

STATUS OF THE HIGH INTENSITY BEAM FACILITY AT LNL-INFN

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Abstract

In 2016 the SPES (Selective Production of Exotic Species) project [1] has entered in the commissioning phase at Laboratori Nazionali di Legnaro (LNL) with the first operations of the proton driver accelerator. The project, whose main goal is the research in nuclear physics with Radioactive Beams (RIBs), has foreseen the construction of a new building hosting the accelerator able to deliver protons up the energy of 70 MeV and 50kW of beam power to be used as a primary beam for the ISOL source and for a production beam for other applications. The new facility design has been expanded and upgraded for taking advantage of the dual simultaneous extraction of beams from the Cyclotron in order to provide a multipurpose high intensity irradiation facility. Today the new facility is partially installed and the Cyclotron supplied by Best Cyclotron System Inc (BCSI) company [2] with the related beam transport lines are under commissioning. The status of the commissioning of the high power accelerator and the capabilities of the facility as multipurpose high intensity proton beam laboratory will be presented.

INTRODUCTION

SPES project aims to provide high intensity and high quality beams of neutron-rich nuclei to perform forefront research in nuclear structure, reaction dynamics and interdisciplinary fields like medical, biological and material sciences. The production of exotic nuclei is based on ISOL technique providing low energy secondary beams that will be isotopically selected by a High Resolution Mass Spectrometer, then ionized by a breeding process, and finally re-accelerated by the actual ALPI machine operating at LNL. The primary beam is provided by a cyclotron able to accelerate H^+ ion up to the energy of 70 MeV and 700 μA of average current. The protons are extracted by the stripping of H^+ at different energies varying from 35 to 70 MeV. The main advantage of the H^+ acceleration is the possibility to extract simultaneously two proton beams by sharing the total current available. Since only 200 μA current is needed for the production of radioactive ions, the remnant current is available for other applications. For that reason an independent area of SPES facility has been built and equipped in order to deliver proton beams for multipurpose applications in parallel sessions with RIBs production. Up to 10 experimental stations are foreseen to be irradiated by proton beams and three of those are put into bunkers shielded for receiving high power beam (up to 50 kW).

FACILITY DESCRIPTION

SPES building has been thought to accommodate the cyclotron, the beam transport lines and the target stations for RIBs productions. In addition, several target areas are arranged around the area A1, where the cyclotron is placed. Figure 2 shows the overall layout of the underground level of the new facility.

Two main extraction beamlines come from the cyclotron, then by means of two switching magnets (SM1 and SM2) the beam may be guided up to 6 beamlines (3 for each SM) that allow to get directly the target stations or to reach additional switching dipoles. Finally, up to 10 target stations can be supplied by the beam.

The actual configuration foresees a single complete beamline (BL1) up to A6 area where a 50 kW beam dumper was installed and the first section of the second extraction line including the switching magnet (SM2).

The 70 MeV Cyclotron

The driver of SPES project is a resistive cyclotron able to deliver two simultaneous proton beams with energy varying within 35 and 70 MeV and 700 μA total current.

The cyclotron and the beamline (see Fig. 1) have been supplied and installed by BCSI on 2015. The cyclotron is a 4 straight sectors machine, accelerating H^+ ion that are extracted by the stripping process to get the proton beams. In order to minimize losses due to the Lorentz stripping during the acceleration, the cyclotron operates with a peak magnetic field of 1.6 T. The extraction radius is about 1300 mm and total weight is 160 tons.



Figure 1: Picture of actual installation at SPES building of LNL.

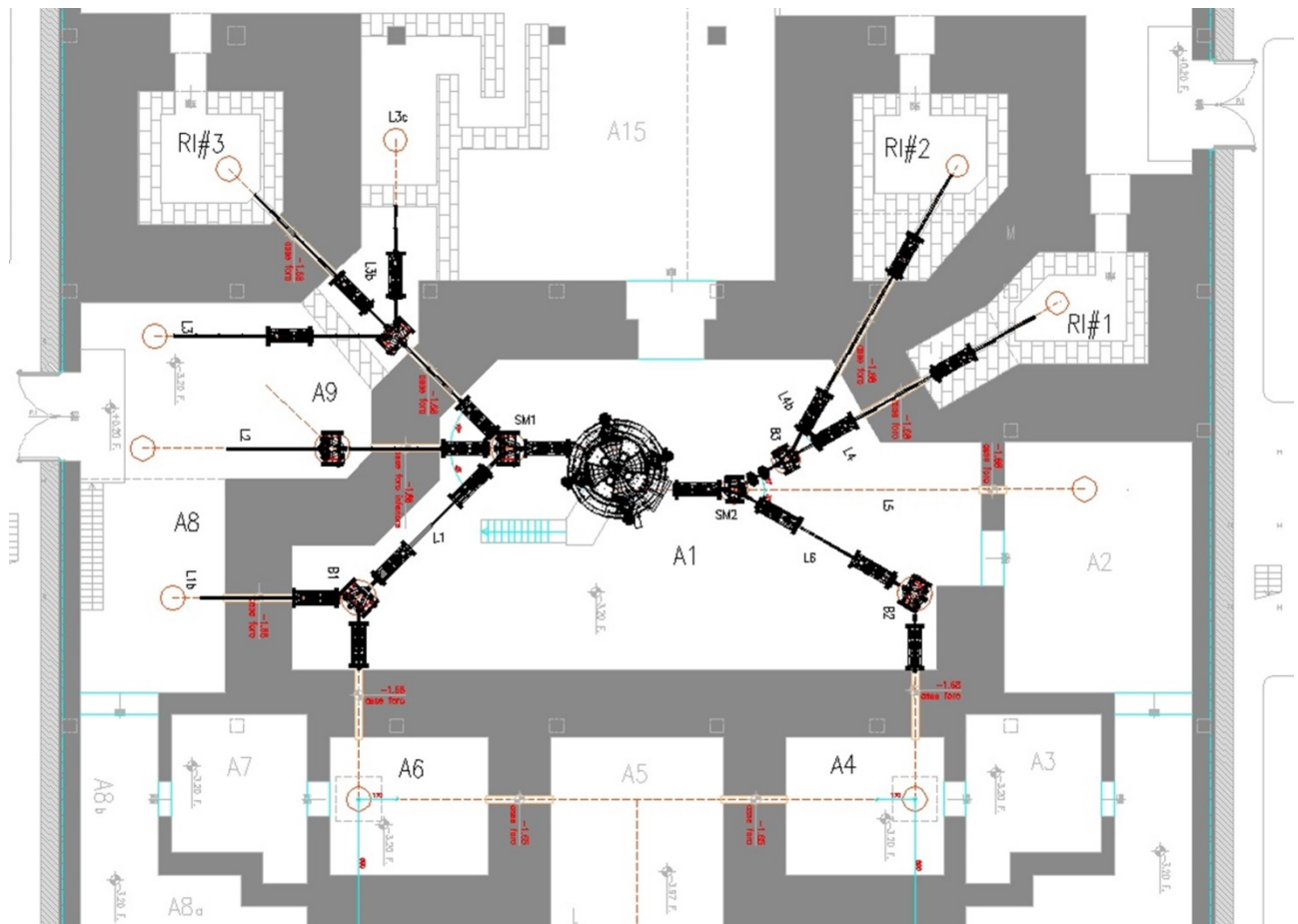


Figure 2: Overall layout of underground level of SPES building.

An external multi-cusp type ion source developed by BCSI provides the H^+ beam to be injected into the cyclotron by the axial beamline

The RF system consists of 2 half-wave cavities placed into the valleys, providing up to 70 KV of accelerating voltage. The device operates in 4th harmonic mode at the frequency of 56 MHz. In order to maximize the performance and to optimize the control of the system, the cavities are independent and two amplifier chains, synchronized by a dedicated oscillator, feed the needed power (100 kW of total power available).

The extraction mechanism allows changing the stripper foil without breaking the vacuum in the accelerating chamber, and a novel design of a cartridge case allows to store up to 20 stripper foils permitting the machine to run for 15 days without long time beam interruptions.

The ISOL Target Stations

The cyclotron can operate at the same time two beamlines. Mainly, at least one extracted beam is dedicated to irradiate the ISOL target placed on A6 and A4 area. We expect to irradiate the ISOL target continuously for 15 days, then the same number of days are expected for cooling and maintenance. In that case, the beam is switched on the other available ISOL target station.

The main target is composed by 7 discs of Uranium Carbide compound (UC_x) appropriately spacing to allow to dump 40 MeV of proton and to get up to 10^{13} fission per second for RIBs production.

To get a uniform beam distribution on the target and to avoid thermal stresses that could destroy it, a wobbler system is placed just before to enter into A6 and A4 rooms.

The Radioisotope Production Stations

Since the necessary current for RIBs production is 200 μA , the residual amount of the available accelerated current is about 500 μA . With such a current and 35-40 MeV of energy, the main purpose of the second available beam extracted from the cyclotron is the research and the production of innovative radioisotopes (LARAMED project [3]) to be used in medical diagnostics.

This activity will be held in the 3 bunkers RI1, RI2 and RI3, where 3 meter concrete shielding walls allow to irradiate the dedicated targets with 40 kW of beam power. The three bunkers are ready to be equipped with pneumatic system for the transportation of irradiated targets to the hot cells. Such a system for radiochemical treatment is still under evaluation.

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The Neutron Generation Stations

The A9 and A8 areas of the facility are dedicated for irradiation of targets with proton for high flux neutrons generation and other applications (NEPIR project [4]). In particular two continuous energy neutron beamlines where the neutrons are produced in a rotating composite target made of Be and a heavy element such Pb or Ta essentially tailored for Single Event Effects (SEE) study. The second beamline is a multipurpose line based on a thick (proton stopping) W high power target: added moderators can be tailored to produce neutrons with the energy spectrum of interest for the measurements for Atmospheric Neutron Emulator (ANEM).

An additional application of high power proton beam is the generation of a quasi mono-energetic neutron (QMN) source with a controllable peak energy in the 35-70 MeV range using an assortment of thin Li and Be production target (1-4 mm thick). A multi-angle collimator will be used to correct data taken in forward direction, by subtracting data obtained at larger angles. This multidisciplinary line is of particular interest for studying threshold effects and to calibrate simulation codes.

BEAM OPERATION

BCSI started the commissioning of the cyclotron and beamlines on March 2016. Such a commissioning is being done in different phases starting from acceleration up to 1 MeV towards extraction and transport of the beam at full power. In early September 2016 the proton beam was extracted and delivered to the end of the beamline 1 (BL1 in Fig. 2) with a maximum energy of 70 MeV and 500 μA [5].

INFN provided the safety and radiological survey systems and the high power beam dumper which has been installed in A6 bunker. Moreover two low power faraday cups have been supplied by INFN and a couple of ionization chambers have been placed along the beamline in order to monitor the beam losses in critical points i.e. at the exit of the switching magnets [6].

The Safety and Radiological Survey System

The Radiological Survey System (RSS) consists of a network of gamma and neutron monitors positioned inside the different areas at underground level, including the control room, the equipment room and the services area on the upper floor. Two Exhaust Gas Analysis Systems (EGAM) monitor the activation of the air coming from A1 and A6 rooms and they are interlocked with the cyclotron in order to stop the beam in case of excess the limit of 1Bq/g.

During the beam operation the level of radiation detected by the monitors placed in the rooms adjacent to the "hot" areas A1 and A6 do not exceed the dose rate of few $\mu\text{S/h}$ (mostly neutrons with beam on), while no variation from background level was measured in second floor. On the other side, the dose rate measured in A1 (cyclotron

room) and A6 (beam dumper bunker) gets high values of neutrons and gamma radiation proportionally to the energy and current delivered.

High Power Beam Dumper

The LNL team has developed and built the dumper able to sustain up to 50 kW of proton beam whose energy does not exceed the 70 MeV and 700 μA of current. It consists of two copper plates tilted by an angle of 10 deg in order to increase the surface where the beam will hit by reducing the power density released. The two copper plates are bolted on an aluminium frame and an indium sealing between these allows the vacuum seal. In order to reduce the residual activation of the bunker environment and allow a fast removing operation of the device once the cyclotron commissioning is completed, a series of shields of lead (50 mm thick) and high density polyethylene layers (350 mm full width) have been assembled around the structure.

The beam dumper has successfully operated up to 500 μA and 70 MeV of proton beam and a small detectable leak actually is limiting its performance.

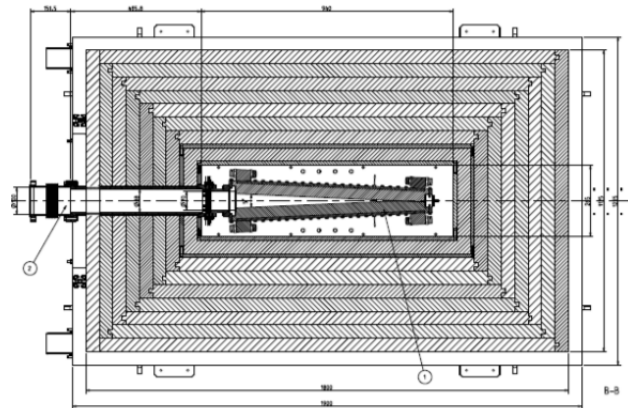


Figure 3: Top view of a section of the beam dumper and its shielding structure.

CONCLUSION

The new facility built for SPES project at LNL is now entered in the operation phase. The commissioning of the cyclotron and the beam transport lines is proceeding and very promising results have been achieved in terms of final performance of Cyclotron and beamlines. The facility is still upgrading since an additional beamline for research on radioisotope production is expected to be supplied by the end of 2017. Moreover the supply of a compound structure for radiochemical treatment of irradiated target is under evaluation.

ACKNOWLEDGEMENT

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