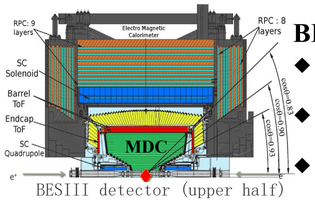
BESIII track reconstruction algorithm based on machine learning

Xiaoqian Jia[1] , Xiaoshuai Qin[1] , Teng Li[1] , Xingtao Huang[1] , Xueyao Zhang[1] , Yao Zhang[2] and Ye Yuan[2]

1. Shandong University, Qingdao, China 2. Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China

Motivation



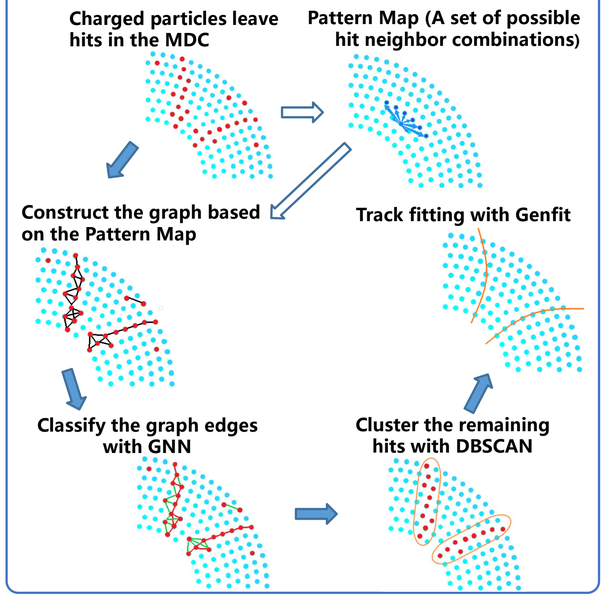
BESIII

- Operate at Beijing Electron-Positron Collider II (BEPCII)
- CMS: 2.0 - 4.95 GeV, τ -charm region
- Study the electroweak and strong interactions

Track finding algorithm

- Play essential roles in the offline data processing
- Traditional algorithms include template matching, track segment finder and Hough transform etc.
- Potential improvement for low momentum tracks and tracks with high noise level.

Methodology



Filtering Noise via GNN

◆ Pattern Map based on MC simulation

- The collection of sense wires that could potentially represent two successive hits on a track
- Two million single tracks ($e^{\pm}$, $K^{\pm}$, $\mu^{\pm}$, $p^{\pm}$, $\pi^{\pm}$) from BESIII MC truth information used to build pattern map
- To reduce the number of fake edges during graph construction

◆ Graph construction

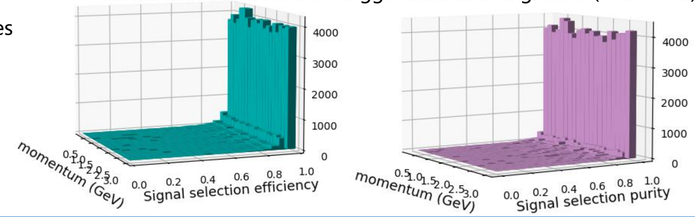
- Edge assignment based on Pattern Map
  - Hit with its neighbors on the same layer, next layer
  - Hit with its neighbors' neighbors on one layer apart
- Node features
  - Raw drift time, 2D coordinates of the sense wires

◆ Edge Classifier based on GNN

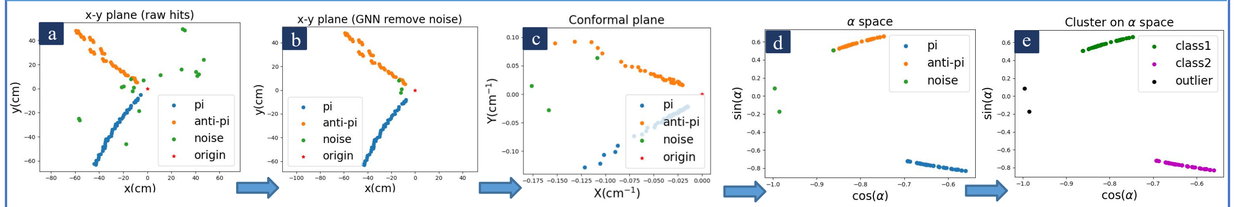
- Input network
  - Node features embedded in latent space
- Graph model
  - Node network and Edge network, MLPs
  - 8 graph iterations
- High classification score
  - The edge belongs to a true particle track
- Low classification score
  - It is a spurious or noise edge

◆ Signal selection performance

- Single-particle ($e^{\pm}$, $K^{\pm}$, $\mu^{\pm}$, $p^{\pm}$, $\pi^{\pm}$) MC sample
- Mixed with BESIII random trigger data as background (~45% hits)



Clustering of Tracks Based on DBSCAN



(a) Original MC data sample

- $J/\Psi \rightarrow \rho^0 \pi^0 \rightarrow \gamma\gamma\pi^+\pi^-$
- π^+, π^- : P_t (0.2GeV - 1.4GeV)

(b) Remove noise via GNN

(c) Transform to Conformal plane

- $X = \frac{2x}{x^2+y^2}$ $Y = \frac{2y}{x^2+y^2}$
- Circle passing the origin transform into a straight line

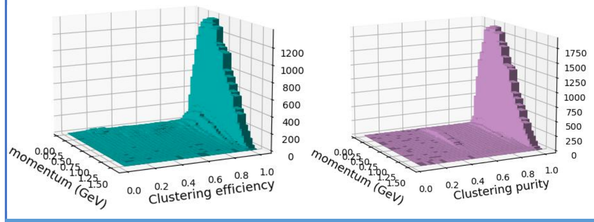
(d) Transform to 'α' parameter plane

- Connect the hits and origin in the X-Y plane
- α as the angle between the straight line and X axis
- The parameter space as cos (α) and sin (α)

(e) DBSCAN clustering in 'α' parameter plane

- Density-Based Spatial Clustering of Application with Noise
- Hits in a cluster are considered to be in the same track

◆ Clustering performance



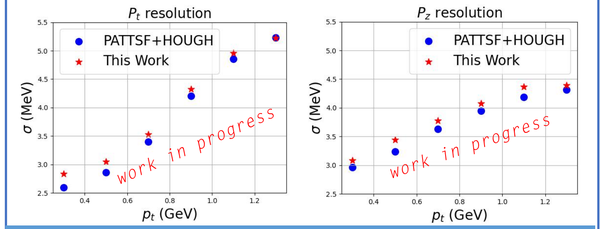
Preliminary Results

Genfit

Track fitting algorithm based on Genfit is used to reconstruct p_t and p_z

Particle reconstructed performance

◆ $J/\Psi \rightarrow \rho^0 \pi^0 \rightarrow \gamma\gamma\pi^+\pi^-$



Conclusions

We demonstrate a novel tracking algorithm based on machine learning method

- GNN to distinguish the hit-on-track from noise hits.
- Clustering method based on DBSCAN to cluster hits from multiple tracks.

The preliminary results present promising performance, and further optimization of the model is needed to boost reconstructed performance.

Reference

1.Steven Farrell et al, arxiv: 1810.06111

2. Jin Zhang et al, DOI:10.1007/s41605-018-0052-4

3. A Generic Track-Fitting Toolkit. *https://github.com/GenFit/GenFit*