BERKELEY LAB
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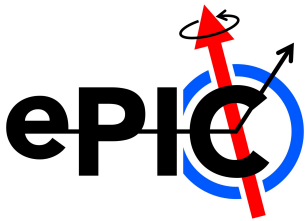
U.S. DEPARTMENT OF ENERGY
Office of Science

Tracking Status Overview

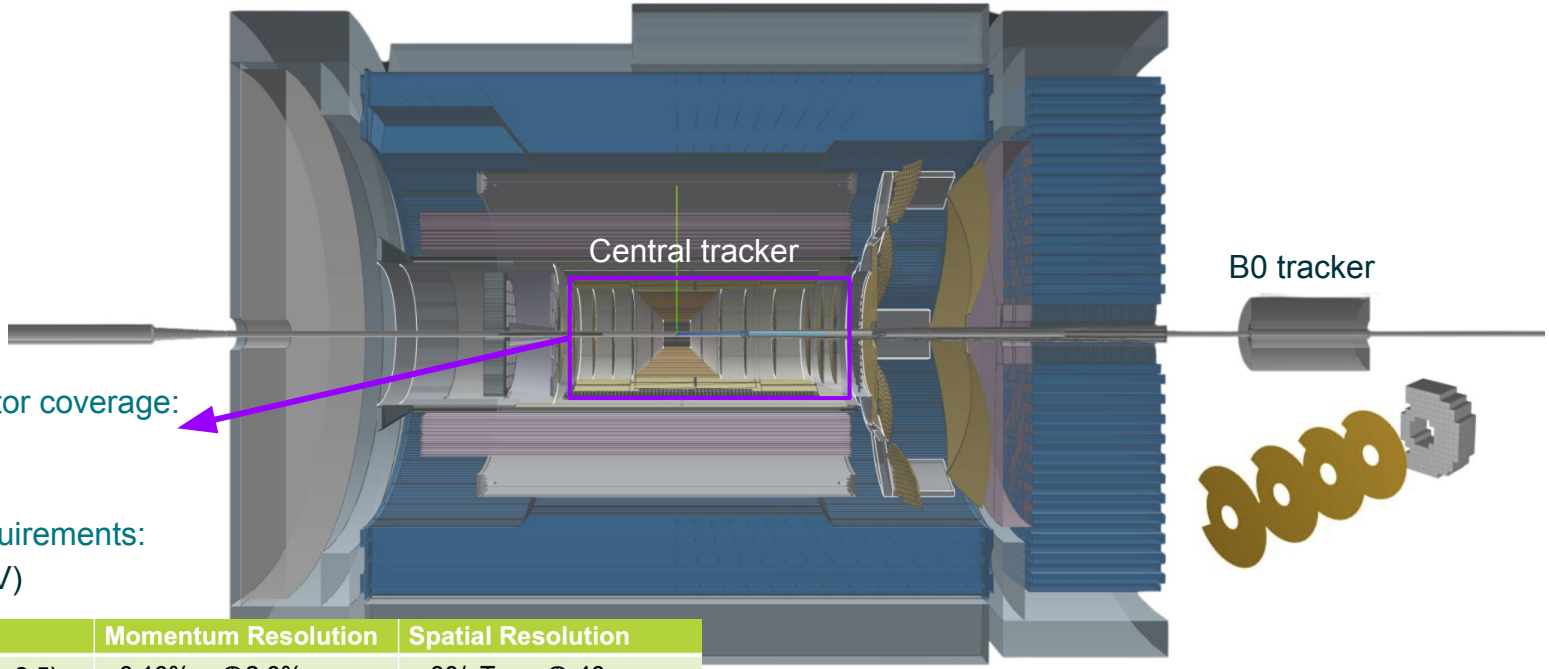
Shujie Li

AC-LGAD TOF DSC @ EICUG 2025

July 16, 2025



ePIC Tracking System



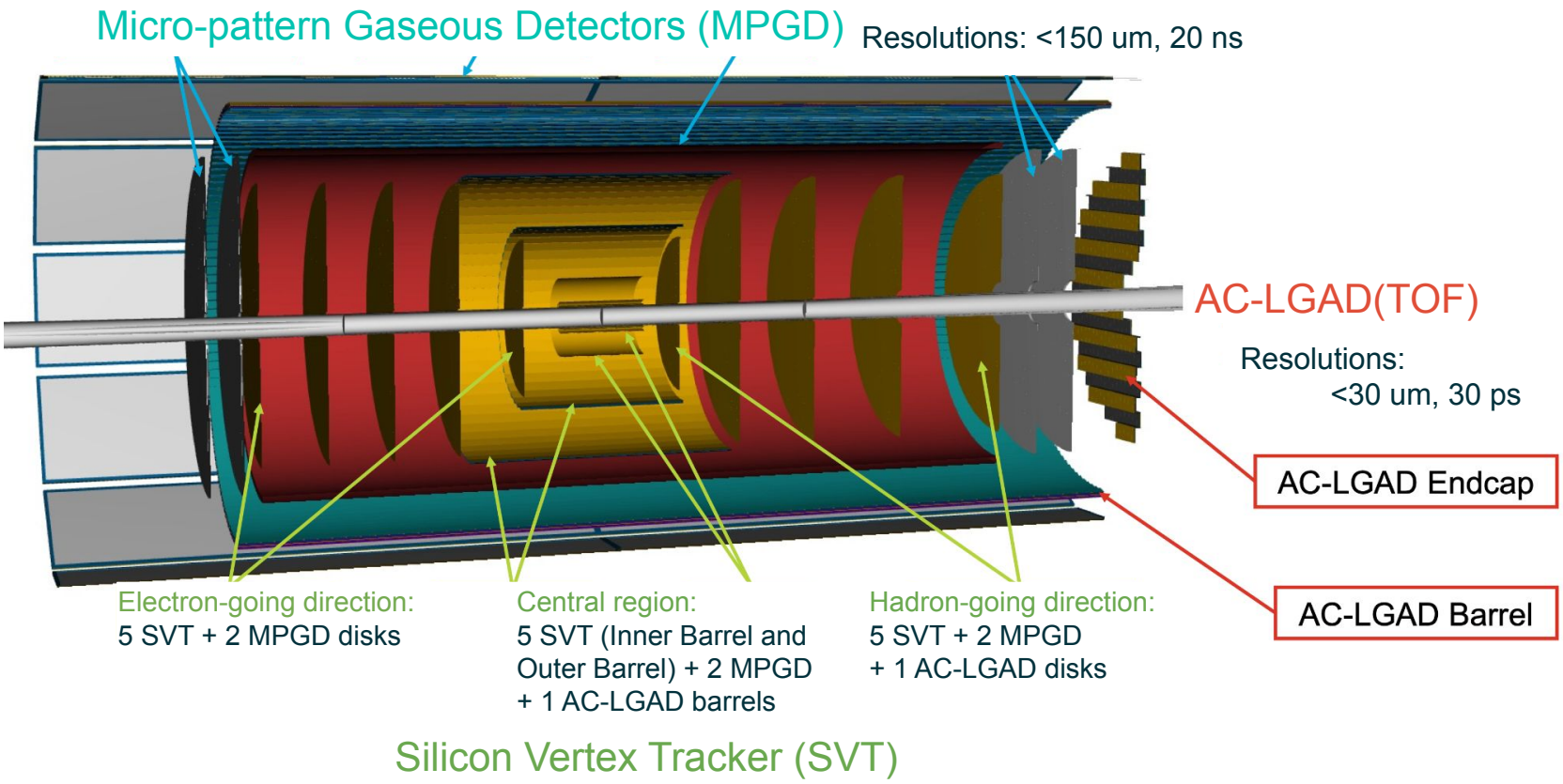
*Central detector coverage:
$-4 < \eta < 4$

Resolution requirements:
(for pT<15 GeV)

	Momentum Resolution	Spatial Resolution
Backward (-3.5 to -2.5)	~0.10%×p⊕2.0%	~ 30/pT μm ⊕ 40 μm
Backward (-2.5 to -1.0)	~ 0.05%×p⊕1.0%	~ 30/pT μm ⊕ 20 μm
Barrel (-1.0 to 1.0)	~0.05%×p⊕0.5%	~ 20/pT μm ⊕ 5 μm
Forward (1.0 to 2.5)	~0.05%×p⊕1.0%	~ 30/pT μm ⊕ 20 μm
Forward (2.5 to 3.5)	~0.10%×p⊕2.0%	~ 30/pT μm ⊕ 40 μm

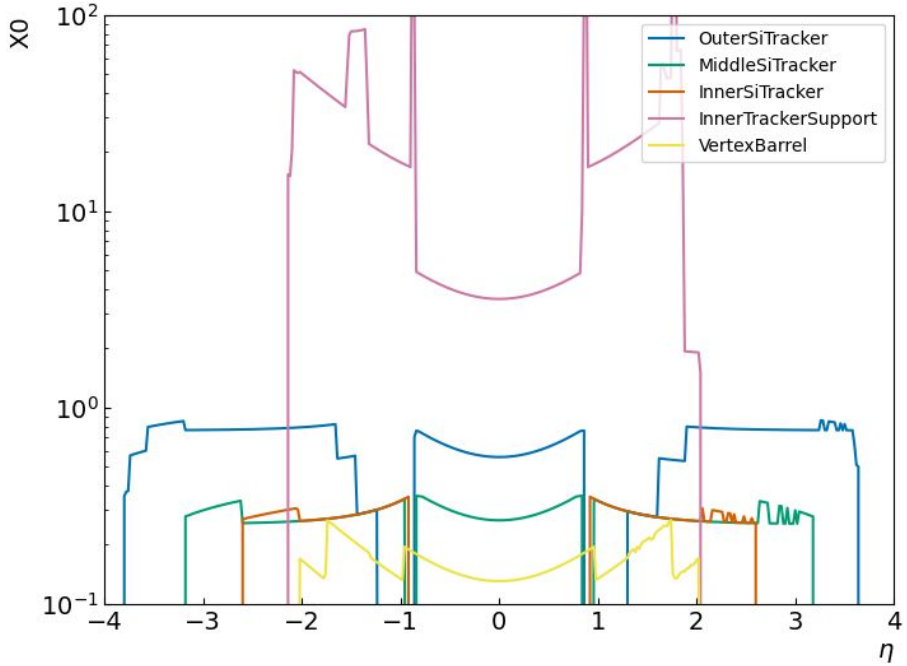
Central Tracker

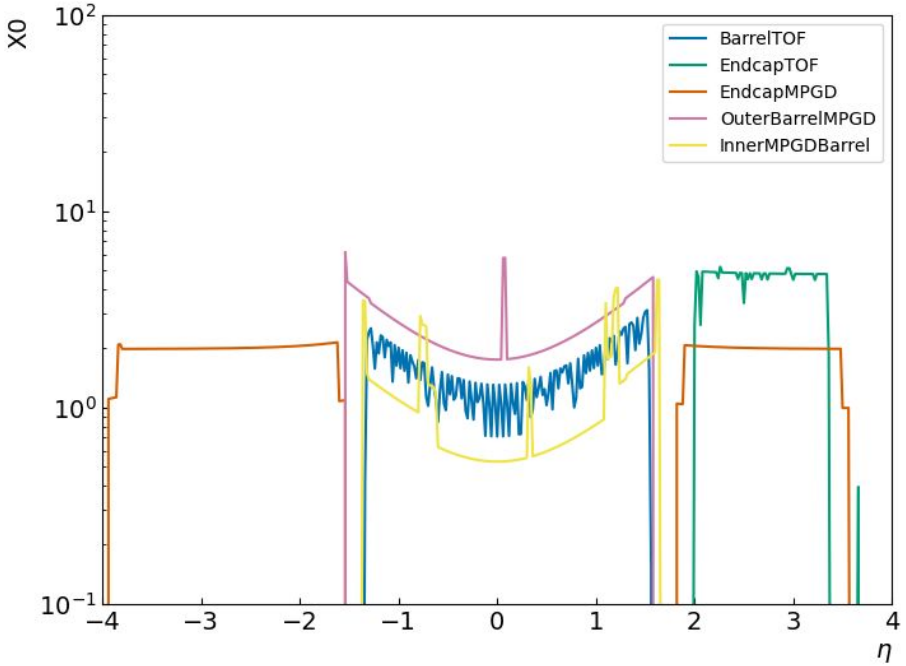
See detector reports from ePIC R&D Day



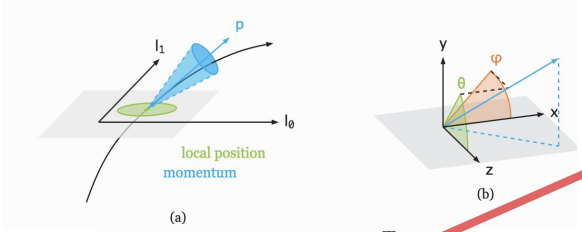
Material Scan

- ePIC 25.07.0 :
  - new material map
  - updated TOF geometry (see Tommy's talk on Tuesday)





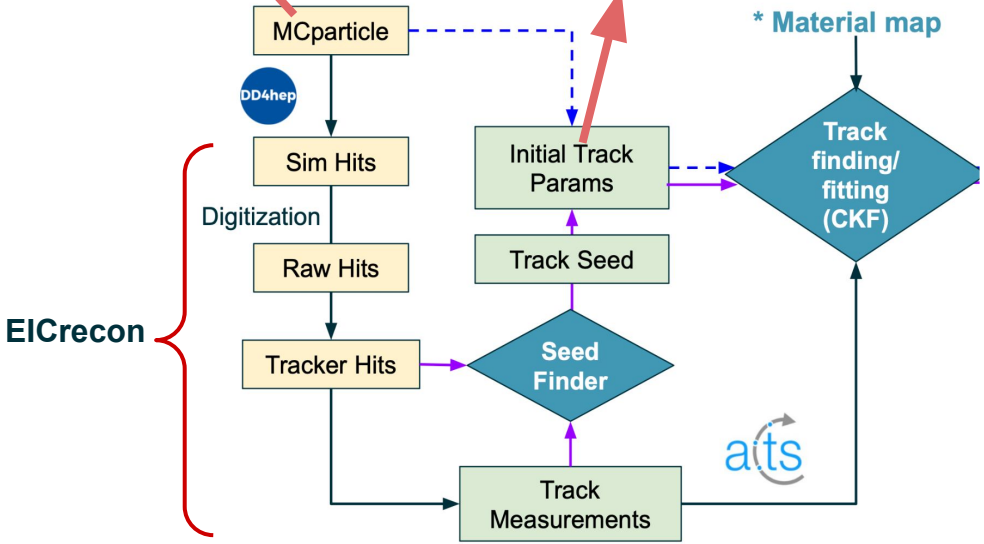
Tracking workflow

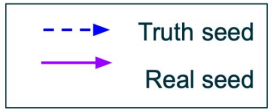


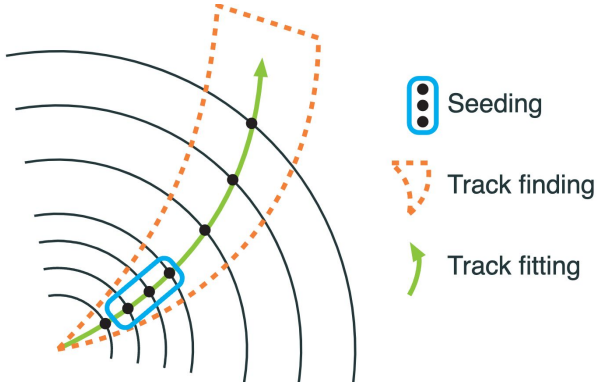
$$\vec{x} = (l_0, l_1, \phi, \theta, q/p, t)^T$$

- No timing info is used in tracking
- To do:
  - Include time into track chi2 calculation
  - Use TOF/MPGD time to tag tracks and vertices

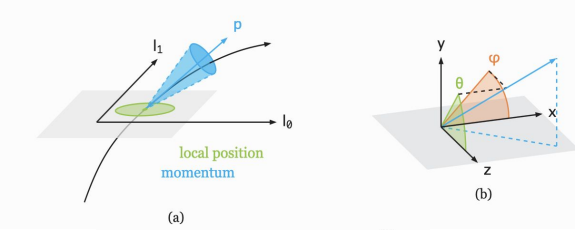
Event generator / particle gun







Tracking workflow



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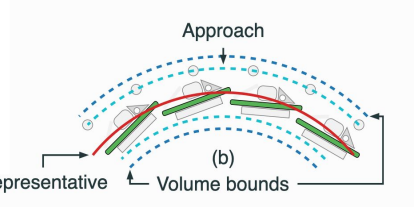
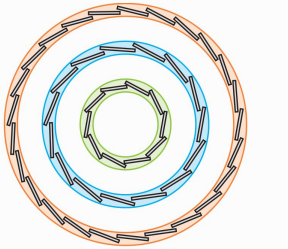




Event generator / particle gun

MCparticle

DD4hep

Sim Hits

Digitization

Raw Hits

Tracker Hits

EICrecon

Initial Track Params

Track Seed

Seed Finder

Track Measurements

* Material map

Track finding/ fitting (CKF)

Truth seed

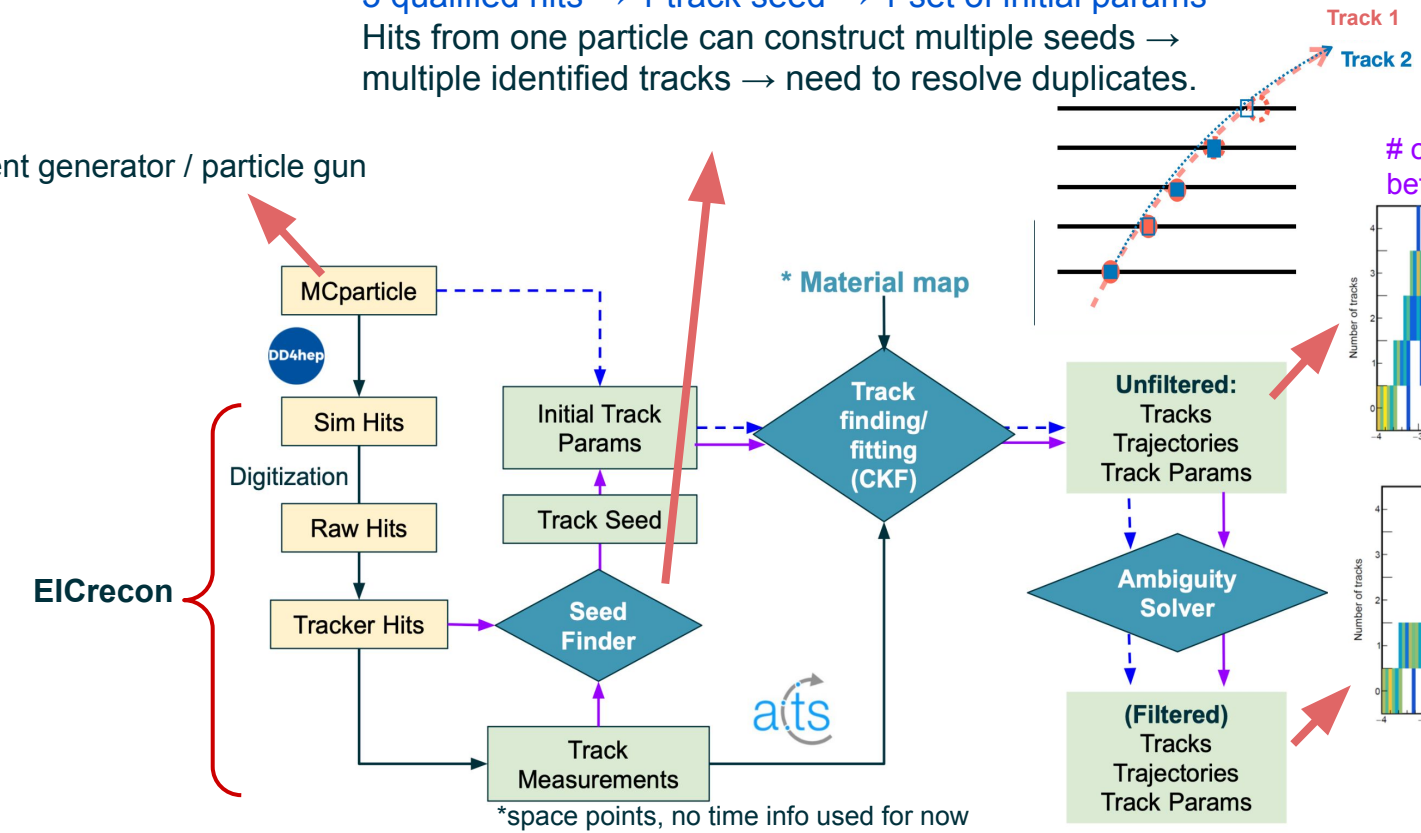
Real seed

acts

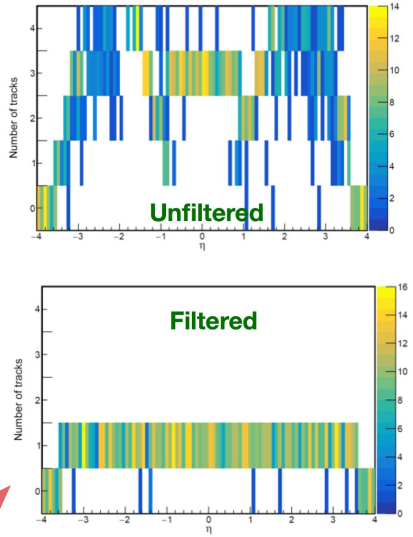
*space points, no time info used for now

Tracking workflow

3 qualified hits → 1 track seed → 1 set of initial params
Hits from one particle can construct multiple seeds → multiple identified tracks → need to resolve duplicates.

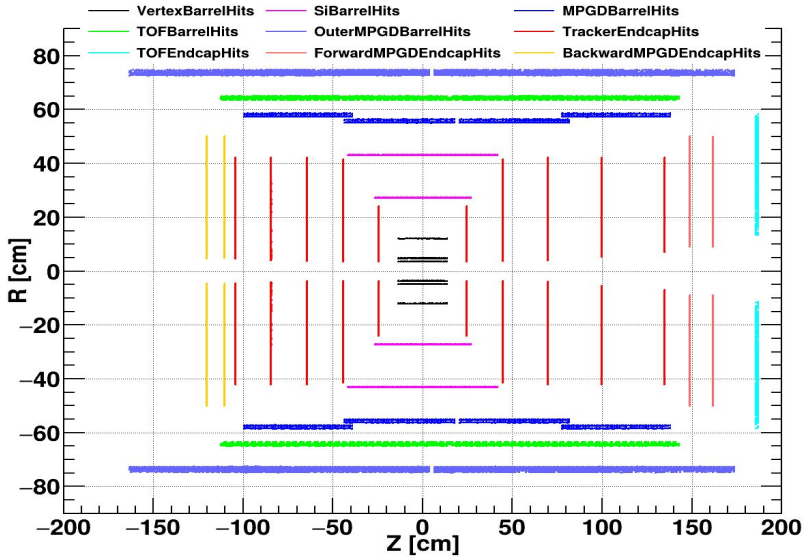


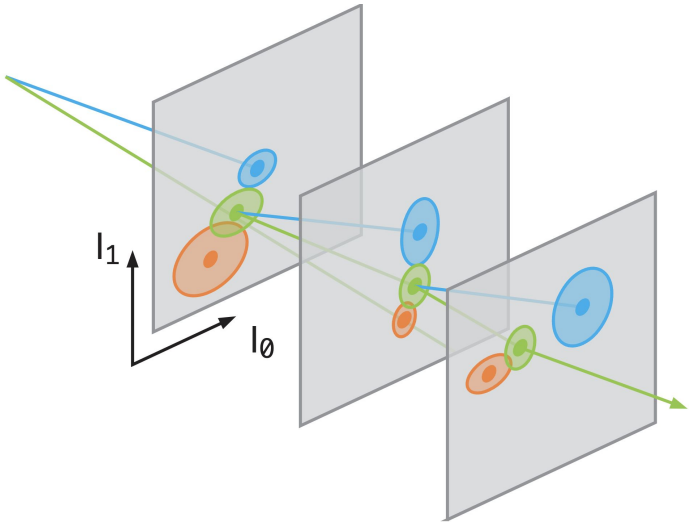
# of tracks per particle before/after



Tracking workflow

- **Core tracking algorithm: Combinatorial Kalman Filter (CKF):**
  - Initial guess from an orthogonal seed finder which forms triplet with hits from five SVT layers.
  - Combined track finding and fitting
  - Demonstrated to handle high multiplicity tracking. Works well with 5+ hits.
    - Expect to have **5-8 hits per particle** with the current tracker design.
    - Hits which deviate from projected track will be rejected by chi2 (residual weighted by resolution and material effects) cut.

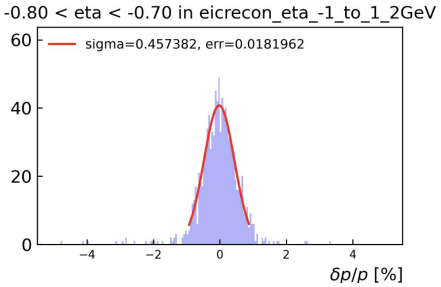


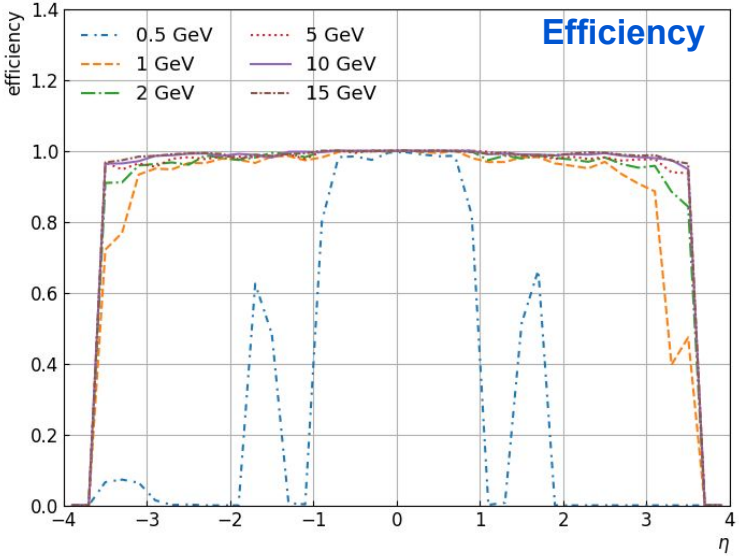


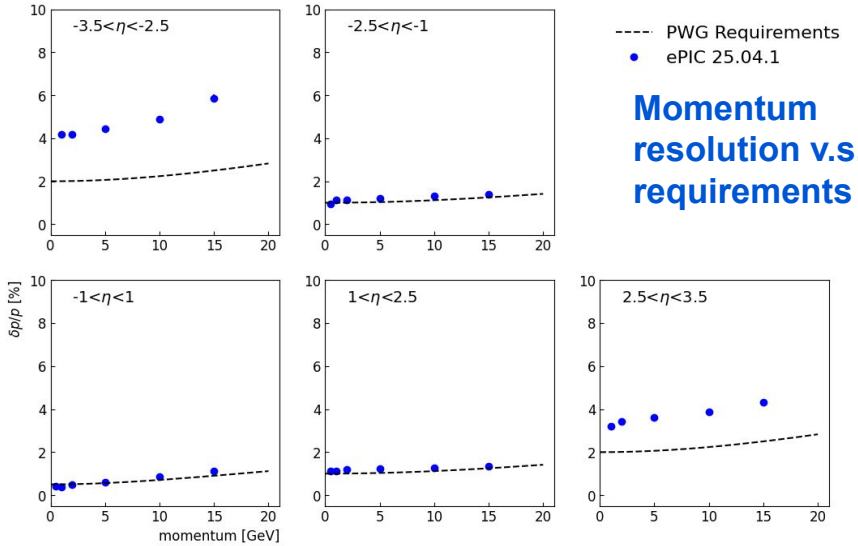
Single Particle Tracking Performance

- **Source events:**
  - Uniformly distributed single pion+ event at fixed momentum
- **Observables:**
  - **Efficiency**: fraction of qualified generated tracks that are reconstructed
  - **Purity**: for a given reconstructed track, the fraction of used hits from the same initial particle.
  - **Resolutions**: dp/p, theta, phi, DCAr

dp/p Resolution fit
(recon - initial)/initial,







Momentum resolution v.s. requirements

Tracking Layer Impact Study

Concern:

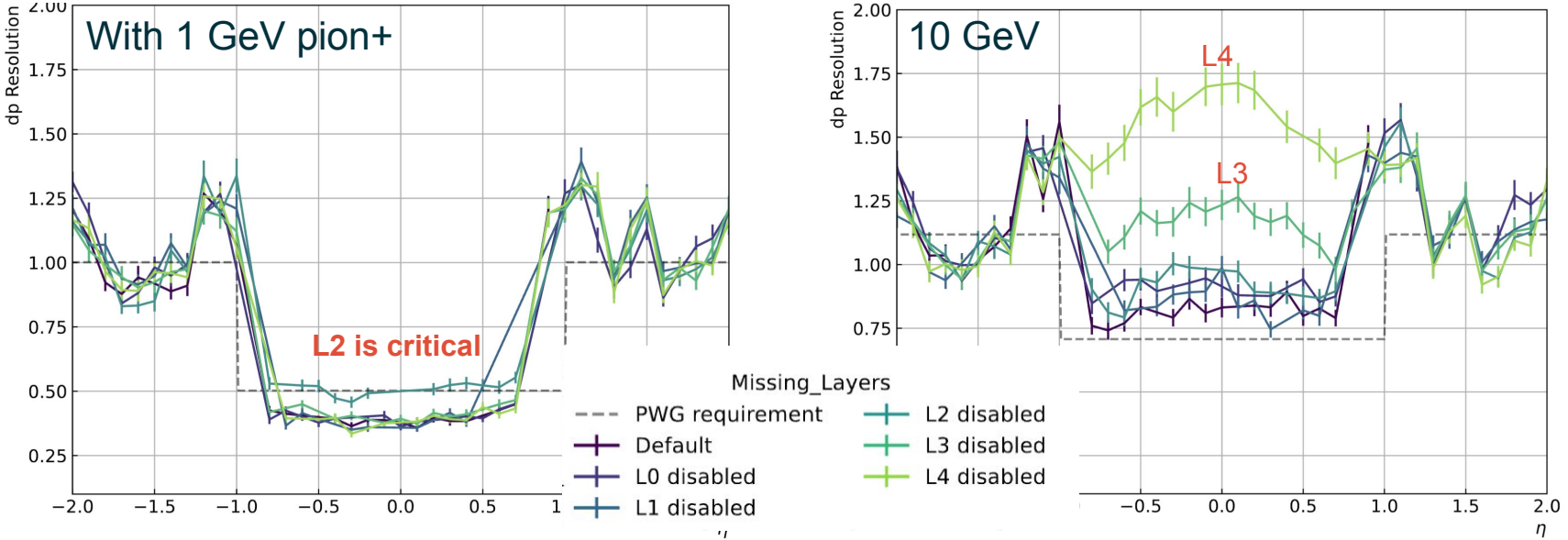
What if a particle doesn't leave hit on a specific tracking layer for any reason?

Simulation setting:

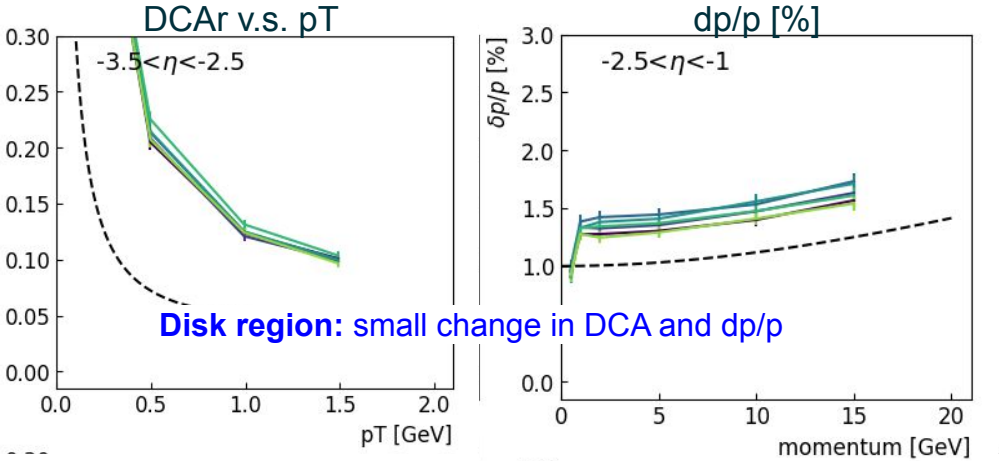
Don't use hits from that layer in track reconstruction while keep the geometry and materials in DD4hep simulation.

Example:

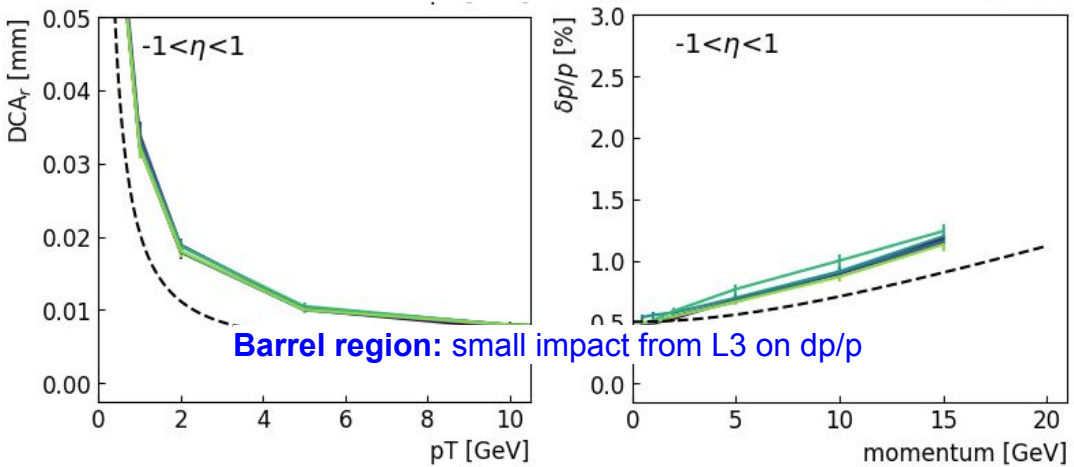
dp/p (%) with disabled **SVT Barrel layer** (L0 to L4 that covers -0.9 < eta < 0.9):



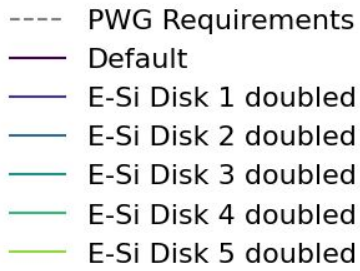
Tracking Layer Material Thickness Study



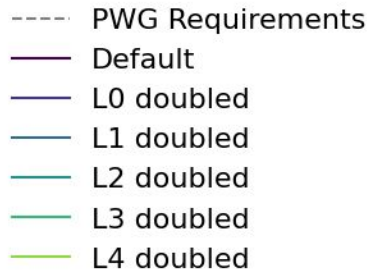
Disk region: small change in DCA and dp/p



Barrel region: small impact from L3 on dp/p



Double the thickness of each layer independently.



Tracking Study with Realistic Environment

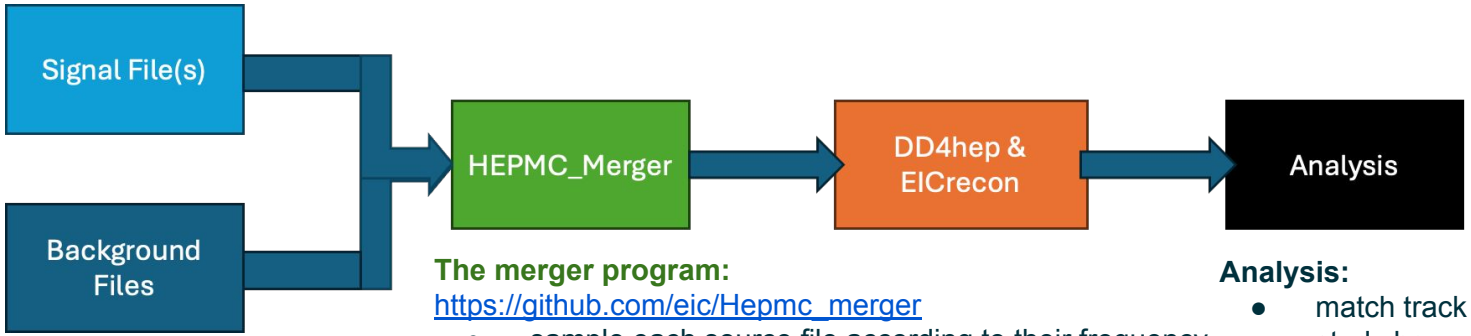
Concern:

How well can our device and tracking algorithm perform with **beam background**

Simulation setting:

Performance study with signal+background merged event

- Reconstructed events from DIS+background, and minbias+background are available in the recent simulation campaign



The merger program:

https://github.com/eic/Hepmc_merger

- sample each source file according to their frequency within a fixed-length (2us) time window
- label each source particle with custom generator code

Analysis:

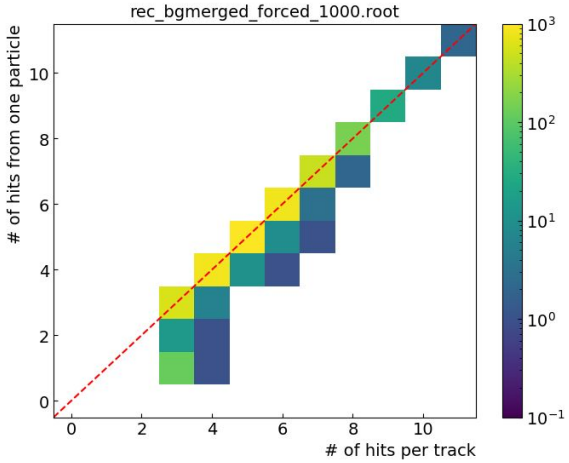
- match track to particles
- study how well we can reconstruct signal particles

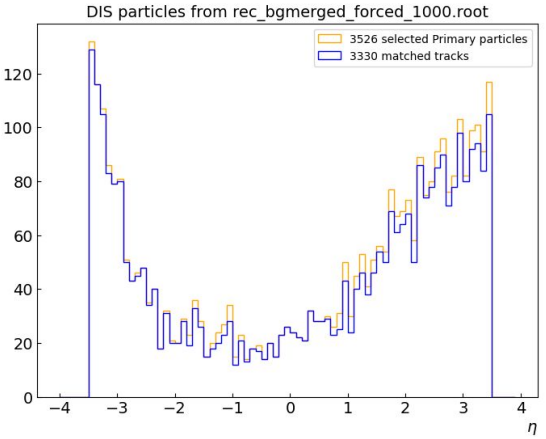
One event = one collision → **merged** → one 2us time slice contains (in this presentation):

- One 18x275 NC DIS events **(This is NOT the highest lumi configuration)**
- Beam background at calculated freq. (SR, electron Bremsstrahlung, Coulomb, Touschek, proton beam gas)

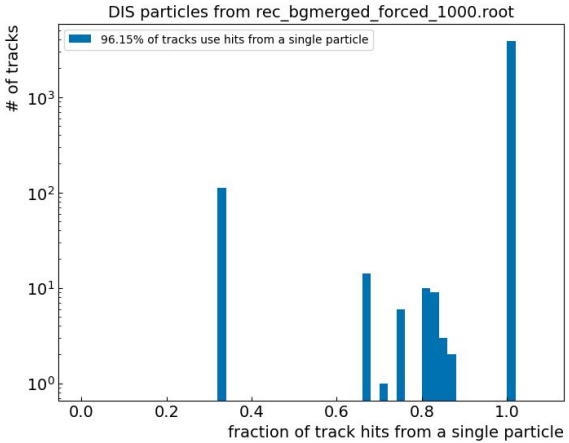
Purity and Efficiency: DIS (forced) + background sample

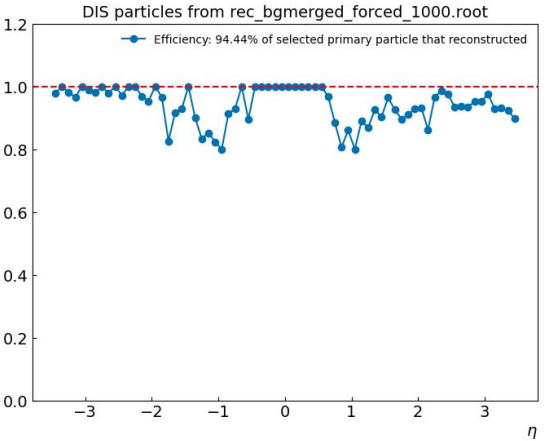
18x275





Overall very good purity except tracks with <5 hits





excellent efficiency for electrons. Inefficiency dominates by low momentum pions.

Track Propagation and DIRC Resolution

Question:

How will our tracker provide constraints on angular resolution on DIRC or other PID detectors

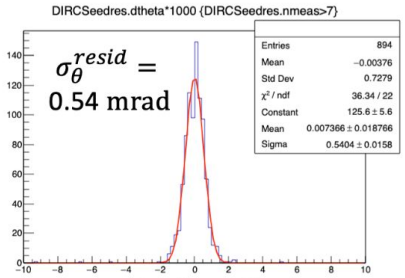
Simulation setting:

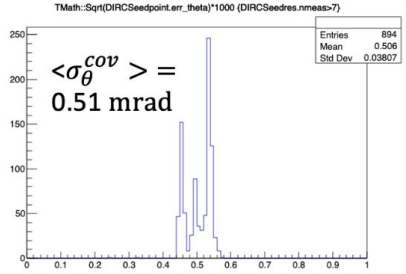
Take the trackstate next to DIRC, then propagate the track to the target surface to evaluate covariance matrix.

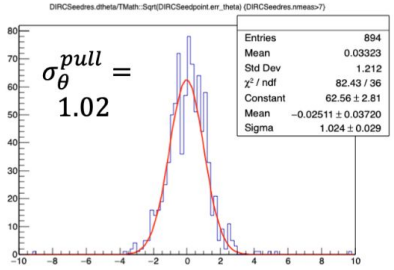
Example from MPGD: See Matt's talk:

- Removing µRWELL-BOT hit collection from tracking.cc (hits not used in CKF, but material is there) removes peak structure
- Small change in residuals, but large change in covariance errors (?)

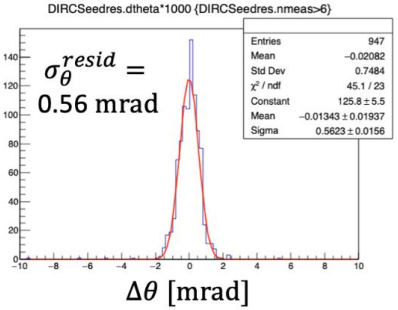
Craterlake_my_material_map.yml

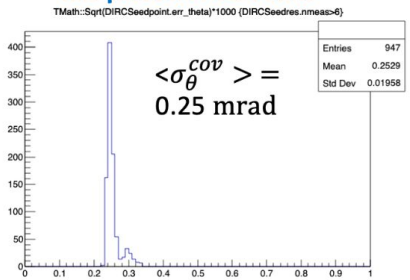


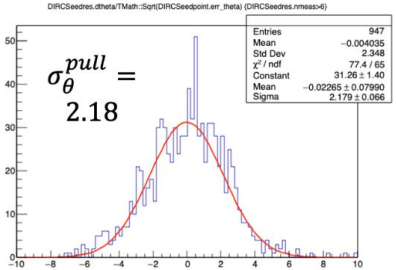




No µRWELL-BOT Hits







Proposed tracking study for TOF

- **Geometry**:
  - Services and mechanical structures?
- BTOF and ETOF **impact** study:
  - with single particles, and background merged samples
  - In longer term, include timing info
- Material **thickness** study
- **Reconstruction:**
  - Charge-sharing and clustering (signal threshold?)
  - Angular resolution at DIRC:
    - Consistency b/w MPGD and TOF?

Discussions?