Detection efficiency of the hit cluster in the sPHENIX-INTT detector

Progress Report

Ryota Shishikura

Outline

Verify whether the INTT detector demonstrates
high detection efficiency, similar to the beam test,
in the p+p collision environment at RHIC.

Unlike during the beam test, the INTT detector in
operation has only two layers. Therefore, verification is
being conducted using the vertex.

Currently, verification is being conducted through **simulation.**

Method

1. Get the coordinates of the cluster in the outer layer in the single event.

2. Determine the expected range in the inner layer using the collision point and cluster A.

3. Check for the presence of clusters within the expected range and count the number of clusters in each case to calculate the detection efficiency.
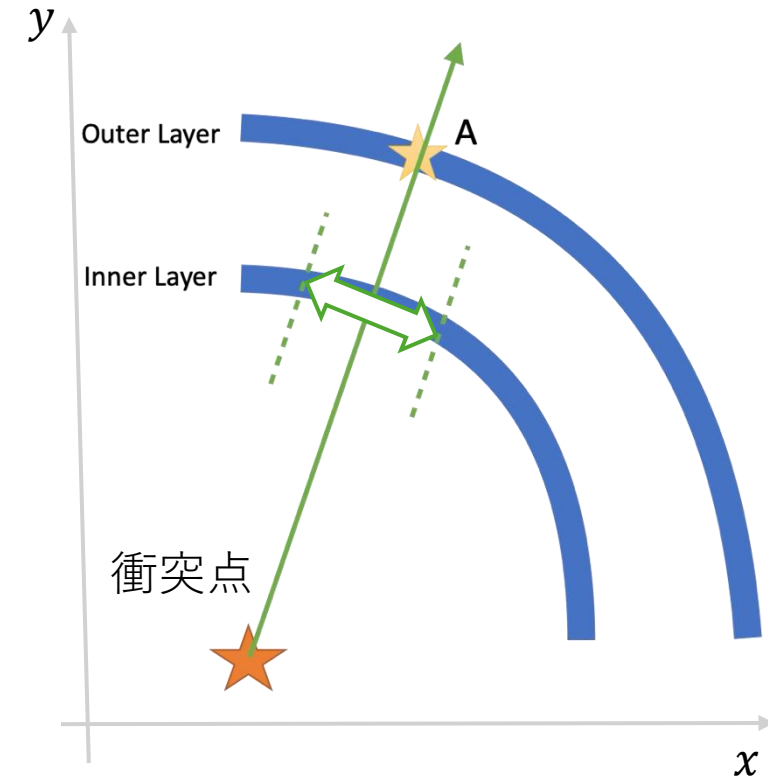
2. Determine the expected range in the inner layer using the collision point and cluster A.
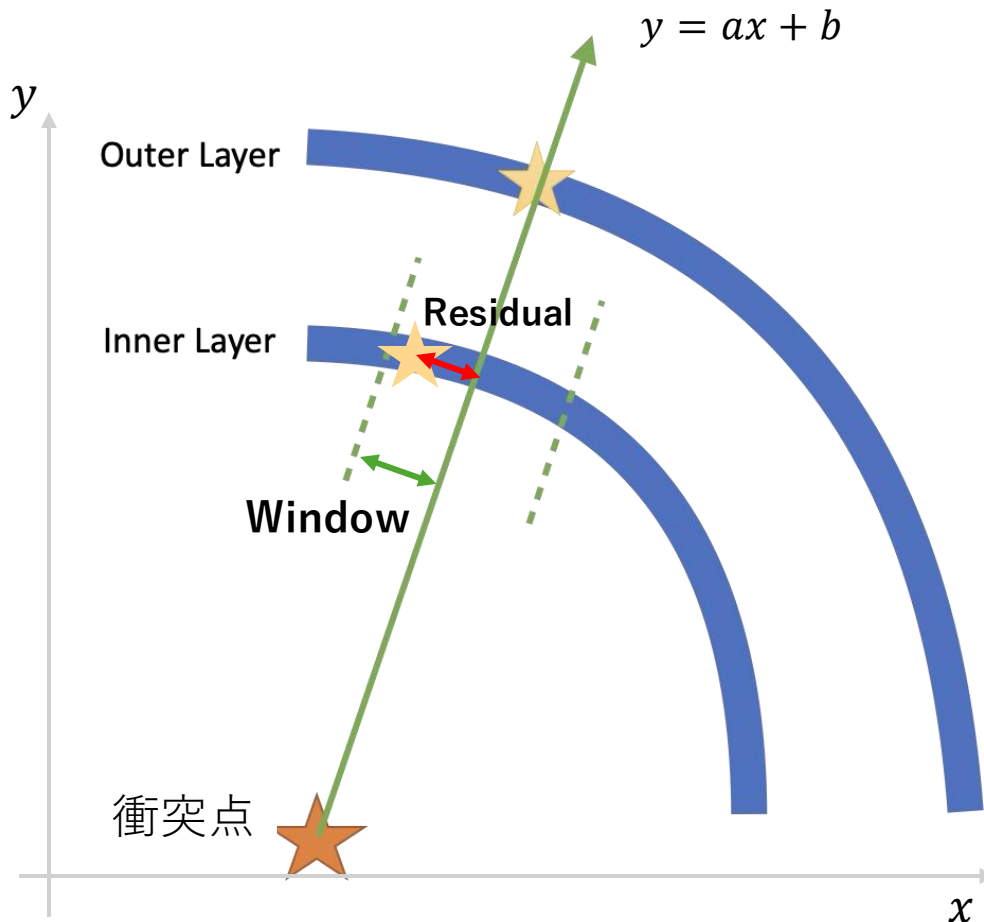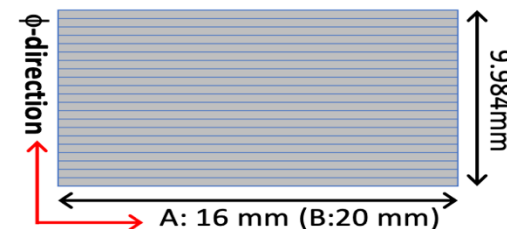
1. Fitting using the outer cluster and the vertex.

2. Calculate "*Residual*" between the fitting line and the inner cluster using the following equation:

$$Residual = \left| \frac{a \cdot x_{in} - y_{in} \cdot b}{a^2 - 1} \right|$$

1. Set the expected range (*window*).
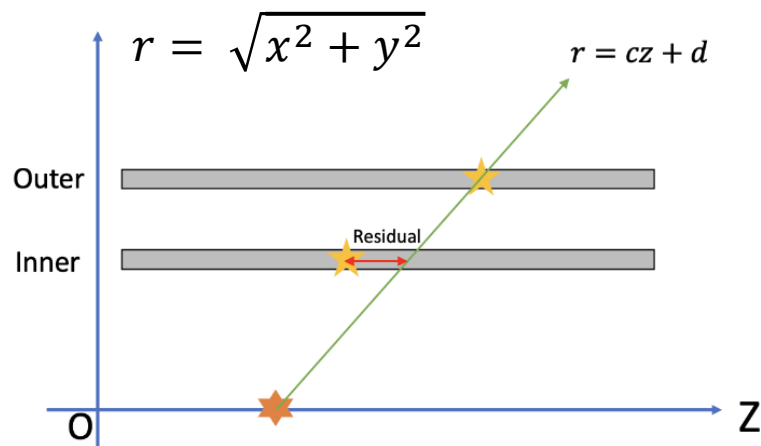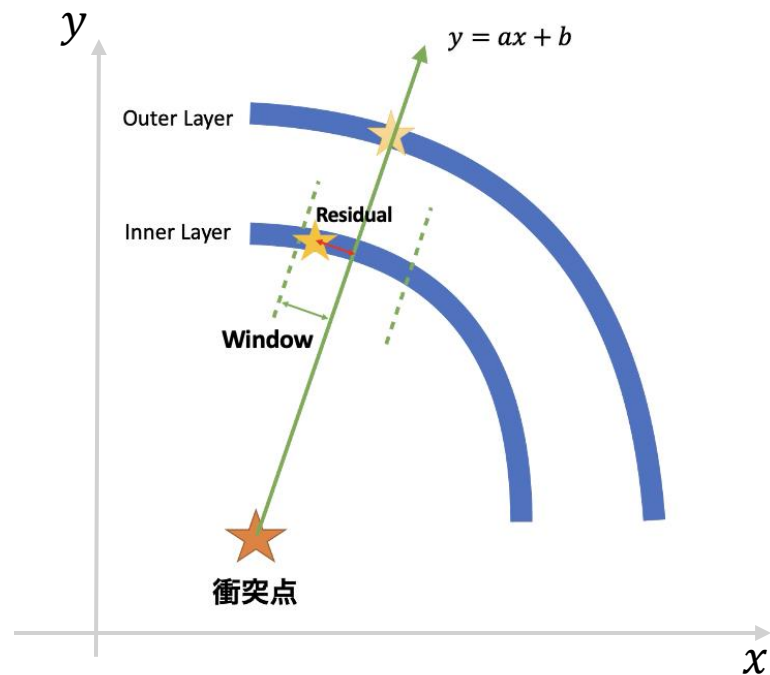   In this case, the window is defined based on the silicon strip width.

$$window = 78 \mu m \cdot i \ (i = 1, 2, 3, \ldots)$$

Outer Layer

Inner Layer

衝突点

$y = ax + b$

y

Residual

Window

x

φ-direction

9.984mm

A: 16 mm (B:20 mm)

Silicon strip sensor
Thickness 320 μm
Width of strip 78 μm
128 strips

3. Check for the presence of clusters within the expected range and count the number of clusters in each case.

y

Outer Layer

$y = ax + b$

Inner Layer

Residual

Window

衝突点

x

$r = \sqrt{x^2 + y^2}$

$r = cz + d$

Outer

Residual

Inner

O

z

1. Select the Inner Cluster that minimizes d^2, calculated using the residuals d_{xy} and d_z in the XY plane and RZ plane, respectively, based on the following equation:

$$d^2 = \left(\frac{d_{xy}}{\sigma_{xy}}\right)^2 + \left(\frac{d_z}{\sigma_z}\right)^2$$

σ_{xy}: The resolution of the INTT sensor in the x-y plane. $78\ \mu m$

σ_z : The resolution of the INTT sensor in the z-axis. $20\ mm$

Tag the selected Inner Cluster to prevent it from being counted again.

2. Count the Outer Cluster as N_{hit} when an Inner Cluster exists within the expected range in the XY plane $(Residual < window)$.

3. Count the Outer Cluster as $N_{no\ hit}$ when no Inner Cluster exists within the expected range.

検出効率 $\varepsilon = \dfrac{N_{hit}}{N_{hit} + N_{no\ hit}}$

5

Used simulation

Simple simulation

- A particle (μ^-)/event
- P_T = 200MeV, 400MeV, 1 GeV
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

Evaluate the algorithm using two simulations.

p+p simulation

- PYTHIA8
- # of events : 10K
- Magnetic field : zero field
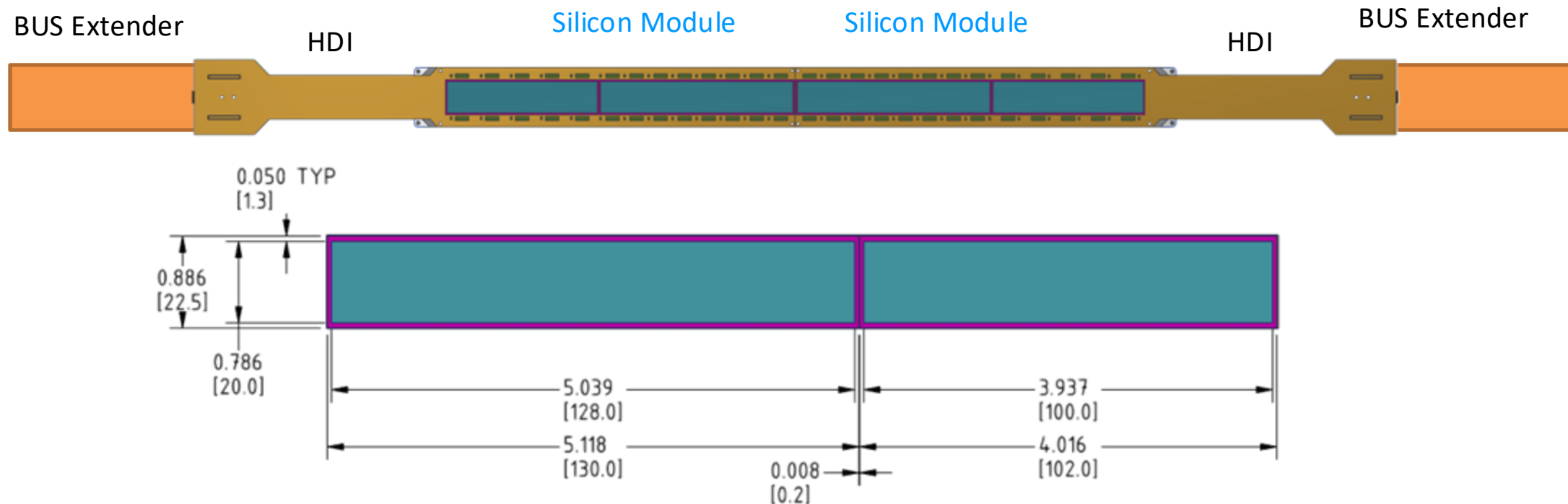- Vertex: Fixed (x, y, z) = (0, 0, 0)cm
- No Dead channel

Used simulation

Simple simulation

- A particle (μ^-)/event
- P_T = 200MeV, 400MeV, 1 GeV
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
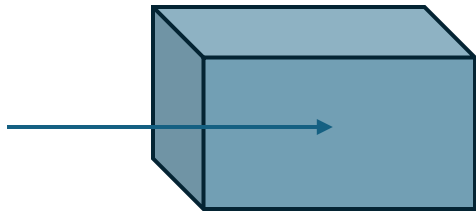- No dead channel

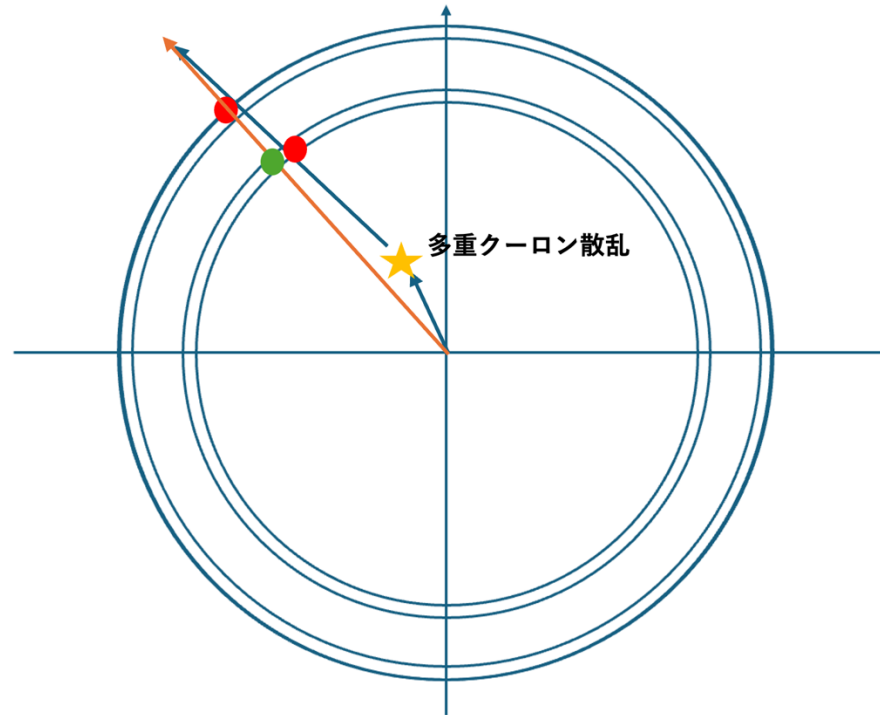# Dead area (barrel junction).
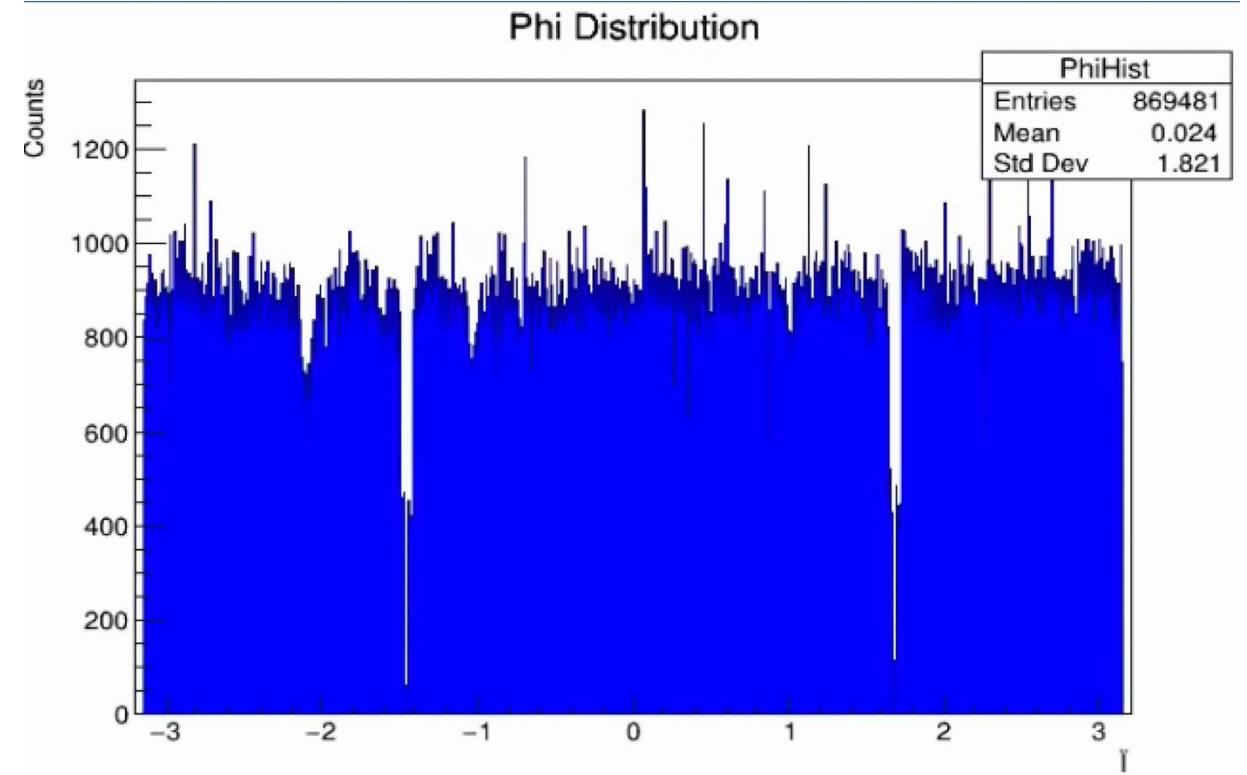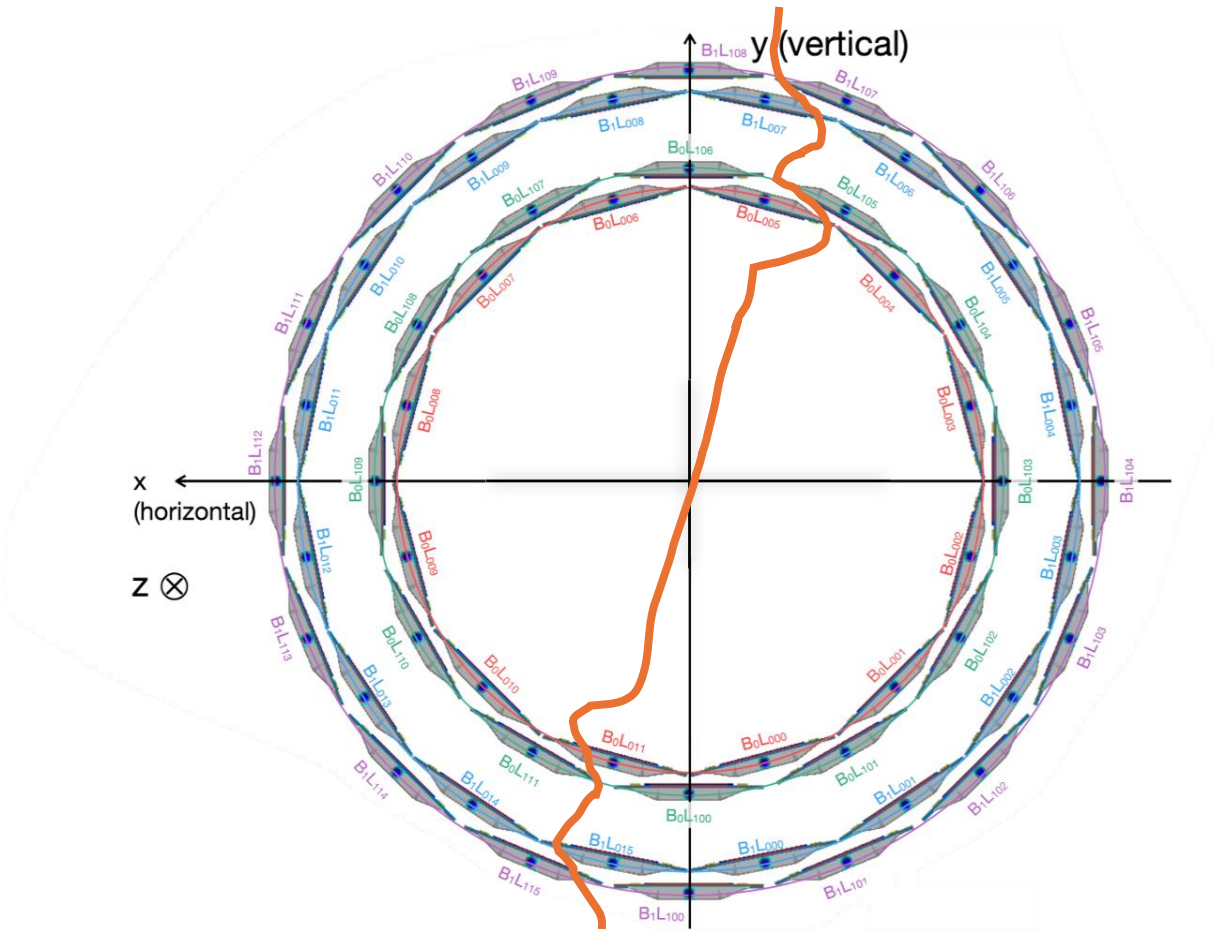
Dead area (between sensors)

Φ-length (single sensor) = 22.5 mm
F-length (active area) = 20.0 mm
Z-length type-A (single sensor) = 130.0 mm
Z-length type-A (active area) = 128.0mm
Z-length type-B (single sensor) = 102.0 mm
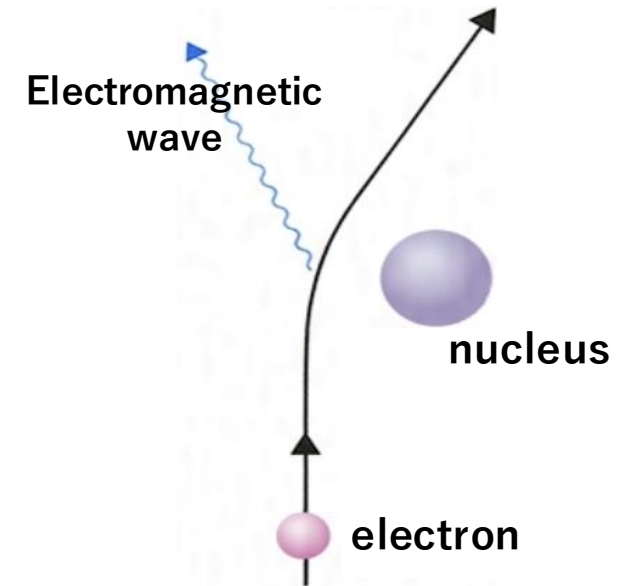Z-length type-B (active area) = 100.0 mm

Interaction

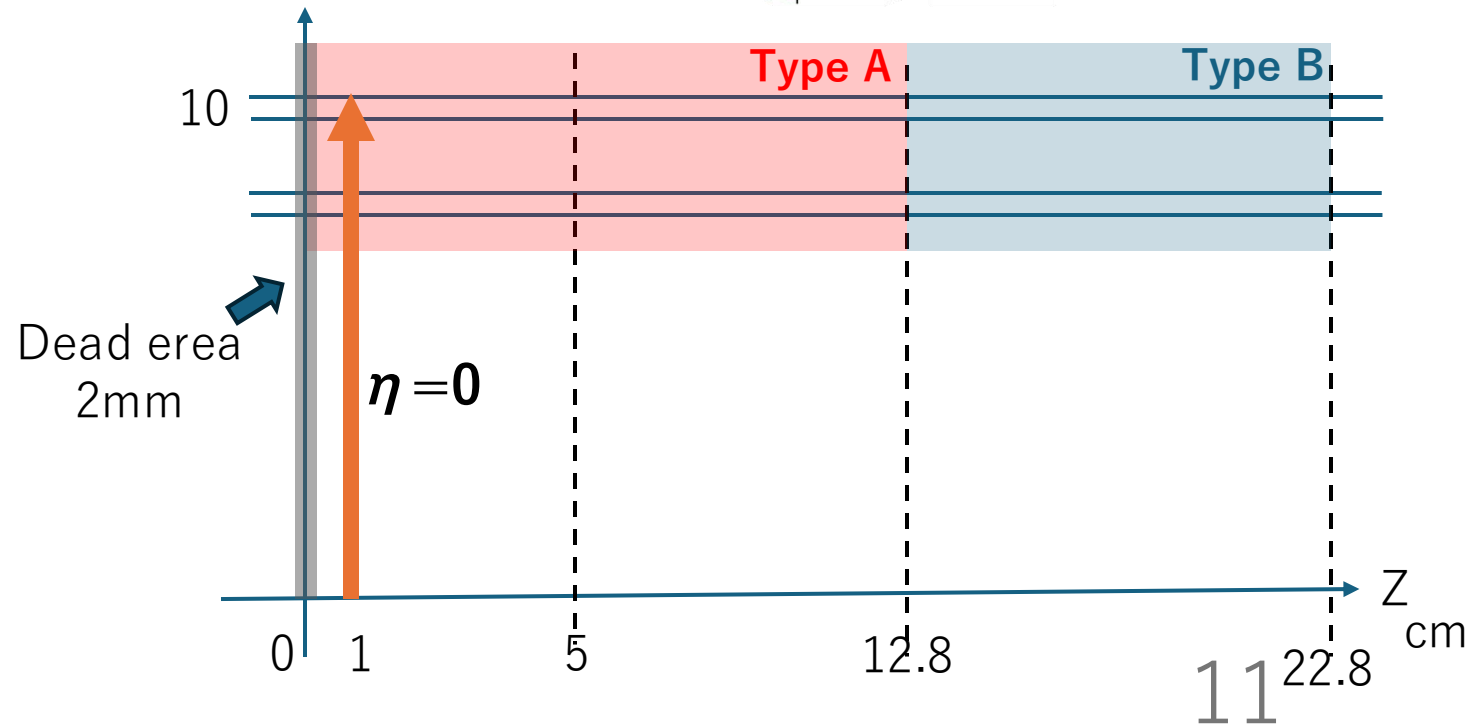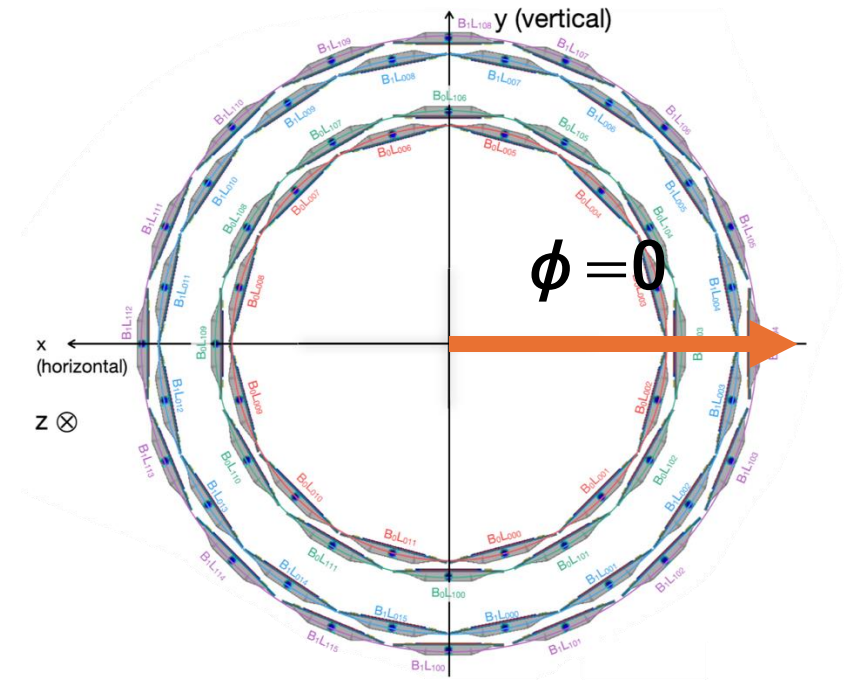**Ionization loss** **Multiple scattering** **Particle generation by bremsstrahlung.**

多重クーロン散乱

Electromagnetic wave

nucleus

electron

低P_T 高P_T

Simple simulation
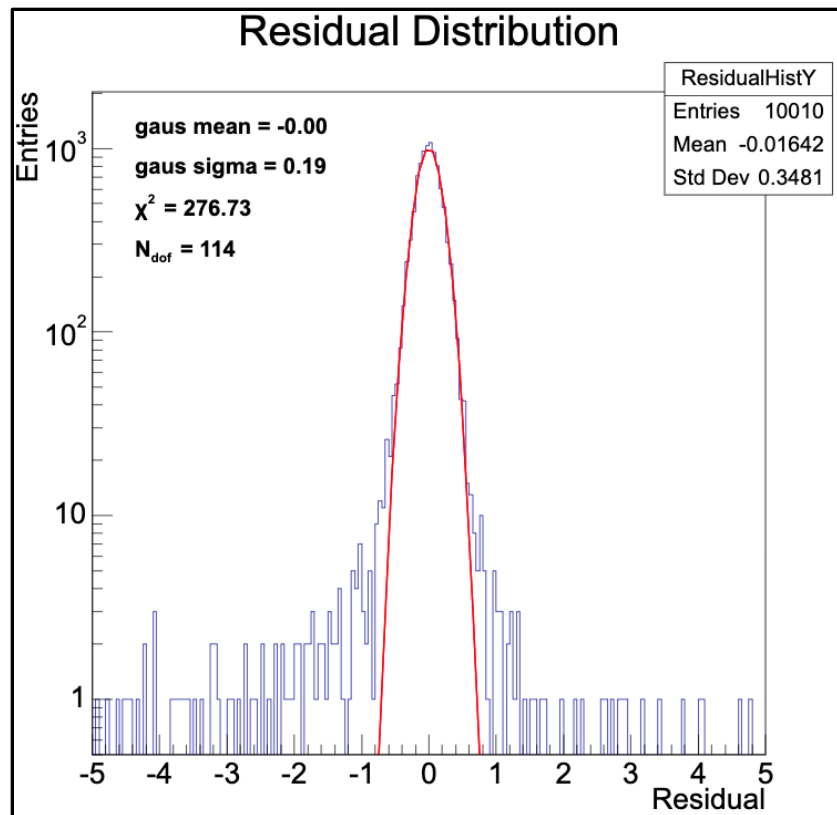
- A particle (μ^-)/event
- P_T = 200MeV, 400MeV, 1 GeV
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$\phi = 0$

Type A   Type B

10

Dead erea
2mm

$\eta = 0$

0 1   5   12.8   22.8

Z
cm

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$cm
- Incident direction : $\phi = 0$ rad, $\eta = 0$
- No dead channel

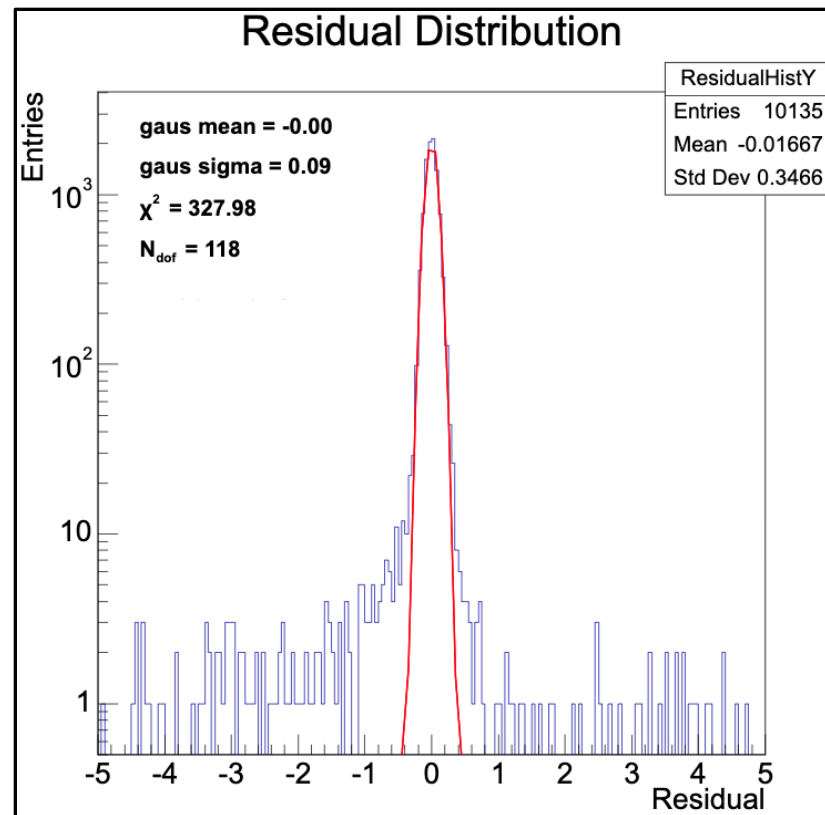$\boxed{P_T = 200\text{MeV}}$ $\boxed{P_T = 400\text{MeV}}$ $\boxed{P_T = 1\text{GeV}}$

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$$P_T = 200\text{MeV}$$

Residual Distribution

ResidualHistY

Entries	10010
Mean	-0.01642
Std Dev	0.3481

gaus mean = -0.00

gaus sigma = 0.19

χ^2 = 276.73

N_{dof} = 114

Entries (y-axis)

Residual (x-axis)

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$ cm
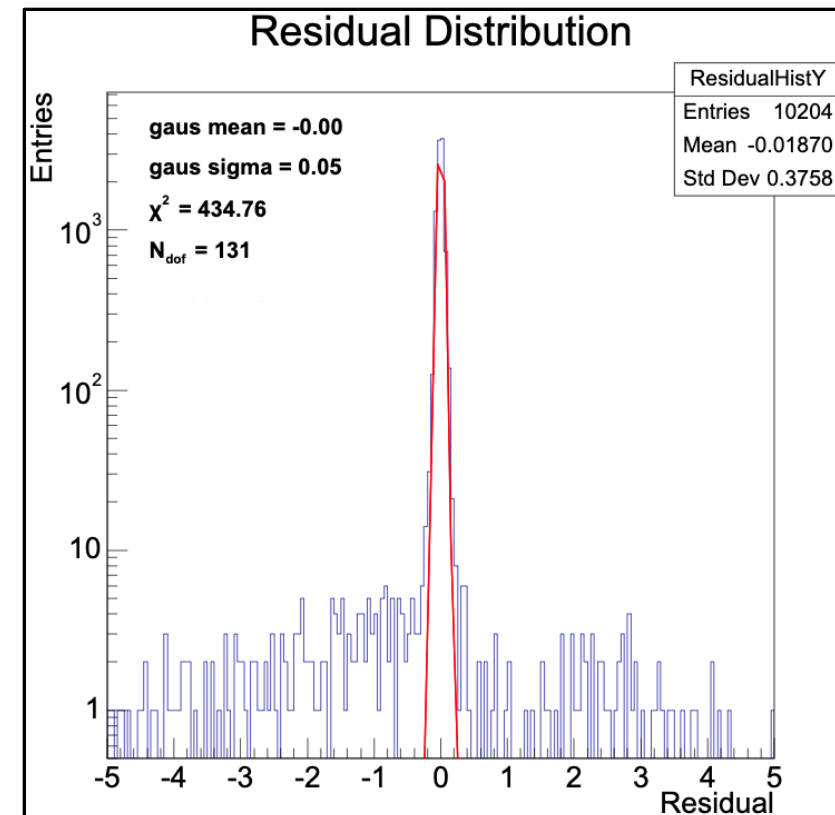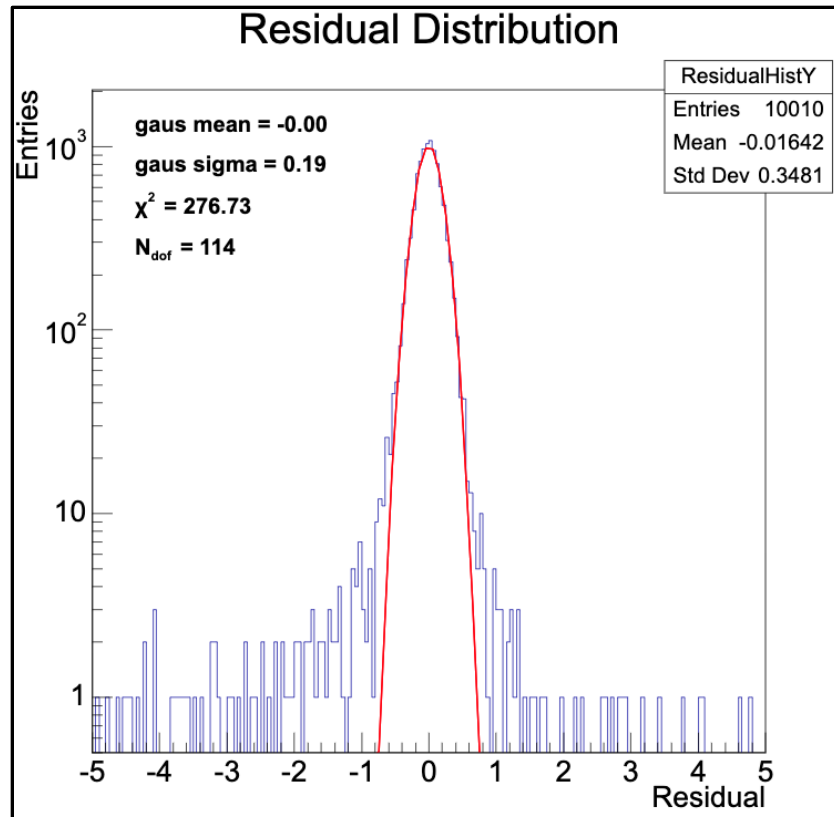- Incident direction : $\phi = 0$ rad, $\eta = 0$
- No dead channel

$$P_T = 200\text{MeV}$$

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.19

χ^2 = 276.73

N_{dof} = 114

window = 0.58

ResidualHistY	
Entries	10010
Mean	-0.01642
Std Dev	0.3481

Entries

Residual

Y axis: Entries
X axis: Residual in X-Y plane

$y = ax + b$

Outer Layer

Residual

Inner Layer

Window

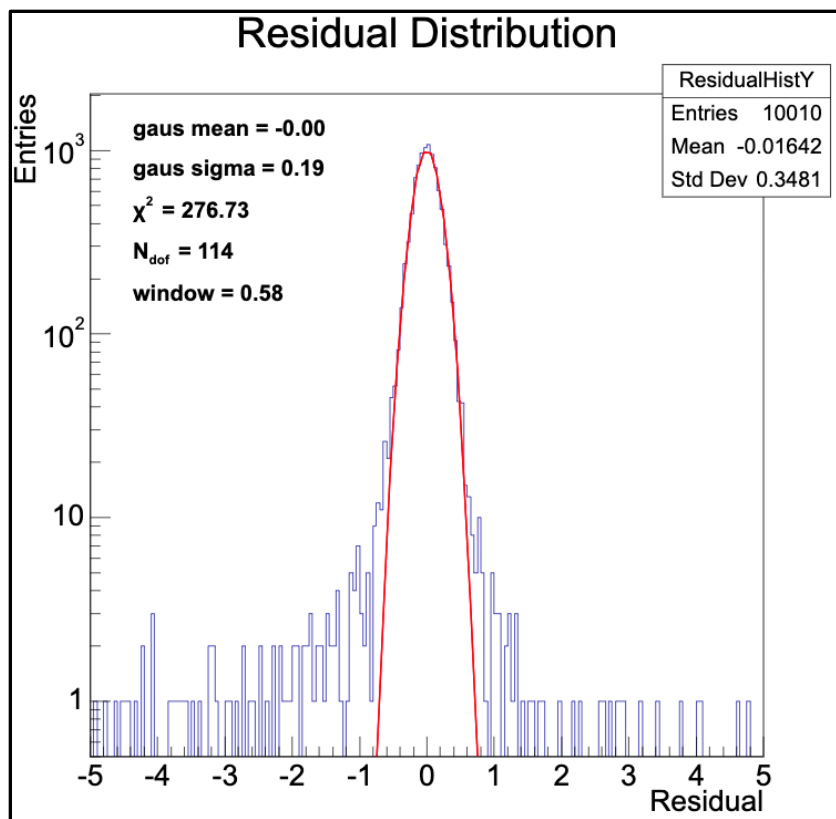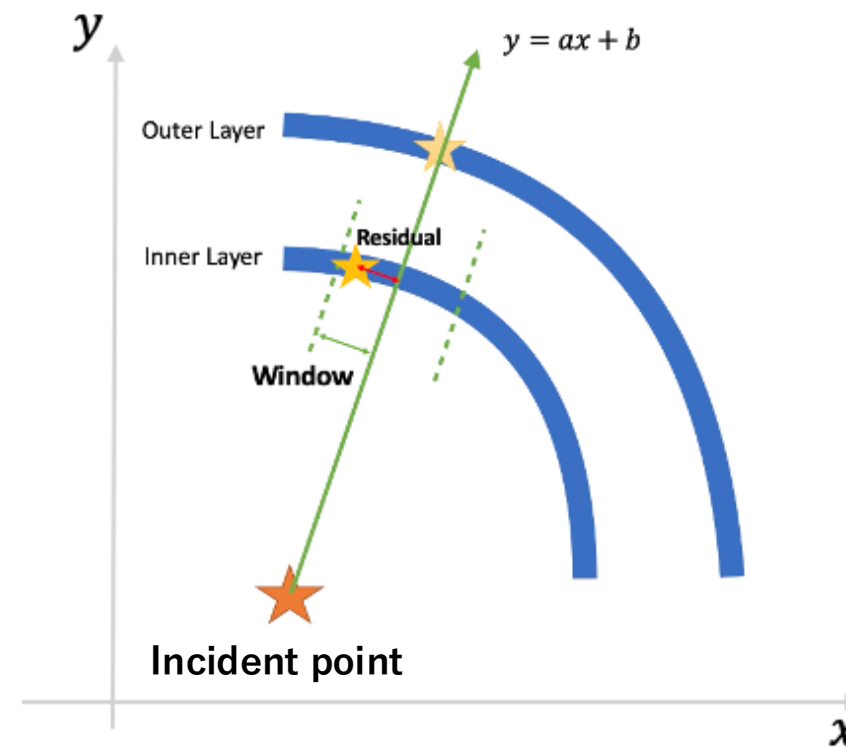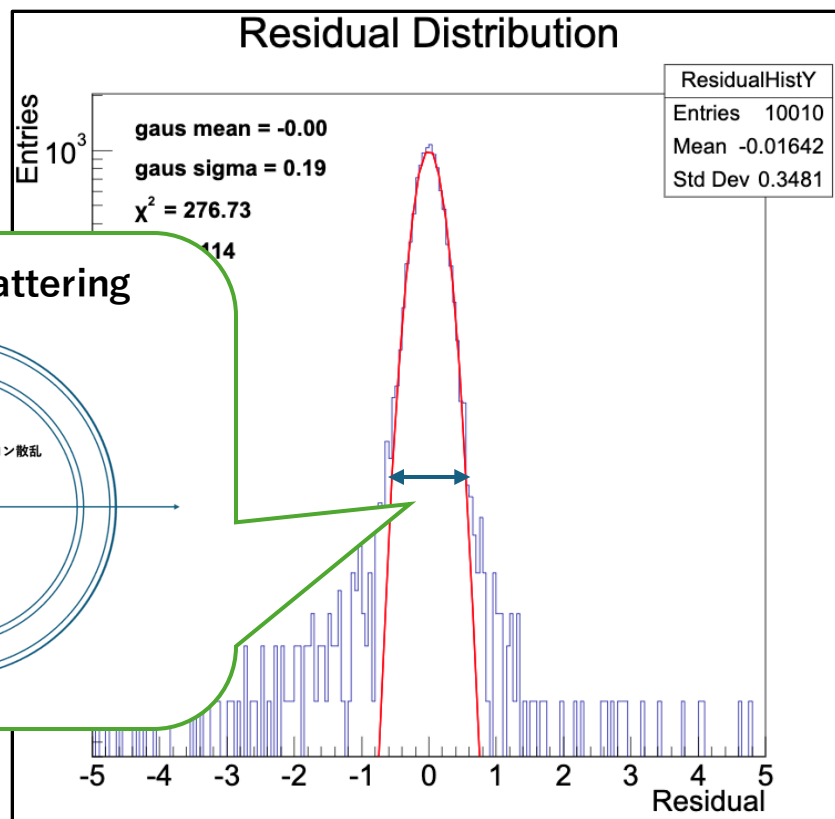**Incident point**

Residual: Distance between Inner cluster and Fit line

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$$\boxed{P_T = 200\text{MeV}}$$

Residual Distribution

Entries

10^3

gaus mean = -0.00

gaus sigma = 0.19

χ^2 = 276.73

114

ResidualHistY	
Entries	10010
Mean	-0.01642
Std Dev	0.3481

Multiple Scattering

多重クーロン散乱

-5 -4 -3 -2 -1 0 1 2 3 4 5
Residual

Y axis: Entries
X axis: Residual in X-Y plane

y

$y = ax + b$

Outer Layer

Residual

Inner Layer

Window

Incident point

x

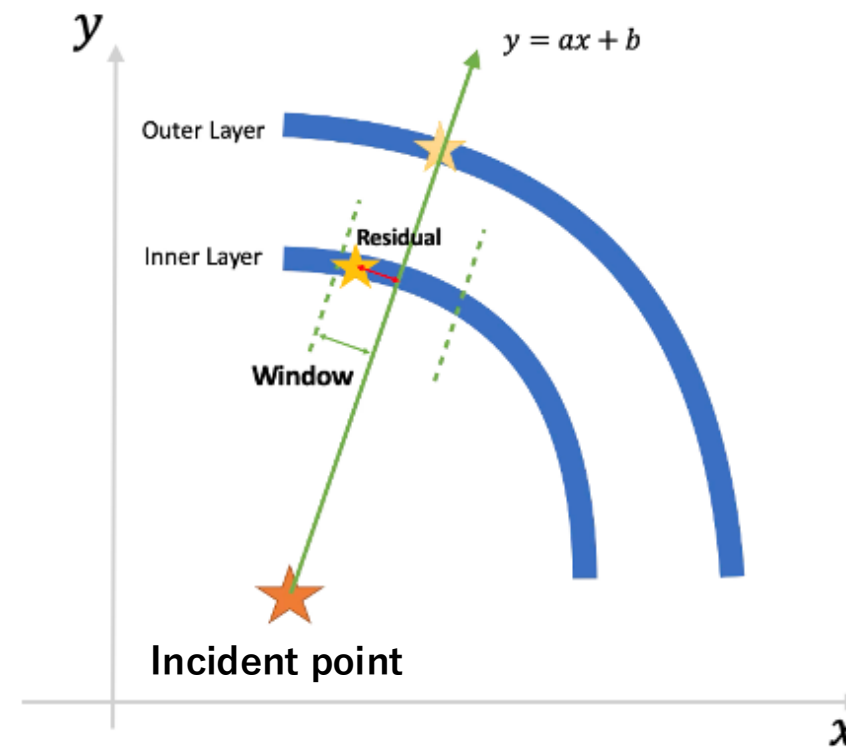Residual: Distance between Inner cluster and Fit line

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1) cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$$P_T = 200\text{MeV}$$

Residual Distribution
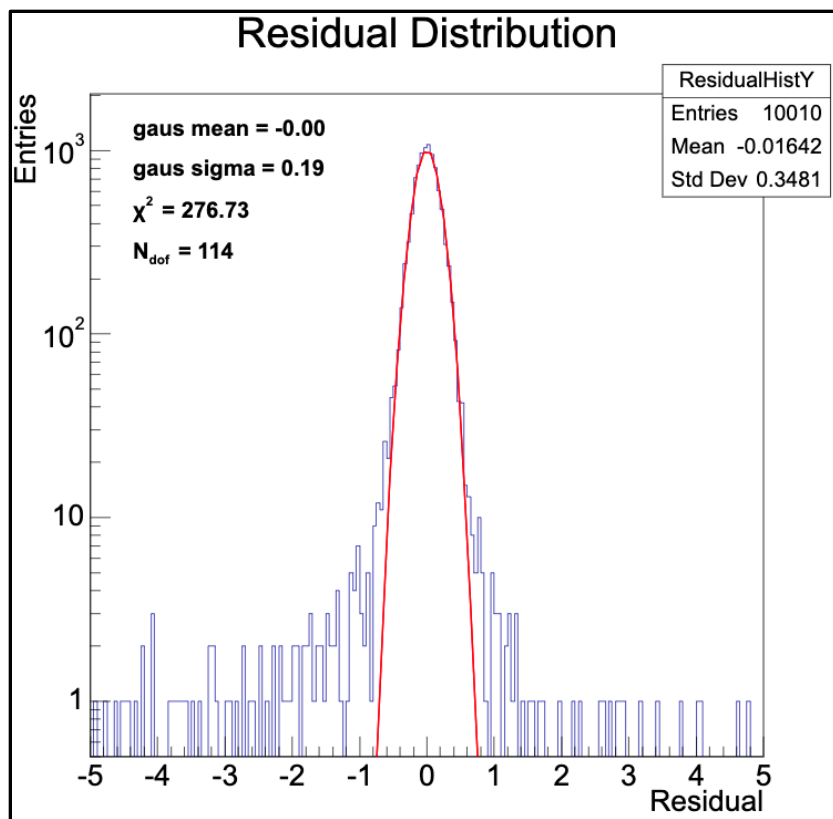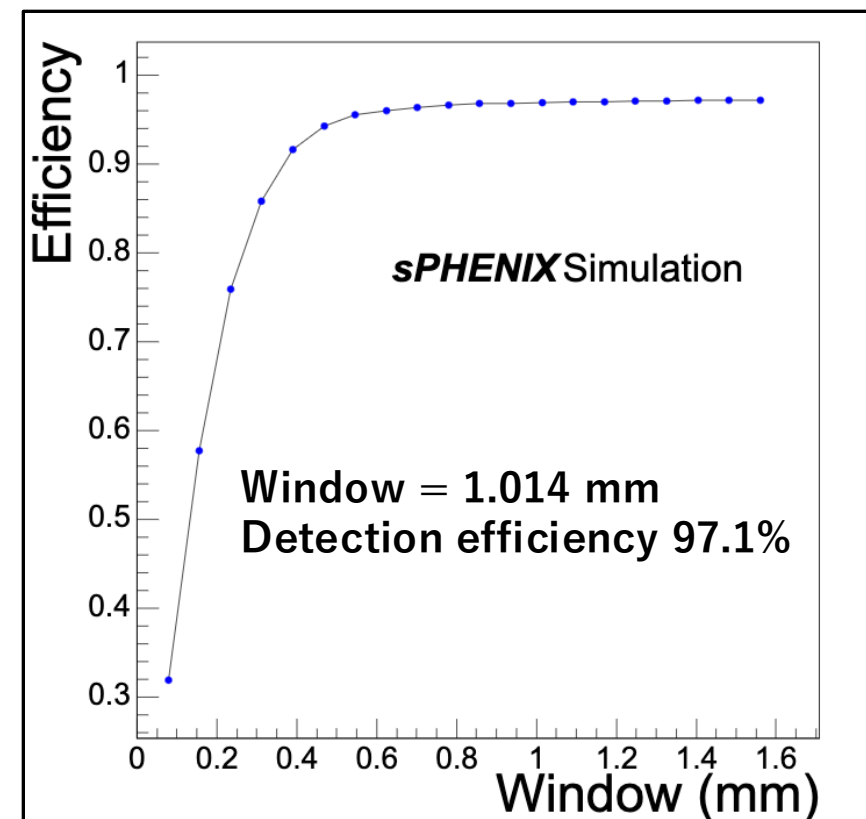
gaus mean = -0.00

gaus sigma = 0.19

χ^2 = 276.73

N_{dof} = 114

ResidualHistY	
Entries	10010
Mean	-0.01642
Std Dev	0.3481

Entries

Residual

Y axis: Entries
X axis: Residual in X-Y plane

sPHENIX Simulation

Window = 1.014 mm
Detection efficiency 97.1%

Efficiency

Window (mm)

Y axis: Efficiency
X axis: Window $= 78\mu m \cdot i \ (i = 1, 2, 3, …)$

16

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$ cm
- Incident direction : $\phi = 0$ rad, $\eta = 0$
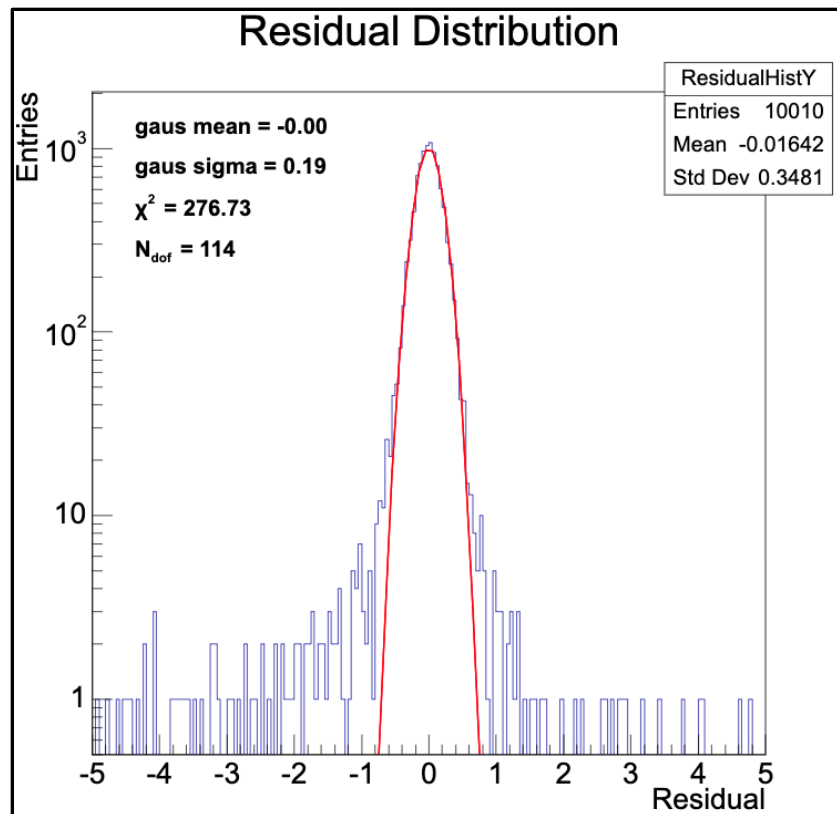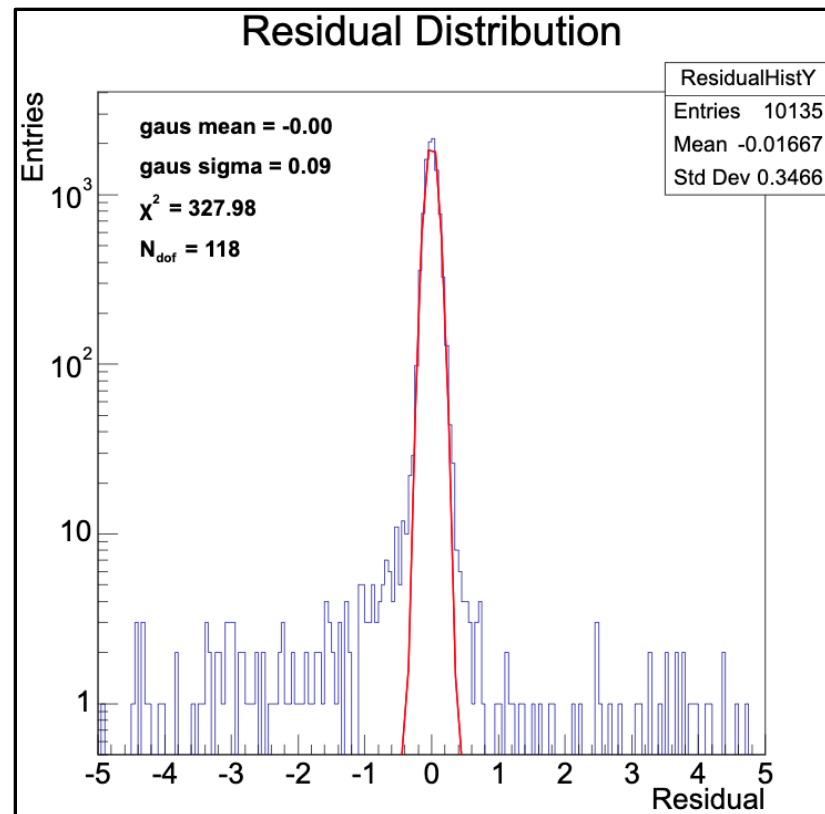- No dead channel

$P_T = 200\text{MeV}$

$P_T = 400\text{MeV}$

$P_T = 1\text{GeV}$

17

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$ cm
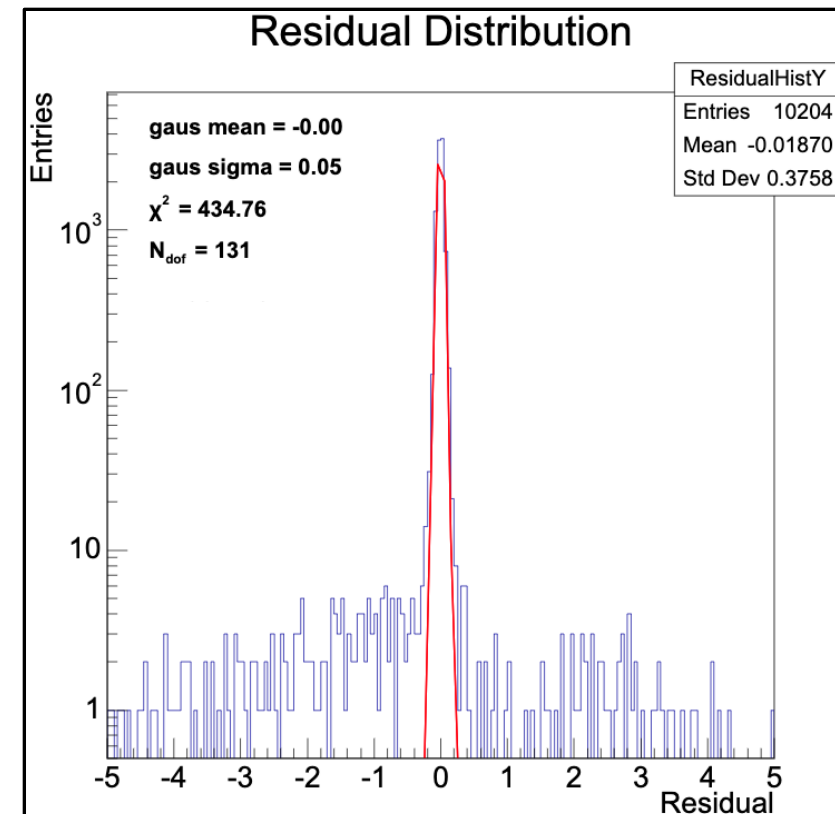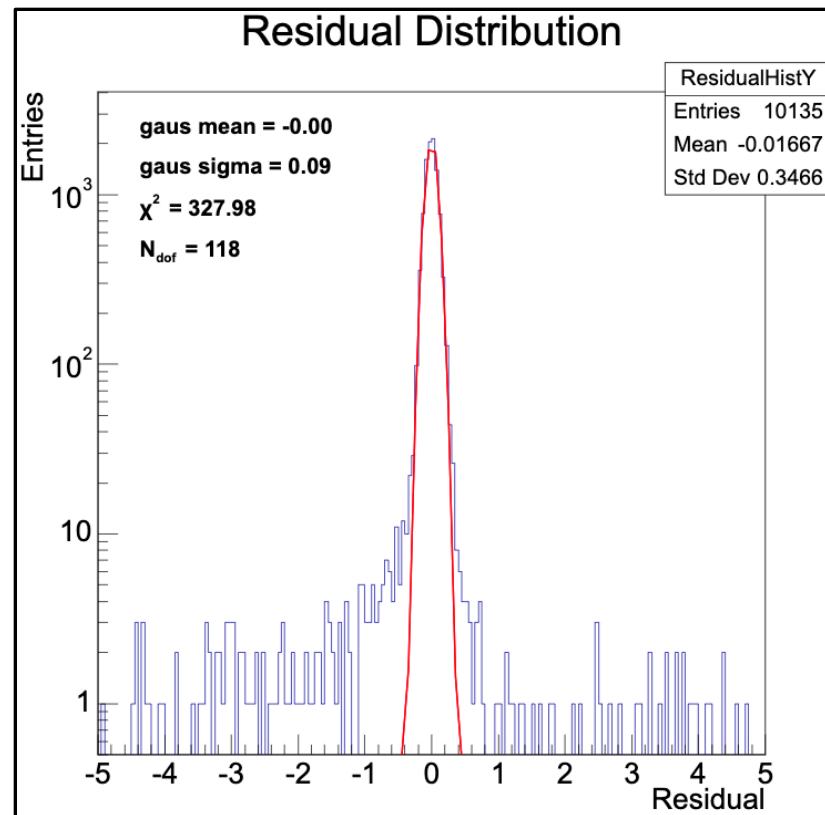- Incident direction : $\phi = 0$ rad, $\eta = 0$
- No dead channel

$$P_T = 400\text{MeV}$$

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.09

χ^2 = 327.98

N_{dof} = 118

ResidualHistY

Entries	10135
Mean	-0.01667
Std Dev	0.3466

Entries

Residual
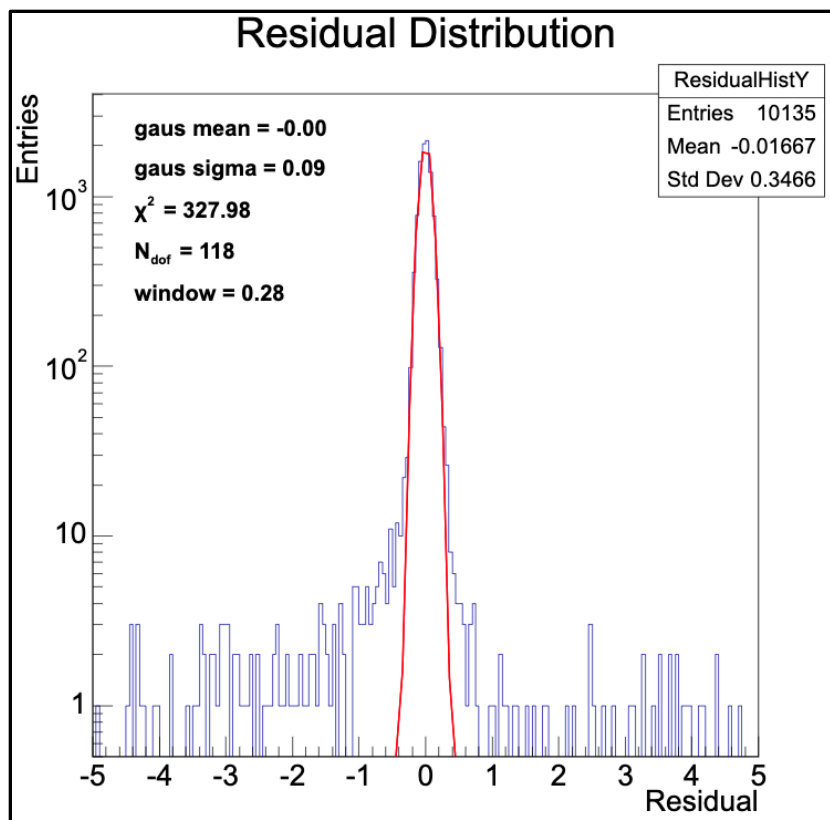
- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$$P_T = 400\text{MeV}$$

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.09

x^2 = 327.98

N_{dof} = 118

window = 0.28

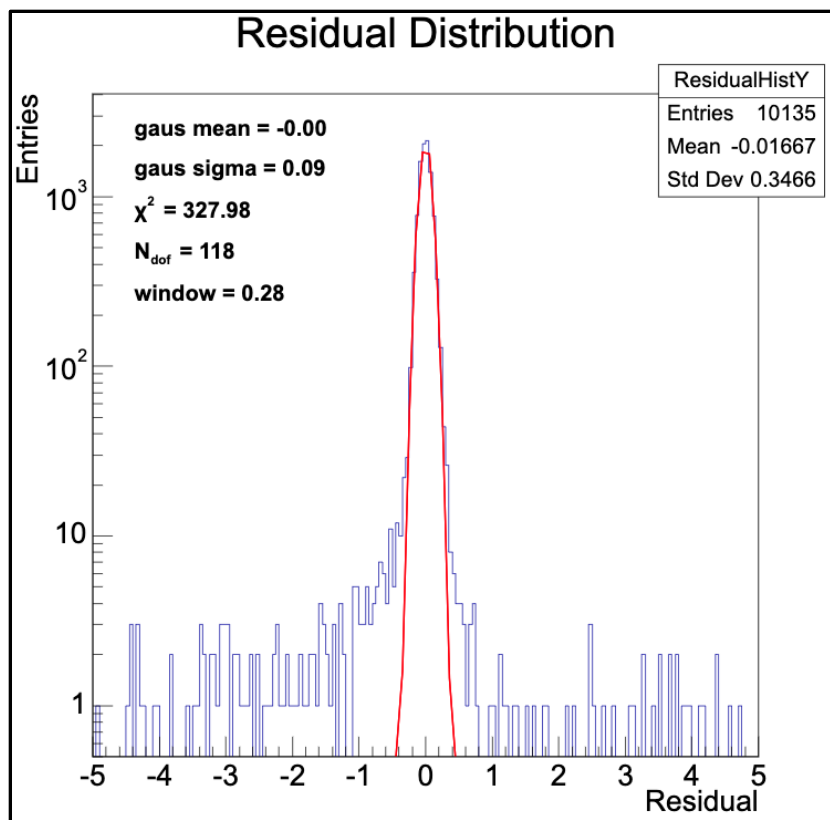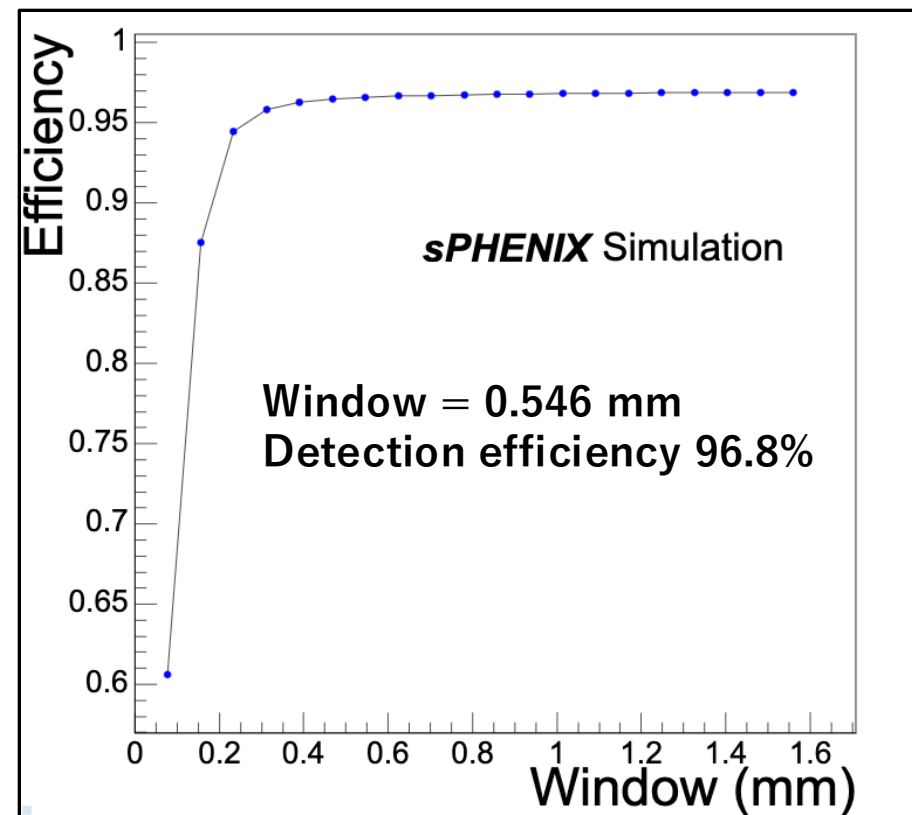| ResidualHistY	
Entries	10135
Mean	-0.01667
Std Dev	0.3466

Y axis: Entries
X axis: Residual in X-Y plane

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1) cm
- Incident direction : $\phi = 0$ rad, $\eta = 0$
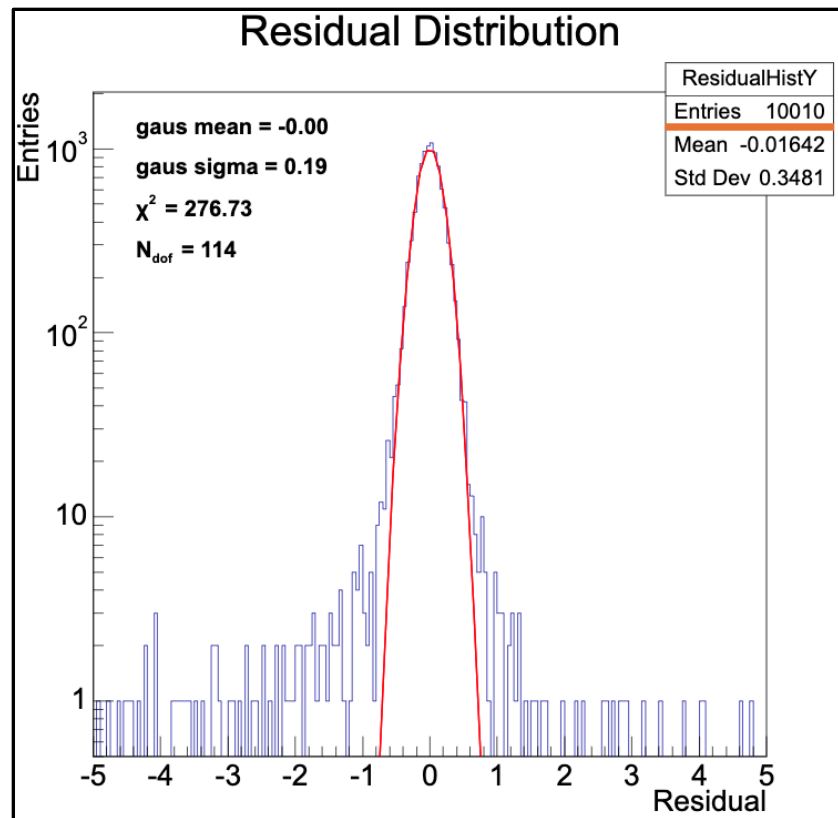- No dead channel

$$\boxed{P_T = 400\text{MeV}}$$

Residual Distribution

ResidualHistY	
Entries	10135
Mean	-0.01667
Std Dev	0.3466

gaus mean = -0.00

gaus sigma = 0.09

χ^2 = 327.98

N_{dof} = 118

window = 0.28

Y axis: Entries
X axis: Residual in X-Y plane

sPHENIX Simulation
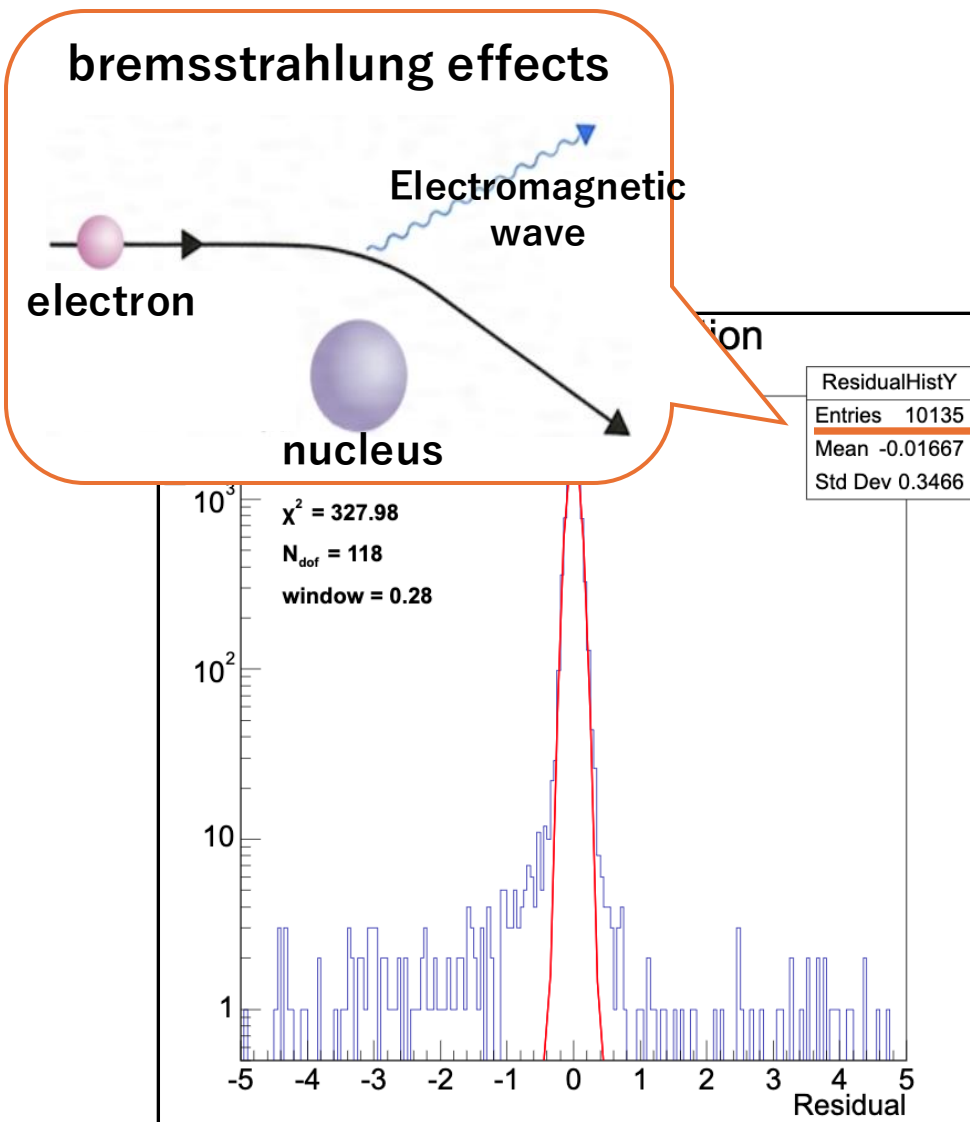
Window = 0.546 mm
Detection efficiency 96.8%

Y axis: Efficiency
X axis: Window $= 78\mu m \cdot i \ (i = 1, 2, 3, \dots)$

20

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
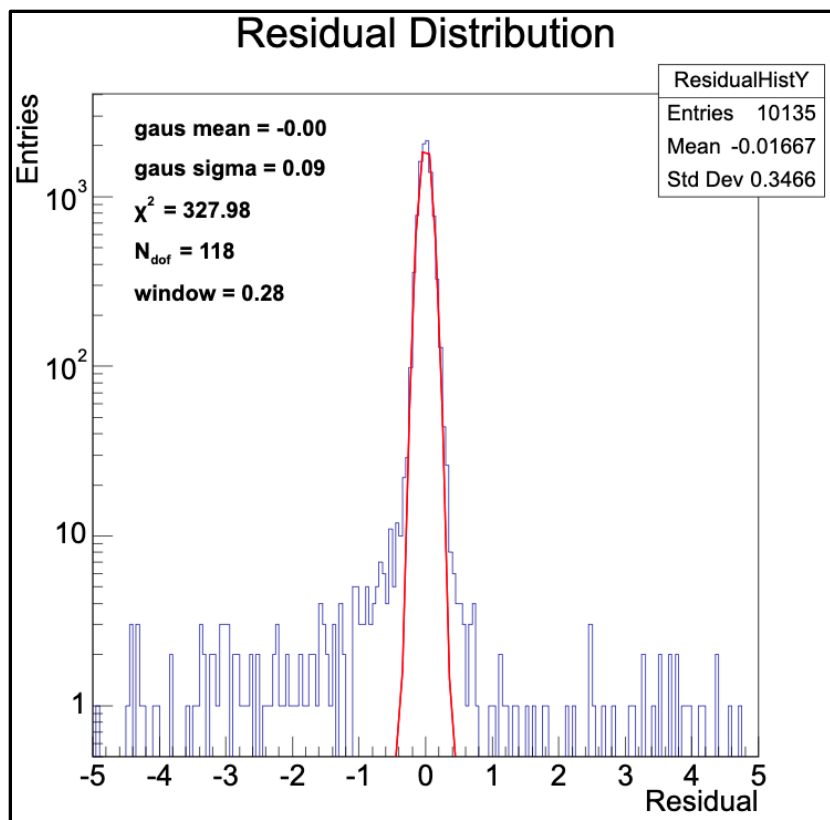- Incident direction : $\phi =0$ rad, $\eta =0$
- No dead channel

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.19

χ^2 = 276.73

N_{dof} = 114

ResidualHistY	
Entries	10010
Mean	-0.01642
Std Dev	0.3481

bremsstrahlung effects

Electromagnetic wave

electron

nucleus

ResidualHistY	
Entries	10135
Mean	-0.01667
Std Dev	0.3466

χ^2 = 327.98

N_{dof} = 118

window = 0.28
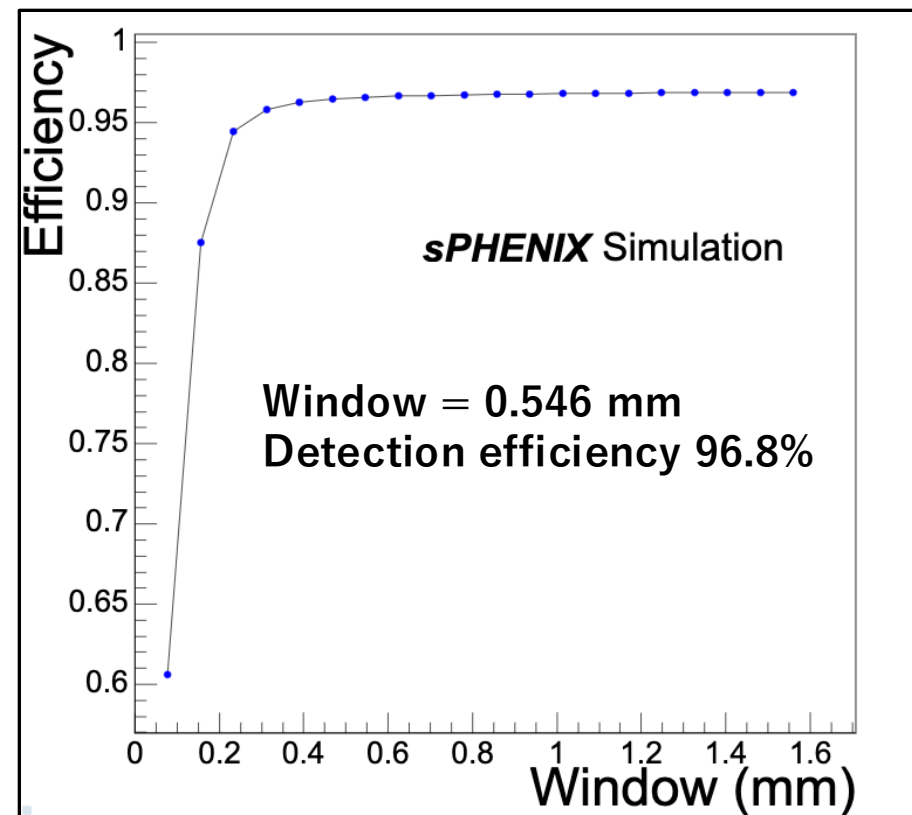
$P_T = 200\text{MeV}$

$P_T = 400\text{MeV}$

21

一粒子(μ^-)/event
イベント数: 10K イベント
磁場: なし
入射位置: 固定 $(x, y, z) = (0, 0, 1)$cm
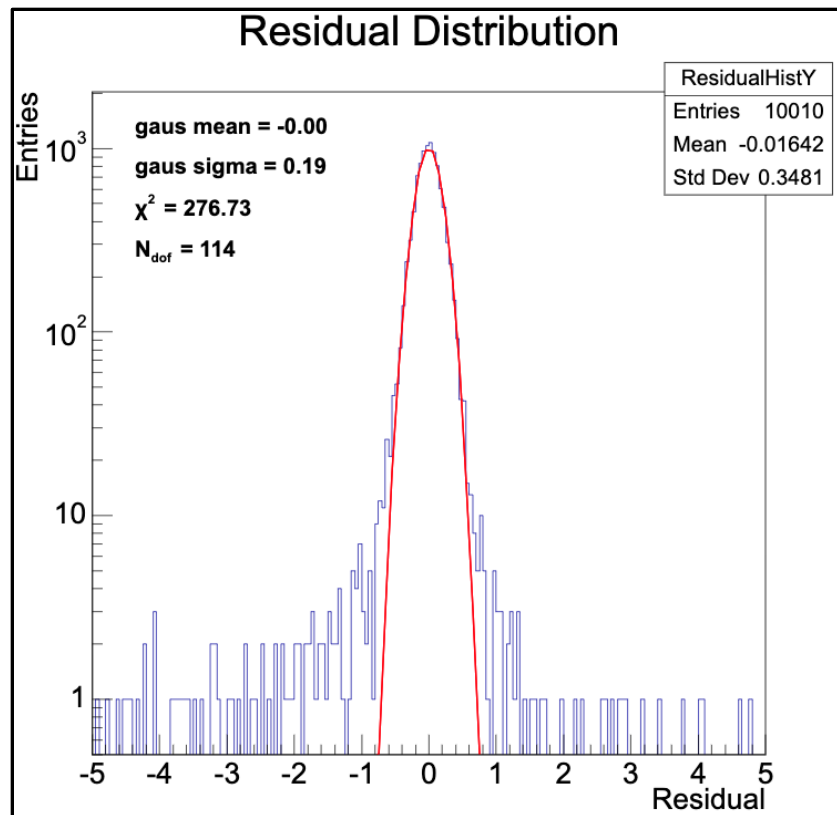入射方向: $\phi = 0$ rad, $\eta = 0$
Dead channelなし

$$P_T = 400\text{MeV}$$

Residual Distribution

gaus mean = -0.00
gaus sigma = 0.09
χ^2 = 327.98
N_{dof} = 118
window = 0.28

ResidualHistY	
Entries	10135
Mean	-0.01667
Std Dev	0.3466

Entries

Residual

Y axis: Entries
X axis: Residual in X-Y plane

sPHENIX Simulation

Window = 0.546 mm
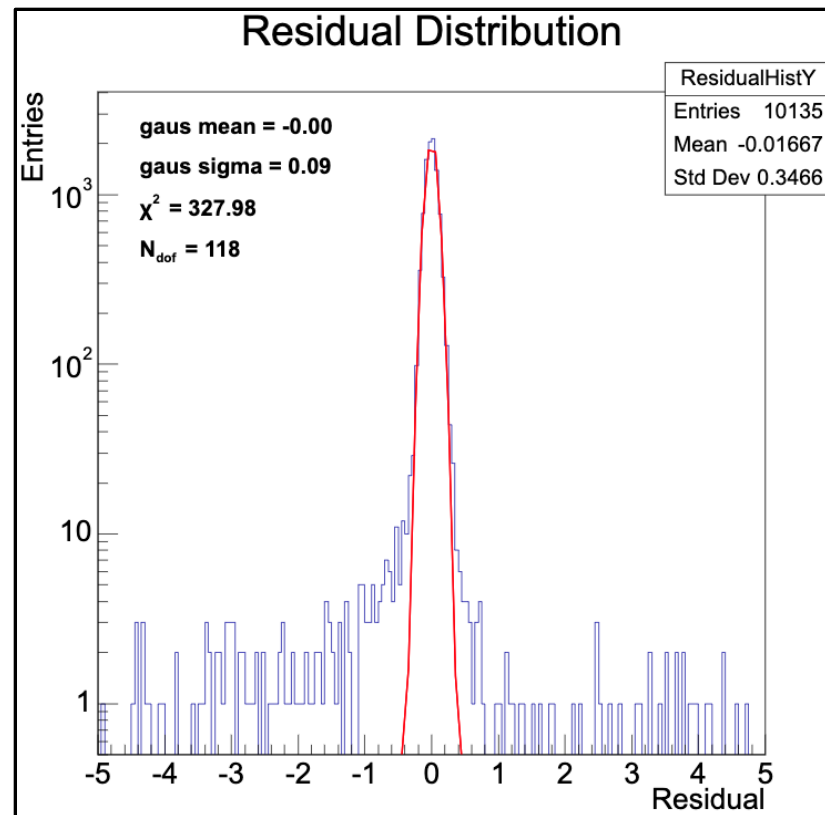**Detection efficiency 96.8%**

Efficiency

Window (mm)

Y axis: Efficiency
X axis: Window = $78\mu m \cdot i$ $(i = 1, 2, 3, \dots)$

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$cm
- Incident direction : $\phi = 0$ rad, $\eta = 0$
- No dead channel

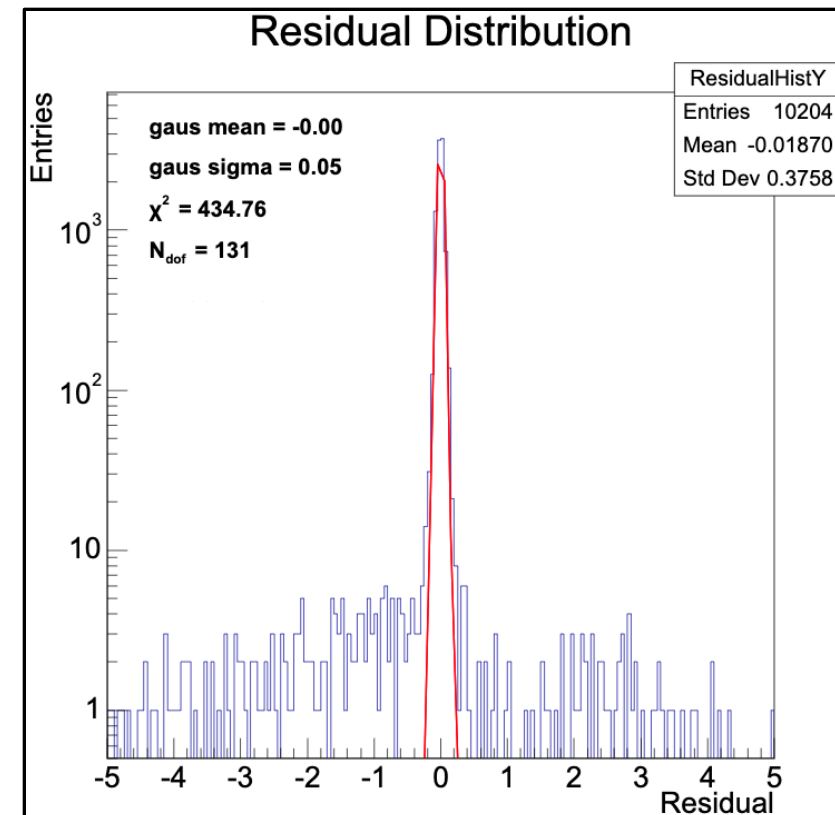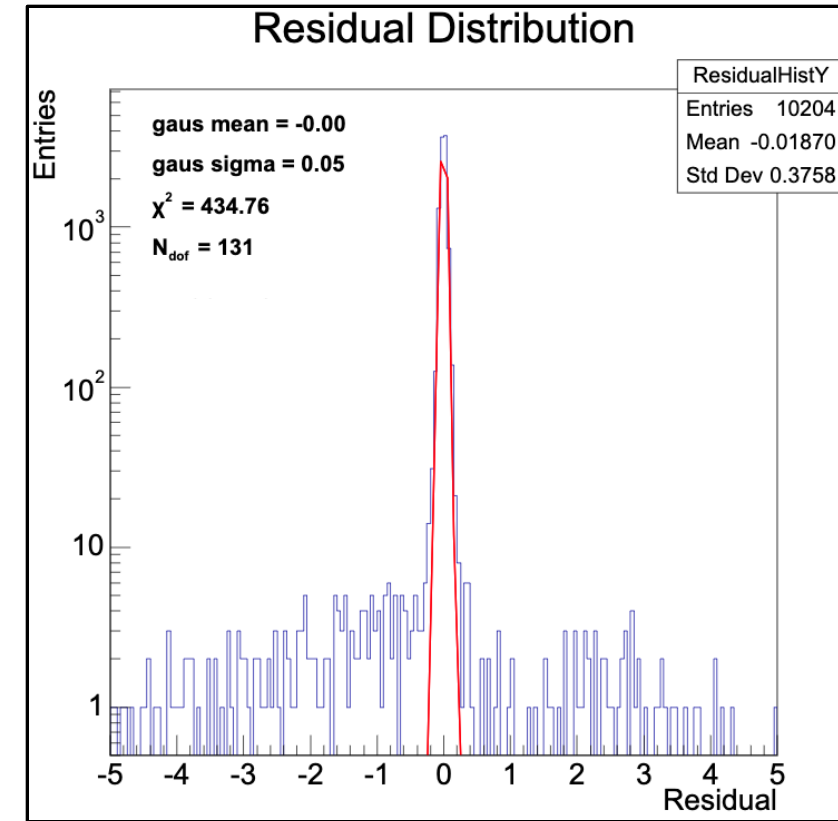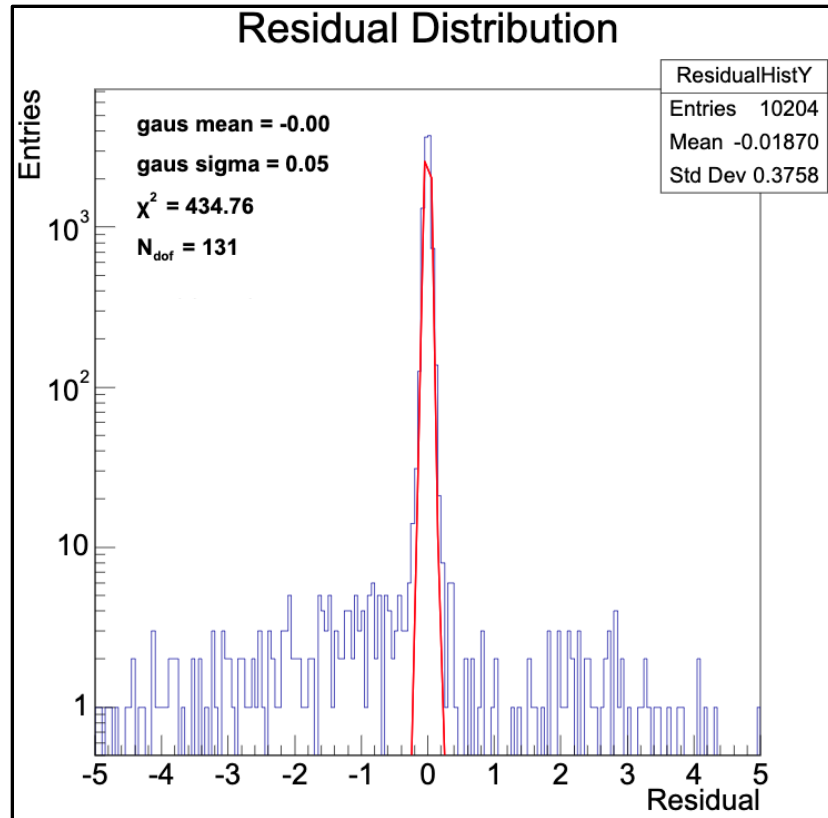$\boxed{P_T = 200\text{MeV}}$ $\qquad$ $\boxed{P_T = 400\text{MeV}}$ $\qquad$ $\boxed{P_T = 1\text{GeV}}$

Residual Distribution

gaus mean = -0.00
gaus sigma = 0.19
$\chi^2 = 276.73$
$N_{dof} = 114$

ResidualHistY
Entries 10010
Mean -0.01642
Std Dev 0.3481

Residual Distribution

gaus mean = -0.00
gaus sigma = 0.09
$\chi^2 = 327.98$
$N_{dof} = 118$

ResidualHistY
Entries 10135
Mean -0.01667
Std Dev 0.3466

Residual Distribution

gaus mean = -0.00
gaus sigma = 0.05
$\chi^2 = 434.76$
$N_{dof} = 131$

ResidualHistY
Entries 10204
Mean -0.01870
Std Dev 0.3758

23

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed $(x, y, z) = (0, 0, 1)$cm
- Incident direction : ϕ =0 rad, η =0
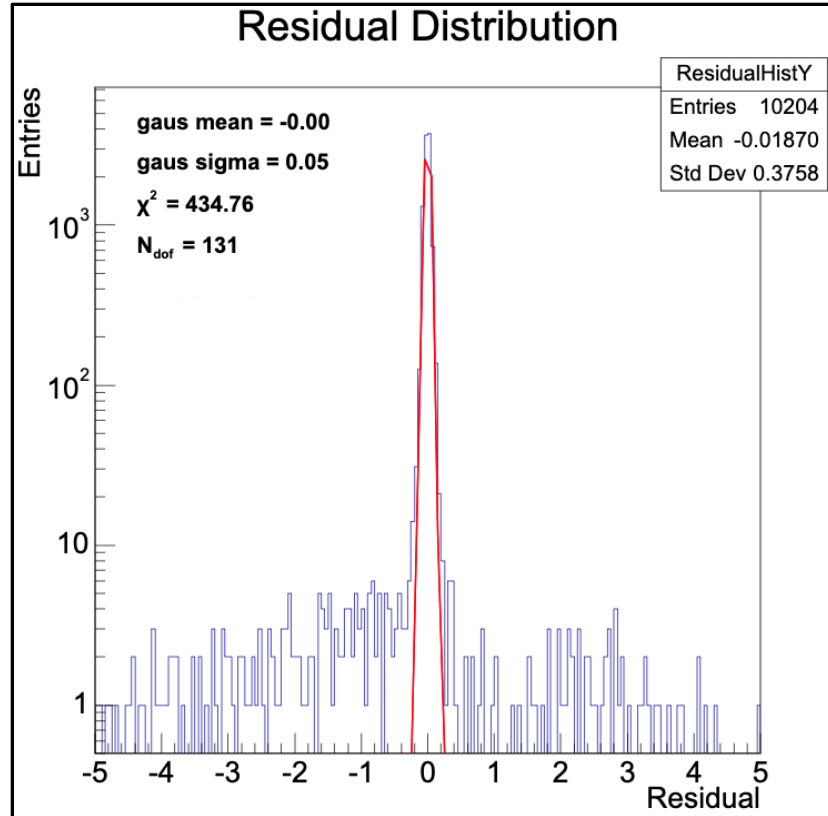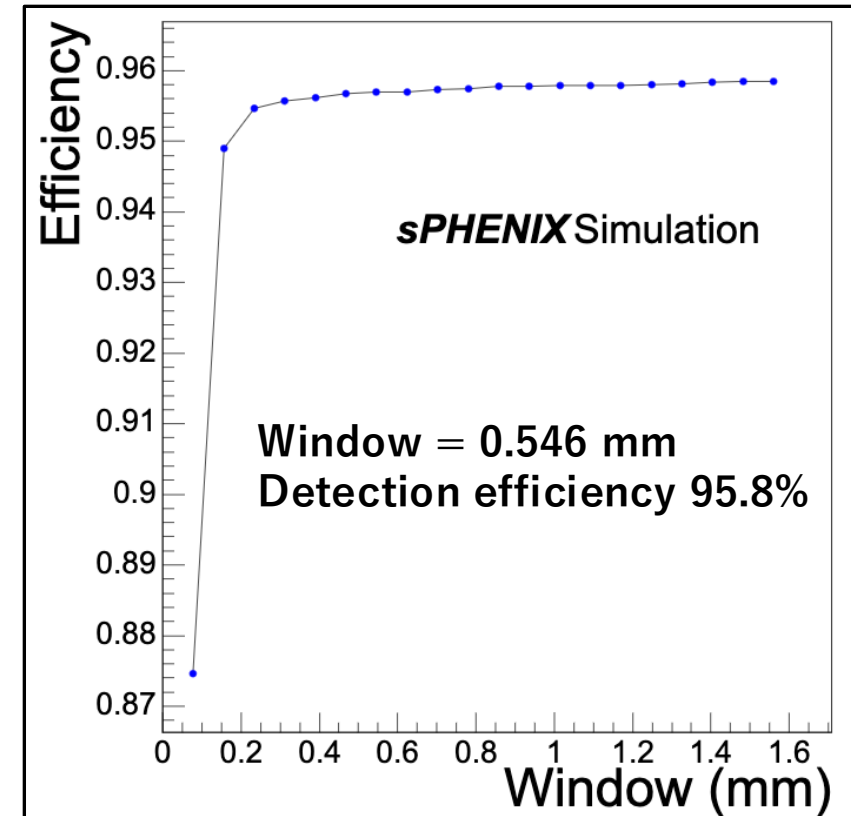- No dead channel

$$P_T = 1\text{GeV}$$

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.05

χ^2 = 434.76

N_{dof} = 131

ResidualHistY	
Entries	10204
Mean	-0.01870
Std Dev	0.3758

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1) cm
- Incident direction : $\phi = 0$ rad, $\eta = 0$
- No dead channel

$$P_T = 1\text{GeV}$$

Residual Distribution

gaus mean = -0.00

gaus sigma = 0.05

χ^2 = 434.76

N_{dof} = 131

ResidualHistY	
Entries	10204
Mean	-0.01870
Std Dev	0.3758

Y axis: Entries

X axis: Residual in X-Y plane

- A particle (μ^-)/event
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1) cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

$$P_T = 1\text{GeV}$$

Residual Distribution

gaus mean = -0.00
gaus sigma = 0.05
χ^2 = 434.76
N_{dof} = 131

ResidualHistY	
Entries	10204
Mean	-0.01870
Std Dev	0.3758

Entries

Residual

Efficiency

sPHENIX Simulation

Window = 0.546 mm
Detection efficiency 95.8%

Window (mm)

Y axis: Entries
X axis: Residual in X-Y plane

Y axis: Efficiency
X axis: Window $= 78\mu m \cdot i \ (i = 1, 2, 3, \dots)$

26

Used simulation

Simple simulation

- A particle (μ^-)/event
- P_T = 200MeV, 400MeV, 1 GeV
- # of events : 10K
- Magnetic field : zero field
- Incident point: Fixed (x, y, z) = (0, 0, 1)cm
- Incident direction : ϕ =0 rad, η =0
- No dead channel

Window 1mm : 97%

p+p simulation

- PYTHIA8
- # of events : 10K
- Magnetic field : zero field
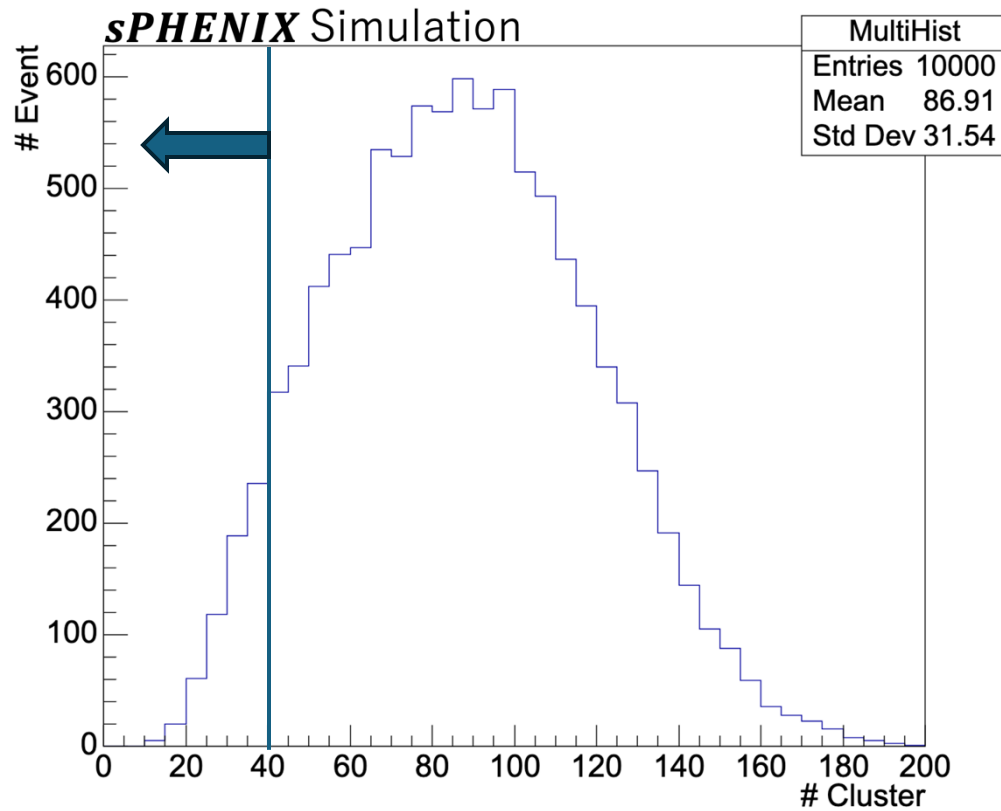- Vertex: Fixed (x, y, z) = (0, 0, 0)cm
- No Dead channel

Used simulation

p+p simulation

- PYTHIA8
- # of events : 10K
- Magnetic field : zero field
- Vertex: Fixed (x, y, z) = (0, 0, 0)cm
- No Dead channel

Event Display(p+p)

Multiplicity distribution

Event Display（p+p）

Multiplicity distribution

sPHENIX Simulation

MultiHist	
Entries	10000
Mean	86.91
Std Dev	31.54

Window 1mm

Event Display X-Y
sPHENIX Simulation

MVTX

Event Display R-Z
sPHENIX Simulation

Low Multiplicity   # of clusters＜40

Event Display（p+p）

Multiplicity distribution
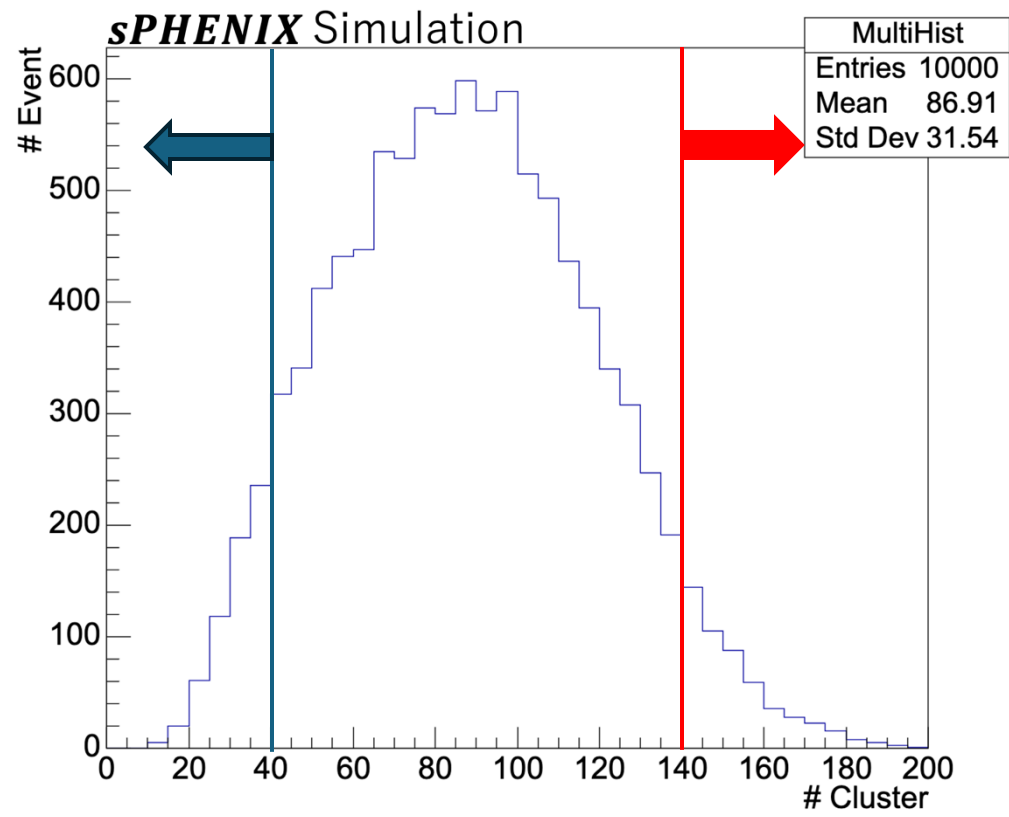
Low Multiplicity # of clusters＜40

High Multiplicity # of clusters ＞140

Window 1mm

Window 1mm

31
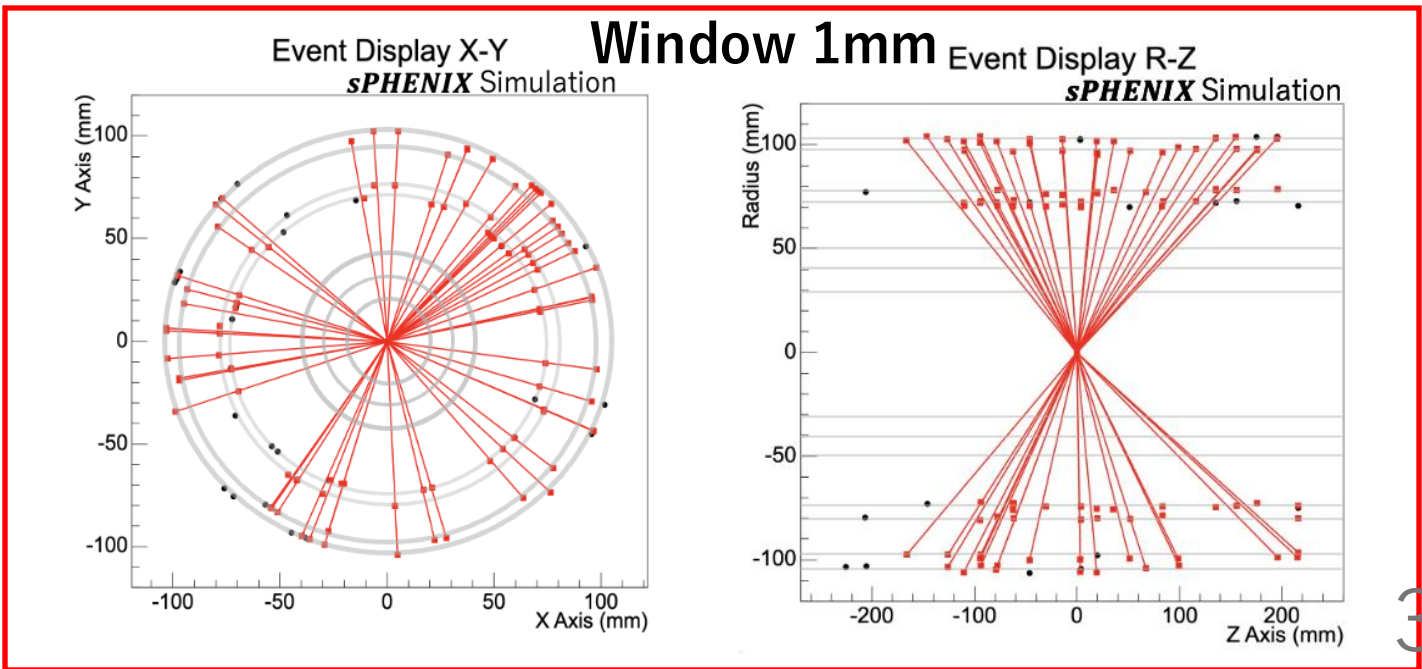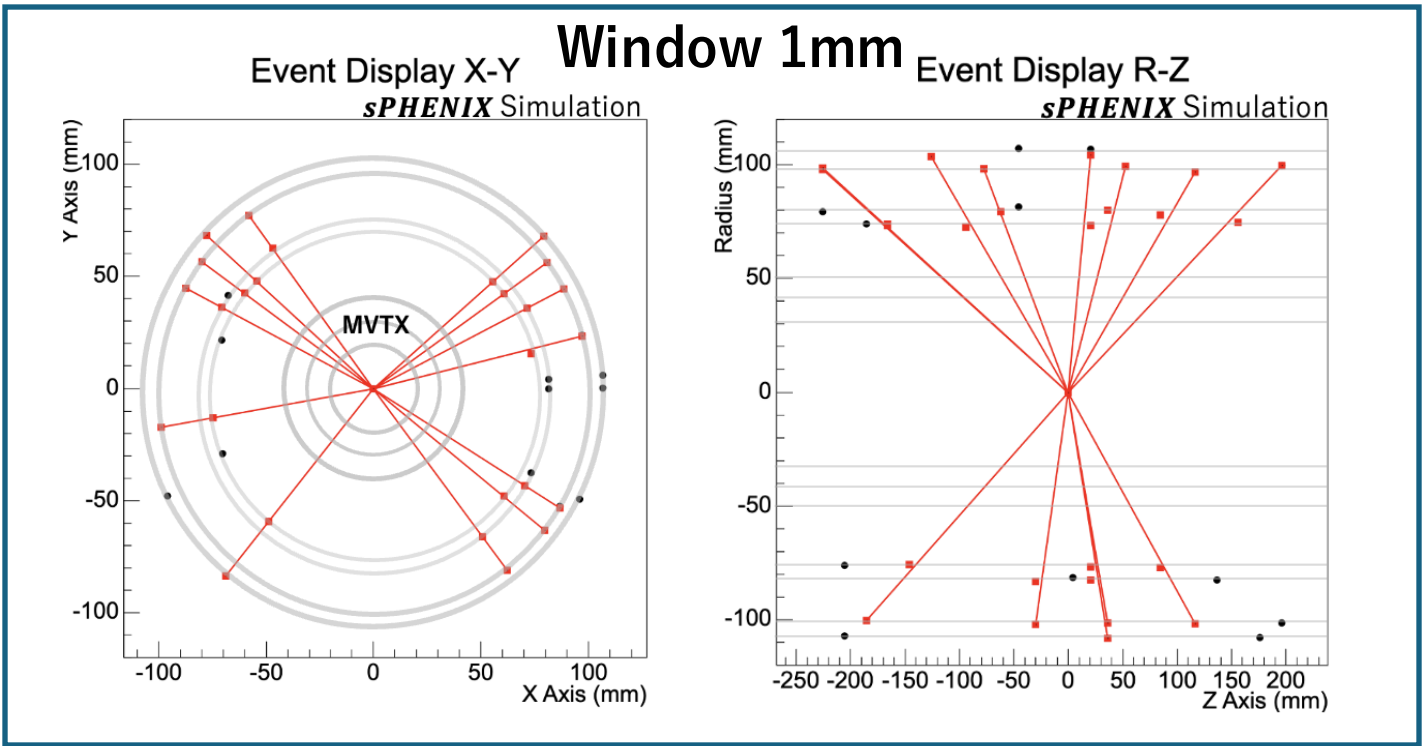
Cutting high-density areas

Event Display X-Y
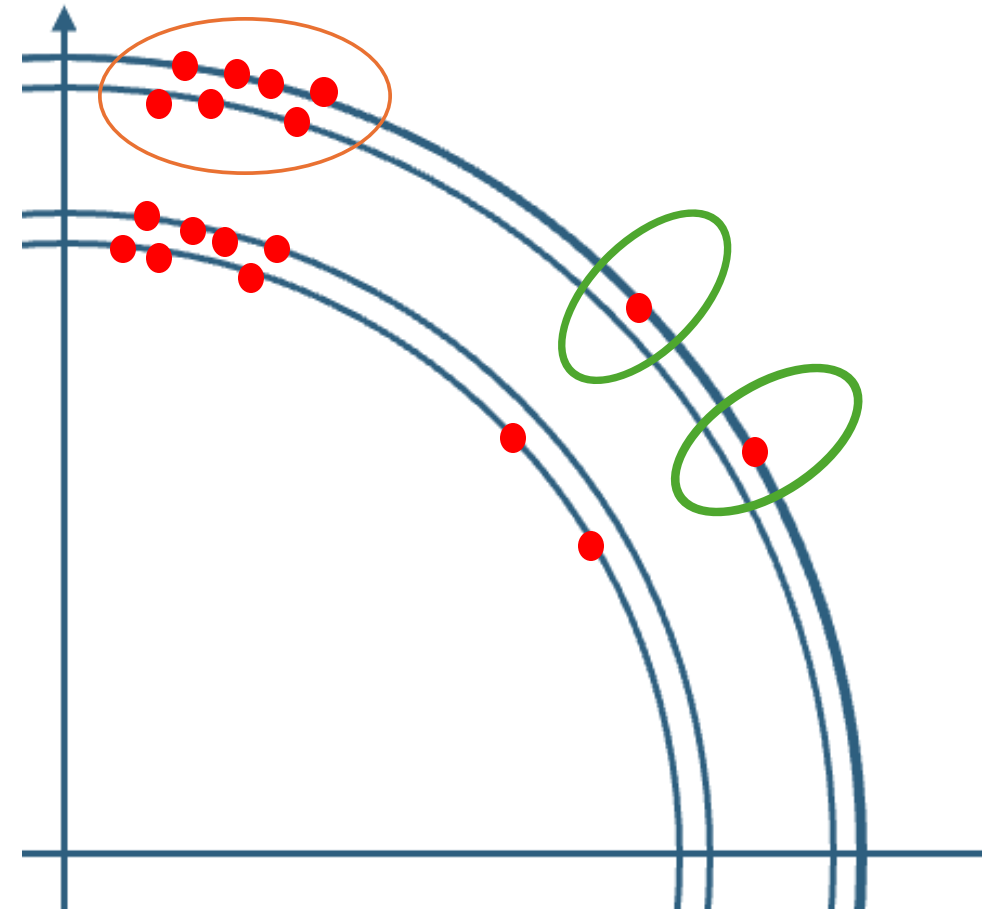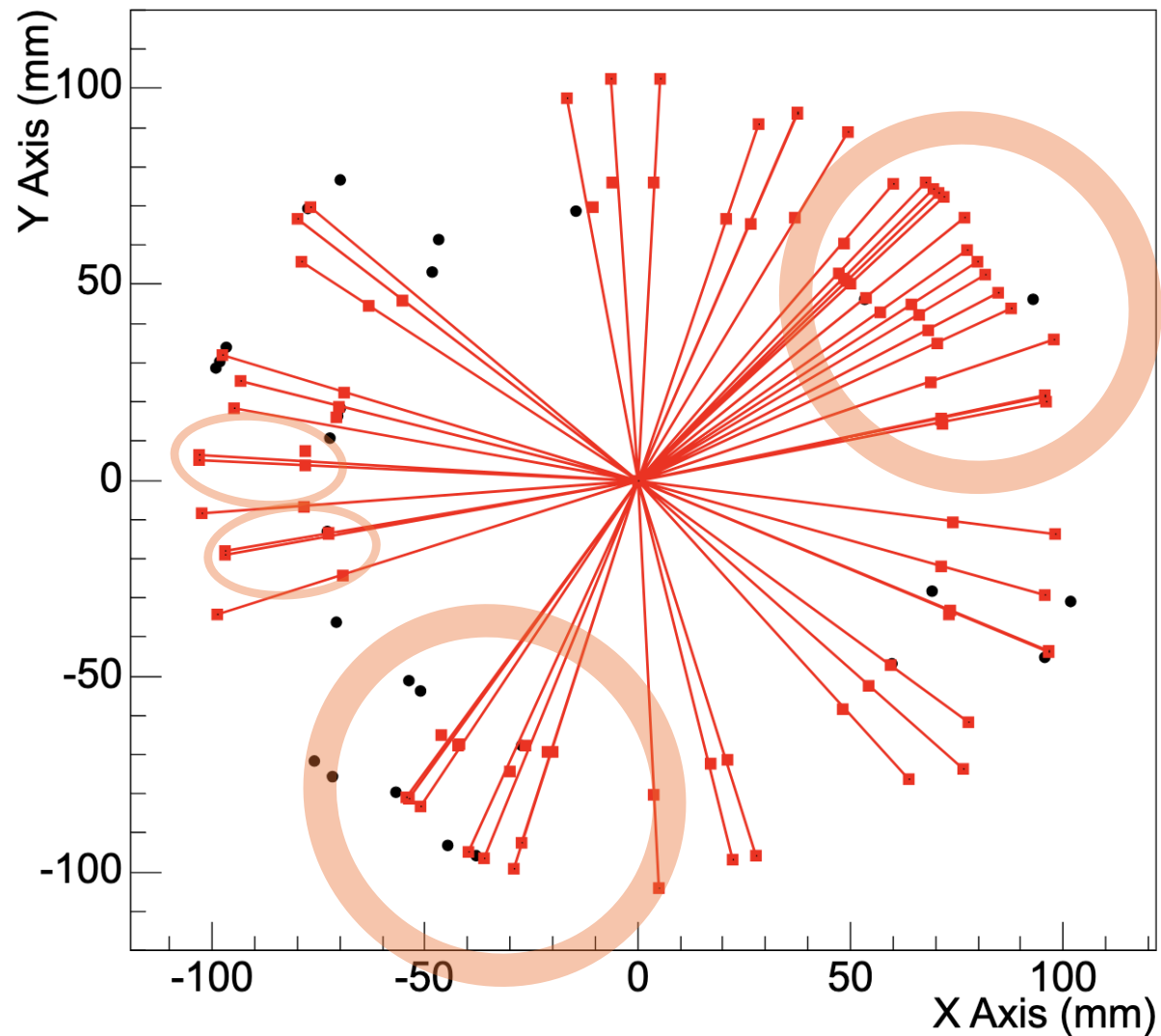
Remove high-density areas in the Outer.

Outer1
Outer2
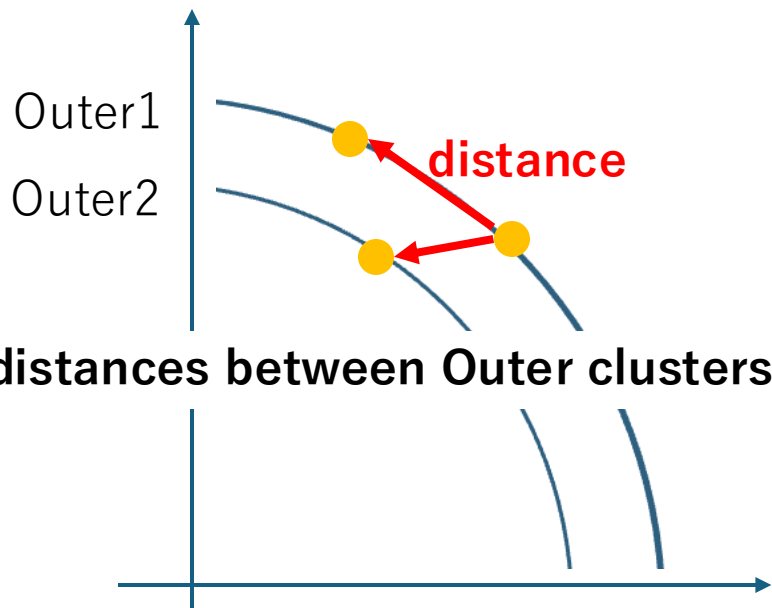
distance

The distances between Outer clusters = Density

```
for (size_t i = 0; i < Clusters.size(); ++i) {
    if (lay->at(i) > 1) { // 外層のみループ
        for (size_t j = 0; j < Clusters.size(); ++j) {
            if (i == j || lay->at(j) < 2) continue;

            double dx = Clusters[i].X() - Clusters[j].X();
            double dy = Clusters[i].Y() - Clusters[j].Y();
            double d = std::sqrt(dx * dx + dy * dy);
            d_hist->Fill(d);

            if (d < 10.0) {
                labeledClusters.insert(i);
                labeledClusters.insert(j);
            }
        }
    }
}
```
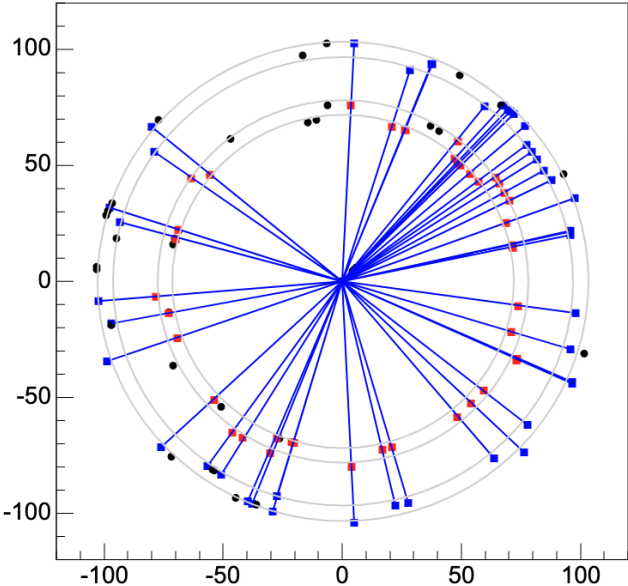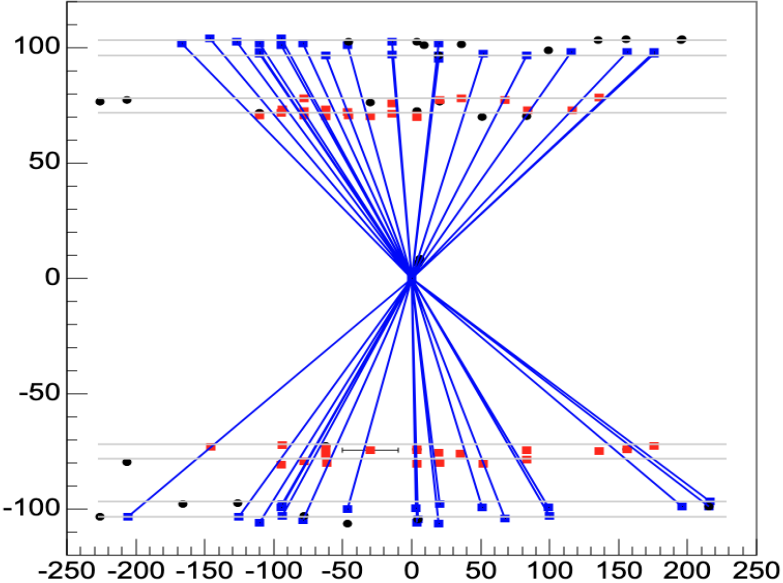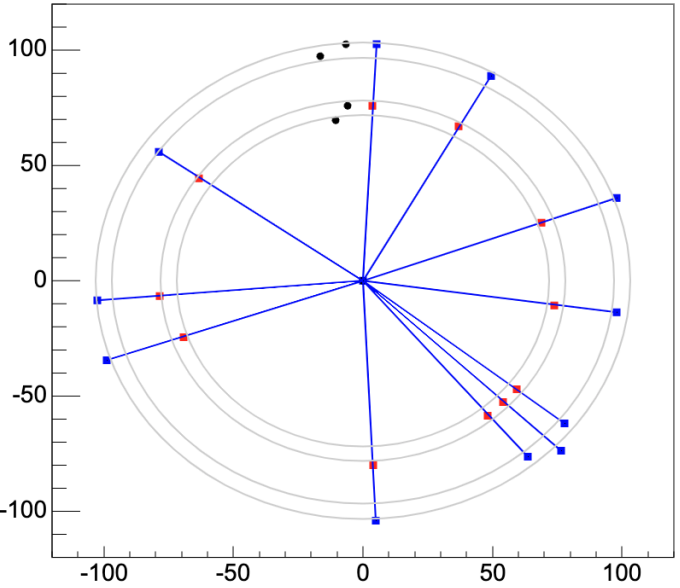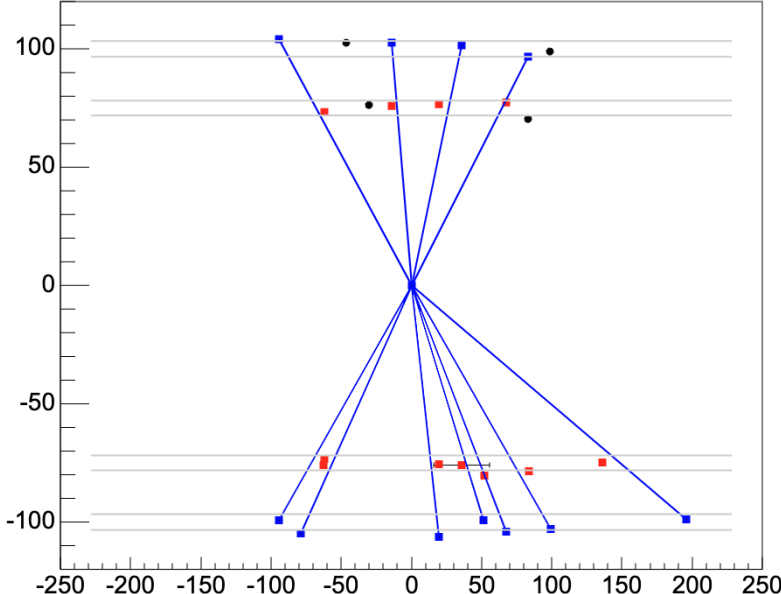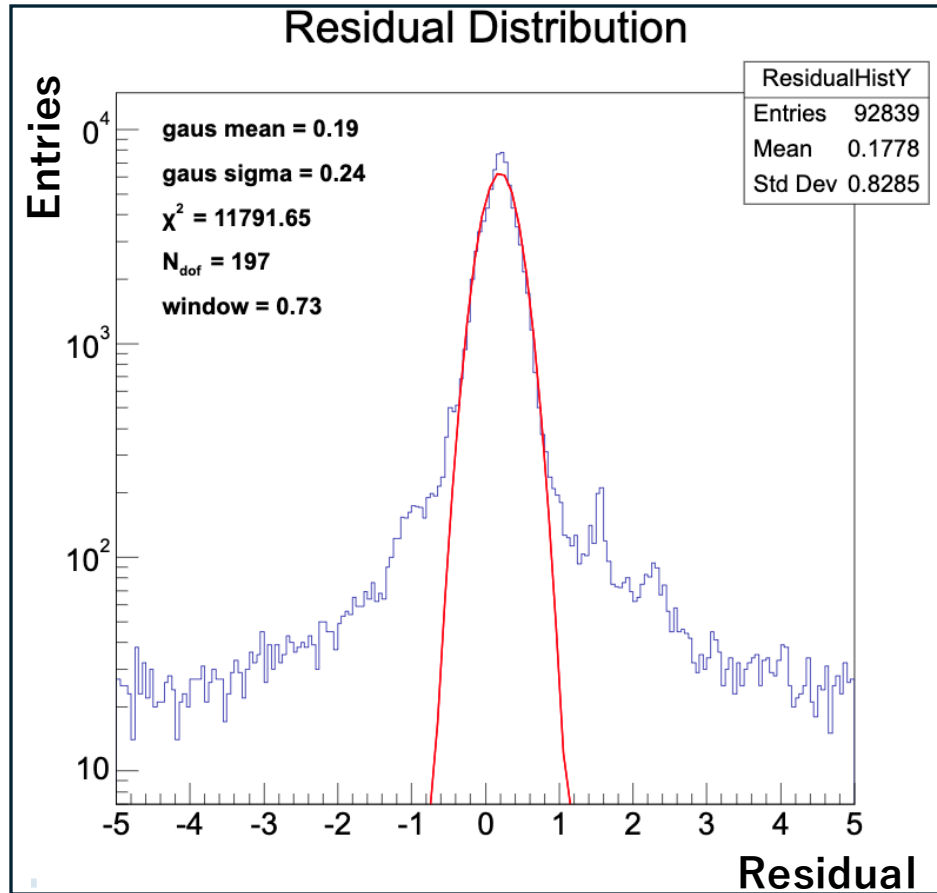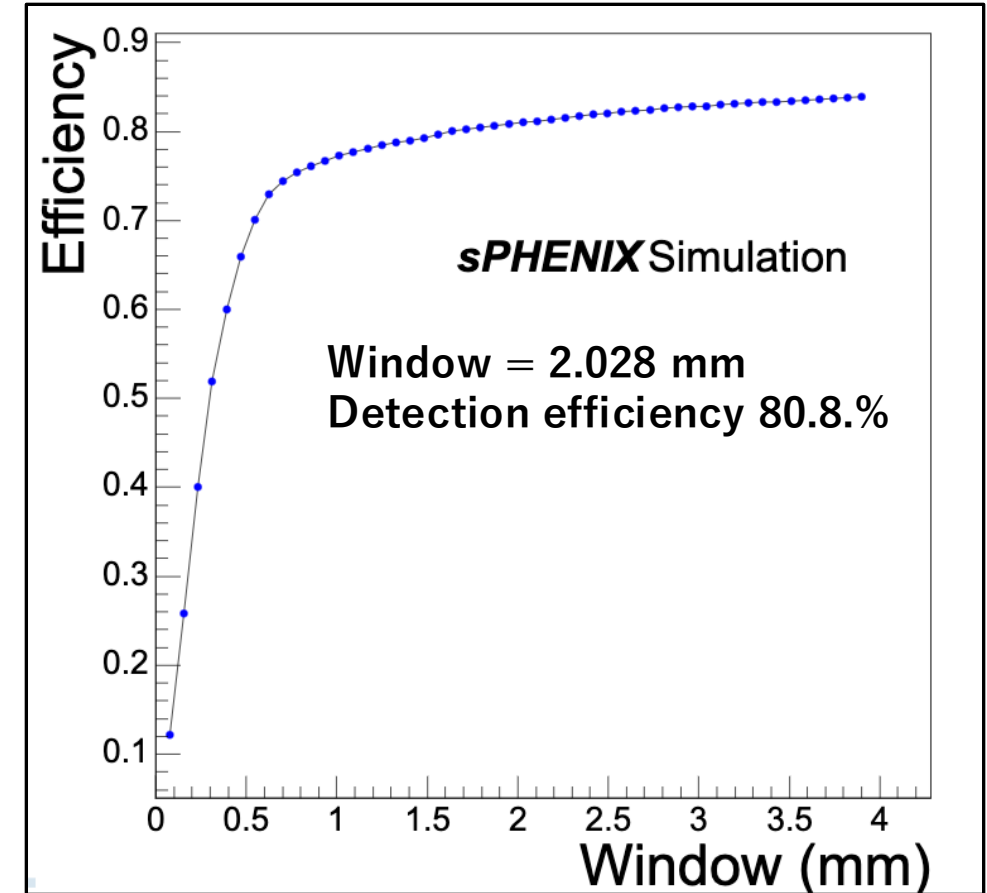
Distance of clusters

d_hist	
Entries	19637342
Mean	49.73
Std Dev	29.18

高　　　　　　　　　密度　　　　　　　　　低

Before

After

34

Result（p+p）

Residual Distribution

gaus mean = 0.19

gaus sigma = 0.24

χ^2 = 11791.65

N_{dof} = 197

window = 0.73

ResidualHistY	
Entries	92839
Mean	0.1778
Std Dev	0.8285

Y axis: Entries
X axis: Residual in X-Y plane

sPHENIX Simulation

Window = 2.028 mm
Detection efficiency 80.8.%

Y axis: Efficiency
X axis: Window $= 78\mu m \cdot i \ (i = 1, 2, 3, \ldots)$

Issues
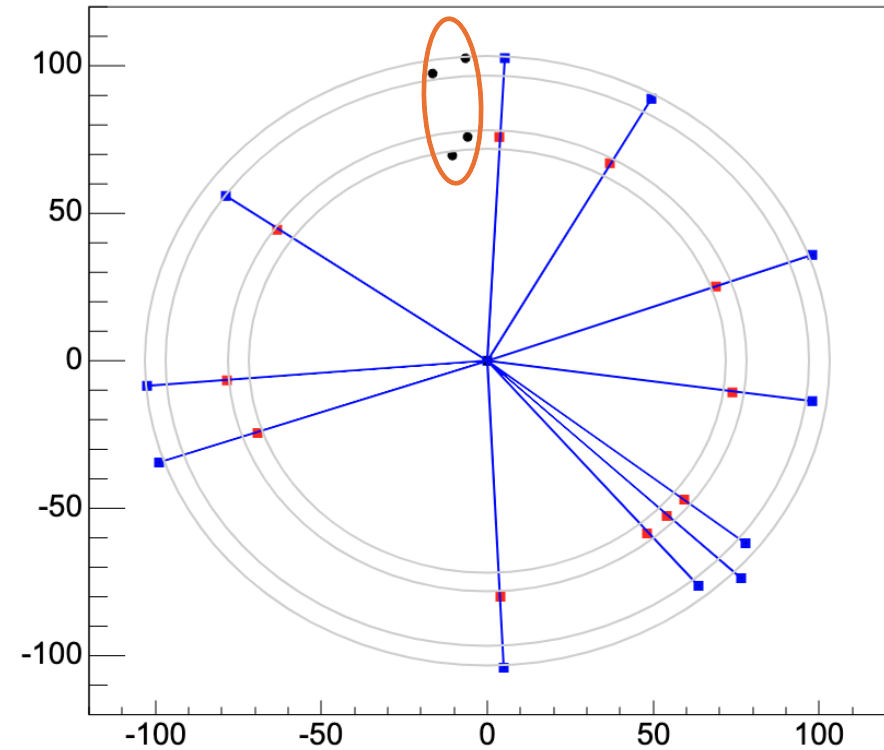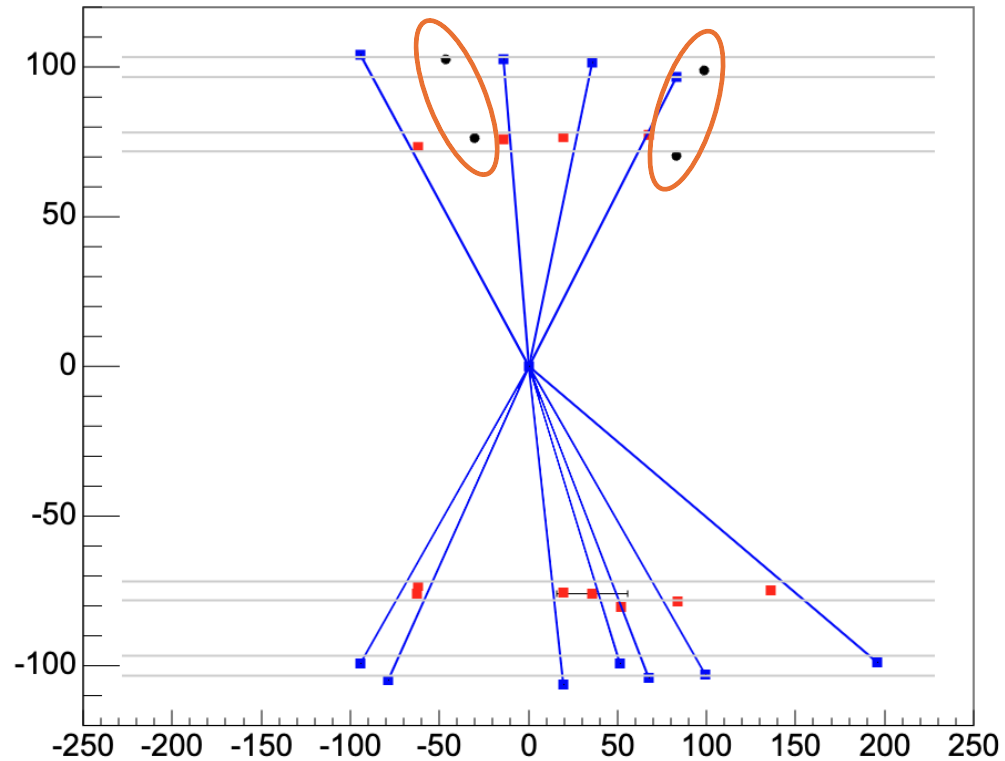
It appears that there are pairs that should be selected but are not.
It is necessary to investigate why these pairs exist and, if they should be selected,
consider improving the algorithm accordingly.

今後の展開

- Particle gun（μ^-）←Done

- p+p(vertex固定) ←ongoing

- p+p(vertex固定)+池本vertex導入←Next

- p+p(vertex変動)+池本vertex導入

- p+p(実データ)+池本vertex導入