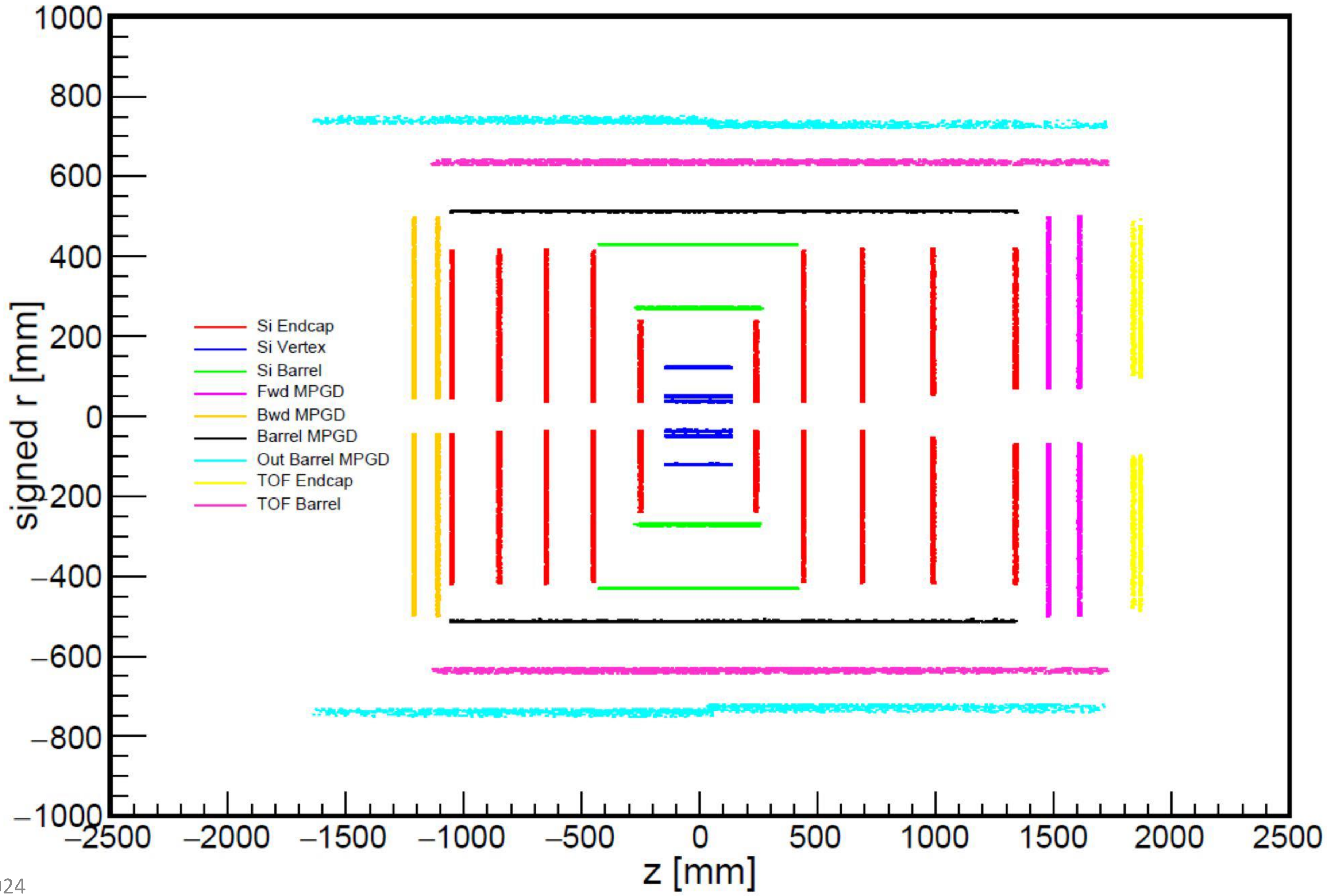
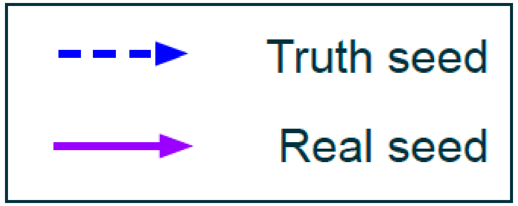
Track reconstruction status

Barak Schmookler

Geant-level tracker hits



Track reconstruction workflow



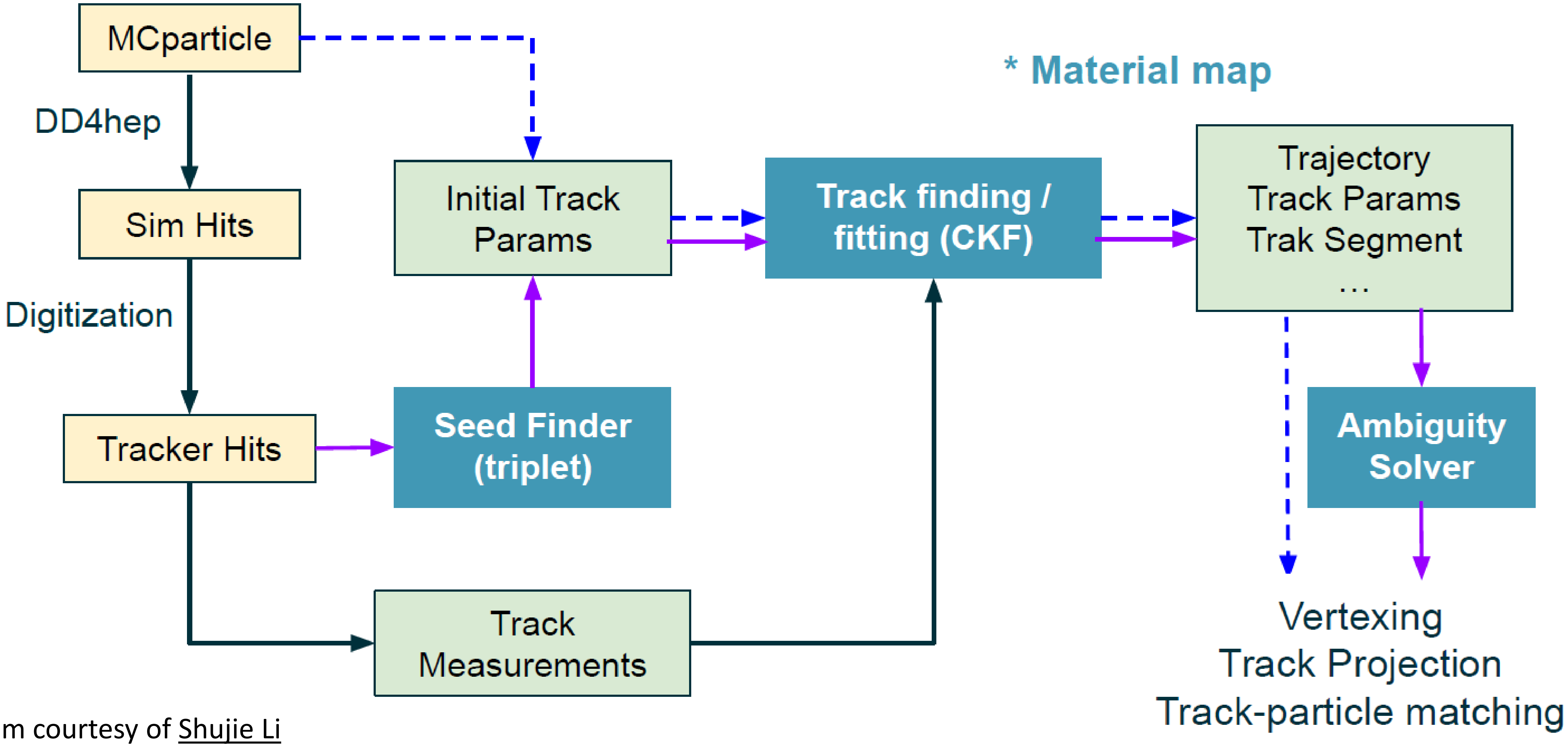


Diagram courtesy of Shujie Li

Seeding and tracking

<u>Seeding implementations</u>

Truth (Ideal) seeding: For every generated, final-state (i.e. status = 1) charged particle, we use the true charge, q/p, theta, phi, and generation vertex to form the seed. Option to smear the initial parameters is included.

Real seeding: The ACTS orthogonal seeder outputs a set of seeds, with each seed consisting of 3 space points. The seeds need to fulfill certain expectations for a particle moving in a uniform magnetic field. The seed finder and seed filter settings configure the allowed search region and tolerances. We then fit the seed space points to determine the charge, q/p, theta, phi, and the initial position coordinates.

A given seed is then passed into the ACTS CKF for track finding and fitting. At the acceptance edges, the truth-seeded tracks can sometimes have fewer than 3 hits. For real seeding, we can have seed duplicates.

We don't currently have an implementation where we separate track finding and fitting. For example, we don't use Geant information to send the true hits for a given particle to a KF.

https://acts.readthedocs.io/en/latest/tracking.html
https://acts.readthedocs.io/en/latest/core/seeding.html#seeding-core

Truth-seeded tracking Status

Track reconstruction workflow

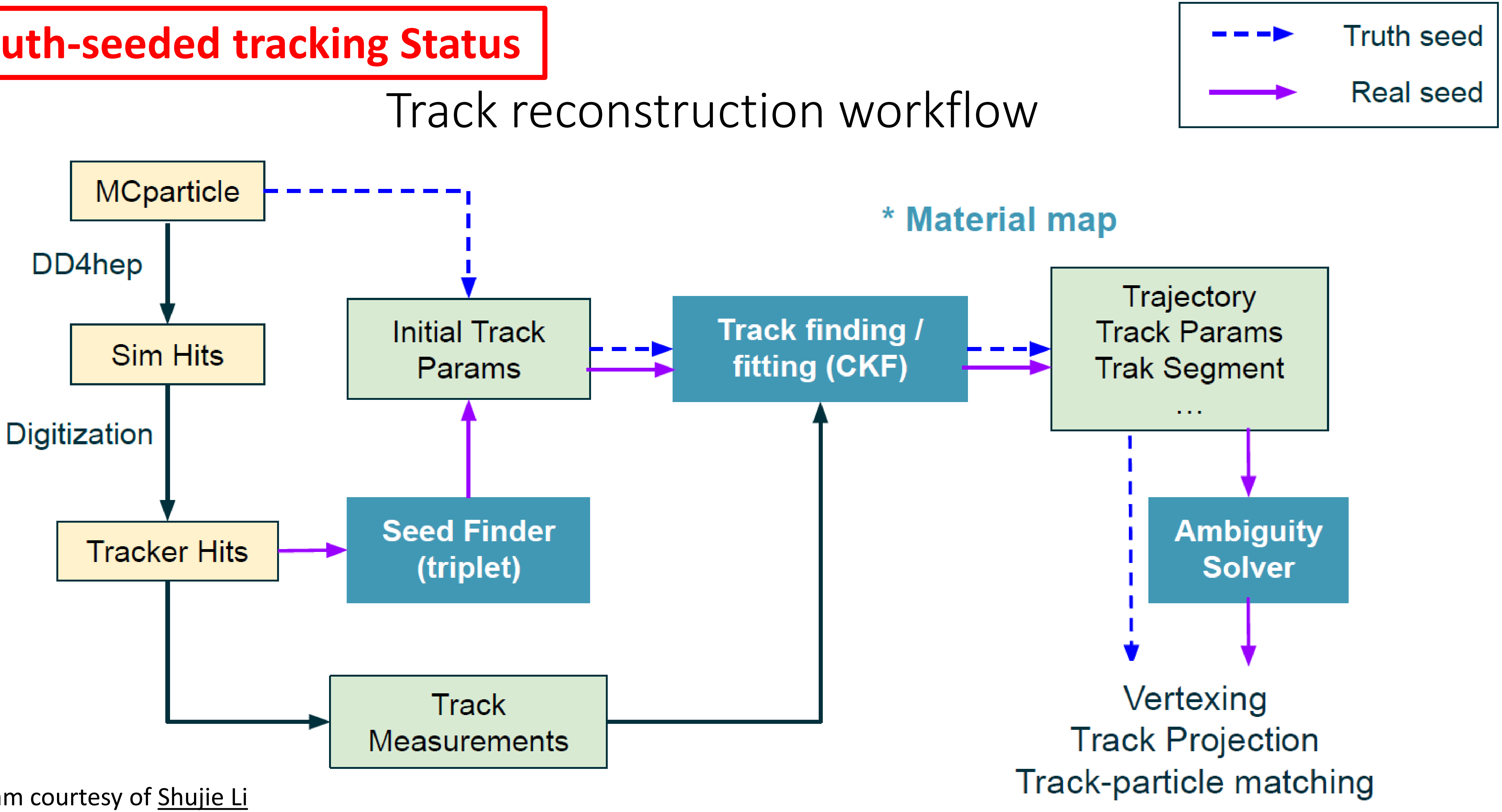


Diagram courtesy of Shujie Li

Single-particle studies over entire beam-spot range

https://github.com/eic/documents/blob/master/reports/general/Note-Simulations-BeamEffects.pdf

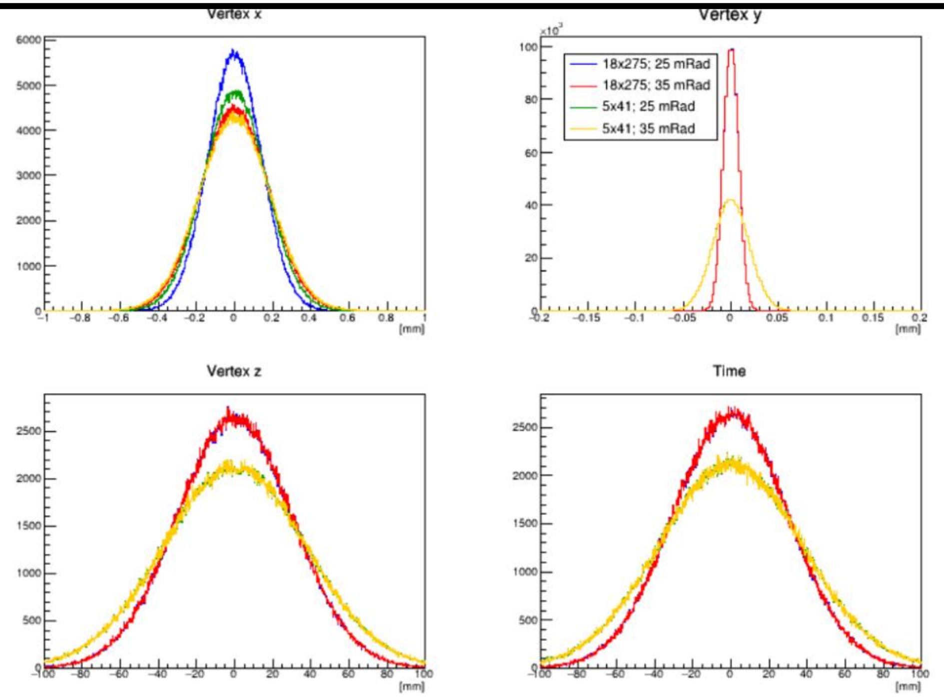


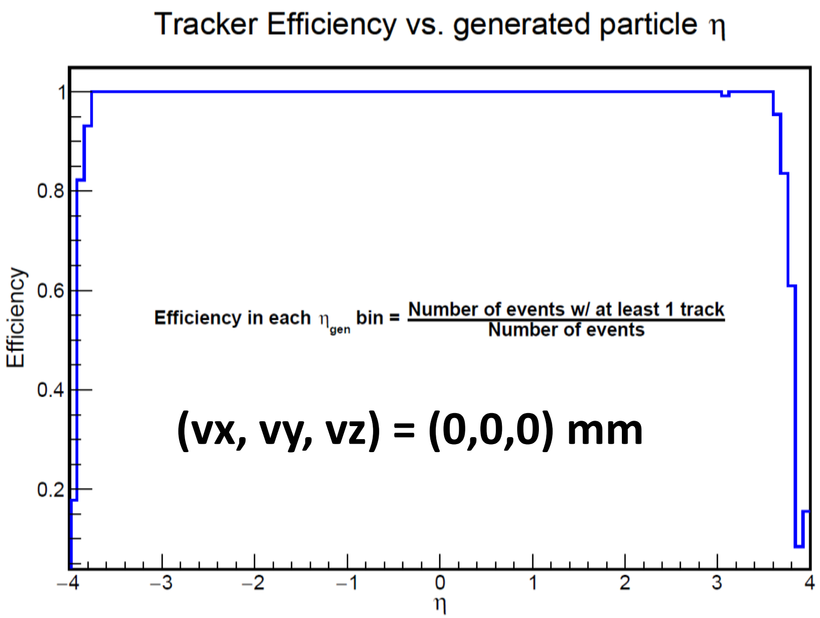
Figure 4: Detector frame vertex position and time distributions for beam energies of 18x275 GeV and 5x41 GeV and crossing angels of 25 and 35 milliradians.

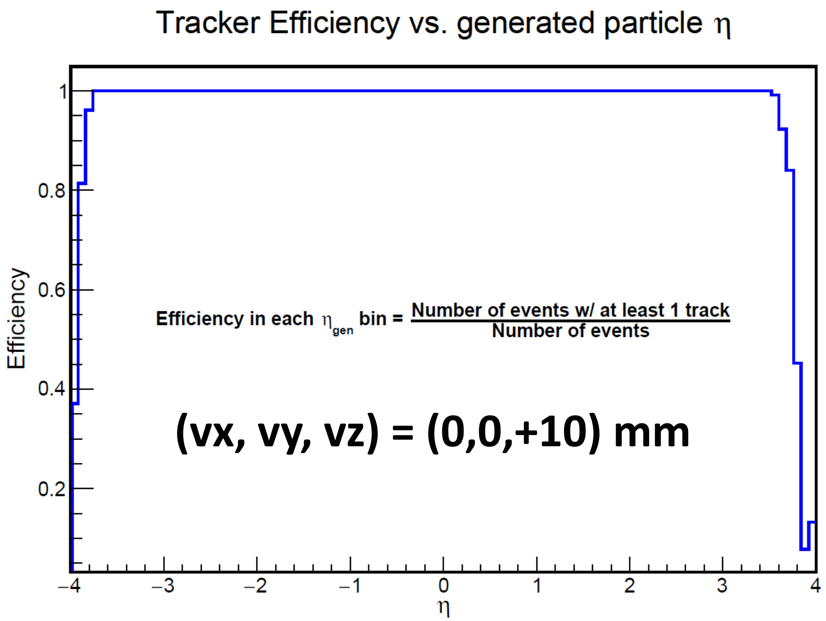
<u>Particle Generation</u>

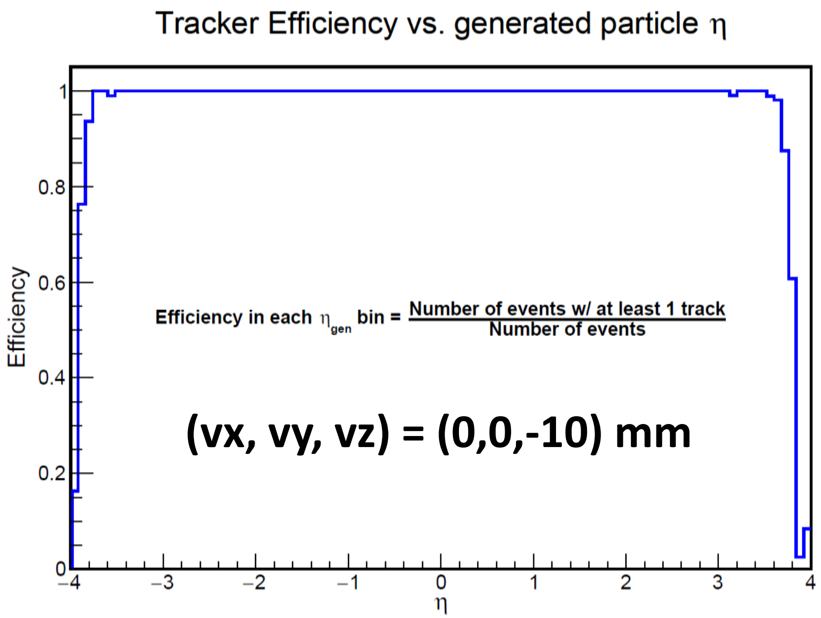
Single negative muons
Uniform momentum [0.5,20] GeV/c
Uniform eta [-4,4]
Uniform phi [0,2Pi]

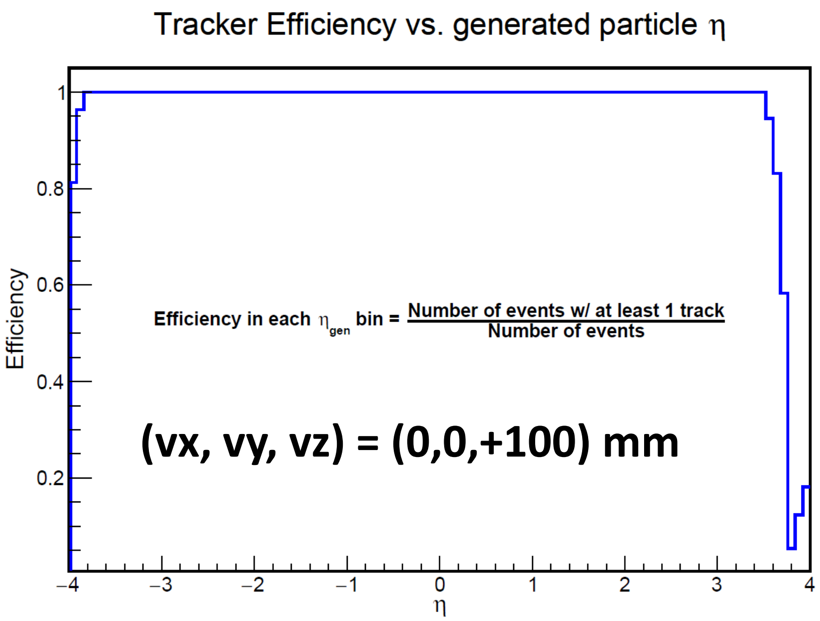
<u>Generation Vertex</u>

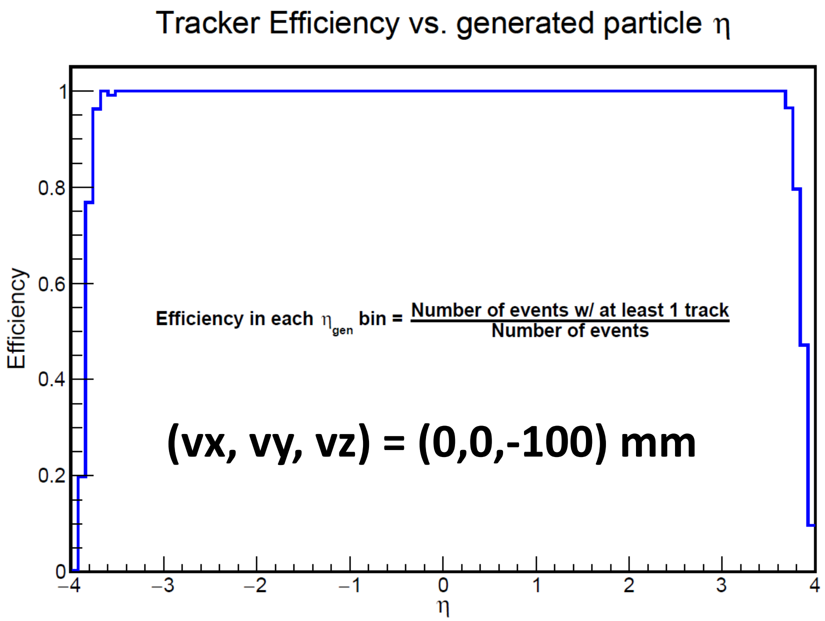
1. (vx, vy, vz) = (0,0,0) mm
2. (vx, vy, vz) = (0,0,10) mm
3. (vx, vy, vz) = (0,0,-10) mm
4. (vx, vy, vz) = (0,0,100) mm
5. (vx, vy, vz) = (0,0,-100) mm



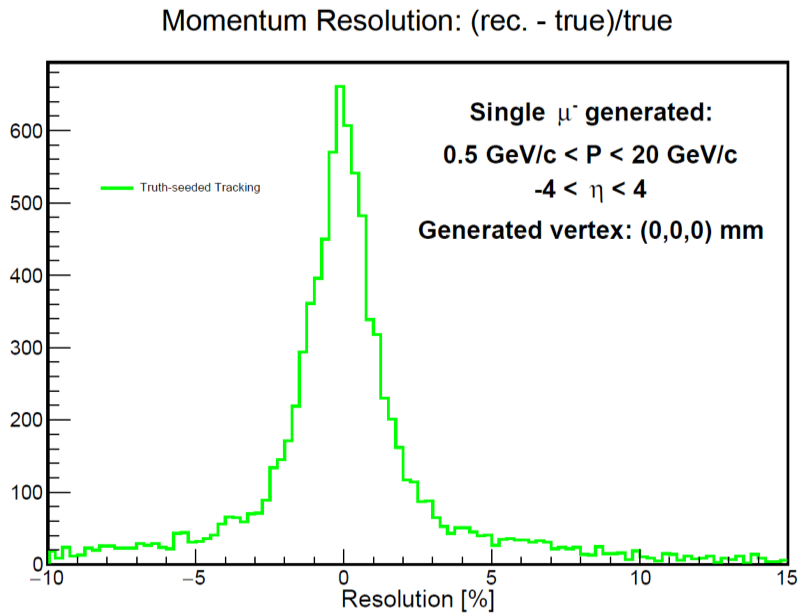


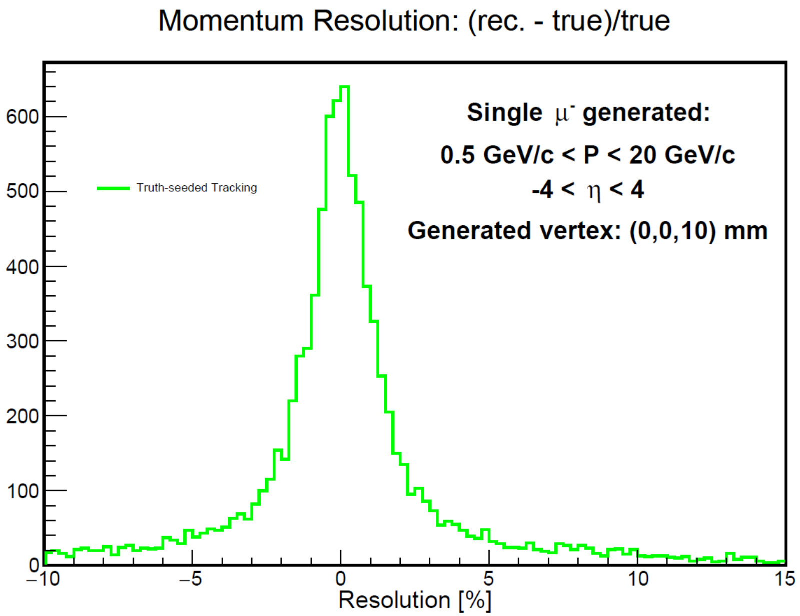


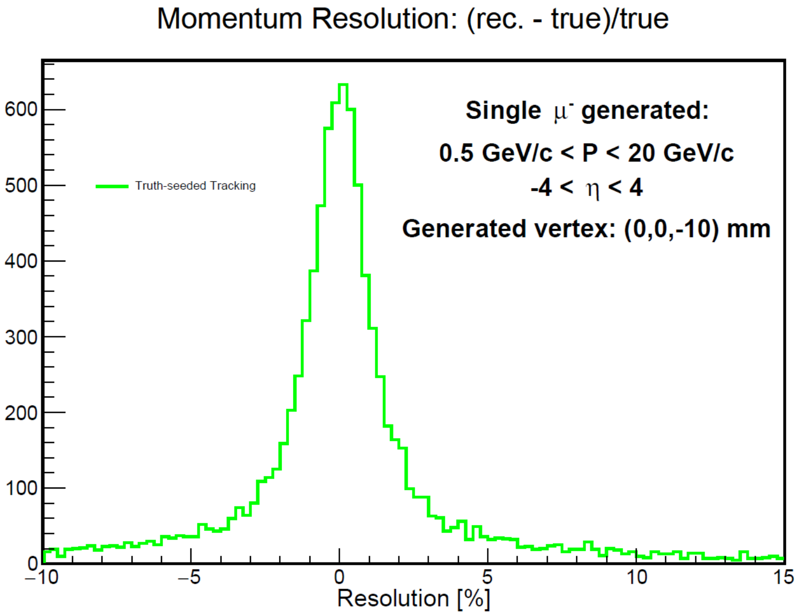


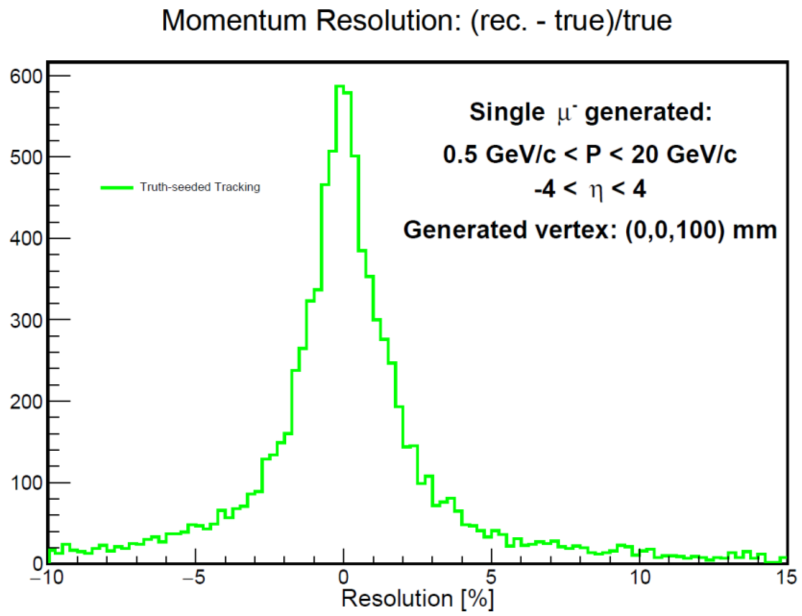


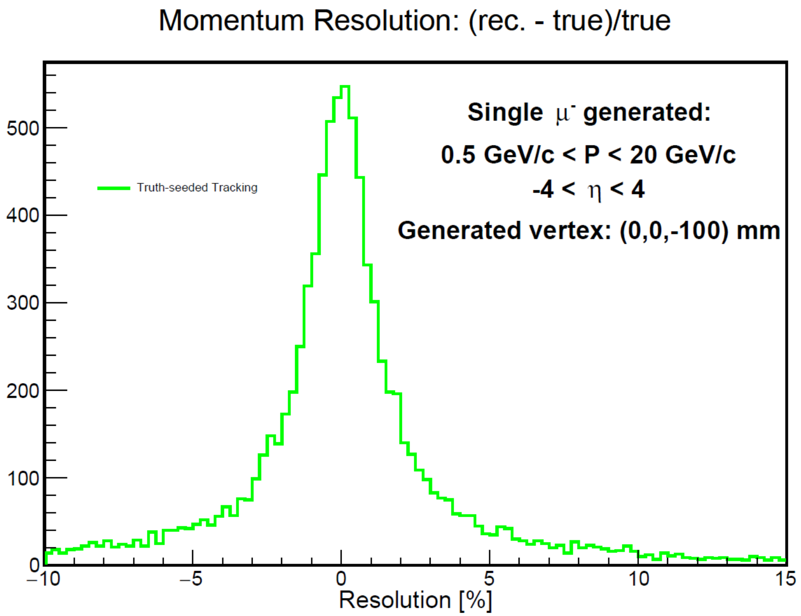
Efficiency as a function of pseudo-rapidity for truth-seeded tracking.









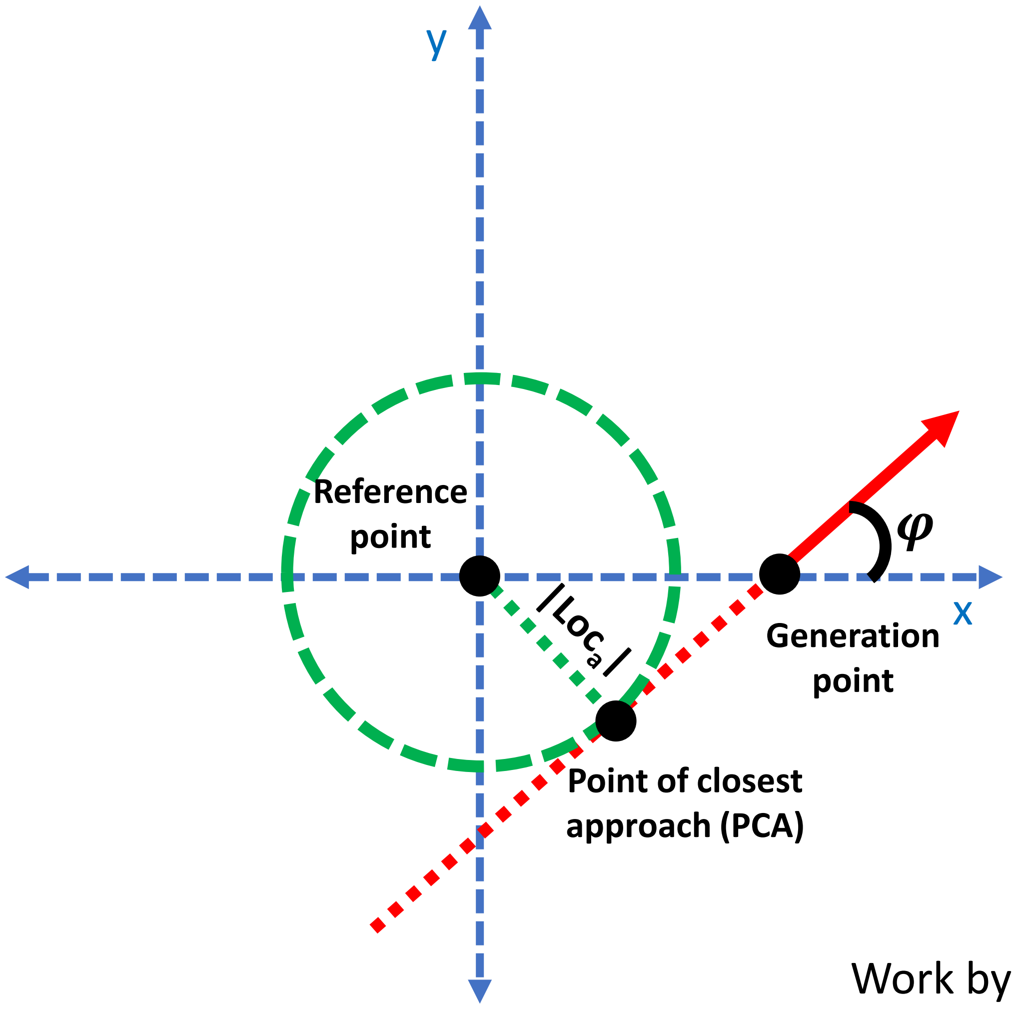


Momentum resolution for <u>truth-seeded</u> tracking.

Results for theta, phi, position parameters, and charge identification also look reasonable. Plots can be found here.

Plan is to repeat previous more-differential studies of the resolution and incorporate all this into the official detector benchmarks repository.

Truth seeding: Initial position parameters

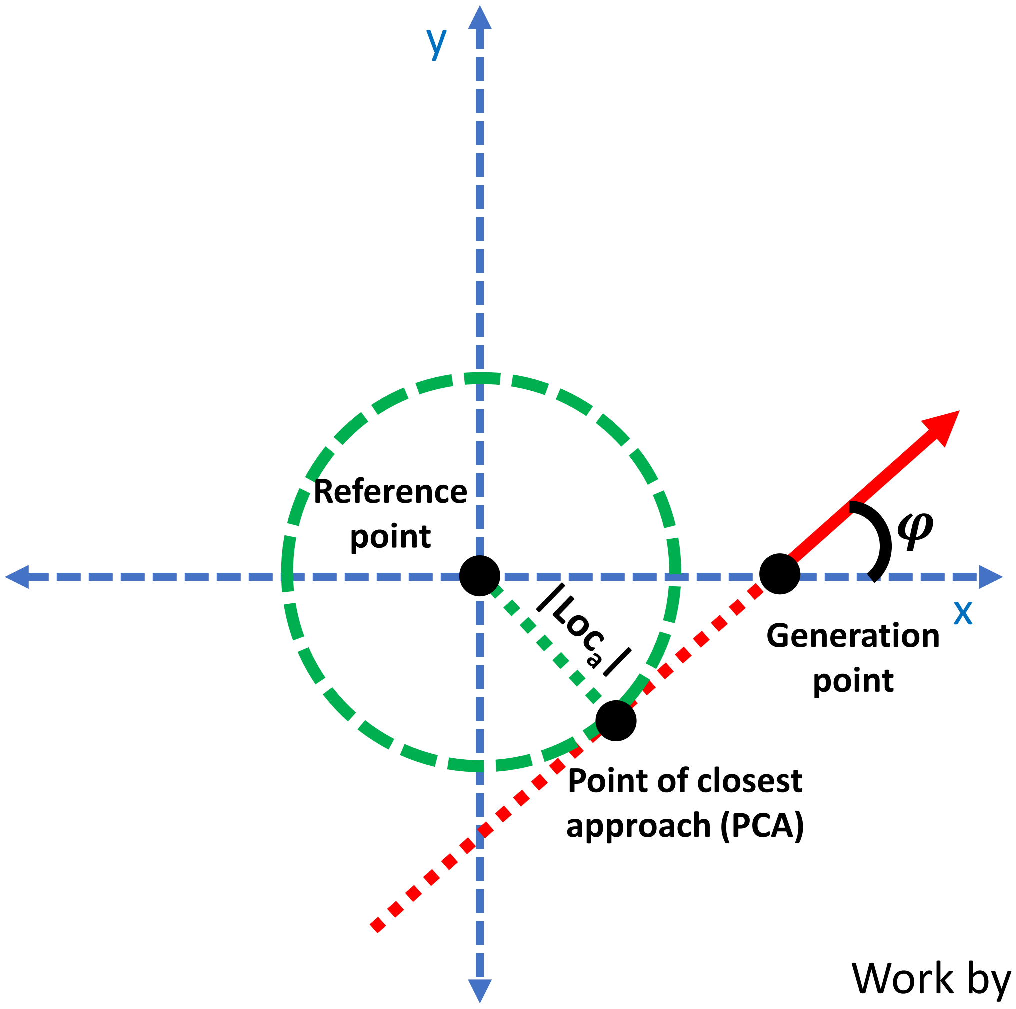


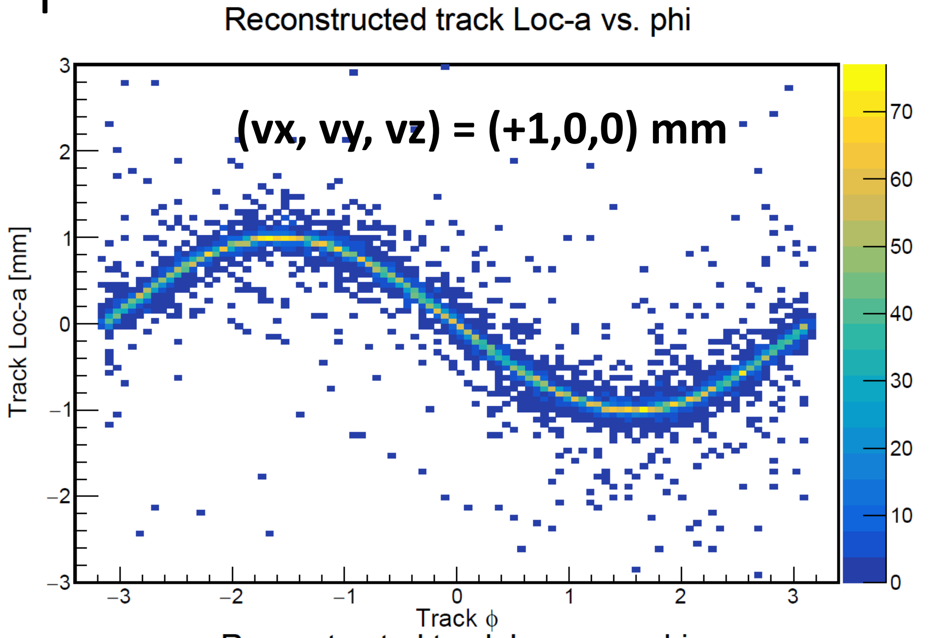
- Example: generation point at (x,y,z) = (+1,0,0) mm. $|Loc_a| = |\sin\varphi|$ under 'straight line' approximation.

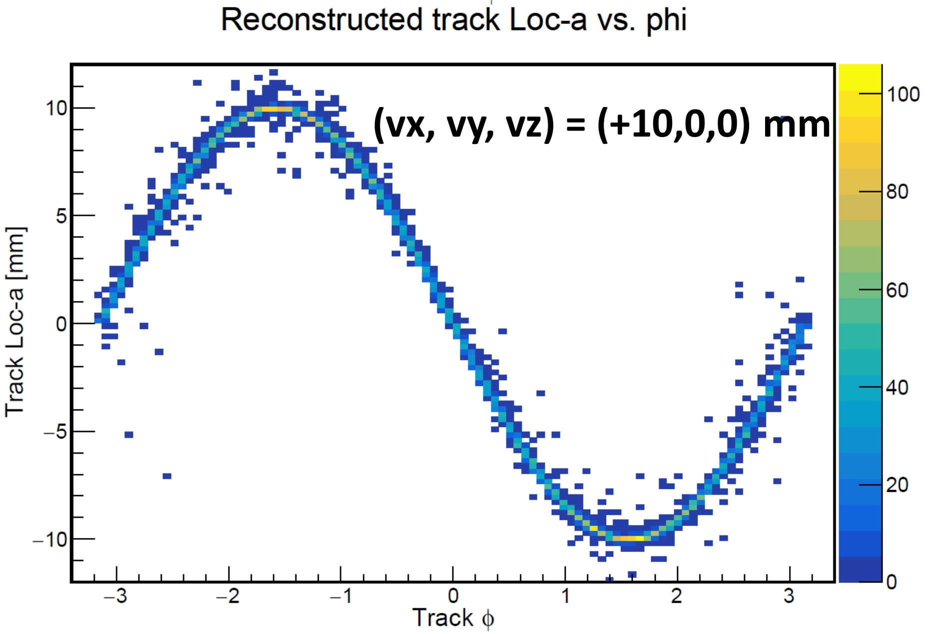
- The sign of Loc_a will be positive if the particle at the PCA transits clockwise around the line surface (reference point) through (x,y) = (0,0). It will be negative if it transits counterclockwise. See here: https://github.com/acts-project/acts/blob/main/Core/src/Surfaces/LineSurface.cpp#L80-L123.

Work by Harsimran Singh

Truth seeding: Initial position parameters

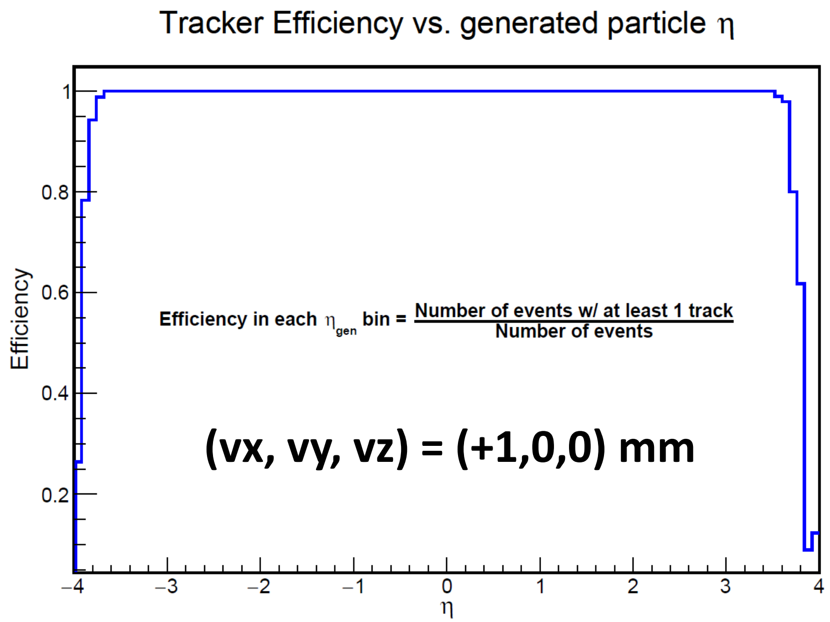


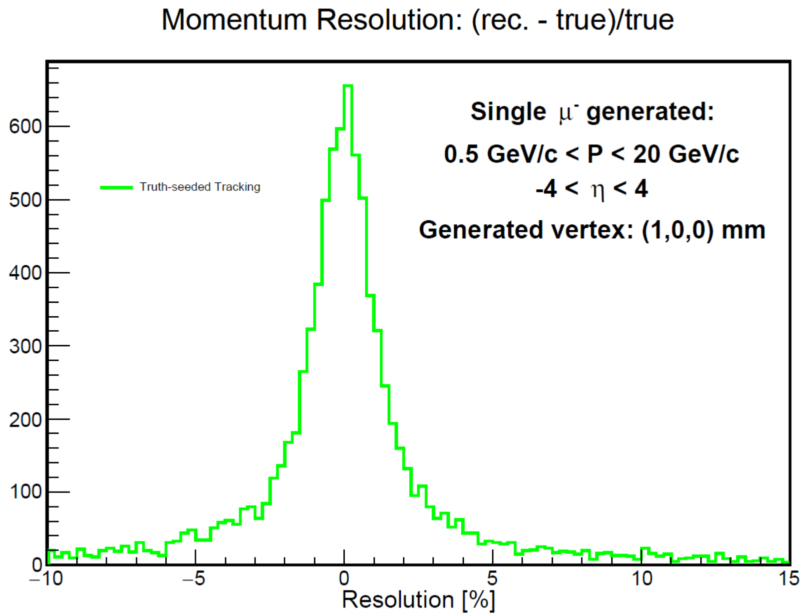


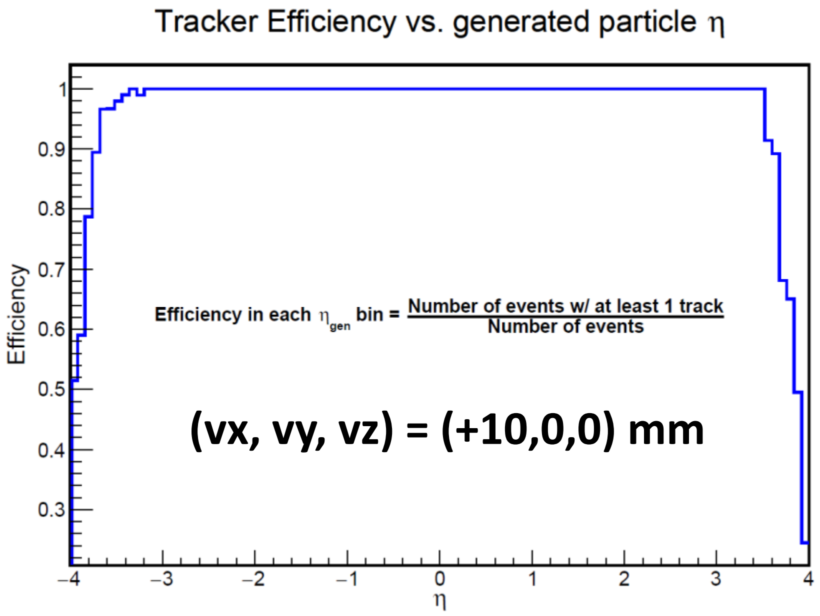


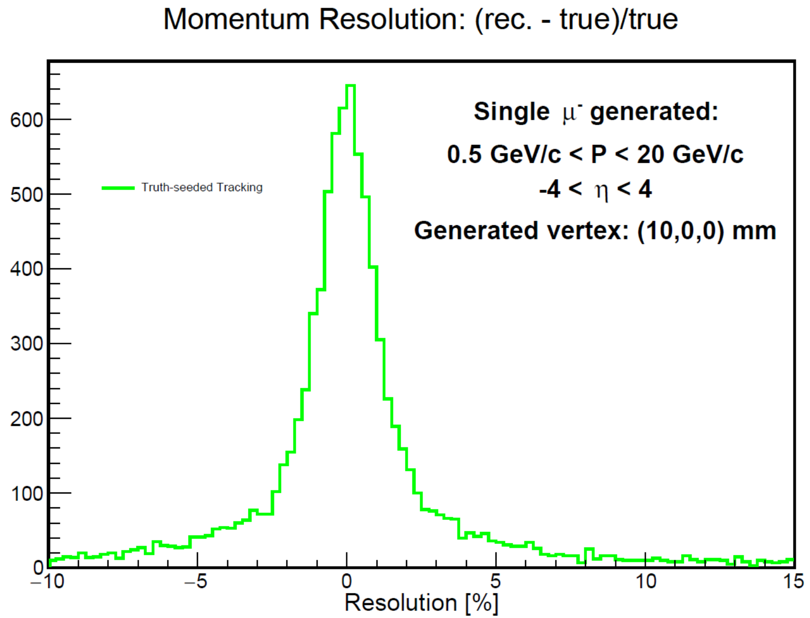
Work by Harsimran Singh

Truth-seeded tracking for off-beamline particles









Real-seeded tracking Status

Track reconstruction workflow

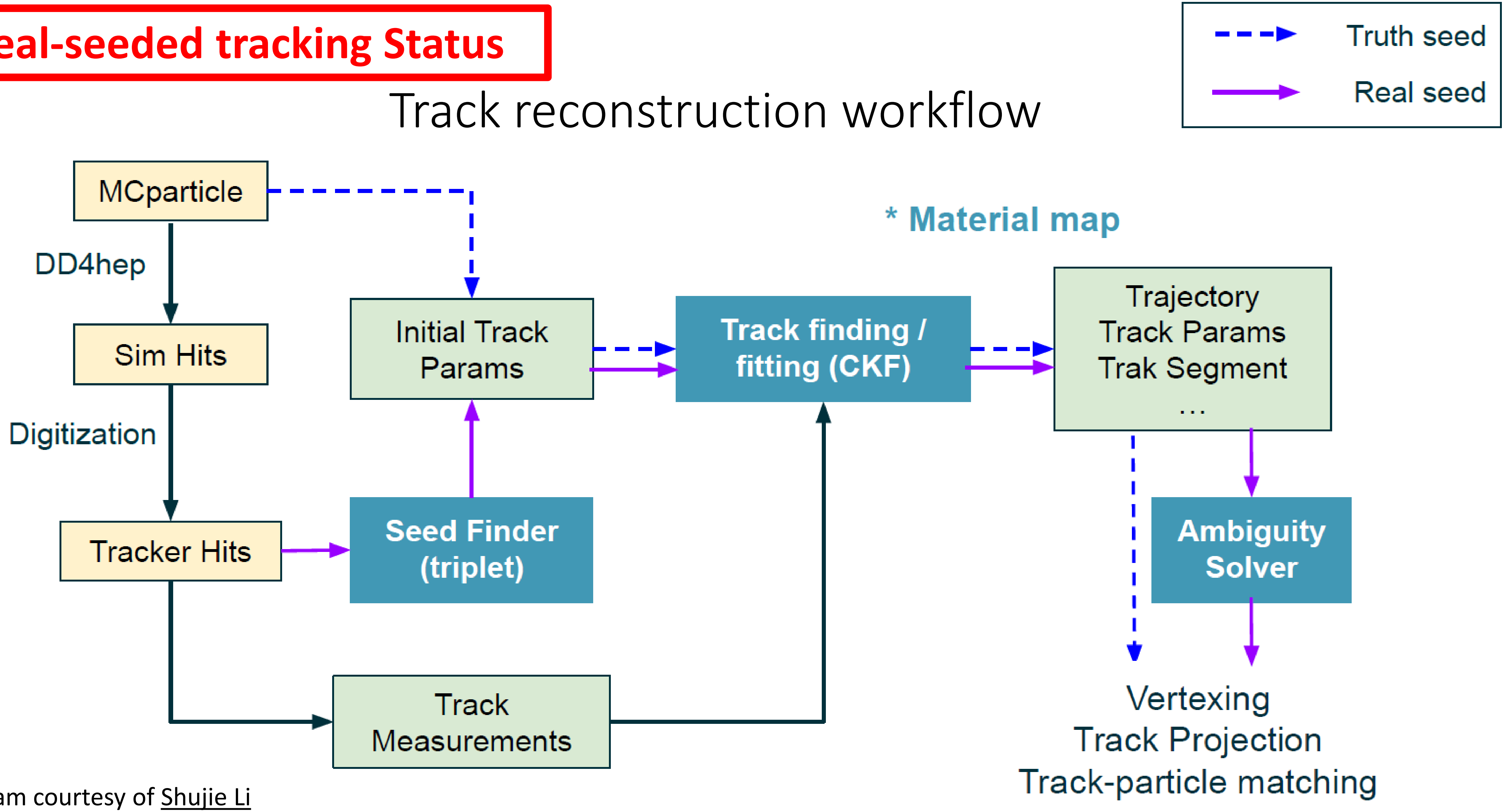
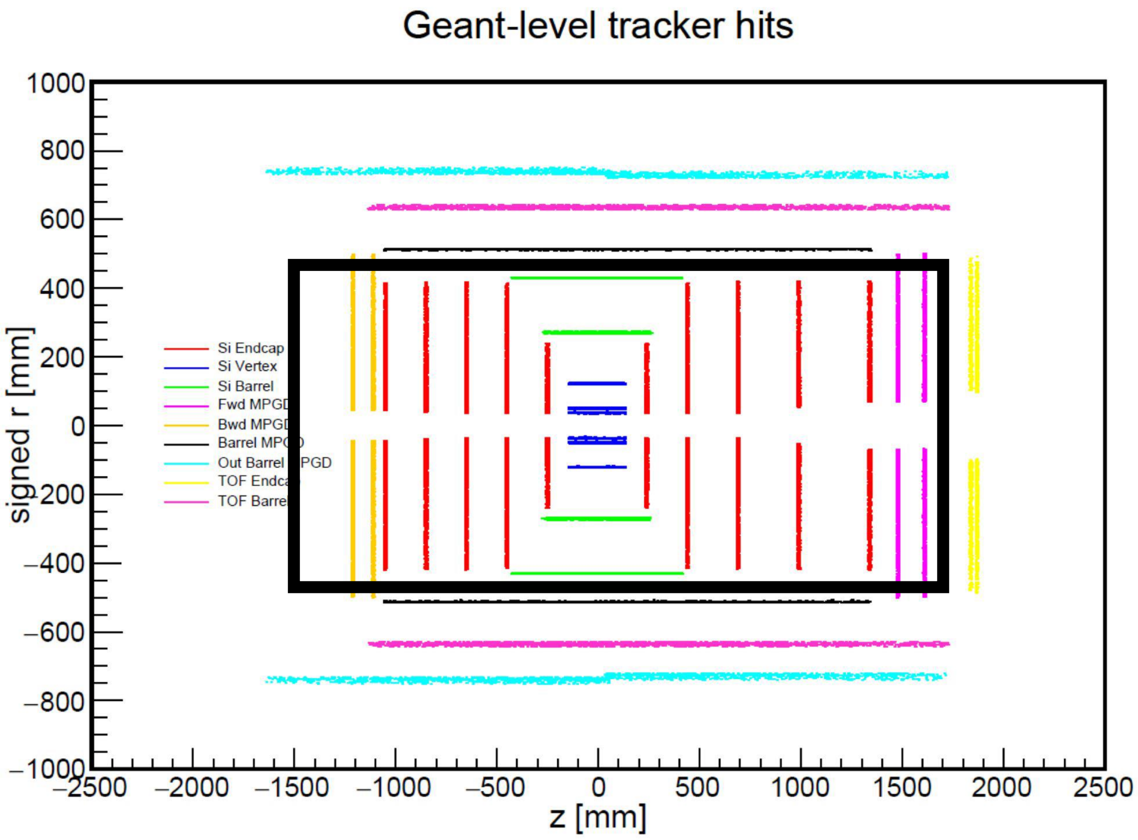


Diagram courtesy of Shujie Li

Seed finding using the ACTS orthogonal seeder

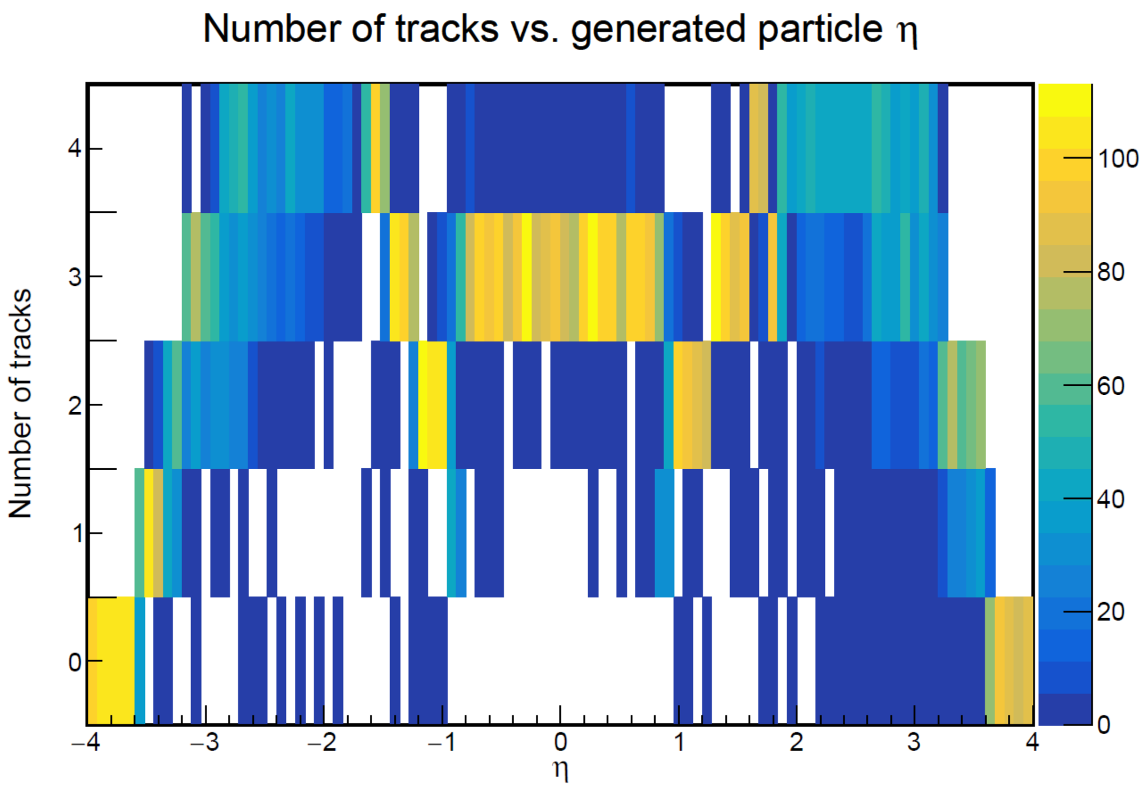
We search for seeds in part of our tracking volume – mostly in our MAPS silicon pixel detectors.



ACTS seed finder and filter parameters

Parameter	Description	Value
bFieldInZ	z component of magnetic field	1.7 T
rMax	Maximum r value to look for seeds	440 mm
rMin	Minimum r value to look for seeds	33 mm
zMin	Minimum z value to look for seeds	-1500 mm
zMax	Maximum z value to look for seeds	1700 mm
beamPosX	Beam offset in x	0
beamPosY	Beam offset in y	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	**10 mm**
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	**10 mm**
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	**200 mm**
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	**200 mm**
collisionRegionMin	Min z for primary vertex	-250 mm
collisionRegionMax	Max z for primary vertex	250 mm
cotThetaMax	Cotangent of max theta angle	**27.29**
minPt	Min transverse momentum	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	0
sigmaScattering	How many standard devs of scattering angles to consider	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1
impactMax	Max transverse PCA allowed	3 mm
rMinMiddle	Min R for middle space point	20 mm
rMaxMiddle	Max R for middle space point	400 mm
bFieldMin	min B field	0.1

Single-particle tracking multiplicity



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zMax	Maximum z value to look for seeds	1700 mm
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beamPosY	Beam offset in y	0
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deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	**10 mm**
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	**200 mm**
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	**200 mm**
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collisionRegionMax	Max z for primary vertex	250 mm
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minPt	Min transverse momentum	100 MeV/cotThetaMax
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impactMax	Max transverse PCA allowed	3 mm
rMinMiddle	Min R for middle space point	20 mm
rMaxMiddle	Max R for middle space point	400 mm
bFieldMin	min B field	0.1

Seed duplicates – particles have multiple seeds

If we have a particle at mid-rapidity which hits layers L0, L1, L2, L3, and L4, then we can make the following combinations:

1. L0,L1,L2
2. L0,L2,L3
3. L0,L3,L4
4. ✖ L0,L1,L3
5. ✖ L0,L1,L4
6. ✖ L0,L2,L4
7. ✖ L1,L2,L3
8. ✖ L1,L2,L4
9. ✖ L1,L3,L4
10. ✖ L2,L3,L4

ACTS seed finder and filter parameters

Parameter	Description	Value
bFieldInZ	z component of magnetic field	1.7 T
rMax	Maximum r value to look for seeds	440 mm
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minPt	Min transverse momentum	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	0
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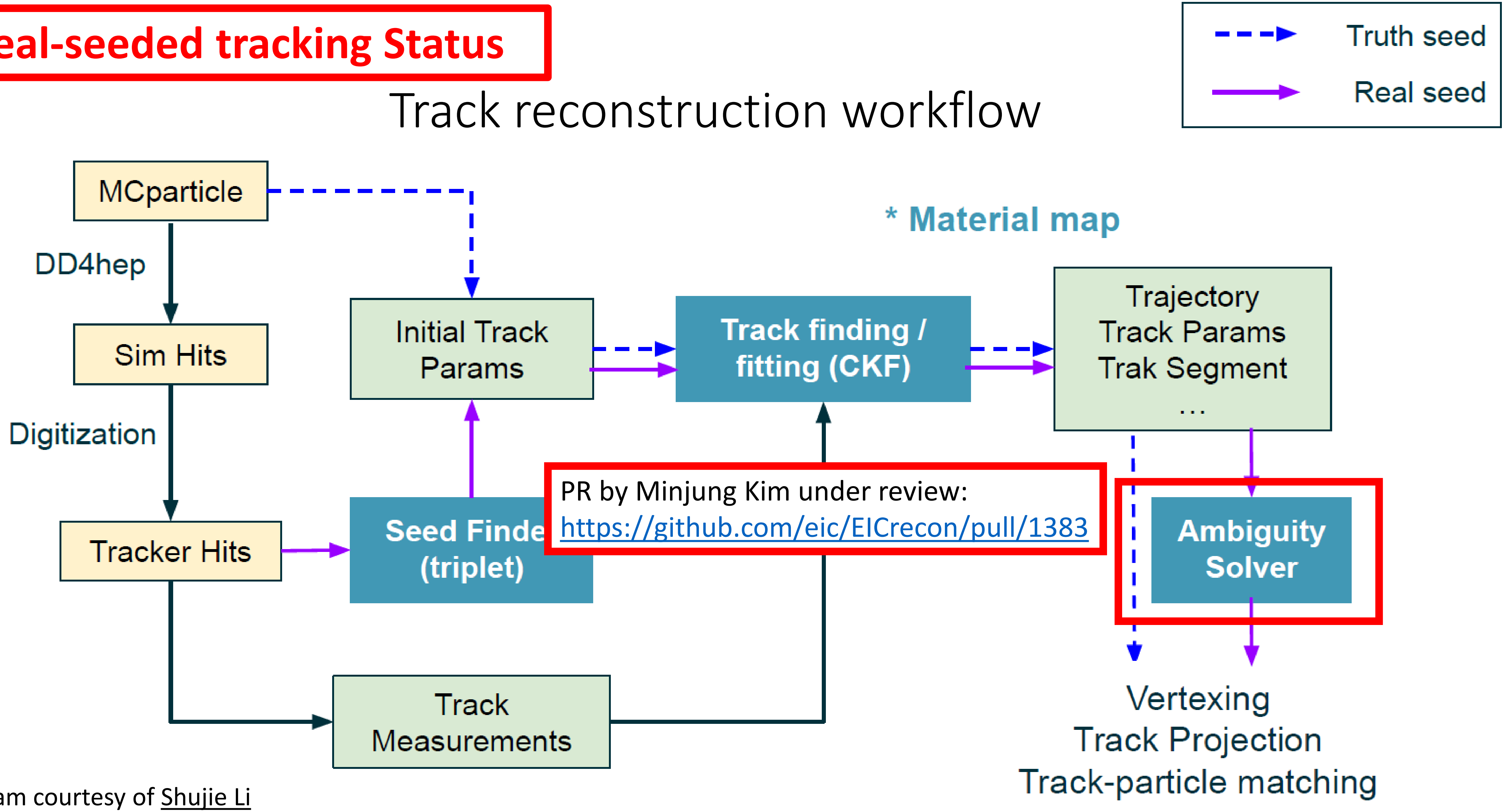
rMinMiddle	Min R for middle space point	20 mm
rMaxMiddle	Max R for middle space point	400 mm
bFieldMin	min B field	0.1

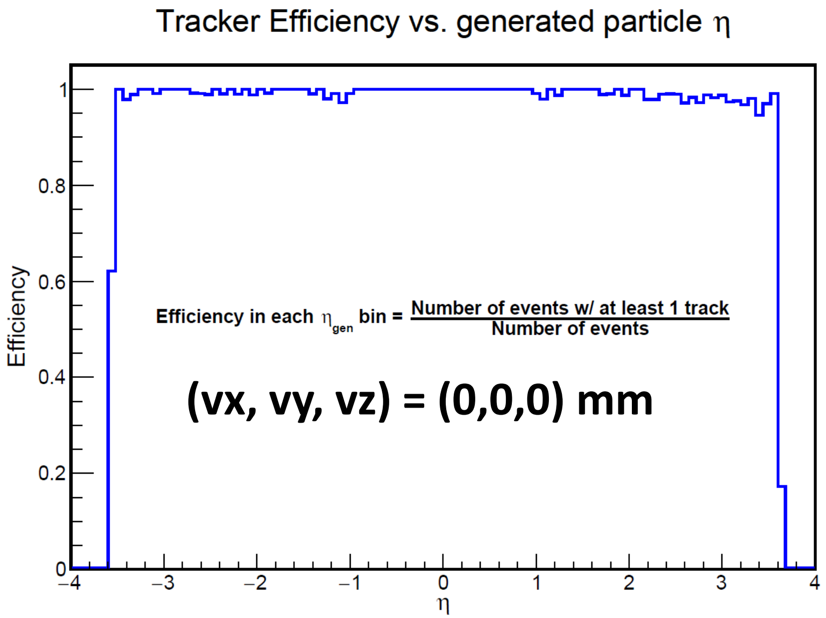
Real-seeded tracking Status

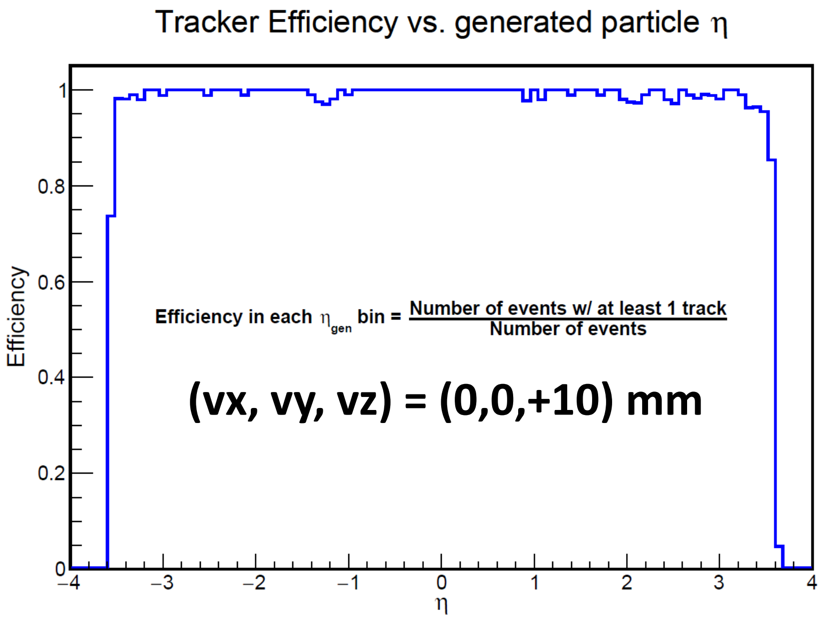
Track reconstruction workflow

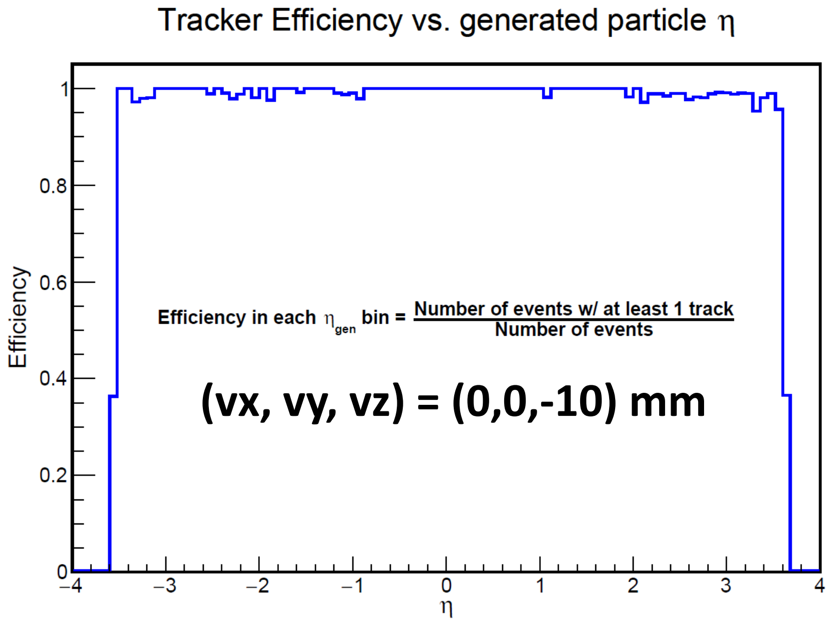


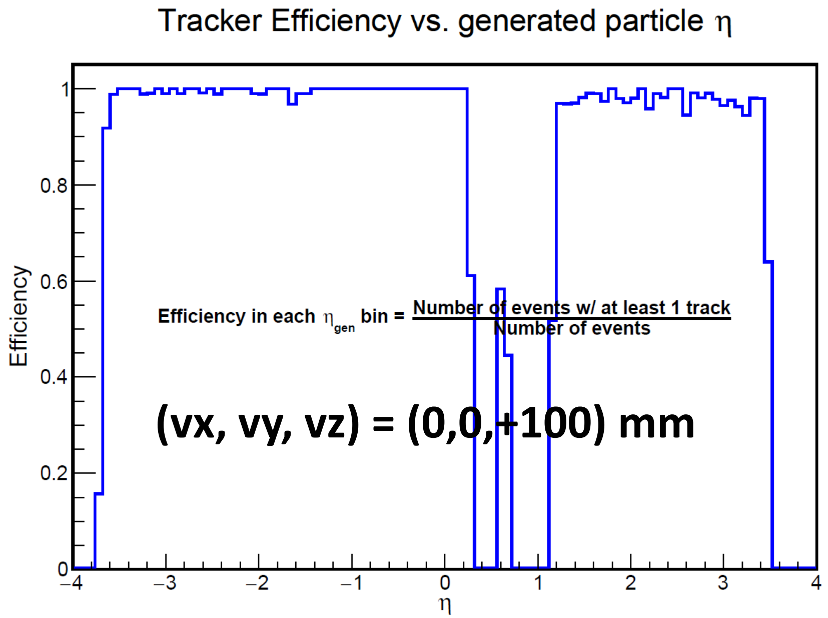
PR by Minjung Kim under review:
https://github.com/eic/EICrecon/pull/1383

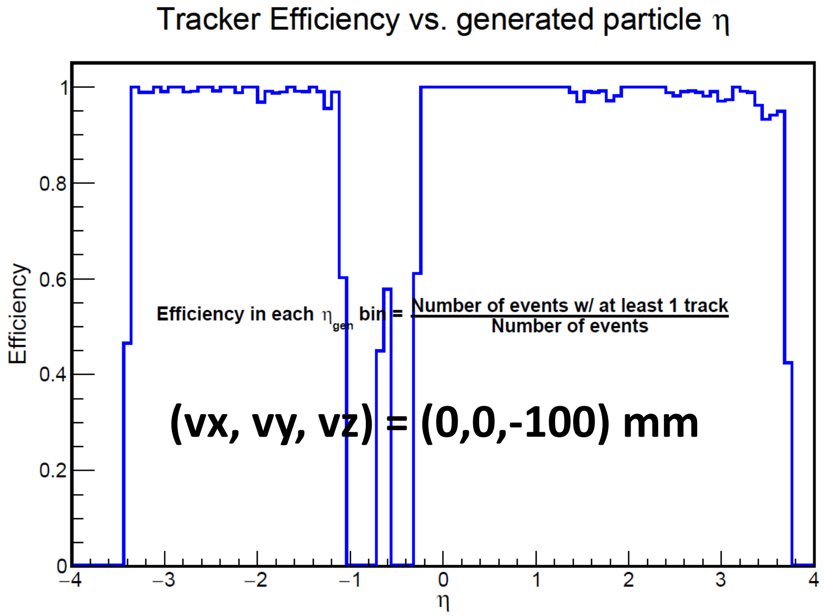
Diagram courtesy of Shujie Li



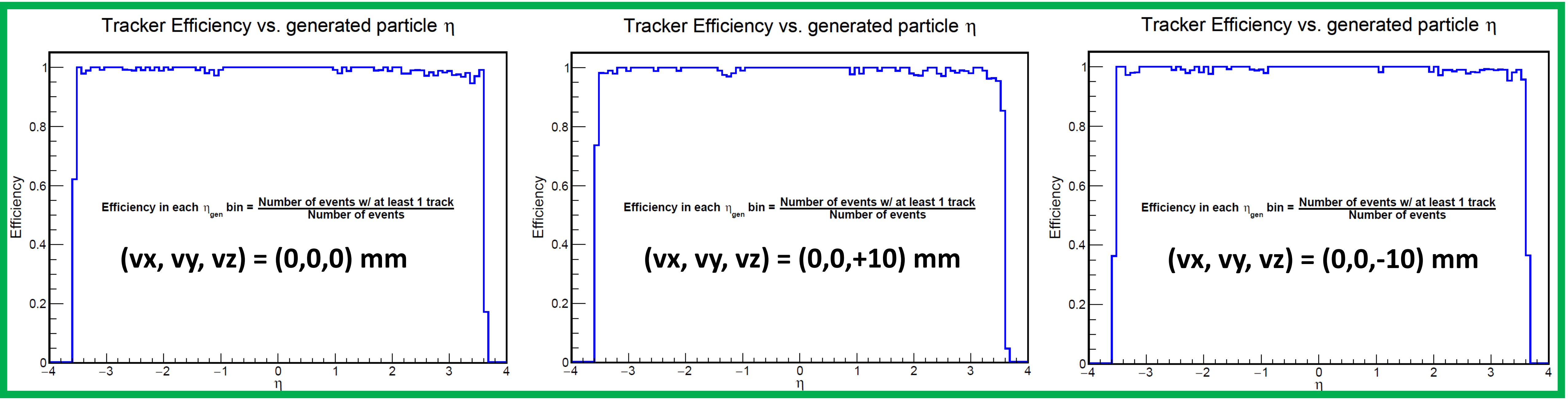


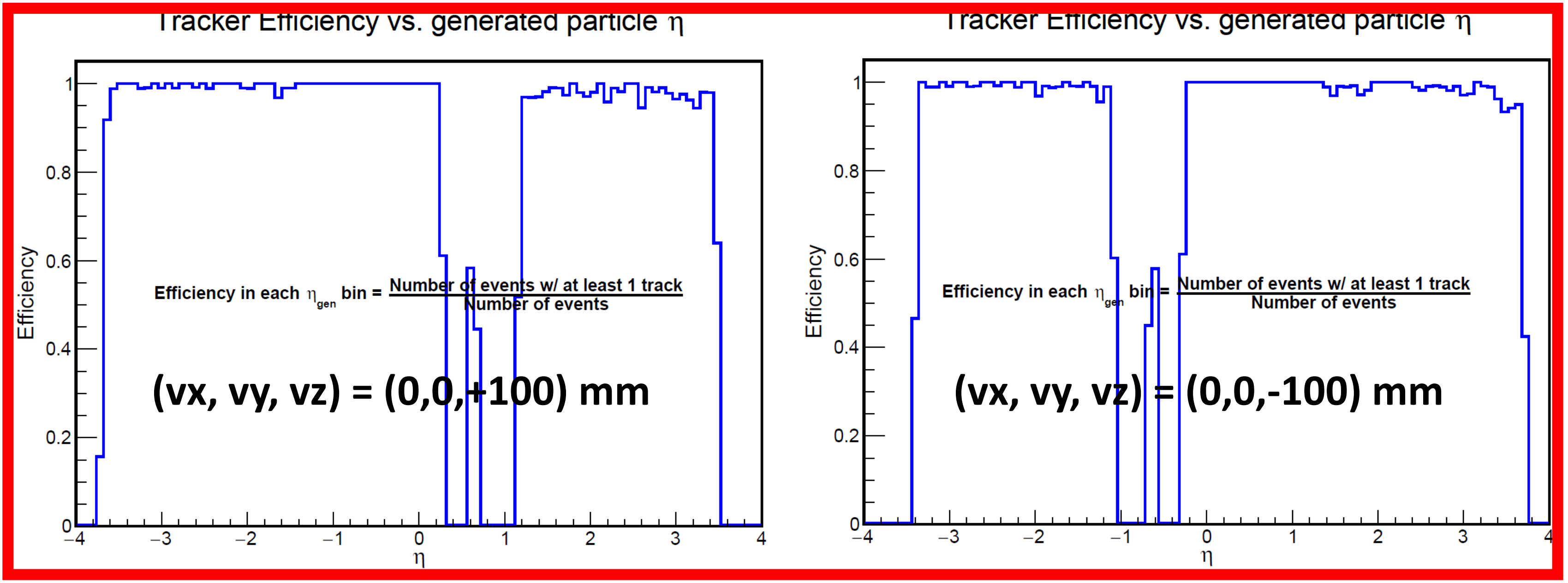






Efficiency as a function of pseudo-rapidity for <u>real-seeded</u> tracking.

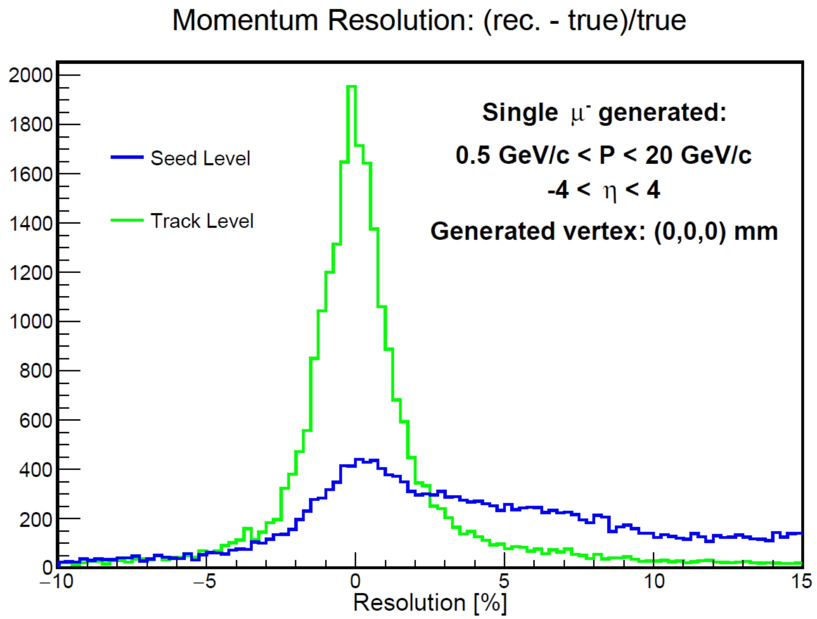


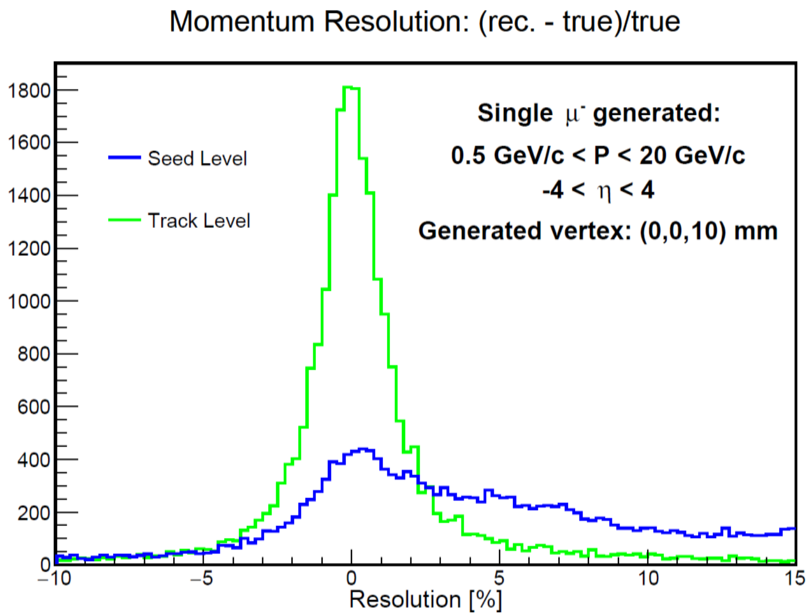


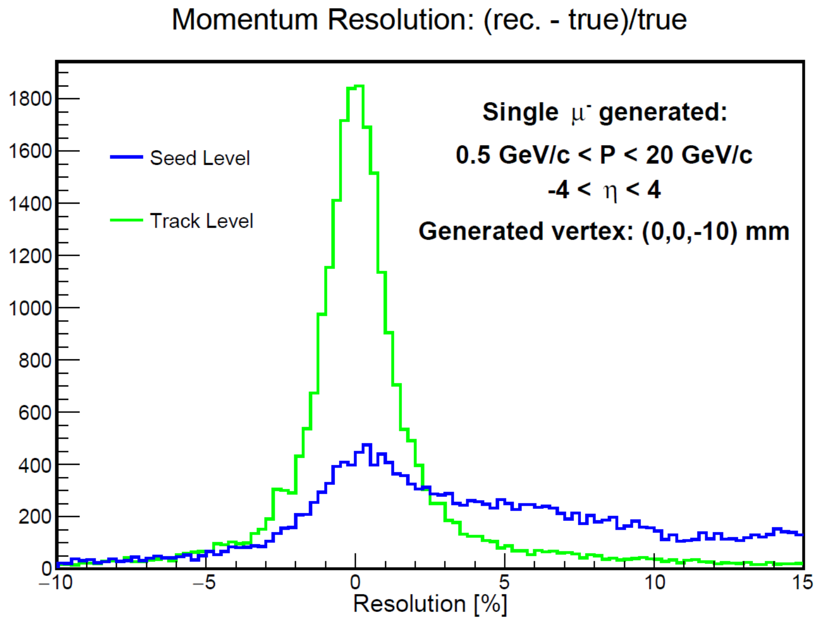
Efficiency as a function of pseudo-rapidity for real-seeded tracking.

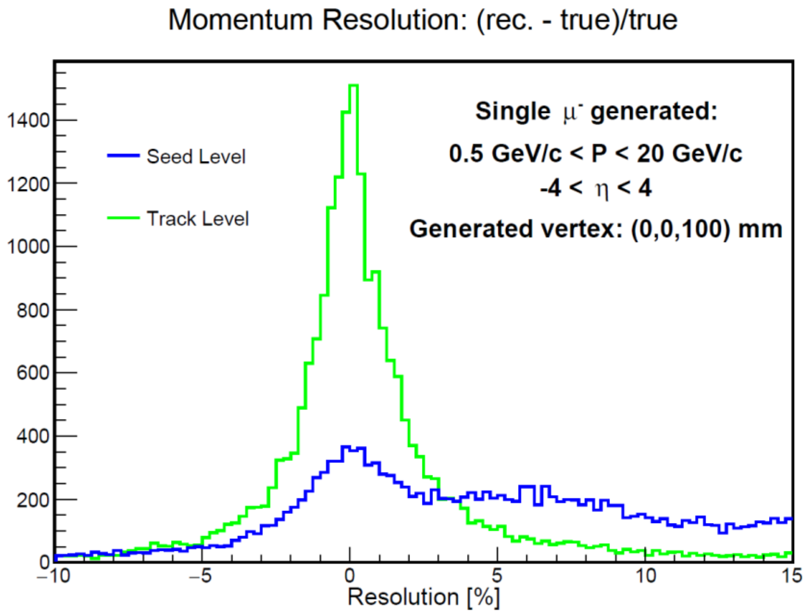
Efficiency looks good over the whole detector acceptance when |z| < 10 mm.

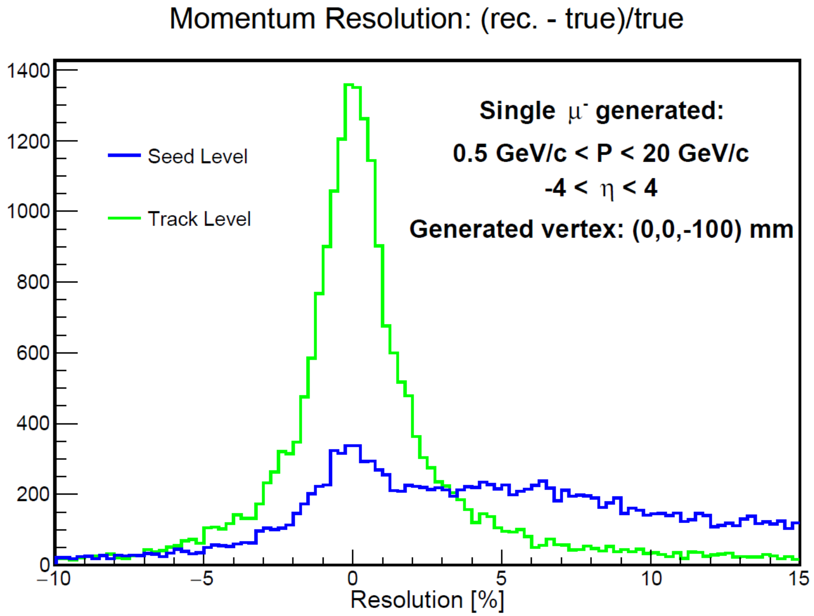
We start to see inefficiencies appear at |z| > 50 mm. These inefficiencies go away when we adjust the volume in which we search for seeds to include the barrel MPGD. Ongoing work by Jeetendra Gupta (https://github.com/eic/EICrecon/tree/seed_finder_update).











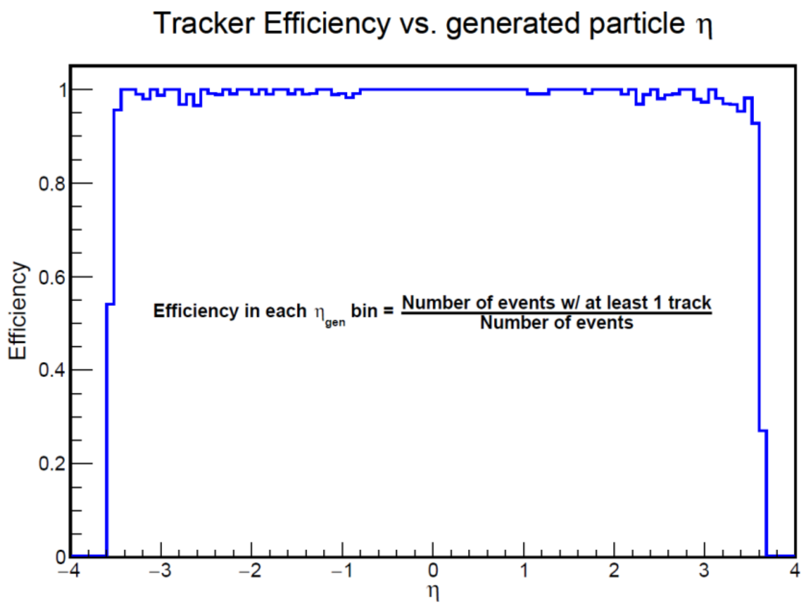
Momentum resolution for real-seeded tracking.

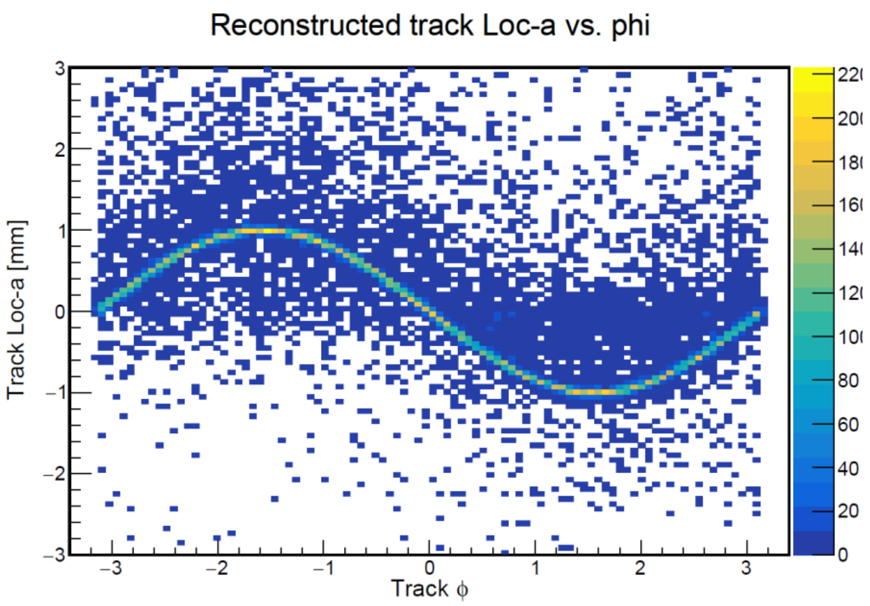
Results for theta, phi, position parameters, and charge identification also look reasonable. Plots can be found here.

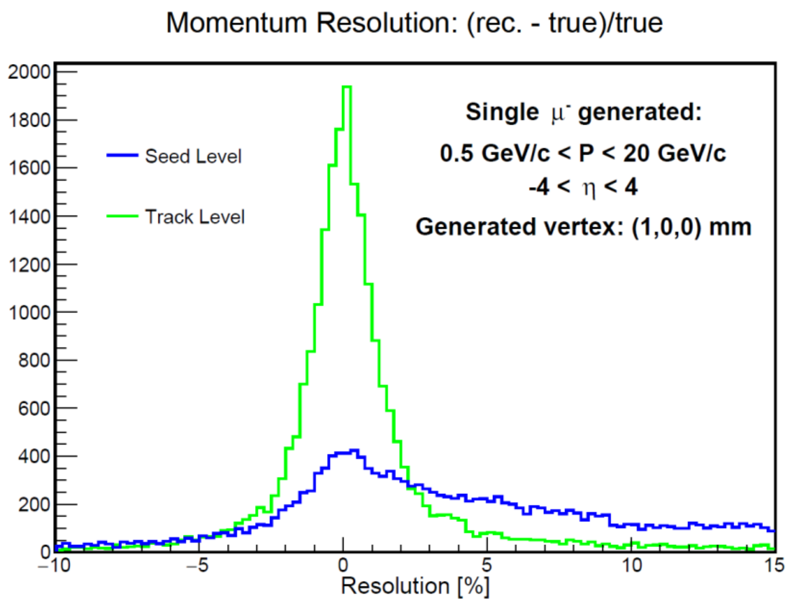
Plan is to repeat previous more-differential studies of the resolution and incorporate all this into the official detector benchmarks repository.

Real-seeded tracking for off-beamline tracking

(vx, vy, vz) = (+1,0,0) mm



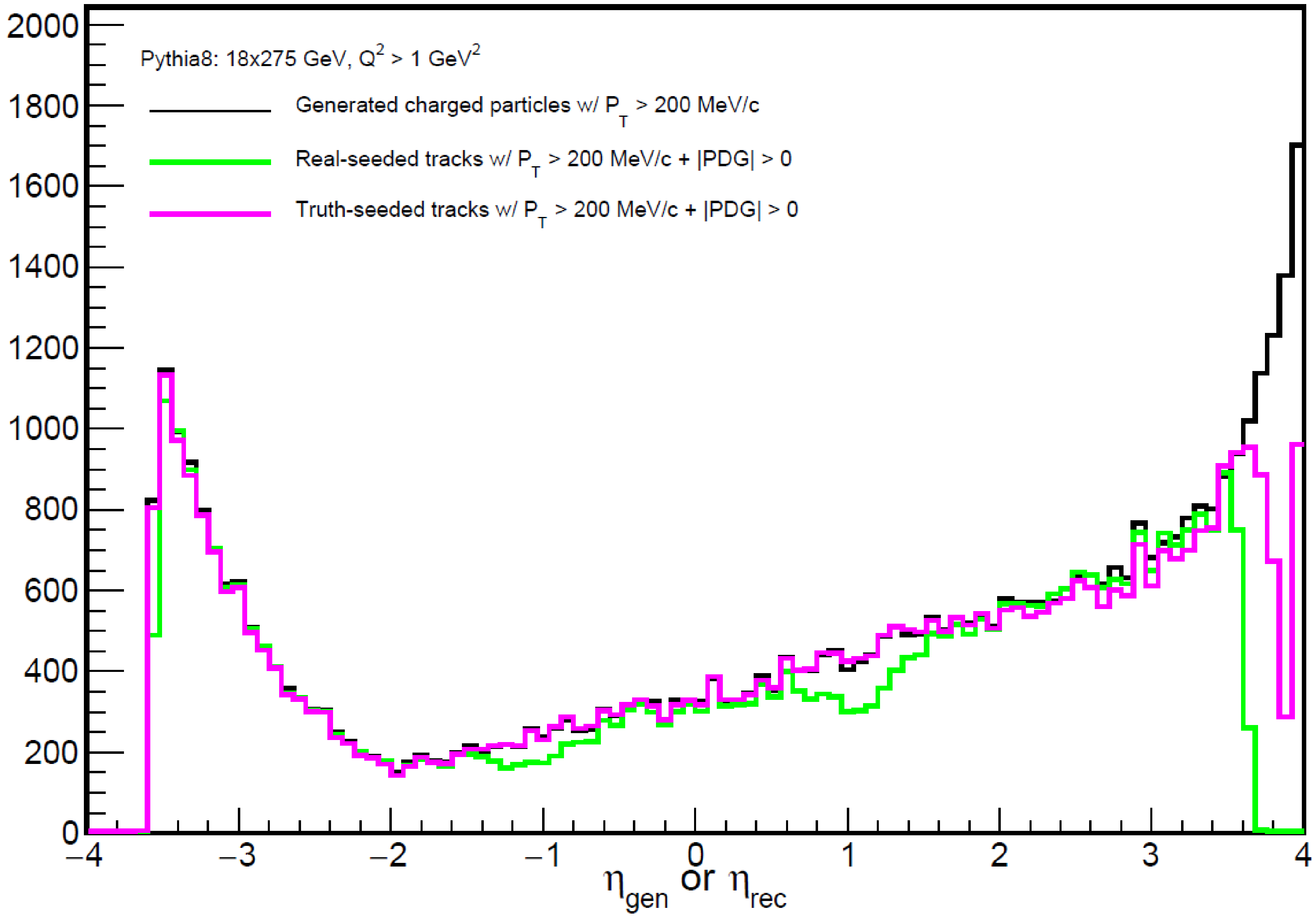




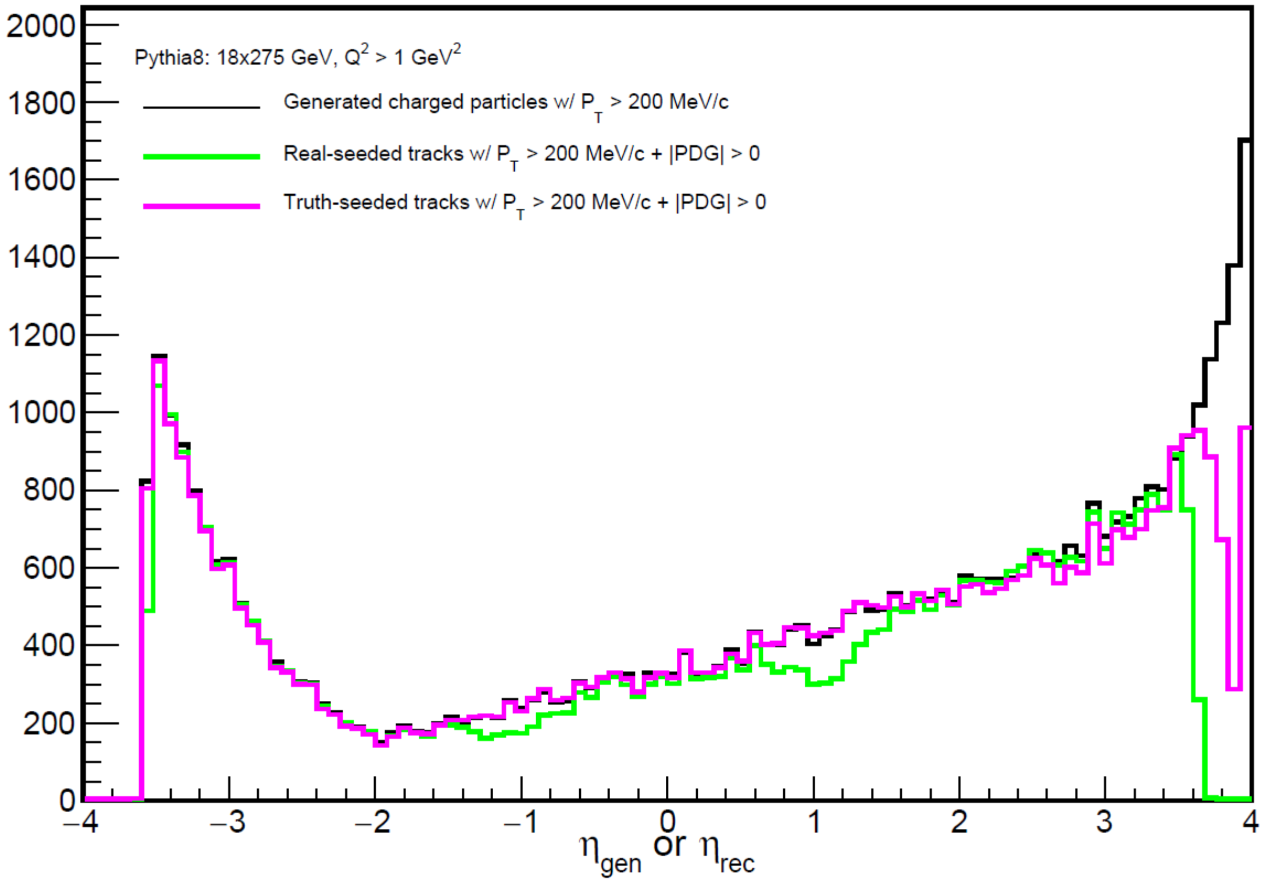
Real-seeded tracking shows expected behavior for particles generated off the z axis.

We currently apply a beamline (z axis) DCA cut of 3mm in the seed finder.

Reconstruction for DIS events



Reconstruction for DIS events



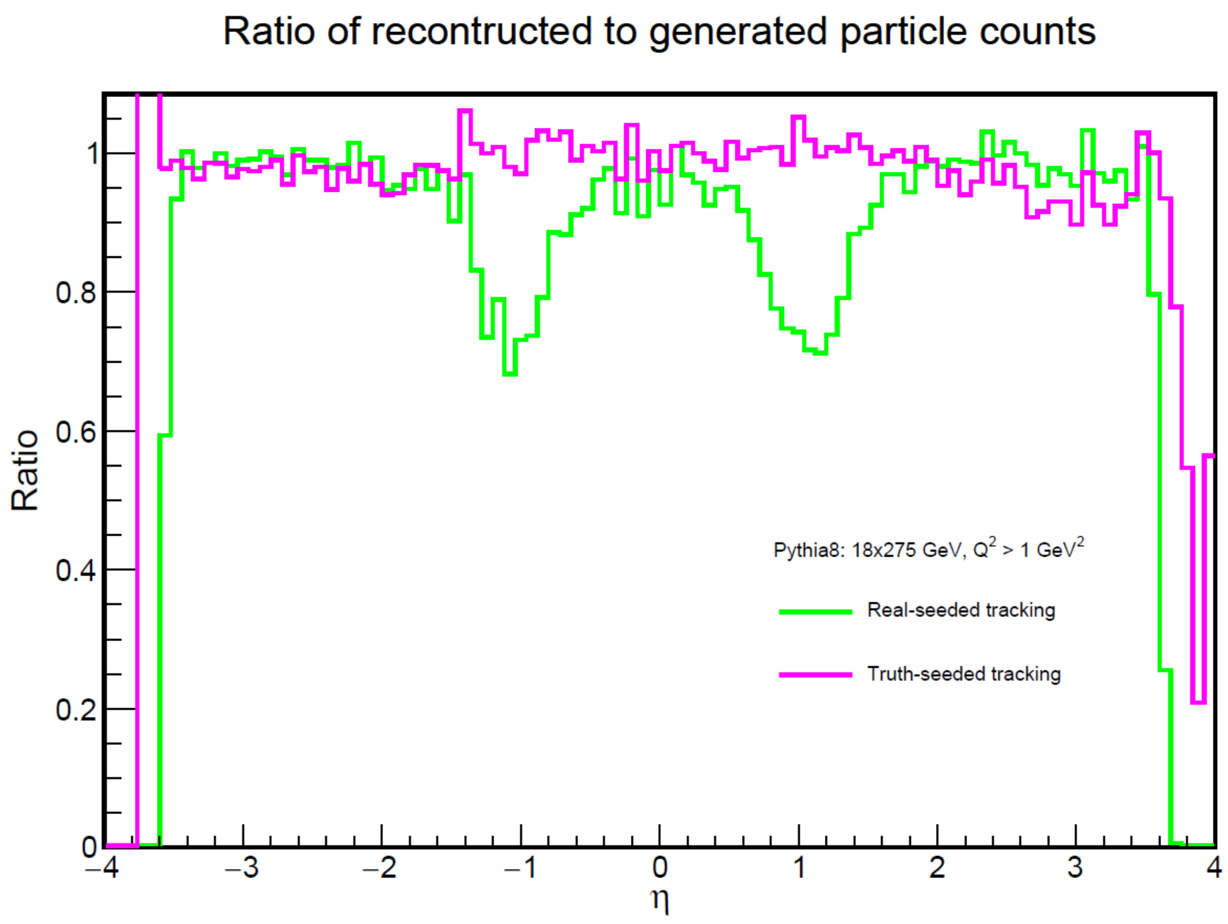
The DIS plot on the left is sensitive to acceptance, resolution, and matching effects.

Generated eta distribution for all final-state, charged particles with generated P_t > 200 MeV/c.

Reconstructed eta distribution with reconstructed P_t > 200 MeV/c. Truth-seeded tracking is used and only tracks which have a 'geometric' (eta-phi) match to a generated particle are shown.

Reconstructed eta distribution with reconstructed P_t > 200 MeV/c. Real-seeded tracking is used and only tracks which have a 'geometric' match to a generated particle are shown. Even prior to implementation of ambiguity resolution solver, only 1 track can be matched to a given generated particle, thus removing any duplicate tracks.

Reconstruction for DIS events



- Observe dips near |eta| = 1 for real-seeded tracking.
- These dips do not go away after implementing Jeetendra's seed finder adjustments for large |z| vertices.
- The results also seem insensitive to the phi limits used for matching a track to a generated particle.
- Some other things to check:
  1. Single-particle efficiency and matching results with particles other than muons.
  2. Implementation of hit-level matching instead of geometric matching.

Summary

- Presented status of track reconstruction for single-particle and DIS events.
- Implementation of ambiguity resolution solver in EICRecon is under review.
- There is ongoing work on seed finder tuning and hit-level track matching to generated particles.
- In the track reconstruction group, there is additional effort on resolution studies (Shyam Kumar), track residuals (Beatrice Liang-Gilman), and tracking with background (Benjamen Sterwerf).