Additional track reconstruction metrics

Barak Schmookler

&

Jeetendra Gupta

Track reconstruction metrics

- When studying track reconstruction performance – with the inclusion of background particles (and noise in the near future) – we start by defining two samples:
  1. **Good signal particles**: These are particles that should have a reconstructed track. For example, we can define this sample as final-state (i.e., status = 1) particles that leave at least 3 hits in our tracking detectors.
  2. **Valid tracks**: These are the reconstructed tracks that pass our basic track quality selection criteria. For example, these can be all tracks with at least four good measurements included in track fit.

Track reconstruction metrics

- Once we have these samples, we define some quantitative figures of merit:
  1. **Hit purity**: For a given particle-track pair, what fraction of the given reconstructed track hits (i.e., measurements) come from the given particle. We say that the pair is **matched** if this hit purity is larger than some threshold (e.g., 50%).
  2. **Tracking efficiency**: the ratio of the number of matched pairs to the number of good signal particles.
  3. **Tracking purity**: the ratio of the number of matched pairs to the number of valid tracks.
- We have done quantitative studies with backgrounds using the three metrics. (See slides by Shujie in previous meetings.)

Track reconstruction metrics

- We can also define one additional metric.
  - **Hit efficiency**: For a given particle-track pair, what fraction of the given particle's tracking detector hits are used as hits (i.e., measurements) in the given reconstructed track.
- The hit efficiency is a useful figure of merit in itself. It can tell us how often certain hits in a given tracking subdetector are being ignored by the track fit.
- In addition, we can use both the hit purity and the hit efficiency to define our pair matching requirement. If we use the **double-majority rule** – where both the hit purity and the hit efficiency are required to be greater than 50% – we will guarantee one-to-one matching between particles and reconstructed tracks.

Extracting hit efficiencies

- We calculate the hit purity directly in EICRecon, and we save this to a data collection in our output file.
- For hit efficiency, however, we do not perform any such calculation inside EICRecon. (There was some discussion about doing this last year.)
  - So, we wrote an analysis code using PODIO classes that allows us to calculate the number of tracking detector hits associated with a given generated particle. This can be used as a basis for putting the hit efficiency calculation inside EICRecon, if we want.
  - I'll go over the logic of the code below and show some output.

PODIO-based code logic

- Start from the MCRecoTrackerHitAssociationCollection
  - This provides the association: RawHit <-> SimHit
- For each association: Retrieve the associated MCParticle
  - Only keep when the associated MCParticle has generatorStatus==1
- Build a fast lookup table: RawHitKey -> { particleID, quality }
  - RawHitKey is a unique 64-bit identifier
  - quality is taken from the SimHit
- Loop over reconstructed hit collections: SiEndcapTrackerRecHits, SiBarrelVertexRecHits , SiBarrelTrackerRecHits, etc…
- For each reconstructed hit:
  - Retrieve the associated RawHit
  - Construct the corresponding RawHitKey
  - Look up the truth information (ParticleID, quality) in the map

PODIO-based code logic

- Build the final truth-hit structure:
  - particleID -> list of reconstructed hits
- Each stored hit contains:
  - reconstructed hit key
  - quality flag
- Naturally extends to:
  - trackID -> reconstructed hits
  - Matching strategy: shared hits(track, particle)

Code can be found here:
https://github.com/eic/snippets/blob/main/Tracking/TrackMetrics/TrackMetrics.C

What do we see

Looking at 26.03 campaign: 10x100 GeV setting with all beam backgrounds included

```
Event 98 | Collection: SiEndcapTrackerRecHits | rechits: 2118
Event 98 | Collection: SiBarrelVertexRecHits | rechits: 1482
Event 98 | Collection: SiBarrelTrackerRecHits | rechits: 636
Event 98 | Collection: MPGDBarrelRecHits | rechits: 101
Event 98 | Collection: OuterMPGDBarrelRecHits | rechits: 17
Event 98 | Collection: BackwardMPGDEndcapRecHits | rechits: 9
Event 98 | Collection: ForwardMPGDEndcapRecHits | rechits: 9
Event 98 | Collection: TOFBarrelRecHits | rechits: 610
Event 98 | Collection: TOFEndcapRecHits | rechits: 4
Event 98 has 7 status==1 particles with tracker hits
  Particle 35 --> 1 reco hits (and 0 quality==0 hits)
  Particle 26 --> 4 reco hits (and 4 quality==0 hits)
  Particle 18 --> 5 reco hits (and 5 quality==0 hits)
  Particle 32 --> 10 reco hits (and 5 quality==0 hits)
  Particle 20 --> 6 reco hits (and 6 quality==0 hits)
  Particle 12 --> 7 reco hits (and 7 quality==0 hits)
  Particle 25 --> 5 reco hits (and 5 quality==0 hits)
```

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```

Many RecoHits coming from background particles.

Seven signal particles leave tracker hits.

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```

Reminder about quality:

- If a hit comes from a particle in the MCParticle list will have quality = 0.
- If a hit comes from a secondary, but that secondary has too small an energy to be included in the MCParticle list, the hit will be associated with the parent and have a non-zero quality.

Particle 32 has 10 RecHits associated with it, but only 5 have quality = 0.

Conclusions

- Tracking hit efficiency is an important metric that we should evaluate.
- We have a PODIO-based analysis code that allows us to do this. We can implement the same logic into EICRecon.
- When calculating hit efficiency, we need to handle the quality flag carefully.