Thick target neutron yields of 100- and 230-MeV/nucleon helium ions

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The thick target neutron yields from 100- and 230-MeV/nucleon helium ions bombarding water, PMMA, and iron targets were measured by using the time-of-flight technique at 0° – 121°. The experimental data were compared with INCL-4.6, RQMD, and ISABEL model calculations respectively by the PHITS, FLUKA, and MCNP6 codes.

Keywords: thick target neutron yield, helium ions, PHITS, FLUKA, MCNP

1. Introduction

Neutrons produced by helium ions are essential for assessing secondary neutron doses in helium ion radiotherapy, a treatment modality currently under consideration for pediatric patients in the heavy ion therapy community [1]. Also, for space radiation shielding, cosmic ray helium interactions in both thin and thick shields can produce up to 30% of the total neutron fluence [2]. However, little information is available on neutron production by medium energy helium ions. Thus this study aims to provide the experimental data of helium ions at 100 and 230 MeV/nucleon.

2. Experimental setup and Monte Carlo simulations

The measurement was conducted at the Heavy Ion Medical Accelerator in Chiba (HIMAC). The targets materials included water, PMMA, and iron, with thicknesses 9%-18% thicker than the helium ranges. The time of flight method with NE213 liquid scintillators was used to measure the thick target neutron yields at six angles from 0° to 121°.

The experimental data were compared with three Monte Carlo simulation codes – PHITS v. 2.82, FLUKA v. 2011.2c, and MCNP6 v. 1.0 with their default models for helium-induced reactions, which are INCL-4.6, RQMD, and ISABEL, respectively for PHITS, FLUKA, and MCNP6.

3. Results and conclusions

The model calculations of the neutron yields generally agree with the measurements, especially in the intermediate and low energy regions at angles at and above 30°. However, some disagreements exist not only between the data and the simulations but also between models. The models need improvements particularly for 1) energies beyond the specific beam energy for PHITS and FLUKA, 2) the high-energy peak at 0° for each model, and 3) low energy neutron yields of light targets for each code. More detailed discussions will be provided in the presentation.

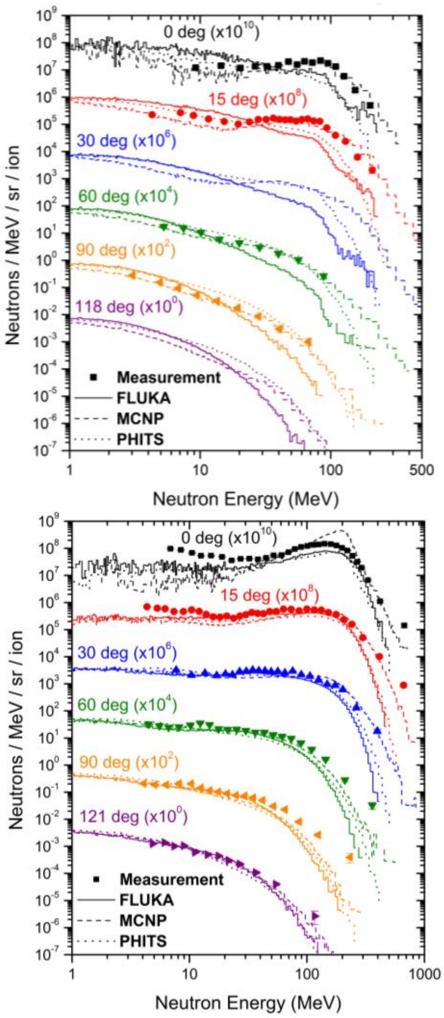

Fig. 1 The double-differential thick-target neutron yields from (a) 100-MeV/nucleon helium stopping in the iron target, and (b) 230-MeV/nucleon helium stopping in the PMMA target.

References

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