Vertex reconstruction by INTT

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National Central University & RIKEN

Aug 21th, 2024
INTT meeting

Analyzed data

- Analyzed run: 20869 (from run 23)
- Configuration: zero-filed, vertex Z off by -20 cm

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

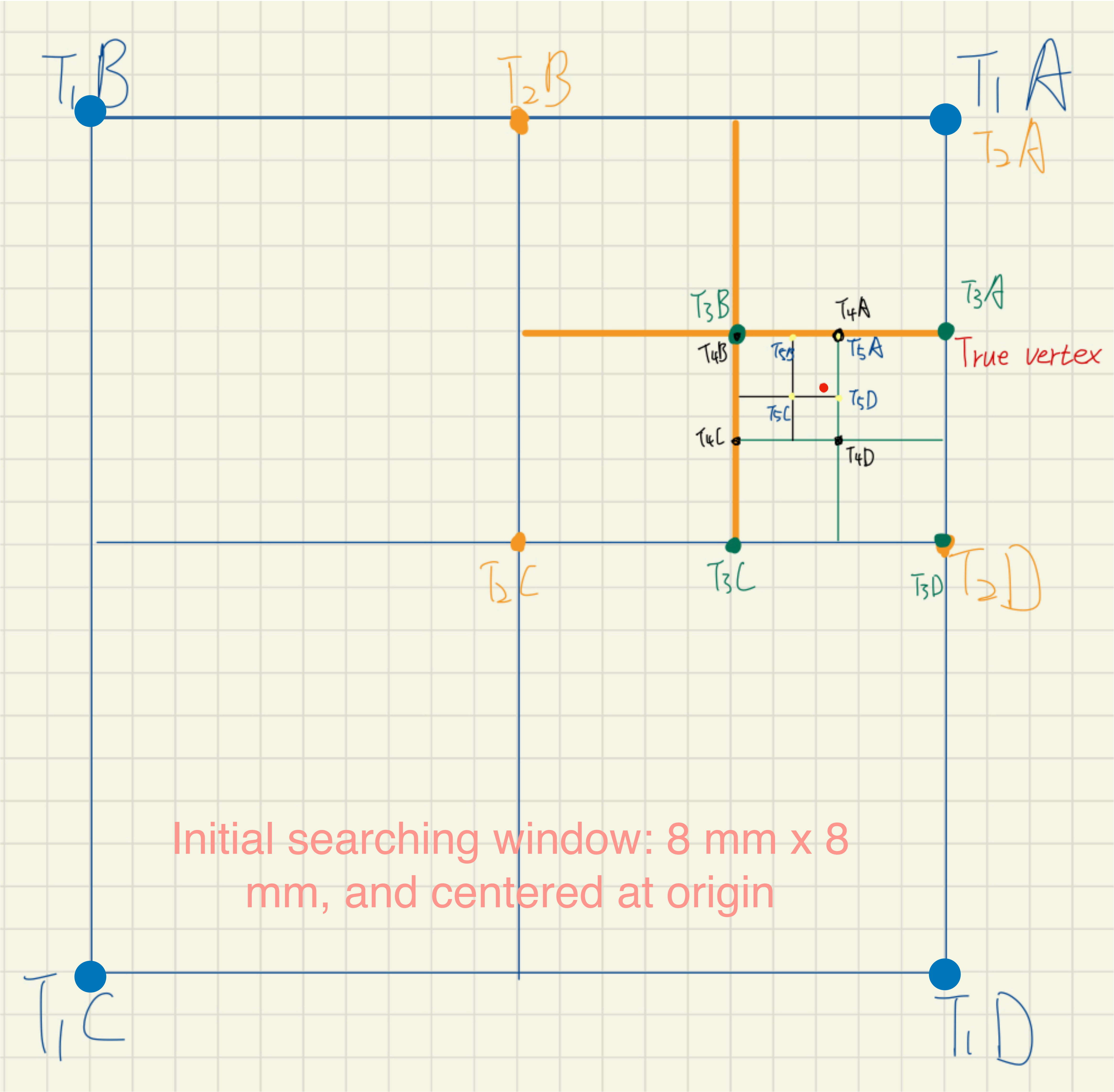
- Simulation file: /sphenix/user/hjheng/sPHENIXRepo/analysis/dNdEta_Run2023/production/Sim_Ntuple_HIJING_new_20240424/ntuple_00{000..199}.root

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 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 **<u>Polynomial 0 fit errors</u>** on both
    - <u>DCA - Clu_{inner} ϕ</u> correlation, and
    - <u>Δϕ - Clu_{inner} ϕ</u> correlation

The area inside the INTT barrel



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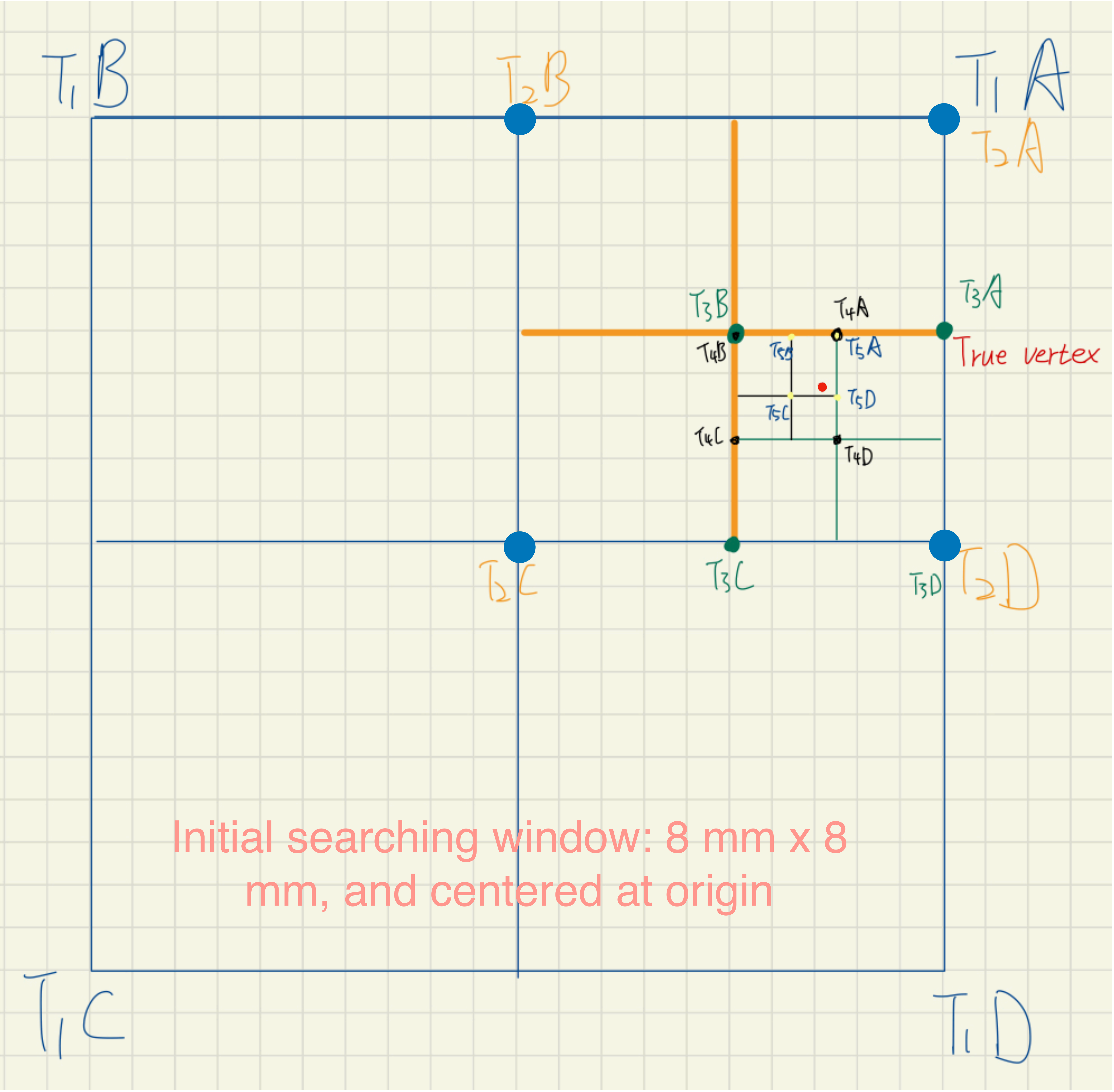

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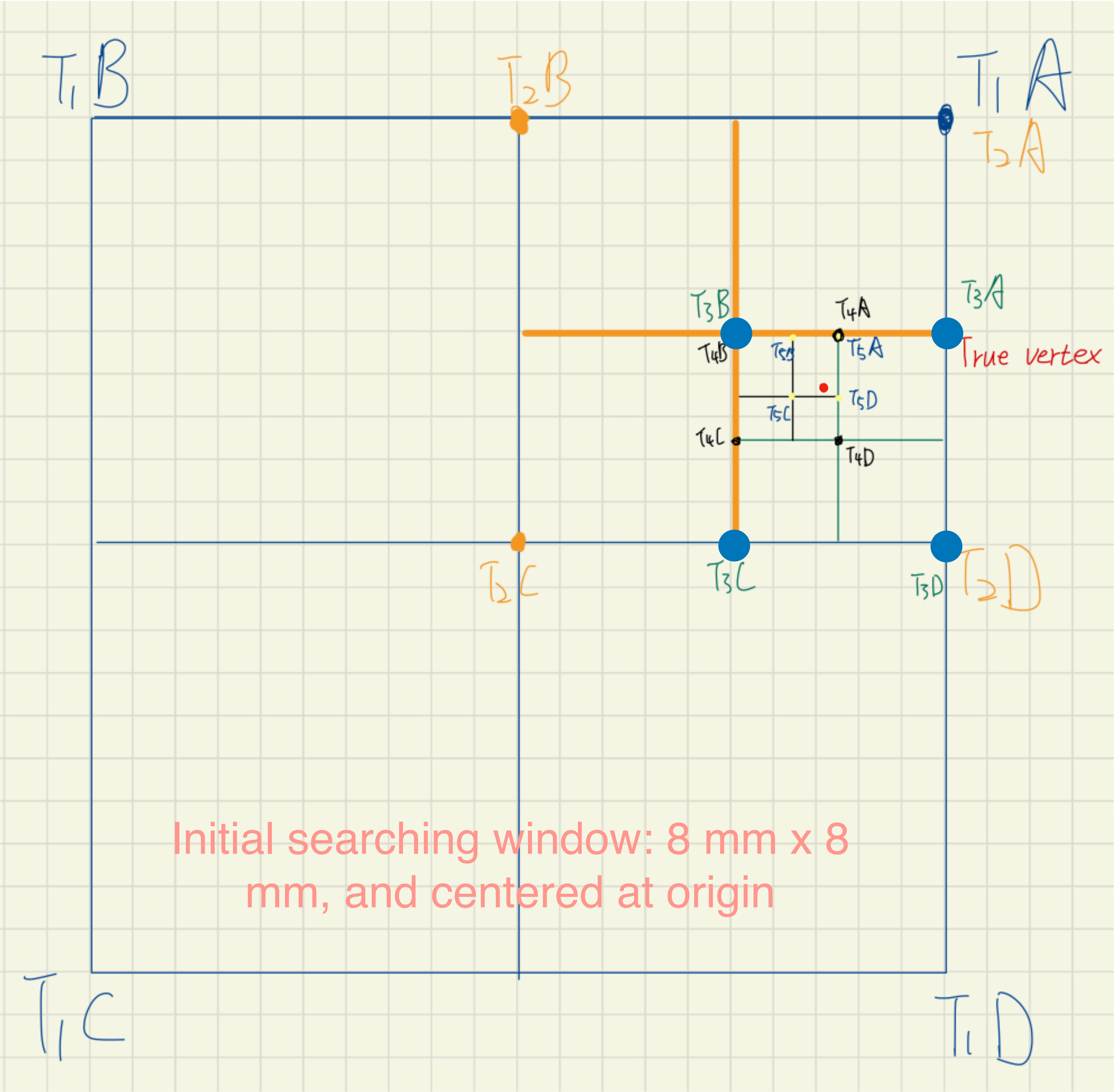

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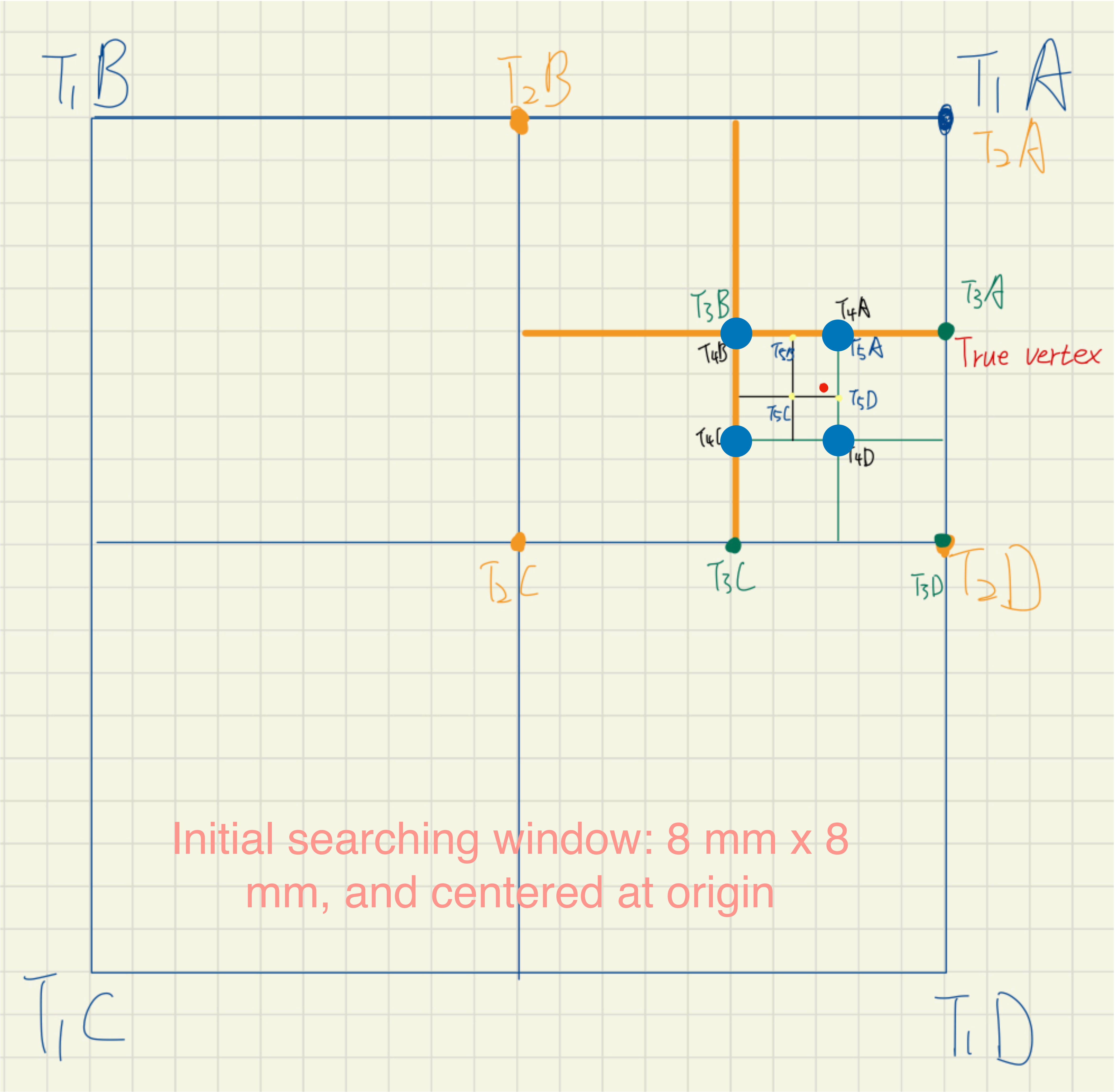

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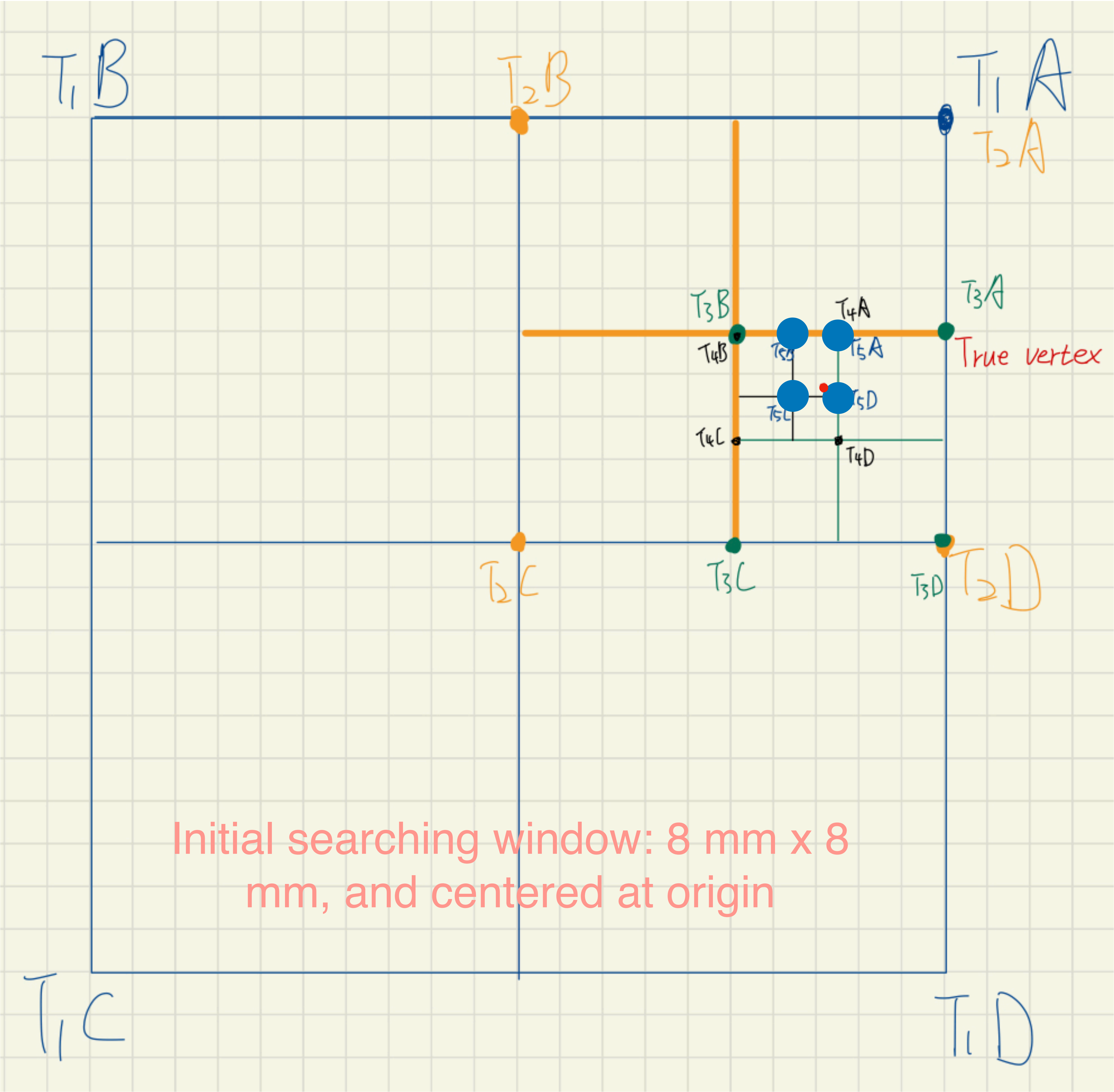

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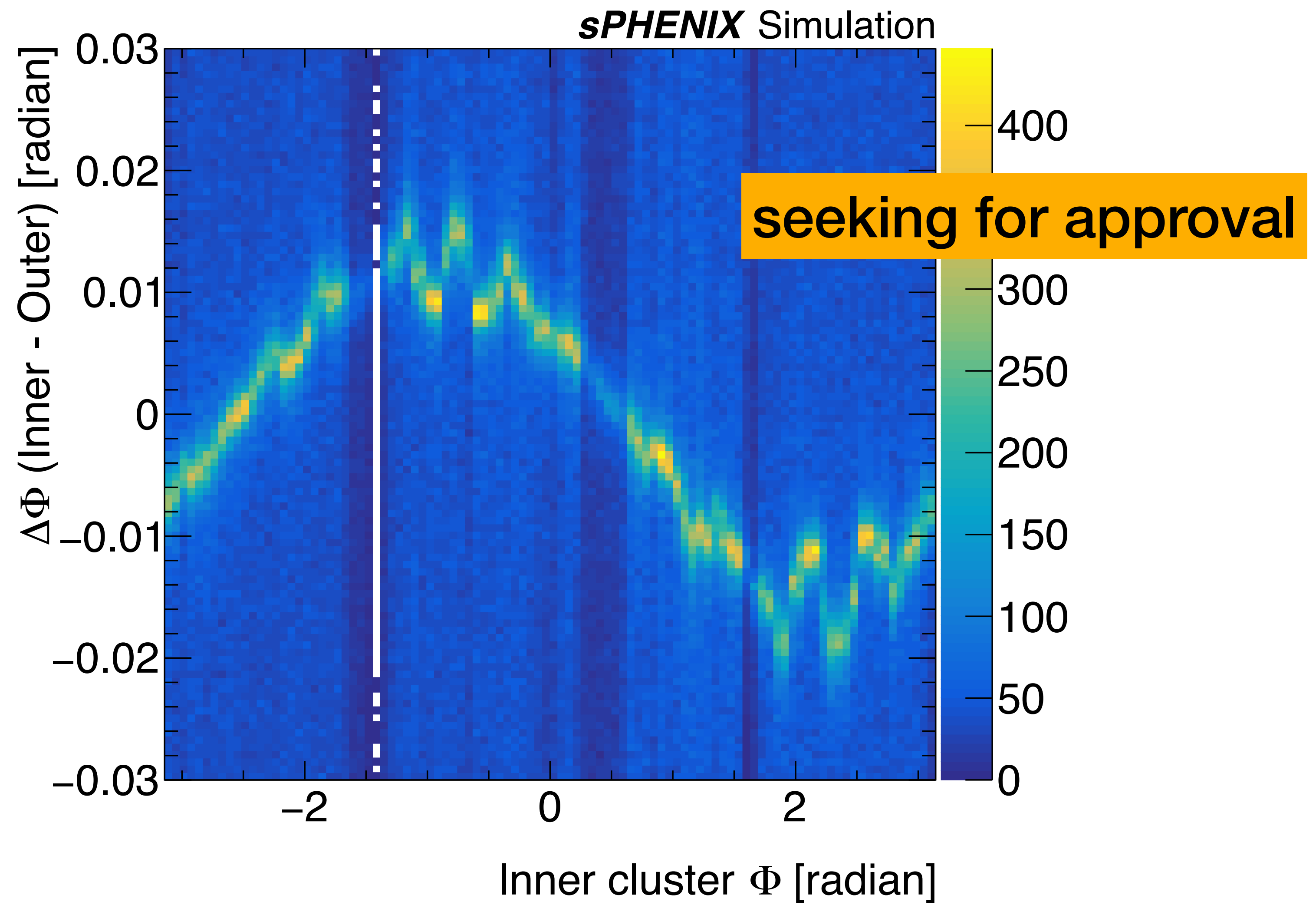
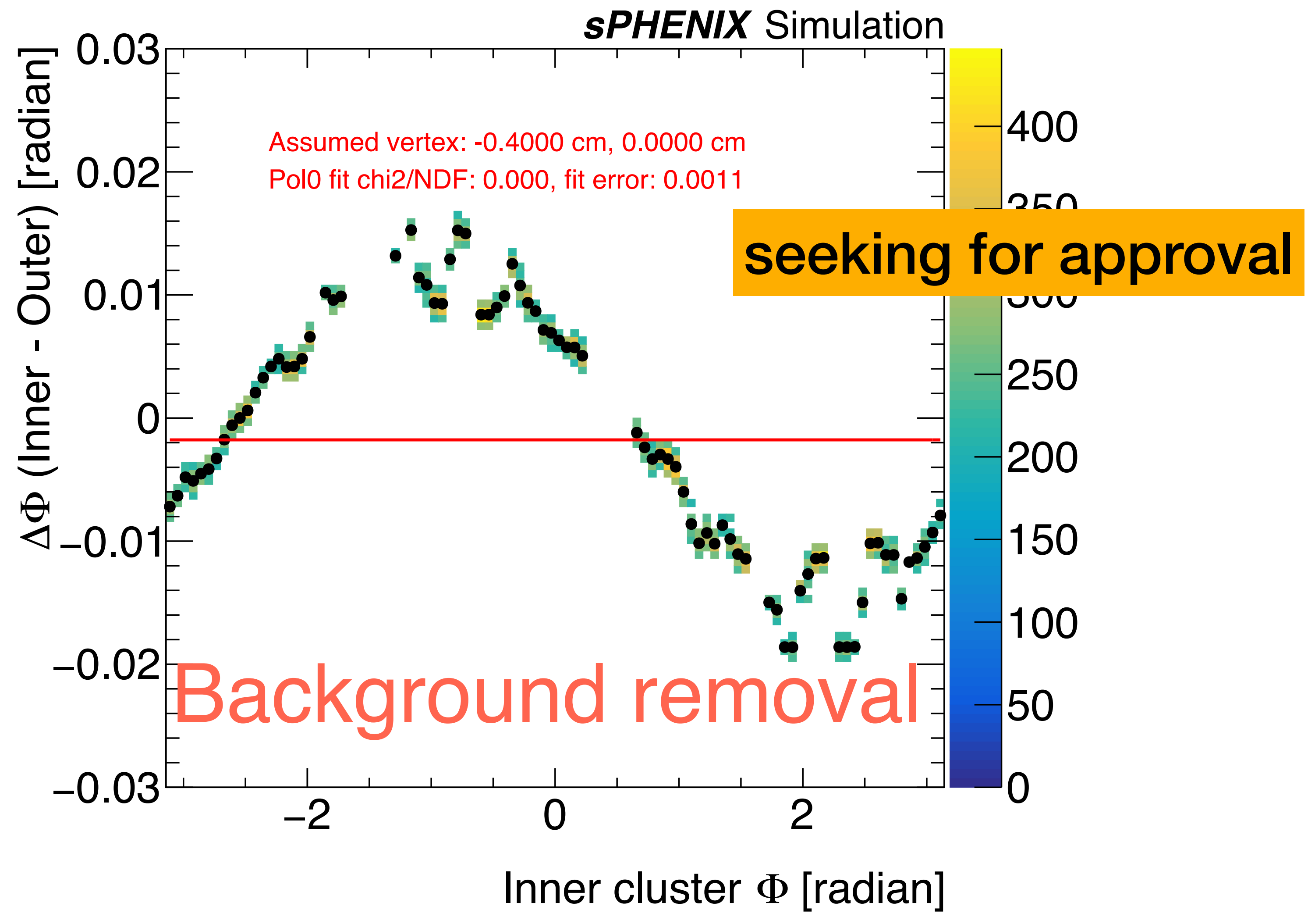
Two correlation plots for **each corner**





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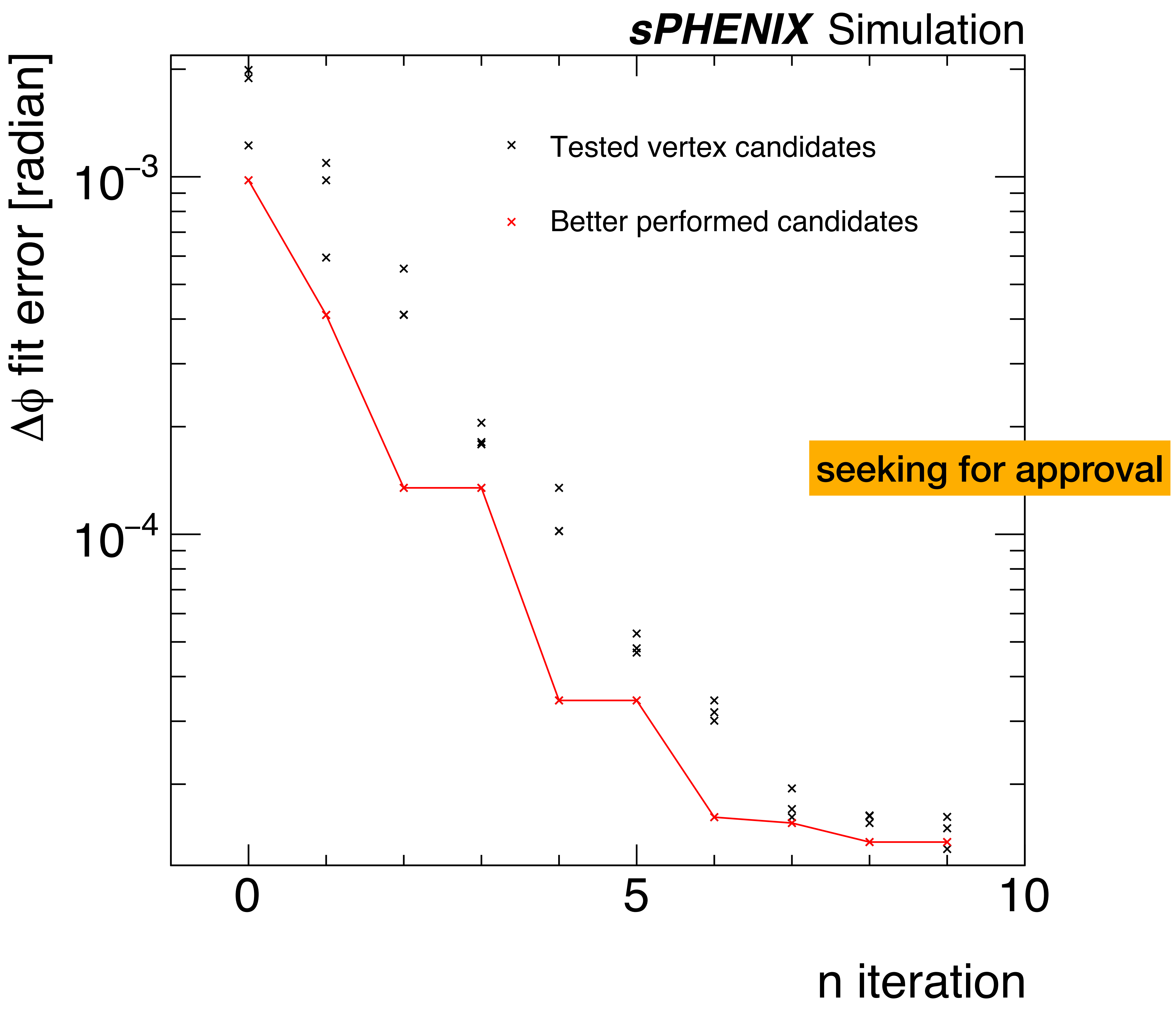

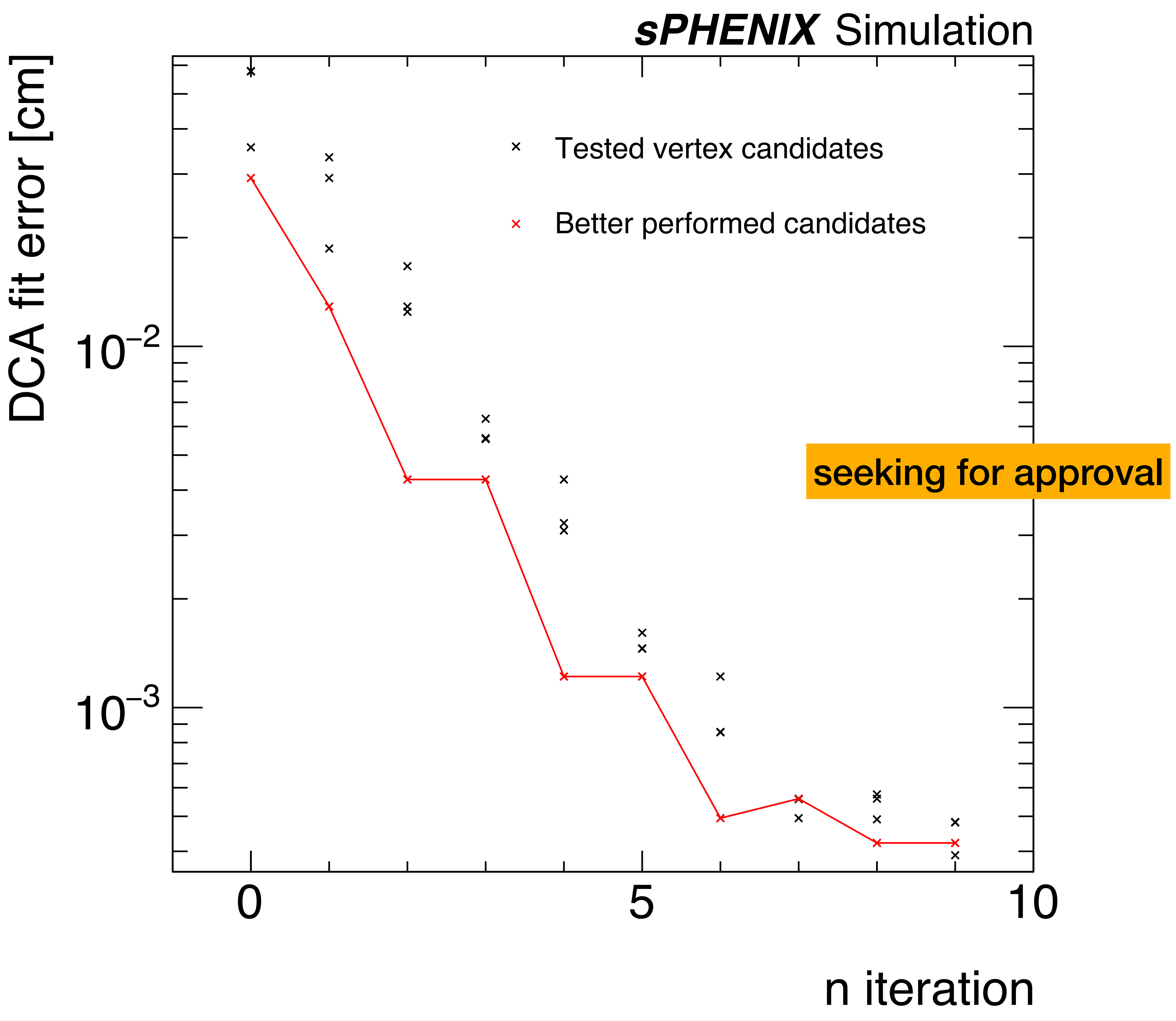

The fit error getting smaller in the deeper iteration

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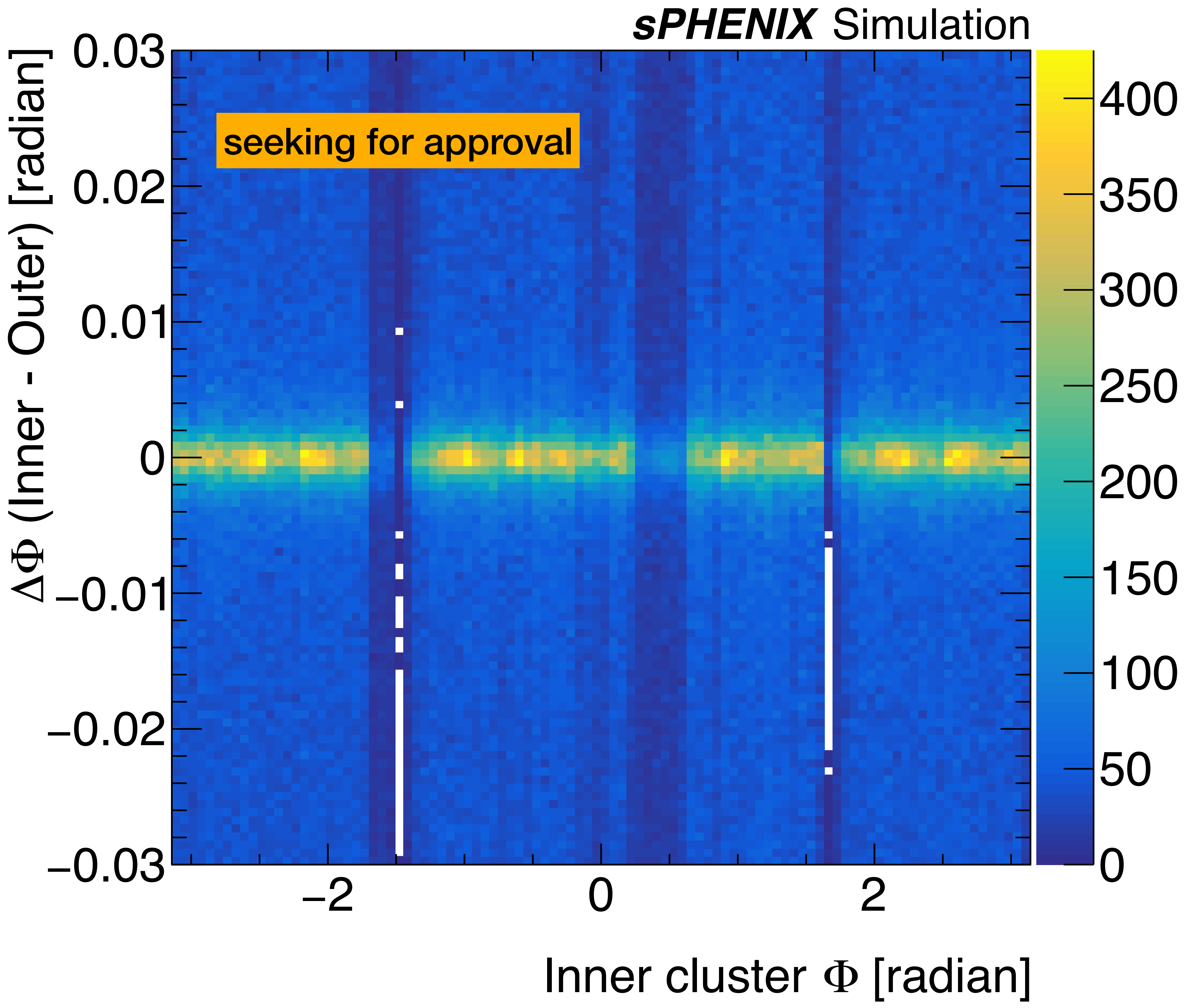
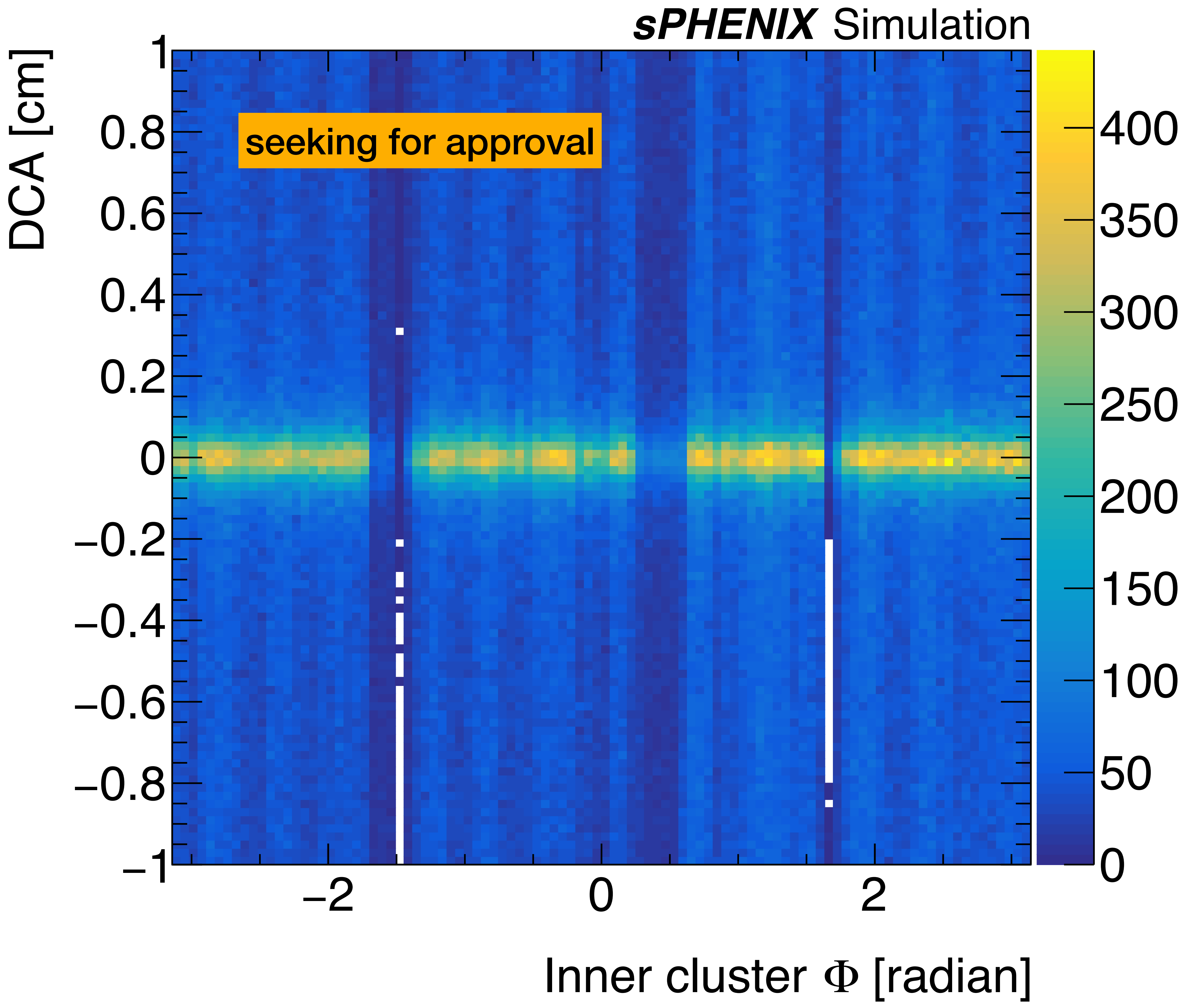


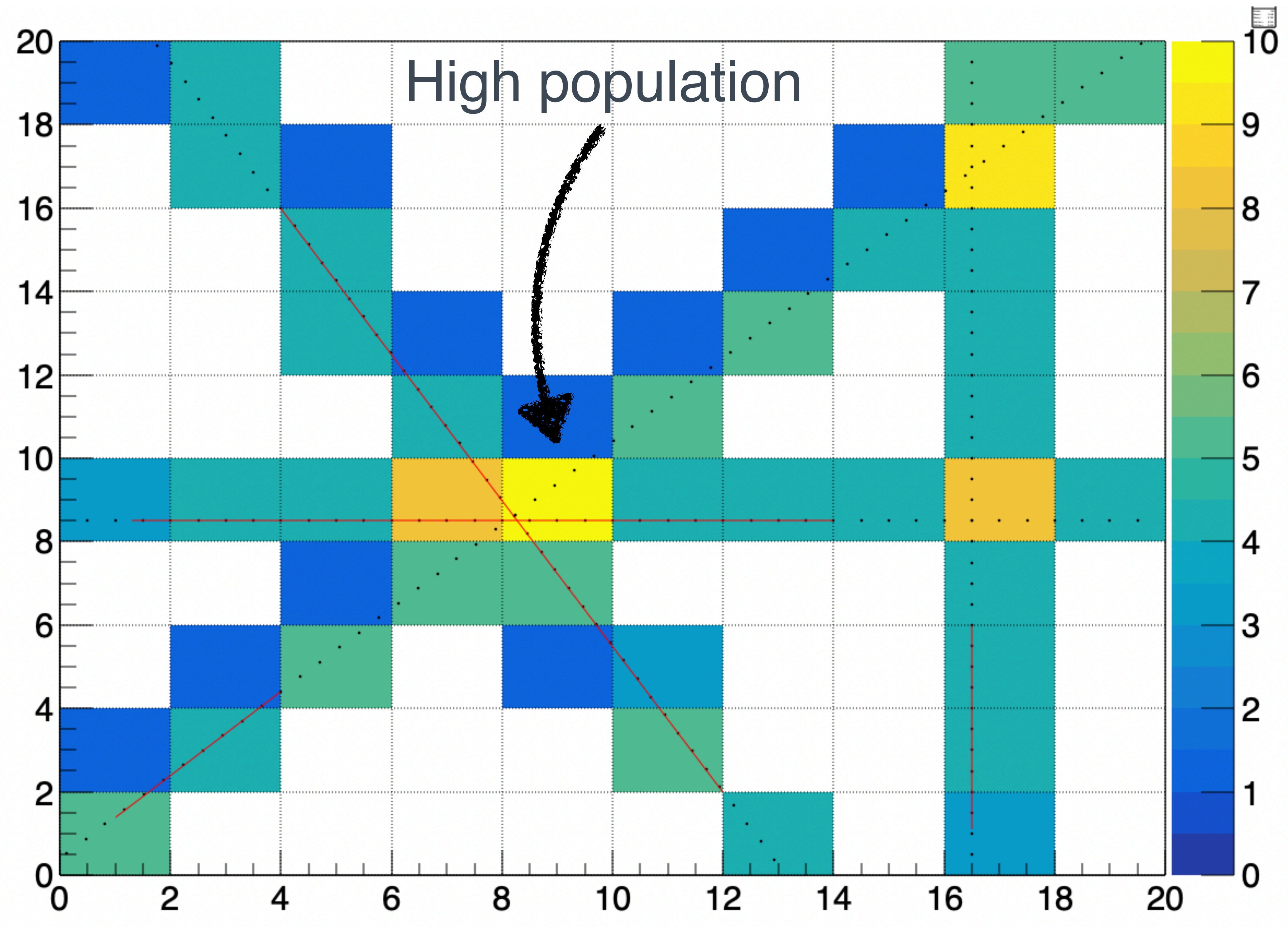


MC set beam spot : -0.04 cm, 0.24 cm
Measured beam spot : -0.0405 cm, 0.2402 cm

Average vertex XY - approach 2

- **Approach 2:** Line-filled method
- **Purpose:** crosscheck
- **Ideal:** vertex can be obtained by populating the 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 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 tracklets can tell the position

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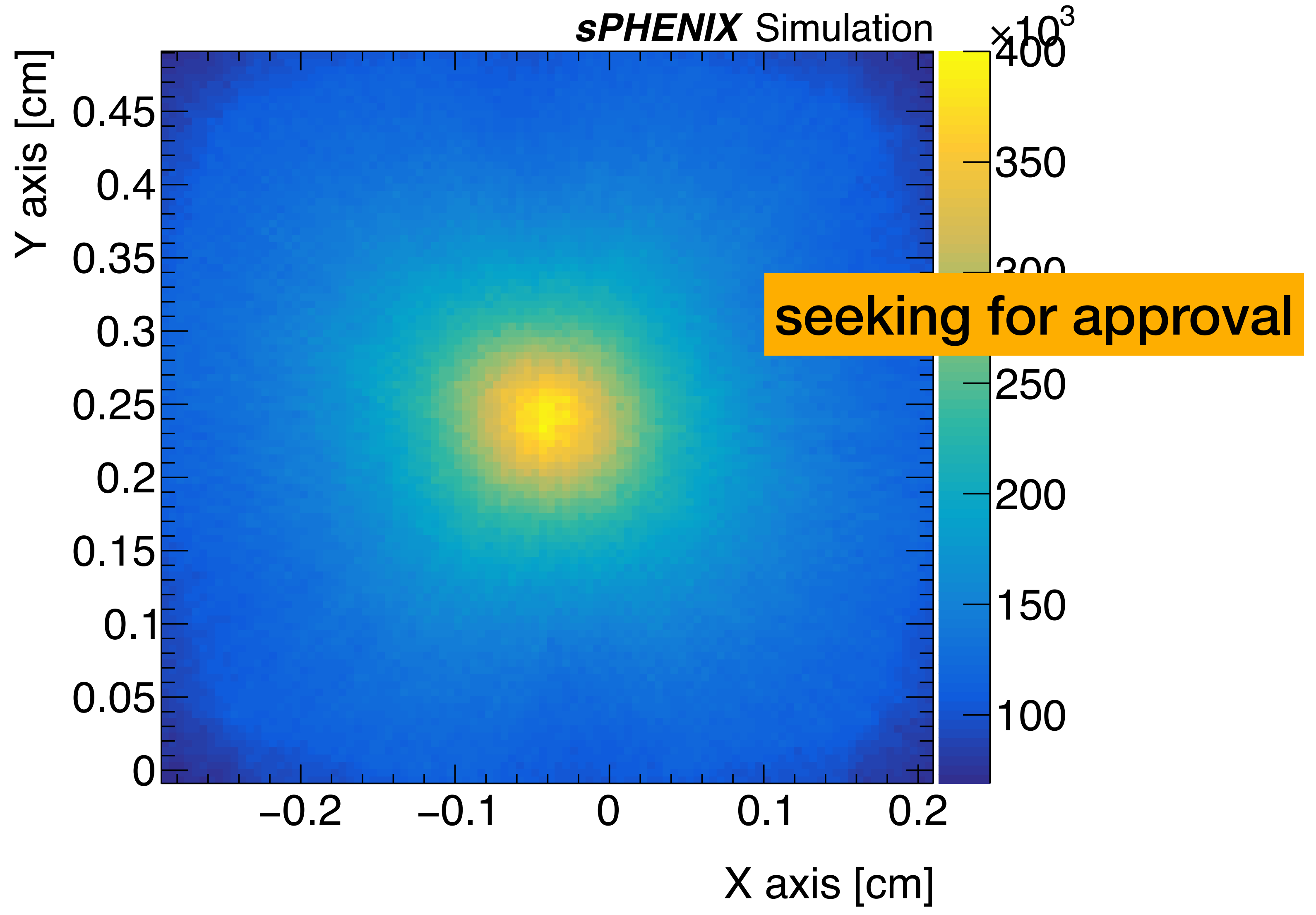
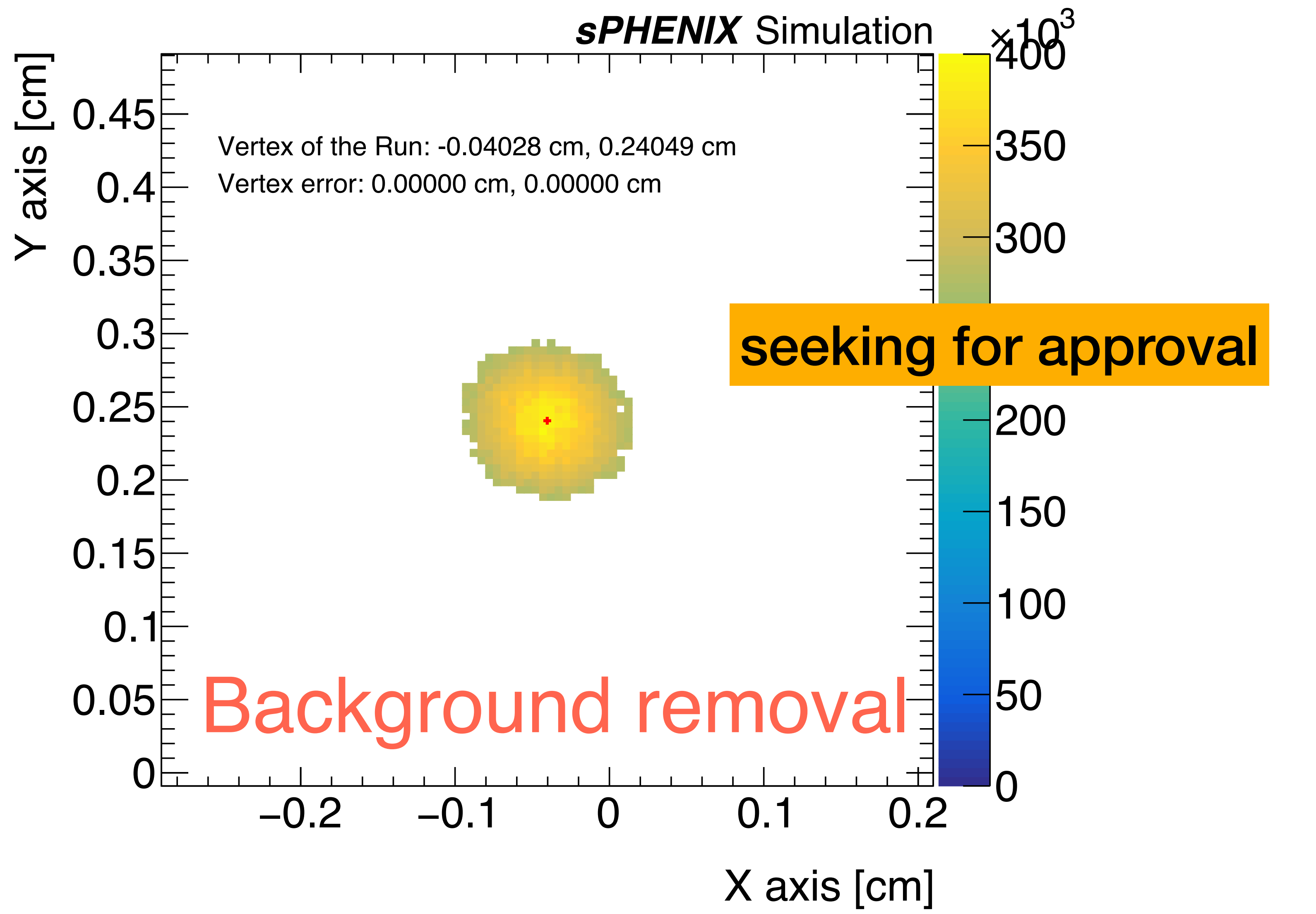
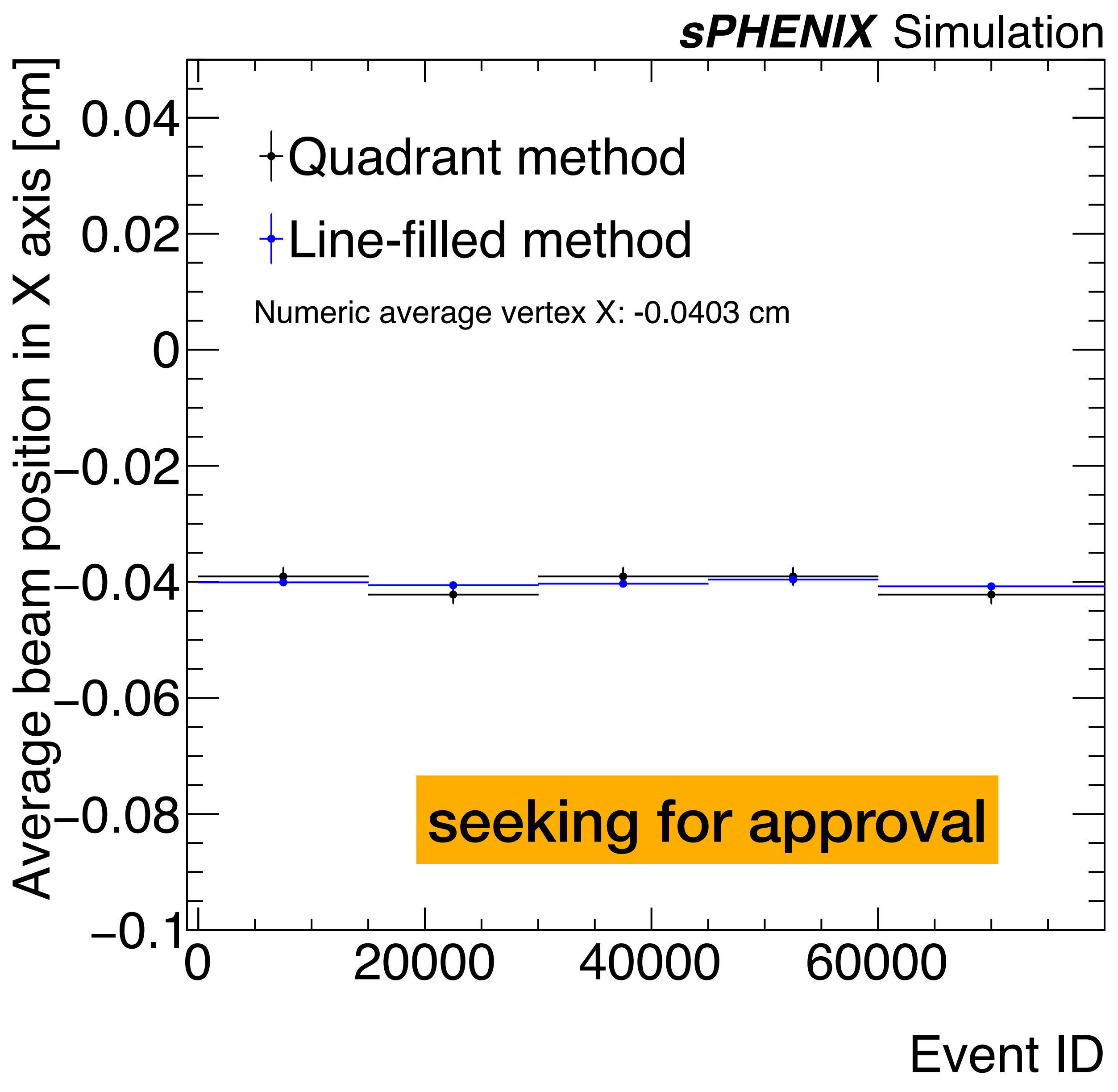


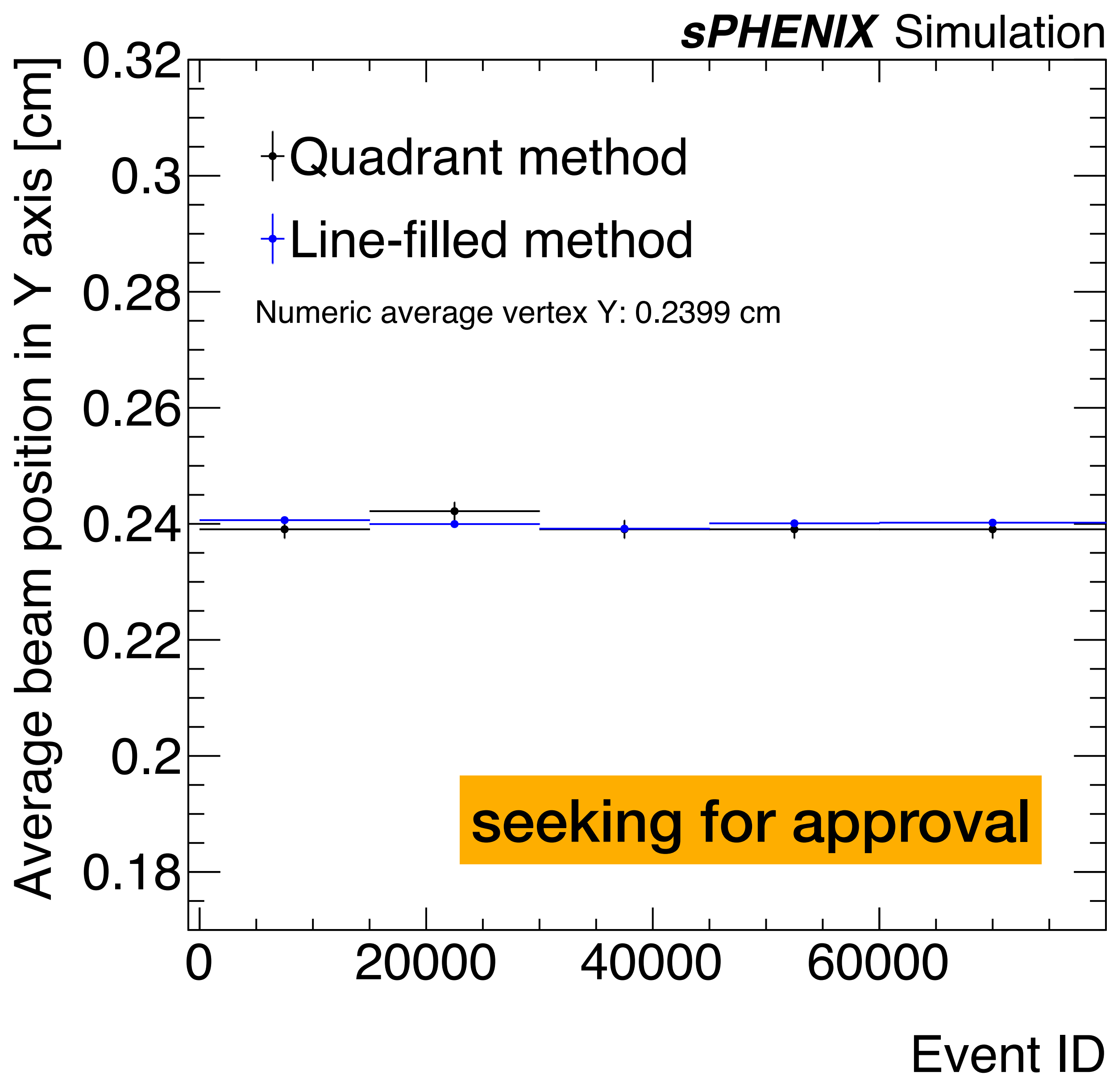


Final estimated vertex: **(-0.0402 cm, 0.2405 cm)**

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 avg vtxXY





final average vertex XY should be used :
line filled X : -0.0402675 +/- 0.000456319
line filled Y : 0.240015 +/- 0.000535473
quadrant X : -0.0403125 +/- 0.00171163
quadrant Y : 0.239687 +/- 0.00139754

Avg: {-0.04029 * cm, 0.239851 * cm}
Setting: {-0.04 cm, 0.24 cm}

Final average vertex XY - data

Data

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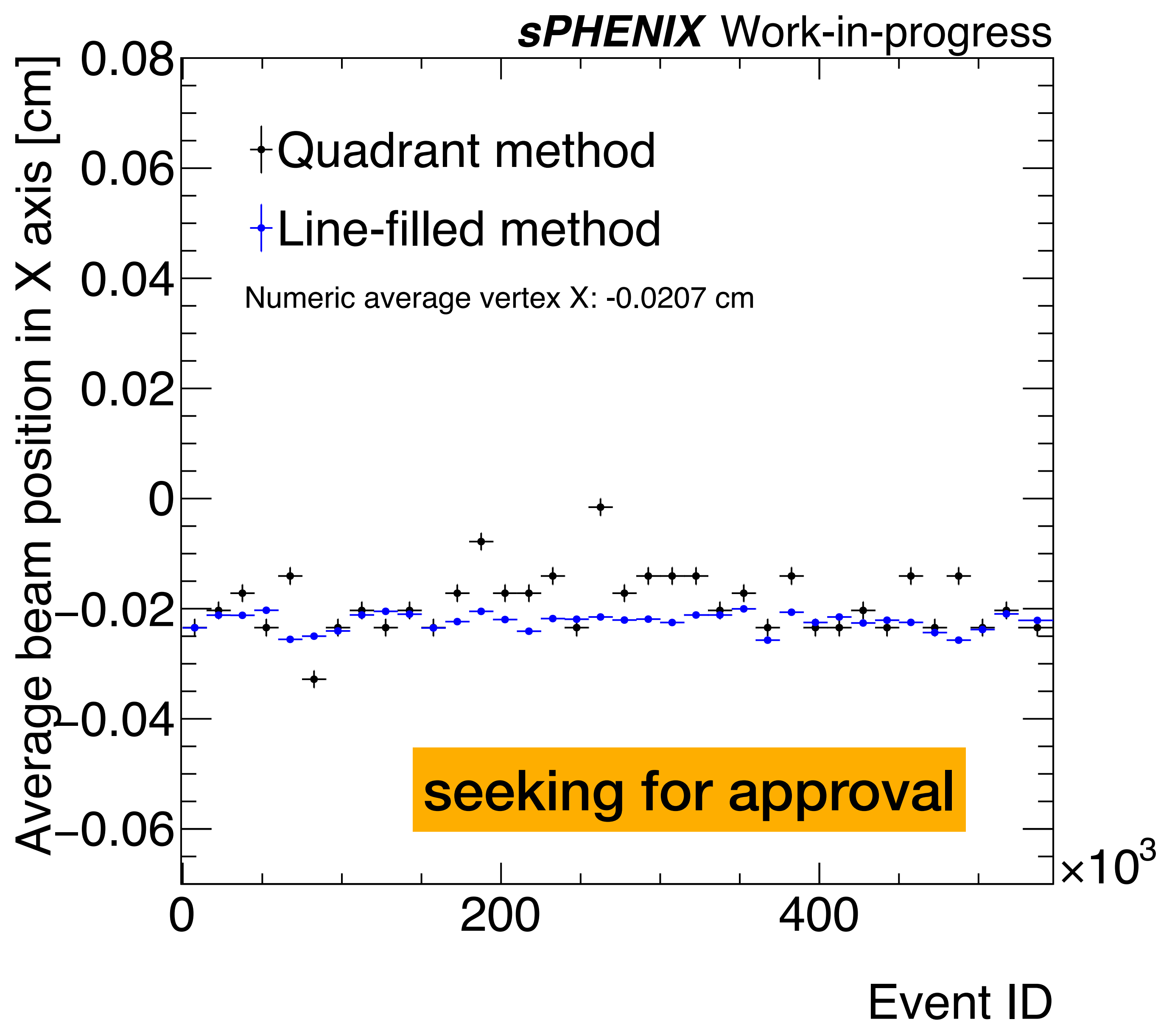
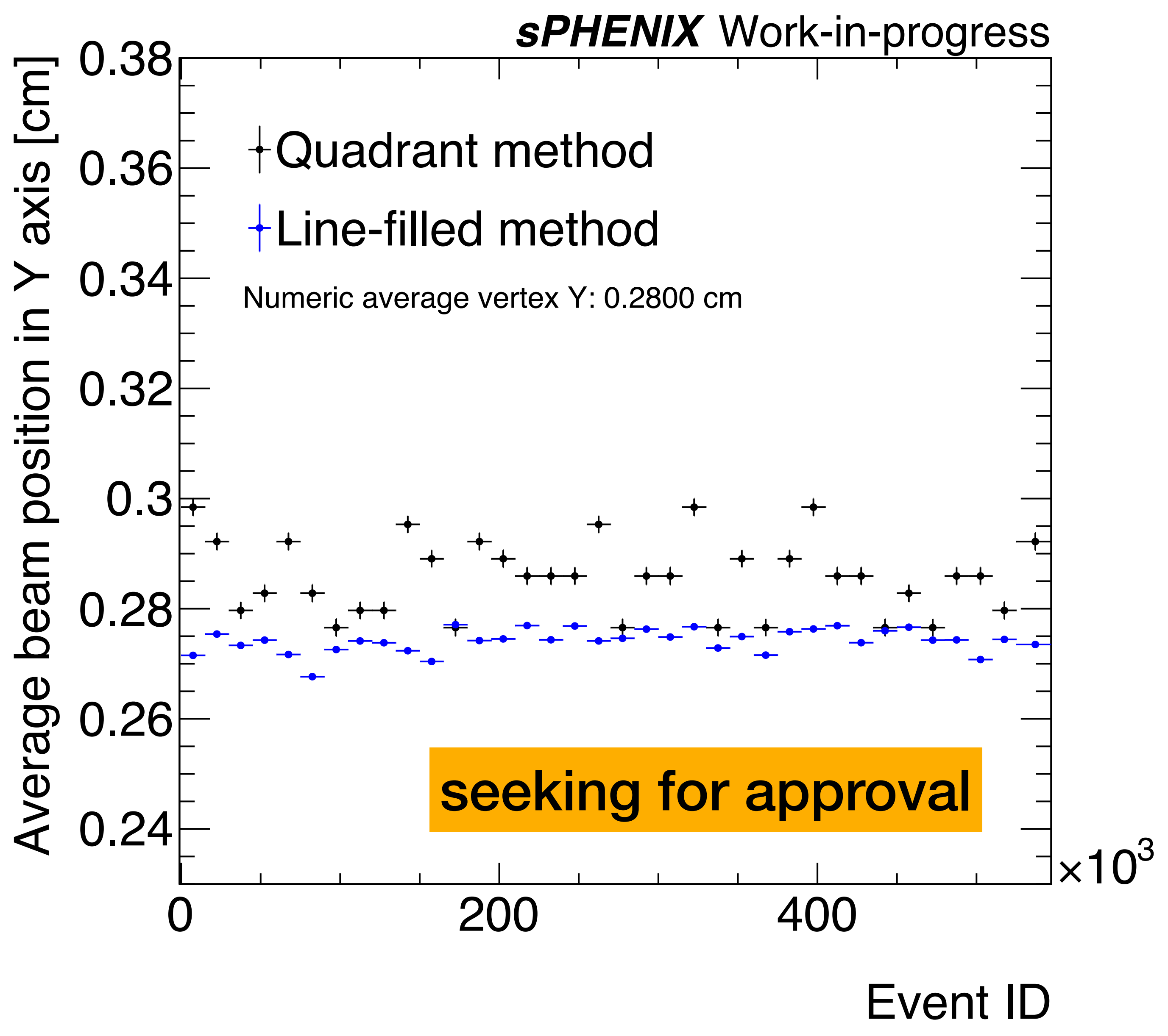
  - 20 < selected_NClus < 350
  - 15k events per data point
  - Take the total average as the final avg vtxXY



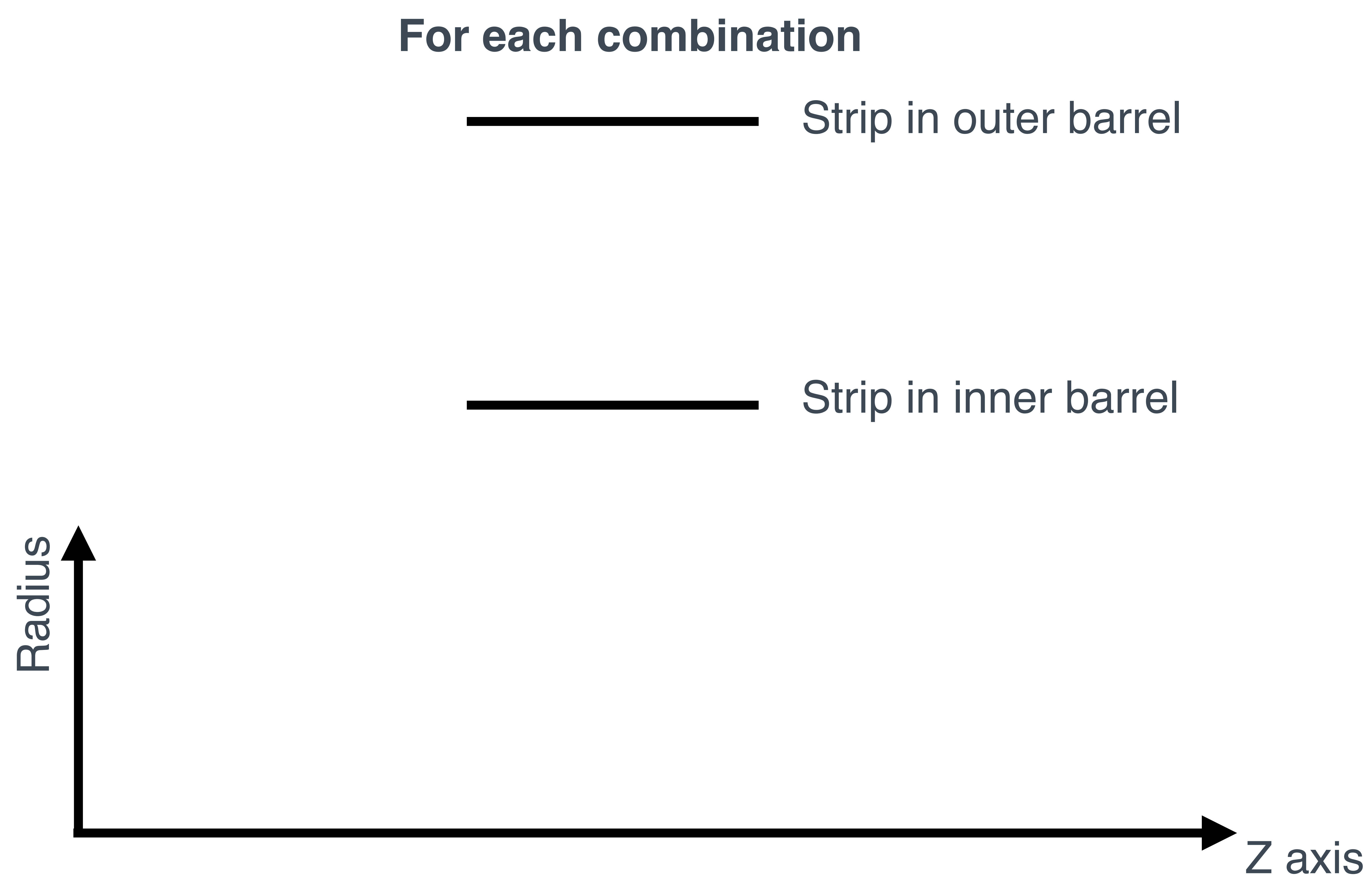


final average vertex XY should be used :
line filled X : -0.0223385 +/- 0.00158029
line filled Y : 0.274166 +/- 0.00212953
quadrant X : -0.0190104 +/- 0.00560886
quadrant Y : 0.285764 +/- 0.00684427

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

Per-event vertex Z reconstruction

- Idea given by Akiba san. For each combination, take into account of the distribution of the possible vertex Z range, and normalize the distribution, and fill into the histogram. (Used to assume the Uniform distribution of the vertex Z)



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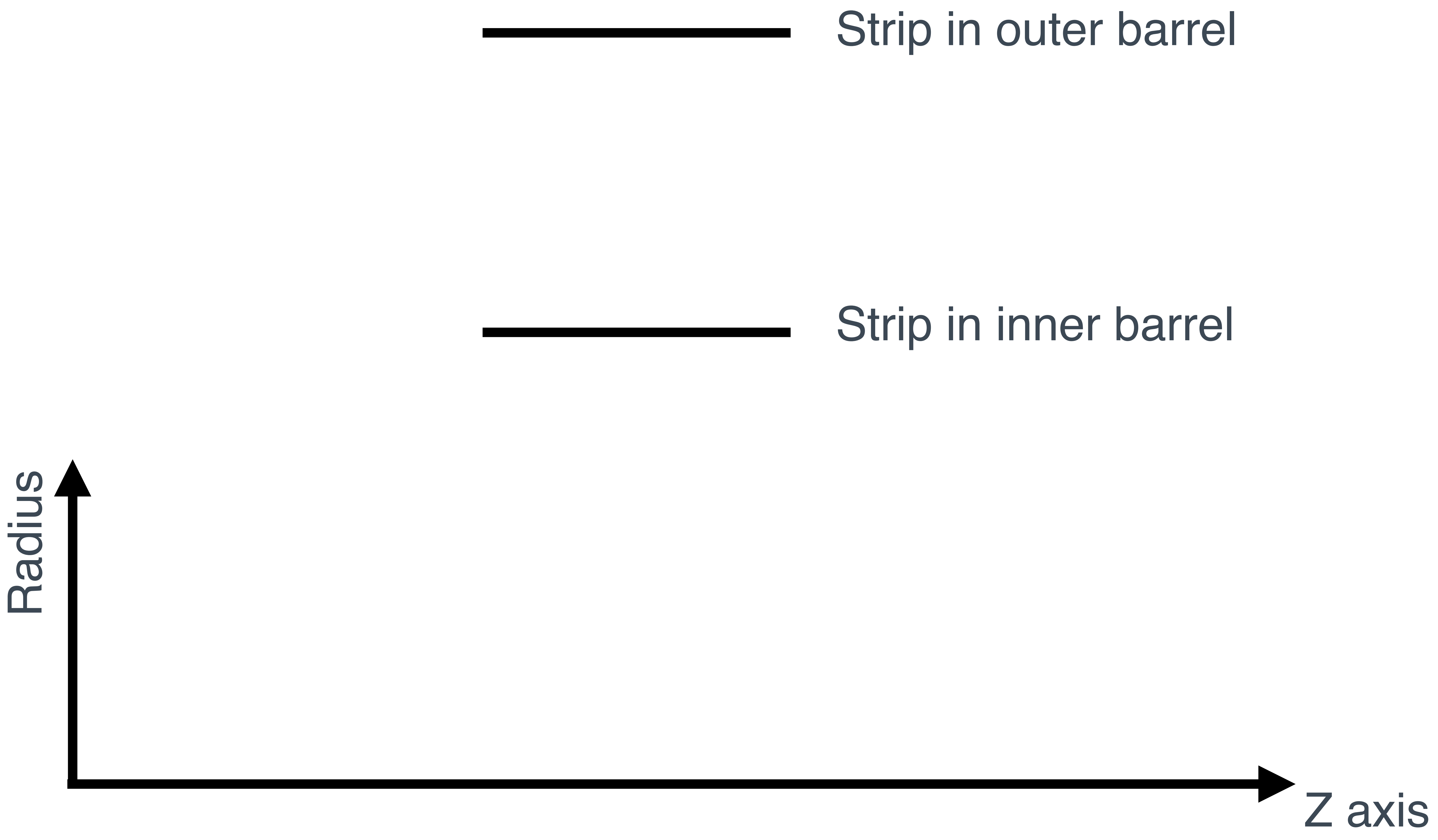

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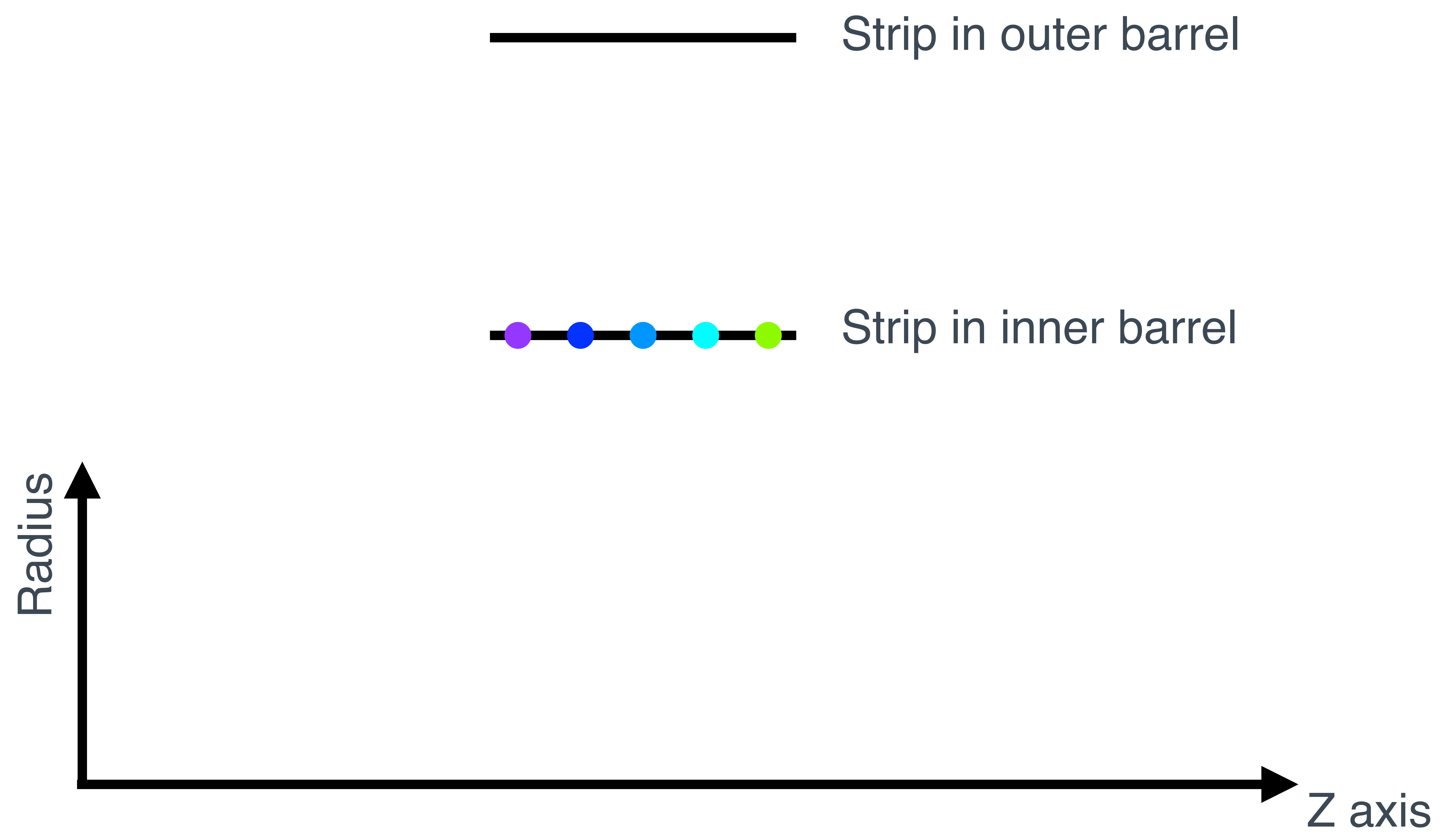

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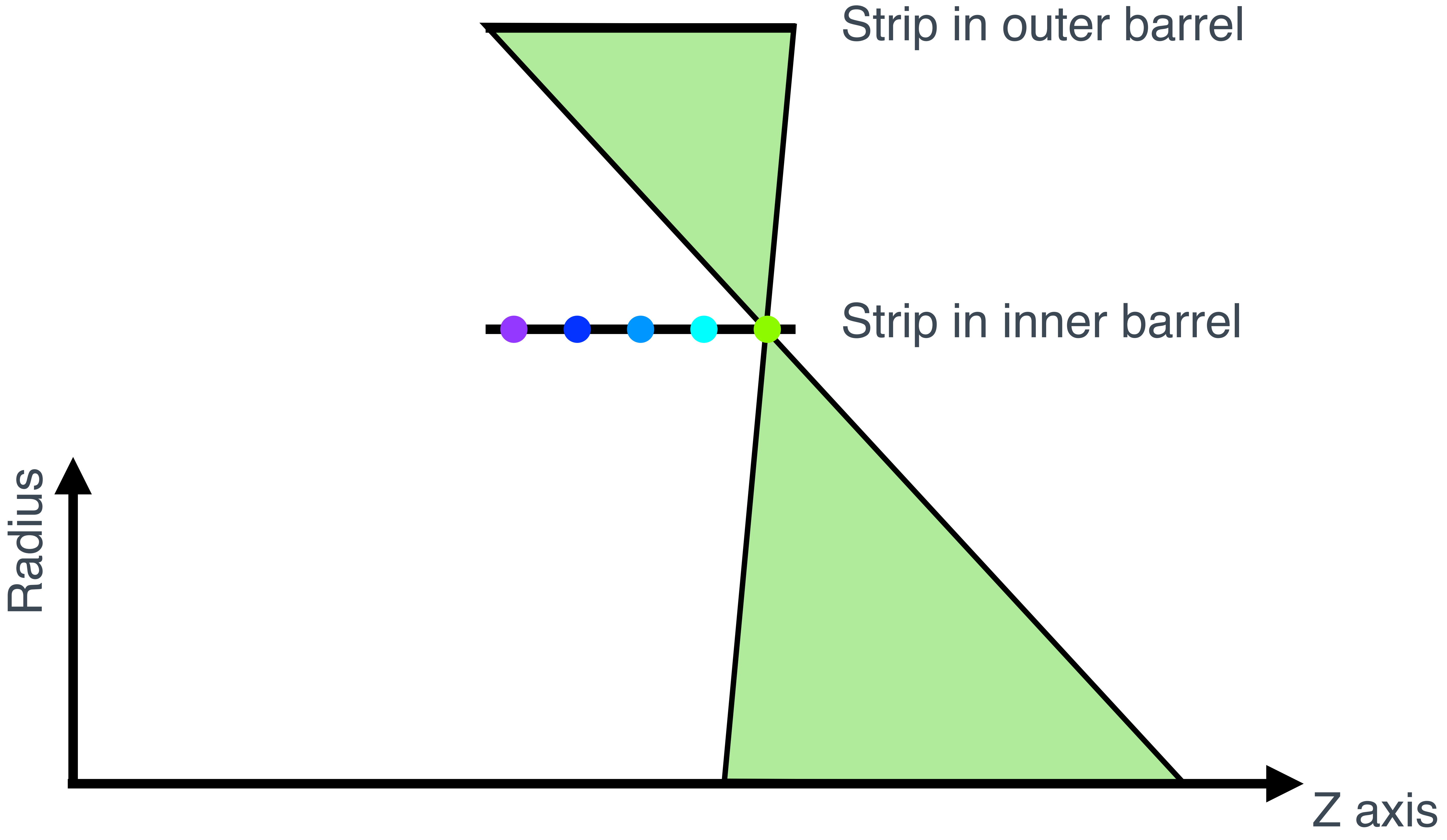

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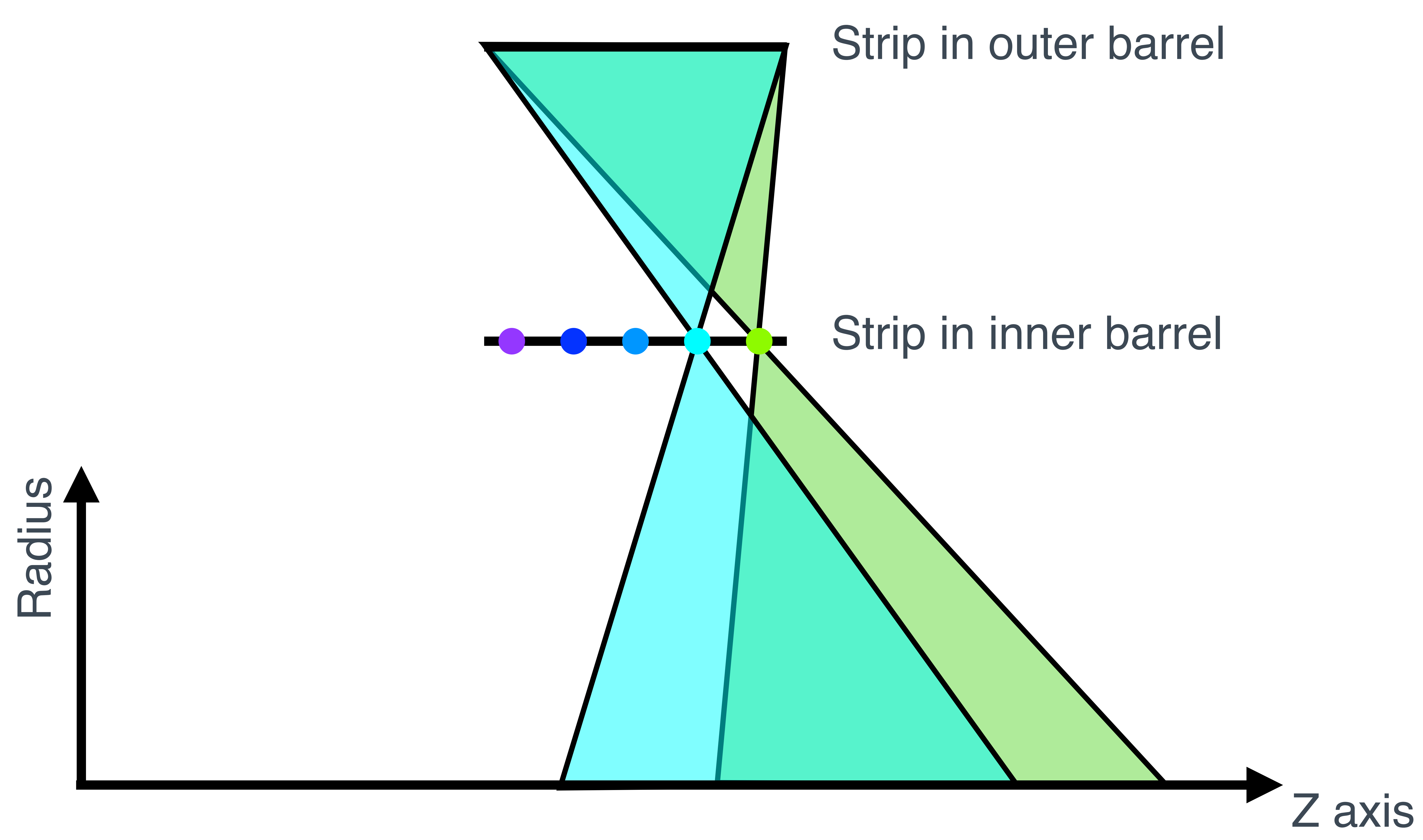

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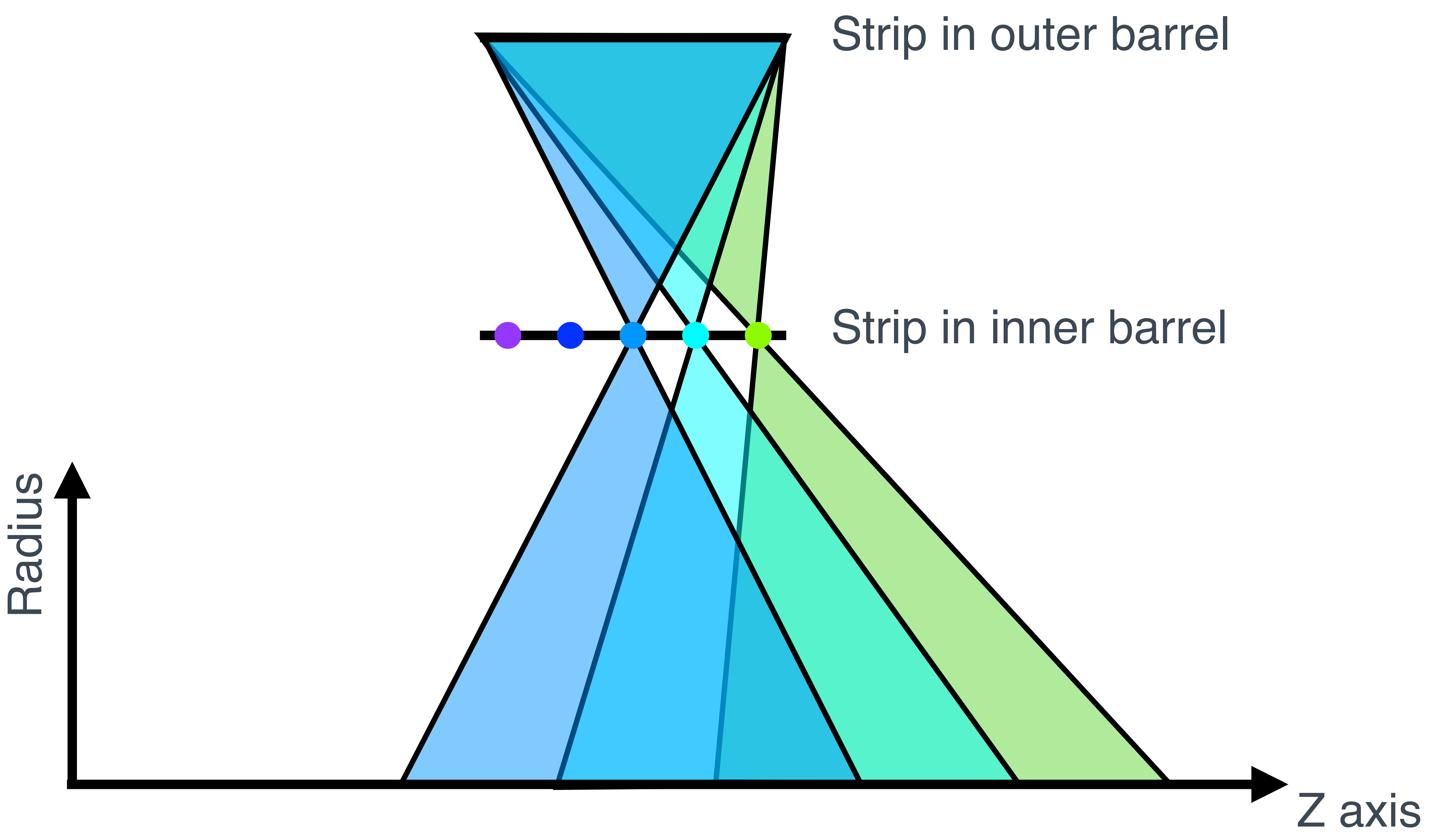

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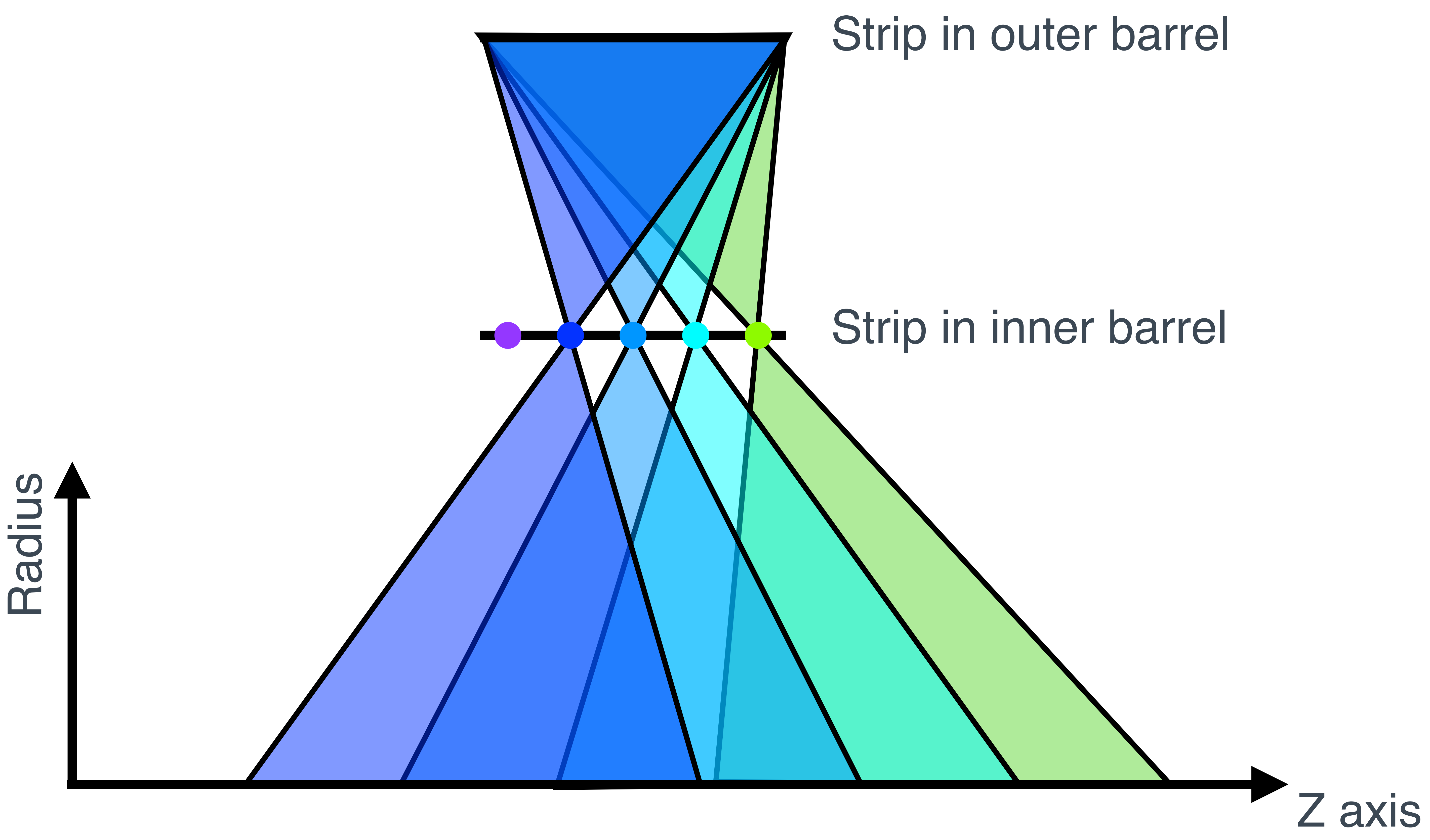

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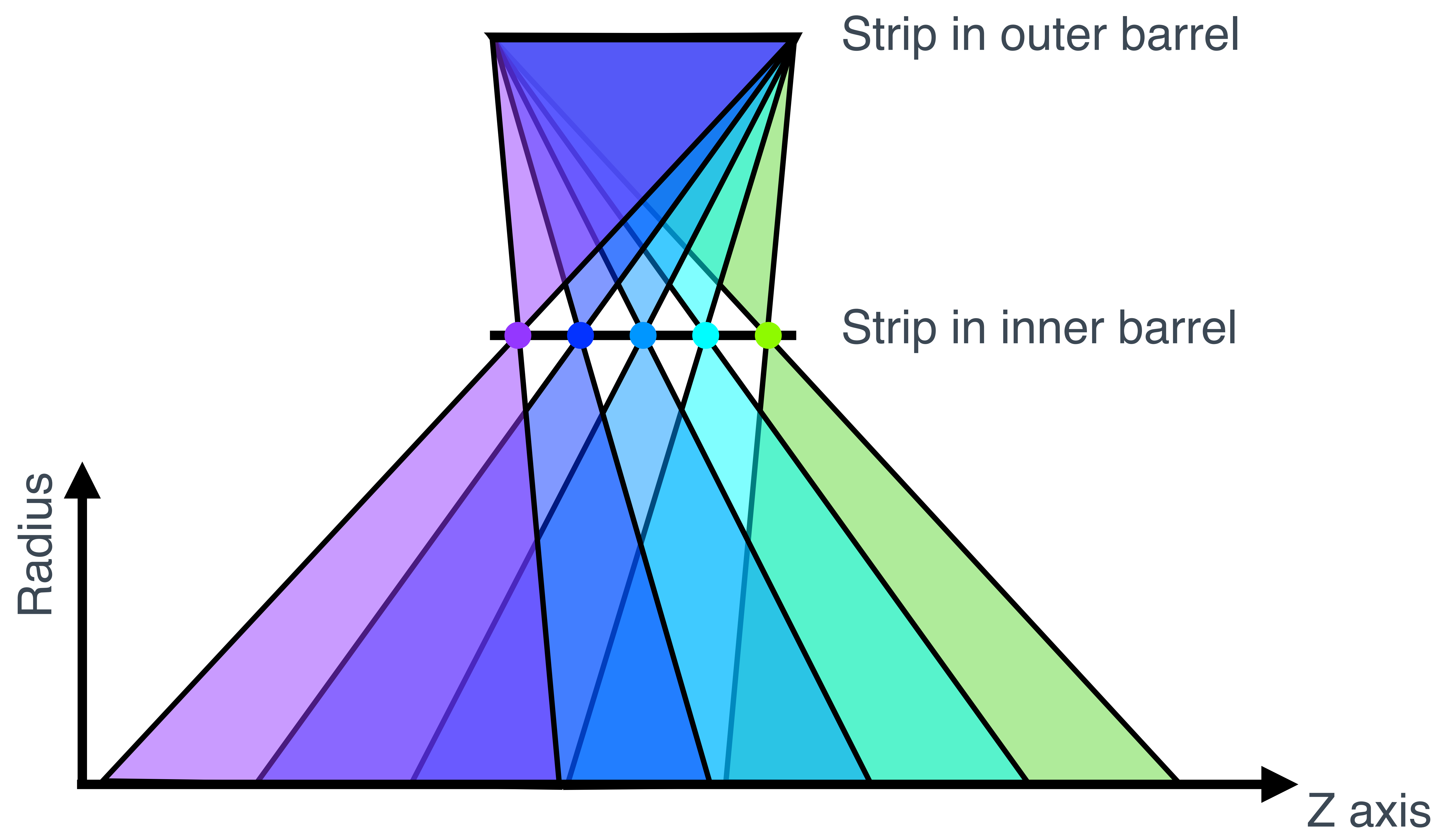

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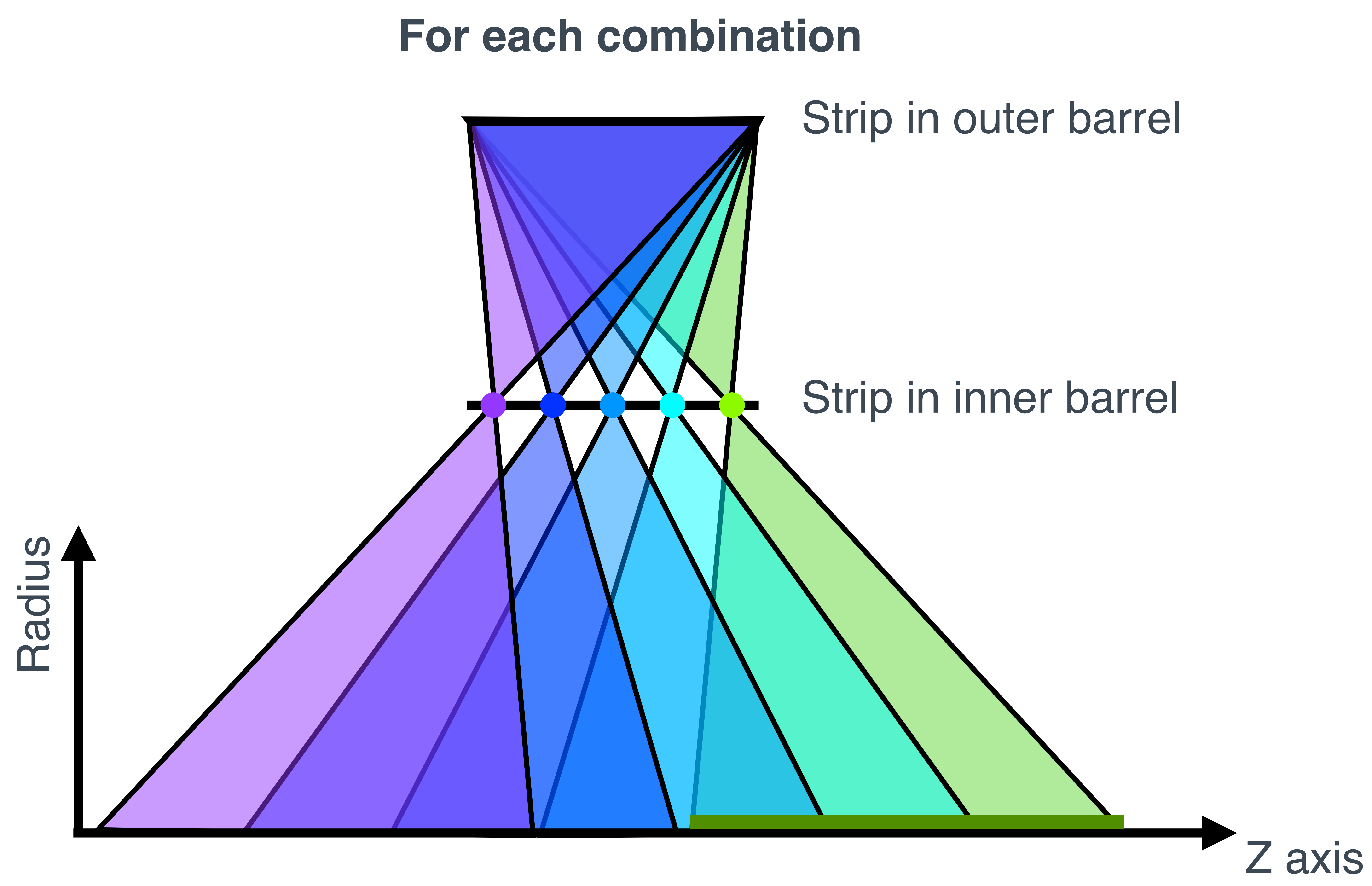

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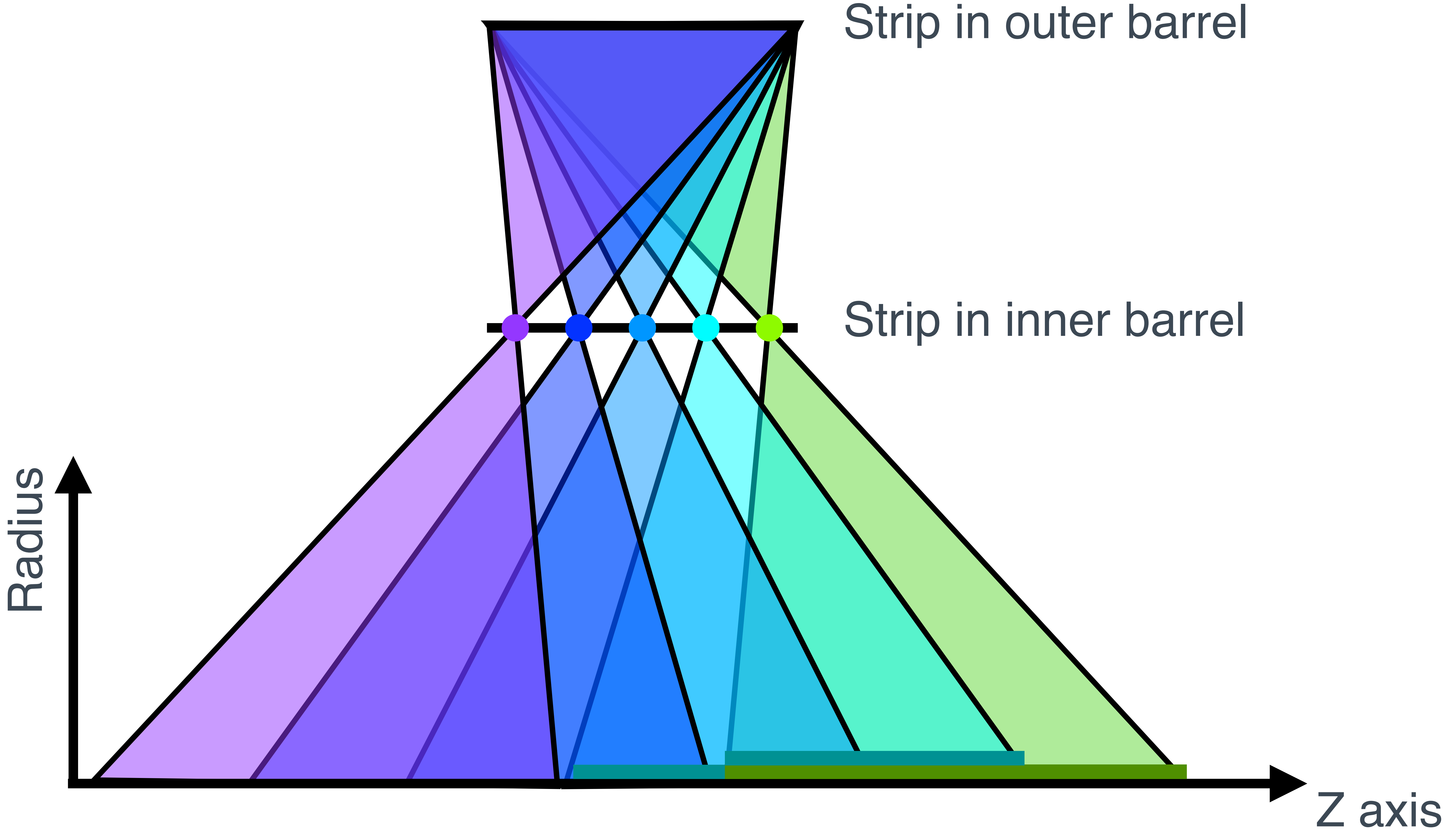

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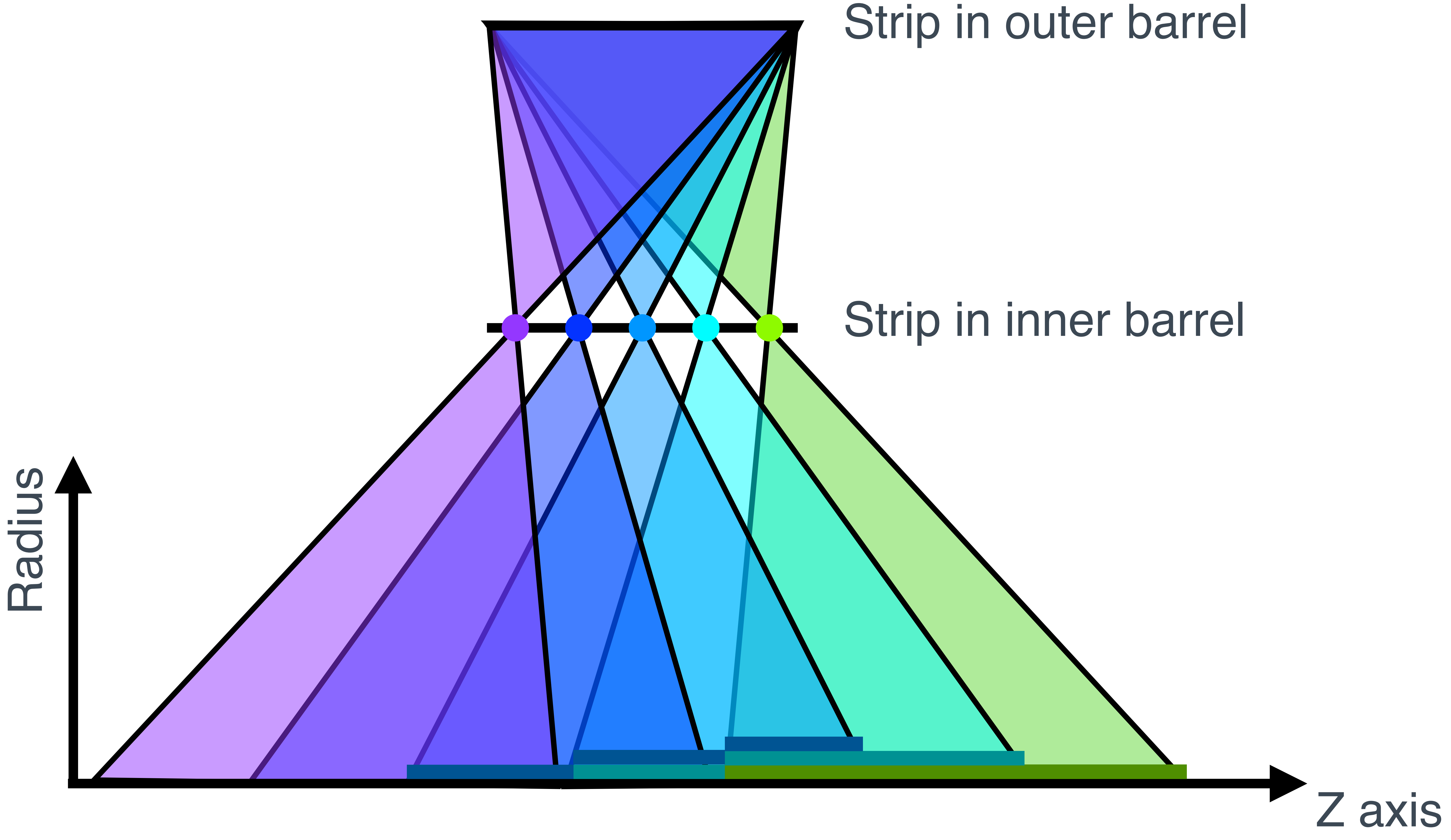

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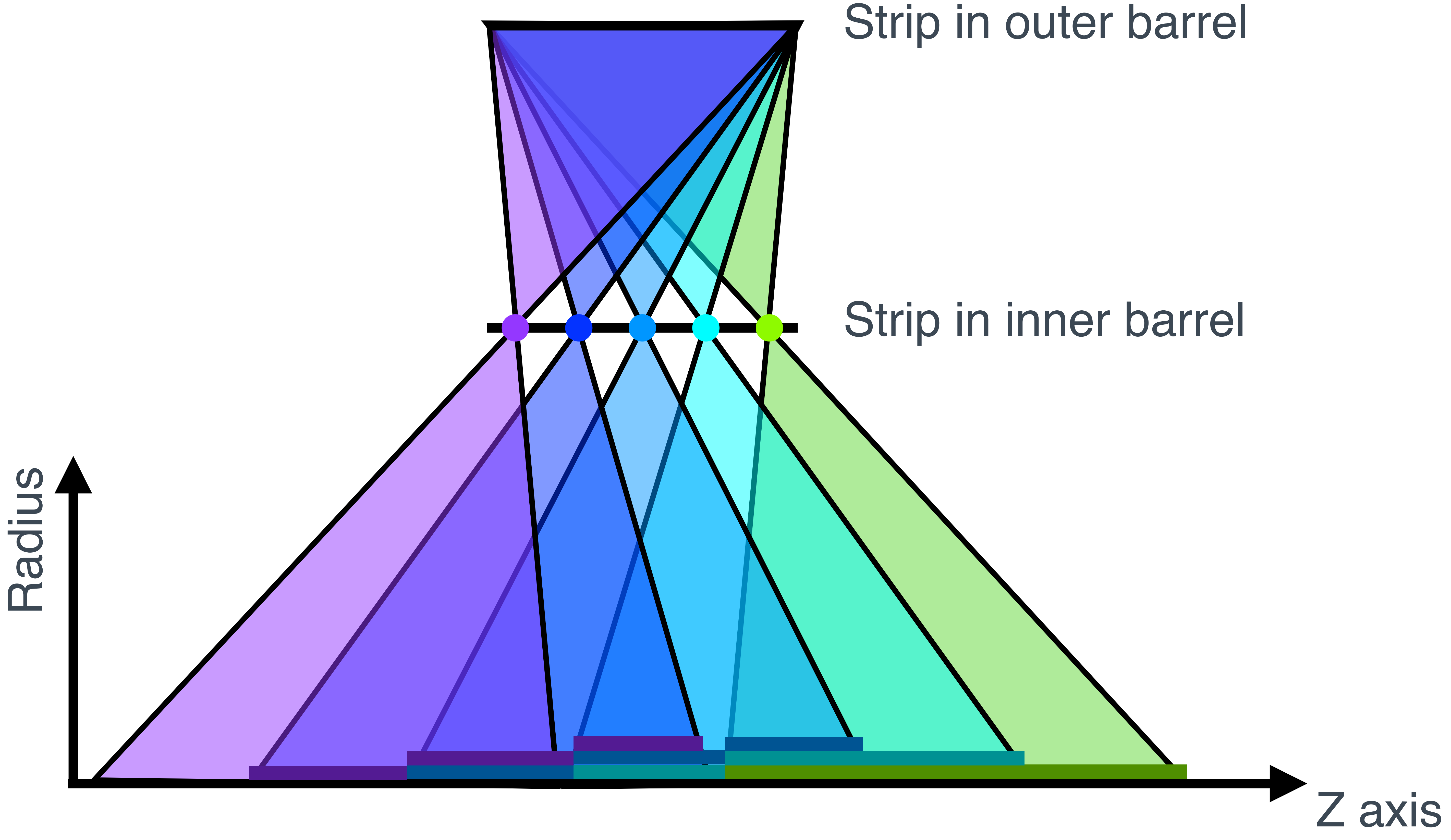

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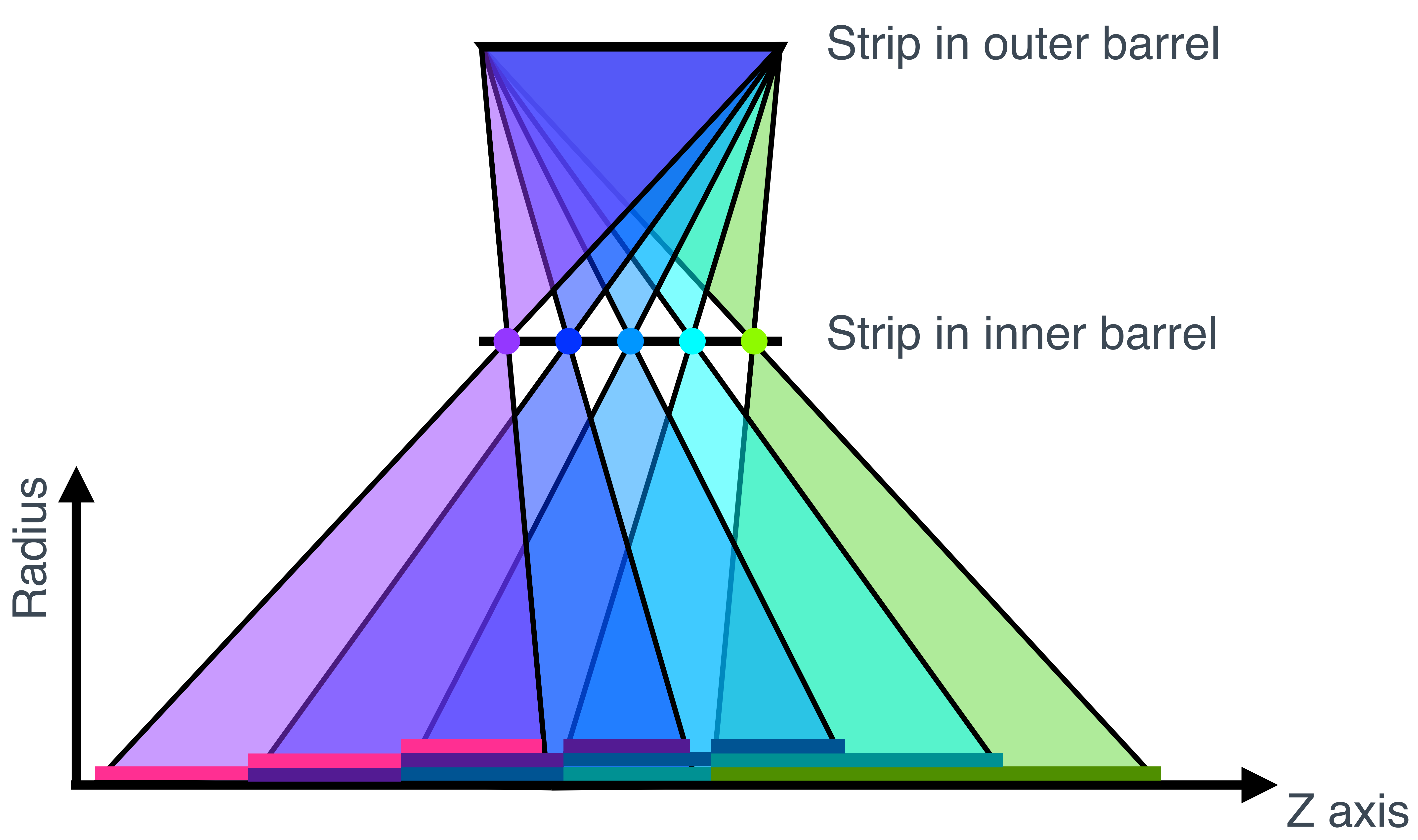

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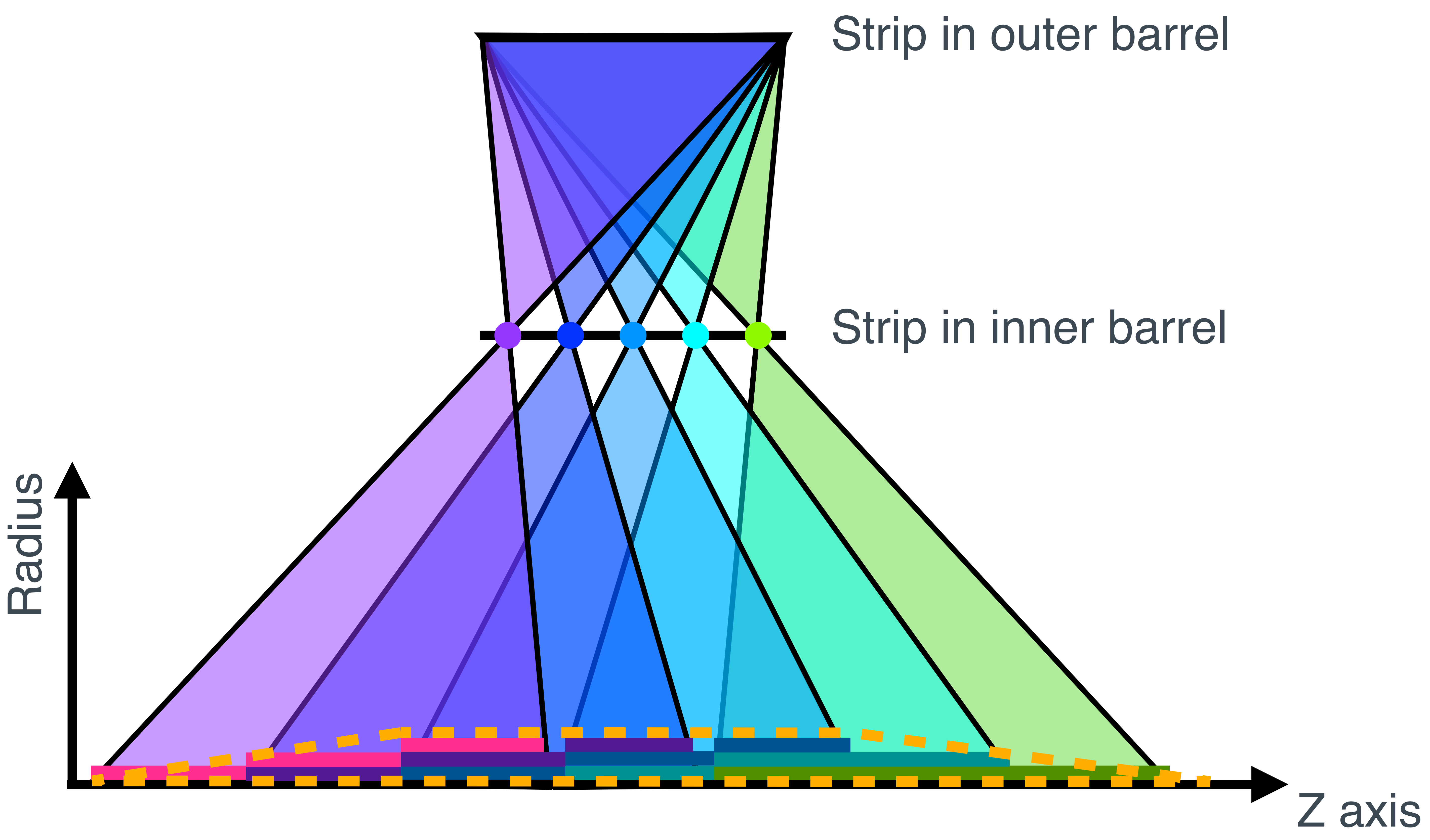

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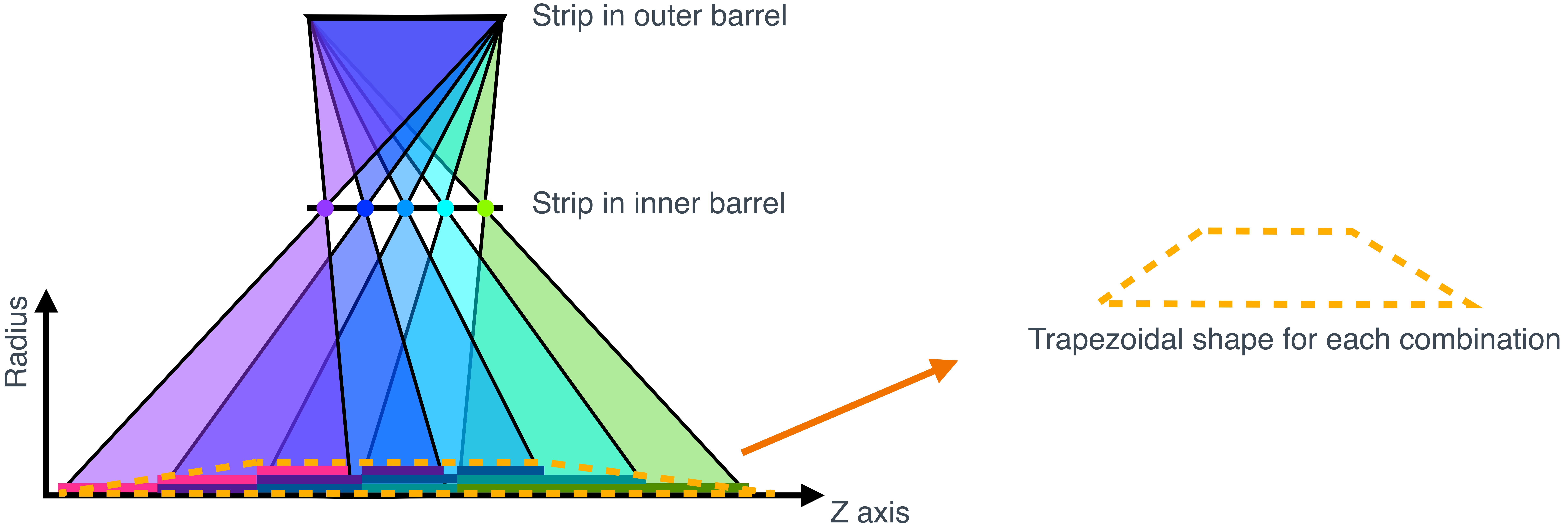

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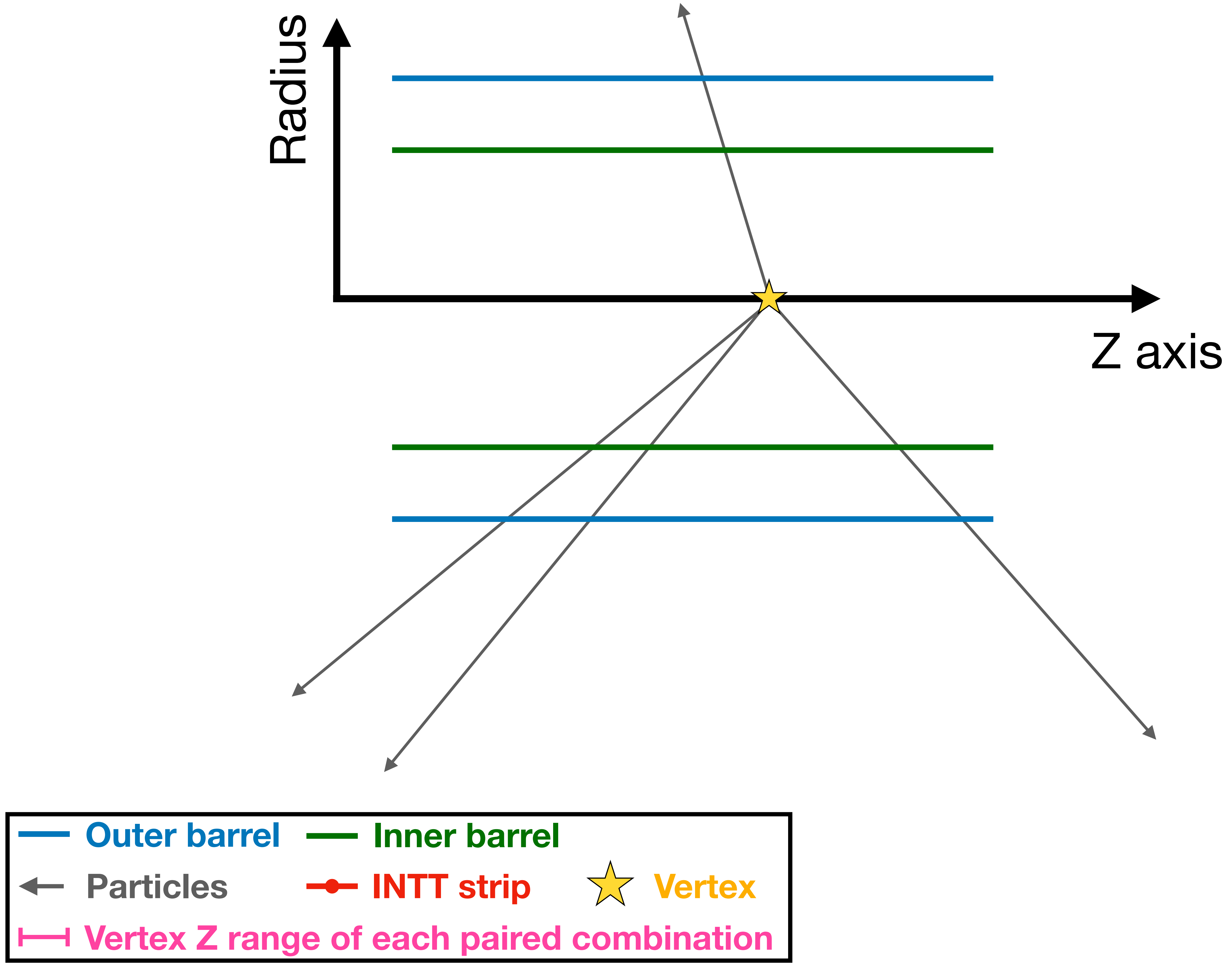
Per-event vertex Z reconstruction

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



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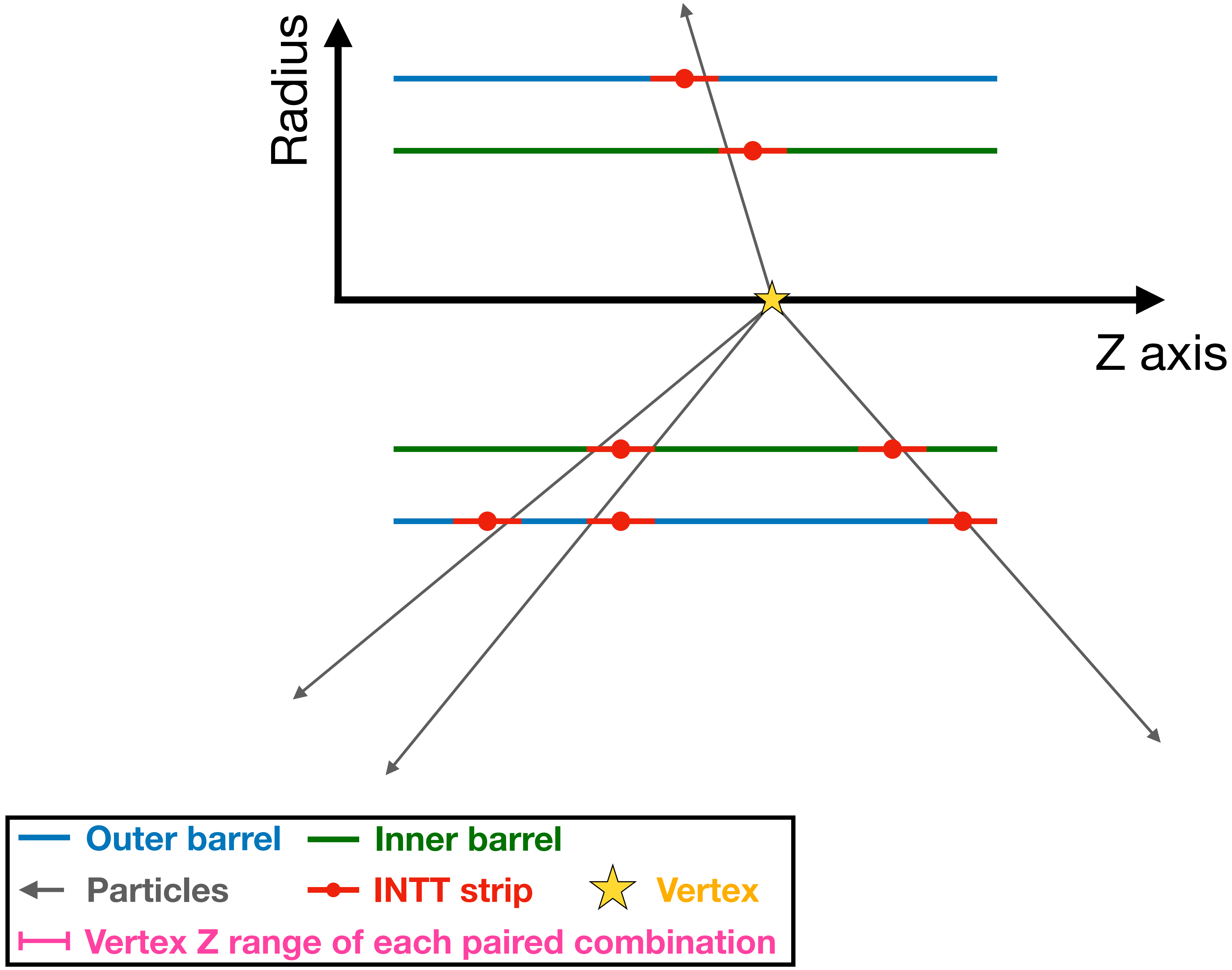

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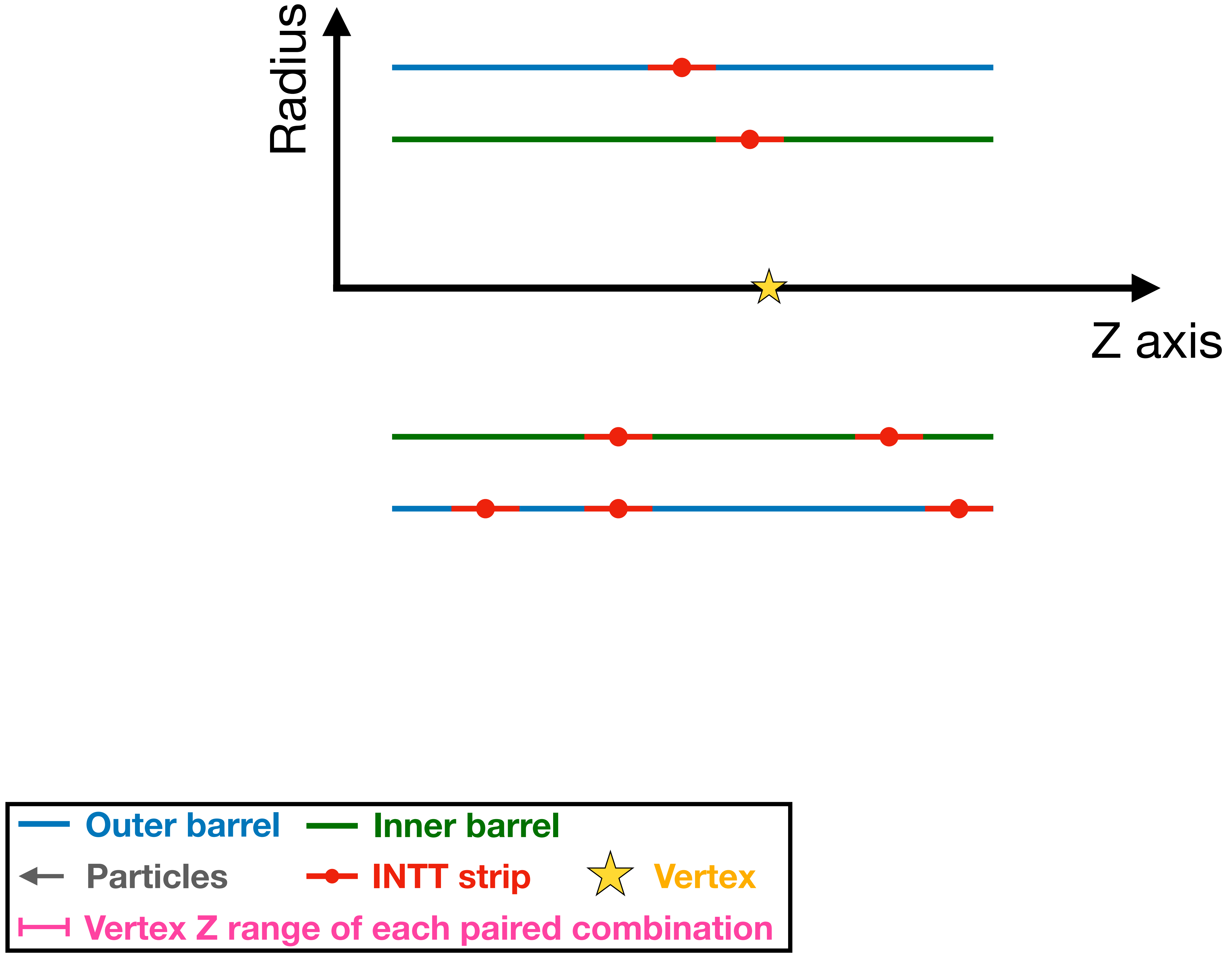

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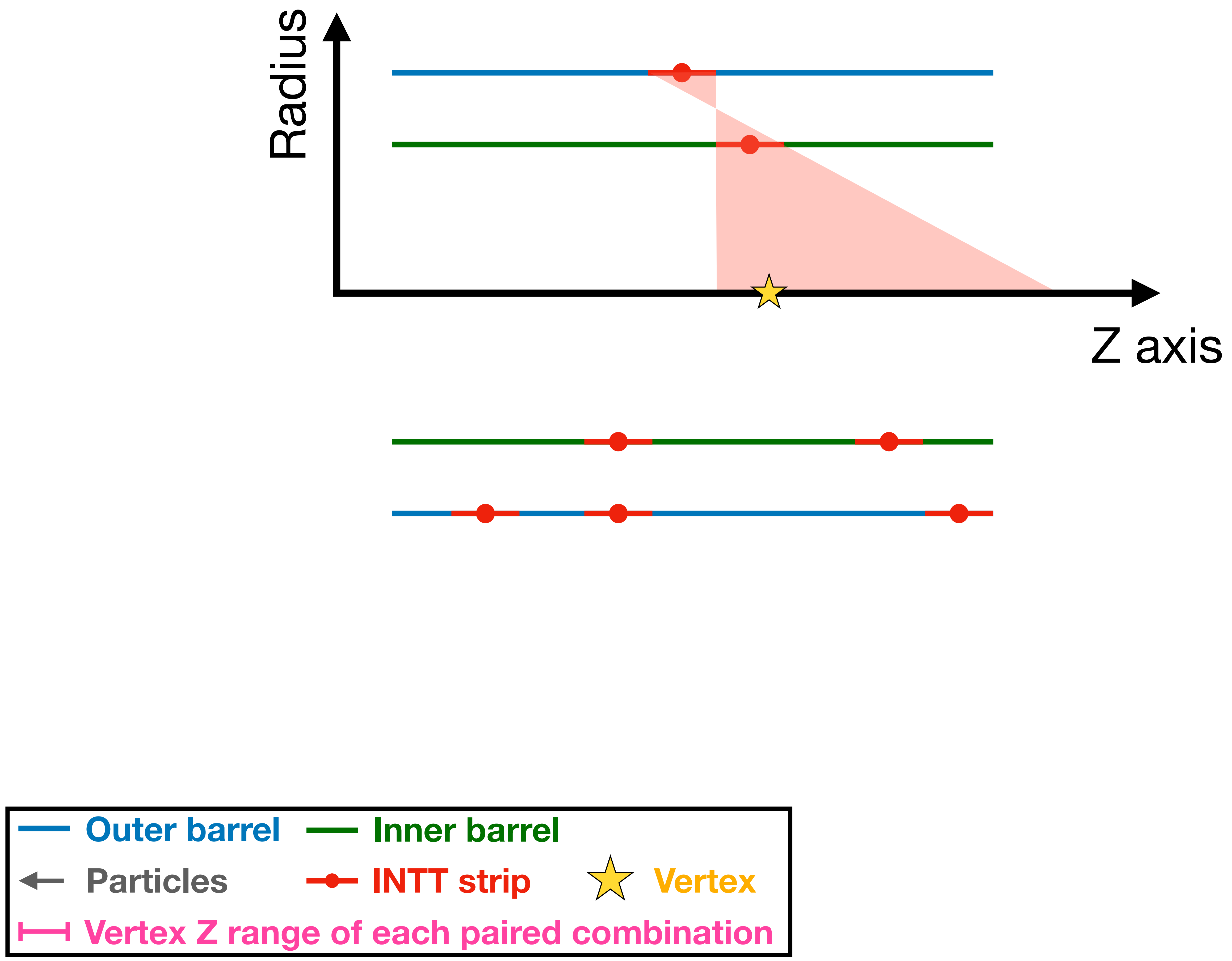

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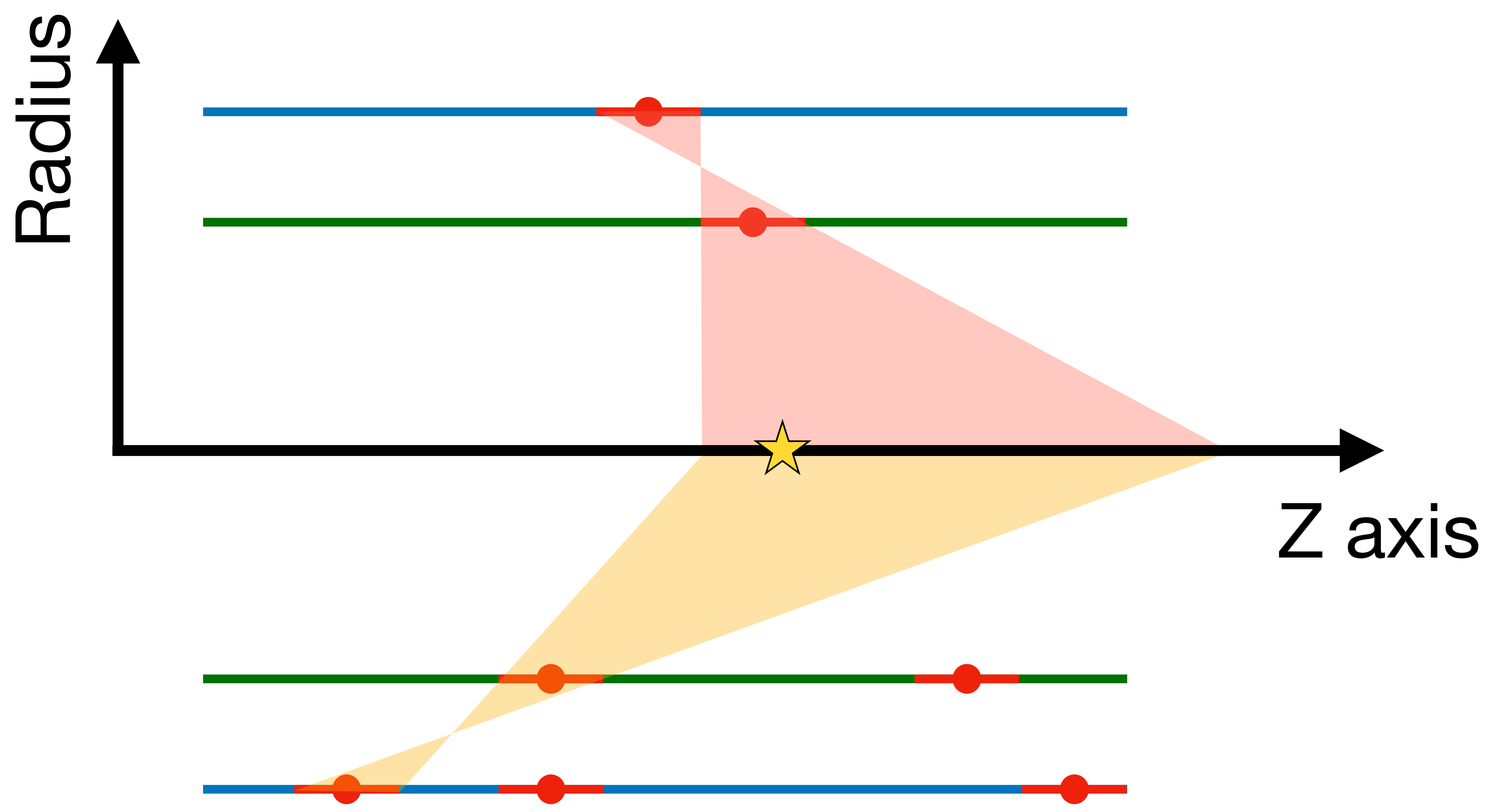

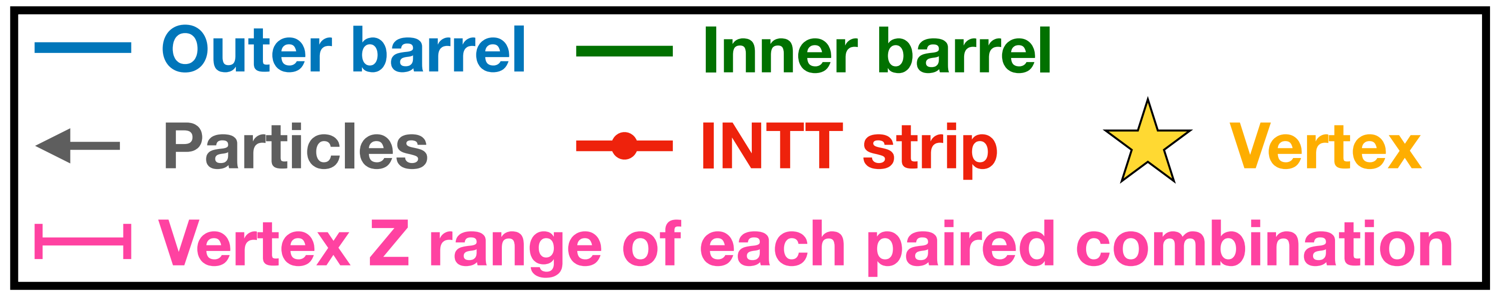

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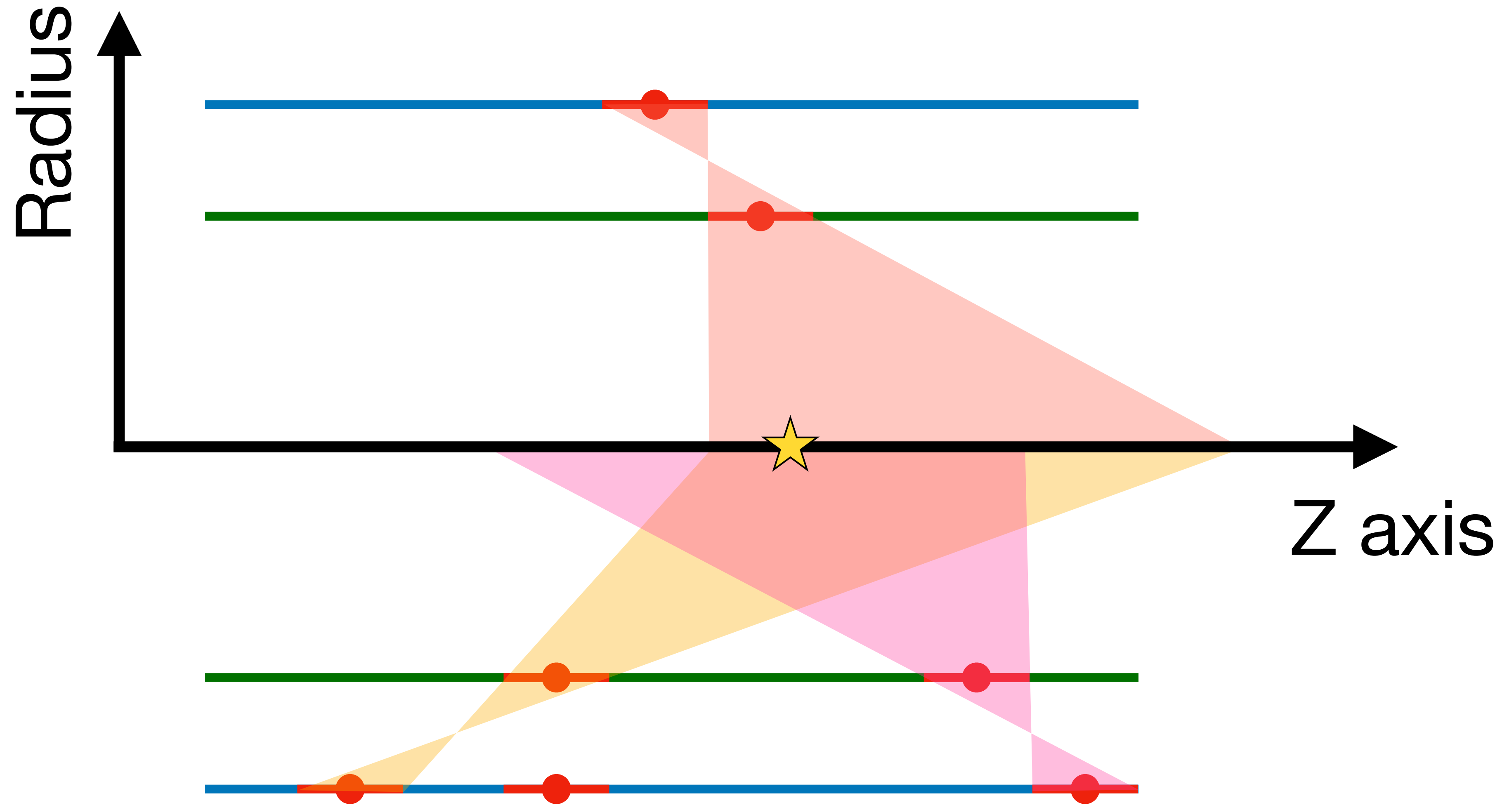

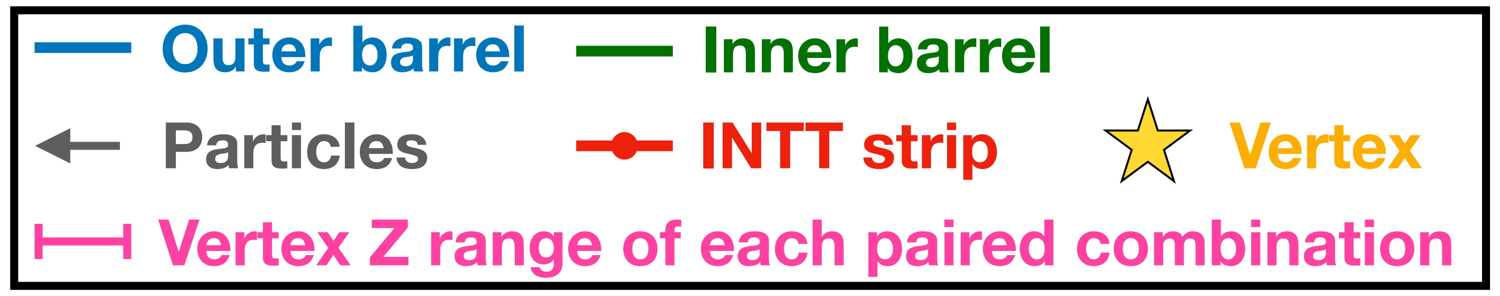

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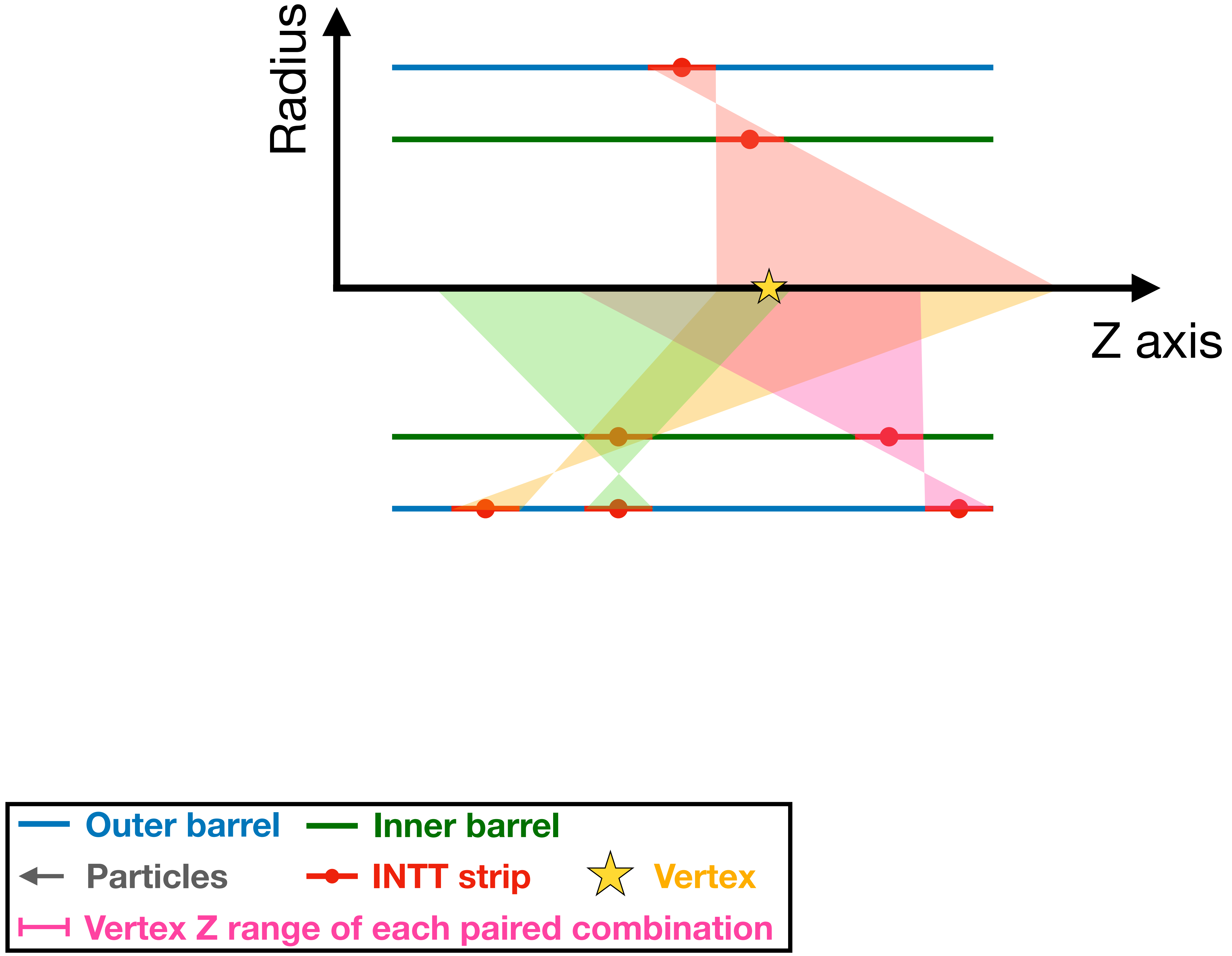

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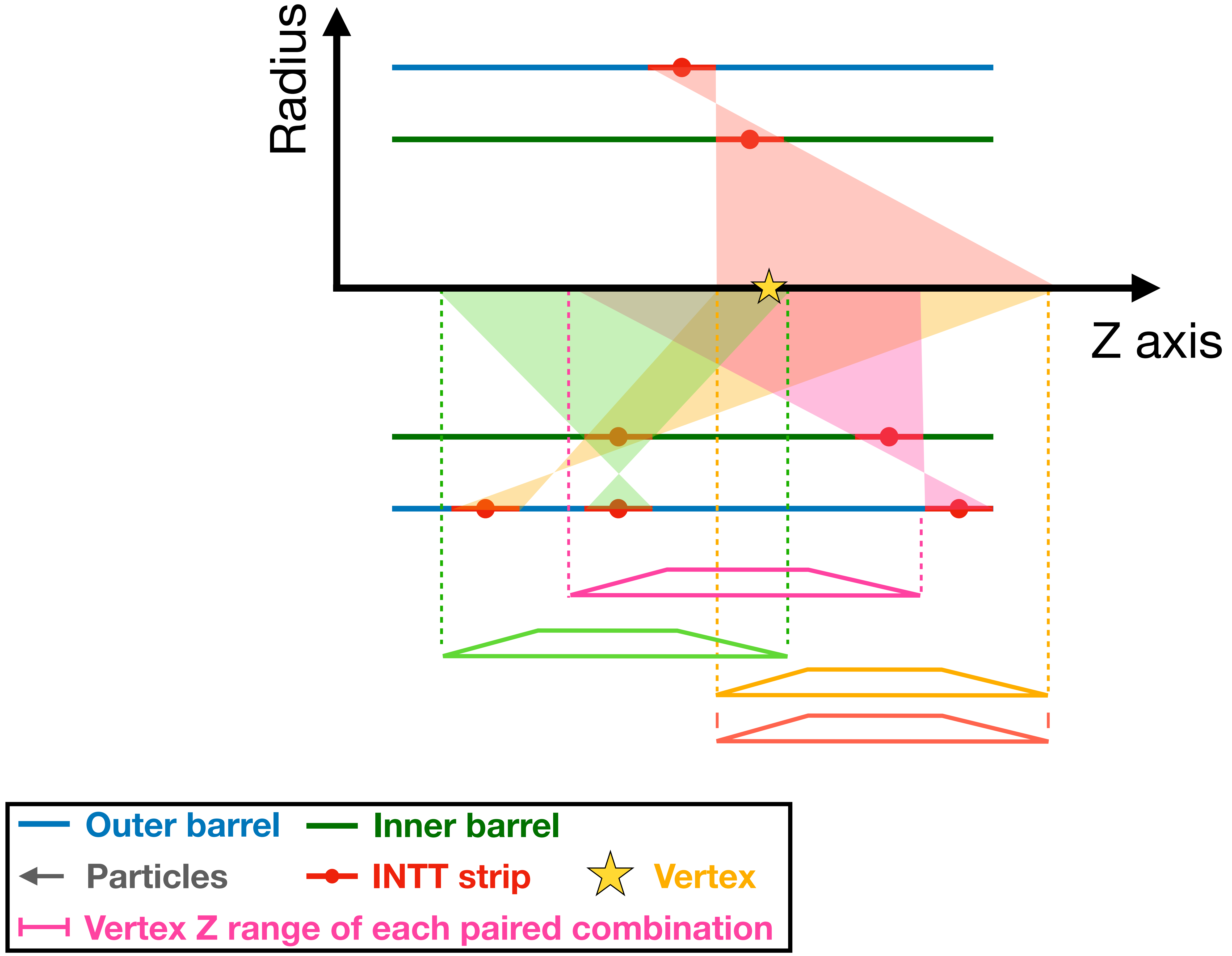
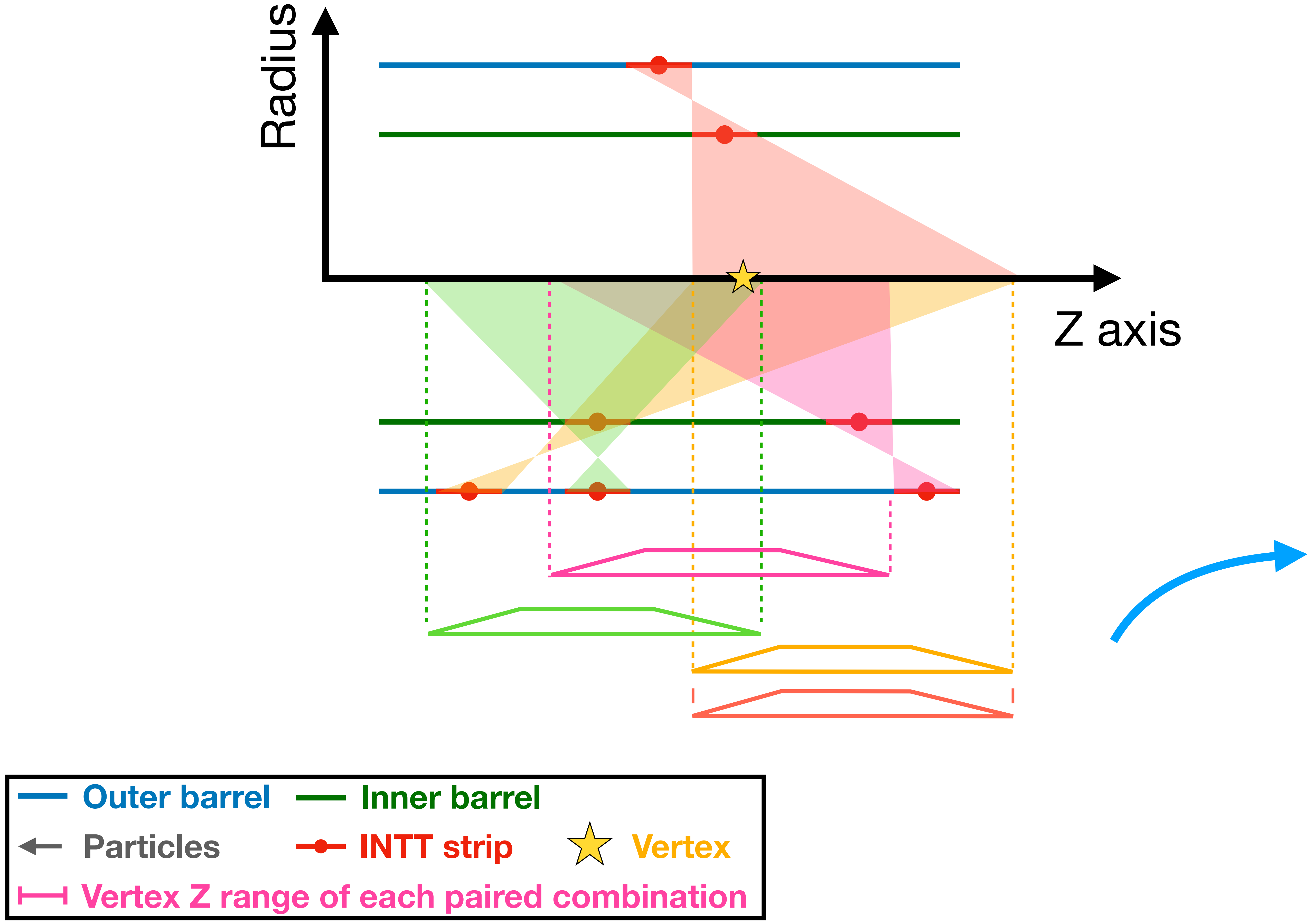
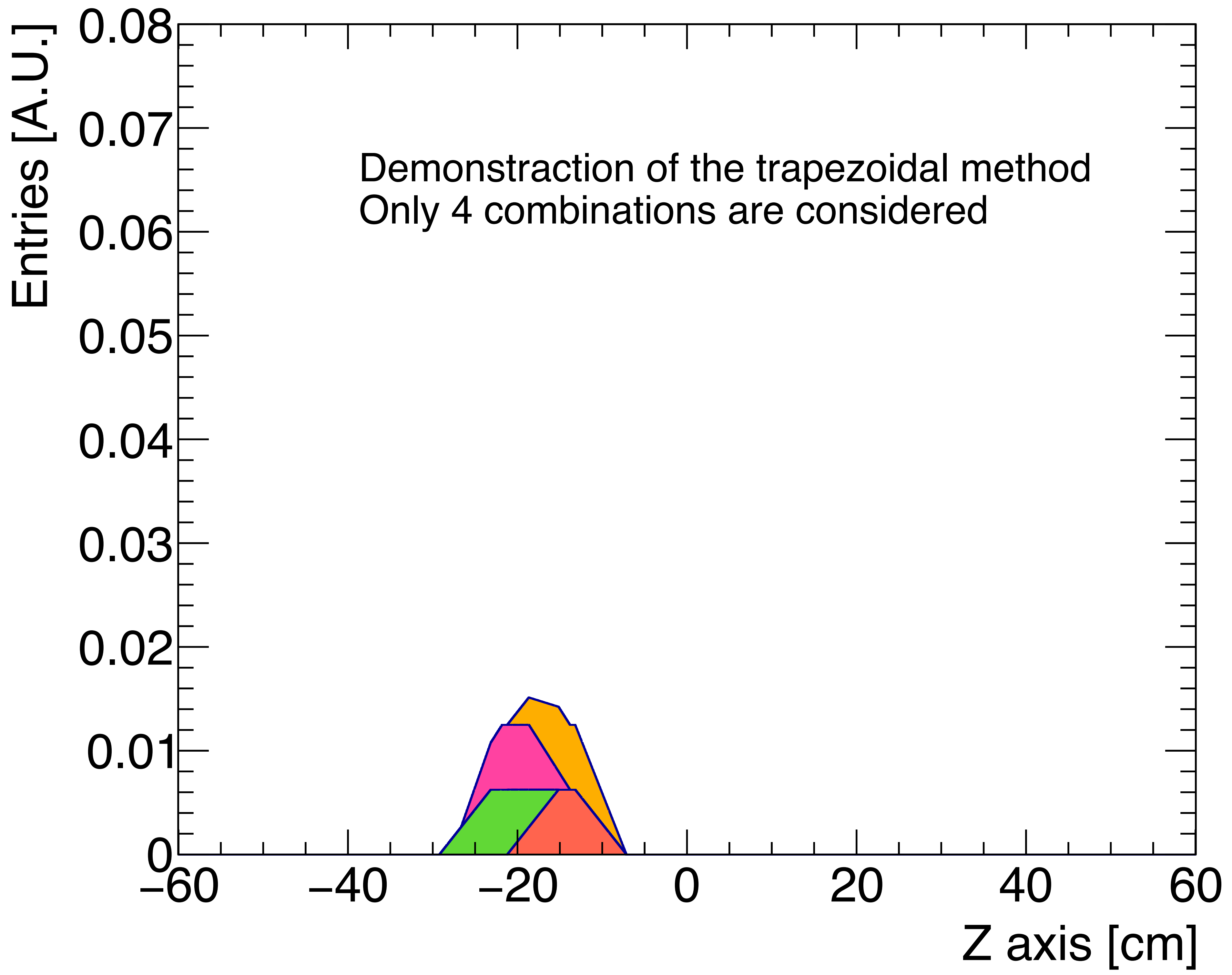
- Loop over the combination, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and $DCA \leqq DCA_{cut}$
- Move to the Z-radius plane



Per-event vertex Z reconstruction

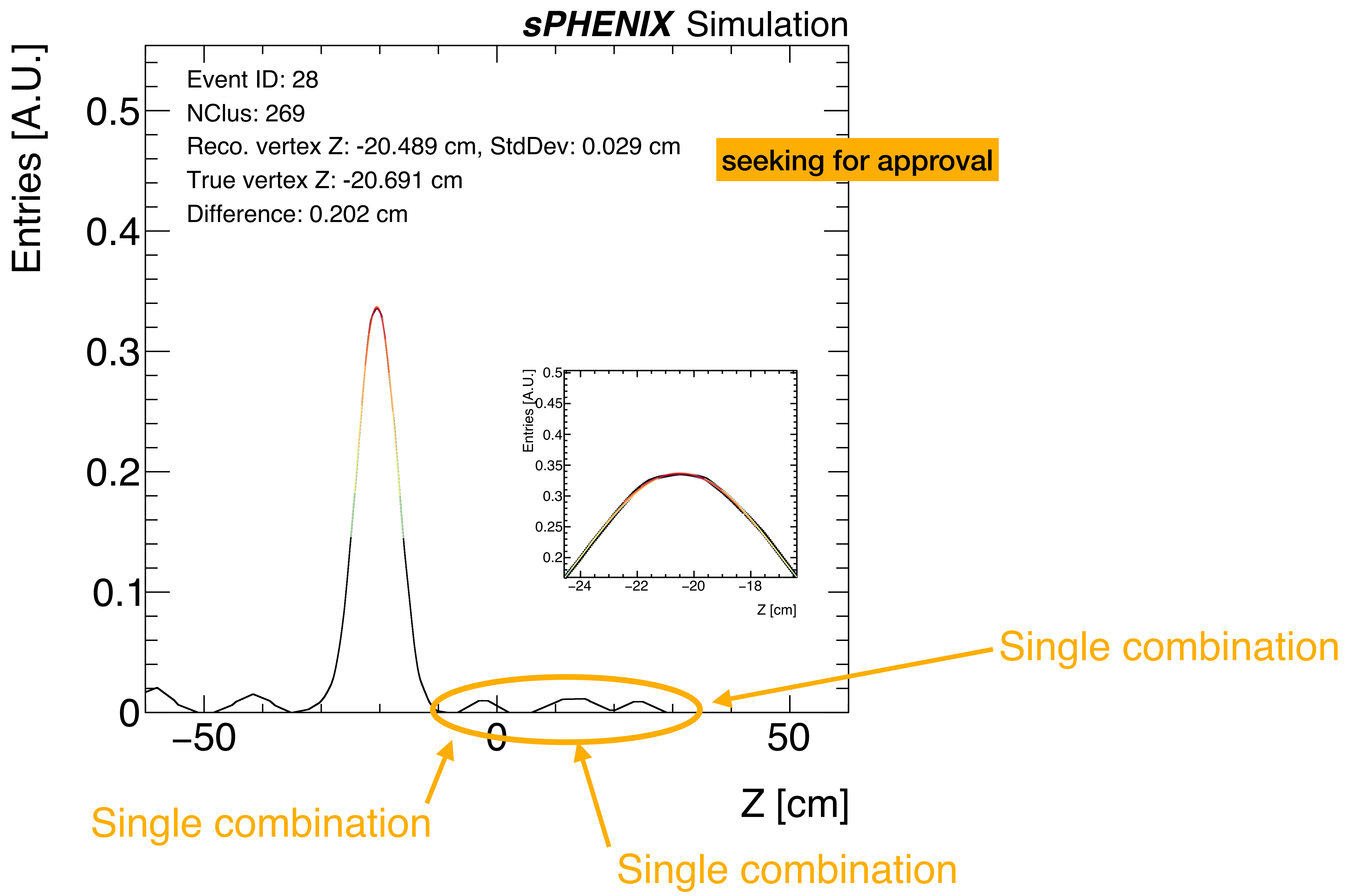
- Correct the cluster ϕ based on the reconstructed average vertex XY
- Loop over the combination, and keep the combinations with $\Delta\phi \leqq \phi_{cut}$ and DCA $\leqq DCA_{cut}$
- Move to the Z-radius plane





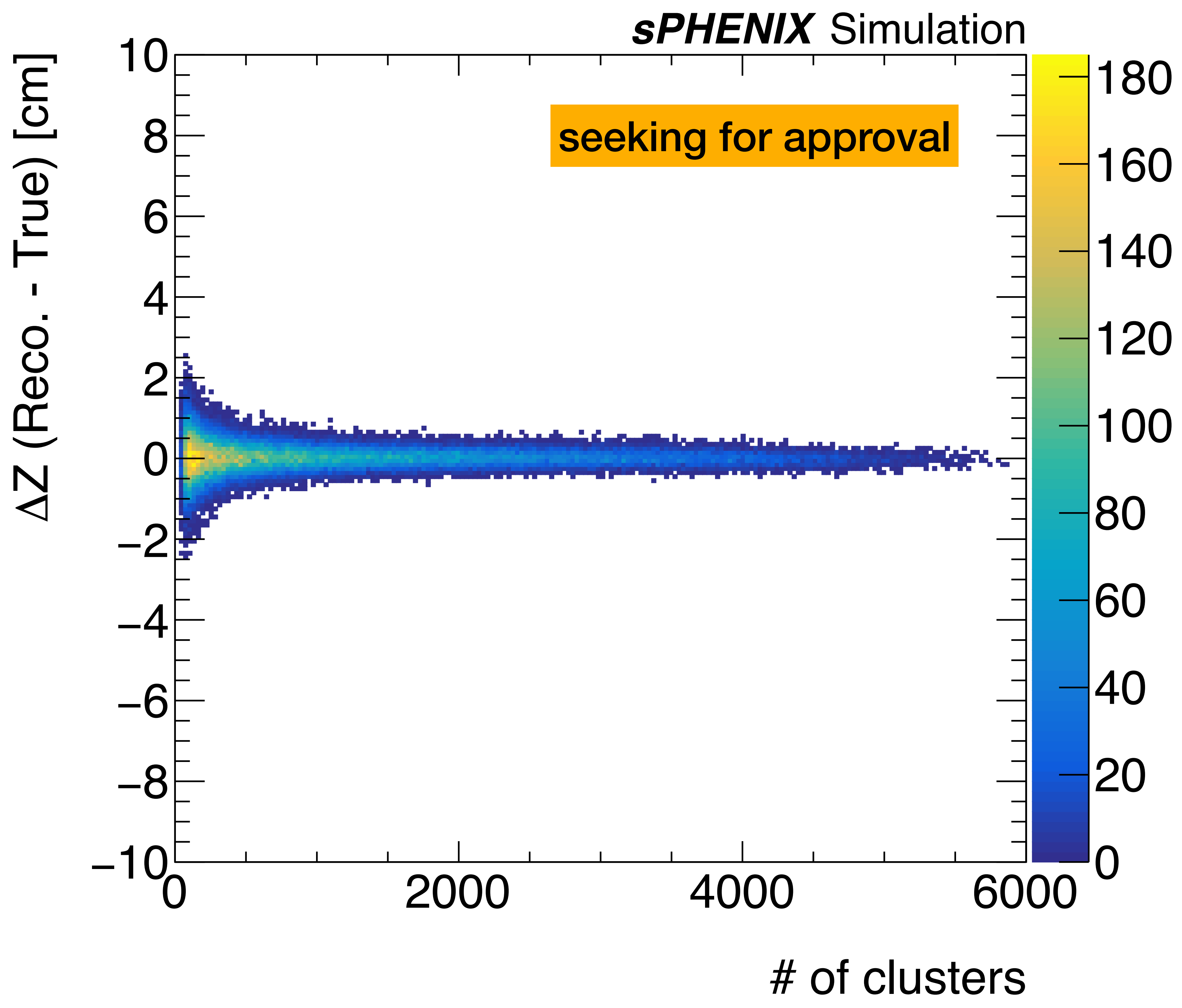
Per-event vertex Z reconstruction

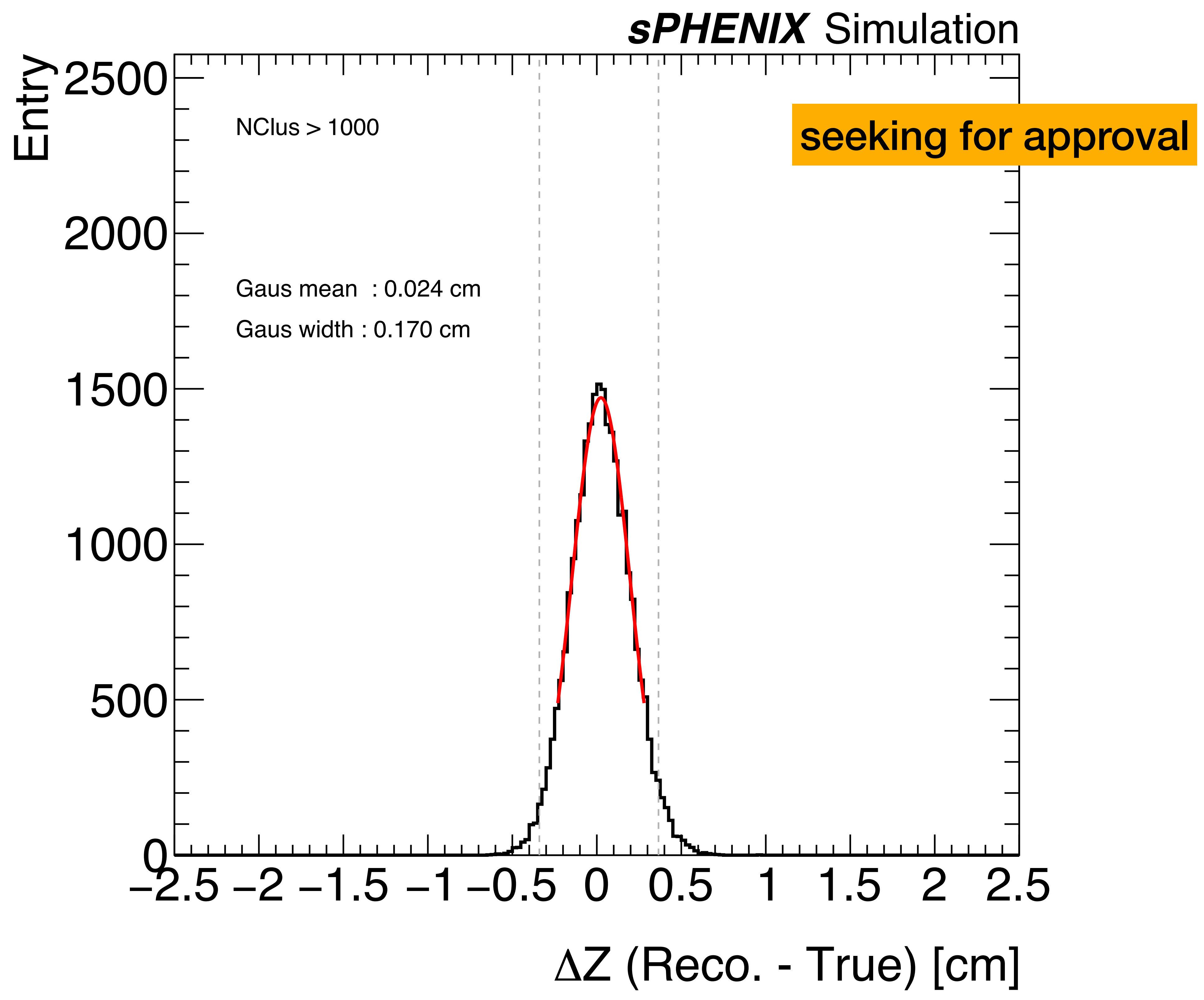
Final vertex Z given by average of 7 gaussian fits with the fit ranges of "mean ±(0.2 + 0.15 x i) x **the_50%_width**"



Per-event vertex Z reconstruction

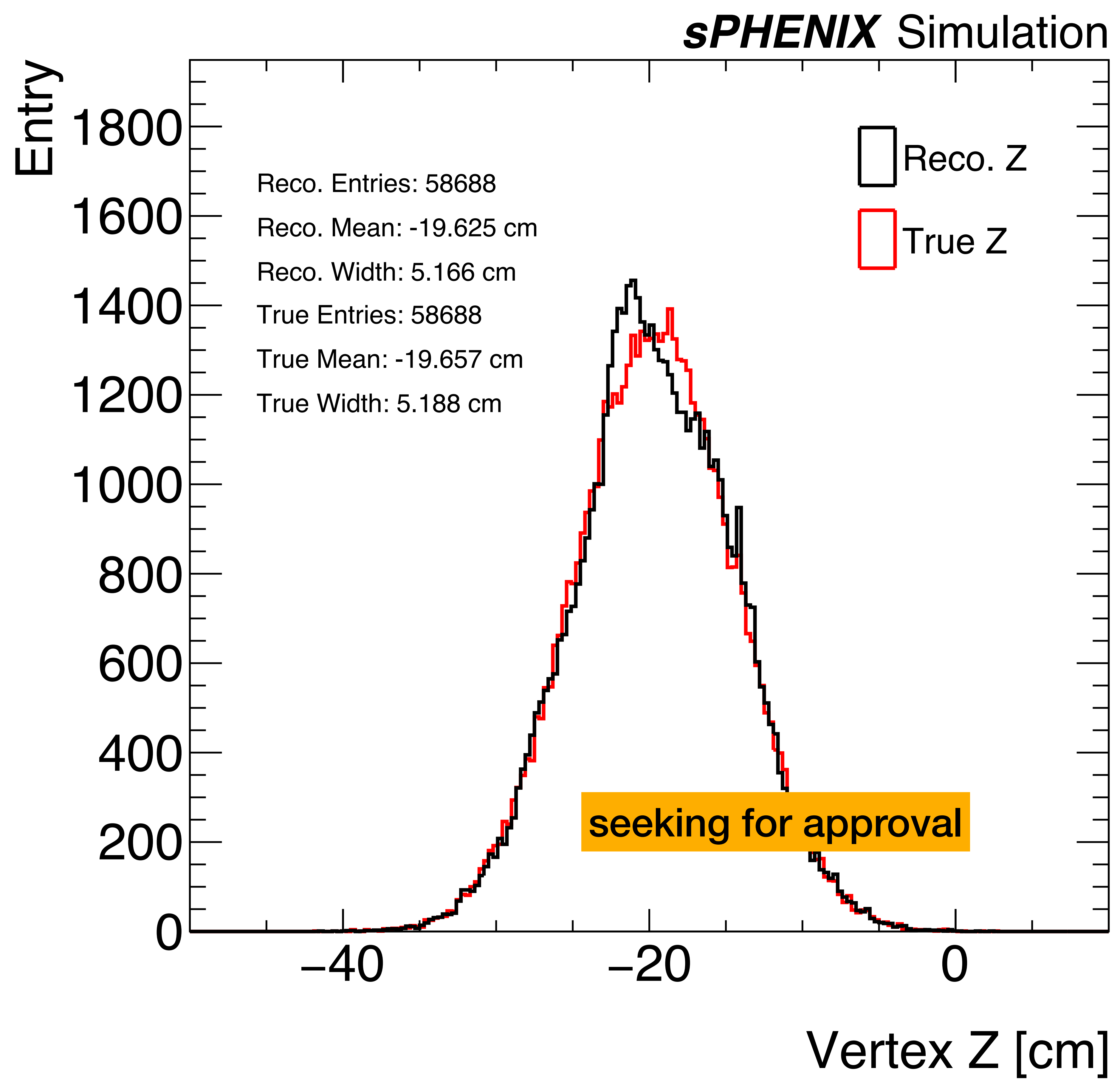
MC zvtx setting: Gaussian (-20 cm, 5 cm)
zvtx rage : -30 cm ~ 0 cm

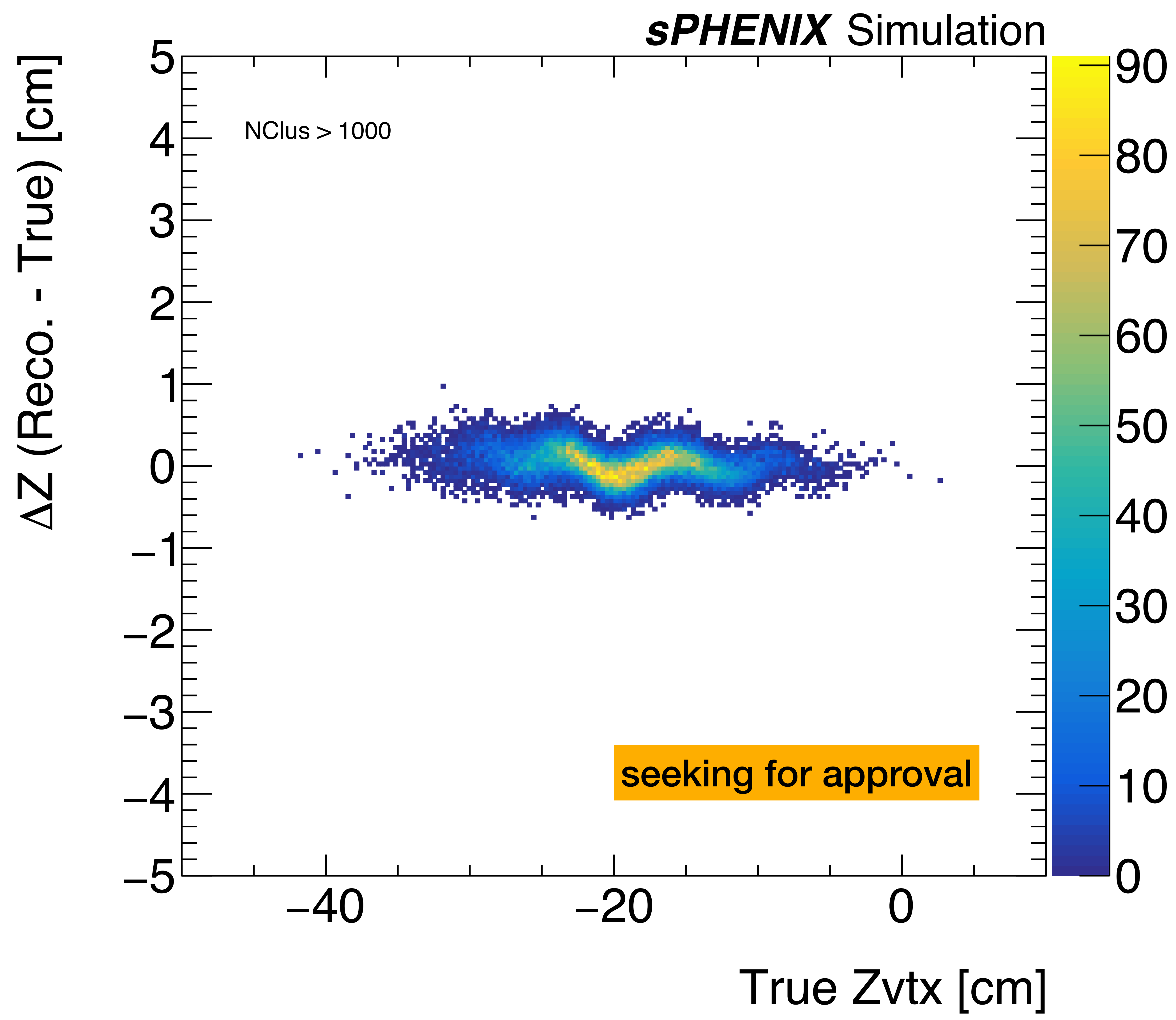




The higher multiplicity the more accurate vertex Z determined
1.7 mm resolution in the region of number of clusters > 1000

Per-event vertex Z reconstruction

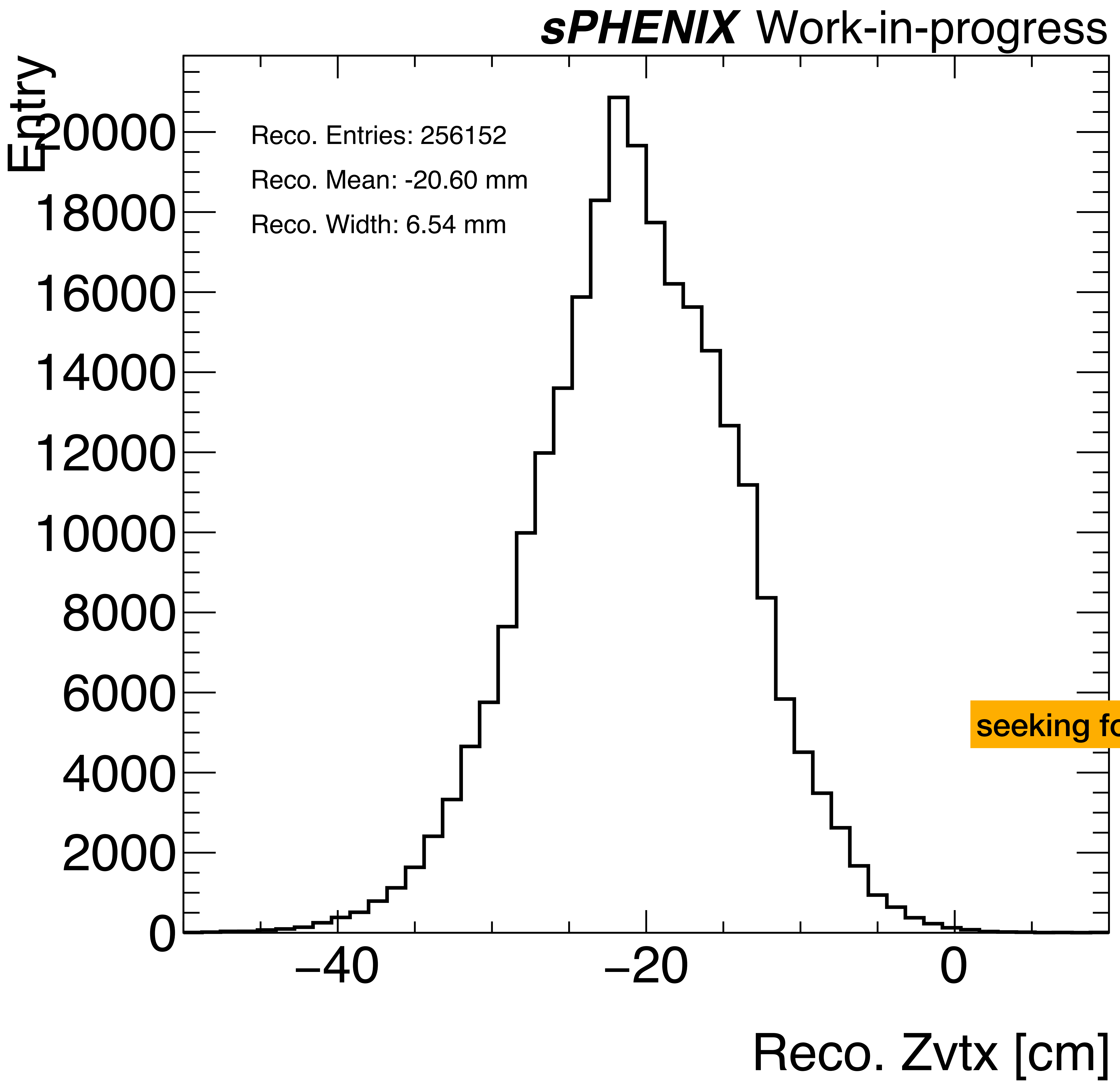




The wiggling structure due to the fact that the collisions happened near the edge of INTT

Per-event vertex Z reconstruction

Data

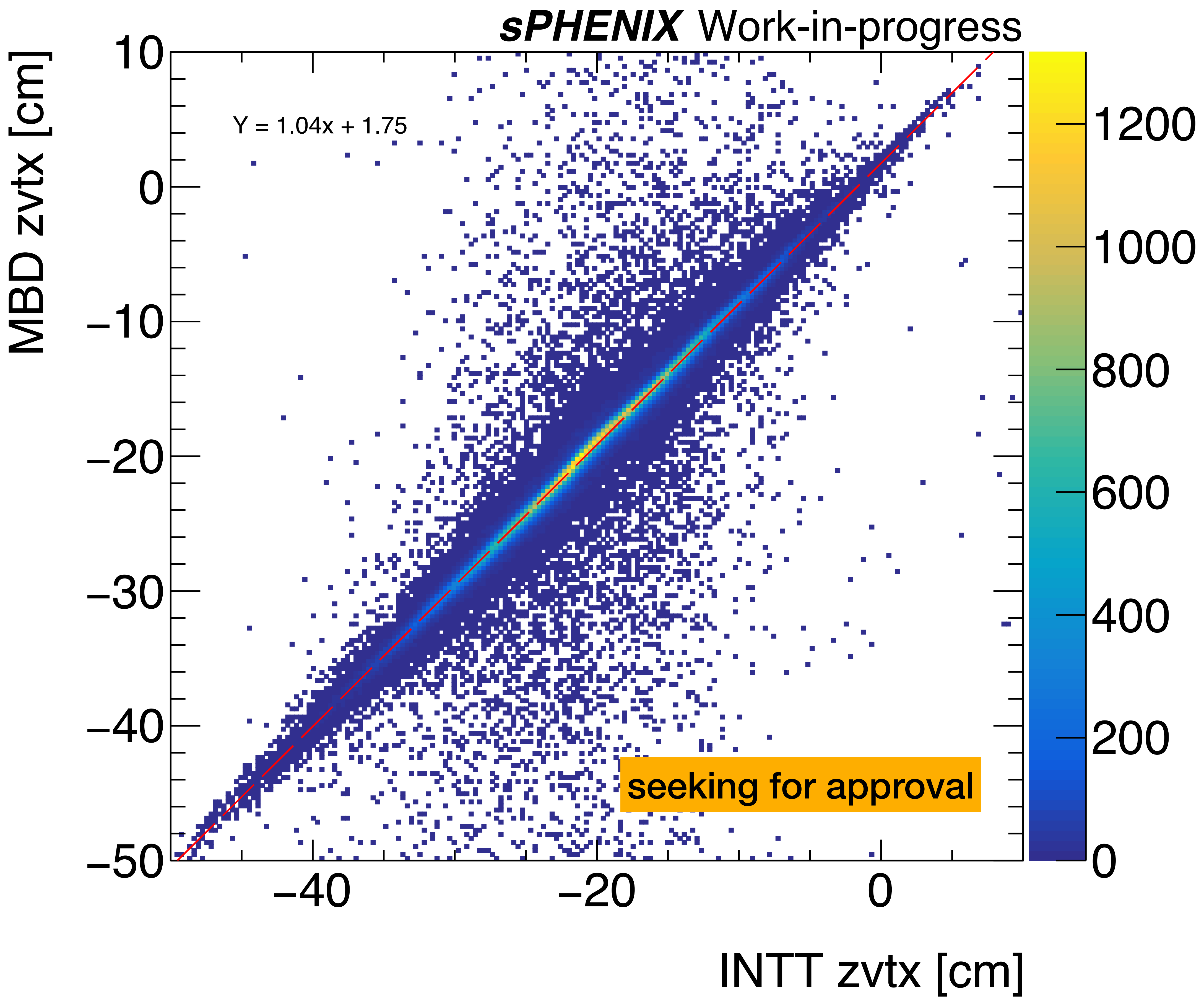


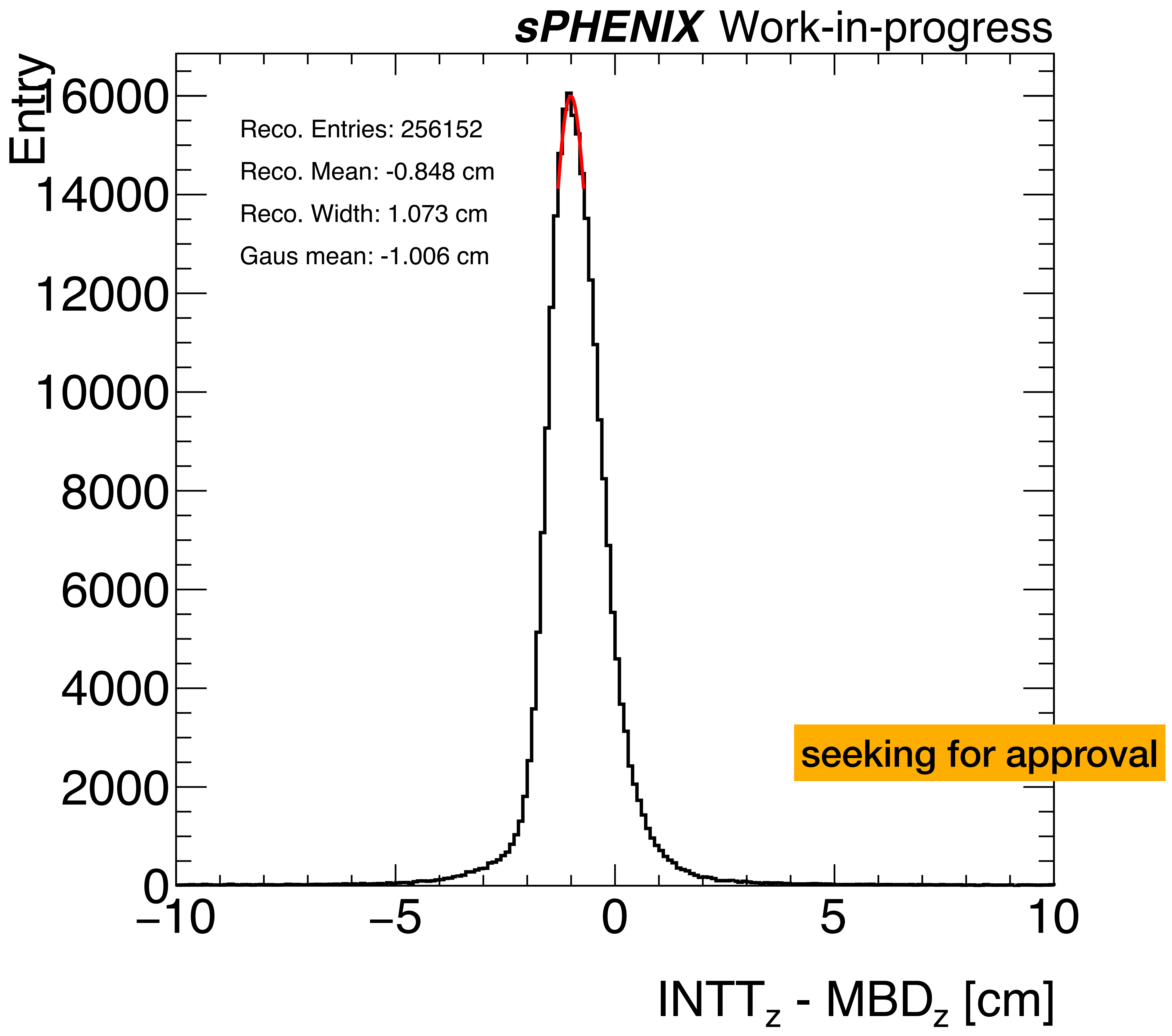
seeking for approval

Per-event vertex Z reconstruction

Data

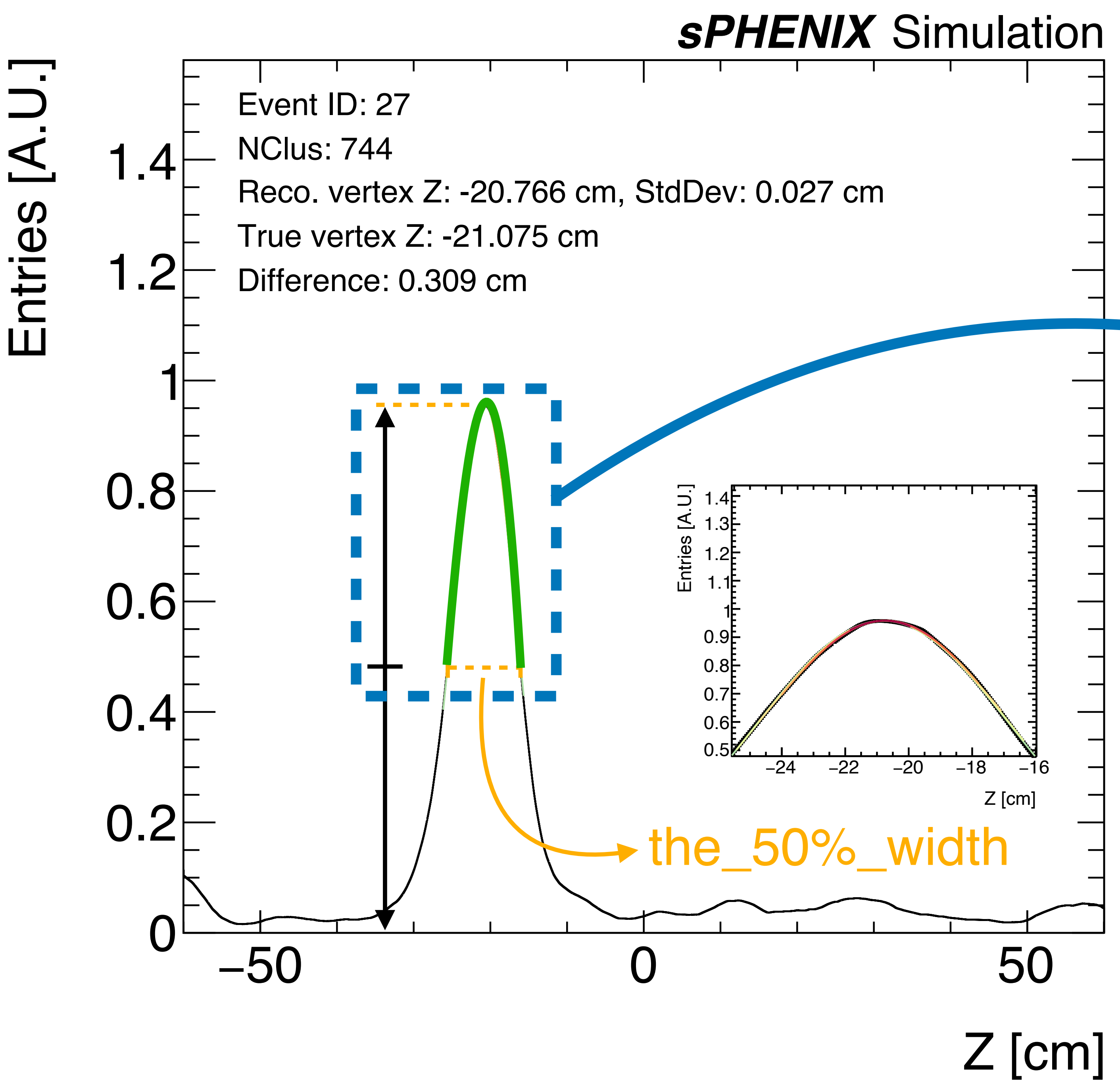
The comparison between MBD reco. vertex Z



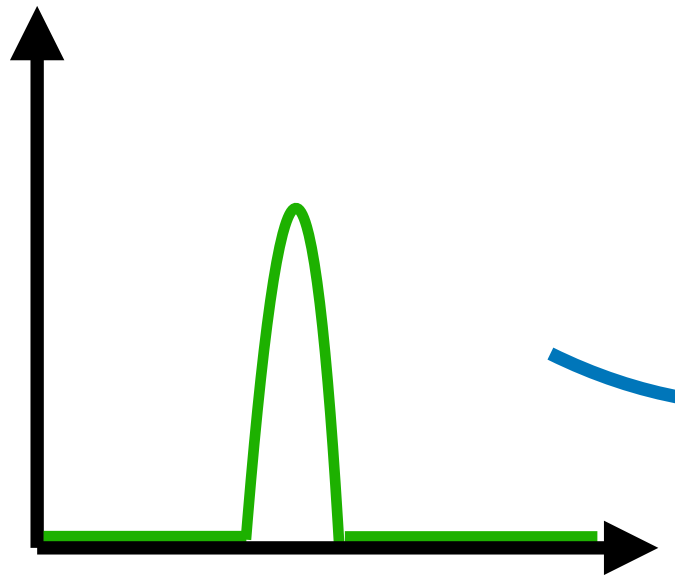


The optimization of vertex Z determination

- 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 50% entry 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 histo. by 50% of the highest bin content (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 variables for each event

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

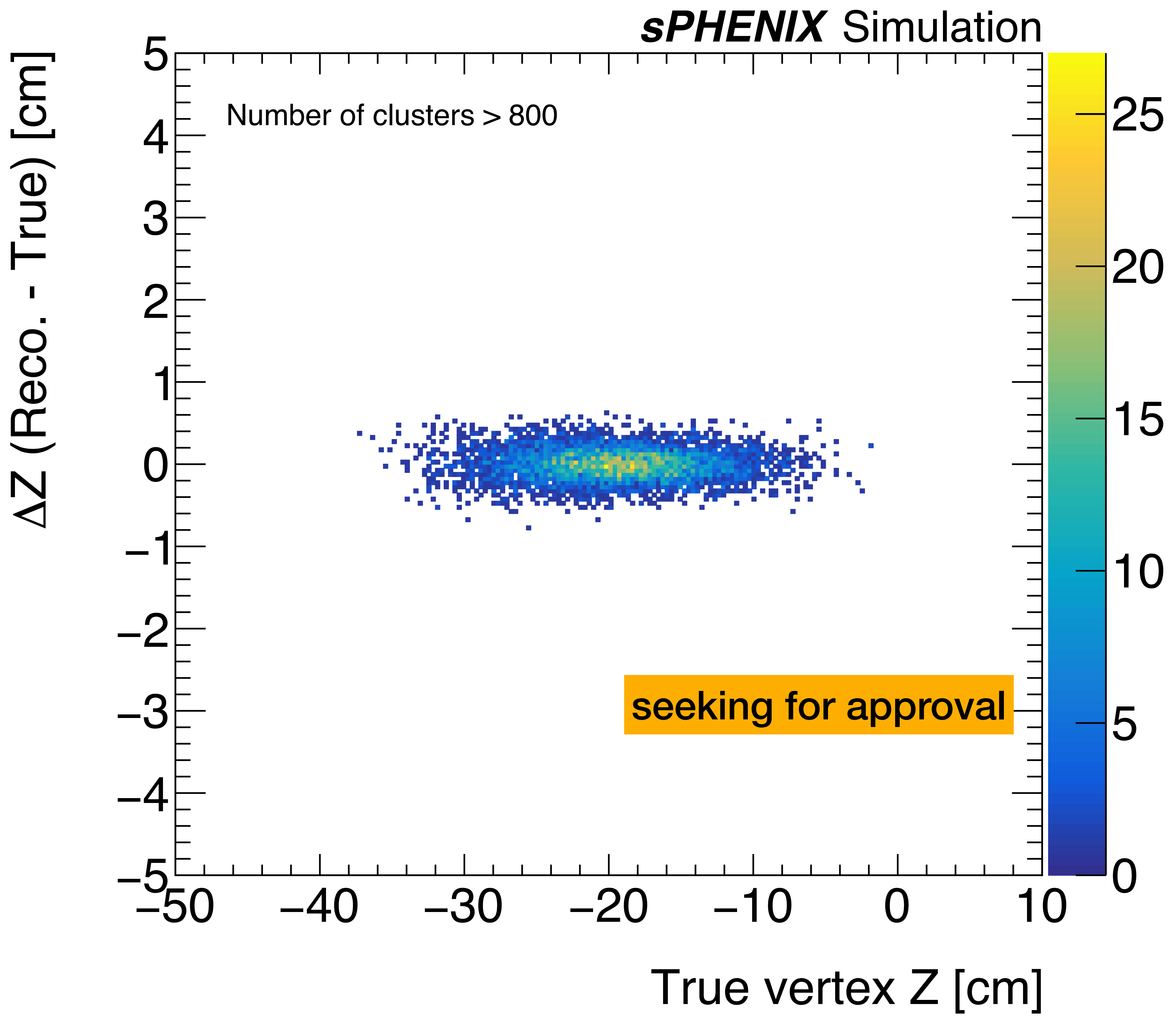
XGBoost

The optimization of vertex Z determination

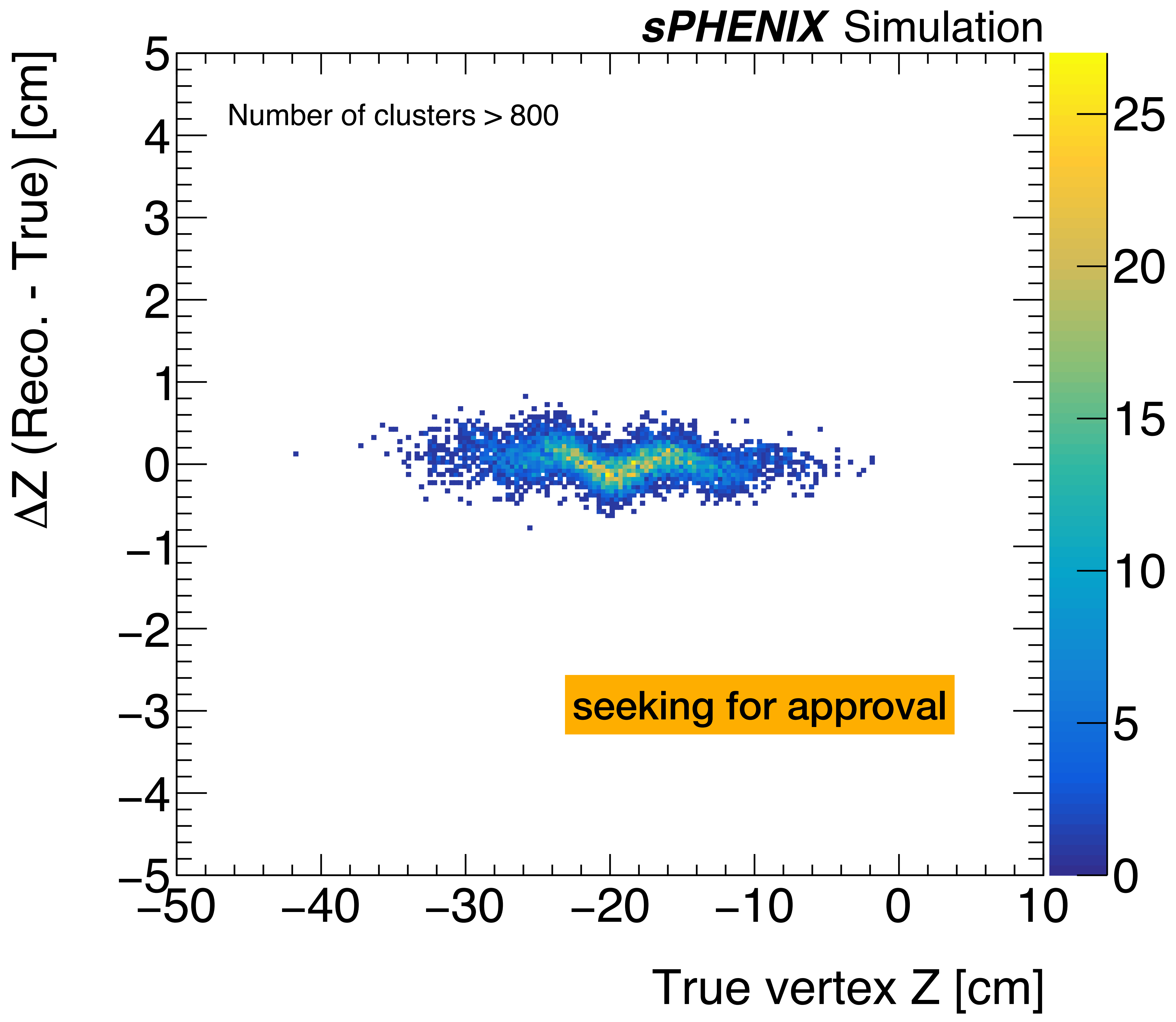
The test sample 25% of the total MC events

Number of cluster* > 800

Reco. vertex Z predicted by training model



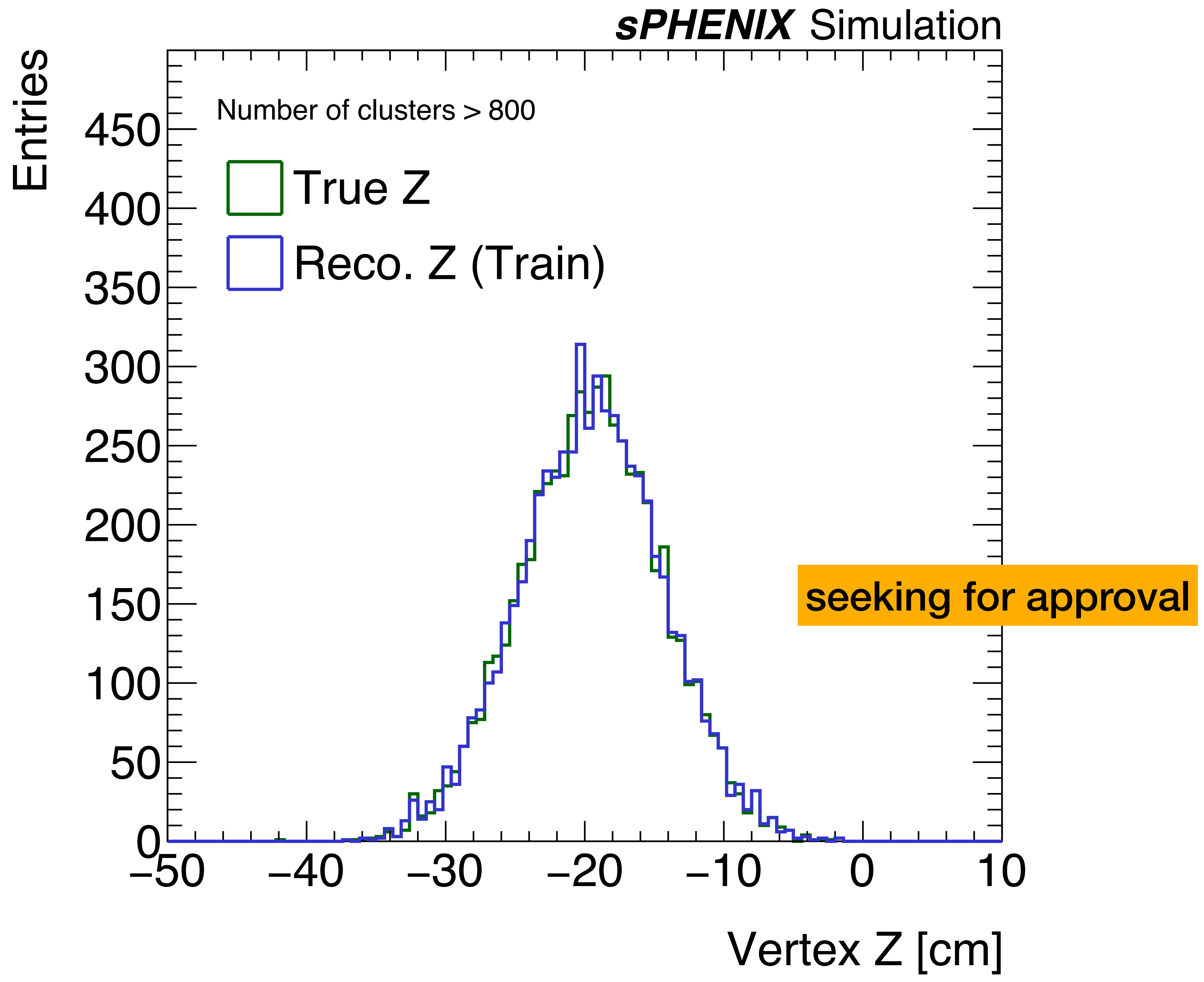
Reco. vertex Z by 7 Gaus fittings

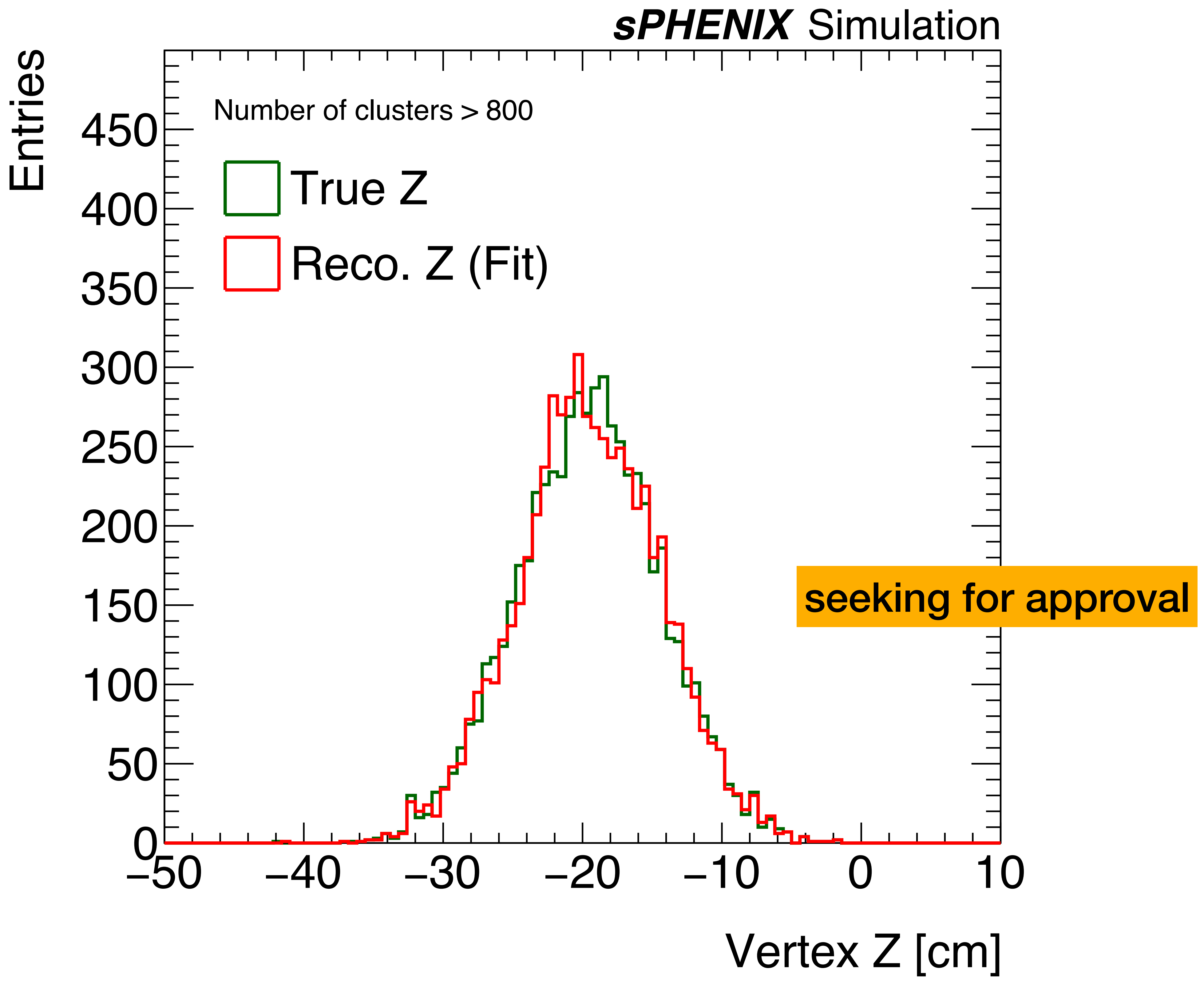


The optimization of vertex Z determination

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





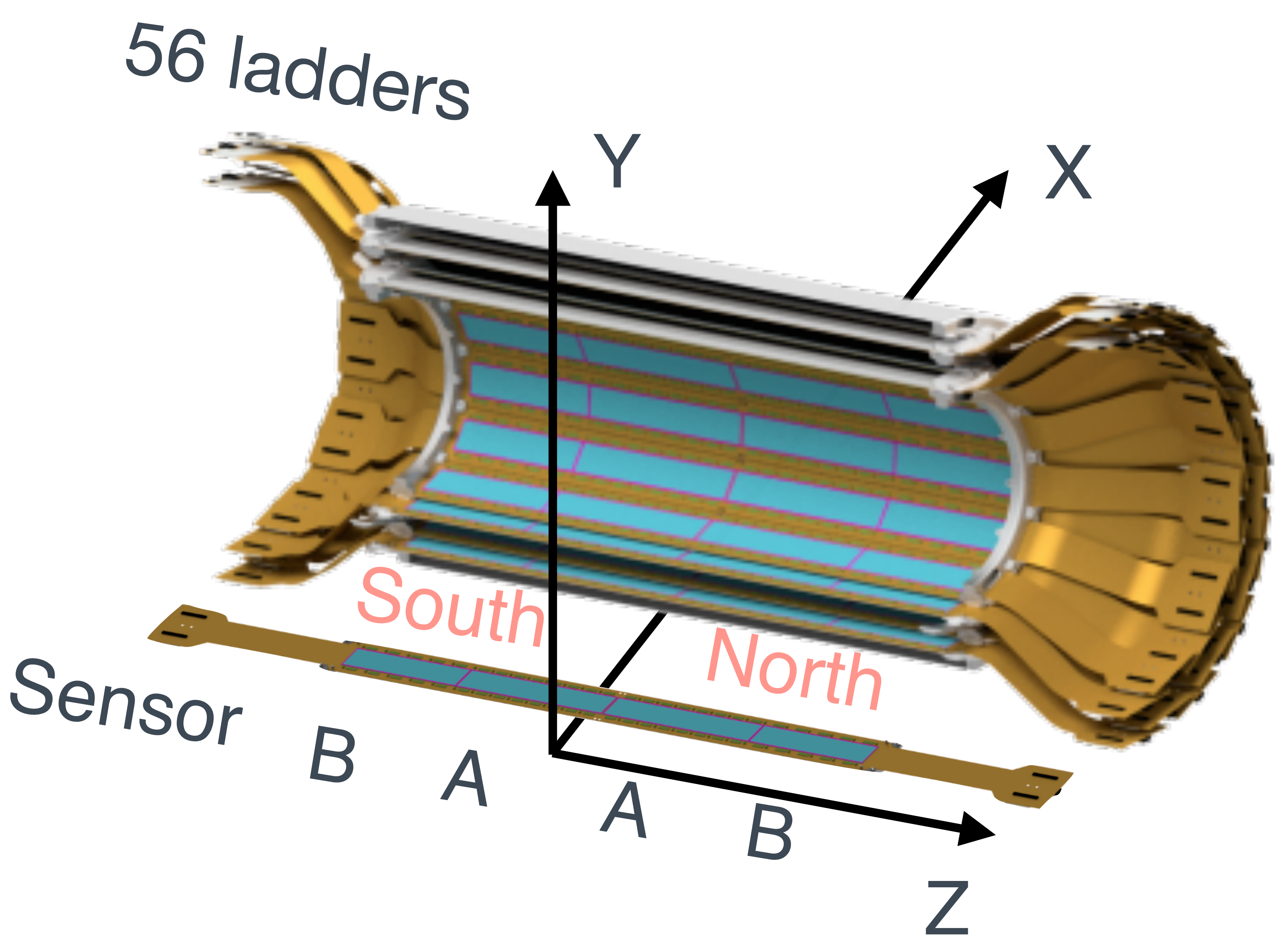
Links

- The link to analysis note : https://www.overleaf.com/project/66c2de6290ee43c025eb17f1

- The analysis code for the INTT vertex reconstruction: https://github.com/sPHENIX-Collaboration/analysis/tree/master/dNdEta_Run2023/analysis_INTT_CW

INTT geometry

INTT: 2 sensors X 2 sides of half-ladders X 56 ladders = 224 sensors



Notation: B_xL_{yzz}
- x: Barrel ID (0 for inner or 1 for outer)
- y: Layer ID (0 for inner or 1 for outer)
- zz: Ladder ID (from 0 to 15)

Axis (Right-haded coordinate)
- x-axis: $\vec{y} \times \vec{z}$
- y-axis: Vertically upward direction
- z-axis: The blue beam direction (pointing to the north)