Drift Chamber

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on behalf of DC PID Group

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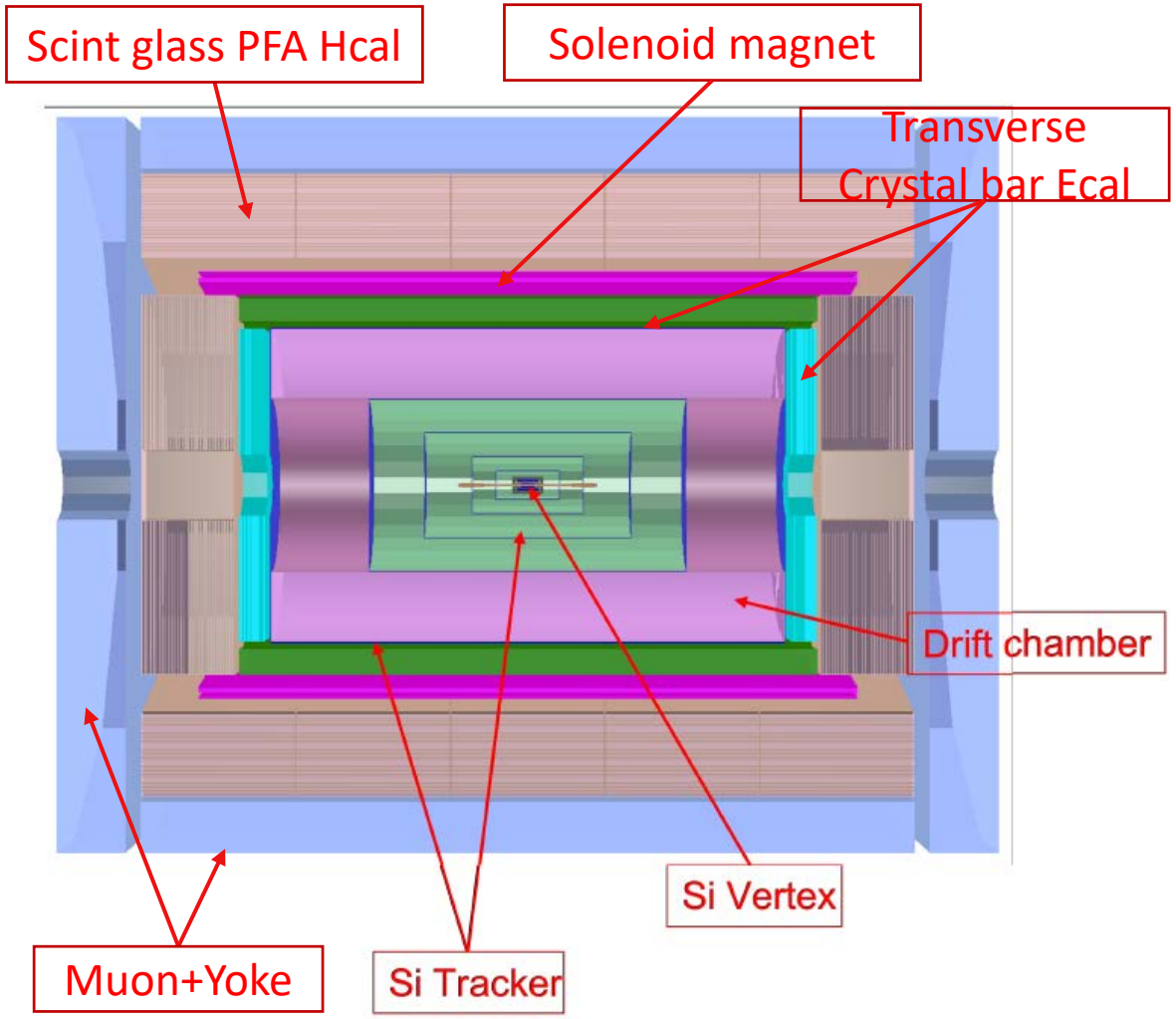
Outline

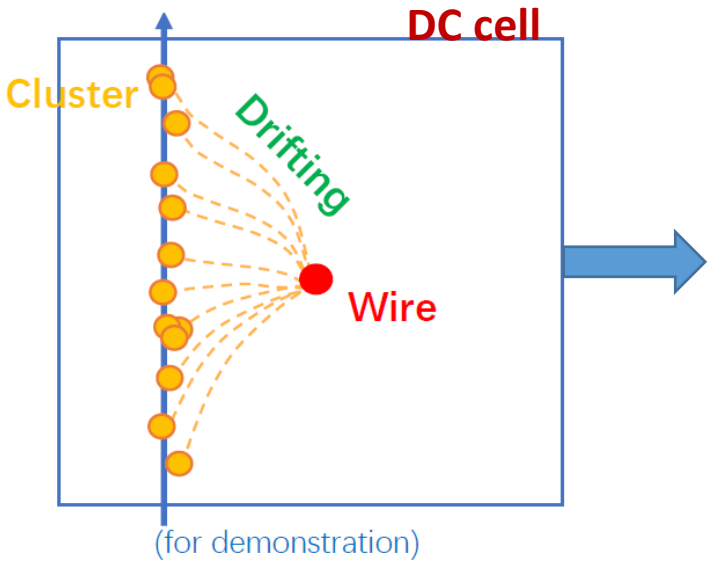
- Introduction
- Simulation study and detector preliminary parameters
- Mechanical design and calculation
- Summary and outlook

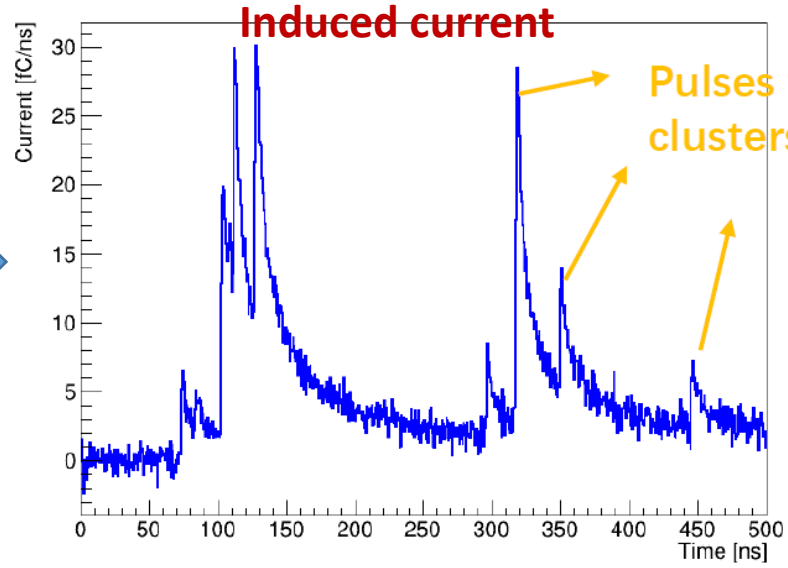
Drift Chamber for CEPC 4th detector design

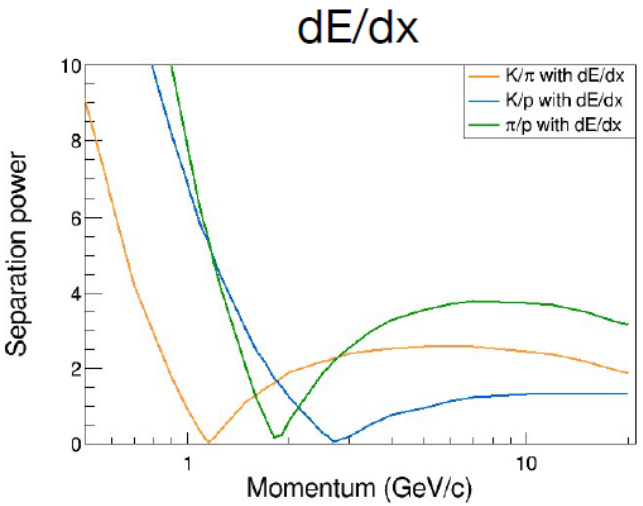
- Drift Chamber is proposed in CEPC 4th detector conceptual design for particle identification (PID)
  - Inserted into Si inner tracker (SIT)
  - Mainly provides PID capability by using cluster counting technique while keeping a reasonable detector size
    - ~3σ separation of K/π with momentum up to 20 GeV/c
  - Could also benefit tracking and momentum measurement

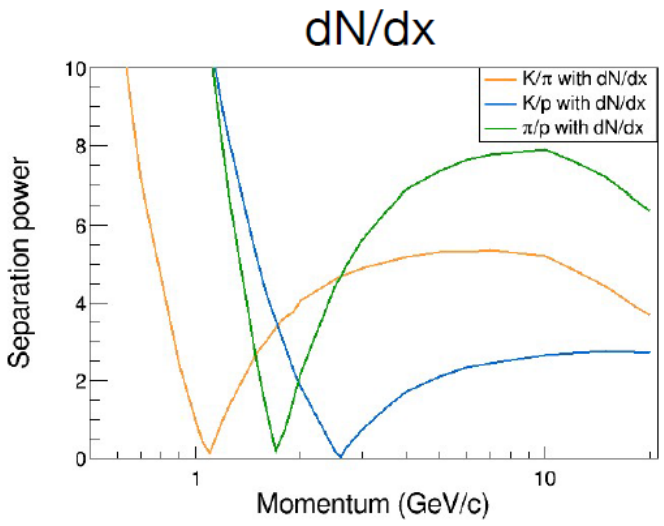


Ionization measurement with dN/dX



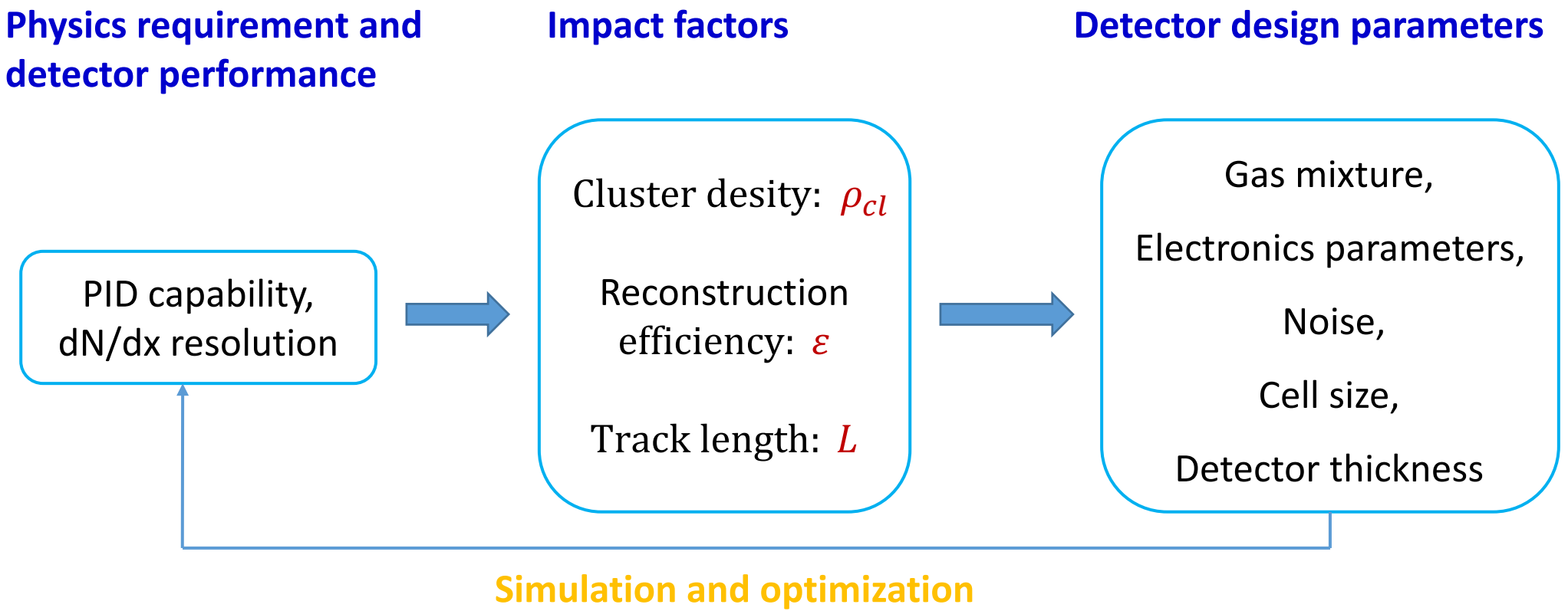




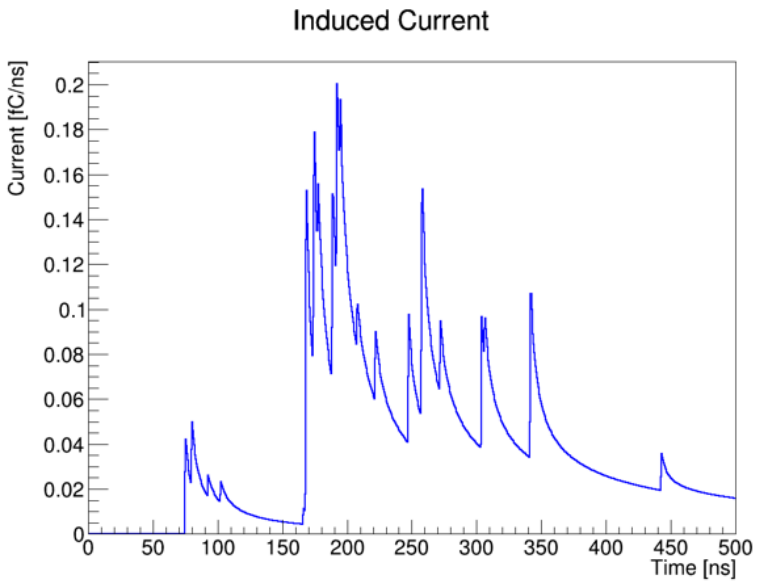


- Cluster counting (dN/dx): Measure number of clusters over the track
- Yield of primary ionization is Poisson distributed: $P(\bar{N}_p, k) = \frac{\bar{N}_p^k}{k!} e^{-\bar{N}_p}$
- Less sensitive to Landau tails than dE/dx
- dN/dx shows better PID performance than dE/dx. (a factor of >2)

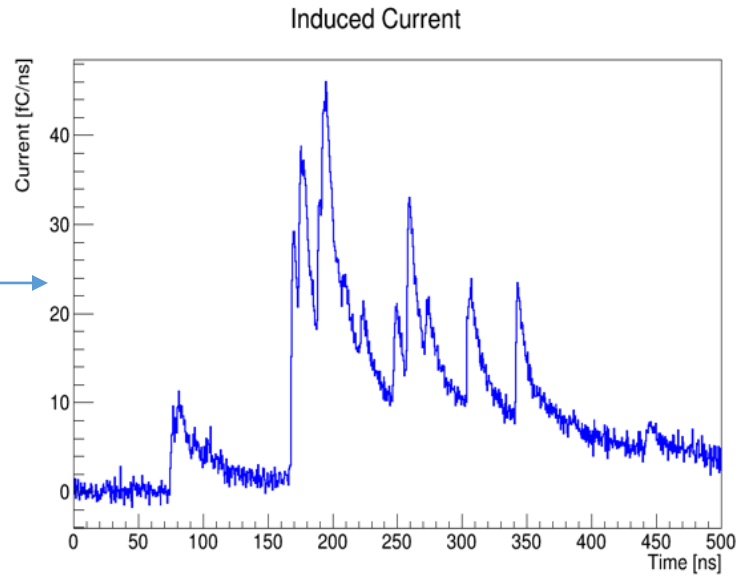
Detector simulation and optimization



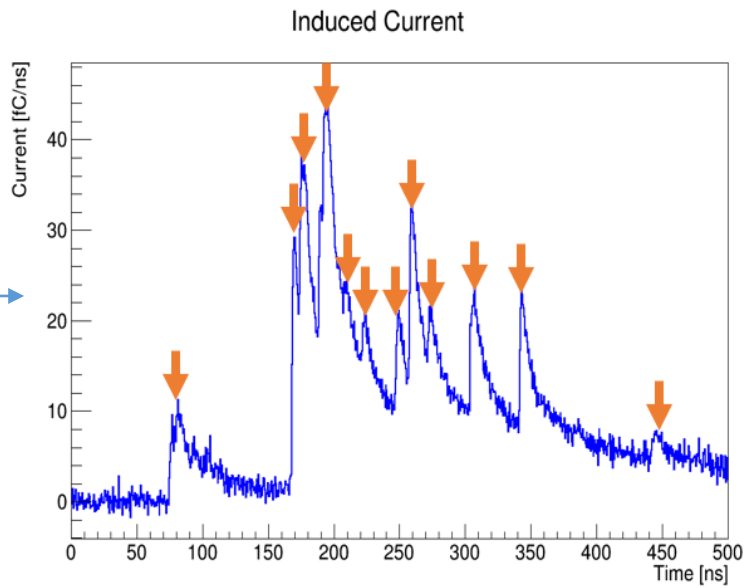
Waveform-based simulation



Simulation



Digitization



Reconstruction

Signal generator (Garfield++)

- Heed: ionization process
- Magboltz: gas properties (drift/diffusion)

Electronics:

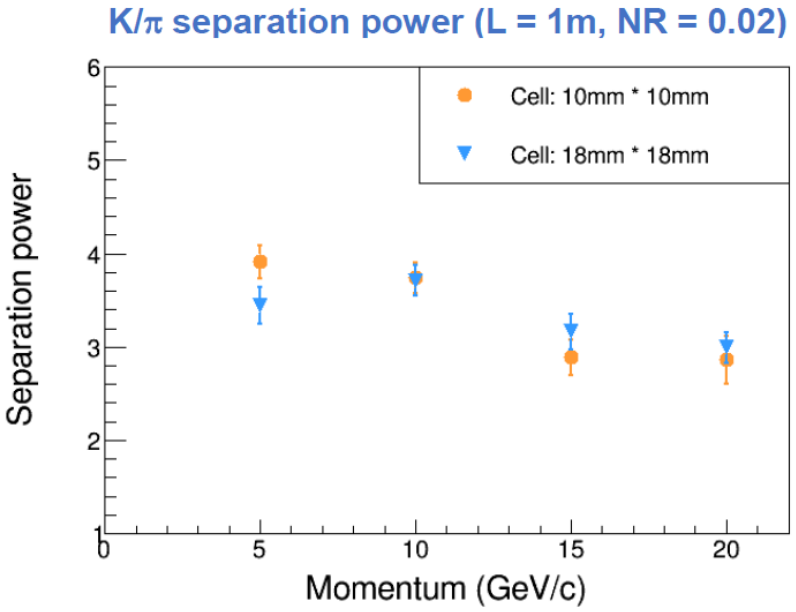
- Preamplifier
- Noise
- ADC sampling rate

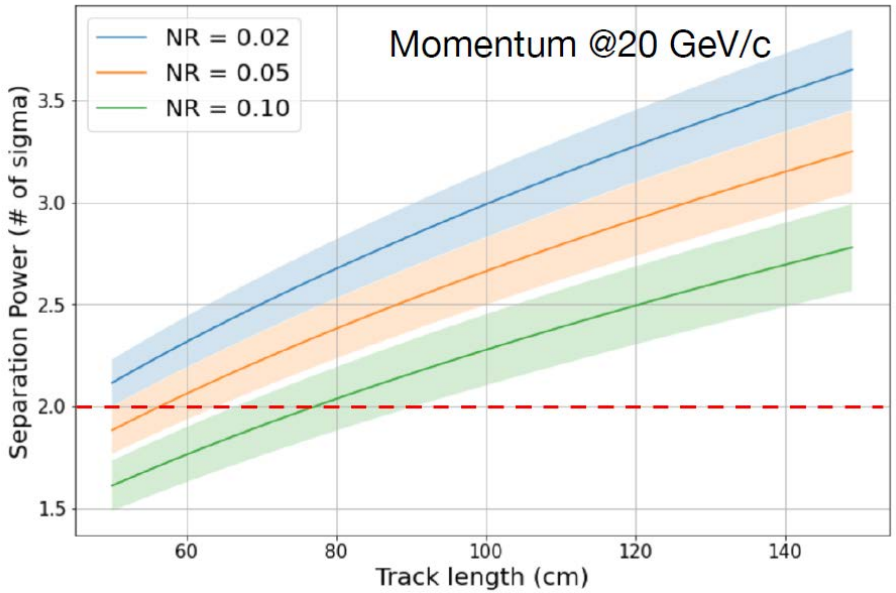
Peak finding algorithm

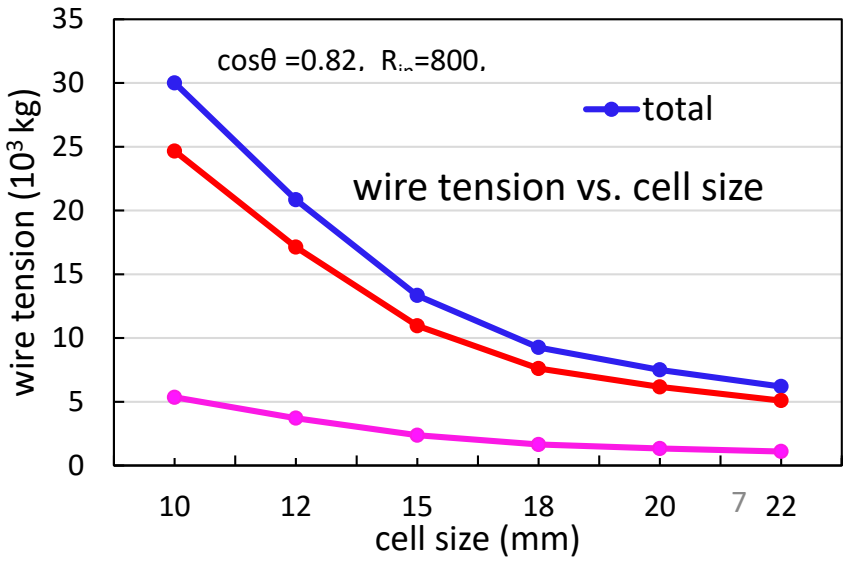
- Second derivative
- Machine Learning

K/π separation vs. cell size and track length

- In principle, the cell size does not affects the PID with cluster counting technique , but it impacts on engineering
  - Large cell size could reduce number of wires and wire tension
- Larger track length will leads to batter PID performance
  - Small radial thickness (while keeping sufficient PID performance) will make the CEPC detector more compact and reduce the cost of other detectors
- About 3σ separation at 20 GeV/c is achieved within 1m track length, 2% noise ratio is taken into account



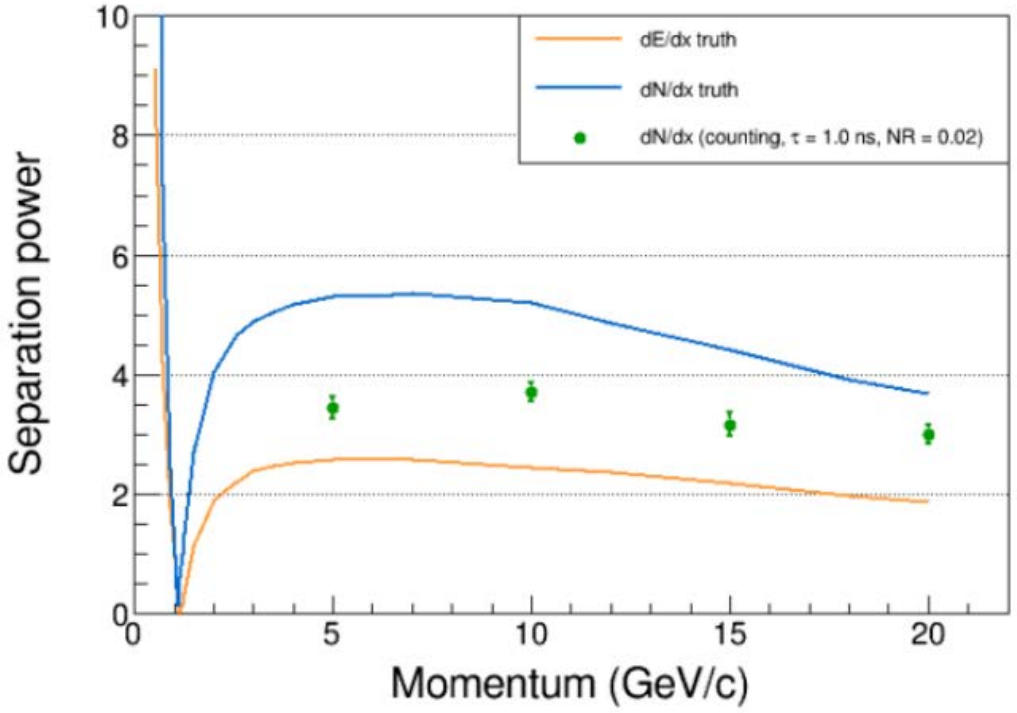


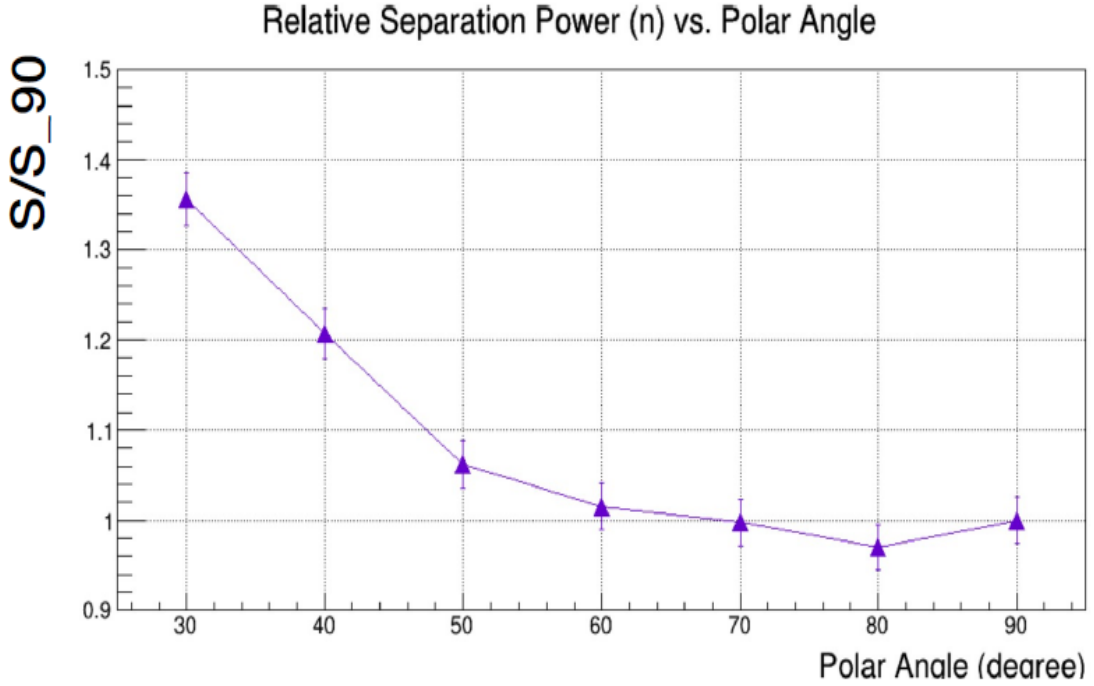


K/ π Separation power

- 3σ K/π separation at 20GeV/c, 1.5 better than dE/dx truth (θ=90˚ , NR = 0.02)
- Polar angle scan: long track length allows better separation power
- Studies with physics channels are ongoing

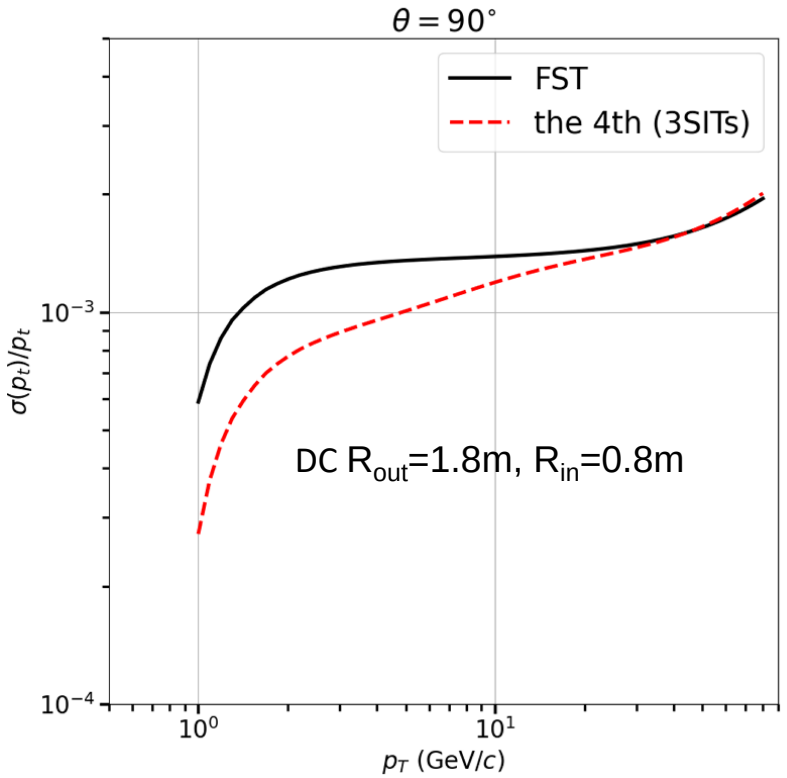
K/π separation vs momentum (θ=90˚)

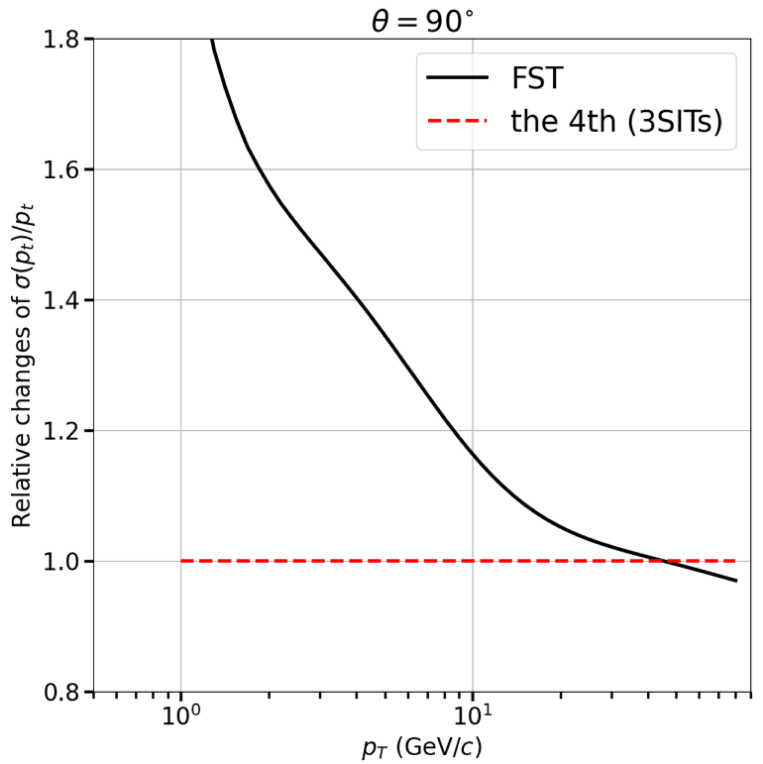




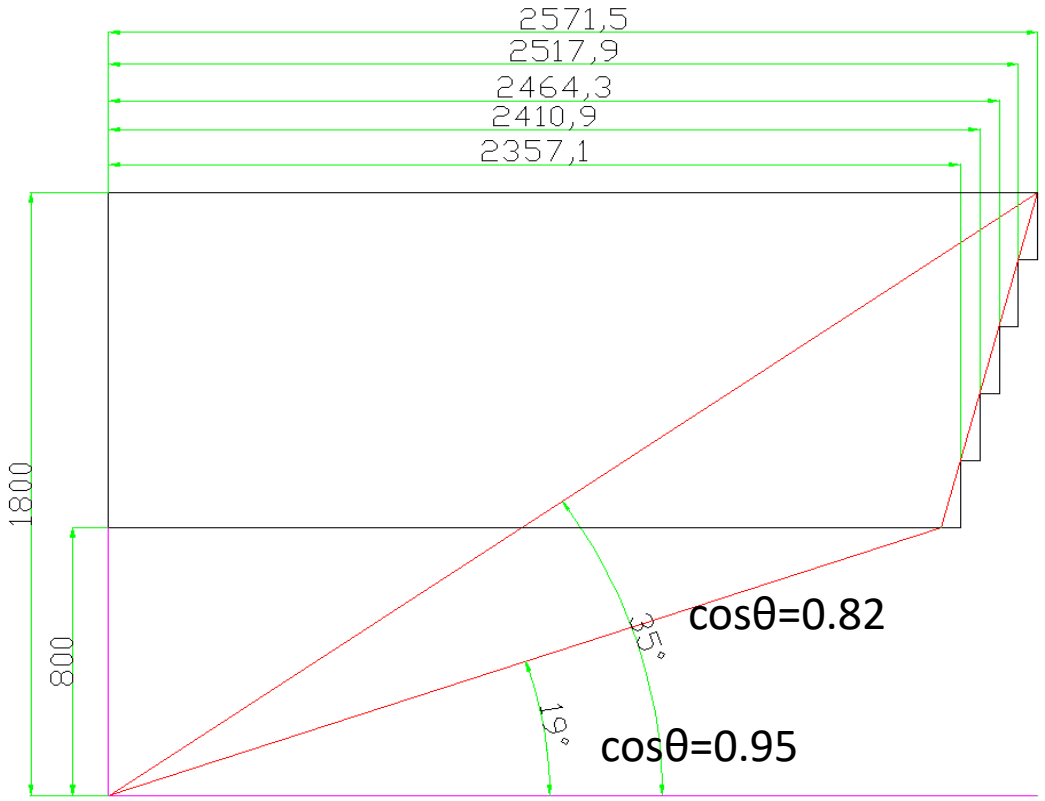
Impact on momentum measurement

- Compared with full silicon tracker (FST), P_T resolution of the hybrid tracker system with drift chamber
  - Improved significantly in momentum range of 0-20 GeV/c
  - Almost no degradation with momentum up to 80 GeV/c





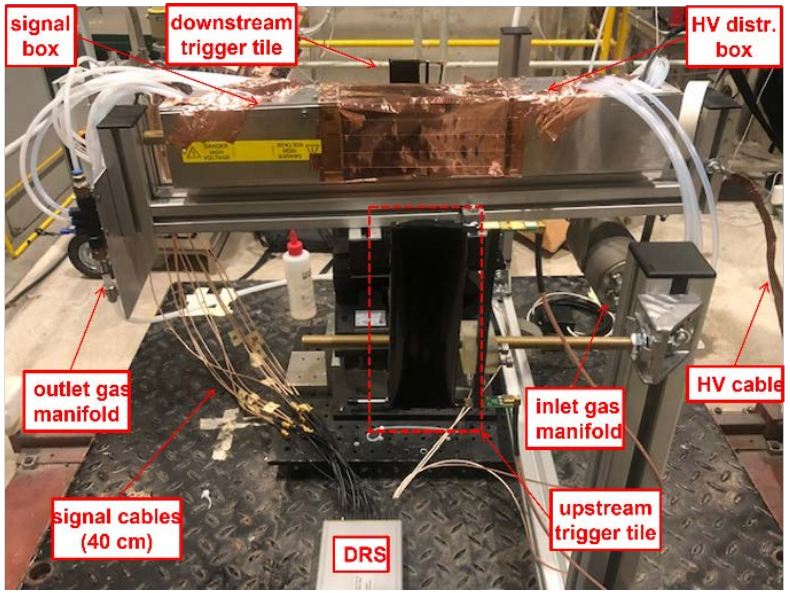
Preliminary parameters

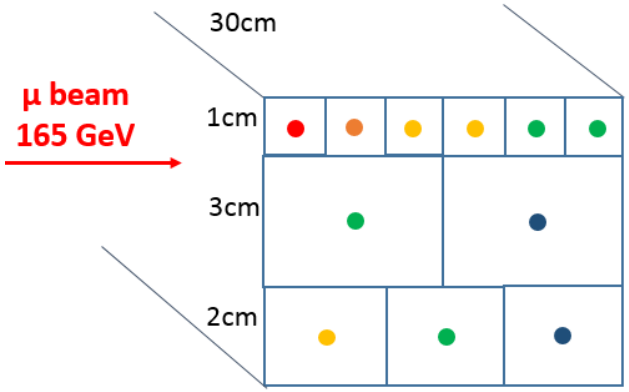


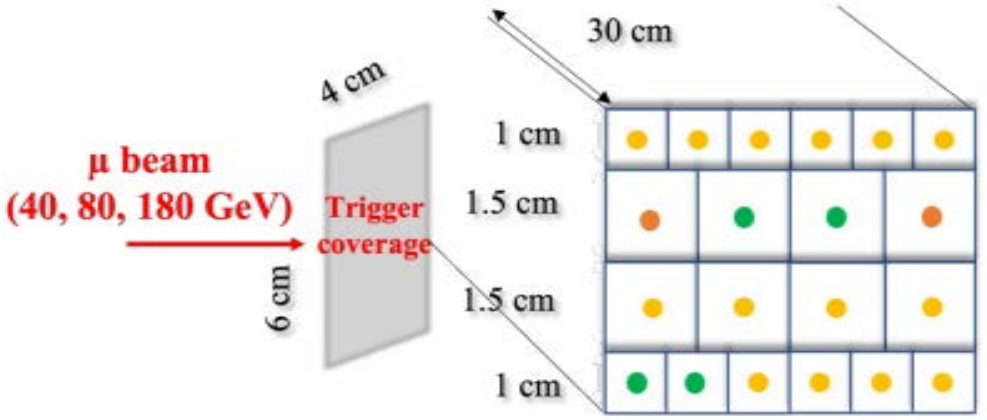
Radius extension	800-1800mm
Length of outermost wires（cosθ=0.82）	5143mm
Thickness of inner CF cylinder：	200μm
Outer CF frame structure：	Equivalent CF thickness: 1.63mm
Thickness of end Al plate	35mm
Cell size:	~ 18 mm × 18 mm
Number of cell	24766
Ratio of field wires to sense wires	3:1
Gas mixture	He/iC_4H_{10}=90:10

Prototype test

- Joined prototype beam tests organized by INFN group in 2021 and 2022
- Data analysis



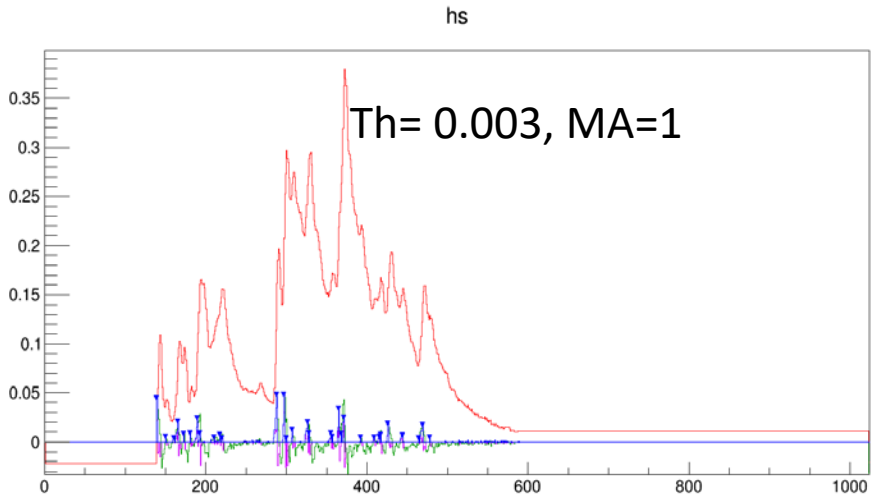


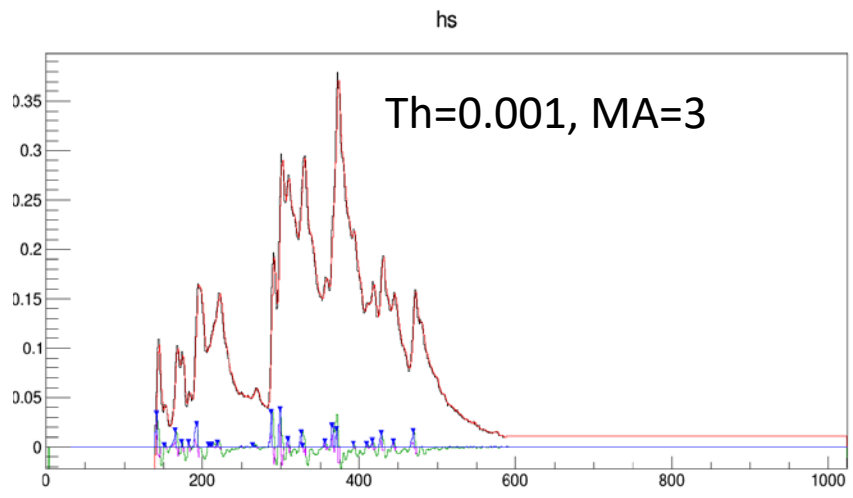


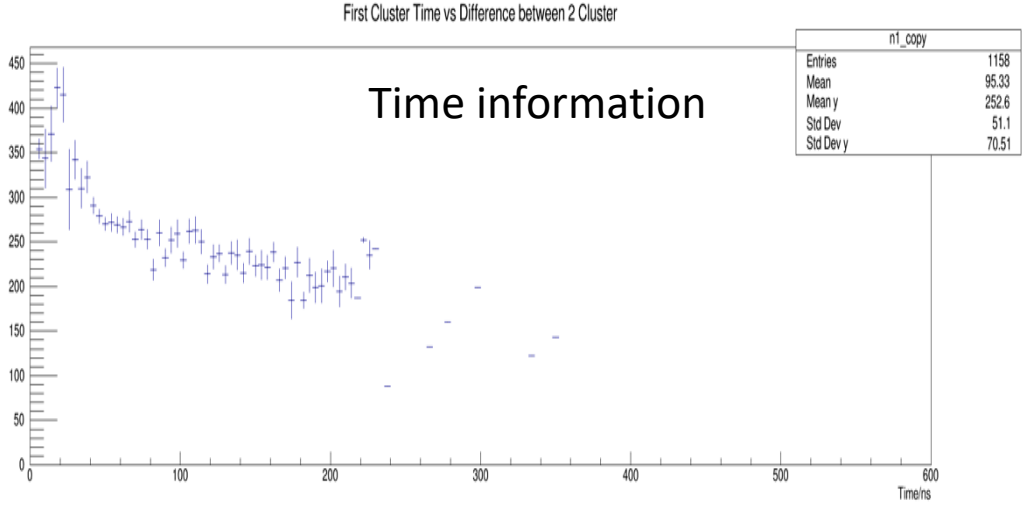
Prototype test

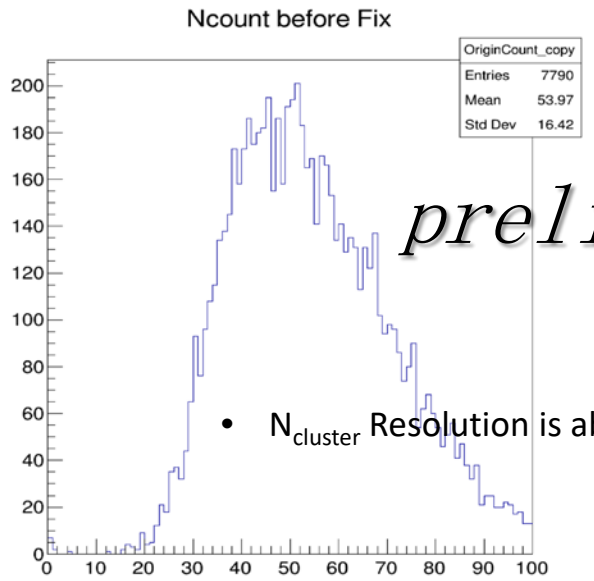
Data analysis

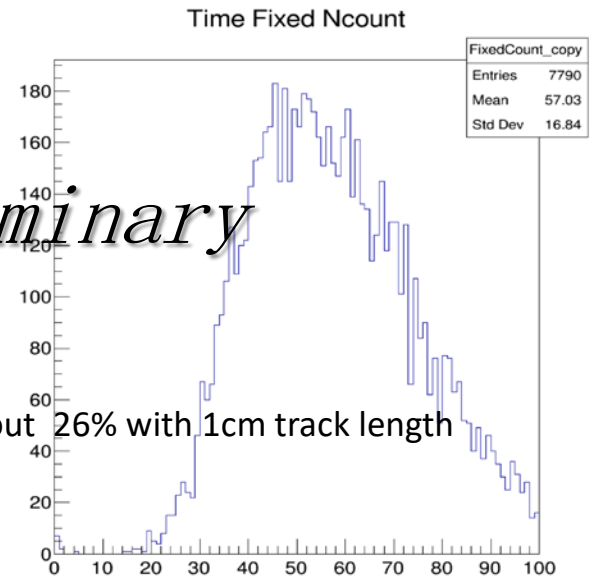
- Moving average
- Peak finding
- Cluster reconstruction









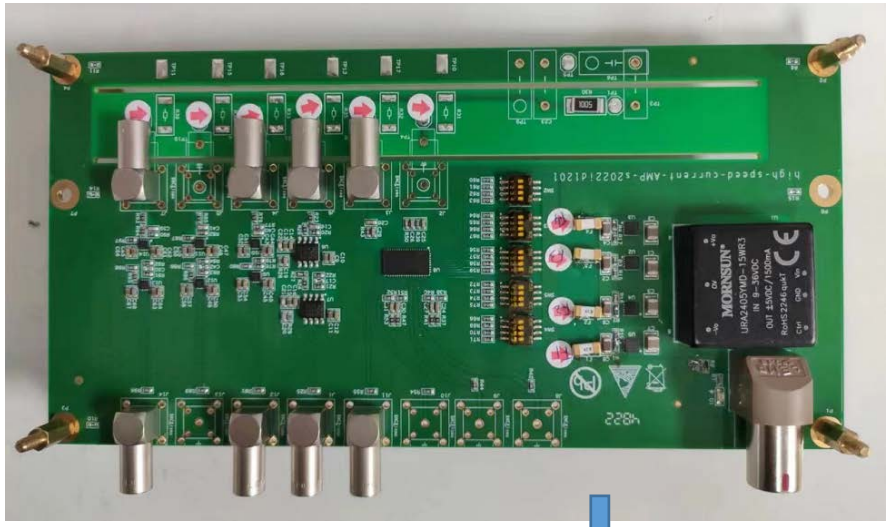


preliminary

- $N_{cluster}$ Resolution is about 26% with 1cm track length

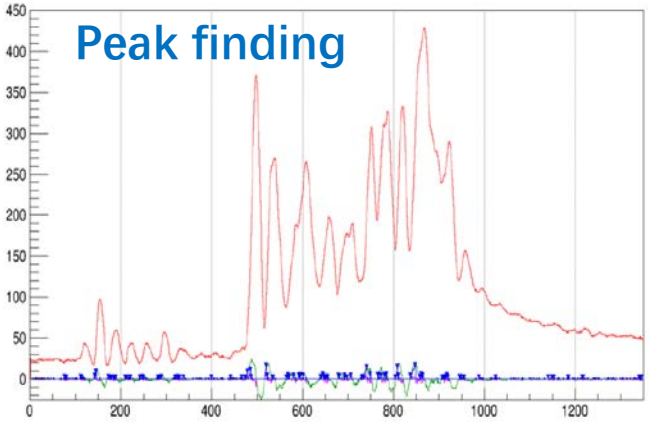
Key issues (1): Electronics

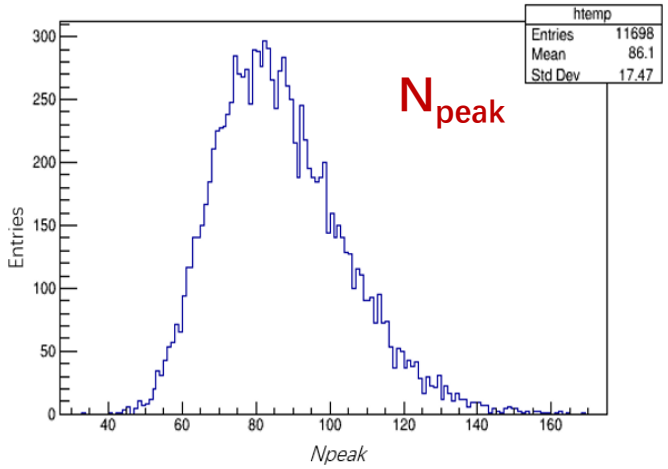
- Design and development of high performance electronics system： Rise time: ~1ns， Sampling rate: >1GHz

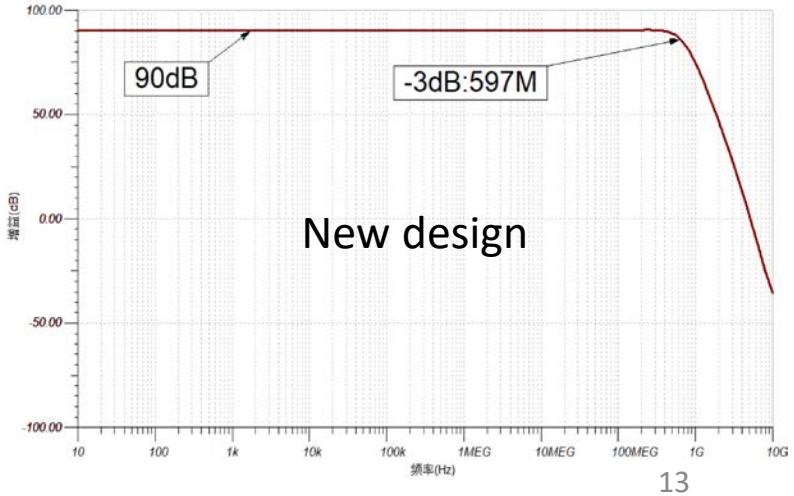


High bandwidth current sensitive preamplifiers based on AD8099 were designed. Tested with a detector prototype

New preamplifiers with better performance are under development

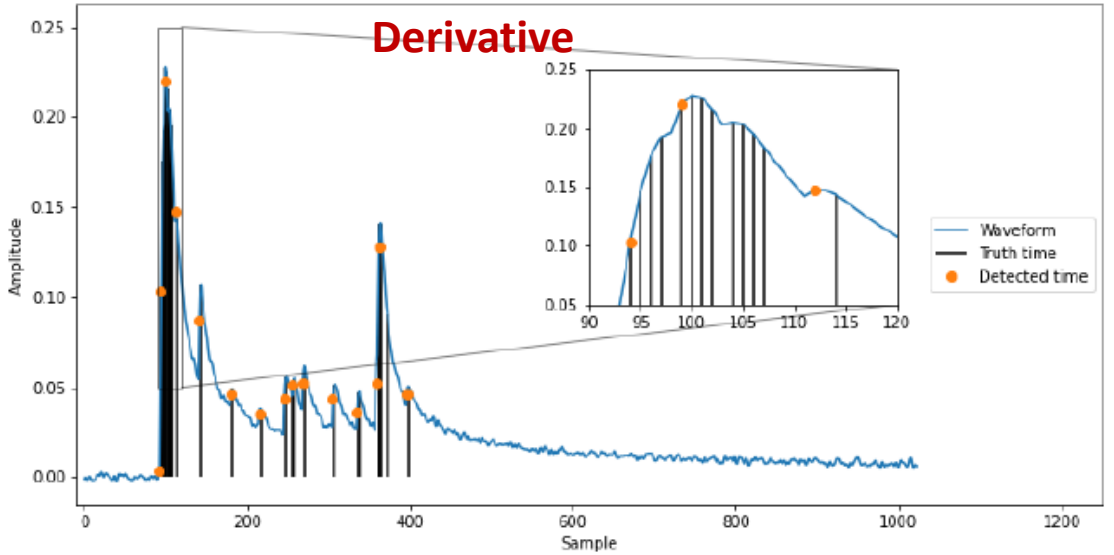


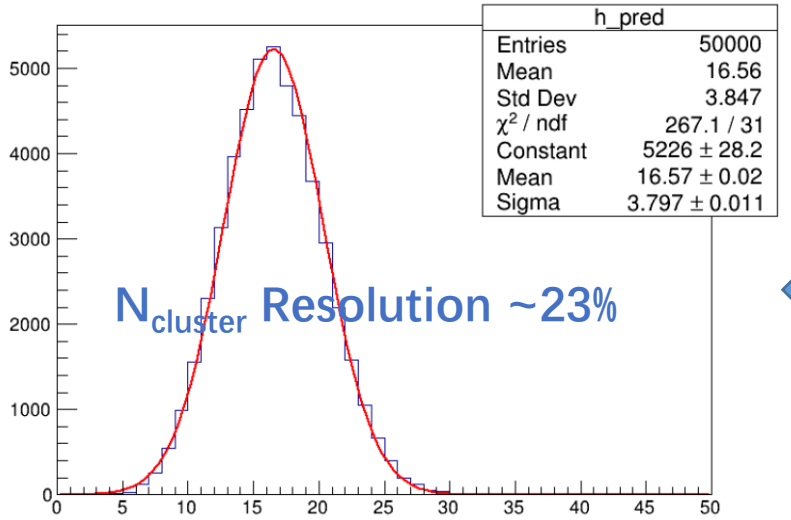


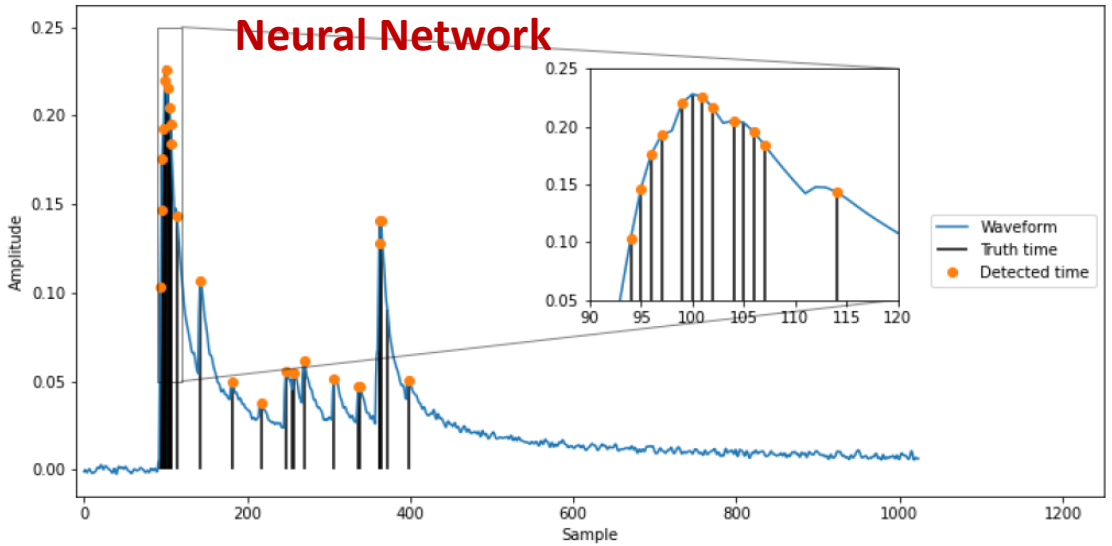


Key issues (2) : Cluster Reconstruction

- 1st and 2nd order derivatives :
  - Moving average for noise filtering , peak finding, cluster reconstruction
- More efficient reconstruction algorithm: machine learning
  - Peak finding
  - Discrimination of the primaries



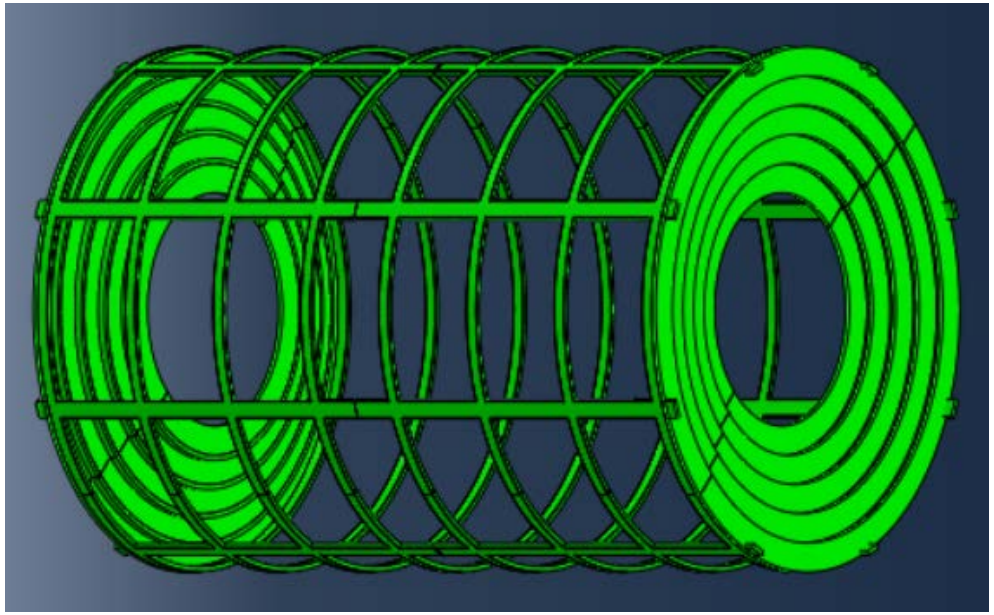


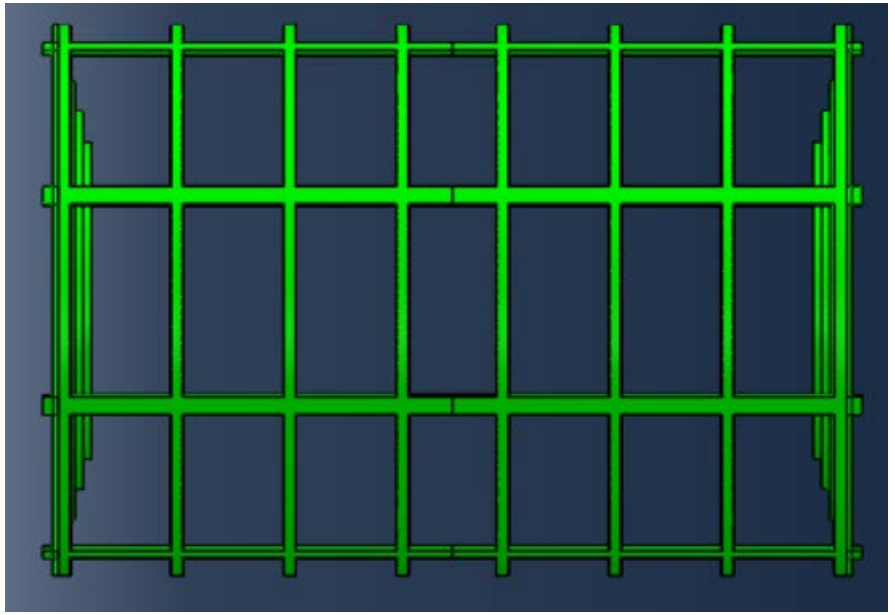


Outline

- Introduction
- Simulation study and detector preliminary parameters
- Mechanical design and calculation
- Summary and outlook

Preliminary mechanical design





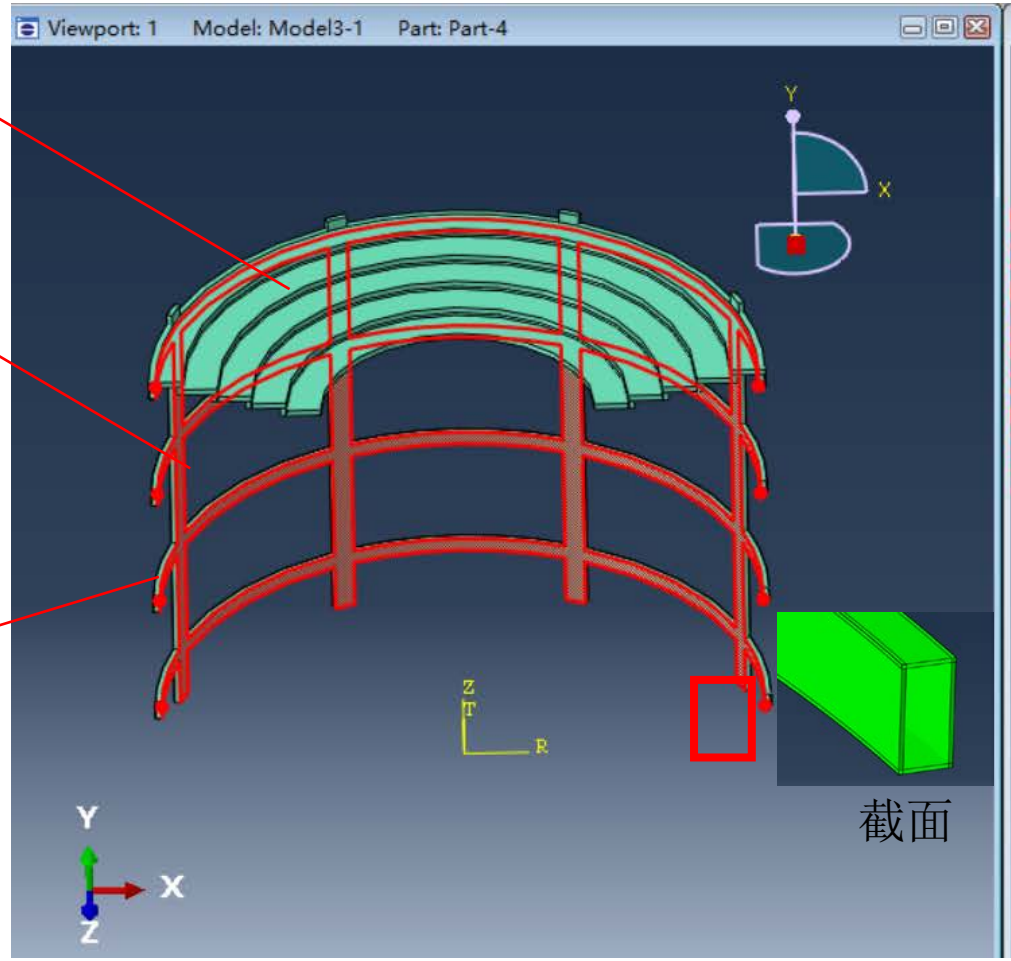
- Includes endplates and carbon fiber frame structure (not include inner CF cylinder)
- Endplates: 35 mm thick Al
- Carbon fiber frame structure: including 8 longitudinal hollow beams and 8 annular hollow beams

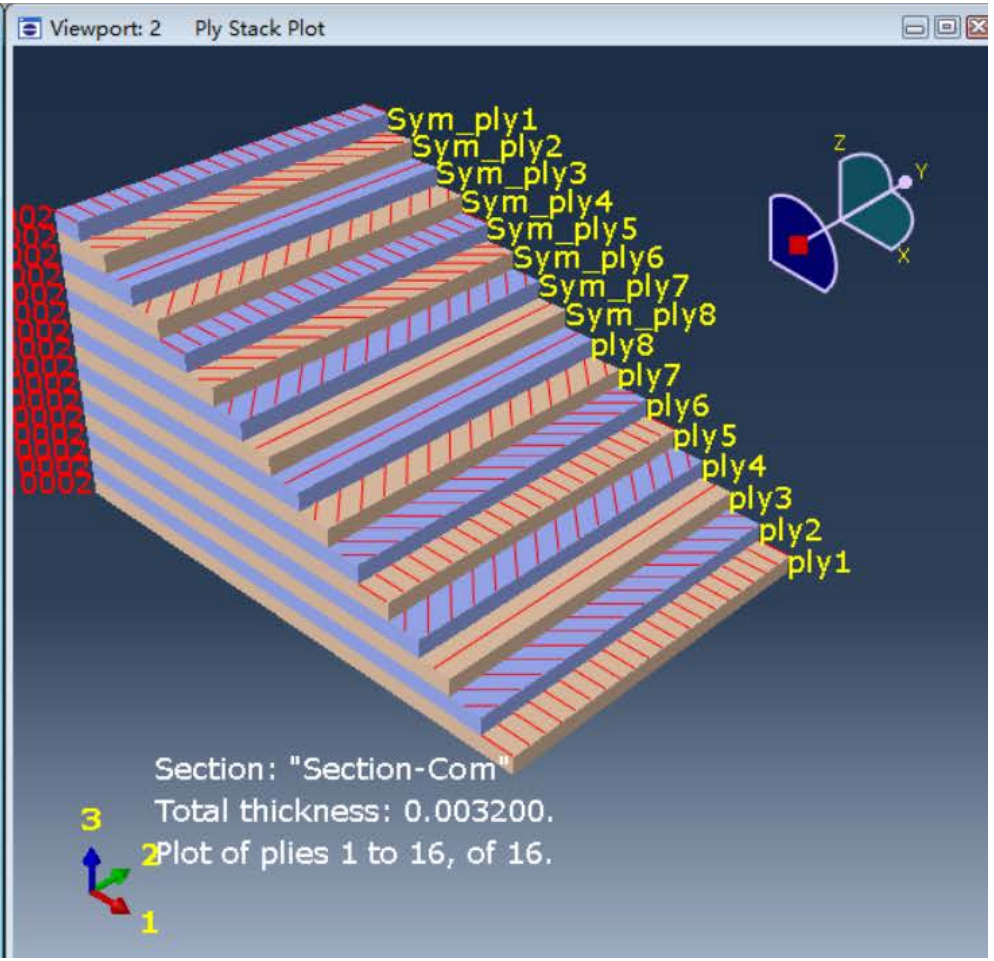
Mechanical structure

Al endplates :
35 mm

Longitudinal beam,
Cross section:
122×40mm

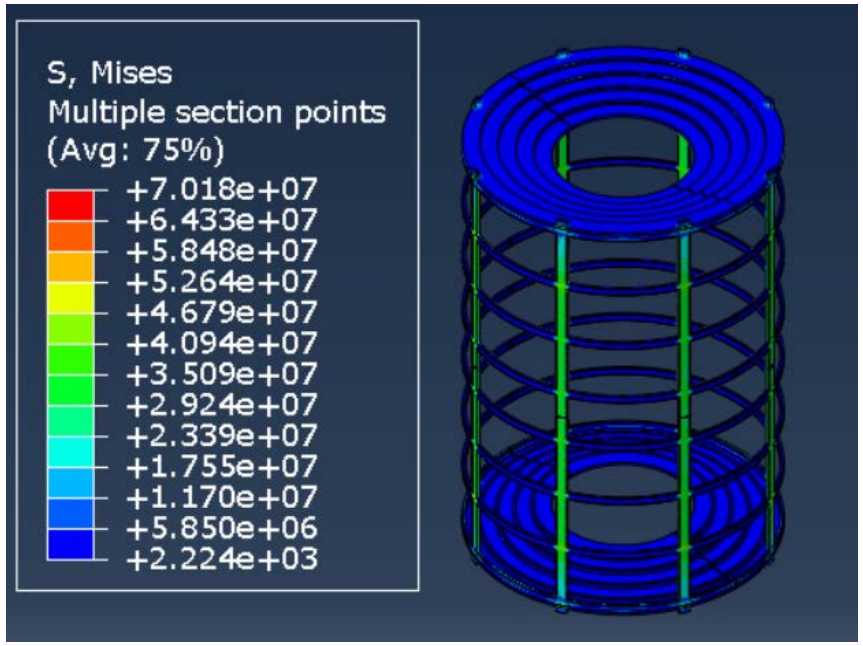
Annular beam,
Cross section:
80×40mm



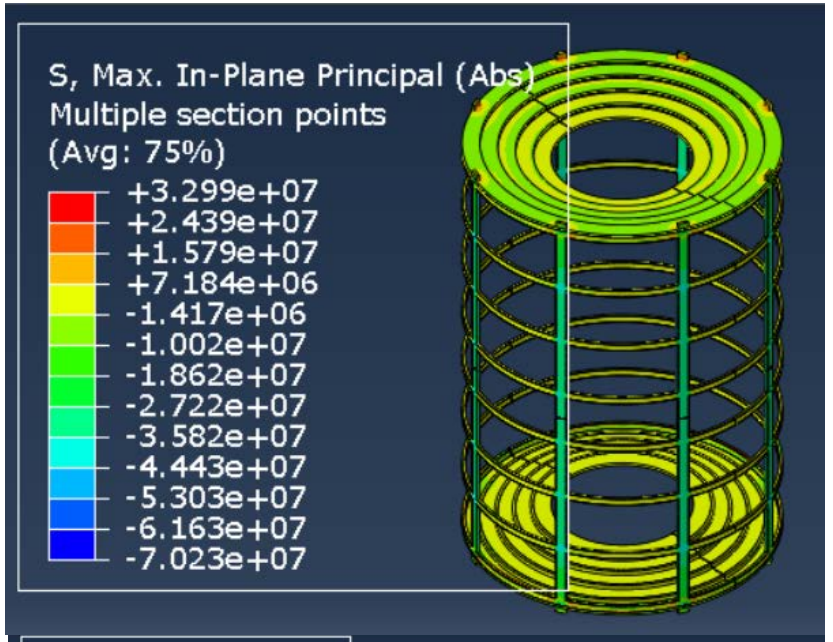


- The thickness of CF: 3.2mm， including 16 layers，200μm(100μm+100μm) / layer

Finite element analysis



Mises stress

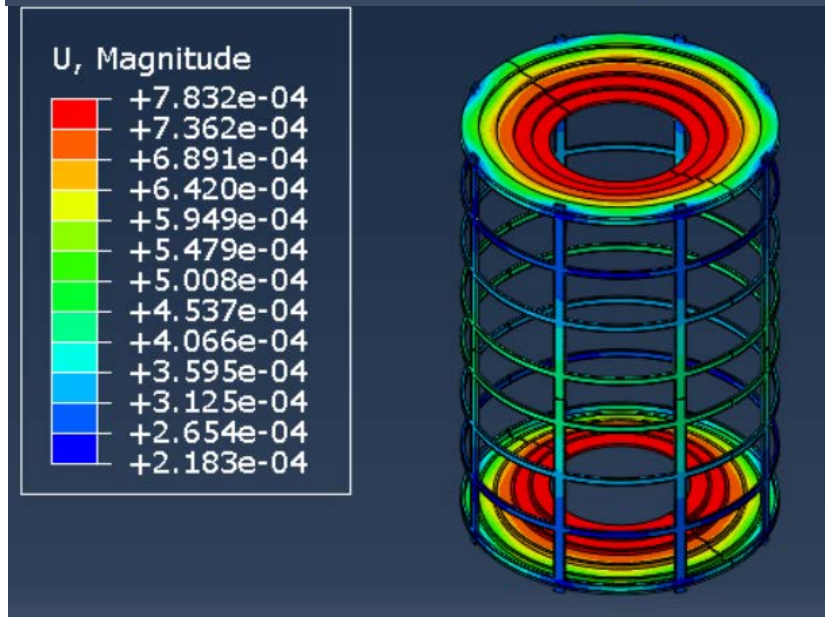


Principle stress

Finite element model——wire tension + weight loads (supported by eight blocks at each endplate)

Mises stress: 70MPa
Principal stress : 33MPa
Deformation: 0.8mm
Buckling coefficient: 17.2 , it is safe

The support structure is stable, and the deformation is acceptable



Deformation

Summary and outlook

- Drift Chamber is proposed in CEPC 4th detector conceptual design for particle identification
- Simulation studies show that 3σ K/π separation at 20GeV/c can be achieved with 1m track length and 2% noise level
- Cluster counting algorithm is developed and shows promising performance for MC samples
- Preliminary mechanical design and calculation were carried out

- Plans:
  - Optimize the reconstruction algorithm and apply to beam test data
  - Detector and readout electronics prototyping and test
  - Extract dN/dx parameters from full simulation and perform physics studies

Thanks for your attention