Update on Vertexing Activities

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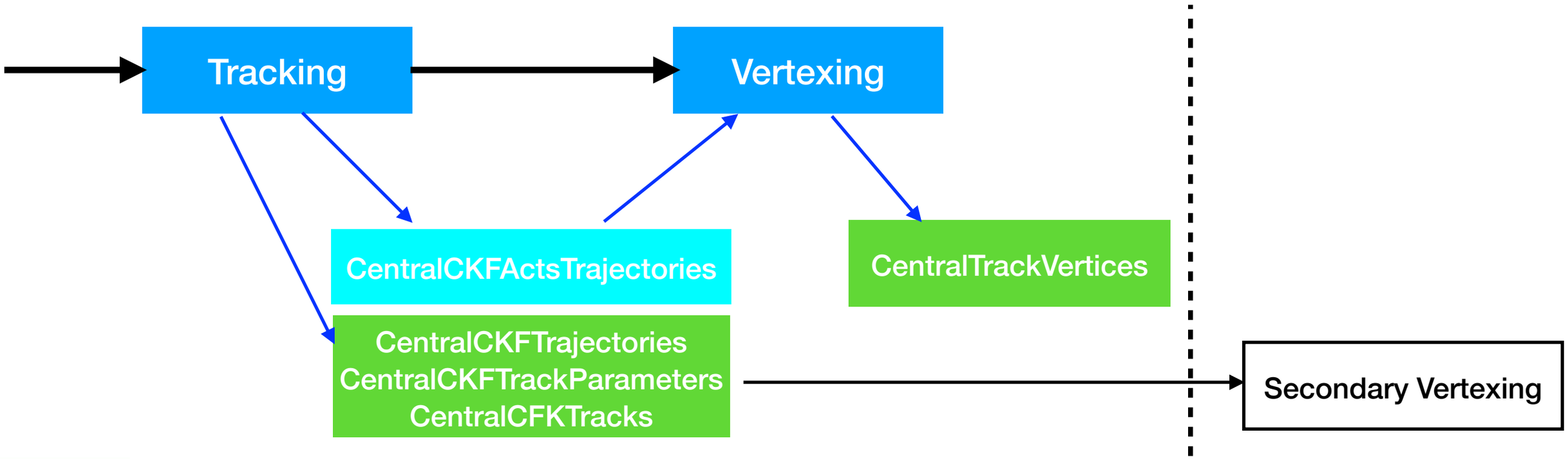
Tracking/Vertexing Workflow



PODIO

Production

Overall Status:
- Basic workflow in place
- What's in place?
  > All basic components
- What's missing?
  > edm4eic::Vertex associatedParticles not filled

Workflow Inputs/Outputs
- Inputs: CentralCKF(Seeded)ActsTrajectories
- Outputs: CentralTrackVertices (edm4eic::Vertex)

Analysis/User?

Near Term Goals:
- ***primary-vertexing benchmark for TDR***
- ***fill in missing associatedParticles in output***

Long Term Goals:
- algorithm/parameter tuning for different classes of events
- MC/generated vertices and associations
- secondary vertexing

Vertexing Algorithm and edm4eic Vertex

IterativeVertexFinder

- Input: CentralCKFActsTrajectories / CentralCFKSeededActsTrajectories
- default 1D ZScan for vertex seeding (options to use beam line constraints, not in default)
    - logPt weight used with pT_min = 0.4 GeV/c
- output written to CentralTrackVertices (edm4eic::vertex)
    - *associatedParticles not filled at this moment*

https://github.com/eic/EICrecon/blob/main/src/global/tracking/tracking.cc

```
210         app->Add(new JOmniFactoryGeneratorT<IterativeVertexFinder_factory>(
211                 "CentralTrackVertices",
212                 {"CentralCKFActsTrajectories"},
213                 {"CentralTrackVertices"},
214                 {},
215                 app
216                 ));
```

"CentralCKFSeededActTrajectories" works well too, want to update for default in main branch

```
460     ## ============================================================================
461     ## Vertexing
462     ## ============================================================================
463
464     edm4eic::Vertex:
465       Description: "EIC vertex"
466       Author: "J. Osborn"
467       Members:
468         - int32_t             type          // Type flag, to identify what type of vertex it is (e.g. primary, secondary, generated, etc.)
469         - float               chi2          // Chi-squared of the vertex fit
470         - int                 ndf           // NDF of the vertex fit
471         - edm4hep::Vector4f   position      // position [mm] + time t0 [ns] of the vertex. Time is 4th component in vector
472         ## this is named "covMatrix" in EDM4hep, renamed for consistency with the rest of edm4eic
473         - edm4eic::Cov4f      positionError // Covariance matrix of the position+time. Time is 4th component, similarly to 4vector
474       OneToManyRelations:
475         - edm4eic::ReconstructedParticle associatedParticles // particles associated to this vertex.
```

Associated Particles in Vertex

According to Woulter, S&C team is working on a global update to the data model so the PODIO output objects keep the links to the Acts objects. This requires a new version of Acts and will need 3+ months?

In the meantime, we are working on an intermediate solution so users have the access to the associated particles from vertices.

tracking plugins

```
app->Add(new JOmniFactoryGeneratorT<IterativeVertexFinder_factory>(
        "CentralTrackVertices",
        {"CentralCKFSeededActsTrajectories","ReconstructedSeededChargedParticles"},
        {"CentralTrackVertices"},
        {},
        app
        ));
```

New input added

Input arguments in IterativeVertexFinder.cc

```
std::unique_ptr<edm4eic::VertexCollection> eicrecon::IterativeVertexFinder::produce(
    std::vector<const ActsExamples::Trajectories*> trajectories,
    std::vector<const edm4eic::ReconstructedParticle*> reconParticles) {
```

New input added

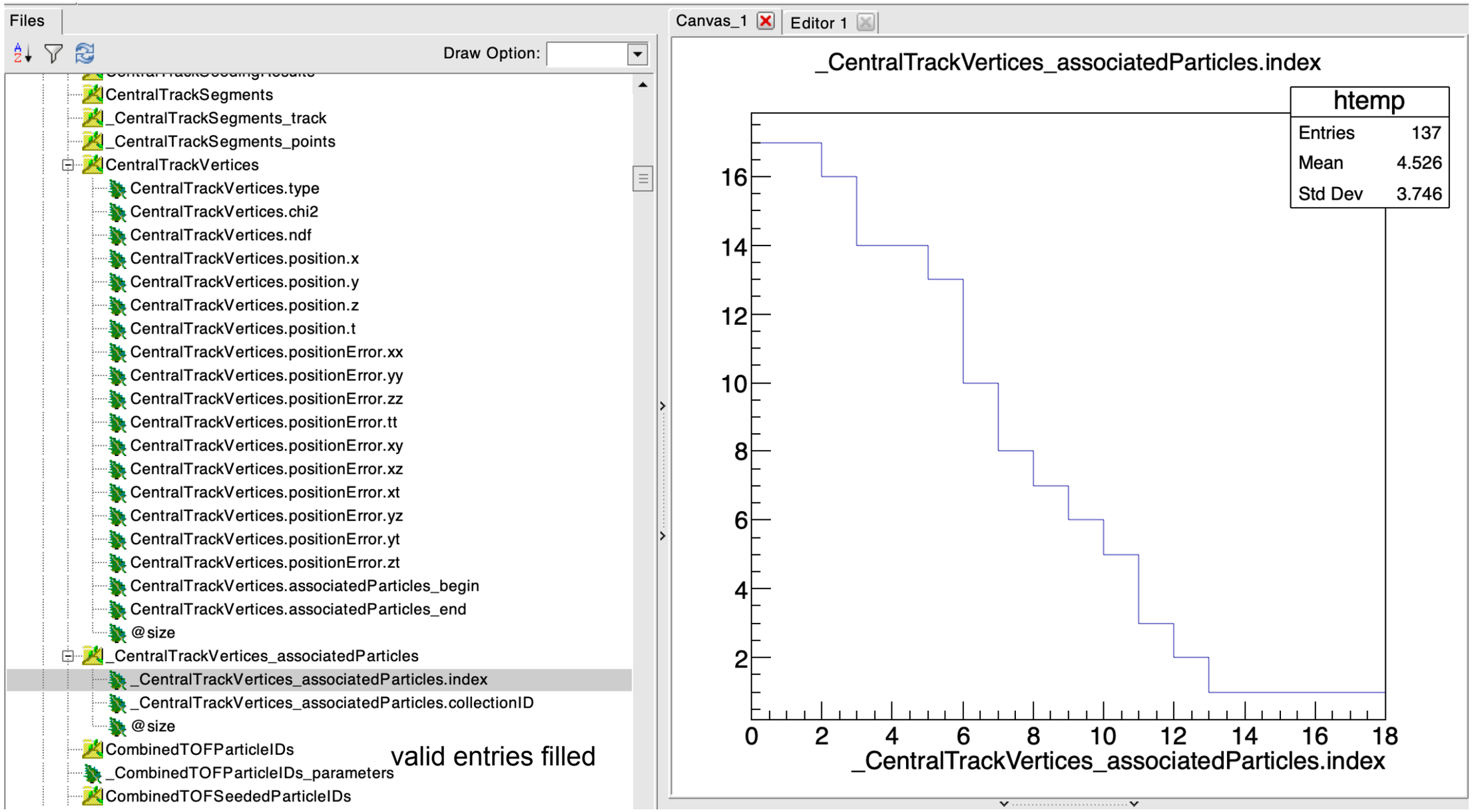
Filling part in IterativeVertexFinder.cc

```
    for (const auto& t : vtx.tracks()) {
#if Acts_VERSION_MAJOR >= 33
      const auto& trk = &t.originalParams;
      const auto& par = finderCfg.extractParameters(trk);
#else
      const auto& par = *t.originalParams;
#endif
      m_log->debug(" === track local position from vertex = {}, {}", par.localPosition().x(), par.localPosition().y());
      float loc_a = par.localPosition().x();
      float loc_b = par.localPosition().y();

      for (const auto part : reconParticles) {
        const auto& tracks = part->getTracks();
        for (const auto trk : tracks) {
          const auto& traj = trk.getTrajectory();
          const auto& trkPars = traj.getTrackParameters();
          for (const auto par : trkPars) {
            if(fabs(par.getLoc().a - loc_a) < 1.e-4 && fabs(par.getLoc().b - loc_b) < 1.e-4) {
              m_log->debug(" --- From ReconParticles, track local position = {}, {}", par.getLoc().a, par.getLoc().b);
//              std::cout << " par from ReconParticles " << par.getLoc().a << "\t" << par.getLoc().b << std::endl;
              eicvertex.addToAssociatedParticles(*part);
            } // endif
          } // end for par
        } // end for trk
      } // end for part
    } // end for t
    m_log->info(" +++ This vertex found at (x,y,z) = ({}, {}, {}) mm.", vtx.position().x(), vtx.position().y(), vtx.position().z());
```

Compare track parameters

PODIO output



Compared the associatedParticle array size, consistent with the ACTS vertexing output
Working on more detailed checks on any potential issue

Next Plan to Update ReconstructedParticle

```
## ============================================================================
## Particle info
## ============================================================================

edm4eic::ReconstructedParticle:
  Description: "EIC Reconstructed Particle"
  Author: "W. Armstrong, S. Joosten, F. Gaede"
  Members:
    - int32_t           type              // type of reconstructed particle. Check/set collection parameters ReconstructedParticleTypeNames and ReconstructedParticleTypeValues.
    - float             energy            // [GeV] energy of the reconstructed particle. Four momentum state is not kept consistent internally.
    - edm4hep::Vector3f momentum          // [GeV] particle momentum. Four momentum state is not kept consistent internally.
    - edm4hep::Vector3f referencePoint    // [mm] reference, i.e. where the particle has been measured
    - float             charge            // charge of the reconstructed particle.
    - float             mass              // [GeV] mass of the reconstructed particle, set independently from four vector. Four momentum state is not kept consistent internally.
    - float             goodnessOfPID     // overall goodness of the PID on a scale of [0;1]
    - edm4eic::Cov4f    covMatrix         // covariance matrix of the reconstructed particle 4vector (10 parameters).
    ##@TODO: deviation from EDM4hep: store explicit PDG ID here. Needs to be discussed how we
    ##       move forward as this could easiliy become unwieldy without this information here.
    ##       The only acceptable alternative would be to store reconstructed identified
    ##       particles in separate collections for the different particle types (which would
    ##       require some algorithmic changes but might work. Doing both might even make
    ##       sense. Needs some discussion, note that PID is more emphasized in NP than
    ##       HEP).
    - int32_t           PDG               // PDG code for this particle
    ## @TODO: Do we need timing info? Or do we rely on the start vertex time?
  OneToOneRelations:
    - edm4eic::Vertex      startVertex    // Start vertex associated to this particle
    - edm4hep::ParticleID  particleIDUsed // particle ID used for the kinematics of this particle
  OneToManyRelations:
    - edm4eic::Cluster     clusters       // Clusters used for this particle
    - edm4eic::Track       tracks         // Tracks used for this particle
    - edm4eic::ReconstructedParticle particles // Reconstructed particles that have been combined to this particle
    - edm4hep::ParticleID  particleIDs    // All associated particle IDs for this particle (not sorted by likelihood)
```

Q: ReconstructedSeededChargedParticles as input and output?

Vertexing Benchmark

1) Barak is working on a "tracking_performance_dis" benchmark; will integrate the vertexing code into this benchmark:

https://github.com/eic/detector_benchmarks/tree/tracking_performance_dis

2) Shujie also suggested to add it to the existing DIS physics benchmark:

https://github.com/eic/physics_benchmarks/tree/master/benchmarks/dis

3) HF&Jet specific?

Khushi and Rongrong will be helping on integrating the vertexing performance plots into the benchmark repositories