EXPLORING THE ENERGY/BEAM CURRENT PARAMETER SPACE FOR THE ISOTOPE PRODUCTION FACILITY (IPF) AT LANSCE*

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Abstract

IPF has recently investigated isotope production with proton beams at energies other than the 100-MeV currently available to the IPF beam line. To maximize the yield of a particular isotope, it is necessary to measure the production rate and cross section versus proton beam energy. Studies were conducted at 800 MeV and 197 MeV to determine cross sections for Tb-159+p. Also, the ability to irradiate targets at different proton beam energies opens up the possibility of producing other radioisotopes with high purity. A proof-of-principle test was conducted to develop a 40-MeV tune in the 100-MeV beam line. Another parameter explored was the beam current, which was raised from the normal limit of 250 µA up to 356 µA via both power and repetition rate increase. This proof-of-principle test demonstrated the capability of the IPF beam line for high current operation with potential for higher isotope yields. For the full production mode, system upgrades will need to be in place to operate at high current and high duty factor. These activities are expected to provide the data needed for the development of a new and unique isotope production capability complementing the existing 100-MeV IPF facility.

BACKGROUND

The Isotope Production Facility at LANL has a long history of isotope production for medical, industrial, homeland defense, and weapons research. Since 2004 we have used a 100-MeV proton beam to irradiate targets (Figure 1). Beam parameters are listed in Table 1. The proton beam is swept in a circle to reduce the power density on the targets. The targets have a nominal diameter of 50 mm. For the routine production of Sr-82 and Ge-68, three targets are irradiated simultaneously with nominal incident energies of 90 MeV, 65 MeV, and 30 MeV. Targets are mounted in the holders and held in the target carrier assembly so that the target faces are separated by 5 mm thick cooling channels. Cooling water flowing over the target faces has a velocity ranging from 2 to 5 m/s. Encapsulated RbCl salt targets are used for the production of Sr-82. The capsule halves are machined from Inconel® 625 with a window thickness of 0.3 mm. The salt pucks are prepared by casting and then sealing inside the capsule under vacuum by means of electron beam welding (see Figure 2). The proton beam is created in a duoplasmatron H^+ source, accelerated to 750 keV in a Cockcroft-Walton electrostatic accelerator, and then accelerated to 100 MeV in an Alvarez drift-tube linac

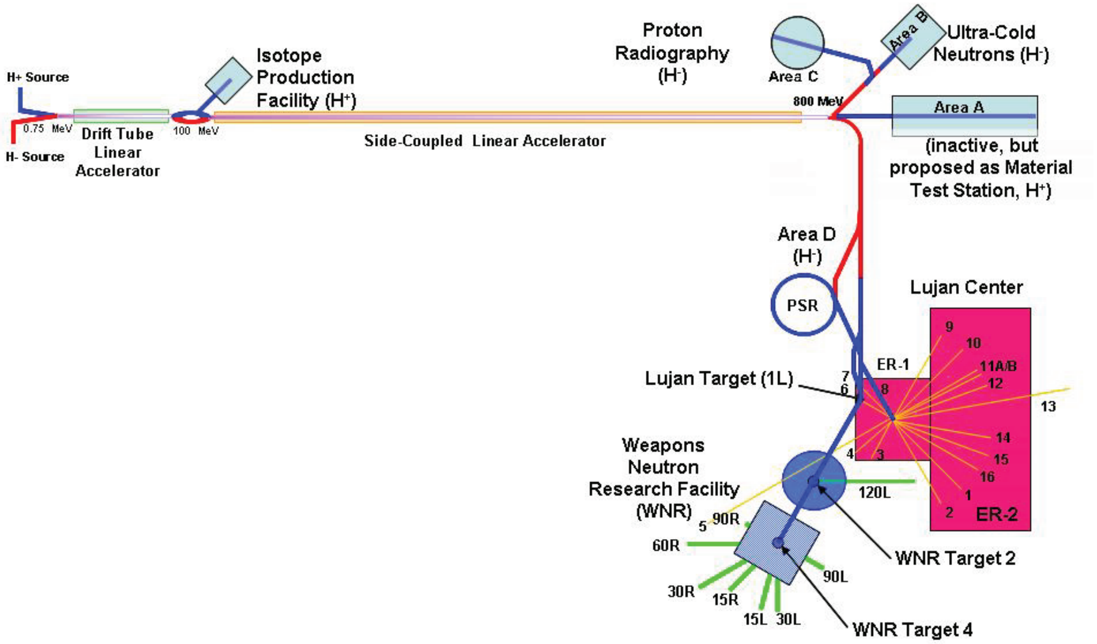

Figure 1: Schematic view of LANSCE showing the layout of the accelerator and experimental facilities.

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[%] European Patent office, The Hague, Netherlands running at a 201.25 MHz RF frequency. LANSCE has Transition Region (TR) which transitions the particle beams from 201.25 MHz into a coupled-cavity linac operating at 805 MHz. It is in this TR that the IPF spur line begins, kicking H+ down to the IPF target station.

Table 1: LANSCE IPF Beam Parameters

Beam Energy	100 MeV
Max. Beam Current	250 µA
Pulse Duration	625 µs
Average Power	25 kW
Spot Size	12.5 mm
Sweep Radius	12.5 mm
Sweep frequency	5 kHz

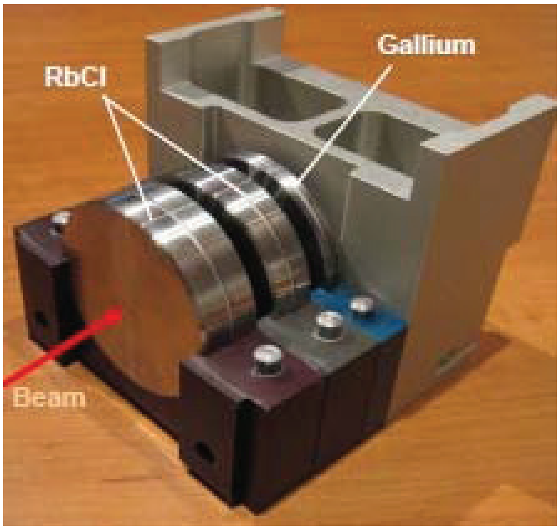

Figure 2: Target stack used for the production of Sr-82 and Ge-68.

The isotopes produced on a large scale are Sr-82 for PET cardiac imaging and Ge-68 for PET machine calibration. With an increasing demand for Sr-82 and Ge-68 isotopes and an expanding R&D isotope portfolio, we are exploring new isotope production capabilities, such as operation of the IPF beam line at 40 MeV instead of 100 MeV, increasing the average beam current to 450 µA at IPF, and exploring isotope production cross sections at 800 MeV and 197 MeV, using the Weapons Neutron Research Facility (WNR) at LANSCE.

40-MeV PROOF-OF-PRINCIPLE EXPERIMENT

The 40-MeV proof-of-principle experiment was conducted with the aim to produce additional R&D isotopes (Cu-64, Y-86, Zr-89, I-124, Pb-203, Eu-152 & 154, Np-236, Pu-236,…) with high levels of isotope purity. In conjunction with 4π-target cooling (both front and back faces of a target), this unique capability offers a significant advantage over the cyclotron solid targets operated in the same energy range with target cooling only on the rear face.

40-MeV tunes were developed in the 201.25 MHz Drift Tube Linac and IPF beam line (see Figure 3) with the drift tube quadrupole magnets set both to values optimized for a 40-MeV tune and for the production 100-MeV tune. Emittance measurements were made at 100 and 40 MeV and input into TRACE calculations to optimize the quadrupole magnet settings. One tune was developed that allowed for leaving the quads at their 100-MeV setpoints.

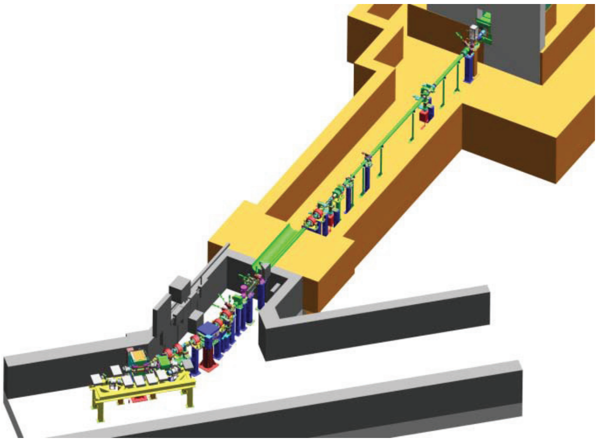

Figure 3: Schematic of the IPF spur line beginning at the TR.

The IPF target stack was configured with one Al target to accommodate a low-energy beam. The target was inspected regularly after being subjected to a current of 150 µA for 5 minutes, 200 µA for 8 and 16 minutes, then 250 µA for 10 minutes and 1 hour.

HIGH CURRENT BEAM TEST TO IPF

The administrative limit for beam current to IPF was recently increased from 250 µA to 450 µA, which has the potential to increase isotope production capability by almost a factor of two. In 2009 a high current test was conducted, during which the safe operation of IPF was demonstrated at 356 µA. This higher current was achieved in a sole-use mode by increasing the repetition rate of the 201 MHz RF system for IPF from 40 Hz to 56 Hz and increasing the peak current slightly. In production mode, LANSCE operates at 60 Hz total with 20 Hz reserved for operation of the 1L Target for the Lujan Experimental Facility. Higher repetition rates or higher peak currents will not be available for production until completion of the LANSCE 120 Hz Restoration Project.

Presently, encapsulated salt targets, such as RbCl targets are not expected to survive at average beam currents beyond 275 µA. A target design to withstand up to 450 µA beam current is a challenge and efforts to address this are underway.

197 MeV AND 800 MeV DUAL-ENERGY DEVELOPMENT

The LANL Isotope Production Program received Sole-Use beam time in December 2008 to conduct cross section measurement experiments with 197-MeV beam in the WNR Blue Room. Such studies cannot be conducted at the present IPF because its energy is limited to 100 MeV.

Low-energy operations to the WNR Blue Room had not been conducted within the last decade and had to be resurrected. This involved using accelerator development time to scale the bending and focusing magnet settings down from their standard 800-MeV values to appropriate values for 197-MeV.

Also, a dual-energy system for delaying RF modules on a pulse-by-pulse basis was resurrected and tested so that Line X can operate at 800 MeV while the WNR Blue Room can operate at 197 MeV at the same time. Line X is the beam line that serves the Proton Radiography and Ultra-Cold Neutron experimental areas. The switches for delaying RF modules are actual switches in each RF sector for selecting which modules are RF-delayed for a particular beam gate. History indicates these energy switches were last used in the 1995-96 era. The switches initially worked poorly with high-peak current and all were replaced.

The current version of the Switchyard Kicker system was also reconfigured for 197-MeV beam energy to WNR. Dual-energy operations had never been tested with the Switchyard Kicker system (this was not a design criteria for the system). The kicker modulators had a lower current limit setpoint that had to be adjusted to accommodate running the kickers at a low current to match the scaled-down values of the local bender magnets.

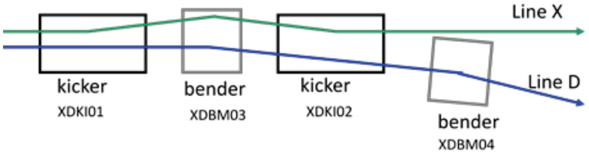

Figure 4: Schematic of the LANSCE switchyard kicking system.

CROSS SECTION MEASUREMENT AND TB SAMPLE ACTIVATION FOR ^{153}GD PRODUCTION AT 197 MeV AND 800 MeV IN THE WNR BLUE ROOM

There is interest in the availability of ^{153}Gd for medical and basic science applications, but there is presently no scalable path for production of useful quantities. Proton irradiation of Tb has been investigated as one possible solution. The region of isotopes near ^{159}Tb is illustrated in Figure 5. Energetic proton irradiation of materials will result in the formation of a wide range of products. The blue arrows in the figure show some of the possible products produced from proton irradiation of ^{159}Tb. Measurement of proton cross sections at different energy ranges will determine optimal nuclear reaction and energy range for producing large quantities of high purity material. 197-MeV and 800-MeV proton beams from the LANSCE accelerator were delivered to the Blue Room where a series of measurements were performed on Tb foils.

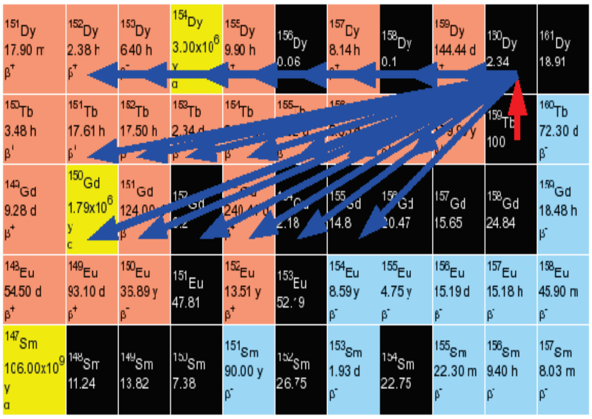

Figure 5: Possible Products from Proton Irradiation of ^{159}Tb.

After irradiation, the Tb foils were taken to a counting station where the gamma decays were tracked with High Purity Germanium (HPGe) detectors. An example gamma taken approximately 12 hours after irradiation spectrum is shown in Figure 6.

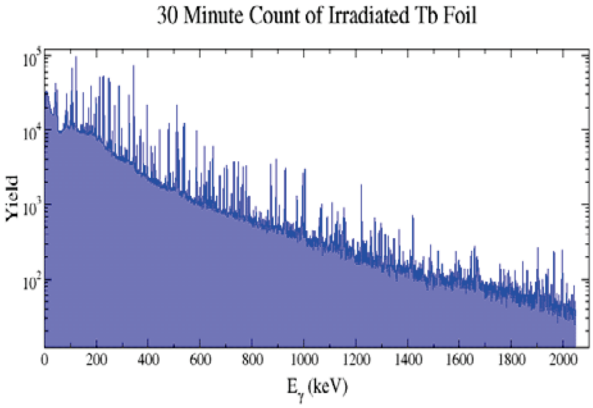

Figure 6: Gamma spectrum from irradiated Tb foil.

With sufficient resolution, the gamma lines can be attributed to decays of individual radioisotopes that were either directly produced or daughters of isotopes that were produced. Tracking the decay of the lines over time gives information about in-feeding as well as helping discriminate between close lying lines.

These activities are recent examples of how the Isotope Production at LANL is exploring the available phase space of beam energy and current to expand our isotope production capabilities.

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