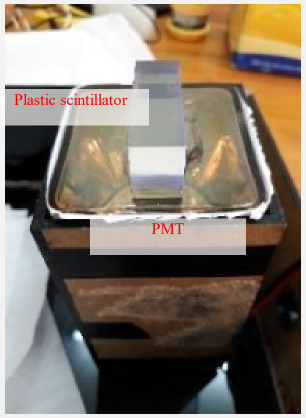
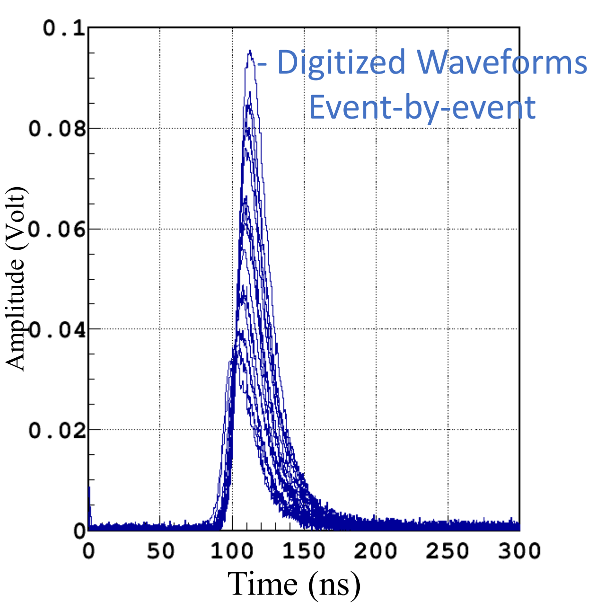
Plastic scintillator EJ276

Used for Neutron-gamma discrimination



DRS-4 board, PSI

- 2 GSPS
- 1024 bin/event
- Event by event



Charge integration ratio method, Q_{ratio}

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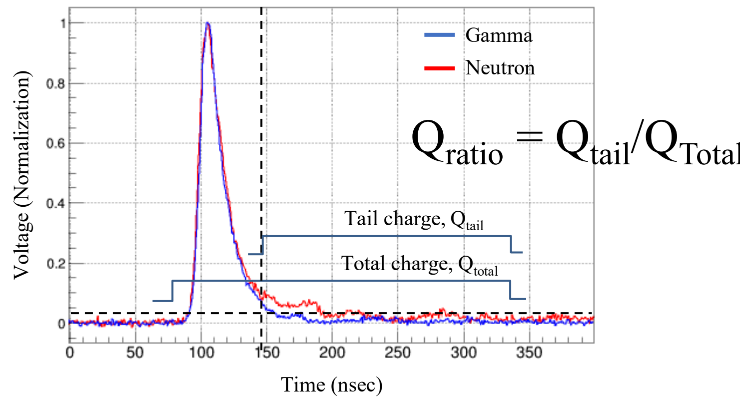

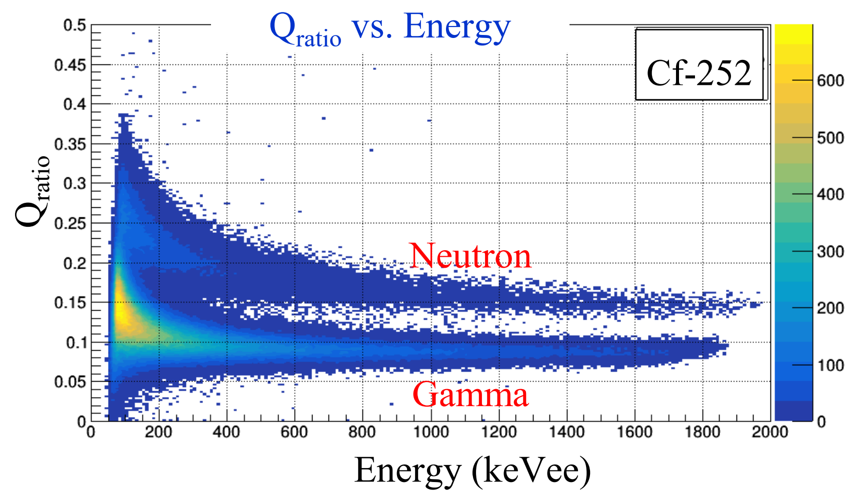

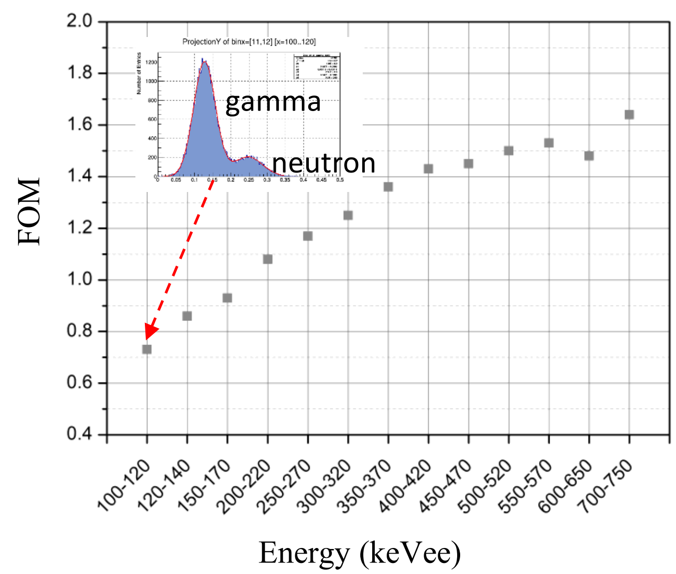

a one-dimensional Convolutional Neural Network (1D-CNN) model

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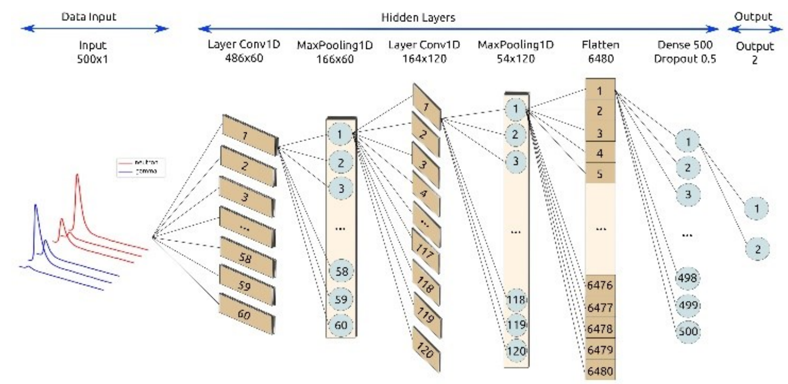
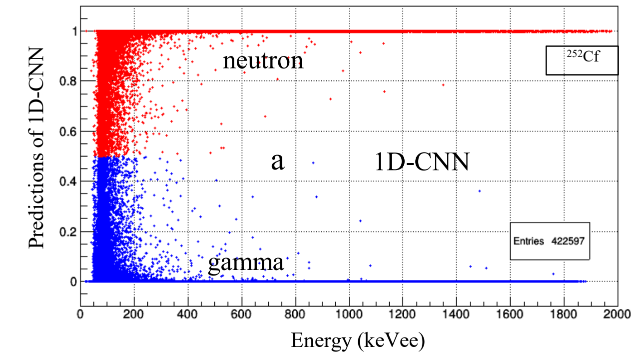
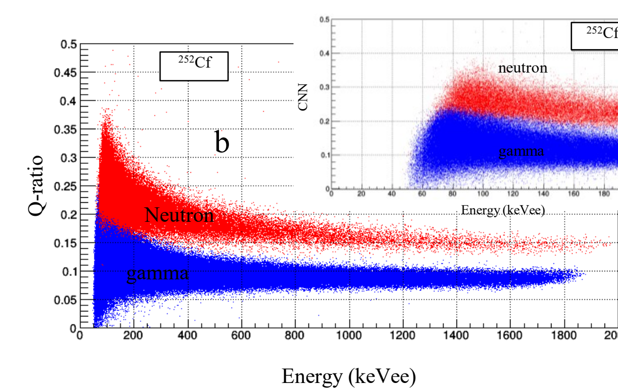
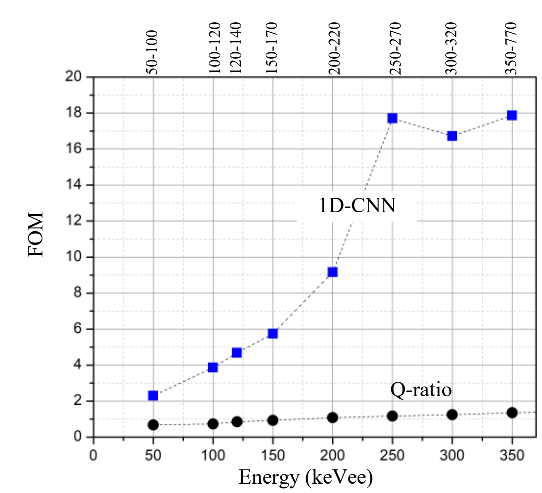




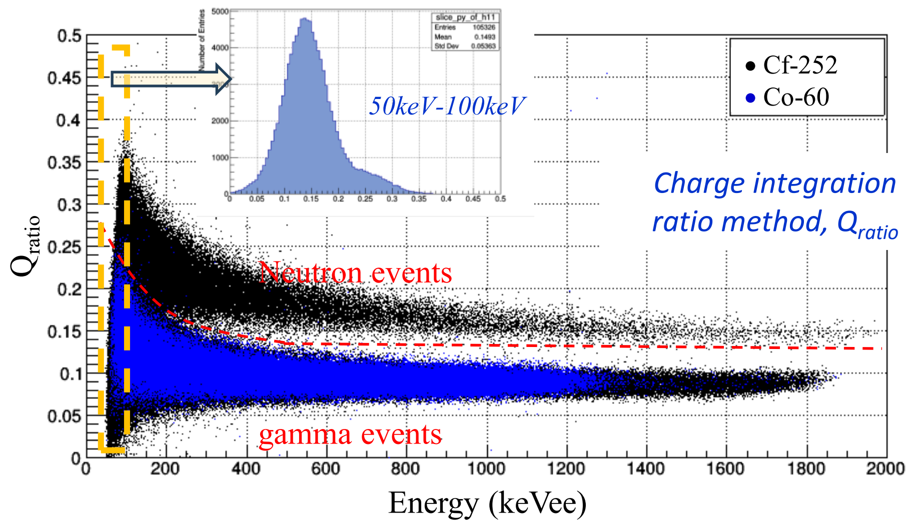




IEEE TNS, vol. 72, no. 3, pp. 225-230, March 2025

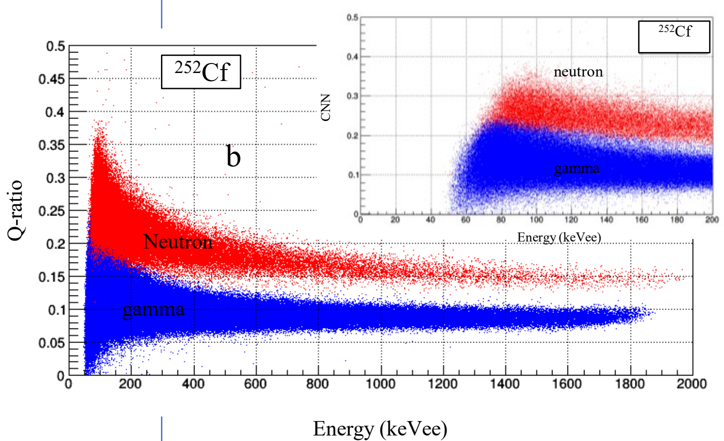
The results demonstrate stable neutron/gamma discrimination for real mixed-field measurements.

IEEE RT Conf. 2018



IEEE RT Conf. 2024

1-D CNN Machine Learning was used to discrimination neutron/gamma



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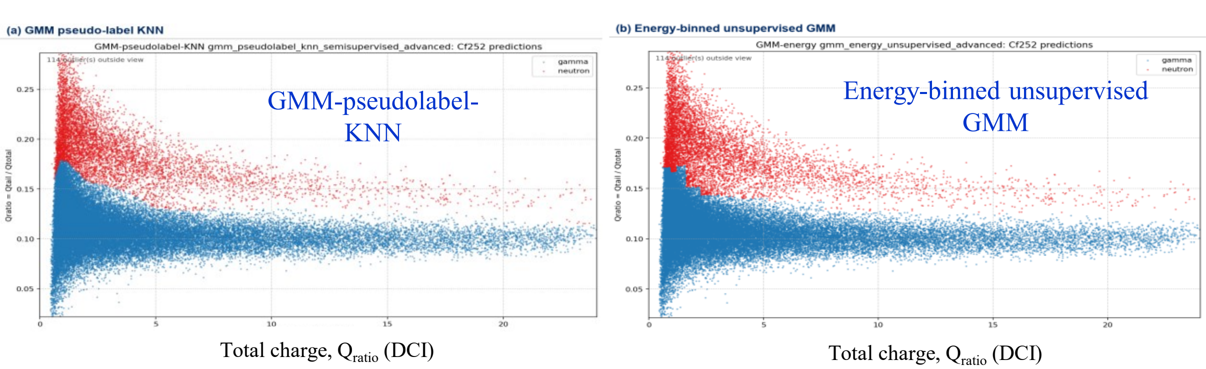

This work, Semi-supervised and unsupervised machine learning methods were applied for neutron/gamma discrimination

PO.219

Self-Supervised and Semi-Supervised Machine Learning for Waveform-Based Neutron/Gamma Discrimination in EJ-276 Plastic Scintillator

Vo Hong Hai[(1)(2)], member, IEEE, Nguyen Tri Toan Phuc[(1)(2)], Truong Huu Ngan Thy[(1)(2)], Lu The Dang[(1)], Mai Quynh Anh[(3)]

[1]Department of Nuclear Physics, University of Science, Vietnam National University-Ho Chi Minh City, Vietnam.

[2] Vietnam National University-Ho Chi Minh City, Vietnam.

[3]Nuclear Research Institute (NRI), Vietnam.

Contact: vhhai@hcmus.edu.vn

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Introduction

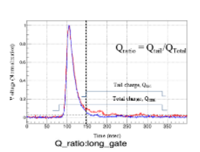
The EJ-276 plastic scintillator is widely used for neutron/gamma discrimination using pulse shape discrimination (PSD). However, conventional charge integration methods show poor separation performance in the low-energy region [1],[2].

In our previous work, a 1D-CNN machine learning method was applied to neutron/gamma discrimination for Cf-252 measurements using EJ-276 waveforms [2].

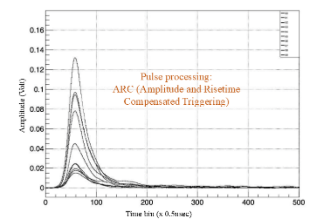
In this work, semi-supervised and unsupervised machine learning methods based on Gaussian Mixture Models (GMM) are investigated for waveform-based neutron/gamma discrimination using physically interpretable PSD features.

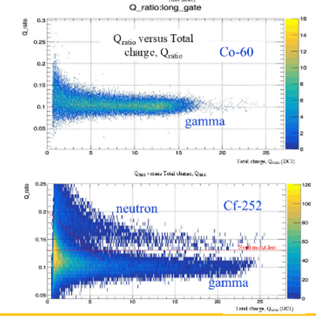
Waveform data and Q_{ratio} method

-EJ-276 plastic scintillation detector [1].



- Pulse data, event by event.
(Waveform recorded by DRS-4 digitizer)





SEMI-SUPERVISED AND UNSUPERVISED METHODS

- EJ-276 waveform signals were processed using charge integration PSD features: Q_{total}, Q_{tail}, and Q_{ratio}
- **A semi-supervised method** using GMM pseudo-labeling followed by KNN classification was also investigated.
- **An energy-binned unsupervised Gaussian Mixture Model** (GMM) was applied to classify neutron/gamma events without labeled calibration data.
- The models were evaluated using **held-out labeled datasets (A)** and applied to **unlabeled Cf-252 mixed-field data (B).**

GMM pseudo-labeling followed by KNN *(semi-supervised)*

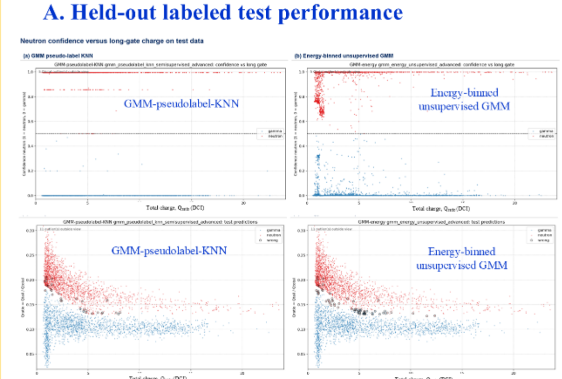
- GMM generated high-confidence pseudo-labels.
- Pseudo-labeled events were used to train a KNN classifier.
- The method improves neutron/gamma discrimination with limited labeled data.

Energy-binned unsupervised GMM (unsupervised)

- GMM was applied to Q_{ratio} in each energy bin.
- Neutron/gamma classification was performed without labeled data.

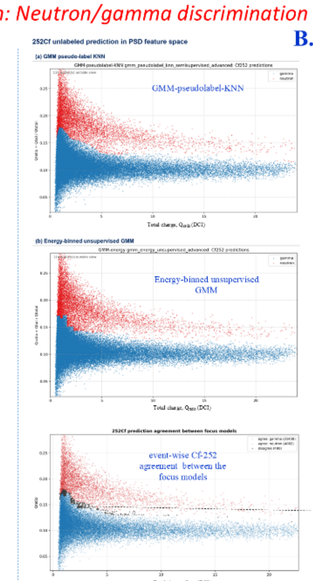
Results and discussion: Neutron/gamma discrimination

A. Held-out labeled test performance



model	Type	Accuracy test	F1 score
GMM-pseudolabel-KNN	semi-supervised	0.9925	0.9925
Energy-binned unsupervised GMM	unsupervised	0.9838	0.9837

B. unlabeled Cf-252 mixed-field data



Model	Total event	gamma-like	neutron-like
energy-binned unsupervised GMM	48790	41426	7364
GMM pseudo-label KNN	48790	41912	6878

- GMM generated high-confidence pseudo-labels.
- Pseudo-labeled events were used to train a KNN classifier.
- The method improves neutron/gamma discrimination with limited labeled data.

Neutron: ~ 1% disagreement between the two methods.

Conclusions

- Semi-supervised and unsupervised machine learning methods were successfully applied for neutron/gamma discrimination using EJ-276 plastic scintillator waveforms.
- GMM pseudo-label KNN model (Semi-supervised) achieved 99.25% accuracy, while energy-binned unsupervised GMM reached 98.38% accuracy.
- Both methods improved separation performance compared with the conventional charge integration PSD method, especially in the low-energy region.
- The proposed approaches provide interpretable and label-efficient solutions for future real-time neutron/gamma discrimination systems.

References

[1] EJ-276 Specification, ELJEN Technology. [Online]. Available: https://eljentechnology.com/

[2] V. H. Hai, N. M. Dang, N. T. T. Phuc, H. T. K. Trang, T. T. H. Loan, P. L. H. Sang, M. Nomachi, "Enhancing Neutron/Gamma Discrimination in the Low-Energy Region for EJ-276 Plastic Scintillation Detector Using Machine Learning", in IEEE Transactions on Nuclear Science, vol. 72, no. 3, pp. 225-230, March 2025.

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Acknowledge

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