Background Study Update

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ePIC tracking++ meeting

Note: the background event sample used in this study significantly underestimated the synchrotron radiation rates. See https://indico.bnl.gov/event/26993/

Please don't quote the efficiency and purity from this particular presentation.

DIS+Background Sample

- New Hepmc merger and background samples described [here](#), See also [discussion](#) at the ePIC TIC meeting
- Reconstructed events from merged sample will be available in next simulation campaign
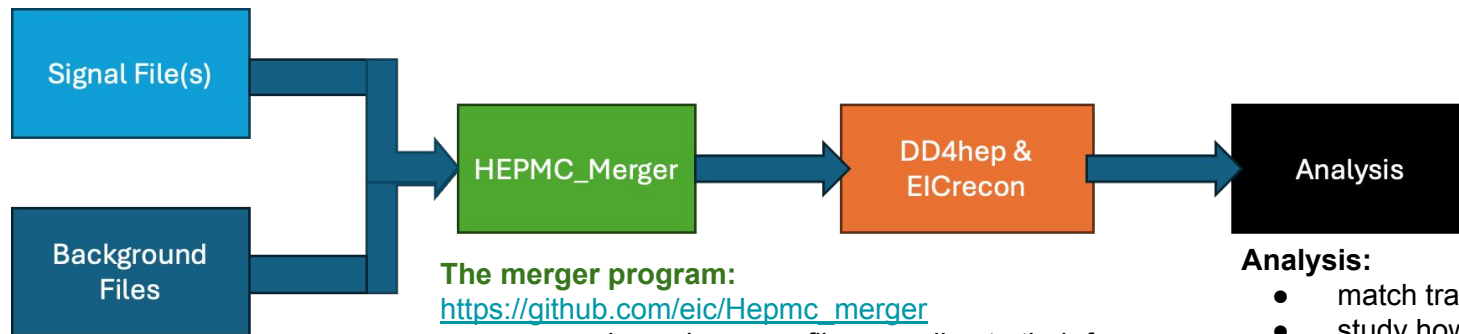
The merger program:
https://github.com/eic/Hepmc_merger
- sample each source file according to their frequency within a fixed-length (2us) time window
- label each source particle with custom generator code

Analysis:
- match track to particles
- study how well we can reconstruct signal particles

Event = one collision → (merged) Event = one 2us time slice

DIS+Background Sample

Two scenarios:

1. In the presence of DIS events, check the impact of background. (1k merged events/ time slices)

```
Signal events file and frequency:
    – pythia8NCDIS_18x275_minQ2=1_beamEffects_xAngle=–0.025_hiDiv_1.hepmc     (one event per time slice)


Background files and their respective frequencies:
    – dataprod_rel_1.0.0_synrad_18x275_run001.hepmc3.tree.root       14000.000000 kHz
Shifting all particle status codes from this source by 2000
    – GETaLM1.0.0–1.1_ElectronBeamGas_18GeV_emin10keV_run001.hepmc3.tree.root      316.940000 kHz
Shifting all particle status codes from this source by 3000
    – dataprod_rel_1.0.0_electron_coulomb_18x275_10000Ahr.hepmc3.tree.root  1.300000 kHz
Shifting all particle status codes from this source by 4000
    – dataprod_rel_1.0.0_electron_touschek_18x275_10000Ahr.hepmc3.tree.root 0.720000 kHz
Shifting all particle status codes from this source by 5000
    – pythia8.306–1.0_ProtonBeamGas_275GeV_run001.hepmc3.tree.root  22.500000 kHz
Shifting all particle status codes from this source by 6000
```
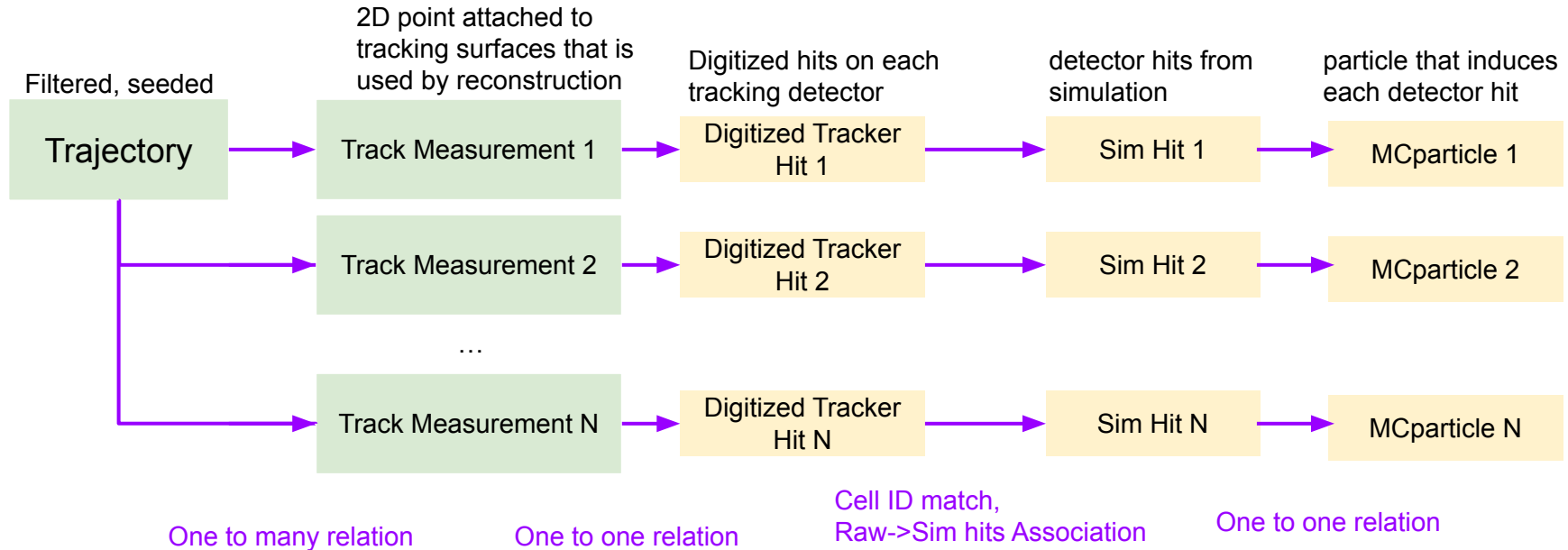
SR +

electron beam gas
(Bremsstrahlung,
Coulomb, Touschek) +

proton beam gas

2. Minbias SIDIS + background (not in the presentation)

Background Study Workflow

- **Match trajectory to simulated particles**

2D point attached to tracking surfaces that is used by reconstruction

Digitized hits on each tracking detector

detector hits from simulation

particle that induces each detector hit

Filtered, seeded

| Trajectory |

| Track Measurement 1 | → | Digitized Tracker Hit 1 | → | Sim Hit 1 | → | MCparticle 1 |

| Track Measurement 2 | → | Digitized Tracker Hit 2 | → | Sim Hit 2 | → | MCparticle 2 |

…

| Track Measurement N | → | Digitized Tracker Hit N | → | Sim Hit N | → | MCparticle N |

One to many relation   One to one relation   Cell ID match, Raw->Sim hits Association   One to one relation

Efficiency: fraction of primary particles that are associated with tracks.
Purity: for a given track, fraction of hits from one particle.

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Background Study Workflow

- **Identify track measurements**

  By definition, the measurement and outlier flags (bitset) are not mutually exclusive. Was assumed to be until recent ACTS upgrade in EICrecon

```
/// @enum TrackStateFlag
///
/// This enum describes the type of TrackState
enum TrackStateFlag {
    MeasurementFlag = 0,
    ParameterFlag = 1,
    OutlierFlag = 2,
    HoleFlag = 3,
    MaterialFlag = 4,
    SharedHitFlag = 5,
    NoExpectedHitFlag = 6,
    NumTrackStateFlags = 7
};

void set(std::size_t pos, bool value = true) {
    std::bitset<kRawBits> bs{*m_raw};
    bs.set(pos, value);
    *m_raw = bs.to_ullong();
}
```

Change in ACTS 36.1

```
auto typeFlags = trackState.typeFlags();
typeFlags.set(TrackStateFlag::ParameterFlag);
typeFlags.set(TrackStateFlag::MeasurementFlag);
if (trackState.referenceSurface().surfaceMaterial() != nullptr) {
    typeFlags.set(TrackStateFlag::MaterialFlag);
}
if (isOutlier) {
    // propagate information that this is an outlier state
    ACTS_VERBOSE(
        "Creating outlier track state with tip = " << trackState.index());
    typeFlags.set(TrackStateFlag::OutlierFlag);
}
```

- Previously:
  - MeasurementFlag: points used in tracking
  - OutlierFlags: points on surface but not used in tracking
- Now:
  - MeasurementFlag: all candidate points on tracking surface
  - OutlierFlags: points on surface but not used in tracking

  Solution:
  - Workaround in EICrecon
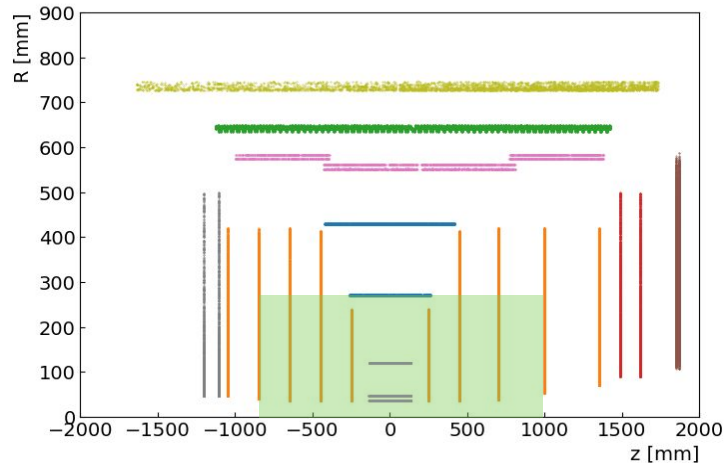 - Discussion with ACTS developers

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DIS sample inspection

1k events from pythia8NCDIS_18x275_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc
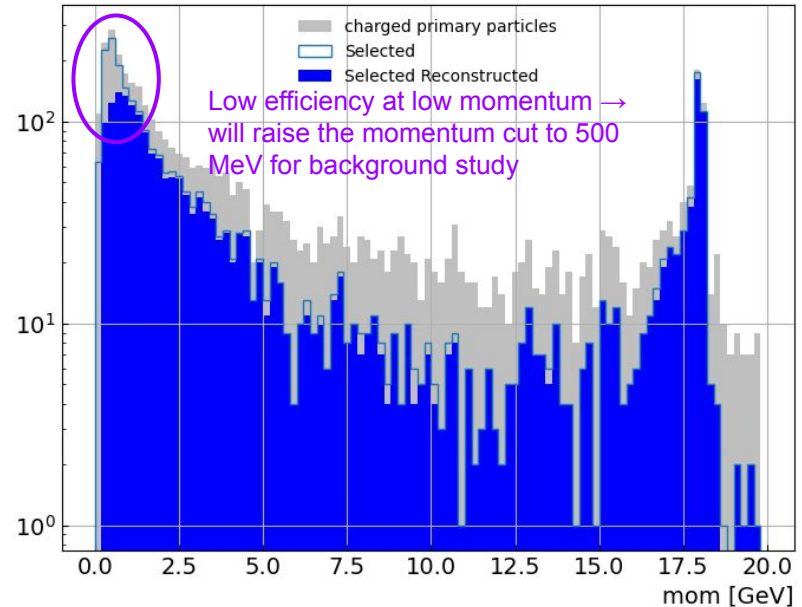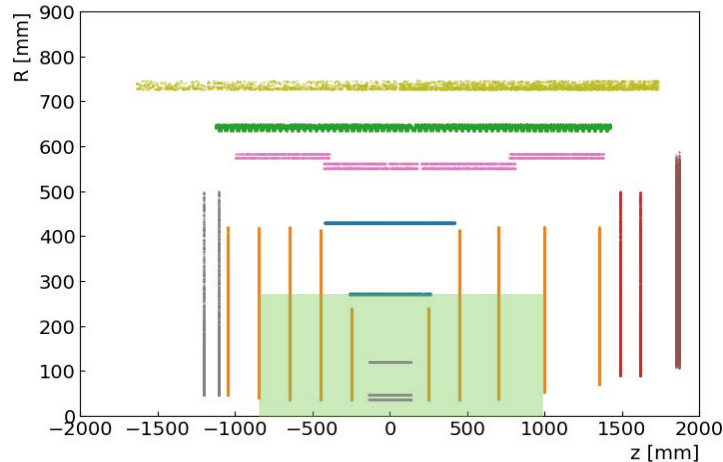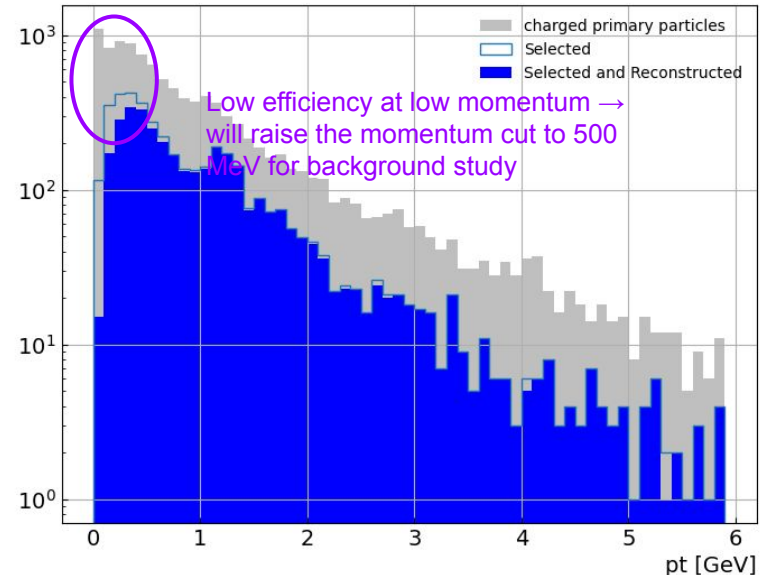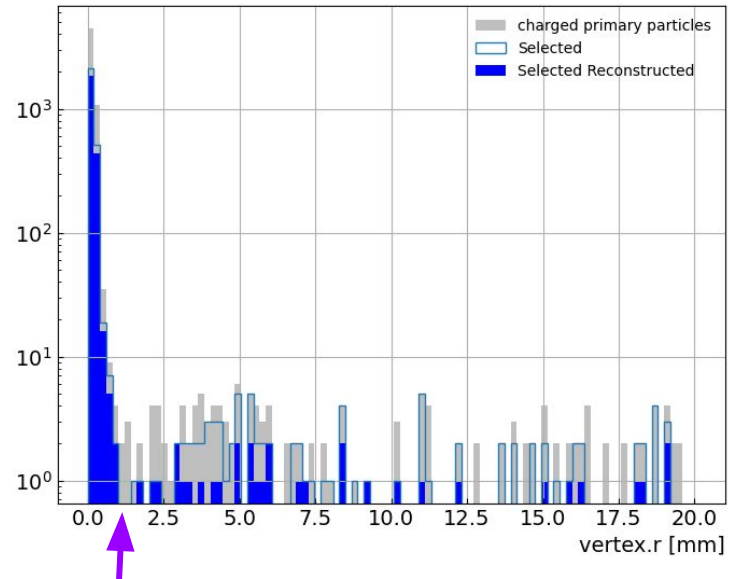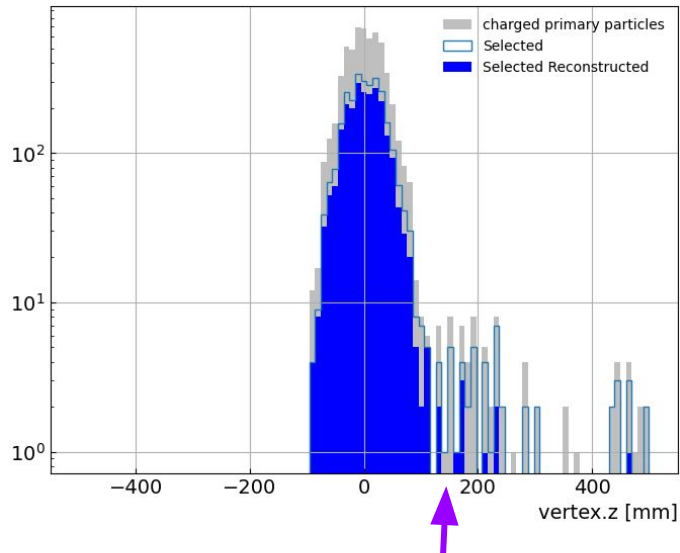
- **Basic particle selection:**
  - Primary (un)decayed particle:
    - generatorStatus==xxx1 or xxx2
    - charged
  - Particle endpoint outside of a barrel with
    - -850<z<1000mm
    - r<270mm

  So that it has high chance to go through 4 layers

- **Need to:**
  - Define cuts where the DIS only events can be reasonably reconstructed

Low efficiency at low momentum → will raise the momentum cut to 500 MeV for background study

DIS sample inspection

1k events from pythia8NCDIS_18x275_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc

- **Basic particle selection:**
  - Primary (un)decayed particle:
    - generatorStatus==xxx1 or xxx2
    - charged
  - Particle endpoint outside of a barrel with
    - -850<z<1000mm (4th endcap disk)
    - r<270mm (L3 barrel)

  So that it has high chance to go through 4 layers

- **Need to:**
  - Define cuts where the DIS only events can be reasonably reconstructed

Low efficiency at low momentum → will raise the momentum cut to 500 MeV for background study

Legend: charged primary particles / Selected / Selected and Reconstructed

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DIS sample inspection

1k events from pythia8NCDIS_18x275_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc

- **Basic particle selection:**
    - Primary (un)decayed particle:
        - generatorStatus==xxx1 or xxx2
        - charged
    - Particle endpoint outside of a barrel with
        - -850<z<1000mm (4th endcap disk)
        - r<270mm (L3 barrel)

    So that it has high chance to go through 4 layers

+ momentum>0.5GeV
+ New vertex cut: r<1mm, abs(z)<100mm

DIS sample inspection

- **Basic particle selection:**
  - Primary (un)decayed particle:
    - generatorStatus==xxx1 or xxx2
    - Charged
  - Momentum > 0.5 GeV
  - Vertex.r<1mm, abs(Vertex.z)<100mm
  - Particle endpoint outside of a barrel with
    - -850<z<1000mm (4th endcap disk)
    - r<270mm (L3 barrel)

    So that it has high chance to go through 4 layers

Red: reconstructed
Grey: passed cut but not reconstructed

electrons

pions

pi-
pi+
e-
K+
p
K-
p~
mu-
e+
mu+
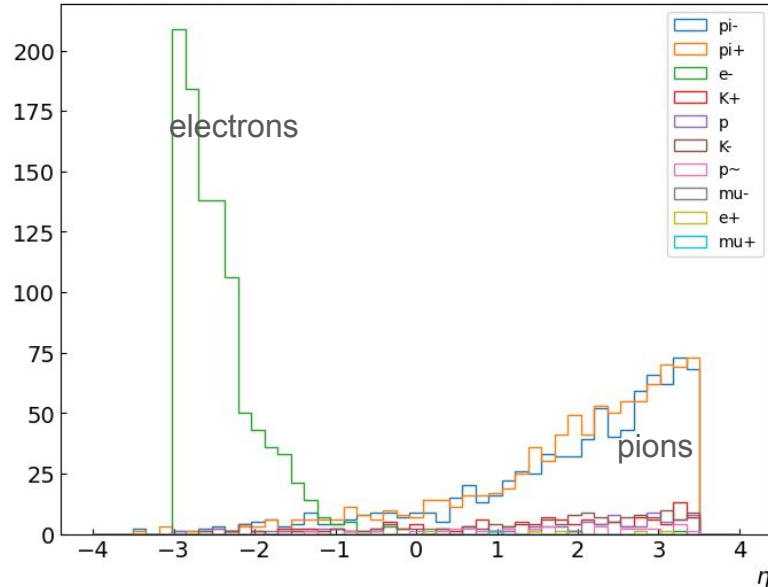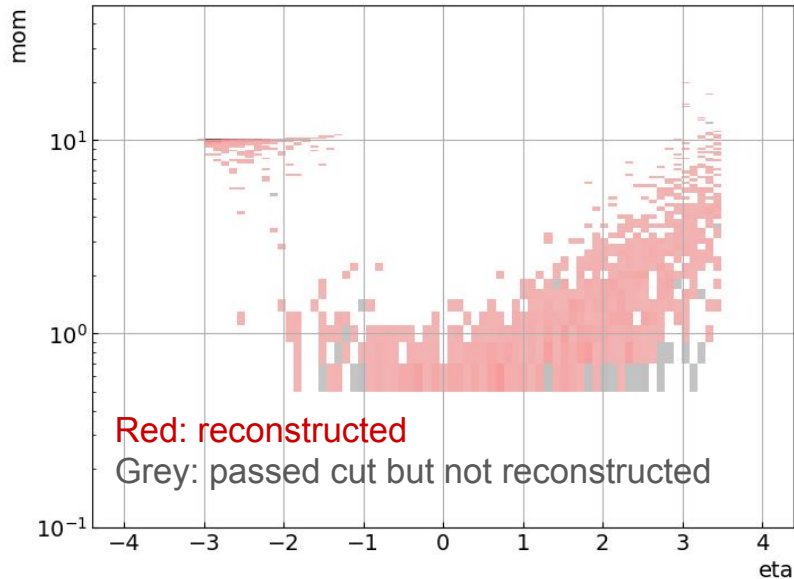
Background samples Inspection:
Fake tracks, noise hits

All charged primary particles from 18x275 DIS (forced) + background, no cuts

Proton beam gas

proton_beamgas_275GeV_350kHz.hepmc3.tree.root
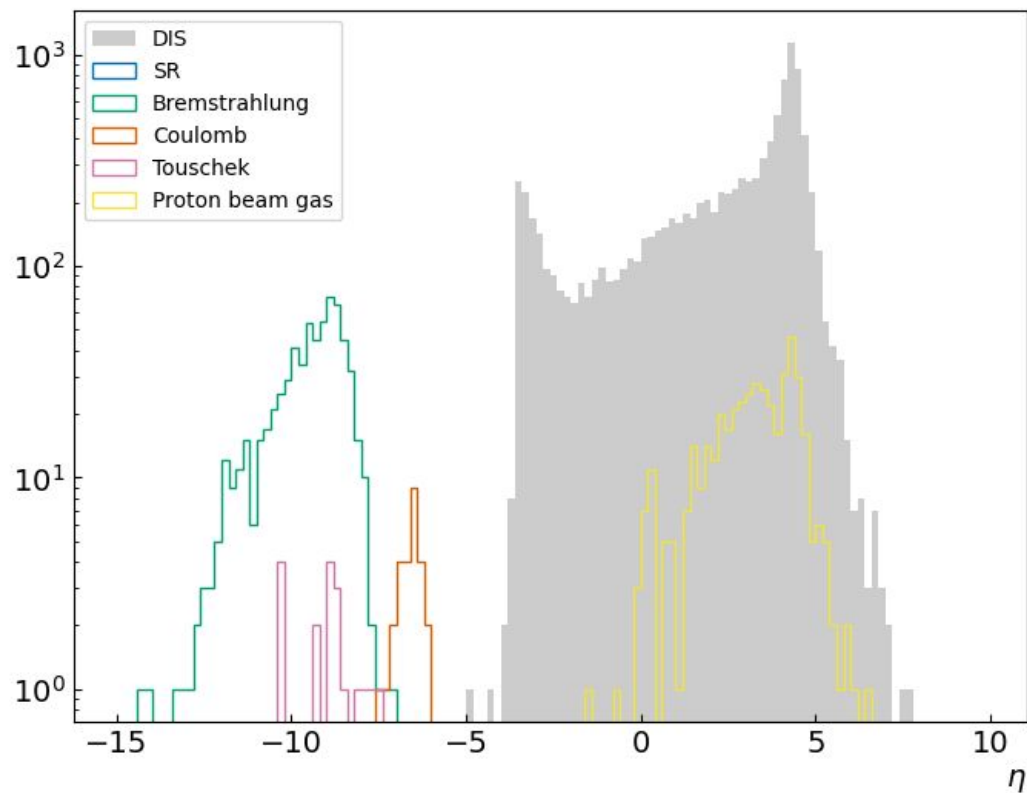
Charged primary particles
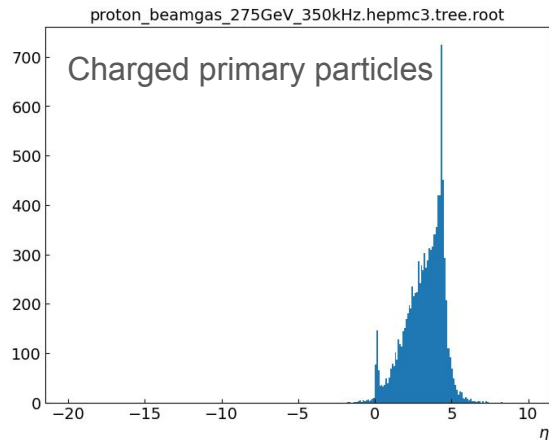
Most particles won't pass vertex cuts
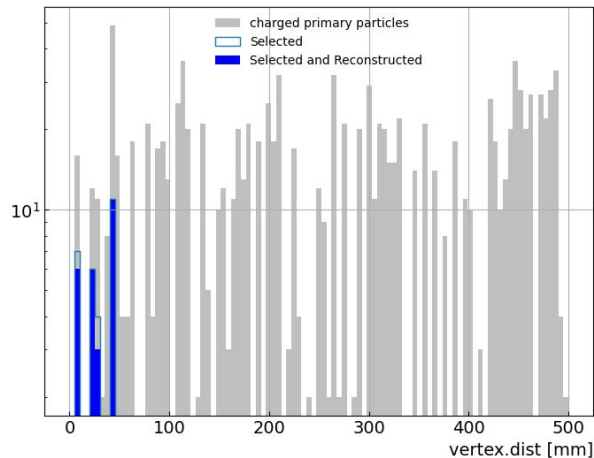
# of digitized hits from 1k DIS (forced) + proton beam gas merged sample:

	DIS	Proton beam gas
SiBarrelTrackerRecHits	2203	1542
SiEndcapTrackerRecHits	26761	18733
TOFBarrelRecHits	7451	5216
ForwardMPGDEndcapRecHits	3656	2559
SiBarrelVertexRecHits	5893	4125
TOFEndcapRecHits	5905	4134
MPGDBarrelRecHits	2027	1419
BackwardMPGDEndcapRecHits	797	558
OuterMPGDBarrelRecHits	2175	1523
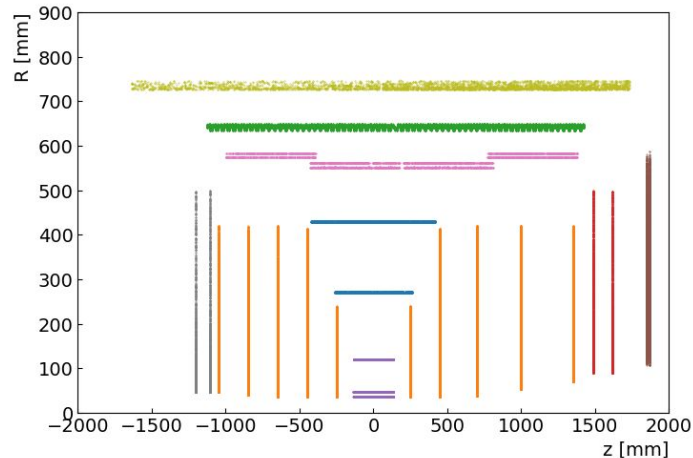
Proton beam gas will introduce many "noise" hits but not tracks to tracker

Electron beam gas

- All primary particles out of eta range.
- Induced a small amount of detector hits
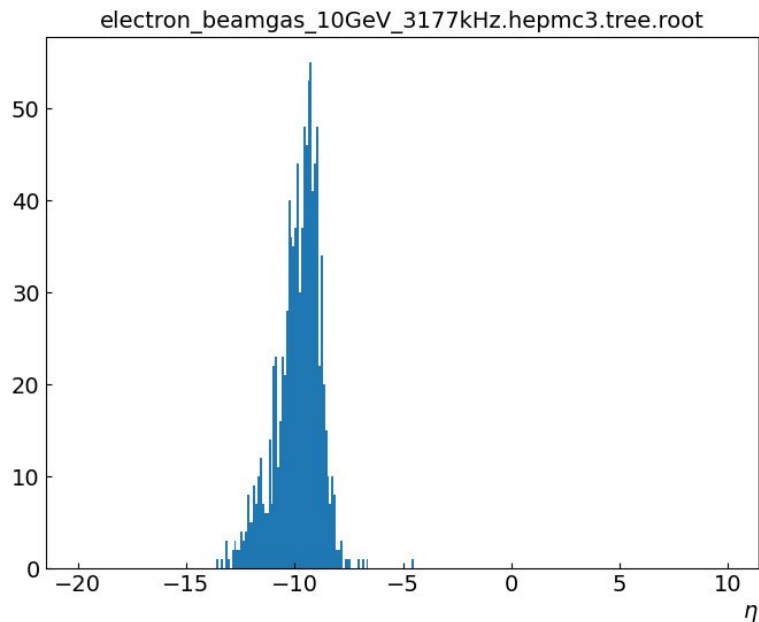
# of digitized hits:
```
SiBarrelTrackerRecHits 79
SiEndcapTrackerRecHits 972
TOFBarrelRecHits 176
ForwardMPGDEndcapRecHits 38
SiBarrelVertexRecHits 507
TOFEndcapRecHits 48
MPGDBarrelRecHits 60
BackwardMPGDEndcapRecHits 54
OuterMPGDBarrelRecHits 35
```


electron_beamgas_10GeV_3177kHz.hepmc3.tree.root
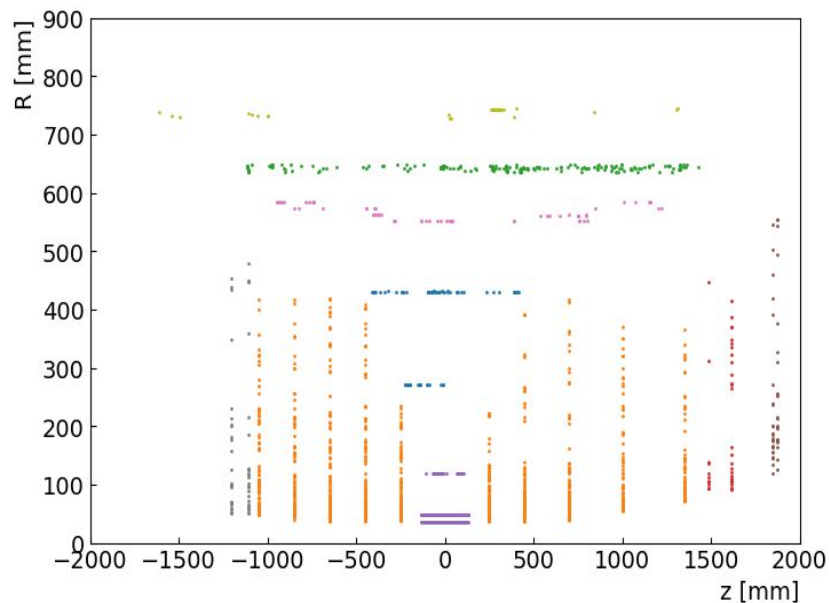
SR

in 1k SR-only merged sample:

# of primary particles

|	
gamma	28024
pi0	5
pi+	4
pi-	3

# of digitized hits:

```
SiBarrelTrackerRecHits 4
SiEndcapTrackerRecHits 99
TOFBarrelRecHits 12
ForwardMPGDEndcapRecHits 7
SiBarrelVertexRecHits 55
TOFEndcapRecHits 9
MPGDBarrelRecHits 0
BackwardMPGDEndcapRecHits 0
OuterMPGDBarrelRecHits 1
```

# of reconstructed track: 0.

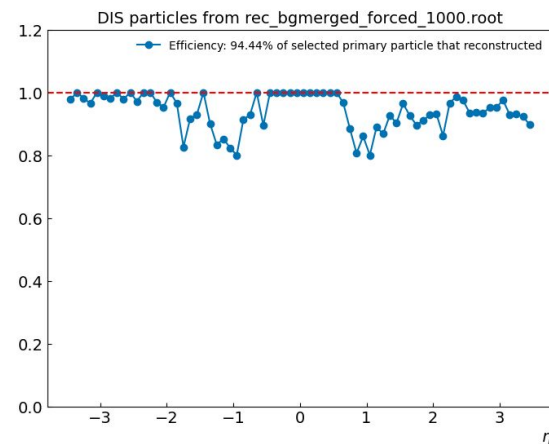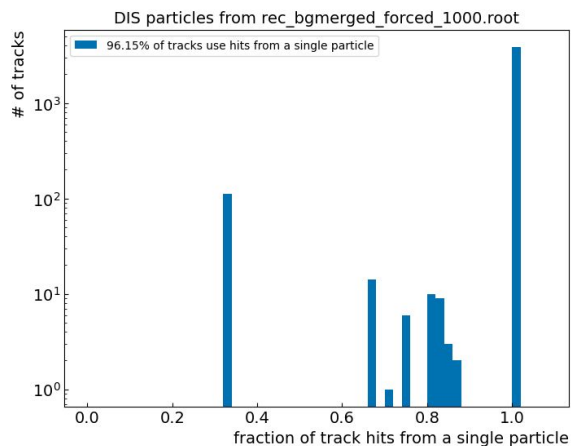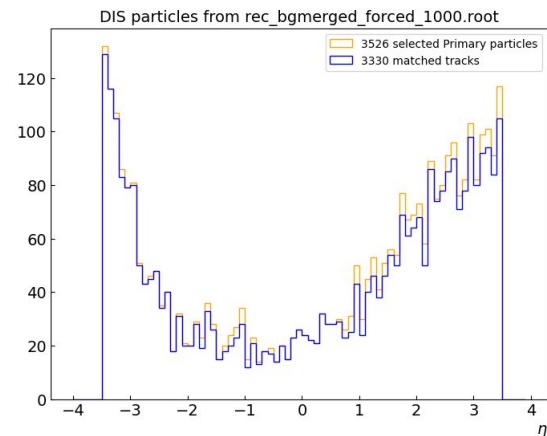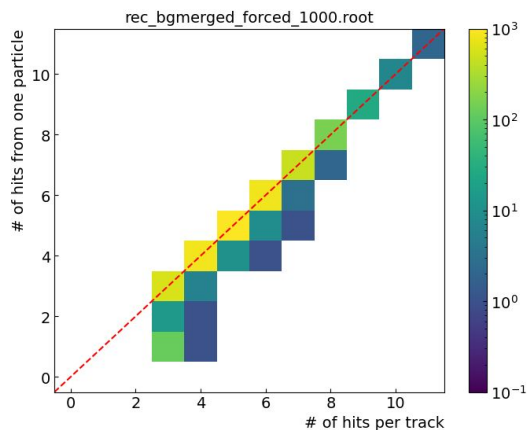digitized hits distribution

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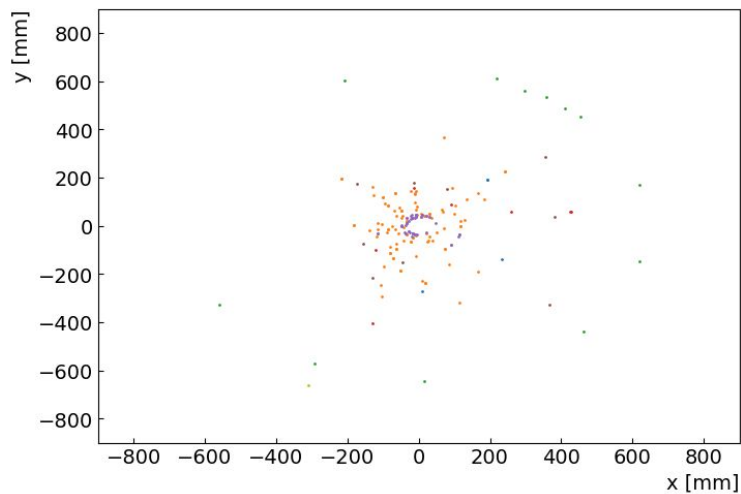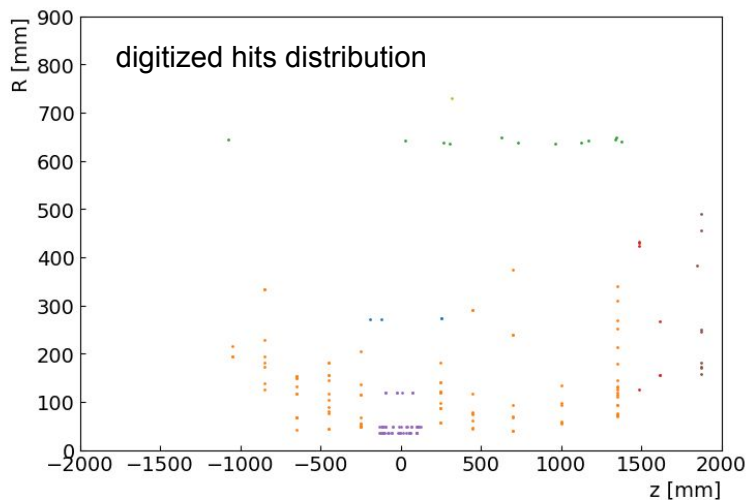
Efficiency and Purity: DIS only sample

18x275
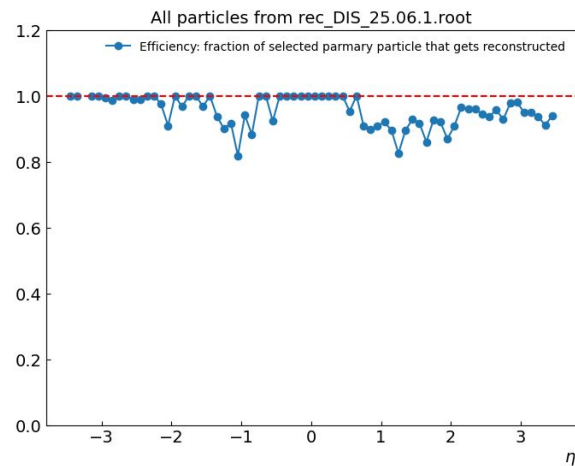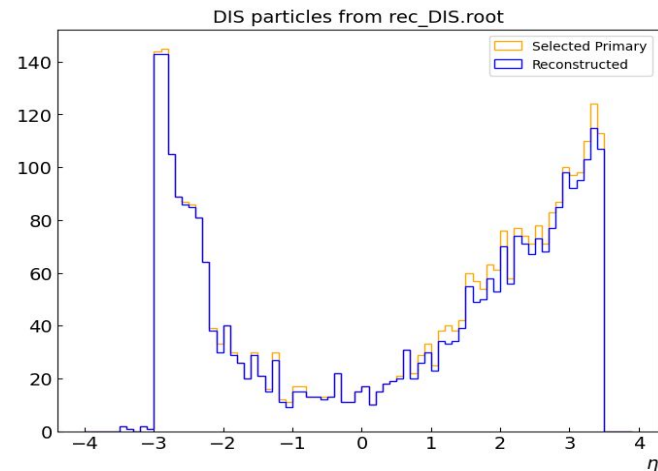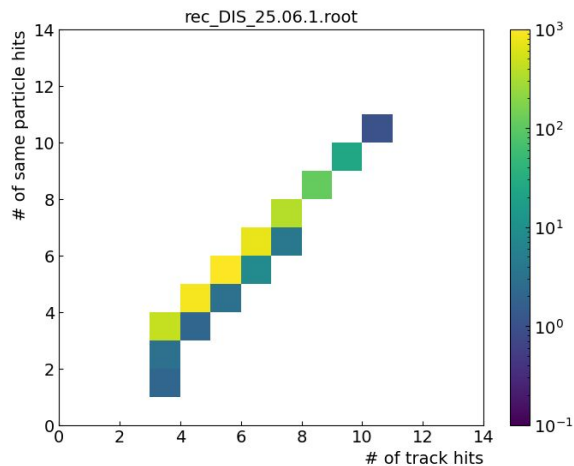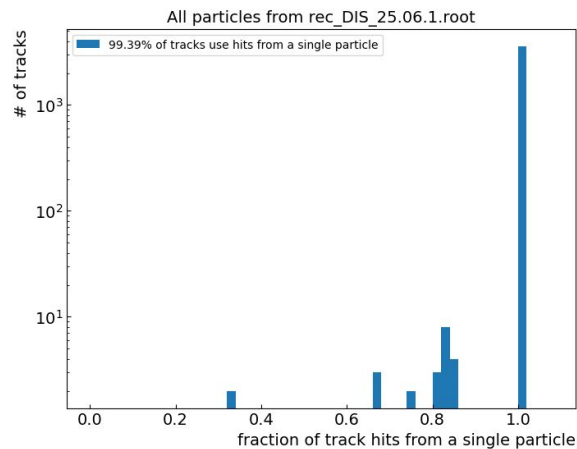
Efficiency and Purity: DIS (forced) + background sample

18x275

Next step:

1. Minbias sample
2. Outer beam configuration
3. More stats

Thanks!