Single-particle simulation study of measurements, outliers, and holes

Barak Schmookler

Motivation and event generation

- Motivation: study how often tracker hits which should be classified as measurement hits are actually classified as outliers or ‘holes’.
  - Distinction between measurement hits and outlier hits in Acts is based on chi-square. 15 by default.
  - I define ‘holes’ as tracker hits that are associated with the generated particle but are completely missing from the track. This may differ a bit from the Acts definition.
- Event generation:

1000 single negative muon events

P = [-0.5,20] GeV/c; eta = [-4,4]

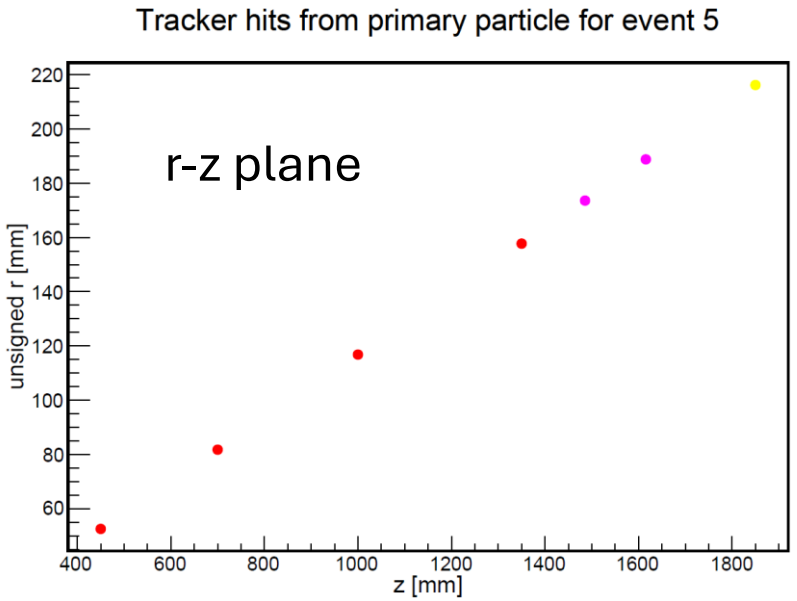
(vx, vy, vz) = (0,0,0)

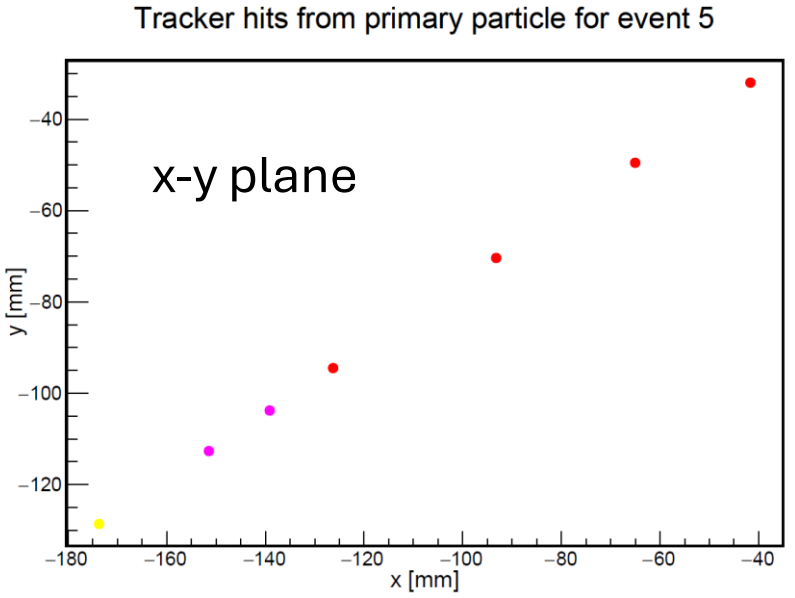
Truth-seeded tracking

Example event 1

```
Event statistics:
SimHits associated with primary particle = 7 / 7
RecHits associated with primary particle = 7
Number of correctly-identified measurement hits = 7 / 7
Number of outlier hits that should be measurement hits = 0 / 0
Number of RecHits associated with primary particle completely missing from track = 0 / 7
```

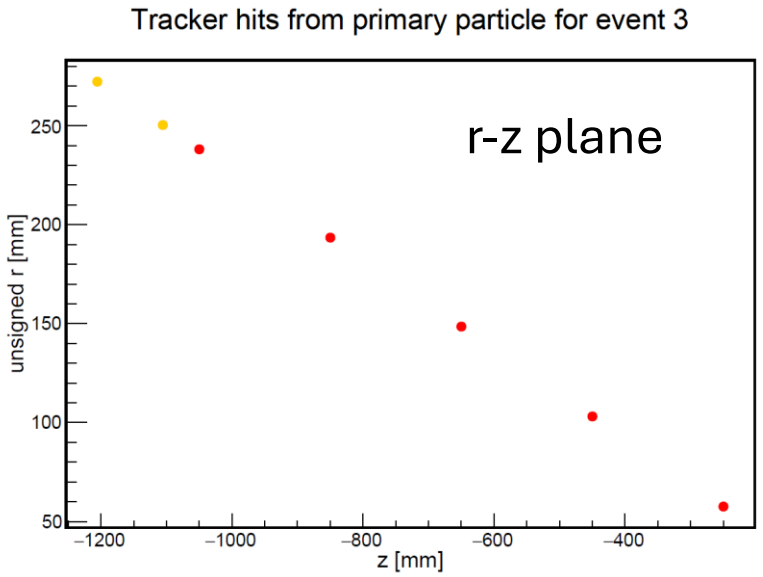
All 7 hits that are associated (on the Geant level) with the primary particle are classified as measurement hits and used in the track fit.



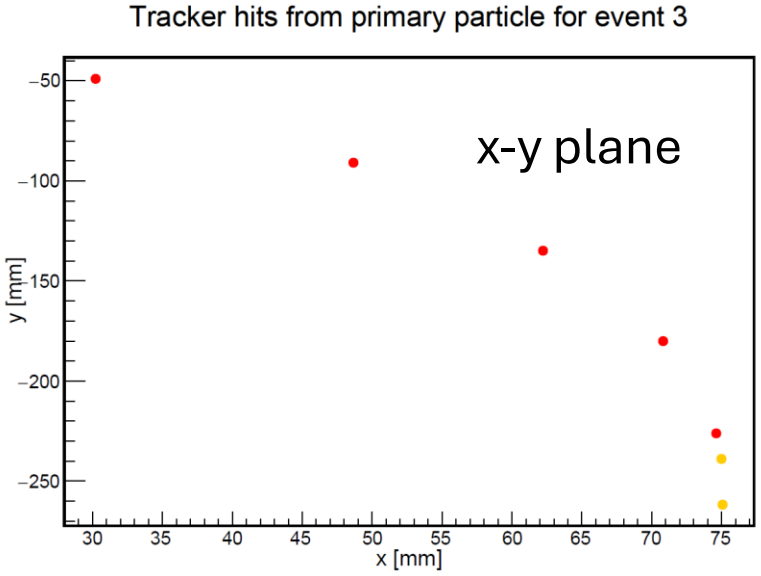


Si Endcap
Si Vertex
Si Barrel
Fwd MPGD
Bwd MPGD
Barrel MPGD
Out Barrel MPGD
TOF Endcap
TOF Barrel

Example event 2



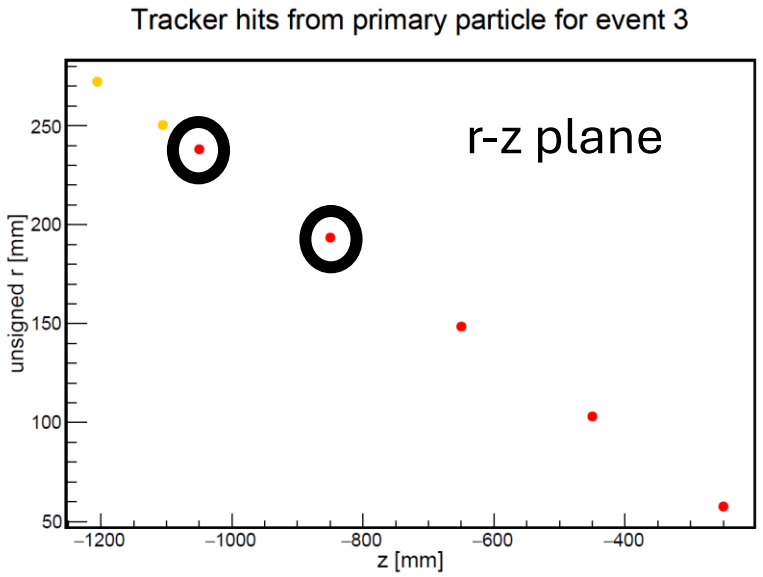

```
Event statistics:
SimHits associated with primary particle = 7 / 7
RecHits associated with primary particle = 7
Number of correctly-identified measurement hits = 2 / 2
Number of outlier hits that should be measurement hits = 0 / 0
Number of RecHits associated with primary particle completely missing from track = 5 / 7
```



Only 2 out of 7 tracker hits associated with the generated particle are classified as measurement hits.

Si Endcap
Si Vertex
Si Barrel
Fwd MPGD
Bwd MPGD
Barrel MPGD
Out Barrel MPGD
TOF Endcap
TOF Barrel

Example event 2

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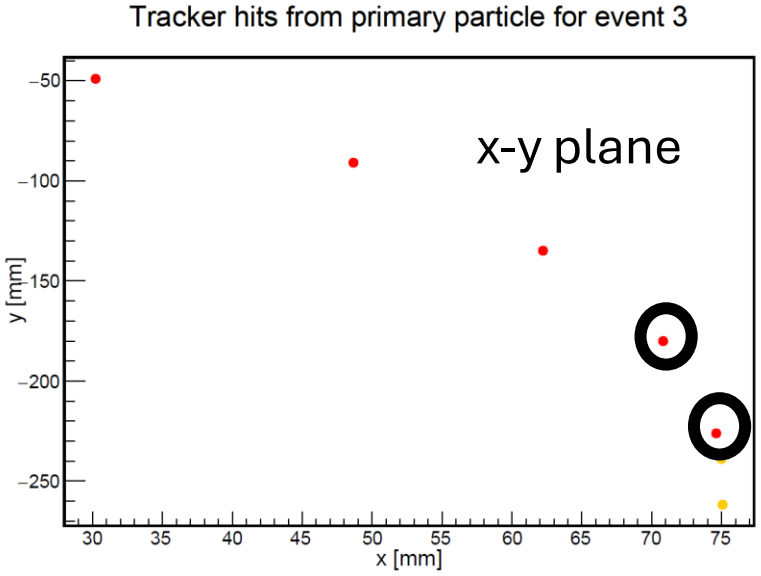
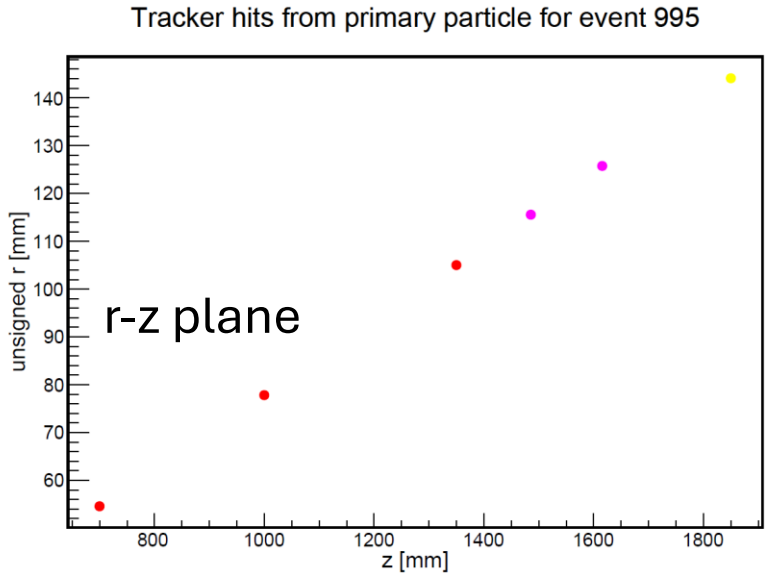


Only 2 out of 7 tracker hits associated with the generated particle are classified as measurement hits.

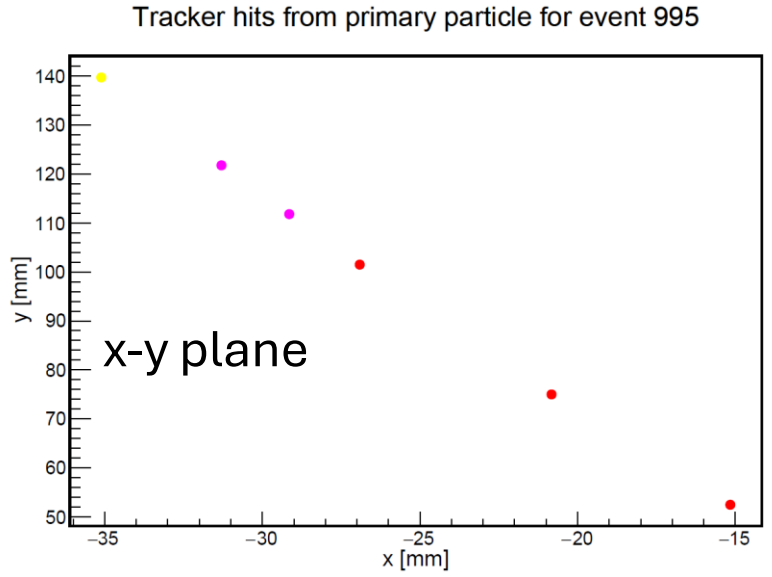
The 2 measurement hits are the outer Si Endcap hits.

Si Endcap
Si Vertex
Si Barrel
Fwd MPGD
Bwd MPGD
Barrel MPGD
Out Barrel MPGD
TOF Endcap
TOF Barrel

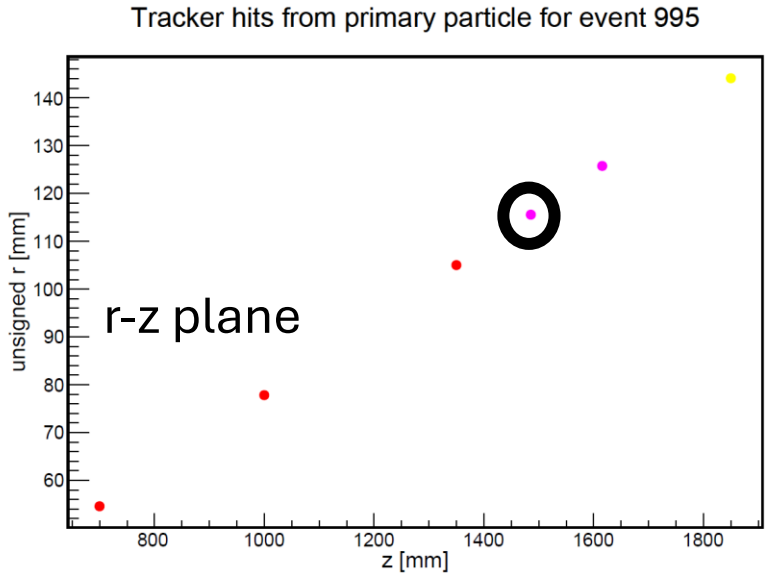
Example event 3

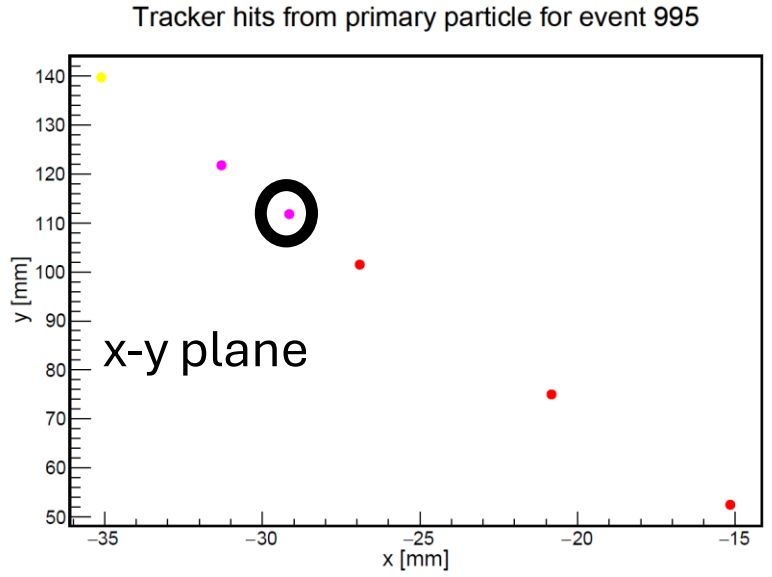



```
Event statistics:
SimHits associated with primary particle = 6 / 6
RecHits associated with primary particle = 5
Number of correctly-identified measurement hits = 3 / 3
Number of outlier hits that should be measurement hits = 1 / 1
Number of RecHits associated with primary particle completely missing from track = 1 / 5
```



Example event 3



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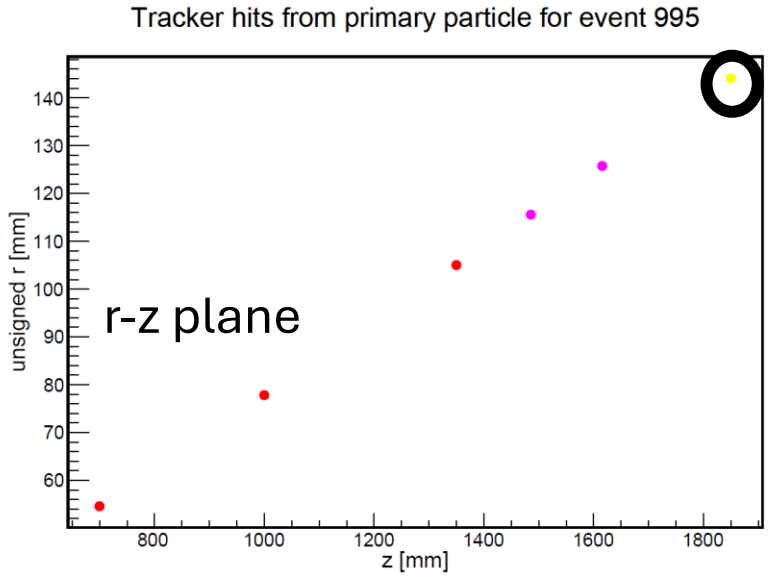
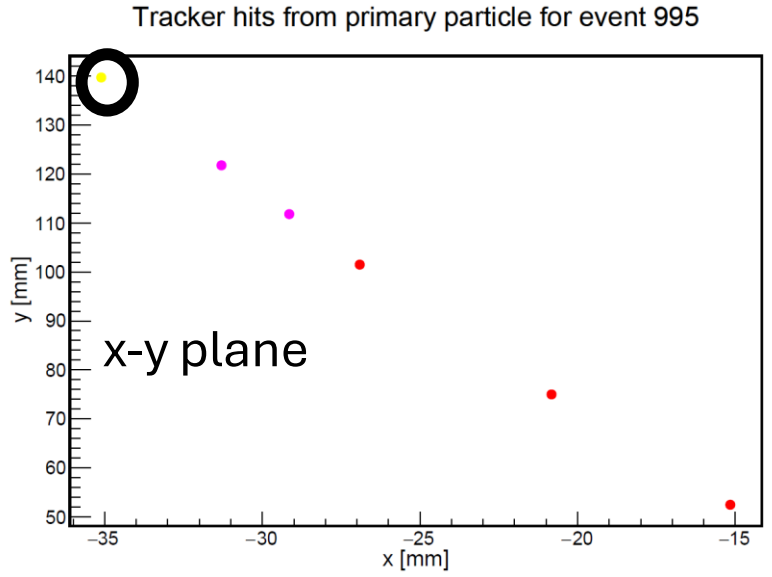
```

Inner (first) MPGD hit is not digitized. So, Acts will not know about it.

Example event 3



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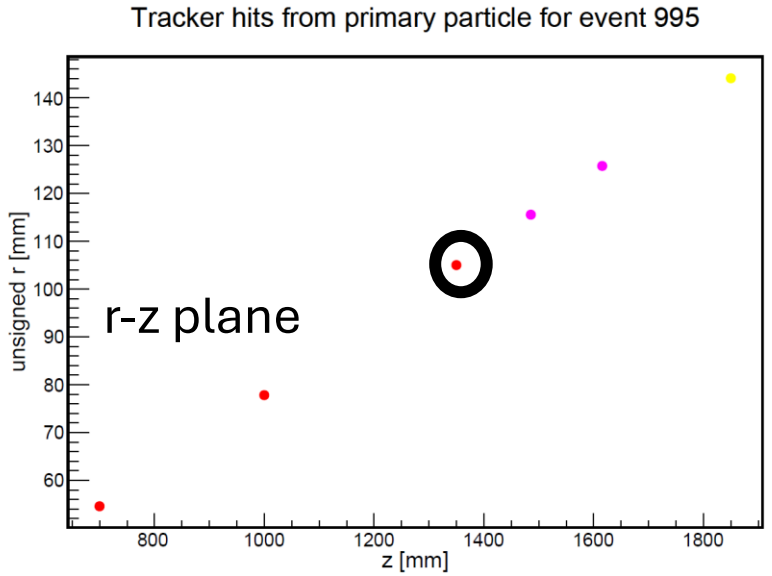
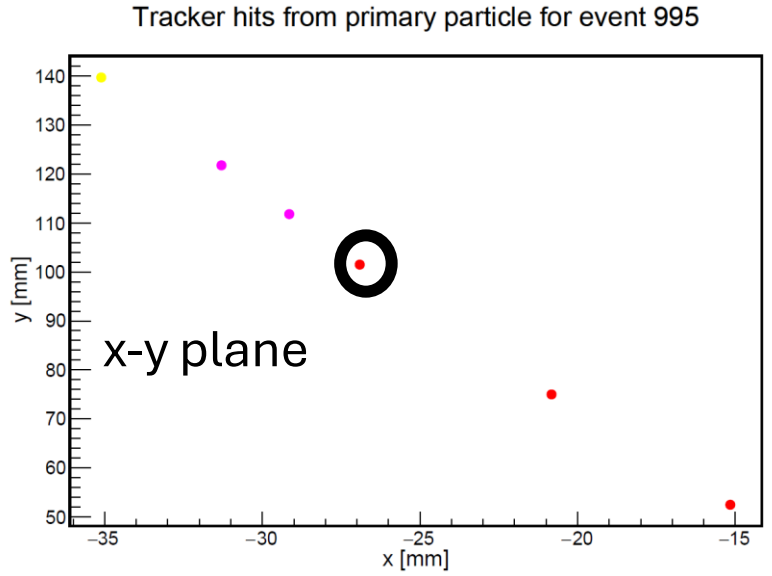
TOF hit is missing from the track.

Si Endcap
Si Vertex
Si Barrel
Fwd MPGD
Bwd MPGD
Barrel MPGD
Out Barrel MPGD
TOF Endcap
TOF Barrel

Example event 3



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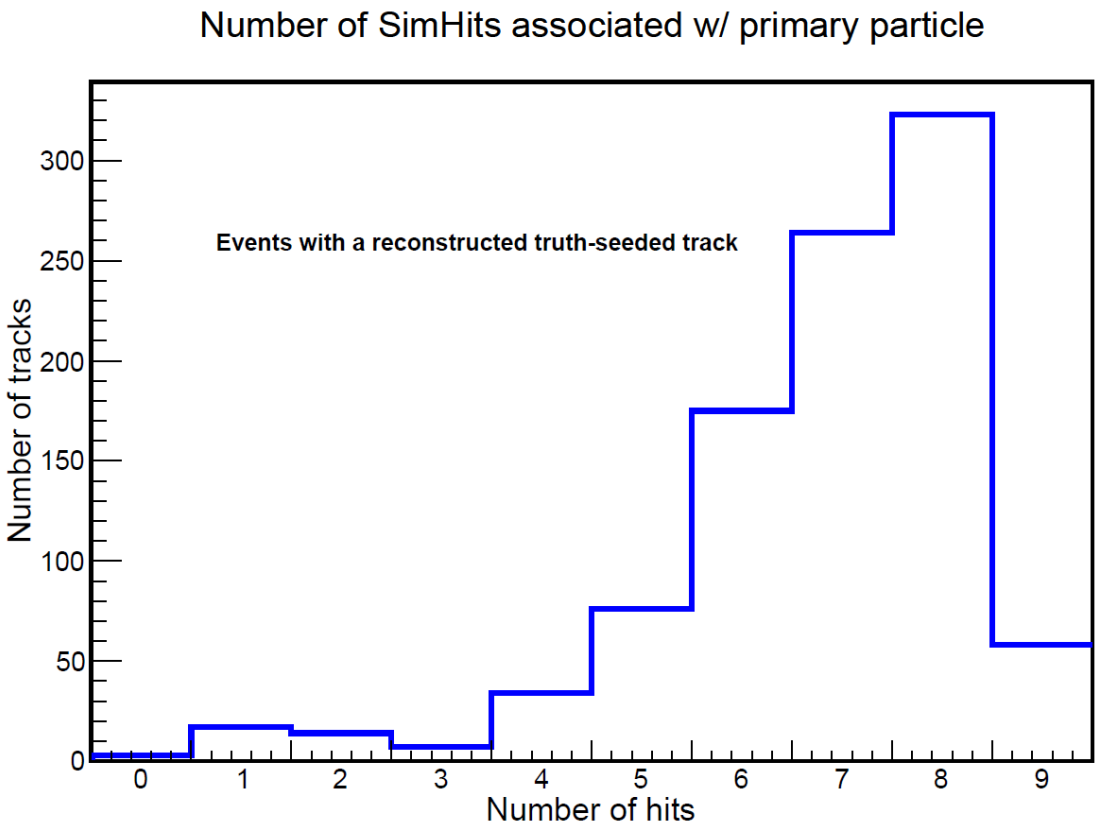
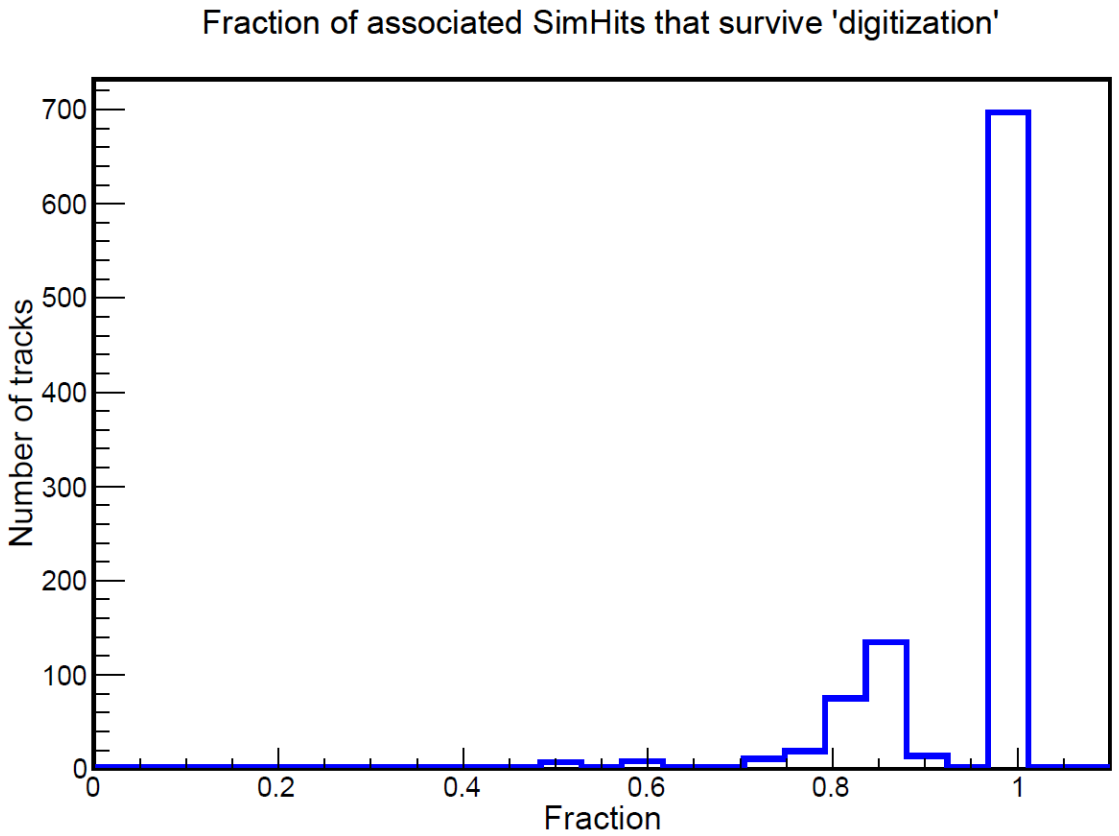
TOF hit is missing from the track.

Outermost Si Endcap hit is classified as an outlier.

Number of tracker hits and fraction of ‘digitization’



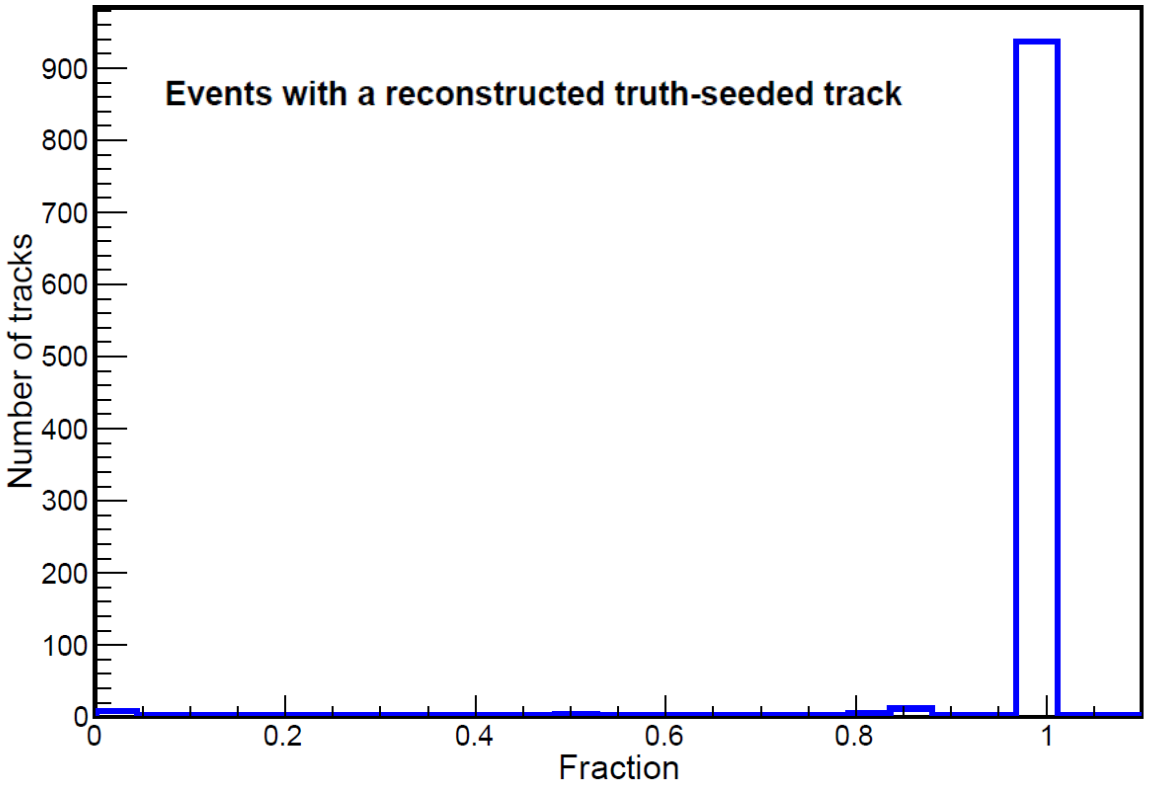
For events with a reconstructed track, this shows the number of hits in the tracking detectors that are associated to the thrown particle at the Geant level.



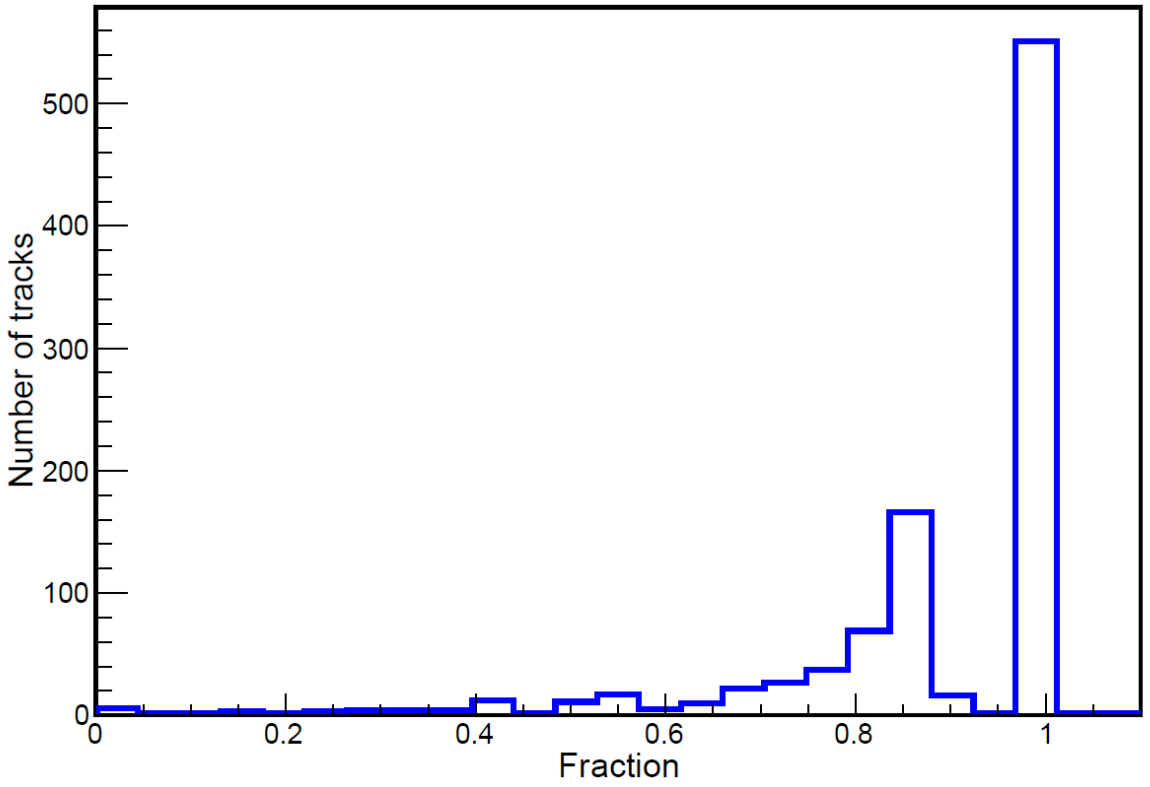
A small fraction of the Geant hits are lost during ‘digitization’. A cut is applied on the energy deposition during this step. Acts is then passed the ‘digitized’ hits.

Fraction of measurement hits

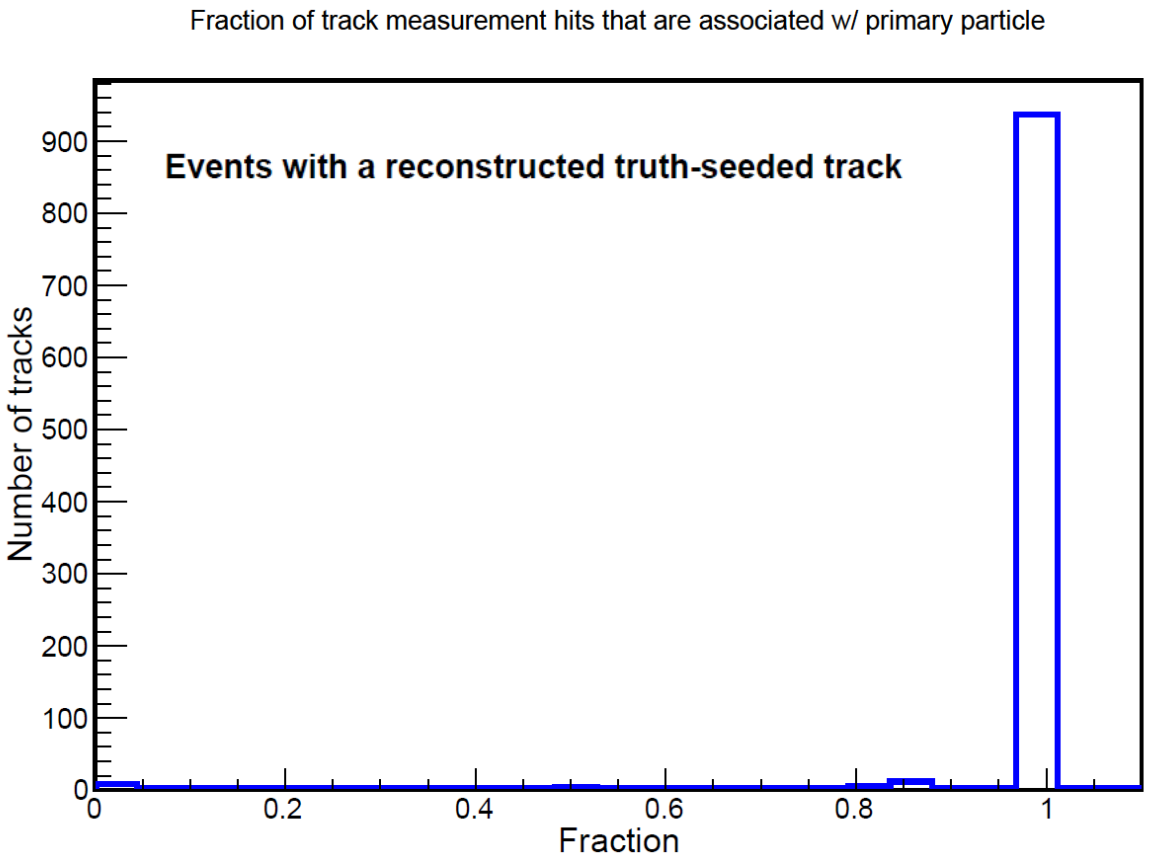
Fraction of track measurement hits that are associated w/ primary particle

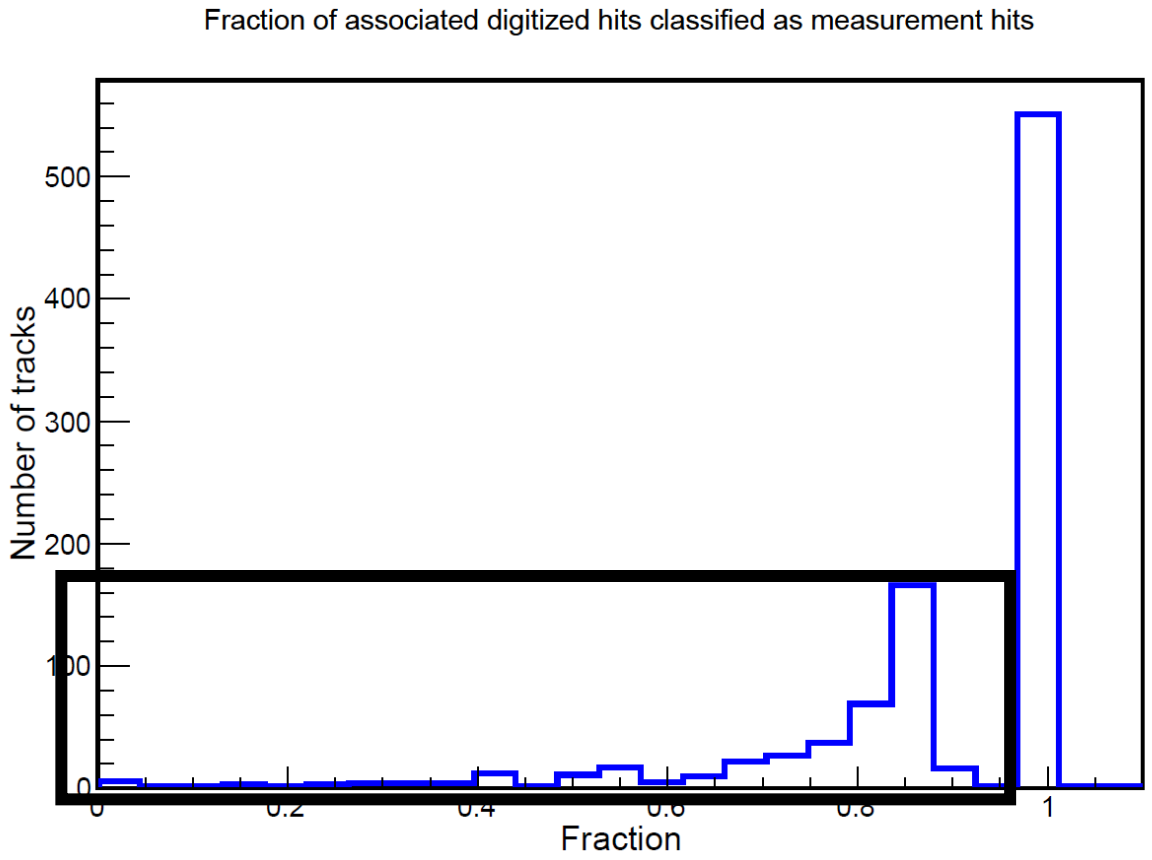


Fraction of associated digitized hits classified as measurement hits



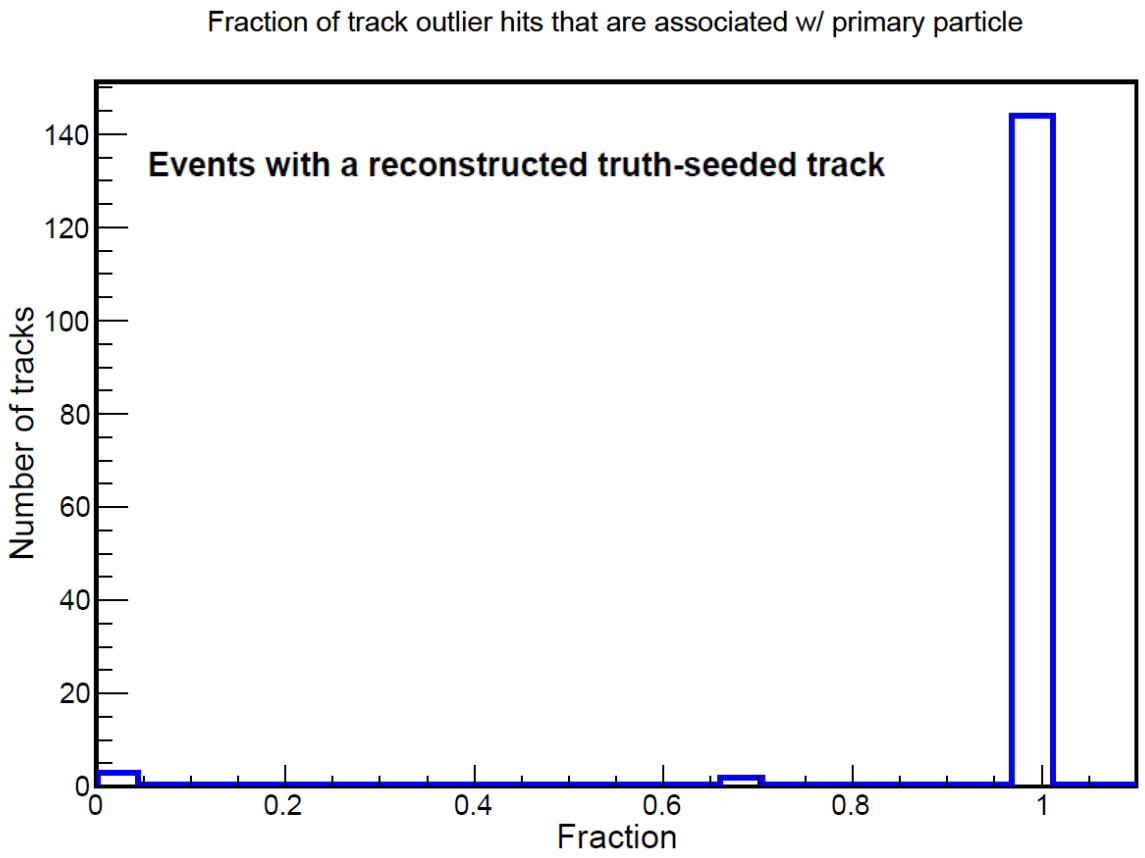
Fraction of measurement hits

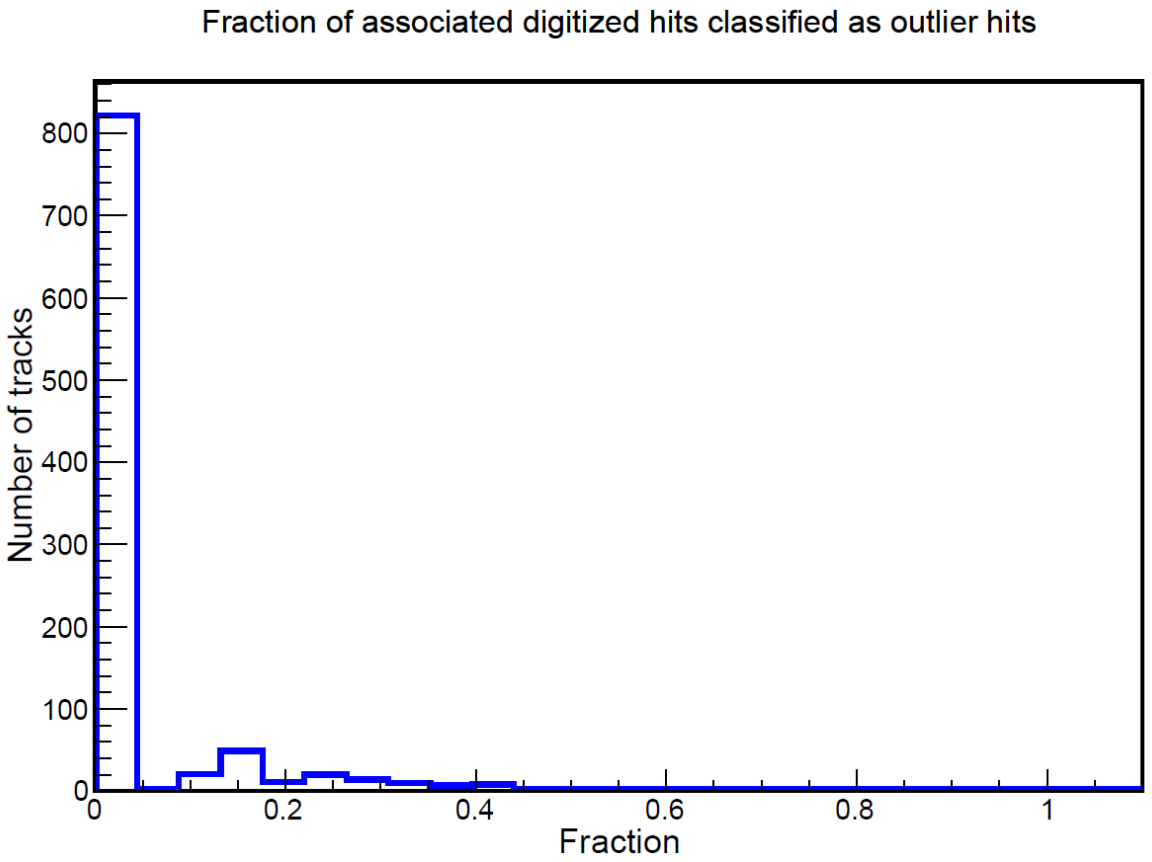




These are tracks where at least 1 digitized hit associated with the primary particle is classified as either an outlier or a ‘hole’. This happens about 30% of the time for single negative muon events.

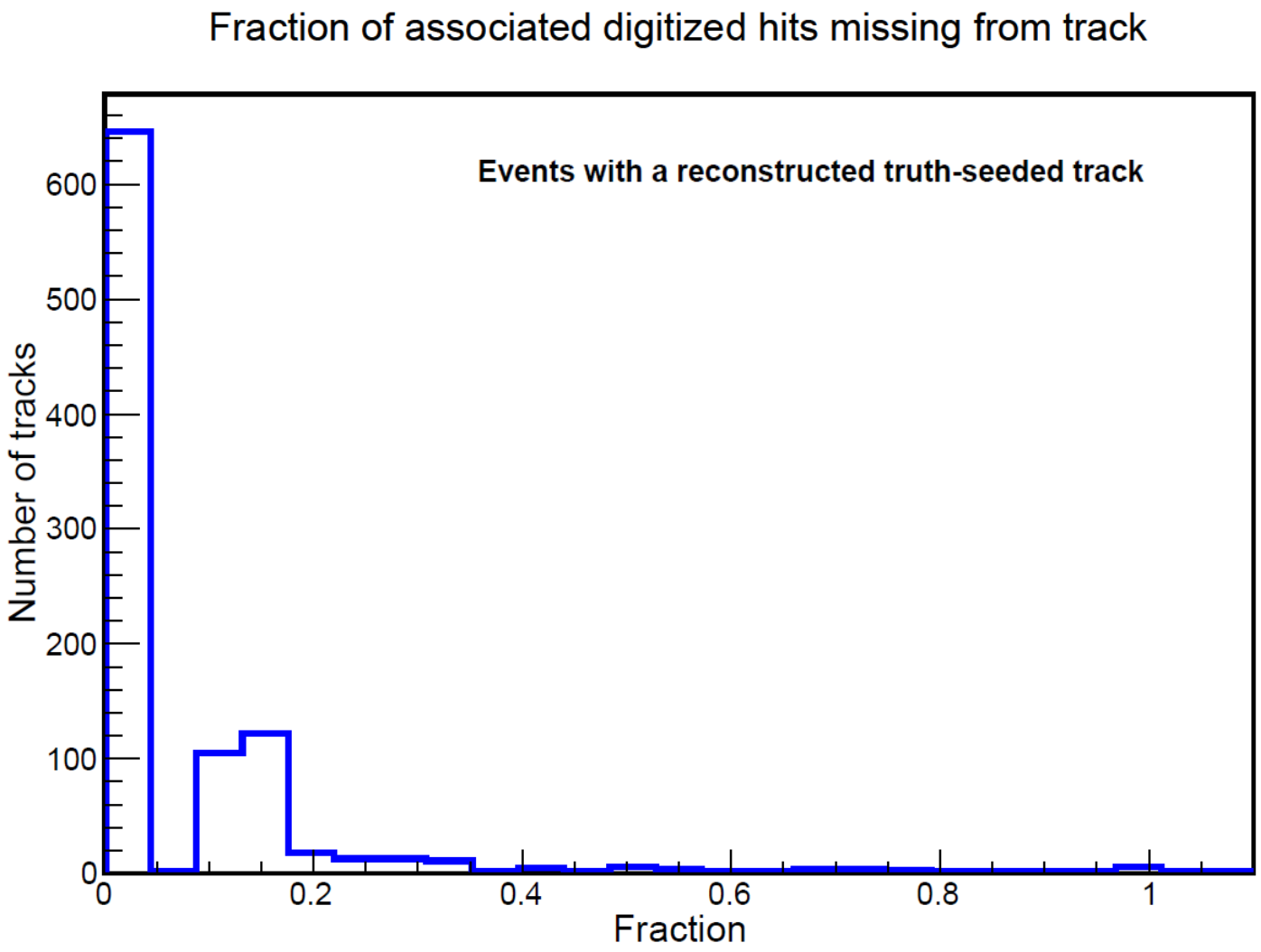
Outlier hits





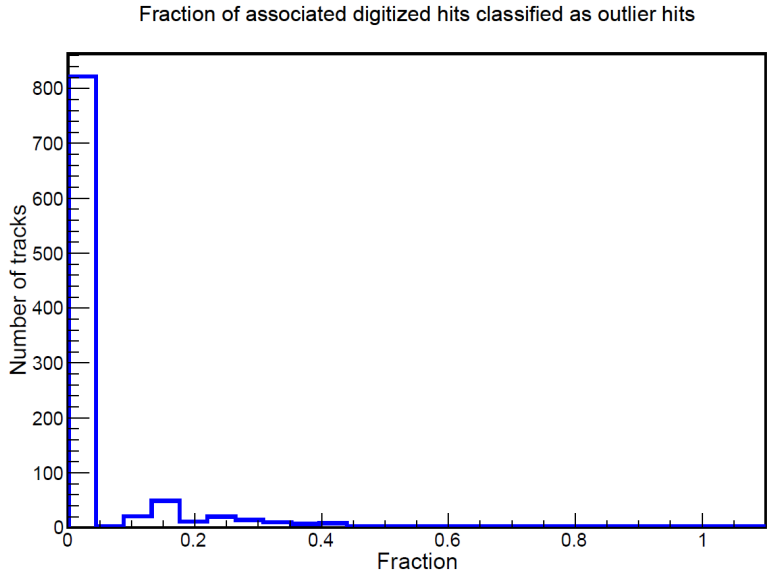
Most outlier hits are associated with the primary particle on the Geant-level. This means they are misclassified?

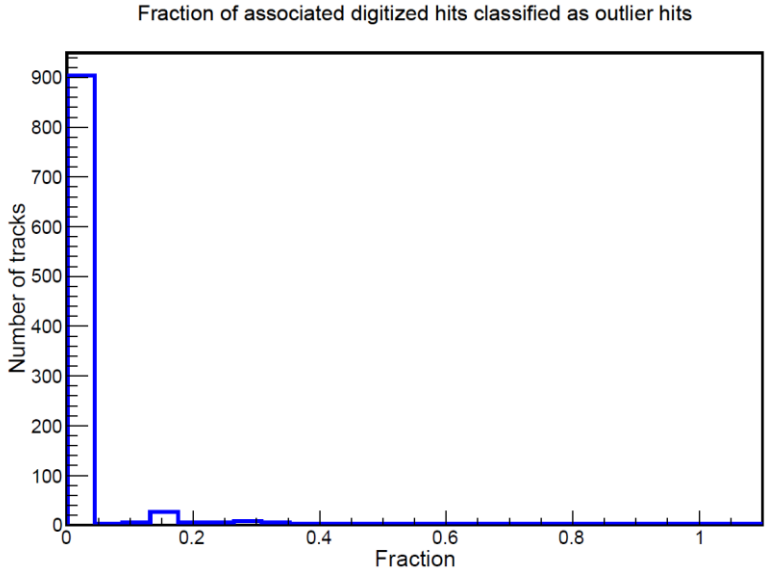
Tracker ‘holes’



A significant number of tracks (~25%) have at least 1 hit associated with the generated particle at the Geant level that is completely missing from the track.

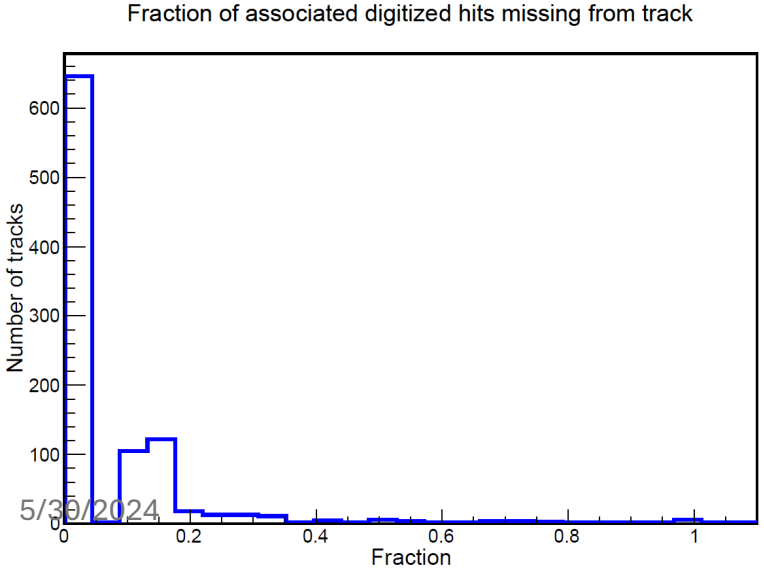
Effect of adjusting outlier definition

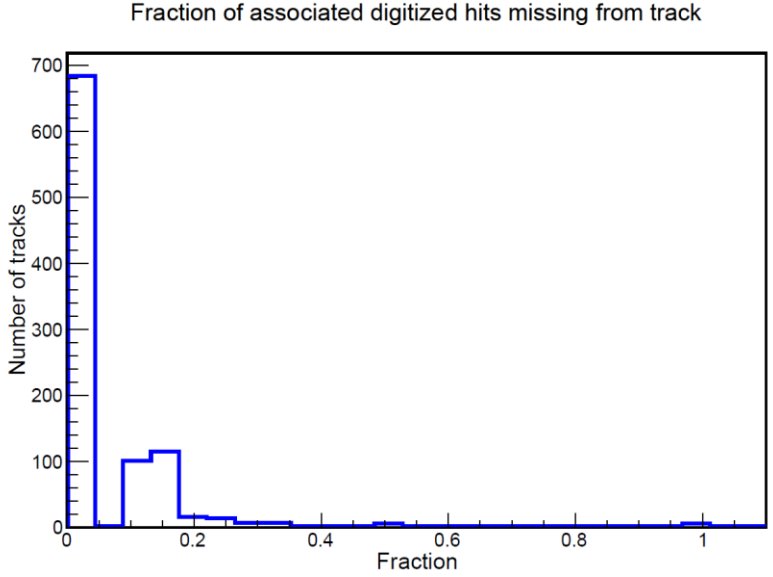




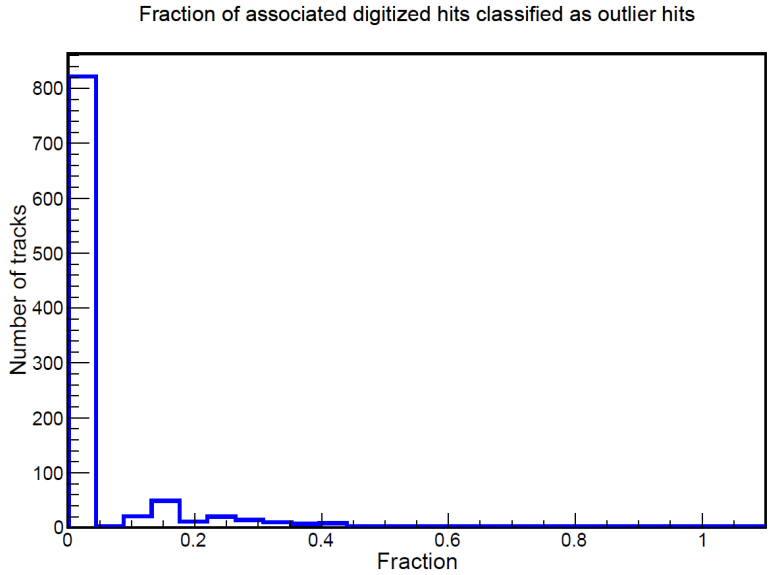
Chi-square cut: 15 -> 50

Results are similar is changed to 100

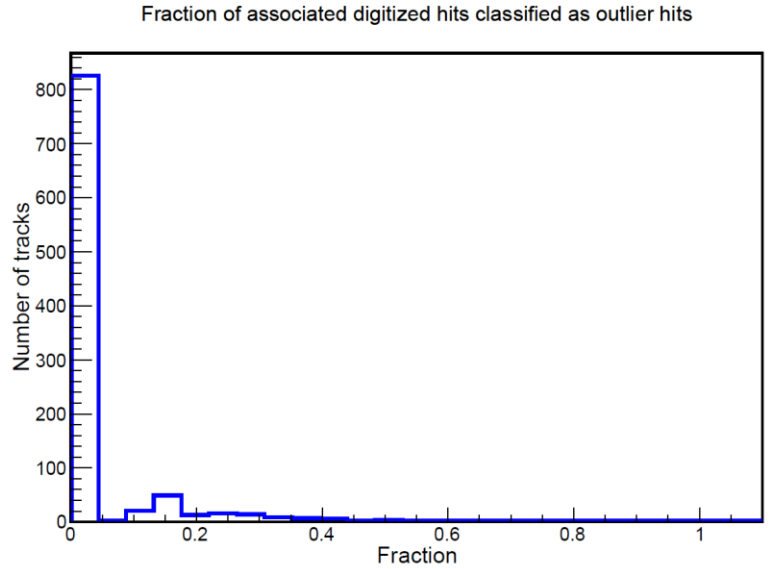


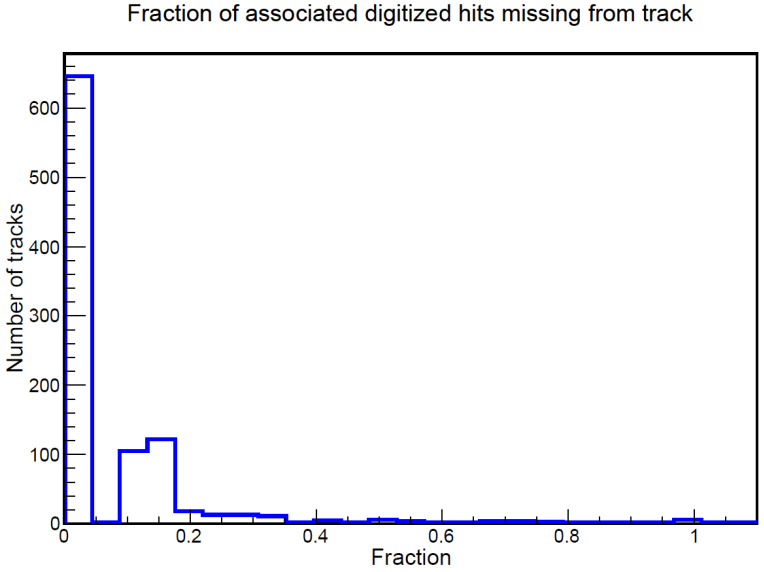


Effect of increasing initial (seed) error matrix values

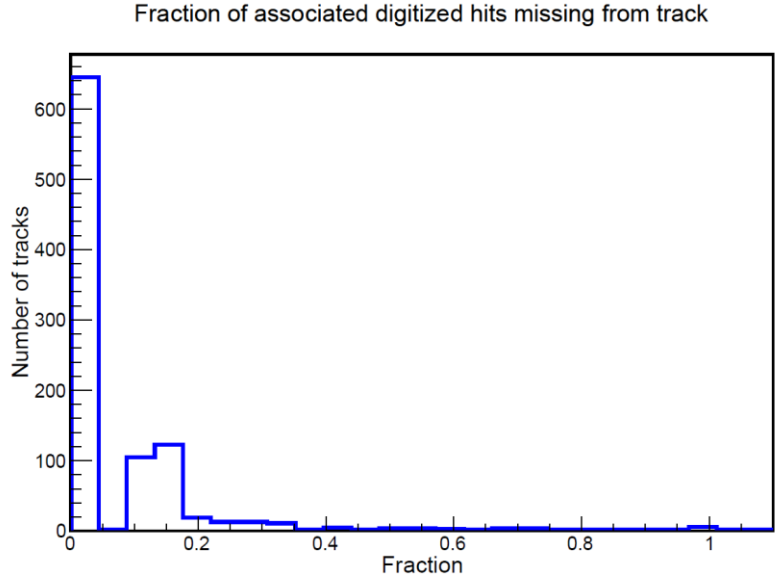


Increase all values by a factor of 10 ->





Similar results when increasing by factor of 100.



Conclusions

- A significant fraction of single-particle tracks have at least one outlier or hole.
- The outlier definition is based a chi-square cut.
- The frequency of ‘holes’ seems to be independent of the chi-square cut and the initial (seed) covariance error matrix values.
- Next step is to study how the predicated covariance matrix changes as we step through the tracking layers.