§36. Applicability of Li-glass Neutron Detector in Neutronics Benchmark Experiments for Liquid Blanket Systems

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Applicability of neutron detectors has been investigated for efficient and quick evaluation of neutron transport in benchmark experiments which are planned for validation of neutronics designs of fusion breeding blanket systems. One of the candidate methods for the neutronics evaluation is the direct measurement of tritium production rates by detecting the ^{6}Li(n, α)T reaction with a Li-glass scintillation detector.

Two detectors, namely, a ^{6}Li enriched Li-glass detector and ^{7}Li enriched Li-glass detector are used in the tritium production rate measurement. As shown in Fig. 1, the peak area obtained by subtracting the response of the ^{7}Li enriched detector from that of the ^{6}Li enriched detector corresponds to the reaction rate of the ^{6}Li(n, α)T reaction. Tritium production rates were evaluated with a high accuracy of several % by using this method in the previous benchmark experiments for a water cooled solid blanket system (Li_2O irradiation assembly).[1] On the other hand, our group applied this method to evaluation of tritium production rates in an irradiation assembly simulating a liquid blanket system (Li/V assembly, 46 x 51 x 51 cm^3) previously [2] and the experimental results obtained with the Li-glass detectors were smaller by ~20 % compared with the calculated values. Although the large undervaluation in the Li/V assembly has been considered due to the higher fast neutron flux compared with the Li_2O assembly, detailed investigation of the reason has not been performed yet. In the present study, a program to calculate energy deposition to the detectors by neutron scattering and nuclear reactions was made and the responses of the Li-glass detectors in the Li/V assembly under 14 MeV neutron irradiation were investigated with the nuclear data library JENDL-3.3.

The result shown in Fig. 2 indicates that the background component at the peak position of the ^{6}Li(n, α)T reaction was formed mainly by the elastic neutron scattering with ^{6}Li in the ^{6}Li enriched detector and ^{7}Li in the ^{7}Li enriched detector, respectively. Comparing those neutron scattering processes, the cross section of the elastic scattering with ^{7}Li is slightly higher than that with ^{6}Li and the magnitude of the energy deposition to ^{7}Li is smaller due to the larger mass. As shown in Fig. 3, these two factors shift the response curve by the scattering with ^{7}Li to the lower energy side, respectively. When the response of the ^{7}Li enriched detector is subtracted from that of the ^{6}Li enriched detector as the background, the peak area obtained as the ^{6}Li(n, α)T reaction rate becomes smaller than the true value, i.e. undervalued. In the Li/V irradiation assembly, the fraction of the fast neutron component is significantly higher than that in the Li_2O assembly. Since the cross section of the ^{6}Li(n, α)T reaction is significantly high for low energy neutrons and small for high energy neutrons, the peak area of the ^{6}Li(n, α)T reaction becomes smaller and the magnitude of undervaluation due to the background subtraction will be more significant in such environment.

The analyzed response curves of the inelastic scattering with ^{6}Li and ^{7}Li have almost similar shape under the peak of the ^{6}Li(n, α)T reaction. Therefore, if the vertical level of the ^{7}Li detector response is corrected, i.e. lowered, based on the present analysis and subtracted from the response of the ^{6}Li enriched detector as the background, the accuracy in the tritium production rate measurement could be improved. Although further investigation is required for the correction method, the Li-glass scintillation detectors would be used also in the neutronics benchmark experiments for other liquid blanket systems such as molten salt and LiPb blankets.

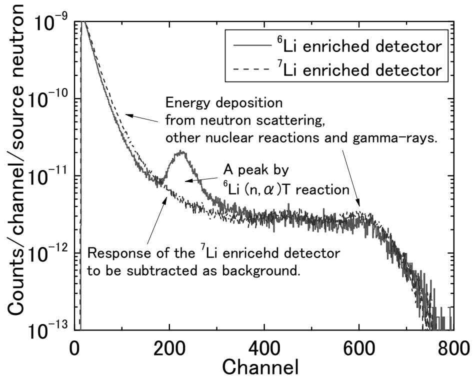

Fig. 1. Response of Li-glass scintillation detectors in the Li/V irradiation assembly under 14 MeV neutron irradiation.

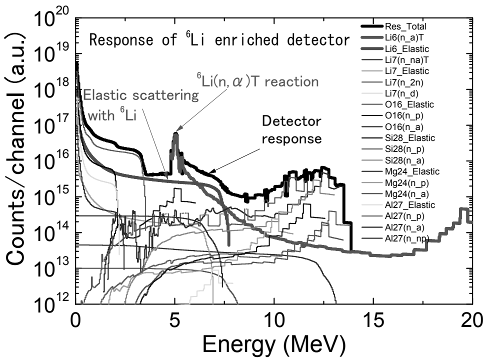

Fig. 2. Calculated response of the ^{6}Li enriched detector and contribution from scattering and nuclear reactions.

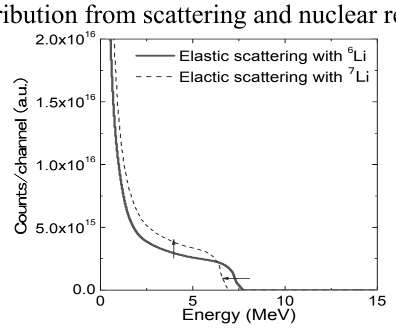

Fig. 3. Comparison of energy deposition by neutron elastic scattering with ^{6}Li and ^{7}Li.

1) Yamauchi, S. et al.: Nucl. Instr. and Meth. **A 254** (1987) 413.
2) Tanaka, T. et al.: Fusion Sci. Tech. **60** (2011) 681.