Status of CGEM-IT Offline Software at BESIII

Liang-Liang WANG

On behalf of CGEM-IT software group

4th LNF Workshop on Cylindrical GEM Detectors

Outline

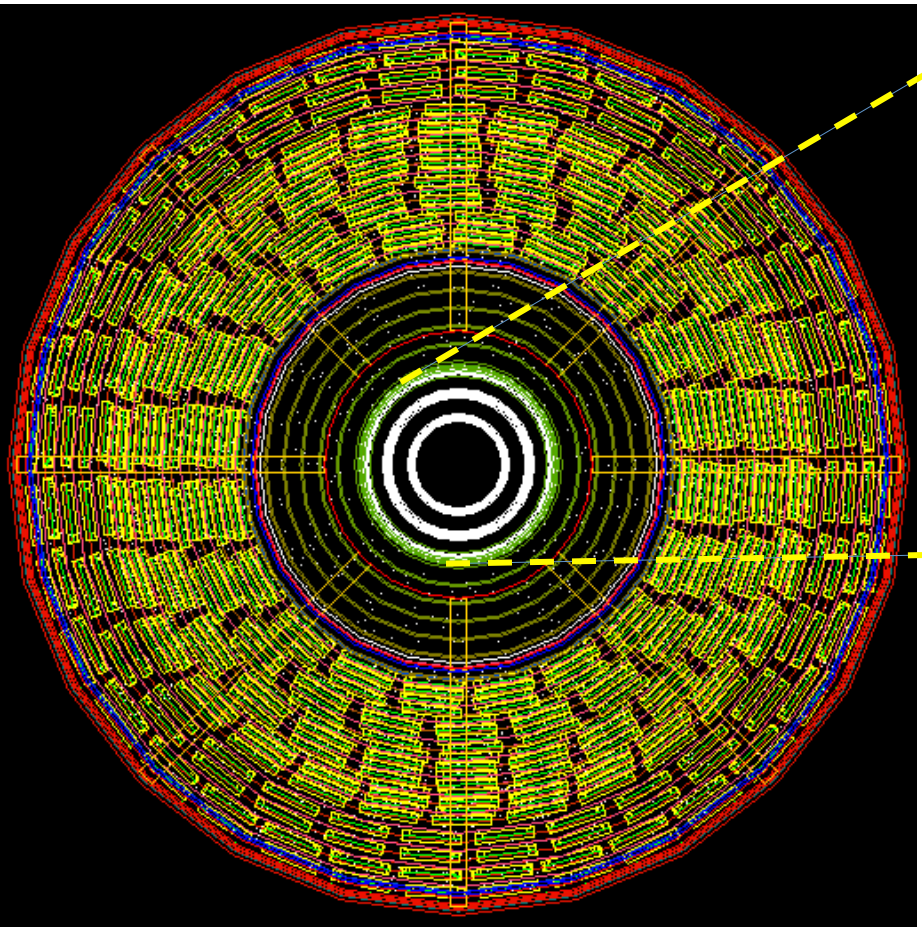
- Introduction
- Simulation of CGEM-IT
- CGEM-IT cluster reconstruction
- CGEM-IT track segment finding
- Track fitting with Kalman Filter
- Release of CgemBoss
- Summary

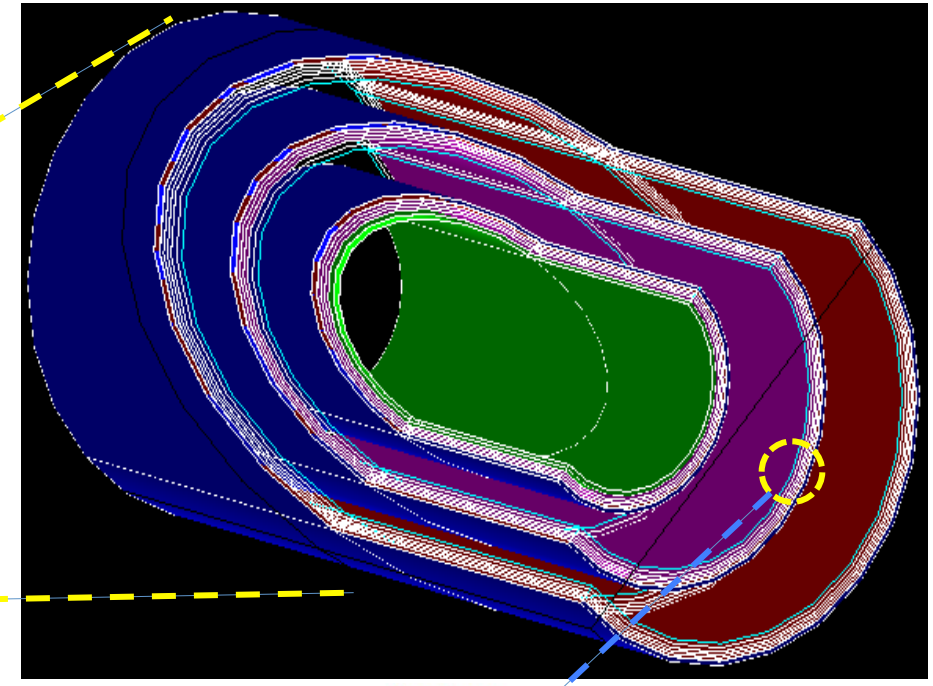
Introduction

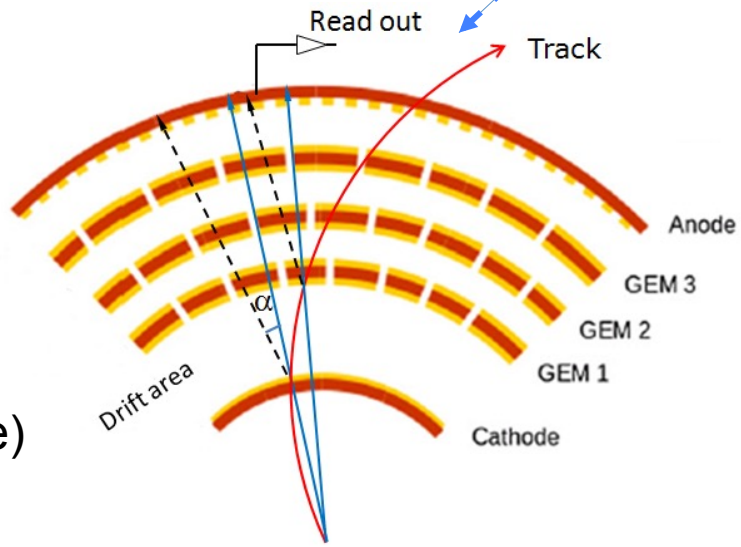
CGEM offline software

- Simulation
  - ✓ Detector description
  - ✓ Digitalization
- Reconstruction
  - ✓ Cluster reconstruction
  - ✓ CGEM track segment finding
  - ☐ Global tracking combining CGEM and MDC (in progress)
  - ✓ Track fitting with Kalman Filter for CGEM+DC
- Calibration (to be started next year)

CGEM detector construction with Geant4







All basic items constructed
Except individual readout strips (just one piece)

CGEM Geometry Service *(CgemGeomSvc)*

- Basic information: nLayers, radii, thickness, readout (strips, pitch, stereo angle), etc.
- The only source of CGEM geometry parameters: used in both CGEM simulation and reconstruction
- If the basic structure of CGEM does not change, it is easy to update the CGEM parameters by changing the parameter file without touch the codes.

CgemBossCvs/Cgem/CgemGeomSvc /CgemGeomSvc

Powered by APACHE

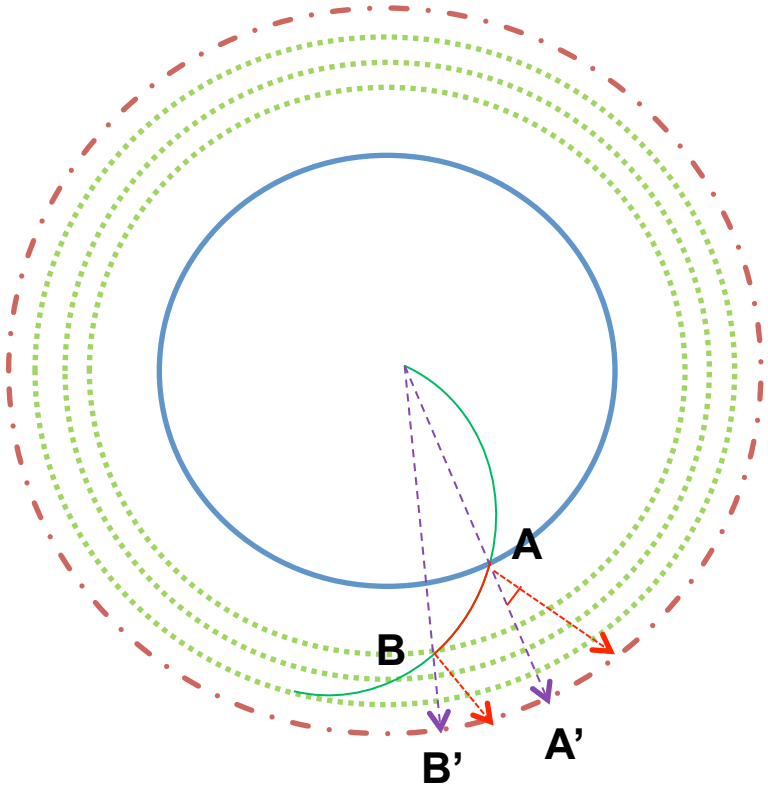
ViewCVS and CVS Help

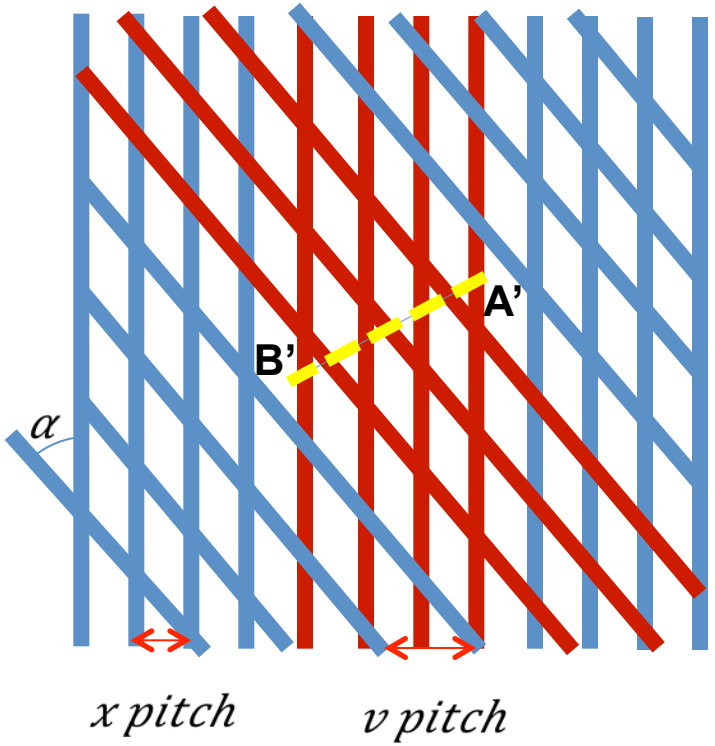
Current directory: [BESIII] / CgemBossCvs / Cgem / CgemGeomSvc / CgemGeomSvc
Files shown: 5

File	Rev.	Age	Author	Last log entry
Attic/ [show contents]				
CgemGeoFoil.h	1.2	5 months	wulh	fix bugs
CgemGeoLayer.h	1.2	5 months	wulh	fix bugs
CgemGeoReadoutPlane.h	1.2	5 months	wulh	fix bugs
CgemGeomSvc.h	1.3	5 months	wulh	fix bugs
ICgemGeomSvc.h	1.3	5 months	wulh	fix bugs

Show files using tag: - Non-branch tags - Show

CGEM digitization

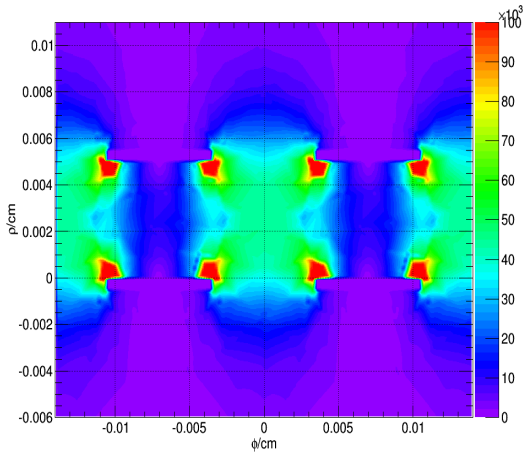


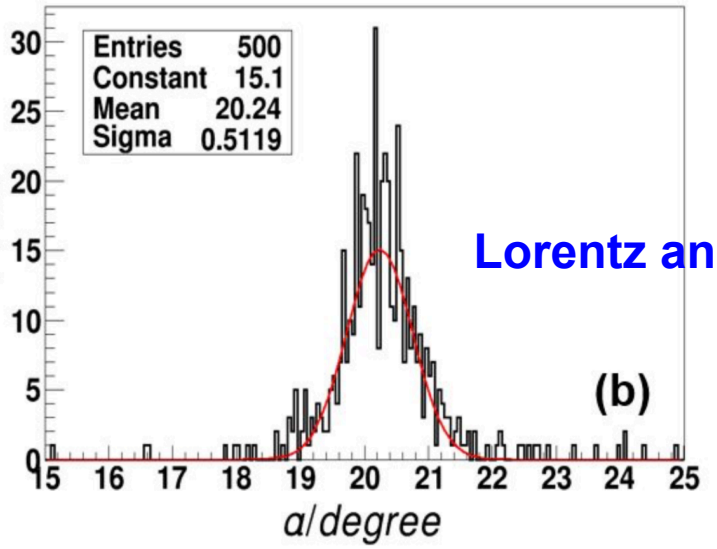


- A simplified model is used at this moment:
  projection of the track segment in the drift region onto the readout plane without any Lorentz angle, diffusion
- Sufficient at the stage of CGEM software development
- To be improved according to the beam test results or Garfield simulation

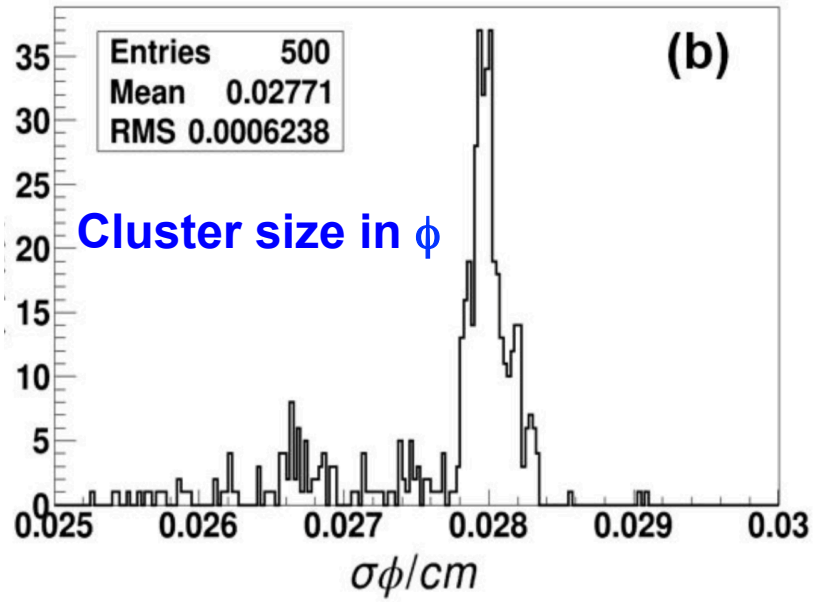
Preliminary Garfield++ simulation of GEM detector

Electric field

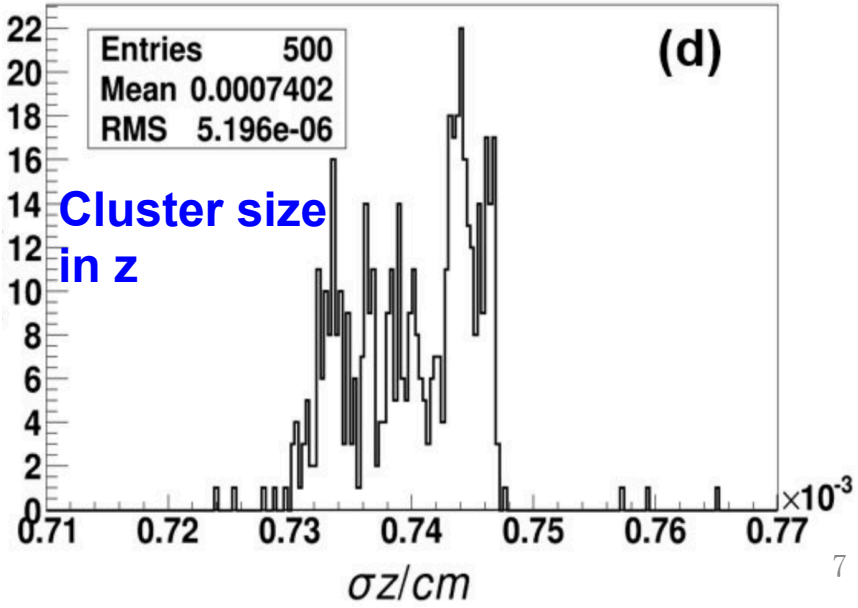




Lorentz angle

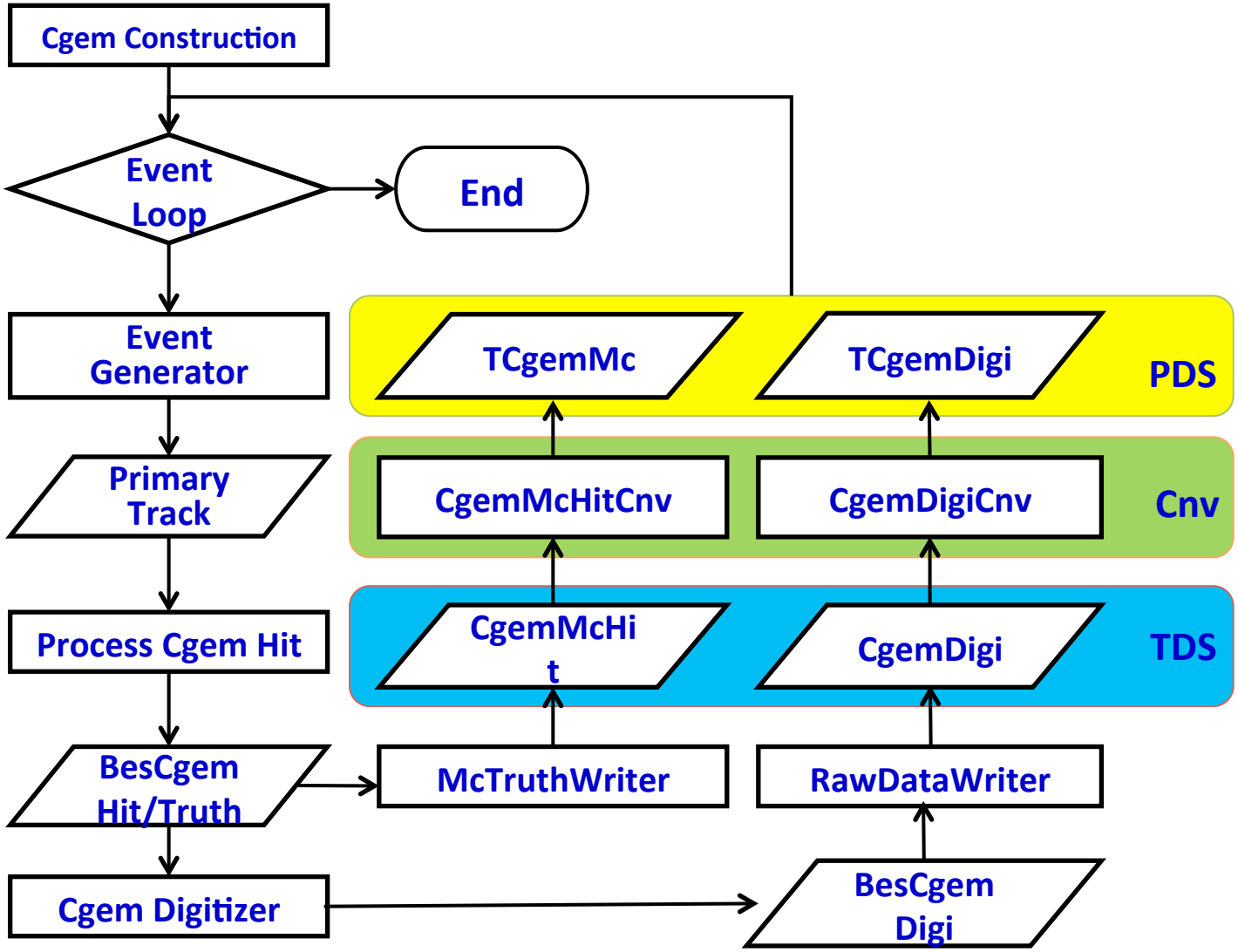


Cluster size in ϕ

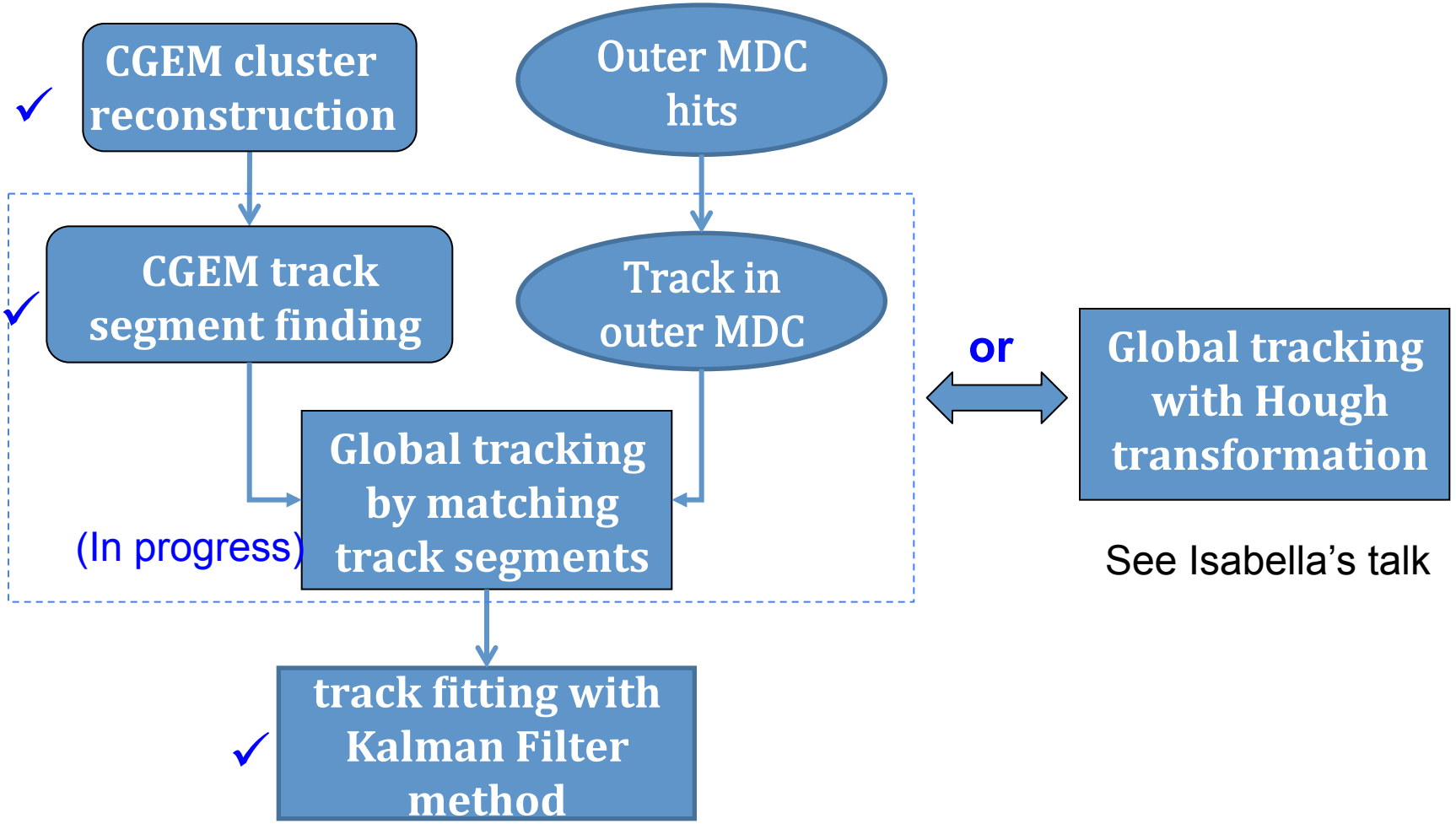


Cluster size in z

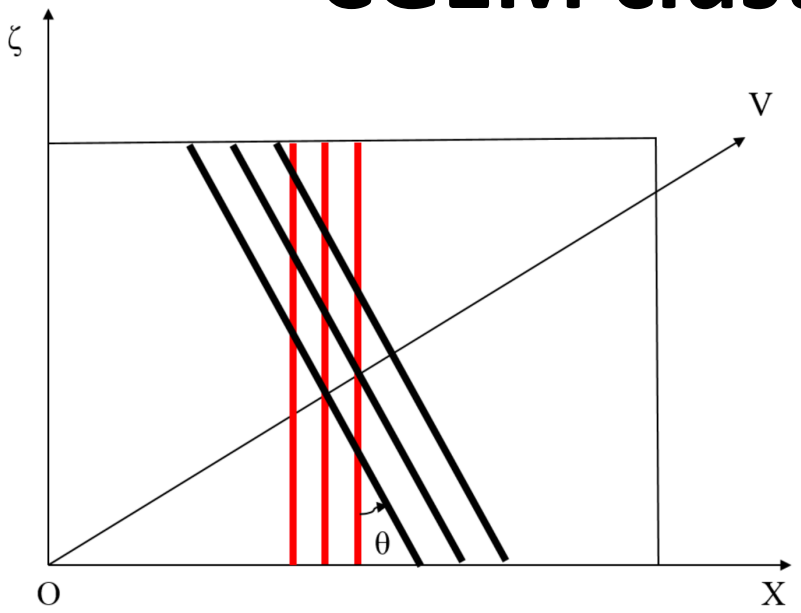
Dataflow of simulation



Track Reconstruction with CGEM-IT

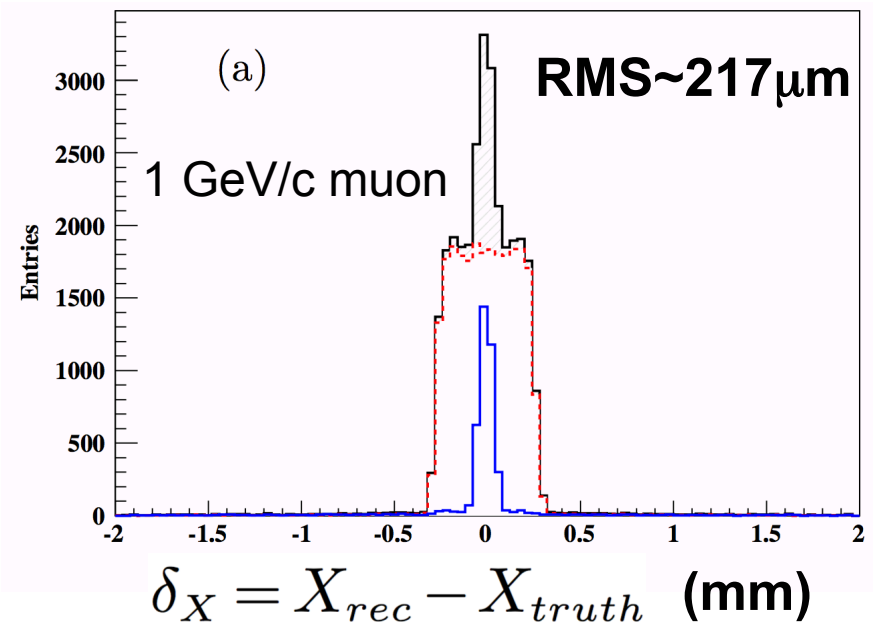


CGEM cluster reconstruction

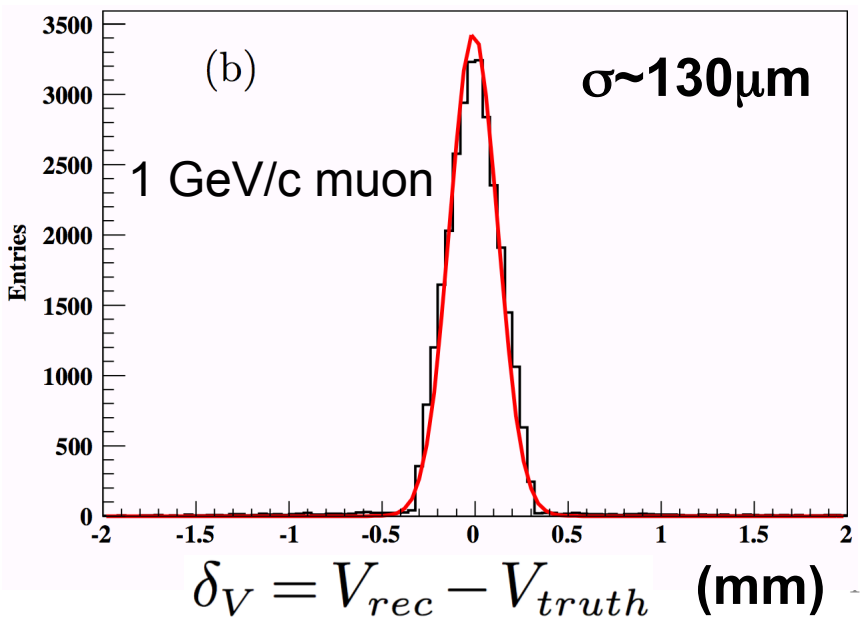


1. **Continuous fired strips in X (or V): X-cluster (or V-cluster)**
2. **Intersection between X and V clusters: XV-cluster**
3. **Position of a XV-cluster:**

$$X = \frac{\sum_{i=1}^{N_X} X_i Q_i}{\sum_{i=1}^{N_X} Q_i} \qquad V = \frac{\sum_{i=1}^{N_V} V_i Q_i}{\sum_{i=1}^{N_V} Q_i}$$

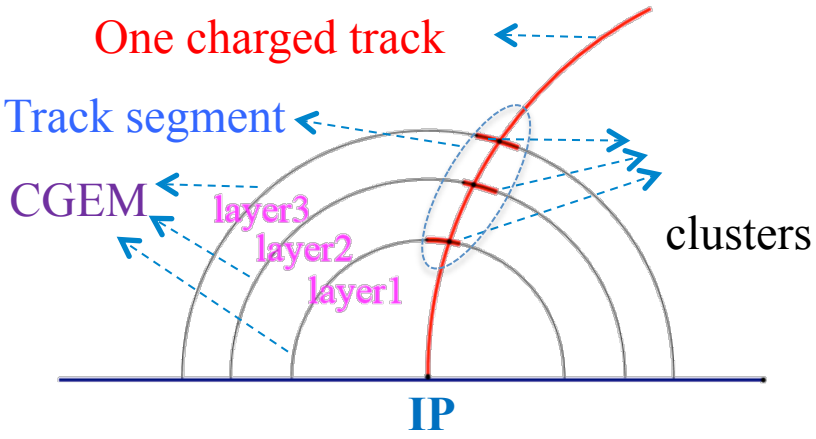


$\delta_X = X_{rec} - X_{truth}$ **(mm)**



$\delta_V = V_{rec} - V_{truth}$ **(mm)**

Track segment finding in CGEM



An explicit method:
find patterns for the 3 clusters from individual charged tracks

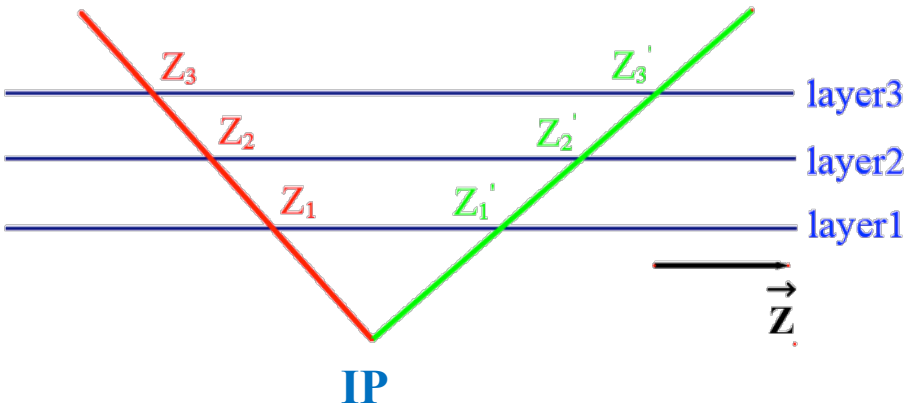
Steps:

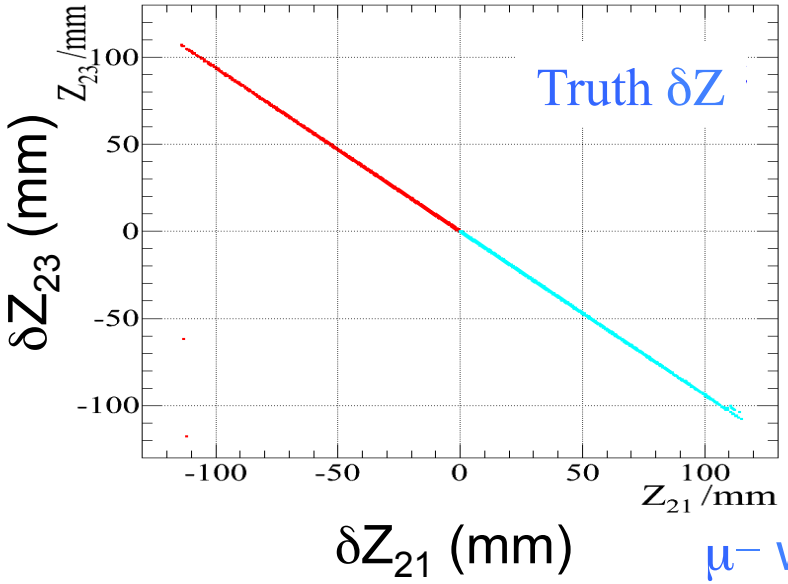
- Introduce two kinds of variables: $\delta\varphi$ and δZ
- Study the patterns of the distributions
- Parameterization of the distributions using mu track
- Define the selection criteria for track segments
- Segment selection with the predefined criteria

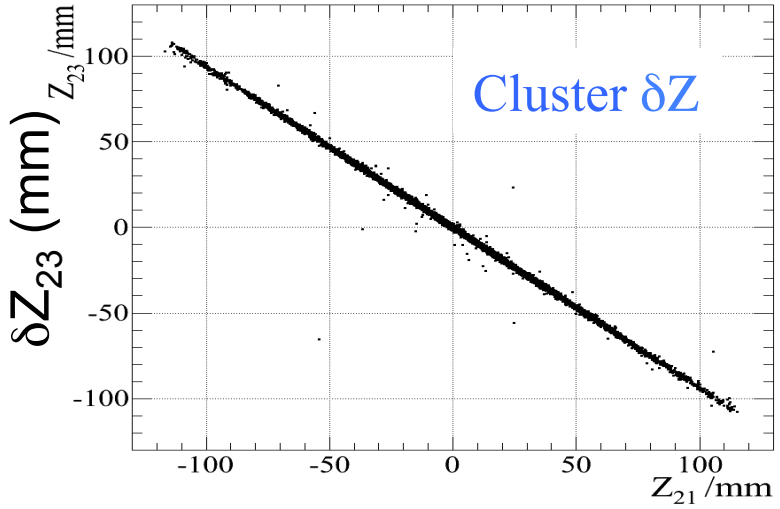
δZ pattern

δZ: differences in Z with respect to Z_2

$\delta Z_{21}=Z_1-Z_2$, $\delta Z_{23}=Z_3-Z_2$



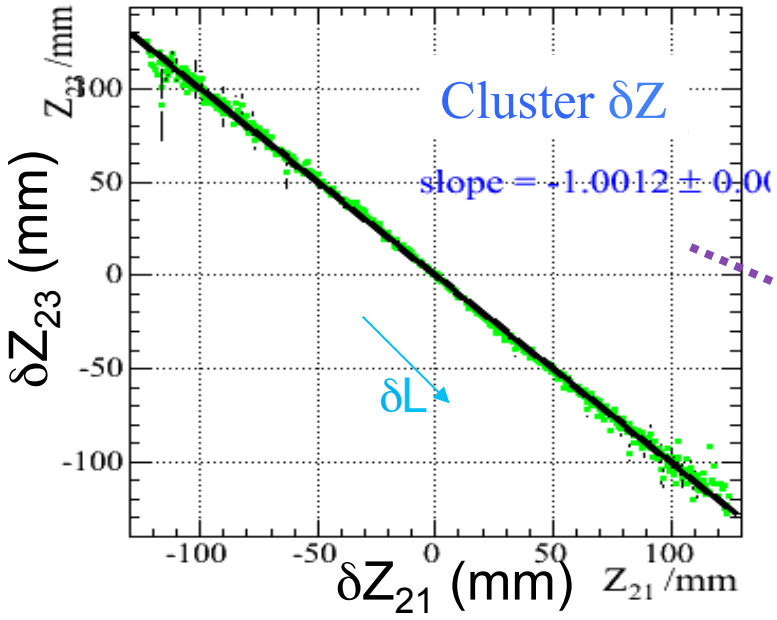


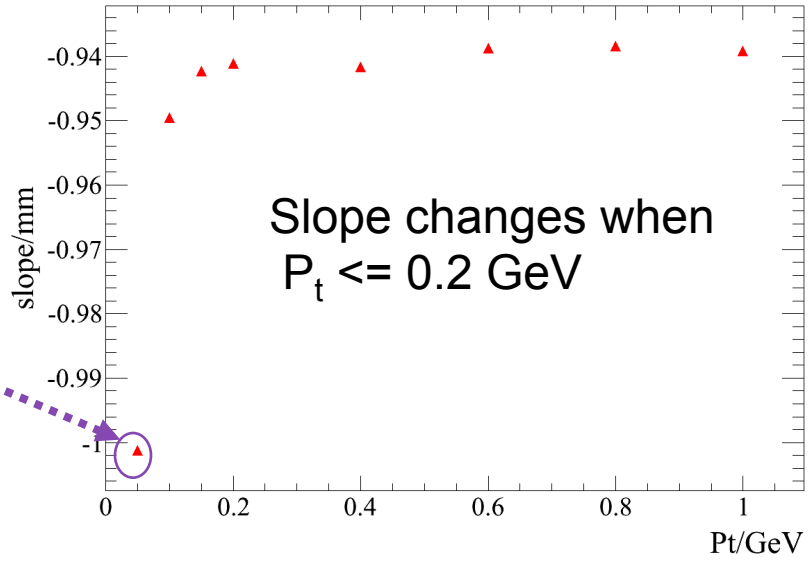


μ^- with p_t=0.8GeV/c

Parameterization of δZ

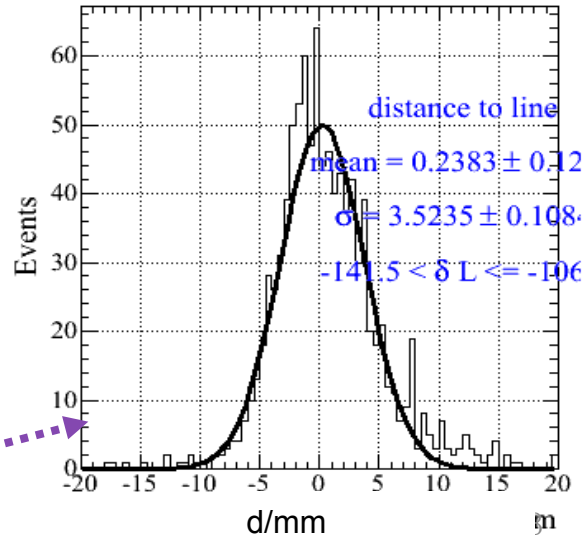
Fit 2D-δZ with 1st- order polynomial



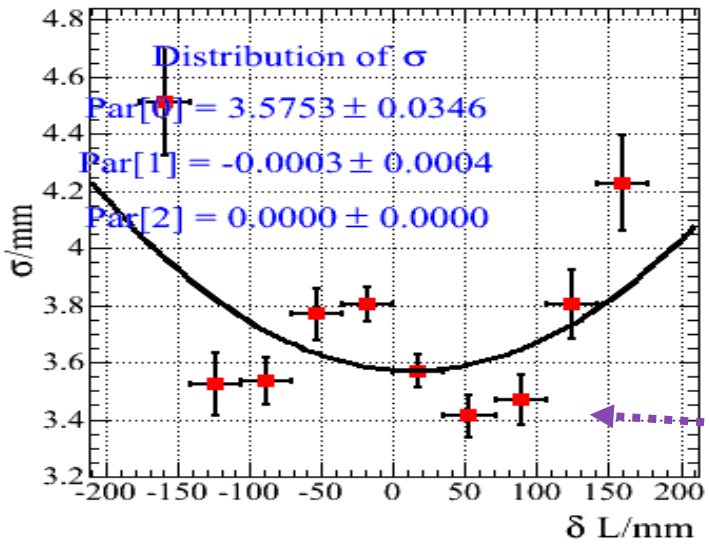


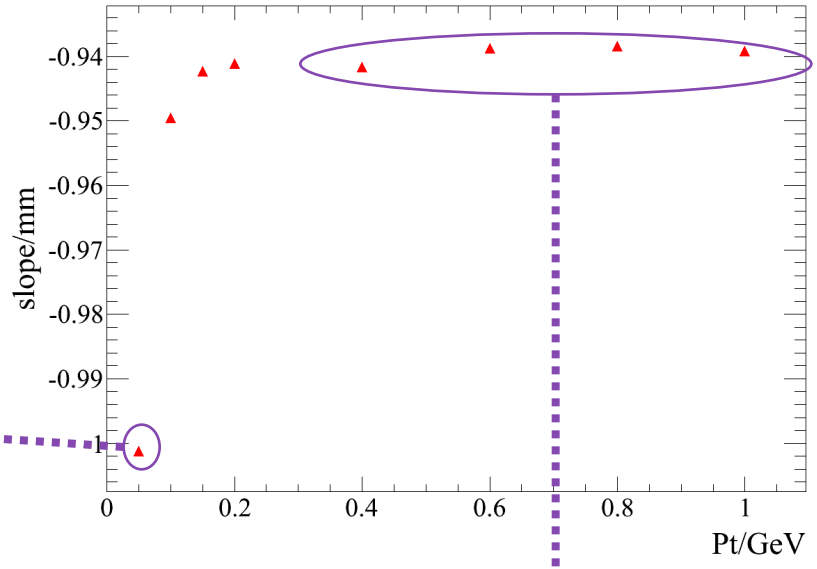
- Resolution is studied with d at different δL
- d: the distance between points and the fitted line
- δL: position on the fitted line

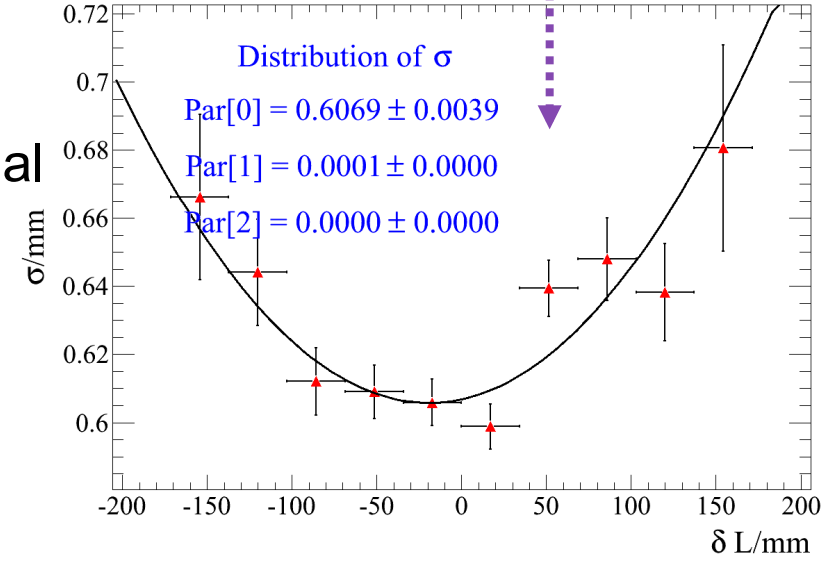
One example of Pt 0.05GeV,
δL (-140.6,-105)
Fitted with Gauss



Parameterization of δZ







σ : standard deviation of Gauss

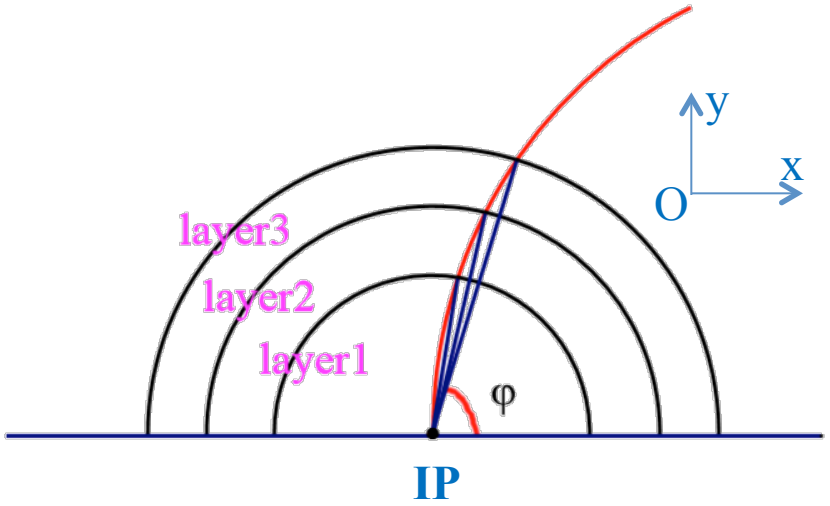
σ(δL) fitted with 2nd-order polynomial

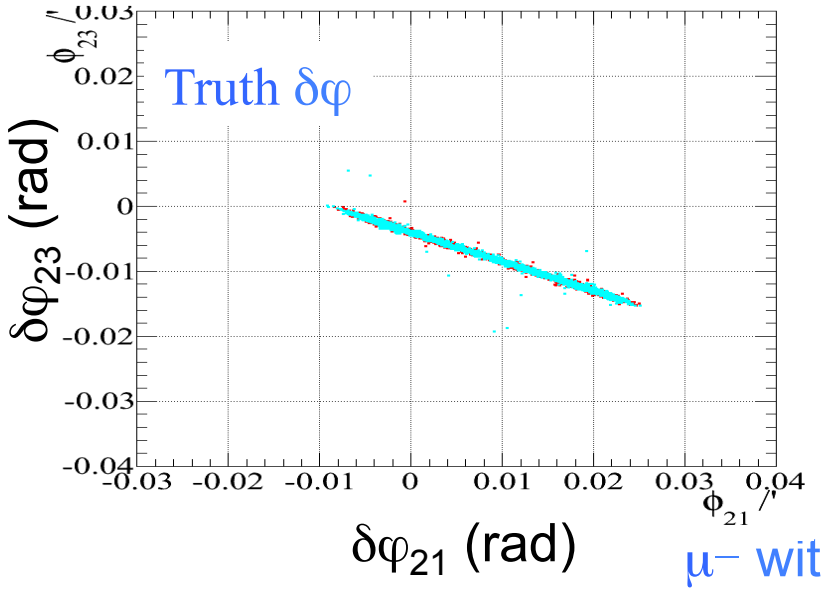
Resolution studied at different P_t

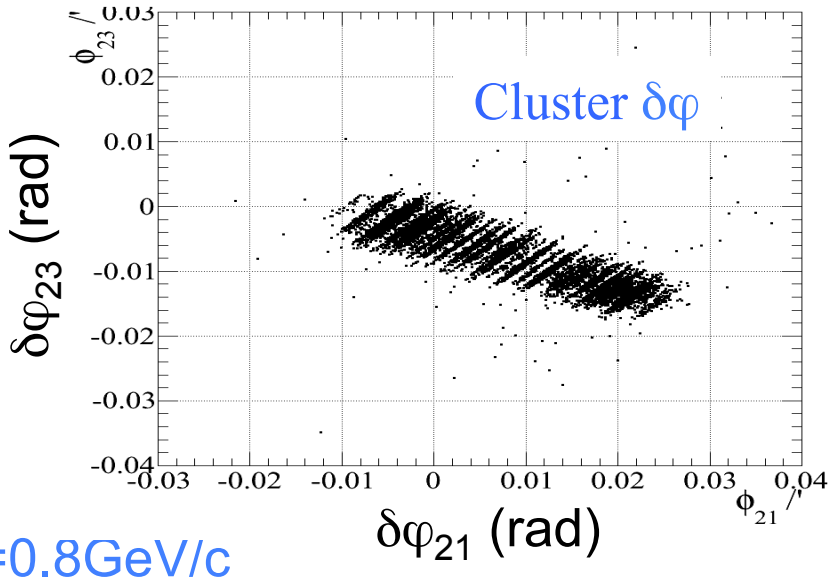
δφ pattern

δφ: differences in φ with respect to φ_2

$\delta\varphi_{21}=\varphi_1-\varphi_2$, $\delta\varphi_{23}=\varphi_3-\varphi_2$

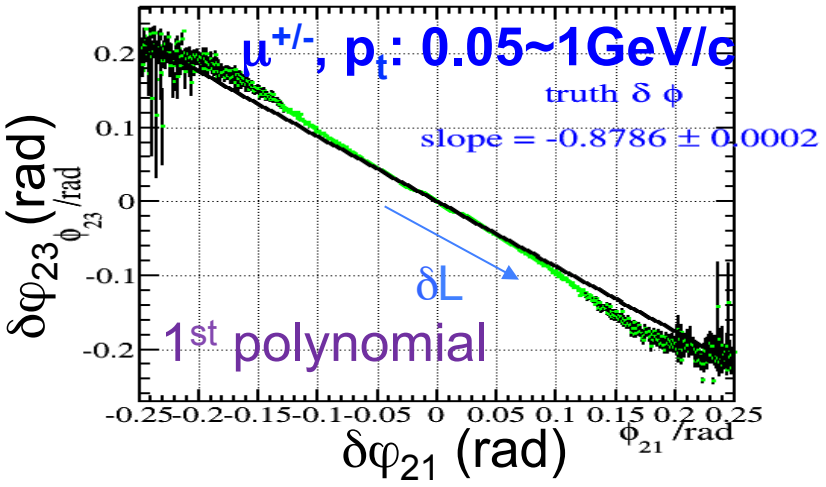




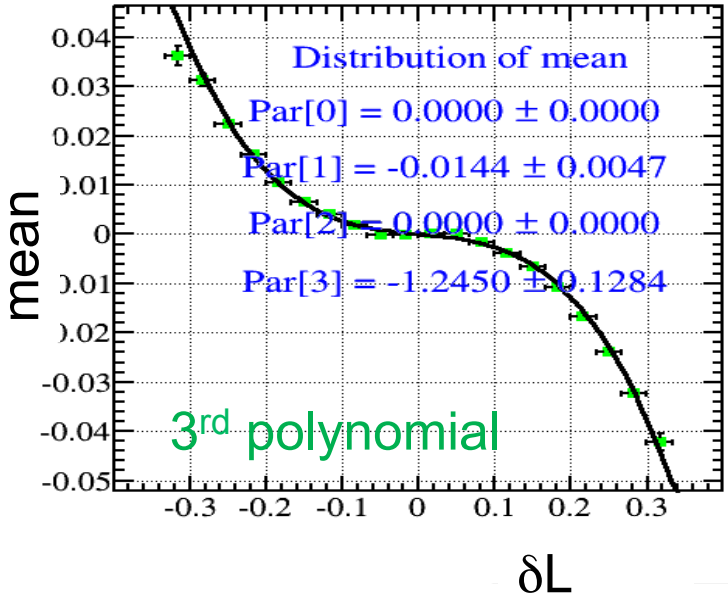


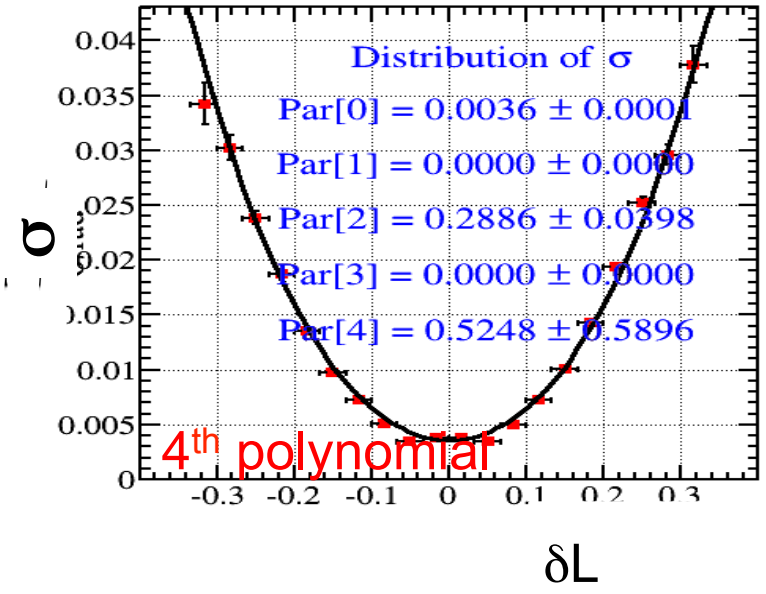
μ− with p_t=0.8GeV/c

Parameterization of δφ



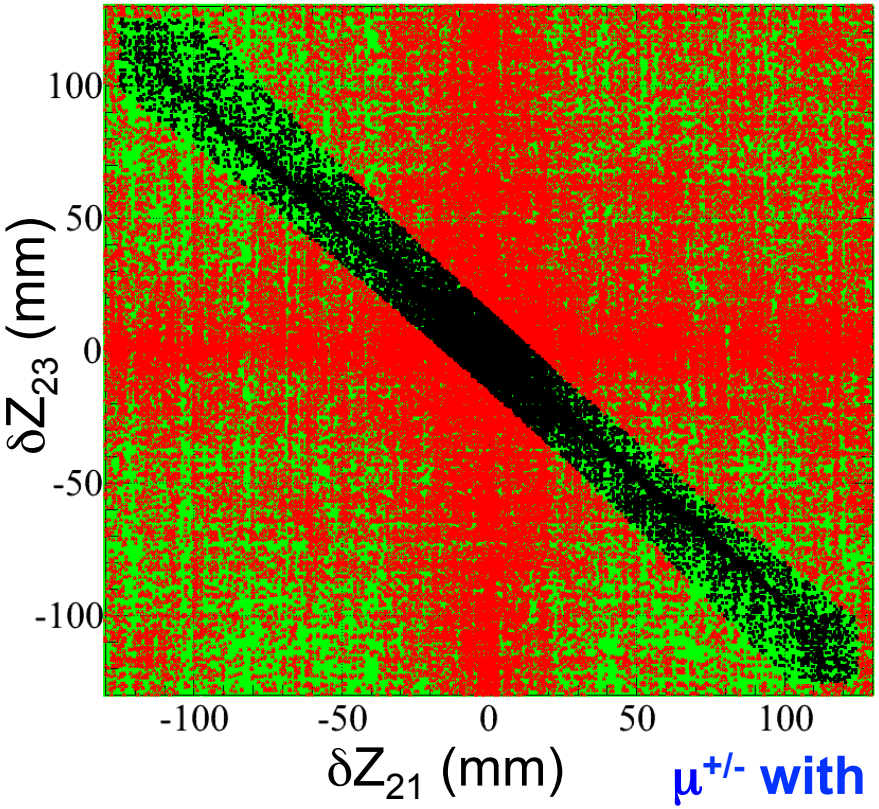
- d distributions at different δL are fitted to Gauss
- d is the distance between points and the fitted line
- δL means position on the fitted line

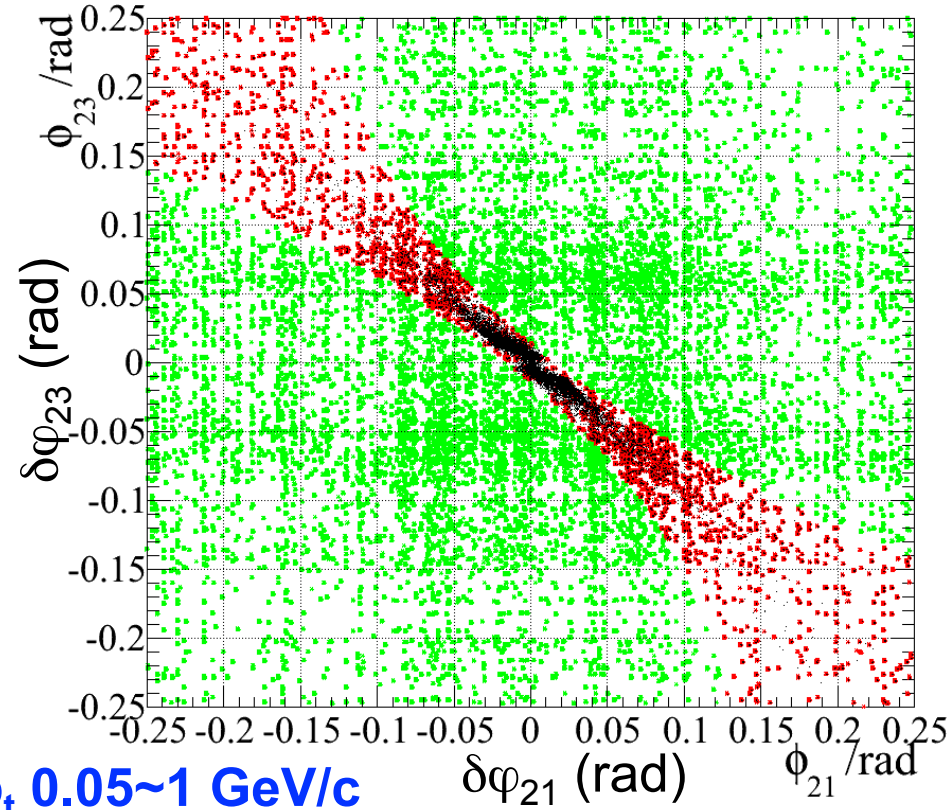




Track segment selection

Track segments: the cluster combinations within 3σ of the parameterized patterns found in δZ and δφ



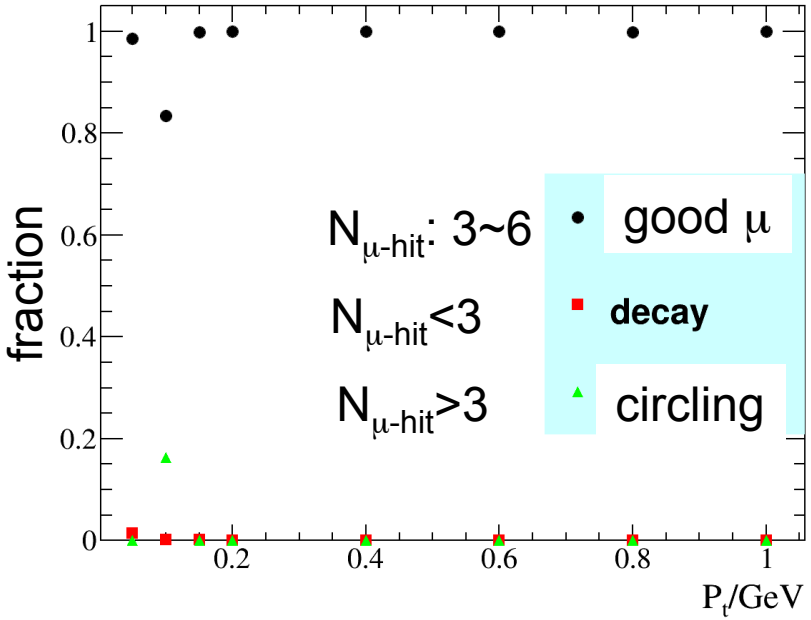


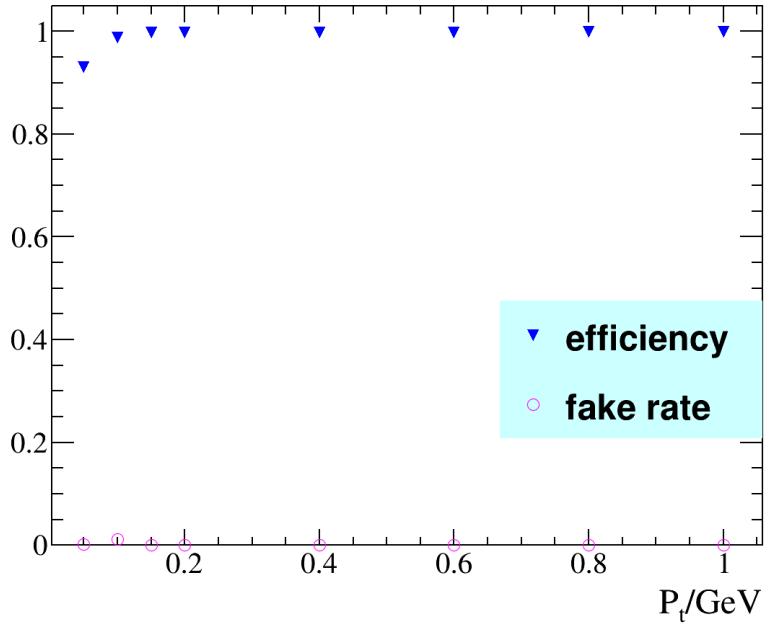
$\mu^{+/-}$ with p_t 0.05~1 GeV/c

Black: selected track segments

Red: inconsistent with δZ pattern, **Green**: inconsistent with δφ pattern

Efficiency of segment finding for μ^-



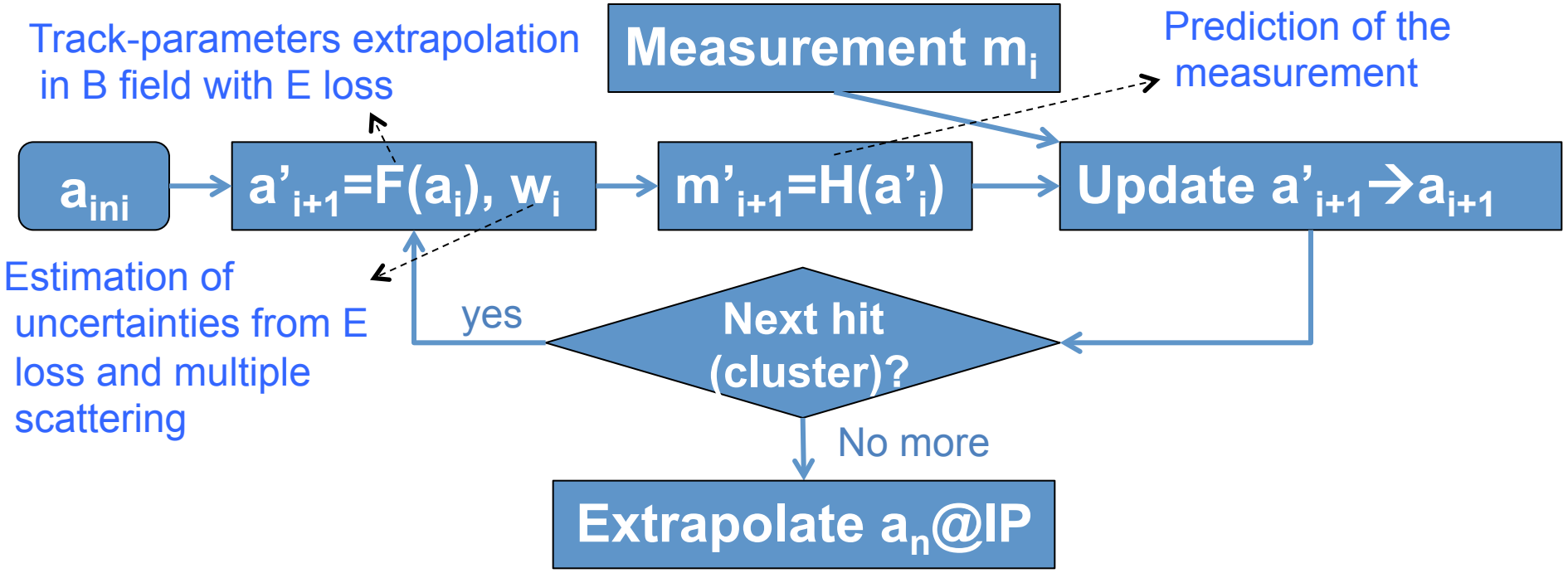


- Muon can decay or circle around in CGEM/DC, in which case no good track segment is expected in CGEM.
- For the efficiency study, these tracks with decay or circling trajectory are excluded.

- Good segments: the 3 clusters can match the MC truth from the muon.
- Efficiency = $N_{goodSeg}/N_{good\text{-}\mu}$
- Fake rate = $(N_{allSeg}-N_{goodSeg})/N_{allSeg}$

Track fitting with Kalman Filter

- Track fitting gives the track parameters as precise as possible.
- Track parameters a are treated as a dynamic system in Kalman Filter method

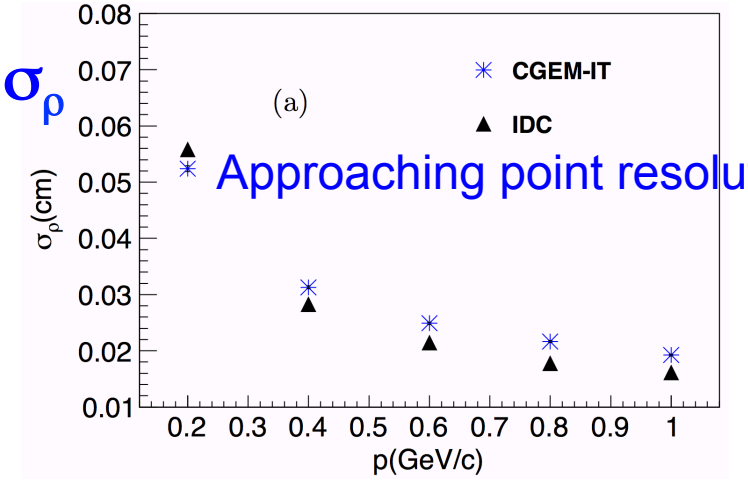


- The Kalman-Filter-based track fitting package for MDC is extended to be able to process CGEM cluster and MDC hits

Track fitting with Kalman Filter (conti.)

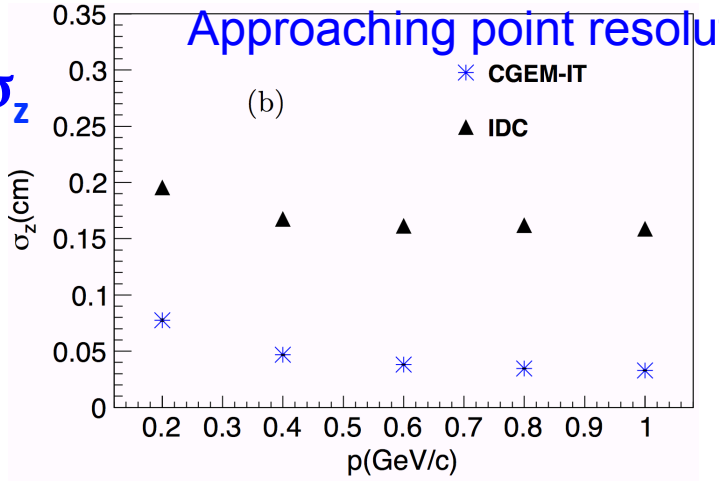
- Extension of track fitting with Kalman Filter
  - ✓ Geometry and material description of CGEM
  - ✓ Calculation of the CGEM cluster predictions
  - ✓ Update of the track parameter with CGEM

σ_ρ



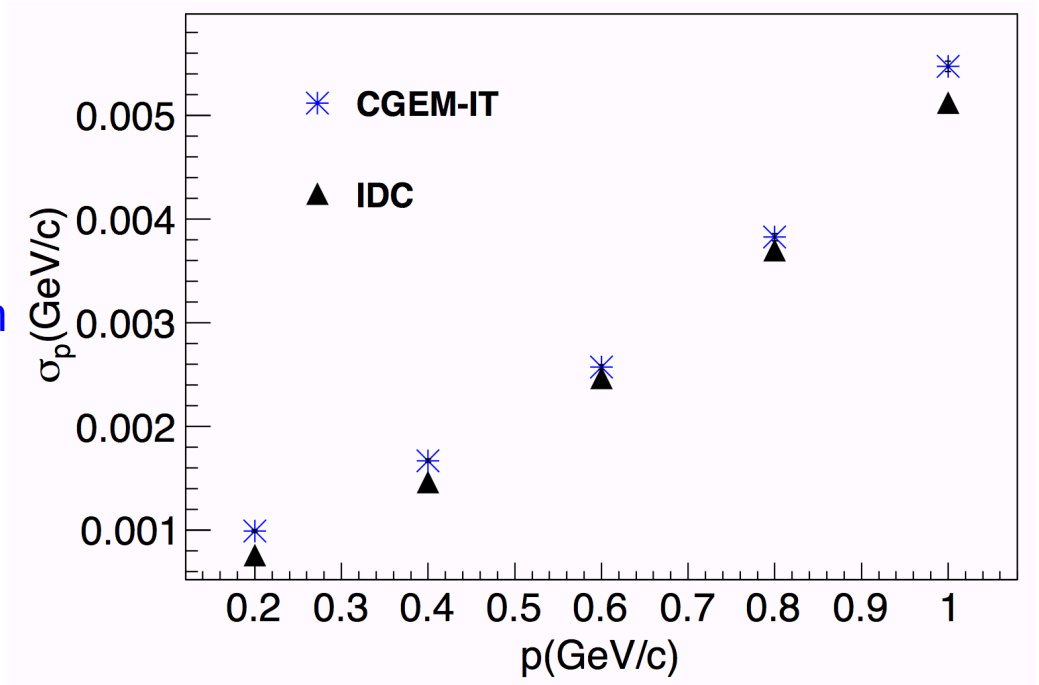
Approaching point resolution

σ_z



Approaching point resolution

Momentum resolution



Releases of CgemBoss

- CgemBossCVS: archive the developments of CGEM related packages, without any influence of current BossCVS
  Inside IHEP: http://koala.ihep.ac.cn/cgi-bin/viewcvs.cgi/CgemBossCvs/
  Outside IHEP:
  http://docbes3.ihep.ac.cn/viewvc/cgi-bin/viewvc.cgi/BESIII/CgemBossCvs/
- CgemBoss releases: offline software environment to test the codes of CGEM related packages but without touching the current Boss releases
  - ✓ Previous versions: 0.0.1, 0.0.2, 0.0.3, 0.0.4, 6.6.3
  - ✓ Test versions: 6.6.3.a, 6.6.3.b, 6.6.5.a
  - ✓ The latest release: 6.6.5
    (Scientific Linux 6, Event model update)
- The updates in BOSS releases are traced and incorporated in CgemBOSS releases to keep the compatibility of CGEM packages.

Summary

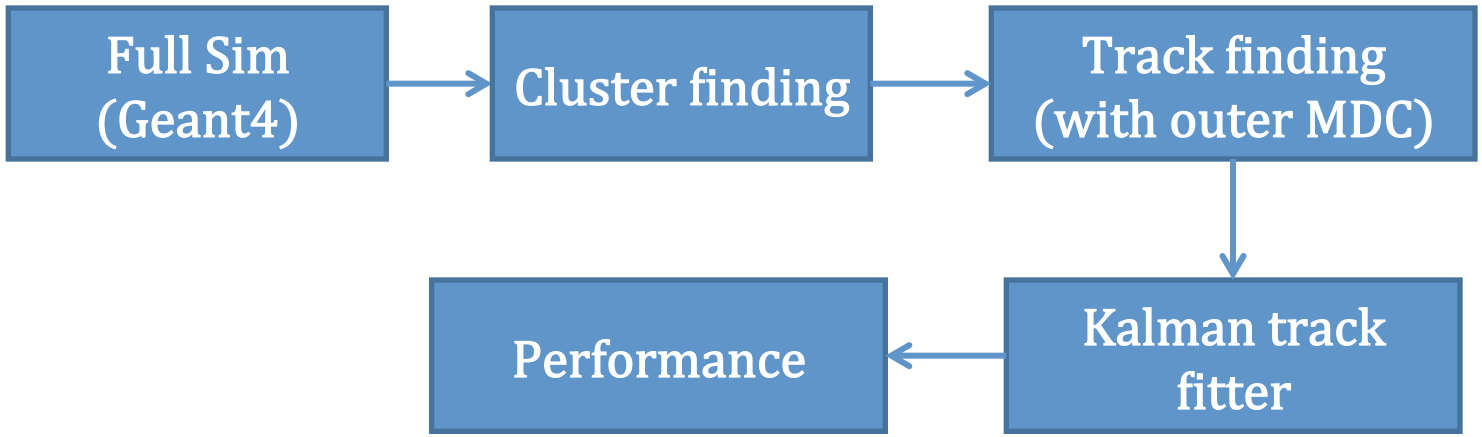
- ✓ CGEM simulation and most reconstruction packages were developed
- ✓ The performance is reasonable
- ✓ CgemBoss are released regularly
- ✧ Global tracking with CGEM and DC is in progress
- ➢ Digitization model for CGEM is to be improved
- ➢ Optimization and fine tuning of simulation and reconstruction is essential
- ➢ The development of calibration packages will start next year

Grazie!

BACKUP

Development of CGEM-IT software

- Monte Carlo study based on full simulation
  - Study the expected performance
  - Optimize CGEM-IT design

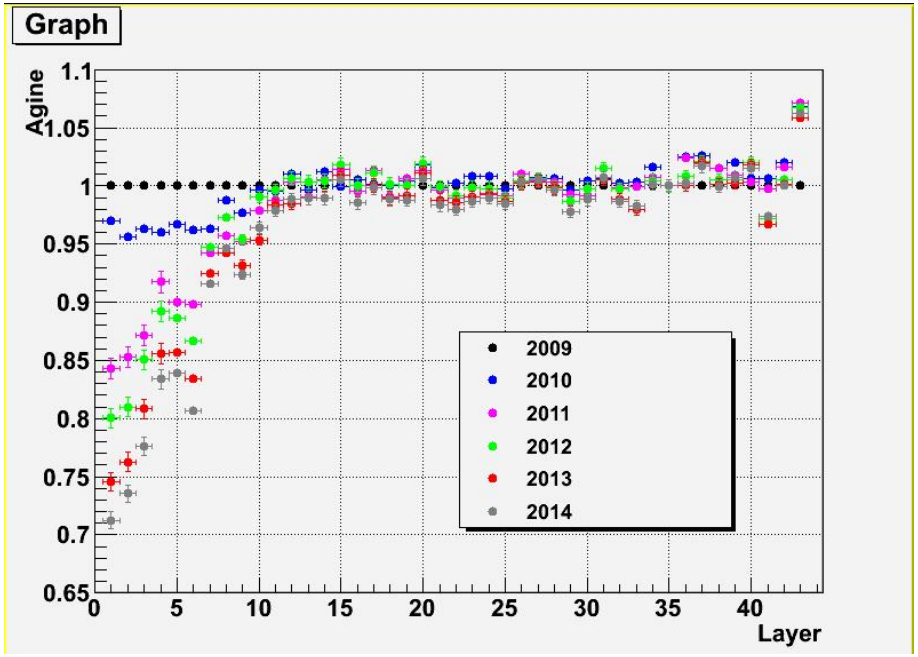


Motivation

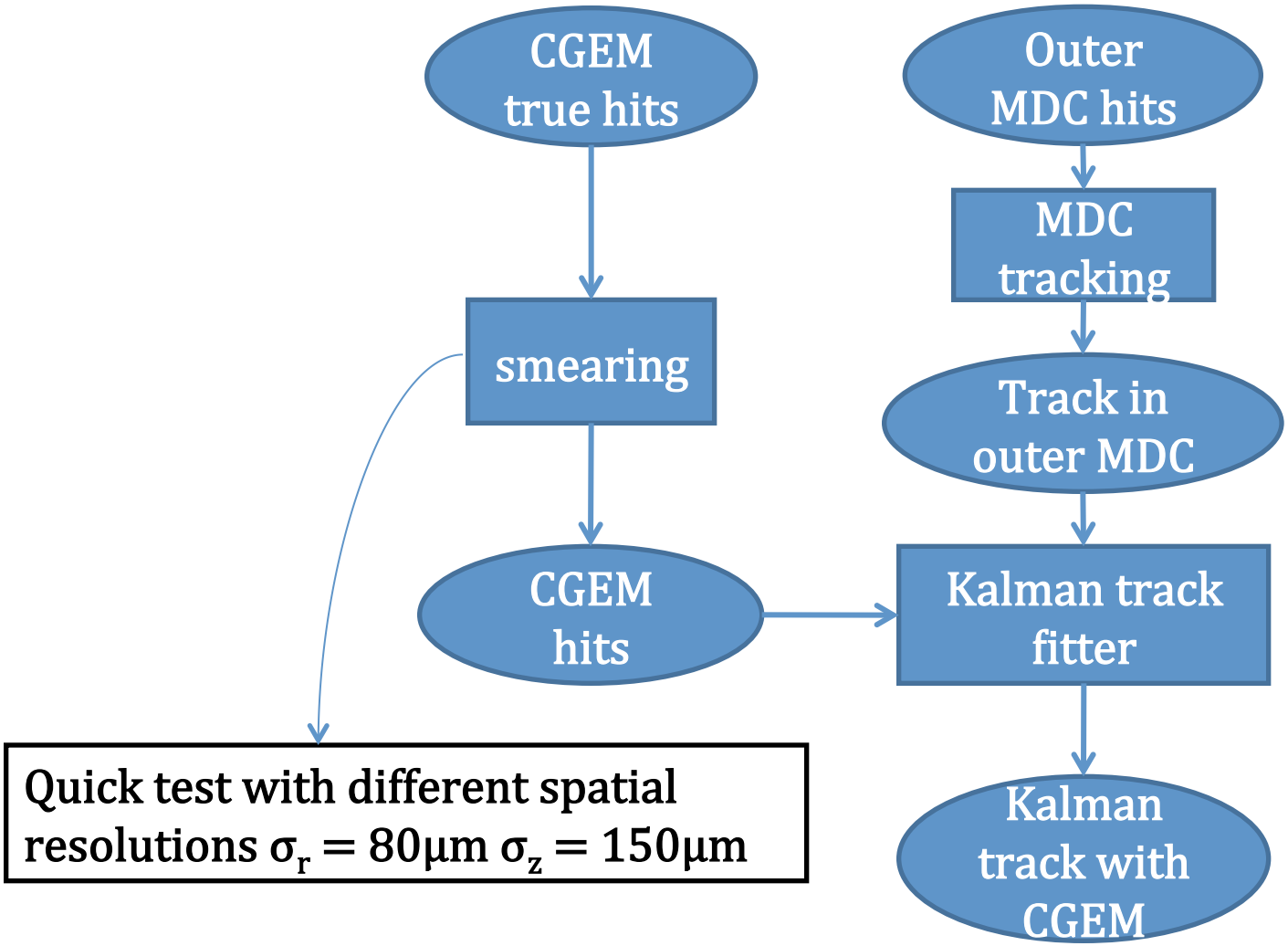
- Aging of BESIII inner drift chamber
  - Gain is dropping year by year
- CGEM-IT (a candidate)
  - Good spatial resolution and radiation hardness
  - Applied in KLOE-2

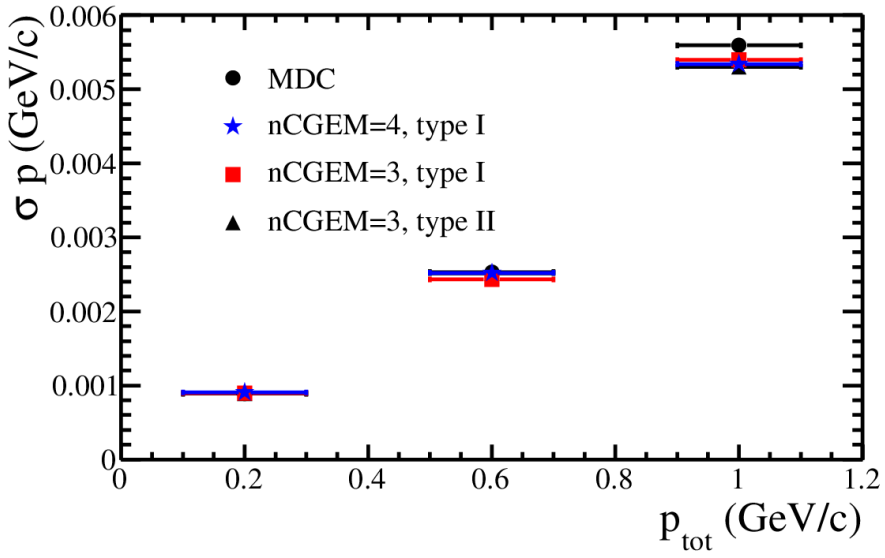
Relative gain vs layer

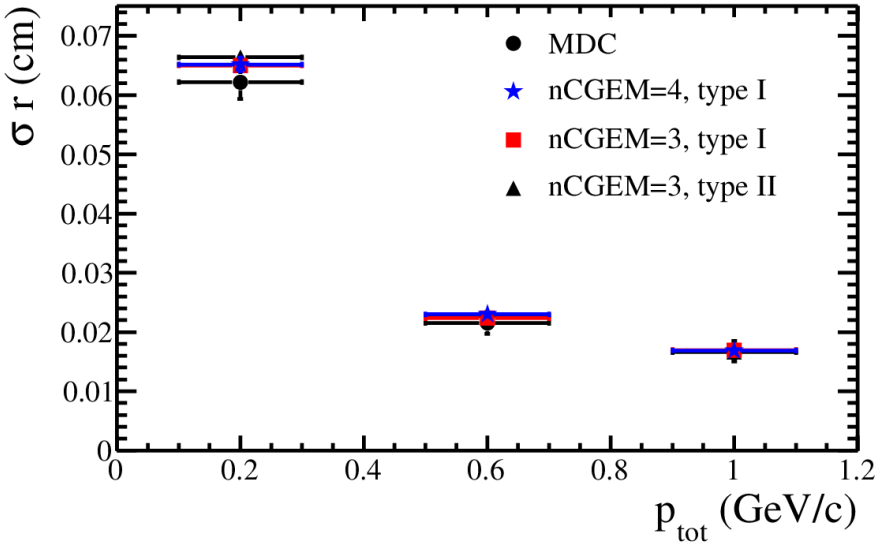
(from M.Y. Dong's report)

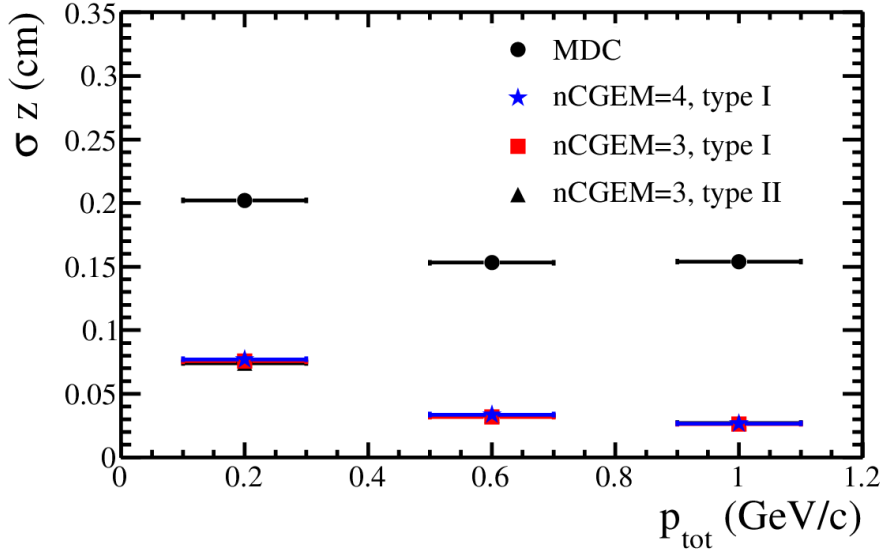


Reconstruction with CGEM-IT









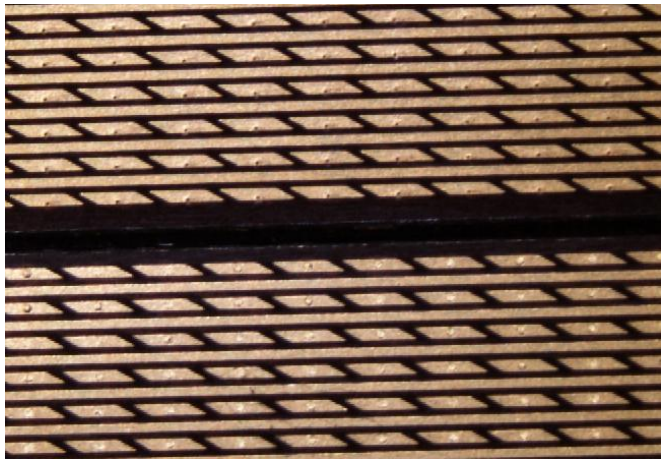
- CGEM inner detector VS MDC inner detector
  - ➢ dz resolution improved significantly
  - ➢ comparable dr resolution and momentum resolution

Geometry

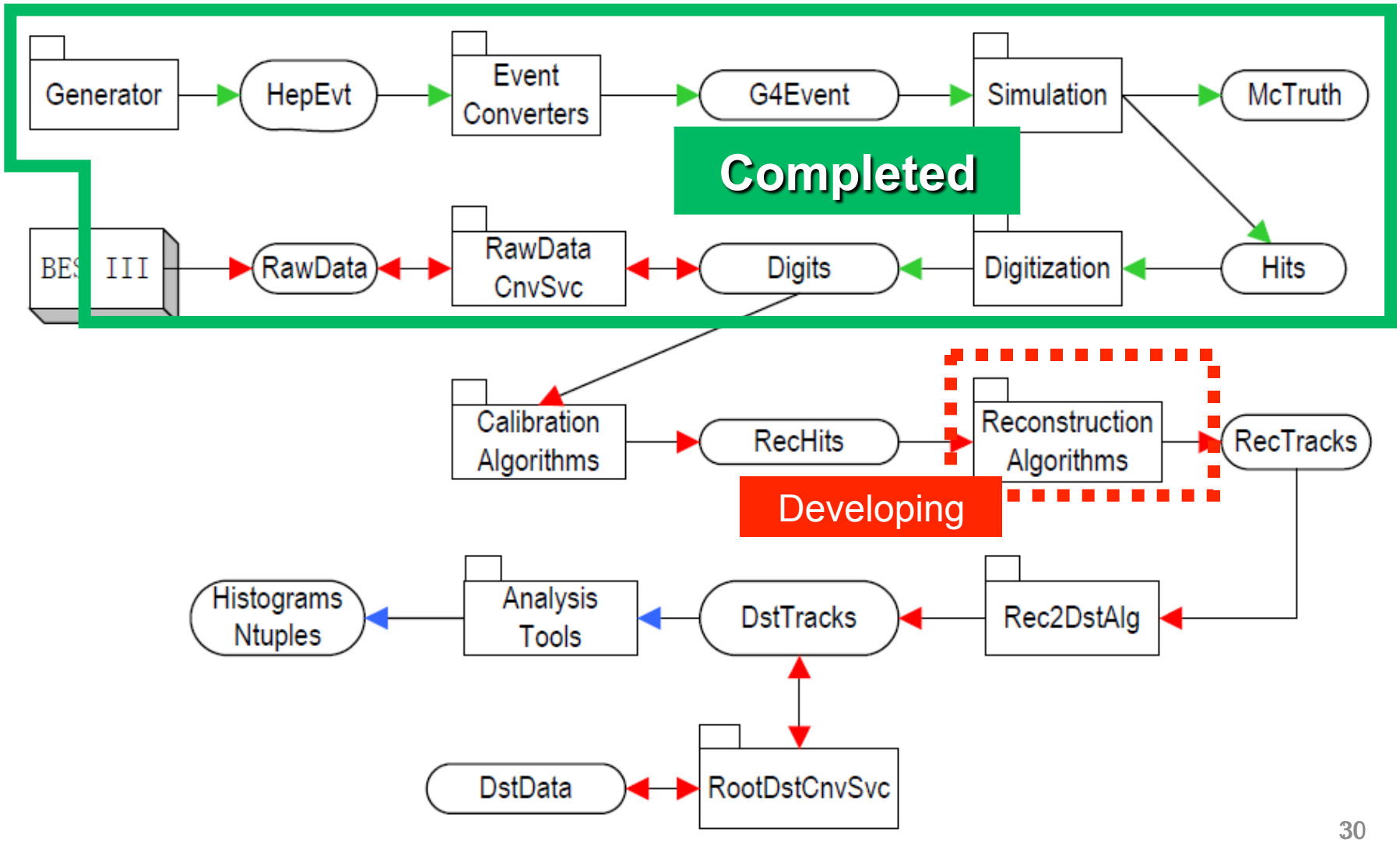
Units (mm)	Layer1		Layer2		Layer3	
	R_{in}	Thickness	R_{in}	Thickness	R_{in}	Thickness
Cathode	75.234	3.104	120.5	3.104	163.0	3.104
Gap_D	78.338	3.0	123.604	3.0	166.104	3.0
GEM 1	81.338	0.054	126.604	0.054	169.104	0.054
Gap_T1	81.392	2.0	126.658	2.0	169.158	2.0
GEM 2	83.392	0.054	128.658	0.054	171.158	0.054
Gap_T2	83.446	2.0	128.712	2.0	171.212	2.0
GEM 3	85.446	0.054	130.712	0.054	173.212	0.054
Gap_I	85.5	2.0	130.766	2.0	173.266	2.0
Anode	87.5	0.2512	132.766	0.2512	175.266	0.2512
CF-Shield	87.7512	3.1	133.0172	3.1	175.5172	3.1
Length/ Thickness	532 / 15.6172		690 / 15.6172		847 / 15.6172	

CGEM readout

	Layer1	Layer2	Layer3
Sheets number	1	2	2
Anode radius(mm)	87.50	132.766	175.266
Layer width(mm)	549.78	834.2	1101.22
Sheet width(mm)	549.78	417.10	550.61
Z length(mm)	532.00	690.00	847.00
Stereo angle(rad)	0.8018	0.5428	0.5758
Pitch(mm)	0.65	0.65	0.65
X channel N	846	1284	1696
V channel N	1177	2198	2844
Total channel N	2023	3482	4540

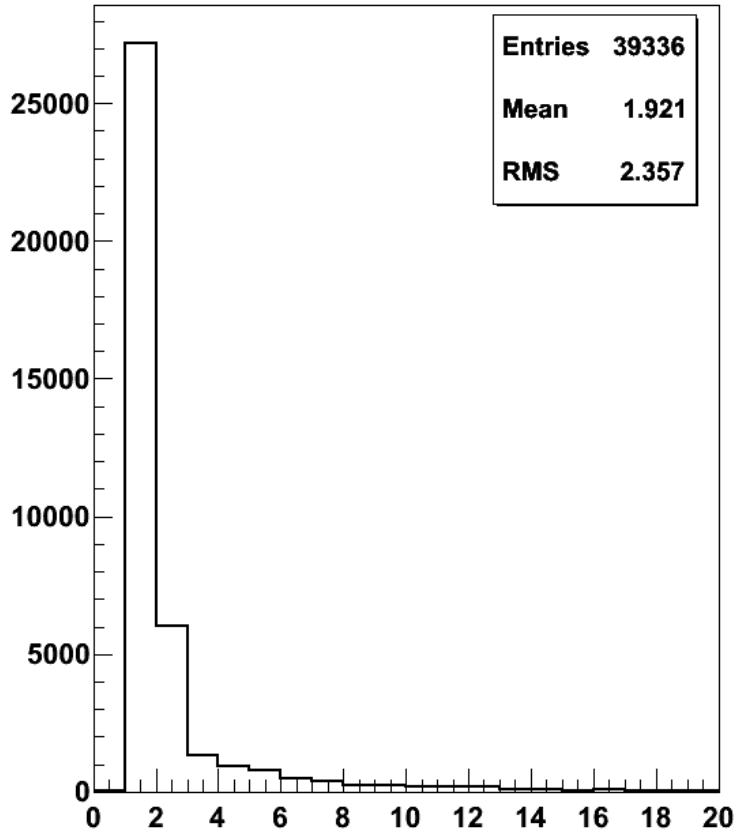


Dataflow

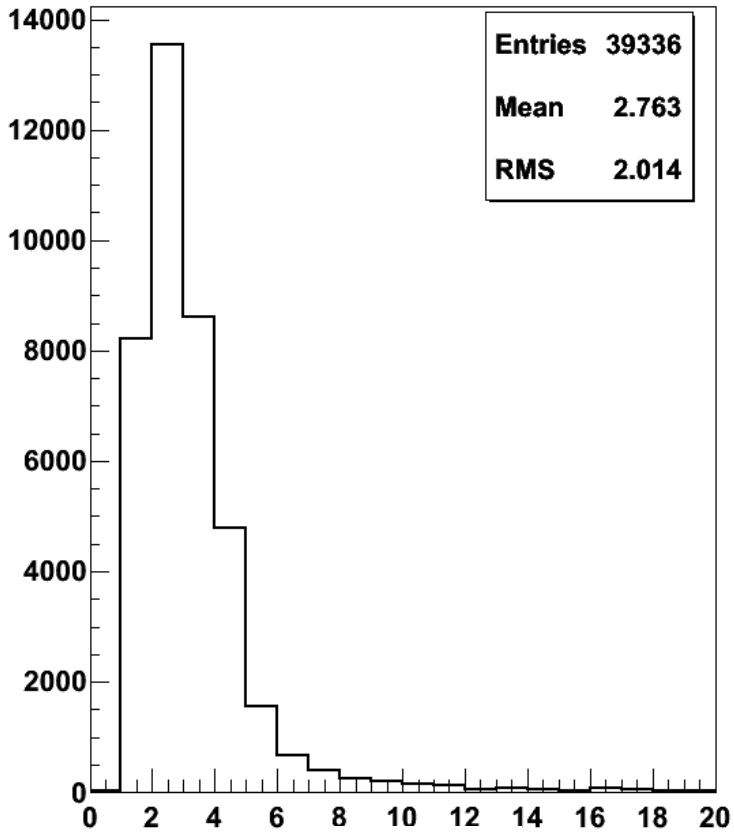

Generator
HepEvt
Event Converters
G4Event
Simulation
McTruth
Completed
BES III
RawData
RawData CnvSvc
Digits
Digitization
Hits
Calibration Algorithms
RecHits
Reconstruction Algorithms
RecTracks
Developing
Histograms Ntuples
Analysis Tools
DstTracks
Rec2DstAlg
DstData
RootDstCnvSvc

Distribution of number of fired strips in each cluster

single muon MC sample 1.0 GeV $|\cos\theta| < 0.93$



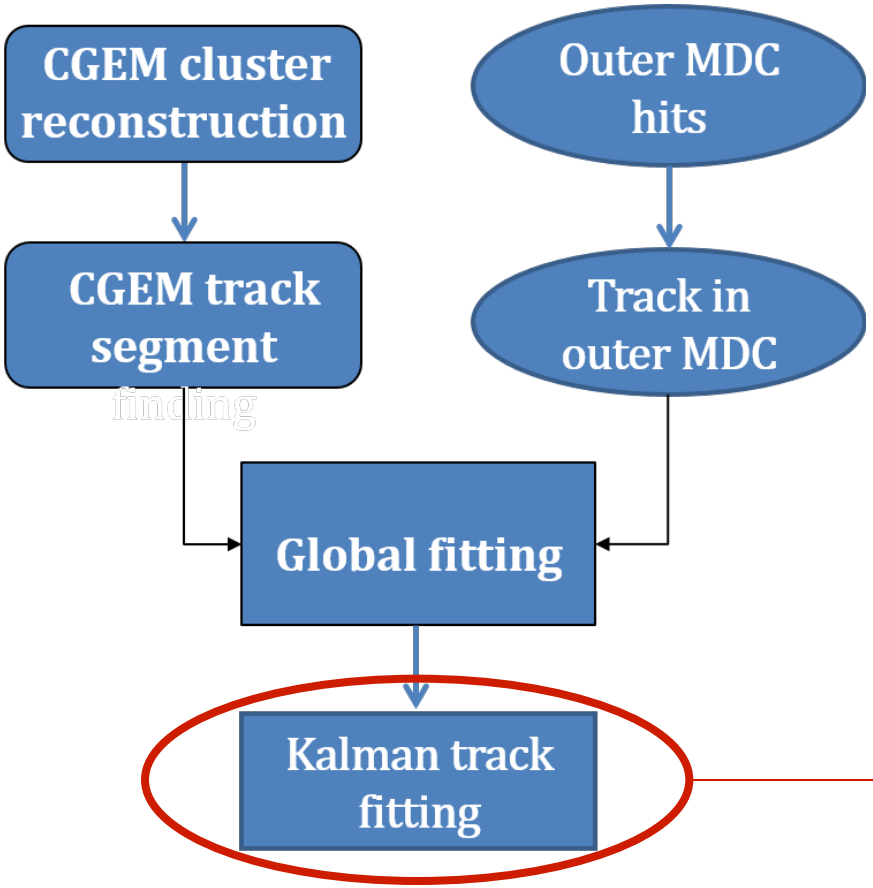
nxstrip



nvstrip

Average number of strips that each cluster contains is 2~3 in either direction

Process of Kalman Fitting



Reconstructed tracks (with MDC outer chamber hits) as input

Use MDC hits and CGEM clusters to update the track parameters from the outermost point to the origin

Take into account the multiple scattering, energy loss and NUMF

Obtain track parameters and covariance matrix under different hypothesis (e,μ,π,K, p)