Vertex reconstruction by INTT in run 23 Au+Au data

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National Central University & RIKEN

Sep 4th, 2024
INTT meeting

Overview

- Goal: seek for the approvals of the data plots of average vertex XY and per-event vertex Z reconstructions by INTT

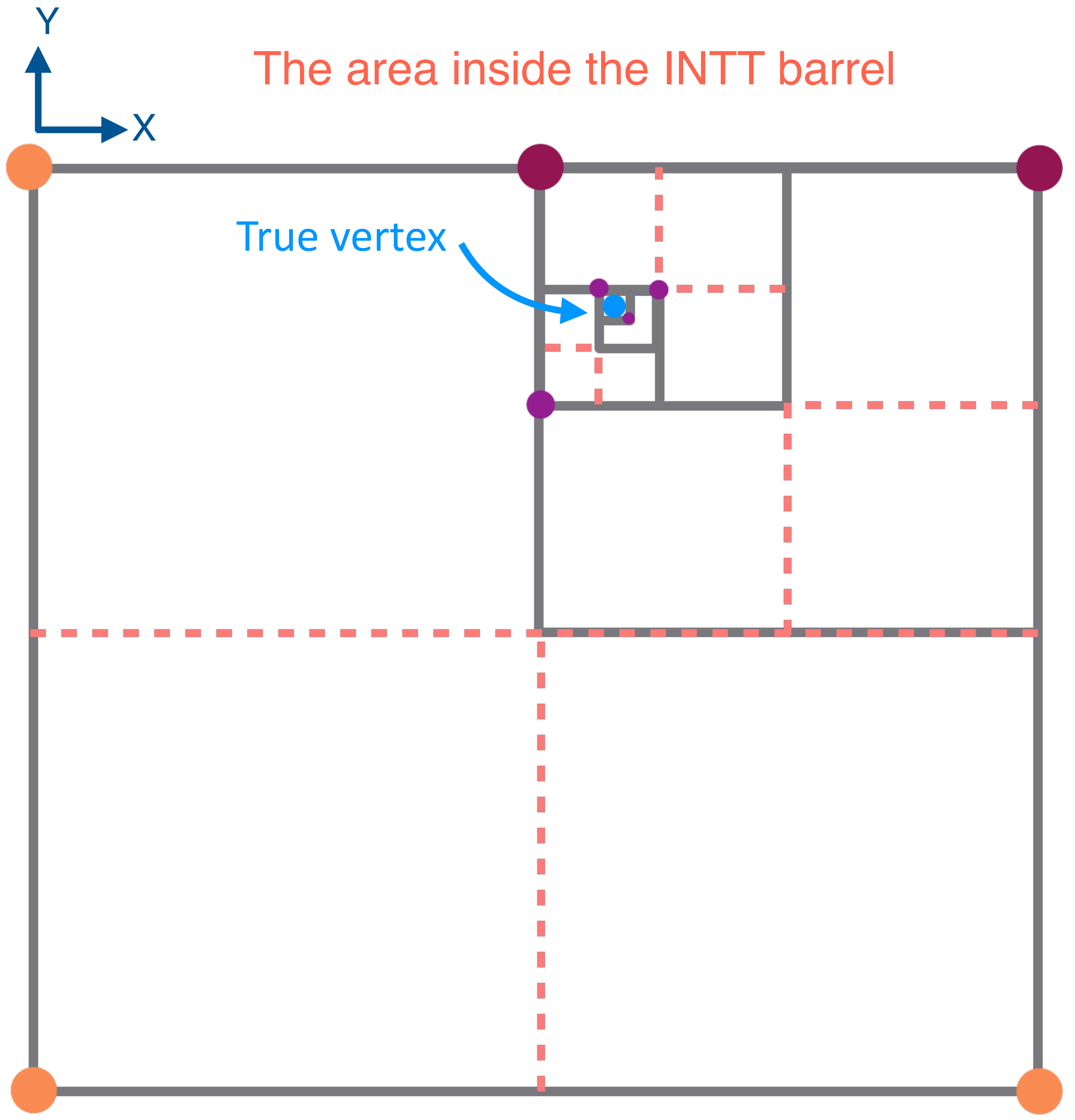
- Analyzed run: 20869, taken on July 8th 2023
- Run condition:
  - Zero-field run
  - Vertex Z distribution off by -20 cm
  - Partition: GL1, EMCal, HCal, INTT, MBD and ZDC
  - ~550k events

- Link to analysis note: Invenio IAN
- Links to the INTT meetings: Aug 21 2024, Aug 28 2024
- Link to the analysis code: GitHub

Average vertex XY - approach 1

- **Approach 1:** Quadrant method
- **Procedures:**
  1. Define the searching window
  2. In each iteration, try with 4 corners
  3. Move searching window to the quadrant that gives better performance
  4. Repeat the procedure with the new 4 corners

- **How to determine the “good” vertex ?**
  - The one with better **Polynomial 0 fit errors** on both
    - DCA - Clu_{inner} ϕ correlation, and
    - Δϕ - Clu_{inner} ϕ correlation



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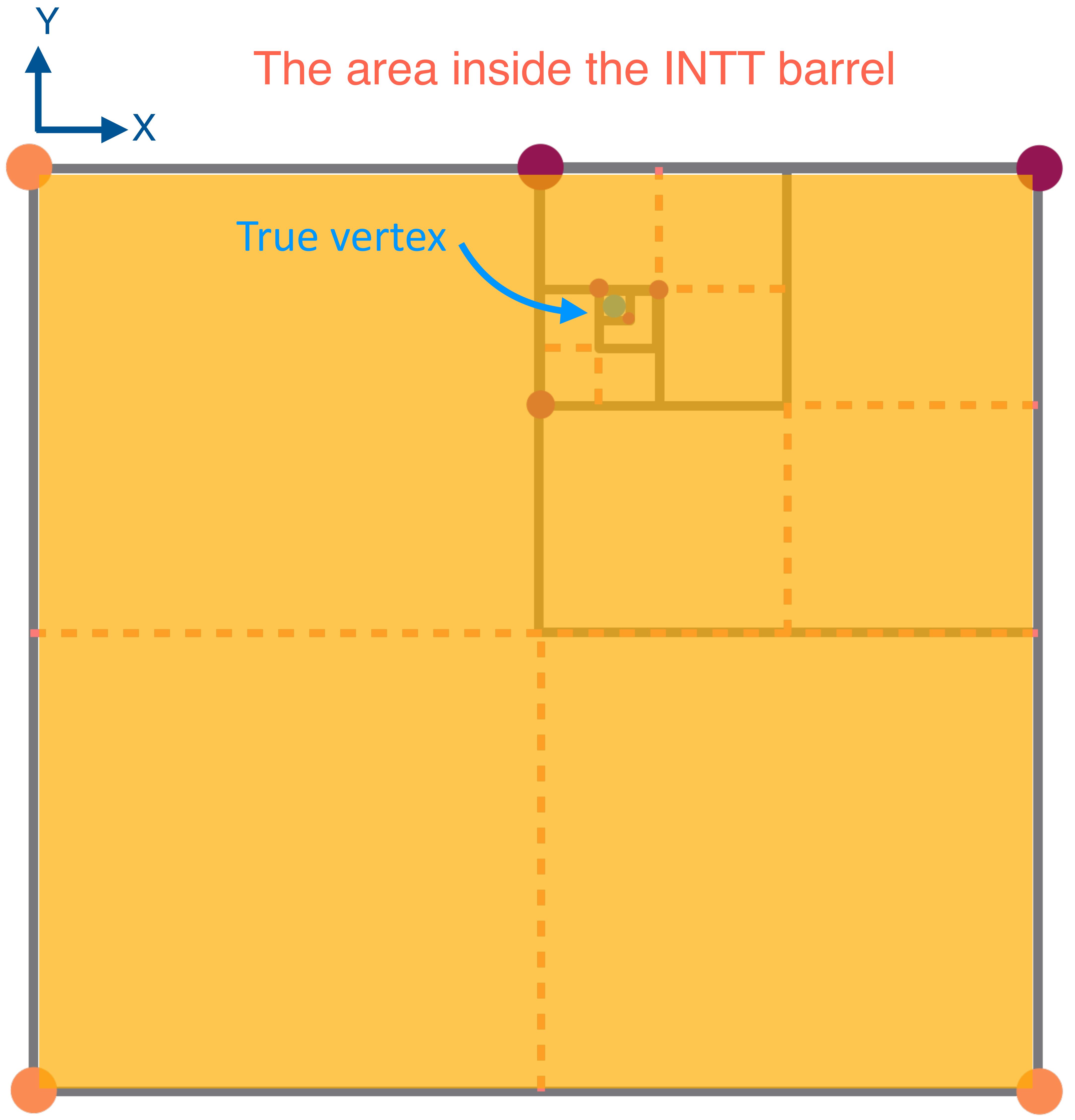

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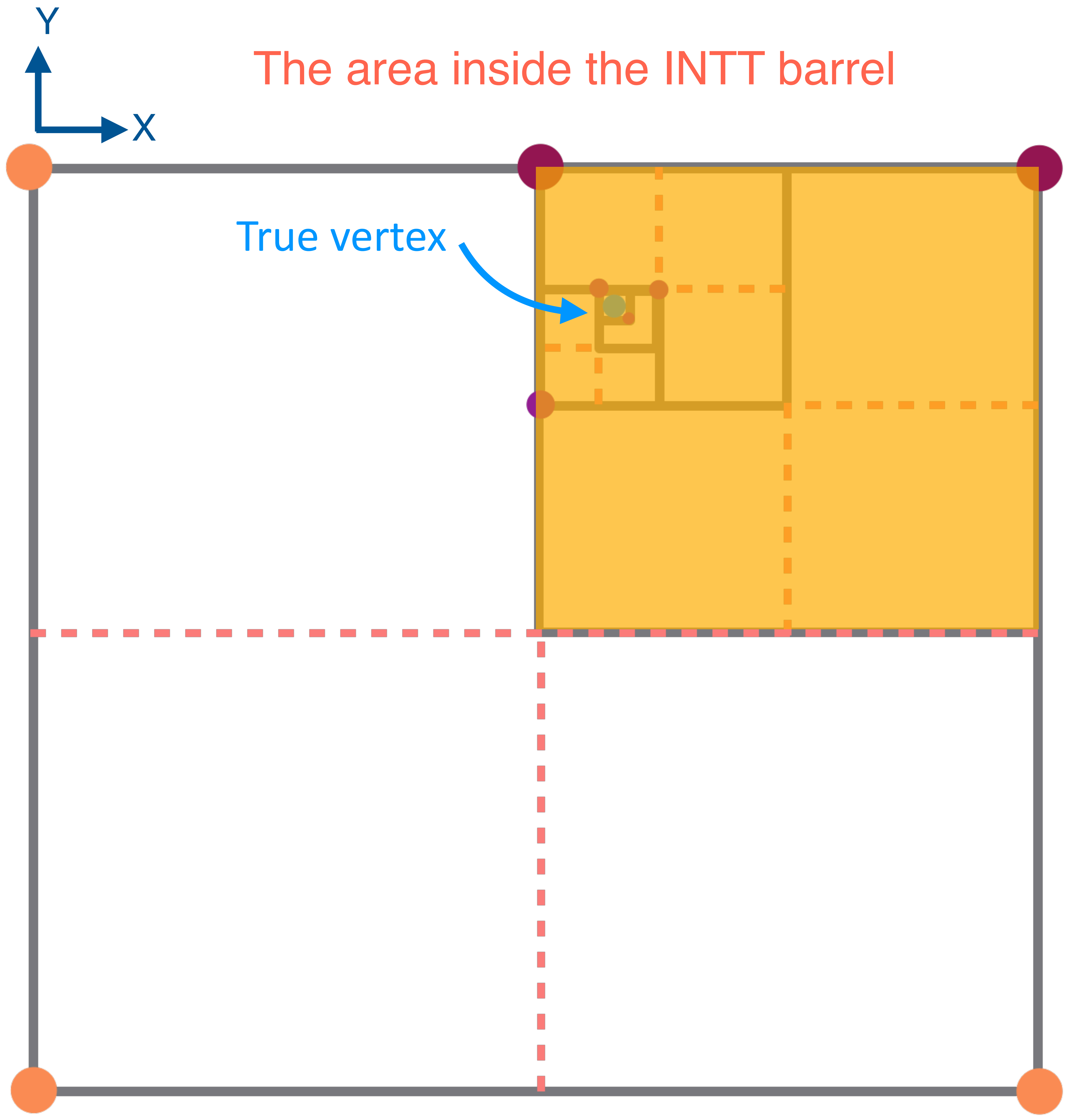

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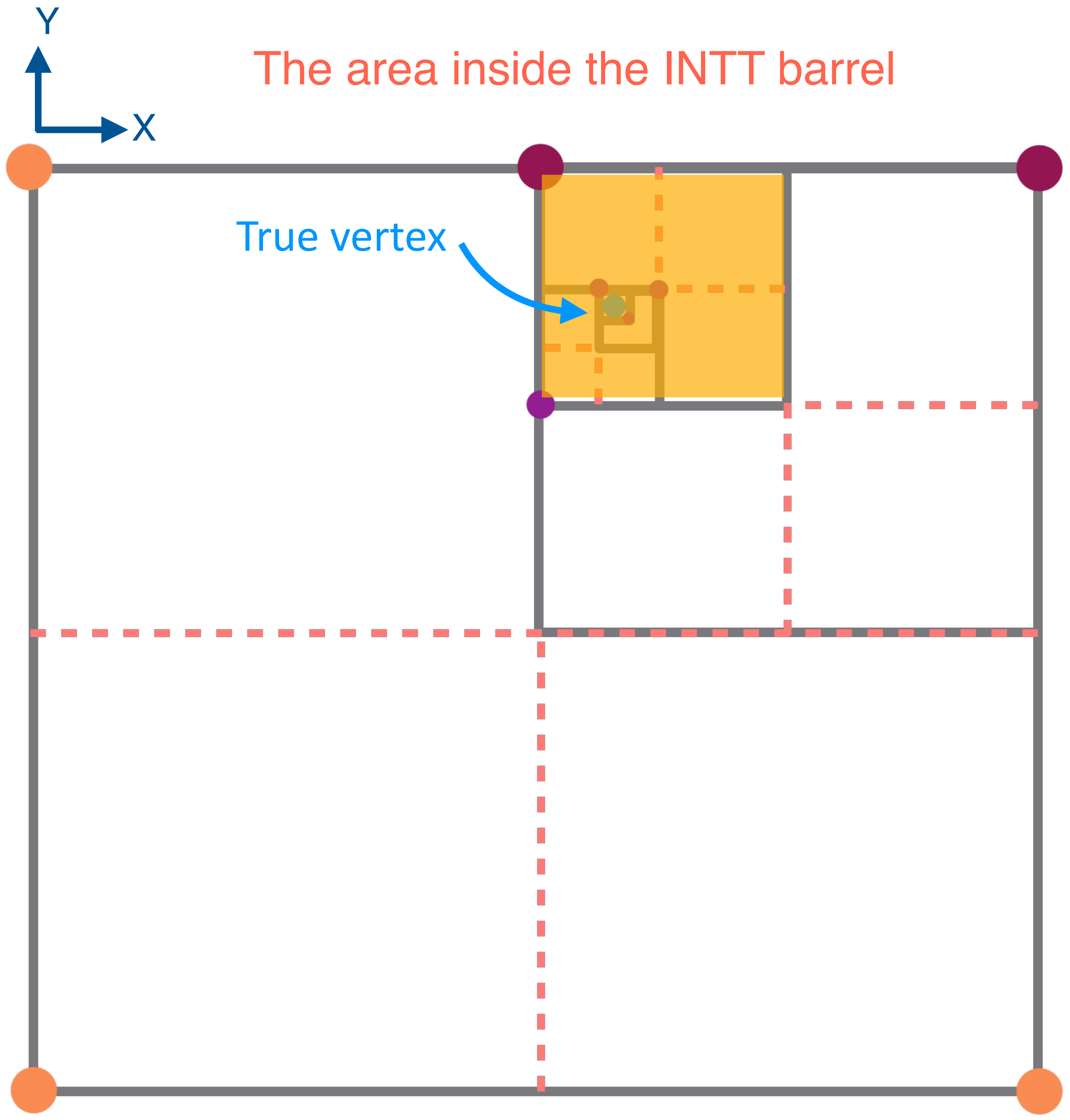

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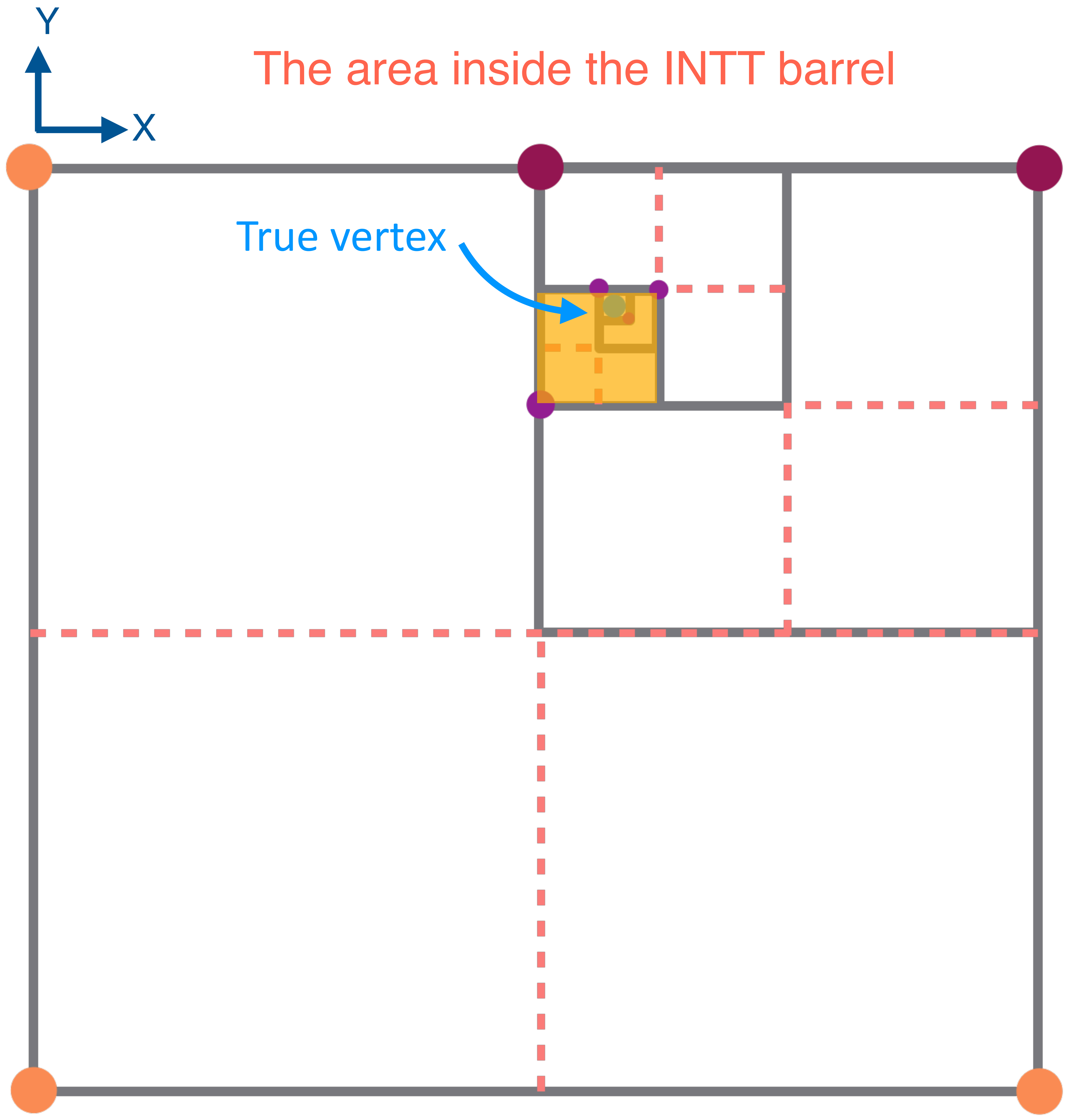

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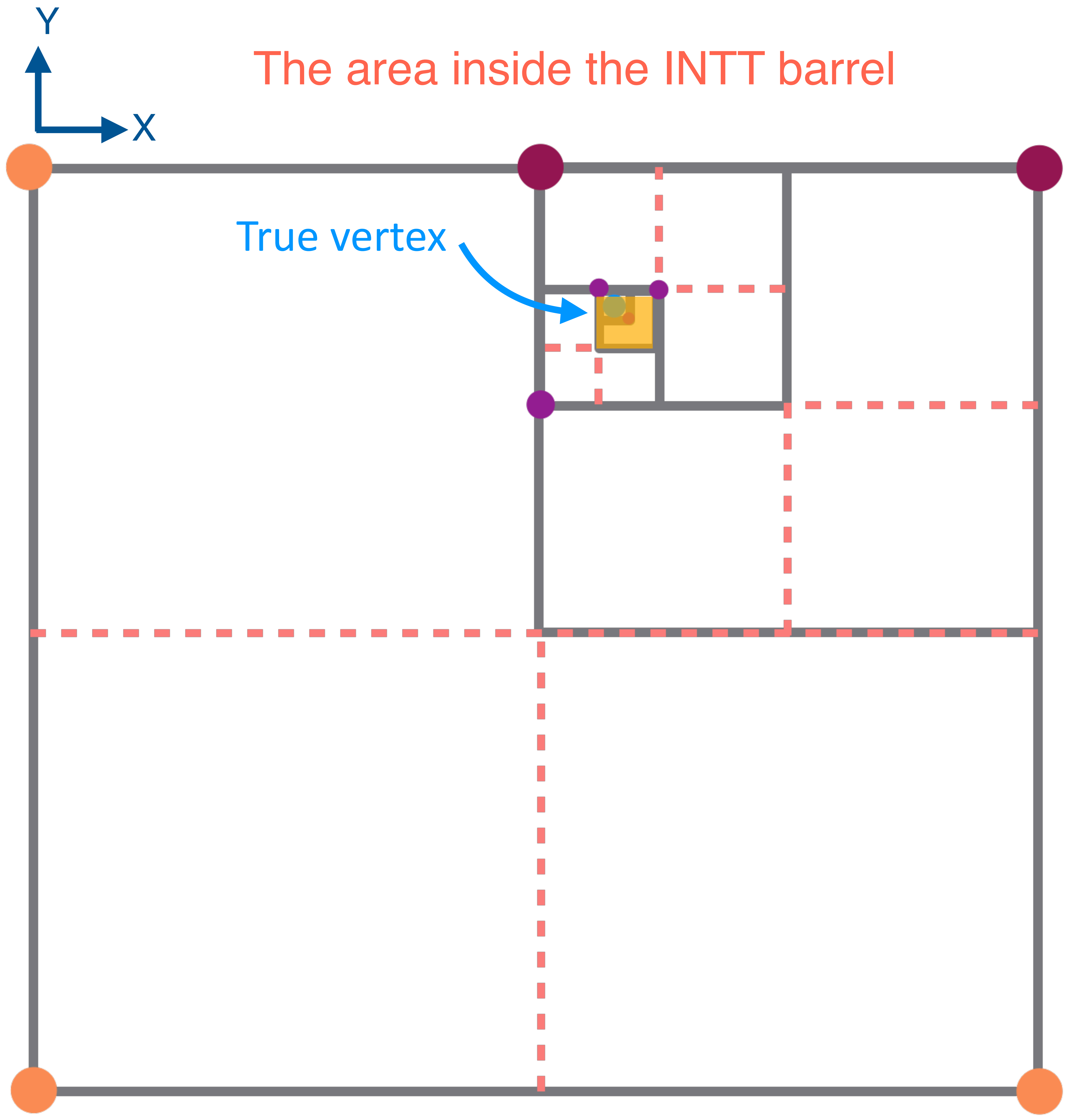

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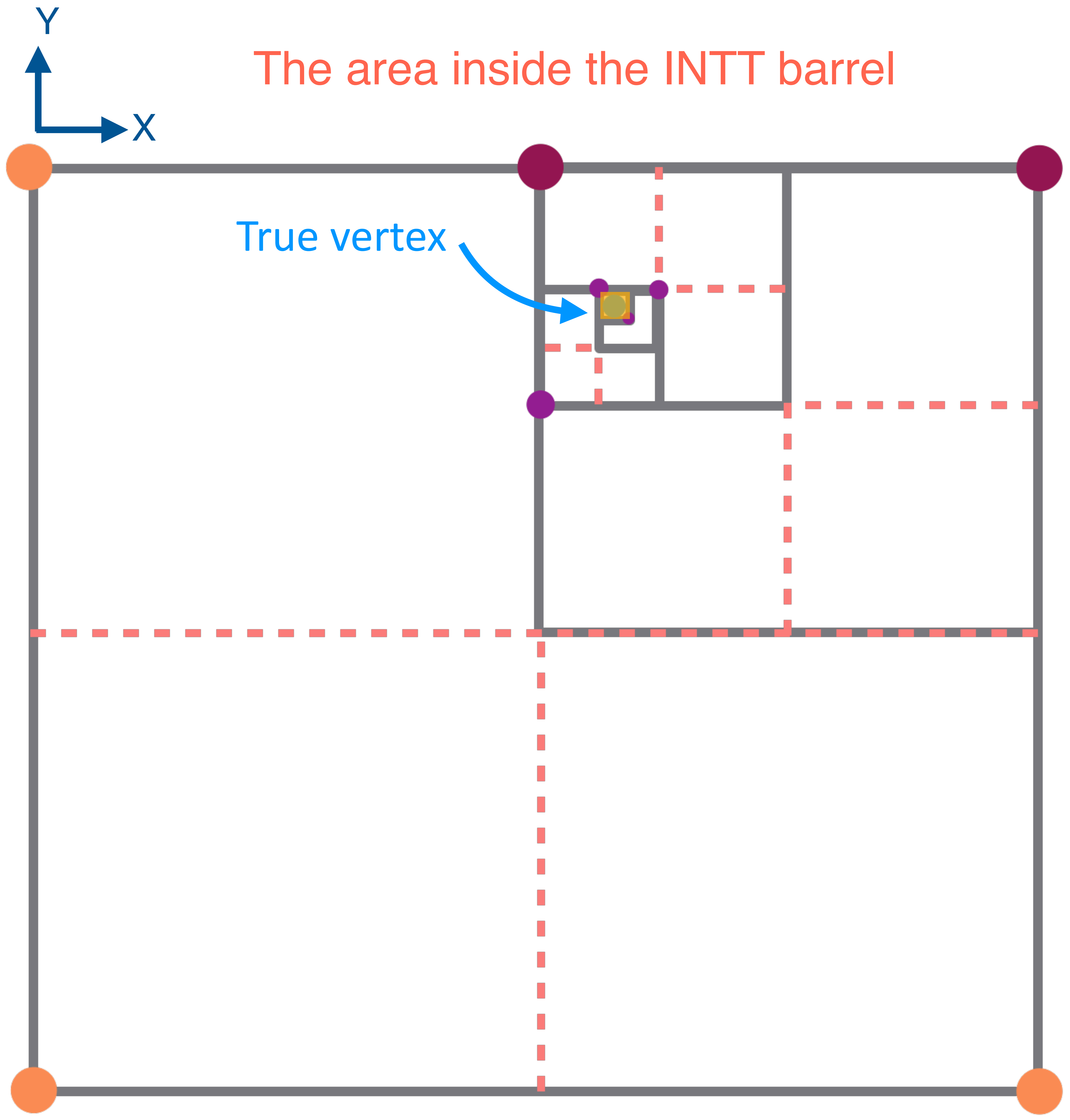
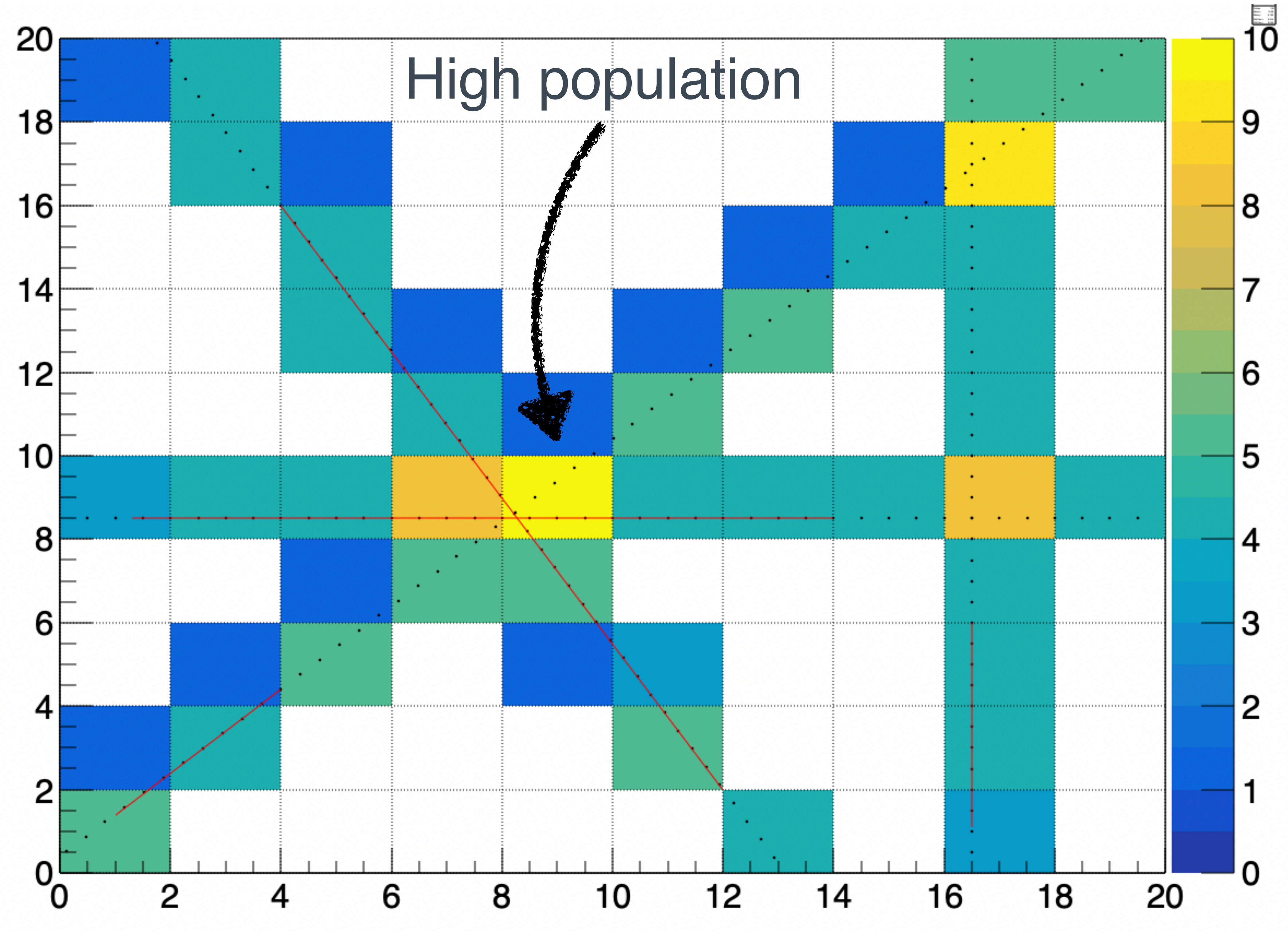


Average vertex XY - approach 2

- **Approach 2:** Line-filled method
- **Concept:** vertex can be obtained by populating the proto-tracklets into a 2D histogram
- **Procedures:**
  1. Define the searching window. Nominally, 3 mm x 3mm, center given by approach 1
  2. Fill the trajectories of proto-tracklets with $|\Delta\phi| < 5$ degrees
  3. Remove the background
  4. Take the averages of both axes as the vertex position XY

Demonstration of Line-filled method



If the variation of the vertex is small, the proto-tracklets can tell the position

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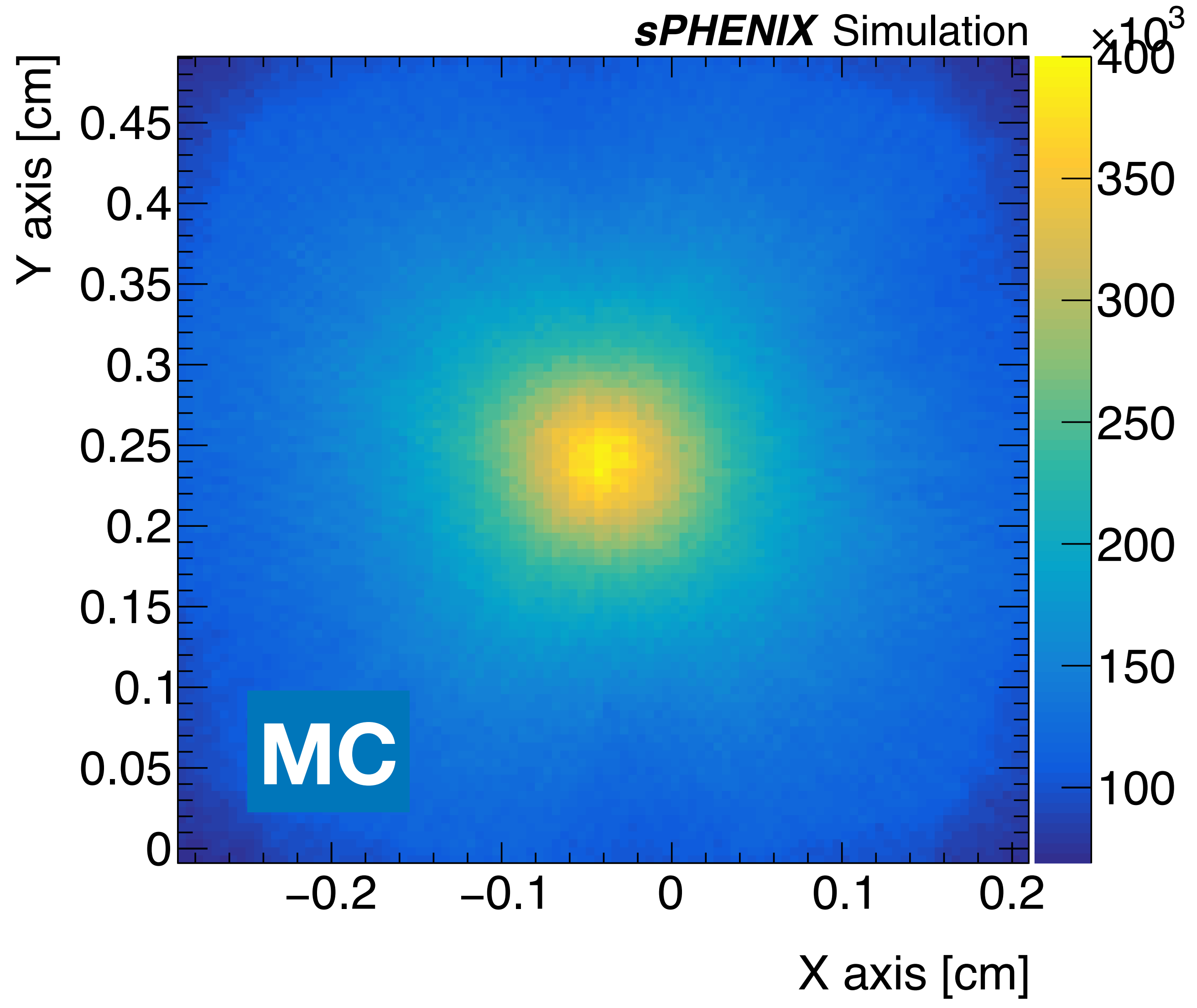
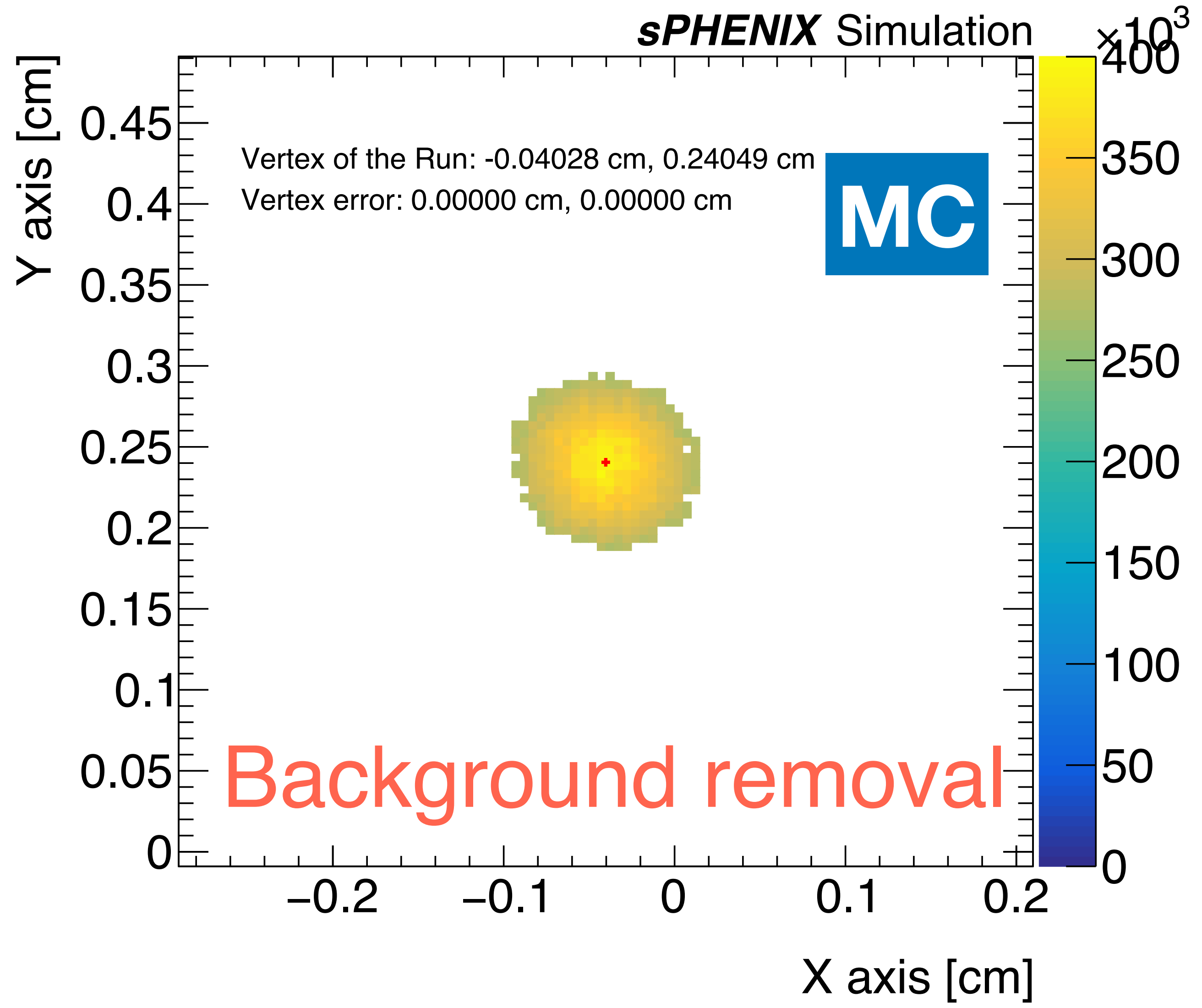
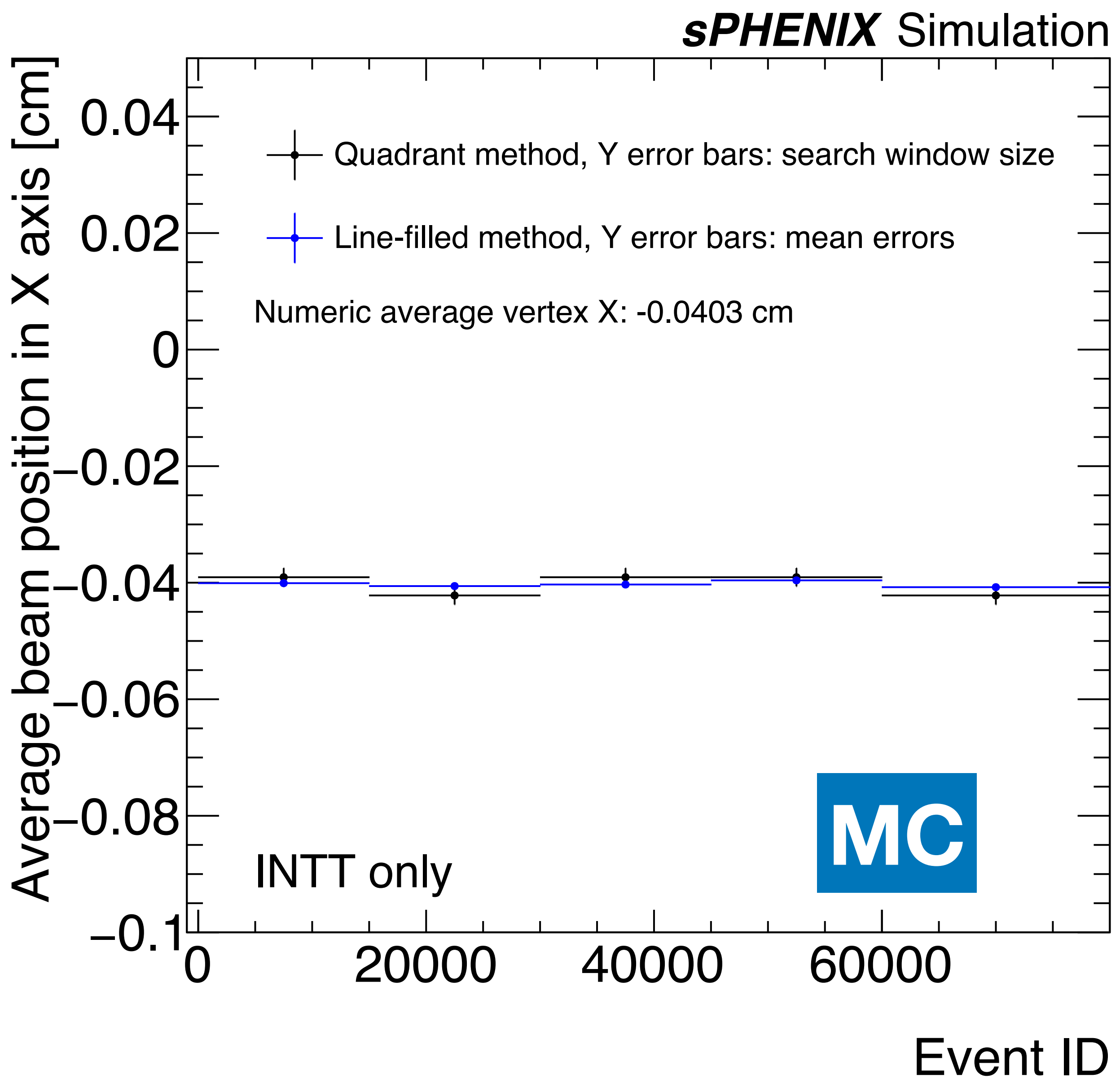


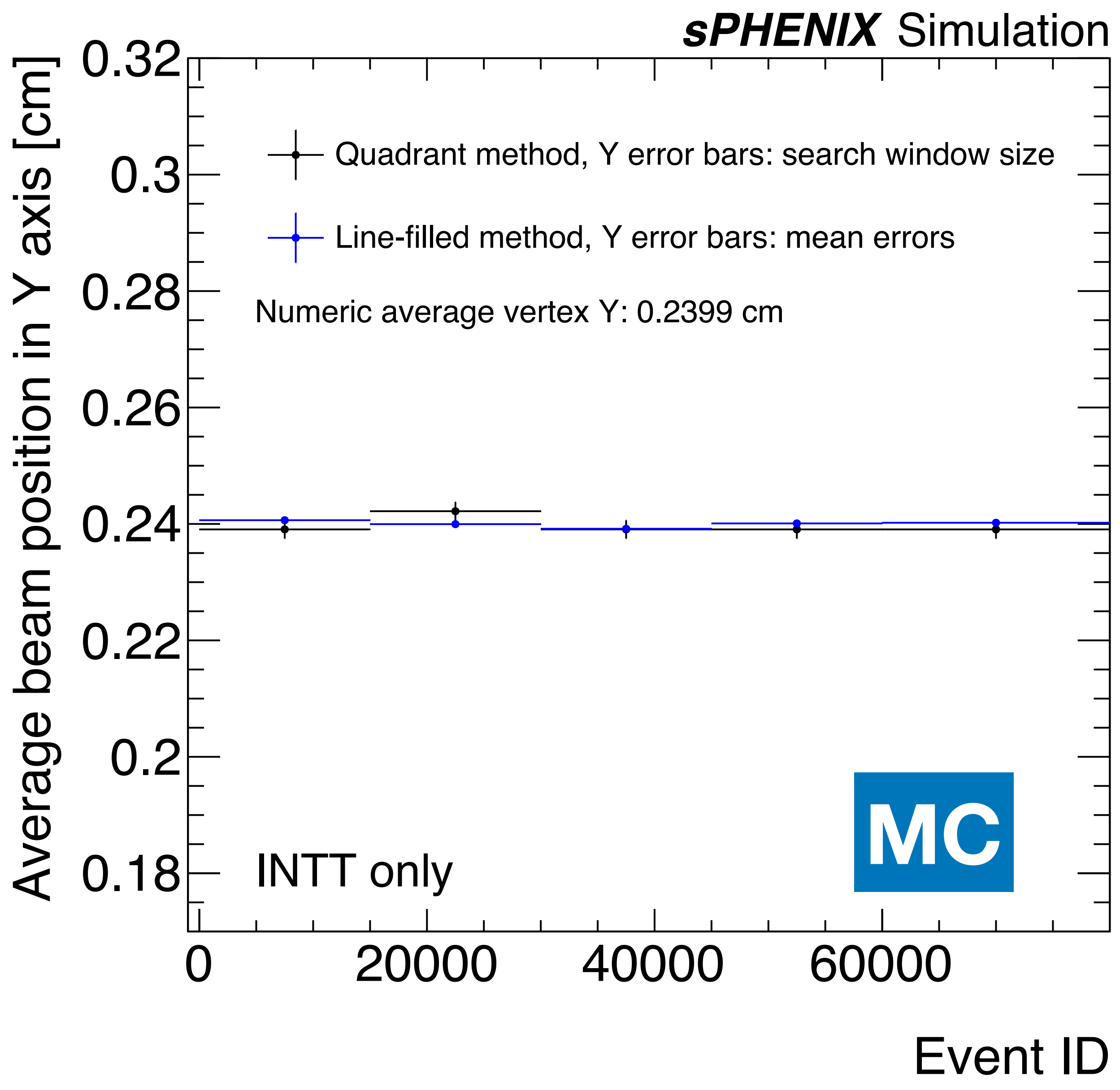


Final estimated vertex: **(-0.0402 cm, 0.2405 cm)**

Final average vertex XY - MC

- Quadrant method + 2D line filled method
  - 20 < selected_NClus < 350
  - 15k events per data point
  - Take the total average as the final average vertex XY





Avg: {-0.04029 * cm, 0.239851 * cm}

Setting: {-0.04 cm, 0.24 cm}

Final average vertex XY - Data

Data

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  - 20 < selected_NClus < 350
  - 15k events per data point
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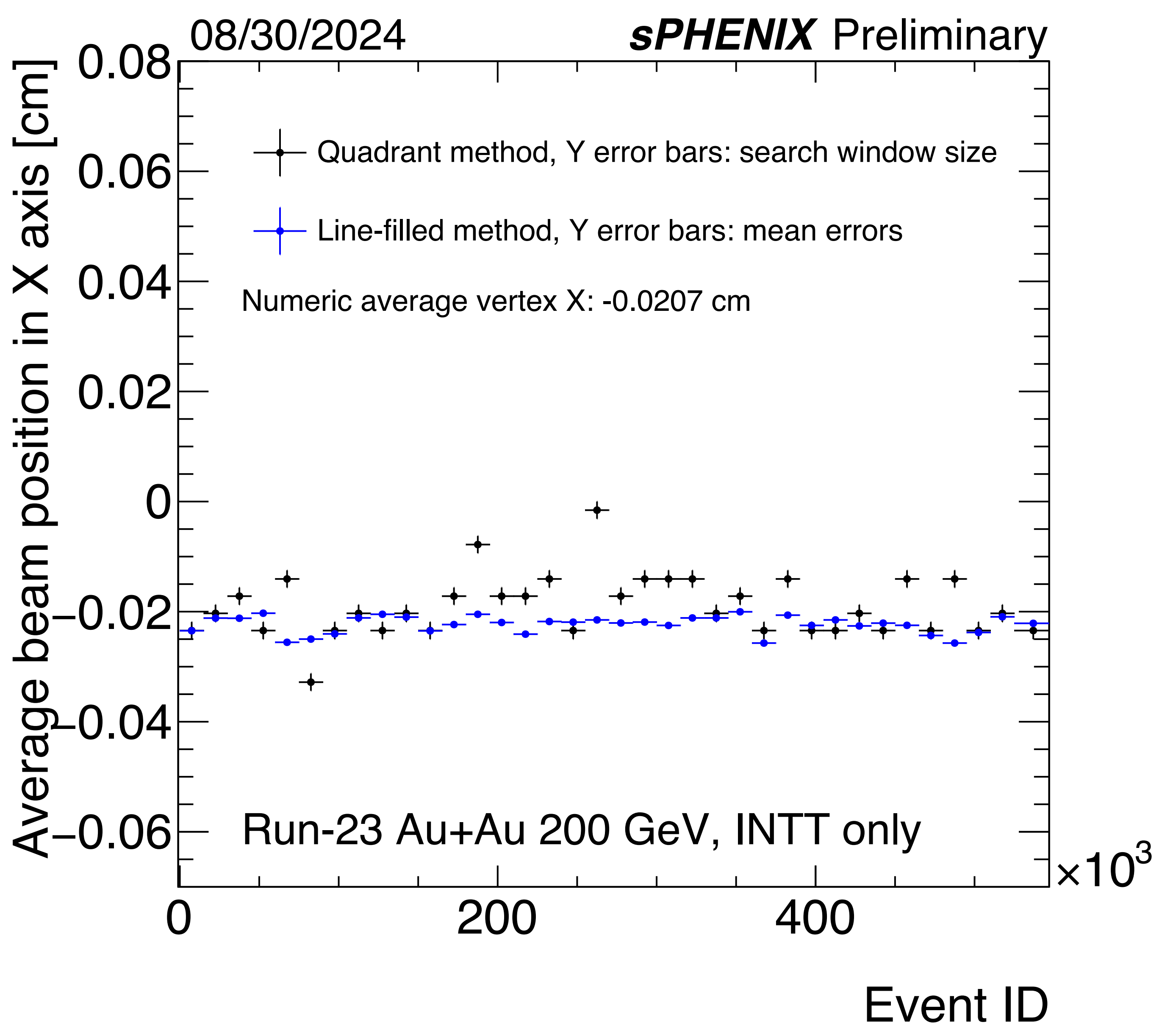
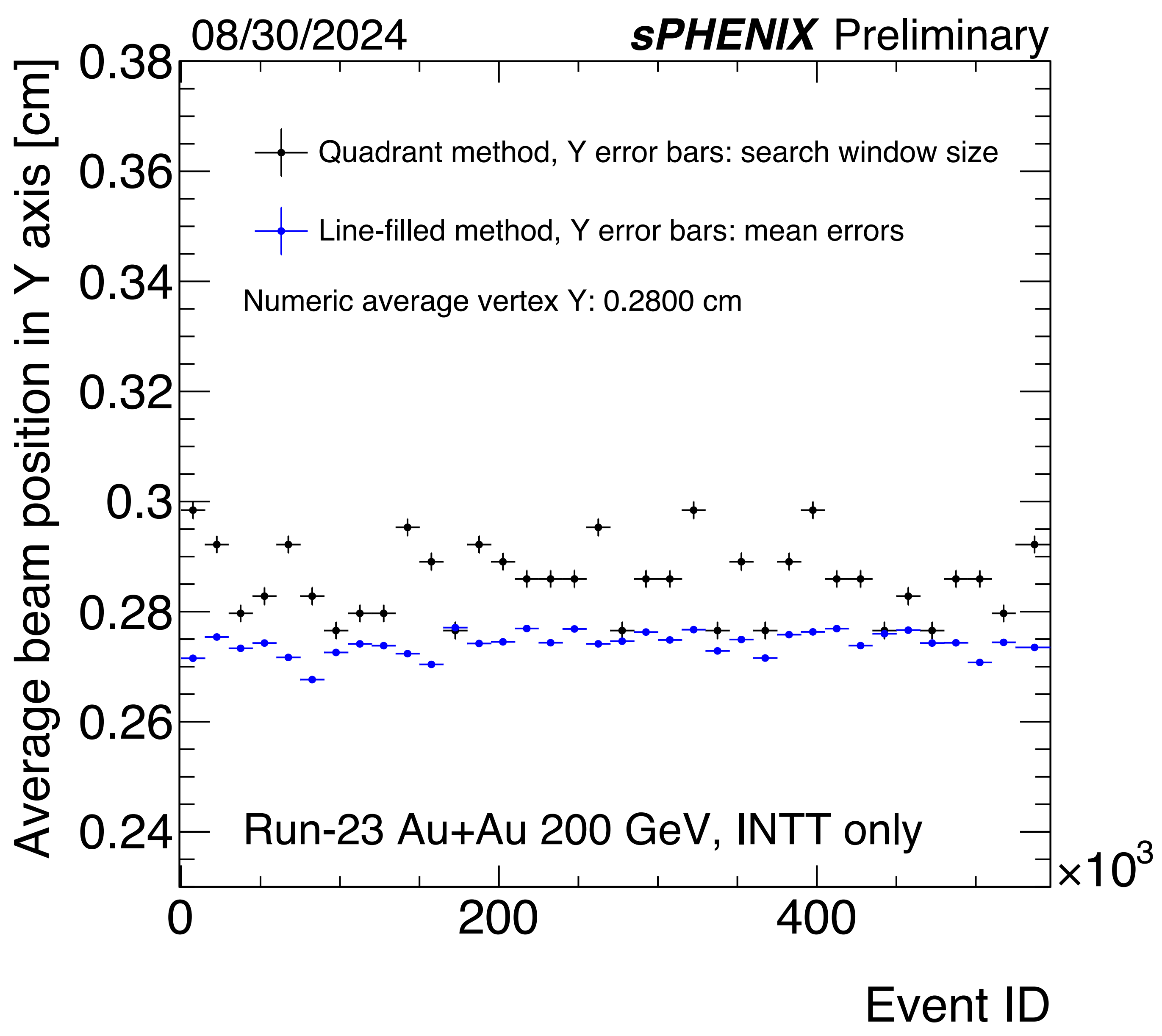


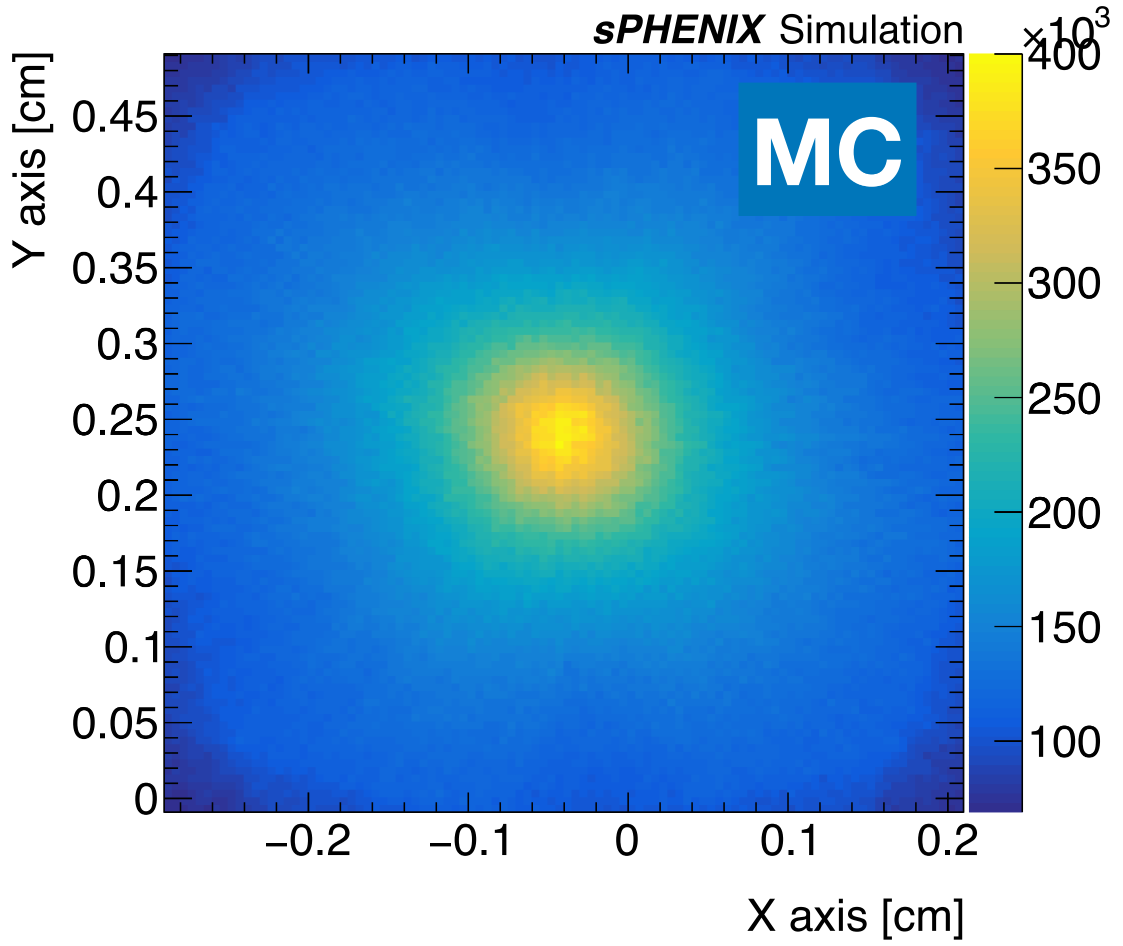


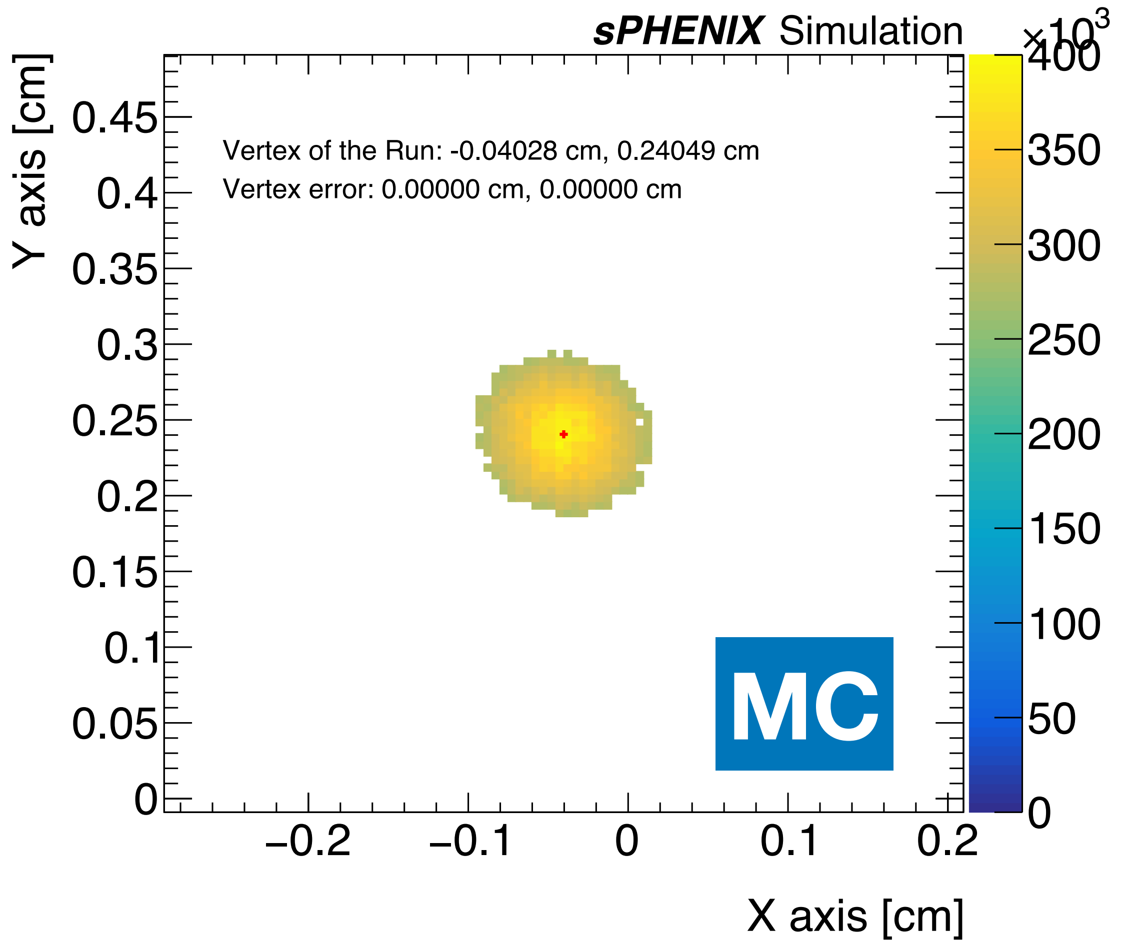
Avg: {-0.0206744 * cm, 0.279965 * cm}

The discrepancy explained in the next page

avg_vtxXY, the discrepancy b/w two methods

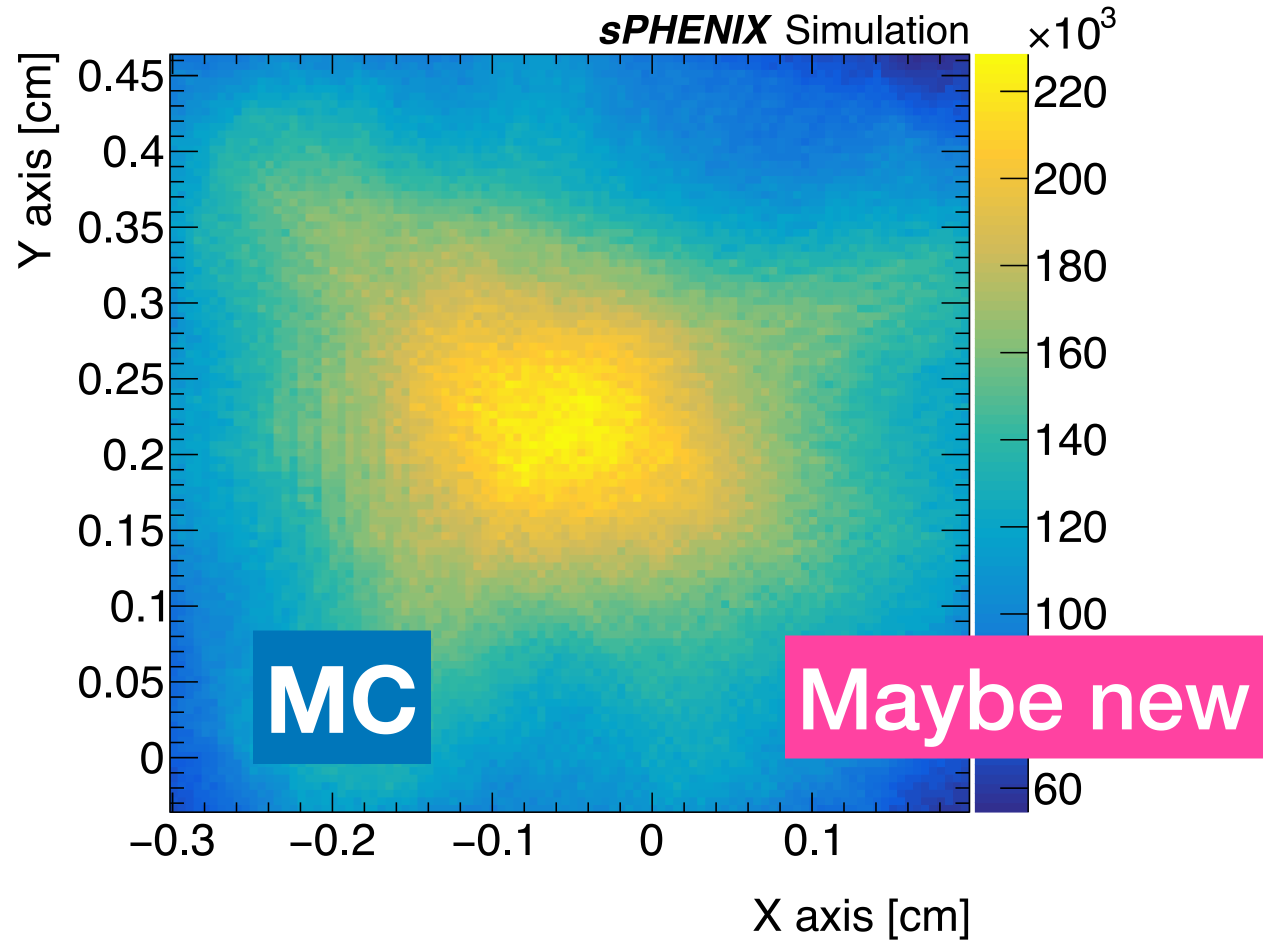
The fully understood geometry (MC)

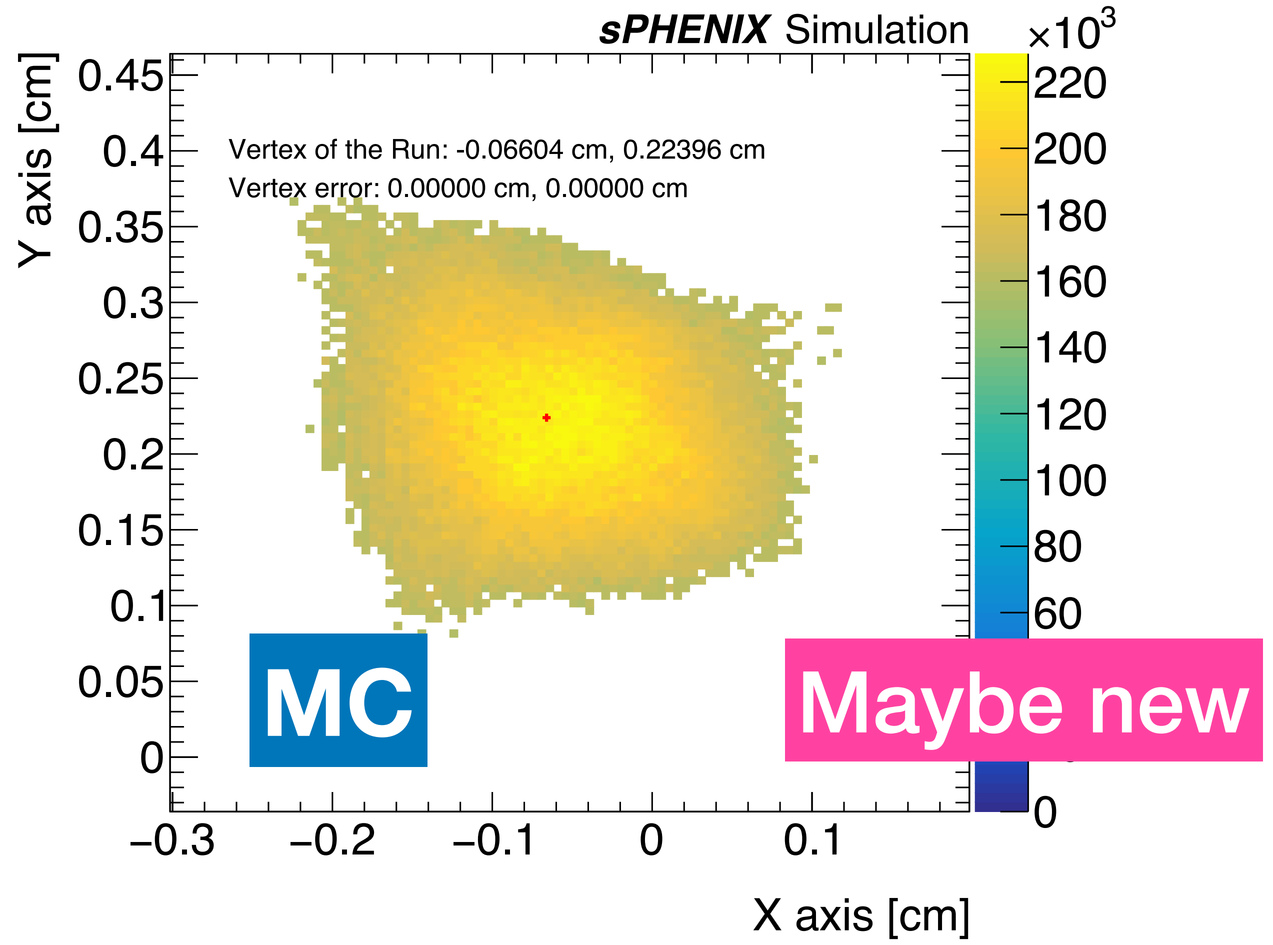




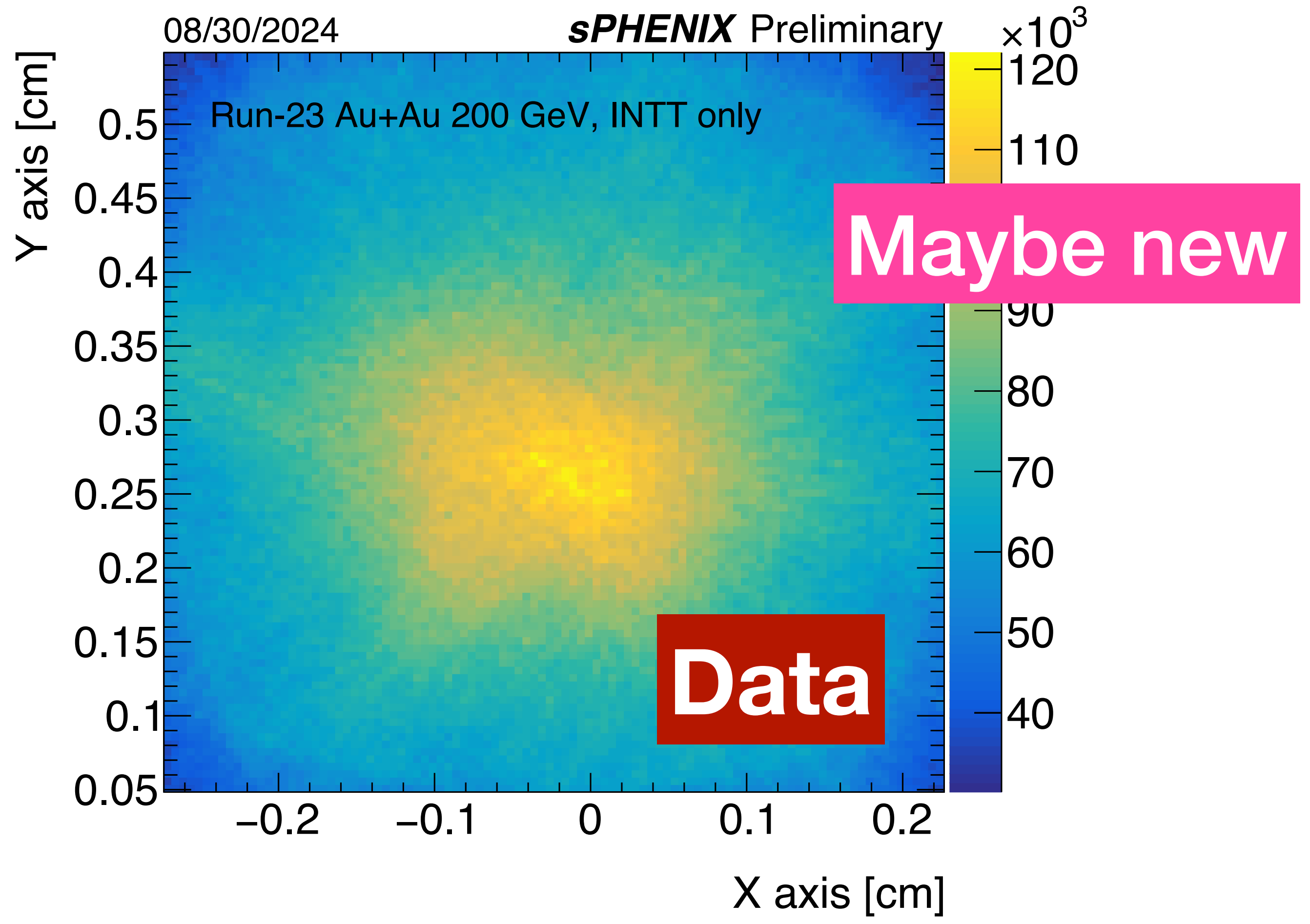
The simulation. Artificially add the offset to each ladder randomly in the offline reconstruction (±0.25 mm in three dim.)

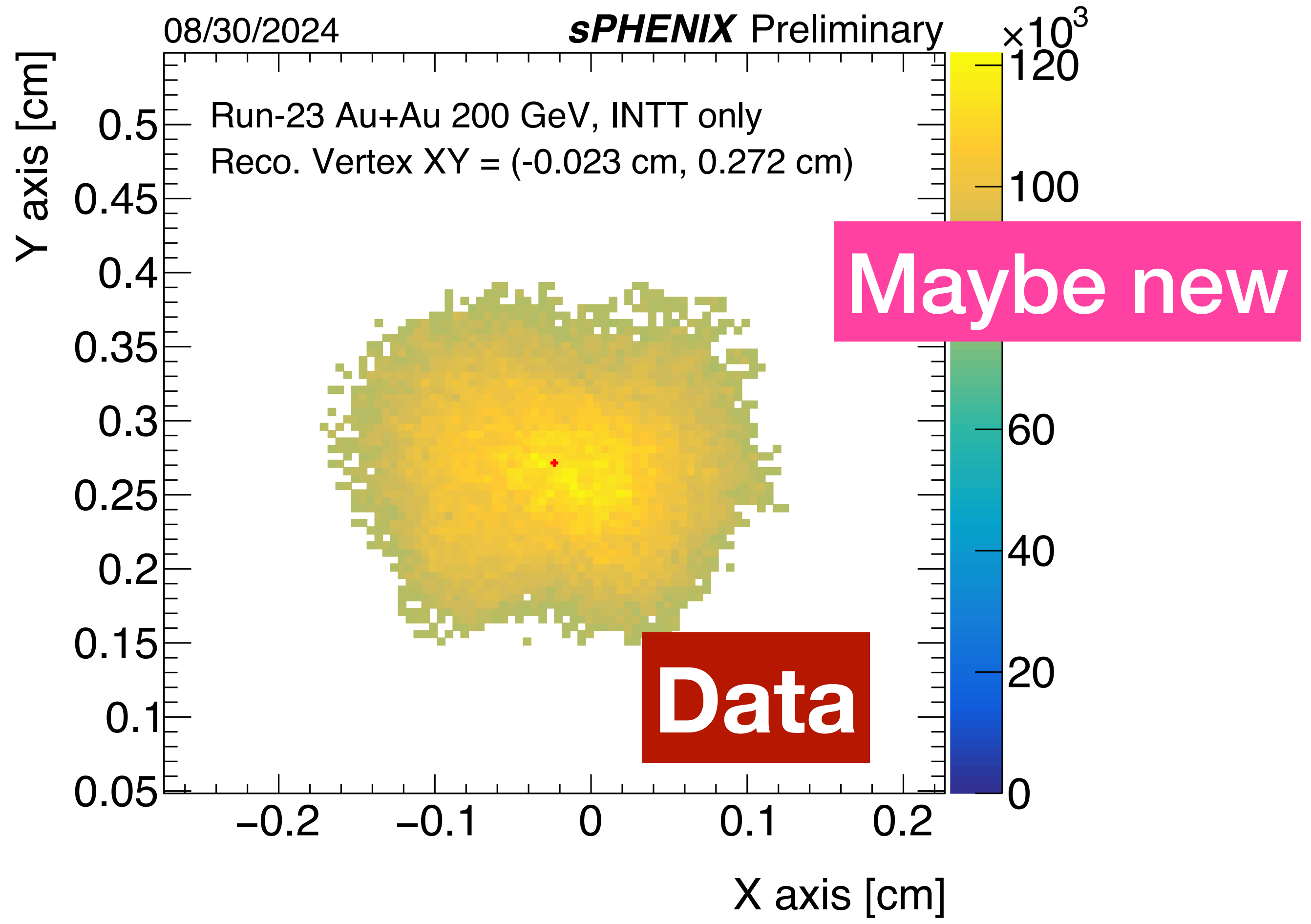
Here shows one of the random trials





The data (offline reco. geometry by the updated GEANT geometry based on "ladder" survey)

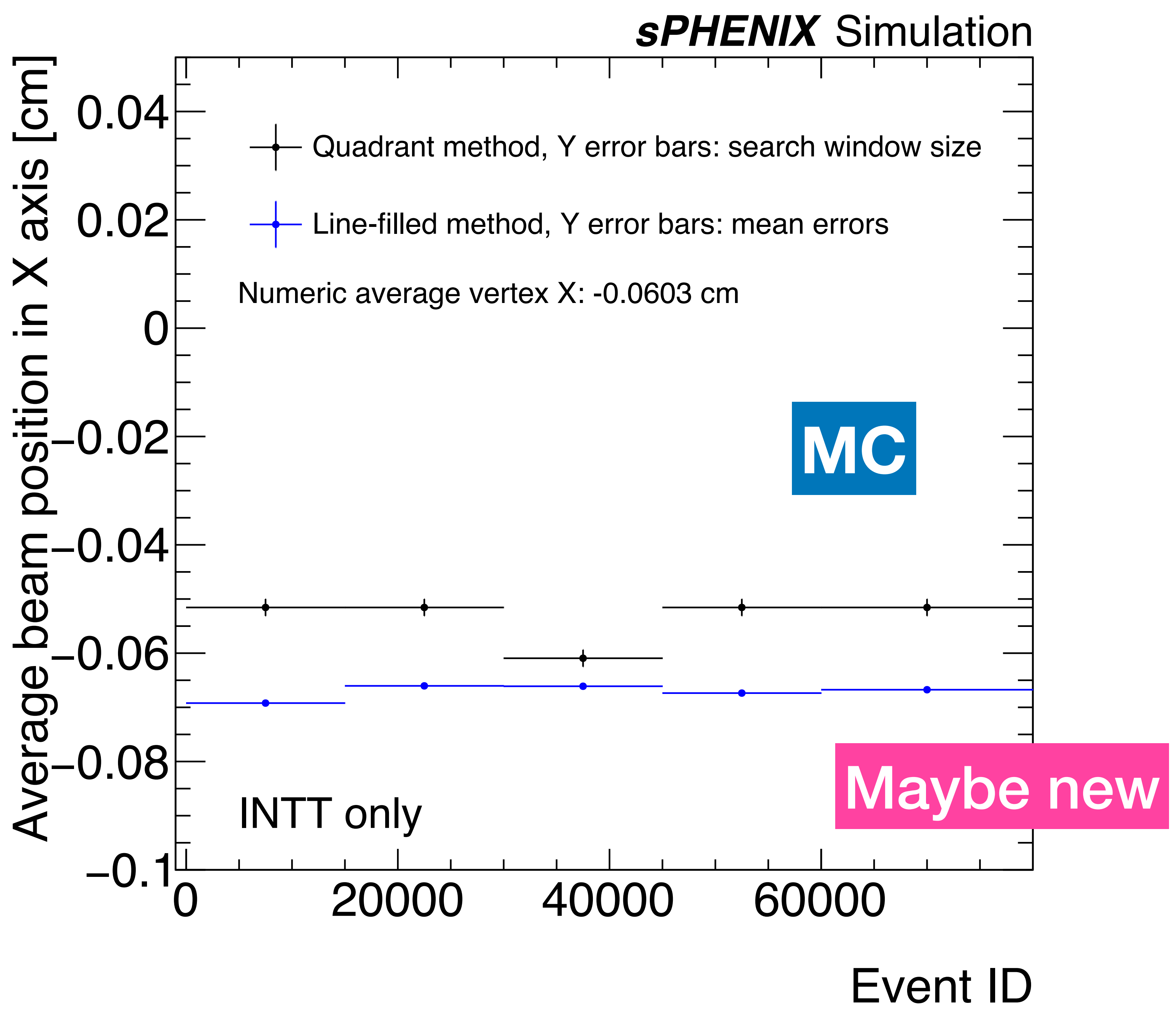


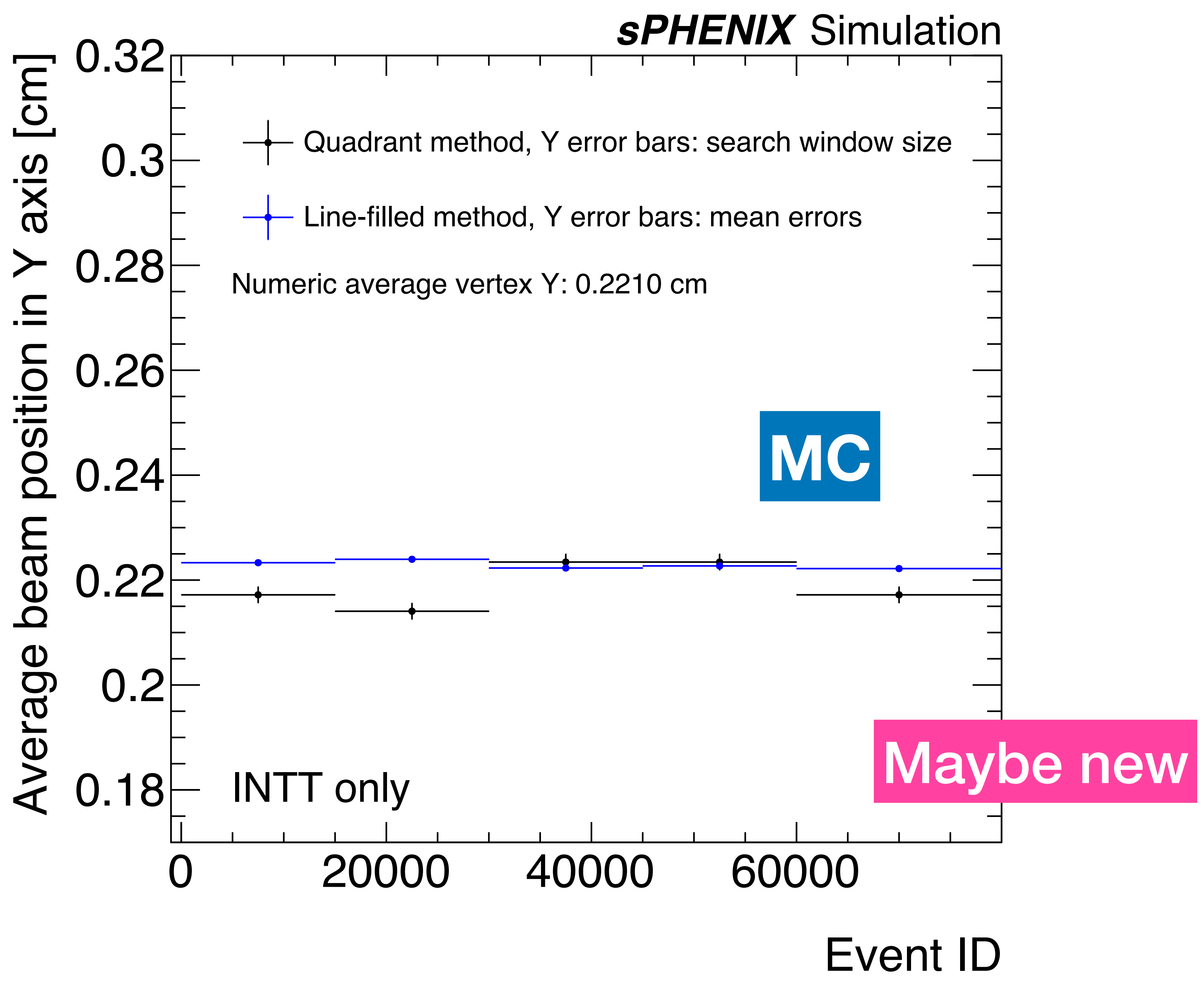


The shape is expected to be circle, if the geometry is fully understood

avg_vtxXY, the discrepancy b/w two methods

The simulation, but artificially added the offset to each ladder randomly in the offline reconstruction (±0.25 mm in three dim.)



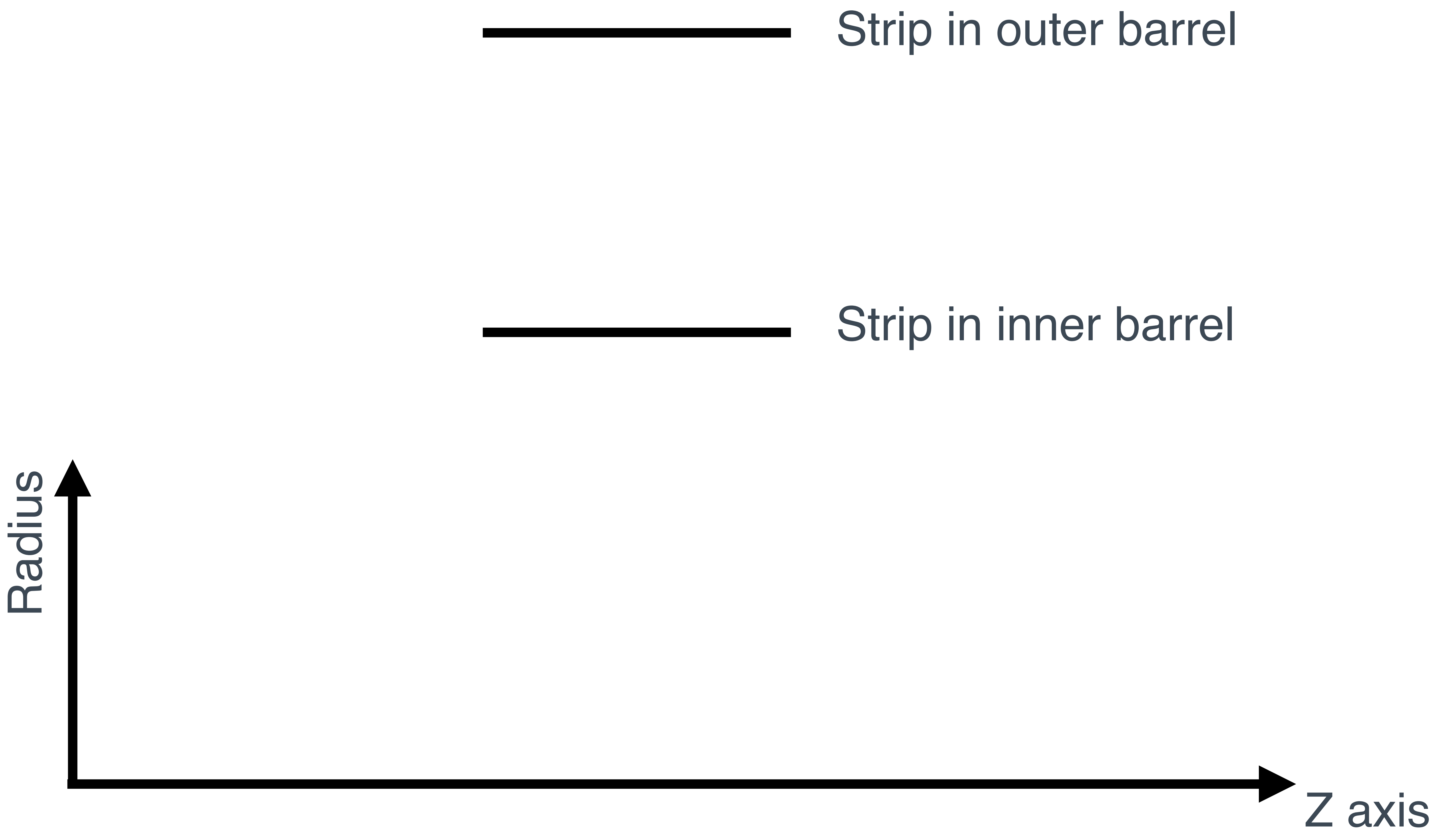


- Some discrepancies b/w two methods are expected if there are some misalignments
- In terms of the dNdη analysis, the misalignment is planned to be included as one of the sys. uncertainties by having hundred sets of random offsets applied in offline reconstruction of MC. The overall variations can be then obtained

Per-event vertex Z reconstruction

- For each combination, take into account of the distribution of the possible vertex Z range, normalize the distribution, and fill it into the fine-segmented 1D histogram

For each combination



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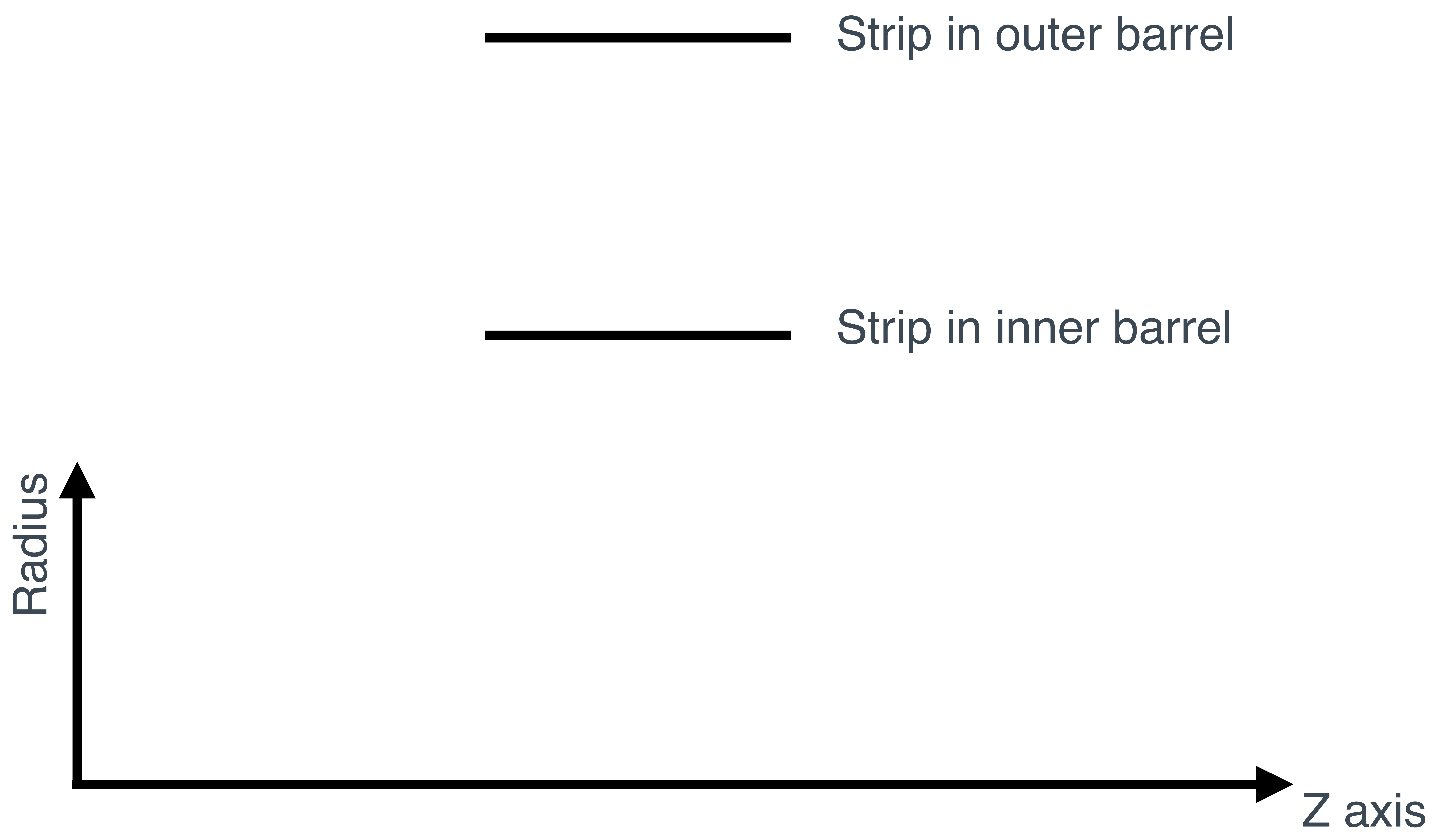

For each combination, the possibility distribution of vertex Z is in the shape of trapezoid

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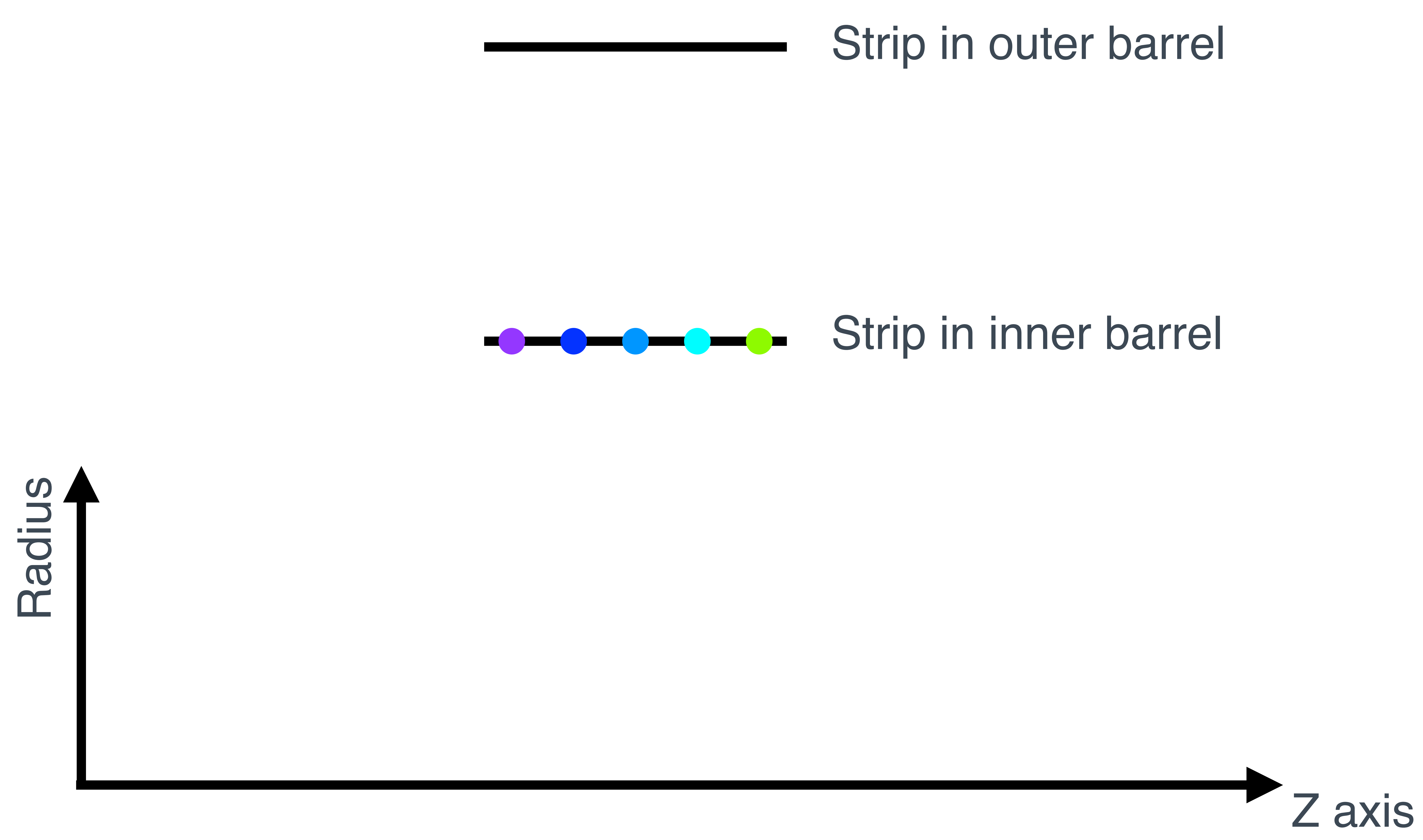

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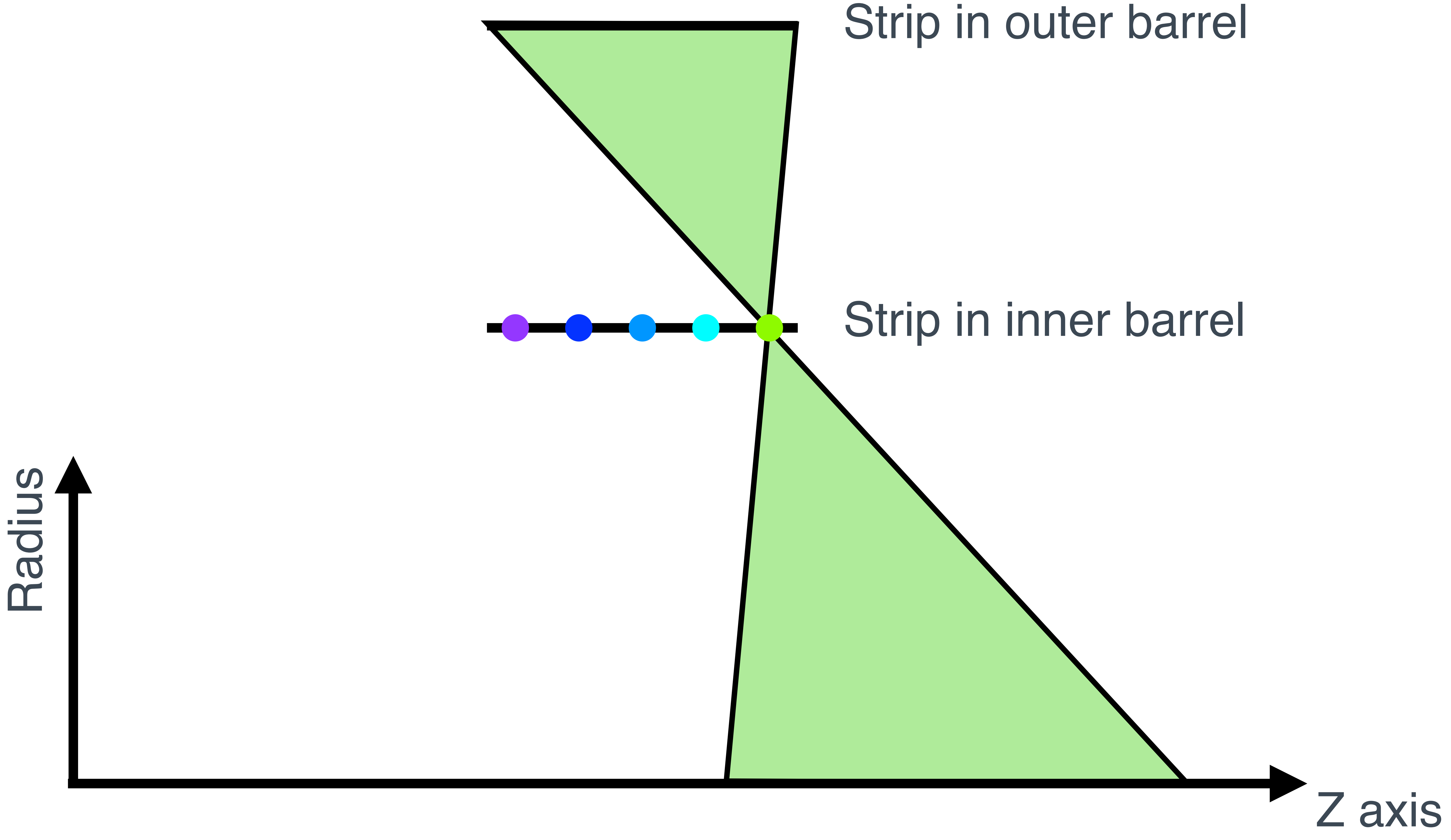

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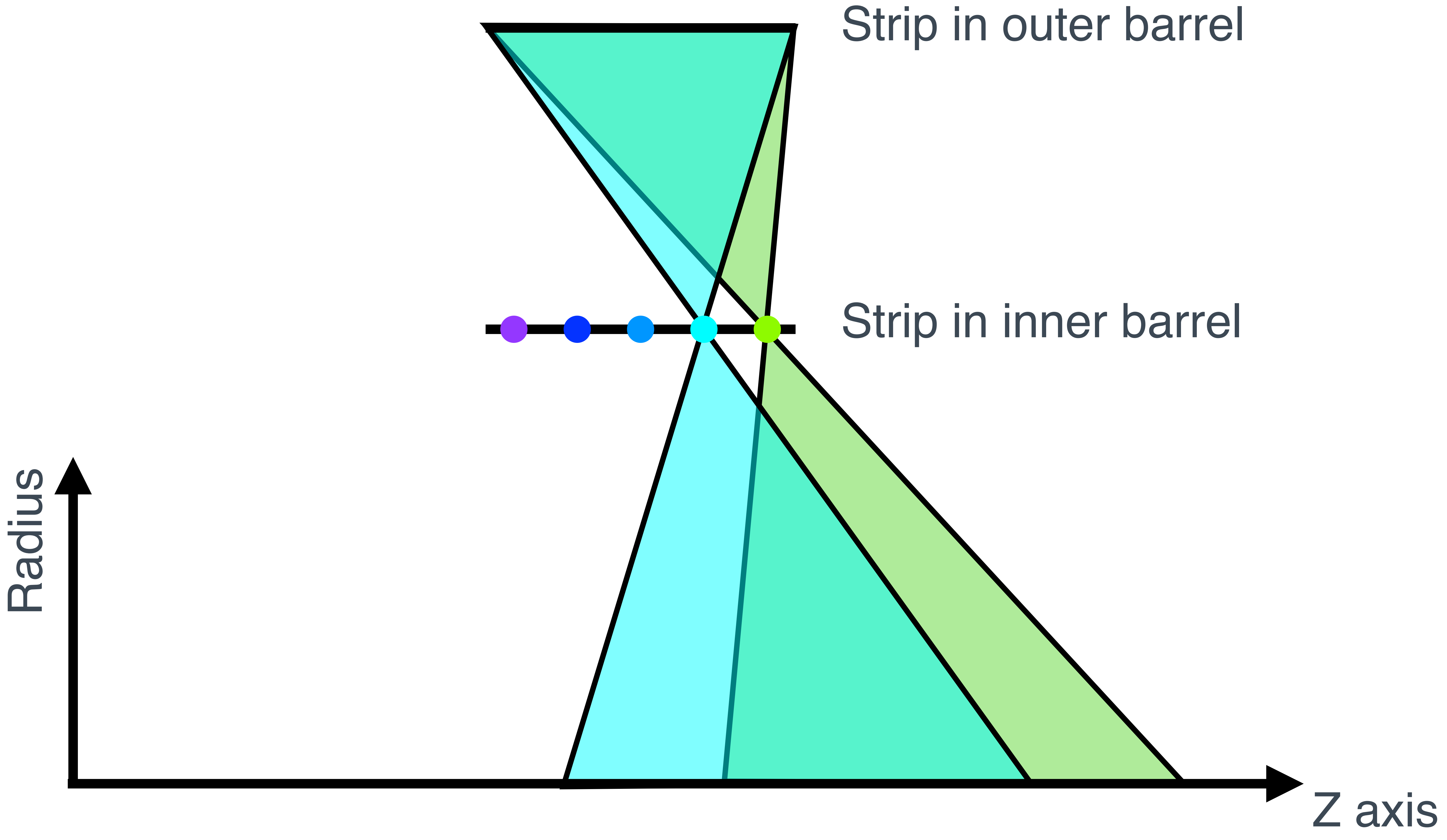

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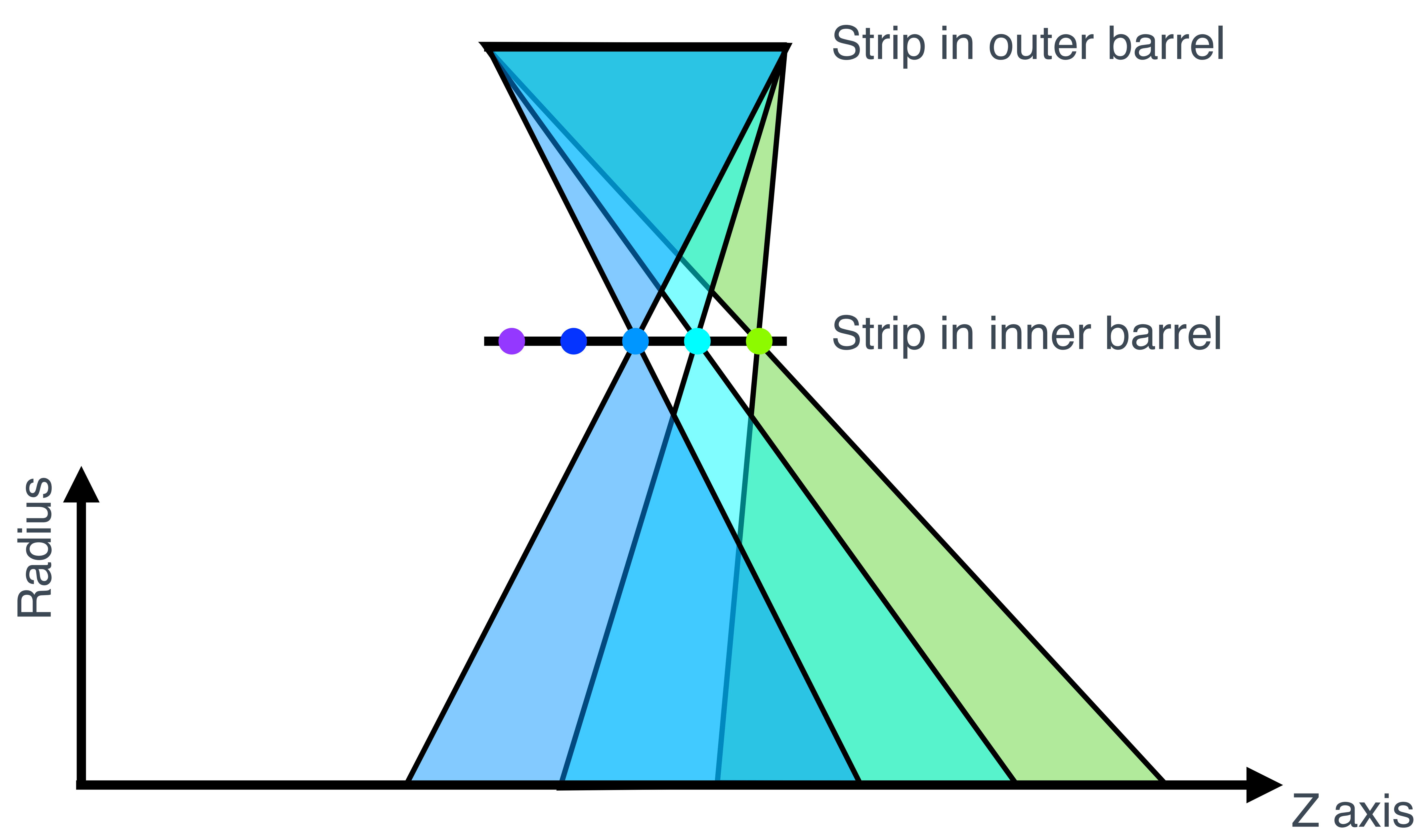

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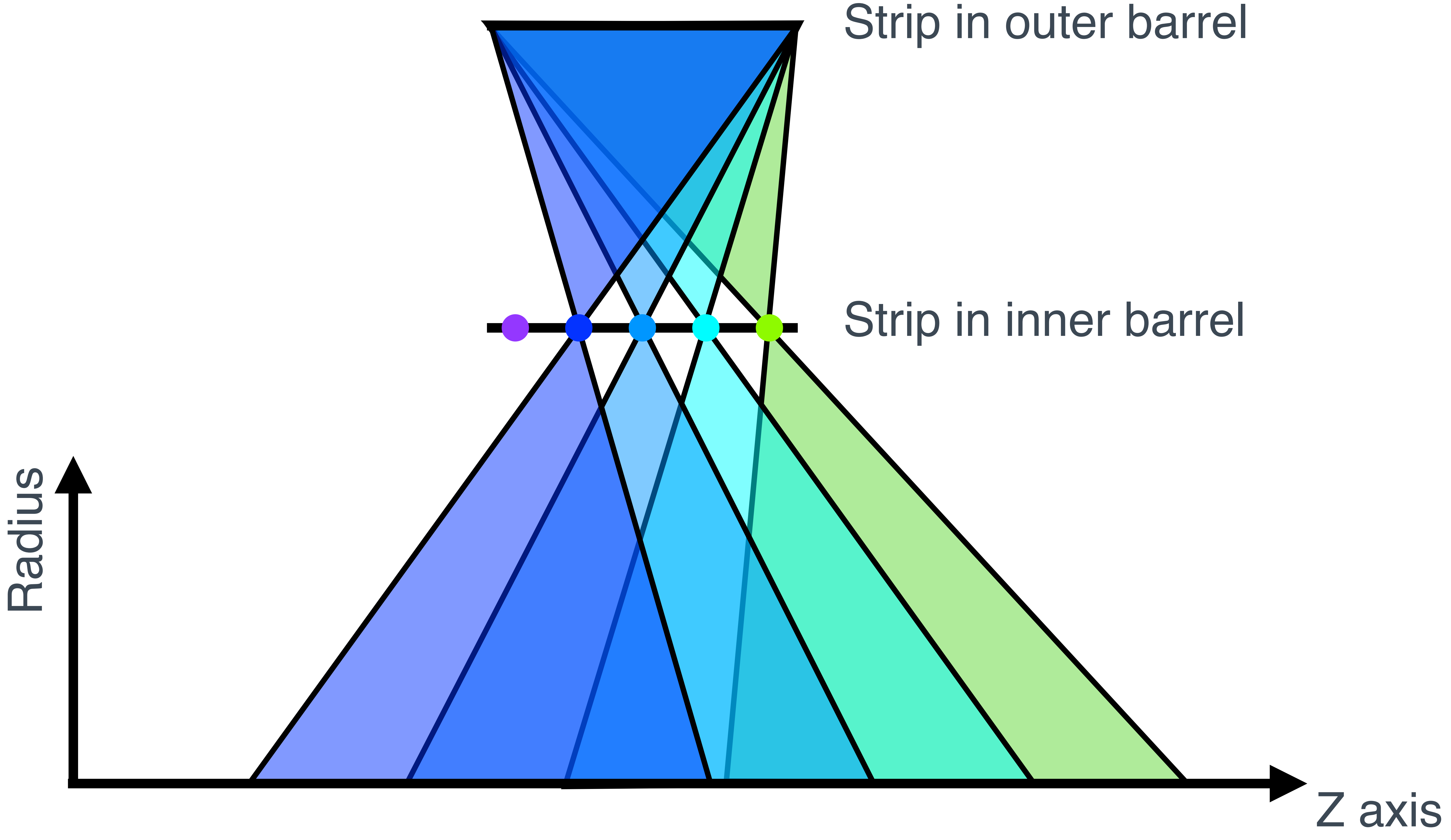

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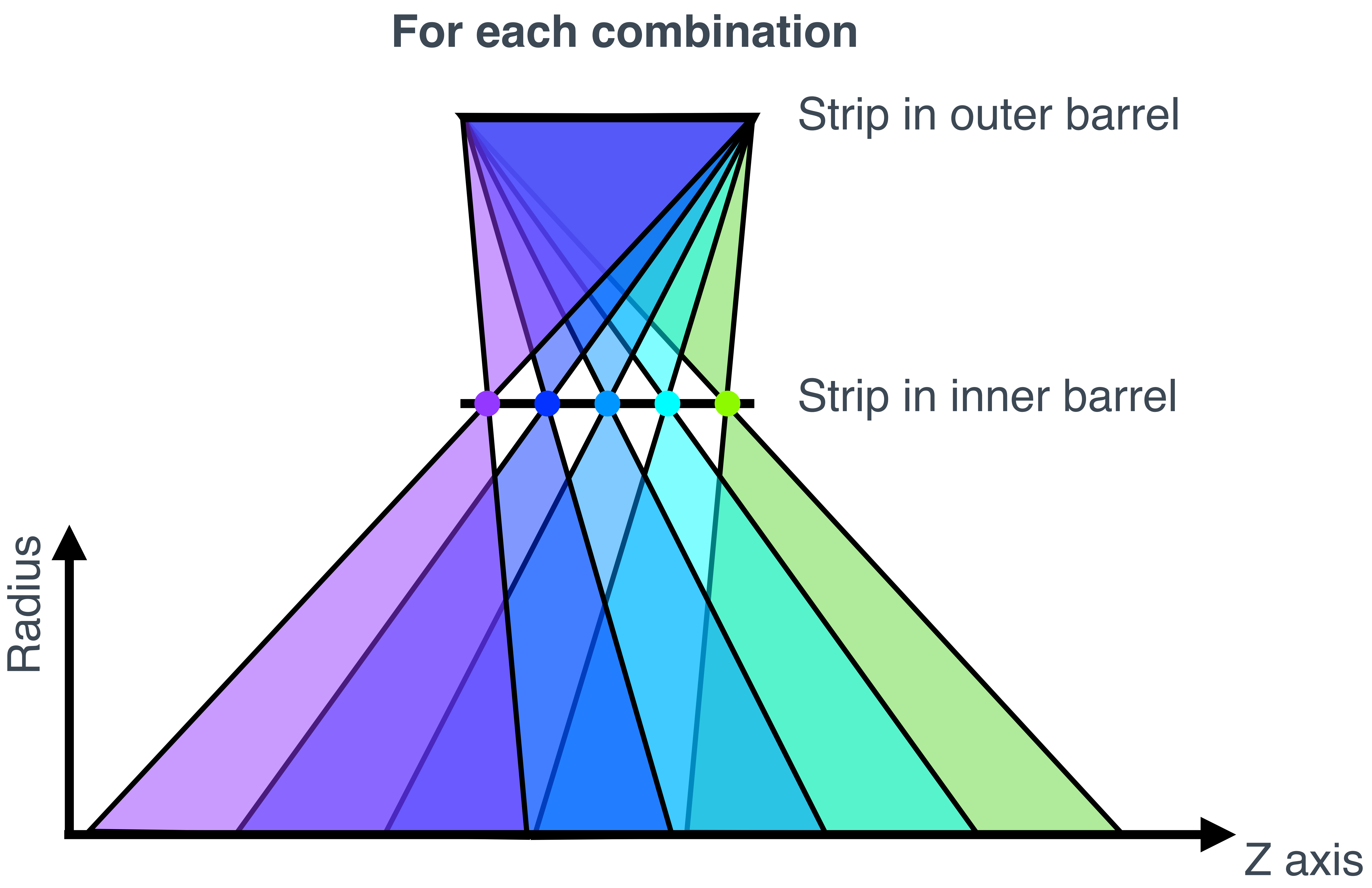

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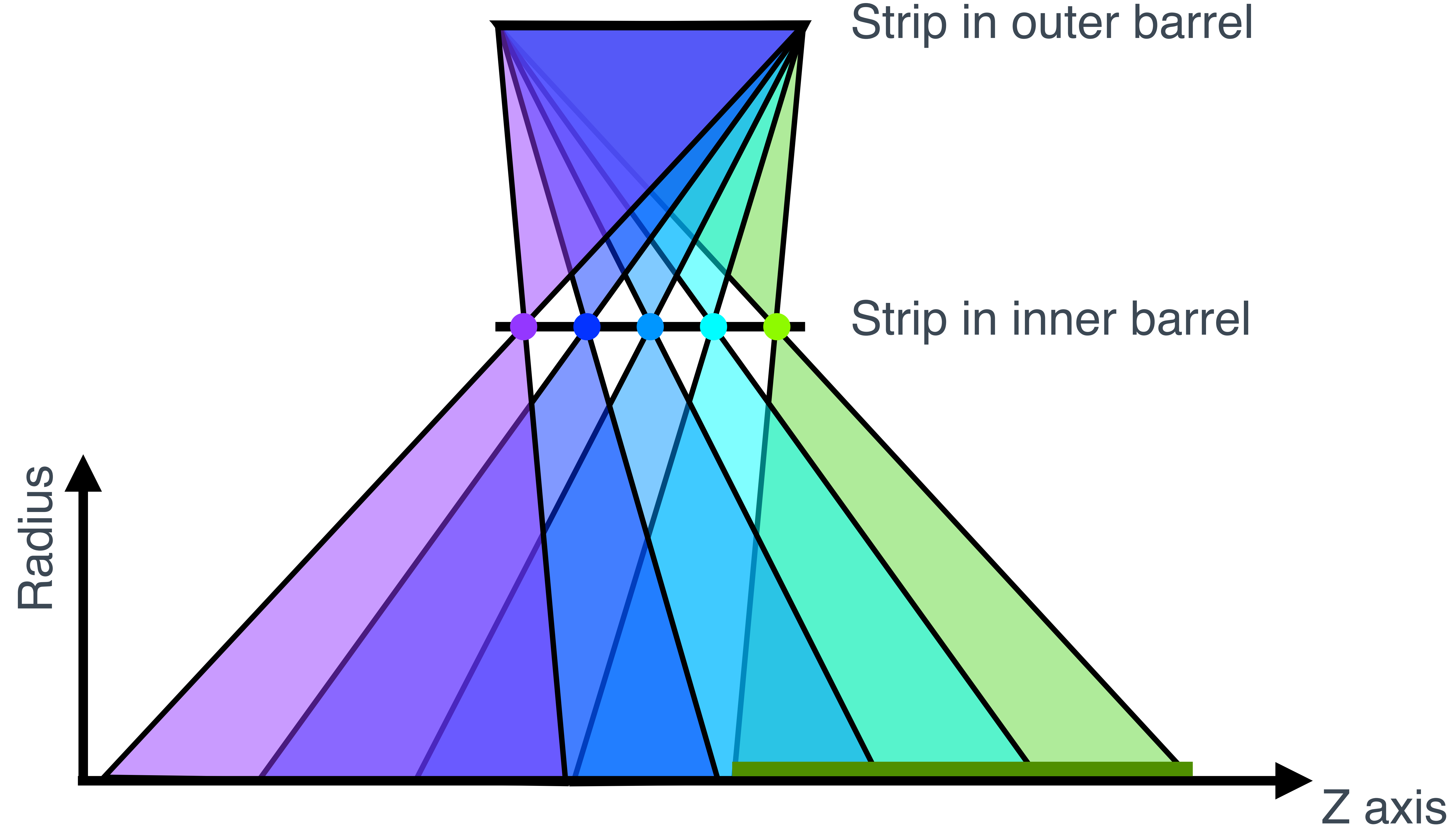

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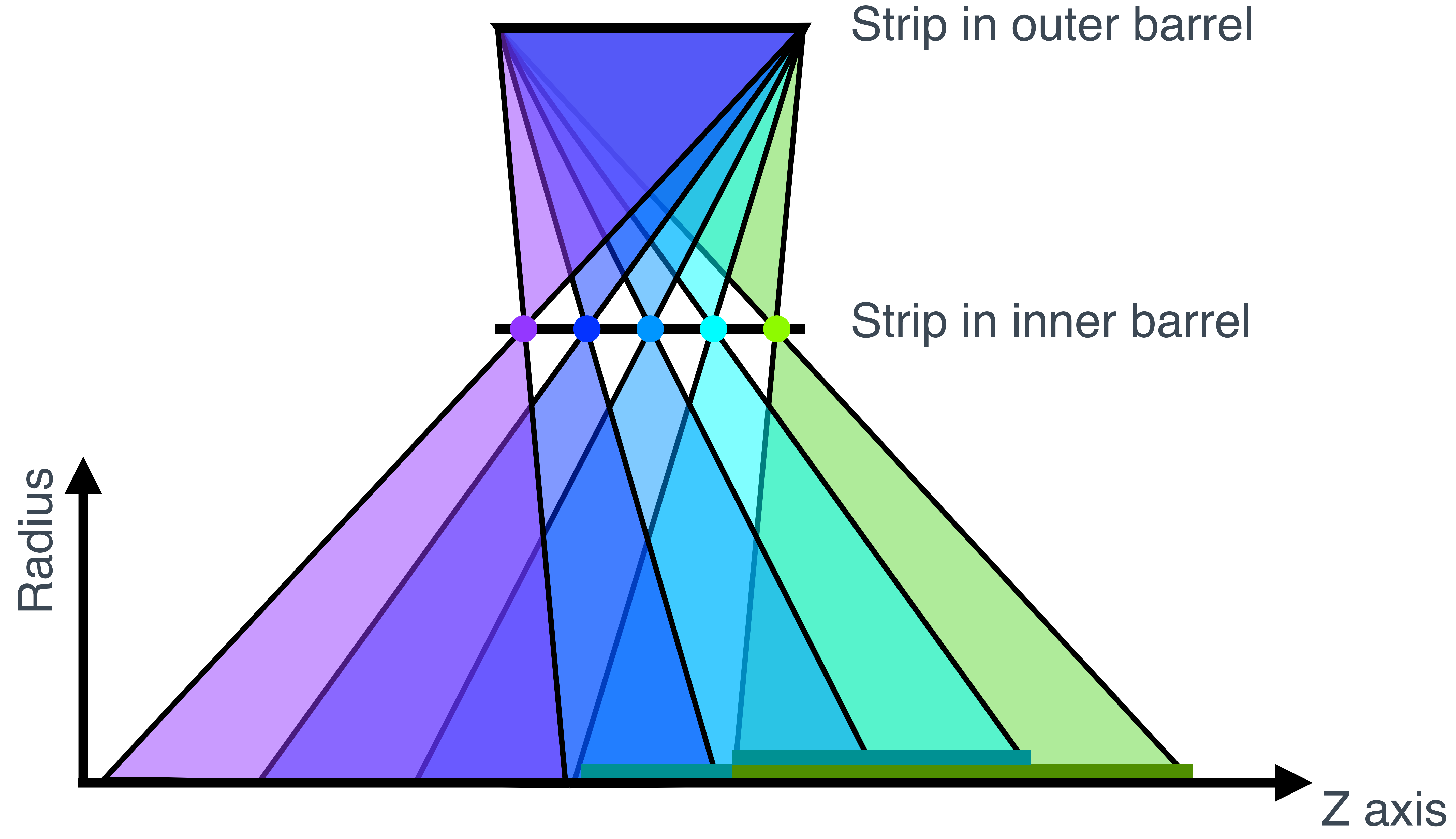

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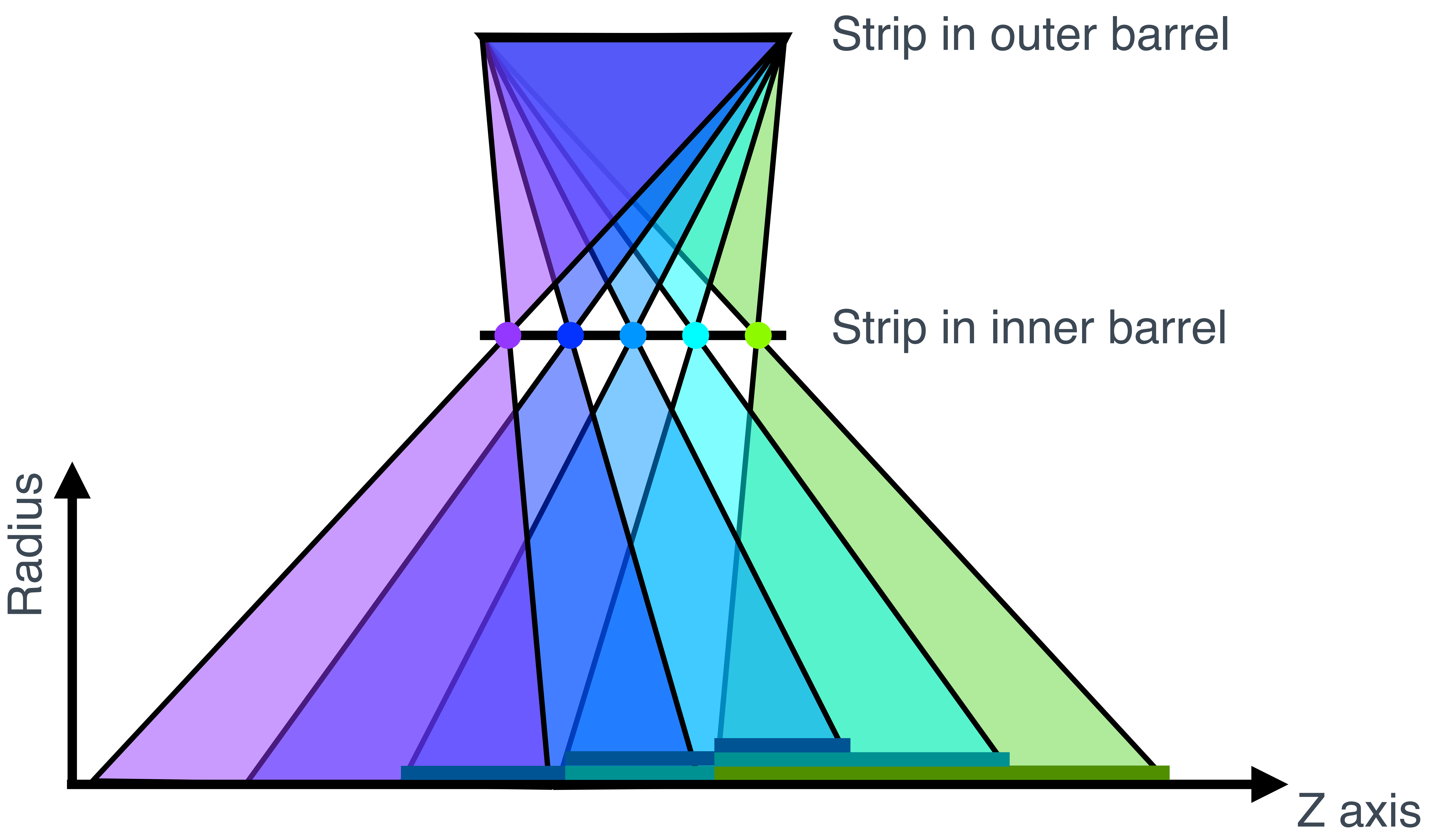

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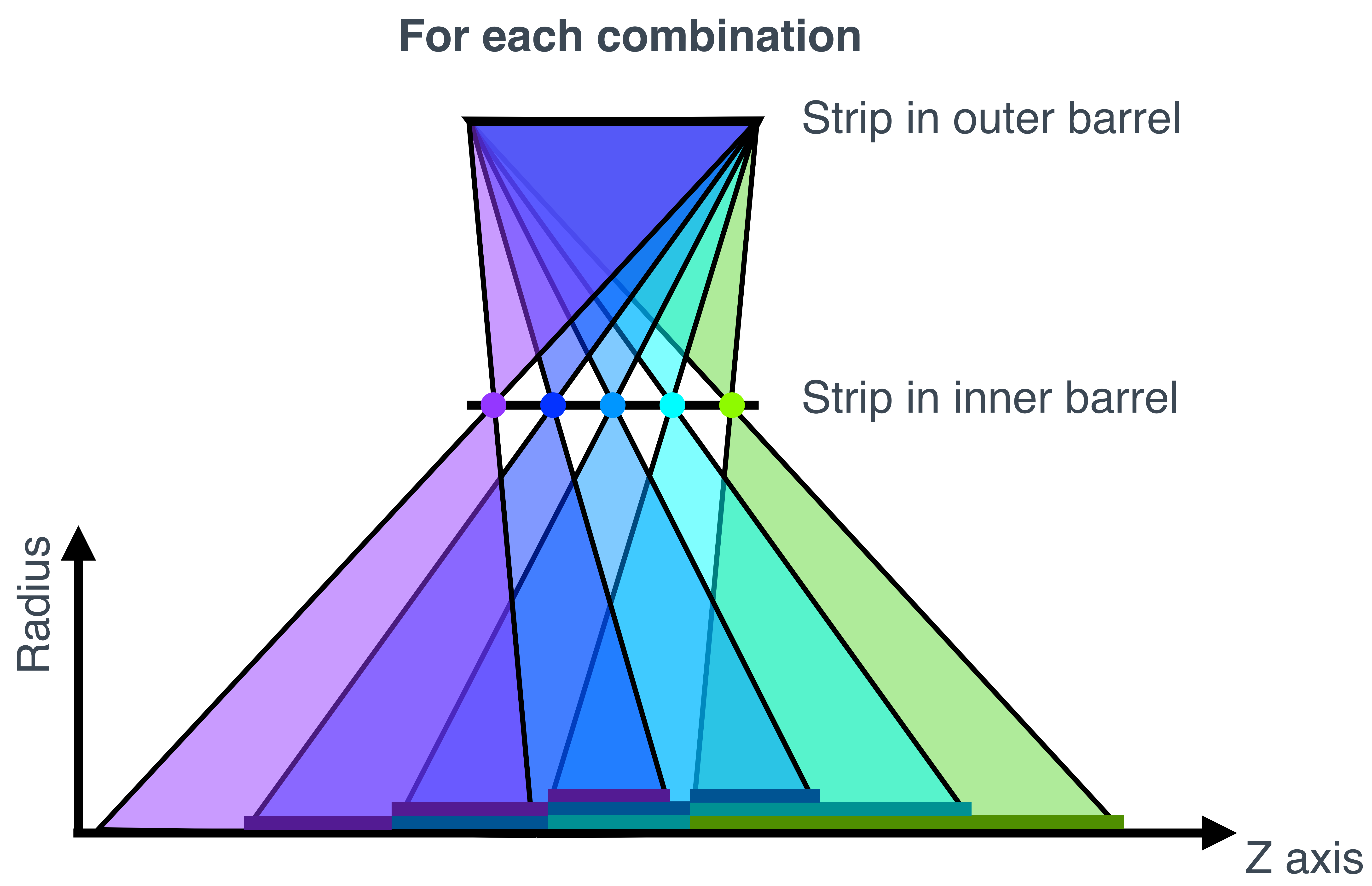

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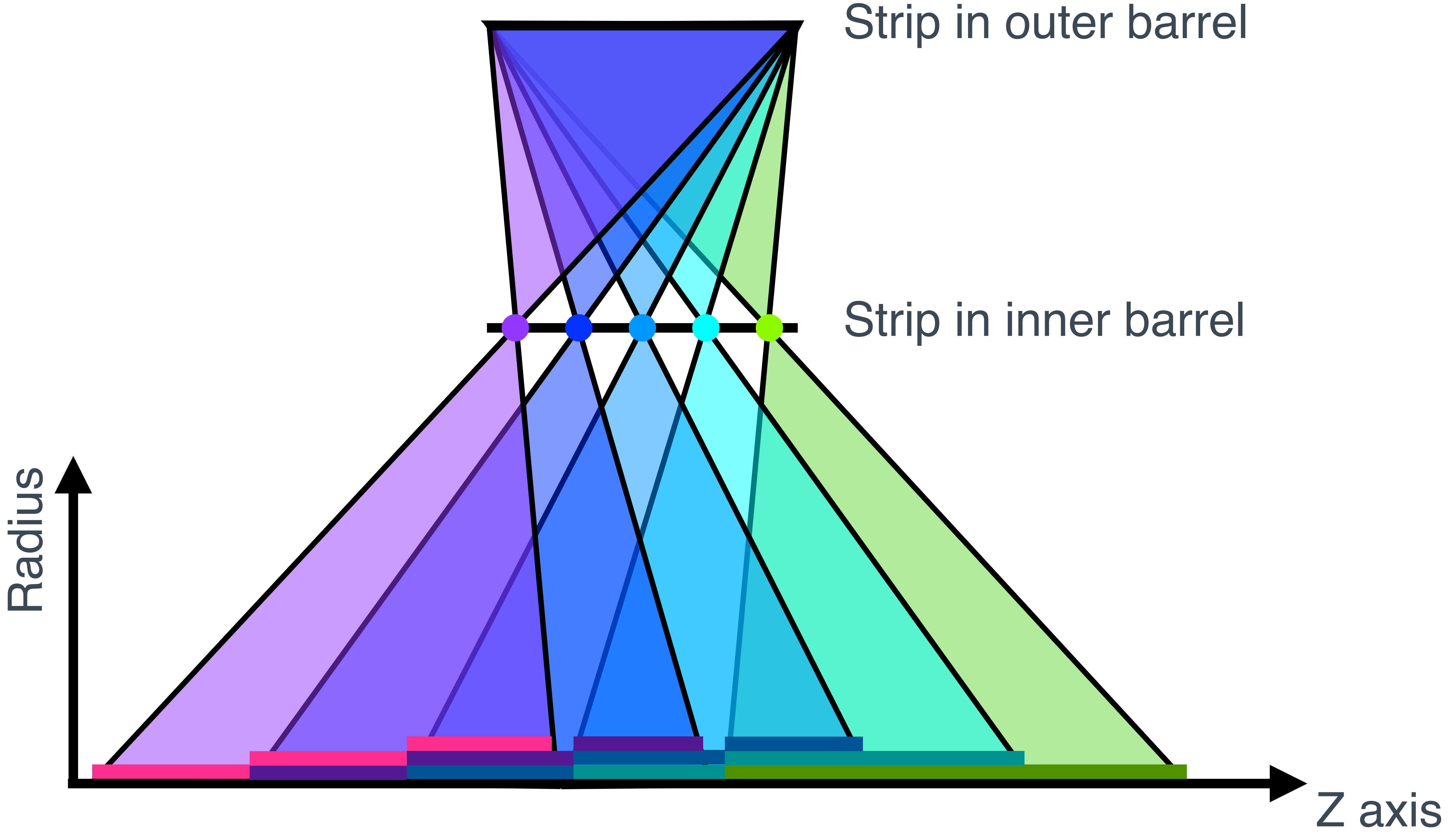

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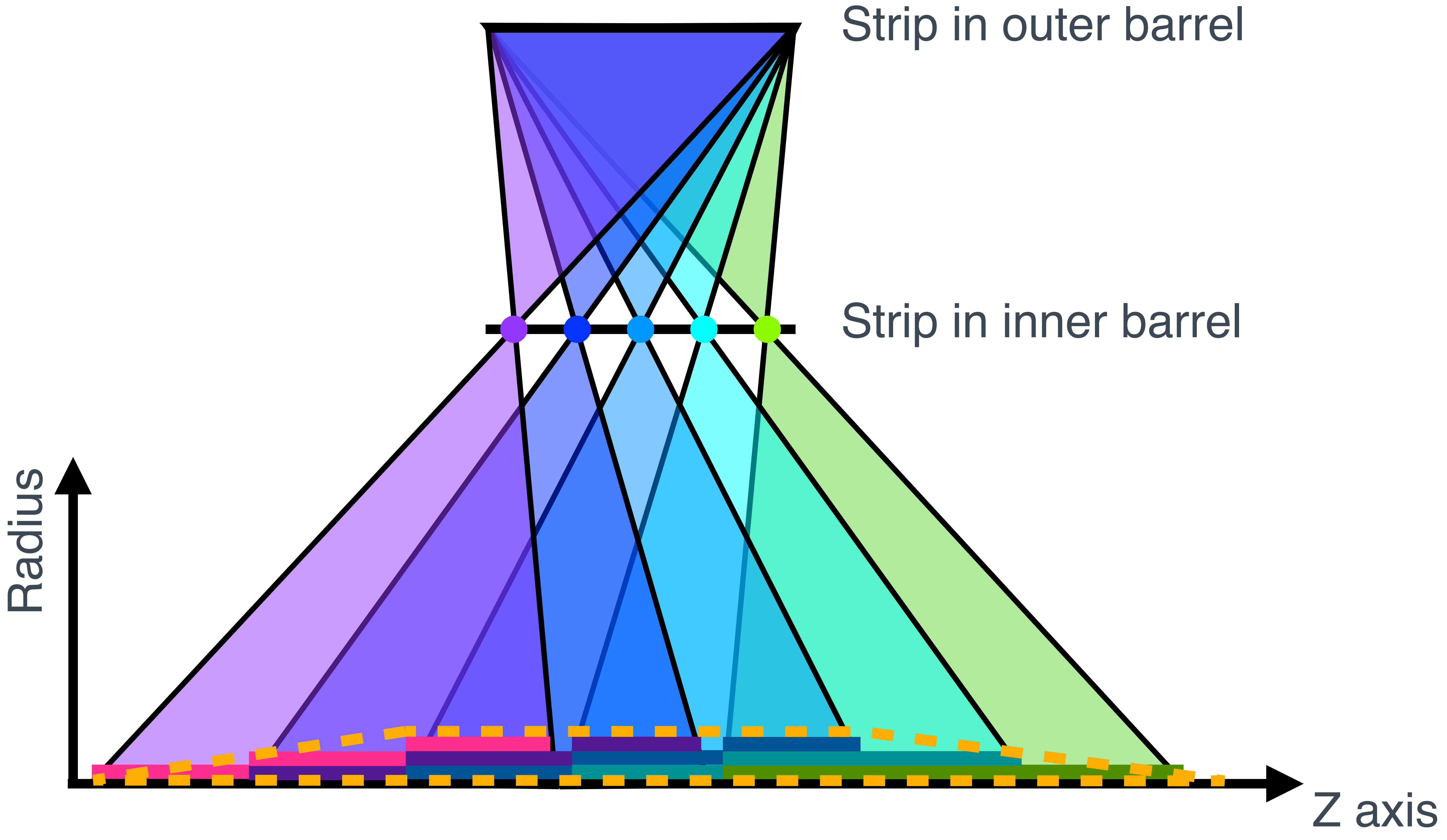

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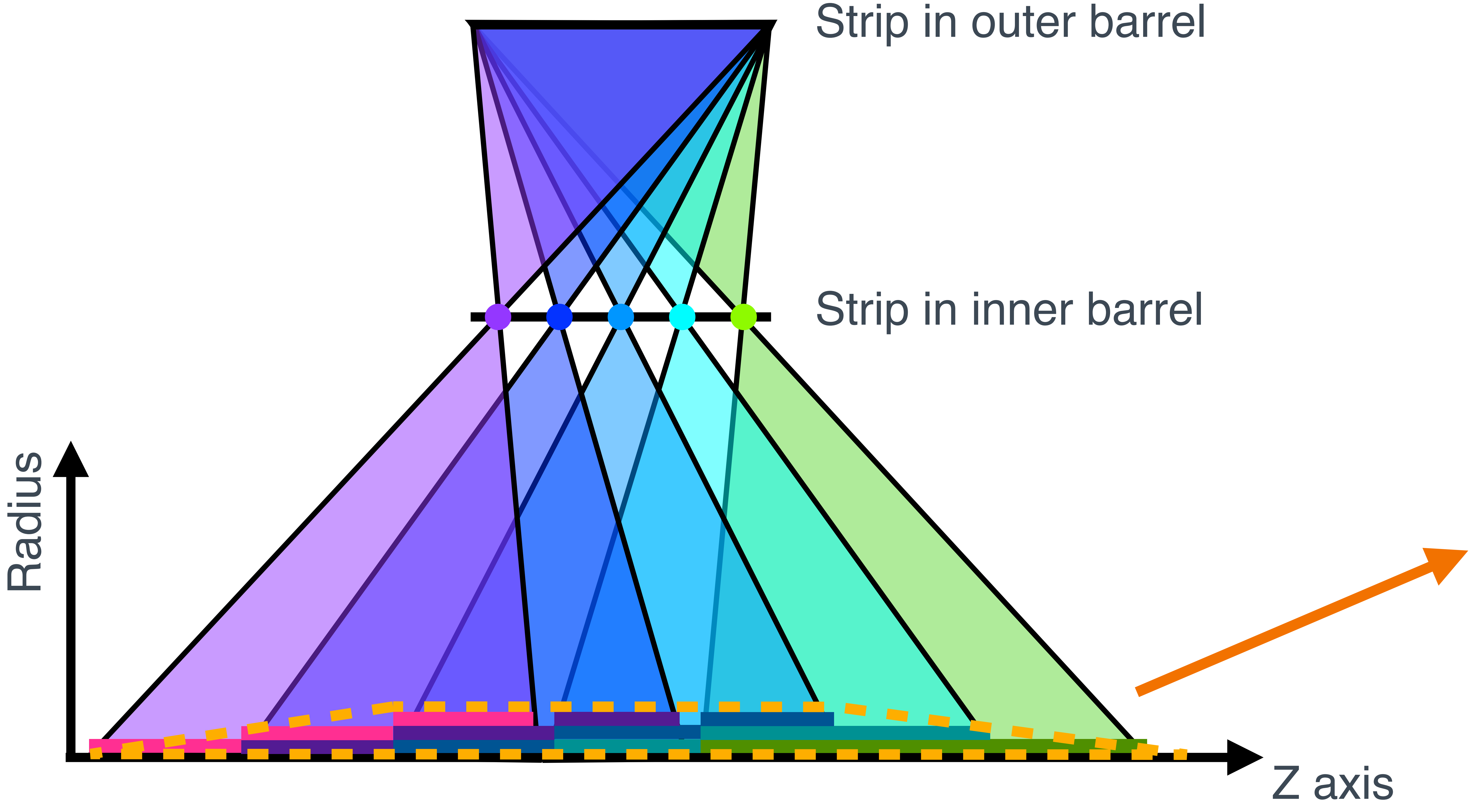

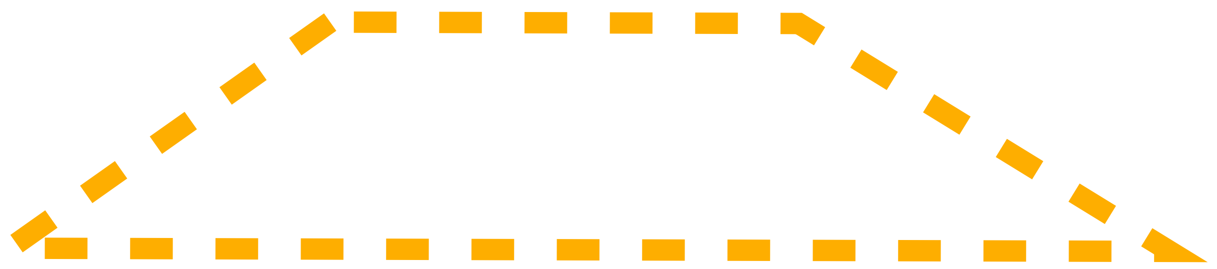

Trapezoidal shape for each combination

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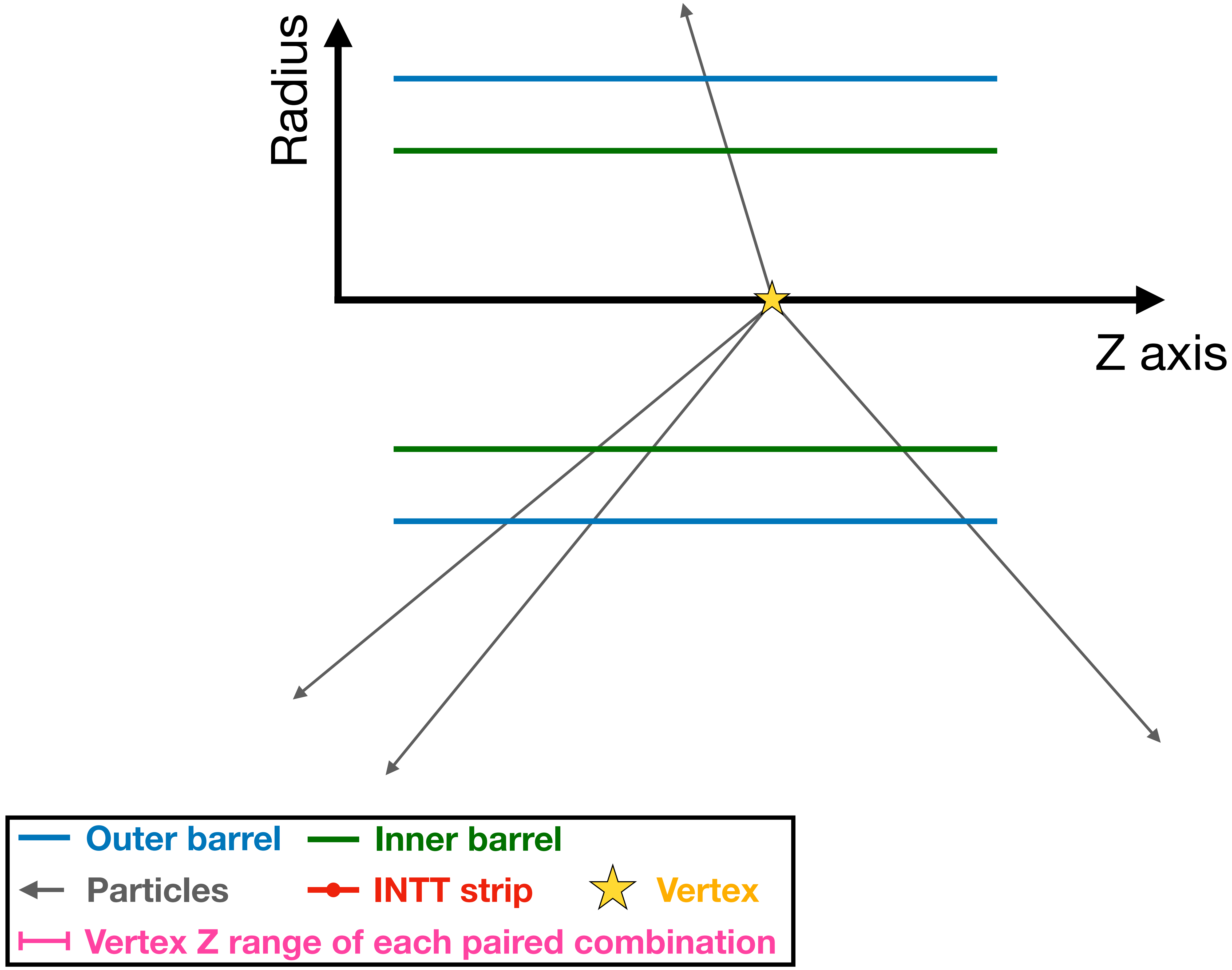
Per-event vertex Z reconstruction

sPHENIX

- Correct the cluster ϕ based on the reconstructed average vertex XY
- Loop over the combinations, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and $DCA \leqq DCA_{cut}$
- Move to the Z-radius plane



Demo

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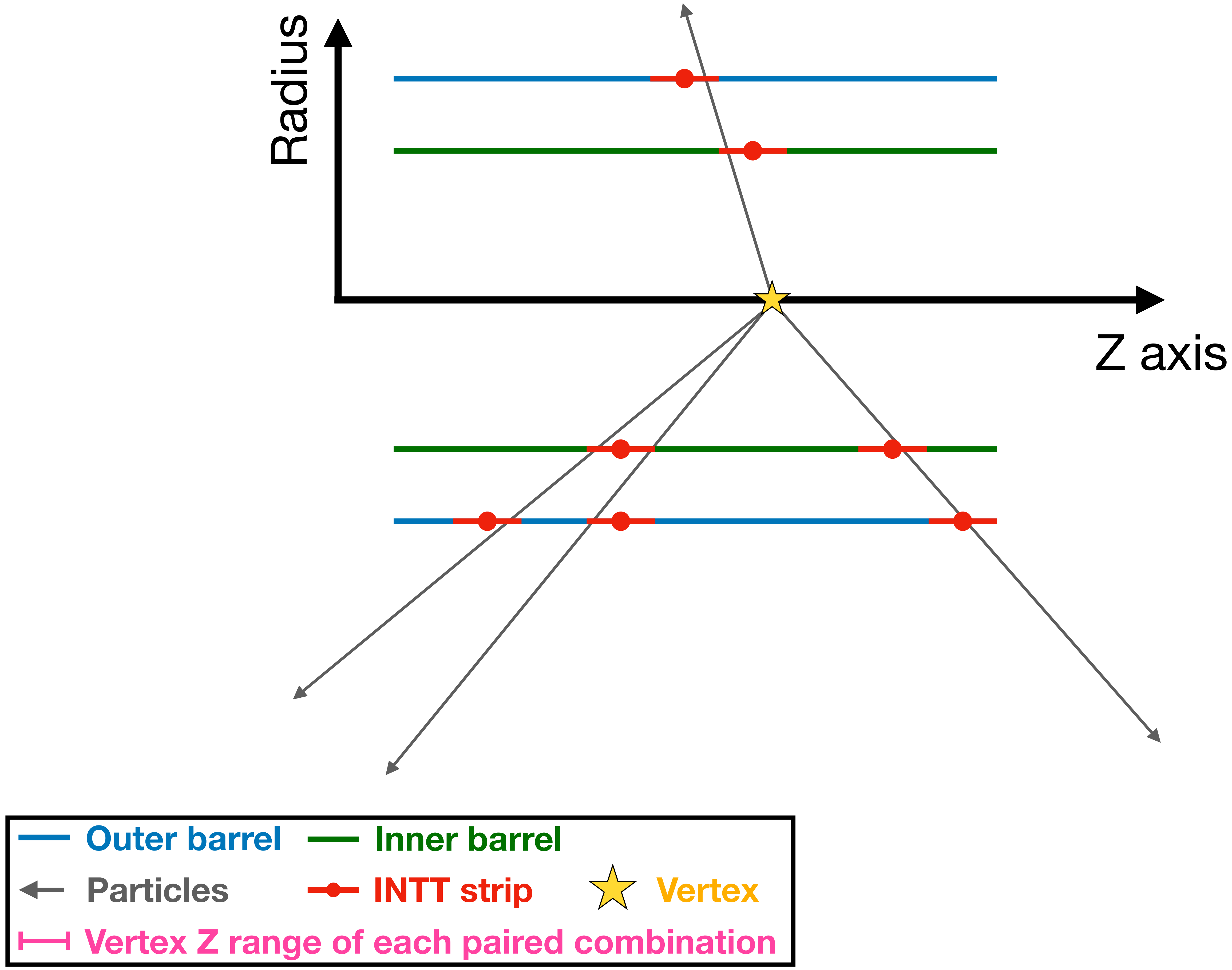

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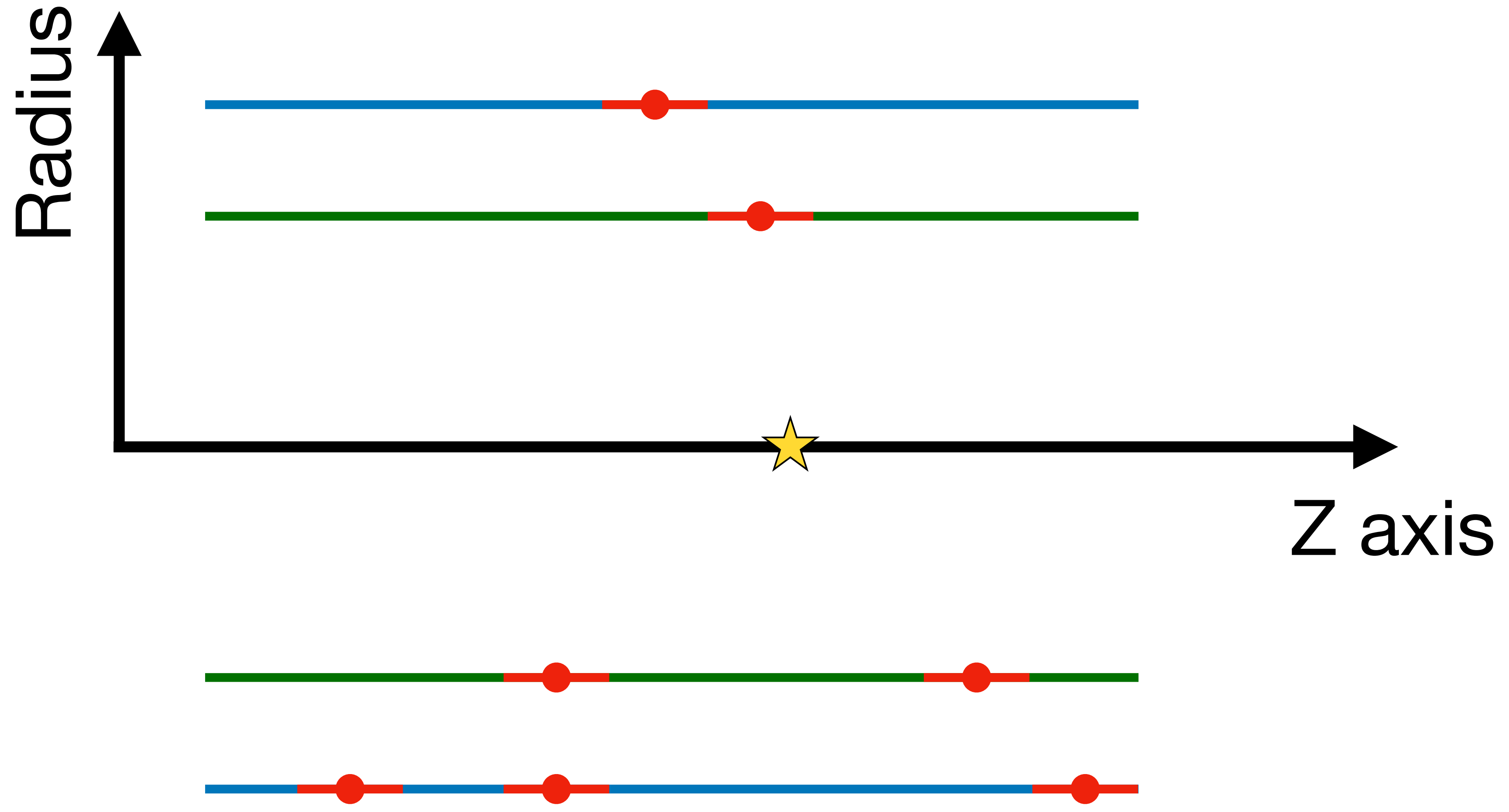

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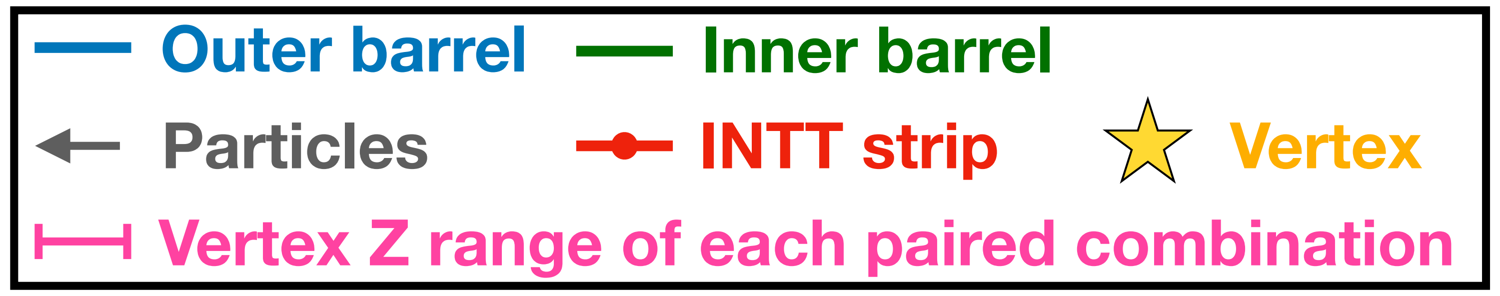

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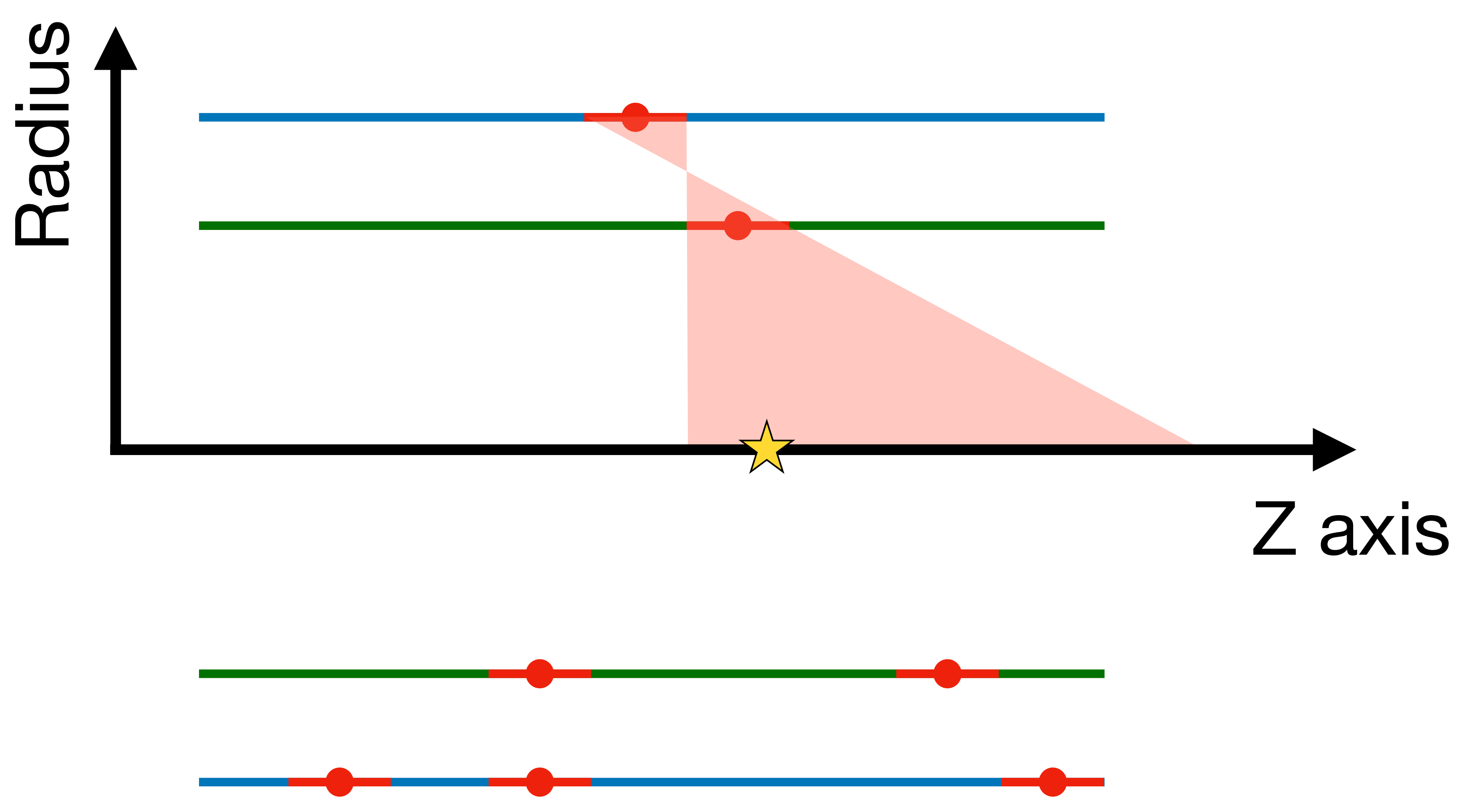

Demo

Outer barrel — Inner barrel
Particles — INTT strip — Vertex
Vertex Z range of each paired combination

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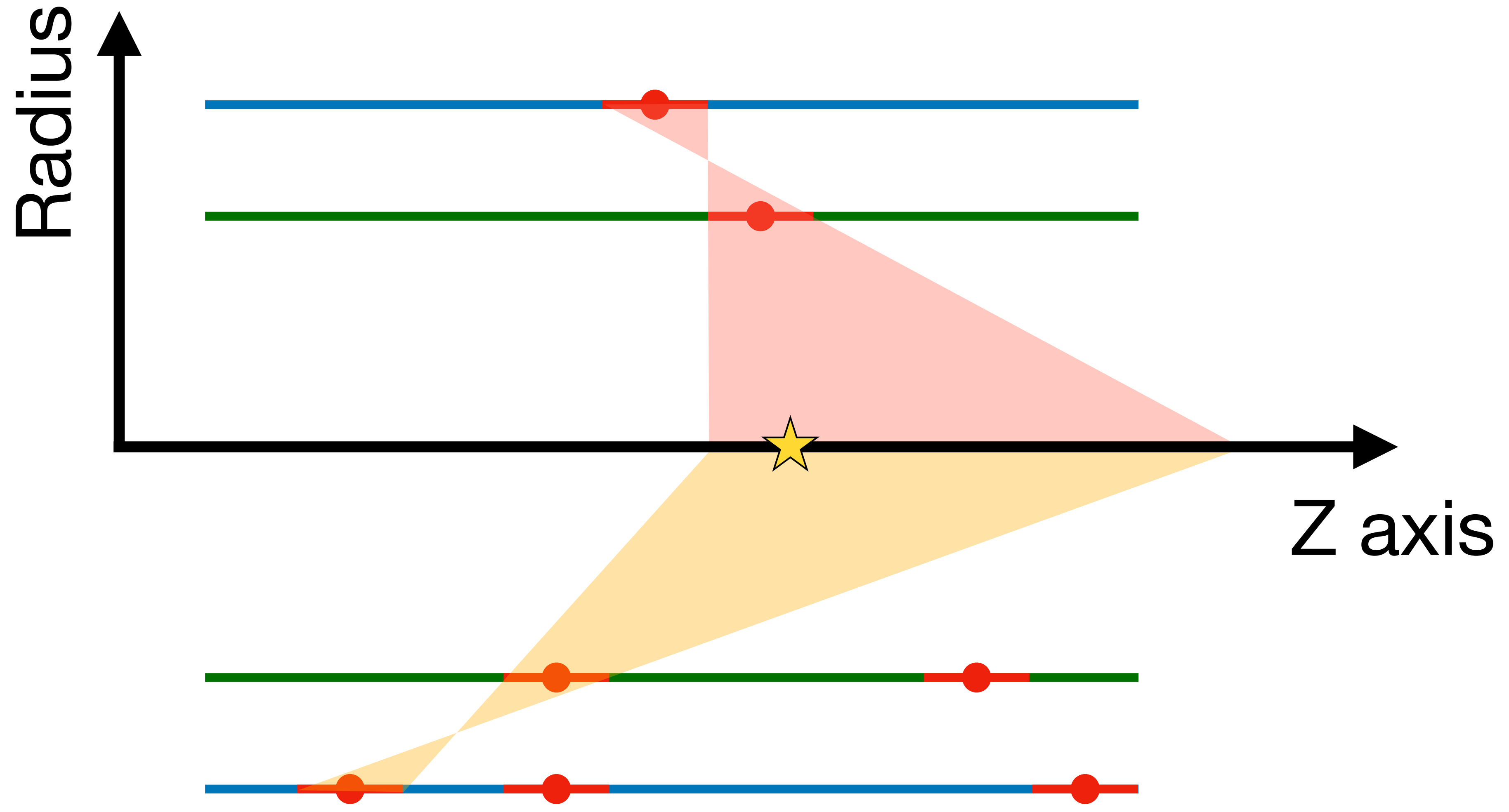

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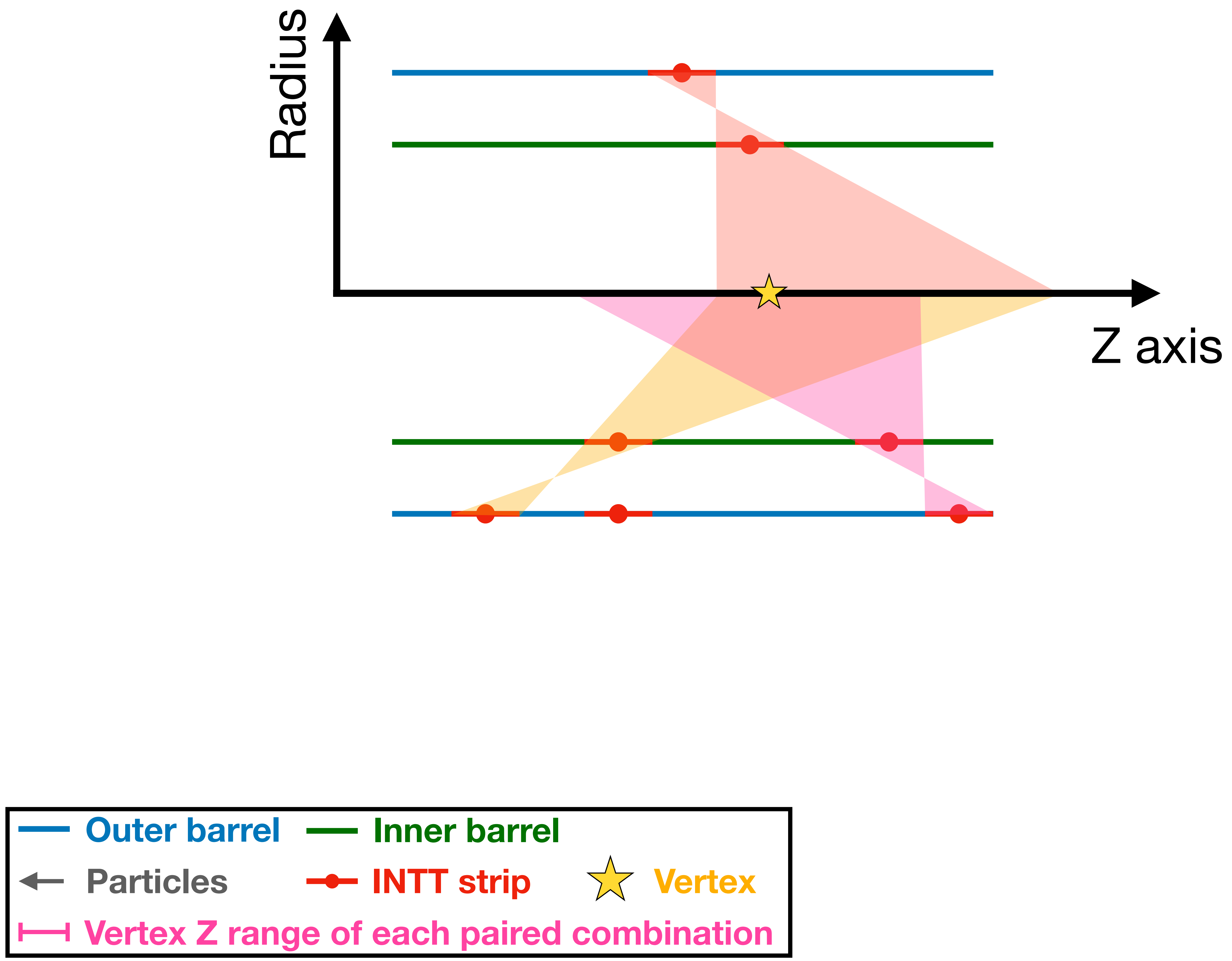

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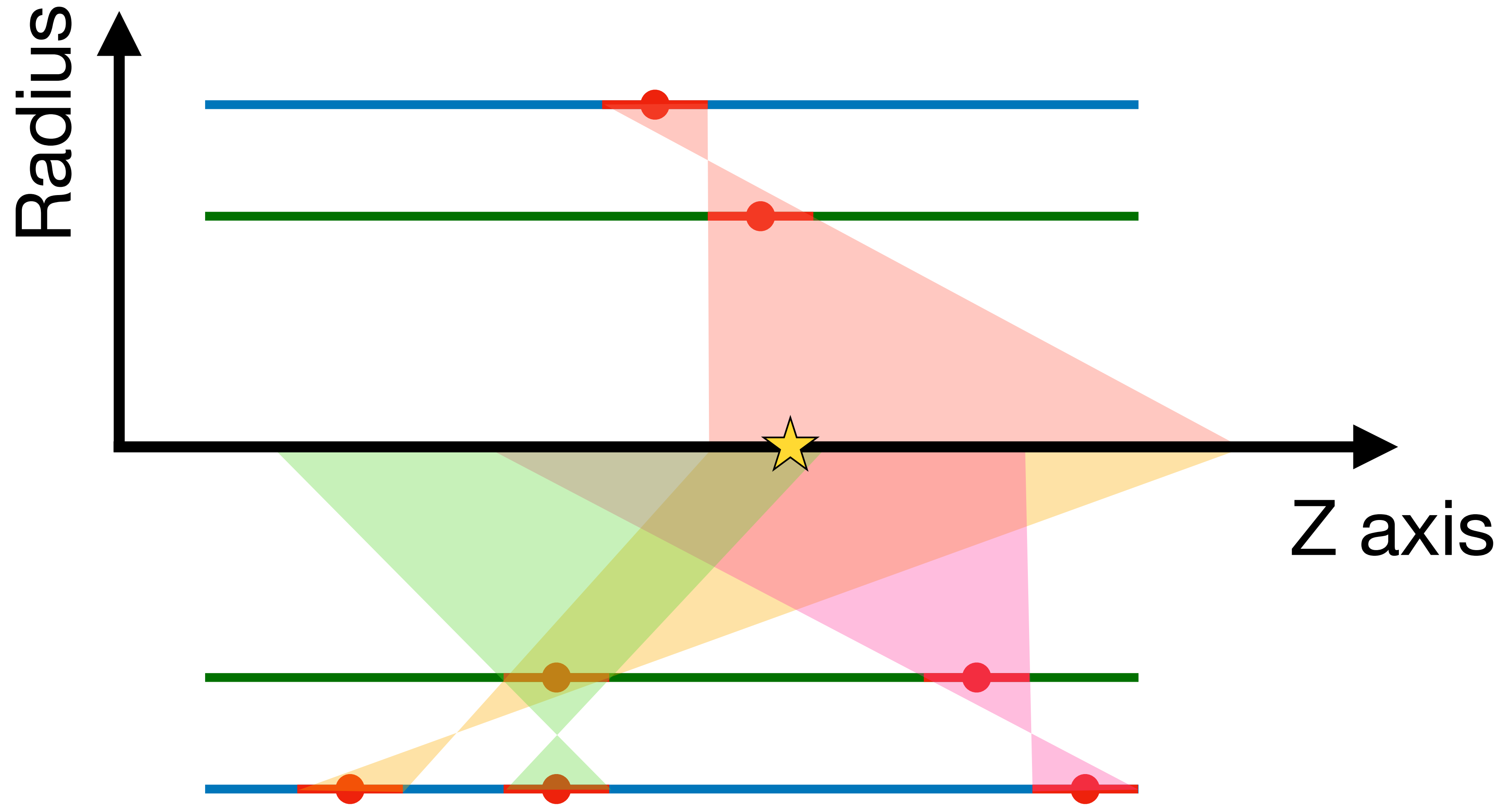
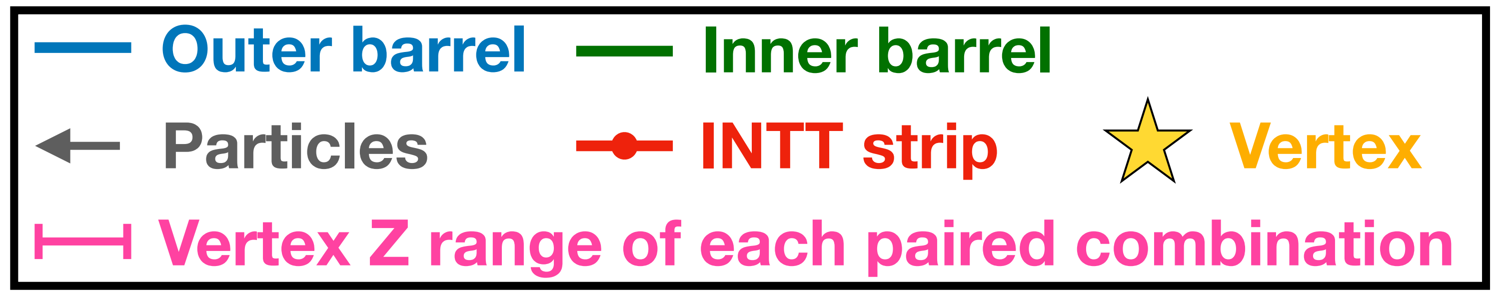
- Loop over the combinations, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and DCA $\leqq DCA_{cut}$
- Move to the Z-radius plane

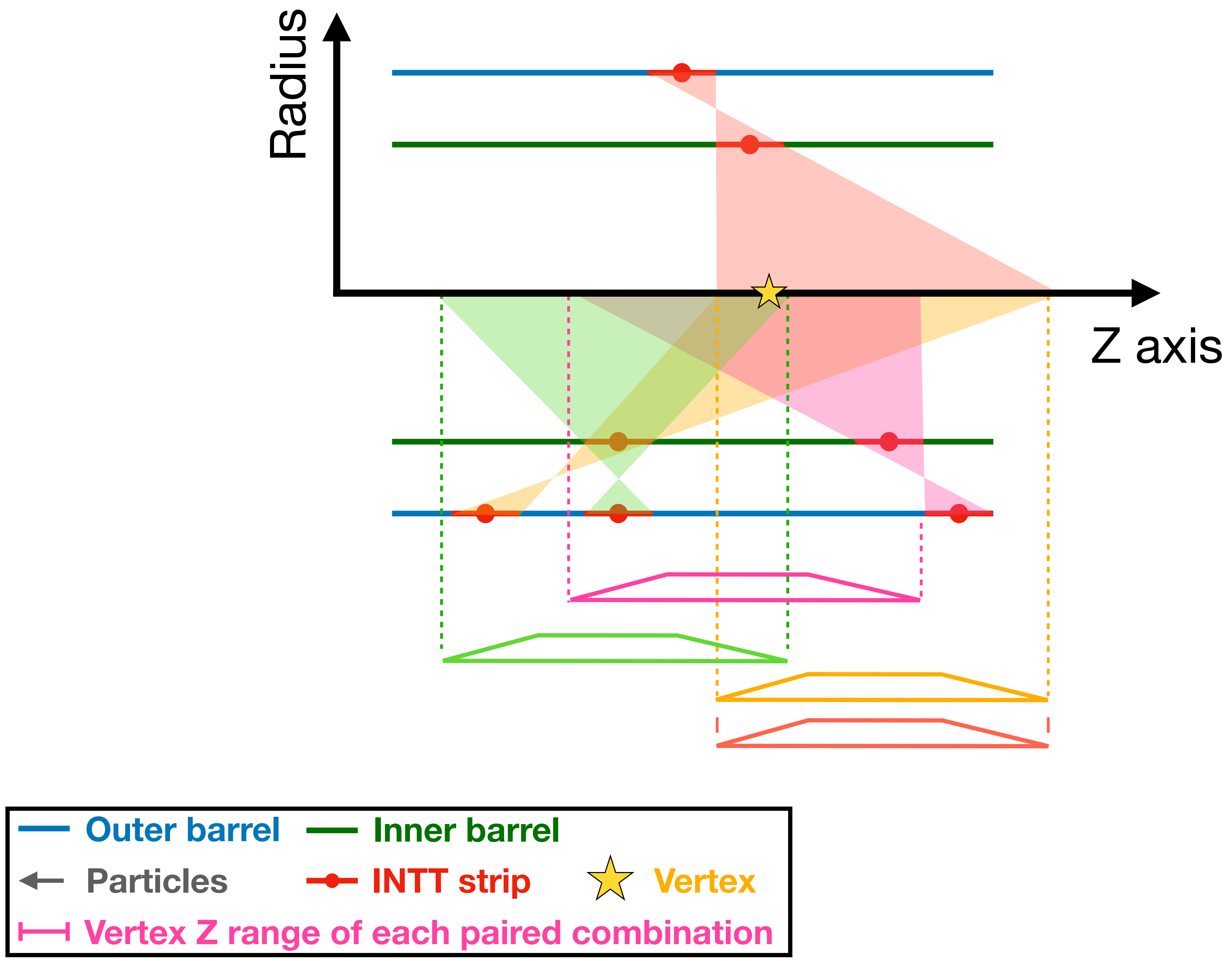


Demo



Per-event vertex Z reconstruction

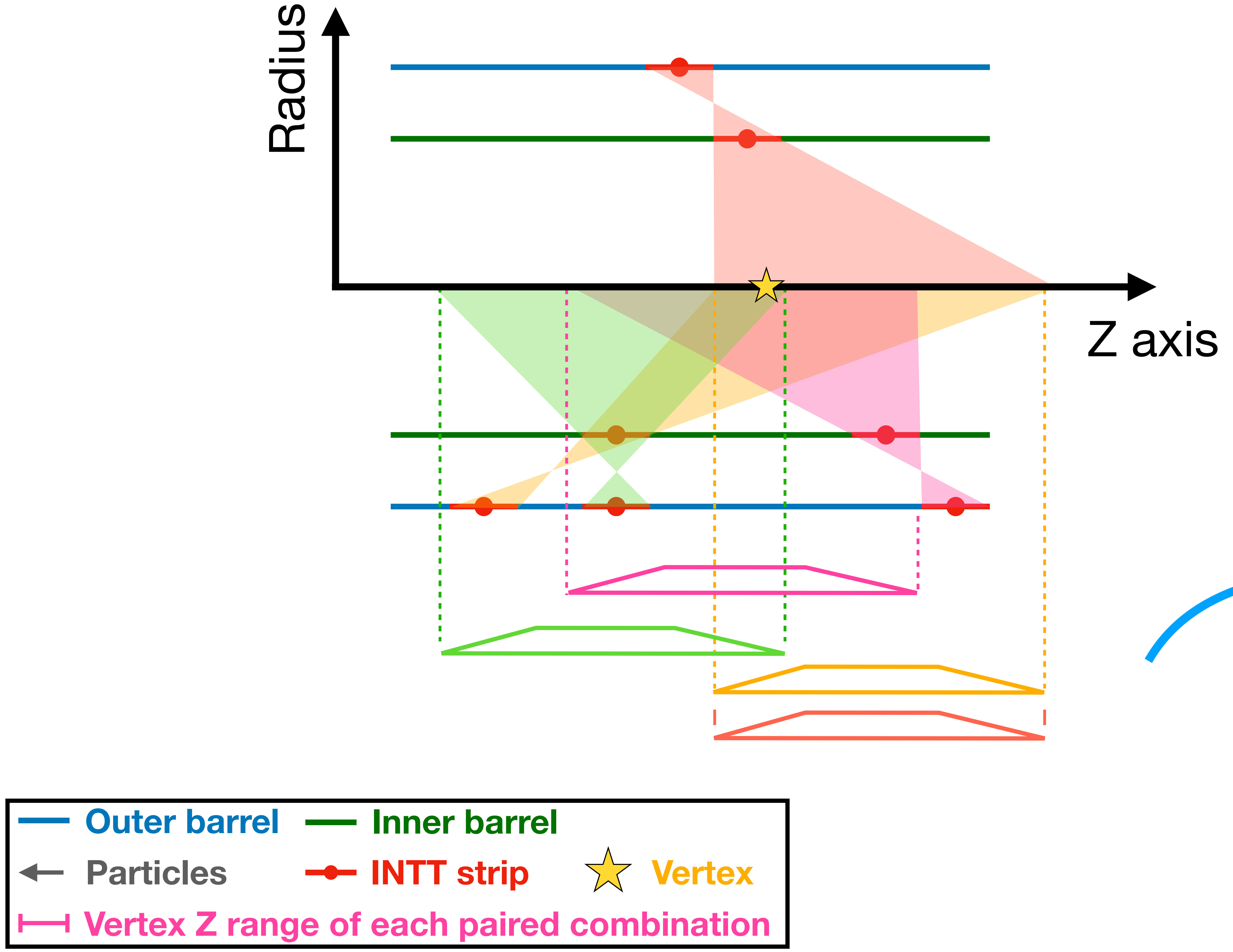
- Correct the cluster ϕ based on the reconstructed average vertex XY
- Loop over the combinations, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and $DCA \leqq DCA_{cut}$
- Move to the Z-radius plane

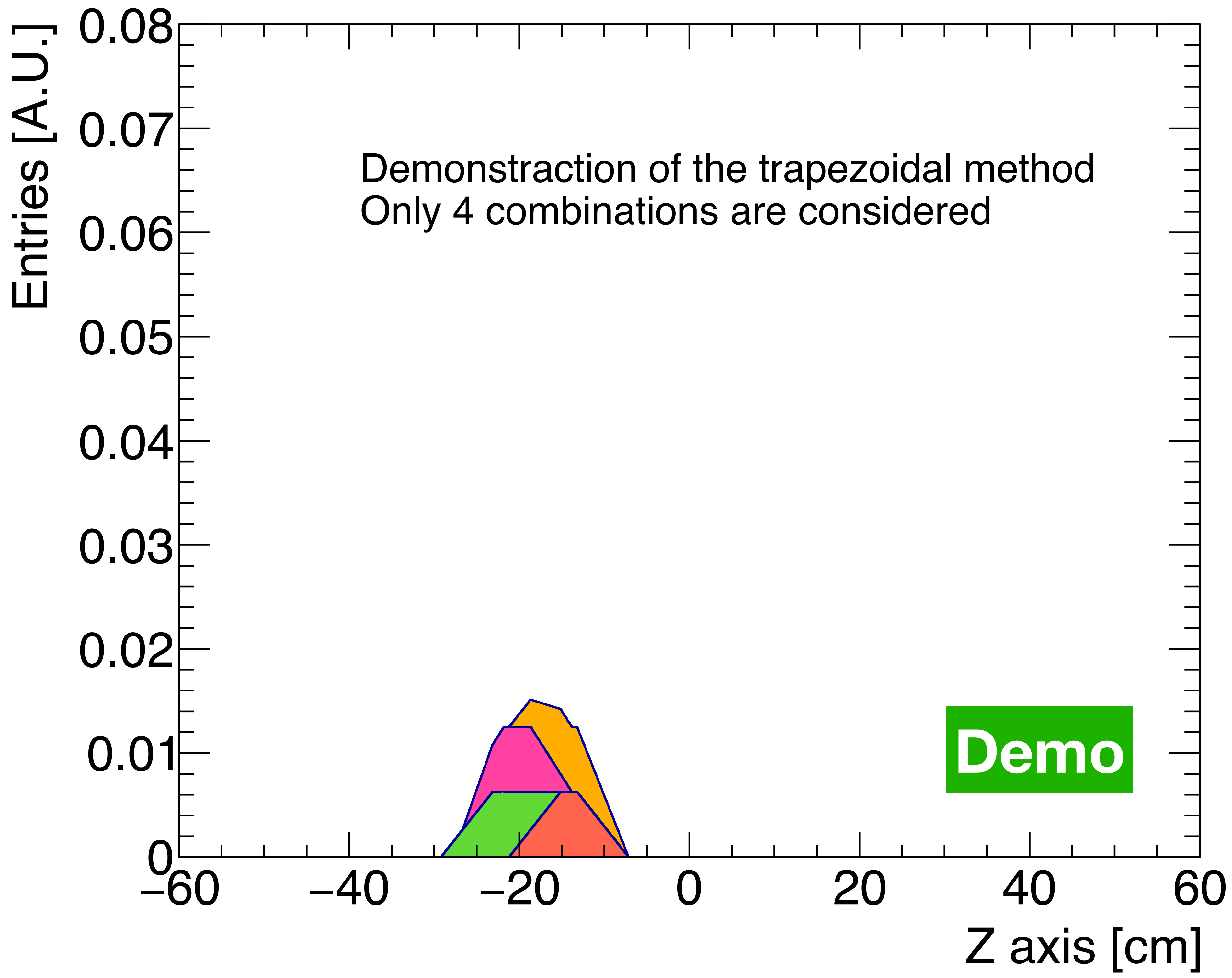


Demo

Per-event vertex Z reconstruction

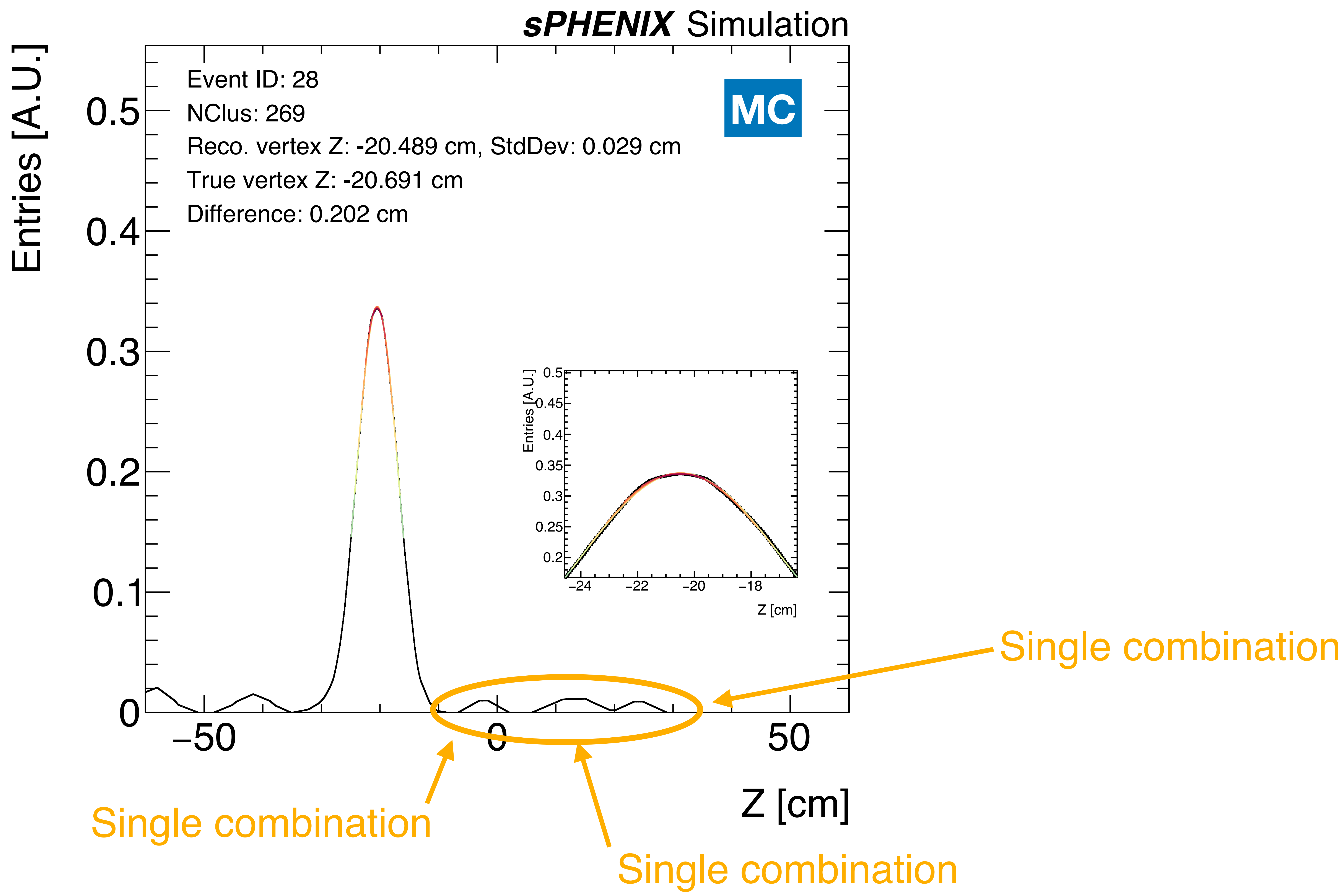
- Correct the cluster ϕ based on the reconstructed average vertex XY
- Loop over the combinations, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and DCA $\leqq DCA_{cut}$
- Move to the Z-radius plane





Per-event vertex Z reconstruction

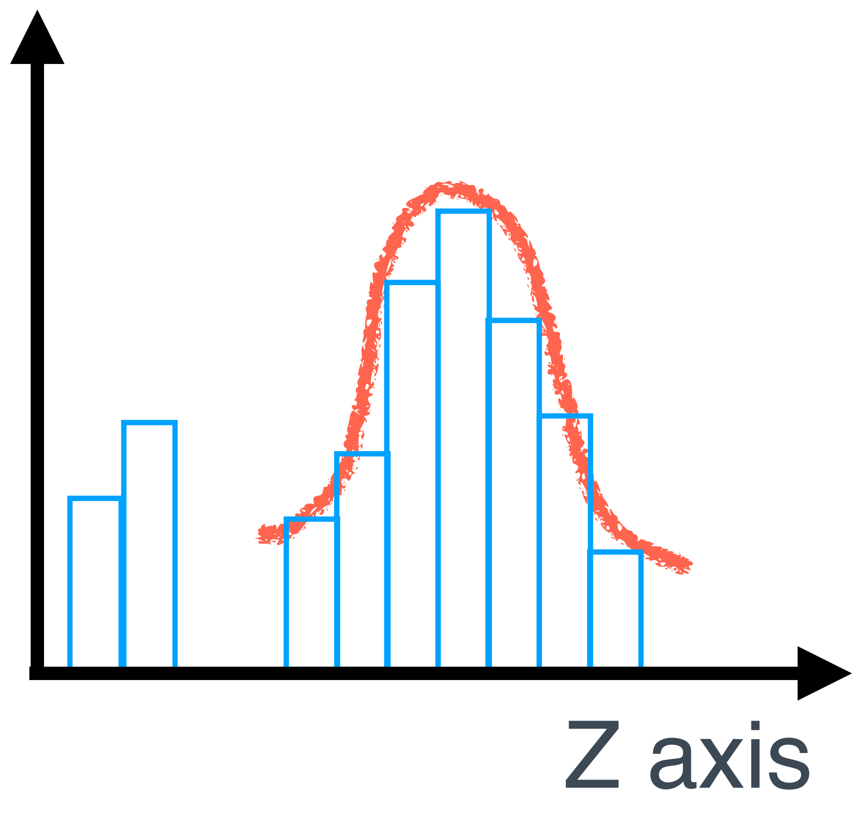
Final vertex Z given by average of 7 gaussian fits with the fit ranges of “mean ±(0.2 + 0.15 x i) x **FWHM**”

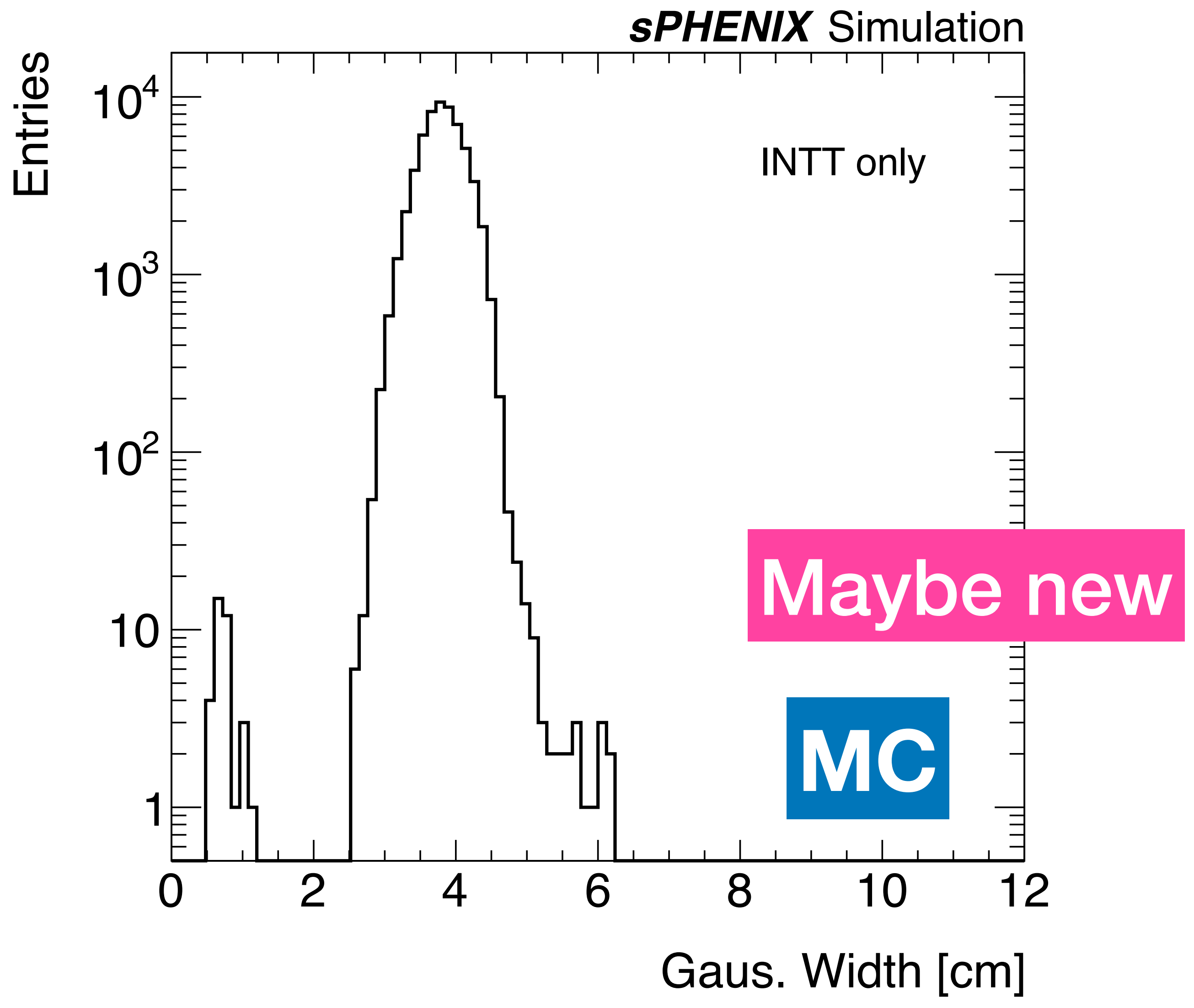


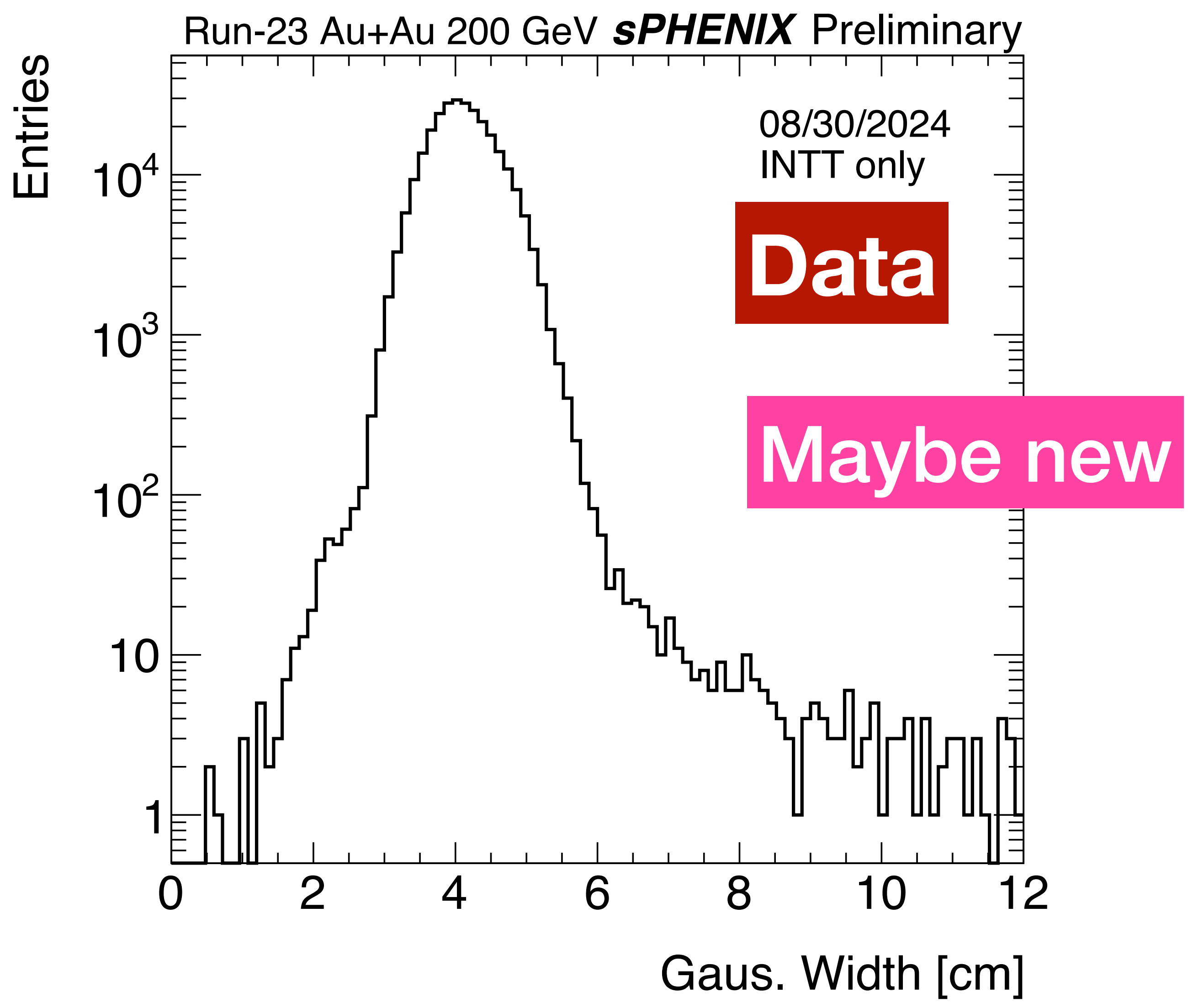
The vertex distribution quality assurance

20 < Width of fit “gaus func + offset“ < 55

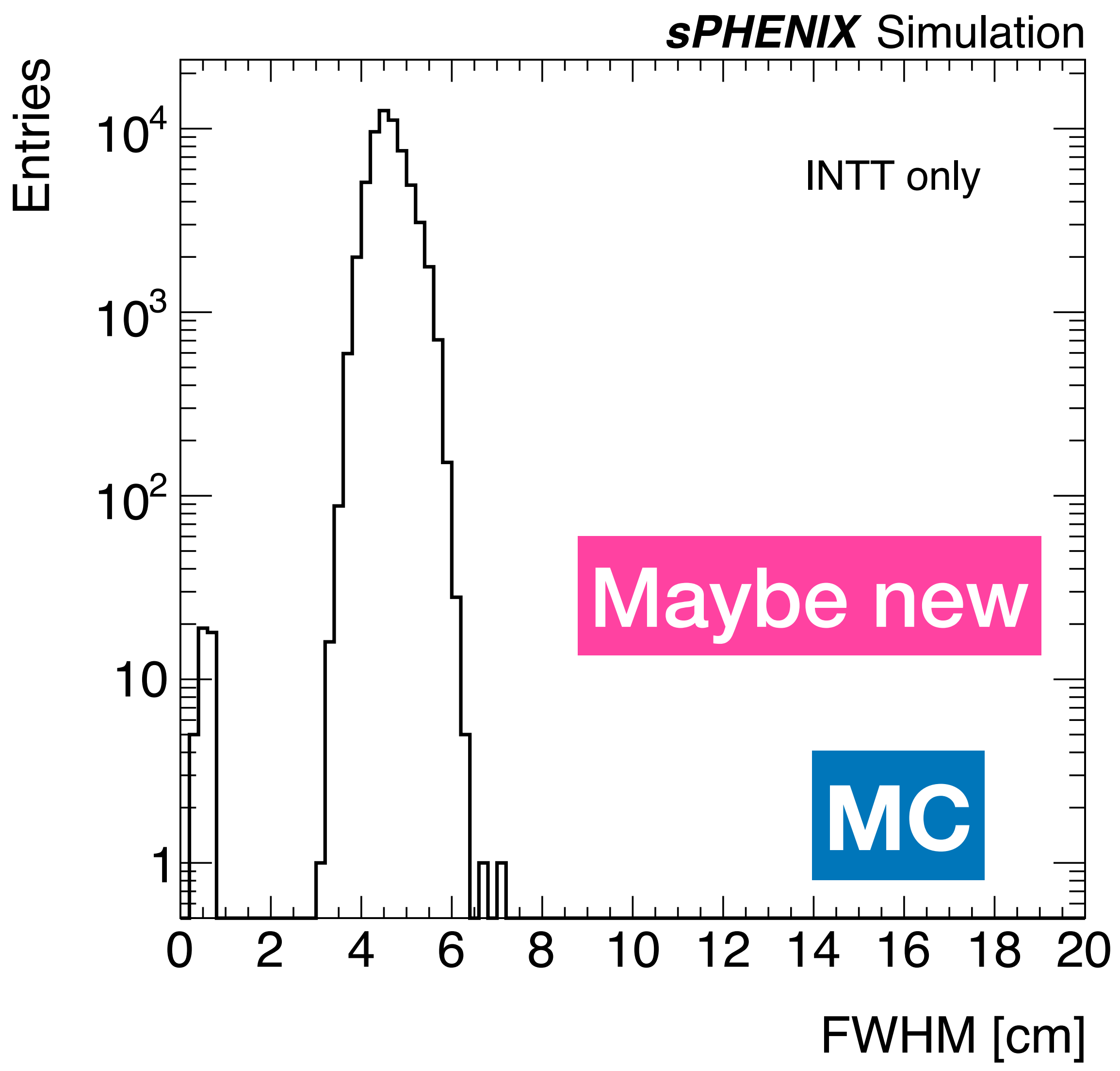
“gaus + offset” fit width

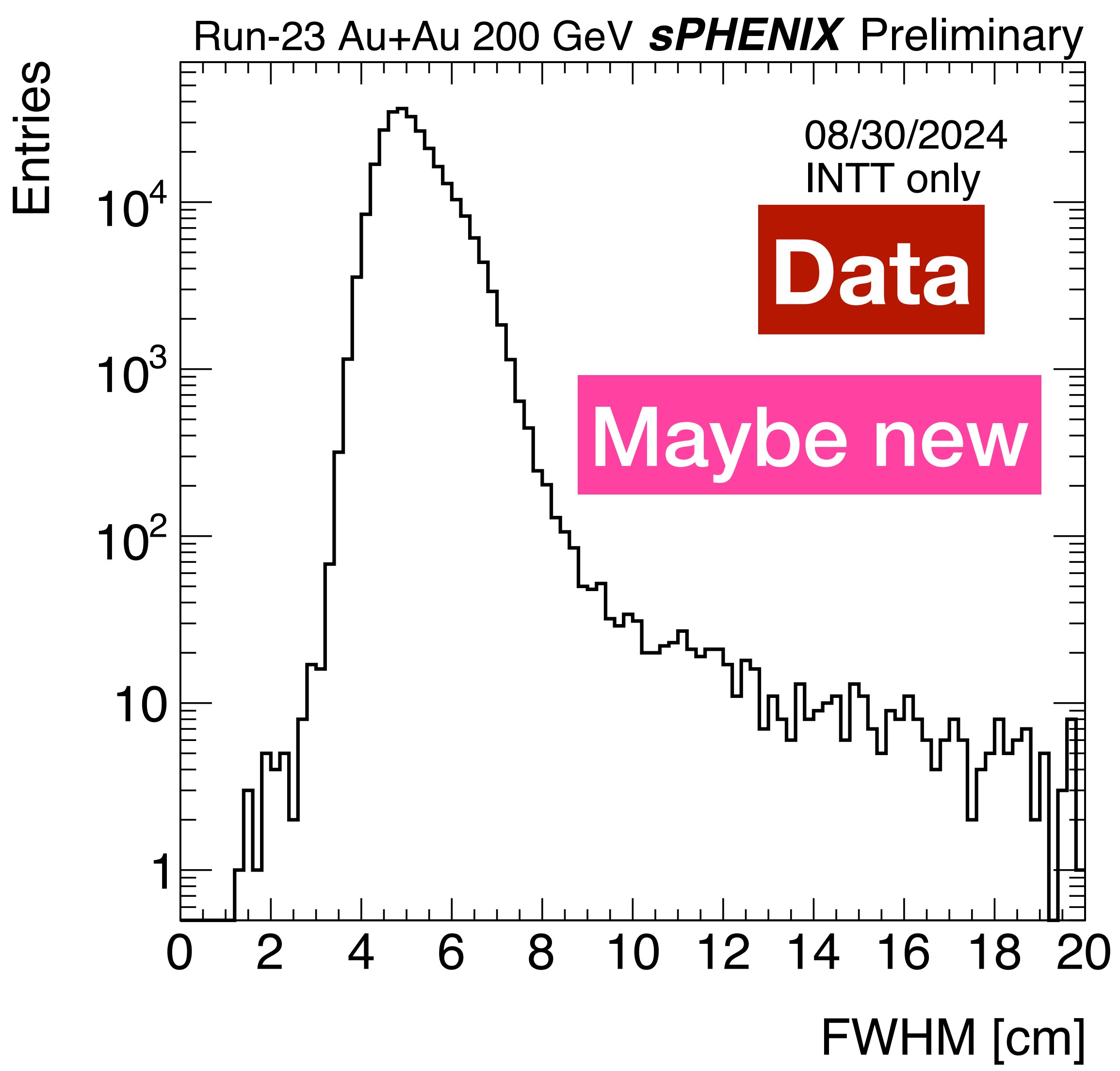


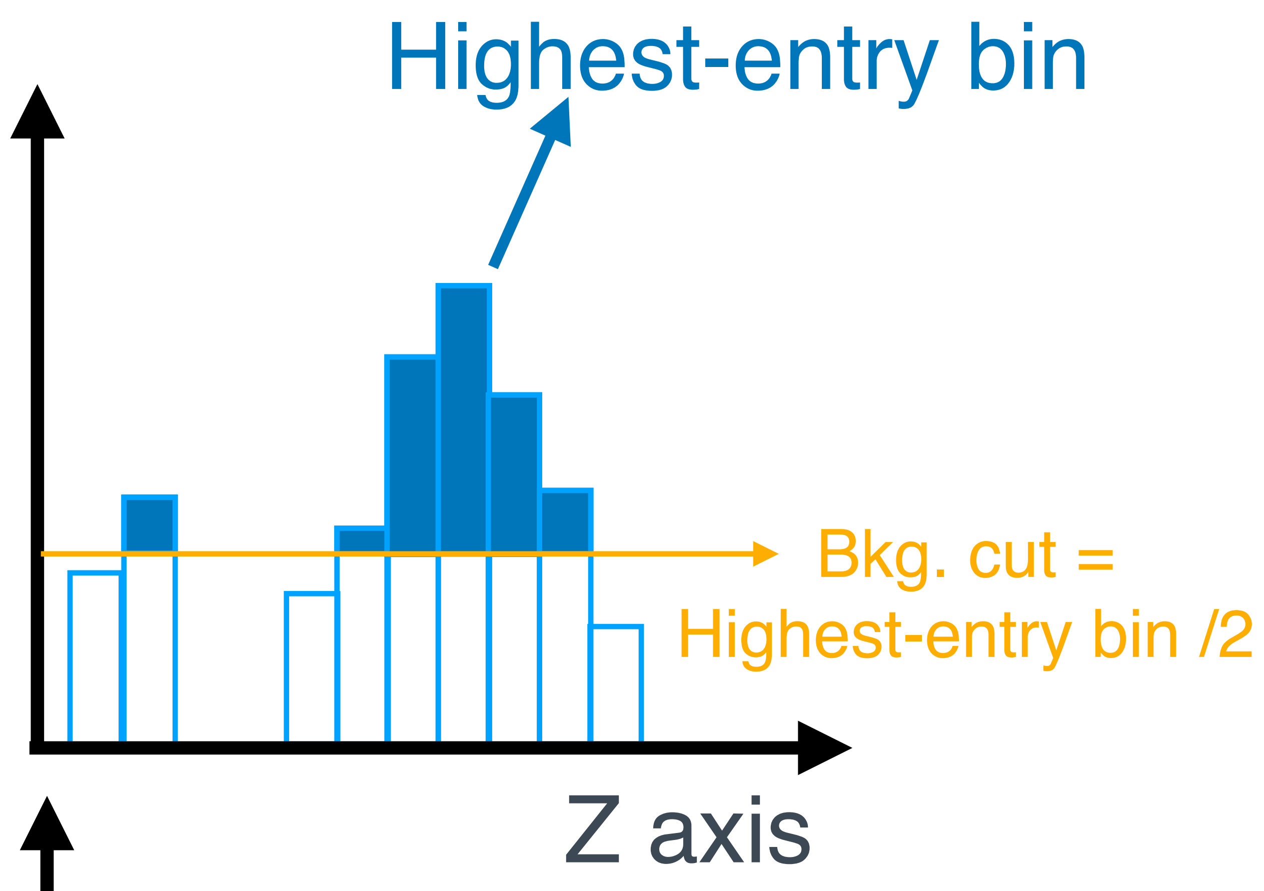


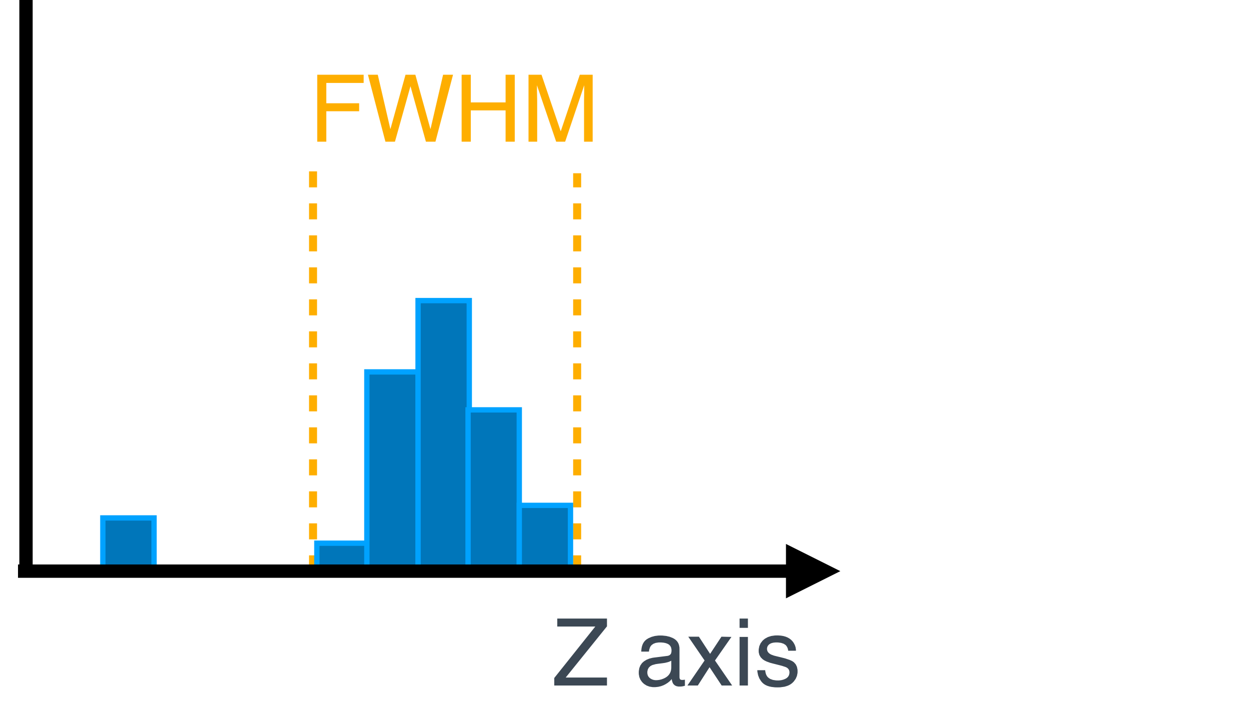


20 < Width of z_range_hist cut < 80







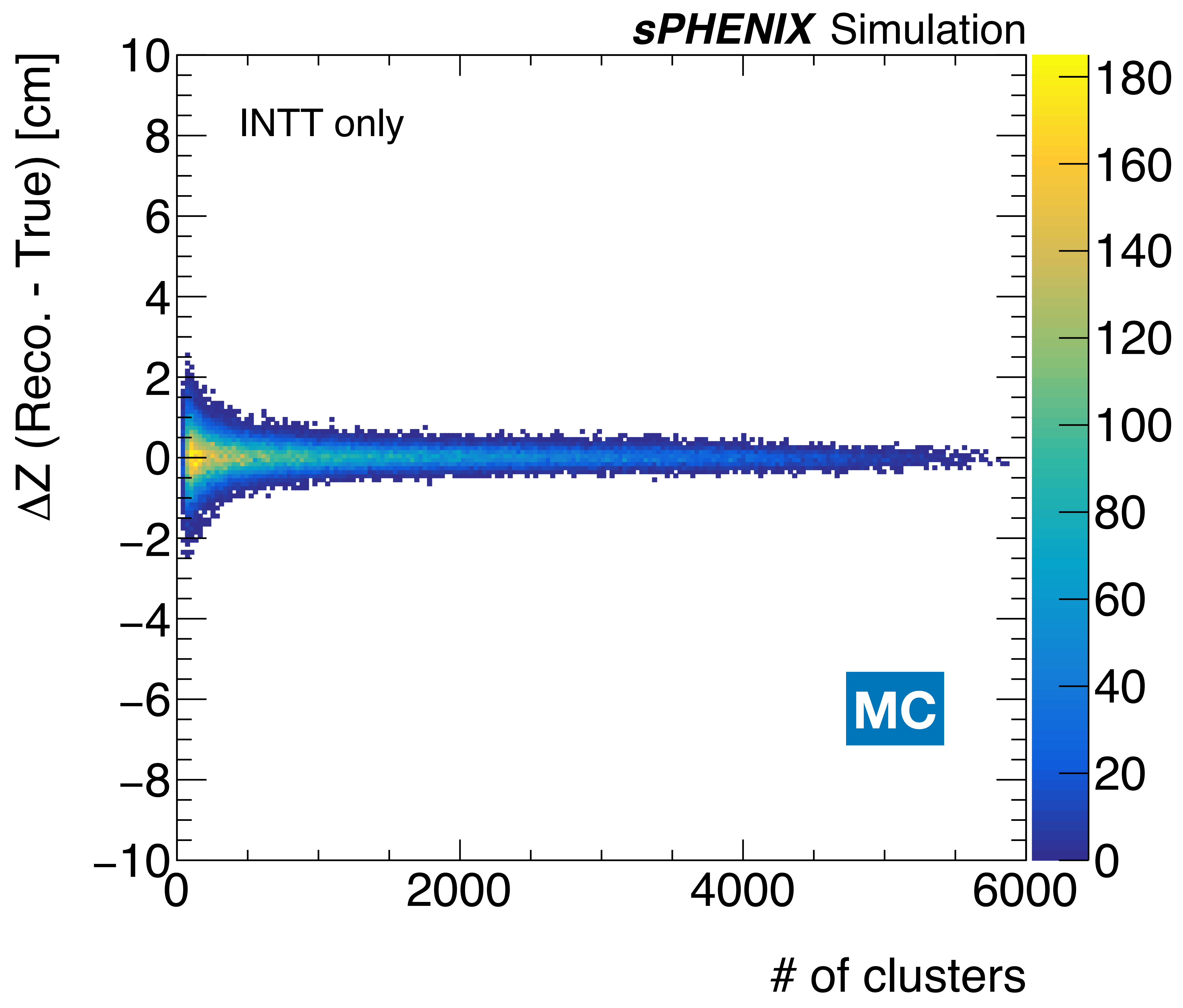


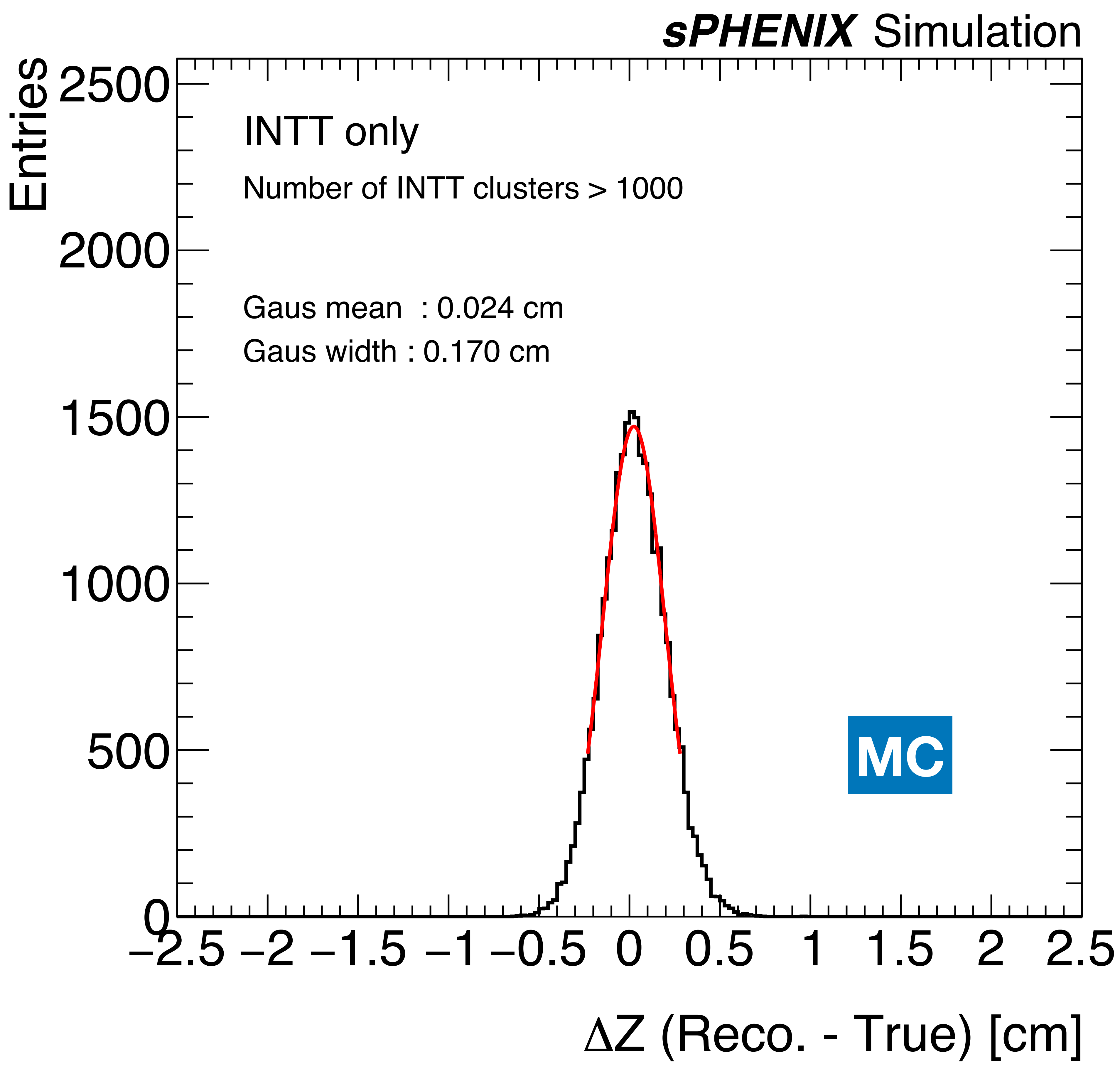
Selections

- Min. Bias event (w/o ZDC requirements)
- $|\Delta\phi|$ of cluster pair ≦ 0.5 degree
- $|DCA|$ ≦ 0.1 cm
- MBD charge asymmetry requirement
- Vertex distribution quality assurance requirement

Per-event vertex Z reconstruction

MC zvtx setting: Gaussian (-20 cm, 5 cm)
zvtx rage : -30 cm ~ 0 cm

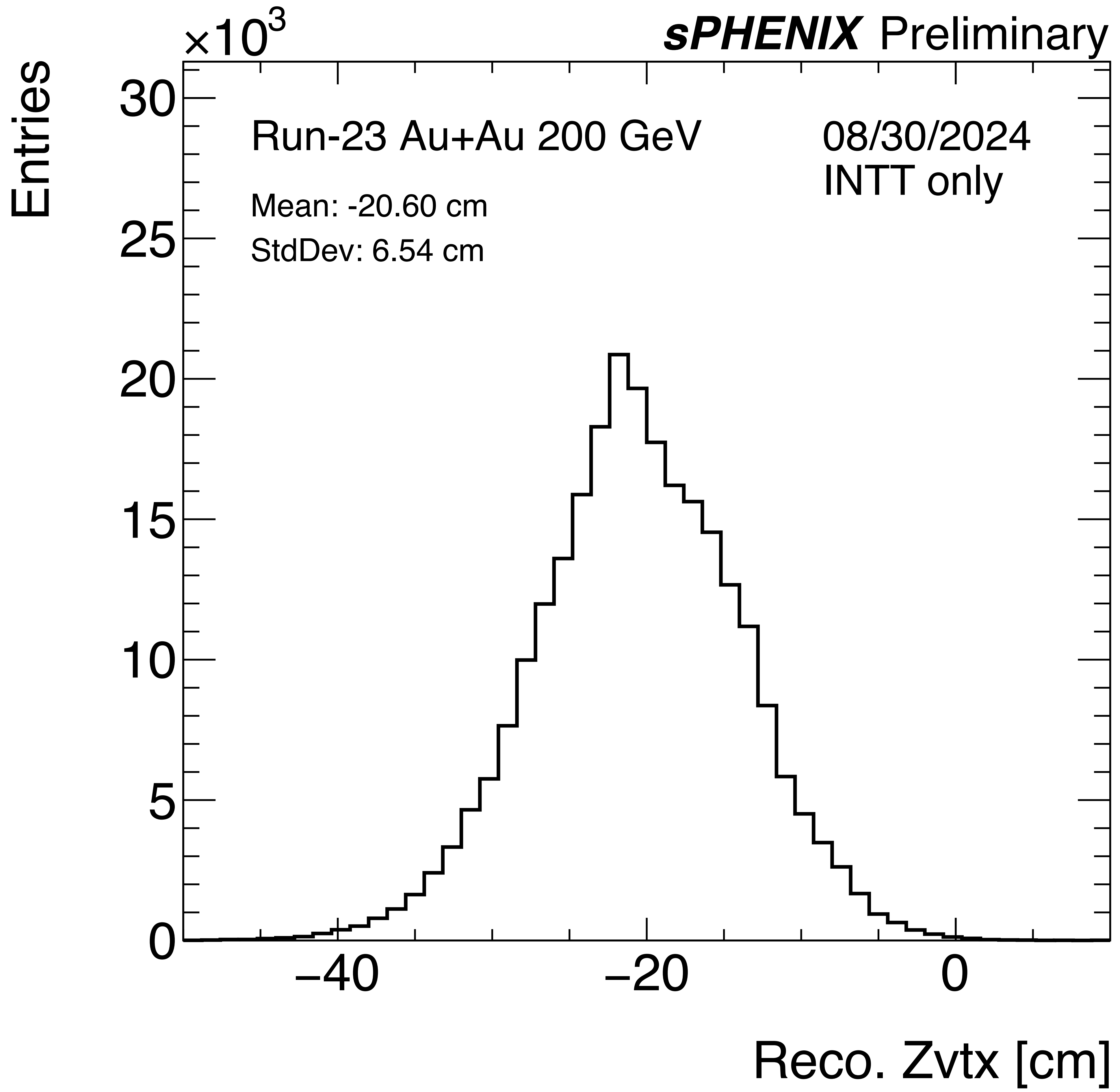




The higher multiplicity the more accurate vertex Z determined
1.7 mm resolution in the region of number of clusters > 1000

Per-event vertex Z reconstruction

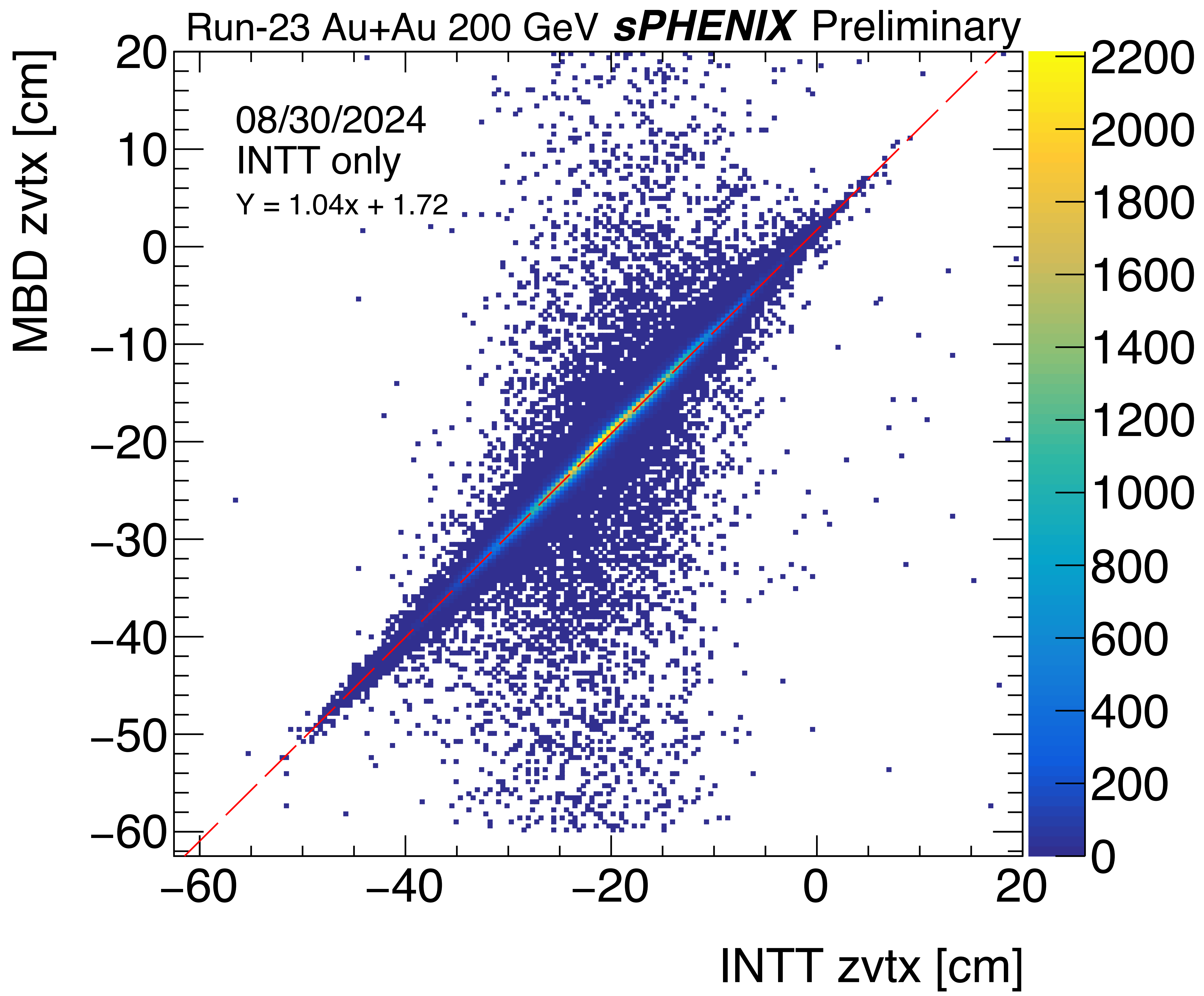
Data

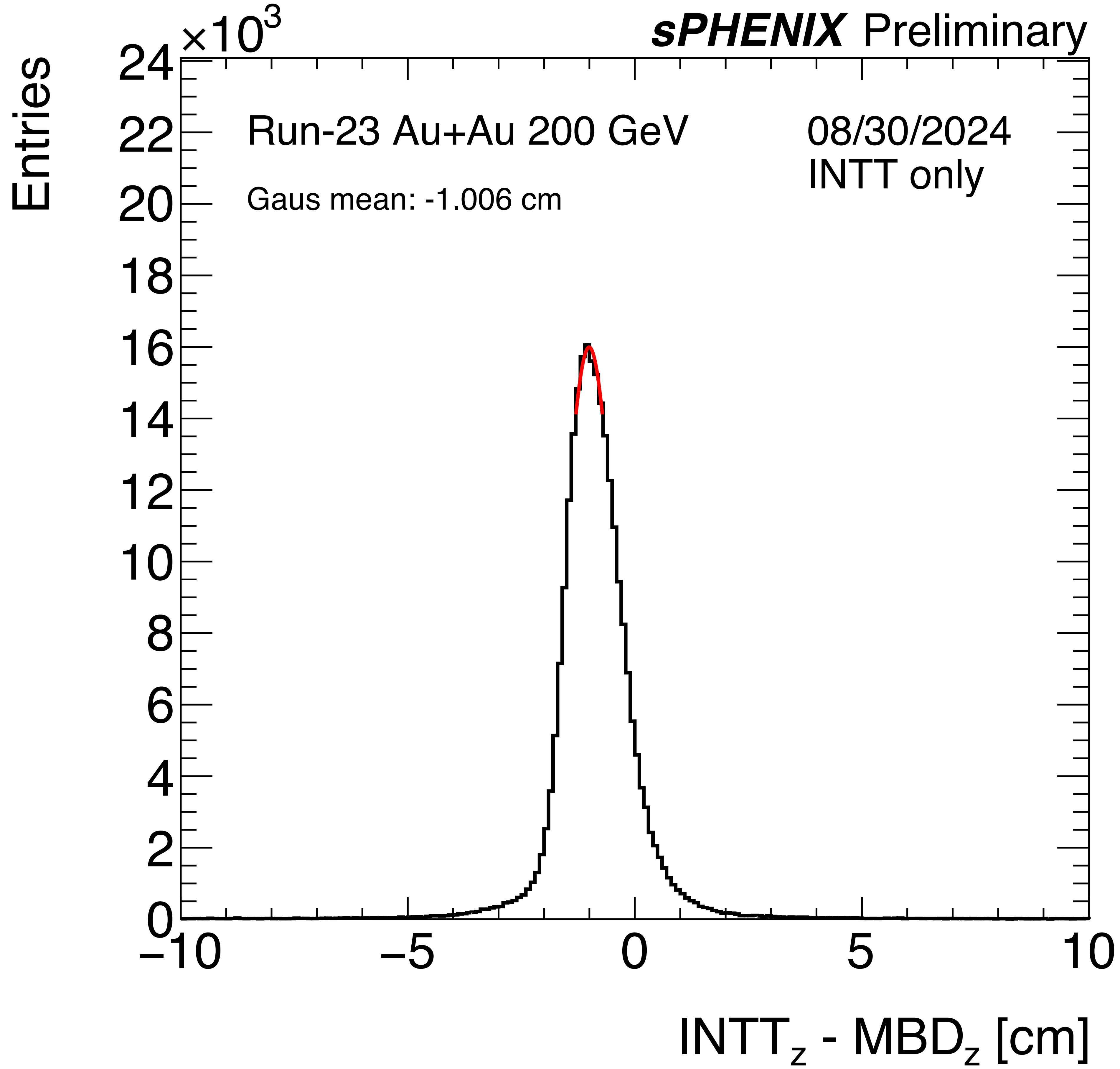


Per-event vertex Z reconstruction

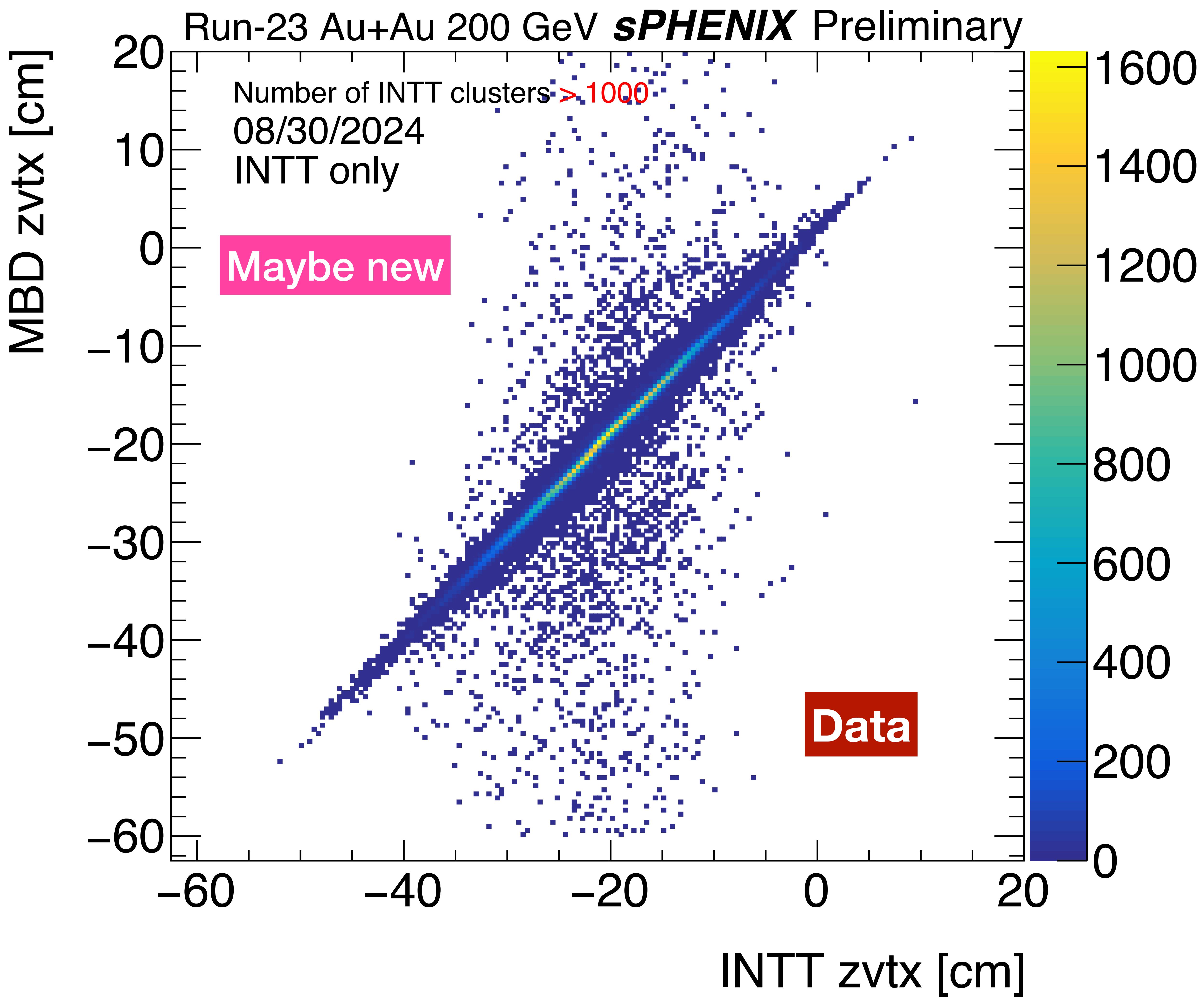
Data

The comparison with MBD reco. vertex Z





The “line” in the correlation plot

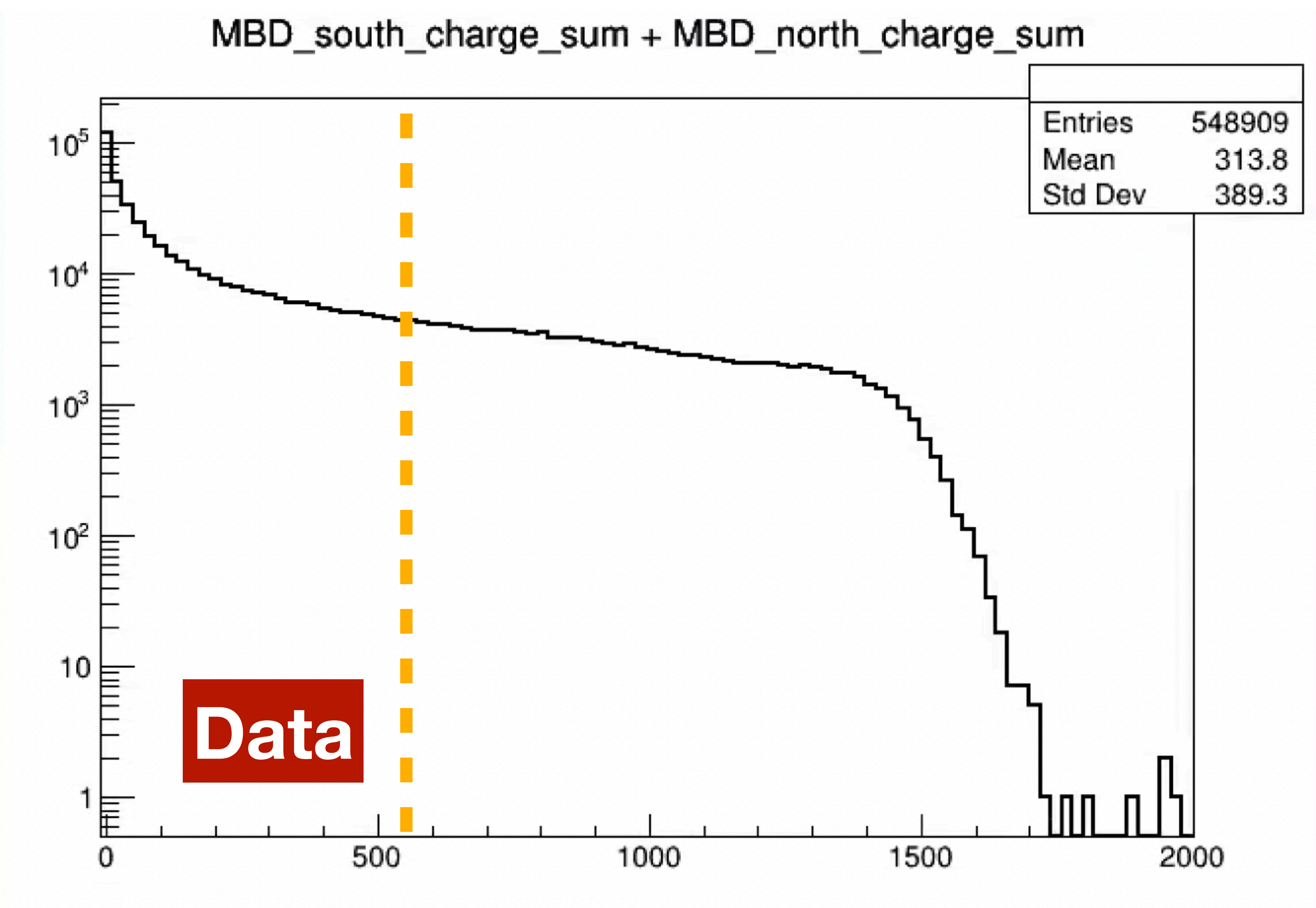


Requiring the number of INTT clusters > 1000, the “line” still there

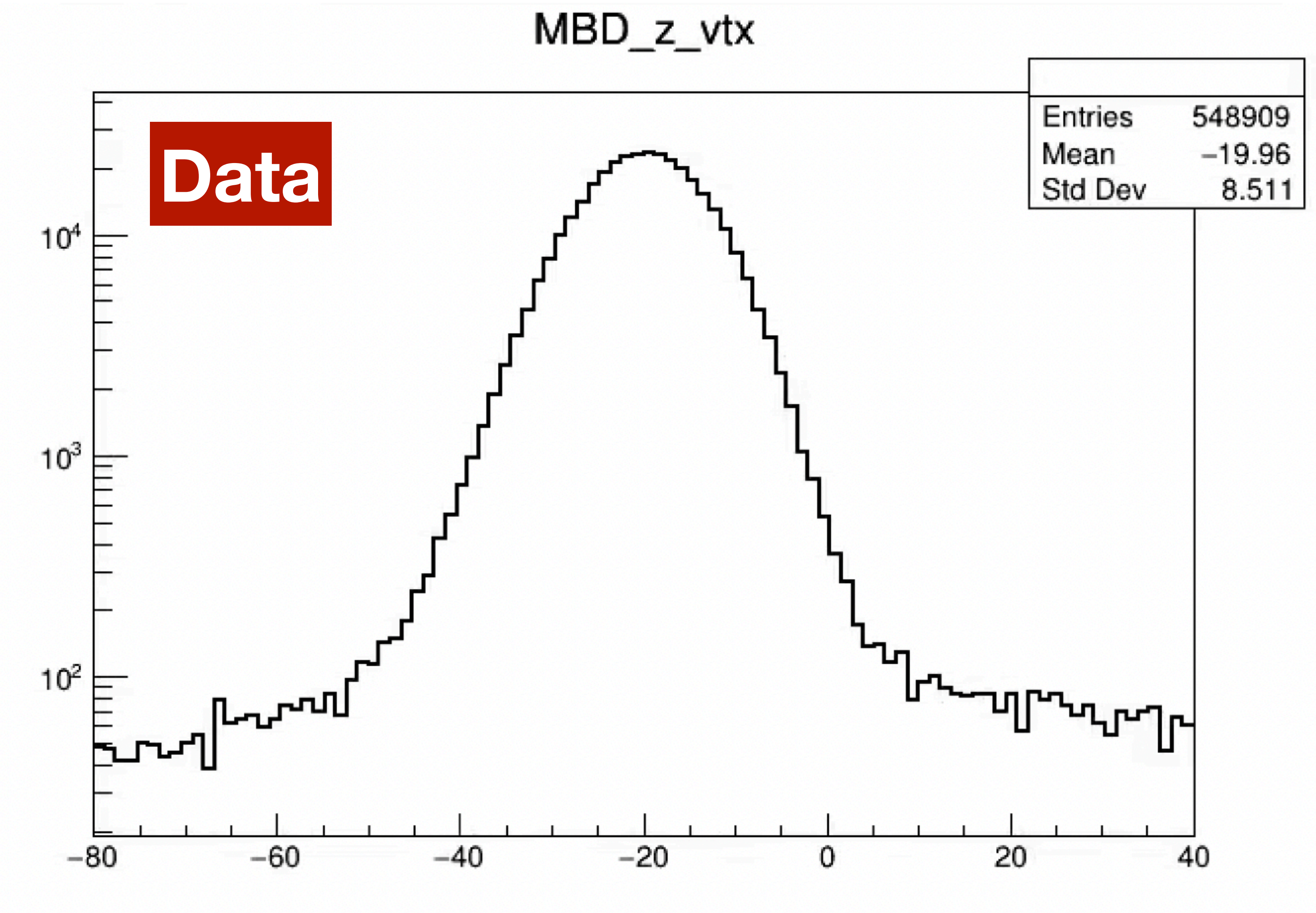
The "line" in the correlation plot

Maybe new

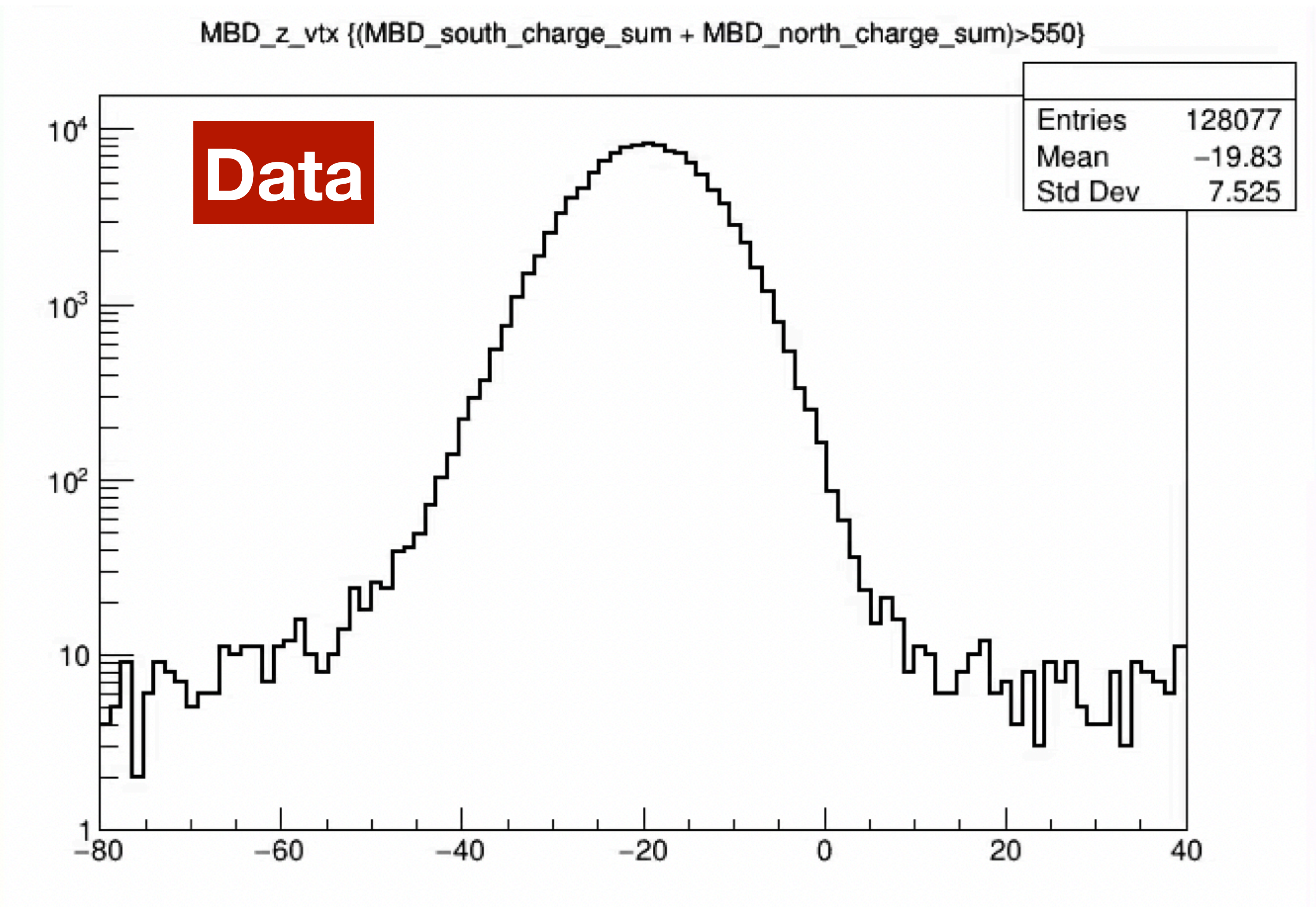
MBD charge sum



Inclusive MBD vertex Z



MBD vertex Z (charge sum > 550)



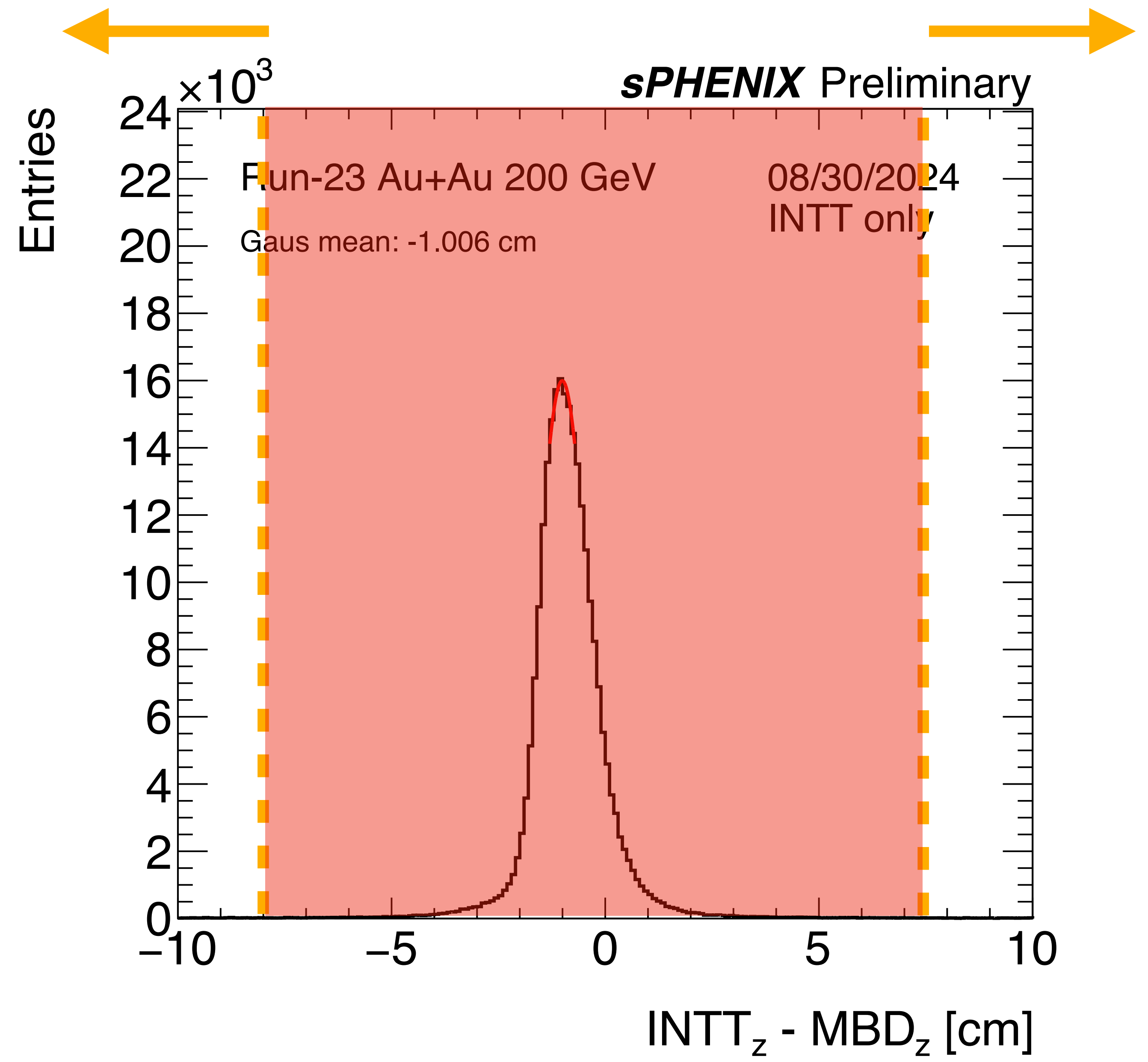
Just the supplementary not for approval

The grass is still there even in the high multiplicity region

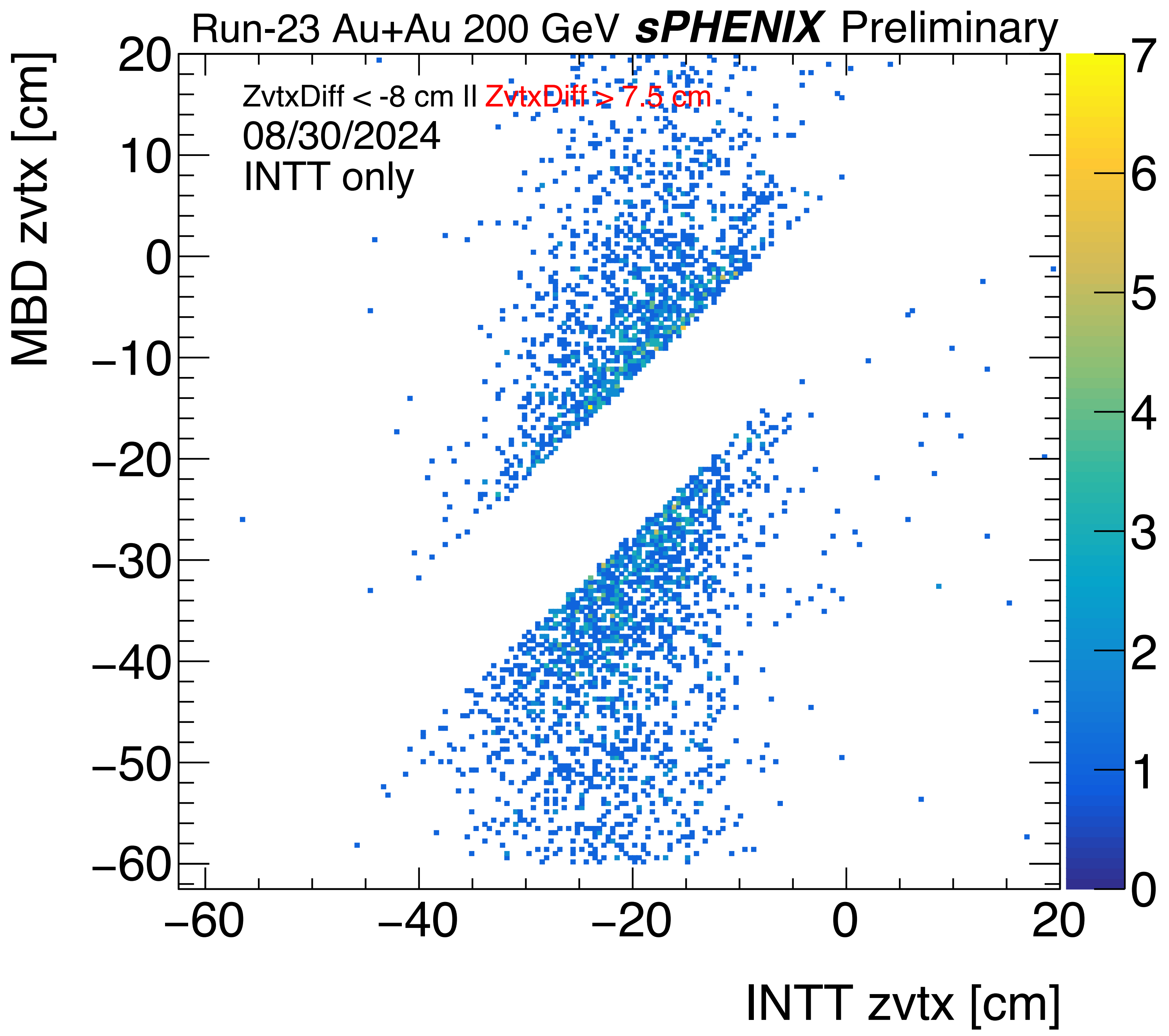
More about the vertex Z correlation

Event selection:

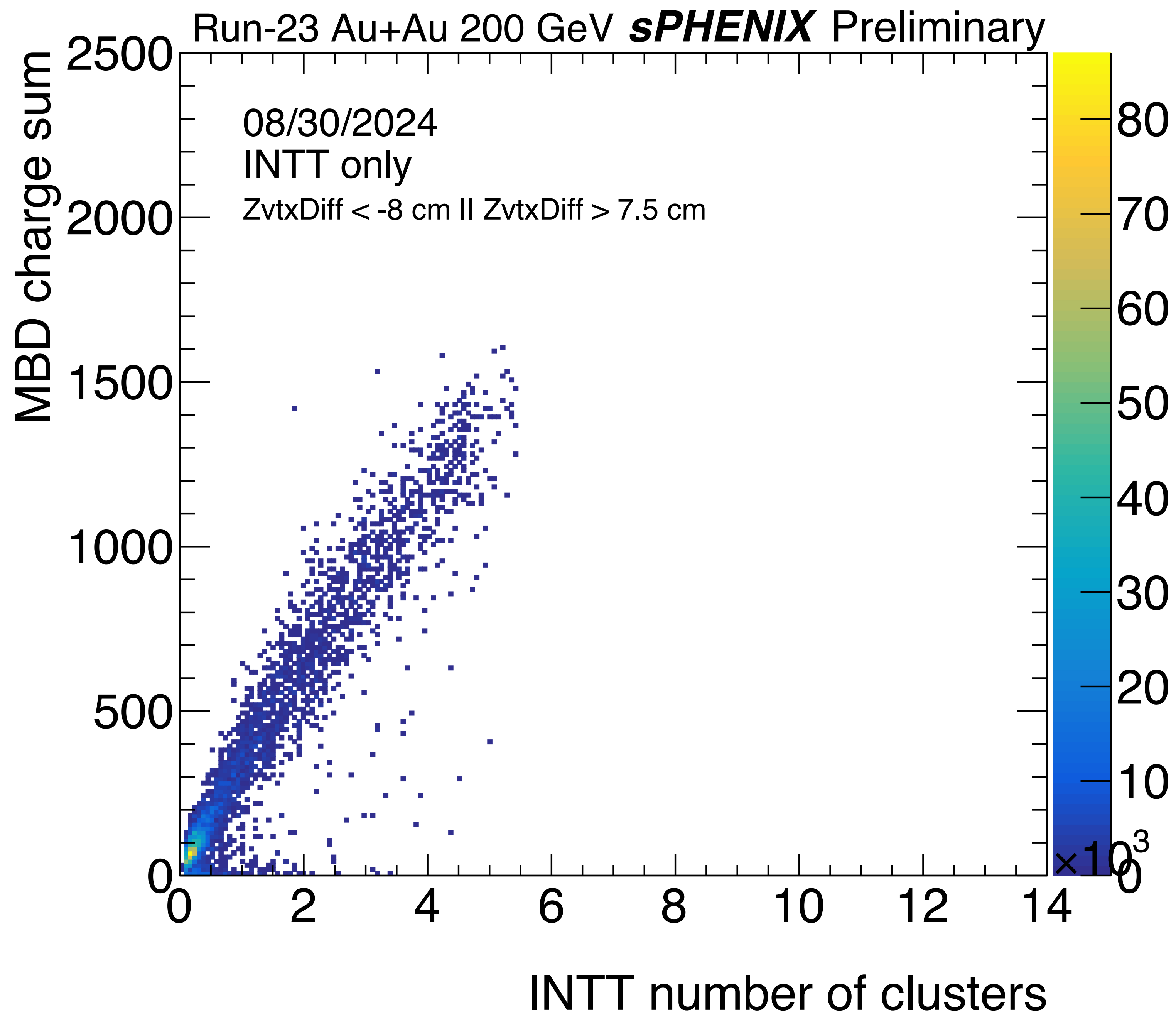
1. is_min_bias_wozdc == 1
2. centrality_float != NaN
3. MBD_vertex_Z != NaN
4. INTT vertex Z quality cut
5. MBD charge asymmetry cut
6. zvtx_diff < -8 cm || zvtx_diff > 7.5 cm



Maybe new



Maybe new

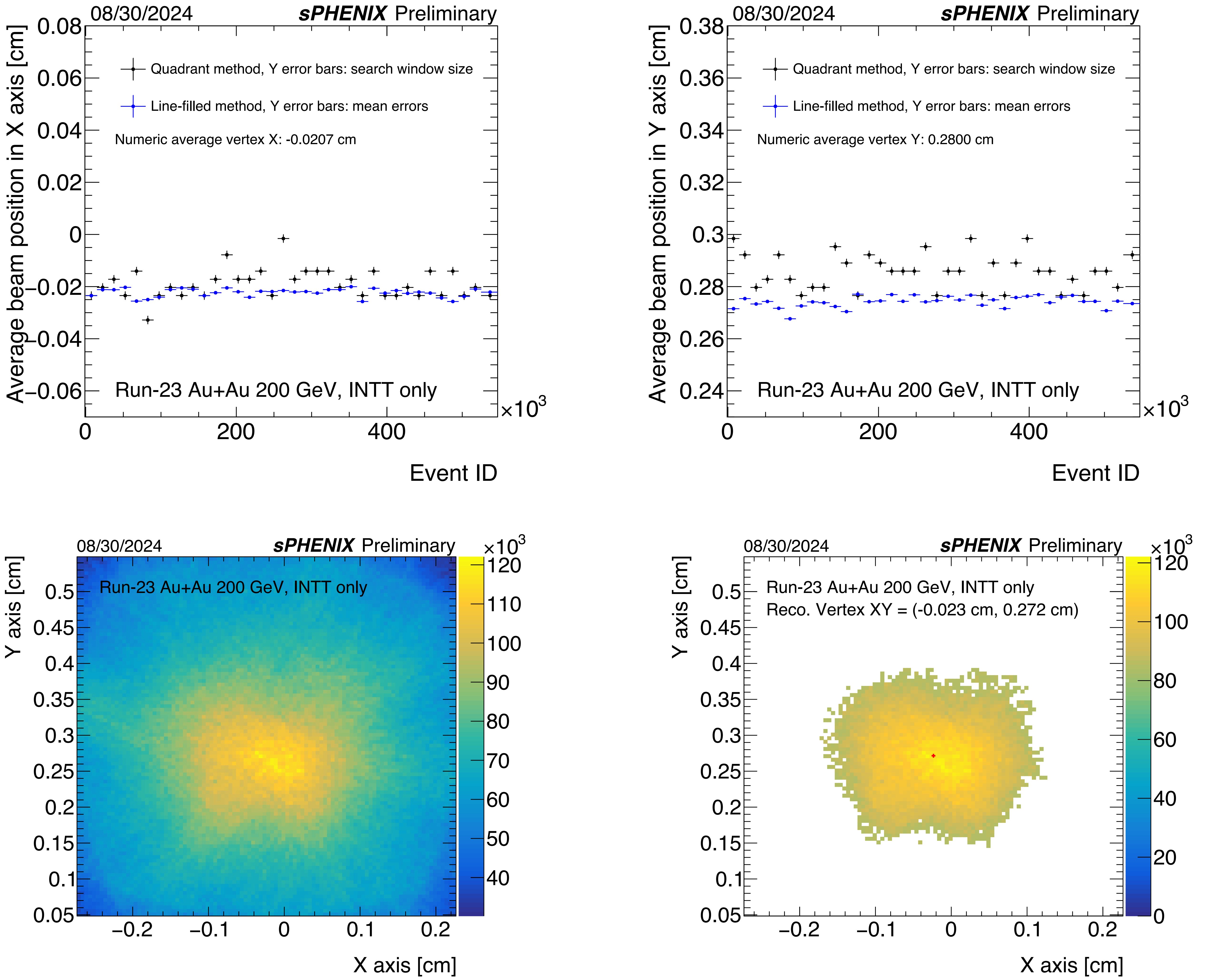


We can still see the positive correlation in the multiplicity even only requiring the outliers

Recap, the DATA plots seeking for approval

Data

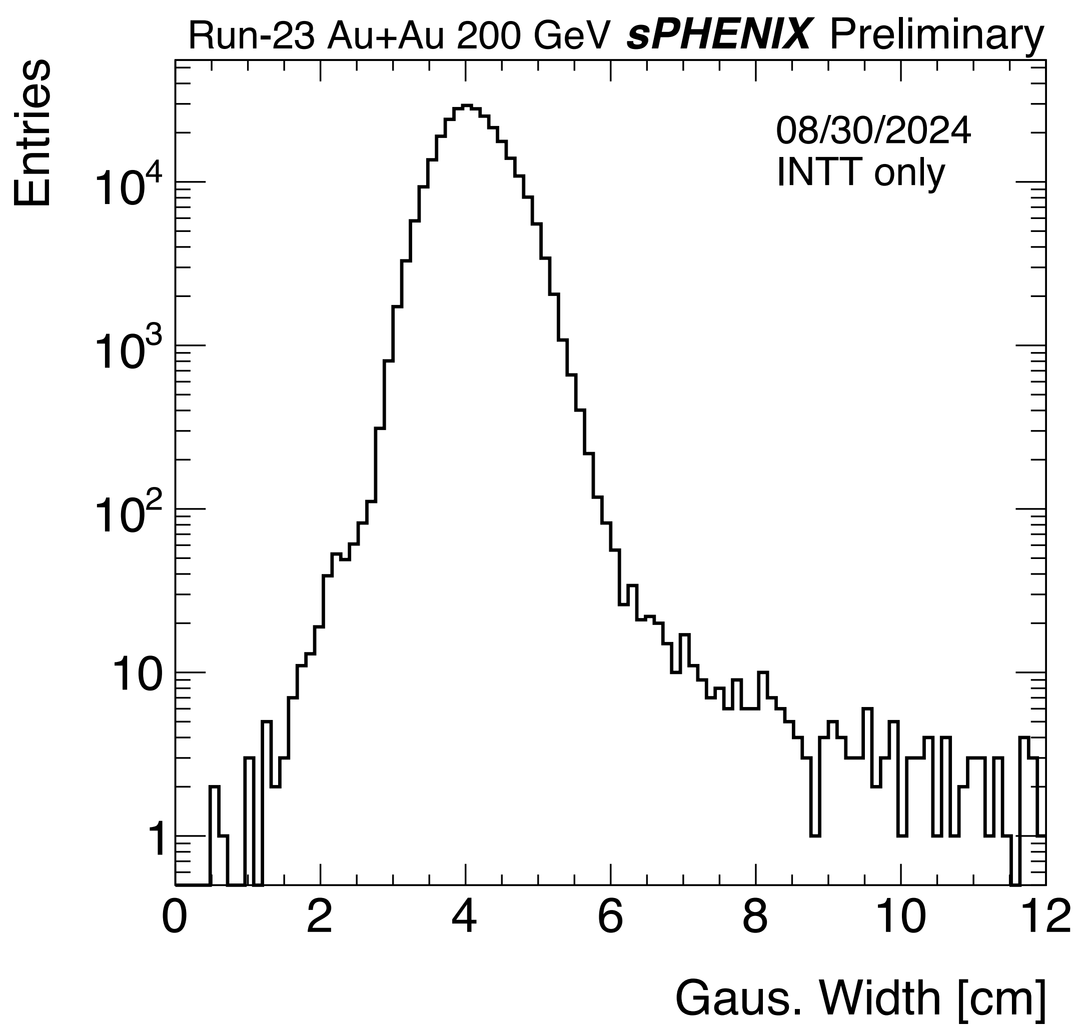
Avg_vtxXY

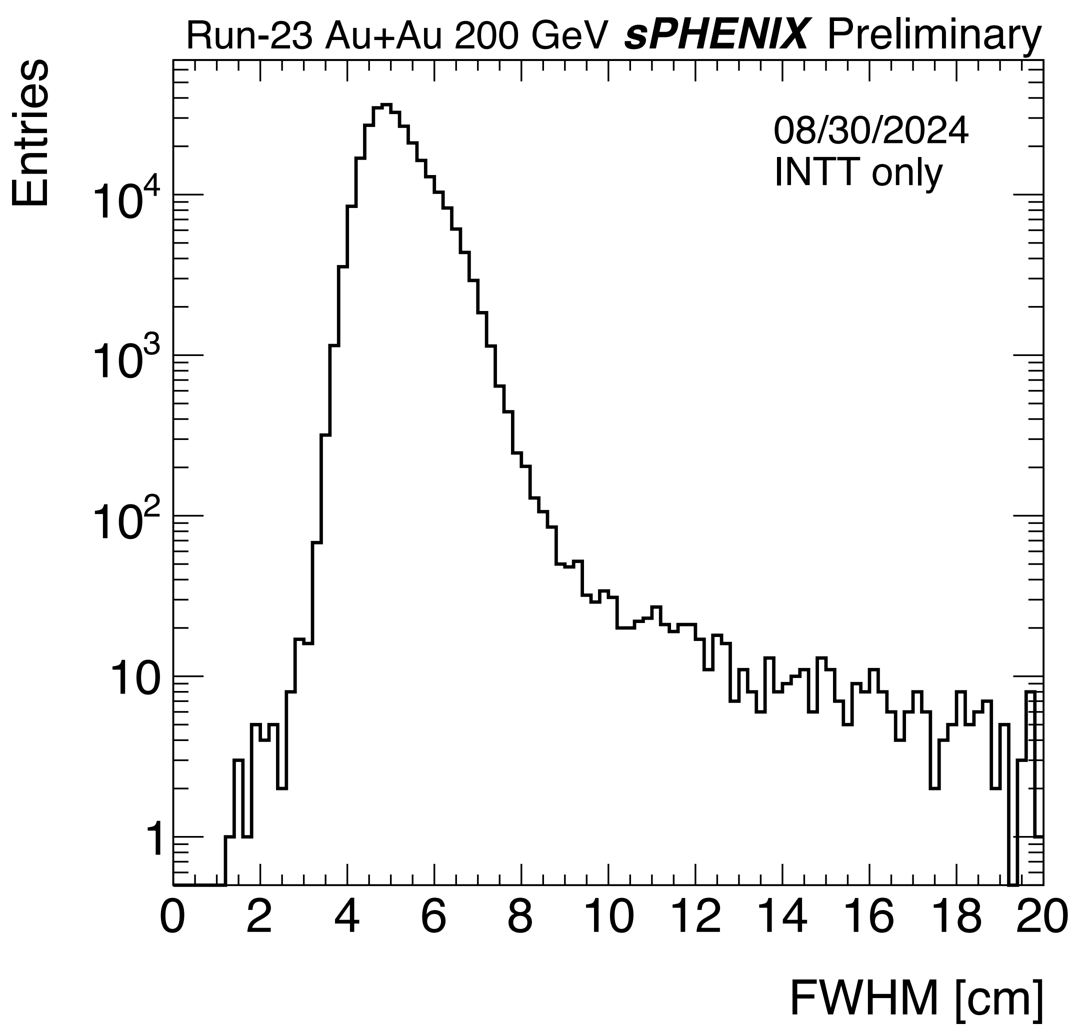


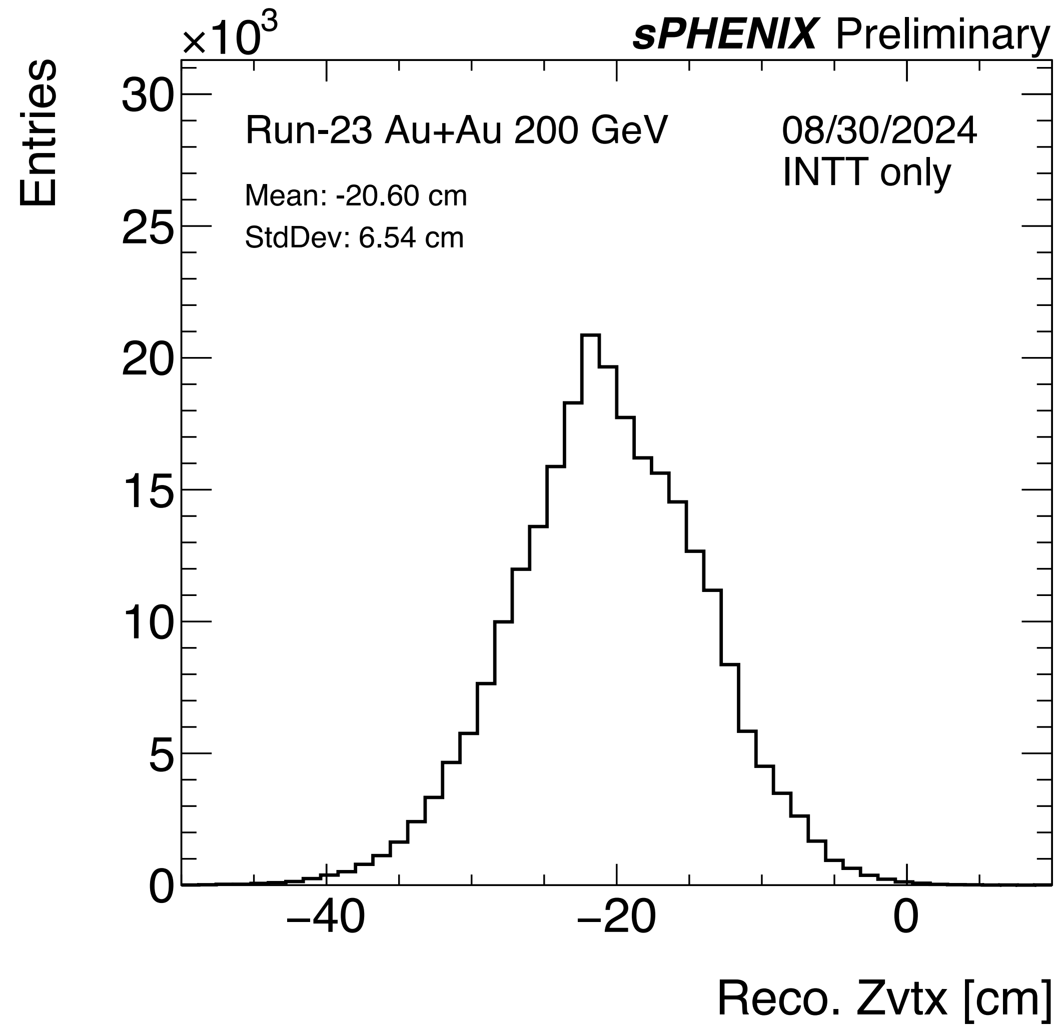
Recap, the DATA plots seeking for approval

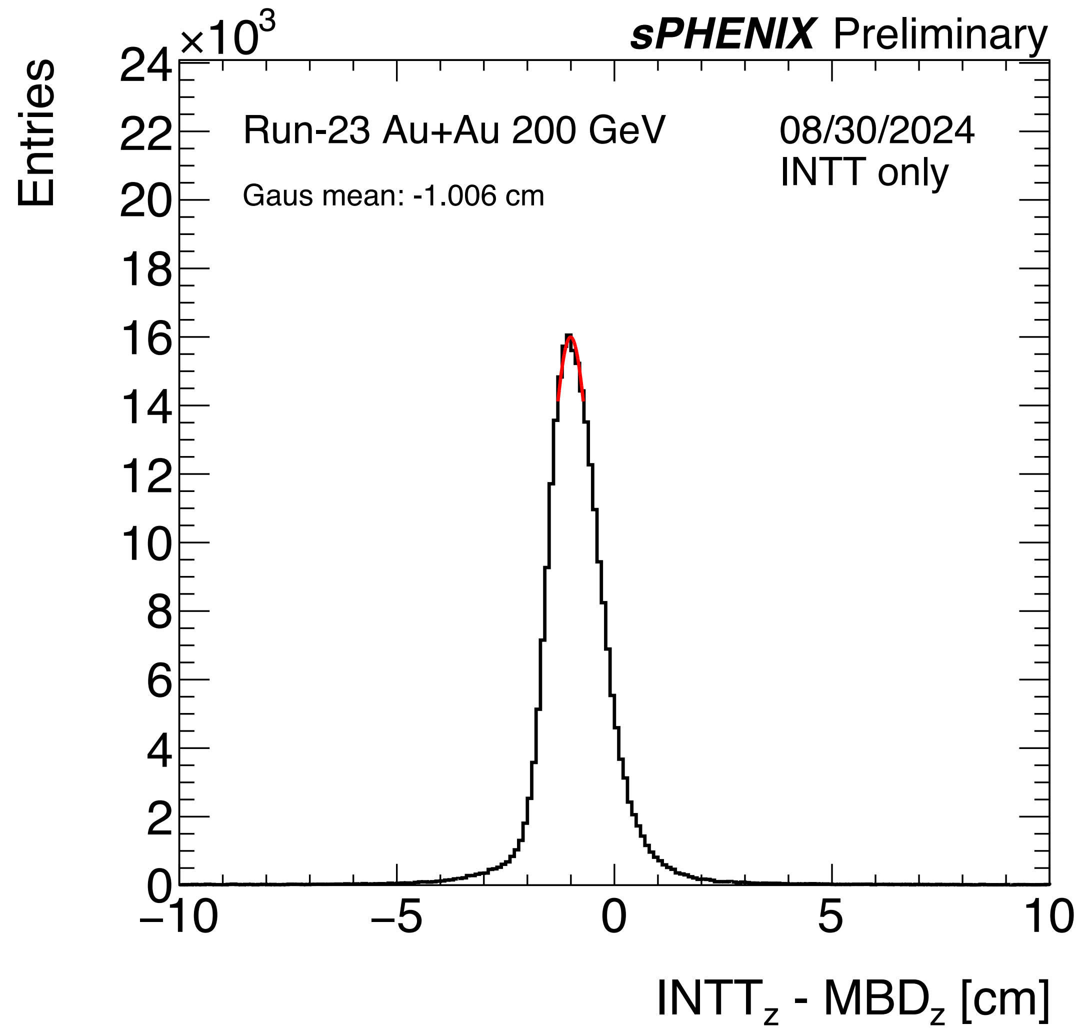
Data

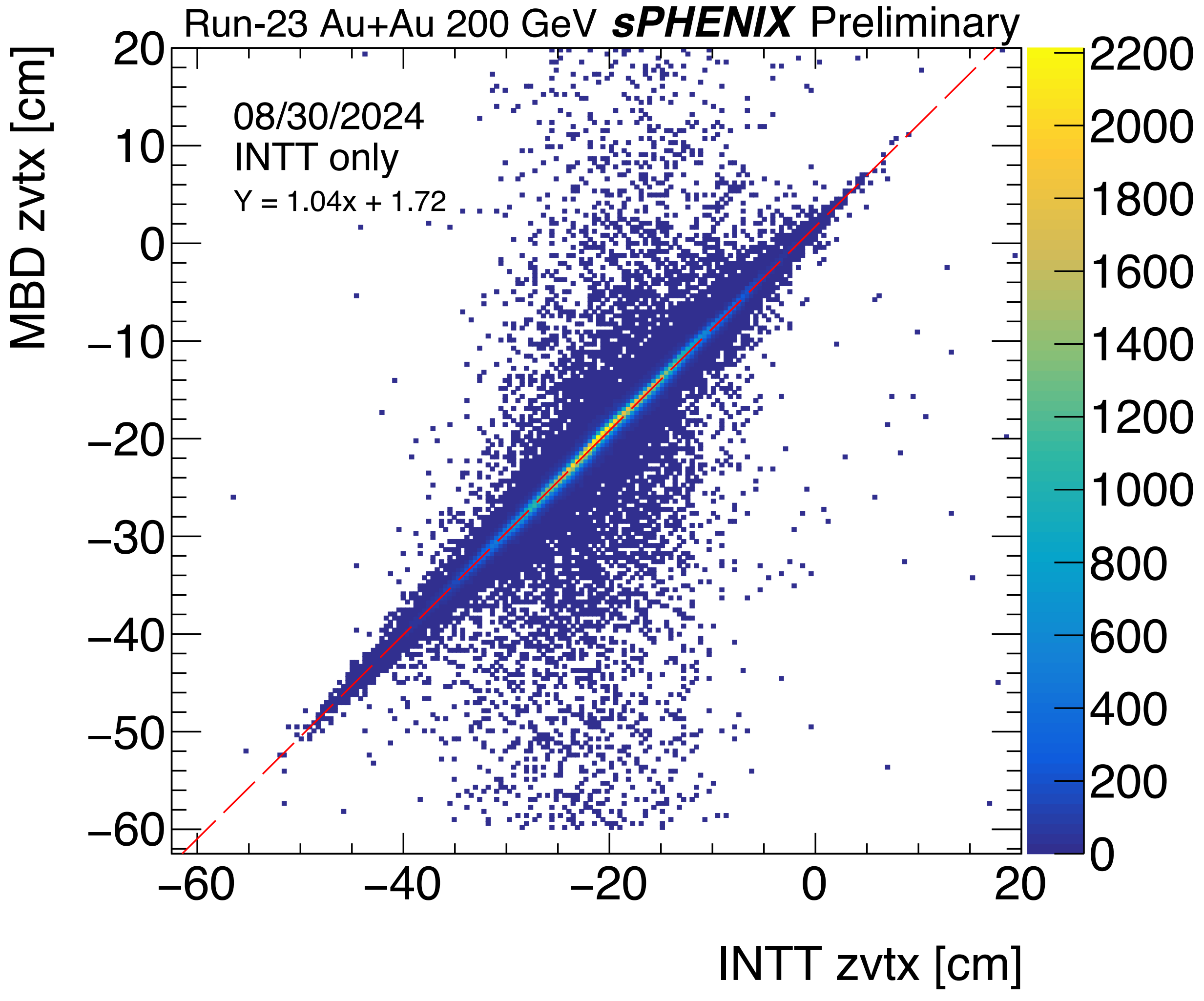
Evt_vtxZ

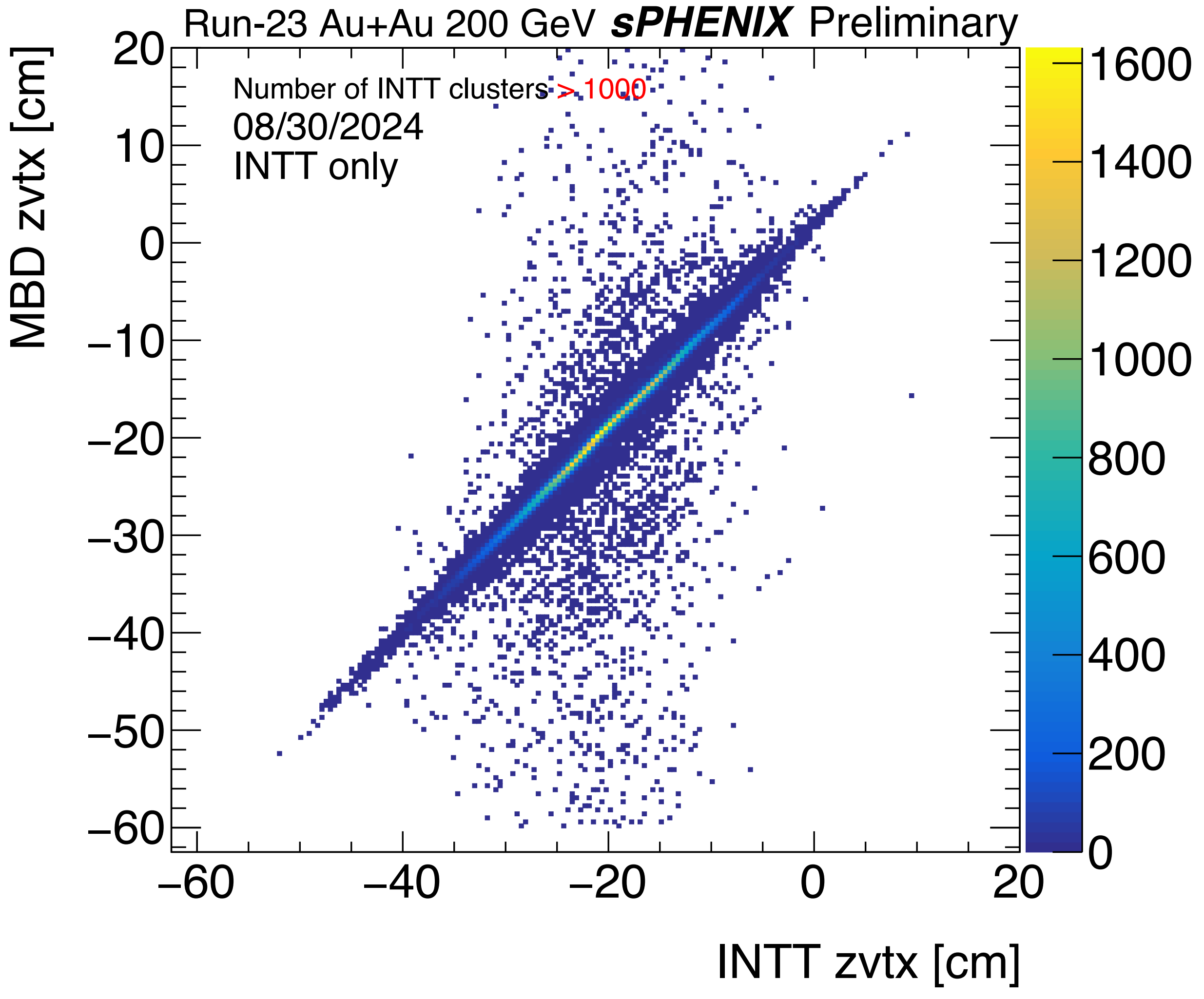


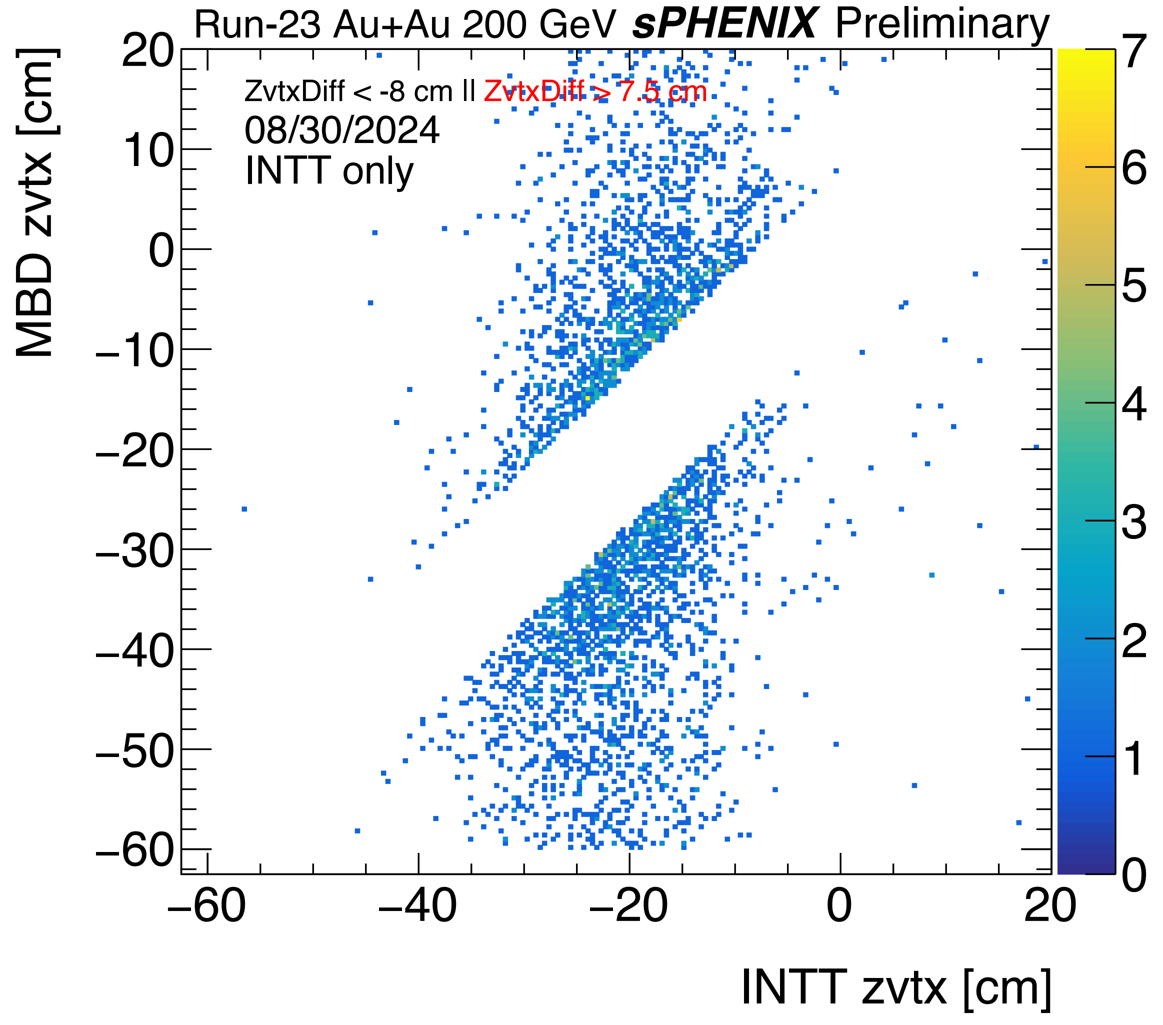


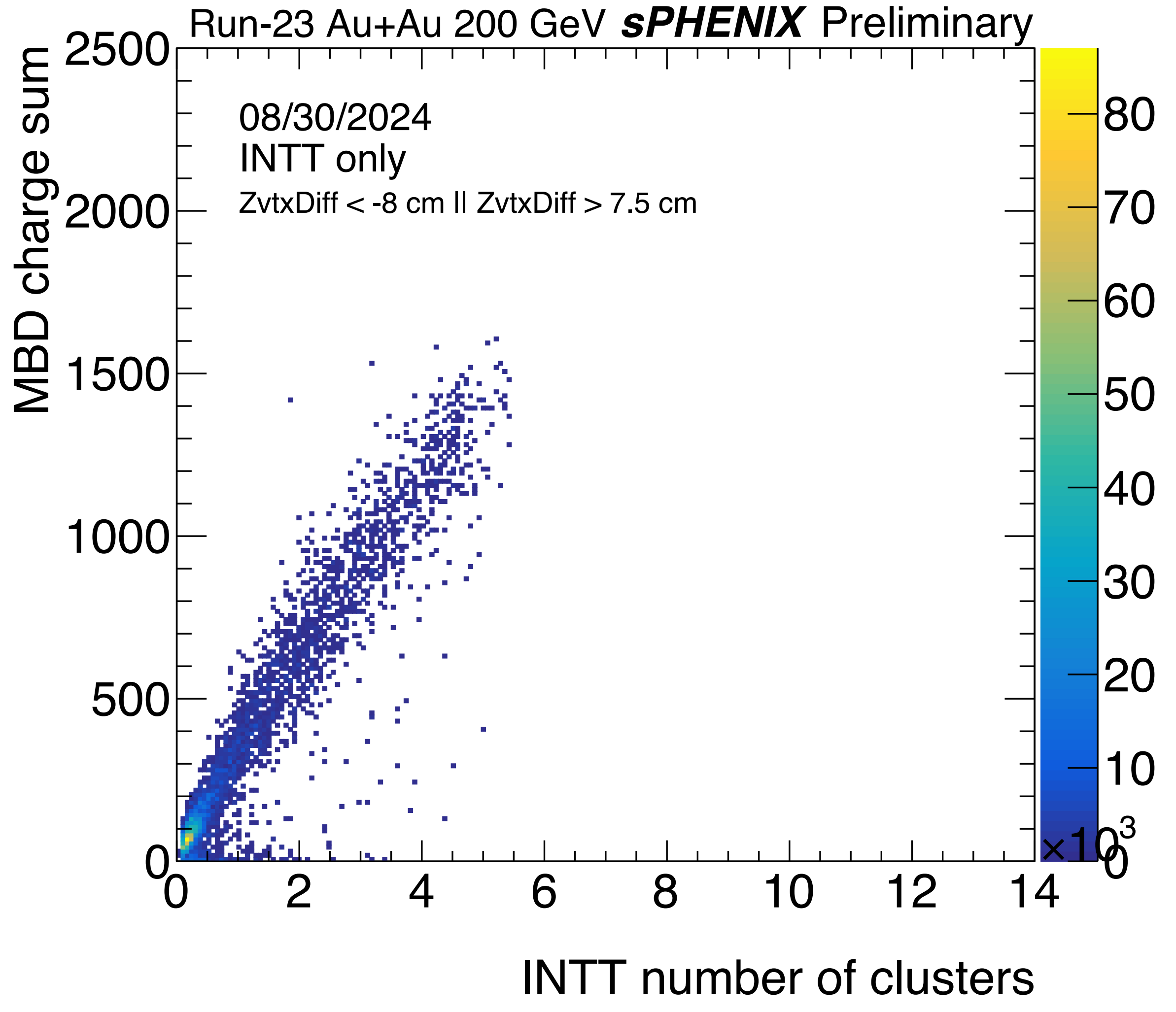




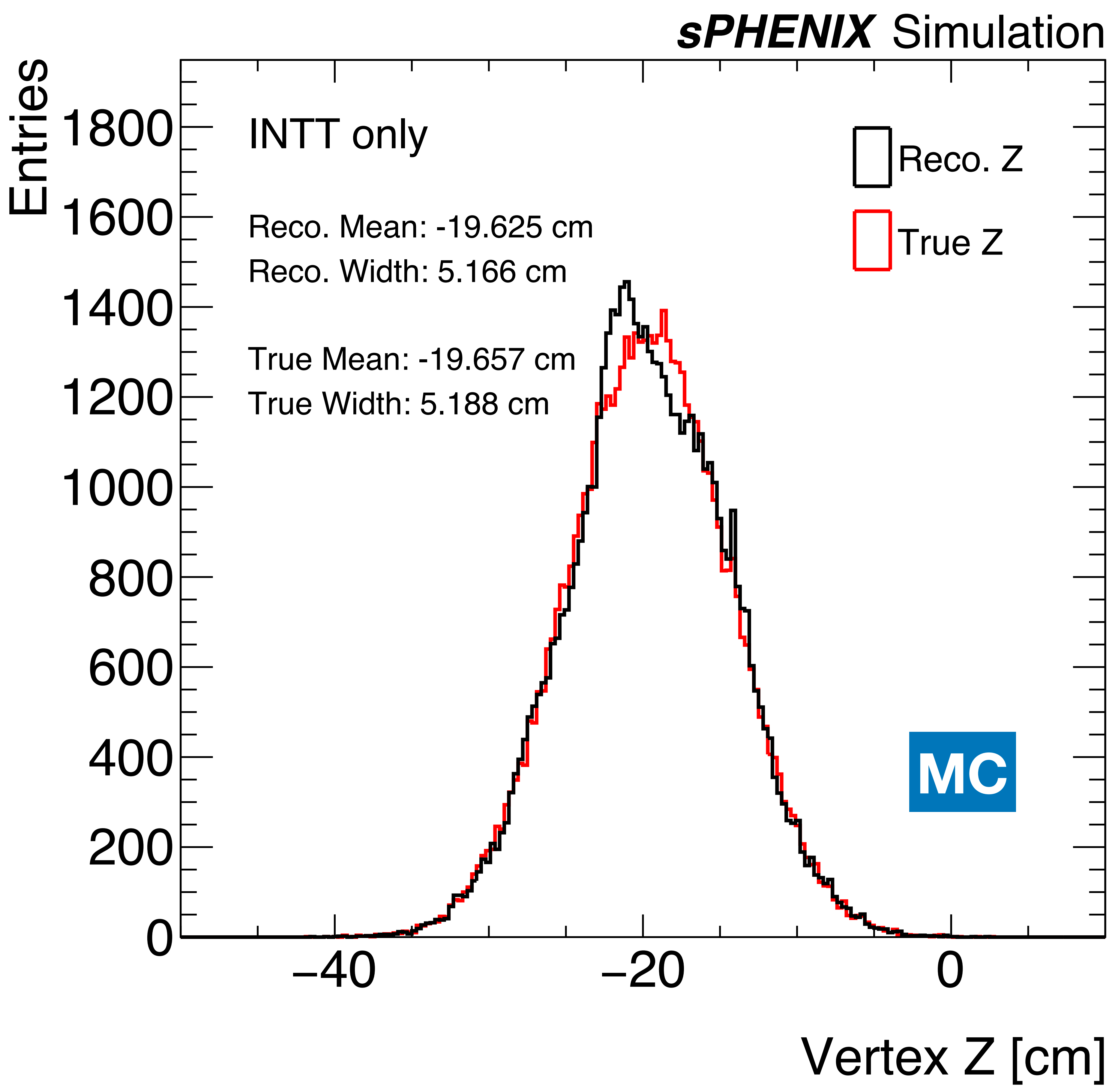


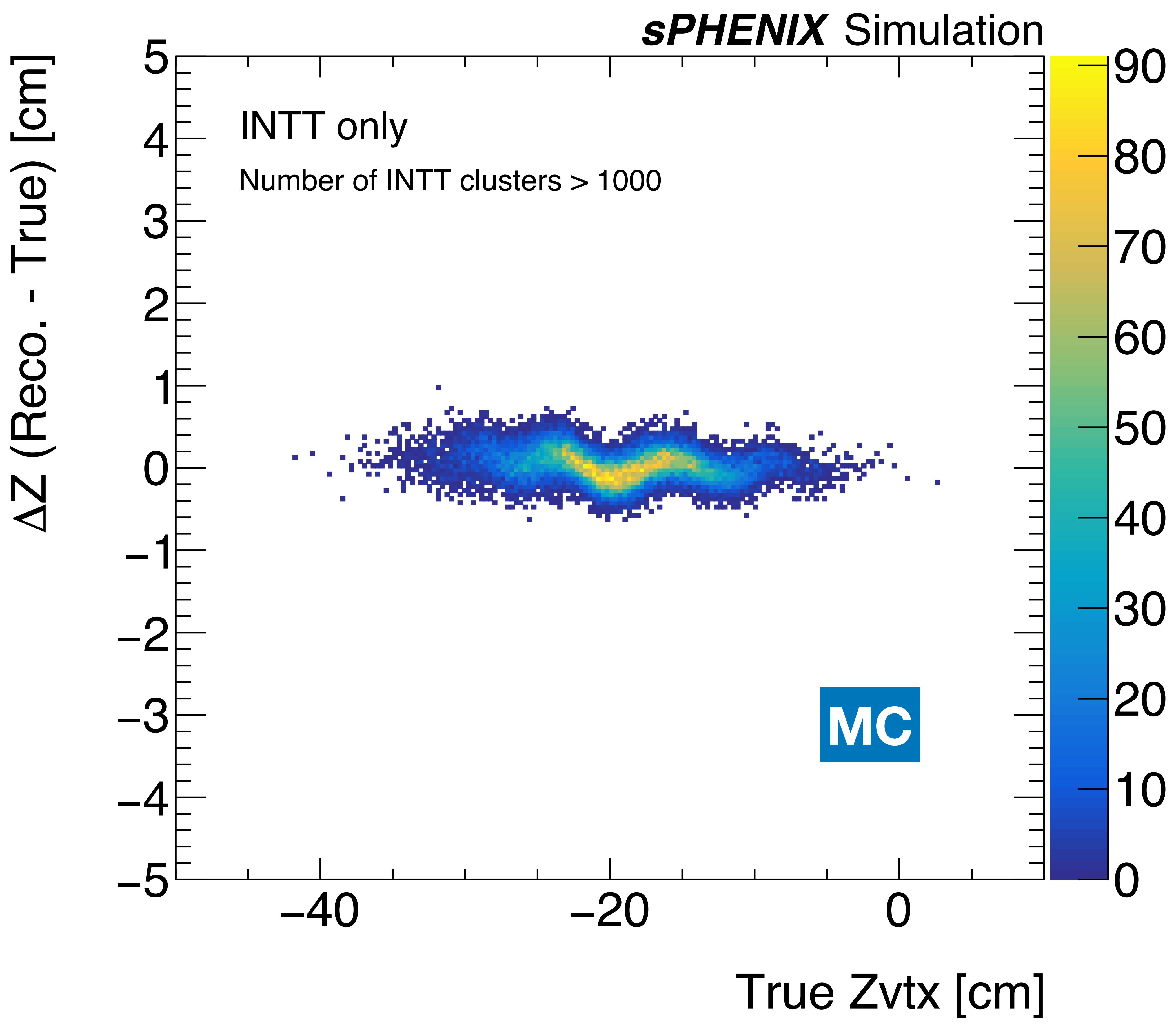






Per-event vertex Z reconstruction

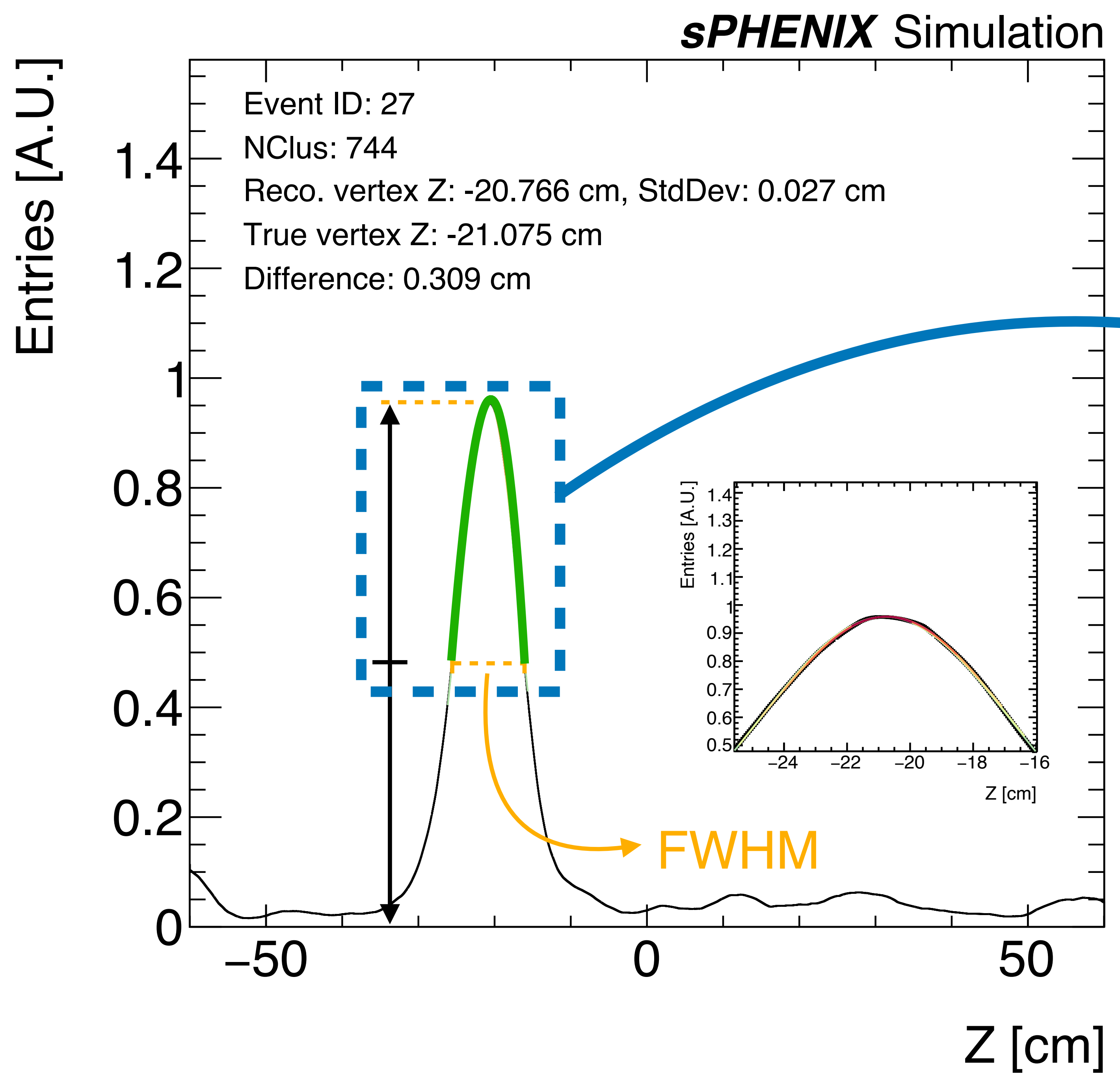




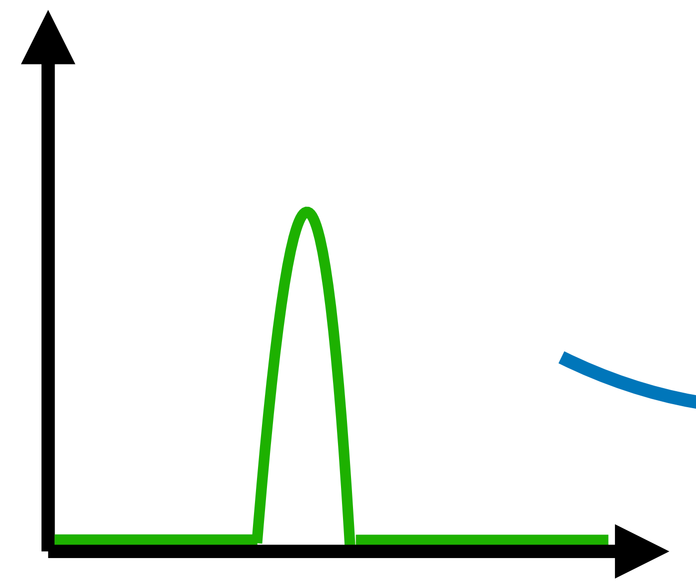
The wiggling structure due to the fact that the collisions happened near the edge of INTT

The optimization of vertex Z determination

- New trial: after having the histograms made of possible vertex Z ranges, use ML (XGBoost) to do the final vertex Z determination
- Training variables: the content of each bin of the histogram post the half-maximum cut (2401 variables currently, corresponding to the number of bins of histogram)
- Total MC events: 80k (75% training, 25% testing)



Post applying the bkg cut on the hist., the half-maximum threshold cut (the head structure)



0
0
0
0
0
0…

0.01
0.014
0.02
0.026….

0.015
0.013
0.008…

0
0
0
0

2401 training variables
(The full pattern of distribution)

Feed to the ML together with the answer (True vertex Z)

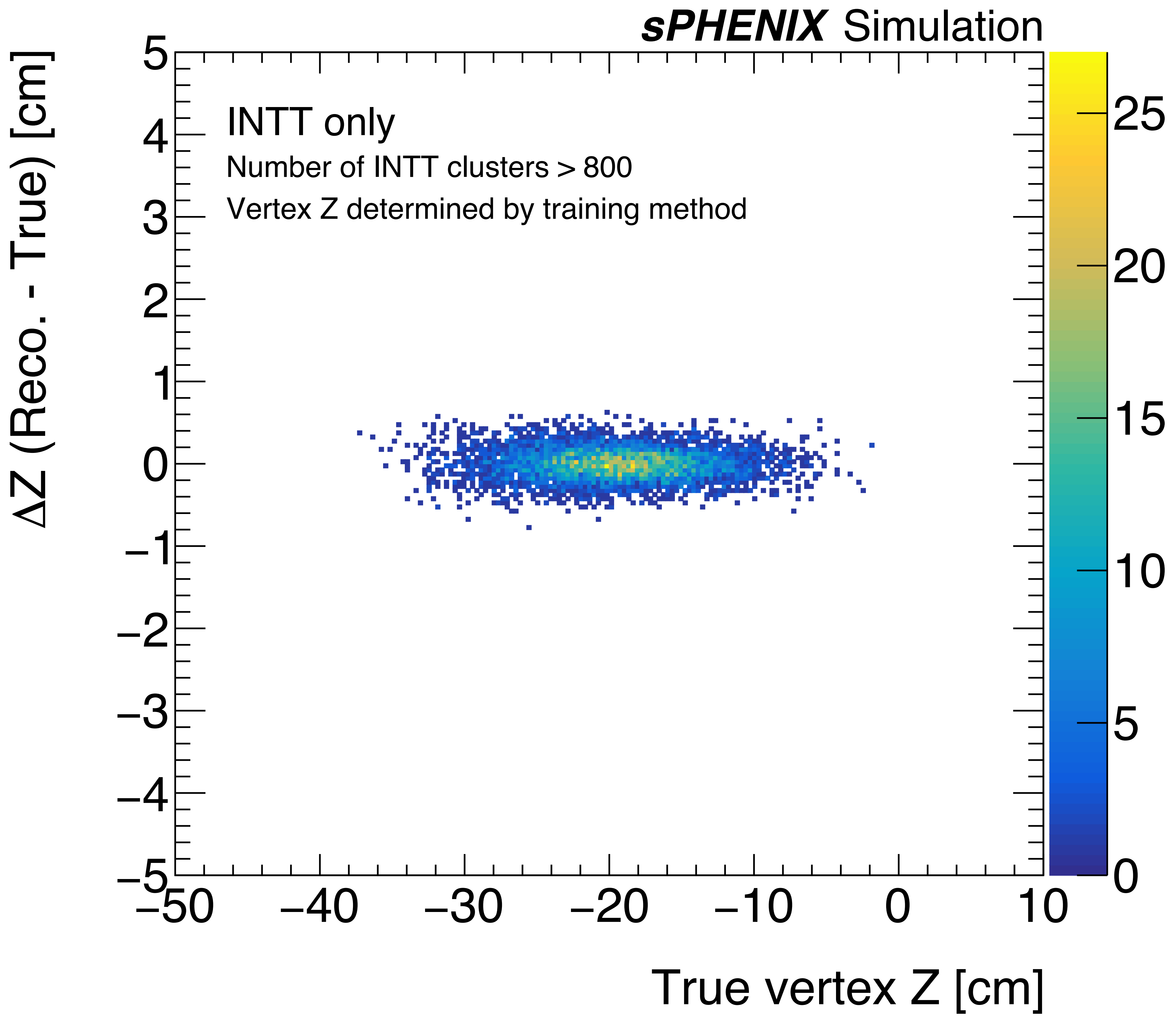
XGBoost

The optimization of vertex Z determination

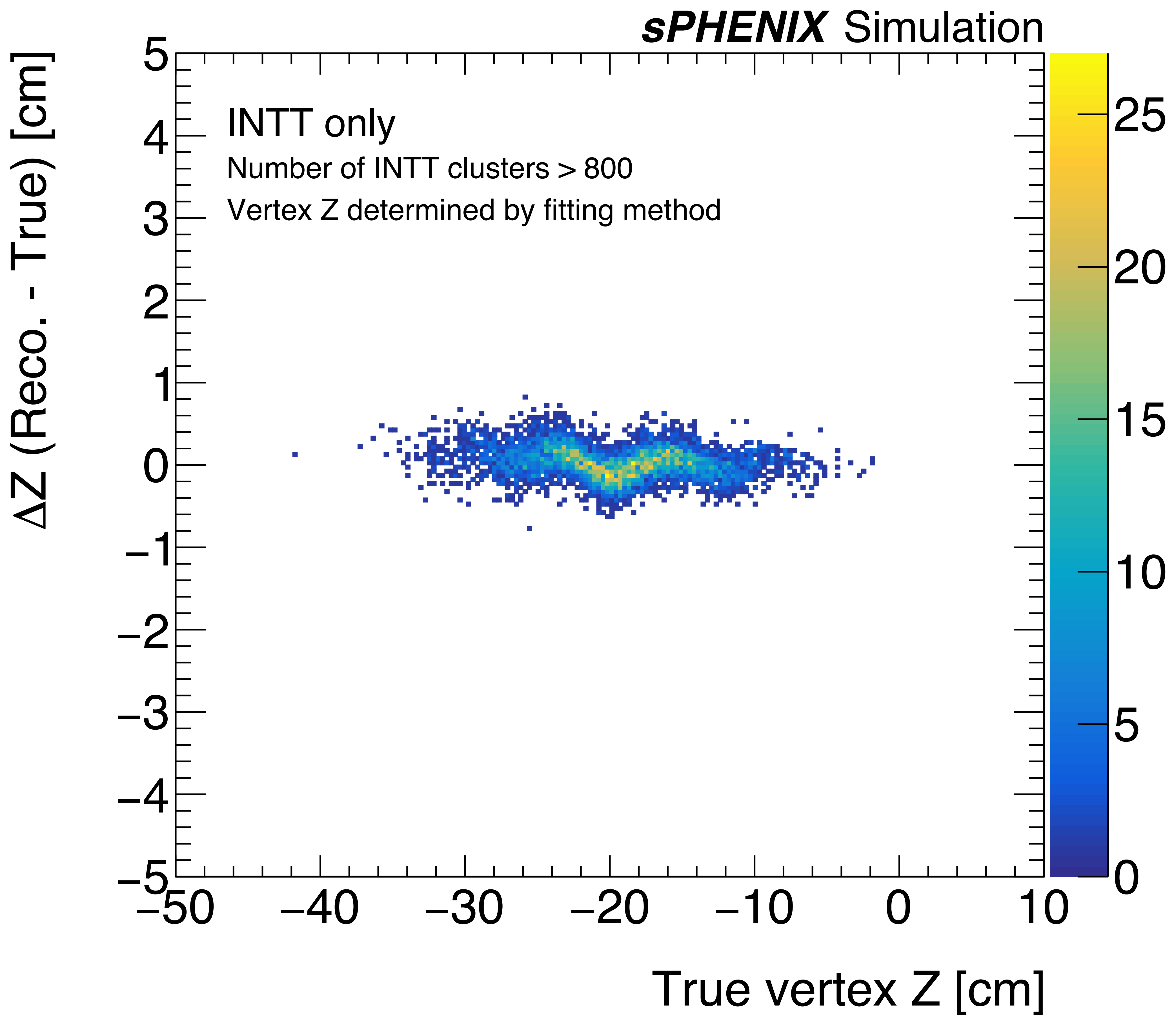
The test sample 25% of the total MC events

Number of cluster* > 800

Reco. vertex Z predicted by training model



Reco. vertex Z by 7 Gaus fittings



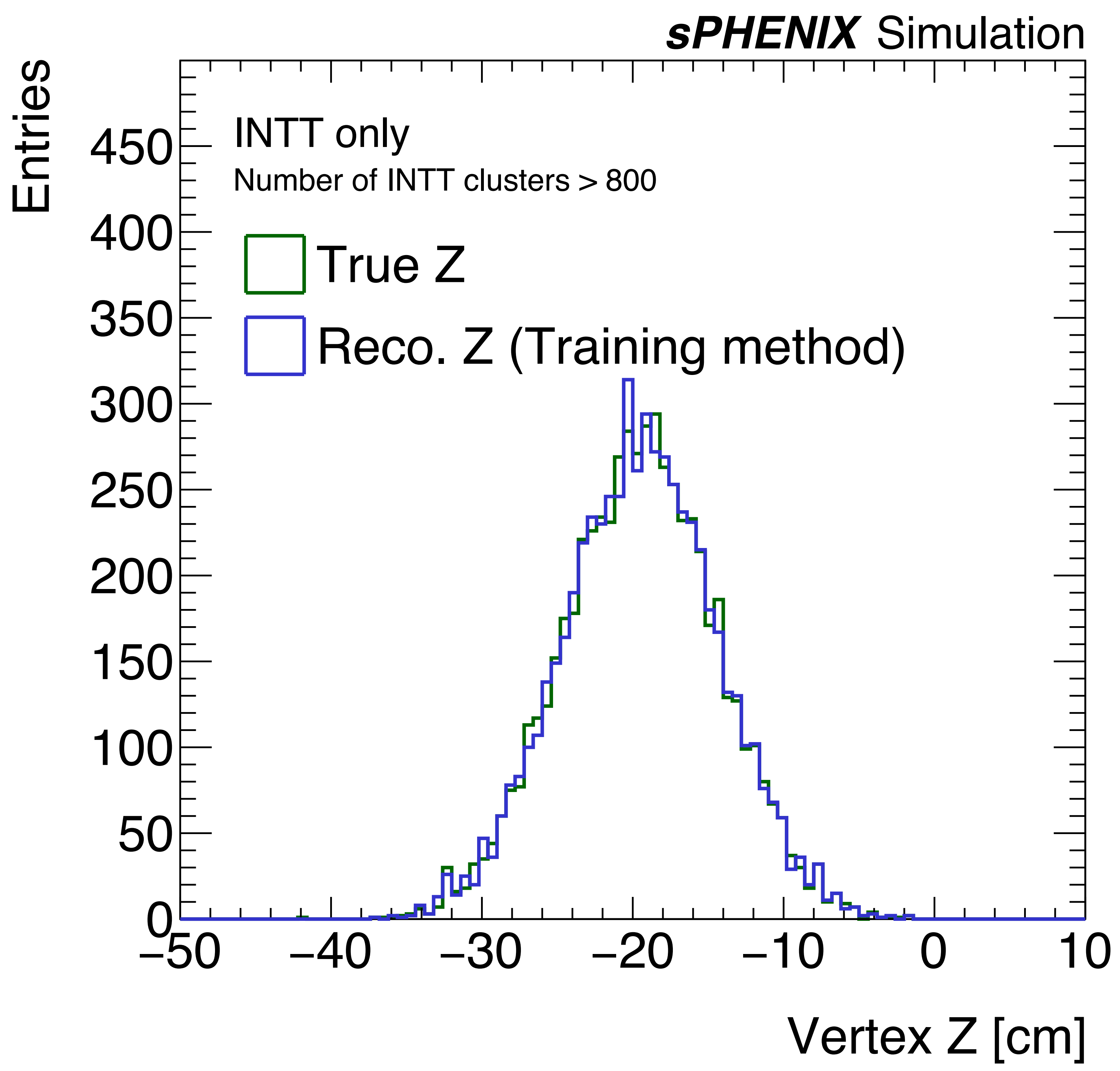
The optimization of vertex Z determination

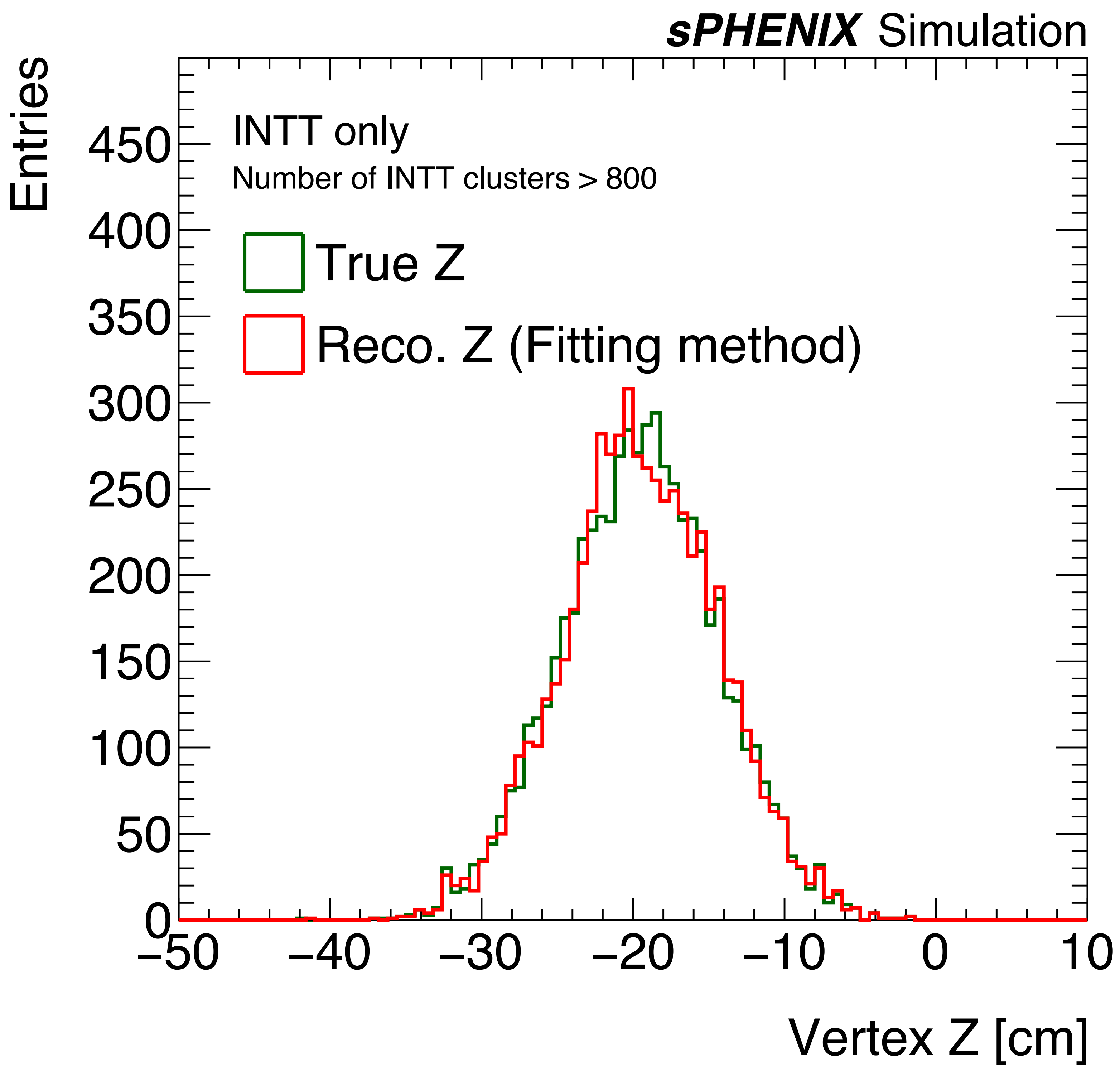
The test sample 20% of the total MC events

True vertex Z

Reco. vertex Z predicted by training model

Reco. vertex Z by 7 Gaus fittings





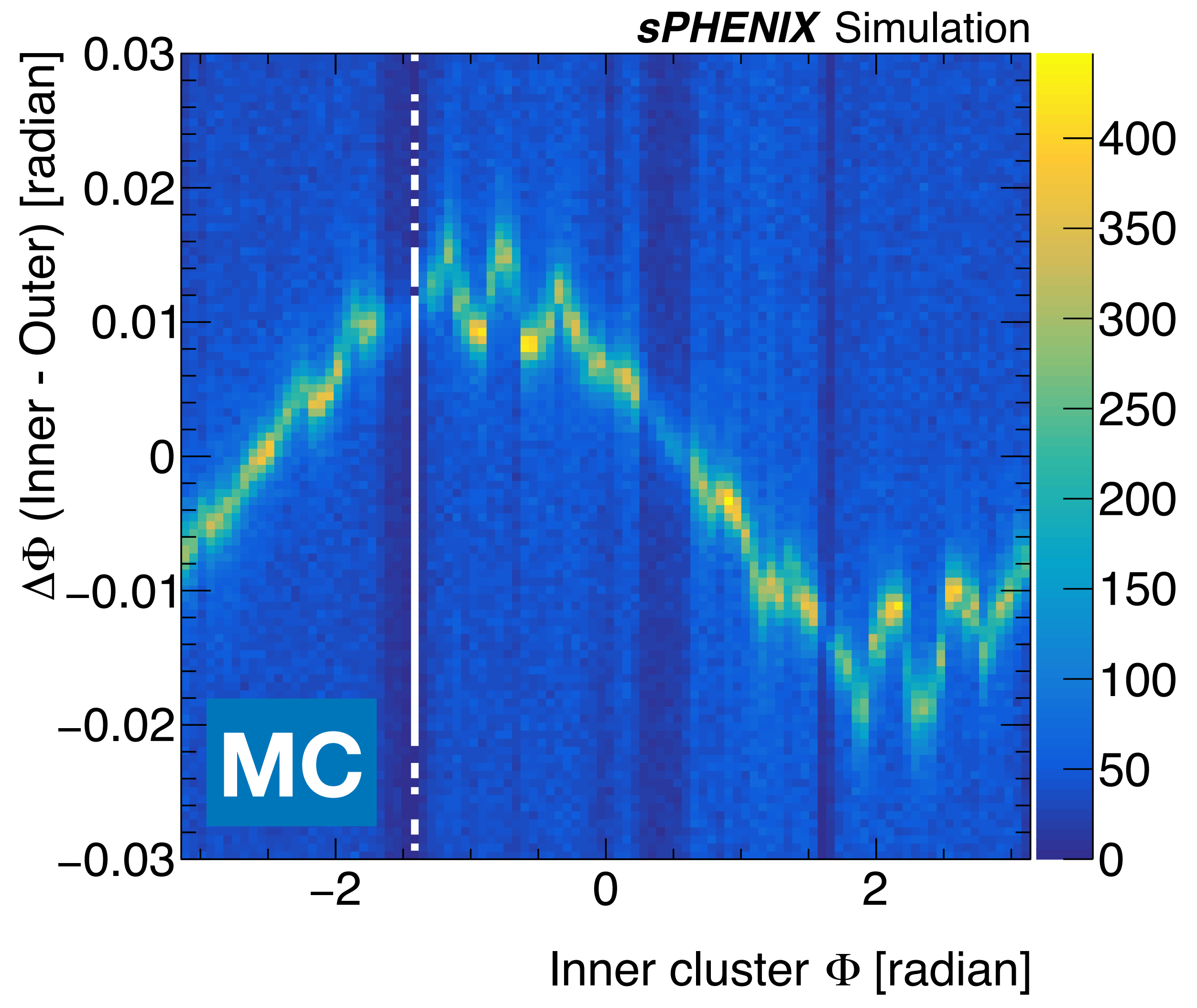
Back up

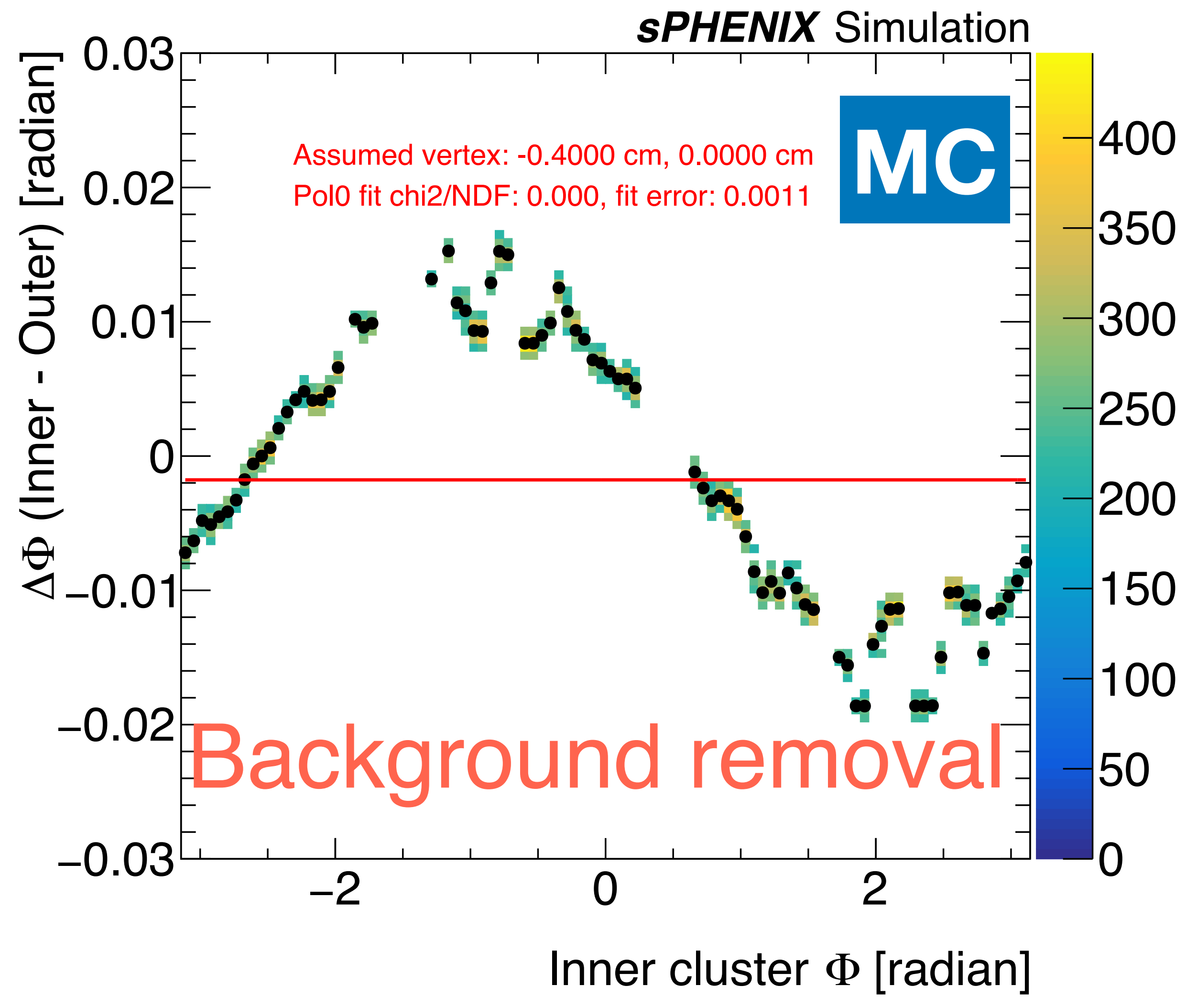
More about approach 1 for avg_vtxXY

- **Approach 1:** Quadrant method
- **Procedures:**
  1. Define the searching window
  2. In each iteration, try with 4 corners
  3. Move to the quadrant that gives better performance, and narrow the searching window half
  4. Repeat the procedure with the new 4 corners

- **How to determine the "good" vertex ?**
  - The one with better **Polynomial 0 fit errors** on both
    - DCA - Clu_{inner} ϕ correlation, and
    - Δϕ - Clu_{inner} ϕ correlation

Two correlation plots for **each corner**





More about approach 1 for avg_vtxXY

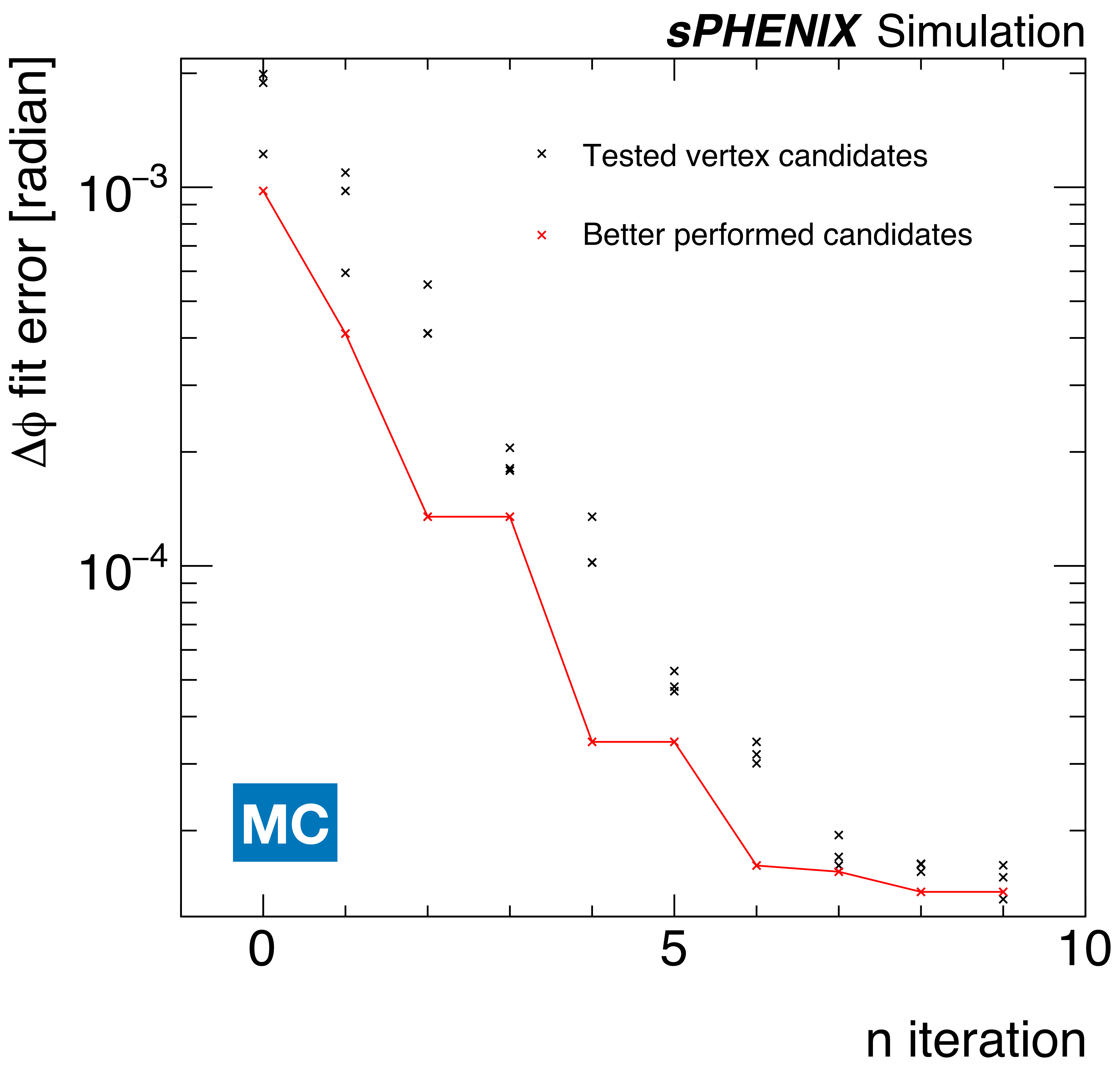
- What quantities are good choices to quantify the performance of the given vertex?
  - If the given vertex is getting closer to the true vertex:
    - DCA - inner ϕ and Δϕ - inner ϕ correlations become flat
    - Δϕ 1D distribution becomes concentrated

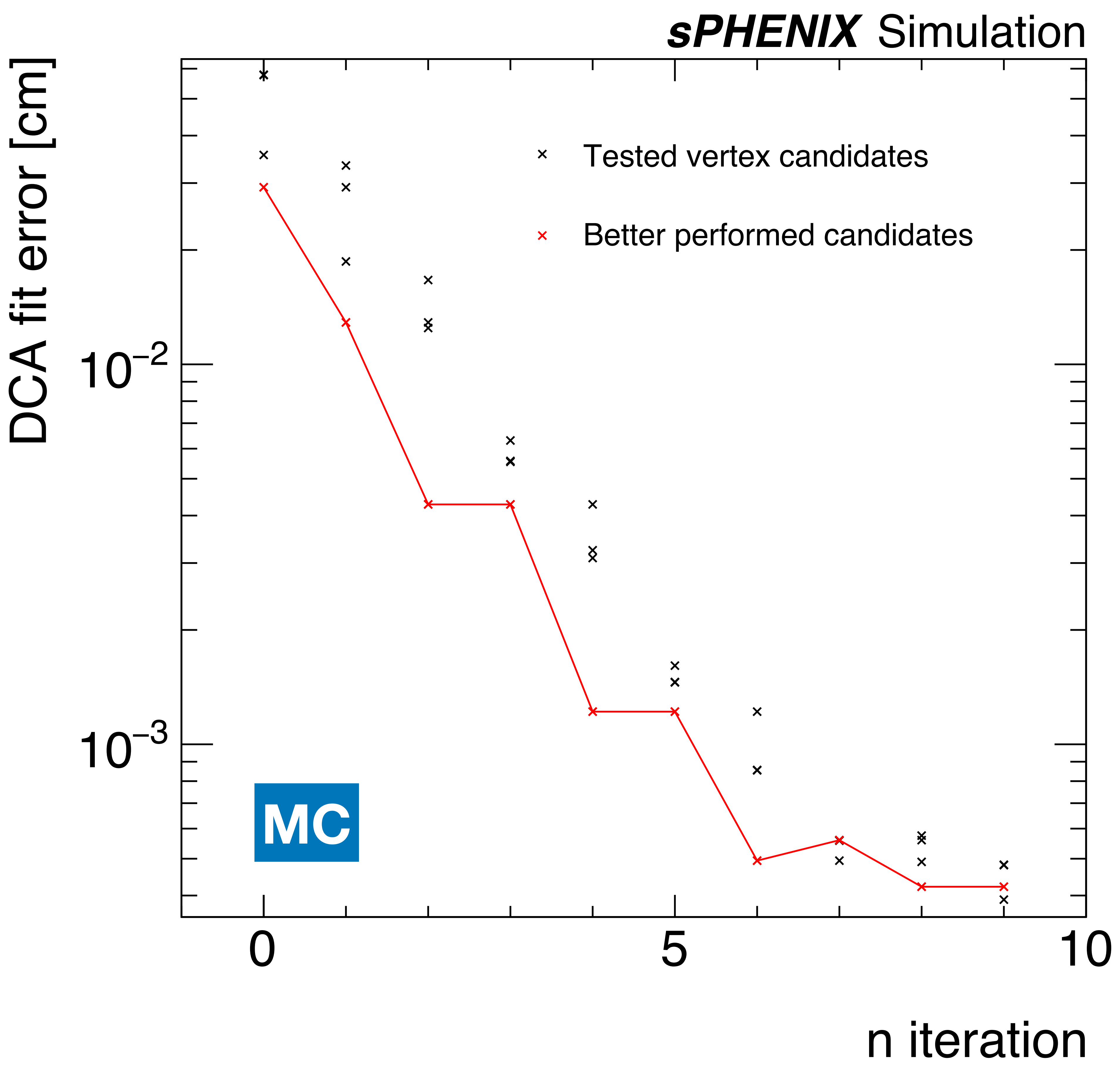
Background removed and fit with pol0

Pol0 fit error is more sensitive in the region that the correlation shape is closer to the horizontal line
Currently require both fit errors of DCA-inner ϕ and Δϕ-inner ϕ have to be better

More about approach 1 for avg_vtxXY

- **Approach 1:** Quadrant method

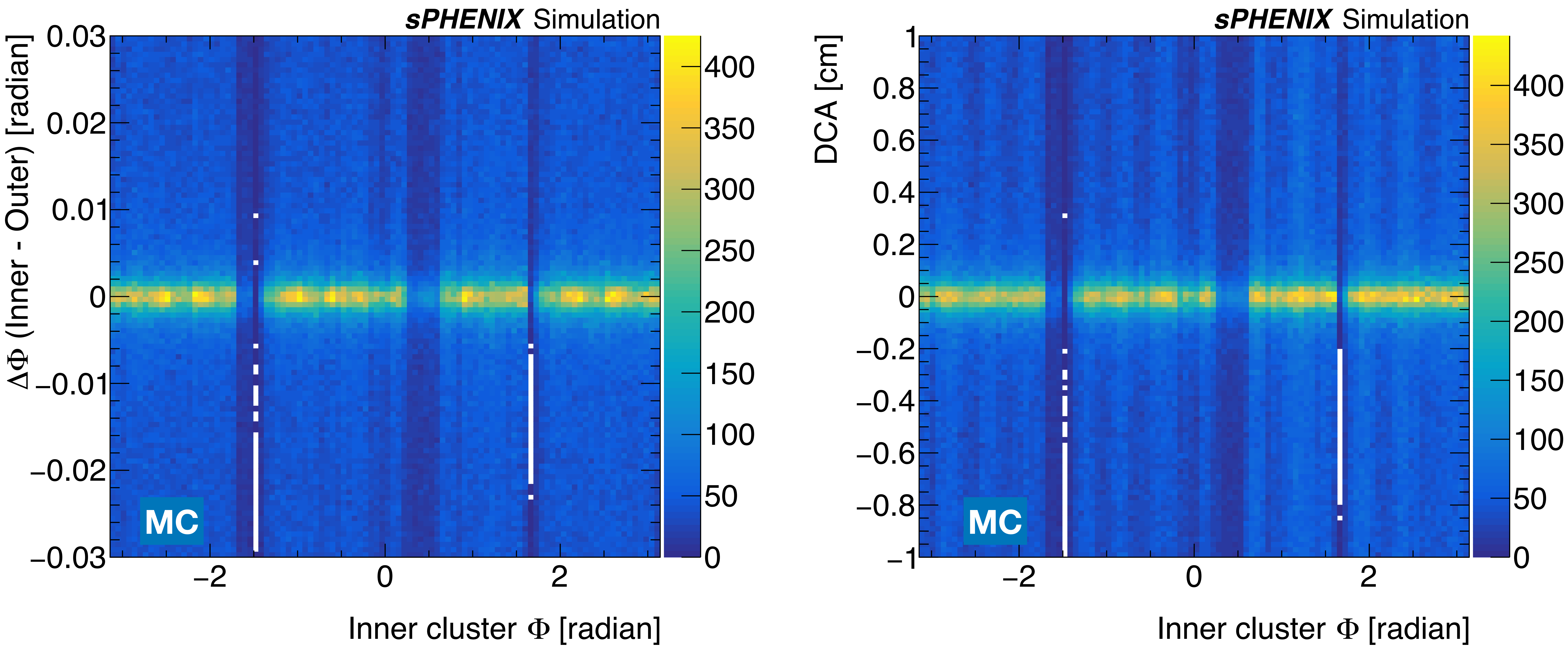




The fit error getting smaller in the deeper iteration

More about approach 1 for avg_vtxXY

- **Approach 1:** Quadrant method



MC set beam spot : -0.04 cm, 0.24 cm

Measured beam spot : -0.0405 cm, 0.2402 cm

File directories

- Data file : SDCC:/sphenix/lustre01/sphnxpro/commissioning/INTT/beam/beam_intt{0..7}-00020869-0000.evt

- Simulation file: SDCC:/sphenix/user/hjheng/sPHENIXRepo/analysis/dNdEta_Run2023/production/Sim_Ntuple_HIJING_new_20240424/ntuple_00{000..199}.root