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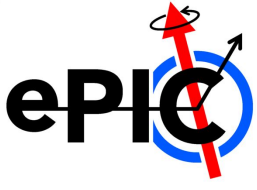
U.S. DEPARTMENT OF ENERGY
Office of Science

ePIC Track Reconstruction Status

Shujie Li
Berkeley Lab

ePIC General Meeting
Feb 10, 2023



Reconstruction Task Forces

Calorimeter Clustering	**Chao Peng** cpeng@anl.gov	**Dmitry Kalinkin** dmitry.kalinkin@gmail.com
Jet Reconstruction	**Derek Anderson** dmawxc@iastate.edu	
PID	**Christopher Dilks** dilks@jlab.org	
Tracking	**Shujie Li** shujieli@lbl.gov	
EICrecon	**Dmitry Romanov** romanov@jlab.org	
Modular Reconstruction	**David Lawrence** davidl@jlab.org	
Simulation Production	**Wouter Deconinck** wouter.deconinck@umanitoba.ca	

track recon task force meeting (the previous EIC-ACTS meeting): 7am PT on Thursdays

https://indico.bnl.gov/category/463/

mailing list:

https://lists.bnl.gov/mailman/listinfo/eic-projdet-trk-recon-l

Joosten
sjoosten@anl.gov

- **Next simulation campaign**:
  - **Target date**: End of March. **tbd**
  - **Goal**: Improved software stack for the reconstruction, including benchmarks.

See https://indico.bnl.gov/event/18274/#1-announcement for details

Track Reconstruction in EICrecon

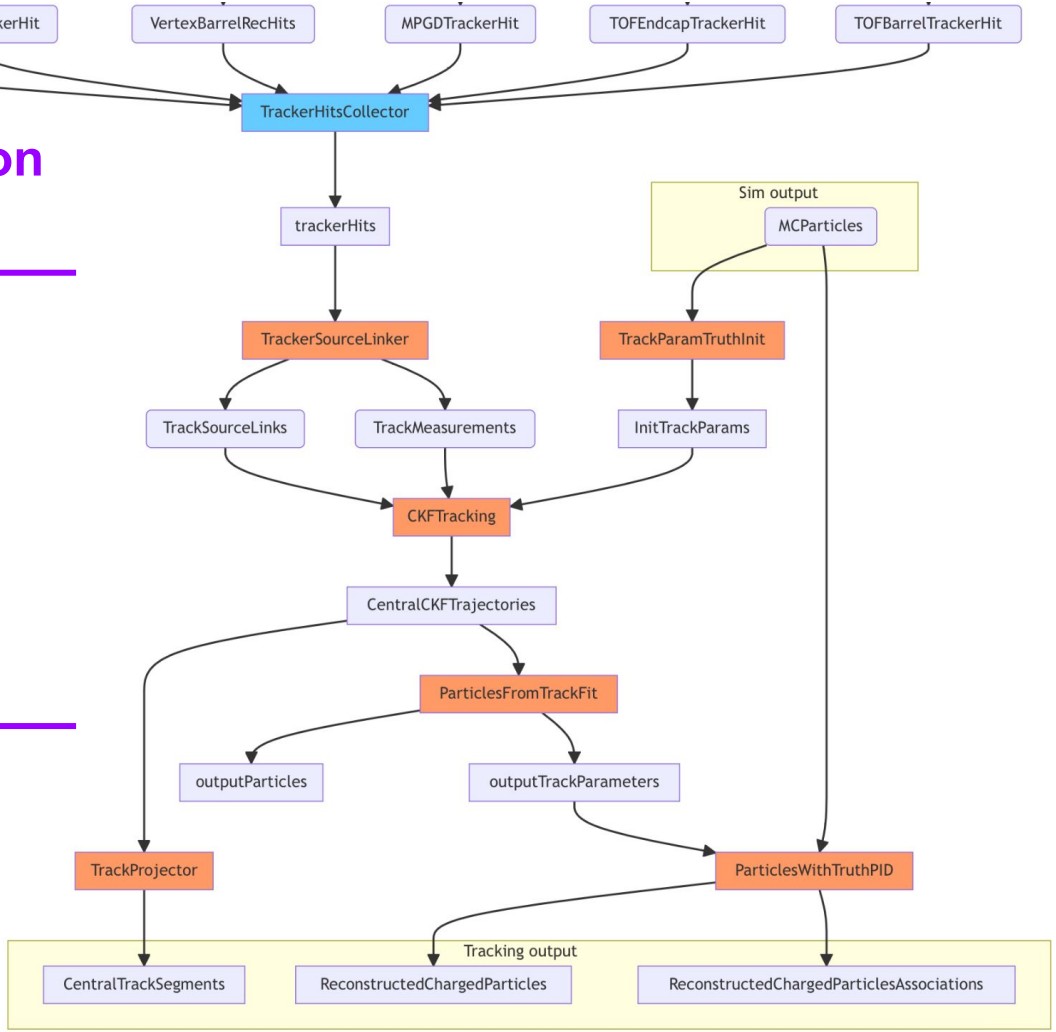
contact: Dmitry Romanov

Full diagram at https://eic.github.io/EICrecon/#/design/tracking?id=full-diagram

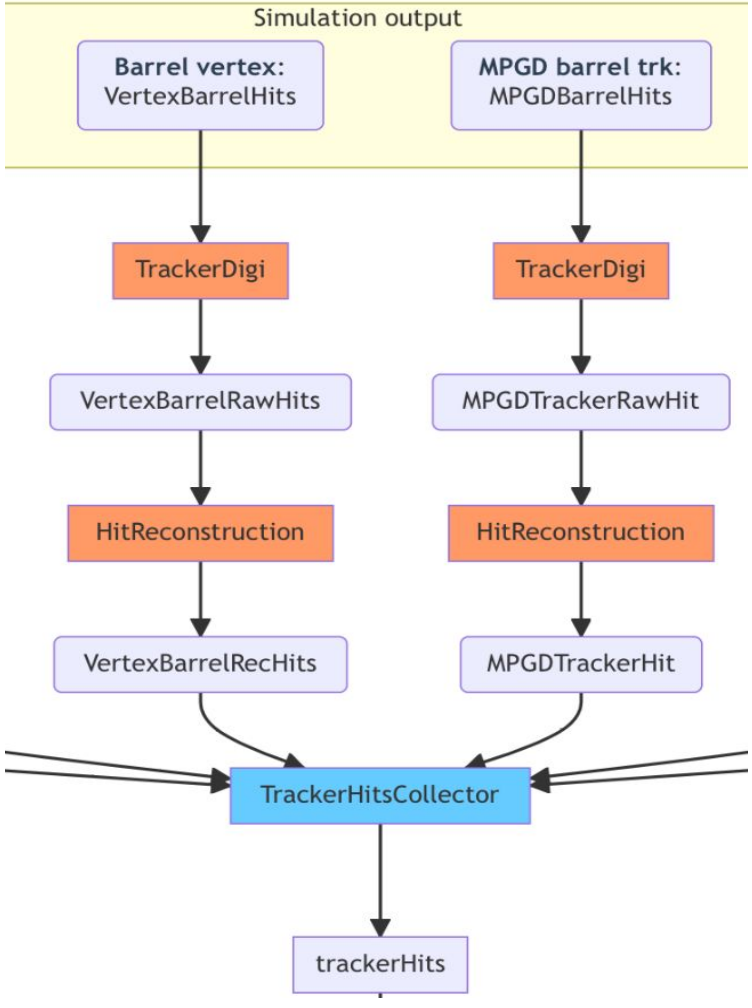
Space point formation

Track finding/fitting with

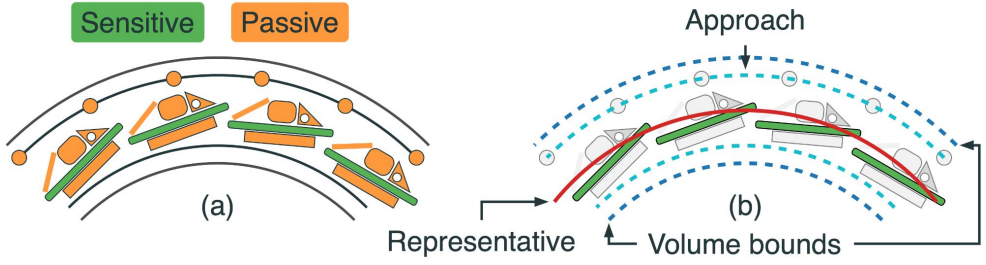
Track info in output



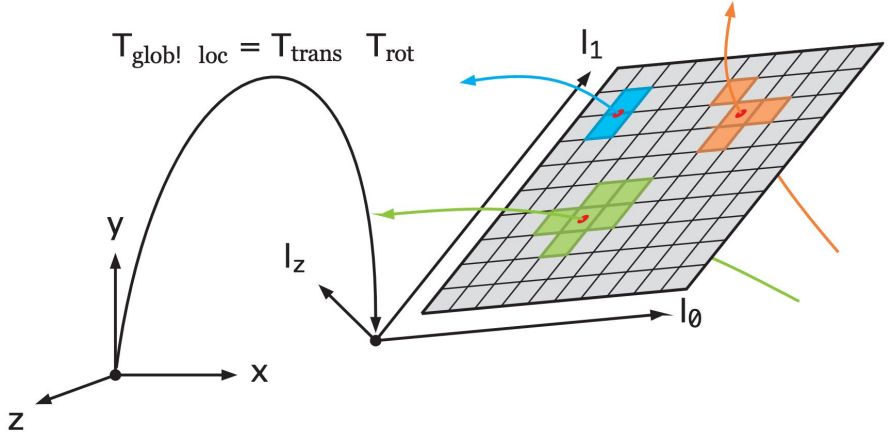
Space Point Formation



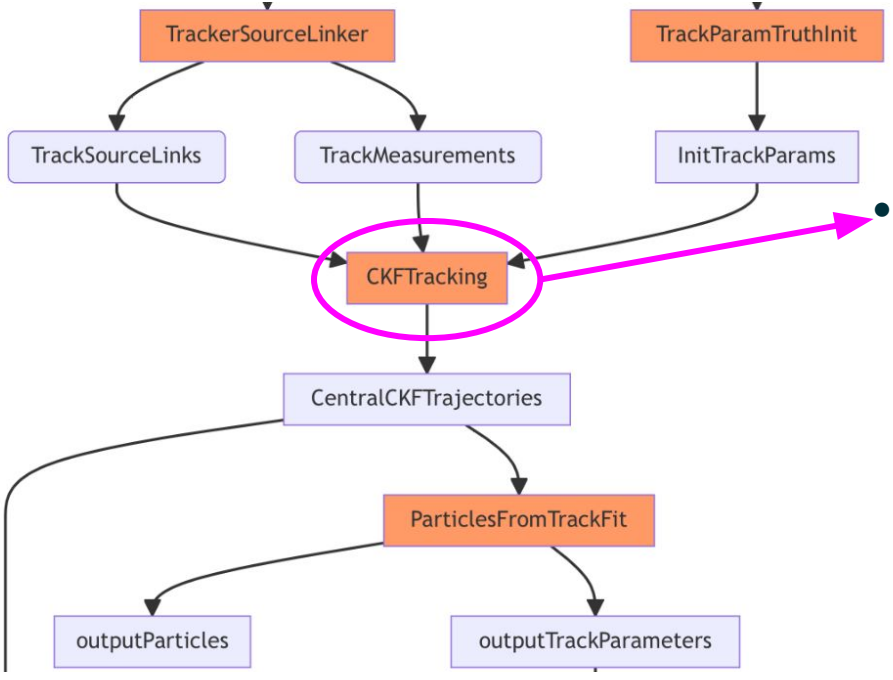
Simplified geometry in ACTS:
detector **volumes** → representing **surfaces**



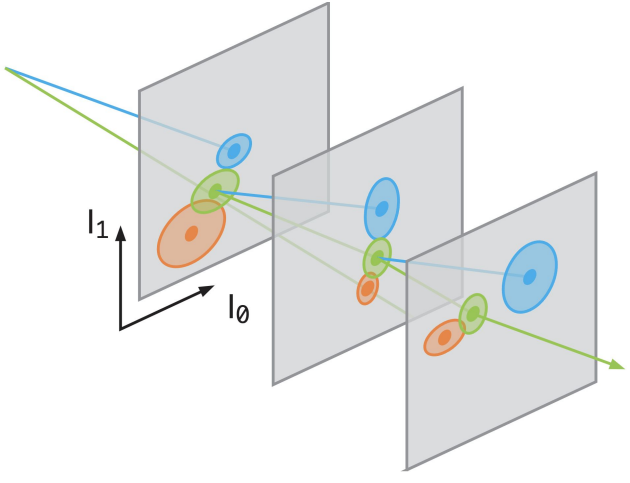
- Global / local coord. transformation
- Associate hits to surfaces
  - Raw hit positions are used, no clusterization
  - ACTS “on surface” check for B0 tracker, see [Sakib Rahman’s work]



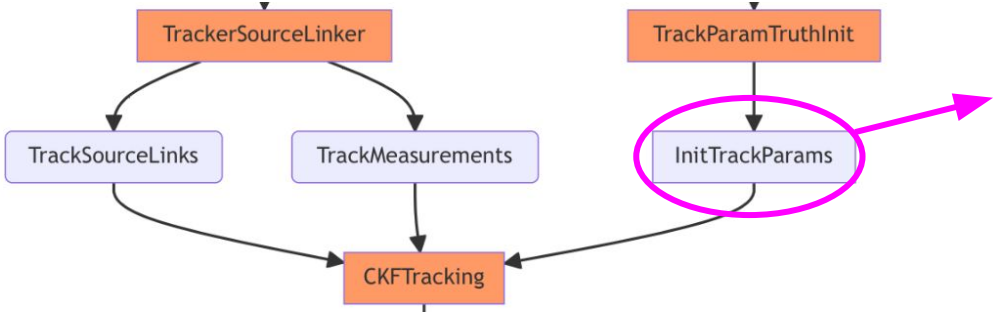
Track Finding/Fitting with ACTS



- **Combinatorial Kalman Filter (CKF)**
  - combine track finding and fitting
  - allows track branching
    - → user-defined measurement selector (number, chi2)
  - high efficiency
  - **Need a reasonable "initial guess"**



Initial Guess for CKF: 1. truth seeding



Use truth initial momentum, angle etc. from simulation

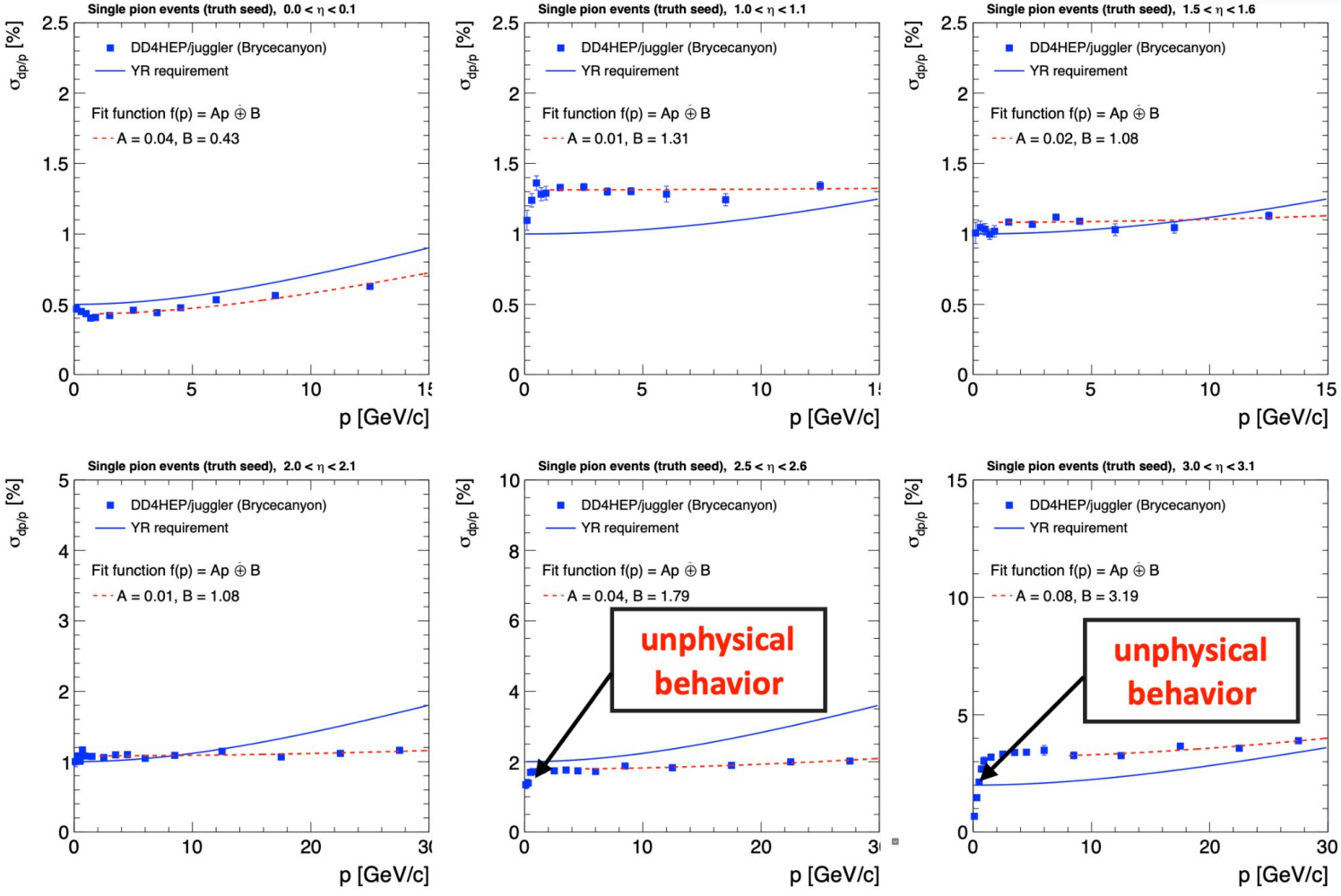
```
// build some track cov matrix
Acts::BoundSymMatrix cov                    = Acts::BoundSymMatrix::Zero();
cov(Acts::eBoundLoc0, Acts::eBoundLoc0)     = 1000*um*1000*um;
cov(Acts::eBoundLoc1, Acts::eBoundLoc1)     = 1000*um*1000*um;
cov(Acts::eBoundPhi, Acts::eBoundPhi)       = 0.05*0.05;
cov(Acts::eBoundTheta, Acts::eBoundTheta)   = 0.01*0.01;
cov(Acts::eBoundQOverP, Acts::eBoundQOverP) = (0.1*0.1) / (GeV*GeV);
cov(Acts::eBoundTime, Acts::eBoundTime)     = 10.0e9*ns*10.0e9*ns;

Acts::BoundVector  params;
params(Acts::eBoundLoc0)   = 0.0 * mm ;  // cylinder radius
params(Acts::eBoundLoc1)   = 0.0 * mm ;  // cylinder length
params(Acts::eBoundPhi)    = phi;
params(Acts::eBoundTheta)  = theta;
params(Acts::eBoundQOverP) = charge / (pinit * GeV);
params(Acts::eBoundTime)   = part->getTime() * ns;
```

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

Initial Guess for CKF: 1. truth seeding

Tracking performance check with single pion events. See Wenqing Fan's work



Initial Guess for CKF: 1. truth seeding

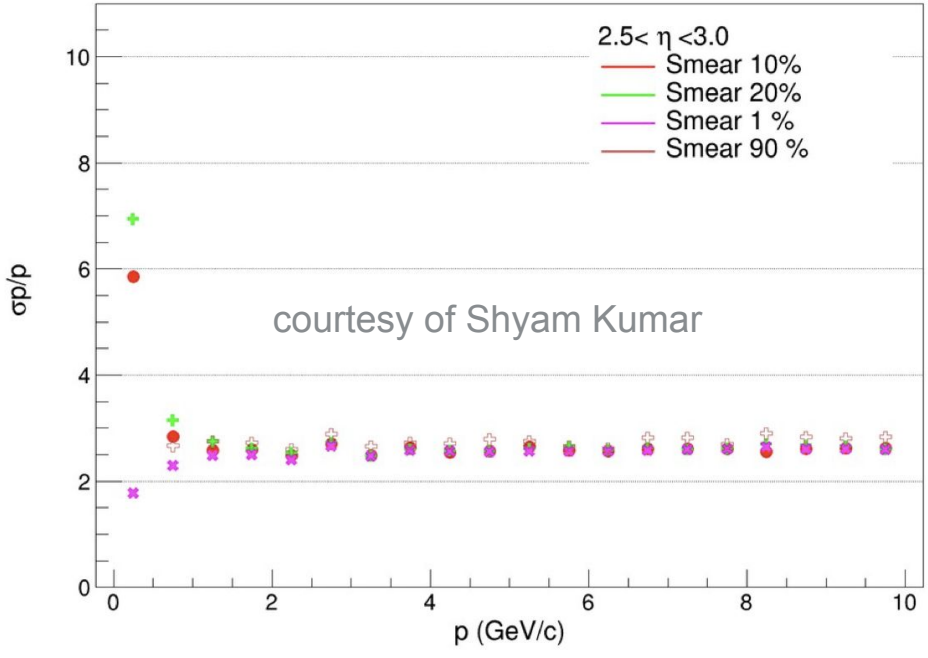
Solutions to the “unphysical behavior” at low momentum:

Short term: add artificial smearing to init parameters. See Shyam Kumar’s work

- address the immediate concern of the reconstruction performance at low p from physics WG
- no clear guidance to a “reasonable” smearing

Long term: use realistic init parameters from seeding

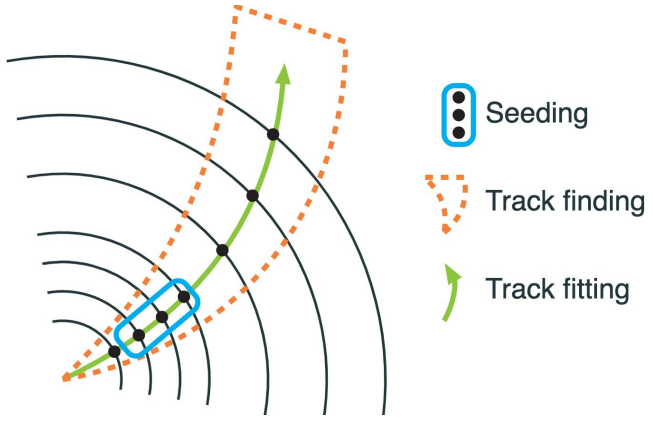
- use smearing parameters from realistic seeding study
- switch to realistic seeding completely



Initial Guess for CKF: 2. realistic seeding

Seeder: a set of three space points to estimate initial track parameters

- **Binned seeder**: loop over φ-z binning to try all combinations. Slow at large η
  - tested and bugs fixed. See YueShi Lai's work
- **Orthogonal seed finder**: can efficiently search for space points within a given range.
  - Initial implementation in EICrecon - Joe Osborn
  - Seeder configuration:
    - default parameters from binned seeder
    - parameter optimization - See Rey Cruz-Torres's work
  - Seeder confirmation/filter

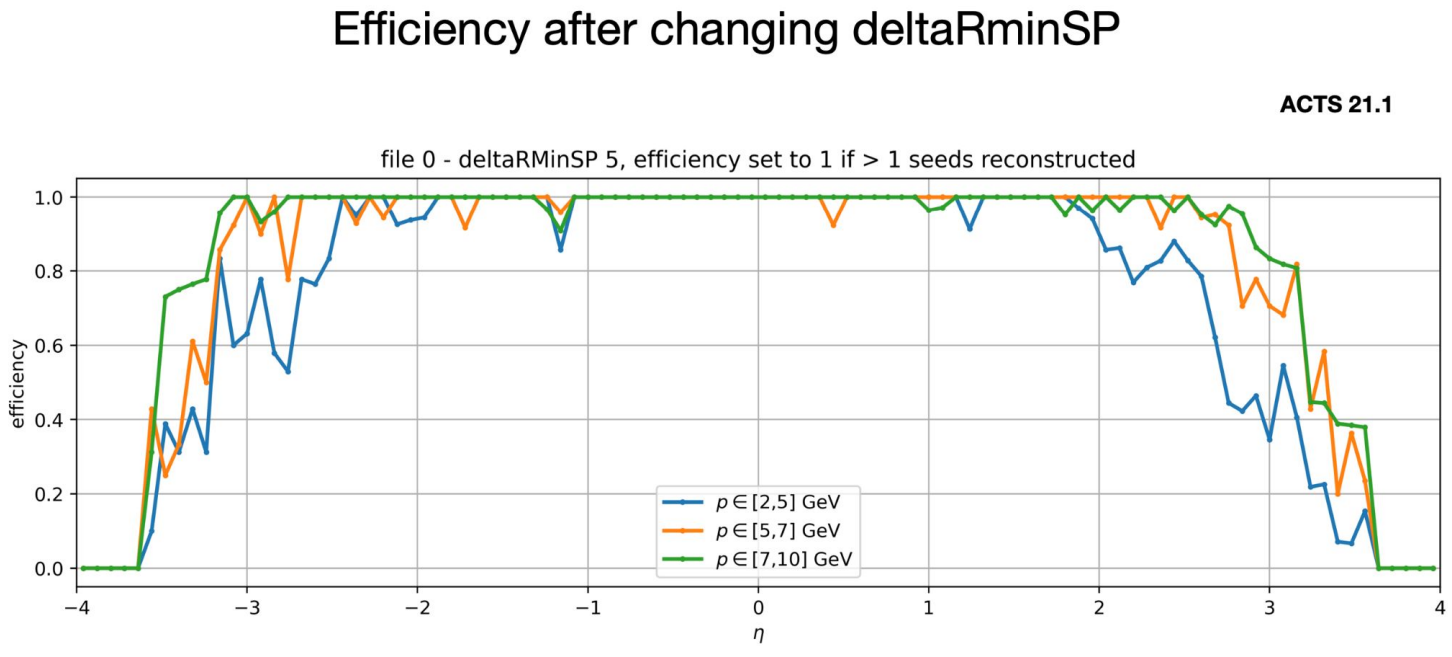


Parameter	Description
bFieldInZ	z component of magnetic field
rMax	Maximum r value to look for seeds
rMin	Minimum r value to look for seeds
zMin	Minimum z value to look for seeds
zMax	Maximum z value to look for seeds
beamPosX	Beam offset in x
beamPosY	Beam offset in y
deltaRMinTopSP	Min distance in r between middle and top SP in one seed
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed
collisionRegionMin	Min z for primary vertex
collisionRegionMax	Max z for primary vertex
cotThetaMax	Cotangent of max theta angle
minPt	Min transverse momentum
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1
sigmaScattering	How many standard devs of scattering angles to consider
radLengthPerSeed	Average radiation lengths of material on the length of a seed

Initial Guess for CKF: 2. realistic seeding

Seeder Configuration

Example of parameter tuning. Use loose settings to obtain seeds for entire eta range despite of high chance to have duplicated seeds. **Ongoing** work of Rey



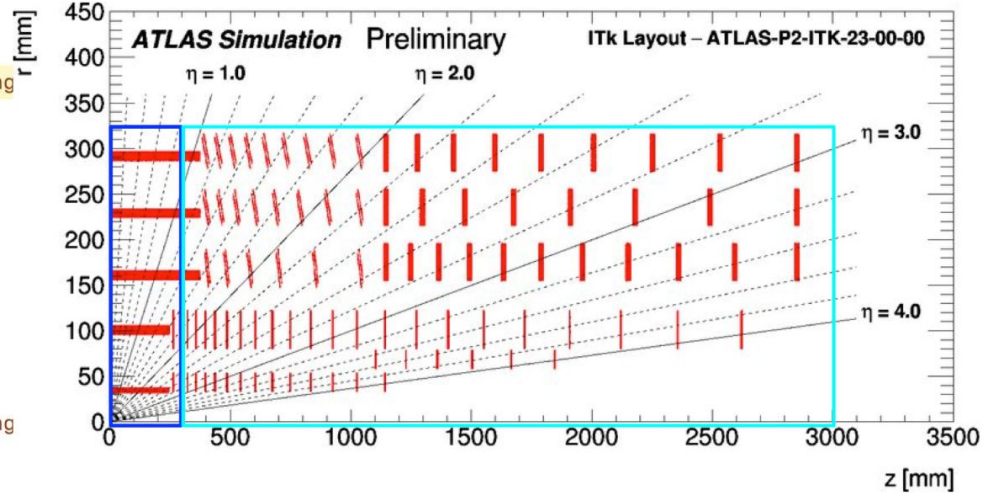
Initial Guess for CKF: 2. realistic seeding

Seed Confirmation/Filter

Individual filter settings for each geometry region.

- Experience from ATLAS-ITK , see Luis Falda Coelho's work
- implementation in EICrecon, **TBD** - Rey, Barak Schmookler

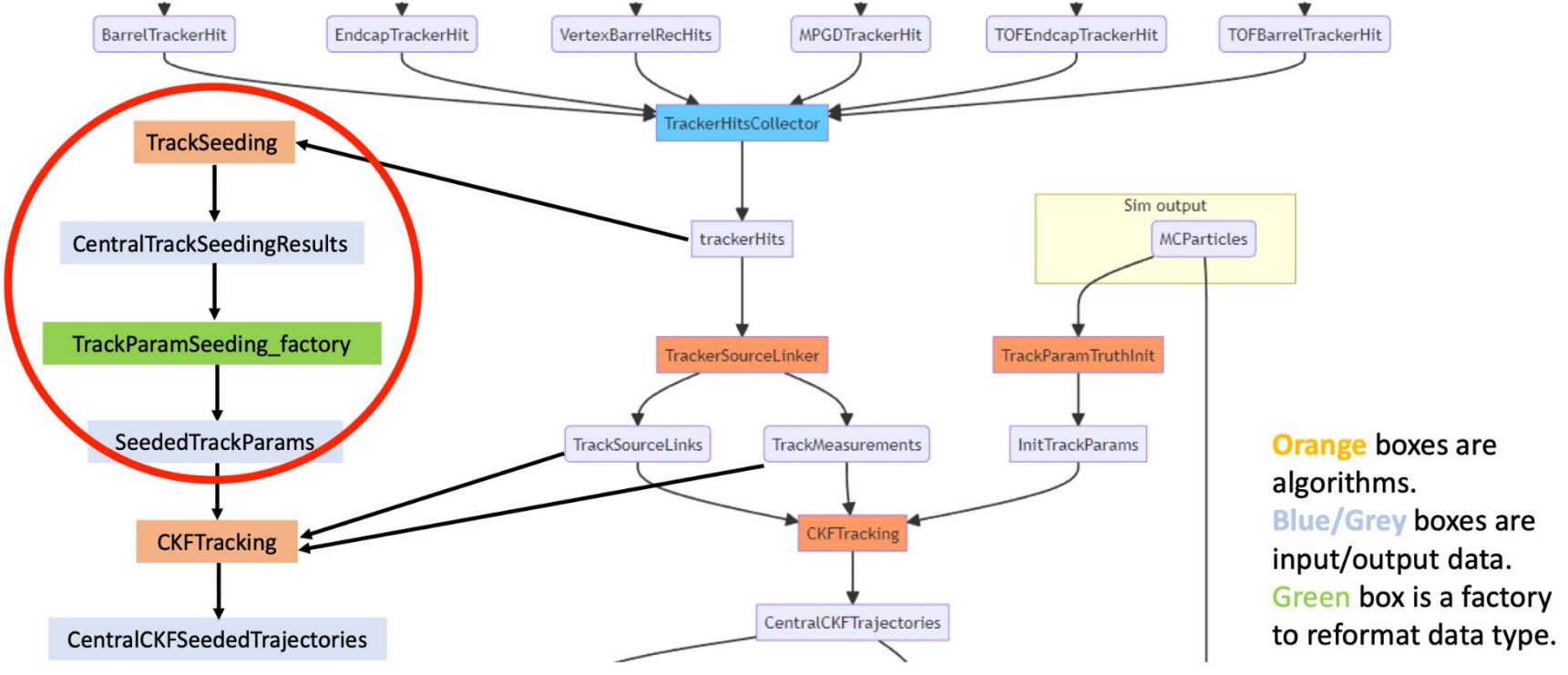
```
centralSeedConfirmationRange = acts.SeedConfirmationRang
    zMinSeedConf=-250 * u.mm,
    zMaxSeedConf=250 * u.mm,
    rMaxSeedConf=140 * u.mm,
    nTopForLargeR=1,
    nTopForSmallR=2,
    seedConfMinBottomRadius=60.0 * u.mm,
    seedConfMaxZOrigin=150.0 * u.mm,
    minImpactSeedConf=1.0 * u.mm,
)  # contains parameters for seed confirmation
forwardSeedConfirmationRange = acts.SeedConfirmationRang
    zMinSeedConf=-3000 * u.mm,
    zMaxSeedConf=3000 * u.mm,
    rMaxSeedConf=140 * u.mm,
    nTopForLargeR=1,
    nTopForSmallR=2,
    seedConfMinBottomRadius=60.0 * u.mm,
    seedConfMaxZOrigin=150.0 * u.mm,
    minImpactSeedConf=1.0 * u.mm,
)
```



Initial Guess for CKF: 2. realistic seeding

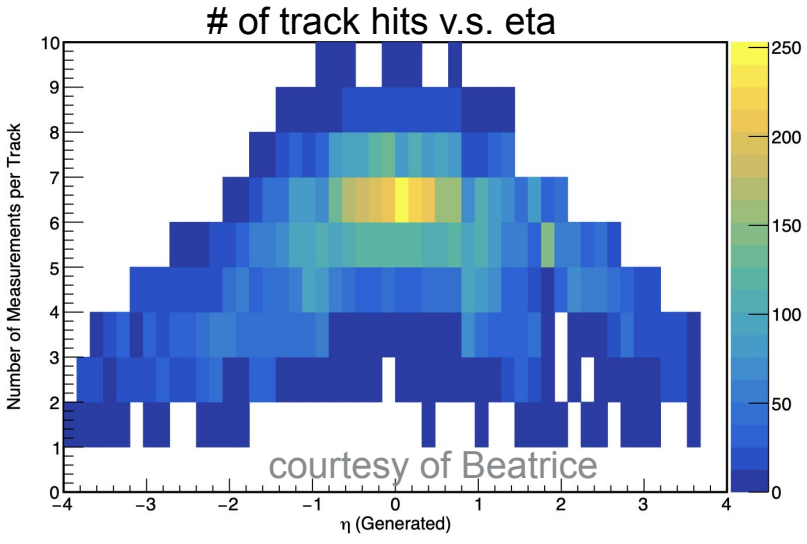
Supply realistic init parameters to CKF

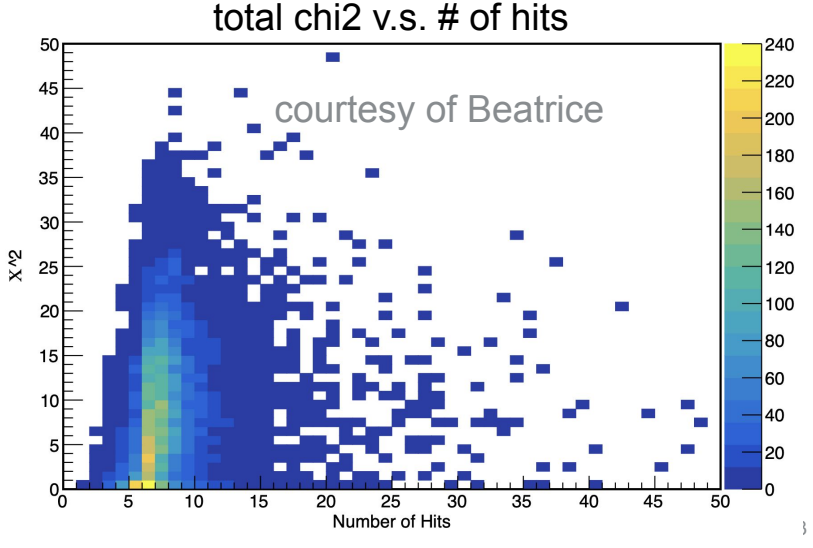
- CKF with realistic seeding in addition to truth seeding. See Barak's work
  - retain data structure for current downstream analysis
- Switch between truth / realistic seeding. TBD. See Dmitry's work



Track Info in Output

- Track parameters from fit - Done
- Track projection - Done
- Trajectory info (chi2, number of hits …)
  - save to histograms with EICrecon plugins:
    - plugin from Nicolas Schmidt https://github.com/eic/EICrecon/blob/angular_studies_tof/src/benchmarks/reconstruction/tracking_studies/tracking_studiesProcessor.cc
    - plugin from Barak https://github.com/eic/EICrecon/tree/track-qa-barak/src/tests/track_qa
    - see also Beatrice Liang-Gilman's study on number of track hits and chi2 (**ongoing**)





Track Info in Output

- Track parameters from fit - Done
- Track projection - Done

- Trajectory info (chi2, number of hits …)
  - save to histograms with EICrecon plugins
  - save to output rootfile:
    - **TBD**: write an EICrecon factory to write trajectory info into data structure

- **TBD:** Hits associated with tracks

```
struct TrajectoryState {
  size_t nStates = 0;
  size_t nMeasurements = 0;
  size_t nOutliers = 0;
  size_t nHoles = 0;
  double chi2Sum = 0;
  std::vector<double> measurementChi2 = {};
  std::vector<double> outlierChi2 = {};
  size_t NDF = 0;
  std::vector<unsigned int> measurementVolume = {};
  std::vector<unsigned int> measurementLayer = {};
  std::vector<unsigned int> outlierVolume = {};
  std::vector<unsigned int> outlierLayer = {};
  size_t nSharedHits = 0;
};
```

trajectory info from ACTS

```
eicd::Trajectory:
  Description: "Raw trajectory from the tracking algorithm"
  Author: "S. Joosten, S. Li"
  Members:
    - uint32_t          type             // 0 (does not have good track fit), 1 (has good track fit)
    - uint32_t          nStates          // Number of tracking steps
    - uint32_t          nMeasurements    // Number of hits used
    - uint32_t          nOutliers        // Number of hits not considered
    - uint32_t                           hits
    - float
    - uint32_t          ndf              // Number of degrees of freedom
    - uint32_t          nSharedHits      // Number of shared hits with other trajectories
  VectorMembers:
    - float             measurementChi2  // Chi2 for each of the measurements
    - float             outlierChi2      // Chi2 for each of the outliers
  OneToOneRelations:
    - eicd::TrackParameters trackParameters // Associated track parameters, if any
  OneToManyRelations:
    - eicd::TrackerHit  measurementHits  // Measurement hits used in this trajectory
    - eicd::TrackerHit  outlierHits      // Outlier hits not used in this trajectory
```

data structure for EICrecon

Track Recon Validation Plots

tracking performance:

- *momentum resolution,*
- *DCA_2D resolutions,*
- *polar angle resolution (at vertex and the various PID detector),*
- *azimuthal angle resolution (at vertex and the various PID detector)*

tracking hits information:

- *hit at generation level,*
- *hit at reconstruction level.*
- *hit locations (x,y,z) associated with tracks*

tracking quality variables (truth + realistic seeding):

- *chi^2 (total, per DOF),*
- *No. of hits of the reconstructed tracks*
- *No. of trajectories per event*
- *No. of seeders (for realistic seeding)*

Proposed by tracking WG, Matt Posik, and LBL group. To be discussed with software/computing WG.

Summary

- Tracker in Acts geometry:
  - central tracker in good shape. B0 tracker needs to be integrated
- Track reconstruction:
  - recon with truth info works well except at low momentum. Parameters need to be smeared.
  - realistic seeder needs to be tuned.
- Track recon quality check:
  - some tracking info is accessible via EICrecon plugins but not in rootfiles
  - need to include validation plots in benchmark tests.

Thank You

Thank You