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202gPb Production Cross Section Measurements via In-Beam Spectroscopy

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To address the lack of accurate data for ^{202g}Pb production, the Tri-Lab Effort in Nuclear Data (TREND) undertook an effort to measure the cross section values for the proposed ^{nat}Tl(p,x)^{202g}Pb reaction pathway. Prompt in-beam gamma and neutron spectroscopy were performed at the LBNL 88-Inch Cyclotron as an extension to the TREND collaboration's recent stacked-target measurement of high-energy proton-induced reactions on thallium.

^{202g}Pb has been used for geochronology via thermal ionization mass spectroscopy techniques and has been proposed as a reference material for accelerator mass spectroscopy [1, 2]. The isotope is also a candidate for neutrino mass determination due to its favorable low Q-value EC decay (ε:100%, Q=50(15) keV) [3, 4]. The ^{nat}Tl(p,x) reaction has been proposed as a method of production of this isotope to meet anticipated needs. However, the long lifetime ($t_{1/2} = 52.5(28) \times 10^3$ y) and absence of measurable decay gamma rays following electron capture make it difficult to assay the production rate of this isotope with typical foil activation measurements [4]. Conventional in-beam spectroscopy techniques adopted in this experiment allow for direct observation of feeding into the various states of the ^{202}Pb nuclide, where the prompt gammas serve as the fingerprints of transitions between the energy levels of each band.

Two natural thallium foils, prepared by the Stable Isotope Materials and Chemistry Group at Oak Ridge National Laboratory [5], were irradiated at 30 MeV and 50 MeV incident proton energy respectively at the LBNL 88-Inch Cyclotron [6]. Gamma emission was simultaneously measured by a CLOVER detector (with BGO Compton suppression) and an ORTEC GEM Series detector; throughout the experiment, the CLOVER detector was positioned at various discrete angles (30°–110°) to allow for observations of angular-dependent properties of the pre-equilibrium emissions. Neutron emission at various angles was measured by an array of Eljen EJ-309 liquid scintillators.

The partial cross section values of the ^{nat}Tl(p,x) reactions extracted from this measurement will be complemented by the TREND effort's parallel ^{nat}Tl(p,x) cross section measurements performed via stacked-target irradiations, providing new insights into the direct production of ^{202g}Pb. An assessment of the production rate and purity of ^{202g}Pb produced via this pathway can therefore be achieved. The results will be interpreted via comparison with computed predictions made by the reaction-modeling code TALYS. Building on past efforts of the TREND collaboration, the measured angular- and energy- differential cross sections of this work will further our capabilities in seeking optimized parameter adjustments in TALYS, leading to improved predictive capabilities for production of emerging medical radionuclides [7, 8, 9, 10].

This measurement not only produces previously unavailable cross section data for the ^{nat}Tl(p,x)^{202g}Pb reactions, but also expands our capability in probing reactions currently inaccessible via post-irradiation spectroscopy. The production of other high-priority stable and quasi-stable nuclides, and those without quantifiable decay radiation, can be assayed by the techniques developed for this work. The increase in measured data via in-beam spectroscopy will strengthen the predictive power in reaction-modeling codes, benefiting yield predictions of other relevant isotopes produced via proton bombardment at similar energy ranges.

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