Status and plans for realistic tracking

Barak Schmookler

(for the Track Reconstruction working group)

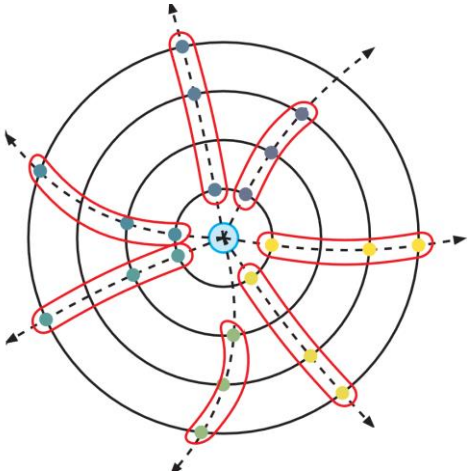
Recent updates by the track reconstruction WG

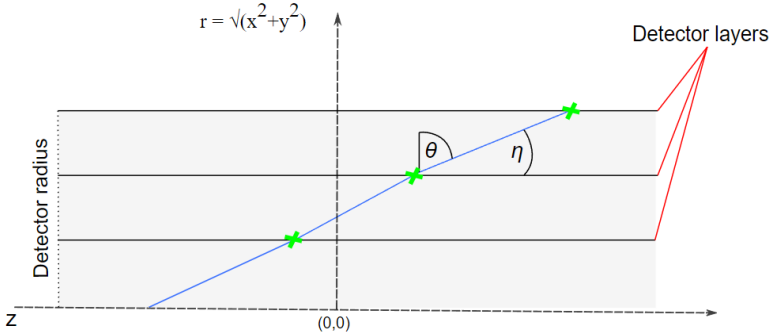
1. Optimization of ACTS orthogonal seed finder parameters: https://github.com/eic/EICrecon/pull/641
2. Fixes to the reconstruction of the seeds' kinematic parameters: https://github.com/eic/EICrecon/pull/544 https://github.com/eic/EICrecon/pull/641
3. Implementation of ACTS iterative vertex finder: https://github.com/eic/EICrecon/pull/662
4. Update to pixel size for silicon detectors: https://github.com/eic/epic/pull/438
5. Parallel data flow for CKF tracking with realistic seeds: https://github.com/eic/EICrecon/pull/711 (**in progress**)

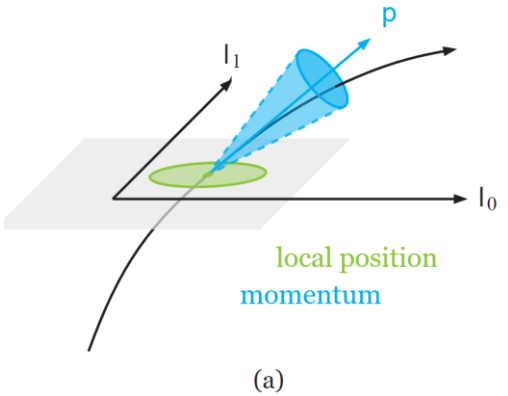
ACTS Orthogonal seeder

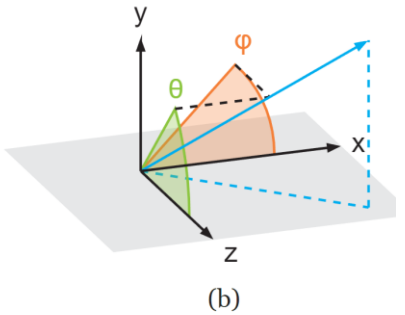
The seeder outputs a set of seeds, with each seed consisting of 3 space points. The seeds need to fulfill certain expectations for a particle moving in a uniform magnetic field. The seed finder and seed filter settings configure the allowed search region and tolerances.

For a given seed, the space points are then fit to determine initial track position and direction which is passed to the Combinatorial Kalman Filter (CKF) tracking algorithm.









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

Emma Yeats
Rey Cruz Torres
Yue Shi Lai

Updated seed finder parameters

Parameter	Description	EICrecon default	Y.S. Lai's default	My New Default
bFieldInZ	z component of magnetic field	1.7 T	1.7 T	1.7 T
rMax	Maximum r value to look for seeds	500 mm	440 mm	440 mm
rMin	Minimum r value to look for seeds	33 mm	33 mm	33 mm
zMin	Minimum z value to look for seeds	-800 mm	-1500 mm	-1500 mm
zMax	Maximum z value to look for seeds	800 mm	1700 mm	1700 mm
beamPosX	Beam offset in x	0	0	0
beamPosY	Beam offset in y	0	0	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	1 mm	50 mm	**10 mm**
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	1 mm	50 mm	**10 mm**
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm	**200 mm**
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	400 mm	220 mm	**200 mm**
collisionRegionMin	Min z for primary vertex	-300 mm	-250 mm	-250 mm
collisionRegionMax	Max z for primary vertex	300 mm	250 mm	250 mm
cotThetaMax	Cotangent of max theta angle	16	16.54	**27.29**
minPt	Min transverse momentum	100	100 MeV/cotThetaMax	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	1	0	0
sigmaScattering	How many standard devs of scattering angles to consider	5	5	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1	0.1	0.1
impactMax	Max transverse PCA allowed	20 mm	3 mm	3 mm
rMinMiddle	Min R for middle space point	20 mm	—	20 mm
rMaxMiddle	Max R for middle space point	400 mm	—	400 mm
bFieldMin	min B field	—	0.1 T	0.1

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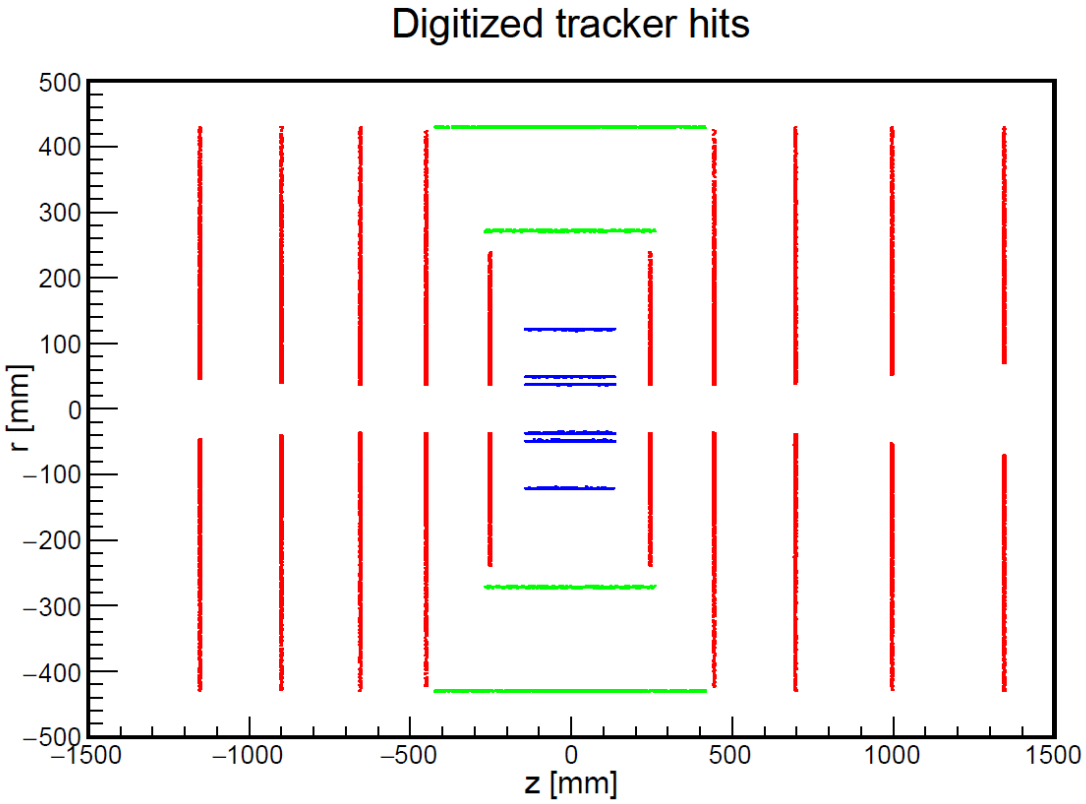
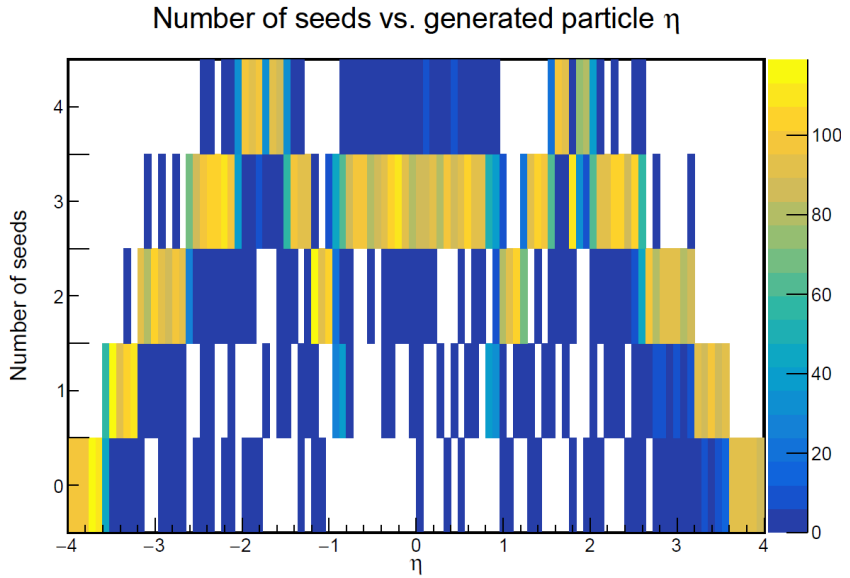
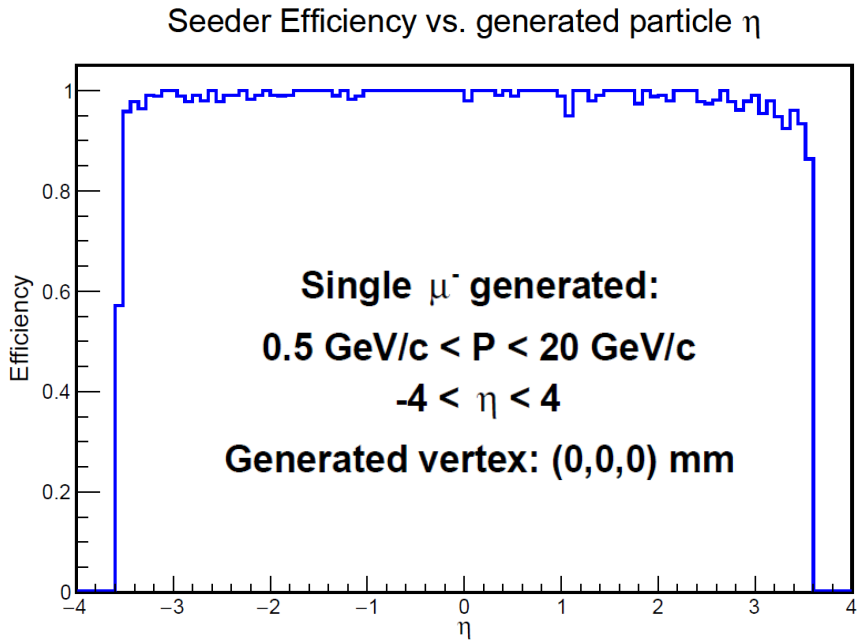
Seed efficiency

We search for seeds in the silicon tracker volume.



An efficient event is defined as one where at least one seed is found. We see high efficiency with a single particle simulation for $-3.5 < \eta < 3.5$.





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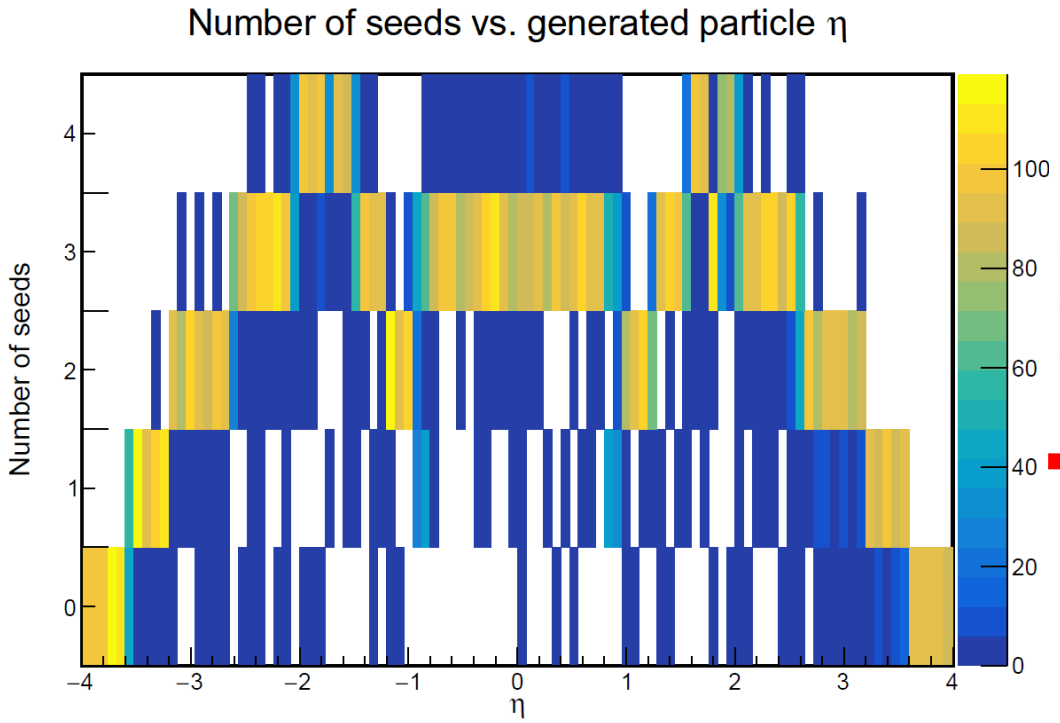
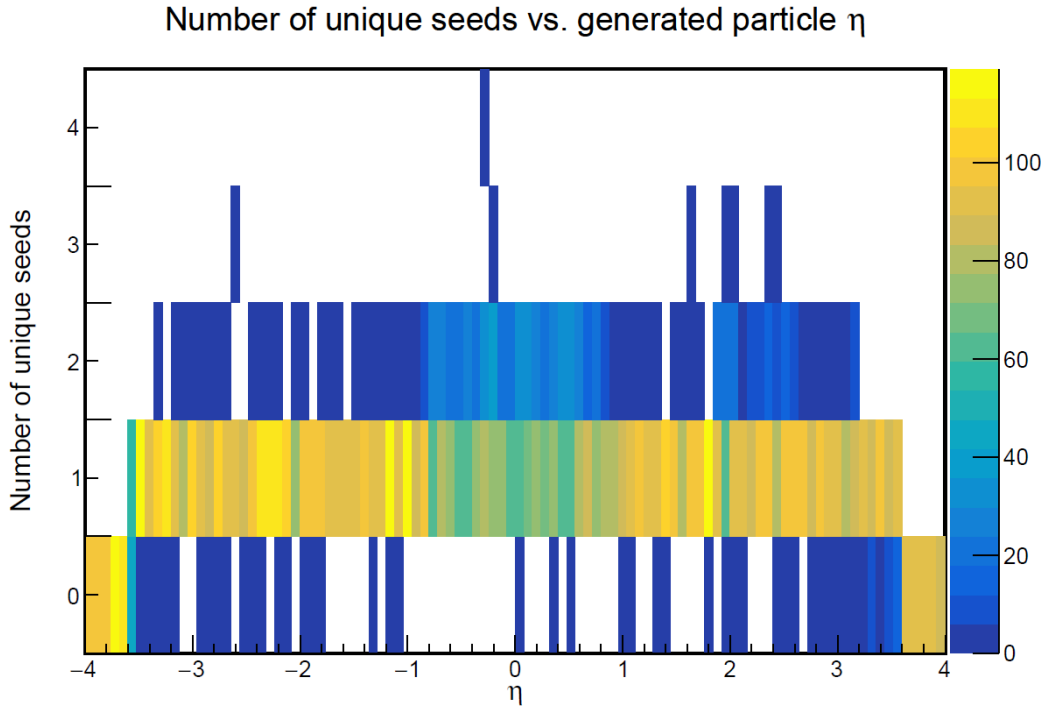
Duplicate seeds

For a single particle simulation, we see multiple seeds over much of our acceptance…



Combining all the seeds where (q/p), θ, and ϕ all differ by less than 20%.

…but many of the seeds belong to the same (primary) particle.



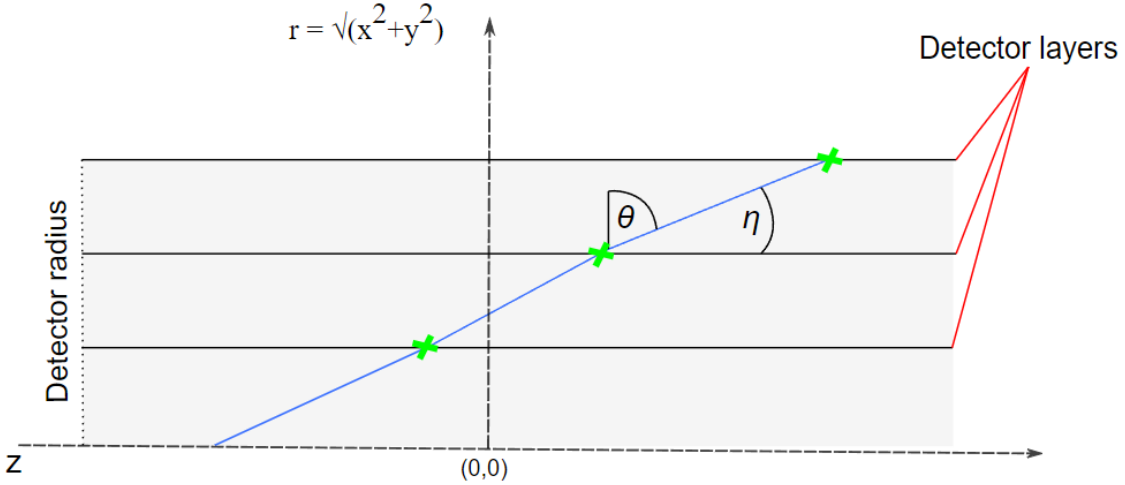
Single μ^- generated:

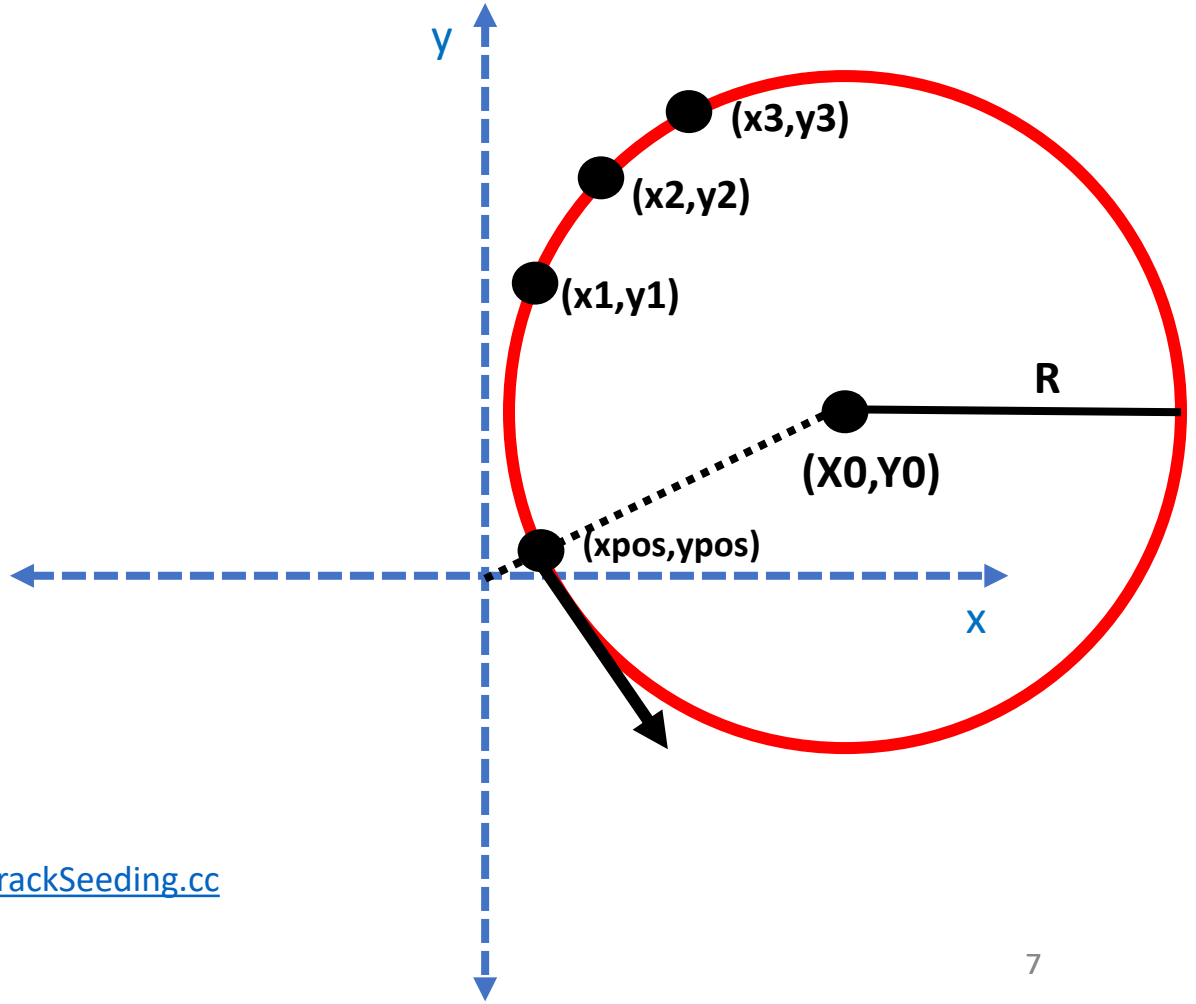
0.5 GeV/c < P < 20 GeV/c

-4 < η < 4

Generated vertex: (0,0,0) mm

Seed reconstruction





https://github.com/eic/EICrecon/blob/main/src/algorithms/tracking/TrackSeeding.cc

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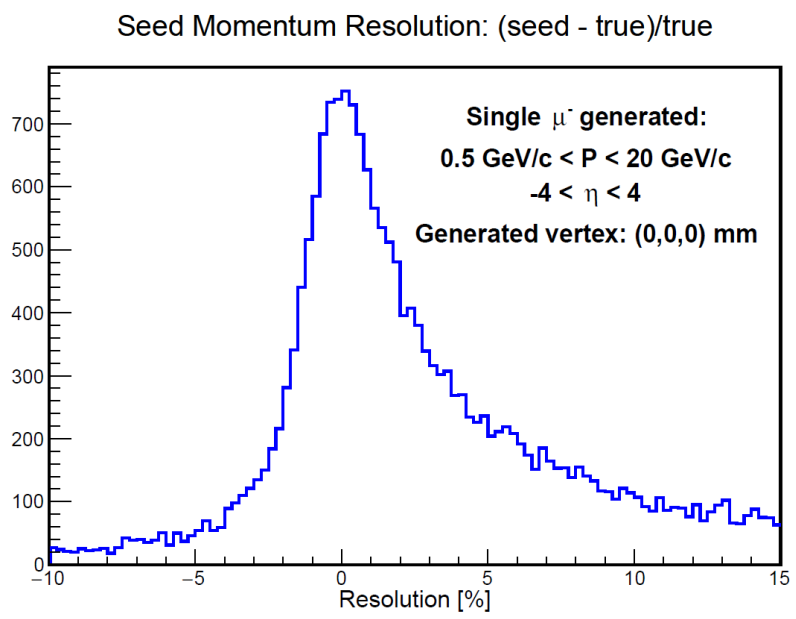
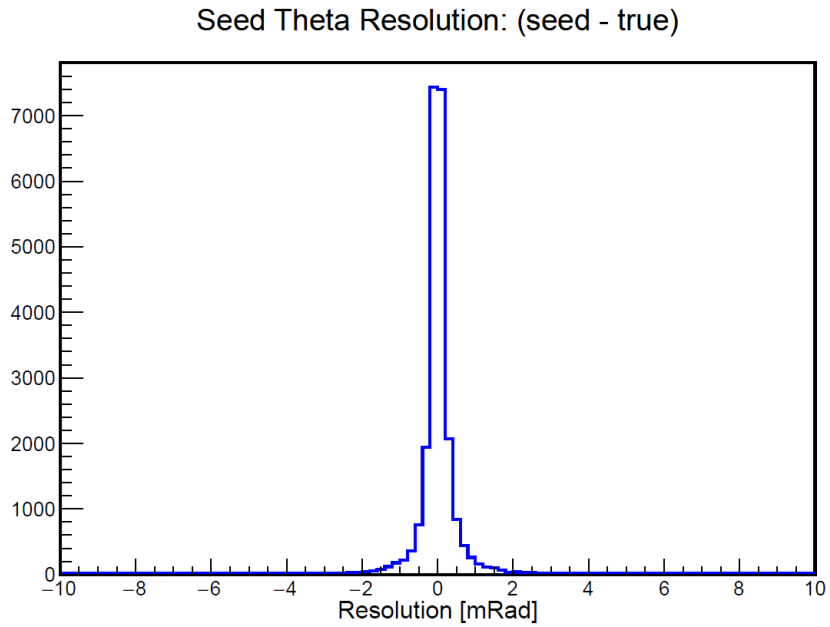
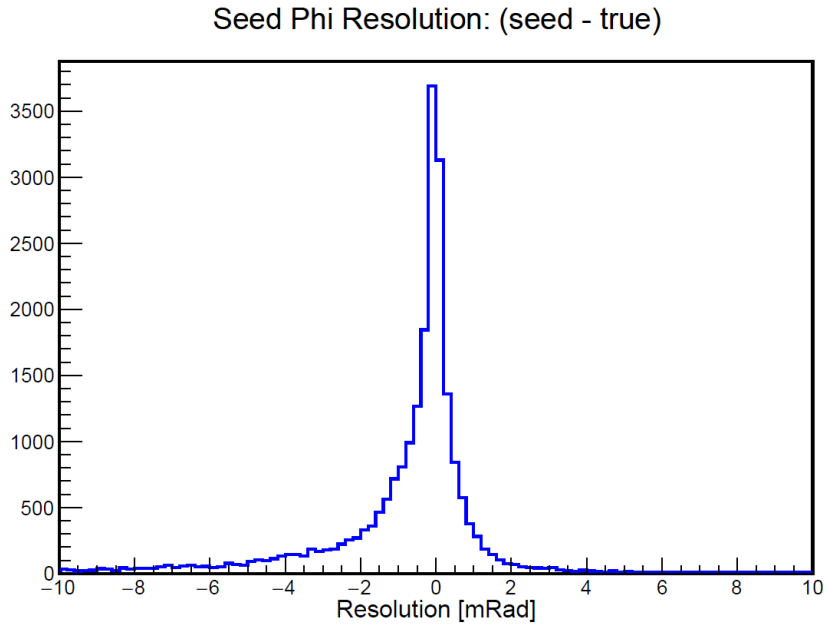
Seed angle and momentum reconstruction







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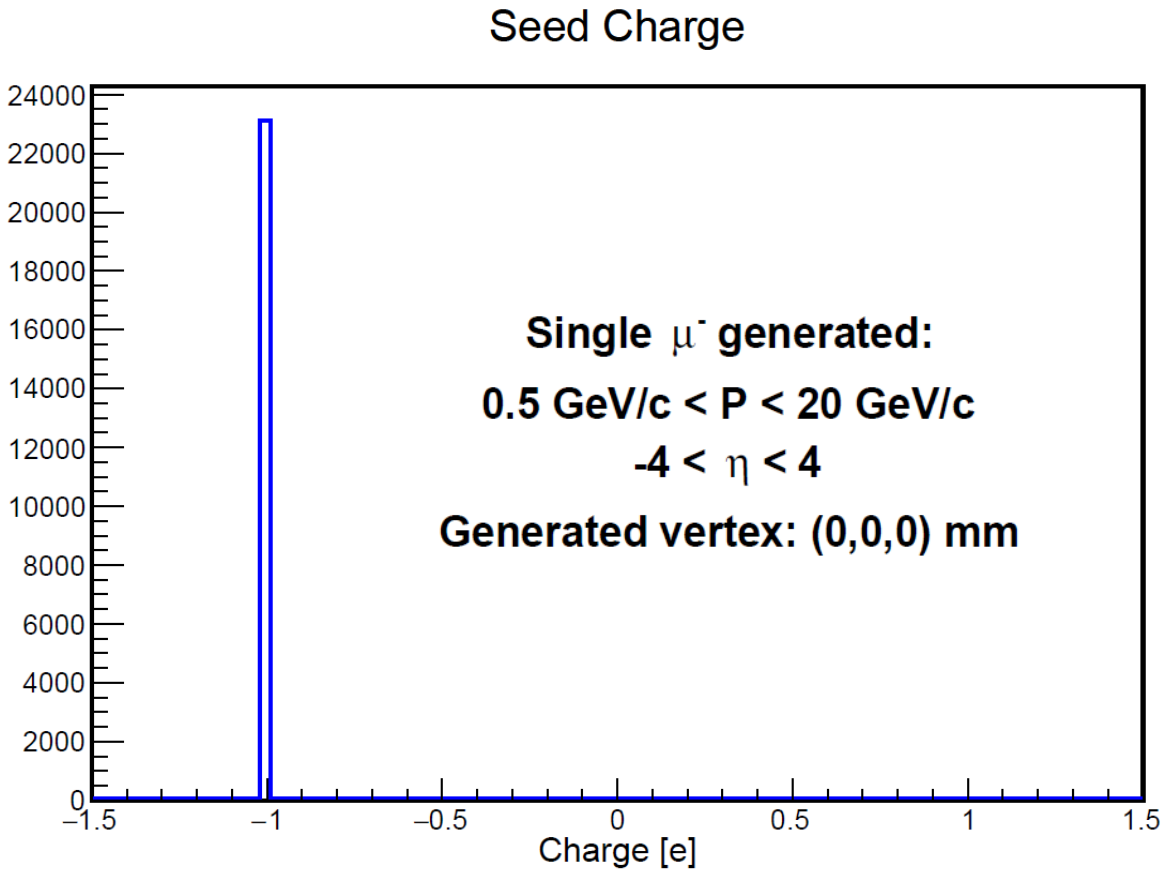
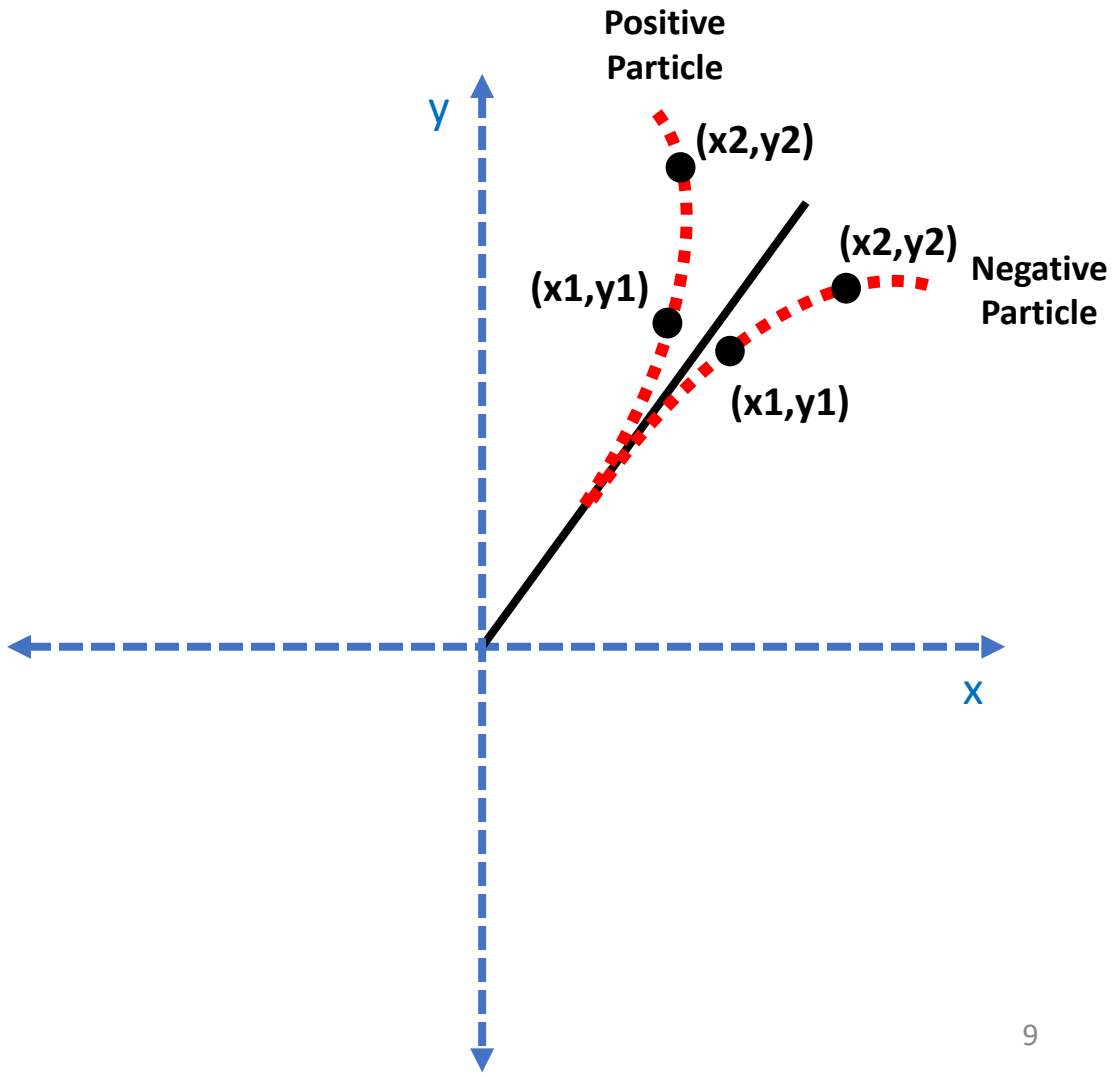
Seed charge reconstruction





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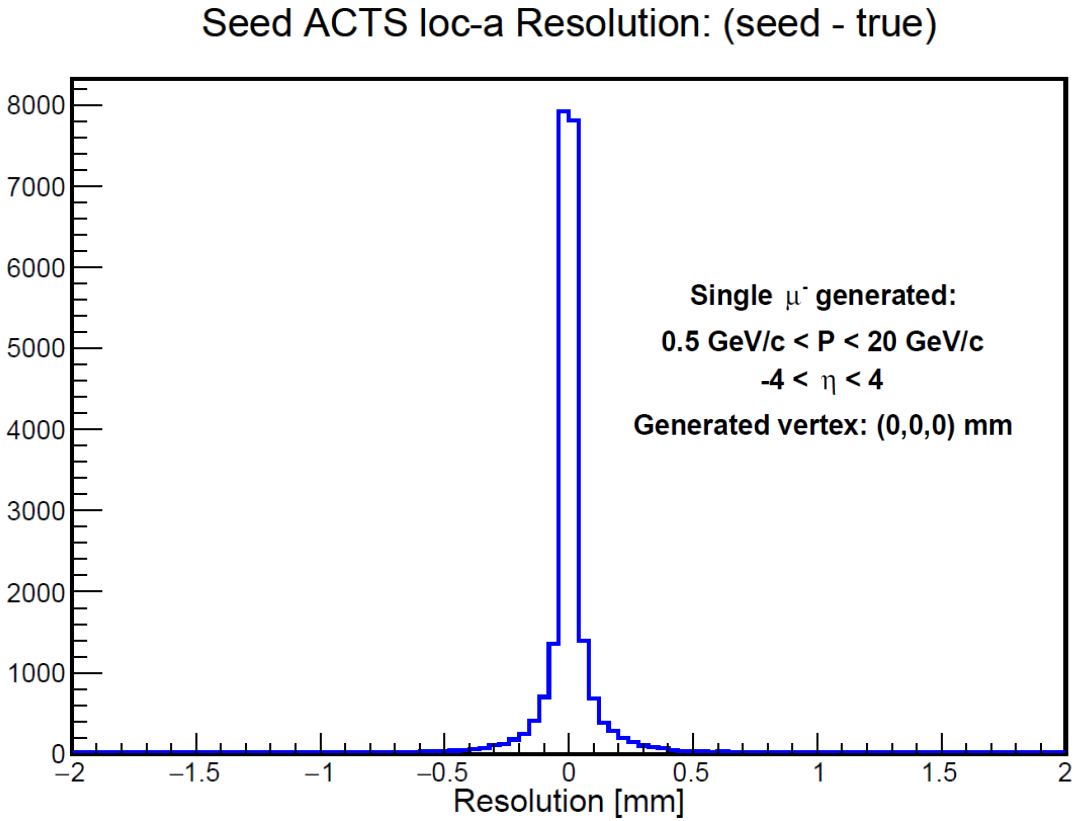
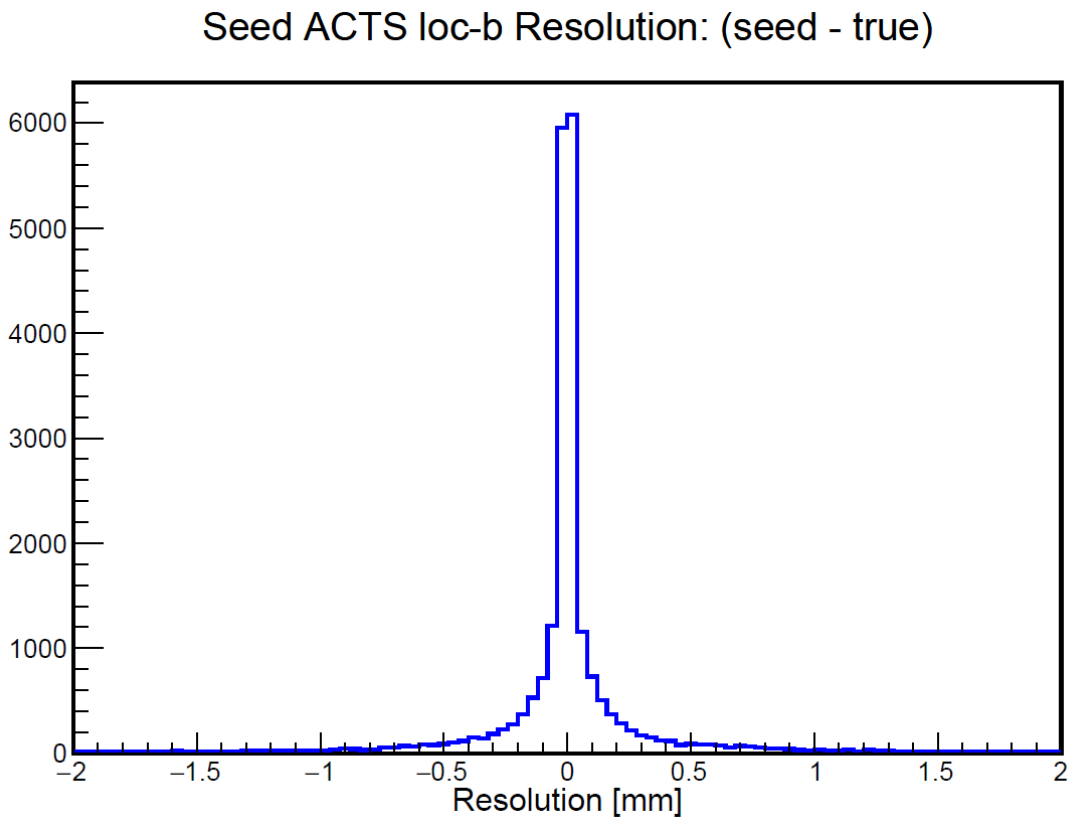
Seed position reconstruction

ACTS loc-a is the point of closest approach to the origin in the x-y plane.



ACTS loc-b is the z intercept (i.e. at r = 0) of linear fit in the r-z plane.



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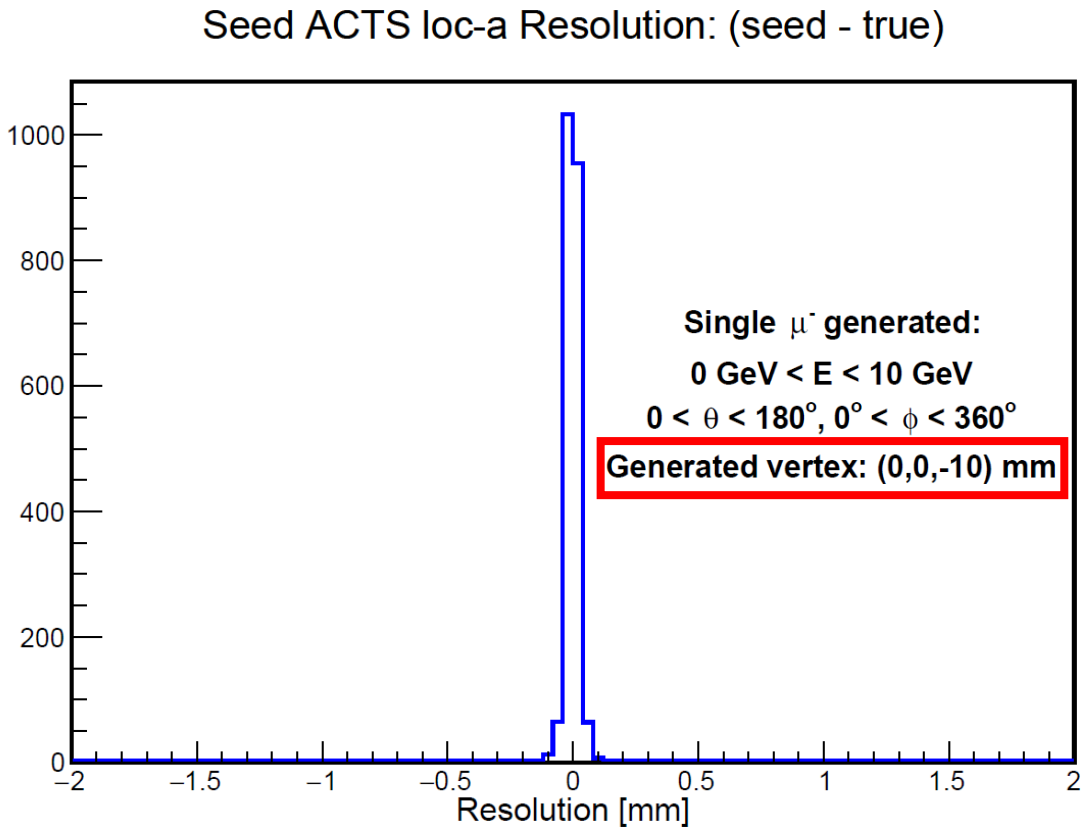

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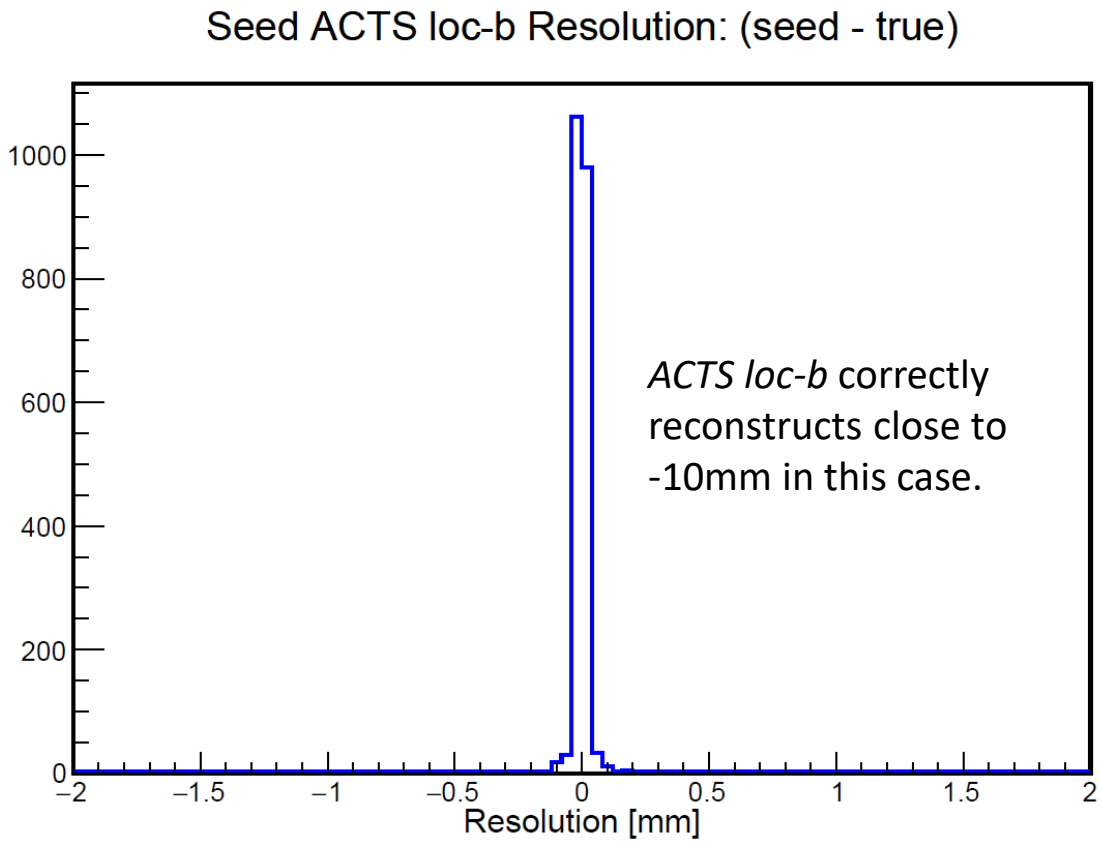
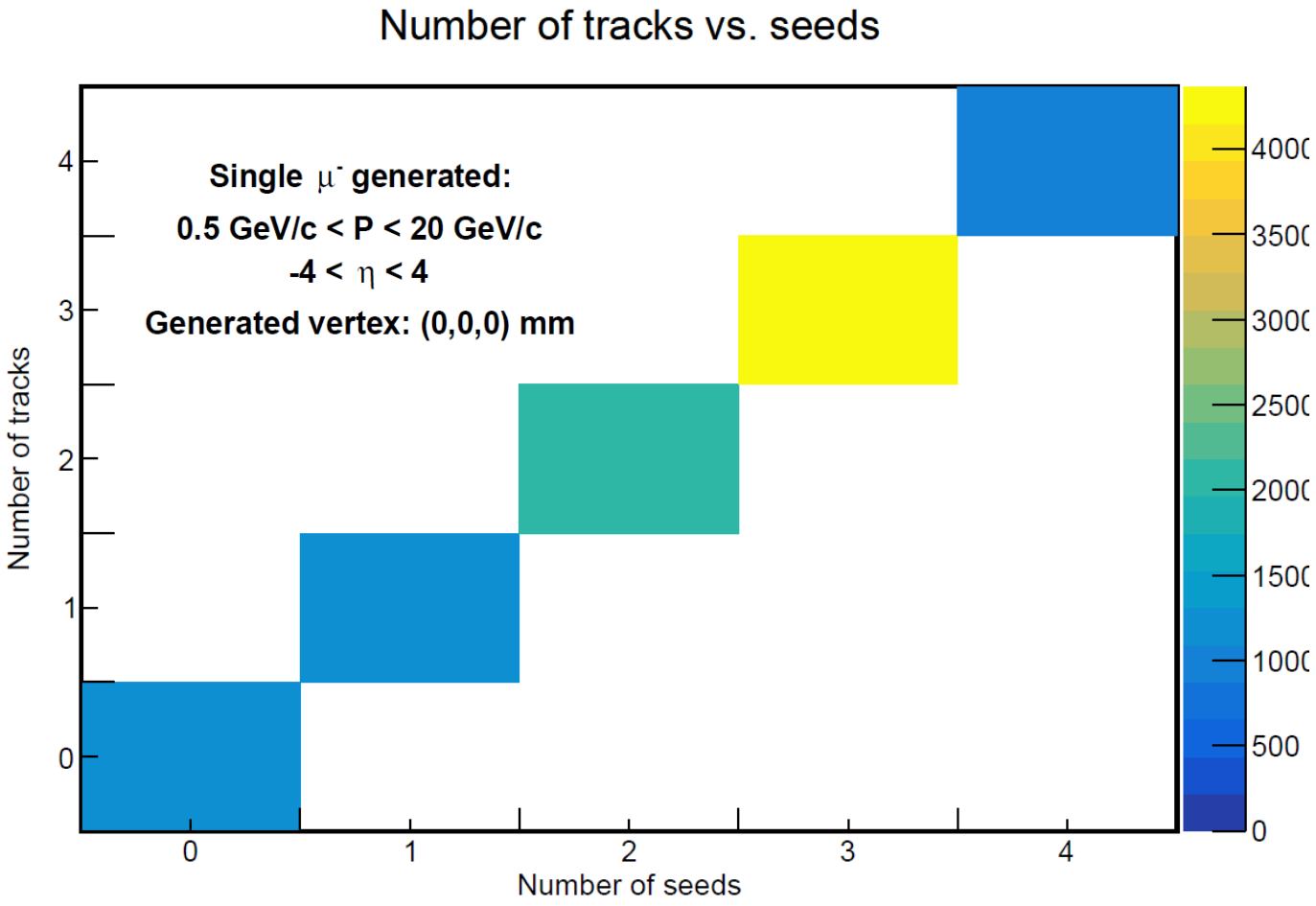
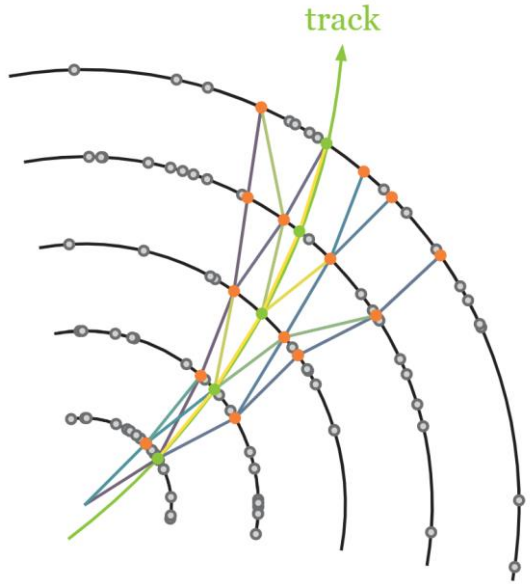


ACTS CKF tracking with real seeds

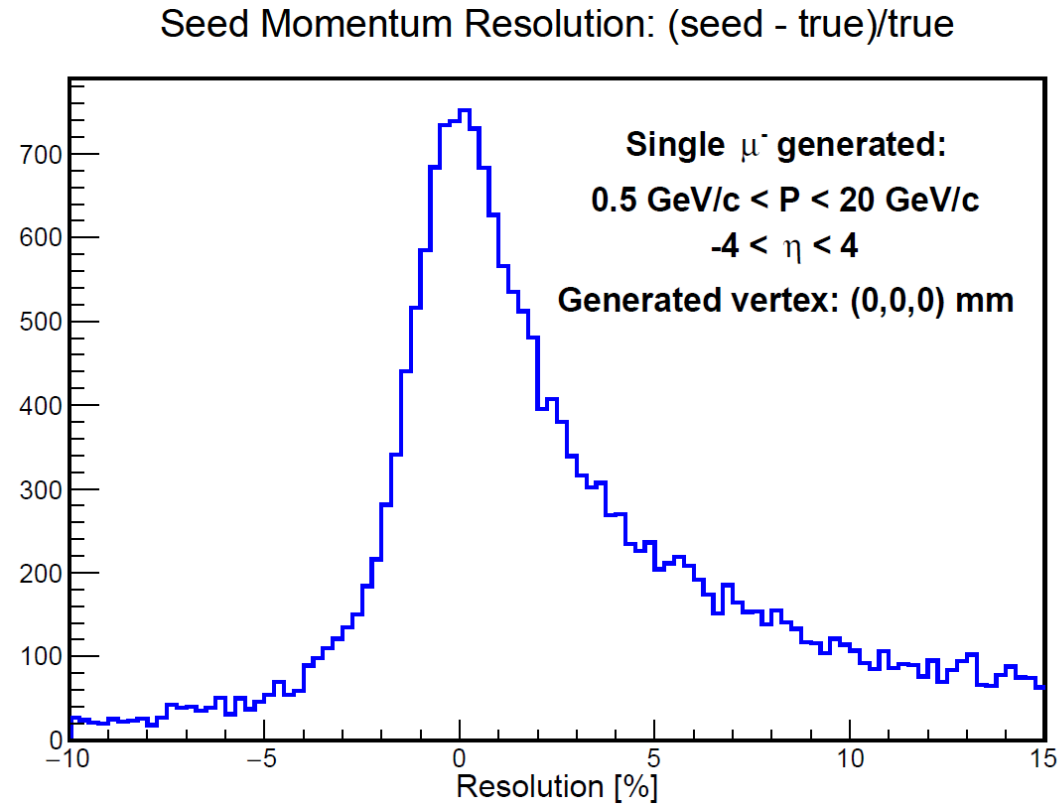


https://acts.readthedocs.io/en/latest/tracking.html#combinatorial-kalman-filter

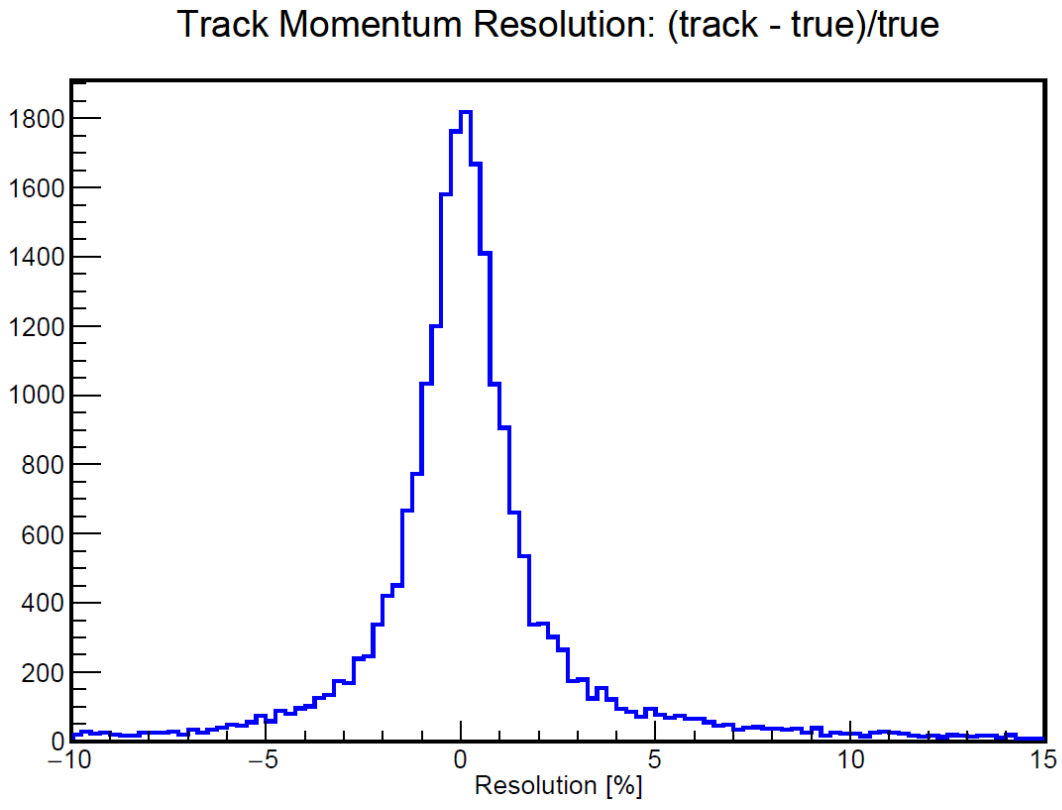


We see a single track reconstructed for each seed. It is possible for the ACTS CKF to return multiple tracks per seed. In our reconstruction, however, we run the command *trackTips.front()*, which saves the trajectory with the longest branch. This may be fine, but it is something which should be studied in more detail.

First look at momentum resolution with CKF with real seeds



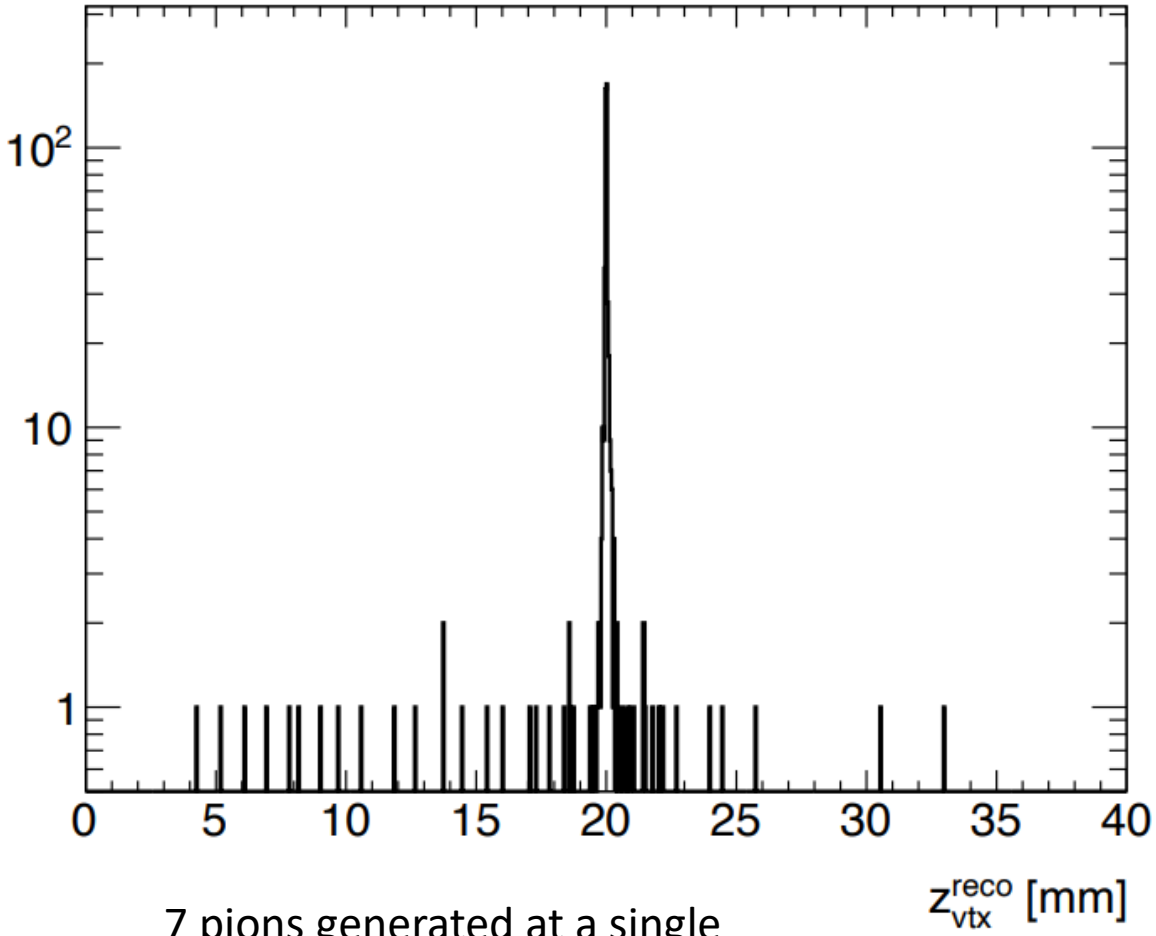
CKF



The CKF improves the seed momentum resolution, as expected.

Iterative vertex finder

- The ACTS Iterative Vertex Finder has been implemented in EICRecon.
- Output is written to the edm4eic::Vertex data type. Efforts are ongoing to include additional information into this data container.
- How does the algorithm work? It takes the output fitted tracks as input and:
  1. Finds a z vertex position seed
  2. Tracks compatible with this seed are used in fitting
  3. Other vertices found are iterated through and checked to confirm that tracks belonging to that vertex are not more compatible with the current vertex
  4. Vertex and tracks are added to vertex collection. Repeat until no tracks are left or max number of vertices are found



7 pions generated at a single vertex of (0,0,20) mm

Ongoing efforts

- Systematic studies of real-seeded track resolution as a function of momentum and angle for single particle simulations: **Stephen Maple**
- Studies of seed efficiency, reconstruction, and purity with embedded backgrounds and for DIS events. Do the current seed finder parameters work well in the presence of background?: **Benjamen Sterwerf**
- Finalizing EICRecon pull request to allow both truth-seeded and real-seeded tracks in the output: **Barak Schmookler**
- Optimization of vertex finder: **Joe Osborn and Xin Dong**
- Updating the vertex data model: **Joe Osborn**

Other topics we can use help with

- Completion of trajectory factory in EICRecon.
- For single particle simulations, studies of duplicate seeds/tracks and effects of secondary particles produced in tracking volume (see here, for example).
- Study ability of ACTS vertex finder to reconstruct secondary vertices. Do the seed finder parameters need to be changed to reconstruct these tracks?
- Implementation of associations between tracking-related data containers.
- Development of tracker validation plots. See here for some proposed plots.

Thanks!

Track Reconstruction WG meetings are Thursday at 10am Eastern US Time

Indico: https://indico.bnl.gov/category/463/
Mailing list: https://lists.bnl.gov/mailman/listinfo/eic-projdet-trk-recon-l