Self introduction and Run23 dN/dη analysis

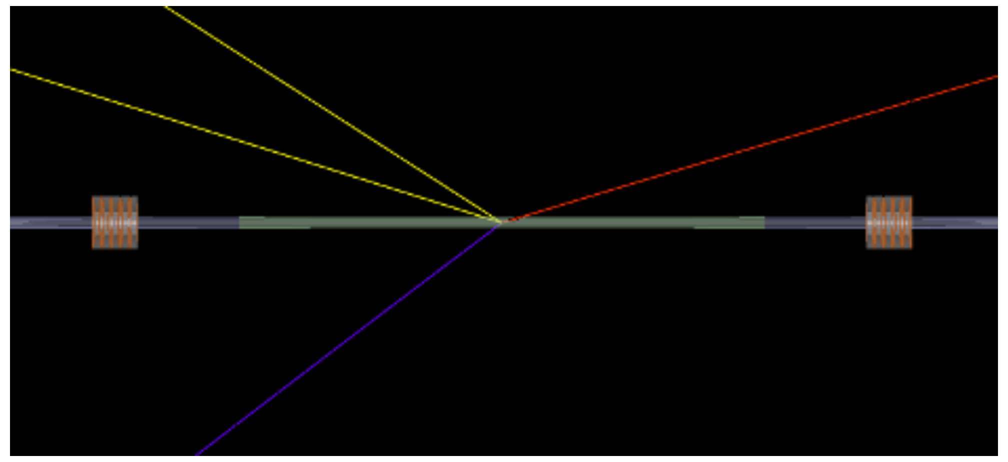
Cheng-Wei Shih

National Central University & RIKEN

June 4th, 2024
RNRC exp. group meeting

Self introduction

- Name : Cheng-Wei Shih
- National : Taiwan (Republic of China, ROC)
- Institute: Department of Physics, National Central University
- Grade: 2nd year of PHD program
- Relation to RIKEN: IPA program (start: May 1st 2024)
- Experience:
  - CEPC, circular electron positron collider
    - Period : the whole 3rd year of bachelor
    - G4 simulation study of the potential geometry of the luminosity calorimeter
  - sPHENIX (current)
    - Participated in INTT group on May 5th 2019 (5 years from now)
    - INTT ladder assembly, beam test analysis, ladder quality classification, commissioning, etc
    - Current main focus : $dN/d\eta$ analysis

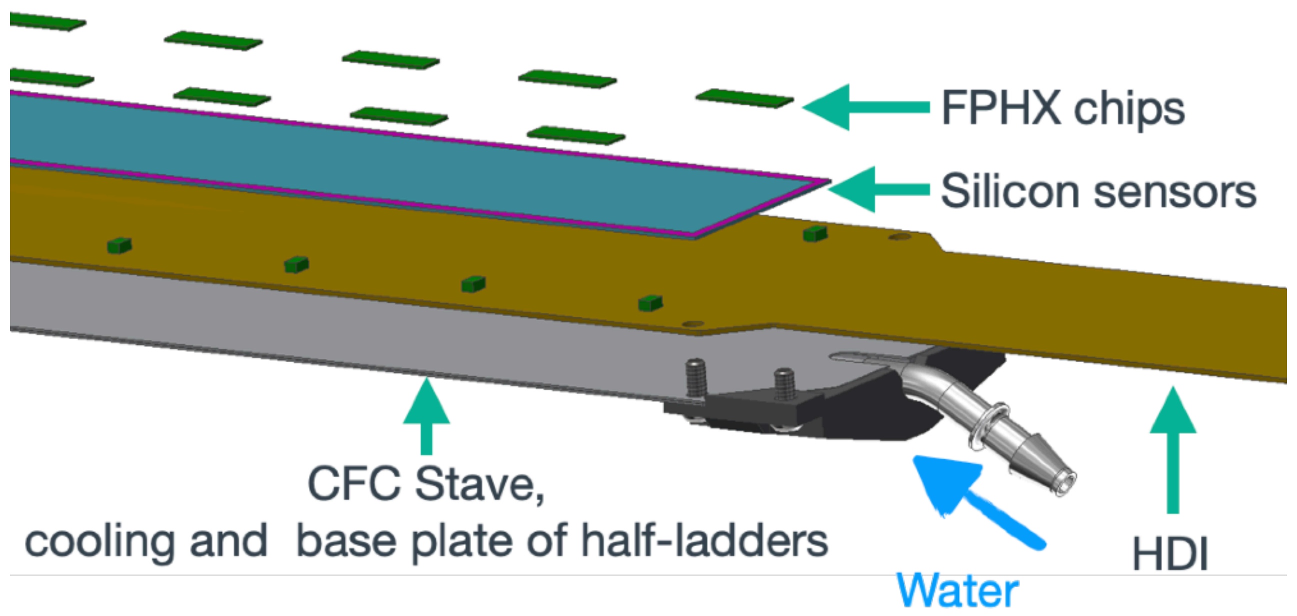


Part of previous work : INTT ladder assembly

sPHENIX

INTT ladder explosion plot

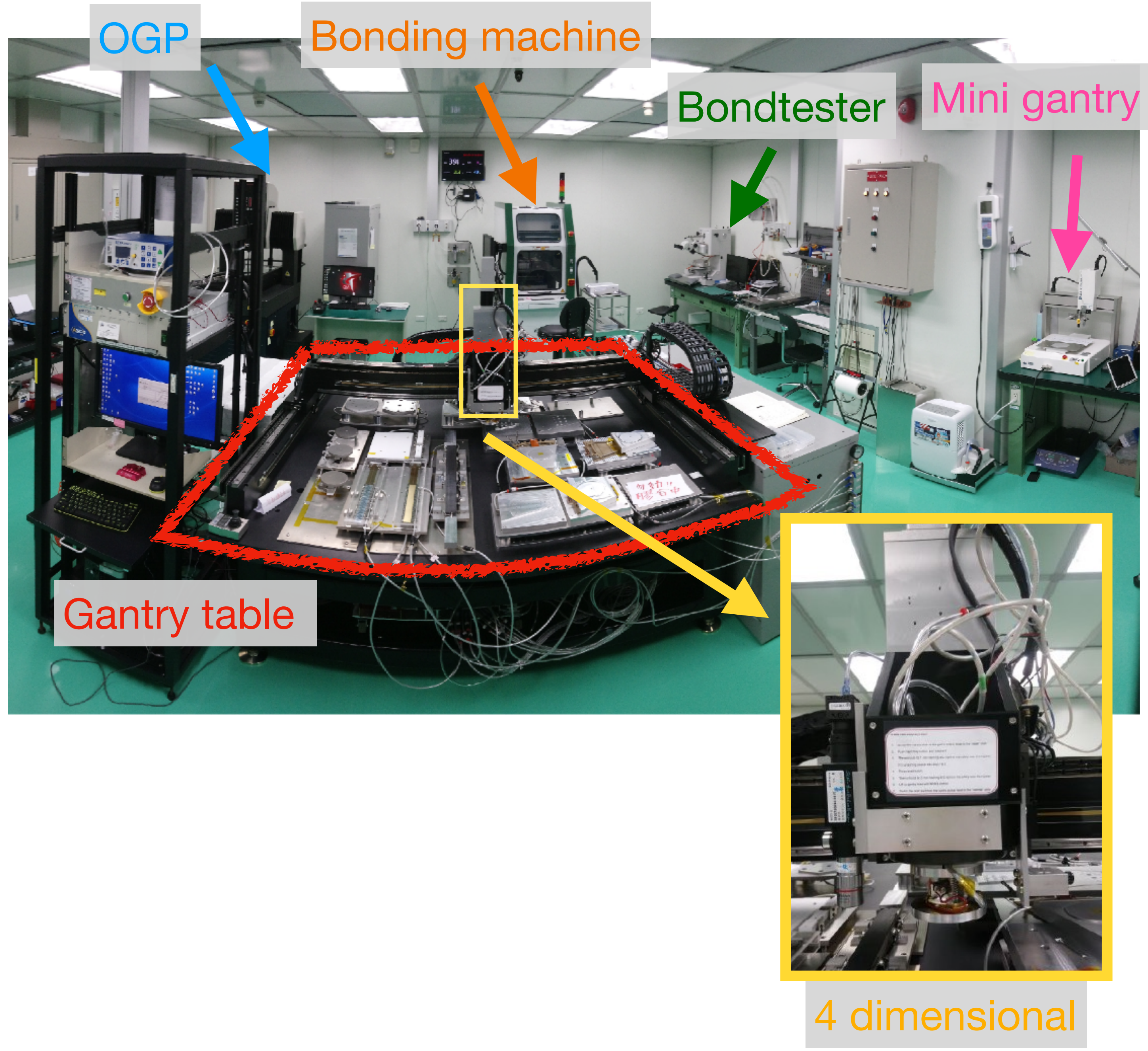
Half-ladder = 1 HDI + 26 chips + 2 silicon sensors (Type A + B)
Ladder = 2 half-ladders + 1 CFC stave

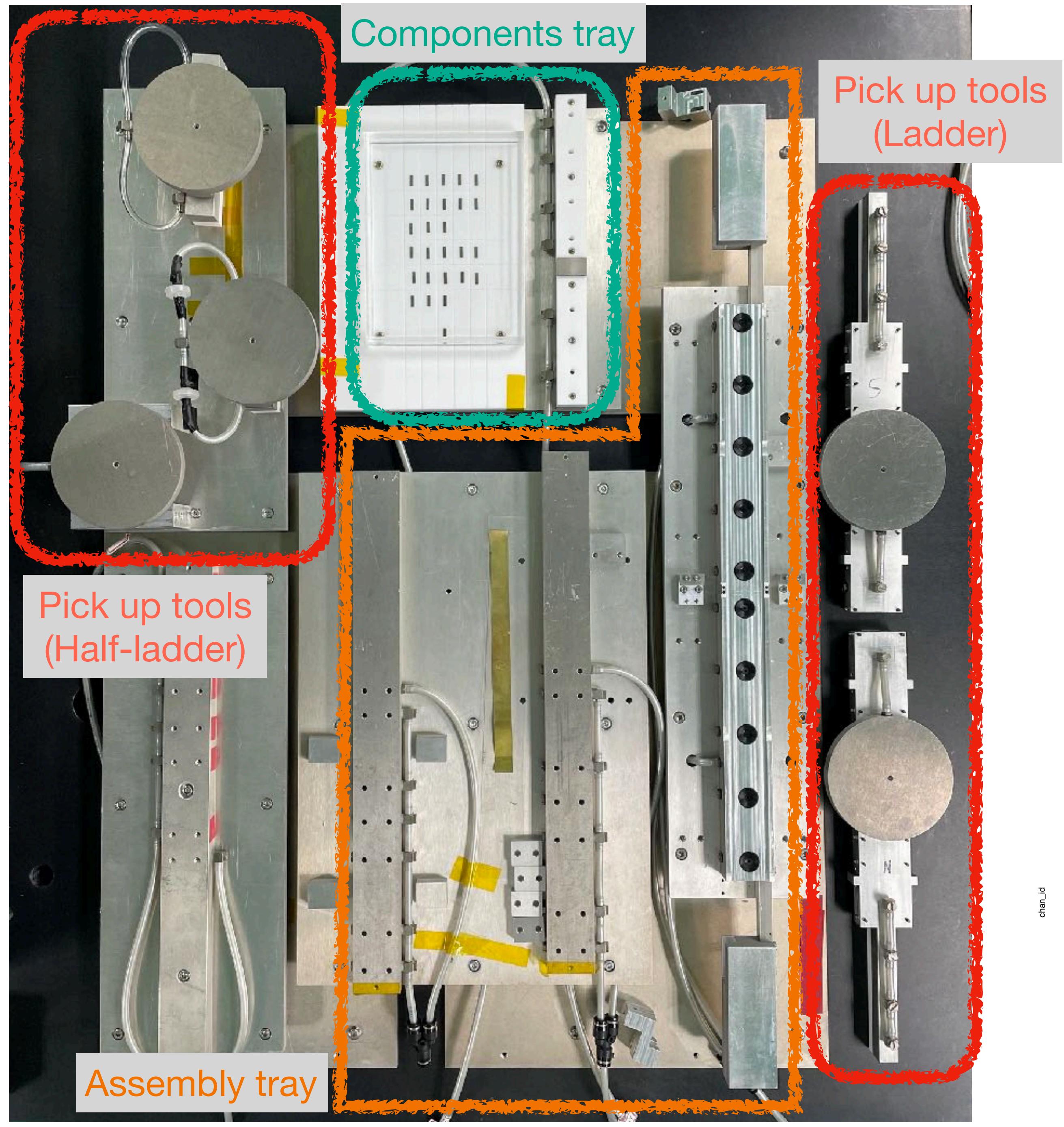


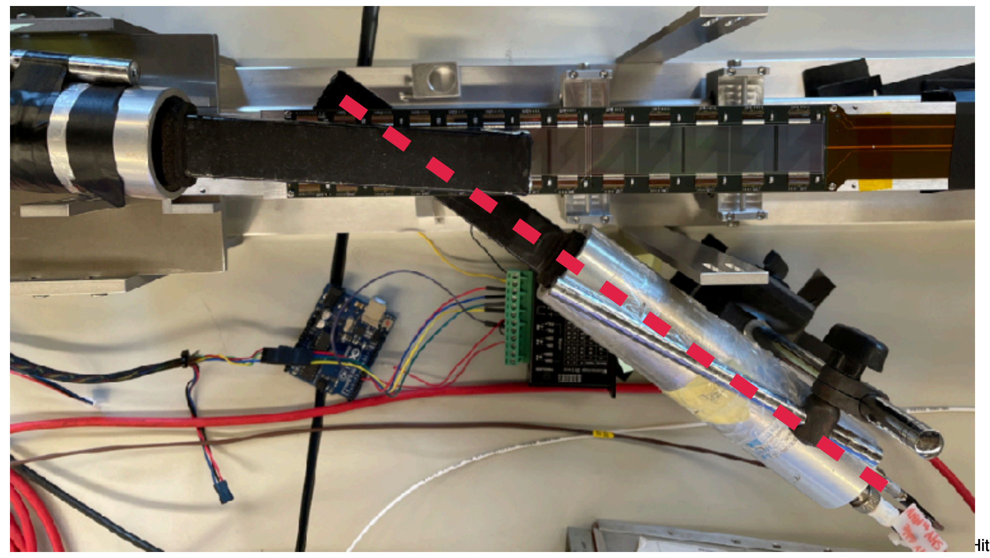
Ladders assembled in Taiwan

[The 2-min assembly video]

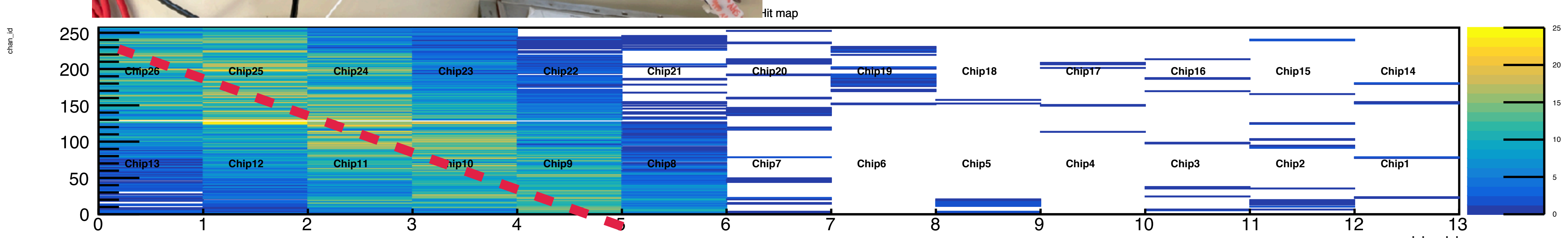
Taiwan Silicon Detector Facility (TSiDF)







Cosmic test performed in Taiwan



40 ladders (1/3 of total) of ladders were assembled in Taiwan

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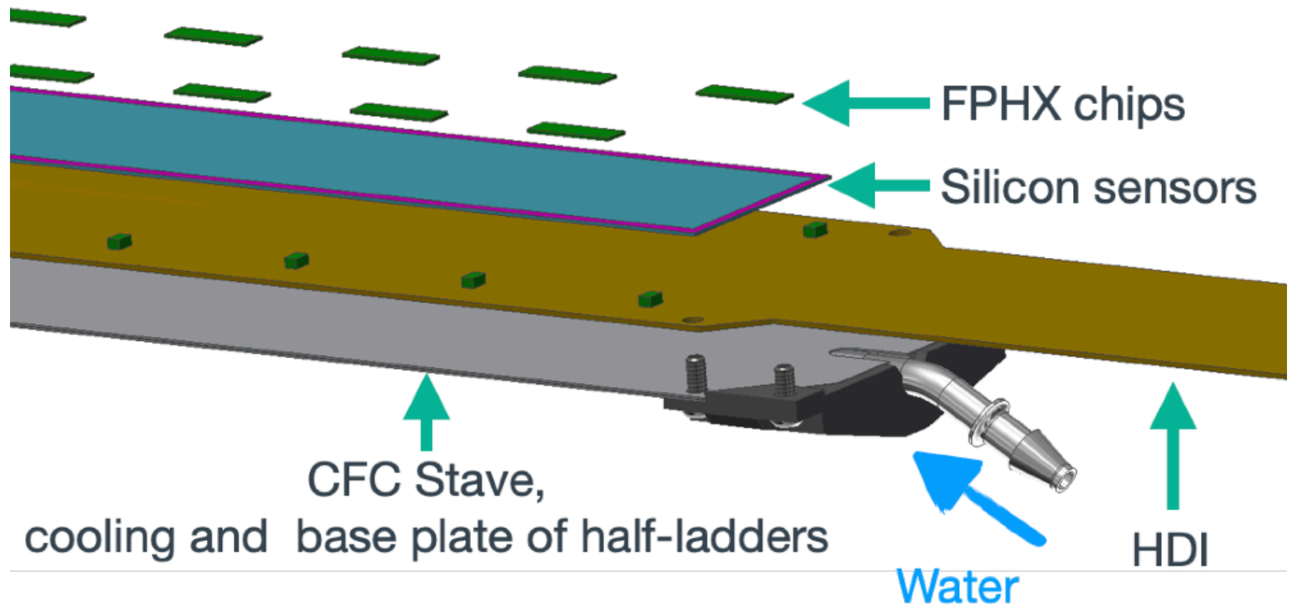

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[The 2-min assembly video]

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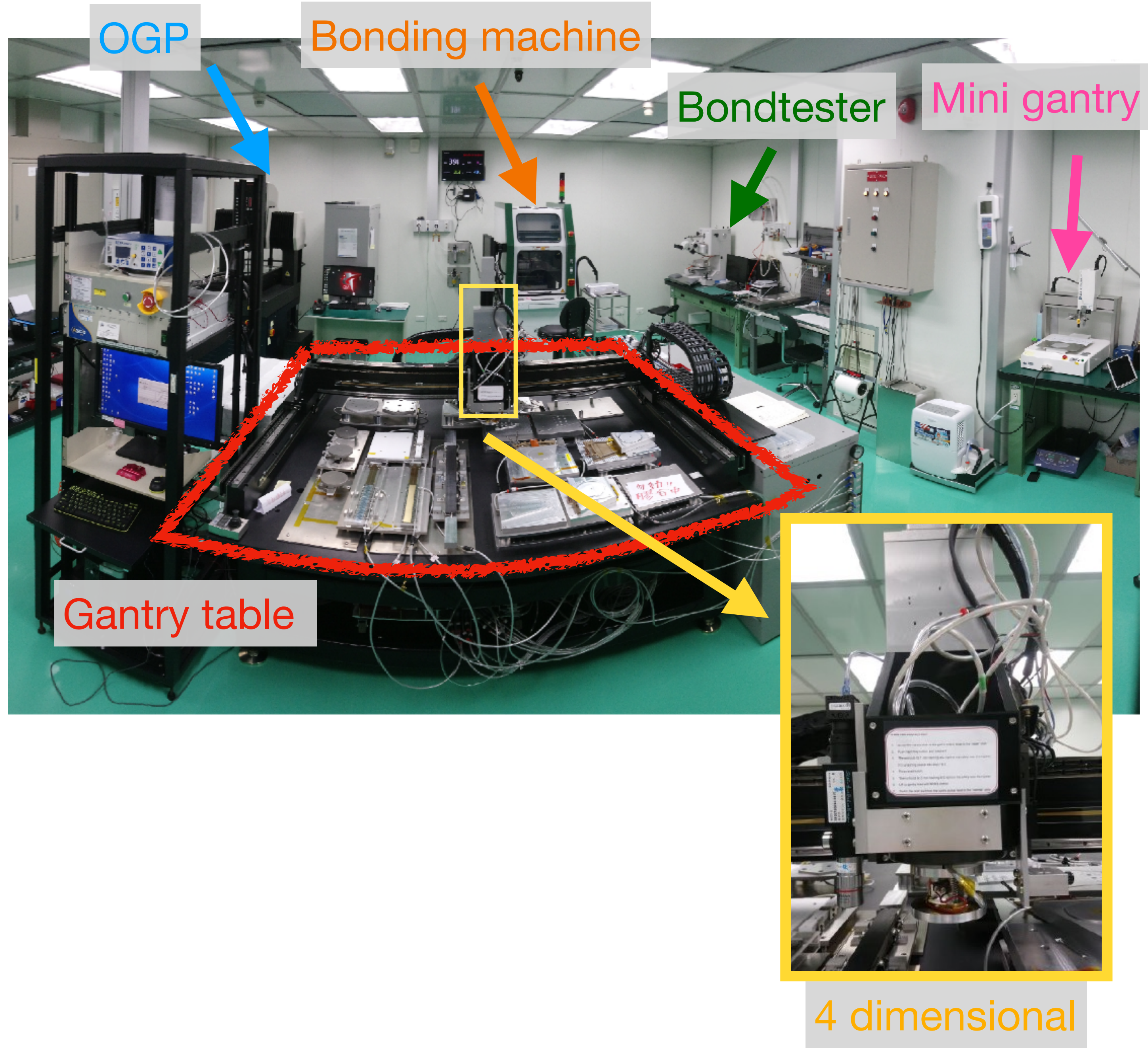

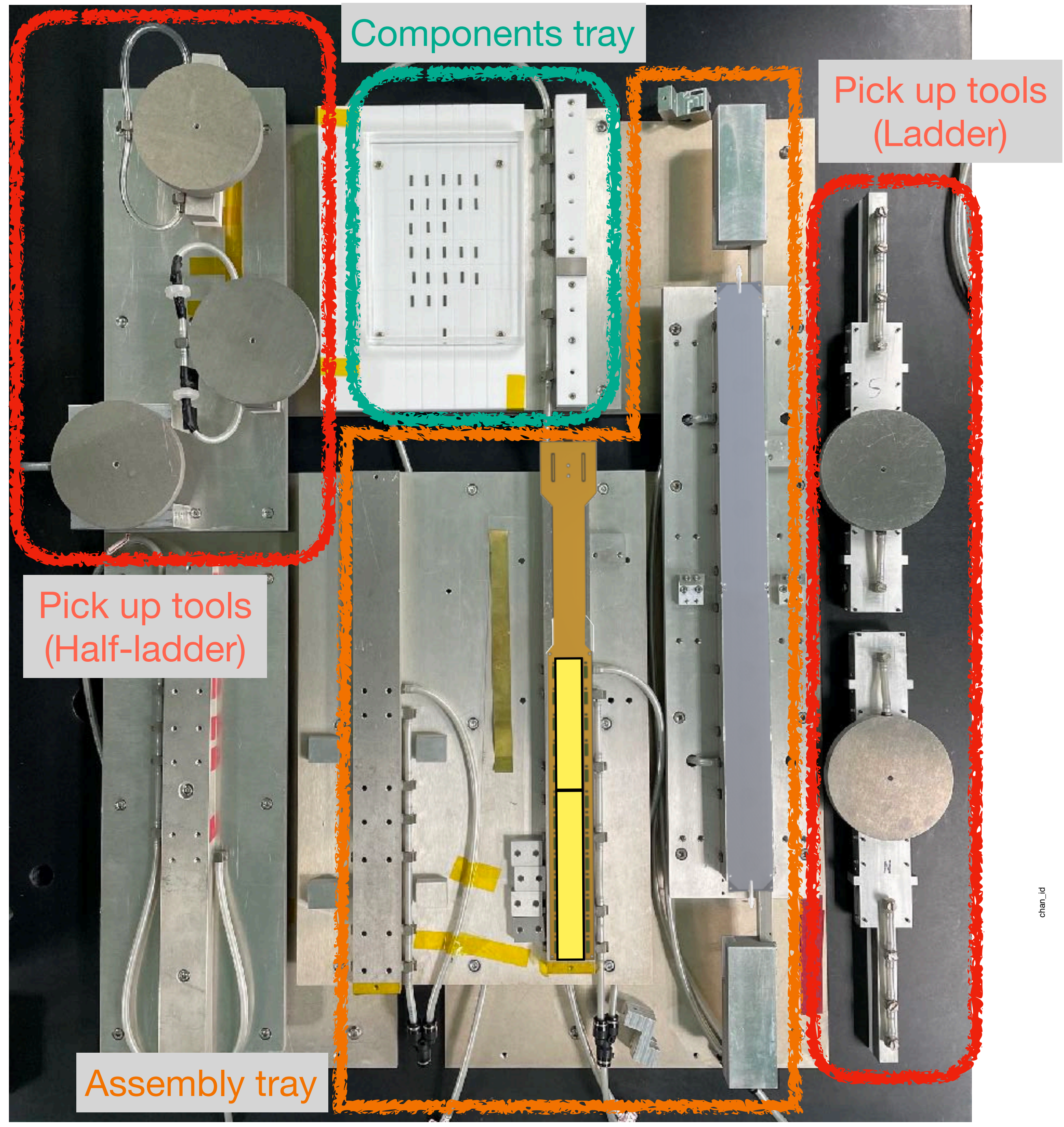

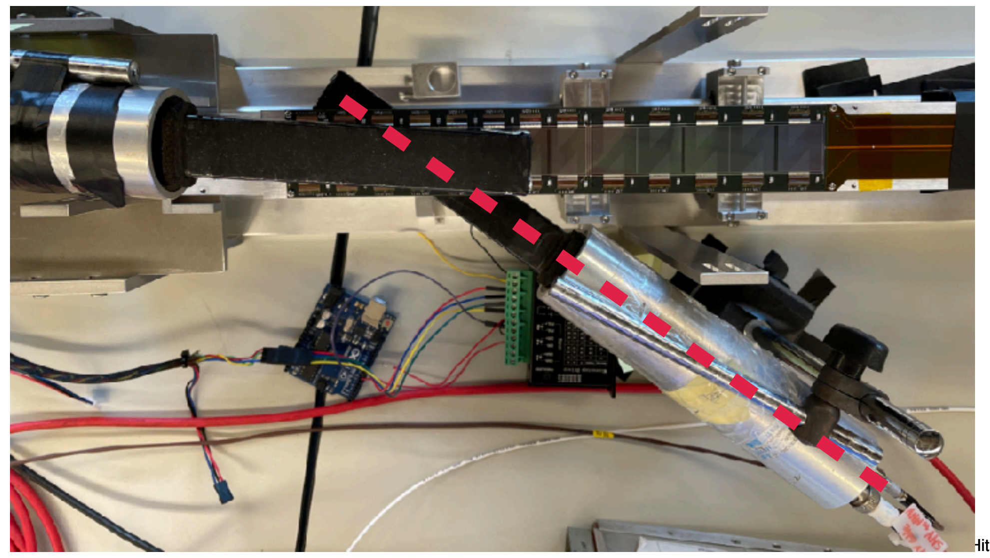

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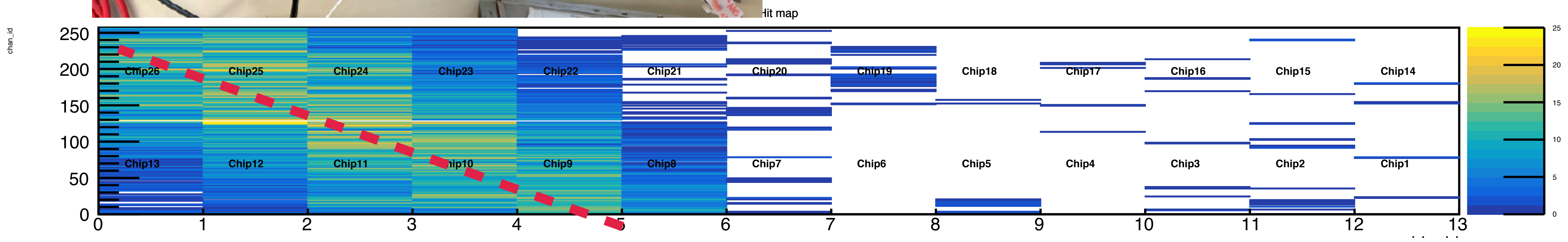

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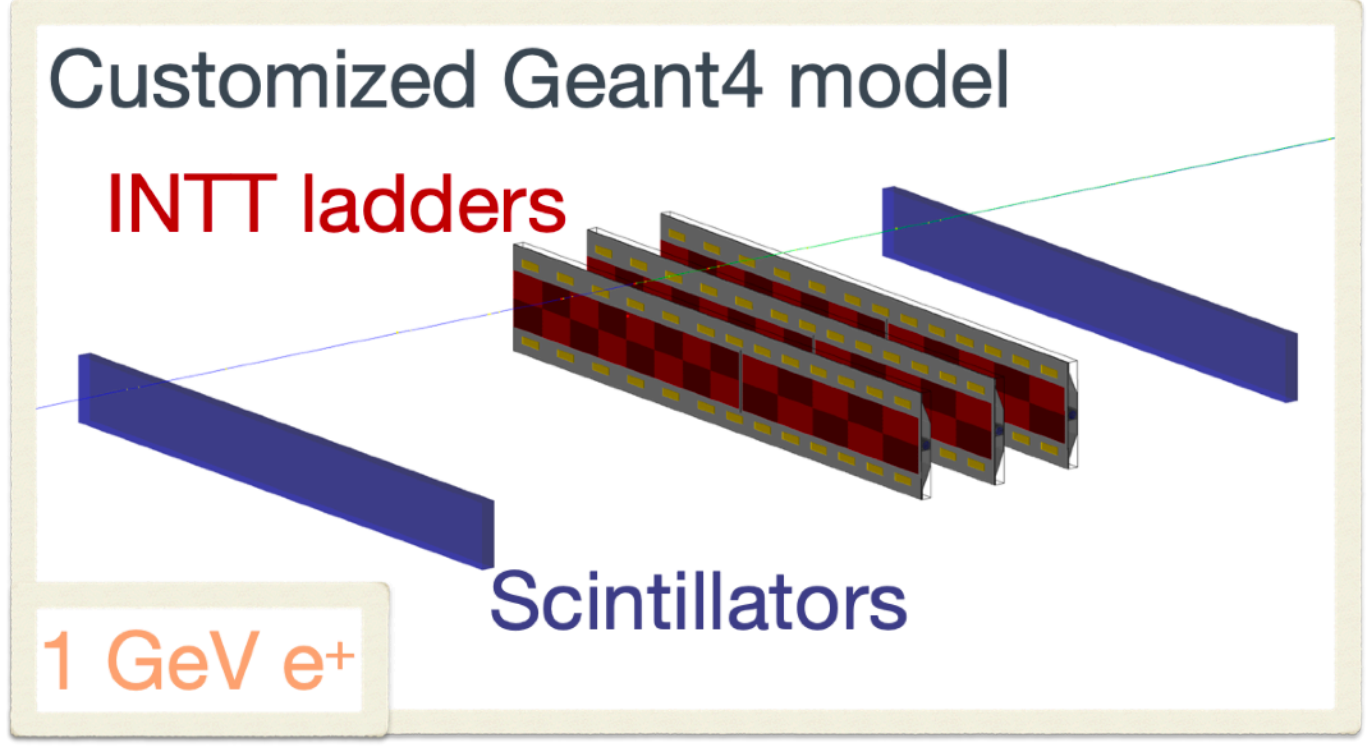
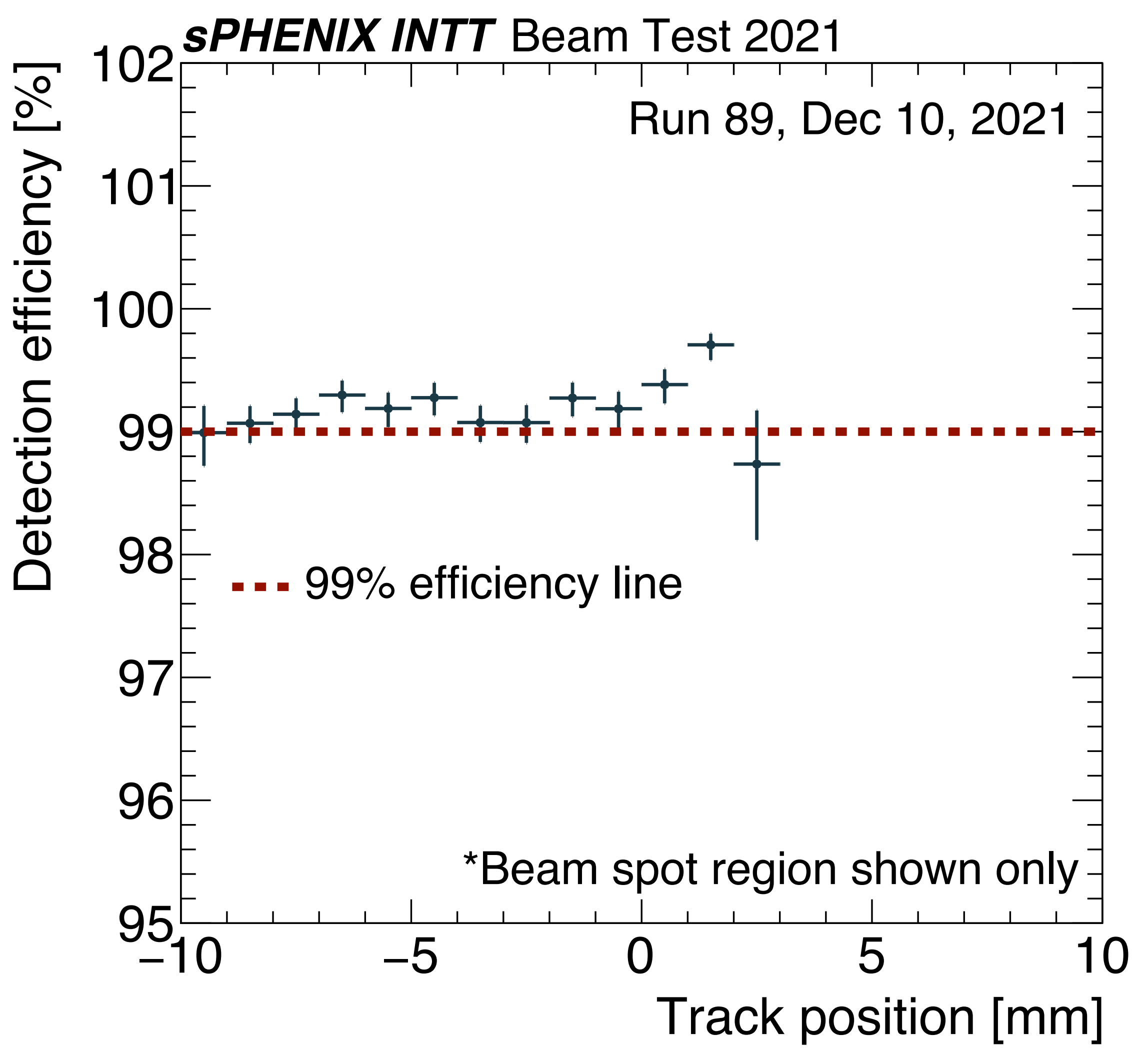
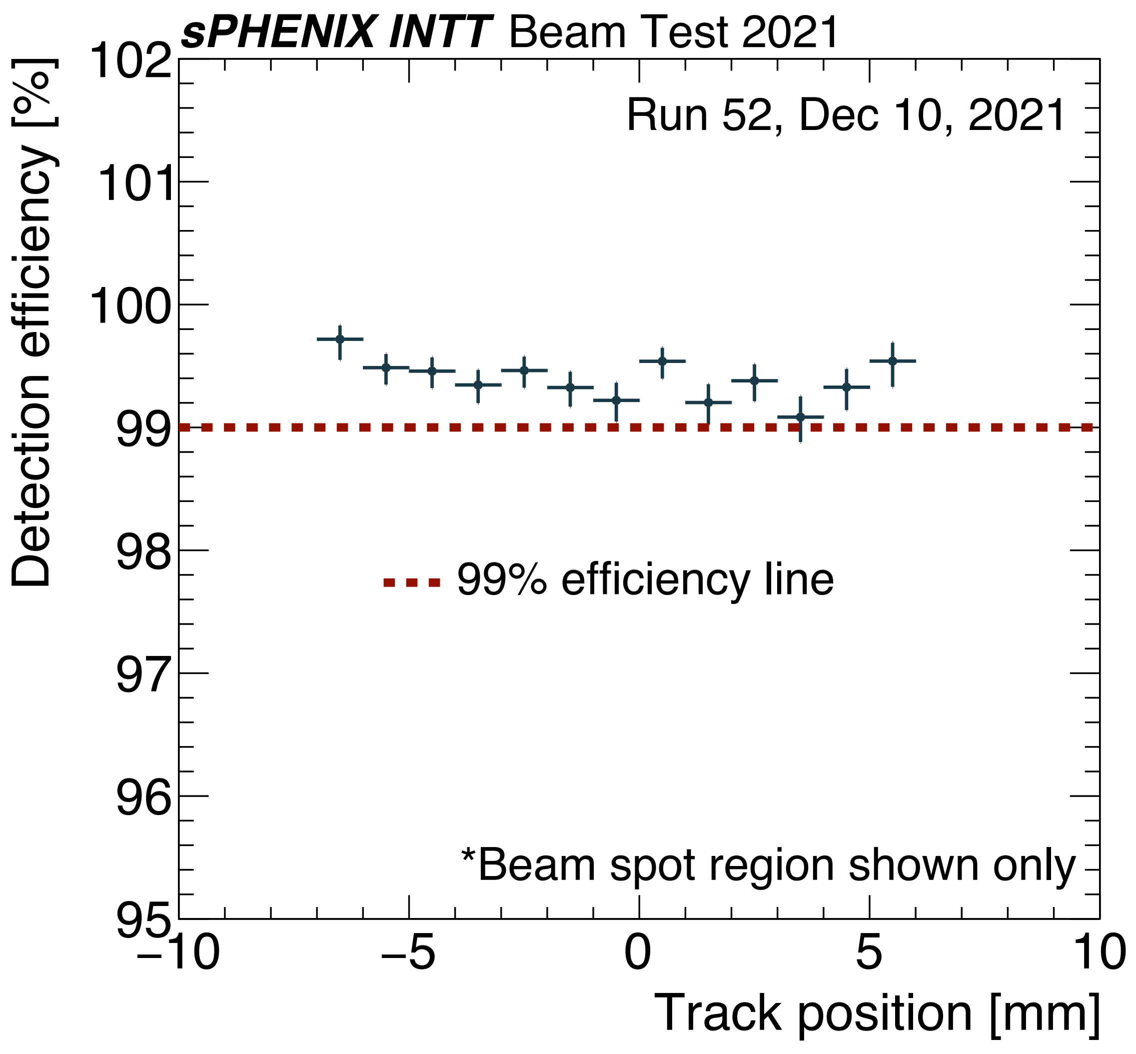
Part of previous work : Beam test analysis

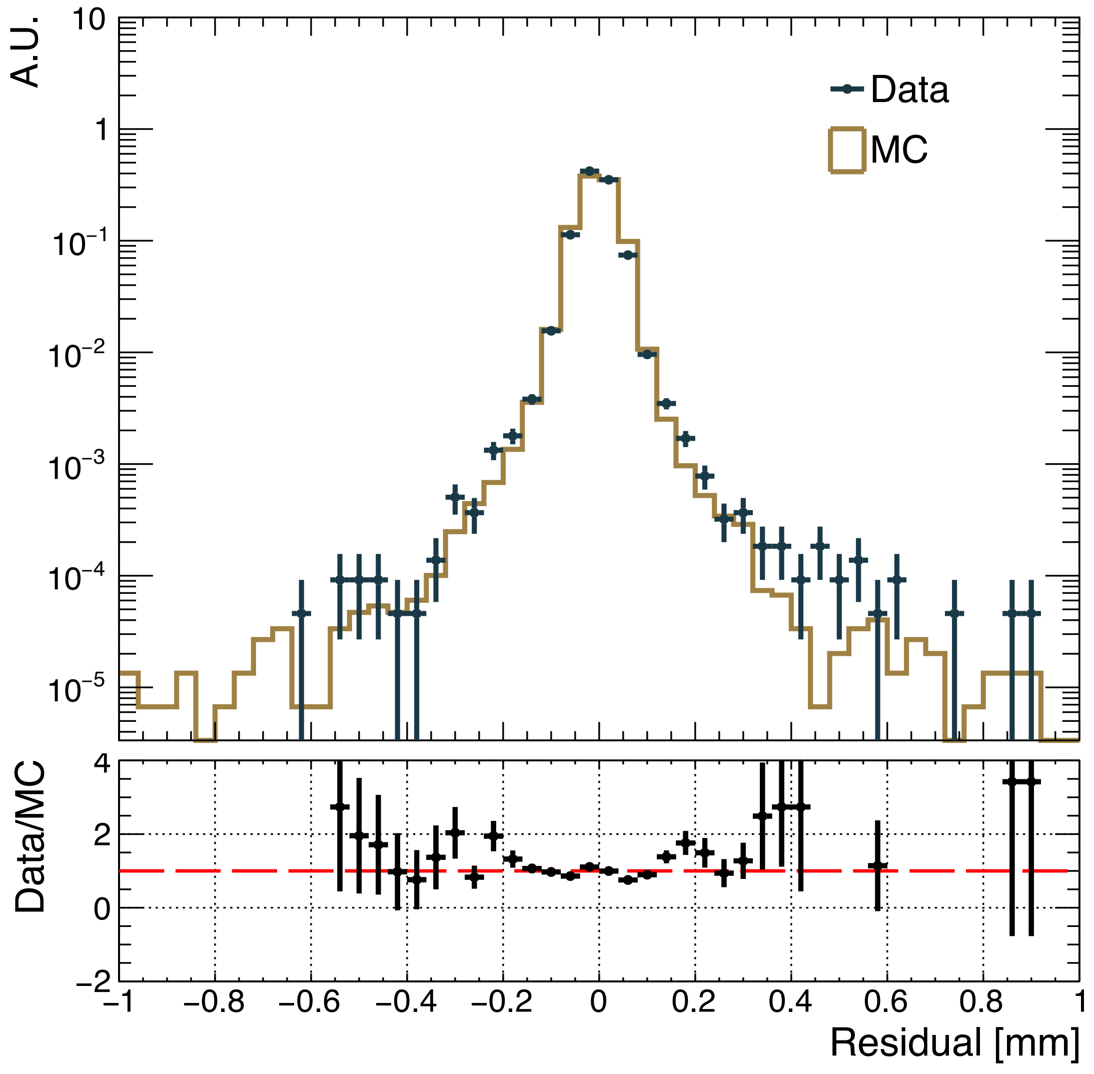


- Beam test 2019 @ Fermilab & Beam test 2021 @ ELPH Tohoku
- Configuration: 3 layers of INTT ladders + 2 scintillators (trigger)
- Bias voltage: 50 V
- Main scope: study the efficiency (to understand the 96% of second beam test)
- **Plan to publish before dN/dη submission**

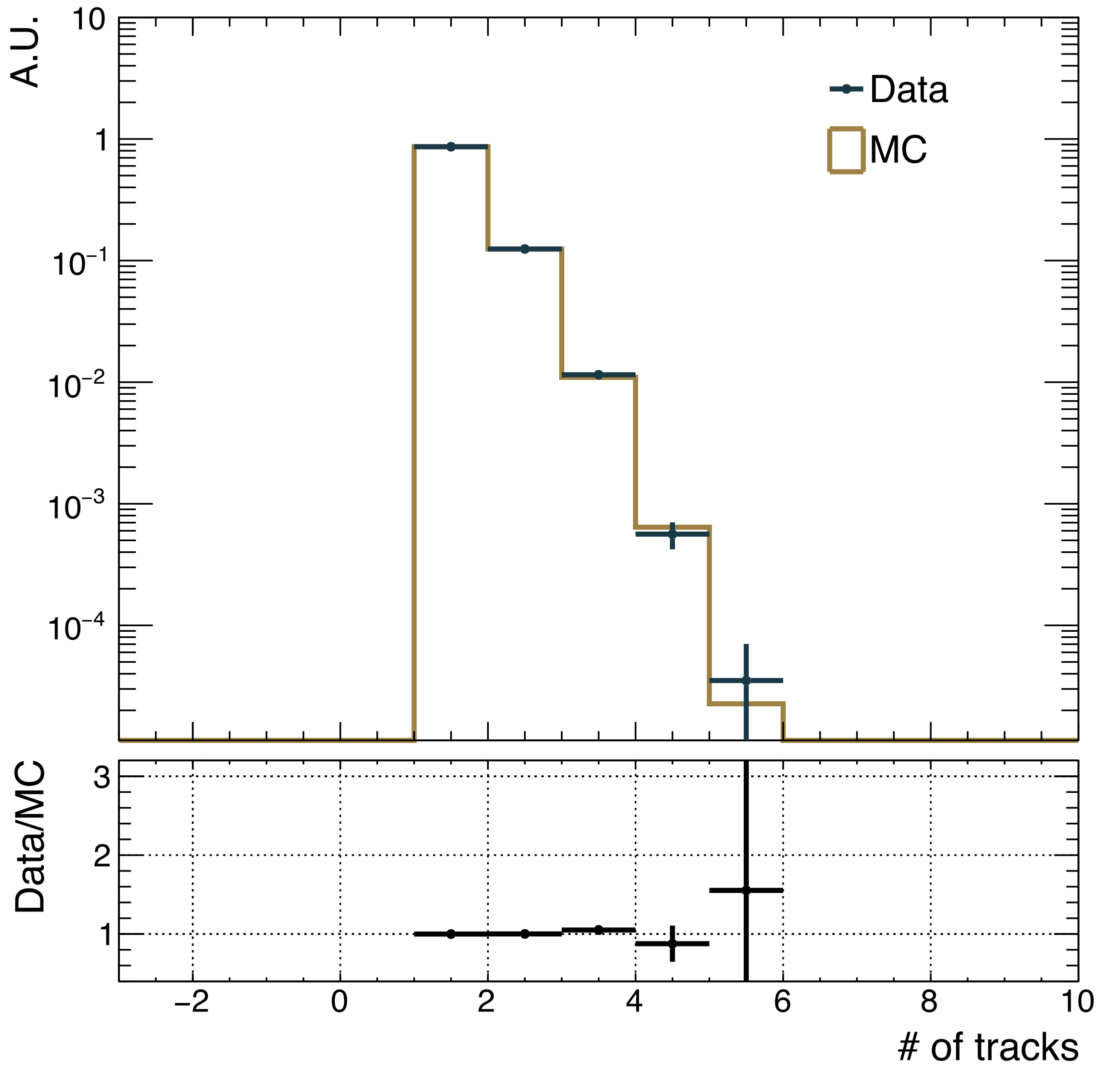




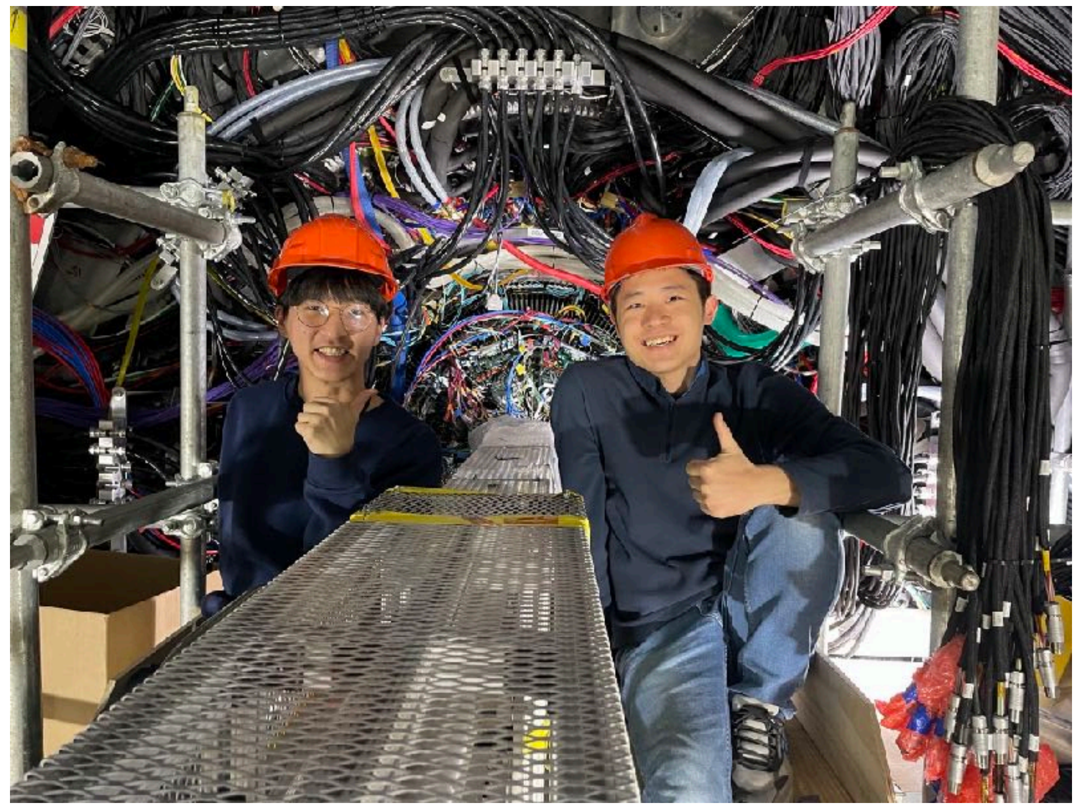
Residual distribution

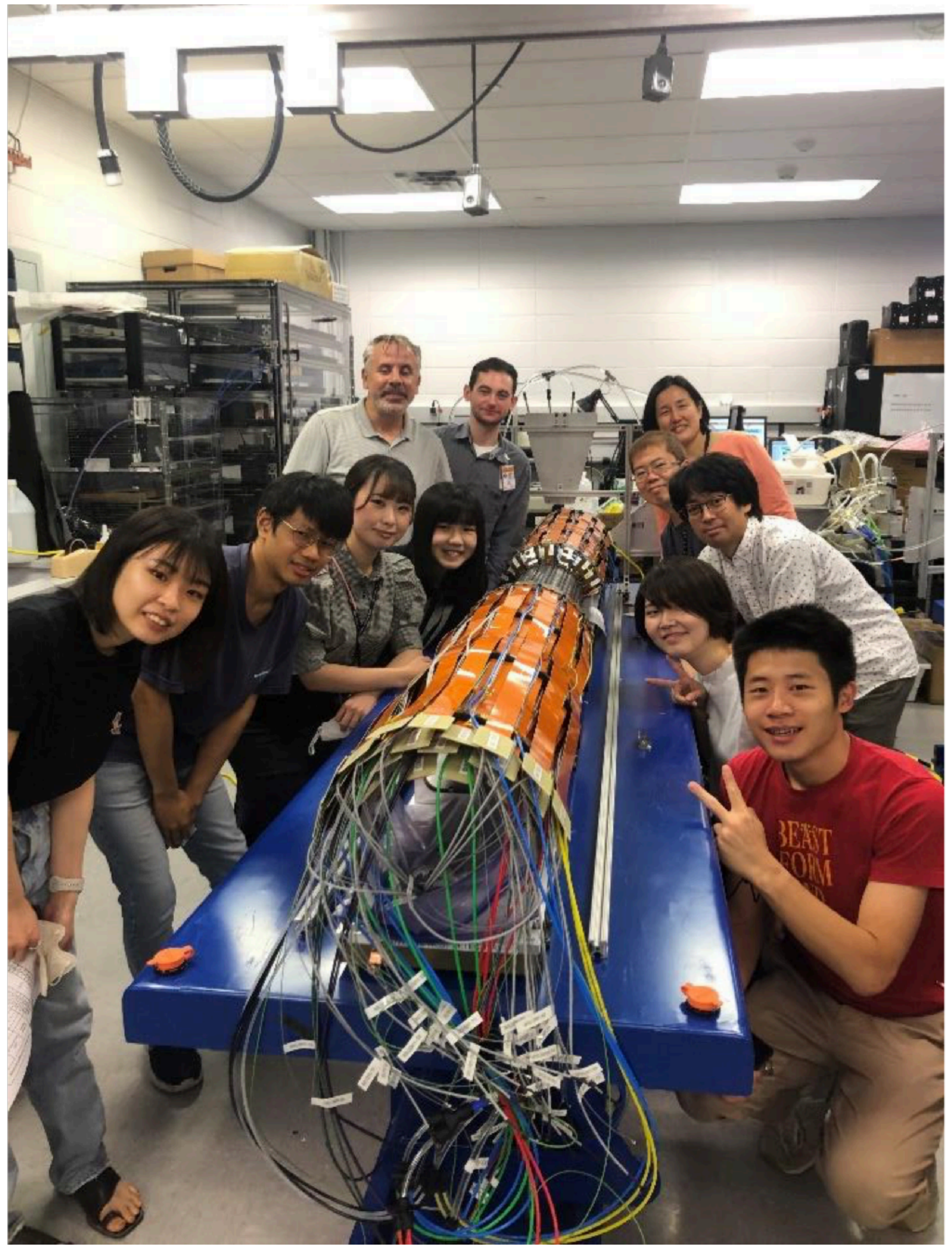


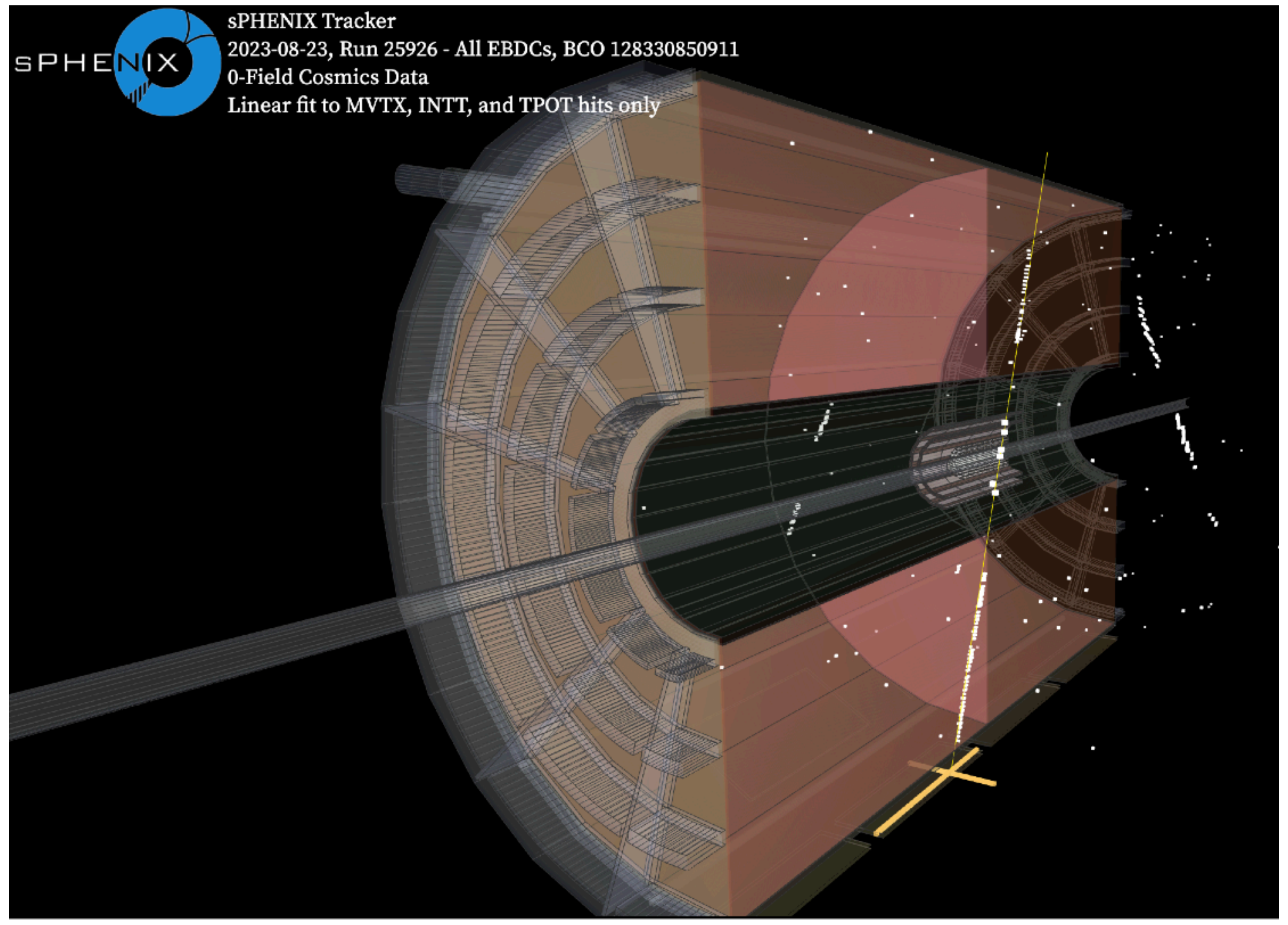
N track distribution

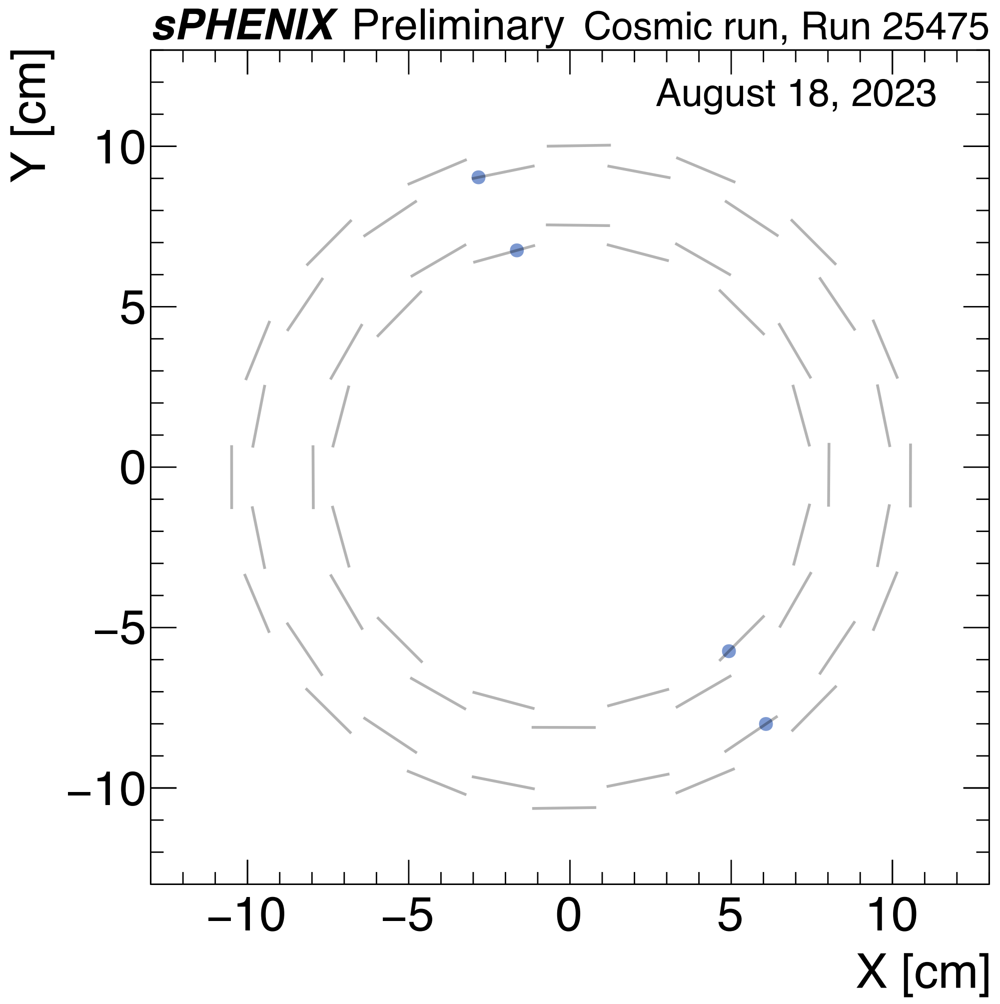


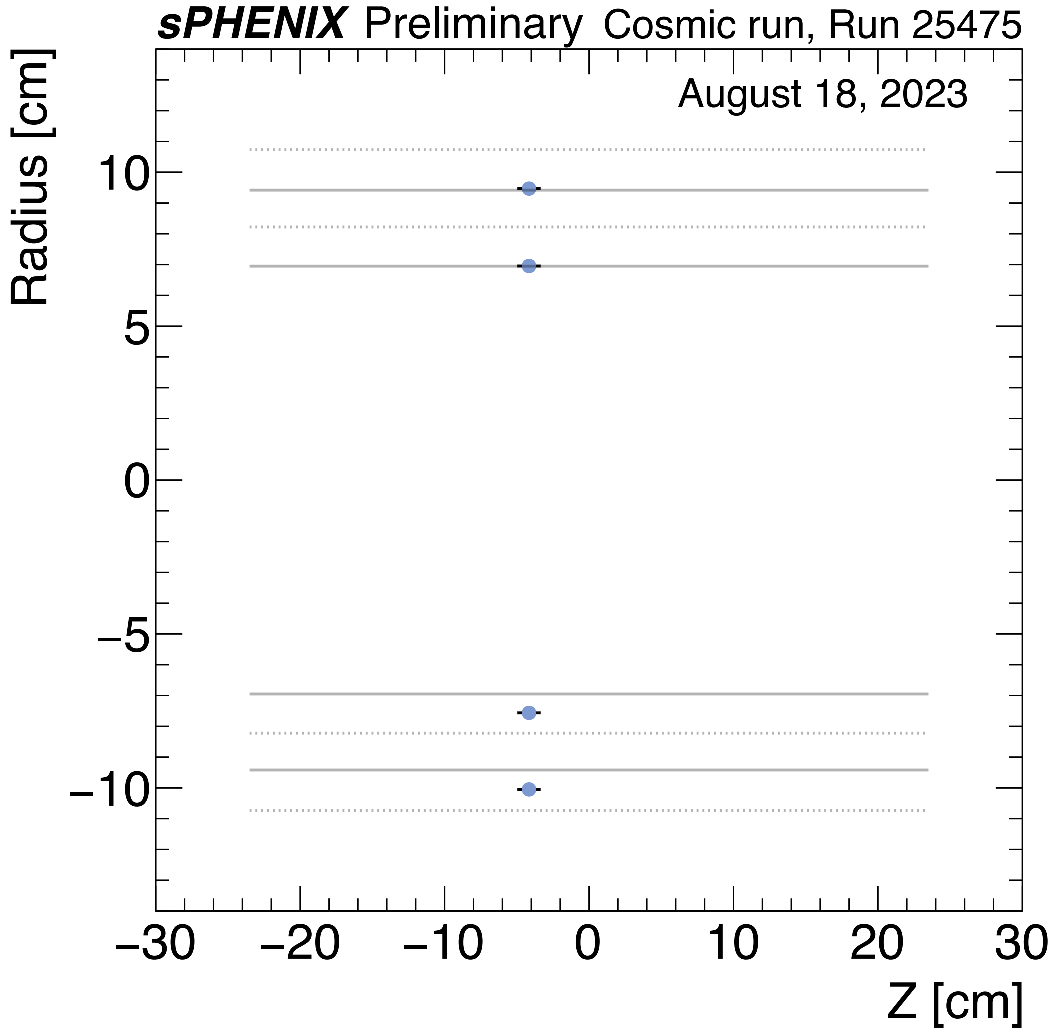
Part of previous work : on-site





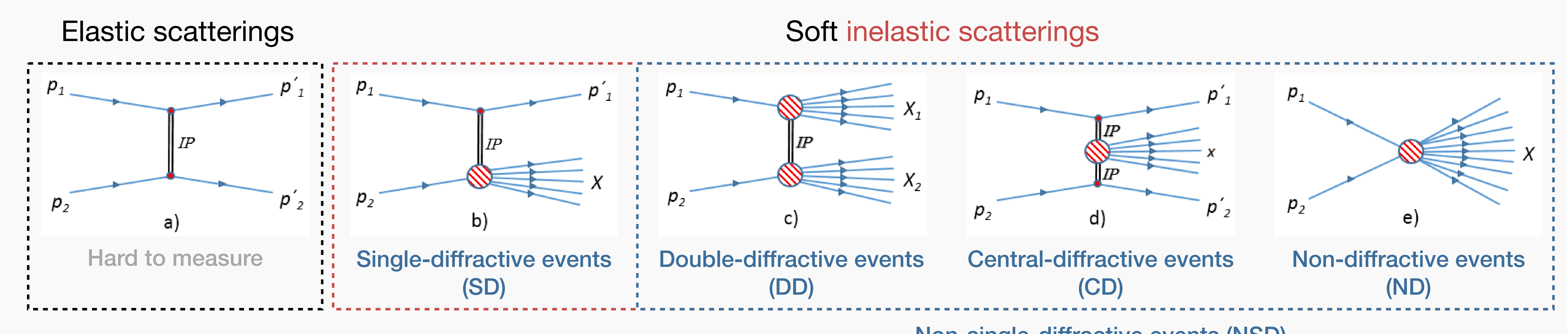






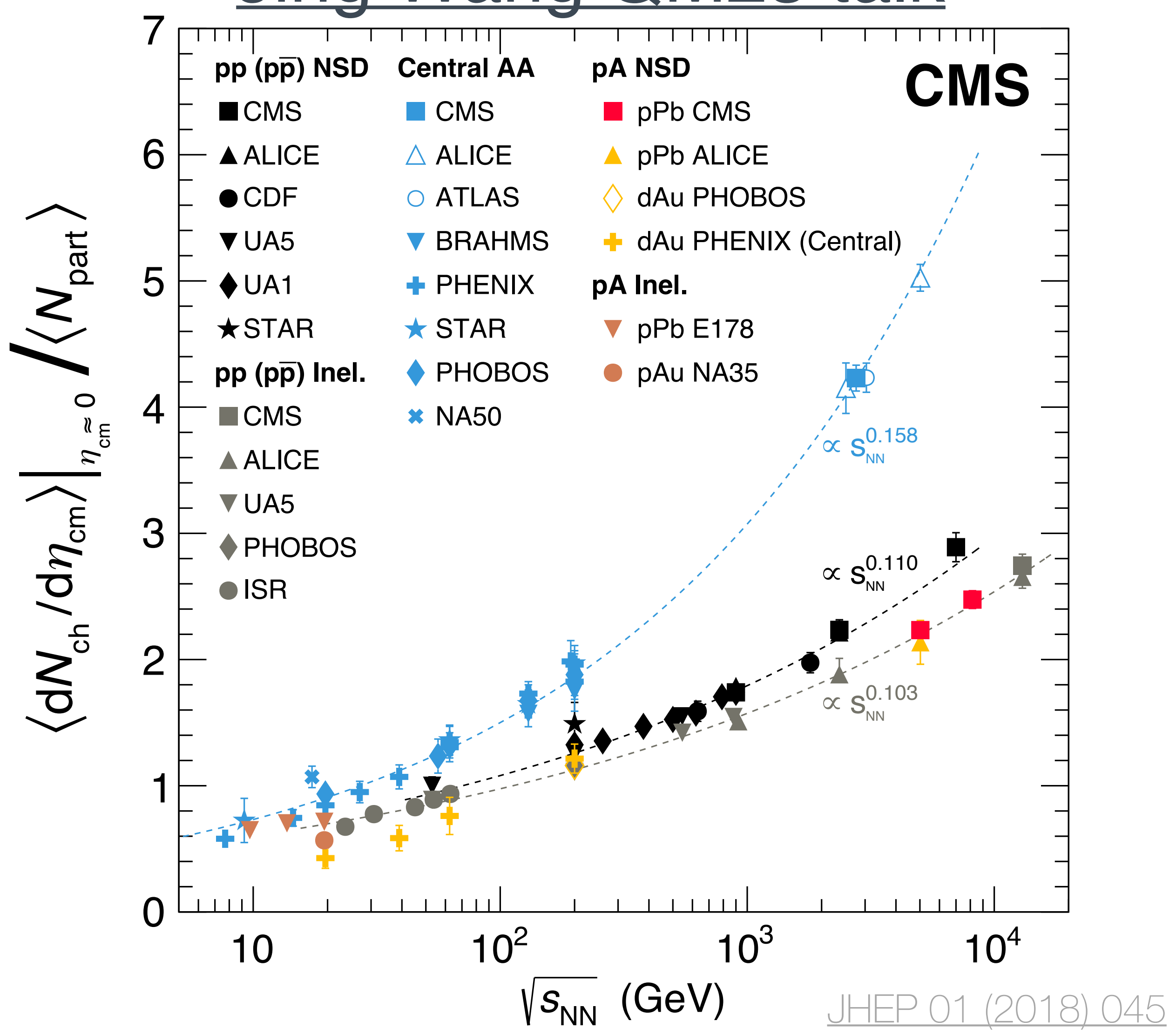
Introduction to $dN_{ch}/d\eta$

- Tells how the energy is re-distributed in phase space
- Heavy-ion collision includes elastic and inelastic scatterings
  - inelastic: diffractive and non-diffractive
- Experimental inputs are crucial to characterize initial states
- Well measured observable across different experiments (> 26 relevant publications)
- Roughly grouped by collision energy
- A baseline measurement to prove that sPHENIX can do the right things



A. B. Martínez

Jing Wang QM23 talk



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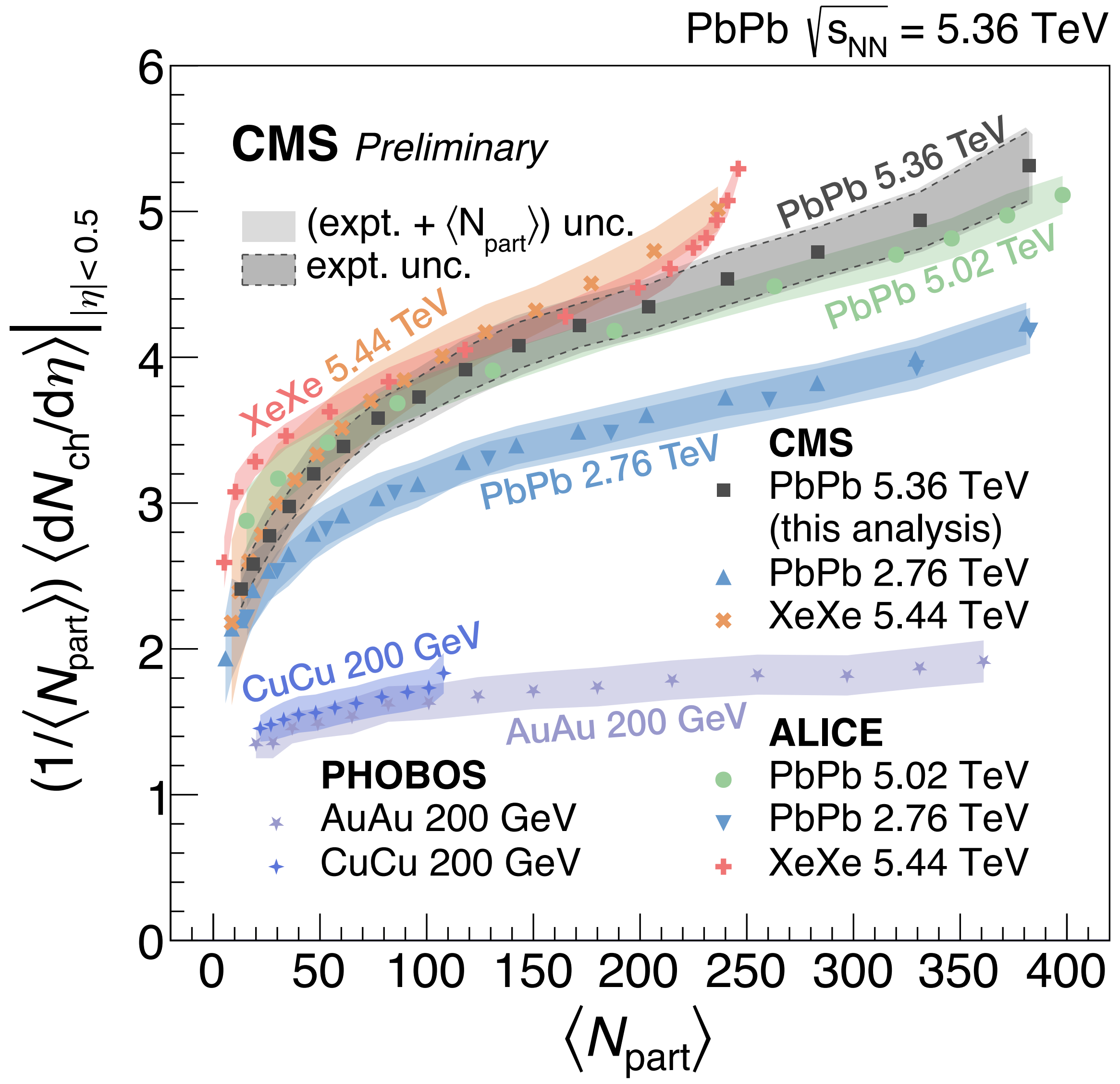


sPHENIX dN/dη analysis with Run23 data

- Utilized by the tracklet analysis with the INTT run23 data taken in zero-field env.

10 INTT zero-field runs in total in run 23, taken on July 8th 2023

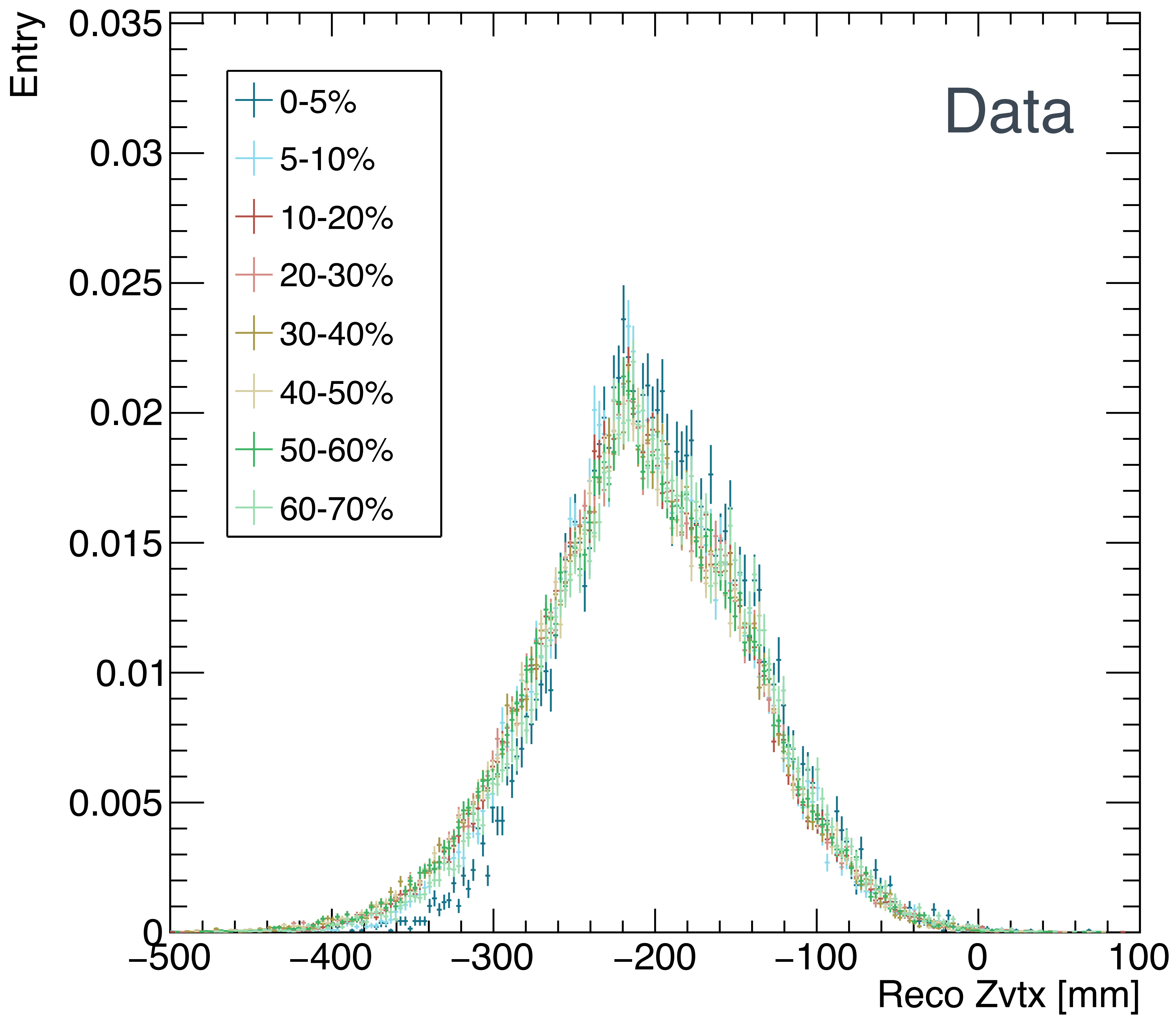
RunNumber (ZF)	Nevents
20864	417,729
20866	26,404
20867	317,047
20868	288,481
20869	550,123
20878	89,238
20880	171,760
20881	31,736
20883	94,249
20885	357,343
Sum	2,344,110

Property	Value
Run	20869
Production tag	2023p011
Centrality calibration tag	2023p011
sPHENIX software build	ana.404
Total number of events in DST	550121
$\langle z_{vertex}^{\mathrm{MBD}} \rangle$	-22.03 cm
$\sigma(z_{vertex}^{\mathrm{MBD}})$	8.67 cm
Nominal Min. Bias trigger efficiency	0.88

Currently focus on one run, run 20869
vertex off by -20 cm (at almost south edge of INTT)

Vertex Z distribution of the run 20869

Reconstructed by INTT
(INTT coverage : ±23 cm in Z axis)



sPHENIX dN/dη analysis with Run23 data

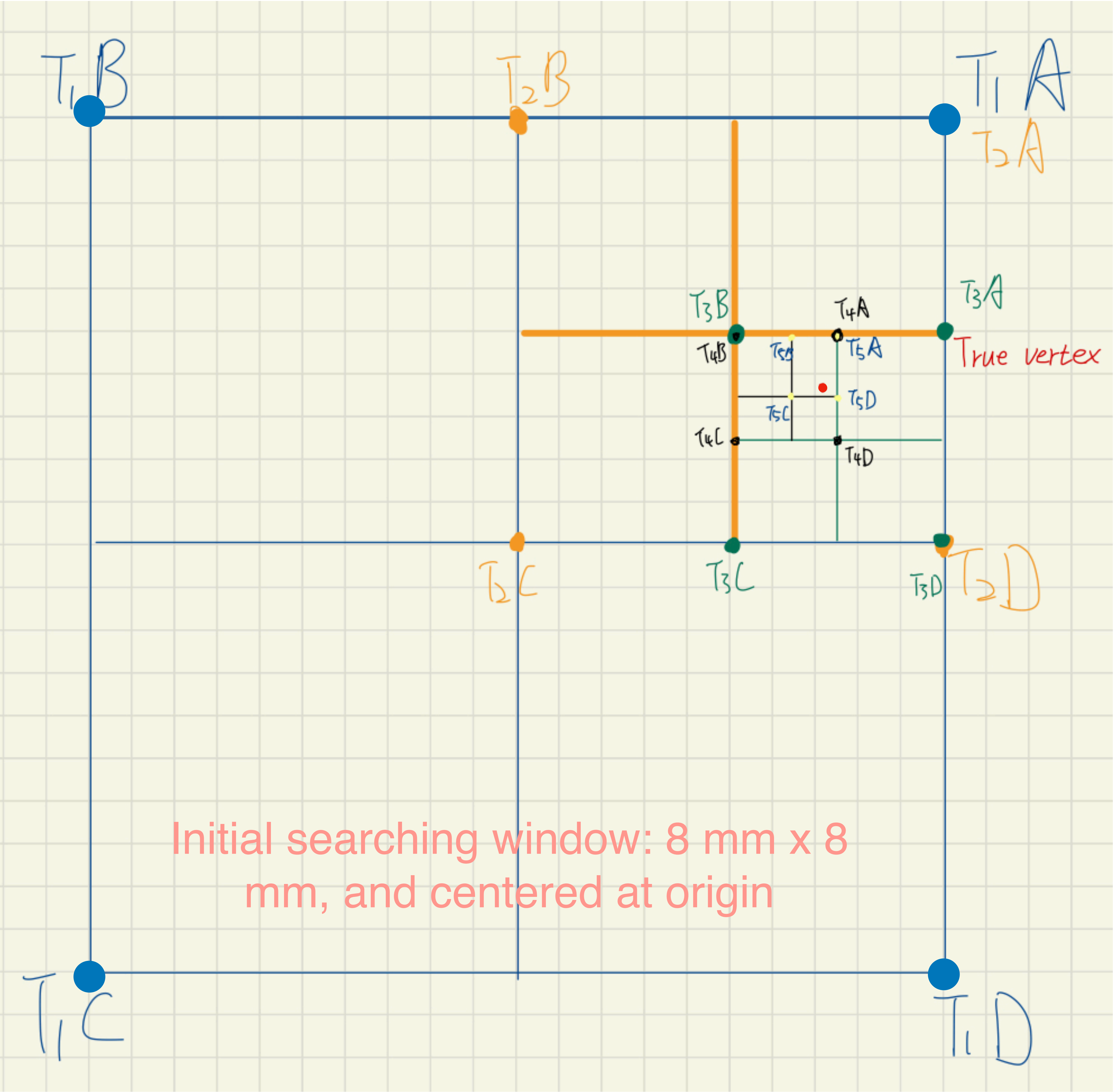
- Utilized by the tracklet analysis with the INTT run23 data taken in zero-field env.
- Analysis procedures (the skeleton):
  - → Average vertex XY
  - → Per event vertex Z
  - → Tracklet reconstruction
  - → Derive the correction factor
  - → Distribution comparison

Vertex: average X and Y positions

- **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
    - $\Delta\phi$ - Clu_{inner} ϕ correlation

The area inside the INTT barrel



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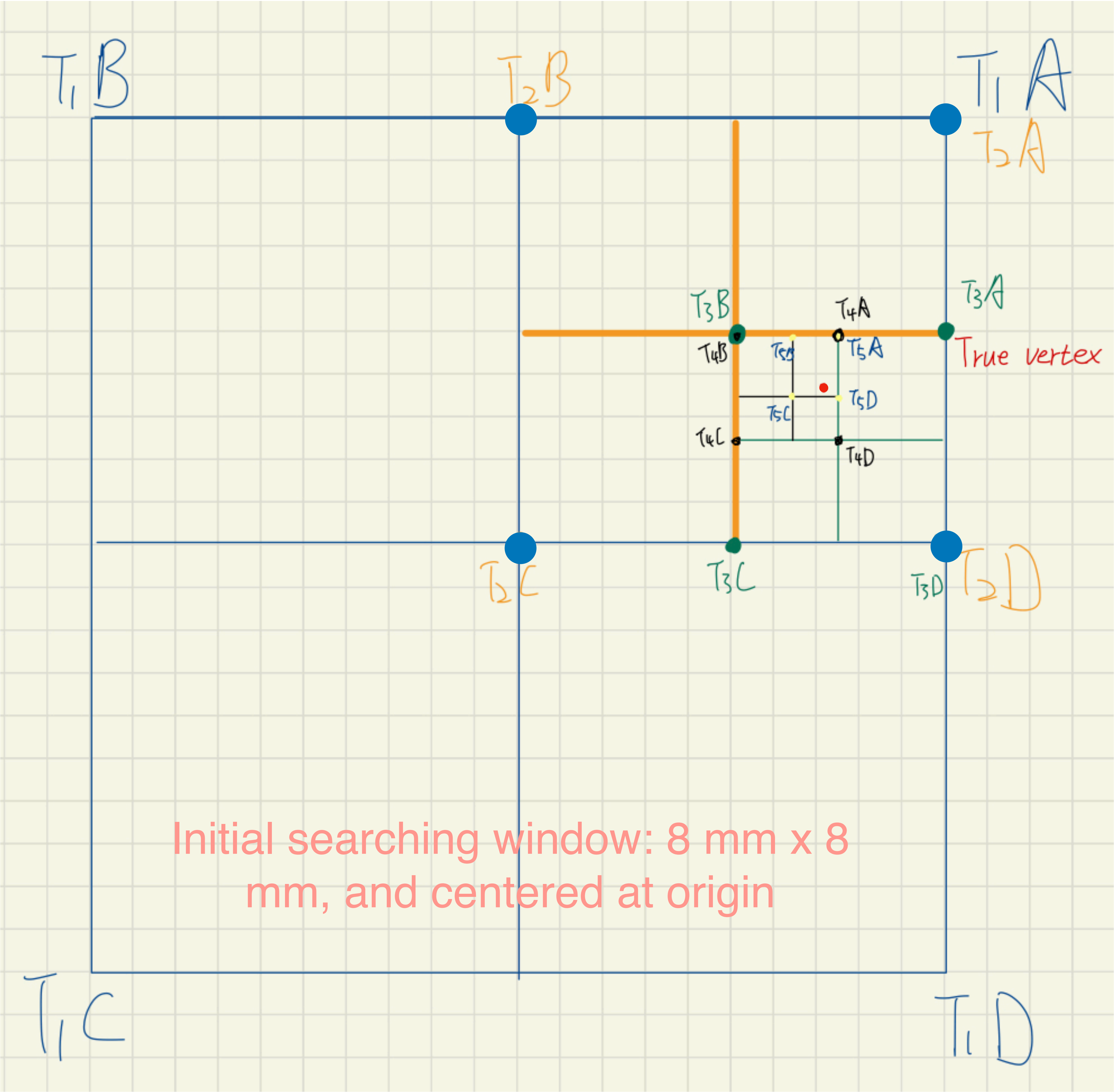

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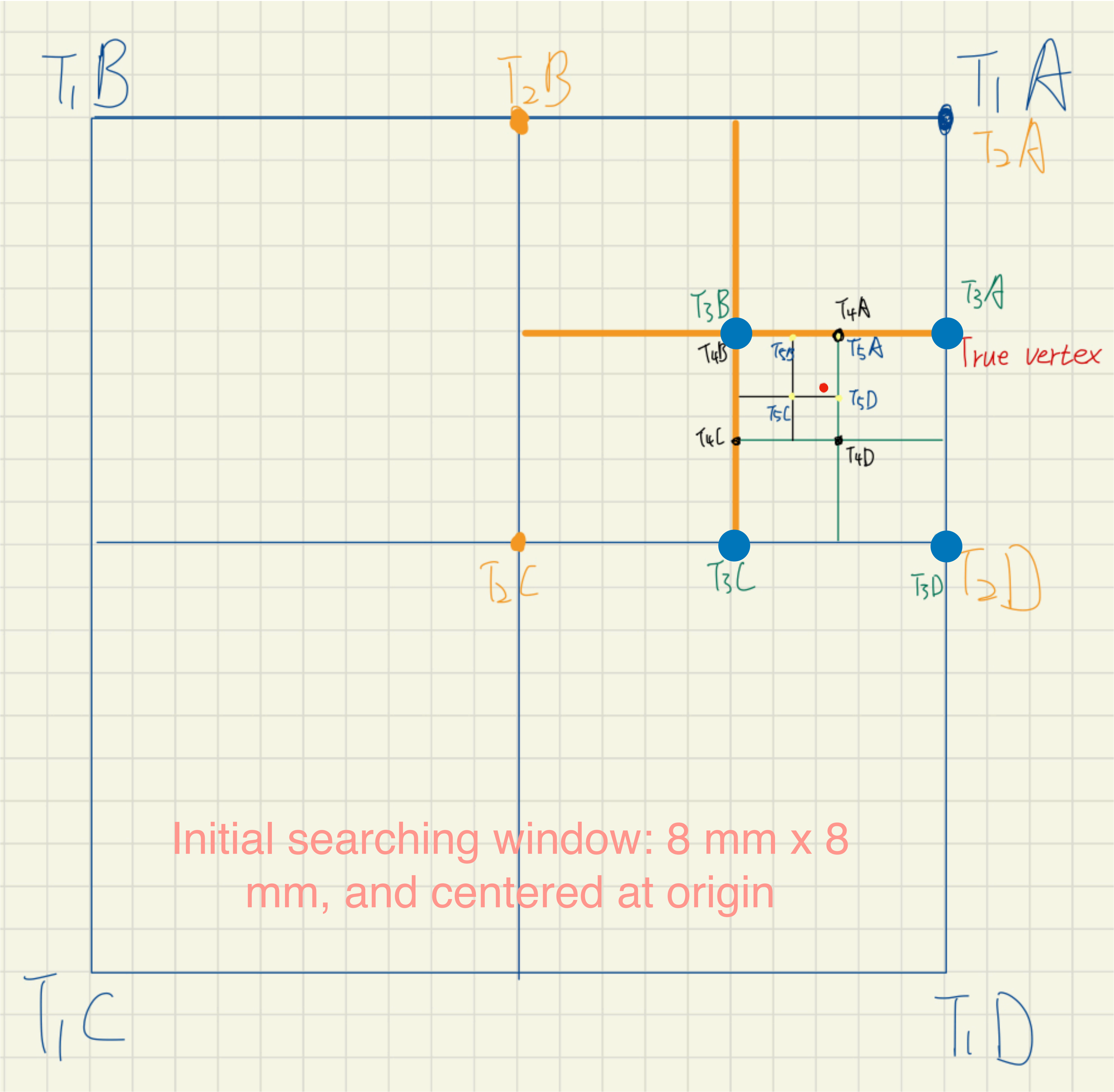

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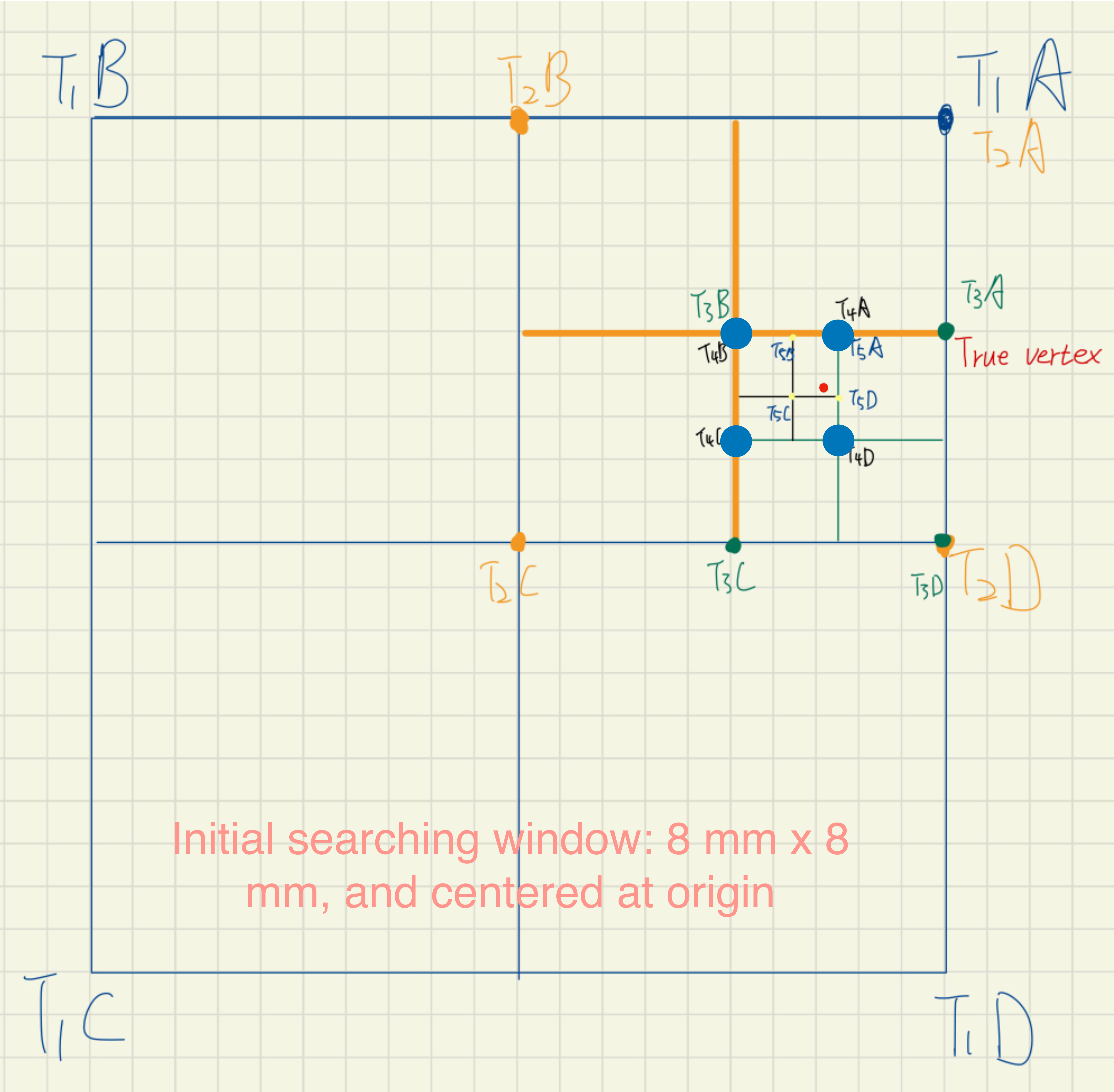

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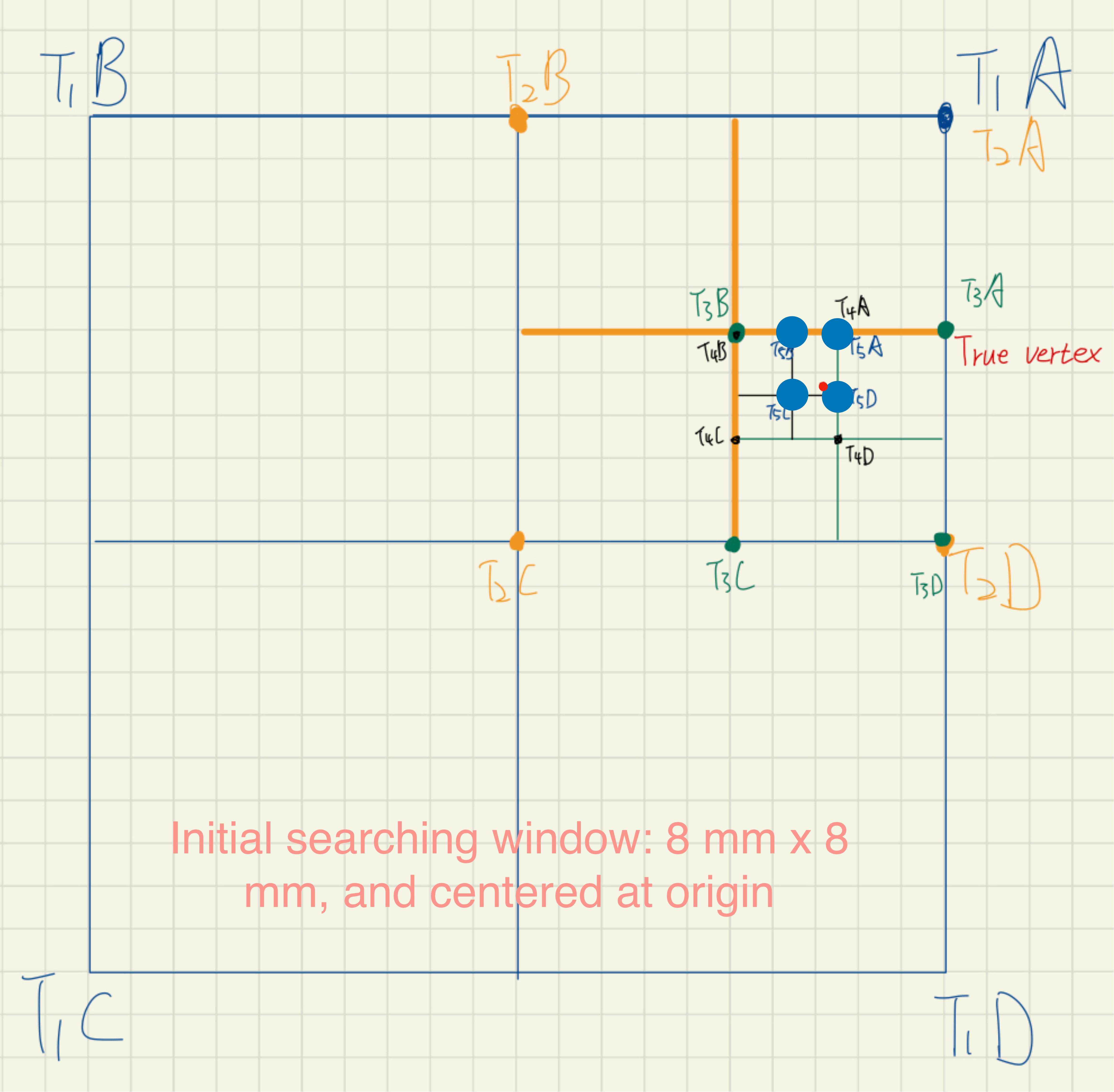

Initial searching window: 8 mm x 8 mm, and centered at origin

Vertex: average X and Y positions

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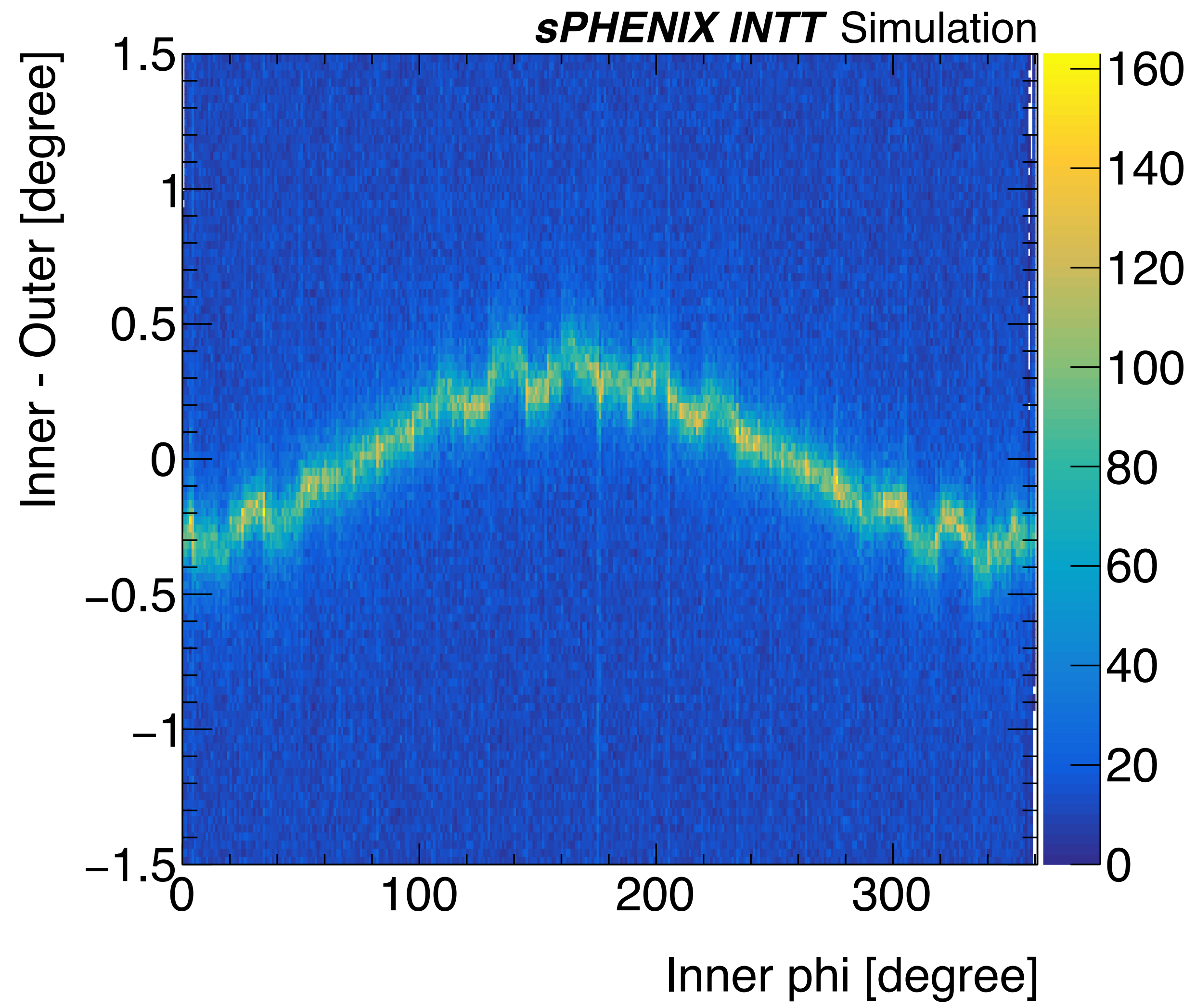
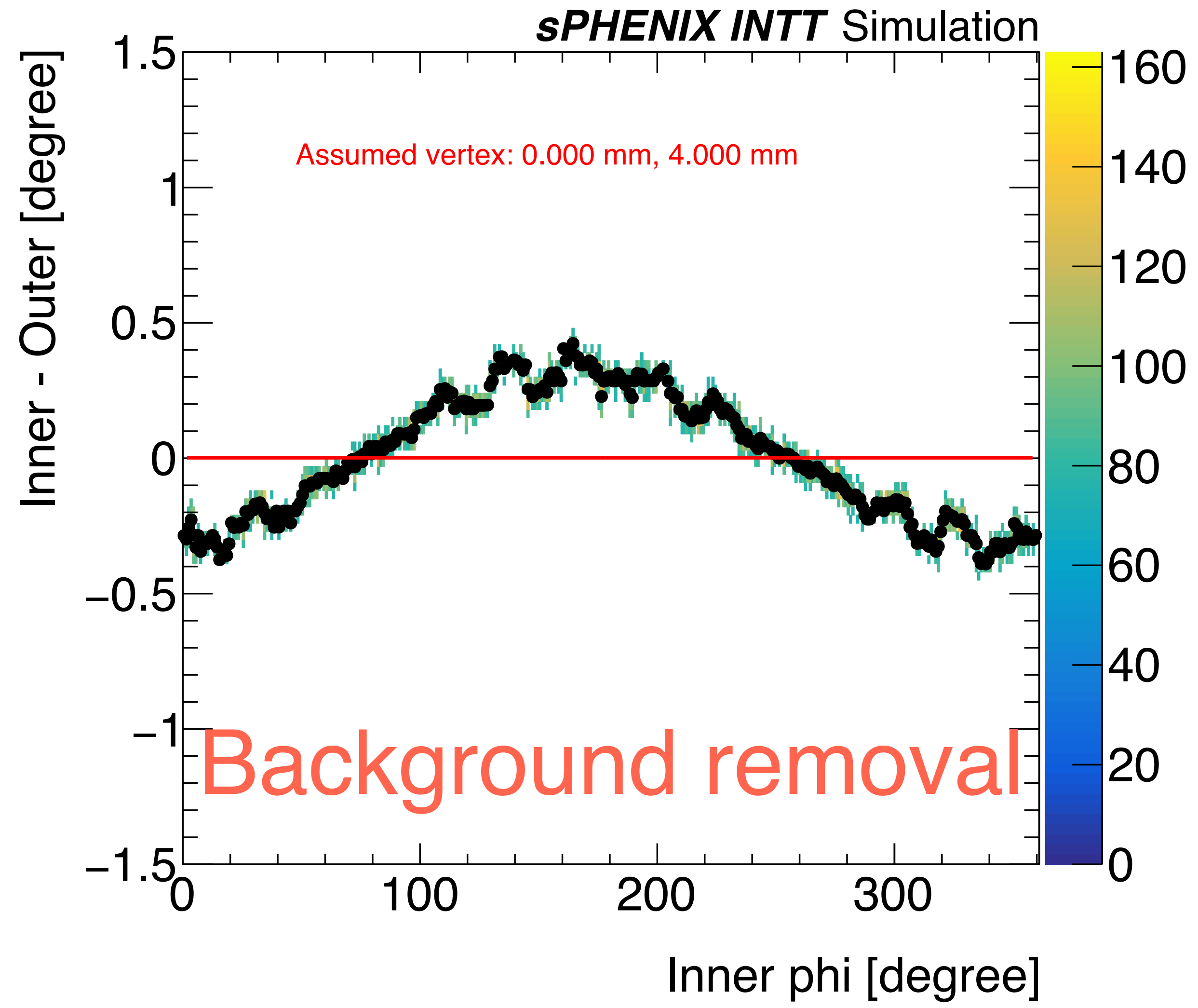
    - <u>DCA - $\mathrm{Clu}_{\mathrm{inner}}\ \phi$</u> correlation, and
    - <u>$\Delta\phi$ - $\mathrm{Clu}_{\mathrm{inner}}\ \phi$</u> correlation

Two correlation plots for **each corner**

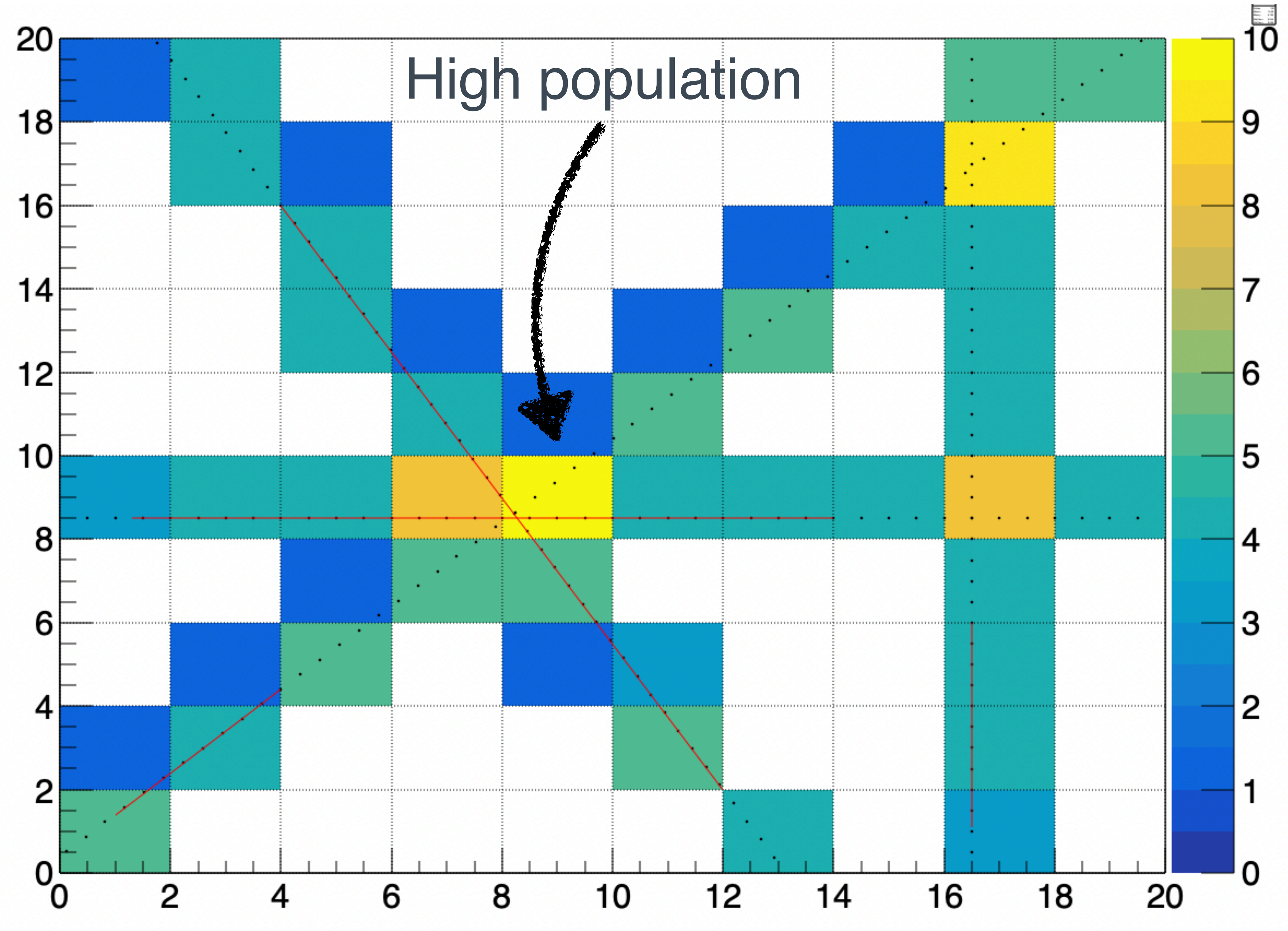




Vertex: average X and Y positions

- **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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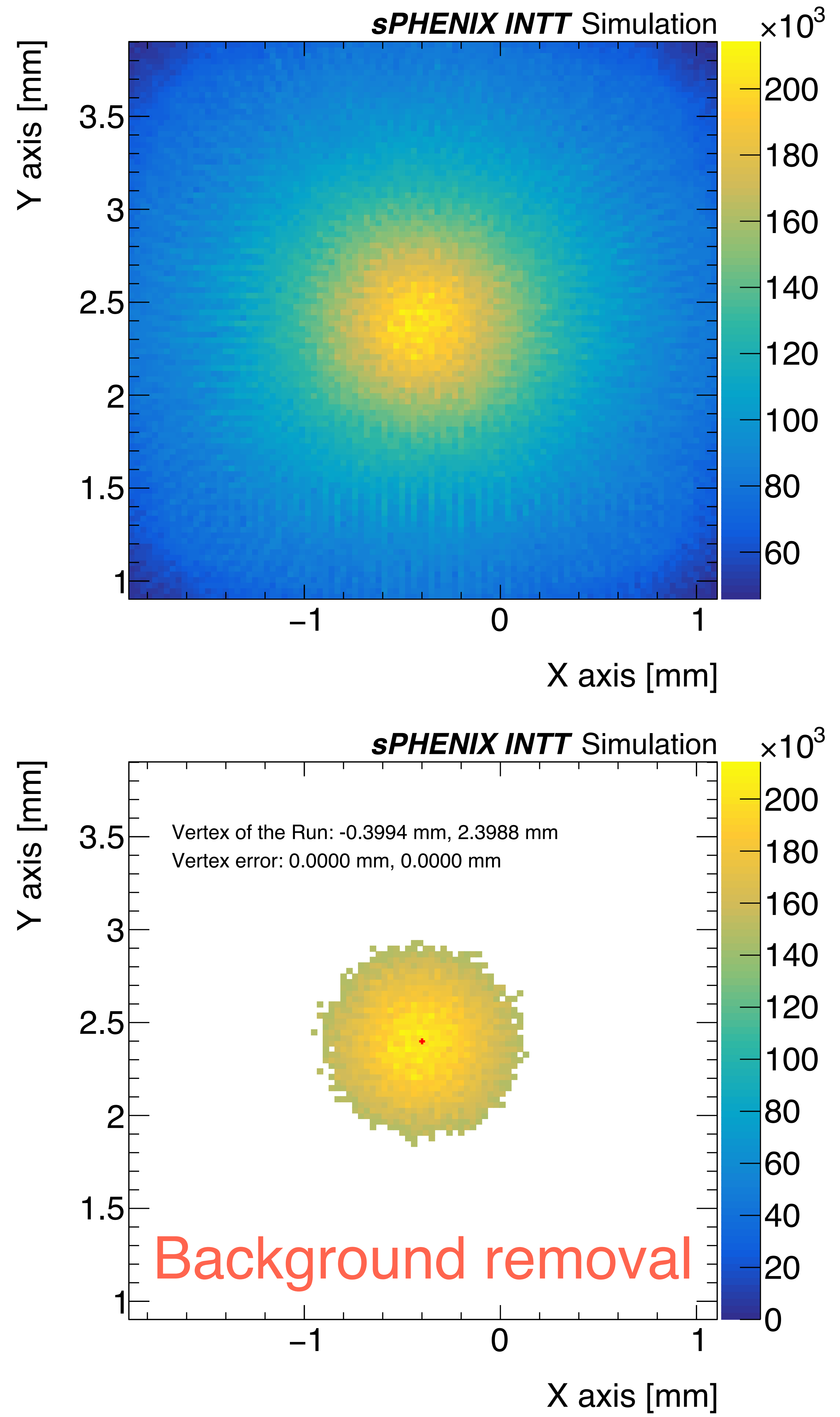
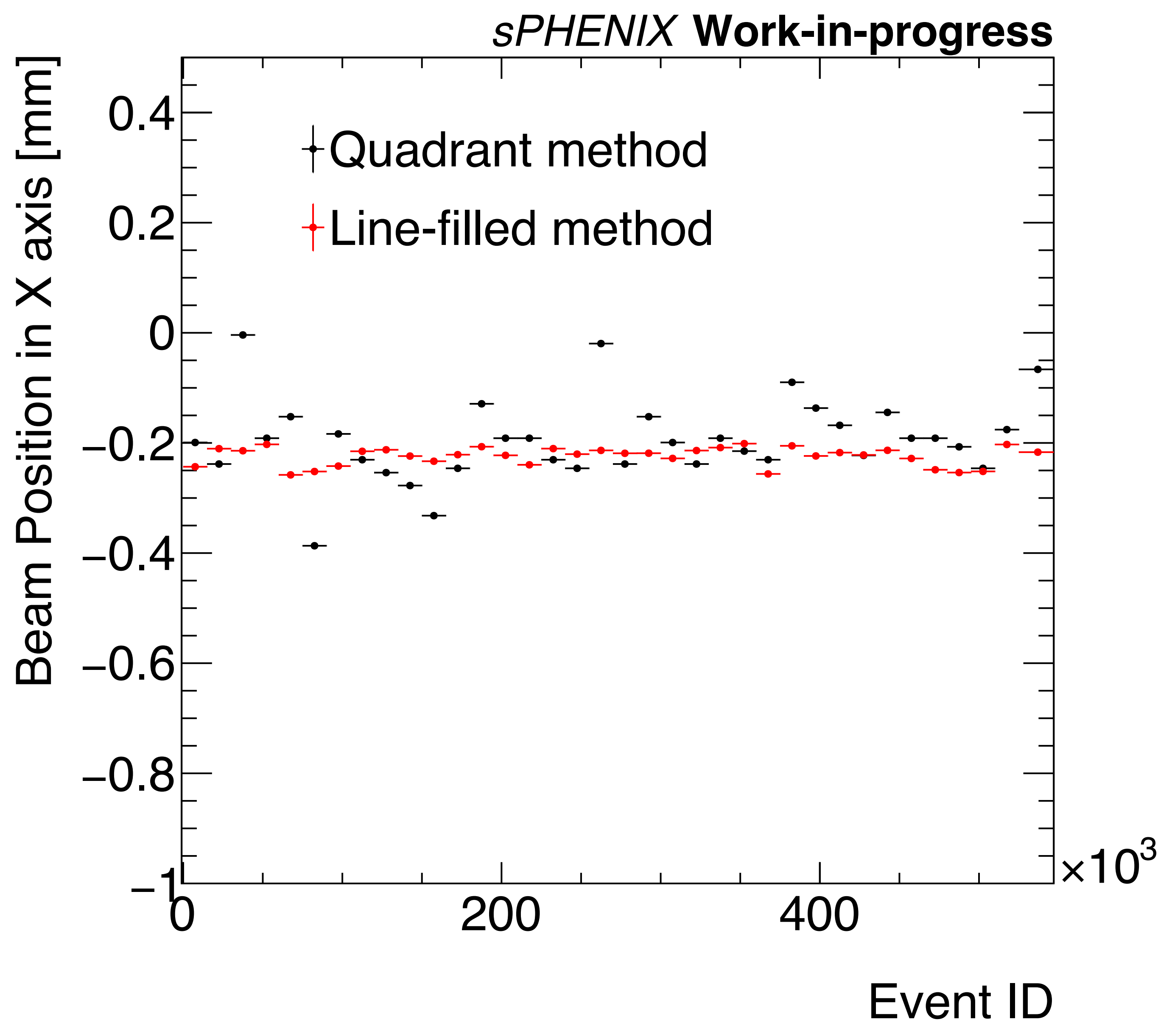
Status: Have the code ready, which can read the files produced by ntuplizer, and find the vertex

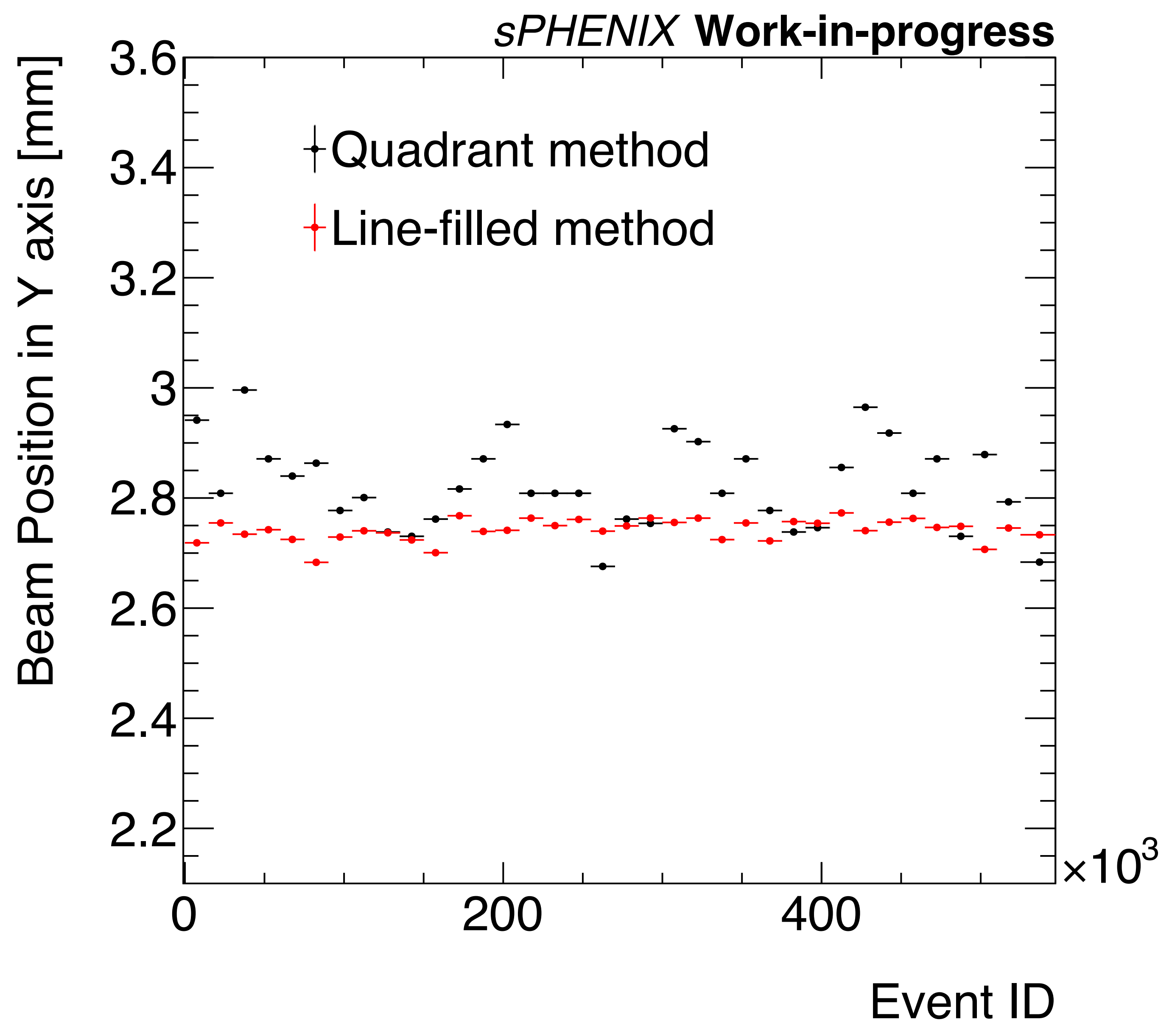


Final estimated vertex: **(-0.399 mm, 2.399 mm)**

Vertex: average X and Y positions

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



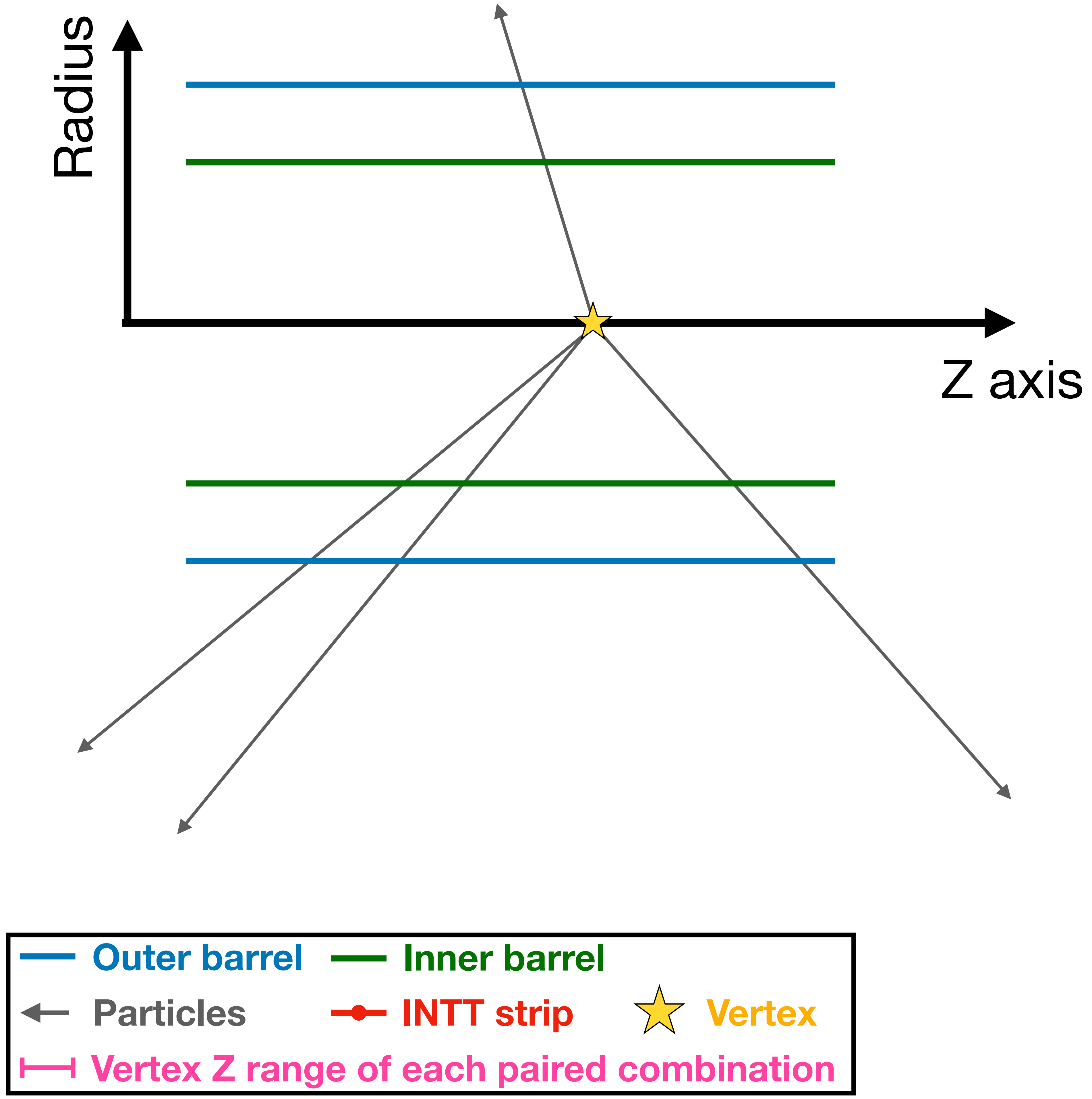


final average vertex XY should be used :
line filled X : -0.224174 +/- 0.0167306
line filled Y : 2.74193 +/- 0.0198086
quadrant X : -0.194661 +/- 0.074547
quadrant Y : 2.82335 +/- 0.0784097
avg: {-0.209417 mm, 2.78264 mm}

Data file : Data_CombinedNtuple_Run20869_HotDead_BCO_ADC_Survey.root

Per event vertex Z

- 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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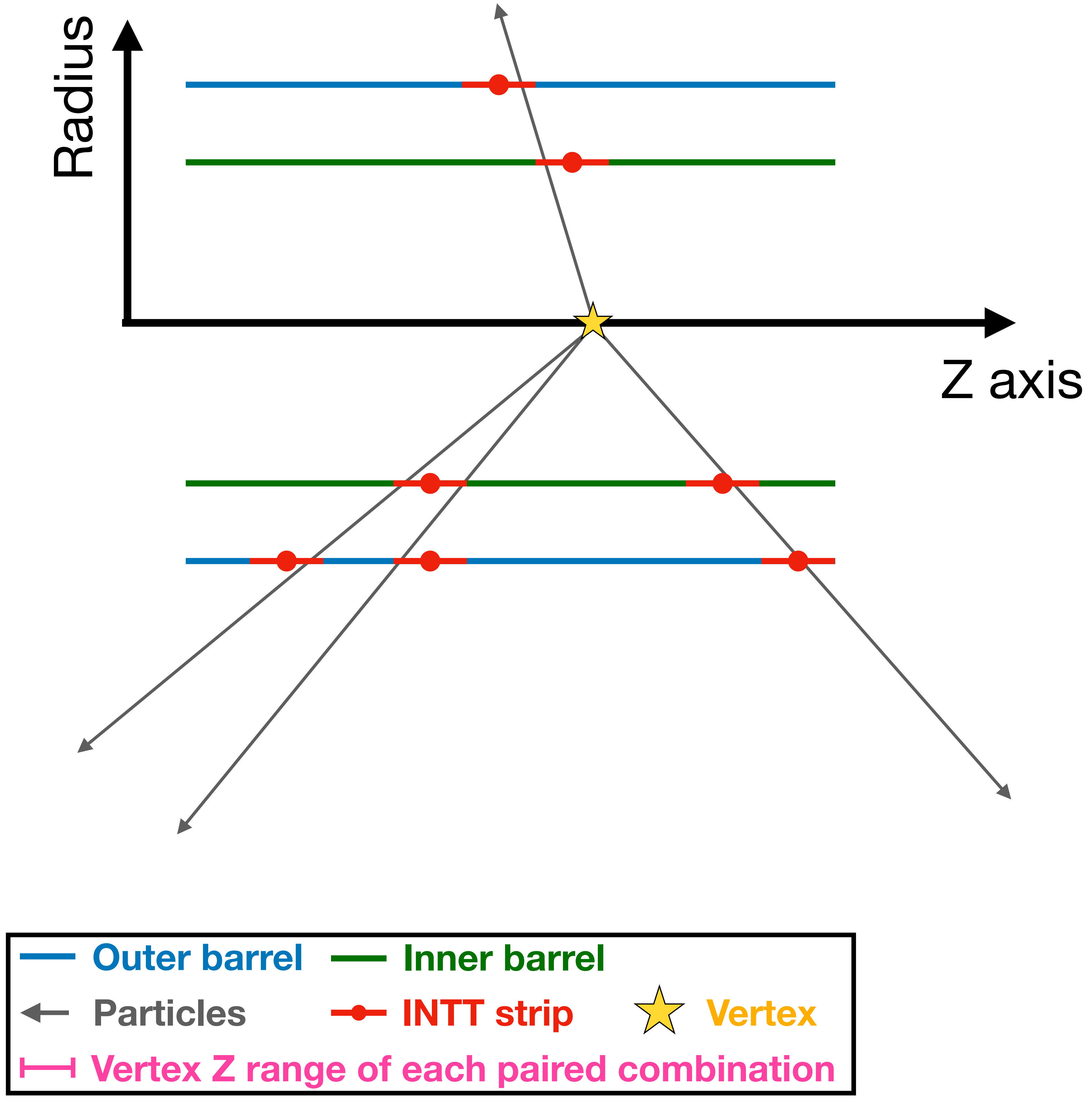

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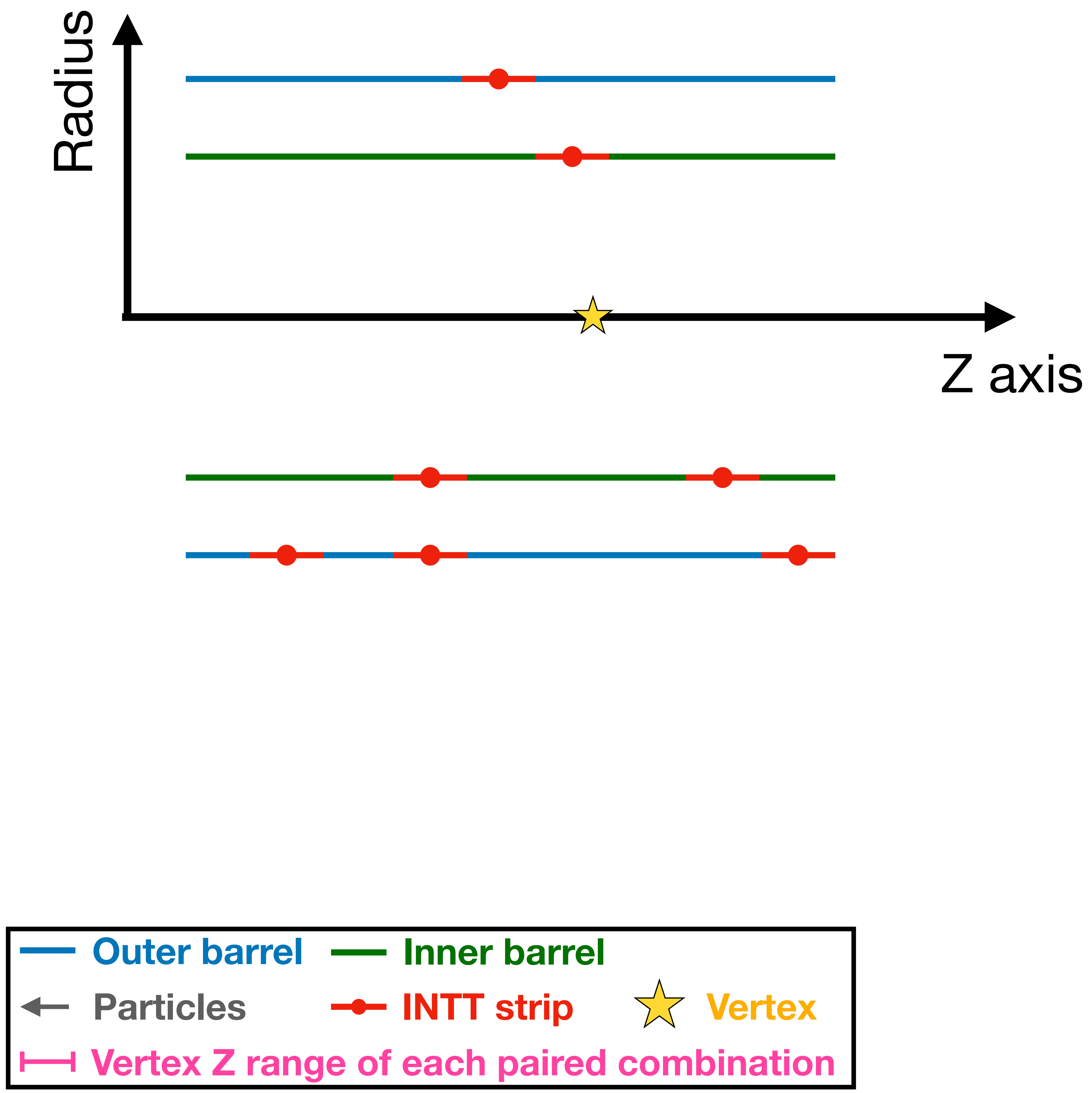

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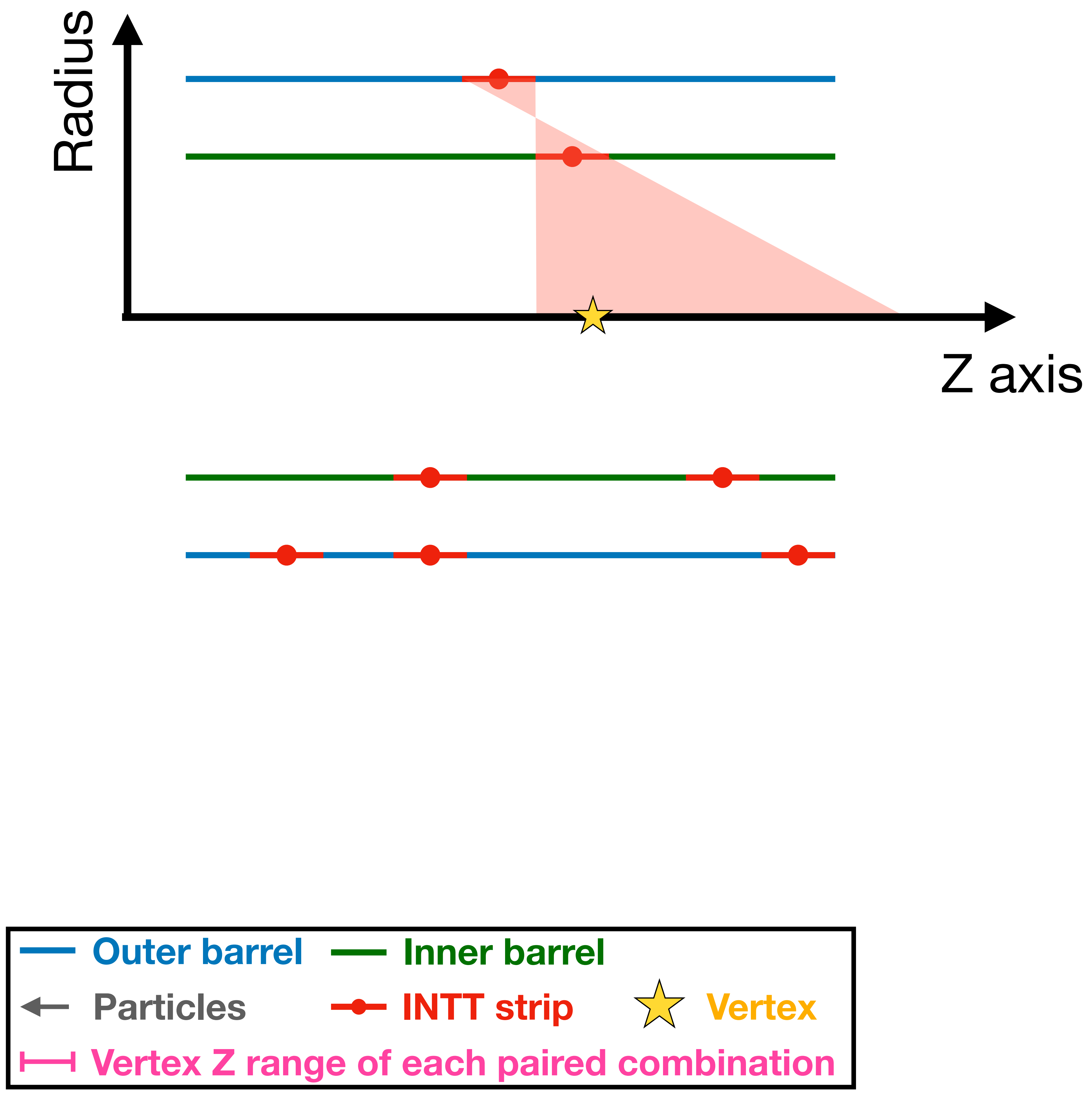

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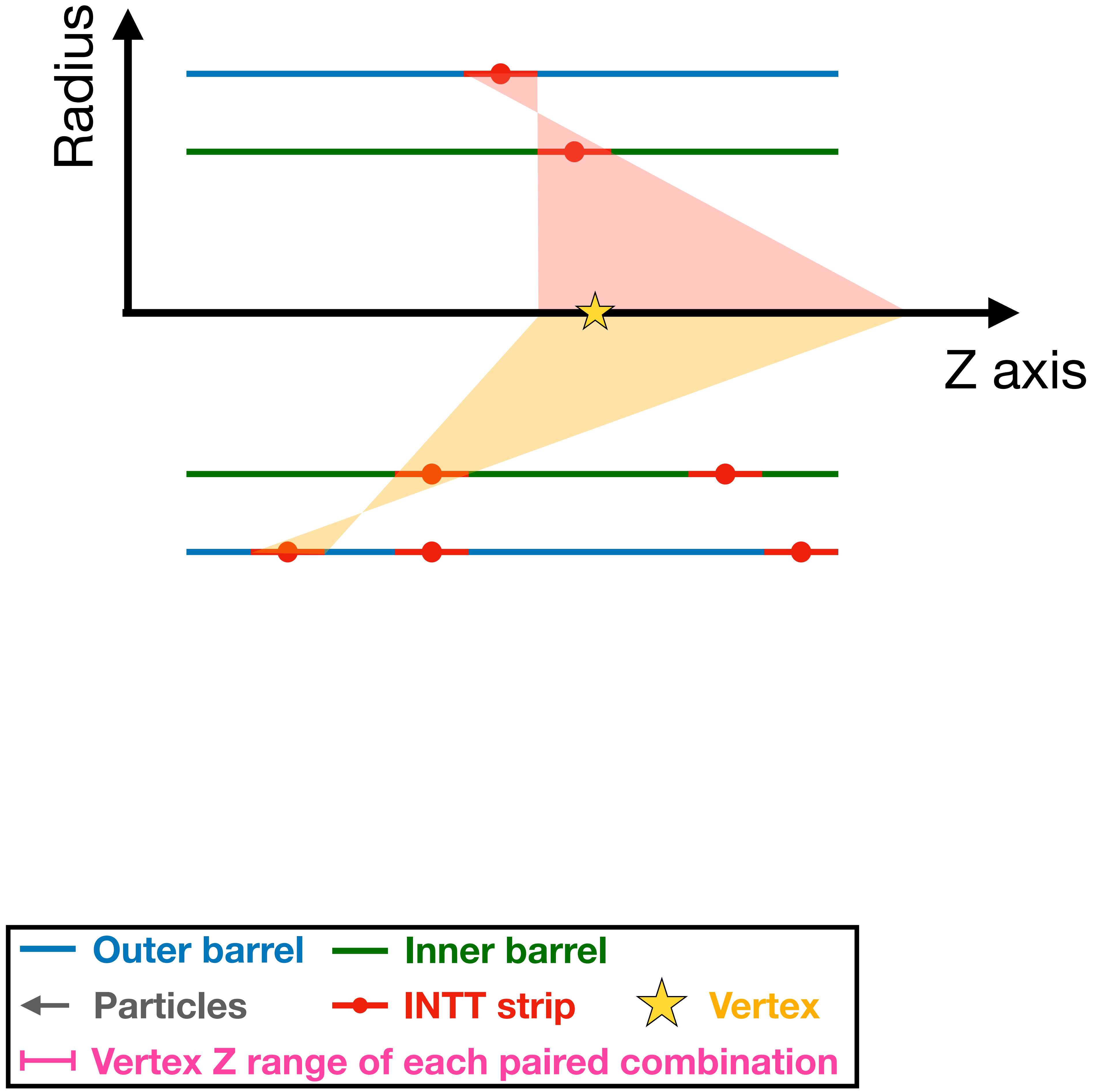

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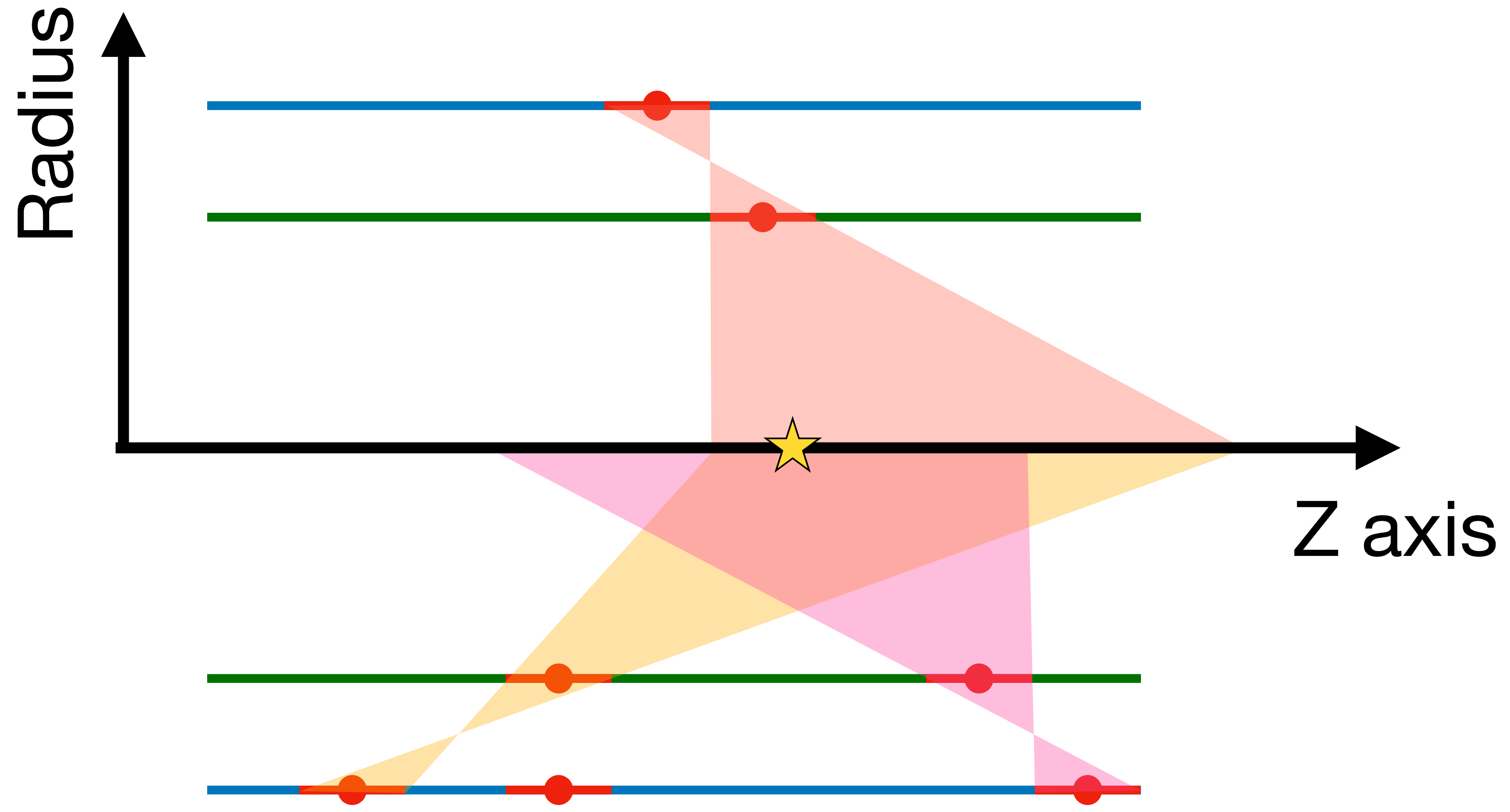

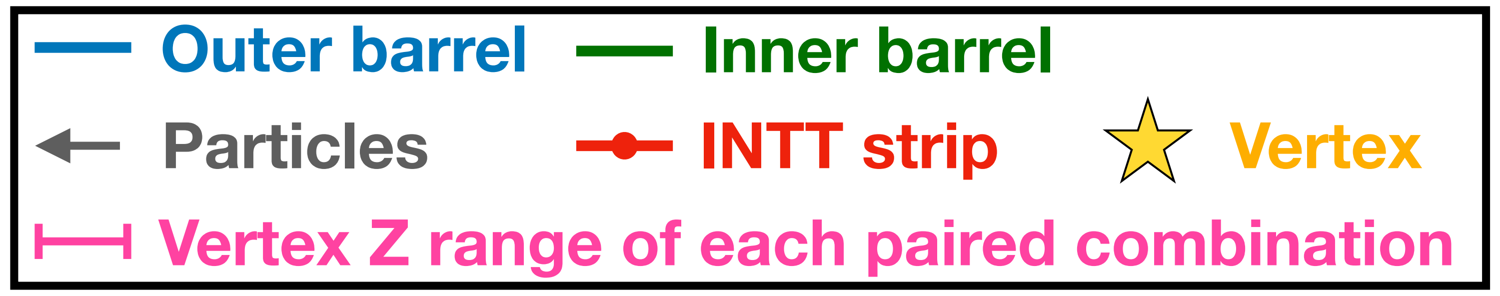

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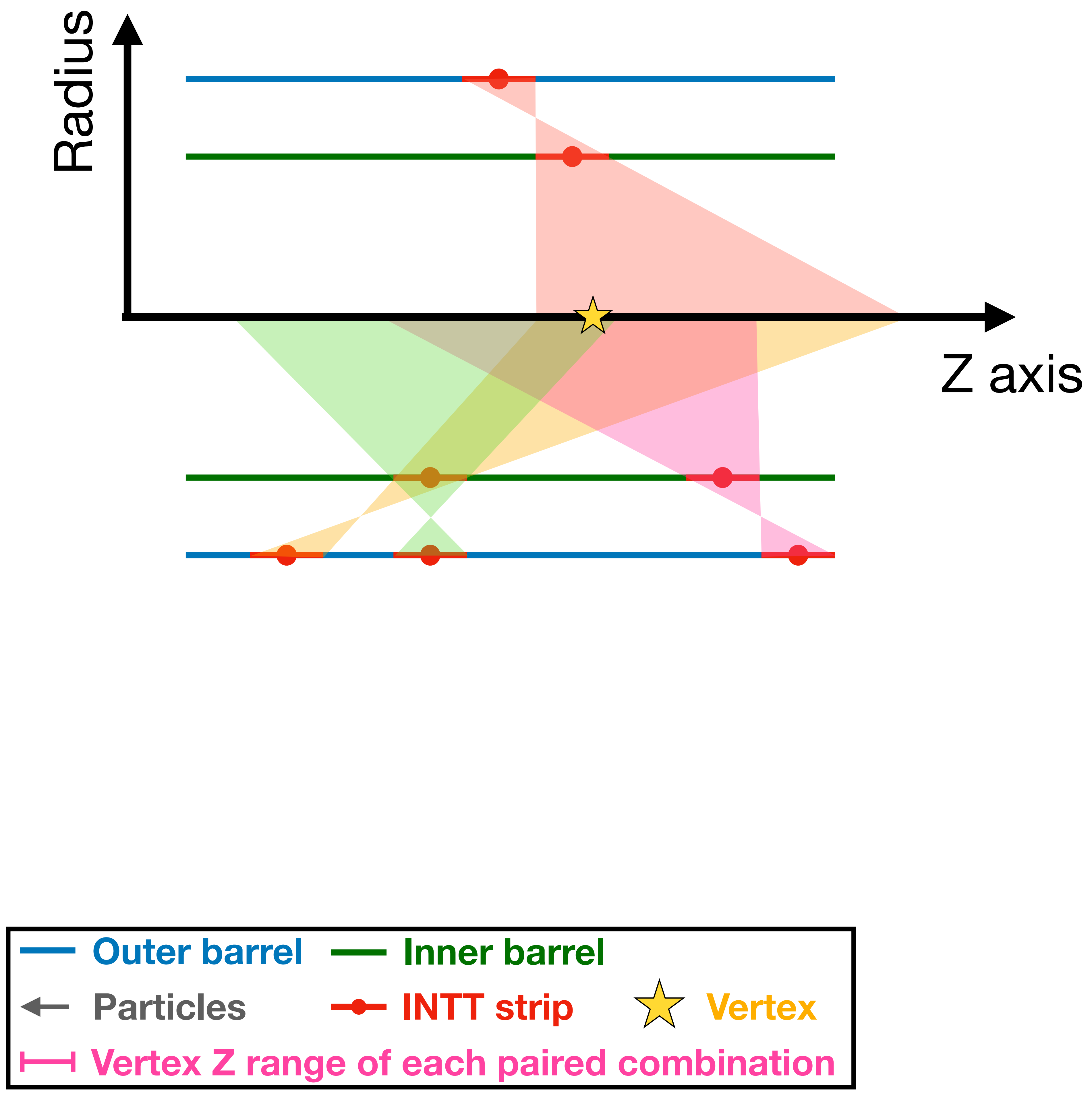

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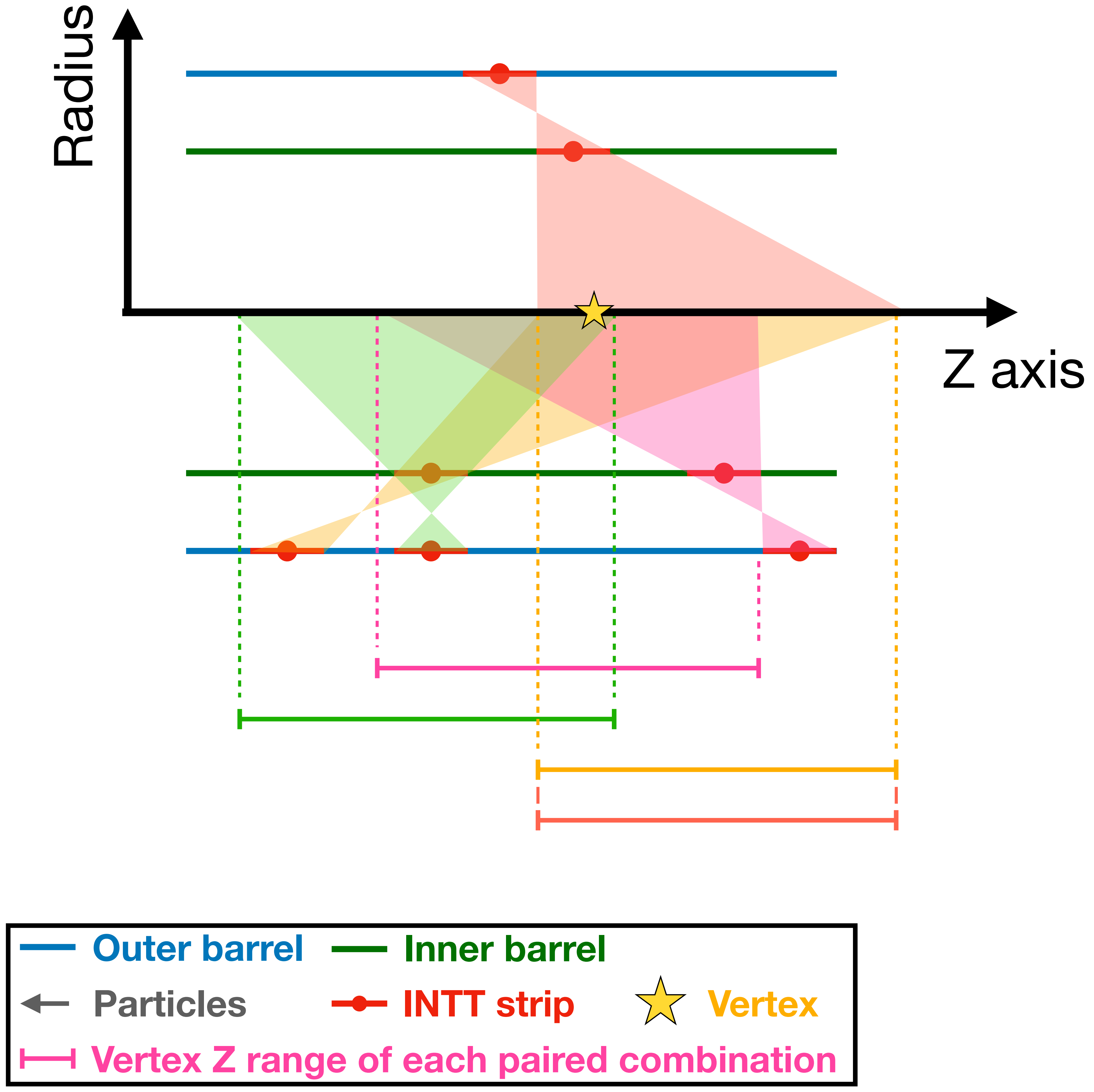

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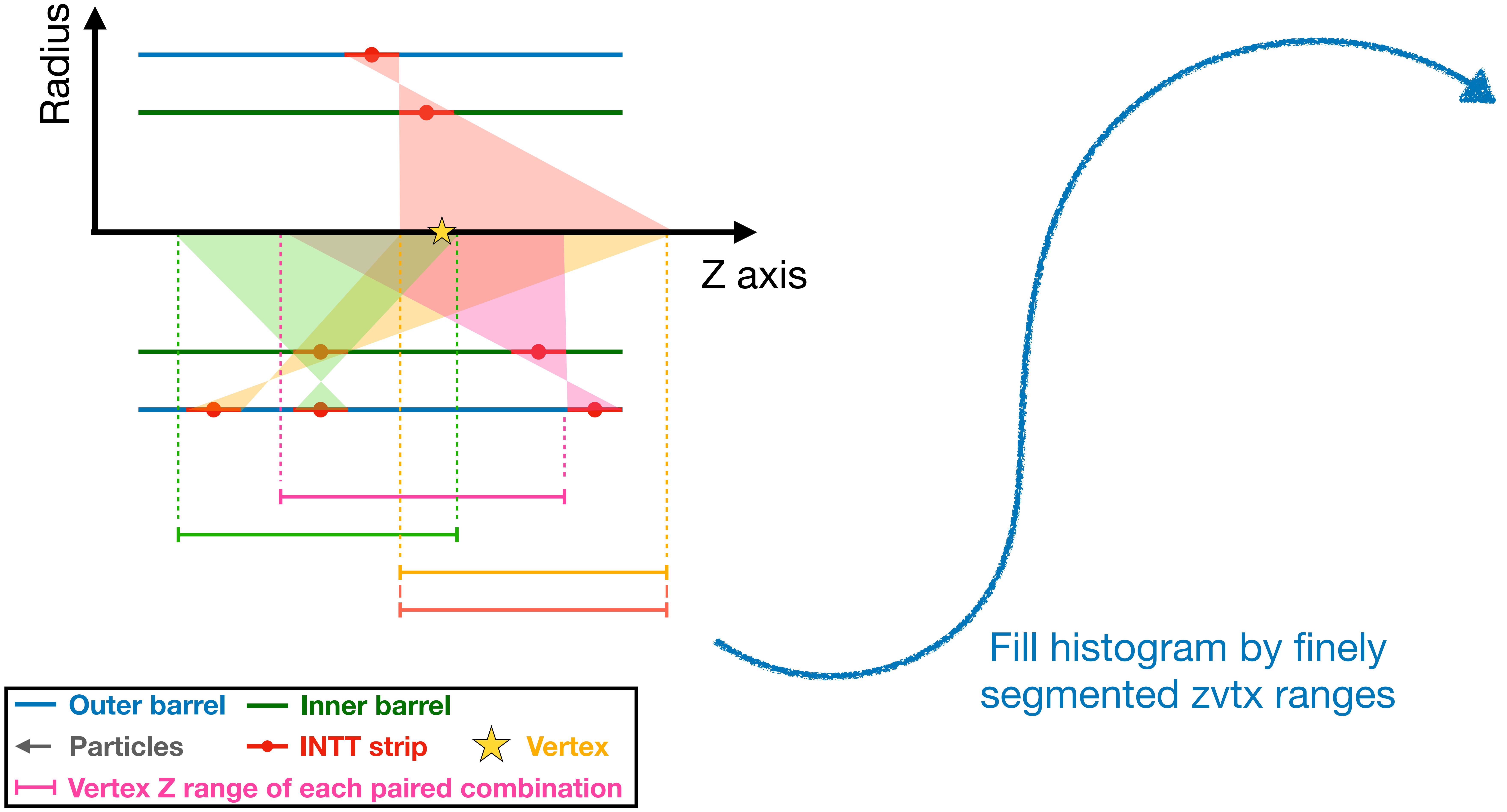

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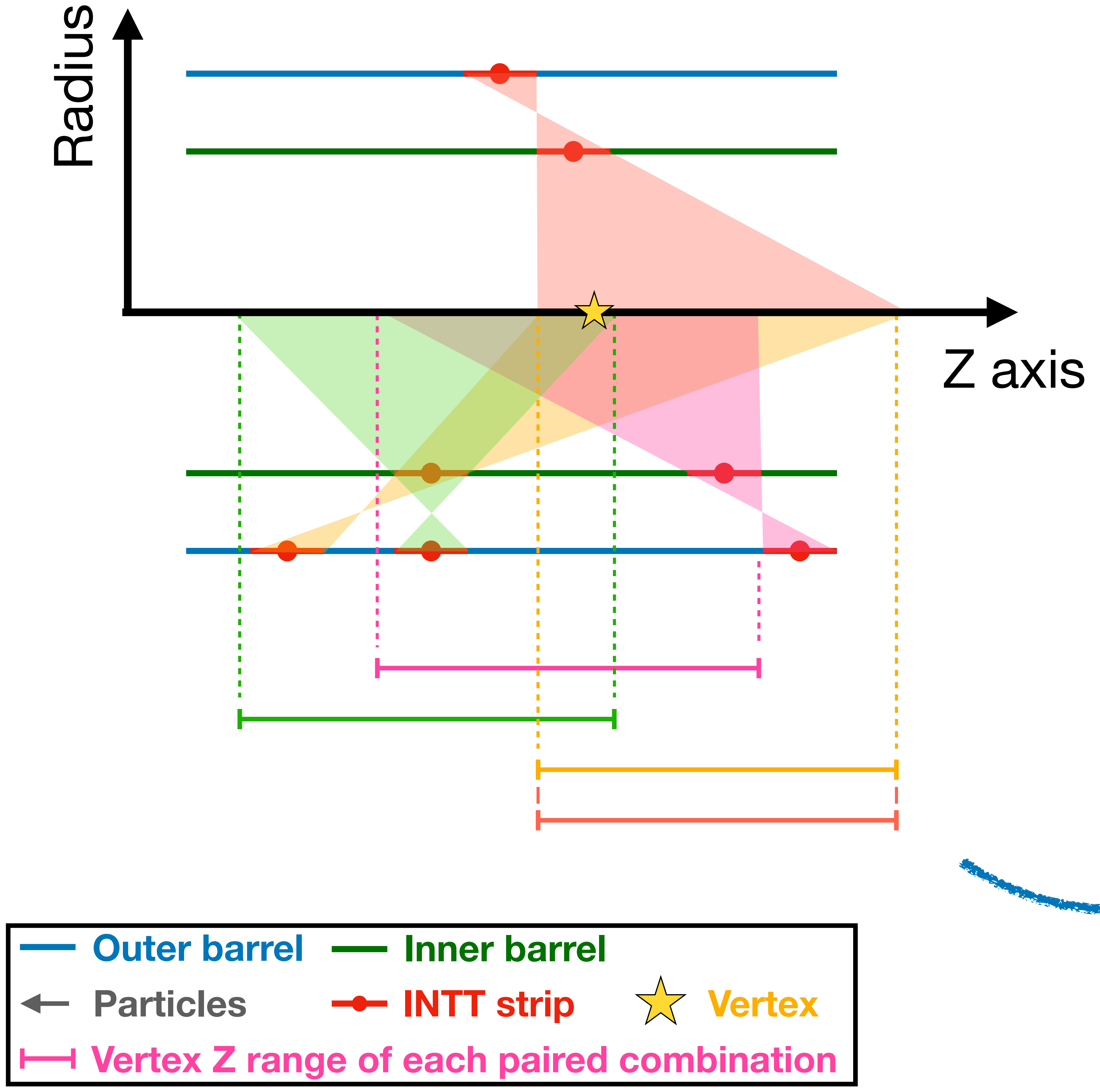
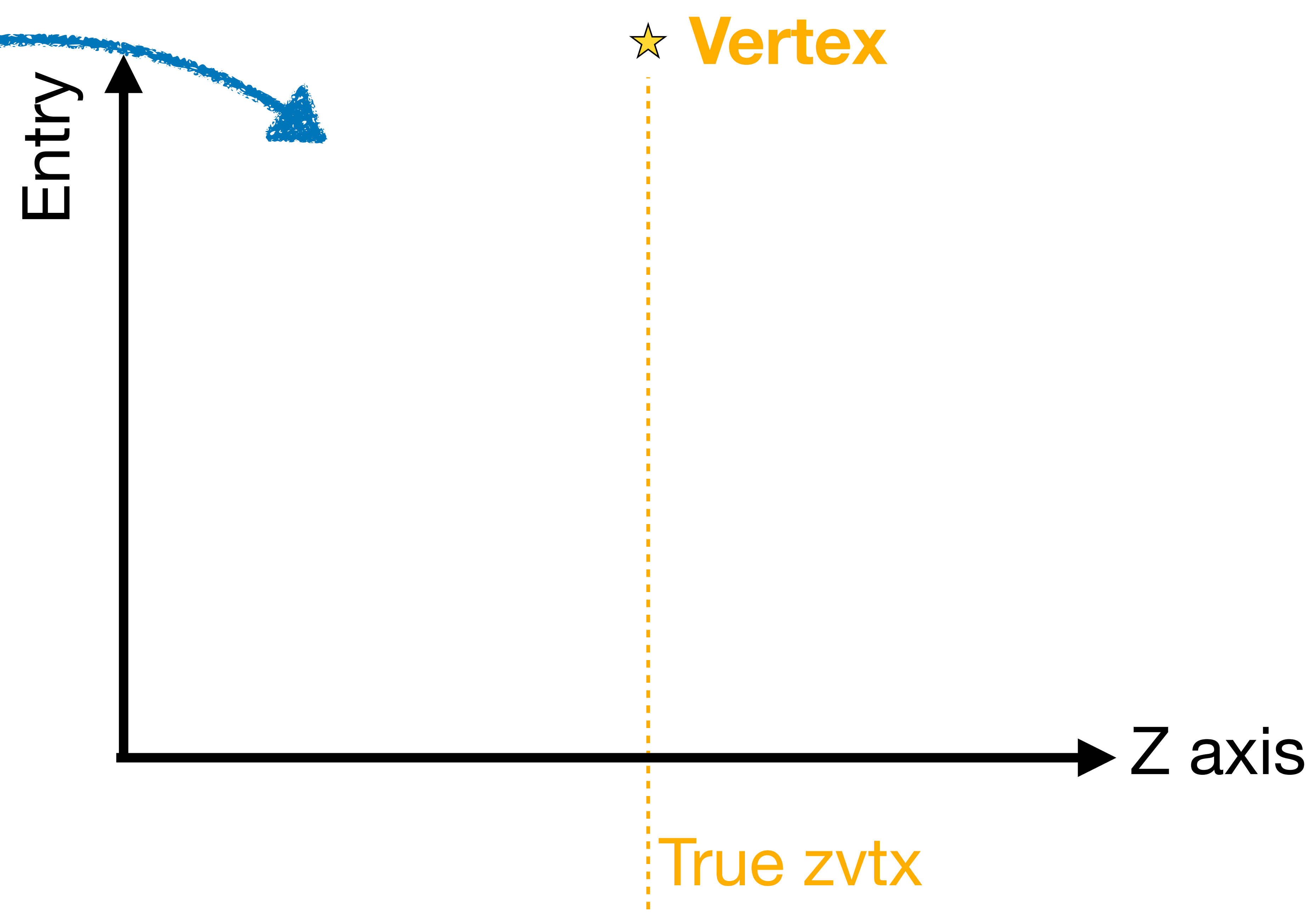
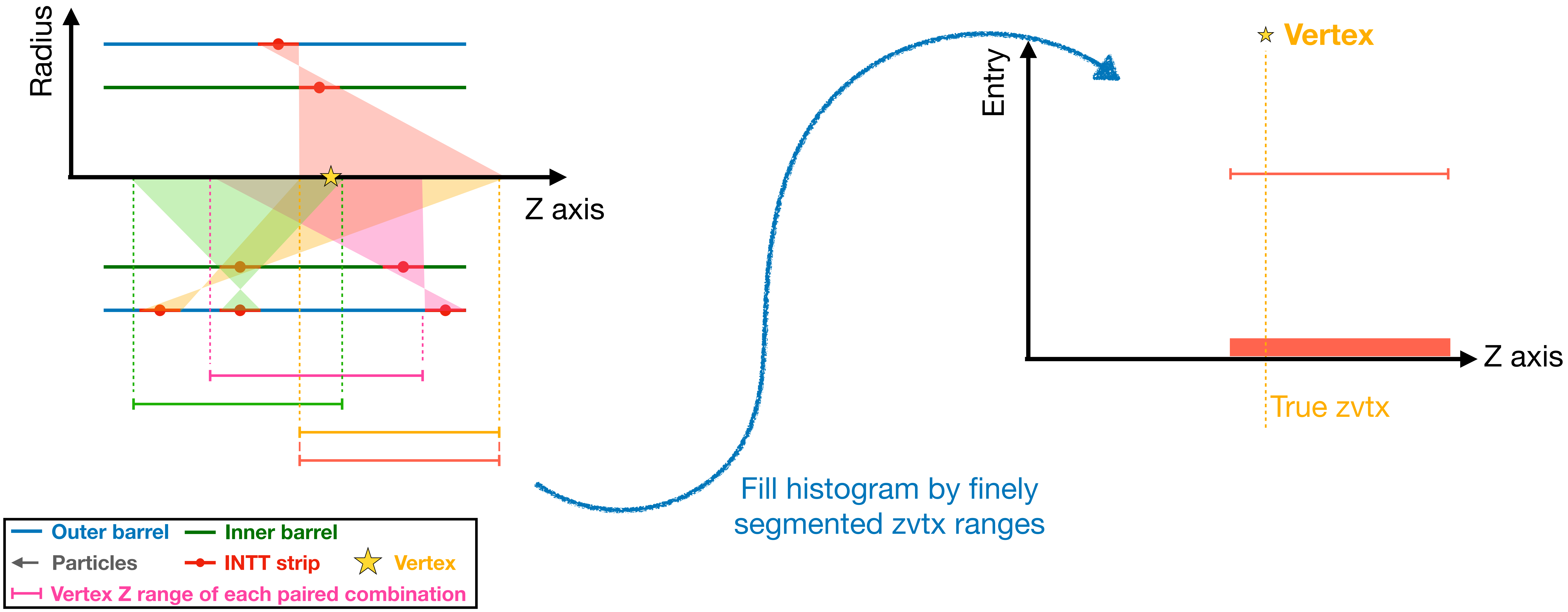




Fill histogram by finely segmented zvtx ranges

Per event vertex Z

- 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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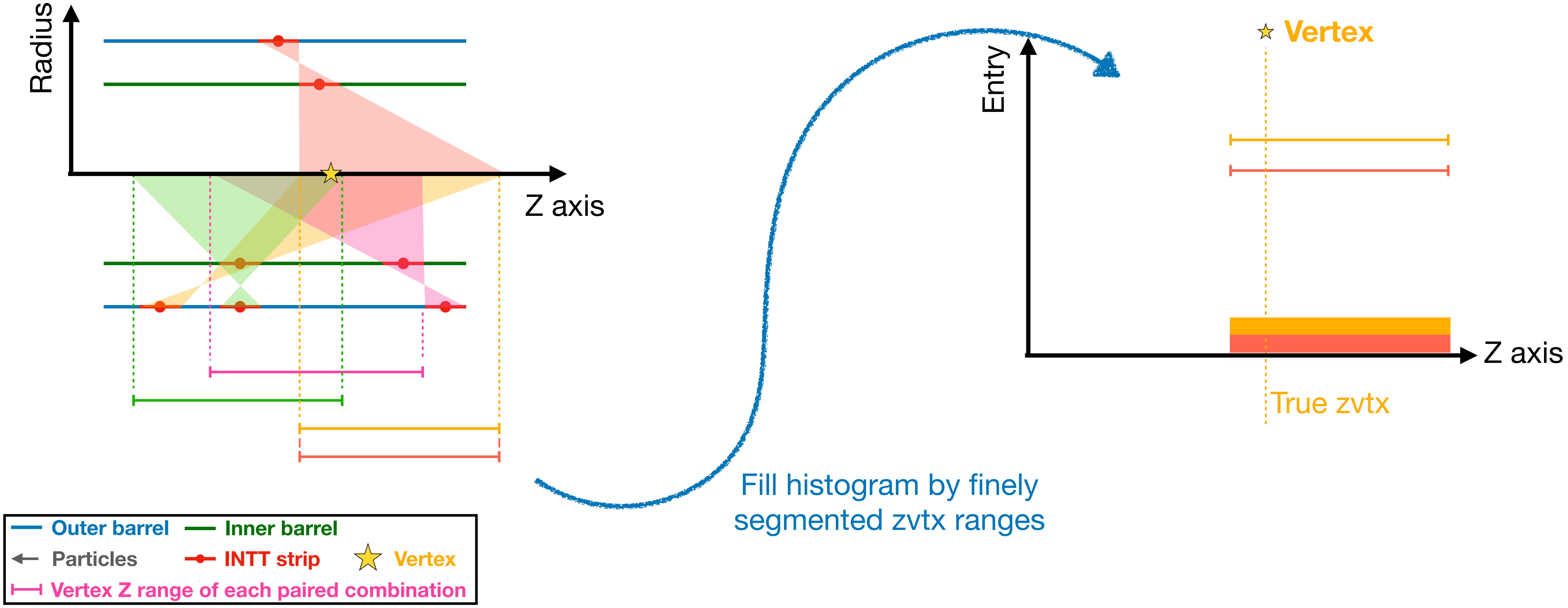

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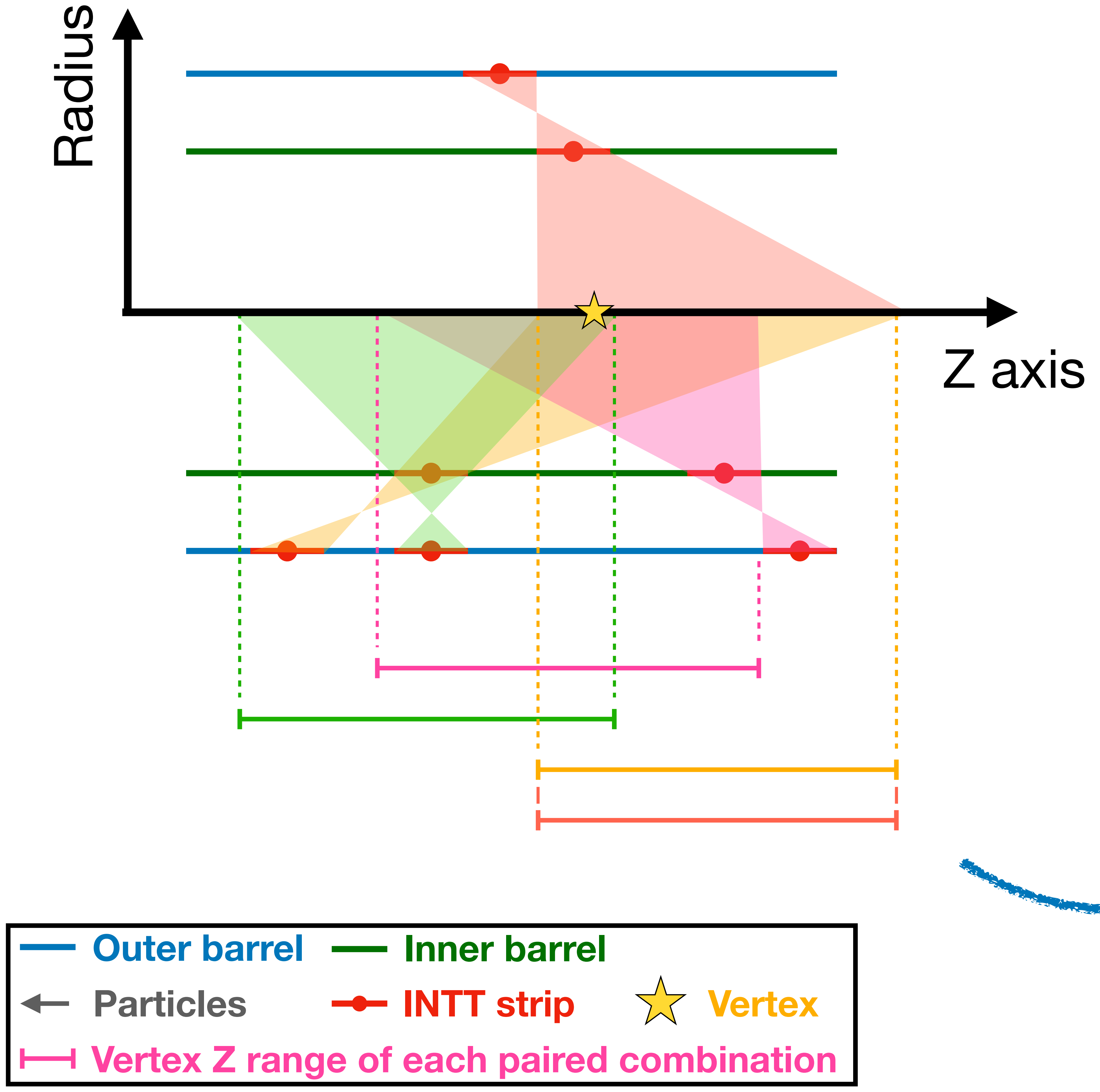

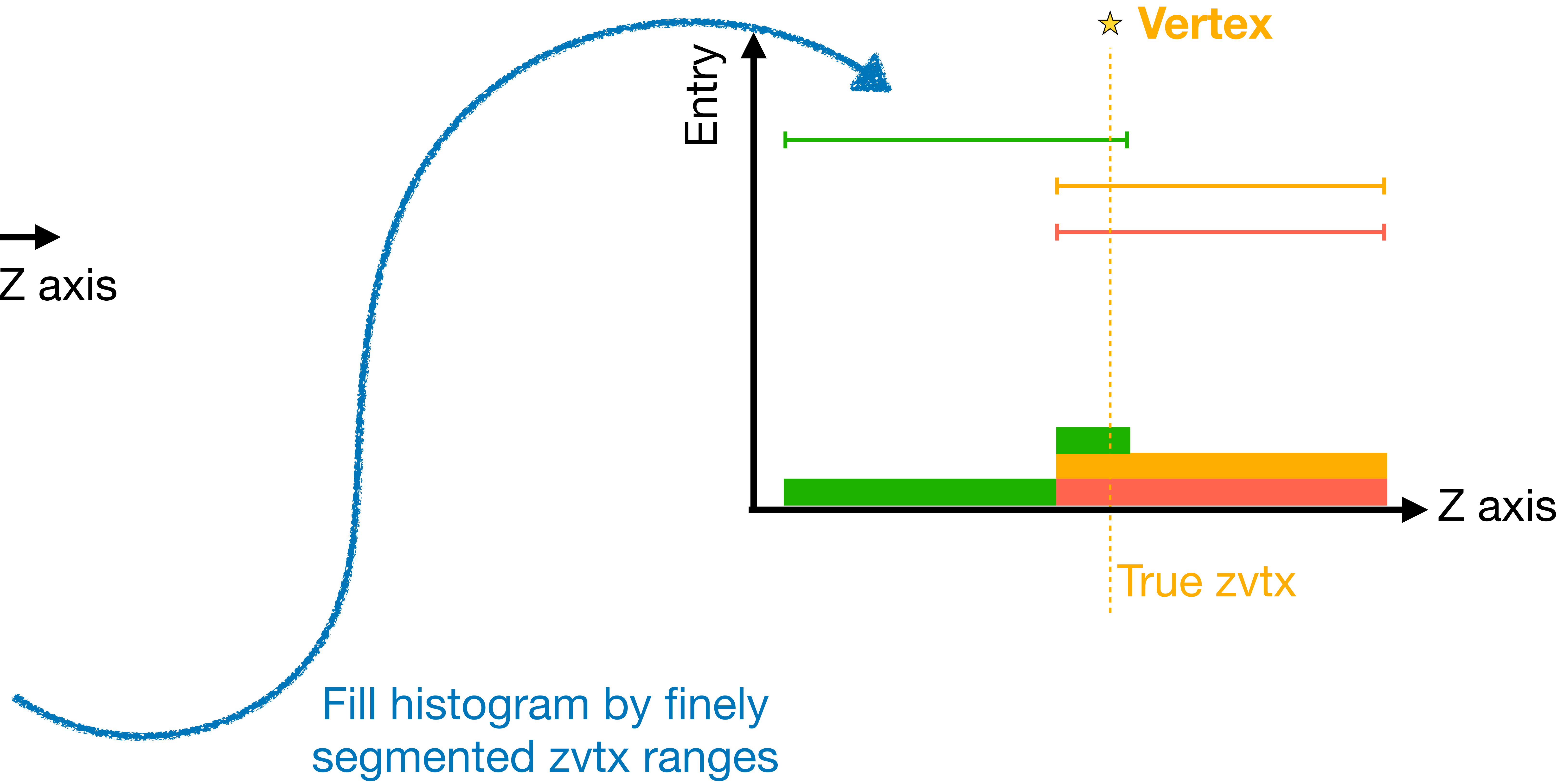

Per event vertex Z

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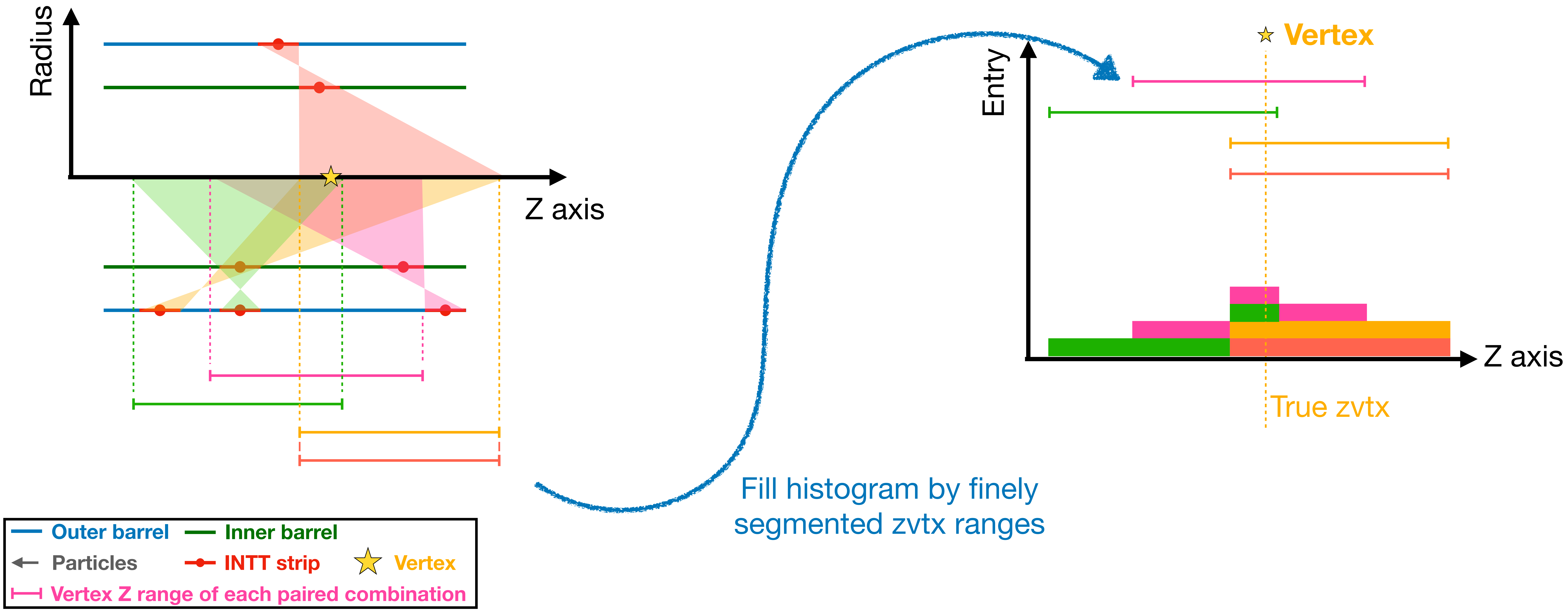
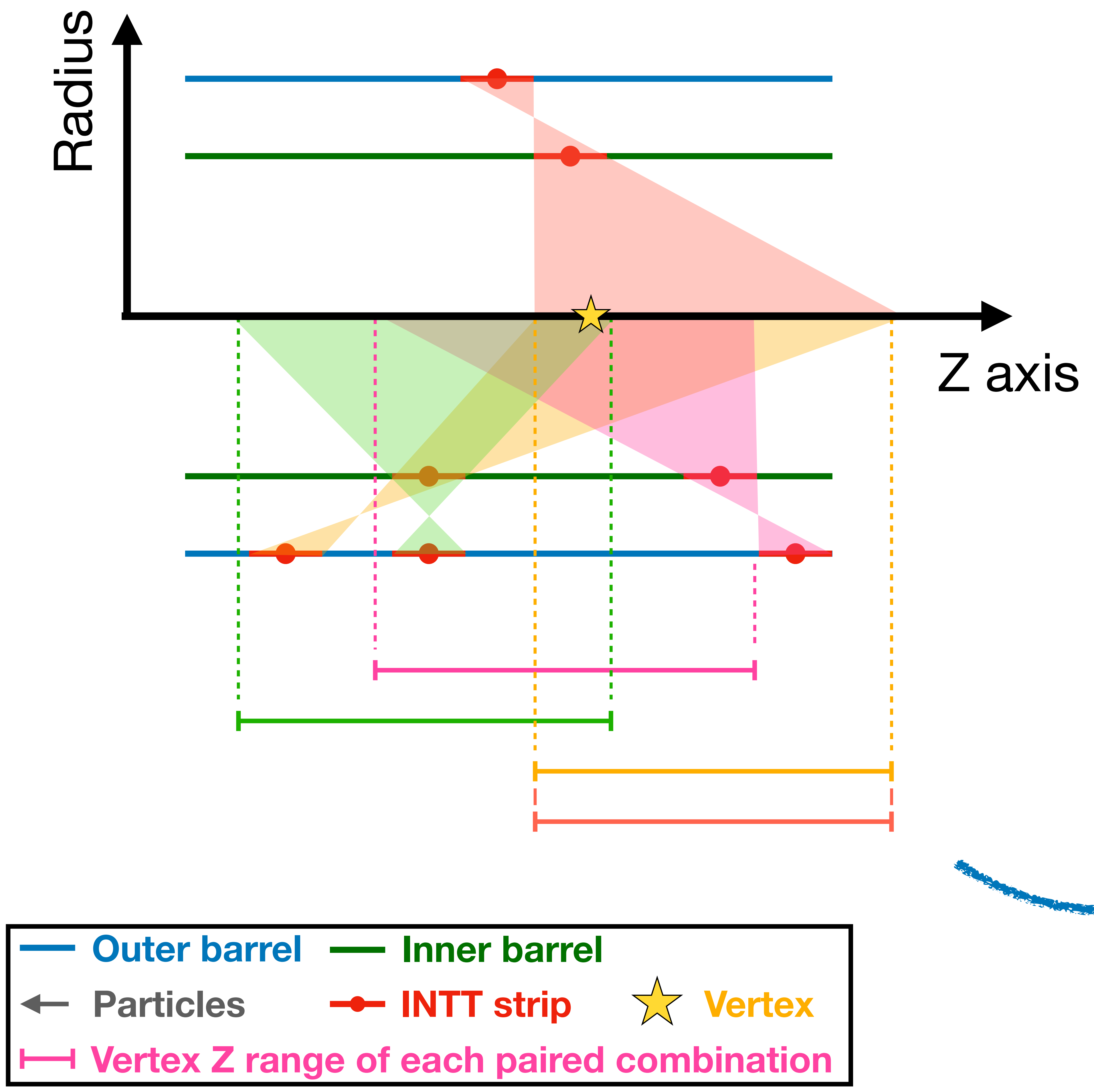
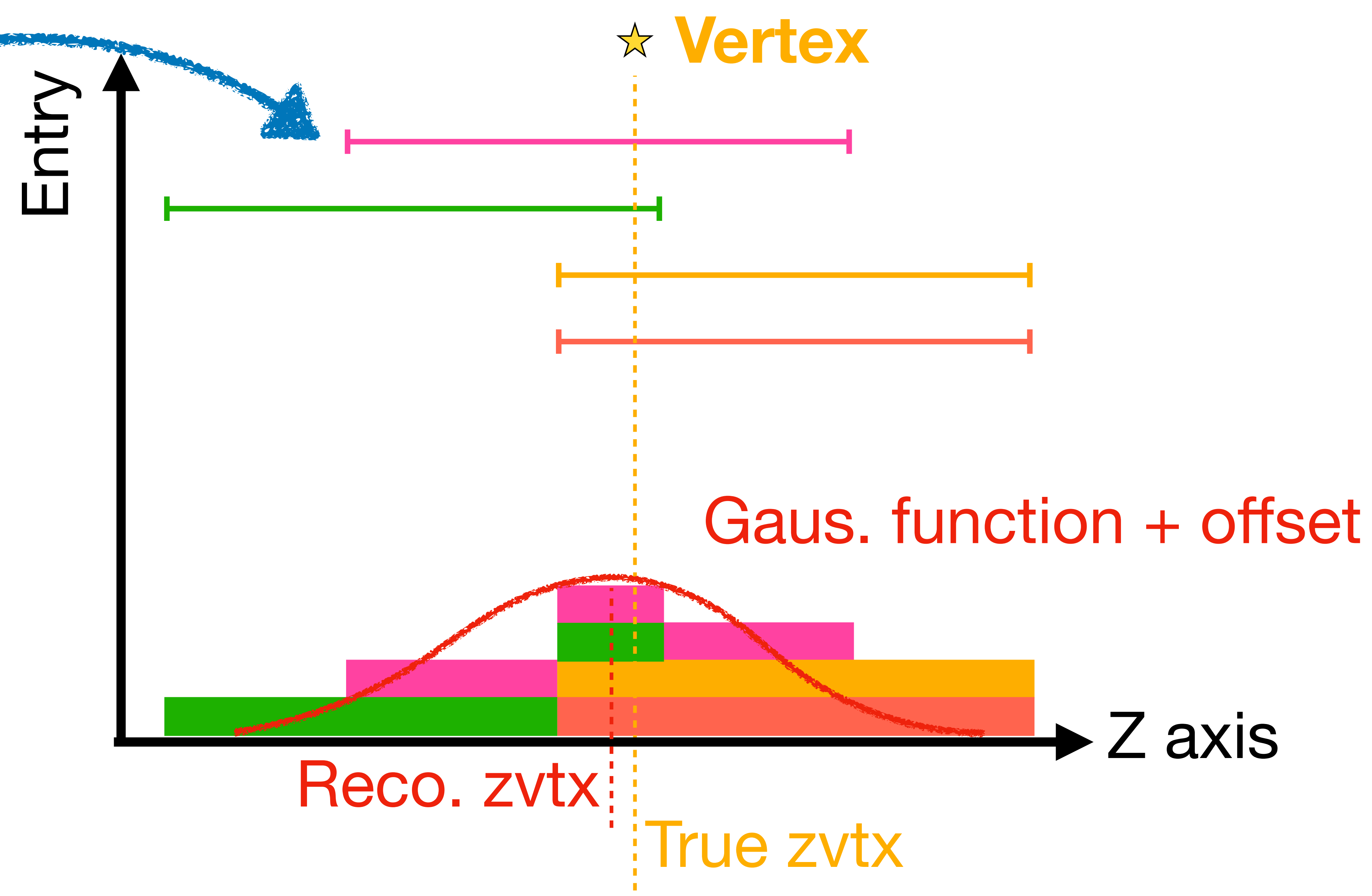


Per event vertex Z

- 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

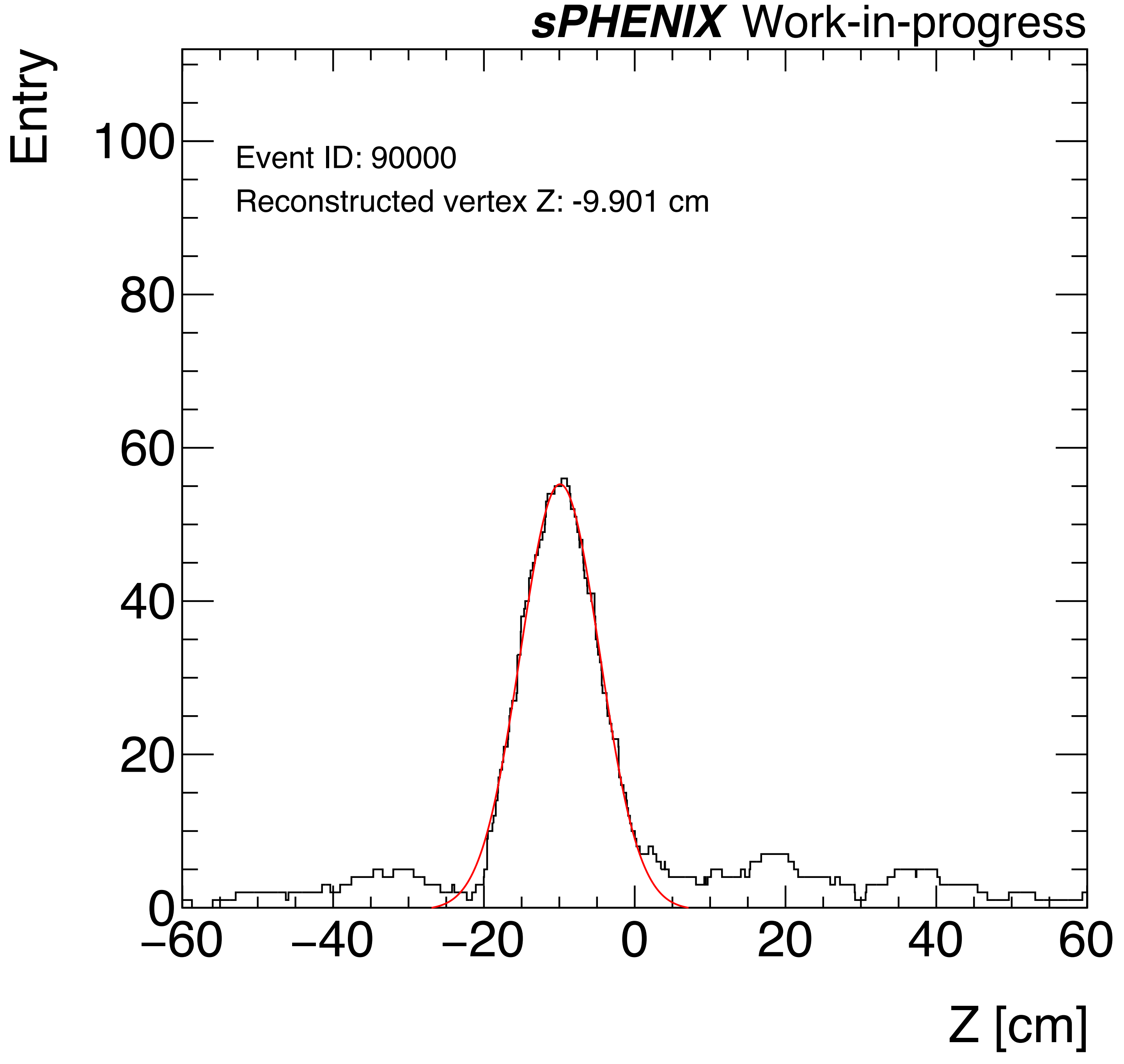




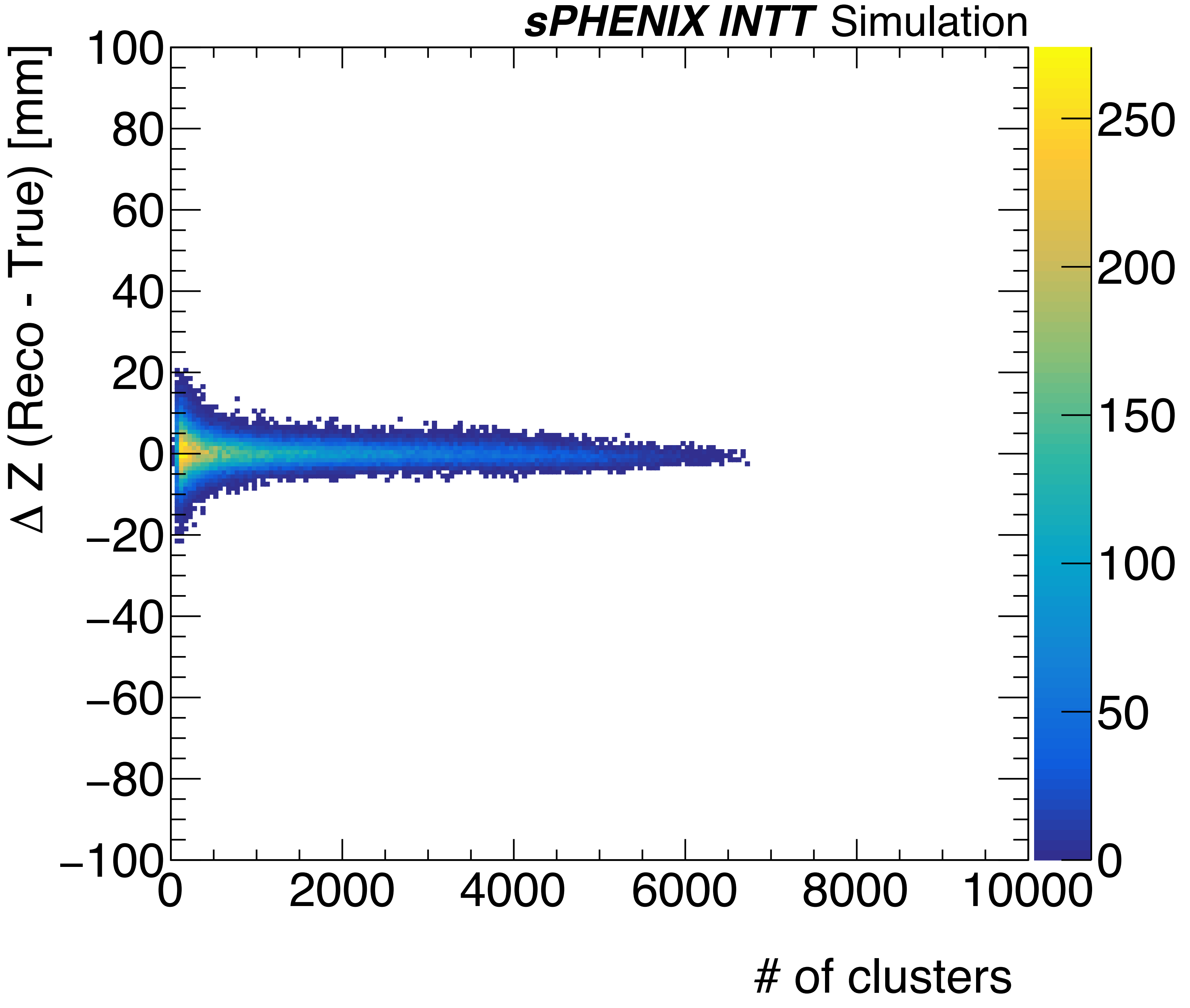
Fill histogram by finely segmented zvtx ranges

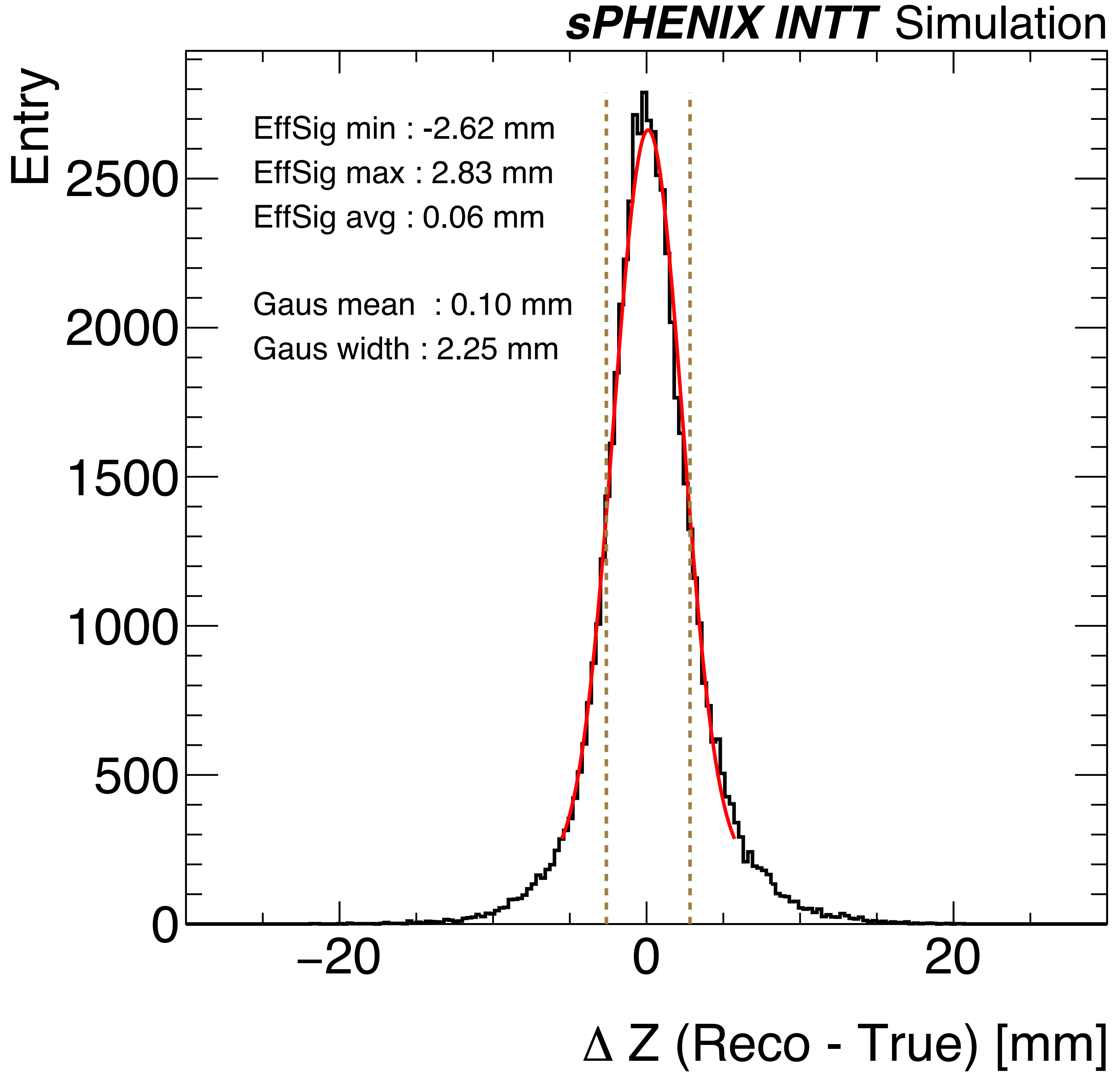
Per event vertex Z

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



Single event

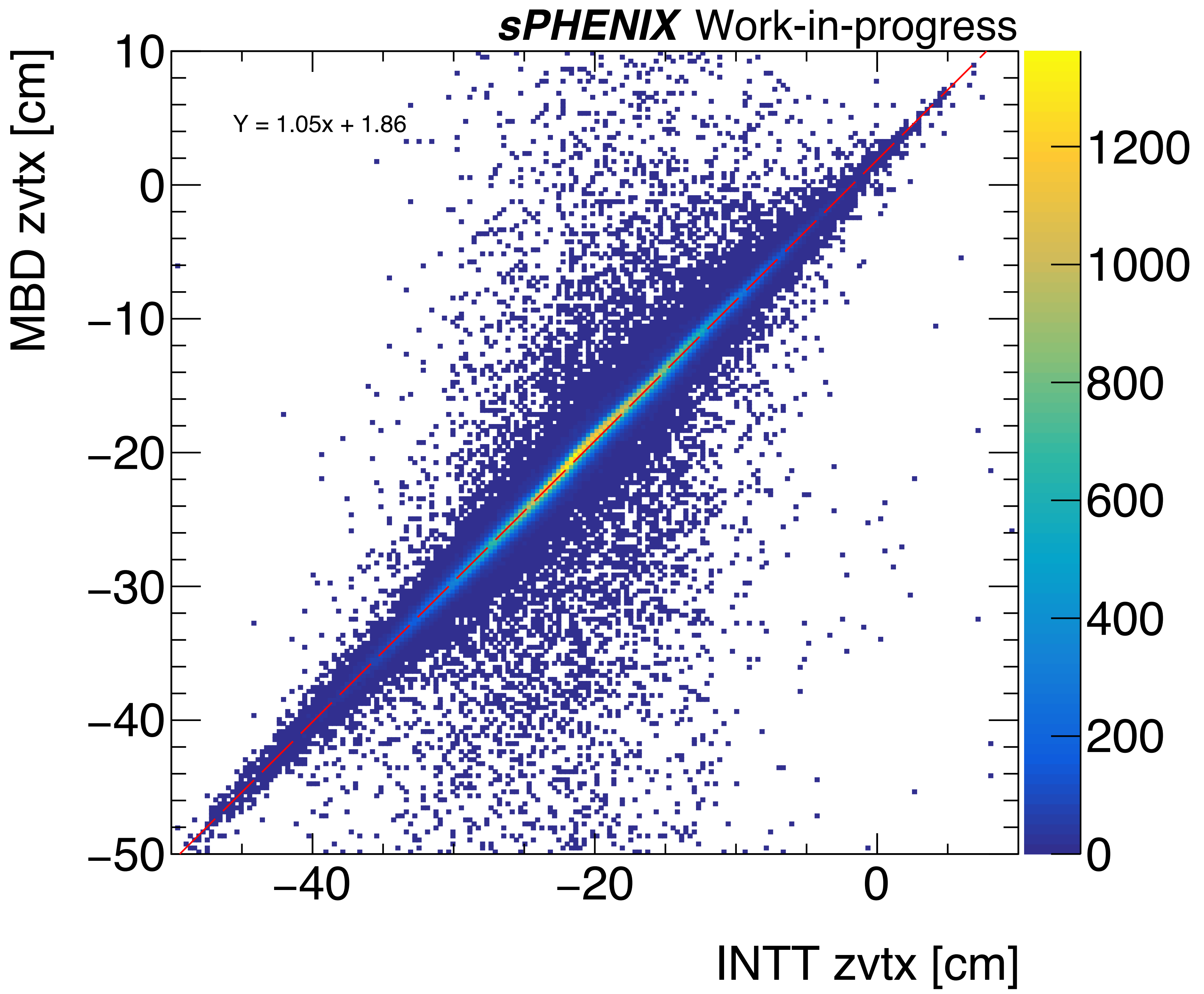


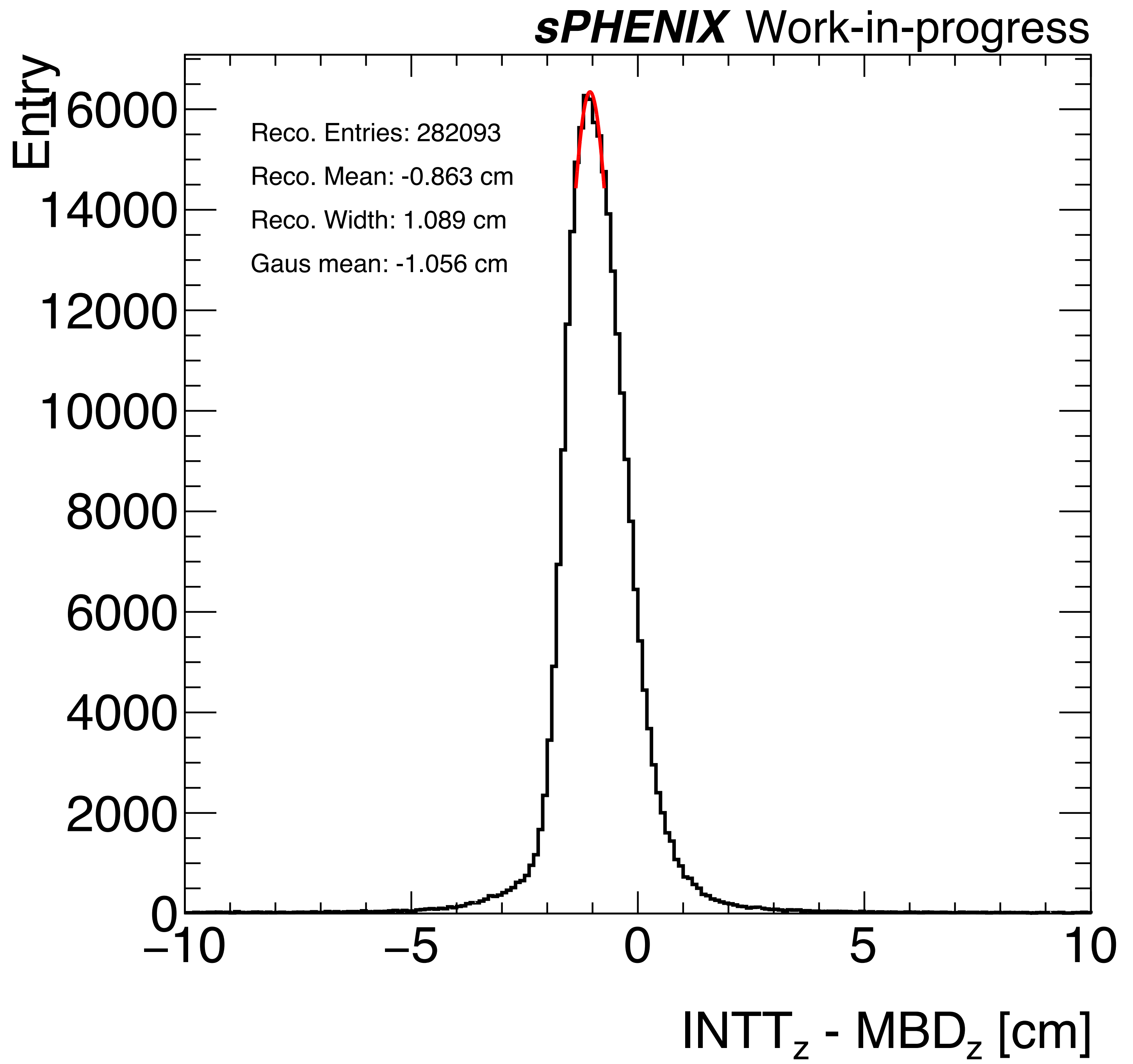


General speaking, ~ 2.3 mm resolution

Per event vertex Z

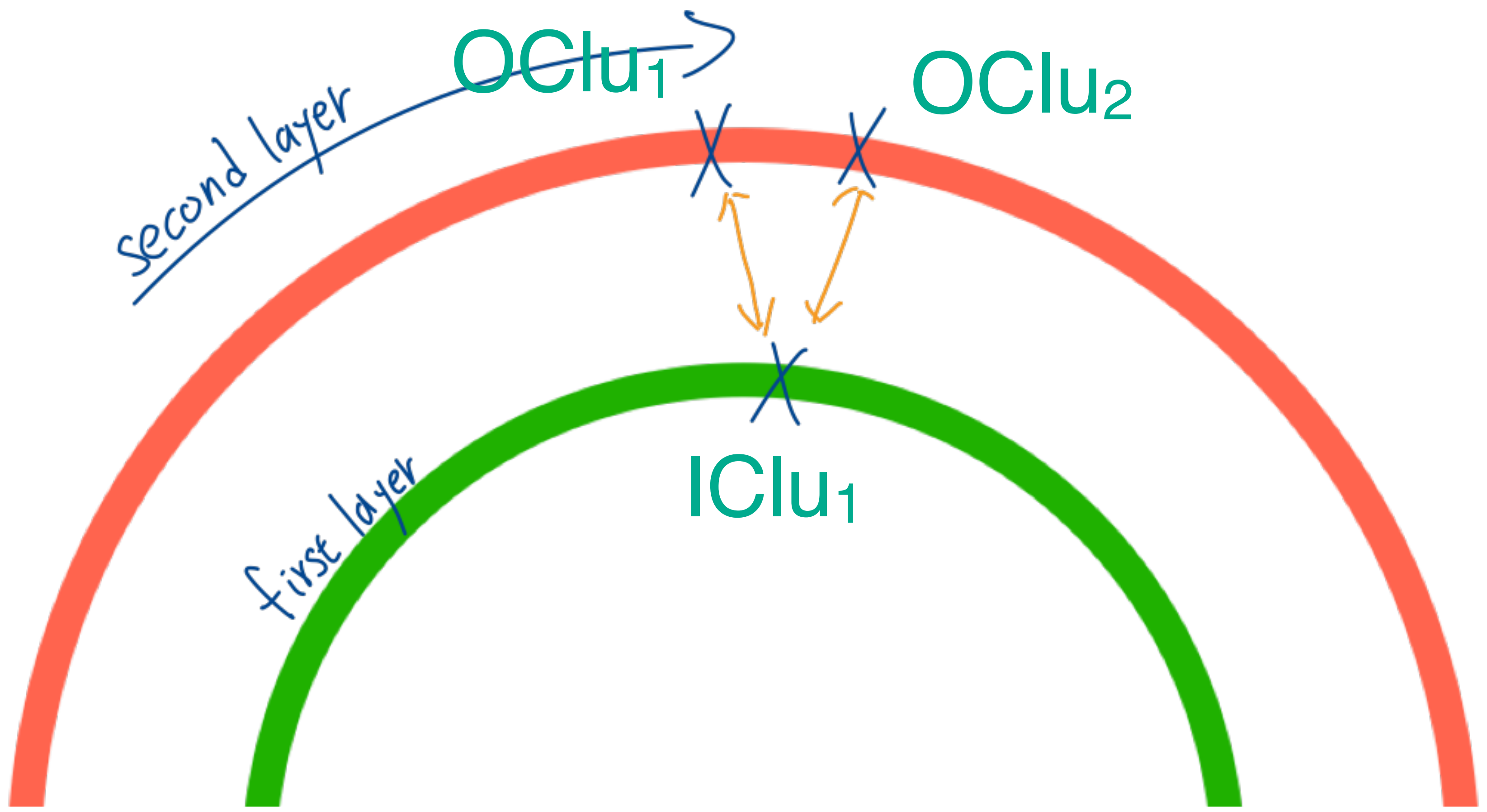
The comparison between MBD reco. vertex Z





Tracklet reconstruction

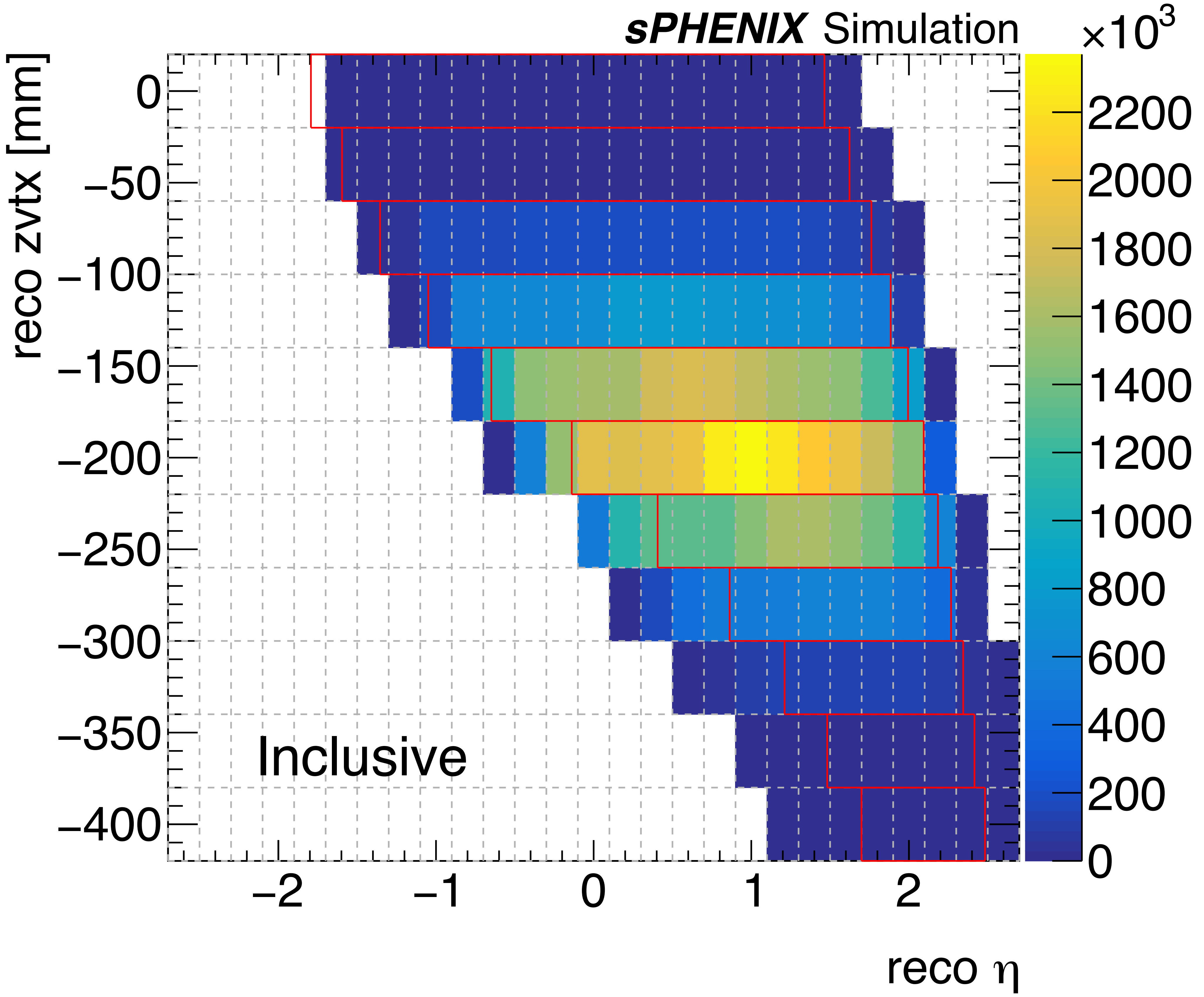
- **2 approaches**: both start with the clusters in the inner layer and search for the clusters in the outer layer to form tracklets; different in:
  - **PHOBOS approach (loose)**: one inner cluster can match to multiple outer clusters. The combinatorial background is estimated by fitting the sideband region of $\Delta\phi$, $|\Delta\phi|>0.0175$ radian, and subtracted afterwards to obtain the number of tracklets
  - **CMS approach (tight)**: one inner cluster can only match to one outer cluster. The cluster combination with the least ΔR is preserved and the others are discarded

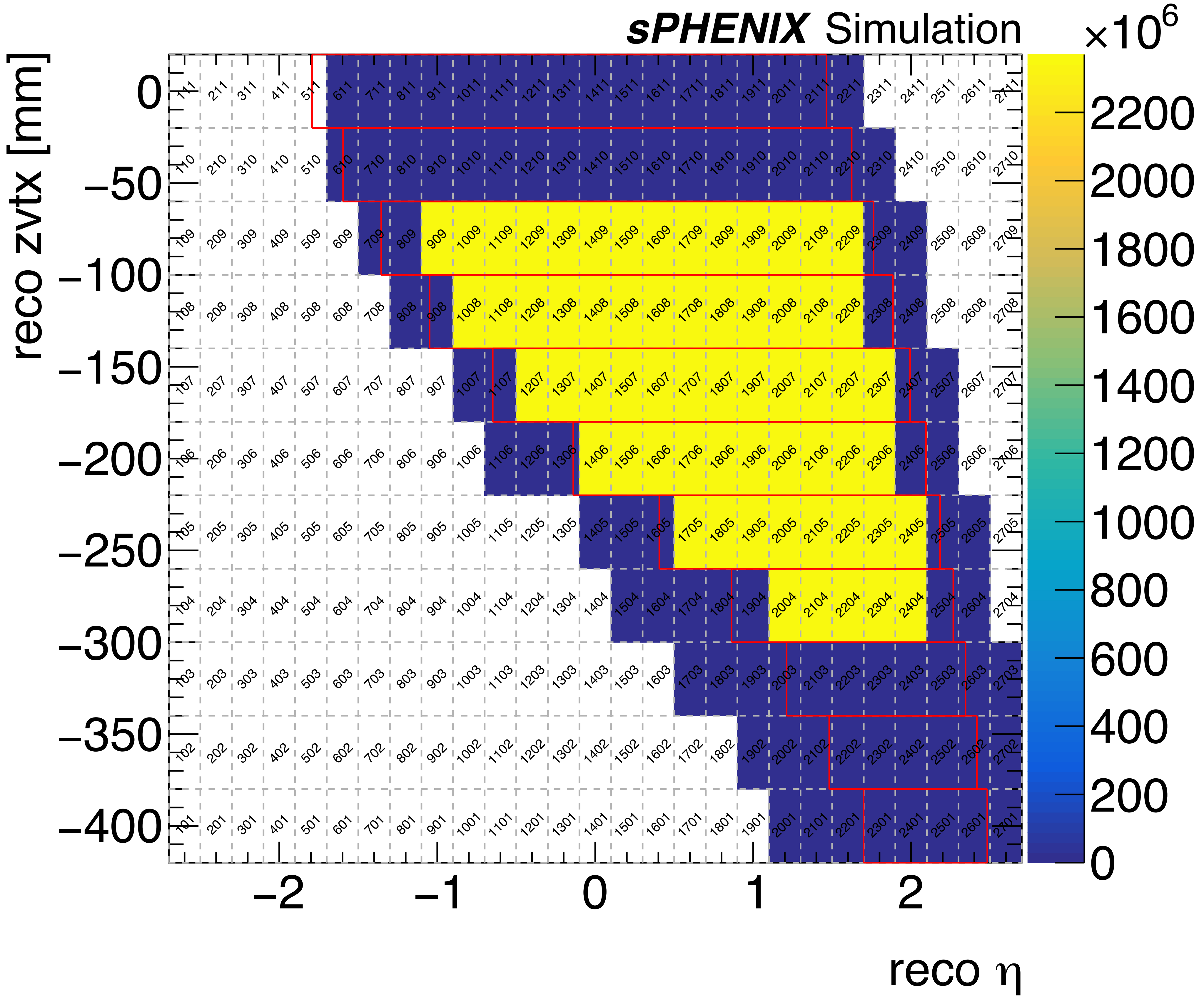


Tracklet reconstruction

- Loose method (PHOBOS/PHENIX) & tight method
- Derive the alpha correction by 40k events, tested by 40k events

INTT reco zvtx-reco. tracklet coverage



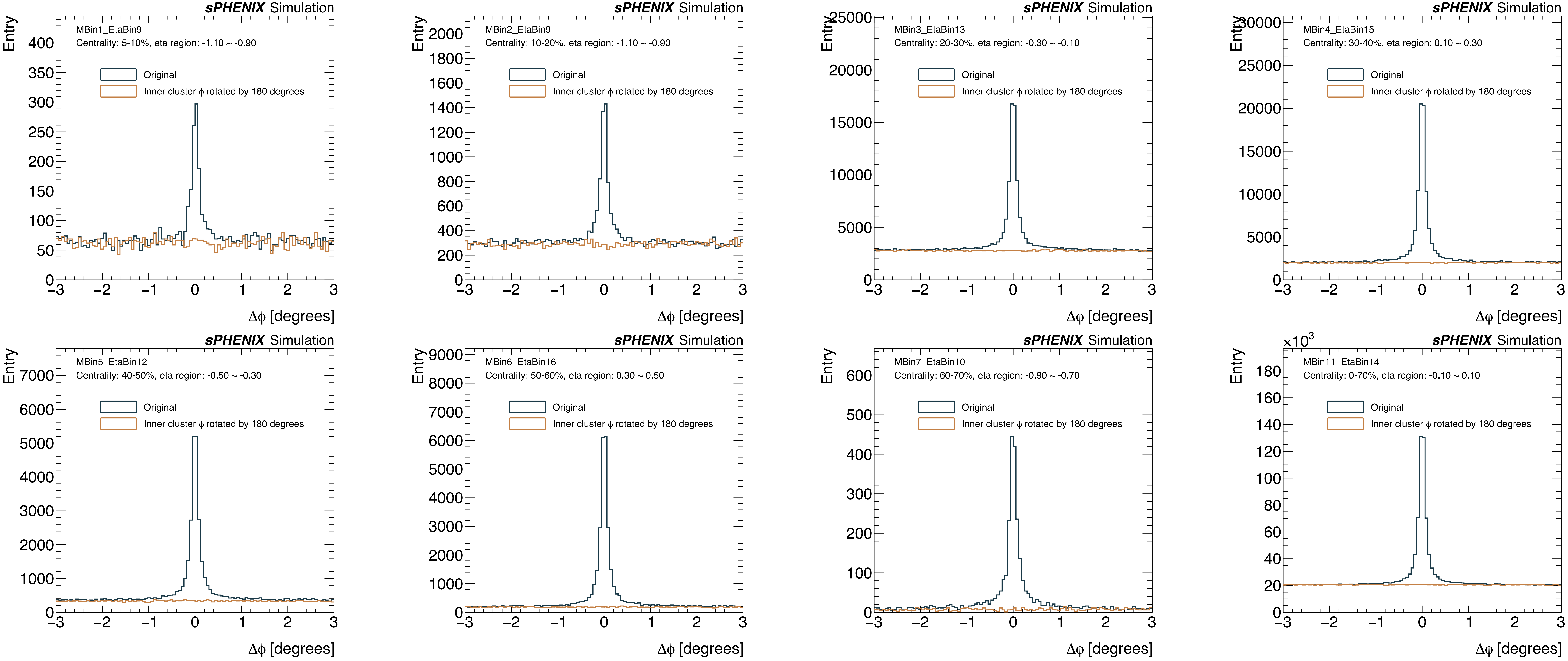


Eta coverage that fits for whole z bin

Selected regions for the further analysis

Tracklet reconstruction

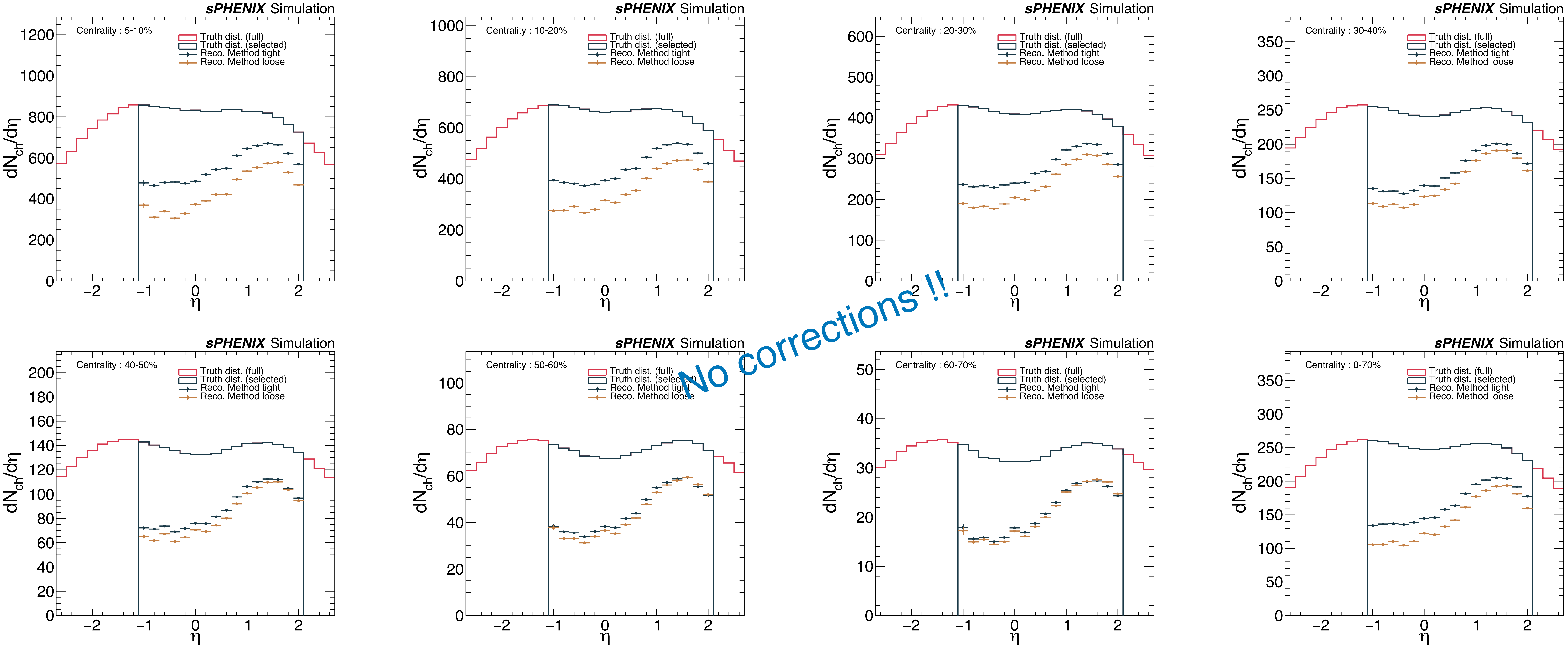
- Loose method (PHOBOS), background estimated by comparing the tracklet $\Delta\phi$ distributions of the original data and the one with inner clusters rotated by π in ϕ angle



20

Tracklet reconstruction

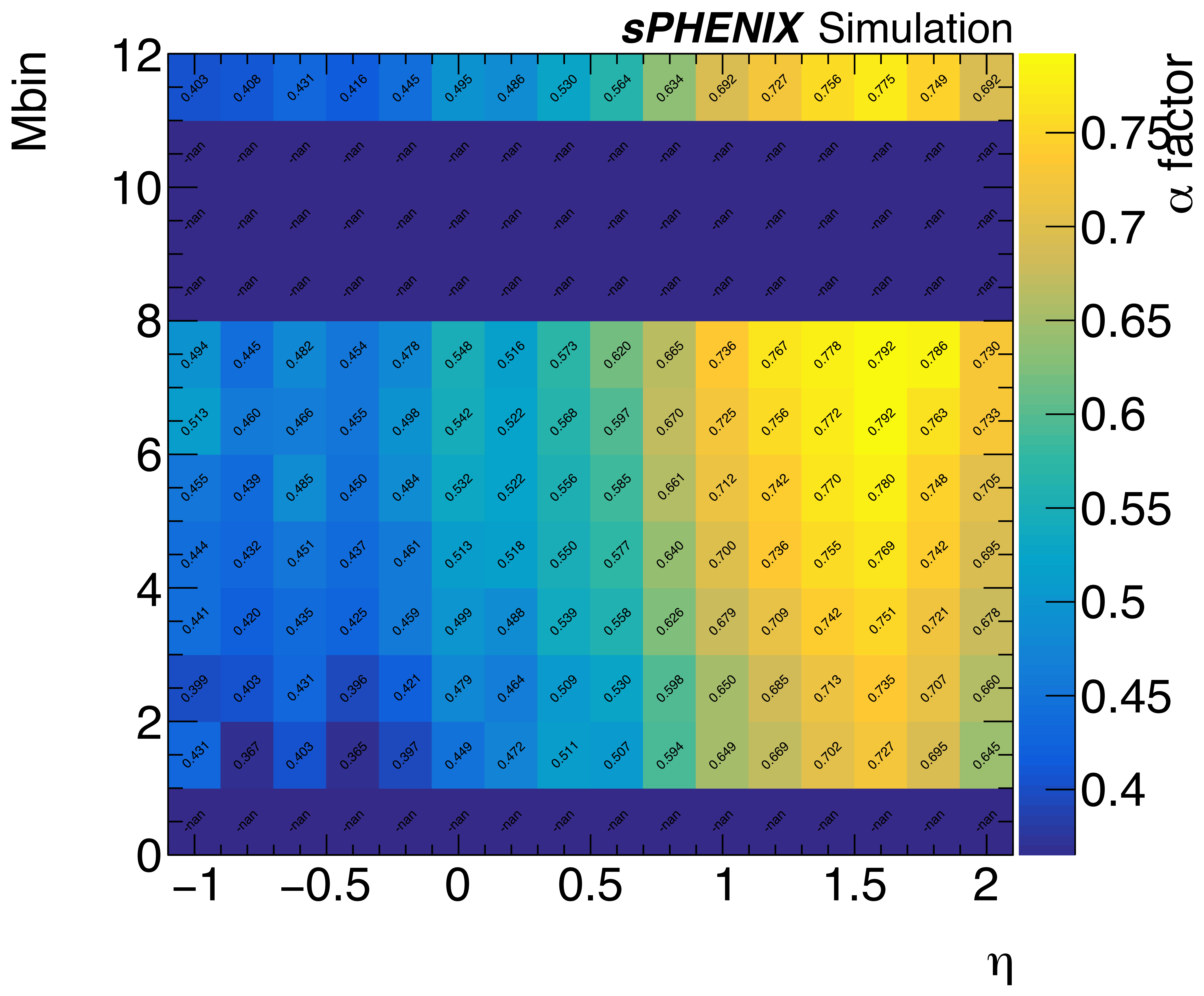
- Loose method (PHOBOS/PHENIX) & tight method
- Derive the alpha corrections by 40k events, tested by 40k events



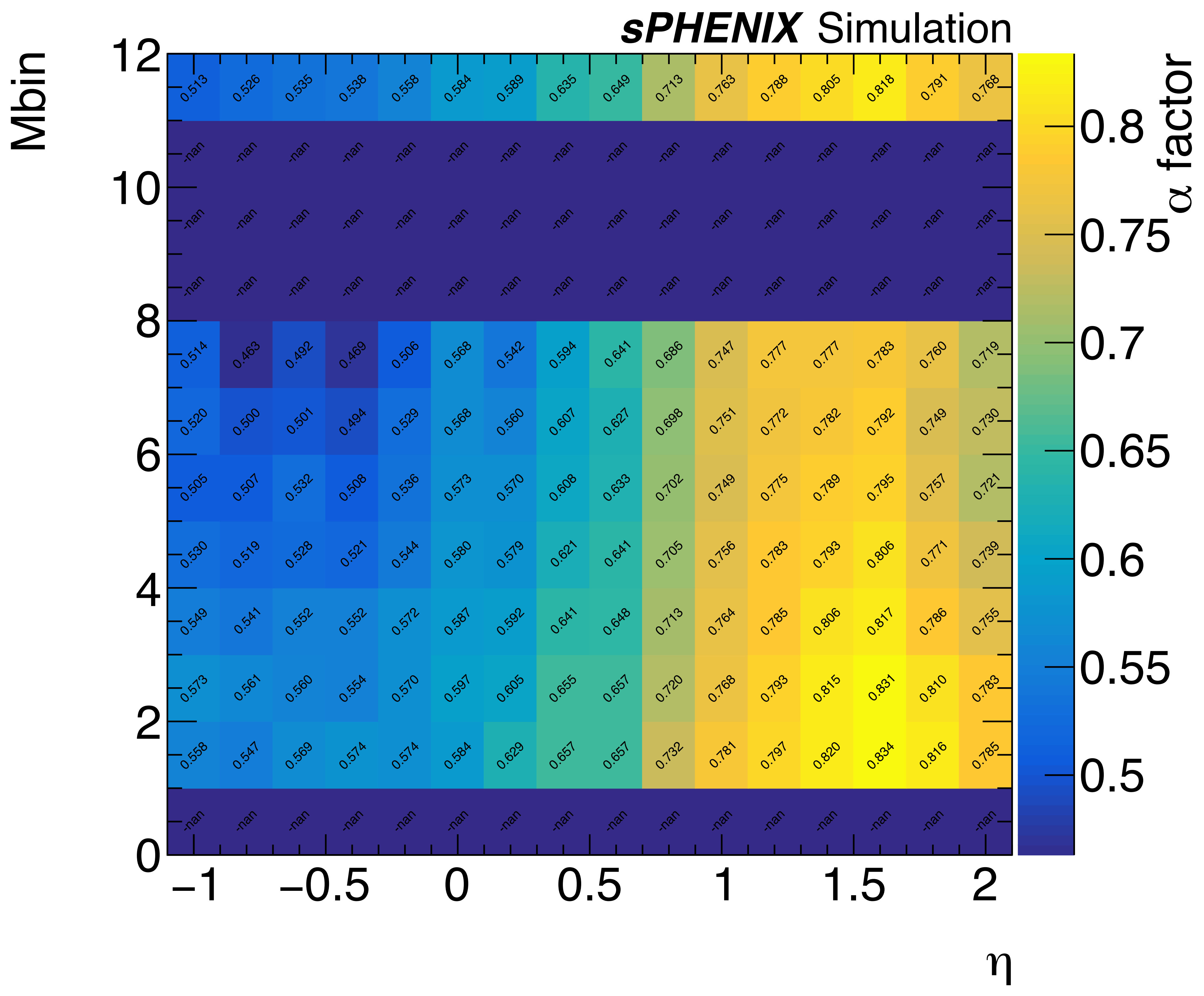
Tracklet reconstruction - α corrections

- Loose method (PHOBOS/PHENIX) & tight method
- Derive the alpha corrections by 40k events, tested by 40k events

Loose method



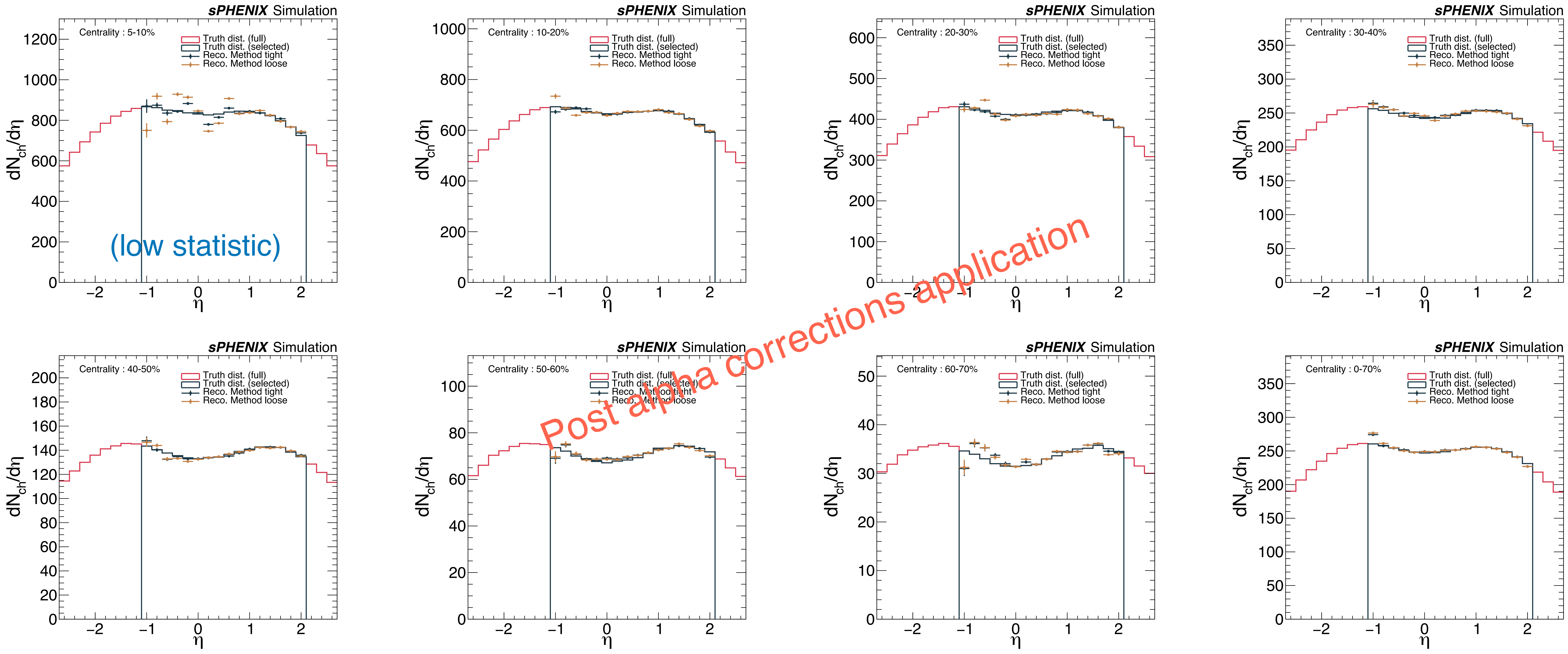
Tight method



Generally, from 0.5 to 0.7

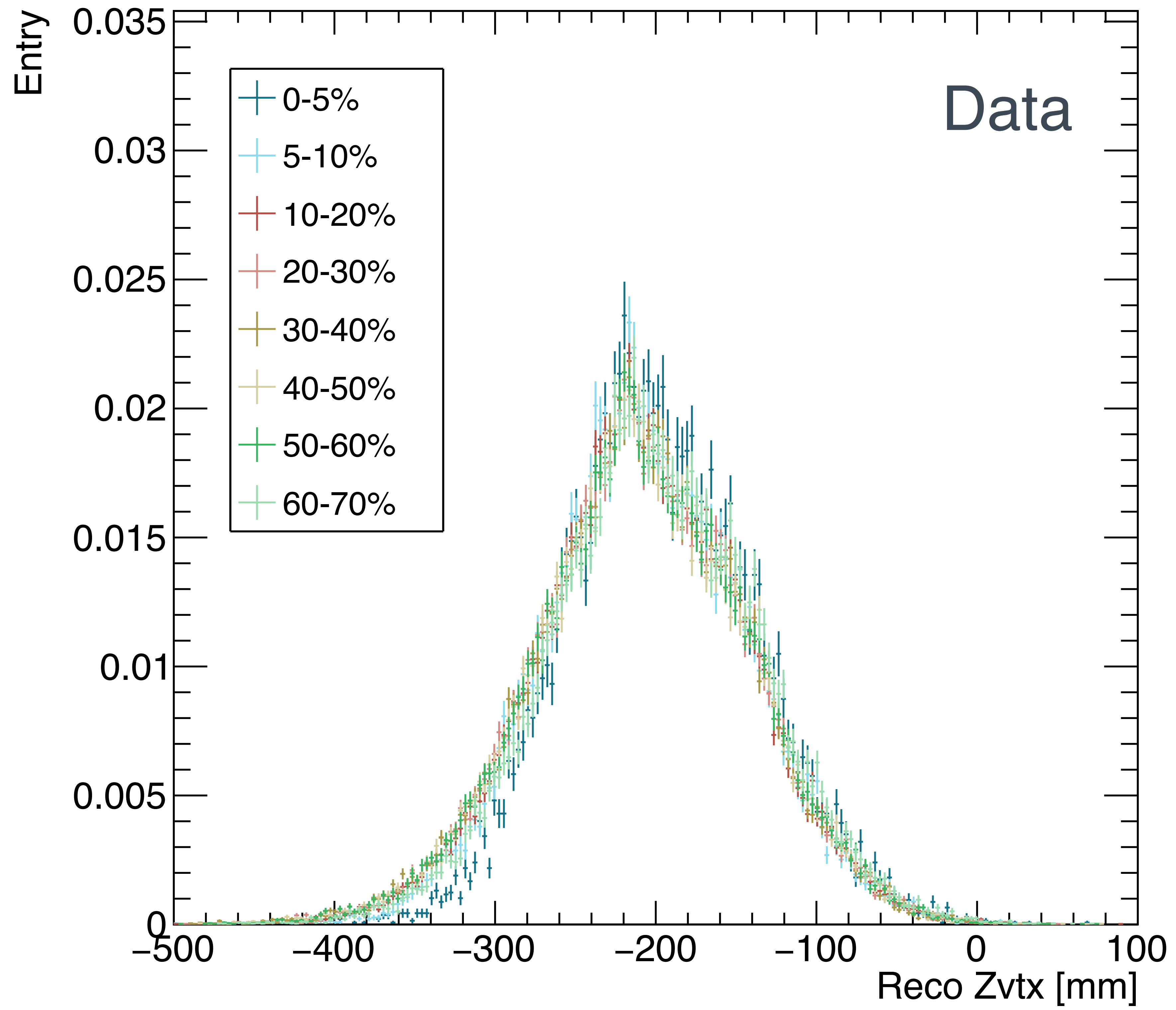
Tracklet reconstruction

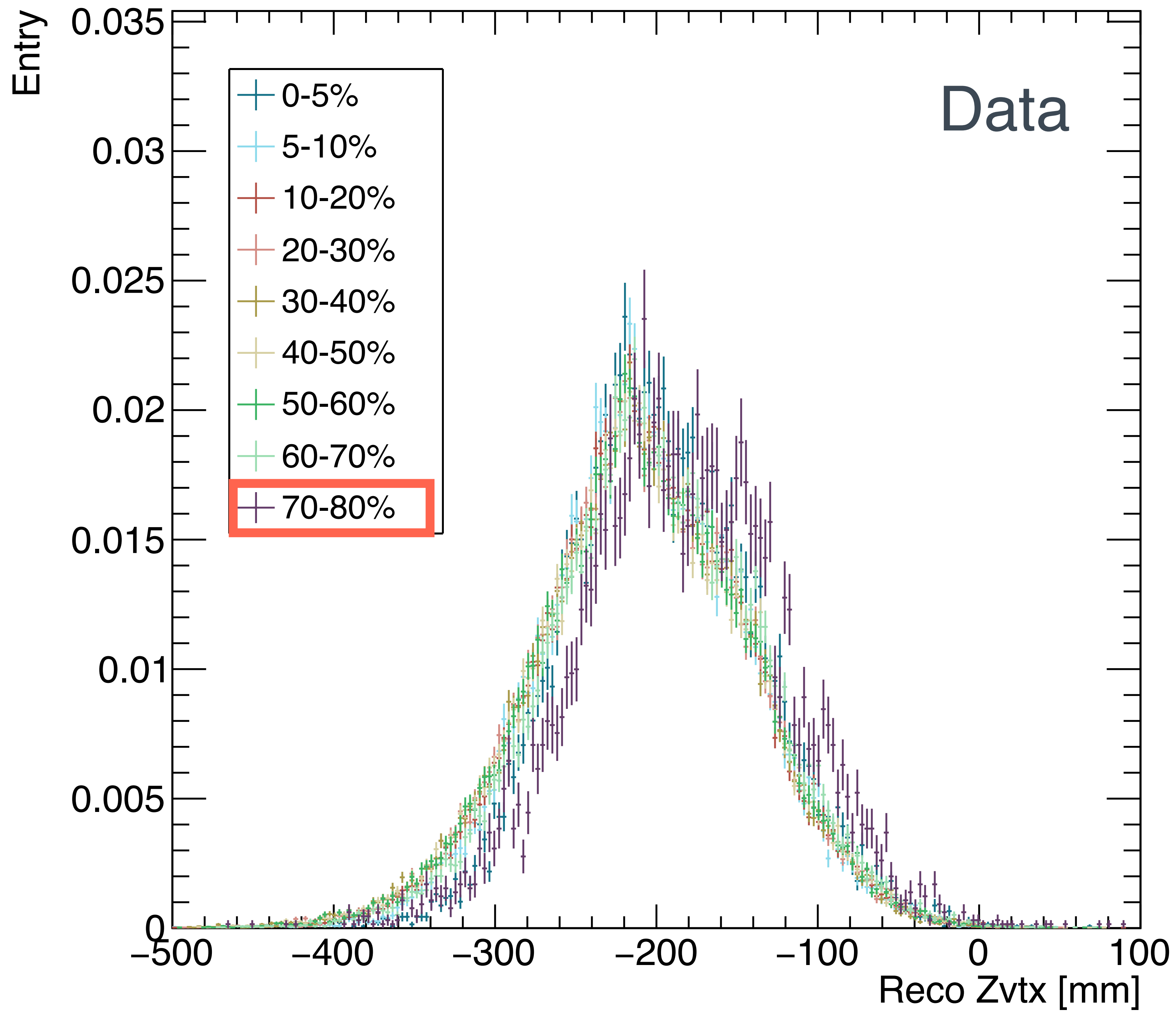
- Loose method (PHOBOS/PHENIX) & tight method
- Derive the alpha corrections by 40k events, tested by 40k events



Vertex Z distribution of the run 20869

- 1D line fill method for zvtx reconstruction

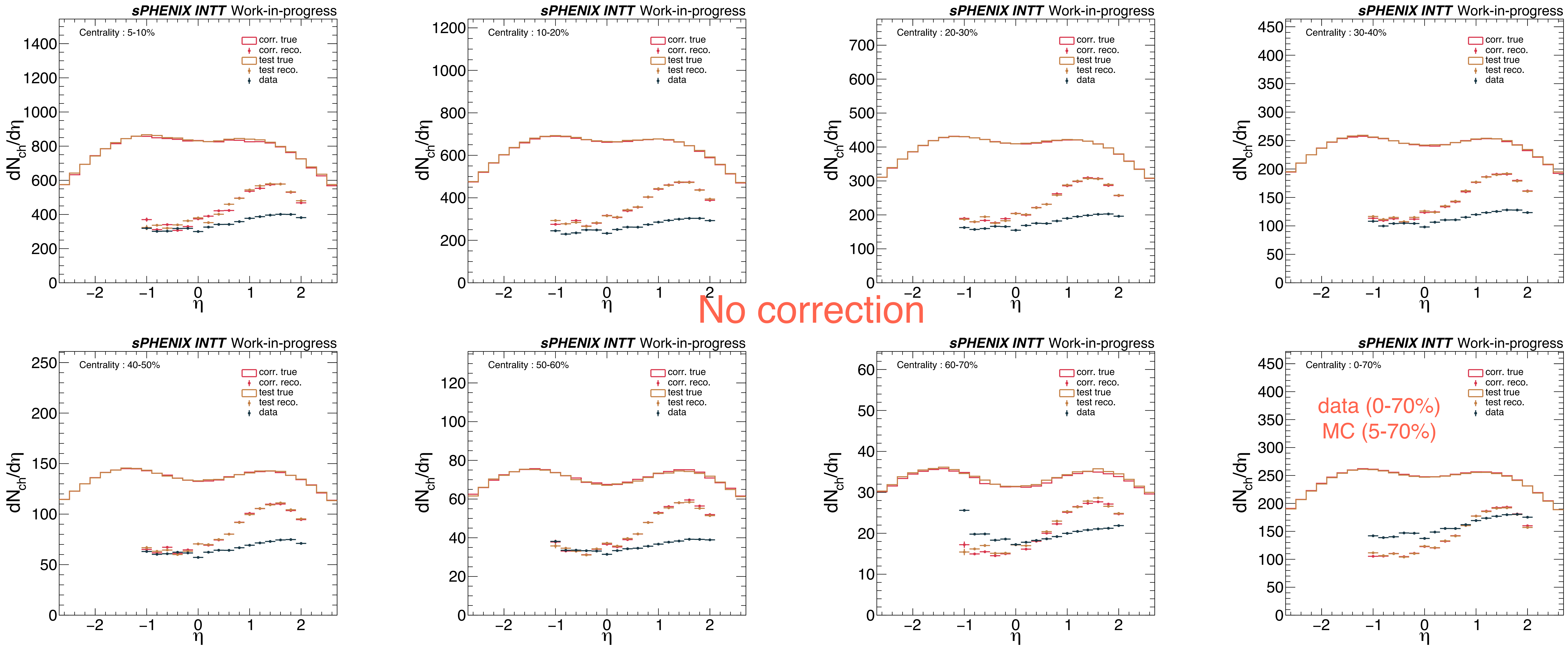




Use the centrality region 0-70% as what the zvtx distribution suggested

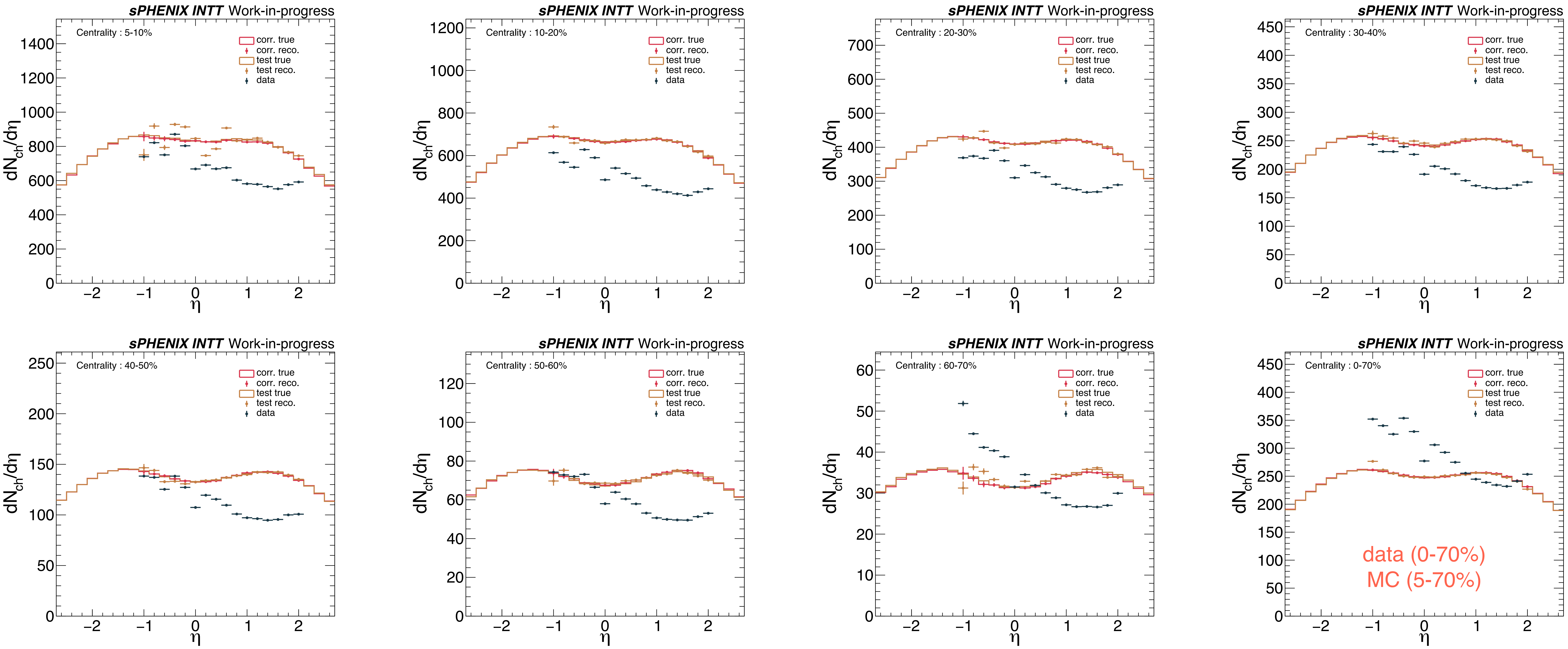
Tracklet reconstruction

- Loose method (PHENIX/PHOBOS)



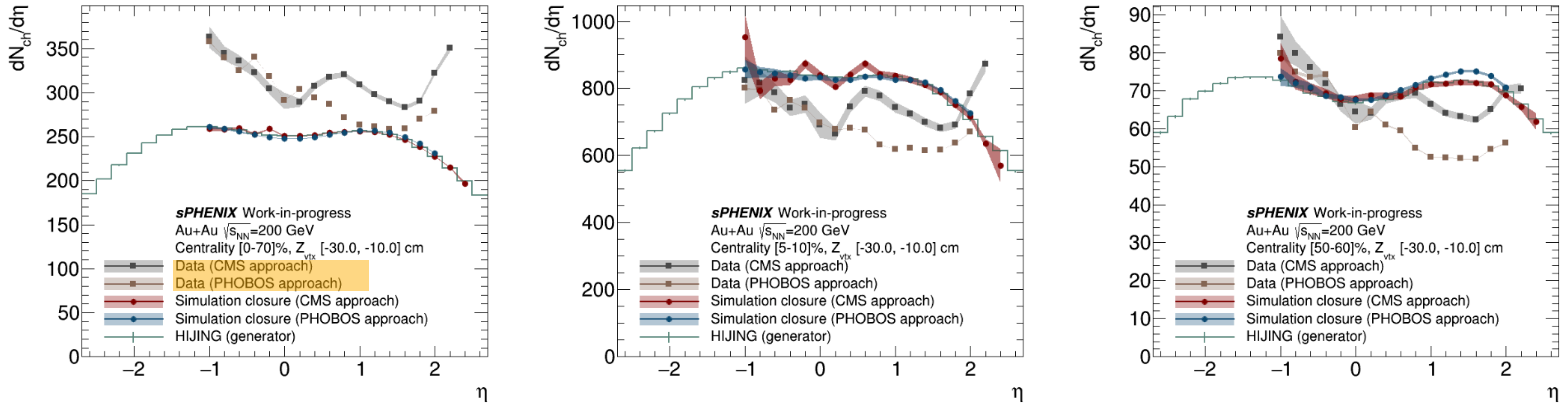
Tracklet reconstruction

- Loose method (PHENIX/PHOBOS)



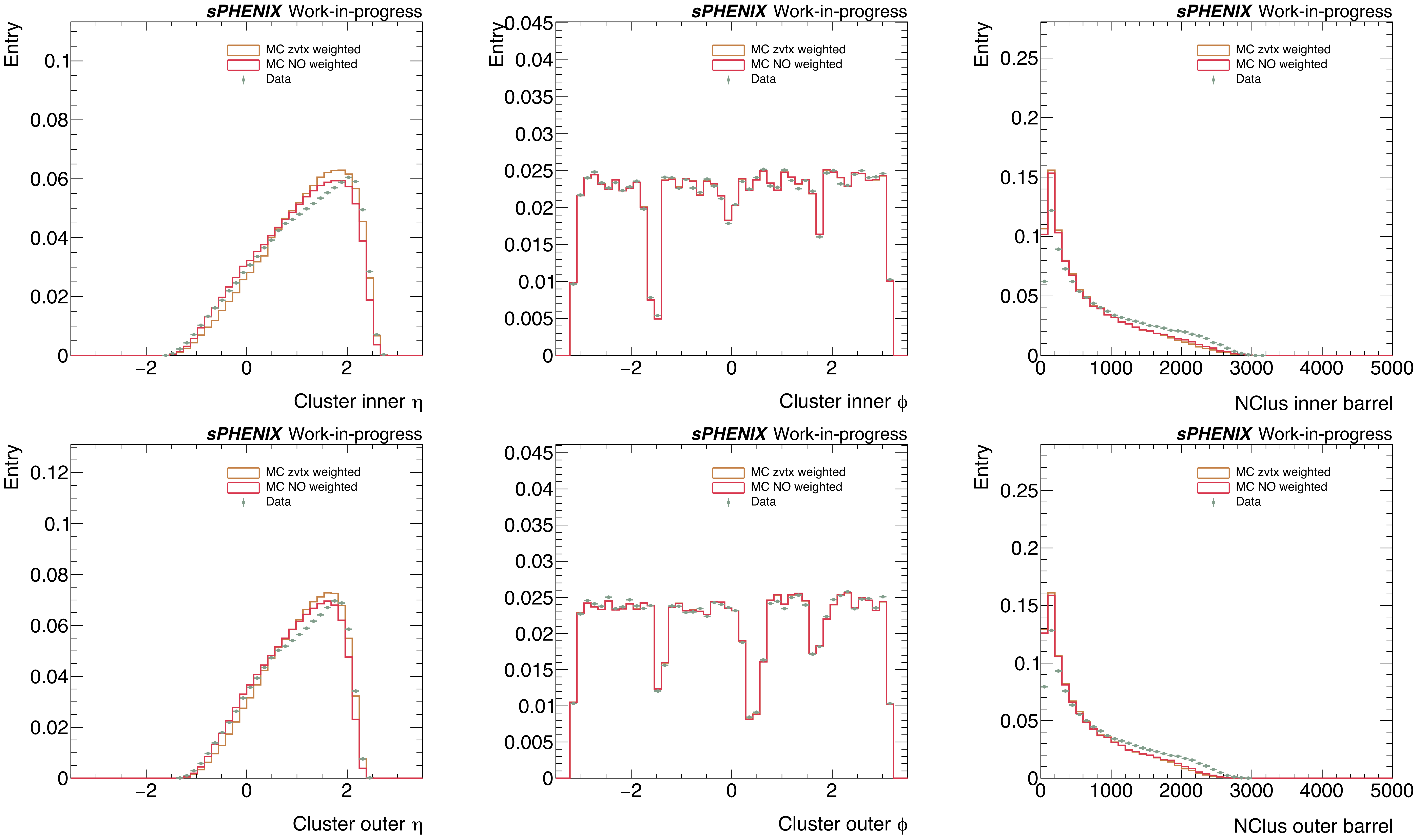
Tracklet reconstruction - latest result

The latest plots we can have now
CMS approach by Hao-Ren, PHOBOS approach by Cheng-Wei



Distribution comparison - cluster

Cluster η and ϕ updated by vertex position



cluster adc > 35
cluster phi size < 6
NClus > 1000

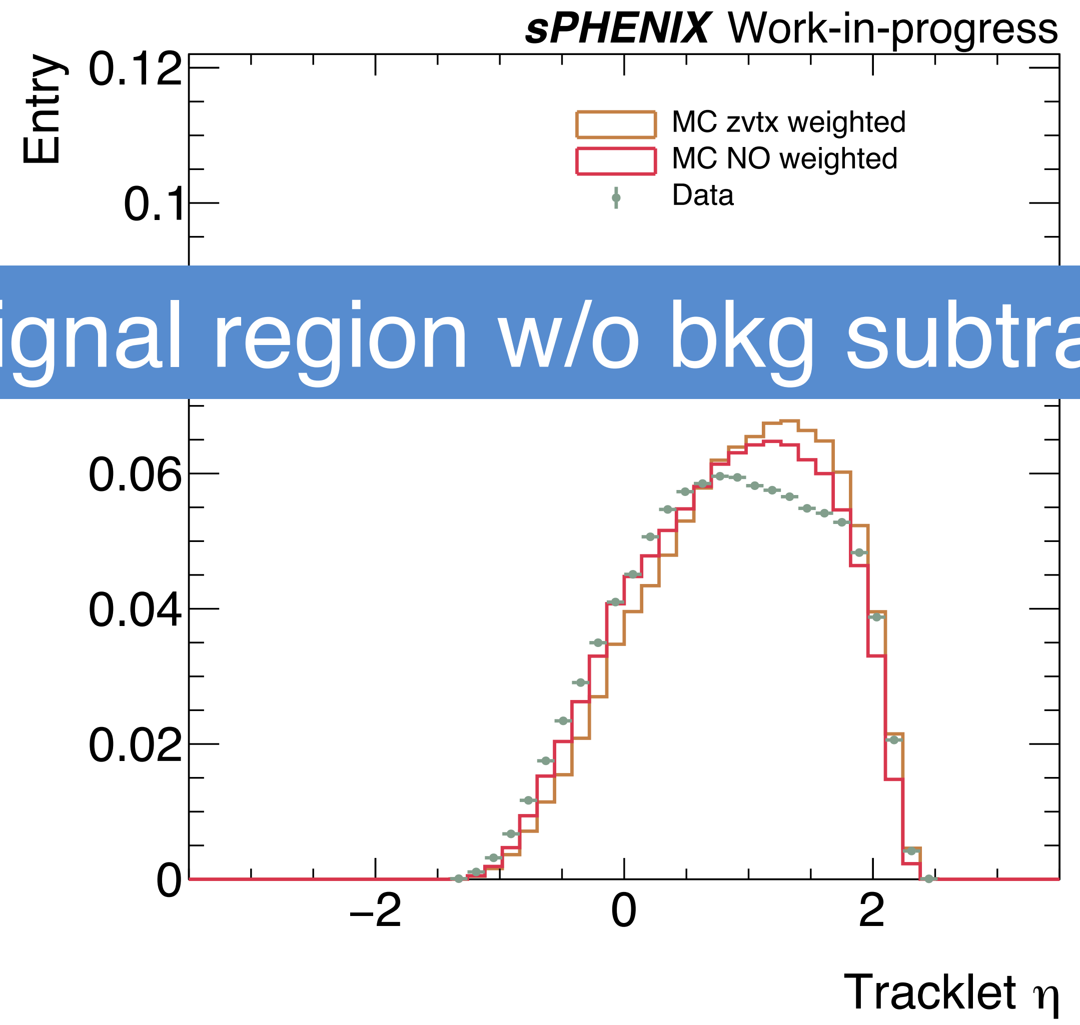
is_min_bias_wozdc == 0
Centrality == Centrality
MBD_z == MBD_z
lMBD_charge_assyl > 0.75
0-70%

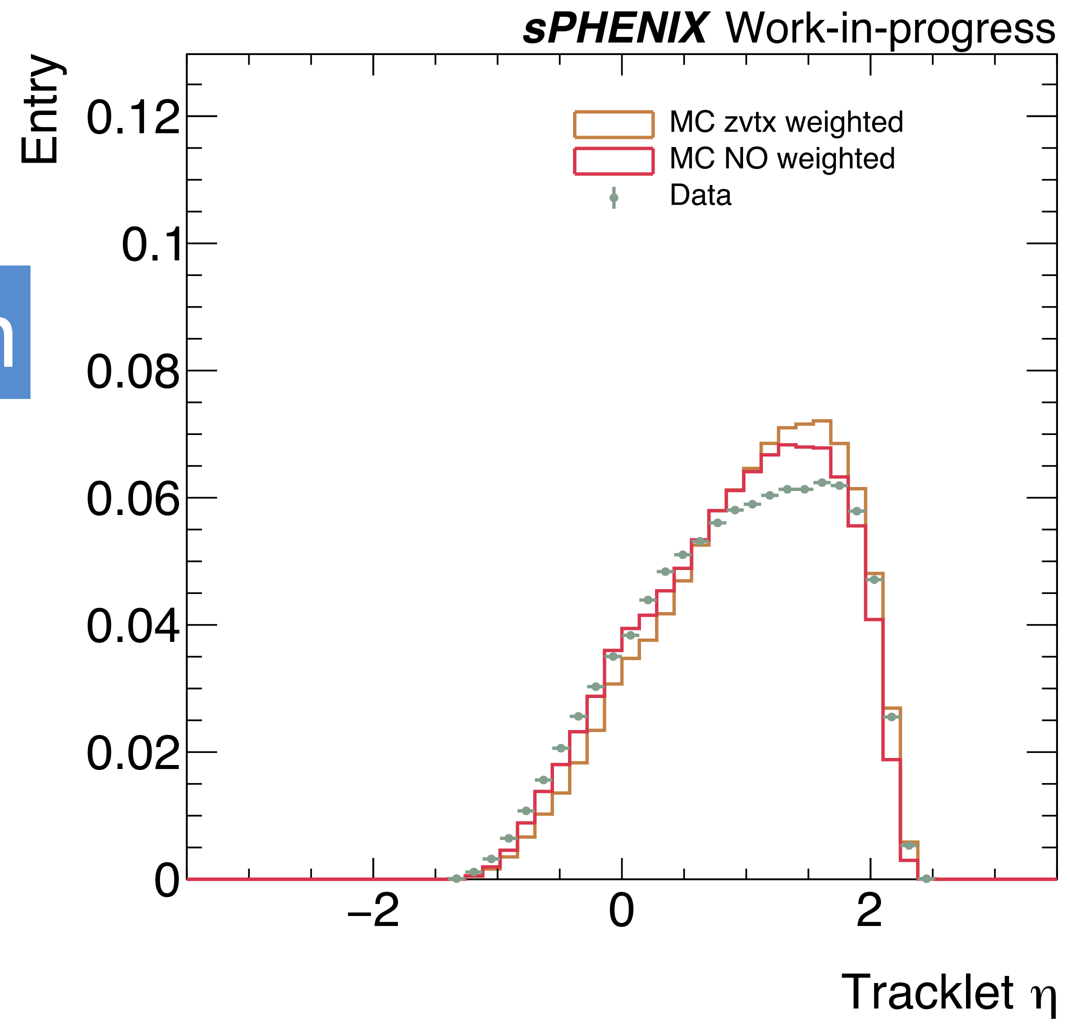
3 cm < zvtx_fit_width < 8 cm
4 < zvtx group bkg cut width < 11 cm
-30 < INTT reco. Z < -6 cm
-5 < INTTz-MBDz < 3 cm (data)
-4 < INTTz-MBDz < 4 cm (MC)

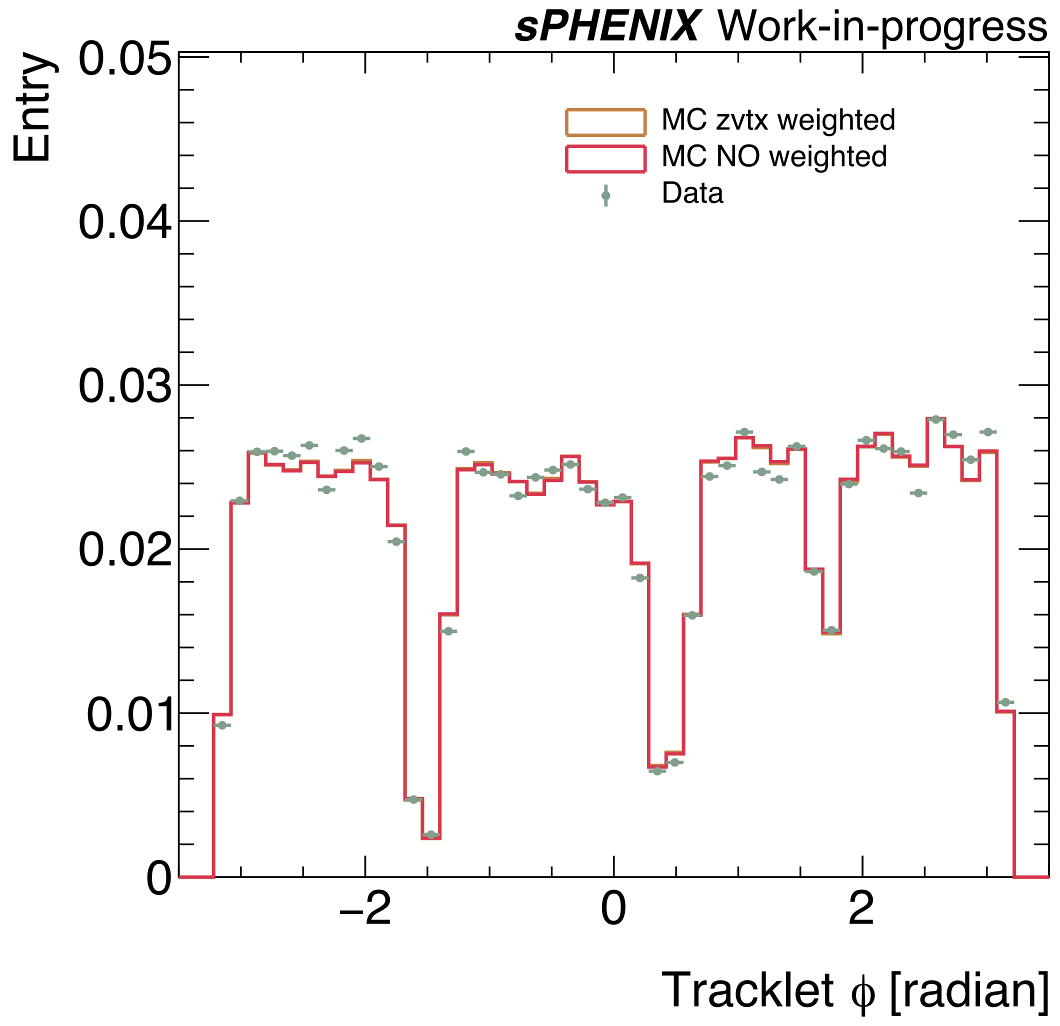
Distribution comparison - tracklet

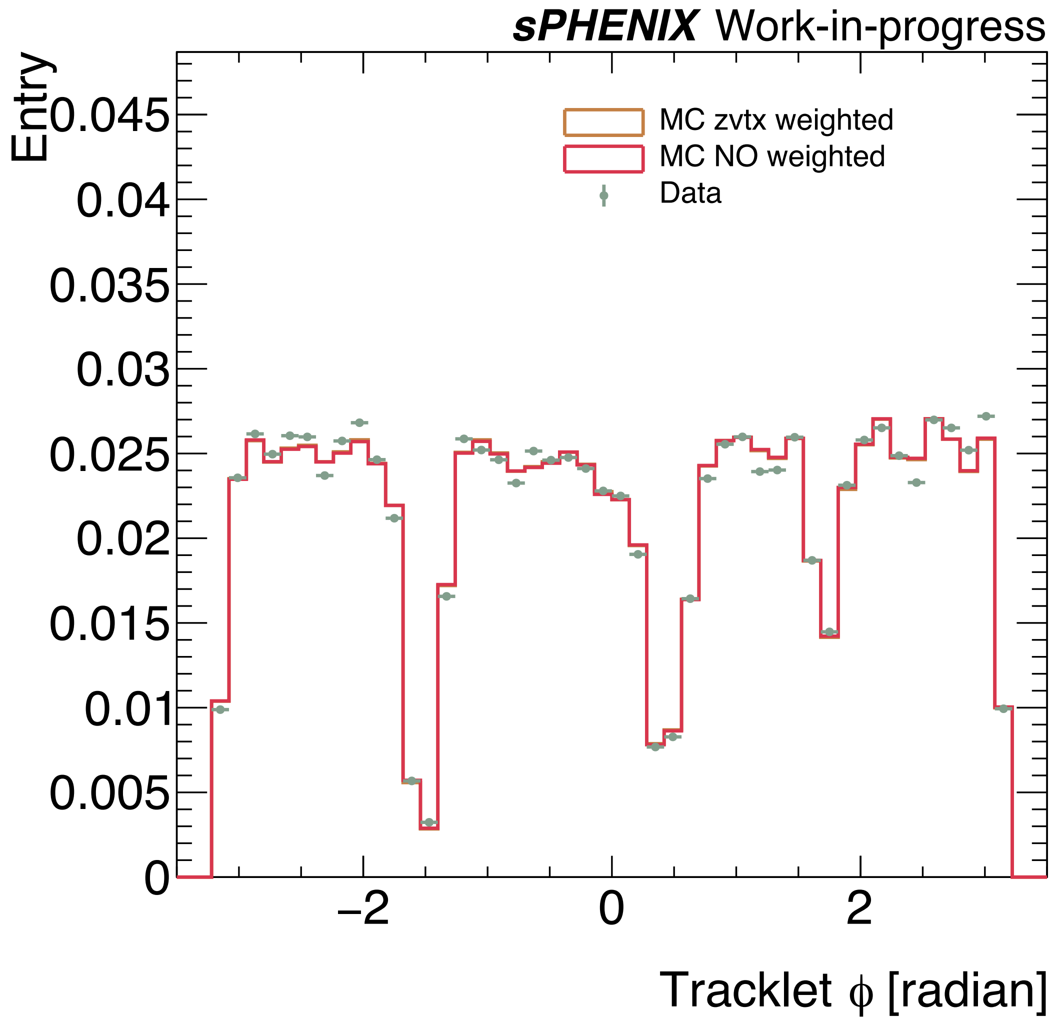
Loose (PHOBOS approach) | Tight

Signal region w/o bkg subtraction









Cluster η and ϕ updated by vertex position

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NClus > 1000

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-5 < INTTz-MBDz < 3 cm (data)
-4 < INTTz-MBDz < 4 cm (MC)

Summary

- The PPG02 was formed after the QM23
- We have developed the analysis workflow down to the very end we can reach now

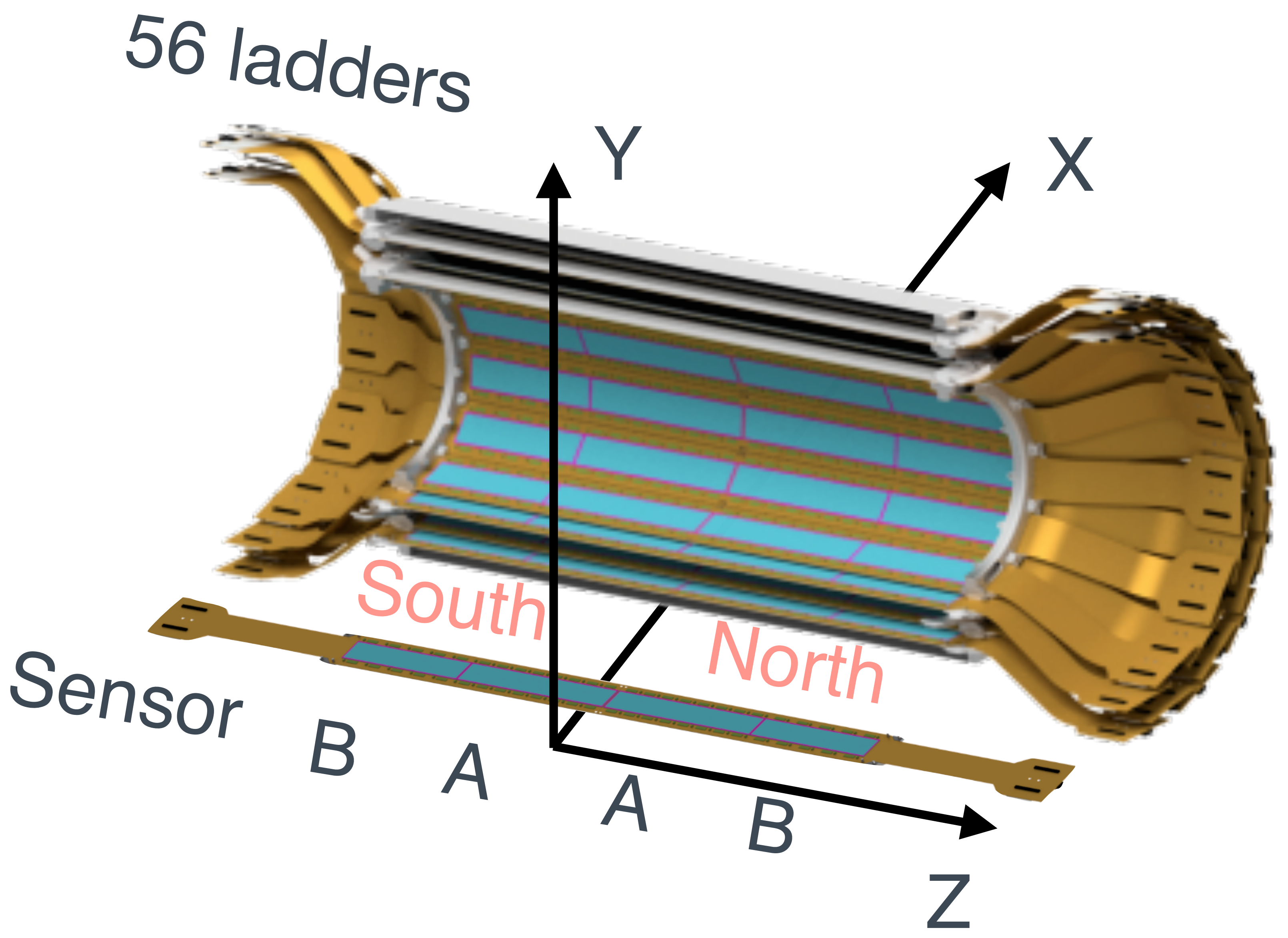
- Issues to be solved
  - MC truth too high
  - dNdeta Data distribution is different that of MC
  - Weird correlation between INTTz and MBDz
  - Incorrect centrality correction for both data and MC
  - No 0 to 5% events in MC
  - (Consistency in vertex reconstruction b/w to approaches) ?
  - Decent QA check to compare the data and MC in all aspects (across the different centrality binning)

- As long as the discrepancy can be addressed/mitigated, we will be ready for the preliminary (paper ?), we are getting there!

Back up

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)