Improvement of photon reconstruction in PandoraPFA

LCWS 15

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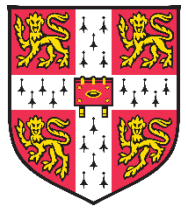

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- Improved fragment removal
- High energy photon recovery
- Improved peak finding
- Restructured photon reconstruction
- Conclusion

Motivations

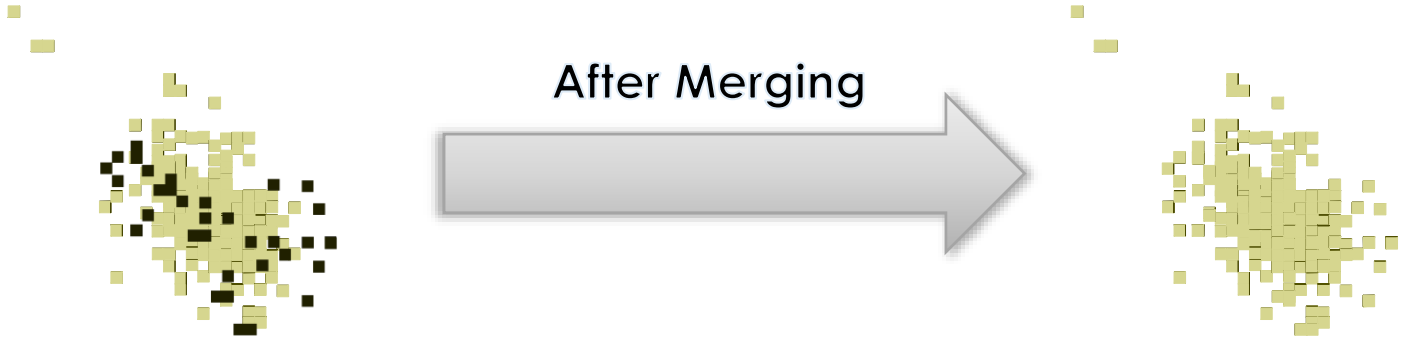
- Photon reconstruction is important.
- Reconstructing π and τ lepton, etc. rely on good photon reconstructions.
- Issues, in the order of difficulty
  - Recover part of photon penetrated into HCAL
  - Remove photon fragments
  - Be more aggressive to separate two nearby photons
  - Identify photons close to tracks

Current status

- Remove photon fragments
  - Photon fragment removal algorithm - released
- Recover part of photon penetrated into HCAL
  - High energy photon recovery – done
- Separate two nearby photons
  - New peak finding algorithm – done
- Identify photons close to tracks
  - Restructuring photon reconstruction algorithm – done

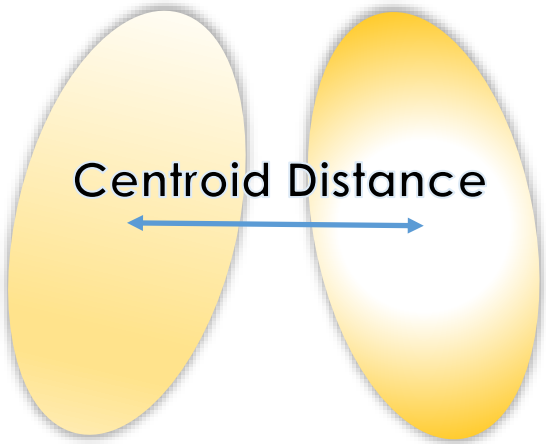
Photon Fragment Removal

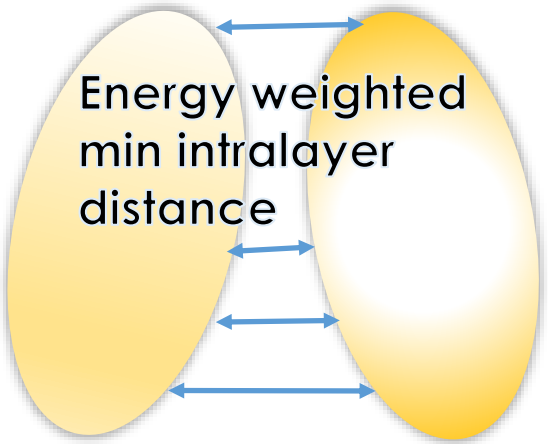
- Improving photon completeness and purity.
- Identifying the fragments; Collecting evidence; Make careful decisions to merge. The aim is to merge as many fragments as possible whilst not merging part of charged hadrons to photons.

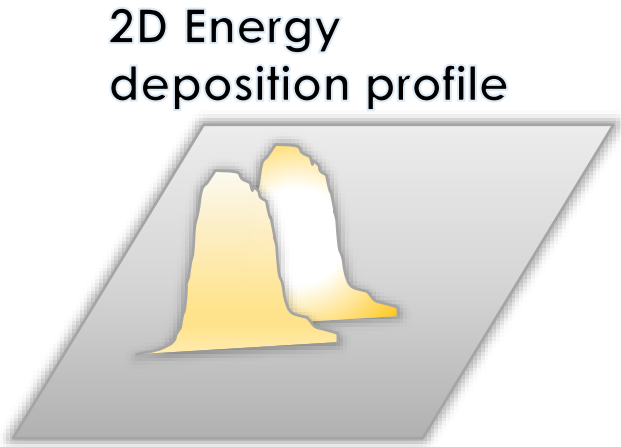


Photon Fragment Removal

- Identify the fragments using generator information
- Collecting evidences. Example quantities below
- Make decisions and apply to reconstructed fragments.

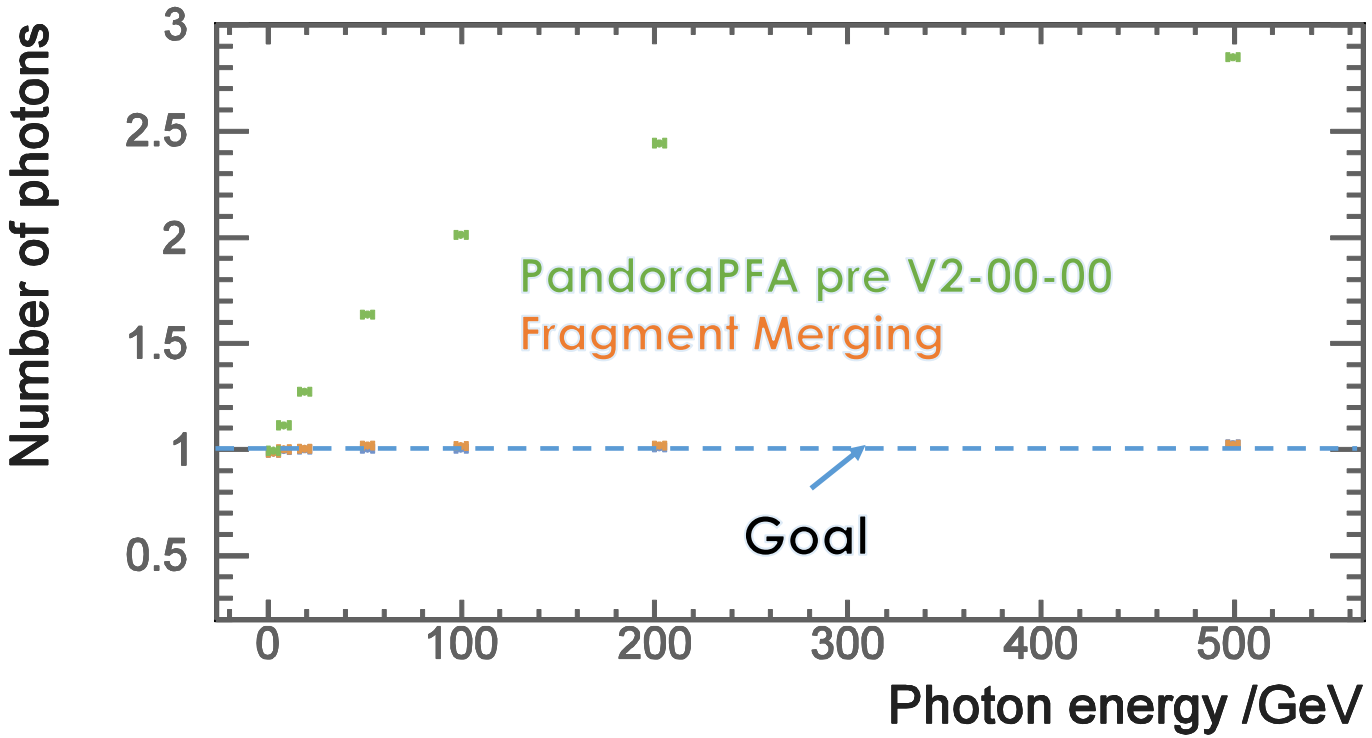






Photon Fragment Removal

- Testing sample：single photon of energy ranged from 0.1 to 500GeV, fired at random directions with CLIC_ILD detector model.



Average number of reconstructed photon as a function of photon energy at generator level

Photon Fragment Removal

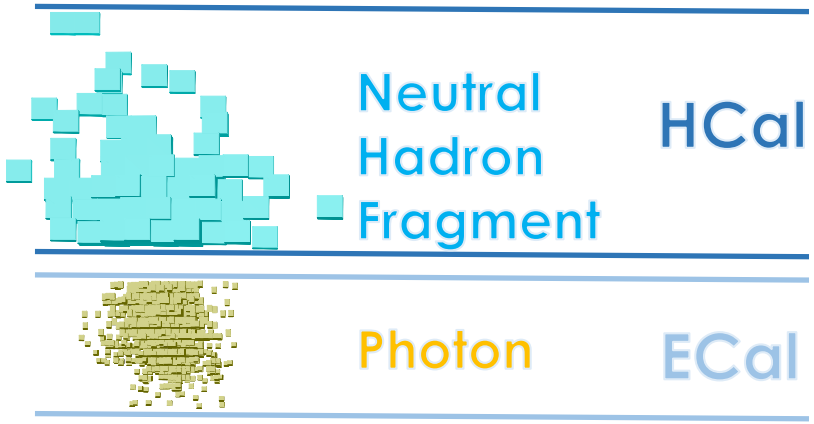
- Conclusion：
- Fragment removal algorithms have been released in PandoraPFA V2-00-00.
- Under the name RecoPhotonFragmentMerging and PhotonFragmentMerging
- They have been incorporated into the default settings for PandoraPFA trunk.

Link:https://github.com/PandoraPFA/MarlinPandora/blob/master/scripts/PandoraSettingsDefault.xml

High energy photon recovery

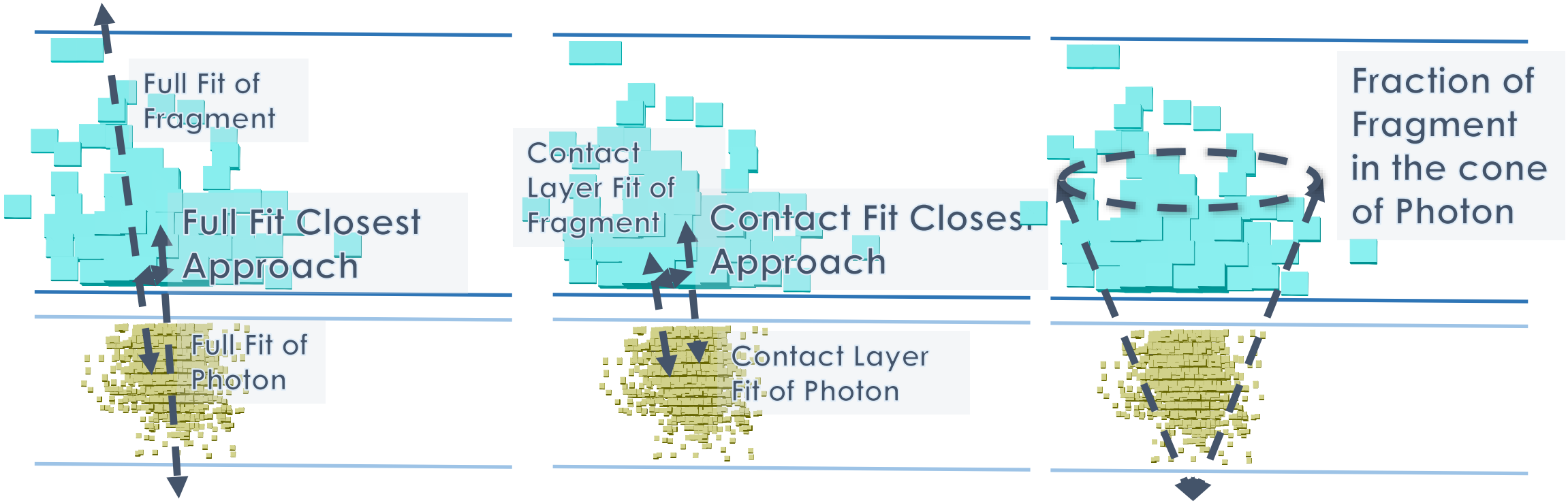
- Recover part of photon penetrated into HCAL
- This typically happens for photon with energy > 50 GeV
- Photon reconstruction implicitly assumes photons deposit all energy in ECAL. Hence energy in HCAL would be typically reconstructed as neutral hadron.

A typical 500GeV photon
Looking at cross section of the calorimeter



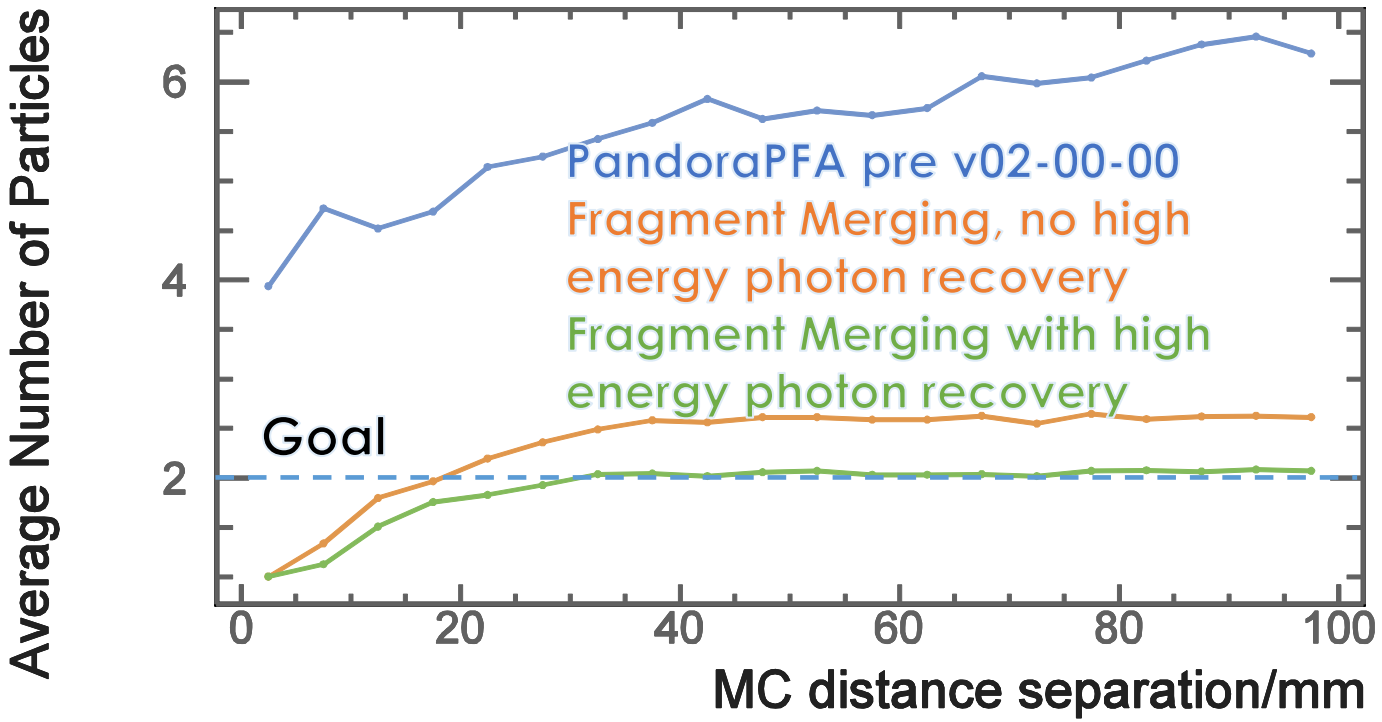
High energy photon recovery

- Collect evidences and make decisions. Example evidences



High energy photon recovery

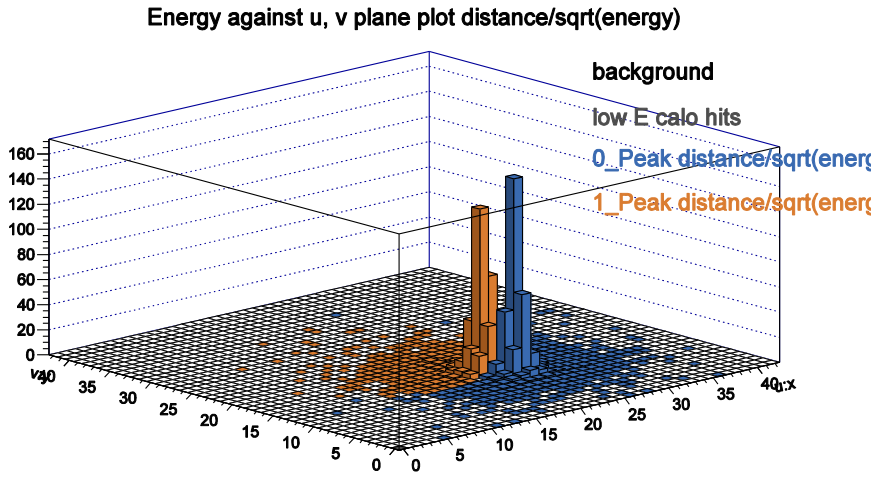
- Testing sample：two photons of energy 500GeV each, fired at random directions



Average number of reconstructed particle as a function of distance separation, in barrel and end cap only

New peak finding

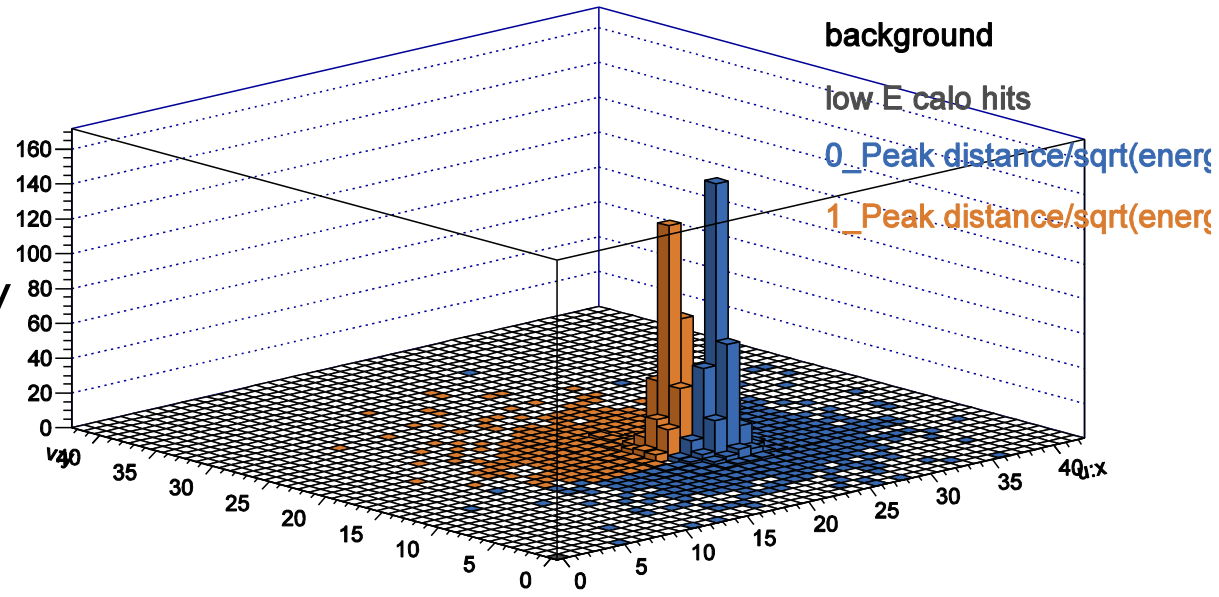
- Improve separation of nearby photons.
- Electromagnetic shower leaves a deterministic profile in the calorimeter.
- Energy deposited in ECAL is used to identify nearby photons.
- New peak finding is exclusive, hopefully creating fewer fragments.



New peak finding

- Project energy to a transverse plane perpendicular to the direction of flight
  - Calo hits are saved in bins
- Identify all peaks in the plane.
- Discard small peaks if energy is < 5% most energetic peak
- Associate non-peak bins to peaks, by minimise metric:
  - $a = d_{\text{peak to bin}} / \sqrt{(E_{\text{peak}})}$

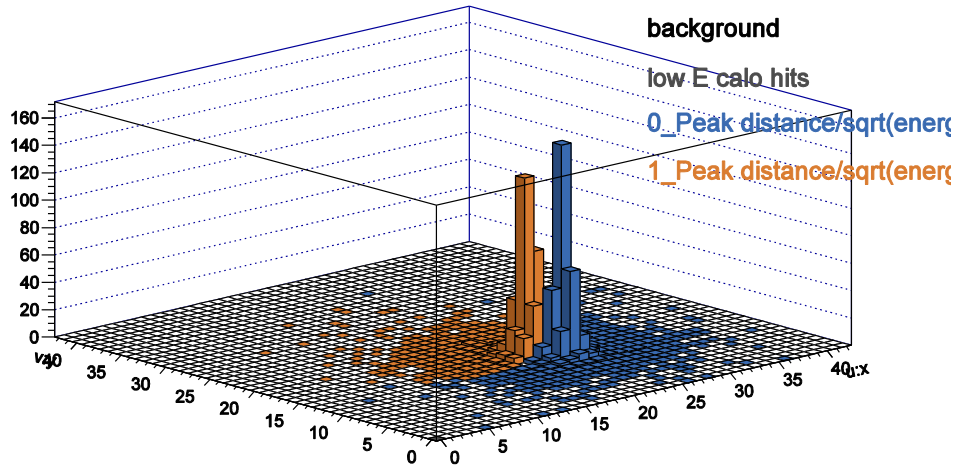
Example: two photons have been identified and each bins have been associated to the peak, marked by colour



New peak finding - Photon splitter

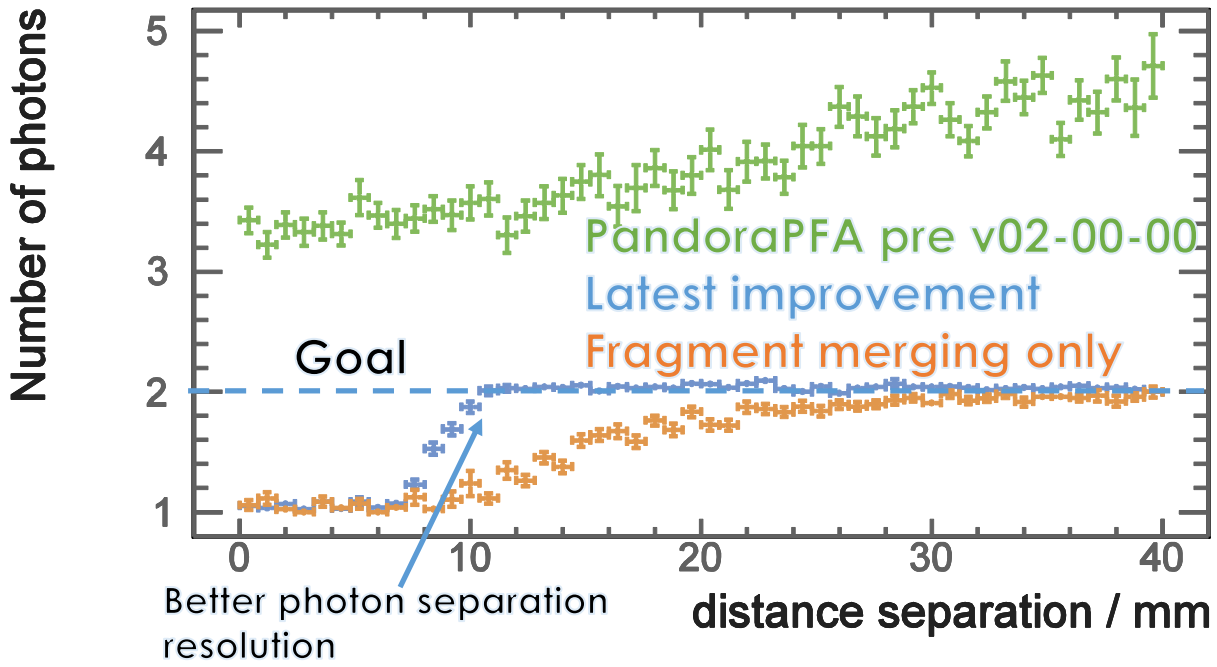
- Is a reconstructed photon one photon or does it actually consist of two photons?
- Use new peak finding algorithm towards the end of PandoraPFA reconstruction, split the photon into two if it finds two peaks in the photon.

One reconstructed photon could occasionally contain two photons, if they are close.
Photon splitter is able to split up the photon, according to the new peak finding result.

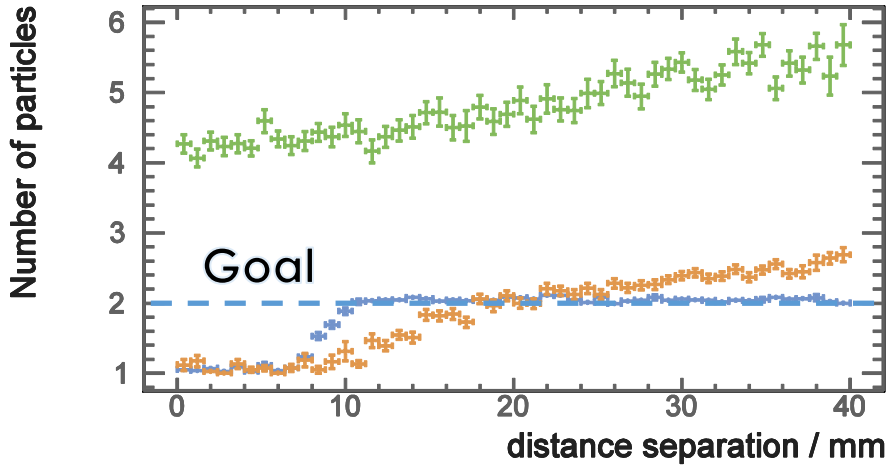


New peak finding

- Testing sample：two photons of energy 500GeV each, fired at random directions

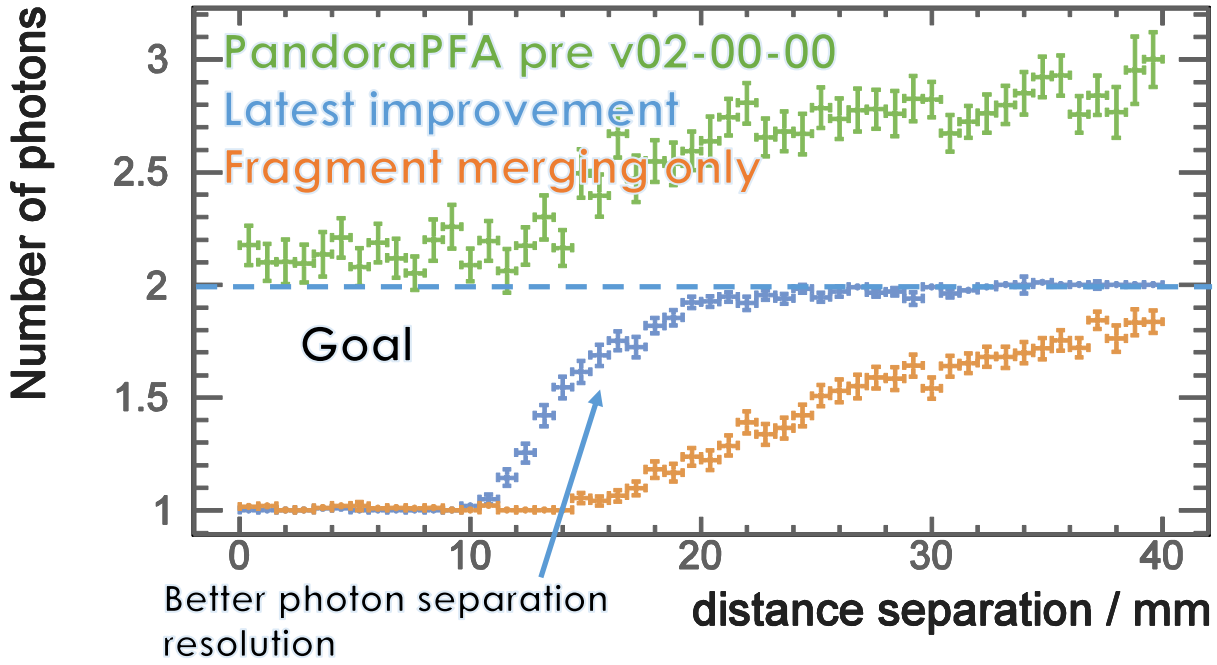


Average number of reconstructed photon/particle as a function of separation, in barrel and end cap only
Particle number = photons + others

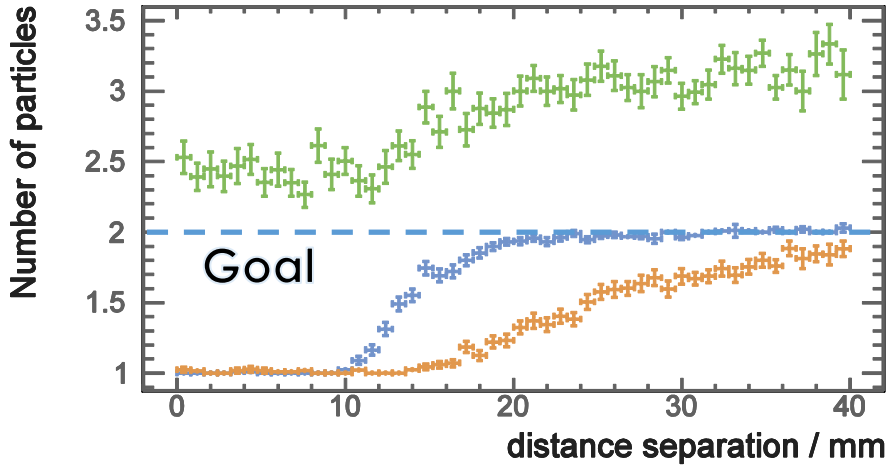


New peak finding

- Testing sample：two photons of energy 100 and 10 GeV each, fired at random directions

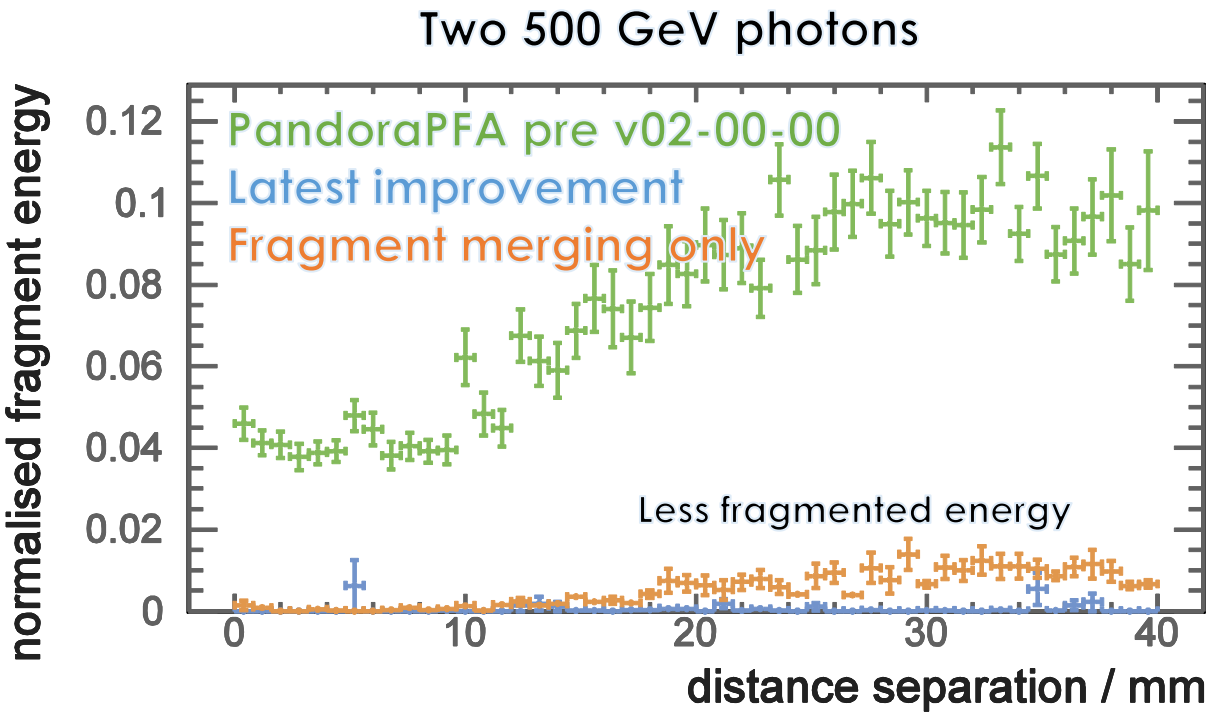


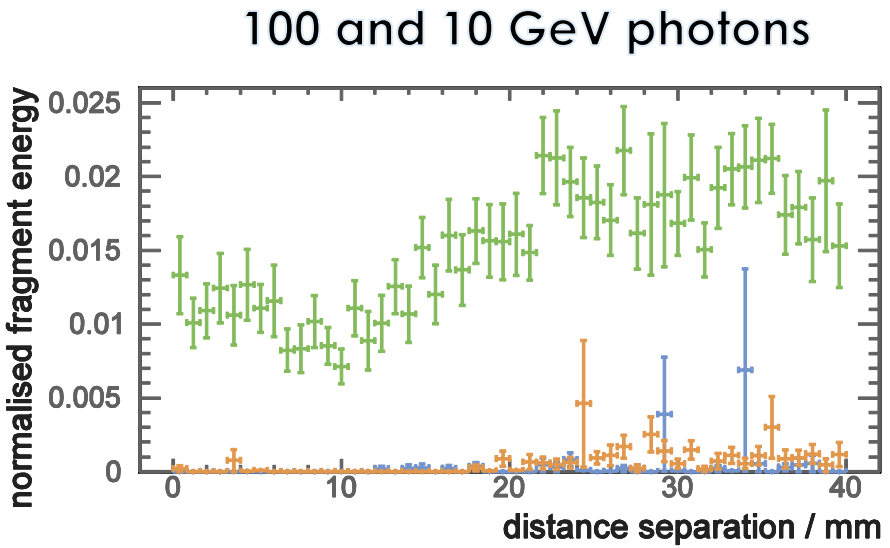
Average number of reconstructed photon/particle as a function of separation, in barrel and end cap only
Particle number = photons + others



New peak finding

- Average normalised fragmented energy as a function of separation, in barrel and end cap only.

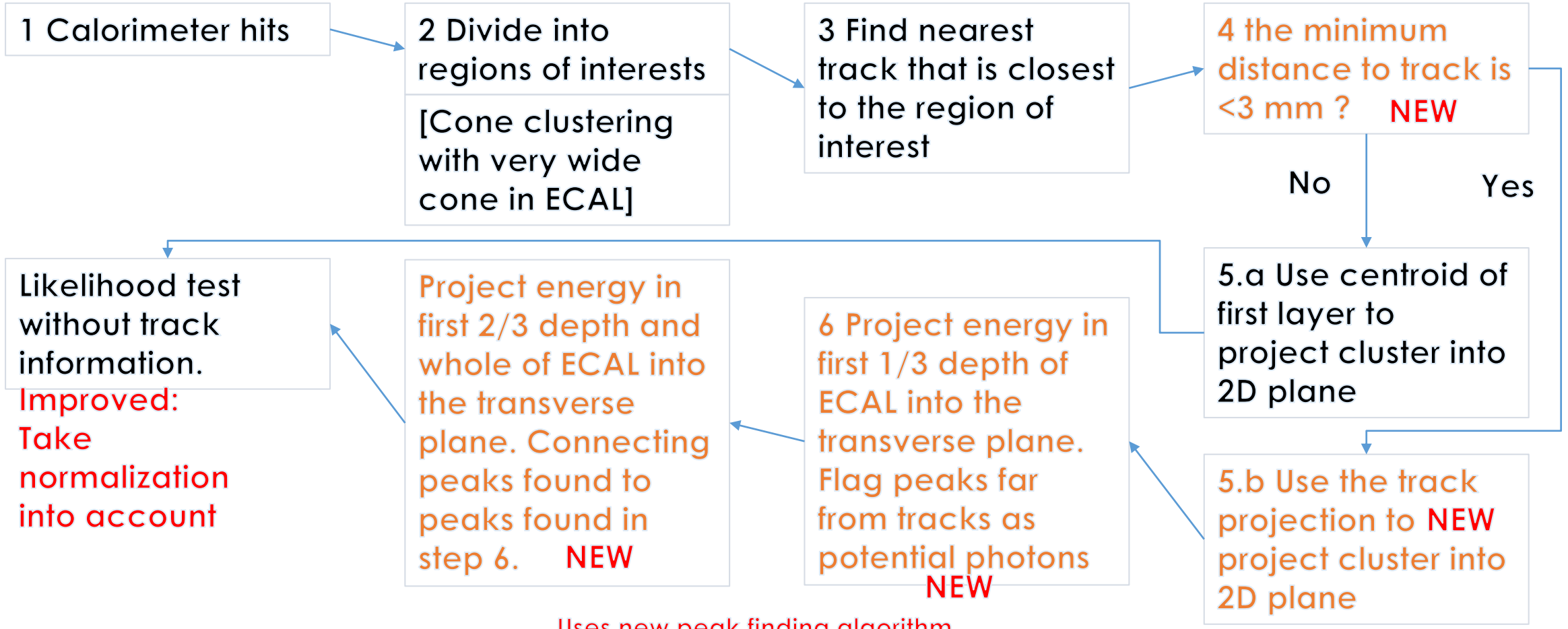




Restructuring photon reconstruction

- Aim to improve the jet energy resolution, especially at high energy.
- Reconstruct photons that are very closed to charged particle, which previously were ignored in the reconstruction.
- Restructured photon reconstruction to able to reconstruct more photons and hence improves the jet energy resolution.

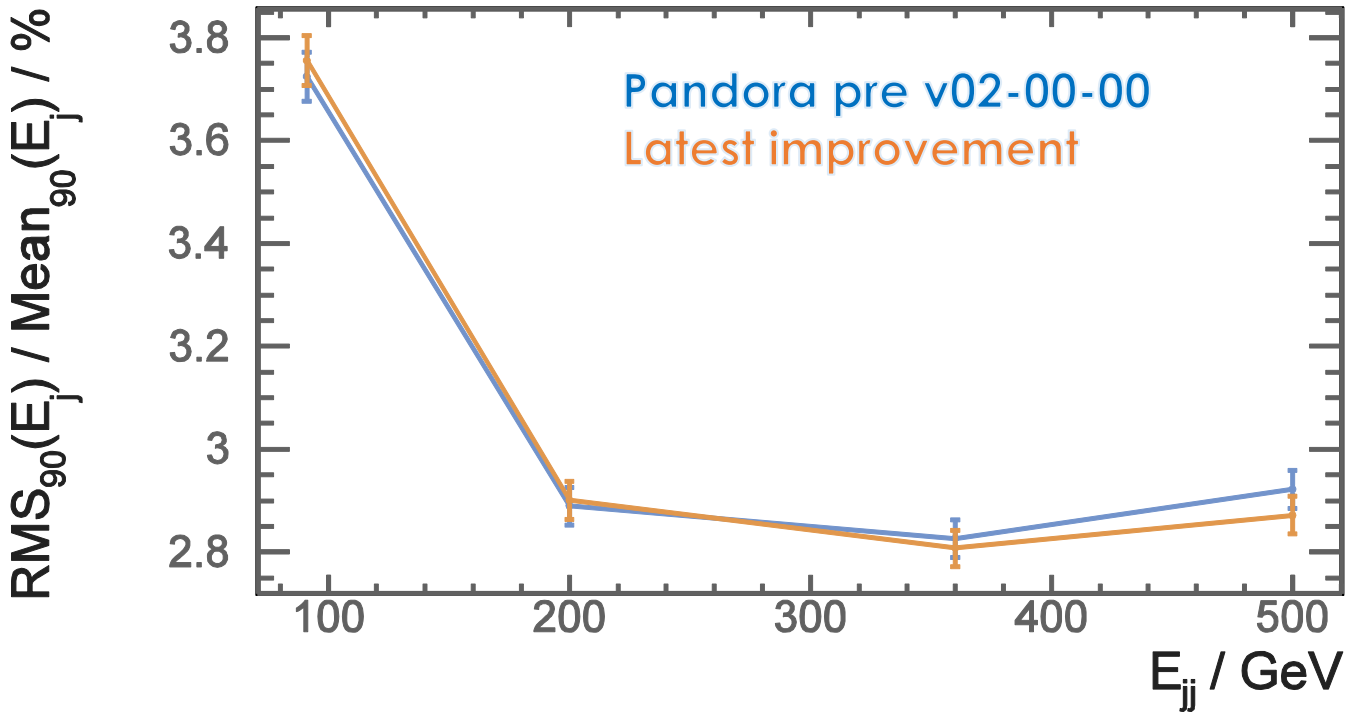
Restructuring photon reconstruction



Uses new peak finding algorithm

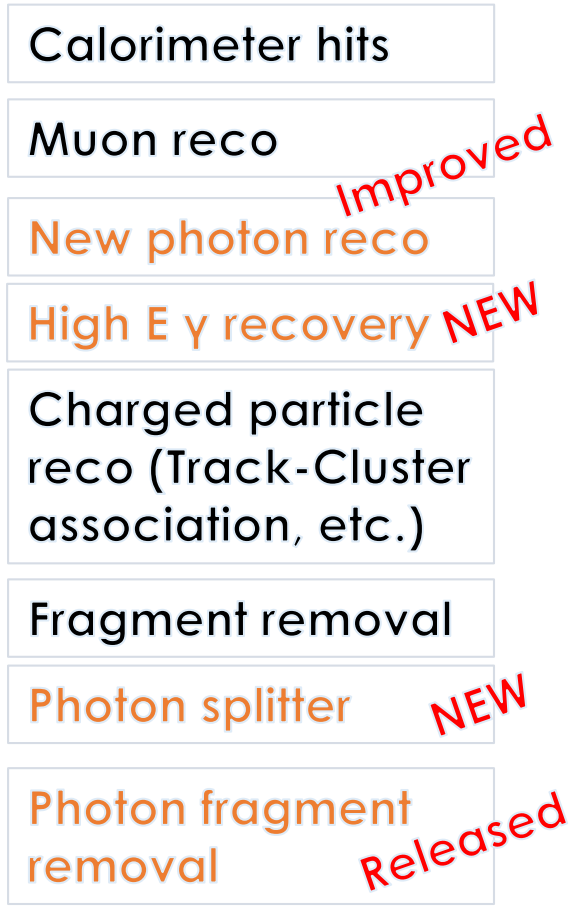
Restructuring photon reconstruction

Better jet energy resolution at high energy



Jet Energy Resolution / %	91GeV	200GeV	360GeV	500GeV
Pandora in iLCSoft v01-17-07	3.727±0.049	2.889±0.037	2.824±0.036	2.924±0.037
Latest improvement	3.754±0.048	2.895±0.037	2.793±0.036	2.870±0.037

Reconstruction in PandoraPFA



- The reconstruction chain in PandoraPFA.
- Photon reconstruction will be replaced by a new one, with new peak finding algorithm.
- Will add:
  - A new high energy photon recovery algorithm.
  - A new photon splitter algorithm.
- Photon fragment merging algorithm has been released.

Conclusion

- Photon fragment removal algorithm
  - Removes photon fragments in ECAL. Improves photon completeness and purity
- High energy photon recovery
  - Remove photon fragments in HCAL, for high energy photon only
- New peak finding algorithm
  - Separate two nearby photons. Basis for photon splitter and restructured photon reconstruction.
- Restructuring photon reconstruction algorithm
  - Identify photons close to tracks. Improves jet energy resolution.

Conclusion

- Single/few photon(s):
  - Fragments for per photon < 0.05 in barrel and end cap region, for photons of energies up to 500 GeV [tested]
  - Nearby photons can be separated as close as to 10 mm (separation angle~0.006 rad) as in CLIC_ILD ECAL.
- Jet(s):
  - More photons close to charged particles are recovered.
  - Jet energy resolution for dijet above 200 GeV is improved.

Conclusion

- Number of reconstructed photon will be close to true photon number
  - Typically number of photon/particle will be fewer
  - N_γ and N_{PFO} should be better physical quantities.
- More reconstructed photons close tracks.
- Energy of a photon will be close to true energy
  - Typically will be increased
- Total energy of a event and total energy of photons are roughly the same

Thank you for your attention!

- PandoraPFA
- Unforgettable moments
- Making you feel secure
- Powerful

Backup

Notes

- All testing events are reconstructed with iLCSoft v01-17-06
- Events are simulated with ILD_o1_v6 detector model, using Mokka
- For reconstructed photon samples, only consider photons without conversions.
- Jet energy resolution is obtained by reconstructing Z'->uds sample, considering barrel region only.