Simulation of thick-target transmission method for interaction cross sections of ^{93}Zr on ^{12}C

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The interaction cross section provides valuable knowledge pertaining nuclear physics[1)] and engineering since it is an essential quantity related to nuclear radii and the transmutation of nuclear wastes. In addition, its excitation function is also important; however, the data of radioactive isotopes are very few and insufficient because it requires huge experimental effort at each energy. Therefore, we propose the thick-target transmission (T3) method to obtain the excitation functions of the interaction cross sections[2)].

The T3 method can derive the excitation function through iterative measurements of beam attenuations with different target thicknesses. Similar to the ordinary transmission method, the interaction cross section σ_I can be derived from the following equation:

$$\sigma_I = \frac{-1}{n_T \Delta L} \ln \frac{N_i(L+\Delta L)}{N_i(L)}, \quad (1)$$

where n_T, L, ΔL and $N_i(L)$ are the number density of the target, thickness of moderator, thickness of reaction target and the number of transmitted incident particles at L, respectively. In other words, $N_i(L)$ passed through the moderator part with L is used as a beam on the reaction part of the thickness ΔL. We performed a simulation with the PHITS code[3)] for the interaction cross sections of ^{93}Zr on ^{12}C, which are typical examples of long-lived fission fragments and stable nuclei. The cross sections are equivalent to inclusive cross sections of ^{12}C-induced transmutation reaction on ^{93}Zr.

The parameters adopted in the simulation are set to cover the expected peak area. The energy is set to 100 MeV/nucleon, which is similar to the recent experiment[4)]. The target density and thicknesses are 2.260 g/cm^3 and 0.02 cm ($0 \leq L \leq 0.2$ cm) and 0.004 cm ($0.2 \leq L \leq 0.24$ cm), respectively. The trial number is 10^5 which are consistent with an intensity of 1,000 pps and individual irradiation period of 100 s. Calculations with different target thicknesses were iteratively performed in the simulation. The beam attenuation and energy at the downstream of the target can be obtained in each calculation and are shown as a function of the target thickness in Fig. 1. The interaction cross sections thus obtained with the moderator part from Eq. (1) are shown in Fig. 2 with expected values of PHITS derived from the traditional transmission method with thin-targets and energy adjustments. The behaviors of the cross sections are in good agreement, and therefore the T3 method may be applicable in real experiments. The derived cross sections, however, have large uncertainties in the low energy region because the uncertainties are accumulated in the moderator part of the target. We continue to investigate the method in more detail to propose a new experiment and also perform additional simulations of other radioactive isotopes.

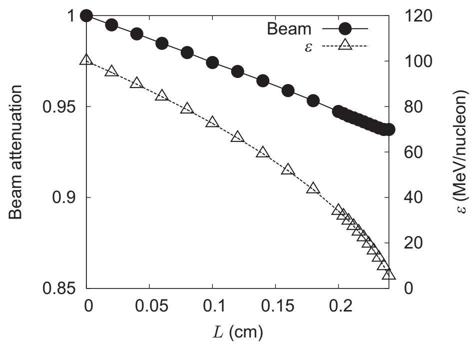

Fig. 1. The attenuation (solid circles with solid line) and energy (open triangles with dotted-line) of the incident beam are shown as a function of the target thickness.

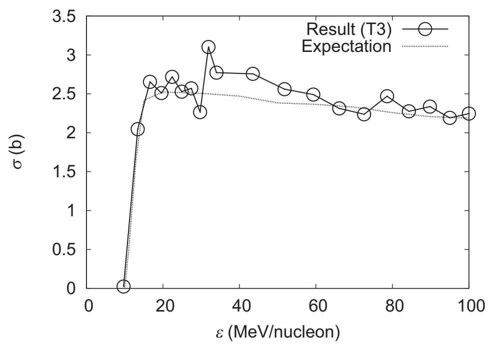

Fig. 2. Interaction cross sections of ^{93}Zr on ^{12}C. The results of the simulation (open circles with solid line) are shown with the expected values in PHITS (dotted-line).

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