Study of vertexing performance in DIS events

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07/26/2024

Simulation & reconstruction

- PYTHIA ep 18x275
- Vertex position: afterburner to apply beam effects
- $Q^2 > 10\ GeV^2$

- EIC geometry: *epic-24.06.0*
- EICrecon: branch *vertexing_group*

The following cases are checked

- Seeding type: truth vs. real

- Selection on tracks used for vertex reconstruction
  - Case 1: default
  - Case 2: $|z0| < 100$ mm, $|d0| < 3$ mm

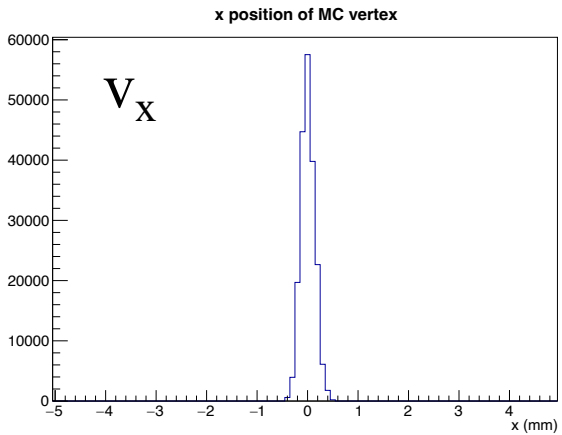
Definitions

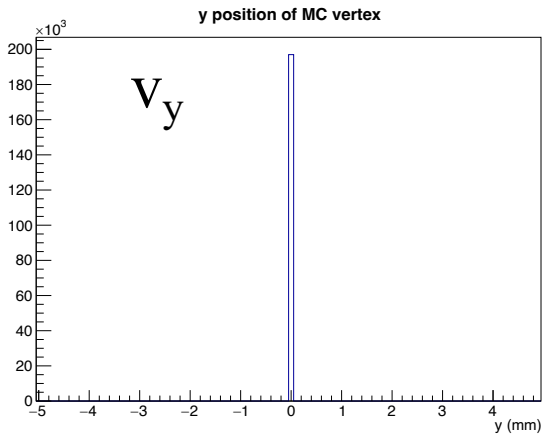
- N_{MC} = number of charged final-state MC particles within $|\eta| < 3.5$ that are associated with the MC vertex
  - Particle production vertex within $1e^{-4}$ mm of the MC vertex

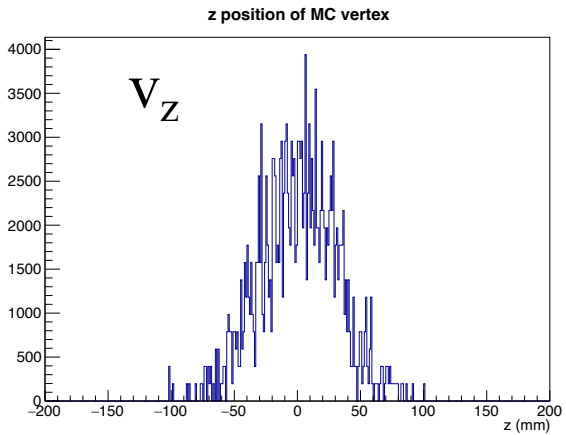
- N_{trk} or N_{RC} = number of charged tracks used to reconstruct the vertex

Vertex distribution

MC vertex distributions



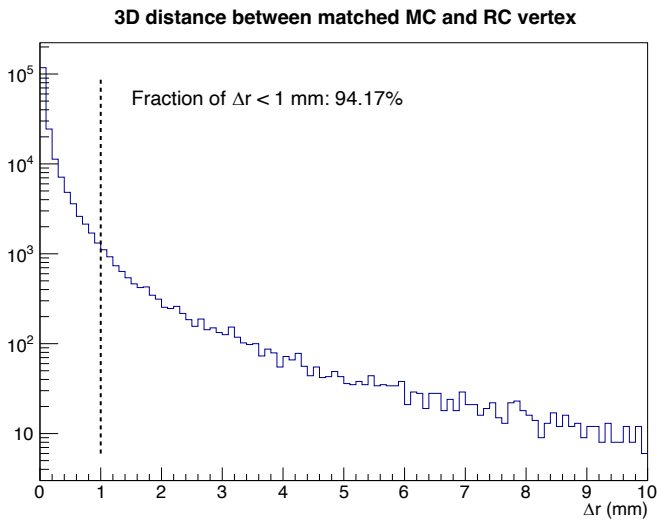


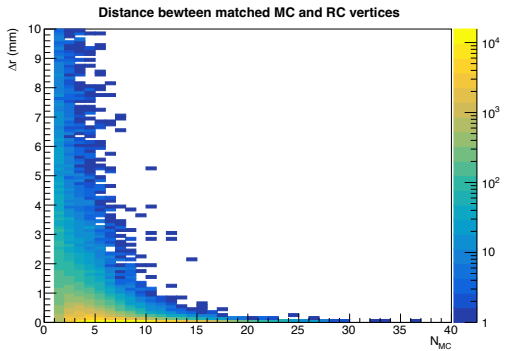


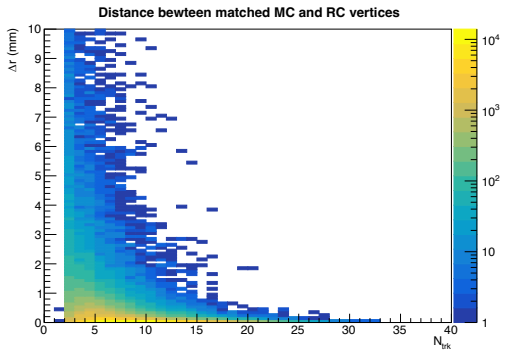
- Clear beam effects: v_z smeared out to 100 mm; negligible smearing for v_y

Distance between matched RC and MC vertex

Truth seeding: default



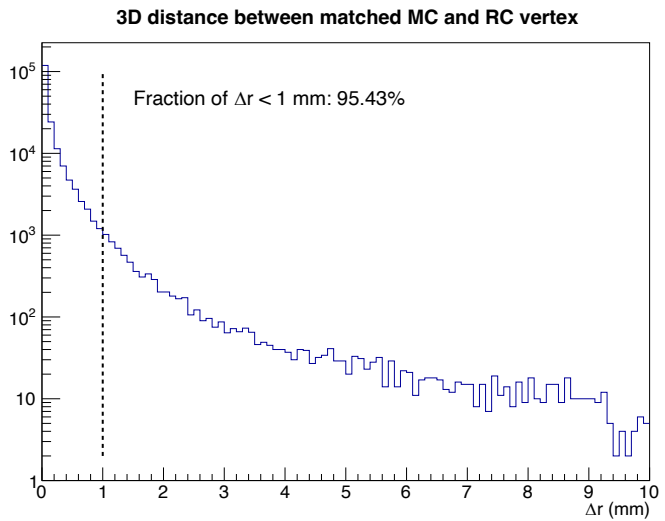


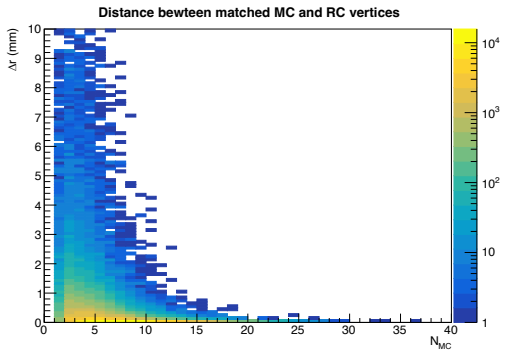


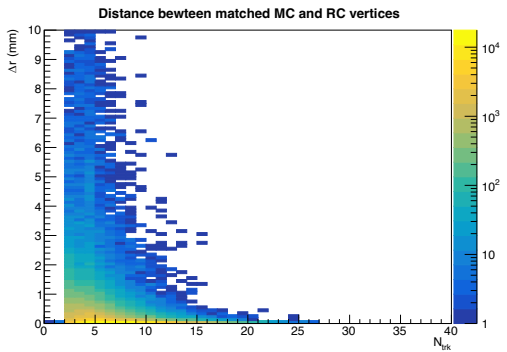
- The RC vertex closest to the MC vertex is chosen as matched
- A cut on the 3D distance ($\Delta r < 1$ mm) is applied to select good matches

Distance between matched RC and MC vertex

Real seeding: default



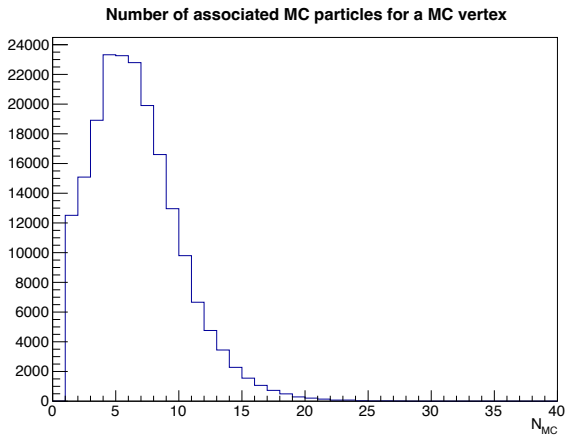


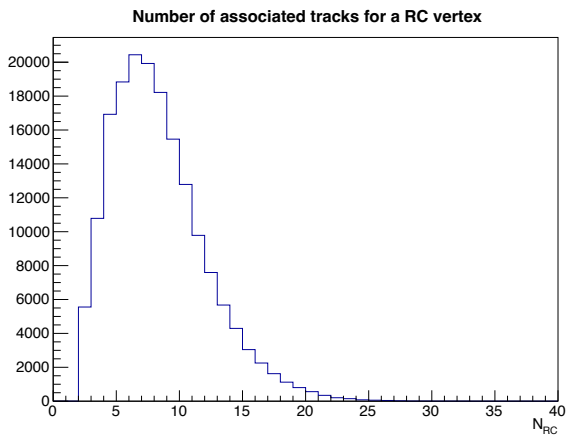


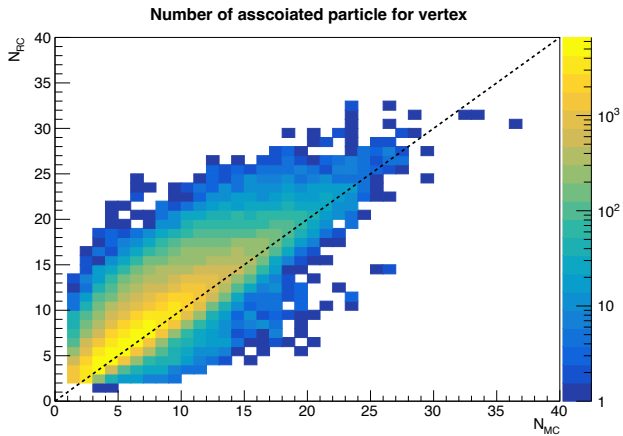
- The RC vertex closest to the MC vertex is chosen as matched
- A cut on the 3D distance ($\Delta r < 1$ mm) is applied to select good matches

of particles associated with vertex

Truth seeding: default



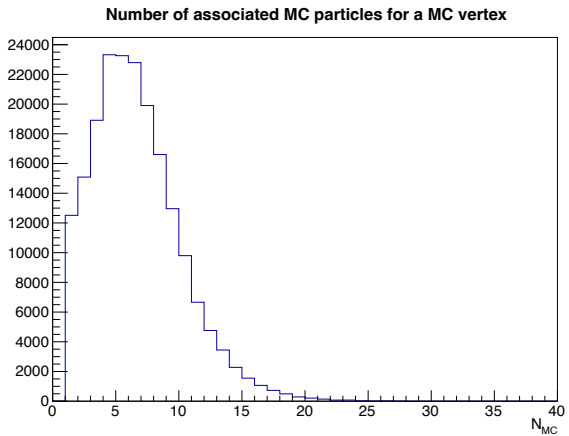


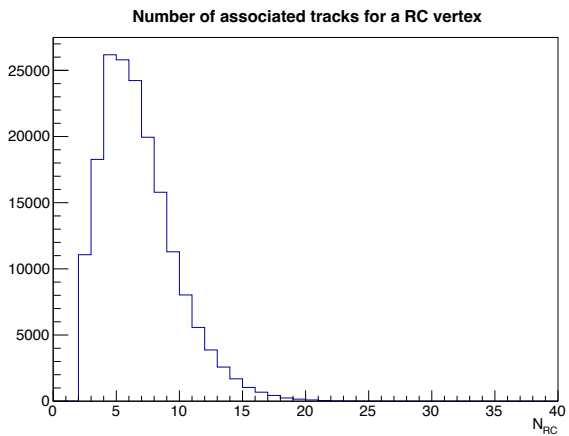


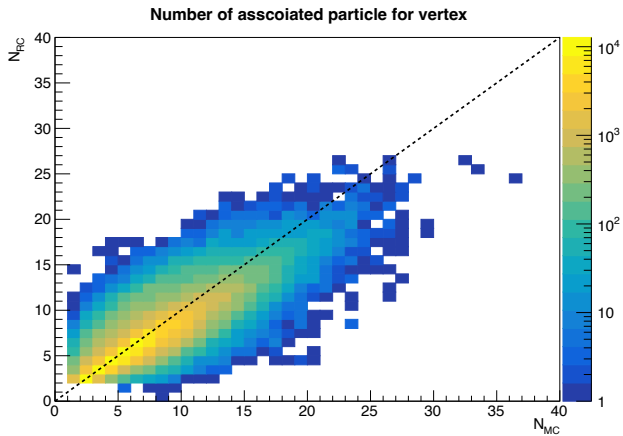
- (Right) Correlation between N_{MC} and N_{RC}; it seems like $N_{RC} > N_{MC}$

of particles associated with vertex

Real seeding: default







- (Right) Correlation between N_{MC} and N_{RC}; it seems like $N_{RC} < N_{MC}$

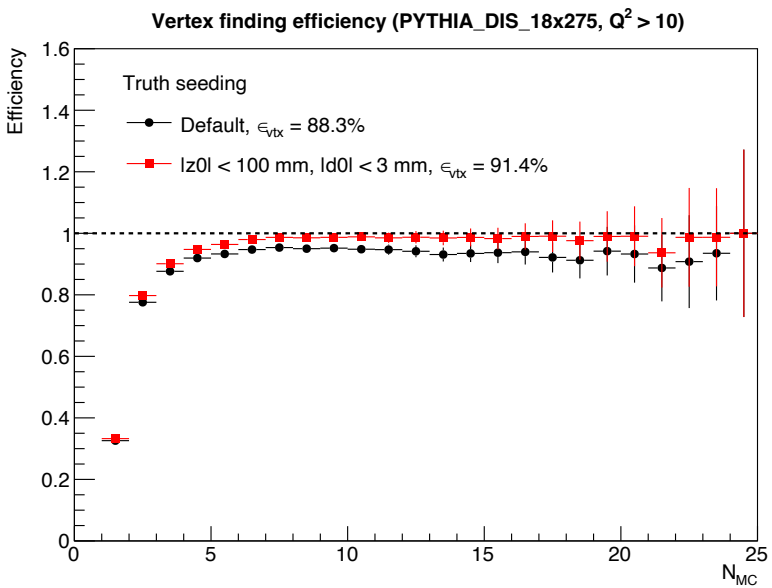
Vertex finding efficiency

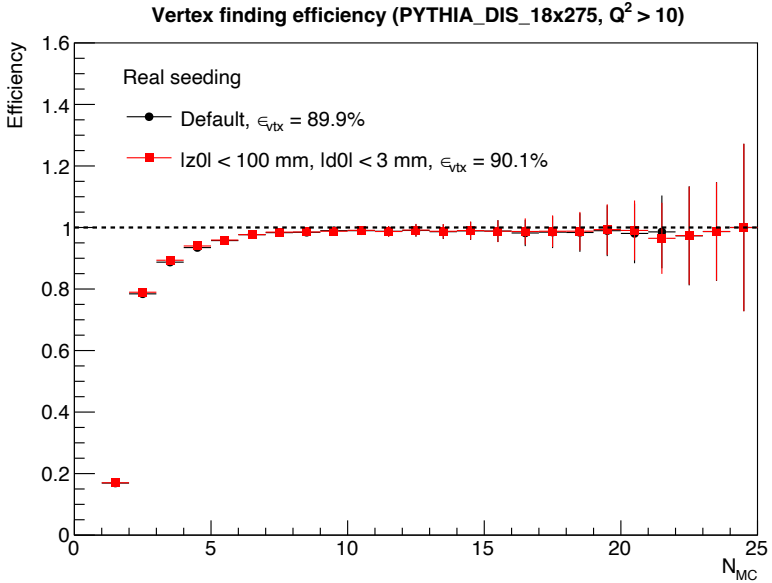
Vertex finding efficiency vs. N_{MC}

Truth seeding

Δr < 1 mm

Real seeding





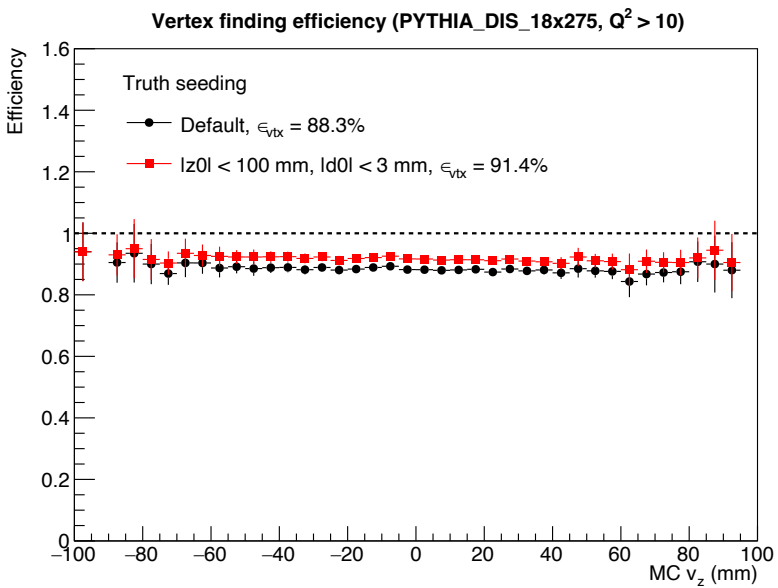
- Truth seeding: ~3% better efficiency than default with tuned track selection cuts
- Real seeding: little difference between default and tuned track cuts

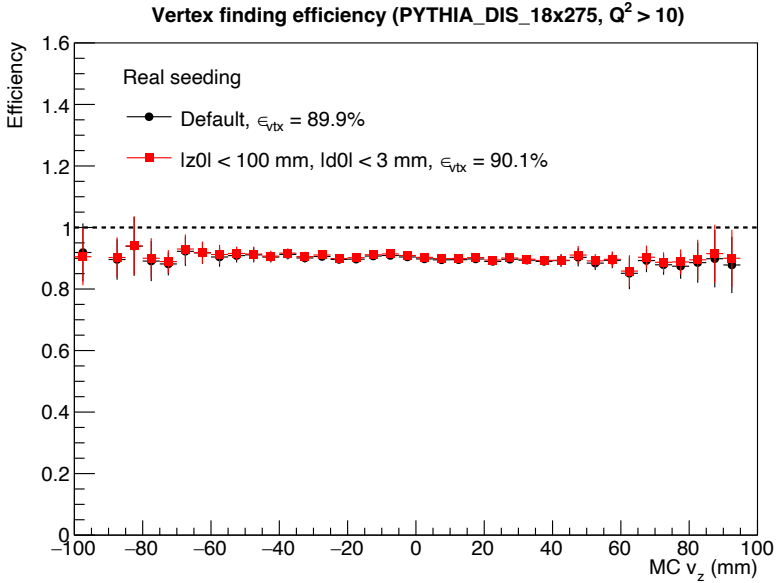
Vertex finding efficiency vs. v_z

Truth seeding

$\Delta r < 1$ mm

Real seeding

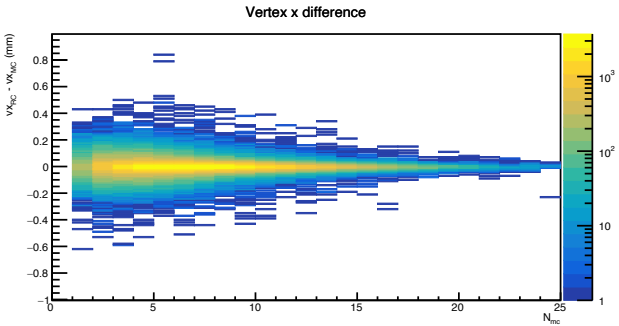


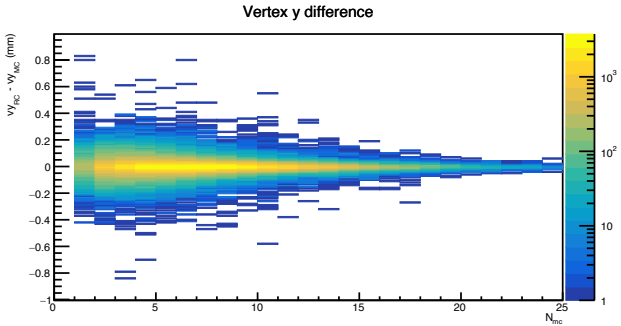


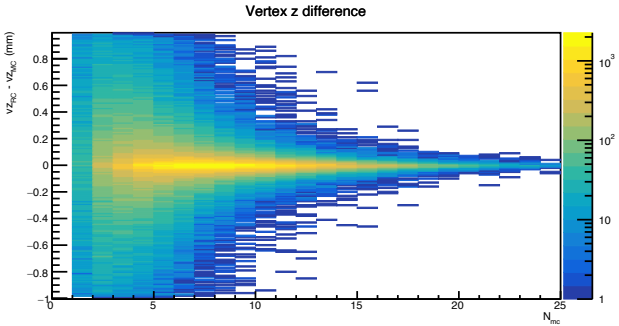
- No strong v_z dependence
- ~1% lower efficiency with real seeding compared to truth seeding for tuned track cuts

Vertex resolution

Vertex difference vs. N_{MC}

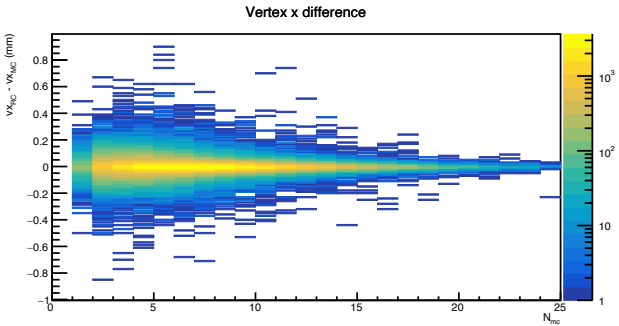


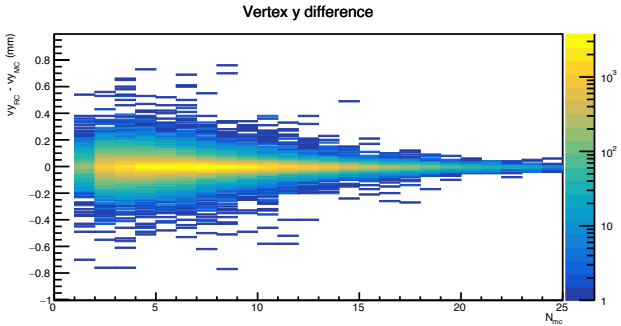


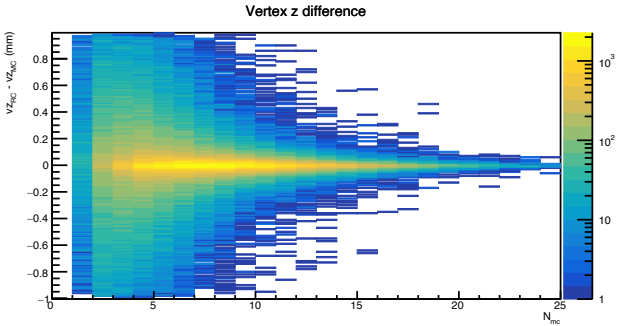


Truth seeding: default

Vertex difference vs. N_{MC}







Real seeding: default

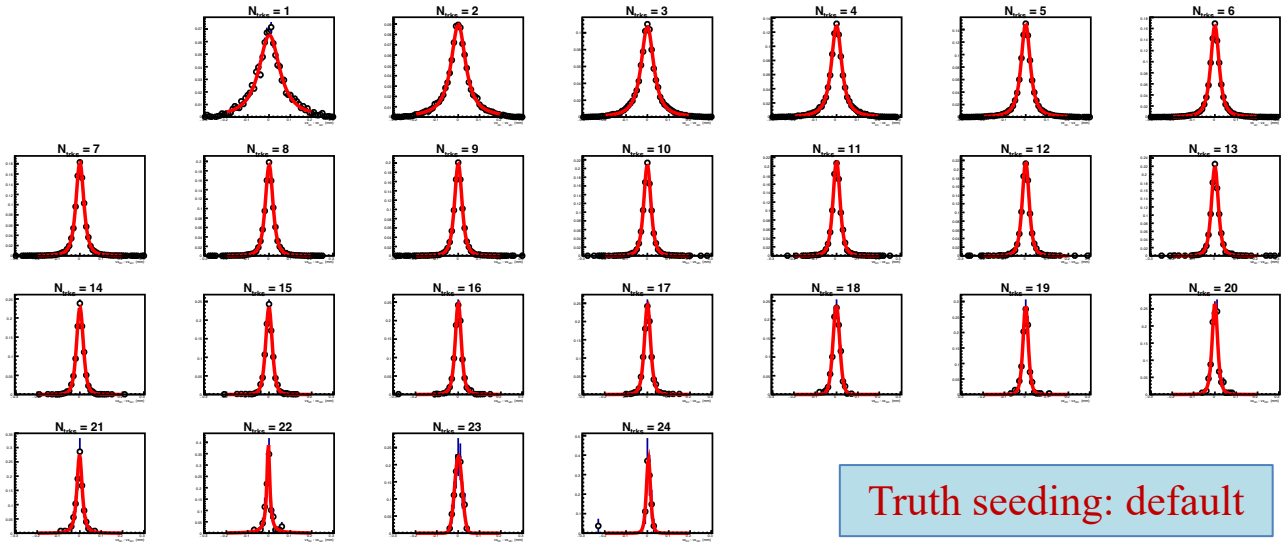
Fitting function

- Due to the significant tails seen in the vertex difference distributions, use *Student's t-distribution* for fitting.

$$f(t) = \frac{\Gamma\left(\frac{\nu+1}{2}\right)}{\sqrt{\pi\,\nu}\,\Gamma\left(\frac{\nu}{2}\right)}\left(1+\frac{t^2}{\nu}\right)^{-(\nu+1)/2},$$

- It is essentially a Gaussian function with a tail. When $\nu \to \infty$, it becomes the Gaussian function.

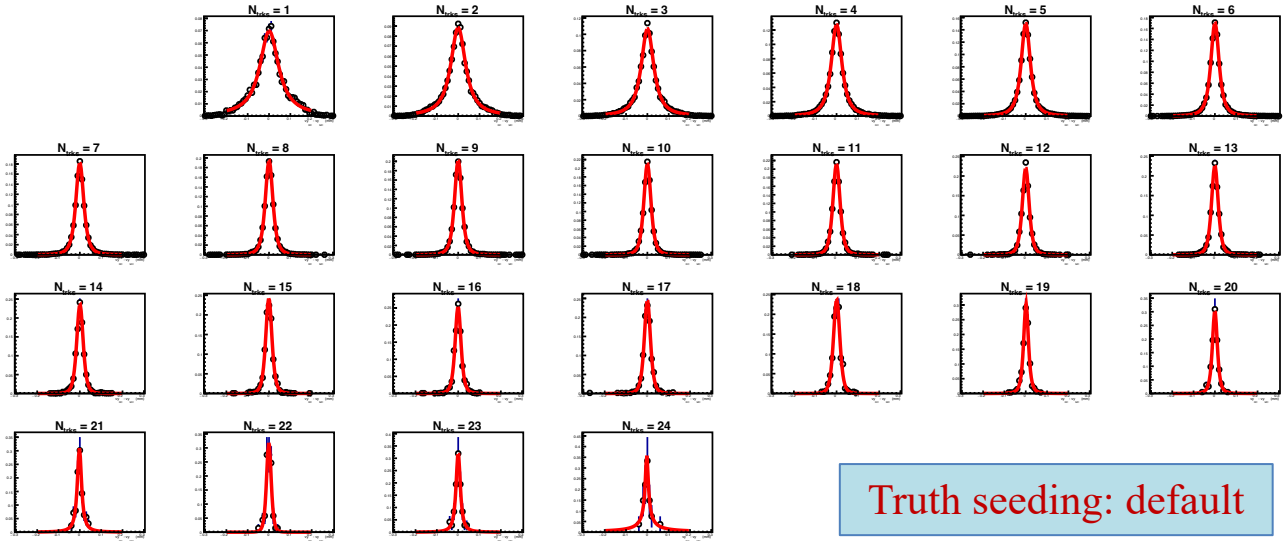
Fit v_x difference in N_{MC} bins



Truth seeding: default

✓ Fitting works well

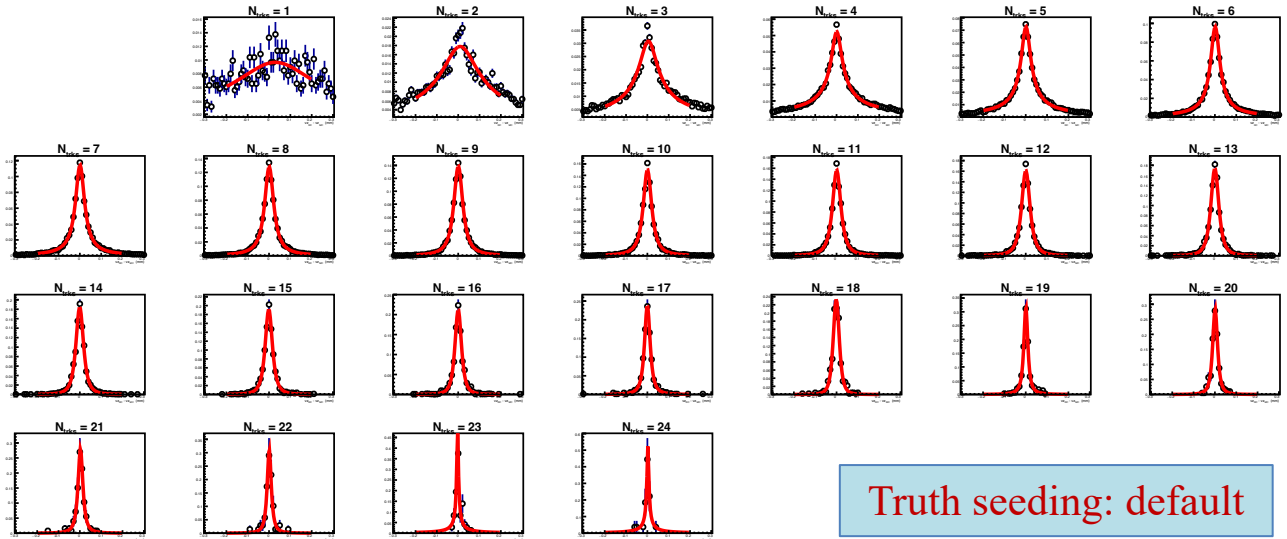
Fit v_y difference in N_{MC} bins



Truth seeding: default

✓ Fitting works well

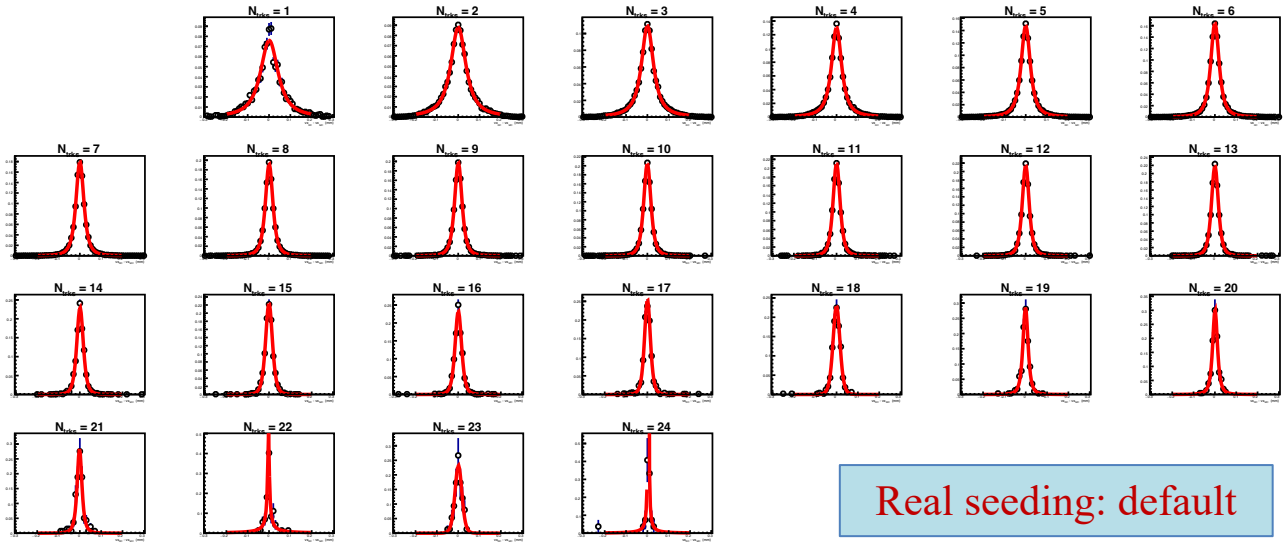
Fit v_z difference in N_{MC} bins



Truth seeding: default

✓ Fitting does not work well for $N_{MC} < 4$. Will check distribution RMS as well.

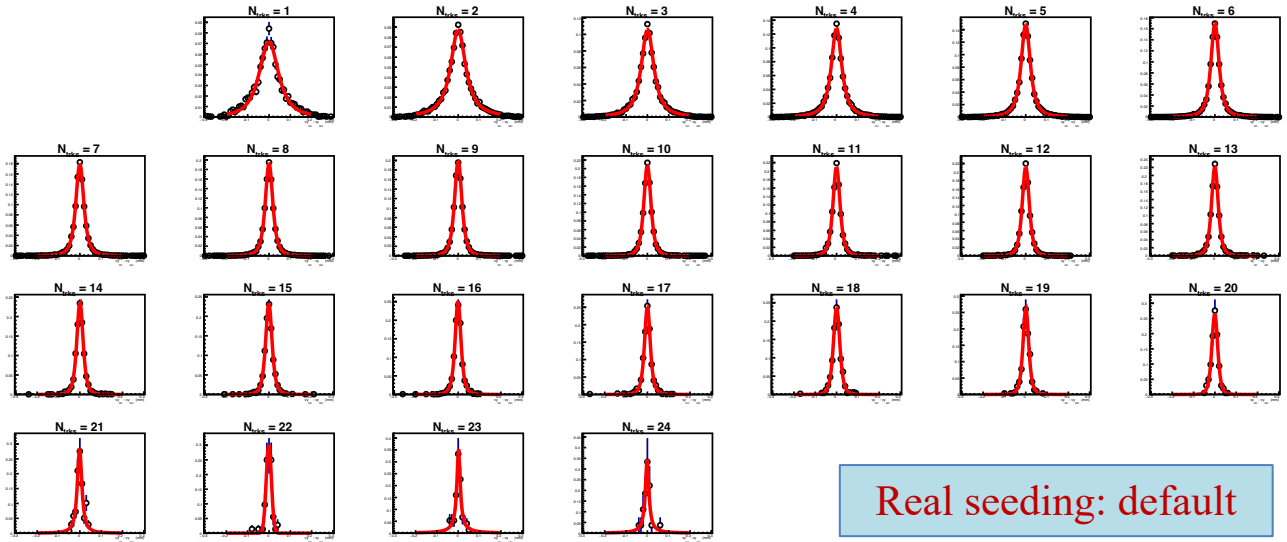
Fit v_x difference in N_{MC} bins



Real seeding: default

✓ Fitting works well

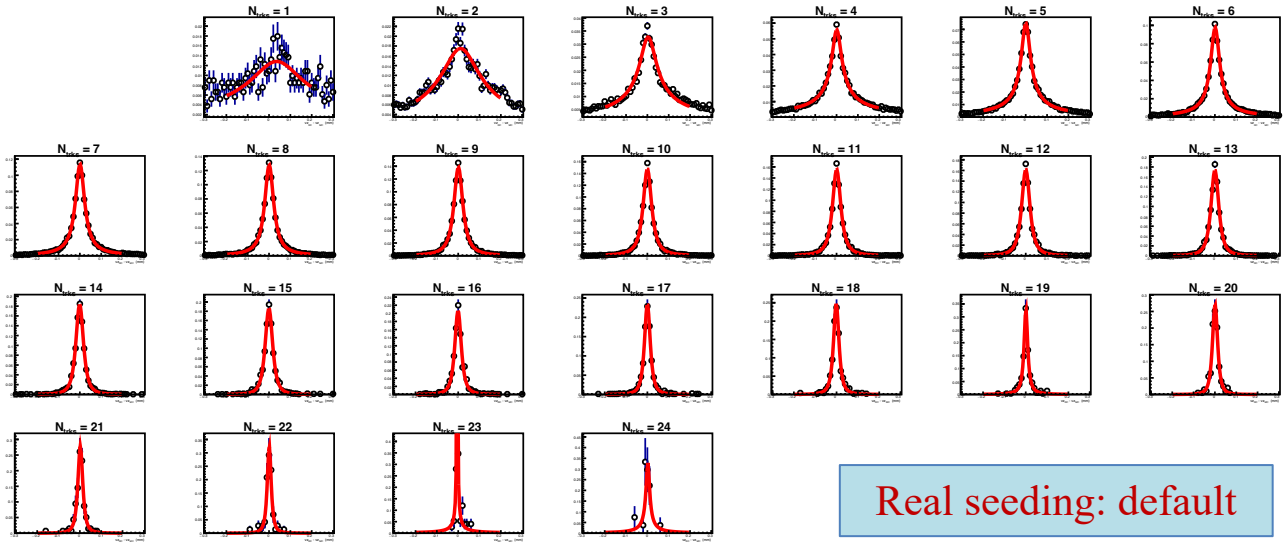
Fit v_y difference in N_{MC} bins



Real seeding: default

✓ Fitting works well

Fit v_z difference in N_{MC} bins

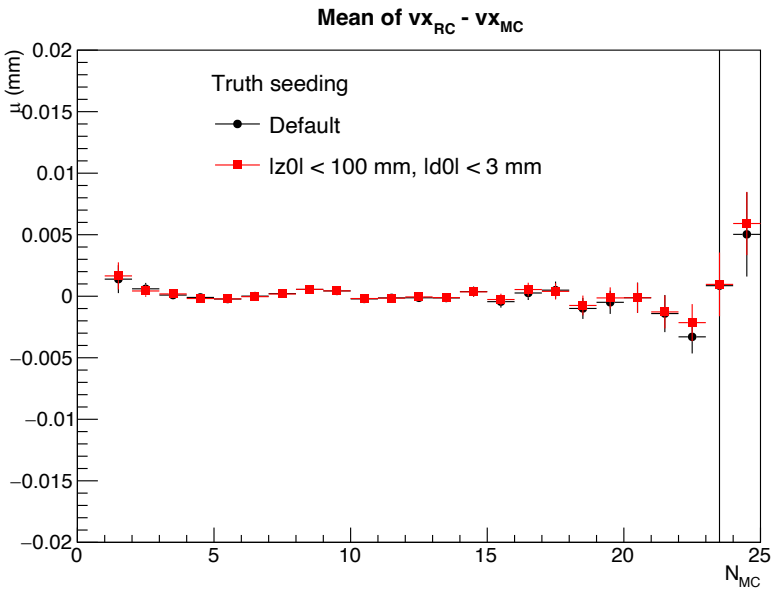


Real seeding: default

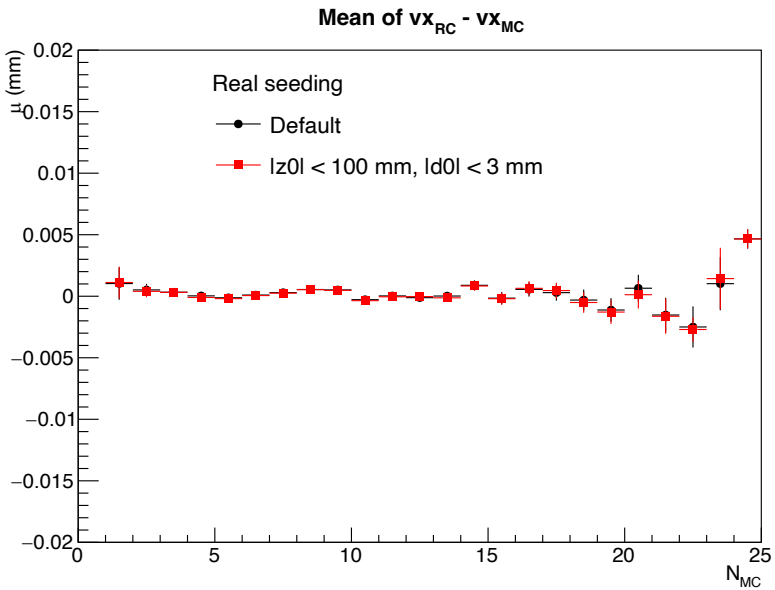
✓ Fitting does not work well for $N_{MC} < 4$. Will check distribution RMS as well.

Mean of v_x difference

Truth seeding

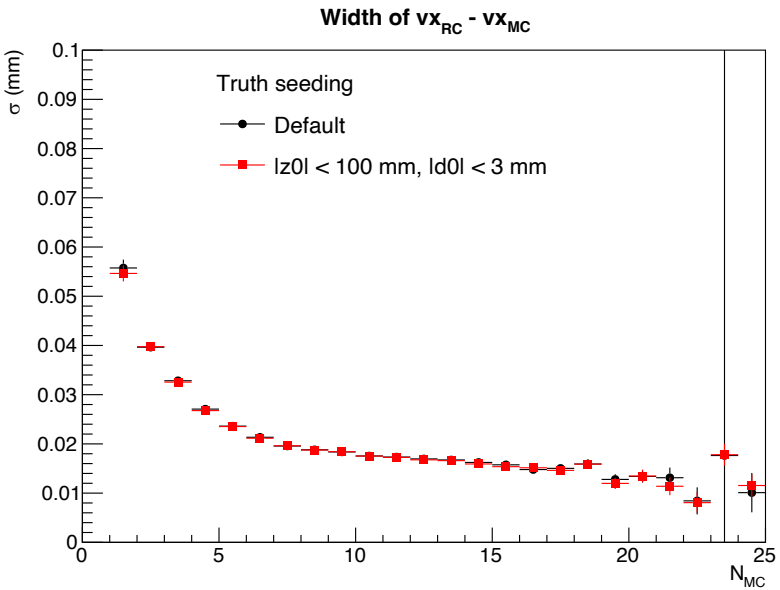


Real seeding

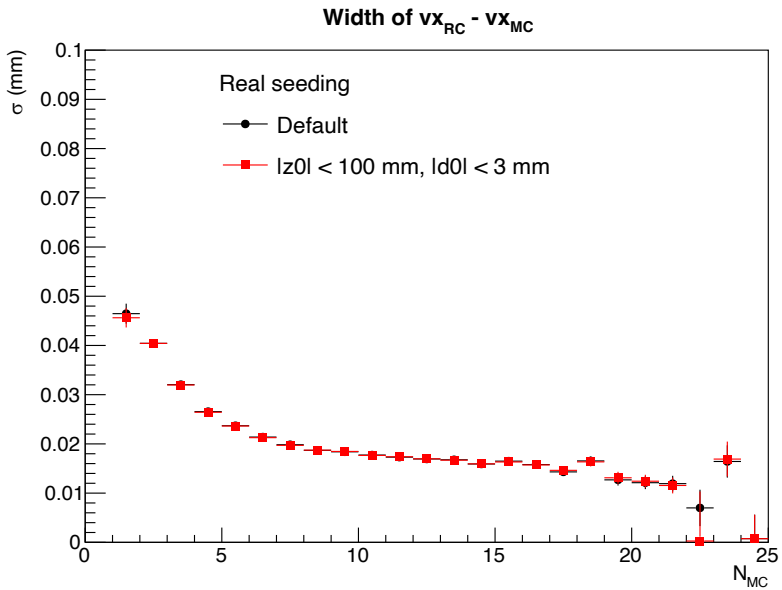


Sigma of v_x difference

Truth seeding

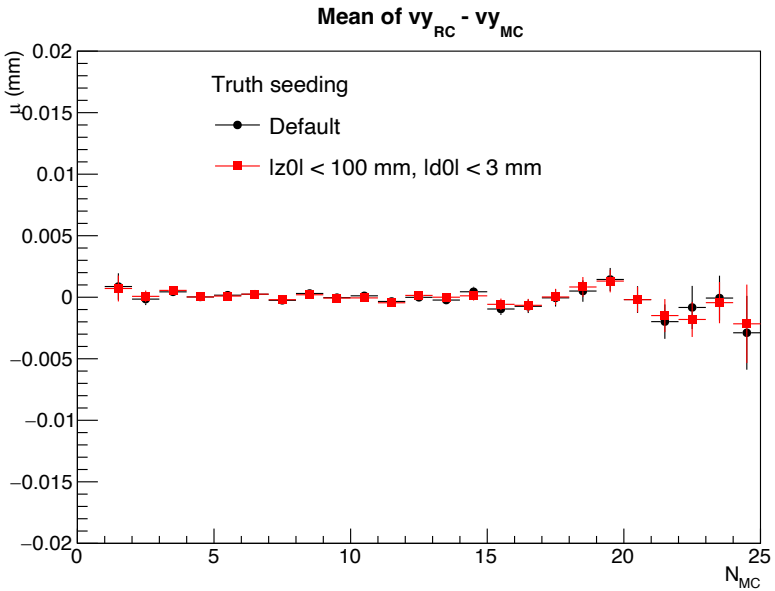


Real seeding

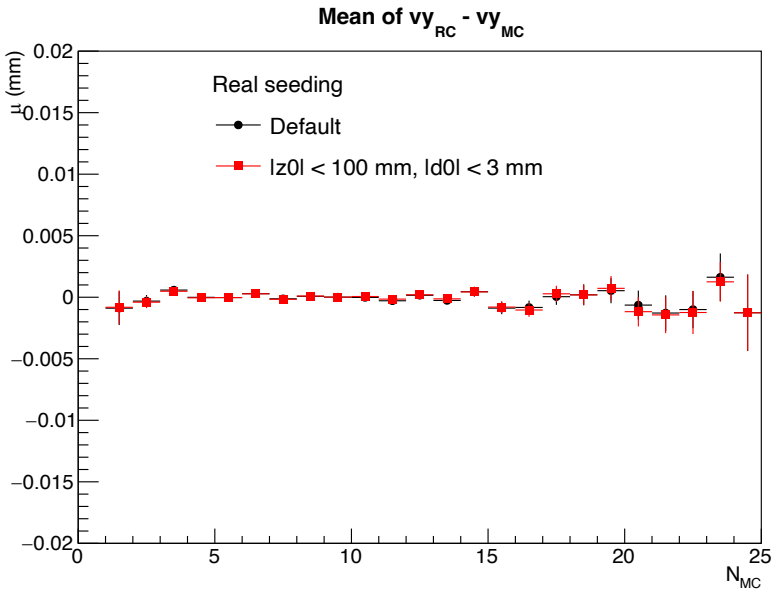


Mean of v_y difference

Truth seeding

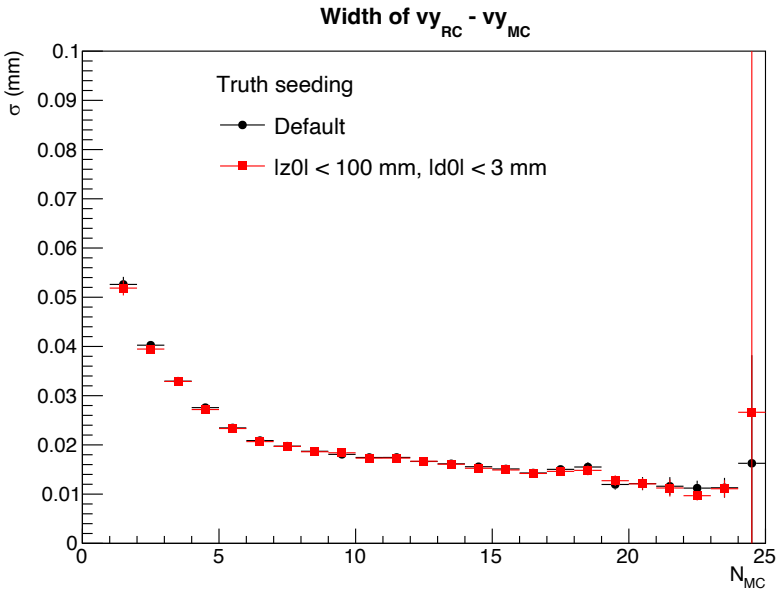


Real seeding

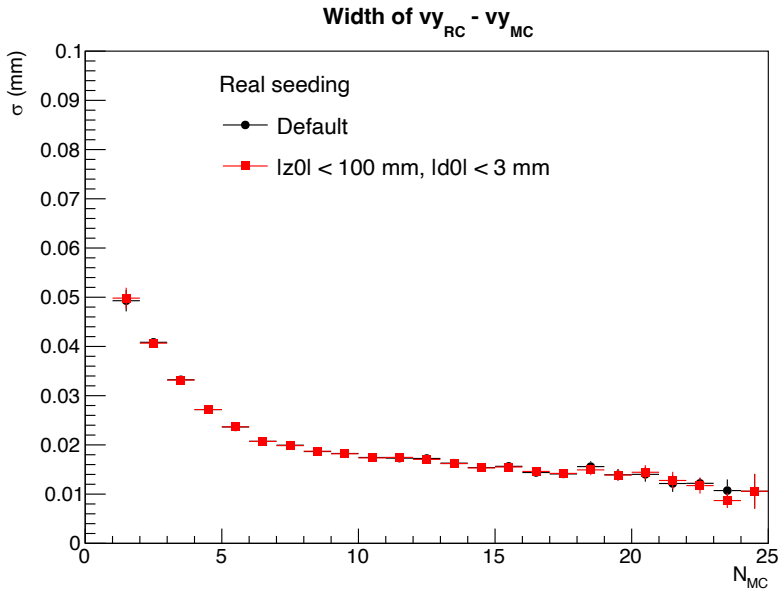


Sigma of v_y difference

Truth seeding

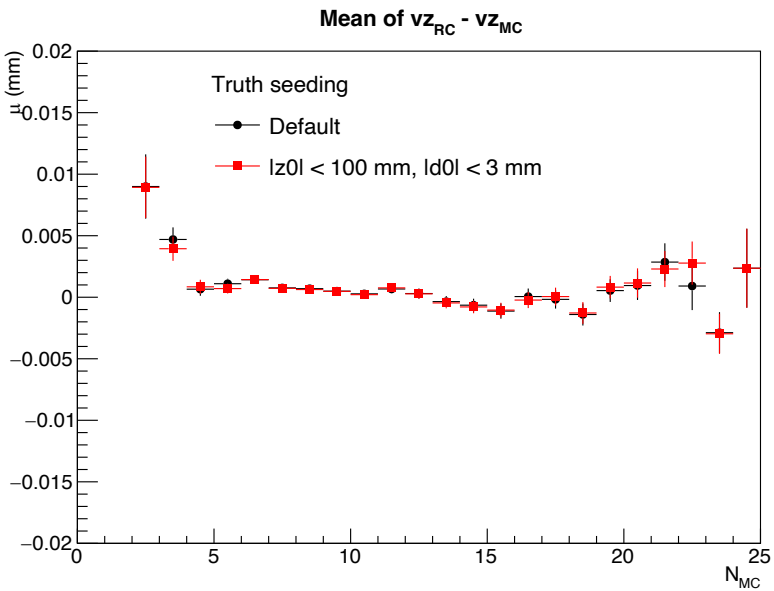


Real seeding

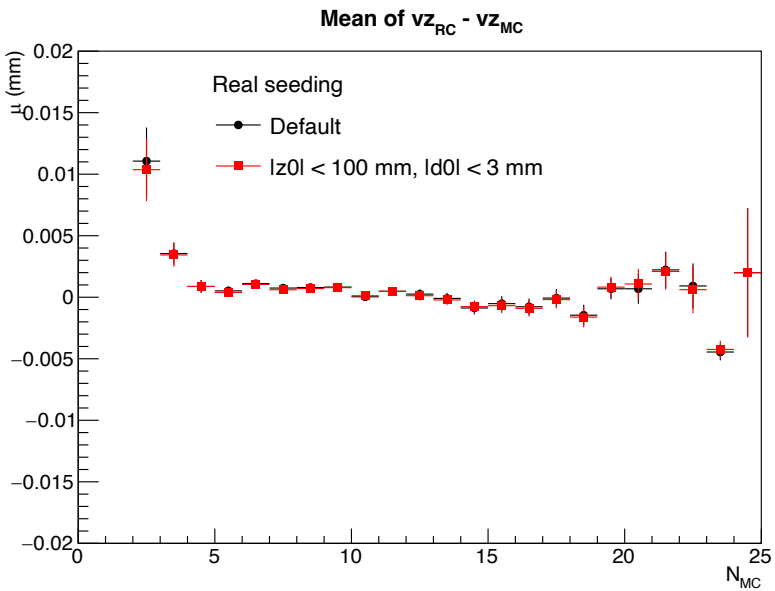


Mean of v_z difference

Truth seeding

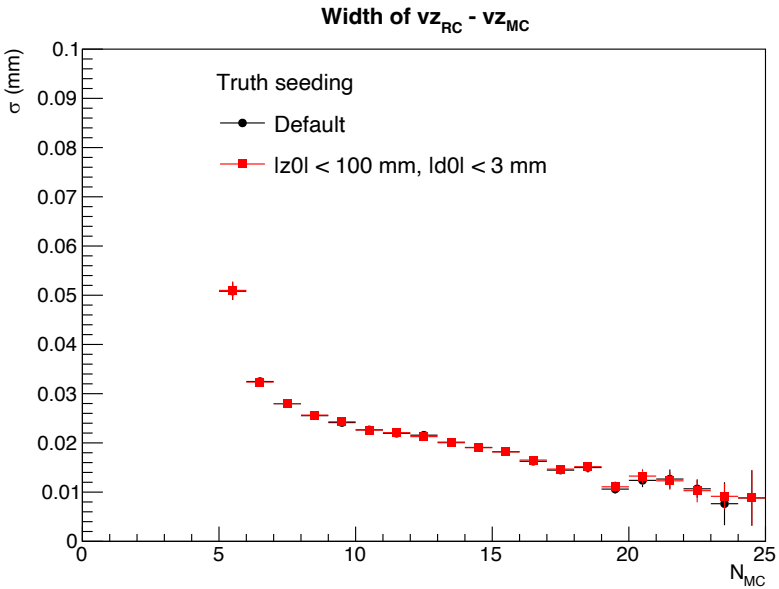


Real seeding

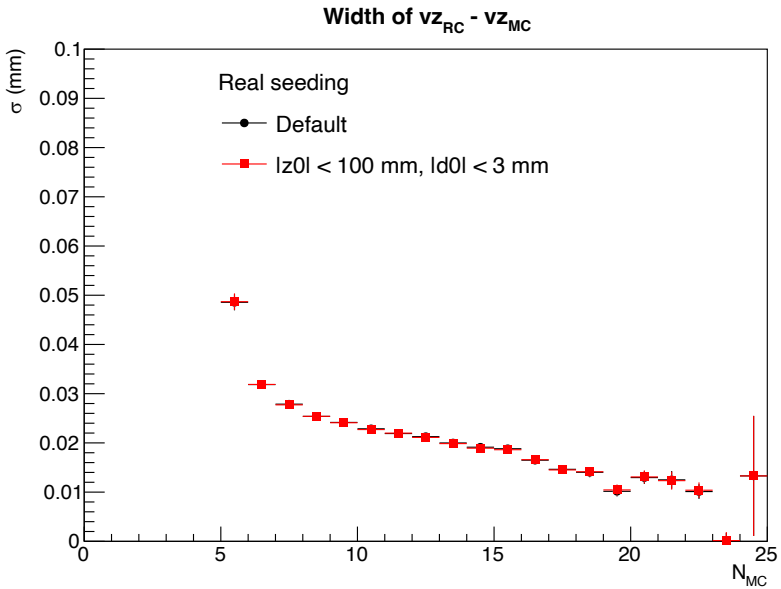


Sigma of v_z difference

Truth seeding



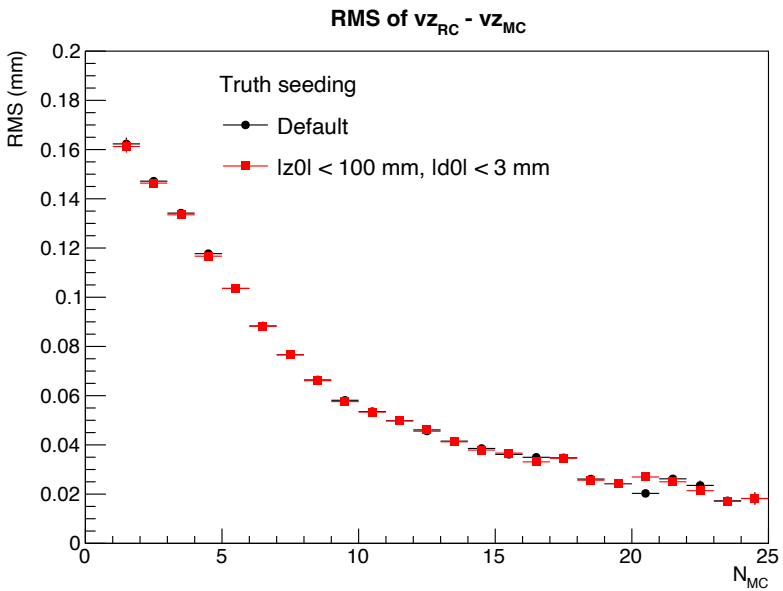
Real seeding



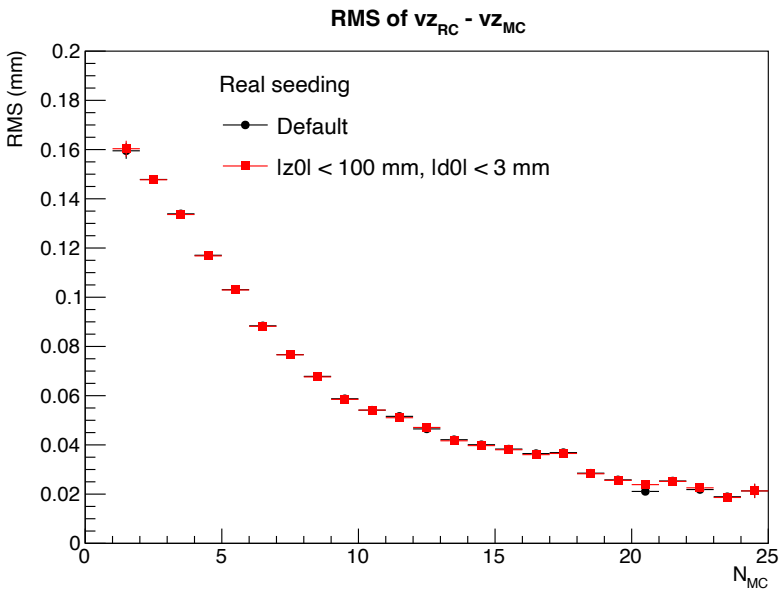
✓ Resolution at low N_{trk} values is out of scale; fitting is unstable

RMS of v_z difference

Truth seeding

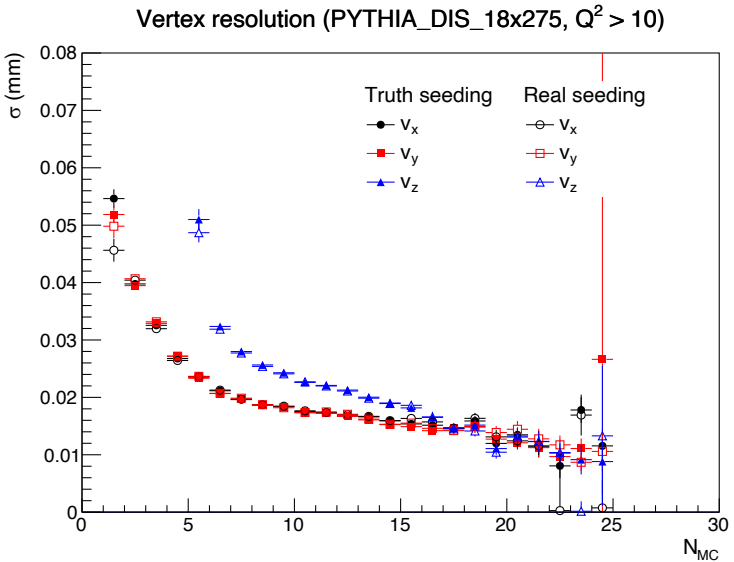


Real seeding

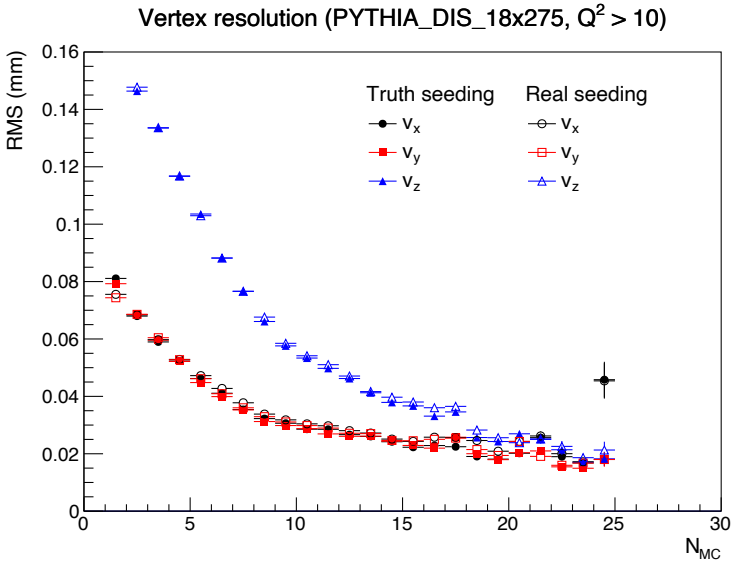


Truth vs. real seeding

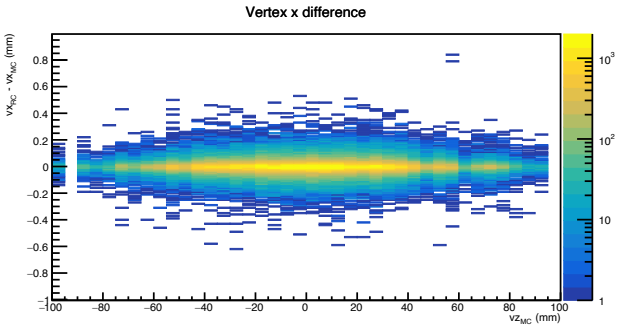
σ vs. N_{MC}

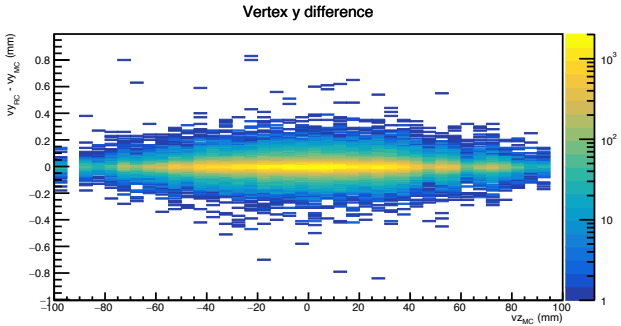


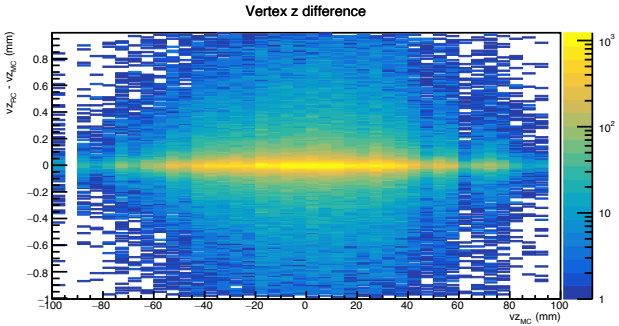
RMS vs. N_{MC}



Vertex difference vs. v_z

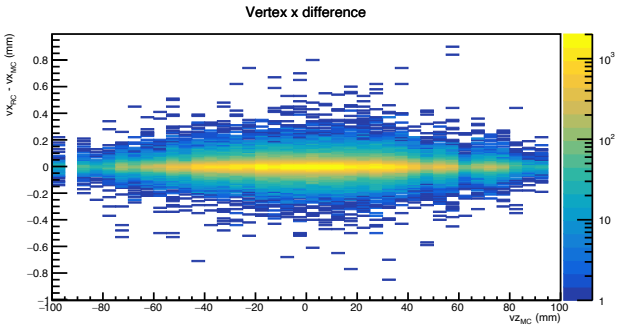


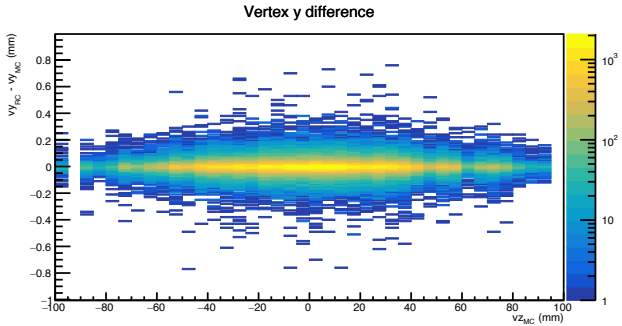


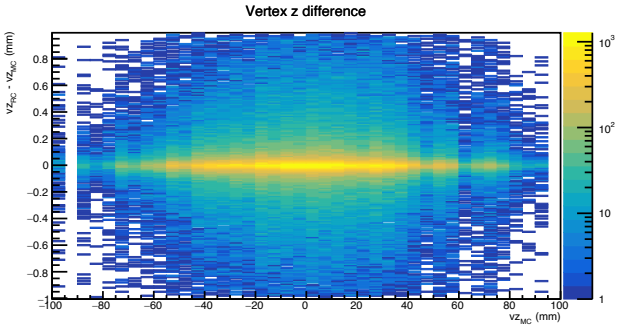


Truth seeding: default

Vertex difference vs. v_z



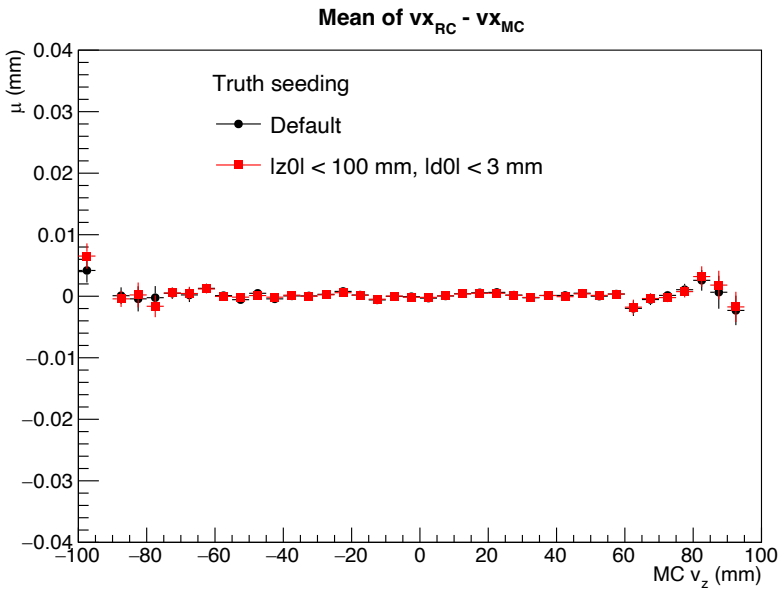




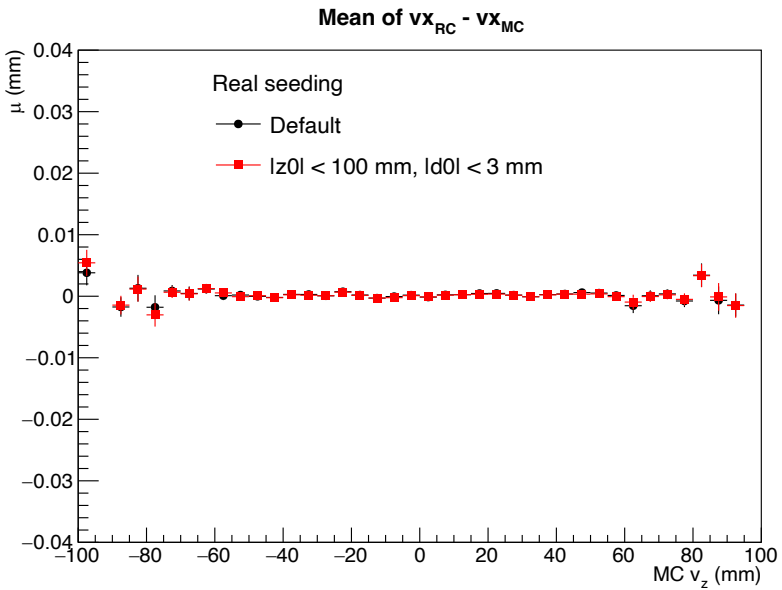
Real seeding: default

Mean of v_x difference

Truth seeding

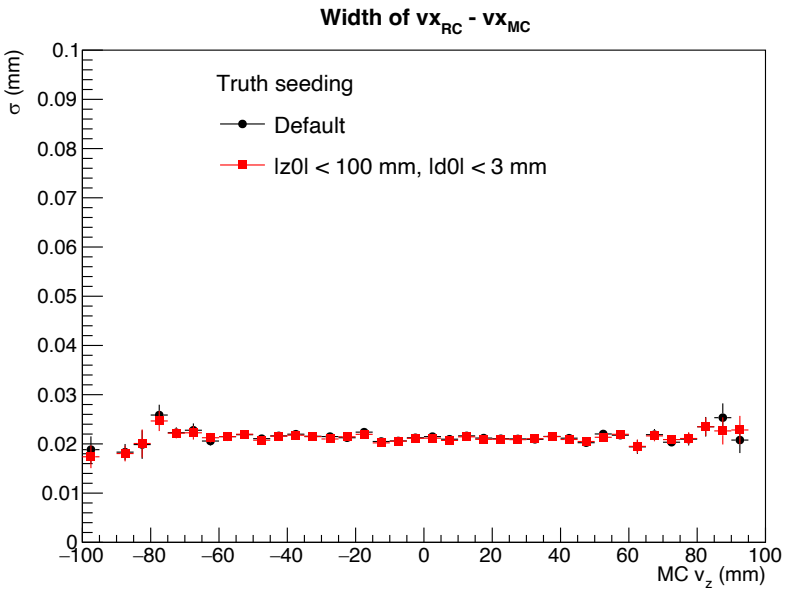


Real seeding

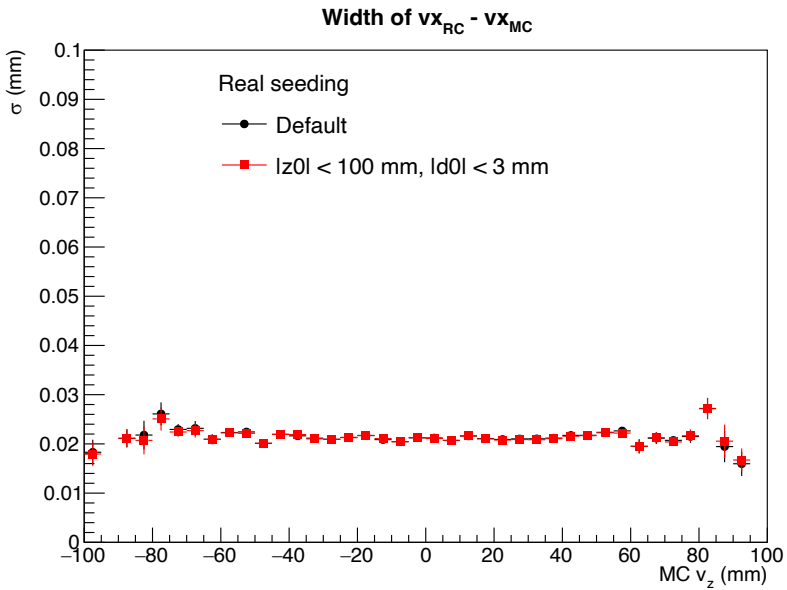


Sigma of v_x difference

Truth seeding

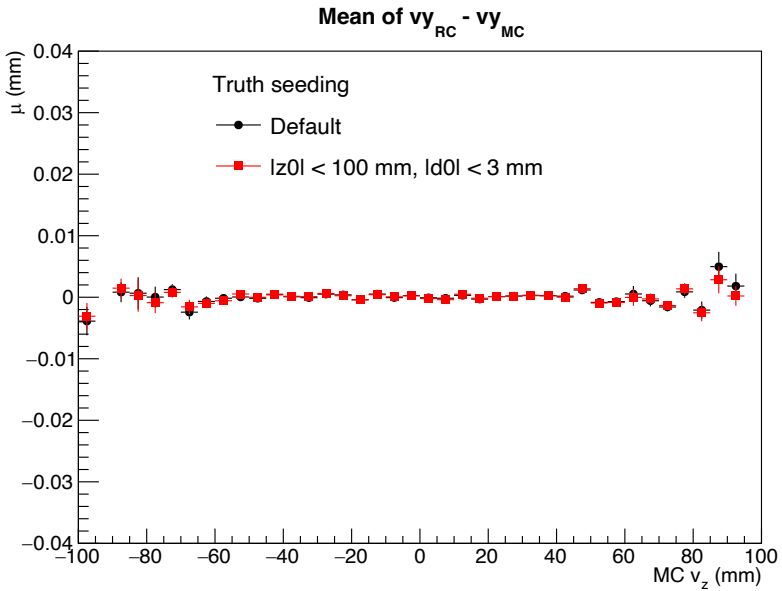


Real seeding

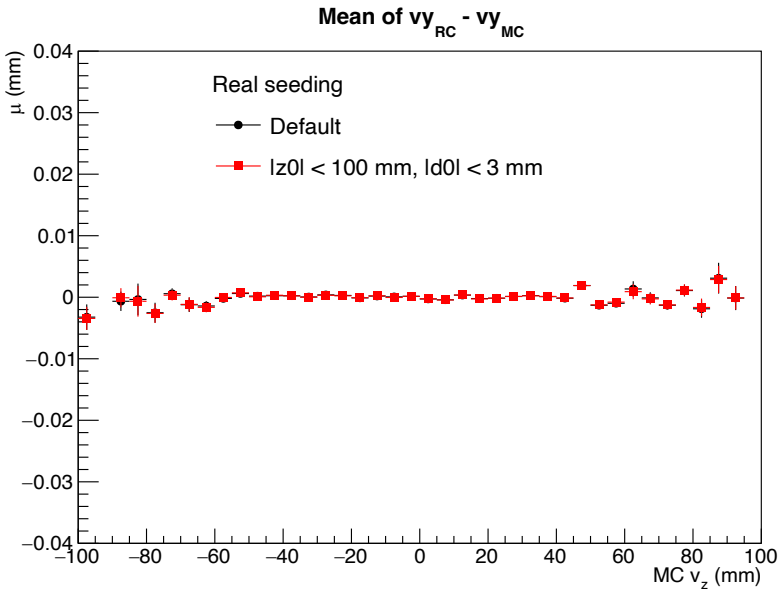


Mean of v_y difference

Truth seeding

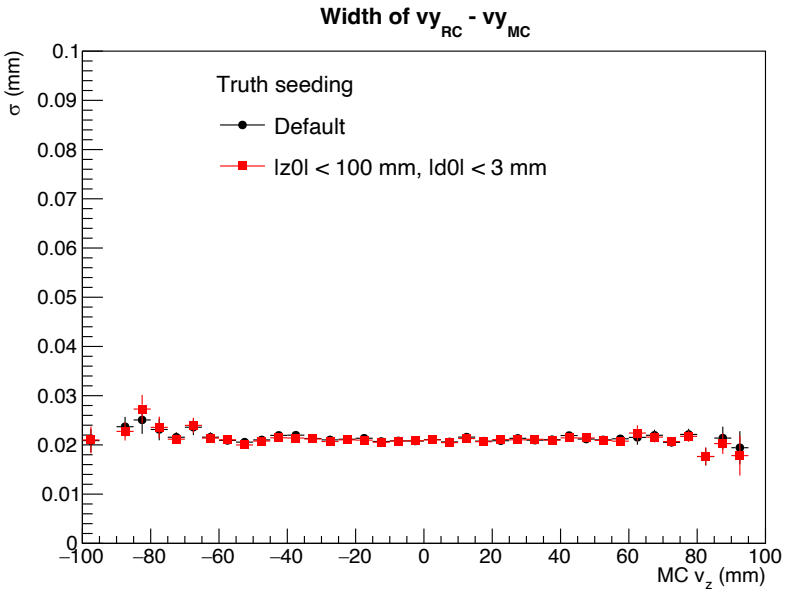


Real seeding

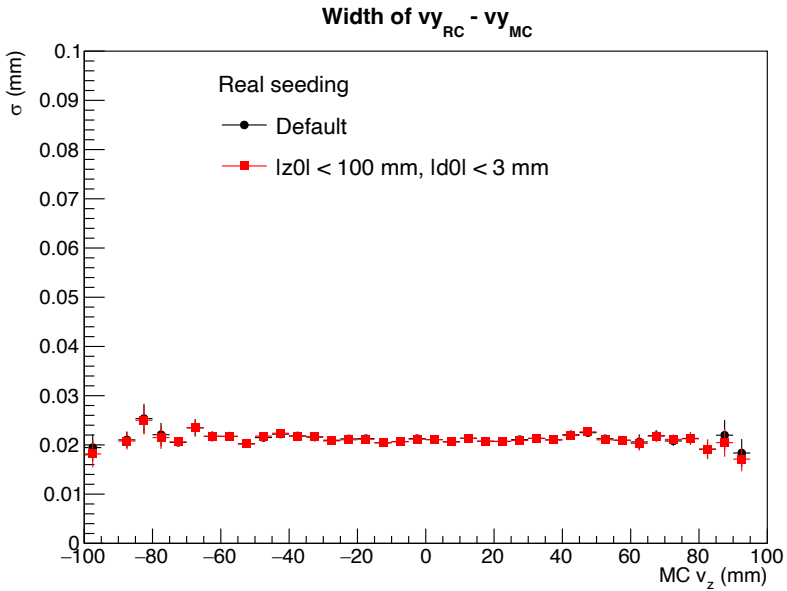


Sigma of v_y difference

Truth seeding

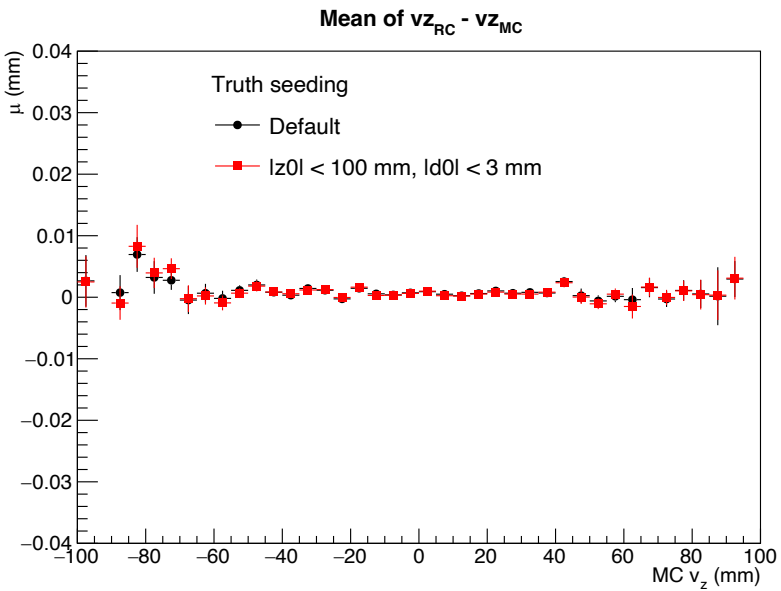


Real seeding

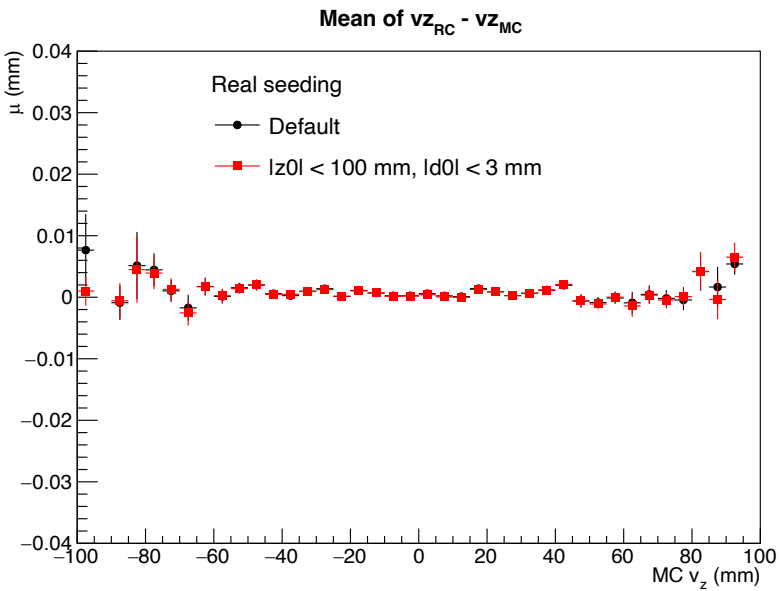


Mean of v_z difference

Truth seeding

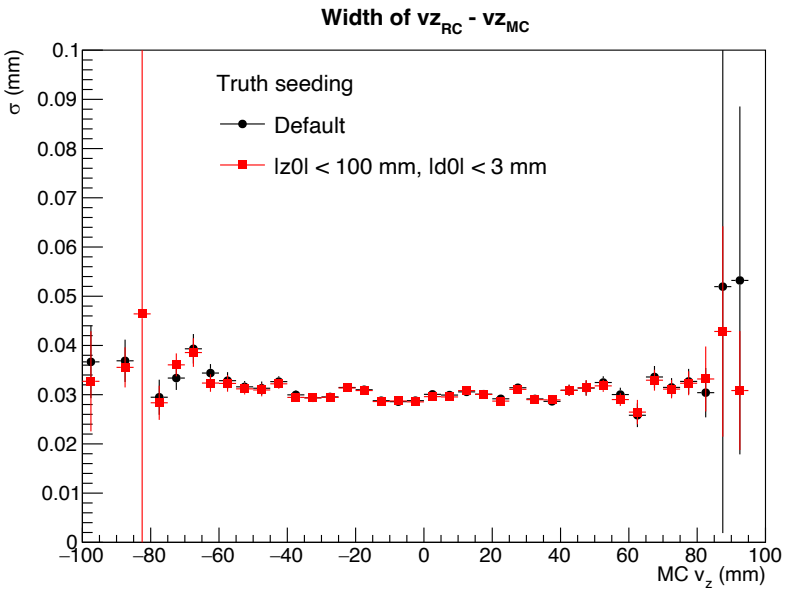


Real seeding

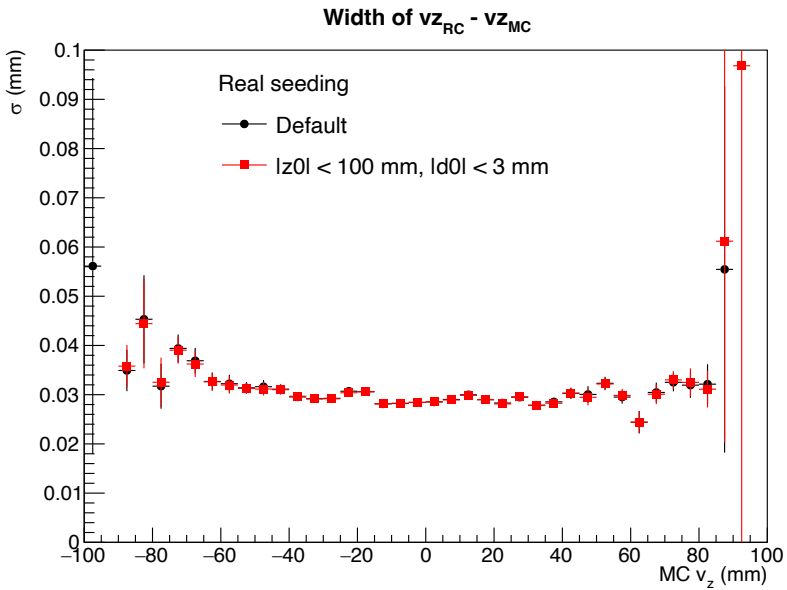


Sigma of v_z difference

Truth seeding

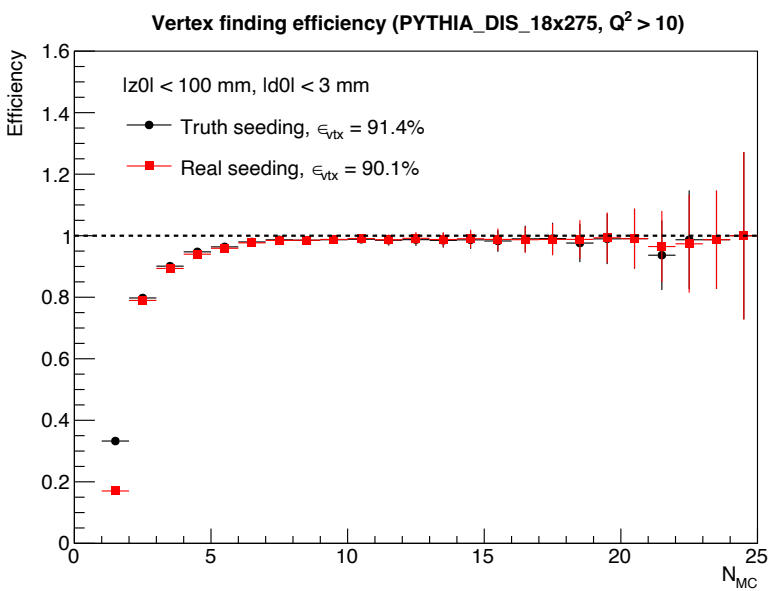


Real seeding

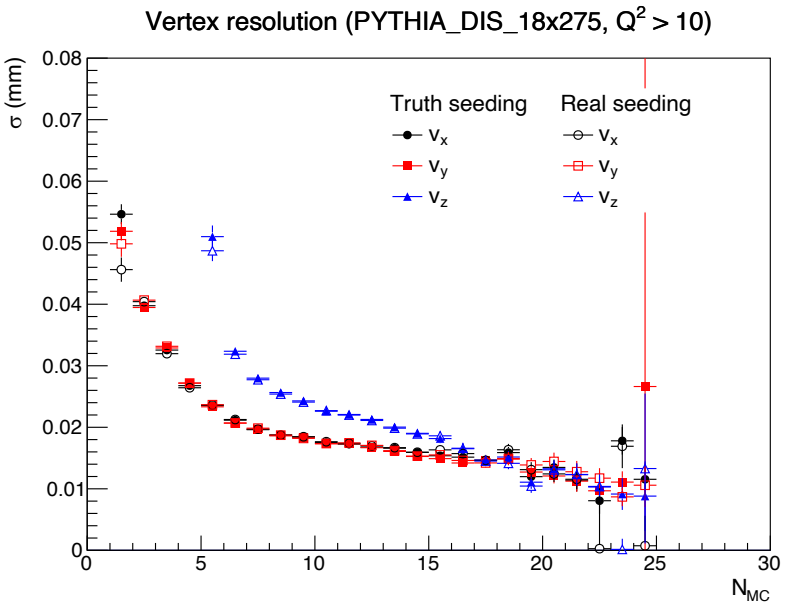


Truth vs. real seeding

Efficiency



Resolution



Summary

- There are more tracks associated with the reconstructed vertex for truth seeding than real seeding

- Vertex finding efficiency
  - Default: 88% for truth seeding and 90% for realistic seeding
  - Tuned track selection cuts can increase the efficiency for truth seeding by about 3%, but has little impact on real seeding

- Vertex resolution
  - Similar resolution for truth and real seeding
  - Different track cuts have no impact on resolution