Drift chamber

Mingyi Dong

Aug. 28, 2020

Outline

- Introduction of silicon + drift chamber tracker
- Main parameters and key techniques of the drift chamber
  - BESIII drift chamber
  - Drift chamber for idea detector concept/ MEG II drift chamber
- Discussion and summary

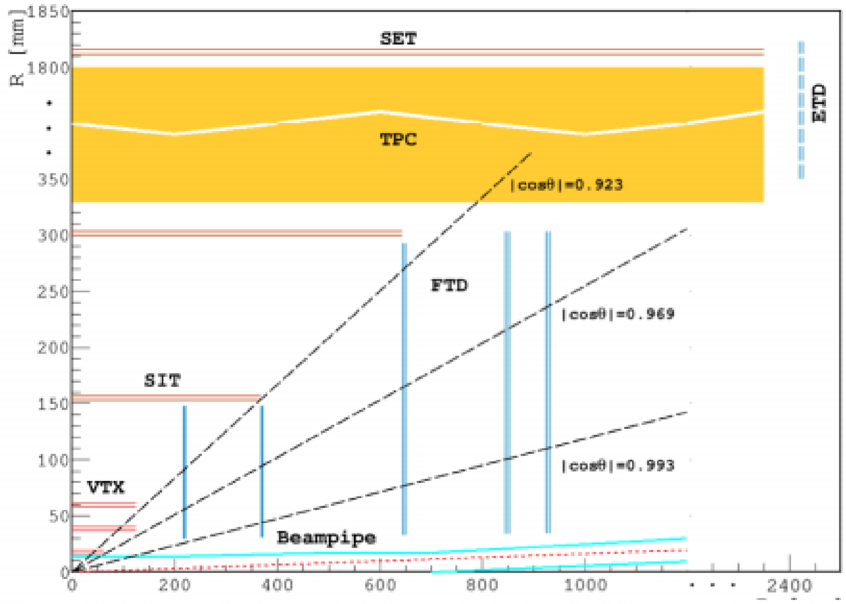
New reference detector design

Jianchuan Wang, CEPC Physics and Detector Plenary Meeting, August 19, 2020

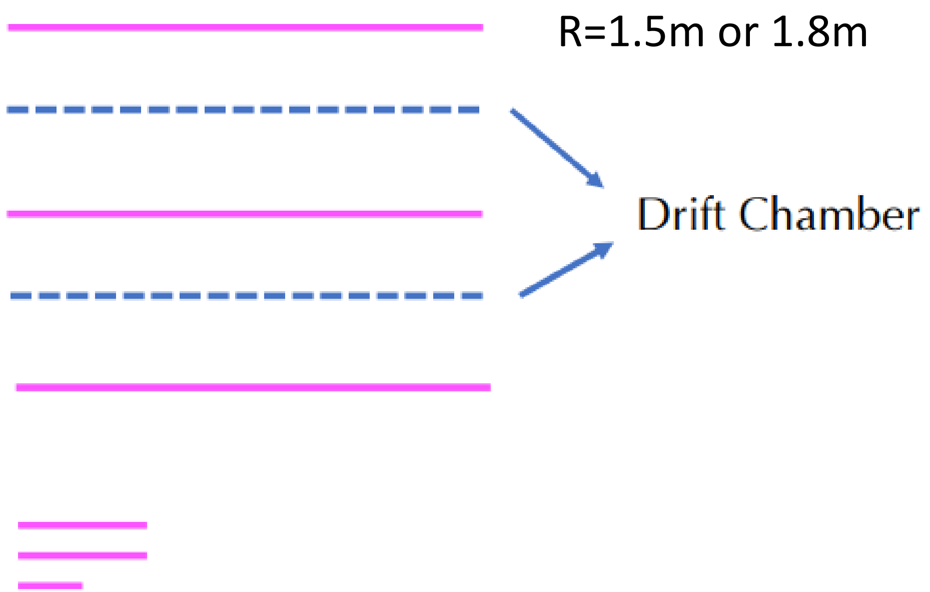
- We want to have a new reference detector design, so that the subdetectors can be optimized within this frame.
  - Basing on the CDR design.
  - A full silicon tracker, + 1 or 2 drift chamber(s) mainly for dE/dX PID.
  - A horizontal crystal bar (~1×1×40 cm^3) solution for the ECAL. The inner radius of ECAL ~1.8 m or ~1.5 m.
  - A HTS magnet between the ECAL & the HCAL, providing 3 Tesla for the Higgs runs and 2 Tesla for the Z pole runs.

Drift chamber in the new design

- Explore the combination of Silicon and Drift Chamber Tracker
- Based on full silicon tracker design
- Insert one or two drift chambers into the gap of the silicon layers
- Aims at PID by accurate measurement of dE/dx



Detector		Radius R [mm]	$\pm z$ [mm]	Material budget $[X_0]$
SIT	Layer 1	153	371.3	0.65%
	Layer 2	300	664.9	0.65%
SET	Layer 3	1811	2350	0.65%



Xin Shi, CEPC Physics and Detector Plenary Meeting, May 20, 2020

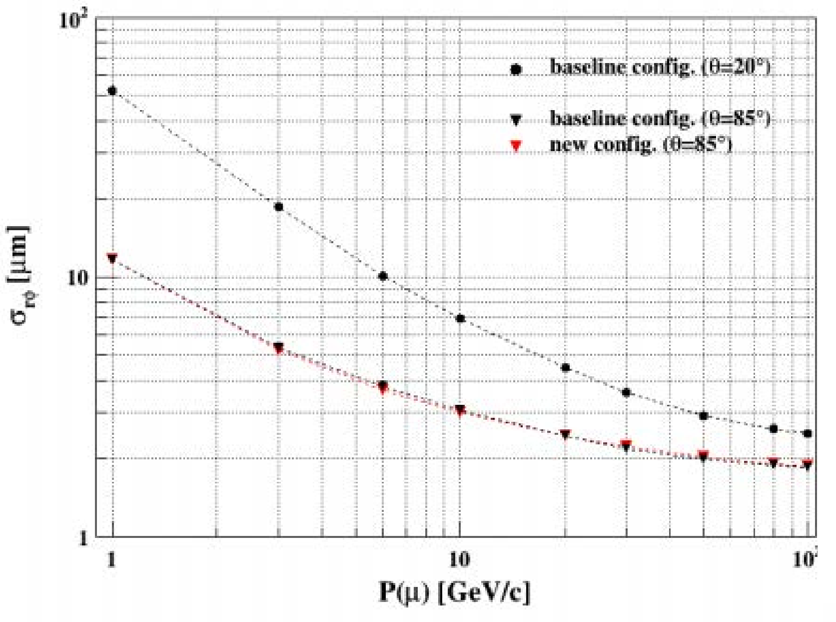
Preliminary Simulation

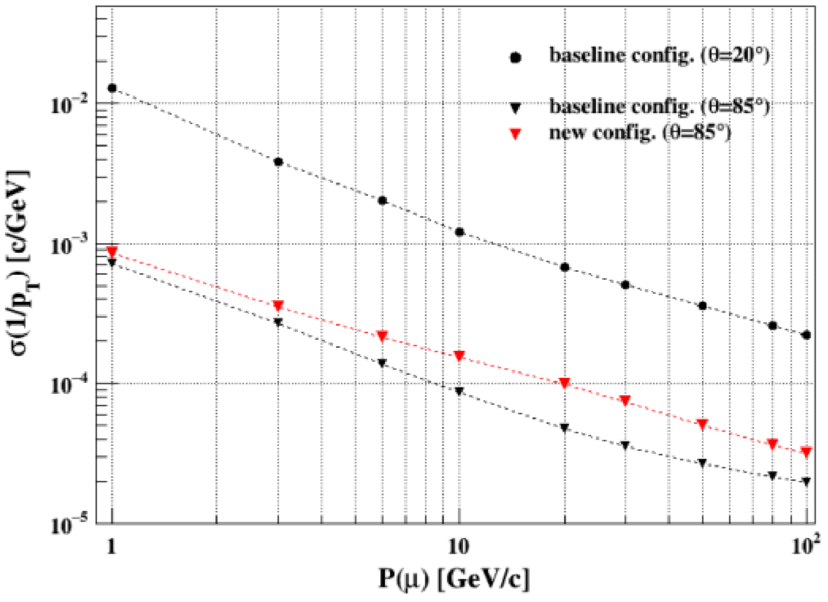
Xin Shi, CEPC Physics and Detector
Plenary Meeting, July 1, 2020

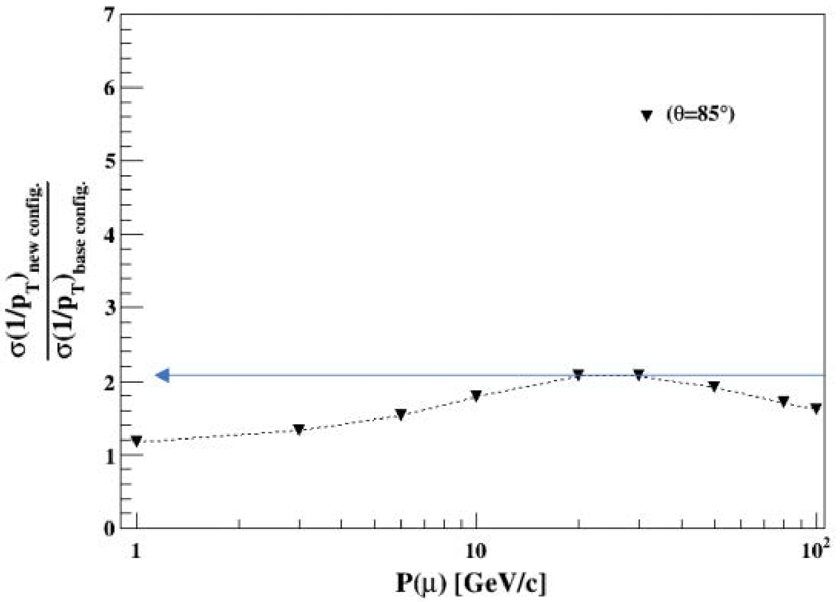
Performance comparison v1.1 (R=1.5m) vs. baseline

No change of impact para. reso.

Slight increase in momentum reso. (<~2)

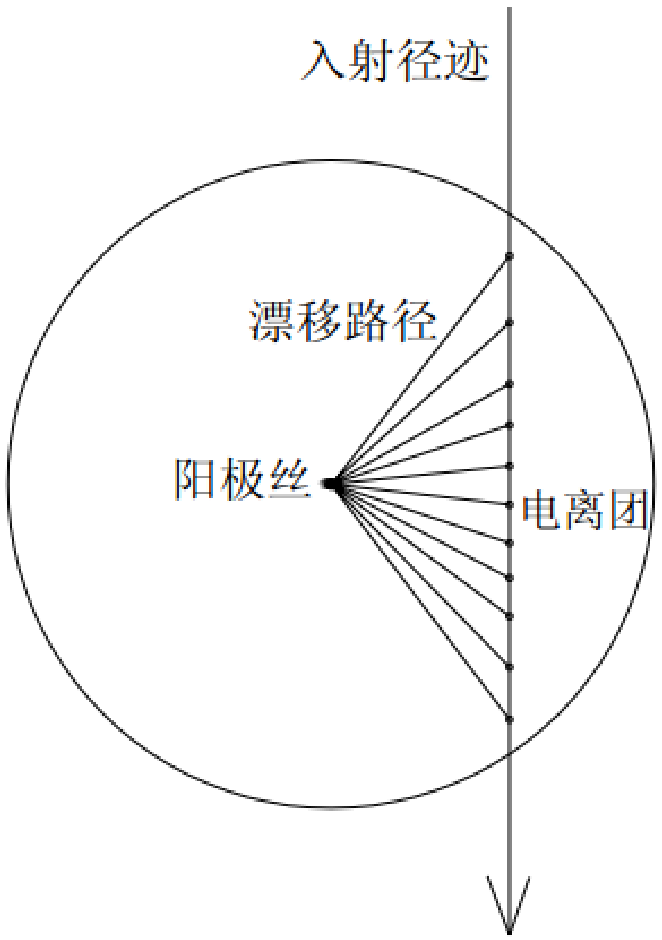




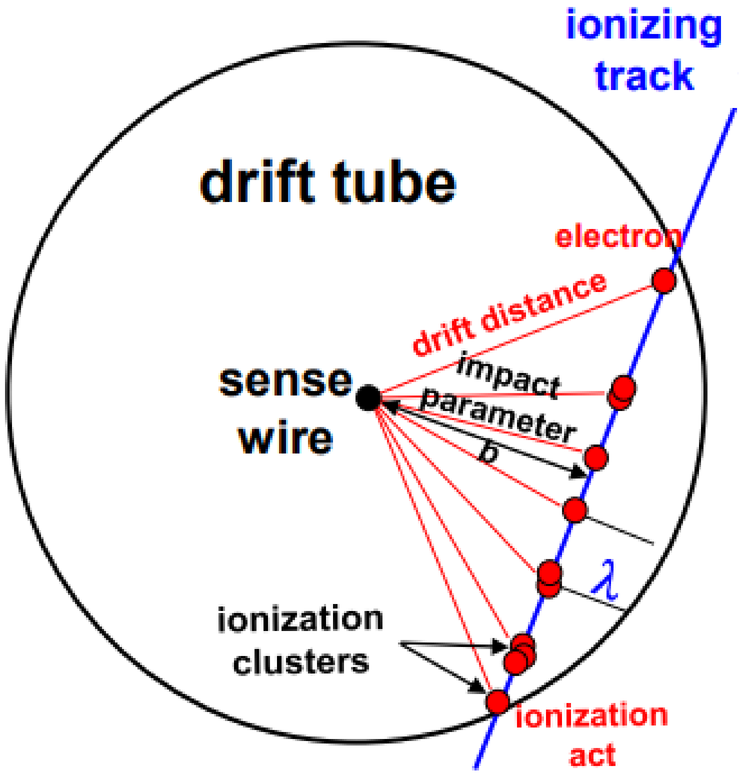


Drift chamber

- Sense wire (+HV) surrounded by few field wires (ground)
- Charged particles pass through the cells of the drift chamber, lose part of energy by inelastic collide with gas atoms, induce excitation or ionization, and produce electron-ion pairs.
- Electrons drift toward sense wire. Avalanche occurs few µm close to the sense wire, induce signal on the sense wire
- The hit position of the particles is determined by drift time of the electrons and X-T relationship
- The charge of the signal indicate the energy loss of the particle. Get the charge per unit length (dE/dx) will be helpful to PID



dE/dx measurement



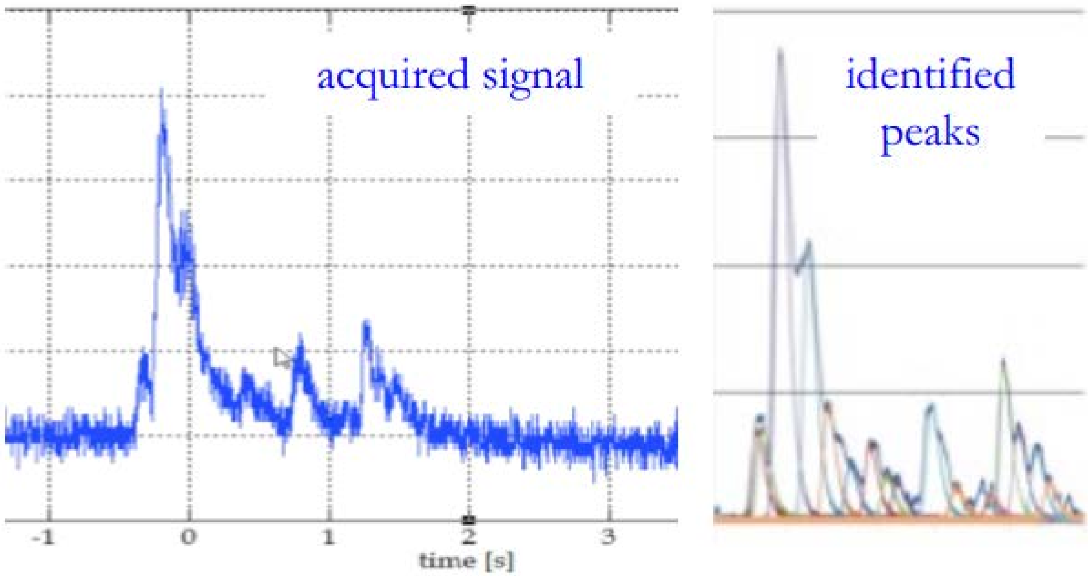
- The resolution of dE/dx is depended on energy resolution (charge measurement), track length, and sampling number
- reconstruct the most probable sequence of clusters drift times
- truncated mean cut (70 -80%) reduces the amount of collected information

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot \left(L_{track}[m] \cdot P[atm]\right)^{-0.32}$$

- n = 112 and a 2m track at 1 atm give σ ≈ 4.3%

Cluster counting

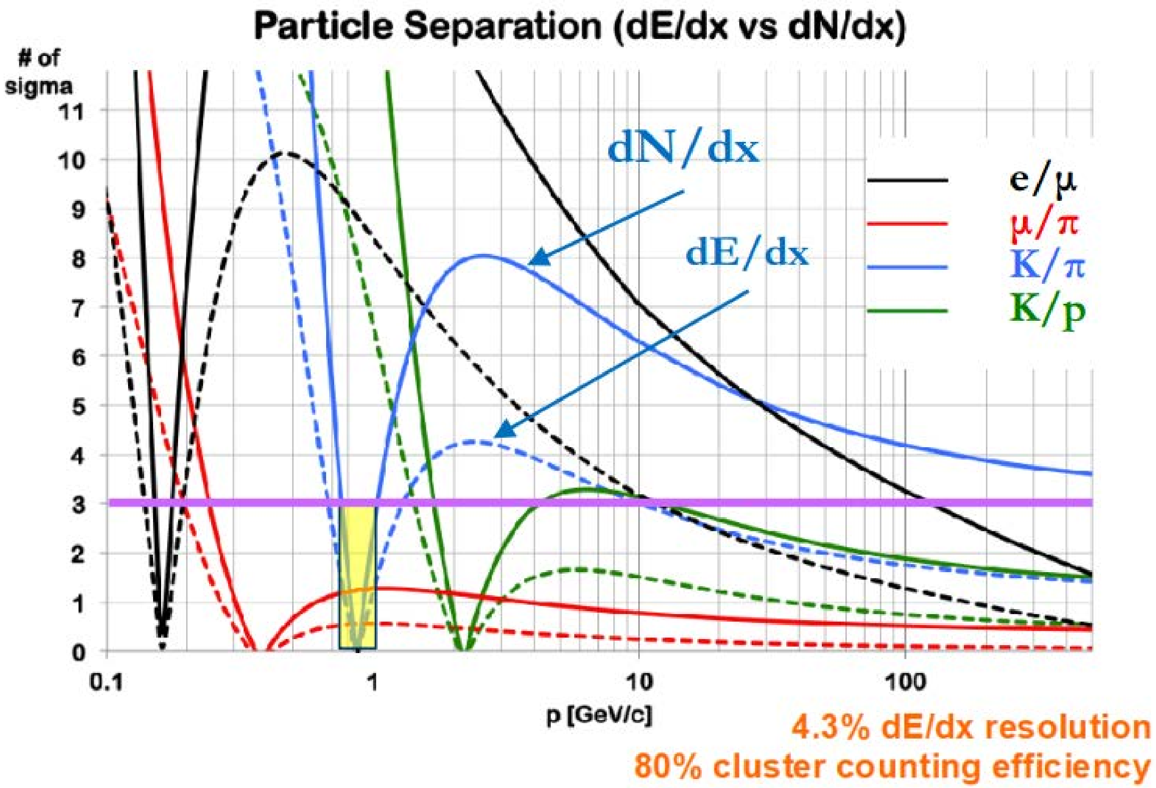
G.F. Tassielli - ICHEP2020



- If each ionization act can be spread in time to few ns
- Counting the number of ionization acts per unit length (dN/dx) to identify the particles (P. I d .) with a better resolution

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = \left(\delta_{cl} \cdot L_{track}\right)^{-1/2}$$

- δcl= 12.5/cm for He/iC_4H_{10} =90/10 and a 2m track give σ ≈ 2.0%



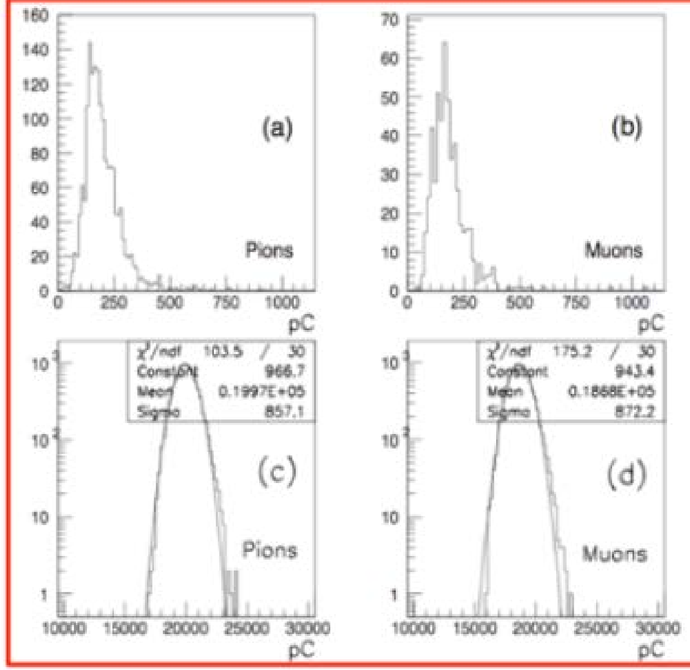
- Expected excellent K/ π separation over the entire range except 0.85<p<1.05 GeV (blue lines)

Cluster counting

The data shown refer to a beam of **μ and π at 200 MeV/c**, taken with a gas mixture **He/iC_4H_{10}=95/5, δ_{cl} = 9/cm, 100 samples, 2.6 cm** each **at 45°** (for a **total track length of 3.7 m**, corresponding to **N_{cl} = 3340, $1/\sqrt{N_{cl}}$ = 1.7%**).

NIM A386(1997) 458-469

Setup:
25 μm sense wire
(gas gain 2x10⁵),
through a high BW preamplifier
(**1.7 GHz, gain 10**),
digitized at
2 GSa/s, 1.1 GHz, 8 bits

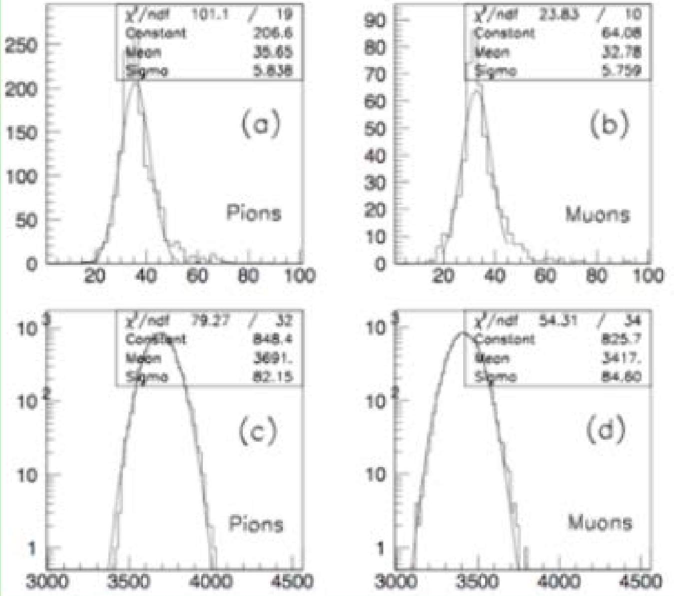


dE/dx

100 samples 3.7 cm

theory:
($\sigma = 0.41\, n^{-0.43} (L[m]P[atm])^{-0.32}$)
σ = 3.7%
≈ 2.0σ separation

experiment
20% truncated mean
σ = 4.5%
≈ 1.4σ separation

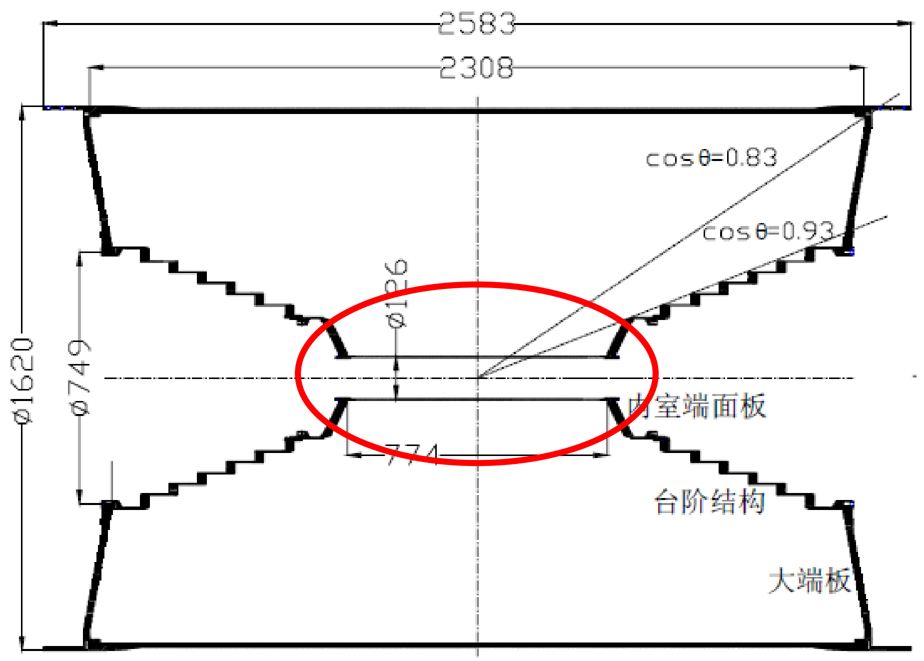


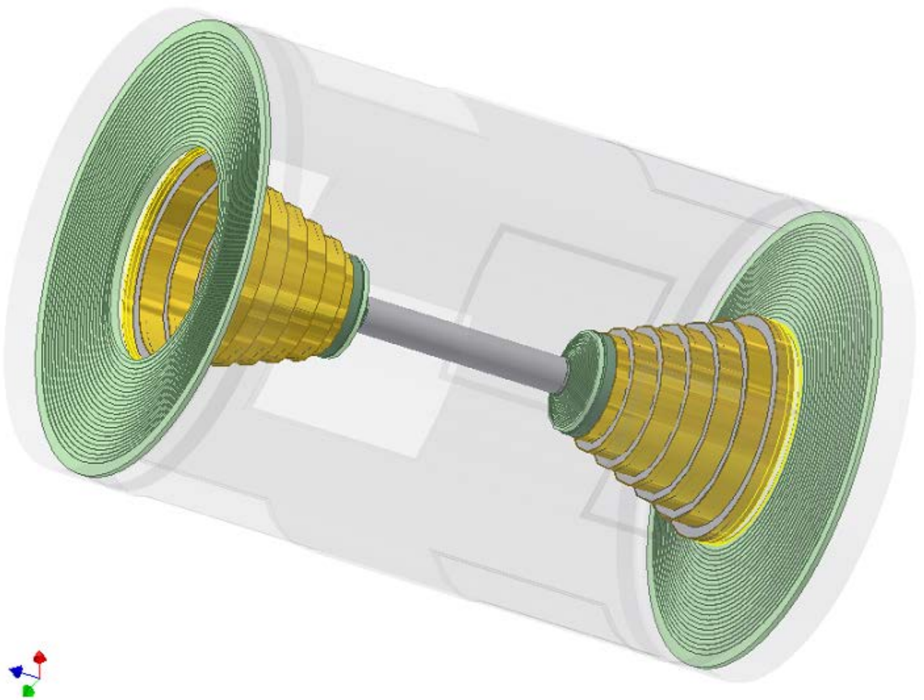
dN_{cl}/dx

theory
Poisson distribution
σ = 1.7%
≈ 5σ separation

experiment
σ = 2.5%
≈ 3.2σ separation

BESIII drifter chamber (MDC)



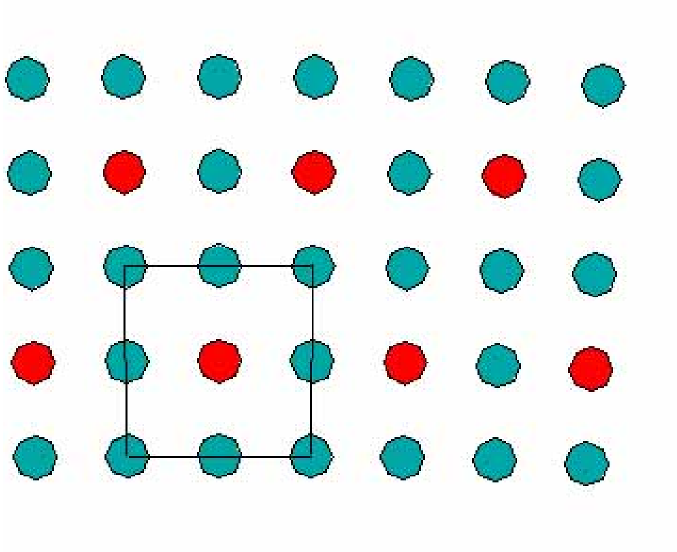


- Consists of an inner chamber (eight layers) and an outer chamber (35 layers)

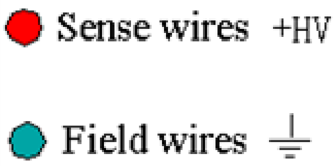
- Radius : 63mm -> 810mm， length: 2308m
- Inner cylinder: 1.2mm carbon fiber
- outer cylinder: 11.5 mm CF with 8 windows
- End plates: 18 mm Al (6 stepped and inner end plates : 25 mm Al)

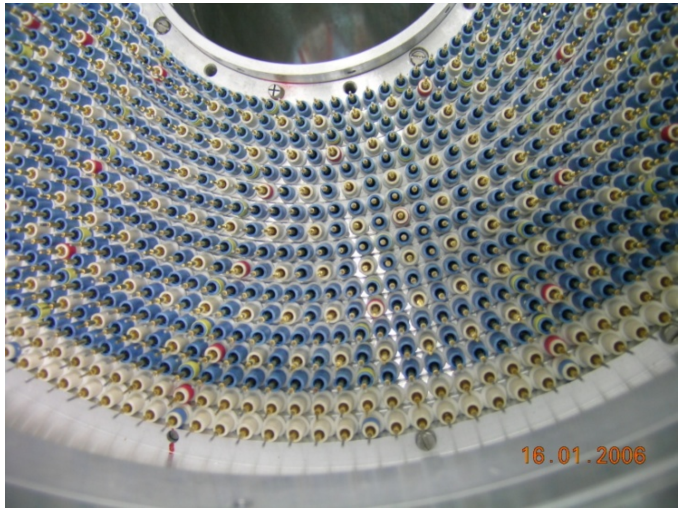
- 43 layers
- 19 axial layer, 24 stereo layer
- 6796 cells in total

Small cell design



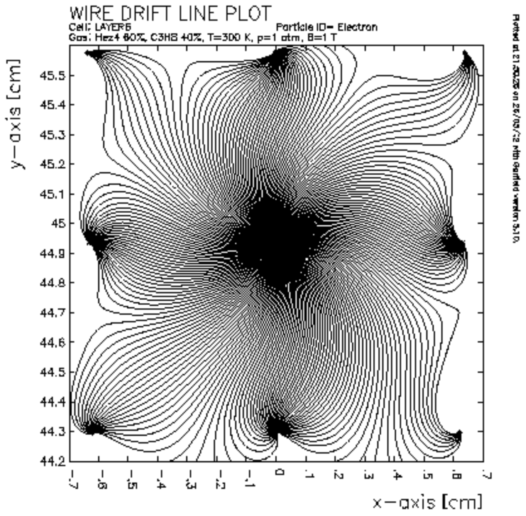
Field to sense wire ratio: 3:1

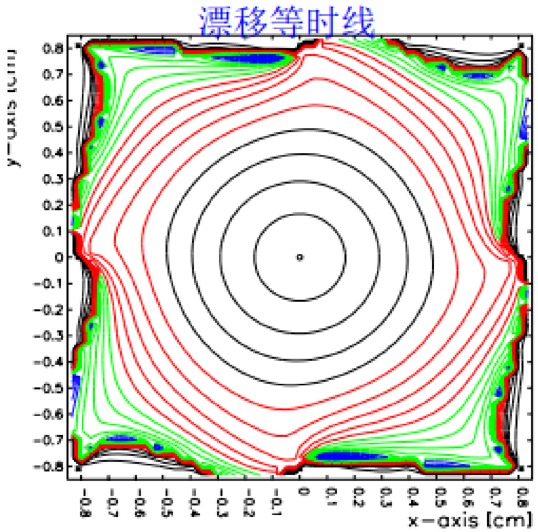




- cell size：
  inner chamber: 12mm×12mm
  outer chamber: 16.2mm×16.2mm

- Sense wires: ϕ25μm W (Au)
- field wires: ϕ110μm Al (Au)
- 28680 wires in total





attractive features of small cells

- Low drift distance, can provide fast trigger signal for the detector working at high luminosity
- can reduce diffusion of electrons, and improve accuracy of time measurement and spatial resolution
- Can put more layers in a limited space to improve the accuracy of charge measurement
- Reduce the average accumulated charge of the cells, and slow down aging

Other main parameters

- **gas: He based gas mixture**

  low material budget to reduce multiple scattering

  He:C_3H_8=60%: 40% X_0: 500m

  v_e=3.8cm/μs M: 2×10^4 @2200V

- **High Voltage:**

  about 2200 V, same for the cells in same layer, little different between each layer

- **Material budget:**

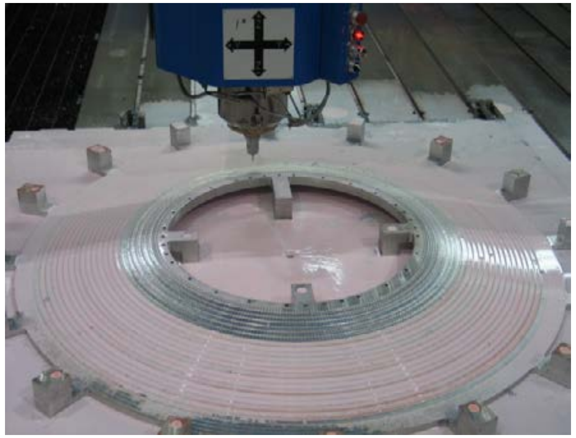
  0.03% (gas + wires) + 0.51% (inner cylinder) + 4.91% (outer cylinder)= 5.45% X_0

  0.54% X_0 per track trun

Wiring and assembly techniques

- key components
  - End plates
  - inner cylinder
  - outer cylinder
  - feed- through

- Assembly techniques
  - Pretension
  - Vertical Wiring
  - Wire positioning: feed- through
  - Wire fixed: clamp the small tube of feed- through

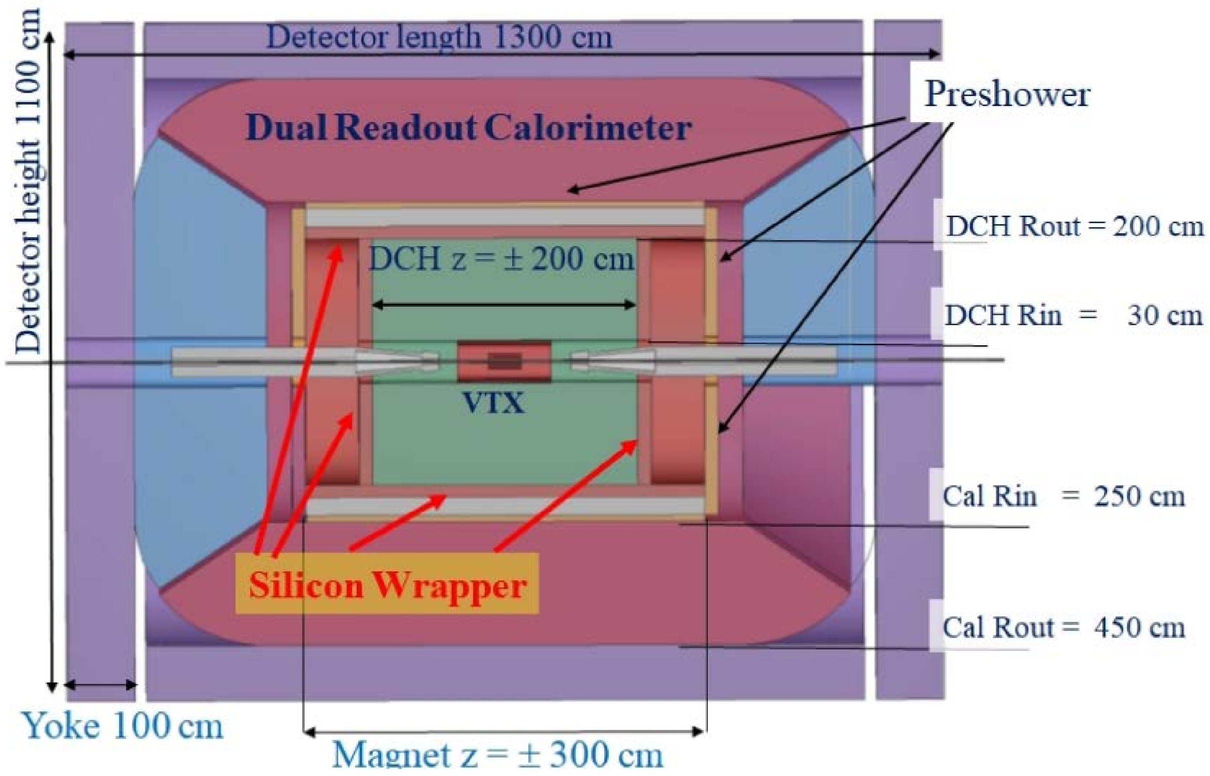


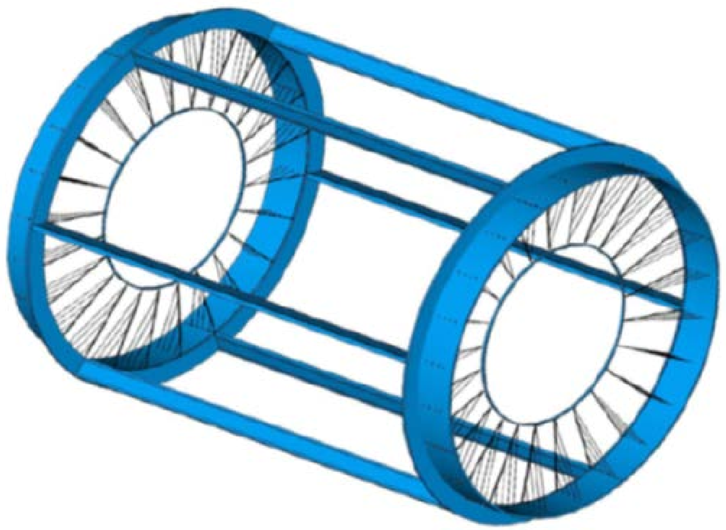
Performance of BESIII MDC

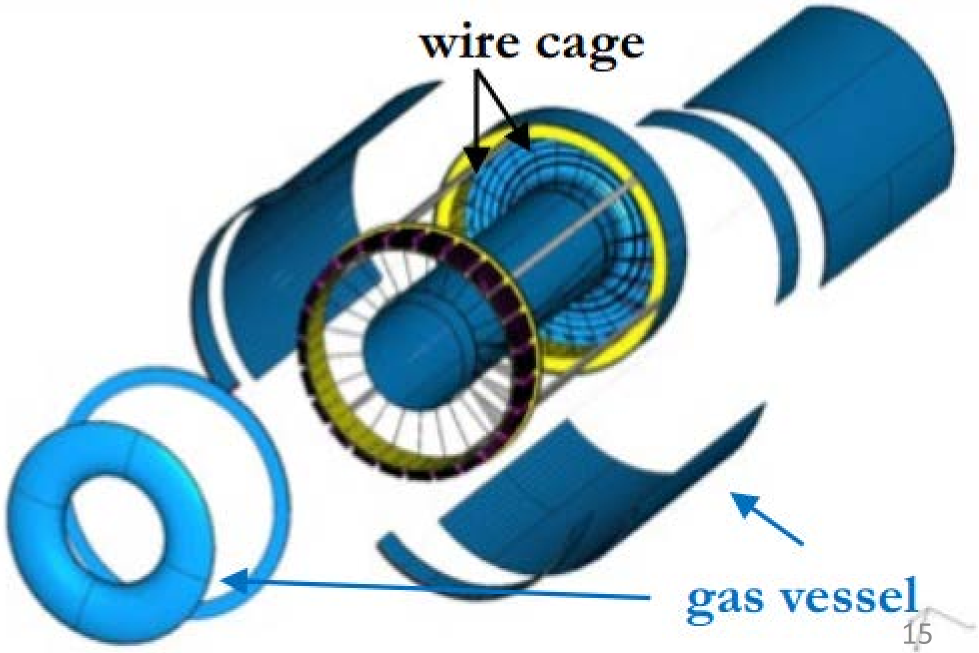
Sub detector	Design Performance	Achieved Performance
MDC	$\sigma_{r\phi} = 130\mu m$ $\Delta p/p = 0.5\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 6\%$	$\sigma_{r\phi} = 115\mu m$ $\Delta p/p = 0.47\%@1GeV$ (B=1T) $\sigma_{dE/dx} = 5.2\%$

	$\sigma_{r\varphi}$	$\sigma_{dE/dx}$	$\Delta p/p$
SLAC BaBar	130 μm	6.8%	0.47%@1GeV/c (B=1.5T)
KEK BELLE	130 μm	5.6%	0.35%@1GeV/c (B=1.5T)
CESR CLEO	110 μm	5.7%	0.35%@1GeV/c (B=1.5T)
BESII	250μm	8.5%	2.5%@1GeV/c (B=0.5T)
BESIII	115 μm	5.2%	0.47%@1GeV/c (B=1.0T)

Idea drift chamber

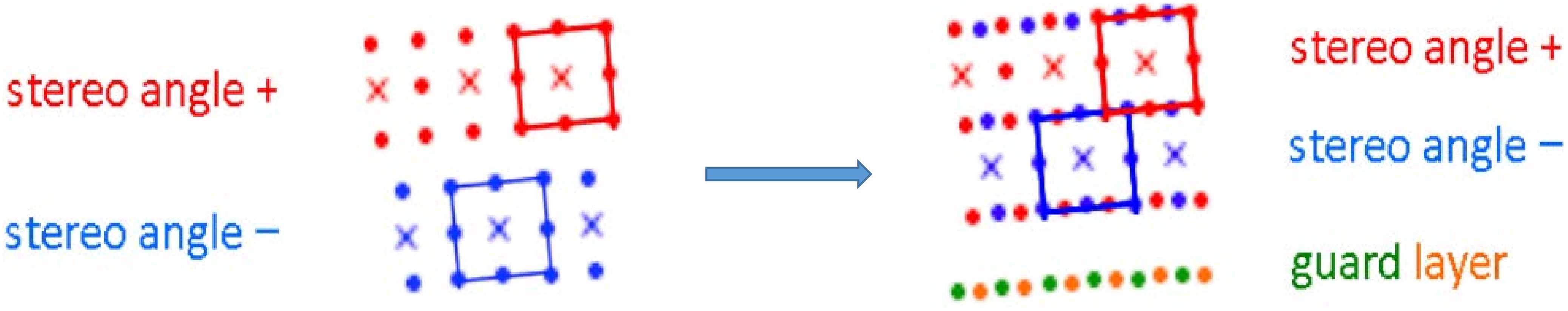






- Low mass
- Small cell size, High density wiring
- Feed -through less
- Cluster counting

Cell design



Field to sense wire ratio: 3:1

Field to sense wire ratio: 5:1

- more field w. per sense w. allowing for thinner field wires
- High density wiring requires a non standard wiring procedure and needs a feed -through -less wiring system

- sense wires: 20 µm diameter W (Au)
- field wires: 40 µm diameter Al (Ag)
- f. and g. wires: 50 µm diameter Al (Ag)

- MEG II developed a novel wiring system and procedure

Main parameters of MEG II drift chamber

NIM, A 936 (2019) 501–502

- length: 1.91 m, inner radius: 17 cm, outer radius: 29 cm
- Consists of 10 concentric layers
- Cell size : 6.6 mm (innermost layer), 9.0 mm (outermost layer)
- Total number of drift cells: 1920, Total number of wires 13056

- **gas：** **He based gas mixture (He : i-C4H10 = 90%: 10%)**
- **Material budget**

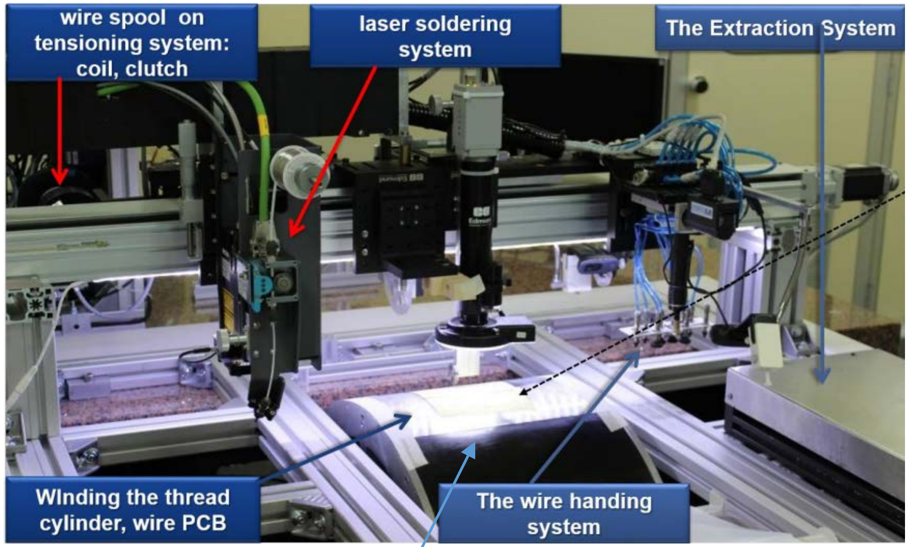
  0.158% X_0 (gas +wires + inner cylinder) , 0.158% X_0 per track turn

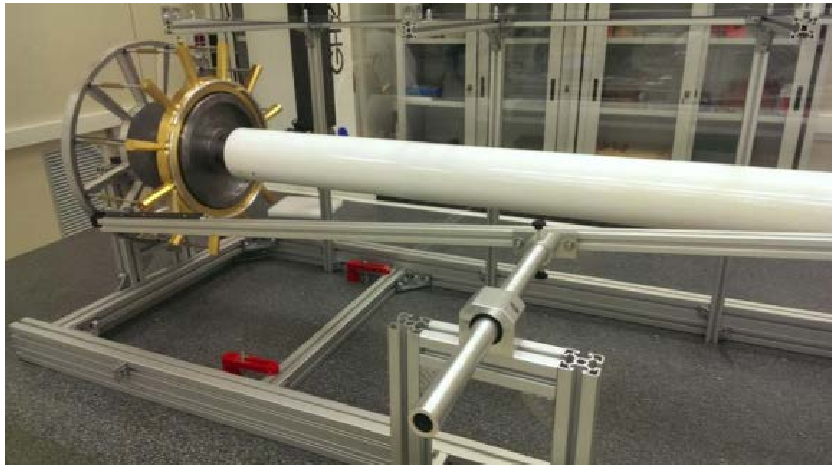
  inner cylinder： 20 µm one-side-Al mylar foil

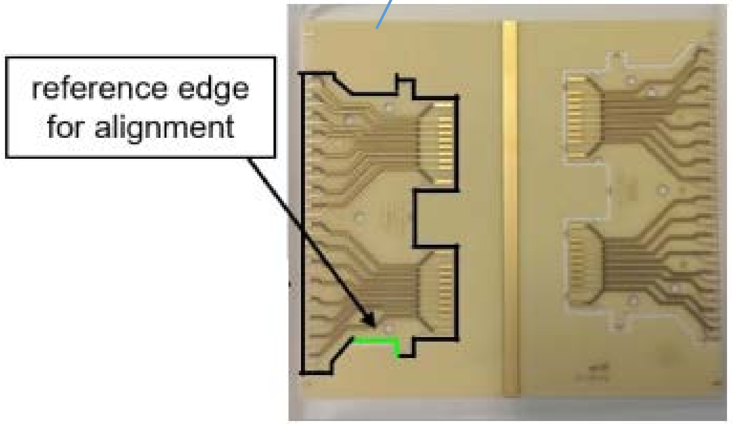
  outer cylinder： a carbon fiber support structure, encloses the gas volume and loads wire tension

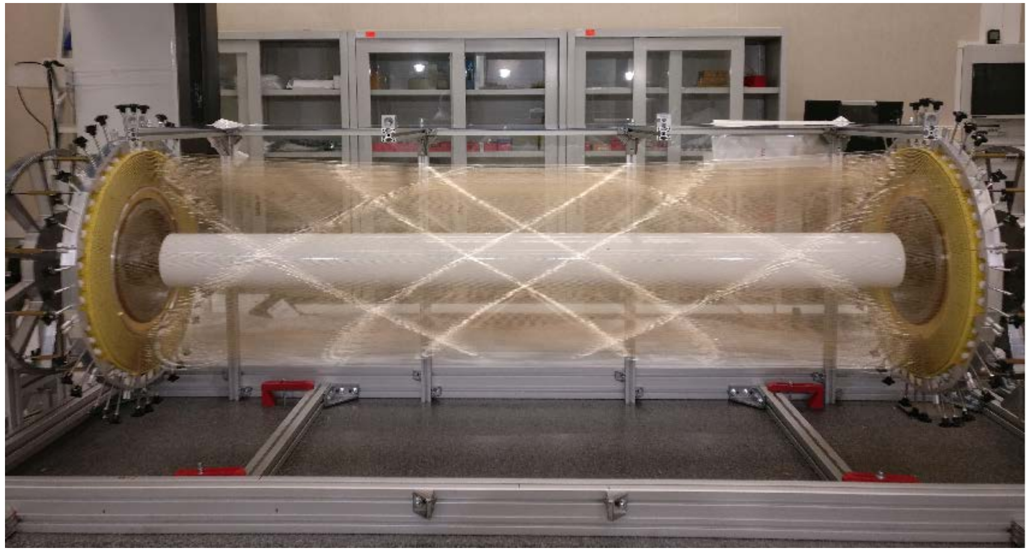
Wiring and assembly techniques

- Feed-through less
- fix the wires on the PCB by soldering
- Handing process: extracts the multi-wire layers from the wiring system and places them in a storage / transport frame
- Complicated assembly tooling and procedure



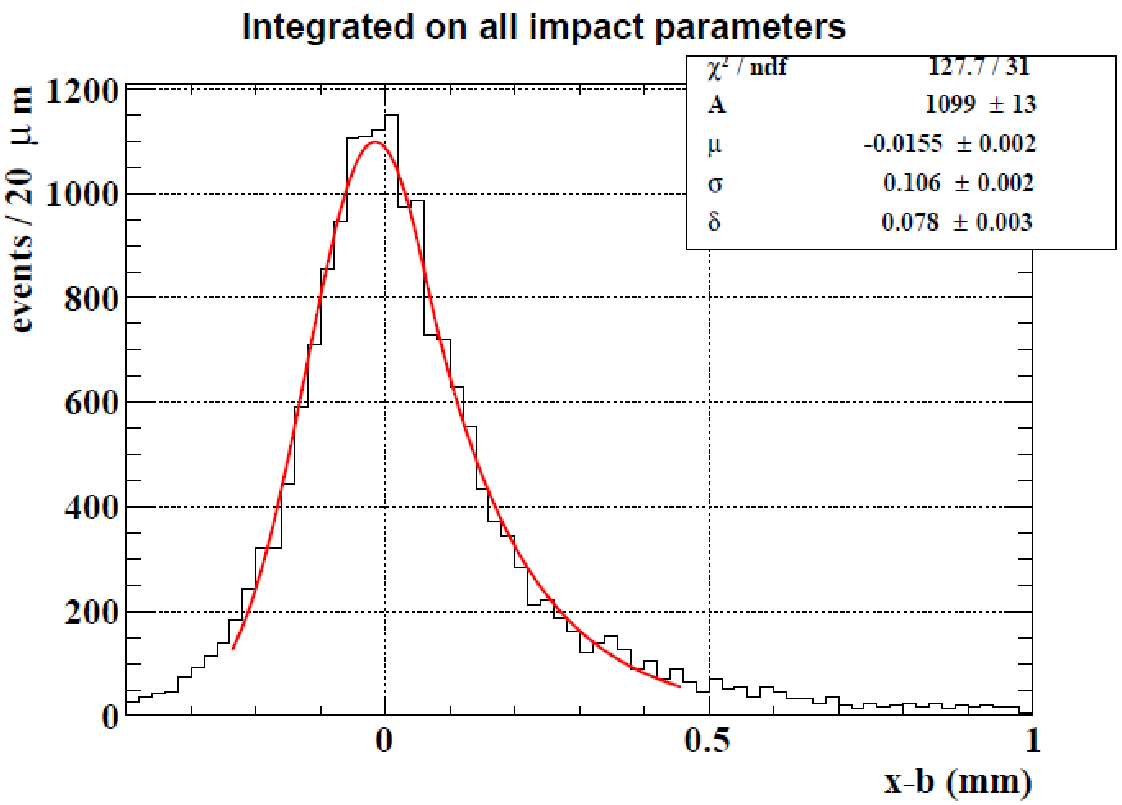






Expected performance

- As preliminary tests, the spatial resolution and the ageing properties of the chamber have been measured on prototypes.
- For a precise measurement of the single-hit resolution, several drift chamber prototypes were tested in a cosmic ray facility set-up
- The final chamber will use new front-end electronics with 1 GHz bandwidth allowing for the exploitation of the cluster timing technique



σ_r = 106 µm

$\sigma_z = \sigma_r / \sin\theta_s$ ~1 mm

Discussion and summary

- A new detector design with drift chamber is proposed, aiming at PID by accurate measurement of dE/dx
- Cluster counting method is proposed for PID with a better resolution
- In order to permit the detection of single ionization clusters, the electronic read-out interface has to process high speed signals
- Key issue: Track length, gas, layer, cell size, assembly technique
- MEG II developed a novel wiring system and procedure for high density wiring
- We have experience in drift chamber. Further simulation and collaboration with working group of Idea drift chamber is needed

Thanks for your attention!