Progress on Noise Effects Study on ePIC Tracking

Mito Funatsu

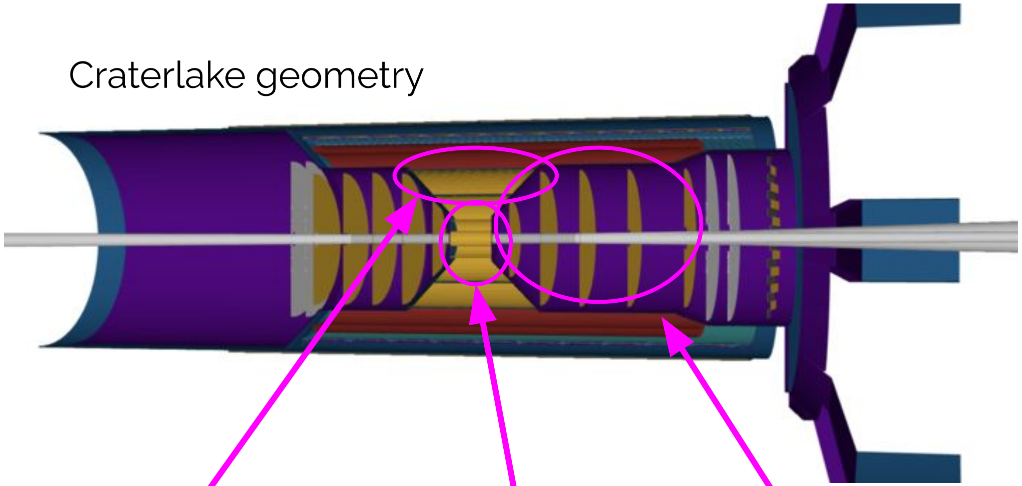
California EIC Consortium Meeting

University of California, Los Angeles

January 9, 2025

ePIC Detector & Silicon Vertex Tracker Geometry

Craterlake geometry



2 outer barrels

3 inner barrels

5 disks (forward & backward)

3 inner barrels
ITS3 sensors (MAPS technology)

2 outer barrels
EIC-LAS (Large Area Sensor)*

5 disks (forward & backward)
EIC-LAS*

Simulations based on MAPS with 20 µm x 20 µm pixels

*modification to ITS3 sensors with no change to pixel matrix

Noise Implementation: Fake-Hit Rate (FHR)

Noise: an signal in the absence of particle hit

Fake-hit rate: noise hits/event/pixel

ITS3 TDR p.44 (2024):

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

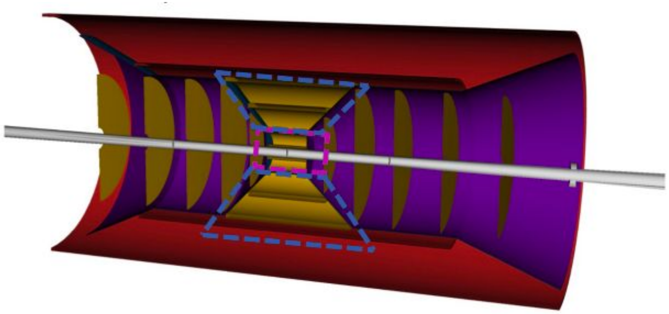
NO noise implemented in official simulation

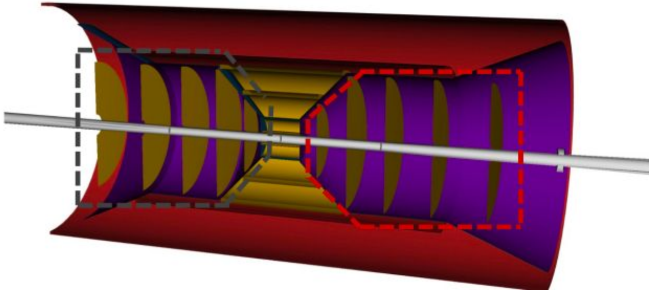
Current Estimation of Noise Hit Count

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

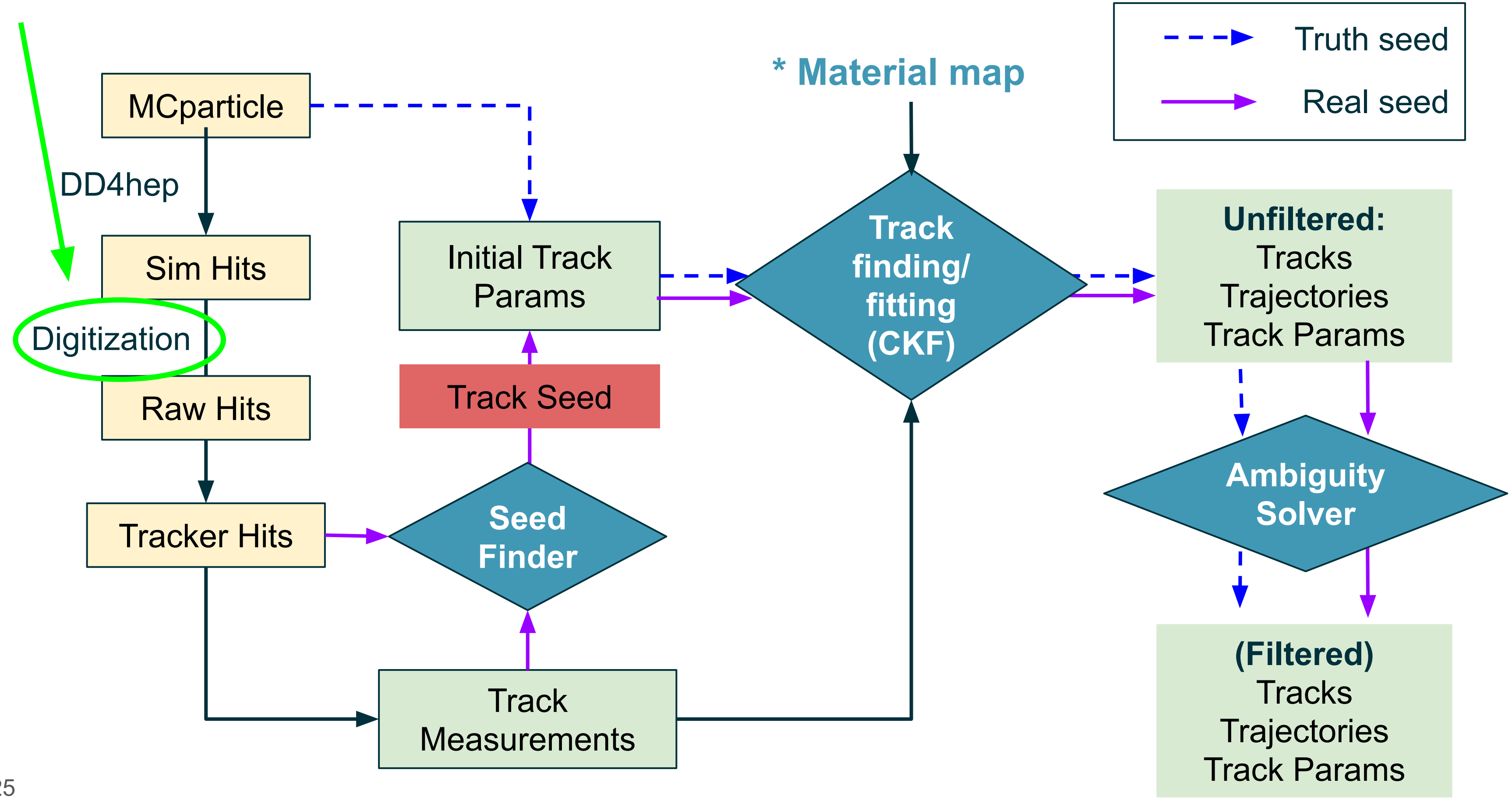
Pixels sizes: **20x20μm²**

	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





Noise Implementation



Digitization/Hit Reconstruction Procedure

Sim Hits → **Digitization/Hit Reconstruction** → **Tracker Hits**

Sim Hits

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

Digitization/Hit Reconstruction

1. Apply energy threshold cut (0.54kev)
2. Generalize sim hit position as the center of its associated cellID
3. Specify resolution

Tracker Hits

→ **By identifying a way to generate additional cellID's that are uniformly distributed on the Inner Barrel, we can treat these additional "sim hits" as noise hits**

Generating 64-bit CellID’s Efficiently and Randomly

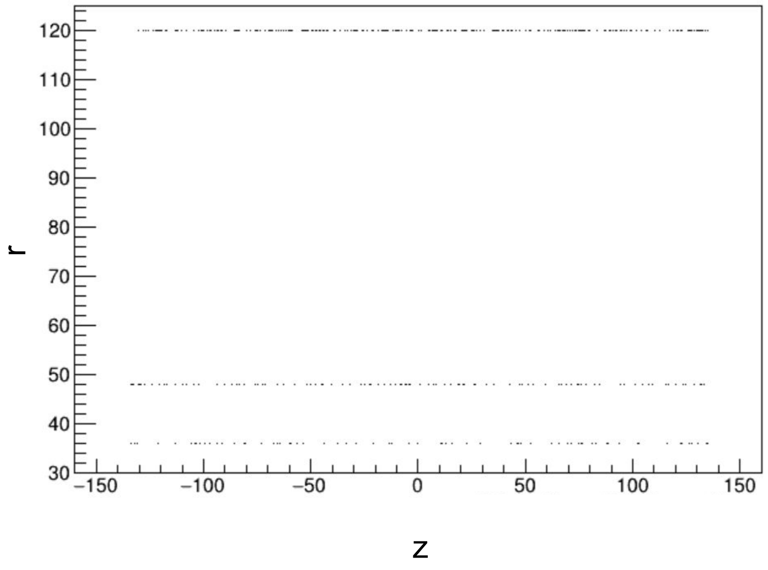
Inner Barrels CellID composition: system:8,layer:4,module:12,sensor:2,x:32:-16,y:-16

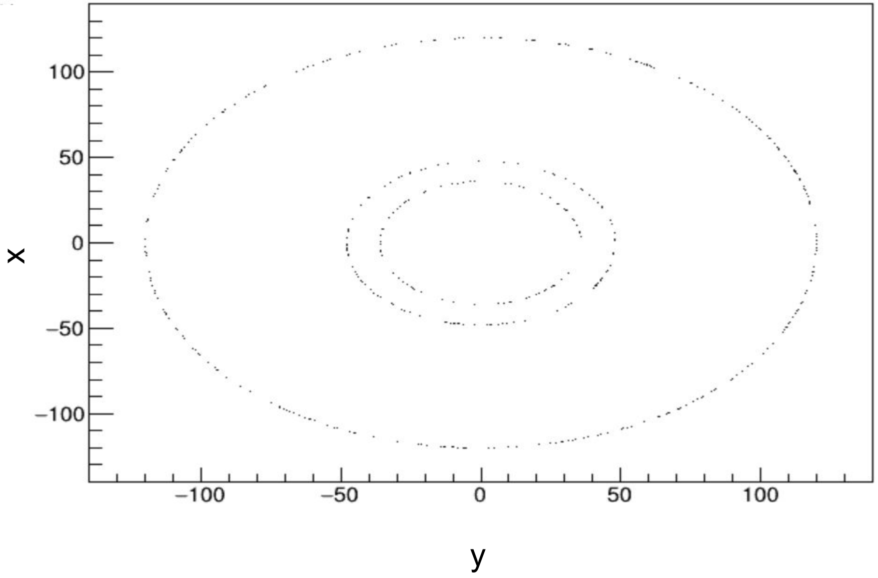
Example IB CellID:
11110101010111011111111111100110000000001000001110010001000011111

1. Find a valid range for each component
2. Generate a random number in the range
3. Combine to form a valid cellID

Inner Barrel Layers (L012) Hit Distribution for Single Event

These are hits from a single event, with **3 of the hits from the simulated particle**, and the remainder 433 hits being noise hits.





Credit: Barak Schmookler

Analyzing Reconstruction Performance

Efficiency analyzed with/without noise as a function of η and p_T

Efficiency

Efficiency is the ratio:

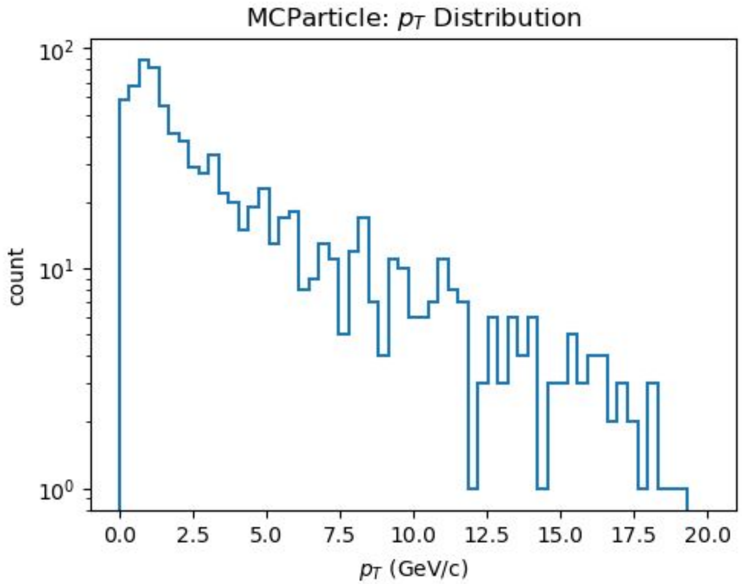
$$\frac{\textbf{\# of MCParticles with reconstructed tracks}}{\textbf{\# of MCParticles}}$$

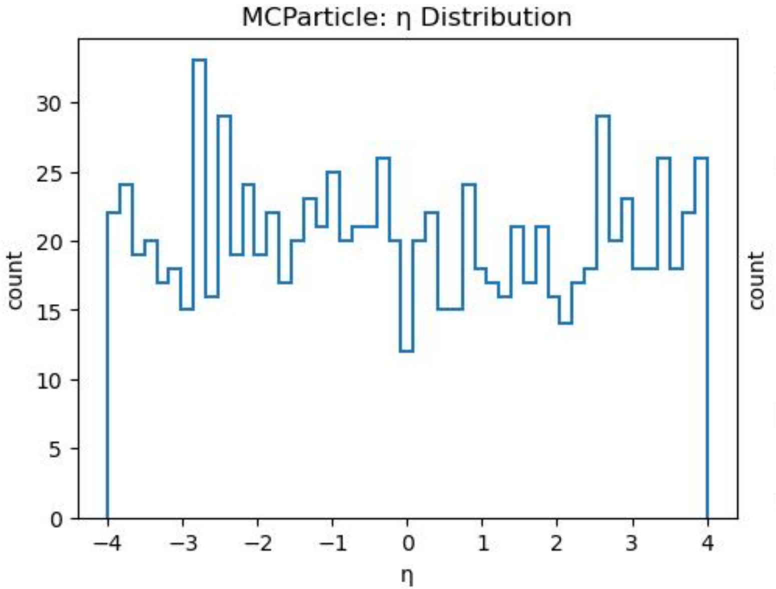
We also define **matching conditions: checks if the reconstructed tracks match with an MCParticle within:

- **ΔΘ (theta) : 0.005 rad**
- **ΔΦ (phi) : 0.03 rad**

Sampled Events

1. 1,000 single-muons events
2. Craterlake geometry
3. 0.5<p<20 GeV/c
4. -4 ≤ η ≤ 4

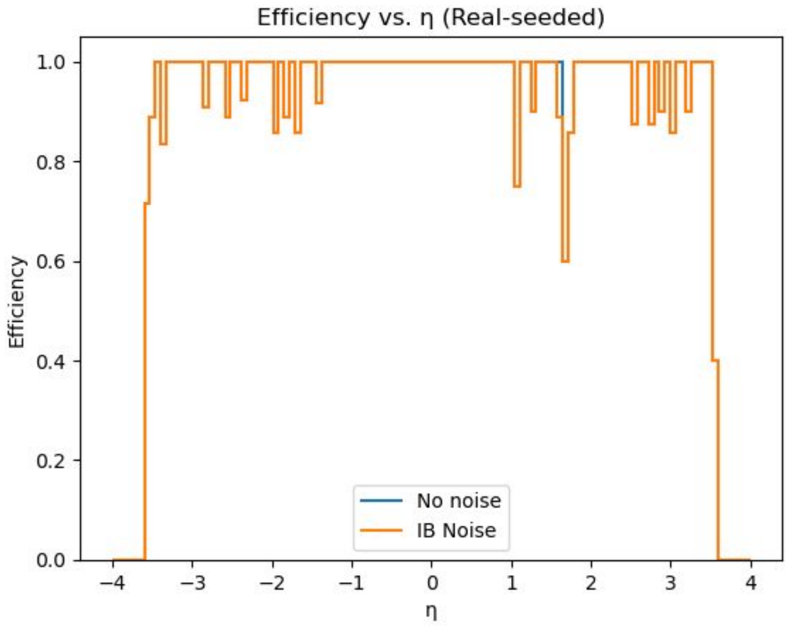




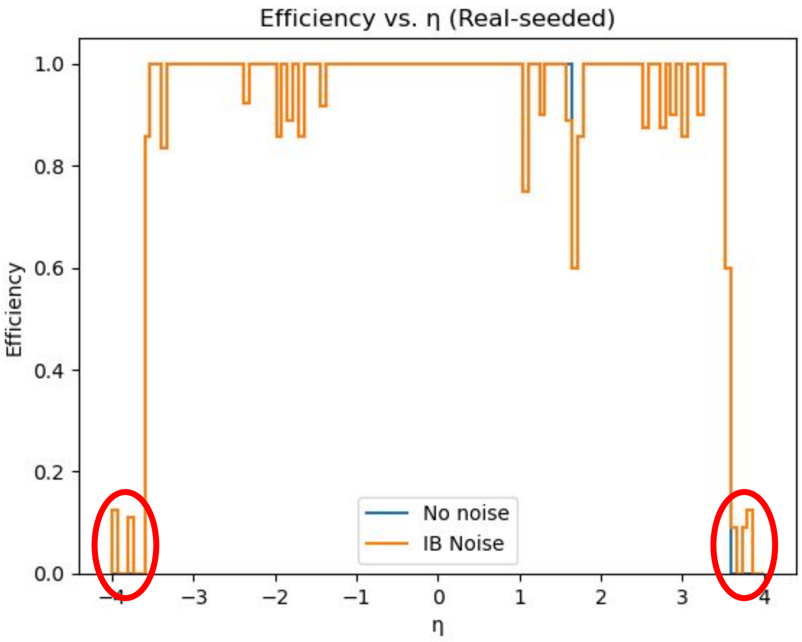
Efficiency = $\frac{\text{\# of MCParticles with reconstructed tracks}}{\text{\# of muon MCParticles}}$

For this particular event that happened at this pseudorapidity, there was a “random” reconstructed track, not necessarily at this angle, but for this event.

Real-Seeded Efficiency Against Pseudorapidity (η)



Only matched tracks

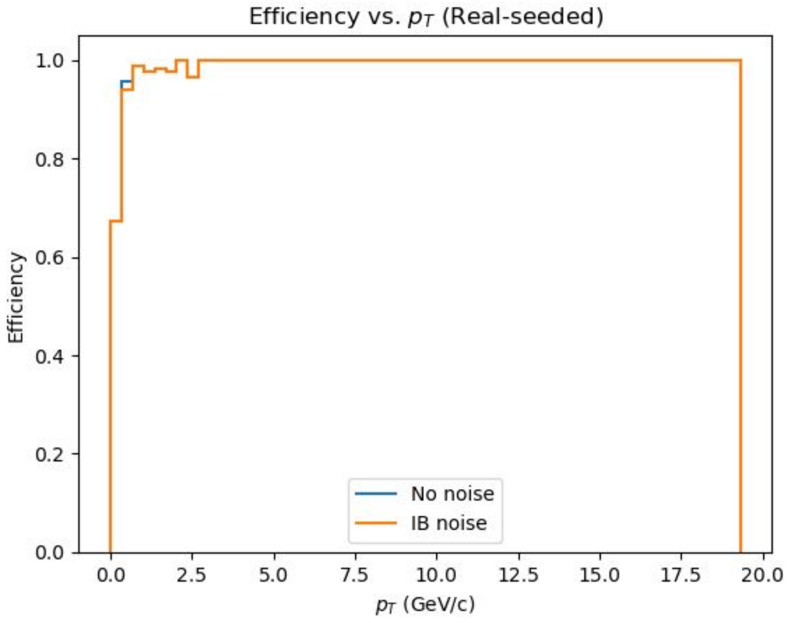


All tracks

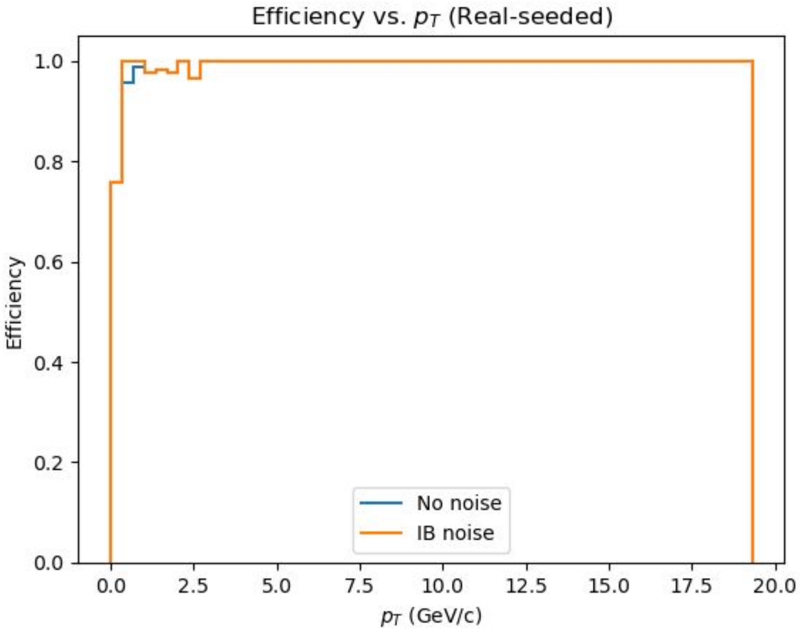
$$\text{Efficiency} = \frac{\text{\# of MCParticles with reconstructed tracks}}{\text{\# of muon MCParticles}}$$

Real-Seeded Efficiency Against Transverse Momentum (p_T)

Specified Eta Range: $-3.6 \leq \eta \leq 3.6$



Only matched tracks



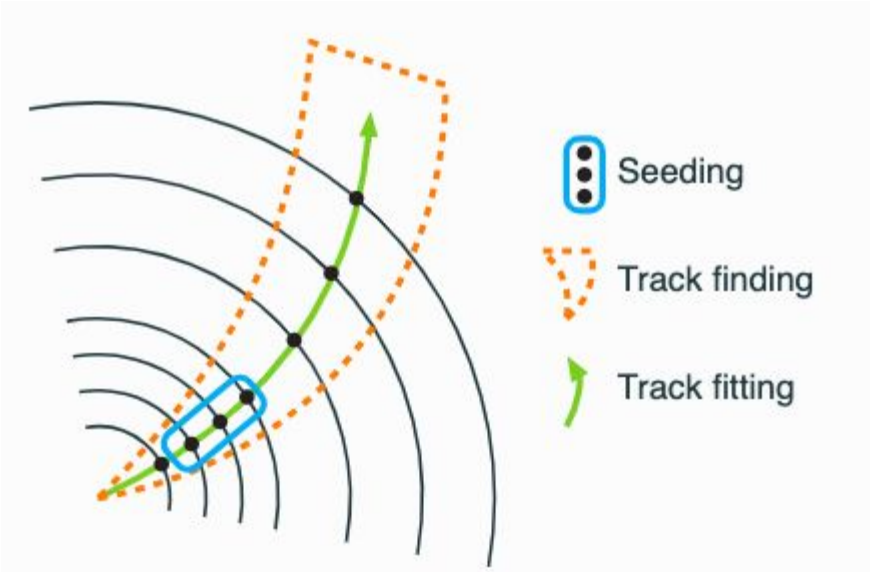
All tracks

Next Steps

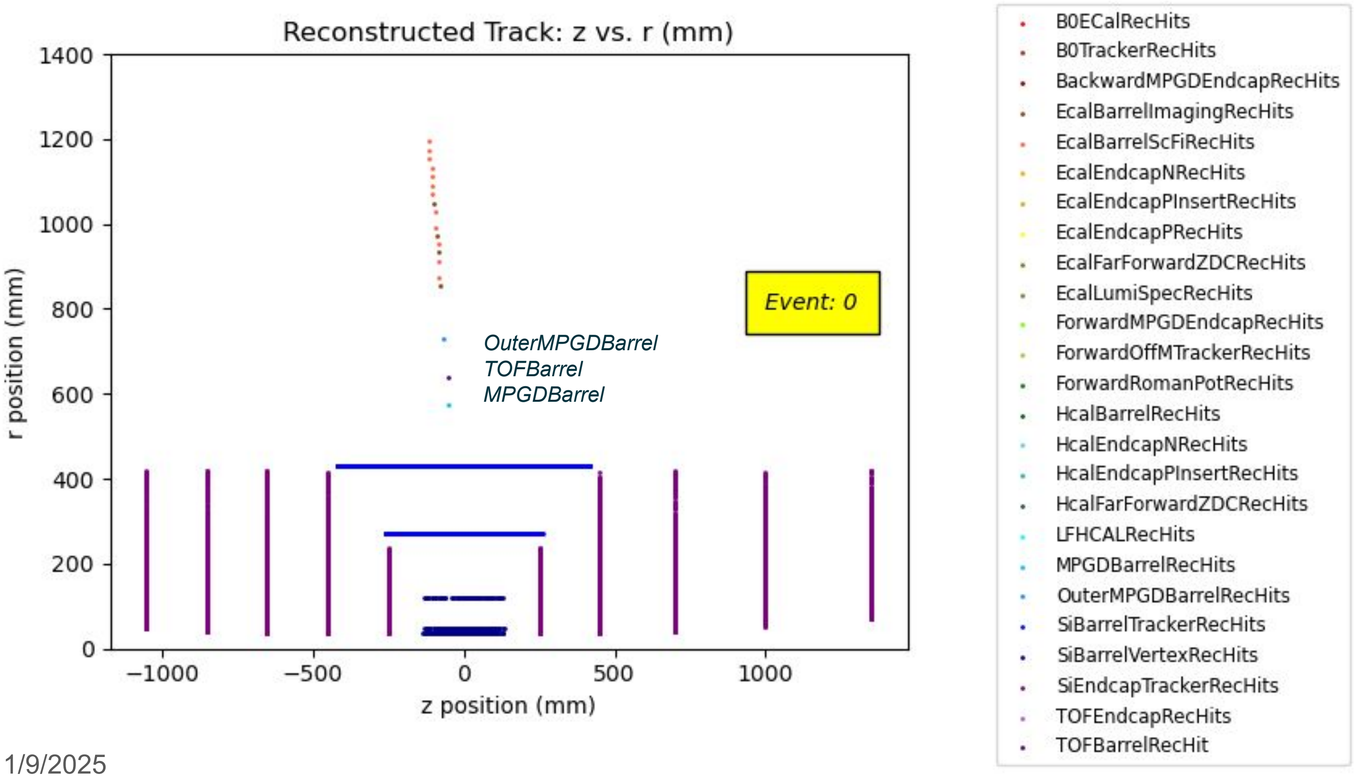
1. Efficiency analysis with noise in outer barrels and endcaps
2. Incorporate hit based matching for a more efficient and concrete matching procedure for multiple particle events
3. Momentum resolution plots

Backup

Seeding Algorithm



Successful reconstruction of manually inputted cellID’s



Description:
Reconstructed hit position plot for one single-muon event. Includes additional SVT hits not from collision event.

Potential Approach for Finding Endcap CellID Range

Suggestion from DD4hep experts: Directly compute the volume boundaries, then, convert to cell ID's. Then, pick a random pixel in this range.

Discussion with DD4hep: https://github.com/AIDASoft/DD4hep/issues/1335

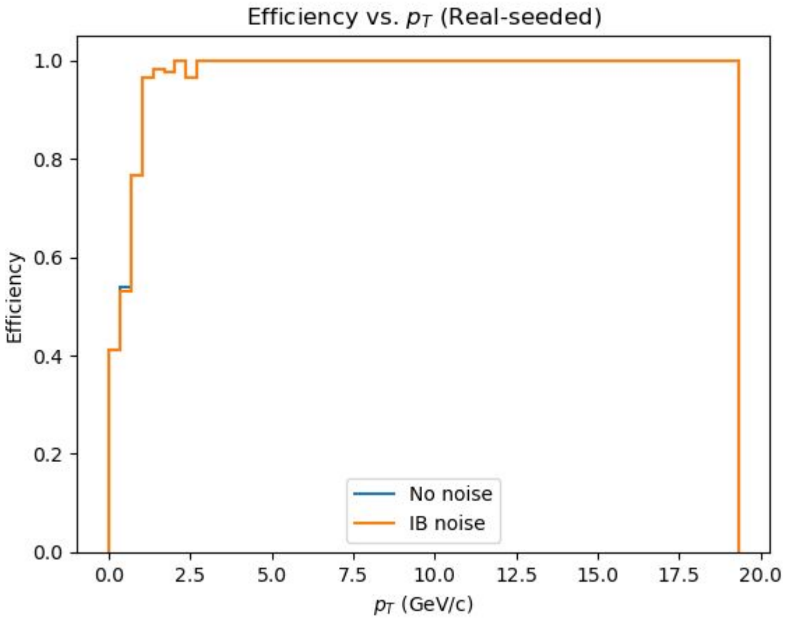
CellID Study

- Color: applies exclusively to the layer/disk
- Black: applies to all layers/disks in the collection

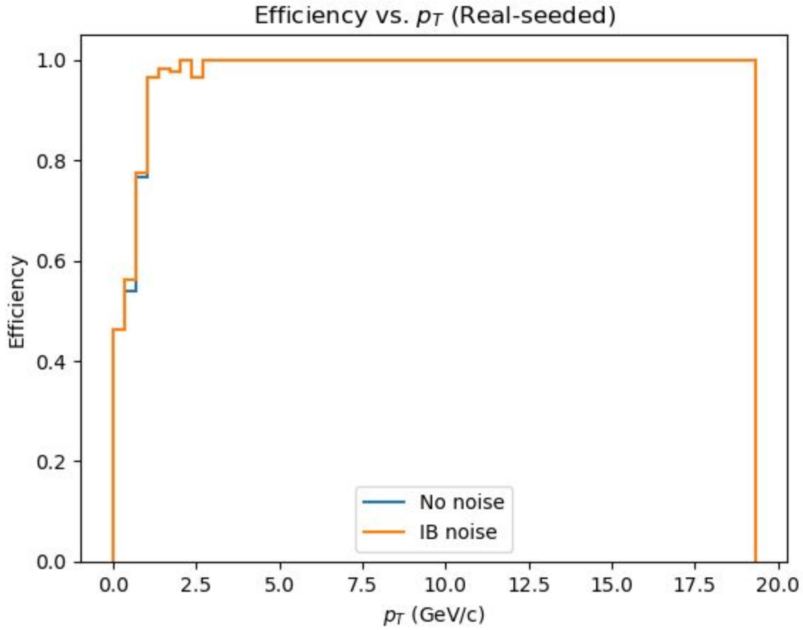
Collect name	Sys_id (L/D0,1,2,3,4)	layer	module (L3,4)	sensor	seg_x (L0,1,2,3,4) [-Φ] or [+Φ]	seg_y/z (L0,1,2,3,4) [-z] or [+z]	# est. noise hits
IB	31	1,2,4	1-128	1	**(0,43) or (65492, 65535)** **(0,57) or (65478, 65535)** **(0,146) or (65386, 65535)**	**(0,6749) or (58786,65535)** *All layers*	433
OB	59, 60	1	**1-44**, **1-69**	1	**(0,999) or (3096,4095)** *All layers*	**(0, 13049) or (1035526, 1048575)** **(0,20999) or (1027576,1048575)**	3920
Disks	68, 69 70, 77, 78, 79	1,2,3,4	1-36	1			5910

$$\text{Efficiency} = \frac{\text{\# of MCParticles with reconstructed tracks}}{\text{\# of muon MCParticles}}$$

Real-Seeded Efficiency Against Transverse Momentum (p_T) Without Eta Cut



With purity cut



Without purity cut