degree with respect to the extracted RIB and interacts in the UCx target. In the last part of the target set-up a Beam Dump, which consists of a series of graphite disks, is present to stop the remnant proton beam. Three different TIS have been developed in order to satisfy the experimental needs: a Surface Ion Source, which has a good efficiency and selectivity for elements like Rb, Cs, Ba; a Plasma Ion Source, which is necessary to ionize elements with high ionization potential, but characterized by a very poor selectivity; a Laser Ion Source, which is based on the laser resonant photo-ionization and it is very powerful and highly selective [5]. As previously reported, the extracted RIBs are then directed towards the Wien Filter, where a first selection of $\Delta M/M \simeq 1/150$ can be obtained, in such a way that the major part of the produced radioactivity is kept inside the bunker. Then, outside the bunker, a first series of elements (a Magnetic Dipole plus a series of electrostatic elements) will complete the selection reaching a resolution of $\Delta M/M \simeq 1/200$. All this is called Low Resolution Mass Separator system (LRMS). Two safety systems (SS) are provided for maintenance operation, able to remotely unlock and replace the target ion-source system from the Front End. Radiation hard materials and sealings have been chosen for the upgraded version of the FE, in collaboration with the University and INFN section of Pavia [6]. The selected RIBs are then sent to a Diagnostic Tape Station for beam characterization. In alternative, RIBs may be transported towards a Beam Cooler necessary to couple the emittance of the beam to the High Resolution Mass Spectrometer (HRMS), which is under design, with the aim to reach a separation up to $\Delta M/M=1/20000$. At the exit of the HRMS, the beam line is splitted either sending the highly resolved RIB back to the Low Energy Area, or towards the post-accelerator. The line towards ALPI is based on ADIGE, which is mainly composed by a Charge Breeding Element (CB), necessary to charge up the isotopic species from 1^+ to n^+, coupled to a Medium Resolution Mass Spectrometer (MRMS) needed to clean up from possible contaminants generated in the CB plasma chamber. In Figure 3 a picture of some of the ADIGE optical elements under installation is shown.

In order to properly inject the RIBS into the ALPI post accelerator, a new normal conductive Resonant Frequency Quadrupole (RFQ), entirely designed at LNL is being

Fig. 3. – The ADIGE Installation phase: on the left: transport line towards the RFQ; center: Optical elements aorund the MRMS; on the right: Cabling the Charge Breeder.

constructed. Moreover, transmission properties, beam intensities and energies will be improved as main objectives of the ALPI post-accelerator upgrade. The strategy covers also an improved beam instrumentation with the implementation of semi-automatic procedures to allow a better tuning and better transmission reproducibility.

The SPES beam intensities at the production/extraction point (after the 1^+ ionization) and, for post accelerated RIBs, at the secondary target position (experiment) have been evaluated with MCNPX and reported on the LNL website [7], where users can download the Beam Tables and associated Read-ME document. Moreover, specific tests on the TIS system have been performed, demonstrating the capability of the sliced SPES target to produce extra yields with respect to the bulk configuration, originally used at HRIBF at ORNL (USA) [8].

The SPES scientific program has been discussed in several international meetings, and analyzed by a Scientific Advisory Committe. Up to date instrumental set-ups (PRISMA [9], GARFIELD [10], GALILEO [11] etc.) together with specific ancillary detectors are present at LNL and have been updated to be used with RIBS. Moreover, European collaboration travelling detectors (like AGATA [12], FAZIA [13] and NEDA [14]) will come to LNL for specific experimental campaigns. Some more instruments are under development on purpose for the experimental activity at SPES, like for example an Active Target for SPES (ATS) and a β-decay station.

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