Analysis of CDC cosmic-ray test

2017.12.28 Year End presentation

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Over view

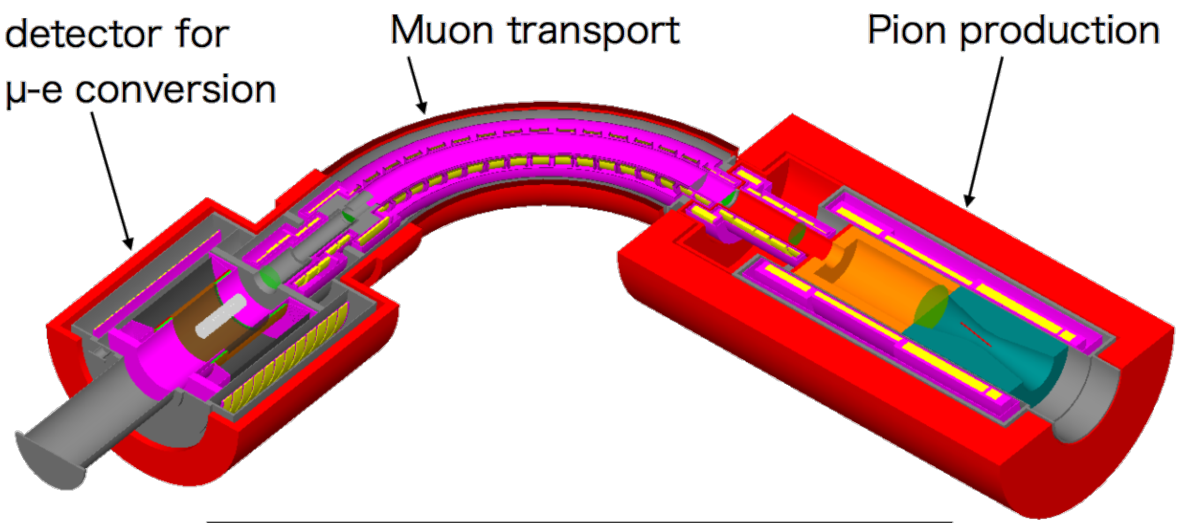
1. Introduction
    - COMET experiment
    - COMET CDC
    - Cosmic ray test

2. XTCurve (relation between drift Time and drift distance)
3. Spatial resolution
4. Hit efficiency
5. Summary

COMET Phase-I

COMET is experiment to detect $\mu \to e$ conversion which is one of the charged lepton flavor violation(=CLFV).

We target to achieve signal sensitivity 3×10^{-15} for Phase-I.



COMET Phase-I Layout

◆Standard model ($\mu \to e\gamma$)

BR: $\sim10^{-54}$

◆New Physics

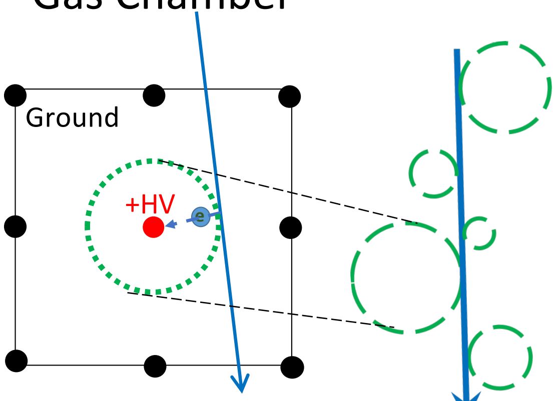
BR: $\sim10^{-15}$

Search for new physics beyond standard model

We use Cylindrical Drift Chamber (CDC) for COMET Phase-I to detect signal of $\mu \to e$ conversion

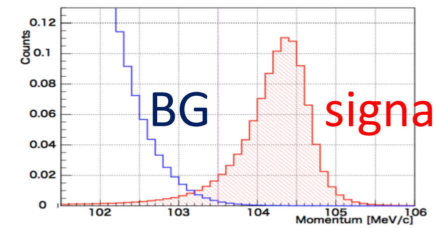
COMET CDC

— Gas Chamber —



— requirement for COMET CDC —

- Momentum resolution< 200keV/c (for electron of 105MeV/c)
- Spatial resolution < 200μm



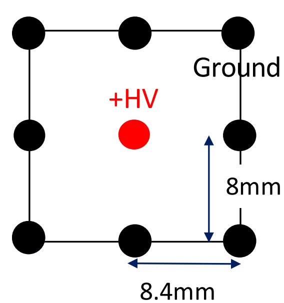
$\mu^- N \to e^- N$ signal and BG for DIO electron (simulation result)

— COMET CDC —

All stereo wire

Number of layer is 20
(include 2 guard layers)

Gas ratio： He:i-C_4H_{10} =90:10
magnetic field： 1T



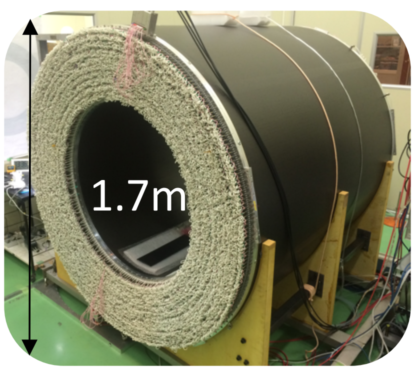
Size for cell of CDC

Sense wire

Material : Au plated W
\# of wires: 4986
diameter of wire: 25μm

Field wire

material: Al
\# of wires: 14562
Diameter of wire: 126μm



Cosmic ray test

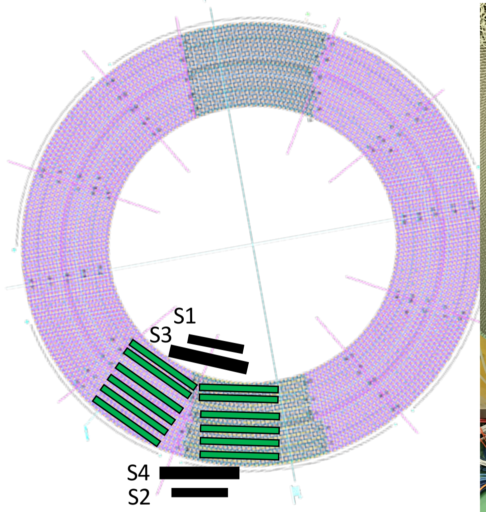
Now we are checking performance for CDC by Cosmic ray test in KEK.

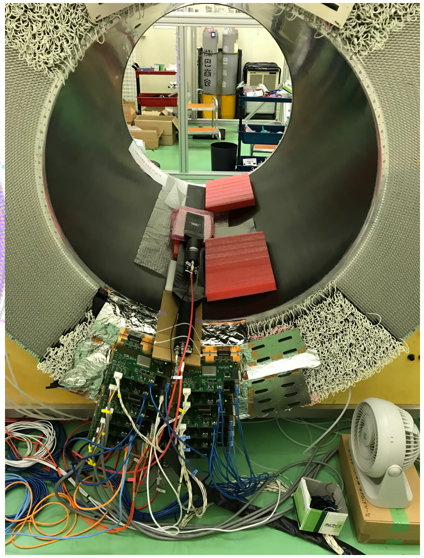
<setup for cosmic ray test>

Applied HV 1750~1850V

*Mainly data applied 1825V is used for detail analysis

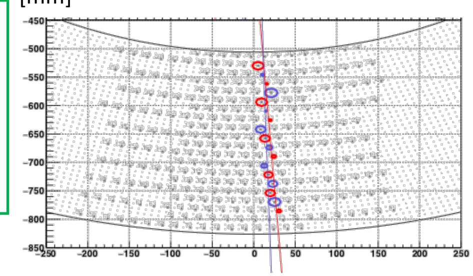
gas ratio $He:i\text{-}C_4H_{10}$ 90:10 (flow rate:90 CCM:10 CCM)





Setup
(view from center plane of CDC)

<information from CDC>
TDC : timing information
ADC : charge information



Track example viewed from center plane of CDC

requirement for CDC
momentum resolution**200keV/c**

↓

1. Create XT for COMET CDC
2. Check spatial resolution
3. Check hit efficiency

<u>I estimate these points.</u>

Analysis

I estimate for XT, spatial resolution and hit efficiency for each cell and each incident angle. I estimated event which meets requirement for events.

Requirements for event

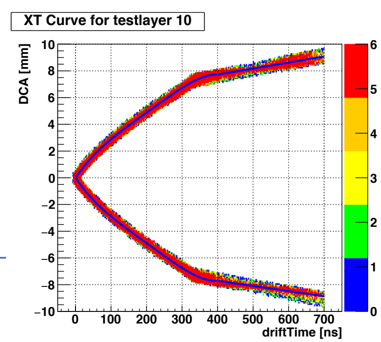
P value for tracking>0.05
\# of layers which has single hit >14
\# of layers which has multi hits<2

XTCurve

XT curve corresponds to the relation between drift distance and drift time for CDC.
Because every cell has vary shape, XT relation is different for each cell.

<Hit condition for XT Curve>

- Hit on the test layer
- P value of tracking>0.05
- residual -0.5mm~0.5mm



~Fitting function for XT~

$$f(t) = \begin{cases} 0 \ldots & t < 0\text{ns} \\ 5^{\text{th}} \text{ pol function} \ldots & 0\text{ns} \le t < T_{switch} \\ \text{linear function} & \ldots T_{switch} \le t < 700\text{ns} \\ \text{N/A} \ldots & 700\text{ns} < t \end{cases}$$

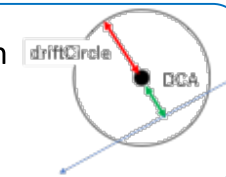
T_{switch} is switch timing for fitting function.
This value is got by fitting.

Spatial resolution

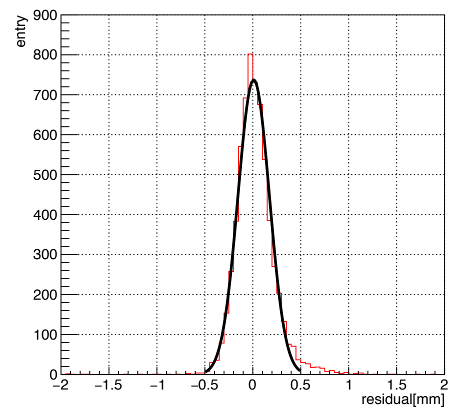
I get σ of residual to understand spatial resolution.

DCA =Distance of Closest Approach

Residual =radius of drift circle – |DCA|



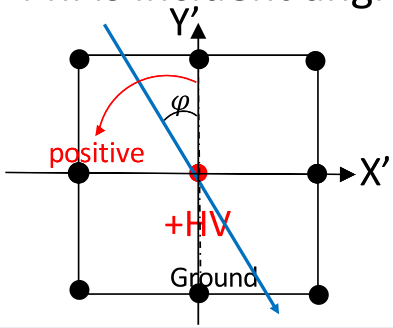
$\sigma_{residual}$ = **spatial resolution** + **Tracking error**



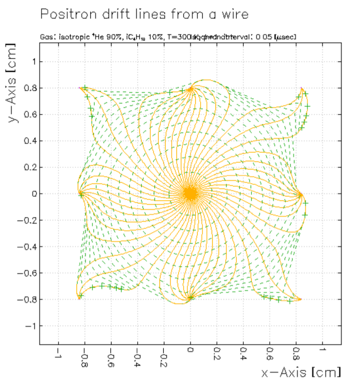
φ dependence for XT

Definition of angle φ

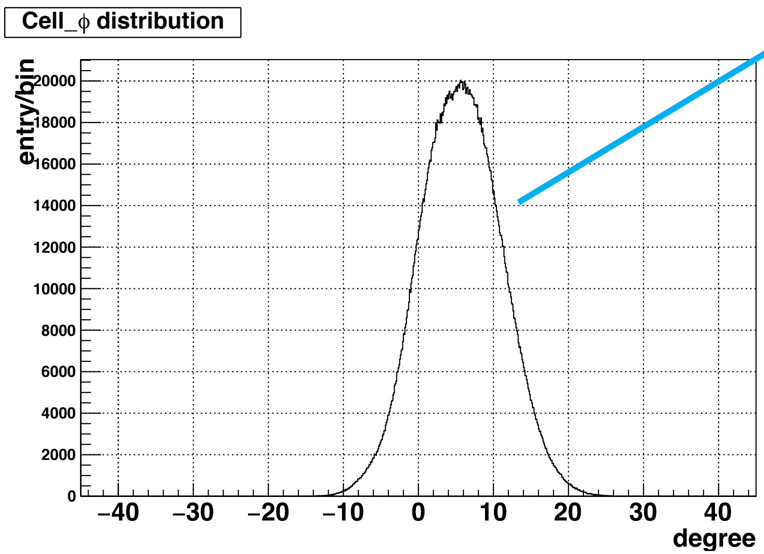
Phi is incident angle of track for cell.



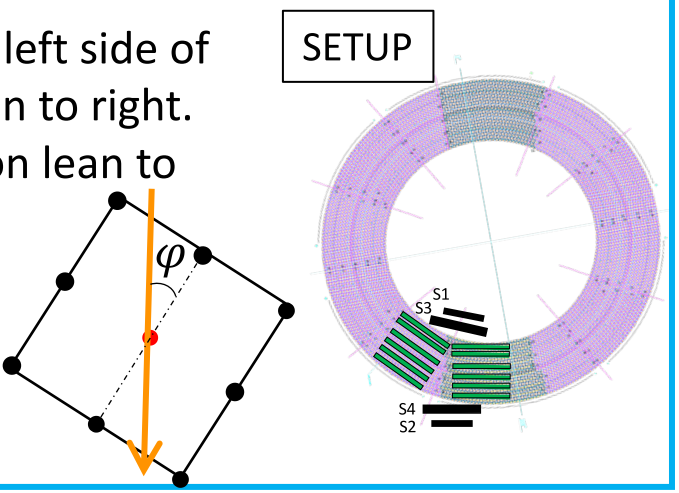
The electric field is different between around center of cell and edge of cell.
So, XT Curves are also different depends on incident angle.
I checked XT difference from checking φ dependence for XT



Electric field simulated by garfield



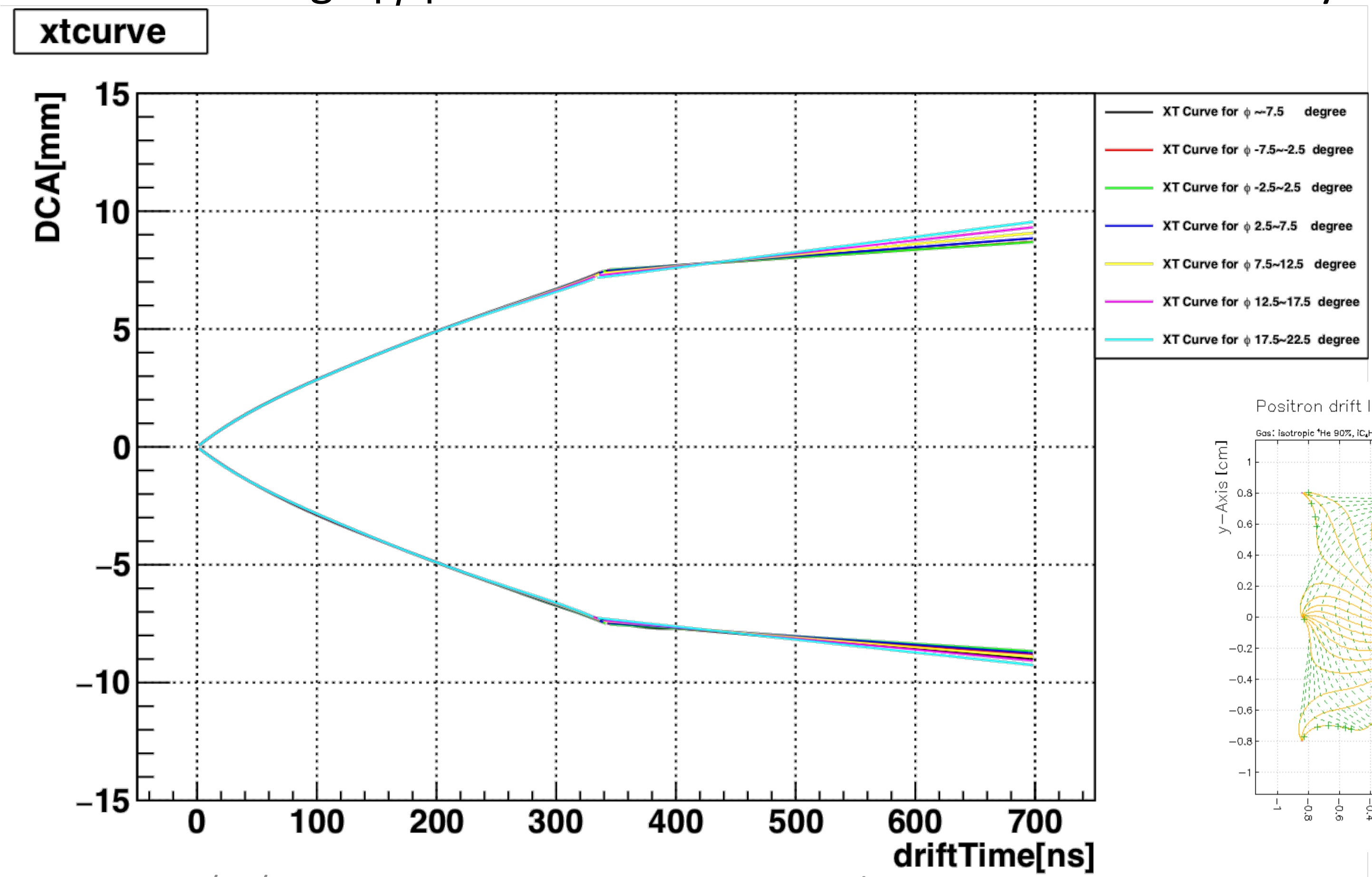
Readout area is left side of CDC and cell lean to right.
So, φ distribution lean to positive value.

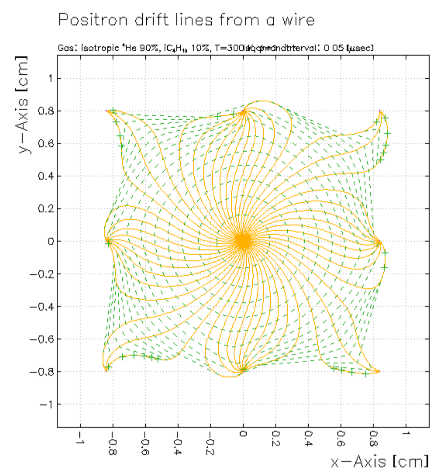


φ dependence for XT

Preliminaly

This is XT curve corresponds to the relation between drift distance and drift time. slope of XT is more steep angle when $|\varphi|$ is larger . It means drift velocity is faster for large $|\varphi|$. Its consistent with electric field studied by simulation.





Spatial resolution -HV dependence-

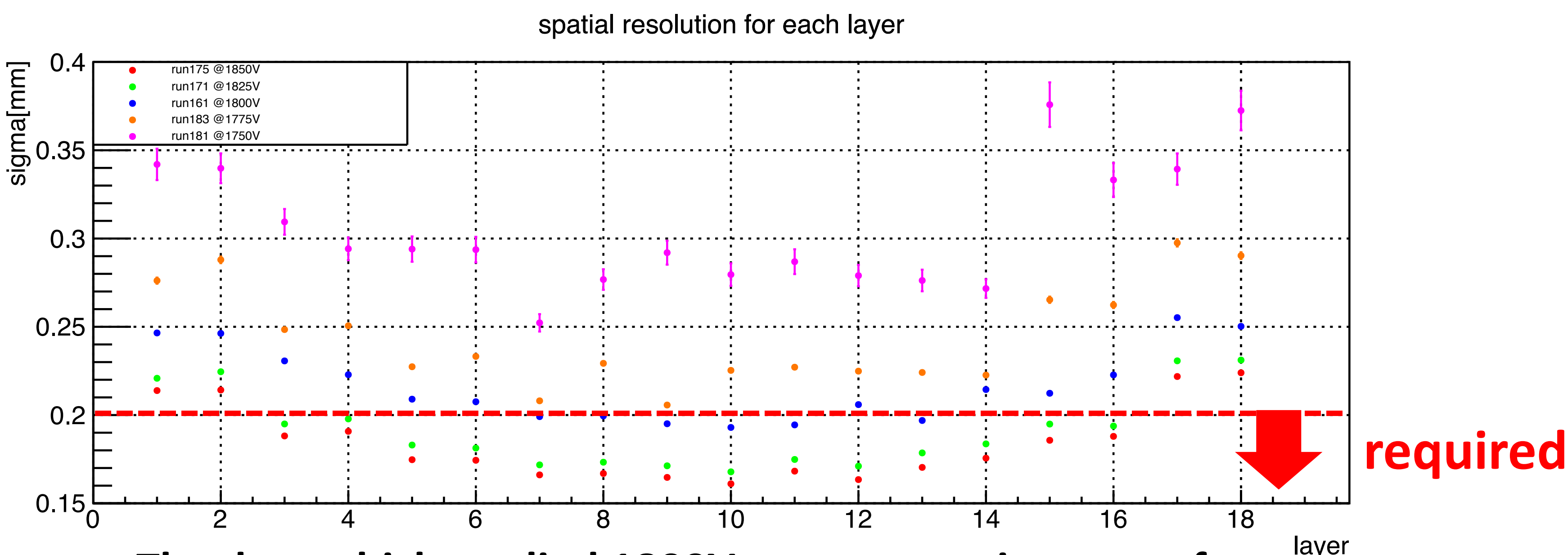
I estimated spatial resolution for each layers from σ of residual .

Requirements for event

P value for tracking>0.05
# of layers which has single hit >14
# of layers which has multi hits<2

σ value is large around guard layer.
Its because tracking error is bigger than middle layer.

$$\sigma_{residual} = \textbf{spatial resolution} + \textbf{Tracking error}$$



The data which applied 1800V~ meets requirement of spatial resolution ($\sigma_{residual}$<200μm)

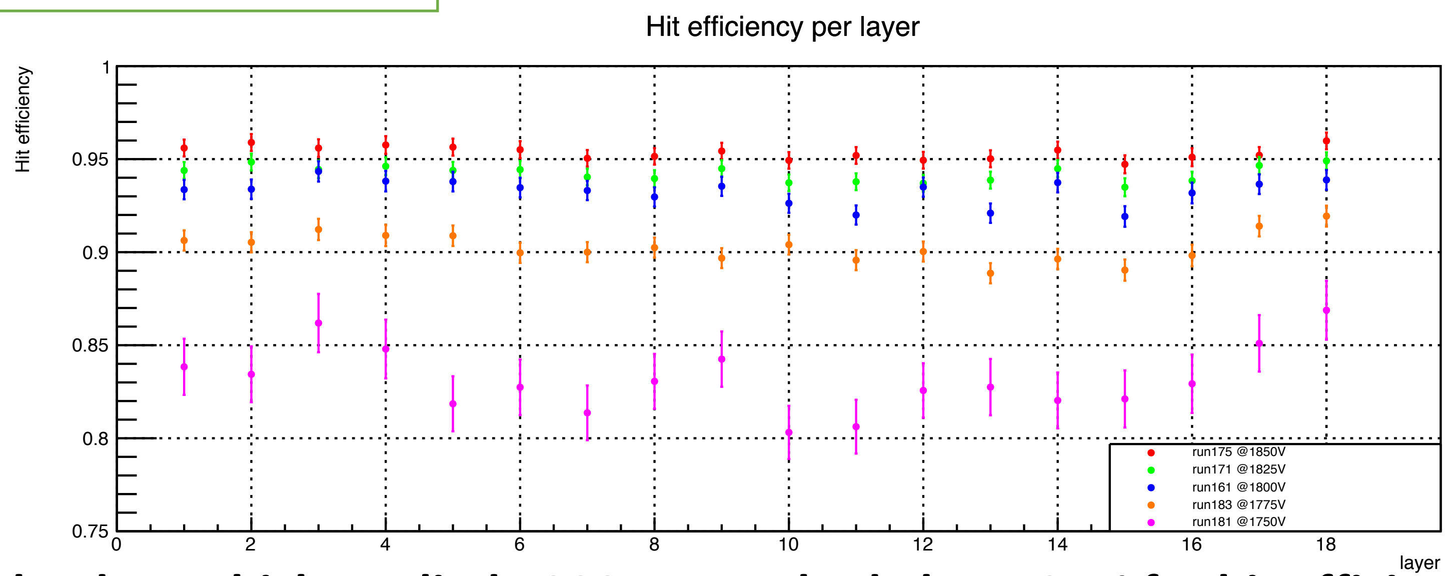
Hit efficiency -HV dependence-

I estimated hit efficiency for each layers.

Requirements for event

P value for tracking>0.05
# of layers which has single hit >14
# of layers which has multi hits<2

$$\text{Hit efficiency} = \frac{\mathit{number\ of\ event\ which\ has\ hit}\ \ (\text{residual} < \mathbf{3\sigma})}{\text{number of events meet the requirements}}$$



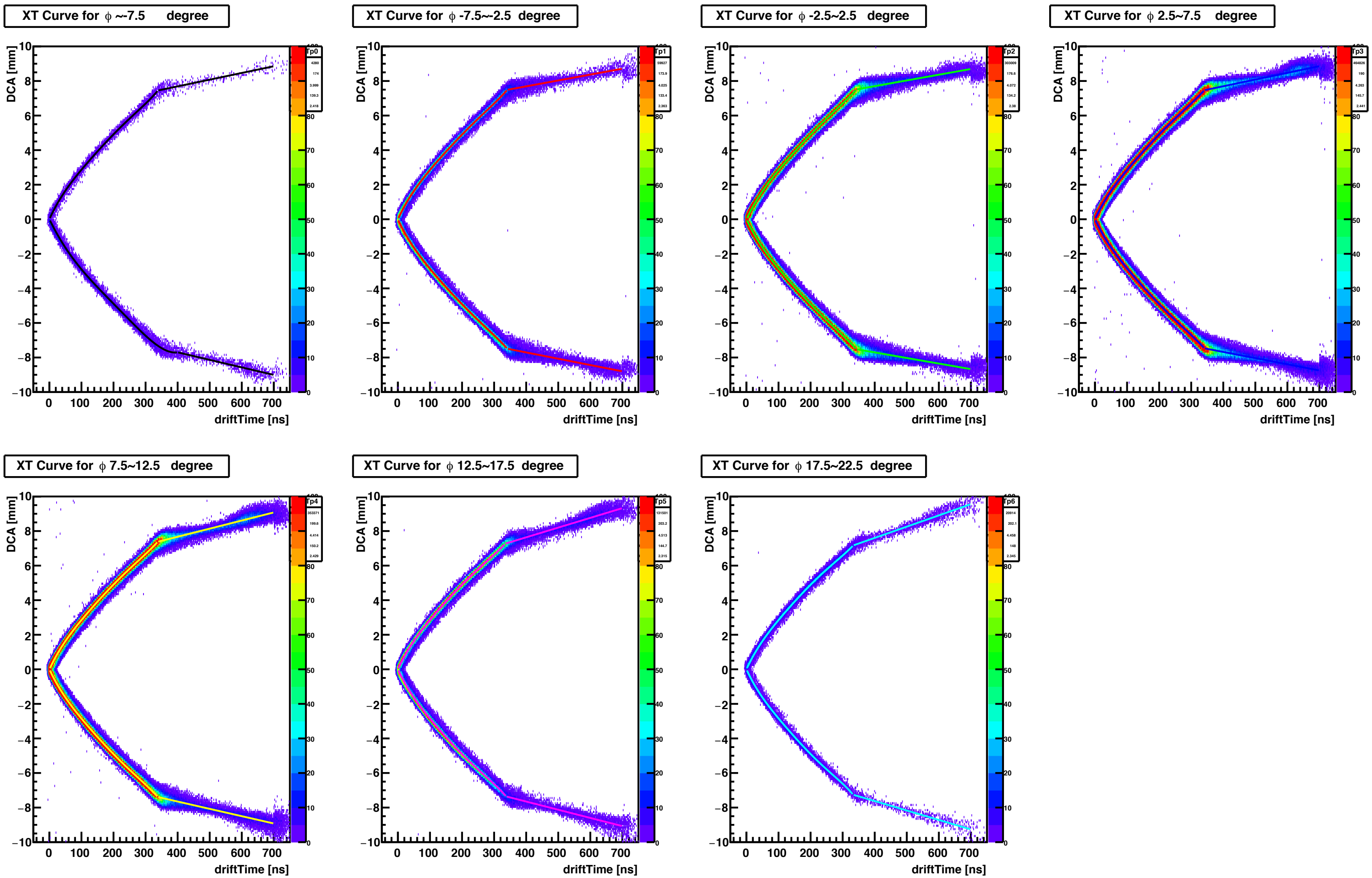
The data which applied 1800V~ reached about 95% for hit efficiency.
From this value and tracking efficiency, we are going to set the definition of hit which use for tracking.

Summary

- COMET is experiment to detect $\mu \rightarrow e$ conversion .
- We are checking performance for CDC which detect mu-e conversion in COMET Phase-I.
- I estimated XT , spatial resolution, hit efficiency.
- I checked that there is φ dependence for XT.
- $\beta \times \varphi$ dependence is also seen by difference of XT.
- I can check HV dependency for hit efficiency and spatial resolution.
  ―When applied HV is over 1800V, spatial resolution meets the conditions for CDC. (CDC requirement : spatial resolution < 200μm)
  ―The data which applied higher than 1800V reached about 95% for hit efficiency.
  -> from these result , we are going to set the definition of hit for tracking , applied HV.

Back up

φ dependence for XT

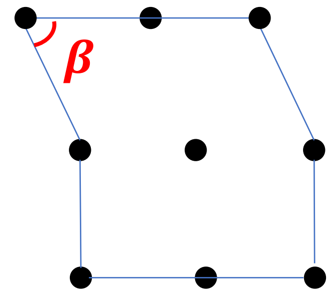


$\beta\times\varphi$ dependence for XT

This is the example of cell shape. Each cells have different β value.

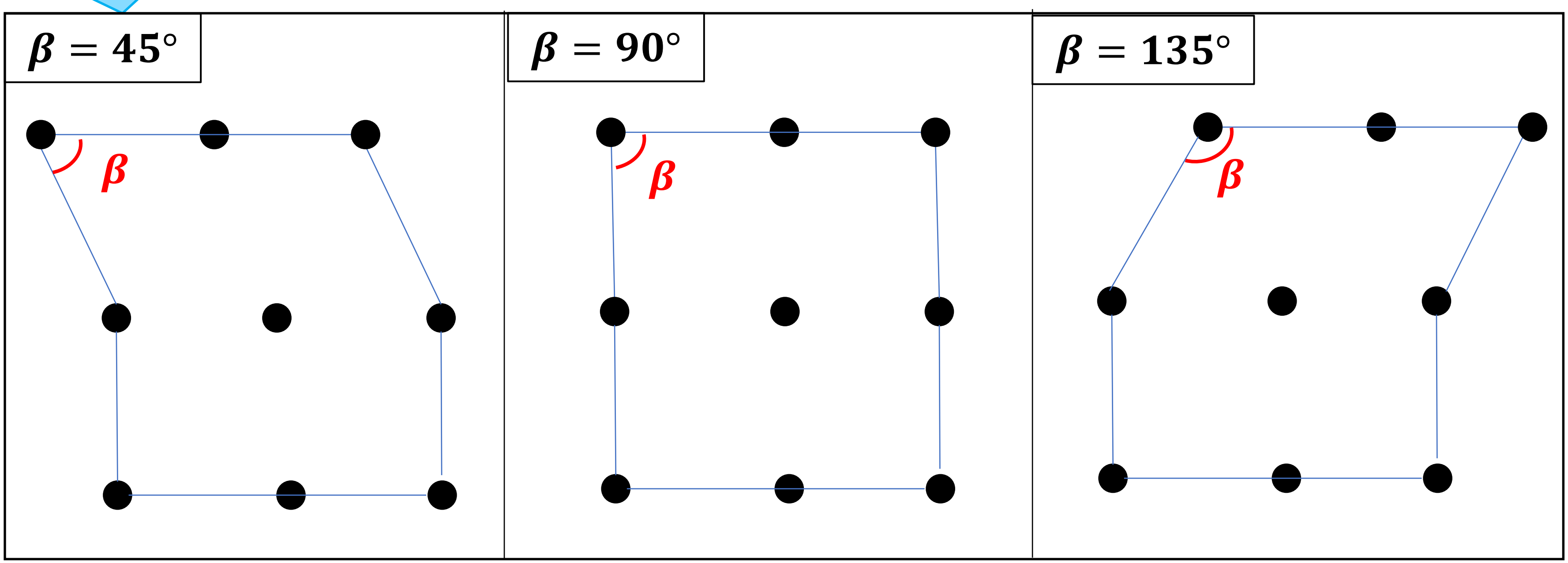
The electric field is varies from β value especially for edge of cell.

I checked $\beta\times\varphi$ dependence for XT.



Cell shape image

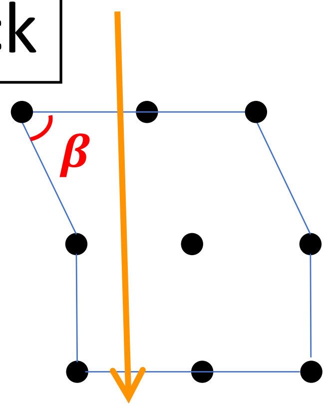
Example…



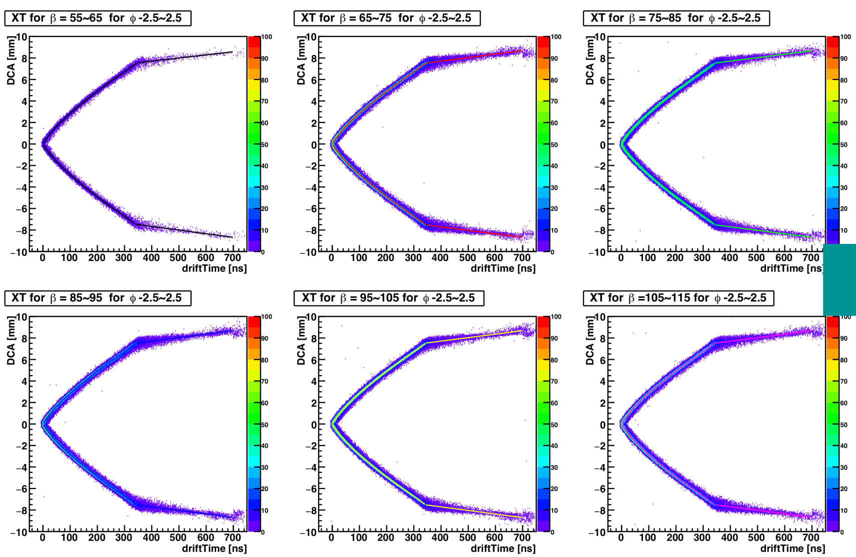
$\beta \times \varphi$ dependence

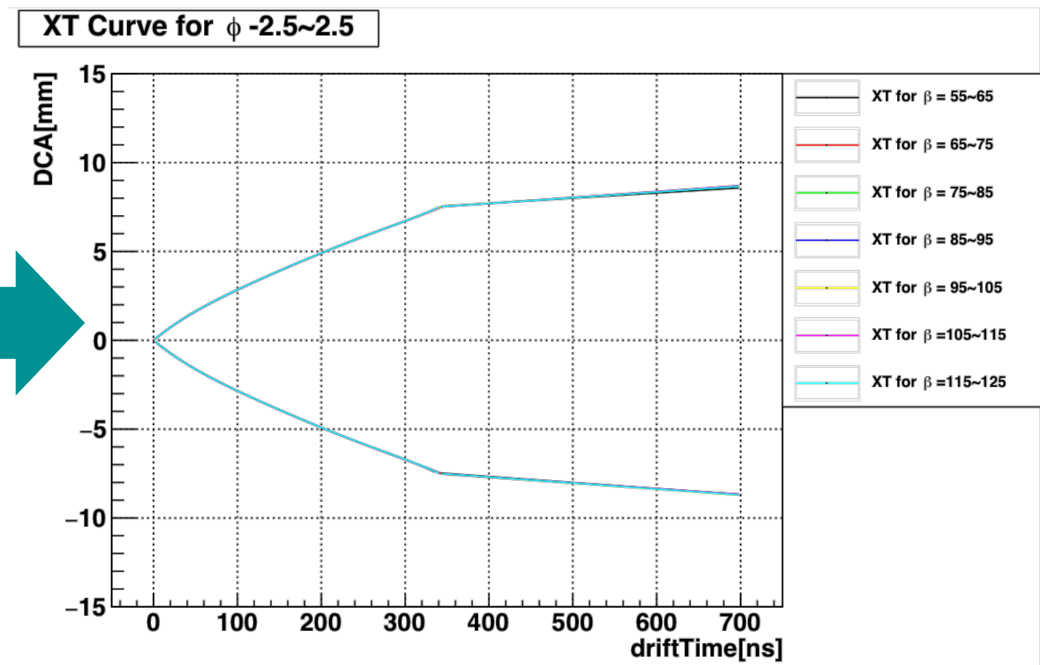
Preliminaly

Vertical track



The initial electron of vertical track comes from horizontal direction of cell.
So, these tracks are not affected by β value.

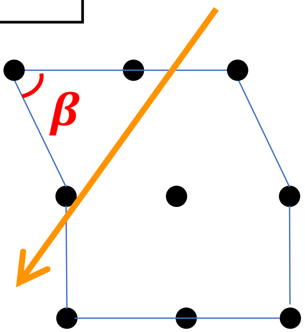




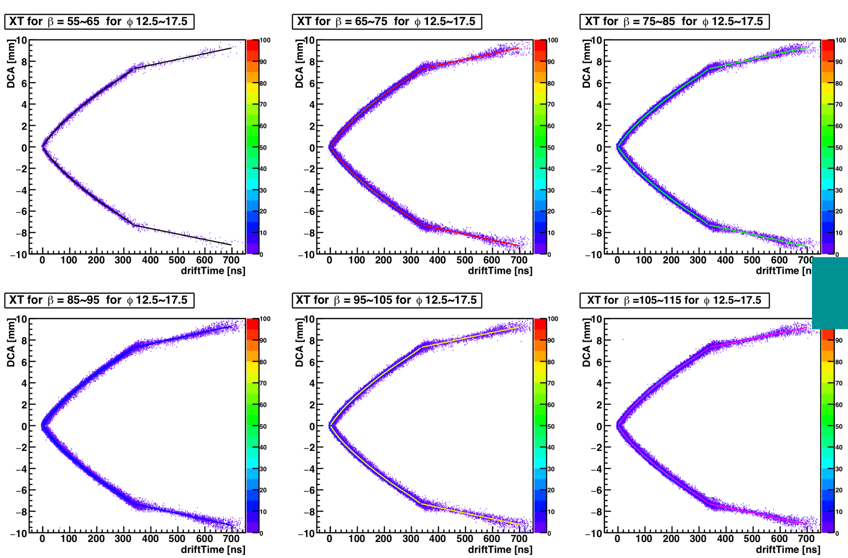
$\beta\times\varphi$ dependence

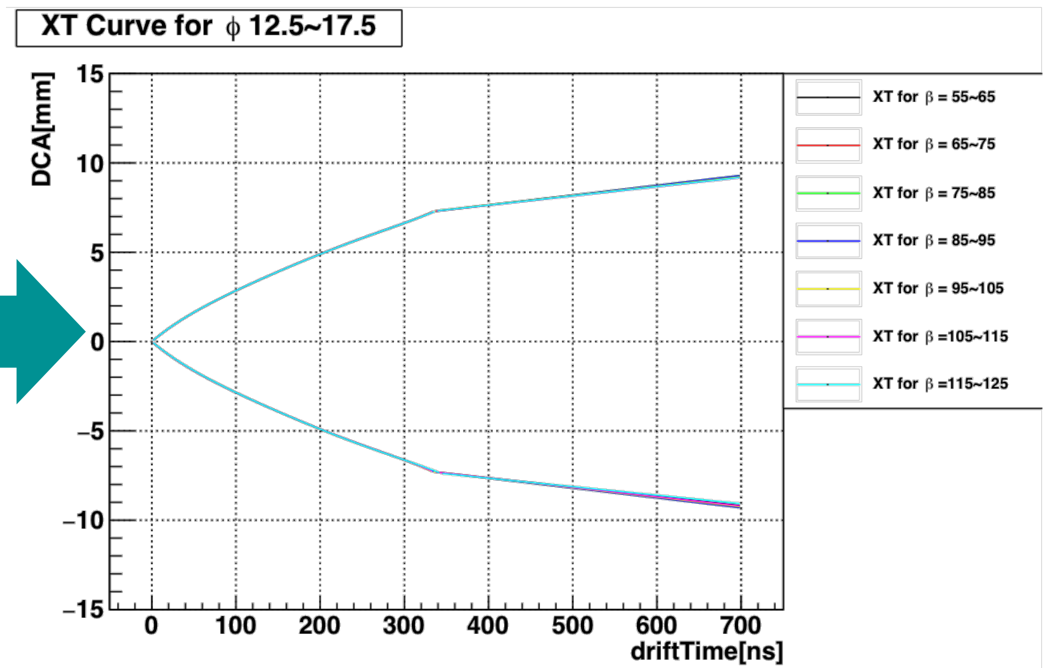
Preliminay

Oblique track

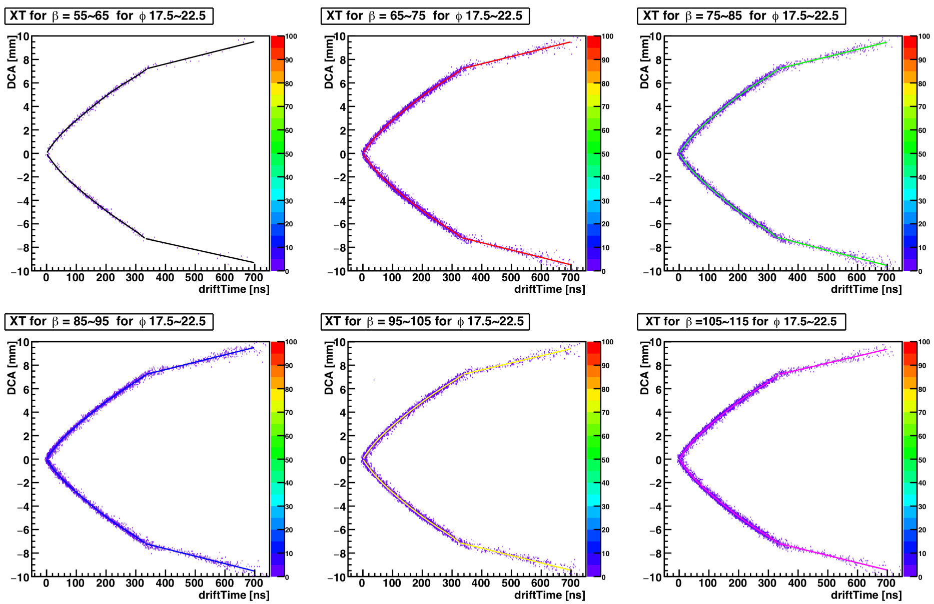


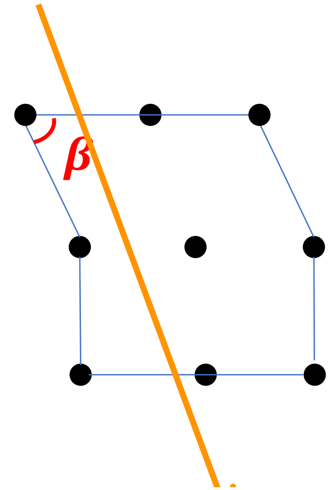
The initial electron generated by oblique track comes from corners of cell.
So, these tracks are affected by β value.

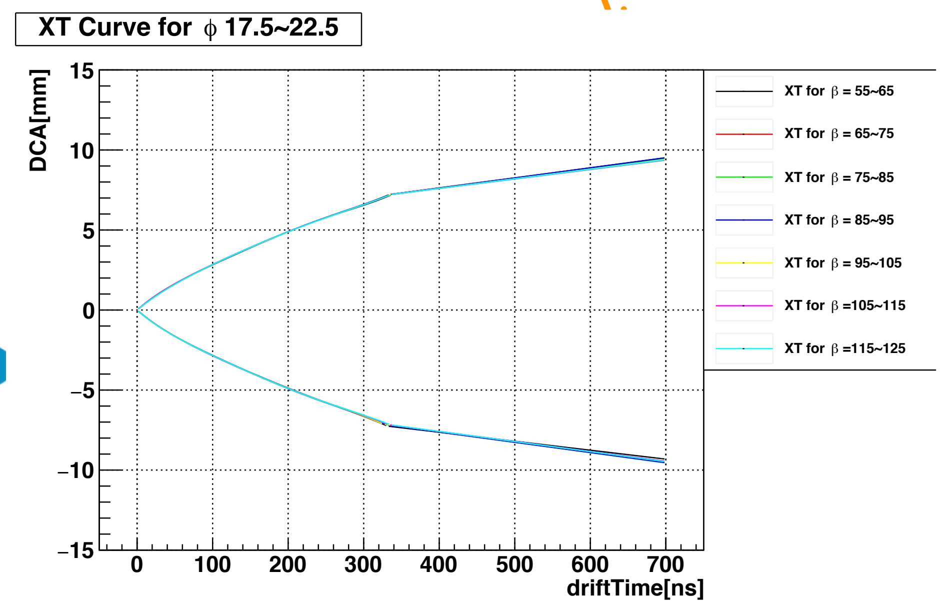




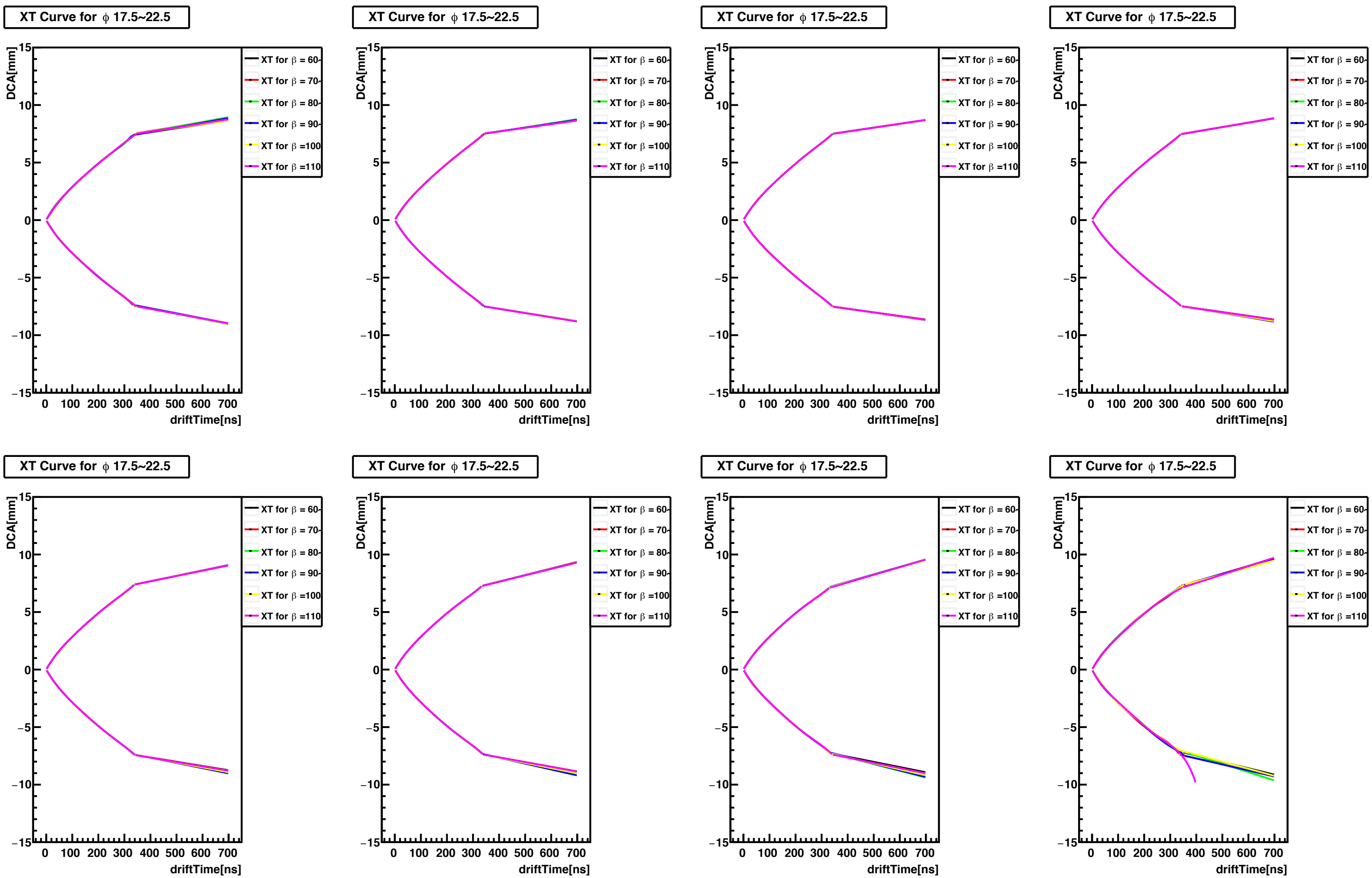
$\beta\times\varphi$ dependence



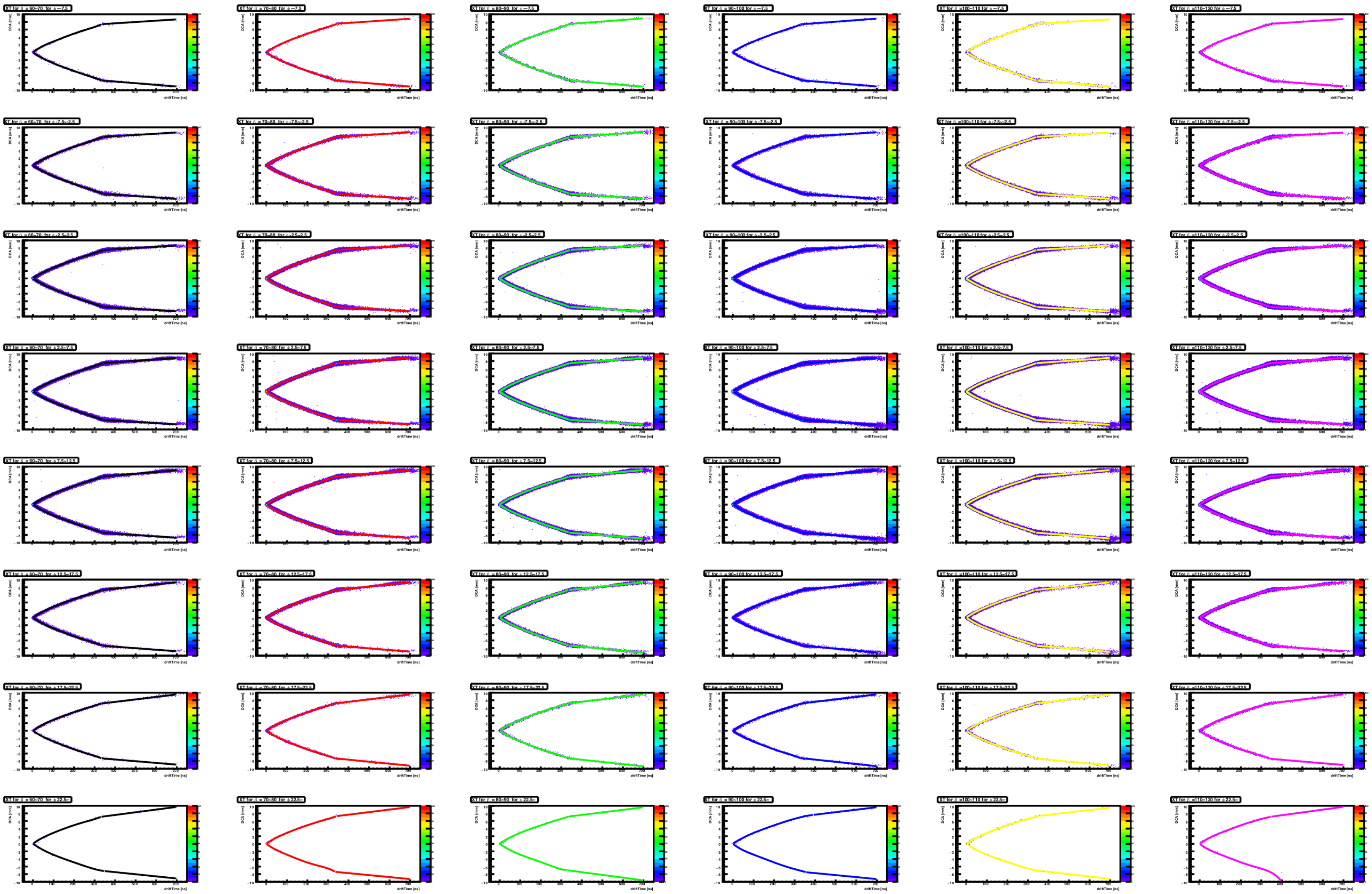




$\beta \times \varphi$ dependence for XT



$\beta\times\varphi$ dependence for XT



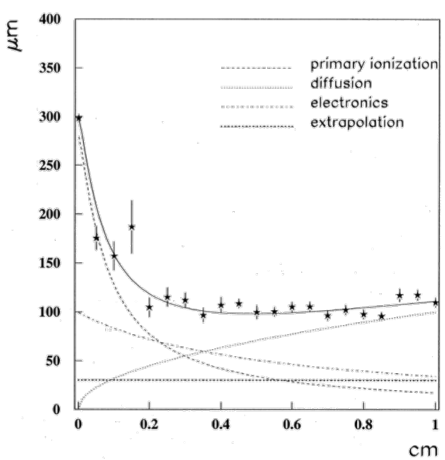
Spatial resolution -DCA dependent-

There are mainly 4 reason for σ value

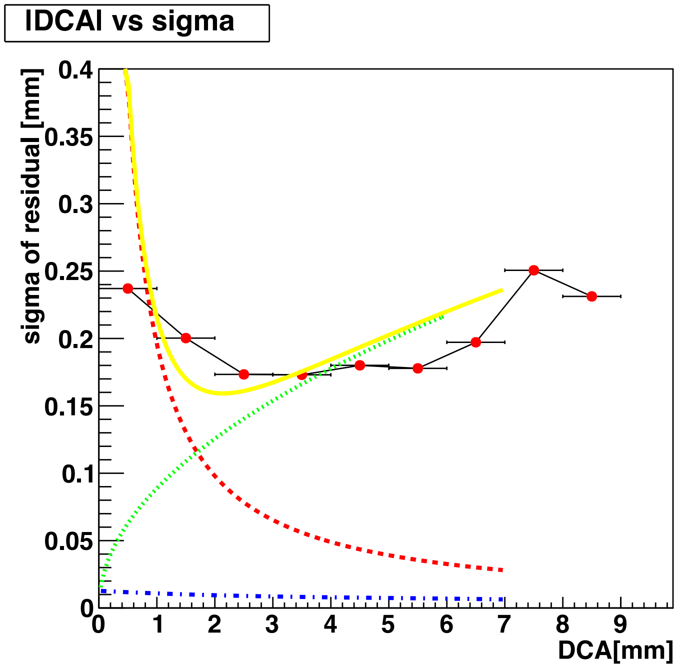
1. Ionization particle
2. Diffusion of particles in gas
3. Time resolution
4. Tracking error

We can fit DCA vs σ by this estimation.

$$\sigma_{total}{}^2 = \sqrt{\sigma_{ion}{}^2 + \sigma_d{}^2 + \sigma_{el}{}^2 + \sigma_{track}{}^2}$$



C. Avanzini et al. / Nuclear Instruments and Methods
in Physics Research A 449 (2000) 237~247

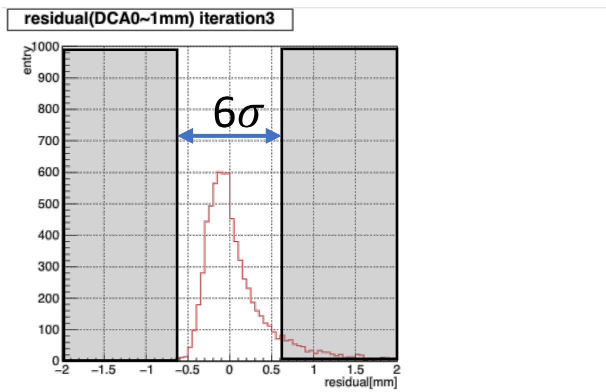


Hit efficiency

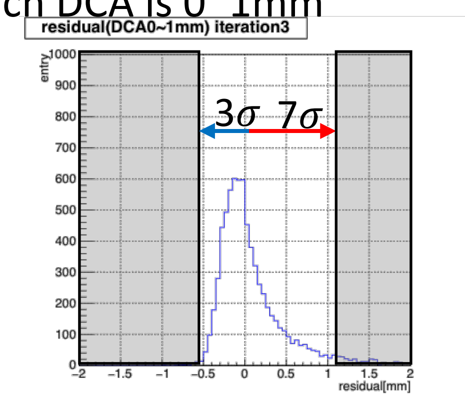
Last year result

これらのヒットを検出できたとみなした場合の検出効率を評価

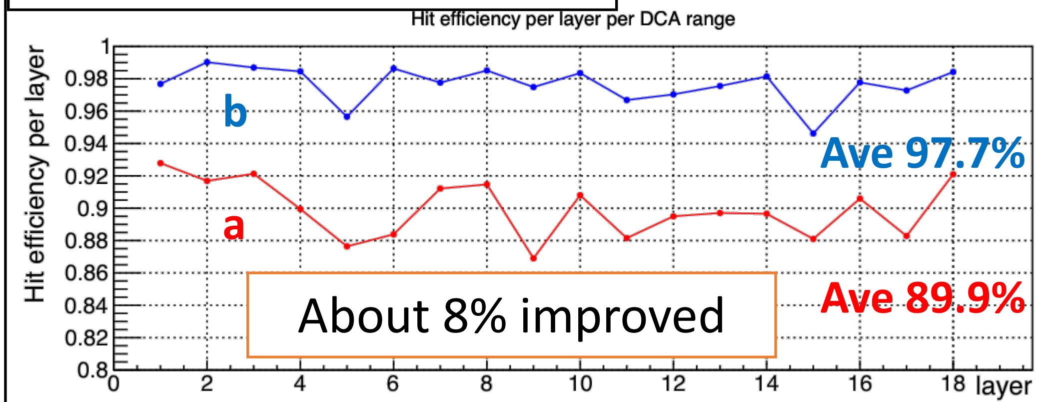
a. Estimation for 3 sigma



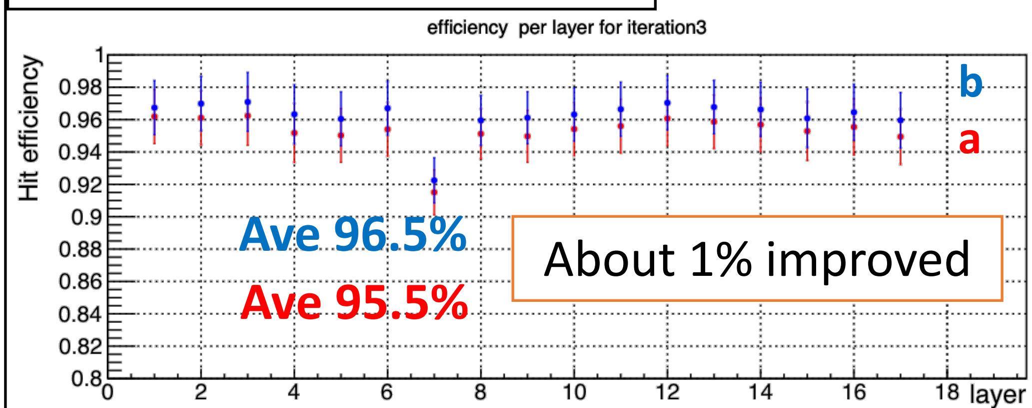
b. Estimation for 7sigma for the hit which DCA is 0~1mm



Hit efficiency for DCA0~1mm



Hit efficiency for all DCA range



Ionization particles

- Electron ion pairs are generated when charged particle through the cells.
- The number of generated electron ion pair is decided by ionization energy and energy deposit . And this values are corresponds to type of gas.
- We use He:i-C_4H_{10} (90:10), and number of generated electron ion pair is 14/cm .

Gas	X_0 (m)	W (eV)	$\frac{dE}{dx}^{MIP}$ (keV/cm)	n_T^{MIP} (cm^{-1})	n_p^{MIP} (cm^{-1})	
He:i-C_4H_{10} (85:15)	954	38	1.14	40	18	
He:i-C_4H_{10} (90:10)	1310	39	0.88	29	14	COMET
He:i-C_4H_{10} (95:5)	2102	40	0.61	19	9	
He:C_2H_6 (50:50)	630	32	1.63	60	27	Belle Ⅱ
He:CH_4 (80:20)	2166	39	1.47	17	11	
He:CH_4 (90:10)	3073	40	0.47	13	8	

Table: nature of type of mixed gas

X_0: radiation length

W: mean energy to generate one electron-ion pair

$\frac{dE}{dx}$: energy deposit for MIP

n_T^{MIP}: number of electron-ion pair for MIP

n_p^{MIP}:number of primary ion pair for MIP

Study of hit efficiency

I estimated 5σ efficiency

$$\text{Hit efficiency} = \frac{\mathit{number\ of\ event\ which\ has\ hit}\ \ (\text{residual} < 5\sigma)}{\text{number of events meet the requirements}}$$

Hit efficiency for each layer