τ decay mode identification in a LAr electromagnetic calorimeter

Status update

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Project goal:

Develop an algorithm in FCCSW for distinguishing different decay channels of the τ lepton in the electromagnetic calorimeter. Most important ingredient is an algorithm for π^0 identification.

Steps:

- Build π^0 reconstruction algorithm based on fast simulation (Delphes)
- Set up full detector geometry and clustering algorithm
- Study and develop algorithm for photon reconstruction in full simulation
- Develop method for separating photons from (merged) π^0's
- Minimizing the off-diagonal terms of the migration matrix by forming a separation mechanism for different τ decay channels

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Simulated LAr geometry

Simple (unrealistic) LAr geometry:

- 70 concentric cylinders
- Each layer is 5.7 mm thick
- PCB simulated by making glue layer thicker and an average material constant is used

Simulation:

- All particles generated at $\theta = \frac{\pi}{2}$, $\phi = 0$
- All geant4 hits saved to root output file

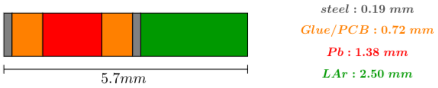


Figure: One sandwich layer

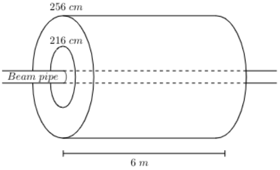
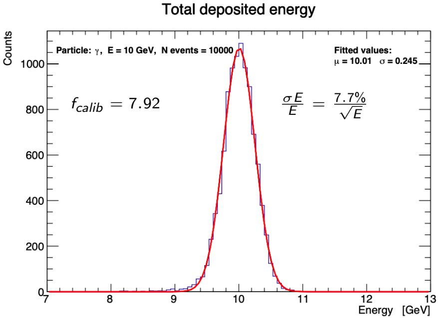
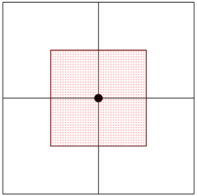


Figure: Drawing of detector

Geant4 hits to cell hits

- Calorimeter divided into 10 layers in the r-direction. 680 cells in ϕ and 300 cells in $z-$direction
- cell size $\sim$ 2 cm$\times$2 cm$\times$4cm
- All geant hits are assigned a cell
- Illuminate evenly over cell surface: position of entire event displaced randomly within the area of one cell





Smearing of event position

Clustering

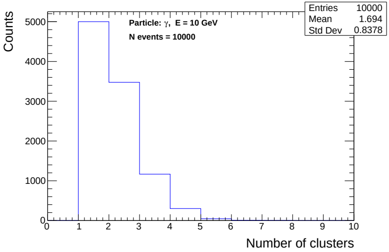
CLUE[1] inspired method using two (adjustable) thresholds:

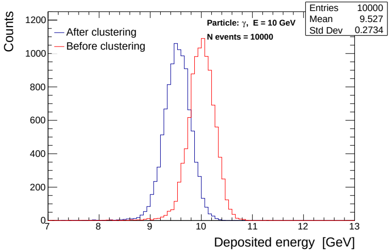
thlow = 12.5 MeV, thhigh = 25 MeV

1. For each cell, point to highest energy (of 26) neighbours exceeding thlow
   - If the cell is local maximum and exceeds thhigh it will be a seed
   - For each cell, define list of followers (cells that point to it)
2. Collect clusters
   - Start by seed cells (local energy maximum) and collect followers iteratively
3. Merging of clusters
   - If two clusters have neighbouring cells with energy exceeding thlow, merge the two clusters

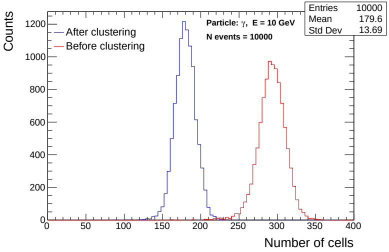
[1] arXiv:2001.09761 [physics.ins-det]

Clustering - 10 GeV photons

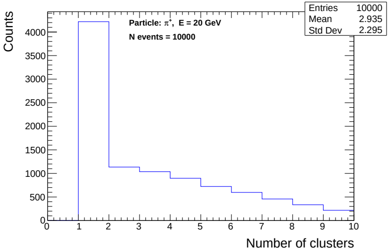


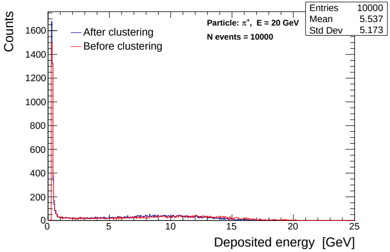


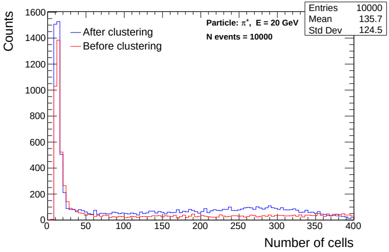
$\Rightarrow$ Need of re-calibration



Clustering - 20 GeV π^+





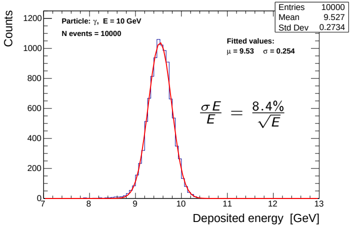


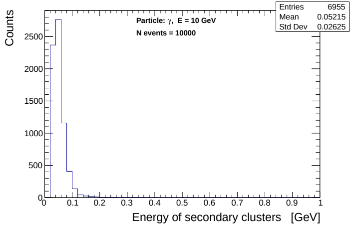
Leading and sub-leading cluster: Reconstructed energy

Leading cluster

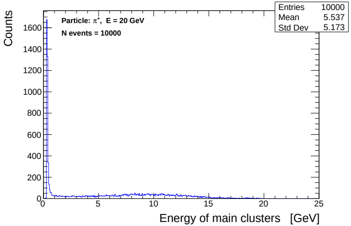
Sub-leading clusters

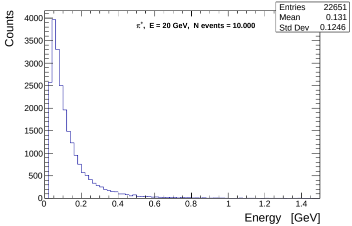
γ





π^+



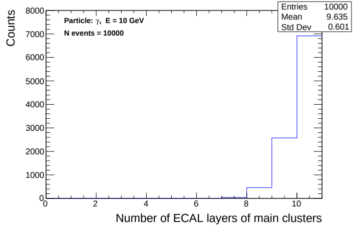


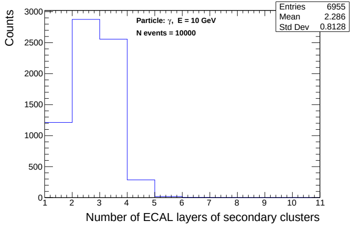
Leading and sub-leading cluster: Number of layers

Leading cluster

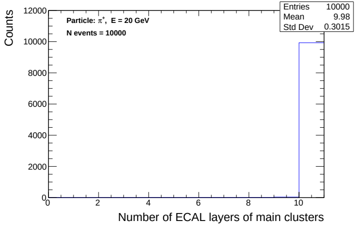
Sub-leading clusters

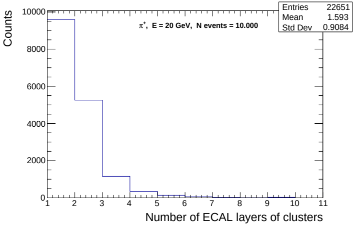
γ





π^+



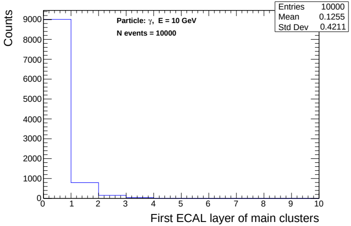


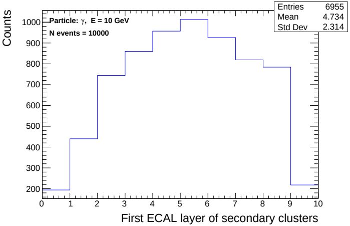
Leading and sub-leading cluster: Start layer

Leading cluster

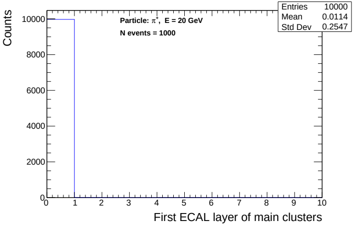
Sub-leading clusters

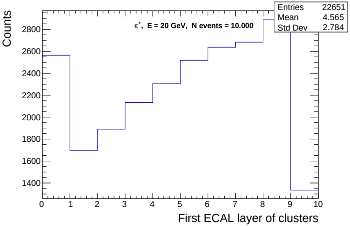
γ





π^+





Leading and sub-leading cluster

Variables for separation:

- Energy of clusters
- Number of layers of clusters
- Start layer of clusters
- Possibly geometrical proximity to primary cluster

Next steps:

- Combining these variables to achieve best possible separation
  - Full τ decays may be needed
  - Maybe using a likelihood method inspired by ALEPH [2]

[2] https://doi.org/10.1007/s002880050134

Investigating separation of EM and hadronic showers

Mean longitudinal energy profile of EM shower:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

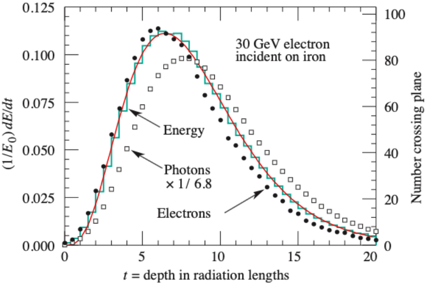


Figure: D.E. Groom et al., Passage of Particles Through Matter

Method:

Classification of showers by fitting the distribution of EM longitudinal shower profile to each shower and determining the level of agreement by $\delta = \frac{1}{E_0}\sum_i \left|\Delta E^i_{obs} - \Delta E^i_{EM}\right|$ inspired by PandoraPFA[3]

[3] arXiv:0907.3577 [physics.ins-det]

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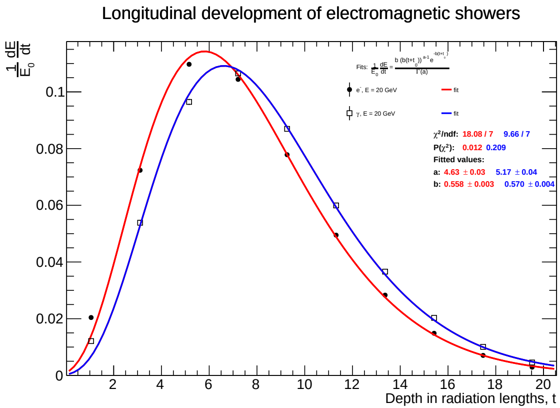
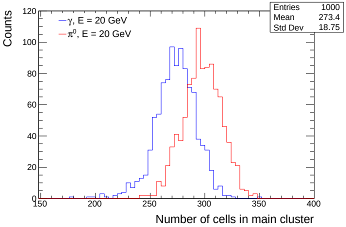
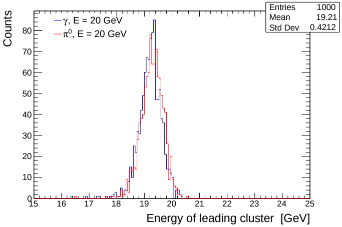


Next steps:

- Fit to each individual shower
- Make separation based on fits

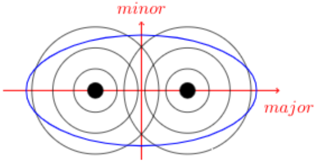
Separation of single photons from π^0's based on shape





Method:

Comparisons the major and minor axis of clusters. This is calculated by diagonalizing the covariance matrix for each layer of the ECAL



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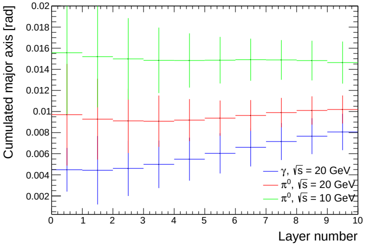
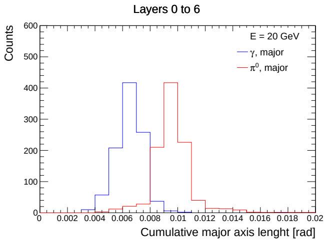
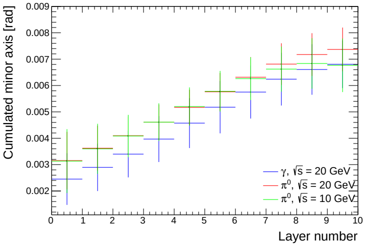
Results:







Next steps

- Implement separation of primary and secondary clusters
- Implement the separation of EM and hadronic showers
- Implement separation of single photons and merged π^0's
- Combine all separation algorithms and incorporate the π^0 reconstruction method
- Create and optimize the migration matrix for τ decays