Design Optimization of a Fast-Neutron Detector with Scintillating Fibers for Triton Burnup Experiments at Fusion Experimental Devices

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ABSTRACT

- For time-resolved triton burnup studies, 14 MeV neutrons emitted through DT reactions in DD plasmas should be measured selectively in the backgrounds of DD neutrons and gamma rays.
- A scintillating fiber (Sci-Fi) based fast-neutron detector has been adapted. In the present study, the authors have carried out the experiments and simulations to understand the phenomena in the detection process.
- From the results, due to its self-shielding of neutrons and the attenuation of scintillation photons, the optimal length of Sci-Fi is concluded to be about 6 cm.

BACKGROUND

- Time-resolved triton burnup studies have been carried out to estimate the behavior of alpha particles in DD fusion experimental devices.
- In those studies, 14 MeV neutrons emitted through DT reactions in DD plasmas should be measured selectively in the backgrounds of DD neutrons and gamma rays.
- A scintillating fiber based detector has been applied to this purpose due to its advantages such as fast response, design flexibility in detection efficiency and discrimination property against 2.4 MeV neutrons.
- However, design parameters of the detector has never been optimized.
- In the present study, we tested three types of Sci-Fi detectors with three different lengths and compared with the simulated results of energy deposition, through which we tried to understand the phenomena in the detection process of fast neutrons.

CHALLENGES / METHODS / IMPLEMENTATION

RESPONSE EVALUATIONS FOR SCINTILLATING FIBER DETECTORS WITH DIFFERENT LENGTH

Response of the Sci-Fi detectors with lengths of 3 cm, 6 cm and 6 cm were evaluated against 14 MeV neutrons, 2.5 MeV neutrons and gamma rays. From the results, its optimum length for triton burnup experiment has been discussed.

MEASURING SYSTEM AND RADIATION SOURCES

Sci-Fi detector is composed of scintillating optical fibers (Kuraray, SCSF-78M) set in each hole made through metal material such as aluminum alloy. A photomultiplier tube (PMT, Hamamatsu, H11934-100MOD) was set to one end and the other end is covered also with aluminum alloy with reflective surface. The pulses from the PMTs were converted to digital signals with the fast DAQ: DT5751 (CAEN), where the sampling was carried out at 1 GHz and the sampled values were integrated for each pulse.

EXPERIMENTS

Response of the detectors were evaluated using 14 MeV neutrons at OKTAVIAN (Osaka Univ.), DD neutrons at FNL (Tohoku Univ.) and fission neutrons from a ^{252}Cf spontaneous fission neutron source. Simulations have been carried out with the monte Carlo Simulation code: PHITS. Also, measurements were done through the operation of LHD in FY2018.

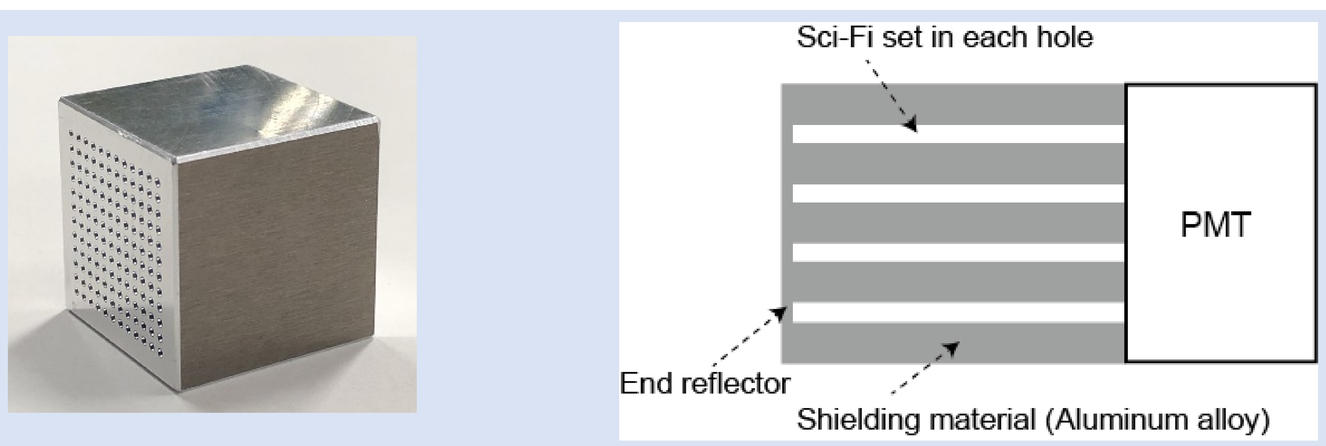

Fig. 1 Photograph and structure of Sci-Fi detector

OUTCOME

Response to 14 MeV neutrons (Fig. 2) and DD neutrons (Fig. 3) neutrons and ^{Co}60 gamma rays (Fig. 4)

By setting the threshold to about 500, we can measure 14 MeV neutrons discriminating DD neutrons and gamma rays with 1-2 MeV .

Optimum Length of Sci-Fi

The total counts over 500 channel are almost comparable for 6 cm- and 9 cm-Sci-Fi, which means that the optimal length is around 6 cm. The reasons should be as followings:

- Self shielding of 14 MeV neutrons by Sci-Fi (Fig. 3)
- Decrease of scintillation photons during transmission to PMT (Fig. 4)

Comparison of measured and simulated detector responses

From the simulated results, we calculated the light emission by recoiled protons (Fig. 5). The assumptions are as follows:

- Light emission: $L\,[MeVee] = 0.211E_{proton}^{1.342}$ Standard deviation: $\sigma=K\sqrt{N}=A\sqrt{E}$.
- Light loss during transmission is not considered.

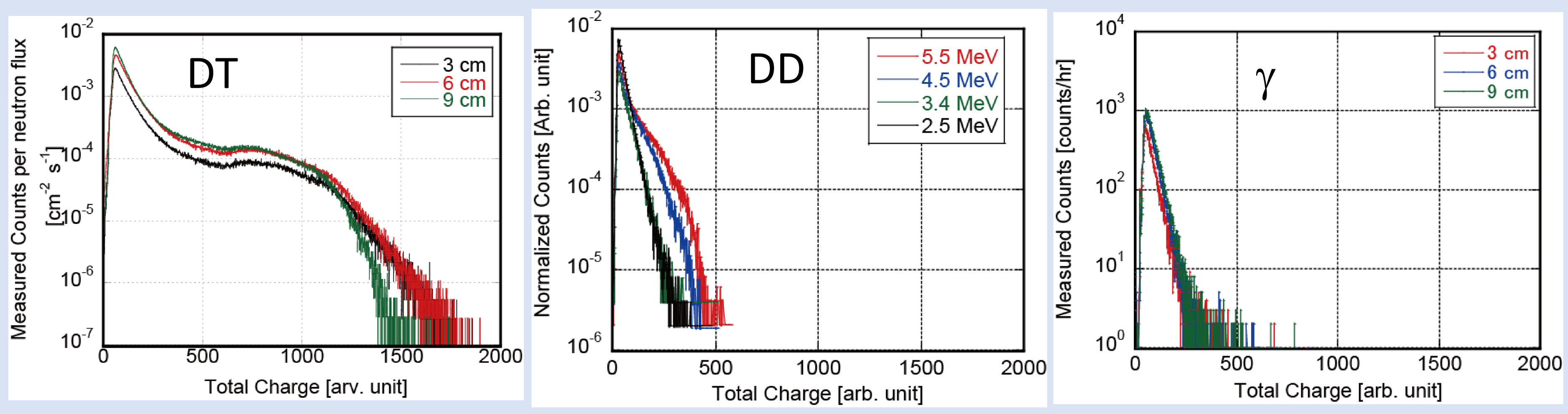

Fig. 2 Response of the Sci-Fi detectors to 14 MeV- /DD- neutrons and ^{60}Co γ rays .

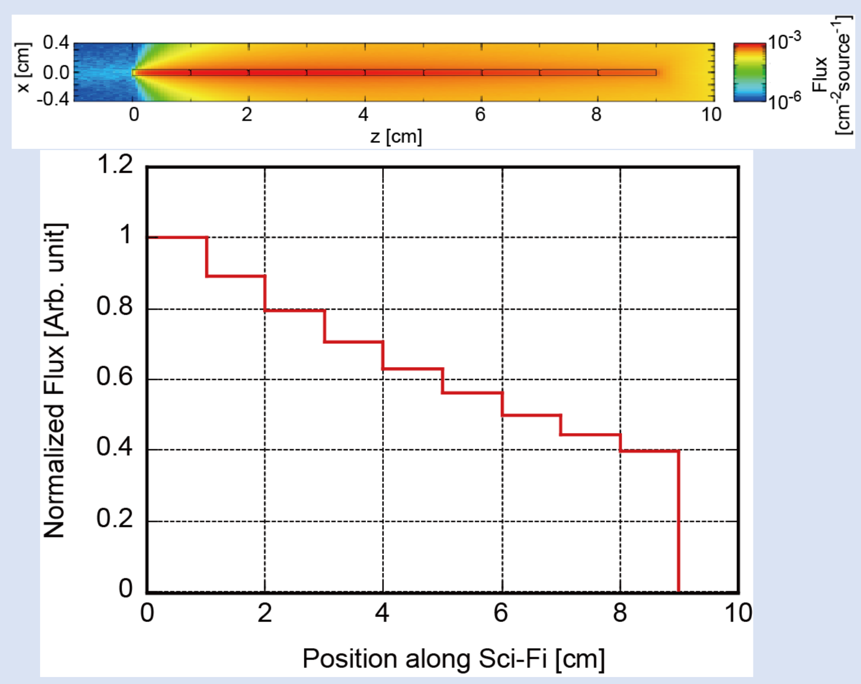

Fig. 3 Calculated proton distribution.

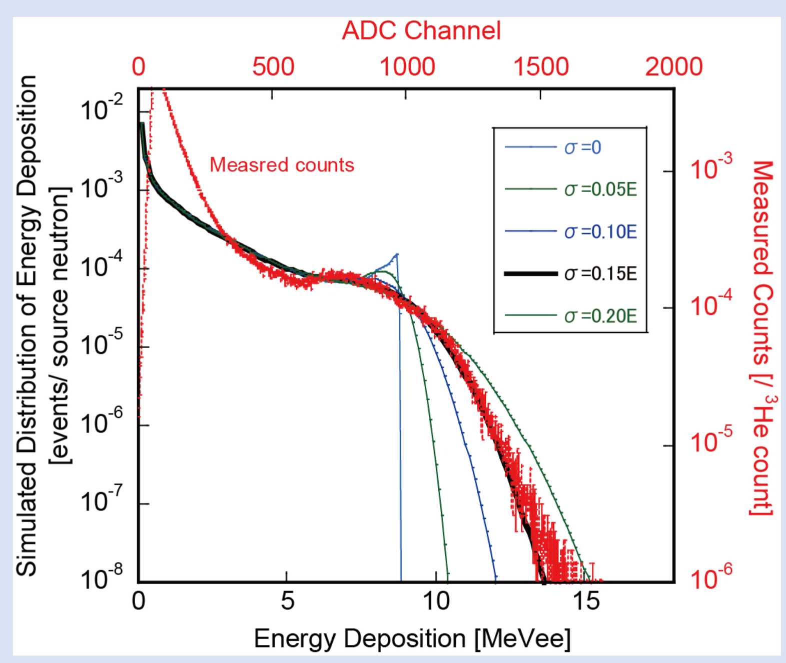

Fig. 5 Comparison of measured and simulated response.

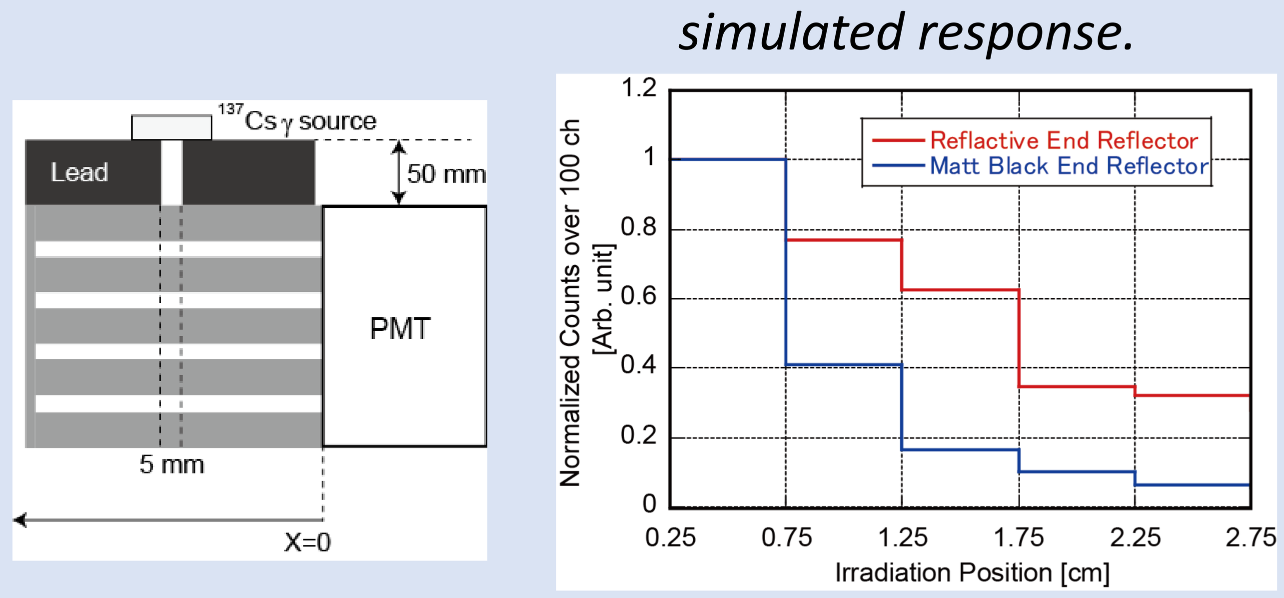

Fig. 4 Measured counts when incident position of γ rays were changed.

CONCLUSION

- For triton burnup experiments, design optimization of Sci-Fi detector has been carried out through experiments and simulations.
- Due to (a) self-shielding of 14 MeV neutrons by Sci-Fi itself and (b) decrease of scintillation photons during their transmission process to the PMT, the optimal length of Sci-Fi was shown to be around 6 cm.

ACKNOWLEDGEMENTS / REFERENCES

- This research was supported by the NIFS Collaboration Research program (NIFS17KLEH068, NIFS15KOAH033) and the Japan-Korea Fusion Collaboration Program