Software for the CEPC Drift Chamber

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On behalf of drift chamber working group

The Joint Workshop of the CEPC Physics

Software and New Detector Concept

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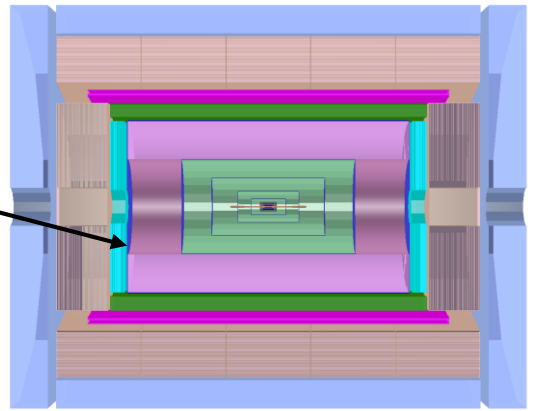
Outline

- Motivation
- Simulation and digitization
- Tracking algorithms
- Summary

Drift Chamber(DC)

- Drift chamber is the key detector in the 4th conceptual detector design to provide PID
  - Good PID ability (2σ π/K separation at P < ~ 20 GeV/c)
  - Precise momentum measurement (eff. ~100%, σp<=0.1%)



- Motivation of DC software
  - A demonstration for the development of CEPC software
  - Provide detector layout optimization with full simulation
  - Detailed dN/dx study

- Requirements for DC software
  - Configurable simulation
  - Fast iteration for dN/dx study
  - Adaptive tracking

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	m_H, $\sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV})\sin^{3/2}\theta}$

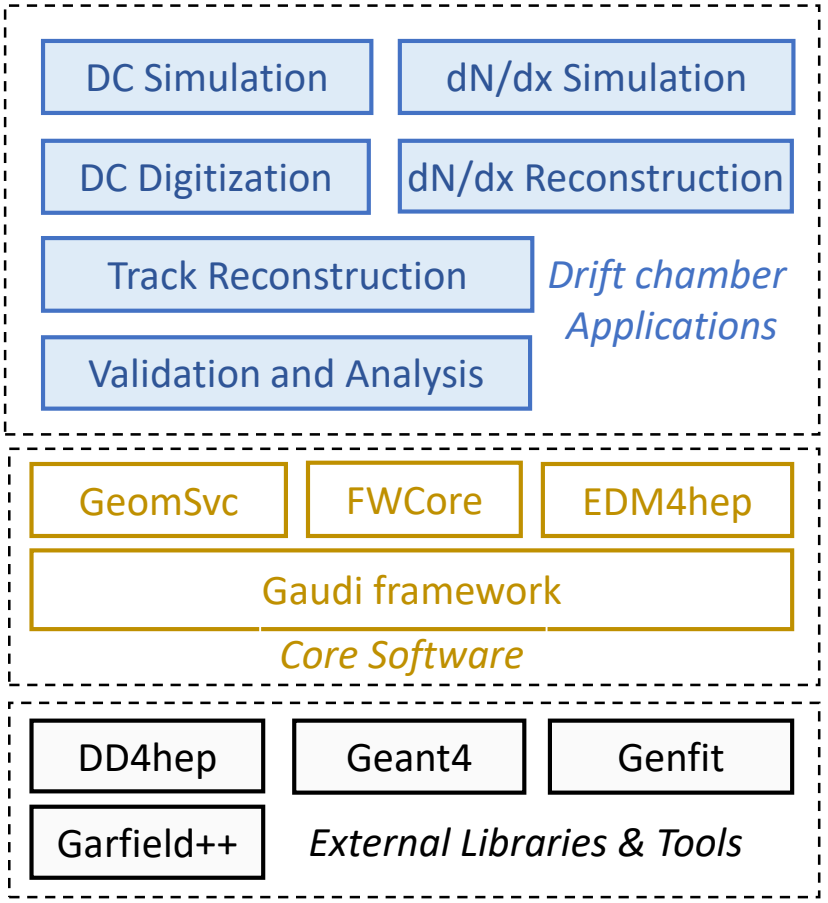
Requirements of The CEPC tracker

- Personpower
  - IHEP: Yao Zhang, Tao Lin, Wenxing Fang, Chengdong Fu, Ye Yuan, Weidong Li
  - SDU: Mengyao Liu, Xueyao Zhang, Xingtao Huang

DC software in CEPCSW

The drift chamber software has been developed from scratch

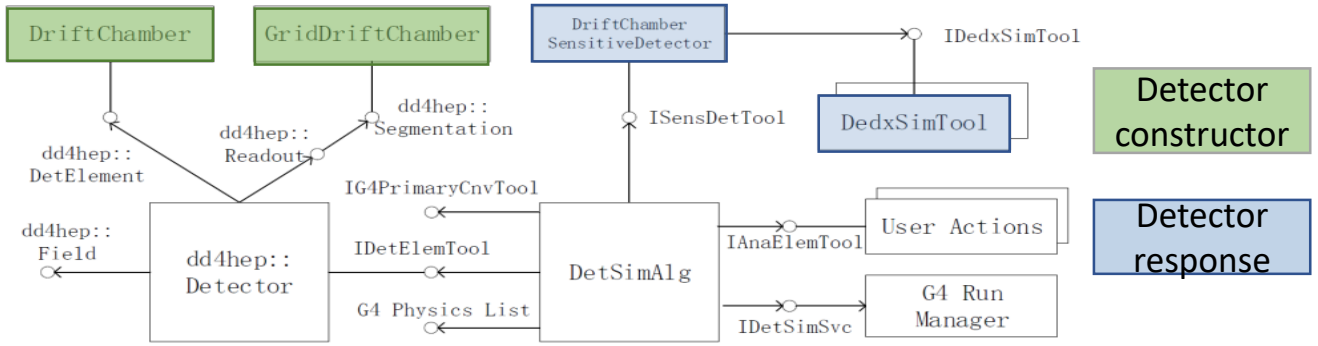
- CEPCSW
  - Gaudi based framework
  - External libraries and tools
- Geometry and field map
  - DD4hep
- Data model
  - EDM4hep and FWCore
- Drift chamber
  - DC Simulation
  - DC Digitization
  - dN/dx simulation
  - dN/dx reconstruction
  - Track reconstruction



https://github.com/cepc/CEPCSW

Simulation and digitization(I)

- The DC simulation is implemented in the simulation framework

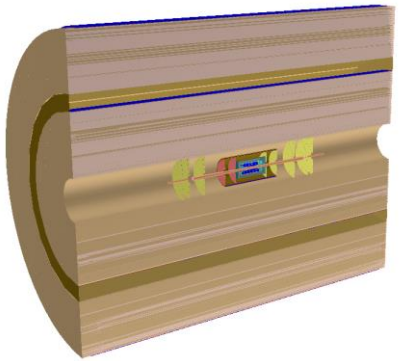


Simulation framework

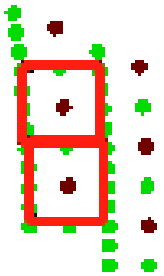
- Detector description
  - Following the common scheme for detector description
  - DC constructor (axial and stereo layers available)
    - Detector/DetDriftChamber/src/driftchamber/DriftChamber.cpp
    - Detector/DetSegmentation/src/GridDriftChamber.cpp
  - Layer and cell partitioning with the segmentation method (consistent with tracking)
  - XML based compact files for drift chamber detector description
    - DC : Detector/DetDriftChamber/compact/det.xml
    - CRD: Detector/DetCRD/compact/CRD_oX_vYY/CRD_o1_vYY.xml
  - Layer and number of DC are configurable
  - Solved overlap between detector elements

Simulation and digitization(II)

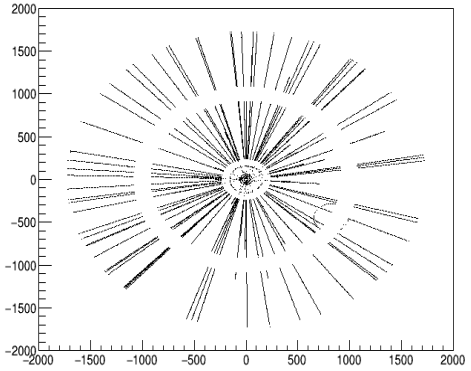
- Detector response
  - One MC hit is generated for each G4Step
  - dE/dx: deposit energy of the hit
  - Association between MC hits and primary MC particles are recorded
  - Both material and BField effects are taken into account by G4
- Simple digitization
  - Constant X-T (V_{drift}=40μm/ns) and fixed spatial resolution (110μm)
- Baseline configuration
  - Two axial drift chambers with silicon layers
  - Radius **1.8**m, **130** layers, He:iC_4H_{10}=**90:10**



CEPC axial drift chamber with silicon layers



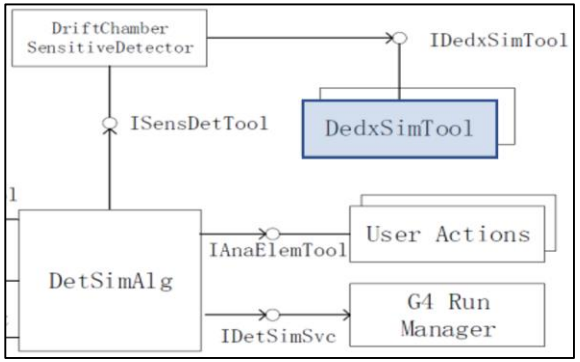
Cell structure
sense:field=1:5



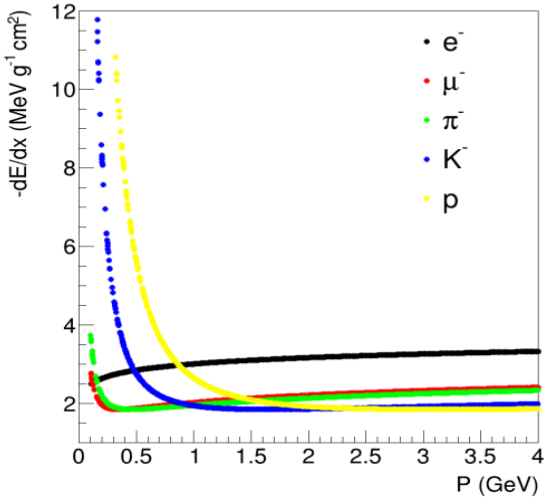
Hitmap of MC hits in DC and silicons

dE/dx simulation

- The configurable fast sampling tool
  - Hit/track level sampling from empirical formula
  - Other sampling method is easy to be plugged in

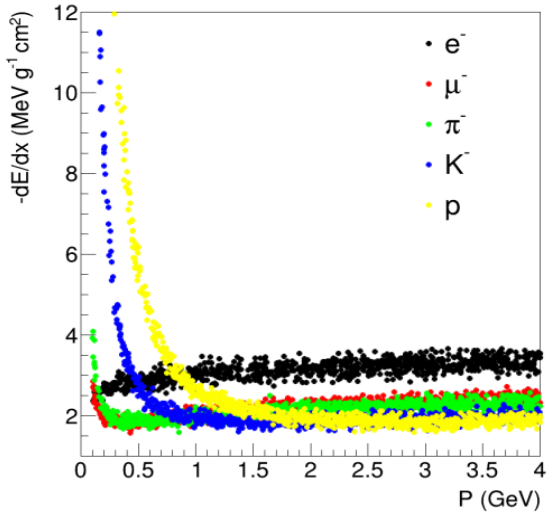


dE/dx from Bethe-Bloch equation



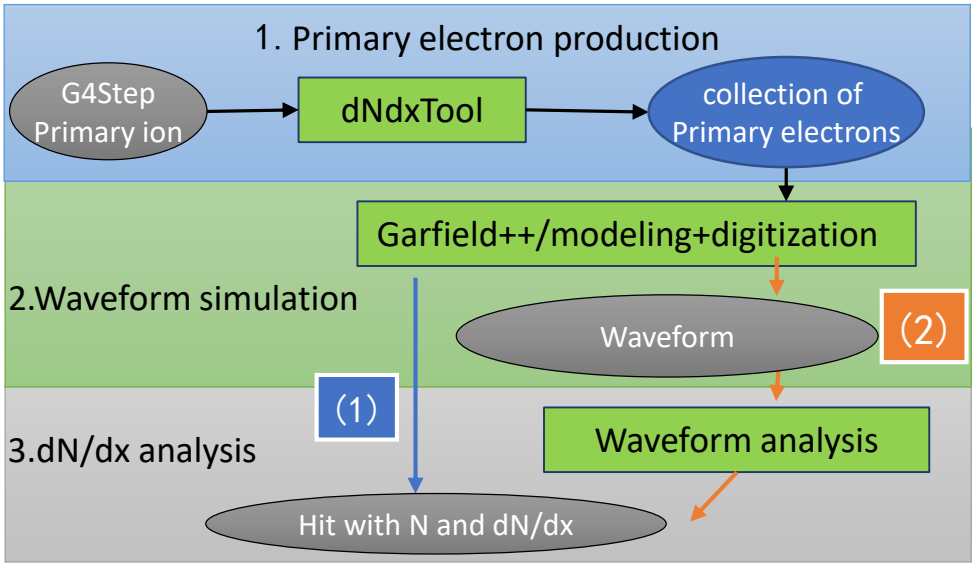
5% smeared

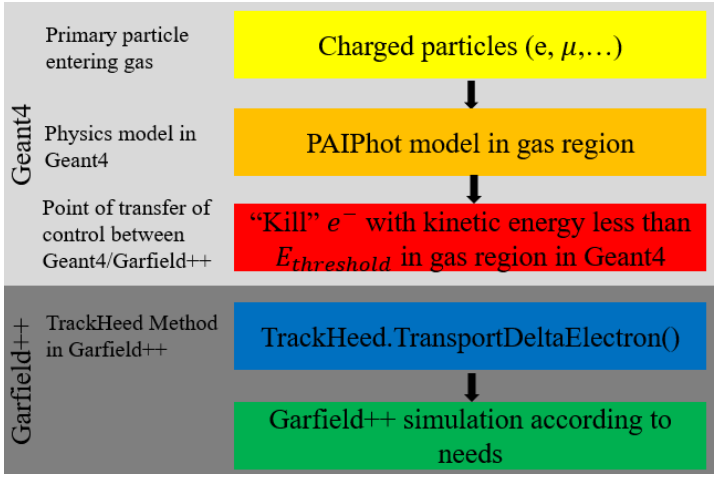
dE/dx after fast sampling



dN/dx simulation

- Primary electron production
  - Geant4 PAI model
  - Parameters to be tuned: electron production cut and the kinetic energy threshold
- Waveform simulation: Delta electron transport, avalanche and induce
  1. Garfield++ realized in CEPCSW (accurate but slow)
  2. Modeling or parameterization (fast but not very precise)
- A track level dN/dx sim. with Garfield++ in CEPCSW is ready

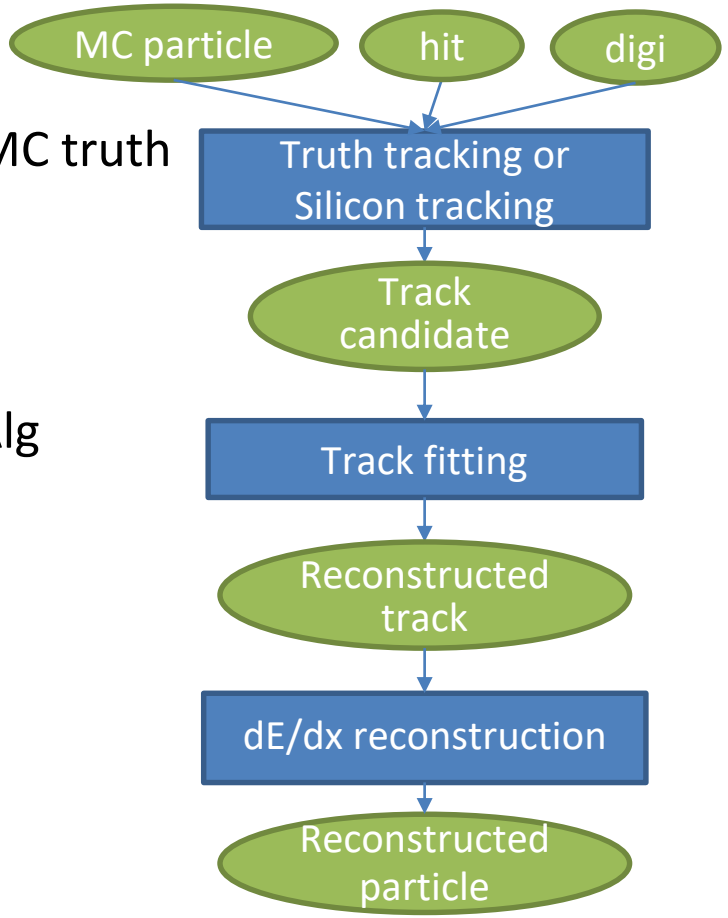




Simulation with Garfield++ in CEPCSW

DC reconstruction

- Track finding
  1. Truth tracking: A fake track finding from MC truth
  2. Silicon tracking
- Track fitting
  1. New developed track fitting -- RecGenfitAlg
     - A combined track fitting of silicon + DC realized
  2. A full silicon+DC tracking -- KalTest
     - Working for DC space point
- dE/dx or dN/dx reconstruction
  - A dummy reconstruction algorithm
    - Provide track level dE/dx or dN/dx

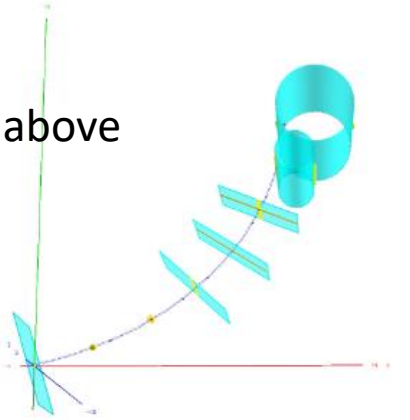


Data flow of DC reconstruction

Track fitting(I)--- RecGenfitAlg

- Based on Genfit https://github.com/GenFit/GenFit/
  - An experiment-independent **generic track fitting** framework
  - Open sourced, active development and large user community
  - **Official track fitting for BelleII,** also used by PANDA, COMET, GEM-TPC etc.
  - **We have join the development of Genfit**
  - Genfit has become of the official external library in CEPCSW

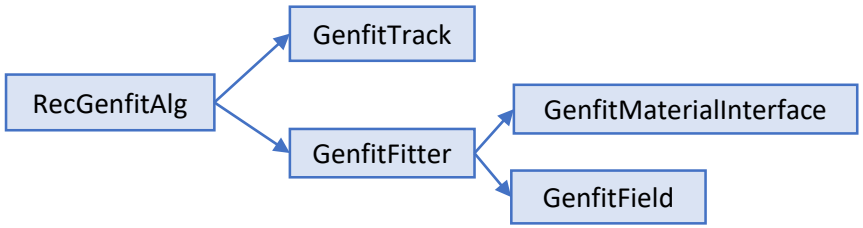
- Main features of Genfit
  - **Support various detector types**:
    - pixel, strip, TPC, drift chamber or tube and combinations of above
  - Detector geometry: ROOT(easy to integrate with DD4hep)
  - Provide several fitting algorithms
    - Kalman filter, DAF, GBL etc.
  - Extrapolation tools



(a) Measurements with covariance (yellow), planar detectors and drift isochrones (cyan), respectively, and reference track (blue).

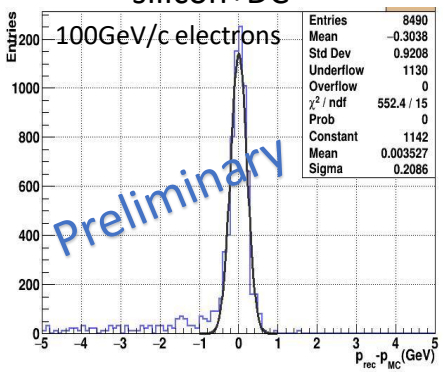
Track fitting(I)--- RecGenfitAlg

- Integration with Genfit in CEPCSW
  - Implemented Genfitfield class to get BField from DD4hep
  - Implemented GenfitMaterlInterface class to get material and geometry from DD4hep
  - A track converter with GenfitTrack with EDM4hep and do unit conversion
  - A wrapper class GenfitFitter to the Genfit track fitters
- RecGenfitAlg is developed for the track fitting using Genfit
  1. Fit the candidate EDM4hep track
  2. Combination fitting of silicon and drift chamber

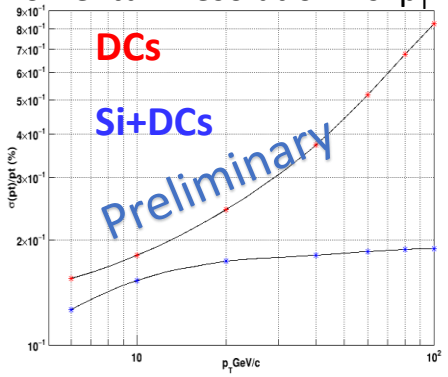


Interface classes to the Genfit in CEPCSW

Momentum distribution for silicon+DC

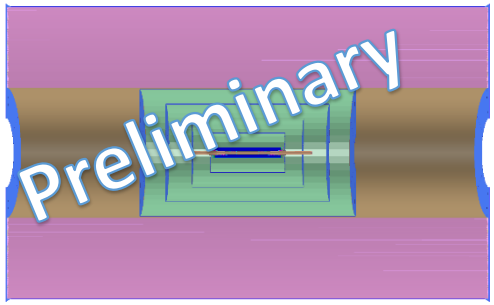


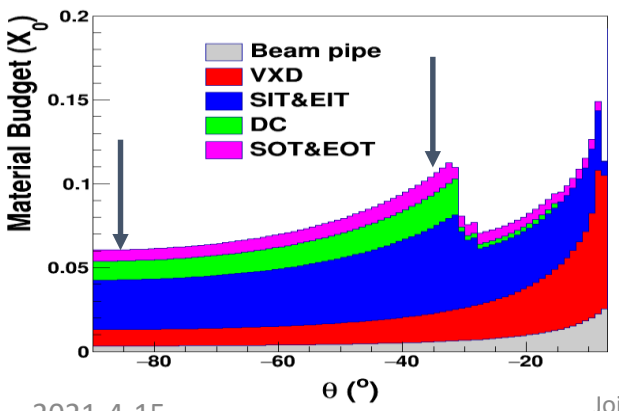
Momentum resolution v.s. p_T

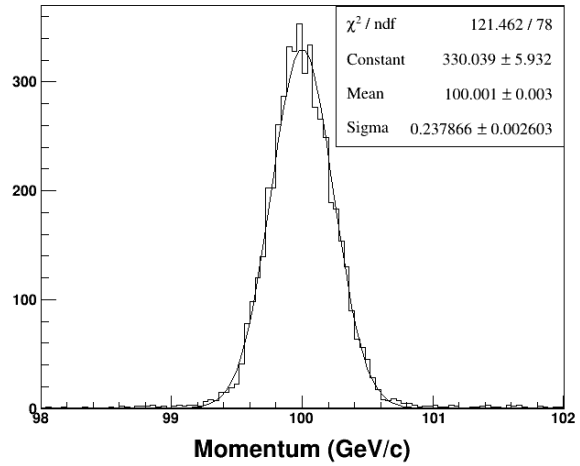


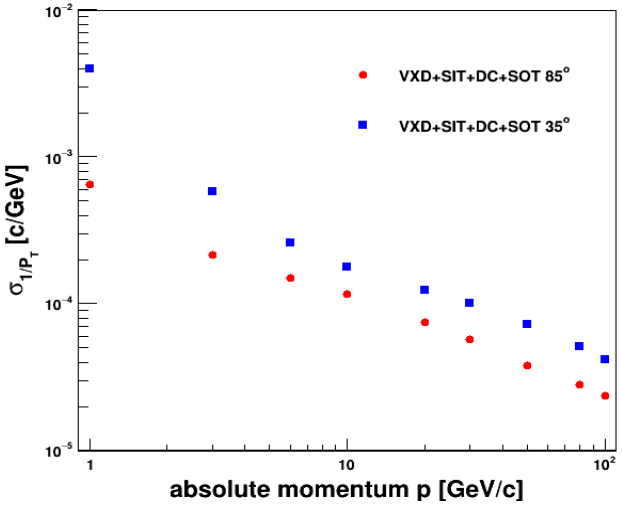
Track fitting(II) --- KalTest

- Geometry
  - VXD×6: $\sigma_{rphi,z}$=2.8μm, 6μm, 4μm, 4μm, 4μm, 4μm
  - SIT ×4: σ_{rphi}=7.2μm, σ_z=86μm
  - DC ×1: σ_{rphi}=110μm, σ_z=1mm
  - SOT×1: σ_{rphi}=7.2μm, σ_z=86μm









Plan

- dN/dx
  - Waveform simulation and waveform analysis
- More realistic sim. and rec.
  - Simulation and fitting under non-uniformed magnetic field
  - Background mixing and tracking with background
- Tracking
  - Validate and optimize the track fitting
- Detector design
  - Study tracker layout performance with full simulation
  - Study dN/dx performance under CEPCSW

Summary

- The drift chamber software developed from scratch
- The first version of DC software is released
  - The configurable simulation
  - Two track fitting algorithms
  - Flow for dN/dx study
- Status
  - Simulation of dN/dx in CEPCSW is start
  - Validation of tracking is on going

Thank you!