First Look at Particle Flow in a LAr Calorimeter using Pandora in the Key4hep Framework

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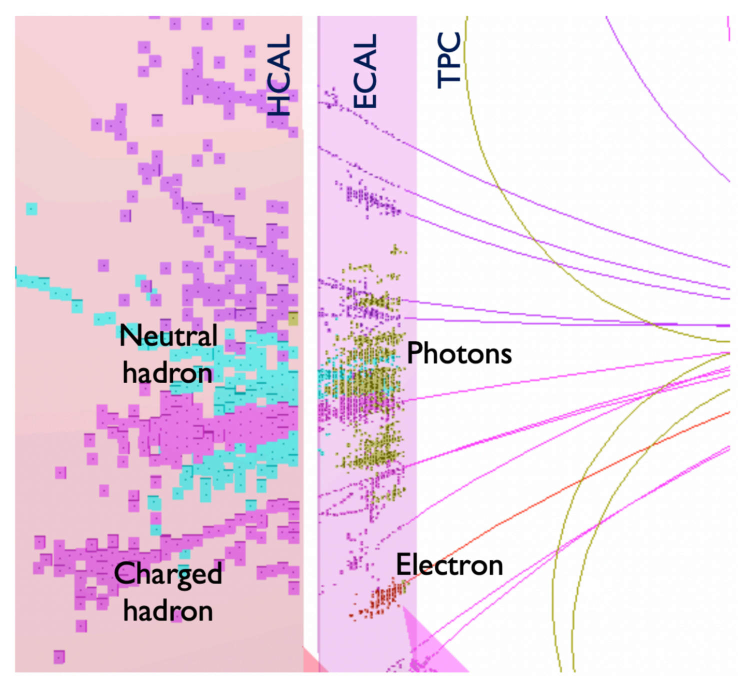
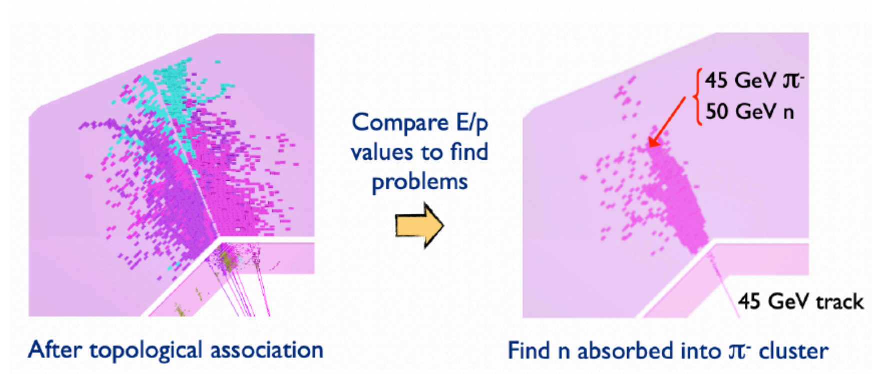
Pandora Particle Flow Algorithm

- Particle flow reconstruction for optimal jet energy resolutions at future Higgs factory experiments
- Particle Flow requires reconstruction of all individual particles
  - Charged particles (62%) through the tracker
  - Photons (27%) through the ECAL
  - Neutral hadrons (10%) through HCAL
- Particle Flow Objects (PFO) built from tracks and (associated) clusters

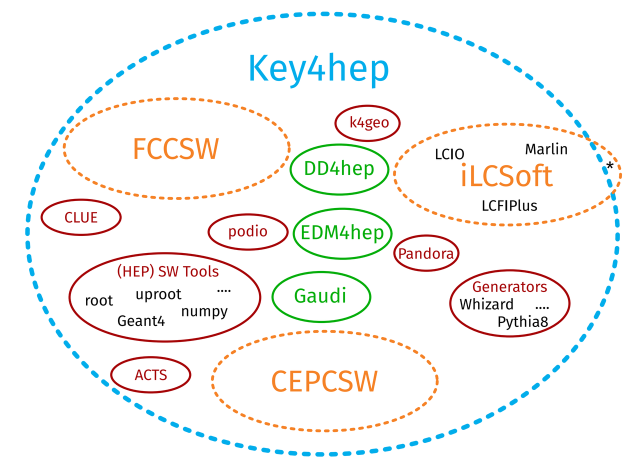


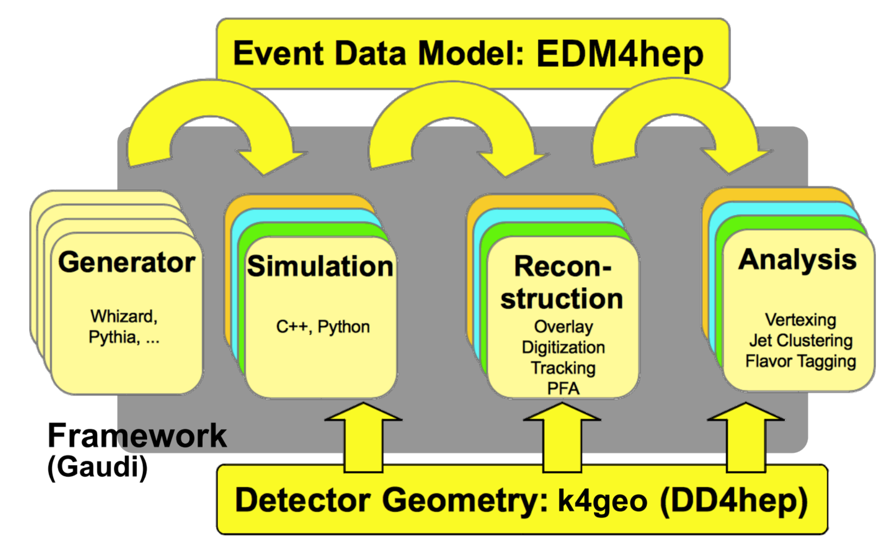
- Track-cluster association: match cluster positions and directions with helix-projected track states at calorimeter
- Recluster until cluster splits and consistent E/p is achieved



Introduction to Key4hep

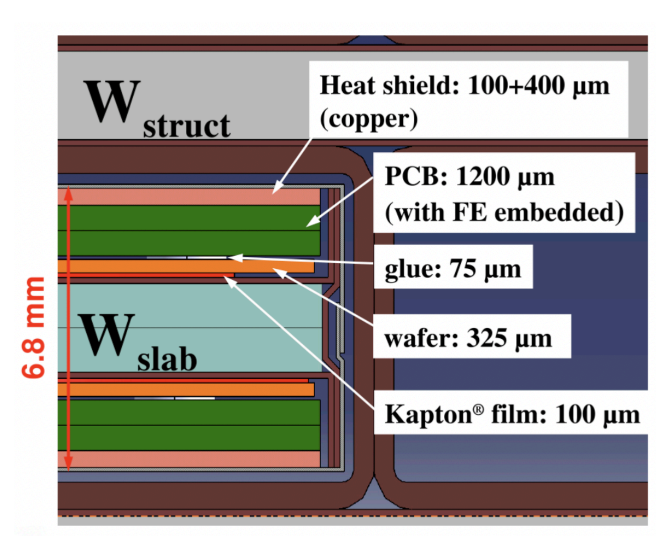
- **A common turnkey software** for future colliders
- **Share components** to reduce maintenance and development cost and allow everyone to benefit from its improvements
- Complete data processing framework from generation to data analysis
- **International Community** with people from different future experiments: FCC, ILC, CLIC, CEPC, C^3, EIC, Muon Collider etc
- Integrate PandoraPFA into key4hep to use it **across multiple detector models**



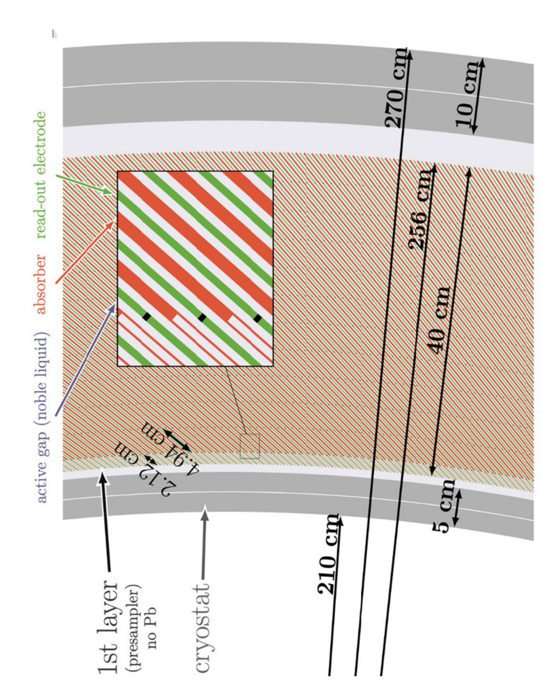


PandoraPFA and Layered Calorimeter Data

- DDMarlinPandora designed for high granularity CALICE sandwich calorimeters
- PandoraPFA uses material properties e.g. radiation lengths and interaction lengths to determine the depth of the particle shower in the detector




```
dd4hep::rec::LayeredCalorimeterData::Layer caloLayer;
caloLayer.distance = rad_first;
caloLayer.inner_nRadiationLengths   = value_of_x0/2.0;
caloLayer.inner_nInteractionLengths = value_of_lambda/2.0;
caloLayer.inner_thickness           = difference_bet_r1r2/2.0;
```

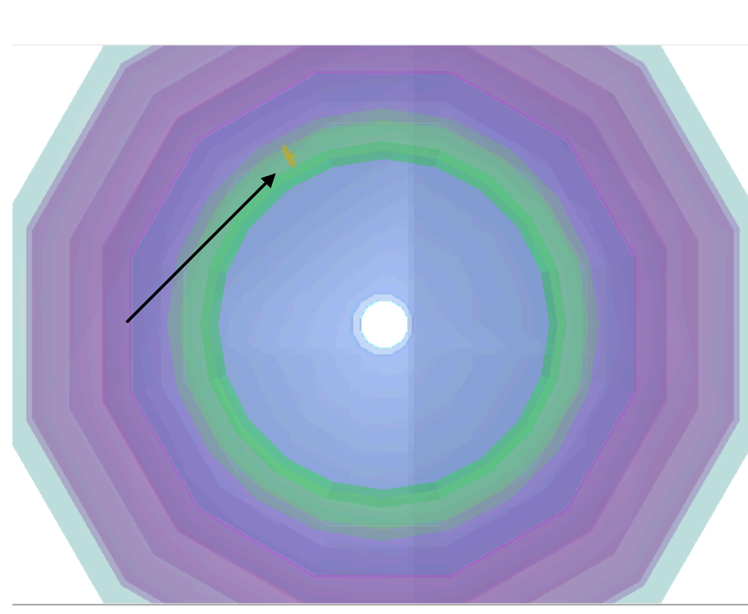


- The FCCee detector ALLEGRO has a Liquid Argon (LAr) electromagnetic calorimeter
- Very different geometry with liquid argon as the sensitive material with steel/Pb absorbers and readouts inclined at an angle of 50 degrees w.r.t. the radius
- Need to use dynamic methods to obtain material properties

```
const dd4hep::rec::MaterialVec& materials = matMgr.materialsBetween(ivr1, ivr2);
auto mat = matMgr.createAveragedMaterial( materials) ;
nRadiationLengths = mat.radiationLength();
nInteractionLengths = mat.interactionLength();
double difference_bet_r1r2 = (ivr1-ivr2).r();
double value_of_x0 = layerHeight[il] / nRadiationLengths;
double value_of_lambda = layerHeight[il] / nInteractionLengths;
```

Can PandoraPFOs be observed at LAr Calorimeter?

- 500 events of photons using a particle gun is simulated at an energy of 10 GeV for the LAr detector model
- By running reconstruction with all the digitized hit collections provided to Pandora, Pandora particle flow objects (PandoraPFO's) from LAr calorimeter could be observed

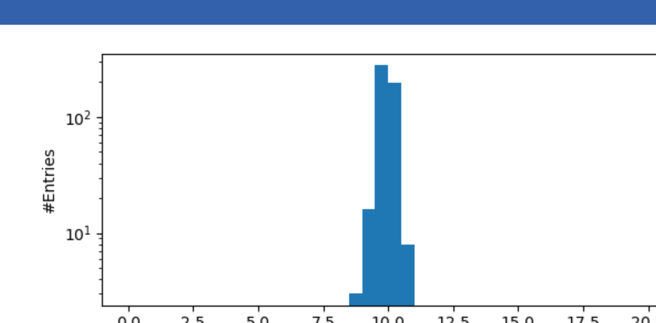


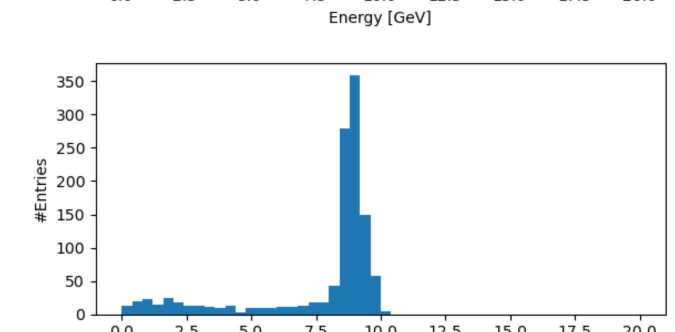
Talk on Key4hep: Tomorrow

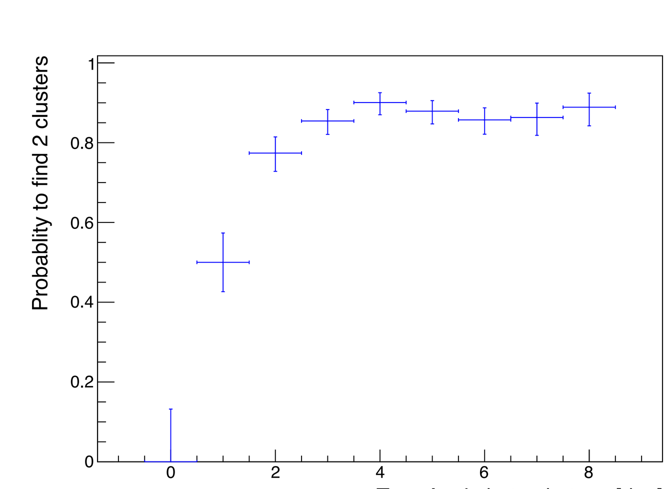
20 Jul 2024, 15:38
(https://indico.cern.ch/event/1291157/contributions/5889612/)

Energy of PandoraPFOs

- The sum of the energies of the digitised sim calorimeter hits peaks nicely at 10 GeV as expected
- The energy of the pandora PFO seen in the second figure mostly peaked at 9 GeV and has a tail
- The correction factor for photon energies needs to be adapted to the LAr calorimeter
- How well the photon clusters can be separated?







- The cell size of ALLEGRO- LAr is 2 x 2 cm^2
- The Molière radius for LAr is 4cm which is larger than SiW calorimeters
- The photons need to be at least 5-6 cms apart for a high probability to be separately clustered : Work in progress

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