Enhancing Neutron/Gamma Discrimination in the Low-Energy Region for EJ-276 Plastic Scintillation Detector Using Machine Learning

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167

Introduction

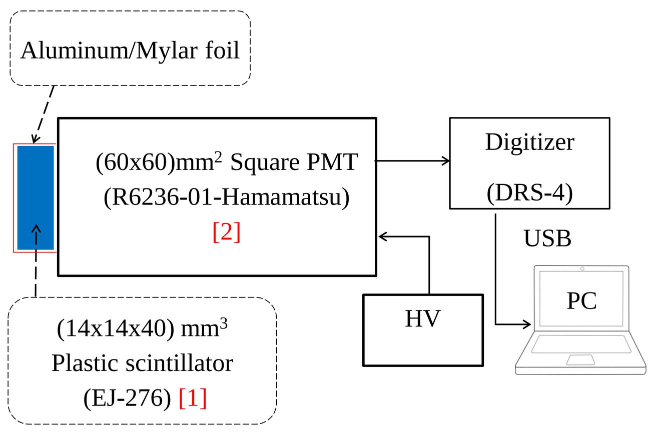
Charge integration ratio (Q_{ratio}), method in Pulse Shape Discrimination (PSD) technique has been widely used to discriminate between fast neutron and gamma in organic scintillation detectors.

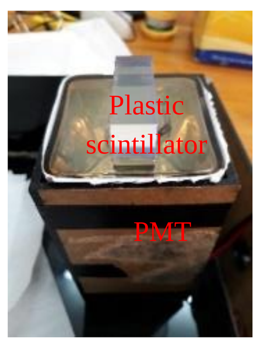
***Problem**: In low-energy region of less than hundred keVee, Q_{ratio} of scintillation detectors has highly energy dependence. This leads to Figure of Merit (FOM), a quantity characterizing for neutron/gamma separation, worse.*

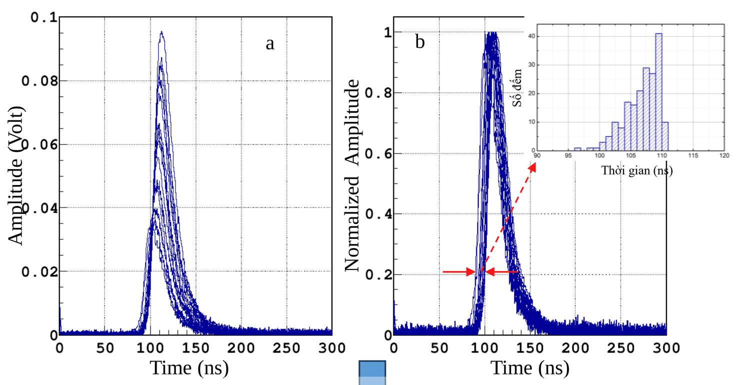
In this work, we employ a 1D-CNN Machine learning method to enhance neutron/gamma discrimination and compare the results with the traditional charge integration ratio in the low-energy region threshold.

We study for an EJ-276 plastic scintillator of (14x40x14)mm^3, a commercial product of ELJEN technology.

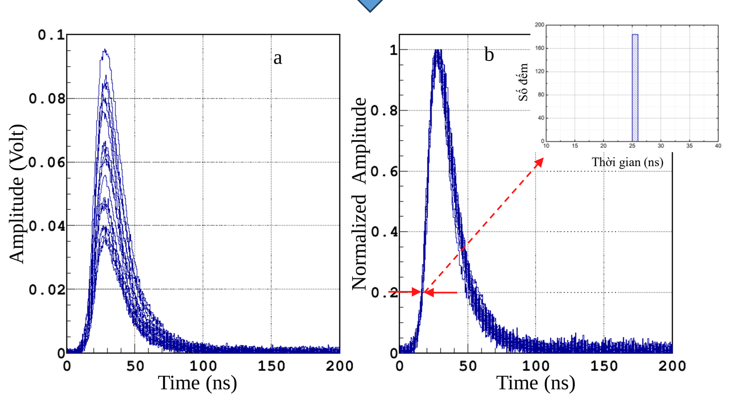
Experimental details and data processing





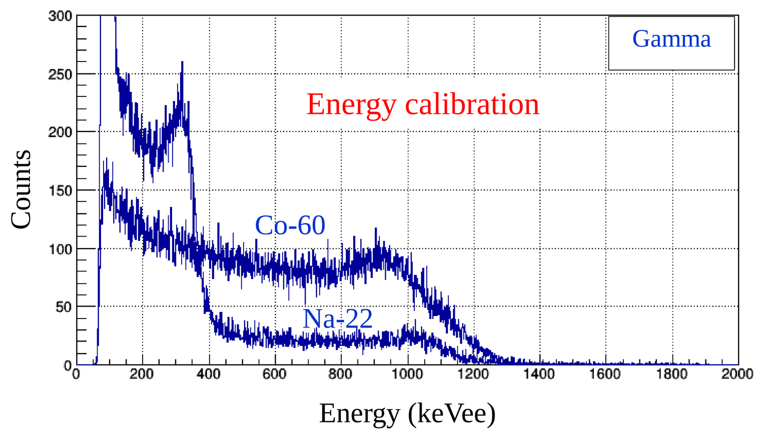


ARC (Amplitude and Risetime Compensated Triggering



- EJ-276 plastic scintillation detector.
- Output of the PMT is directly feed into the DRS-4 board [3], a fast digitizer, for pulse digitizing.

DRS-4 board [3]:
- Sampling rate: 2GSPS.
-Timing and Voltage calibrations are executed before measurement.

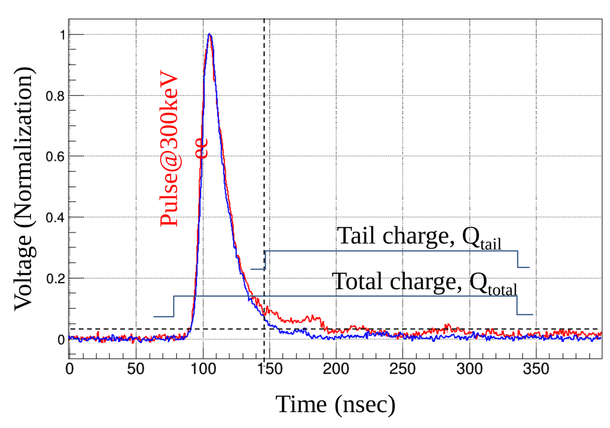


Methods

Charge integration ratio method, Q_{ratio},

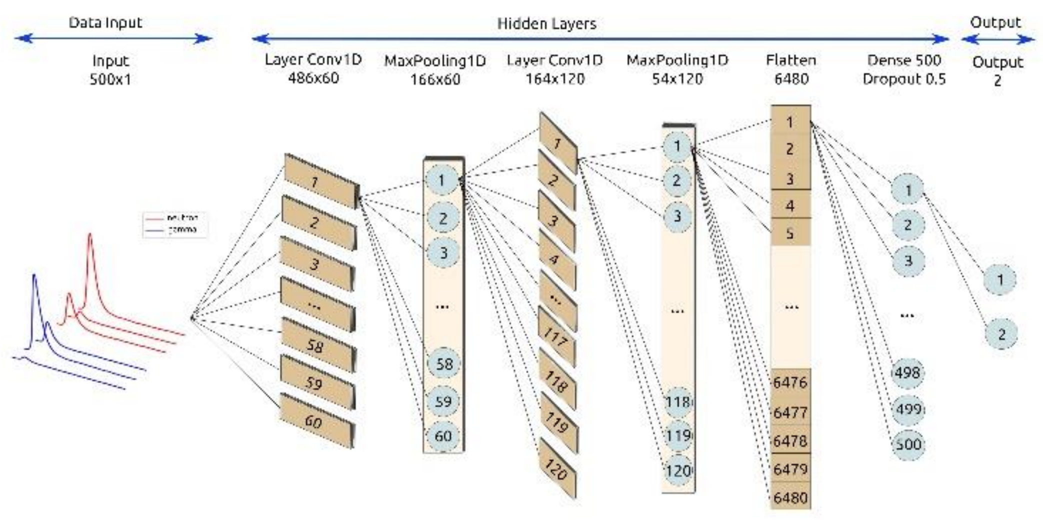
$$Q_{ratio} = \frac{Tail\ charge, Q_{tail}}{Total\ charge, Q_{total}}$$

Q_{tail}, Q_{total} the charge of tail and total of the pulse, respectively.



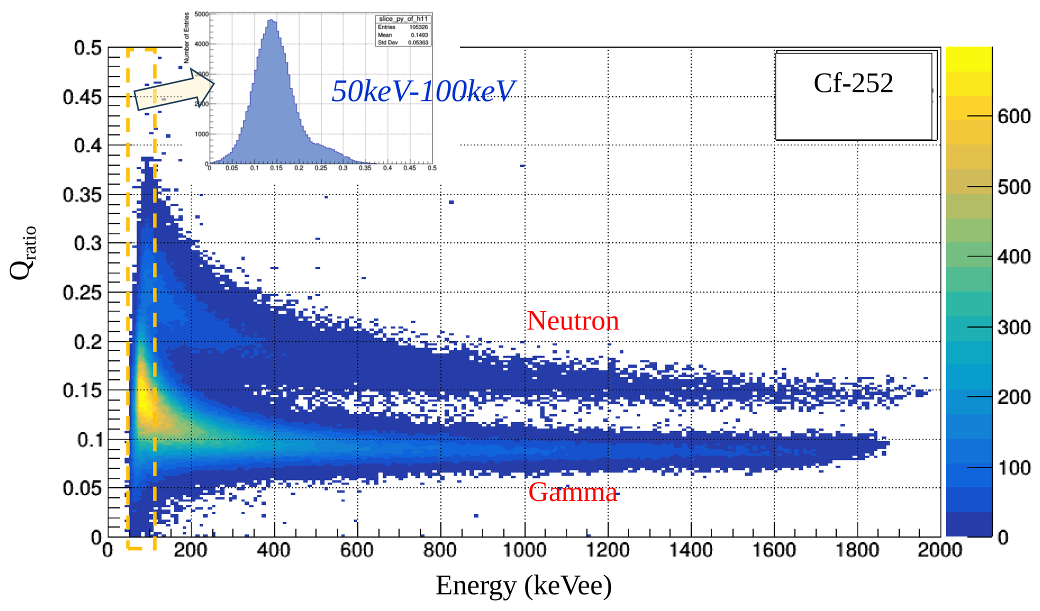
1D-CNN Machine learning method

- Keras library with TensorFlow [4][5]
- Each waveform a unique input, Rectified Linear Unit (ReLU) activation functions (hidden layers) + Softmax activation function (output layer)
- Stochastic Gradient Descent (SGD) optimizer, sparse_categorical_crossentropy loss function



Results and discussion: Neutron/gamma discrimination

Charge integration ratio method, Q_{ratio}



Previous work, RT IEEE conf. 2018 [6]

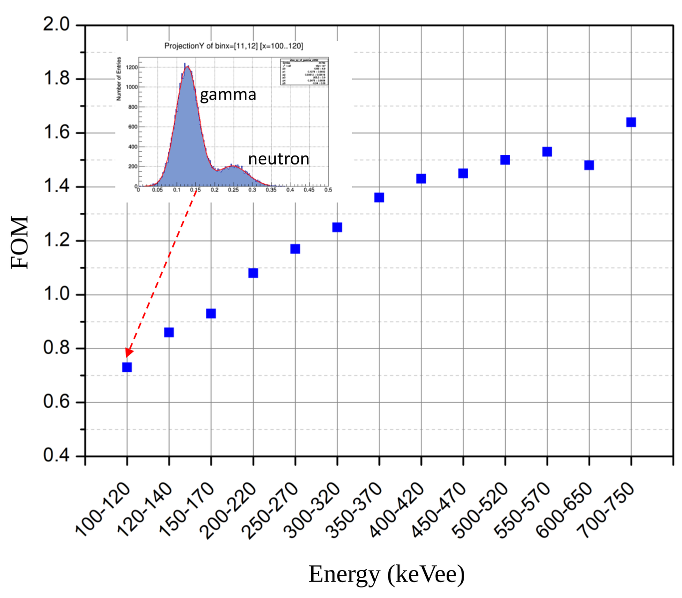
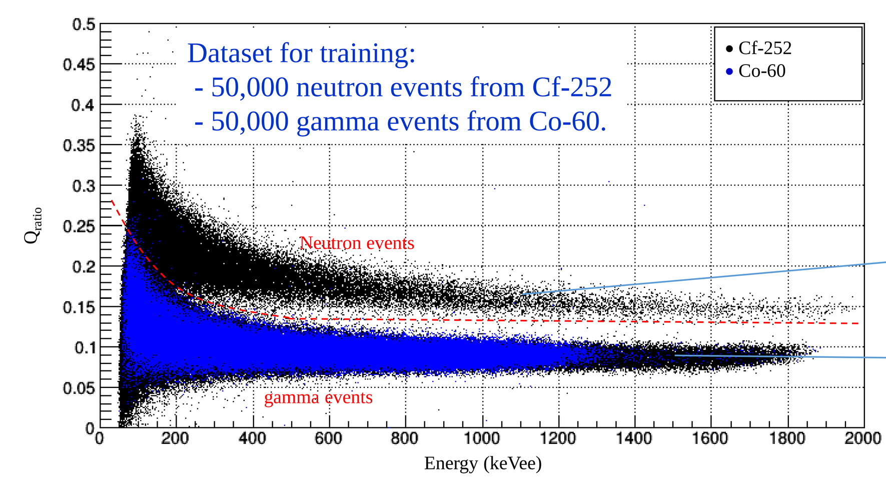
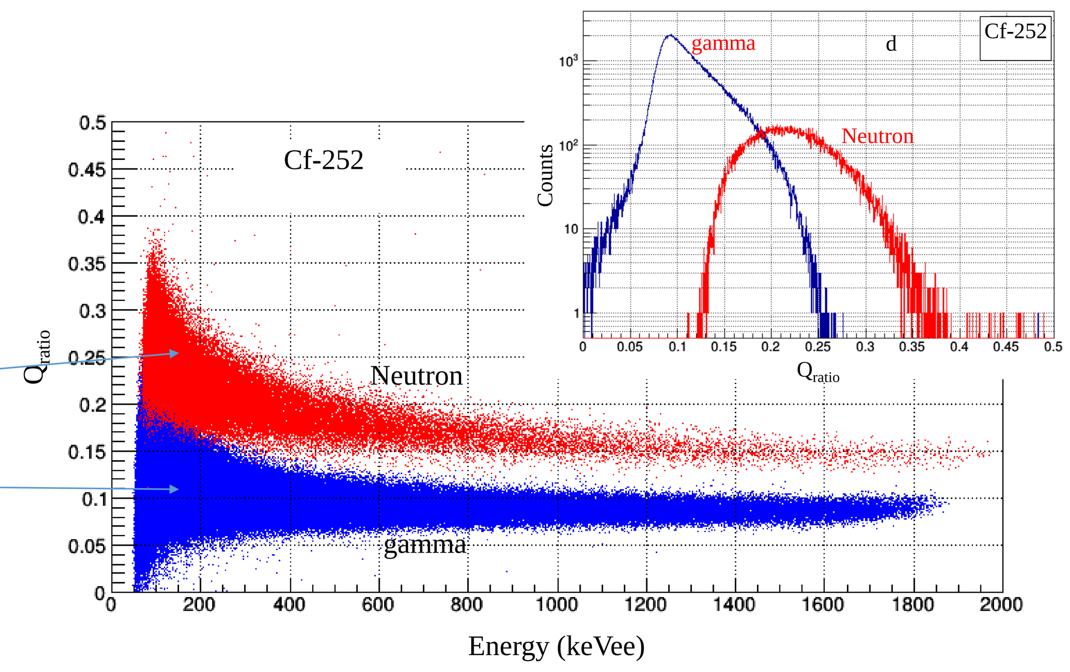


Table 1.

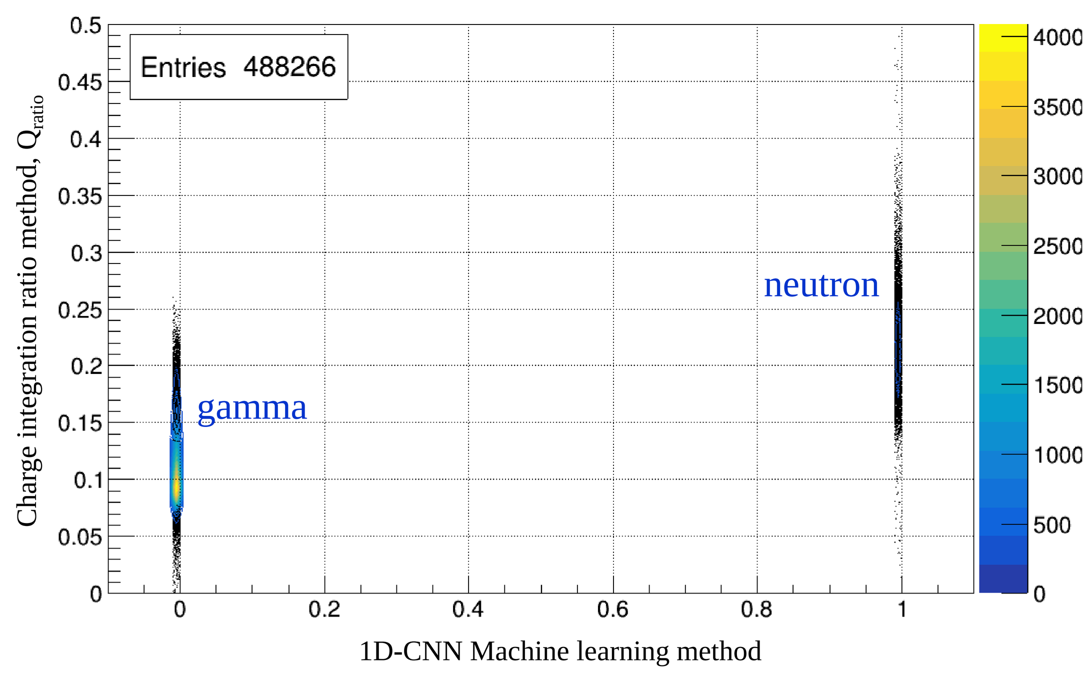
Energy (keVee)	FOM
100-120	0.73
120-140	0.86
150-170	0.93
200-220	1.08
250-270	1.17
300-320	1.25
350-370	1.36
400-420	1.43
450-470	1.45
500-520	1.50
550-570	1.53
600-650	1.48
700-750	1.64

1D-CNN machine learning method





- Utilized 80% of the dataset for training and 20% for validation.
- After 500 epochs, validation loss (0.0046) and validation accuracy of 0.9995.



The CNN analysis, shown in Figures for Cf-252, offers remarkable discrimination capabilities between neutron events and γ events.

Conclusions

- Charge integration ratio method (Q_{ratio}) in discriminating neutrons and gammas for energies above 200keVee, as evidenced by a favorable Figure of Merit (FOM) detailed in Table 1.
- 1D CNN demonstrate good performance across the entire energy spectrum. The 1D CNN successfully addresses the limitations of traditional methods, offering a promising opportunity for improved neutron/gamma discrimination.

References

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[6] Vo Hong Hai, al., "A new method of PSD technique on charge integration ratio to improve neutron/gamma discrimination in low-energy region for EJ-299-33 plastic scintillation detector", 21st IEEE Real Time Conference, June 2018, Colonial Williamsburg, US.

Acknowledgement

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