STATUS OF SPES FACILITY FOR ACCELERATION OF HIGH INTENSITY PROTONS AND PRODUCTION OF EXOTIC BEAMS

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Abstract

In 2010 the SPES project [1] has entered in the construction phase at Laboratori Nazionali di Legnaro (LNL), Italy. The new high power cyclotron is being assembled and tested by BEST Cyclotron Systems (BCSI) company [2] in Canada and the installation at LNL site is scheduled for fall 2014. Such machine is able to deliver two simultaneous proton beams in the energy range of 35-70 MeV and current varying within 250-500 µA and the facility has been designed in order to serve at the same time two different experimental areas. The three main uses of the high power beams are: production of radioactive beams (RIBs) by ISOL technique, production of radioisotopes for research purpose and high intensity neutron beams generation. The configuration of the facility and the further capabilities as multipurpose experimental 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 an High Resolution Mass Spectrometer, then ionized by a breeding process, and finally re-accelerated by the actual ALPI machine operating at LNL [3]. The primary beam is provided by a cyclotron able to accelerate H- ion up to the energy of 70 MeV and 750 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 250 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 is being realized 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).

THE 70 MEV CYCLOTRON

The driver of SPES project is a resistive cyclotron able to deliver two simultaneous proton beams with energy varying within 30 and 70 MeV and 750 uA total current. The cyclotron (see Fig. 1) is being constructed by BCSI, and the installation in site is scheduled for end of 2014.

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 avoid 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 tonnes.

An external multi-cusp type ion source developed by BCSI provides the H- beam to be injected into the cyclotron by the axial beamline. In order to study and optimize the ion source and injection system BCSI has assembled in its Vancouver office a 1 MeV cyclotron development platform. To accommodate different injection line configurations, the main magnet median plane is vertically oriented and rail mounted which also allows easy access to the inner components. In addition, the main magnet central region is equipped with interchangeable magnetic poles, RF elements, and inflector electrodes in order to replicate the features of the simulated cyclotrons [4].

The RF system consists of 2 half wave cavities placed into the valleys, providing up to 70 KV of accelerating voltage [5]. 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).

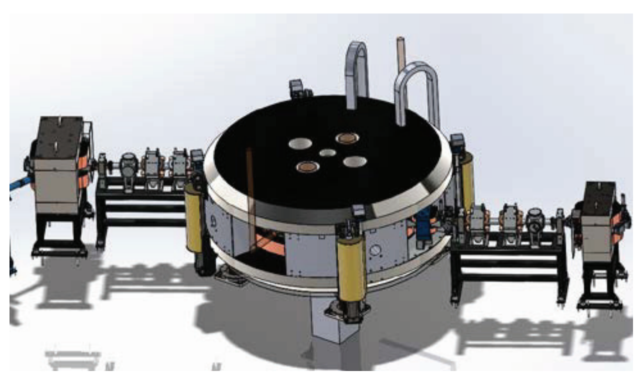

Figure 1: Layout of the cyclotron and the two exit beamlines.

The extraction mechanism allows to change 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 day without long time beam interruptions.

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DESCRIPTION OF BEAMLINES

The SPES building at LNL, has been thought to accommodate the cyclotron, the related beam transport lines and the target stations for RIBs productions. In addition, several target areas are arranged around the core area A1, where the cyclotron is placed (see fig. 2).

Two main extraction beamlines come from the cyclotron (see fig. 1), 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 ISOL Target Stations

The cyclotron can operate at the same time, two beamlines extending on its right and left side. Mainly, at least one beam is ever dedicated to irradiate the ISOL target placed on A6 or A4 area. We expect to irradiate the ISOL target continuously for 15 days, then as many days are expected for cooling and maintenance. In that case, the beam is switched on the other available ISOL target.

The main target is composed by 7 discs of Uranium Carbide compound (UCx) 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 an 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. A set of final water cooled collimators are placed into the ISOL target rooms in order to shape the beam so that a final spot of 40 mm diameter is achieved, minimizing the beam losses as well.

The Radioisotope Production Stations

Since the needed current for RIBs production is 250μA, the residual amount of the available accelerated current is about 500μA. With such a current and 35 MeV of energy, the main purpose of the secondary beam is the production and the research on innovative radioisotopes production. Hence, a theoretical assessment study has been preliminary carried out for both ^{99}Mo and ^{99m}Tc productions with proton beam in the range of 20-35 MeV and 500μA current [6].

This activity will be held in the 3 bunkers RI1, RI2 and RI3, where 3 meter shielding walls allow to irradiate the dedicated targets with 40 kW of beam power. In case of more power available, the additional shielding done by moveable bricks has been taken into account. 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.

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 [7].

In particular two continuous (white) 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) studies. The second beam line 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 on the floor; e.g. mimic the neutron atmospheric one, down to epithermal and thermal energy range, or lower for special neutron irradiation applications.

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.

The following table shows the possible arrangement of the different areas of the facility by considering energy and current of beam.

Table 1: Beam Specs of Irradiation Rooms

Room	Beam Requirements	Main Purpose
A1	35-70 MeV, up to 750 μA	Cyclotron and Beamlines
A6, A4	40 MeV, 250 μA	ISOL target stations for RIBs production
RI1, RI2, RI3	35-70 MeV, up to 500 μA, possible current increase with additional shielding	Radioisotope production and research
A8, A9	35-70 MeV, actually <50μA, possible current increase with additional shielding	High flux Neutron generation, SEE study and QMN source
A2, L3c	35-70 MeV, low current (<50μA)	Applications

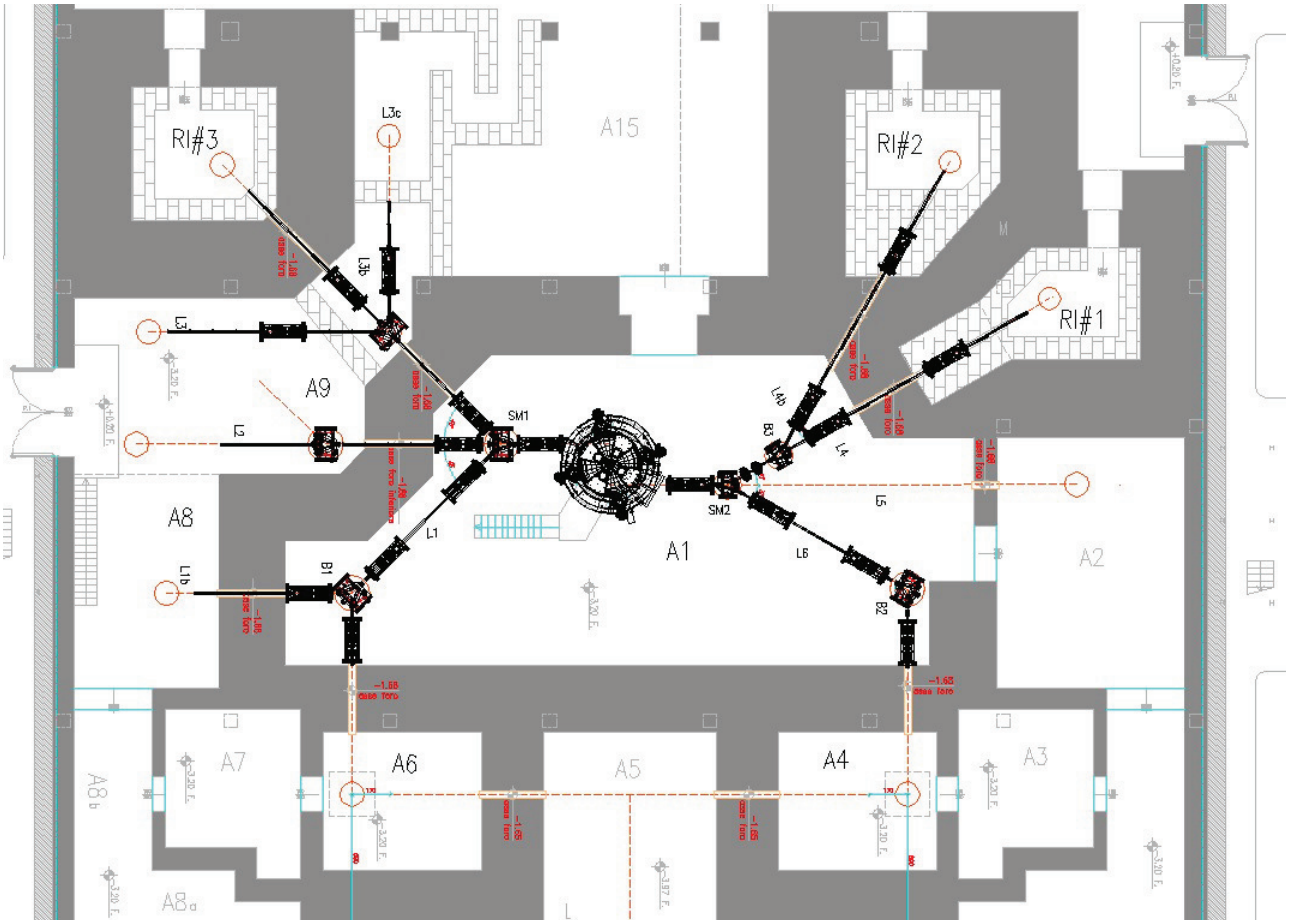

Figure 2: Layout of the SPES facility dedicated to the accelerating and transport of high power proton beams. The cyclotron is placed in the middle of A1 vault. The bunkers for the production of RIBs by means of ISOL targets are A6 and A4 respectively. Moreover, the circles represent the possible target stations. The area devoted to the selection and the re-acceleration of RIBs is not showed.

CONCLUSION

The facility of SPES is being constructed at LNL and the commissioning of the cyclotron is scheduled on early 2015. The project plan foresees to start the test of ISOL target with 8 kW of proton beam on fall 2015 and the production of first RIB at low energy on 2016. In the meantime the design of the high power beamline is under evaluation and will be finalized in order to obtain the needed authorization to operate. In fact, actually the facility is authorized to irradiate with 35 kW of proton beam power (70 MeV and 500uA), the high Z target into the A4 and A6 areas. The UCx target, for the first phase, can be irradiated for limited time and with 5µA of current. While the A1 is authorized for running the cyclotron at full power (70 MeV and 750 µA).

The new authorization is being prepared by the LNL radioprotection group in order to extend the permission to irradiate with high power beam the remaining areas. It should be ready for 2017, when the facility will start its operating phase.

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