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TITLE: THICK TARGET SPALLATION PRODUCT YIELDS FROM 800 MEV PROTONS ON TUNGSTEN

AUTHOR(S): J.L. Ullmann, P. Staples, G. Butler, M. Fowler, A. Gavron, R. Gritzo, D. Jagnow, J.D. King, R. Laird, P.W. Lisowski, D. Mayo, R.O. Nelson, L. Waters, S.A. Wender, J. Wilhelmy, W. Wison, M.A. Yates, and C. Zoeller

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Thick Target Spallation Product Yields from 800 MeV Protons on Tungsten

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Los Alamos National Laboratory,
Los Alamos, NM

(505) 667-2517

ABSTRACT

A measurement of W spallation product yields was made for a stopping length W target in an 800 MeV proton beam. The yields are compared to intra-nucleon cascade model calculations. In general, reasonable agreement is found.

I. INTRODUCTION

A number of newly-conceived accelerator based technologies will employ medium-energy particles stopping in thick targets to produce large numbers of neutrons. It is important to quantify the residual radionuclides in the target because one must understand what nuclei and decay gammas are produced in order to design adequate shielding, to estimate ultimate waste disposal problems, and to predict possible effects of accidental dispersion during operation.

Because stopping-length targets are considered, radionuclide production must be known as a function of energy. Moreover, secondary particle production, mostly neutrons, implies a need to be able to calculate particle transport. To test our overall ability to calculate radionuclide yields, a thick-target measurement was carried out and the results compared to detailed calculations.

Although numerous measurements of thin-target spallation yields have been made (See, for example, the summary in Ref. 1), there have been only a few measurements on thick systems.[2,3] The most complete study[2] showed results for Pb and U systems. In this contribution, we report on measurements made for a stopping-length W target. Special efforts were made to measure short-lived isotopes, and reliable data on isotopes with two or three minute half-lives were obtained.

II. EXPERIMENT

The experiment was done at the "Target 2" external proton beam at the Weapons Neutron Research facility (WNR) at the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos. A thick natural tungsten target was irradiated with an 800 MeV proton beam approximately 1 cm in diameter. Thin natural tungsten foils were inserted at various locations to sample the radiation environment inside the target. The foils were then removed and counted with high-resolution germanium detectors. The radioisotopes produced were identified through their characteristic gamma ray energy spectra.

The tungsten target was 45.7 cm long and 20.3 cm square. Foils were inserted at 5 cm intervals from the front of the target. The foils were held in a lexan plate. At each interval, up to five foils, arranged radially, were inserted. Foils on the beam axis measured reactions due primarily to the incident beam, off-axis foils sampled reactions due to scattered and secondary particles. The foils were 1.91 cm diameter disks either 0.051 cm or 0.102 cm thick.

Irradiation times varied from a few seconds up to 8 hours to study short-lived and long-lived isotopes respectively. Fourteen short irradiations, 1 one-hour, and 1 eight-hour tungsten irradiations were made. The proton beam fluence was determined from activation of thin Al foils using the $^{27}Al(p,3pn)^{24}Na$ reaction. The cross section for this reaction was taken to be 10.94 ± 0.24 mb/sr.[4]

Five germanium detectors were set up at the WNR so that the short-irradiation foils could be counted immediately for information on the short-lived radioisotopes. Foils could be removed from the target and placed on the counters in about five minutes. Foils from the 1 hr irradiation were first counted at the WNR, and then taken to the automated counting facility of the Isotope and Nuclear Chemistry Division (INC) for counting to long decay times. All of the 8 hr foils were counted at INC up to 35 days after irradiation.

Approximately 2500 spectra were obtained from the short-irradiation foils, each containing approximately 100 analyzable peaks. About 500 spectra were measured at longer times, each containing 200 to 300 peaks. Gamma peak areas were determined using the automated peak-fitting code GAMANAL.[5] The energy determination was typically accurate to better than 1 keV. The radionuclide identification was based on the decay gamma ray tabulation of Spanier and Ekstrom.[6] A set of computer codes was written to partially automate the half-life fitting and nuclide identification procedure.

III. CALCULATIONS

The Monte Carlo program LAHET[7] was used to calculate both spallation radionuclide production and the transport of all secondary particles except neutrons with energies below 20 MeV. In the calculations, the entire tungsten target including the lexan holders and tungsten foils was modeled in the simulation. In this program, spallation products were calculated using the Bertini intranuclear cascade model.[8]

IV. RESULTS

The results for the on-axis summed mass yields at foil positions 15.2 cm and 20.3 cm from the front of the W target assembly are shown in Figures 1 and 2. The yields for each isotope, normalized to nuclei/cm^3/proton, were extrapolated to end of bombardment. All yields were corrected for contributions from parents within a given mass chain. The figures show the measured mass yields, summed over all measurable masses at the given A. It must be noted that many nuclei were not measurable because of an unfavorable decay scheme or because parent corrections, where required, could not be made. Thus, the absence of an isotope from the figure does not necessarily indicate that it was not produced, only that it could not be measured reliably.

The solid lines in the figures show the LAHET calculations for the mass yield summed over all nuclei with a given A. These include nuclide production by secondary particles above 20 MeV, but not absorption of neutrons below 20 MeV. On the beam axis, the contribution of low-energy neutrons is small. The dashed lines show the calculated yield summed over only the nuclei that could be measured. The dashed lines should therefore be compared to the data. For the foil 15.2 cm from the front (Fig. 2), thirty-six percent of the calculated mass yields are within a factor of two of the measured values.

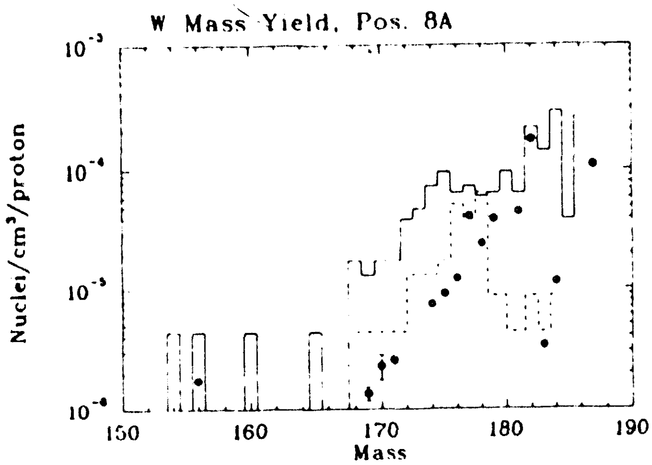

Figure 1. Comparison of measured and calculated summed mass yields for 800 MeV protons on ^{nat}W for a foil at position 8A, 20.3 cm from the front of the target. The solid line indicates calculated yield summed over all nuclei at the given mass; the dashed line is the calculated sum over only those nuclei that were observed. The dashed line should be compared to the data.

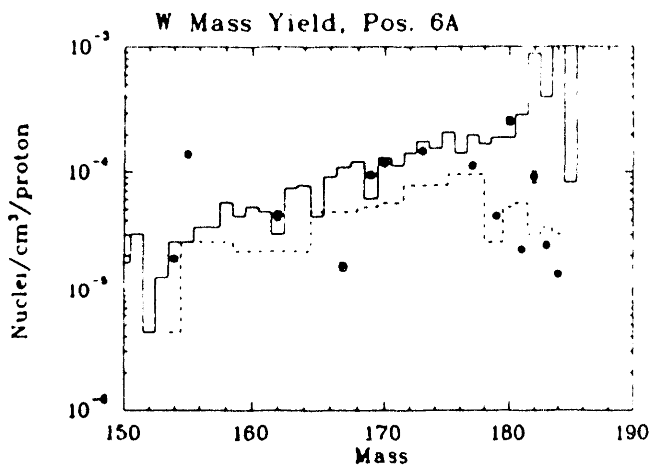

Figure 2. Same as Fig. 1, but for a foil at position 6A, 15.2 cm from the front of the W target.

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