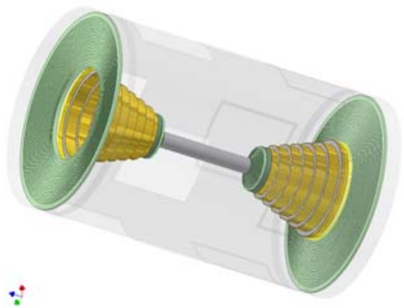

A Hybrid Tracking Proposal on BESIII

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Outline

- 1.Motivation
- 2.Hybrid tracking concept
- 3.Simulation procedure and results
- 4.Conclusion and outlook

Motivation

- 1.Silicon vertex detectors have been widely used in HEP experiments with E_{cms} well above BEPCII energy: accurate tracking near IP, secondary vertex reconstruction…
- 2.When E_{cms} is reduced,multiple scattering dominates: distortion of track shape. Materials near IP is a disadvantage…e.g. from CLEOIII->CLEO-c
- 3. Can we coordinate the pros and cons of silicon detector to make it available for BESIII tracking?
- 4. For my own study purpose, get to know the offline analysis framework of HEP experiment such as BESIII

Before Hybrid tracking…

Current MDC performance:

1.Single wire resolution: $< 130\ \mu m$

2.σ_p/p for 90° tracks @ 1GeV and 1T ~ 0.5%

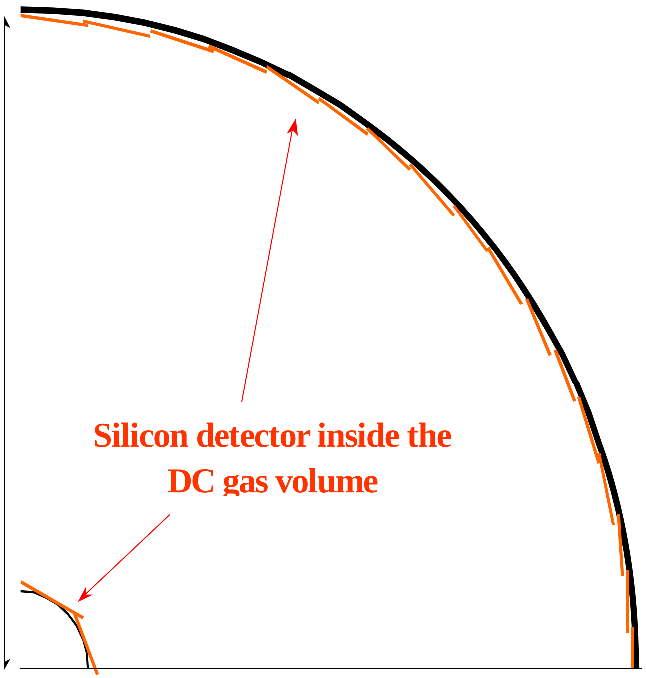
3. $\sigma(dE/dx)$ 6~7%~ π /K 700MeV/c

4.. π /K separation by dE/dx up to 0.77 GeV/c

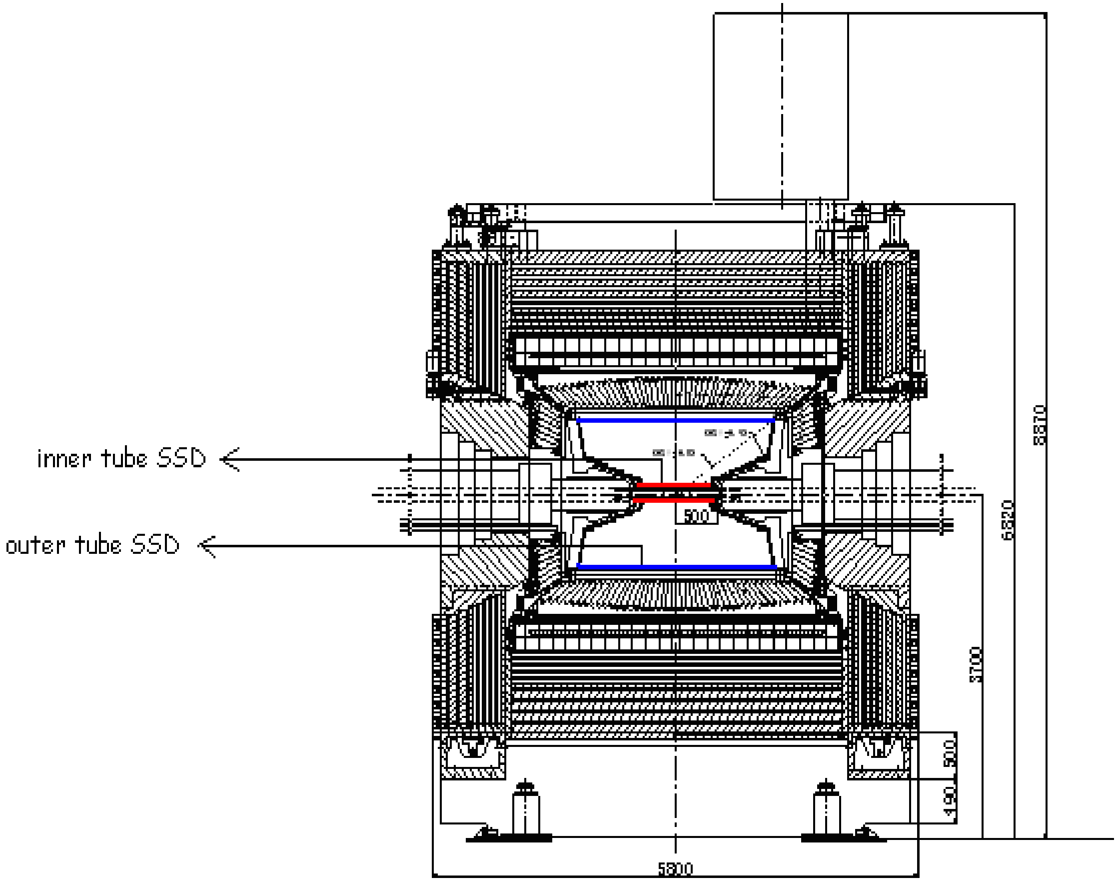
Hybrid tracking concept : overview

--by Prof.Zhao Tianchi

- 1. Hybrid tracking design to improve momentum resolution (SSD+MDC)
- 2. Low production threshold of e-/ion pair allows more precise dE/dX measurement
- 3. Need to deal with multiple scattering->on p direction



SSD in BESIII



Hybrid tracking: SSD performance

1. **Configuration of Silicon Micro-Strip Detector**:

Strip pitch: D = 50 μm

Single layer position resolution: σ=7~8μm (MDC wire resolution 130 μm)

Typical silicon thickness: 300 - 500 μm （0.15 – 0.25 X_0）

2. **dE/dX:**

production of e^-/ion pair in He-C_3H_8 gas is ~60/cm

In silicon, production of e^-/hole pair is 80/μm

40,000 e^-/hole pairs in one layer of 500 μm silicon detector

4,000 ions all through MDC track(~0.7m)

Hybrid tracking: advantage

multiple scattering…

Silicon thickness: 300 - 500 μm （0.15 – 0.25 X_0）

The material of the 43 layers of MDC is only 0.29% X_0

(~0.72m long track)

$$\frac{\sigma_{P_t}}{P_t}\bigg|_{MS} = \frac{0.05}{BL} \times \frac{1}{\beta} \times \sqrt{1.43\frac{L}{X_0}}[1 + 0.038\ln\frac{L}{X_0}]$$

Significant influence especially on low momentum tracking

->advantage of hybrid tracking approach: track shape will not be distorted by silicon layers, other than traditional silicon vertex trackers with multi-layer complex

Simulation objectives:

- 1.To test whether(or how much) momentum resolution can be improved if we have two (nearly) fixed hit point at inner and outer tube of MDC?
- 2.influence of multiple scattering(on p direction)

Simulation procedure and results

- 1.Detector definition
- 2.Track reconstruction:

  a. joint track reconstruction based on Kalman Filter

  b. modified MDC layers for the purpose of using MdcPatRec
- 3.Effects of multiple scattering

1.Detector definition

A. simple silicon cylinder fixed on the wall of beam pipe

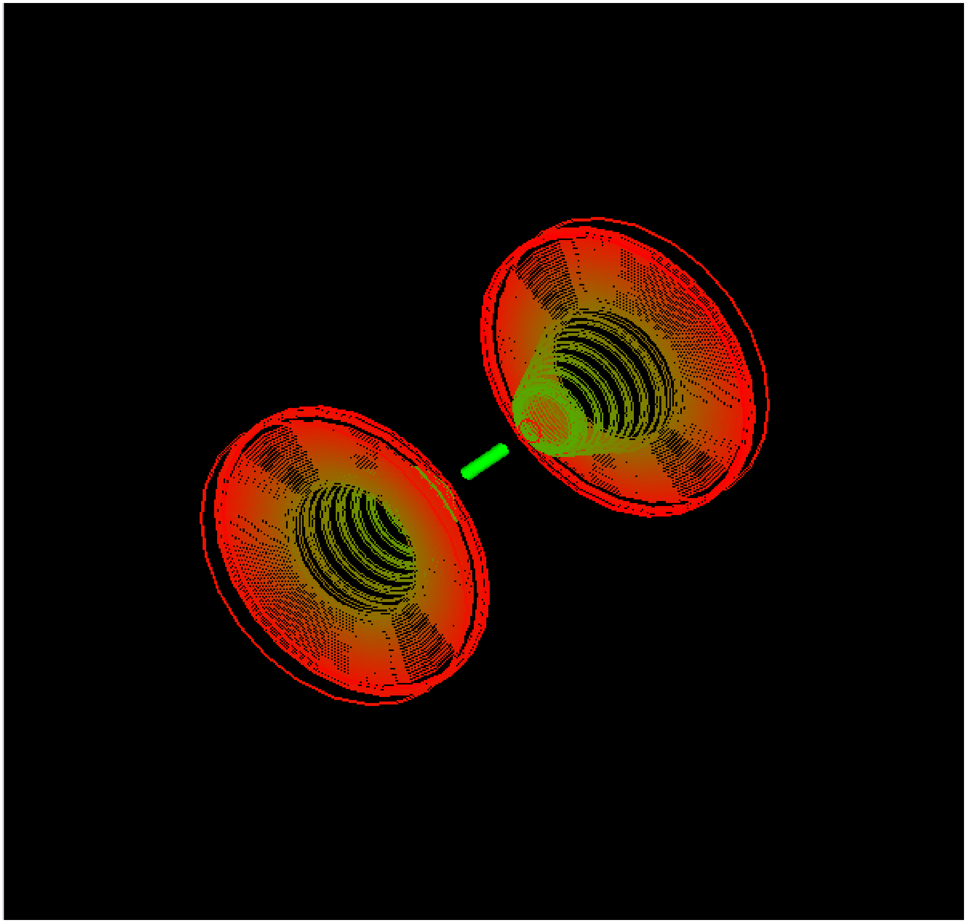
B. length: 300mm

thickness: 500μm

C. record hit position and energy deposit

no smear to hit position

Detector geometry:



2. Track reconstruction

A. Joint track reconstruction based on Kalman Filter --BOSS 6.3.1

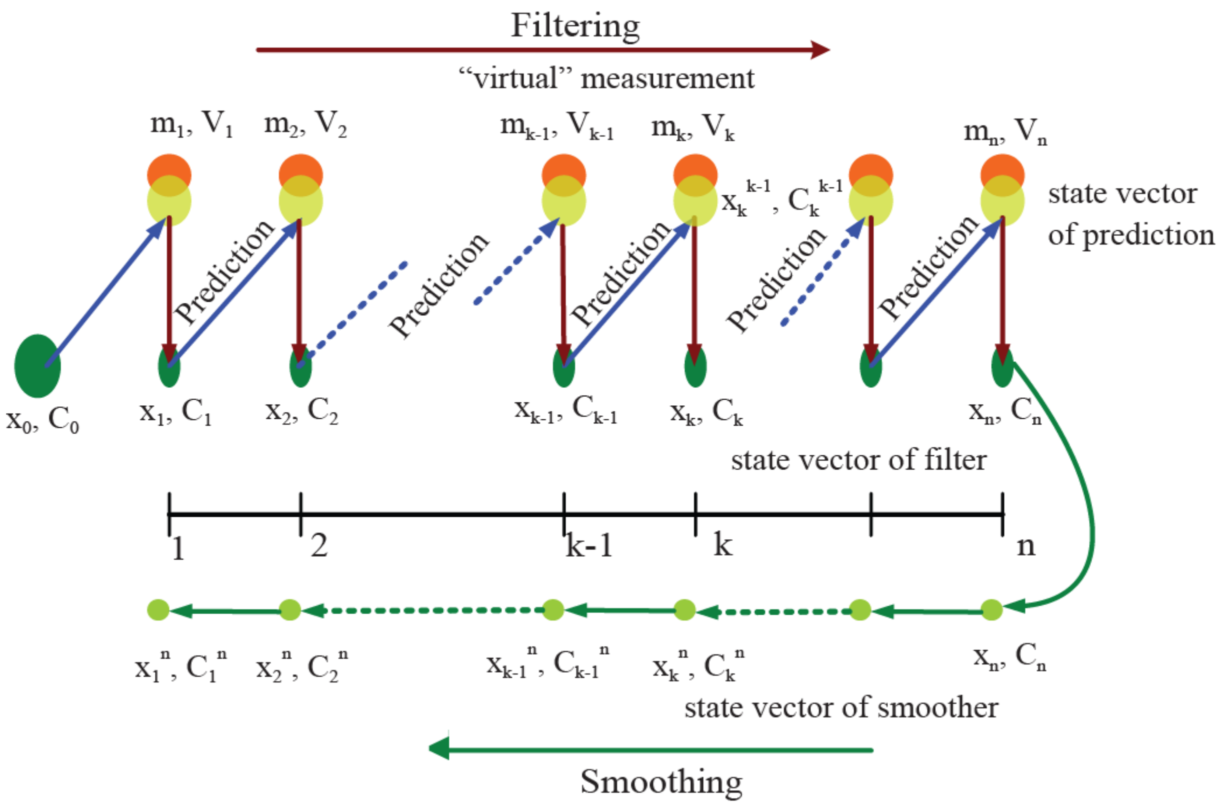
Kalman Filter: a recursive solution to the discrete-data linear(or nonlinear) filtering problem; widely used in track and vertex fitting

common process:

predict->filter->smooth.

Kalman Filter

- Common process:



Kalman Filter

- Track fitting with hits on silicon detector combined:

  5 track parameters represent state vector:

  $X_k = \{d_0, \phi_0, \kappa, dz, \tan\lambda\}^T$

  X_k uniquely describes an helix

Joint track fitting

- Add hits on inner silicon detector to Kalman routine:

  state prediction: $X_k^- = X_{k-1}$ (from MDC)

  $\boldsymbol{P}_k^- = \boldsymbol{P}_{k-1} + \boldsymbol{Q}$

  measurement: $Z_k = H_K X_K + V_K$ V_K :noise

  define $H_k = \{0,0,1,0,0\}$ measurement matrix;

  use κ to be the measurement quantity;

  $\kappa = 1/Pt$

Joint track fitting

Calculate residual:

Residual= κ_{mea} - κ_{pre}

where κ_{mea} is from:

$\kappa_{mea}=1/pt_{mea}$; $pt_{mea}=0.3BR_{mea}$;

R_{mea}=distance(hit position on silicon detector-circle center)→using 90deg outgoing tracks

Joint track fitting

- Calculate circle center:

$X_0=(R_{pre}-d_0)\cos(\phi_0)$

$Y_0=(R_{pre}-d_0)\sin(\phi_0)$

Feedback residual to update state vector by Kalman gain coefficient: K_k

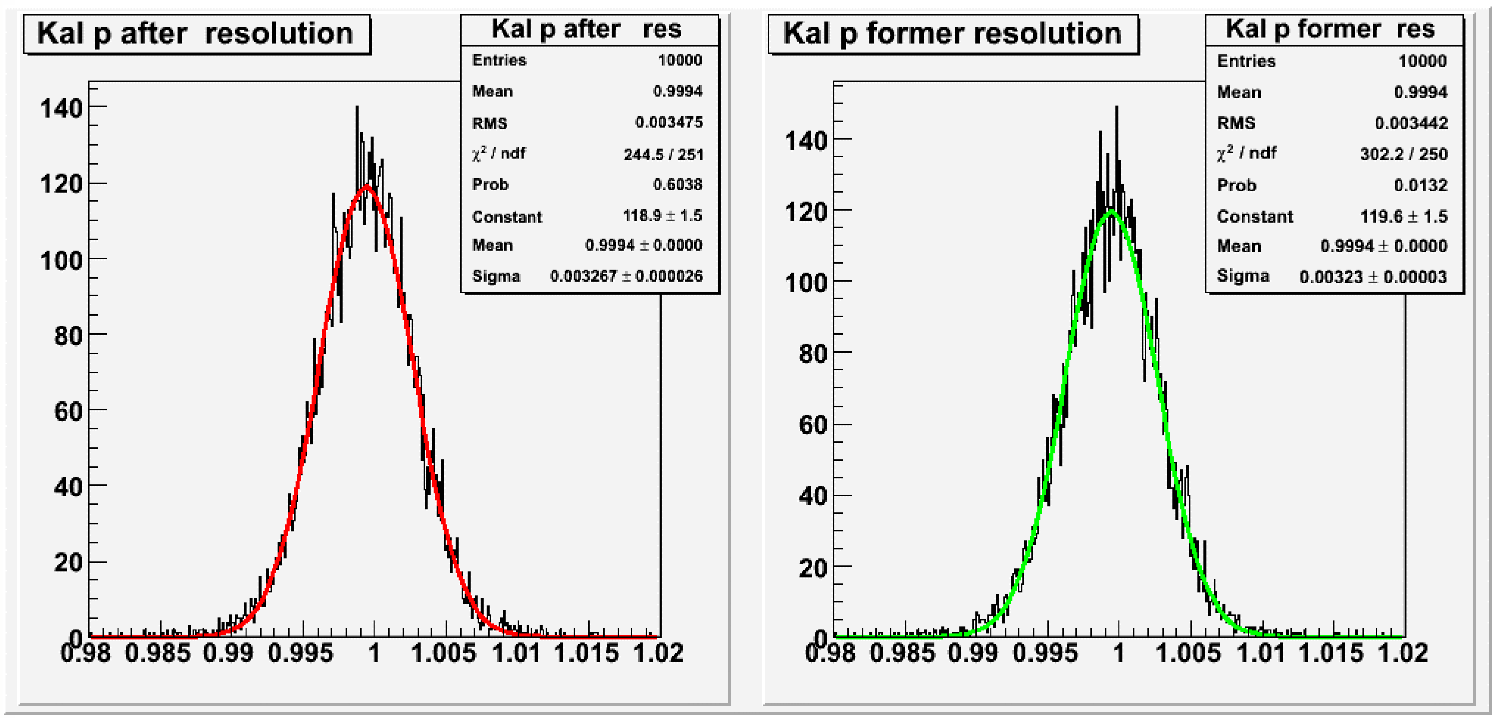
$K_k = P_k^- H^T (H P_k^- H^T + R)^{-1}$ ***(R: covariance of measurement noise)***

$X_K = X_k^- + K_k (Z_k - H_k X_k^-)$

Joint track fitting

- Retrieve updated track parameter κ

  Pt statistics: 1GeV muon-, theta=90deg



Joint track fitting

- Result:

momentum resolution before silicon detector was added: 0.323%

after: 0.327%

no significant change

maybe due to the insensitivity of measurement quantity

Joint track fitting

- Further improvement of this algorithm:

  use BESIII original definition of measurement matrix and state prediction equation;

2. Track reconstruction

B. Modified MDC layers for the purpose of using MdcPatRec:

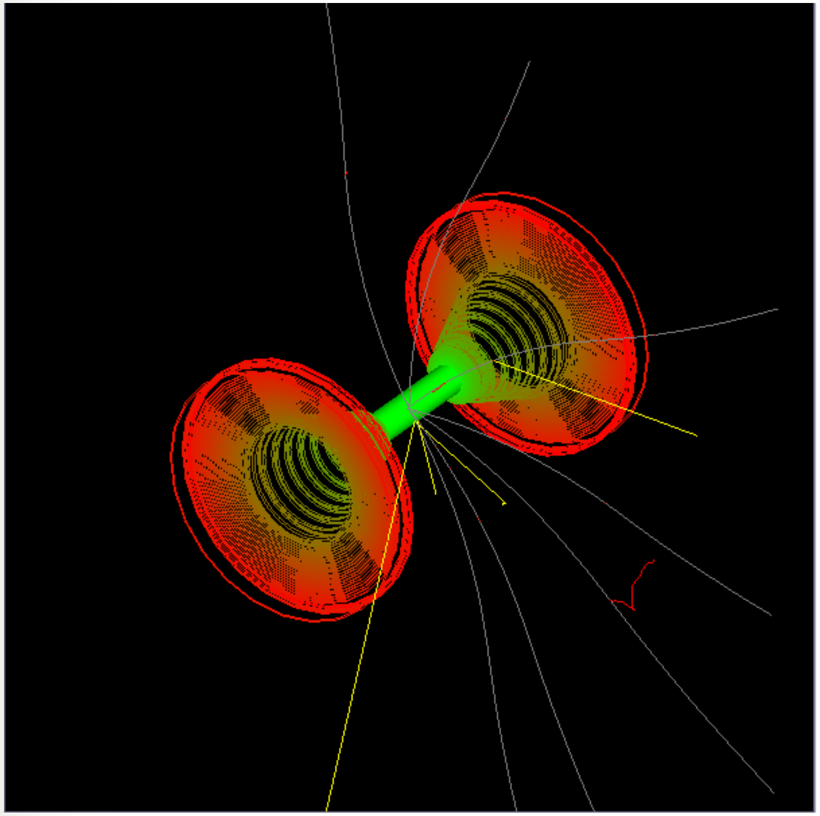
--BOSS 6.4.1

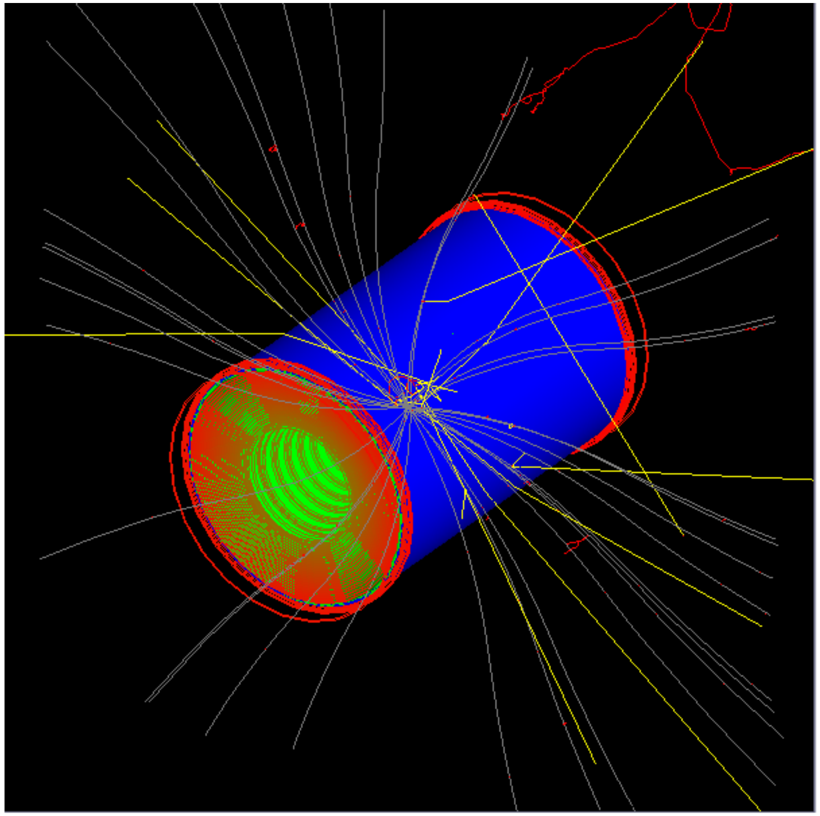
1.Change the materials of 1/43 MDC layers to silicon

2.Spatial resolution of these two layers are set to be 10um

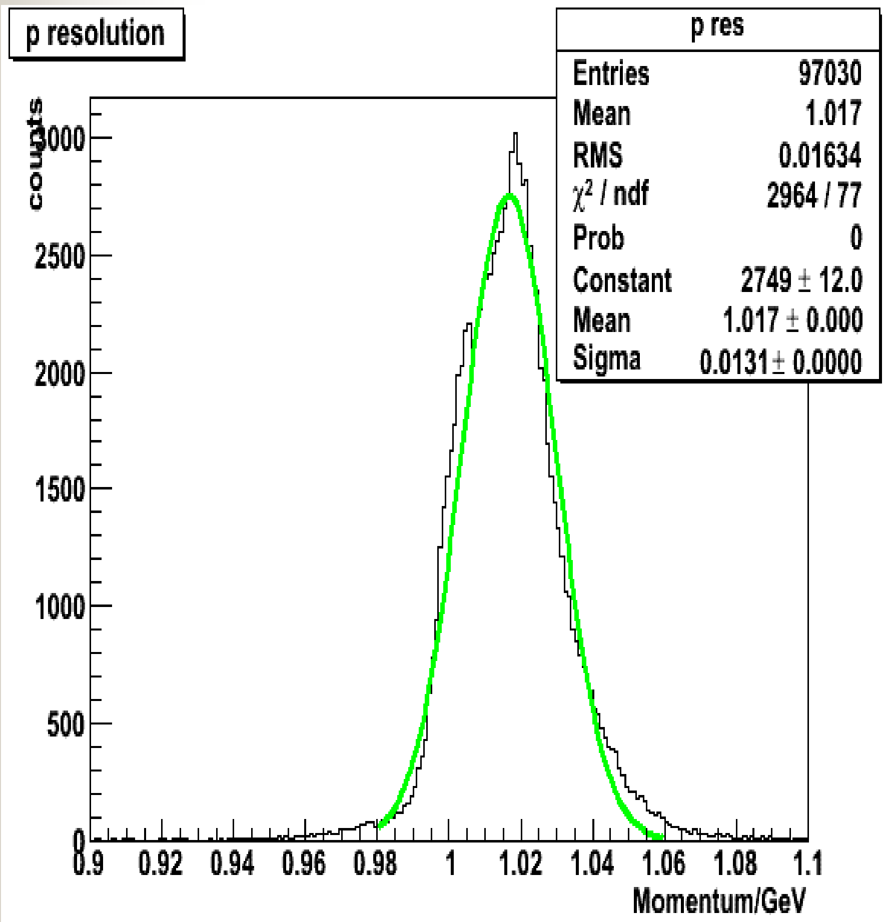
So we can use MdcRecPat algorithm to reconstruct charged tracks without too much modification of the code

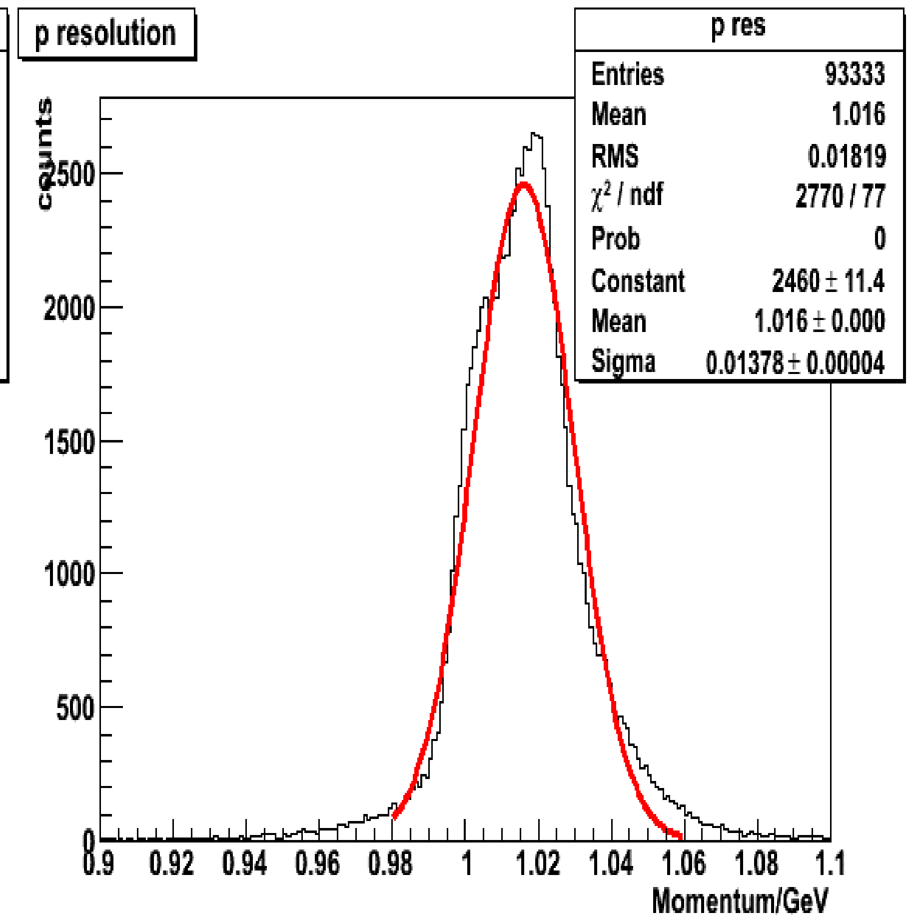
Detector geometry:





Momentum resolution





Momentum resolution

- 1.no silicon layers
- 2. double gaussian spatial resolution in digitization (from Calib Func)

p resolution: 1.31%

1GeV u- with even cos(theta) distribution

- 1.1/43 silicon layers with fixed resolution 10um
- 2.other layers adopt double gaussian

p resolution: 1.38%

But the unsatisfying Chi^2/ndf renders the result trustless…maybe due to the limitation of MdcPatRec

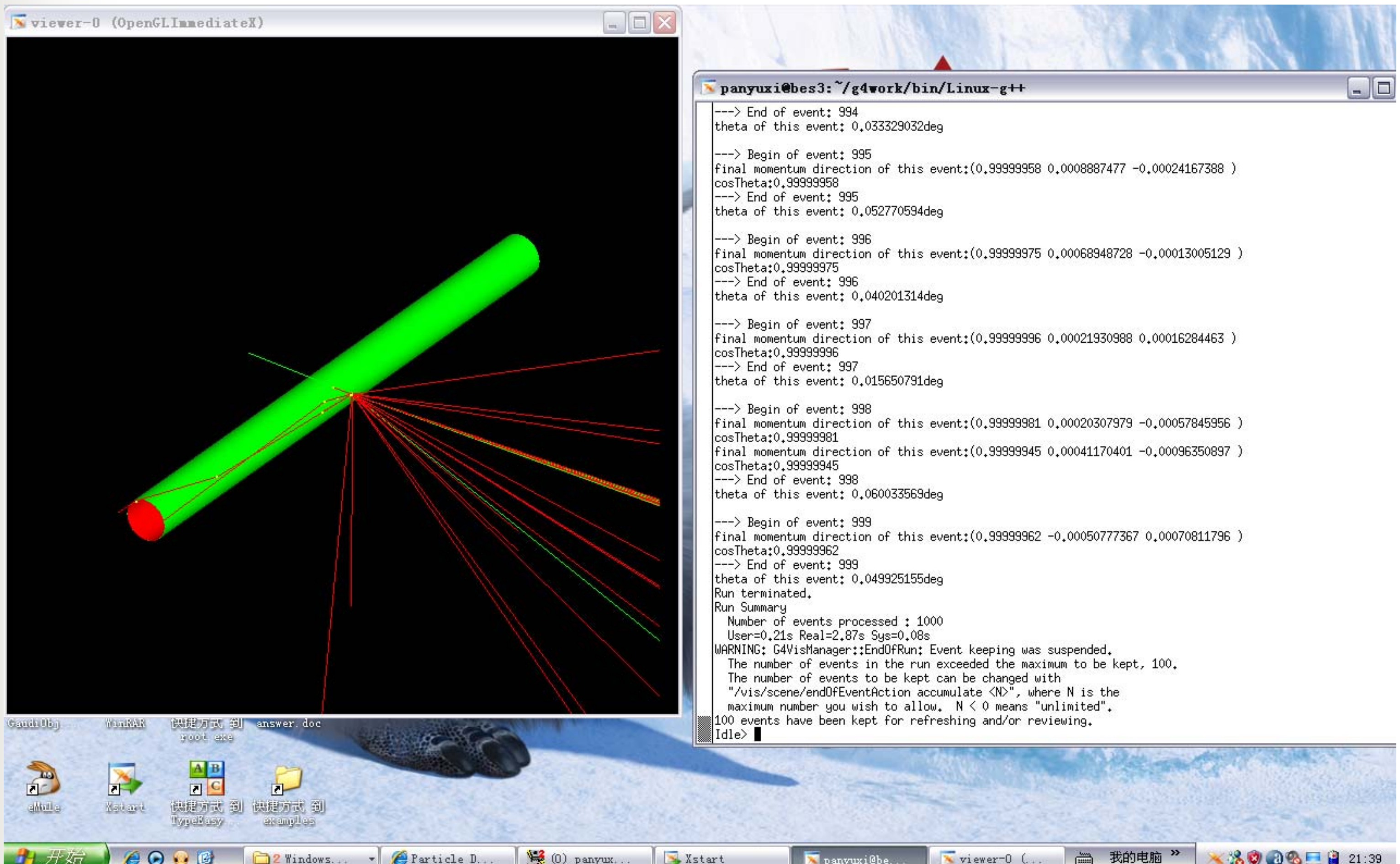
Momentum resolution

- A better way to obtain the momentum resolution might be achieved if we can modify the definition of materials in KalFitAlg

3.Effects of multiple scattering

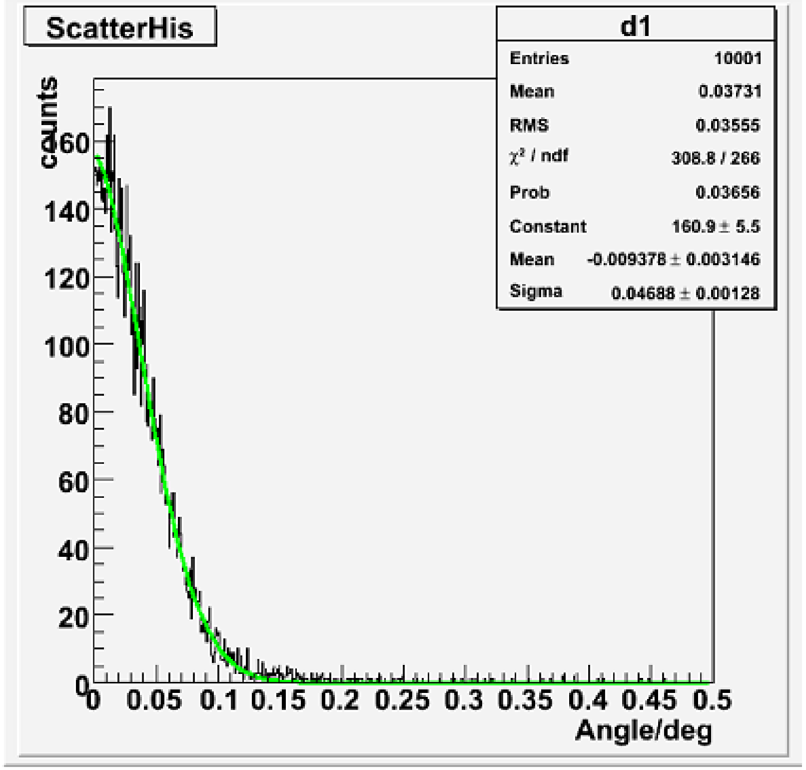
- 1.estimate the influence of multiple scattering after SSD been adopted→change of P direction;
- 2.energy deposit during particles penetrating SSD→the influence on P magnitude;

Simulation process



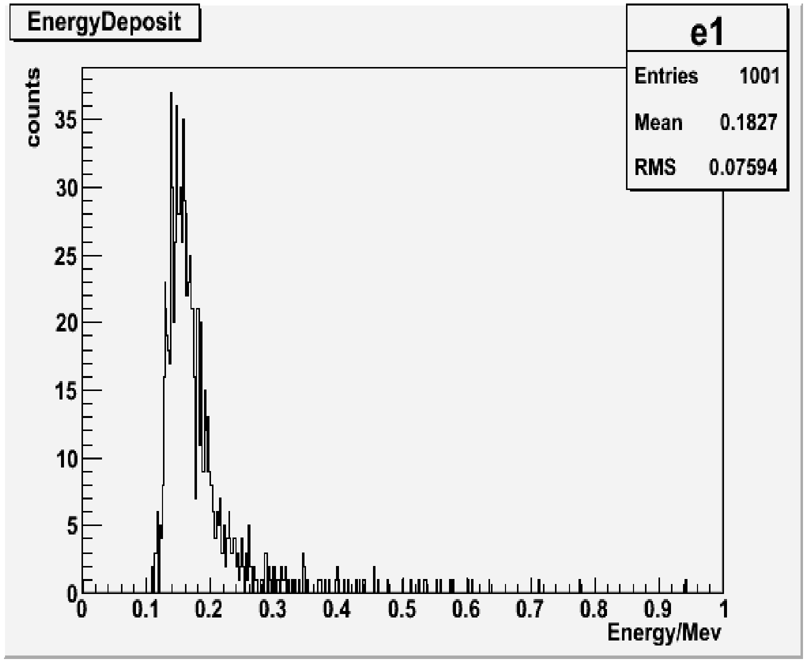
Simulation result: Scattering angle

- 1. 1GeV electron
- 2. 1000 events;
- 3. mean value 0.037°
  ~0.02° from theoretical prediction
- 4.need to estimate this influence on vertex location after track extrapolation



Simulation result: energy deposit

- 1. 1GeV electron
- 2. 1000 events;
- 3. Mean value:0.18MeV ~insignificant influence on p magnitude
- 4. Approximately Landau shape



Conclusion and outlook

- Conclusion:

1. Silicon detector has been added to BESIII detector definition;
2. Calculate momentum resolution by joint track fitting and MdcPatRec: no significant improvement had been seen;
3. Simulate the influence of inner silicon layers on particle's momentum

Conclusion and outlook

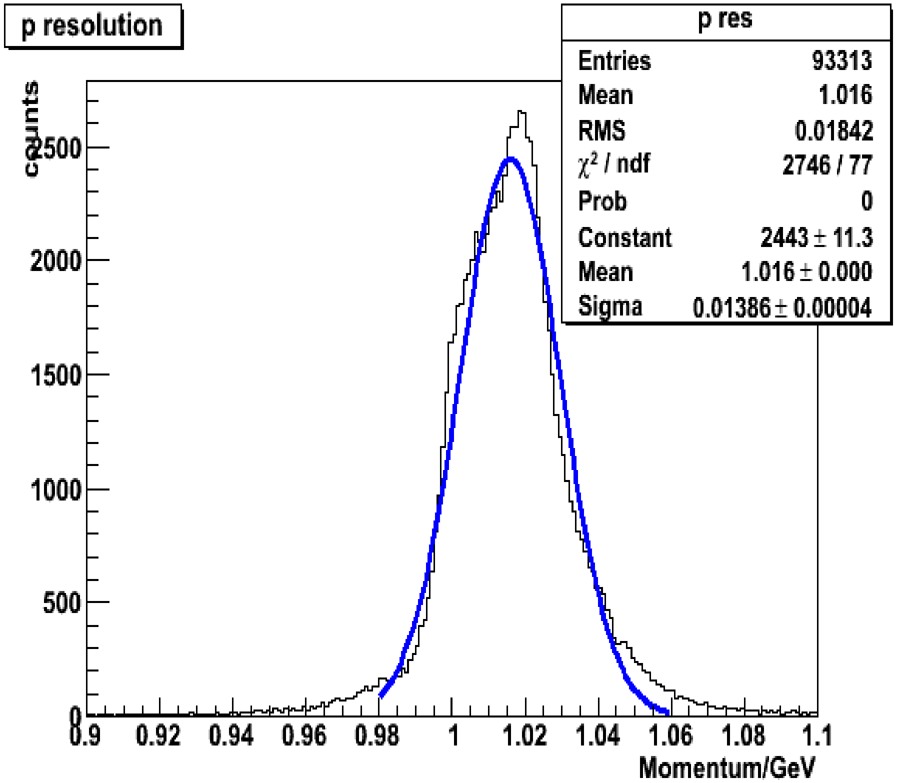
- Outlook:

  Both track reconstruction method need to be refined: hope this work could be done by me or someone else under guidance of a specialist from IHEP

Thank you!!

- 3. No silicon layers but reduce 1/43 spatial resolution to 10 um

p resolution 1.39%



$$\left(\frac{\sigma_{pt}}{p_t}\right)_{pos} = \frac{3.3\times10^2 \times \sigma_x}{B\times L^2} \times p_t \times \sqrt{\frac{720}{n+5}}$$

Change the fitting weight in MdcPatRec

- When LayerNo=1 or 43

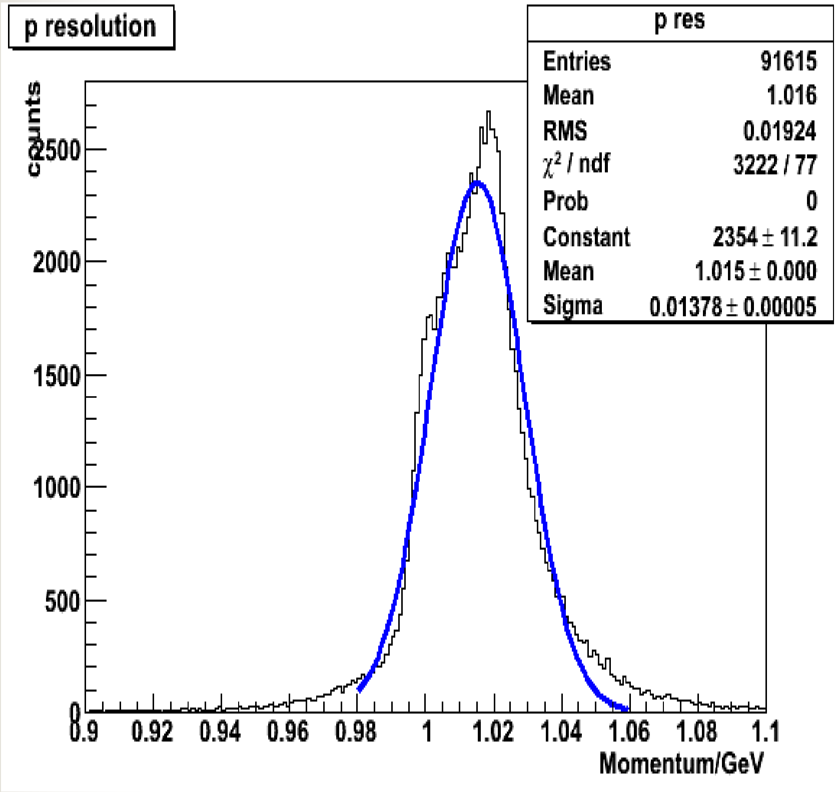
  MdcHit->sigma=10um

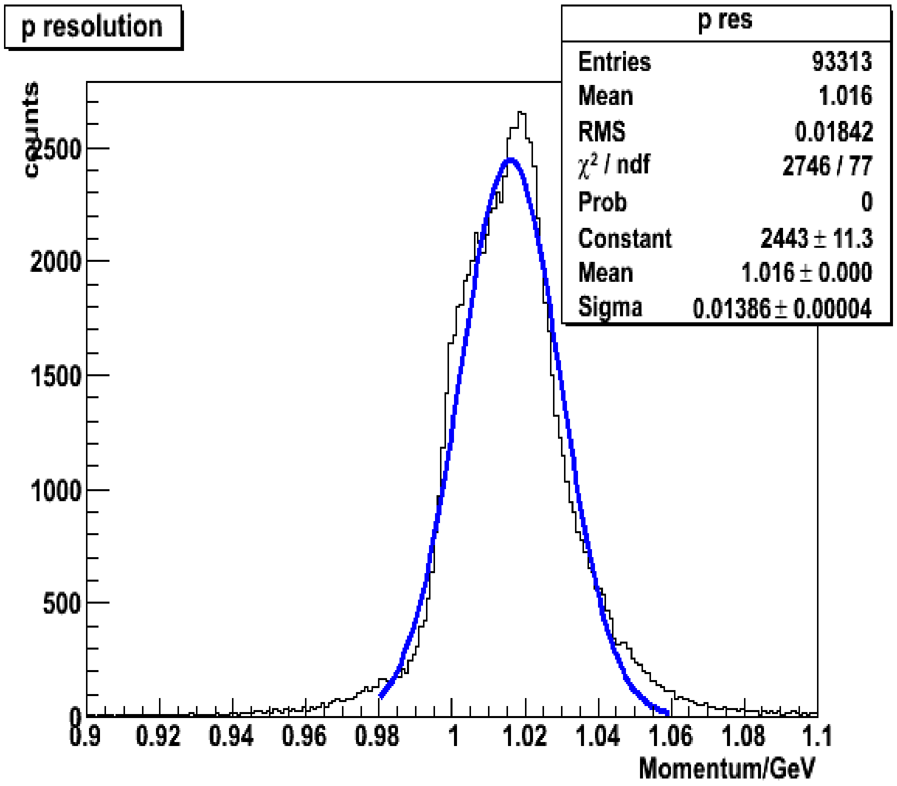
  others retrieved from CalibFunSvc

$$\text{Chi\^{}2}=\sum_i \frac{drift_i - doca_i}{sigma_i}$$

weight=1/sigma

Result


p resolution
p res
Entries 91615
Mean 1.016
RMS 0.01924
χ² / ndf 3222 / 77
Prob 0
Constant 2354 ± 11.2
Mean 1.015 ± 0.000
Sigma 0.01378 ± 0.00005
counts
Momentum/GeV


p resolution
p res
Entries 93313
Mean 1.016
RMS 0.01842
χ² / ndf 2746 / 77
Prob 0
Constant 2443 ± 11.3
Mean 1.016 ± 0.000
Sigma 0.01386 ± 0.00004
counts
Momentum/GeV

Result

- 1. No silicon layers but 1/43 spatial resolution change to 10 um

weight with new layer resolution

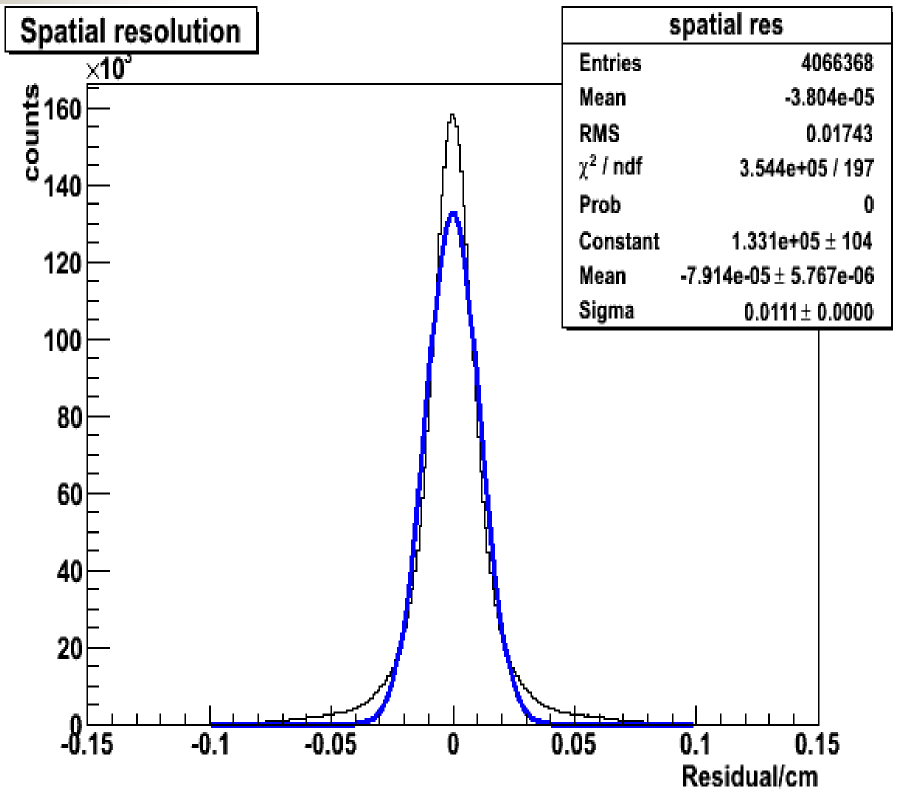
1.378%

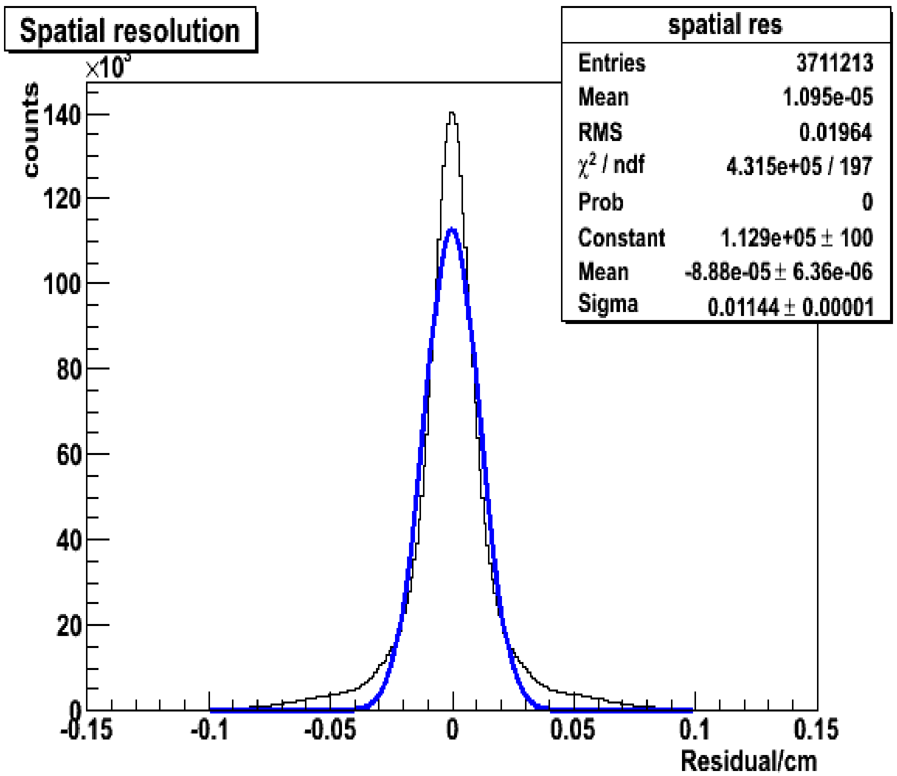
- 2. No silicon layers but 1/43 spatial resolution change to 10 um

weight with previous Mdc layer resolution

1.386%

Wire resolution: all layers



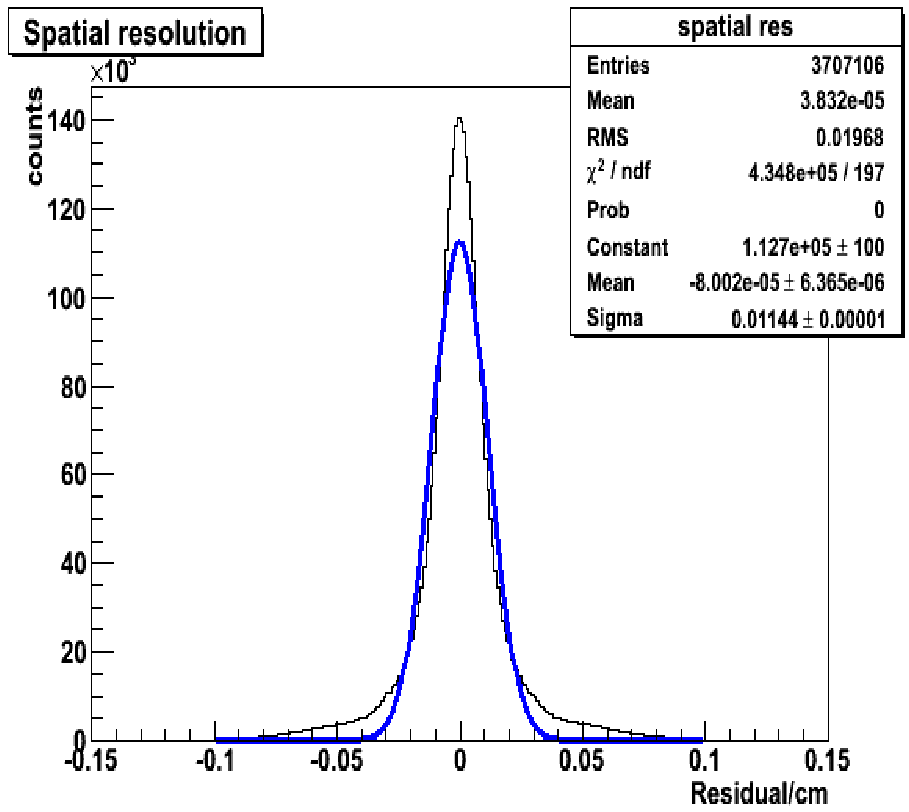


- No silicon layers:111um
- With 1/43 silicon layers:114um

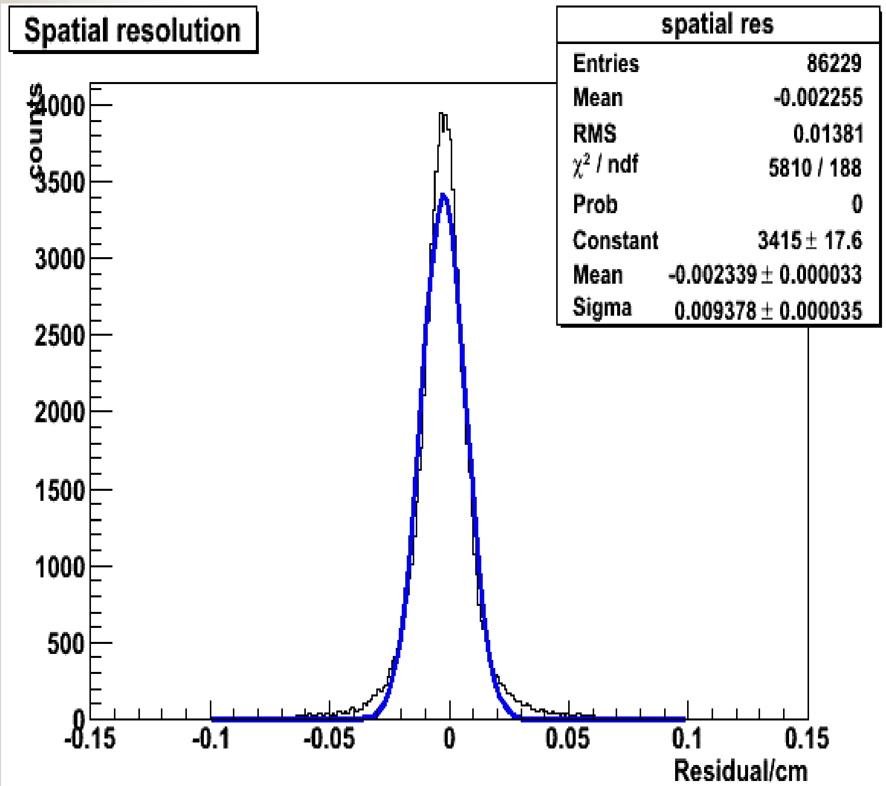
Wire resolution: all layers

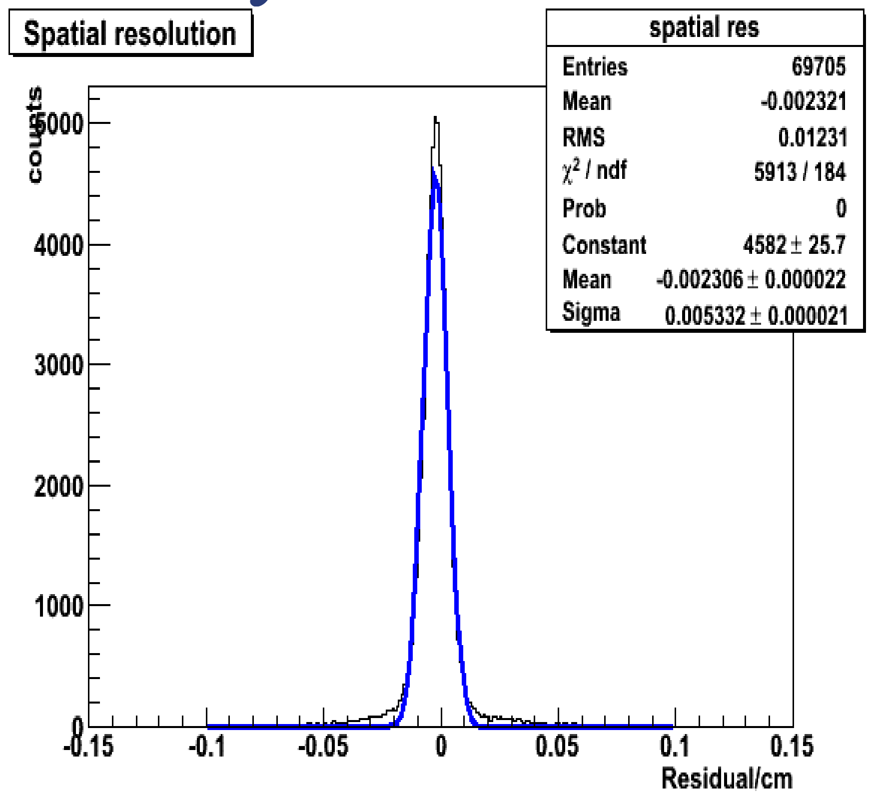
- No silicon layers but with reduced spatial resolution of 1/43 layers

  114um



Wire resolution: first layer



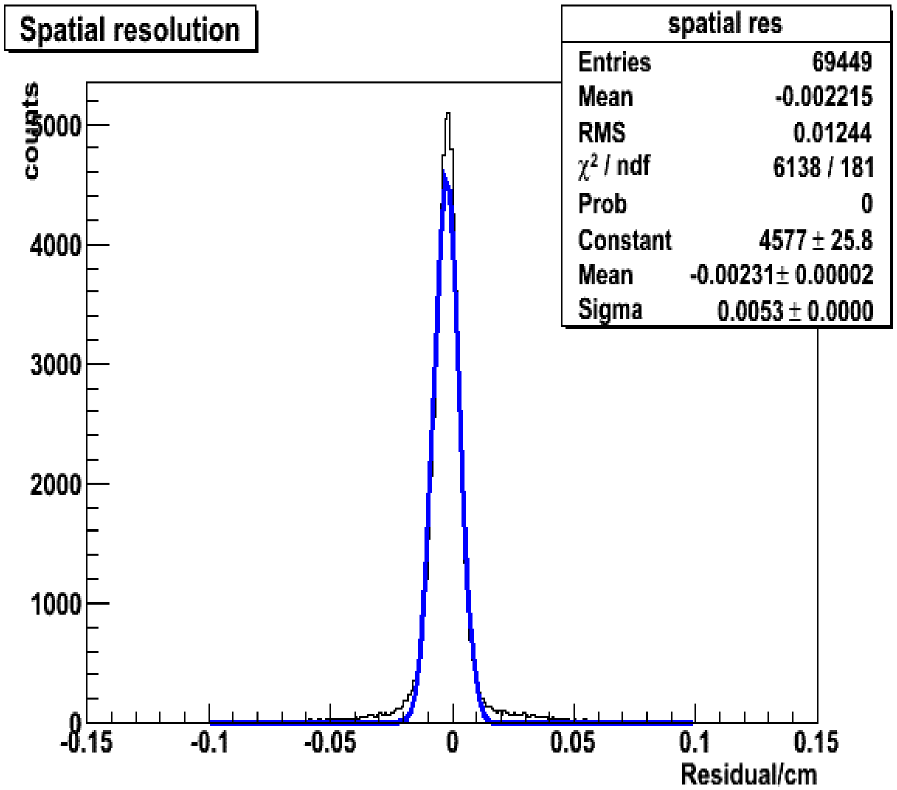


No silicon layers :94 um

With 1/43 silicon layers 53um

Wire resolution: first layer

No silicon layers but reduced 1/43 spatial resolution: 53um



Outlook: Shifted inner SSD layers

- In gaps between inner tube and inner SSD, several layers of sense wire will determine the momentum direction before scattered by SSD layers
- Simulation is still in need