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Improved Signal Processing Algorithm for the ^{3}He Proportional Chamber in High Gamma-Ray Fields

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1. Introduction

In neutron measurement system, neutrons can be detected by collecting the neutron-induced secondary charged particles. However, in case of the neutron detection in neutron-gamma mixed fields, gamma rays also induce electrical signals through the same mechanism as neutrons so that it is essential to discriminate the neutron and gamma-ray signals for precise measurement. The ^{3}He proportional chamber has been widely used for neutron measurement because of its high detection efficiency for the neutrons and low sensitivity for the gamma rays [1]. In this detector, they can be easily discriminated by pulse height analysis method (PHA method) [2], because pulse height of gamma-ray signals is much lower than that of neutron signals. However, for neutron measurement at the high gamma-ray background such as spent-fuel measurement for burnup verification, repository acceptance and high-level waste measurement, gamma-ray signals are indistinguishable from neutron signals owing to gamma-ray pile-up [3].

In this study, the algorithm for discriminating neutron and gamma-ray signals even in high gamma-ray fields was proposed and tested.

2. Methods and Results

2.1 Experimental Setup

Experiments were conducted at the gamma-ray irradiation facility in ORBITECH Co. Ltd. The high gamma-ray environments (exposure rate = 500 mR/h and 1 R/h) were realized using intense ^{137}Cs sources and the rail system which can adjust the distance between source and ^{3}He detector. The 6.5 μCi ^{252}Cf was used as a neutron source and attached to the upper side of the polyethylene (P.E) shield. The side of P.E shield containing the ^{3}He detector was positioned facing the gamma ray source.

The CANBERRA 133NH30/5 ^{3}He Proportional chamber was used as a detector, CANBERRA Model 2006 for preamplifier, Ortec`s 572A for amplifier, Ortec`s 556 for high voltage power supply. Each pulse from amplifier was stored using NOTICE FADC500 (flash analog-to-digital converter). For the both of neutron and gamma ray, 50,000 pulses were recorded and 20,000 pulses for the gamma ray only. Fig.1 and 2 show the picture and schematic view of the experimental setup.

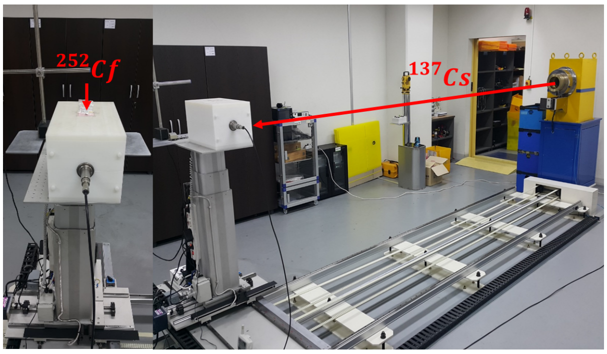

Fig.1 Configuration of detector, shield and sources.

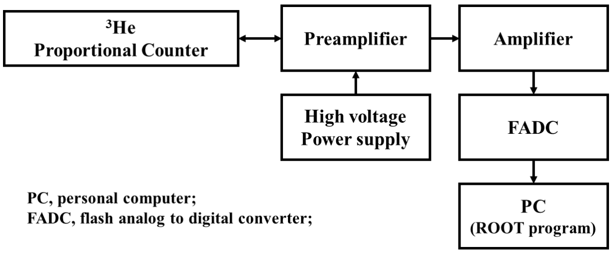

Fig.2 Schematic view of the experimental setup

2.2 Energy Spectrum in High Gamma Fields

Fig.3 shows ^{252}Cf energy spectrum in various gamma-ray exposure rates. In the low gamma-ray fields (black line), the spectrum has clearly distinguished regions of neutron and gamma ray. The neutron region, consisting of Q-value peak and wall effect continuum, can be separated from low energy region where the gamma ray and noise exist by PHA method. However, in 500 mR/h (blue line) and 1 R/h (red line), there is no clear boundary between neutron and gamma-ray region because the gamma-ray spectrum completely covers the neutron spectrum. In order to precisely separate neutron signals from gamma-ray signals in these fields, an improved signal processing algorithm for n/γ discrimination is required

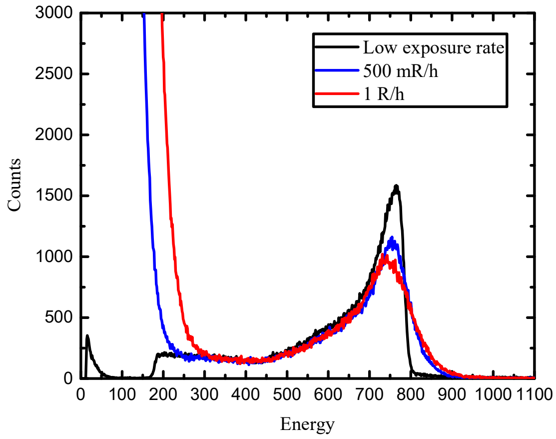

Fig.3 ^{252}Cf energy spectrum obtained by the ^{3}He detector in various gamma-ray exposure rates. The energy unit is keV.

2.3 Improved Signal Processing Algorithm

The pulse height of neutron signals is higher than that of gamma-ray signals because the deposit energy of gamma ray is much lower than that of neutron, which originated from a $^{3}He(n,p)^{3}H$ reaction with a high Q value. In terms of the rise time, neutron signals generally have a shorter rise time than the gamma-ray signals and have a specific distribution determined by the reaction positions in the detector geometry [4]. In high gamma-ray fields, it is expected that the rise time of the gamma-gamma piled-up signal increases with the pulse height at the same time. On the other hand, there is little change in rise time and pulse height of neutron-gamma piled-up signal because there is no big influence on the existing neutron signal which is much larger than gamma-ray signal. Therefore, it was expected that the distribution of the rise-time-to-pulse-height ratio (new parameter) of neutrons and gamma rays is almost independent of the gamma-ray exposure rate.

Based on above mentioned characteristics, an improved algorithm for n/γ discrimination with new parameter was developed using the data analysis framework ROOT [5]. The algorithm process is as follows:

Firstly, this identifies the noise threshold to distinguish the noise and true signal. The signal processing starts only for the signal that exceed this. For the true signal, this finds the baseline and peak point. Then calculates the height of baseline to peak point, pulse height. Next, this finds 10% of the pulse height, which is the starting point of the signal. Then calculates the time length from the starting point to the peak point, rise time. Finally, the pulse height and rise time information of each pulse is stored. Consequently, the neutron and gamma-ray signals can be separated by difference of rise-time-to-pulse-height ratio.

2.4 Application of Improved Algorithm

Signal processing using the developed algorithm was tested using the signal data stored in various gamma-ray fields. Fig.4(a) and (b) show the spectrum of new parameter (rise-time-to-pulse-height ratio) in various gamma ray fields with ^{252}Cf source and without ^{252}Cf source, respectively. It was confirmed that neutron and gamma ray clearly distinguished by specific value of 10 in fig.4(a). Furthermore, in fig.4(b), gamma-ray signals were distributed over the value of 10, except for some neutron-background signals in the laboratory. Therefore, signals distributed in excess of 10 can be removed as a gamma ray.

For quantitative evaluation of gamma-ray elimination, the ratio of the removed signals from 20,000 gamma-ray signal data was confirmed. Table I summarizes the result of evaluation. The total signal was defined as number of signal passing noise threshold. The ratio of gamma-ray elimination was percentage of the removed signal to total signal. In all exposure rate, the ratio was more than 99%.

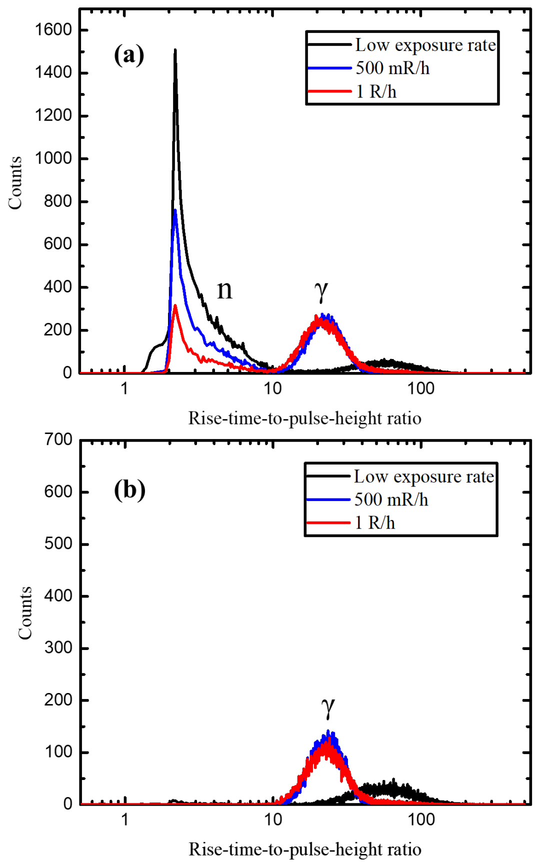

Fig.4 Spectrum of rise-time-to-pulse-height-ratio in various gamma-ray fields with ^{252}Cf source (a) and without ^{252}Cf source (b)

Table I: Evaluation Result of Gamma-ray Elimination

Exposure rate	Number of gamma-ray signal		Ratio of gamma-ray elimination (%)
	Total	Removed	
Low	19999	19921	99.6
500 mR/h	19946	19945	99.9
1 R/h	19824	19805	99.9

3. Conclusions

Neutron-gamma separation using the ^{3}He proportional chamber were carried out at high gamma-ray fields of 500 mR/h and 1 R/h. From the energy spectra, it was confirmed that discrimination boundary to discriminate the neutron and gamma-ray signals using the existing PHA method was ambiguous in high gamma-ray fields. Whereas, rise-time-to-pulse-height ratio spectra, which was obtained using the proposed algorithm in this study, showed good performance even at the high gamma-ray exposure rate. Applying the algorithm to the neutron measurement system, more precise measurement is expected to be possible even in high gamma-ray fields.

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