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Fast reconstruction-based ROI triggering via anomaly detection in the CYGNO optical TPC

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Optical-readout TPCs produce megapixel-scale images whose rich topological information is essential for rare-event searches, yet their size makes real-time data selection increasingly challenging as detectors grow in resolution and throughput. This contribution presents an exploratory baseline study of an unsupervised, reconstruction-based anomaly-detection strategy designed to address this challenge in a detector-agnostic manner. The approach employs a convolutional autoencoder trained solely on pedestal images—frames acquired with the amplification disabled, containing only the intrinsic noise morphology of the detector. This allows the model to learn the characteristic noise patterns without labels, simulation, or detailed calibration. When applied to standard data-taking frames, particle-induced structures naturally emerge as anomalies in the reconstruction residuals, from which compact Regions of Interest can be automatically extracted. The method is applied to real data from the CYGNO optical TPC prototype, demonstrating how an unsupervised, pedestal-based training paradigm can provide a transparent and robust foundation for ML-assisted online data reduction in future large-scale CYGNUS detectors. The study also highlights the strengths of this approach and the unique challenges posed by sparse, noise-dominated megapixel images in optical TPCs.

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