Introduction

In high-energy physics, particle accelerators are built to gain insight into elementary particles by colliding them into a nuclear target or against other particles. The reactions from the collision transform the incoming particles into a sort of output particles, known as physics "events." Existing high-energy accelerators include the LHC at CERN for proton-proton collisions, CEBAF at Jefferson Lab for po-larized electron-hadron scattering, as well as the future Electron-Ion Collider (EIC) [6].

Overview

The goal of this project is to develop a machine learning event generator (MLEG) that can faithfully reproduce particle events at the vertex level that is free of theoretical assumptions about underlying particle dynamics. By training the model at the event level using the reconstructed detector-level particle four-vectors, the model can capture all the relevant particle correlations without the need to a priori specify certain observables of the study. The MLEG can thus be viewed as a compactified data storage utility that can provide future access to observables not conceived of at the time of the original experiments. The successfully trained MLEG will be a valuable software tool for phenomenological studies at JLabs and beyond, providing a unique avenue for quantitatively testing the validity of theoretical approximations implemented in QCD factorization theorems.

Methods

During the initial phase of the project, we have successfully developed an event generator that can simulate particle events.

- We use generative adversarial networks (GANs) [1] to build the MLEG. Since the GAN is trained at the event level, the major challenge has been to identify a suitable data representation.
- We incorporate maximum mean discrepancy kernel test [7] to increase the precision of the generated distributions.
- We transform the features to address the sharp peaks in the dataset. For example, instead of directly using $p_T$ as a generated feature, we use the transformed variable $E/p_T - z$.
- We enhance the training by augmenting new features to increase the sensitivity of the discriminator. For instance, we use a customized layer to calculate the momentum energy which than passed to the discriminator. The energy $E$ can be calculated as $E = \sqrt{p_T^2 + p_x^2 + p_y^2 + p_z^2}$.

Results

To validate the MLEG, we first train on synthetic events generated from Pythia 8 [2]. Our results [8] show a good agreement with the true distribution (Pythia). We also see in Fig. 2 the model can capture the underlying correlations between the features.

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end-to-end physics event generator

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