Thick-target transmission method for excitation functions of interaction cross sections†

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Nuclear transmutation is one of the promising technologies to dispose of nuclear waste with high-level radioactivity, such as long-lived fission products (LLFP). Although the nuclear data of transmutation reactions for LLFP are essential to develop the technology, the data are scarce in the present database because the experiments are restricted by the radioactivity and chemical instability of LLFP. To avoid these restrictions experiments in inverse kinematics are available for charged-particle-induced data. Indeed, the cross section data of nuclear waste composed of 90Sr and 137Cs have recently been measured at RIBF.1) The excitation function of the interaction cross sections \( \sigma_I \), leads to the thick-target yields of LLFP transmutation. To measure \( \sigma_I \), we propose the thick-target transmission (T3) method, which extends the conventional transmission method to that with a thick target. In the T3 method, the target also plays the role of energy moderator and its thickness corresponds to the energy degradation \( I(0) \) decreases to \( I(x) \) after passing through a target with the thickness \( x \). By using the attenuation ratios \( I(x)/I(0) \) and \( I'(x+\Delta x)/I'(0) \) of different runs, the \( \sigma_I(x) \) is derived as

\[
\sigma_I(x) = \frac{1}{n_T \Delta x} \ln \left[ \frac{I'(x+\Delta x)/I'(0)}{I(x)/I(0)} \right],
\]

where \( n_T \) is the number density of target (cm\(^{-3}\)). When the LLFP beam is applied in the T3 method, \( \sigma_I(x) \) is the transmutation cross section.

To obtain \( \sigma_I(e) \) by the conventional transmission method, it is necessary to change the beam energy for each cross section \( \sigma_I(e) \). The T3 method is likely applicable with less efforts to stack a foil on the target than to change the beam energy.

To test the usefulness of the T3 method, we performed a simulation on the interaction cross sections for the \(^{12}\text{C}\)-induced reaction on \(^{27}\text{Al}\) with the Monte Carlo simulation code PHITS.2) In the simulation, the incident energy of the \(^{12}\text{C}\) beam is set to 100 MeV/nucleon, which is stopped at approximately 1.23 cm from the surface of an Al target. The target of the maximum thickness consists of 21 foils with a thickness of 0.1 cm from 0.0 cm up to 1.0 cm and of 0.02 cm from 1.0 cm up to 1.22 cm. A beam intensity of 1000 pps and an irradiation time of 100 s are assumed and correspond to a trial number of \( 10^5 \) in the PHITS simulation.

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References