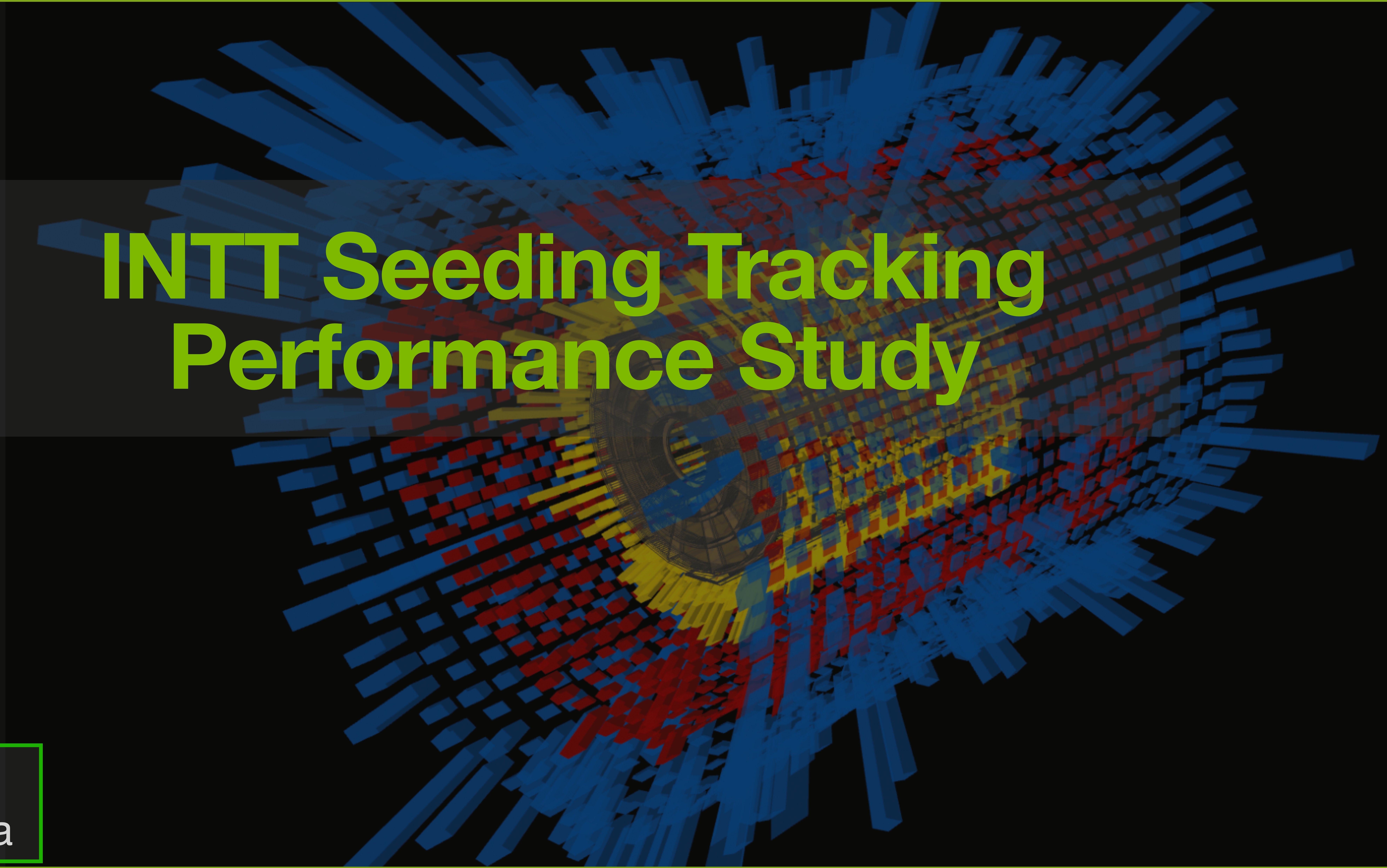
INTT Seeding Tracking Performance Study



RIKEN
Takuya Kumaoka

Aim of this study

Improve electron tracking using INTT + calorimeters

→ By adding calorimeter hit point, the tracking quality is expected to improve.

<**Final goal**> Identify the particles using ***E/p*** and reconstruct **J/ψ**

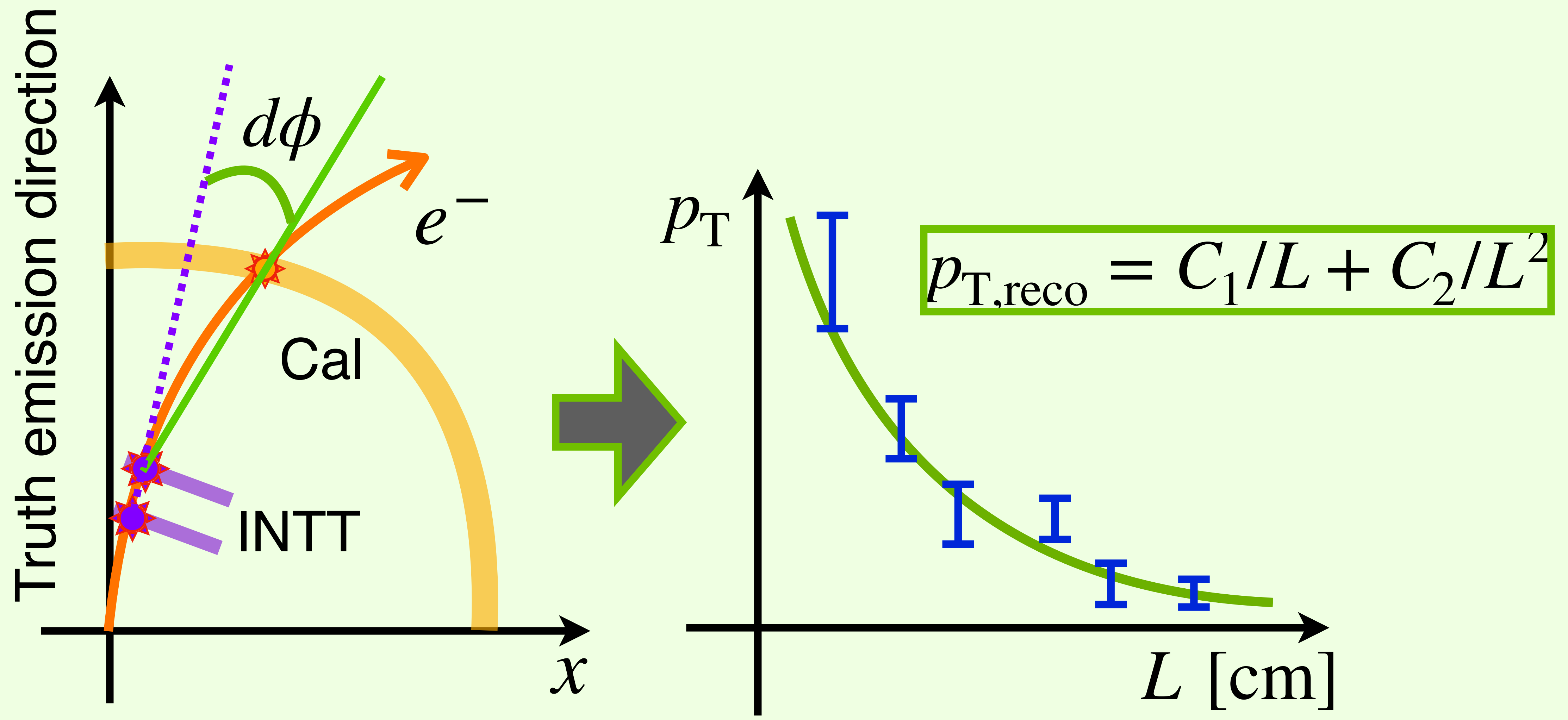
<**My study goal**> Evaluate how improve the **p_T resolution** by including the calorimeter hits.

We expect the p_T can be described by a magnetic shift angle ($d\phi$) equation.

The coefficients (C_1 and C_2) is estimated using single electron simulation.

→ The function performance is evaluated by:

$$\sigma p_T = \frac{p_{\mathrm{T,reco}} - p_{\mathrm{T,truth}}}{p_{\mathrm{T,reco}}}$$



My Study Informations

Study Wiki Page:

https://wiki.sphenix.bnl.gov/index.php?title=INTT_AnalysisWorkshop2024_TakuyaKumaoka

Git link of this study:

- Particle Generation Simulation Codes
  https://github.com/sPHENIX-Collaboration/INTT/tree/main/general_codes/tkumaoka/InttSeedingTrackDev/ParticleGen

- INTT Seed Tracking Codes ← It will be explained in this slides of the algorithm part
  https://github.com/sPHENIX-Collaboration/INTT/blob/main/general_codes/tkumaoka/InttSeedingTrackDev/InttSeedTrackPerformance/src/InttSeedTracking.cxx

- INTT Seed Tracking Performance Estimation Codes ← It will be explained in this slides of the result part
  https://github.com/sPHENIX-Collaboration/INTT/blob/main/general_codes/tkumaoka/InttSeedingTrackDev/InttSeedTrackPerformance/src/InttSeedTrackPerformance.cxx

How to run this study codes

https://indico.bnl.gov/event/24622/contributions/99967/attachments/58840/101806/2024Dec16_Kumaoka_HowToRunMyCode.pdf

INTT Seeding Algorithm

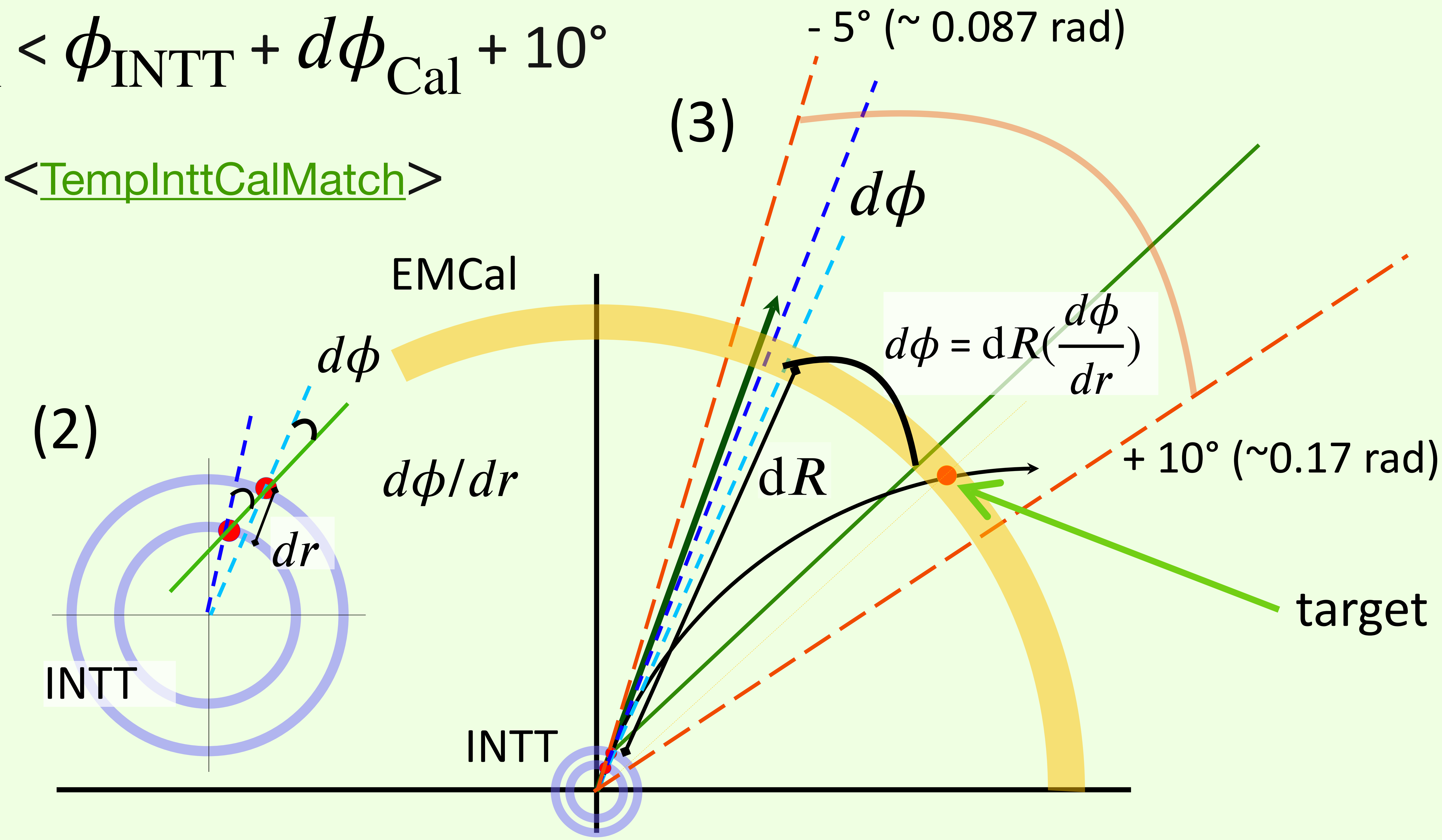
INTT + EMcal Hit Matching Algorithm

(1) Find a inner INTT cluster having the closest $\phi_{\mathrm{outer\ INTT}}$ <TempINTTIOMatching>

(2) Caclulate $d\phi/dr$ (outer INTT - inner INTT) <TempCalcdPhidR>

(3) Searching for an EMCal cluster (> 0.1 MeV) having the highest energy in the ϕ_{Cal} range ϕ_{INTT} - 5° < ϕ_{Cal} < $\phi_{\mathrm{INTT}} + d\phi_{\mathrm{Cal}}$ + 10°

$$d\phi_{\mathrm{Cal}} = d\phi/dr * (R_{\mathrm{EMCal}} - R_{\mathrm{INTT}})$$ <TempInttCalMatch>

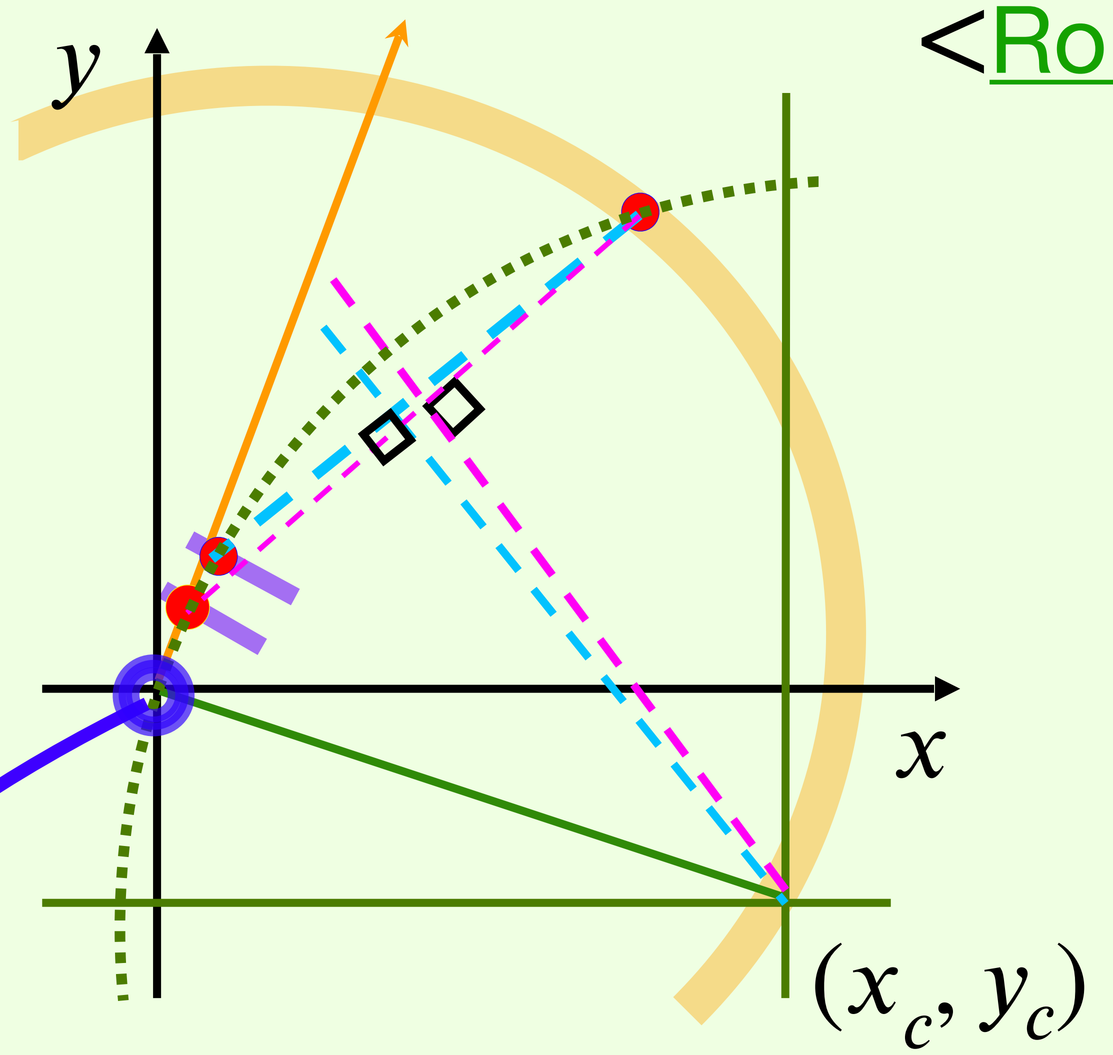


MVTX Hit Matching Algorithm

(1) Draw a circle using three hit points (iINTT + oINTT + EMcal)

(a) No fit approach (The last page result)

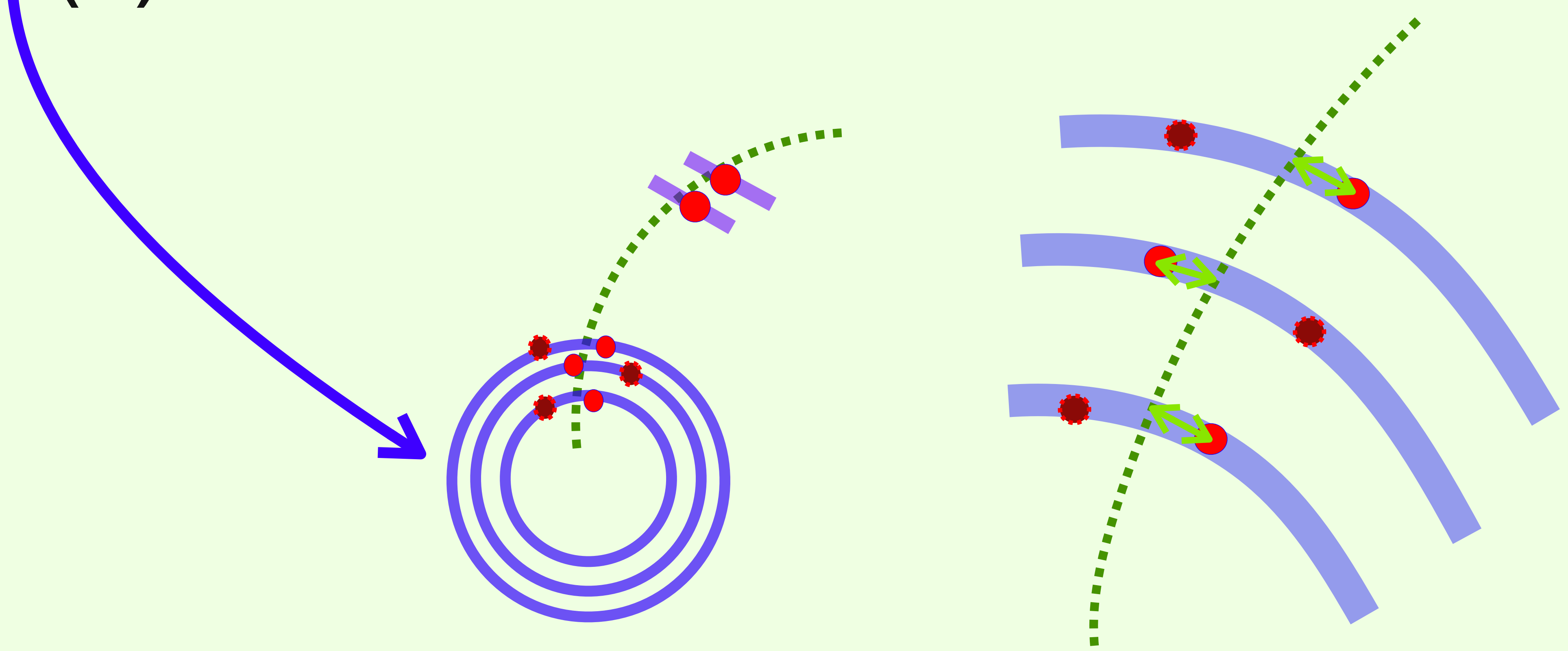
<RoughEstiSagittaCenter3Point>



(b) Use ROOT fit <SagittaRByCircleFit>

$$(y = \sqrt{R^2 - (x - x_c)^2} - y_c)$$

(2) Select Closest Points of MVTX <AddMvtxHits>



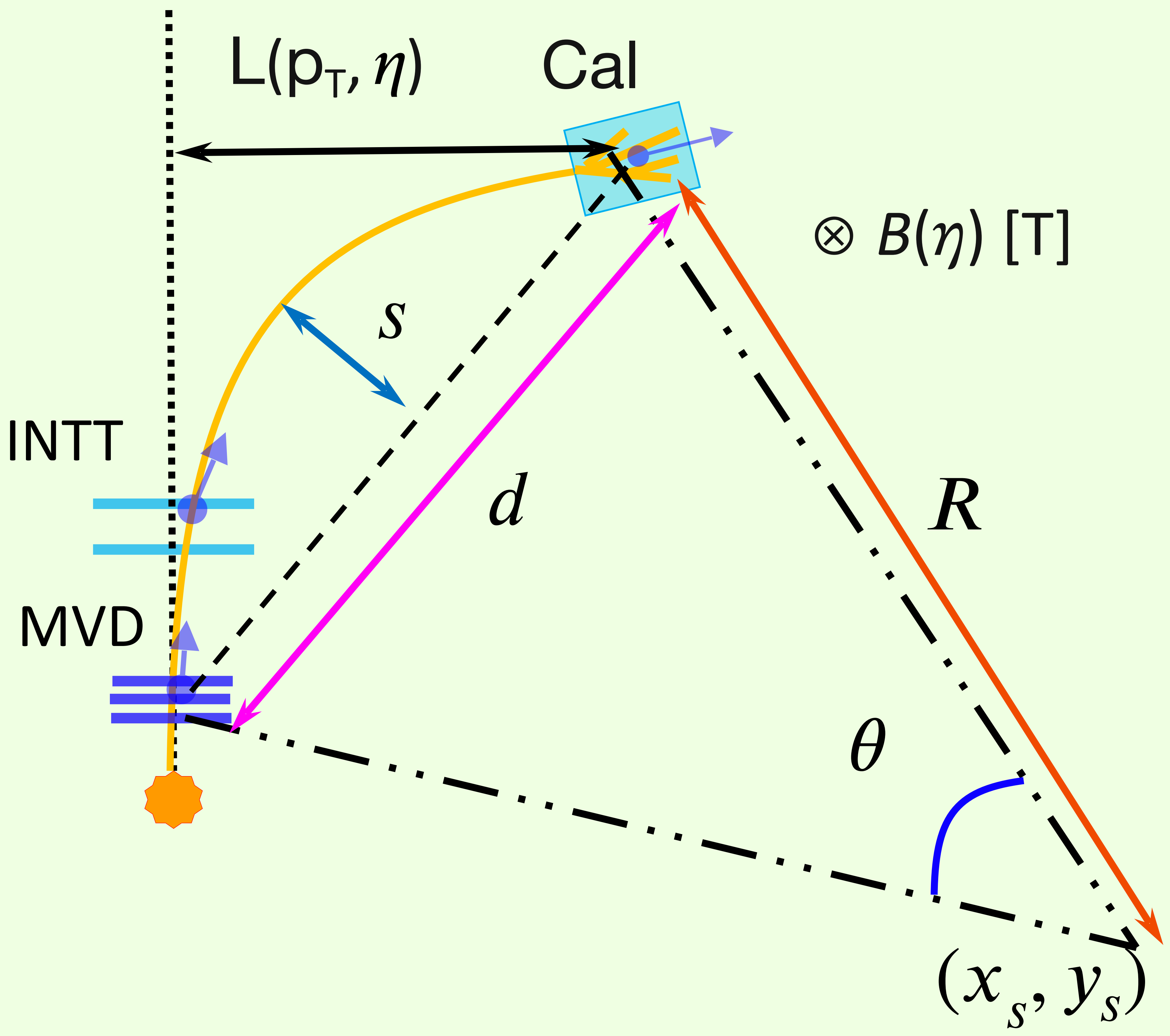
p_T calculation way1

Sagitta p_T equation

$$p_T[\mathrm{GeV}] = qBR$$
$$= 0.3B[T]R[m]$$

Fitting the circle equation ($y = \sqrt{R^2 - (x - x_s)^2} + y_s^2$) for the three points (inner INTT, outer INTT, and EMCal) and estimate the R.

Using this R, the p_T can be calculated.

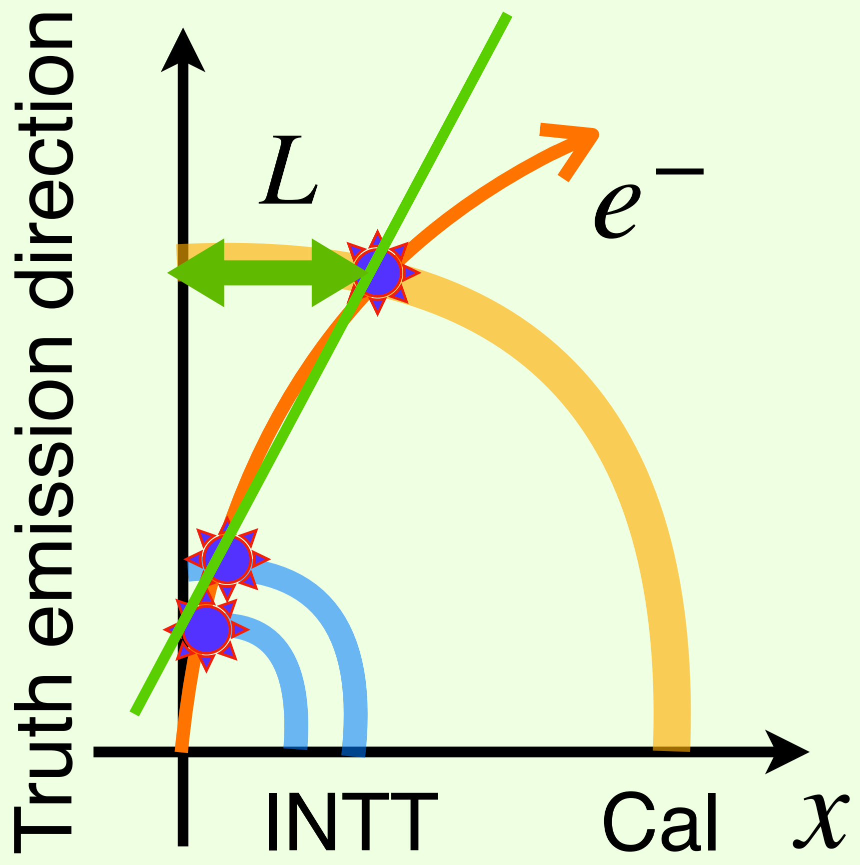


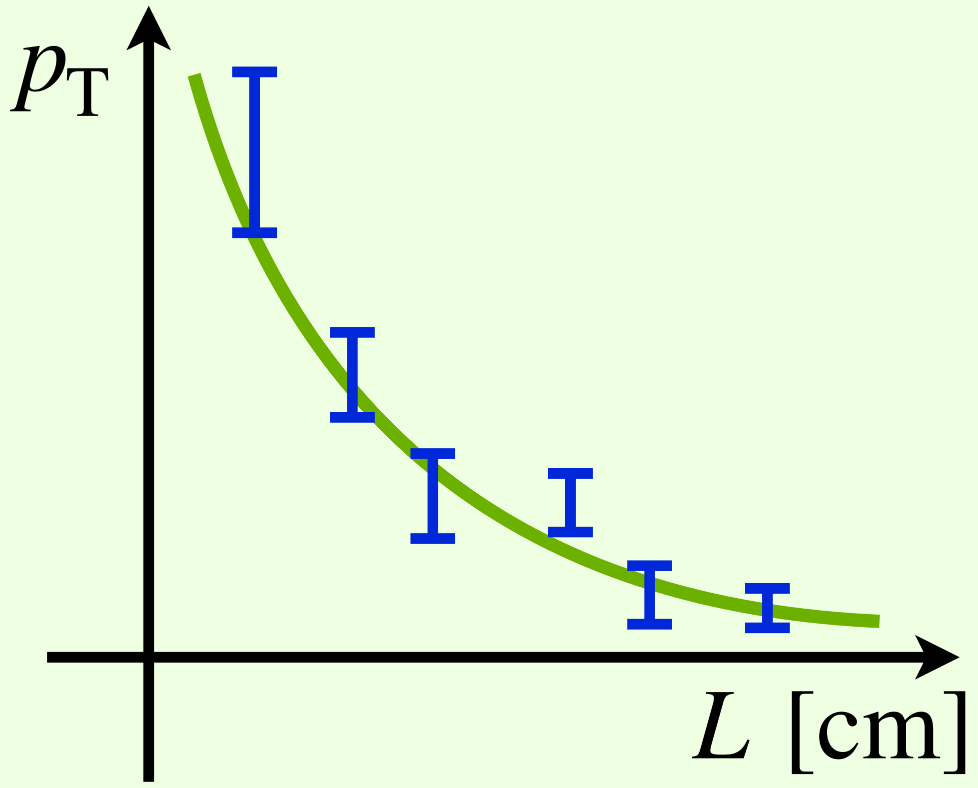
Acculate p_{T} Estimation Idea

We expect the p_{T} can be described by a magnetic shift length (L) equation.

Now, I am estimating the coefficients (C_1 and C_2) using single electron simulation.
→ I need to estimate the function performance.

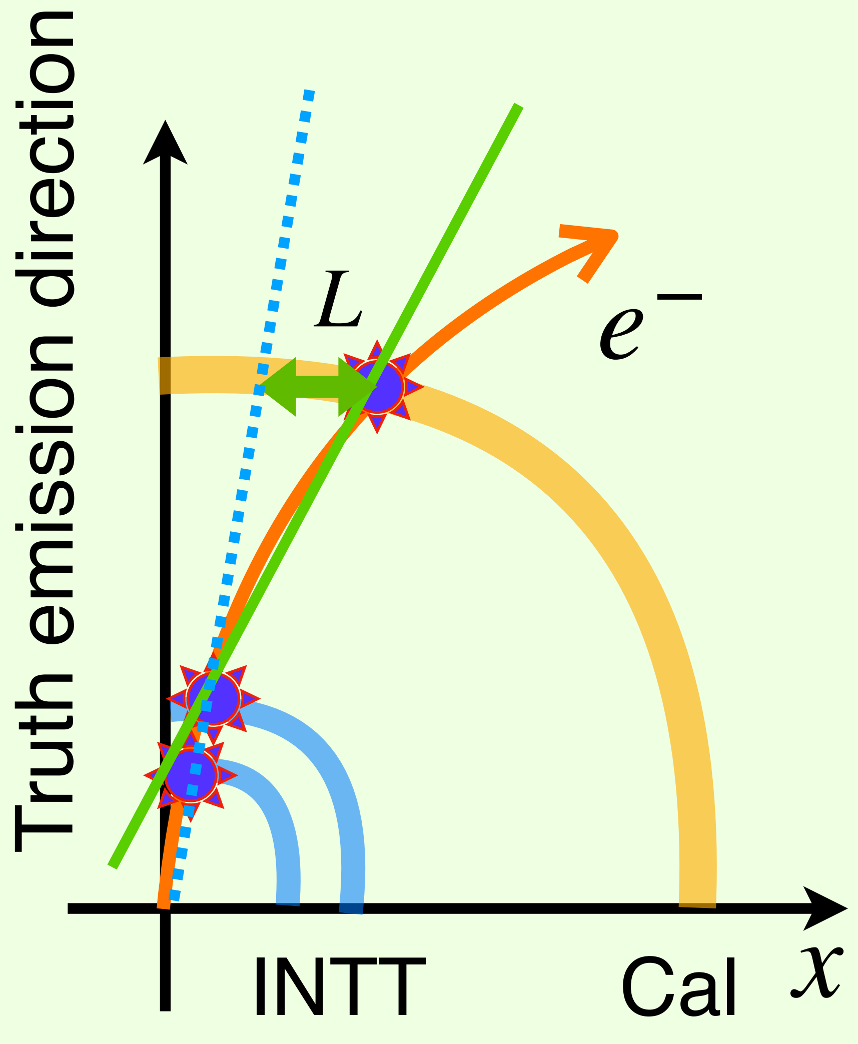
$$\sigma p_T = \frac{p_{\mathrm{T,reco}} - p_{\mathrm{T,truth}}}{p_{\mathrm{T,reco}}}$$



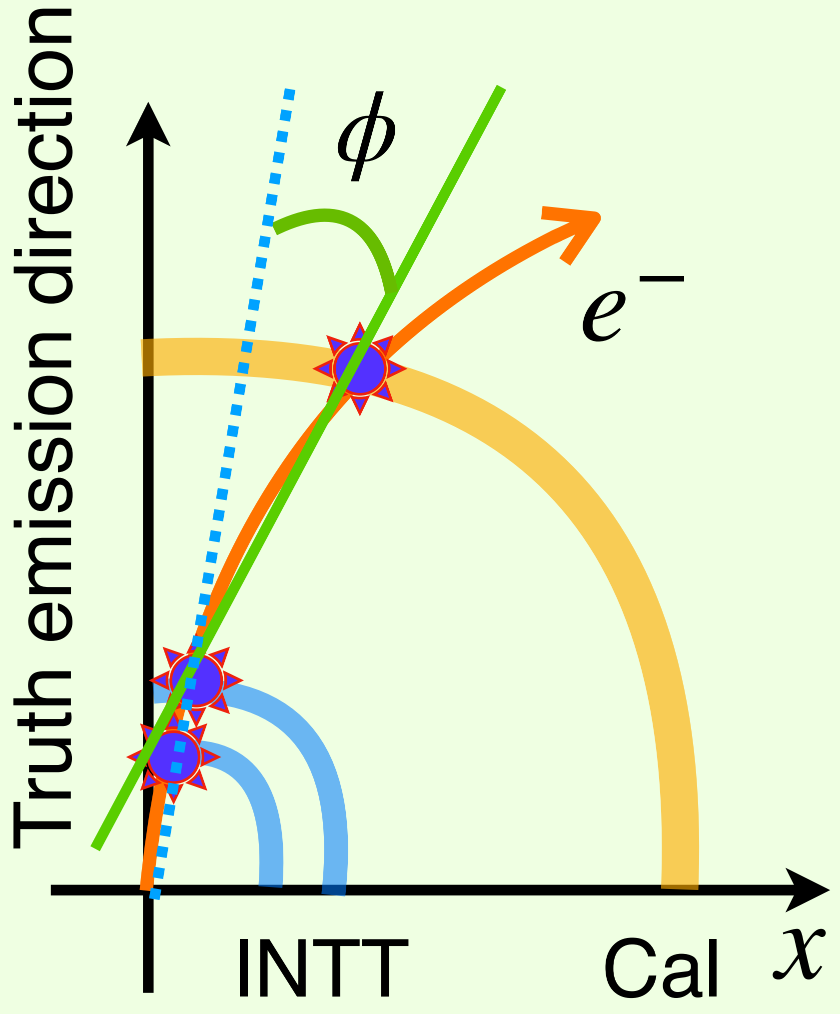


$p_{\mathrm{T}} = C_1/L + C_2/L^2$

We do not know the truth emission direction.



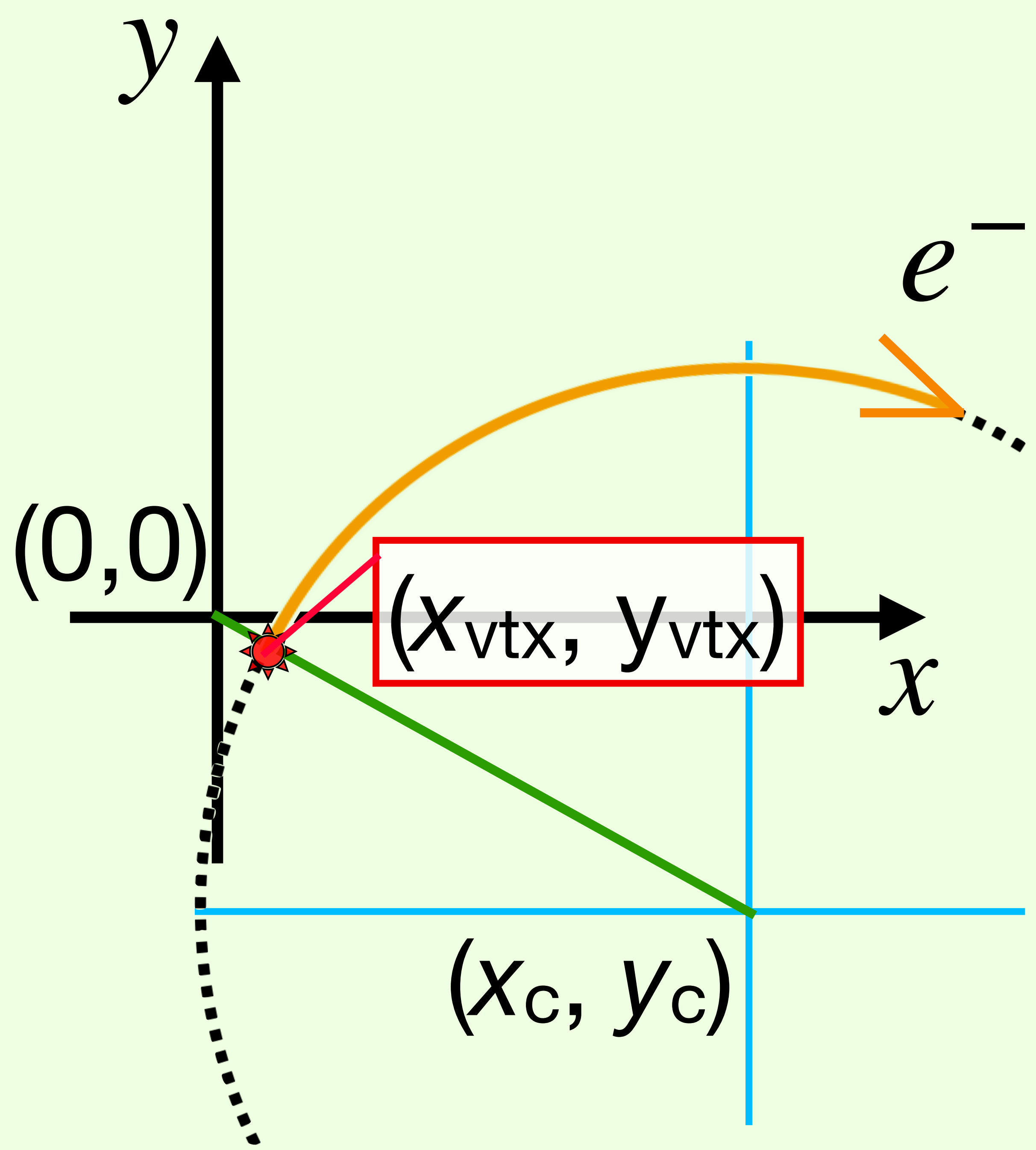
or

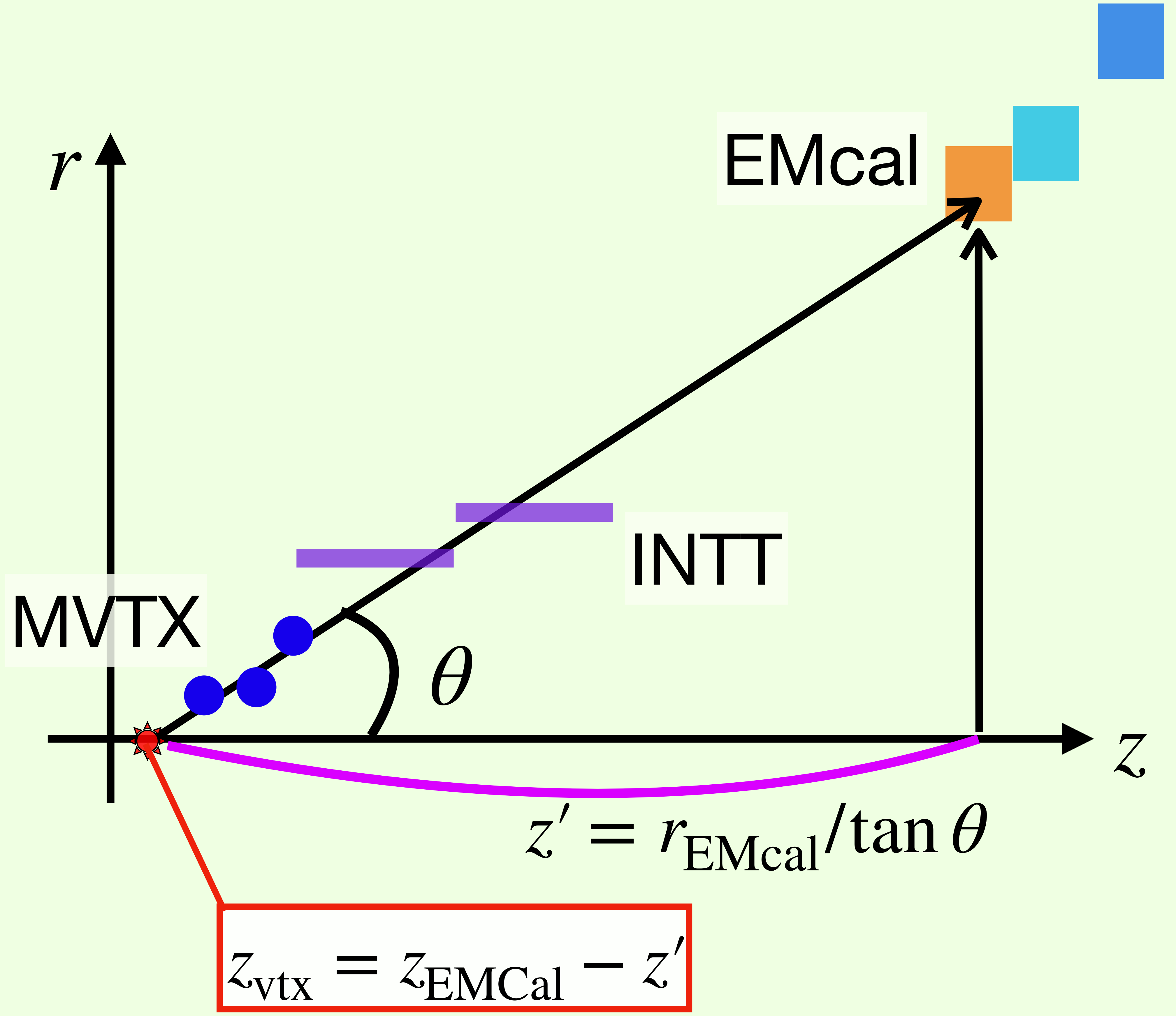


Vertex Determination

x, y position: <CrossLineCircle>
The cross point of the circle drown by the hits connection and the line between the (0, 0) and the center of circle.

z position:
The cross point of the line drown by the hits and the horizontal line.





Tracking Performance Results

Input Event File

Simulation: Single particle gun + GEANT4
→ output: DST file format

Inject electron p_T : 0-10 GeV/c

Inject range: ϕ: $-\pi$ to π, η: -1 to 1

GEANT4 Setting: Magnet 1.4 T
Detector: MVTX, INTT, TPC, EMCal, iHCal, oHCal

sPHENIX Magnetic Field

Document Location

https://indico.bnl.gov/event/7081/attachments/25527/38284/sphenix_tdr_20190513.pdf

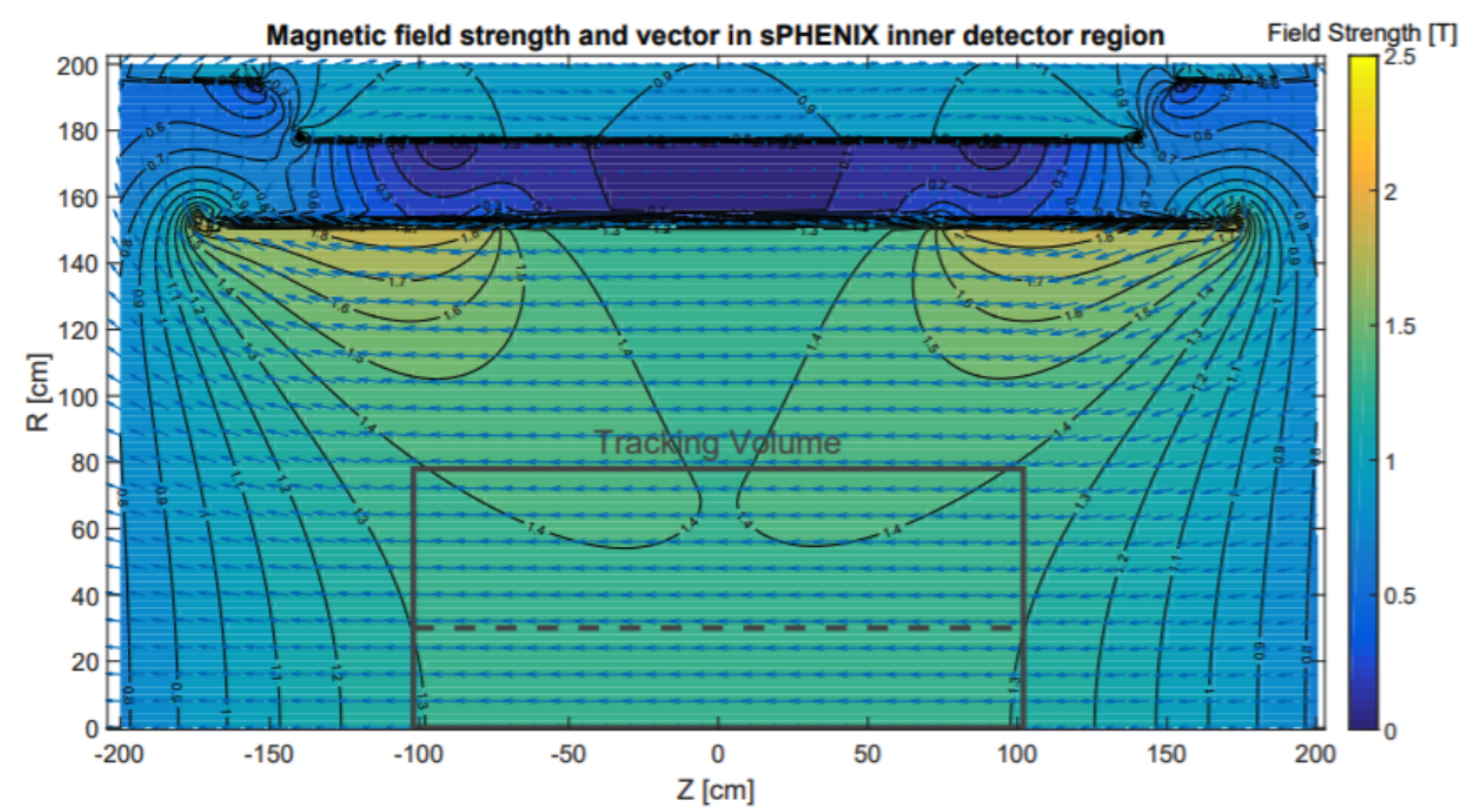
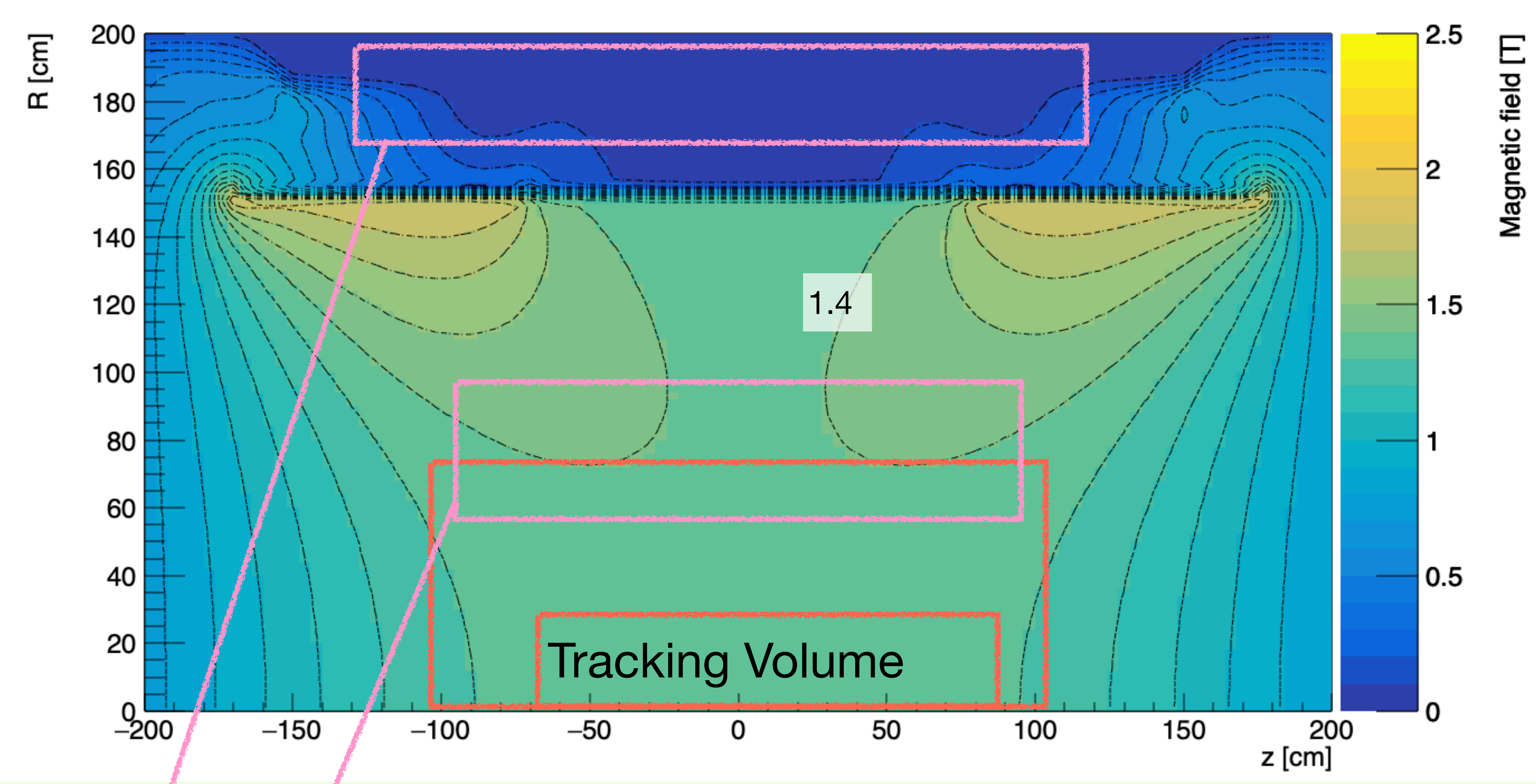


Figure 12. Field Map of the sPHENIX Solenoid

ROOT file Location

/cvmfs/sphenix.sdcc.bnl.gov/calibrations/sphnxpro/cdb/FIELDMAP_GAP/65/a9/65a930ed6de9c0e049cd0f3ef226e6b4_sphenix3dbigmapxyz_gap_rebuild_v2.root



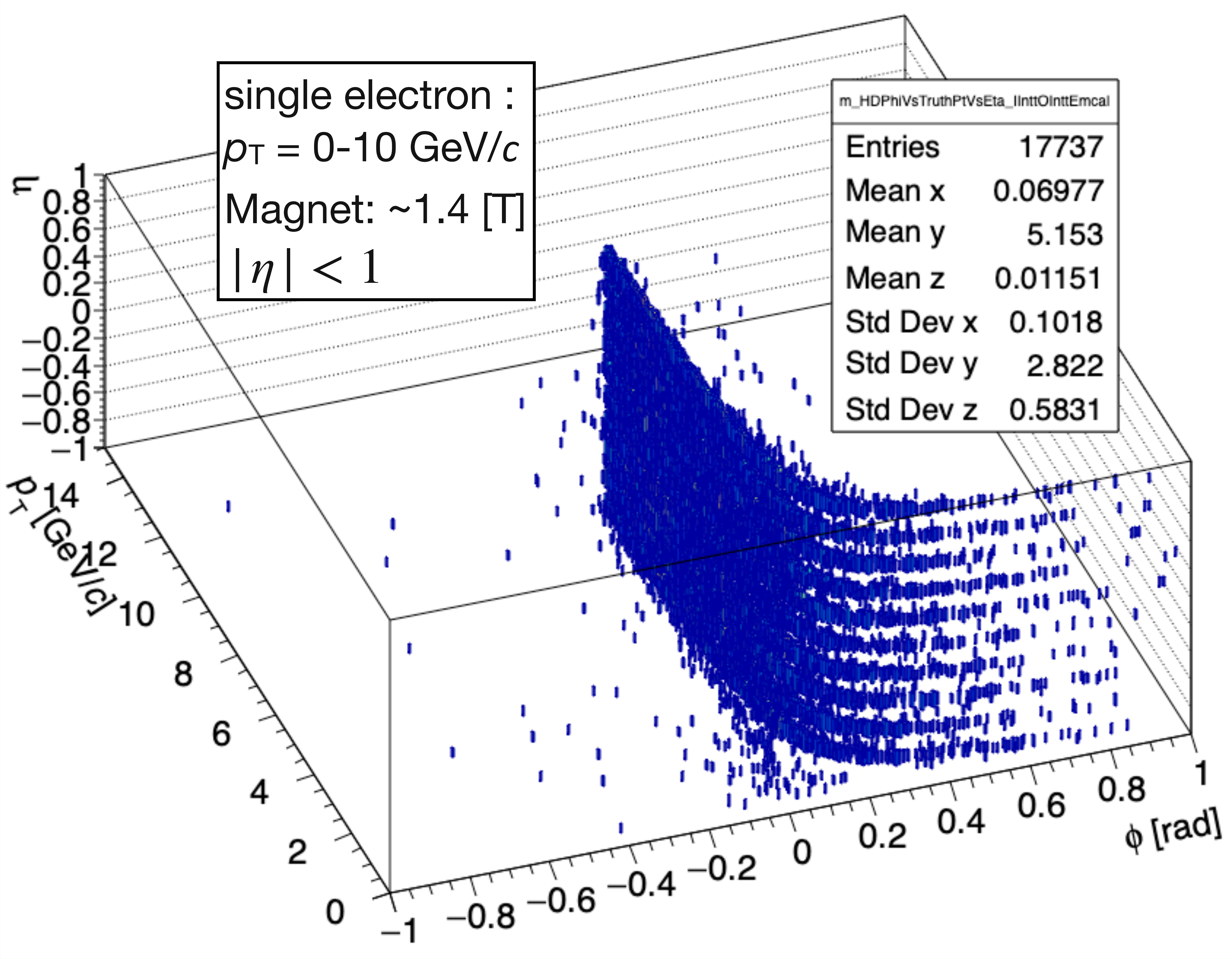
Different behavior:
However, I do not know what is this magnetic field.

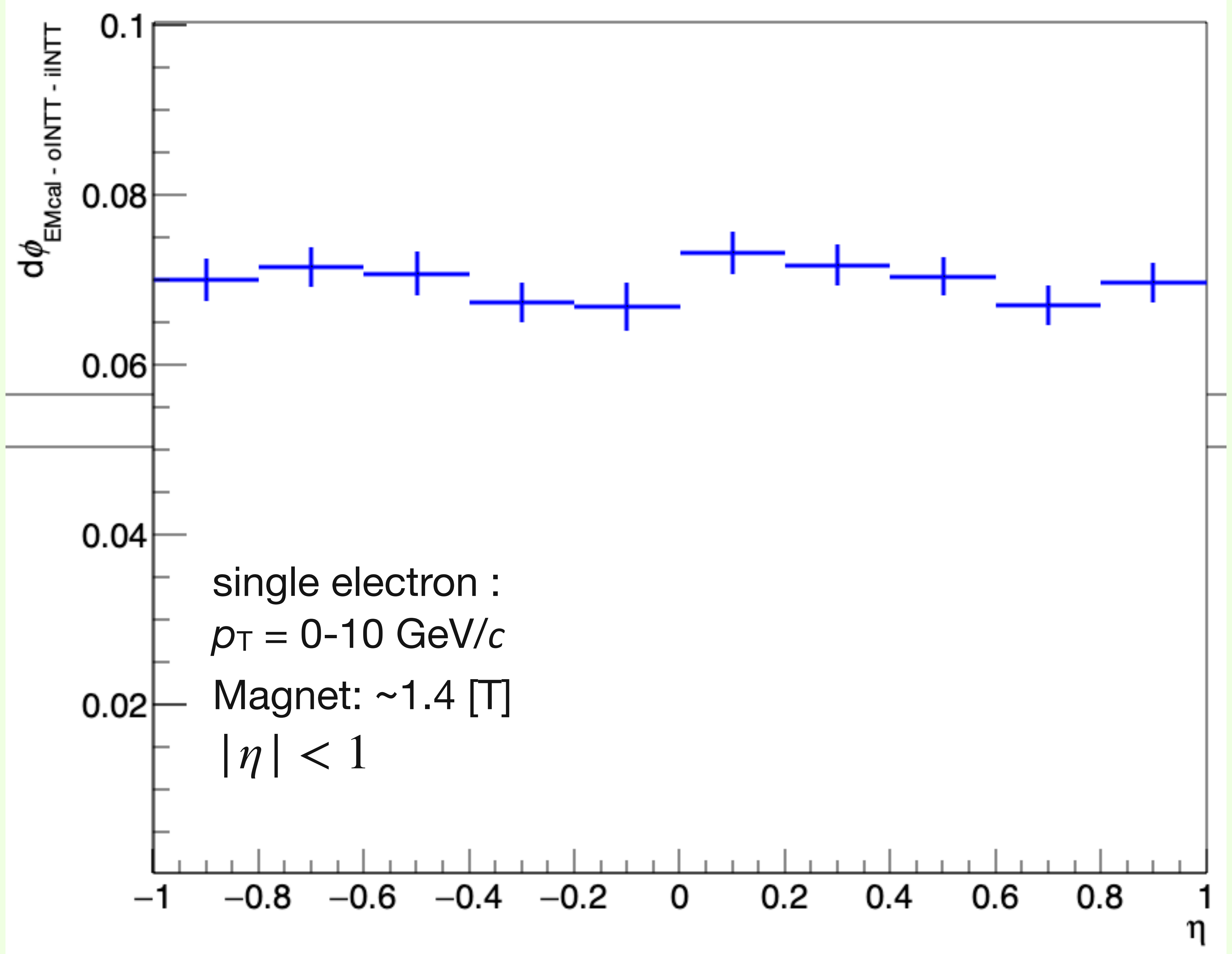
η Dependency of the Emission Angle Shift dϕ by Magnetic Field

There is a possibility that the bending of a track by magnetic field is depends on η.

a. The magnetic field is not completely uniform for η.

b. Flight length in the higher η region is longer than the smaller η one.



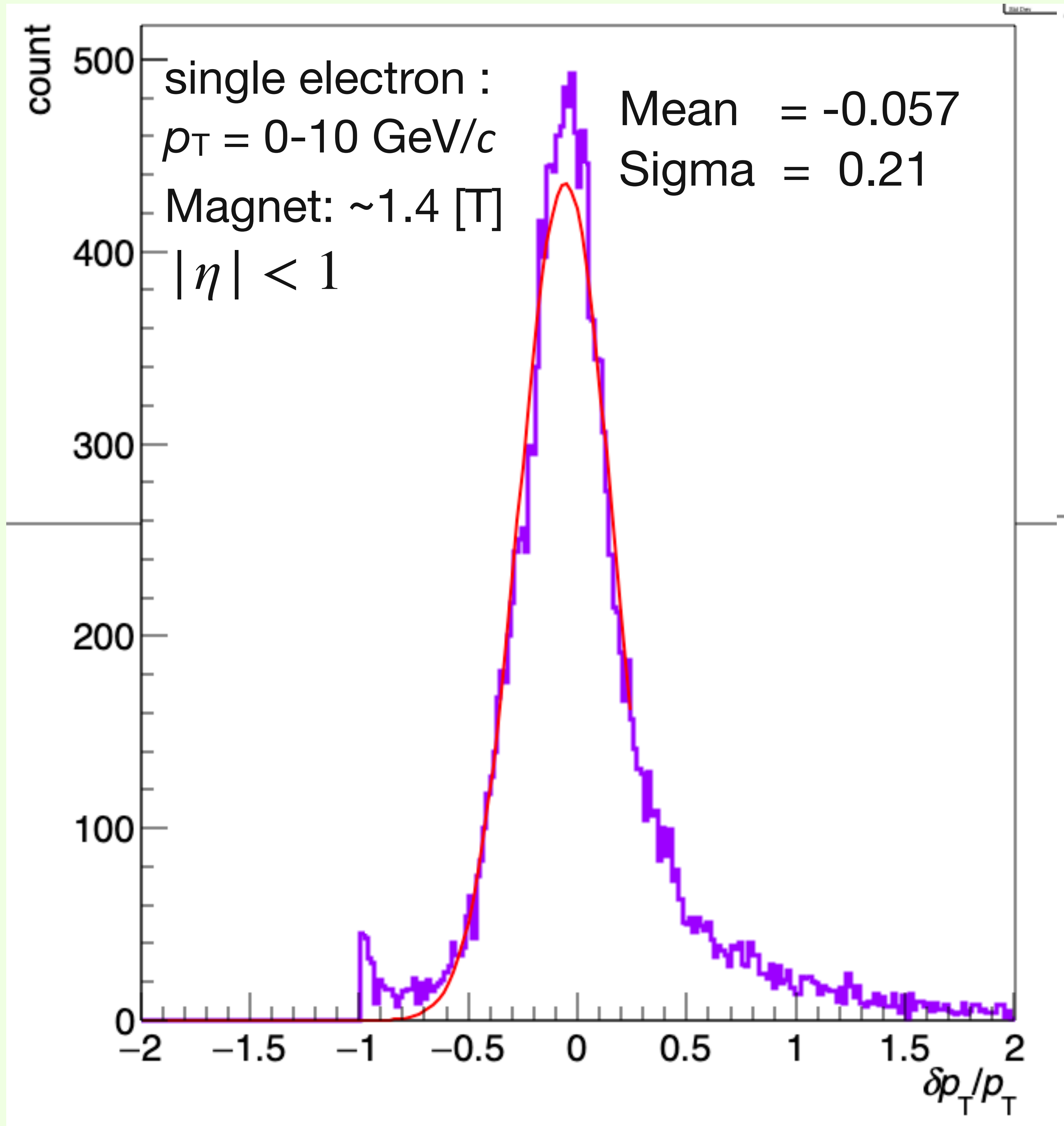


➡ The η dependency seems negligible.

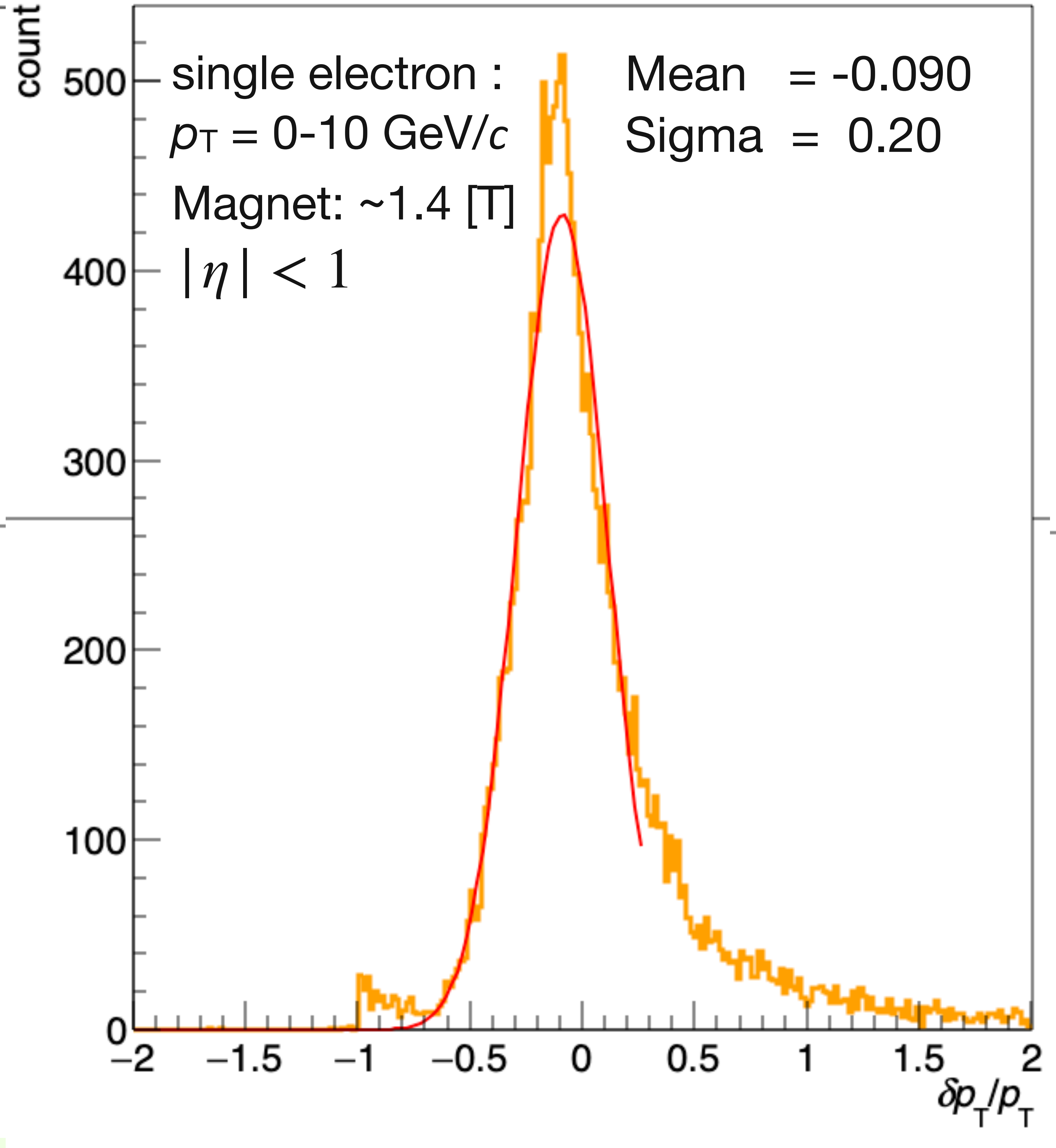
pT resolution

(reco - truth)/truth

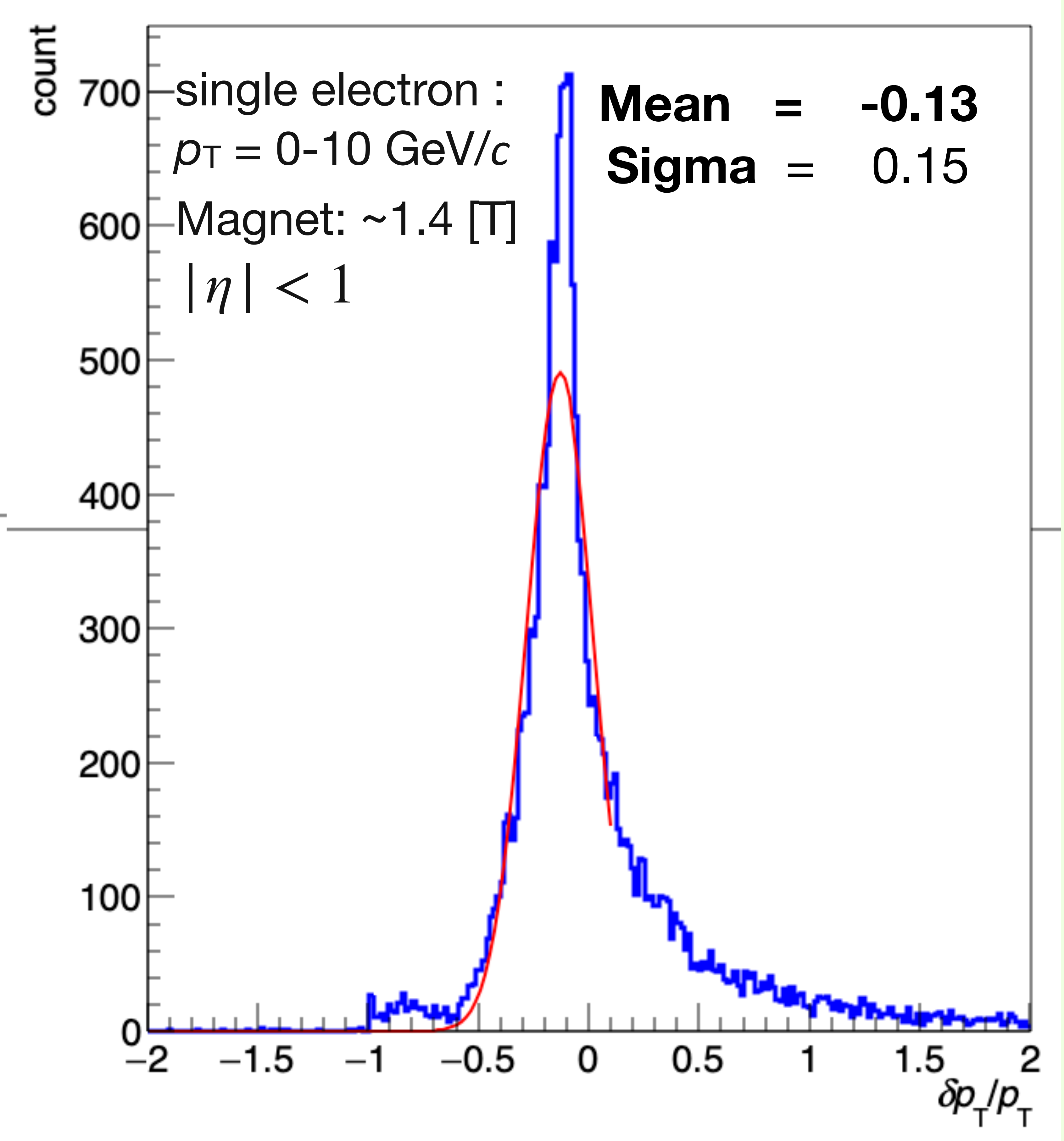
iINTT+oINTT+EMCal



Vertex+iINTT+oINTT+EMCal

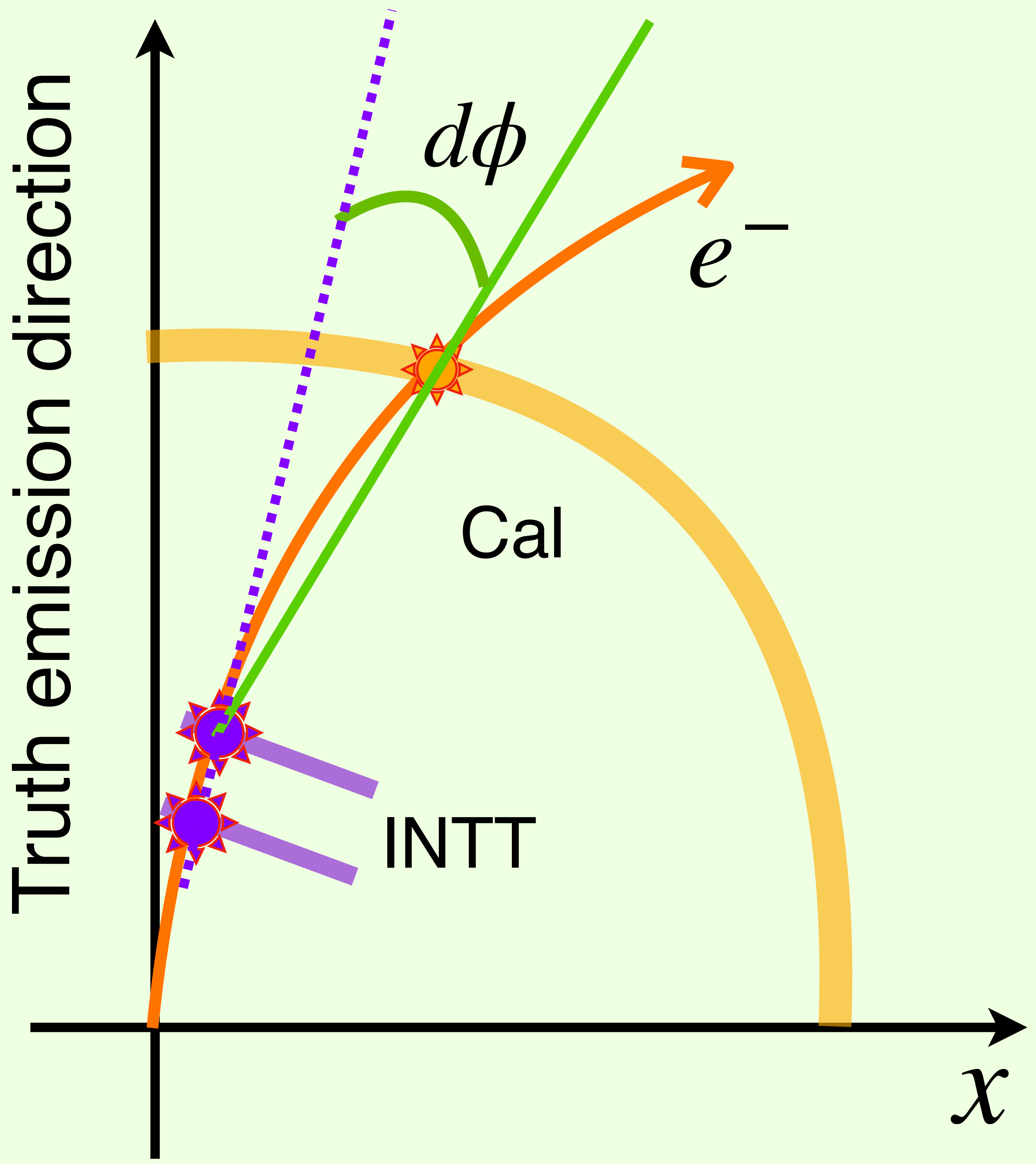


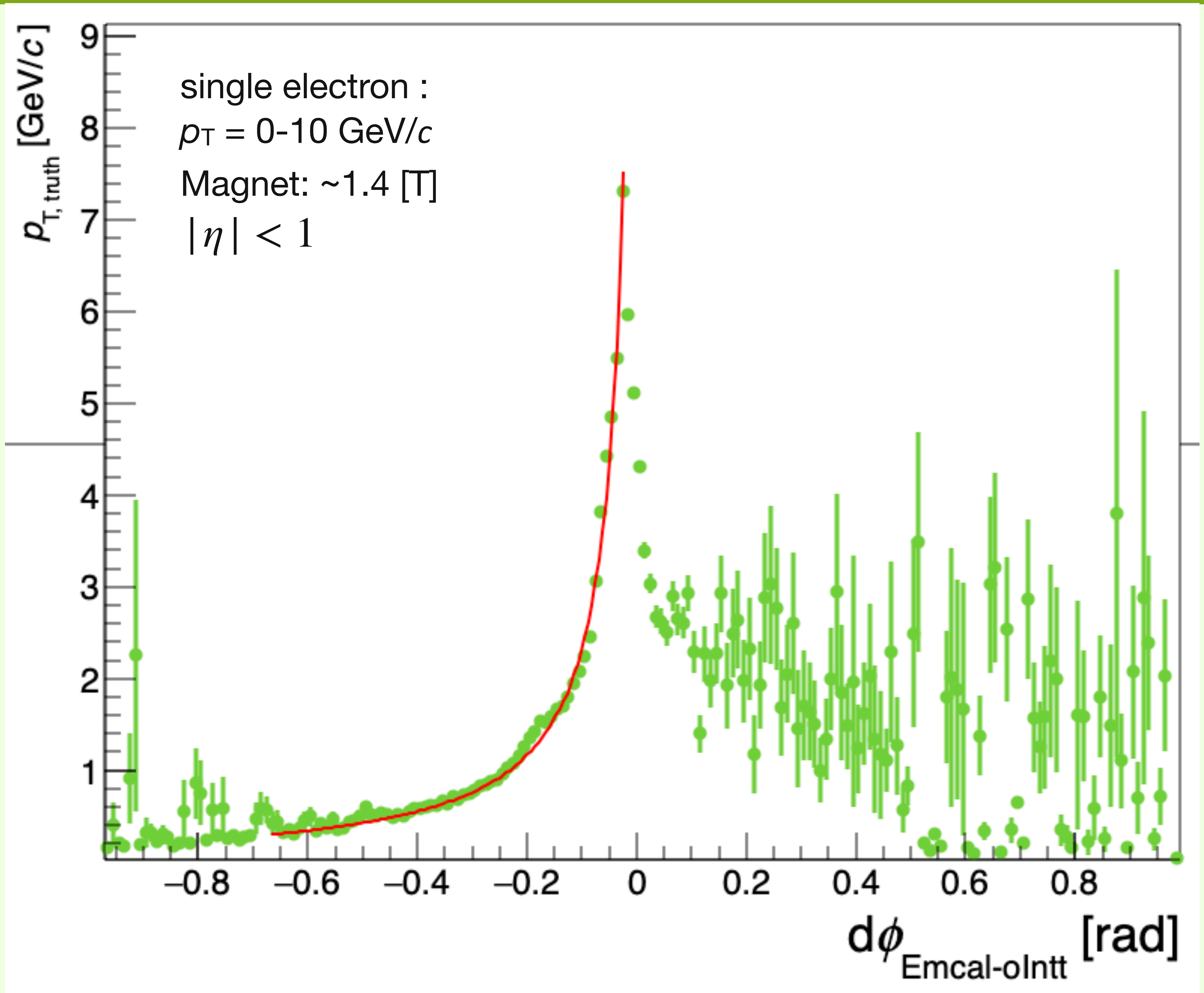
MVTX+iINTT+oINTT+EMCal



Use fitting function

$$p_{\mathrm{T}} = \mathrm{p0} + \frac{\mathrm{p1}}{d\phi} + \frac{\mathrm{p2}}{d\phi^2}$$





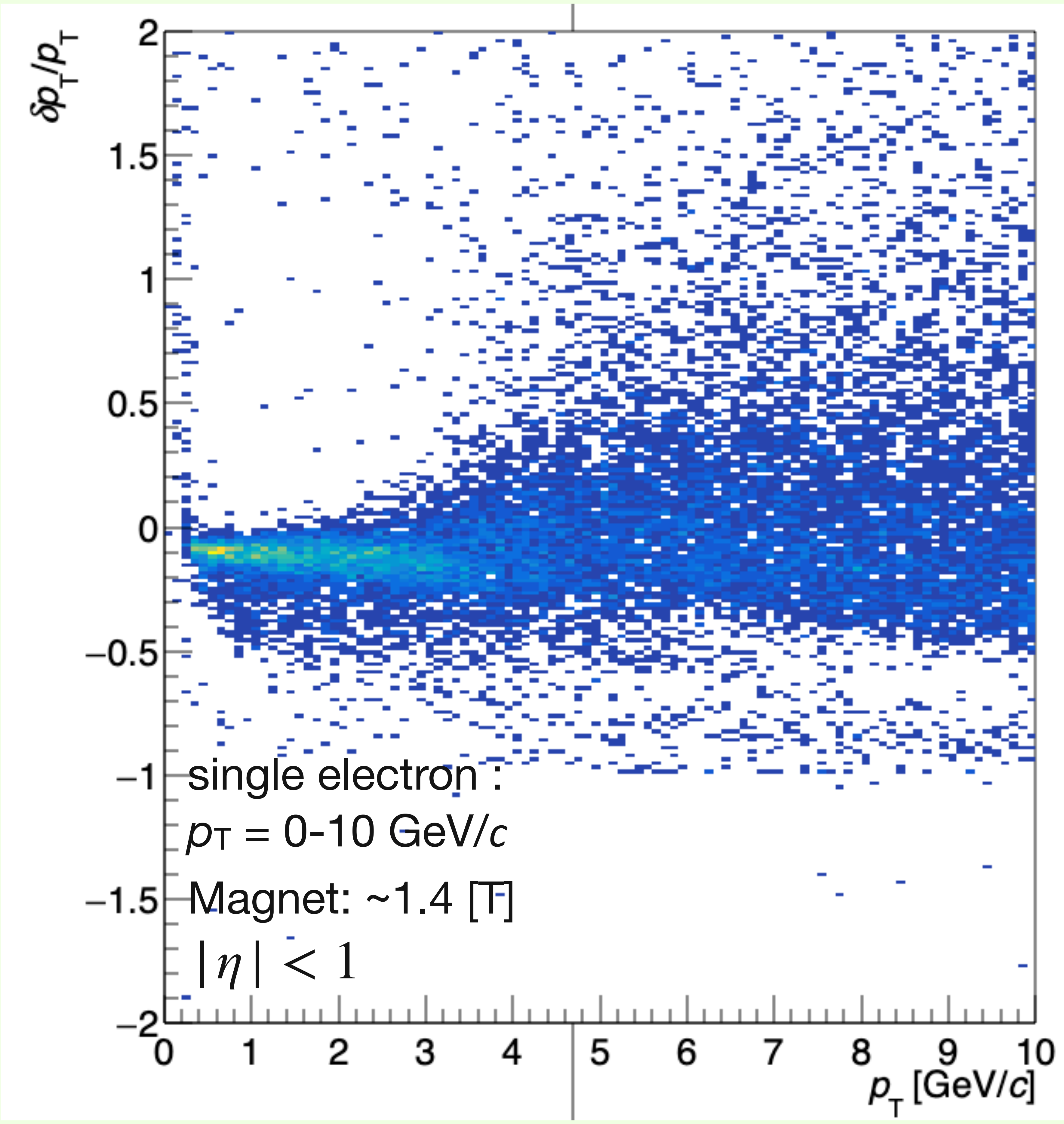
$$p_{\mathrm{T}} = \mathrm{p0} + \frac{\mathrm{p1}}{x} + \frac{\mathrm{p2}}{x^2} = -0.085 - 0.26/x - 0.0019/x^2$$

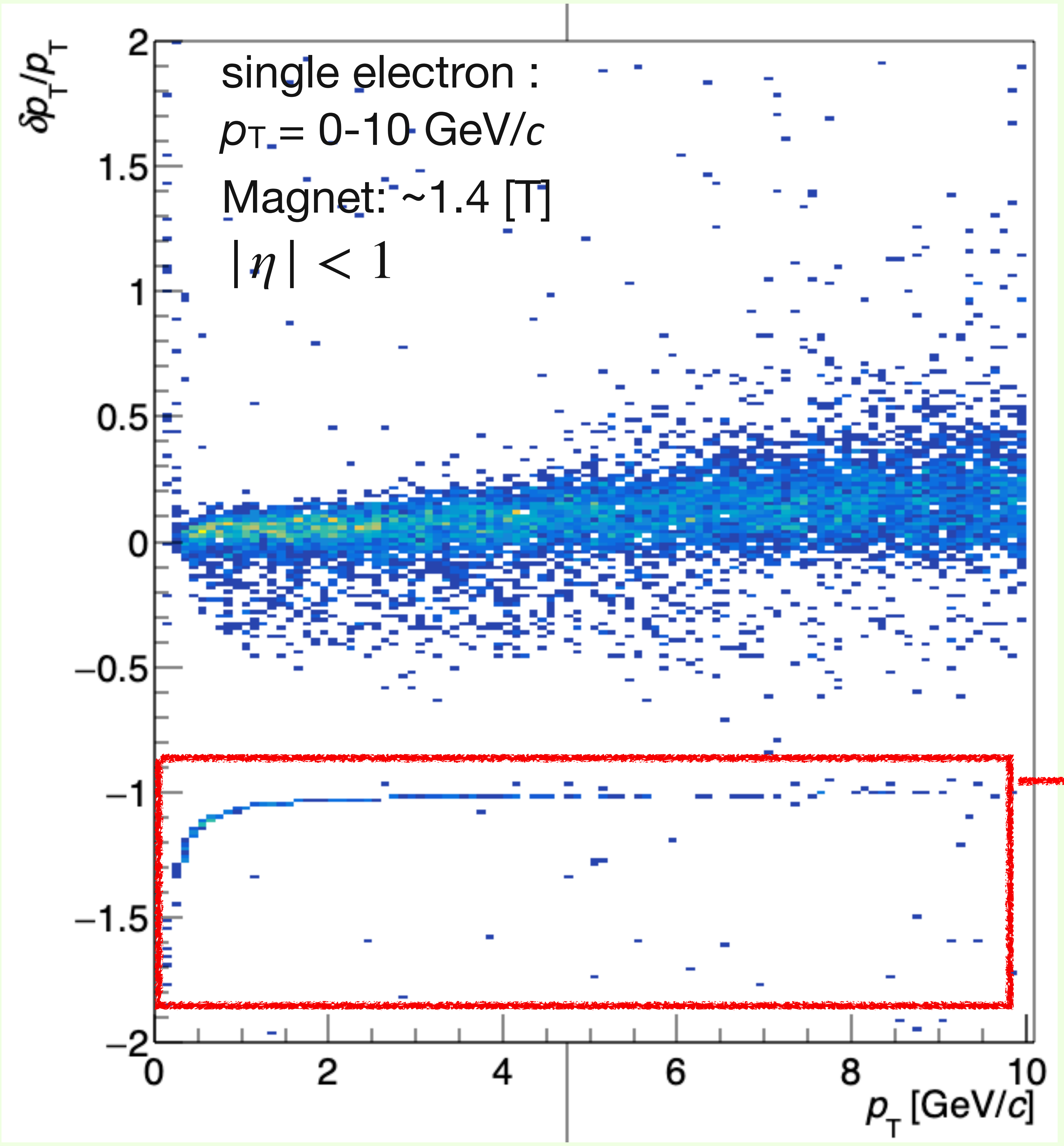
p_T resolution vs p_T

MVTX+iINTT+oINTT+EMCal

ordinal way: $p_T[\mathrm{GeV}] = qBR$

Fitting Function way: $p_T = \mathrm{p0} + \frac{\mathrm{p1}}{d\phi} + \frac{\mathrm{p2}}{d\phi^2}$





?
Probably it made by mis-tracking
(reco-truth)/truth

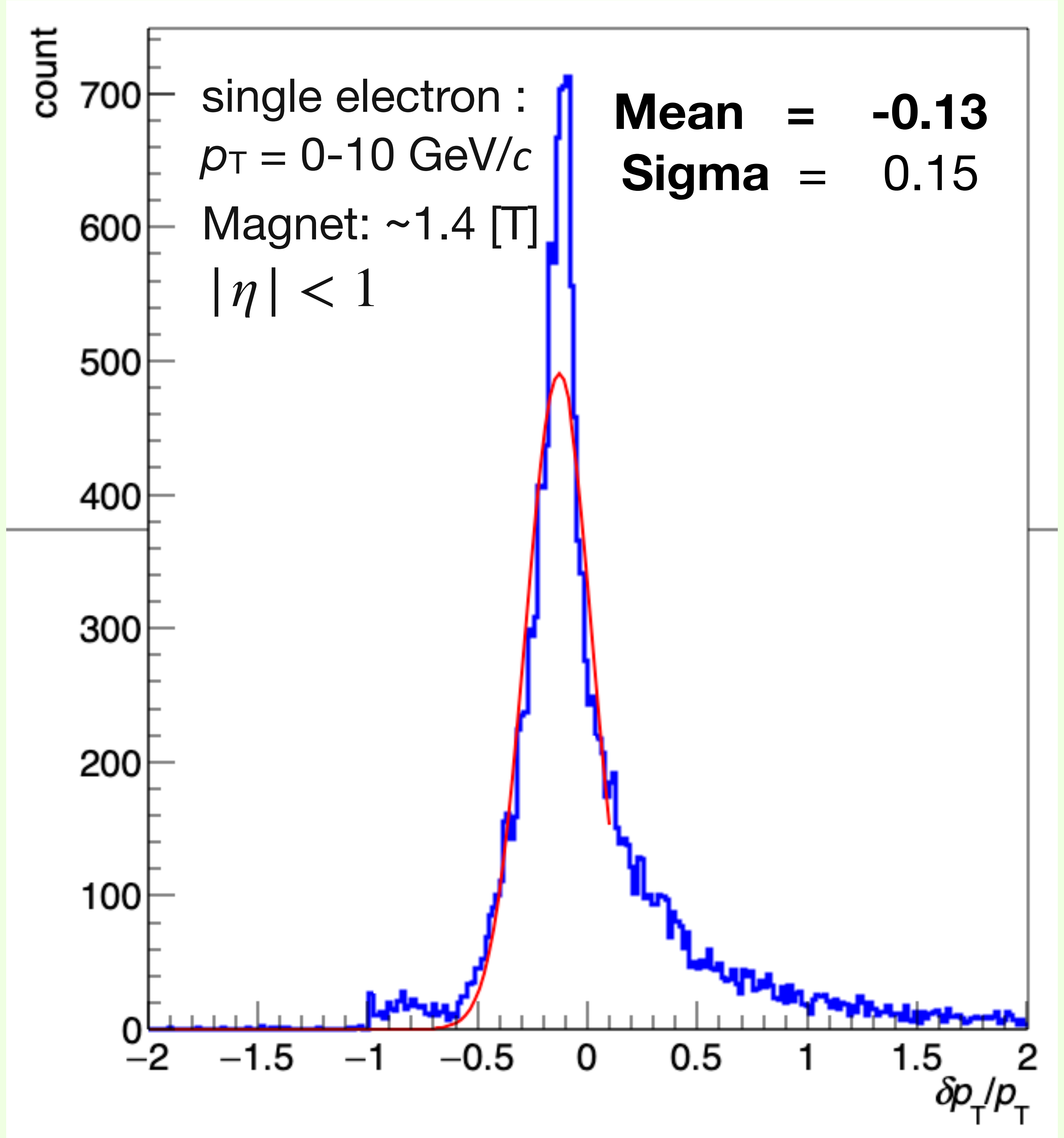
For the pT fluctuation, the fitting function way is clearly better than the ordinal way.

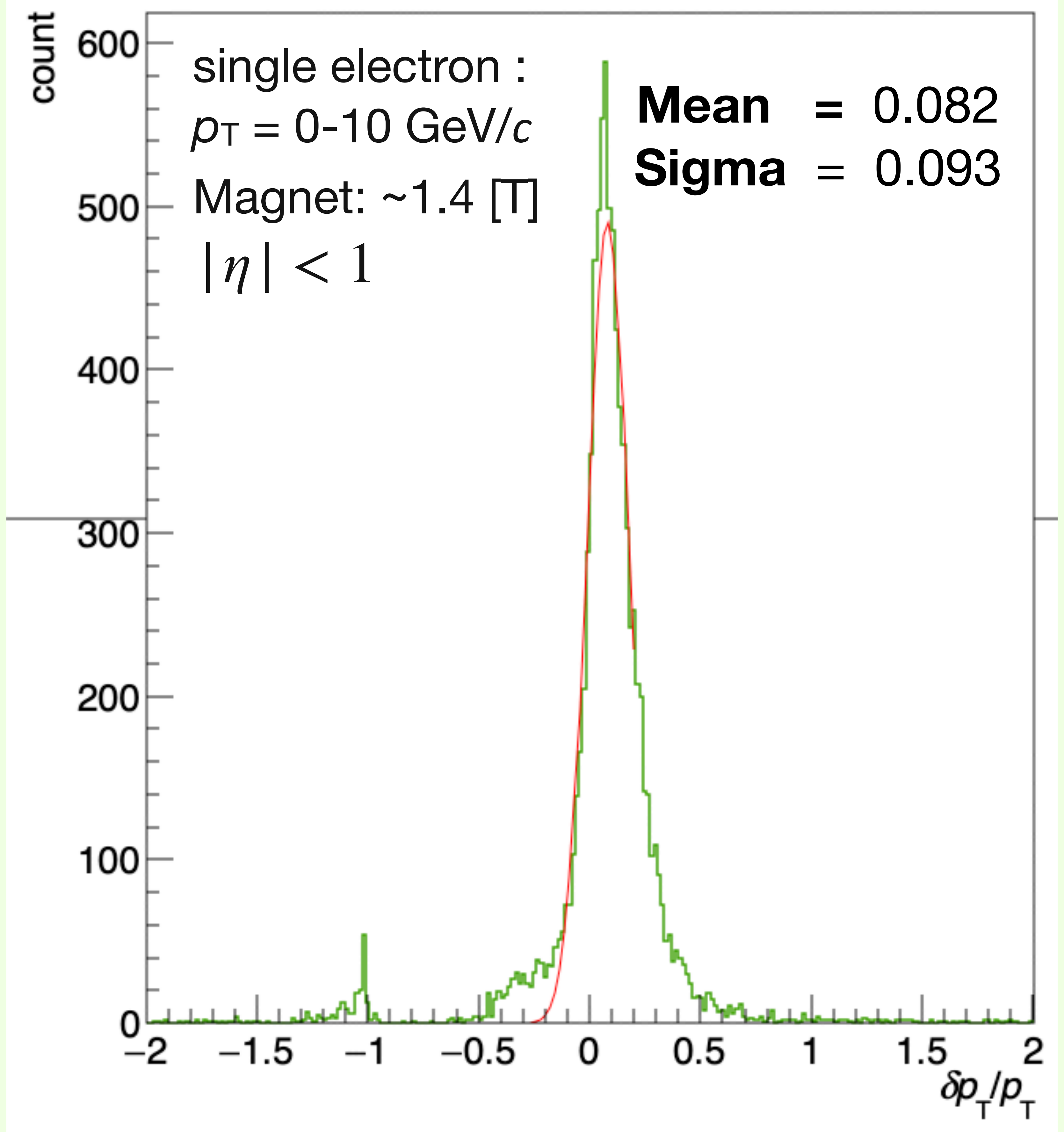
p_T resolution with fitting function

MVTX+iINTT+oINTT+EMCal

$$p_T[\mathrm{GeV}] = qBR$$

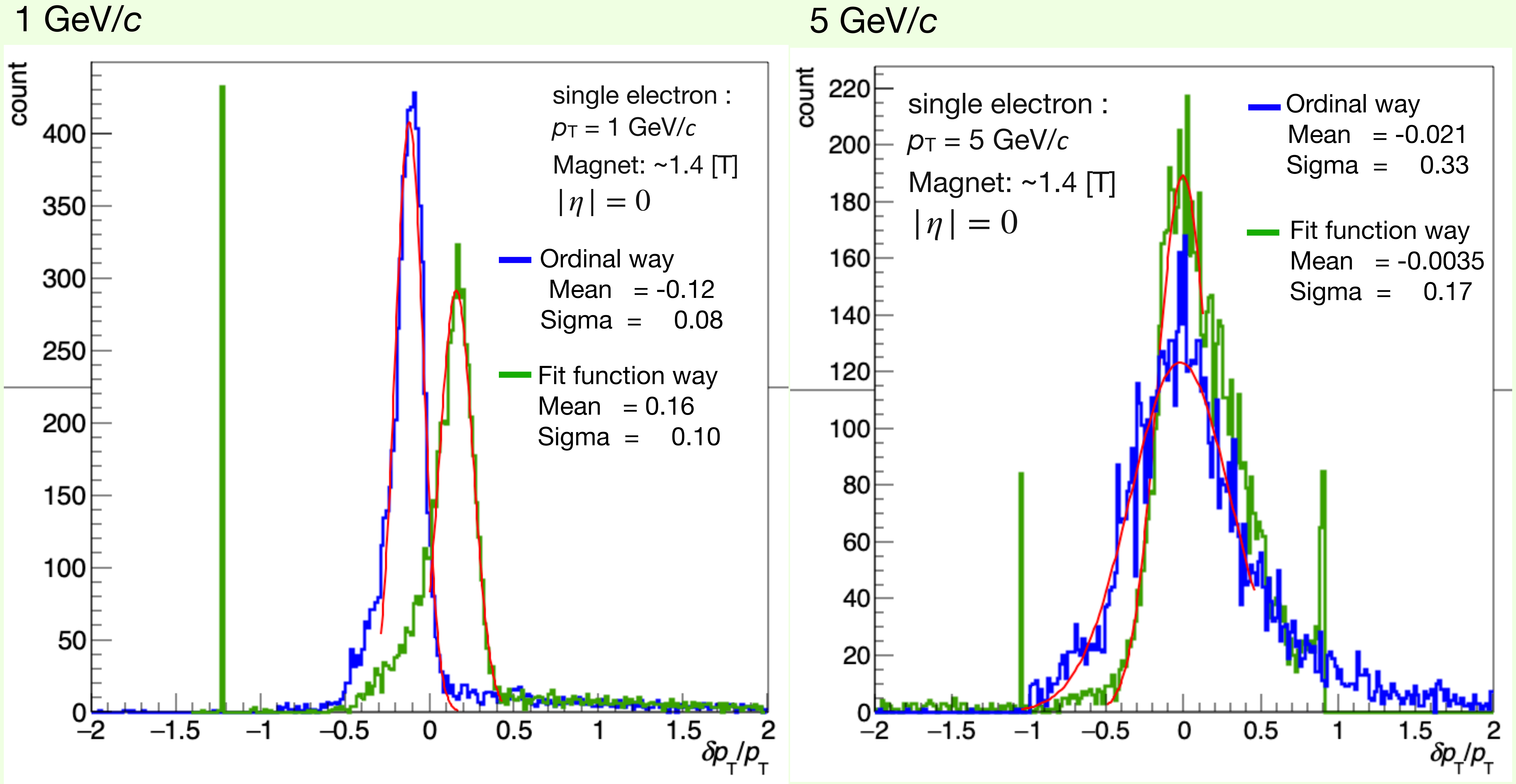
$$p_T = \mathrm{p0} + \frac{\mathrm{p1}}{d\phi} + \frac{\mathrm{p2}}{d\phi^2}$$





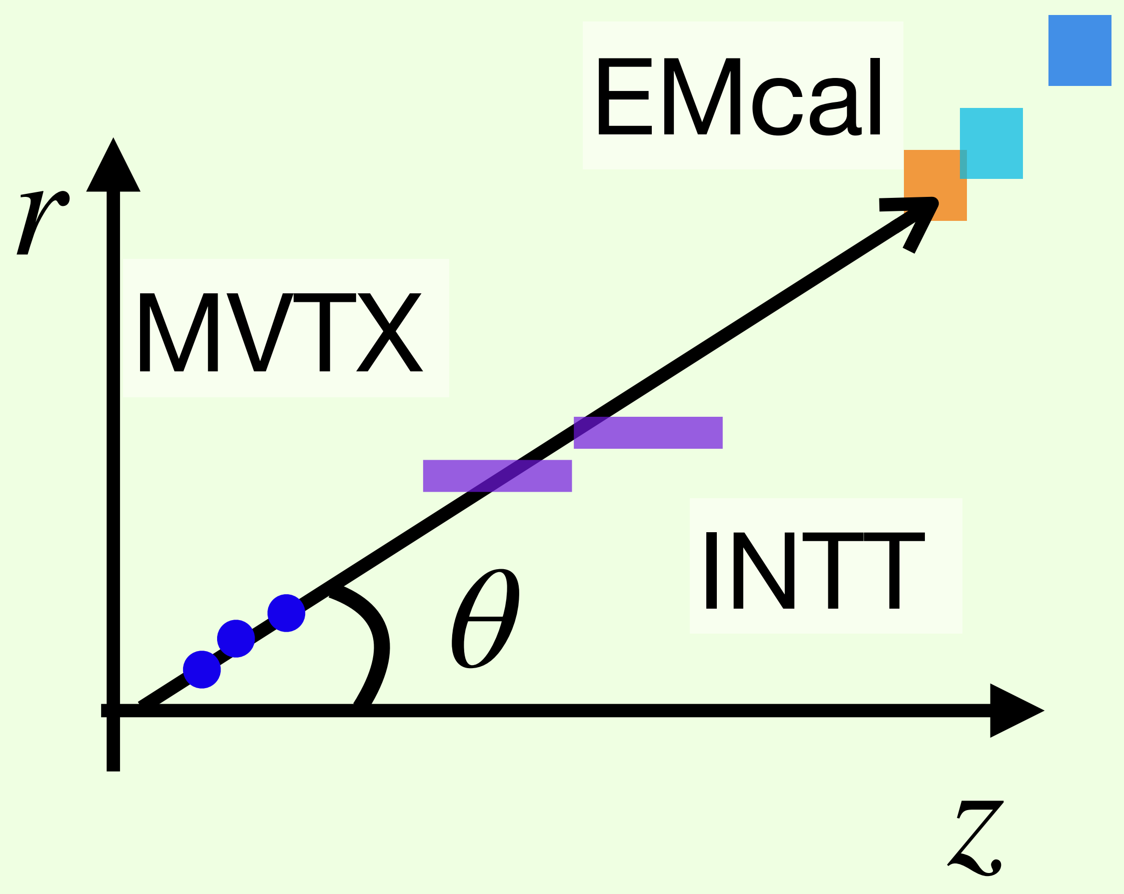
The comparison is not fair because the fitting does not work well.
While the shape seems sharper than the old way.

p_T resolution with fitting function (pT slice)

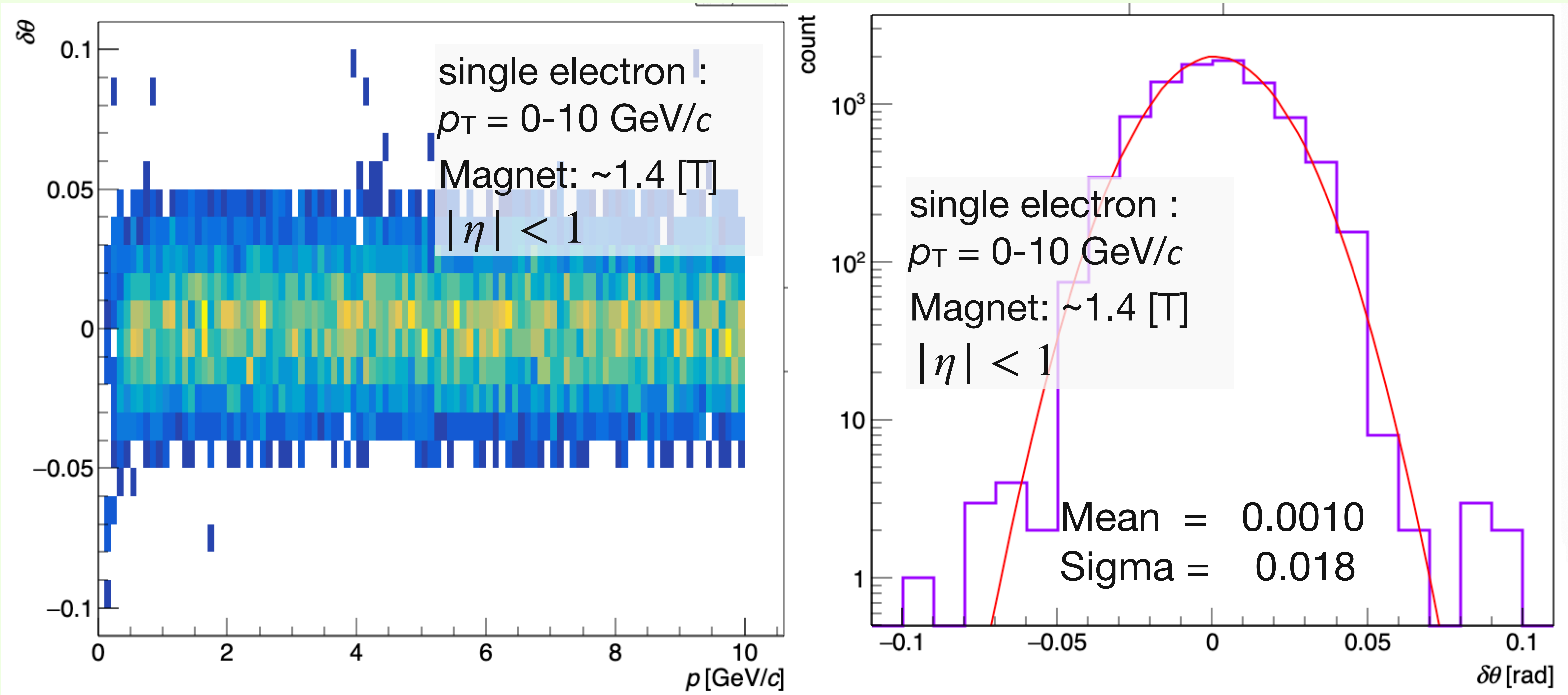


The fit function does not work well in low p_T region, and the peak also non-zero.
I have to check the fit function more.

dθ (reco - truth)



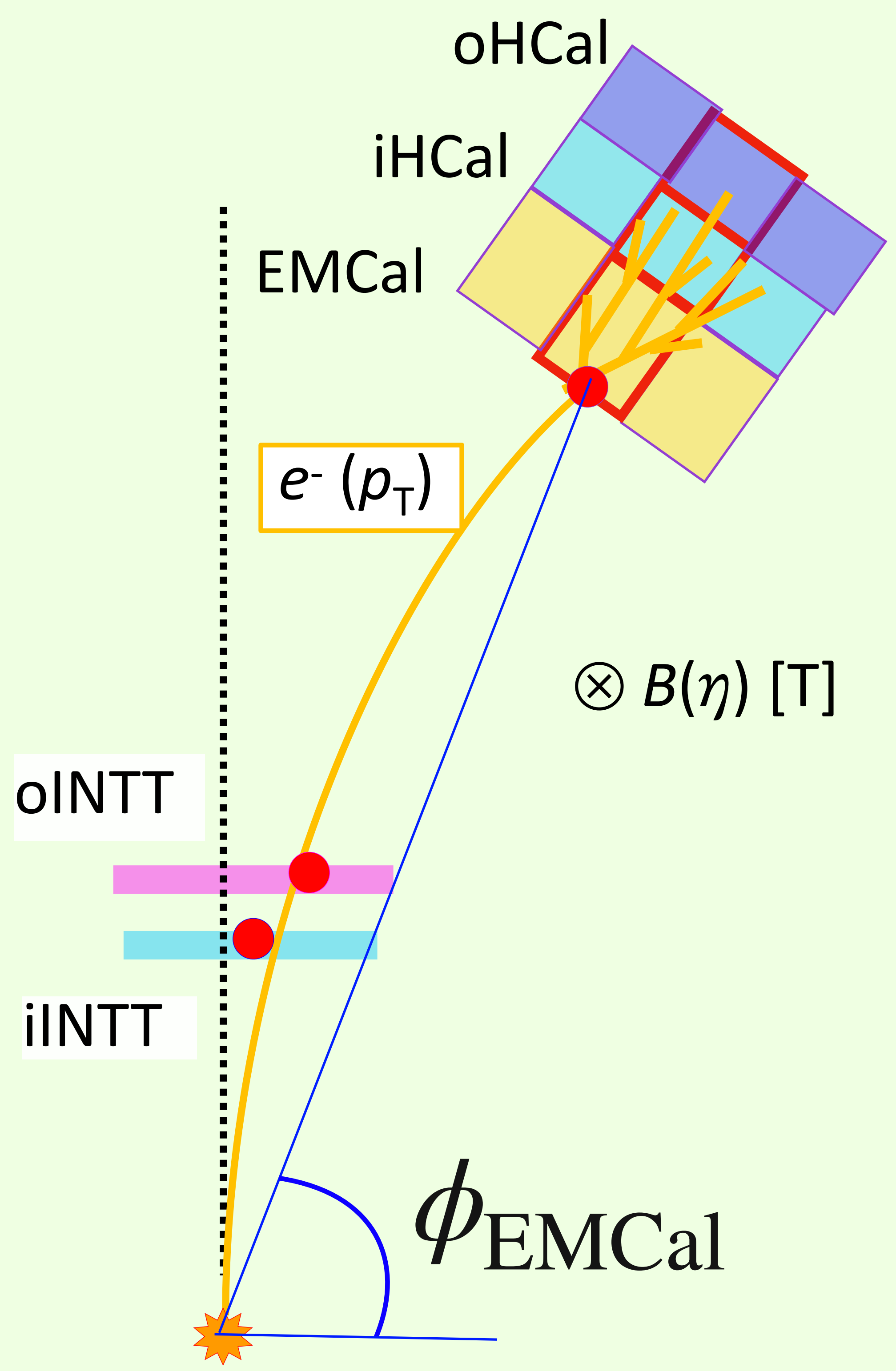
MVTX+iINTT+oINTT+EMCal

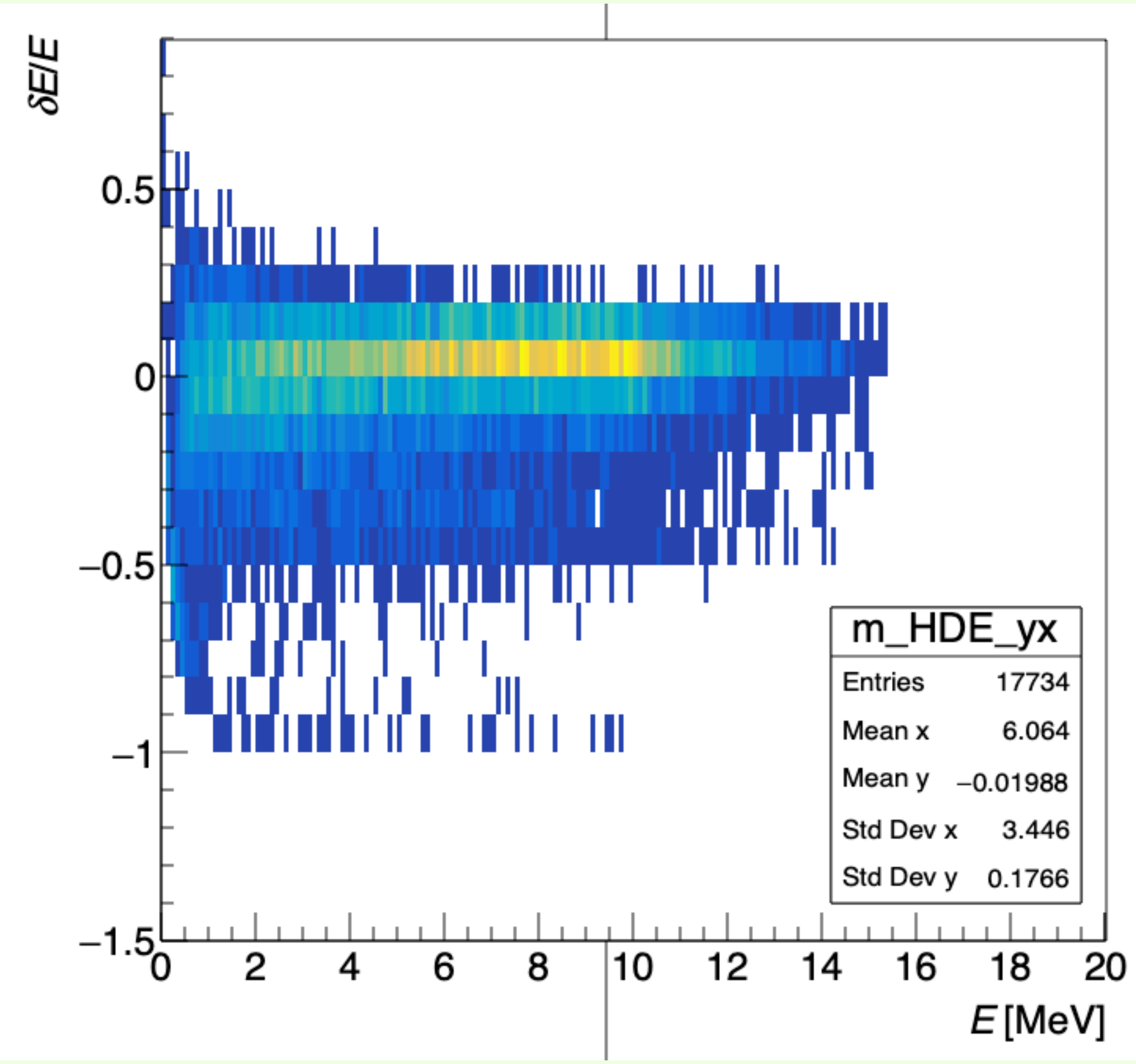


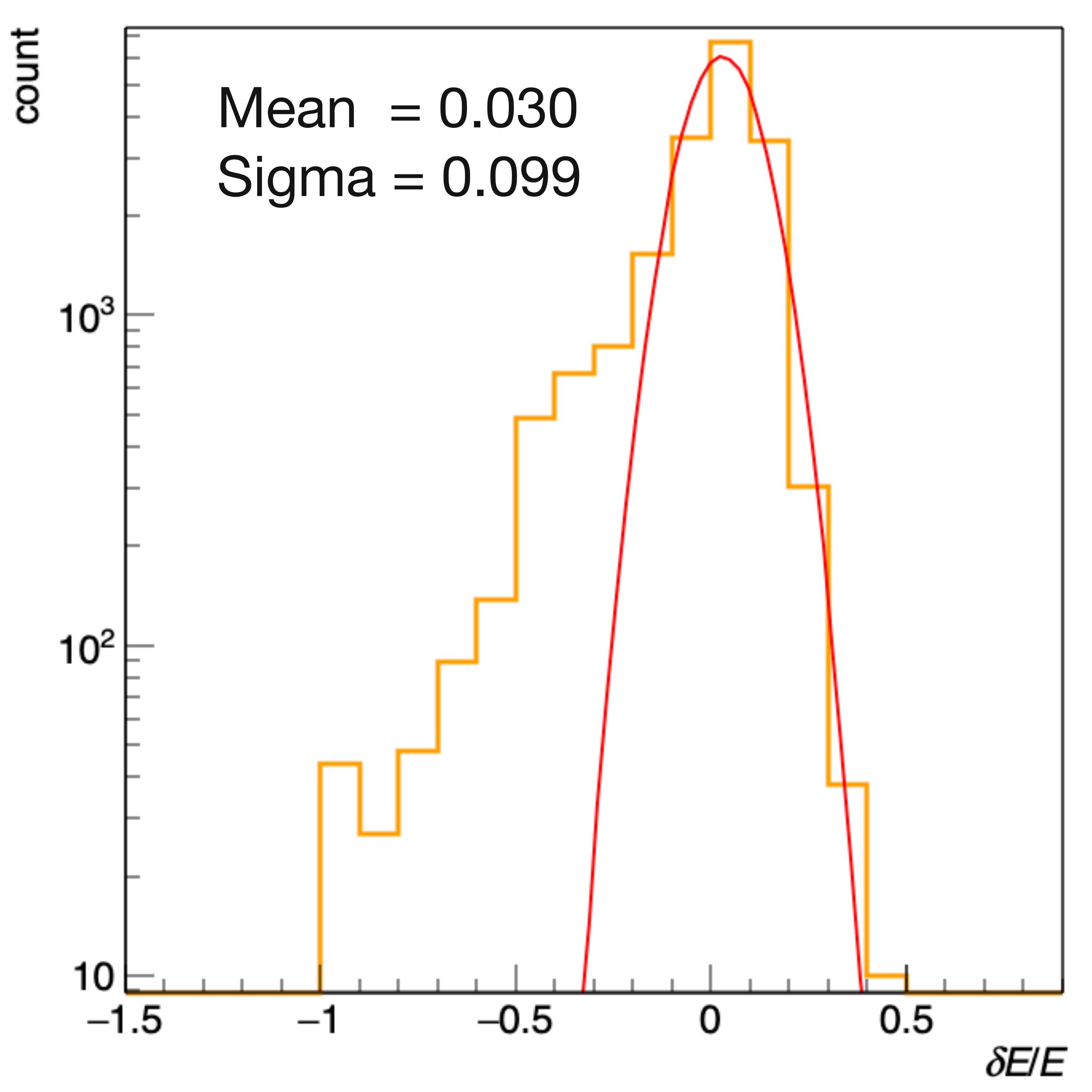
θ affect to the momentum calculation ($p = p_{\mathrm{T}}/\sin\theta$).
It is necessary to improve the quality using more sophisticated algorithm.

The track energy use the EMCal + iHCal + oHCal.

Only the HCal cluster which locate on the closest ϕ_{EMCal} is selected.







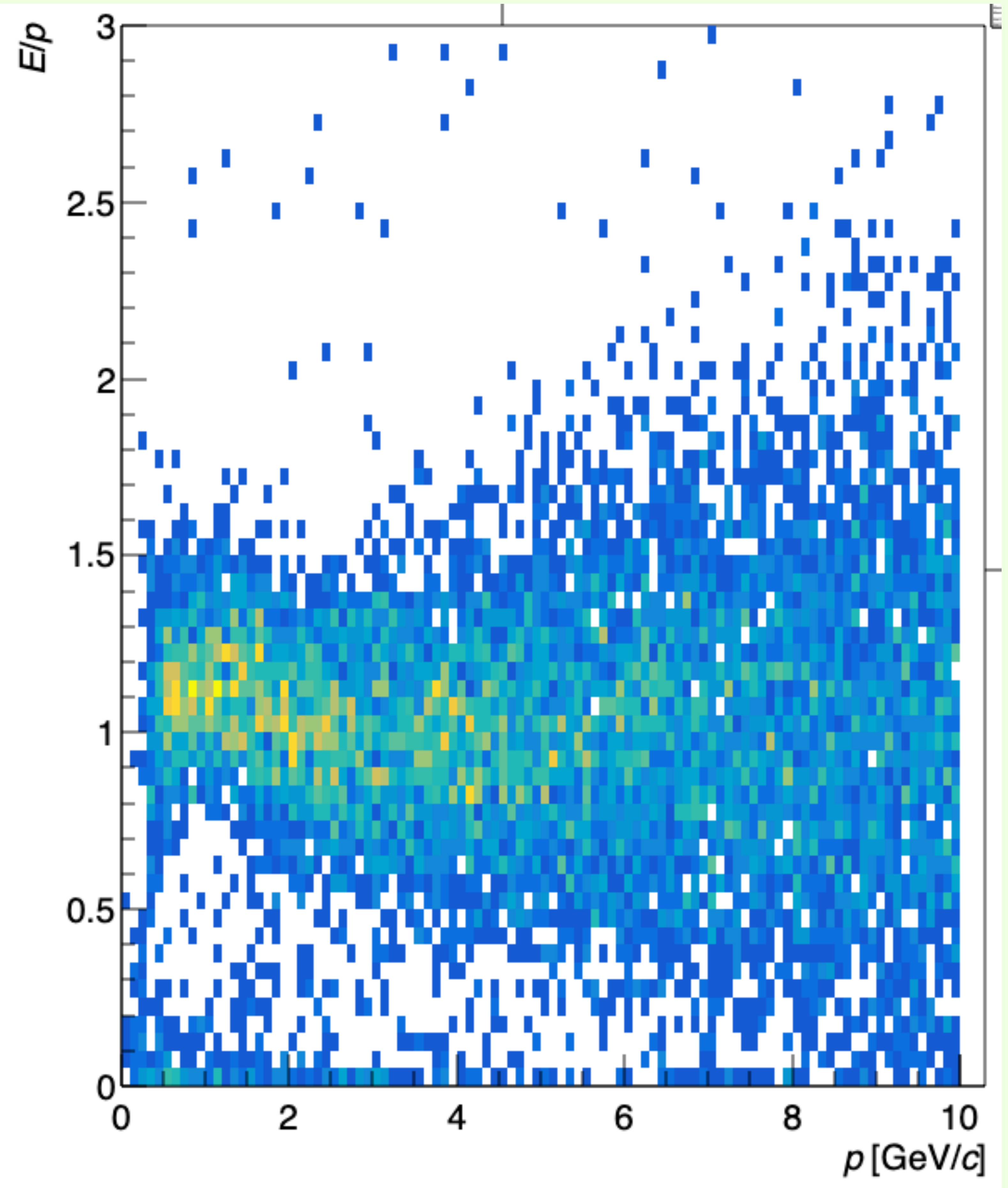
The $\delta E/E$ distribution has a long negative tail.

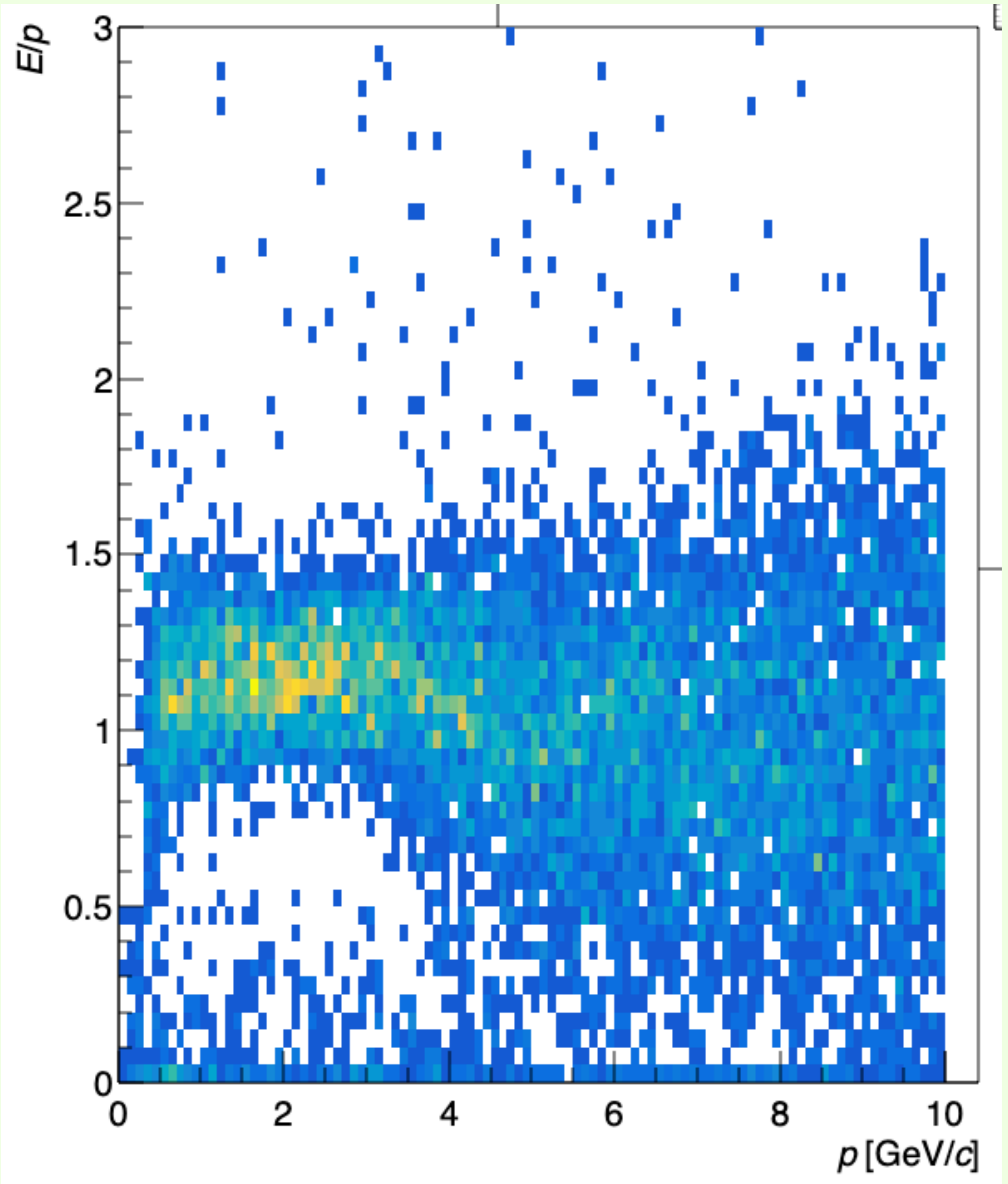
It is necessary to cluster or merge around calorimeter clusters or towers.

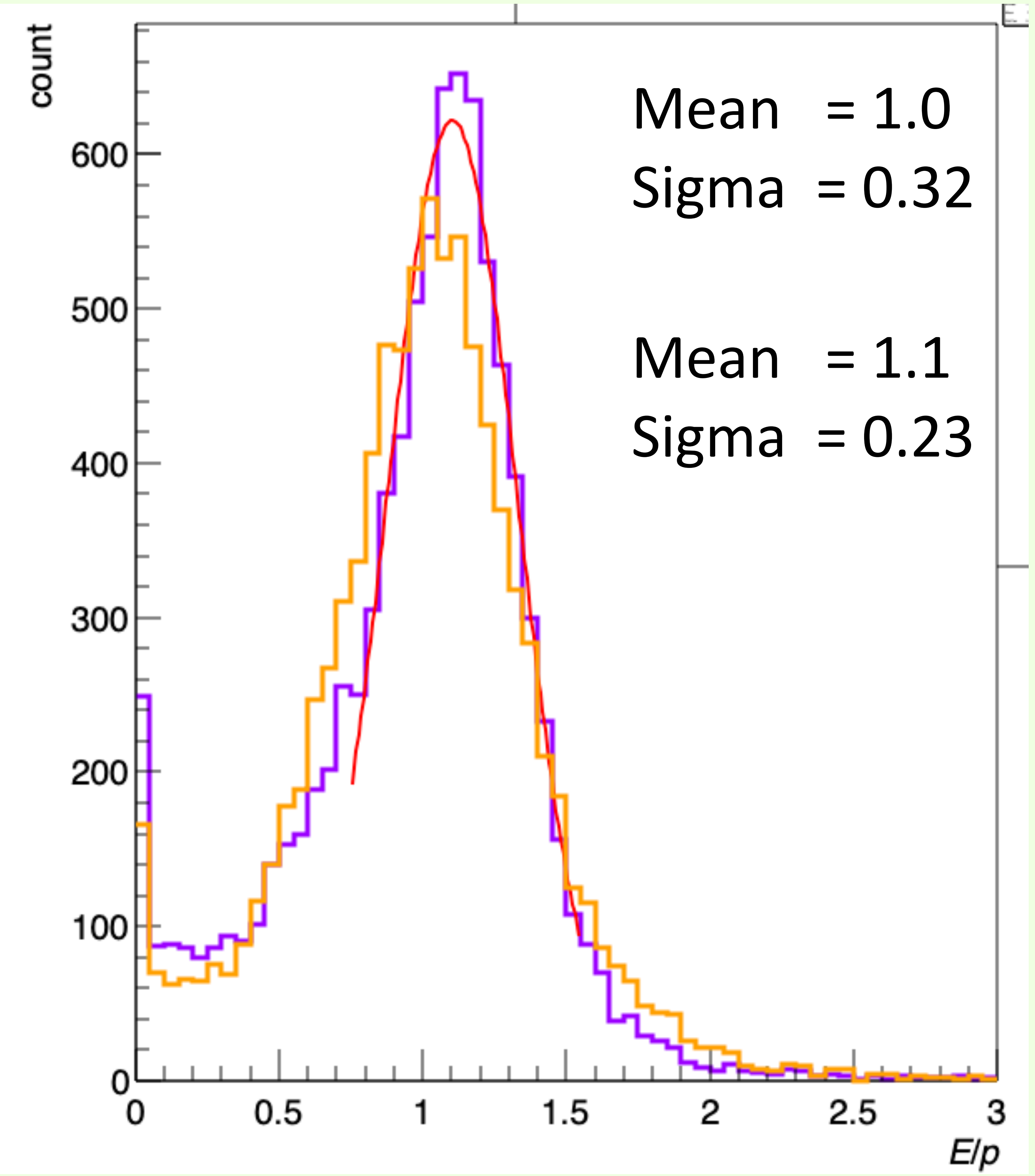
E/p

iINTT+oINTT+EMCal

MVTX+iINTT+oINTT+EMCal







The peak is expected around 1 in the electron case.

$$(E = \sqrt{m^2 + p^2}, \;\; m \ll p \;\to E = p)$$

Remain Tasks

Remanings

1. Implement a more sophisticated hit matching algorithm.
2. Study the calorimeter clustering algorithm.
3. Estimate tracking efficiency.
4. Run other particles simulation. (Hadrons)
5. Multi-particles simulation (ex: PYTHIA)

Tracking Fail Events Ratio

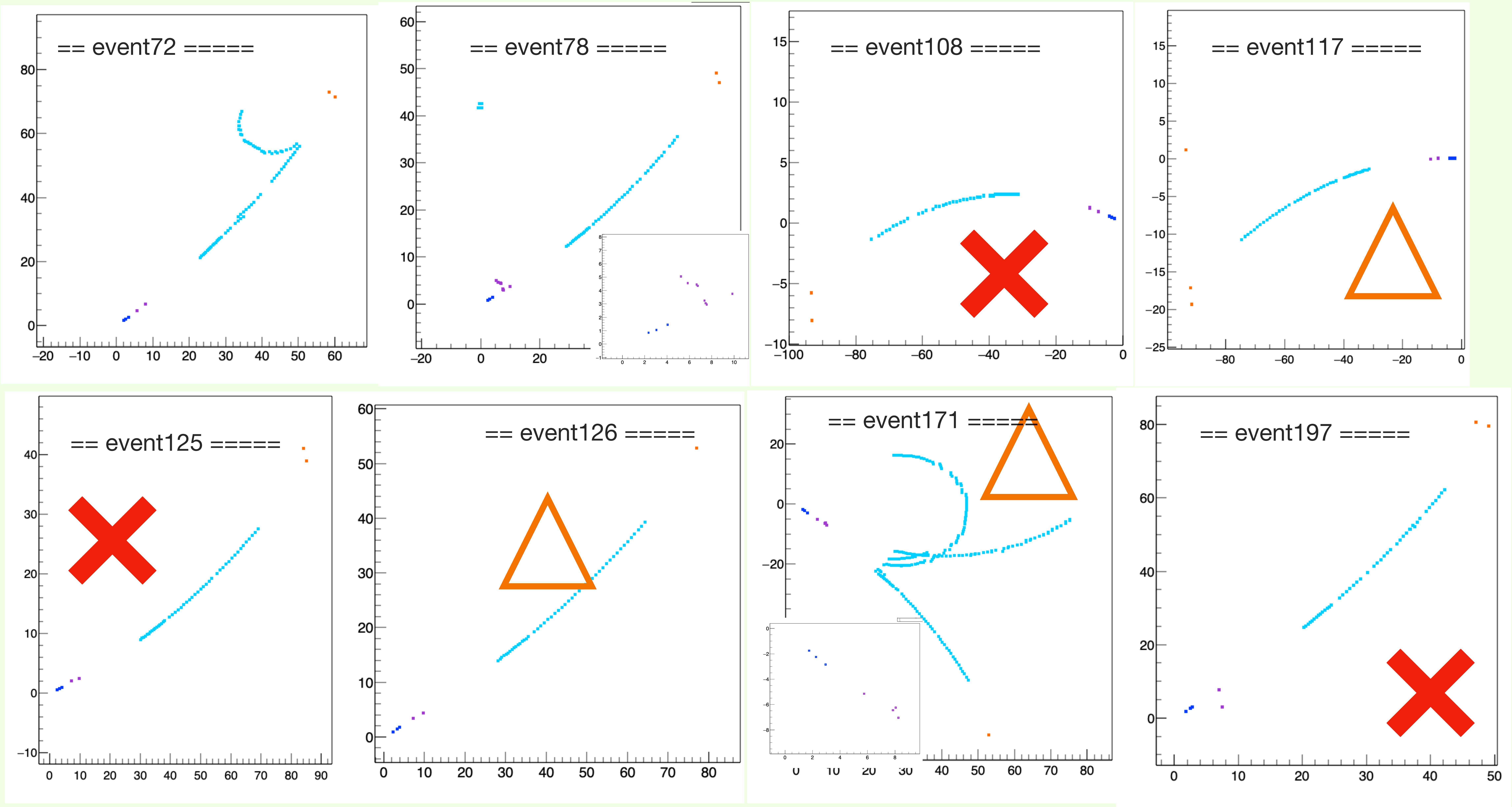
Event Ratio

(1) Only single INTT Cluster (only iINTT or oINTT): ~7%

(2) Matching fail by the algorithm reason: ~2%

(3) Large p_T tracking: ~8% (by mostly decayed events)

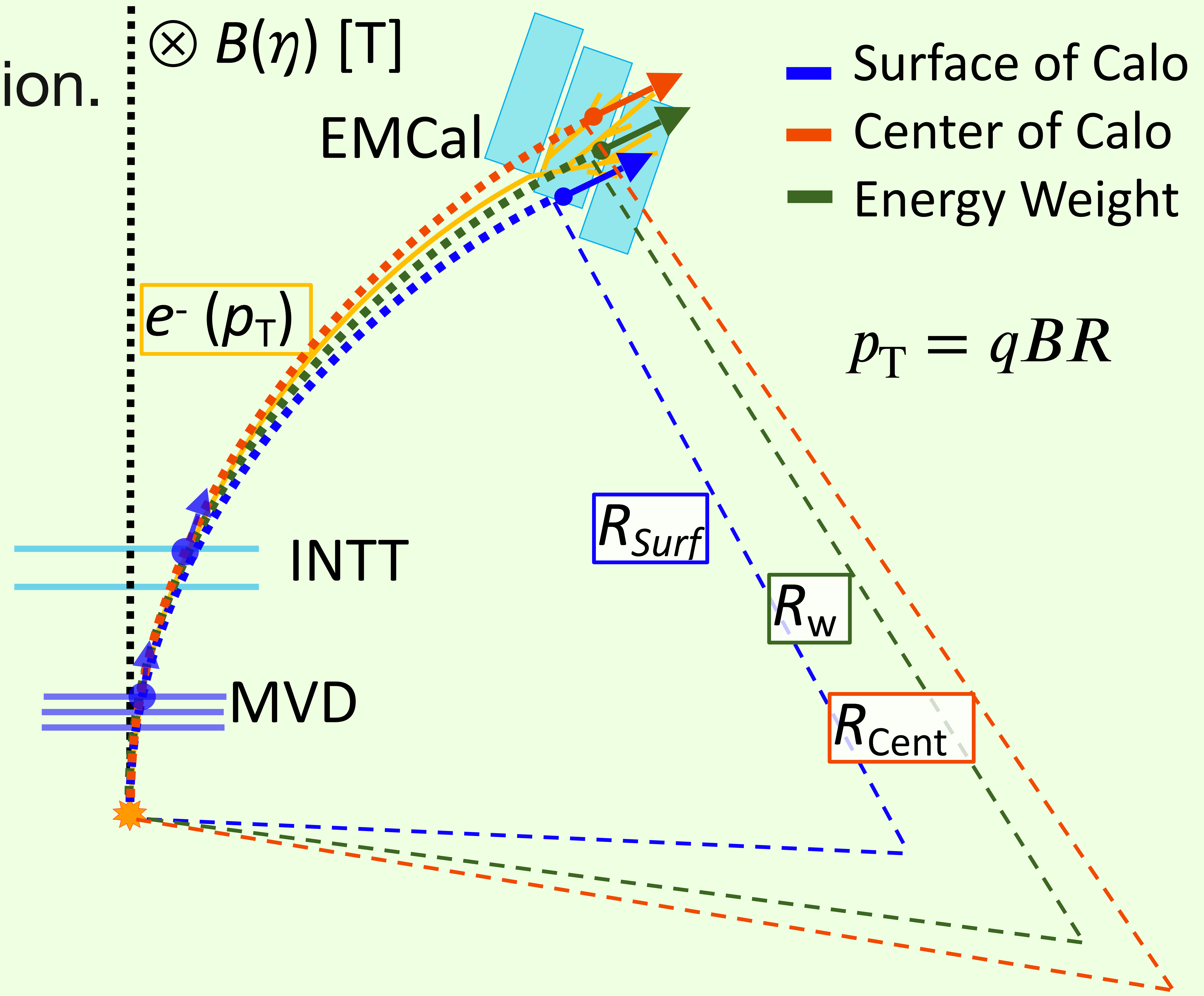
(2) Fail Track Event Display Examples (~20%)



(3) Large dpT Events Examples (~8%)

Clastering way and the postion is very sensitive for the p_T estimation.

→ Need to modify clustering or shift position.



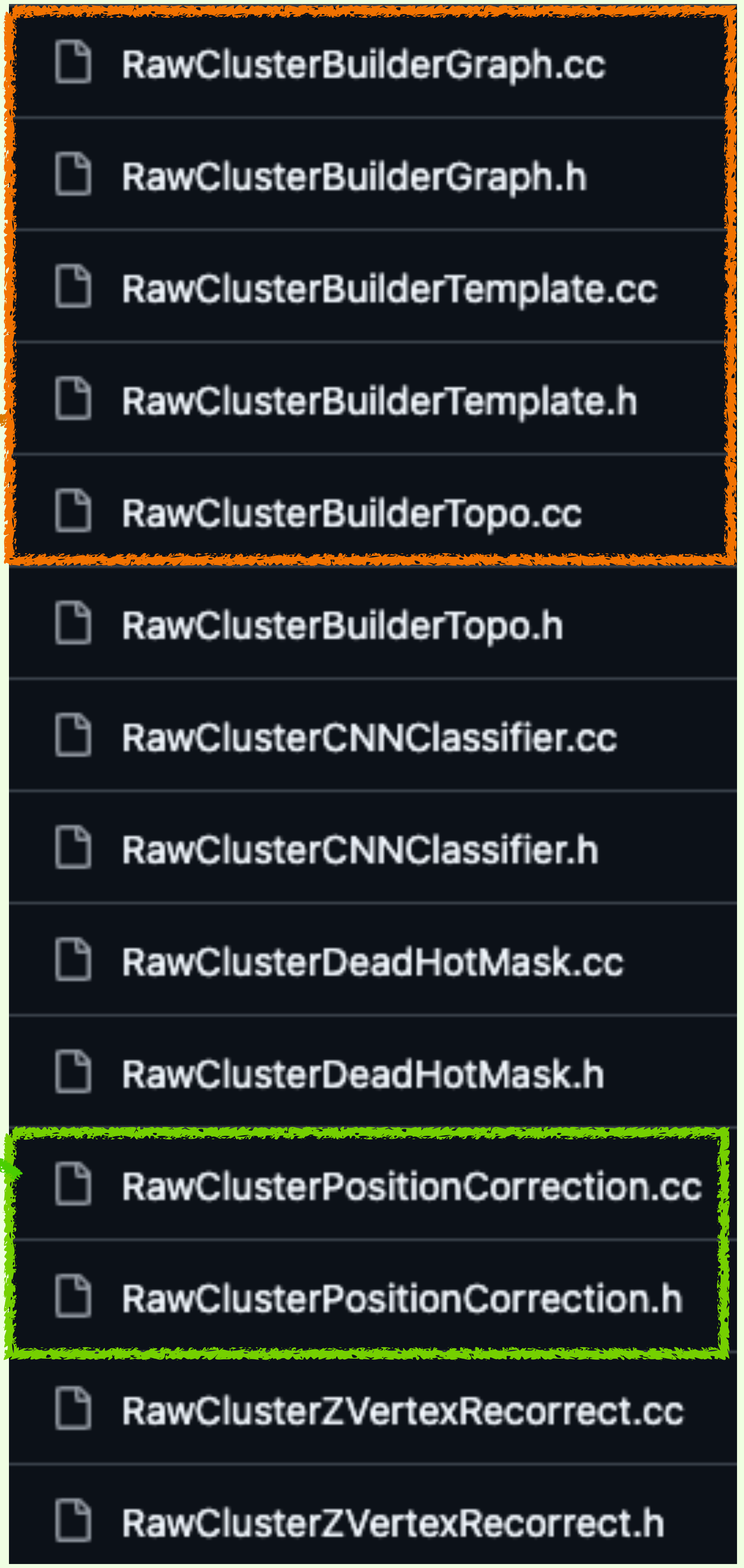
Calorimeter Clustering code

RawClusterContainer (← Now I am using):
https://sphenix-collaboration.github.io/doxygen/d6/d12/classRawClusterContainer.html

RawCluster:
https://sphenix-collaboration.github.io/doxygen/d2/d4e/classRawCluster.html

I think the algorithm making calorimeter cluster is written in the "ClusterBuilder" source codes .
However, there are three codes having the name "ClusterBuilder"…

The RawClusterPositionCorrection seems important for tracking…
However, I have not yet read it.



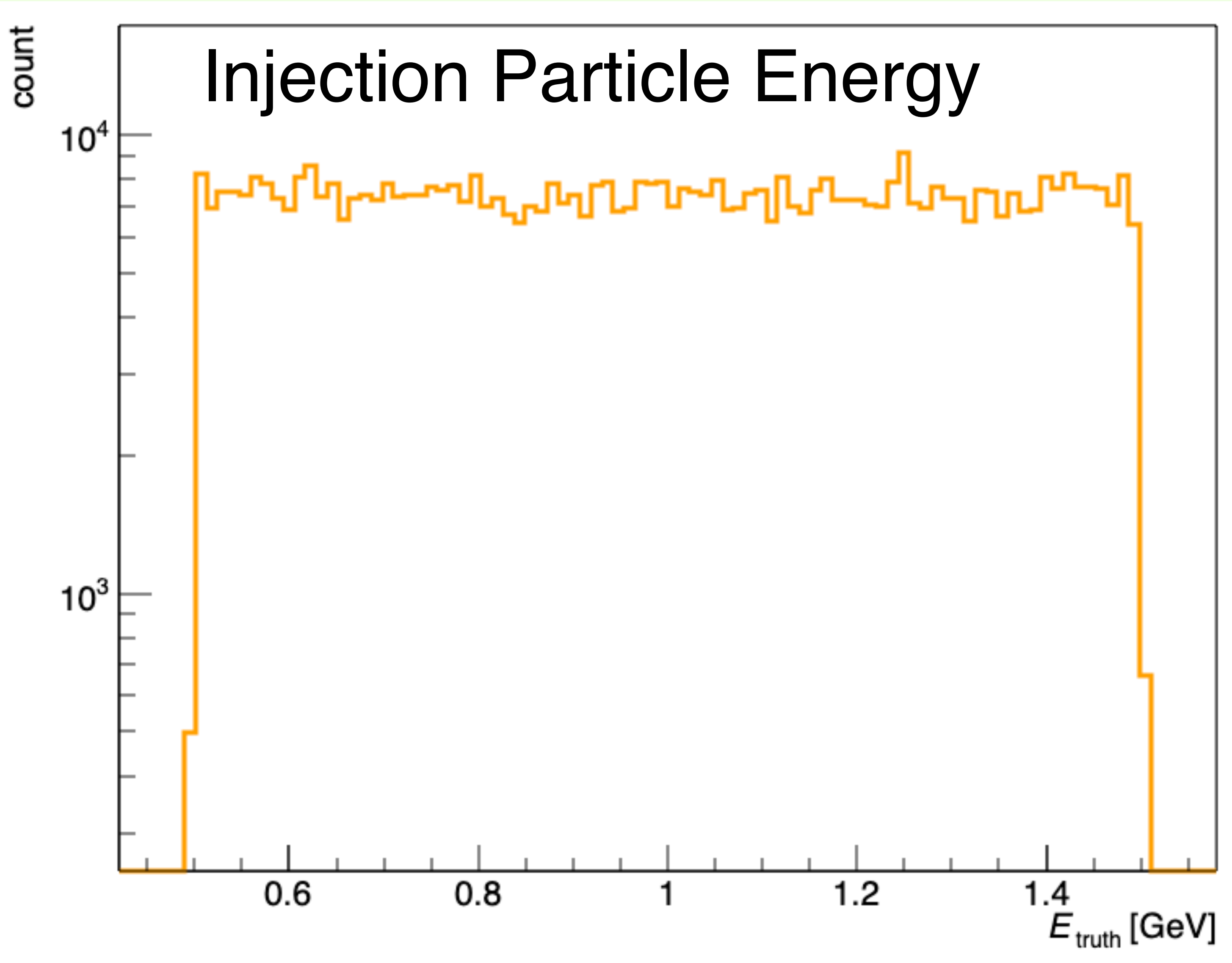
https://github.com/sPHENIX-Collaboration/coresoftware/tree/02804b5a691b92395e4aae83726ae2c04979c0e2/offline/packages/CaloReco

Compare between EMCal Tower and Cluster

Single electron generator simulation

injection p_T: 0.5-1.5 [GeV/c]

$\eta = 0, |\phi| < \pi$



Calorimeter Tower

("TOWERINFO_CALIB_CEMC")

<TowerInfo>

Calorimeter Cluster

("CLUSTER_CEMC")

<RawCluster>