Progress in CEPC Drift Chamber Track Reconstruction

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2023 CEPC workshop at Nanjing

27-October-2023

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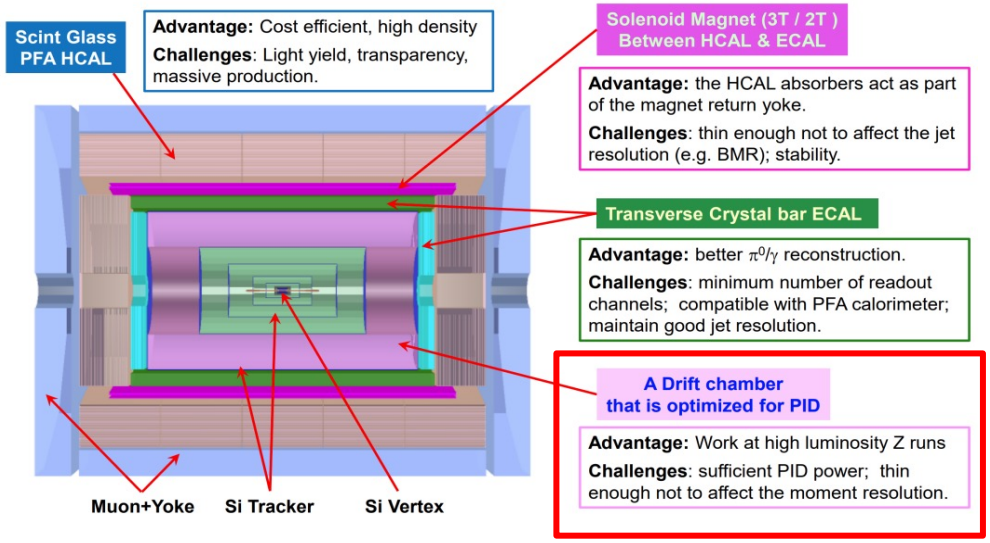
Detector

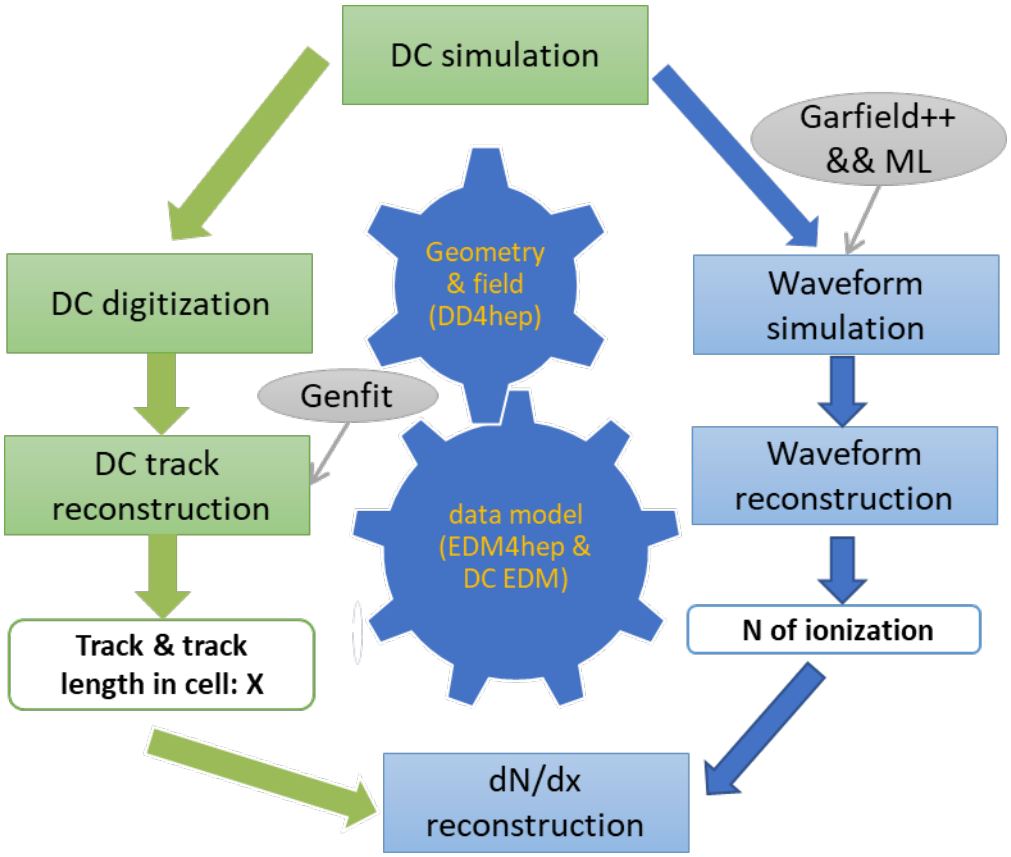
- The CEPC experiment mainly aims to precisely measure the property of the Higgs boson.
- Physics requirements: high track efficiency (~100%), momentum resolution (<0.1%), PID (2σ p/K separation at P < ~ 20 GeV/c), etc.



- For the 4th conceptual detector, silicon detector and drift chamber (DC) are designed to provide both tracking and PID for charged particles.
- Both detector design and physics potential studies needs strong support of simulation and reconstruction software.

DC software

- The drift chamber software has been developed from scratch
- CEPCSW
  - Gaudi based framework
  - External libraries and tools
- Geometry and field map
  - DD4hep
  - Non-uniform magnetic field
- Data model
  - EDM4hep and FWCore
  - dN/dx event model
- Drift chamber
  - DC simulation
  - DC digitization
  - Track finding
  - Track fitting
  - Multi track reconstruction
- Implemented offline simulation and reconstruction software

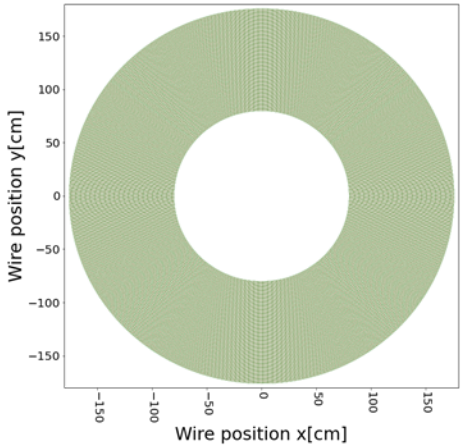


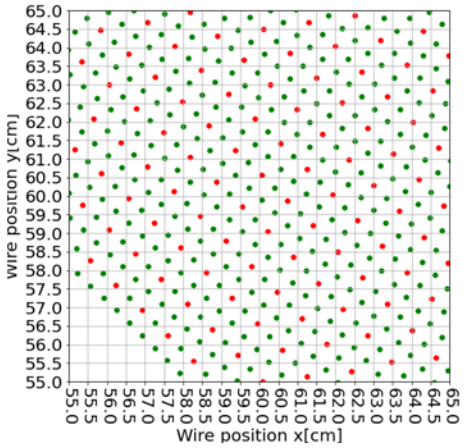
Drift chamber simulation and reconstruction flow

Drift Chamber

- The baseline configuration of DC in CEPCSW
  - The following results with the 55-layer geometric configuration

Half length	2980 *mm*
Inner and outer radius	800mm to 1800 *mm*
# of Layers	100/55
Cell size	~10mmx10mm/18mmx18mm
Gas	He:iC_4H_{10}=90:10
Single cell resolution	0.11 *mm*
Sense to field wire ratio	1:3
Total # of sense wire	81631/24931
Stereo angle	1.64~3.64 *deg*
Sense wire	Gold plated Tungsten ϕ=0.02*mm*
Field wire	Silver plated Aluminum ϕ=0.04*mm*
Walls	Carbon fiber 0.2 *mm*(inner) and 2.8 *mm*(outer)





Cell structure

DC Simulation

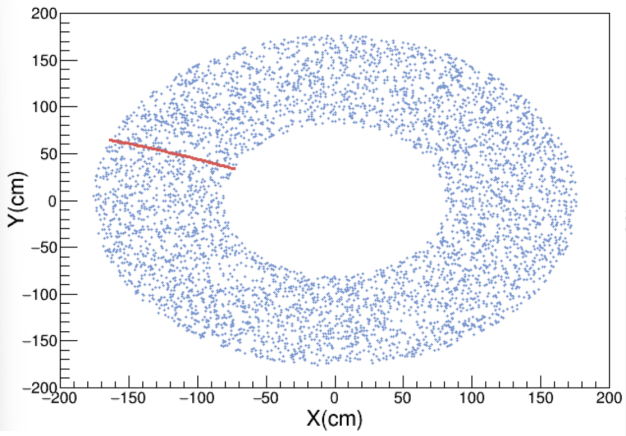
- Following the common scheme for detector description
  - XML based compact files for drift chamber detector description
  - CRD: Detector/DetCRD/compact/CRD_oX_vYY/CRD_o1_vYY.xml
  - Geometry parameters can be flexibly configured

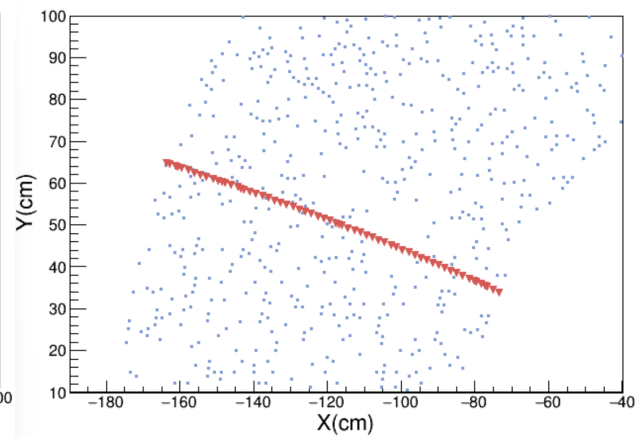
```
<constant name="DC_layer_number" value="55"/>
<constant name="DC_cell_width" value="18*mm"/>
<constant name="Alpha" value="12*deg"/>
```

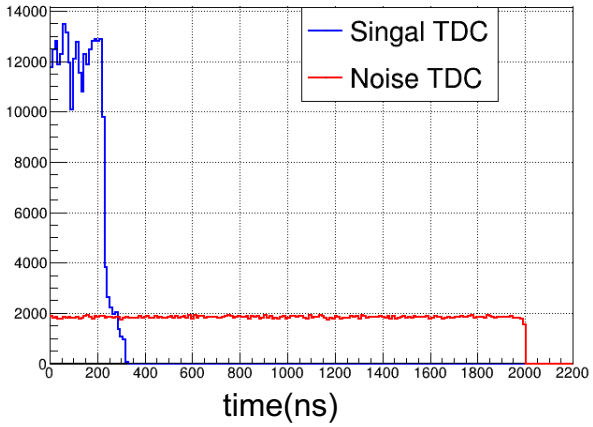
- Cell partitioning with segmentation
  - Consistent between simulation, reconstruction, and analysis
- Simple digitization
  - Constant drift velocity: V_{drift}=40μm/ns & fixed spatial resolution: σ=110μm

Mixing Background

- To simulate the real detector condition
- Noise level:
  - uniform, random
  - can be configured flexibly
- Signal & Noise TDC
  - Noise time window: 0~2000ns







The position of the noise hit (blue) with a noise level of 20% and signal hit (red) on the XY plane

- Introduction
- Track reconstruction
  - Track finding
  - Track fitting
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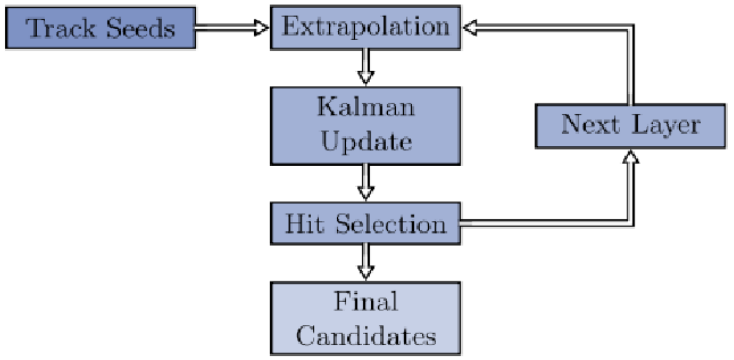
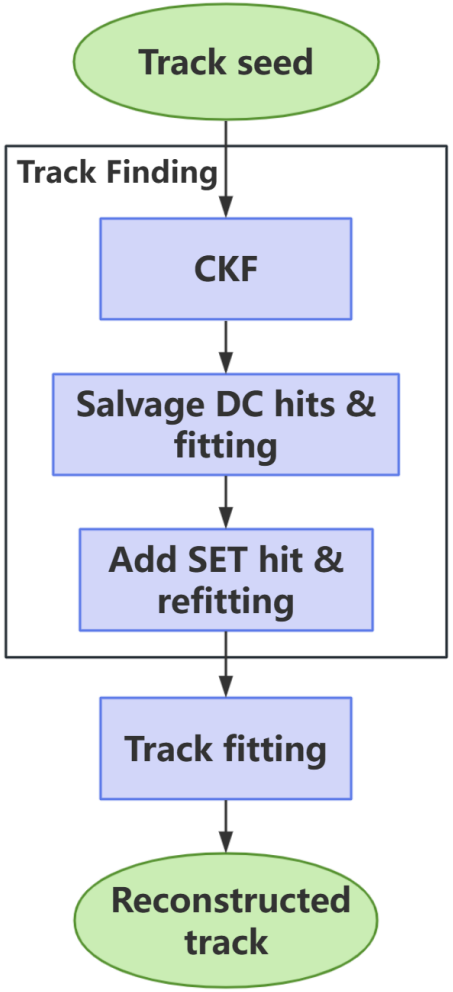
Track Finding

- Tracking strategies:
  - Track seed:
    - Reconstructed track of the silicon tracker
  - CKF(Combinatorial Kalman Filter):
    - Migrated from BelleII
      - Geometry
      - Field
      - Data IO
    - Finding most of the DC hits at the same track
    - One hit can be found in each layer



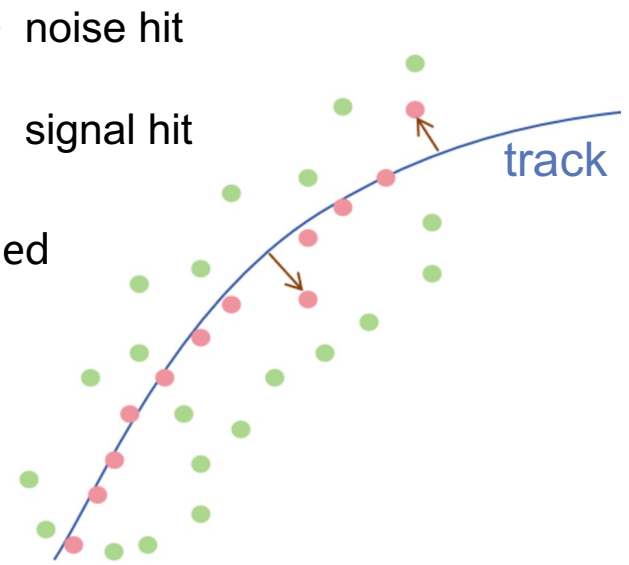
Basic procedure behind the CKF

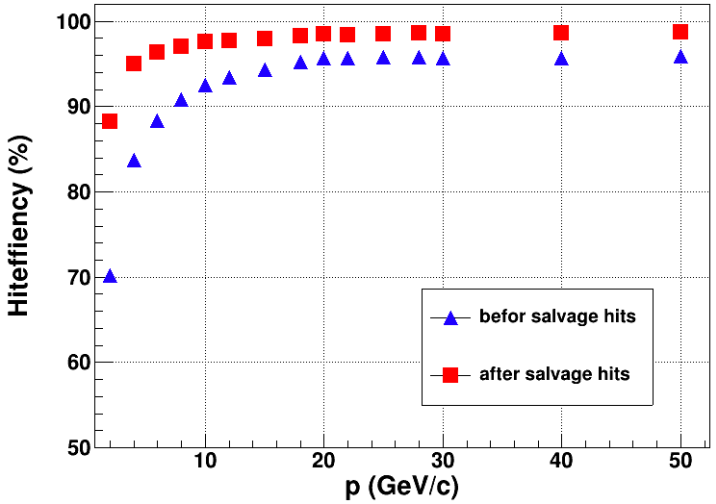


Workflow of track reconstruction

Track Finding

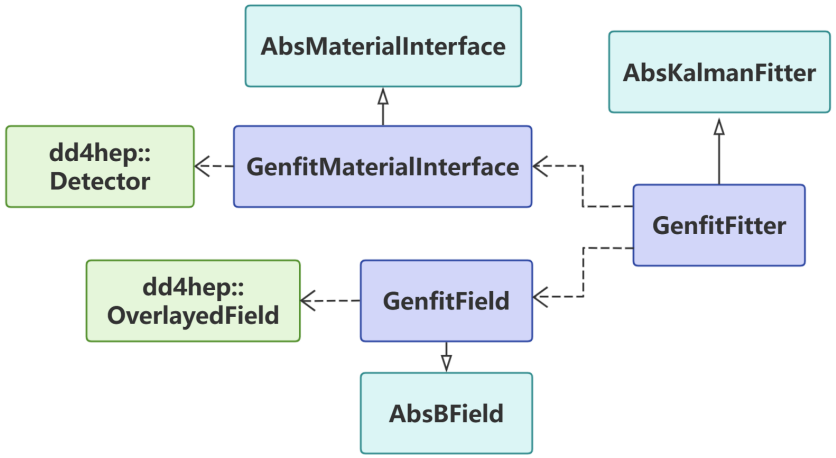
- Tracking strategies:
  - Salvaging the remaining DC hits:
    - Fully self-developed
    - Hits belonging to the same track are be salvaged
    - Using extrapolation based on GenFit
    - Significantly improve hit efficiency
      - $\epsilon = N_{Found\ signal\ hits}/N_{Truth\ signal\ hits}$
  - Add Silicon External Tracker(SET) hit:
    - Located on the outer side of the DC
    - Sorting hits for track fitting: track length



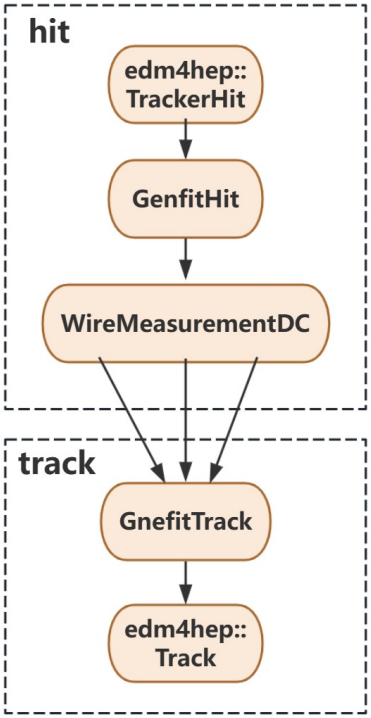


Track Fitting

- GenFit: https://github.com/GenFit/GenFit/
  - Experiment-independent generic modular framework for track-fitting
  - Official track fitting for BelleII, also used by PANDA, COMET, GEM-TPC etc.
  - Kalman Filter, ***Deterministic Annealing Filter***, and General Broken Lines fitter, etc.
- Integration:
  - Genfitter: the core of track fitting algorithm
  - GenfitField, GenfitMaterialInterface
  - GenfitHit, GenfitTrack



Integration of GenFit with CEPCSW



Data Stream of track reconstruction

- Introduction
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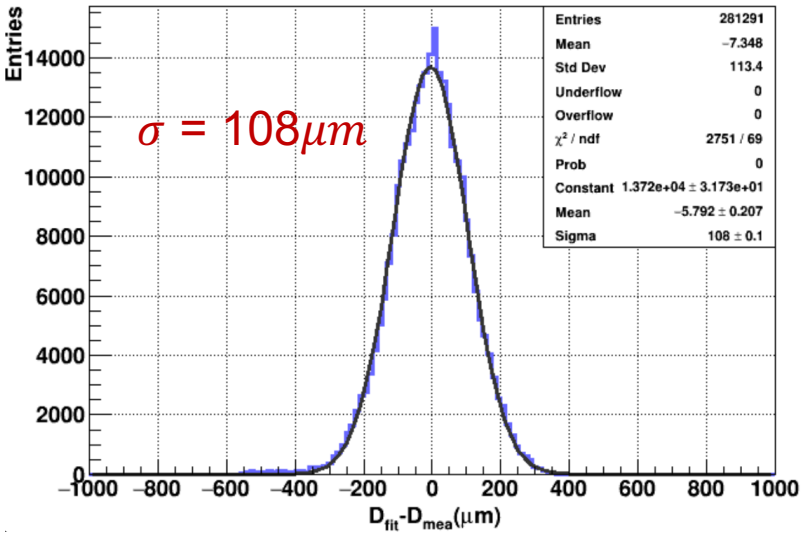
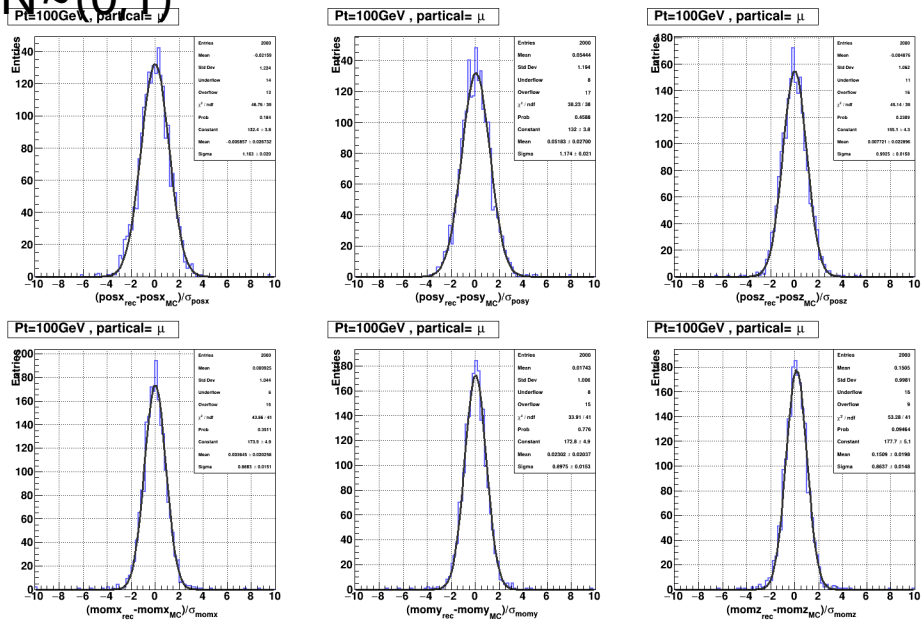
Quality of track fitting

- Data Sample: Single $\mu^-, |cos\theta| \in [0,0.766], p_T = 10GeV/c$ with single cell resolution of $110\mu m$
- Spatial resolution smaller than $110\mu m$ because use the fitting of including the current hit
- Track pull distribution follows N~(0,1)



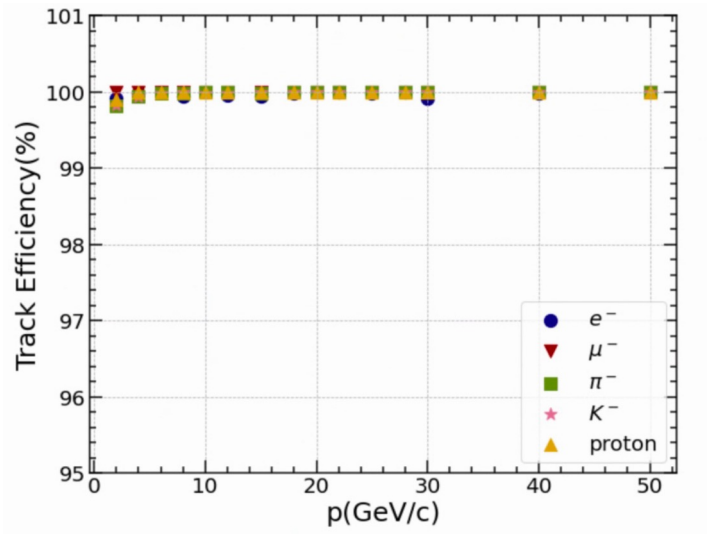


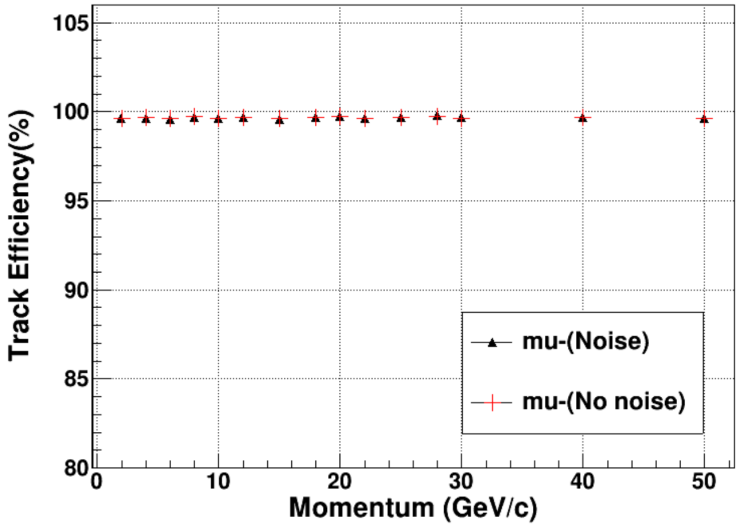
Normalized parameter residual distributions

- The estimation of the track parameter and error is reliable

Tracking Efficiency

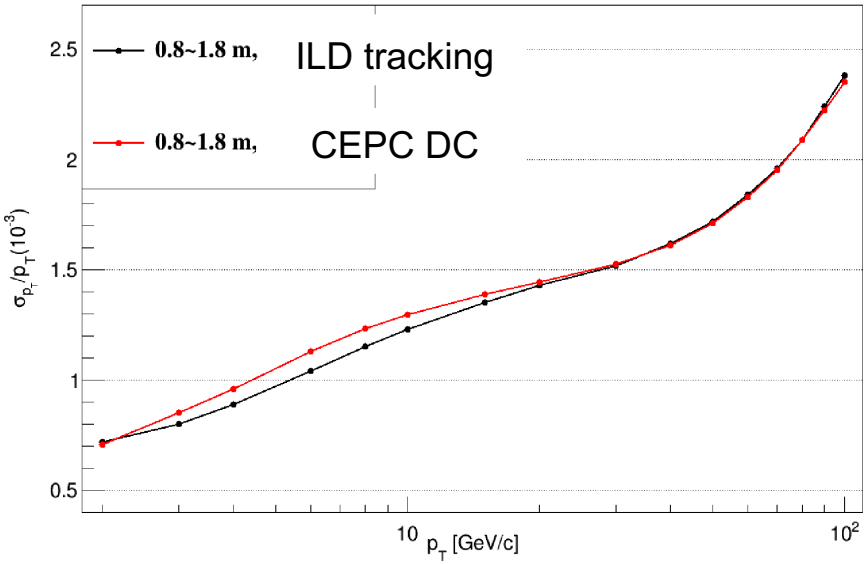
- Data sample: Single particle , $|cos\theta| \in [0,0.766]$
- Track Efficiency = N_1/N_2
  - N_1 is the number of track satisfying:
    - $\chi^2 < 400$
    - $N_{DC\ signal\ hits\ on\ track} > 6$
  - N_2 is the numbre of silicon track
- >99.8% tracking efficiency for single particle
- Track efficiency is closely to 99.8% for single μ^- both without noise and with a noise level of 20%

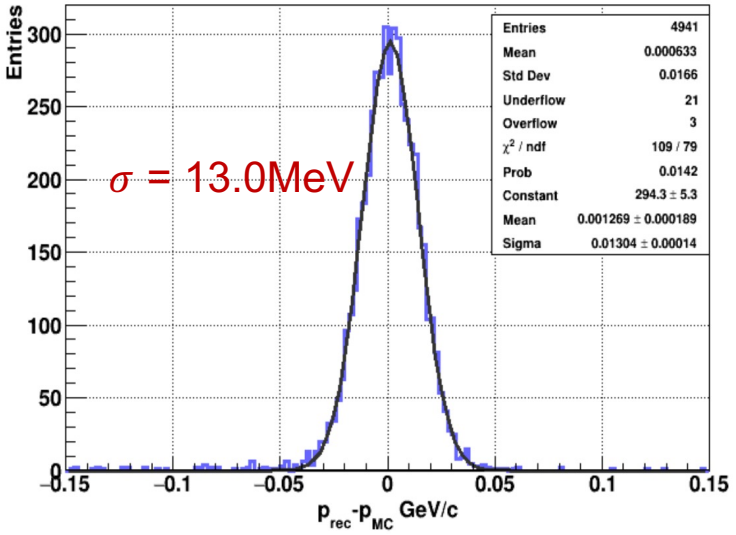




Momentum Resolution

- Data Sample: Single particle $\mu^-, \theta = 85°$
- Combined measurement of Silicon and Drift Chamber
- Momentum resolution is reasonable and consistent with ILD tracking

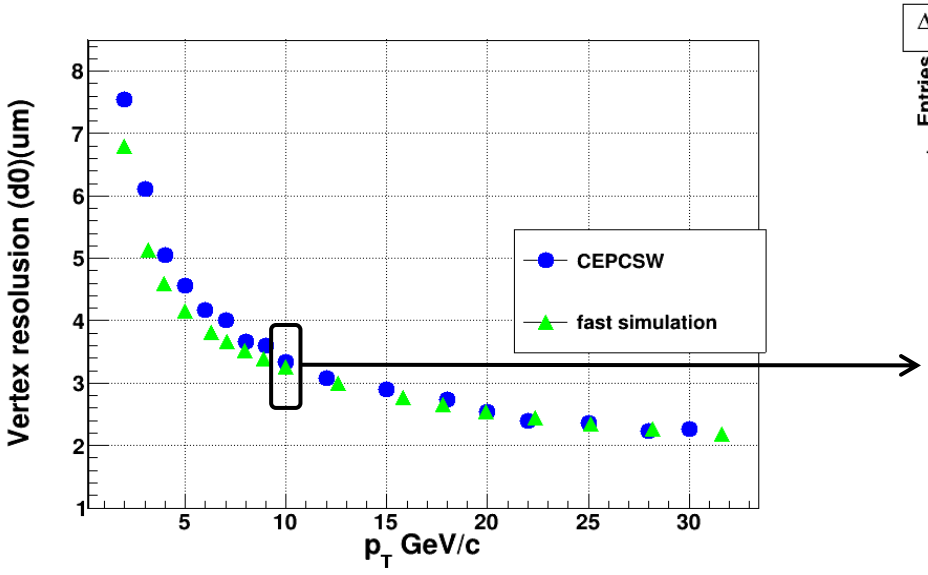


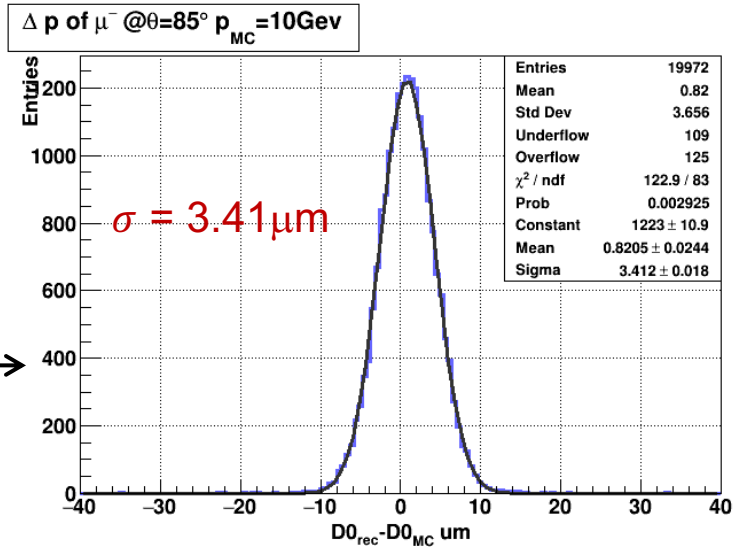


Momentum distribution of 10GeV/c μ^-

Impact Parameter

- Data Sample: Single particle $\mu^-, \theta = 85°$
- Impact parameter
  - $\sigma_{d0} = 3.41\mu m \ with \ p_T = 10GeV/c$
  - Consistent with fast simulation

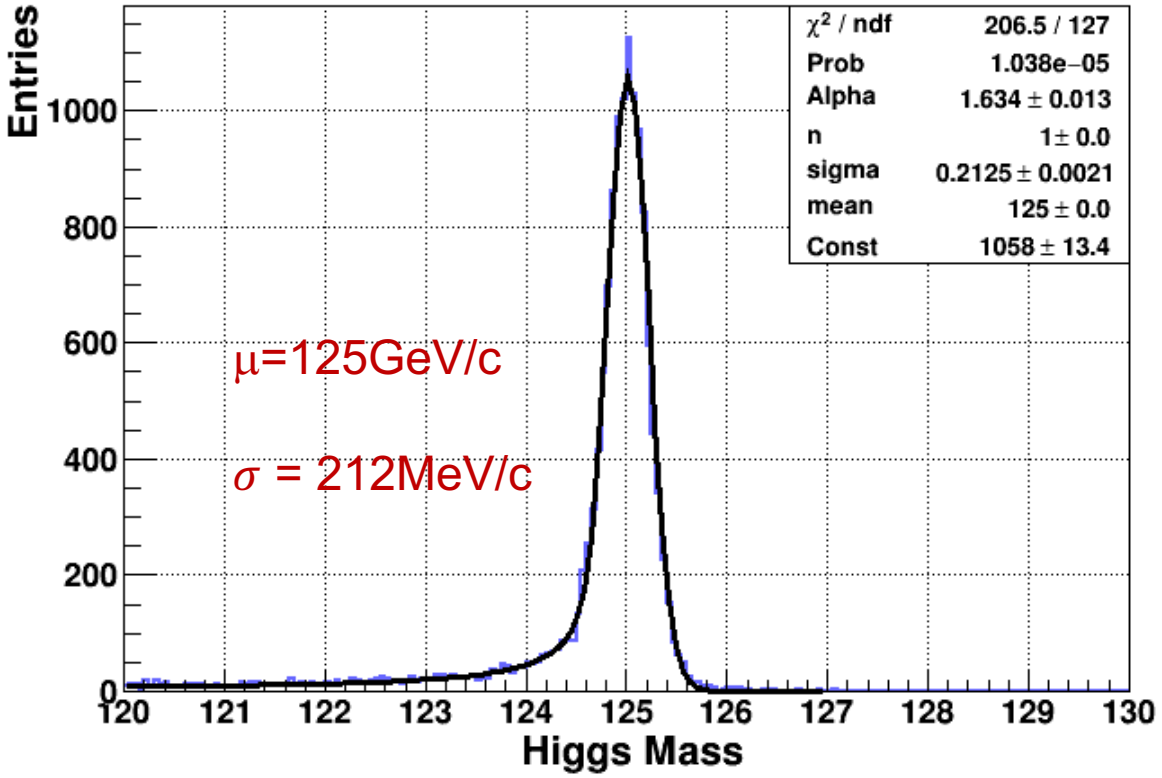




Momentum distribution of 10GeV/c μ^-

Physics Event Reconstruction

- Higgs reconstruction for $H \rightarrow \mu^+\mu^-$
- Can be used for physics simulation studies



Summary

- Developed independently a seed-based DC tracking algorithm starting from scratch
- Tracking is preliminarily implemented with noise at CEPC
- Promising tracking performance is achieved
  - >99.8% track efficiency for single particle
  - Tracking exhibits good robustness
  - Implementing the physics event reconstruction and get reasonable result

Thank You !