Primary results of cosmic-ray recognition for a Plastic Scintillation Detector Using Machine Learning

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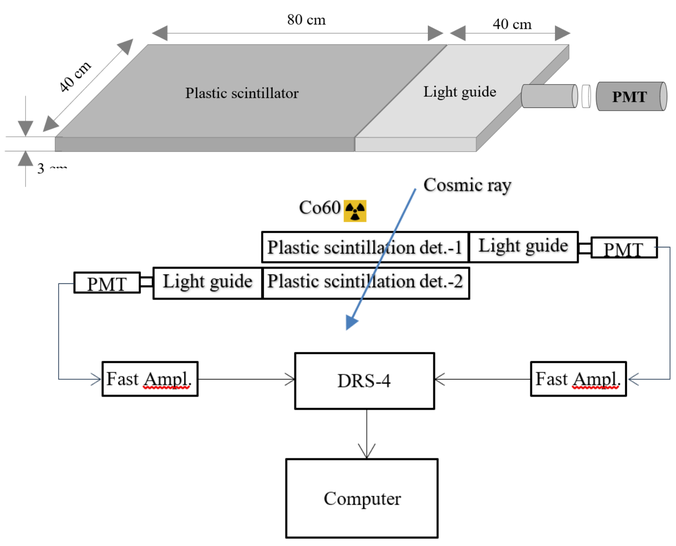
Introduction

Cosmic rays at ground level are well-known products resulting from the interaction between primary cosmic rays from outer space and molecules, primarily oxygen and nitrogen, in Earth's atmosphere. The predominant cosmic rays at ground level are highly energetic muons, with smaller amounts of protons, neutrons, electrons, positrons, neutrinos, etc. In recent years, machine learning technology has many applications in radiation studies [1][2].

In this study, we propose the use of a one-dimensional Convolutional Neural Network (1D CNN) to identify cosmic rays in background measurements using a single plastic scintillation detector.

Experimental details

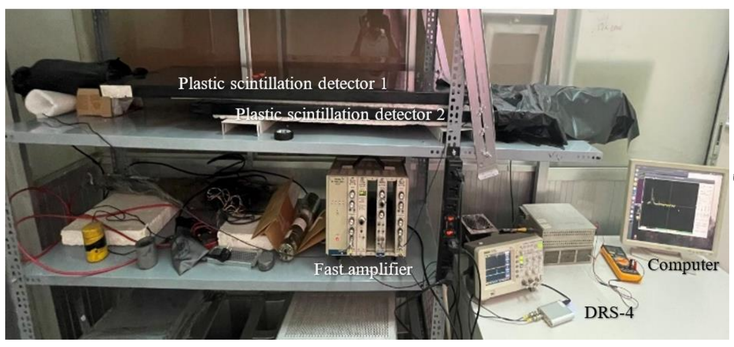


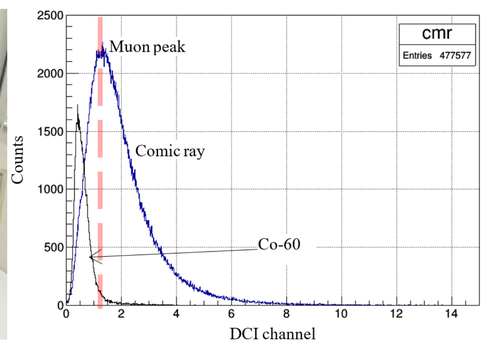
Output of the PMT is amplified by a fast amplifier and recorded by the digitizer of DRS-4 [3] in the form of basic waveforms.

DRS-4 board:

- Sampling rate: 2GSPS.
- Timing and Voltage calibrations are executed before measurement.

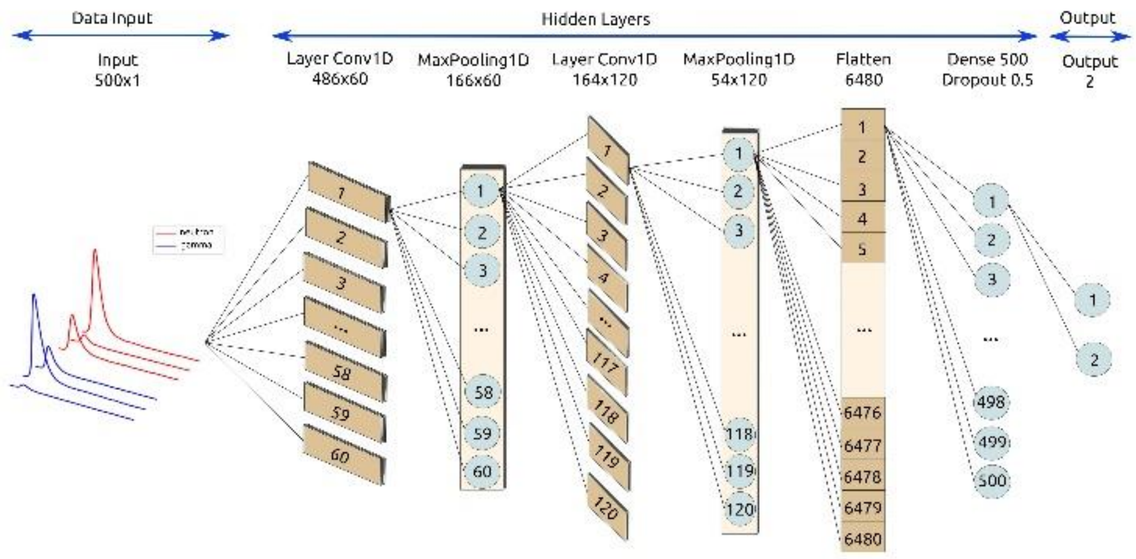
Digital charge integration (DCI) is applied with a time window of 200 nanoseconds



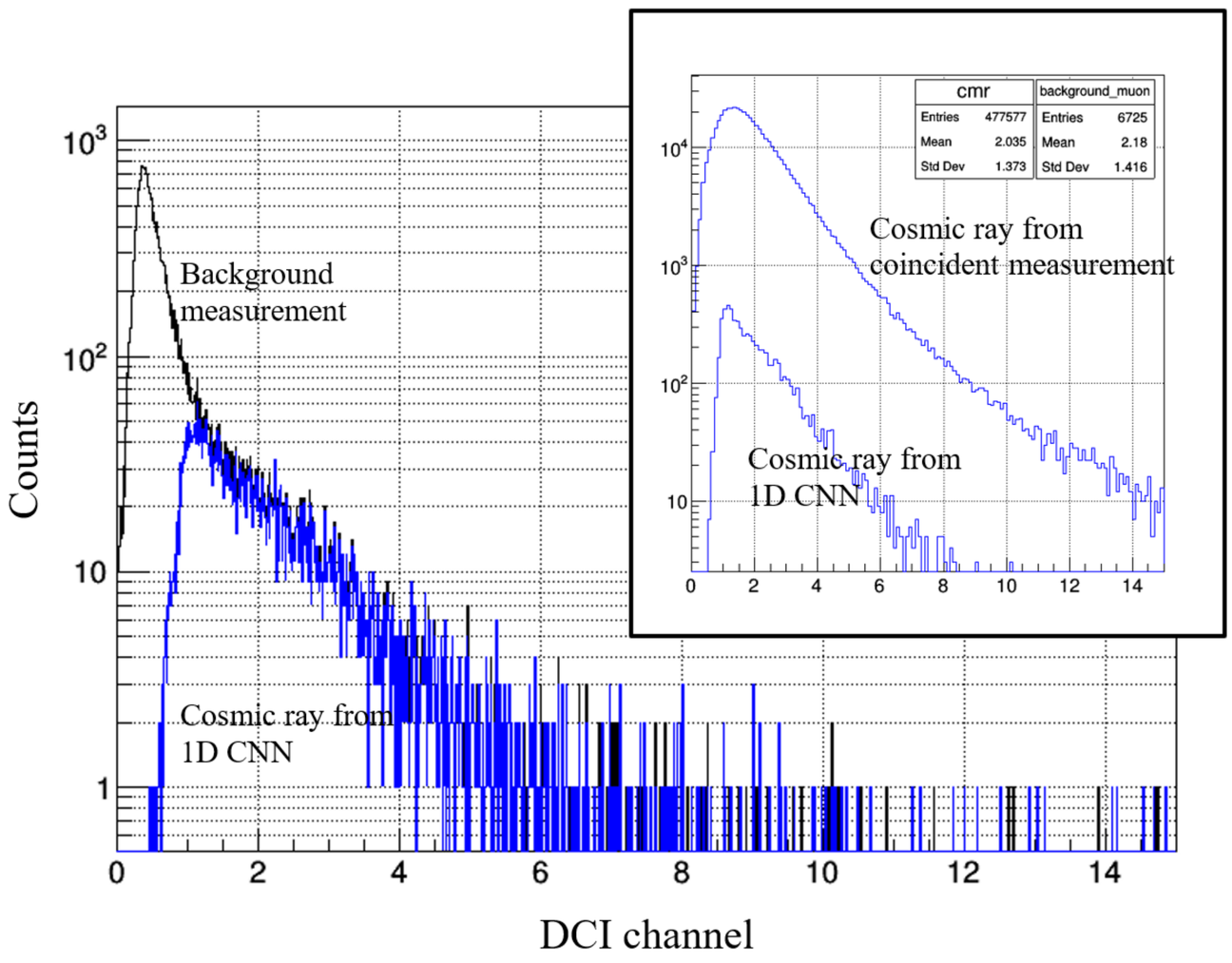


1D-CNN Machine learning method

- Keras library with TensorFlow
- 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
- Dataset of 78,000 cosmic-ray + 78,000 gamma events. Cosmic-ray and gamma events are identified using coincidence measurements and Co-60 source.
- 80% dataset for training and 20% for validation. After 1000 epochs, validation loss of 0.33 and validation accuracy of 0.87



Results and discussion



Radiation background measurement for plastic scintillation detector-1.

The 1D-CNN analysis showcased the capabilities to identify the cosmic-ray muons (blue line), demonstrating similarities to cosmic-ray measurement with the coincidence of two detectors.

Cosmic ray component can be extracted from the radiation background with 1.4% in the total.

Conclusions

Results from the 1D CNN analysis illustrated the good capability of recognition of cosmic-ray muons in the plastic scintillation detector, aligning with measurements obtained through the coincidence of two detectors.

References

[1] Vo Hong Hai, Nguyen Tri Toan Phuc, Science&Technology Development Journal, 26(1):2645-2651, 2023.
[2] Dane Morgan, Ghanshyam Pilania, Adrien Couet, Blas P. Uberuaga, and Cheng Sun, Current Opinion in Solid State and Materials Science, 26 (2022) 10095.
[3] DRS-4 board, Paul Scherrer Institute. [Online]: https://www.psi.ch/drs/evaluation-board

Acknowledge

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