CGEM探测器离线软件研究

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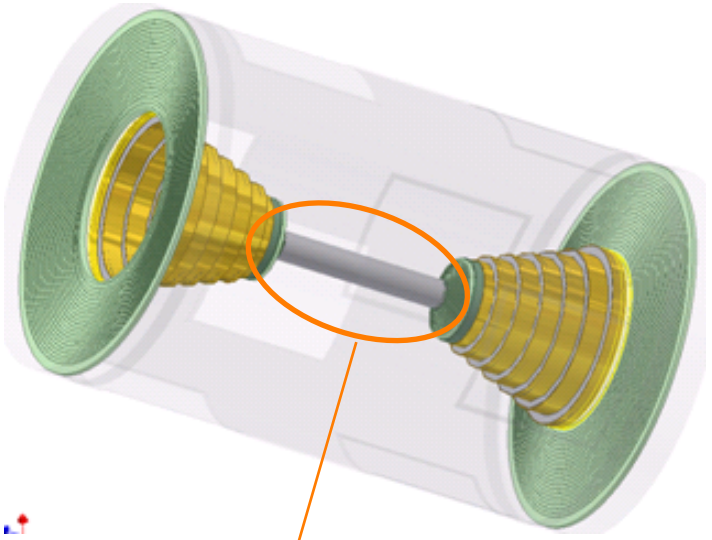
Outline

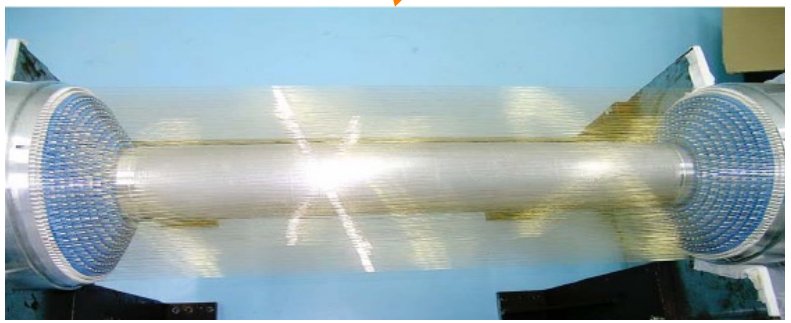
- Introduction
- Full detector simulation
- Track reconstruction
- Summary

Aging of MDC inner chamber

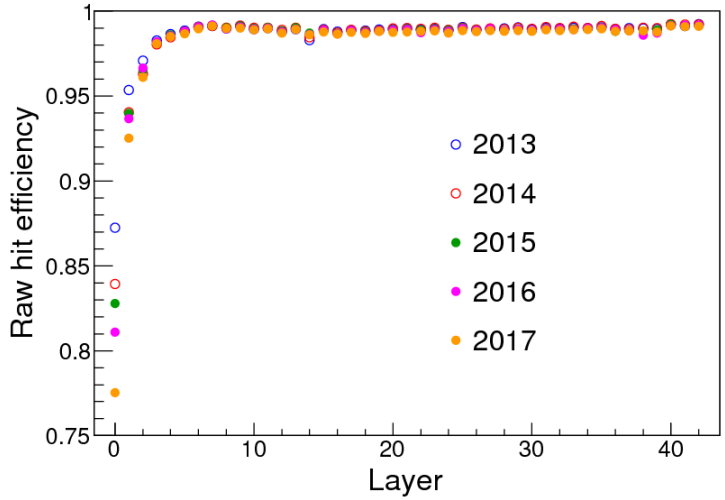
- Hit efficiency of the BESIII MDC inner layers drops year by year due to aging
- Cylindrical GEM inner tracker (CGEM-IT) is a candidate for upgrade of MDC inner chamber



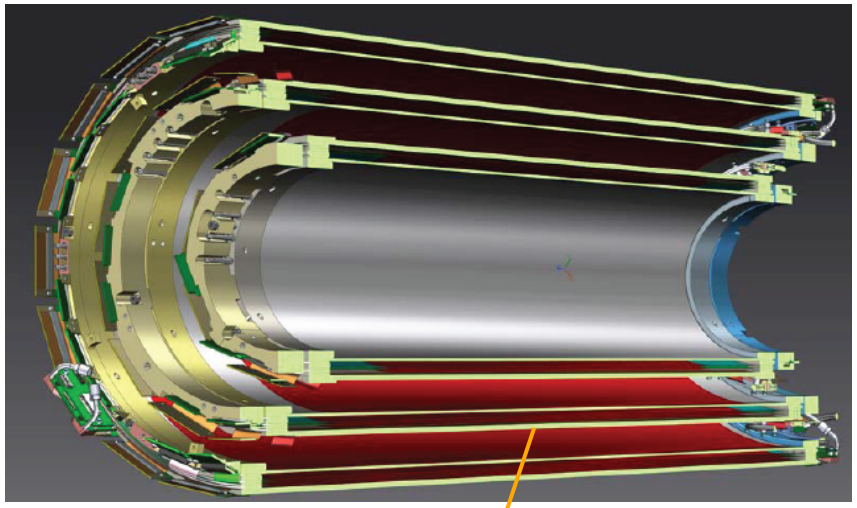
Inner drift chamber



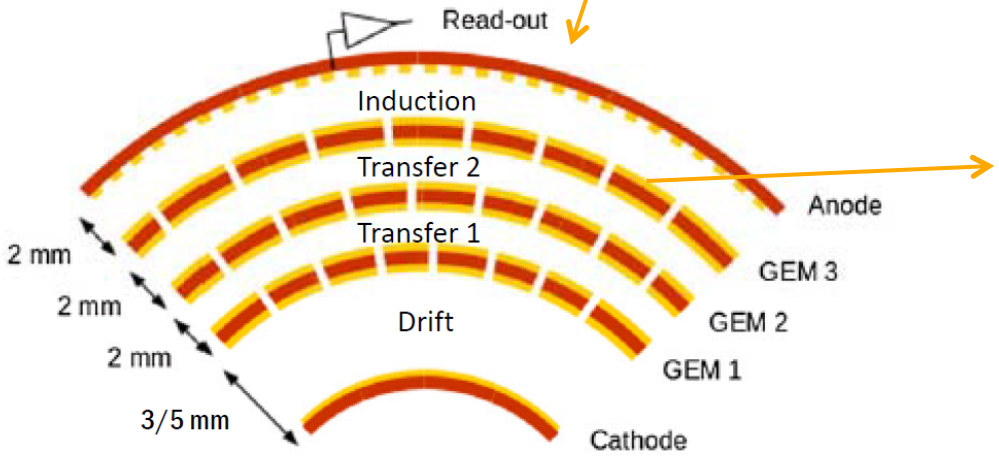
Raw hit efficiency vs layer

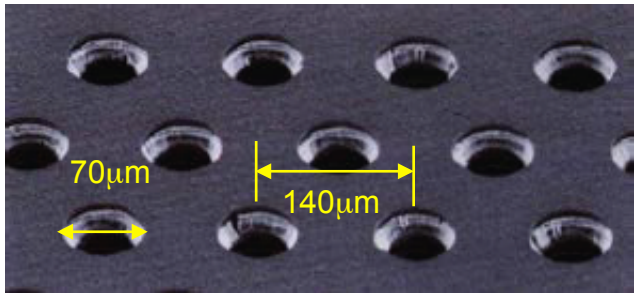


CGEM Inner Tracker (CGEM-IT)



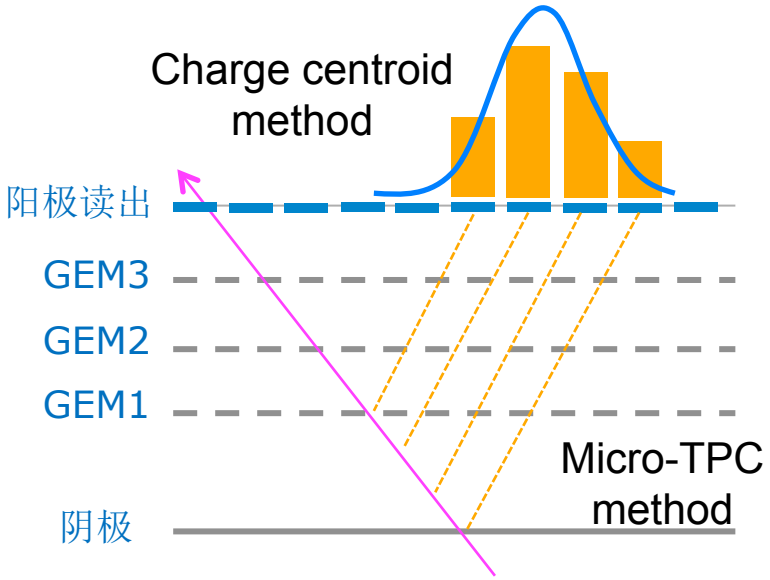
- 3 layer Cylindrical GEM
- Each layer composed by 3 gem foils
- Spatial resolution
  - $\sigma_{r\phi}$ ~ 130μm
  - σ_z < 1mm
- Coverage: 93%

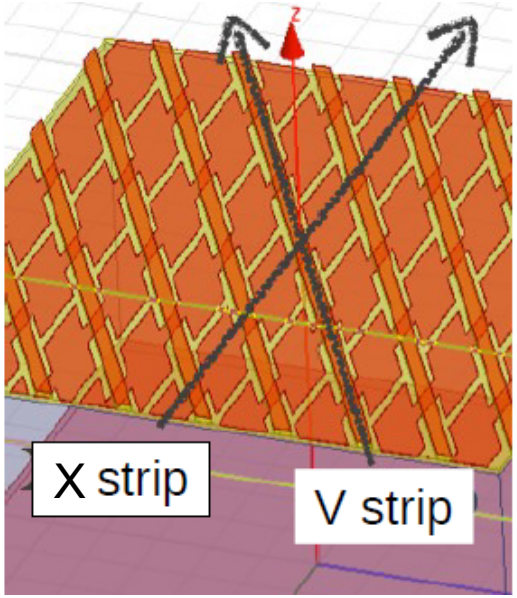




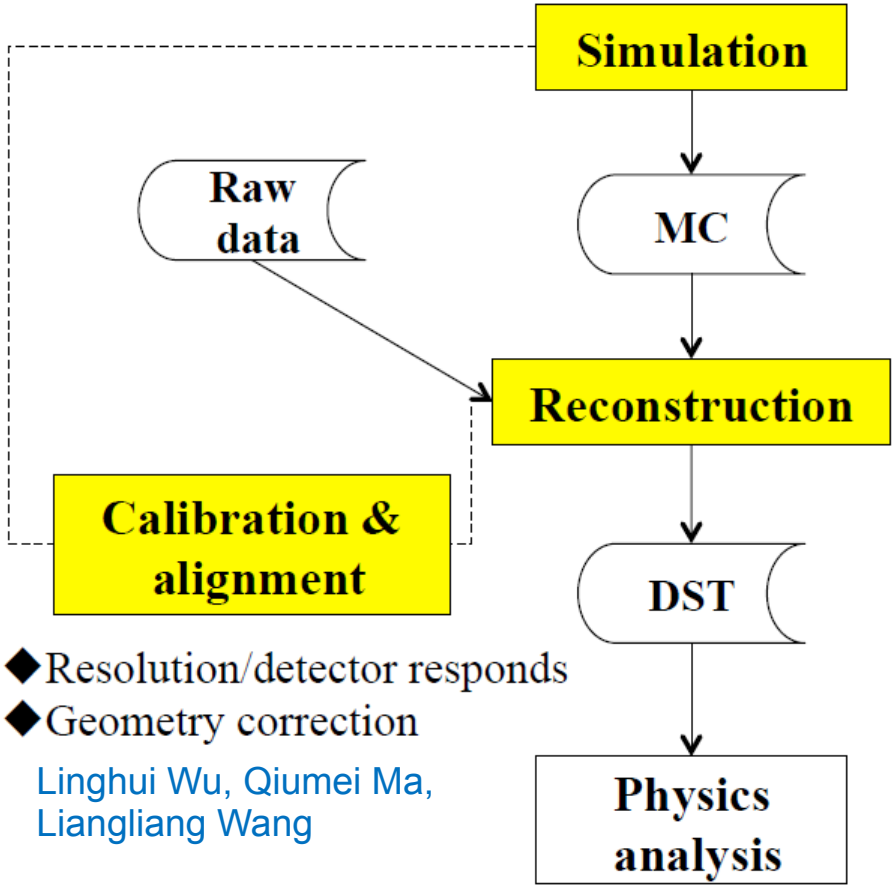
Readout method of CGEM-IT

- Analog readout
  - Q for charge centroid method in cluster reconstruction
  - T for micro-TPC method in track segment reconstruction





CGEM-IT Offline Data Processing Software



- Resolution/detector responds
- Geometry correction

Linghui Wu, Qiumei Ma, Liangliang Wang

- Detector description (Geometry/material)
- Digitization

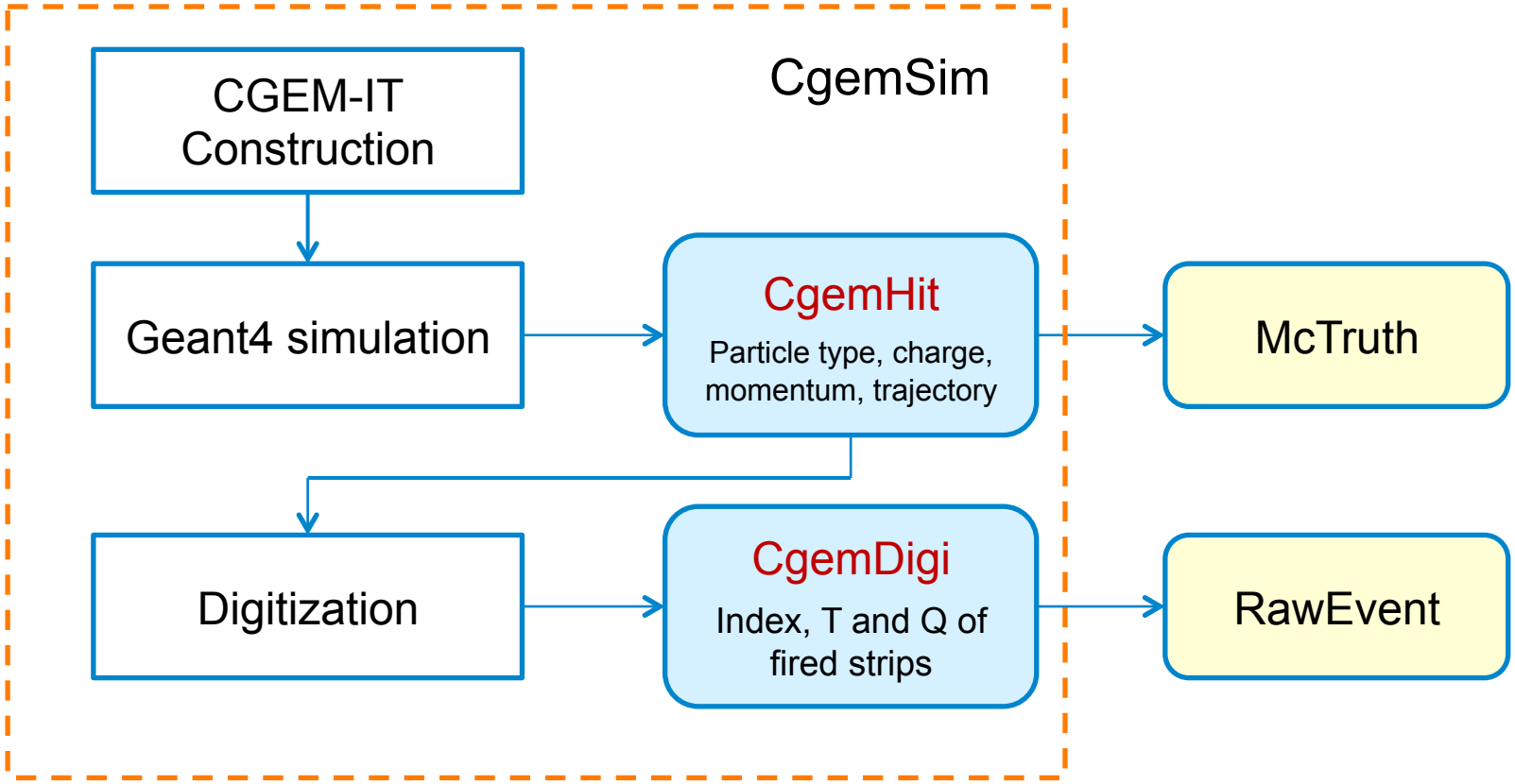
Xudong Ju, Nannan Miao, Lia Lavezzi, Linghui Wu, Liangliang Wang

- Cluster reconstruction
- Track segment finding with CGEM
- Track matching
- Global track finding with Hough transform
- Track fitting

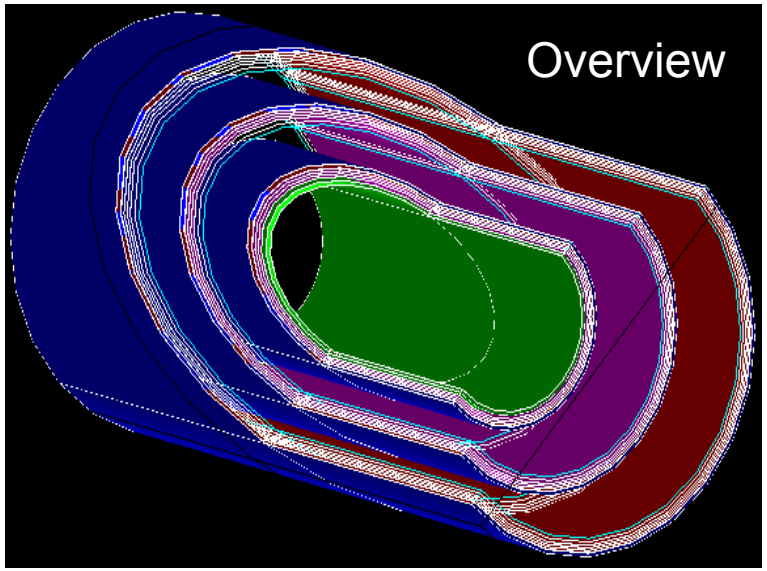
Zhen Huang, Liangliang Wang, Yue Guo, Xinhua Sun, Jin Zhang Yao Zhang, Linghui Wu

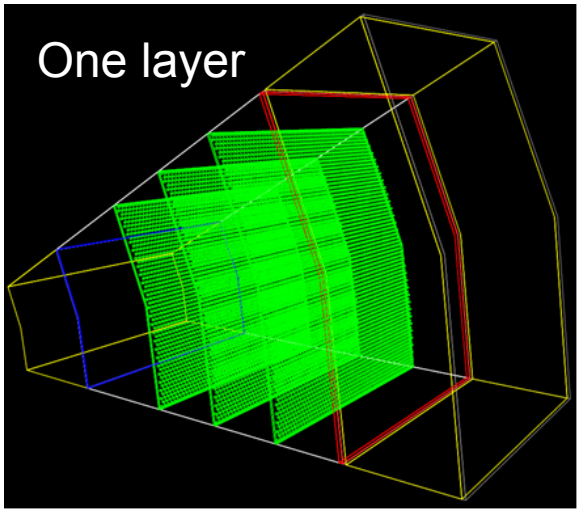
- performance check

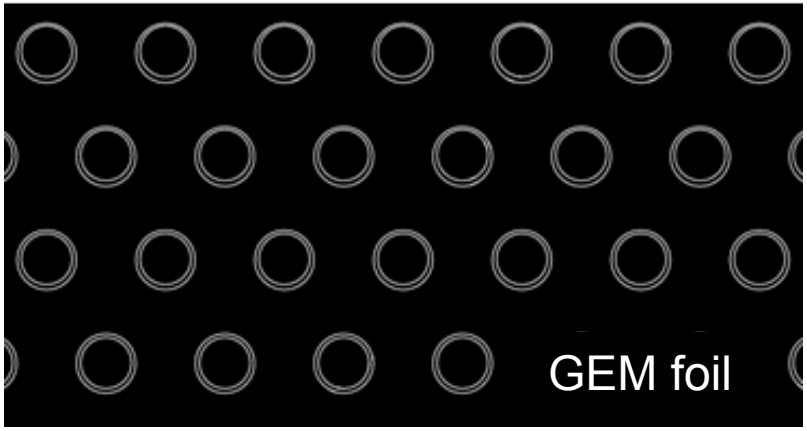
Full detector simulation

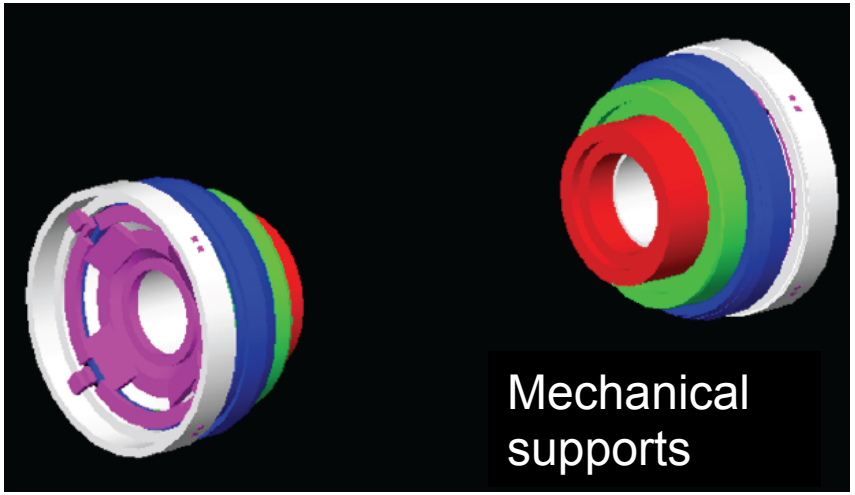


Detector construction in Geant4



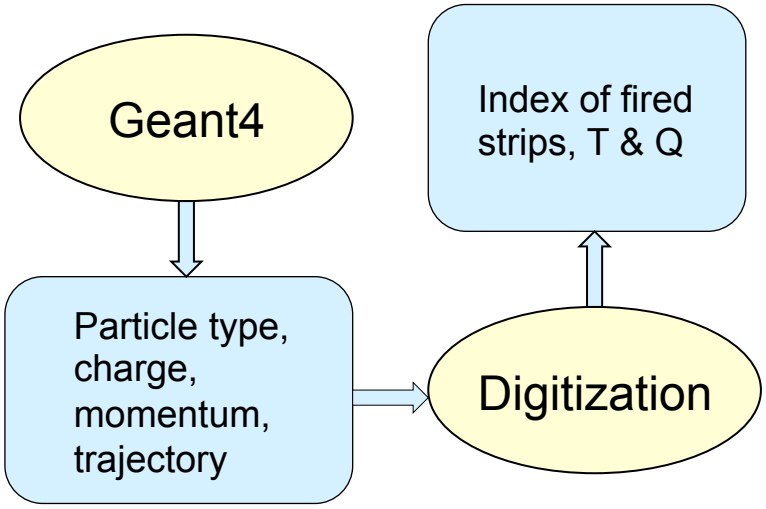


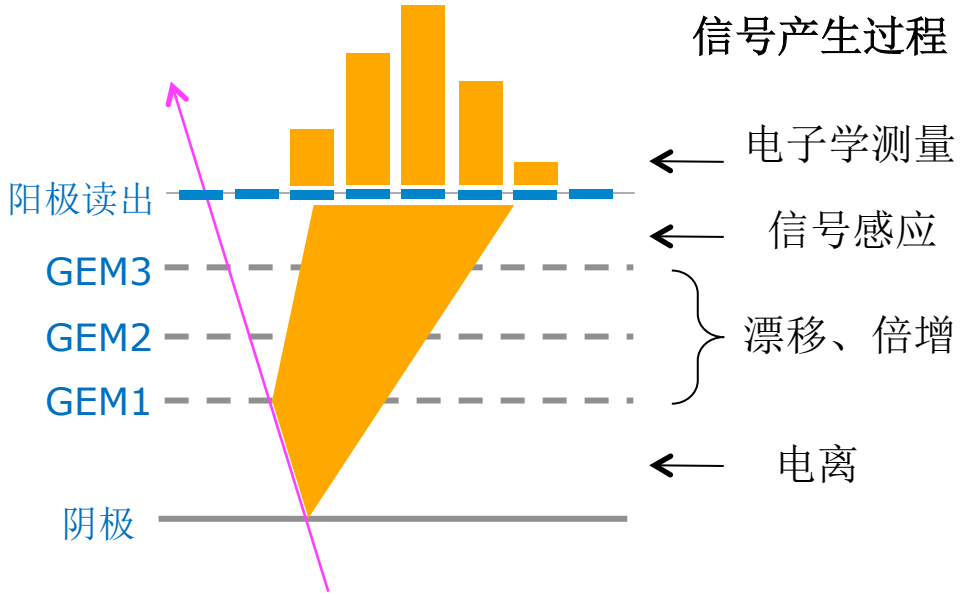




Digitization

- Digitization is the simulation of detector response



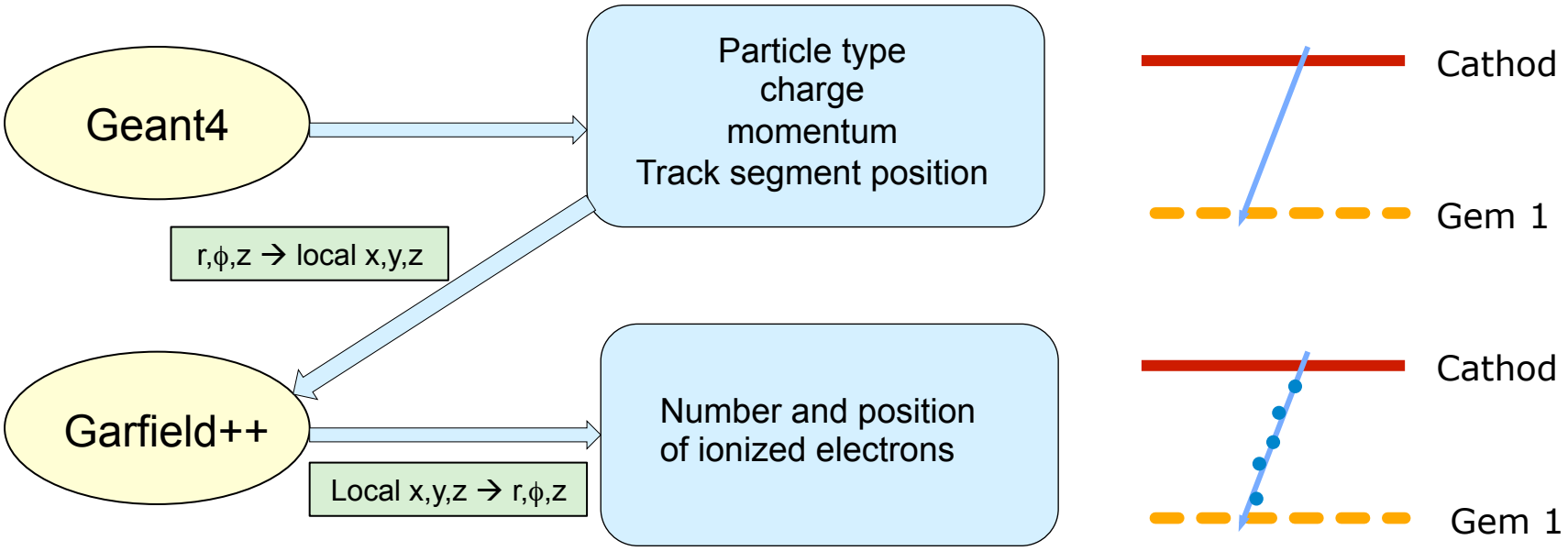


Digitization modeling

- Ionization
- Drift and multiplication
- Induction

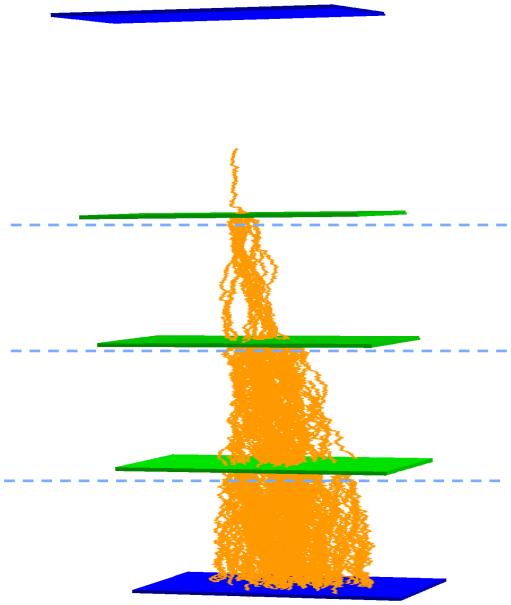
Ionization

- Garfield++ has been integrated into BESIII software system as an external package to simulate ionization
- Conversion of global and local coordinate is used to simplify the geometry construction in Garfield
- Ignore the energy loss from Geant4



Drift and multiplication

- Sample the parameters of multiplied electrons in 3 steps
  - Number of multiplied electrons (n)
  - Position (ϕ, z)
  - Drift time (t)
- Preliminary sampling parameters are obtained from Garfield++ simulation



Sampling

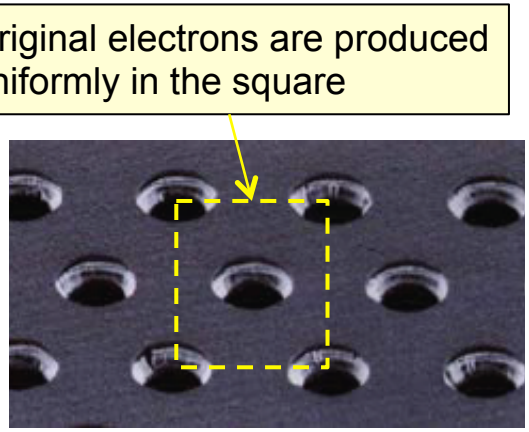
n_1, ϕ_1, z_1, t_1

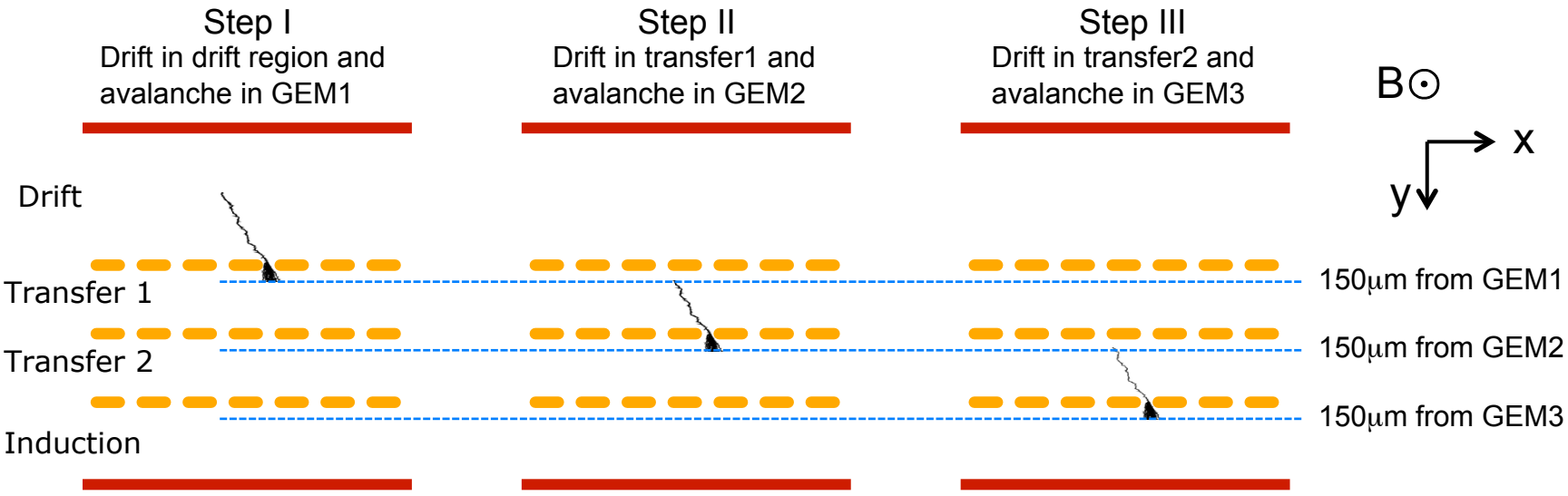
n_2, ϕ_2, z_2, t_2

n_3, ϕ_3, z_3, t_3

Garfield++ simulation

- To study the drift behavior and multiplication of a single electron
- The simulation is divided into 3 parts to reduce CPU time
- Preliminary parameters for sampling are obtained from the simulation
  - Lorentz angle, diffusion, drift time, effective gain





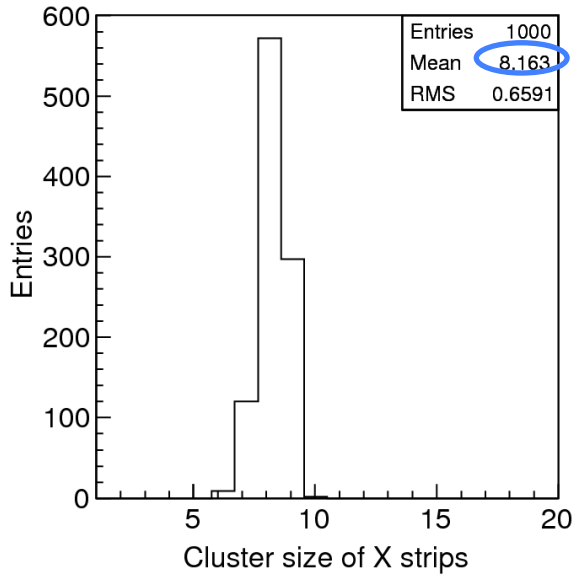
Parameters for sampling from Garfield++

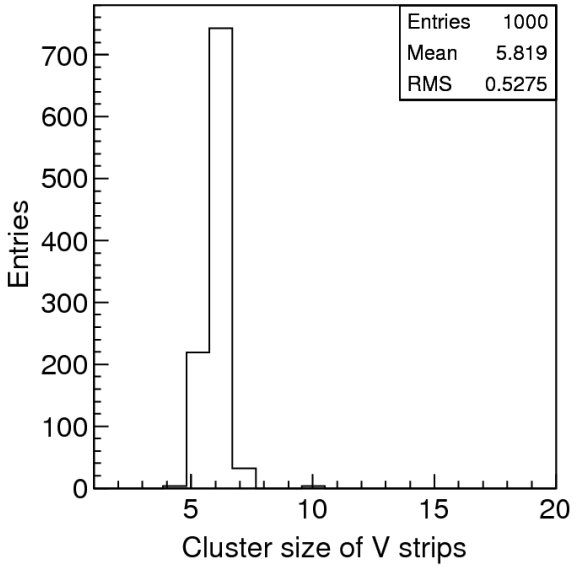
Region	Drift	Transfer1	Transfer2	Induction
Lorentz angle (degree)	25.5	10.9	10.9	6.5
Sigma_X (mm)	$0.0725+0.0918*\delta Y-0.0140*(\delta Y)^2+0.00121*(\delta Y)^3$	0.174	0.174	0.155
Sigma_Z (mm)	$0.0674+0.0762*\delta Y-0.0111*(\delta Y)^2+0.00089*(\delta Y)^3$	0.170	0.169	0.152
T (ns)	$4.917+29.16*\delta Y$	58.47	58.33	52.77
δT (ns)	$0.855+1.116*\delta Y-0.202*(\delta Y)^2+0.0200*(\delta Y)^3$	2.152	2.132	1.859
τ (%)	80.9	61.4	61.6	-
G_0	20.0	21.0	27.9	-

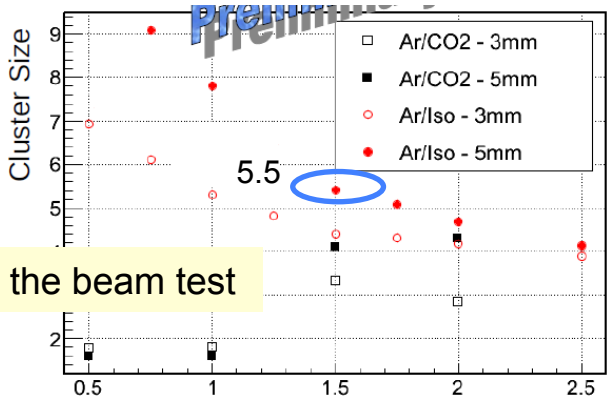
Induction

- Under study
- Described by drift in the first version

Preliminary results of digitization algorithm



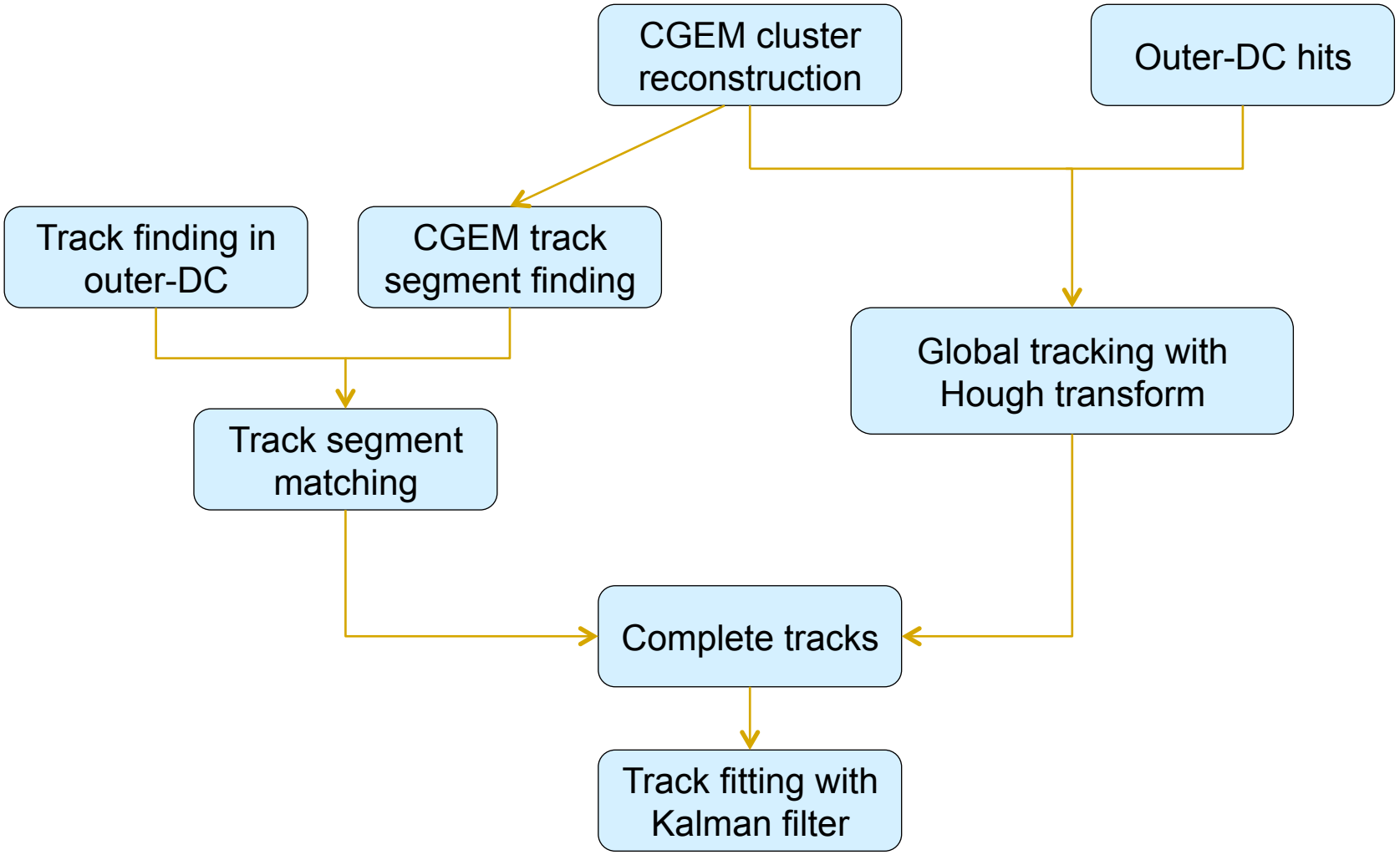




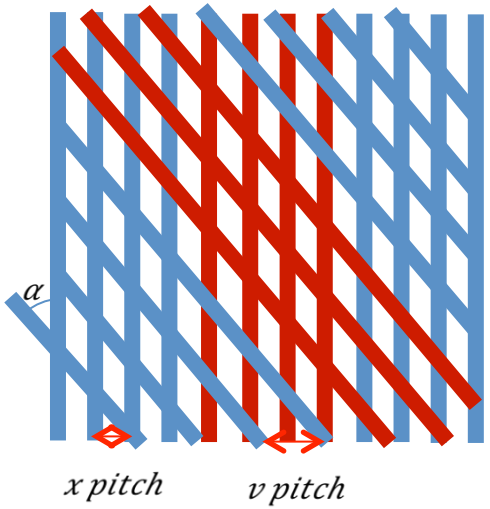
From the beam test

- The digitization model need to be improved to reduce the difference between simulation and experiment
  - Consideration of threshold
  - A correct induction model
  - Tuning the sampling parameters

Track reconstruction

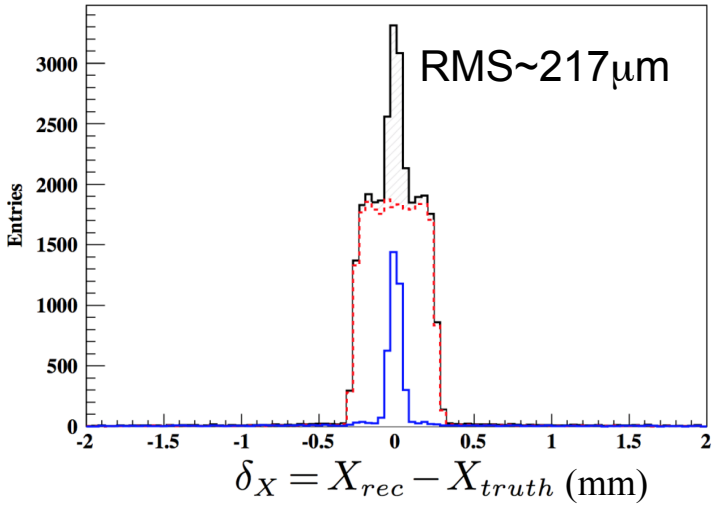


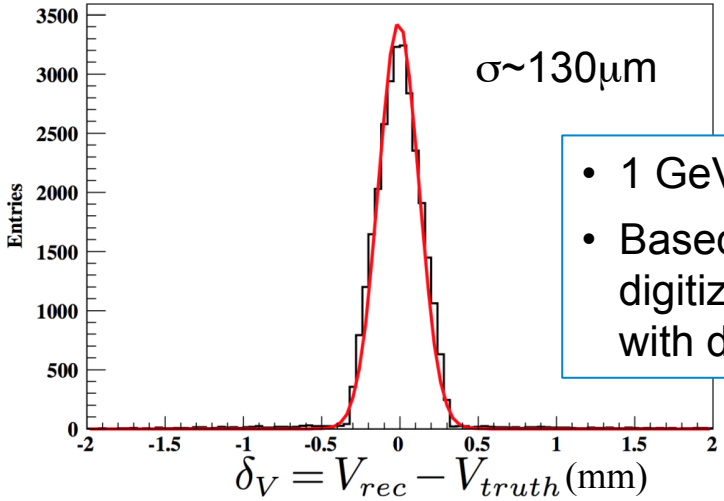
CGEM cluster reconstruction



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

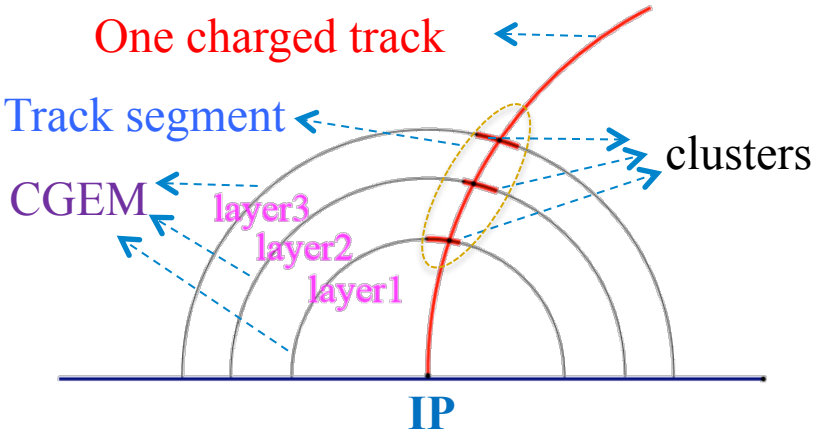
$$X = \frac{\sum_{i=1}^{N_X} X_i Q_i}{\sum_{i=1}^{N_X} Q_i} \qquad V = \frac{\sum_{i=1}^{N_V} V_i Q_i}{\sum_{i=1}^{N_V} Q_i}$$



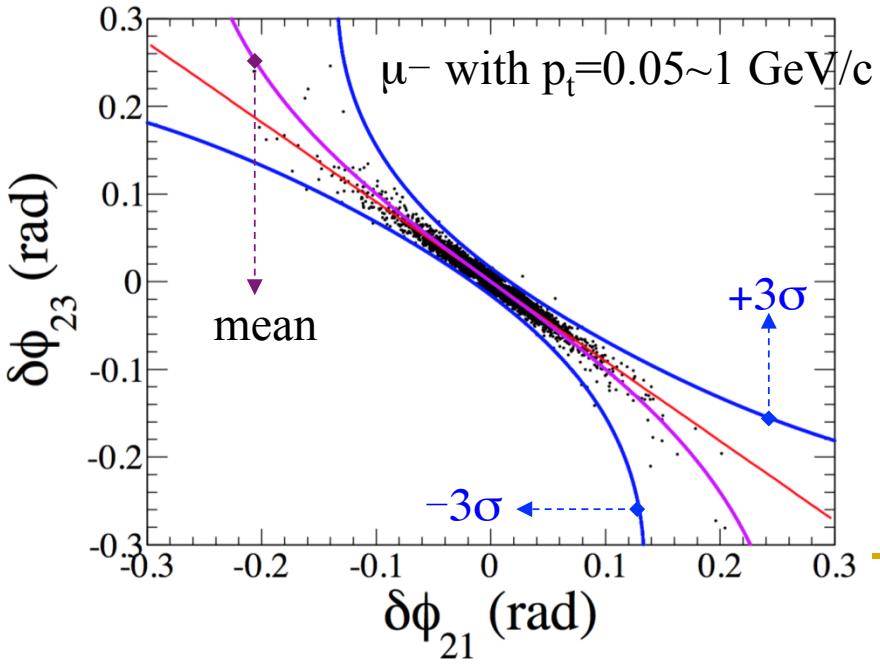


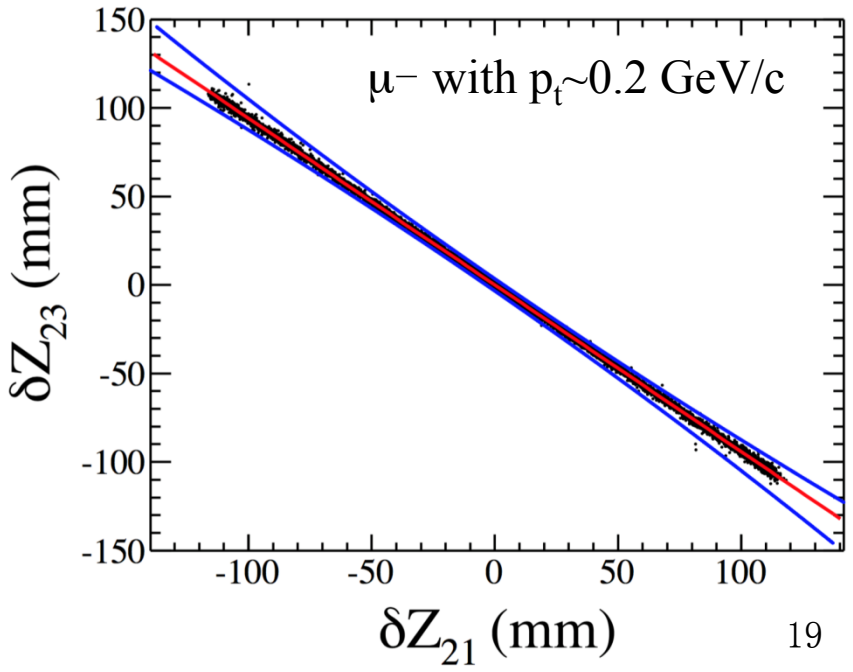
- 1 GeV/c muon
- Based on a simple digitization model with digital readout

Track segment finding in CGEM-IT



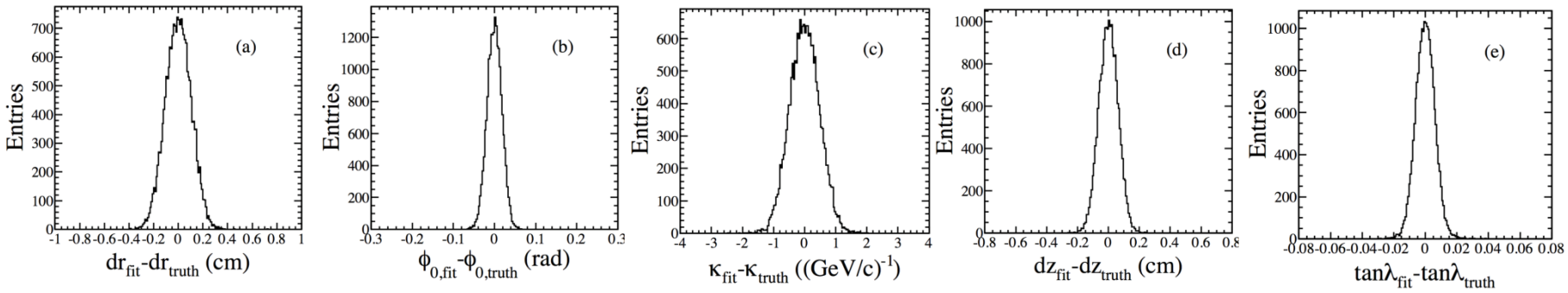
- Parameterization of the track segment patterns
- $\delta\phi_{21}=\phi_1-\phi_2$ vs $\delta\phi_{23}=\phi_3-\phi_2$
- $\delta Z_{23}=Z_3-Z_2$ vs $\delta Z_{21}=Z_1-Z_2$
- Regions covering $\pm 3\sigma$ of the 2D distributions to find segments candidates => efficiency >99.7%





CGEM track segment fitting

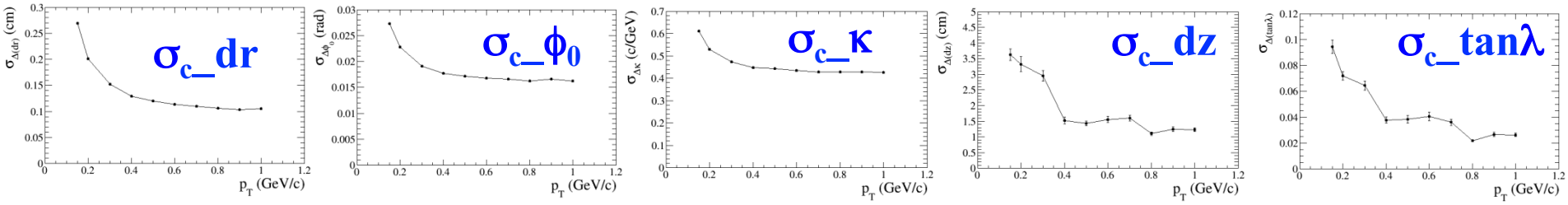
- Track segment in CGEM-IT is fitted to a helix model with 5 parameters with Least Square Method (MINUIT)
- Residual distributions of the five parameters (taking μ with pt~0.8GeV/c as an example) => Results are reasonable and unbiased



- Success rate > 99.8%

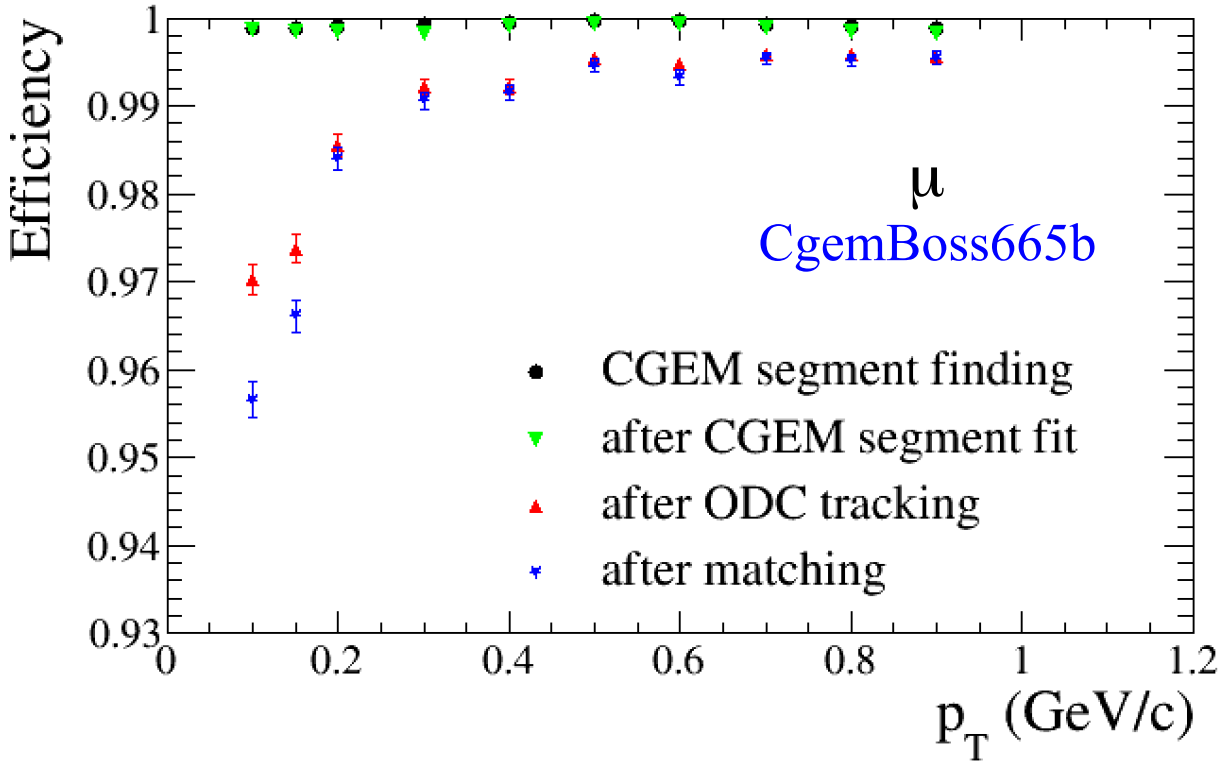
Matching of the tracks between CGEM-IT and Outer-DC

- Calibrate the resolution of the residual between CGEM & ODC track parameters



- $\chi^2=(H_{CGEM}-H_{ODC})^2/\sigma_c^2$ is calculated between track segments in CGEM-IT and Outer-DC to valuate the consistency quantitatively
- Proper matching criteria are chosen (χ^2<30~100)
- Distinguish with ϕ_0, κ, tanλ if multiple matching candidates
- efficiency ~99.9% with p_T>0.2 GeV/c

Efficiency for track segment finding and matching



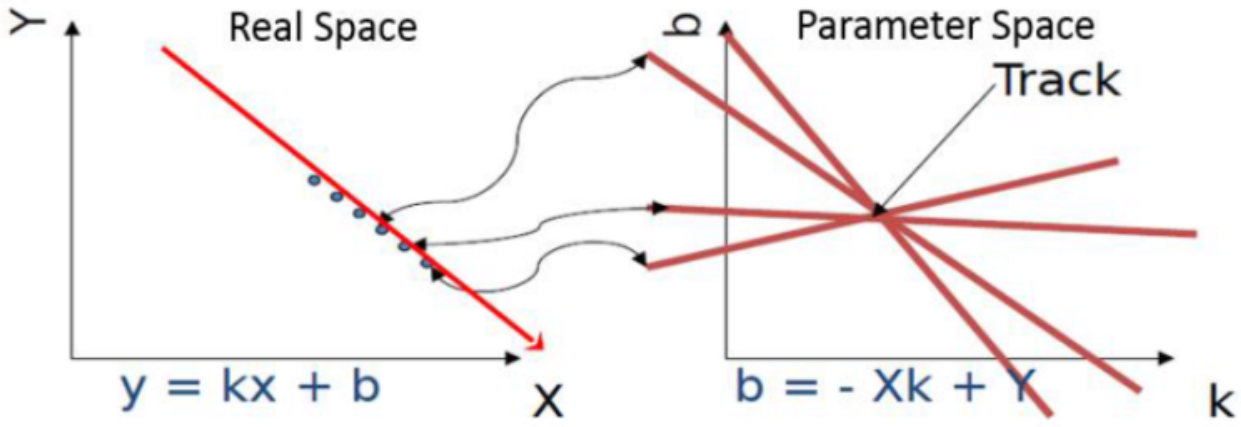
- Efficiency for track segment finding/fitting with CGEM-IT >99.8%
- Relative efficiency for track matching >99% (~100% with p_T>0.2GeV/c)

Global track finding with Hough transform

- Motivation: increase the track finding efficiency (especially for low momentum tracks)
- Global: directly use both clusters in CGEM and hits in ODC to find track candidates

Please see Ye/Jin's talk

image space → parameter space
patterns recognition → intersection (peaks) finding

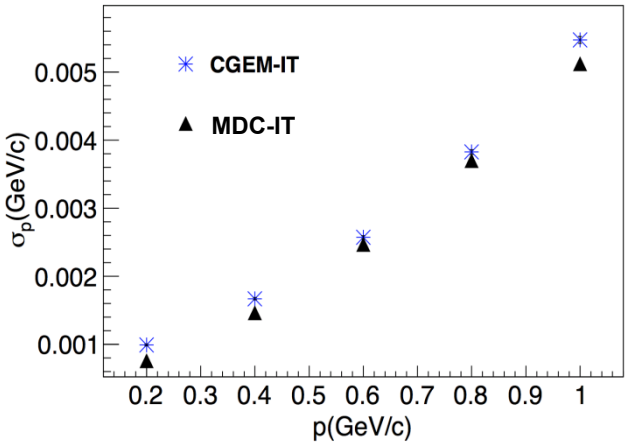


Tracking fitting with Kalman filter

- Kalman filter (linear quadratic estimation) estimates information using a series of measurements over time with random noise.
- The Kalman-Filter-based track fitting package for MDC is extended to be able to process CGEM clusters and MDC hits
  - Geometry and material description of CGEM
  - Calculation of the CGEM cluster predictions
  - Update of the track parameter with CGEM clusters

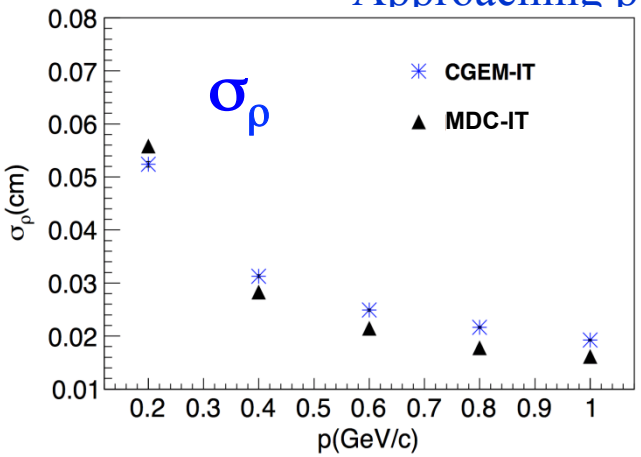
Resolutions after Kalman Filter (single muon)

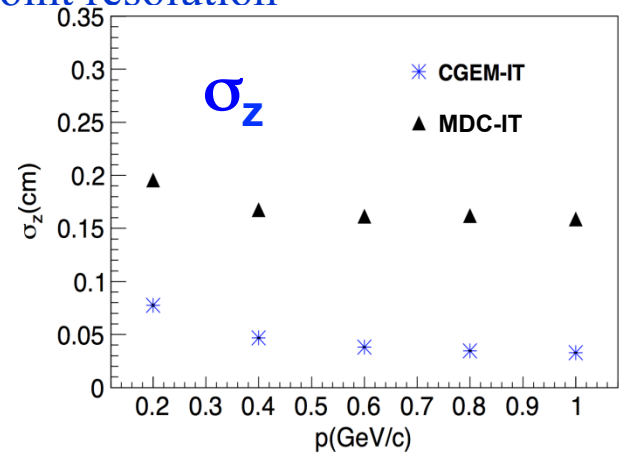
Momentum resolution



- Spatial resolution in z is improved significantly

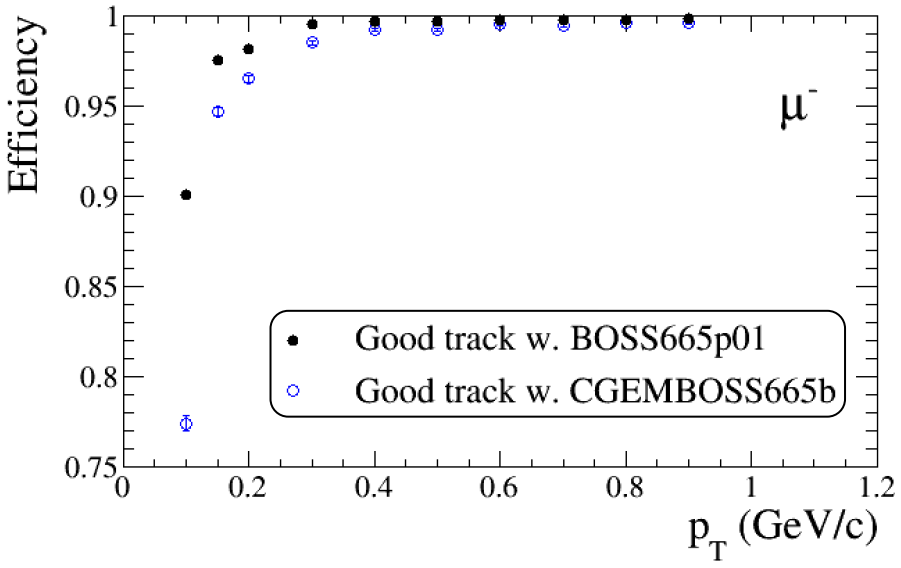
Approaching point resolution

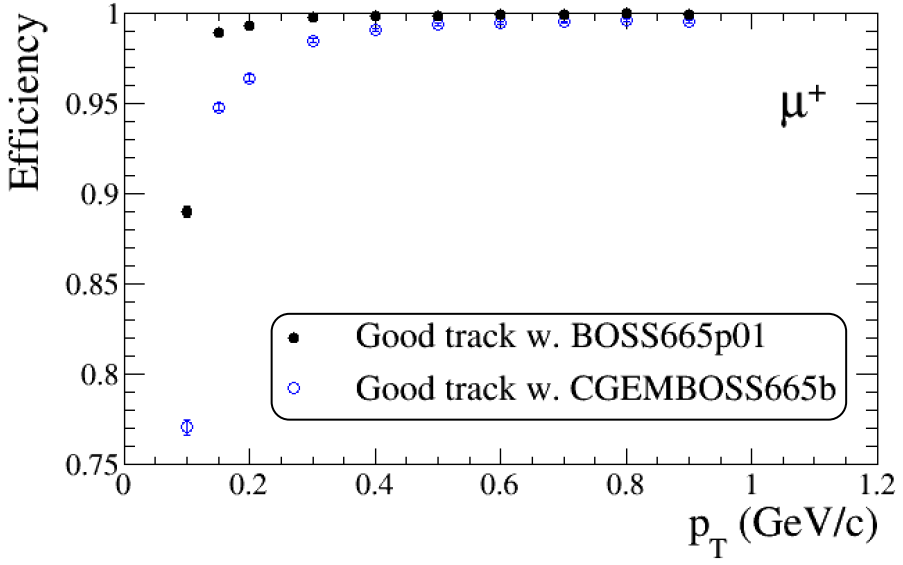




First test with CgemBoss665b for single track

Efficiency for good reconstructed tracks (dr<1cm, |dz|<10cm)
Without global track finding using Hough transform





Summary and plan

- A good progress in simulation and tracking software
  - A Geant-4 based simulation software has been developed and a preliminary digitization model is implemented
  - Tracking software can work and the results are reasonable
- Plan
  - Calibration and alignment
  - Global tracking with Hough transformation
  - Micro-TPC mode reconstruction
  - Background and noise simulation
  - Full digitization