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A-FNS、IFMIF等の材料照射施設のためのd-Liターゲット中性子収量のPHITSによるベンチマーク計算

Benchmark calculation of d-Li target neutron yield by PHITS for fusion material irradiation facilities such as A-FNS and IFMIF

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International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based neutron source where a couple of deuteron beams with 40 MeV and 125 mA bombard a flowing liquid lithium target. Also, design works of Advanced Fusion Neutron Source (A-FNS) and DEMO-Oriented Neutron Source (DONES), which are a half-size IFMIF with a single deuteron beam of 40 MeV and 125 mA, are advanced in Japan and EU, respectively.

In the neutronics design of IFMIF and similar facilities, neutron yield evaluation including angular neutron spectra at d-Li thick target is essential. In those neutronics designs, Monte Carlo codes such as MCNP and PHITS are generally used. Previously, there was no suitable d-Li reaction data for those Monte Carlo codes. MCNP and PHITS calculate d-Li neutron yield by built-in nuclear reaction models. However, the calculated d-Li neutron yield had a large discrepancy with the measured data. In the present IFMIF design work, the McDeLicious Monte Carlo code [1] is used for the d-Li neutron yield evaluation, which has been developed by the Karlsruhe Institute of Technology (KIT), however, is not open code. Therefore, a nuclear data file of d-Li reaction for more general Monte Carlo codes such as MCNP and PHITS has been desired.

Recently, the d-Li reaction library is released by JAEA in formats of ACE and Frag-data as JENDL/DEU-2020 [2]. The ACE file is readable in both MCNP and PHITS. Frag-data is an external data format of the double-differential cross-section for PHITS. The previous version of PHITS (3.25 or earlier) could not use ACE format files of deuteron-induced reaction and can use Frag-data only. However, PHITS-3.26 (the latest version) is able use ACE format files.

We carried out the benchmark calculations of the d-Li neutron yield by using PHITS and MCNP with JENDL/DEU-2020 compared with experimental data, McDeLicious, and PHITS/MCNP with built-in nuclear reaction models. In the calculations with built-in nuclear reaction models, PHITS uses two models; one is INCL (Intra-Nuclear Cascade of Liége) model, and another is INCL+DWBA (Distorted-Wave Born Approximation). As the reference experimental data, we employ double-differential neutron yields of the d-Li thick target measured by Hagiwara [3] at the deuteron energy of 25 and 40 MeV, and by Sugimoto [4] at 32 MeV.

Figure 1 shows the calculated and measured double-differential neutron yields of the d-Li thick target at 0, 10, and 30 degrees for E_d of 40 and 32 MeV. McDeLicious reproduces experimental data of Hagiwara remarkably, which is considered that McDeLicious has been adjusted to the experimental data for the IFMIF design. Also, PHITS and MCNP with JENDL/DEU-2020 are in good agreement with the experimental data of Hagiwara and Sugimoto. We confirm that JENDL/DEU-2020 is useful in the d-Li target yield calculation for IFMIF and similar facilities.

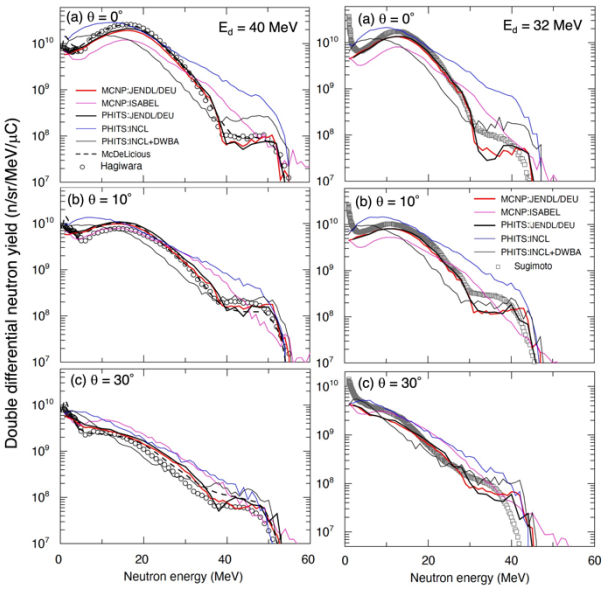

Fig.1 Calculated and measured double-differential neutron yields of the d-Li thick target at (a) 0, (b)10, and (c)30 degrees for incident deuteron energy of 40 and 32MeV.

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