Extraction of Neutron Pulses from Coincidence Summed Events via Machine Learning - Like Algorithm

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INTRODUCTION

Neutron scintillators are generally used for detecting fast neutrons through the elastic scattering with protons inside the detector medium. Due to the isotropic behavior of elastic scattering, the energy spectrum produced by the neutron scintillator is continuous from zero to energy of interacting neutron. For a non-monoenergetic distribution of neutrons, this response will be more complicated. However, the neutron spectrum can be rebuilt from this information via spectrum unfolding. There are different methods reported for unfolding the neutron spectrum with better accuracies[1].

However, the signal response of these neutron scintillator is affected by γ-pulse, intrinsic neutron pulse, electronic noise etc. In most of the pulses, the neutron pulse and electronic noise will be mixed together. There are events like neutron coincidence summed with γ and intrinsic neutrons. This generates a wrong information in the recoil spectrum which leads to a wrong unfolded spectrum. The electronic noise can be identified independently than other events by assigning some trigger level. The ordinary pulse shape discriminators can't account for the coincidence summed events of neutron and γ rays. Also, the pulse shape discriminators reduces the efficiency of the system and makes a significantly higher background.[2] However, recoil spectrum which is free from such noises is required to generate the real neutron spectrum via unfolding techniques.

The issue is solved by classifying pulses using a machine learning -like algorithm[3]. This extracts neutron pulses from the coincidence summed pulses. The methodology and results of classification algorithm is explained in the following sections.

MATERIALS AND METHODS

The analysis was performed using pulses generated from Saint-Gobain BC501A liquid scintillator. The signal pulses were recorded using a digital storage oscilloscope (DSO). Neutron pulses were generated using a ^{252}Cf neutron source. γ pulses were generated by placing ^{137}Cs and ^{60}Co sources. The pulses of γ -neutron, γ - γ and neutron - neutron events were generated by placing different permutations of ^{252}Cf, ^{137}Cs and ^{60}Co sources. The electronic noise was rejected by choosing trigger level of 1mV.

The time constant of exponentially falling edge is selected as classification criteria which is a unique property of the pulses which corresponds to same particle channels. These pulses were fitted with exponential function and the time constant and its standard deviation were tabulated for each pulse channel. The neutron-γ coincidence pulses were also identified from the logged data with multiple sources and processed as above. This is then verified by summing γ and neutron pulses. The second moment approach is used for propagation of the standard deviation, where the statistical correlation between neutron and γ pulses were used for generating the covariance. This procedure was repeated for each coincidence channel.

Further, an algorithm was developed and implemented using C++ language including Root libraries

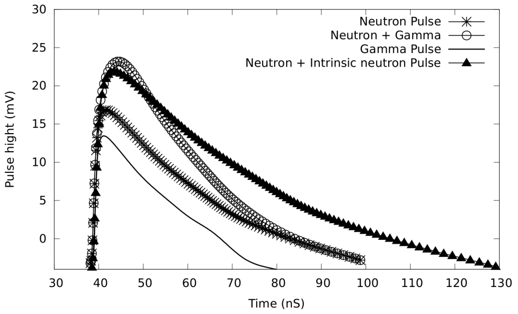

Figure 1: *Pulse responses of particle events*

for mathematical analysis [1]. The recorded pulse data were pushed into the program in FIFO (First In First Out) mode. Algorithm selects the pulses as rising edge triggered, and the falling portion is converted as the Legendre interpolation polynomial. This is then numerically differentiated for getting the time constant. This time constant was compared with previously tabulated time constants for each pulse channel and pulses get classified. If it is identified as a single particle event, a probability distribution function of pulse amplitude will be updated.

When a coincidence summed pulse were identified by the algorithm via tabulated classification, the pulses were unfolded iteratively by selecting a_0 values from the generated PDF and the stack of channel were updated. The probability distribution function for a count of 10^6 in each coincidence channels were generated. The neutron stack is then binned into the recoil spectrum and unfolded using RooUnfold spectrum unfolding framework.

RESULTS AND DISCUSSION

The time constants obtained for pulse classification and its acceptance window levels for each channel are tabulated in Table 1, and the pulse shapes correspond to each channel is shown in Figure 1. The acceptance windows of time constants corresponding to each channel are well separated from other and hence the pulses could very well be classified. The neutron pulses from coincidence summed events were extracted via self learned probability distribution. The unfolded ^{252}Cf-neutron spectrum compared with the evaluated spectrum recommended by ENDF/B-VII library[4] is shown in Figure 2. It is evident that the neutron energy distribution obtained from present procedure well reproduces the data recommended by ENDF/B-VII library. The uncertainty level of measured data is also less due to the higher number of recorded counts. This method can be used for discriminating neutrons, from high gamma background if Time Of Flight (TOF) is not employed.

Table 1: *Trained time constants and window levels for event channels*

	Neutron	γ
Neutron	0.031±0.00063	
γ	0.037±0.0088	0.0058±0.0018
Intrinsic Neutron	0.013±0.001	

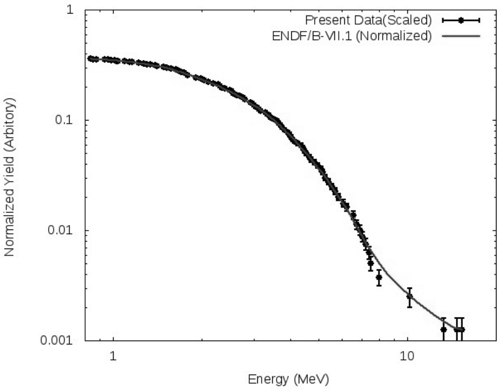

Figure 2: *The measured ^{252}Cf Neutron spectrum and ENDF/B-VII recommended data*

ACKNOWLEDGMENTS

This work is a part of DAE-BRNS supported research project.

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