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TOWARDS THE FIRST BEAMS FROM THE ADIGE INJECTOR FOR THE SPES PROJECT

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Abstract

The ADIGE (Acceleratore Di Ioni a Grande carica Esotici) injector of the SPES (Selective Production of Exotic Species) project is now in an advanced phase of installation. Its main components have been designed following particular needs of the project: first, an Electron Cyclotron Resonance (ECR)-based Charge Breeder (SPES-CB), to boost the charge states of the radioactive ions produced at SPES and allow their post-acceleration. Then, a stable 1+ source and a complete electrostatic beam line to characterize the SPES-CB. Finally, a unique Medium Resolution Mass Spectrometer (MRMS, R=1/1000), mounted on a high voltage platform downstream the SPES-CB, to clean the radioactive beam from the contaminants induced by the breeding stage. This contribution describes the status of the injector, in particular the installation of the platform housing the MRMS, the access and safety system adopted and the first beams to be extracted from the stable 1+ source.

INTRODUCTION

SPES [1] (Selective Production of Exotic Species) is an INFN project with the aim at developing an Isotope Separation On Line (ISOL) Radioactive Ion Beam (RIB) facility as an intermediate step toward EURISOL. The SPES project is under construction at the INFN-Laboratori Nazionali di Legnaro (LNL): the main goal is the production and post-acceleration of exotic beams to perform forefront research in nuclear physics by studying nuclei far from stability. The project is concentrating on the production of neutron-rich radioactive nuclei with a mass range A=80–160: they are fission fragments that will be produced by delivering a proton beam on a UC_x target developed at LNL. The proton driver will be a commercial cyclotron [2] with a variable energy (30–70 MeV) and a maximum current of 0.75 mA (upgradeable to 1.5 mA), with the possibility to split the beam on two exit ports. The radioactive species produced will be extracted as a 1+ beam from dedicated sources [3], cooled in a RFQ-cooler [4] and purified from the isobars contaminants through a High Resolution Mass Spectrometer (HRMS) presently in the design phase. In order to allow post-acceleration with the LNL booster ALPI (up to 10 MeV/A for A/q = 7), the project will employ an Electron Cyclotron Resonance (ECR)-based charge breeding technique [5]: the Charge Breeder will be equipped with a complete test bench totally integrated with the SPES beam line. This part of the post-accelerator, together with the newly designed RFQ [6], composes the so-called ADIGE (Acceleratore Di Ioni a Grande carica Esotici) injector [7], whose layout is shown in Fig. 1. Since fall 2017, the injector entered the installation phase: the following sections will give a brief description of the injector, the present status of its installation and a plan for the first expected beams.

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BEAM LINE DESCRIPTION

Depending on the particular element to be charge bred, two kind of 1+ sources will be employed (alternatively), sharing the same vacuum chamber: a surface ionization source (SIS) or a plasma ionization source (PIS). Those sources are simplified copies of the ones which will be installed in the target-ion source-system of SPES and are described elsewhere [3]. The stable 1+ ions produced will be extracted by applying a positive high voltage between 20 keV and 40 keV to the common vessel through a 3 mm hole, and placing a movable electrode at ground potential, in order to optimize the electric field depending on the extracted intenisty. The beam will pass through two couples of X-Y electrostatic steerers (±2 kV max) that will correct possible beam misalignments, and will be transported through an electrostatic beam line consisting of two triplets (5 kV max, total length 848 mm), a 90° bending dipole, two beam instrumentation boxes equipped with faraday cups, beam profile monitors and selection slits, and an emittance measurement device, consisting of slit-grid systems. Charge breeding at SPES will be based on the ECR technique: in particular, the model adopted (SPES-CB) derives directly from the PHOENIX Charge Breeder installed at the Laboratoire de Physique Subatomique et de Cosmologie (LPSC) [8]. The SPES-CB was delivered to LNL at the end of 2015, after succesfull acceptance tests carried out between March and April [5]. Highly charged ion beams in the range 4≤A/q≤7 will be extracted from this device through a three electrodes extraction system designed at LNL [9], and initially focused by two solenoids (effective length 325 mm, maximum field B=1.5 T). Special

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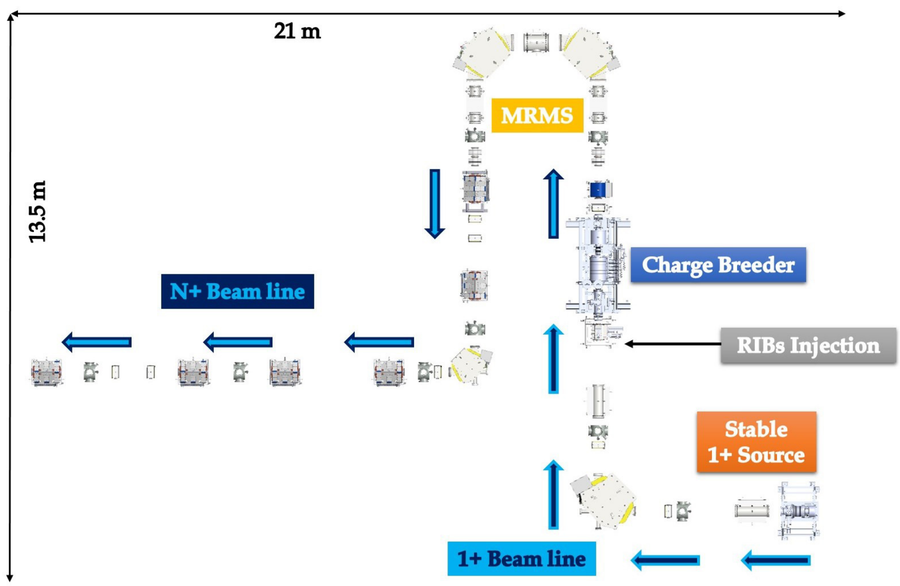

Figure 1: Upper view of the ADIGE injector with its 1+ beam line (from the 1+ Source to the Charge Breeder) and N+ beam line (from the Charge Breeder on). The position where the 1+ beam line for RIBs will be connected is also shown.

attention to the surfaces treatment and the implementation of a Medium Resolution Mass Spectrometer [10] (MRMS, see Fig. 1), designed with an expected resolving power of R=Δ(M/q)/(M/q)=1/1000 and to be installed downstream the SPES-CB, will allow the possibility to accelerate clean charge bred radioactive ions. The beam coming out from the MRMS will be focused by magnetic quadrupoles triplets (gradient 1.97 T/m and effective length 237 mm for each quadrupole) and characterized in a beam instrumentation box equipped with an emittance measurement device of the Allison scanner type (not shown in Fig. 1). A further 90° dipole (radius 500 mm, edge angles 26.6°) will bend the beam towards the injection line into the new RFQ (horizontal line in Fig. 1). More or less 30% of the future users at SPES will request beams bunched at 5 MHz instead of the usual 80 MHz of the LNL accelerating structures: to satisfy those requests, two low energy bunchers (LEB) operating at 5 and 10 MHz will be installed in the final part of the ADIGE beam line.

STATUS AND FUTURE PLANS

An update on the status of the installation just after Summer 2018 can be found in [10]: compared to that situation, a lot of progresses have been made. All the electrical boards, including those feeding electricity from UPS, have been installed and connected. The 1+ source and its power supplies operate at high voltage: for safety reasons, its area is shielded by a Faraday cage designed at LNL and constructed by an external company. The access to this area is managed by a PLE safety level system, designed at LNL and validated by the PILZ company (in charge of the safey system of different parts of SPES). Its main components were already mounted and the logic controlling the access succesfully tested. The water cooling system, whose installation started in 2018, is now completed. The cooling of the 1+ source (two separated circuits), the plasma chamber of the Charge Breeder and its coils (necessary pressure drop ΔP=10 bar) is not compliant with the characteristics of the cooling circuit of the ADIGE installation site: for those utilities, a dedicated cooling skid was designed in collaboration with the Technical Division of the LNL, installed and tested. The skid consists of a pump, raising the water pressure to the value necessary for the coils circuit, followed by two branches equipped with manual and pneumatic valves: each branch is then split in two sub-branches, two for the 1+ source, one for the plasma chamber of the Charge Breeder and the other for its coils. In those sub-branches where the very high pressure is not necessary, pressure regulaturs will lower it to usable values. All the beam instrumentation boxes and the emittance measurements device of the 1+ beam line are already in their final position. The other beam instrumentation boxes are in the construction phase and should be available by June 2019; their installation will then follow. The vacuum system of the 1+ beam line was installed, togheter with the beam pipes: it consists of four pumping groups, one for the 1+ source and three mounted on the vacuum chambers of the beam instrumentation boxes. All the pumping groups are controlled by a PLC, mounted in a single rack with the necessary hardware. Leak tests on this part of the beam line gave positive results. The pumping groups and the vacuum tubes of the N+ beam line will be installed after the delivery of the respective beam instrumentation boxes. The construction of the high voltage platform housing the MRMS has been commissioned to the Pantechnik company: the factory acceptance tests were completed in the middle of September 2018. Then, the installation at LNL started in December 2018, together with the optical elements and the necessary power supplies of the MRMS, and was completed at the beginning of February

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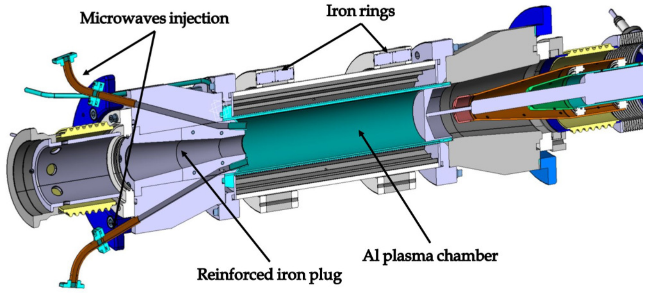

Figure 2: Sketch of the internal part of the modified SPES-CB with the main components indicated: the new aluminium plasma chamber, the modified injection of the microwaves, the reinforced iron plug and two movable iron rings to modify the magnetic field profile.

2019 with the factory acceptance tests. The planning for the ADIGE injector forsees to start the operation with the 1+ source by the end of May 2019: the first beams will be Rb^{1+} and Cs^{1+} produced with the surface ionization source; than, tests with the plasma ion source will follow. Both kind of sources will be completely characterized in terms of emittance, intensity and beam stability: such experimental activity will be carried out without interfering with the completion of the rest of the ADIGE beam line, due to the absence of Radiation Protection issues and to the proper shielding adopted for the high voltage parts. Starting from June 2019, the work necessary to operate the N+ beam line will start: the rest of the beam instrumentation boxes will be constructed, delivered and installed within 2019. At the same time, the design and construction of all the necessary mechanical supports will be carried out, and the development of the control system for the already installed power supplies will start. Three replicas of the vacuum system rack for the 1+ beam line, two for the rest of the line and one for the high voltage platform of the MRMS, will be constructed and installed. The N+ beam line should be available for operation from the beginning of 2020: the first tests will be carried out with the Charge Breeder in "source-mode", that is without injecting the 1+ beam. This will allow to continue the characterization of the 1+ sources and, at the same time, to verify the resolving power of the MRMS. The tests will proceed with the injection of the first 1+ beams into the Charge Breeder and will continue during 2020, with the entire beamline up to the injection of the RFQ operational. In this view, an important upgrade will be applied to the SPES-CB in collaboration with LPSC. In September 2018 a Research Collaboration Agreement has been signed with this Laboratoty, whose scope is the reduction of the beam contamination induced by the breeding stage: part of this agreement consists in the design and construction of two aluminium plasma chambers for the SPES-CB. Due to the particular design of the present plasma chamber, the choice of aluminium involved a change of the geometry, with a modification of the injection scheme for the microwaves and the adoptation of a reinforced iron plug at the injection side, rising the maximum of the magnetic field from 1.2 to around 1.6 T. A sketch of the new layout is shown in Fig. 2: the modification of the iron plug has been already tested during charge breeding experiments with several beams at LPSC [11], showing an important improvement of the performances in terms of global charge breeding efficiency and extracted charge state distribution.

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