Progress on Noise Effects on ePIC Tracking

Mito Funatsu

California EIC Consortium Meeting

University of California, Davis

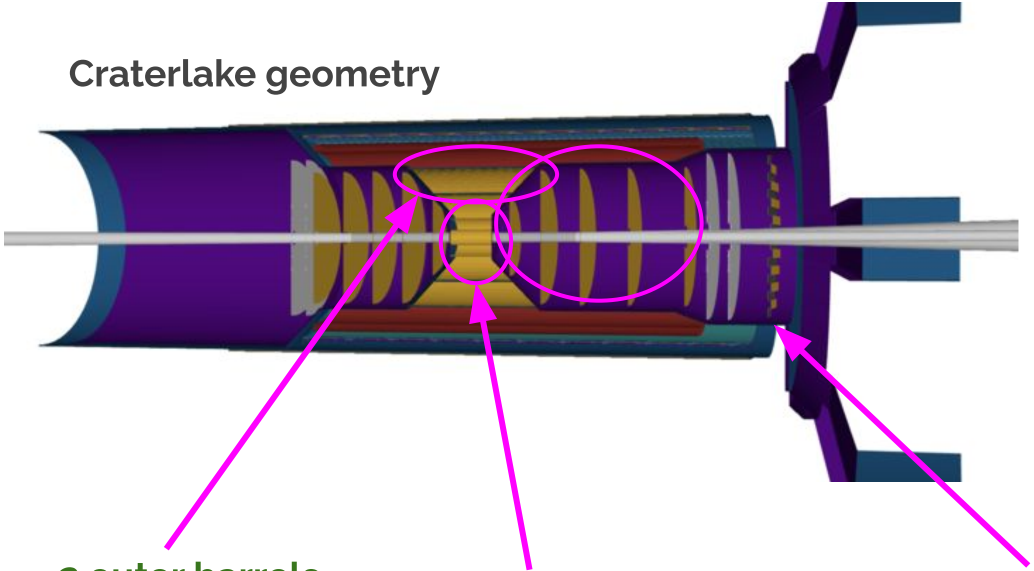
August 15, 2024

Outline

1. Silicon Vertex Tracker and MAPS sensors
2. Tracking performance study procedure
3. Progress on noise implementation
4. Summary and next steps

ePIC Detector & Silicon Vertex Tracker Geometry

Craterlake geometry



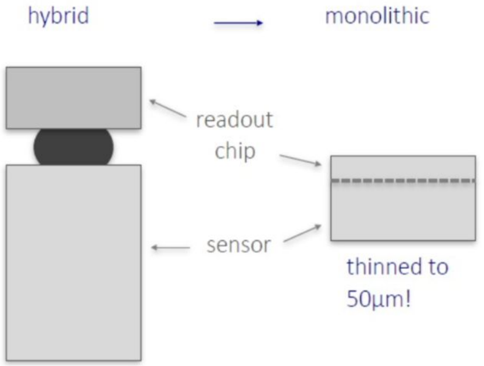
3 inner barrels
ITS3
2 outer barrels
EIC-LAS (Large Area Sensor)
5 disks (forward & backward)
EIC-LAS

ITS3 65nm MAPS (Monolithic Active Pixel Sensors)

- 65nm MAPS Sensors being developed in collaboration with ALICE ITS3.

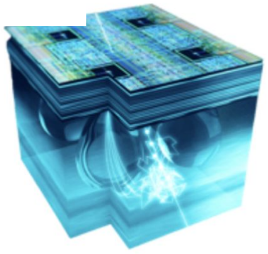
Why MAPS?

- High granularity
- Low power consumption
- Low material budget
- High spatial resolution

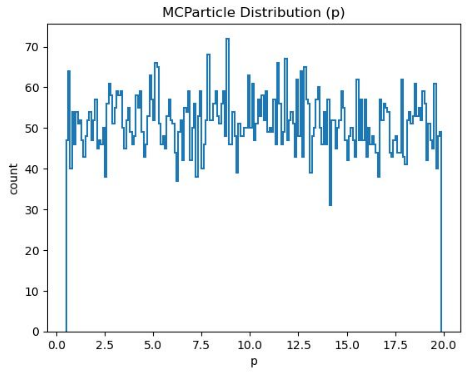


Simulations based on MAPS with 20um x 20 um pixels*

*EIC-LAS is based on the ITS3 design (no changes to pixel matrix), therefore their performance is assumed to be the similar.

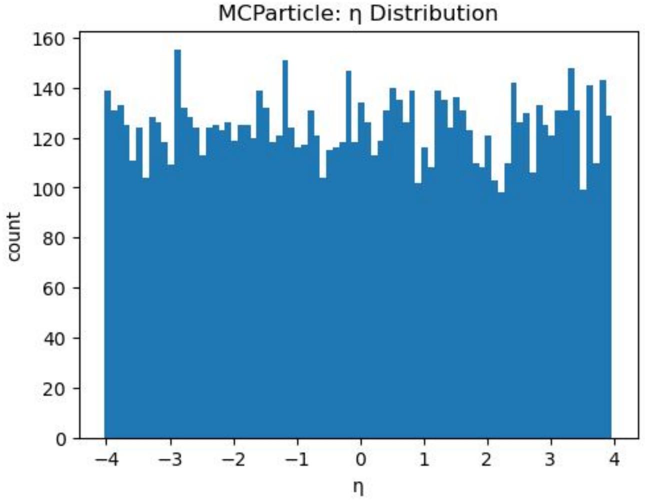


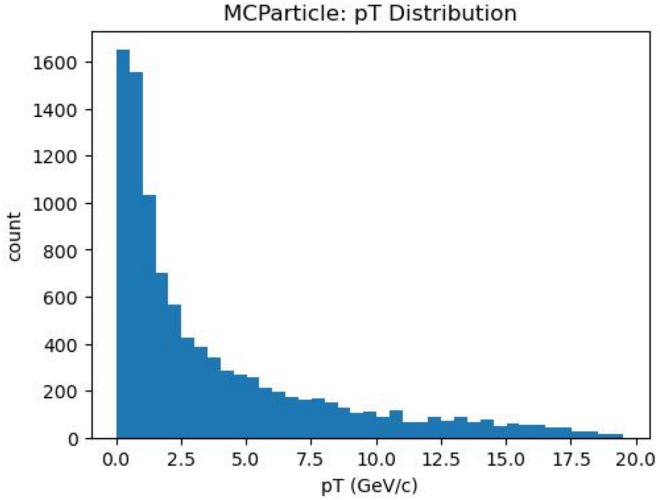
Tracking Performance Study Procedure



→ Generate **10,000 single-muons** events in **Craterlake geometry** with momentum and pseudorapidity ranges:

a. **$0.5<p<20$ GeV/c**
b. **$-4 \leq \eta \leq 4$**





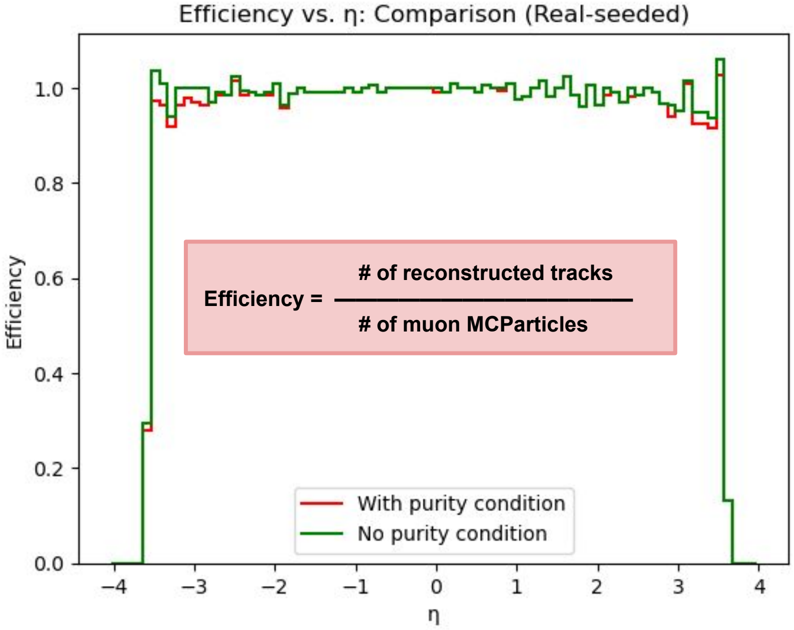
How does noise affect track reconstruction?

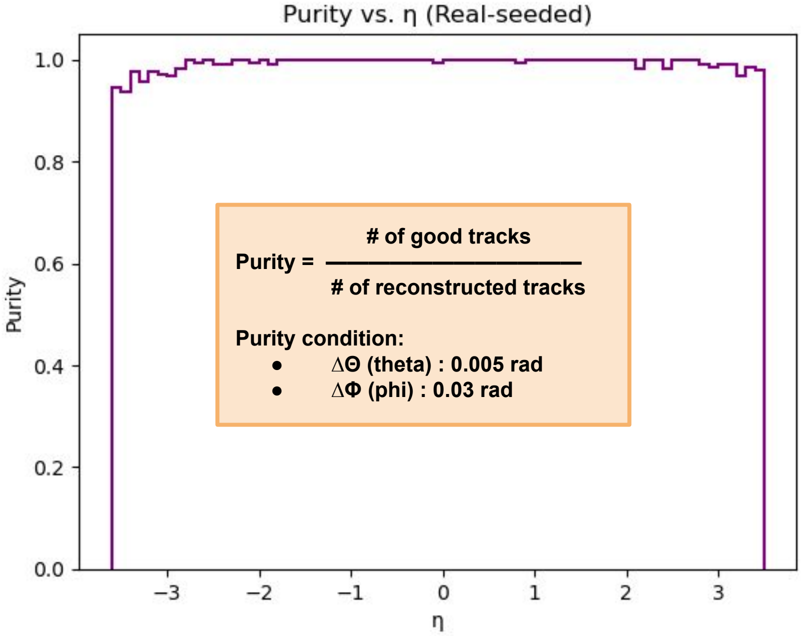
→ Compare efficiency and purity with/without noise as a function of η and p_T

Efficiency	Purity
Efficiency is the ratio: $$\frac{\textbf{\# of reconstructed tracks}}{\textbf{\# of MCParticles}}$$	**Purity** is the ratio: $$\frac{\textbf{\# of good** tracks}}{\textbf{\# of reconstructed tracks}}$$ **A reconstructed track is considered **good** if it can be matched with an MCParticle within: • **ΔΘ (theta) : 0.005 rad** • **ΔΦ (phi) : 0.03 rad**

No noise

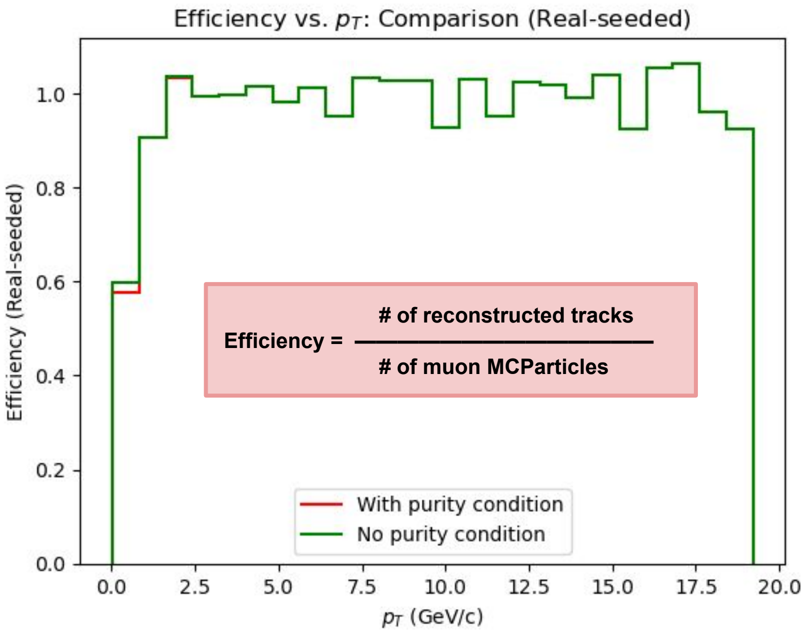
Real-Seeded Efficiency and Purity Against Pseudorapidity (η)

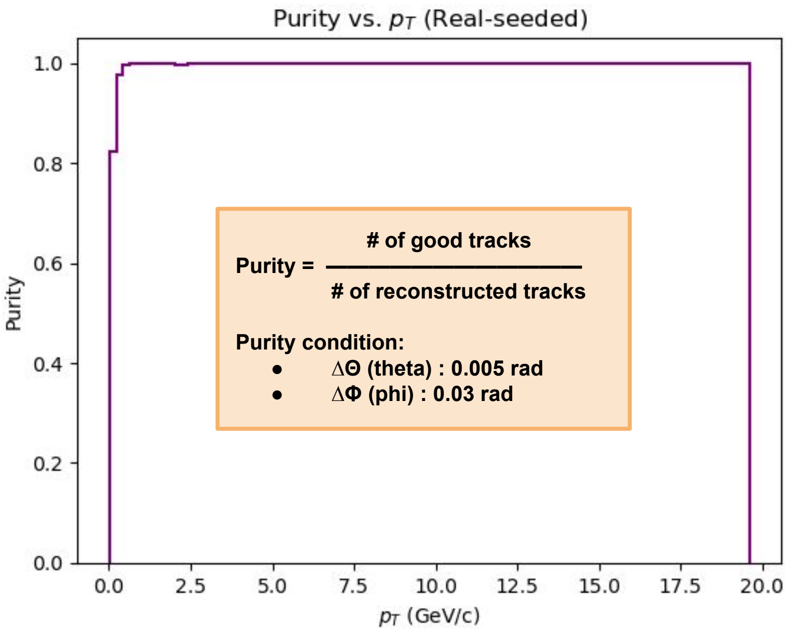




No noise

Real-Seeded Efficiency and Purity Against Transverse Momentum (p_T)





Noise Implementation: Fake-Hit Rate (FHR)

Noise: an electronic signal in the absence of external stimuli

Fake-hit rate: noise hits/event/pixel

Yellow Report p.441 (2021):

- Preliminary specifications for EIC SVT MAPS sensor:
  - FHR < 10^{-5} /event/pixel

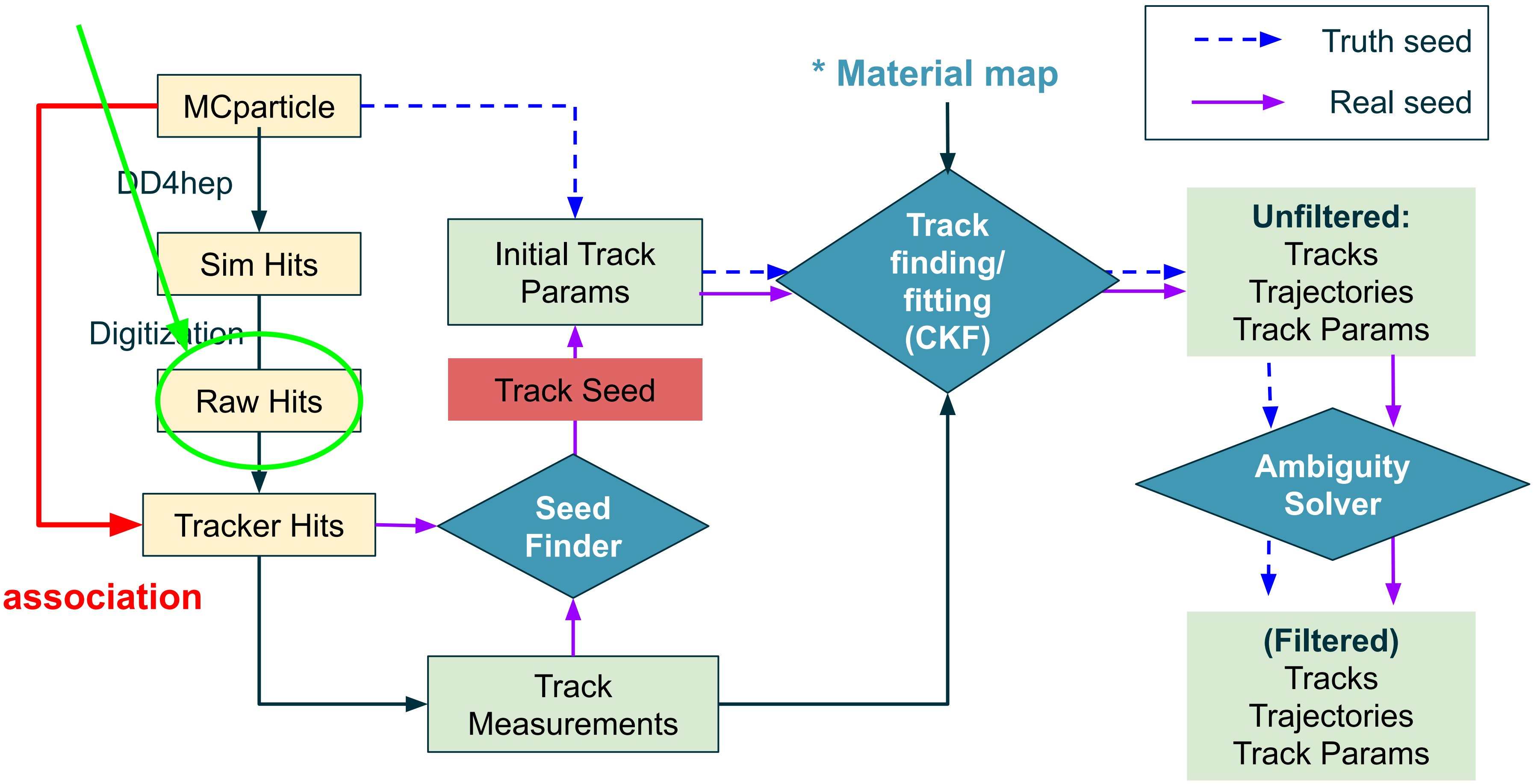
ITS3 TDR p.44 (2024):

- General requirements for the ITS3 upgrade:
  - FHR < 2-5 x 10^{-7} /event/pixel

Currently **NO** noise in simulation

Noise Implementation

Red: work in progress



Digitization/Hit Reconstruction Procedure

Simulated Hits

1. CellID (a unique pixel identifier)
2. edep (energy deposited)
3. time

Digitization/Hit Reconstruction

1. Apply energy threshold (0.54kev)
2. Generalize the simulated hit position as the center of its associated cellID and specify resolution
3. **ADDITION** apply noise for SVT according to noise hit rate

Reconstructed Hits

Work in progress

Noise Implementation Methodology*

Step 1

For each silicon **collection****, calculate the total number of pixels that would become noise hits using a sample FHR.

Step 2

Given the total number of noise hits per collection, randomly generate the appropriate amount of cellID's to be registered as noise (raw) hits.

Step 3

Reconstruct noise hits along with the raw hits from simulation, and study the tracking performance with efficiency and purity.

*Recent beam test shows average clustering size for a typical pixel threshold will not be distinctly different from the noise hit size (pixel=1), hence will not be helpful.

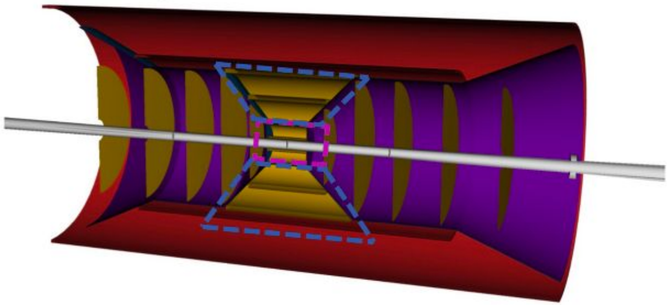
**The simulated hits get reconstructed by collection in EICrecon.

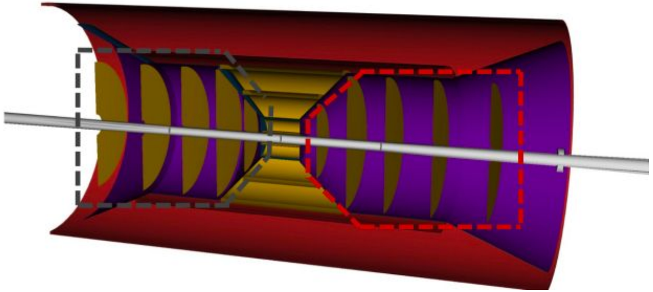
Current Estimation of Noise Hit Count

Sampled fake-hit rate: FHR < 5×10^{-7} per event per pixel.
Fake hits/event/collection: FHR x total pixels

Pixels sizes: **20x20μm²**

	Inner Barrel	Outer Barrel	Endcaps
Total pixels	8.65E+08	7.83E+09	1.18E+10
Fake hits/event	4.33E+02	3.92E+03	5.91E+03





Summary & Next Steps

Summary

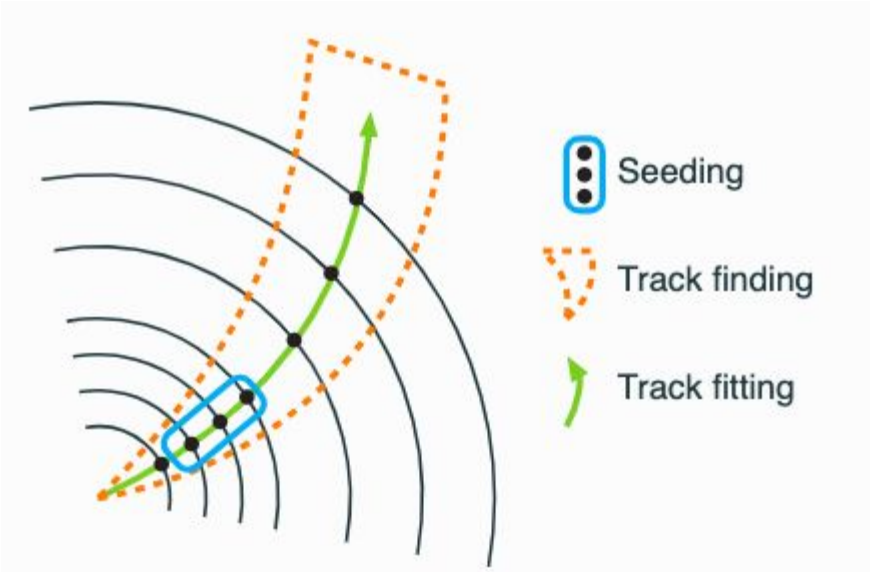
- Efficiency measures how many simulated tracks were reconstructed. For single-muon events:
    - Falls off in forward/backward pseudorapidity ranges
    - Falls off in low p_T ranges
- Purity is defined with geometrical constraints.
- Noise being implemented in the digitization step as random cellID's per event.

Next Steps:

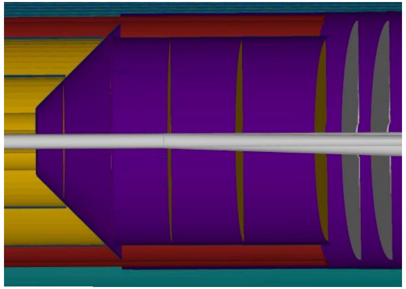
1. Implement cellID randomization algorithm in EICrecon
2. Compare efficiency and purity for noise implemented single-muon events
3. Study tracking performance for DIS events
4. Devise an alternative method for noise implementation that does not register noise hits as raw hits (if computationally expensive)

Backup

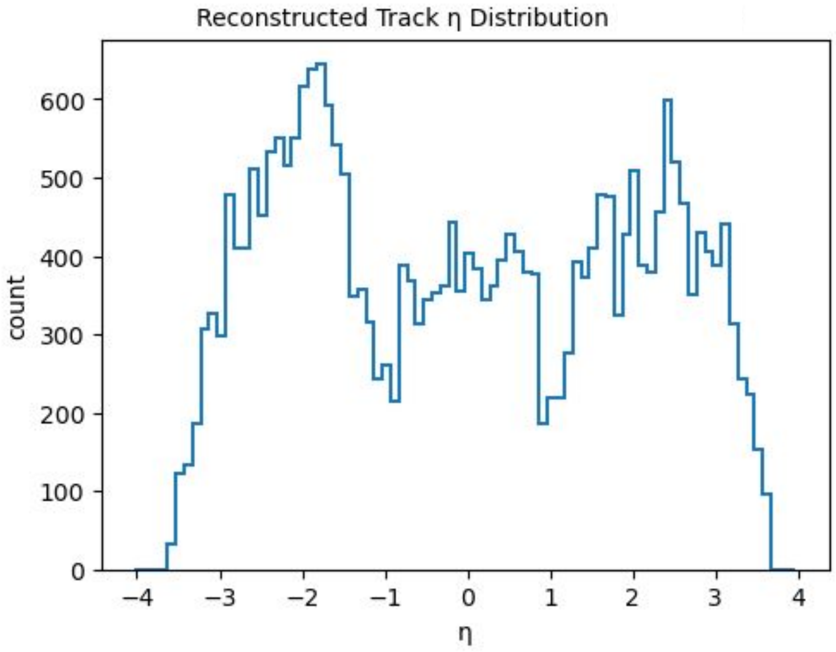
Seeding Algorithm



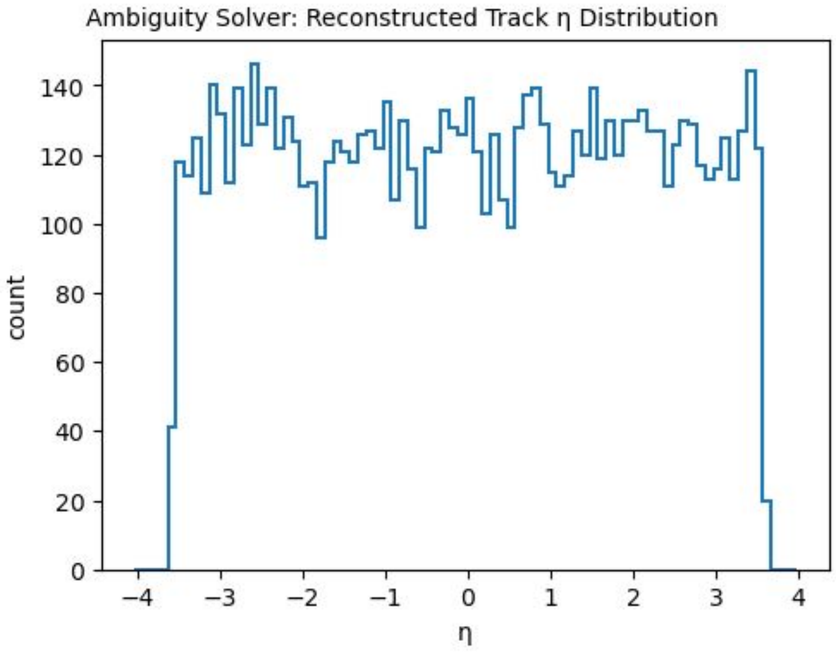
Ambiguity Solver



WITHOUT ambiguity solver

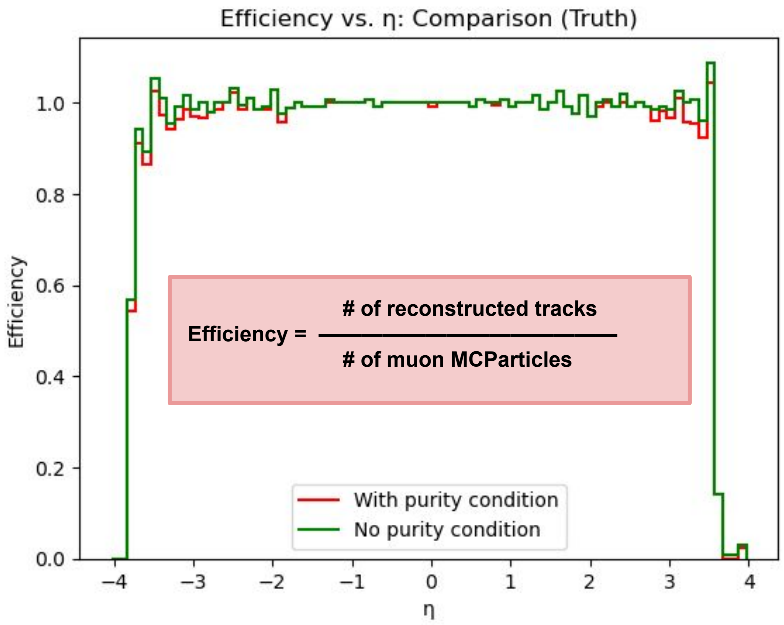


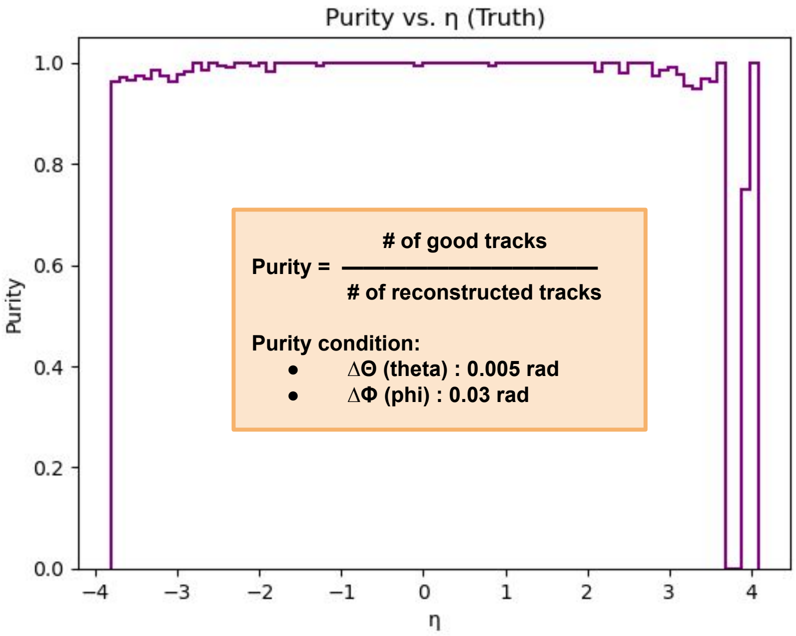
WITH ambiguity solver



No noise

Truth-Seeded Efficiency and Purity Against Pseudorapidity (η)





No noise

Truth-Seeded Efficiency and Purity Against Transverse Momentum (pT)