Development of z_vertex reconstruction method for the sPHENIX-INTT detector

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Introduction

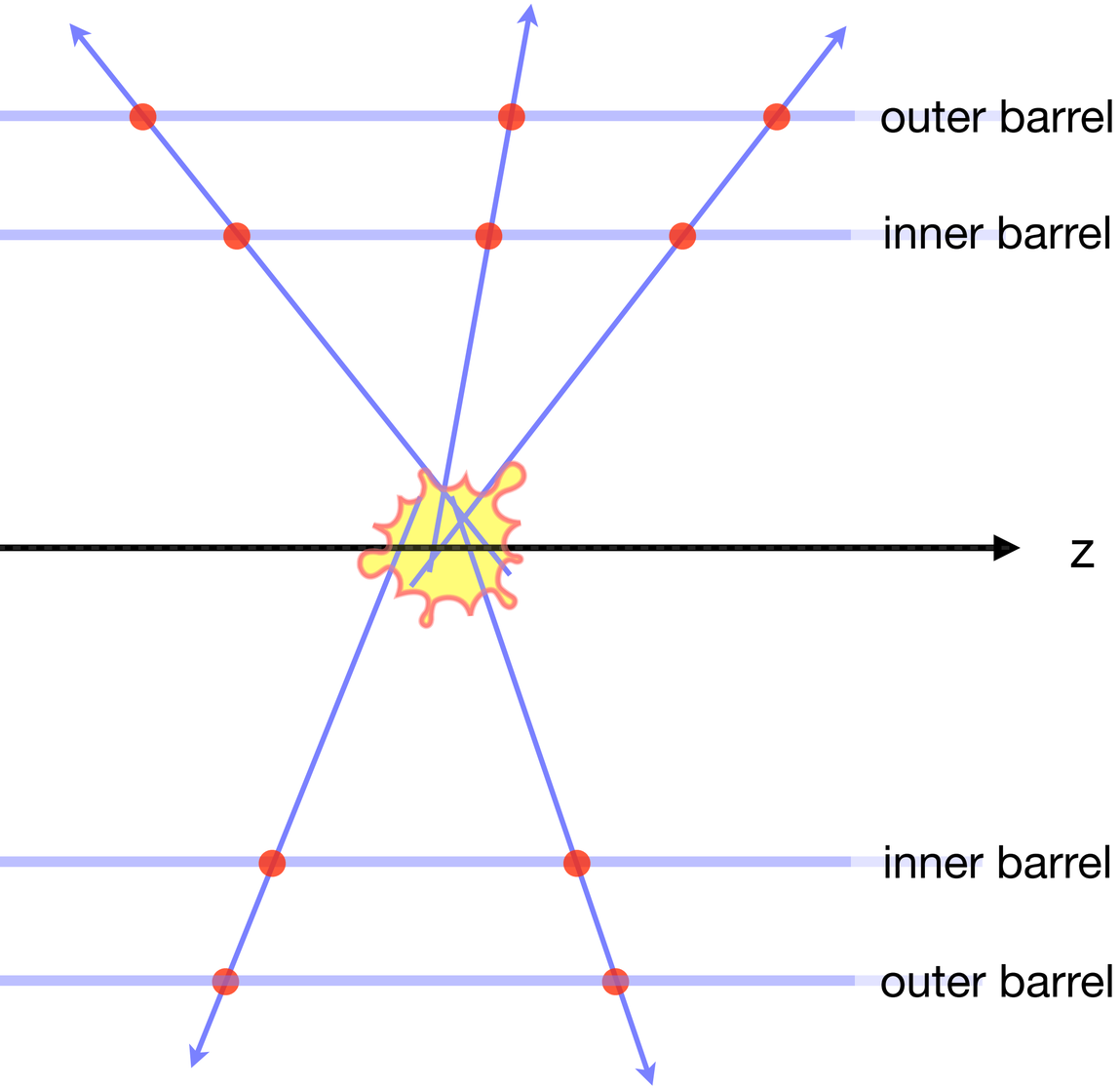
Introduction

1. Calculate z_vertex per event by following the steps described below.
   - Using DCAz plots to calculate
     - Mean method
     - Peak method
     - Mean method(only DCAz points within 1σ from the DCAz mean used)
   - Weighted average method
2. Comparing resolution to determine the best method

usage data：simurtion data, p+p collision, no magnetic field(Pythia (8.307))

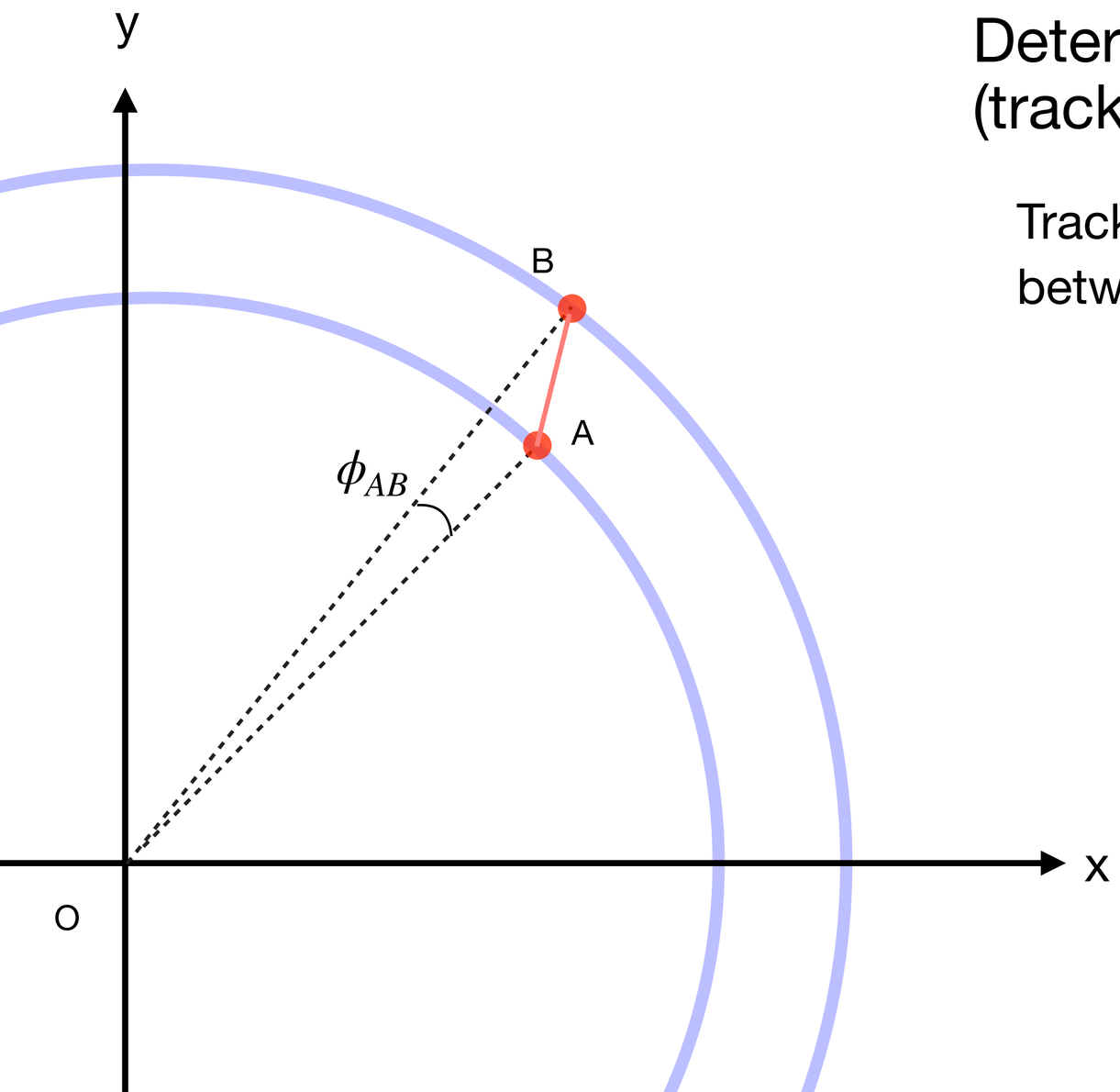
x_vertex:0、y_vertex:0、z_vertex:σ=20cm、10K events

Reconstruction of collision point



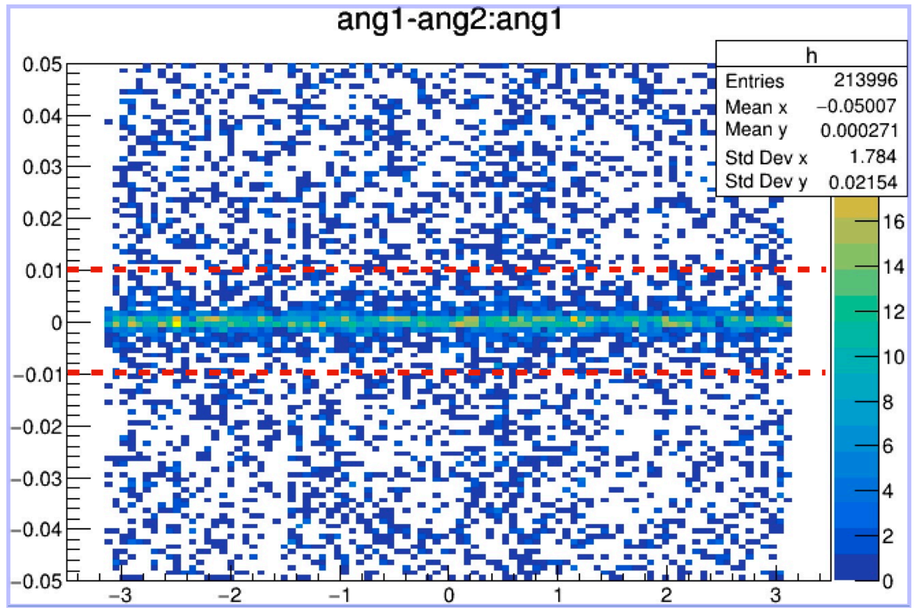
1. Clustering.
2. Select each cluster on the inner barrel and outer barrel.
3. Connect them with a line.
   Calculate the distance of closest approach(DCAz) to line of x=0,y=0 and DCAz point.
4. Determine the z_vertex.

Tracklet



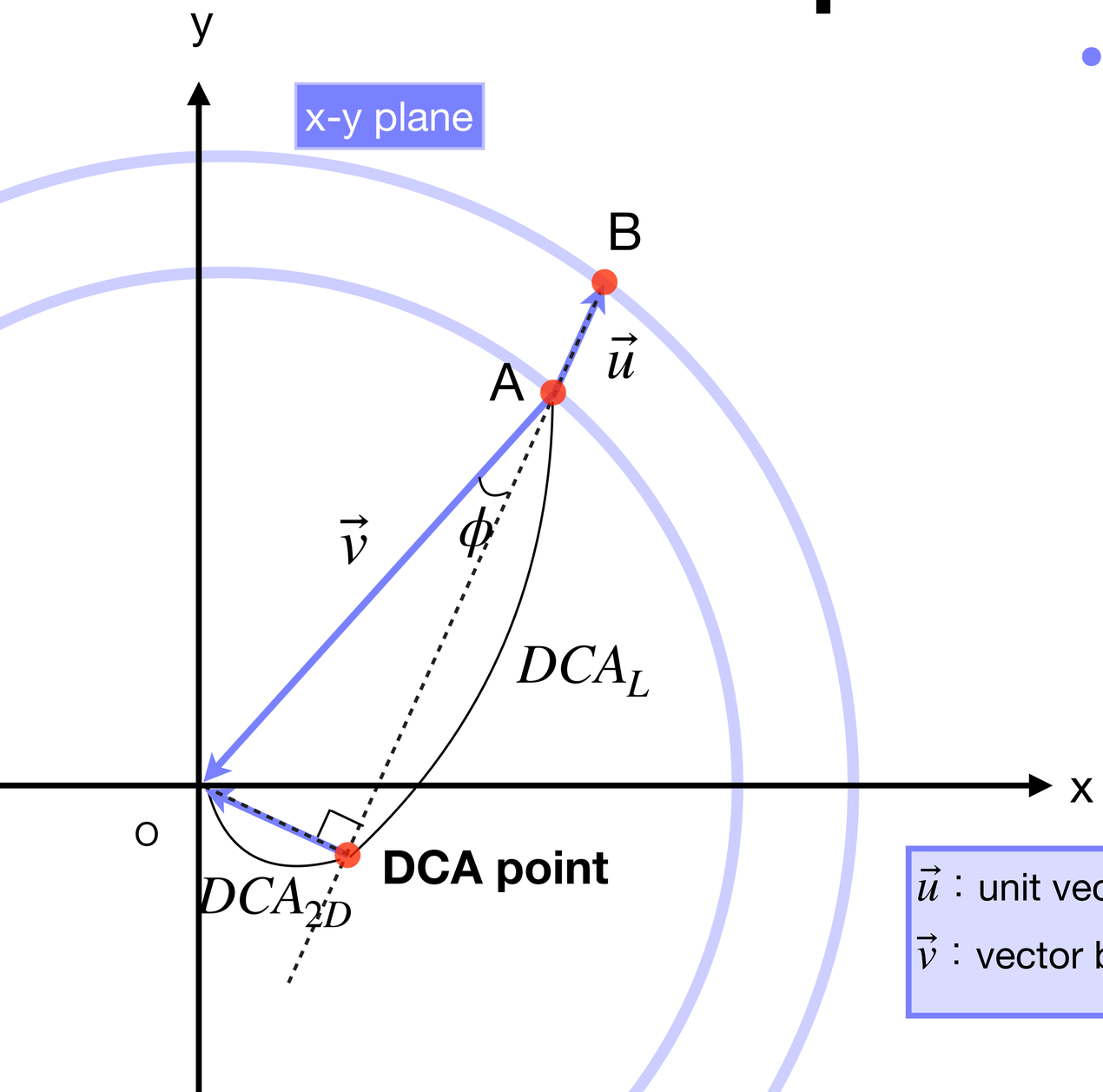
Determine the pair of Cluster A and Cluster B (tracklet) on the x-y plane.

Tracklets are selected for which the angular difference between cluster A and B $|\Delta\phi_{AB}| < 0.01$ [rad].



horizontal axis : angular of cluster A
vertical axis : angular difference between cluster A and cluster B

Calculate DCAz point



- Calculate the distance of closest approach between A and the origin.

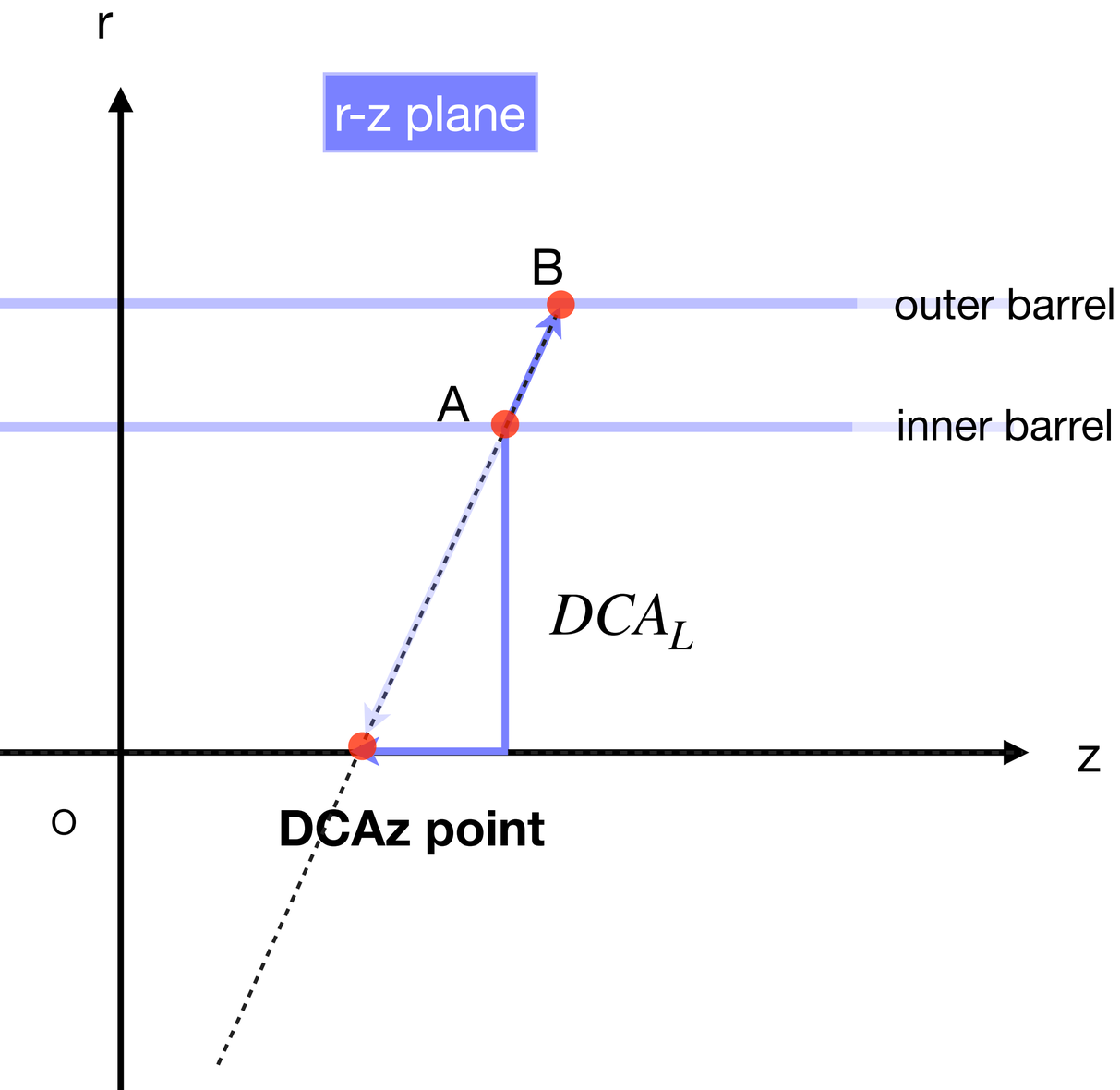
  Calculate the distance between DCA point and A (DCA_L),
  the distance between DCA point and origin(DCA_{2D}).

$$DCA_L = \vec{v} \cdot \vec{u} = \vec{v} \cdot \cos\phi$$
$$DCA_{2D} = \vec{v} \times \vec{u} = \vec{v} \cdot \sin\phi$$

$\vec{u}$: unit vector between point A and B

$\vec{v}$: vector between point A and O

DCAz座標の求め方



- Calculate the distance of closest approach between A and the origin.

  Calculate the distance between DCA point and A (DCA_L),
  the distance between DCA point and origin(DCA_{2D}).

$$DCA_L = \vec{v} \cdot \vec{u} = \vec{v} \cdot \cos\phi$$
$$DCA_{2D} = \vec{v} \times \vec{u} = \vec{v} \cdot \sin\phi$$

- Calculate DCAz point to use DCA_L.

$$DCA_Z = DCA_L \times \vec{u}_Z + A_Z$$

Result

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1. Calculate z_vertex per event by following the steps described below.
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   - Weighted average method
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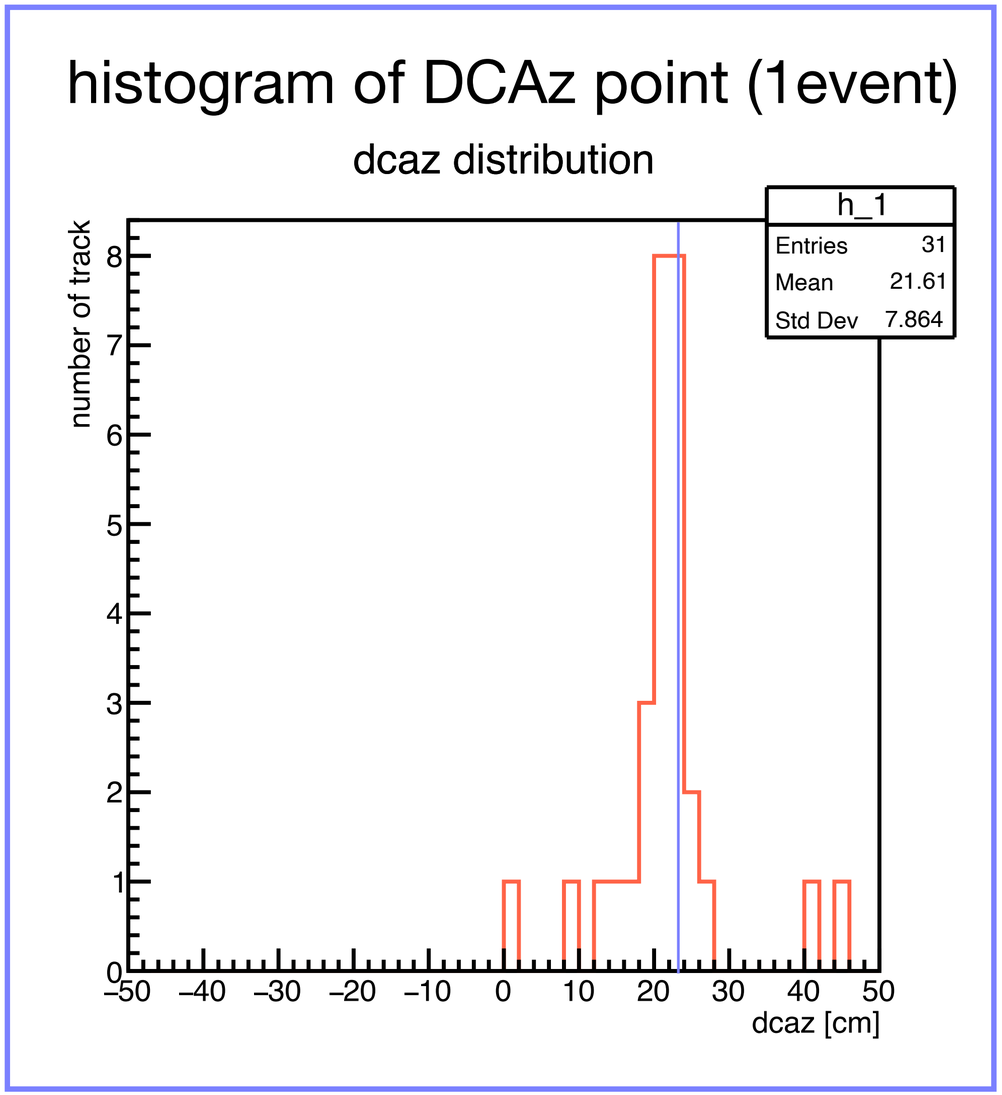
usage data：simurtion data, p+p collision, no magnetic field(Pythia (8.307))

x_vertex:0、y_vertex:0、z_vertex:σ=20cm、10K events

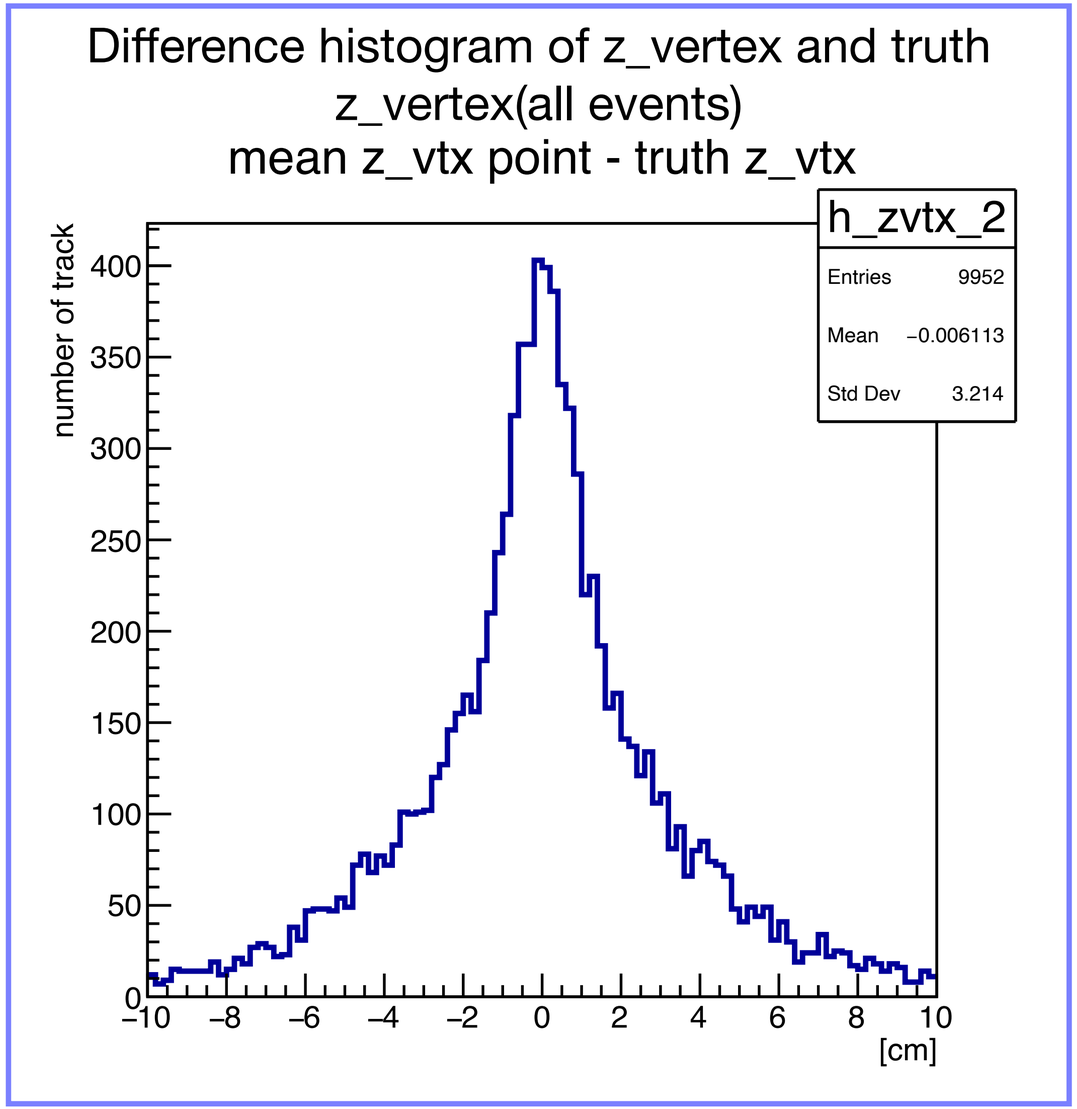
Mean method (use the DCAz plot)



- Make the plot of DCAz point per event to calculate the mean value.
  ⟹ determine the mean value as z_vertex.

- Make the plot in the same way for all events and calculate z_vertex.

Mean method (use the DCAz plot)



- Plot the difference between z_vertex obtained by the mean method and the true value of z_vertex(truth z_vertex) of the simulation data for all events.
- It shows the accuracy of the calculated z_vertex value.
  The more accurate it is, the closer the value is to 0, and the thinner the histogram.
- The value of standard deviation (std) is the resolution.

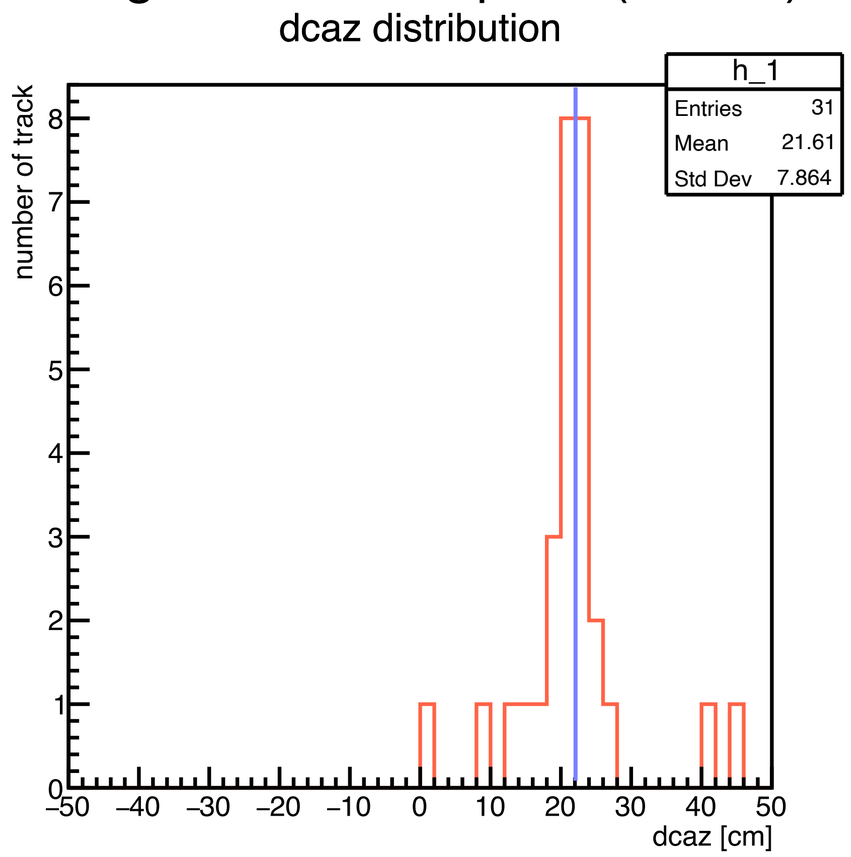
Std ：3.214[cm]

Peak method (use the DCAz plot)

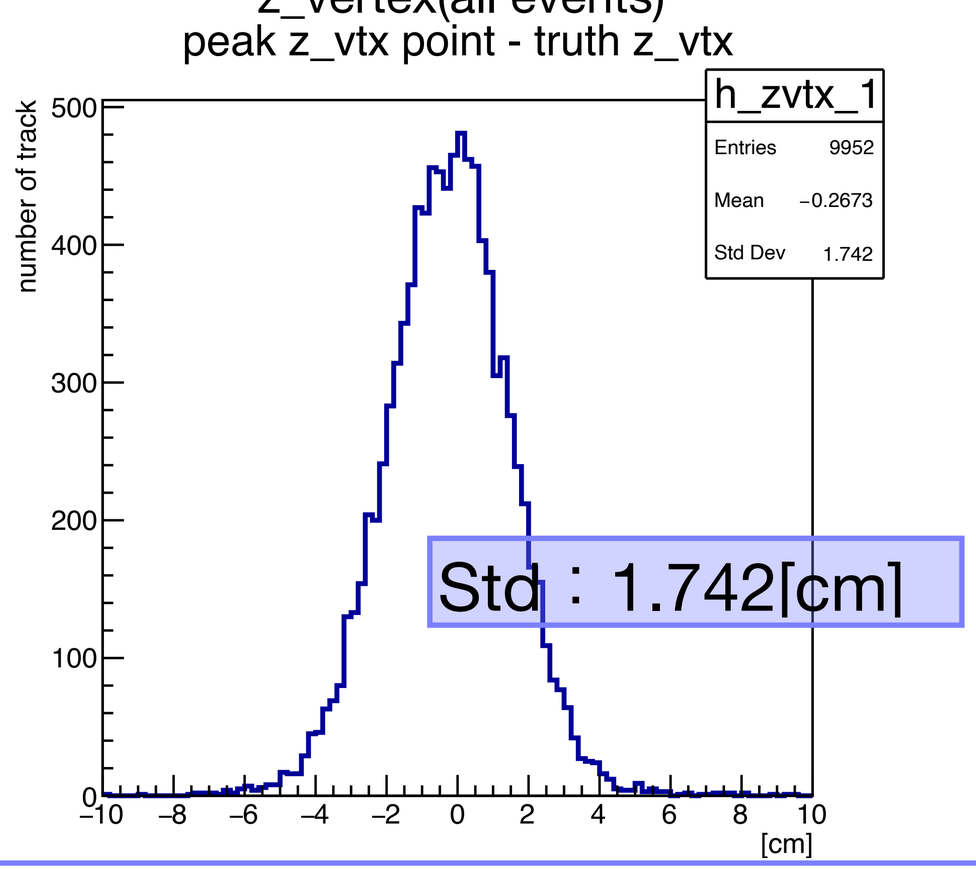
Make the plot of DCAz point per event to calculate the peak point.

⇨ determine the peak value as z_vertex.

histogram of DCAz point (1event)



Difference histogram of z_vertex and truth z_vertex(all events)

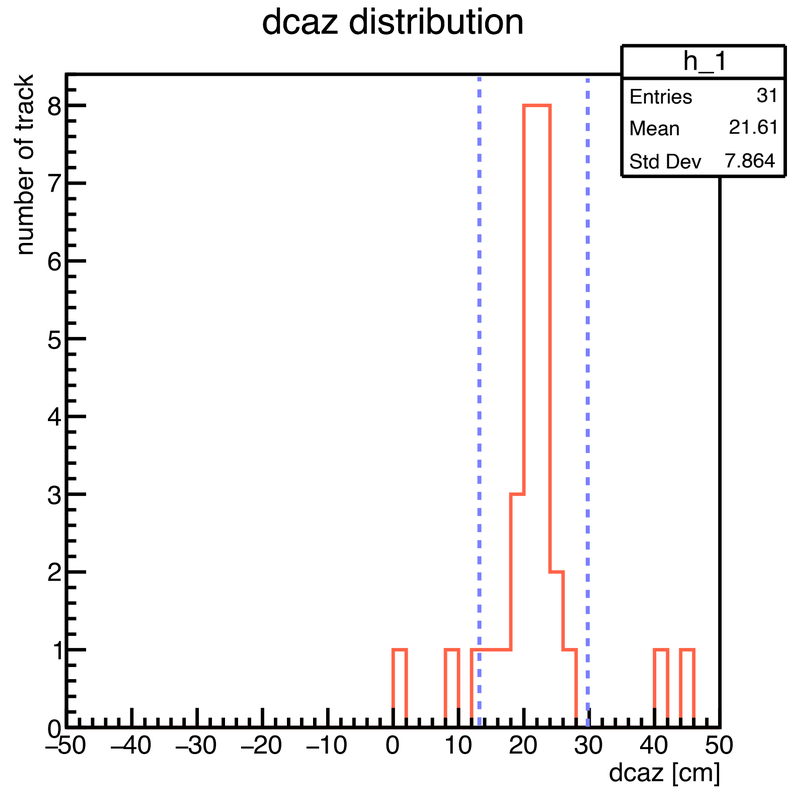


Resolution value (std) is 1.742[cm].

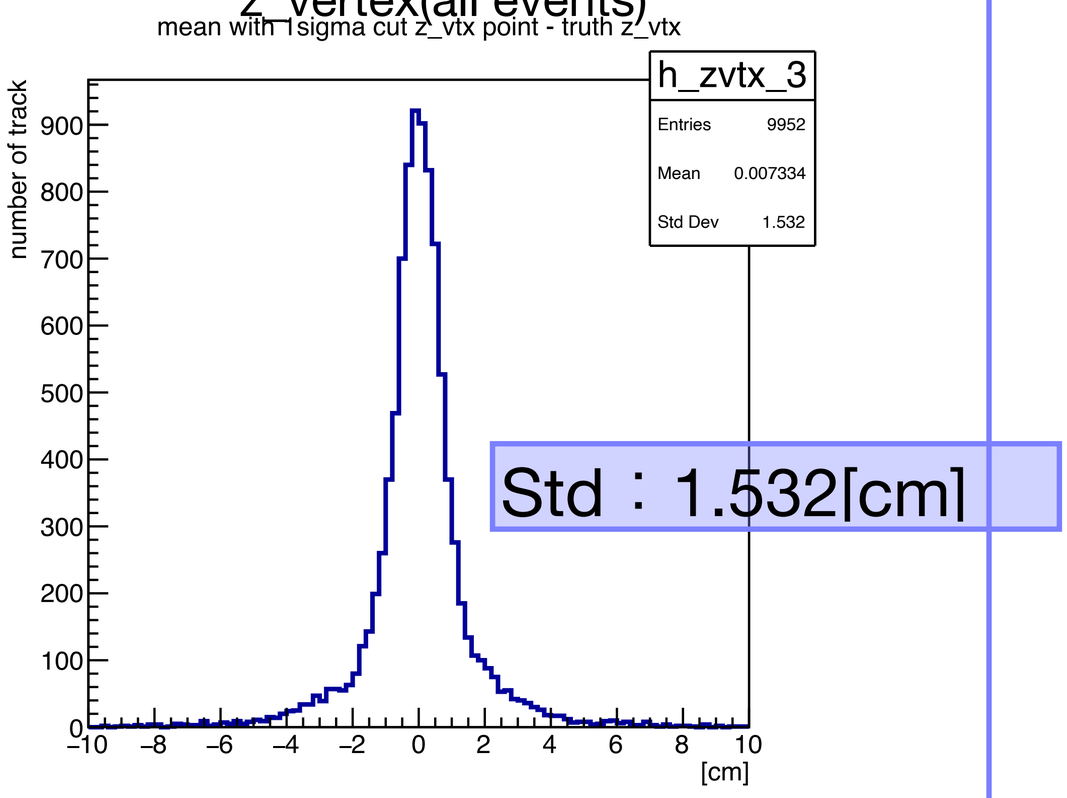
1 sigma mean method (use the DCAz plot)

Calculating the average without including data at a distance may give better resolution.
⇨Determine the mean value using only data within 1sigma as z_vertex.

histogram of DCAz point (1event)



Difference histogram of z_vertex and truth z_vertex(all events)

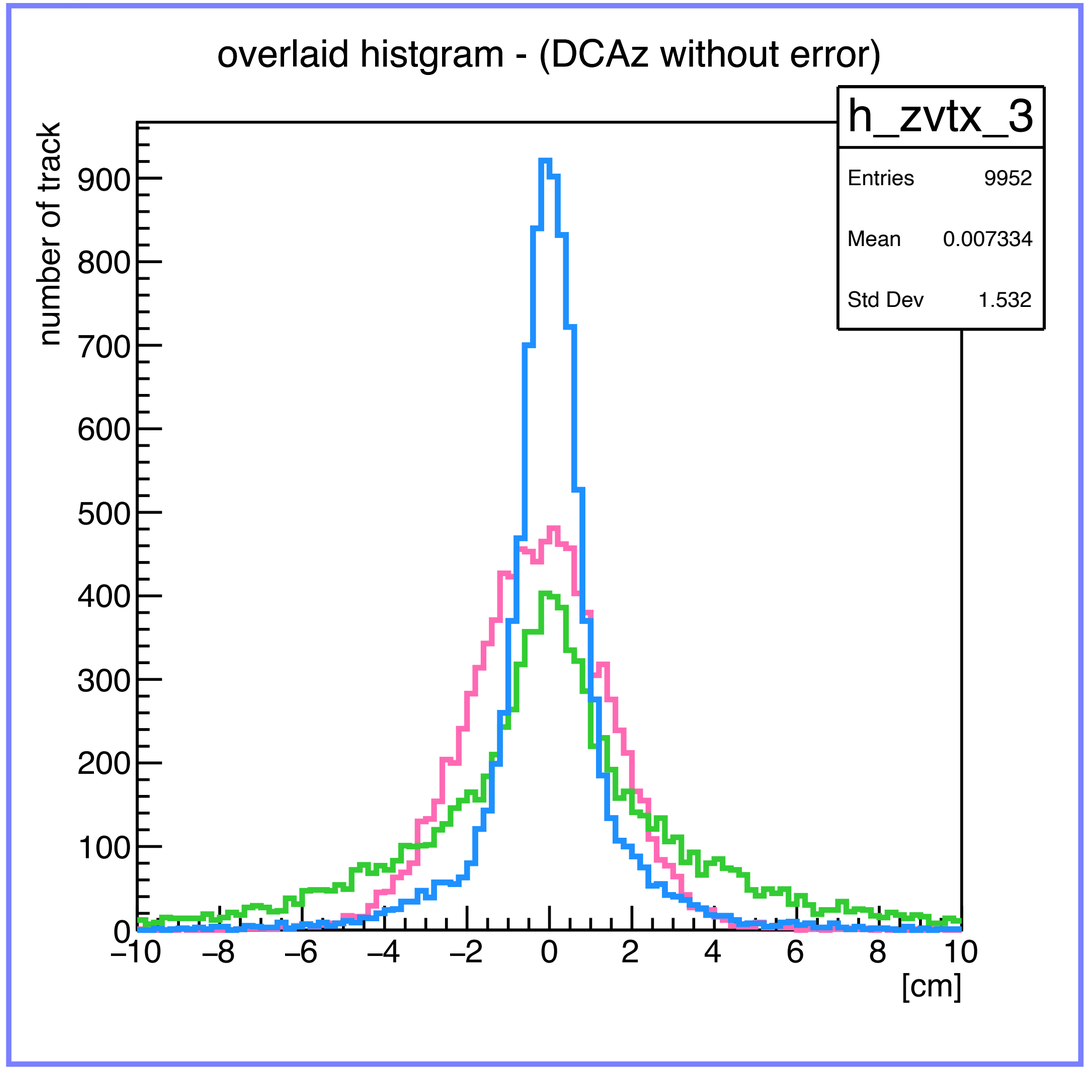


Std：1.532[cm]

Resolution value (std) is 1.532[cm].

Comparing the z_vertex plot and resolution

Compare the z_vertex plots and resolutions obtained by mean method, peak method and 1siguma mean method.



	Std[cm]
mean method	3.214
peak method	1.742
1sigma mean method	1.532

- **1sigma mean method has the most accurate results.**
- The difference in values between peak method and 1sigma mean method is small, but the shape of the histogram is different.
  ⇒1sigma mean method one is thinner and longer. It shows that Measurement stability is higher.

Add error to DCAz plot

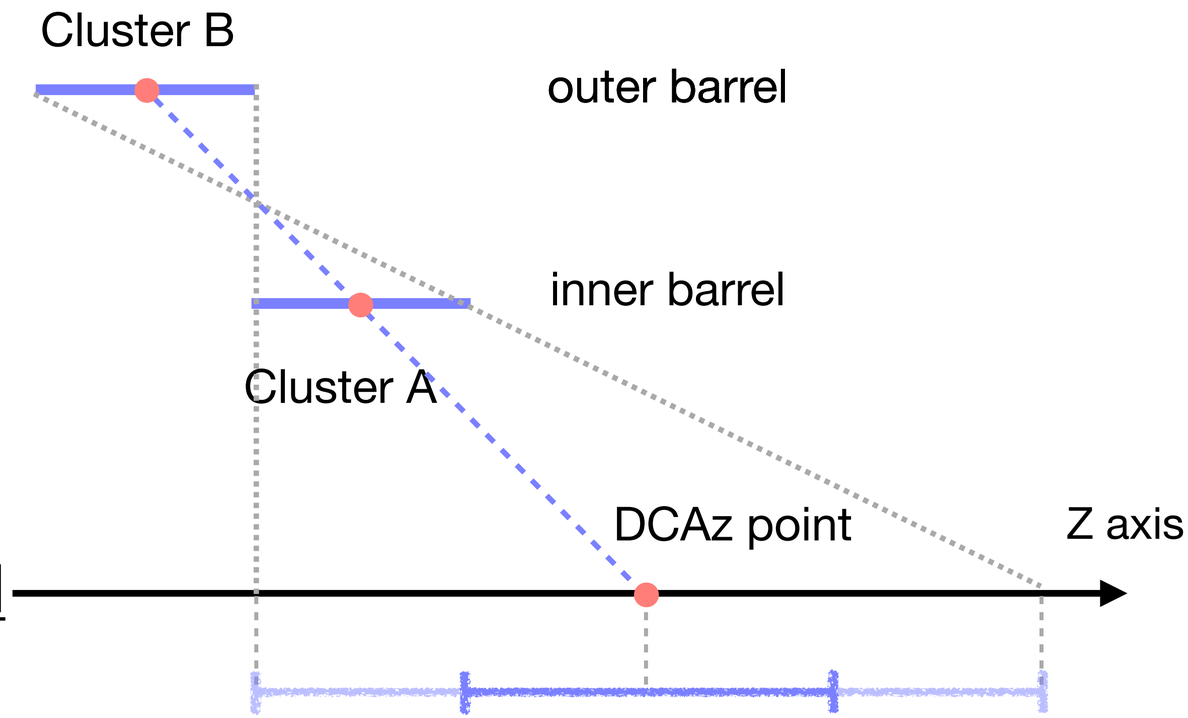
The z-position on the cluster has been assumed to be the center of the strip.

⇨In fact, particles can pass the anywhere on the strip.

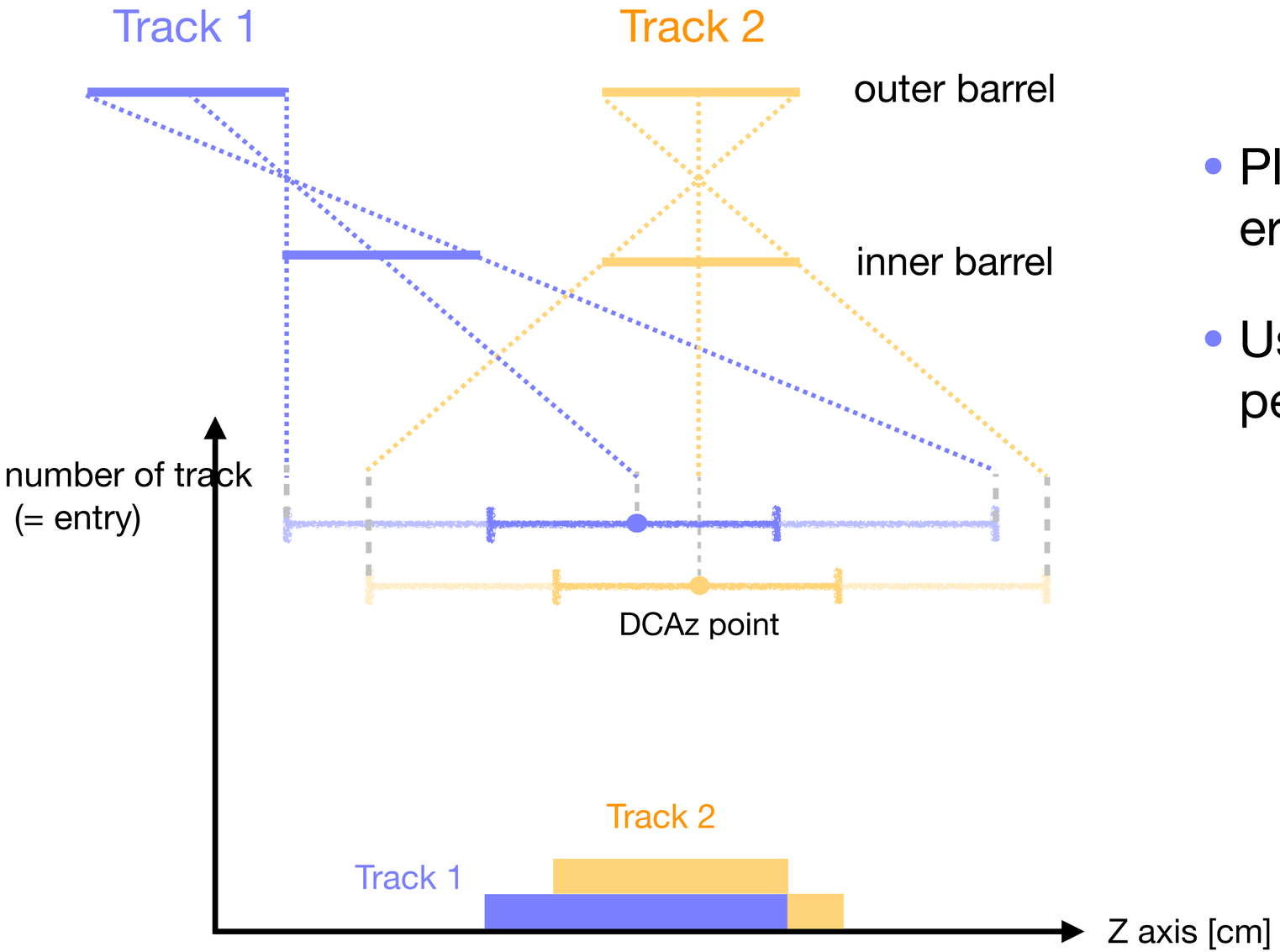
⇨To consider the possible range of z-position of the clusters, the strip size is taken as the error of the clusters.

The range of DCAz points by tracklets is determined by the line connecting the errors of the two layers.

<u>The position resolution width of the defined range is the error in the DCAz points.</u>



Add error to DCAz plot

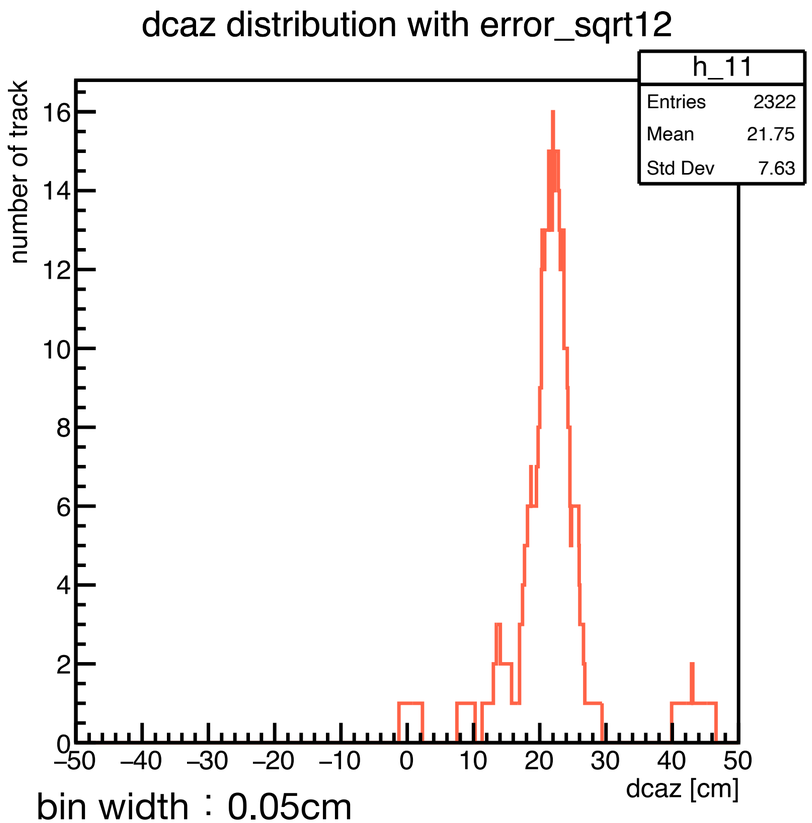


- Plot the DCAz points including the error range.
- Use the plot to calculate z_vertex per event.

Chip type-A : strip size = 1.6cm
Chip type-B : strip size = 2.0cm

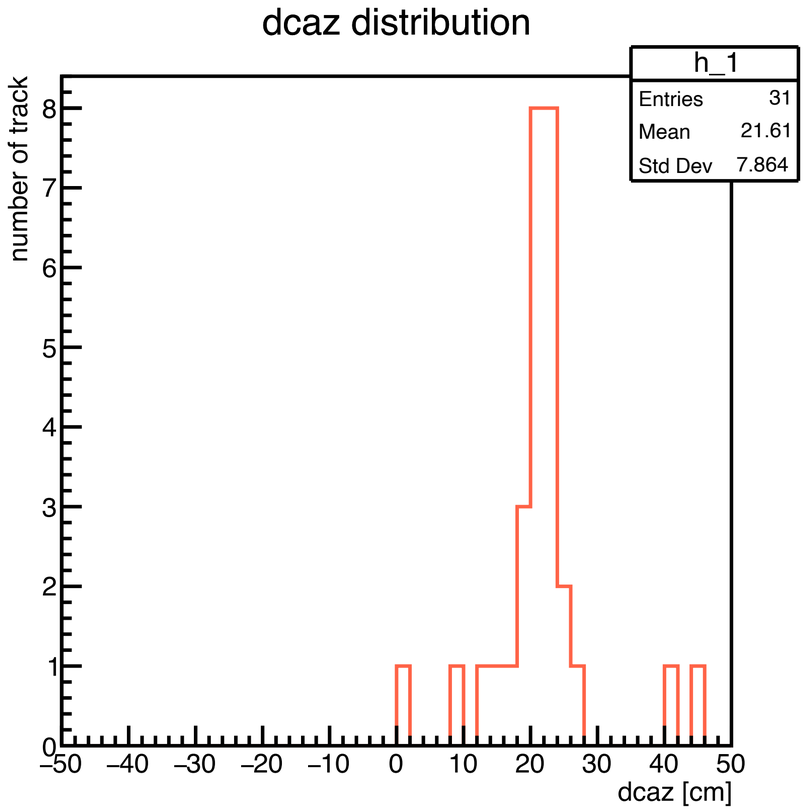
Comparing the DCAz plot

DCAz points with error (1event)



bin width：0.05cm

DCAz points without error (1event)

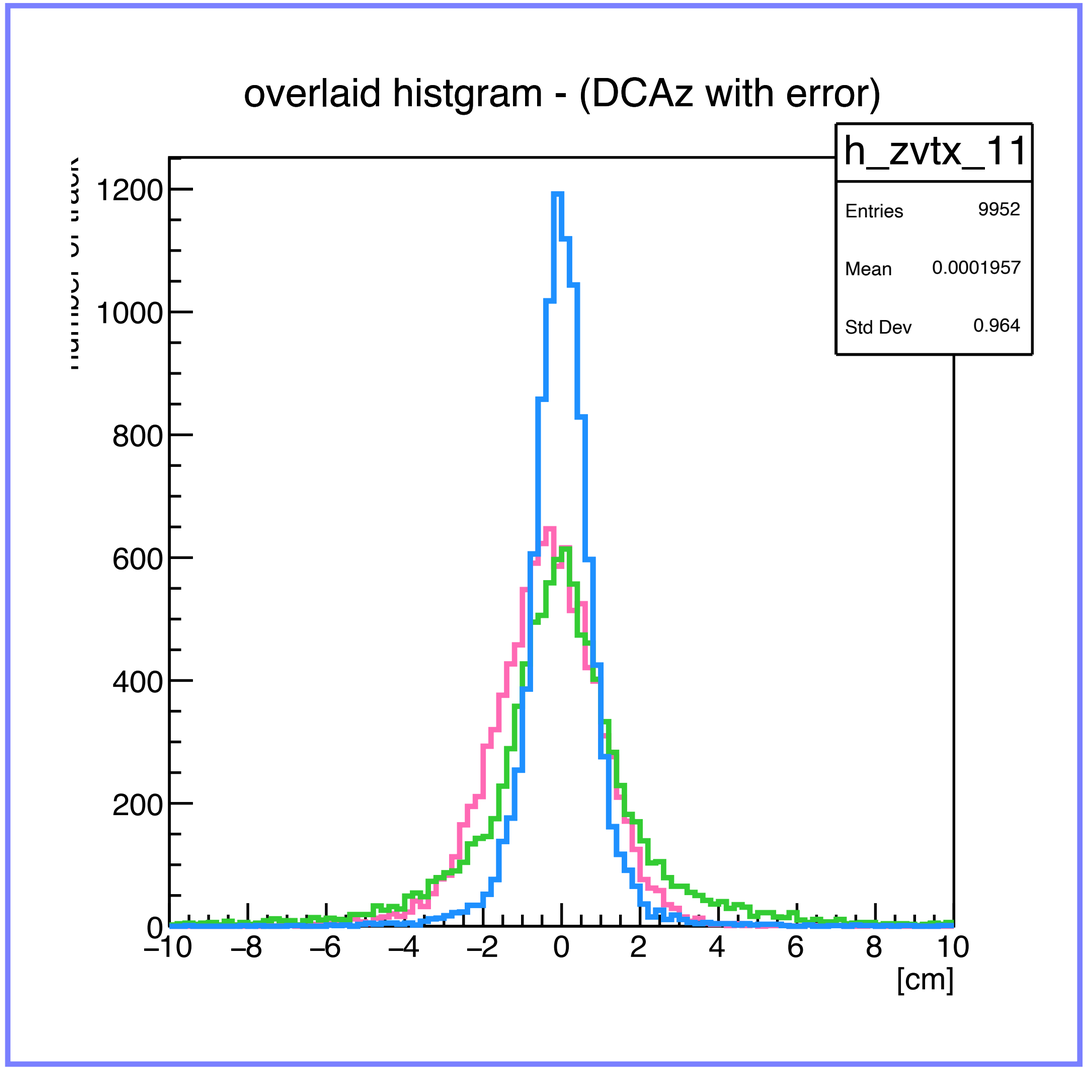


bin width：2.0cm

The values became to have error margin width.

For left histogram, the bin width is 0.05cm because the error width is plotted separated by 0.05cm.
For right one, the maximum chip width in the z-axis is 2.0cm, so the bin width is plotted at 2.0cm accordingly.

Comparing the z_vertex plot and resolution(use the DCAz plot with error)



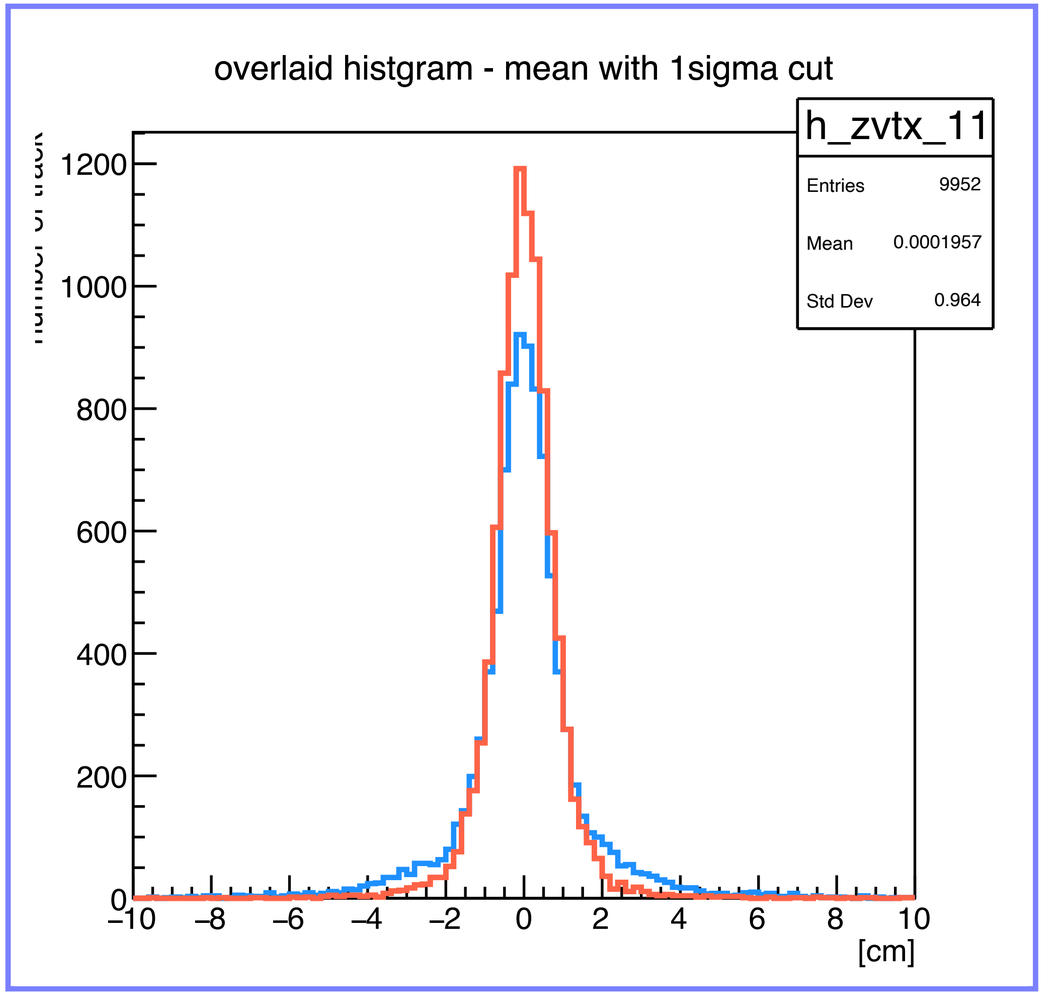
	Std[cm]
mean method	2.119
peak method	1.423
1sigma mean method	0.964

Histogram obtained by 1sigma mean method is the longest and thinnest.Also resolution is the highest.

⇒**1sigma mean method has the most accurate results.**

Comparing the z_vertex plot and resolution of 1sigma mean method

Compare the z_vertex obtained by the 1sigma mean method when using DCAz plot with error and without error.



1sigma mean method	Std[cm]
DCAz plot without error	1.532
DCAz plot with error	0.964

Histogram is longer and thinner when using DCAz plot with error. Also resolution is higher.

⇨ **More accurate results are obtained by using DCAz plot with error to calculate z_vertex.**

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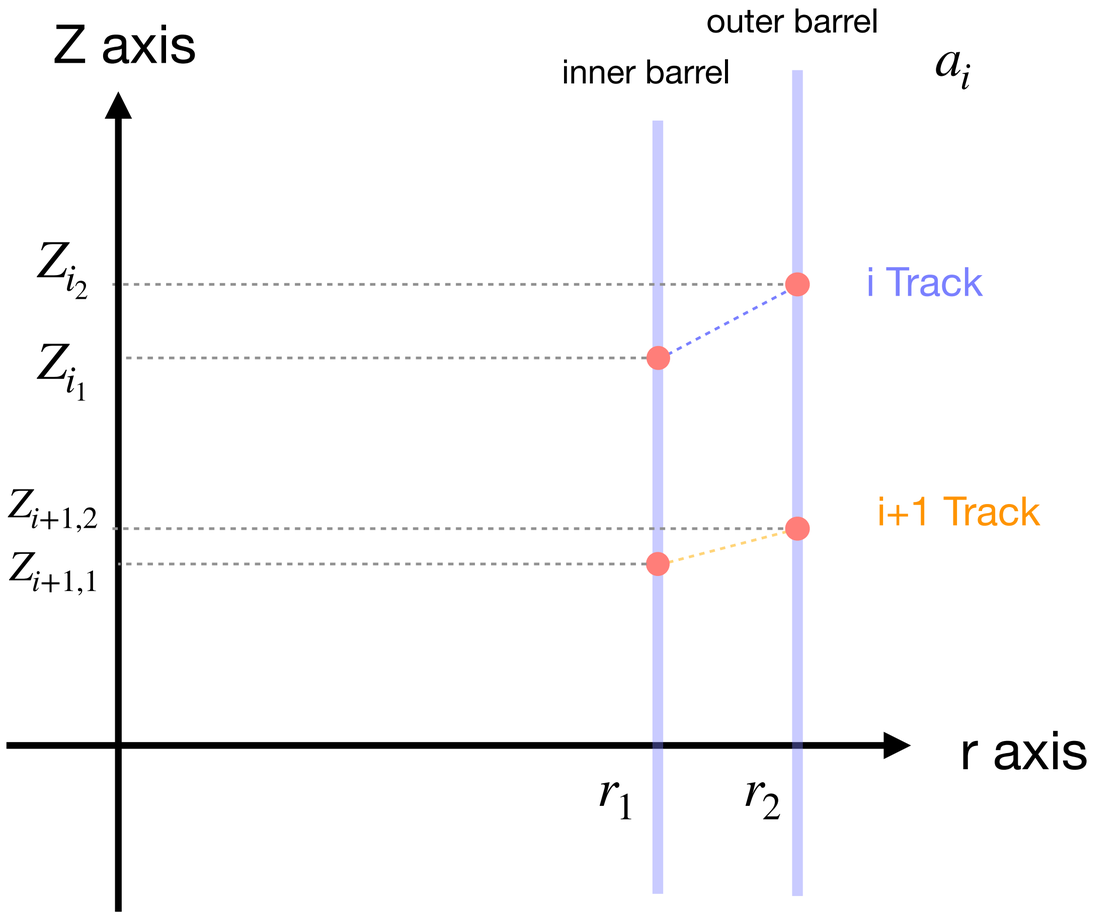
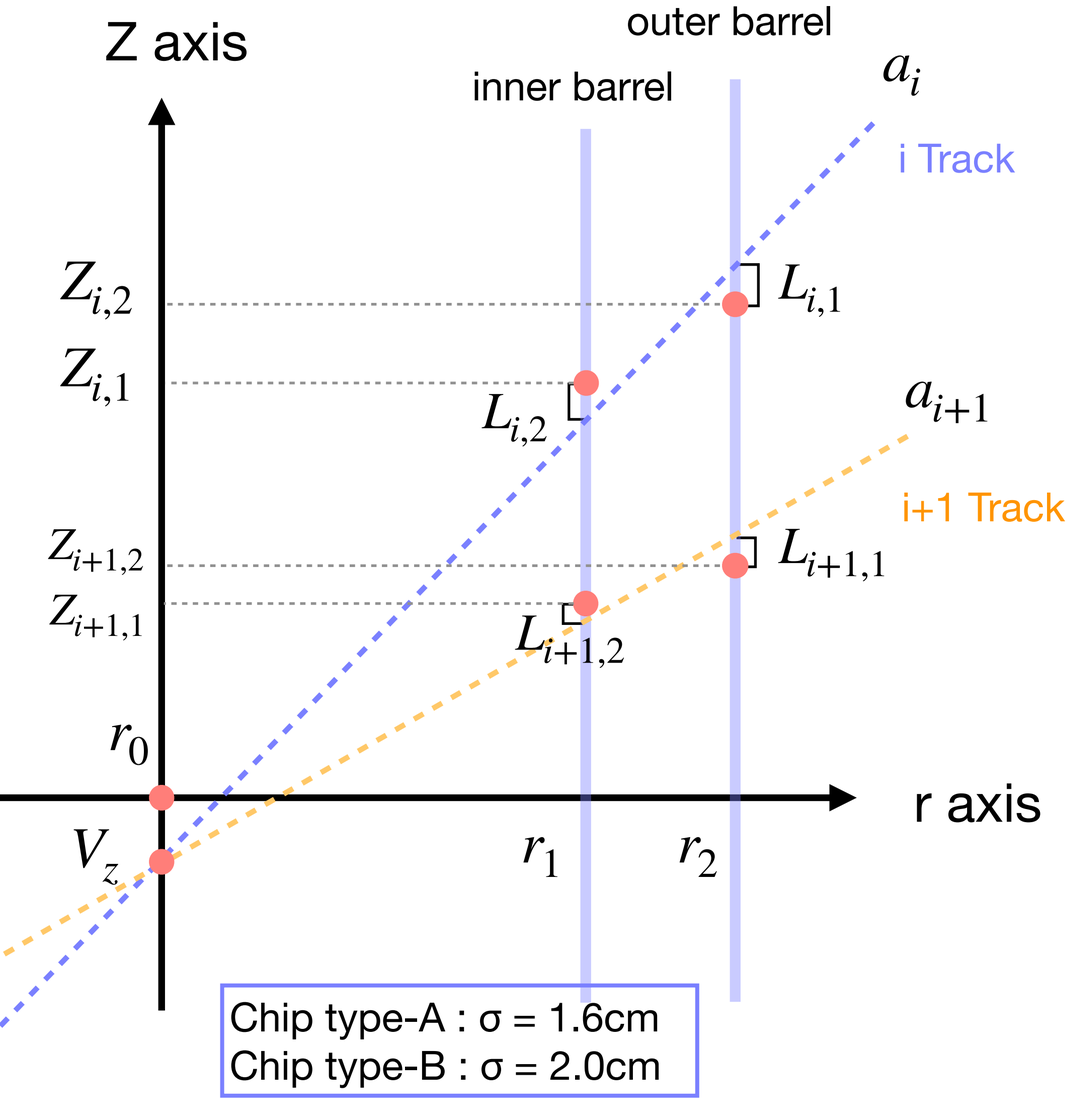
Weighted average method with the z distribution of clusters and track slope a_i

Calculate a collision point through which all tracks in one events pass.



Weighted average method with the z distribution of clusters and track slope a_i

Calculate a collision point through which all tracks in one events pass.



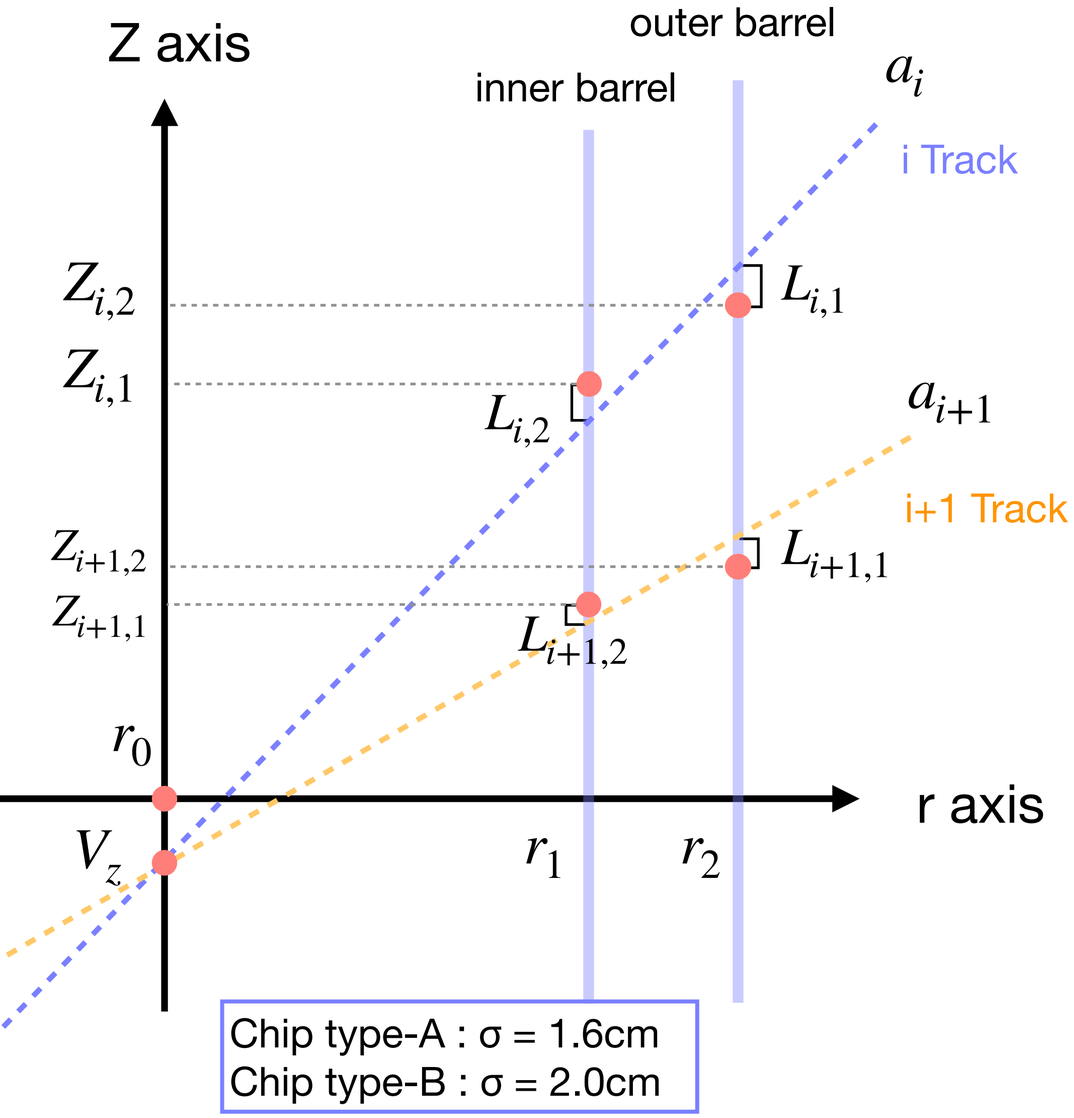
- Connect the line from the z_vertex point V_z to the clusters pair, and let a_i be the slope of the line.
- Calculate the distance L between the point on the barrel through which the line with slope a_i passes and the Z point of the cluster.

$$L_{ij} = \frac{(Z_{ij} - (a_i(r_j - r_0) + V_z))^2}{\sigma^2_{z_{ij}}}$$

$$(r_0 = \sqrt{x\_vtx^2 + y\_vtx^2}, j = 1,2, \sigma_{z_{ij}} = 1.6 \text{ or } 2.0\,)$$

Weighted average method with the z distribution of clusters and track slope a_i

Calculate a collision point through which all tracks in one events pass.



- Calculate V_z by the least-squares method when the sum L of the distance L_{ij} of all tracks in one event has the smallest.

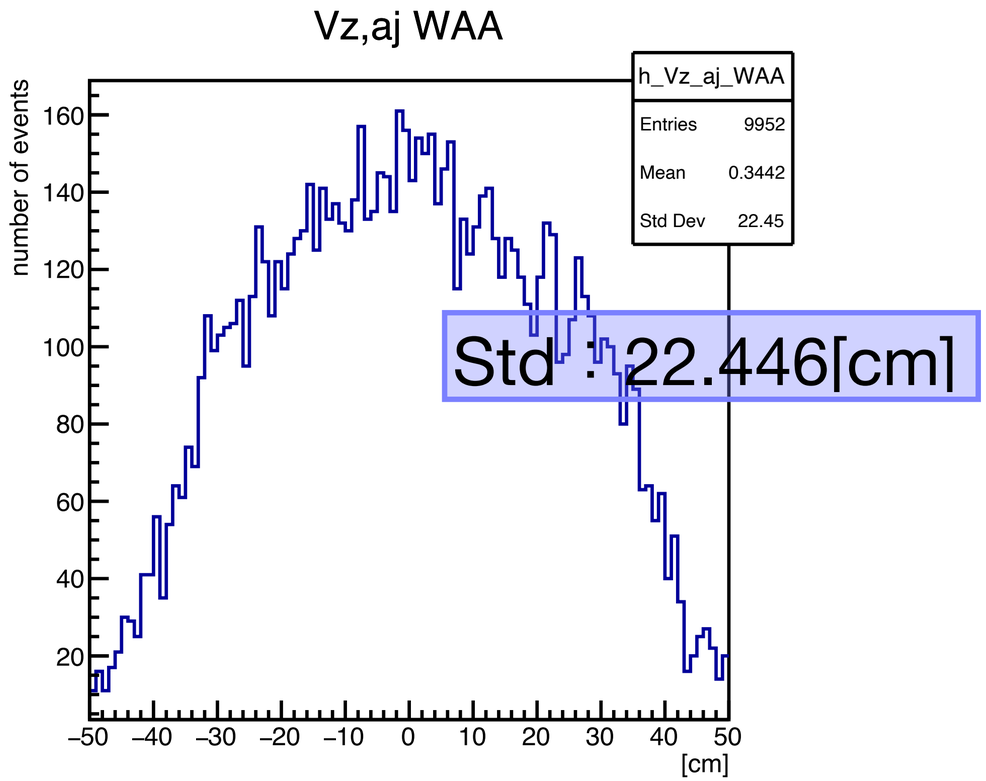
$$L = \sum_{i=1}^{n} \sum_{j=1}^{2} \frac{(Z_{ij} - (a_i(r_j - r_0) + V_z))^2}{\sigma_{z_{ij}}^2}$$

(n = number of tracks, $r_0 = \sqrt{x\_vtx^2 + y\_vtx^2}$, $j = 1,2$, $\sigma_{z_{ij}} = 1.6$ or 2.0)

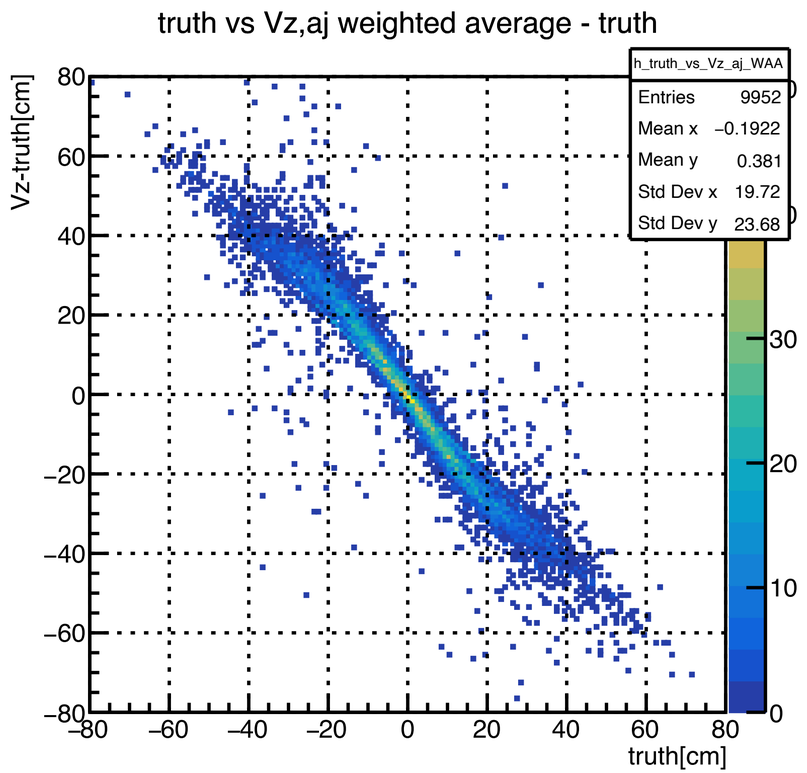
- Calculate for all events.

Z_vertex obtained by weighted average method

Differential histogram of z_vertex and truth z_vertex (all events)



2D histogram of difference between z_vertex and truth z_vertex, truth z_vertex



The z_vertex histogram is much thicker than before, and the std value is large.
In the 2D histogram, the diagonal correlations is seen.
Calculations and macros probably incorrect. I have to recheck and improved.

Summary

Summary

I calculated z_vertex using several different method and compared the resolution to find the best calculation method.

z_vertex resolutions

	method	Std[cm]
Using the DCAz plot without error	mean method	3.214
	peak method	1.742
	1sigma mean method	1.532
Using the DCAz plot with error	mean method	2.119
	peak method	1.423
	1sigma mean method	0.964
Weighted average	Z distribution and track slope	22.446

- The 1sigma mean method using the DCAz plot with error is the best method.
- When using the DCAz plots, the error should be added.
- Result of weighted average method is not good. There is room for improvement.

Next To-Do

- Review the weighted average method.
- Calculating z_vertex with simulation data of gold nucleus collision.
- Reflected in the actual data.

Back Up