# Status and plan of a PID drift chamber

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On behalf of CRD drift chamber working group

CEPC day, Dec 28, 2020

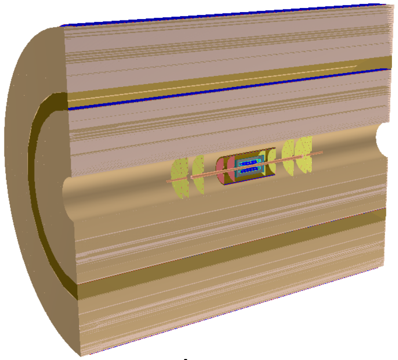
# Outline

- Motivation
- Prototype system
- Cluster counting for PID
- Software development
- Fast optimization on tracker design
- Summary

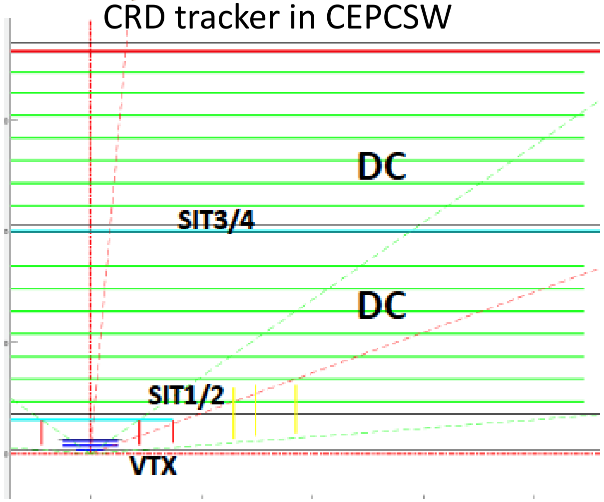
# Motivation

- Particle identification is essential for flavor physics and jet study
  - Reduce combinatorial background
  - Improve mass resolution
  - Improve jet energy resolution
  - Benefit flavor tagging
- A design of CEPC tracker combined with silicon tracker and drift chamber
  - Silicon + DC for tracking
  - Drift chamber for PID (with dE/dx or cluster counting)

We start with silicon tracker layout, and will optimize the Silicon + DC design through simulation.



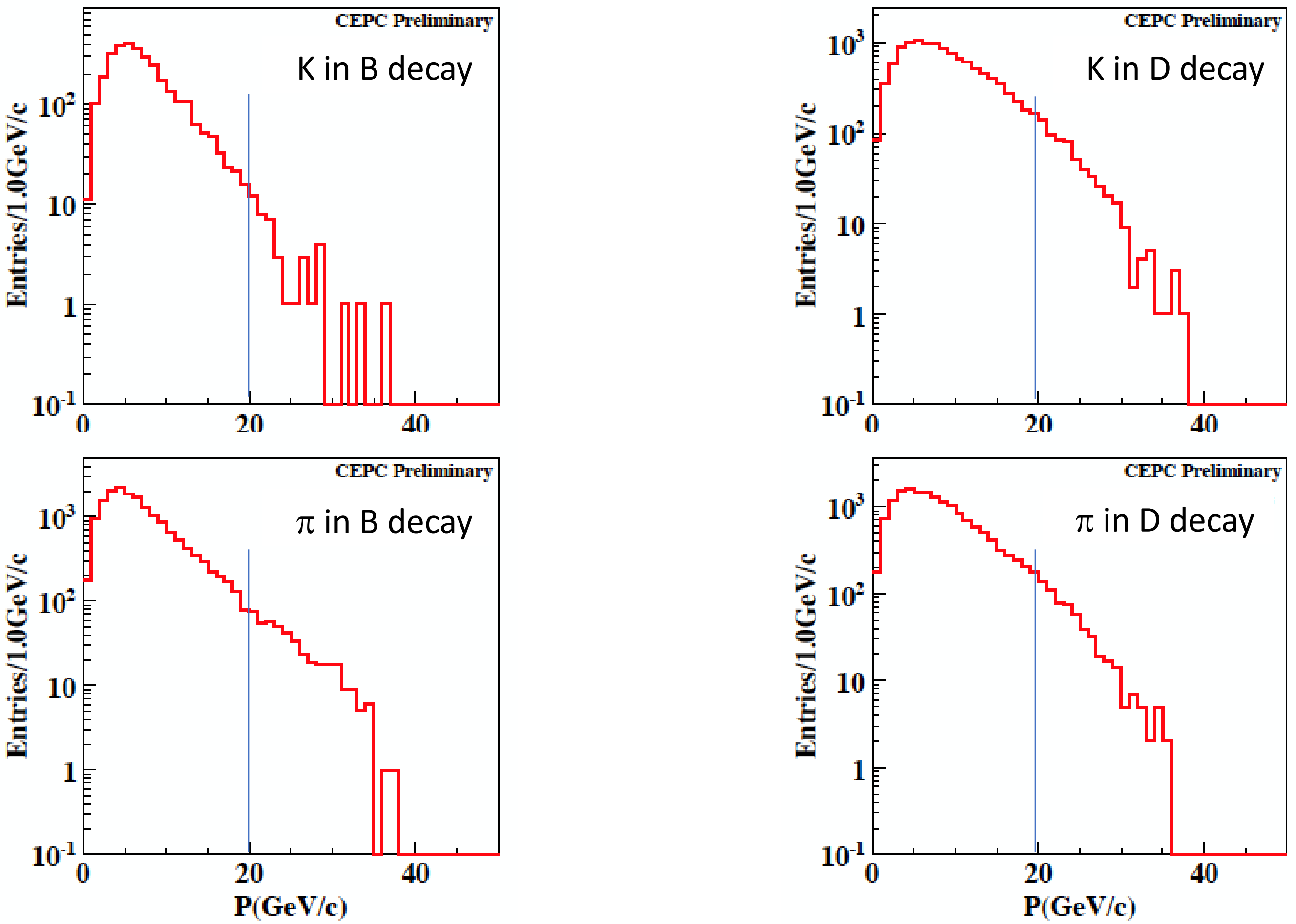
CRD tracker in CEPCSW




Xin's talk in CEPC day (Sep 23, 2020)

# Momentum distribution of K & $\pi$

Gang Li



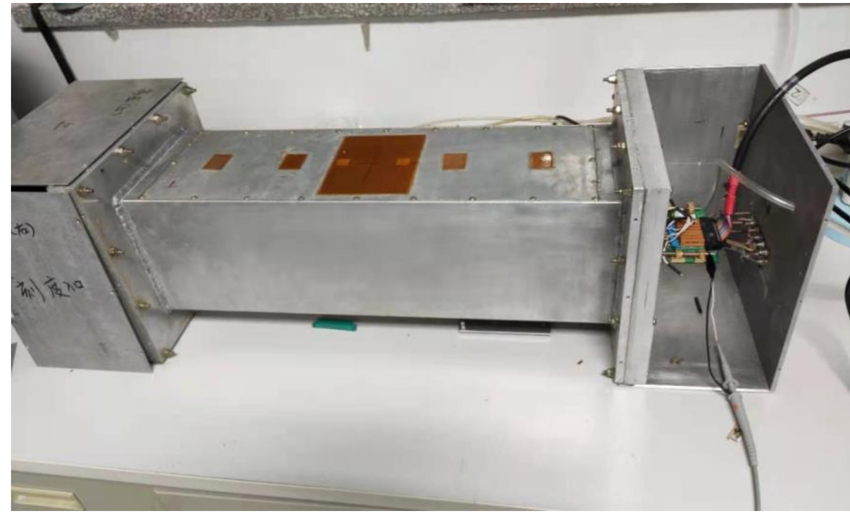

Most of K & $\pi$ with the momentum less than 20 GeV/c

# Major tasks and key personnel

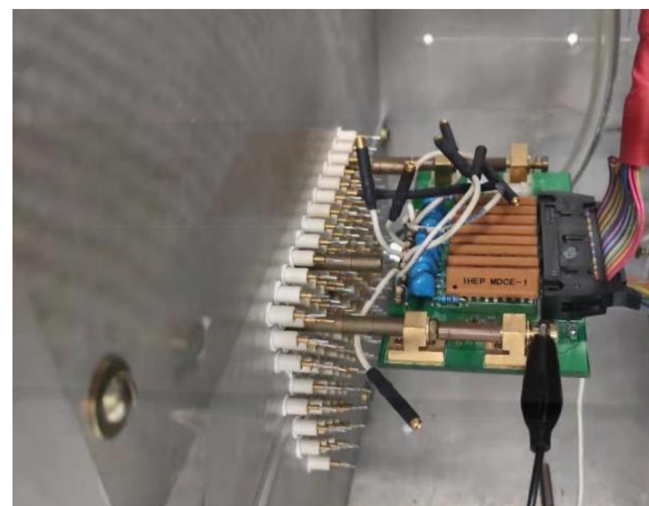
- **Prototyping system** Mingyi
  - To study the PID performance with the currently available electronics
  - To understand what is critical to PID (rising time, gain, noise, etc.), and what may be achievable in a reasonable future.
  - To provide realistic inputs for simulation
- **Cluster counting simulation** Linghui, Guang, Shuiting, Shengsen, Gang
  - To polish the cluster counting algorithm
  - Quick comparison of different parameters (gas, sampling frequency, etc.)
  - To provide empirical model to the sophisticated CEPCSW
- **Software development in CEPCSW** Yao, Mengyao, Tao, Wenxing, Chengdong
  - Provide more reliable tool to optimize the tracker through physics outputs
- **Optimization of tracker design** Linghui, Ryuta, Chengdong, Xin, Gang
  - Fast simulation to determine a preliminary tracker design
  - Coherent optimization of tracker & PID with CEPCSW

# Setup of a prototype system

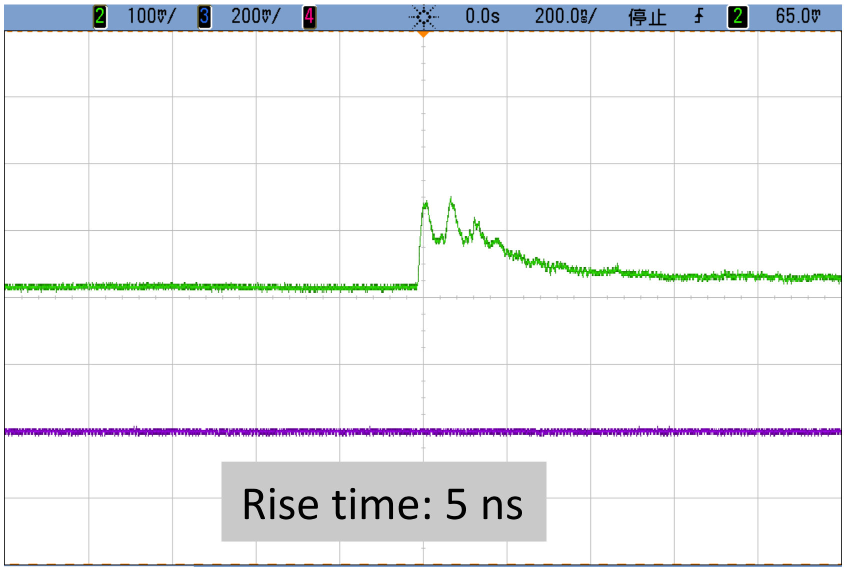
- A prototype test system was setup
  - 4 layers, 6 cells/layer
  - Cell size: 16×16 $mm^2$
  - Wire length : 600 mm
  - Read out: preamplifier + oscilloscope

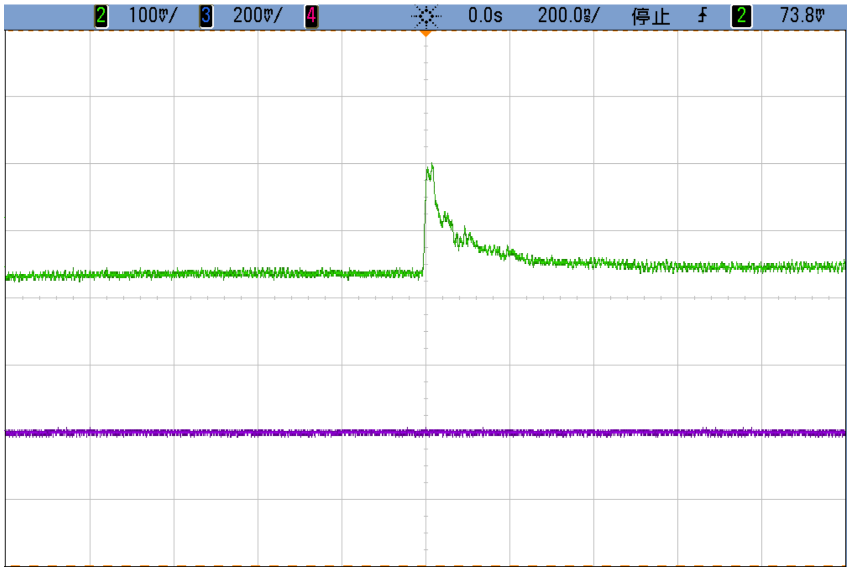


- Temporarily tested with the transimpedance preamplifiers used in BESIII MDC
  - Gain: 12 kΩ  (12 mV/μA)
  - Rise time: 5 ns
  - Band width: 70 MHz
  - Output impedance 2×50 Ω
  - Power dissipation 30 mW @ 6 V



# Signals



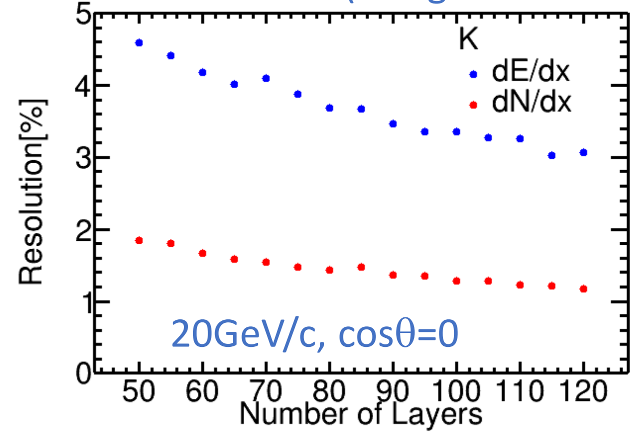




- Tested using cosmic rays
- Gas mixture: He (80%)+i$C_4H_{10}$(20%), HV=2000V (high gas gain)
- Can not separate the clusters well
- Fast preamplifier (<1ns rise time) with low noise is needed
- Another fast preamplifier with a rise time of less than 1ns is used, but noise problem has not been solved
- We are searching for better electronics.

# Cluster counting for PID

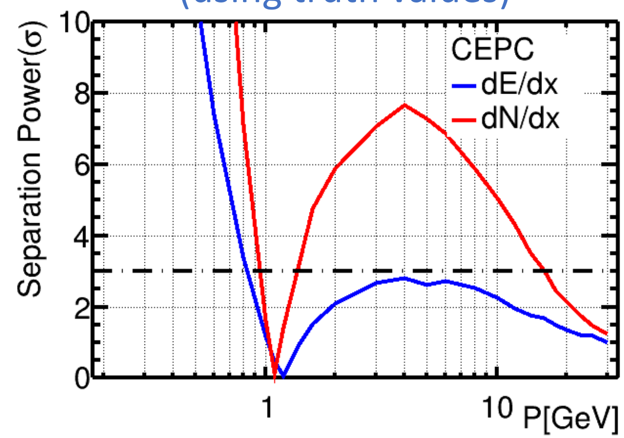
- A simulation with Garfield is been performed
  - ✓ Study of resolutions and separation power with truth values
  - ✓ Peak finding with simulated signals
  - ➢ PID performance study with dN/dx sampling in CEPCSW ongoing

Resolution of K (using truth values)



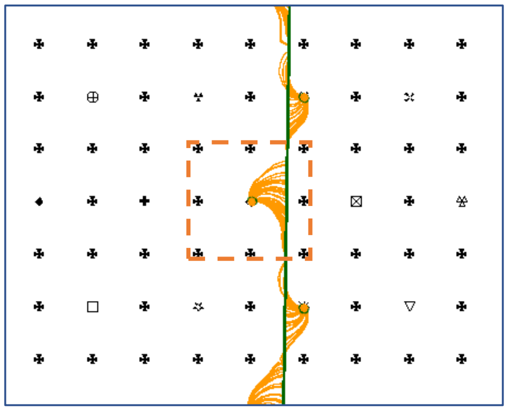

- Parameters
  - Two DCs between the silicon trackers
  - Cell size: 1cm*1cm
  - Outer radius = 1.5m (118 layers)
  - He (50%)+$iC_4H_{10}$(50%)
  - Truncated mean cut (70%) for dE/dx

Separation power for K/π (using truth values)

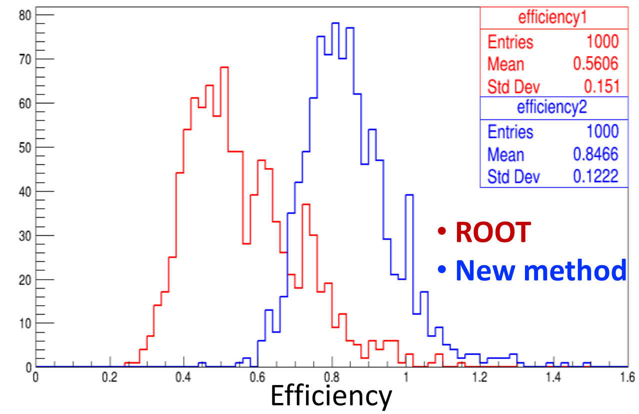



$$S = \frac{|<\frac{dE}{dx}>_\pi - <\frac{dE}{dx}>_K|}{\sqrt{\sigma\left(\frac{dE}{dx}\right)^2_\pi + \sigma\left(\frac{dE}{dx}\right)^2_K}}$$

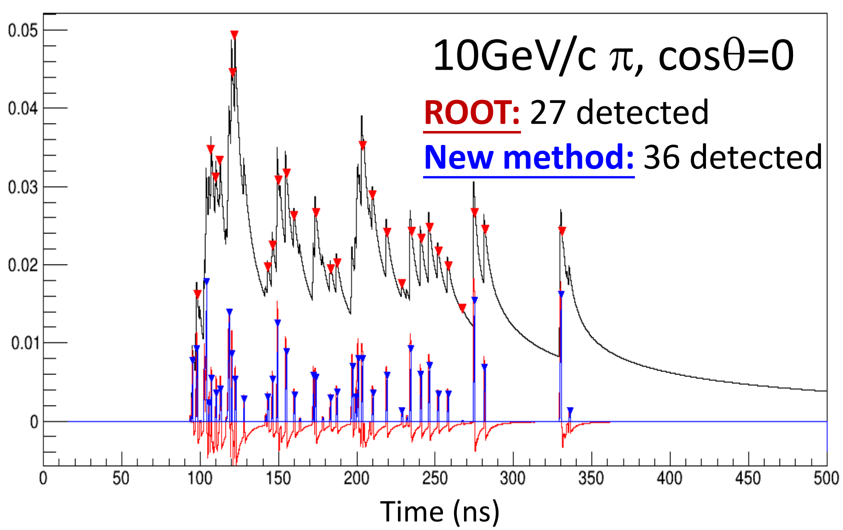
# Simulation of the signal



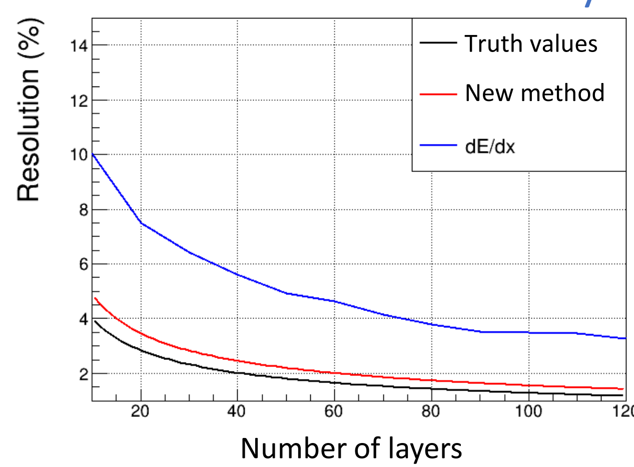
Efficiency of peak finding




Signal simulated with Garfield




Resolution vs number of layers

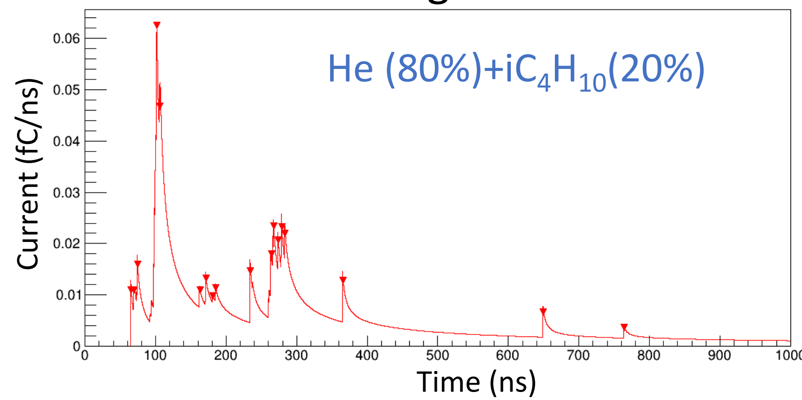



Contribution of electronics not been taken into account in this stage

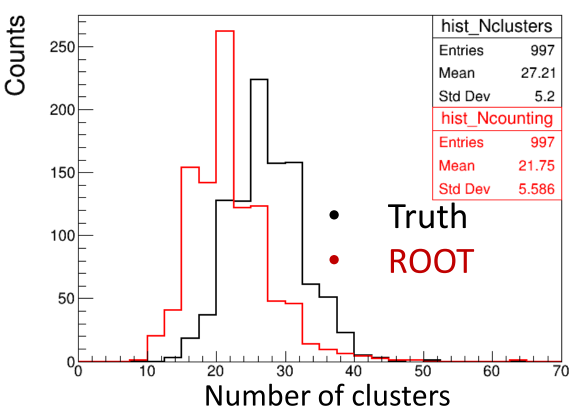
# Study on different gas ratio

- The cluster density can be reduced by increasing the ratio of He
- Lower cluster density would be better to cluster finding
- More studies ongoing
  - Optimized gas mixture, pressure …

Signal

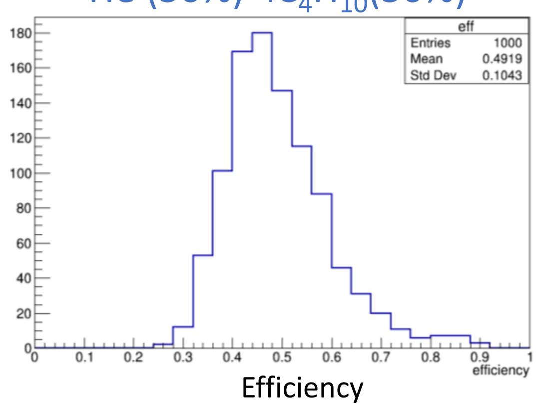



Number of clusters

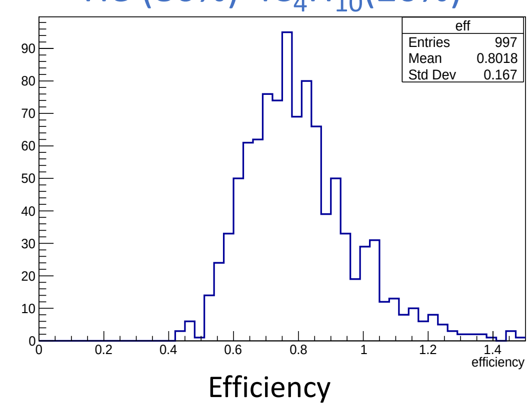



Efficiency of peak finding with ROOT

He (50%)+$iC_4H_{10}$(50%)




He (80%)+$iC_4H_{10}$(20%)



# Software development

- **A drift chamber software has been developed from scratch**

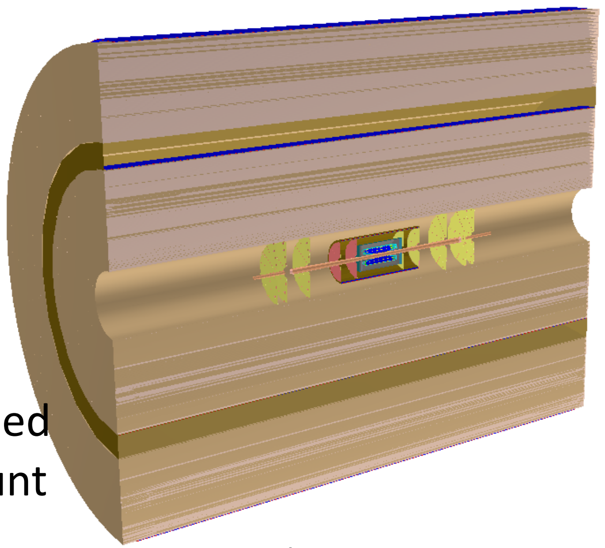
- Motivation
  - Study the PID with **cluster counting method**
  - A demonstration for the development of CEPC software

- Requirements for DC software
  - Configurable simulation
  - Adaptive track fitting
  - Provide fast iteration for dE/dx or dN/dx study

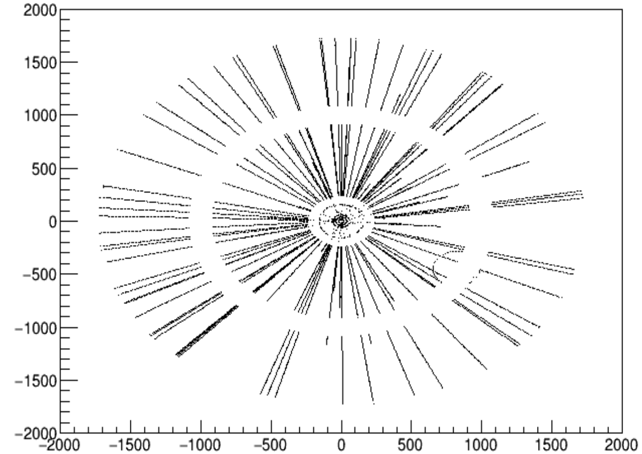
- Personpower
  - IHEP: Yao Zhang, Tao Lin, Wenxing Fang, Chengdong Fu, Ye Yuan, Weidong Li
  - SDU: Mengyao Liu,  Xueyao Zhang,  Xingtao Huang

# Simulation and digitization realized in CEPCSW

- Detector description
  - DC constructor
  - Cell partitioning with the segmentation method
- Detector response
  - dE/dx: deposit energy of the hit
  - Association between MC hits and particles are recorded
  - Both material and B-Field effects are taken into account
- Simple digitization
  - Constant X-T (Vdrift=40$\mu$m/ns)
  - Fixed spatial resolution (110$\mu$m)
- Baseline configuration
  - Two drift chambers with silicon layers
  - Radius 1.8m, 130 layers, He (90%)+i$C_4H_{10}$(10%)



CRD tracker in CEPCSW

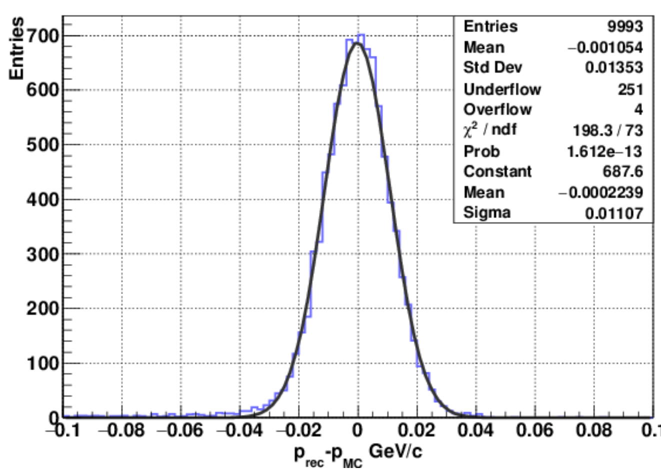



Tracker hitmap

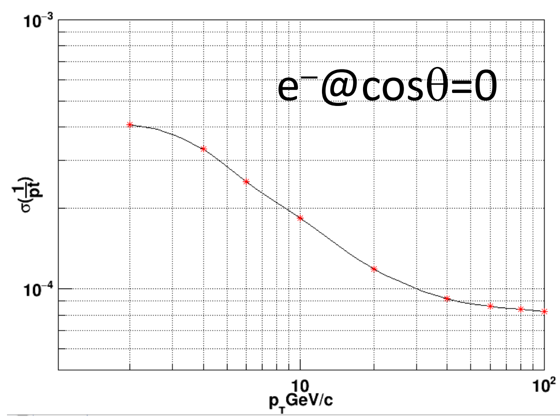
# Flow of track reconstruction completed

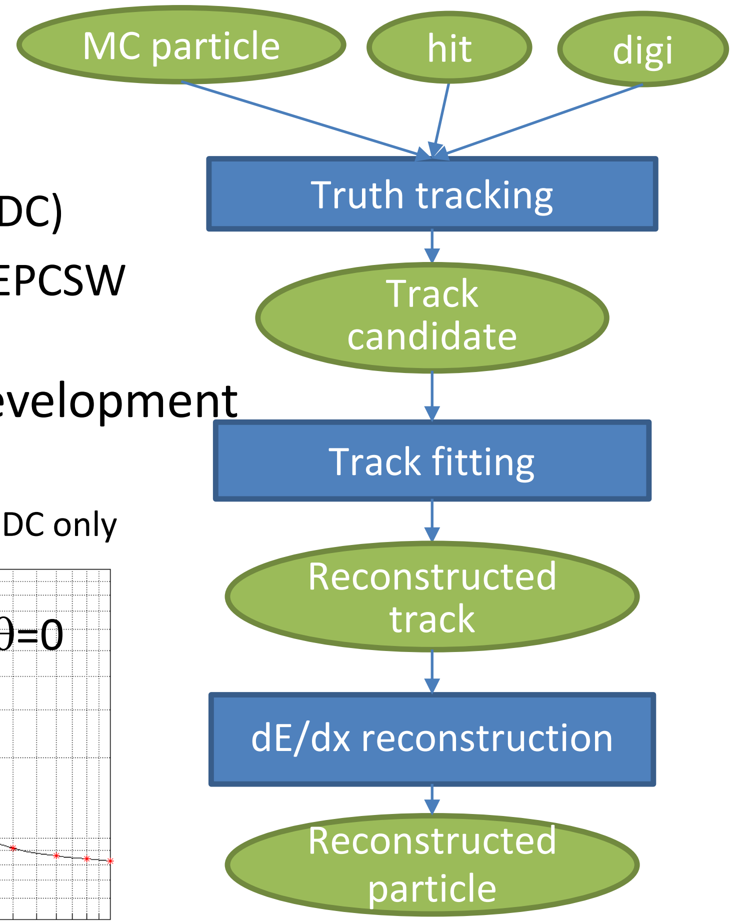
- Track finding based on MC truth
  - Will rely on the silicon track seed in the real system
- Drift chamber track fitting
  - Based on Genfit (The official track fitting for BelleII DC)
  - A track fitting algorithm integrated with Genfit in CEPCSW
- A combined track fitting of silicon + DC is under development

$\Delta$ p of $e^-$ @cos$\theta$=0 10GeV/c electrons




Momentum resolution with DC only



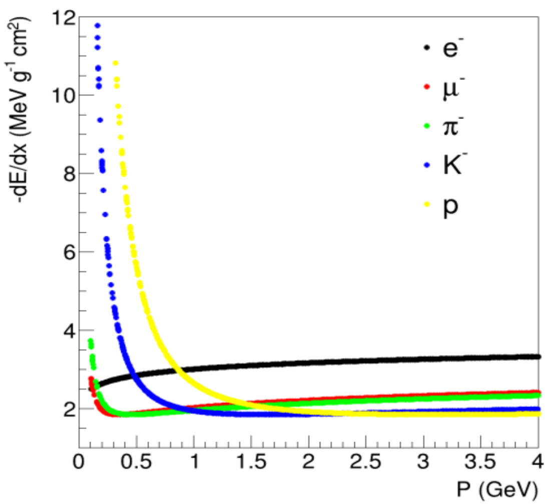

Data flow of DC reconstruction

# Flow for dE/dx or dN/dx study ready

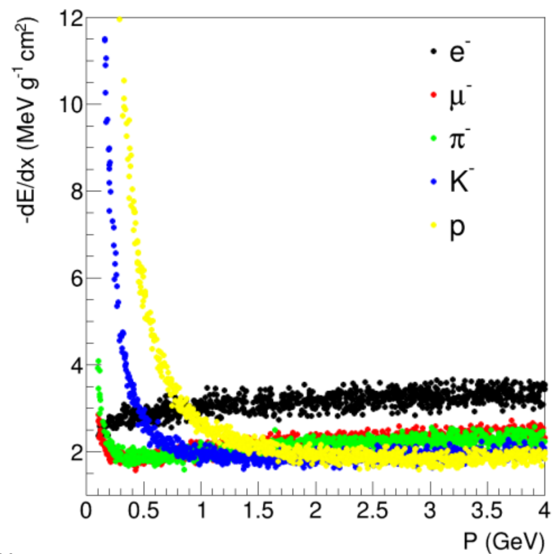
- A fast sampling tool
  - Hit level sampling from empirical model
- A dummy algorithm
  - Track level dE/dx or dN/dx reconstruction

- A track level dN/dx from Garfield will be integrated soon

dE/dx from Bethe-Bloch equation




5% smeared



# Release plan of CRD

| | Tasks | CRD V0<br>15th Jan.<br>2021 | CRD V1<br>End of March<br>2021 |
|---|---|---|---|
| **Detector description** | DC axial layers with wires and walls | | |
| **Simulation & digitization** | Track level dE/dx sampling with modeling | | |
| | Track level dN/dx sampling with modeling | | |
| **Track finding** | Truth tracker | | |
| | Track seed from silicon tracker | | |
| **Track fitting** | Fitting with truth information | | |
| | Combined fitting with DC and silicon | | |

# Optimization on tracker design

- Optimizing the design of tracker
  - Momentum resolution
  - Impact parameter resolution
  - dE/dx or dN/dx resolution
- Different fast simulation tools being used for cross validations
- Plan
  - Number of Si layers
  - Number of drift chamber
  - Tracker size, layout and cell size
  - Effect of the magnetic field.
- Long term plan
  - Optimize the design with benchmark physics channels.

# Summary

- We are setting up a prototype DC for dN/dx study. Better electronics is needed
- Garfield simulation results show that the resolution and separation power with cluster counting method are significantly better than traditional dE/dx method. PID study with dN/dx sampling at track level is ongoing
- The first version of CRD tracker software is ready
- Optimization of tracker design with fast simulation tools ongoing

**Thank you!**