Discrimination of neutrons and γ-rays in wide energy range by Digital Charge Comparison method

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Introduction

The unambiguous discrimination of neutrons and γ-rays from a mixed radiation field has wide range of applications in the field of nuclear safeguards, nuclear fission instrumentation, radiation therapy etc. The liquid scintillators are widely used for n-γ discrimination as the relative decay rate of neutron pulse is less as compared to γ-ray pulse in these detectors. The most popular and easy technique for pulse shape discrimination (PSD) is the charge comparison (CC) [1]. Nowadays, the traditional analogue techniques can be implemented in digital domain due to the availability of fast digitizers, by sampling the PMT pulses and representing them as a sequence of data-points. The performance of a PSD method depends on various parameters like sampling rate, noise distortion in the pulses the duration of processing gate etc. In this paper, the optimized version of CC method has been applied to a large number of experimentally collected mixed pulses from a liquid scintillator. The efficacy of PSD has been evaluated in terms of figure of merit (FoM).

Experimental Setup

The mixed n-γ pulses are recorded with the help of 5”×5”, BC501 liquid scintillator coupled to R4144 PMT from Hamamatsu. The pulses have been sampled at 2.5 GSamples/s with the help of a digital oscilloscope from Lecroy. The collected data-set has been corrected with operations viz. pileup rejection, pulse phase alignment and clipped pulse rejection [2] to obtain useful pulses. The energy range of the data-set has been obtained by finding Compton edge of γ-spectra obtained with the detection system used and the channel number corresponding to 75% of Compton edge has been used [3]. The mixed pulses used in this research have energy from 50 keVee to 5 MeVee as depicted in Fig. 1.

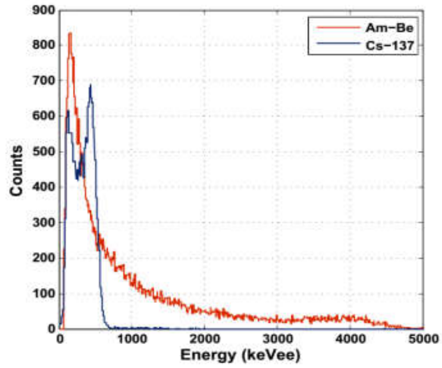

Fig. 1: The pulse height spectra for Cs-137 and Am-Be sources. The dataset contained the pulses from 50 keVee to 5 MeVee.

The CC method

The CC method exploits the ratio of the short integral to the long integral as a discrimination parameter over an optimized processing gate [3]. The starting point of the long integral is kept at peak amplitude and end-point long integral t_e and the starting point of short integration t_s were optimized to give maximum figure of merit which is calculated from the probability distribution graph and is given as,

$$FoM = \frac{|\mu_n - \mu_\gamma|}{2.35(\sigma_\gamma + \sigma_n)} \quad (1)$$

Here μ_n and μ_γ are the arithmetic means and σ_γ and σ_n are standard deviations of neutron and γ-ray Gaussian distributions respectively. The optimized values of t_e and t_s are 80 ns and 12 ns respectively.

Results and discussion

The CC method has been applied to the recorded data set with optimized processing-gate. A 2-D scatter-plot of charge-ratio against energy deposited inside the scintillator, has been obtained to verify the discrimination of events as depicted in Fig. 2. Since, the relative magnitude of total charge deposited by the pulse induced by neutrons is larger than that of γ-rays, the upper cluster in Fig. 2 corresponds to the neutron events while the lower cluster corresponds to γ-rays. This fact has been verified by applying CC method to the pulses obtained from Co-60 source and superimposing the events on the same plot of Fig. 2. The blue cluster corresponds to γ-ray events produced by Co-60 source. The blue line in the 2-D plot is discrimination line. Fig. 3 shows the variation of FoM with energy threshold of recorded events. Clearly the quality of discrimination gets improved for high energy events. The FoM is greater than unity for $E_{Thr}{\sim}350\ keVee$.

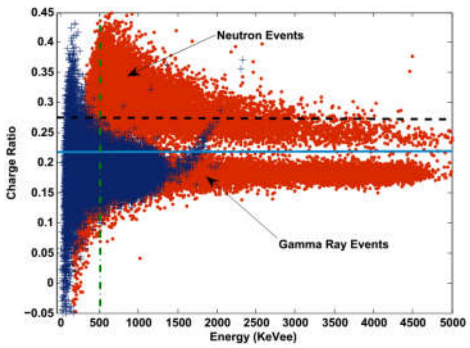

Fig.2: Energy versus charge-ratio plot of pulses from Am-Be neutron source and Co-60 obtained by CC method.

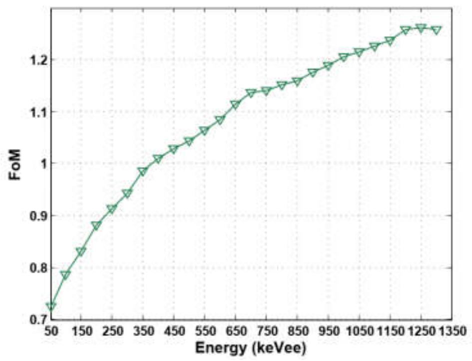

Fig. 3: Variation of FoM obtained with CC methods with energy threshold

Fig. 3 shows the deposited energy distributions of neutrons and gamma rays, in electron equivalent units, obtained with the CC method. The energy distributions show a smooth response of the BC501 to the Am/Be neutrons up to ~5MeVee of energy, which corresponds approximately to a proton recoil energy of 11.5MeV [1].

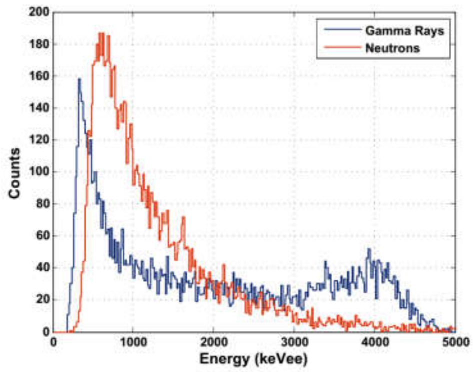

Fig. 3: Energy deposition spectra of Am-Be source obtained for neutron and gamma-ray induced events discriminated by CC method.

The Compton edge observed at 4.4 MeVee in gamma-ray energy spectrum is due to the de-excitation of $^{12}C^*$ from its first excited state following the reaction $^{9}Be(\alpha, n)$. The energy resolution of CC method has been established in the energy range 50 keVee to 5 MeVee in this work.

Acknowledgement

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