Tracking Simulation/Reconstruction

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Incremental Design and Safety Review
of the EIC Tracking Detectors
March 20-21, 2024

Electron-Ion Collider

Charge Questions Addressed

Grey out charge text not being addressed.
GRY RGB HEX CODE: #BFBFBF

1. Are the technical performance requirements appropriately defined and complete for this stage of the project?
2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?
3. Are the current designs and plans for detector, electronics readout, and services sufficiently developed to achieve the performance requirements?
4. Are plans in place to mitigate risk of cost increases, schedule delays, and technical problems?
5. Are the fabrication and assembly plans for the various tracking detector systems consistent with the overall project and detector schedule?
6. Are the plans for detector integration in the EIC detector appropriately developed for the present phase of the project?
7. Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?

Outline

- Software Framework
- ePIC Tracking Detector in DD4HEP
  - Coverage
  - Detector Hits
  - Material and Detector Response
- Reconstruction
  - Workflow
  - Seeding
  - Tracking Performance
  - Tracking in Background
  - Vertex Reconstruction
- Summary

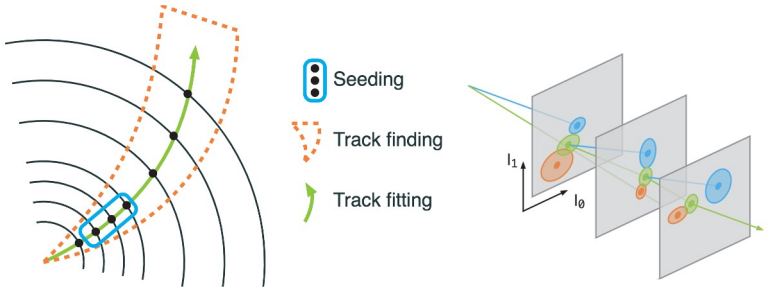
Software Framework

Charge 2, 3

- Geometry Framework (epic)
  - Material and segmentation
  - Based on DD4HEP
- Reconstruction Framework (EICRecon)
  - Based on PODIO/JANA
  - Digitization
  - Track Reconstruction
    - Based on ACTS Combinatorial Kalman Filter (CKF)
    - Combined track finding and fitting
    - Realistic seeder
- ePIC data structure (EDM4eic) modeled after EDM4hep

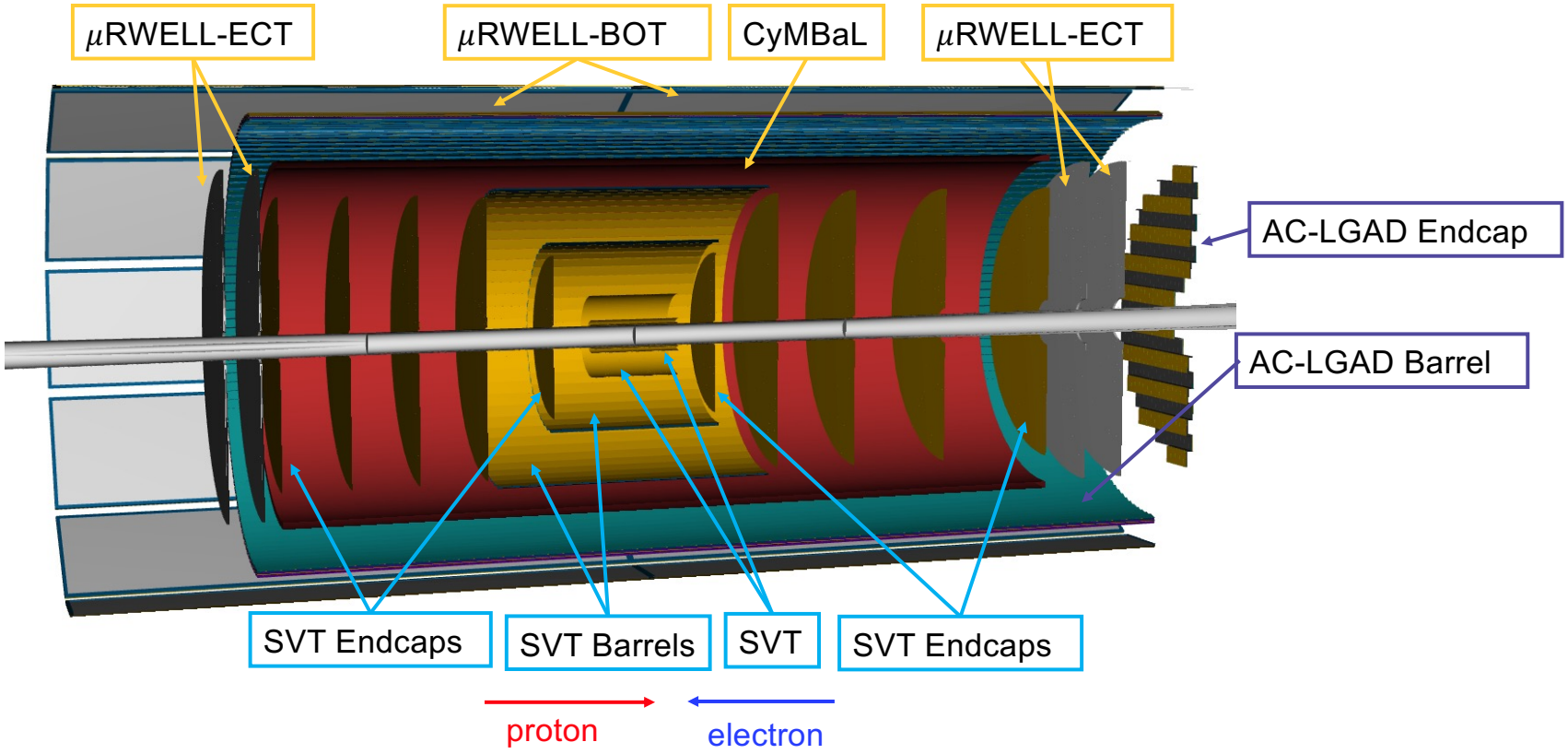
DD4hep

acts A Common Tracking Software



ePIC Tracking Detector in DD4HEP

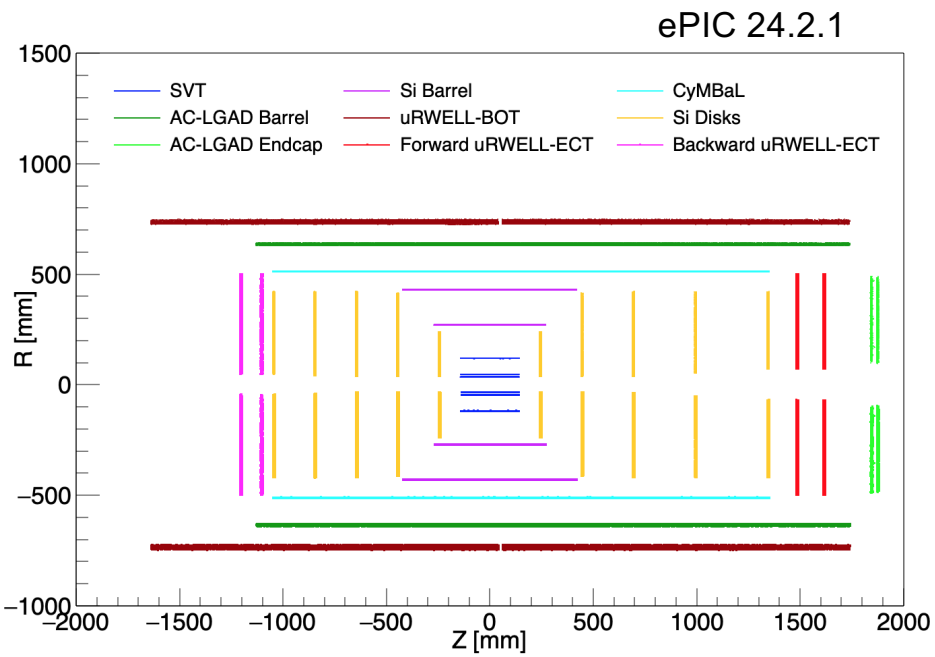
Charge 2, 3

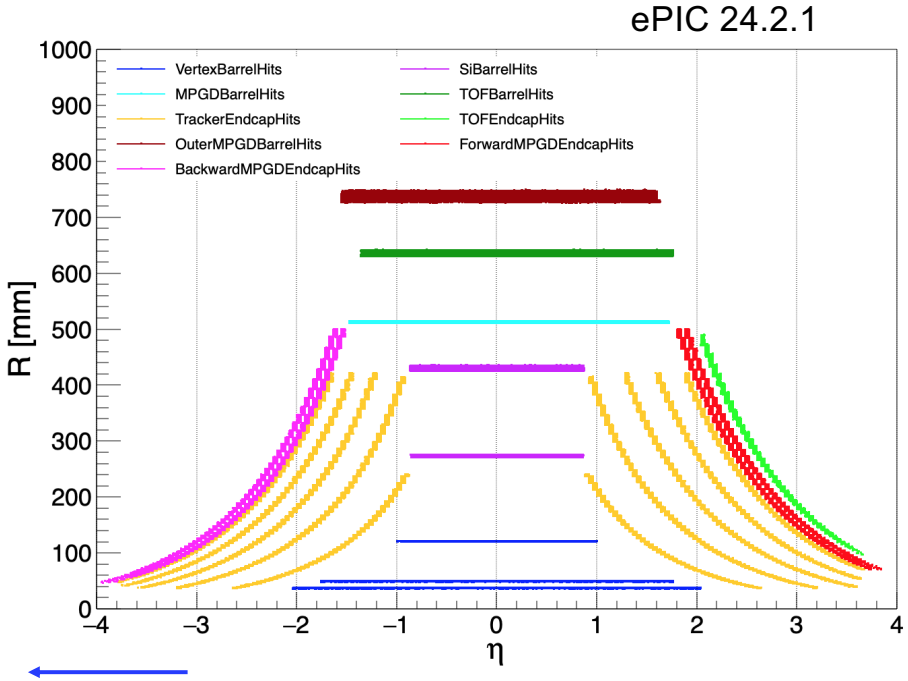


Coverage

Charge 2, 3

- GEANT-level tracker hits showing geometric coverage





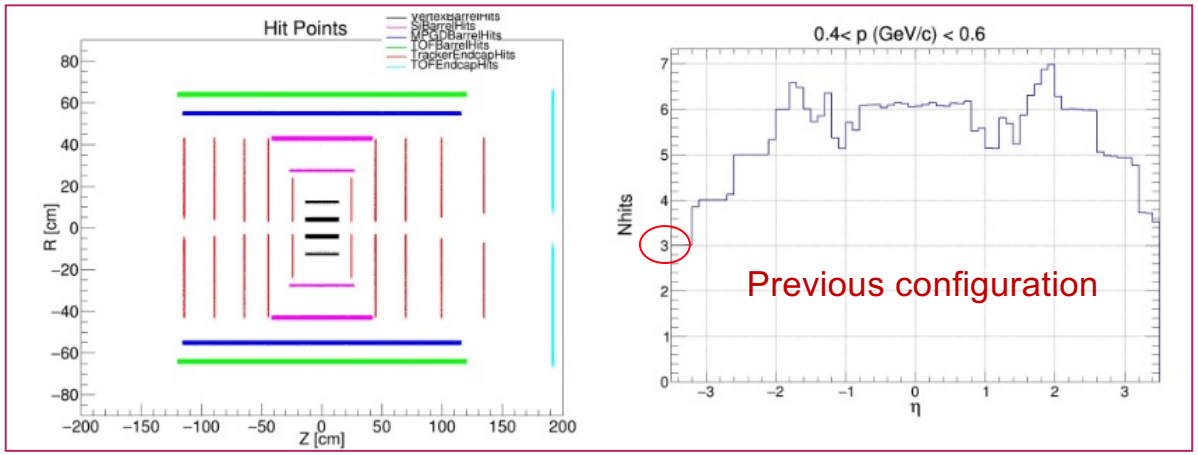
proton

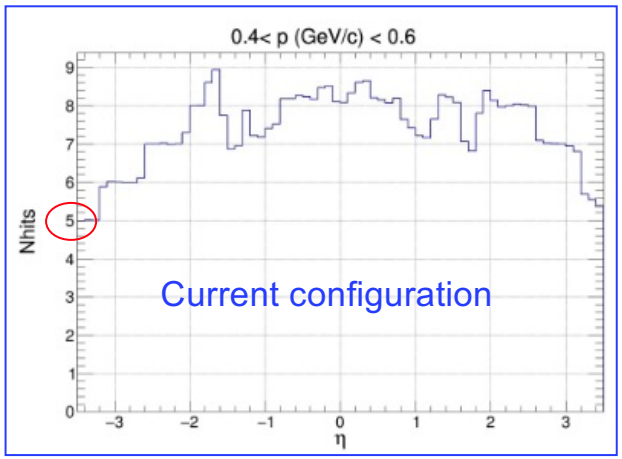
electron

Tracker Hits

Charge 2, 3

- Additional MPGD layers increased number of hits
  - Extreme $|\eta| > 3$ see hits increasing from ~3 to 5
  - Hits vs. η (Generator Level)

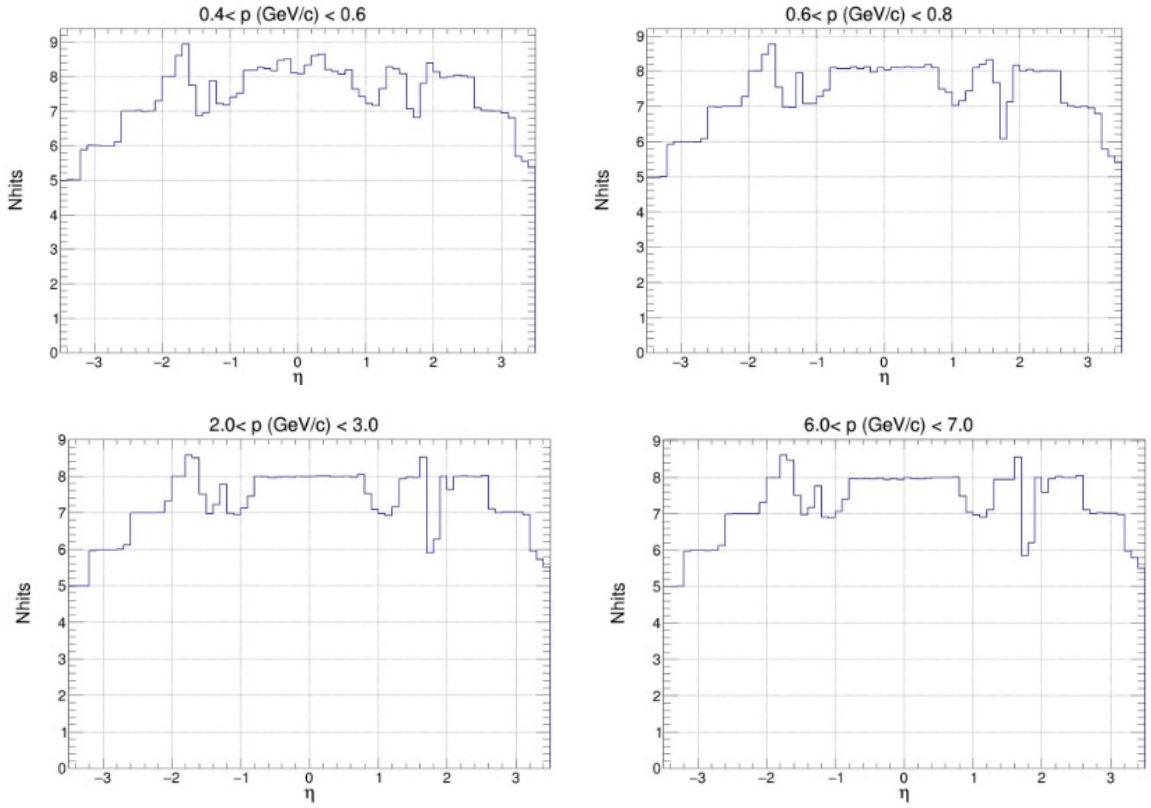




Tracker Hits: Current Configuration

Charge 2, 3

- Additional MPGD layers increased number of hits
  - Current configuration
  - Hits vs. η (Generator Level)

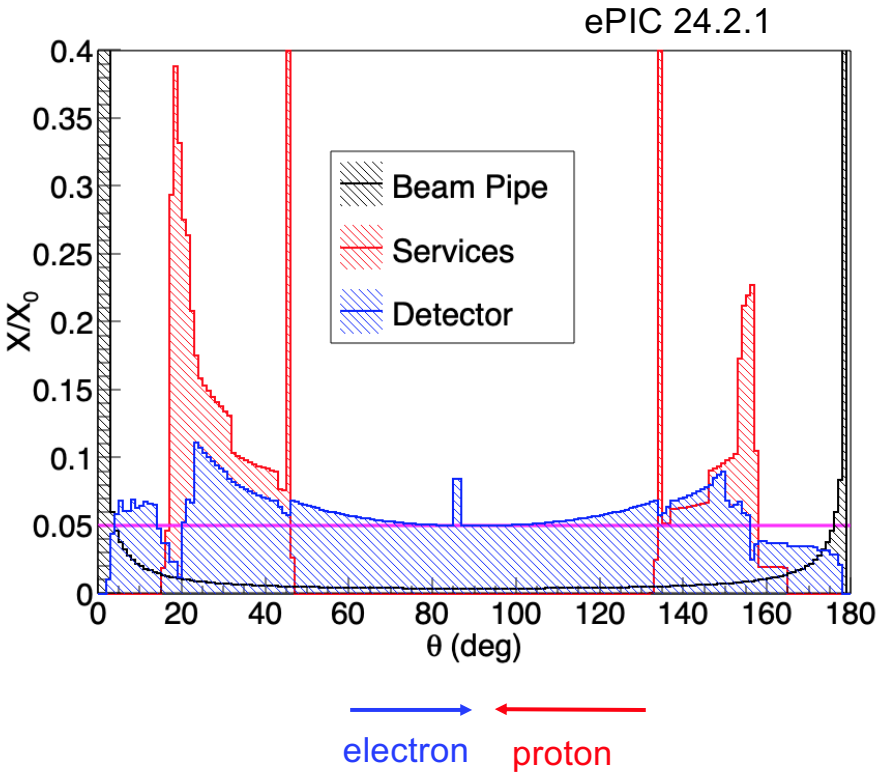


Detector Material and Response

Charge 2, 3

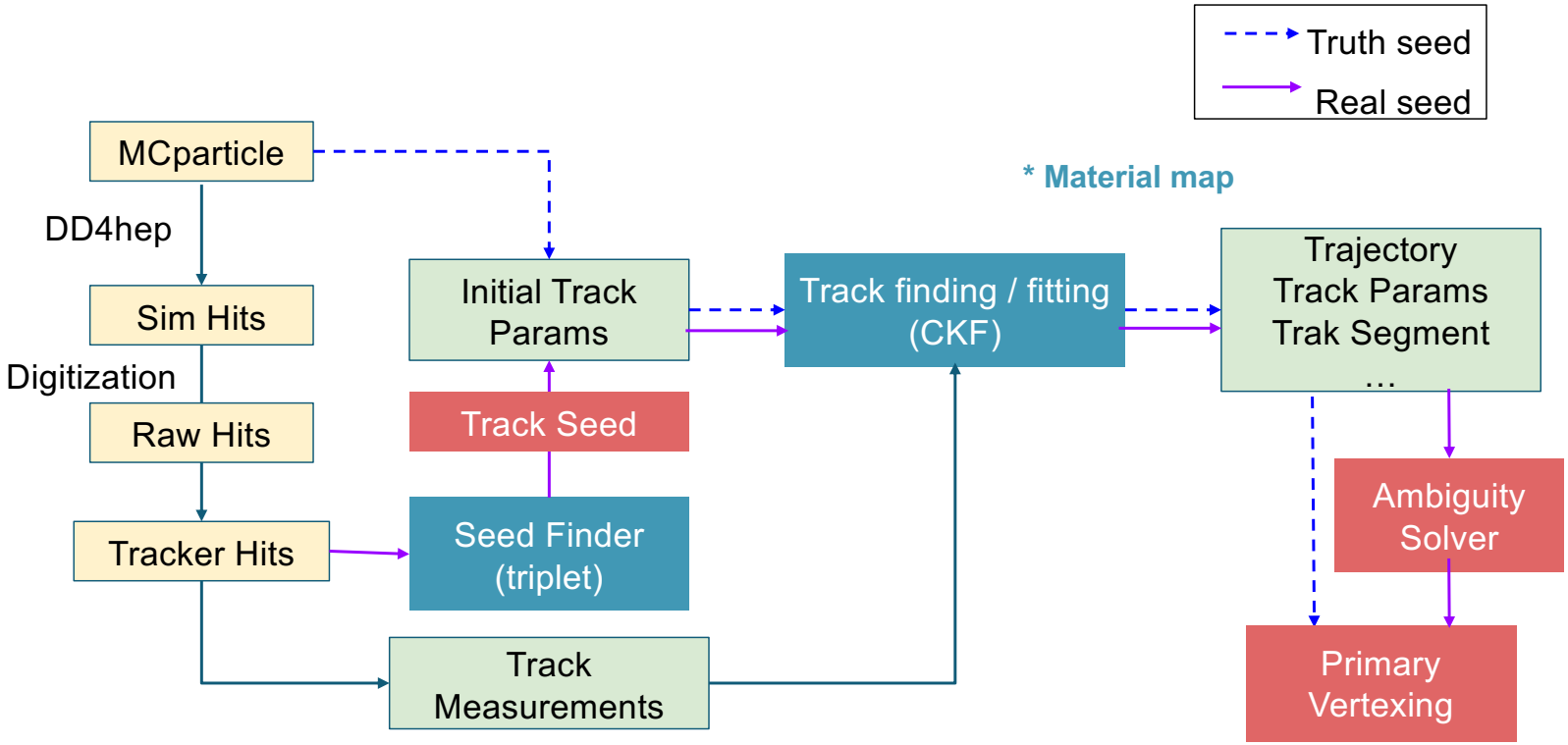
- Detector Response
  - Segmentation implemented as to reproduce expected hit resolution
  - Digitization based on deposited energy in detector
  - Spatial resolutions used in simulation:

Detector	Resolution [μm]
SVT Detectors	5.8
MPGD Detectors	150
AC-LGAD Barrel	28.9 x 2,890
AC-LGAD Endcap	28.9 x 289



Reconstruction Framework

Charge 2, 3

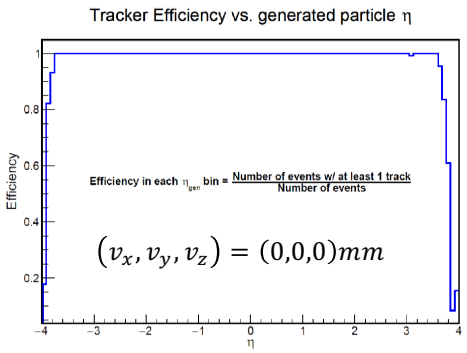


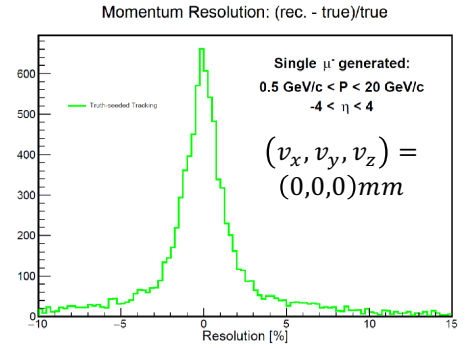
Track Seeding

Charge 2, 3

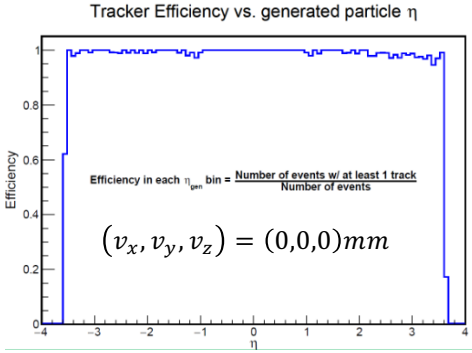
- Realistic track seeding done using ACTS orthogonal seeder algorithm
  - Realistic seeded results consistent with truth seeded results
- Tracking studied with generated vertices spanning the beam spot width ($\Delta z = \pm 100\ mm$)
  - Reasonable results for $|z| < 10mm$
  - Efficiency gaps seen near the edge of the beam spot ($|z| = 100mm$)
  - Off-beamline ($|x| = 1mm$) are also reasonable
- Additional seed-finder parameter tuning ongoing

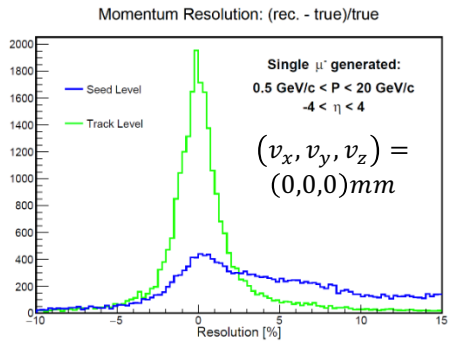
Truth Seed





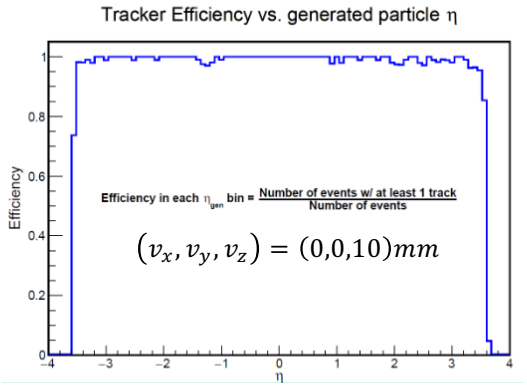
Realistic Seed

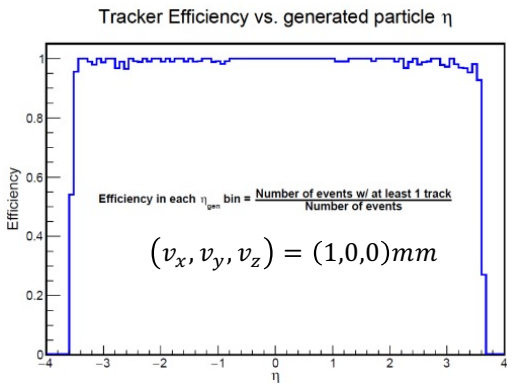


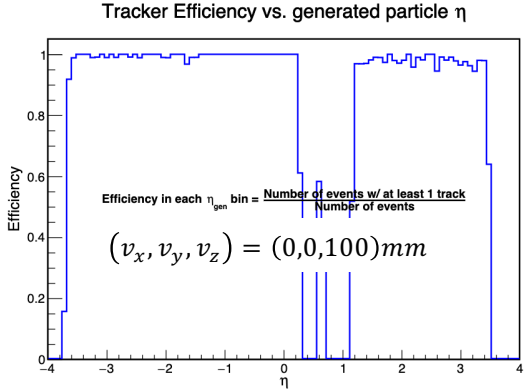


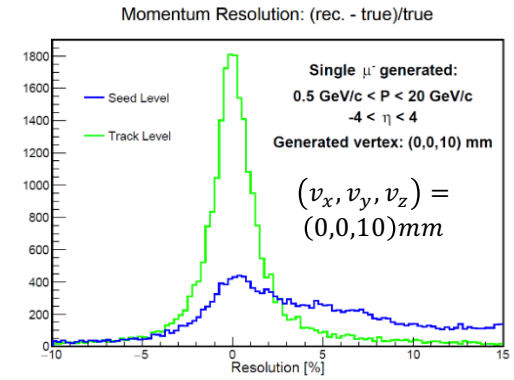
Track Seeding: Realistic Seeding

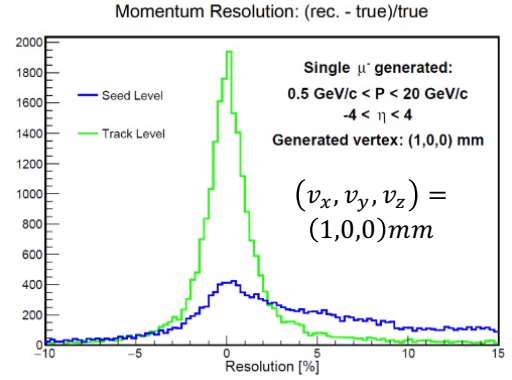
Charge 2, 3

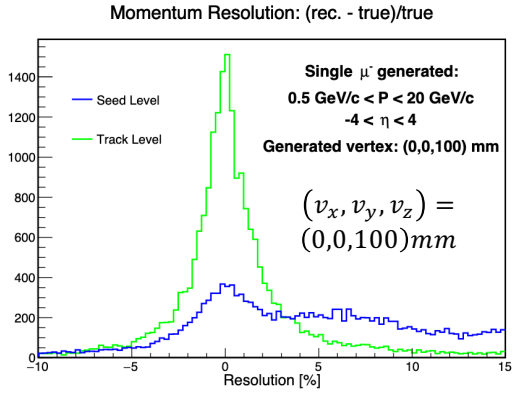










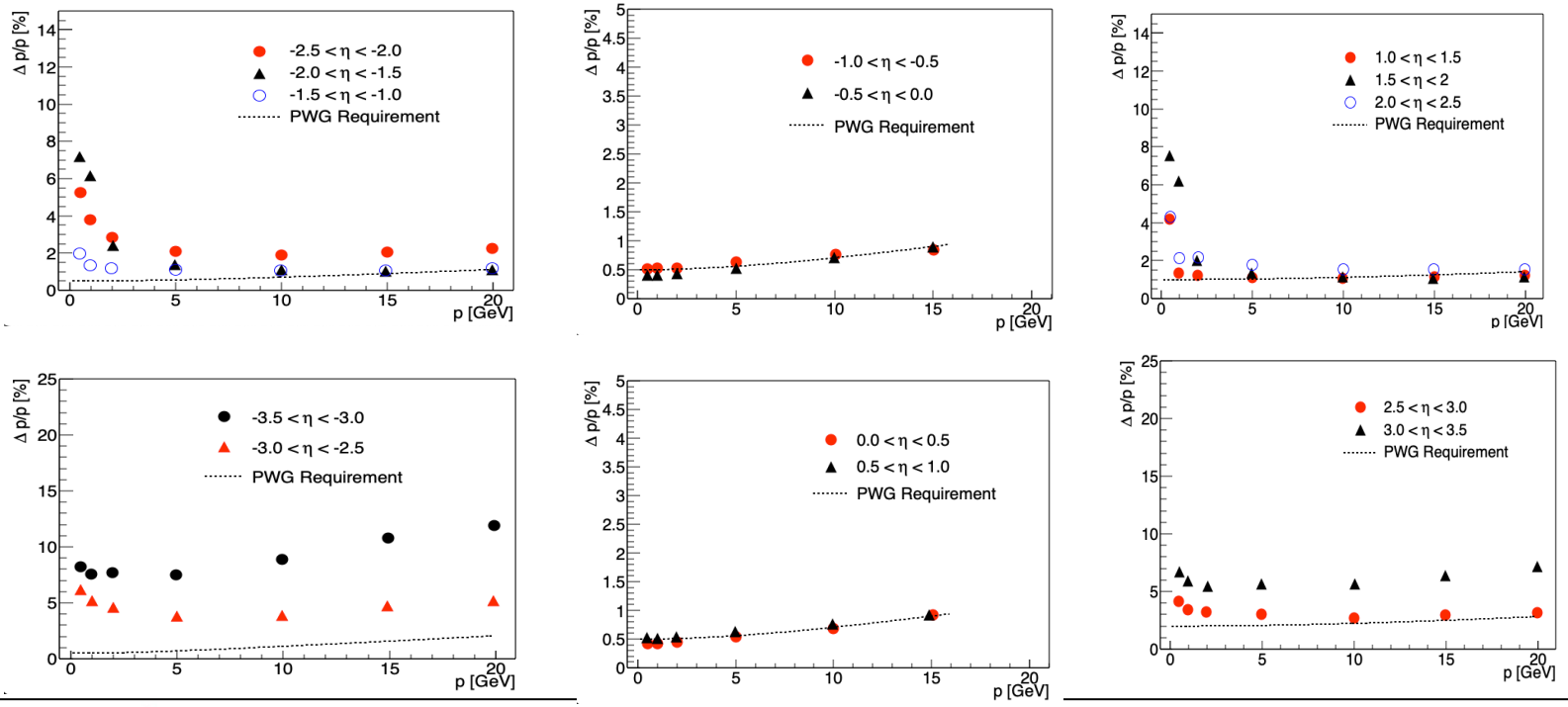


Preliminary Tracking Performance:
Momentum Resolution

Charge 2, 3

- Single particle (*includes AC-LGAD systems, update real seed)

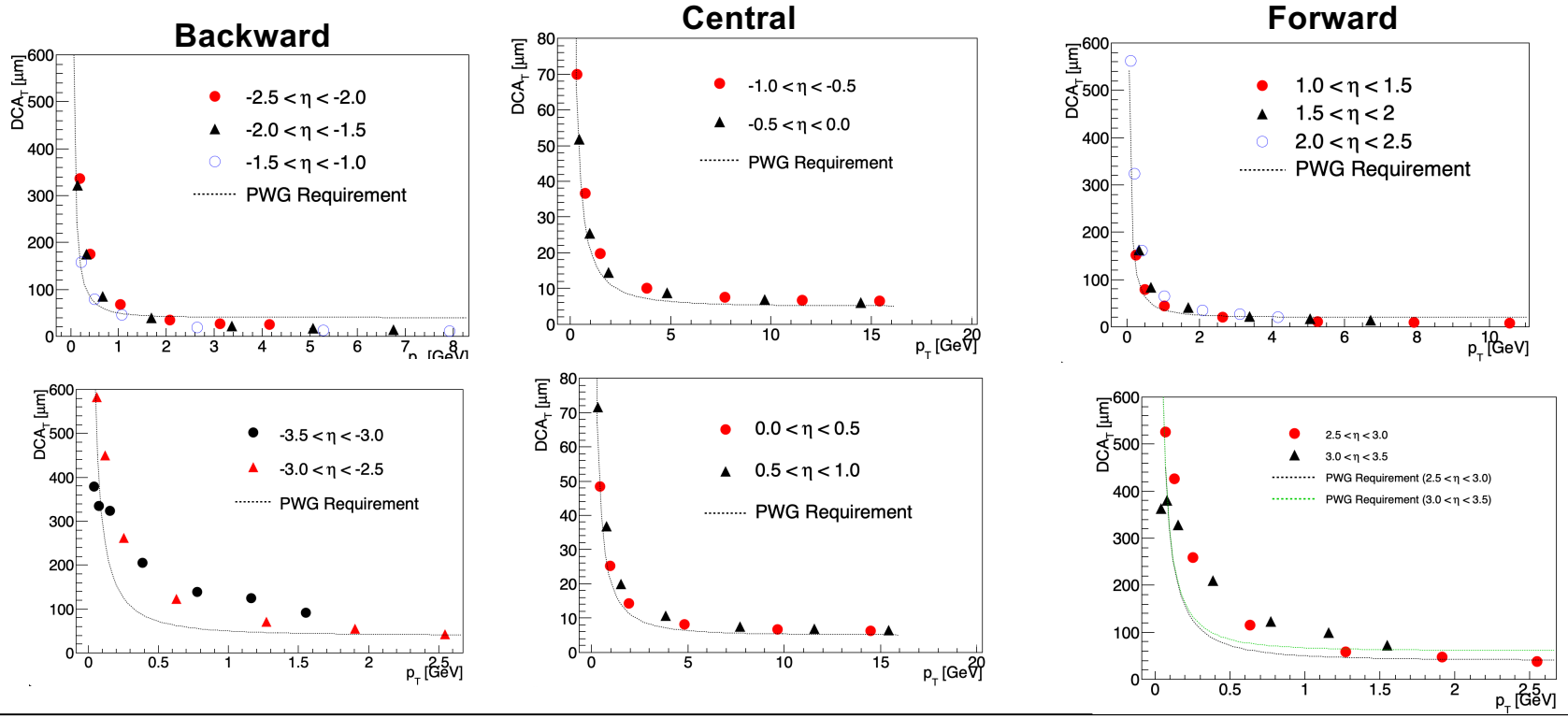
Backward | **Central** | **Forward**



Preliminary Tracking Performance: Pointing Resolution

Charge 2, 3

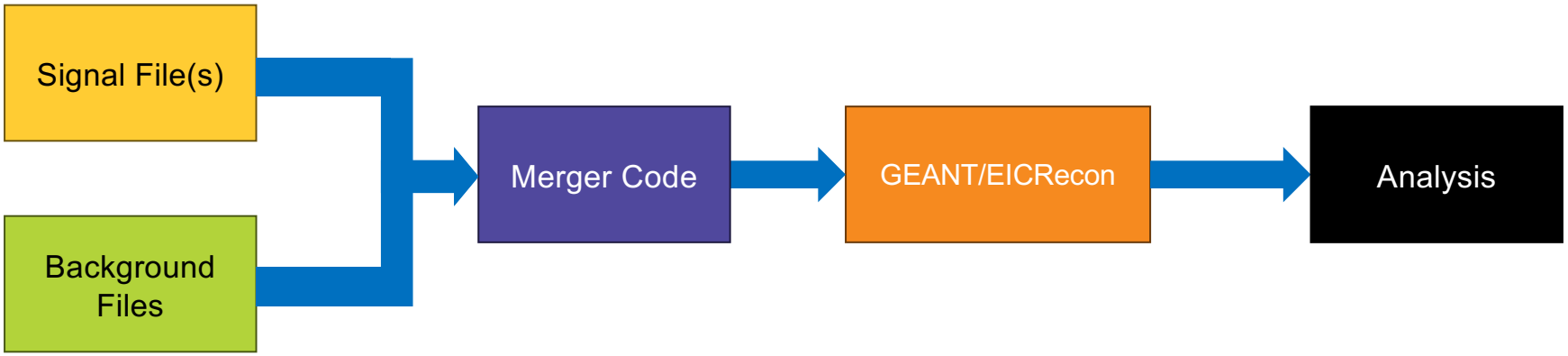
- Single particle (*includes AC-LGAD systems, update to real seed)



Structure for Tracking in Background

Charge 2, 3

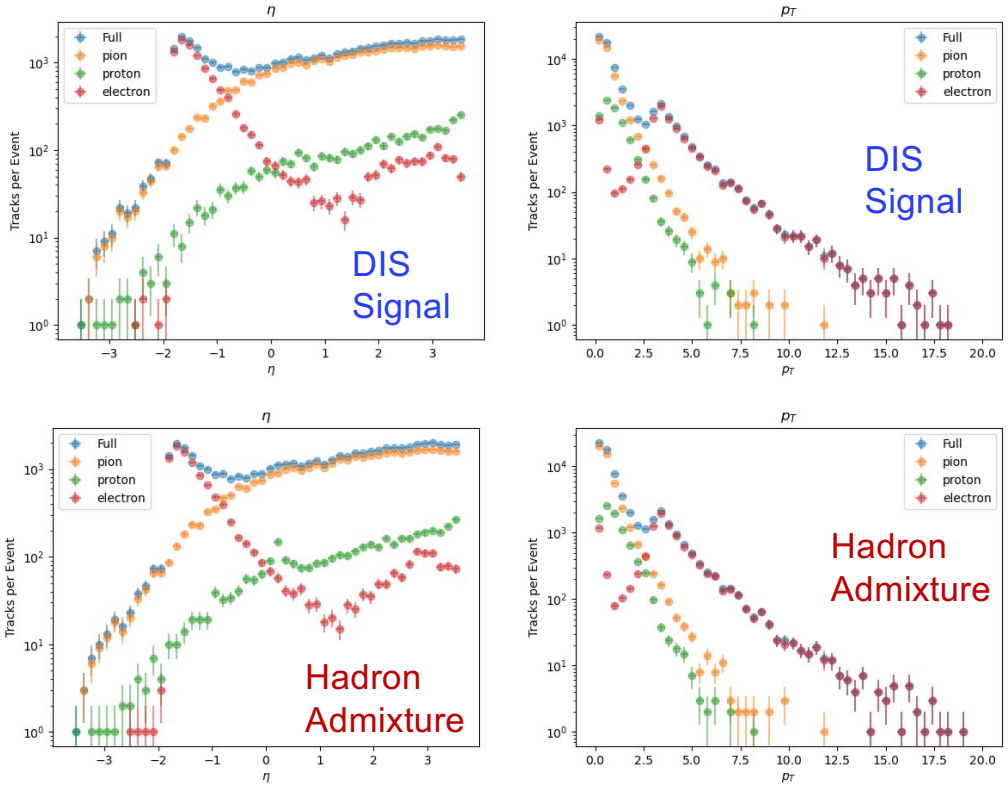
- HEPMC Admixing code implemented
  - merges signal and background files
- Considers three main background contributions
  - Synchrotron radiation, hadron beam-gas, and electron beam-gas



Tracking in Background

Charge 2, 3

- Track reconstruction within a background environment is beginning
- DIS signal event:
  - $10{\times}100\ GeV^2$,
  - $p_T > 150\ GeV$,
  - $Q^2 > 10\ GeV^2$
- Initial exploration of tracking (truth/realistic seeding) in hadron-beam gas background

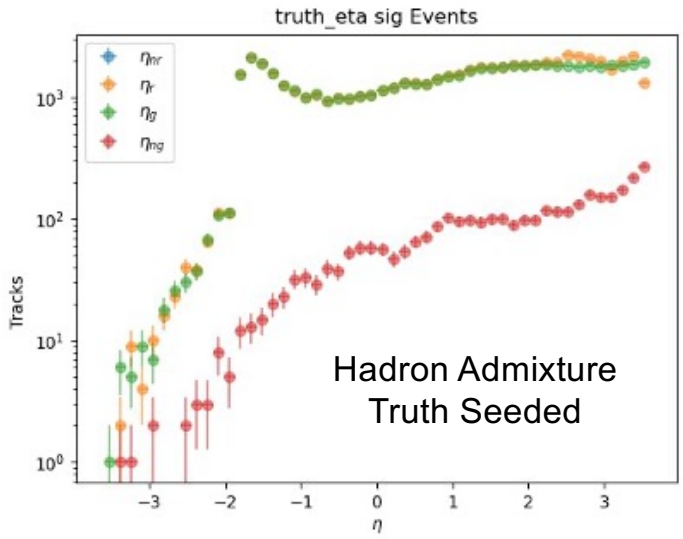


Tracking in Background

Charge 2, 3

- Ongoing work to:
  - Look at other background sources: synchrotron radiation, electron-beam gas, and full background admixture
  - Use timing information in track fitting
  - Understand better MC Particles that do not get reconstructed
  - Pattern recognition algorithm

- Yellow=Reconstructed Particles that get matched
- Green=MC Particles that get Reconstructed
- Red=MC Particles that do not get Reconstructed



Vertex Reconstruction

Charge 2, 3

- ACTS Iterative vertex finder algorithm implemented for vertex finding
  - Initial vertex reconstruction studies have begun
- Vertex object data structure being reviewed for ePIC software framework

Summary

- Reasonable performance in realistic seeded tracking across the beam spot width
  - Efficiency drop seen at edge of beam spot being investigated
- Preliminary tracking performance with single particles has been assessed
  - Current tracker configuration improves upon number of tracker hits, particularly at large $|\eta|$
  - The tracking system alone meets Yellow Report requirements in some regions, and misses in others
- Structure and tools are in place for performing tracking in background environment
  - Structure and tools are in place
  - On going work to focus on studying impact of background sources,
  - implementing timing,
  - and pattern recognition algorithm
- Vertex reconstruction work has begun
  - Initial vertexing algorithm in place
  - Vertex object being defined for EDM4EIC

Detector Material

Charge 2, 3