Evaluating Angular Dependence of Stilbene Neutron Diagnostic System for KSTAR

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1. Introduction

The stilbene scintillator was proposed as a neutron-flux monitor in measuring the characteristics of neutron radiation at the Korea Superconducting Tokamak Advanced Research (KSTAR). Various neutron diagnostic tools are used in fusion reactors for measurement of plasma parameters such as fusion power, power density, ion temperature, fast ion energy, and their spatial distribution. In this study, to evaluate the properties of the stilbene neutron diagnostic system, the efficiency of the radiation shielding was tested experimentally by changing the orientation of the n, γ source. Polyethylene was used to keep neutrons out of the sight line and gamma-rays were blocked by lead. A neutron tagger module was used for a signal digitization, which consists of Flash-ADC and FPGA implemented with real-time n-γ separation processor by using a charge comparison method. As a result, the designed and fabricated stilbene neutron diagnostic system show a good performance measuring neutrons and it was proper as the collimator to measure neutrons from fusion reaction at KSTAR.

2. Methods

In this experiment, a stilbene single crystal scintillator (Φ50mm x 40mm) was used.

Single crystal stilbene ($C_{14}H_{12}$) scintillators have been used for many years as the one of the standards for fast neutron detectors in 500 keV to 20 MeV range due to their good timing performance (< 10 ns), detection efficiency and excellent pulse shape discrimination (PSD) properties in mixed neutron and gamma radiation fields [1]. It makes also possible to perform neutron field spectrometry and estimate the neutron-yield evolution with a high temporal resolution against the background of accompanying gamma rays in experiments with non-stationary neutron sources.

The signals of neutrons and gamma-rays are discriminated by using a digital charge pulse shape discrimination method, which uses total to partial charge comparison [2]. The signals are digitized by a Flash Analog-to-Digital Converter (FADC) part of the data acquisition system shown in Fig. 1.

The n-γ separation result is verified with a graph that is drawn a specialized computer program written in C code.

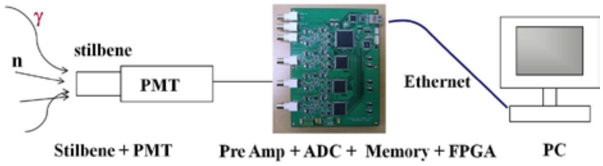

Fig. 1. The analog signal is directly fed into the Flash ADC and digitalized. Neutron/gamma-rays are real-time discriminated by the FPGA processor where a Digital Charge Comparison (DCC) method was implemented. The analyzed data is transferred to an on-line monitoring PC via Ethernet.

3. Experimental setups

The stilbene detector system is composed of polyethylene, lead and the flash ADC, is shown in Fig. 2.

The polyethylene is used as collimator and to shield sight line from neutron. Gamma-rays were blocked by lead and the Flash ADC was used for data acquisition.

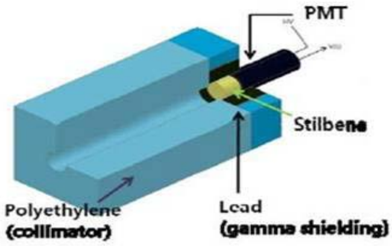

Fig. 2. Design of stilbene detector system.

The experimental setup for the angular dependence measurement is shown in Fig. 3. HAMAMATSU H7195 and H6614-70 PMTs were used in this experiment, and a high voltage of 1600V and 1300V was applied to the each of the PMTs respectively.

The angular dependence was tested experimentally by changing the orientation of the n, γ source with respect to the collimator axis, the angles were 0°, 30°, 45°, 60°, 90°. The source was ^{252}Cf, and the distance from stilbene to source was 400mm. Data was obtained for 15 minutes for each point.

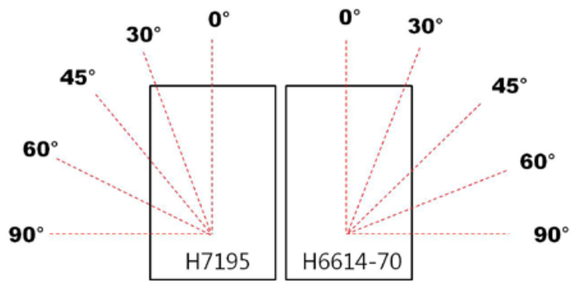

Fig 3. Experimental setup for the angular dependence.

3. Analysis

Stilbene detection efficiency was calculated from n-γ separation results that were obtained according to the following steps. First, the x,y coordinate were acquired from the tial to body graph. Secondly, using these coordinate an equation for the boundary line was determined by means of ORIGIN. Finally, all neutrons above the boundary line were counted.

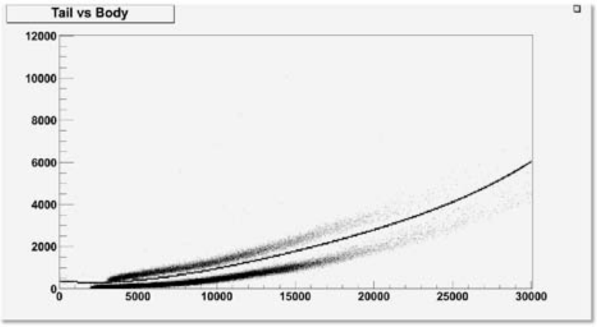

Fig 4. Tail to body graph with calculated boundary line.

Stilbene detection efficiency was calculated from the number of neutron counts and the number of neutron incident on the stilbene.(1) Source activity was 33μCi from reference date. The number of neutron incident on stilbene obtained was 1188.93 counts/sec.

$$\frac{number\ of\ \ pulses\ recorded}{number\ of\ \ neutrons\ incident\ on\ stilbene} \quad (1)$$

4. Results

The measured number of count for each PMT and each measurement angle are listed together with the respective detection efficiency in Table I

Table I : neutron counts and detector efficiency

	H7195		H6614-70	
	Counts	Eff.	Counts	Eff.
0°	24626	0.023	15069	0.014
90°	12059	0.011	6597	0.0062
60°	8691	0.0081	4000	0.0037
45°	6772	0.0063	2151	0.002
30°	4339	0.0041	1393	0.0013

.Fig. 5. display the angular detection efficiencies relative to the efficiency for frontal irradiation (0°) for each of the PMTs.

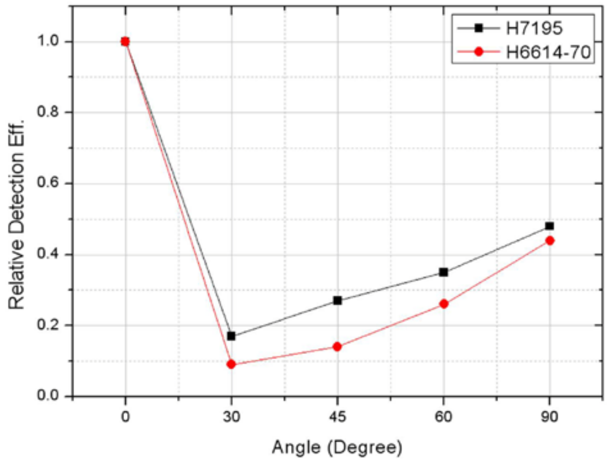

Fig. 5. Angular dependence of relative detection efficiency

The radiation shielding efficiency of the neutron diagnostic system is over 52% using H7195 PMT and over 56% for H6614-70.

5. Conclusions

We did find that the shielding effect has an angular dependence. As the angle become smaller, the neutron path length of the collimator grows longer. Thus, the number of detected count was confirmed to be lower.

We calculated that the shielding efficiency of this diagnostic system used in this experiment is over 50%.

This neutron diagnostic system can be utilized at KSTAR.

REFERENCES

[1] G. F. Knoll, “Radiation Detection and measurement”, John Willey and Sons, New York, (1999) 220

[2] J.H. Heltsley, et. al., Nucl. Instr. And Meth. A 263 (1988) 441