

Attention is all photons need

Transformer for Energy Calibration in the ATLAS Electromagnetic Calorimeter

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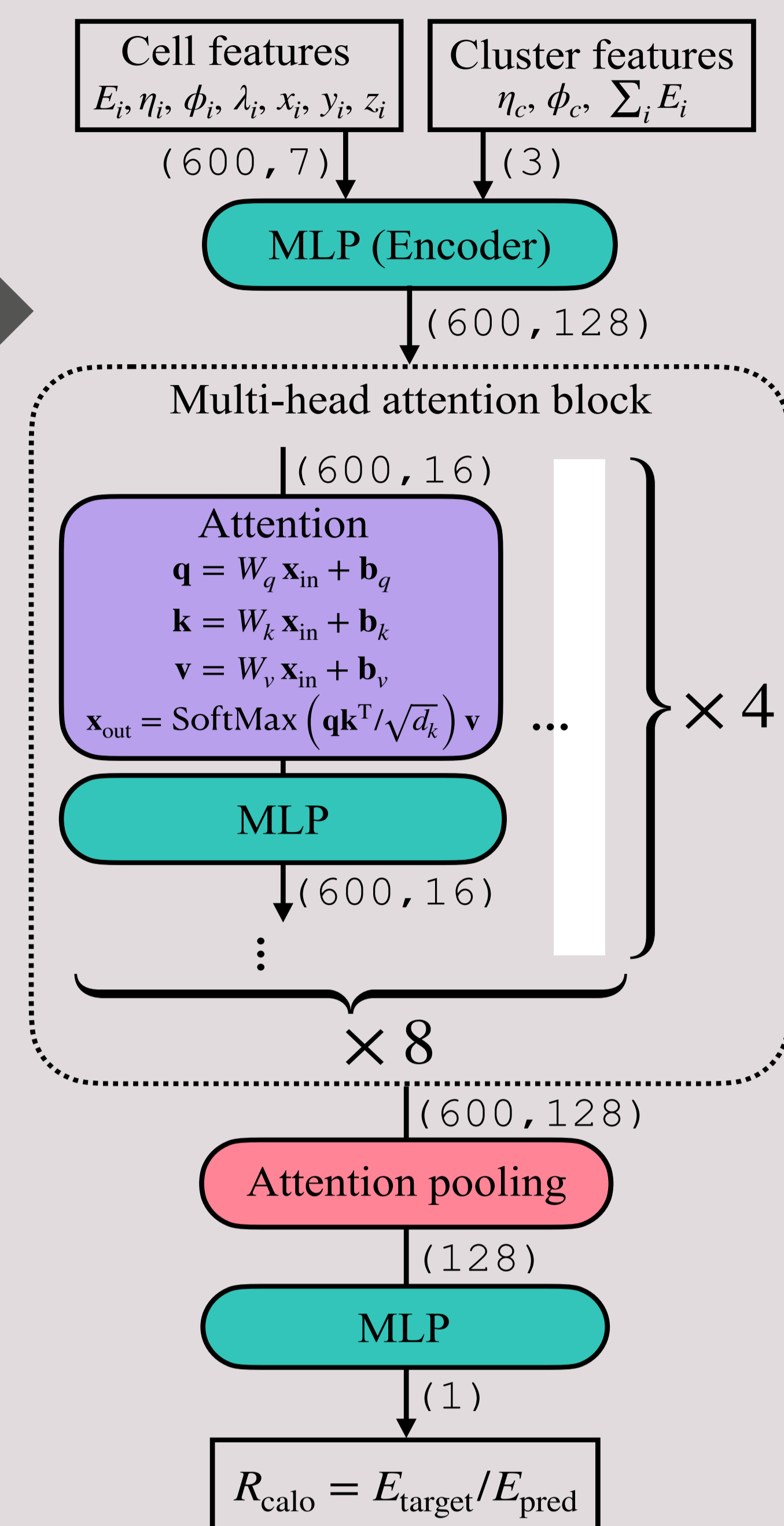
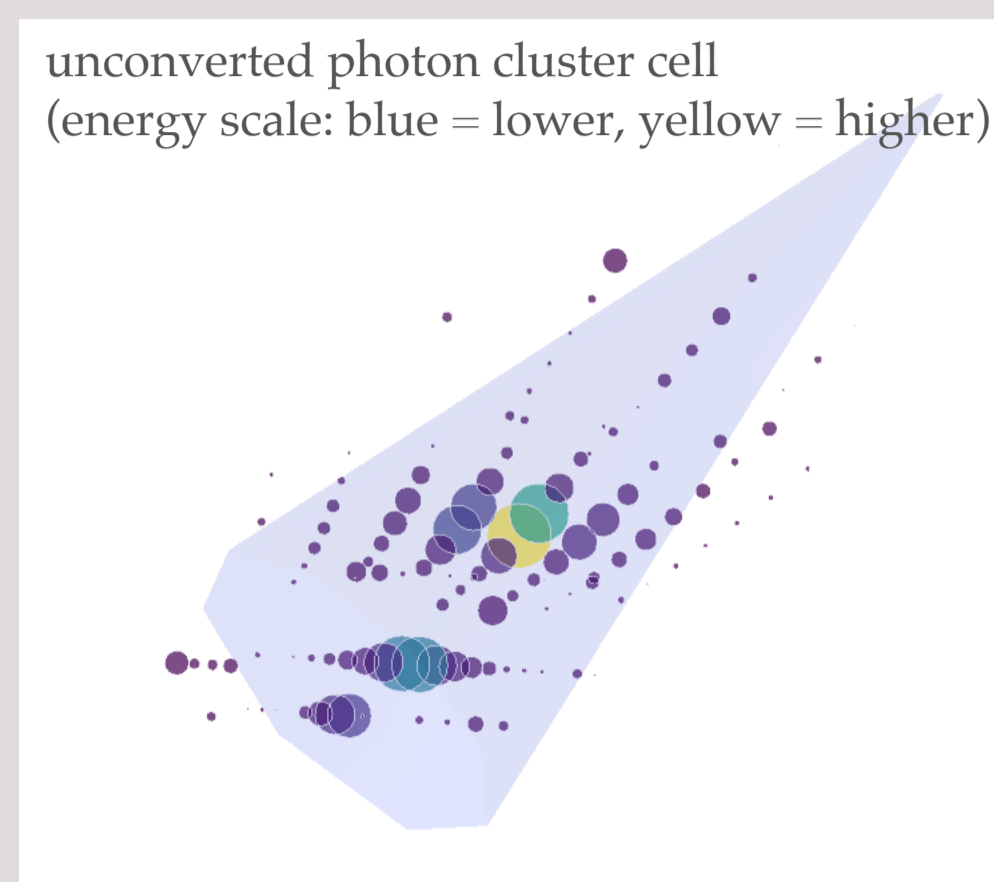
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Intro

- Electrons and photons are reconstructed from energy clusters detected in the ATLAS ECAL.
- Energy corrections** are applied to measured cluster energy to account for *losses within the passive calorimeter material*, upstream energy loss, leakage into out-of-cluster, and the hadronic calorimeter.

Design

- MVA methods like **BDT** employed in ATLAS [1] use high-level cluster variables describing the longitudinal shower development to correct the *raw deposited energy* to the *true particle energy*.
- The inclusion of **cell-level** data has the potential to improve the performance of the calibration via taking the energy distribution and geometric spread of the cluster in the calorimeter into account.
- Rebuilt the processing pipeline with **Transformer** model implemented in the SALT [2] framework.



- Much more informative feature design: up to **350 active cells** in the topo-cluster.
- Training was done using **MC single particle samples and with Run 3 pileup conditions**.
- Electron and photon candidates required to have $p_T > 5 \text{ GeV}$, lie outside the crack region ($1.37 < |\eta| < 1.52$), and pass **Loose ID**.
- Resolution defined as **inter-quartile range of energy response distribution divided by 1.35 (energy response)**.

Result

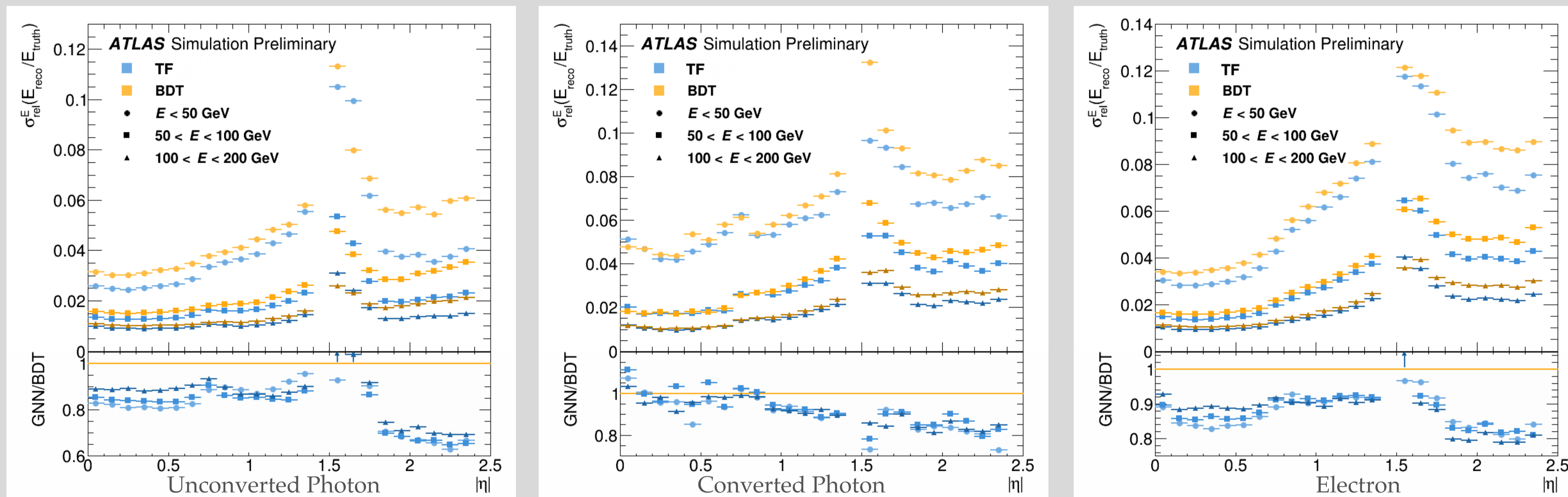
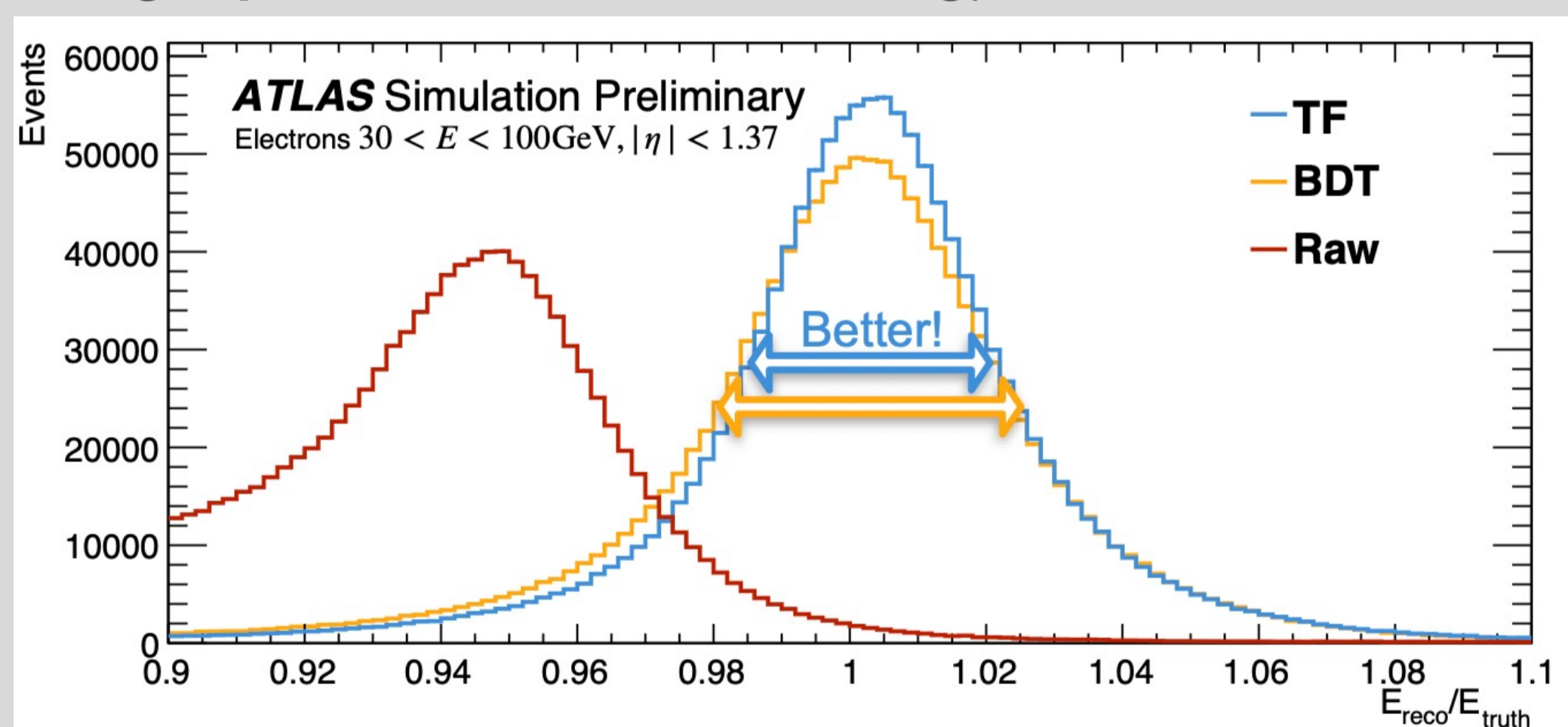


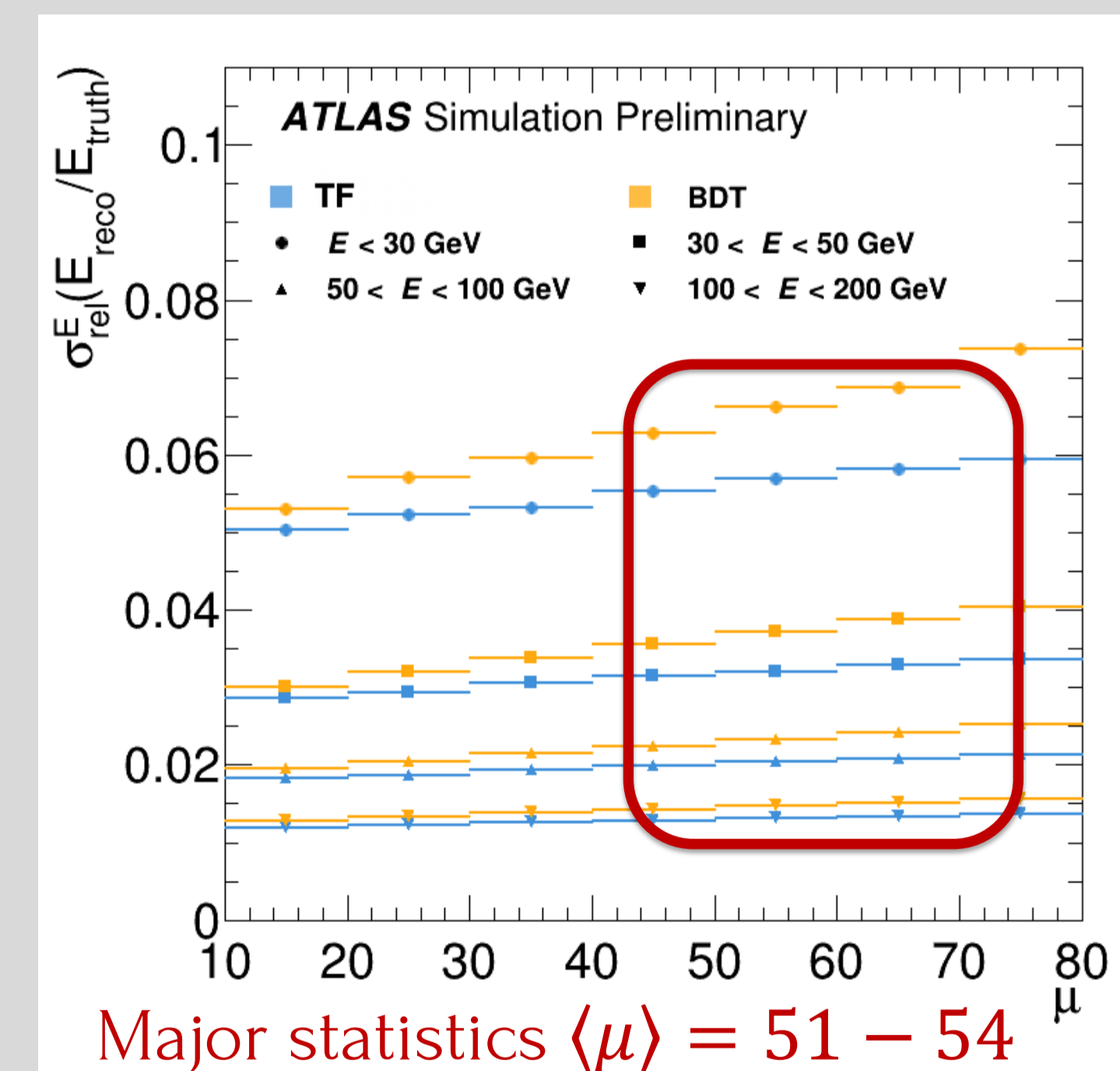
Fig.L: pull for reconstructed energy of electron



A smaller inter-quartile range means a narrow width, *those calibration improvement finally contribute toward a higher resolution on Higgs!*

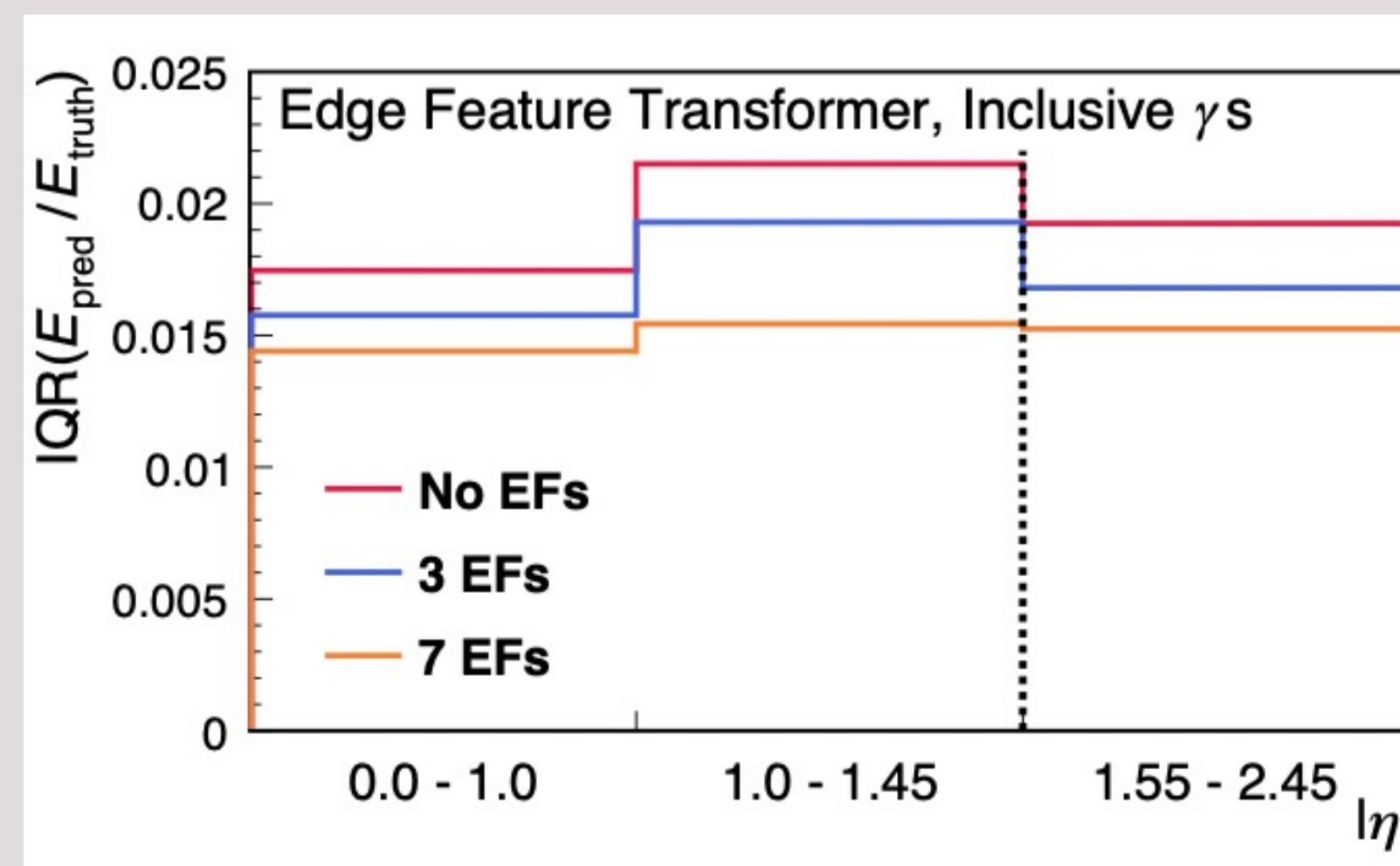
- Resolution of the transformer energy calibration is better by up to **30-40%** for *unconverted photon* at larger η region, less obvious for barrel converted photon. [3]
- More robust against pileup increase** shown in Fig.R.
- More plots in [public results](#).

Fig.R: electron IQR (resolution) against pileup.



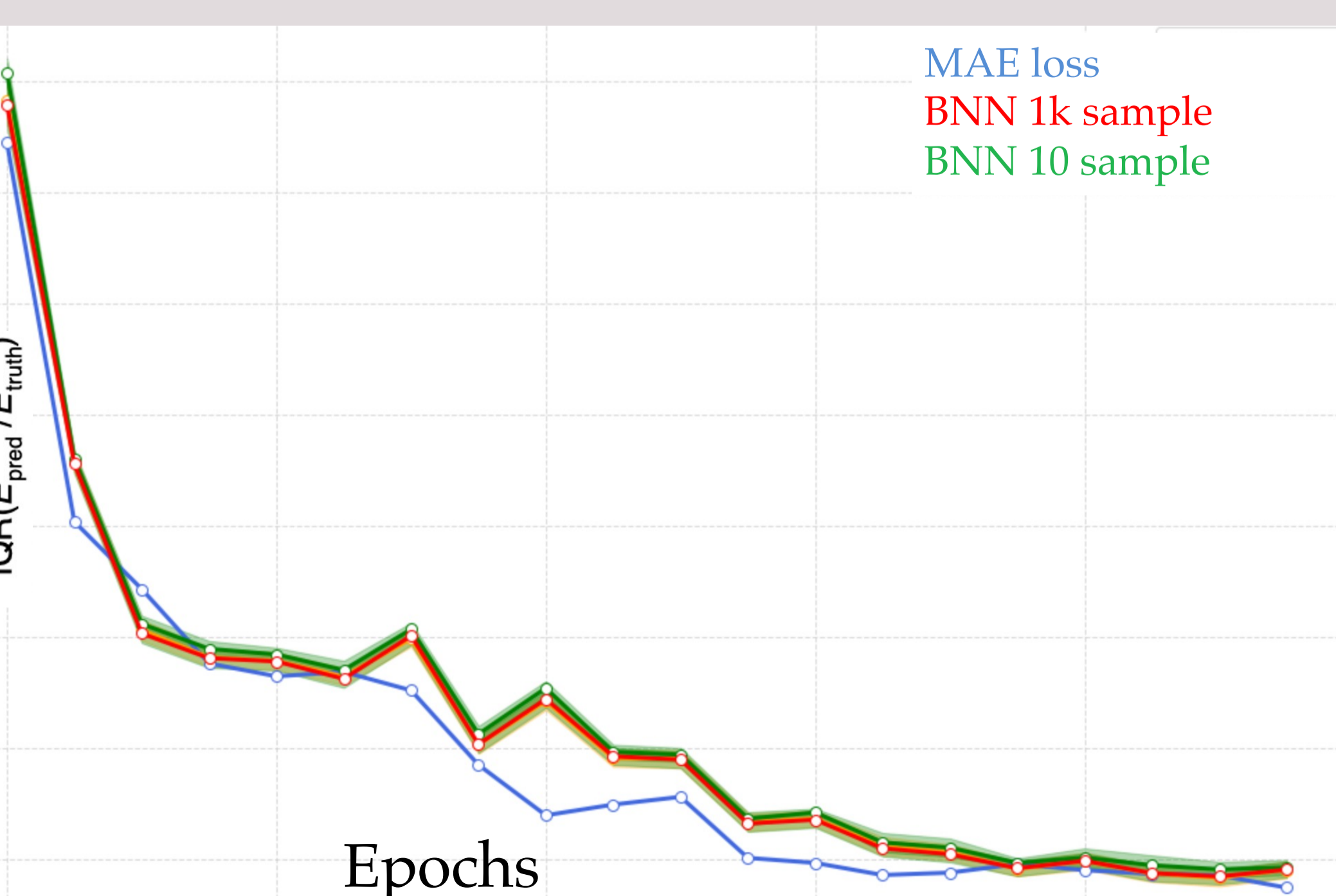
Development

- On-going investigation about archs/loss designs/edge features to boost performance



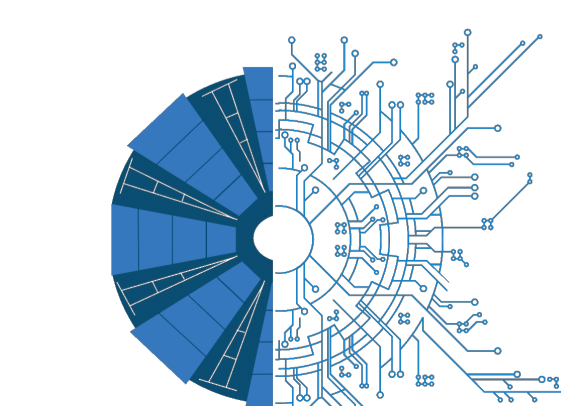
Next

- New model outperforms early-Run3 BDT almost everywhere.
- Test the performance on Data.
- Integrate into official calibration pipeline with latest recommendations.



- Uncertainty-aware decoder head to quantify how certain (or uncertain) those predictions are, improve robustness of the model, more usage to be explored.

[1] ATLAS Collaboration, 'Electron and photon energy calibration with the ATLAS detector using LHC Run 2 data,' JINST 19 P02009, 10.1088/1748-0221/19/02/P02009
 [2] SALT Framework, <https://tag-salt.docs.cern.ch/>
 [3] Roberts, Ryan, Jiang, Cheng, Soppio, Alex, Tarek, Ahmed, and Wang, Haichen. "Transformer for Energy Calibration in the ATLAS Electromagnetic Calorimeter." <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EGAM-2023-01/>



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