DUAL-ENERGY OPERATIONS AT LANSCE FOR PROTON INDUCED NUCLEAR CROSS SECTION MEASUREMENTS *

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Abstract

The Weapons Neutron Research (WNR) facility at LANSCE conducted a set of proton induced cross section measurements in support of the LANL Isotope Production Program. To determine the best way to produce particular isotopes, it is necessary to measure the production rate's energy dependence. The first measurements used a 197-MeV proton beam, which prompted recovery of the facility's ability to transport multiple energy proton beams simultaneously to different experimental areas to ensure that an 800-MeV beam is available for Proton Radiography or Ultra-Cold Neutron experiments while a sample is irradiated with a lower energy beam for the cross section measurements. The ability to change the beam energy pulse-to-pulse was built into the original accelerator controls, but the multiple energy controls were unused for over a decade and the system was re-commissioned for this effort. These experiments form part of an effort to establish a capability for the measurement of cross sections in the 197 to 800 MeV energy range. The experiments are expected to provide the needed data for activities that may develop into a unique isotope production capability to compliment the existing 100-MeV IPF facility.

BACKGROUND

The Isotope Production Program received Sole-Use Beam Time in December 2008 at the Los Alamos Neutron Science Center (LANSCE) to conduct experiments with 197-MeV beam at the Target 2 Experimental Station (Blue Room) at WNR. Such studies cannot be conducted at the present Isotope Production Facility (IPF) because its energy is limited to 100 MeV (see Figure 1 for a schematic of the facility). Development time in October and November 2008 was requested because a low-energy tune to the Blue Room had not been developed within the last decade or so and never with a beam energy lower than 256 MeV. Another factor was a desire to retest the dual-energy system so that Line X, which serves the Proton Radiography and Ultra-Cold Neutron experimental areas, may continue Operations. Dual-energy operations had also not been tested with the latest version of the Switchyard Kicker system (this was not a design criteria for the system).

LOW- AND DUAL-ENERGY OPERATION

We started with a 256-MeV tune all the way to the Blue Room (Historical tune numbers from the 1990s were used as a starting point for the 256-MeV set-up). We then scaled down from 256 MeV to 197 MeV and tweaked based on TRANSPORT calculations. The Switchyard kicker modulator system was designed with a lower current limit of 180 A, for reasons mainly to do with current readout resolution. The Magnet Power Supply/Pulsed Power Team made appropriate changes to the modulators to run at lower current (and still be able to operate at 800-MeV setpoints). The kicker system current control was local and the readback was uncalibrated due to these changes for the experiment, but these will be corrected in the next major maintenance period.

In recent years, a programmable logic controller (PLC) was installed in the last module of the linac as a test set-up for controls hardware upgrades. The hook-ups to tell it to communicate the dual-energy switching to the Beam Fast Protect system had not been implemented and were installed using a National Instruments cRIO system. This system is being used as a test bed for future refurbishment of the control system at LANSCE.

Historical records implies the energy switches were last used in the 1995-96 era. Most switches worked without a snag. A few required some mechanical agitation to get them to function properly. However, the dual energy switching worked poorly with high-peak currents. What caused the poor performance will be a topic of investigation during scheduled accelerator development time in the 2009 Run Cycle.

We have a tune for 197 MeV (and 256 MeV) to the WNR Target 2 Experimental Station. We have the ability to adjust the Switchyard Kickers to accommodate 800-MeV beam to Line X during this (see Figure 3). We have re-established dual-energy Ops for tuning-level beams. The Energy switches have been replaced and we are requesting more development time during the 2009 Run Cycle to investigate making the dual-energy operations be able to support production-level beams.

ISOTOPE PRODUCTION AT LANSCE

Radioisotopes are important for medical therapy, medical diagnostic tests, basic research, and other applications. The high-current LANSCE accelerator provides a unique facility to investigate the production of new radioisotopes over a range of proton beam energies and to produce usable quantities of isotopes at the IPF. This capability

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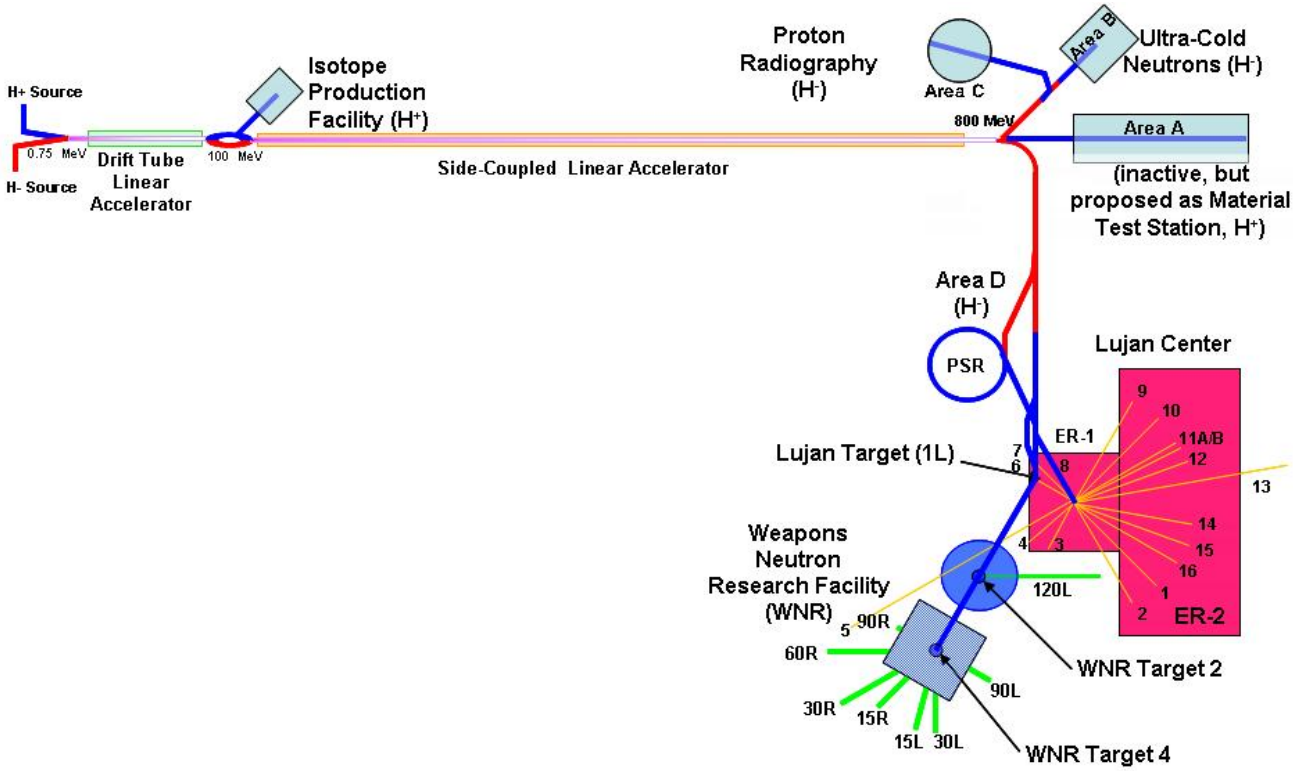

Figure 1: Schematic of the LANSCE Facility. The present Isotope Production Facility is shown in the upper left. WNR Target 2, where these experiments were conducted, is in the lower right. The Proton Radiography and Ultra-cold Neutron areas, which can run 800-MeV experiments while WNR runs 197-MeV experiments, are in the upper right.

was demonstrated by measuring the energy-dependent reaction probabilities (cross sections) to make gadolinium-153 (153Gd) by proton irradiation of naturally-occurring terbium-159 (159Tb). Gadolinium-153 is a low-energy gamma-ray source for medical imaging and diagnostic scanning and is also needed for

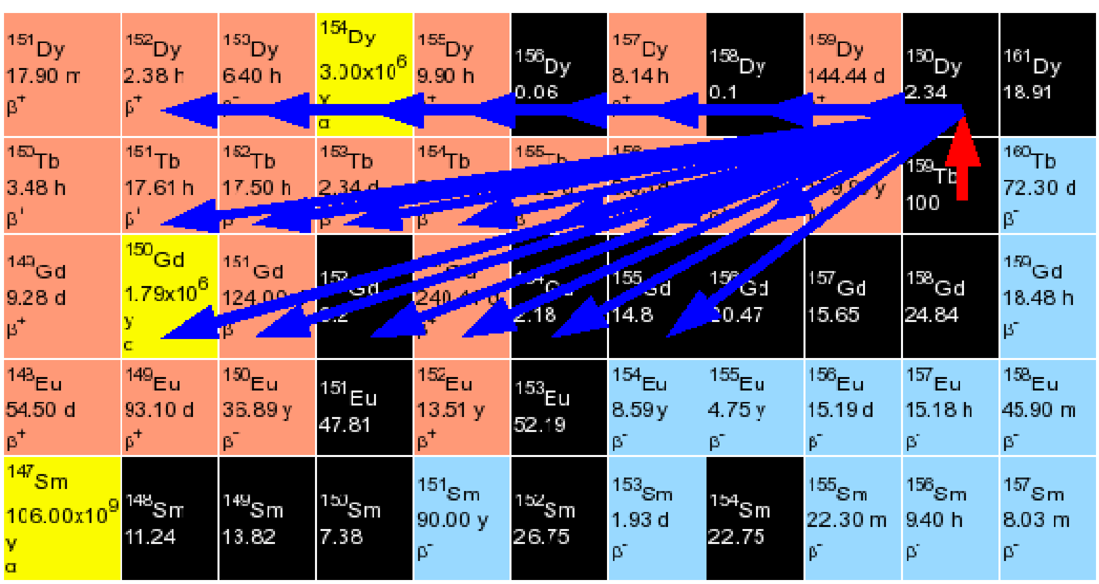

Figure 2: The region of isotopes near terbium-159 (^{159}Tb) is illustrated above. Energetic proton irradiation of materials will make a wide range of products. The blue arrows show some of the possible products from proton irradiation of ^{159}Tb. The 197-MeV proton beam from the accelerator was used to perform energy dependent measurements of the isotope production cross sections.

basic research in nuclear astrophysics and stockpile stewardship. The experiment demonstrates the measurement of energy-dependent cross sections from 100 to 800 MeV to optimize the beam energy for future gadolinium-153 production and reestablishes the research techniques for development of other radioisotopes.

The IPF produces radioactive isotopes by bombarding material with energetic protons. This process results in a net removal of protons and neutrons from the original nucleus, mostly leaving a distribution of neutron-deficient products (shown in Figure 2 above). Chemical separation is performed to extract the radioisotope of interest. With detailed knowledge of the energy-dependent production cross sections, the irradiation can be designed to enhance the production of the desired isotope and suppress production of undesirable or difficult-to-separate by-products. This present experiment is designed to measure those production cross sections over a wide energy range.

The sample activation was performed at Target 2 at the WNR facility at LANSCE. Irradiations were performed with the LANSCE proton beam energies of 800 MeV and 197 MeV. The accelerator operations team reestablished the ability to deliver a lower-energy proton beam (197 MeV) and measurements were performed at six energies between 197 MeV and 100 MeV by further degrading the beam energy in the experiment target assembly (Figure 3).

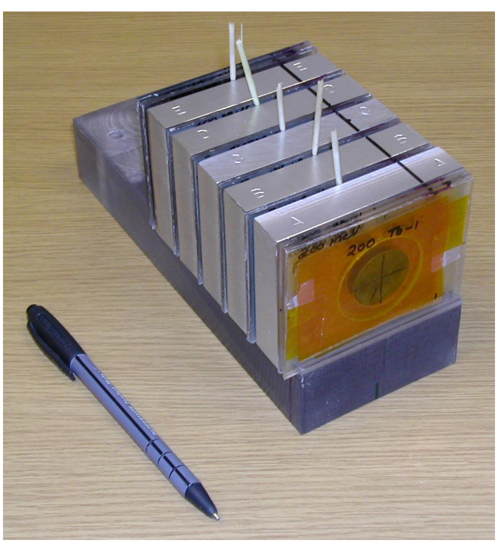

Figure 3: Shown above is the stack used for the sample irradiation. It consisted of 6 Tb foils, 5 Al degraders, and several Al beam monitors.

Immediately after irradiation, the targets were transported to a nearby counting room where the abundance of radioactive isotopes with half-lives as short as 15 minutes were measured (Figure 4). The samples were subsequently transferred to the TA-48 Count Room where the radioactive decay will be tracked to follow the isotope populations as they slowly decay back to stability.

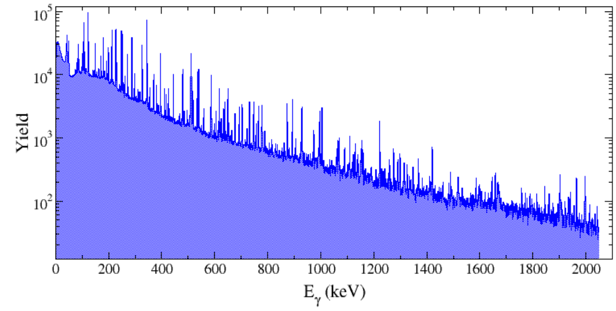

Figure 4: After irradiation, the Tb foils were taken to a counting station where the gamma decays were tracked with High Purity Germanium (HPGe) detectors. A spectrum from 30 minutes of counting approximately 12 hours after irradiation is shown above.

This measurement combined the capabilities of the Los Alamos isotope production program, the C-NR Count Room, the AOT accelerator operations group, and the LANSCE-NS expertise in nuclear cross section measurements. This unique combination of capabilities provides the ability to measure the energy dependence for production of new isotopes and can extend the range of isotopes that could be used for medicine, basic science, and industrial applications both at Los Alamos and throughout the nation. This developmental work is part of the LANSCE user program.