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AI-Driven Pattern Recognition for Self-tuning PMT Gain Optimization in the Forward Wall Detector

The Forward Wall (FW) detector in the HADES experiment at GSI/FAIR relies on accurate photomultiplier tube (PMT) gain tuning to ensure precise energy measurements and correct energy measurement range. Traditional calibration methods depend on iterative manual adjustments using cosmic muons, making them time-consuming and susceptible to systematic variations caused by PMT aging and environmental factors.

To automate and enhance calibration accuracy, we introduce an AI-driven self-calibrating algorithm based on pattern recognition in spectral data. A deep neural network (DNN) is trained to identify characteristic patterns in time-over-threshold (ToT) spectra, distinguishing between optimal and shifted gain states. The algorithm detects anomalies in spectral distributions and corrects deviations by predicting the necessary high-voltage (HV) adjustments. Additionally, an anomaly detection module based on unsupervised learning identifies unexpected deviations that may indicate hardware degradation or changing experimental conditions.

This approach improves calibration efficiency, reduces reliance on manual corrections, and enhances long-term detector stability. Validation with cosmic muon and heavy-ion collision data (C+C, Au+Au) demonstrates that the algorithm effectively recognizes gain shift patterns and adapts PMT settings accordingly. By leveraging AI-based pattern analysis, this method offers a scalable solution for automated calibration in large-scale scintillator-based detectors.

AI keywords

Anomaly detection; Pattern recognition; Reinforcement learning;

Primary author: KOHOUT, Pavel (Palacký University Olomouc)

Presenter: KOHOUT, Pavel (Palacký University Olomouc)

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