Determination of Optimal Operating Conditions of ^{3}He Proportional Chamber for the Neutron Survey Meter

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1. Introduction

The ^{3}He proportional chamber has been widely used for the neutron detector because of its high efficiency for the neutrons and low sensitivity for the gamma-rays [1]. Furthermore, the signals of gamma-rays can be easily discriminated by the pulse height threshold because the heights of the gamma ray signals are lower than those of the neutrons in this detector [2].

However, the detection characteristics, such as neutron count rates, resolution and degree of gamma-ray discrimination, vary with the operating conditions of the circuit elements of the survey meter. In order to develop a high precision survey meter for wide energy neutrons with better detection characteristics, it is needed to determine the optimal operating conditions.

In this study, the operating conditions such as shaping time of the amplifier and operating voltage of the high voltage supply constituting the survey meter are determined through the experiments using ^{3}He proportional counter.

2. Methods and Results

2.1 Operational condition

In a measurement system, signal pulse height must exceed a given threshold level to be counted. Therefore, as the detector bias voltage increases, the number of neutron counts changes. However, stable counting is possible at a specific voltage range where the variation is very small [3]. This voltage range is called as plateau. It is necessary to find the plateau and to determine the operating voltage for stable measurement results.

It is common to use a short shaping time in order to prevent pulse pile-up. However, it leads to relatively large ballistic deficit. If the shaping time is chosen too short, the loss of signal occurs and the peaks in the pulse height spectrum are broaden [3]. These changes reduce the length of the plateau and degrades the ability to separate gamma-rays. On the other hand, if the shaping time is chosen too large, the probability of pile up increases and the ratio of dead time increases. It leads to decrease of the neutron counting rate and increase of the level of the gamma-ray signal height. However, large shaping time is good for resolution in the pulse height spectrum. Therefore, determining the appropriate shaping time is needed for optimal neutron detection characteristics.

2.2 Experimental setup

At the present study, the detection systems consist of a detector (CANBERRA 133NH30/5 5bar ^{3}He proportional counter), preamplifier (CANBERRA Model 2006), amplifier (Ortec`s 572A), multi channel analyzer (Ortec`s 919E) and high voltage supply (Ortec`s 556). Fig 1 shows schematic view of experimental setup.

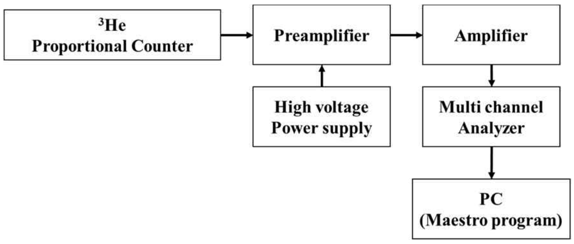

Fig. 1. Schematic view of experimental setup

The 6.7 μCi ^{252}Cf was used as neutron source for experiment 1 (exp.1) and experiment 2 (exp.2). The 7.88 μCi ^{137}Cs was used as gamma-ray source for experiment 3 (exp.3). Because ^{252}Cf source emits wide energy neutrons, it was measured after decelerating to thermal neutrons using polyethylene (P.E) shield. The shield is 22*22*40 cm^3 with a 2-inch hole in the center. The detector was placed in the hole and ^{252}Cf was attached to the outside as shown in fig 2.

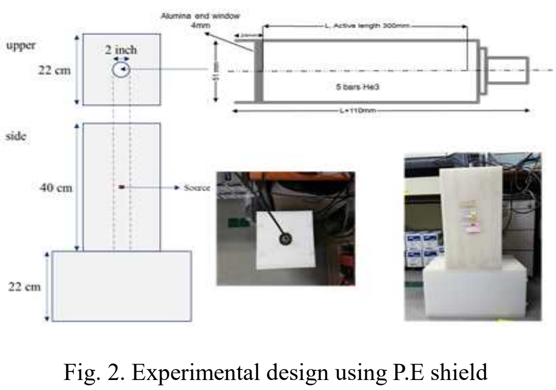

Fig. 2. Experimental design using P.E shield

In exp.1, the neutron signal was measured and the change in the count rates was observed while changing the bias voltage of the high voltage supply from 0 to 2100 V to determine the operating voltage. In exp.2 and exp.3, while the shaping time of the amplifier was varied from 0.5 to 10 μs, neutron and gamma ray signals were measured respectively. The resolution was evaluated and the change in the neutron count rates was observed in exp.2. The extent of the pileup effect was evaluated by checking the end energy of the gamma-ray spectrum and the degree of gamma-ray discrimination, in exp.3.

2.3 Results of experiment

The result of exp.1 is shown in fig 3.

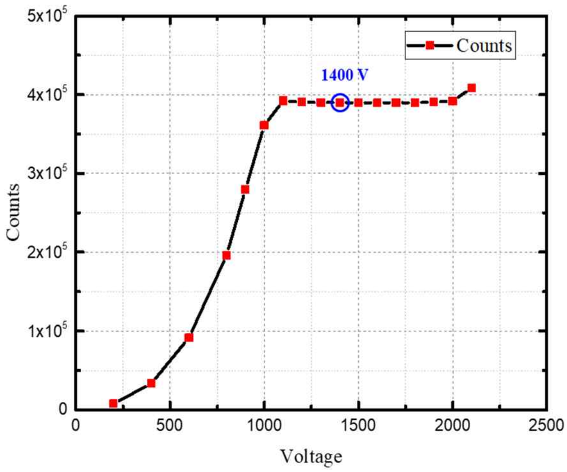

Fig. 3. Plateau curve from exp.1

The start of the plateau was found at 1100 V and it was confirmed that the plateau range ended at about 2100 V. The slope (%/100V) of plateau curve was very stable as 0.0103983% / 100V and the length of the plateau range is 900 V. The operating voltage was set at 1400V, which is 1/3 of the plateau range, to obtain stable measurement results.

In exp.2, As the shaping time increases, the dead time increases and the total count rates decrease as shown in fig 4. The dead time change is shown in table I.

Table I: Dead time change in exp.2

Shaping time (μs)	0.5	1.0	2.0	3.0	6.0	10.0
Dead time (%)	1.83	2.0	2.5	3.0	4.3	4.83

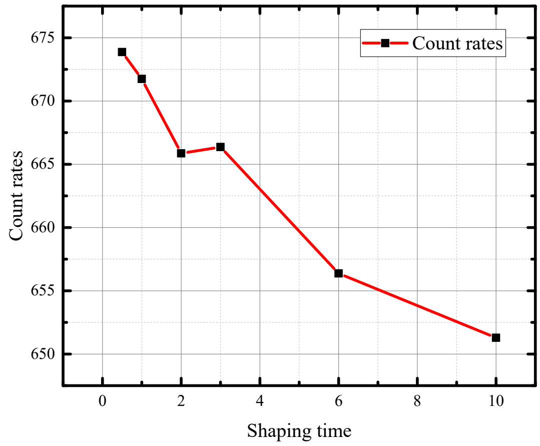

Fig. 4. Total neutron count rates in exp.2

In addition, the Q-value peak of neutron and ^{3}He reaction in the neutron spectrum was fitted with Gaussian function, and the resolution was evaluated from fitting function. It was confirmed that it is improved with increasing shaping time. Fig 5 shows an example of Gaussian fitting and the result of evaluation of resolution.

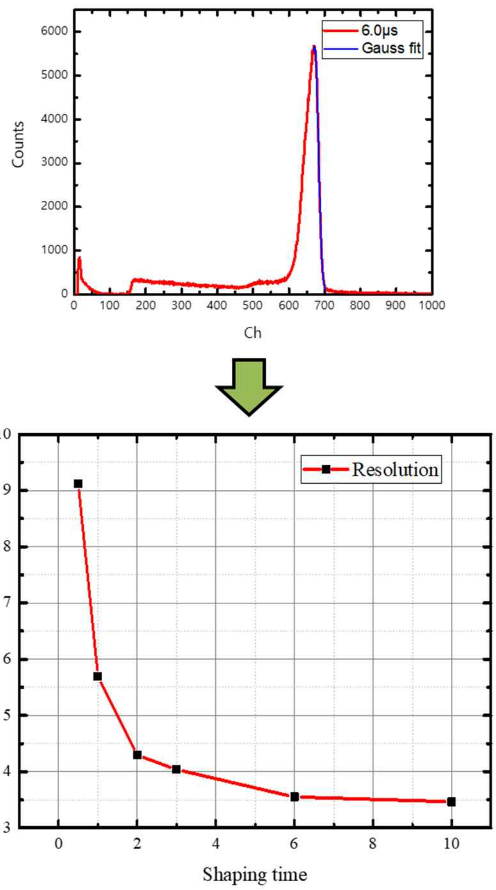

Fig. 5. The result of evaluation of resolution in exp.2

As the shaping time increases, the pileup of the gamma ray signal increases, and it is confirmed that the signal is superimposed and enters the high energy channel of multi channel analyzer as shown in fig 6.

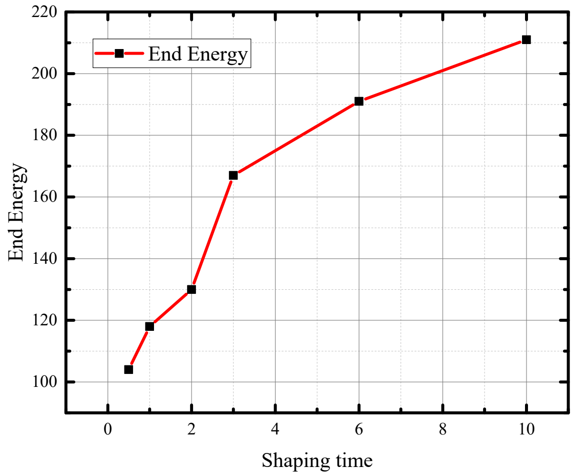

Fig. 6. Gamma-ray end energy in exp.3

3. Conclusion

From the results of exp.1, the operating voltage of 1400V was determined for stable measurement. The changes due to shaping time were observed from exp.2 and exp.3. As expected, the resolution of neutron spectrum has been improved with increasing shaping time, but it became worse in terms of total count rates and gamma-ray pile up effect. It is confirmed that the highest performance is achieved at 2 μs shaping time by normalizing the results of exp.2 and exp.3 as shown in fig 7.

Finally, the operating conditions of 1400 V operating voltage and 2 us shaping time are determined and it is expected that it will be possible to manufacture a survey meter with optimal detection characteristics.

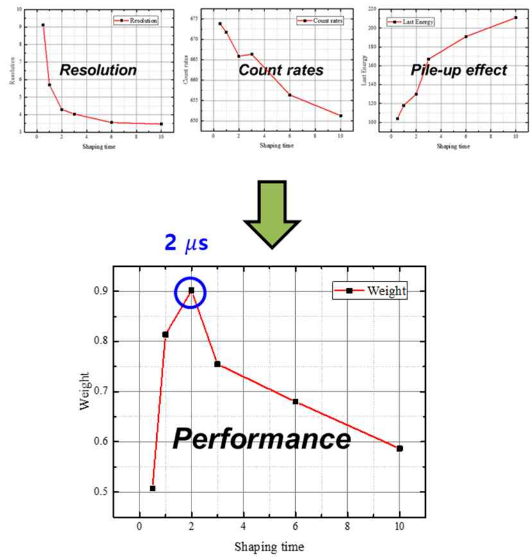

Fig. 7. Determination of optimal shaping time

REFERENCES

[1] T. W Crane, M. P Baker, Neutron detectors, Passive Nondestructive Assay of Nuclear Materials, p.386-391, 1991.

[2] H. Tagziria, W. HANSEN, Neutron spectrometry in mixed fields: proportional counter spectrometers, Radiation protection dosimetry, 107.1-3: p.73-93, 2002.

[3] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp113-115, 534-536, 2010.