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Transformer for Energy Calibration in the ATLAS Electromagnetic Calorimeter

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The ATLAS experiment reconstructs electrons and photons from clusters of energy deposits in the electromagnetic calorimeter. The reconstructed electron and photon energy must be corrected from the measured energy deposits in the clusters to account for energy loss in passive material upstream of the calorimeter, in the passive material in the calorimeter, out of cluster energies and leakage in the hadronic calorimeter. This correction is performed by a machine learning algorithm trained on Monte Carlo simulations to predict the true electron or photon energy based on a set of inputs describing the reconstructed electromagnetic cluster. This is complicated by the difficult pileup conditions observed in Run 3 and anticipated at the HL-LHC. It has been noted that a graph representation can naturally encode the irregular geometrical structure of calorimeter data. Transformer models are particularly suited for this task, as they can process graphs of arbitrary size and excel at capturing long-range dependencies between cells. Thanks to the self-attention mechanism, the transformer can weigh the importance of individual cells within the cluster and effectively model the complex relationships between them. We demonstrate that a transformer model has the potential to substantially improve the energy resolution with respect to the current binary decision tree (BDT) calibration, while adding resilience against pileup in nearly all kinematic regions studied. The transformer model is implemented in the SALT framework [1], commonly used on ATLAS for applications including jet flavor tagging, which allows a high degree of model customization for the calibration task and straightforward deployment to the ATLAS software framework.

[1] S. Van Stroud et al. 2024, https://ftag-salt.docs.cern.ch/

Track

Reconstruction

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