29 – May – 2018

Measurement of dE/dx resolution using electron beam

Asian Linear Collider Workshop 2018 @ Fukuoka

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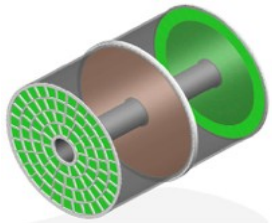
on behalf of the LCTPC group



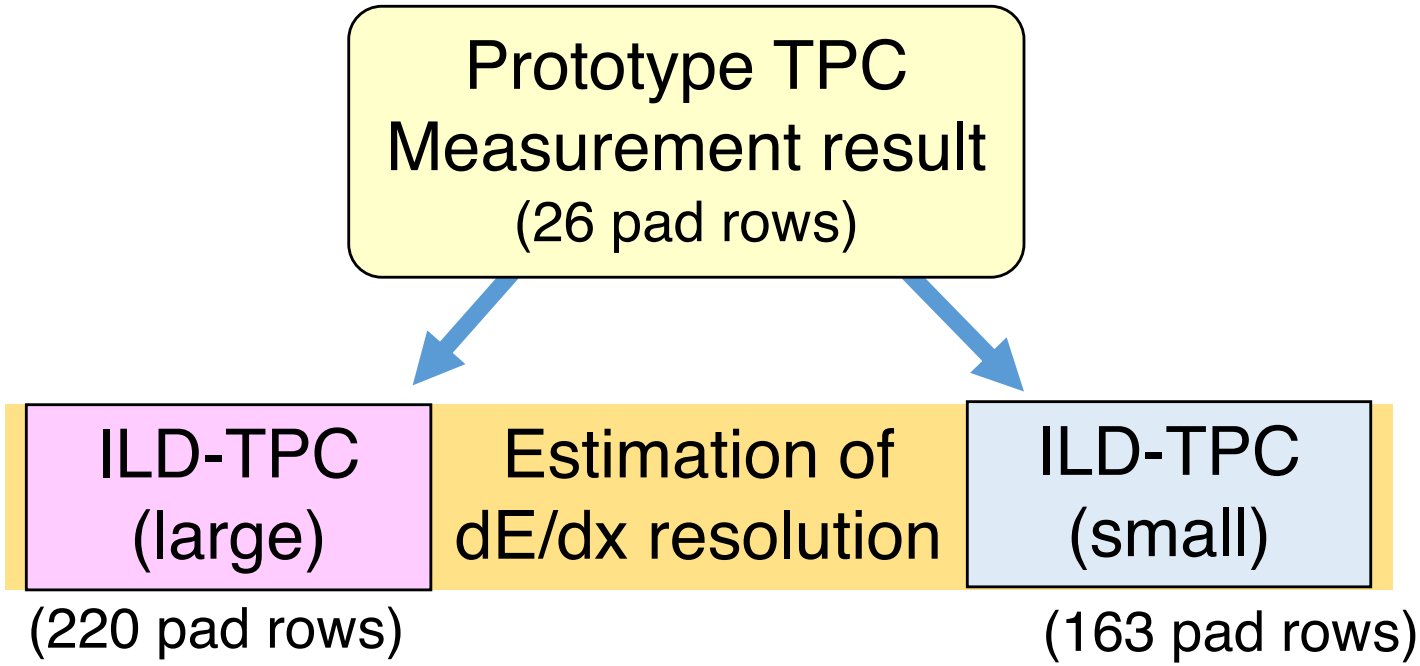
Outline

- Brief introduction
- Simulation (Relation between charge and drift distance)
- dE/dx resolution v.s. fraction [experiment and simulation]
- dE/dx resolution using Landau Fit
- dE/dx resolution [beam incident angle θ dependence]

dE/dx resolution

- The dE/dx resolution with Asian GEM module with/without gating foil (GEM) was measured at DESY test beam in a magnet field.

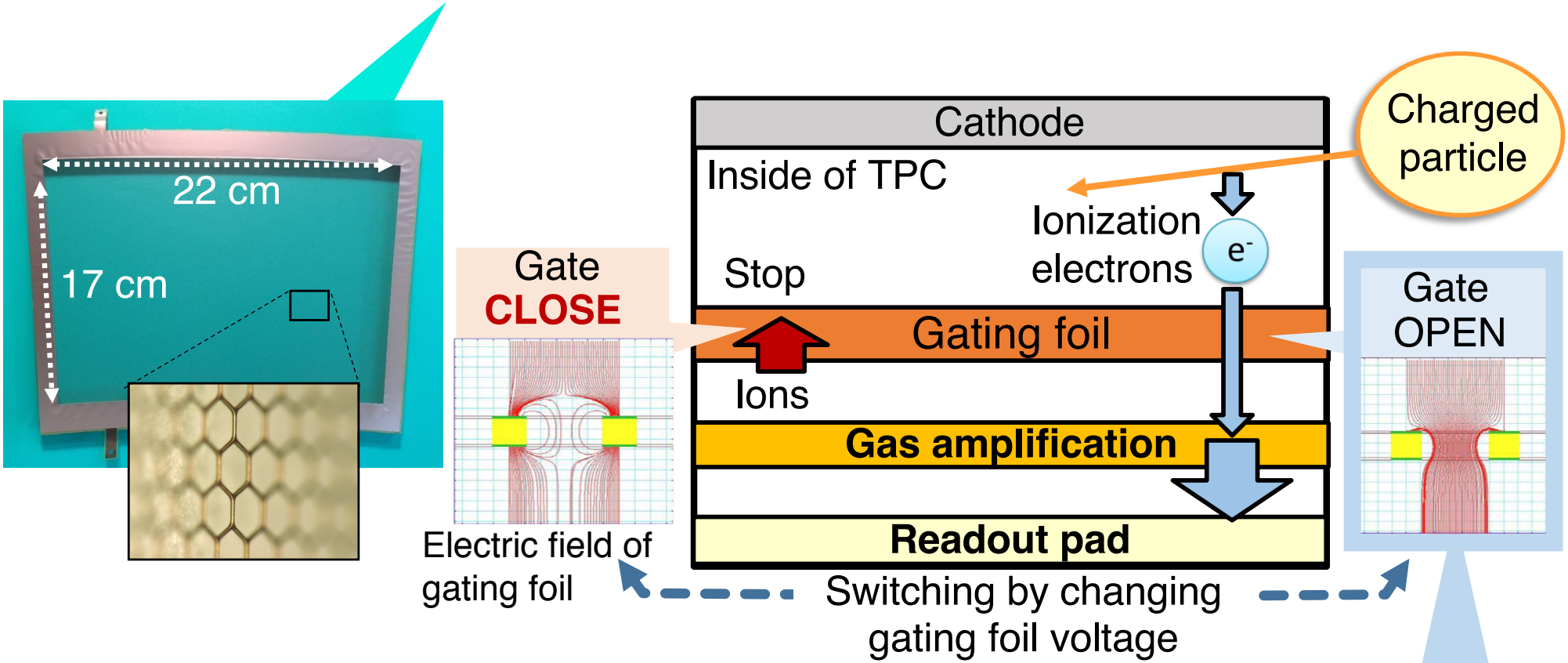
- The dE/dx resolution of ILD-TPC was estimated using this beam test data and simulation soft (Garfield++/Heed).



Gating foil (GEM)

ILC-TPC problem: Positive ions feedback

- The ions feedback causes distortion of reconstructed tracks.
  - Mounting a **gating foil** to stop the feedback of positive ions.

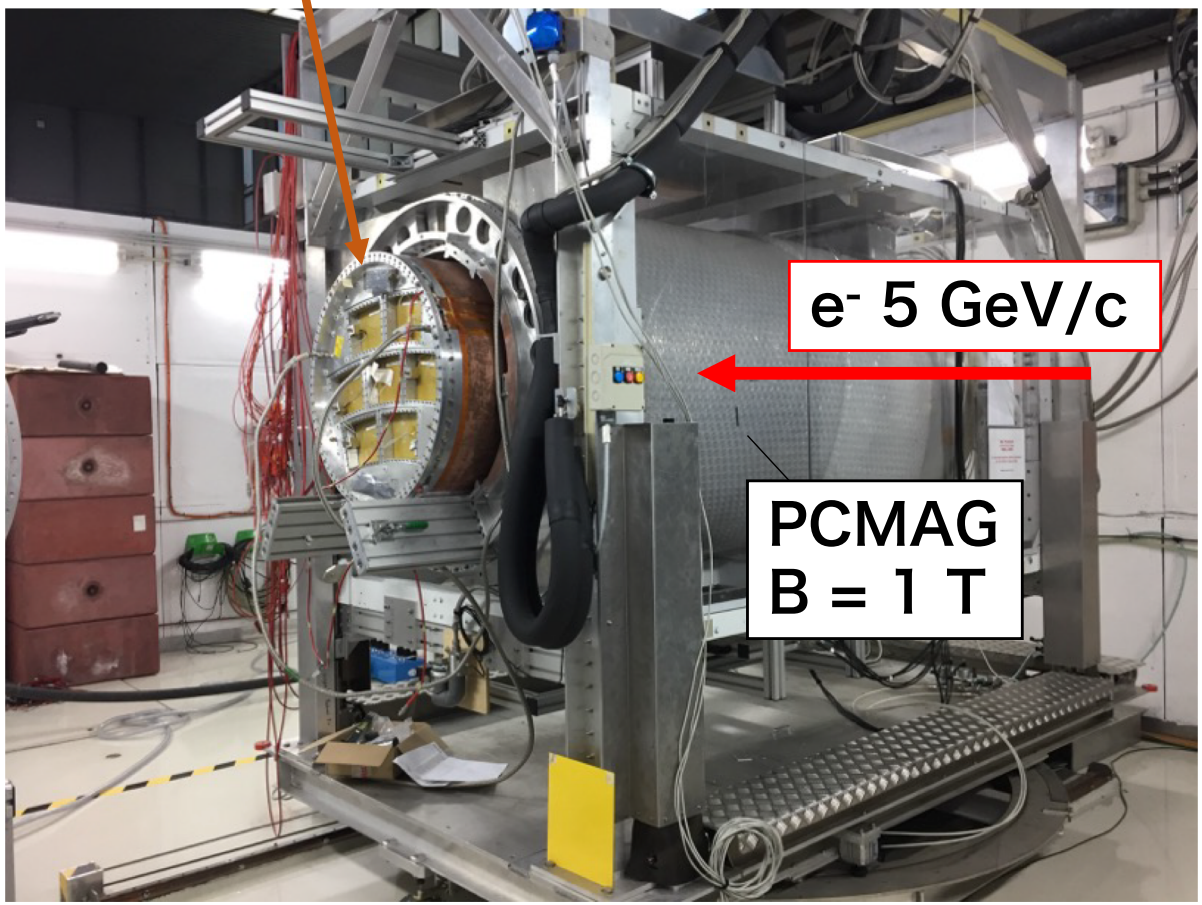


Investigate the dE/dx resolution in the case of a potential difference is 3.5 V of gating foil at which the electron transmission rate is maximum.

Beam Test

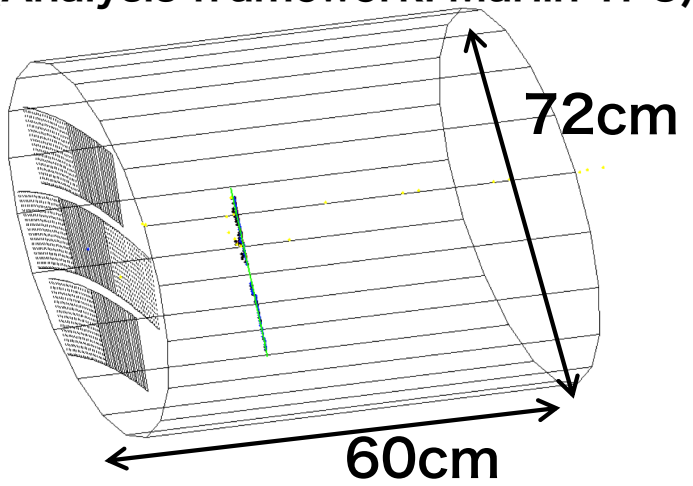
We performed the beam test at the facility in DESY.

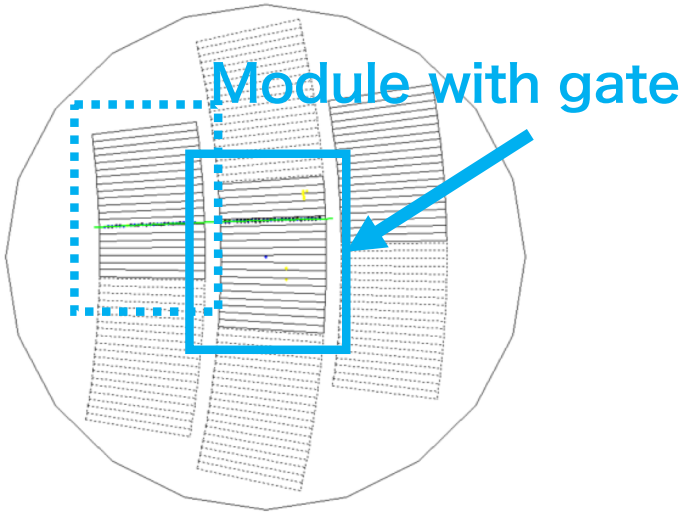
Prototype TPC with the gating foil exposed to an electron beam in B-field.



T2K gas（Ar : CF_4 : Iso-C_4H_{10} = 95 : 3 : 2 ）

▼Example of the track
(Analysis framework: Marlin TPC)



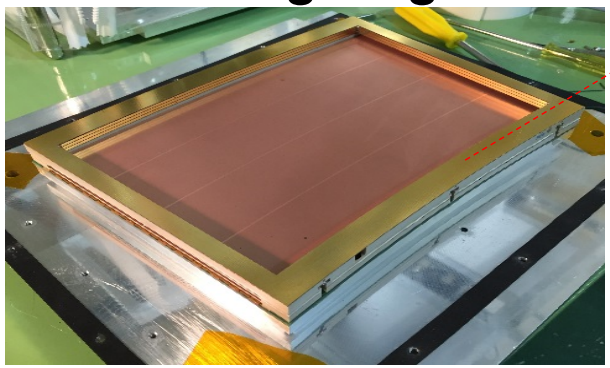


Readout module

- We measured at the both of with or without gating foil.

With gating foil

Without gating foil



Field shaper

A field shaping frame was mounted on the top of the amplifying GEMs in the absence of the gating foil.

（Voltage・Electric field）

Cathode

Drift region E_D = 230 V/cm

Gating foil ↕ ΔV= +3.55 V

Amp GEM1 ↕ ΔV_{GEM1}=355 V

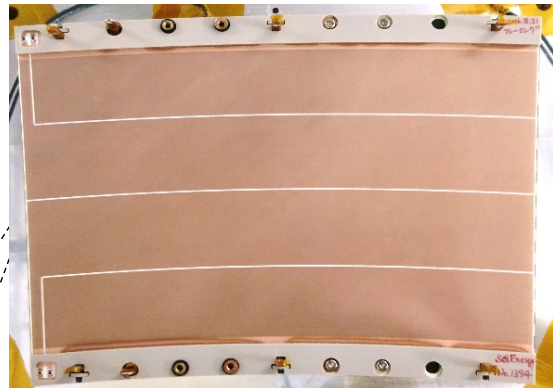
Transfer region E_T = 887.5 V/cm

Amp GEM2 ↕ ΔV_{GEM2}=315 V

Induction region E_I = 2700 V/cm

Anode Readout Pad

GEM



100 μm thick（LCP）

Electrode gap

Pad

1.15~1.25 mm

5.26 mm

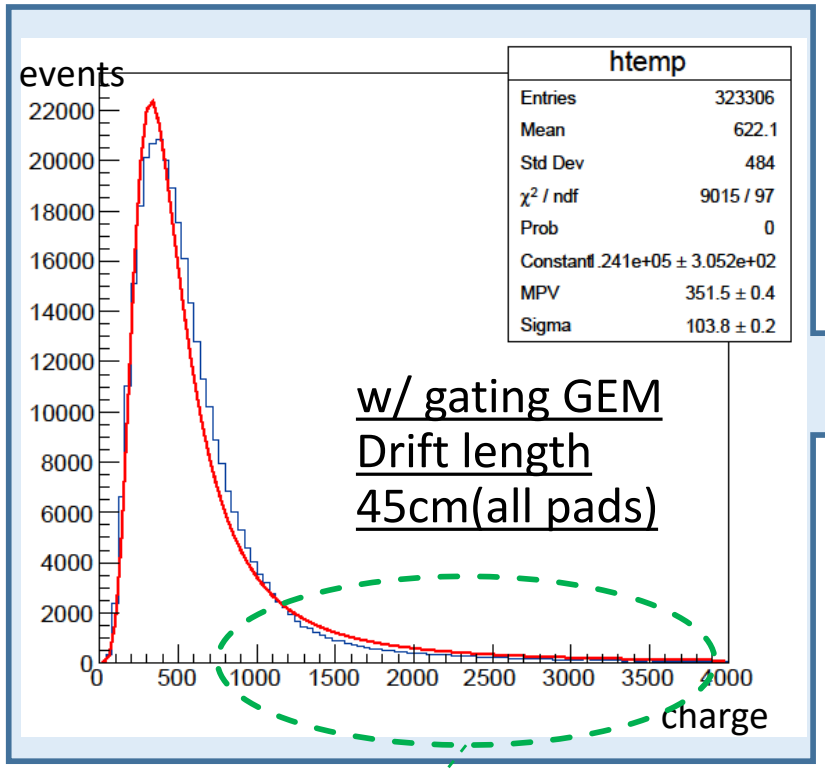
×5152 pads

28 pad rows

Truncated Mean

The dE/dx resolution was estimated using the charges measured by 26 pad rows (out of 28), excluding the innermost and the outermost ones near the supporting frame.

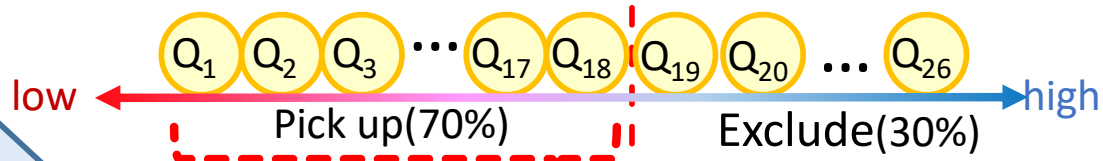
▼Example of charge distribution



Calculating the dE/dx resolution including this part is undesirable because it causes fluctuation

Truncated Mean Method

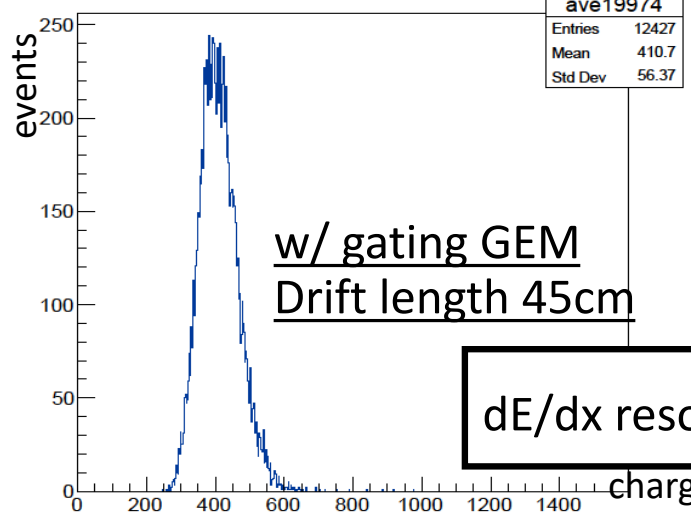
The pad rows were sorted by their charges and the average charge over those giving the lowest 70% were used in order to get rid of the Landau tail.



$26 \times \underline{0.7} \fallingdotseq 18$

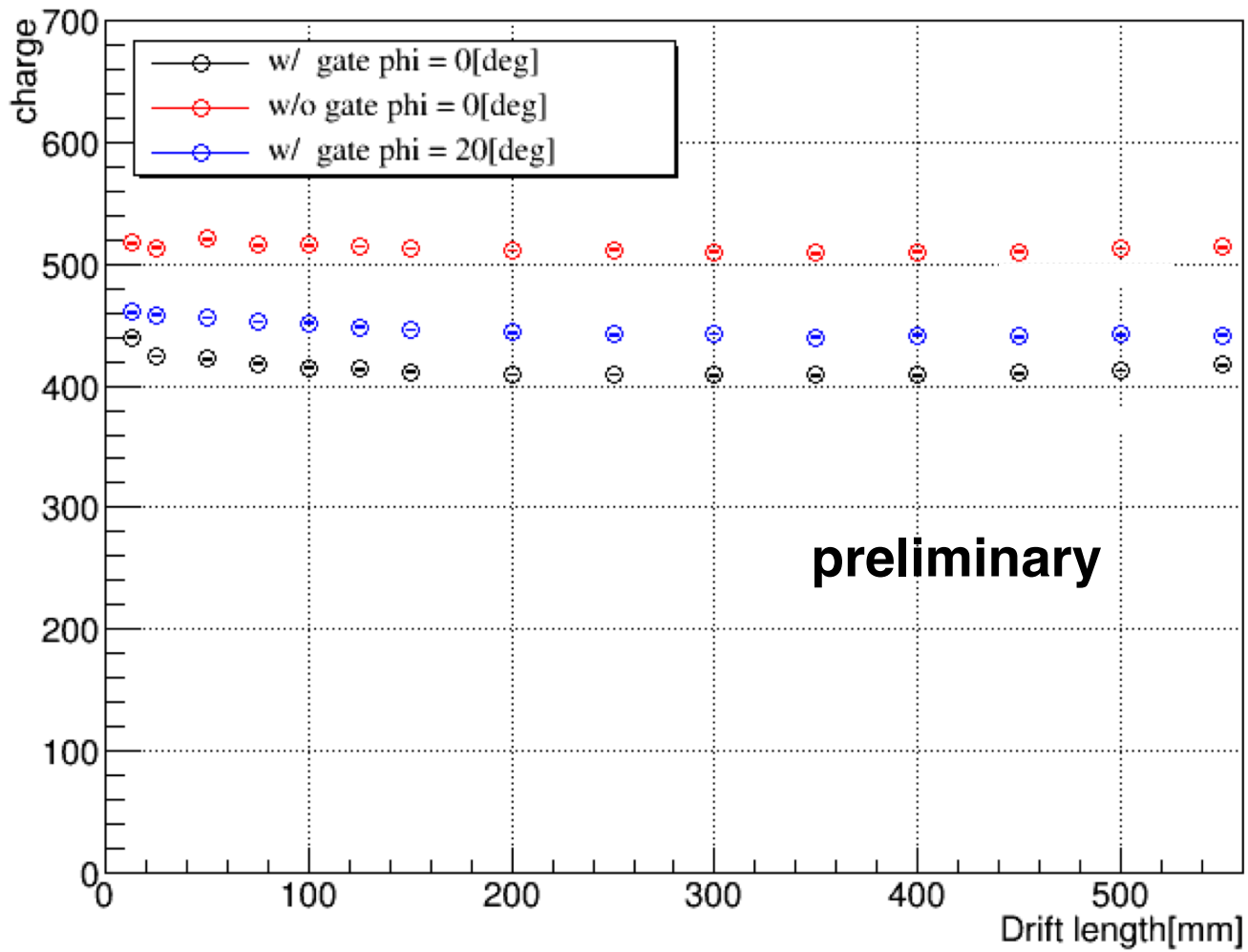
Average $\bar{Q} = \frac{1}{18}\sum_{i=1}^{18} Qi$

Plots

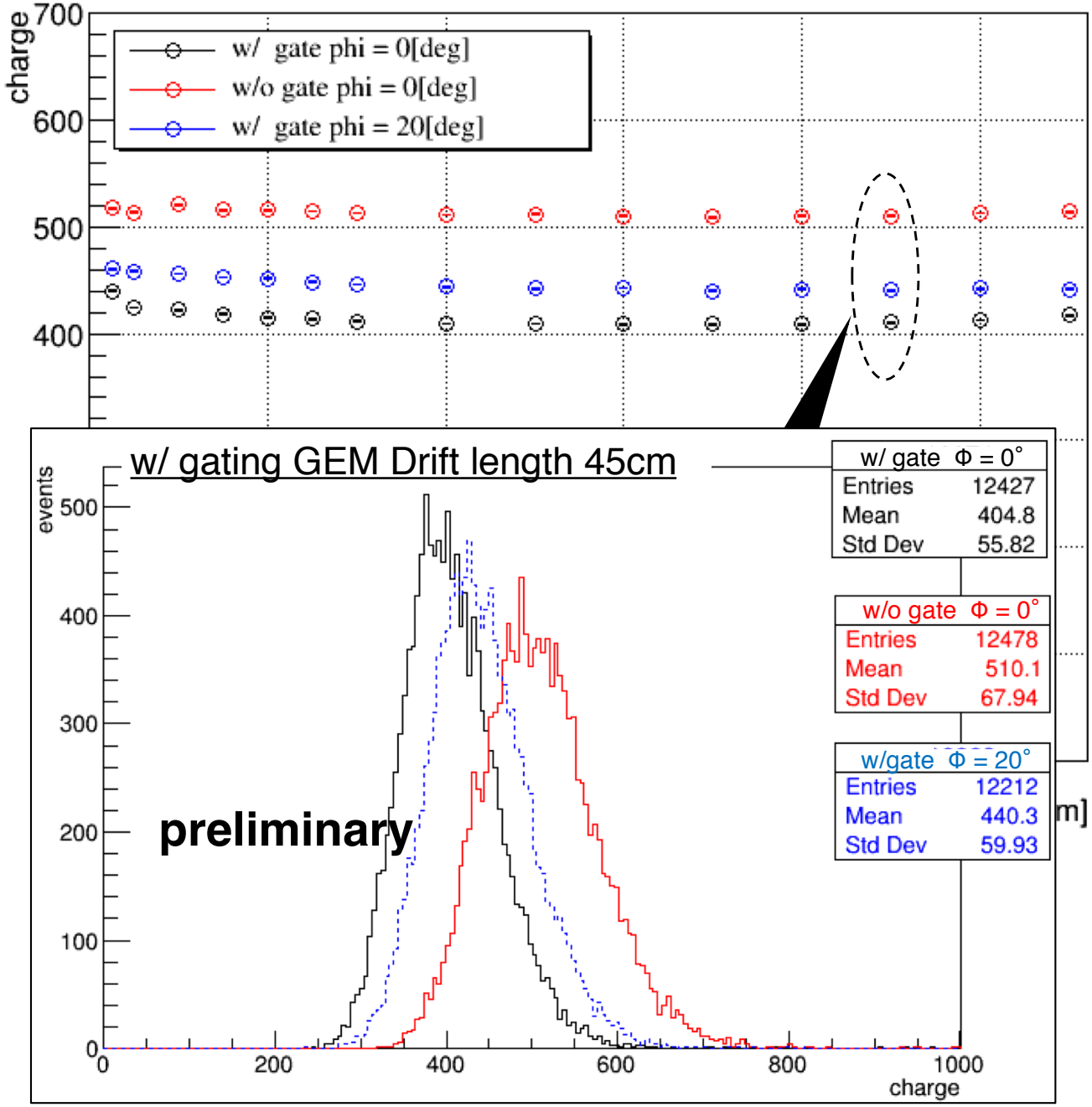


$$\text{dE/dx resolution} = \frac{Std\ Dev}{Mean}$$

Signal charge (Truncated mean)

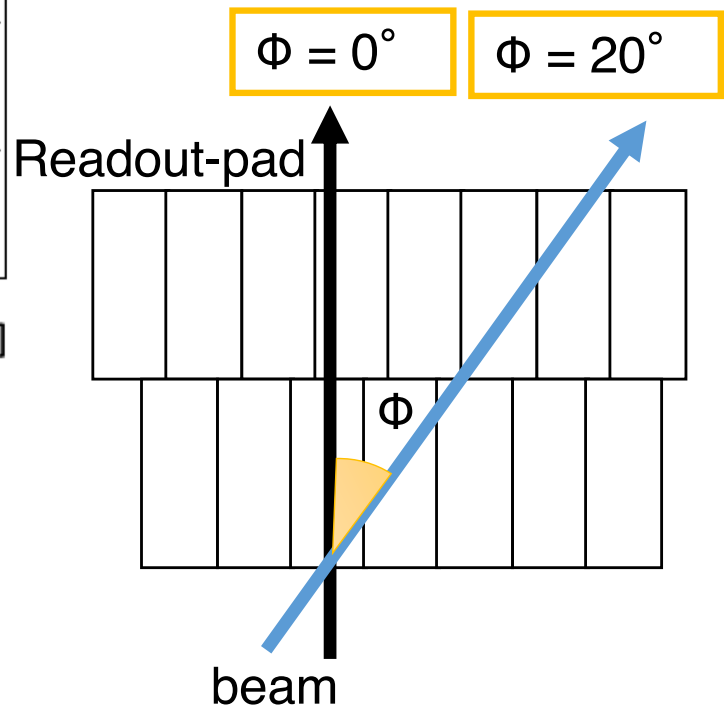


Signal charge (Truncated mean)

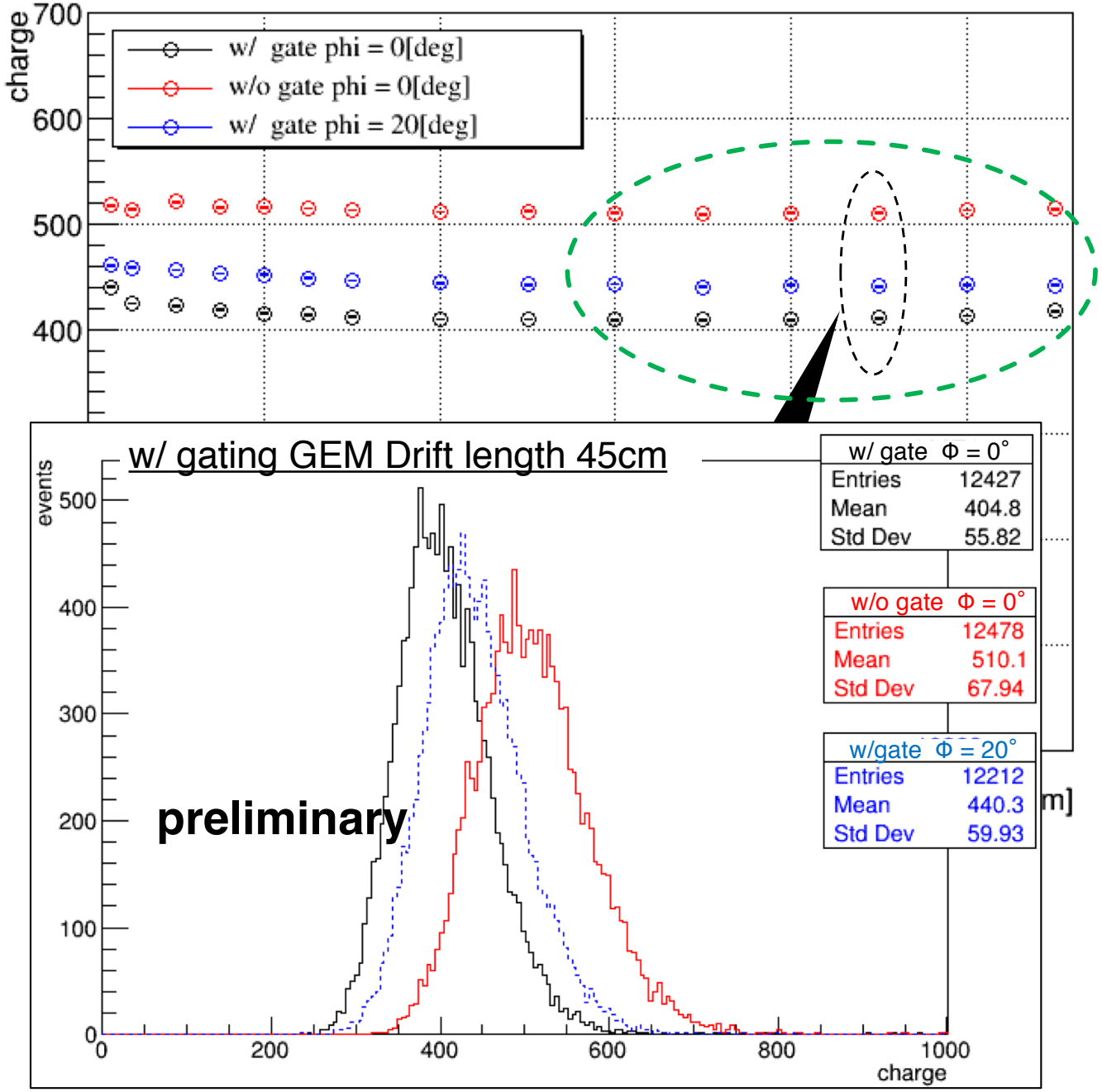


- In the case of with gate, the signal charge is less than without gate.

- In the case of angled beam, the signal charge increases because the track becomes long.



Signal charge (Truncated mean)

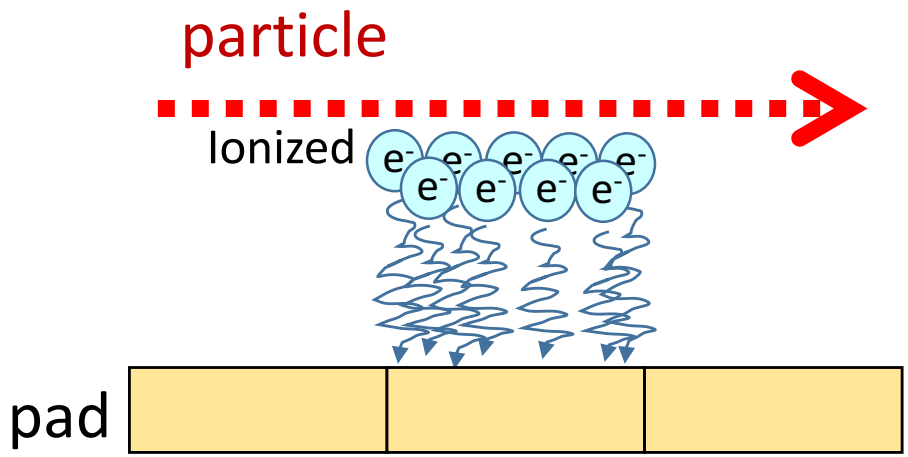


Longer the drift distance is, more charge seems to increase gradually.

Simulation: Charge and Drift Distance

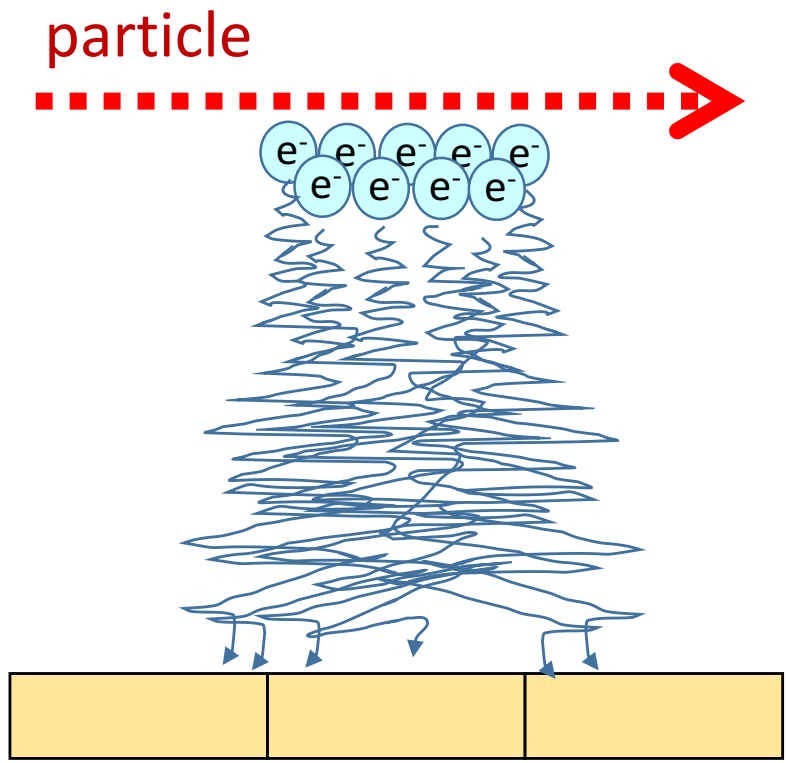
I simulated drift distance dependence of Truncated Mean using Heed.

▼Drift distance : short



*Image

▼Drift distance : long



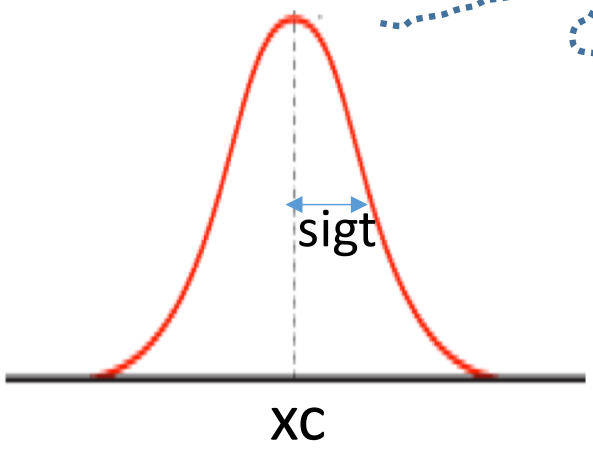
Some electrons move to next pad rows
⇒Give effect on Truncated Mean (?)

Drift distance Long ⇒ Diffusion Large ⇒ Give (small) effect on charge (?)

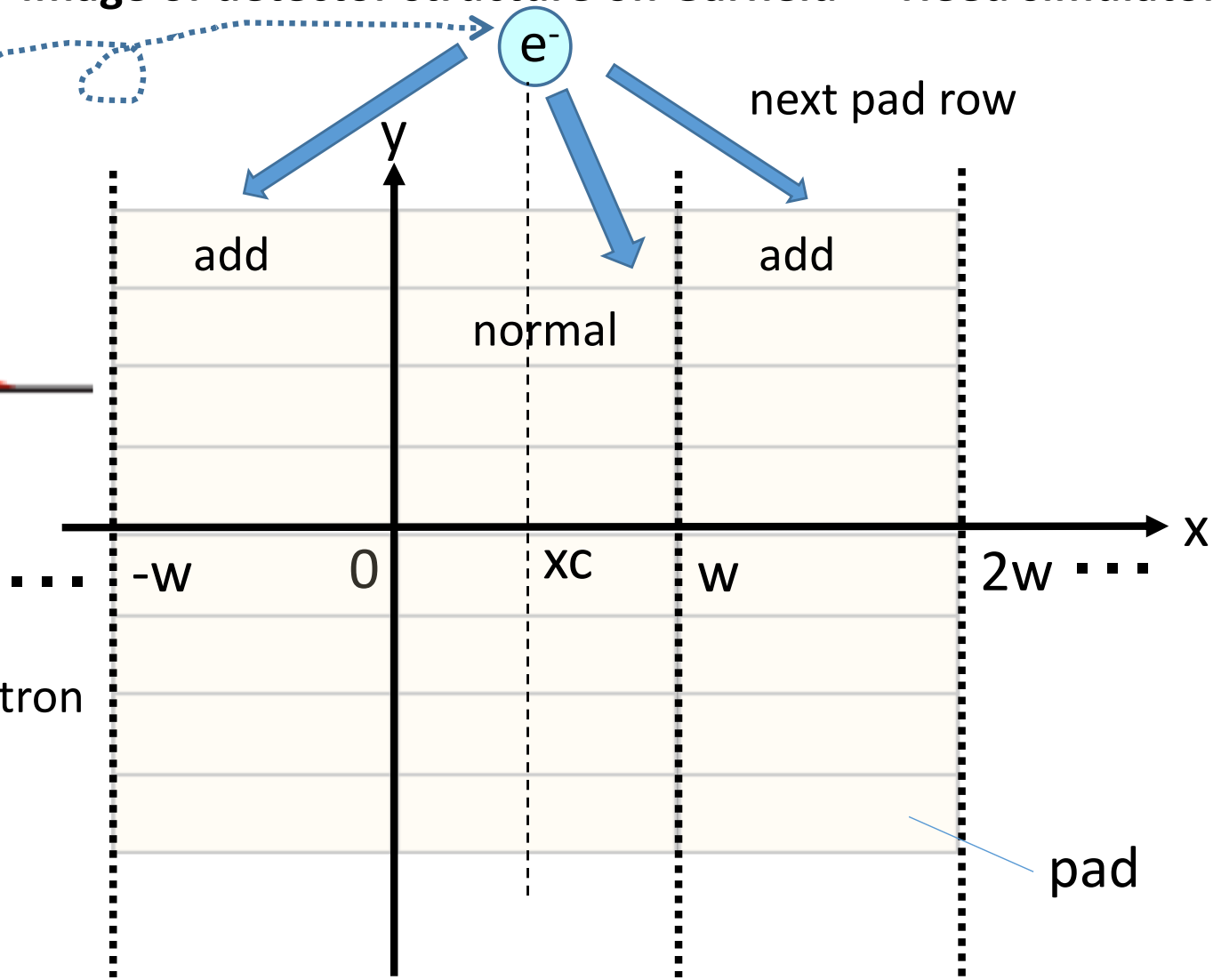
Reproduce the effect of drift diffusion by Heed

Generate random number following Gaussian distribution(Gaus(xc,sigt))
⇒Decide which pad row electrons drop down

▼Gaus(xc,sigt)



▼Image of detector structure on Garfield++ Heed simulator

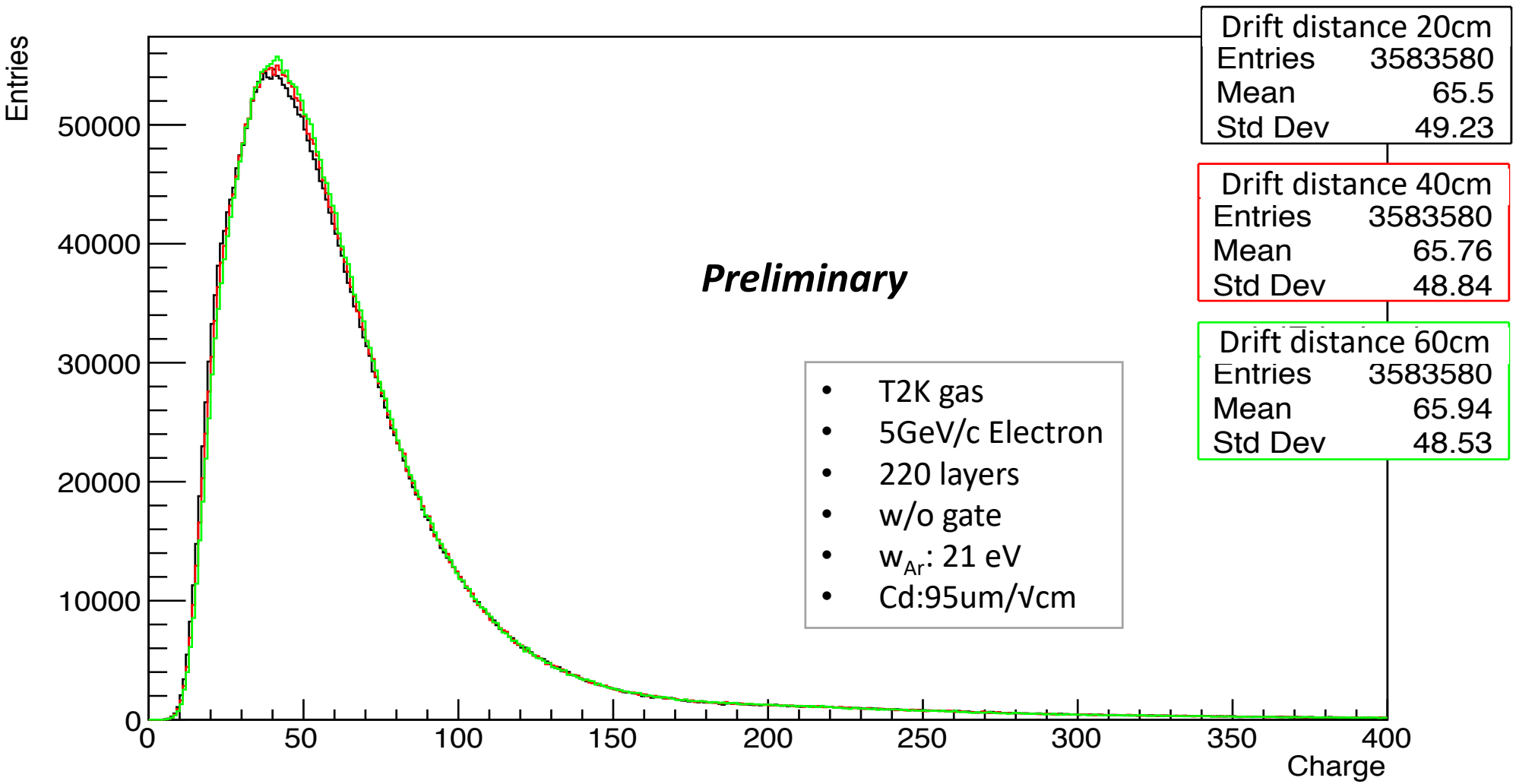


xc: original position of electron

sigt=Cd*√(drift distance)

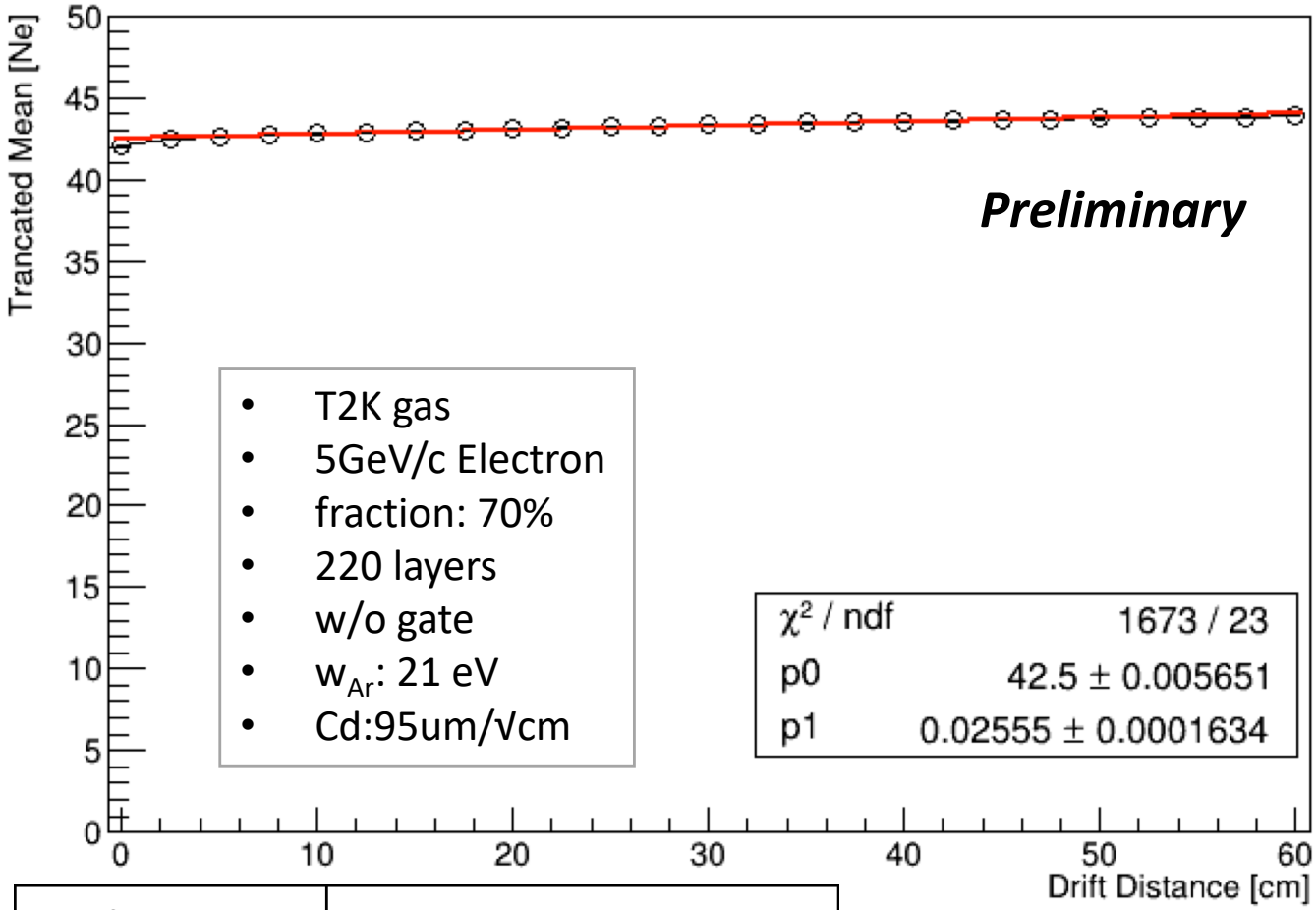
Cd=95um/√cm

Simulation (Landau distribution)

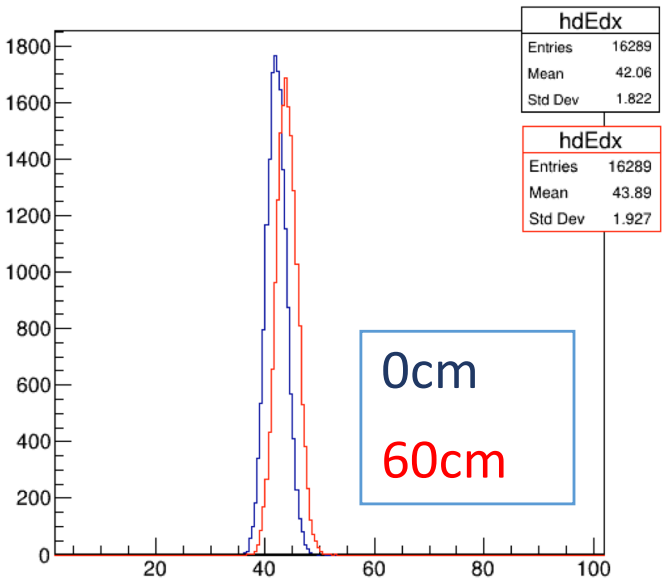


Longer the drift distance is, more the mean value of the Landau distribution seems to increase gradually.

Simulation (Truncated Mean)



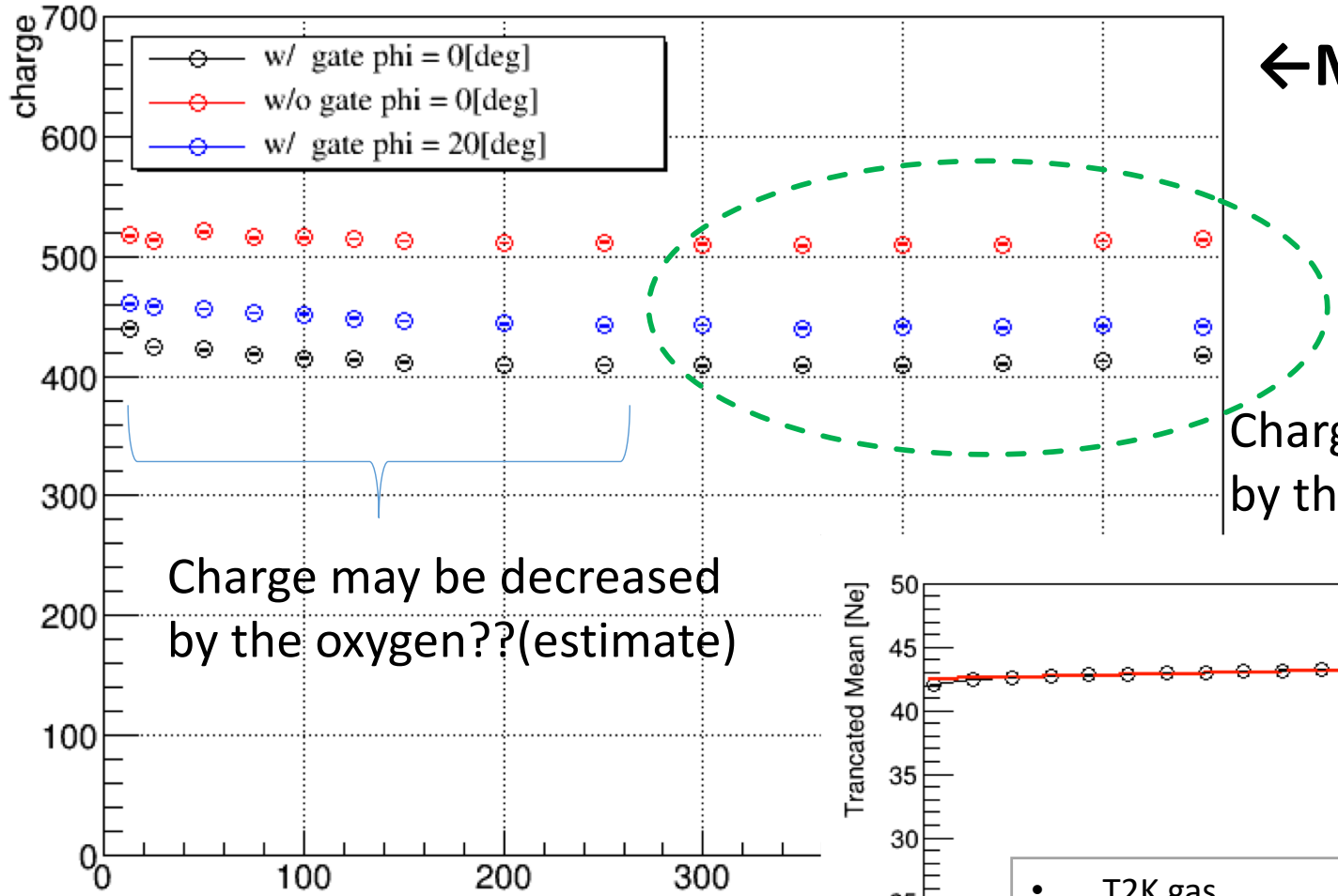
▼Truncated Mean



Drift distance	Truncated Mean
0 cm	42.06 +/- 0.014
60 cm	43.89 +/- 0.015
Increase ratio	+3.4 +/- 0.05 %

Longer the drift distance is, more the diffusion increases, the charge shares between next pad rows, the distribution approaches the Gaussian distribution, so the Truncated Mean becomes large.

Comparison measurement with simulation

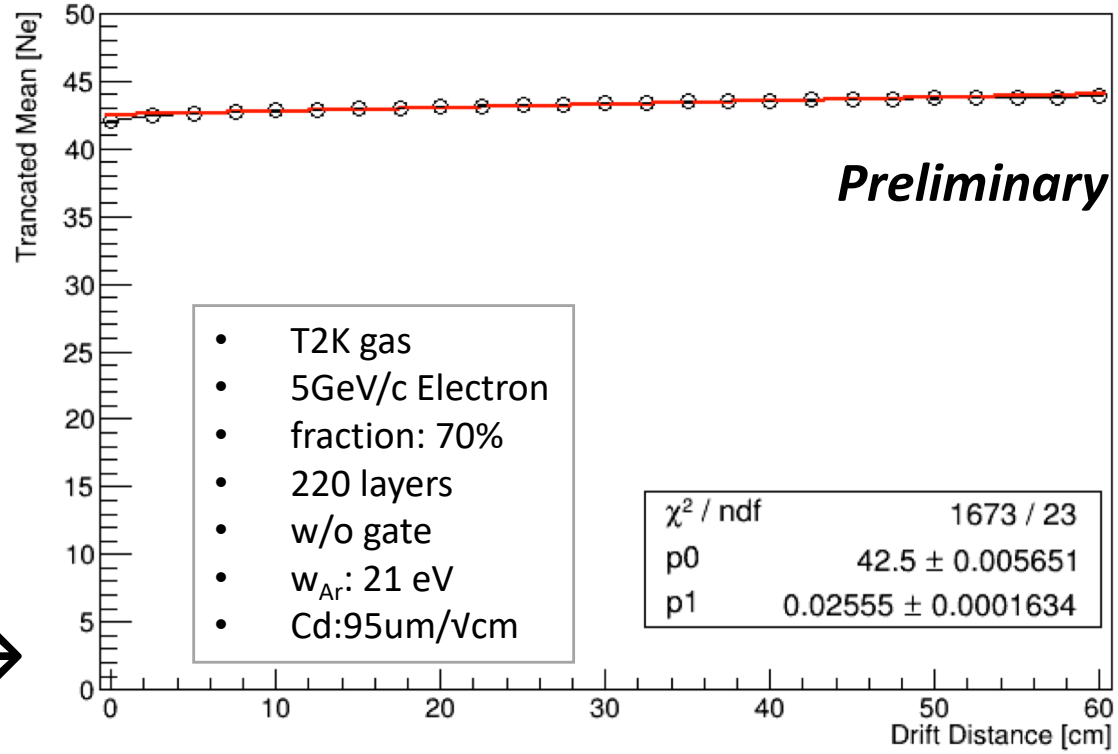


←Measurement result

Charge may be increased by the effect of drift diffusion?

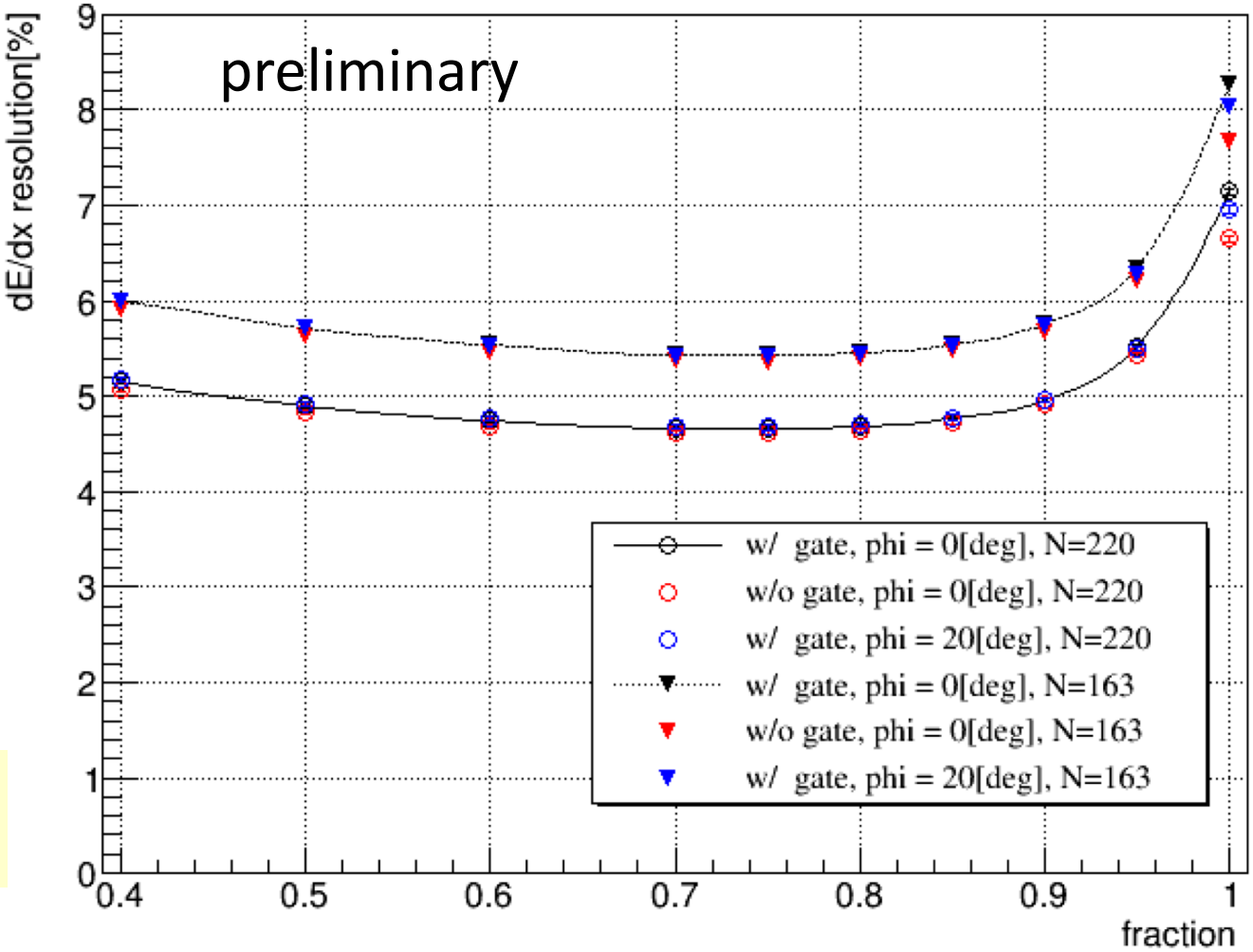
Charge may be decreased by the oxygen??(estimate)

Simulation result→



Expected dE/dx resolution v.s. fraction

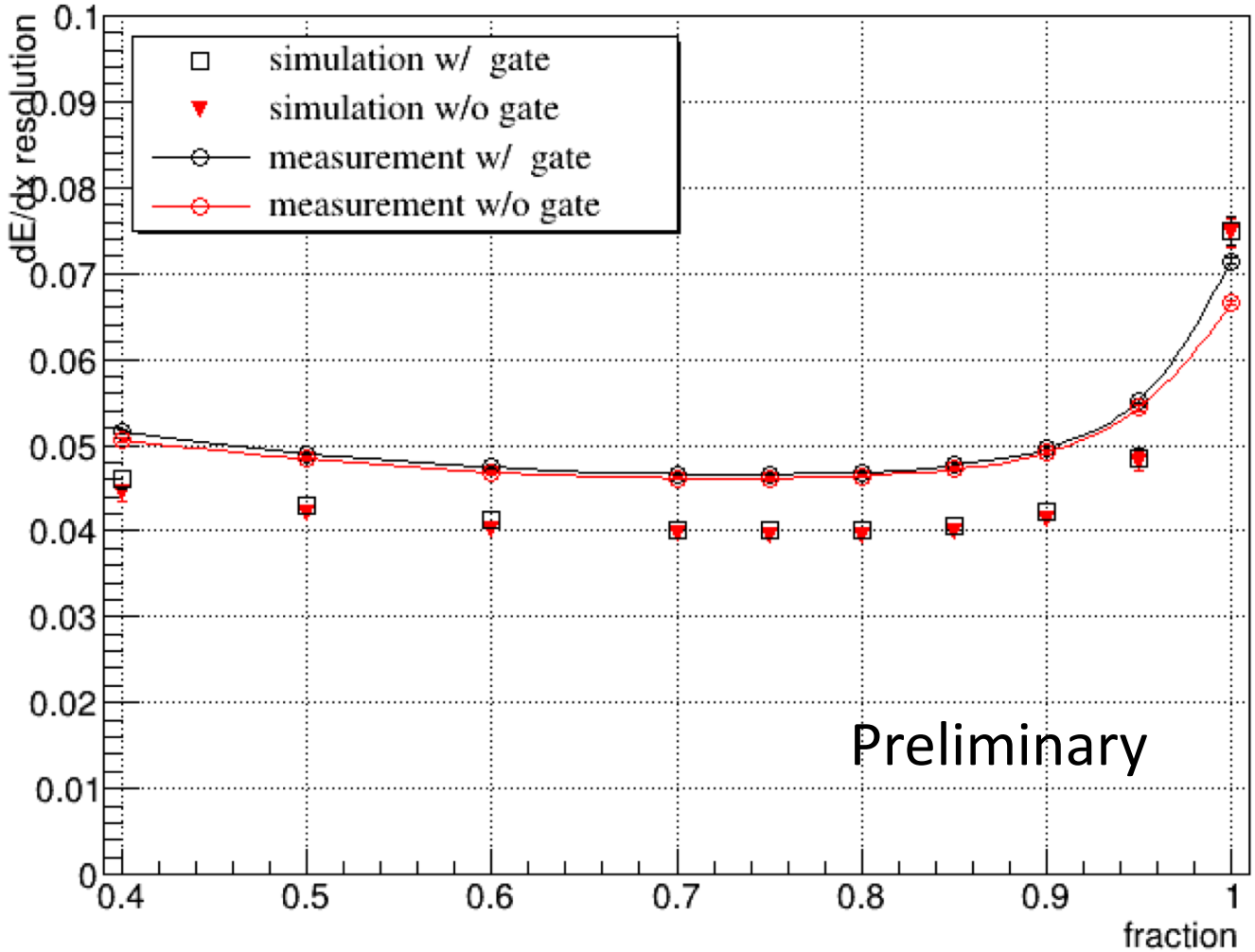
The dE/dx resolution of ILD-TPC **(large: Pad rows: 220, small: Pad rows: 163)** was estimated.



The dE/dx resolution at fraction:70 % is the best.

↓*fraction:70%	Large-TPC	Small-TPC
w/ gating foil, ϕ= 0°	4.67 +/- 0.02 %	5.43 ± 0.02%
w/o gating foil, ϕ= 0°	4.62 +/- 0.02 %	5.36 ± 0.02%
w/ gating foil, ϕ= 20°	4.68 ± 0.02 %	5.42 ± 0.02%

Measurement v.s. Simulation



*electron (5 GeV)

*220 layers

*T2K gas

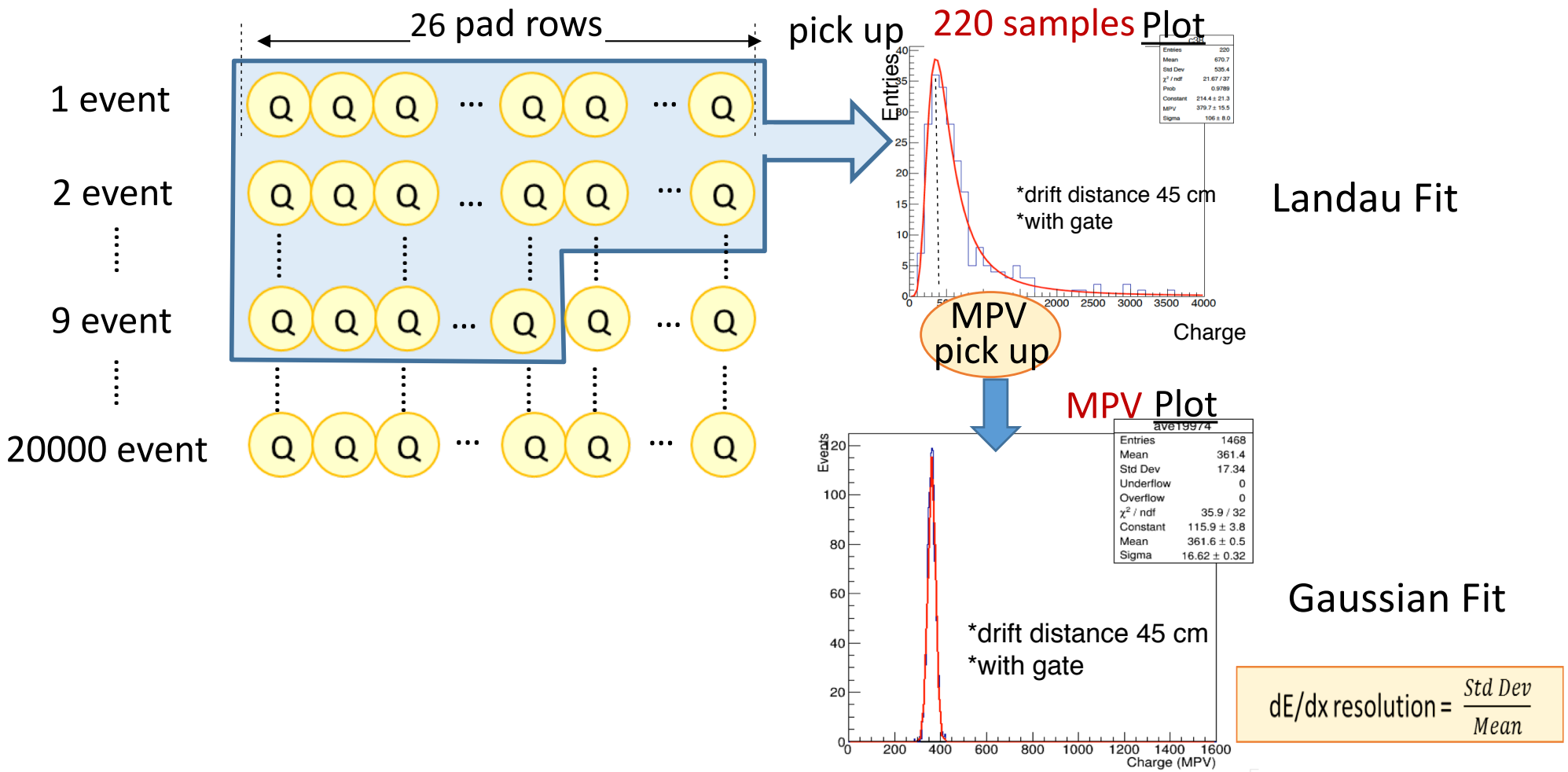
simulation soft : Garfield++/Heed

Simulation result was better than experimental result, but, the difference between the with/without gate was almost same and small.

↓*fraction:70%

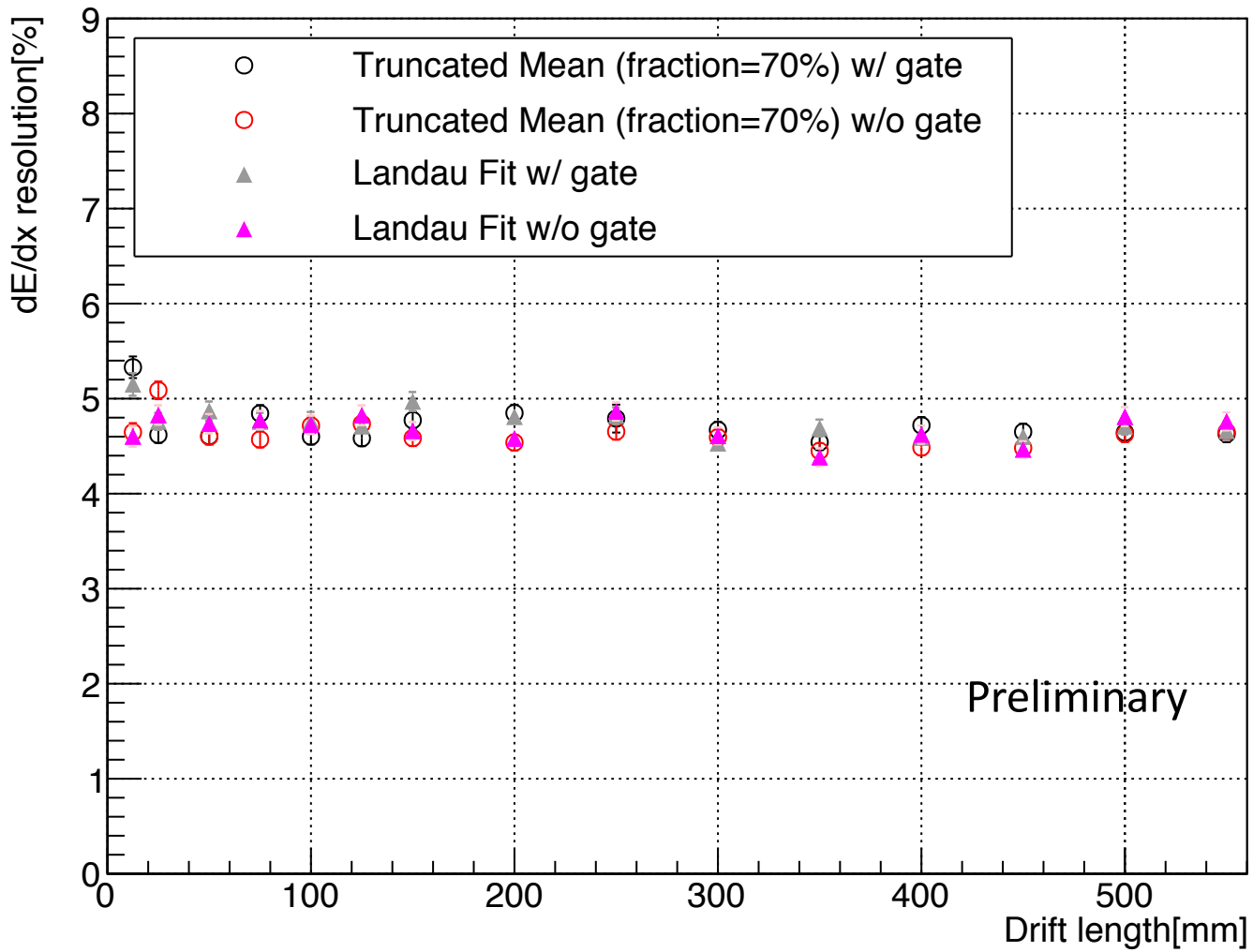
	Simulation	Measurement
dE/dx resolution w/gate	4.02 +/- 0.09 %	4.67 +/- 0.02 %
dE/dx resolution w/o gate	3.96 +/- 0.09 %	4.62 +/- 0.02 %
Δ dE/dx resolution	0.06 +/- 0.13 %	0.05 +/- 0.03 %

Calculation of dE/dx resolution using Landau Fit



- Tracks with 220 hit pad rows were simulated by combining the charge measurements in 9 events (tracks).
- Fitting with the Landau function every 220 hits and plotting the obtained MPV gives a Gaussian distribution. The dE/dx resolution is calculated from the obtained Gaussian distribution.

dE/dx resolution using Landau Fit



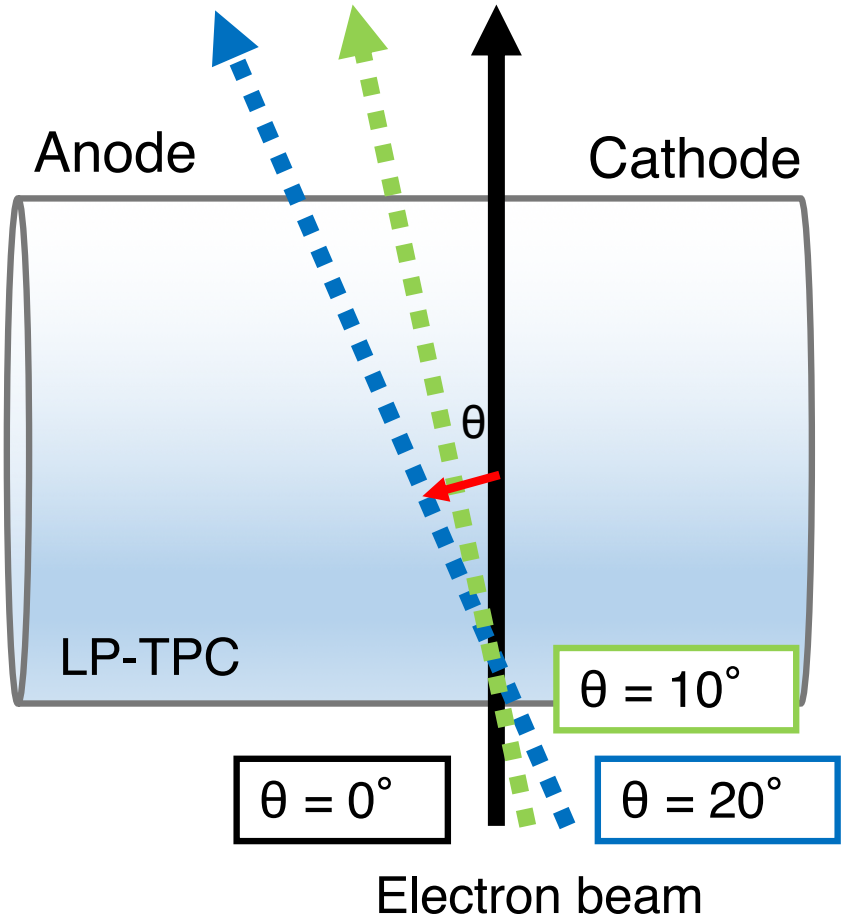
The dE/dx resolution using truncated mean is as well as (or better than) the dE/dx resolution using landau fit.

The average of dE/dx resolution	Truncated(70%)	Landau fitting
w/ gating foil, $\phi = 0^\circ$	4.66 ± 0.02%	4.72 ± 0.02 %
w/o gating foil, $\phi = 0^\circ$	4.61 ± 0.02%	4.68 ± 0.03 %

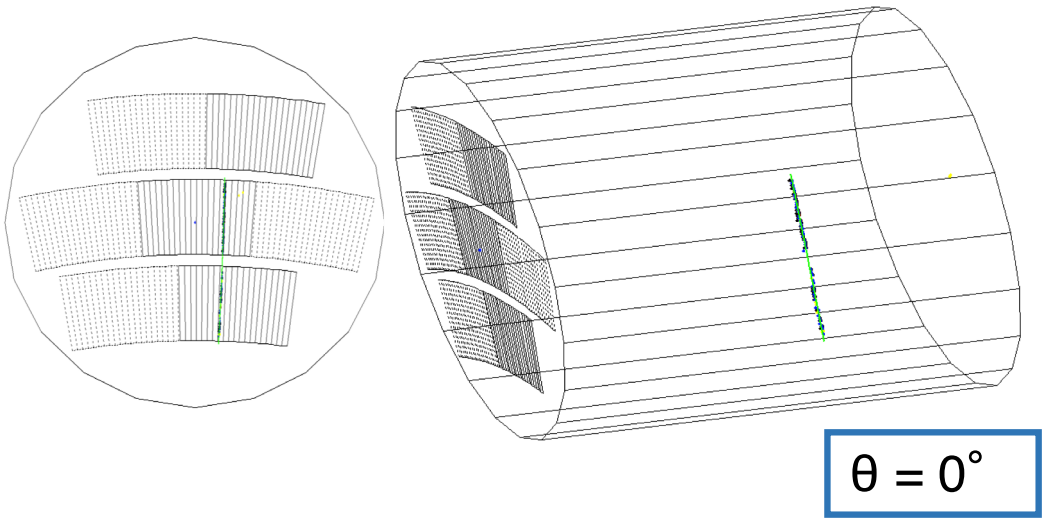
*Exclude of 12.5 mm because shower may cause.

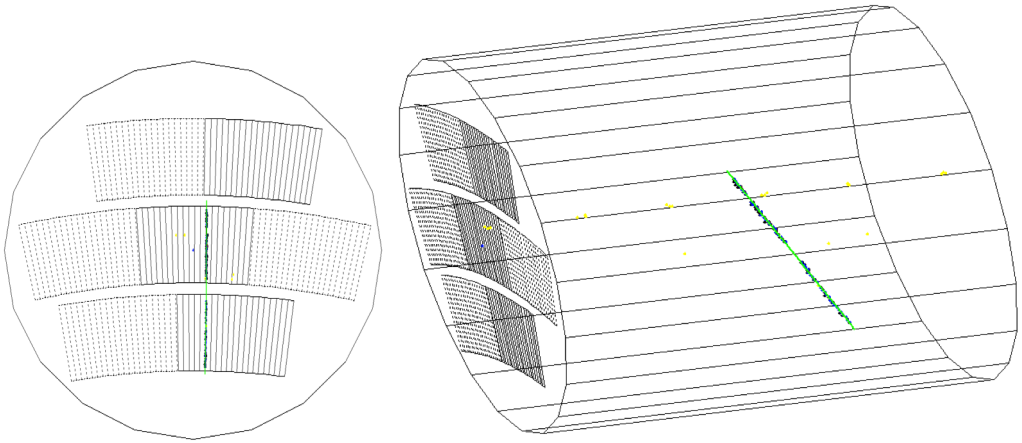
Incident angle θ of the beam

*A view of LPTPC from above



*Example of tracks

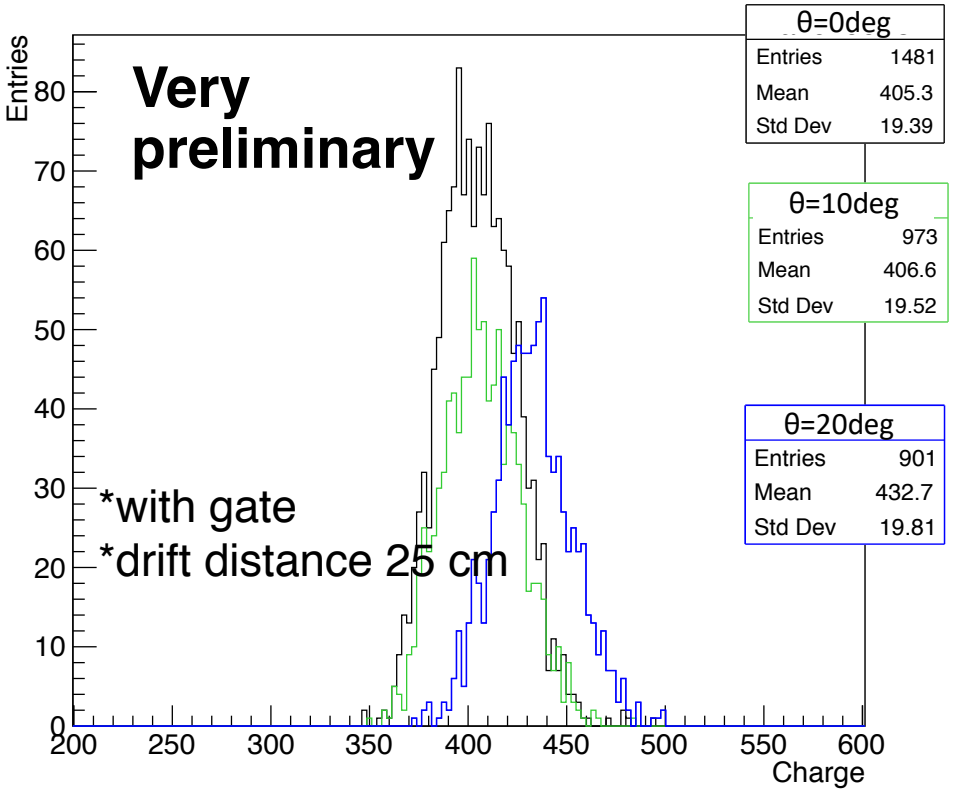


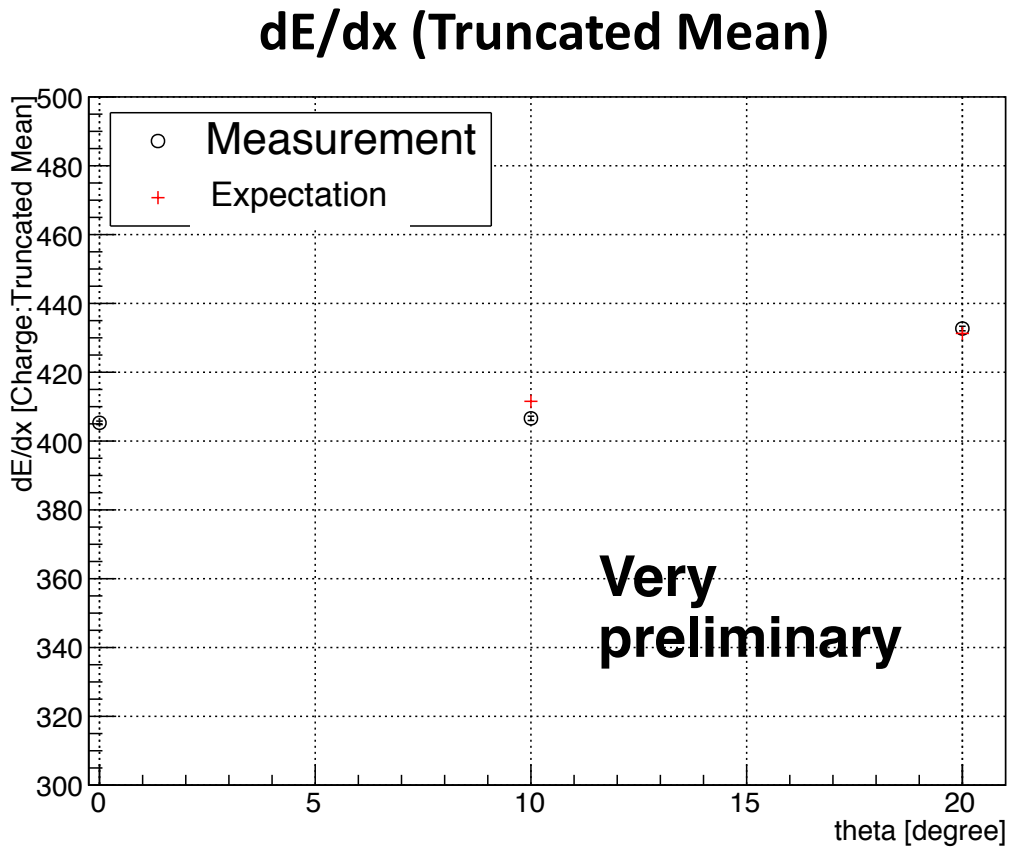


→ Compare dE/dx θ = 0° with θ = 20°

θ dependence on dE/dx

Signal charge(Truncated Mean [fraction 70%,Nsample 220])





Angled beam

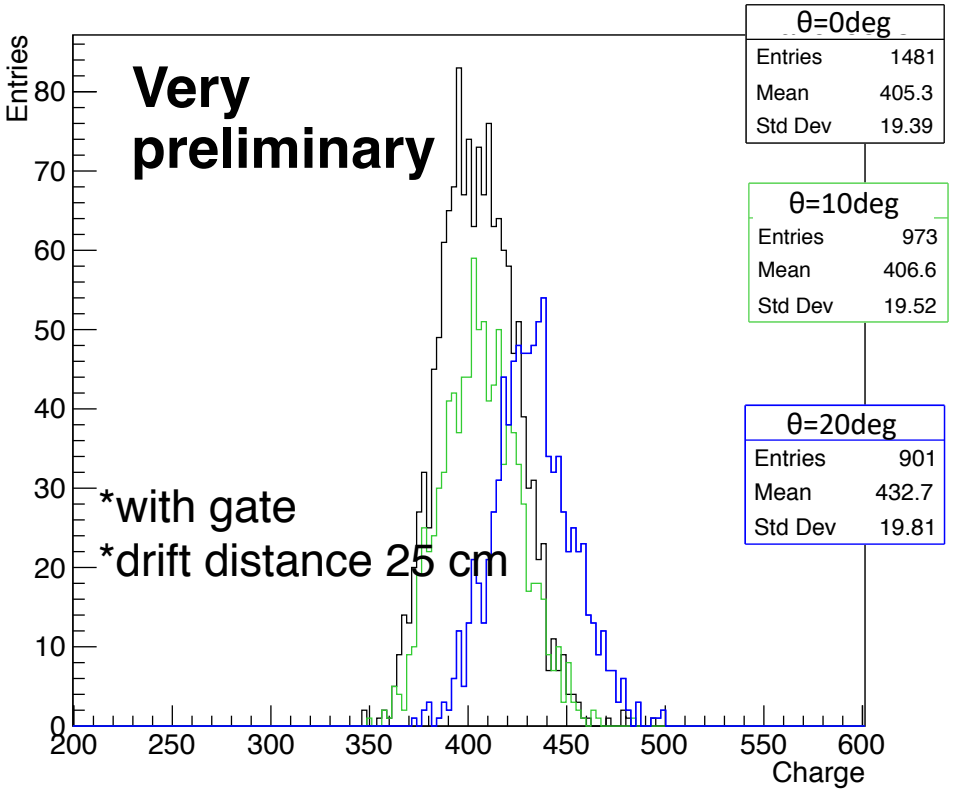
→the track becomes long

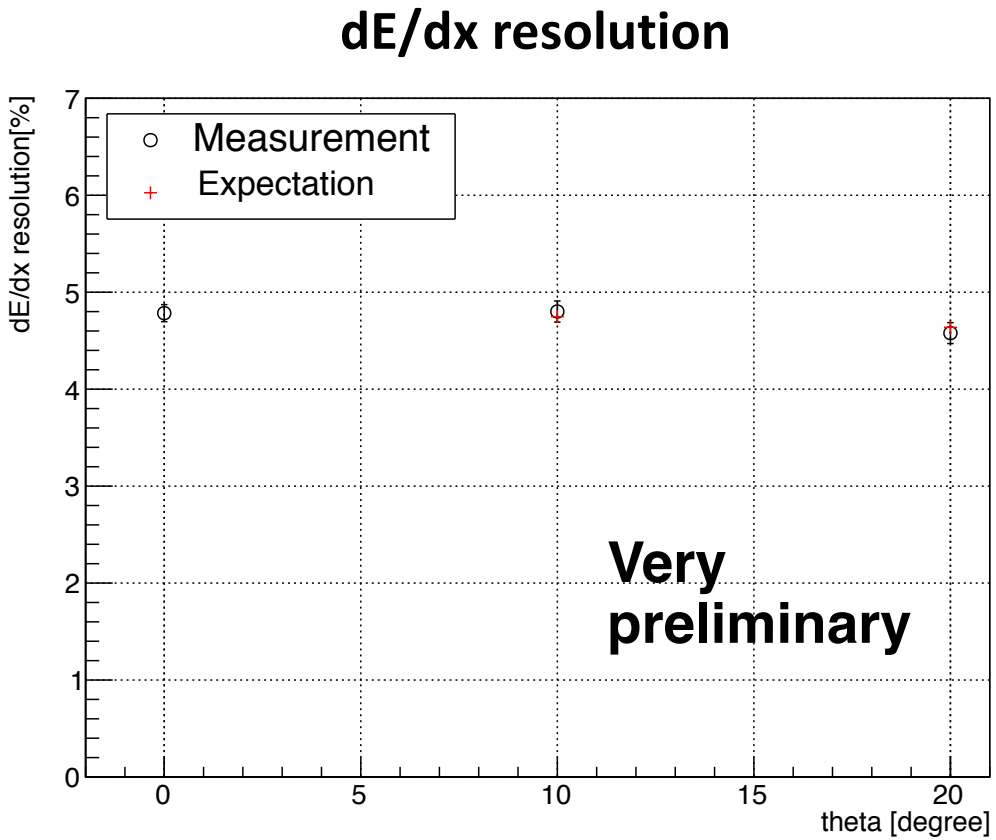
→signal charge should increase $\frac{1}{\cos\theta}$ ---Expectation

As the angle θ increases, dE/dx increases as expected.

θ dependence on dE/dx resolution

Signal charge(Truncated Mean [fraction 70%,Nsample 220])





Angled beam

→the track becomes long

→signal charge should increase $\frac{1}{\cos\theta}$ ---Expectation

As the angle θ increases, dE/dx resolution becomes better as expected

Summary

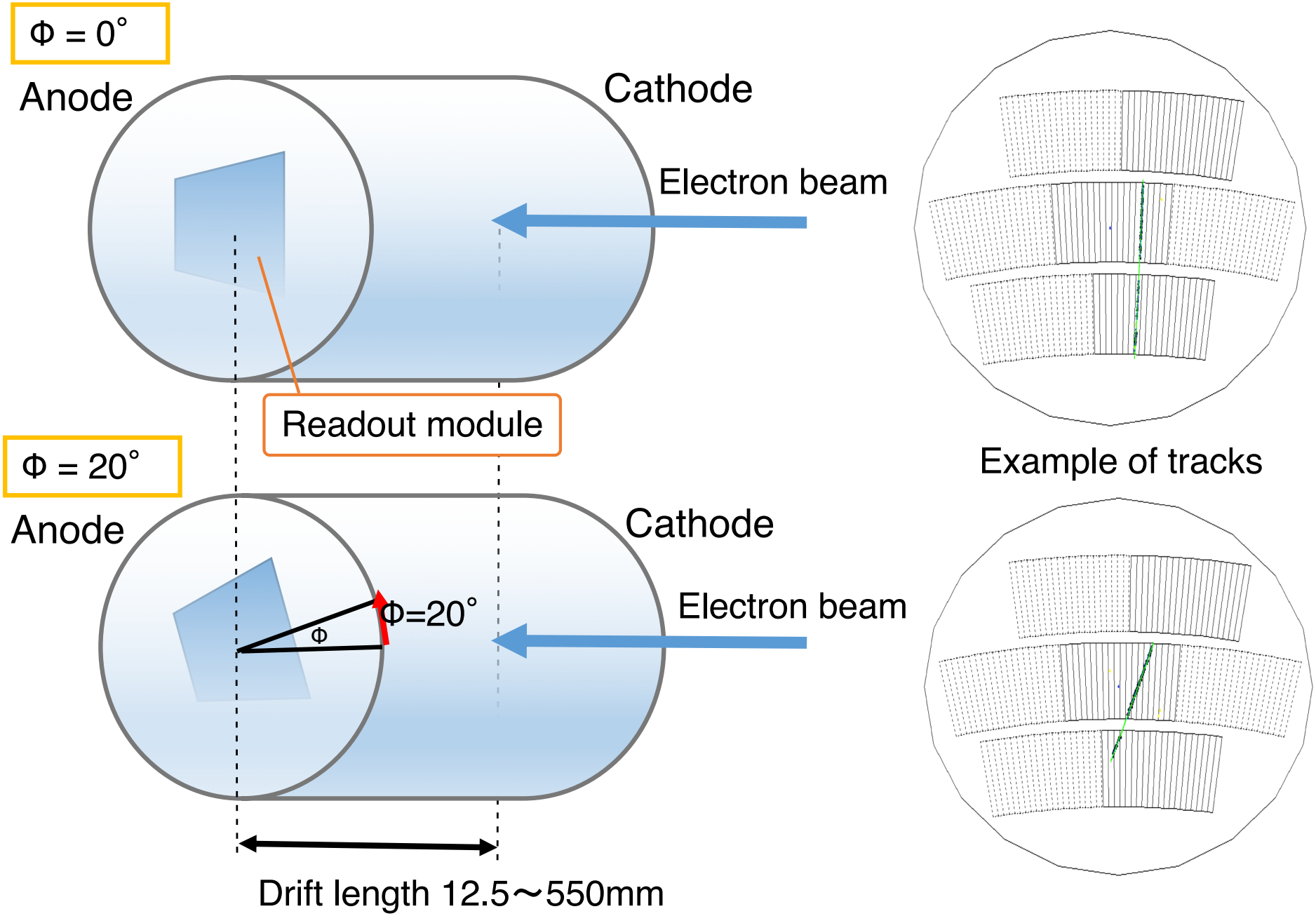
- The dE/dx resolution of ILD-TPC (both models) was estimated using beam test data with Truncated Mean.
- The dE/dx resolution of the ILD-TPC (large-model) with a gating foil was estimated to be about 4.7 % for 5 GeV/c electrons on the Fermi plateau. In the small-model TPC, the dE/dx resolution was estimated to be about 5.4 %.

- The dE/dx resolution of with/without the gating foil was simulated.
- Simulation result was better than experimental result, but, the difference between the with/without gate was almost same and small.

- The dE/dx resolution was calculated using Landau Fit. The dE/dx resolution using truncated mean is as well as (or better than) the dE/dx resolution using landau fit.

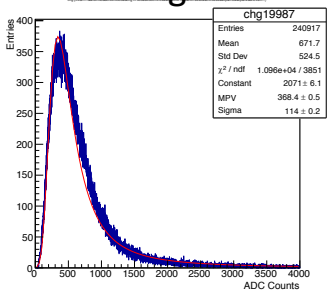
- As the angle θ increases, dE/dx resolution becomes better as expected.

Incident angle φ of the beam

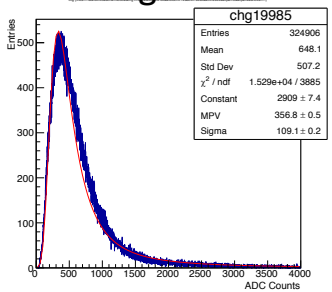


Charge distribution w/gate

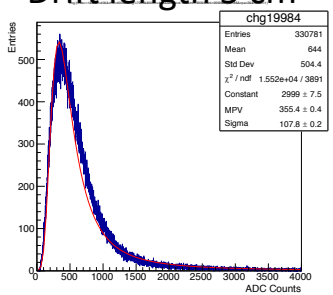
Drift length1.25 cm



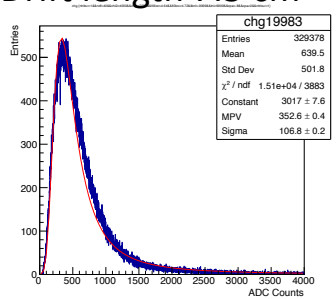
Drift length 2.5 cm



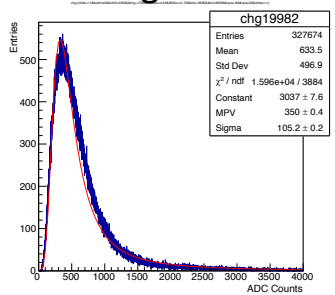
Drift length 5 cm



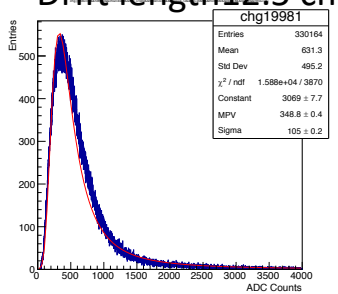
Drift length 7.5 cm



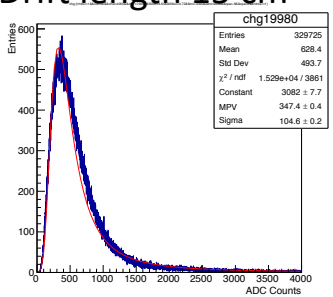
Drift length 10 cm



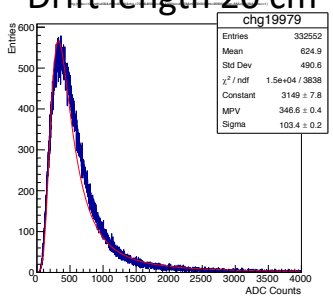
Drift length12.5 cm



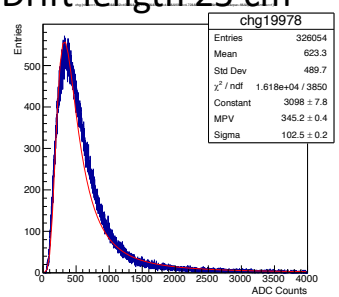
Drift length 15 cm



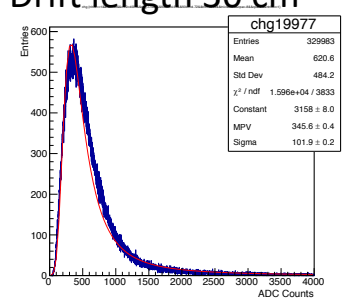
Drift length 20 cm



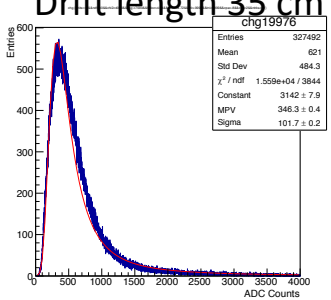
Drift length 25 cm



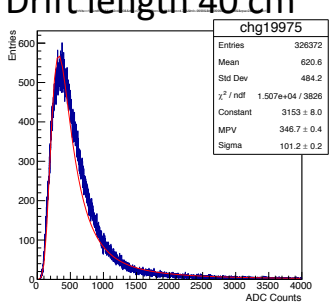
Drift length 30 cm



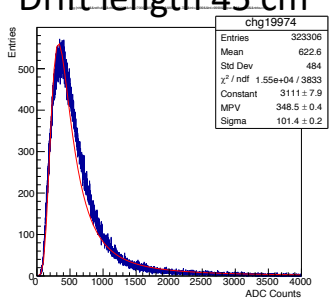
Drift length 35 cm



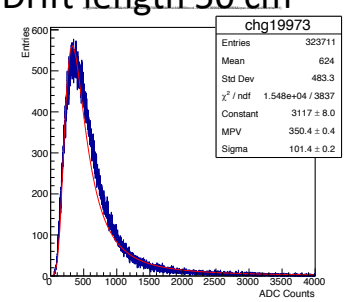
Drift length 40 cm



Drift length 45 cm



Drift length 50 cm



Drift length 55 cm