The progress on track distortion study and tracking software

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Introduction

- High performance of tracking is essential to the physics program on the future linear collider experiment:
  - Time Projection Chamber in ILD has to have very excellent spatial resolution and **minimized track distortion**
  - Tracking algorithm needs the ability to get **momentum with high accuracy** in the real non-uniform magnetic field

- The distortion study for Asian GEM readout module：
  - Track distortion simulation
  - Correction is done to the beam test data (at 0 and 1 Tesla)

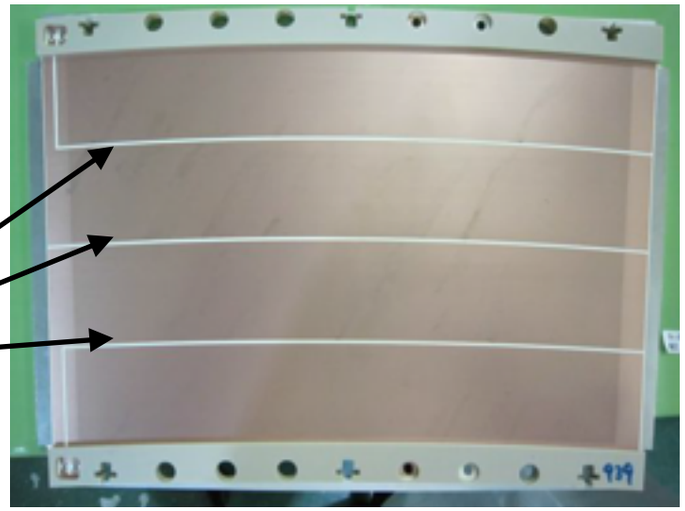
- The Kalman-filter based tracking software package, KalTest, was updated for non-uniform magnetic field. Performance study for the new KalTest in the framework of ILCSoft (e.g., working with Clupatra and MarlinTPC) is investigated.

I. Distortion study of Asian GEM readout module

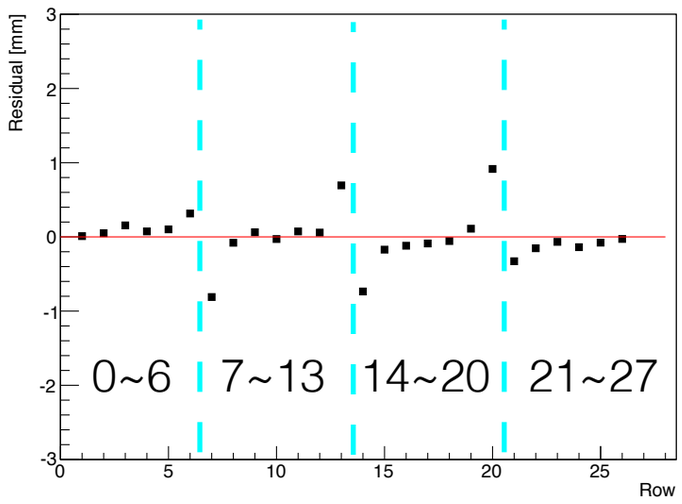
Track distortion in GEM module

- Asian GEM module and laser test facility in KEK

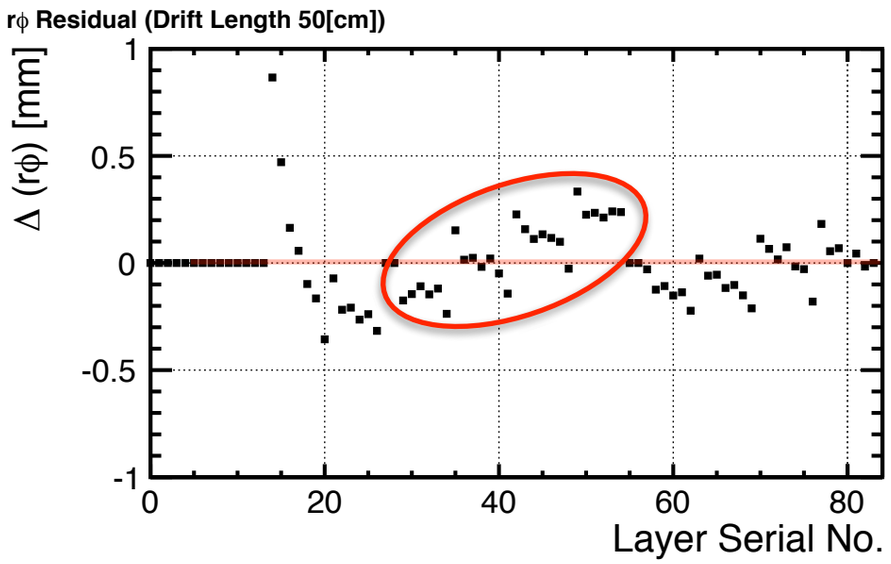
GEM gap:
1 mm



- Track distortion is observed in laser test and beam test.



laser test, 2010, 0 T



beam test 2012, 1 T

Distance between pad and gap

From R. Yatsukawa's thesis:

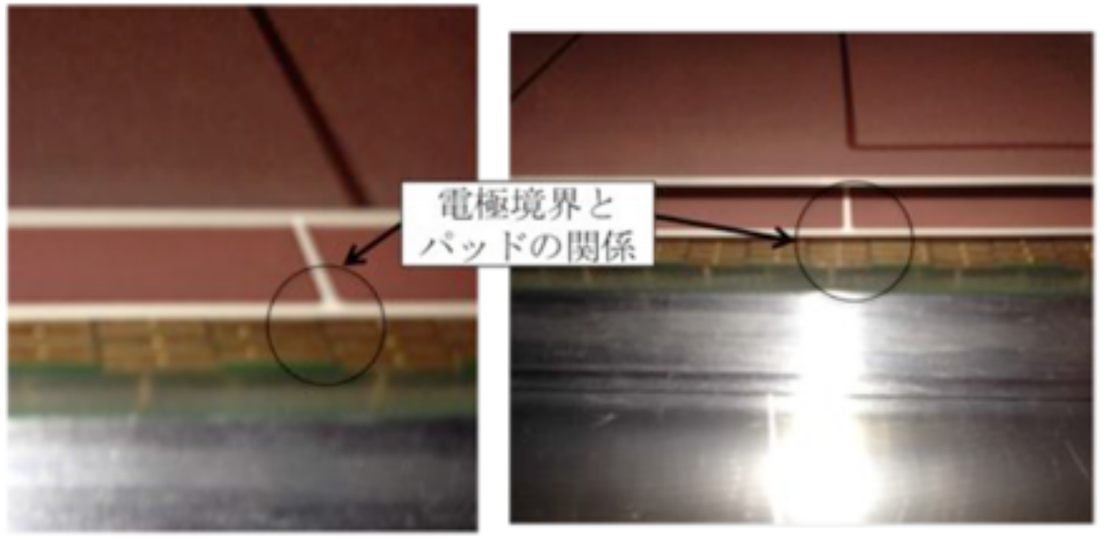
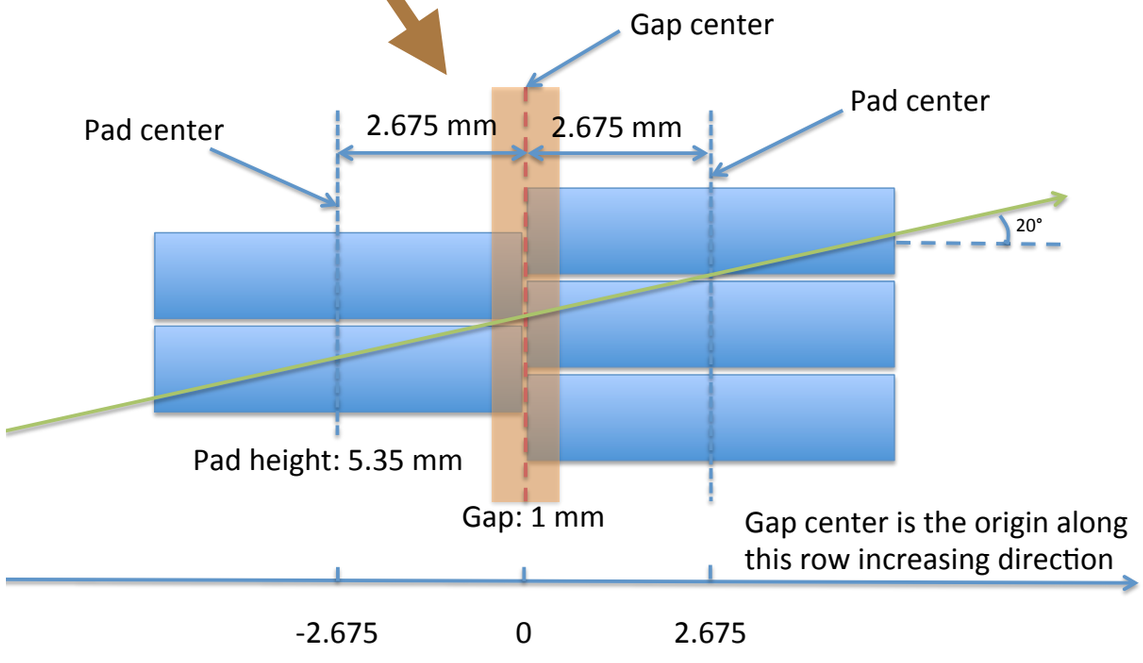
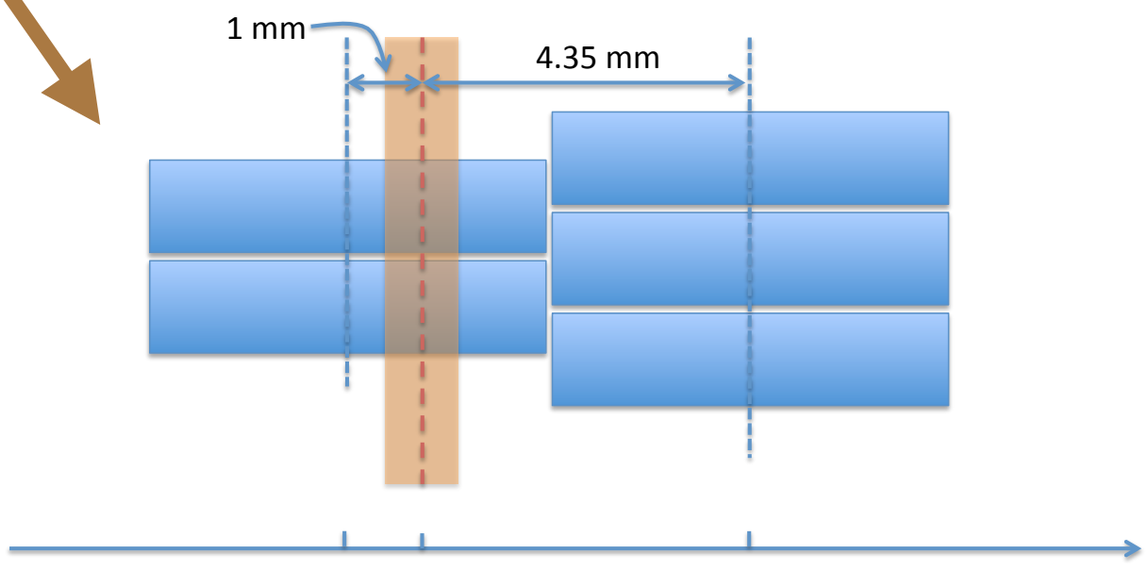


図 5.2.3　中心の GEM の電極境界とパッドの関係図

図 5.2.4　左右の GEM の電極境界とパッドの関係図

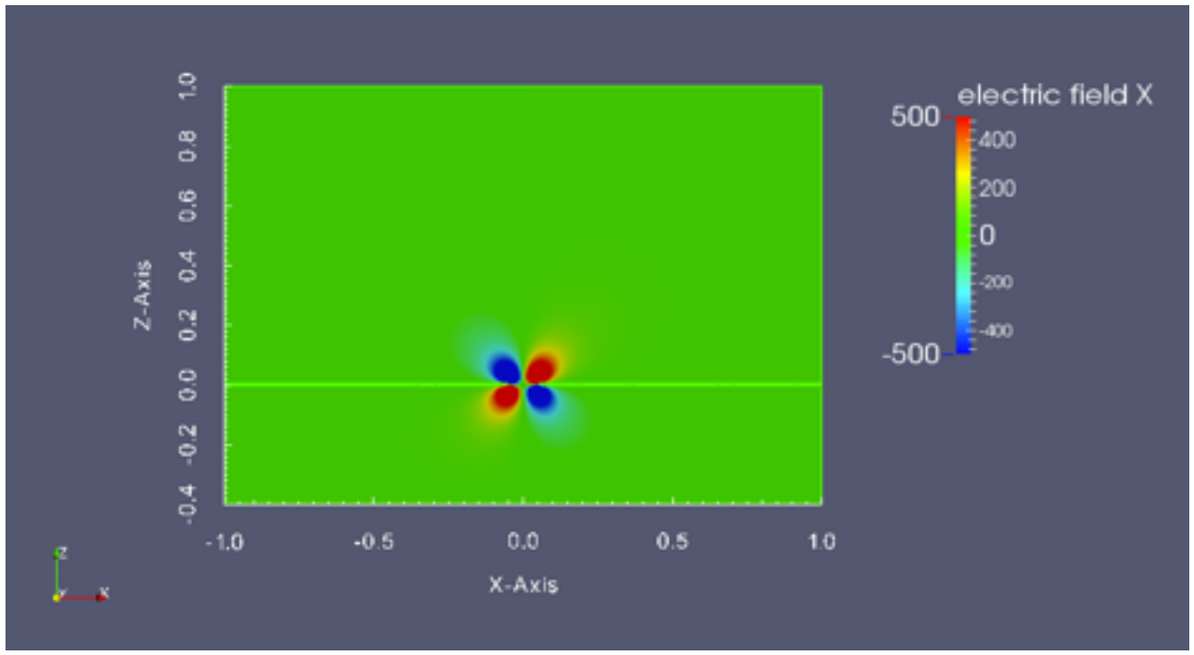
Row	Distance(mm)
6	-4.35
7	1
13	-2.65
14	2.65
20	-1
21	4.35

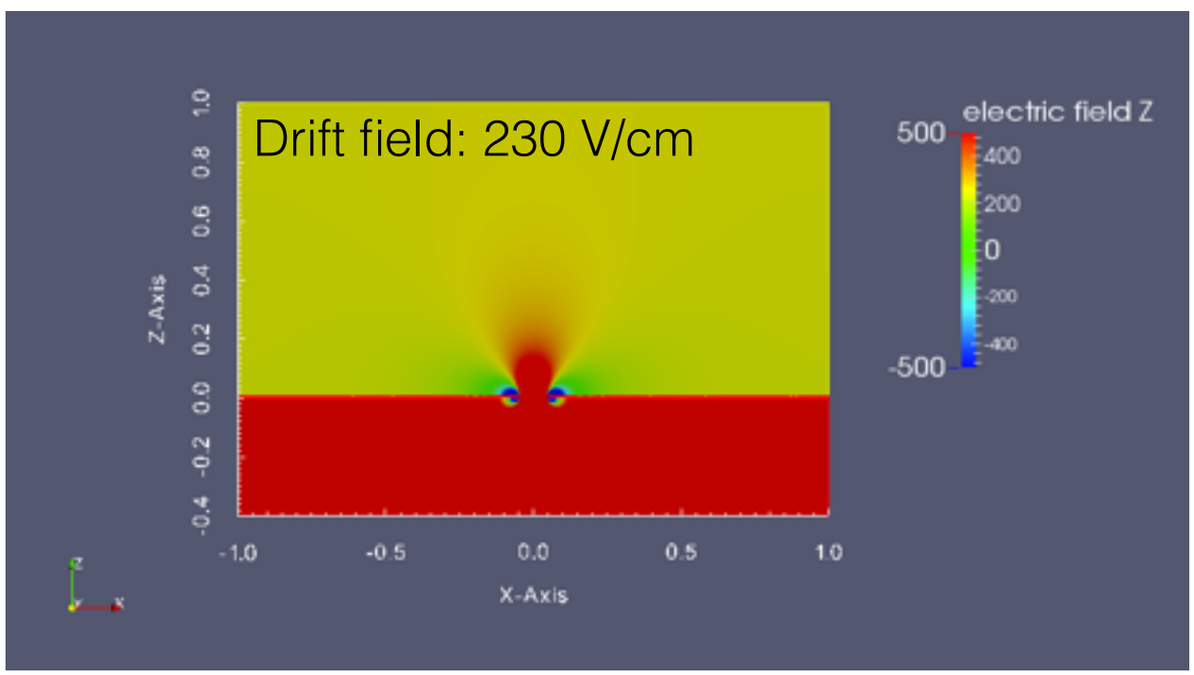




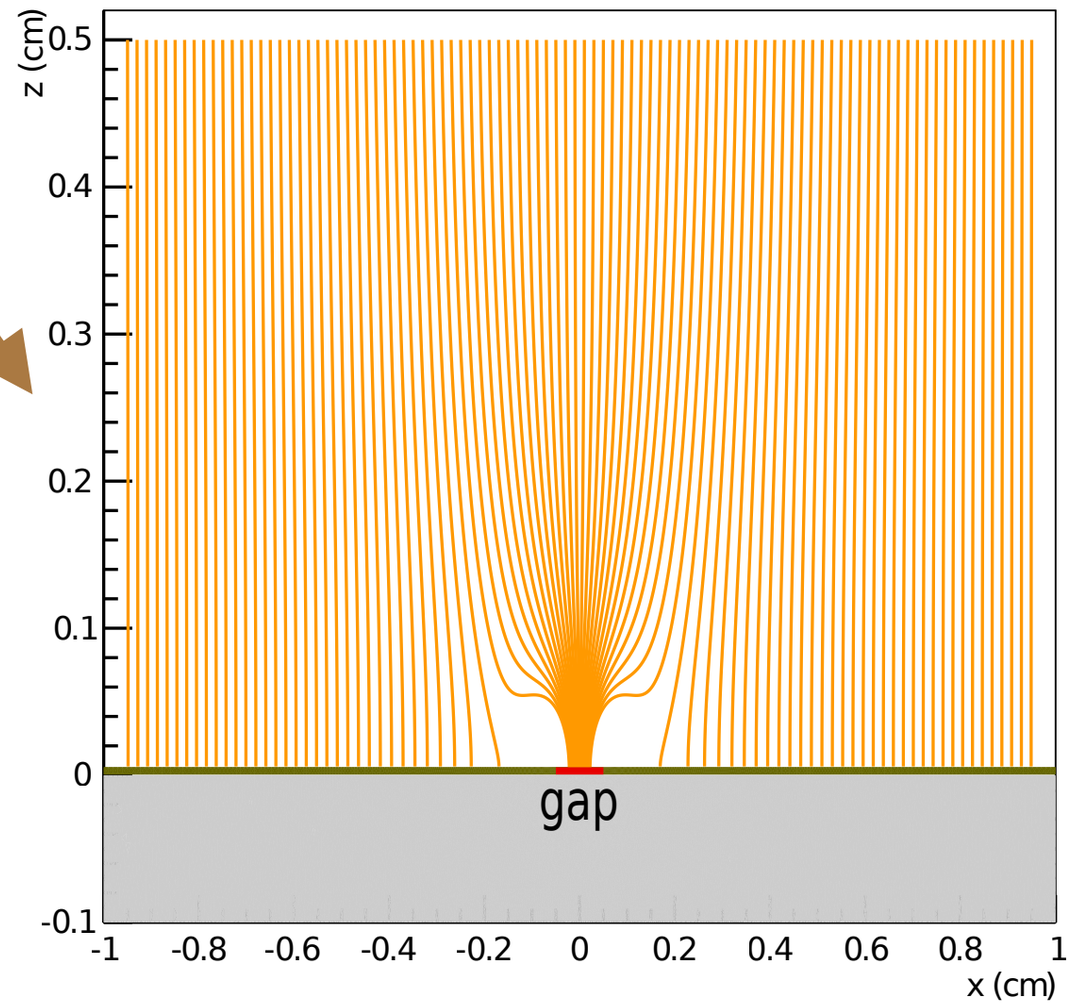
☞ Simulation will show how the distortion depends on the relative distance

Electric field near GEM gap



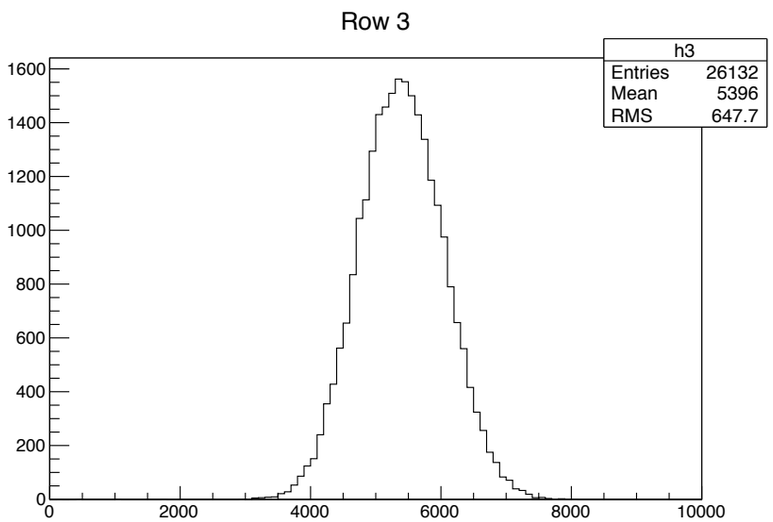


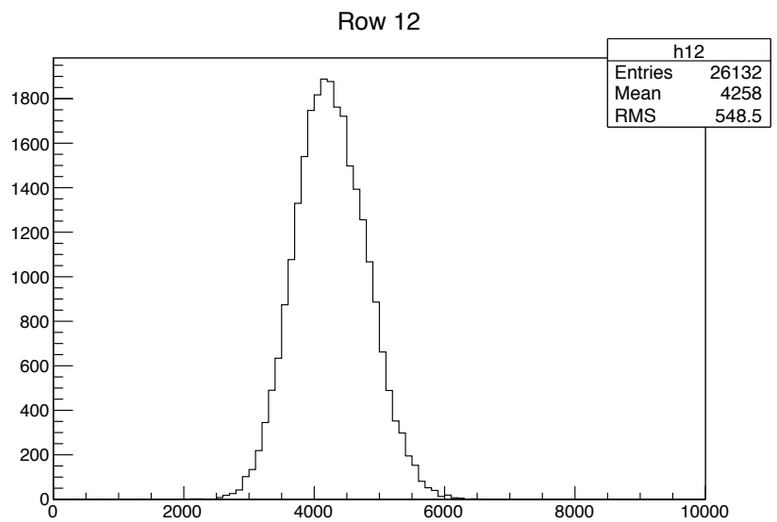
- The electric field is calculated by Elmer, a free Finite Element Method software.
- The electric field in the direction which is perpendicular to drift causes electron loss.

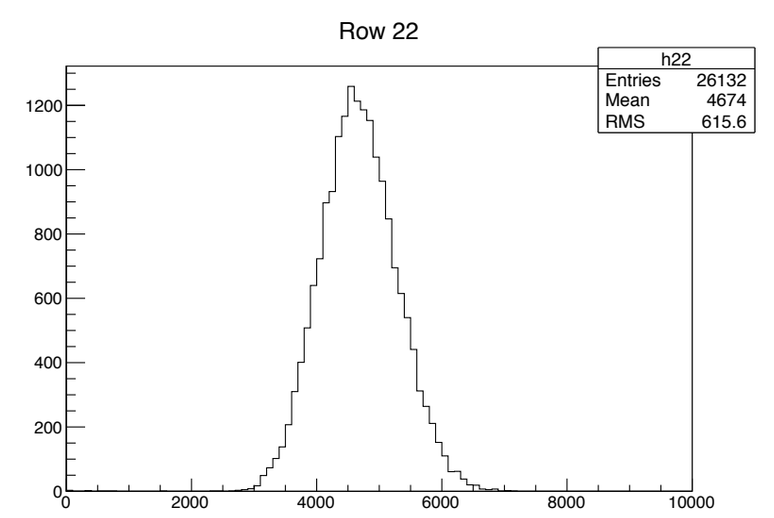


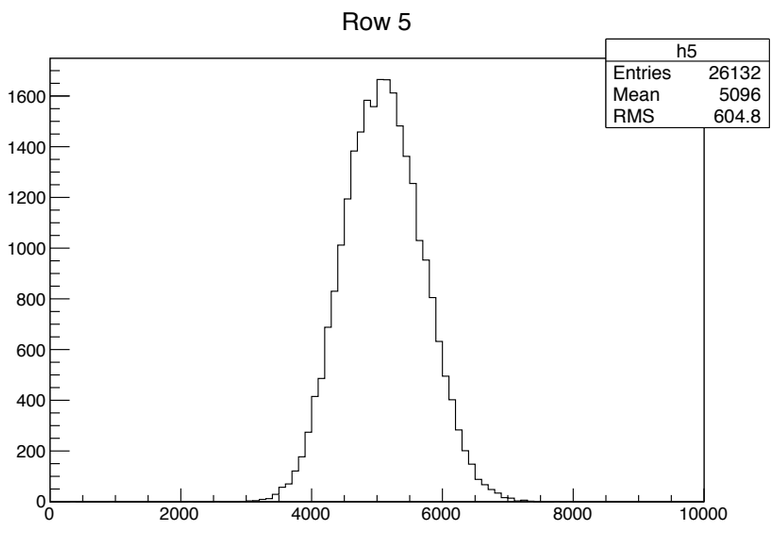
Charge on pad row

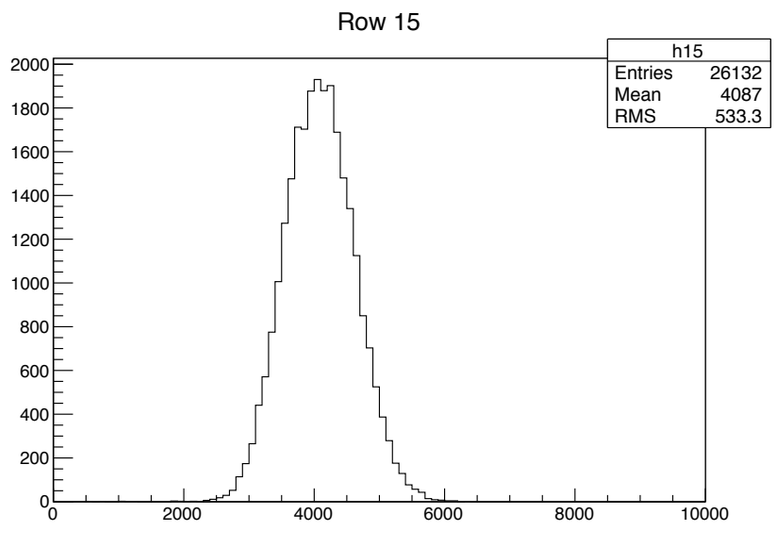
The collected charge in a pad row in the laser test:

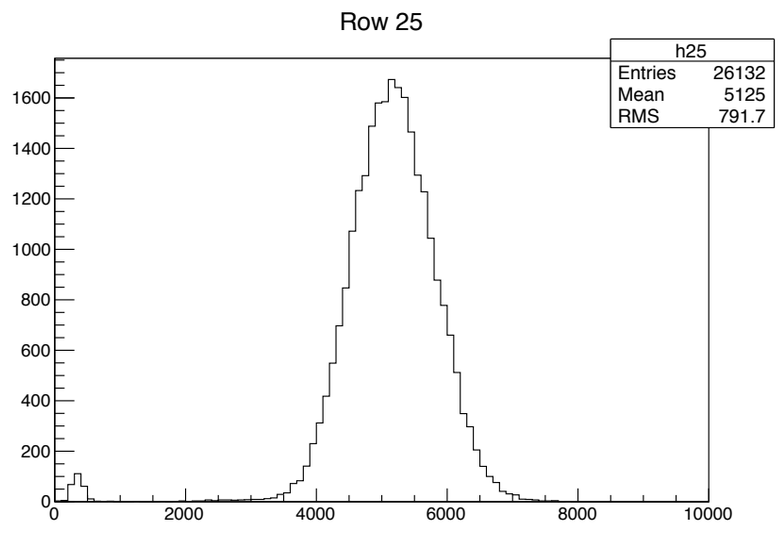




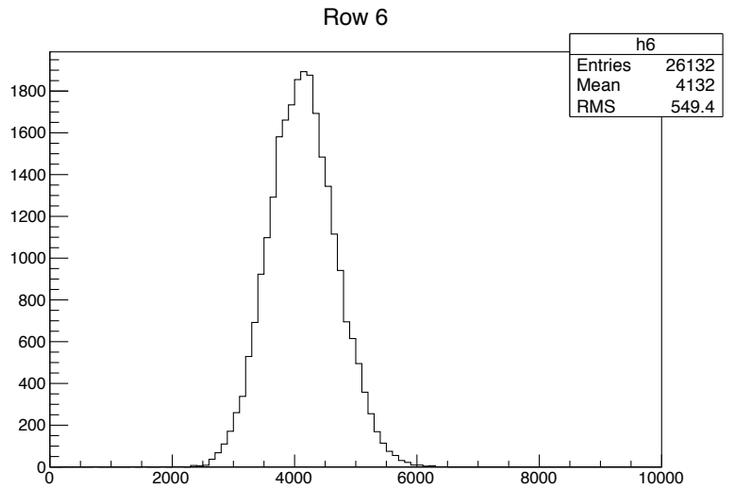


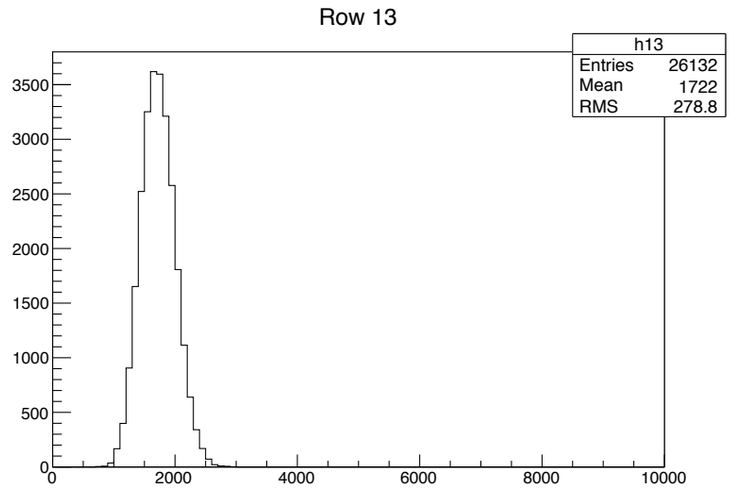


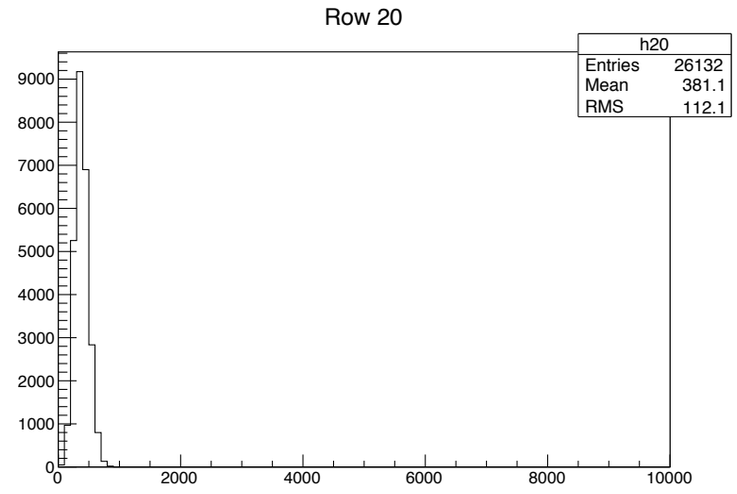


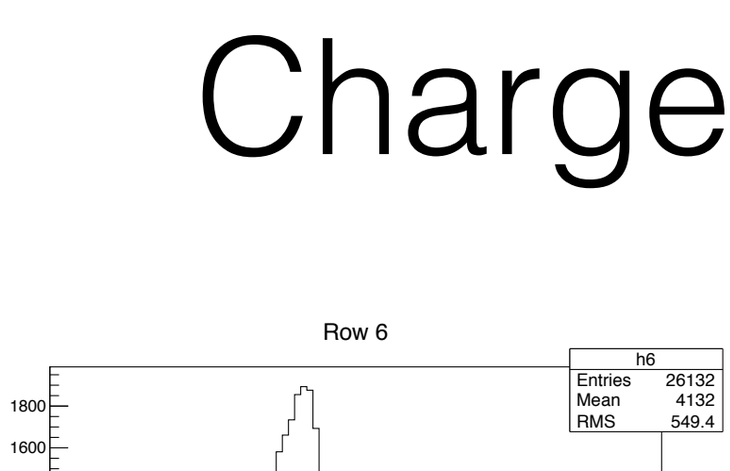


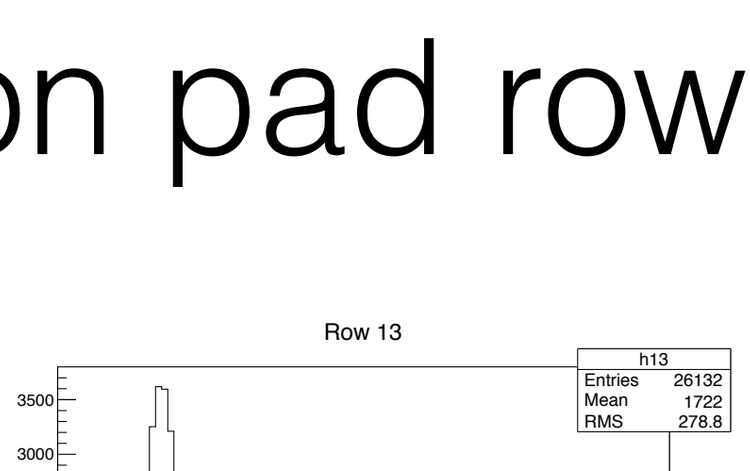
Charge on pad row (cont'd)

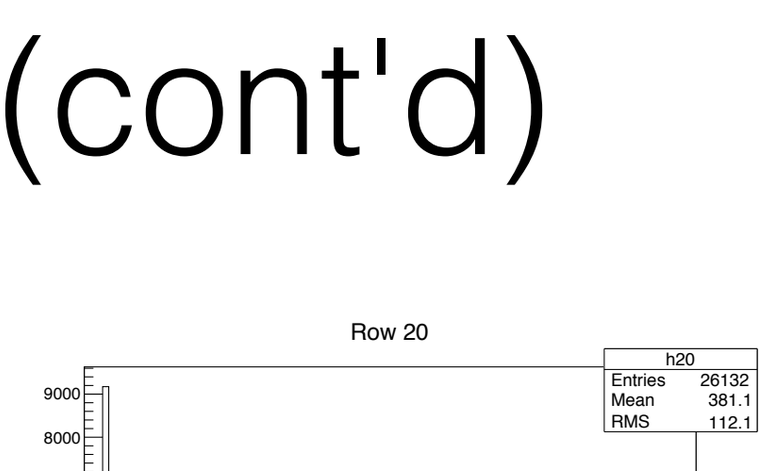








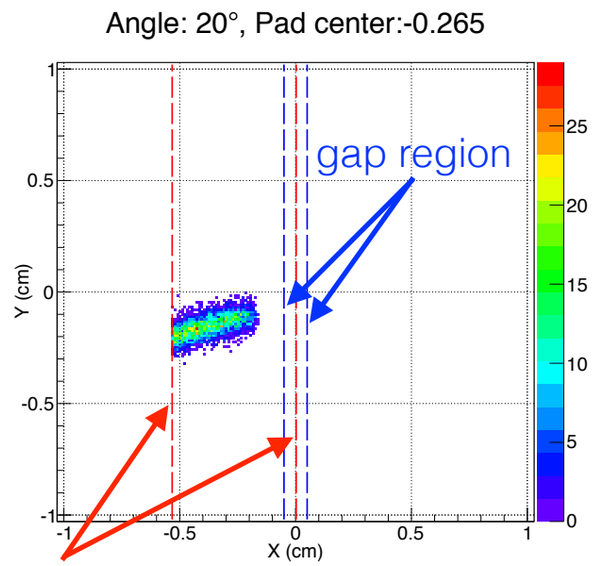


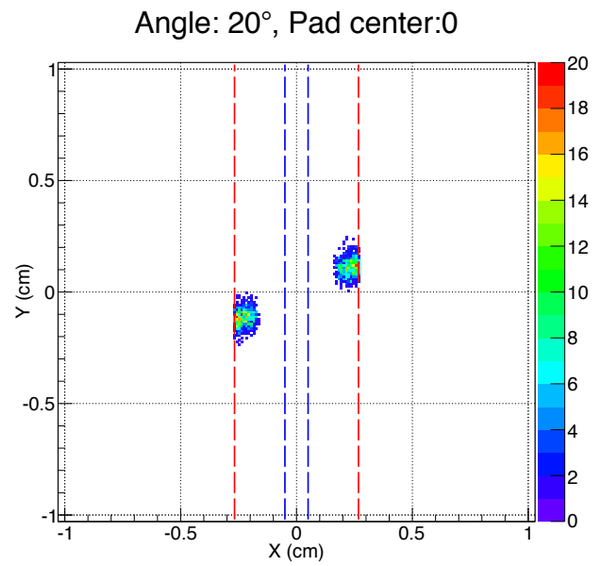


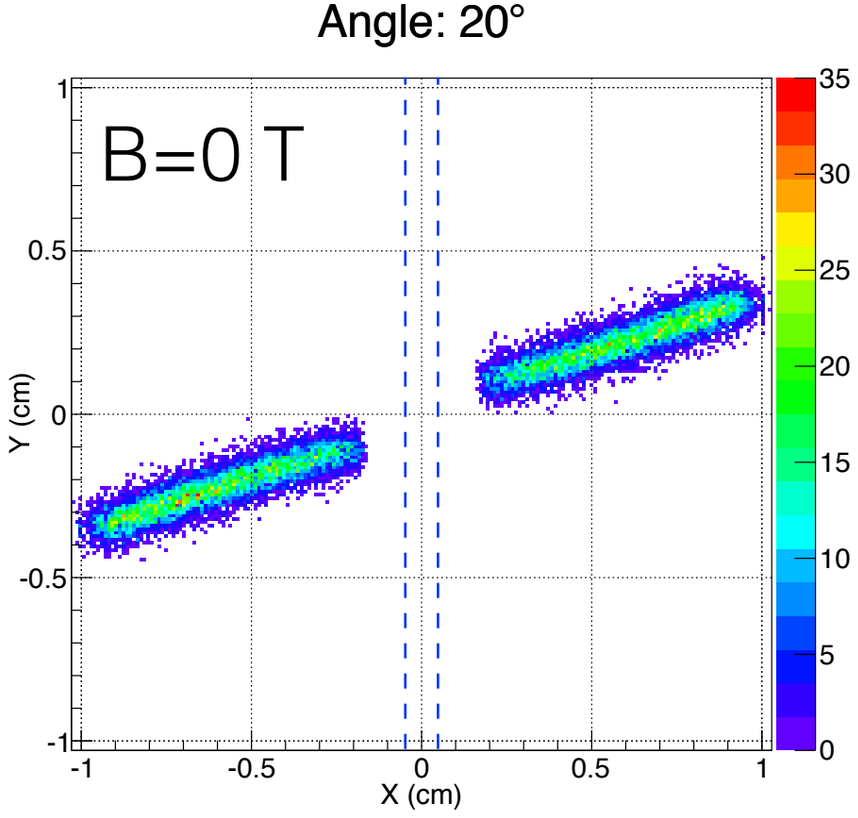
☞ The experimental data of charge also confirms the charge loss on the pad row near the gem gap.

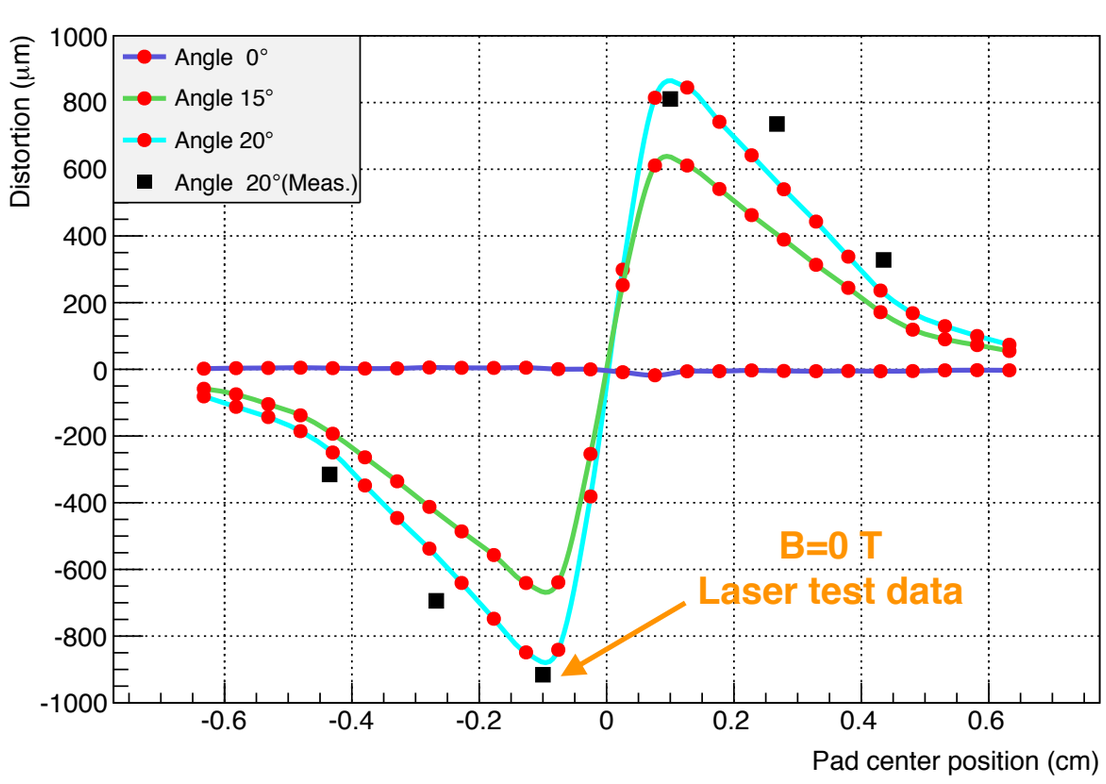
Simulation result of track distortion

- The electron position on GEM is simulated by Garfield++, and it's also deemed as the position of amplified charge collected by pad.
- Track distortion is calculated as the difference between expected track and position obtained by C.O.G. method.





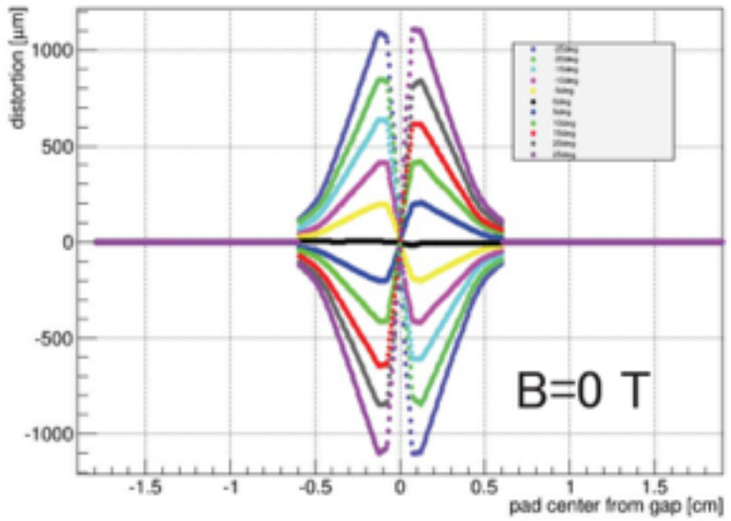




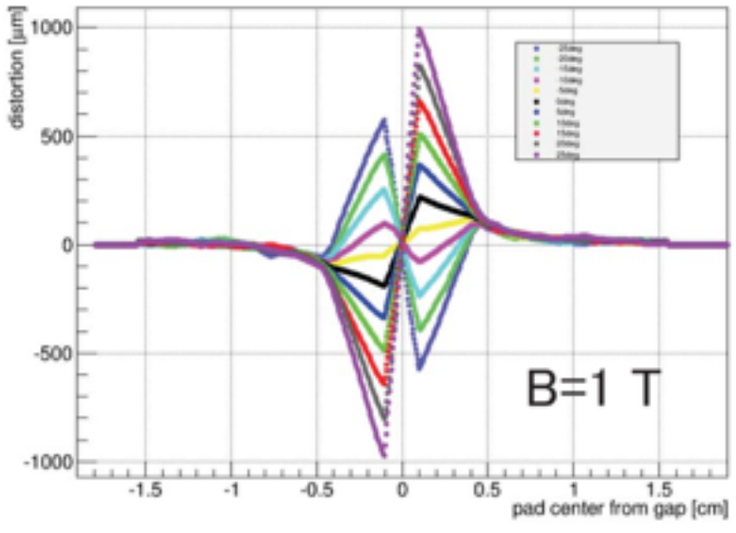
☞ Simulation agrees with the measured distortion

Distortion correction

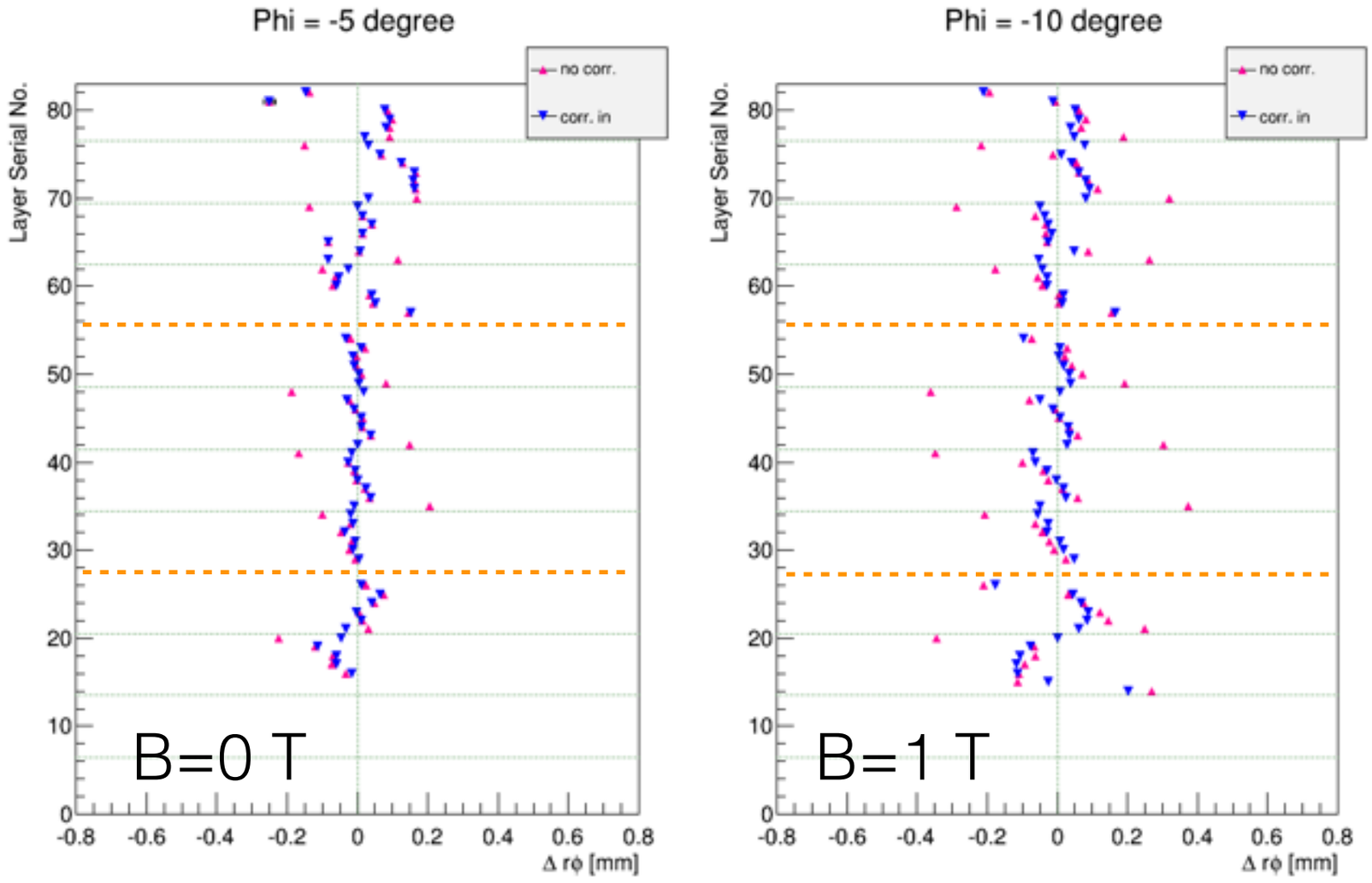
M. Nozoe *et al*, JPS meeting, 2015



- Distortion also depends track angle.
- The asymmetry in B=1 T case is due to ***E×B*** effect.



Distortion correction is applied to beam test data of LP1 in 2012:

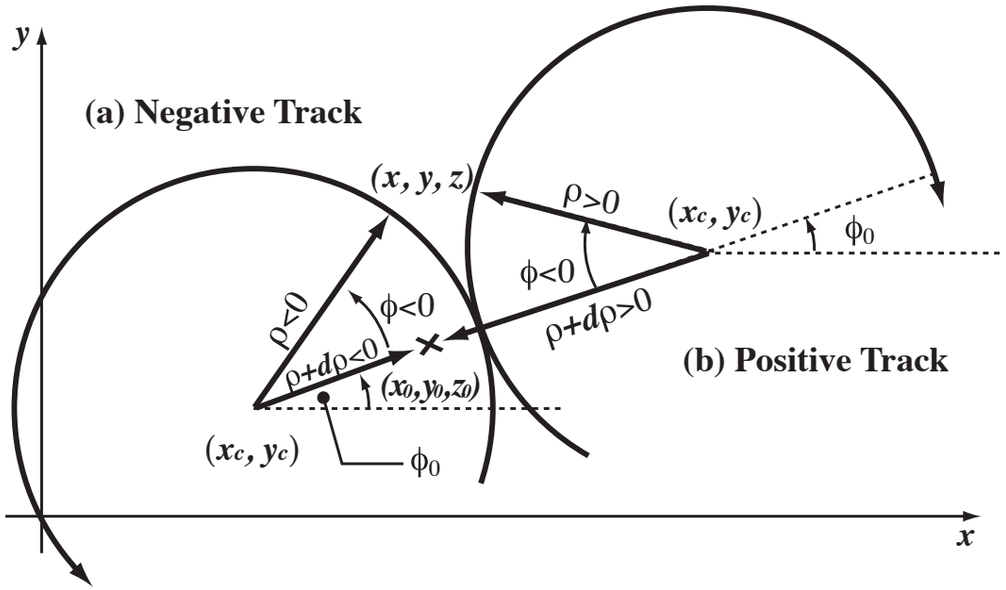


☞ Track distortion can be reduced largely, although we still want to understand the tilts.

II. Track fitting in non-uniform magnetic field

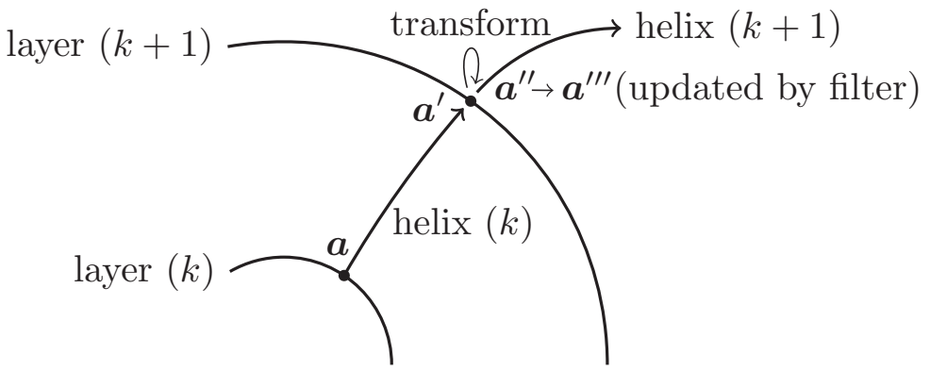
Status of KalTest

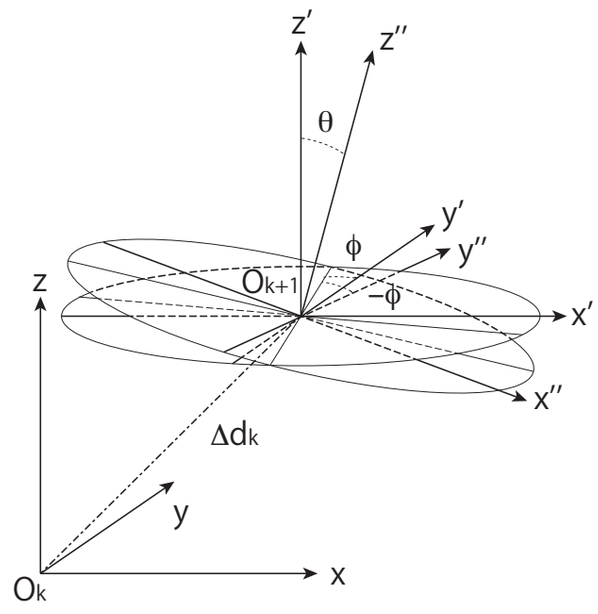
- Helical track model in the uniform magnetic field:



K. Fujii, Extended Kalman Filter, http://www-jlc.kek.jp/subg/ offl/kaltest

- In non-uniform magnetic field, the imperfect helix can be approximated by segmented helical track with frame transformation:

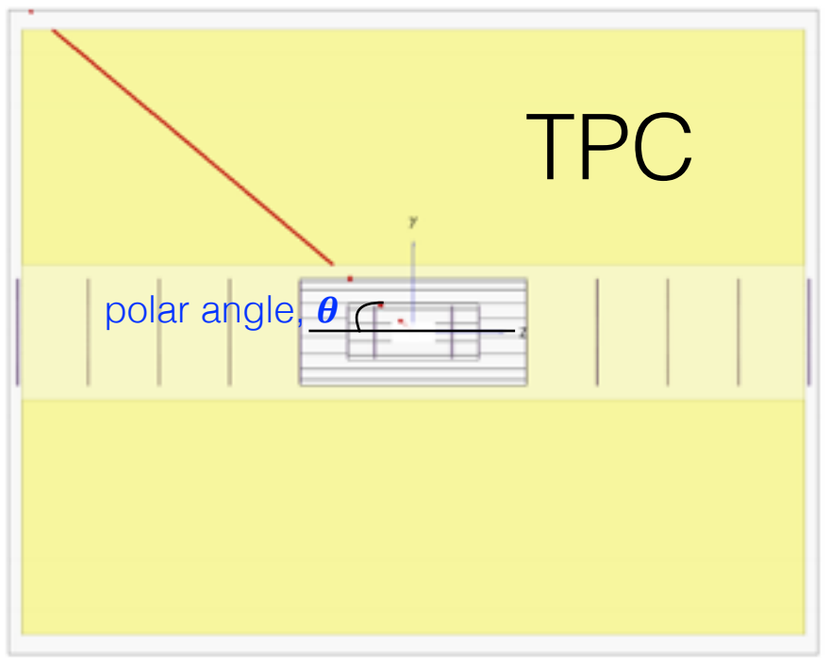


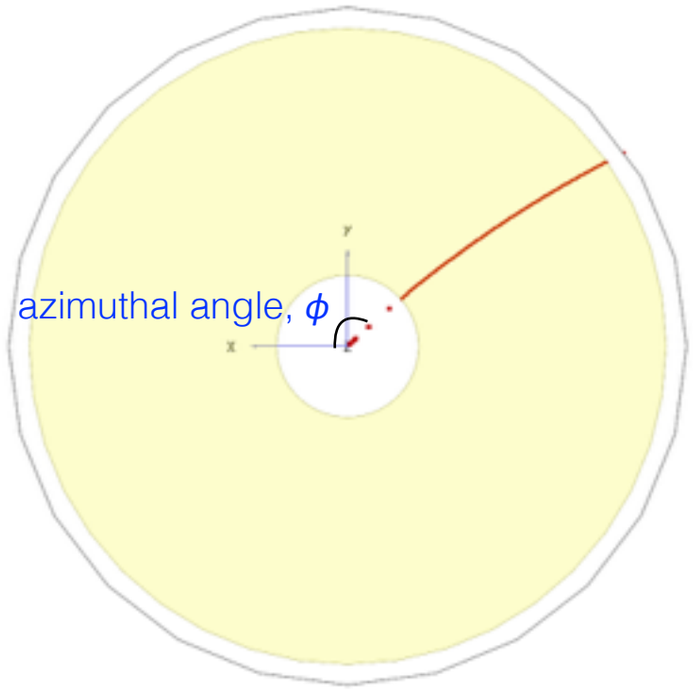


- KalTest for non-uniform magnetic field was committed to ILCSoft repository.
- Now the implemented functionalities for non-uniform field are merged into the code of trunk, and we can choose to use the original or new fitting by a setting function in KalTest.

Magnetic field in ILD

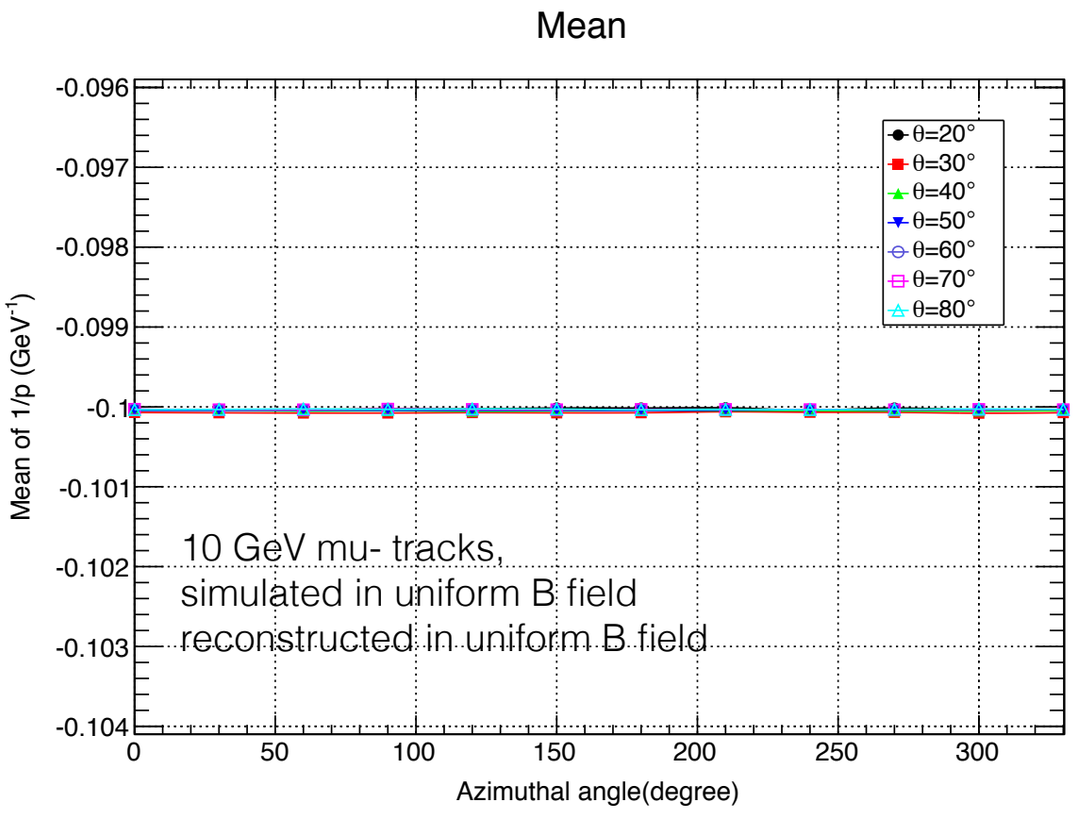
- Study the influence of non-uniformity in ILD magnetic field on track reconstruction results, such as momentum resolution.
- The Anti-DID field, which was implemented in Mokka for pair background study, is used in this study,.
- The non-uniform field in Mokka database is dumped to a local file as a field map for KalTest.
- The tracking efficiency of Clupatra is 99%. When the non-uniformity is less than 10%, its affect on tracking efficiency can be neglected.

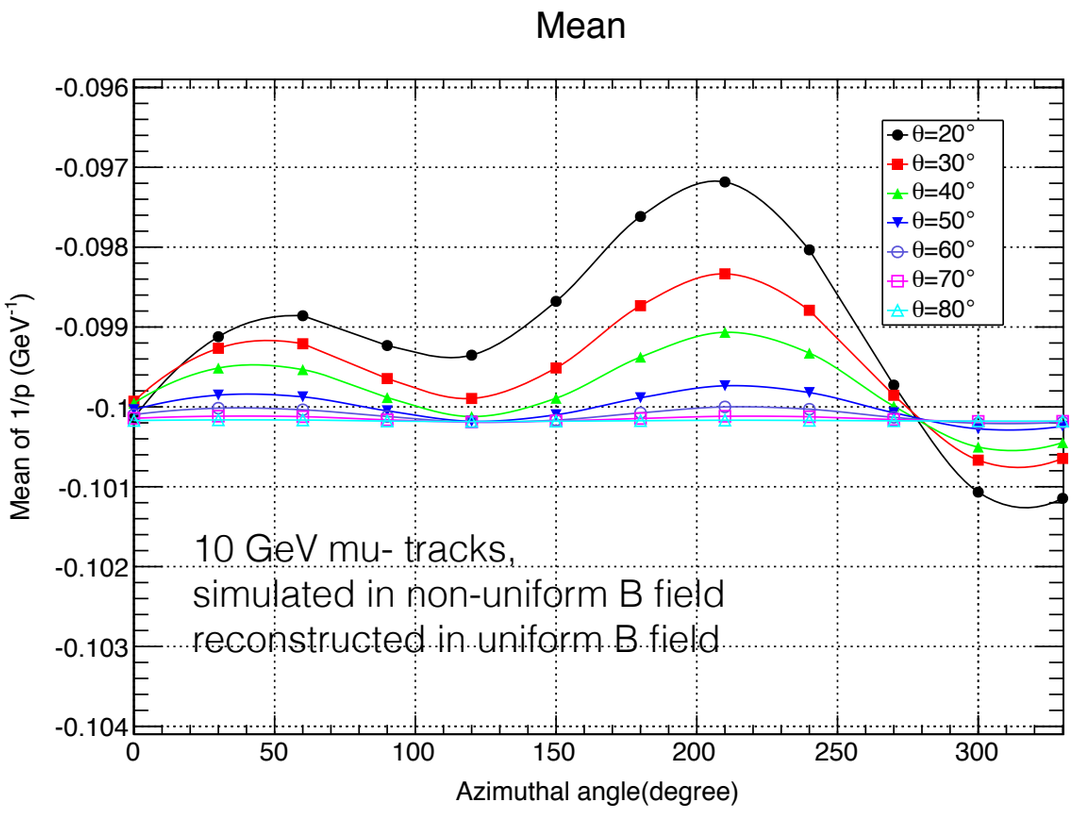




Mean

- Mean of 1/p at different track angle:

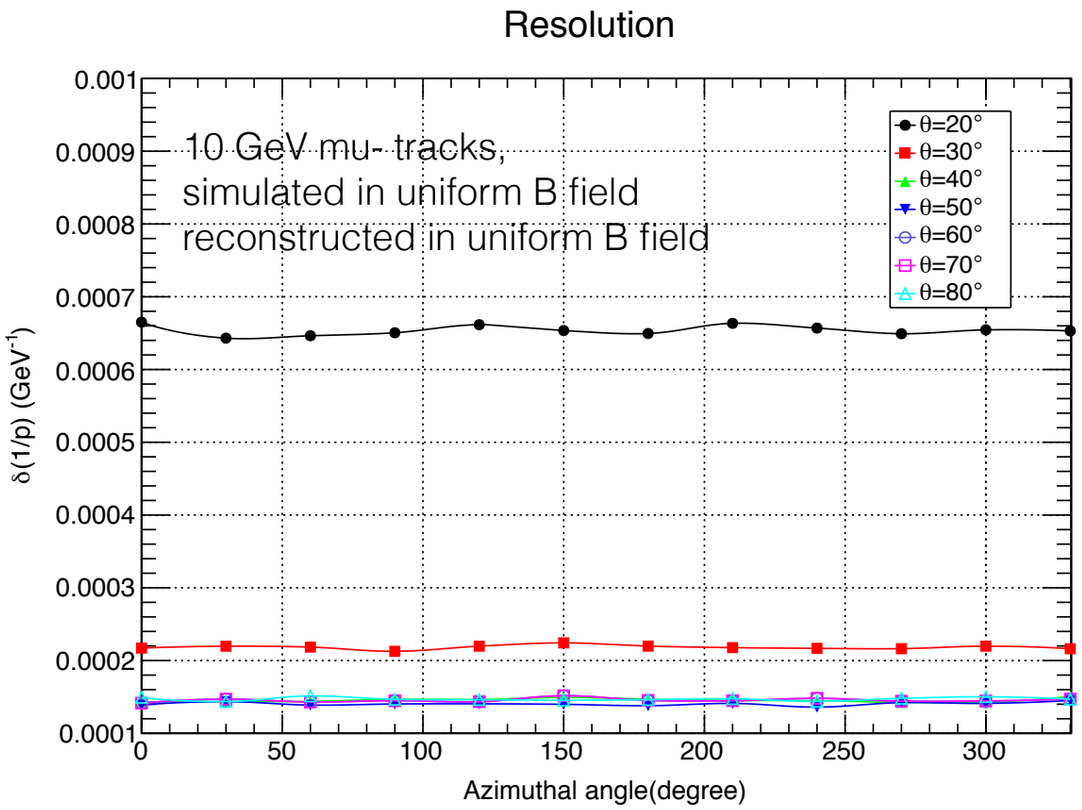


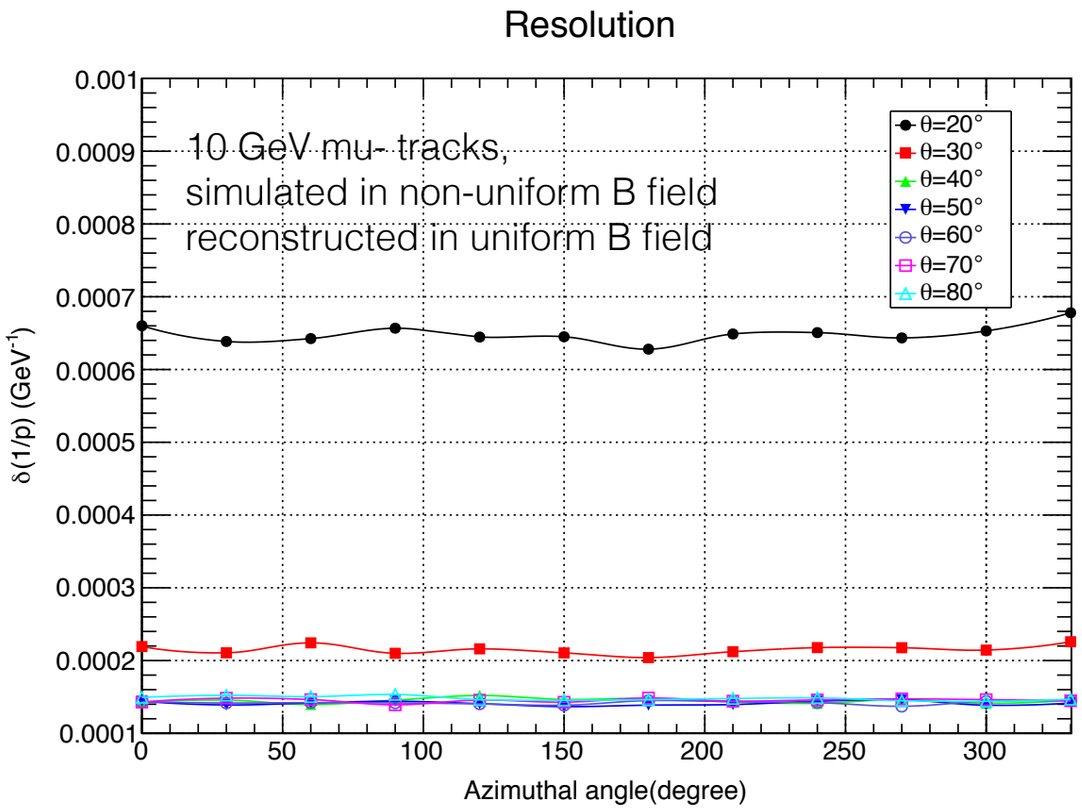


- The mean of momentum is shifted by the anisotropic magnetic field, and it seems that the inner region of detector probably has a relatively big non-uniformity.

Momentum resolution

- Momentum resolution at different track angle:

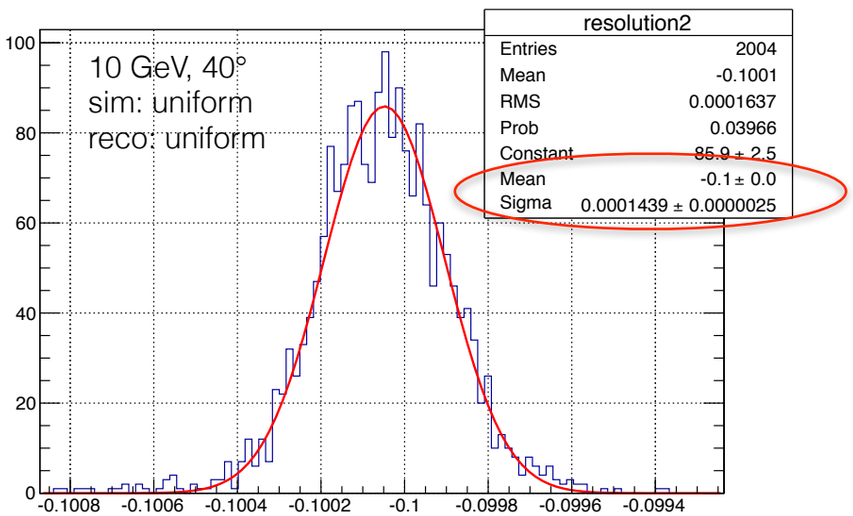


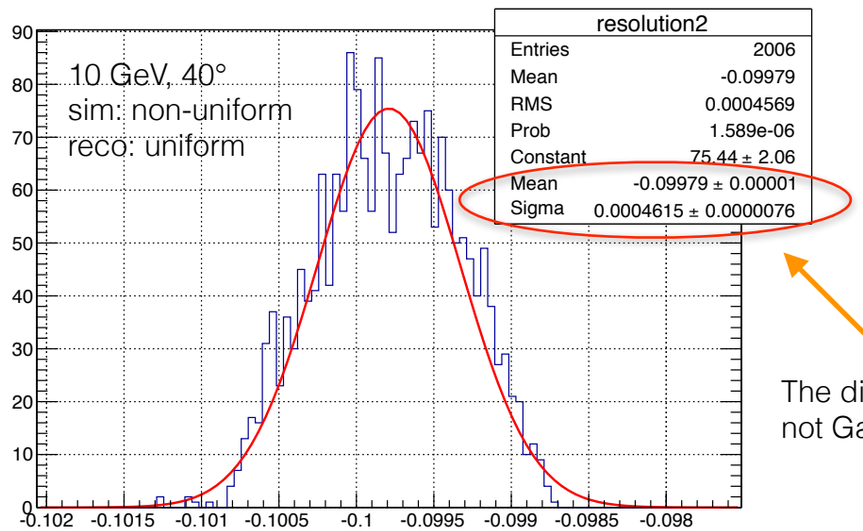


- Therefore, in this case the momentum resolution is not affected although the non-uniformity is not taken into account in track fitting.

The effective momentum resolution

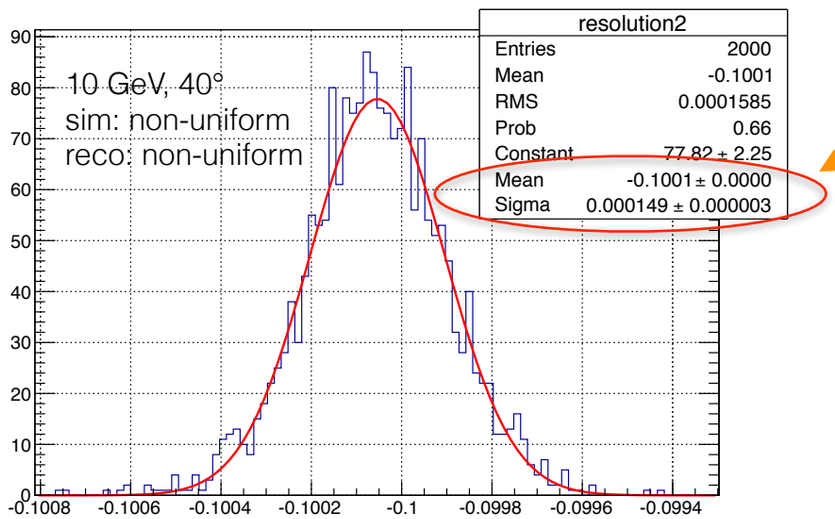
- If only fixing polar angle, the shift of mean contributes the momentum resolution, so we obtain a big **effective** momentum resolution:





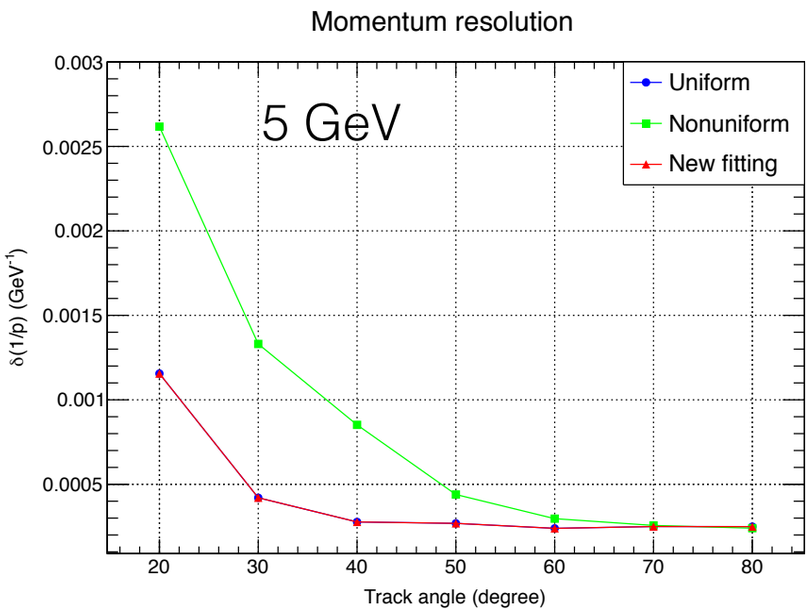
The distribution is actually not Gaussian.

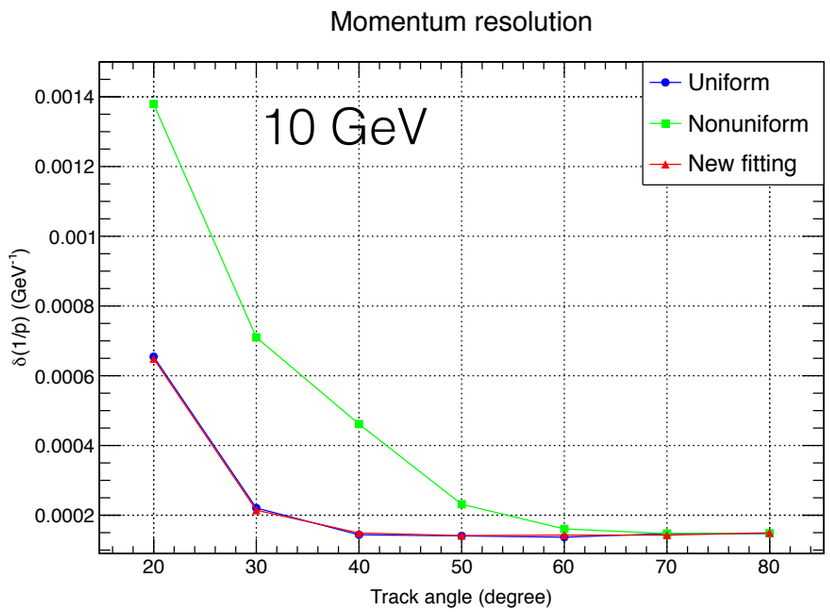
- The track fitting by the new KalTest can recover the momentum distribution in non-uniform magnetic field

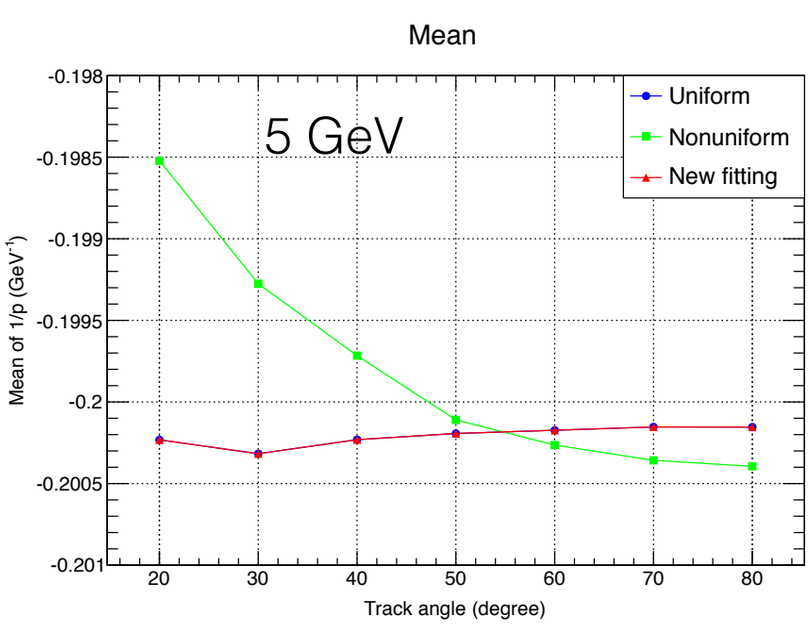


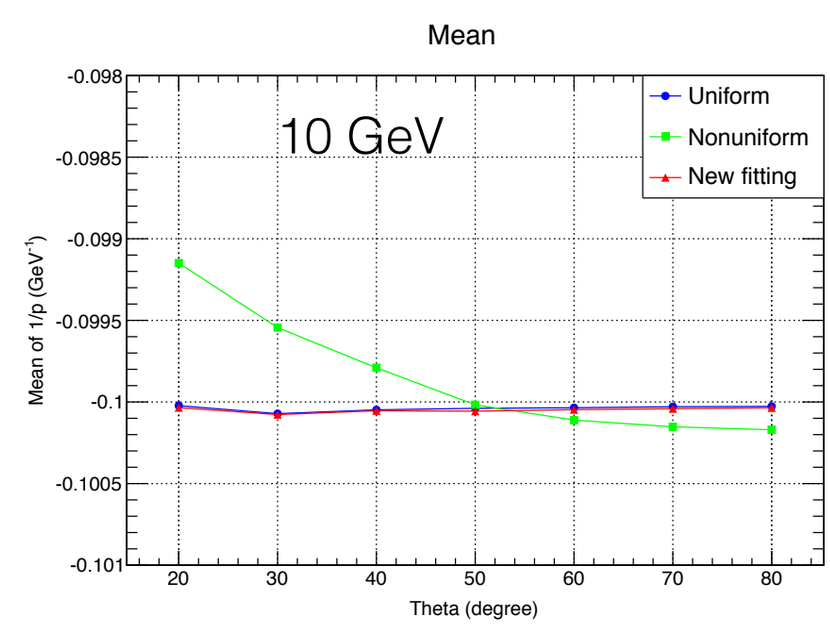
This is what we expect 😊

Comparison of track fitting results









☞ By taking field non-uniformity into account, the new KalTest can obtain consistent track fitting results with the original one for uniform magnetic field.

Conclusion

- Track distortion near the GEM gap of Asian readout module is caused by electron loss, and ExB effect when the magnetic field is on. A correction has been made to reduce the distortion.
- We have to consider non-uniformity of real ILD magnetic field for tracking detector. The new KalTest has the ability to deal with it.