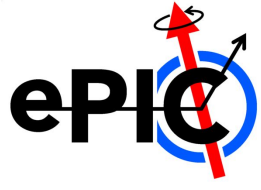
BERKELEY LAB
Bringing Science Solutions to the World

U.S. DEPARTMENT OF ENERGY
Office of Science

ePIC Track Reconstruction Status

Shujie Li
RNC EIC group meeting

Feb 21, 2023



Track Reconstruction in EICrecon

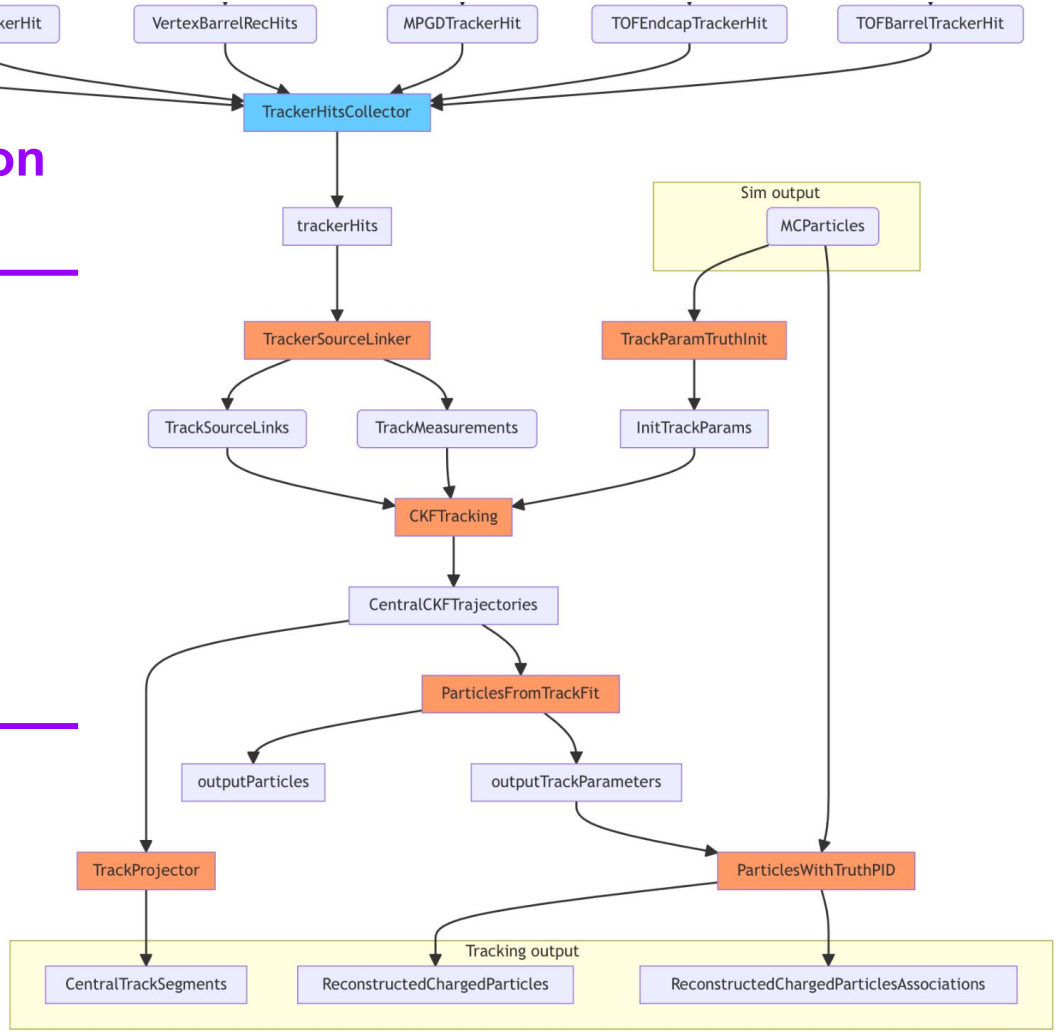
contact: Dmitry Romanov

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

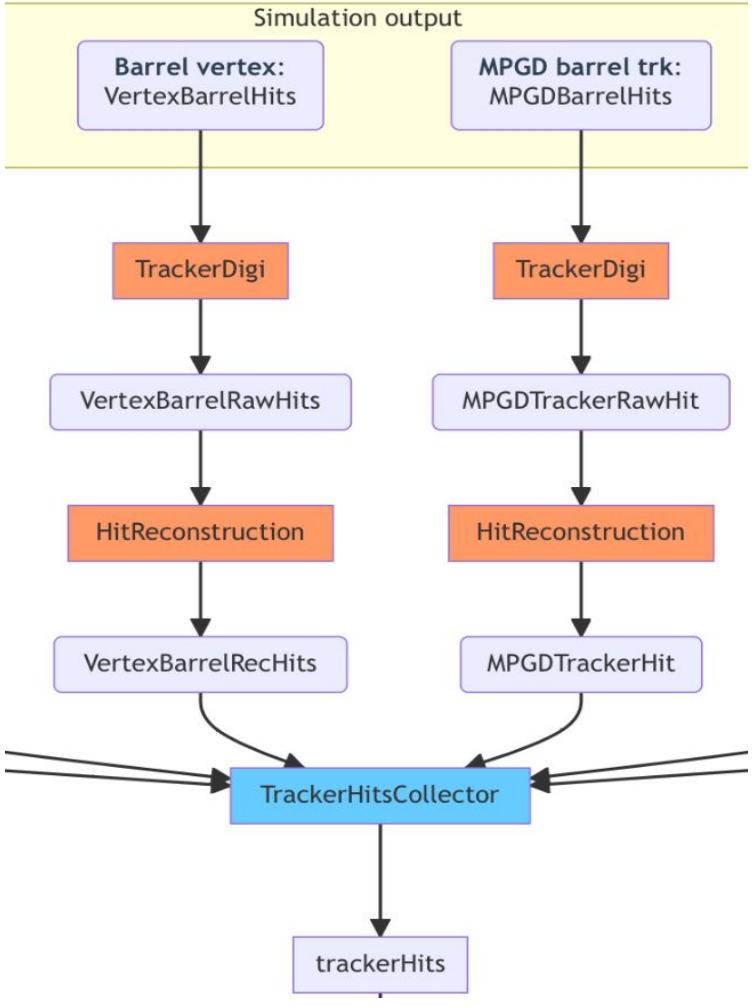
Space point formation

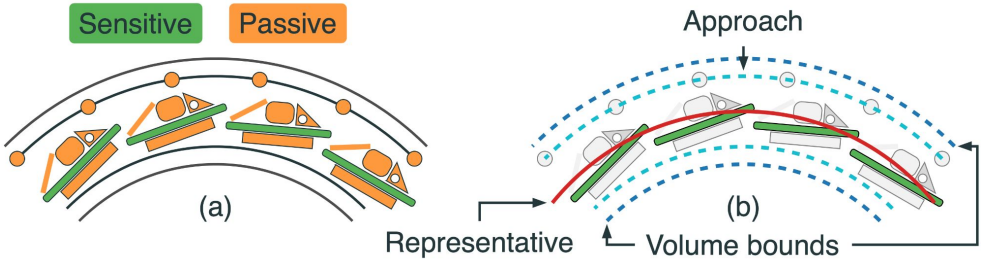
Track finding/fitting with acts

Track info in output

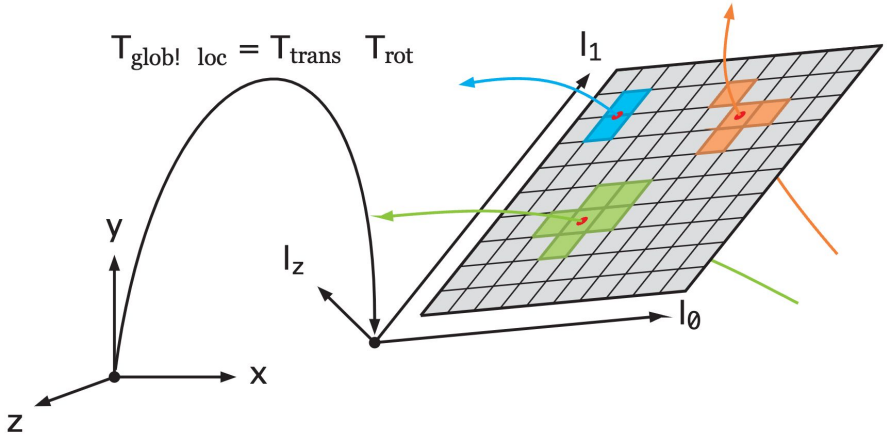


Space Point Formation

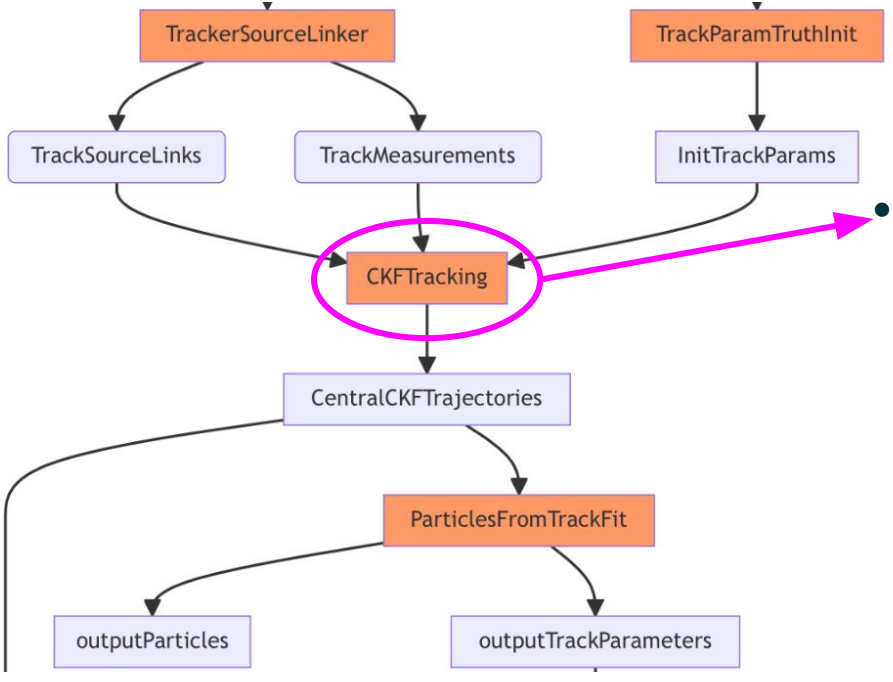




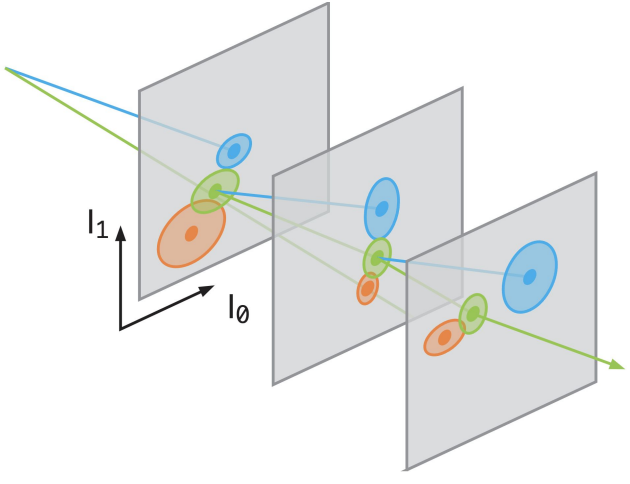
- Global / local coord. transformation
- Digitization:
  - Raw hits -> Surface and cell ID
  - Energy deposit threshold: 0 (110 electrons->eV? Check ALICE code)
- Clustering algorithm available at https://github.com/acts-project/acts/pull/1190 (Louis-Guillaume Gagnon, March 9th)



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"**



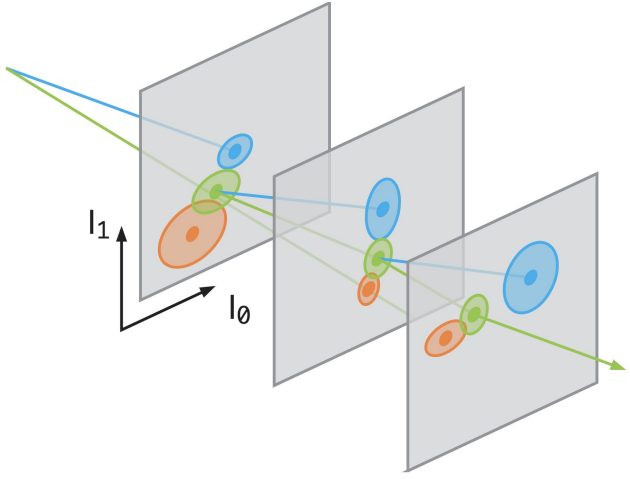
EICrecon: JANA2 based recon framework

EICrecon factory (interface)

ACTS: CKF Algorithm

Hits selection

acts/Core/include/Acts/TrackFinding/MeasurementSelector.hpp



CKF:

if no hits on surface→ nHoles++

for (track state : track state candidates):

Track state → hits on surface

Calculate chi2 of all hits and rank, find chi2min

if chi2min >chi2CutOff → save chi2min as outlier

<chi2CutOff → save up to numMeasurementsCutOff candidates

```
9   namespace eicrecon {
10      struct CKFTrackingConfig {
11          std::vector<double> m_etaBins = {};  // {this, "etaE
12          std::vector<double> m_chi2CutOff = {15.}; //{this, "
13          std::vector<size_t> m_numMeasurementsCutOff = {10};
14      };
15  }
```

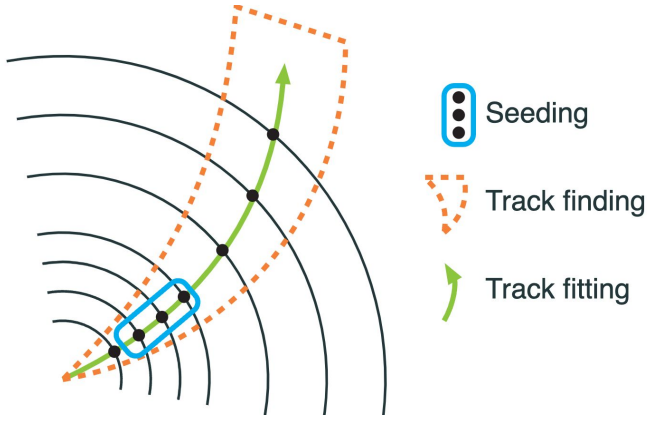
optimize cuts (Beatrice)

# of sensitive surfaces = nHoles + nMeasurements + nOutliers

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

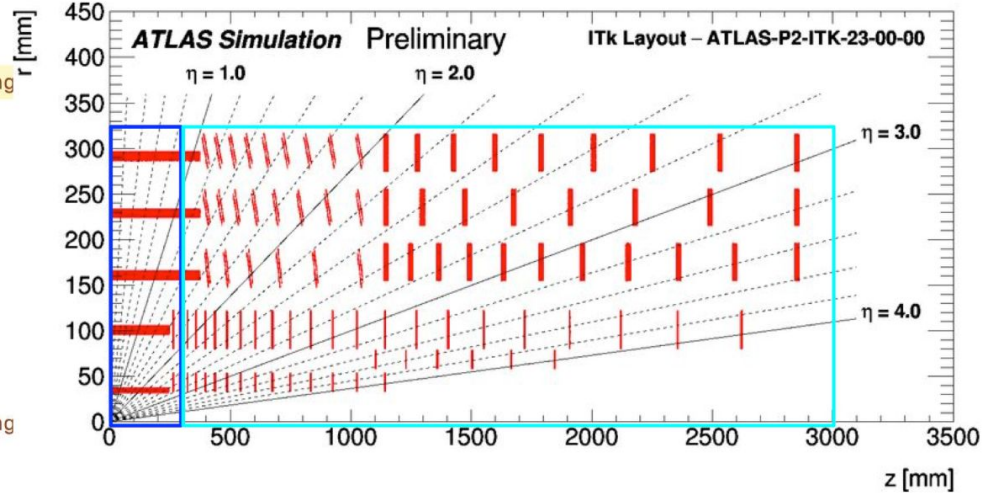
Initial Guess for CKF: 2. realistic seeding

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

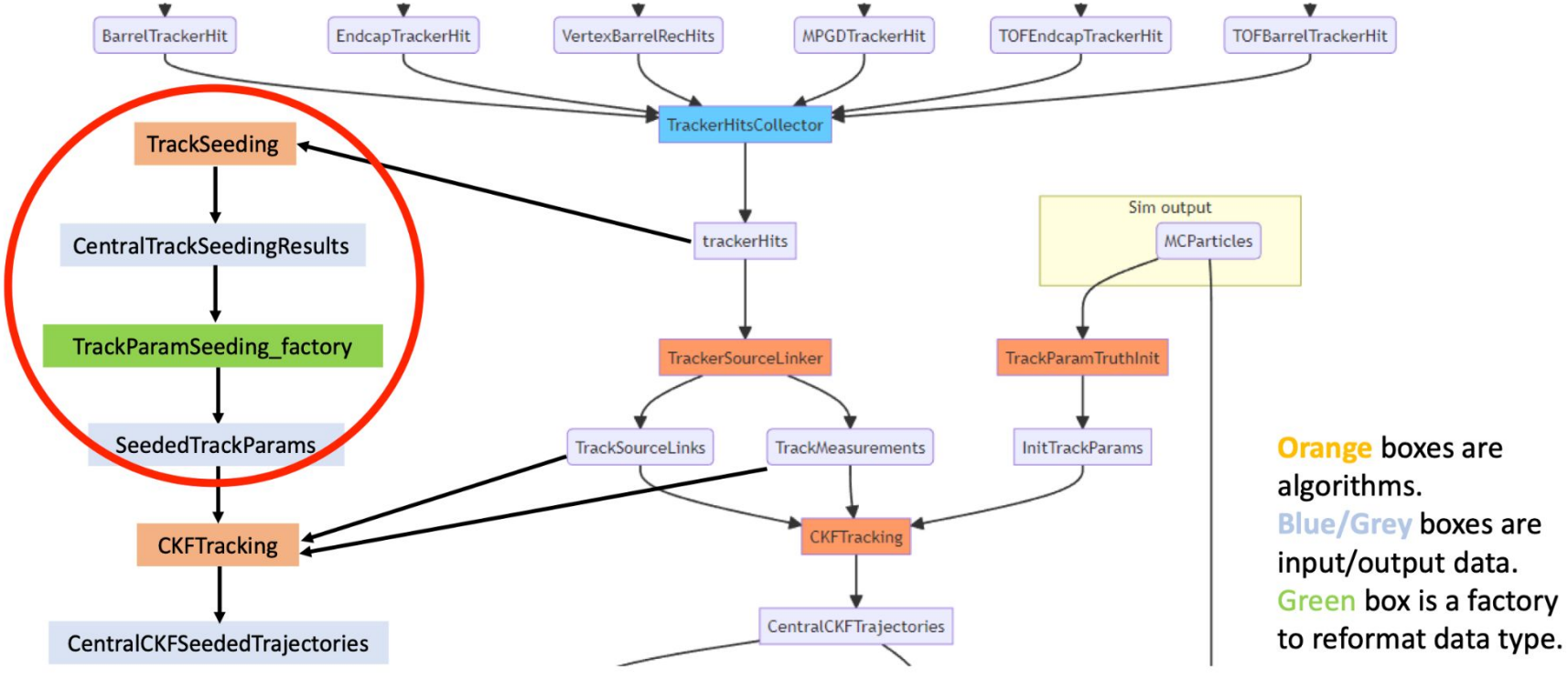
```
centralSeedConfirmationRange = acts.SeedConfirmationRang
    zMinSeedConf=-250 * u.mm,
    zMaxSeedConf=250 * u.mm,
    rMaxSeedConf=140 * u.mm,
    nTopForLargeR=1,
    nTopForSmallR=2,
    seedConfMinBottomRadius=60.0 * u.mm,
    seedConfMaxZOrigin=150.0 * u.mm,
    minImpactSeedConf=1.0 * u.mm,
)  # 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
  - save to output rootfile:
    - **TBD**: write an EICrecon factory to write trajectory info into data structure

- **TBD:** Hits associated with tracks

trajectory info from ACTS

```
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;
};
```

data structure for EICrecon

```
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          nHoles            // Number of missing hits
    - float             chi2              // Total chi2
    - 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
```

Summary

works

- Generate test particles
- GEANT simulation
  - Detailed geometry
  - Digitization at pixel level*
- Hit info to ACTS
- Initial guess for CKF
  - truth params smeared
  - seeding to init params
- CKF track finding/fitting algorithm
- Track params from fit
- Event display (Shyam)
  - code available on github)

To finish

- Hit clustering (Shujie)
  - Smearing at hit rather than pixel level to resolve multi hits
  - *clusterization algorithm*
- ACTS Seed finding/filter (Rey, Barak)
- Track info from ACTS
  - Raw hits → primary particle association (Barak)
  - Hits used w/track association
  - χ^2, # of measurements to rootfile (Shyam)
- Optimize track quality cuts (Beatrice)
  - χ^2 , # of measurements
- Validation plots
- Background embedding (Kolja?)