AI-Assisted Object Condensation Clustering for Calorimeter Shower Reconstruction at CLAS12

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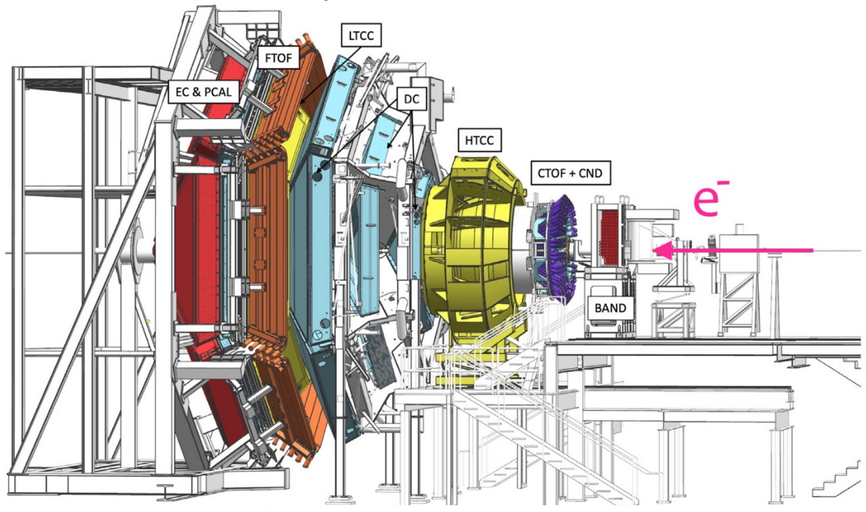
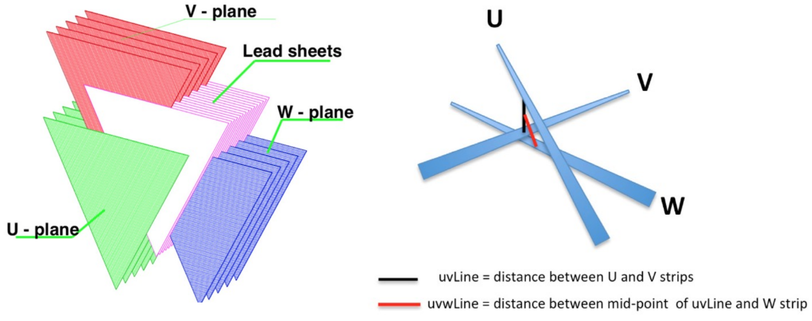
Abstract

- Accurate reconstruction of neutral particles, neutrons and photons, is critical for a broad range of nuclear physics measurements
- Current reconstruction software at CLAS12, COATJAVA, produces an overabundance of false neutral clusters, forcing conservative selection cuts
- AI-based hit clustering model for the CLAS12 ECal built on the object condensation framework
- The model combines GravNet layers for local detector topology encoding with a Transformer encoder for long-range hit relationships
- Evaluated on 1M simulated e⁻+p events:
  Neutron trustworthiness 8.88% → 30.73%,
  Photon trustworthiness 51.07% → 64.73%
- First application of AI clustering to hodoscopic detectors

CLAS12 Detector System

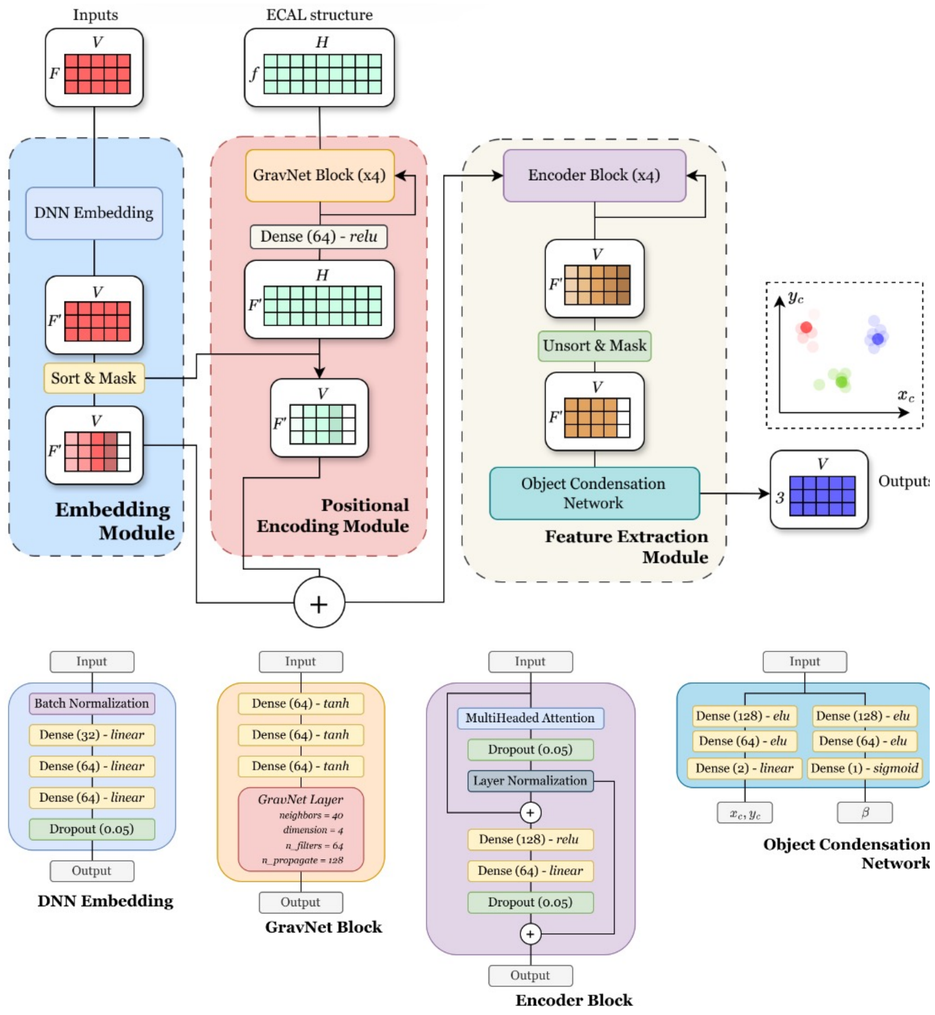
The electromagnetic calorimeter consists of the PCal, ECin and ECout subsystems.





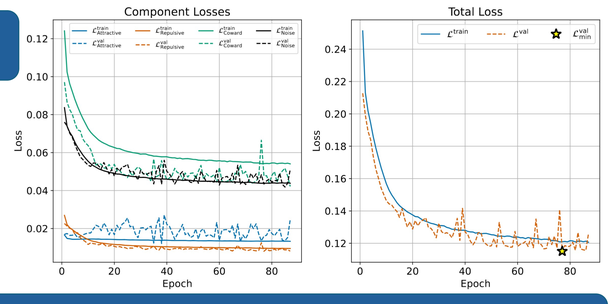
View of the U, V, W scintillating strip plane layout at CLAS12

Architecture

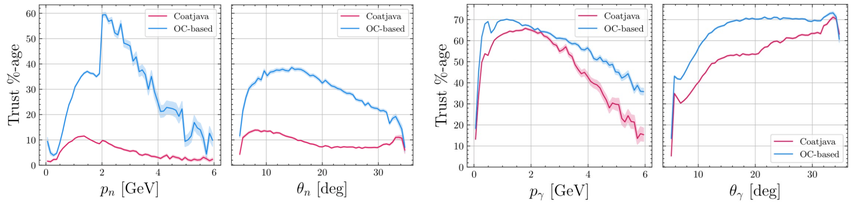


Loss Function

$$\mathcal{L} = \mathcal{L}_V + \mathcal{L}_\beta$$
$$\mathcal{L}_V = \mathcal{L}_{att} + \mathcal{L}_{rep}$$
$$\mathcal{L}_\beta = \mathcal{L}_{cow} + \mathcal{L}_{nse}$$

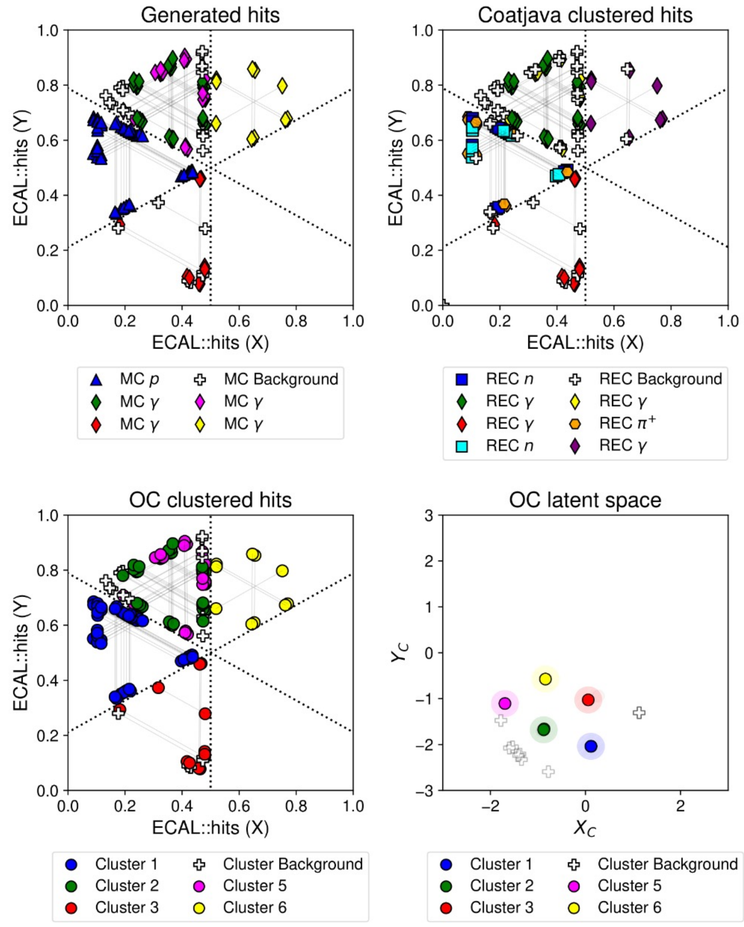


Results



All plots reproduced from arXiv:2503.11277v3 (Matousek & Vossen, 2025)

Inference



- Top Left: ECal hits left by generated SIDIS particles in a collision event.
- Top Right: The clusters and particles reconstructed by COATJAVA after interpreting the generated hits.
- Bottom Left: The clusters reconstructed by our Object Condensation model from the same generated ECal hits.
- Bottom Right: A snapshot of the clustered 2-D latent space from which the Object Condensation model maps the generated hits.

Next Step

- Evaluate sim-to-real gap: Test model sensitivity to strip timing and ADC values, which are less faithfully reproduced in simulation
- Integrate model into COATJAVA via a secondary REC::Particle bank

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