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Performance evaluation of pulse shape discrimination based on CCM and CNN according to light output threshold

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1. Introduction

Fast neutron detection using organic scintillators has been developed due to its potential use for homeland security, and nuclear safeguards. Unlikely to the conventional neutron measurement based on He-3 proportional counters, pulse shape discrimination (PSD) is essential in fast neutron detection because high gamma sensitivity with using the organic scintillators. Diverse PSD techniques (time/frequency domain) have been verified their good performance. However, quite high threshold should be applied to confirm reasonable PSD performance, and this leads to neutron count losses. Because neutron cross section with materials drastically drops according to neutron energy, the statistical uncertainty of measurement results from detecting fast neutron (>= 0.5 MeV) is difficult to be achieving lower than 1% thus longer counting time should be required. To that ends, in this study, the PSD performance according to light output threshold was first evaluated using a conventional PSD technique and deep learning model, respective.

2. Methods and Results

Energy calibration was conducted for commercial organic scintillators coupled to high voltage PMTs using Cs-137, Na-22 gamma-ray sources. DAQ system was connected to DT-5730B digitizer (CAEN, 14-bin resolution, 500 MS/s sampling rate), and CoMPASS software was used to adjust the optional parameters of the digitizer. To confirm the dependency of PSD performance on light output, both gamma sources and Cf-252 were measured with 100-350, 350-600, 600-850, and 850-1100 keVee of energy bands. Charge comparison method (CCM), a representative conventional PSD technique, was applied varying energy band. For PSD based on machine learning, convolution neural network (CCN), which has been widely used deep learning model was constructed through trials and errors. Neutron and gamma waveforms were acquired according to the energy bands, and all dataset were pre-processed to be appropriately recognized as inputs toward to the model training and validation.

The higher PSD performance based on CCM was showed for higher light output of energy band. However, significant count loss of neutrons was confirmed. CCN-based PSD also similar trend but lower decreasing rate of PSD accuracy was confirmed for lower light outputs compared to the conventional PSD technique.

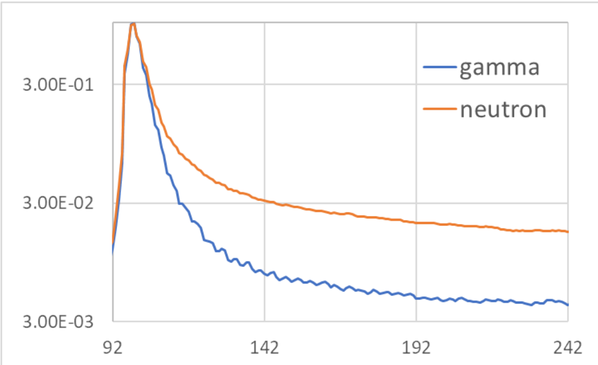

Fig. 1 Experimentally measured neutron and gamma pulses using organic scintillators.

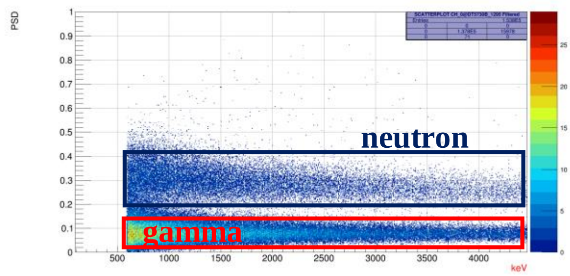

Fig 2.2D-spectrum of neutron and gamma pulses according to PSD parameter. The above

3. Conclusions

In this study, the performance of PSD based on both CCM and CNN was evaluated according to light output. Consequently, less decreasing trend of PSD performance for lower light output in the case of CNN-based algorithm. Through updating the models or the conditions of input dataset, it would be possible to reduce the neutron count loss by applying deep learning.

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