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Neutron Measurement using Stilbene Detector in 2013 KSTAR Campaign

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1. Introduction

Currently, a study of fusion is being progressed for application of fusion energy, and in Korea, the study is being performed through Korea Superconducting Tokamak Advanced Research (KSTAR), which is the totamak to use plasma.

A study related conditions of plasma generating fusion reactions is important for applying the fusion energy, and to evaluate these conditions, diagnostic devices are also important. Various diagnostic devices are used for measuring the plasma conditions in tokamak [1], a measurement of neutrons emitted from inside of plasma is an important factor because the fusion reactions can be confirmed by these neutrons.

A neutron emitted from KSTAR is a fast neutron with energy of 2.45 MeV, and a detector was manufactured using stilbene scintillator, which is representation for detecting the fast neutrons.

In 2013 KSTAR campaign, we measured the neutrons using this detector.

2. Methods and Results

2.1 Stilbene Detector Design

Stilbene detector used in this study is composed with a stilbene scintillator with a diameter of 25 mm and height of 20 mm and H6152-70 photomultiplier tube (PMT) manufactured by Hamamatsu in Japan. And PMT was covered by soft iron with thickness of 1 cm for shielding magnetic effects occurred in KSTAR tokamak, and polyethylene and lead were used to shield neutrons and gamma-rays incident on side of scintillator.

Since gamma-rays were much more than neutrons in previous campaign, for improving this problem, lead was extended about 5 cm in front of stilbene scintillator in this study. In addition, a setting position of detector was close to a tokamak window about 1 m compared with the position in previous campaign.

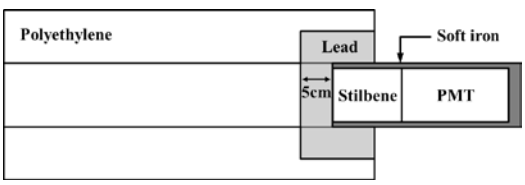

Fig. 1. Design of stilbene detector used in 2013 KSTAR campaign.

2.2 Data Acquisition

In this study, data acquisition was performed by Flash Analog to Digital Convertor (FADC). Analog signals obtained by stilbene detector are directly fed to FADC and digitalized. Neutron and gamma-ray are discriminated by Digital Charge Comparison (DCC) method [2] based on pulse shape difference of neutron and gamma-ray.

2.3 Energy Evaluation

Energy evaluation of neutrons measured by stilbene scintillator can be performed using mono energetic neutron source or various gamma-ray sources.

In this study, energy evaluation of neutrons was performed by various gamma-ray sources. In case of neutrons, recoil protons are produced in stilbene scintillator, and light outputs are occurred by the recoil protons. In case of gamma-ray, compton electrons are generated and produce light outputs. But the light outputs happened by recoil protons and electrons with same energy are different [3,4]. To evaluate the neutron energy using the gamma-ray sources, thus, a correlation between light outputs of protons and electrons is necessary.

For obtaining the correlation between the light outputs of protons and electrons, we performed monte carlo simulation and applied following equation [4]

$$L = 0.693E_p - 3\left[1 - \exp\left(-0.2E_p^{0.965}\right)\right] \quad (1)$$

Where L is the light output of electrons in unit of MeVee, and Ep is proton energy in unit of MeV.

As a calculation result, the neutron with energy of 2.45 MeV was corresponded to the light output with energy of 0.58 MeVee, and it was corresponded to about 4500 ch.

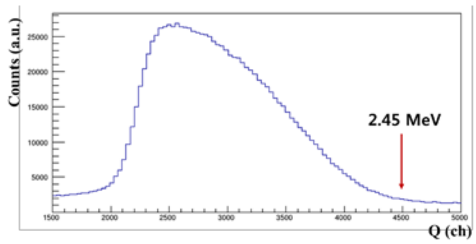

Fig. 2. Neutron spectrum measured in 2013 KSTAR campaign.

Fig. 2. Shows the neutron spectrum measured in 2013 KSTAR campaign. As shown in Fig. 2., edge channel of neutrons was about 4500 ch. We could find out the neutrons measured in 2013 KSTAR campaign is D-D neutron.

2.4 Performance Comparison

Above mentioned, stilbene detector was improved geometrically because of noise. It was considered that main cause of noise is pile up of gamma-ray incident on scintillator from surroundings.

Fig. 3. shows neutron spectrums in 2012 and 2013 KSTAR campaign. For comparing detector performance, we compared the noise ratio in range of neutron data, which is from 2000 to 4500 ch. Where 2000 ch is a threshold set by FADC and 4500 ch is corresponding to the neutron energy.

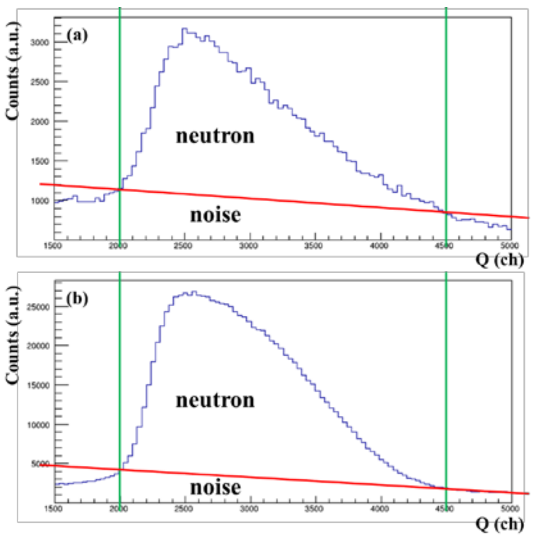

Fig. 3. Neutron spectrum in (a) 2012 and (b) 2013 KSTAR campaign.

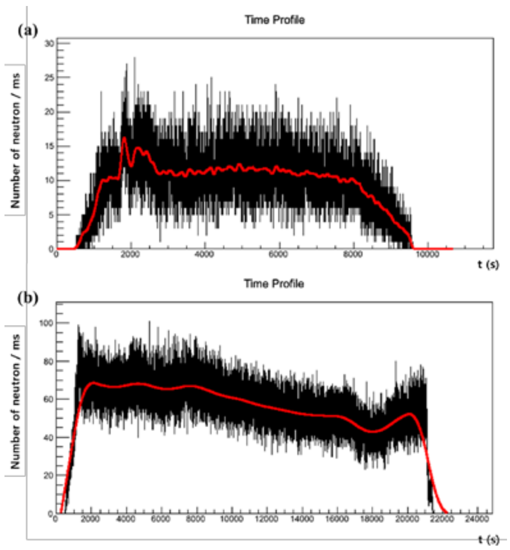

Fig. 4. Time profile in (a) 2012 (b) 2013 KSTAR campaign.

As a result, the noise occupied about 50 % and 20 % of total counts in 2012 and 2013 KSTAR campaign, respectively. Fig. 4. Shows time profile in 2012 and 2013 KSTAR campaign. While number of neutrons per ms in 2012 KSTAR campaign was about 25 counts/ms, in 2013 KSTAR campaign, it was about 90 counts/ms.

Through this result, we knew that the performance of detector is improved.

3. Conclusions

We measured the neutrons in 2013 KSTAR campaign using stilbene detector. As the energy evaluation results, it was confirmed that measured neutrons have energy of 2.45 MeV. As the performance comparison results, we found out that the performance of detector in 2013 KSTAR campaign was advanced.

In the future, energy evaluation will be carried out using unfolding method for more precise energy evaluation.

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