Tracking Simulation/Reconstruction

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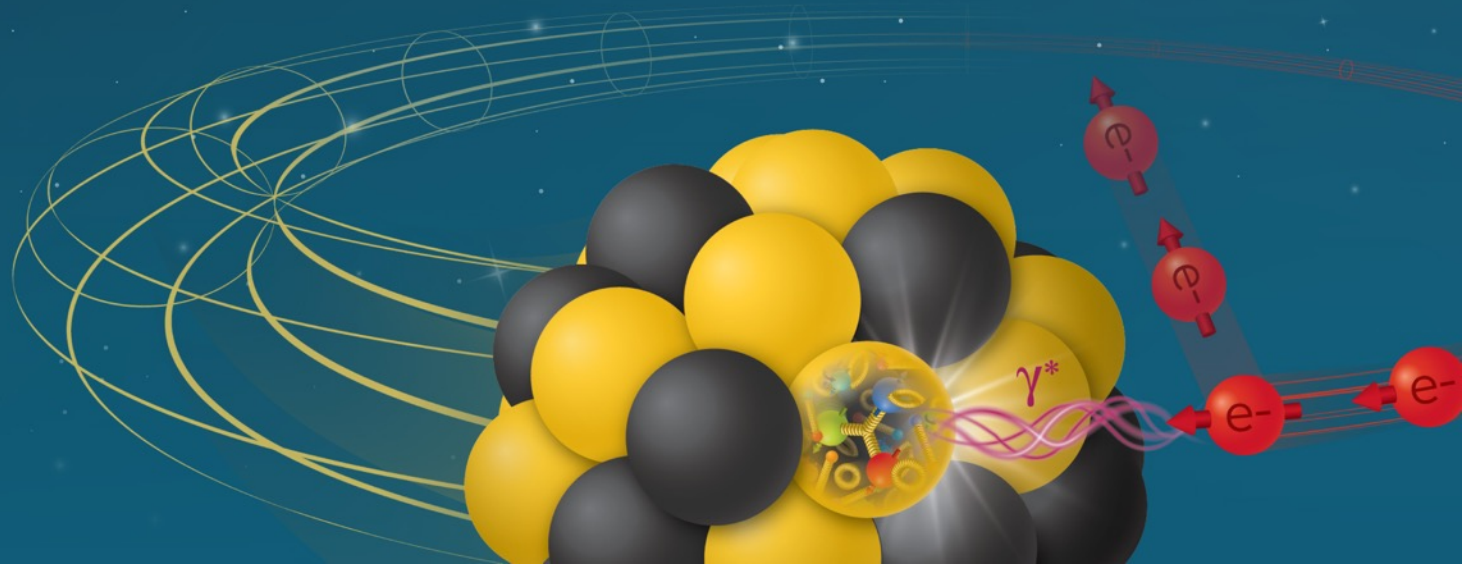
Incremental Design and Safety Review
of the EIC Tracking Detectors
March 20-21, 2024

Electron-Ion Collider



Charge Questions Addressed

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?

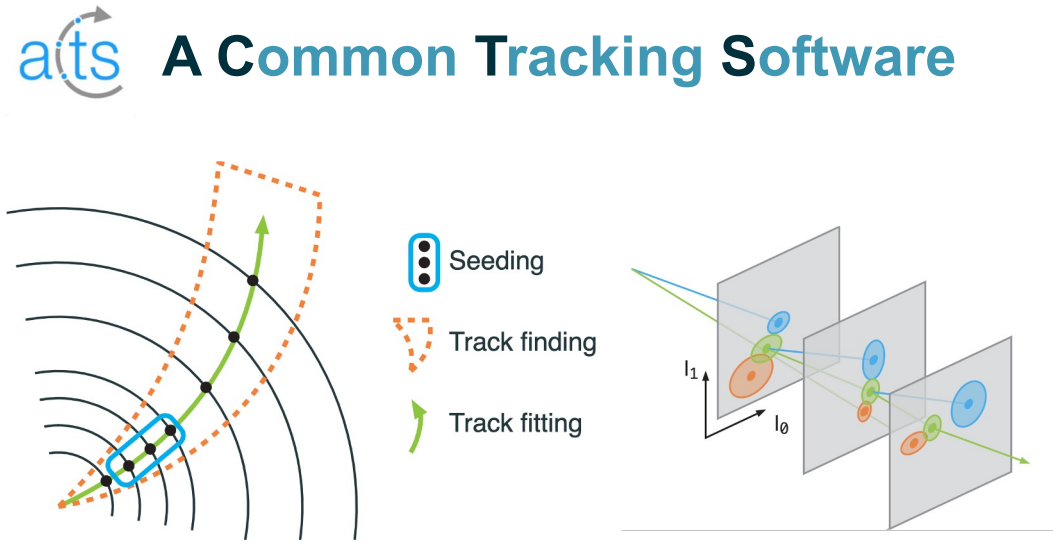
Outline

- 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

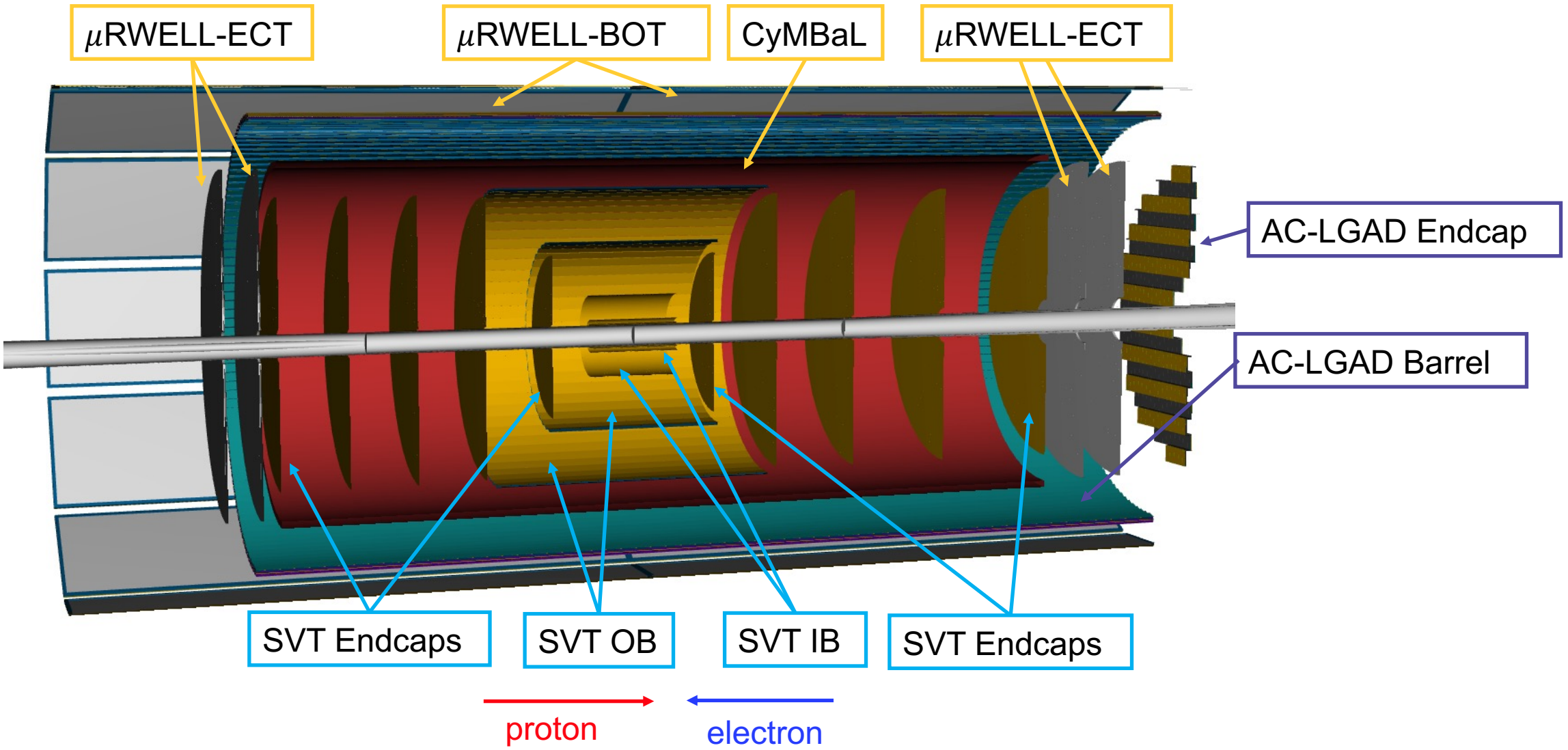
Charge 2, 3

- 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



ePIC Tracking Detector in DD4HEP

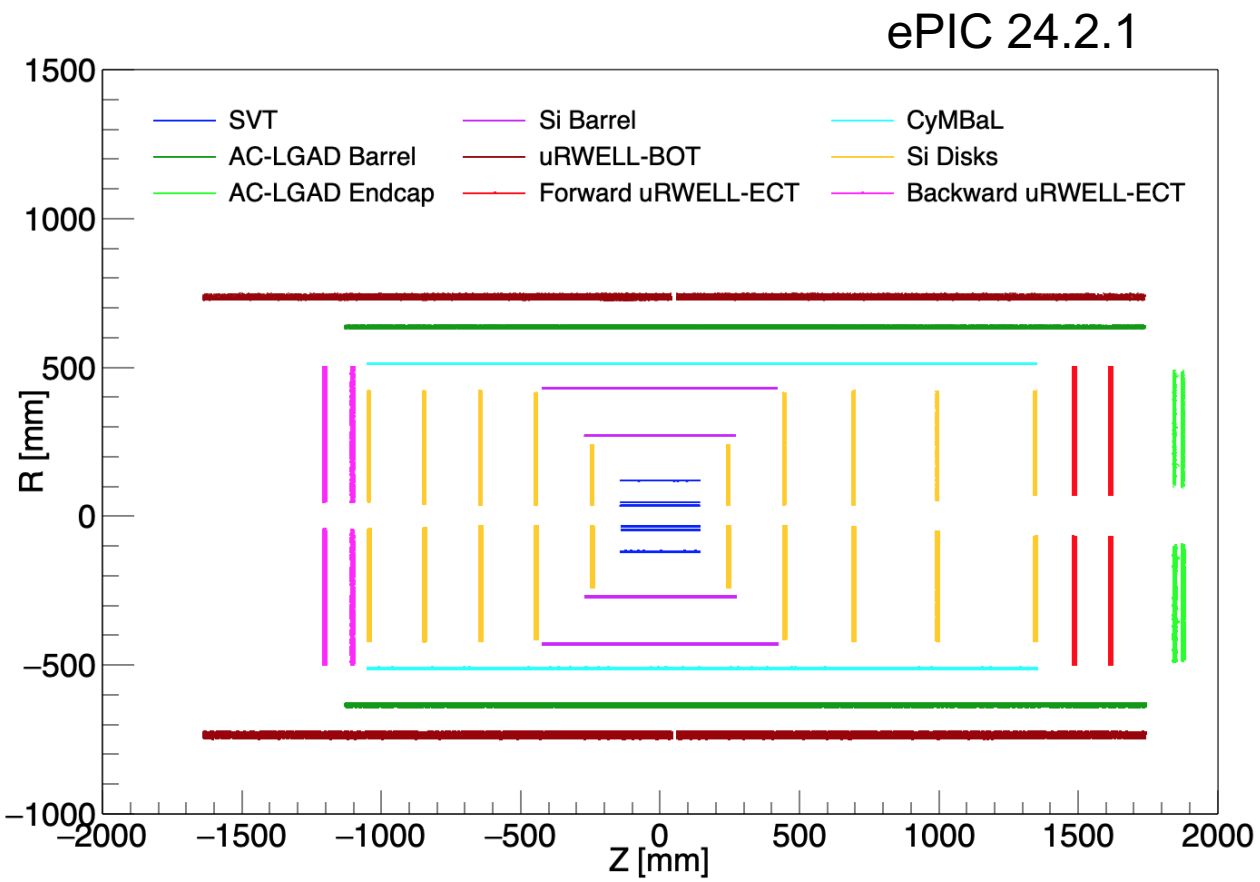
Charge 2, 3

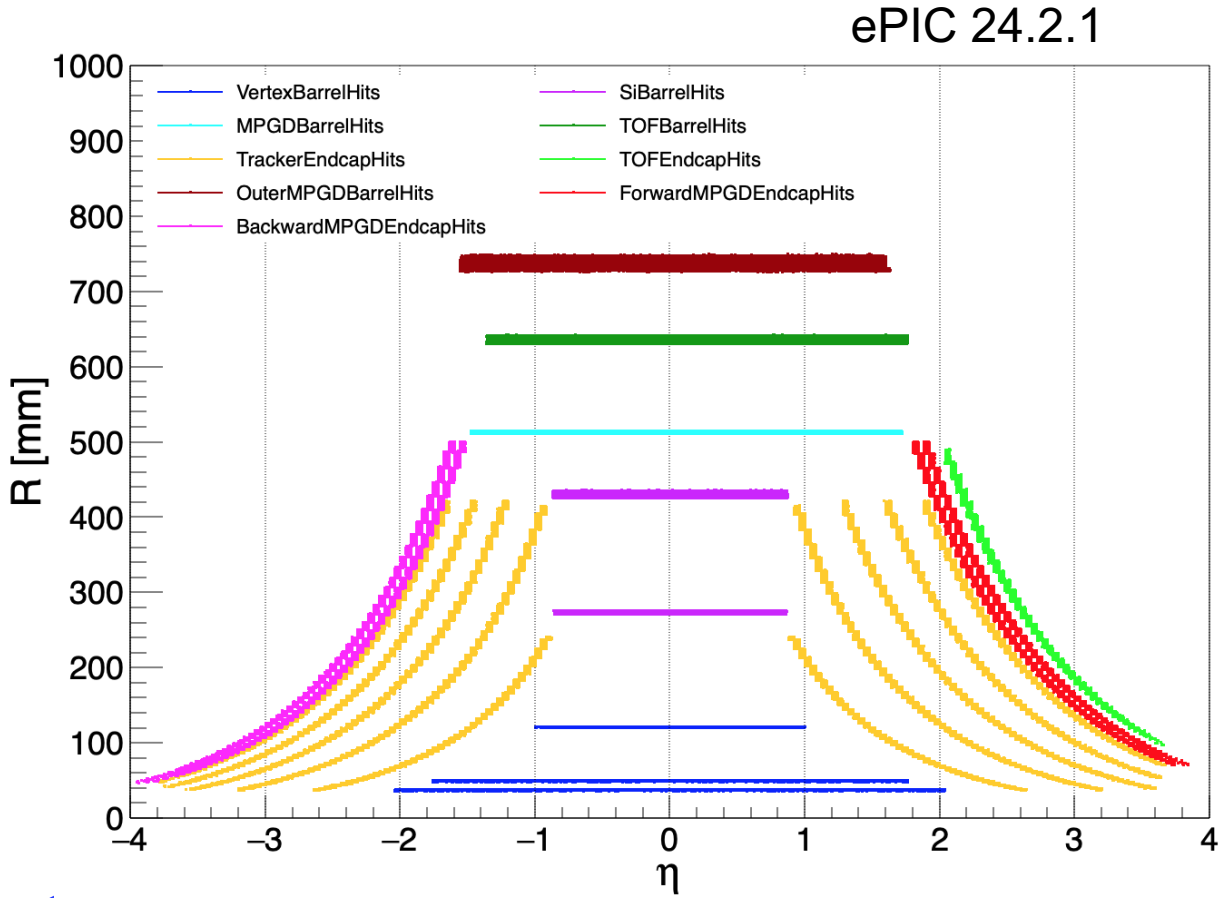


Coverage

Charge 2, 3

- GEANT-level tracker hits showing geometric coverage





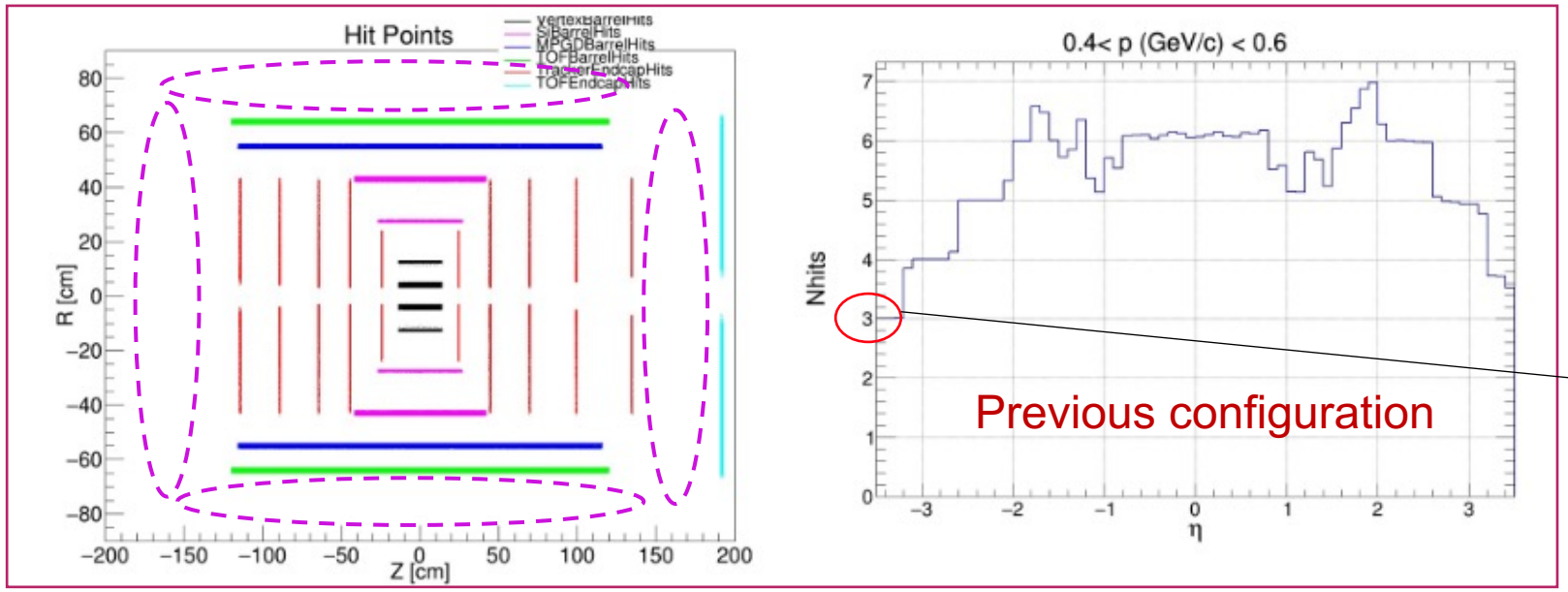
proton

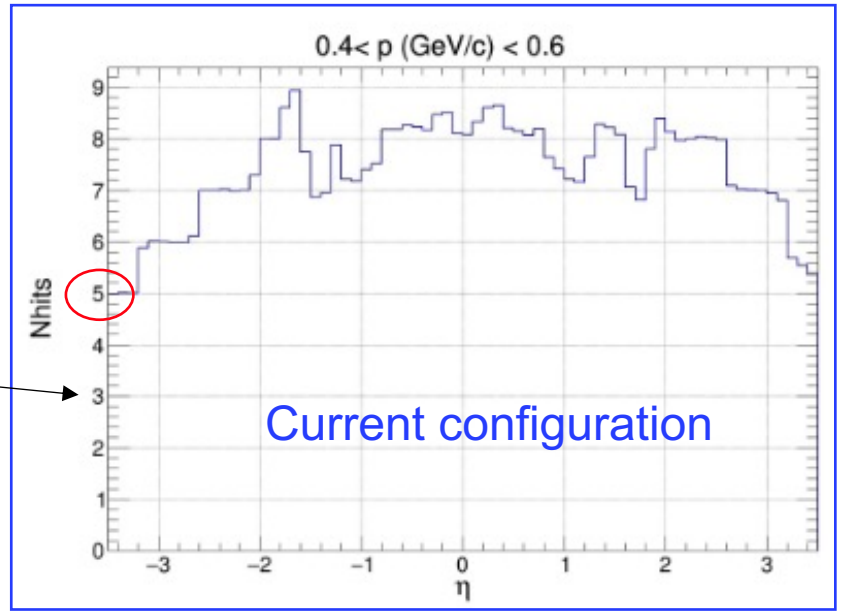
electron

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)



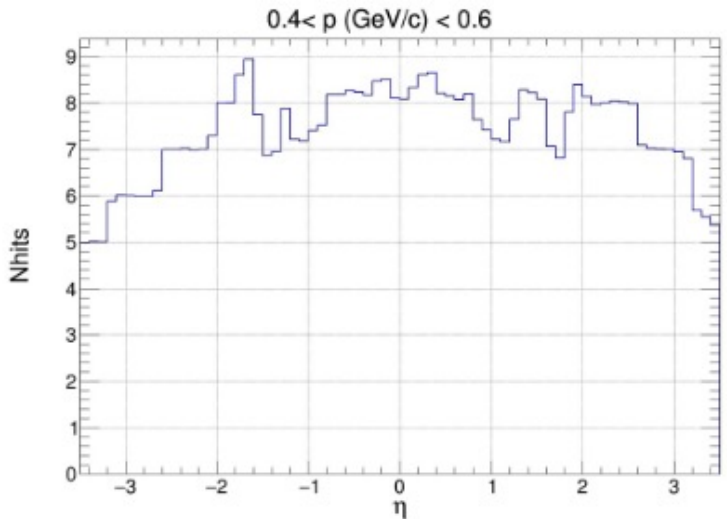


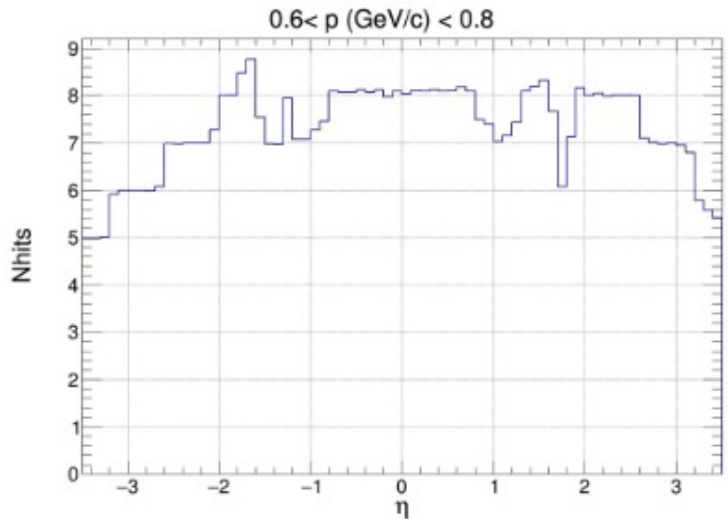
- Missing sub detectors: μRWELL-BOT, μRWELL-ECT

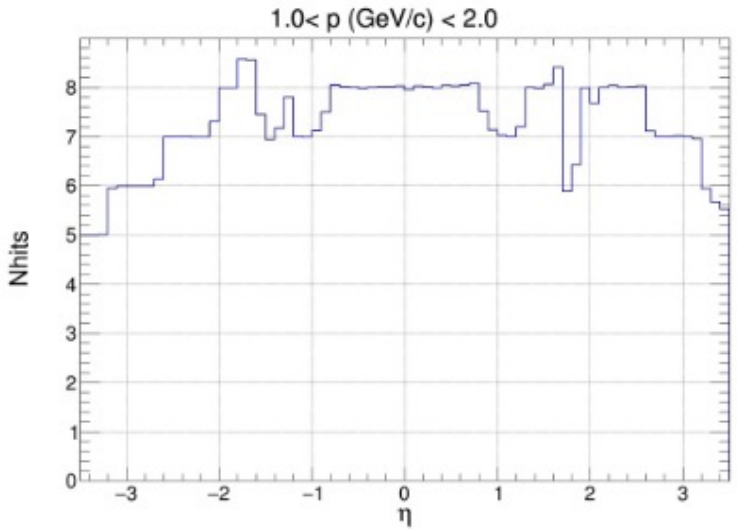
Tracker Hits: Current Configuration

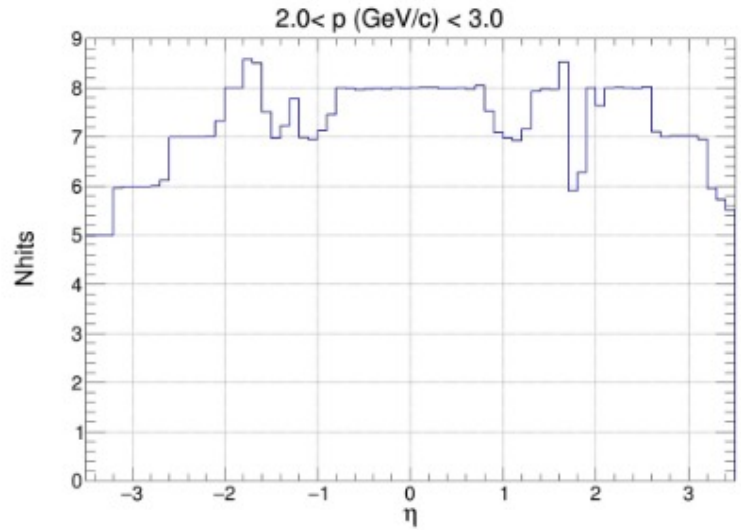
Charge 2, 3

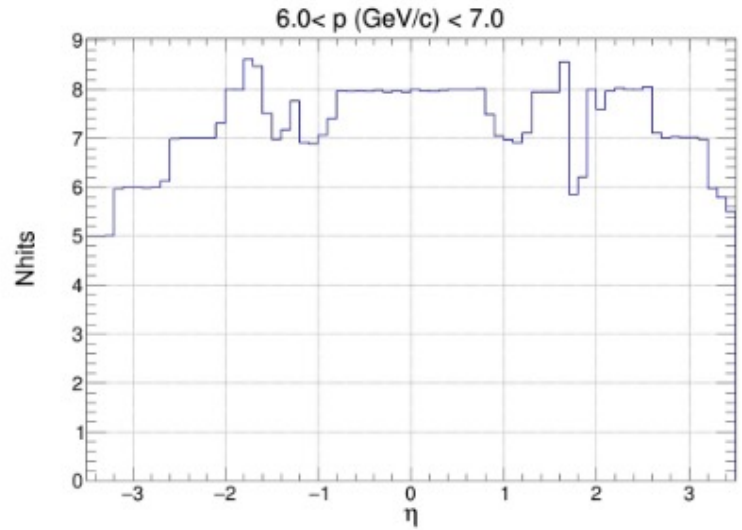
- Additional MPGD layers increased number of hits
  - Current configuration
  - Hits vs. η (Generator Level)









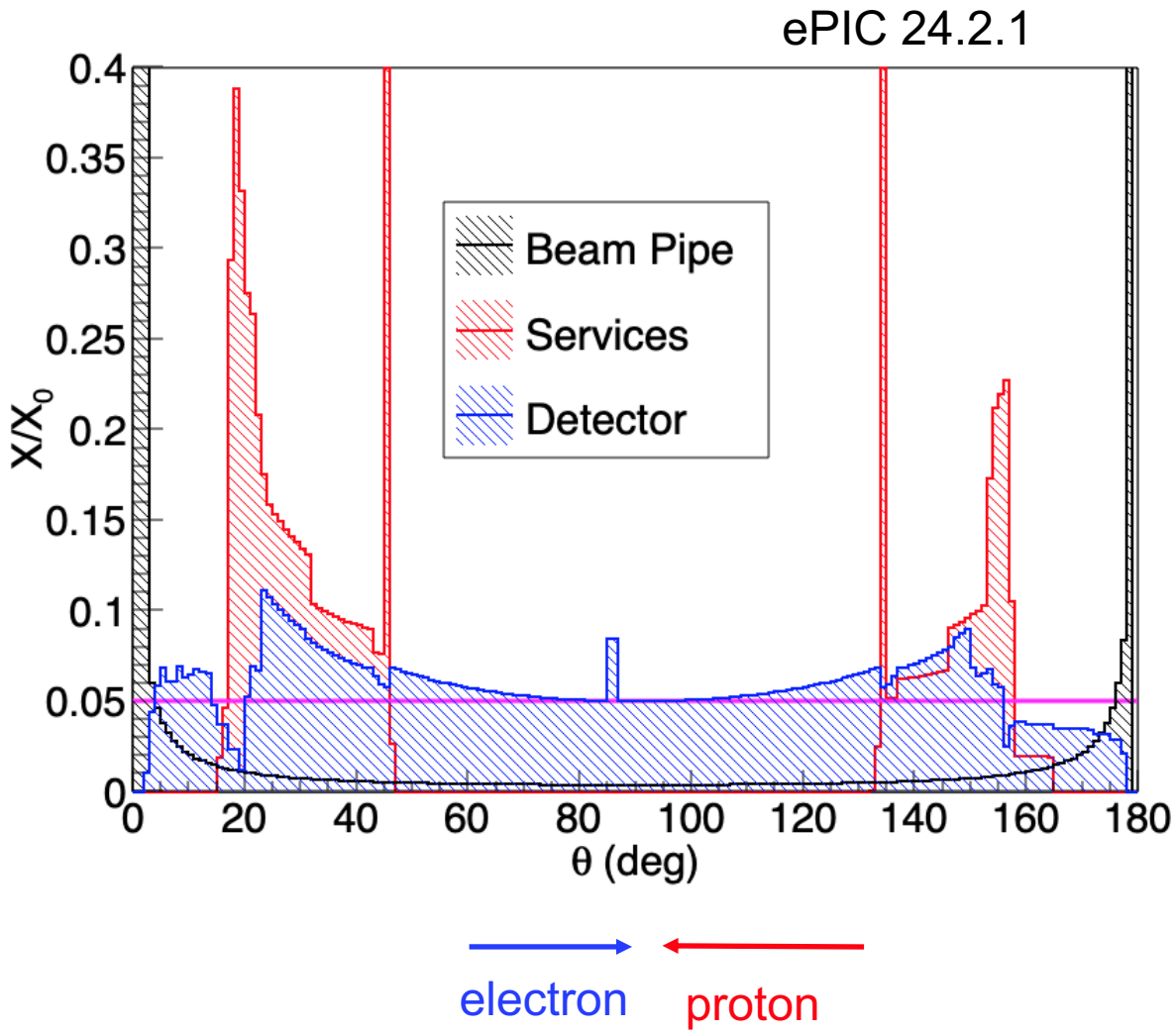


Detector Material and Response

Charge 2, 3

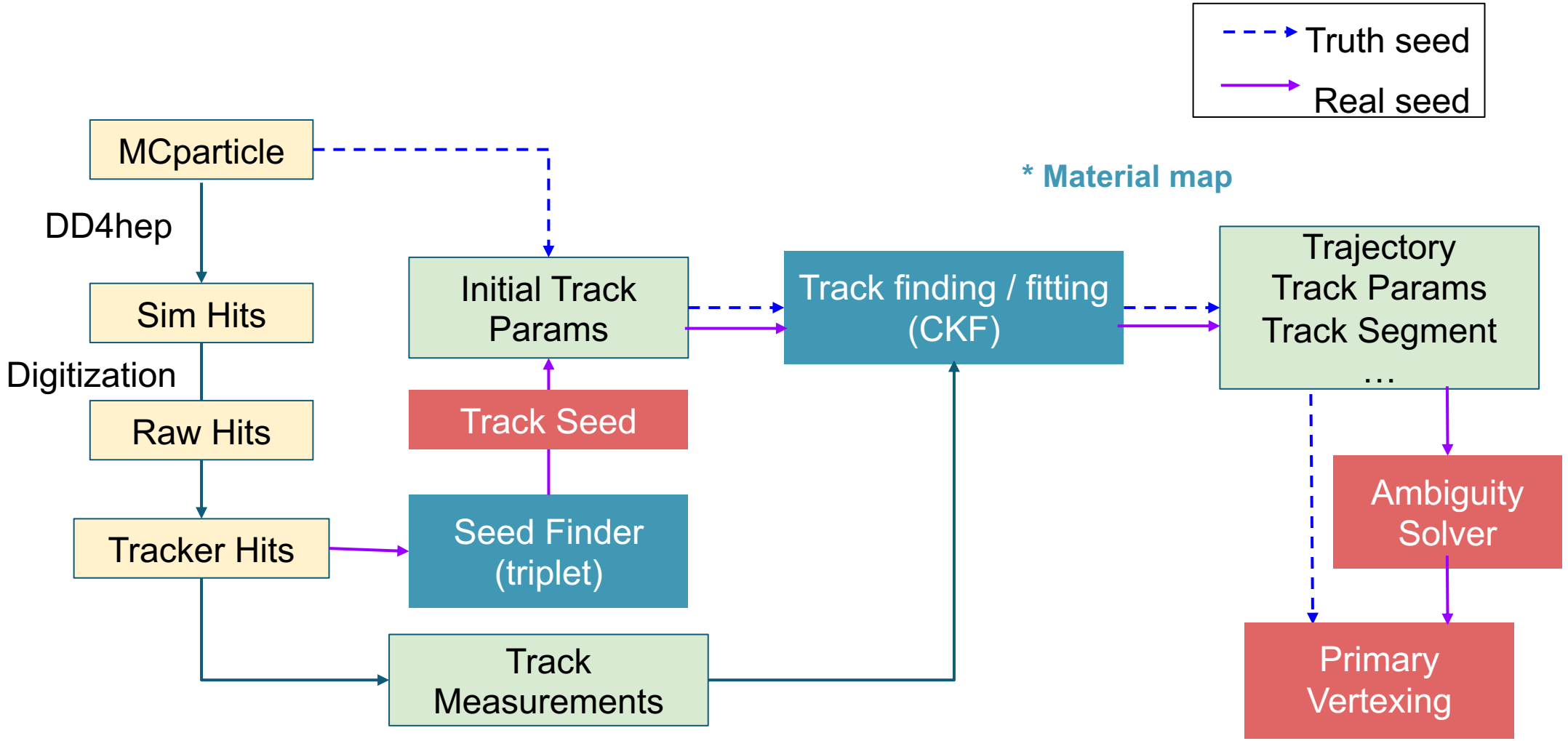
- Detector Response
  - Segmentation implemented as to reproduce expected hit resolution
  - Digitization based on deposited energy in detector
  - Spatial resolutions used in simulation:

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



Reconstruction Framework

Charge 2, 3

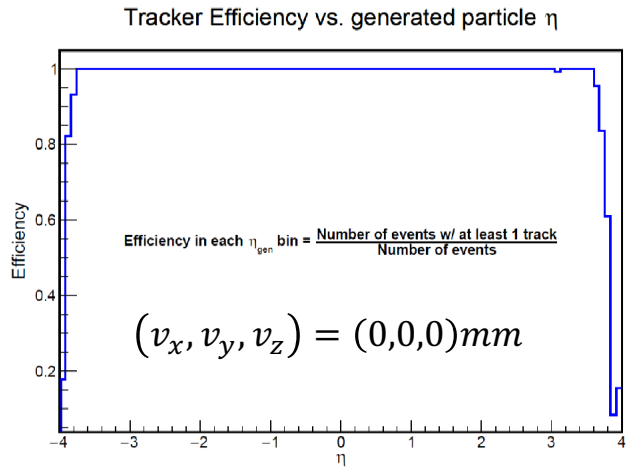


Track Seeding: Single Particle

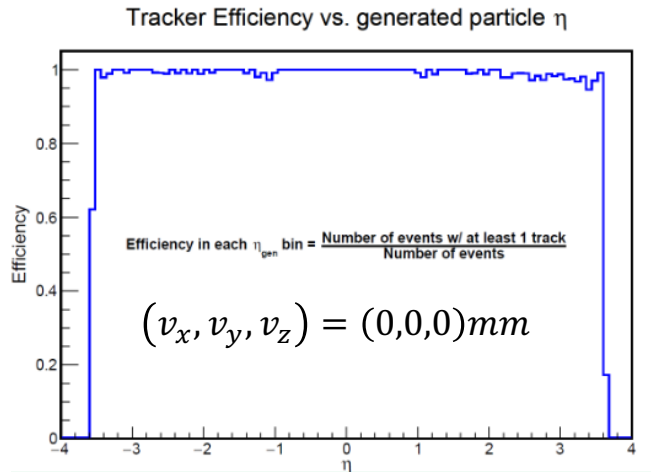
Charge 2, 3

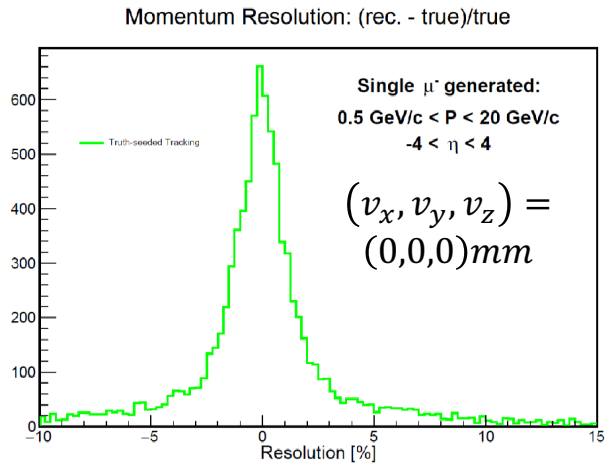
- Realistic track seeding done using ACTS orthogonal seeder algorithm
  - Realistic seeded results reasonable compared with truth seeded results
- Tracking studied with generated vertices spanning the beam spot width ($\Delta z = \pm 100\, mm$)
  - Reasonable results for $|z| < 10mm$ and Off-beamline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

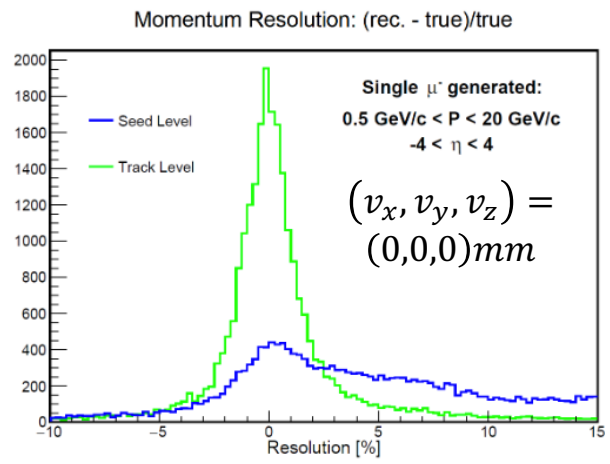
Truth Seed



Realistic Seed

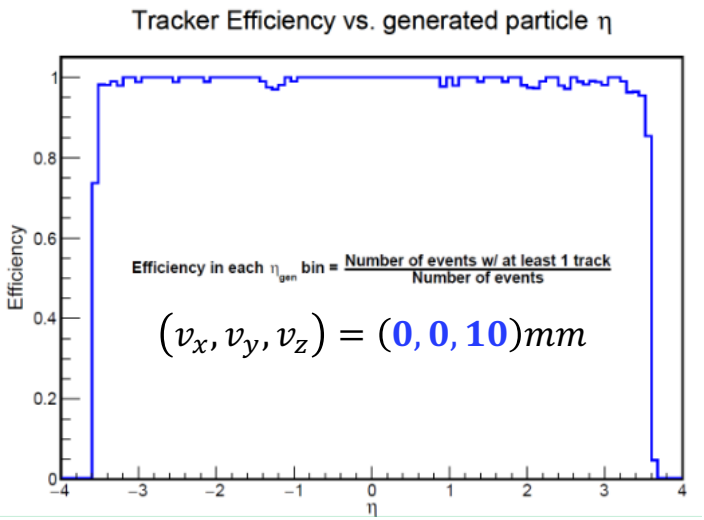


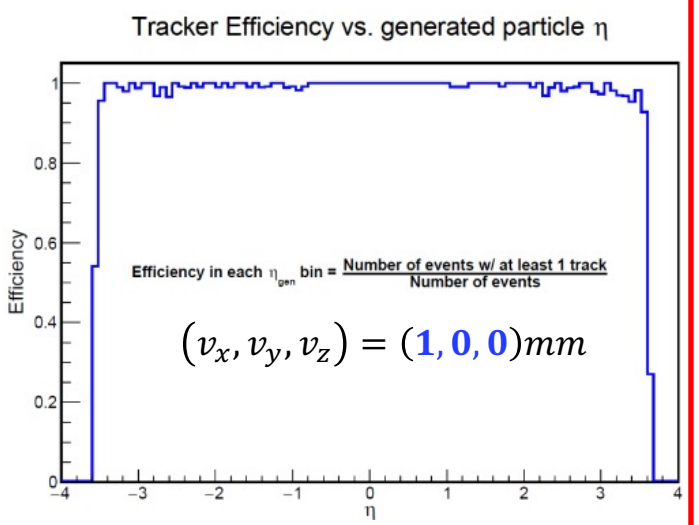


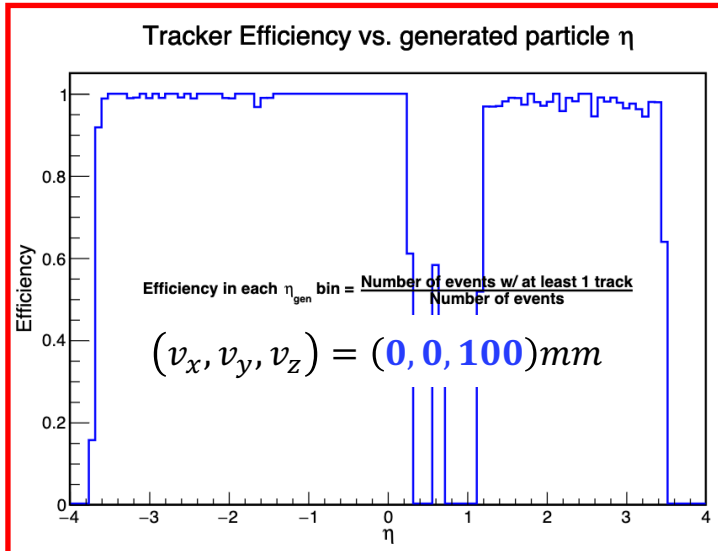


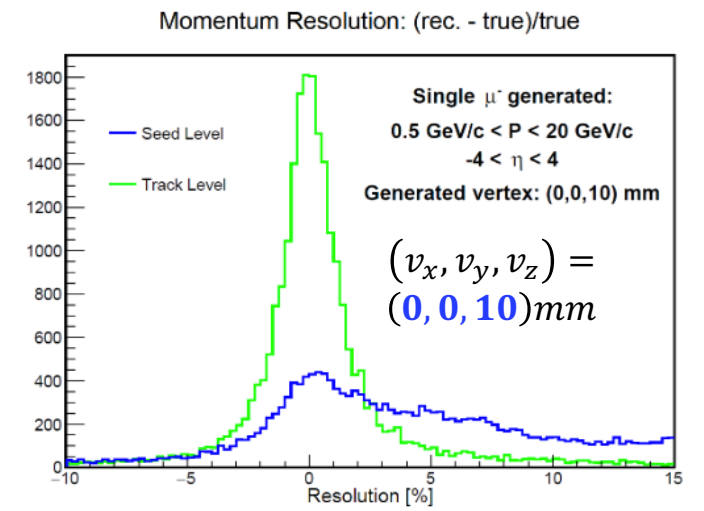
Track Seeding: Single Particle

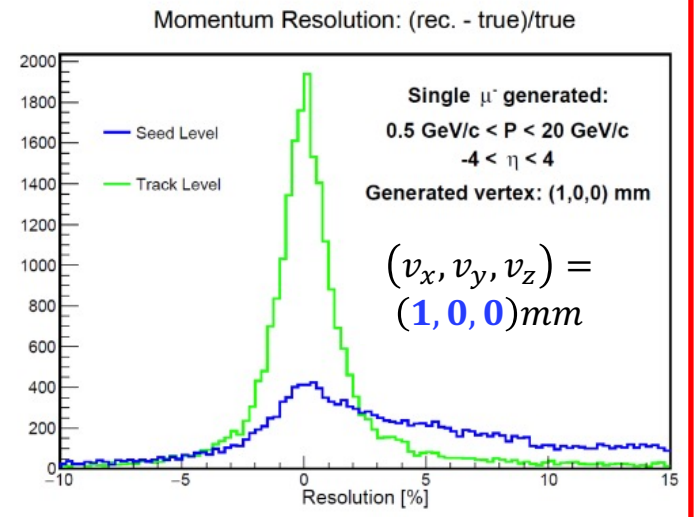
Charge 2, 3

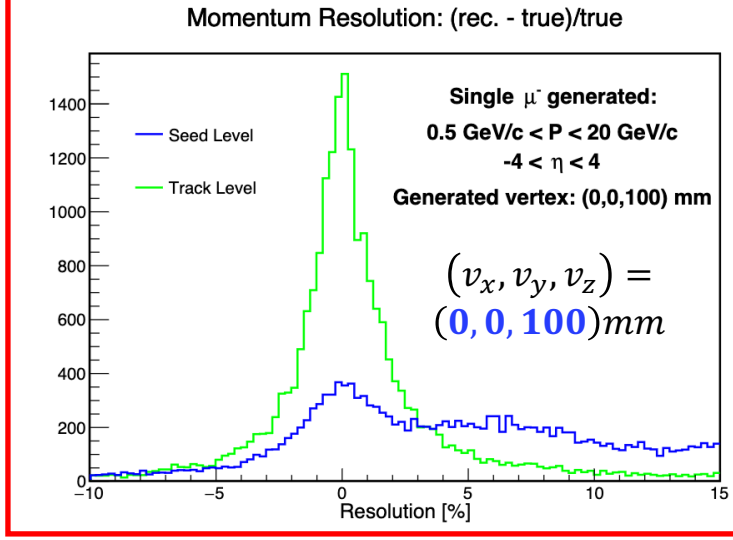








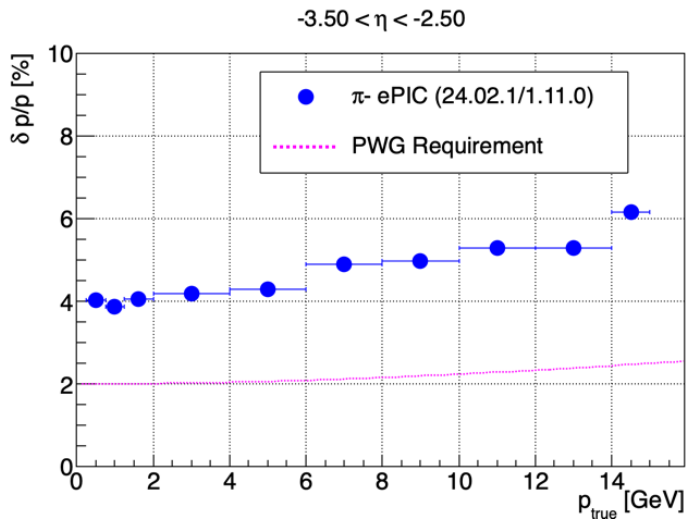


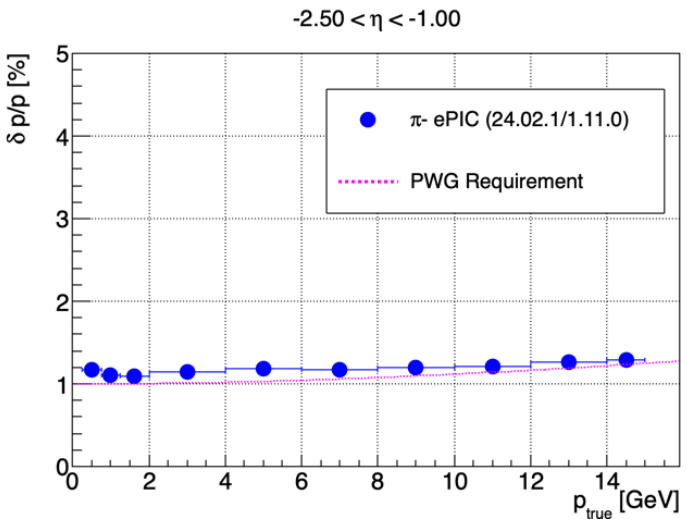


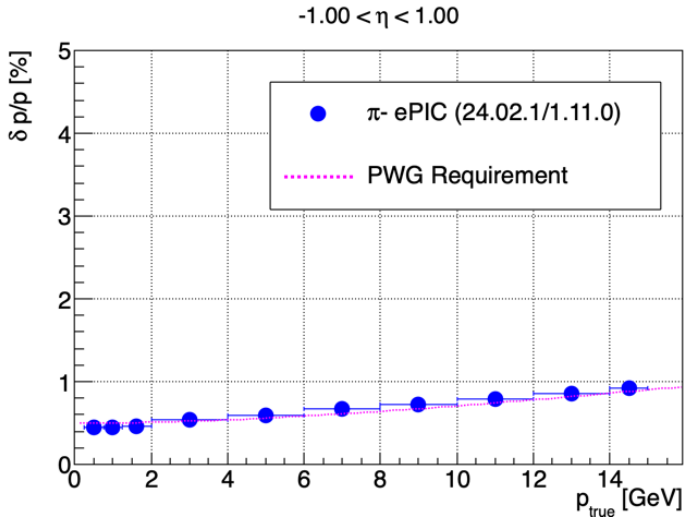
Preliminary Tracking Performance: Momentum Resolution

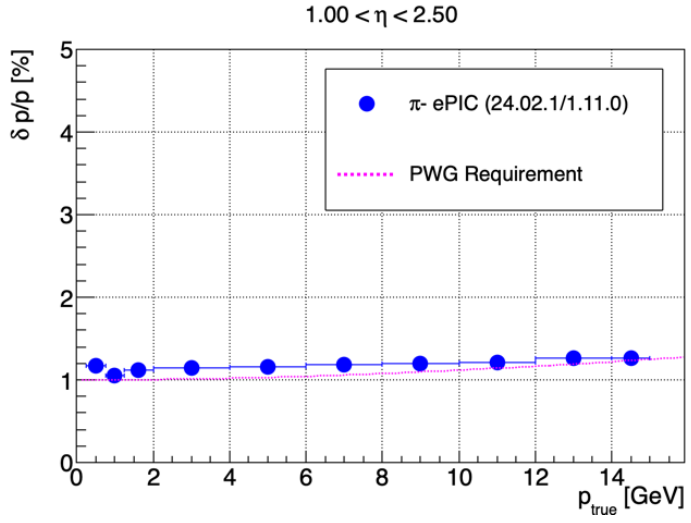
Charge 2, 3

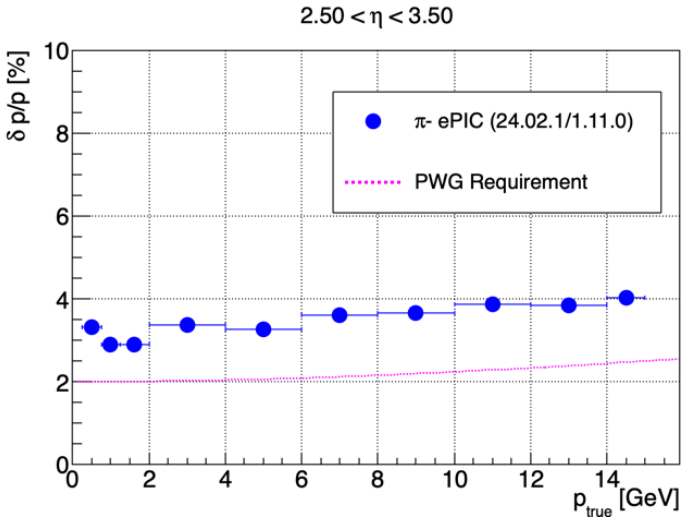
- Single particle
  - Includes AC-LGAD layers
  - Extreme η regions will require use of other ePIC sub detector information
  - Follows requirements elsewhere







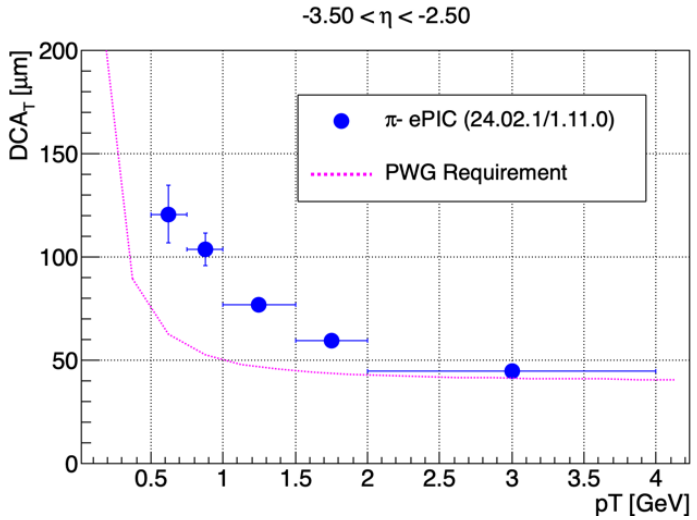


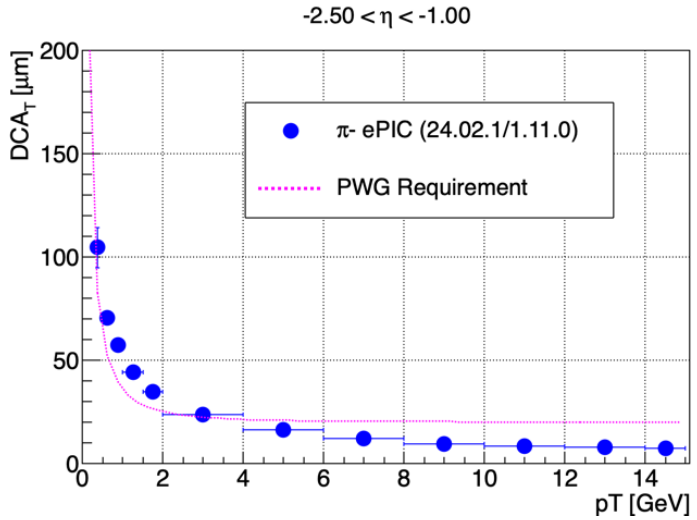


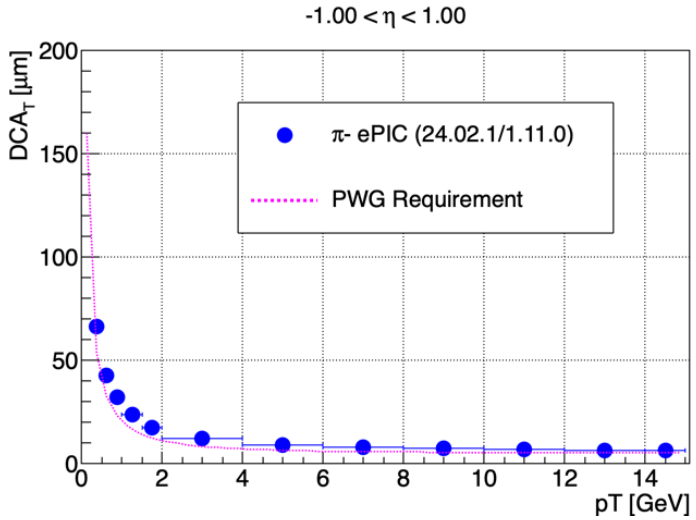
Preliminary Tracking Performance: Pointing Resolution

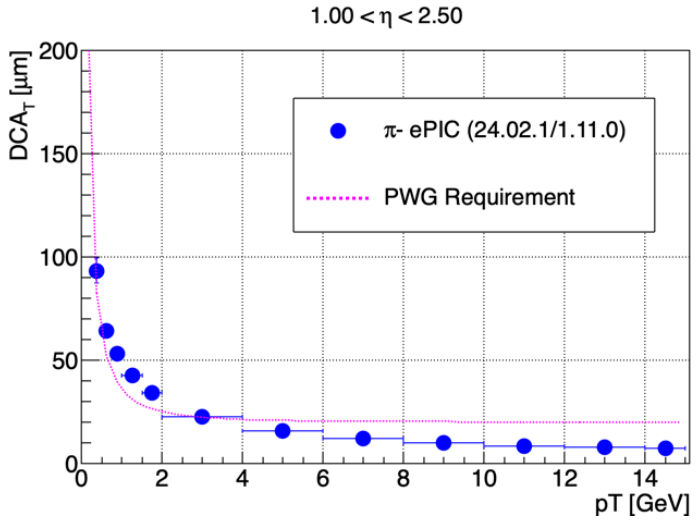
Charge 2, 3

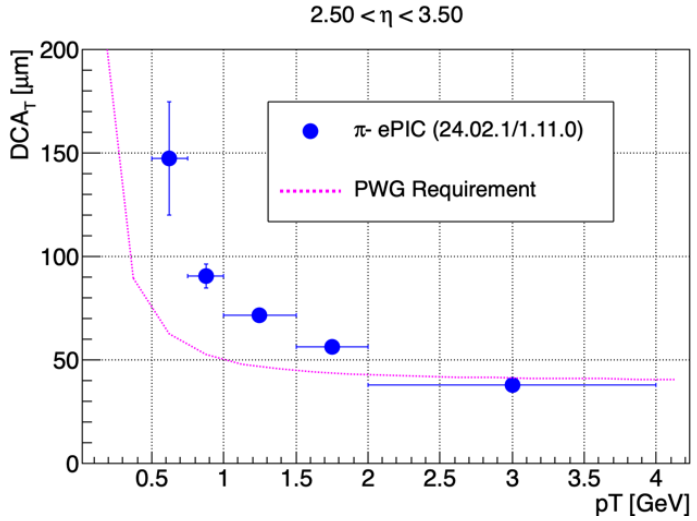
- Single particle
  - Includes AC-LGAD layers
  - Requirements missed in extreme η regions
  - Follows requirements elsewhere







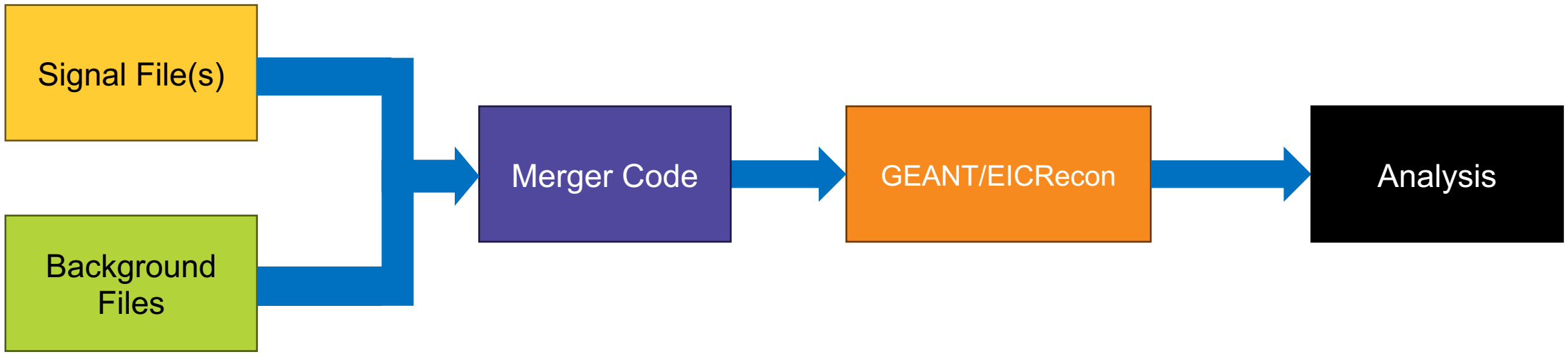




Structure for Tracking in Background

Charge 2, 3

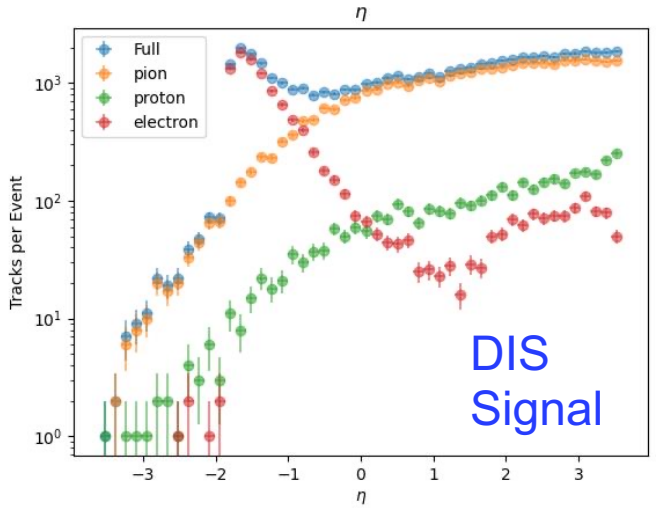
- HEPMC Admixing code implemented
  - merges signal and background files
- Considers three main background contributions
  - Synchrotron radiation, hadron beam-gas, and electron beam-gas

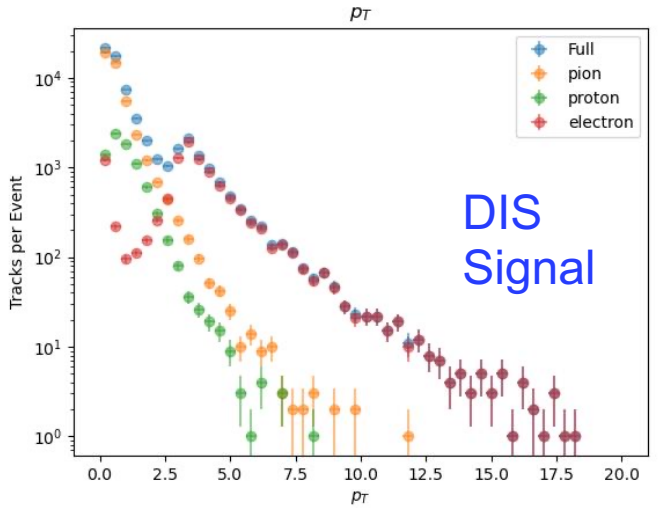


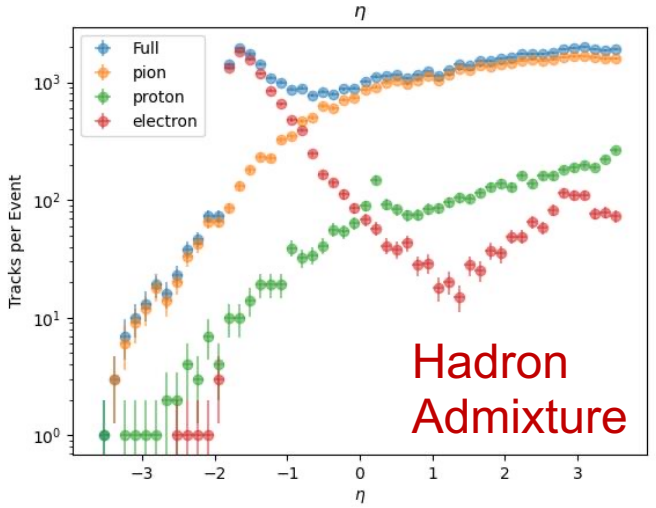
Tracking in Background

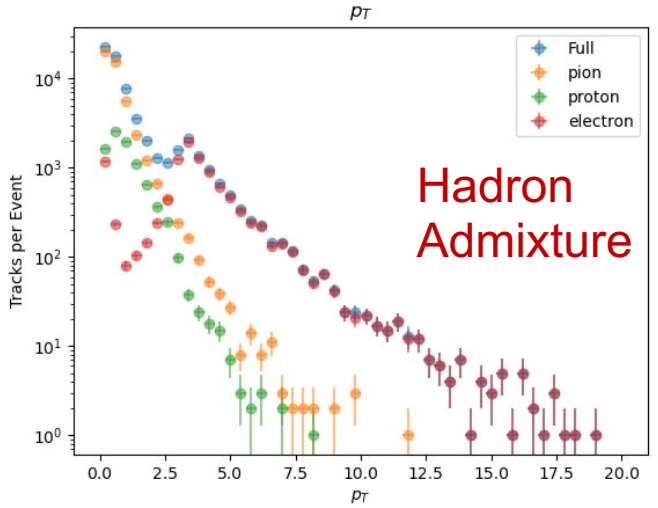
Charge 2, 3

- Software tools in place to study backgrounds on track reconstruction
- 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







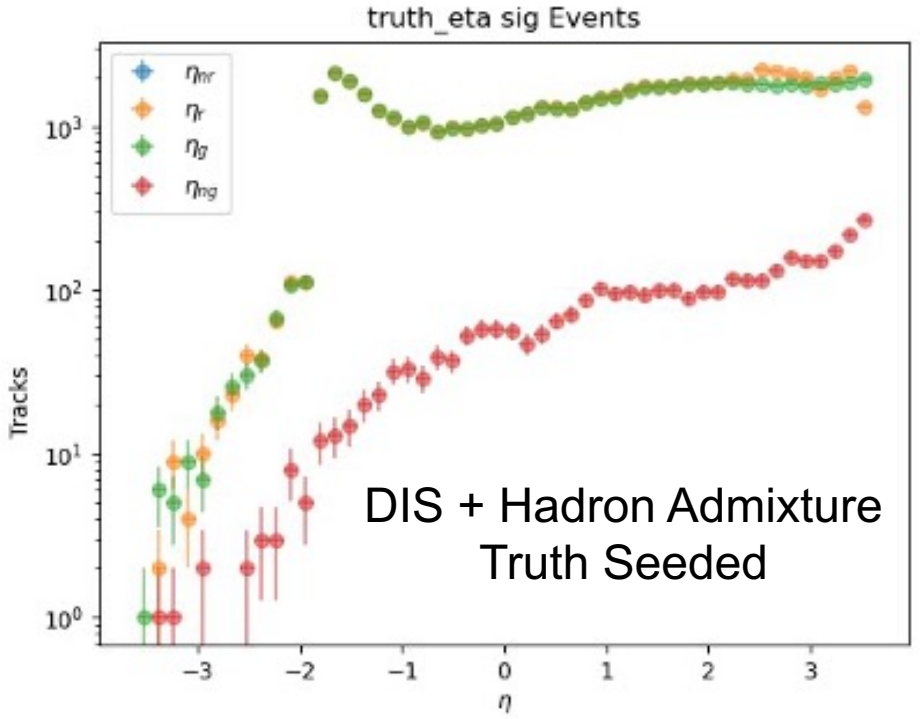


Tracking in Background

Charge 2, 3

- With software tools in place, reconstruction code is being further developed/validated
  - Study 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 most regions, and will need other detector information in extreme η regions
- Structure and tools are in place for performing tracking in background environment
  - On going work to focus on studying impact of background sources,
  - Implementing timing,
  - Pattern recognition algorithm
- Vertex reconstruction work has begun
  - Initial vertexing algorithm in place
  - Vertex object being defined for EDM4EIC

Backup

Detector Material

Charge 2, 3