Realstic seeding with ACTS in ATHENA track reconstruction

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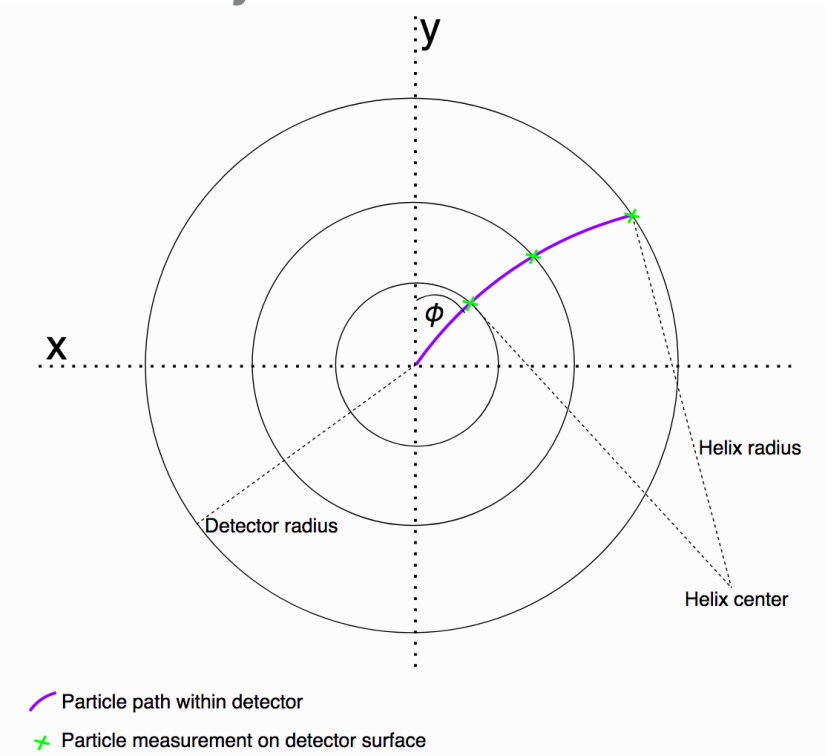
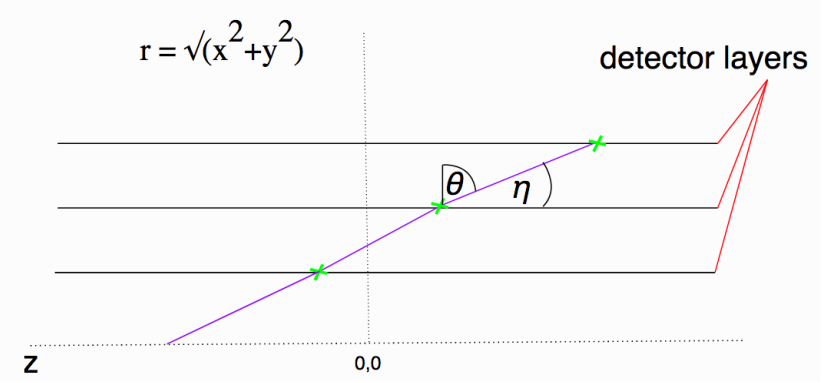
LBNL

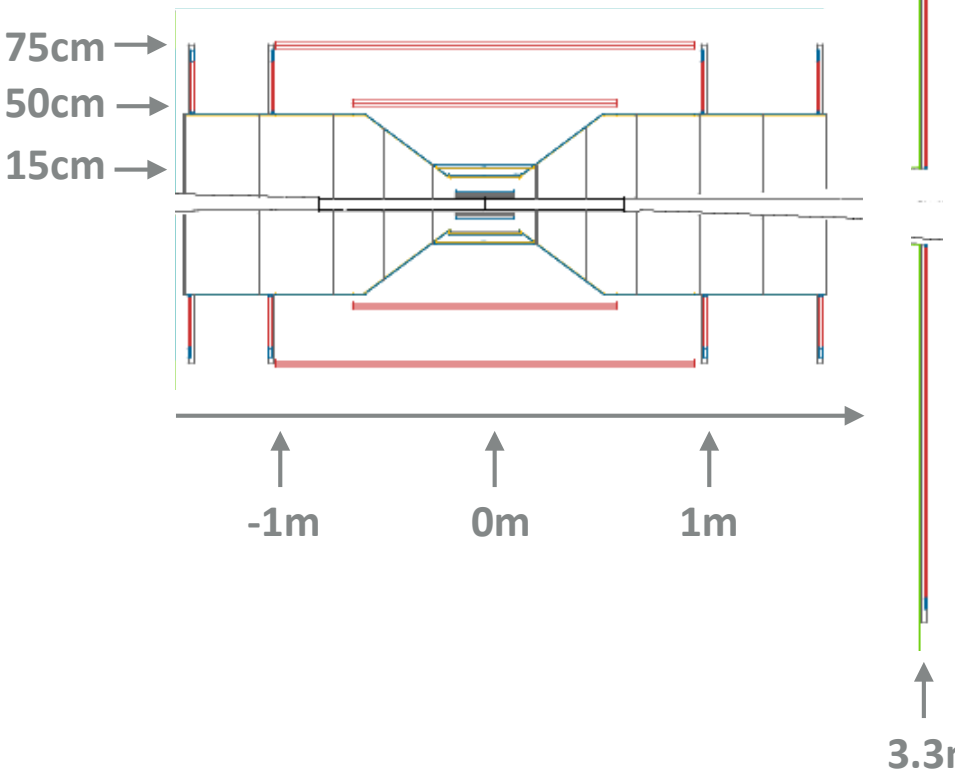
- A good seeding algorithm
  - It finds at least one seed for each particle that should be found
  - It doesn't find many seeds which do NOT correspond to particles
  - It doesn't find many seeds per particle
- ACTS seeding
  - Use triplet of hits for seed finding
  - Currently all hits used in ATHENA for seed finding





Seeding

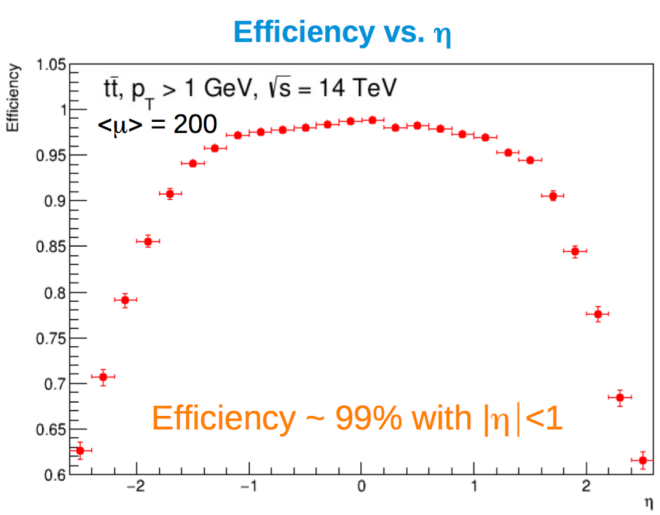
- Configuration
  - We cannot adjust deltaRMmax to much higher value
  - Tighter beam spot contraints
  - Any suggestions on tuning the parameters?

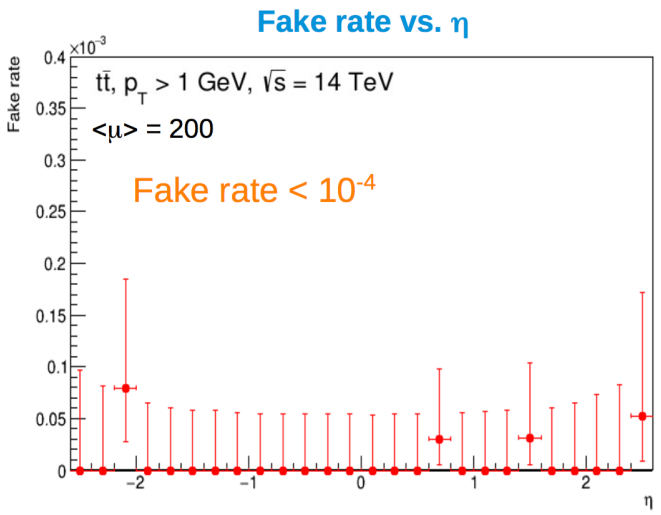


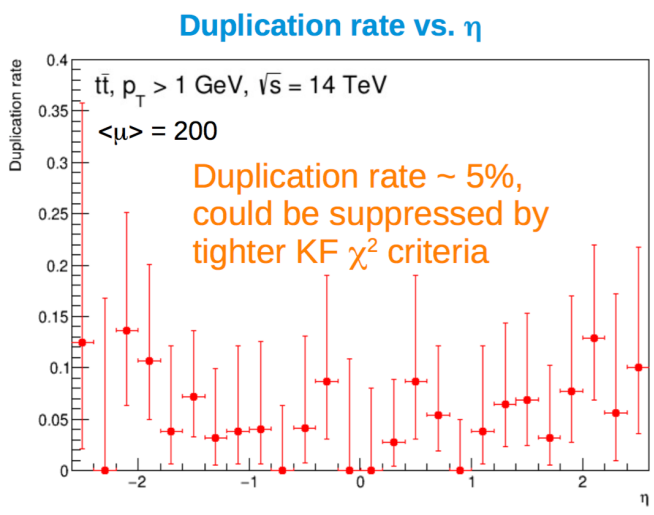

```
std::vector<std::string> inputSpacePoints;
/// Output track seed collection.
std::string outputSeeds;
/// Output proto track collection.
std::string outputProtoTracks;
float bFieldInZ = 3 * Acts::UnitConstants::T;
float minPt = 150 * Acts::UnitConstants::MeV;
float rMax = 320 * Acts::UnitConstants::mm;
float zMin = -4000 * Acts::UnitConstants::mm;
float zMax = 4000 * Acts::UnitConstants::mm;
float deltaRMin = 1 * Acts::UnitConstants::mm;
float deltaRMax = 320 * Acts::UnitConstants::mm;
float cotThetaMax = 45.003; // 27.2899; // About eta = 4
// 7.40627;  // 2.7 eta
//
float collisionRegionMin = -250 * Acts::UnitConstants::mm;
float collisionRegionMax = 250 * Acts::UnitConstants::mm;
float maxSeedsPerSpM = 10;
float sigmaScattering = 50;
float radLengthPerSeed = 0.1;
float beamPosX = 0 * Acts::UnitConstants::mm;
float beamPosY = 0 * Acts::UnitConstants::mm;
float impactMax = 3 * Acts::UnitConstants::mm;

/// The minimum magnetic field to trigger the track
/// parameters estimation
double bFieldMin = 0.1 * Acts::UnitConstants::T;

/// Constant term of the loc0 resolution.
double sigmaLoc0 = 25 * Acts::UnitConstants::um;
/// Constant term of the loc1 resolution.
double sigmaLoc1 = 100 * Acts::UnitConstants::um;
/// Phi angular resolution.
double sigmaPhi = 0.02 * Acts::UnitConstants::degree;
/// Theta angular resolution.
double sigmaTheta = 0.02 * Acts::UnitConstants::degree;
/// q/p resolution.
double sigmaQOverP = 0.1 / Acts::UnitConstants::GeV;
/// Time resolution.
double sigmaT0 = 1400 * Acts::UnitConstants::s;
```

Efficiency, fake rate, duplicate rate

- A well **reconstructed track**: tracks can be associated to a generated particle by mathcing the momentum algorithm (**association criteria: Δp/p within 10%, Δϕ within 50mrad, Δθ within 10mrad**)
- A track that is not associated to any simulated particle is considered to be a **fake track**.
- Duplicate tracks occur when multiple tracks are associated to the same generated particle.
- **Currently looking at single particle events**

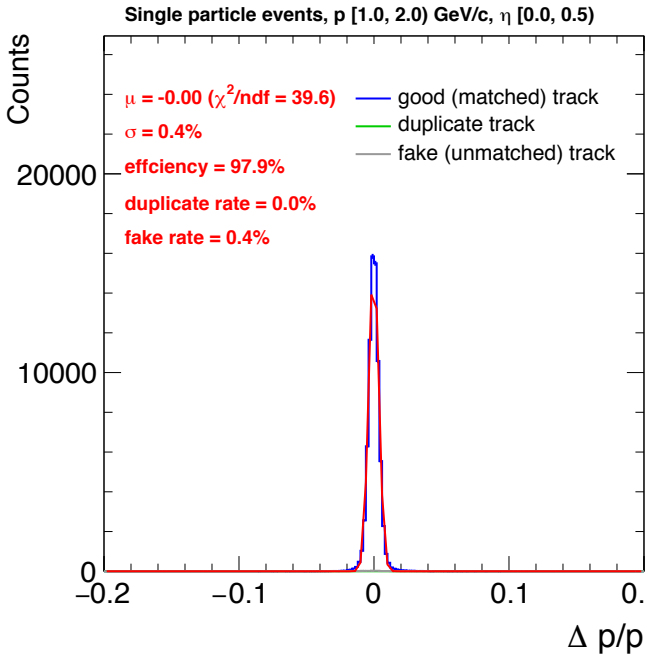


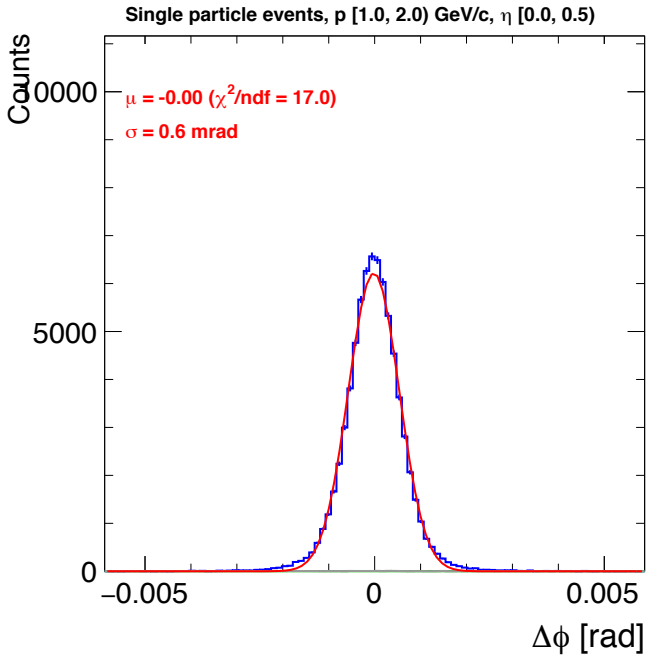


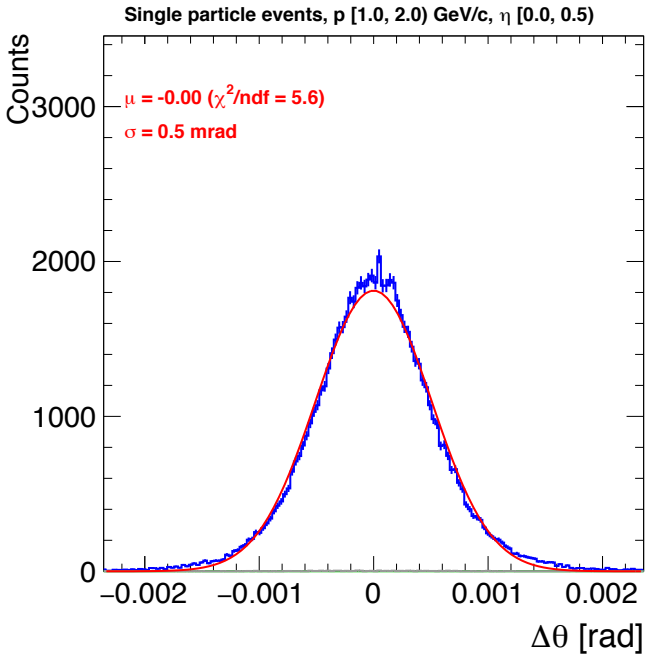


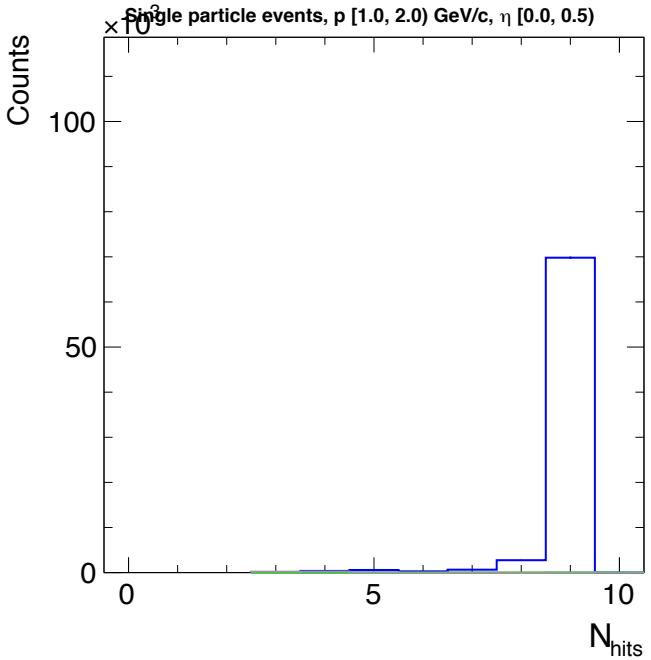
From Xiaocong Ai's presentation, TrackML detector, ATLAS B field

Truth seeding (p~1GeV, η~0)

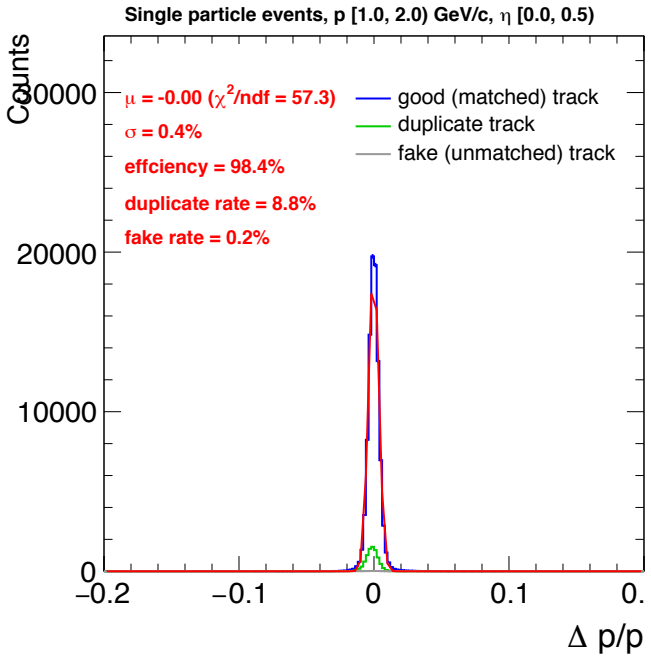


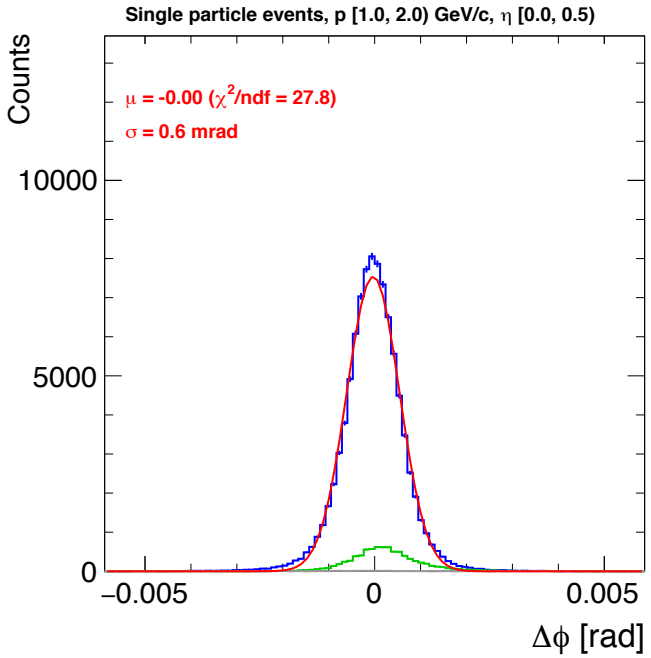


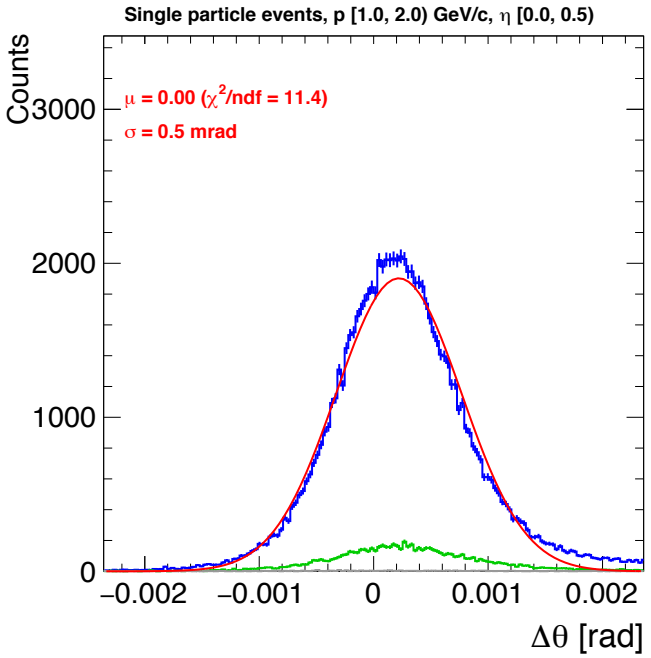


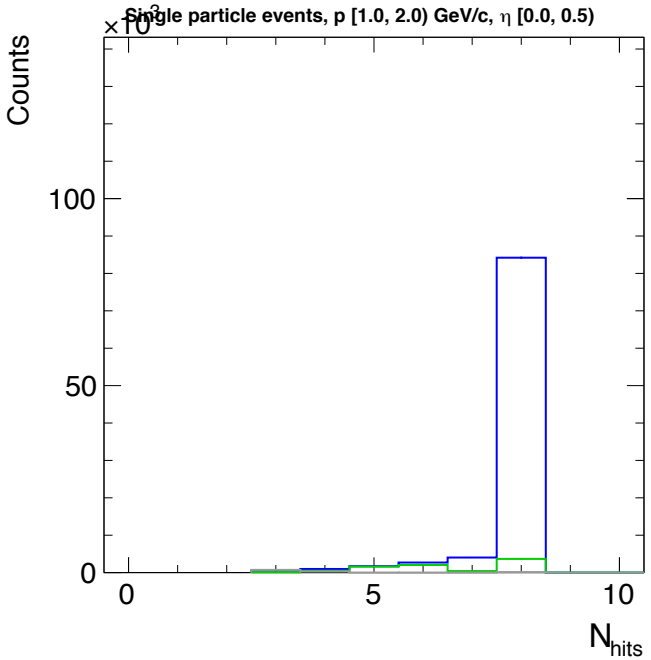


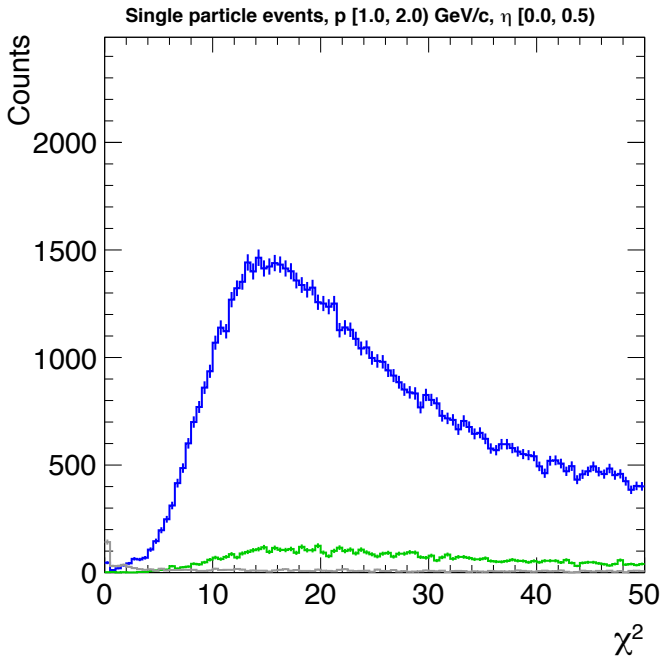
Realistic seeding (p~1GeV, η~0)







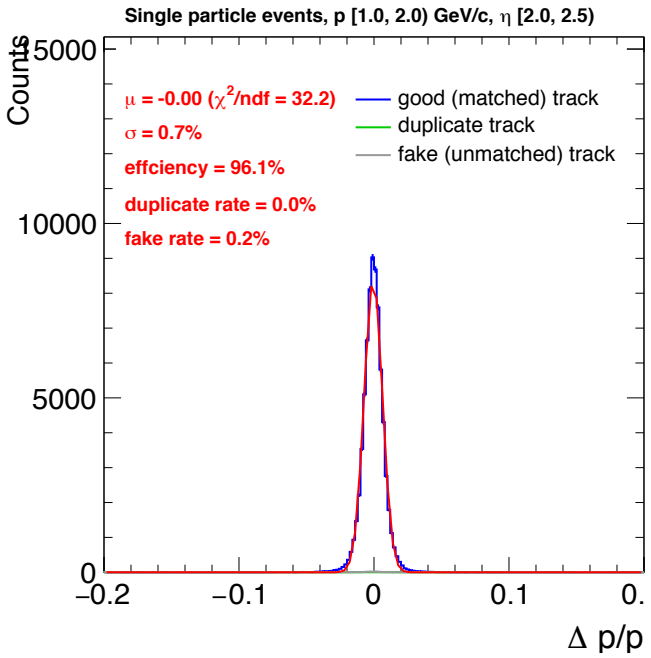


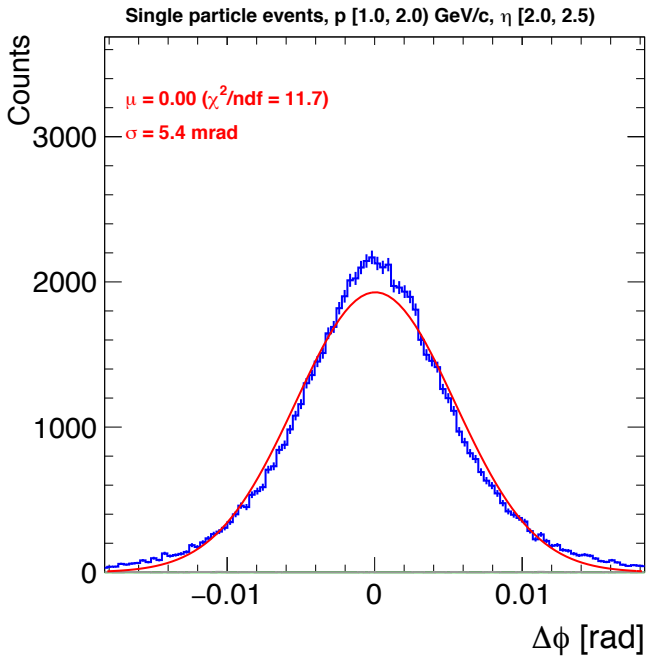


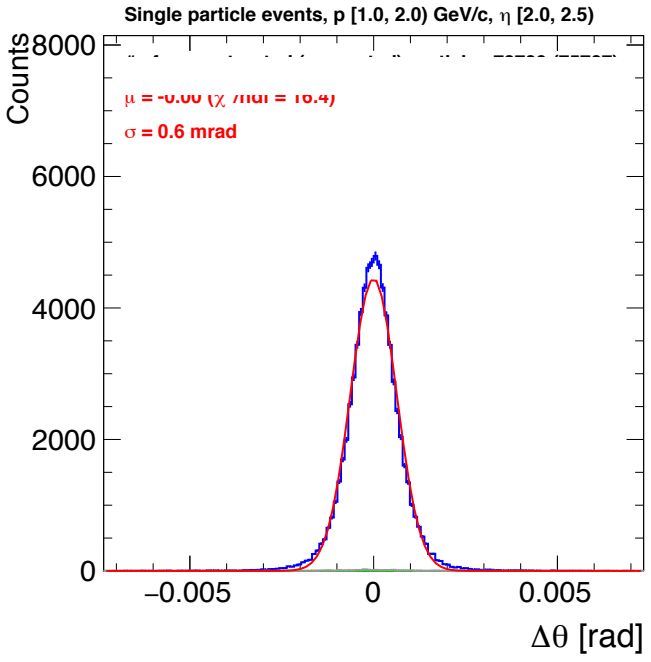
For 1GeV tracks at mid-rapidity: high efficiency, ~10% duplicate tracks with realistic seeding

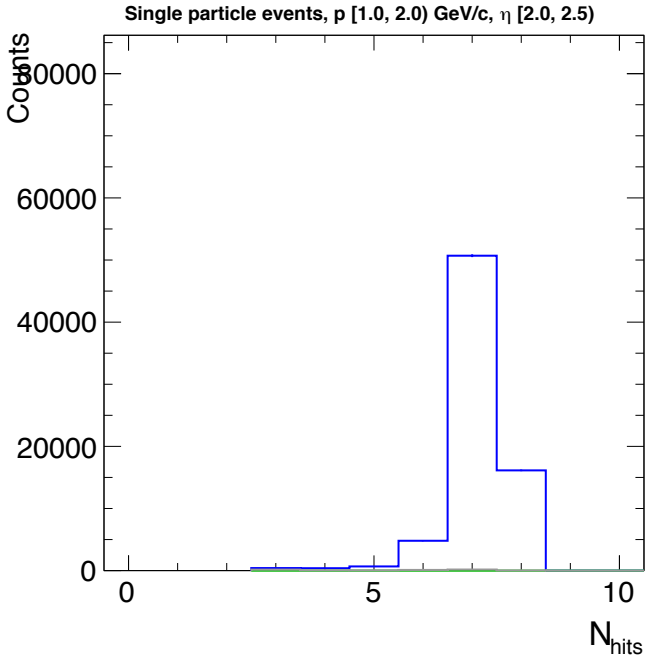
No obvious difference between good track and duplicate track χ^2

Truth seeding (p~1GeV, η~2)

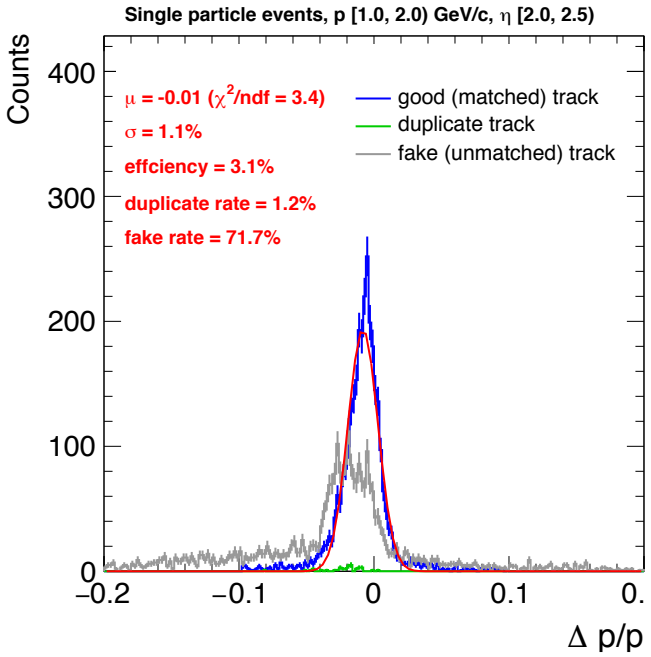


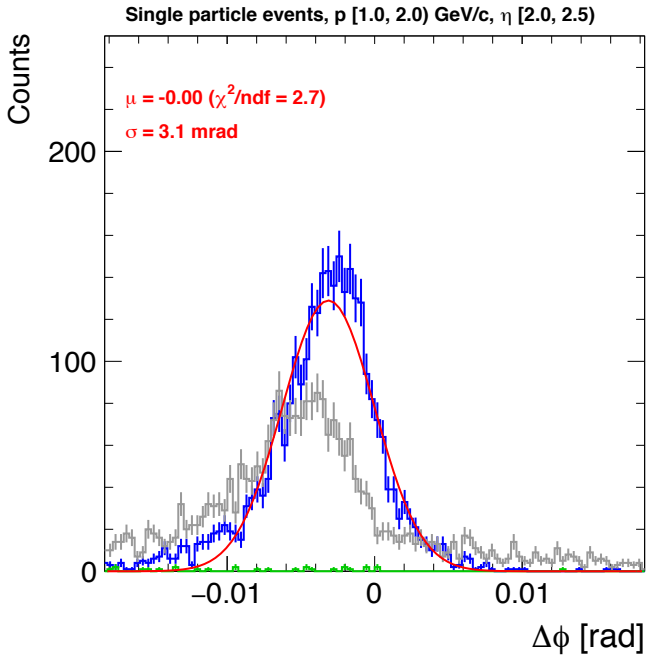


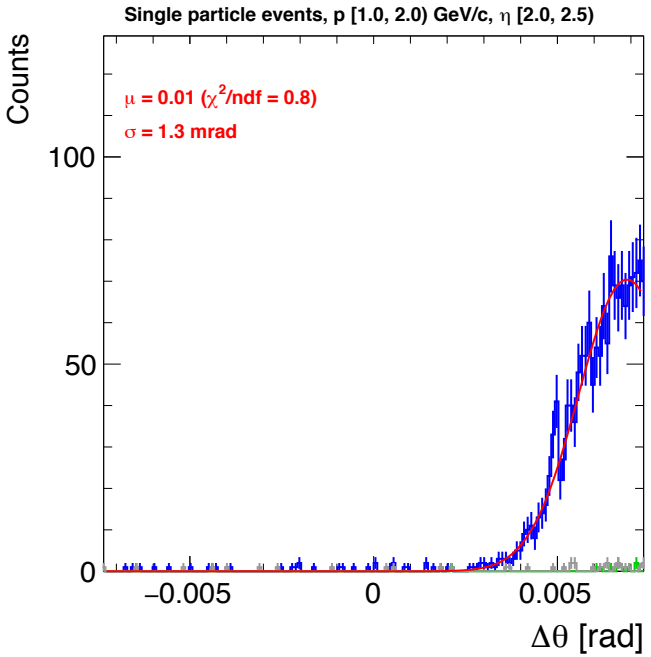


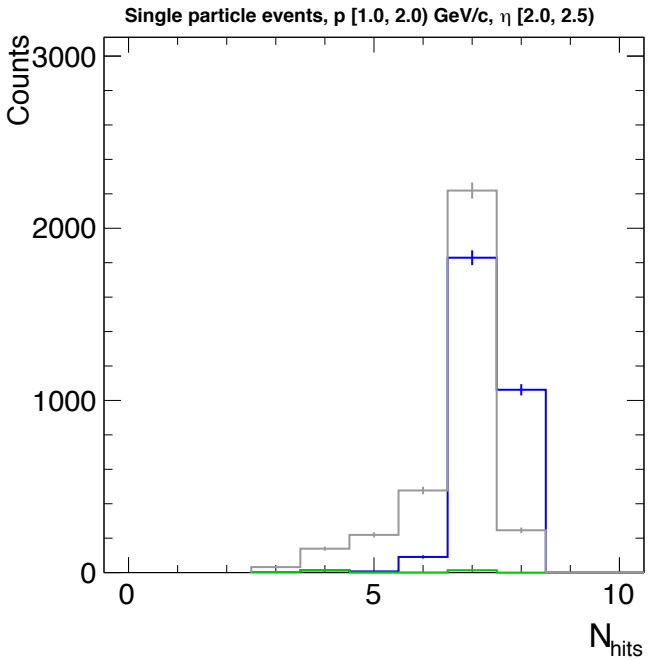


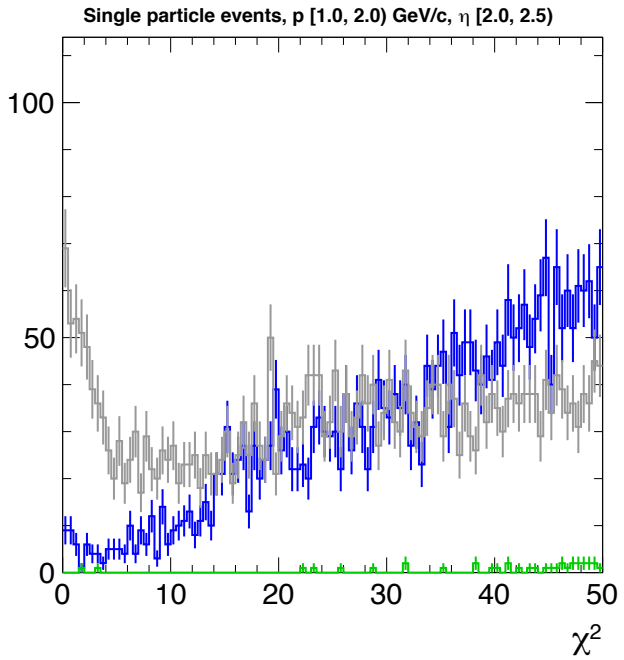
Realistic seeding (p~1GeV, η~2)





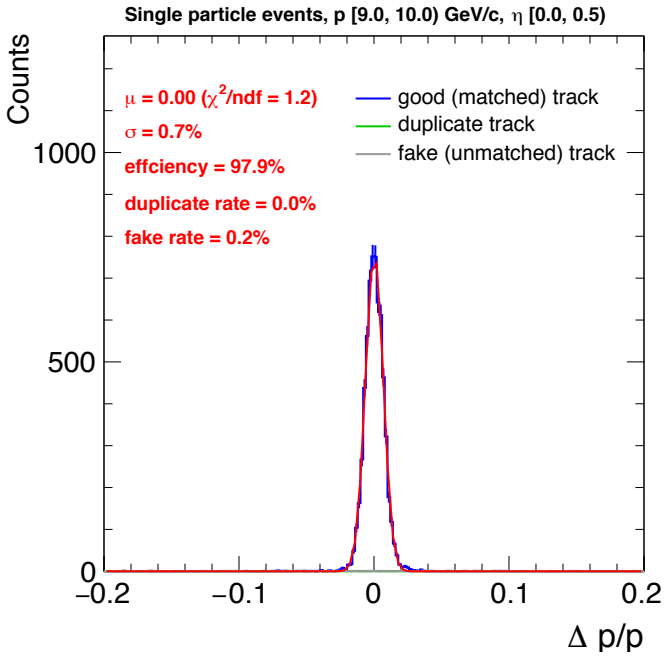


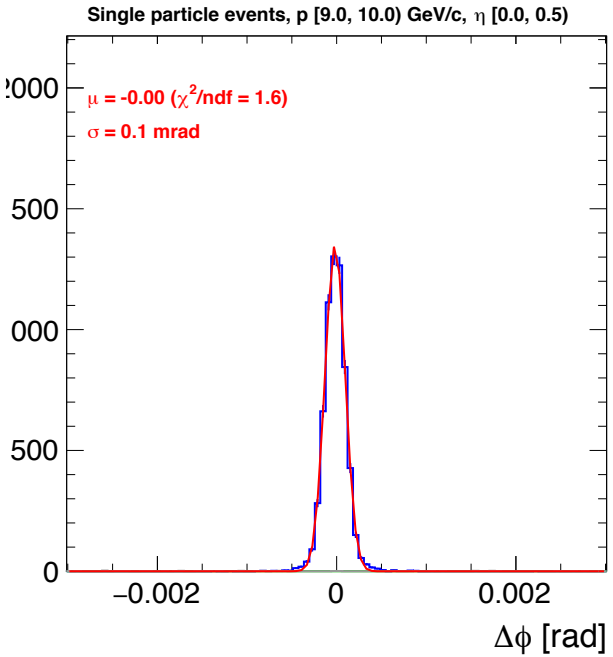


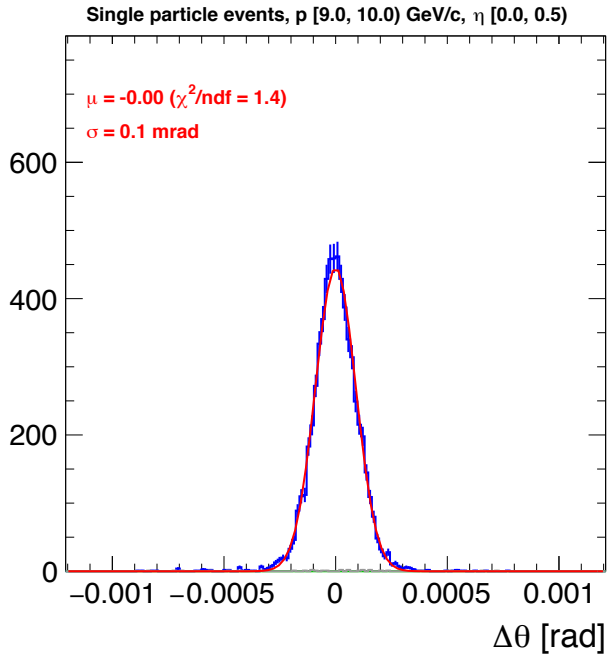


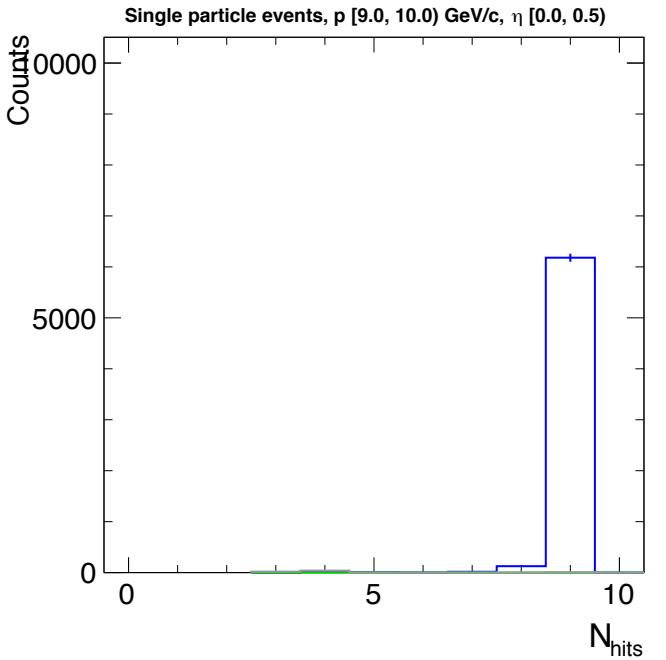
For 1GeV tracks at forward-rapidity: low efficiency, bad reconstruction for track momentum direction

Truth seeding (p~10GeV, η~0)

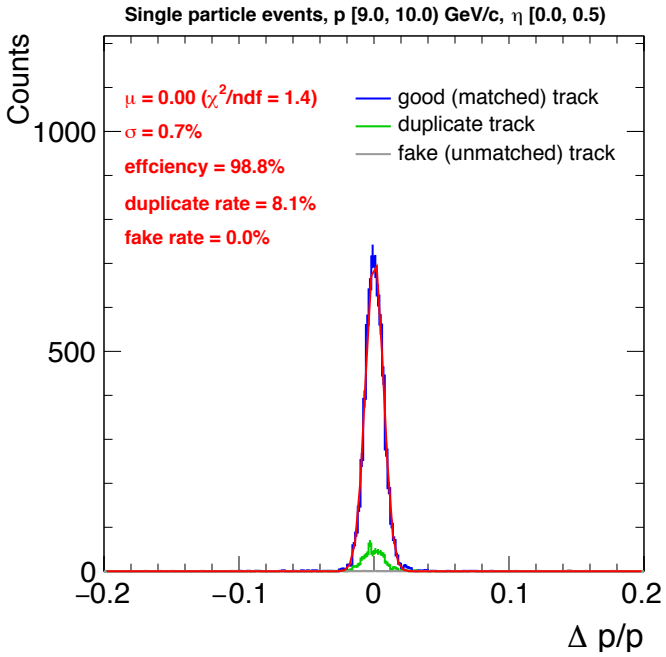


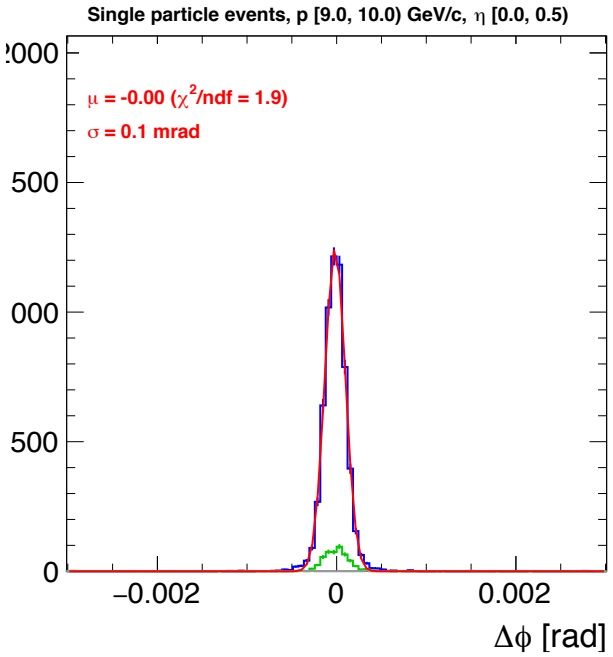


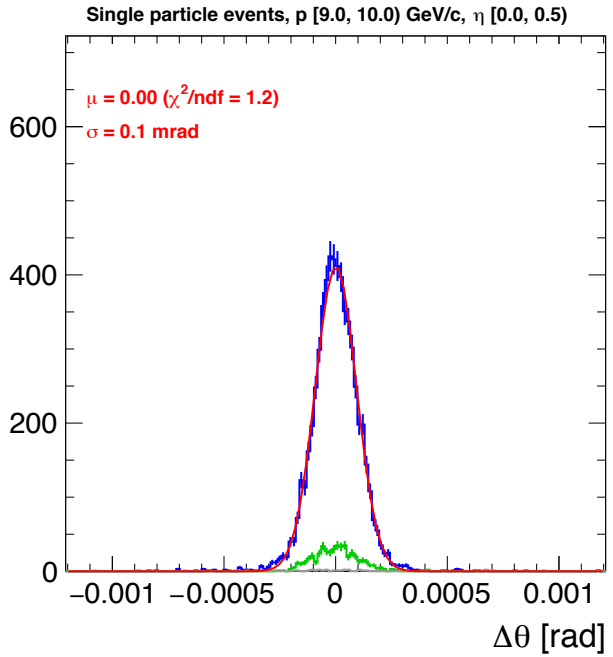


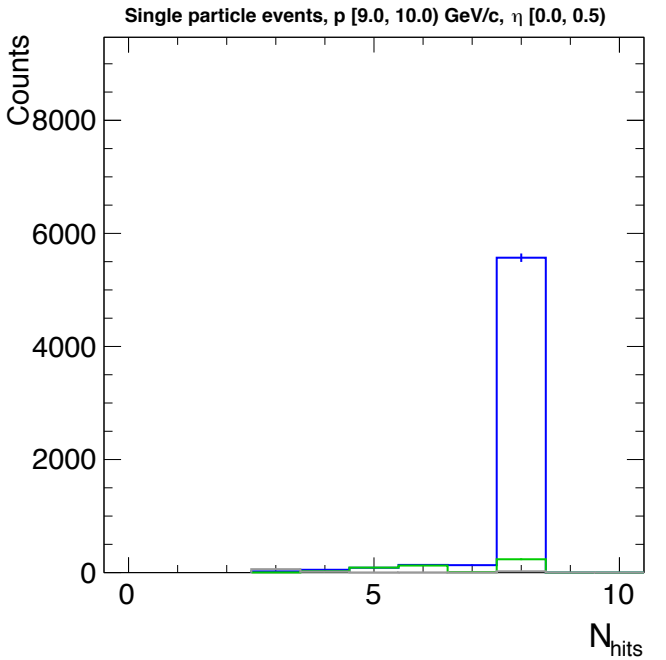


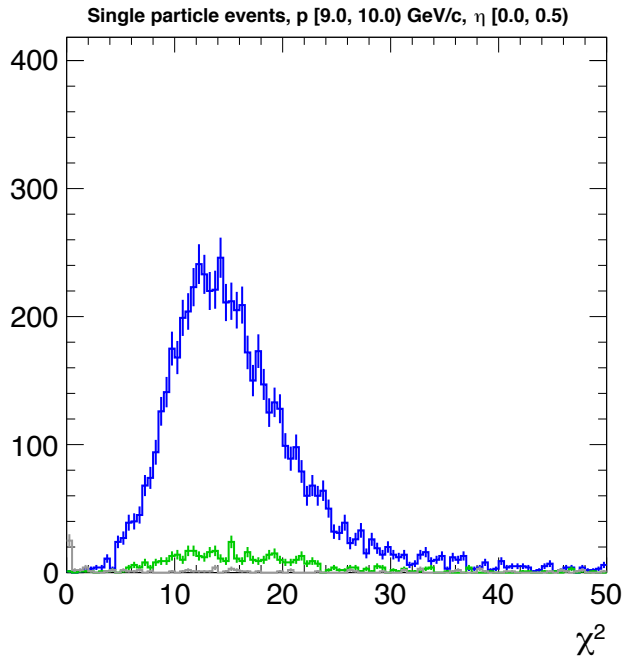
Realistic seeding (p~10GeV, η~0)





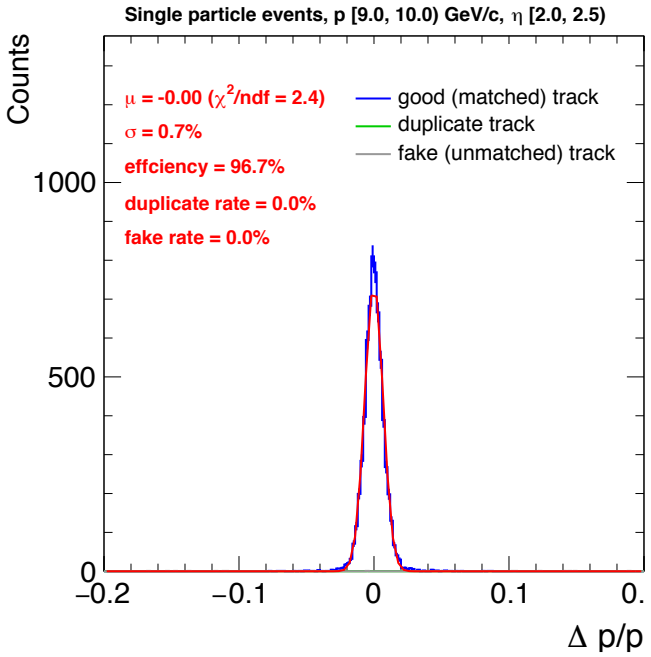


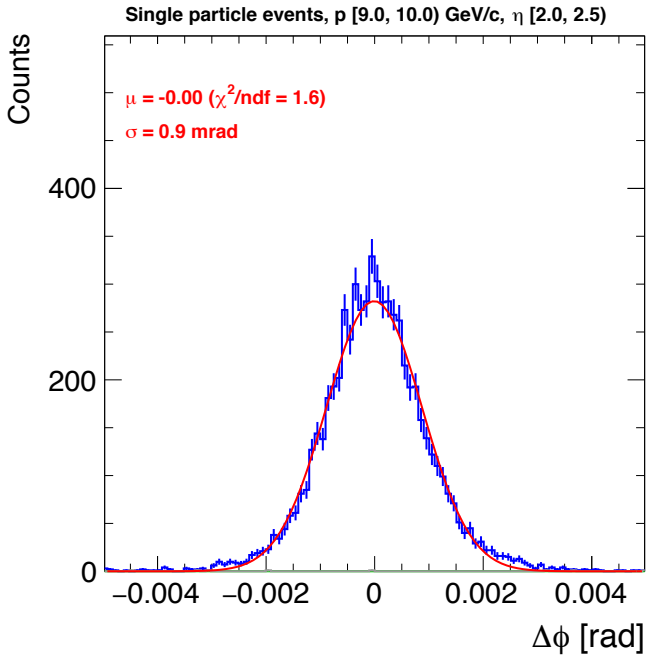


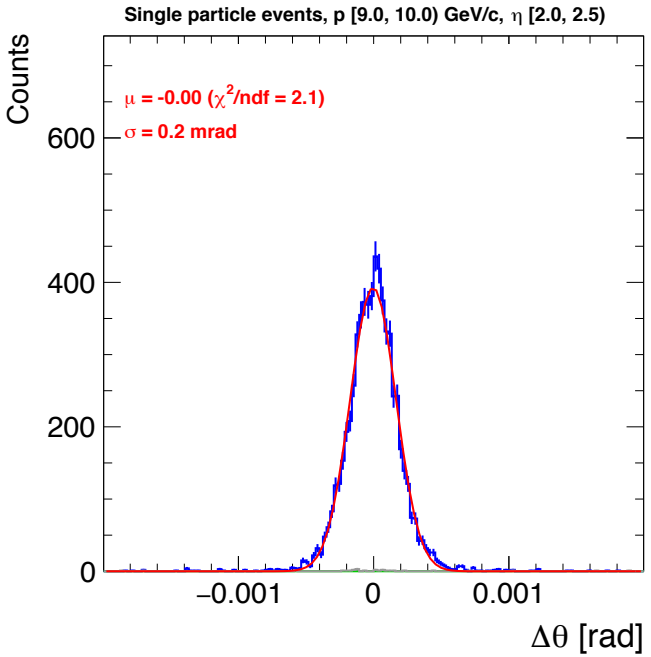


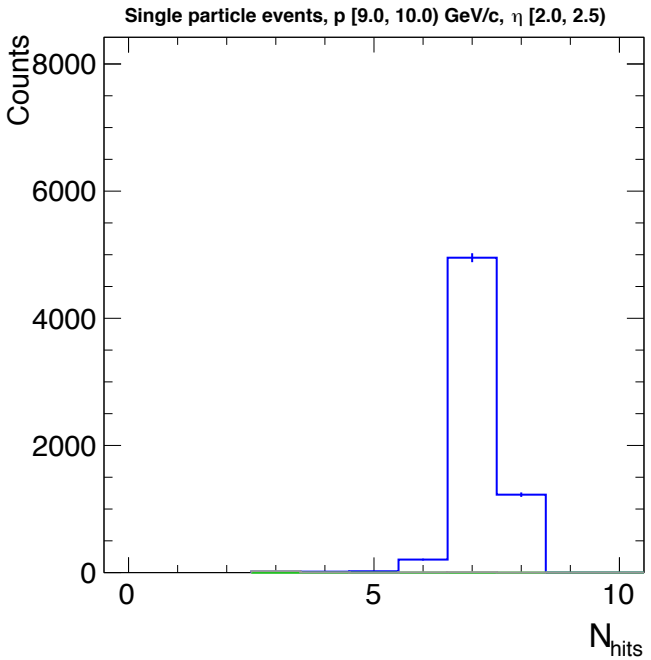
For 10GeV tracks at mid-rapidity: high efficiency, ~10% duplicate tracks with realistic seeding

Truth seeding (p~10GeV, η~2)

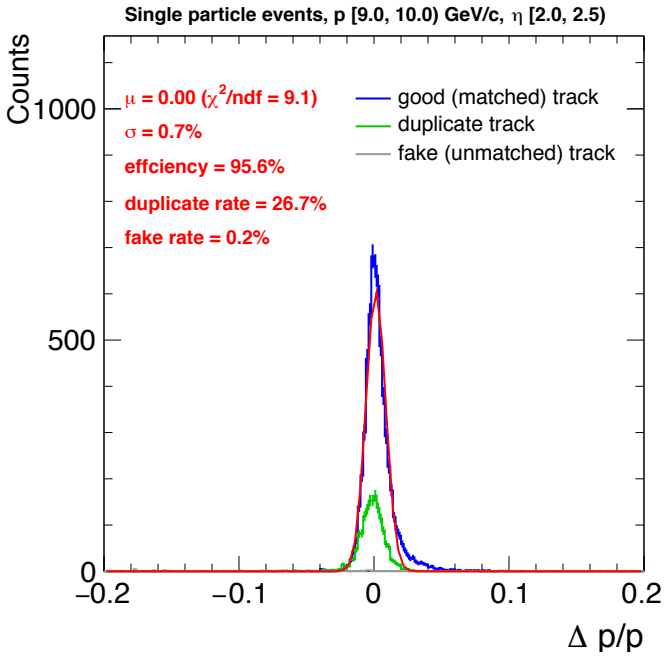


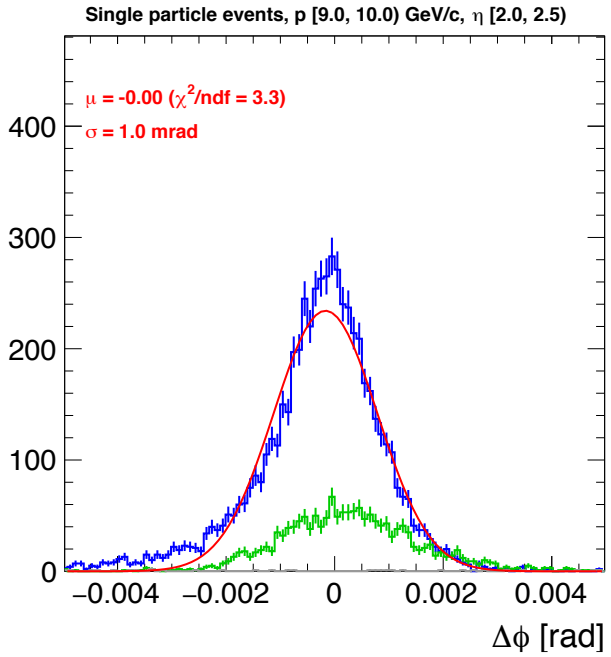


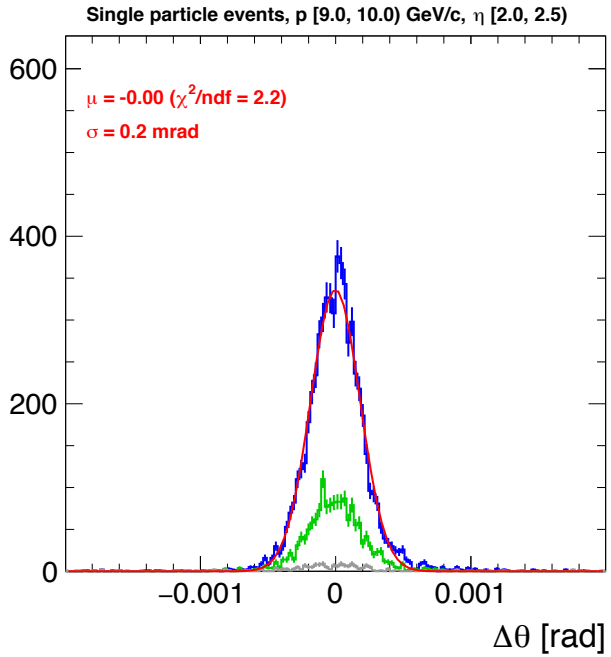


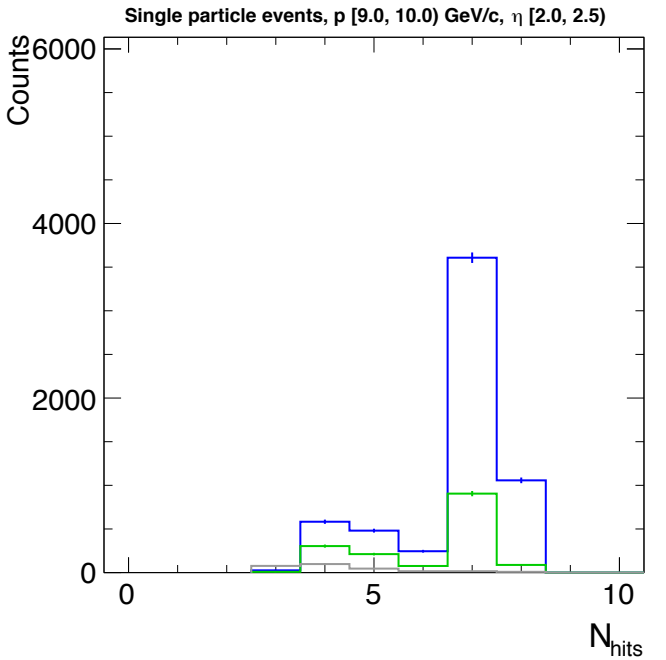


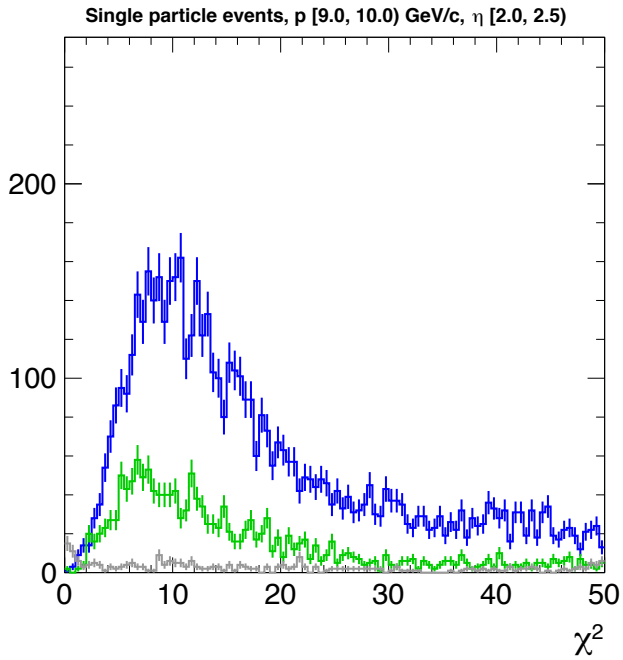
Realistic seeding (p~10GeV, η~2)









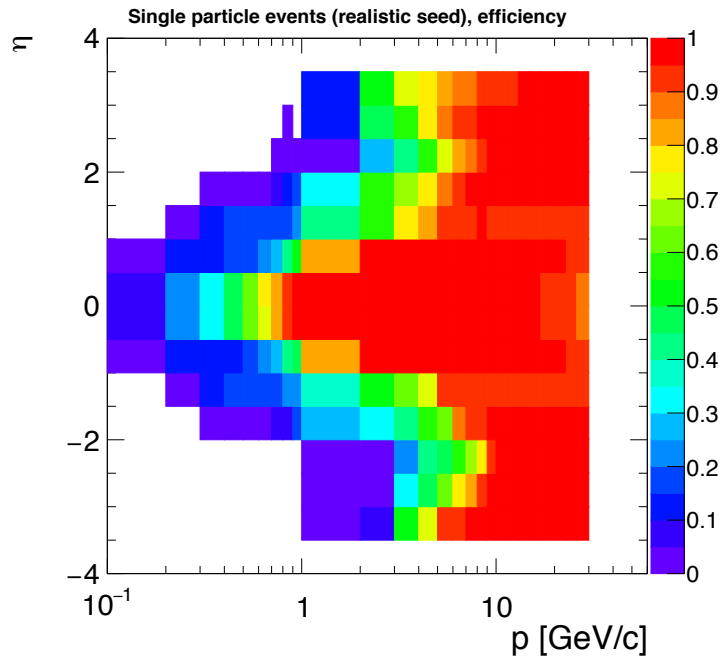


For 10GeV tracks at forward-rapidity: high efficiency, ~25% duplicate tracks with realistic seeding

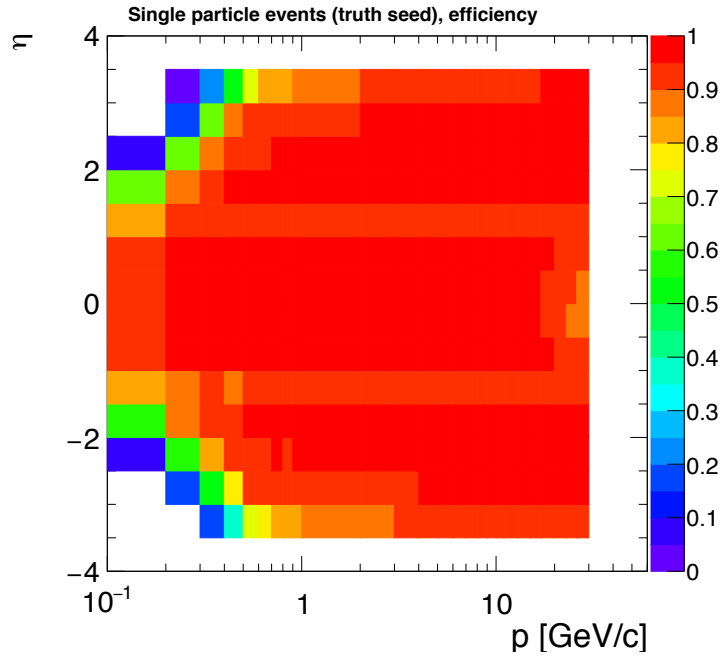
Comparison between truth and realistic seeding

- In high p and mid-rapidty
  - Realistic seeding consistent with truth-seeding results (p resolution, efficiency)
  - More fake tracks (<10%)
- In low p or forward(backward)-rapidty
  - Much lower efficiency with realistic seeding, a lot of fake tracks with wrongly reconstruct momentum direction
  - More fake tracks (~25%)
- For low effcincy case
  - Look into whether there is no good seed or no track reconstructed with given seed

Realistic seeding



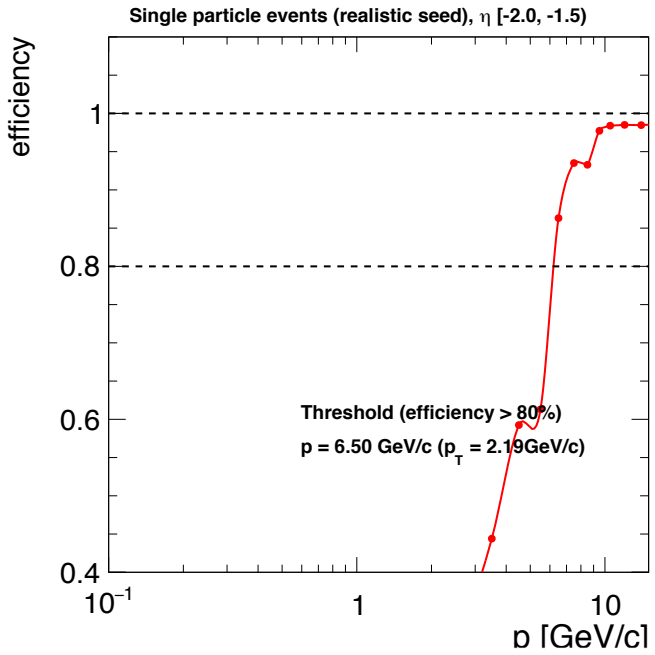
Truth seeding

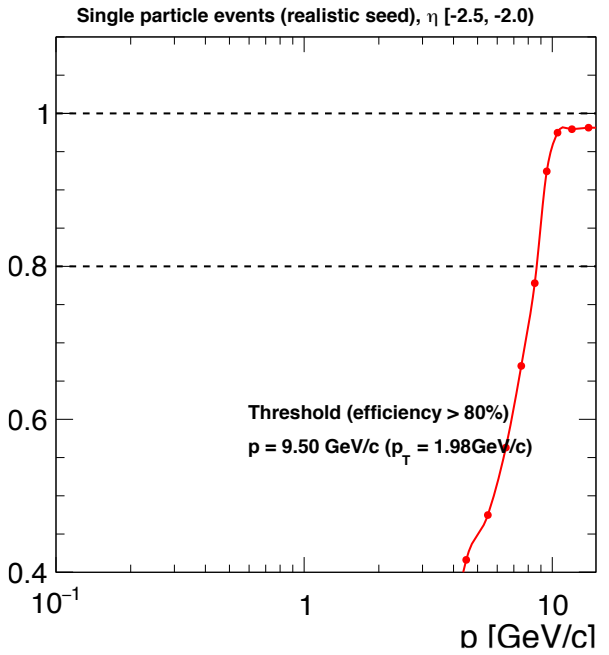


Comparison between forward and backward rapidity

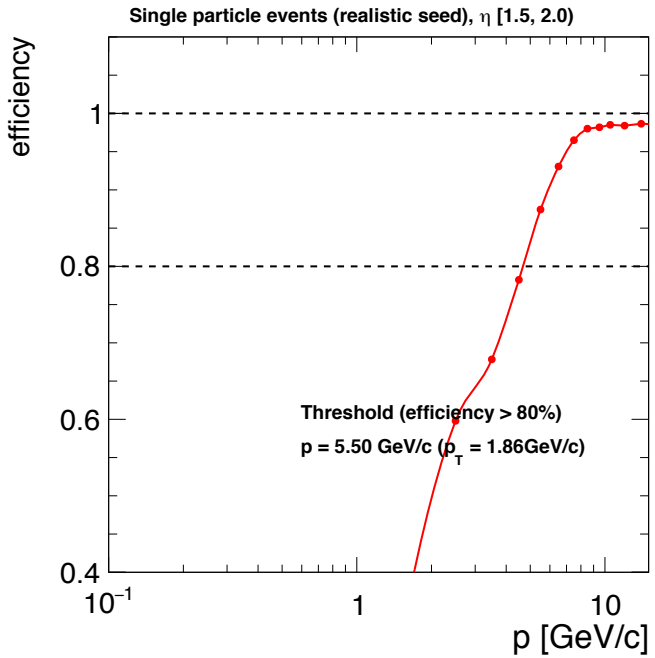
- Efficiency curve look asymetric between the forward and backward rapidity

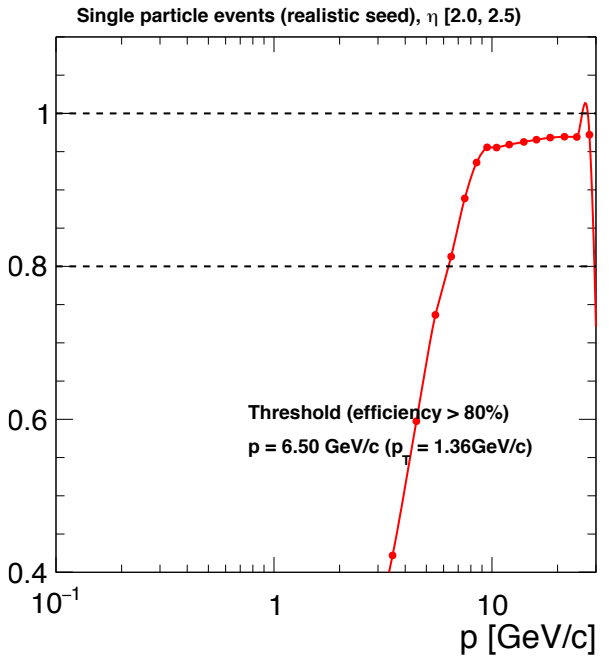
Backward rapidity





Forward rapidity





Addtional info on low efficiency events

- Single pion p = 1GeV, ϕ = 0 rad, θ = 1.57 rad (η = 2.5)
  - No filtering
  - All of the seeds are with q/p systematically higher than the true q/p
  - All of the seeds are with θ systematically higher than the true θ
  - All of the seeds are with ϕ systematically lower than the true ϕ

```
acts_seeding_init   DEBUG seeds.size() = 16
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:366:
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:396:
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:435: iseed = 0, 4, 218.675, -79.5911, 729.865
acts_seeding_init   DEBUG Estimation of track parameters for seed 0 is with q/p 1.23827 phi-0.687094 theta 0.200557 and
 charge 1
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:435: iseed = 1, 4, 218.675, -79.5911, 729.865
acts_seeding_init   DEBUG Estimation of track parameters for seed 1 is with q/p 1.51977 phi-0.692229 theta 0.249507 and
 charge 1
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:435: iseed = 2, 4, 107.021, -18.8706, 249.865
acts_seeding_init   DEBUG Estimation of track parameters for seed 2 is with q/p 2.12836 phi-0.249091 theta 0.34663 and
charge 1
acts_seeding_init   DEBUG /global/project/projectdirs/m3763/wenqing/eic/juggler/JugTrack/src/components/TrackParamACTSS
eeding.cpp:435: iseed = 3, 4, 107.021, -18.8706, 249.865
acts_seeding_init   DEBUG Estimation of track parameters for seed 3 is with q/p 1.7577 phi-0.248101 theta 0.28413 and c
harge 1
```