Contribution ID: **90**

Type: **Oral**

Attention-Enhanced Lightweight GNNs for LHCb Next-generation Particle reconstruction and Identification

Monday 8 September 2025 15:10 (20 minutes)

We present lightweight, attention-enhanced Graph Neural Networks (GNNs) tailored for real-time particle reconstruction and identification in LHCb's next-generation calorimeter. Our architecture builds on node-centric GarNet layers, which eliminate costly edge message passing and are optimized for FPGA deployment, achieving sub-microsecond inference latency. By integrating attention mechanisms and encoder-decoder structures, our models achieve up to 8× faster inference than traditional message-passing GNNs, while maintaining superior performance over conventional algorithms in terms of energy resolution. Through model compression and firmware-level integration, we enable real-time data filtering in the LHCb trigger system. This work highlights the synergy between efficient AI accelerators and high-energy physics, offering scalable solutions for future particle detection pipelines.

Significance

This work extends the principles of the original GarNet layer with its node-centric aggregation, which eliminated explicit edge features to reduce time complexity. By incorporating learnable attention mechanisms inspired by Graph Attention Networks (GAT), we further improve the model's ability to learn representations. Additionally, a trainable encoder-decoder architecture is introduced to enhance model flexibility. We explore how different variants affect the ability to satisfy the real-time analysis resource and latency constraints.

References

References on the GarNet layer and its FPGA implementation
arXiv:2008.03601
arXiv:1902.07987

Experiment context, if any

LHCb reconstruction with simulations of photons and pions with the baseline PicoCal

Author: PEREZ, Cilicia Uzziel (La Salle, Ramon Llull University (ES))

Co-authors: GOLOBARDES RIBE, Elisabet (La Salle, Ramon Llull University (ES)); SOUZA DE ALMEIDA, Felipe Luan (Syracuse University (US)); ESCHLE, Jonas (Syracuse University (US)); BARTZ, Justin (Syracuse University (US)); CALVO GOMEZ, Miriam (La Salle, Ramon Llull University (ES)); SILVA COUTINHO, Rafael (Syracuse University (US)); VILASIS CARDONA, Xavier (La Salle, Ramon Llull University (ES))

Presenter: PEREZ, Cilicia Uzziel (La Salle, Ramon Llull University (ES))

Session Classification: Track 2: Data Analysis - Algorithms and Tools

Track Classification: Track 2: Data Analysis - Algorithms and Tools