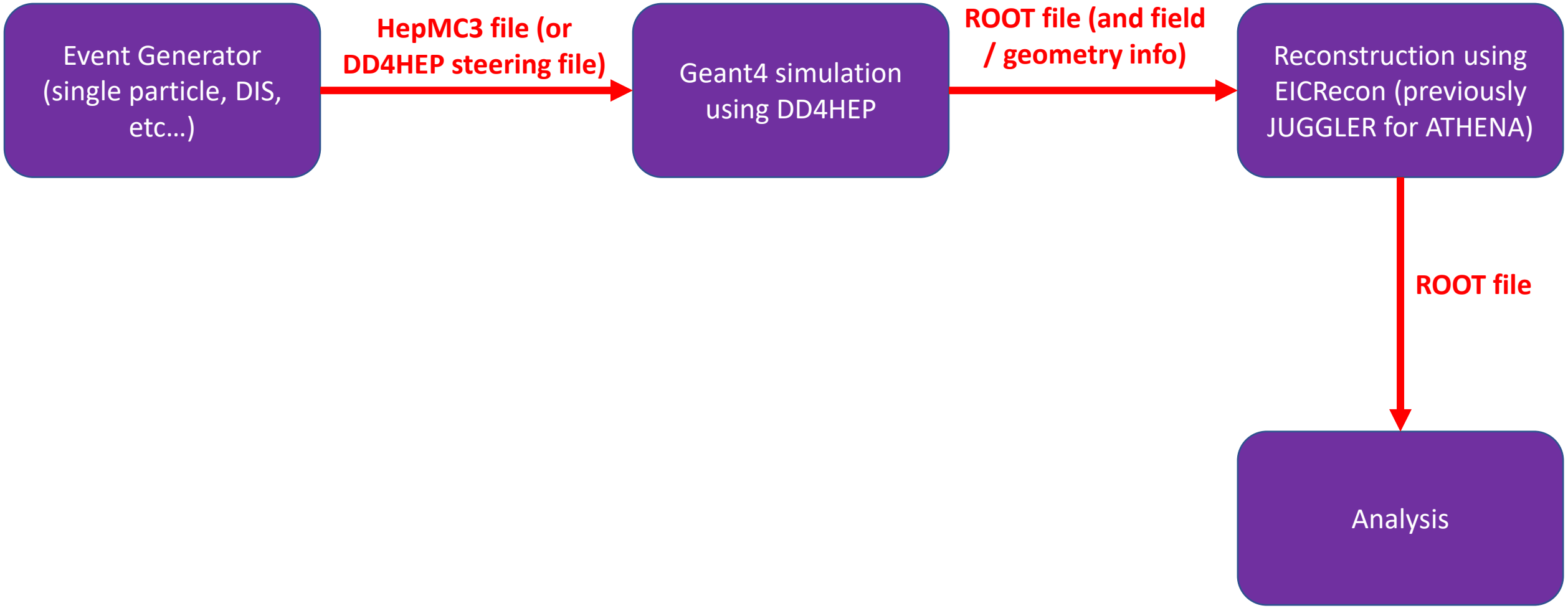
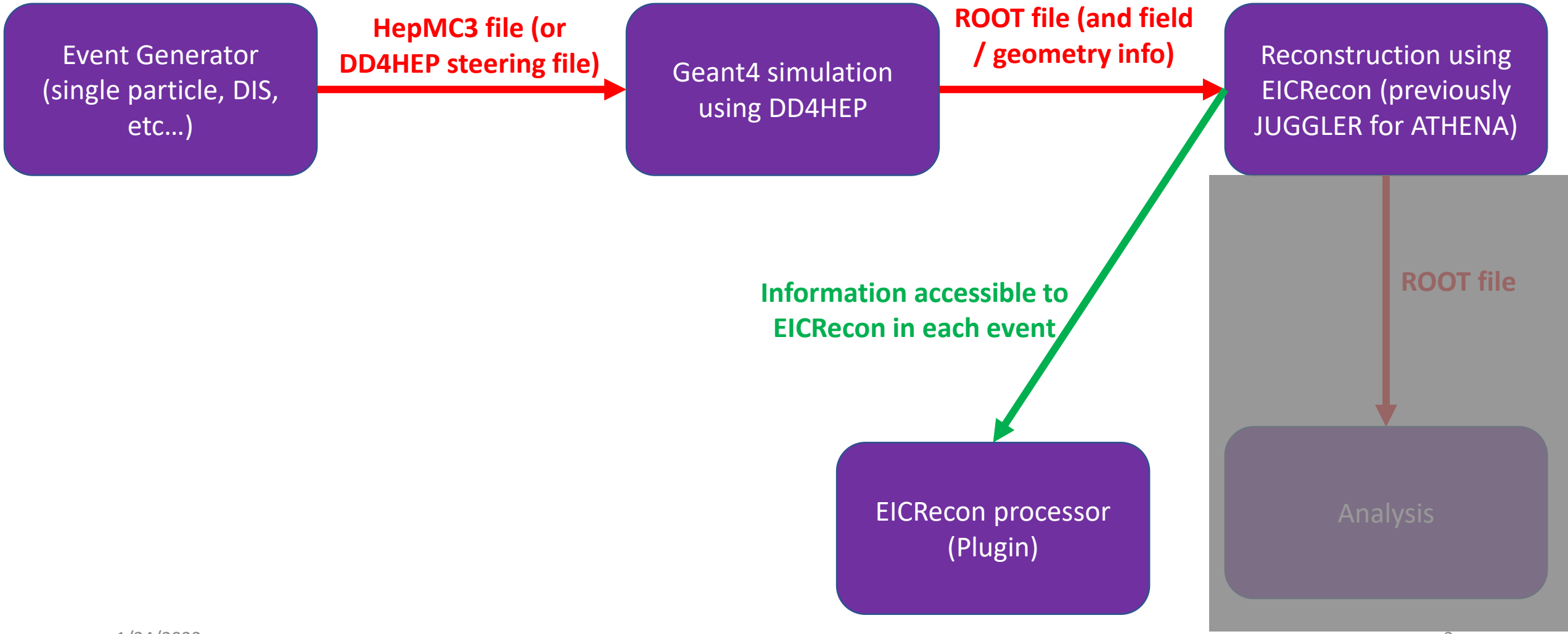
Track QA processor for EICRecon

Barak Schmookler

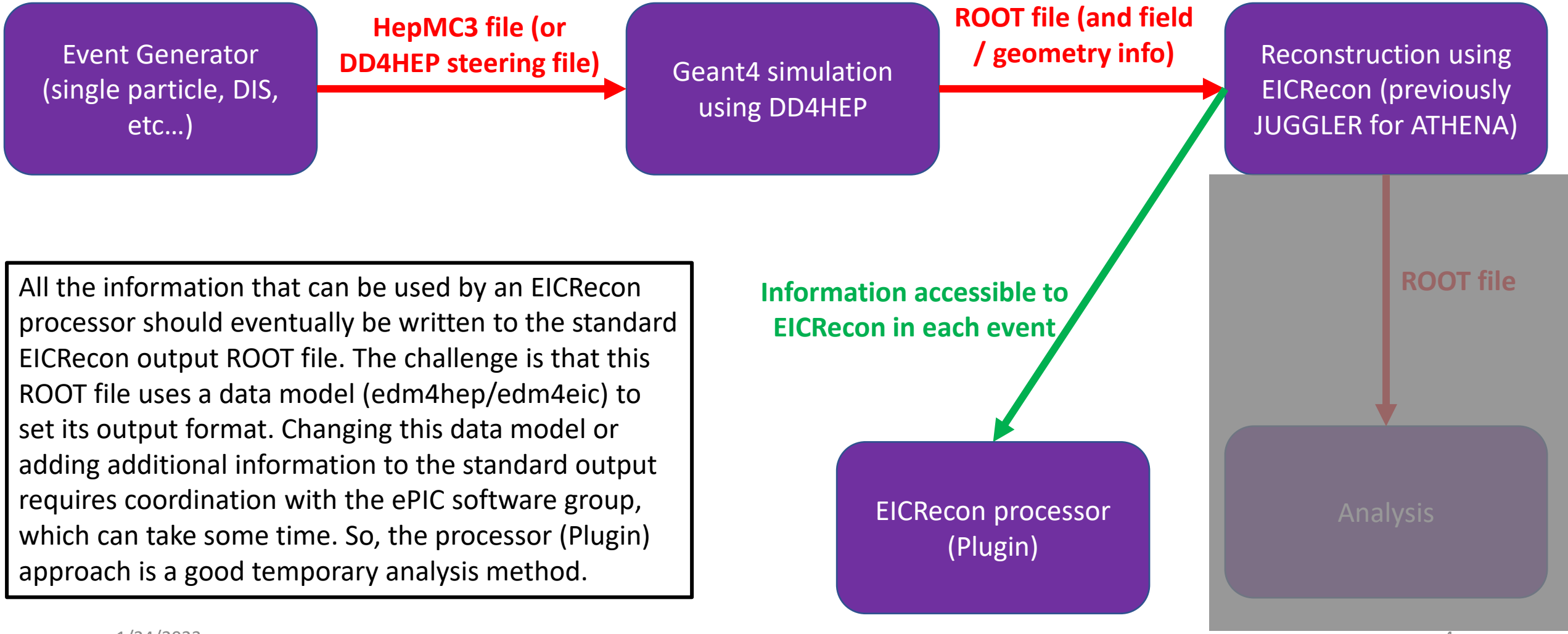
Simulation workflow for ePIC



Simulation workflow for ePIC



Simulation workflow for ePIC

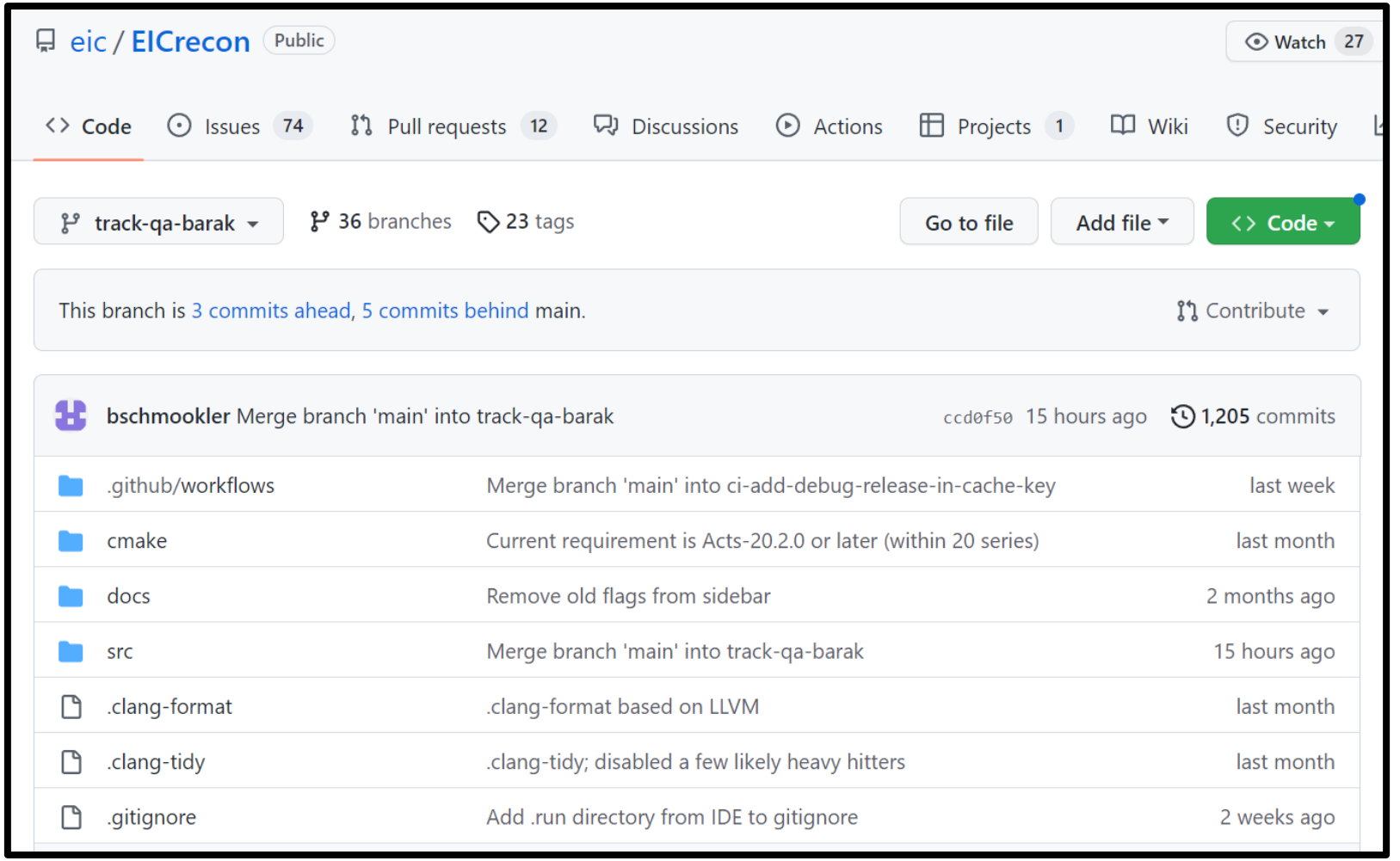


All the information that can be used by an EICRecon processor should eventually be written to the standard EICRecon output ROOT file. The challenge is that this ROOT file uses a data model (edm4hep/edm4eic) to set its output format. Changing this data model or adding additional information to the standard output requires coordination with the ePIC software group, which can take some time. So, the processor (Plugin) approach is a good temporary analysis method.

What tracking QA information do we need?

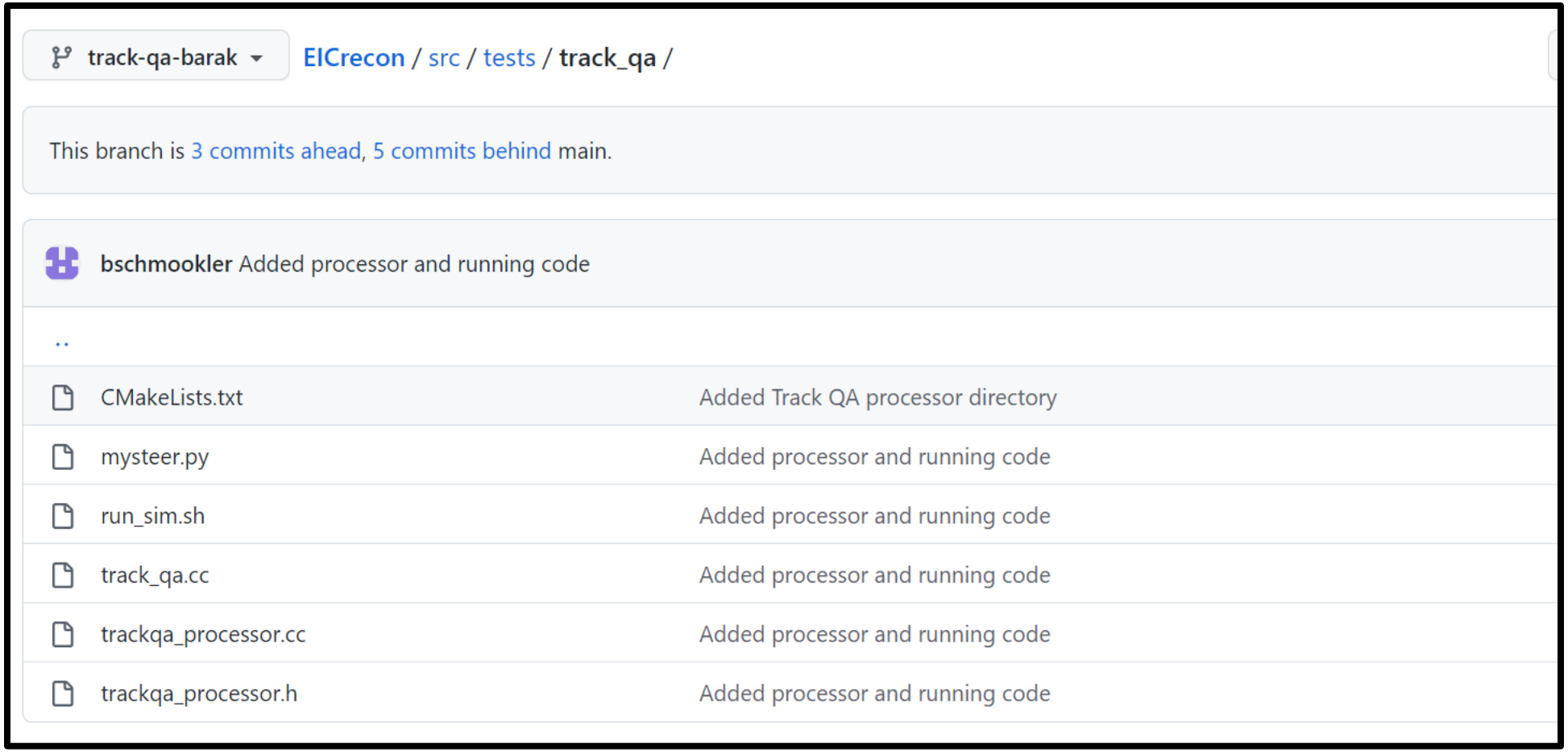
- In the EICRecon output ROOT file, we have access to the following:
  1. Digitized hits (positions) in the tracking detectors
  2. Track momentum vector at vertex for each track
- Other tracking information can currently only be accessed by an EICRecon processor:
  1. Number of measurements for a track
  2. Track chi-square and covariance matrix
  3. Track state information at tracking detector surfaces. This allows for the calculation of hit residuals, for example.

Track QA processor for EICRecon



https://github.com/eic/EICrecon/tree/track-qa-barak

Track QA processor for EICRecon



https://github.com/eic/EICrecon/tree/track-qa-barak/src/tests/track_qa

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

The Plugin first accesses the generated particle information

```
[2023-01-23 21:47:08.745] [track_qa] [trace] trackqa_processor event
[2023-01-23 21:47:08.745] [track_qa] [trace] -------------------------
[2023-01-23 21:47:08.745] [track_qa] [trace] Number of primary generated particles:
[2023-01-23 21:47:08.745] [track_qa] [trace]          1
[2023-01-23 21:47:08.745] [track_qa] [trace] Generated particle id, eta, p, E:
[2023-01-23 21:47:08.746] [track_qa] [trace]         11      -0.00       2.00       2.00
```

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

Then it gets the digitized tracker hit information

```
[2023-01-23 21:47:08.746] [track_qa] [trace] Detector SiBarrelTrackerRecHits has 2 digitized hits.
[2023-01-23 21:47:08.746] [track_qa] [trace] For digitized hit number 1:
[2023-01-23 21:47:08.746] [track_qa] [trace] Hit x, y, z, r, eta:
[2023-01-23 21:47:08.746] [track_qa] [trace]    -421.71      80.18       0.26     429.26       0.00
[2023-01-23 21:47:08.746] [track_qa] [trace] For digitized hit number 2:
[2023-01-23 21:47:08.746] [track_qa] [trace] Hit x, y, z, r, eta:
[2023-01-23 21:47:08.746] [track_qa] [trace]    -267.56      45.23       0.11     271.36       0.00
```

```
Detector SiBarrelVertexRecHits has 3 digitized hits.
For digitized hit number 1:
Hit x, y, z, r, eta:
   -118.69      17.72       0.04     120.00       0.00
For digitized hit number 2:
Hit x, y, z, r, eta:
    -47.54       6.66      -0.00      48.00       0.00
For digitized hit number 3:
Hit x, y, z, r, eta:
    -35.66       4.94      -0.00      36.00       0.00
```

```
Detector SiEndcapTrackerRecHits has 0 digitized hits.

Detector MPGDBarrelRecHits has 0 digitized hits.

Detector MPGDDIRCRecHits has 0 digitized hits.

Detector TOFBarrelRecHit has 1 digitized hits.
For digitized hit number 1:
Hit x, y, z, r, eta:
   -623.21     135.96      -0.00     637.87       0.00

Detector TOFEndcapRecHits has 0 digitized hits.
```

```
[2023-01-23 21:47:08.746] [track_qa] [trace] Total number of tracker hits is 6
```

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

Then, for each ACTS track, it finds general track information and the track parameters at the vertex

```
[2023-01-23 21:47:08.746] [track_qa] [trace] ------------------------
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of ACTS Trajectories: 1
[2023-01-23 21:47:08.746] [track_qa] [trace]
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of elements in trackTips 1
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of measurements in trajectory: 5
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of states in trajectory     : 11
[2023-01-23 21:47:08.746] [track_qa] [trace] Total chi-square of trajectory    :     6.18
[2023-01-23 21:47:08.746] [track_qa] [trace]  [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
[2023-01-23 21:47:08.746] [track_qa] [trace]    -0.01    -0.02     3.01     1.57    -0.50    0.00043    0.00042     0.0009
[2023-01-23 21:47:08.746] [track_qa] [trace] Trajectory p, eta:
[2023-01-23 21:47:08.746] [track_qa] [trace]       2.00       0.00
```

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

Then, for each ACTS track, it finds general track information and the track parameters at the vertex

```
[2023-01-23 21:47:08.746] [track_qa] [trace] ------------------------
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of ACTS Trajectories: 1
[2023-01-23 21:47:08.746] [track_qa] [trace]
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of elements in trackTips 1
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of measurements in trajectory: 5
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of states in trajectory     : 11
[2023-01-23 21:47:08.746] [track_qa] [trace] Total chi-square of trajectory    :     6.18
[2023-01-23 21:47:08.746] [track_qa] [trace]  [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
[2023-01-23 21:47:08.746] [track_qa] [trace]    -0.01    -0.02     3.01     1.57    -0.50    0.00043    0.00042     0.0009
[2023-01-23 21:47:08.746] [track_qa] [trace] Trajectory p, eta:
[2023-01-23 21:47:08.746] [track_qa] [trace]       2.00       0.00
```

General information about the track

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

Then, for each ACTS track, it finds general track information and the track parameters at the vertex

```
[2023-01-23 21:47:08.746] [track_qa] [trace] ------------------------
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of ACTS Trajectories: 1
[2023-01-23 21:47:08.746] [track_qa] [trace]
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of elements in trackTips 1
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of measurements in trajectory: 5
[2023-01-23 21:47:08.746] [track_qa] [trace] Number of states in trajectory     : 11
[2023-01-23 21:47:08.746] [track_qa] [trace] Total chi-square of trajectory    :     6.18
[2023-01-23 21:47:08.746] [track_qa] [trace]  [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
[2023-01-23 21:47:08.746] [track_qa] [trace]    -0.01    -0.02     3.01     1.57    -0.50    0.00043    0.00042     0.0009
[2023-01-23 21:47:08.746] [track_qa] [trace] Trajectory p, eta:
[2023-01-23 21:47:08.746] [track_qa] [trace]       2.00       0.00
```

Track parameters at vertex

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

For the track, it then steps through each track state and accesses the track parameters at that location

```
Now at State number 1
This is a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
    7.05    -0.35     2.84     1.57    -0.50     0.0014     0.0014     0.0011
State global x, y, z, r and pathlength:
   -622.27     128.82       0.02     635.46     638.52

Now at State number 2
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
 1844.65     0.34     2.85     1.57    -0.50    0.00049    0.00041     0.0011
State global x, y, z, r and pathlength:
    630.00      -0.01      -0.02     630.00     630.67
```

•••

```
Now at State number 7
This is a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
    0.14    -0.00     2.98     1.57    -0.50      0.004    0.00034        0.1
State global x, y, z, r and pathlength:
   -118.70      17.60       0.02     120.00     120.00
```

•••

```
Now at State number 10
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
  105.14    -0.01     3.00     1.57    -0.50       0.05       0.01        0.1
State global x, y, z, r and pathlength:
     35.00      -0.01      -0.02      35.00      35.00

Now at State number 11
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
   84.89    -0.01     3.00     1.57    -0.50       0.05       0.01        0.1
State global x, y, z, r and pathlength:
     28.25      -0.01      -0.02      28.25      28.25

Number of calibrated states: 6
------------------------
```

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

For the track, it then steps through each track state and accesses the track parameters at that location

```
Now at State number 1
This is a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
    7.05    -0.35     2.84     1.57    -0.50     0.0014     0.0014     0.0011
State global x, y, z, r and pathlength:
   -622.27     128.82       0.02     635.46     638.52

Now at State number 2
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
 1844.65     0.34     2.85     1.57    -0.50    0.00049    0.00041     0.0011
State global x, y, z, r and pathlength:
    630.00      -0.01      -0.02     630.00     630.67
```

•••

```
Now at State number 7
This is a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
    0.14    -0.00     2.98     1.57    -0.50      0.004    0.00034        0.1
State global x, y, z, r and pathlength:
   -118.70      17.60       0.02     120.00     120.00
```

•••

```
Now at State number 10
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
  105.14    -0.01     3.00     1.57    -0.50       0.05       0.01        0.1
State global x, y, z, r and pathlength:
     35.00      -0.01      -0.02      35.00      35.00

Now at State number 11
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
   84.89    -0.01     3.00     1.57    -0.50       0.05       0.01        0.1
State global x, y, z, r and pathlength:
     28.25      -0.01      -0.02      28.25      28.25

Number of calibrated states: 6
------------------------
```

Number of calibrated states is equal to number of digitized tracker hits and is close to number of measurements in the track

Example event: single electron with p = 2 GeV, η = 0
Truth seeded tracking

Using the above information, we can compare the digitized tracker hits to the track parameters at that detector surface.

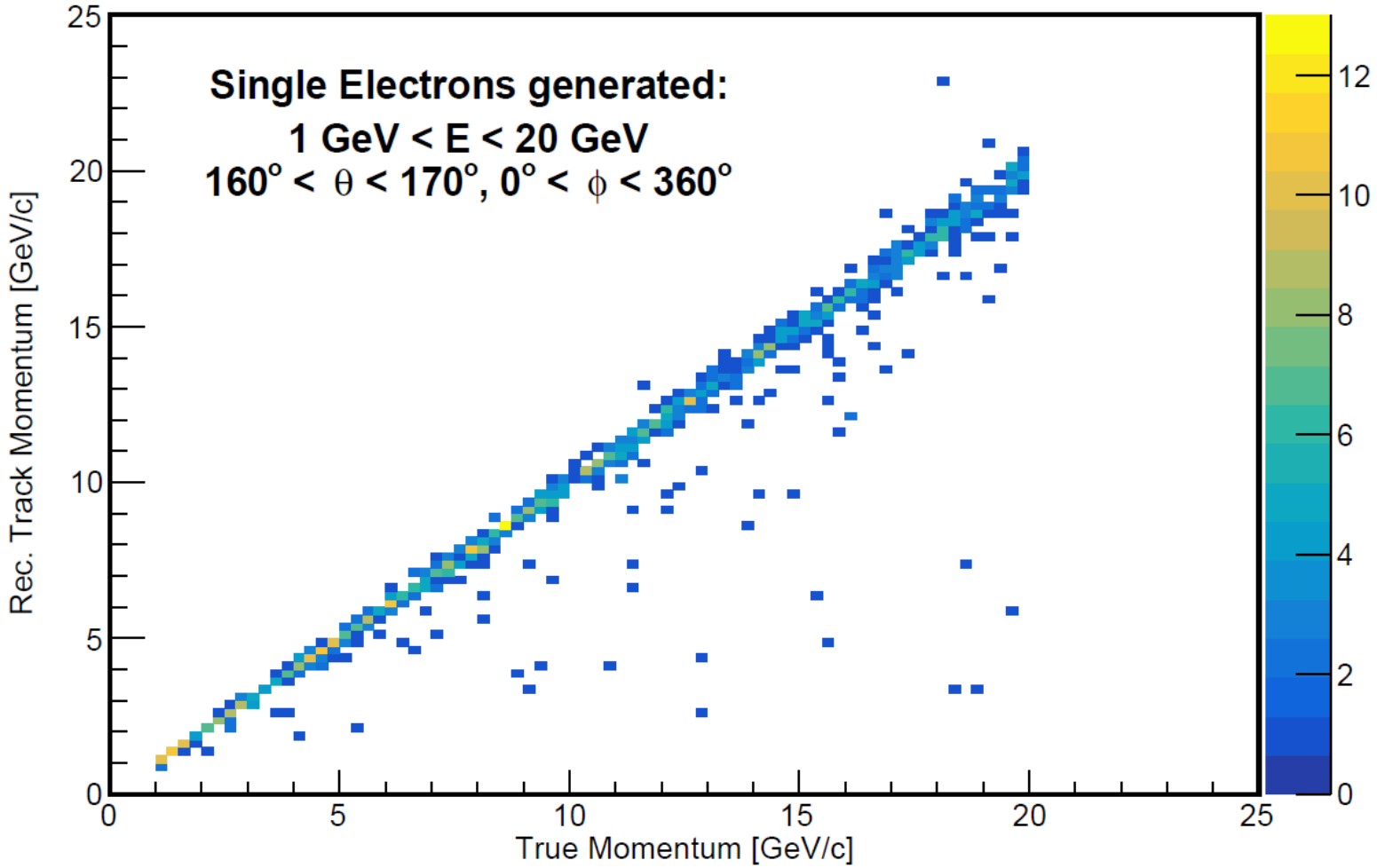
Digitized hits

```
Detector SiEndcapTrackerRecHits has 0 digitized hits.

Detector MPGDBarrelRecHits has 0 digitized hits.

Detector MPGDDIRCRecHits has 0 digitized hits.

Detector TOFBarrelRecHit has 1 digitized hits.
For digitized hit number 1:
Hit x, y, z, r, eta:
   -623.21      135.96       -0.00      637.87        0.00

Detector TOFEndcapRecHits has 0 digitized hits.
```

Track parameters

```
Now at State number 1
This is a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
    7.05    -0.35     2.84     1.57    -0.50     0.0014     0.0014     0.0011
State global x, y, z, r and pathlength:
   -622.27     128.82       0.02     635.46     638.52

Now at State number 2
This is NOT a calibrated state.
 [loc 0]  [loc 1]    [phi]  [theta]    [q/p]  [err phi]   [err th]  [err q/p]
 1844.65     0.34     2.85     1.57    -0.50    0.00049    0.00041     0.0011
State global x, y, z, r and pathlength:
    630.00      -0.01      -0.02     630.00     630.67
```

We can make plots directly in this processor



Summary / Next steps

- We have written an EICRecon processor (Plugin) which can access additional information compared to the standard reconstructed ROOT file.
- We need to better understand some of the variables and decide what plots we want to make.
- Then we can use this processor for our track seeding studies.