Preliminary Study of Identification/Rejection of Pile-ups and Baseline Correction in High Radiation Fields induced by Accelerators using an EJ276G plastic scintillator

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1. Introduction

There are limits in detecting radiations accurately in high flux and high energy conditions. Two major effects may interrupt accurate detection of radiations. In the case where two or more pulses overlap consecutively, this could be misinterpreted as a single event, or single pulse. This phenomenon is known "pile-up [1]". While two pulse signals generated by radiation are far enough to be identified as separate ones, another phenomenon may occur. If a posterior pulse is generated before the first pulse fully decays from above zero or recovers from below zero, it is called "baseline shift" [1]. To increase accuracy in radiation detection, pile-up pulses should be identified and rejected, and baseline correction should be implemented.

The aim of this study is to make up for the aforementioned limits in detecting appropriate photons and neutrons via post-processing of signals induced from a high energy electron accelerator. This was originally installed for an integrated X-ray and neutron NDT (Non-Destructive Test) within single accelerator, but X-ray – to – neutron ratio up to 4071:1, simulated by Monte Carlo N-Particle Transport Code (MCNP6) [2] makes photon and neutron detection difficult.

2. Materials and Methods

2.1 Materials

The experiment was conducted in Advanced Radiation Technology Institute of KAERI, with a 15 MeV electron accelerator. A 30 mm - tungsten was used as a target. Bremsstrahlung X-rays with a continuous spectrum are the products of the interaction between the accelerated electrons and tungsten target. It is known that photons with energy greater than 8 MeV generate neutrons through photonuclear reaction when interacting with high Z tungsten [3].

Eight EJ-276G plastic scintillators with a geometry of 1 x 1 x 3 cm^3 and eight Hamamatsu 13360 series 6025CS SiPM sensors were employed. Each of plastic scintillators and SiPMs are coupled one by one, forming a 2 x 4 array. The detector was placed 330 cm away from the target with 10 cm lead-shielding on every side since high energy radiation without sufficient distance and any shielding may damage the scintillator easily.

EJ-276G plastic scintillator is widely used for separating gamma-rays and fast neutrons according to their timing features. Discrimination of gamma-rays and neutrons was performed through Pulse Shape Discrimination (PSD), using DAQ manufactured by NOTICE technology to digitize the radiation signals, with a 10-bit resolution and 400 MHz.

2.2 PSD (Pulse Shape Discrimination)

PSD is a method utilizing the decay time difference between gamma-rays and neutrons in the organic scintillators. Typical decay time of neutrons are longer than gamma-rays', which attributes to neutrons' linear energy transfer (LET). Among several PSD methods, charge comparison method was used.

Q_{total} or Q_{Body} refers to the total charge of the entire pulse and Q_{slow} or Q_{tail} refers to the charge of the decaying part of the pulse. By exploiting the ratio of Q_{slow} and Q_{total}, an index called Figure of Merit (FOM) can be further exploited to evaluate the performance of discrimination and be utilized for optimization of the delay time and pulse width [4]. Typical gamma and neutron pulses are shown in Figure 1.

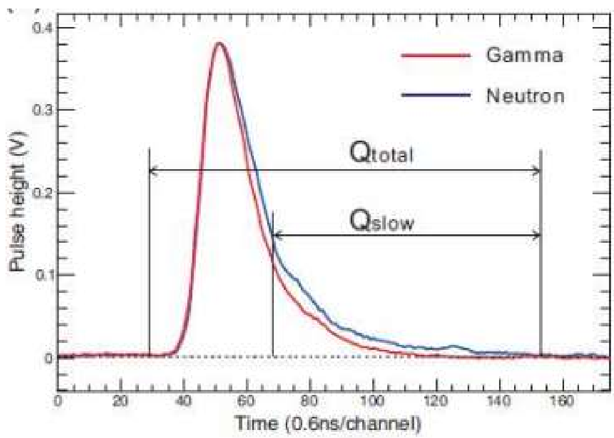

Fig 1. Typical PMT signals induced by neutrons and γ -rays. The γ -ray pulse decays more quickly than the neutron pulse, with a small difference in the tail [5].

3. Experiments and Results

3.1 PSD performed with ^{252}Cf

^{252}Cf is one of the well-known sources which emits not only photons, but neutrons as well by spontaneous fission. ^{252}Cf emits approximately 3.8 neutrons and 8 gamma-ray photons in a single fission [1]. PSD was performed with ^{252}Cf before the actual operation of 15 MeV electron accelerator as a reference for gamma and neutron region. Applied parameters include rise time as 50 ns, delay time as 100 ns, and pulse width as 1000 ns. The PSD result of ^{252}Cf is shown in Figure 2.

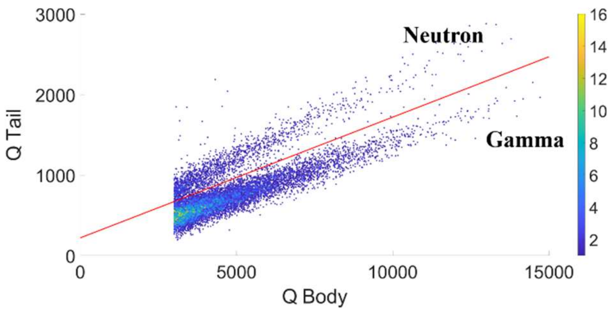

Fig. 2. The PSD result of reference ^{252}Cf.

3.2 Result Before Pile-up Rejection and Baseline Correction

Since ^{252}Cf was used as reference for determining gamma and neutron region, same parameters were applied in detecting radiation from the 15 MeV accelerator.

Following examples shown in Fig 3 are pulses from raw data during the operation. These kinds of pulses deteriorate the accurate detection of photons and neutrons and lead to an overestimation and an underestimation of actual integral charges. Hence, if not discarded, a degradation in PSD is inevitable. While some of pulses should be rejected, pulses restored after baseline correction should be used as normal pulses.

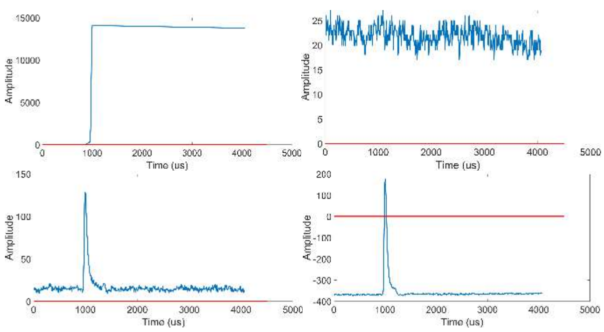

Fig. 3. Examples of pulses interrupting PSD, where red lines are desirable to be baselines. Top two pulses should be rejected and bottom two pulses should be modified with baseline correction.

Figure 4. shows PSD results based on raw pulse data without any post-processing. Due to the undershoot of some signal pulses, Q_{slow} and Q_{total} indicate even negative values. Moreover, although not shown in Figure 4, some of Q_{slow} and Q_{total} values are ten-fold of typical values.

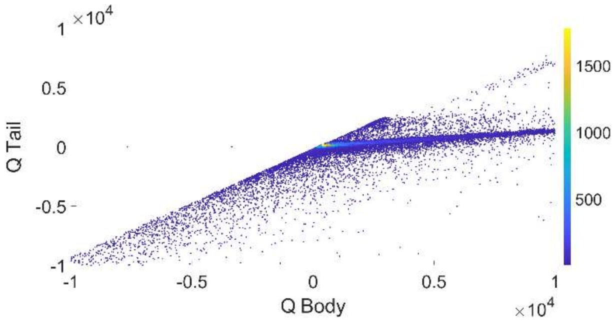

Fig. 4. PSD result based on raw pulse data collected during the 15 MeV electron accelerator operation.

3.3 Result after Pile-up Rejection and Baseline Correction

Figure 5 shows examples of before and after correction for baseline shifted pulses. The baseline correction algorithm not only drifts the baseline to near zero, but reduces signal noise as well.

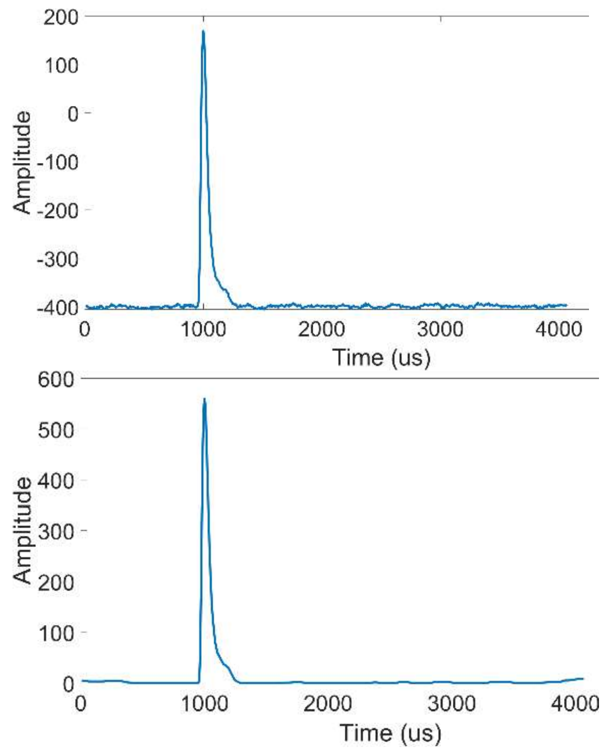

Fig. 5. Baseline shifted pulse before correction (top) and after correction (bottom)

Figure 6 shows PSD result after pile-up rejection and baseline correction. Most of the overestimated and underestimated charge integral values were removed.

The region below the red line is gamma region, which is almost the same as that of ^{252}Cf. But region which should be called as neutron region is not identified clearly because much of raw data is eliminated.

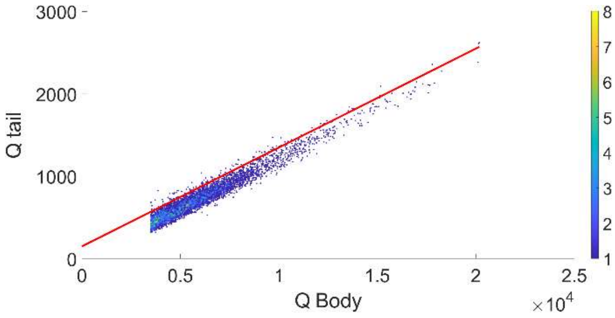

Fig 6. PSD result after pile-up rejection and baseline correction

7. Conclusion

In this paper, we showed some extreme cases of pile-ups and baseline shifts due to high count rate, and anomalies of digitized signals due to high energy.

Although most of pile-ups rejections and baseline corrections were carried out, we could not concede the existence of sufficient neutrons, due to such a high X-ray-to-neutron ratio in the situation.

In the future, we will investigate into each signal shots to figure out more cases of pile-ups, and sort out useful pulse signals. Furthermore, we will endeavor to modify parameters to enhance the discrimination of X-rays and neutrons during the operation of 15 MeV electron accelerator.

ACKNOWLEDGEMENT

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