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Deep Learning Algorithm for dN/dx in a Pixelated TPC

Particle identification (PID) plays a crucial role in particle physics experiments. A groundbreaking advancement in PID involves cluster counting (dN/dx), which measures primary ionizations along a particle's trajectory within a pixelated time projection chamber (TPC), as opposed to conventional dE/dx measurements. A pixelated TPC with a pixel size of 0.5x0.5 mm2 has been proposed as the gaseous detector for the Circular Electron Positron Collider (CEPC) to achieve exceptional hadron identification, which is particularly vital for flavor physics studies.

One of the major challenges in dN/dx lies in the development of an efficient reconstruction algorithm capable of extracting cluster signals from 2D pixel readouts. Machine learning algorithms have emerged as state-of-the-art solutions for PID. To address this challenge, we have designed a sophisticated simulation software framework that incorporates detector geometry, gas ionization, electron drift and diffusion, signal amplification, and pixel readout to generate large datasets. A deep learning algorithm tailored for point cloud data has been developed, utilizing a graph neural network implementation of the point transformer. By training the neural network on a substantial dataset of simulated events, the particle separation power has improved by 15% to 30% for pions and kaons within a momentum range of 2.5 to 20.0 GeV/c, compared to traditional dN/dx reconstruction algorithm.

Significance

The pixelated TPC is a key tracker detector for the CEPC, designed to deliver outstanding PID capabilities crucial for physics studies. The deep learning algorithm developed in this study significantly enhances particle separation power by 15% to 30% for momenta in the tens of GeV/c, compared to the traditional truncated mean method. Furthermore, when compared to the conventional dE/dx approach in a large pad (1×6 mm^2) readout TPC, the particle separation power is improved by an additional 20%. This represents a major breakthrough in PID technology.

References

I have been working on the dN/dx reconstruction for the drift chamber, which is related to this topic. Two related publications are:
https://doi.org/10.1016/j.cpc.2024.109208 (published by Comp. Phys. Commu.)
https://arxiv.org/abs/2402.16493 (accepted by Nuclear Science and Techniques)

Experiment context, if any

CEPC

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