First results on electron reconstruction

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International MUON Collider Collaboration

INFN PADOVA

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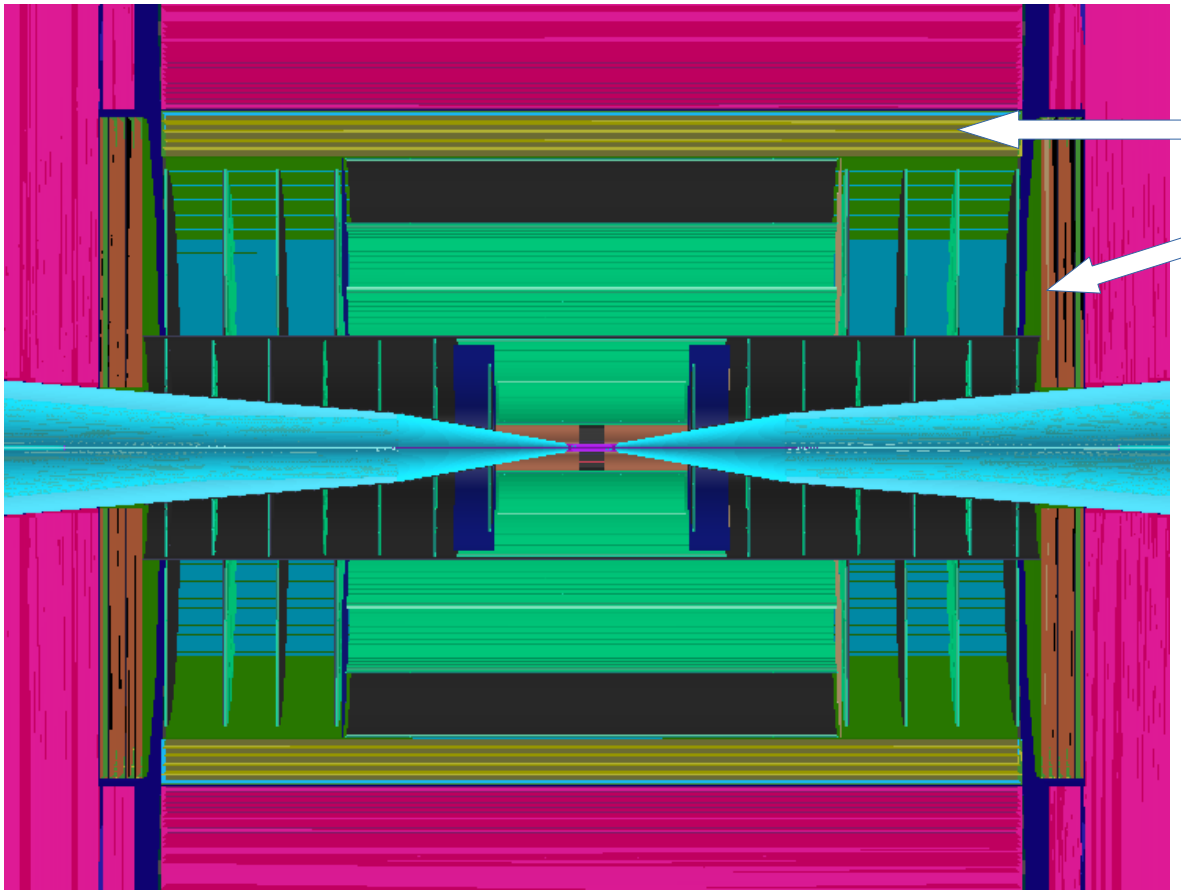
Simulation and methods

- Dataset: single electrons 1-1000 GeV, no BIB overlay (next step).
- Geometry: standard MCD, B = 4T, CRILIN EM Calorimeter.



CRILIN calorimeter:
5 layers
1x1x4 cm^3 cells
PbF_2 crystals
$22X_0$ depth

For more: arXiv:2206.05838

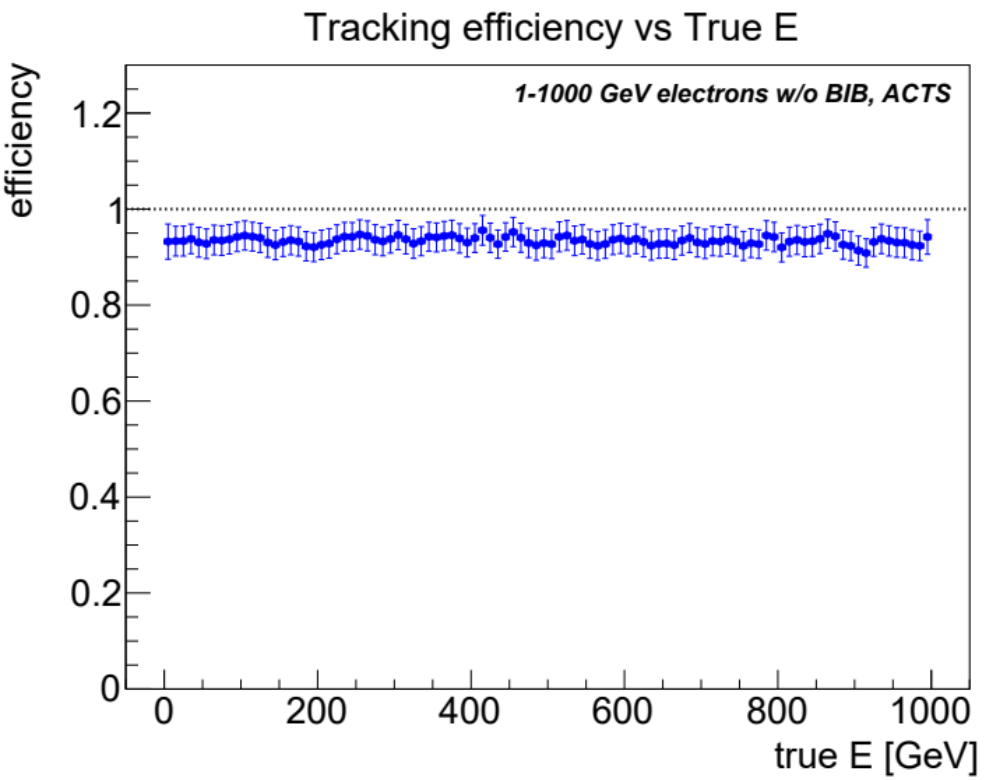
Simulation and methods (2)

- Tracking: ACTS (geometry v1.1).
- Reconstruction: PandoraPFA, /LCContent repo.
- Tracking efficiency: inclusive, track inside R=0.05 from MC particle.
- ECal resolution: manual procedure, extract track state at ECal surface, sum SimHits in R=0.1, get σ from $(E_{hits}-E_{MC})/E_{MC}$.
- Correct ID efficiency: identified electron in R=0.1 from MC particle.

Each study is performed dividing the events in energy and angle bins.

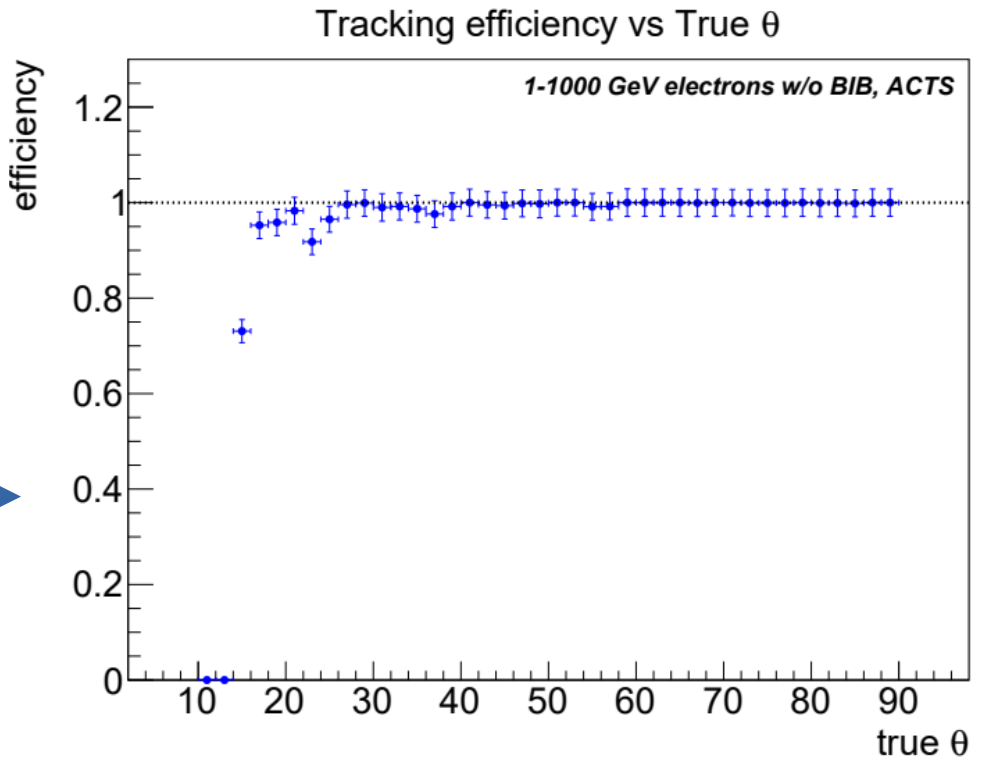
Inclusive tracking efficiency

$$\epsilon = \frac{\text{track candidates}}{\text{MC events}}$$

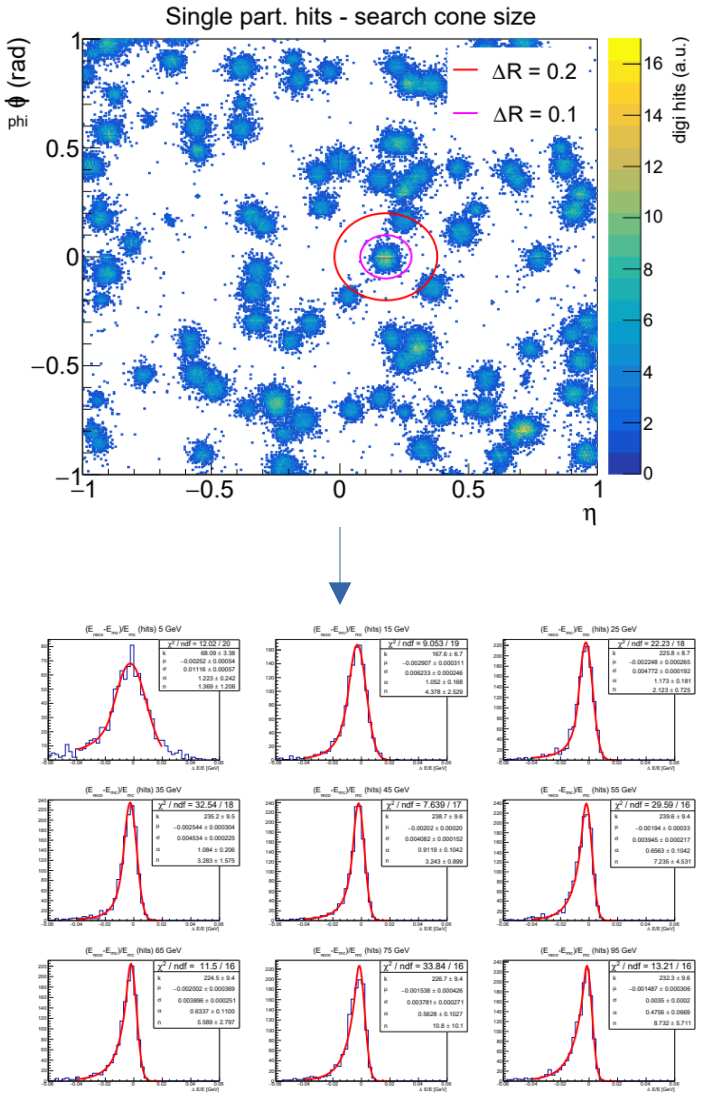


>90% at all energies, no low-p drop (will be critical with BIB)

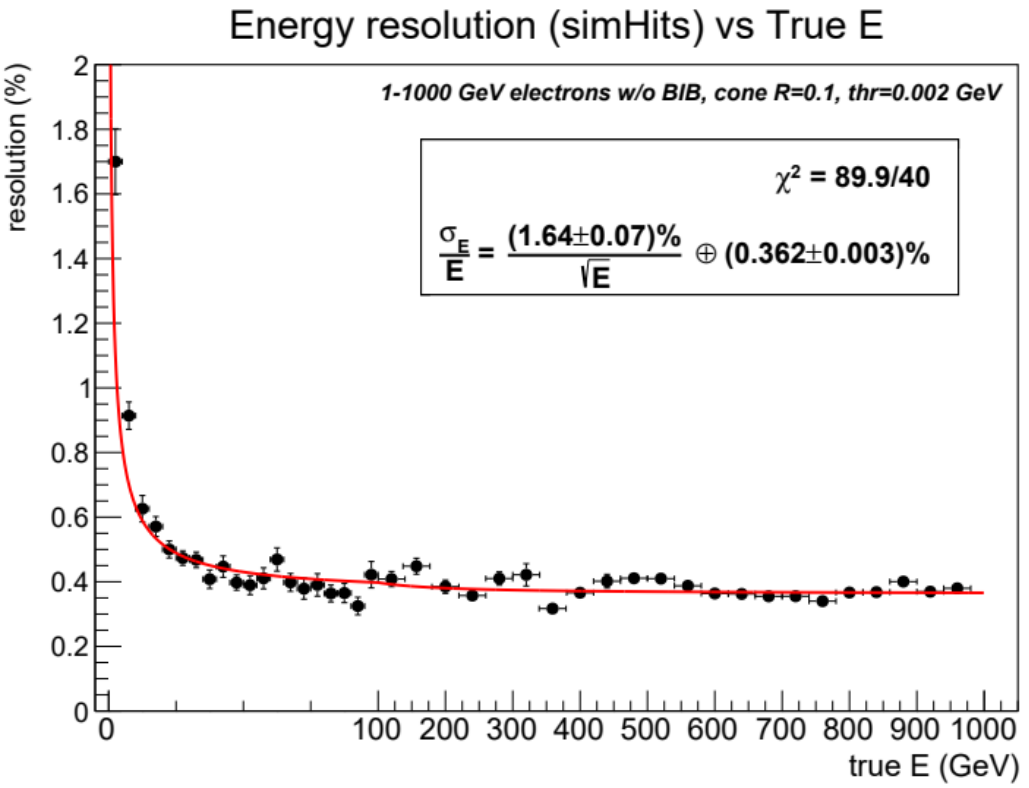
Almost perfect in the central region, drops abruptly below 15°



Calorimetry performance

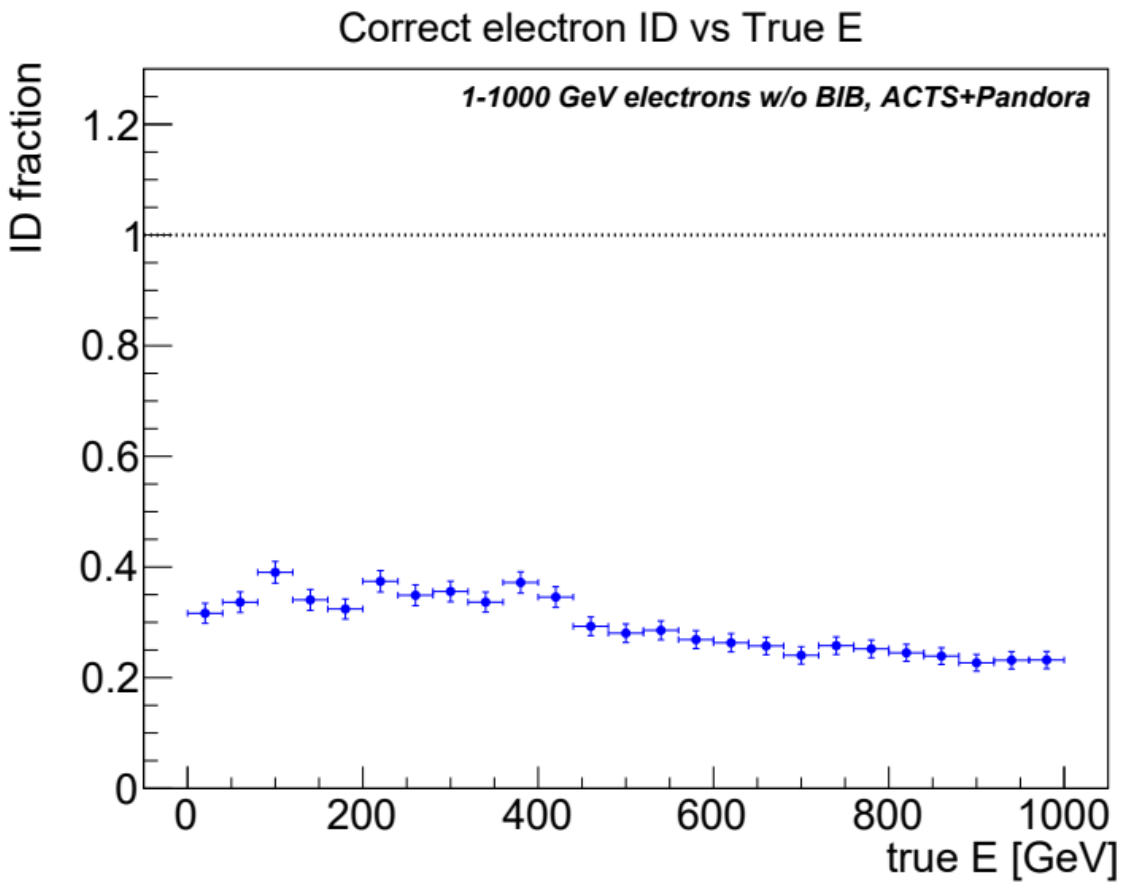


Sum hits inside R=0.1 from track state at ECal surface, plot $(E_{HITS}-E_{MC})/E_{MC}$, fit with a Crystal Ball distribution, obtain the σ parameter.



Simulation level! → calorimeters' performance, not reconstruction accuracy

Pandora reco and ID performance



$$\epsilon = \frac{\text{el. candidates}}{\text{MC events}}$$

Unexpectedly low across the range, with a mild energy trend (bad news!)

Given the ACTS efficiency w/o BIB, only Pandora responsibility here

Pandora works with a combination of tens of algorithms (some not crystal clear…), its reconstruction flow is untouched from the LCContent repository.

→ worked well in jet performance studies, but old geometry (no CRILIN Ecal)
→ worked well with photons with the new geometry (Carlo's thesis)

Pandora workflow

LCReco / settings / PandoraSettingsDefault.xml

Code | Blame | 464 lines (436 loc) · 25.5 KB | Code 55% faster with GitHub Copilot

```
    </algorithm>

    <!-- Standalone photon clustering -->
    <algorithm type = "PhotonReconstruction">
        <algorithm type = "ConeClustering" description = "PhotonClusterFormation">
            <ClusterSeedStrategy>0</ClusterSeedStrategy>
            <ShouldUseTrackSeed>false</ShouldUseTrackSeed>
            <ShouldUseOnlyECalHits>true</ShouldUseOnlyECalHits>
            <ConeApproachMaxSeparation>250.</ConeApproachMaxSeparation>
        </algorithm>
        <ClusterListName>PhotonClusters</ClusterListName>
        <ReplaceCurrentClusterList>false</ReplaceCurrentClusterList>
        <ShouldMakePdfHistograms>false</ShouldMakePdfHistograms>
        <HistogramFile>PandoraLikelihoodData9EBin.xml</HistogramFile>
    </algorithm>

    <!-- Clustering parent algorithm runs a daughter clustering algorithm -->
    <algorithm type = "ClusteringParent">
        <algorithm type = "ConeClustering" description = "ClusterFormation"/>
        <algorithm type = "TopologicalAssociationParent" description = "ClusterAssociation">
            <associationAlgorithms>
                <algorithm type = "LoopingTracks"/>
                <algorithm type = "BrokenTracks"/>
                <algorithm type = "ShowerMipMerging"/>
                <algorithm type = "ShowerMipMerging2"/>
                <algorithm type = "BackscatteredTracks"/>
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                <algorithm type = "ShowerMipMerging3"/>
                <algorithm type = "ShowerMipMerging4"/>
                <algorithm type = "ProximityBasedMerging">
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                <algorithm type = "ConeBasedMerging">
                    <algorithm type = "TrackClusterAssociation"/>
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                </algorithm>
                <algorithm type = "SoftClusterMerging">
                    <algorithm type = "TrackClusterAssociation"/>
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                <algorithm type = "IsolatedHitMerging">
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                </algorithm>
            </associationAlgorithms>
        </algorithm>
        <ClusterListName>PrimaryClusters</ClusterListName>
        <ReplaceCurrentClusterList>true</ReplaceCurrentClusterList>
    </algorithm>

    <!-- Reclustering algorithms run multiple clustering algorithms -->
```

Hits and tracks preparation

↓

Standalone muon clustering

↓

Standalone photon clustering

↓

First cone-based clustering

↓

Topological merging,
track-cluster association

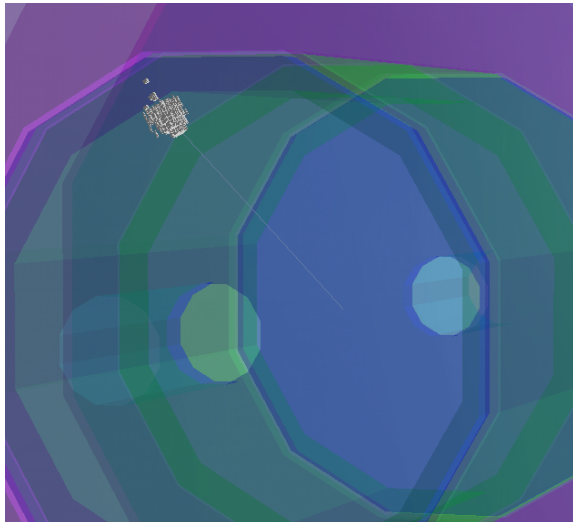
↓

Many rounds of reclustering
Quality selection

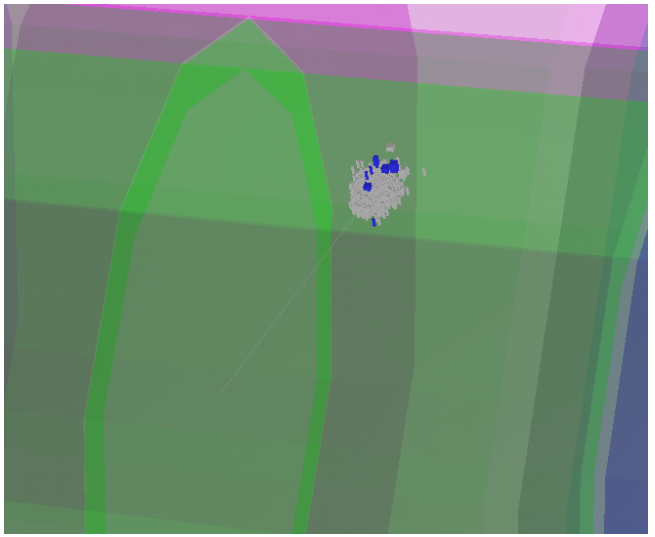
↓

PFO creation
Particle ID

Pandora workflow visualized

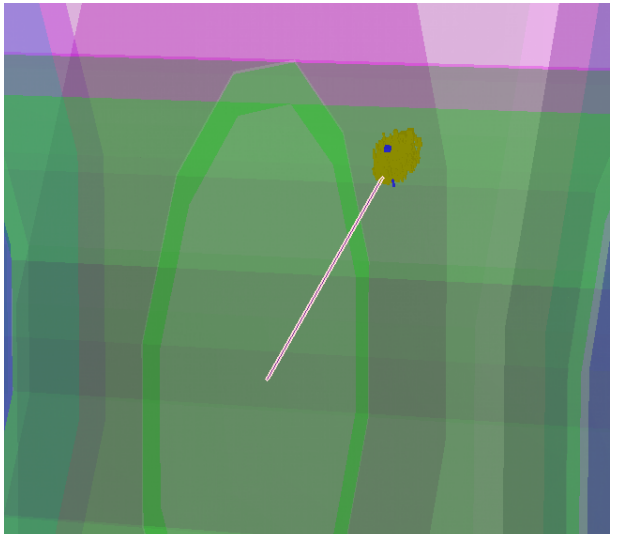


Preparation
Hits + ACTS track



First algorithm
Clustered hits (blue)

Final PFOs:
unassociated track +
photon (yellow)



Pandora workflow modified

Standalone photon clustering

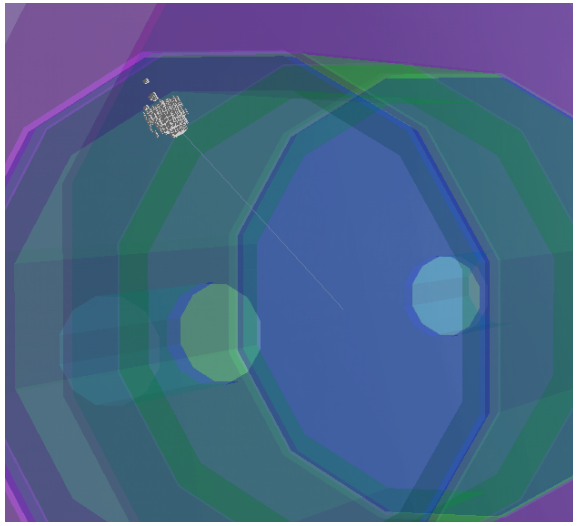
```
76          </algorithm>
77
78          <!-- Standalone photon clustering -->
79          <algorithm type = "PhotonReconstruction">
80              <algorithm type = "ConeClustering" description = "PhotonClusterFormation">
81                  <ClusterSeedStrategy>0</ClusterSeedStrategy>
82                  <ShouldUseTrackSeed>false</ShouldUseTrackSeed>
83                  <ShouldUseOnlyECalHits>true</ShouldUseOnlyECalHits>
84                  <ConeApproachMaxSeparation>250.</ConeApproachMaxSeparation>
85              </algorithm>
86              <ClusterListName>PhotonClusters</ClusterListName>
87              <ReplaceCurrentClusterList>false</ReplaceCurrentClusterList>
88              <ShouldMakePdfHistograms>false</ShouldMakePdfHistograms>
89              <HistogramFile>PandoraLikelihoodData9EBin.xml</HistogramFile>
90          </algorithm>
91
92          <!-- Clustering parent algorithm runs a daughter clustering algorithm -->
93          <algorithm type = "ClusteringParent">
94              <algorithm type = "ConeClustering" description = "ClusterFormation"/>
95              <algorithm type = "TopologicalAssociationParent" description = "ClusterAssociation">
96                  <associationAlgorithms>
97                      <algorithm type = "LoopingTracks"/>
98                      <algorithm type = "BrokenTracks"/>
```

Data-based clustering!
Based on ILD

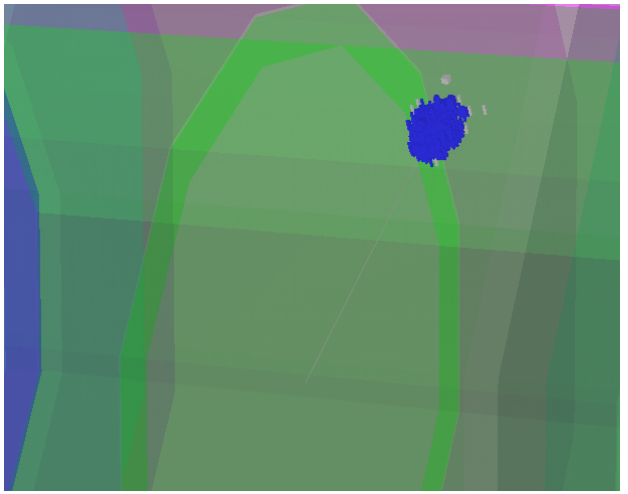
Works ok with old (ILD based) MCD geometry

Pandora workflow modified (2)

REMOVED STANDALONE PHOTON CLUSTERING

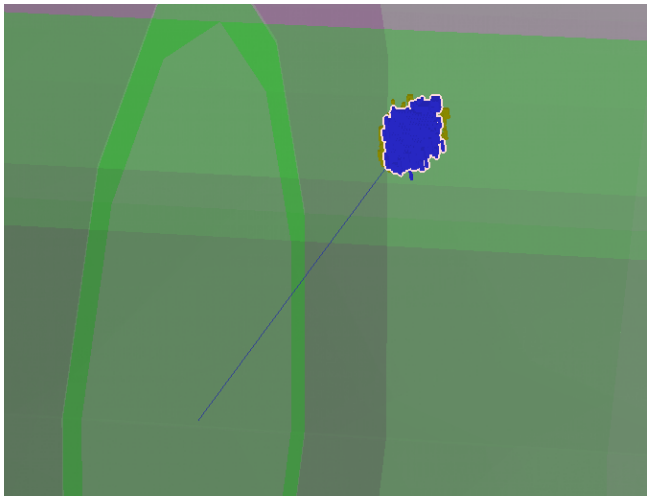


Preparation
Hits + ACTS track

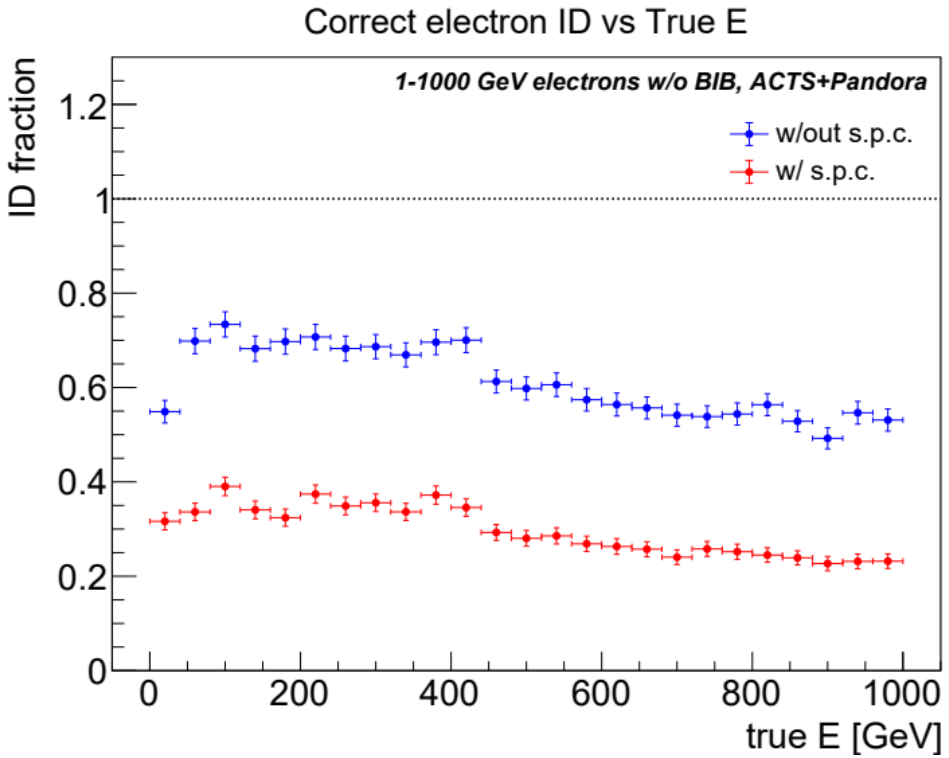


First algorithm
Clustered hits (blue)

Final PFOs:
cluster+track (blue)
=correctly ID electron



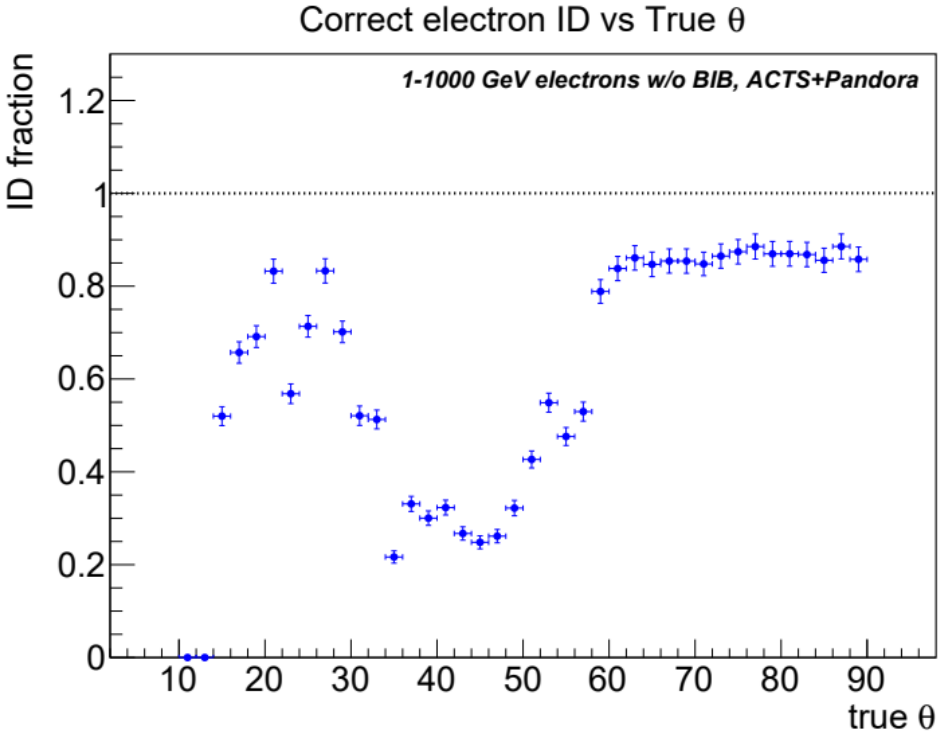
Pandora workflow modified: results



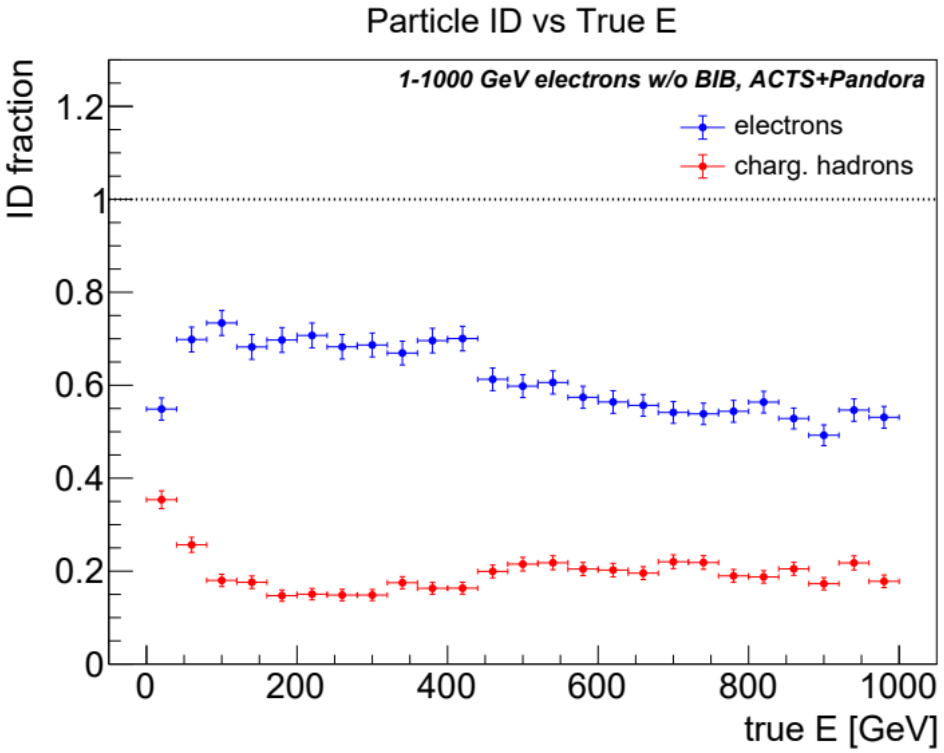
~2 times better, but still far from being enough for a physics case study!

The worst region is the barrel to endcap transition (from >85% to 20%)

→ same transition as ILD!

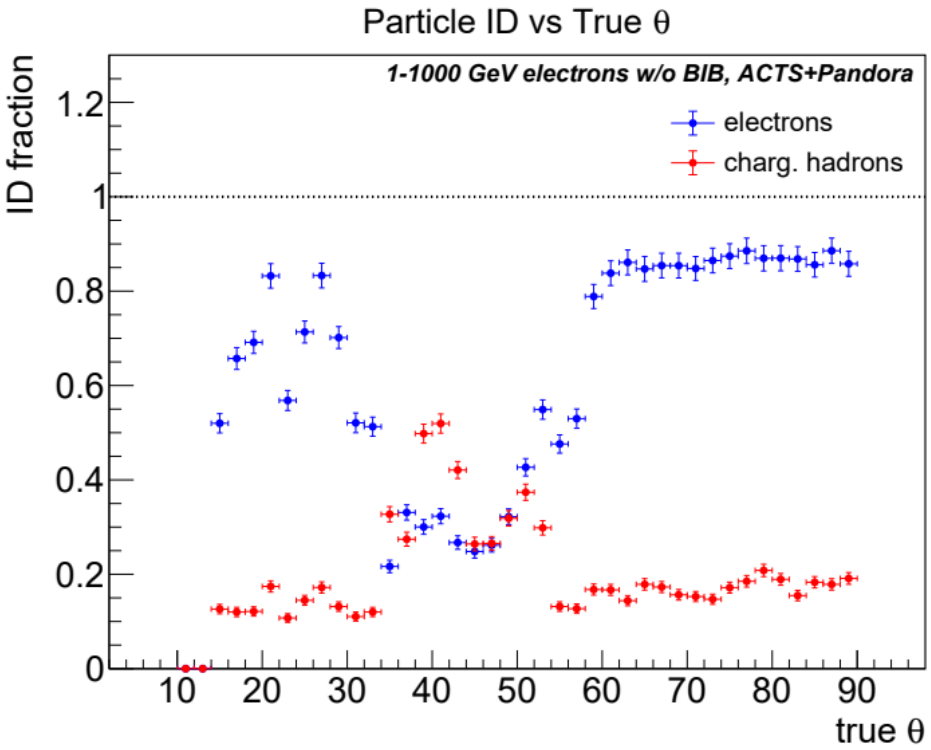


What are we confusing them for?



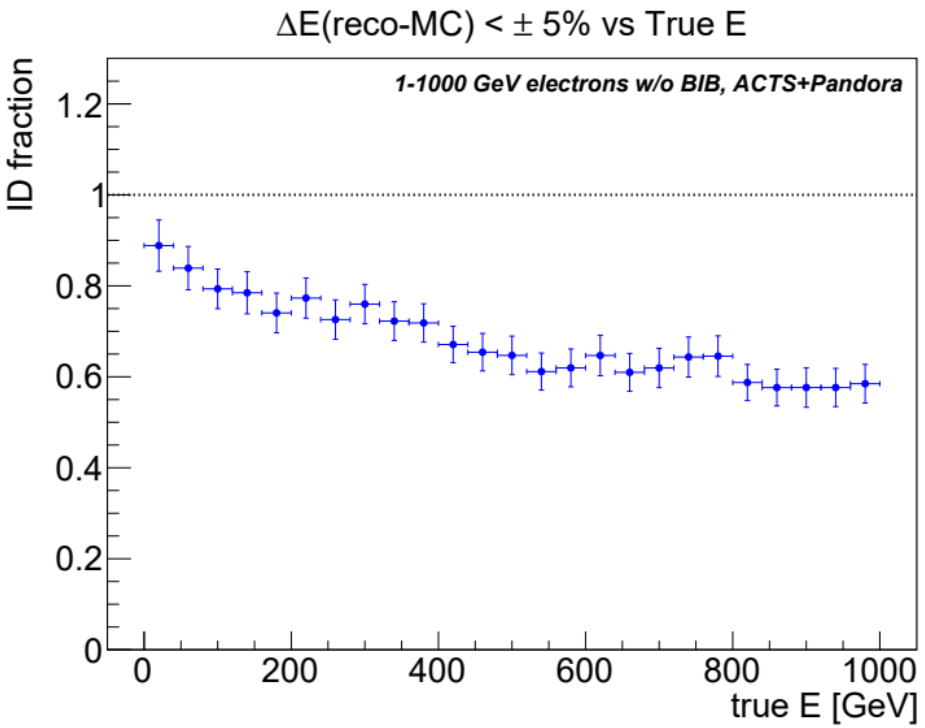
Most of the inefficiency comes from the mis-ID to charged hadrons (the others are neutral hadrons/photons)

The inefficiency in the barrel to endcap transition is partially compensated by the hadrons



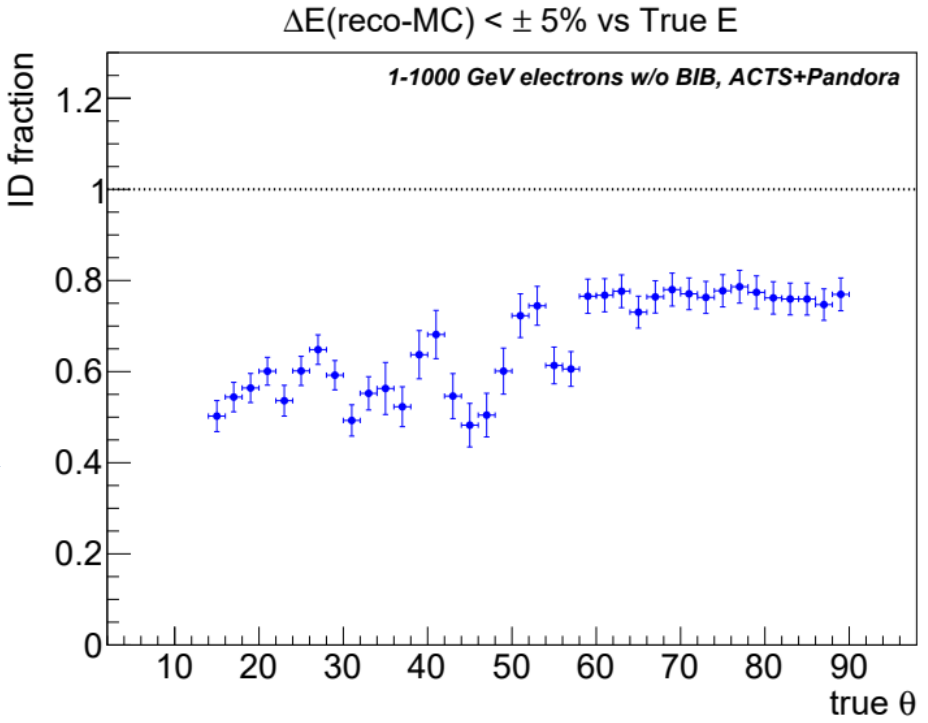
This means that now the issue really comes from the pattern recognition / particle ID (not easily solvable as for the s.p.c.)

How well are we reconstructing them?



$$\epsilon = \frac{\text{el. candidates with } \left(E_{RECO} - E_{MC}\right)/E_{MC} < 5\,\%}{\text{el. candidates}}$$

From 90% to 60% correct energy reconstruction → Pandora prioritizes the momentum estimation from the tracker



Mild variation from barrel to endcap, most probably for the same reason.

Issues to work on

- Remaining (large) reconstruction inefficiency
  Some possibilities to explore:
  → parameters (EMShower ID, Electron ID, clustering itself) may be optimized for the old geometry
  → quality parameter is p-E matching (may be an issue, but only at high momenta)
  → (?) ways to reduce the impact of endcap-barrel transition

- Final PFO energy
  For p > 100 GeV, calorimeters perform better than the tracker. Yet, Pandora always prioritizes the tracking estimation when building the final PFOs (that's what Particle Flow is about…).
  → understand whether there's a configurable option about that.

  CARE NEEDED: don't spoil what's already working (eg jets)!

Suggestions/indications are welcome!