28th IAEA Fusion Energy Conference (FEC 2020)

ID: 819
TECH

Evaluation of tritium production rate in a blanket mock-up using a compact fusion neutron source

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ABSTRACT

- A DD neutronics study in a blanket mock-up using a discharge-type compact fusion neutron source is reported here.
- Tritium production rate (TPR) per source neutron was measured by a single-crystal diamond detector (SDD) with a 6LiF
- Error in ratio of computational and experimental TPR were evaluated.

BACKGROUND

- An experimental measurement of tritium production rate (TPR) is needed to guarantee the tritium fuel self-sufficiency
- But, opportunities for neutron irradiation experiments have been limited by low availabilities of fusion neutron irradiation facilities. An alternative approach for a facile neutronics experiment is desired.
- Here, we employ a discharge-type compact fusion neutron source and single crystal diamond detector (SDD) with ^{6}LiF film to evaluate TPR in a fusion blanket mock-up.
- This work aims to evaluate calculated to experimental (C/E) value of TPR and its error in a DD operation (neutron energy: 2.45 MeV).

METHODS

Neutron source

2.45 MeV DD fusion neutrons were generated by a discharge-type cylindrical fusion device with 60 kV and 9 mA.

K. Mukai et al. 2020 *IEEE Trans. Plasma Sci.* **48** 1831–1835

Neutron Irradiation

Blanket mock-ups were composed of graphite, polyethylene, and Li2CO3 breeder (Fig. 1,2). Single crystal diamond detector with ^{6}LiF film (^{6}LiF enrichment: 95.6%) was calibrated with α-sources (Fig.3).

The calibration coefficient (triton count per ^{6}Li(n, t) reaction) was 8.33×10^{-2}.

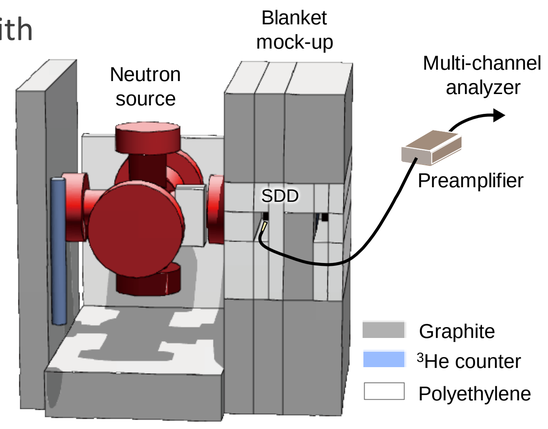

Fig. 1 Experimental assembly

Computation

- MCNP 6.0 with FENDL 2.1 & 3.1
- PHITS code

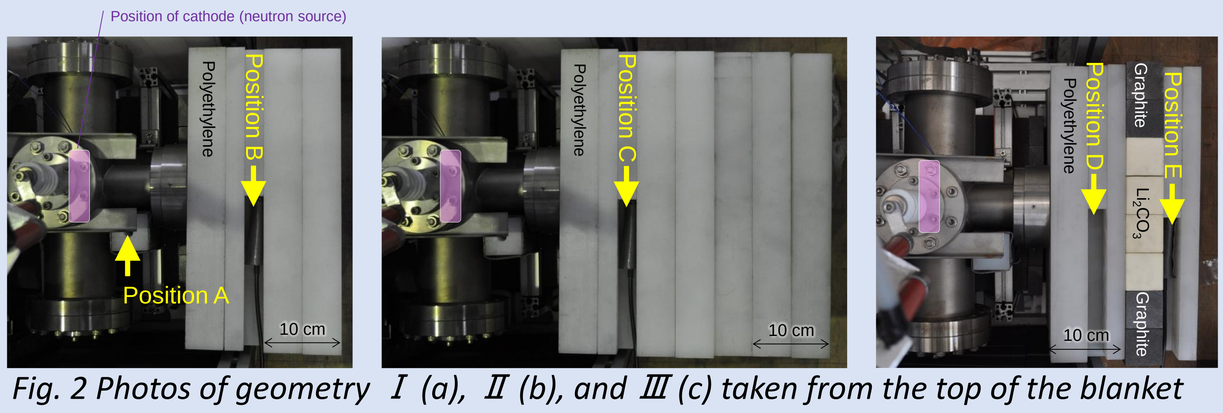

Fig. 2 Photos of geometry Ⅰ (a), Ⅱ (b), and Ⅲ (c) taken from the top of the blanket mock-ups, representing the detector positions and arrangements of the blocks.

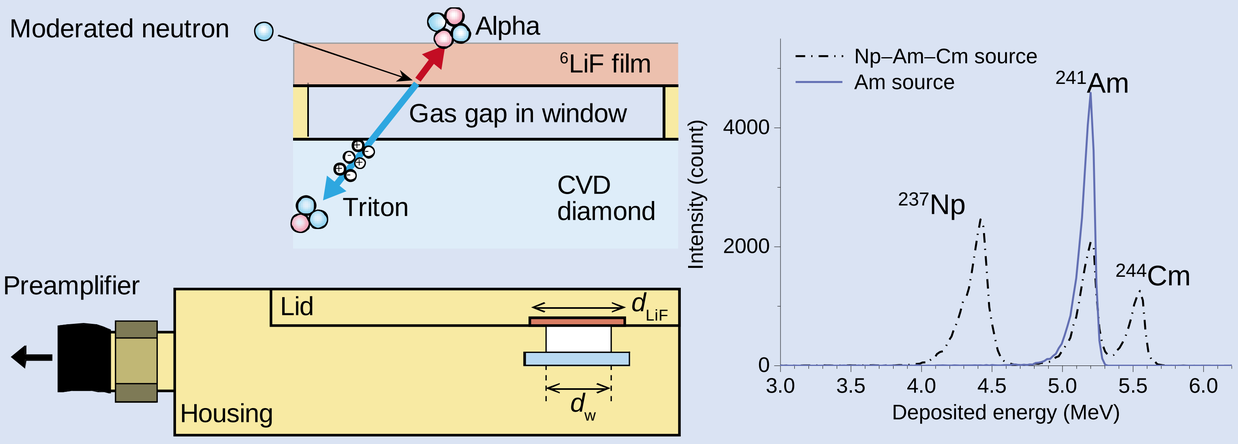

Fig. 3 Single crystal diamond detector with 6LiF film (left), energy spectra using Am and Np-Am-Cm sources for a calibration (right).

OUTCOME

Neutron Irradiation

Irradiation was performed for 2 h (position A,B, D, and E) and 5 h (position C) where average neutron production rate was 2×10^{5} n/s. Triton peaks appeared in $2.40 < E_d < 2.69$ MeV (Fig. 4). The signal to noise (S/N) ratio was high (48-72) because of low activation of materials in the source.

Evaluation of TPR

Triton count obtained with calibration factor k ($k = 8.33 \times 10^{-2}$ /s.n.)

- **TPR**: Experimental TPR was evaluated to be 0.13-3.19 $\times$ 10^{-7} per source neutron (s.n.) with experimental error of 8.4-8.5% (1σ level).
- **C/E**: Computational and Experimental ratios of TPR were 0.91-1.42 and 0.96-1.41 with FEDL 2.1 and FENDL 3.1 libraries respectively.

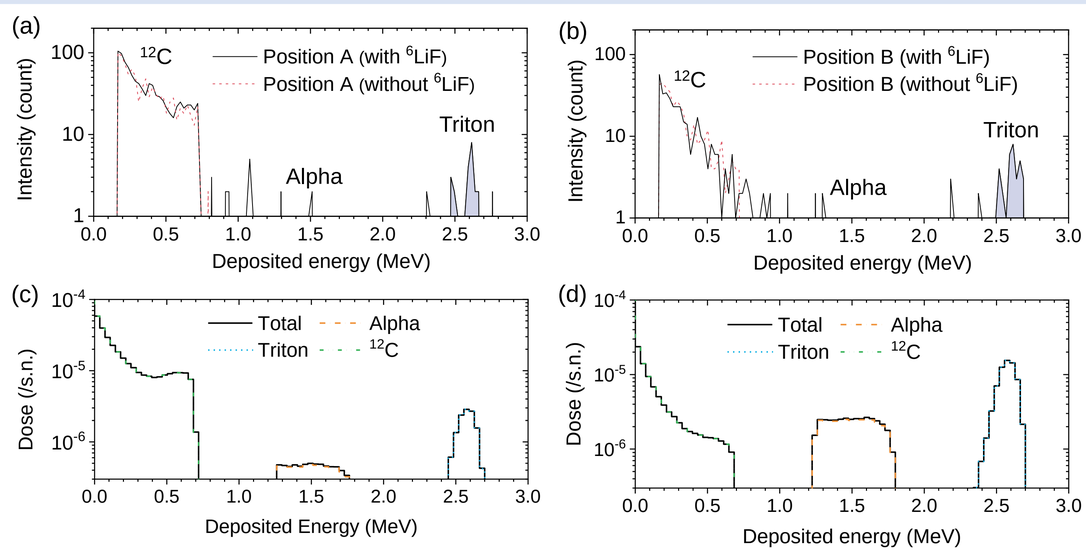

Fig. 4 Energy spectra by the single-crystal diamond detector at position A (a) and B (b) with calculated energy depositions onto the diamond at position A (c) and B (d).

Table: total neutron production (n_{total}), reaction rate of 6Li(n,t) (R) and C/E values

	Position A	Position B	Position C	Position D	Position E
n_{total} ($\times 10^{9}$ s.n.)	1.41 ± 0.11	1.58 ± 0.13	3.27 ± 0.26	1.55 ± 0.12	1.85 ± 0.15
R_{exp} ($\times 10^{-7}$ /s.n.)	2.04 ± 0.17	2.73 ± 0.23	3.19 ± 0.27	2.32 ± 0.20	0.129 ± 0.034
R_{cal} by FENDL 2.1 ($\times 10^{-7}$ /s.n.)	1.86 ± 0.06	3.00 ± 0.09	3.05 ± 0.09	2.96 ± 0.09	0.184 ± 0.011
R_{cal} by FENDL 3.1 ($\times 10^{-7}$ /s.n.)	1.96 ± 0.07	2.97 ± 0.09	3.00 ± 0.09	2.97 ± 0.09	0.183 ± 0.012
C/E (FENDL 2.1)	0.91 ± 0.08	1.10 ± 0.10	0.96 ± 0.09	1.27 ± 0.11	1.42 ± 0.38
C/E (FENDL 3.1)	0.96 ± 0.09	1.08 ± 0.10	0.94 ± 0.08	1.28 ± 0.12	1.41 ± 0.38

CONCLUSION

- A neutronics study using a compact fusion neutron source (neutron production rate: ~2×10^{5} n/s in a DD operation) is proposed.
- The ^{6}Li(n,t) reaction rate was successfully measured from triton count in the $2.40 < E_d < 2.69$ MeV with the experimental errors of 8.4–8.5%.
- The C/E values of TPR were 0.94–1.28 with the FENDL-3.1 library.
- In a future DT experiment, neutron yield is expected to increase two orders of magnitude.

ACKNOWLEDGEMENTS

This work was supported by a Grant-in-Aid for startup (17H06794) and a Grant-in-Aid for young scientists (20K14442) from the Japan Society for the Promotion of Science (JSPS), and performed under NIFS Collaboration Research Program (NIFS19KLPA001).

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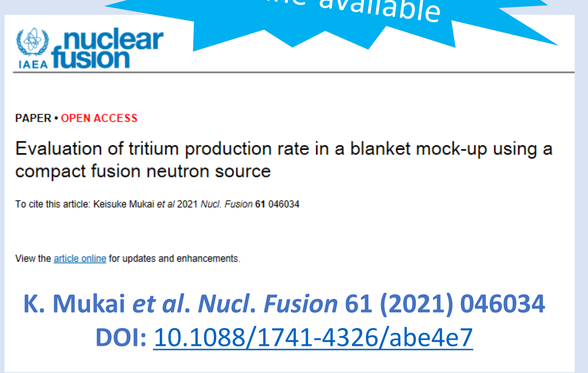
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To cite this article: Keisuke Mukai *et al* 2021 *Nucl. Fusion* **61** 046034

View the article online for updates and enhancements.

K. Mukai *et al*. *Nucl. Fusion* 61 (2021) 046034
DOI: 10.1088/1741-4326/abe4e7