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Deep Learning for Primary Vertex Identification in the ATLAS Experiment

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The exponential time scaling of traditional primary vertex reconstruction algorithms raises significant performance concerns for future high-pileup environments, particularly with the upcoming High Luminosity upgrade to the Large Hadron Collider. In this talk, we introduce PV-Finder, a deep learning-based approach that leverages reconstructed track parameters to directly predict primary vertex positions and track-to-vertex associations. Primary Vertex identification is achieved using a multi-layer perceptron (MLP) that converts track data into one-dimensional probability distributions, known as kernel density estimations (KDEs). These KDEs then serve as inputs to a convolutional neural network (CNN), specifically utilizing UNet and UNet++ architectures, to refine vertex position predictions. More recently, we have also explored the integration of graph neural networks (GNNs) to enhance track-vertex association. Preliminary results demonstrate that PV-Finder offers improved vertex reconstruction efficiency and accuracy, making it a compelling alternative to traditional methods.

Significance

This presentation introduces novel algorithmic development in the form of PV-Finder, a new deep learning-based framework for primary vertex reconstruction, tailored for the challenges of high-pileup environments expected at the HL-LHC. Rather than simply reporting on existing approaches, it presents a new methodology that replaces traditional, computationally intensive vertexing algorithms with a machine learning pipeline. The preliminary results suggest clear performance improvements in both efficiency and accuracy over existing techniques, which is essential for scaling to HL-LHC conditions. These advancements represent a substantial step forward in applying modern ML techniques to solve a core reconstruction problem in high-energy physics.

References

Experiment context, if any

ATLAS, CMS

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