

dE/dx Study
with Asian module

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on behalf of the LC-TPC group

➤ **Brief introduction**

➤ **Beam test**

➤ **Measurement of dE/dx resolution**

- **dE/dx resolution and signal charge @ prototype TPC**
- **dE/dx resolution @ small TPC**
- **dE/dx resolution @ large TPC**

➤ **Summary**

➤ **Brief introduction**

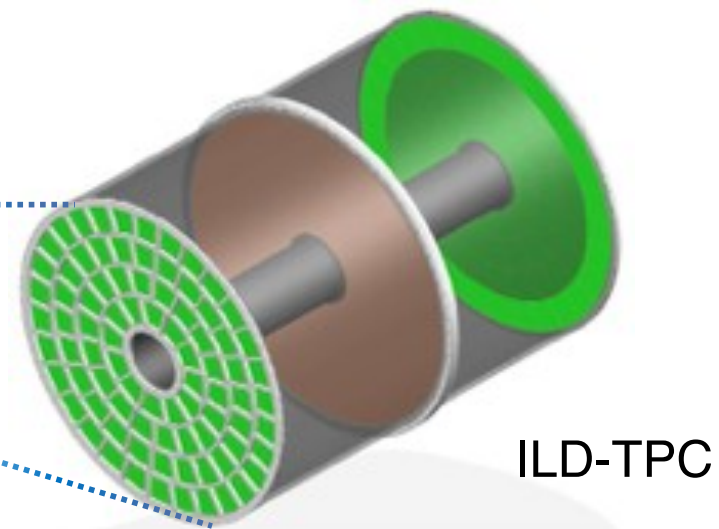
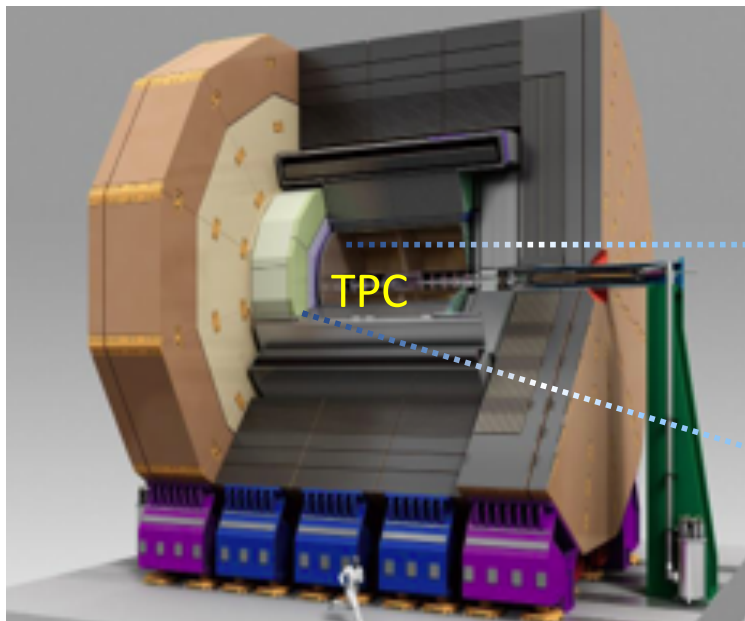
➤ Beam test

➤ Measurement of dE/dx resolution

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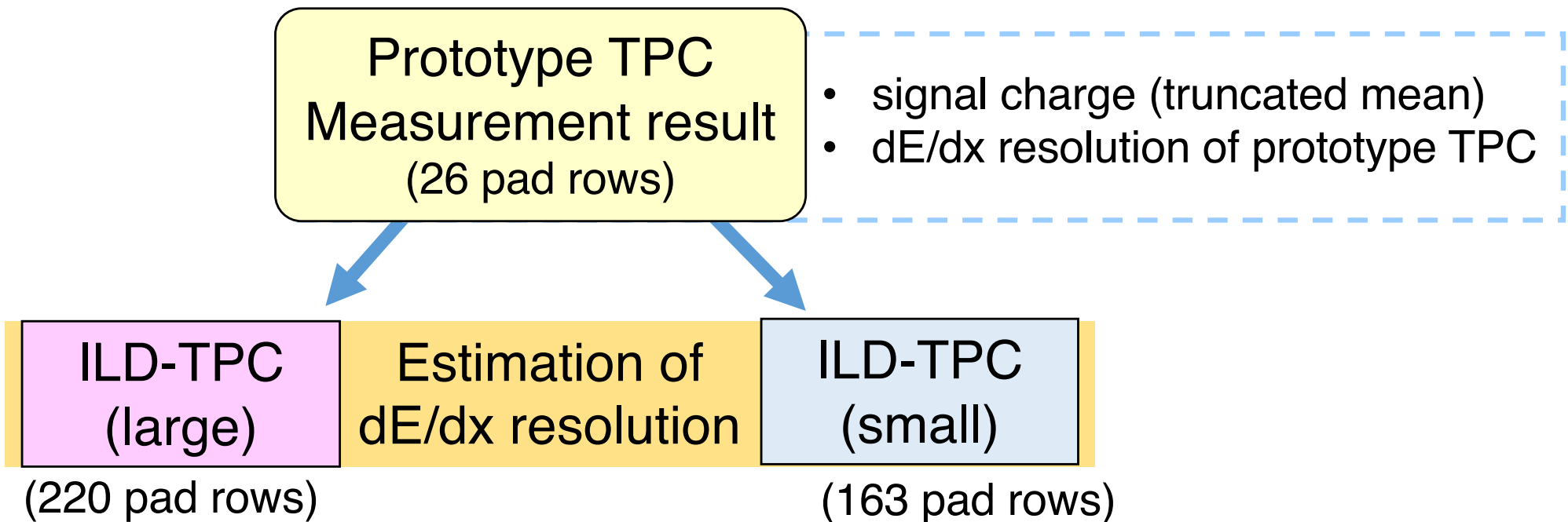
➤ Summary

- At the ILC experiment, the TPC (Time Projection Chamber) will be used as a central tracker in the ILD (International Large Detector).
 - TPC can identify particle species using energy loss (dE/dx) measured by the readout pad rows.
- For the ILD-TPC, expected dE/dx resolution is 5 % (TDR).



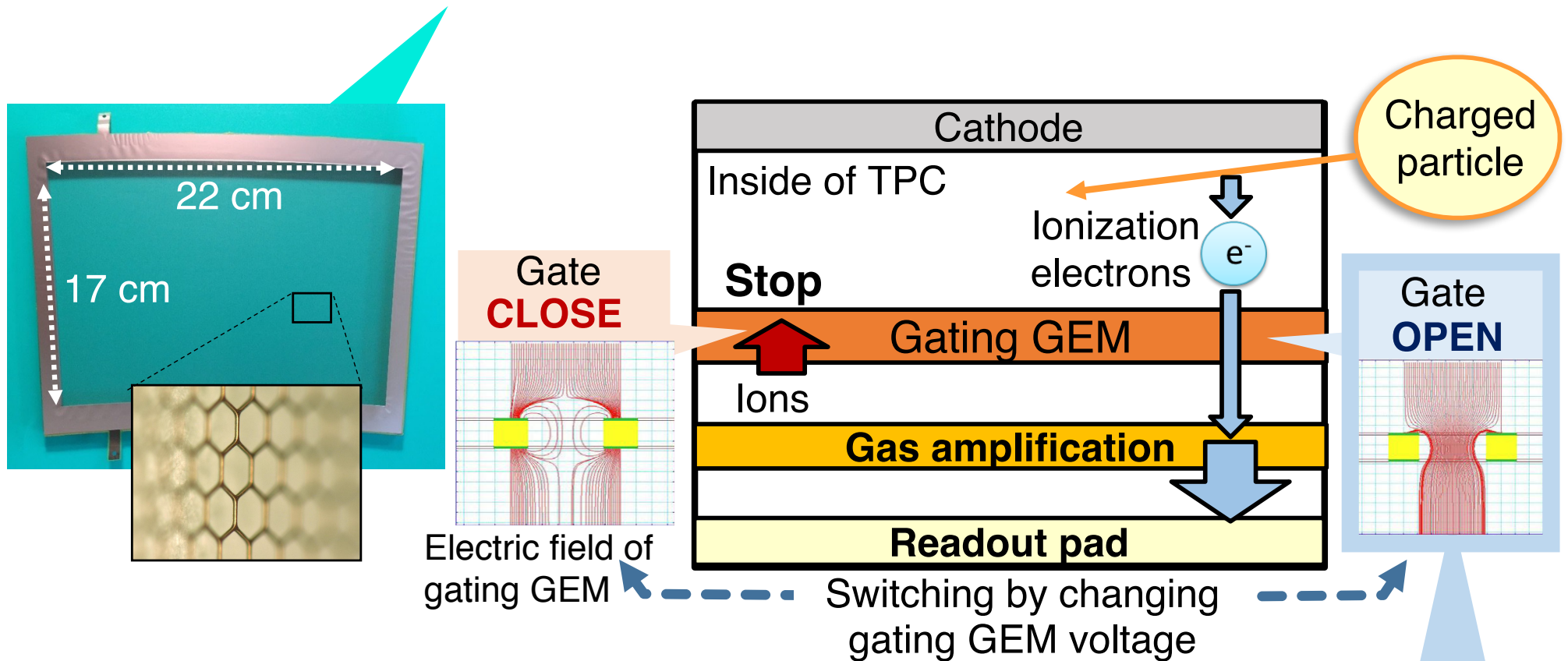
ILD (International Large Detector)

- The dE/dx resolution of our prototype TPC with gating GEM was measured using the electron beam in a magnet field.
- The dE/dx resolution of ILD-TPC (both models) was estimated using this beam test data.



ILC-TPC problem: Positive ions feedback

- The ions feedback causes distortion of reconstructed tracks.
- Mounting a **gating GEM** 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 GEM at which the electron transmission rate is maximum.

➤ Brief introduction

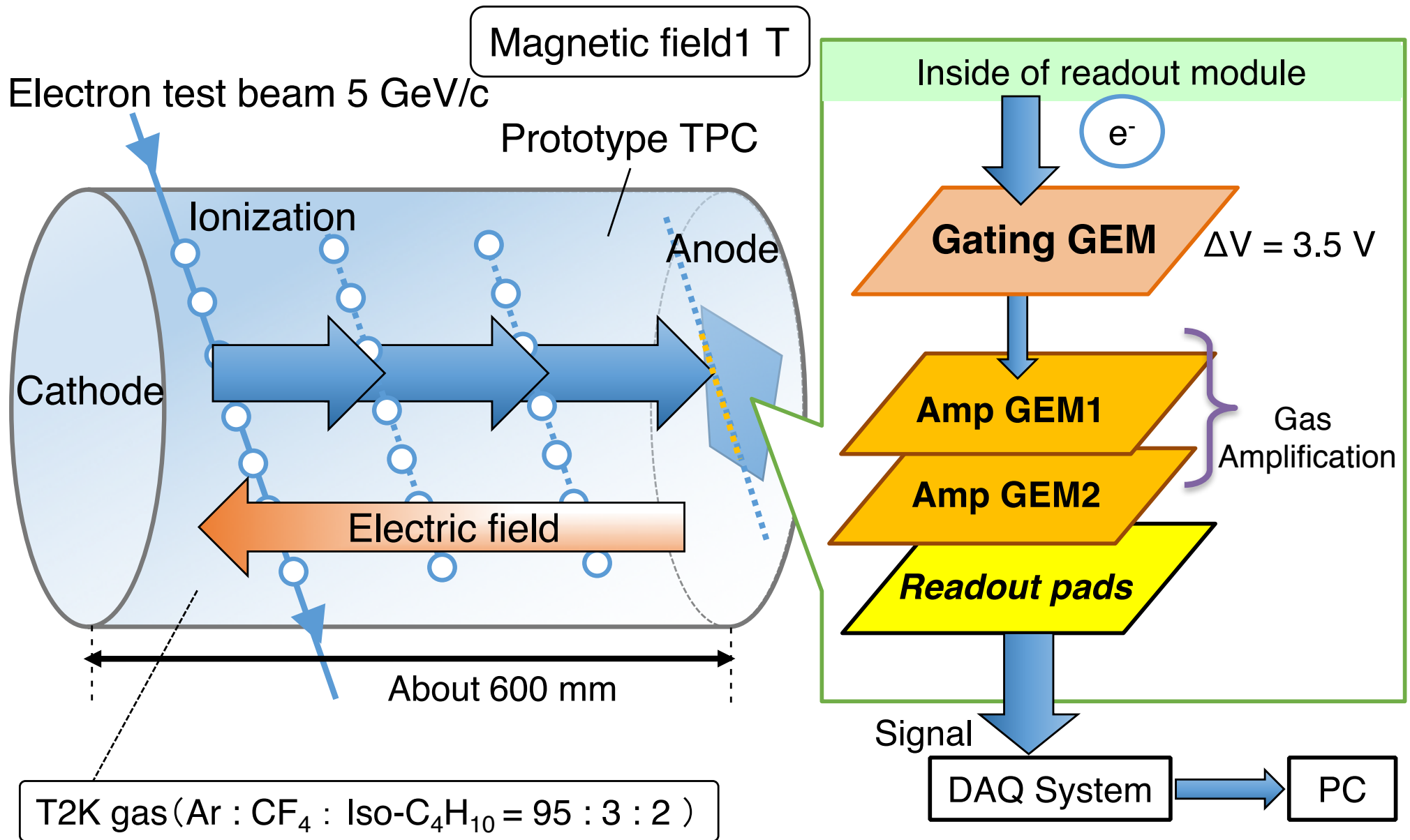
➤ **Beam test**

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➤ Summary

Beam test ~Set up~

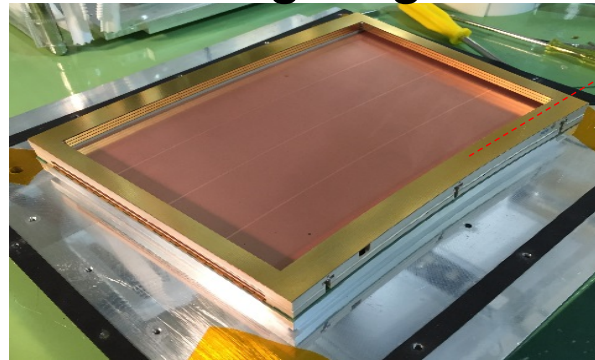


- We measured at the both of with or without gating GEM.

With gating GEM



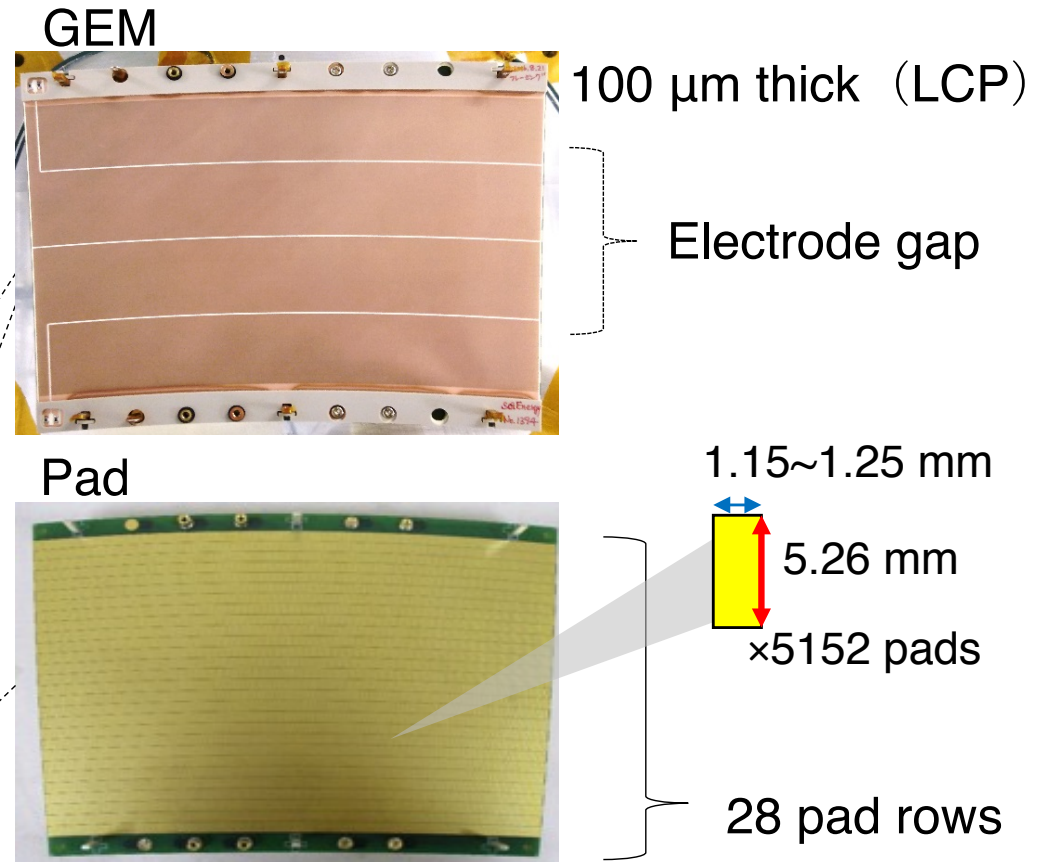
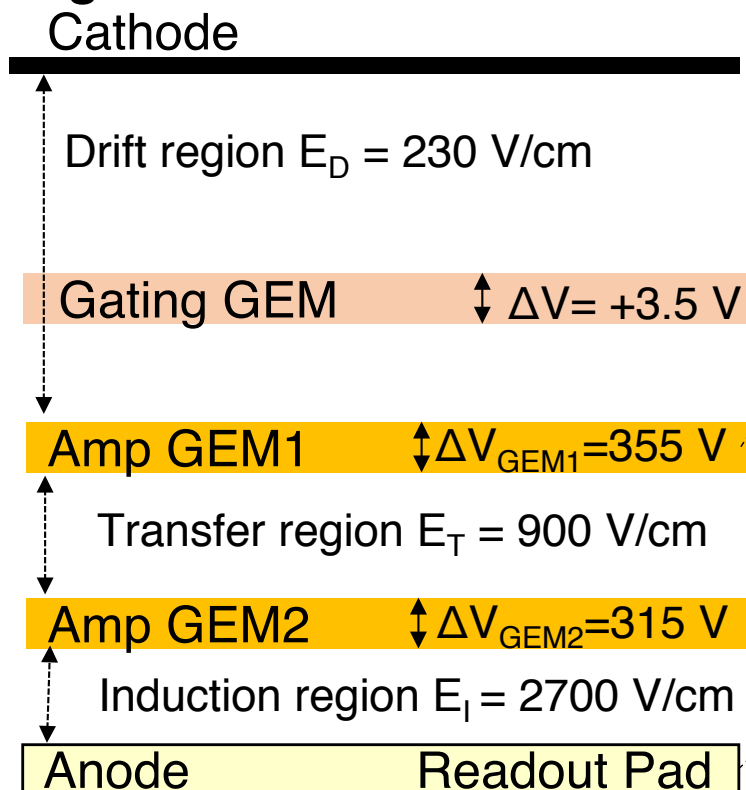
Without gating GEM



Field shaper

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

(Voltage · Electric field)



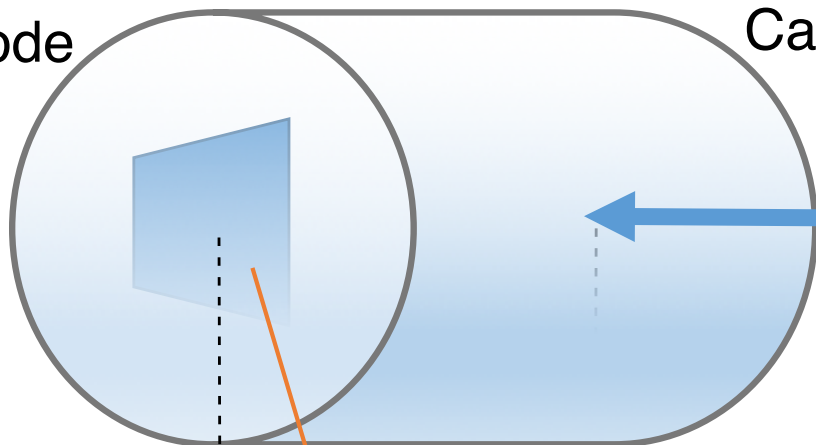
Incident angle ϕ of the beam

$\Phi = 0^\circ$

Anode

Cathode

Electron beam



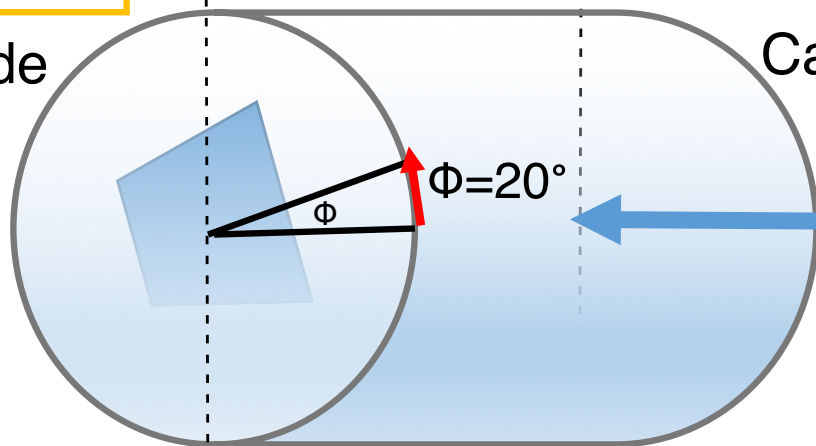
Readout module

$\Phi = 20^\circ$

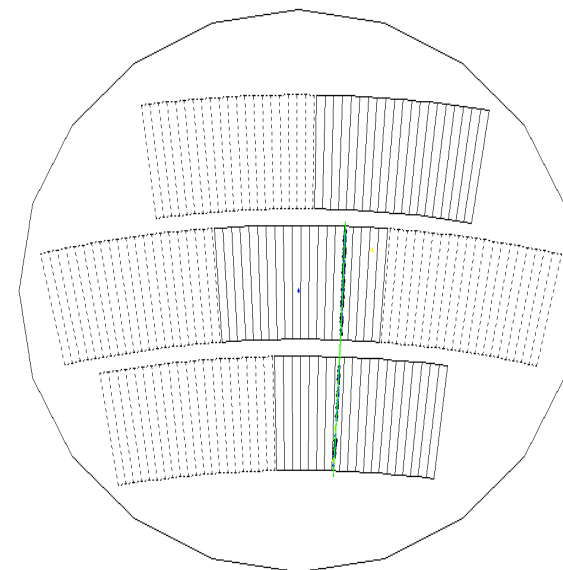
Anode

Cathode

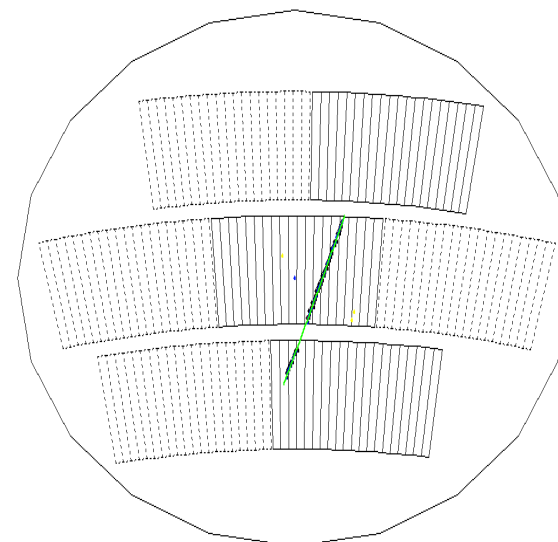
Electron beam



Drift length 12.5~550mm



Example of tracks



➤ Brief introduction

➤ Beam test

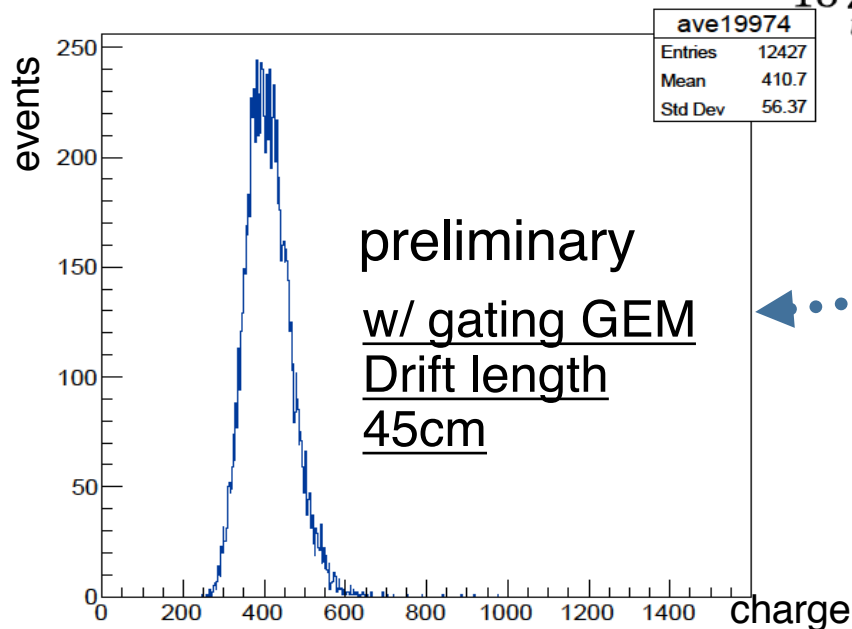
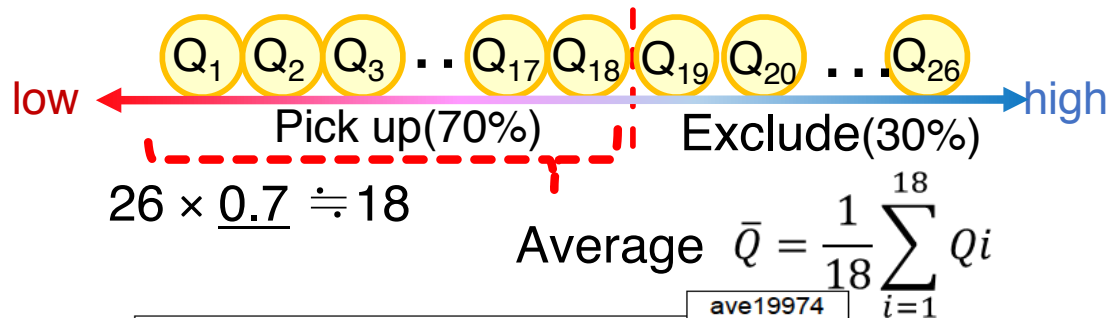
➤ **Measurement of dE/dx resolution**

- **dE/dx resolution and signal charge @ prototype TPC**
- dE/dx resolution @ small TPC
- dE/dx resolution @ large TPC

➤ Summary

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

Truncated Mean Method

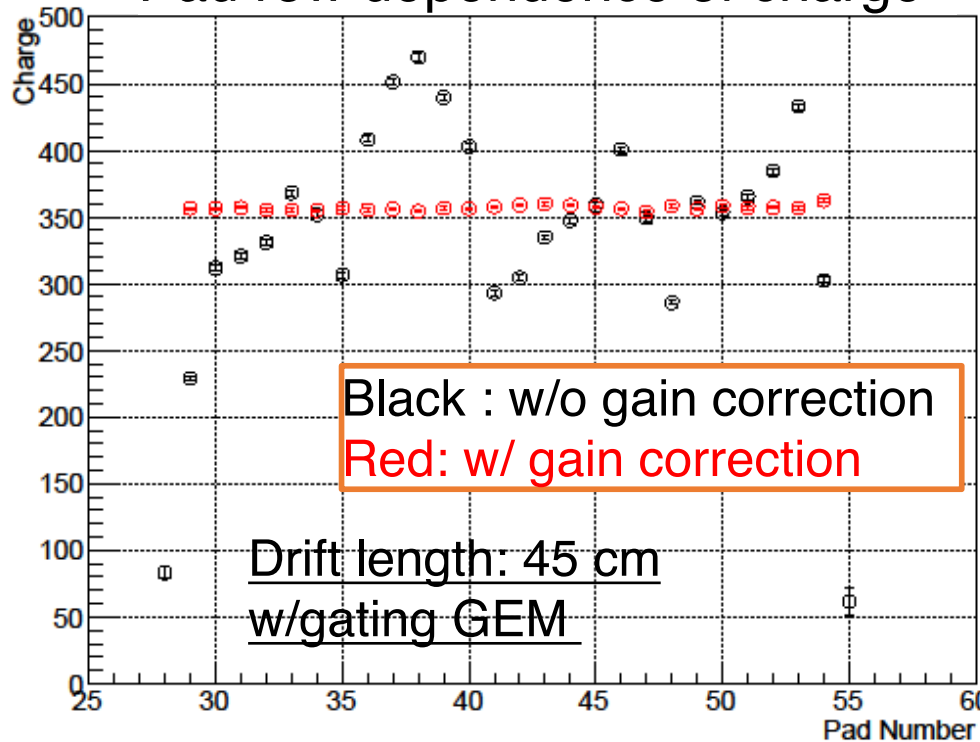


The pad rows were sorted by their charges and the average charge over those giving the lowest 70% were used in order to get rid of the Landau tail.

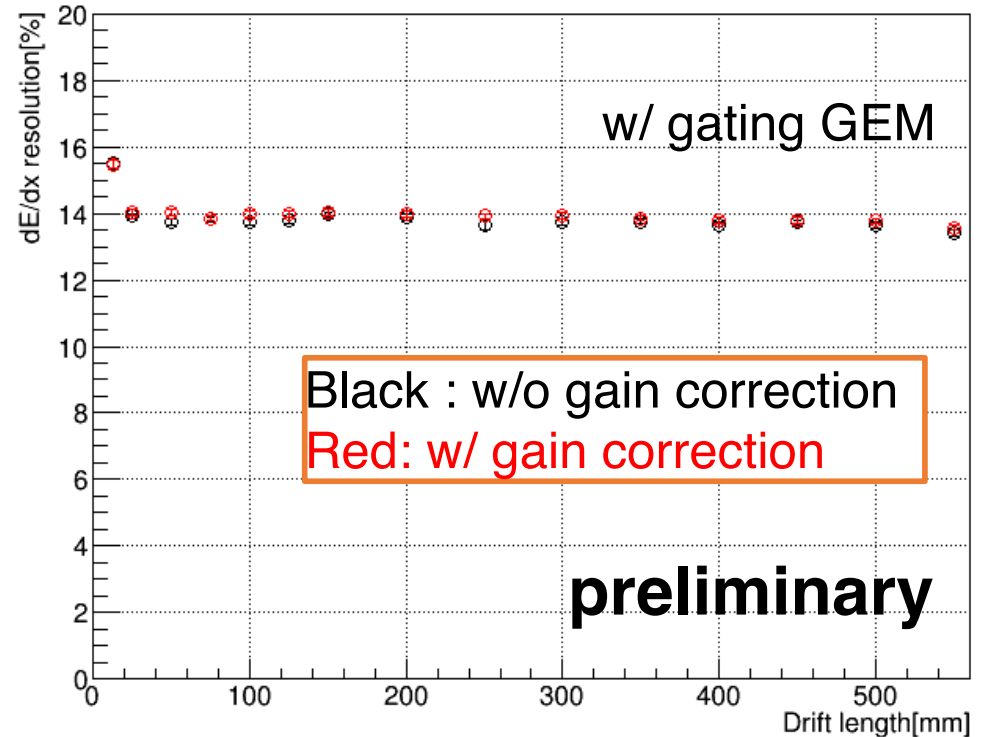
$$dE/dx \text{ resolution} = \frac{Std \ Dev}{Mean}$$

The signal charge has been corrected for the pad-row to pad-row gain variation before sorting for getting the truncated mean.

Pad row dependence of charge



dE/dx resolution(fraction 70%)

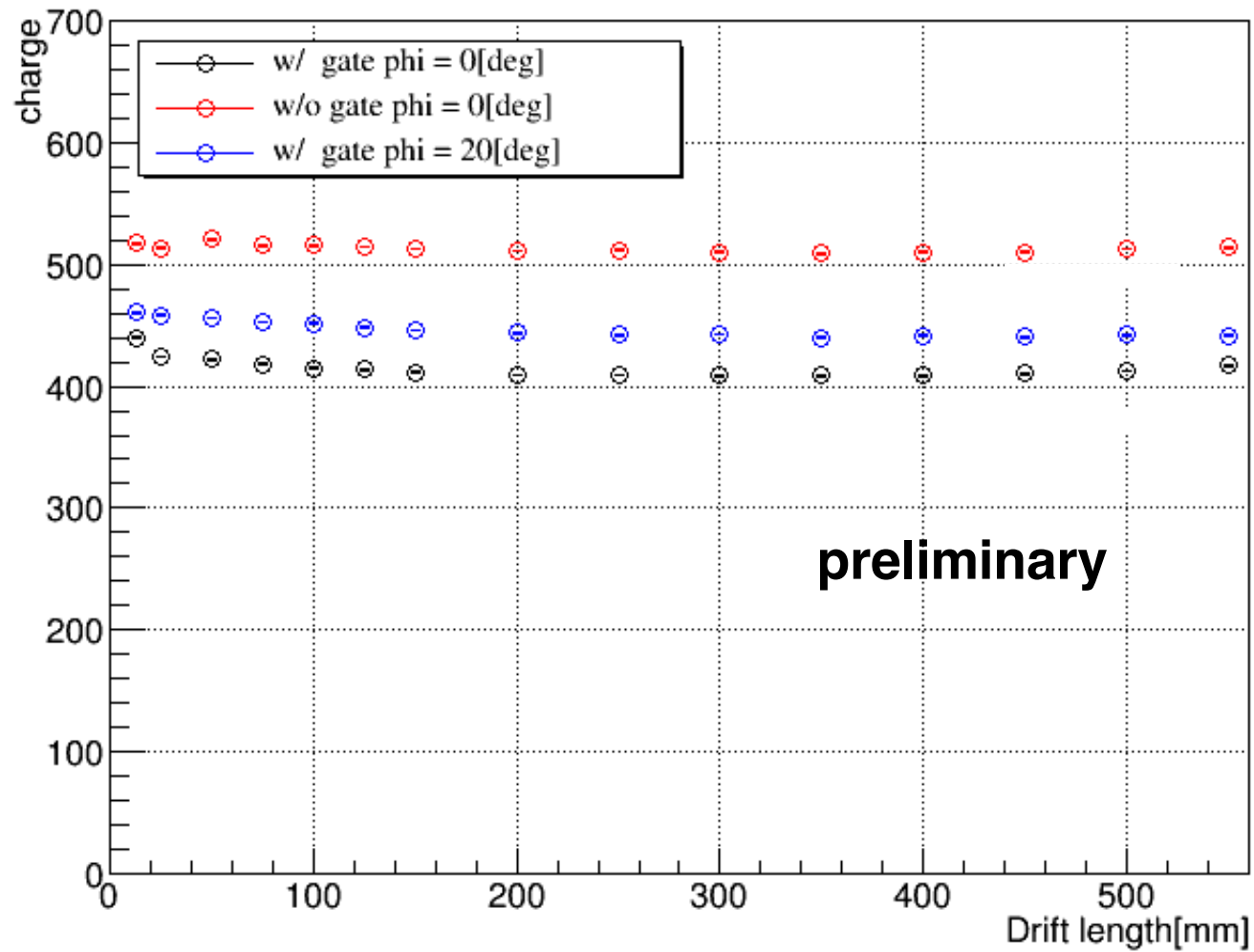


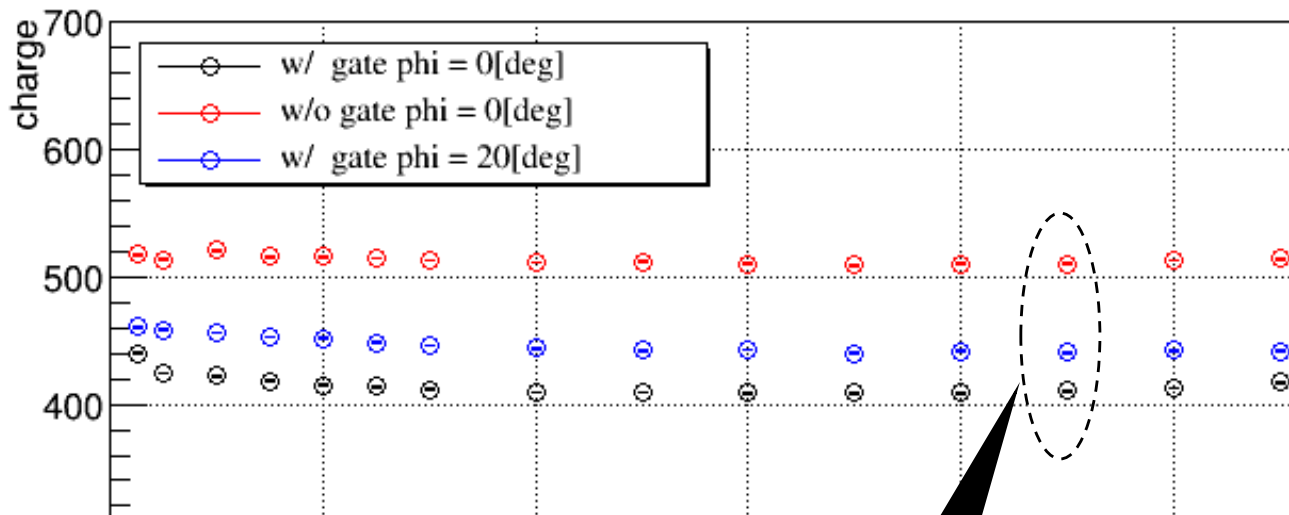
$$\text{Correction factor} : \frac{\text{charge}(each\ pad)}{\text{Averaged charge}(all\ pads)}$$

	The average of dE/dx resolution
without gain correction	$13.96 \pm 0.02\%$
with gain correction	$13.87 \pm 0.02\%$

→ The dE/dx resolution is rather insensitive to the pad-row to pad-row gain variation as expected.

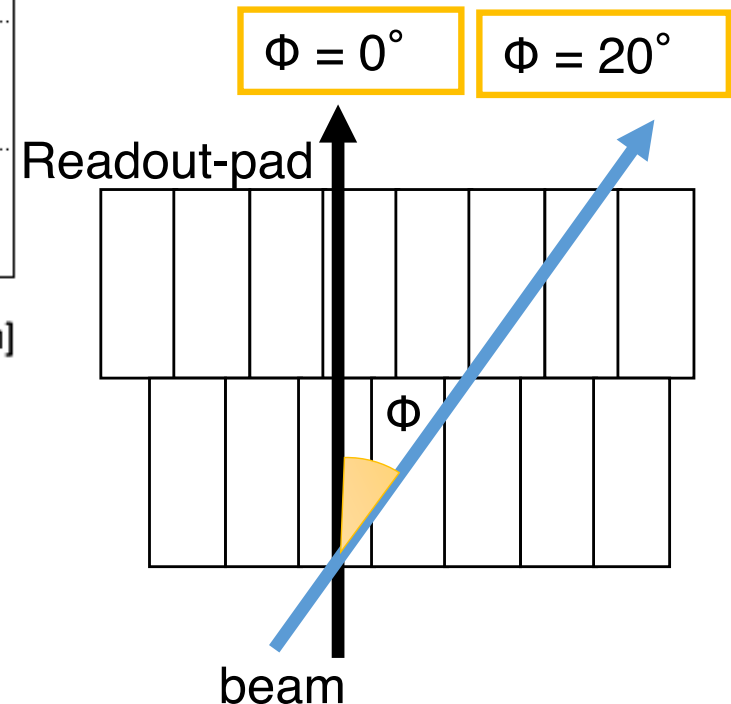
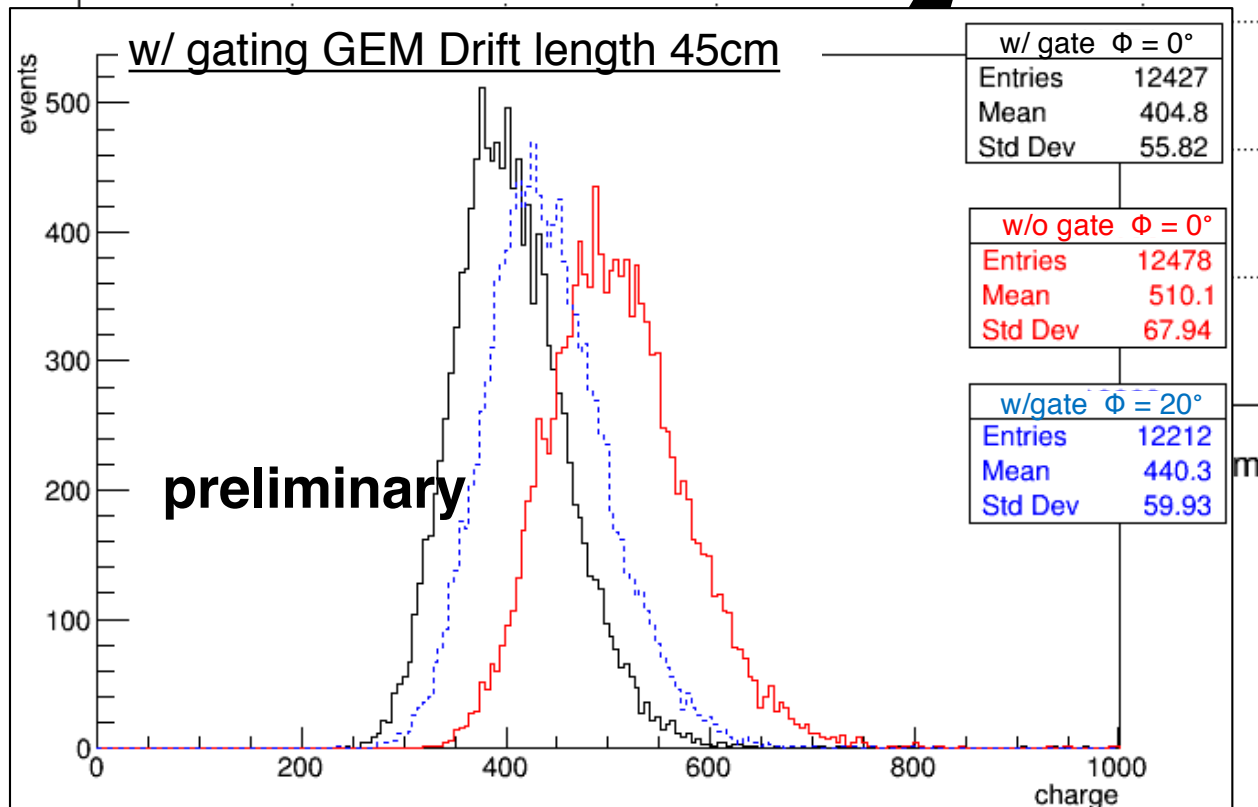
Signal charge (Truncated mean)

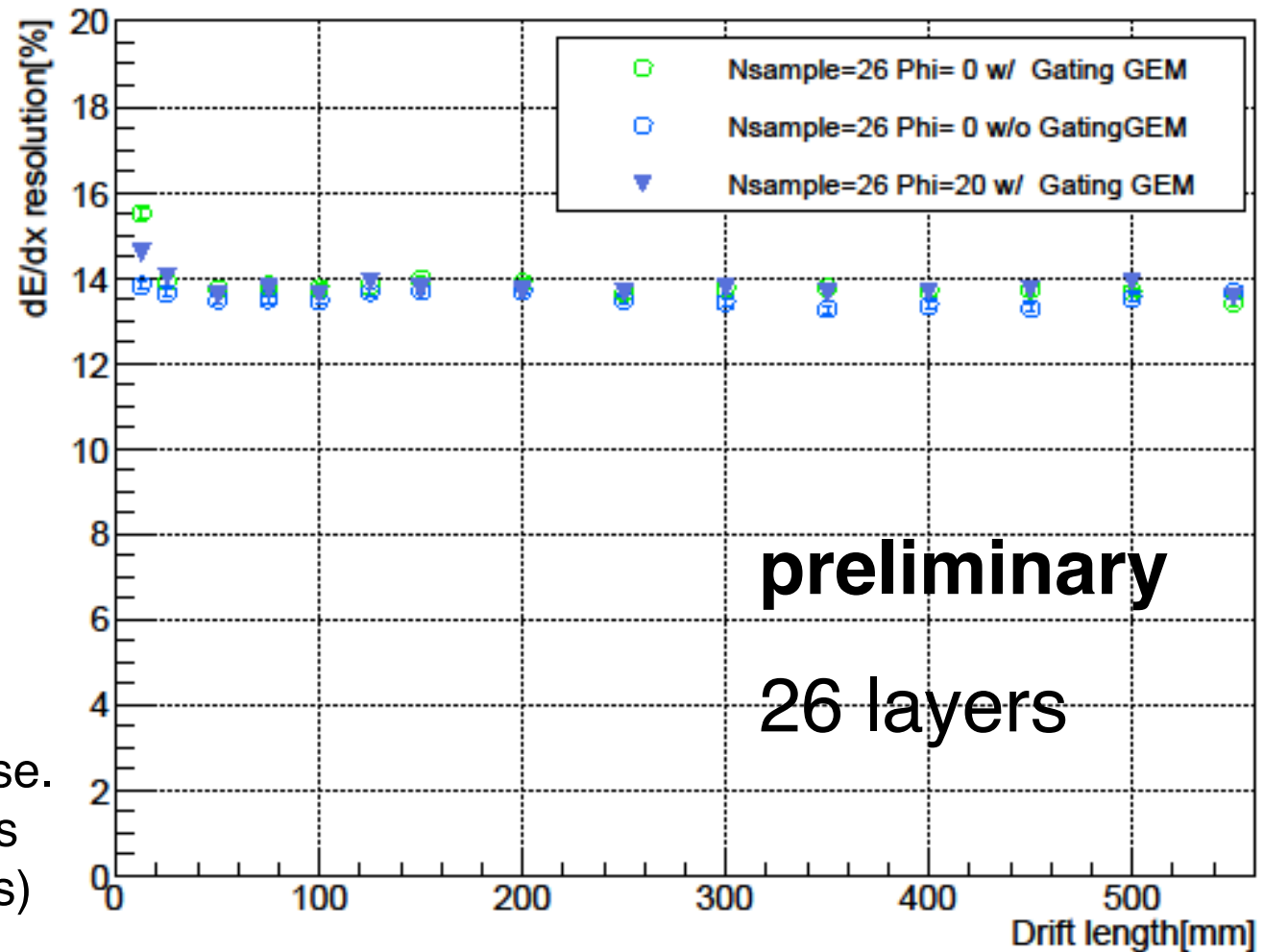




• In the case of with gate, the signal charge is less than without gate.

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





*Exclude of 12.5 mm because shower may cause. (The same processing was done on subsequent slides)

*fraction:70%	The average of dE/dx resolution
w/ gating GEM, $\phi=0^\circ$	$13.80 \pm 0.02\%$
w/o gating GEM, $\phi=0^\circ$	$13.52 \pm 0.02\%$
w/ gating GEM, $\phi=20^\circ$	$13.70 \pm 0.02\%$

The dE/dx resolution is rather insensitive to the presence or absence of the gating GEM.

➤ Brief introduction

➤ Beam test

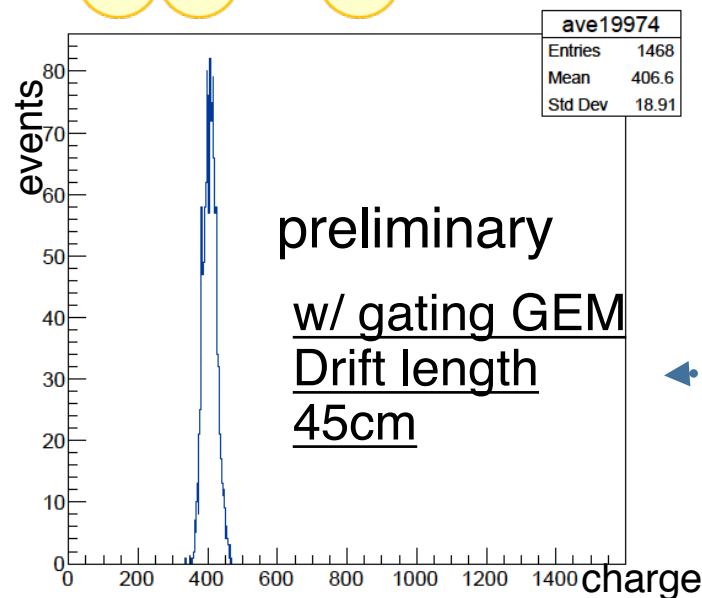
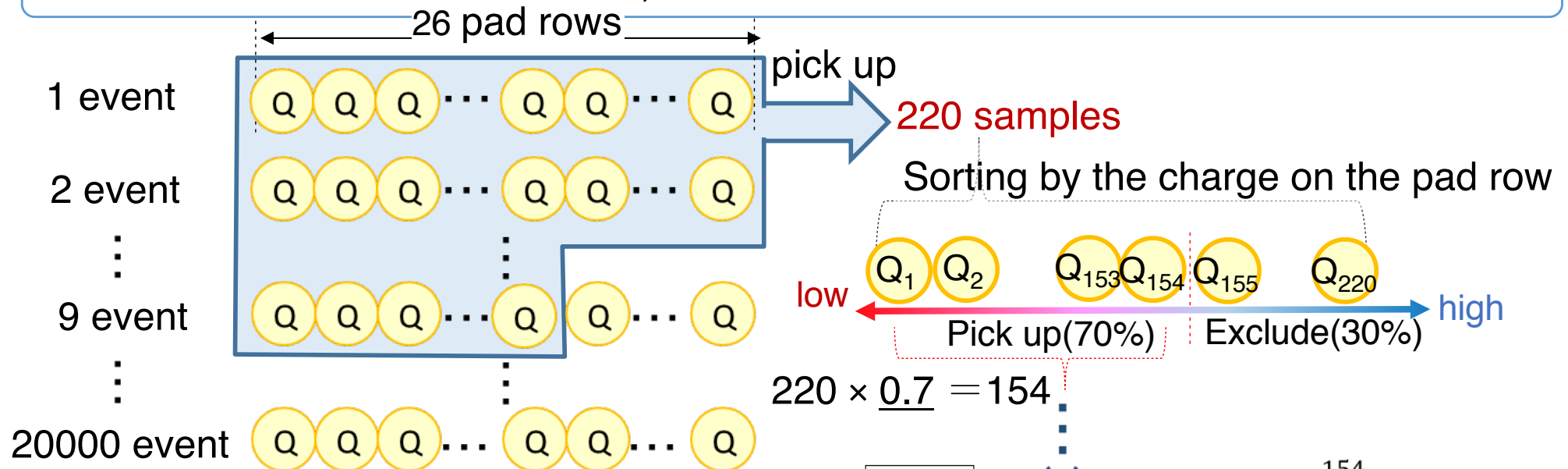
➤ **Measurement of dE/dx resolution**

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- **dE/dx resolution @ large TPC**

➤ Summary

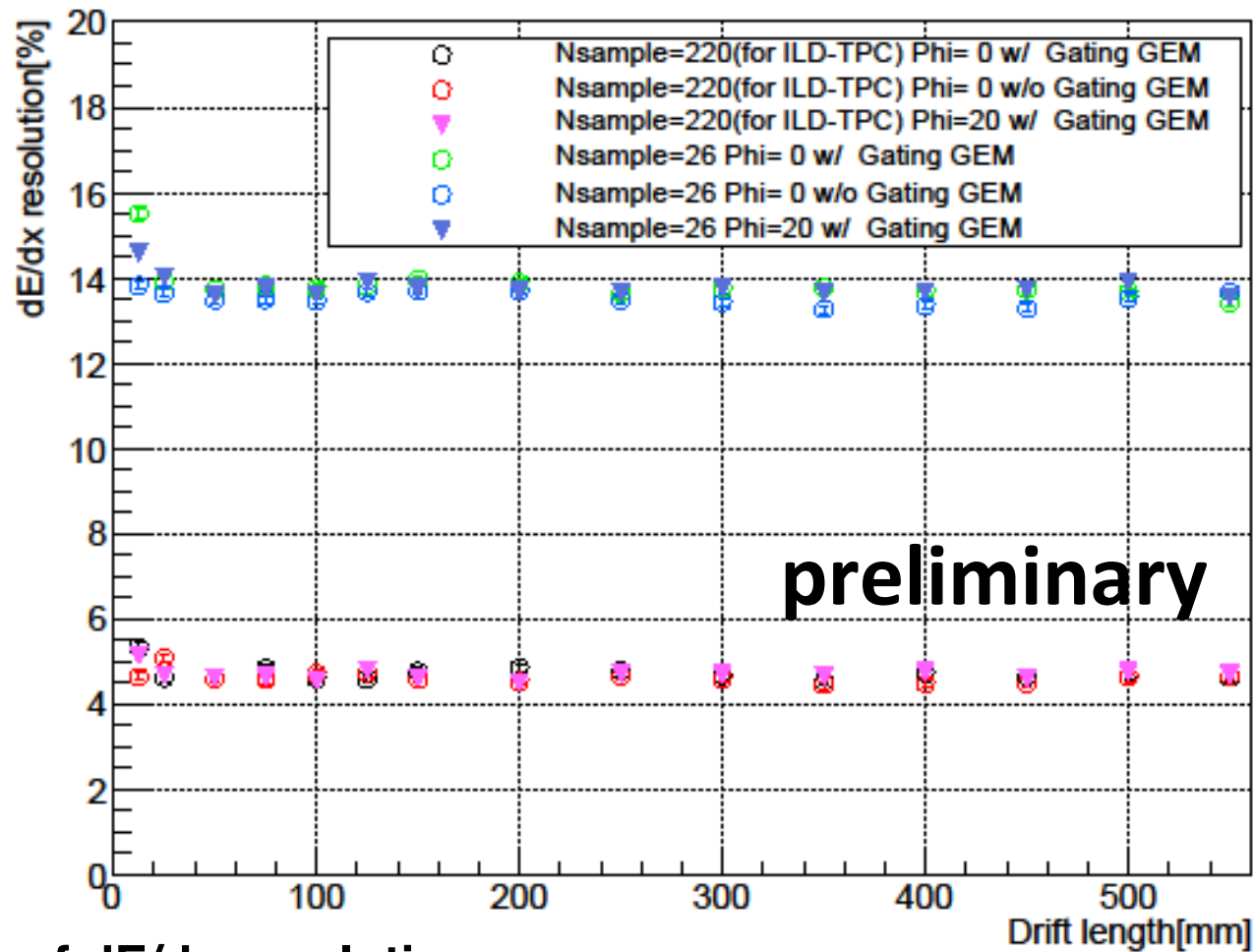
Expected dE/dx resolution of *ILD-TPC*(large) ①

Method ①: For the estimation of the dE/dx resolution of the *ILD-TPC* (large), tracks with 220 hit pad rows were simulated by combining the charge measurements in 9 events (tracks).



Average $\bar{Q} = \frac{1}{154} \sum_{i=1}^{154} Q_i$

Plots



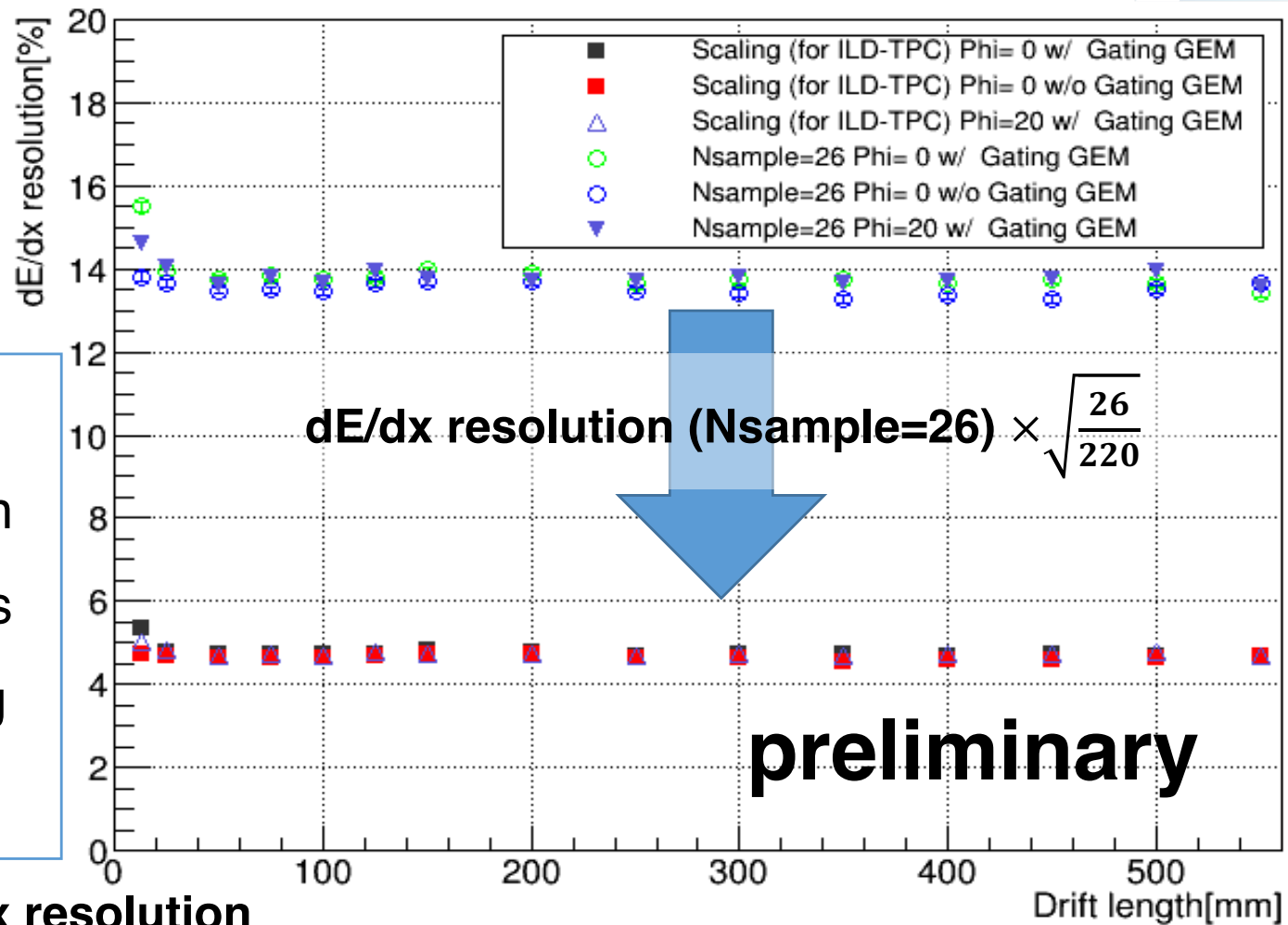
The average of dE/dx resolution

	Method① Sampling
w/ gating GEM, $\phi = 0^\circ$	$4.66 \pm 0.02\%$
w/o gating GEM, $\phi = 0^\circ$	$4.61 \pm 0.02\%$
w/ gating GEM, $\phi = 20^\circ$	$4.68 \pm 0.02\%$

The dE/dx resolution is rather insensitive to the presence or absence of the gating GEM as expected.

Method②:

The dE/dx resolution of *ILD-TPC* (large) is estimated by scaling with $1/\sqrt{N}$.

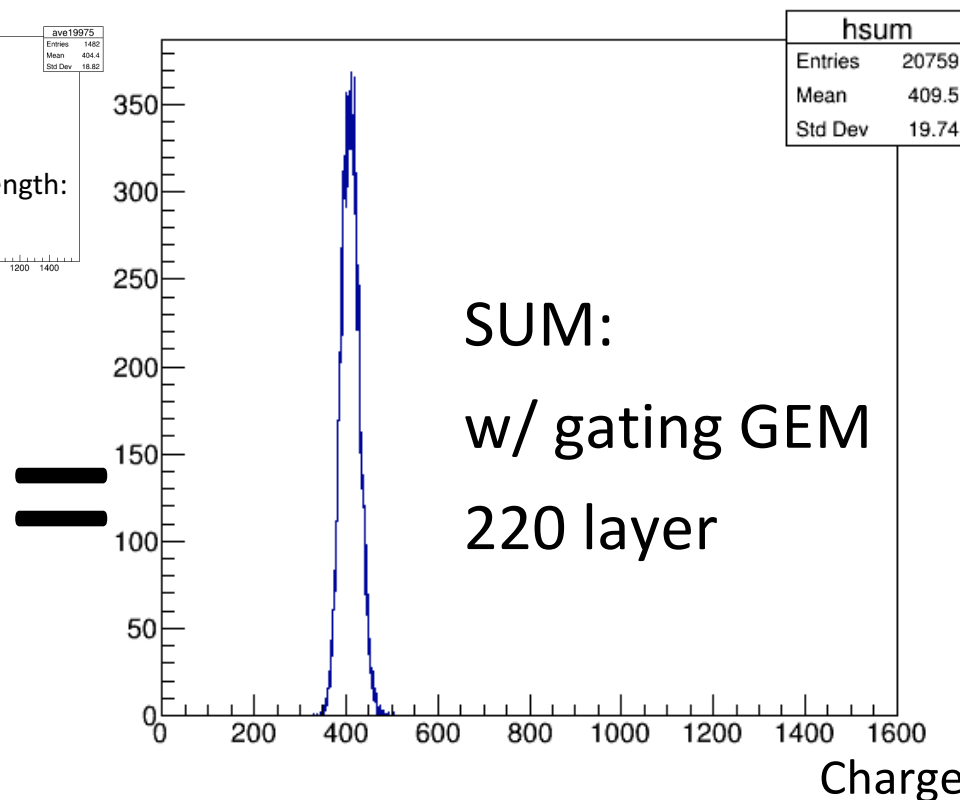
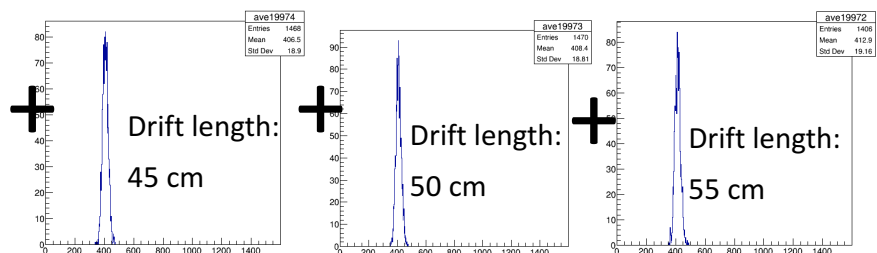
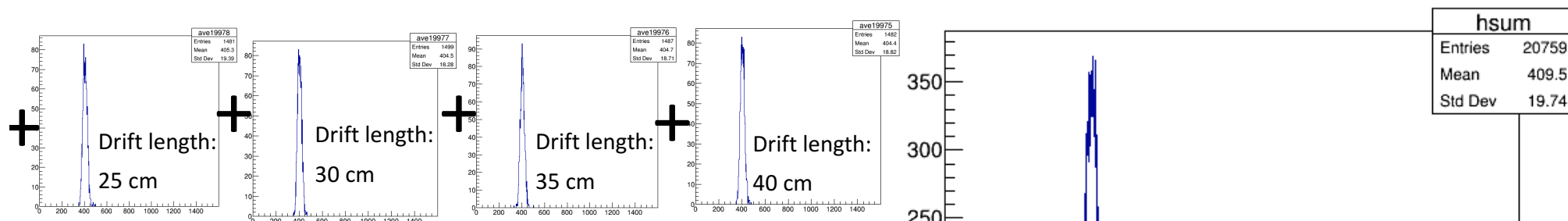
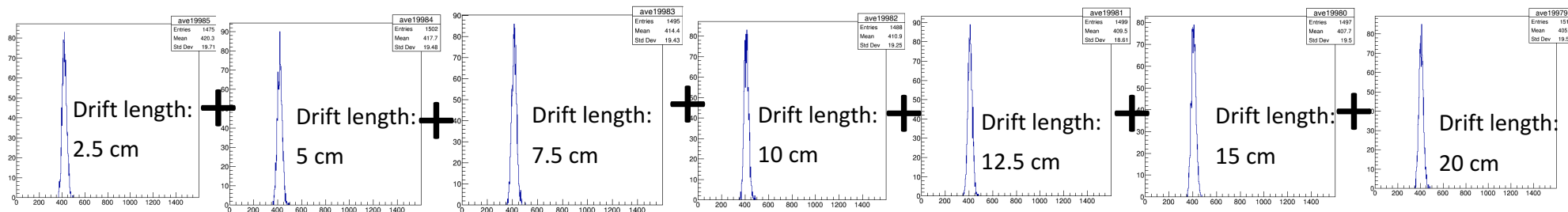


The average of dE/dx resolution

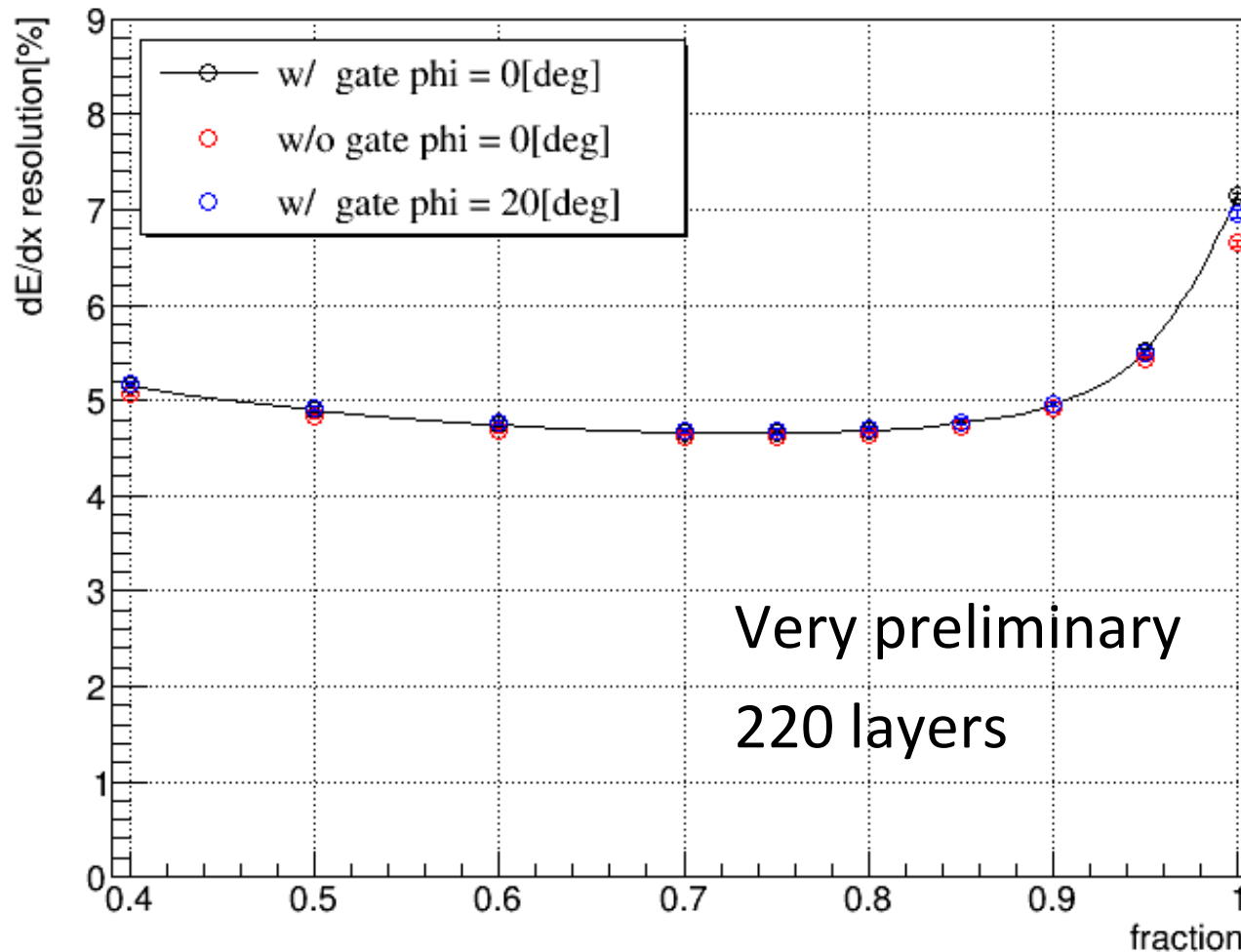
	Method① Sampling	Method② Scaling
w/ gating GEM, $\phi=0^\circ$	$4.66 \pm 0.02\%$	$4.73 \pm 0.01\%$
w/o gating GEM, $\phi=0^\circ$	$4.61 \pm 0.02\%$	$4.64 \pm 0.01\%$
w/ gating GEM, $\phi=20^\circ$	$4.68 \pm 0.02\%$	$4.73 \pm 0.01\%$

① and ②:
consistent

Method③: Sum all charge histograms



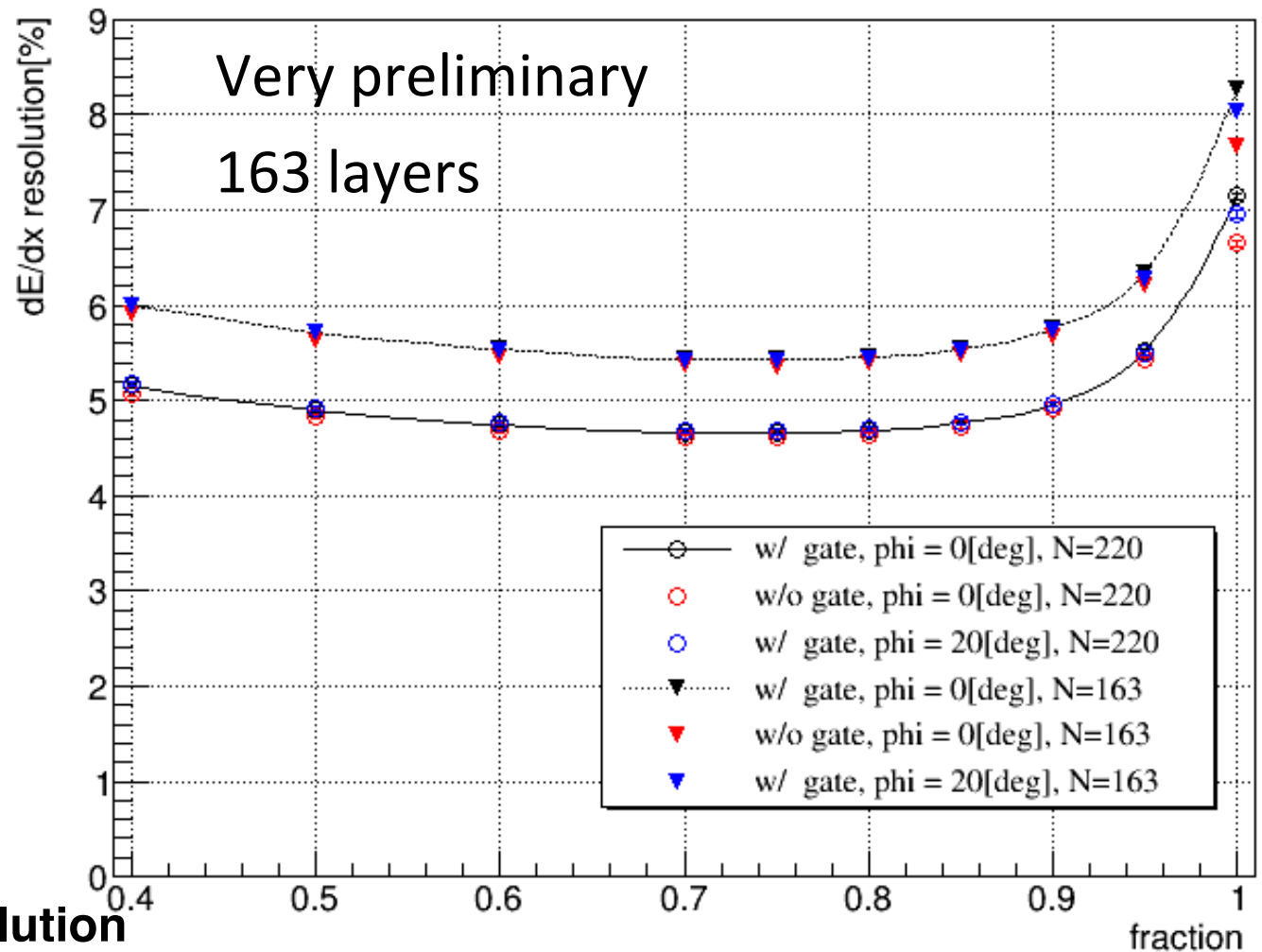
$$dE/dx \text{ resolution} = \frac{\text{Std Dev}}{\text{Mean}}$$



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

*fraction:70%	Method① Sampling	Method② Scaling	Method③
w/ gating GEM, $\phi= 0^\circ$	$4.66 \pm 0.02\%$	$4.73 \pm 0.01 \%$	$4.67 \pm 0.02 \%$
w/o gating GEM, $\phi= 0^\circ$	$4.61 \pm 0.02\%$	$4.64 \pm 0.01\%$	$4.62 \pm 0.02 \%$
w/ gating GEM, $\phi= 20^\circ$	$4.68 \pm 0.02\%$	$4.73 \pm 0.01\%$	$4.68 \pm 0.02 \%$

Also, the dE/dx resolution of ILD-TPC (small, Pad rows: 163) was estimated by method①, ② and ③.



The average of dE/dx resolution

	Method① Sampling	Method② Scaling	Method③
w/ gating GEM, $\phi = 0^\circ$	$5.46 \pm 0.02\%$	$5.49 \pm 0.01\%$	$5.43 \pm 0.02\%$
w/o gating GEM, $\phi = 0^\circ$	$5.35 \pm 0.02\%$	$5.40 \pm 0.01\%$	$5.36 \pm 0.02\%$
w/ gating GEM, $\phi = 20^\circ$	$5.42 \pm 0.02\%$	$5.49 \pm 0.01\%$	$5.42 \pm 0.02\%$

The dE/dx resolution of our **prototype TPC** with gating GEM was measured using the electron beam in a magnet field.

- The dE/dx resolution is rather insensitive to the pad-row to pad-row gain variation, as well as to the number of primary electrons, i.e. to the presence or absence of the gating GEM.

The dE/dx resolution of **ILD-TPC (both models)** was estimated using this beam test data.

- The dE/dx resolution of the ILD-TPC (**large-model**) with a gating GEM was estimated to be about 4.66 % for 5 GeV/c electrons on the Fermi plateau. In the **small-model TPC**, the dE/dx resolution was estimated to be about 5.46 %.

Thank you for your attention !

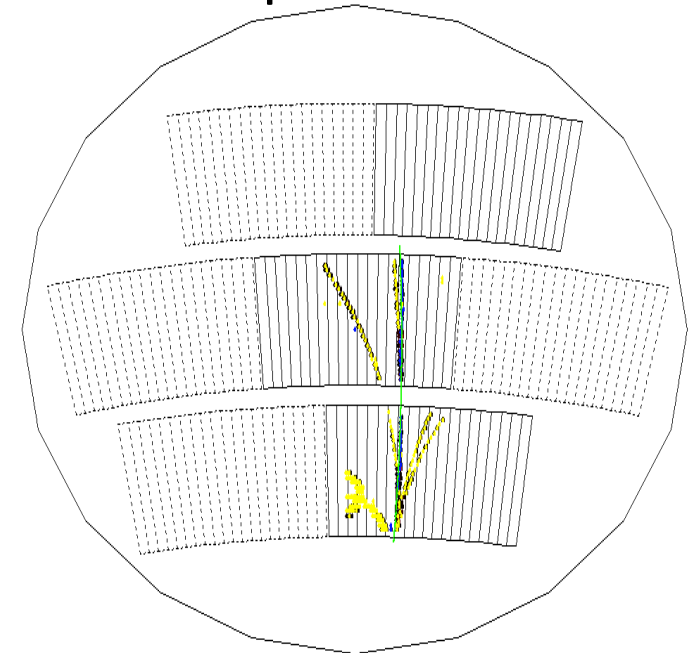
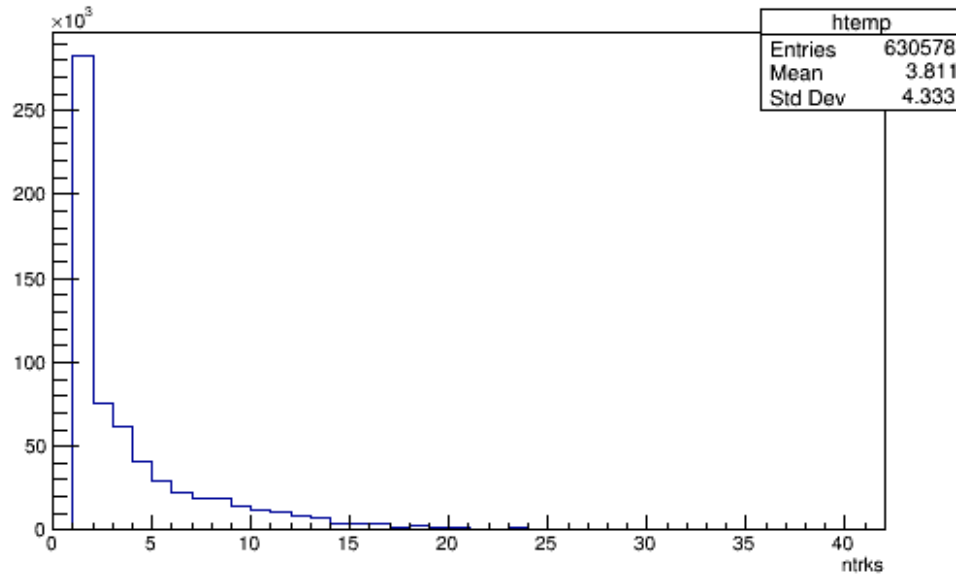
Back up

Drift length

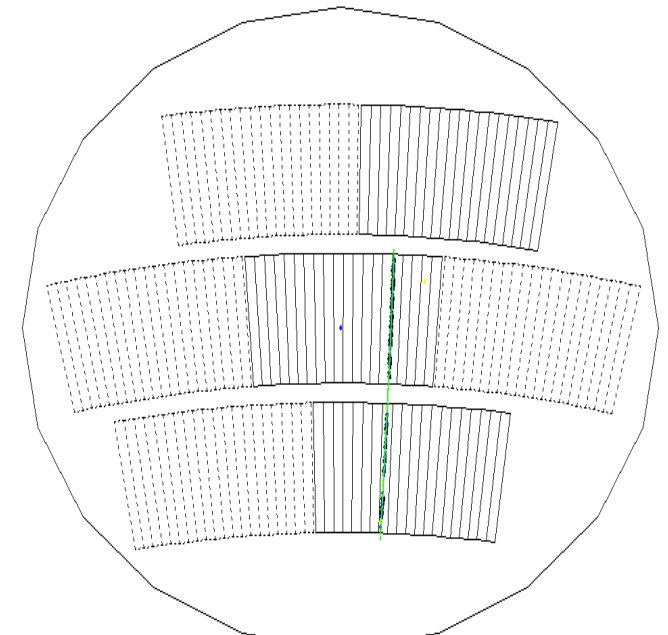
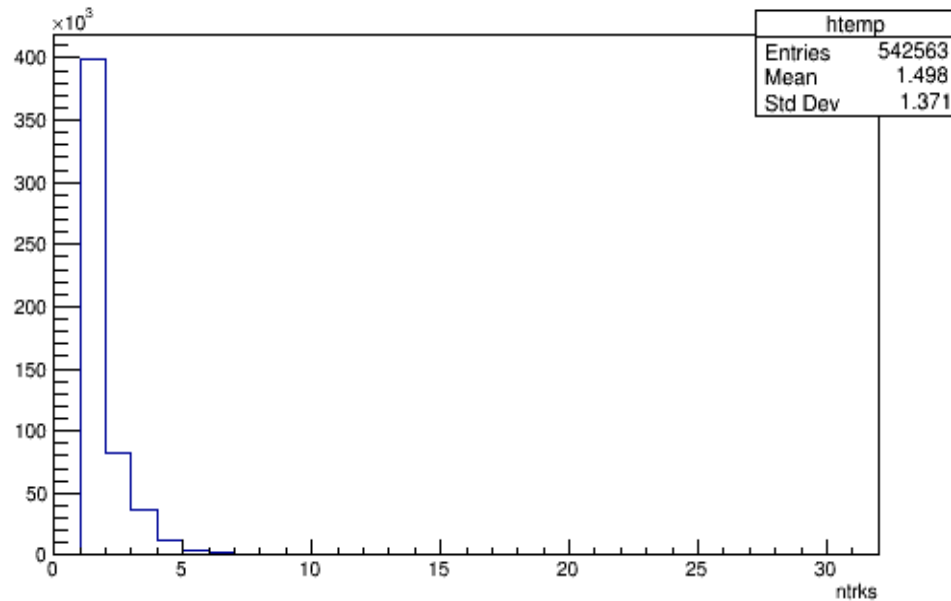
Number of tracks

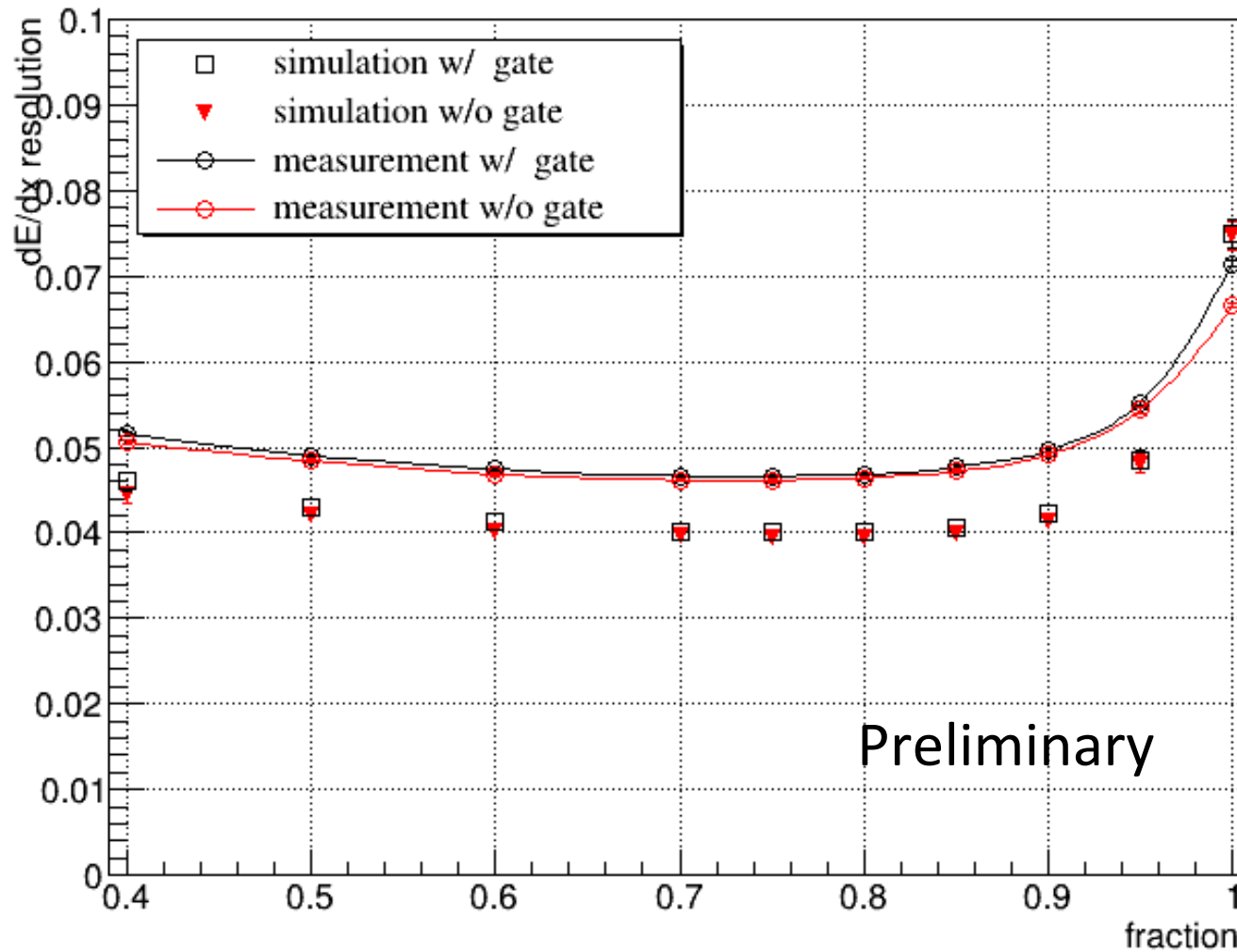
Example of tracks

1.25 cm



45 cm





*electron (5 GeV)

*220 layers

*T2K gas

*Asian double GEM

↓*fraction:70%

	Old method	Simulation (nsum)	New method w/corr
dE/dx resolution w/gate	4.66 +/- 0.02 %	4.02 +/- 0.09 %	4.67 +/- 0.02 %
dE/dx resolution w/o gate	4.61 +/- 0.02 %	3.96 +/- 0.09 %	4.62 +/- 0.02 %

dE/dx resolution (Drift length 35cm)

