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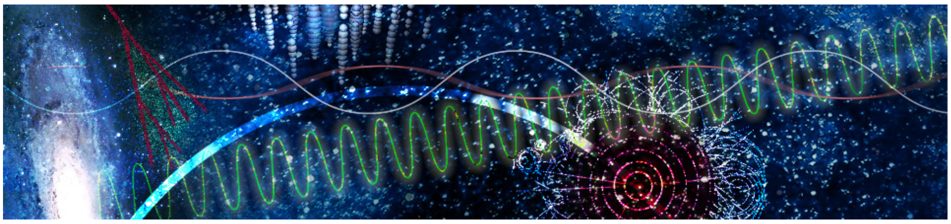

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Identifying Complex Weak Decay Topologies with Graph Neural Networks at the HADES Experiment

Identifying weak decays is a challenging task as they are often obscured by other types of interactions and combinatorial background. However, recent advancements in machine learning have provided new tools to tackle this problem. In particular, Graph Neural Networks (GNNs) have emerged as a promising technique for identifying complex weak decay topologies.

To identify this decay topology, a heterogeneous graph is reconstructed for each collision event. This graph contains two types of nodes: spatial nodes, which are the interaction vertex and the decay vertex, in addition to the final state particles that are represented as graph nodes. In addition, a graph is connected by two types of edges: weighted and unweighted. The interaction vertex and the delayed vertex are connected by an edge that is weighted by the distance between the vertices. In addition, the decay products of the weakly decaying particle are connected by an edge that is weighted by the opening angle between the particles. Furthermore, daughter particles are connected to the delayed vertex and primary particles are connected to the interaction vertex by unweighted edges.

A preliminary GNN model has been developed to identify Lambda hyperon ($\to p\pi^-$) as a case study, and it was shown to be effective. The model architecture utilized two Graph convolution layers, which were implemented using using PyTorch-Geometric. The GNN model was able to identify the Λ hyperon with high accuracy, demonstrating the effectiveness of the proposed approach. Future work includes scaling up the GNN model to handle larger datasets and applying it to other complex decay topologies that involve multiple delayed vertices.

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