

Hit-based track to MC particle association for DIS events & background studies

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Hit-based track to MC particle matching

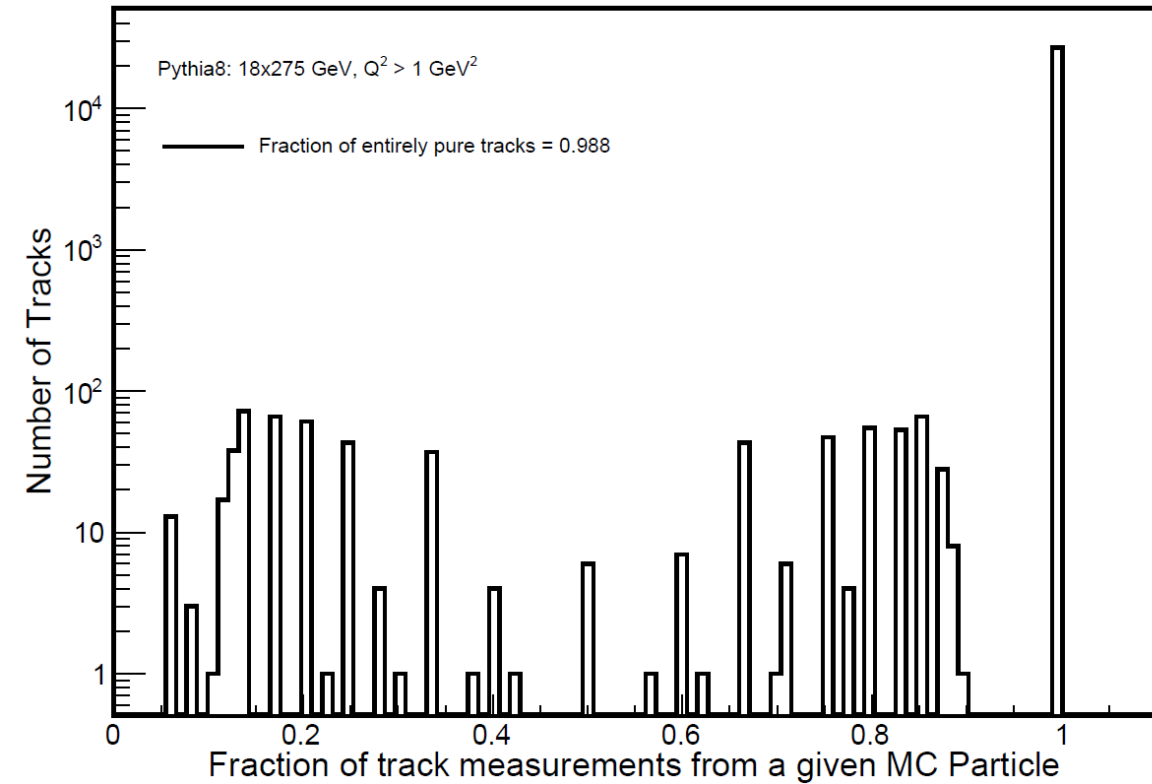
- Hit-based track to MC particle matching has been implemented into EICRecon (<https://github.com/eic/EICrecon/pull/1564>).
- For each measurement hit used in a track fit, we know which MC particle caused that hit (based on the Geant4 information). We use this to create hit-based associations between the tracks and the MC particles, with the association weight determined by the fraction of the hits caused by a given particle.
- Note that the association weights are based on the good measurement hits from the track fit, and do not consider outlier hits.

Event number | Association index | Weight | MC Particle index | Track index

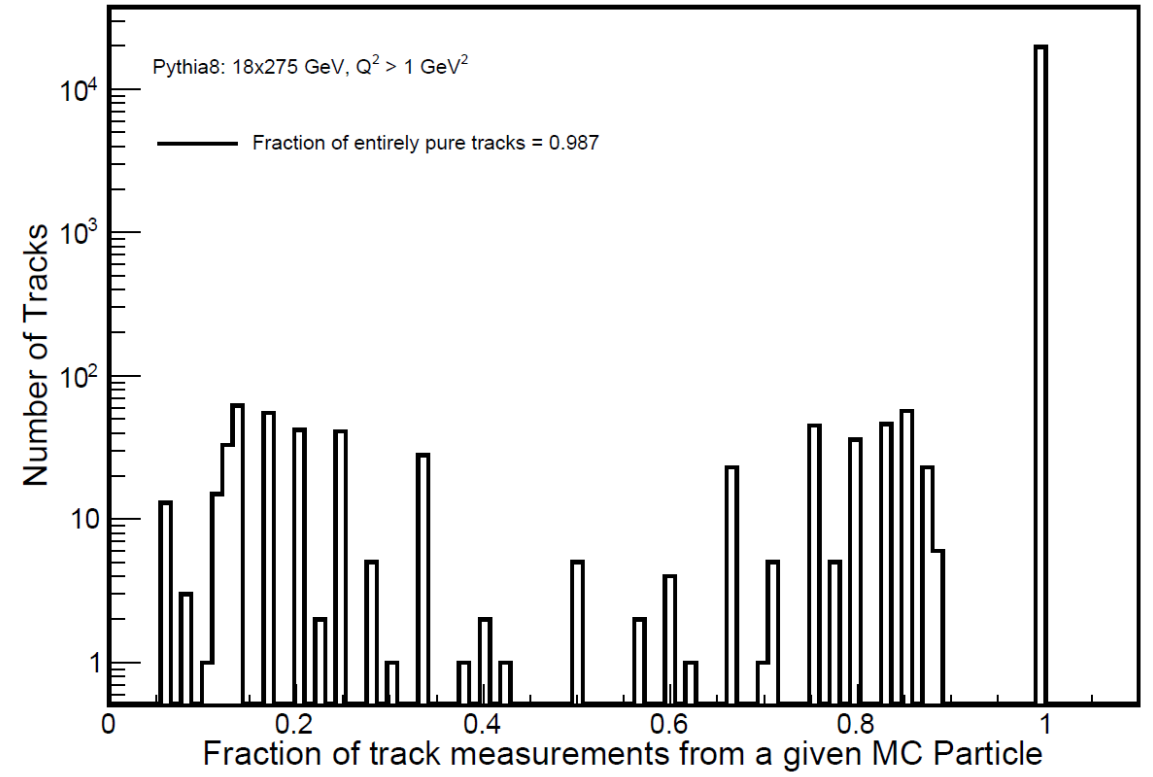
```
*      1 *      0 *      1 *      12 *      0 *
*      1 *      1 *      1 *      19 *      1 *
*      1 *      2 *      1 *      32 *      2 *
*      1 *      3 *      1 *      25 *      3 *
*      9 *      0 *      1 *      39 *      0 *
*      9 *      1 *      1 *      22 *      1 *
*      9 *      2 *      1 *      11 *      2 *
*      9 *      3 * 0.8571428 *      43 *      3 *
Type <CR> to continue or q to quit ==>
*      9 *      4 * 0.1428571 *      154 *      3 *
*      9 *      5 *      1 *      27 *      4 *
*      9 *      6 *      1 *      46 *      5 *
*      9 *      7 *      1 *      53 *      6 *
*      9 *      8 *      1 *      52 *      7 *
*      9 *      9 *      1 *      8 *      8 *
```

Track hit purity in DIS events

Truth-seeded tracks



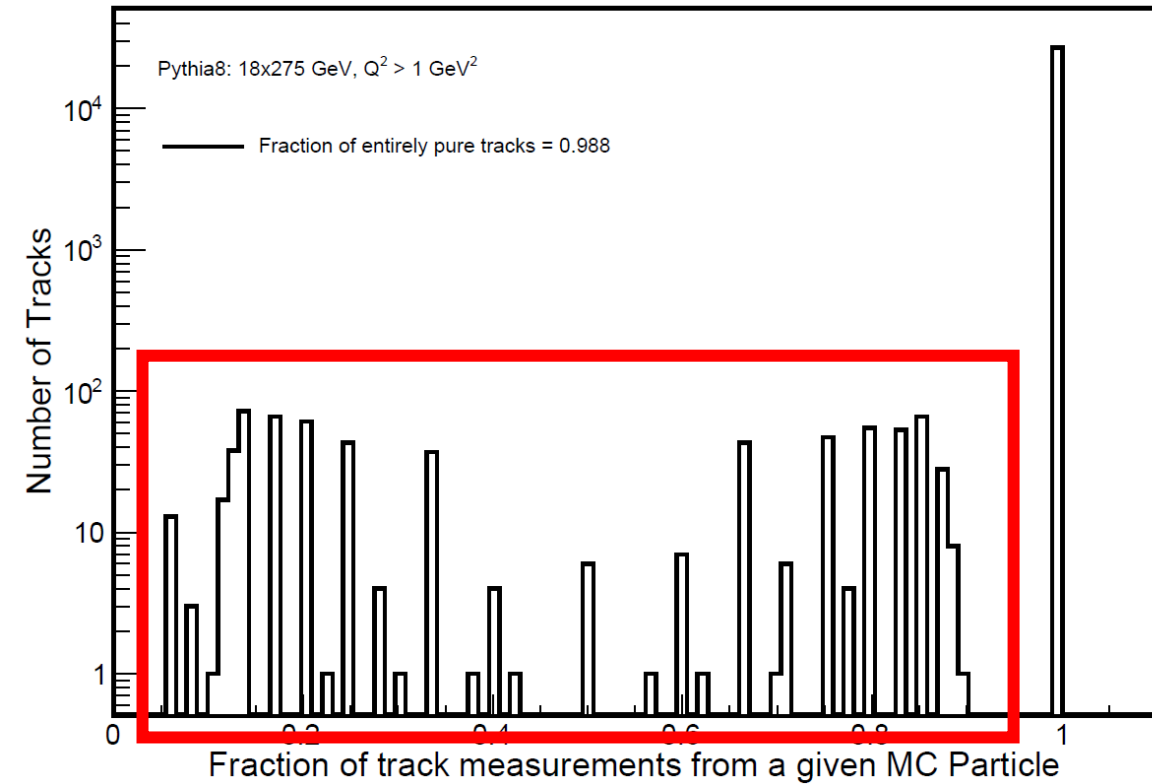
Real-seeded tracks



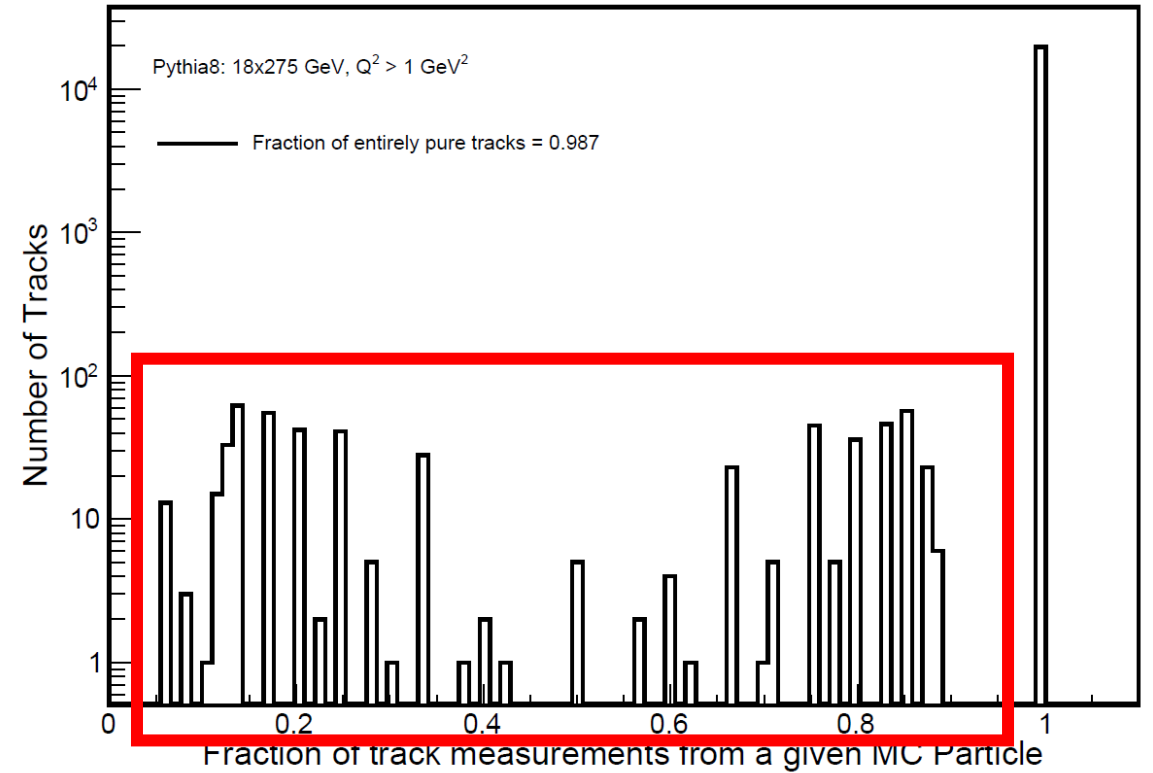
Track hit purity in DIS events

Same reconstructed track gets filled into histogram multiple times when associated with multiple MC particles.

Truth-seeded tracks



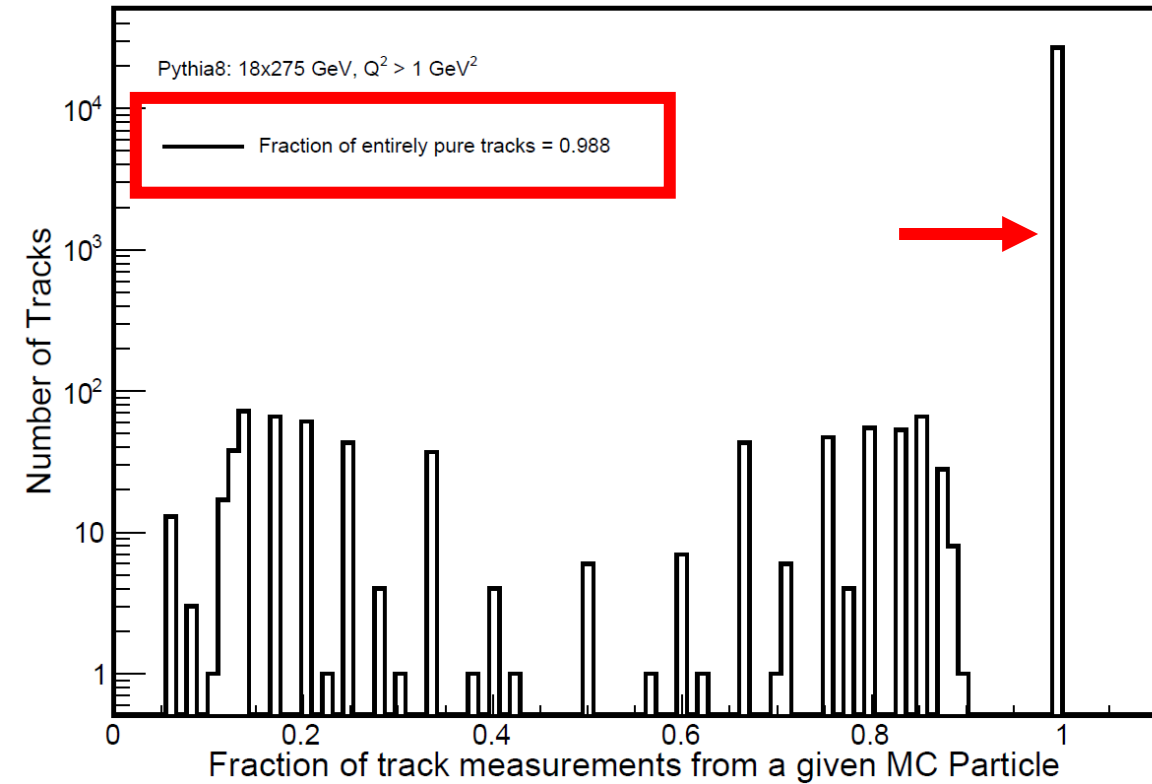
Real-seeded tracks



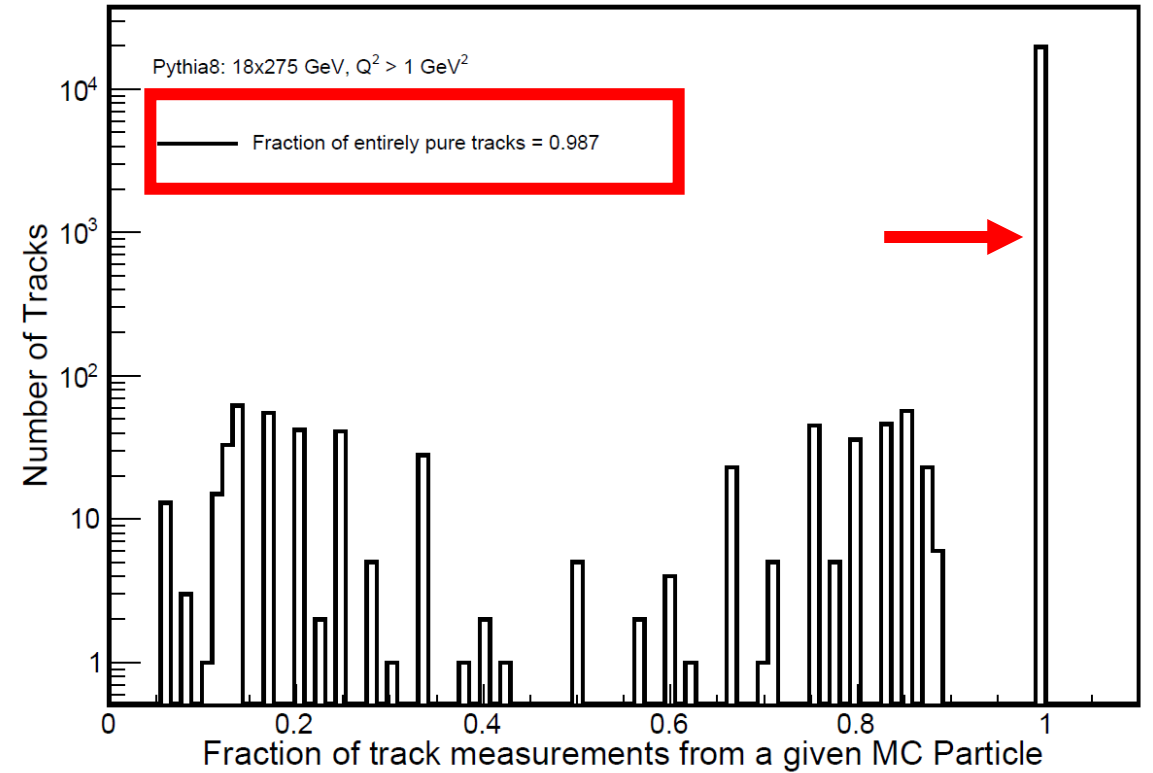
Track hit purity in DIS events

For this setting, >98.5% of the reconstructed tracks have measurement hits associated with only one MC particle.

Truth-seeded tracks



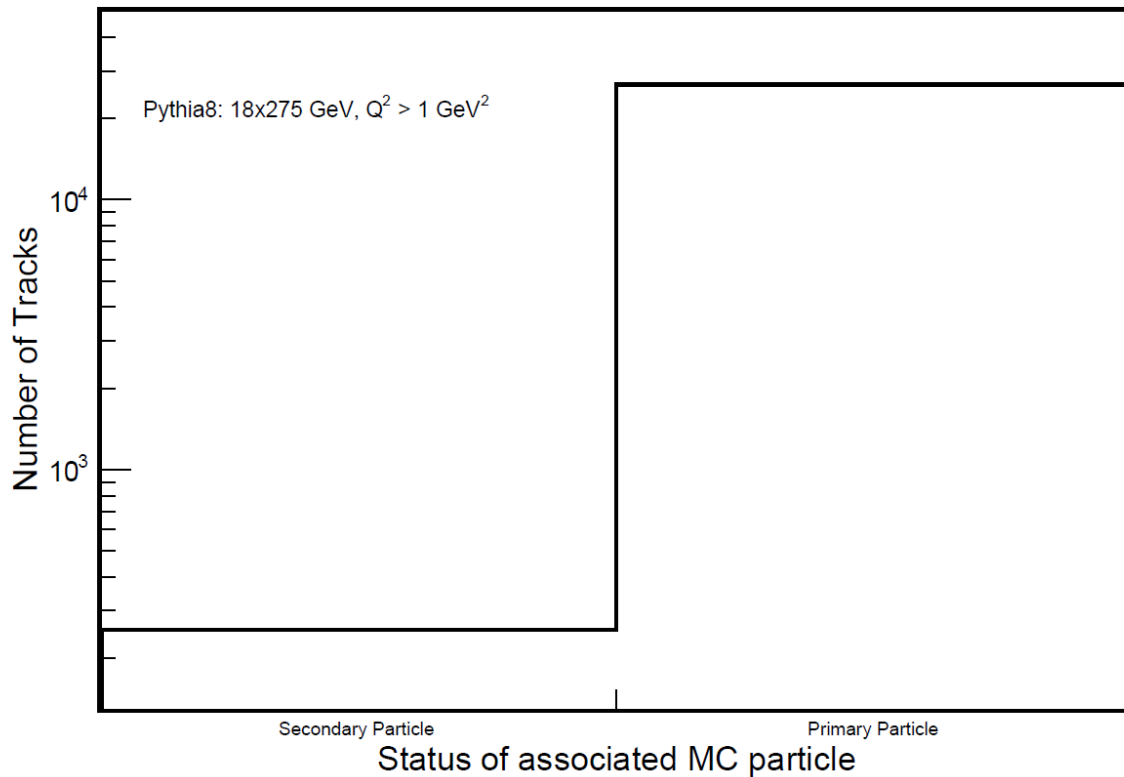
Real-seeded tracks



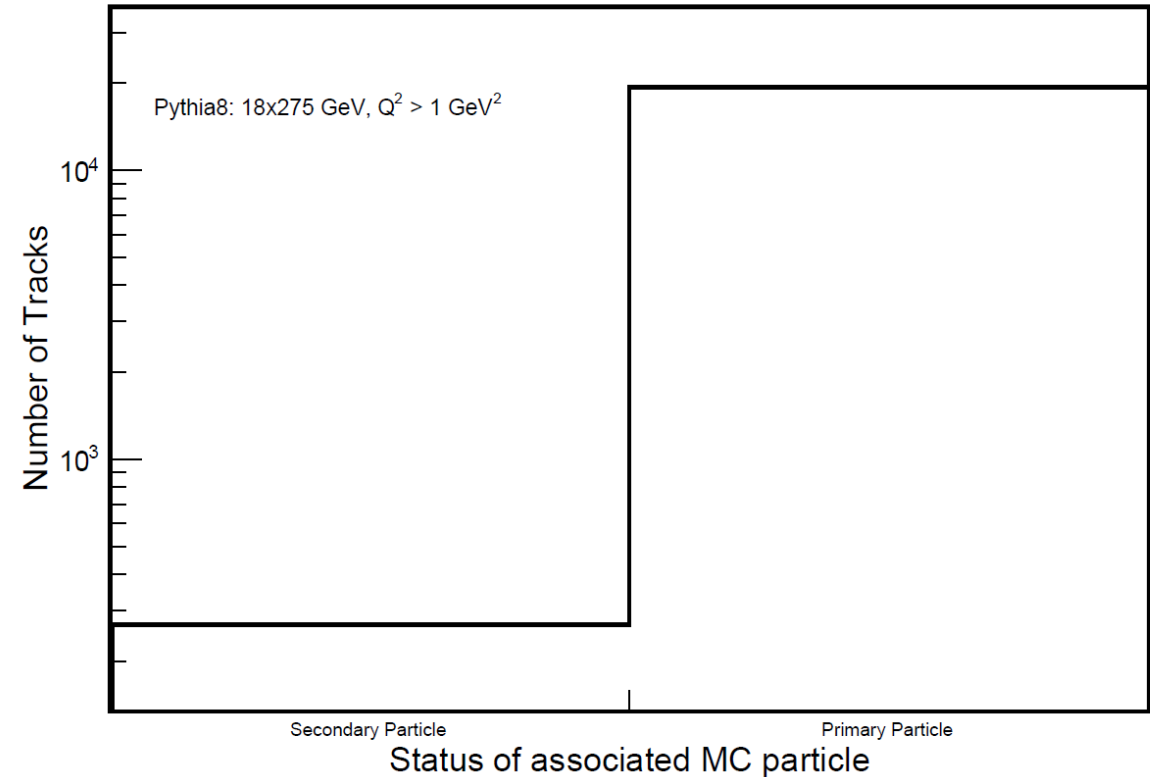
Associated particle type

Primary particle (status == 1): A final-state particle as set by the event generator.
Secondary particle (status == 0): A particle created in detector material which has enough energy to be included in the MC particle list; or the products of a primary particle decayed by Geant4.

Truth-seeded tracks: Entirely pure tracks



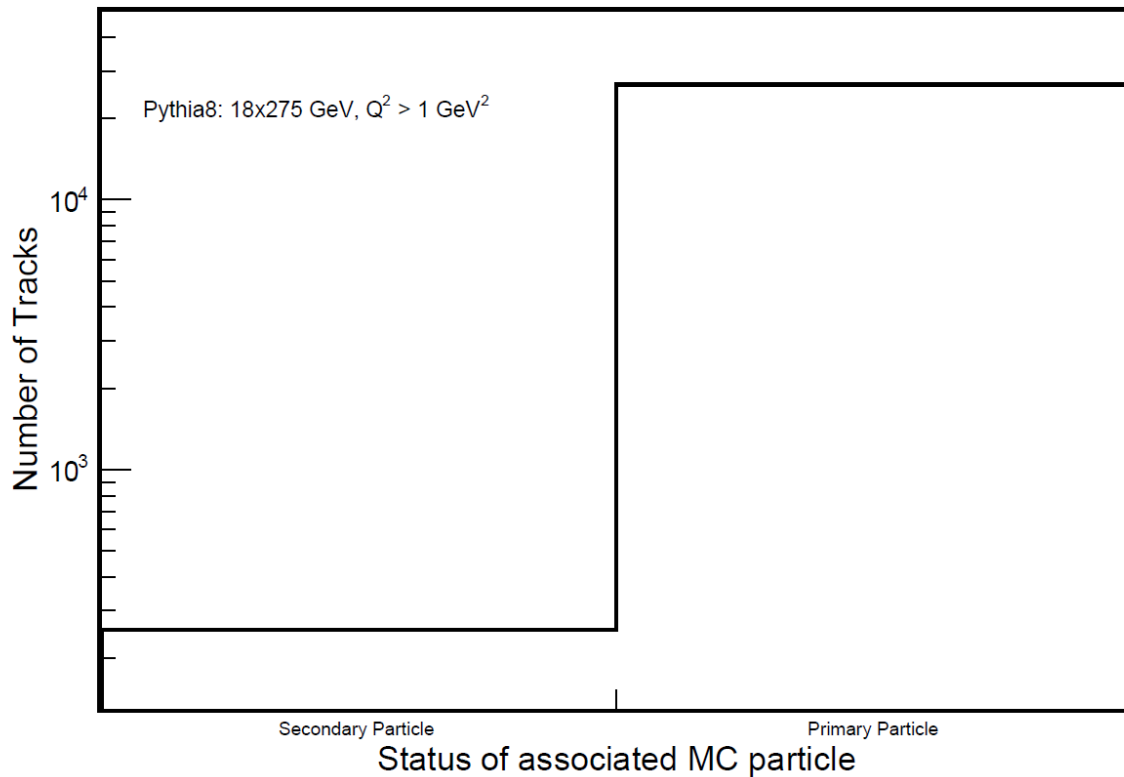
Real-seeded tracks: Entirely pure tracks



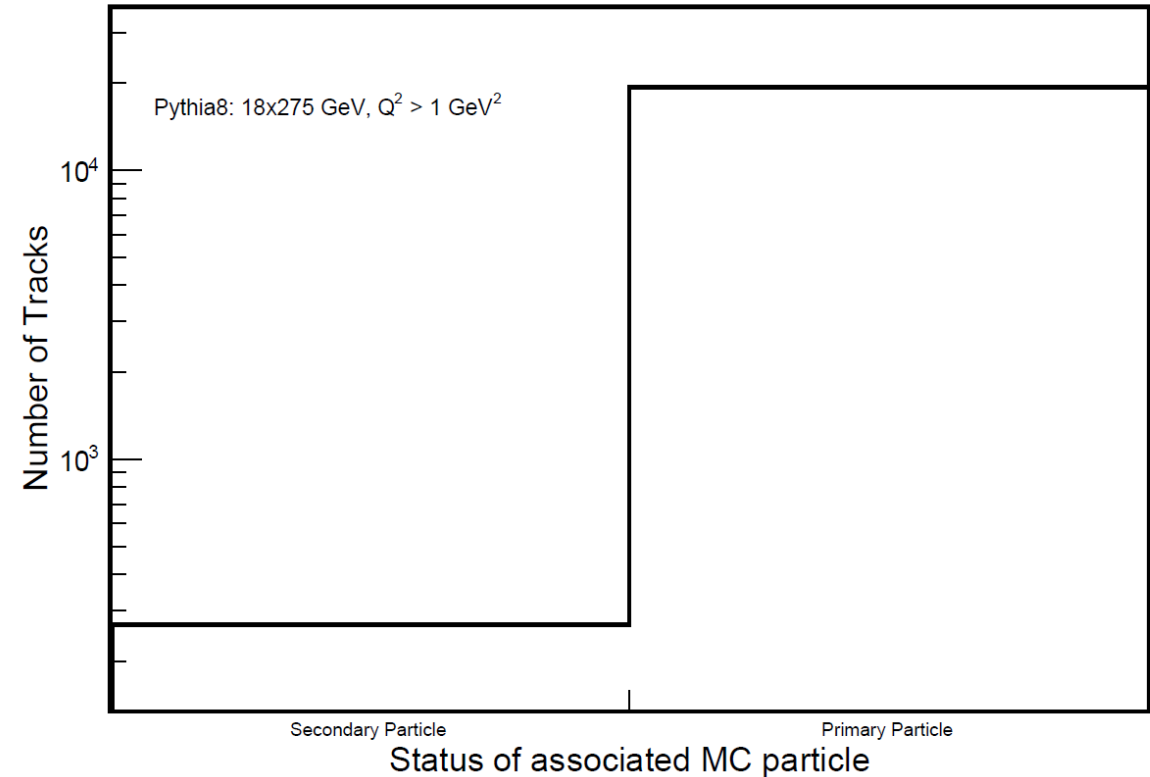
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Truth-seeded tracks: **Entirely pure tracks**



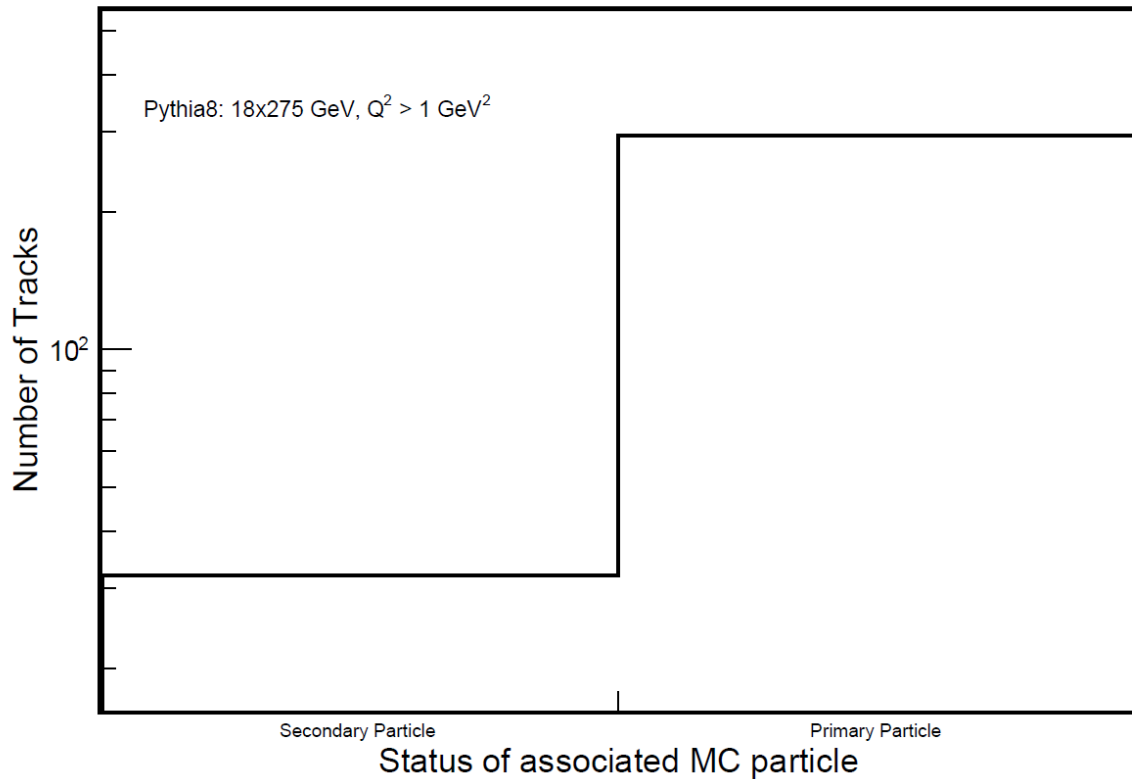
Real-seeded tracks: **Entirely pure tracks**



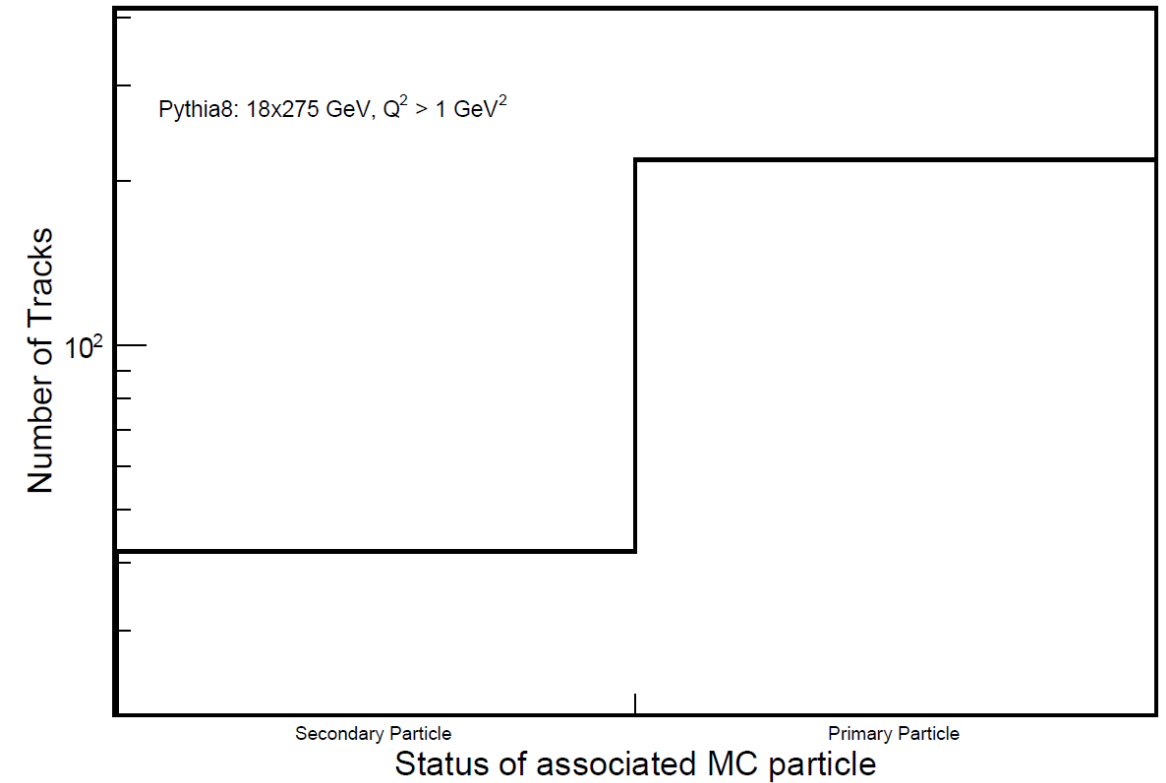
Associated particle type

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Truth-seeded tracks: Status of most-associated particle for mixed tracks



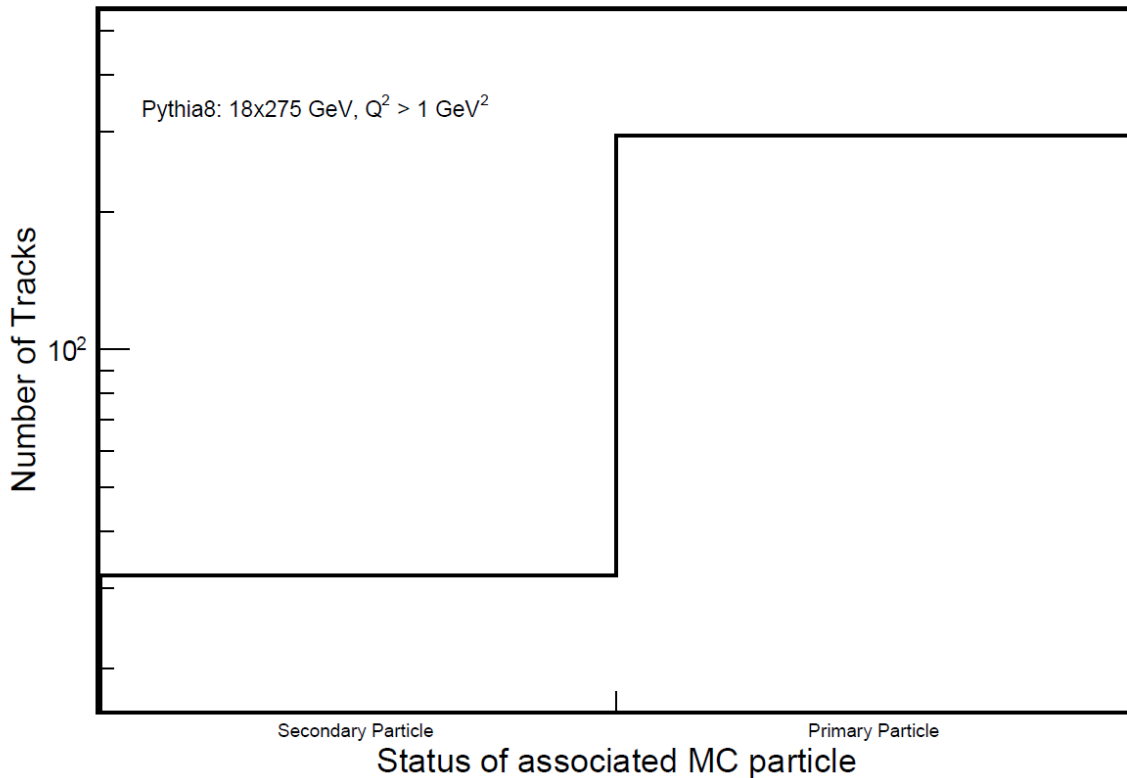
Real-seeded tracks: Status of most-associated particle for mixed tracks



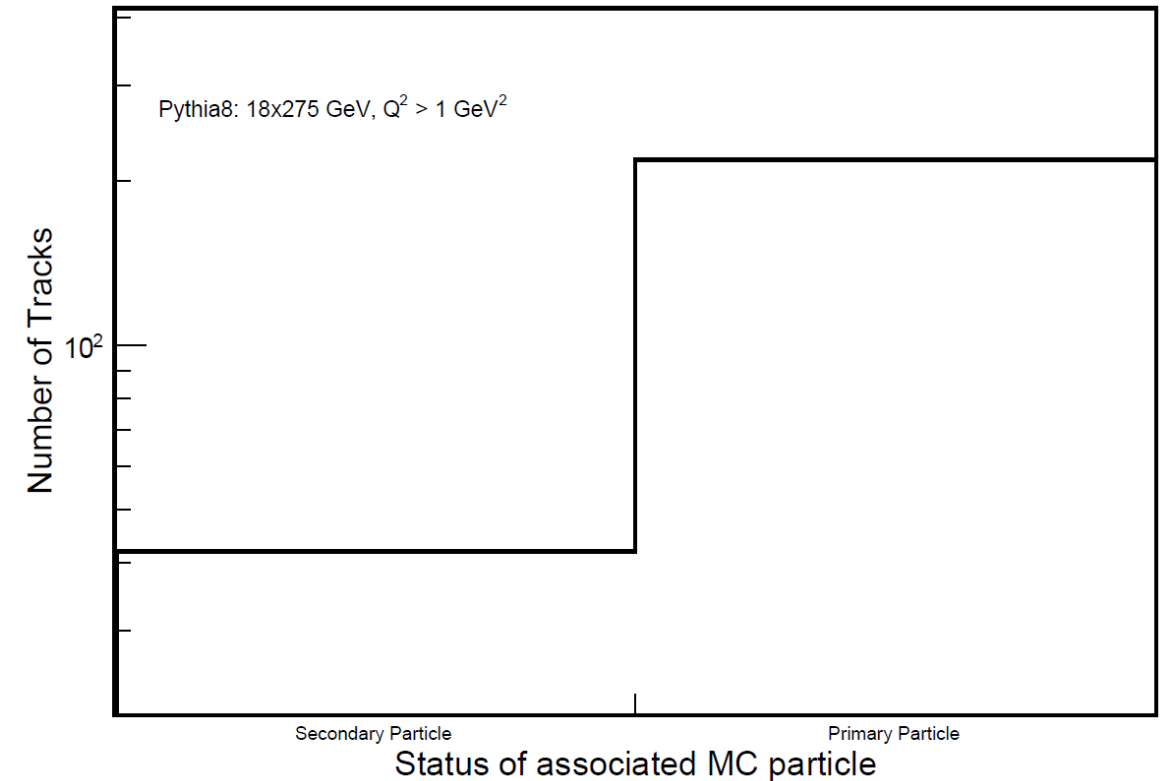
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Truth-seeded tracks Status of most-associated particle for mixed tracks



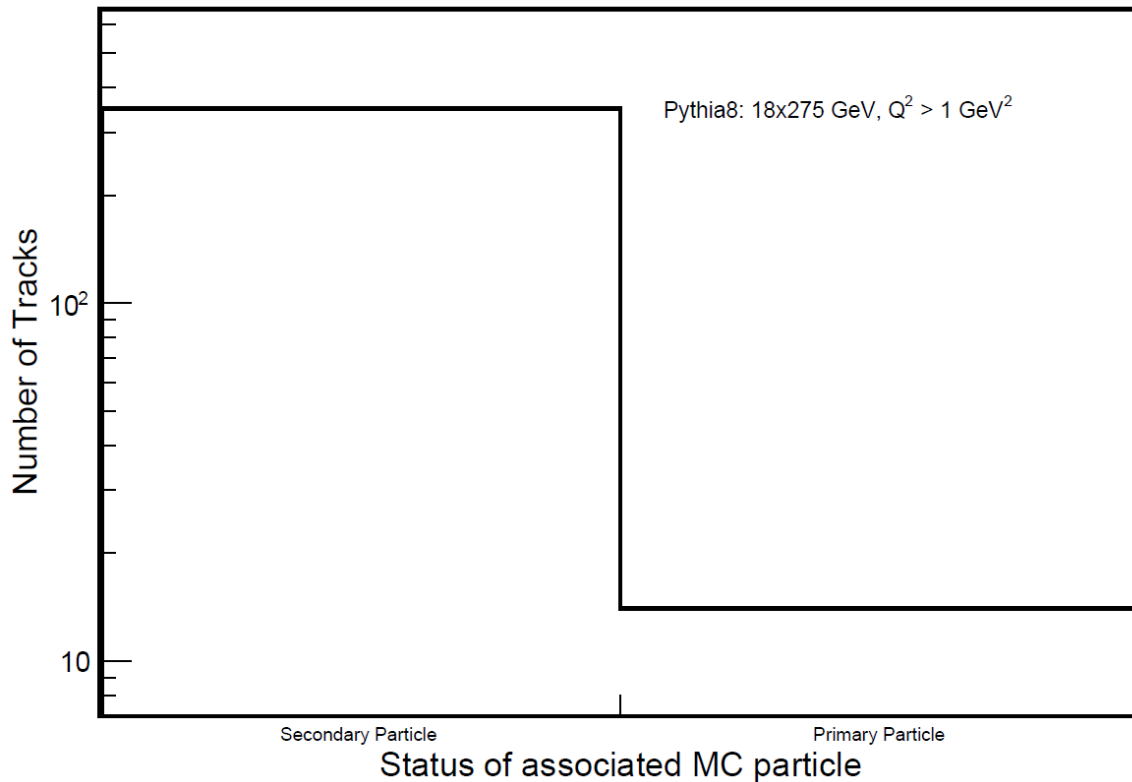
Real-seeded tracks Status of most-associated particle for mixed tracks



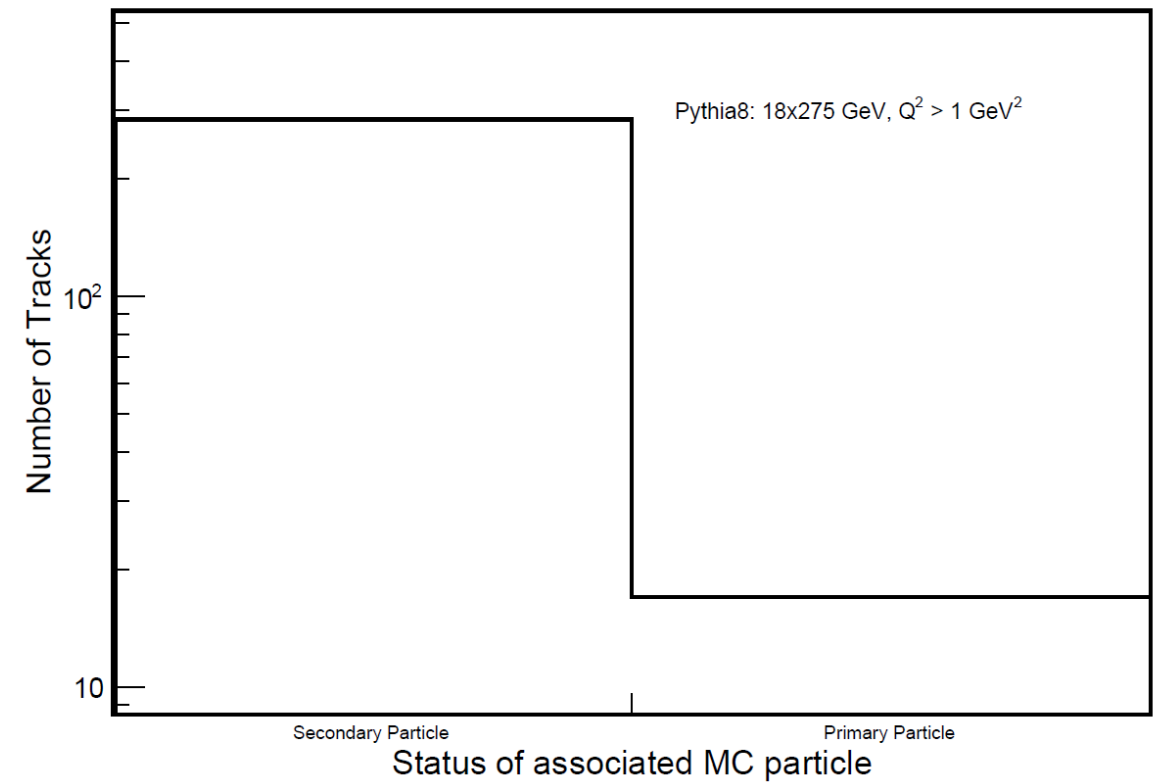
Associated particle type

Primary particle (status == 1): A final-state particle as set by the event generator.
Secondary particle (status == 0): A particle created in detector material which has enough energy to be included in the MC particle list; or the products of a primary particle decayed by Geant4.

Truth-seeded tracks: Status of less-associated particles for mixed tracks

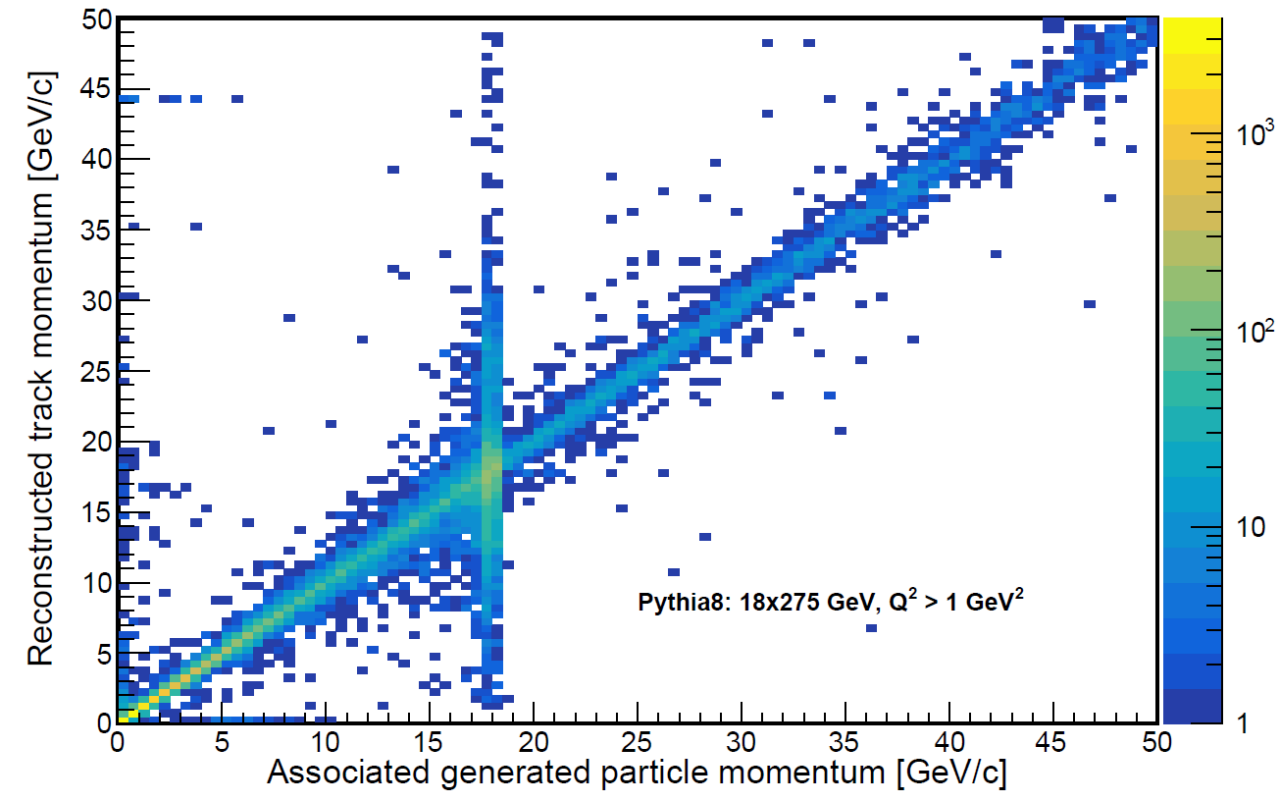


Real-seeded tracks: Status of less-associated particles for mixed tracks

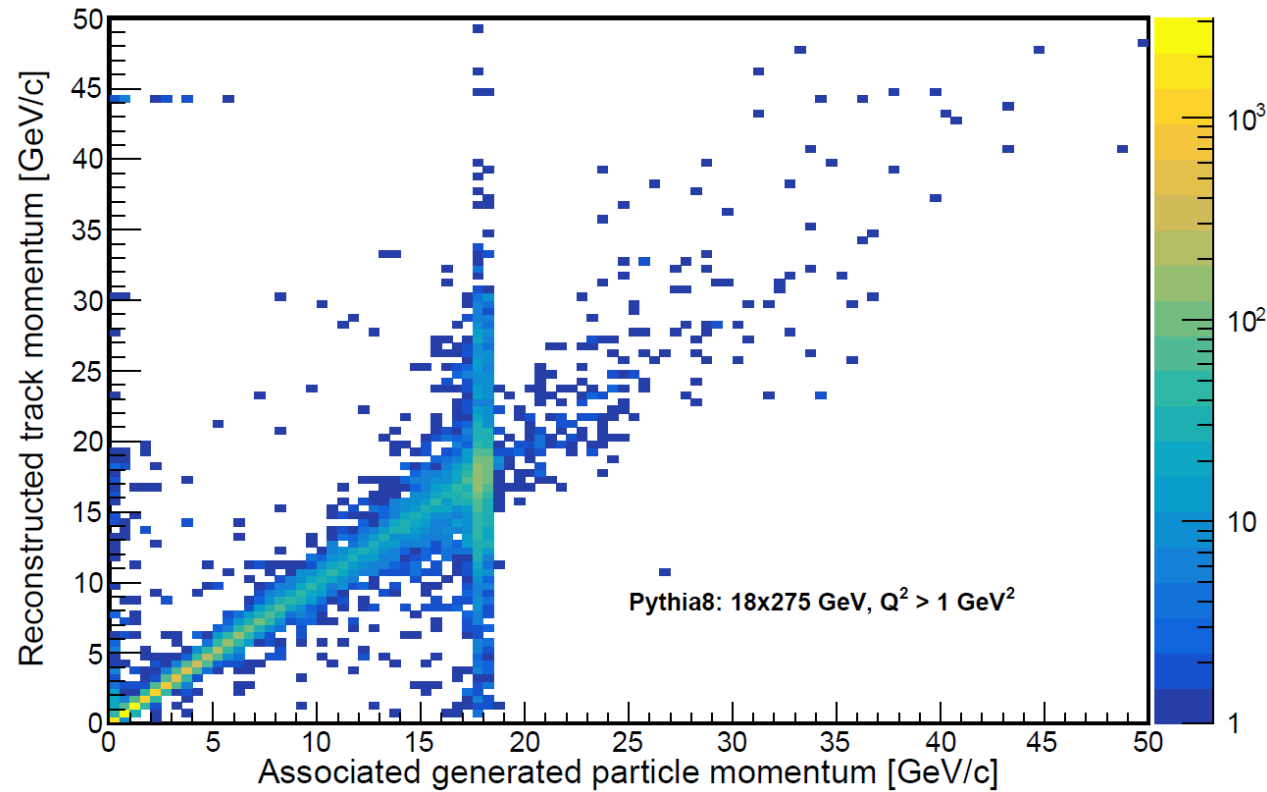


Momentum reconstruction

Truth-seeded tracks



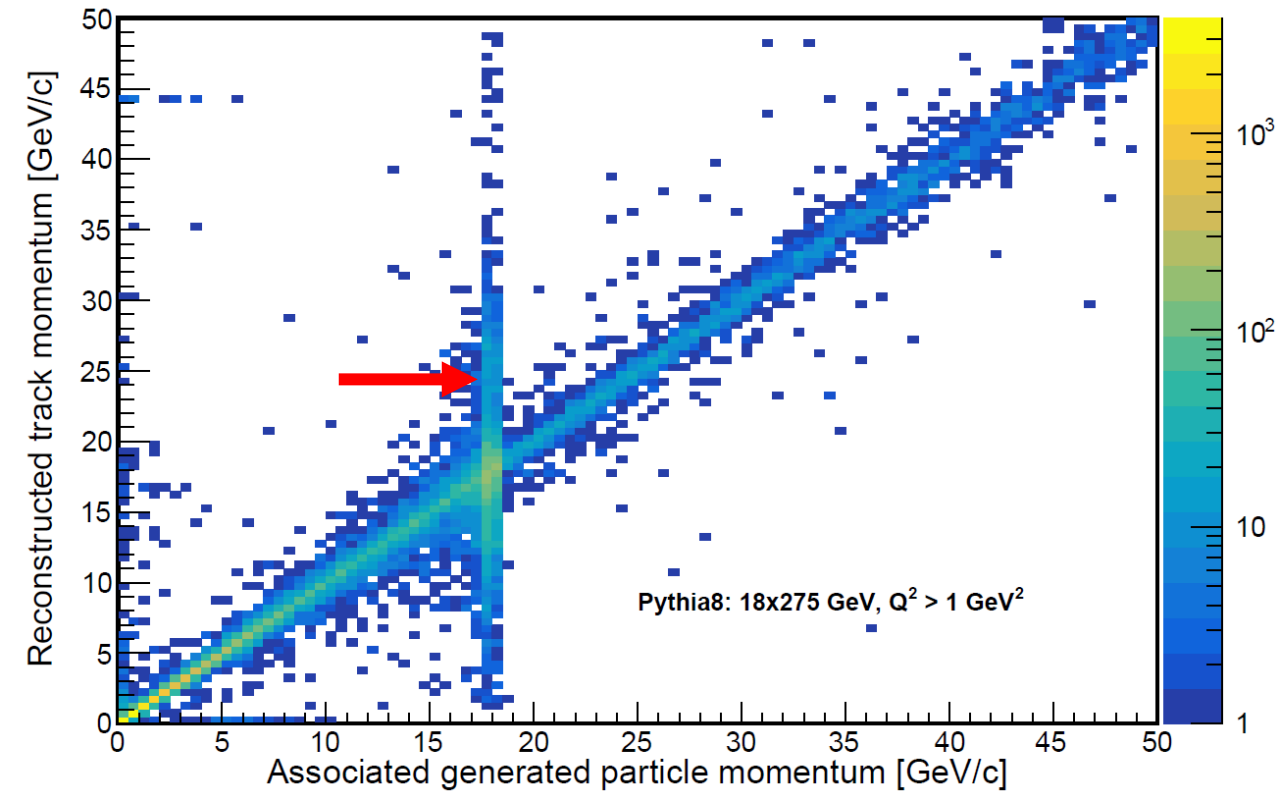
Real-seeded tracks



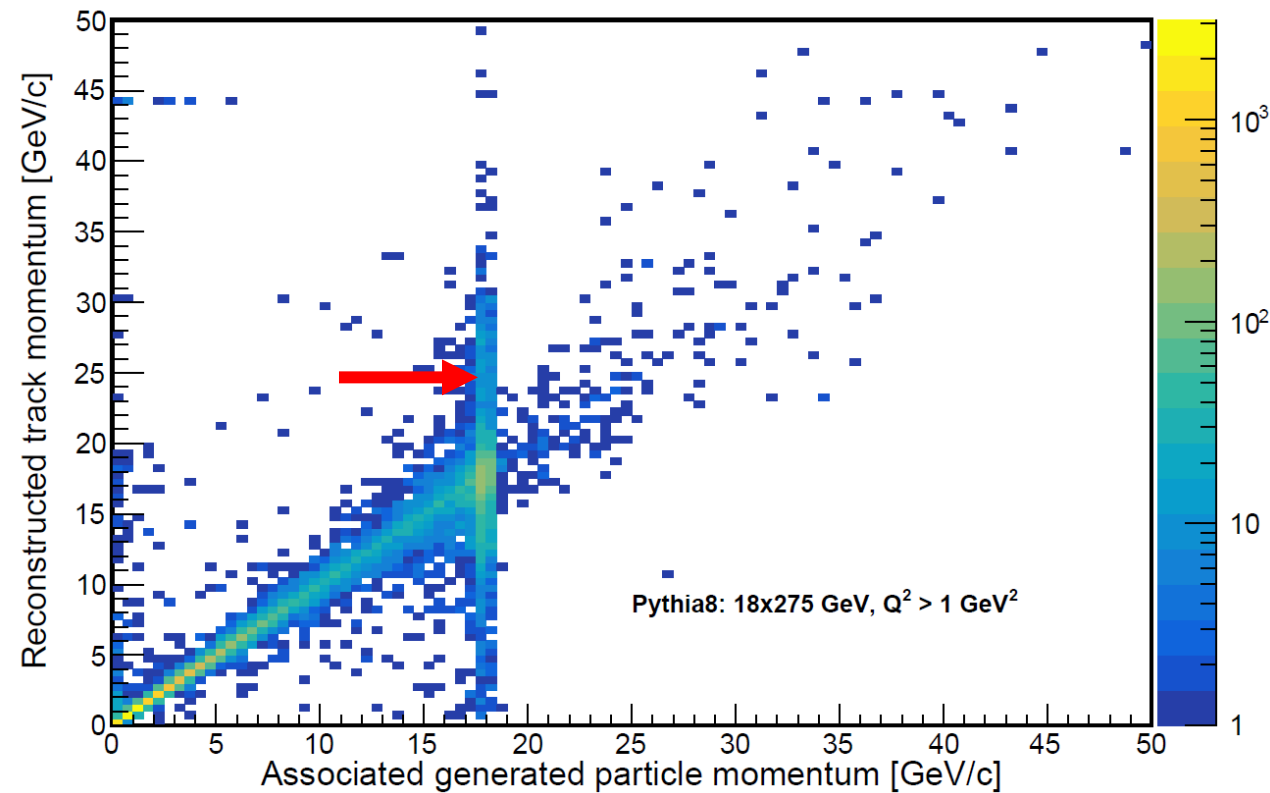
Momentum reconstruction

Scattered electron with $Q^2 \sim 1 \text{ GeV}^2$ in negative endcap

Truth-seeded tracks



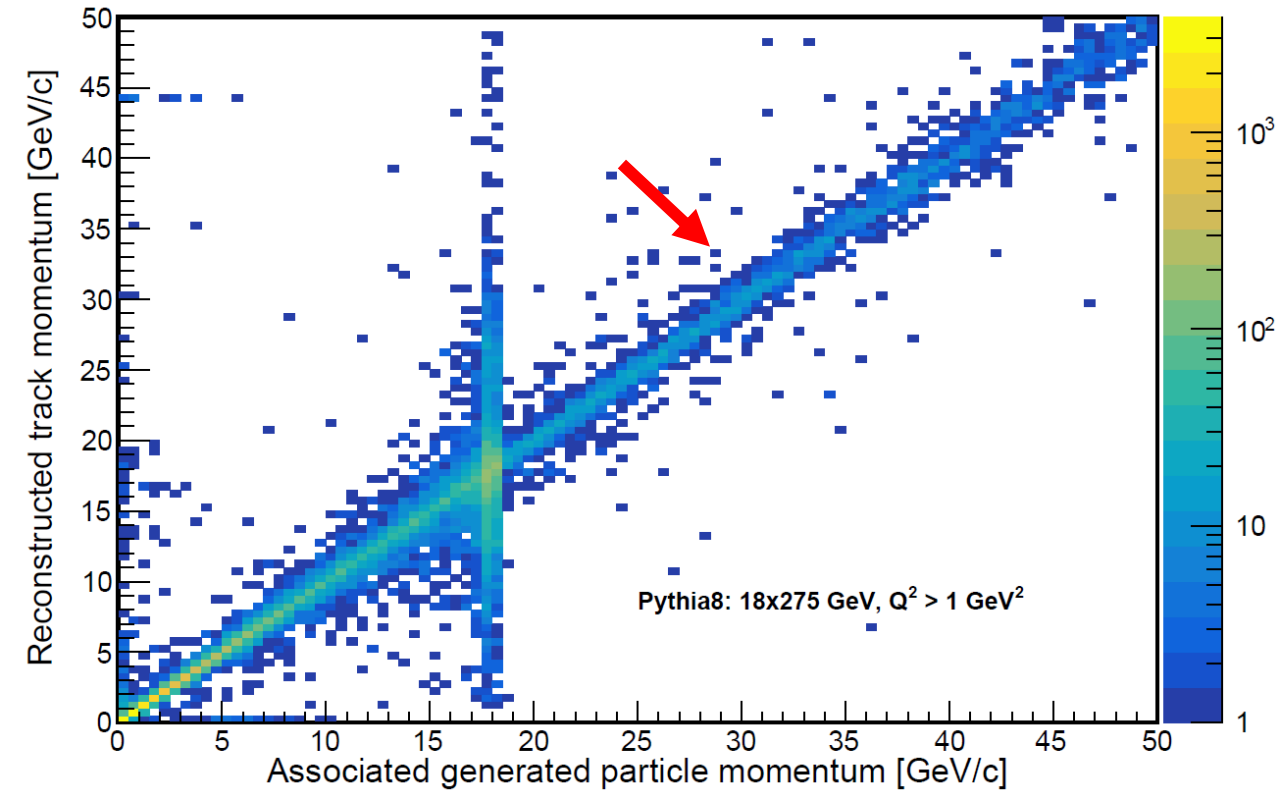
Real-seeded tracks



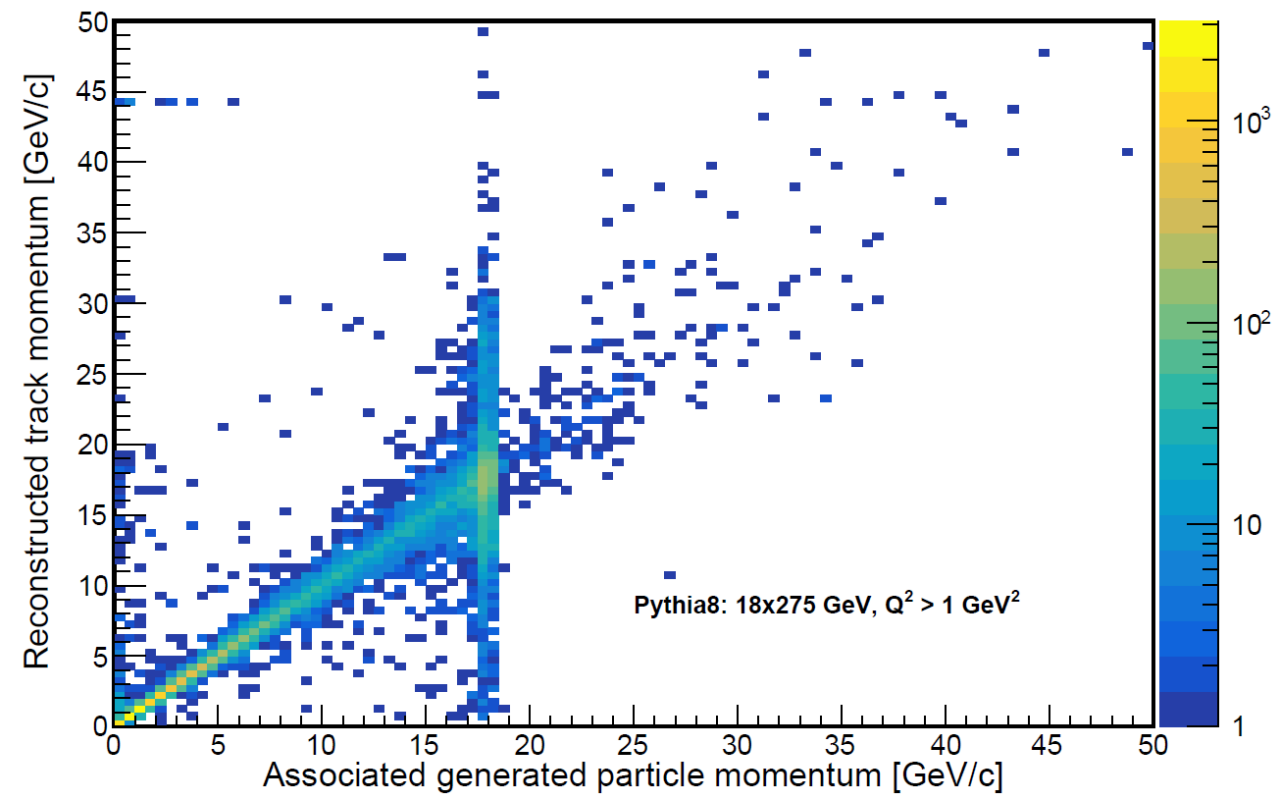
Momentum reconstruction

Far-forward particles reconstructed in truth-seeded tracking

Truth-seeded tracks



Real-seeded tracks

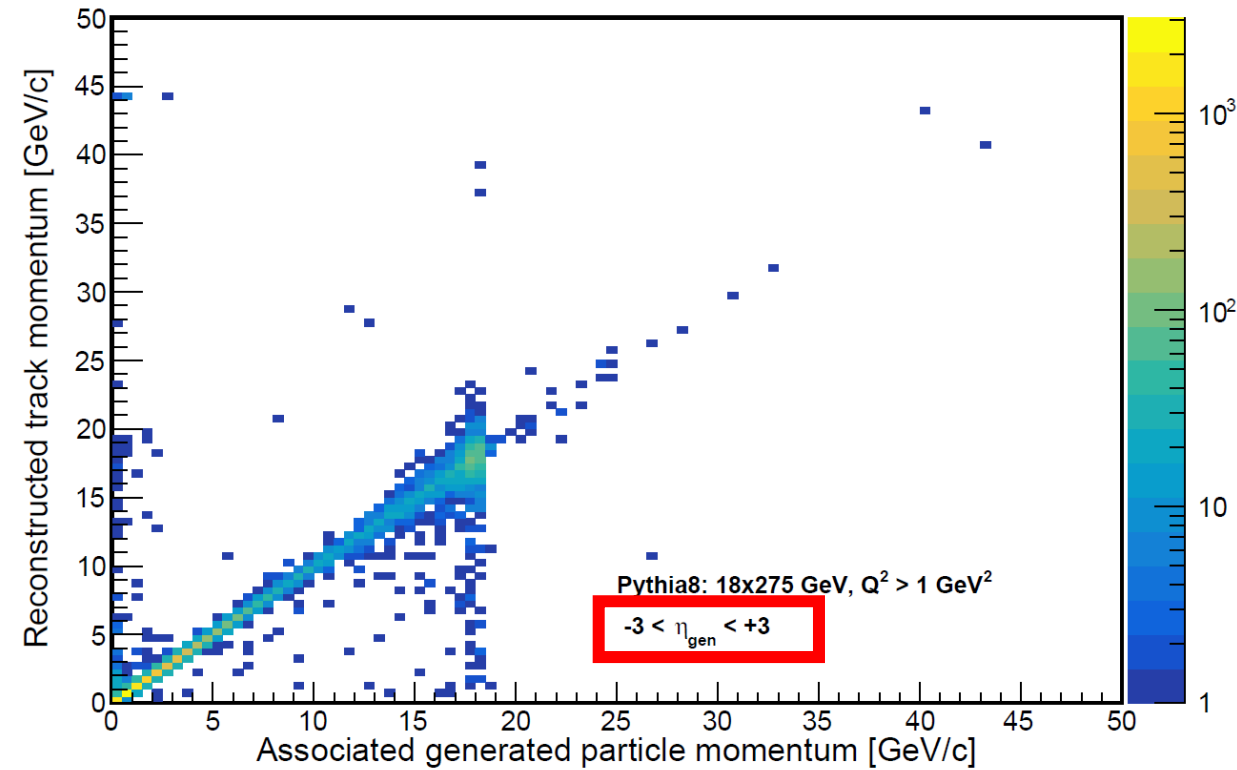
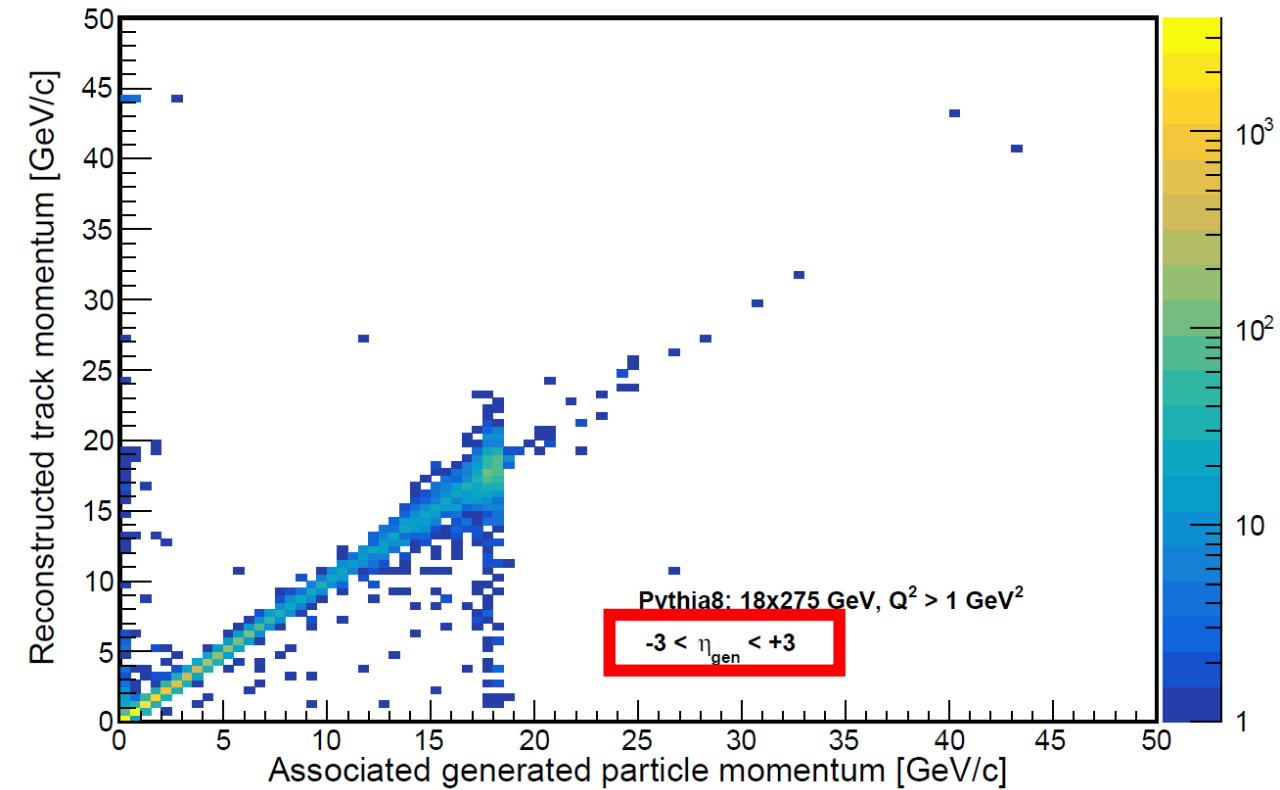


Momentum reconstruction

When limiting the angular rang of the associated MC particle, we see that the scattered electron peak and the far-forward particles are removed.

Truth-seeded tracks

Real-seeded tracks



Summary

- Hit-based track to MC particle associations have been implemented into the standard reconstructed output. Thanks, Wouter!
- The results look good for DIS events with 18×275 GeV and $Q^2 > 1$ GeV². I am also making a similar set of plots for $Q^2 > 100$ GeV².
- We can use these associations to study, for example, momentum resolutions in DIS events and compare to the single-particle results. Since most tracks are associated with a single particle in these DIS events, we should see the same performance, I think.
- The next step is to repeat the purity study with background mixed in. It will be interesting to see to what extent the synchrotron photons hits, for example, cause a decrease the track purities. (Ben started some of these studies.)

Background files on S3

On S3, we currently have these generator-level background files:

➤ Proton-beam gas only:

`eictest/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/proton/275GeV_HiAc_25mrad_Asciiv3.hepmc`

(and similar ones for 41 GeV and 100 GeV).

➤ Electron-beam gas only:

`eictest/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/electron/beam_gas_ep_10GeV_foam_emin10keV_10Mevt_vtx.hepmc`

Are there equivalent files for 18 GeV and 5 GeV electron beam energies?

Background files on S3

On S3, we currently have these generator-level background files:

➤ Synchrotron radiation:

`eicctest/EPIC/EVGEN/BACKGROUNDS/SYNRAD/SR_single_1.8M_2.5A_10GeV.hepmc`

`eicctest/EPIC/EVGEN/BACKGROUNDS/SYNRAD/SR_single_1.8M_2.5A_10GeV.hepmc3.tree.root`

The HepMC file is dated April 2023, while the HepMC ROOT tree file is dated April 2024. Are these the same files? Or is one more up to date? And if they are different, which is used in the merged files?

➤ Merged signal+background level:

`eicctest/EPIC/EVGEN/BACKGROUNDS/MERGED/HEPMC_merger-1.0.2/10x100/1SignalPerFrame`

`eicctest/EPIC/EVGEN/BACKGROUNDS/MERGED/HEPMC_merger-1.0.2/10x100/RealisticSignalPerFrame`

The first set always includes a signal event in the 2 μ s window; the second set has realistic rates for the signal. Which signal HepMC file on S3 was mixed in with the backgrounds here?

Background files on S3 and merger code

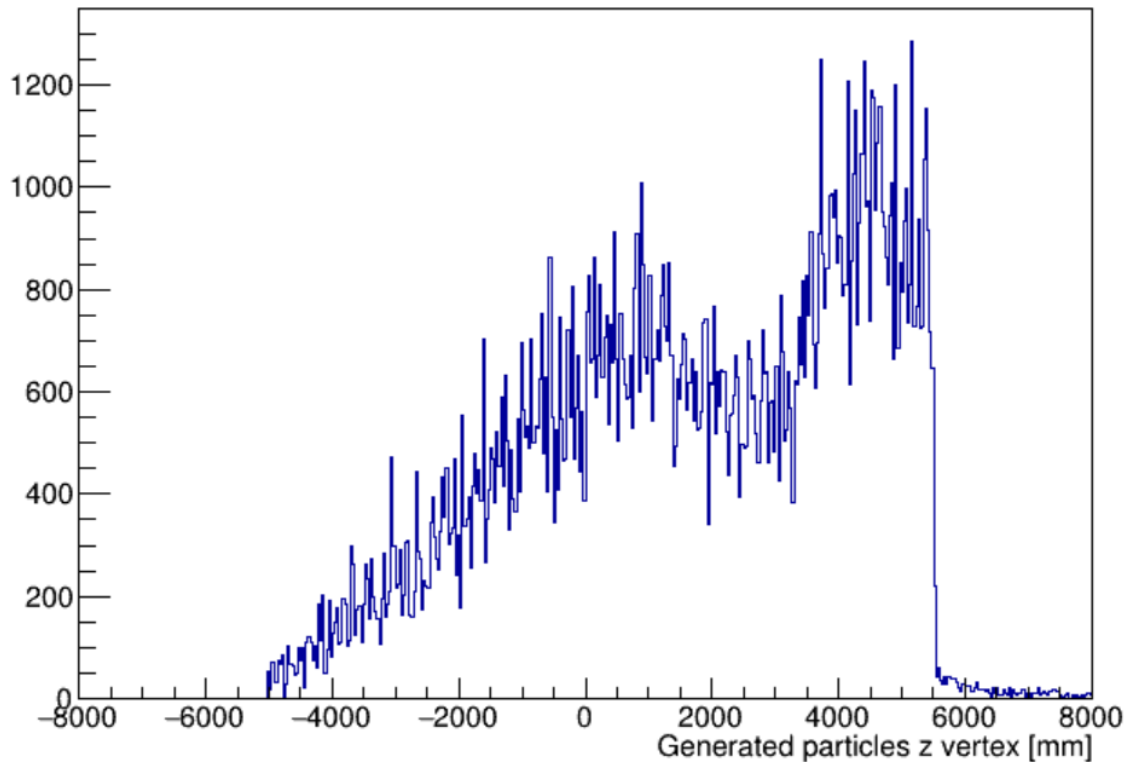
- I contacted the backgrounds WG with the above questions a week ago, but I haven't heard back yet.
- Ben will send me instructions on running the merger code to mix signal and background events (including for a single background type) soon.
- So far, I have looked at some background-only generator-level distributions.

Proton – beam gas events only (no signal): generator-level vertex

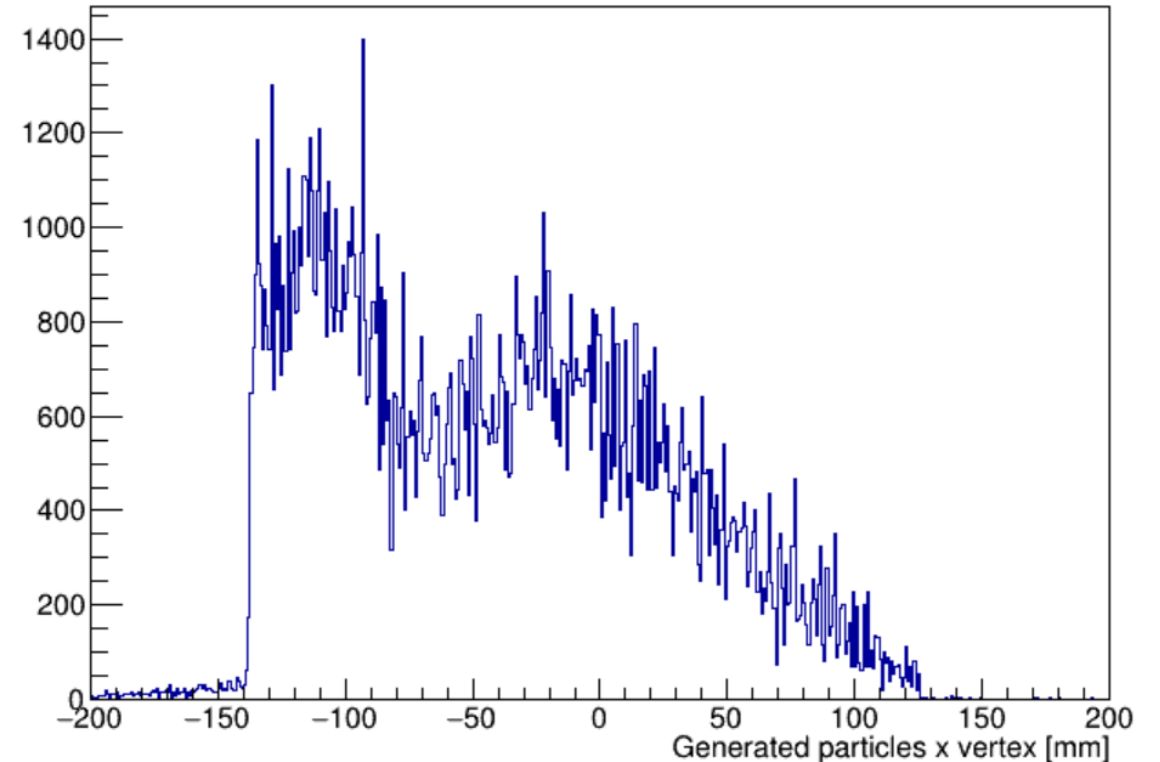
Proton – beam gas events consist of the proton beam scattering off a stationary proton. The events are a mix of elastic and inelastic scattering events.

Plotted below is the creation point of all generated final-state particles for 10k of these events.

275 GeV Proton-Beam Gas events



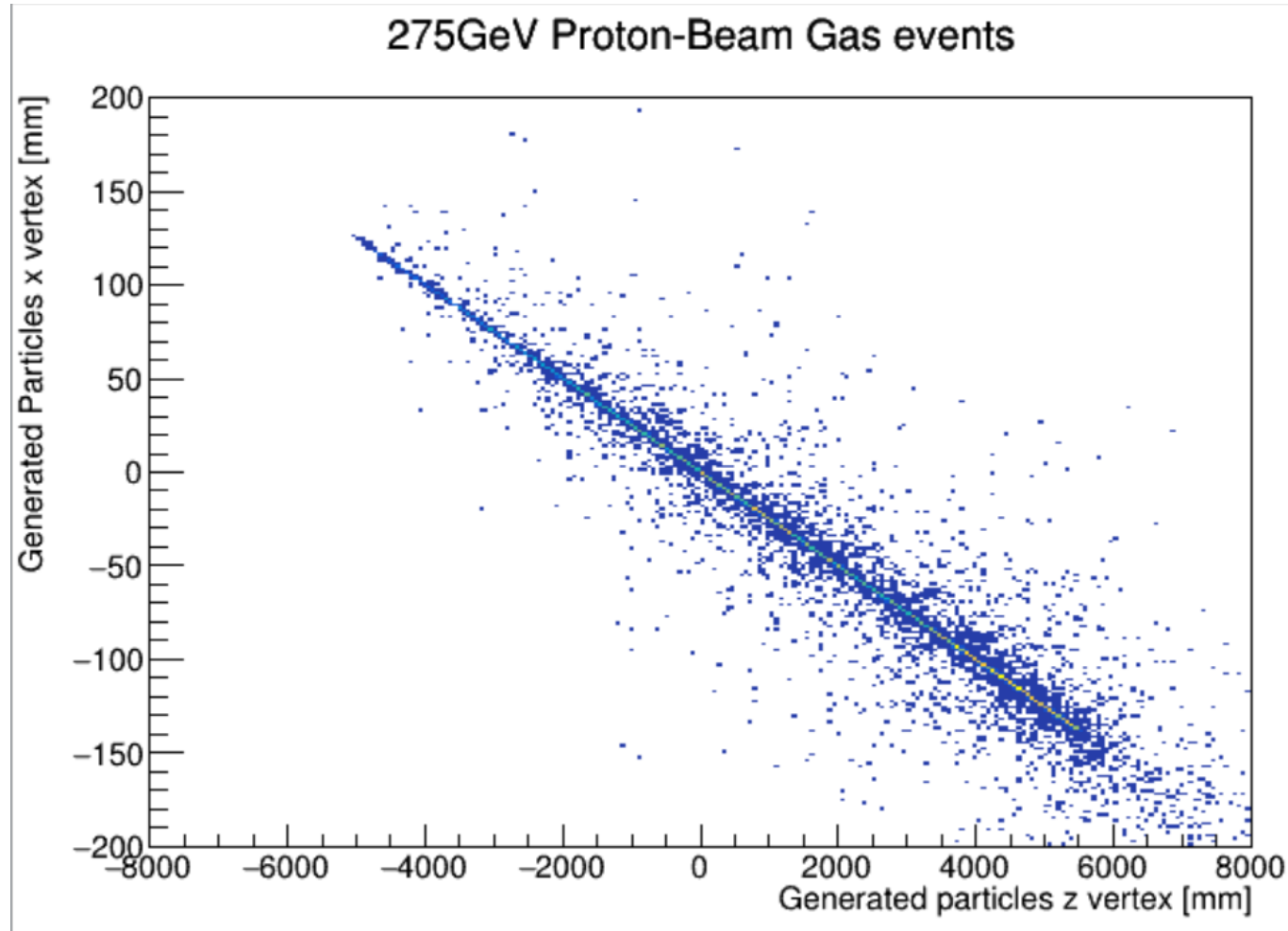
275 GeV Proton-Beam Gas events



Proton – beam gas events only (no signal): generator-level vertex

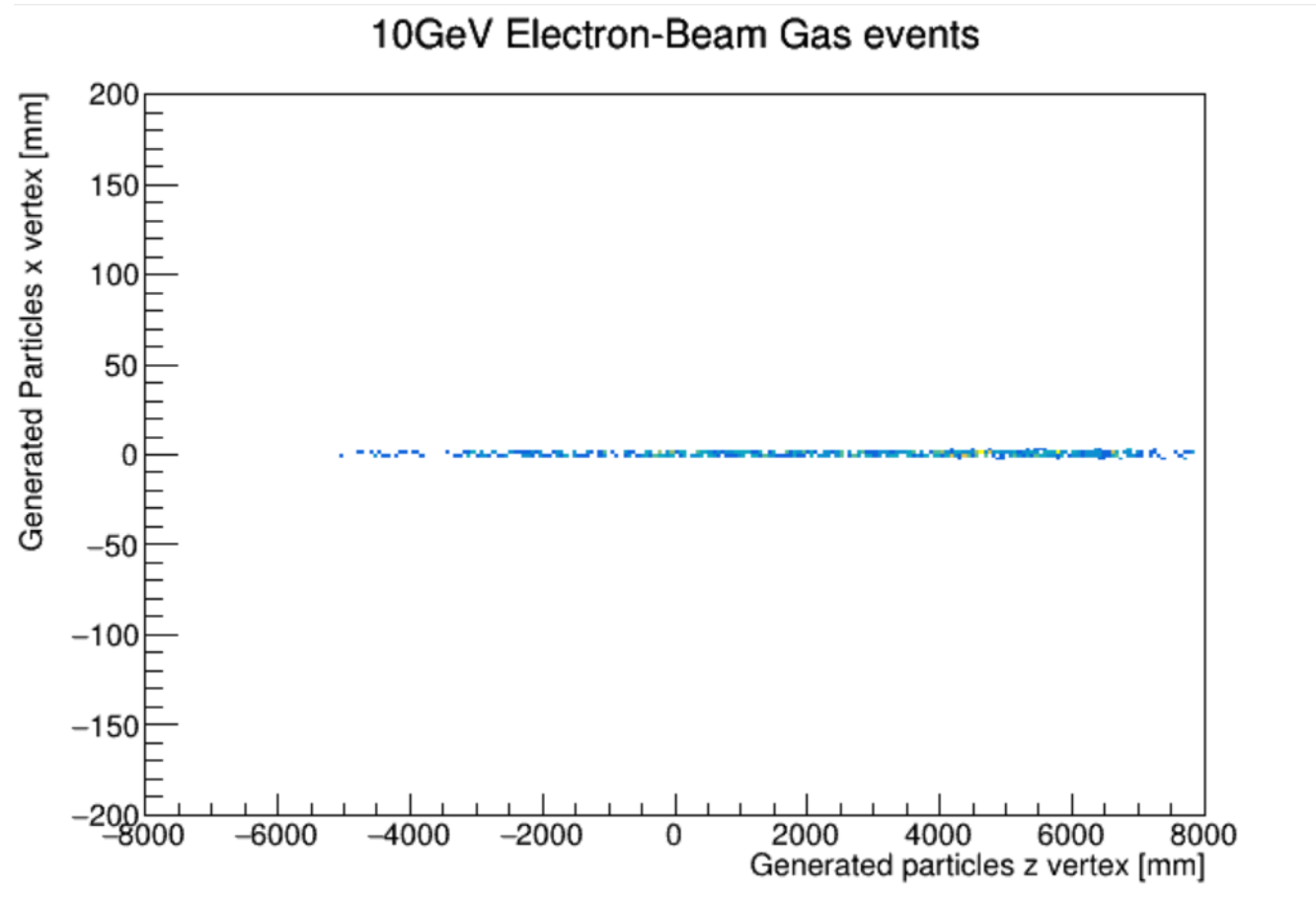
Proton – beam gas events consist of the proton beam scattering off a stationary proton. The events are a mix of elastic and inelastic scattering events.

Plotted below is the creation point of all generated final-state particles for 10k of these events.



Electron – beam gas events only (no signal): generator-level vertex

Electron – beam gas events consist of the electron beam scattering off a stationary proton. Plotted below is the creation point of all generated final-state particles for 1k of these events.



Electron – beam gas events only (no signal): final-state particles

In all 1k of the electron – beam gas events that I simulated, the events all have only 2 final-state particles – an electron and a photon. Does this make sense?

```
root [2] hepmc3_tree->Scan("particles.pid","particles.status==1")
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*****
```

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* Row * Instance * particles *
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*****
```

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* 0 * 1 * 22 *  
* 0 * 2 * 11 *  
* 1 * 1 * 22 *  
* 1 * 2 * 11 *  
* 2 * 1 * 22 *  
* 2 * 2 * 11 *  
* 3 * 1 * 22 *  
* 3 * 2 * 11 *  
* 4 * 1 * 22 *  
* 4 * 2 * 11 *  
* 5 * 1 * 22 *  
* 5 * 2 * 11 *
```