STCF ITKW mTPC

Jiajun Tang

University of Science and Technology of China

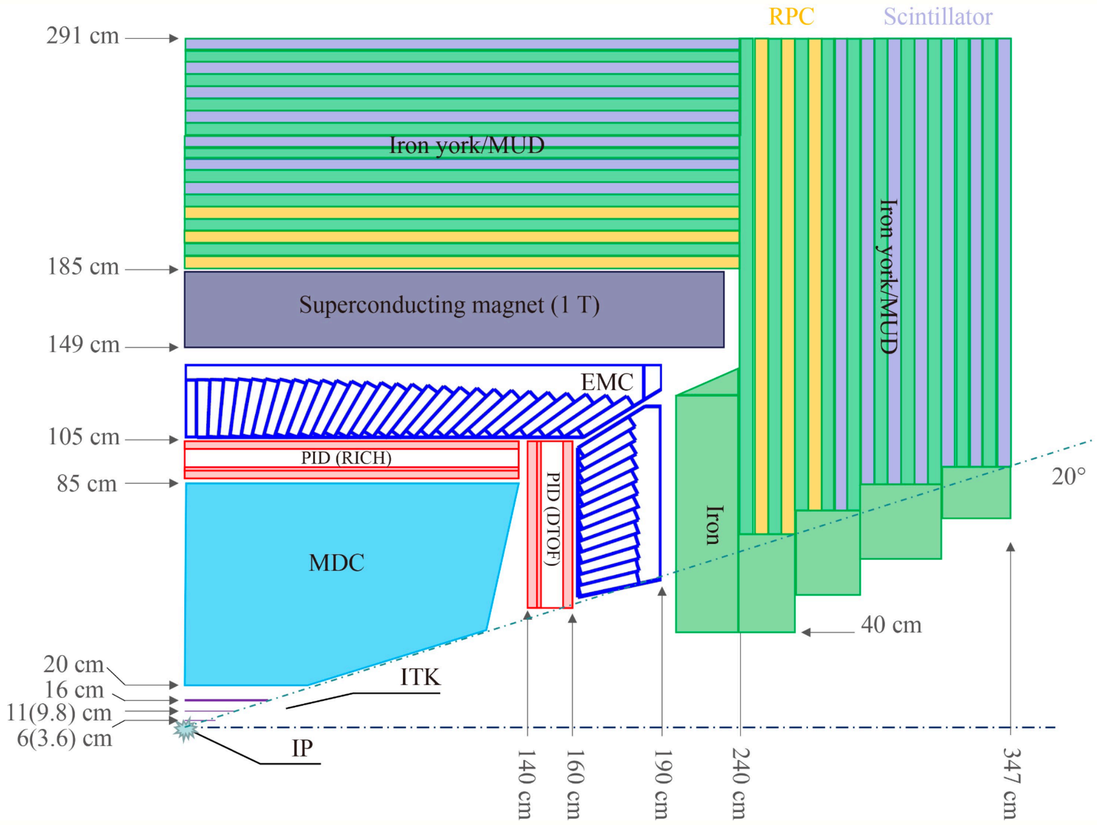
July 23, 2025

Outline

- Geometry
- Digitization & Clustering
- Reconstruction correction
- Summary

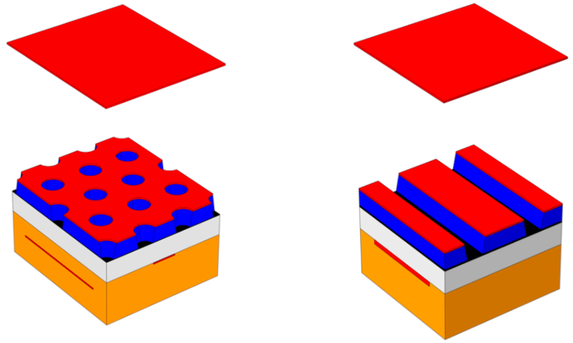
Geometry

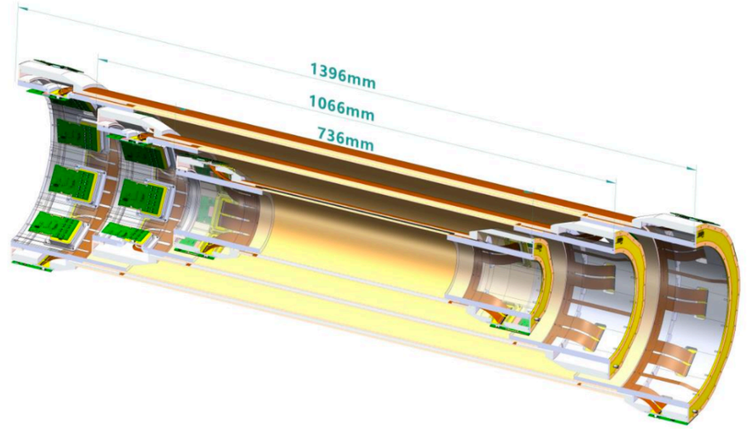
muRGroove on STCF



MPGD-based ITK

µRWELL → µRGroove

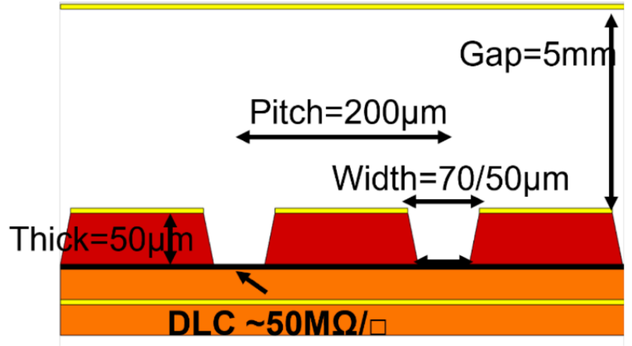




three cylindrical detector layers

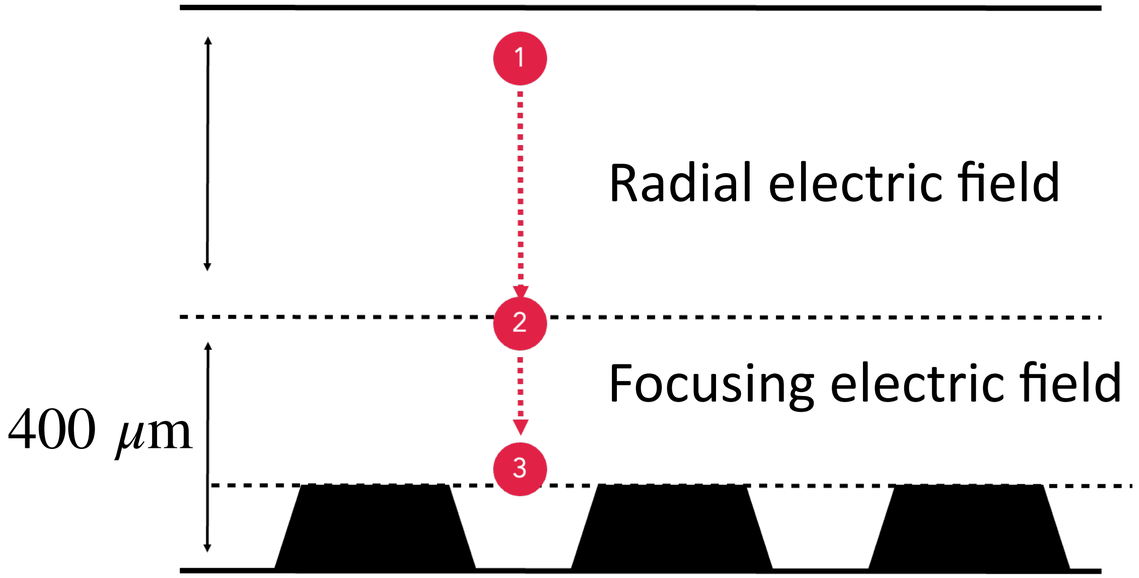
covering polar angle: $20^\circ - 160^\circ$

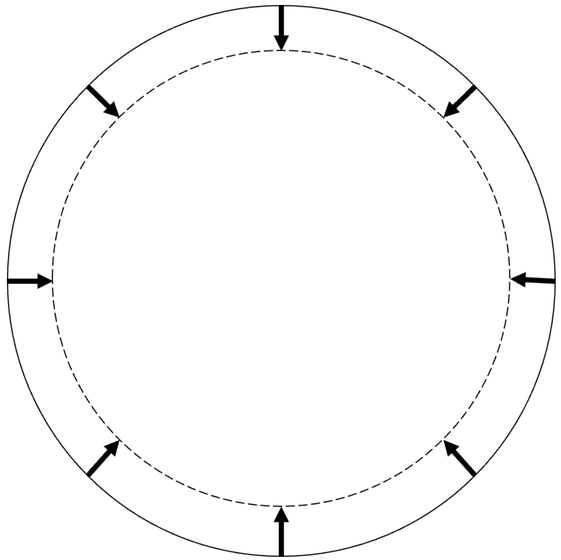
Ar-based gas ($Ar:CF_4:CO_2$/45:40:15)

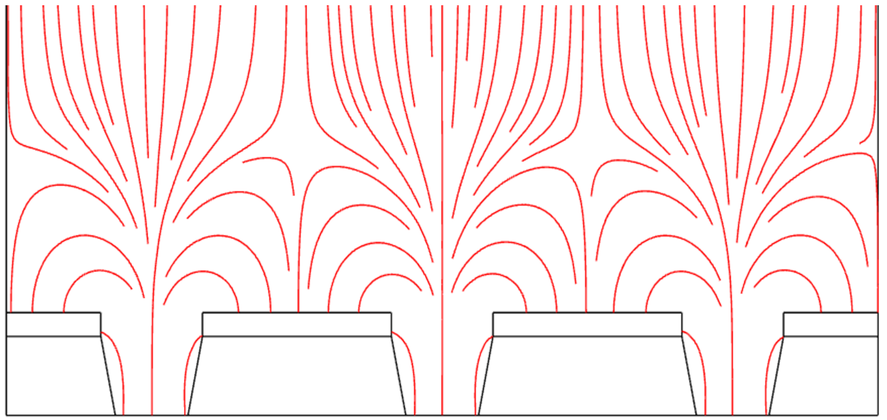


Digitization & Clustering

Digitization — Electric field







Digitization

★: Primary ionization

↘: drift in EM field (T_i) — drift time, relative position within groove

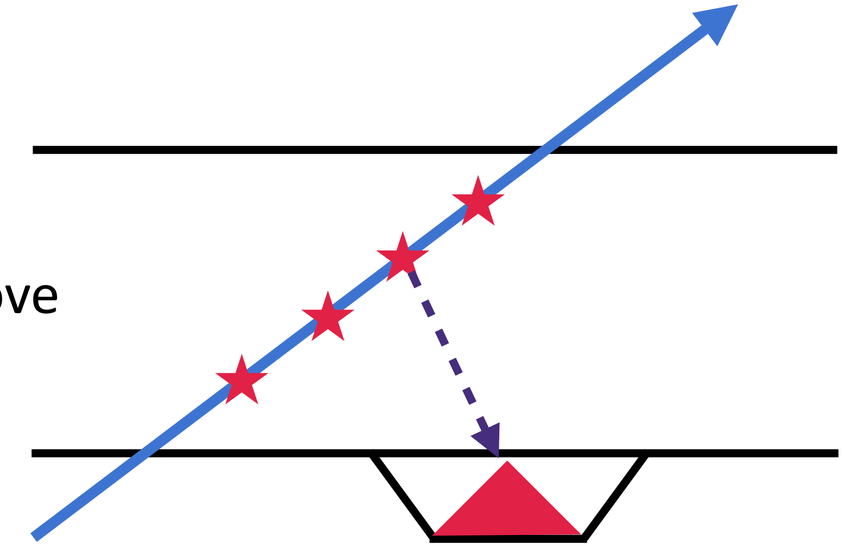
(magnet, gas, voltage, velocity, diffusion …)

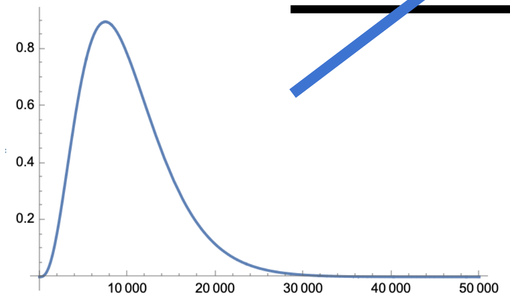
▲: avalanche — polya distribution

sensing signal (Q_i) — electronics response function

wave amplitude, time to peak

Superimposed single-electron waveform → Threshold-crossing time

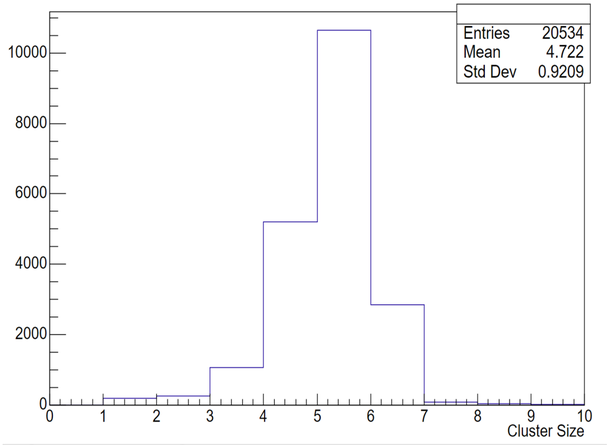




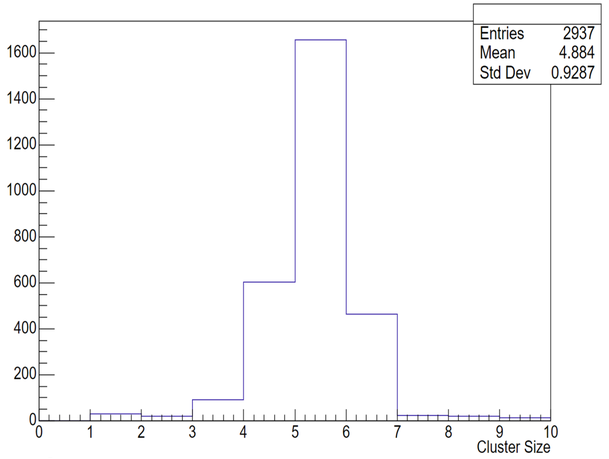
Digitization

Compare with experiment

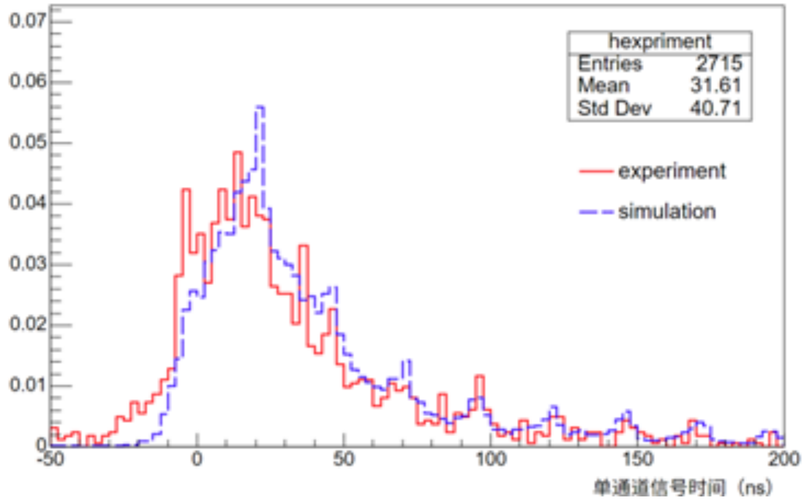
Digitization



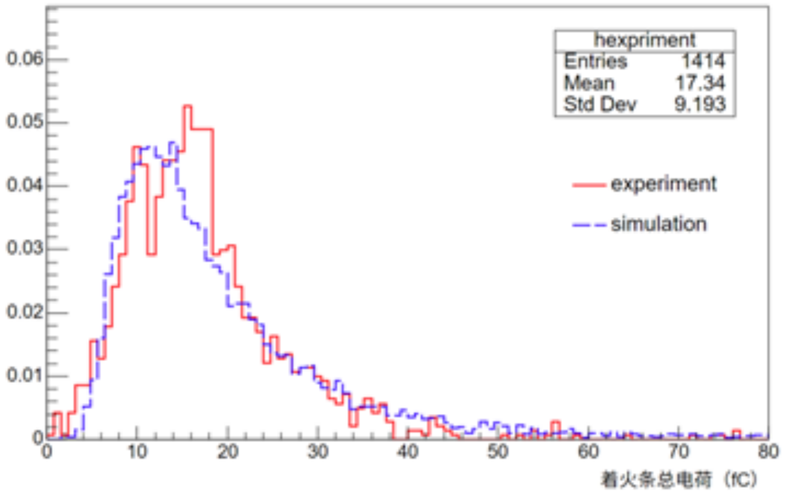
Beam test



Single channel signal time



Fired strips charge



Clustering

Pack up digits into clusters

Before:

continuous group of digits(one break point is allowed)

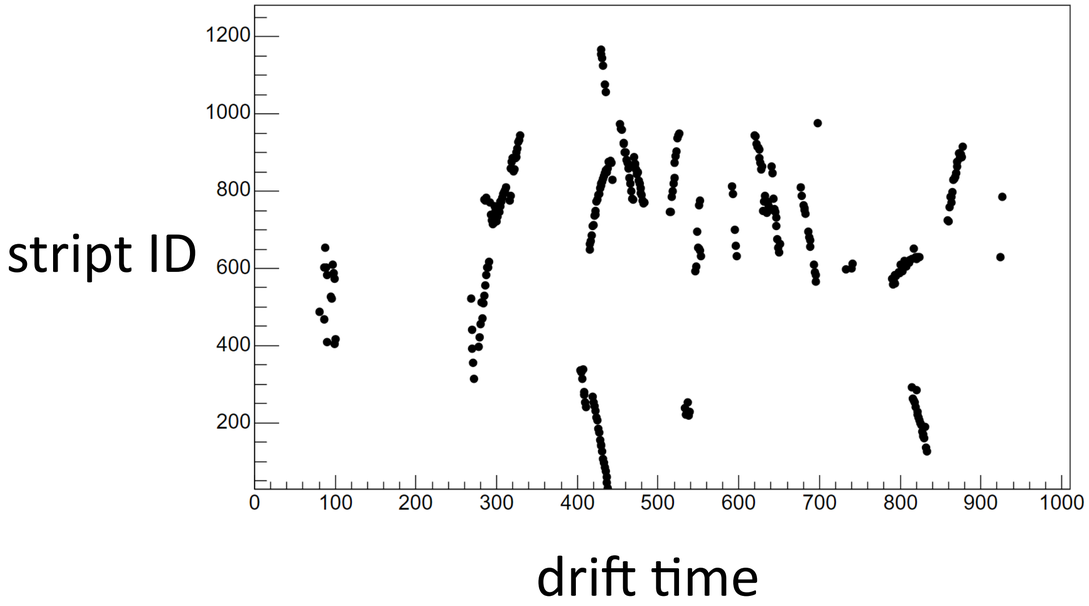
Updated:

two break points are allowed

within 350 ns

signal over threshold (1 fC)

time monotonicity (less than 100 ns per strip)

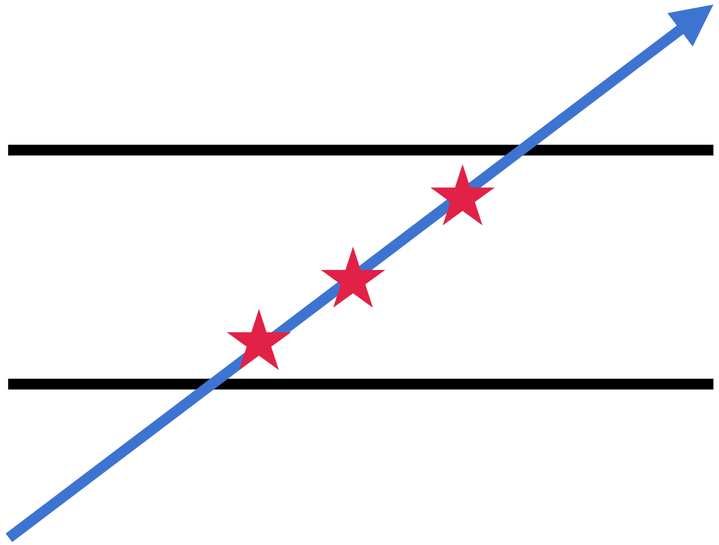


Rec efficiency(%):

(87.42, 95.18, 96.31) → (90.50, 97.51, 98.25)

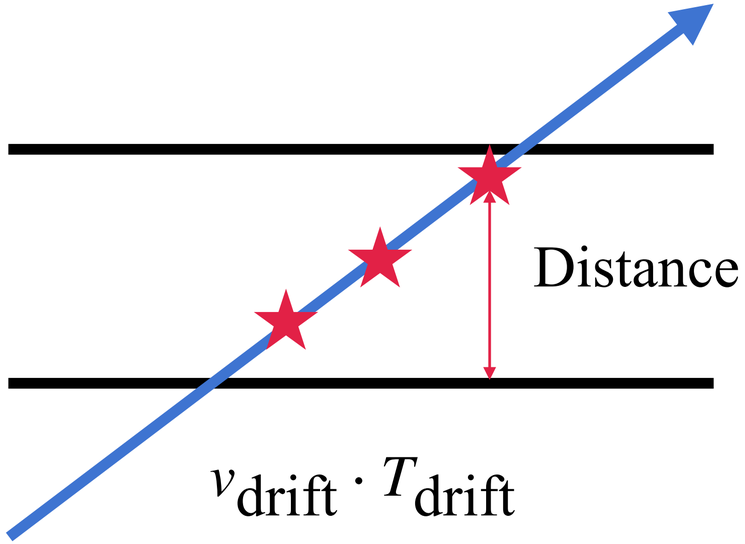
Reconstruction correction

Charge center

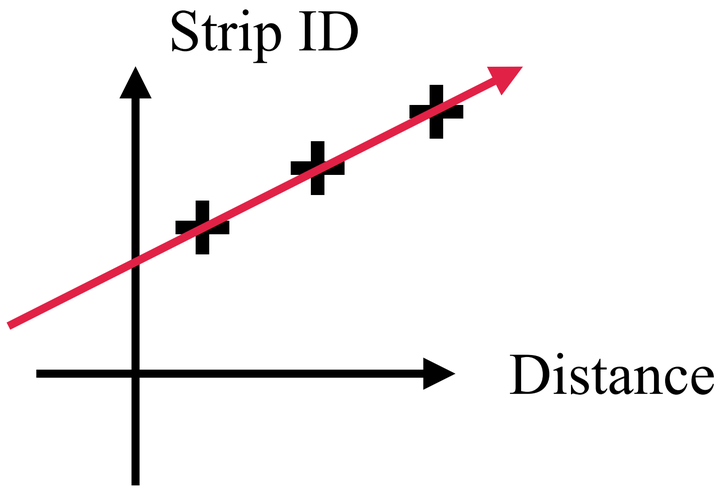


$$\mathrm{Pos} = \frac{\Sigma_i X_i Q_i}{\Sigma_i Q_i}$$

Micro TPC



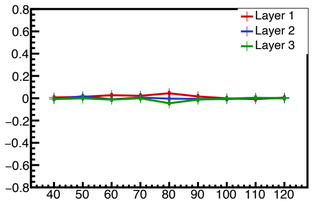
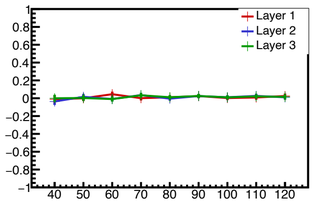
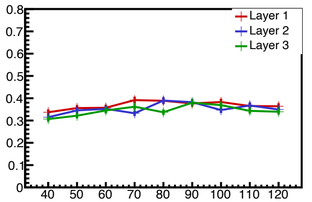
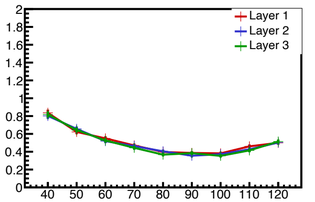
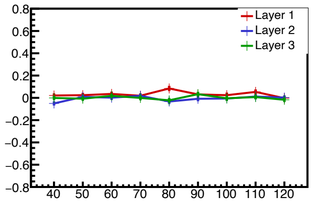
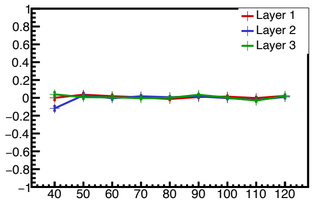
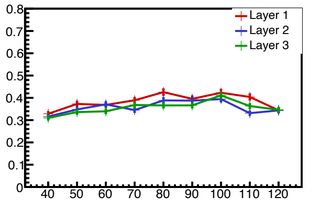
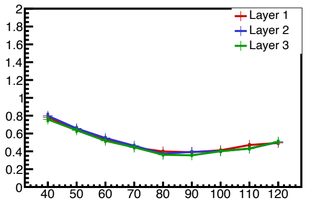
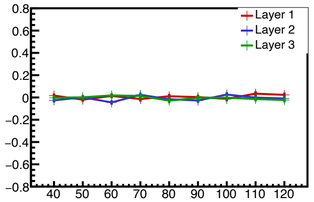
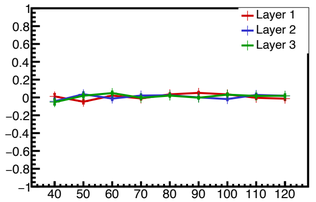
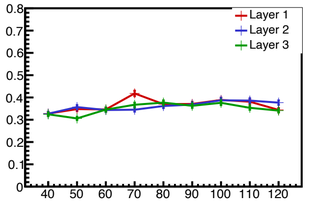
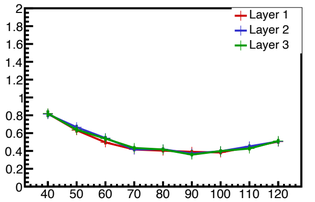
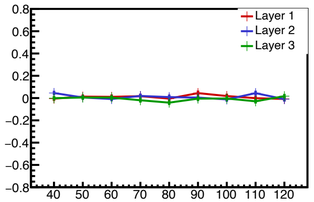
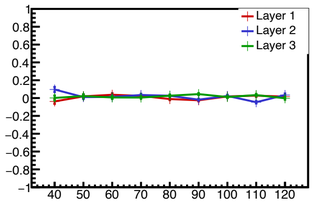
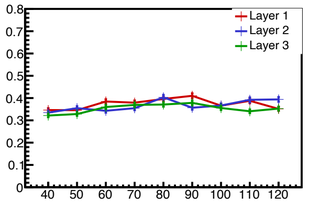
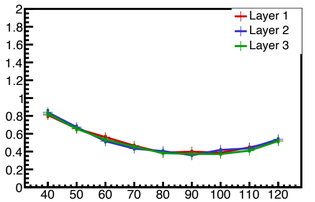
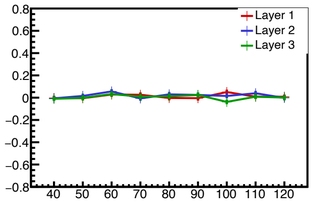
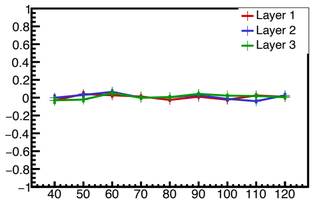
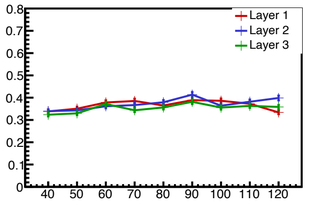
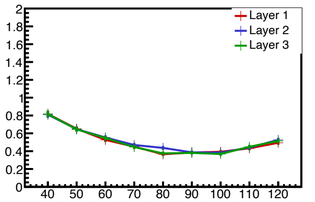
$$v_{\mathrm{drift}} \cdot T_{\mathrm{drift}}$$



$$\mathrm{Pos} = \mathrm{ID}\big|_{\mathrm{D=2.5mm}}$$

Charge center

Performance

	$\Delta R\phi$	ΔZ	$\sigma_{R\phi}$	σ_Z
500 MeV				
600				
700				
800				
900				

no deviation

but large resolution

Micro TPC

Drift velocity

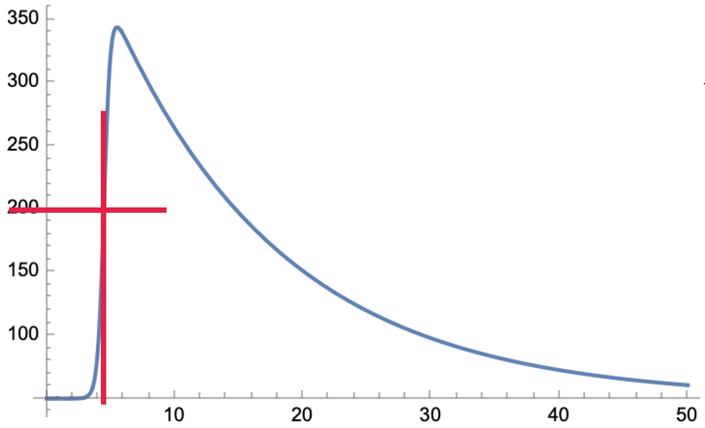
$$R(t) = A + \frac{B \cdot e^{-C(x-D)}}{1 + e^{-(x-E)/F}}$$

$$R'(t)\,|_{t=T_x} = 0 \rightarrow T_x = E - F \ln \frac{CF}{1 - CF}$$

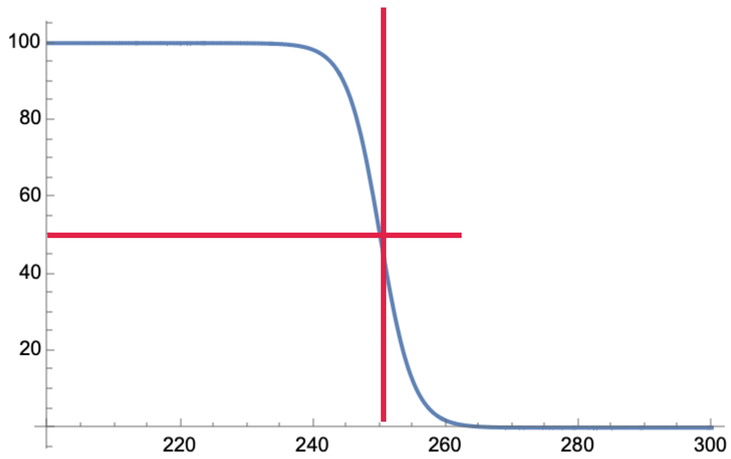
$$T_{min} = R^{-1}(\frac{R(T_x)}{2})$$

$$F(t) = A + \frac{A}{1 + e^{-(x-B)/C}}$$

$$T_{max} = B$$



T_{min}



T_{max}

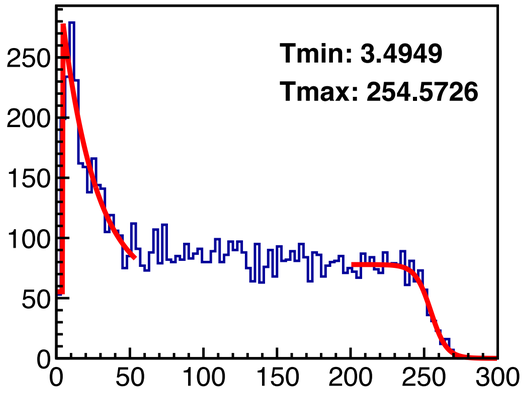
$$D = \frac{t - T_{min}}{T_{max} - T_{min}} \cdot 5\text{mm}$$

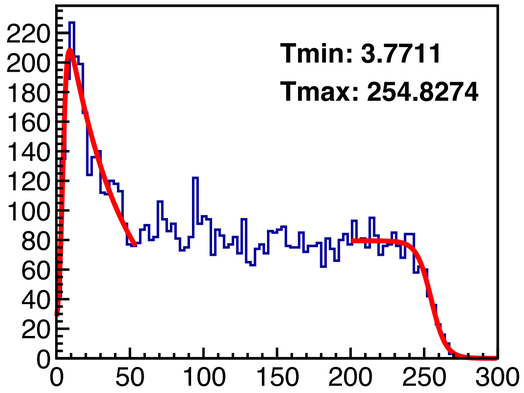
Micro TPC

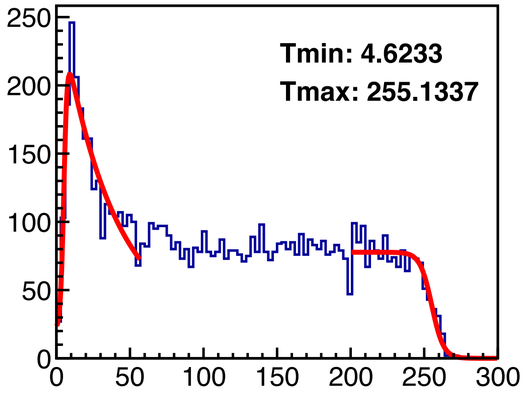
Drift velocity

Layer1 Layer2 Layer3

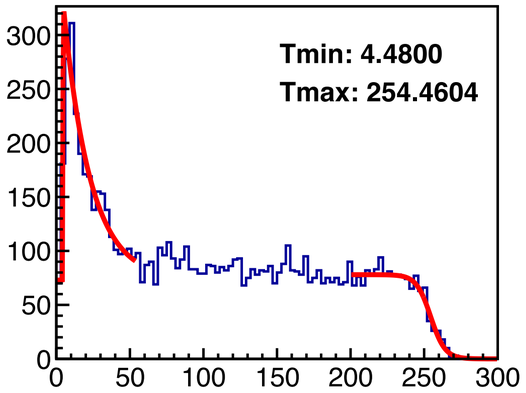
X strip

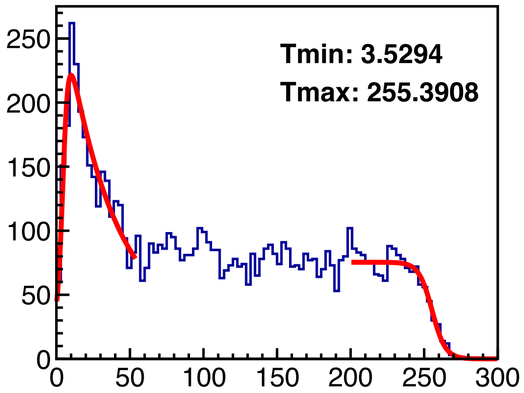


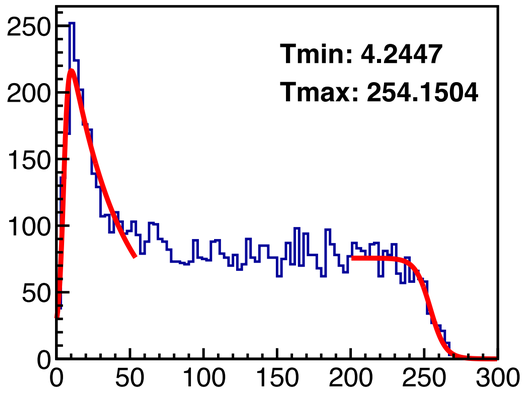




V strip





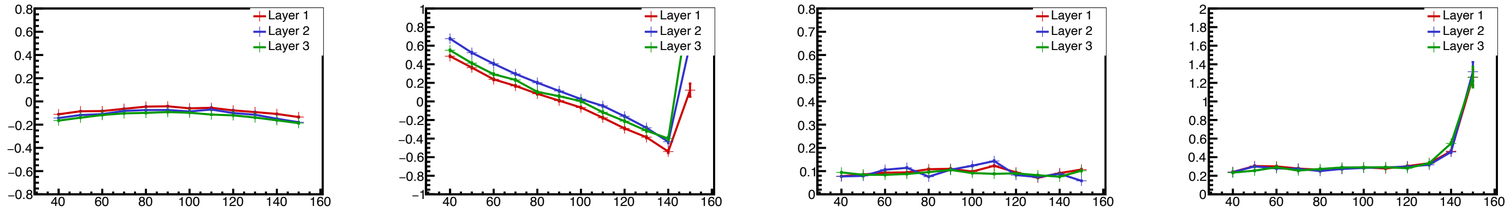


Micro TPC

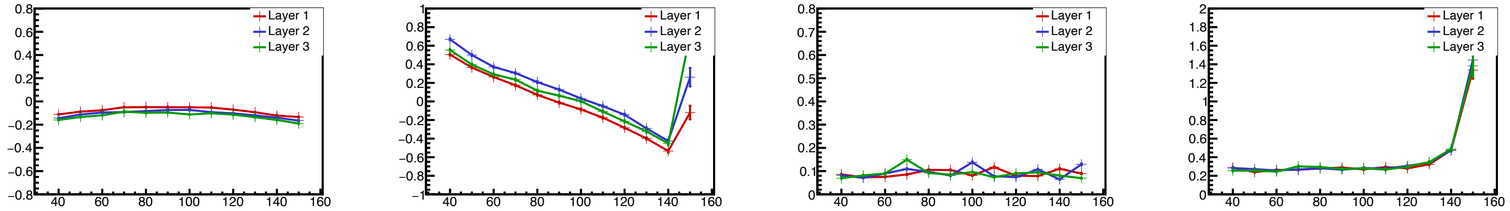
Performance

$\Delta R\phi$ ΔZ $\sigma_{R\phi}$ σ_Z

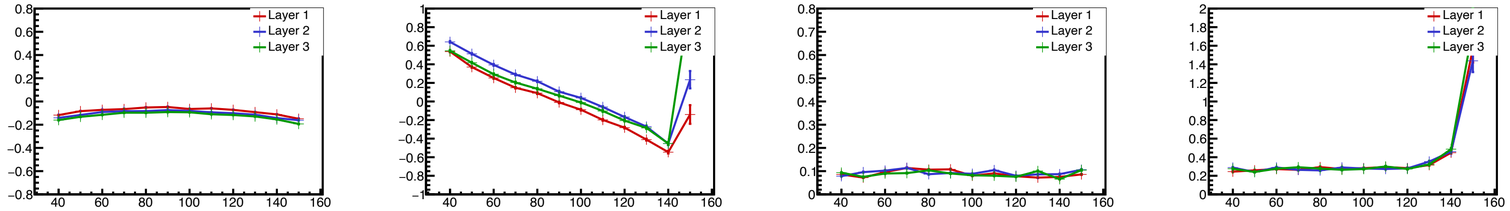
500 MeV



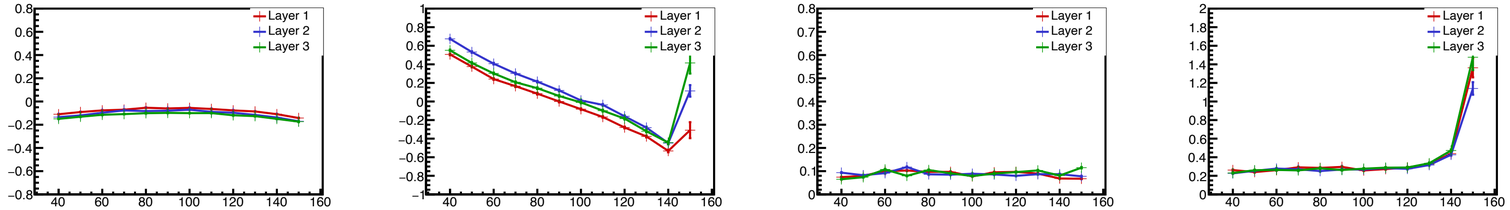
600



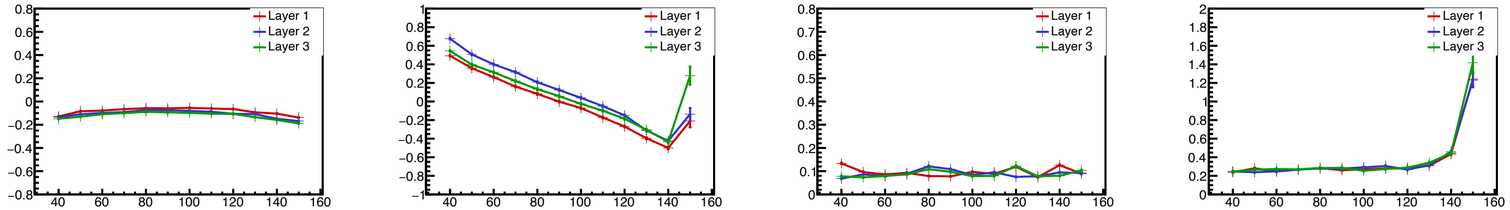
700



800



900



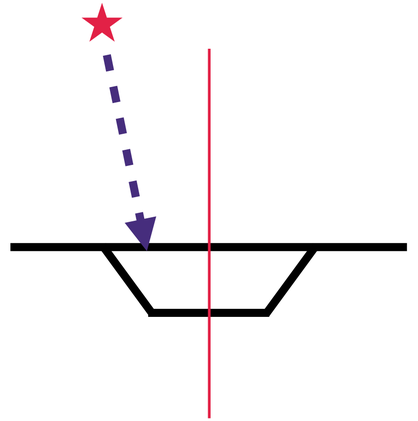
large deviation

mTPC correction

★: reach point is not the center of the strip

if N_e original ionization,

the T_{drift} is determined by the first one



Source of deviation

Inaccurate estimation of drift time & drift velocity

Time advance caused by multiple signals collected by one strip

Each step of digitization may bring deviation

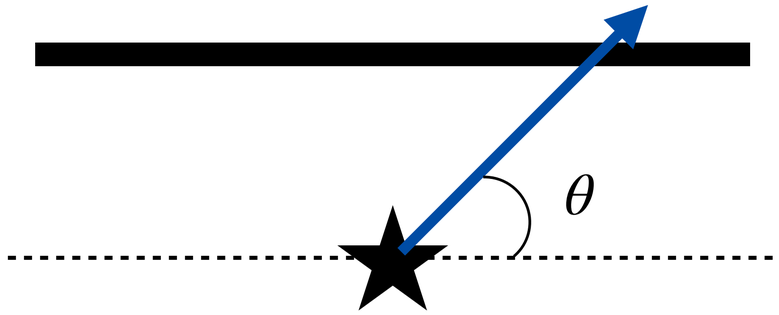
……

Temporary solution

Data (MC) driven method:

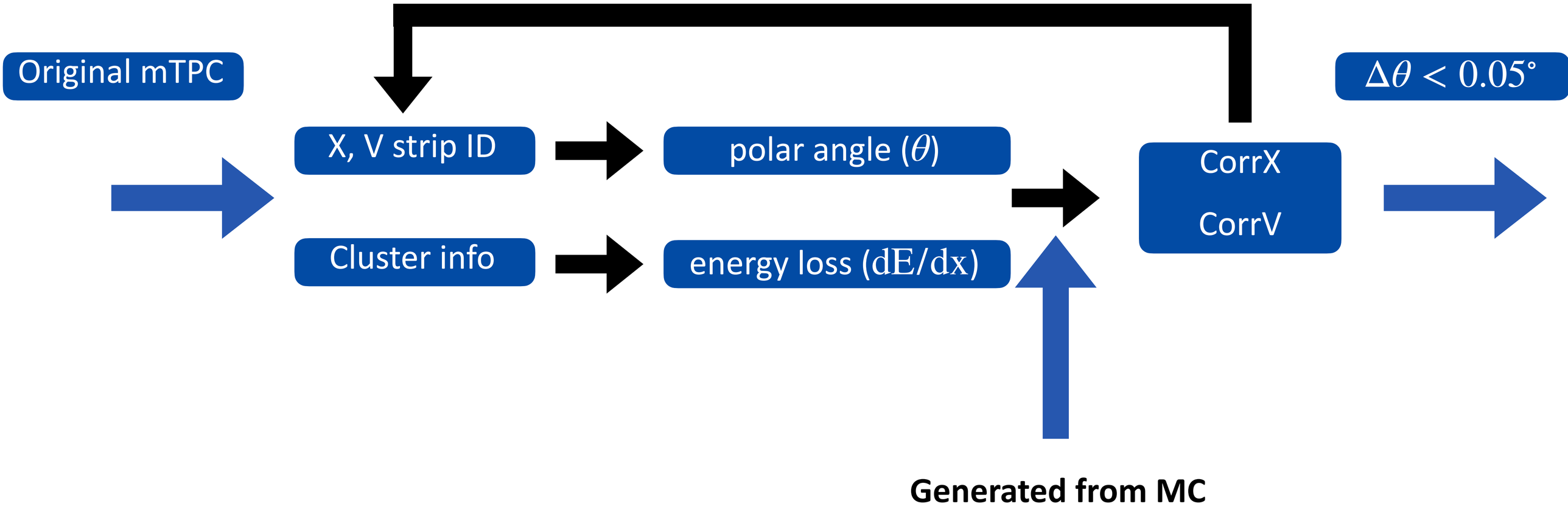
Get a set of correction matrix based on

different momentum, polar angle, particle type



mTPC correction

Correction flow



mTPC correction

Standard MC

5 types of particles e, μ, π, K, p

momentum range from $250\ \mathrm{MeV}$ to $700\ \mathrm{MeV}$

covering polar angle from 20° to 160°

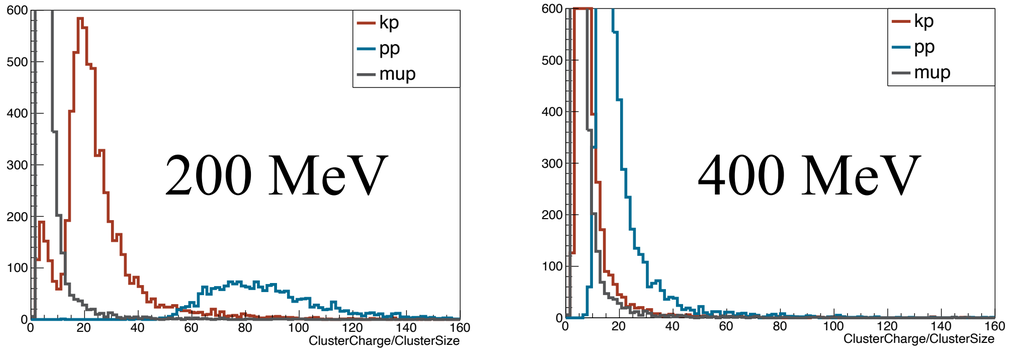
no correction is applied

Correction matrix

compare with MC truth to calculate **CorrX** & **CorrV**

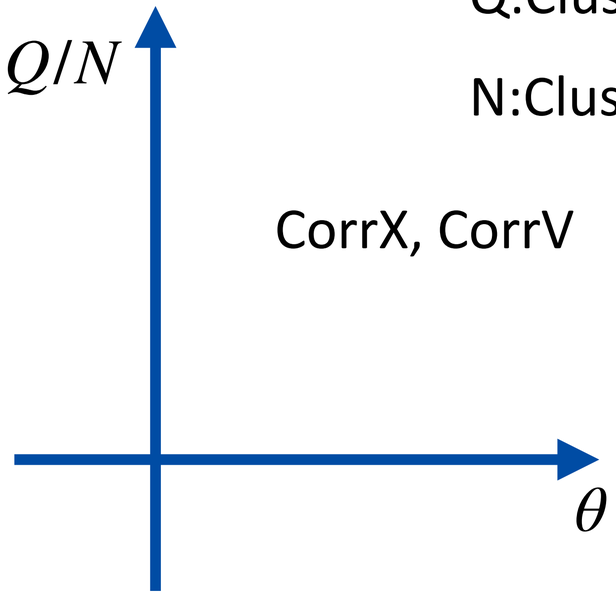
energy loss is estimated by Q/N

Q/N distribution



Q:Cluster charge

N:Cluster range

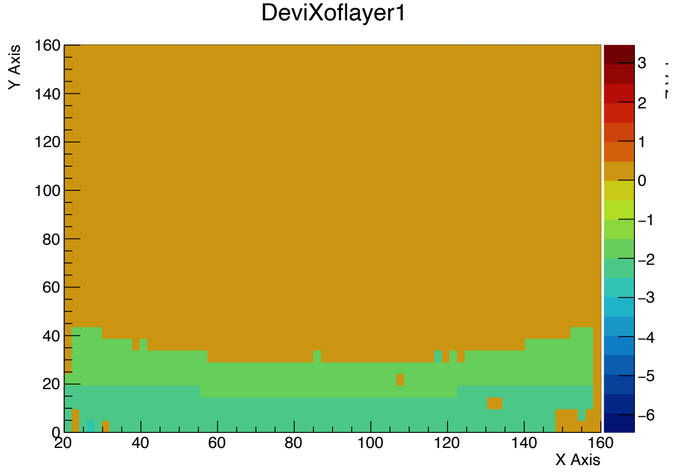


CorrX, CorrV

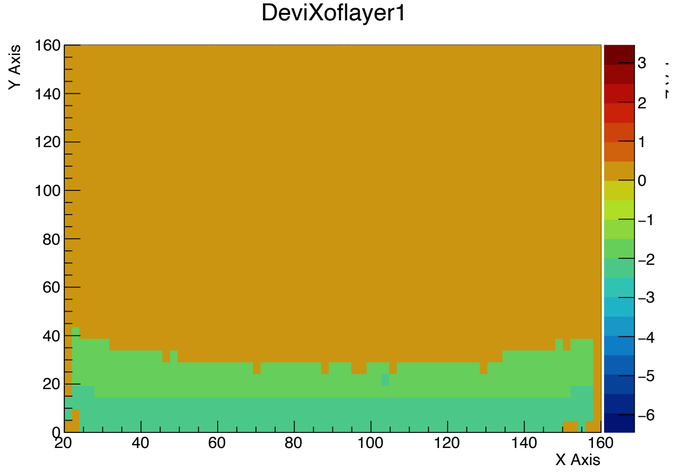
mTPC correction

X deviation, unit: strip (Layer1)

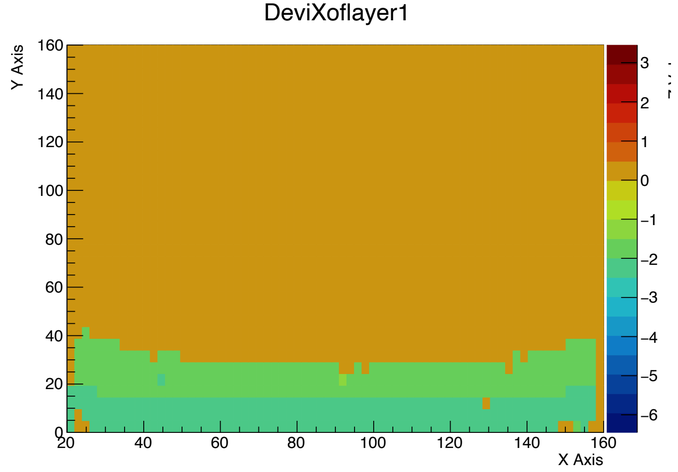
e^+



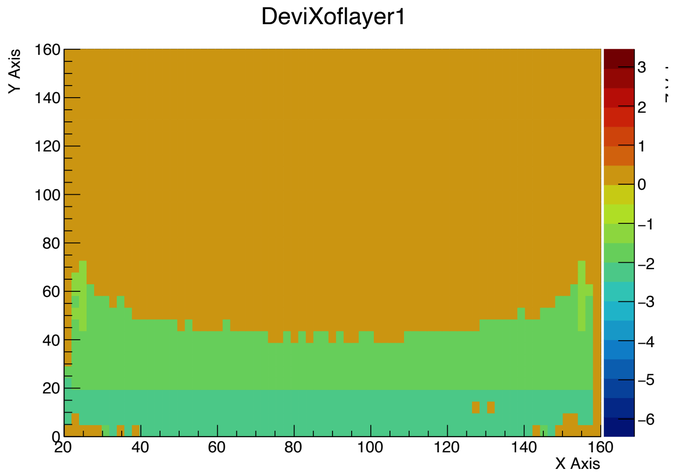
μ^+



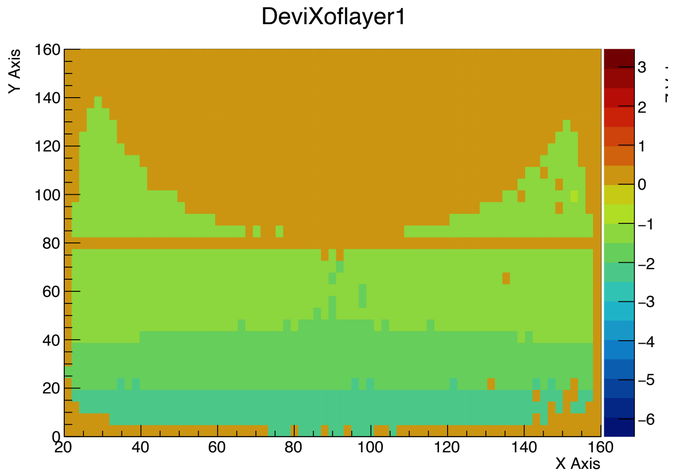
π^+



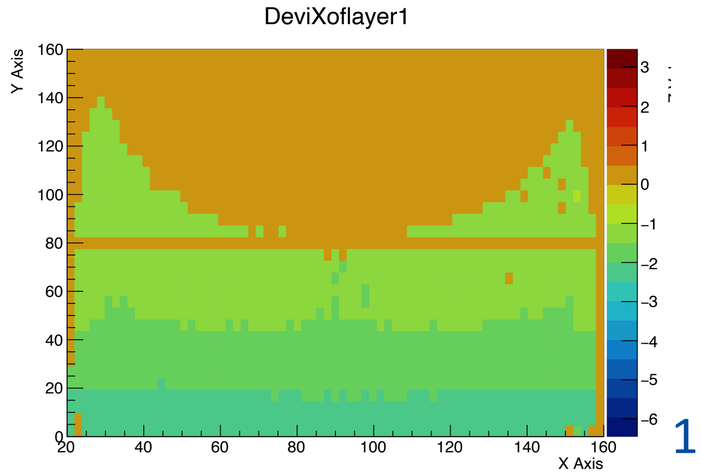
K^+



p^+



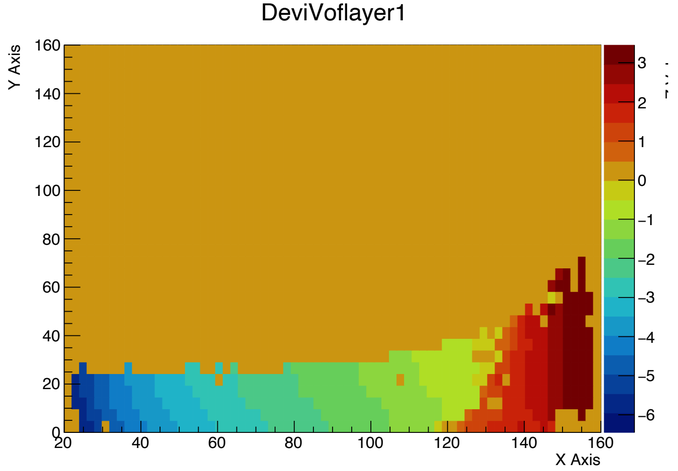
Combine



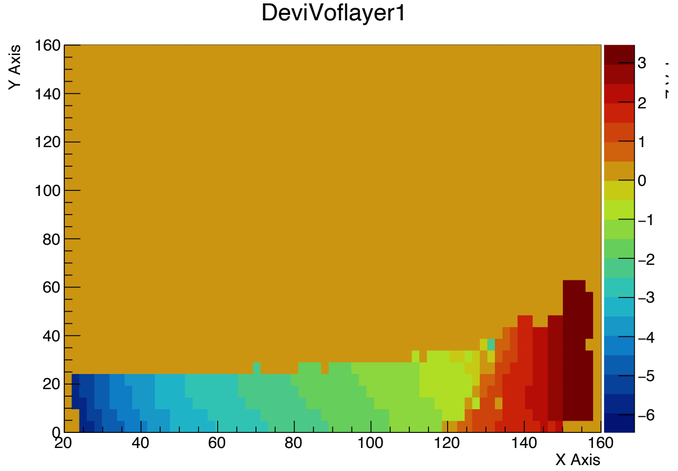
mTPC correction

V deviation, unit: strip (Layer1)

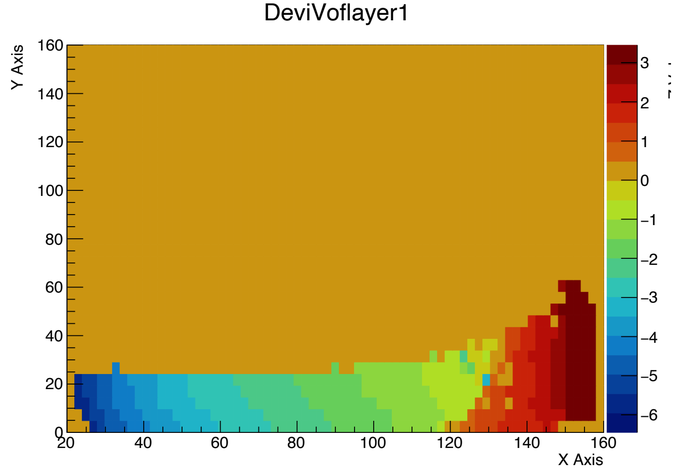
e^+



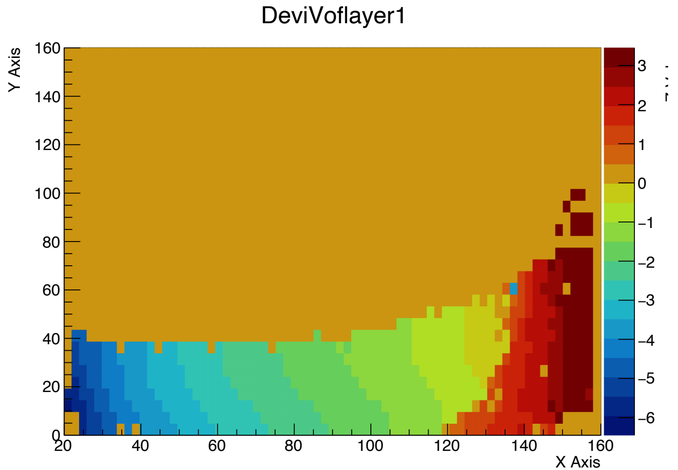
μ^+



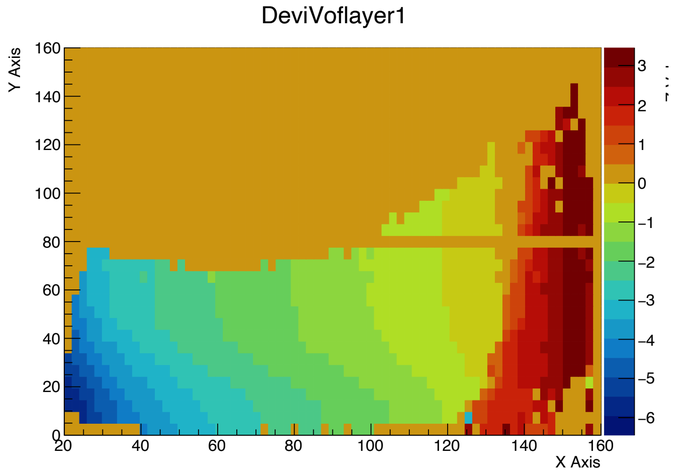
π^+



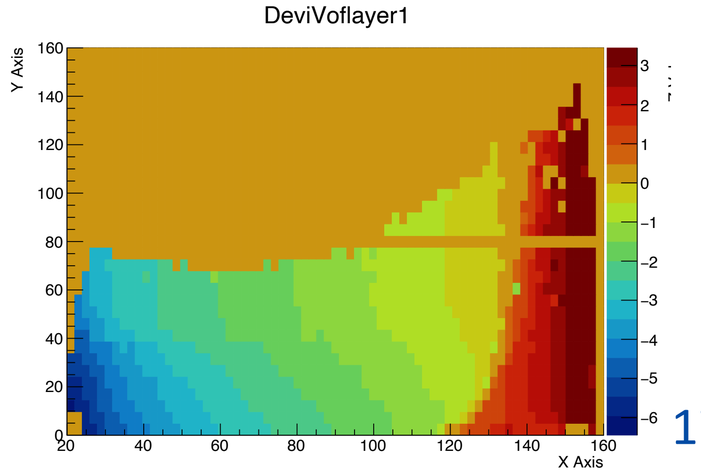
K^+



p^+



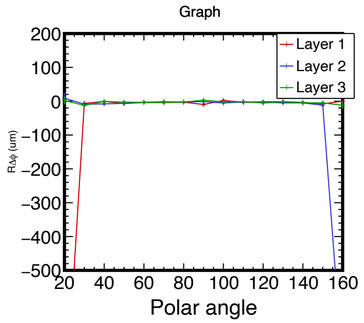
Combine

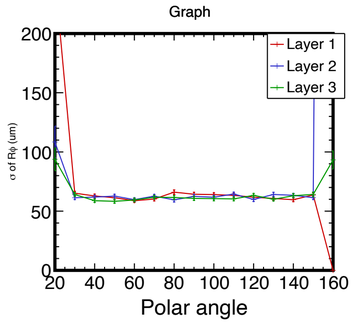


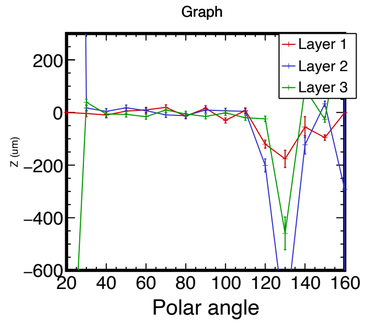
mTPC correction

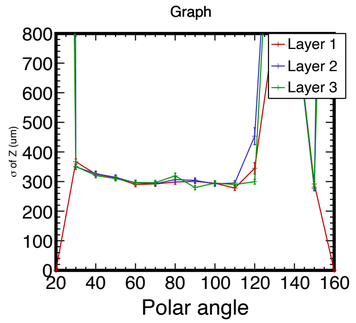
High momentum — 700 MeV

e^+

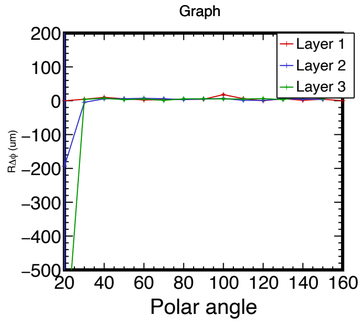


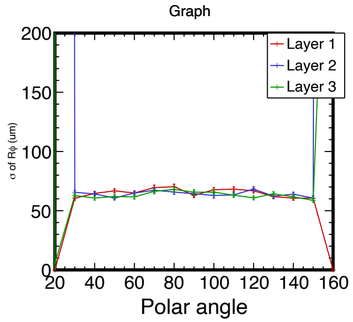


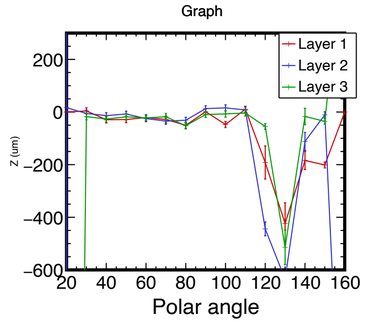


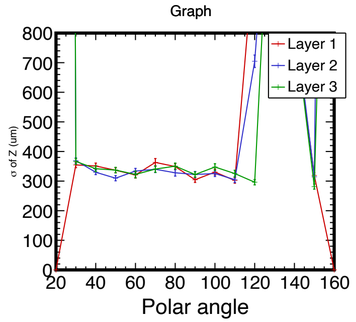


μ^+

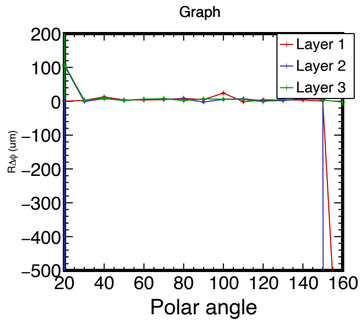


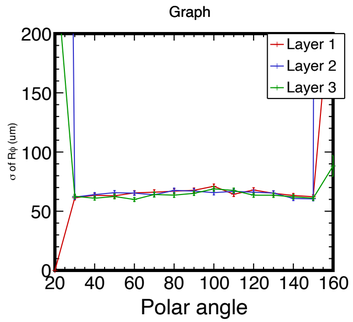


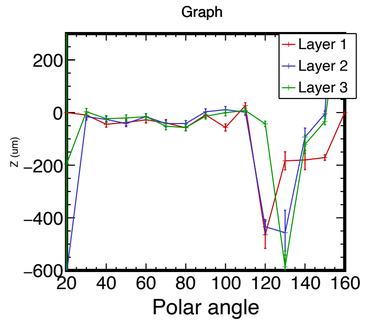


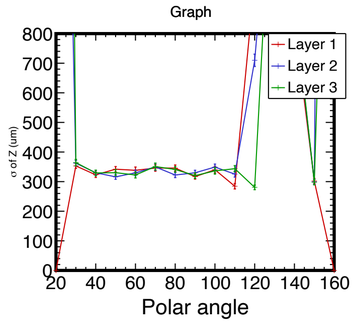


π^+







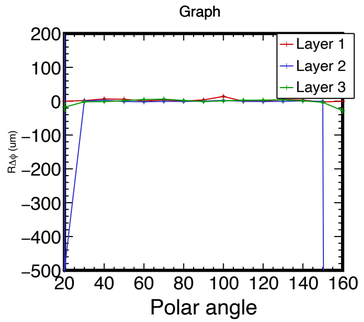


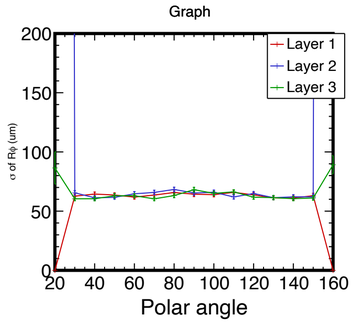
note: new geo parameters are implemented to cover polar angle $20^\circ \rightarrow 160^\circ$

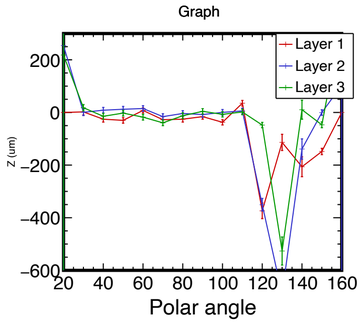
mTPC correction

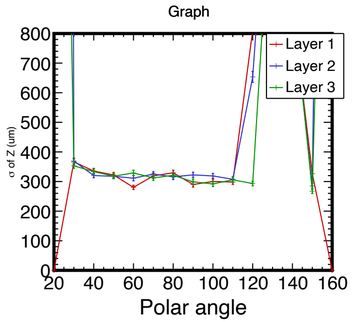
High momentum — 700 MeV

K^+

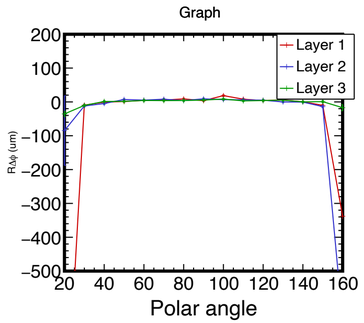


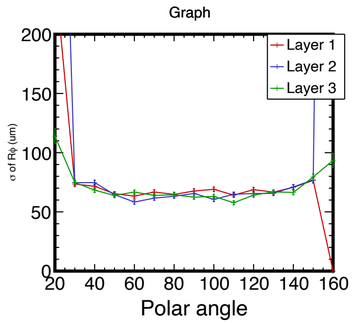


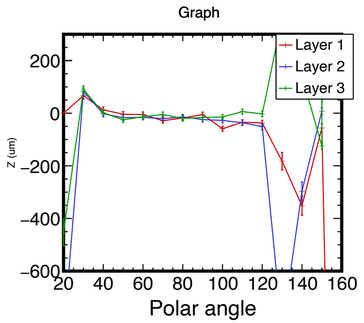


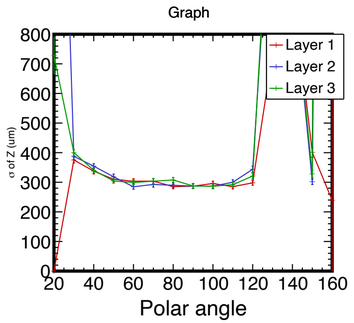


p^+





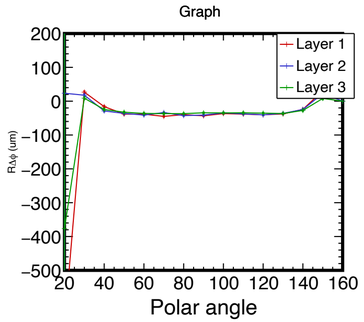


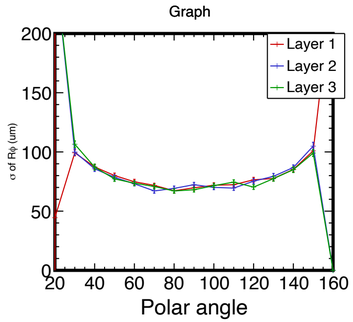


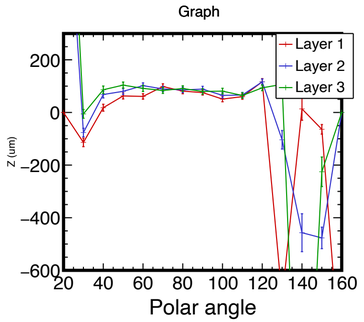
mTPC correction

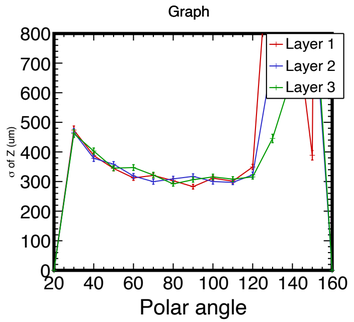
Low momentum — 250 MeV, 300 MeV

K^+

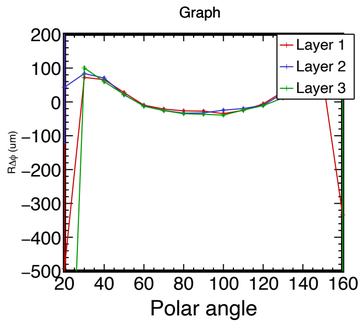


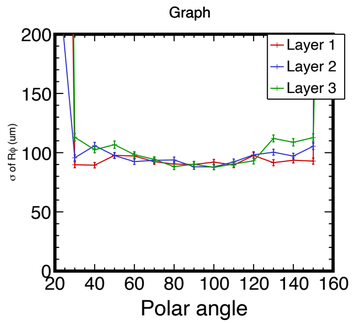


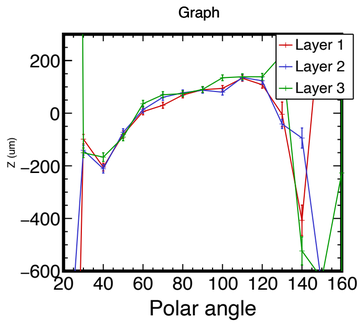


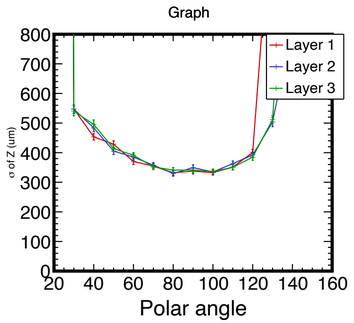


p^+









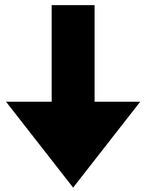
correction will deteriorate at low momentum for K, p

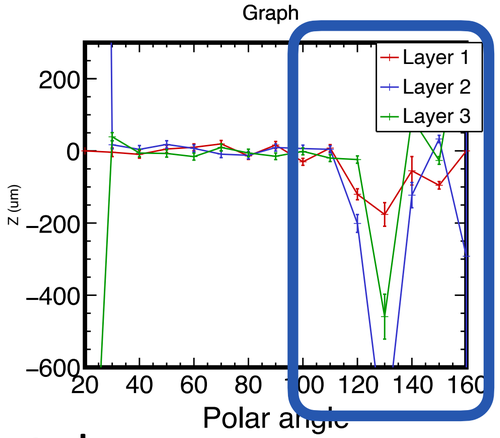
mTPC correction

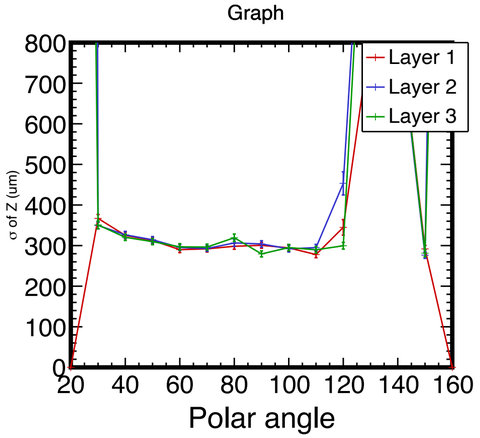
Hybrid construction

Caused by Lorentz angle → seldom V strips have signal (about $130^\circ \rightarrow 150^\circ$)

$N_{hits} < 3 \rightarrow$ can not use mTPC, use CC instead







corrections of V strip deviation should be considered separately

(still ongoing)

Summary

- Introduced digitization, reconstruction and correction of ITKW

- MC based correction achieved some progress

  not good performance at low-p for p & K (or high energy loss tracks)

  need to reconsider with θ at $130^\circ \rightarrow 150^\circ$

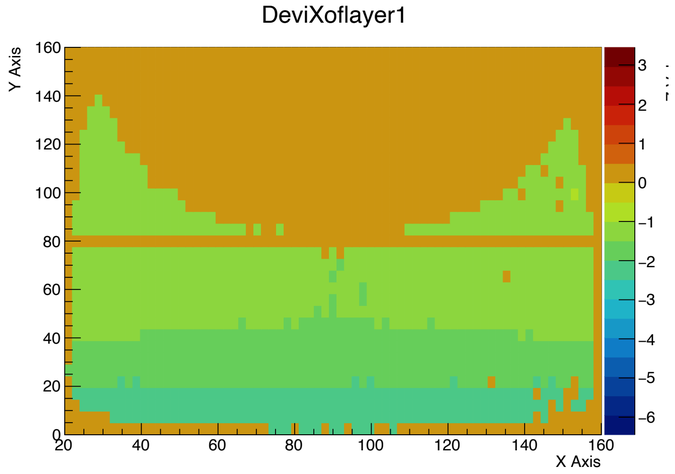
  highly rely on correct digitization

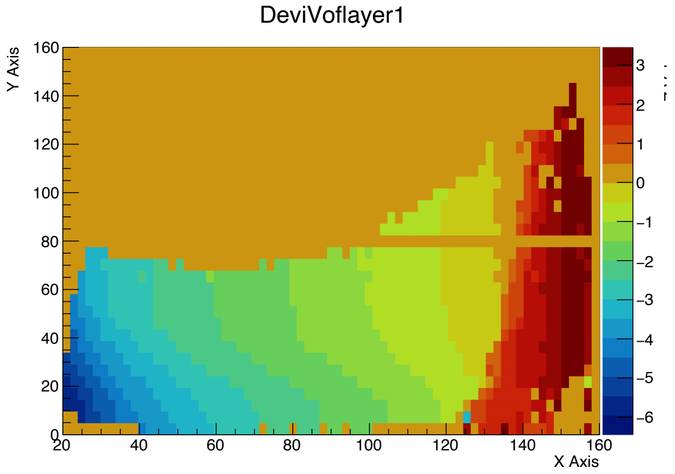
Looking for your advice

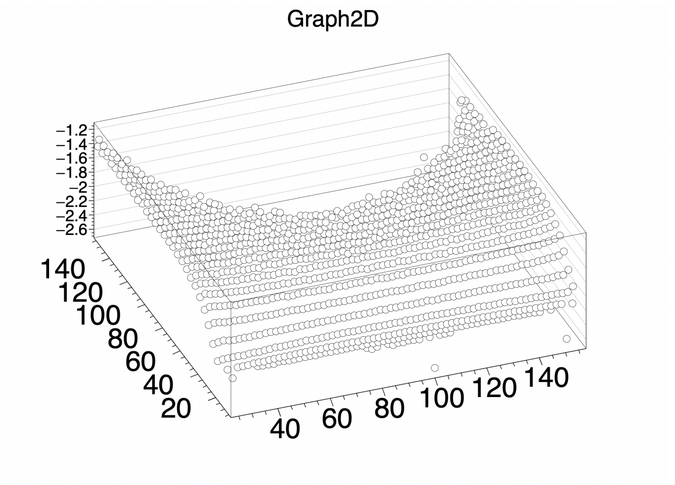
Jiajun Tang

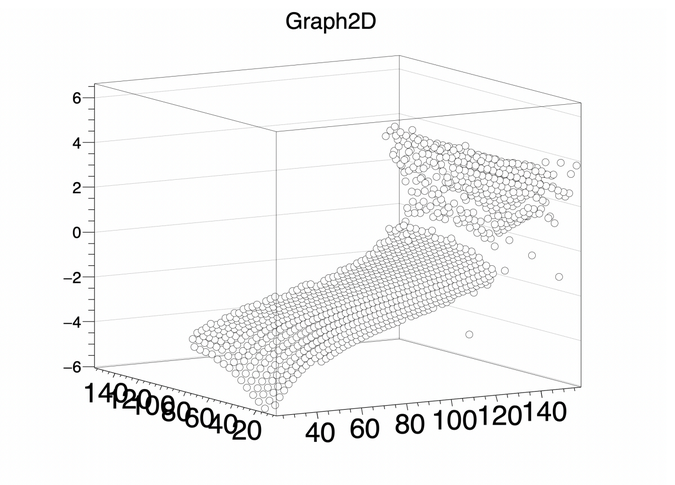
e-mail:
mbb0303@mail.ustc.edu.cn

Backup


DeviXoflayer1
Y Axis
X Axis

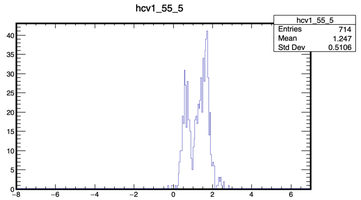

DeviVoflayer1
Y Axis
X Axis

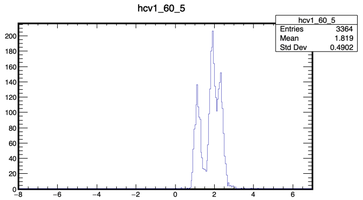

Graph2D

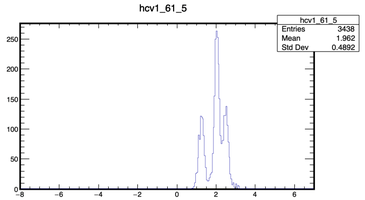

Graph2D

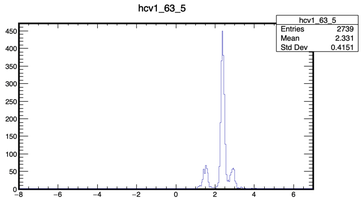
Backup

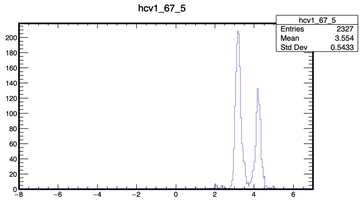
$\theta = 130°$ $\theta = 142°$ $\theta = 158°$

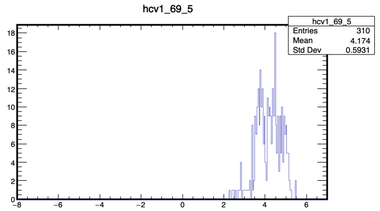




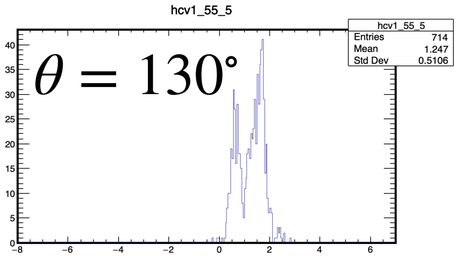






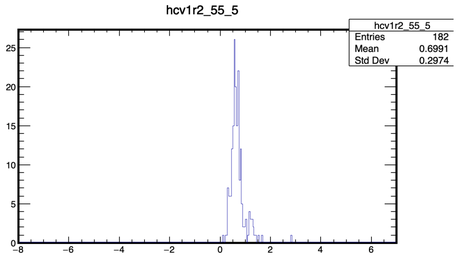


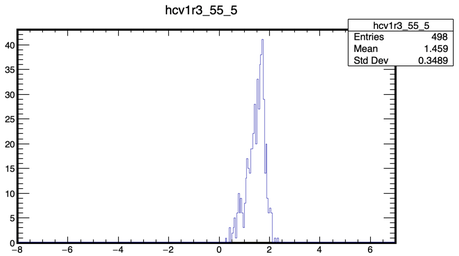
ClusterRange=2 ClusterRange=3



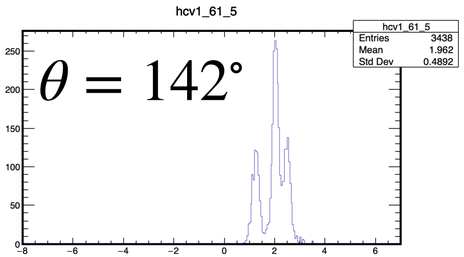
$\theta = 130°$

=



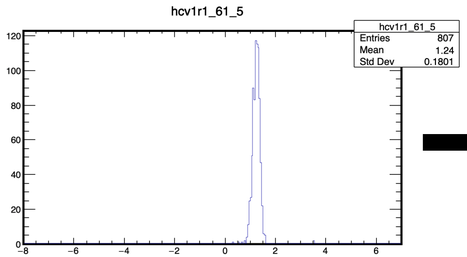


ClusterRange=1 ClusterRange=2 ClusterRange=3

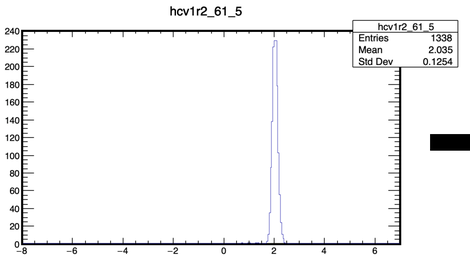


$\theta = 142°$

=



+



+