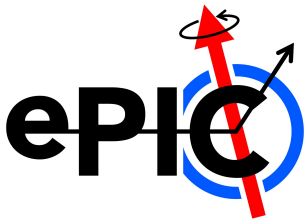
BERKELEY LAB
Bringing Science Solutions to the World

U.S. DEPARTMENT OF ENERGY
Office of Science

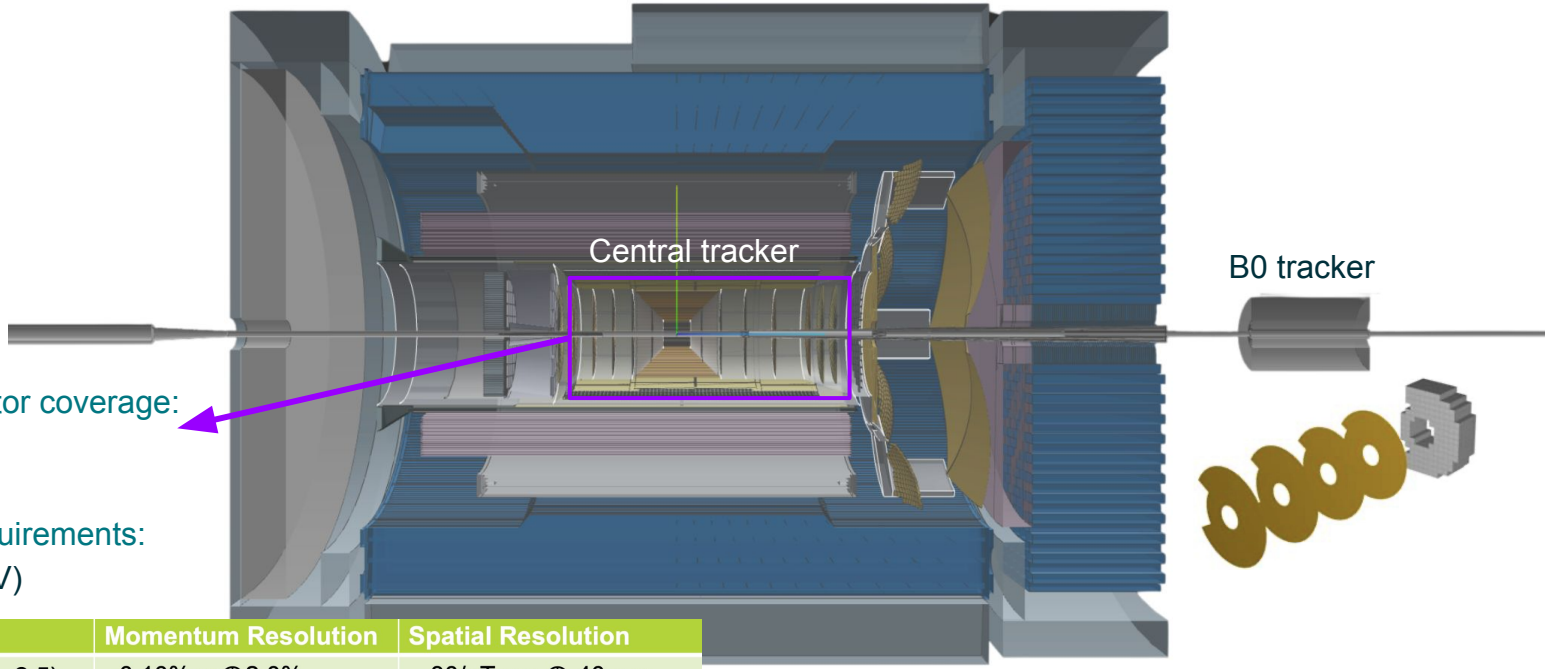
ePIC Tracking Status and Plan

Shujie Li

May 20, 2025 @ RHIC/AGS Annual Users Meeting



ePIC Tracking Systems



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

Resolution requirements:
(for pT<15 GeV)

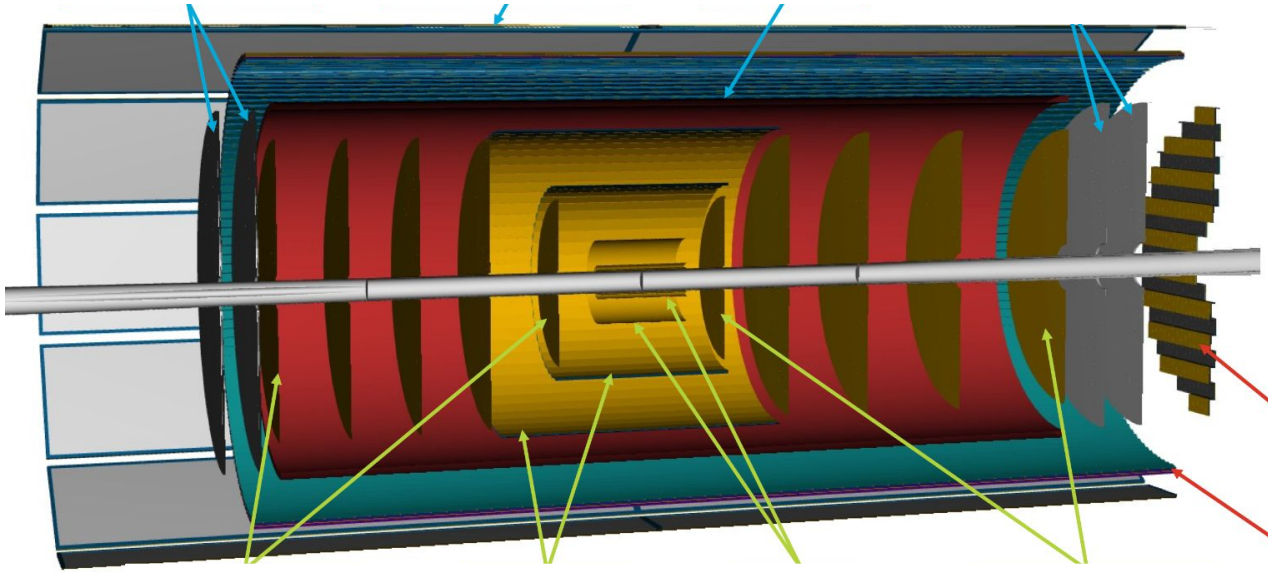
	Momentum Resolution	Spatial Resolution
Backward (-3.5 to -2.5)	~0.10%×p⊕2.0%	~ 30/pT μm ⊕ 40 μm
Backward (-2.5 to -1.0)	~ 0.05%×p⊕1.0%	~ 30/pT μm ⊕ 20 μm
Barrel (-1.0 to 1.0)	~0.05%×p⊕0.5%	~ 20/pT μm ⊕ 5 μm
Forward (1.0 to 2.5)	~0.05%×p⊕1.0%	~ 30/pT μm ⊕ 20 μm
Forward (2.5 to 3.5)	~0.10%×p⊕2.0%	~ 30/pT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

Central Tracker

See detector reports from ePIC R&D Day

Micro-pattern Gaseous Detectors (MPGD)

Resolutions: <150 um, 20 ns



AC-LGAD(TOF)

Resolutions:
<30 um, 30 ps

AC-LGAD Endcap

AC-LGAD Barrel

Electron-going direction:
5 SVT + 2 MPGD disks

Central region:
5 SVT (Inner Barrel and Outer Barrel) + 2 MPGD + 1 AC-LGAD barrels

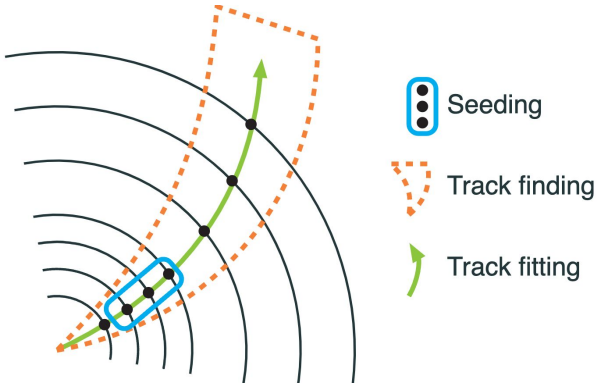
Hadron-going direction:
5 SVT + 2 MPGD + 1 AC-LGAD disks

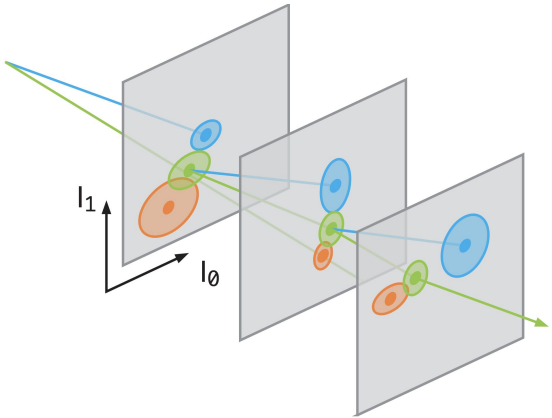
Silicon Vertex Tracker (SVT)

- Low mass, ~20x20 um pixel
- ~2 us time window

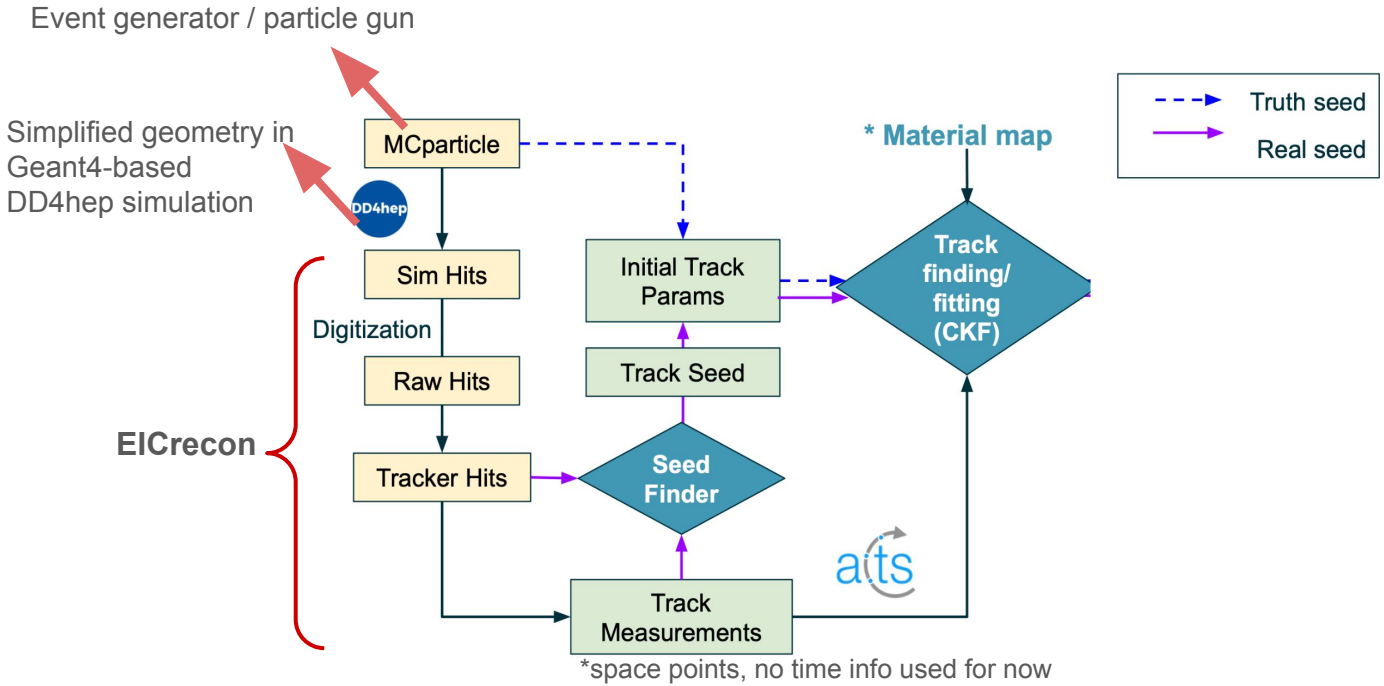
ePIC Tracking in Simulation

- DD4hep for detector description and particle propagation.
- In-house developed EICrecon framework for digitization, track and particle reconstruction, and analysis
  - Use tracking algorithms from ACTS :
    - Developed for ATLAS, widely used in HEP/NP experiments
    - Core tracking algorithm:
      Combinatorial Kalman Filter (**CKF**):
      - Initial guess from an orthogonal seed finder which forms triplet with inner five SVT layers.
      - Combined track finding and fitting
      - Demonstrated to handle high multiplicity tracking. Works well with 5+ track layers.
  - See recent ACTS4NP@LBNL workshop for tutorials and more
  - ePIC joint tracking, track and vertex reconstruction meeting every Thursday

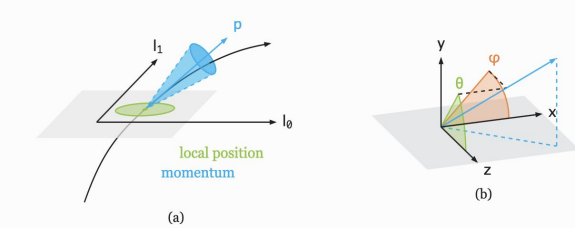




ePIC Tracking in Simulation



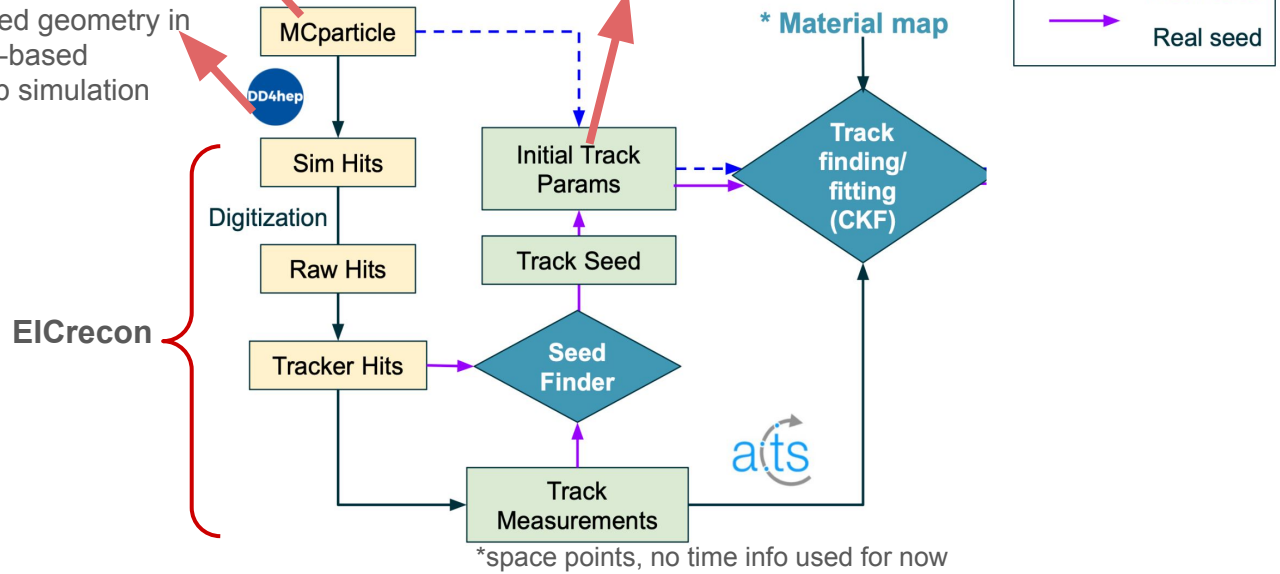
ePIC Tracking in Simulation



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

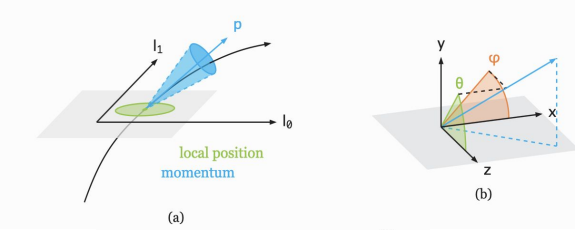
Event generator / particle gun

Simplified geometry in Geant4-based DD4hep simulation

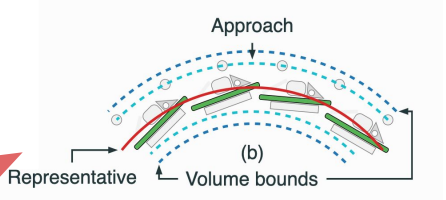


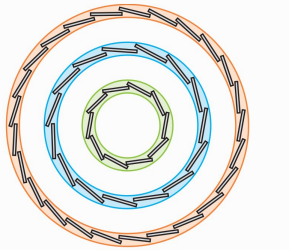
*space points, no time info used for now

ePIC Tracking in Simulation



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





Event generator / particle gun

Simplified geometry in Geant4-based DD4hep simulation

MCparticle

DD4hep

Sim Hits

Digitization

Raw Hits

Tracker Hits

ElCrecon

Initial Track Params

Track Seed

Seed Finder

Track Measurements

acts

Track finding/ fitting (CKF)

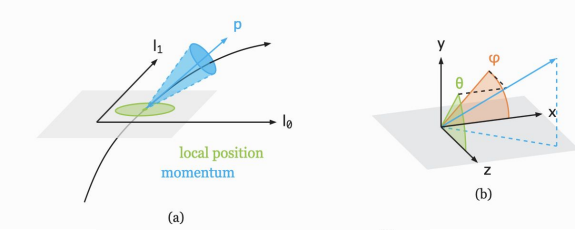
* Material map

Truth seed

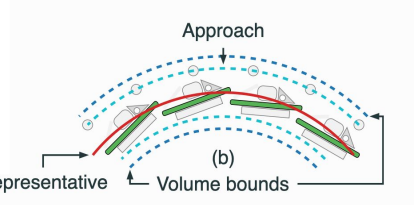
Real seed

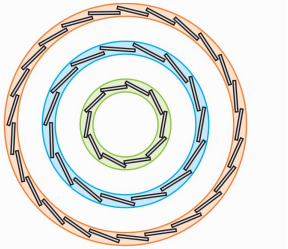
*space points, no time info used for now

ePIC Tracking in Simulation



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





Event generator / particle gun

Simplified geometry in Geant4-based DD4hep simulation

MCparticle

DD4hep

Sim Hits

Digitization

Raw Hits

Tracker Hits

ElCrecon

Initial Track Params

Track Seed

Seed Finder

Track Measurements

acts

Track finding/ fitting (CKF)

* Material map

Truth seed

Real seed

*space points, no time info used for now

ePIC Tracking in Simulation

Event generator / particle gun

Simplified geometry in Geant4-based DD4hep simulation

MCparticle

DD4hep

Sim Hits

Digitization

Raw Hits

ElCrecon

Tracker Hits

Seed Finder

Track Measurements

Initial Track Params

Track Seed

* Material map

Track finding/ fitting (CKF)

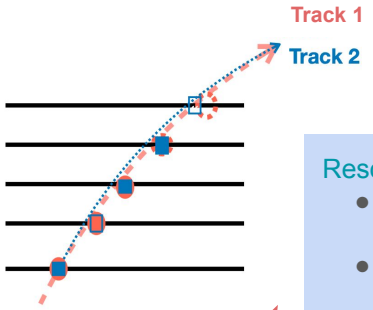
Unfiltered: Tracks Trajectories Track Params

Ambiguity Solver

(Filtered) Tracks Trajectories Track Params

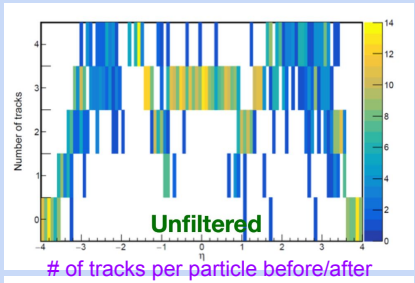
acts

*space points, no time info used for now

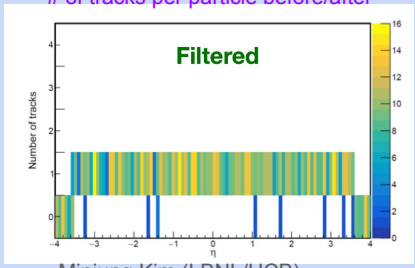


Resolving ambiguity:

- Overlapped tracks and mis-assigned hits.
- On average 3 seed triplets per single particle track



# of tracks per particle before/after



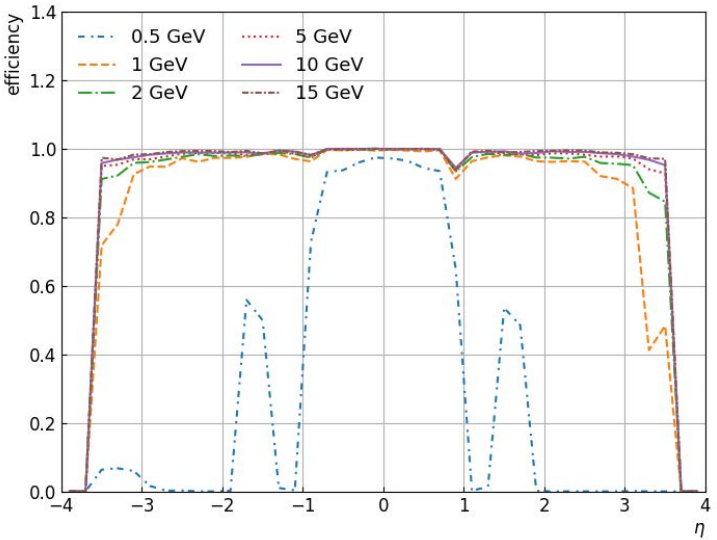
Tracking Study Status

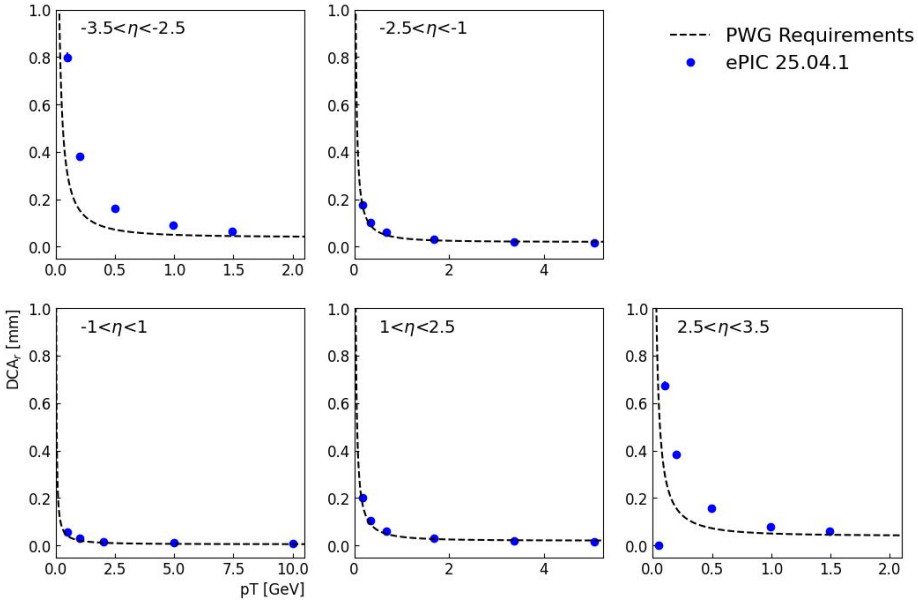
Infrastructure:

- The full chain of track reconstruction (seeding+CKF+ambiguity resolution) is set up in EICrecon
- Primary vertexing ready, with analysis script included in benchmarks
- Ongoing: secondary vertex reconstruction e.g. for decayed particles
- Planned: include time info in CKF, ML-powered pattern recognition for B0 tracker, …

Tracking performance benchmark:

- With uniformly-generated single pion+ events:



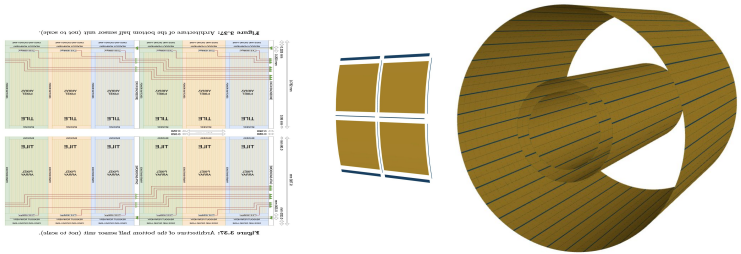


Towards TDR

Demonstrate tracking performance with

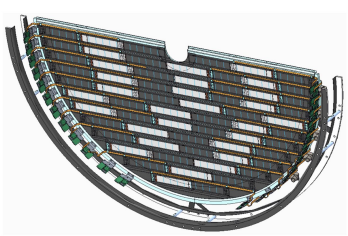
- Realistic detector setup

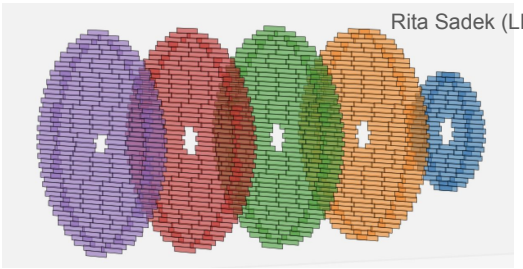
Inner barrel with RSU tiles



Disk module pavement

See SVT R&D report

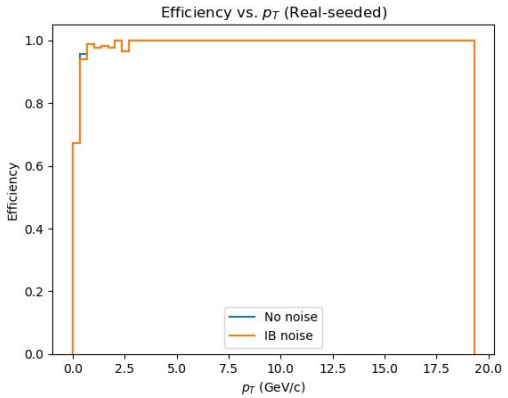




SVT Random pixel noise Mito Funatsu (UCB)

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

	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



Also: study with missing hits/layers, tracker position and material change…

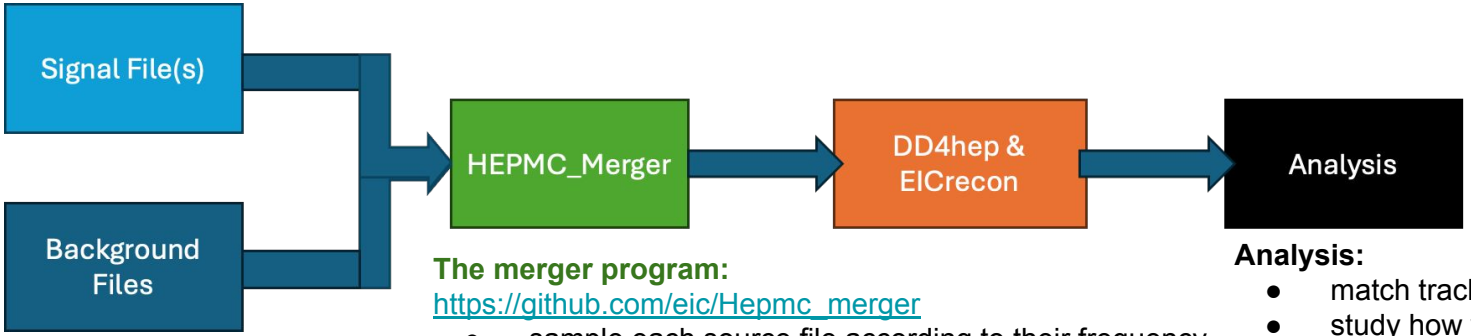
Towards TDR

Demonstrate tracking performance with

- Realistic collision environment (See discussion at the ePIC TIC meeting)

In one merged DIS+Background event (2us, 18x275 GeV beam as an example):

	DIS(Q2>1)	minBias (SIDIS)	Electron beam gas	Synchrotron radiation	Proton beam gas
# of events	0.002	0.9	6.4	28	0.7
# of particles	0.037	14.9	12.8	28	12.4



The merger program:
https://github.com/eic/Hepmc_merger

- sample each source file according to their frequency within a fixed-length (2us) time window
- Will be able to label each source particle with custom generator code in DD4hep v1.32

Analysis:

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

Also: performance study in DIS, Jets, HF, etc ongoing within various WG

Thanks!