Contribution ID: **79** Type: **Poster + Flashtalk**

Mixture of Expert Graph Transformer for Particle Collision Detection

The Large Hadron Collider (LHC) at CERN generates vast amounts of data from high-energy particle collisions, requiring advanced machine learning techniques for effective analysis. While Graph Neural Networks (GNNs) have demonstrated strong predictive capabilities in high-energy physics (HEP) applications, their "black box" nature often limits interpretability. To address this challenge, we propose a novel Mixture-of-Experts Graph Transformer (MGT) model that enhances both predictive performance and interpretability in collision event classification.

Our approach combines a Graph Transformer architecture with Mixture-of-Experts (MoE) layers, allowing for specialized expert subnetworks that improve classification while maintaining transparency. Attention maps from the Graph Transformer provide insights into key physics-driven features, while the MoE structure enables an analysis of expert specialization, highlighting the model's decision-making process. We evaluate our model using simulated collision events from the ATLAS experiment, focusing on distinguishing rare Supersymmetric (SUSY) signal events from Standard Model background processes. Results show that our model achieves competitive classification accuracy while offering interpretable outputs aligned with known physics principles.

This work underscores the significance of explainable AI in HEP, ensuring greater trust in machine learning-driven discoveries. By embedding interpretability into the model architecture, we provide a powerful and transparent framework for analyzing complex particle collision data, paving the way for more reliable AI-assisted research in fundamental physics.

AI keywords

Graph Transformers; Mixture-of-Experts; Explainability

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Track Classification: Explainability & Theory