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Machine Learning-Driven Gamma-Ray Cluster Reconstruction for CALIFA at R^{3}B

The R^{3}B experiment at FAIR investigates nuclear reactions induced by high-energy radioactive beams. A key detector of this experiment is the CALIFA calorimeter, which consists of 2544 CsI(Tl) scintillator crystals, for the detection of gamma rays and light charged particles with high angular resolution and precise Doppler correction.

Accurate cluster reconstruction from sparse hit patterns, particularly for gamma rays, is crucial for precise energy determination. For current data evaluation a proprietary algorithm with fixed cluster size and geometric thresholds has been used. To improve clustering performance, this algorithm was compared with widely used machine learning-based clustering techniques, such as Agglomerative Clustering from SciPy, incorporating timing information from CALIFA, which had not been utilized previously. Further enhancements were explored using a Graph Neural Network (GNN).

This study presents the methodology and results of this machine learning-driven analysis based on simulated Geant4 data. The findings demonstrate significant improvements in cluster reconstruction accuracy, highlighting the potential of state-of-the-art machine learning techniques for high-energy nuclear physics experiments.

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