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U.S. DEPARTMENT OF ENERGY
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Tracker Hits to Trajectory

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With lots of help from Wouter and Dmitry

LBL EIC meeting
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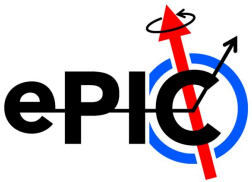
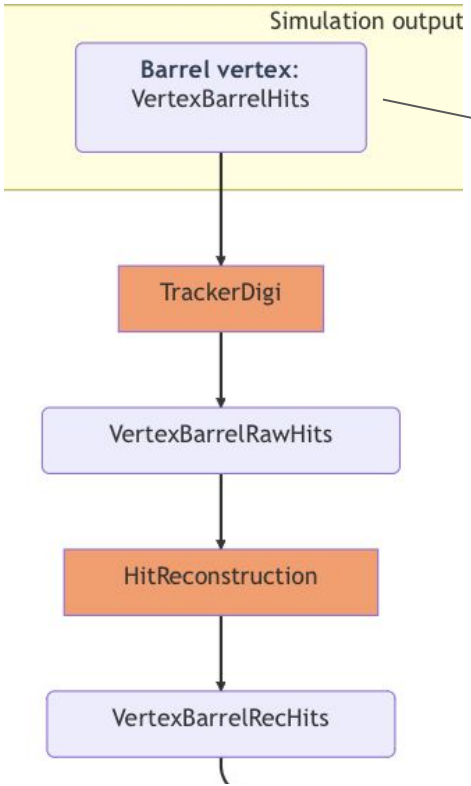
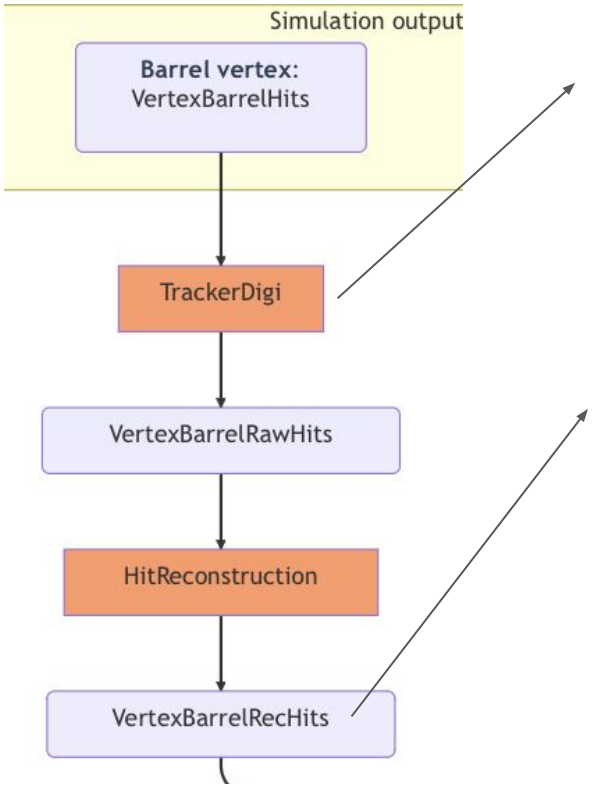





```
#---------- SimTrackerHit
edm4hep::SimTrackerHit:
  Description: "Simulated tracker hit"
  Author: "F.Gaede, DESY"
  Members:
    - uint64_t cellID      //ID of the sensor that created this hit
    - float EDep                    //energy deposited in the hit [GeV].
    - float time                    //proper time of the hit in the lab frame in [ns].
    - float pathLength              //path length of the particle in the sensitive material that resulte
    - int32_t   quality                 //quality bit flag.
    - edm4hep::Vector3d position    //the hit position in [mm].
    - edm4hep::Vector3f momentum    //the 3-momentum of the particle at the hits position in [GeV]
  OneToOneRelations:
    - edm4hep::MCParticle MCParticle //MCParticle that caused the hit.
  MutableExtraCode:
```



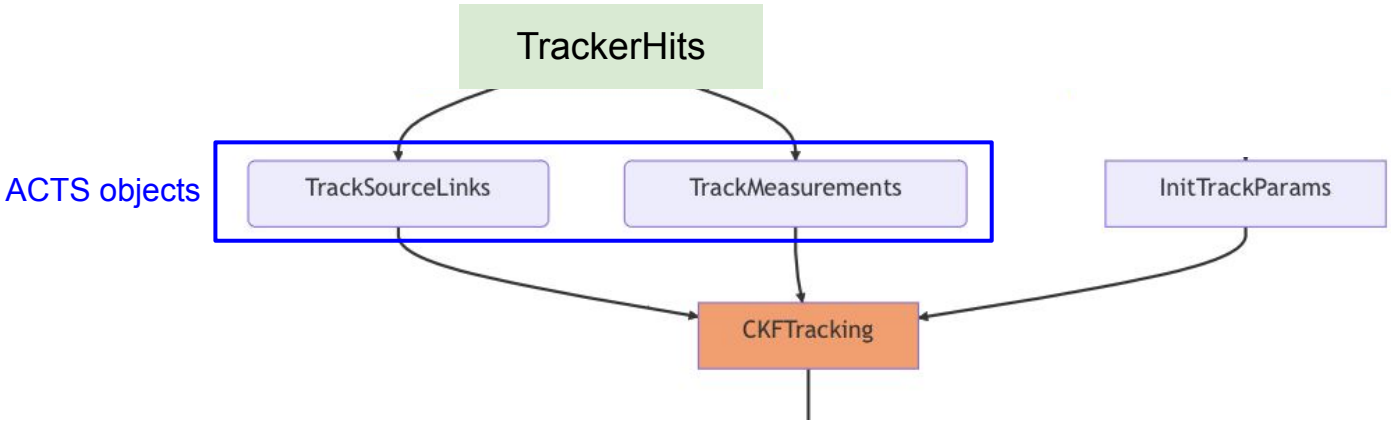

```
eicd::RawTrackerHit:
  Description: "Raw (digitized) tracker hit"
  Author: "W. Armstrong, S. Joosten"
  Members:
    - uint64_t          cellID            // The detector specific (geometrical) cell id.
    - int32_t           charge            // ADC value
    ## @TODO: is charge appropriate here? Needs revisiting.
    - int32_t           timeStamp         // TDC value.

eicd::TrackerHit:
  Description: "Tracker hit (reconstructed from Raw)"
  Author: "W. Armstrong, S. Joosten"
  Members:
    - uint64_t          cellID            // The detector specific (geometrical) cell id.
    - edm4hep::Vector3f position          // Hit (cell) position and time [mm, ns]
    - eicd::CovDiag3f   positionError     // Covariance Matrix
    - float             time              // Hit time
    - float             timeError         // Error on the time
    - float             edep              // Energy deposit in this hit [GeV]
    - float             edepError         // Error on the energy deposit [GeV]
```

Previous:

```
// Create source links
auto sourceLink = std::make_shared<ActsExamples::IndexSourceLink>(surface->geometryId(), hit_index);
sourceLinks.emplace_back(sourceLink);

auto measurement = Acts::makeMeasurement(*sourceLink, loc, cov, Acts::eBoundLoc0, Acts::eBoundLoc1);
measurements->emplace_back(std::move(measurement));
```

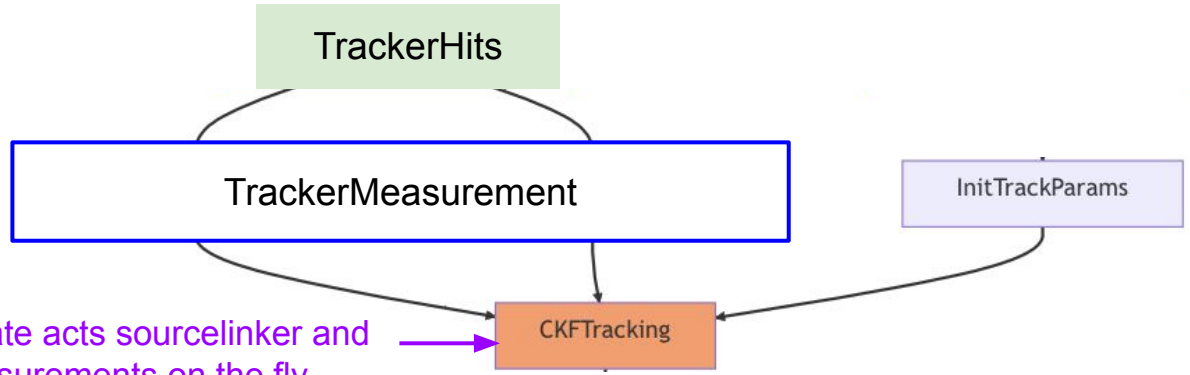


Now:

New data structure proposed by Wouter, link

```
edm4eic::Measurement2D:
  Description: "2D measurement (on an arbitrary surface)"
  Author: "W. Deconinck"
  Members:
    - uint64_t          surface          // Surface for bound coordinates (geometryID)
    - edm4hep::Vector2f loc              // 2D location on surface
    - float             time             // Measurement time
    - edm4eic::Cov3f    covariance       // Covariance on location and time
  VectorMembers:
    - float             weights          // Weight for each of the hits, mirrors hits array
  OneToManyRelations:
    - edm4eic::TrackerHit hits           // Hits in this measurement (single or clustered)
```

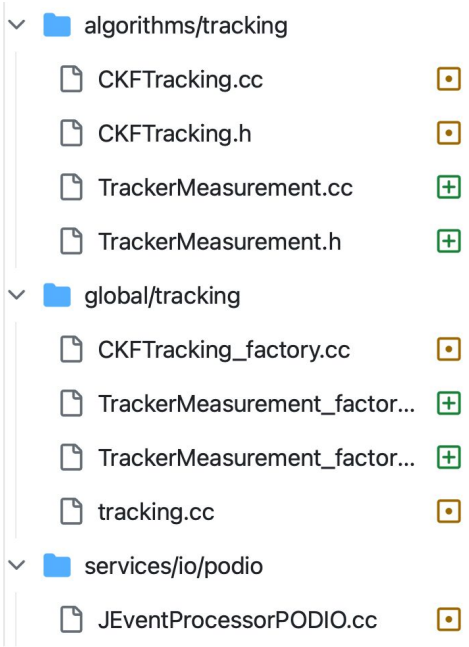
PODIO objects

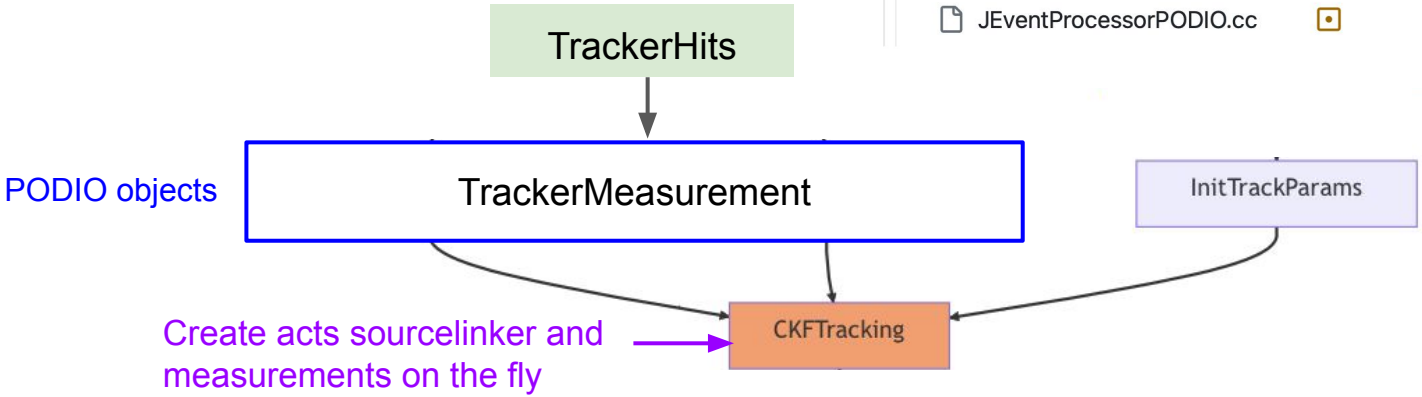


Create acts sourcelinker and measurements on the fly

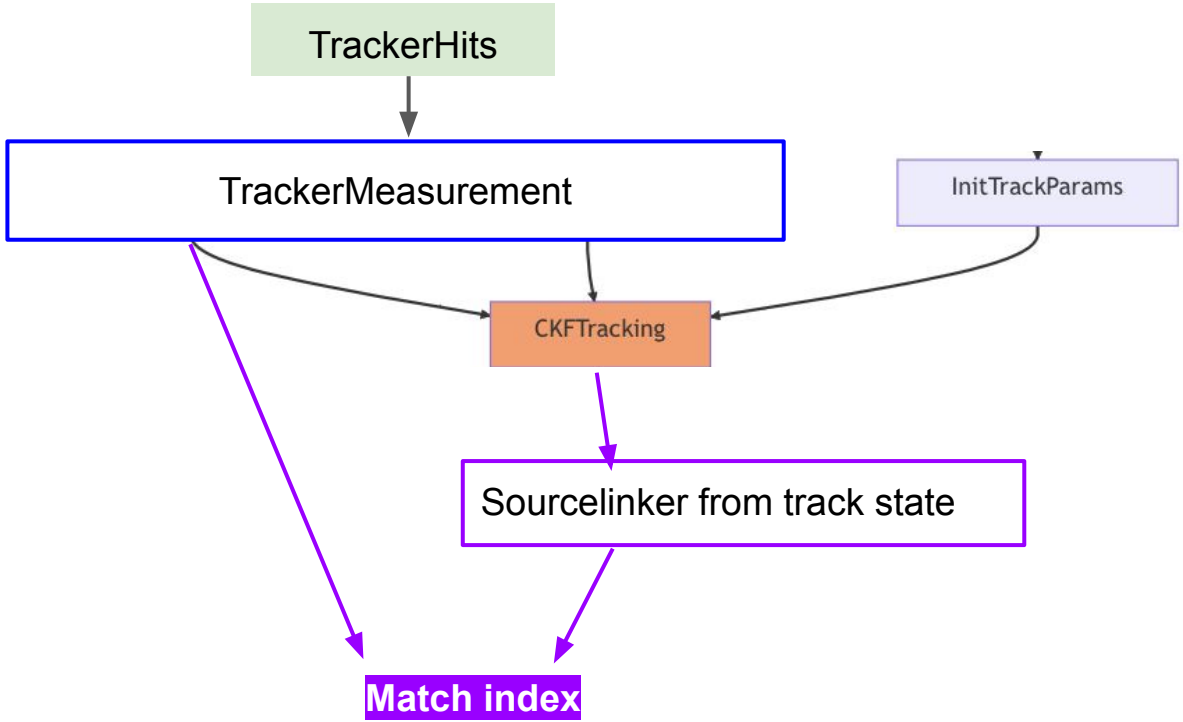
Now:

New factory, PR almost ready
https://github.com/eic/EICrecon/pull/1076





Associate Hits/TrackerMeasurement to Trajectory



geometryID (uint64_t) can be converted to volume and surface ID
https://acts.readthedocs.io/en/latest/core/geometry.html#geometry-identifier

```
[tracking:CentralTrackerMeasurements] [debug] TrackerMeasurement_factory::Process
[tracking:CentralTrackerMeasurements] [debug] All hits processed. Hits size: 8  measurements->size: 8
Create sourcelink:
2017612907939913759  0
2017612770500960287  1
2594073522804362575  2
2377900740690578766  3
2161727958576794957  4
3026419087031961180  5
2810246304918170429  6
3098476681069859392  7
trajectory state,measurement, outlier, hole: 11 4 3 0
visit backward
Measurement: GeoID=3026419087031961180 index=5
Outlier: GeoID=2810246304918170429 index=6
Outlier: GeoID=2594073522804362575 index=2
Outlier: GeoID=2377900740690578766 index=3
Measurement: GeoID=2161727958576794957 index=4
Measurement: GeoID=2017612907939913759 index=0
Measurement: GeoID=2017612770500960287 index=1
trajectory state,measurement, outlier, hole: 11 4 3 0
visit backward
Measurement: GeoID=3026419087031961180 index=5
Outlier: GeoID=2810246304918170429 index=6
Outlier: GeoID=2594073522804362575 index=2
Outlier: GeoID=2377900740690578766 index=3
Measurement: GeoID=2161727958576794957 index=4
Measurement: GeoID=2017612907939913759 index=0
Measurement: GeoID=2017612770500960287 index=1
trajectory state,measurement, outlier, hole: 11 4 3 0
visit backward
Measurement: GeoID=3026419087031961180 index=5
Outlier: GeoID=2810246304918170429 index=6
Outlier: GeoID=2594073522804362575 index=2
Outlier: GeoID=2377900740690578766 index=3
Measurement: GeoID=2161727958576794957 index=4
Measurement: GeoID=2017612907939913759 index=0
Measurement: GeoID=2017612770500960287 index=1
```

Hit index

3 trajectories reconstructed from exactly the same group of hits

Trajectory info in EICrecon output

_begin / _end: index range of the corresponding vector
e.g. measurementChi2[8…15] gives hit chi2 for the 2nd trajectory

_0: the first scalar vector in this data structure, e.g. measurementChi2

#1: the second vector of pointer (relation) in this data structure, e.g. measurementHits

```
CentralCKFSeededTrajectories.measurementChi2_begin = 0, 6, 12
CentralCKFSeededTrajectories.measurementChi2_end = 6, 12, 18
CentralCKFSeededTrajectories.outlierChi2_begin = 0, 0, 0
CentralCKFSeededTrajectories.outlierChi2_end = 0, 0, 0
CentralCKFSeededTrajectories.trackParameters_begin = 0, 1, 2
CentralCKFSeededTrajectories.trackParameters_end = 1, 2, 3
CentralCKFSeededTrajectories.measurementHits_begin = 0, 6, 12
CentralCKFSeededTrajectories.measurementHits_end = 6, 12, 18
CentralCKFSeededTrajectories.outlierHits_begin = 0, 0, 0
CentralCKFSeededTrajectories.outlierHits_end = 0, 0, 0
CentralCKFSeededTrajectories#0 = (vector<podio::ObjectID>*)0x55b59dcbd510
CentralCKFSeededTrajectories#0.index = 0, 1, 2
CentralCKFSeededTrajectories#0.collectionID = 59, 59, 59
CentralCKFSeededTrajectories#1 = (vector<podio::ObjectID>*)0x55b599dcf3b0
CentralCKFSeededTrajectories#1.index = 5, 0, 1, 2, 3, 4, 5, 0, 1, 2, 3, 4, 5, 0, 1, 2, 3, 4
CentralCKFSeededTrajectories#1.collectionID = 57, 57, 57, 57, 57, 57, 57, 57, 57, 57, 57, 57
CentralCKFSeededTrajectories_0 = (vector<float>*)0x55b59e4008d0
CentralCKFSeededTrajectories_1 = (vector<float>*)0x55b59e400b10
```

Collection ID → Names

```
root [1] podio_metadata->Show(0)
======> EVENT:0
 events___idTable = (podio::CollectionIDTable*)0x55df2c649230
 m_collectionIDs = (vector<int>*)0x55df2c649230
 m_names         = (vector<string>*)0x55df2c649248
 events___CollectionTypeInfo = (vector<tuple<int,string,bool,unsigned int> >*)0x55df2854bd80
 events___CollectionTypeInfo._3 = 400, 1, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400, 400,
400, 400
 events___CollectionTypeInfo._2 = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0
 events___CollectionTypeInfo._1 = edm4eic::ClusterCollection, edm4hep::RawCalorimeterHitCollection, edm4eic::CalorimeterH
tCollection, edm4eic::TrackerHitCollection, edm4eic::TrackerHitCollection, edm4eic::TrackSegmentCollection, edm4eic::Trac
ParametersCollection, edm4eic::TrajectoryCollection, edm4eic::TrackParametersCollection, edm4eic::TrajectoryCollection, e
m4eic::TrackParametersCollection, edm4eic::TrackSegmentCollection, edm4eic::VertexCollection, edm4eic::Measurement2DColle
tion, edm4eic::TrackerHitCollection, edm4eic::RawTrackerHitCollection, edm4eic::CherenkovParticleIDCollection, edm4eic::T
ackSegmentCollection, edm4eic::CherenkovParticleIDCollection, edm4eic::TrackSegmentCollection
 events___CollectionTypeInfo._0 = 30, 27, 28, 33, 35, 36, 59, 58, 62, 61, 56, 63, 64, 57, 55, 65, 66, 67, 68, 69
```

Measurement2D

root [1] uint64_t ss=2522015928766443068
(unsigned long) 2522015928766443068
root [2] std::cout << std::hex << ss<<endl;
2300002000002e3c

```
CentralTrackerMeasurements = (vector<edm4eic::Measurement2DData>*)0x55b59fa26830
CentralTrackerMeasurements.surface = 2522015928766443068, 2305843146652654139, 2017613045378873375, 2017612907
CentralTrackerMeasurements.loc.a = 7.500001, -0.280001, 0.700002, 0.660000, 0.540000, -1.000006
CentralTrackerMeasurements.loc.b = -6.460000, -4.040000, -1.800000, -0.720000, -0.540000, 300.000000
CentralTrackerMeasurements.time = 16.811001, -0.594000, -9.233000, 15.533000, -1.379000, 2.119000
CentralTrackerMeasurements.covariance.xx = 0.000033, 0.000033, 0.000033, 0.000033, 0.000033, 0.000833
CentralTrackerMeasurements.covariance.yy = 0.000033, 0.000033, 0.000033, 0.000033, 0.000033, 8.333333
CentralTrackerMeasurements.covariance.zz = 10.000000, 10.000000, 10.000000, 10.000000, 10.000000, 10.000000
CentralTrackerMeasurements.covariance.xy = 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
CentralTrackerMeasurements.covariance.xz = 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
CentralTrackerMeasurements.covariance.yz = 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
CentralTrackerMeasurements.weights_begin = 0, 1, 2, 3, 4, 5
CentralTrackerMeasurements.weights_end = 1, 2, 3, 4, 5, 6
CentralTrackerMeasurements.hits_begin = 0, 1, 2, 3, 4, 5
CentralTrackerMeasurements.hits_end = 1, 2, 3, 4, 5, 6
CentralTrackerMeasurements#0 = (vector<podio::ObjectID>*)0x55b59fa56900
CentralTrackerMeasurements#0.index = 0, 1, 0, 1, 2, 0
CentralTrackerMeasurements#0.collectionID = 38, 38, 40, 40, 40, 44
CentralTrackerMeasurements_0 = (vector<float>*)0x55b59fb46530
```

https://acts.readthedocs.io/en/latest/core/geometry.html

- Volume
- Boundary surfaces (for a volume)
- Layers (confined within a volume)
- Approach surfaces (for a layer)
- Sensitive surfaces (confined to a layer, also called modules)

Private Static Attributes

static constexpr Value **kApproachMask** = 0x0000000ff0000000

(2^8)-1 = 255 approach surfaces

static constexpr Value **kBoundaryMask** = 0x00ff000000000000

(2^8)-1 = 255 boundaries

static constexpr Value **kExtraMask** = 0x00000000000000ff

(2^8)-1 = 255 extra values

static constexpr Value **kLayerMask** = 0x0000fff000000000

(2^12)-1 = 4095 layers

static constexpr Value **kSensitiveMask** = 0x000000000fffff00

(2^20)-1 = 1048575 sensitive surfaces

static constexpr Value **kVolumeMask** = 0xff00000000000000

(2^8)-1 = 255 volumes

```
root [1] uint64_t ss=2522015928766443068
(unsigned long) 2522015928766443068
root [2] std::cout << std::hex << ss<<endl;
2300002000002e3c
```

```
eic::Measurement2DData>*)0x55b59fa26830
2015928766443068, 2305843146652654139, 2017613045378873375, 2017612907
001, -0.280001, 0.700002, 0.660000, 0.540000, -1.000006
0000, -4.040000, -1.800000, -0.720000, -0.540000, 300.000000
001, -0.594000, -9.233000, 15.533000, -1.379000, 2.119000
= 0.000033, 0.000033, 0.000033, 0.000033, 0.000033, 0.000833
= 0.000033, 0.000033, 0.000033, 0.000033, 0.000033, 8.333333
= 10.000000, 10.000000, 10.000000, 10.000000, 10.000000, 10.000000
= 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
= 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
= 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
= 0, 1, 2, 3, 4, 5
1, 2, 3, 4, 5, 6
0, 1, 2, 3, 4, 5
2, 3, 4, 5, 6
dio::ObjectID>*)0x55b59fa56900
, 0, 1, 2, 0
) = 38, 38, 40, 40, 40, 44
oat>*)0x55b59fb46530
```

To do:

1. Finalize PR
2. Prepare analysis scripts to convert geometry ID to surface, 2D position to 3D (Beatrice)
3. Next step: matching tracks and particles? (Minjung)