Path Towards Holistic Reconstruction: Intro and Context

ePIC Collaboration Meeting
07.25.2024

Workfest Agenda

1) **[8 – 9:45 am] Morning 1:**
Intro and Context
   - Flash updates from different *categories* of reconstruction
   - Frames forward-focused open discussion

2) **[9:45 – 10 am] Coffee break**

3) **[10 am – noon] Morning 2:**
Open Discussion
   - What do we need for truly *holistic* recnonstruction
   - What are the steps to get there?

4) **[noon – 1 pm] Lunch**

5) **[1 – 1:30 pm] Afternoon 1:**
The BELLE-II PID Experience

6) **[1:30 – 2 pm] Afternoon 2:**
Overflow Discussion
   - Accommodate discussion from morning or BELLE-II

7) **[2 – 3 pm] Afternoon 2:**
Electron-Finder Working Session I
   - Focused work session on the electron-finder

8) **[3 – 3:15 pm] Coffee Break**

9) **[3:15 – 4:15 pm] Afternoon 3:**
Electron-Finder Working Session II

10) **[4:15 – 4:30 pm] Afternoon 4:**
Closeout discussion

Introduction
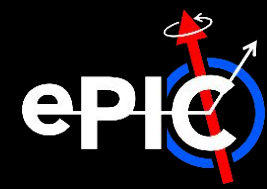
- ○ S&C focus during 1st half of 2024 on priorities for (pre-) TDR identified at January CM
  - 👉 See S&C report on Saturday [8:30 am] for detailed discussion

- ○ **Focus for today's discussion:** what do we need for truly *holistic* reconstruction?
  - 👉 What's missing? What are the steps to to get there?

- ○ Today part of ongoing discussion for identifying priorities for remainder of year and beyond
  - 👉 Previous discussions:
    - ■ 07.09.2024 reco meeting
    - ■ 07.17.2024 S&C meeting

Identified priorities in 2023
- – Primary vertexing
- – Electron finder
- – Low-Q2 tagger
- – Particle flow

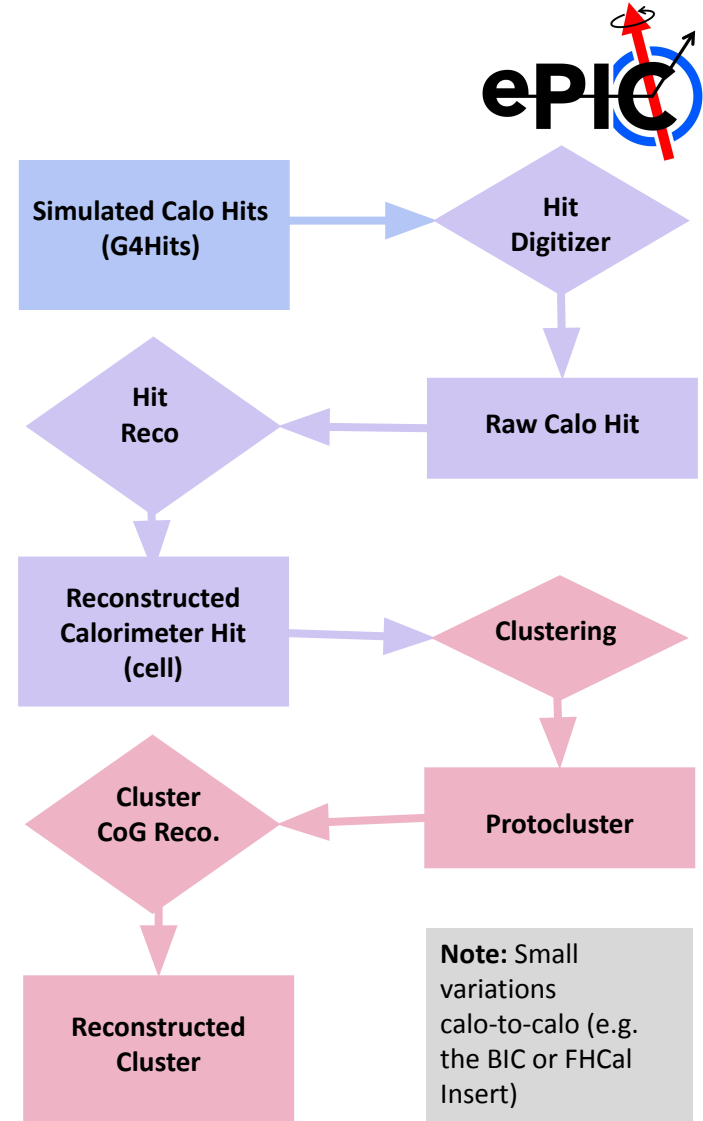**All in EICrecon with optimization in progress**

Identified priorities from CERN Workshop 2024
- – Modularity of algorithms
- – Use holistic information from various detector components in algorithms
  - – Integration of FF/FB systems
- – Web-based event display

So… What's in our reconstruction?

Reco Status | Calorimeter

o Overall Status
- Basic workflow in place
- **What's in place?**
  - › All basic components (e.g. simple clustering)
- **What's missing?**
  - › More system-specific reconstruction routines

o Workflow Inputs/Outputs:
- **Input:** *Hits,* e.g. *EcalEndcapNHits*
  - › (edm4hep::SimCalorimeterHit)
- **Output:** *Clusters,* e.g. *EcalEndcapNClusters*
  - › (edm4eic::Cluster)

o Near Term Goals:
- Track-based re-clustering
- Proper truth-reconstructed cluster associations
o Longer Term Goals:
- System-specific digitization routines
- Proper digitized-simulated hit associations

Derek A., ISU

Simulated Calo Hits (G4Hits)	→	Hit Digitizer
Hit Reco	←	Raw Calo Hit
Reconstructed Calorimeter Hit (cell)	→	Clustering
Cluster CoG Reco.	←	Protocluster
Reconstructed Cluster		

Note: Small variations calo-to-calo (e.g. the BIC or FHCal Insert)

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Reco Status | Tracking

o **Workflow Inputs/Outputs:**
  - **Input:** *RecHits from silicon tracker, MPGD, TOF, B0
  - **Output:** CentralCKF(*Seeded*)Trajectories(*Unfiltered*)
    Tracks
    TrackParameters

o **Overall Status**
  - Basic workflow in place
  - **What's in place?**
    › tracking finding/fitting with space points
    › realistic seeding and ambiguity resolution
  - **What's missing?**
    › Charge sharing and hits clusterization
    › Timing info

*see Barak's talk in general meeting for more info

Seed finder Can find multiple triplets from one track
CKF allow track candidates split in track finding from one initial guess
⇒ use ambiguity solver to **filter** duplicates

o **Near Term Goals:**
  - Understand tracking behaviors with hit-track and seed-track associations
  - Optimize algorithm performance
o **Longer Term Goals:**
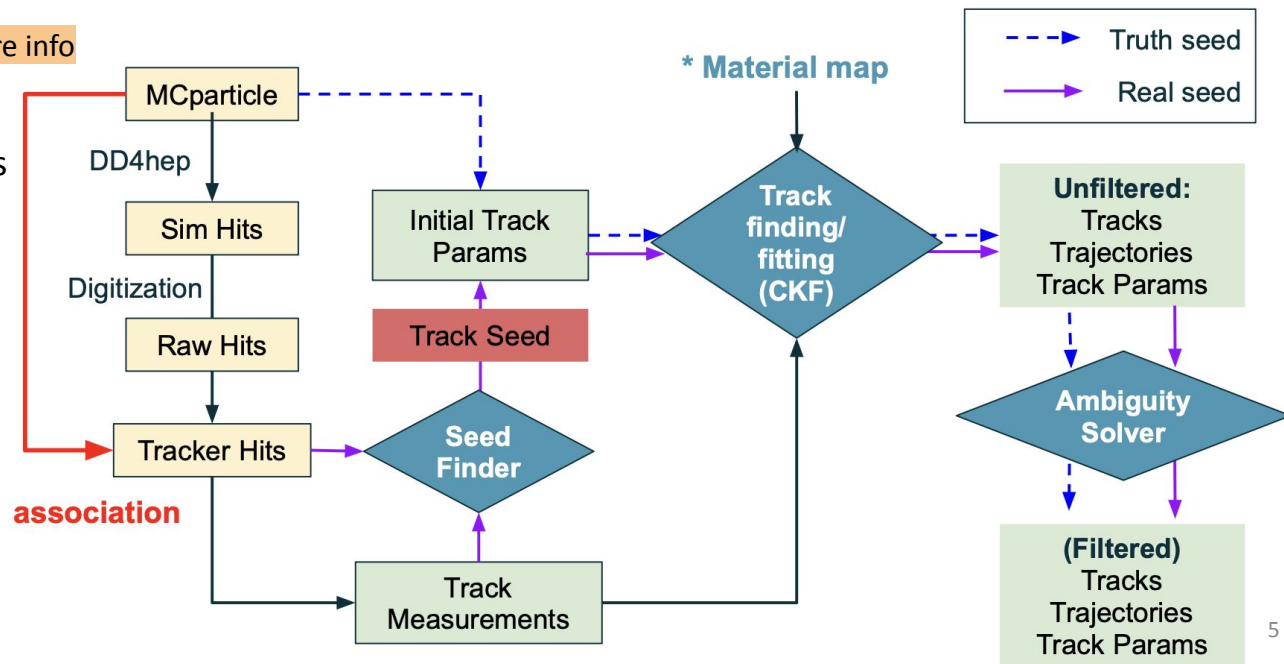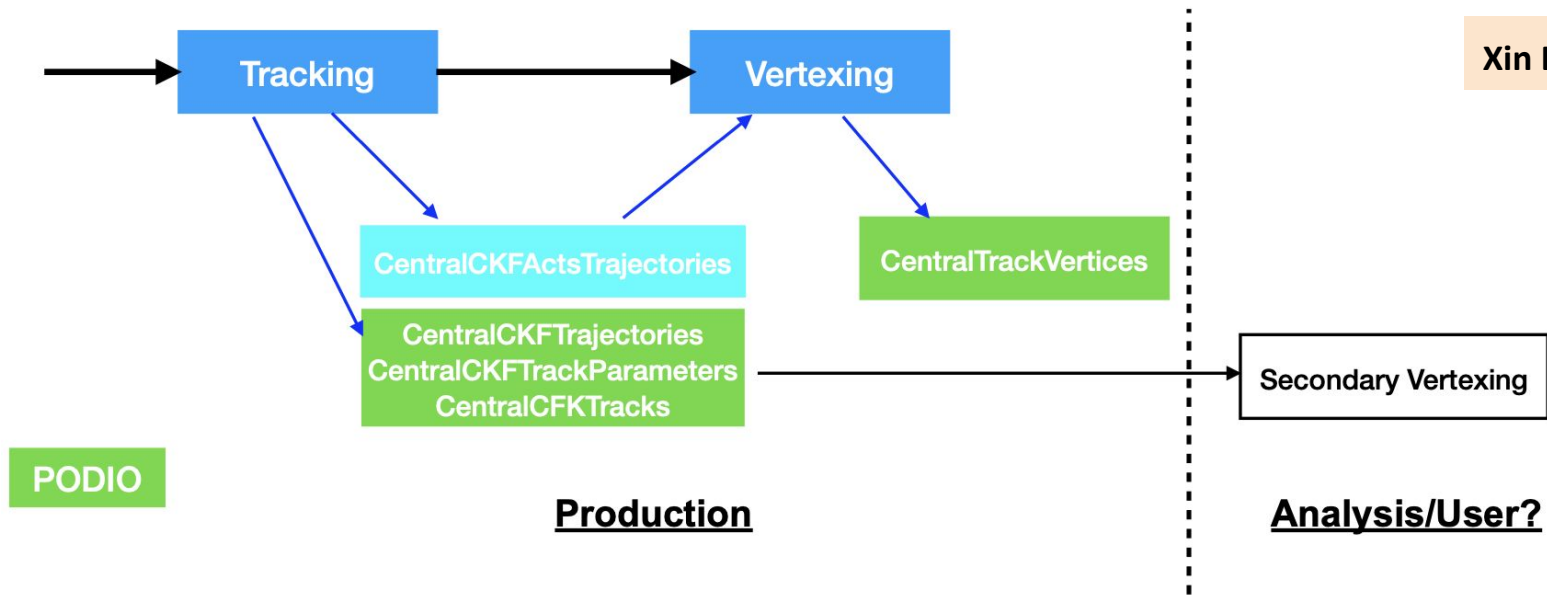 - Tracking with time frame
  - Noise and clustering

Red: work in progress

Shujie Li, Berkeley Lab

Tracking/Vertexing Workflow

Xin D., LBNL

PODIO

Production

Analysis/User?

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)

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

More info available at
https://indico.bnl.gov/event/20727/contributions/93551/attachments/56058/95919/20240725_ePIC_Vtx.pdf

Reco Status | Secondary Vertex Finding

o **Overall Status**
  - Basic workflow in place based on ACTS
  - **What's in place?**
    › SecondaryVertexFinder class available
    › FullbilloirFitter and DCA cut working
  - **What's missing?**
    › Import of primary vertices for track rejection

o Workflow Inputs/Outputs:
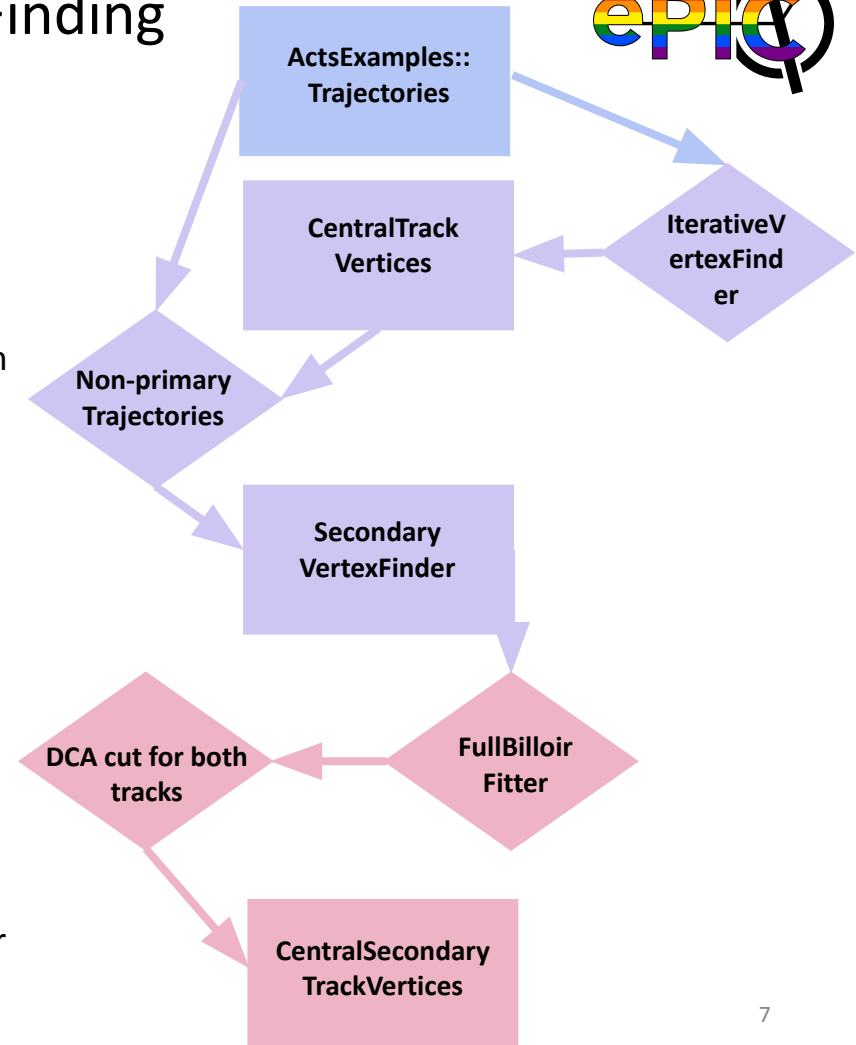 - **Input: *Tracks and primary Vertex***
    › (ActsExamples::Trajectories)
    › (edm4eic::VertexCollection)
  - **Output: *Secondary vertices***
    › (edm4eic:: VertexCollection)

o **Near Term Goals:**
  - Improvement via primary vertex import
 - Full pythia event validation
o **Longer Term Goals:**
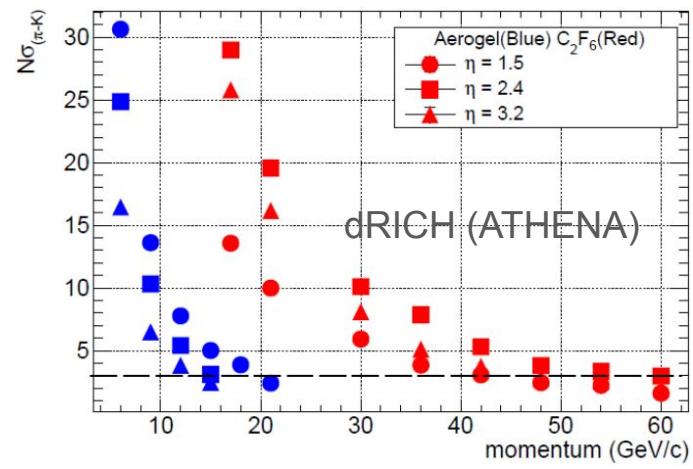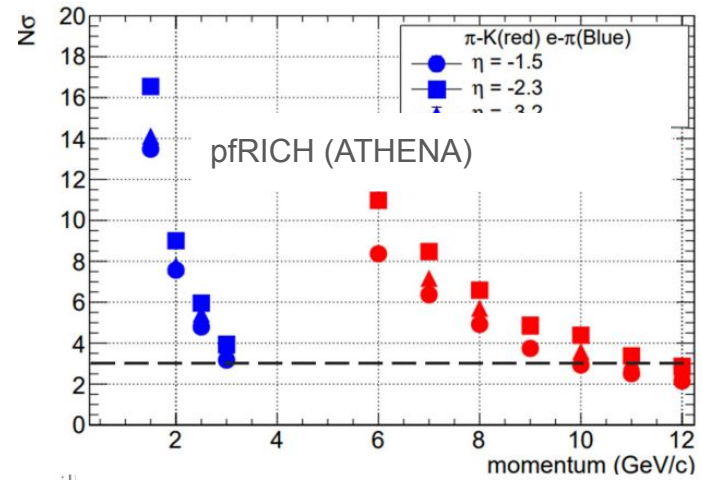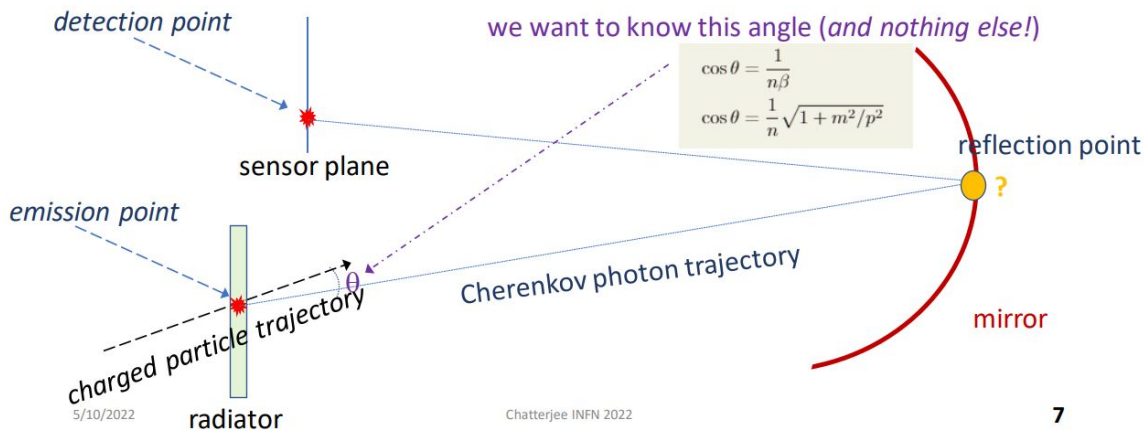 - Comparison to KFParticle secondary vertex finder

Nico S., ORNL

Reco Status | ToF

o **Overall Status**
  - <mark>Digitization (Yellow in right chart)</mark>
    - in progress
  - **What's in place?**
    › In progress but EICRecon w/o Digitization looks working
  - **What's missing?**
    › EICRecon w/ Digitization

o Workflow Inputs/Outputs:
  - **Input: ToF Raw hits + Raw Hits other than ToF**
  - **Output: ToF RecHits**

o **Mid Term Goals (for preTDR):**
  - Complete Digitization
  - Optimize material Budget
  - Performance study under beam backgrounds
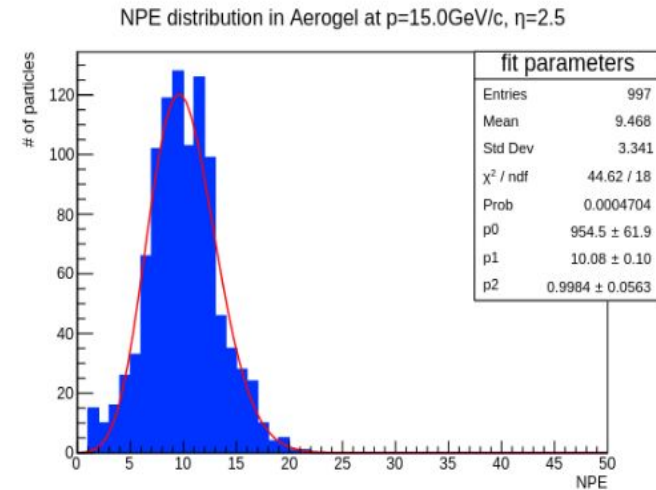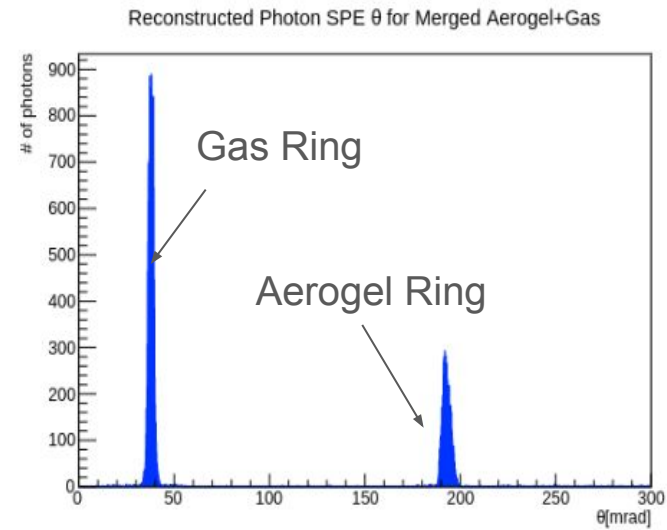

Kentaro K., Shinshu U.
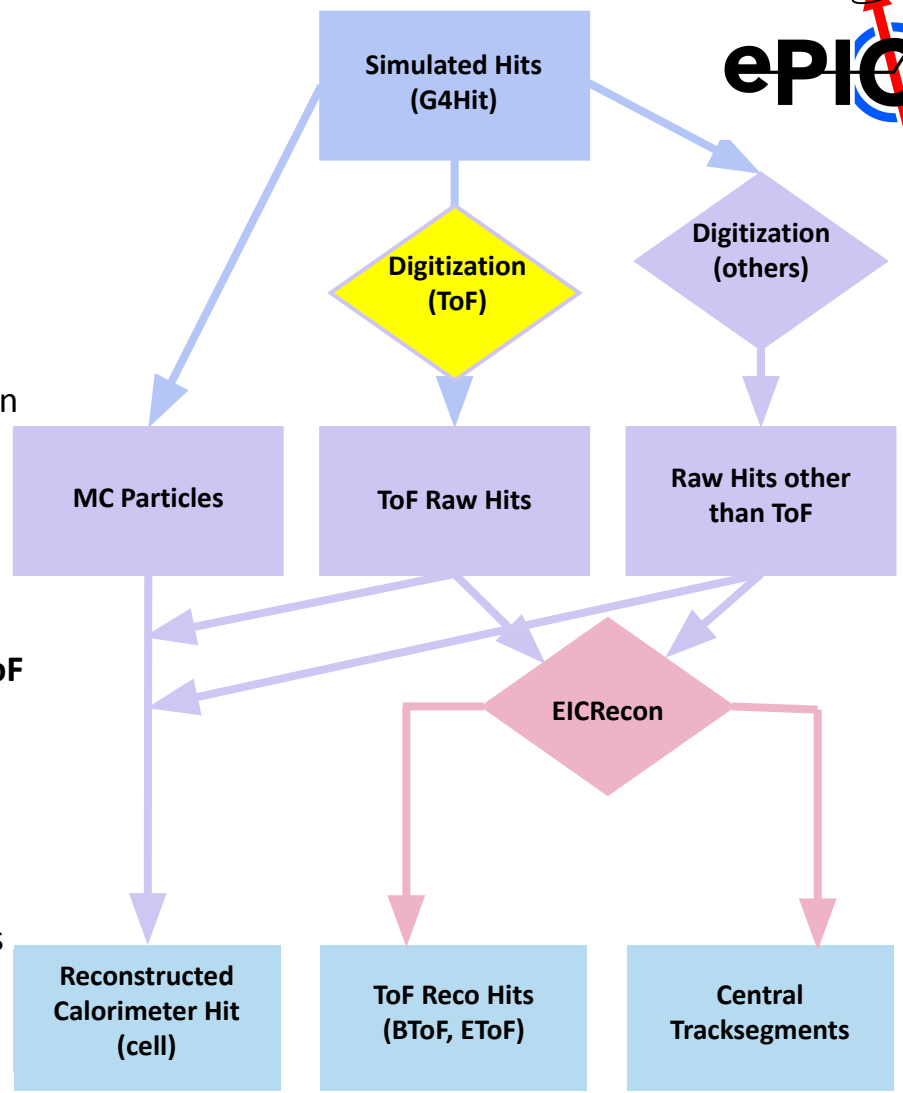
Synergy between pfRICH and dRICH

- ❏ The RICH reconstruction software was started at the ATHENA times.
- ❏ The reconstruction is based on Inverse Ray Tracing (IRT).
- ❏ A baseline reconstruction algorithm.
- ❏ First version evaluate separation power for single particles and few more analysis. Mainly focused to detector optimization.

pfRICH (ATHENA)

π-K(red) e-π(Blue)
- $\eta = -1.5$
- $\eta = -2.3$
- $\eta = 3.2$

momentum (GeV/c)

detection point

we want to know this angle (*and nothing else!*)

$$\cos\theta = \frac{1}{n\beta}$$
$$\cos\theta = \frac{1}{n}\sqrt{1 + m^2/p^2}$$

reflection point

sensor plane

emission point

θ

Cherenkov photon trajectory

charged particle trajectory

mirror

radiator

dRICH (ATHENA)

Aerogel(Blue) C_2F_6(Red)
- $\eta = 1.5$
- $\eta = 2.4$
- $\eta = 3.2$

momentum (GeV/c)

Chandra C., INFN

Situation with ePIC (dRICH)

- ❏ ATHENA IRT is ported to EICRECON (IRT-v1) and is used by dRICH.
- ❏ IRT-v1 works and all cross-checks have been made.
- ❏ IRT-v1 can handle SiPM noise with some tricks.
- ❏ IRT-v1 can even handle multi particle events given they are substantially far away.

Reconstructed Photon SPE θ for Merged Aerogel+Gas

Gas Ring

Aerogel Ring

NPE distribution in Aerogel at p=15.0GeV/c, η=2.5

| fit parameters	
Entries	997
Mean	9.468
Std Dev	3.341
χ^2 / ndf	44.62 / 18
Prob	0.0004704
p0	954.5 ± 61.9
p1	10.08 ± 0.10
p2	0.9984 ± 0.0563

Chandra C., INFN

IRTv-2

- ❏ A second version of IRT has been developed during backward RICH review.
- ❏ A sophisticated chi-square based PID algorithm is used to handle much more complicated event topology.
- ❏ Tested thoroughly in a Standalone code.
- ❏ Kolja has made an effort to import the stand-alone code to EICRecon. Does not work out-of-the box. Requires, testing and step-by-step debugging.
- ❏ Alexander and Chandra plan to work on it. Will be used in both RICHes.
  Standalone code plots:
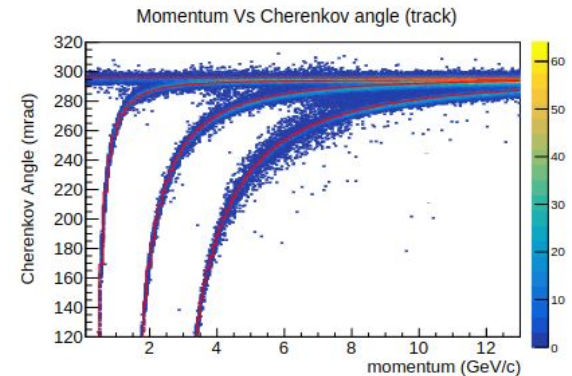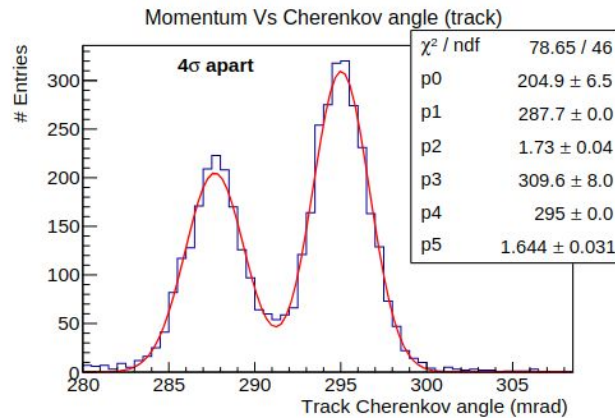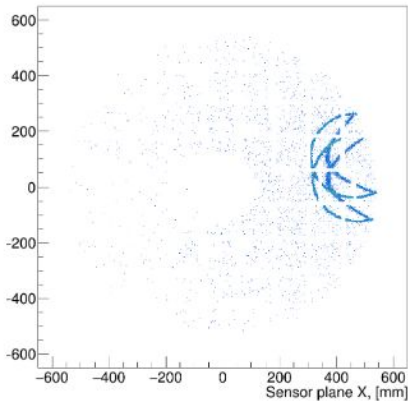
Reco Status | Roman pots/OMD

- **Overall Status**
  - Full reco with static transfer matrix exists and works. (**note:** special cases need to be considered, e.g. light nuclei).
  - ML algorithm exists, integration with EICrecon in-progress.
- **Workflow**
  - Input(s): ForwardRomanPotsRecoHits
  - Output(s): ForwardRomanPotsRecoParticles
    - (similar for Off-Momentum Detectors)
- **Near-Term goals**
  - Get ML algorithm fully-integrated.
  - Fix a few dangling issues for nuclei, and sorting of hits.
- **Long-Term Goals**
  - Replace static matrix code with dynamic (polynomial) matrix code.

Alex J., BNL

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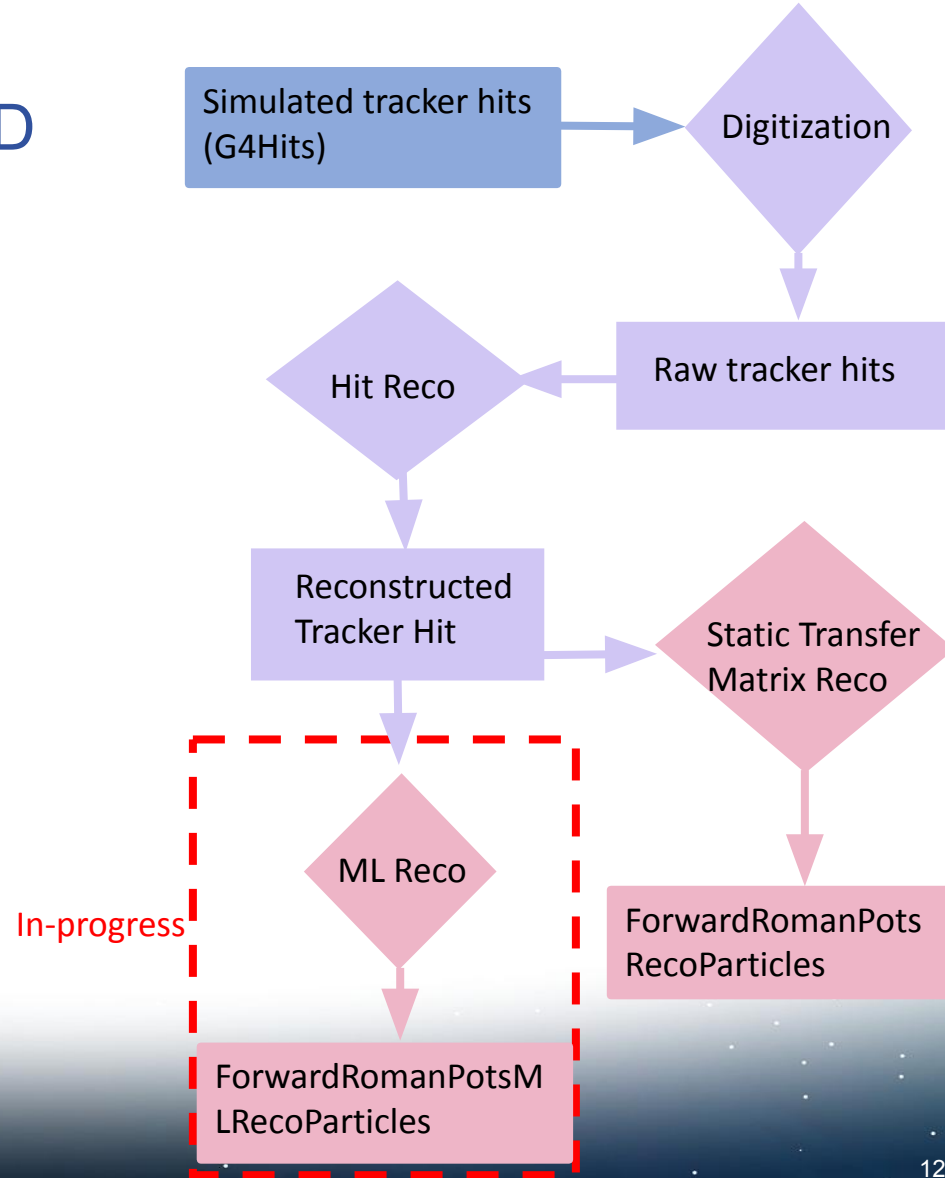
Reco Status | B0 tracker

- **Overall Status**
  - Full reco has been tested, but with recent changes, correct output for ACTS tracking a bit unclear.
  - B0 field map needs to be put into a PR and merged (see below).
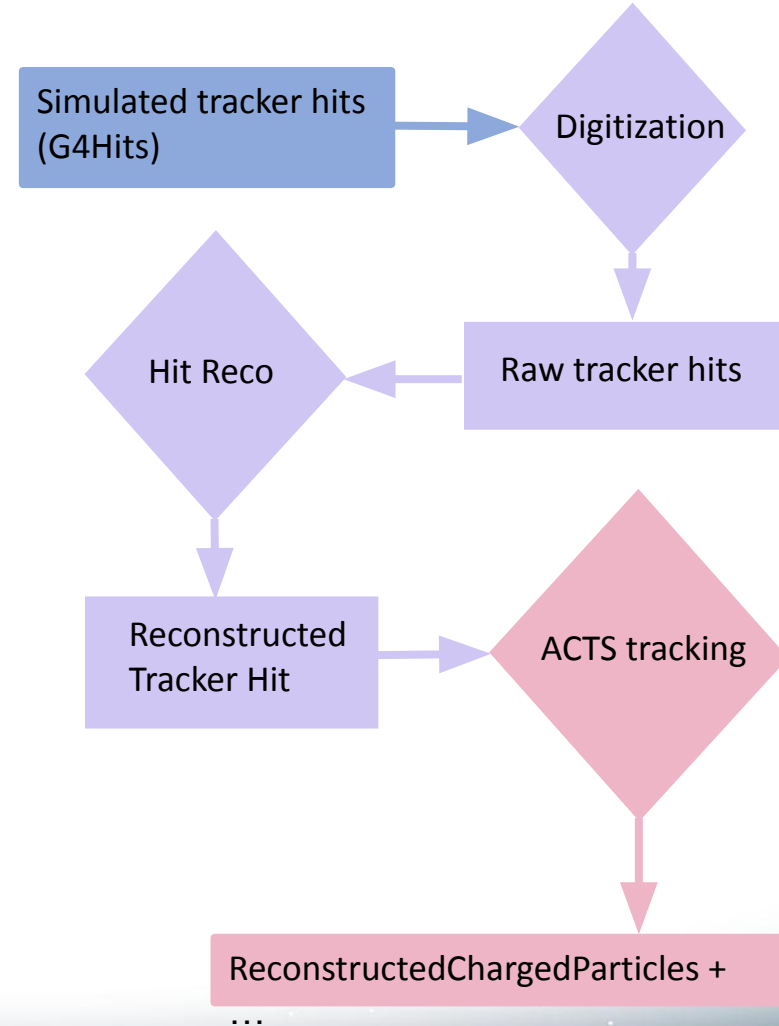- **Workflow**
  - Input(s): B0TrackerRecoHits
  - Output(s): ReconstructedChargedParticles***
- **Near-Term goals**
  - Make PR for the B0 field map (on a private branch), and get it merged.
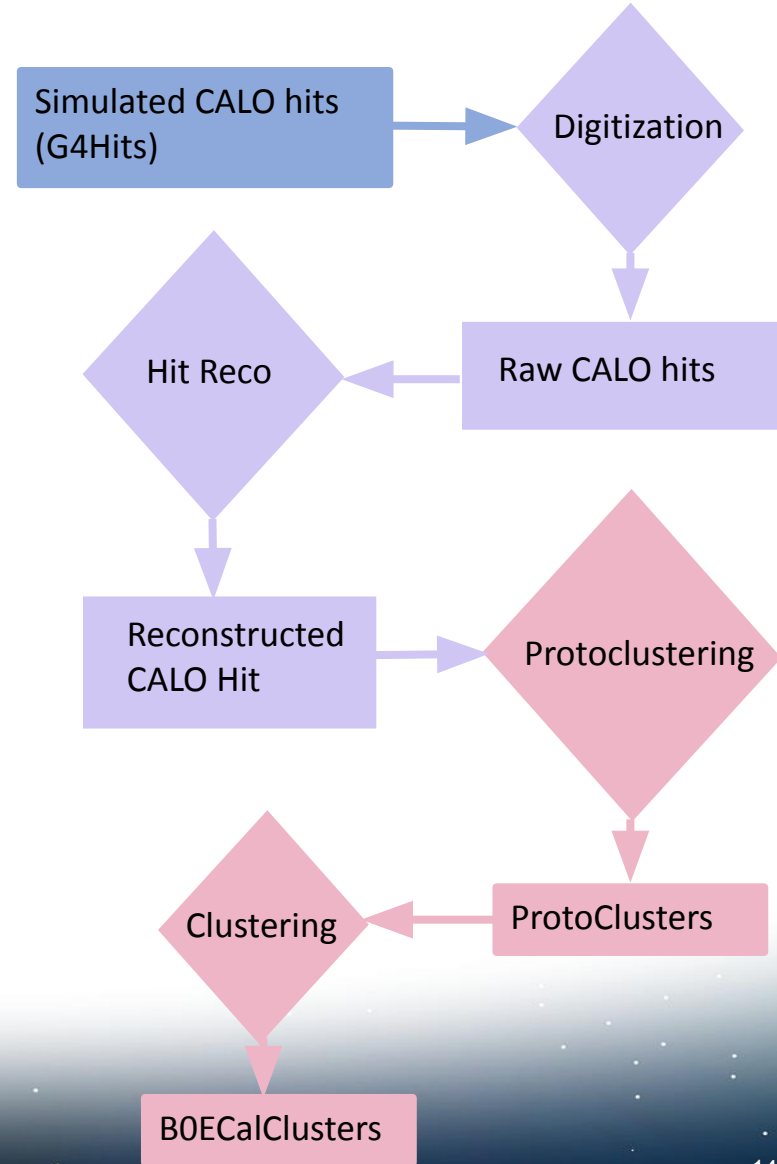- **Long-Term Goals**
  - Include charge sharing digitization and change segmentation to correct value (currently set to a value to provide expected resolutions).

Alex J., BNL

Simulated tracker hits (G4Hits) → Digitization

Digitization → Raw tracker hits

Raw tracker hits → Hit Reco

Hit Reco → Reconstructed Tracker Hit

Reconstructed Tracker Hit → ACTS tracking

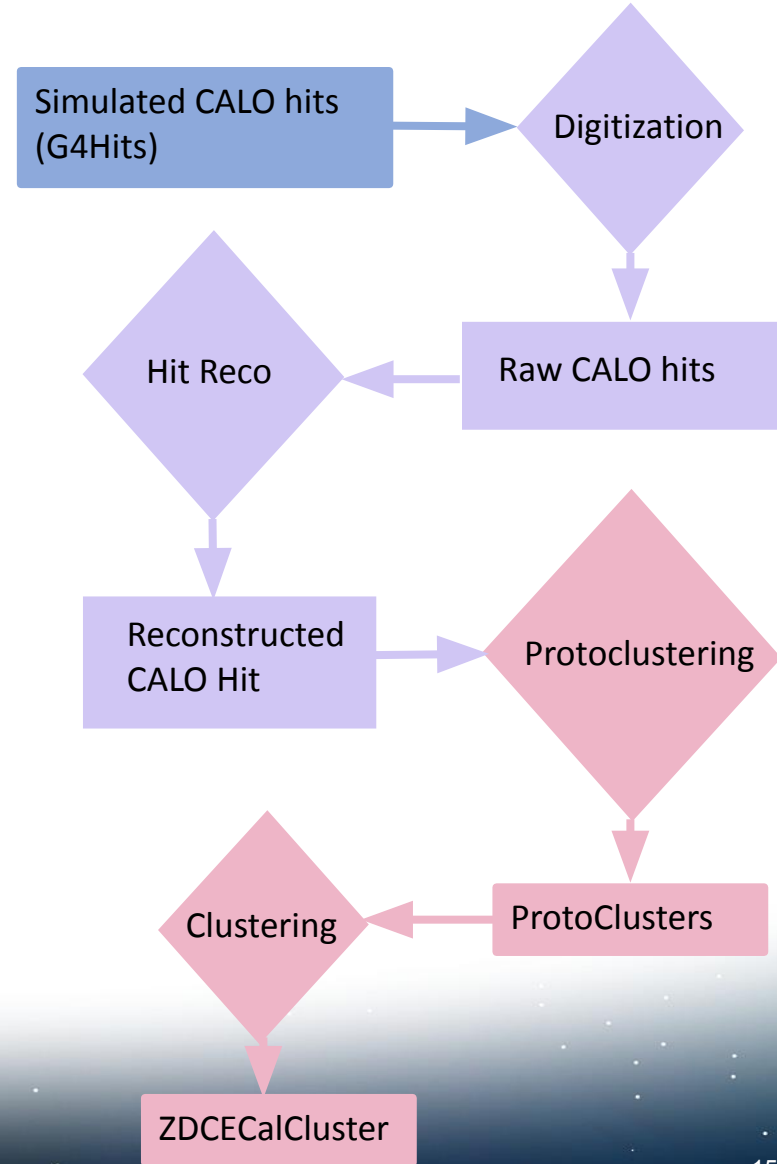ACTS tracking → ReconstructedChargedParticles + …

Reco Status | B0 EMCAL

- **Overall Status**
  - B0 EMCAL is a crystal EMCAL – uses components which already exist.
- **Workflow**
  - Input(s): B0ECalRecHits
  - Output(s): B0ECalClusters
- **Near-Term goals**
  - TBD
- **Long-Term Goals**
  - Include any changes to digitization to reflect final choice of electronics (SiPM).

Simulated CALO hits (G4Hits) → Digitization

Digitization → Raw CALO hits

Raw CALO hits → Hit Reco

Hit Reco → Reconstructed CALO Hit

Reconstructed CALO Hit → Protoclustering

Protoclustering → ProtoClusters

ProtoClusters → Clustering

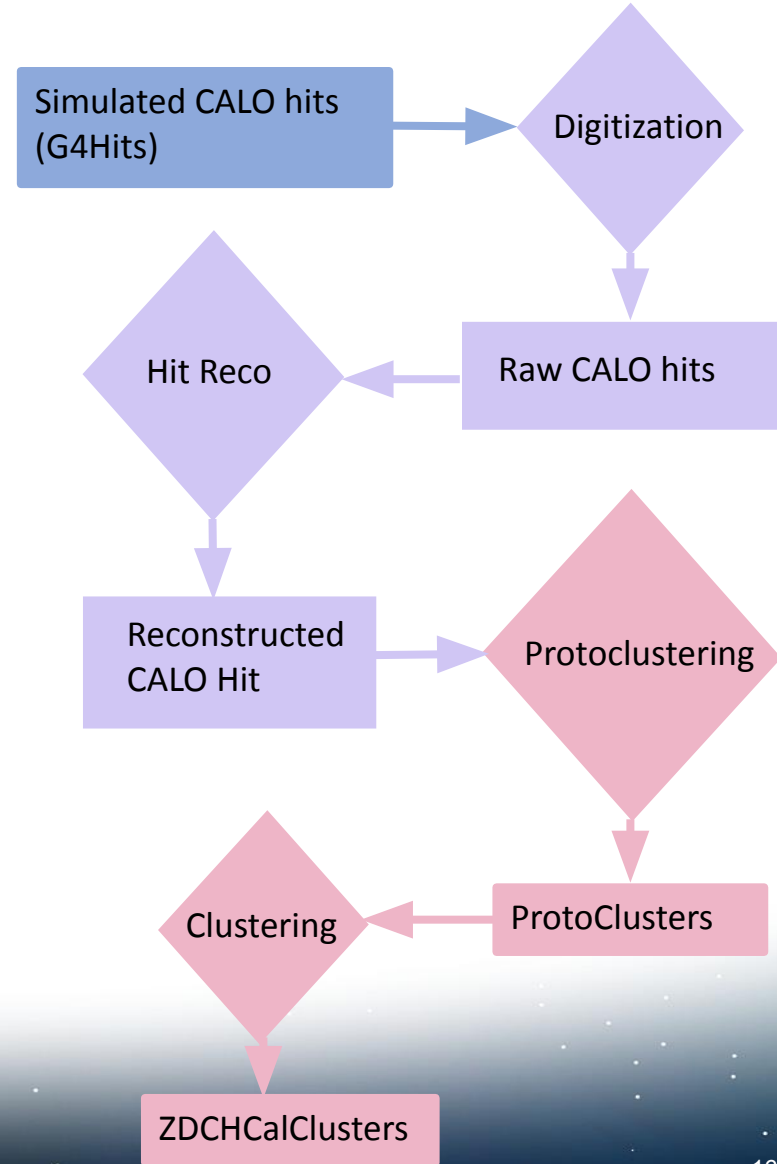Clustering → B0ECalClusters

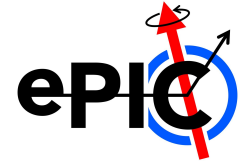Alex J., BNL

Reco Status | ZDC EMCAL

- **Overall Status**
  - ZDC EMCAL is a crystal EMCAL – uses components which already exist.
- **Workflow**
  - Input(s): EcalFarForwardZDCHits
  - Output(s): EcalFarForwardZDCClusters
- **Near-Term goals**
  - TBD
- **Long-Term Goals**
  - Include any changes to digitization to reflect final choice of electronics (SiPM, APD).
  - Work on integrated reconstruction for full ZDC (HCAL + EMCAL).

Simulated CALO hits (G4Hits) → Digitization

Raw CALO hits ←

Hit Reco

Reconstructed CALO Hit → Protoclustering

ProtoClusters → Clustering

ZDCECalClusters

Reco Status | ZDC HCAL

- **Overall Status**
  - ZDC HCAL is the same SiPM-on-Tile technology and reco as the HCAL insert
- **Workflow**
  - Input(s): HcalFarForwardZDCHits
  - Output(s): HcalFarForwardZDCClusters
- **Near-Term goals**
  - TBD
- **Long-Term Goals**
  - Work on integrated reconstruction for full ZDC (HCAL + EMCAL).

Simulated CALO hits (G4Hits) → Digitization

Digitization → Raw CALO hits

Raw CALO hits → Hit Reco

Hit Reco → Reconstructed CALO Hit

Reconstructed CALO Hit → Protoclustering

Protoclustering → ProtoClusters

ProtoClusters → Clustering

Clustering → ZDCHCalClusters

Electron ID + reconstruction status

o **Overall Status**
  - Basic workflow in place
  - **What's in place?**
    - › All basic components
  - **What's missing?**
    - › Fully reconstruction-based matching/associations
    - › eID parameters (E/p, E-pz) in output
    - › Calorimeter energy for electron reconstruction

o Workflow Inputs/Outputs:
  - **Input:** *Reconstructed particles, calorimeter clusters, cluster-particle associations (truth info)*
    - › (edm4eic::ReconstructedParticle)
    - › (edm4eic::Cluster)
    - › (edm4eic::MCRecoClusterParticleAssociation)
  - **Output:** *DIS electron candidates (subset of reconstructed particles)*
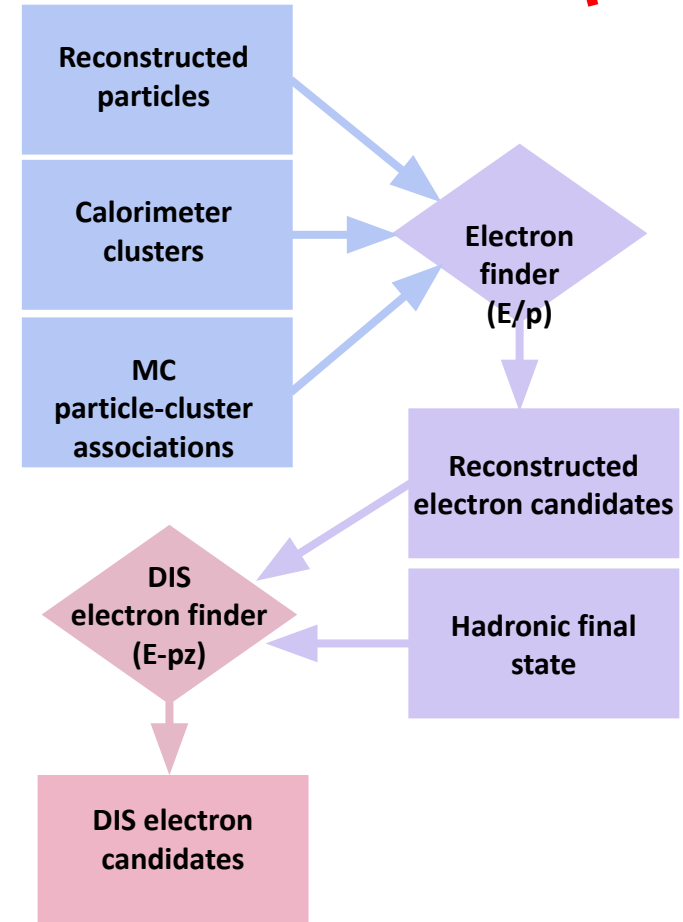   - › (edm4eic::ReconstructedParticle)

Tyler K., MIT
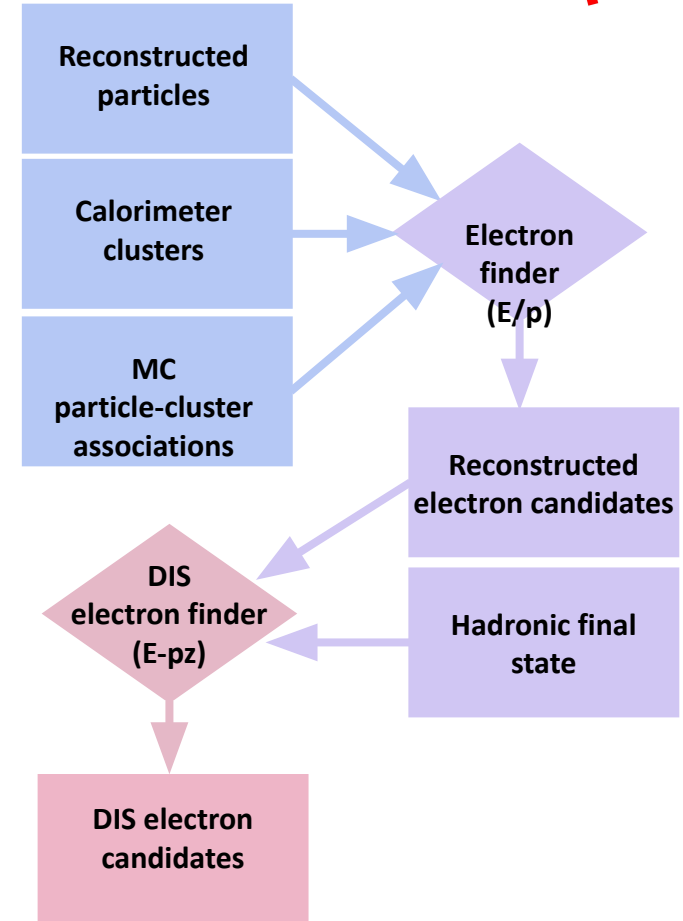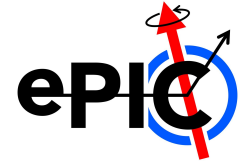
Electron ID + reconstruction status

- o **Near Term Goals:**
  - Track-cluster matching
  - Electron ID variables in output
    - New data type for electron candidates?
  - Electron ID output feed back into reconstructed particle ID?
  - Tune electron ID cuts
  - Calorimeter clusters in electron energy reconstruction

Tyler K., MIT

Reco Status | Particle Flow

- **Overall Status**
  - Work started, but on hold…
  - **What's in place?**
    - › Truth-based track-EMCal matching
      (i.e. *MatchClusters* algorithm)
  - **What's missing?**
    - › Non-truth based track-cluster matching
    - › Integration of HCal info
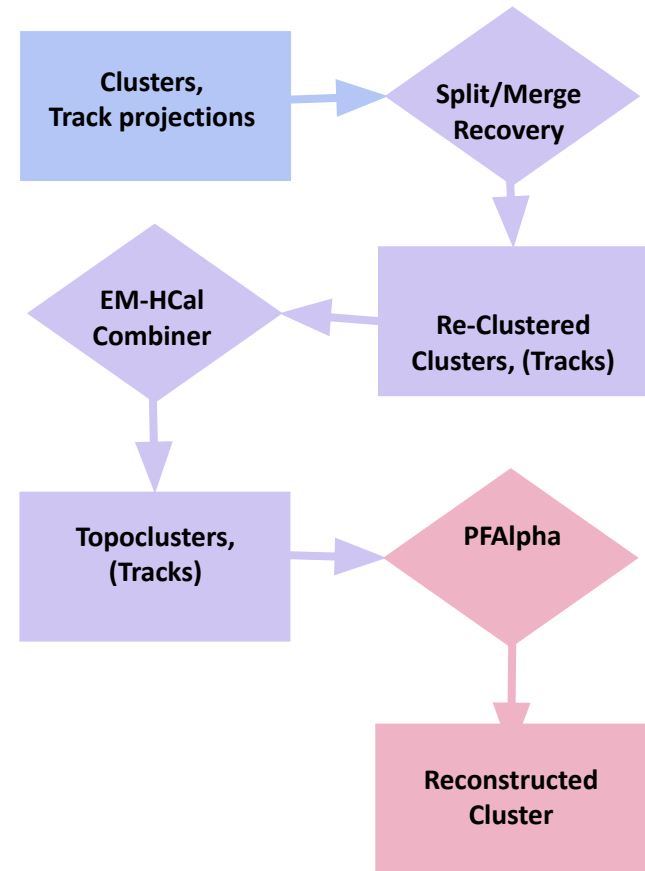
- PFAlpha Inputs/Outputs:
  - **Input:** Track projections, Clusters,
    - › (edm4eic::TrackSegment)
    - › (edm4eic::Cluster)
  - **Output:** Reconstructed particles
    - › (edm4eic::ReconstructedParticle)
- **Near Term Goals:**
  - Finish implementation of PFAlpha
- **Longer Term Goals:**
  - Refinement of PFAlpha using PID
  - Explore alternative algorithms vs. eta

Derek A., ISU

```
Clusters,
Track projections  →  Split/Merge Recovery
                            ↓
EM-HCal Combiner  ←  Re-Clustered Clusters, (Tracks)
       ↓
Topoclusters, (Tracks)  →  PFAlpha
                              ↓
                         Reconstructed Cluster
```

Detector Info Integration

Electron-finder
Particle flow
Reconstructed(Charged)Particles
…

Link to mindmap

Backup