Tracking performance for ePIC

Tracking&background workfest @ ePIC Collaboration Meeting
Argonne National Laboratory

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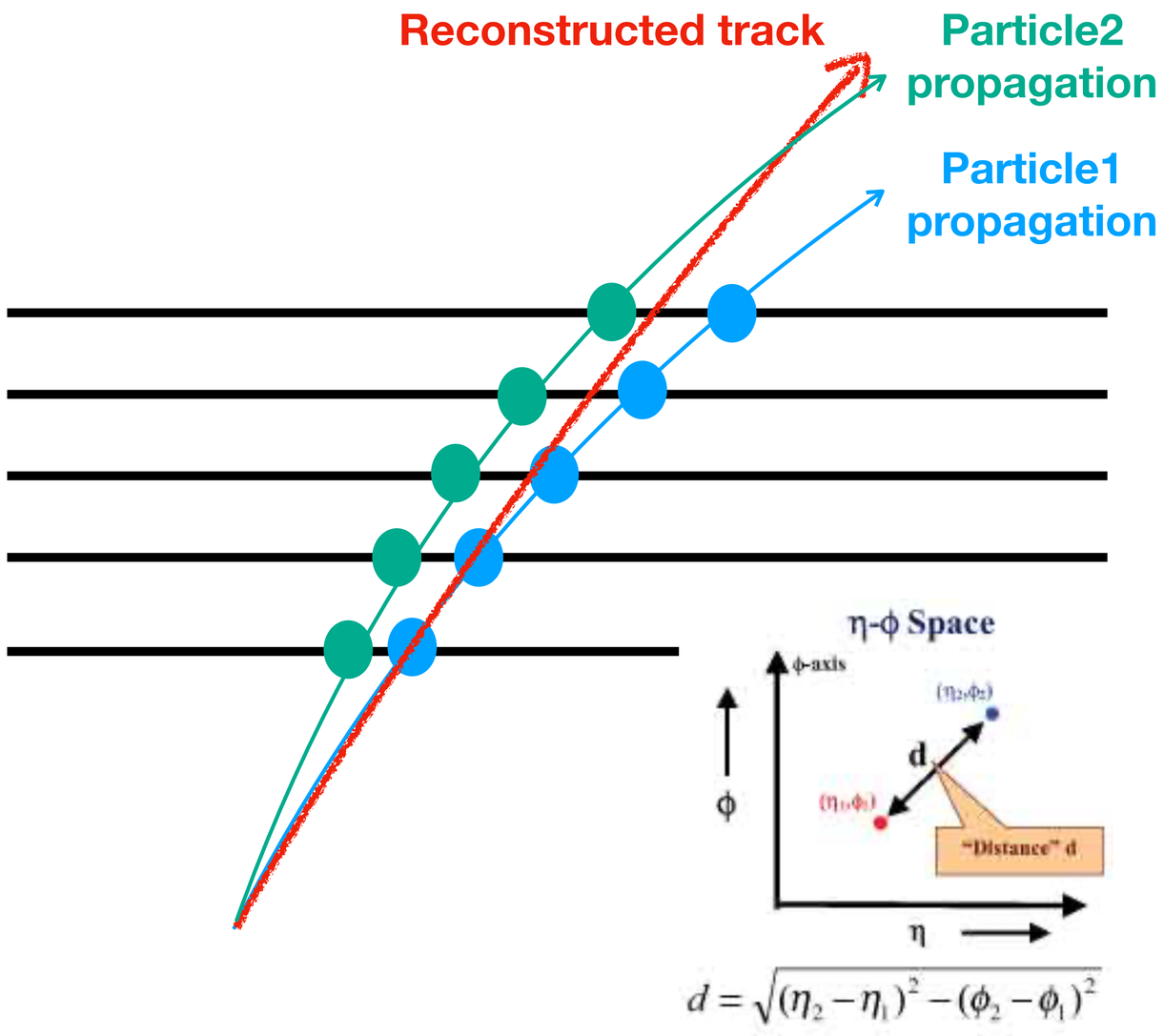
Tracking performance for ePIC

- Observables for tracking performance:
  - Tracking efficiency and purity
  - Position and momentum resolution
  - And so on…

  ➡ Compare reconstructed tracks with simulated particles
- Tracking performance for ePIC
  - Now: evaluate the tracking algorithms of realistic seeding and CKF tracking based on ACTS
  - Estimate the expected tracking performance upon change of detector geometry and experiment conditions and the feasibility of physics measurements

Matching between MC particle and reconstructed track

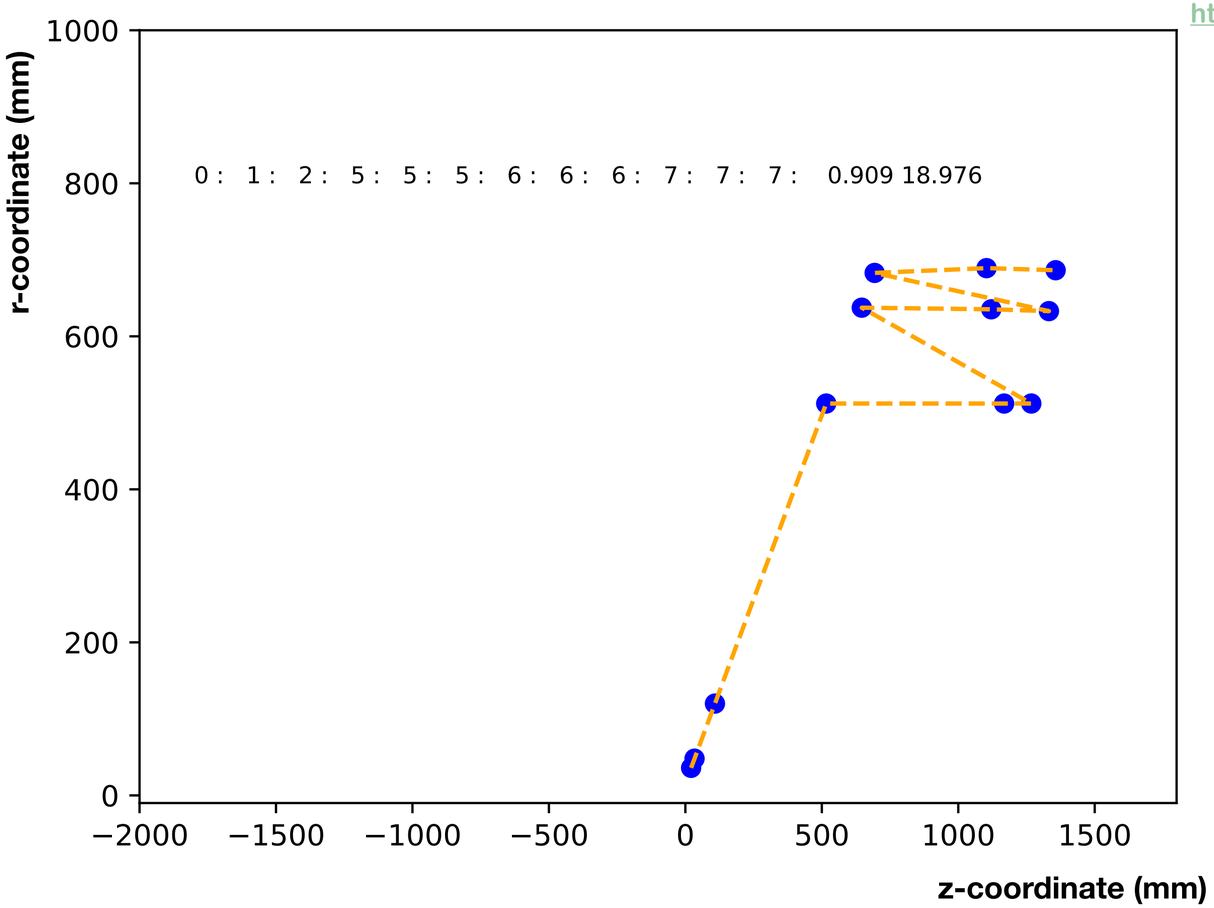


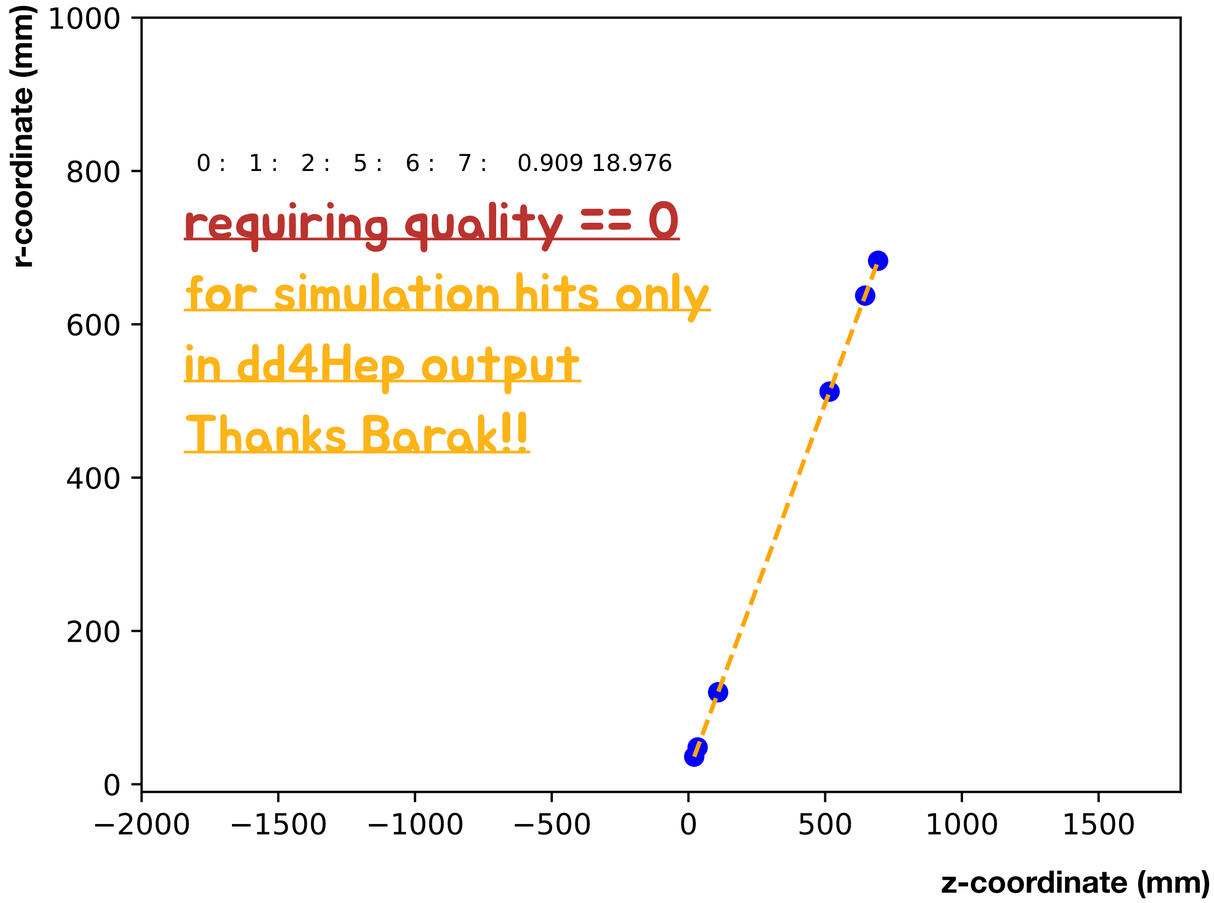
- Two different matching methods were considered:
  - Hit level matching: check the source of hits in the track and matching to the particle giving maximum contribution
  - Angular distance matching: matching reconstructed track with the particle having the closest value of the distance (similar to EICrecon way)
- Angular distance based matching gives similar result with hit level matching, but not always
  →Can we introduce hit level matching used at the LHC exp. in EICrecon? MC source of generated hits not written in TrackerHit object

Multiple generated hits on single layer (npsim)

- One charged particle generates more than one hit on single layer more pronounced in MPGDs and TOF → random association of hits from secondary particles in Geant4

https://indico.bnl.gov/event/18368/contributions/73607/attachments/46169/78083/tracking_022323.pdf



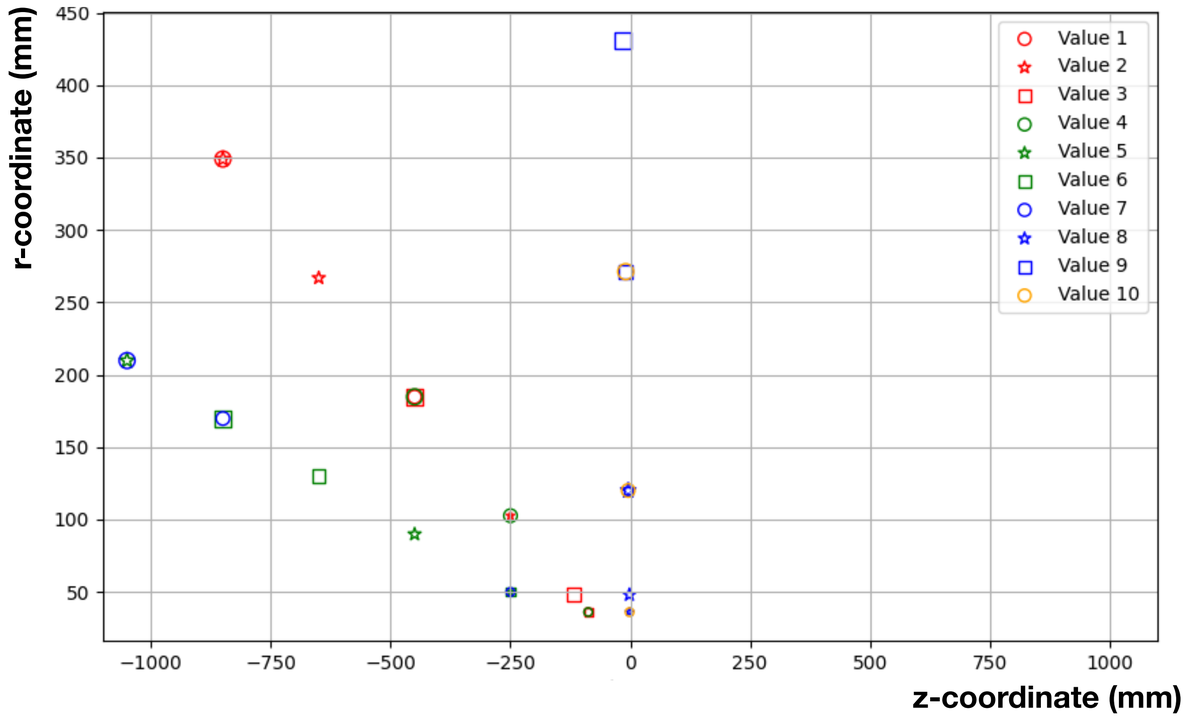


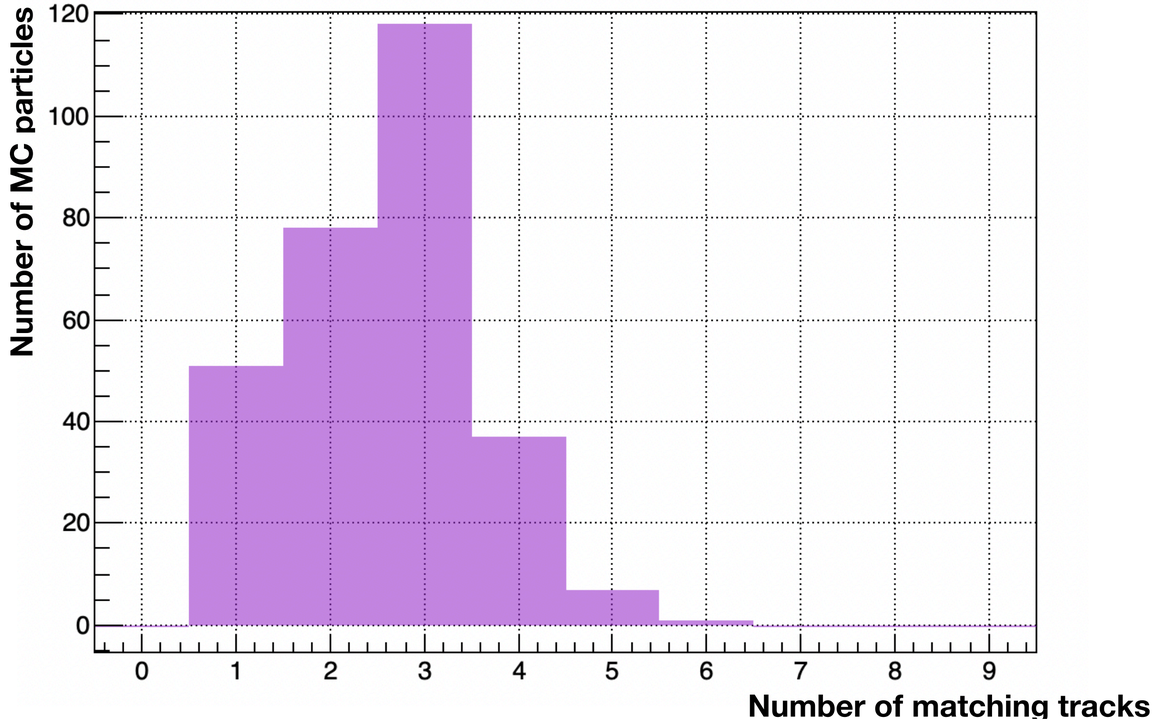
Duplicate tracks in realistic seeding

- Seed is made with 3 hits → several seeds can be found along one trajectory, leading duplicate tracks
- Correlation between a number of generated hits (N_{hit}) and a number of duplicate tracks (N_{trk}):

$$N_{trk} \propto {}_{N_{hits}}C_3$$

- Reduction by requiring using middle space point only once (as a middle space point), but still there





Seed Confirmation in ACTS (1)

https://indico.cern.ch/event/1252748/contributions/5561968/attachments/2731962/4749842/Connecting%20The%20Dots.pdf

CPU Based Seeding - ACTS Default Seeding

Seed Confirmation:

After selecting the SP-triplets, a seed confirmation procedure is applied to all the triplet combinations:

- Compare seeds with similar helix radius
- Rank the seeds based on a customisable weight

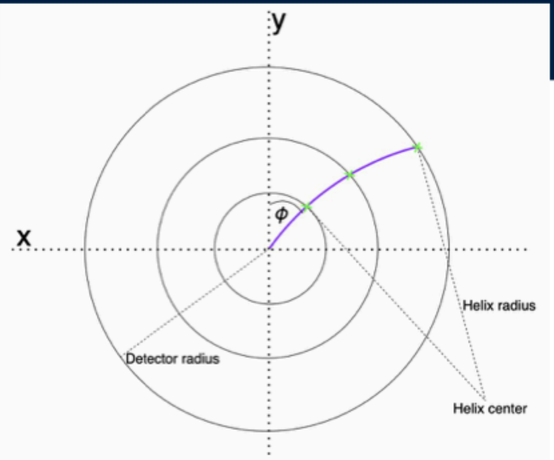
$$w = (c_1 \cdot N_t - c_2 \cdot d_0 - c_3|z_0|) + \text{detector specific cuts}$$

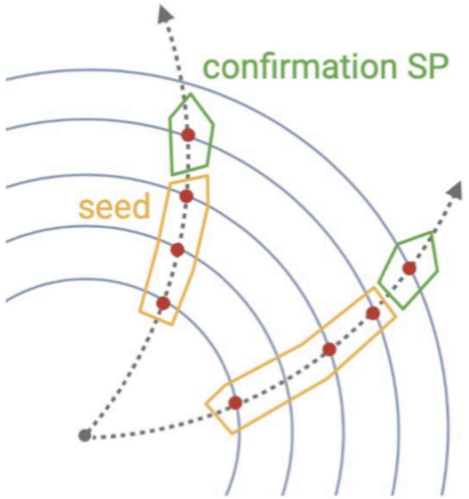
More measurements leads to higher quality

Smaller IP → higher probability of track arriving from the interaction point

Improving the quality of the final track collections by rejecting lower-quality seeds

In the end we keep only the best ranked seeds





Connecting The Dots 2023

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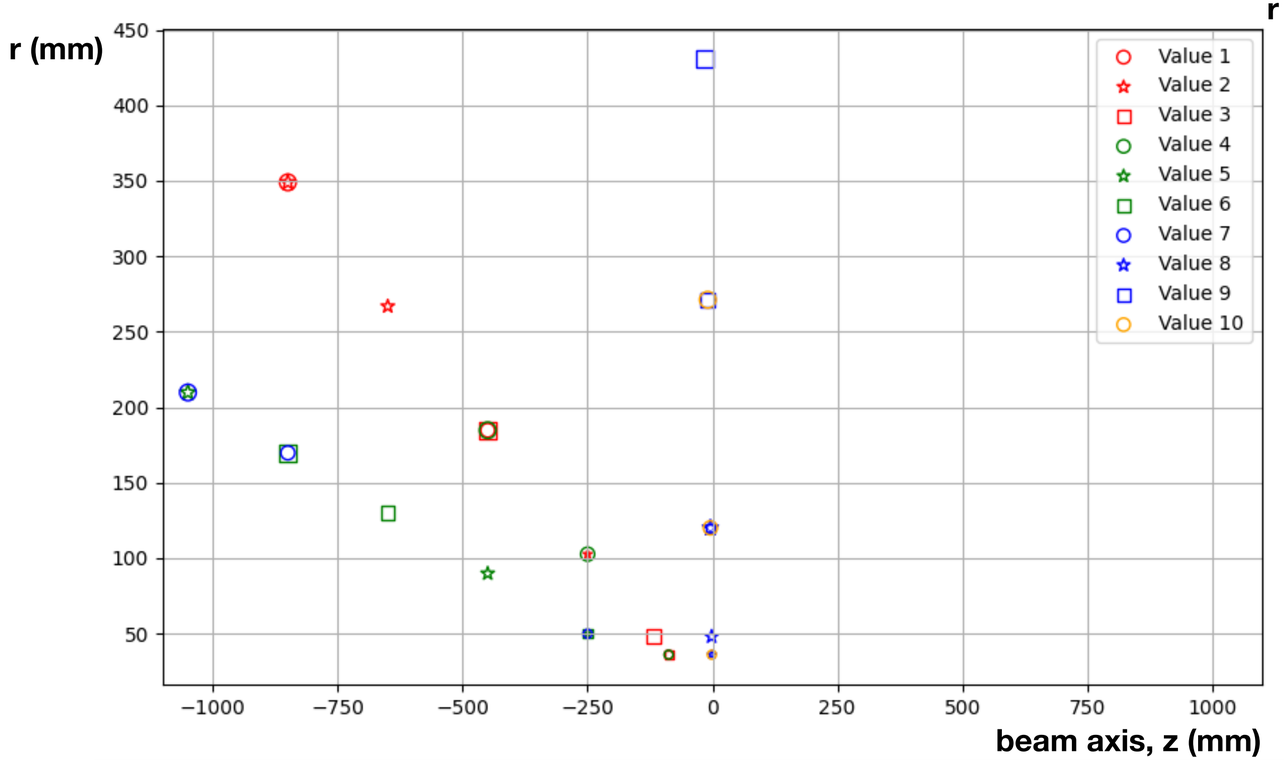
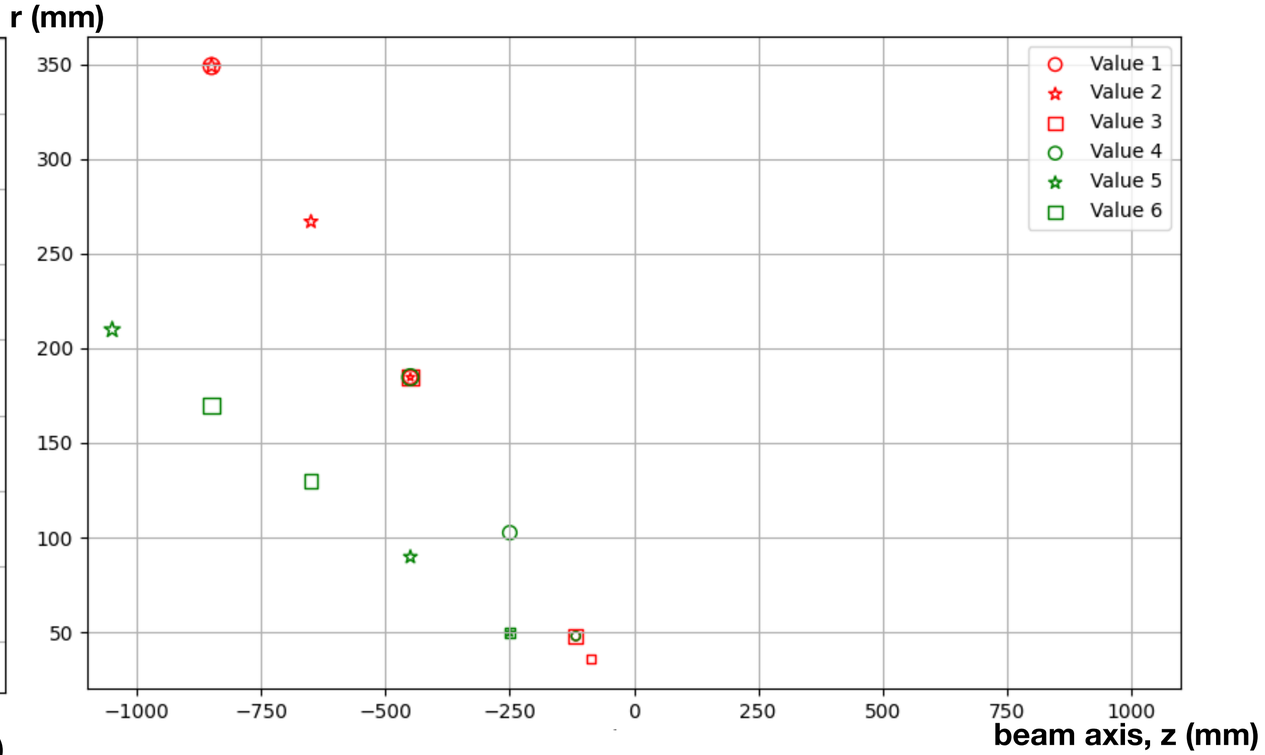
Seed Confirmation in ACTS (2)

- Post seeding process natively implemented in ACTS
- Idea is simple but parameters should be optimized

filtering (confirmation) off

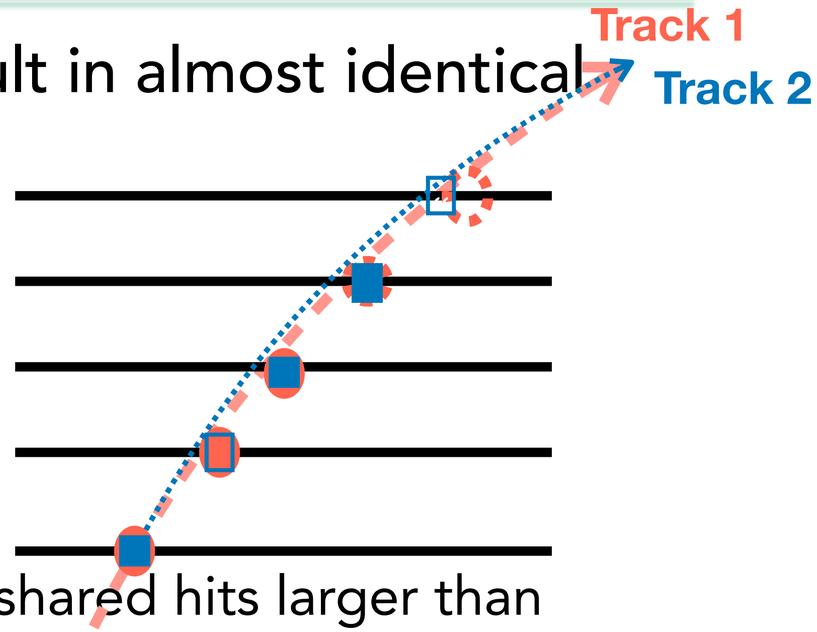


filtering (confirmation) on with default parameters



Greedy ambiguity resolution solver

- After tracking, seeds originated from same particle result in almost identical reconstructed tracks
  - More or less similar reconstructed kinematic variables
  - Almost same sets of associated hits
- **Greedy ambiguity resolution solver**:
  1. Iterate trajectories and find the trajectory having number of shared hits larger than certain threshold
  2. Find the competetors and keep better quality trajectory only
  3. Repeat till you have trajectories having shared hits below certain threshold: number of shared hits required!

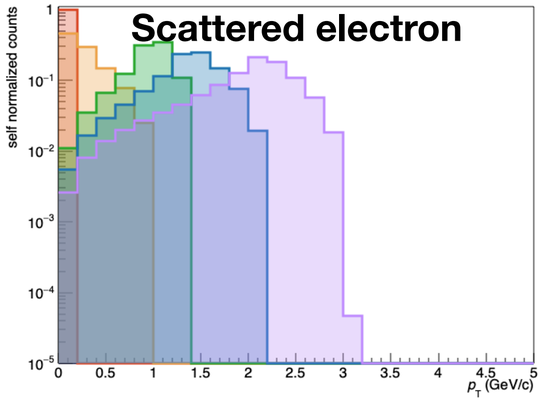


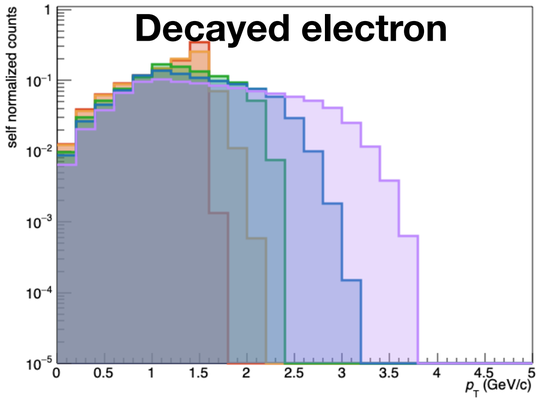
➡ **Native support in ACTS,** not implemented in official EICrecon yet

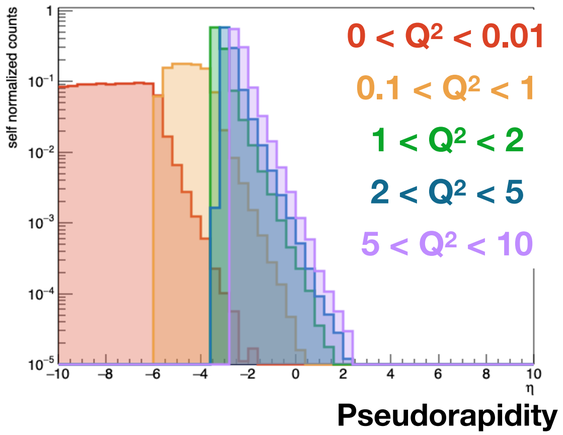
★ ML based methods under development

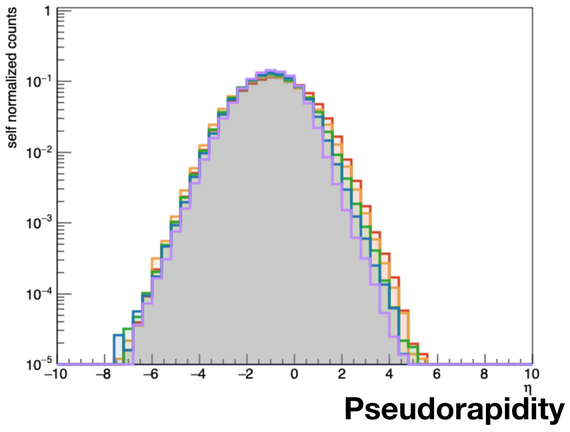
Reminder: J/ψ photoproduction ($5 < Q^2 < 10$) in EIC

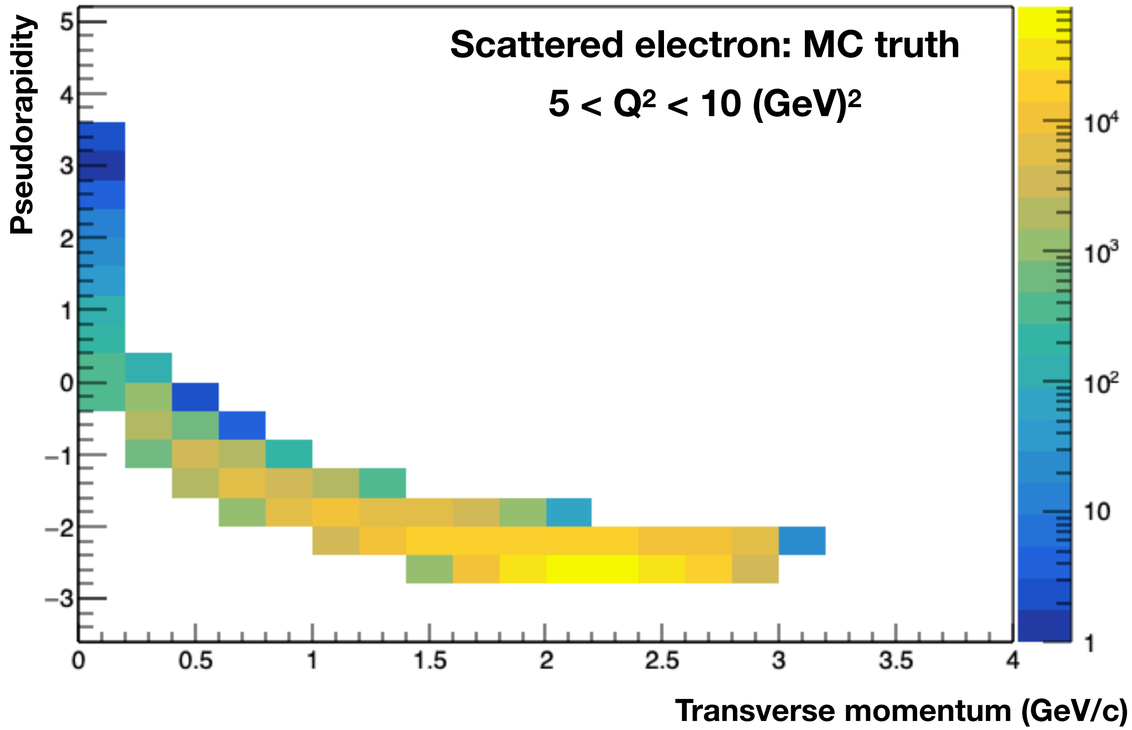
- Coherent production of eA→eA′J/ψ→e(e+e-)A′ with eSTARLight
- Final state particle kinematics are well constrained; most of cases 3 electrons





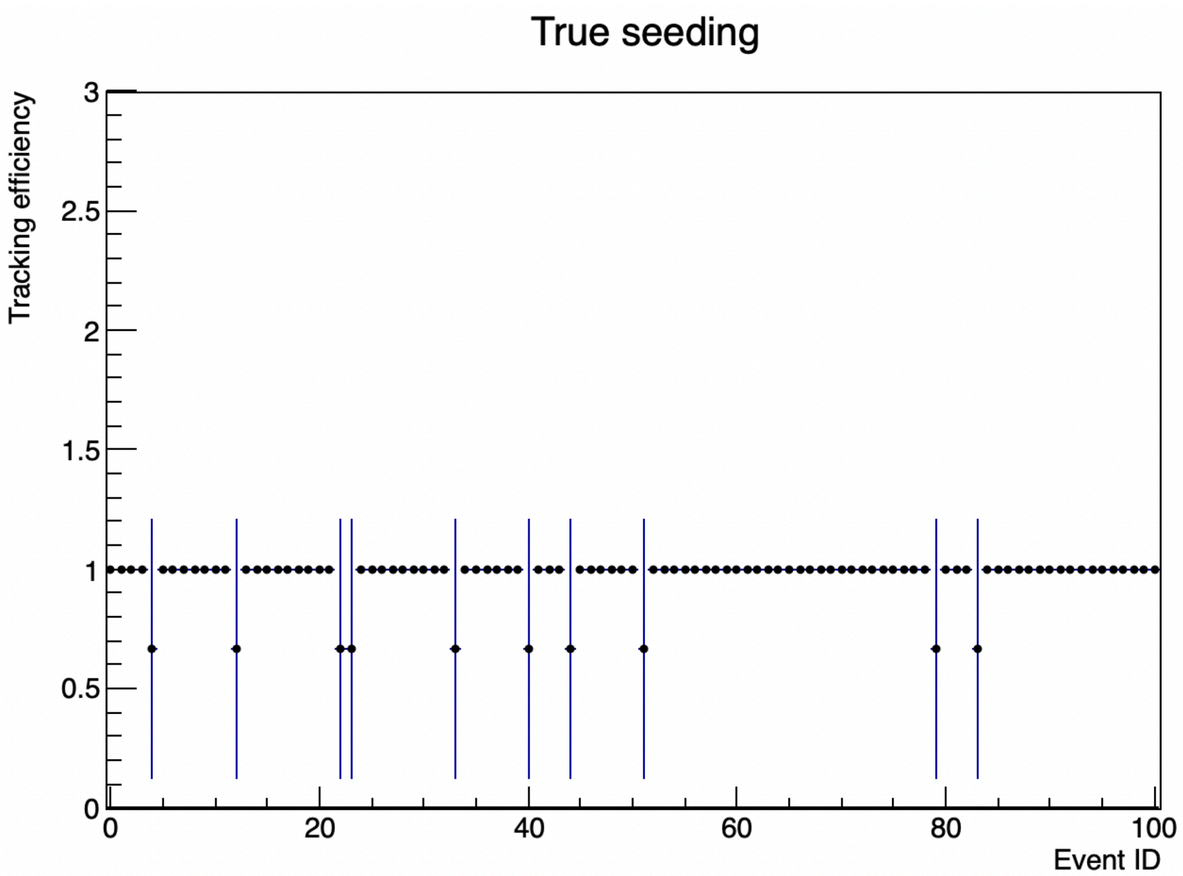


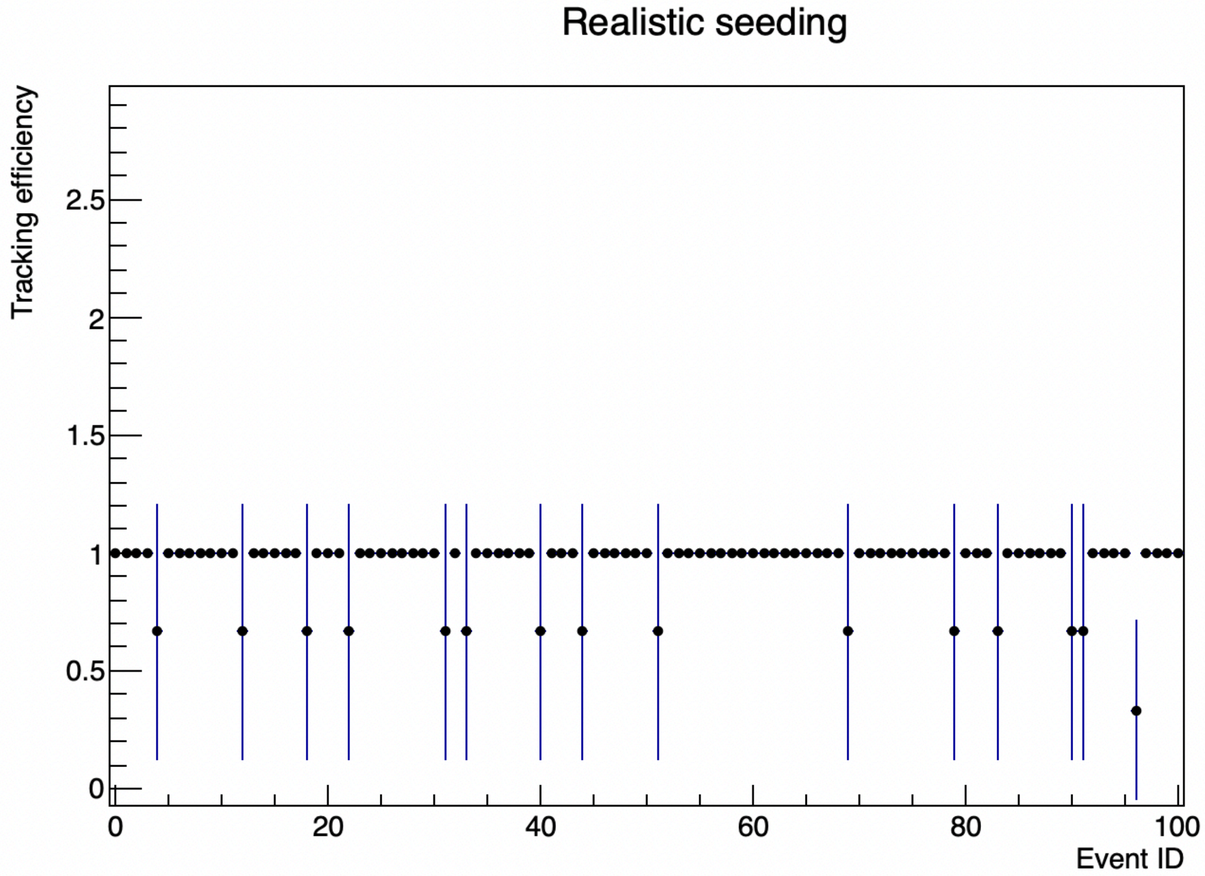




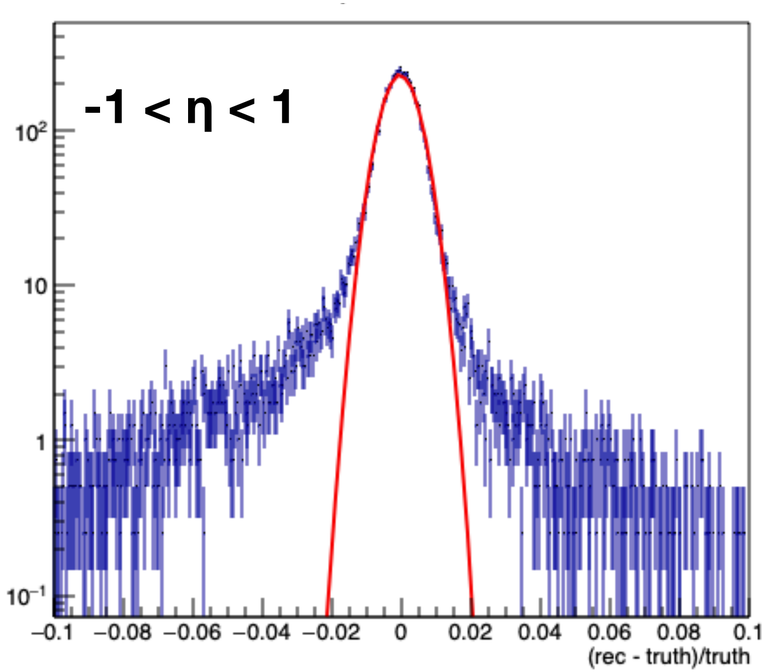
Duplicate track rejection in photoproduction events

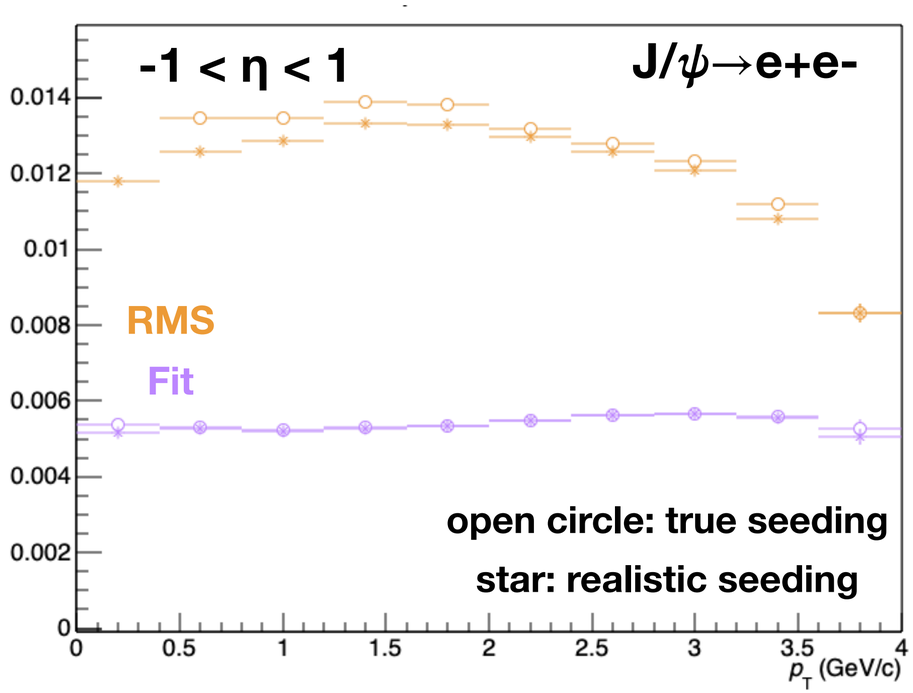
- Event-by-event tracking efficiency estimated: $\frac{\text{number of reconstructed tracks}}{\text{number of generated final state particles}}$
- Greedy ambiguity resolution solver works well!! (No events with duplicate tracks!)





Transverse momentum resolution

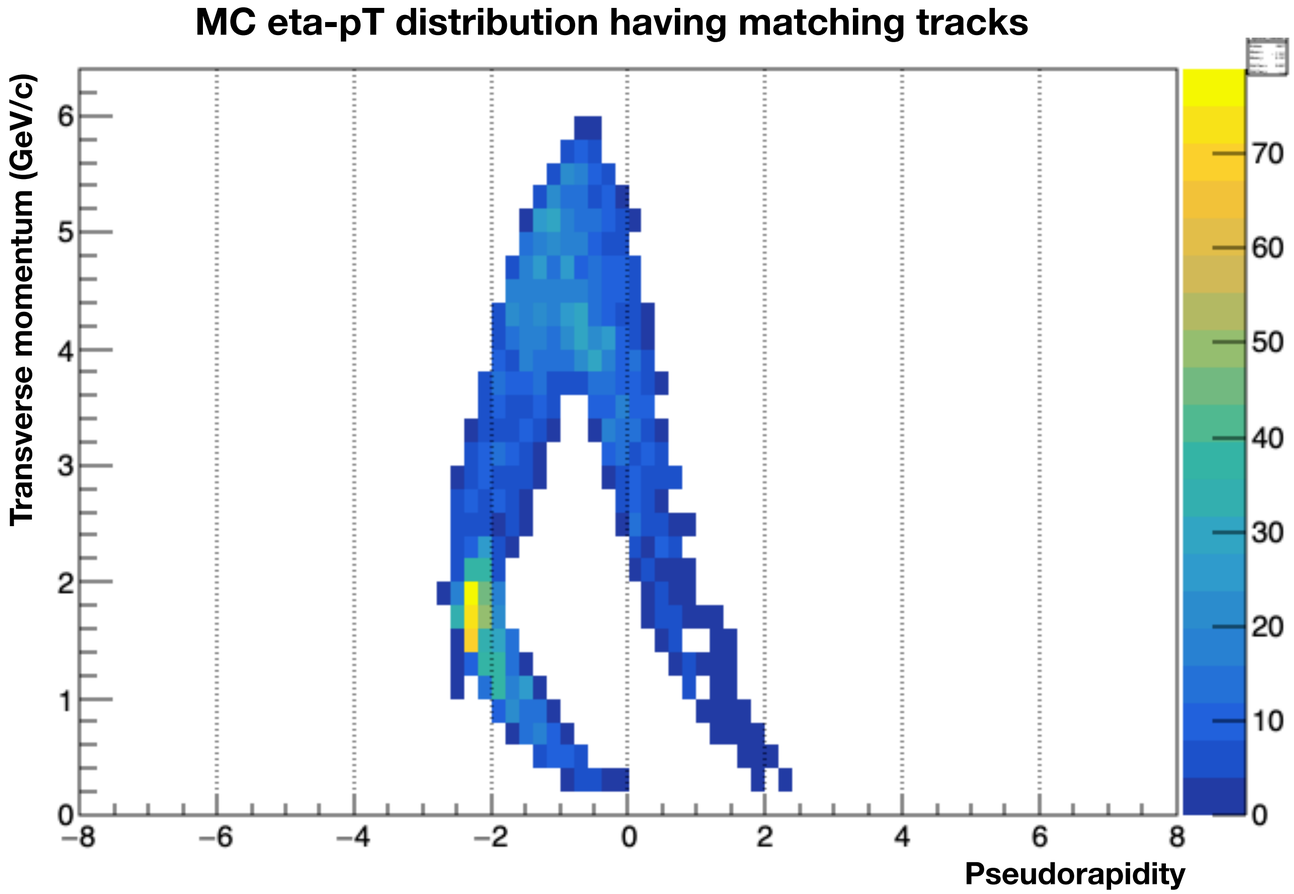


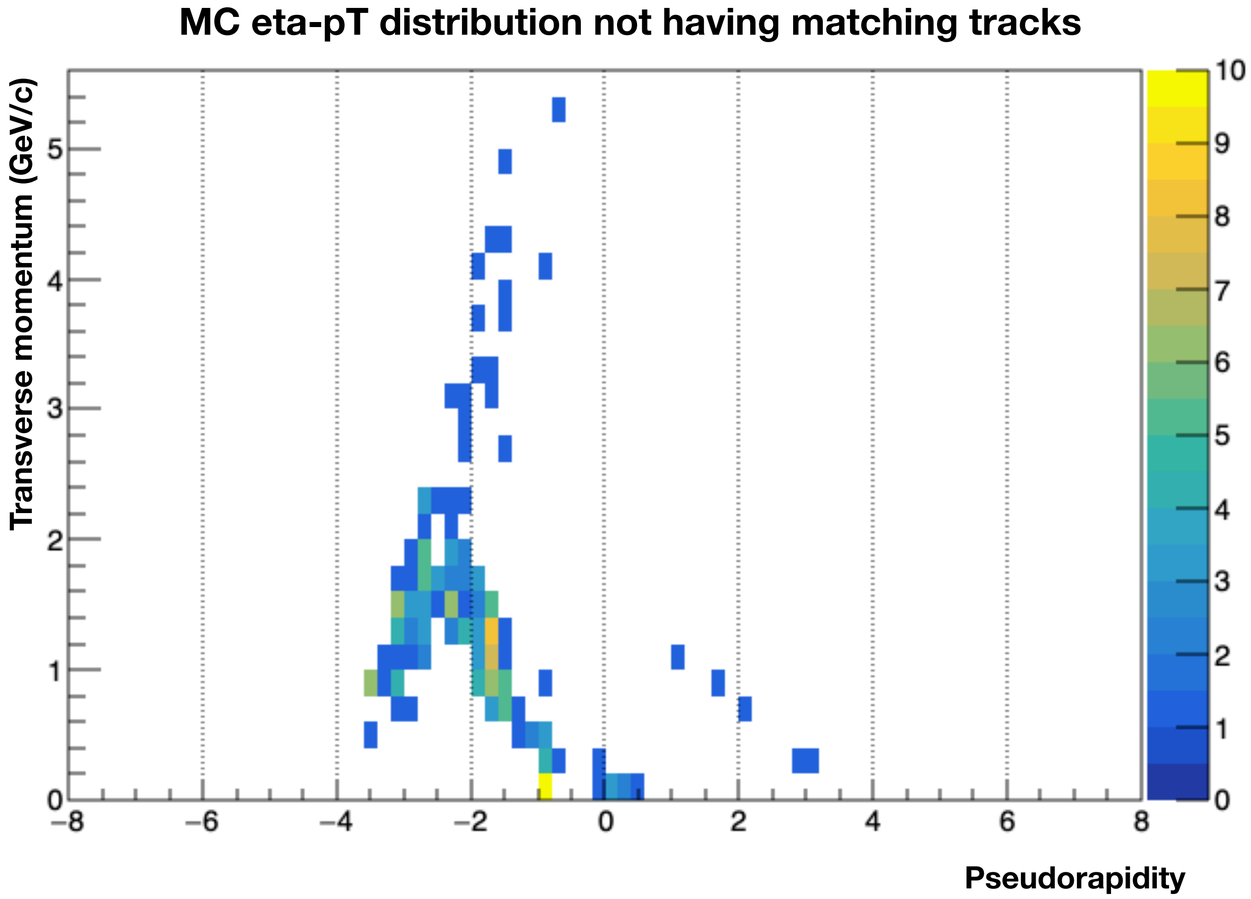


- For MC particles in small transverse momentum (p_T) range:
  - Find the matching tracks
  - Calculate the deviation of reconstructed p_T w.r.t. truth p_T
  - Take the RMS or the width from gaussian fit as the resolution
- Larger negative tail due to the multiple scattering/Bremsstrahlung

First look of tracking efficiency of the ePIC tracker

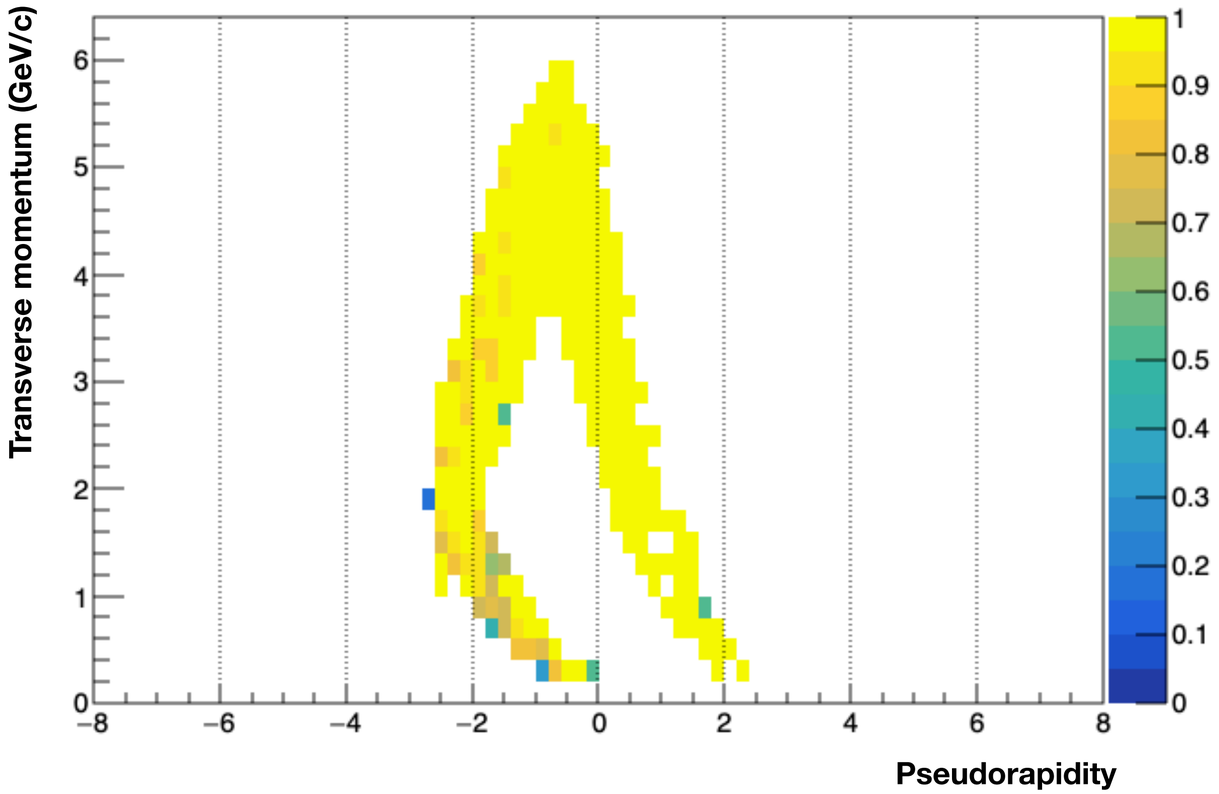
- Most of efficiency lost in low p_T below 200 MeV/c
- Limited kinematic coverage of photoproduction events

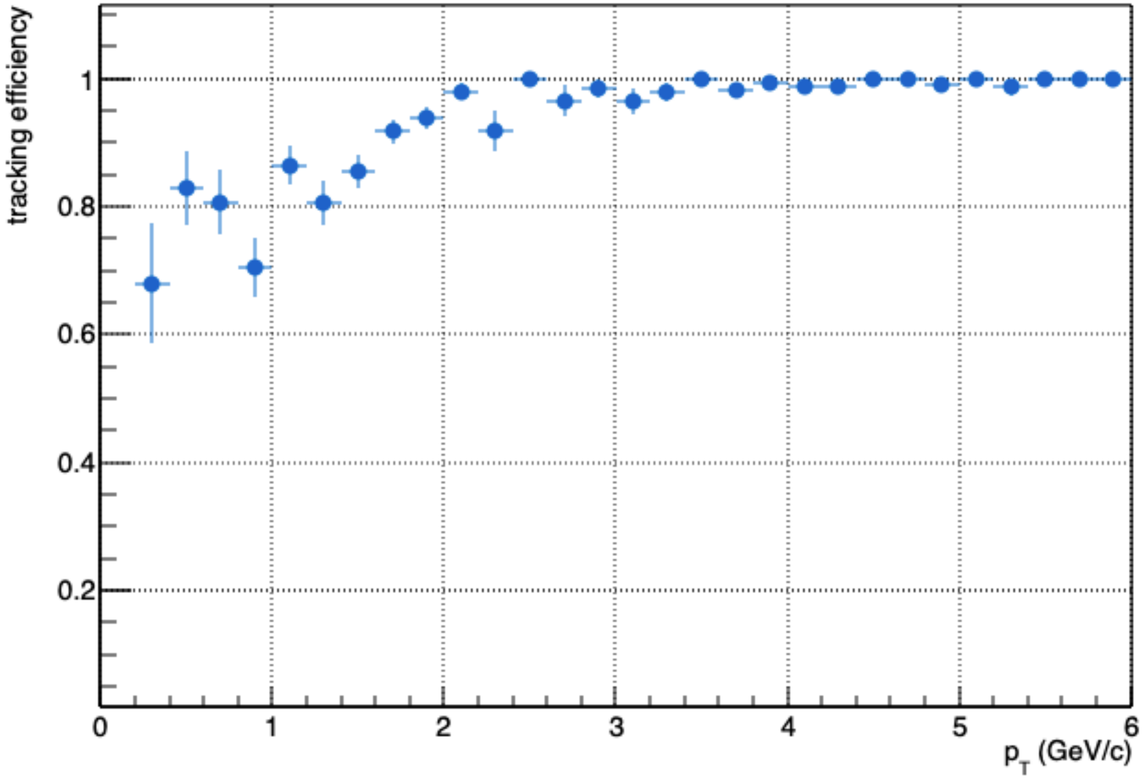




First look of tracking efficiency of the ePIC tracker

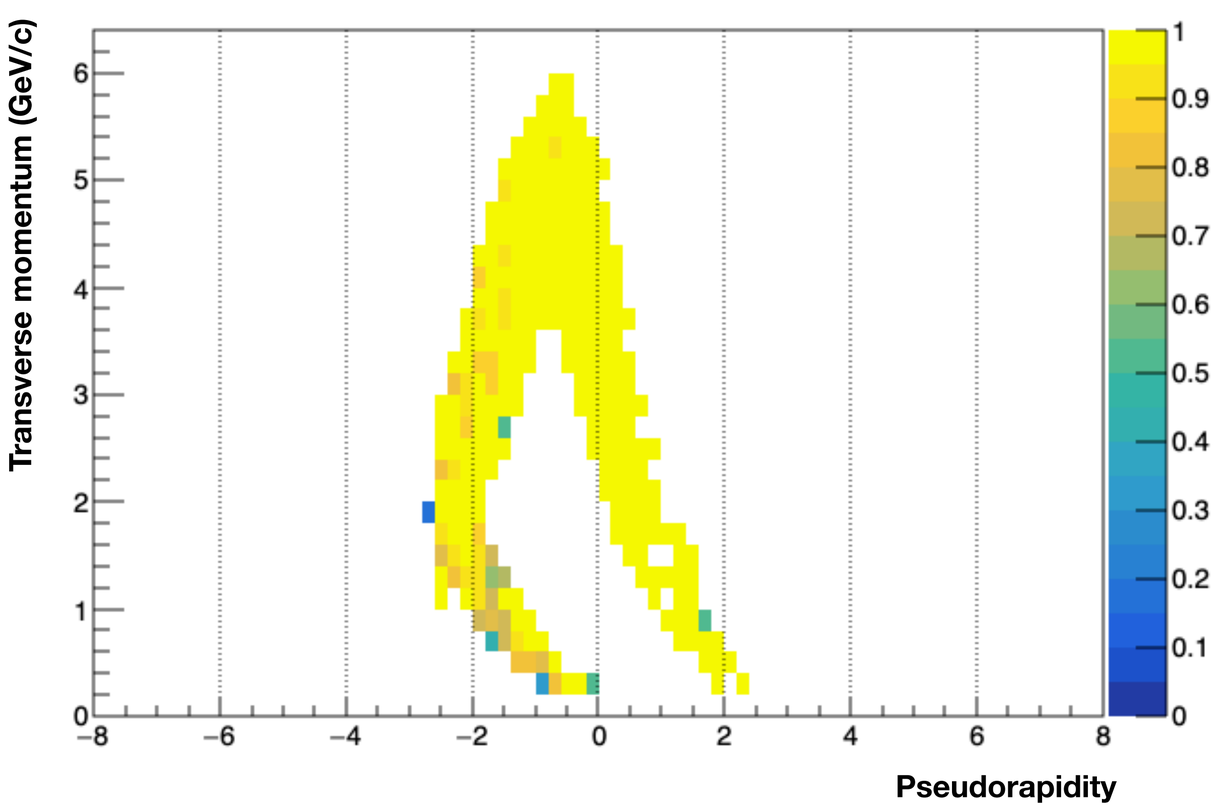
- Fully efficiency above 2 GeV/c
- Tracking efficiency: $\frac{\textbf{number of reconstructed, matched tracks}}{\textbf{number of generated final state particles}}$

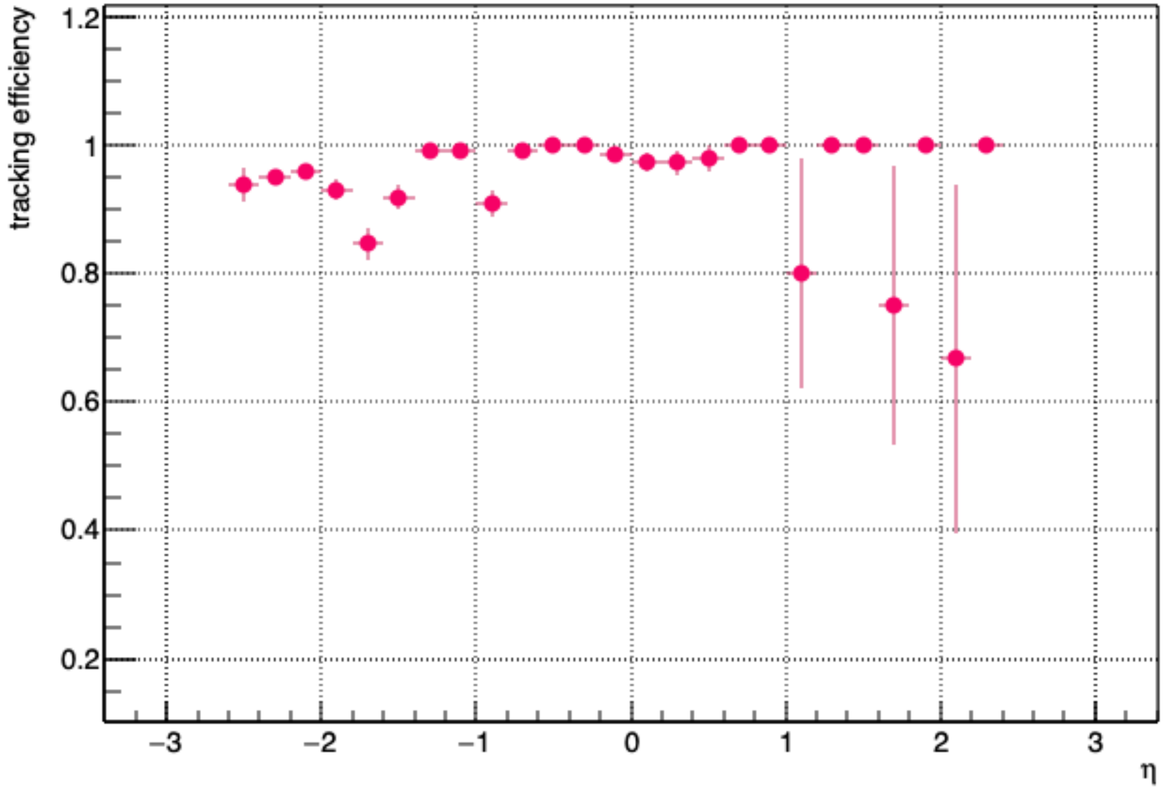




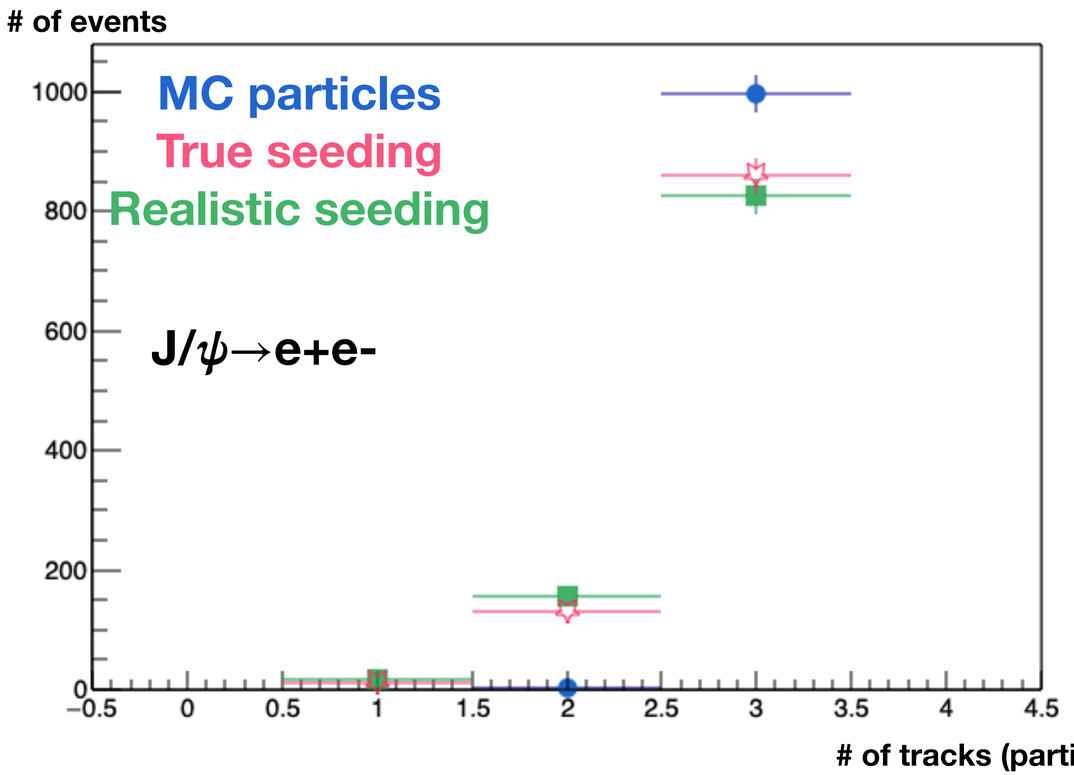
First look of tracking efficiency of the ePIC tracker

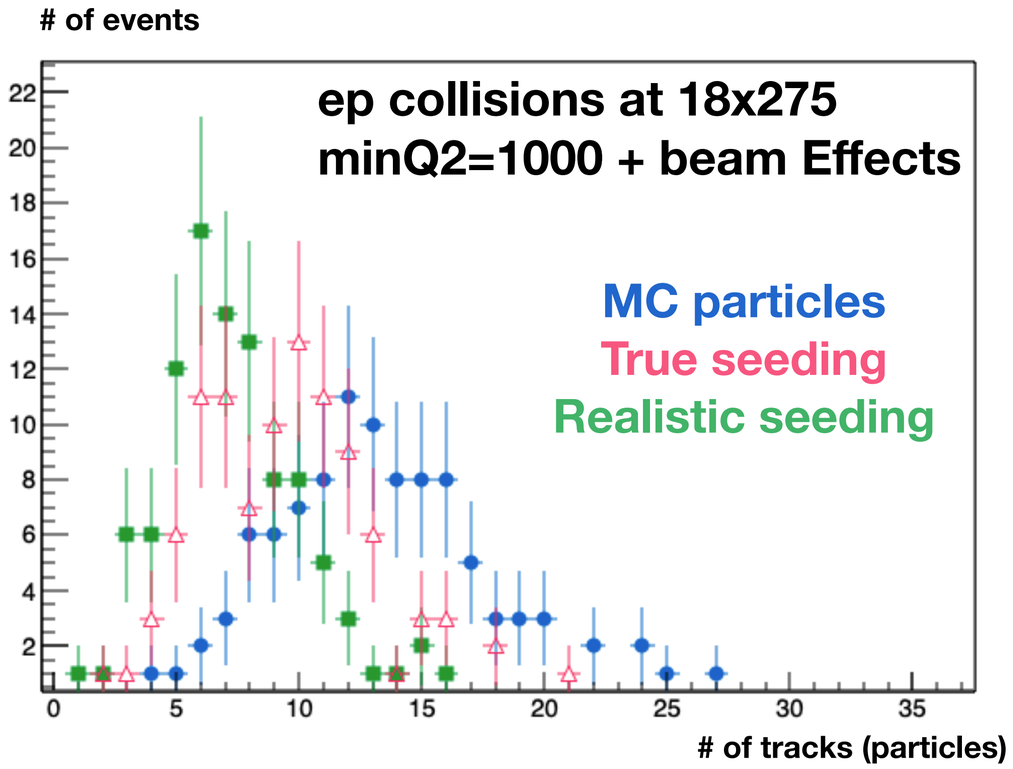
- No eta dependence found within -2.5 < eta < 2.5
- Tracking efficiency: $\frac{\textbf{number of reconstructed, matched tracks}}{\textbf{number of generated final state particles}}$





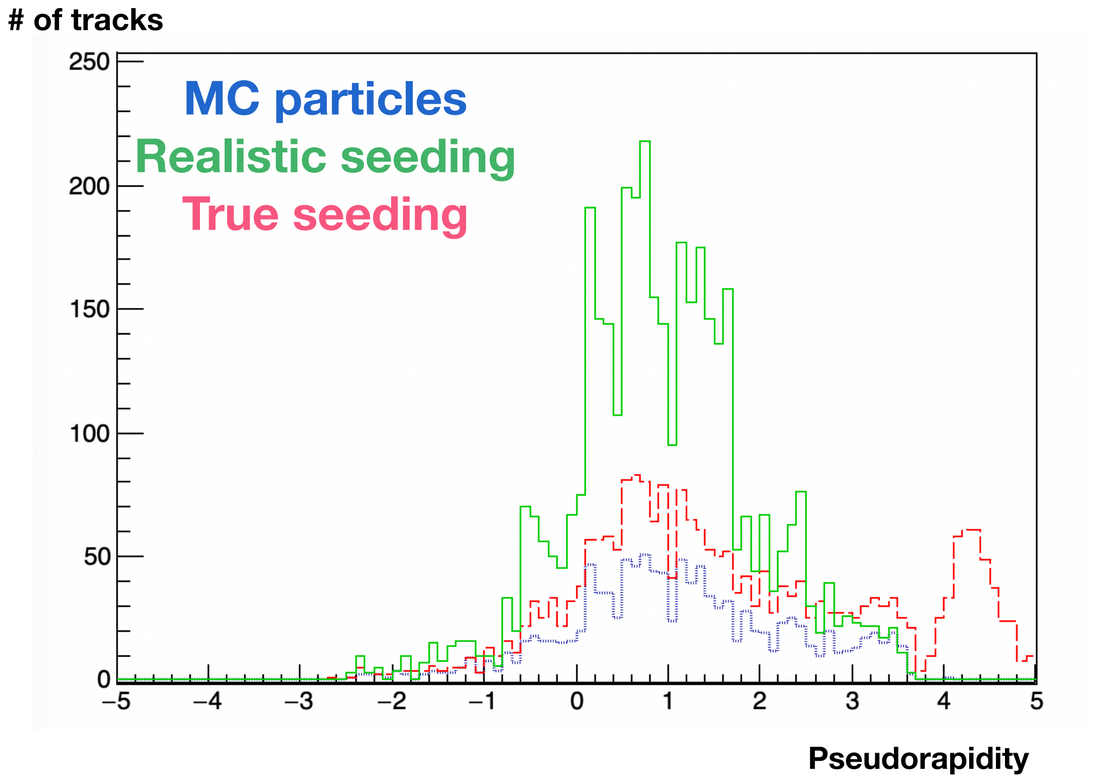
Moving towards complicated environment

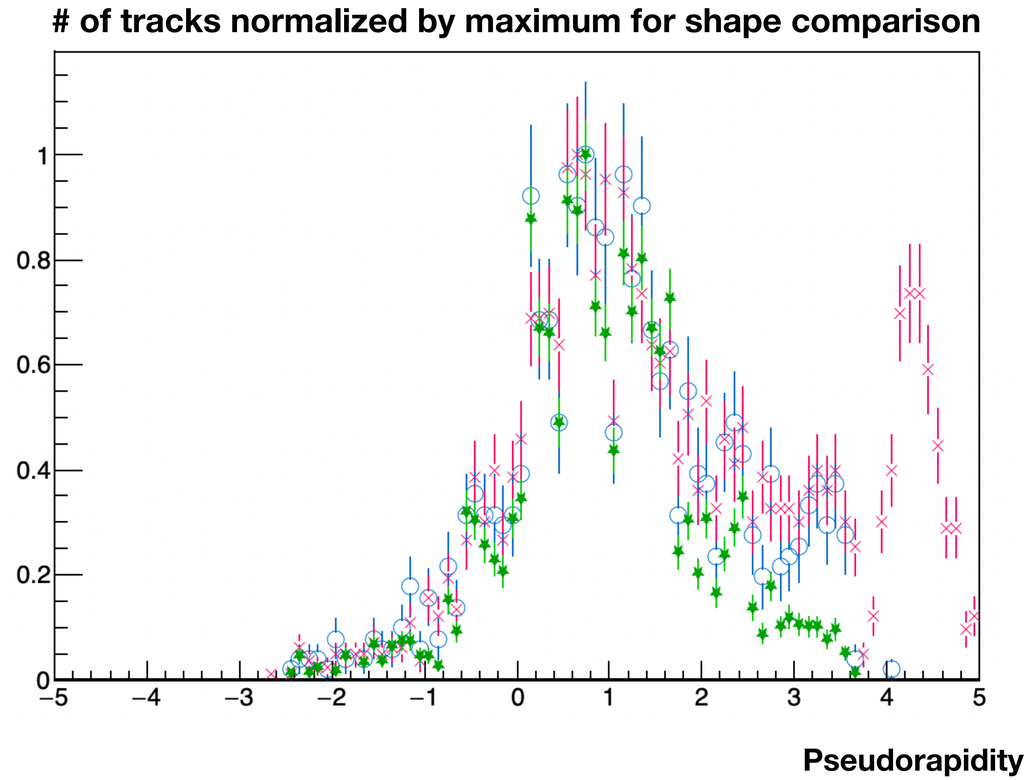




- Efficiency loss in true seeding/realistic seeding: No kinematic cuts on MC particles yet
- Slightly worse performance in realistic seeding: over-suppressed by duplicates rejection?
- More complicated in DIS

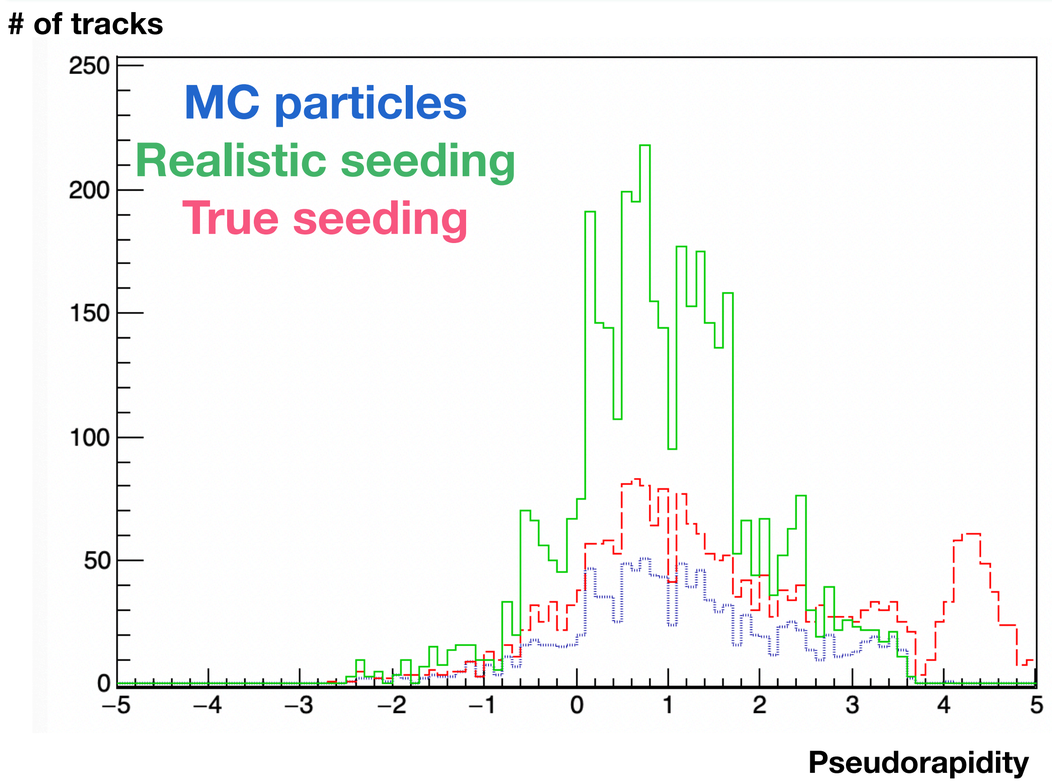
High Q^2 DIS events: seed-level QA

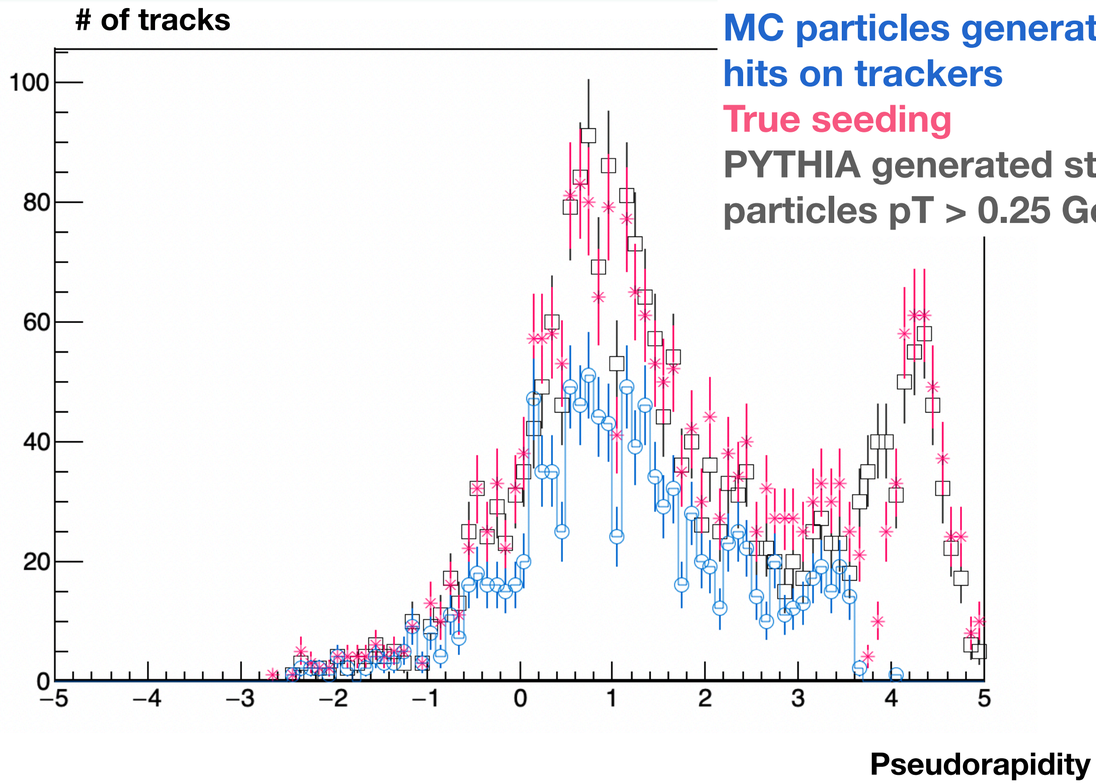




- MC particles: stable particles generating at 3 hits on silicon trackers
- Much larger entries w.r.t. MC particles in realistic seeding: duplicate seeds visible as expected
- Larger entries in true seeding w.r.t. MC particles in true seeding, with seeds in B0 acceptance

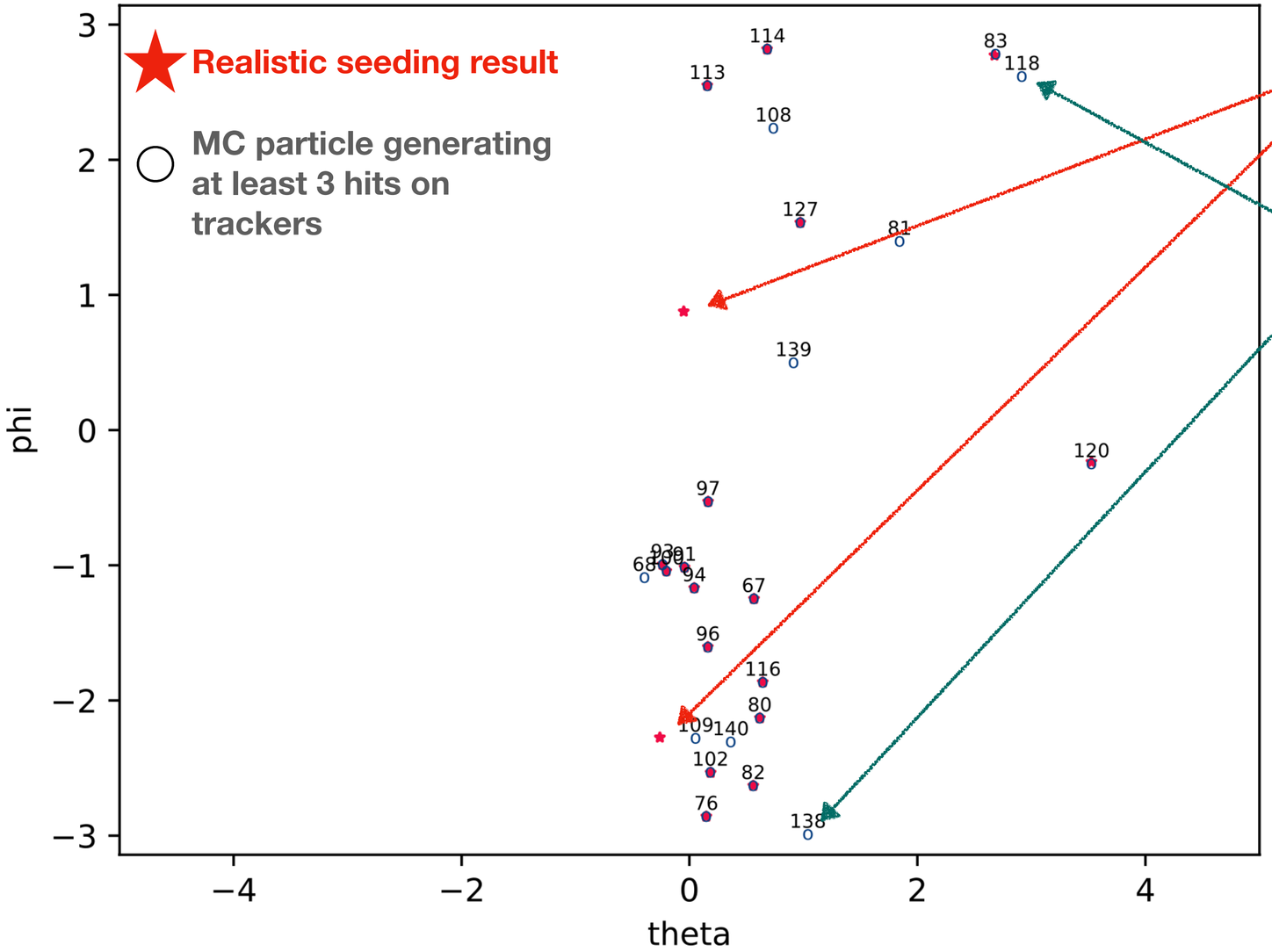
Caution for true seeding usage





- Larger entries in true seeding w.r.t. MC particles in true seeding, with seeds in B0 acceptance
- True seeding takes PYTHIA generated charged particle with min. pT: doesn't guarantee whether they are really trackable in the detector! **min. # of generated hits for input MC particles?**

Fake seeds and missed particles in realistic seeding



- Seeds without matching trackable MC particles
- Particles without matching seeds
- More quantitive analysis required! **tracker hits associated with seed**

Summary

- Duplicate track rejection for realistic seeding
  - Seed confirmation in ACTS requires optimization
  - Greedy ambiguity resolution solver in ACTS effectively remove the duplicate tracks based on shared hit information and track quality
- Track momentum resolution and tracking efficiency estimated in vector meson photoproduction events
  - Results look reasonable in restricted kinematic range
- Difficulties in high Q2 DIS event tracking
  - True seeding: input MC particles are not optimal - results cannot be directly used as a reference for realistic seeding results
  - Realistic seeding: Fake seeds from random associations and inefficiency of seed-finding (missing trackable MC particles) found

Outlook

- Duplicate track rejection for realistic seeding
  - Implementation to EICrecon required, directly adopt the methods defined in ACTS
- Track momentum resolution and tracking efficiency estimated in vector meson photoproduction events
  - Move to minimum bias (DIS) events to study in wide acceptance, in particular the edge and the overlap regions between barrel and endcap and the edge of the endcap where magnetic field strength grows rapidity
  - Impact of MPGDs and TOF in tracking, tracking performance for different particle species,……
- Difficulties in high Q2 DIS event tracking
  - Quantification of fake rate and inefficiency in seed/track level

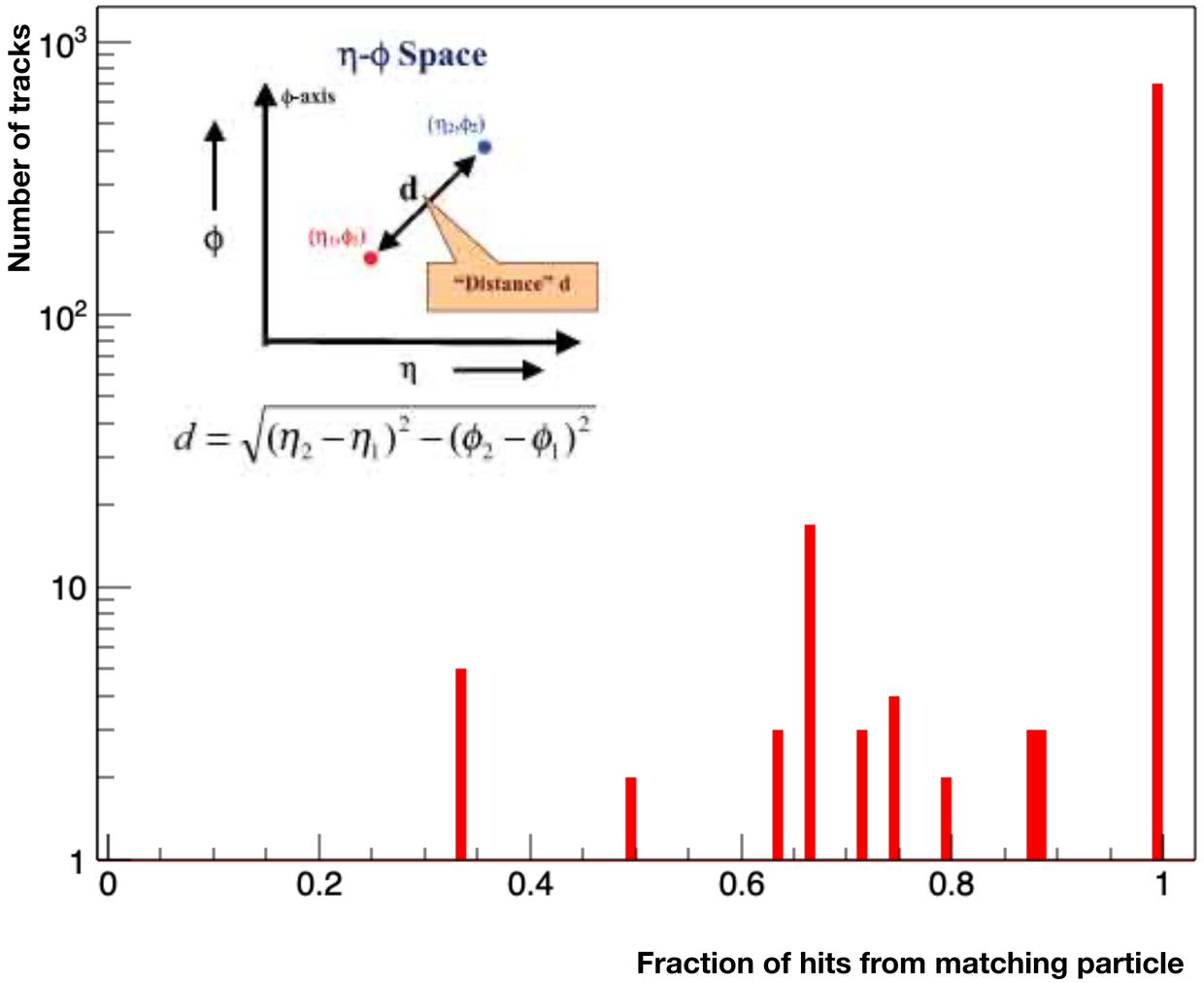
Wishlist

- **MC source and quality of tracker hit**: already there in dd4HEP output but not in podio data structure
- **Number of shared hits for trajectory**: already there in podio data structure but not updated properly → should be updated after CKFtracking and before filling trajectory information (some examples available in ACTS repo.)
- **List of tracker hits associated with seed**

- **Native support of greedy ambiguity resolution solver**
- **Improved selection criteria for true seeding input MC particles**?

Backup

Matching between MC particle and reconstructed track



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