Simulation Study of fourth conceptual drift chamber

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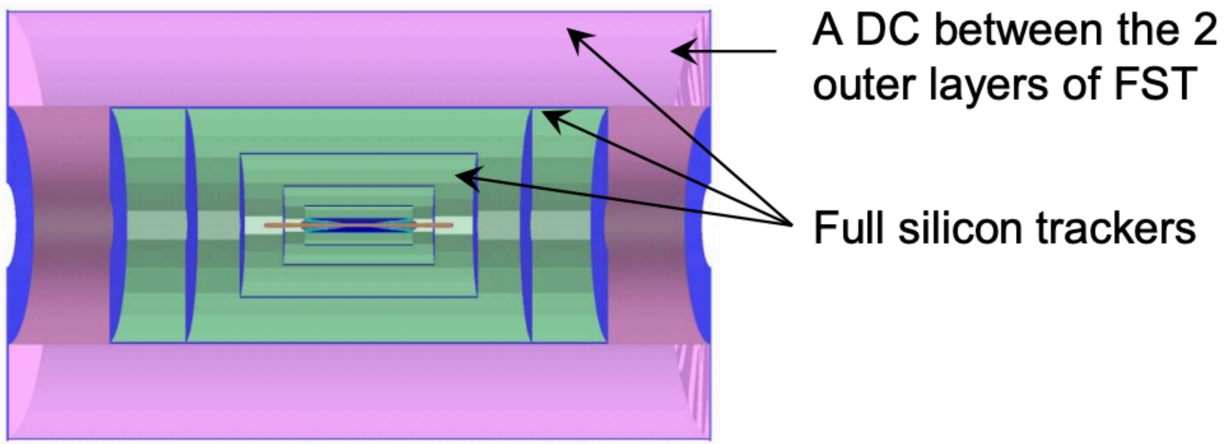
Outline

- ❖ The fourth concept tracker
- ❖ Principle of a drift chamber
- ❖ Optimization

The fourth concept tracker

- ❖ Good momentum/impact resolution
- ❖ Excellent PID, better than 2s separation of p/K at momentum up to ~20 GeV.

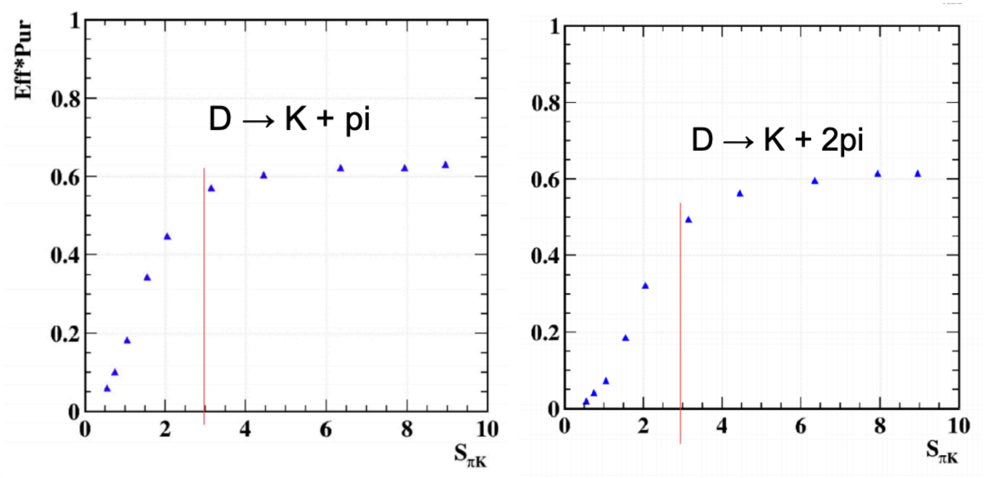
Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$



- Silicon Vertex + Silicon Tracker for momentum measurement
- Drift chamber : have sufficient PID power

Introduction

- Drifter Chamber
  - Aim to provide PID capability other than silicon tracker
- CEPC physics
  - 2-sigma separation of k/pi would be appreciate

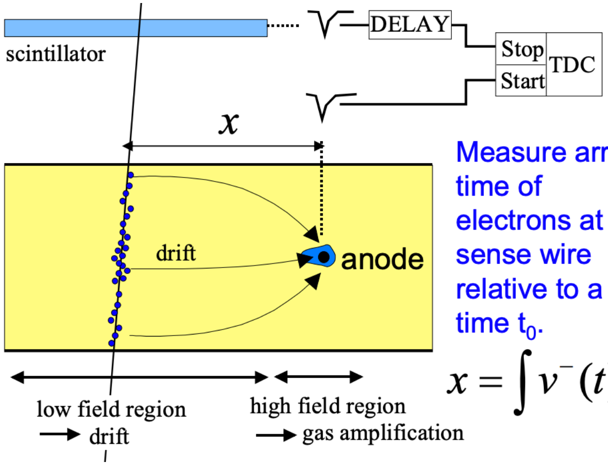


- A desired detector
  - Suitable gain and drift velocity(choice of gas)
  - Stability(choice of quencher)
  - In optimized Size(A balance on PID performance and tracking measurement)

Principle of drift chamber

- Ionization measurement.
  - A charged particle passing through the gas ionizes a few gas molecules
  - Electrons from ionization move in the electric field and are multiplied around the anode wire
  - the movement of electrons and ions result in induced currents in the anode wire

- Function of drift chamber
  - For tracking
    - Calculating space position by measuring the drift time.
  - For particle identification
    - Traditionally it is implemented by energy loss(dE/dx)
    - Possibly better PID performance by measuring primary ionizations(dN/dx)



Measure arrival time of electrons at sense wire relative to a time t_0.

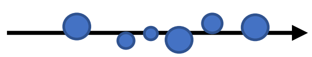
$$x = \int v^{-}(t)dt$$

Principle of dE/dx measurement

❖ The average energy loss is described by Bethe-Bloch formula

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2mc^2\beta^2\gamma^2T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$$

❖ Mass of a charged particle is exploited by knowing energy loss for a certain momentum.



$$dE = \sum \delta E_i$$

❖ The differential cross-section has a $1/E_i^2$ shape if E_i lager than E_K.

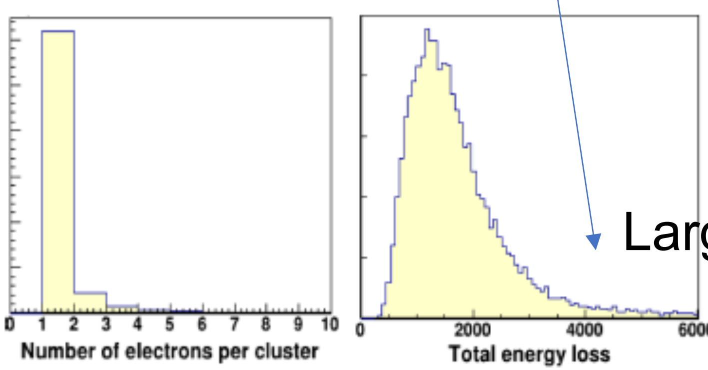
$$\frac{\mathrm{d}\sigma}{\mathrm{d}E_i} \to \frac{2\pi r_e^2}{\beta^2}\frac{mc^2}{E_i^2}(E_i \gg E_\mathrm{K})$$ ➡ large energy electrons(δ electrons) sometimes

❖ The energy loss is a statistical process involving

- ◇ Fluctuations of number of primary electrons -> poisson distribution
- ◇ Fluctuations of transferred energy δE_i

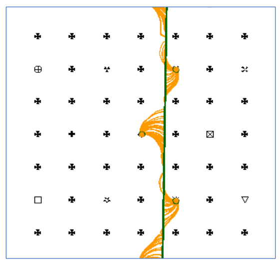
⬇

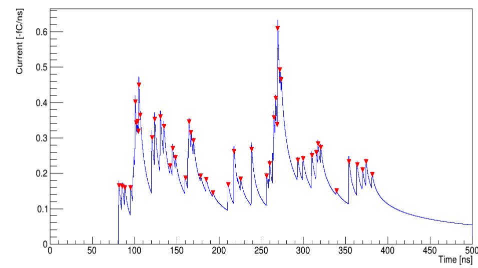
Together result in Landau distribution



Principle of dN/dx measurement

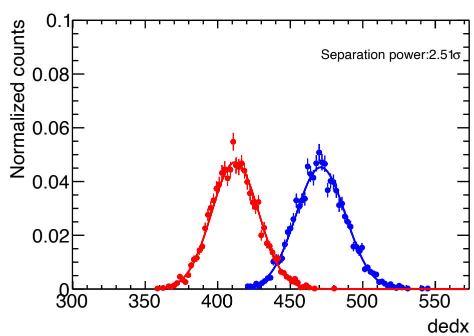
- Instead of measuring charge, if counting on primary electrons
  - Number of pluses -> number of primary electrons
  - Uncertainly is number fluctuations
  - Pure poisson statistics that less fluctuation

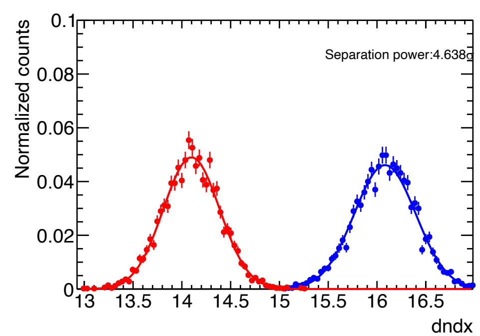




Number of pluses

- Comparing dN/dx with dE/dx





- 10GeV pion/kaon in 90%He,10%iC4H10 gas, truncated mean is applied for dE/dx
- dN/dx achieves better resolution and better k/pi separation

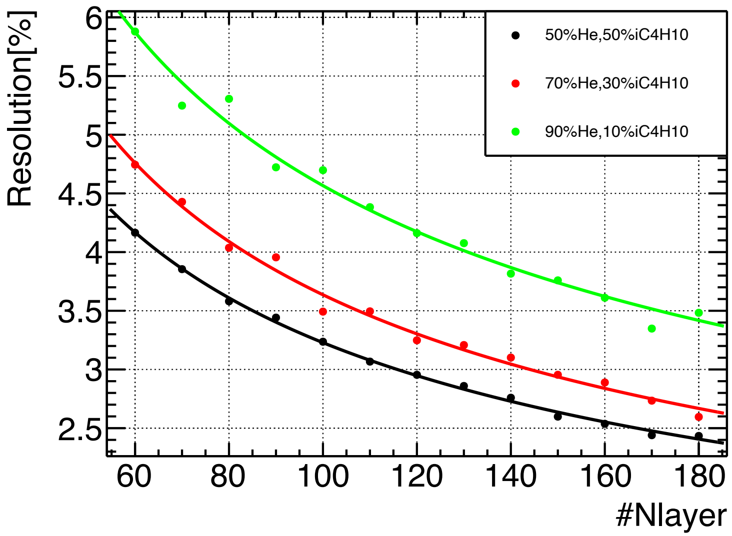
Optimized parameters

- Gas fraction of two component, He and iC4H10
  - Why He: less primary ionization so that low cluster density making pluses separatable
  - Why Quencher: to absorb photons produced by charged particle and He atom collision. Choosing iC4H10

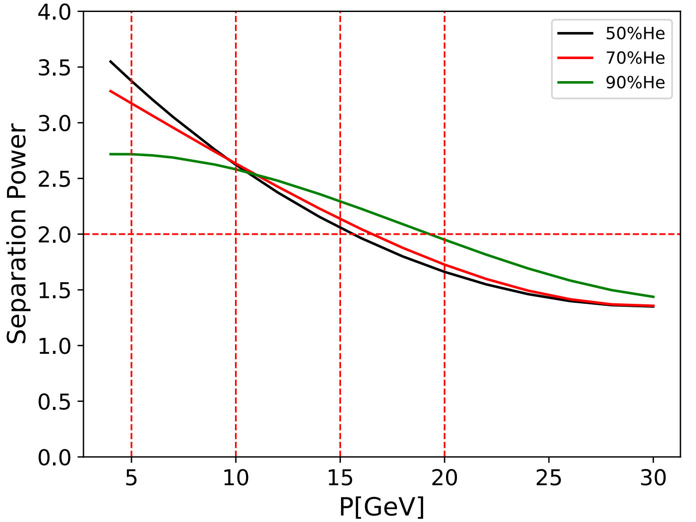
- Number of layers
  - Although PID performance is improved with more layers.
  - Worsen the space resolution of a track.

Mixture gas component

❖ Ionization level information simulated by Garfield++



dE/dx resolution



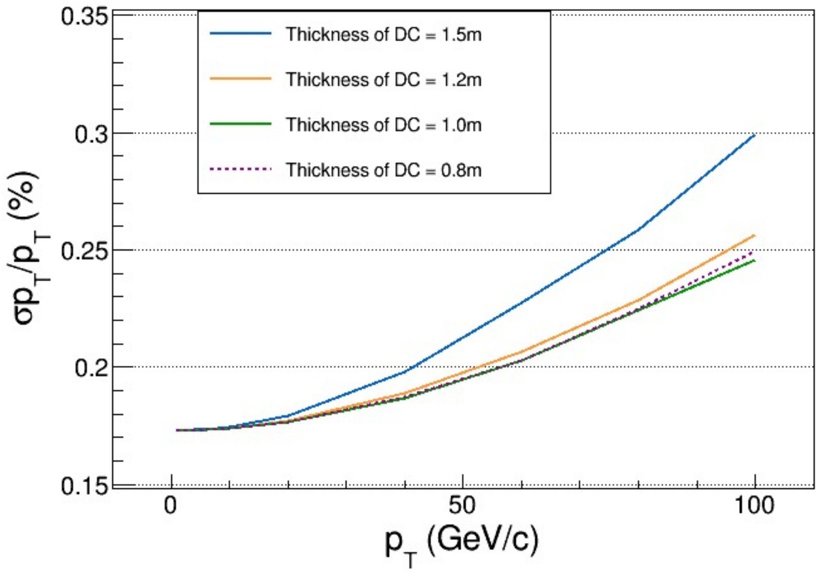
- ◇ 3 gas mixture -> no big difference between 50% and 70% in separation plot.
- ◇ The fit curve follows $1/\sqrt{N}$ relation
- ◇ Above 10GeV, separation of 90%He is better than with 50%He, and 90%He is beneficial for cluster counting.

Size of DC: tracking

$$\frac{\sigma P_T}{P_T} = a \cdot P_T \oplus \frac{b}{sin^{1/2}\theta}$$

a: related with spatial resolution

b: related with multiple scattering

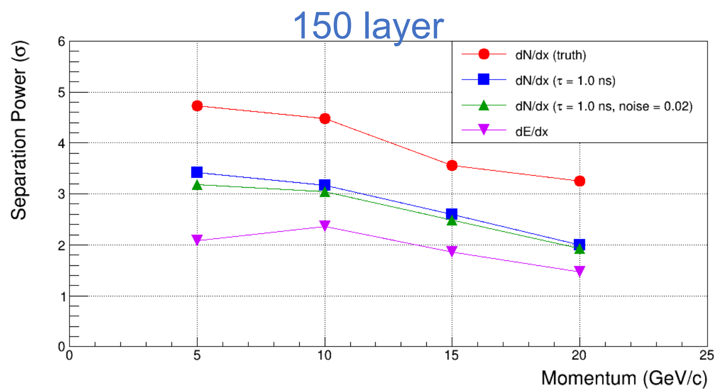


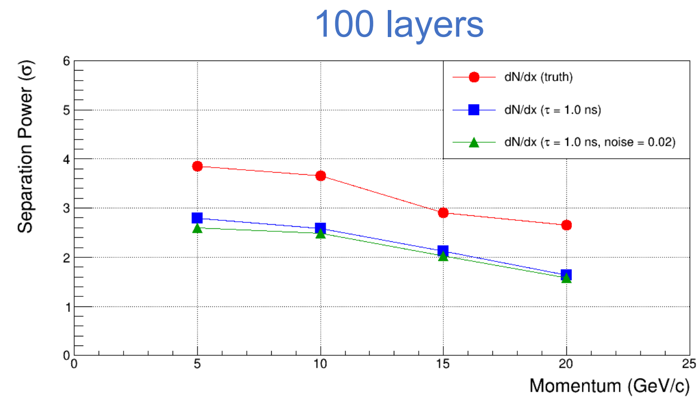
- ◇ Investigating momentum resolution using FastTrkSim
- ◇ Tracker geometry configurations
  - ◇ Outer R of DC is fixed to be 1.8m, one layer of silicon tracker outside of DC (R=1.8m)
  - ◇ Keep vertex detector same as before (3 double-sided layers)
  - ◇ N layer of silicon tracker between vertex detector and DC with equal spacing (N=3,4,5)

- ◇ Reducing size of DC could improve momentum resolution significantly.
- ◇ Best momentum measurement at inner_R_{DC} = 0.8 ~ 1m (i.e. 80 ~100 layers)

Size of DC :PID

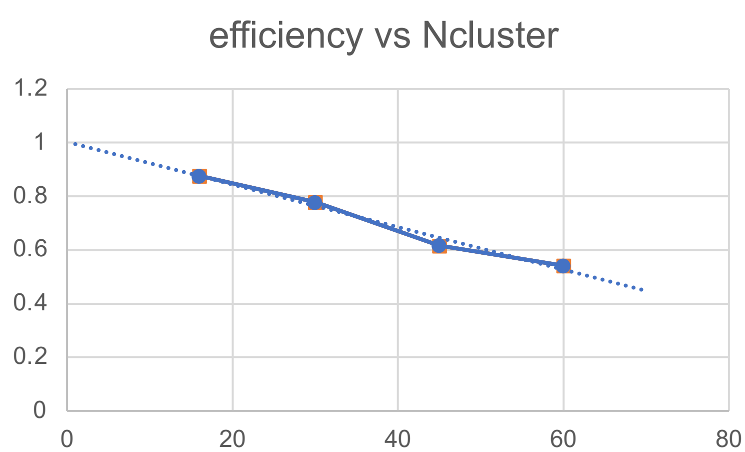
❖ A full simulation including signal induction, response of pre-amplifier and white noise is performed. Details in Guang's talk

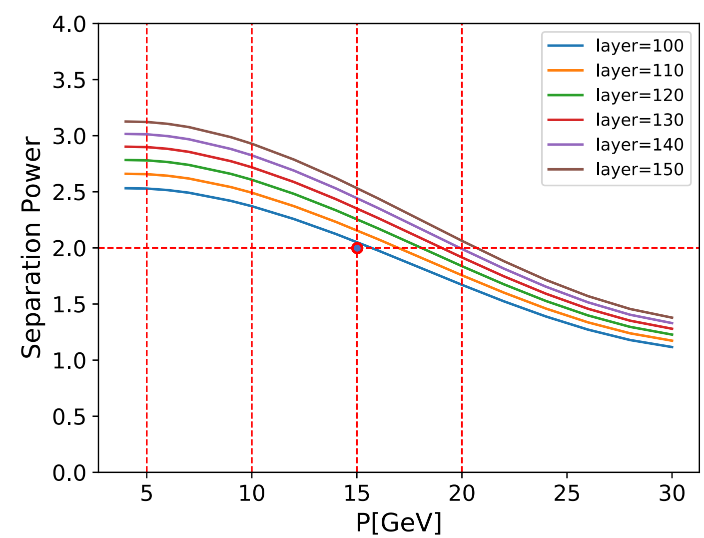




❖ Fast simulation

- ◇ Apply a Ncluster dependent efficiency to simulation. Estimated from fixed Ncluster samples.
- ◇ Slightly different with full simulation. Further Investigation on this model undergoing

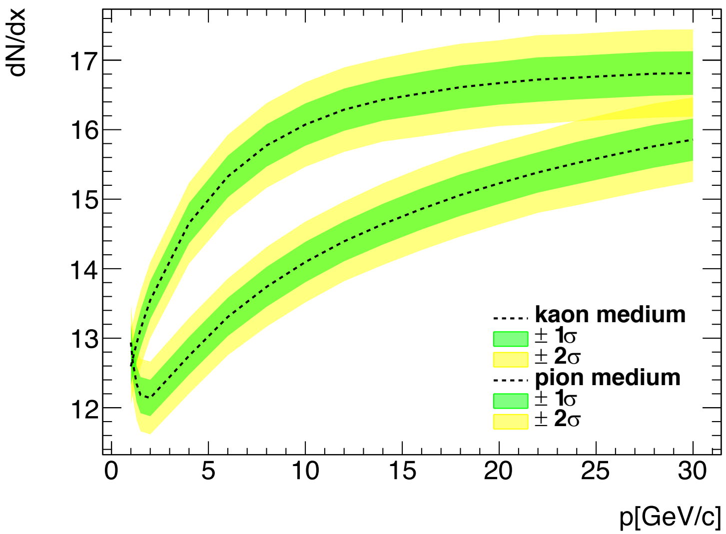




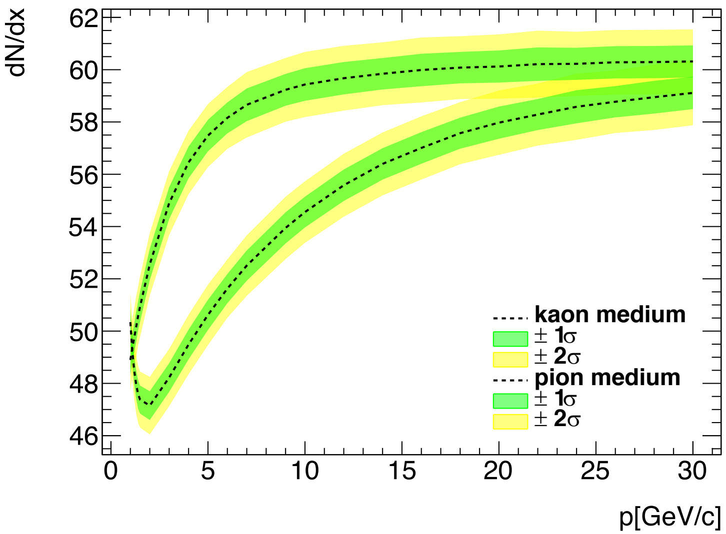
Summary and Outlook

- ❖ The working gas is chosen to be 90%He to meet the requirement at high momentum
- ❖ Momentum resolution can be improved significantly by reducing size of DC. 100 layers might be better
- ❖ Drift chamber with 100 layers (0.8m ~ 1.8m)
  - ◇ can reach up to 2σ K/p separation at 15 GeV
  - ◇ 1.5σ K/p separation at 20 GeV
- ❖ Need further validation and optimization.

Backup



90%He



50%He