Level 3 Trigger Status

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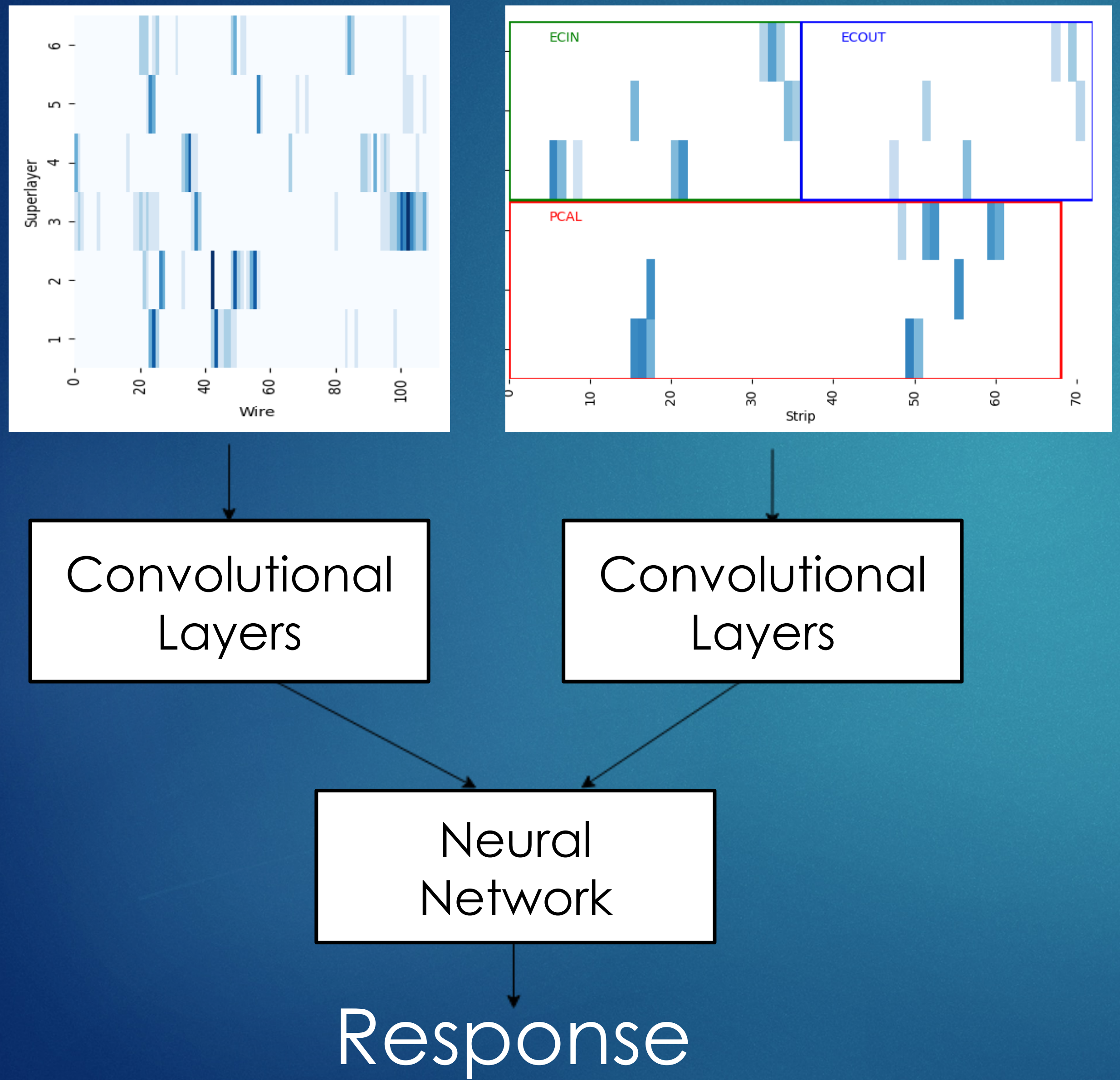
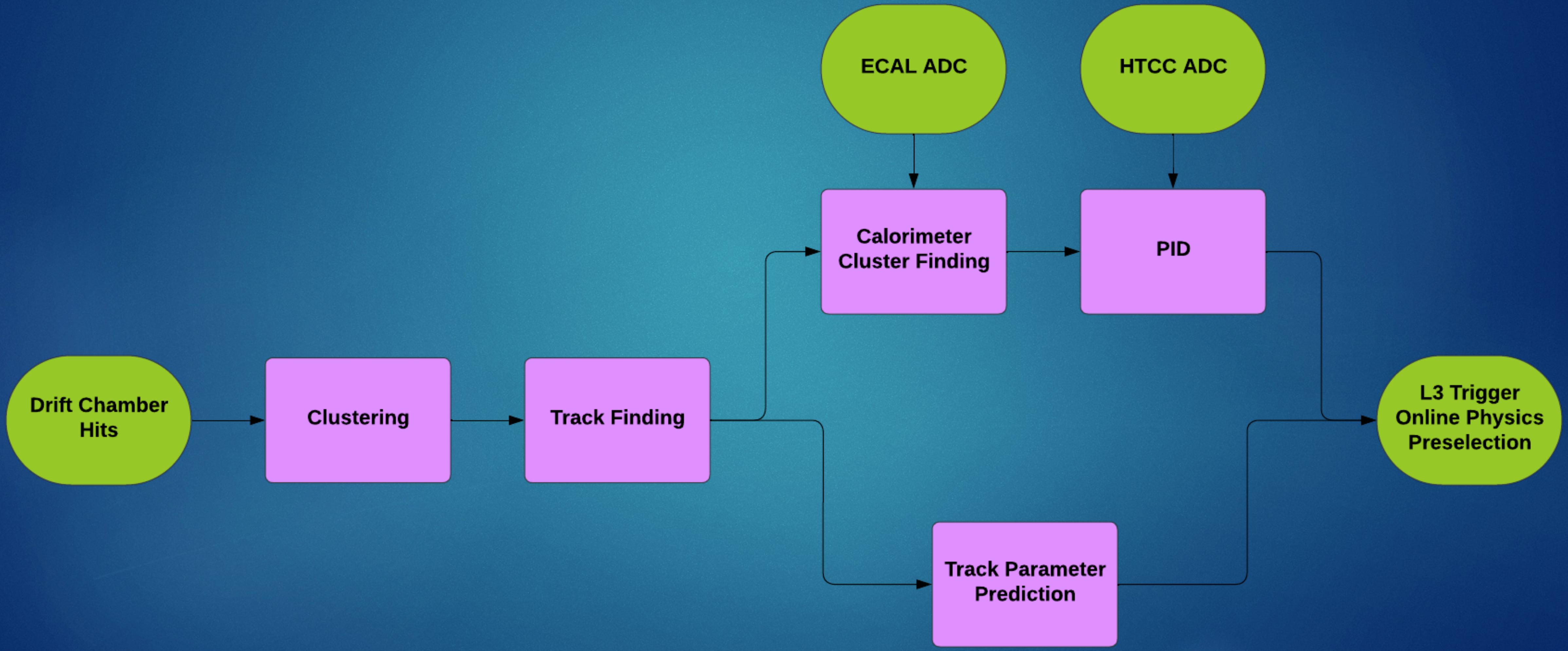
Level 3 Electron Trigger – In the Past

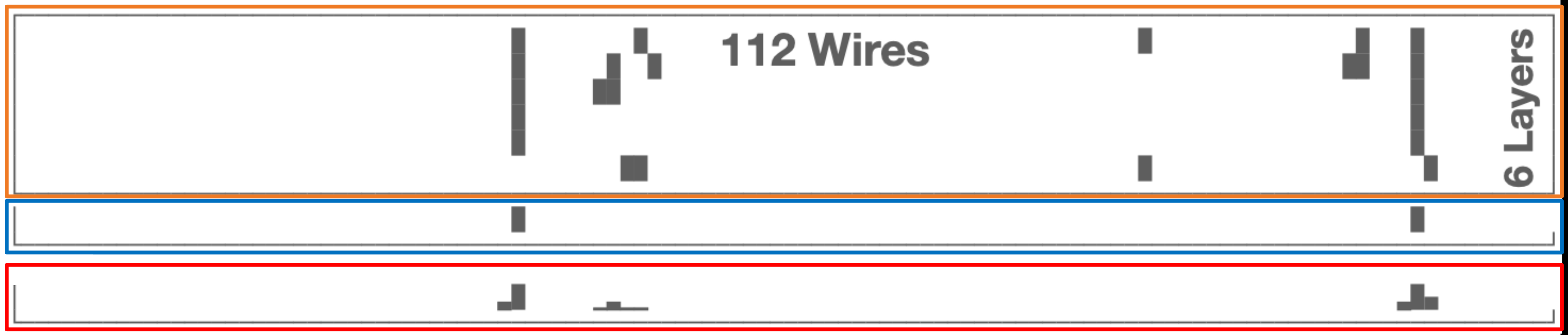


- Previously the Level 3 trigger design employed a convolutional neural network to classify sectors with/without an electron.
- We've now decided to change this to align with the online reconstruction (InstaRec). Benefits:
  - PID available online
  - Reduces complexity of networks, increases event rate
  - Simpler task and validation

Online Reconstruction



Online Reconstruction

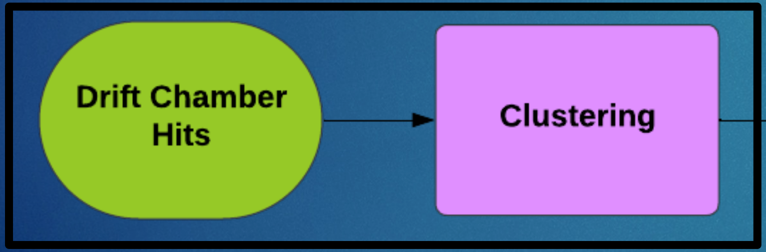


Input – Hit Wire Positions

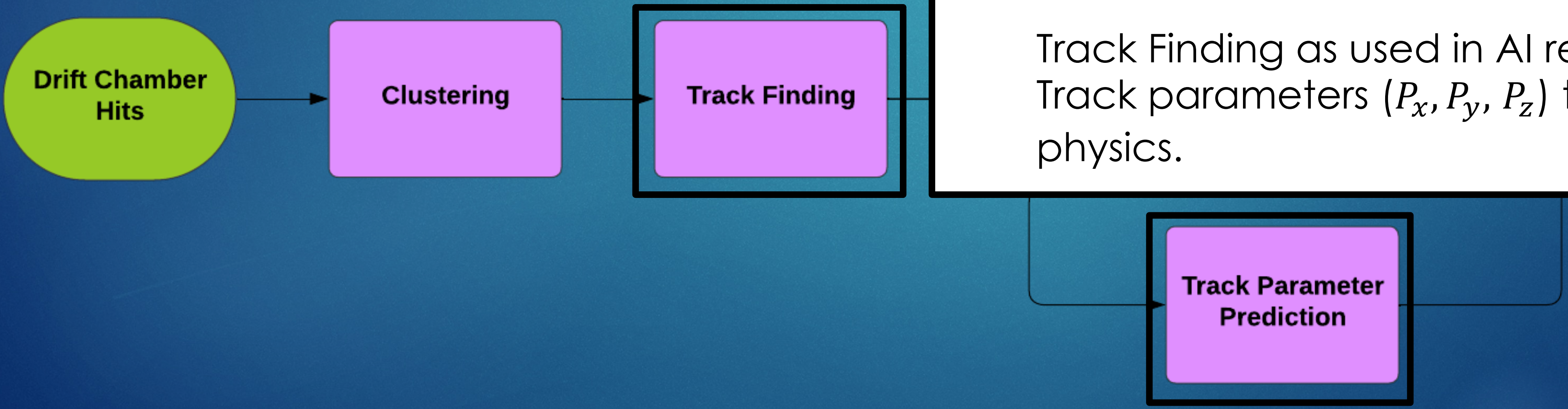
Reconstruction – Cluster Wire Positions

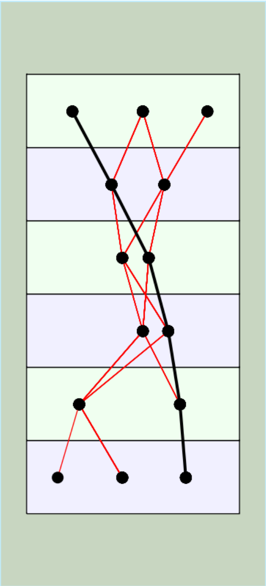
Prediction – Cluster Wire Positions

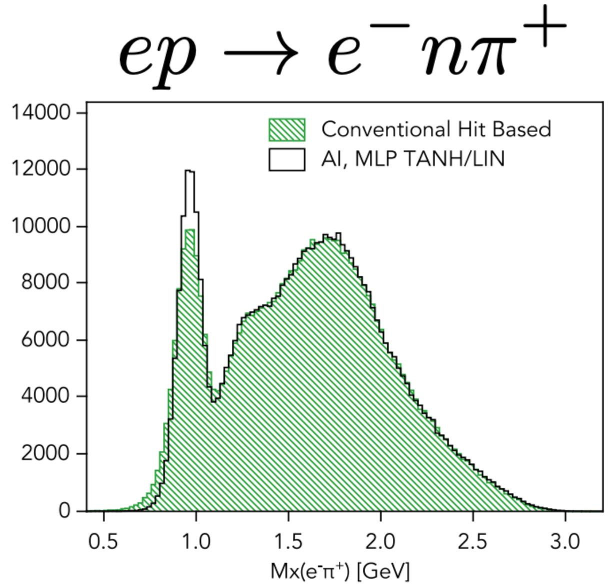
Work in Progress – not used in this talk



Online Reconstruction







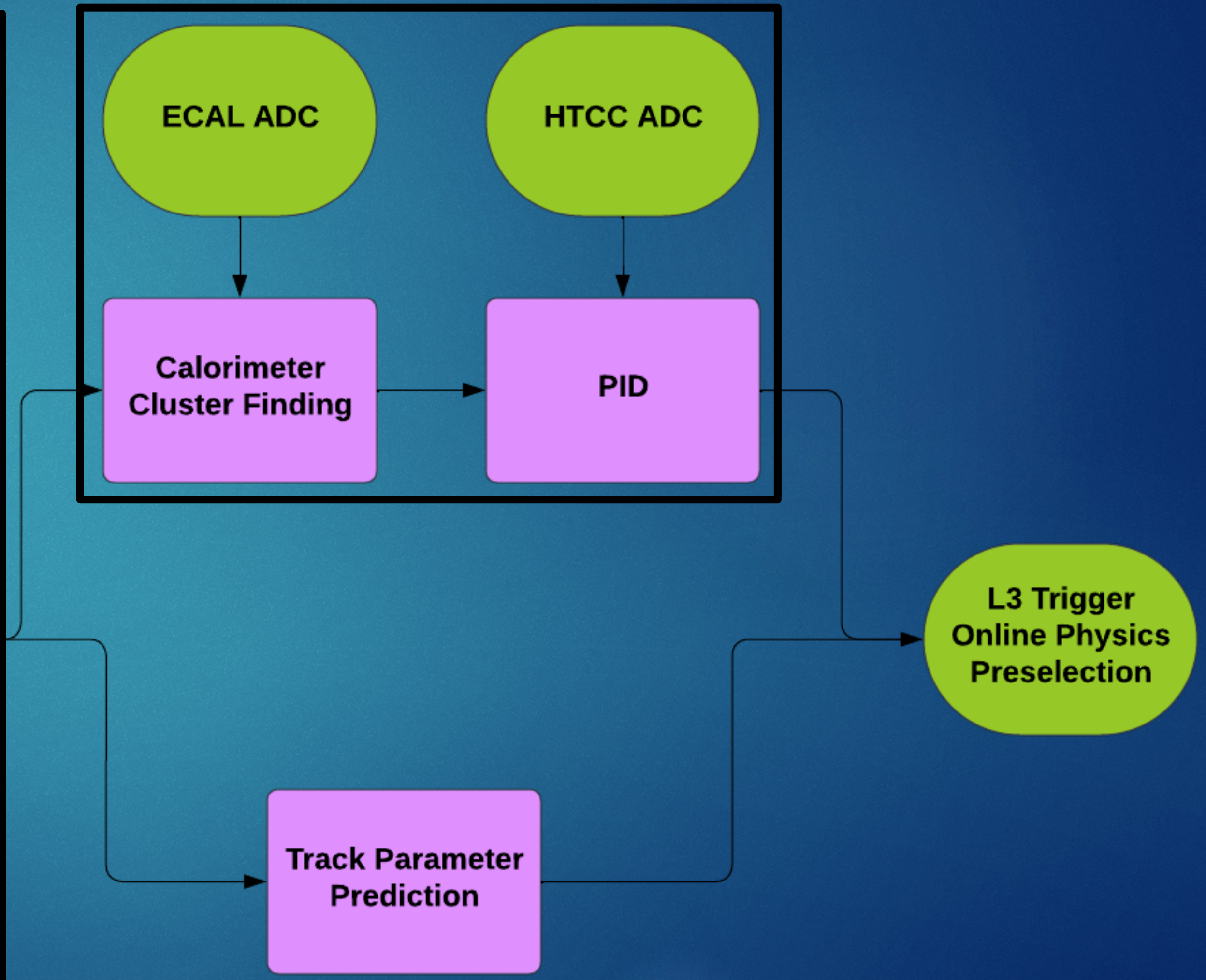
Track Finding as used in AI reconstruction. Track parameters (P_x, P_y, P_z) then used for physics.

Online Reconstruction

Subject of this talk.

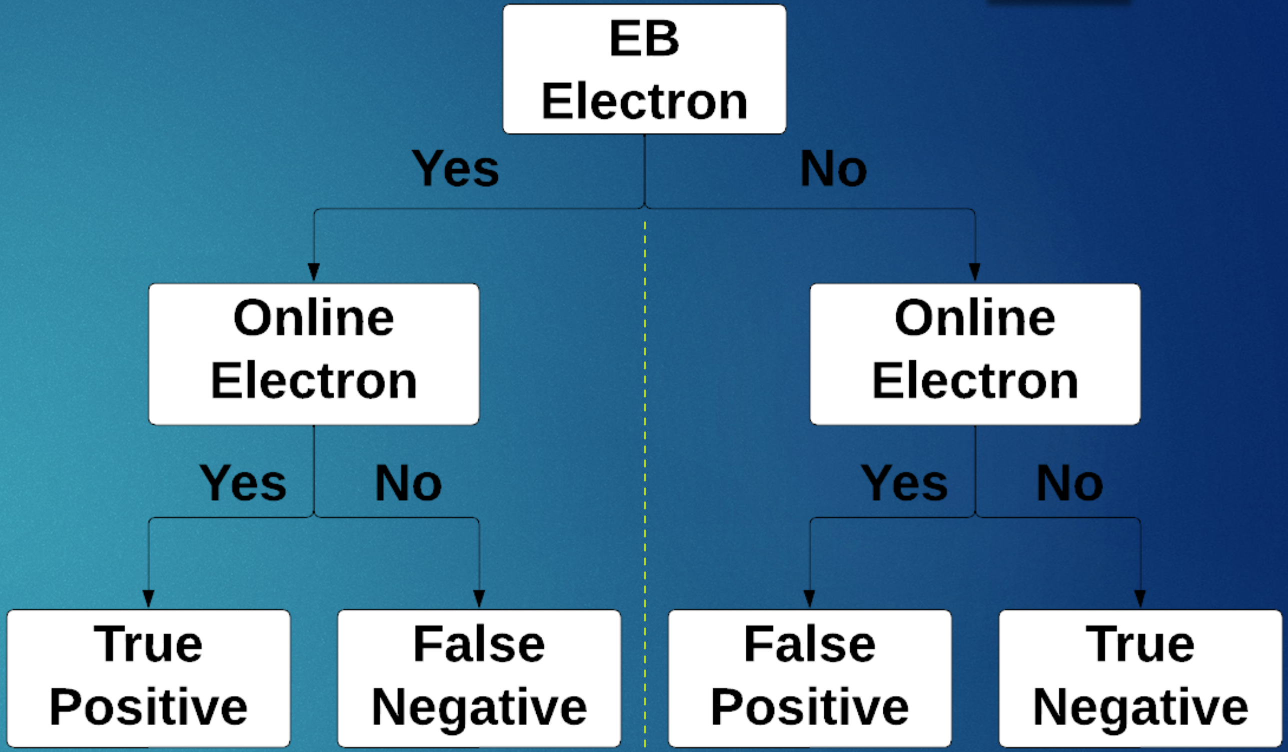
Aim is to combine tracking information to ECAL and HTCC to ID electrons

~10 kHz prediction rate on single CPU Core (prediction rate scales linearly with CPU cores)



Electron ID

- We focus on electrons for now.
- Reasons are simple:
  - Simplest benchmark to Level 1 trigger
  - Good Event Builder PID, easy to create training sample
  - Plenty of statistics
- Aim of the algorithm is therefore to determine if a sector has an electron:
  - Event Builder PID
  - $-13 < V_z < 12$ cm
  - Non empty HTCC in same sector
  - 6 superlayer tracks

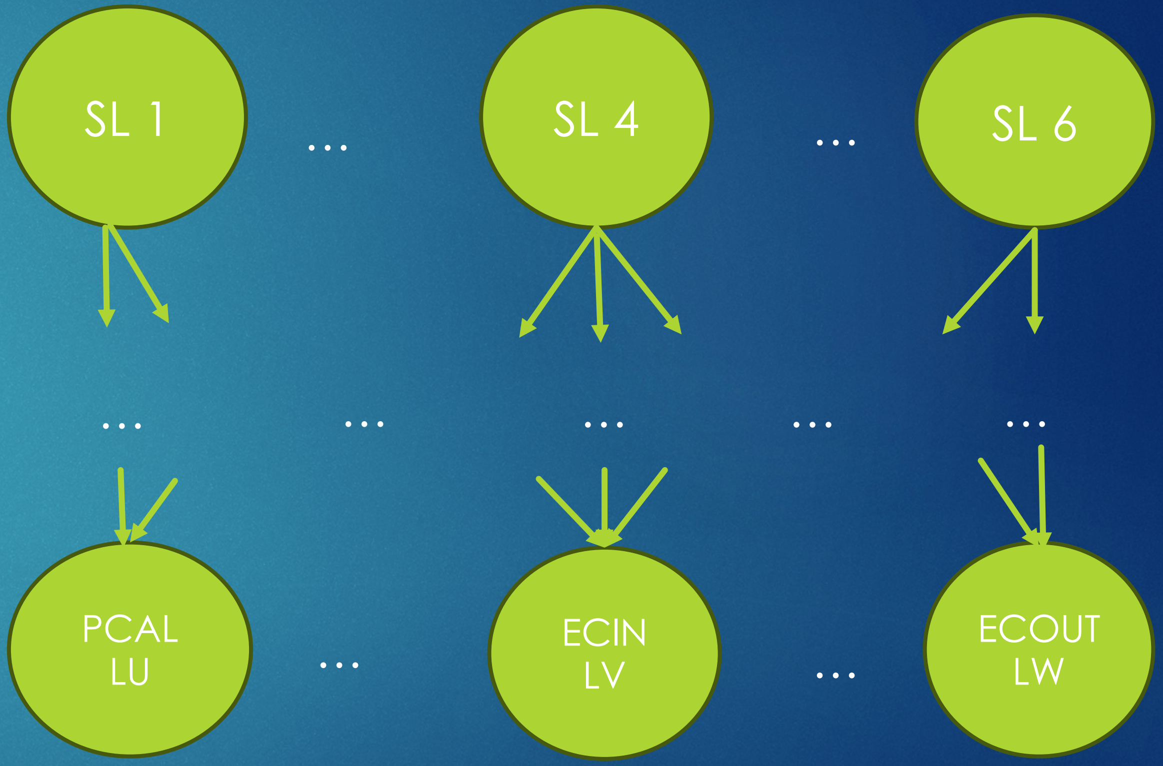


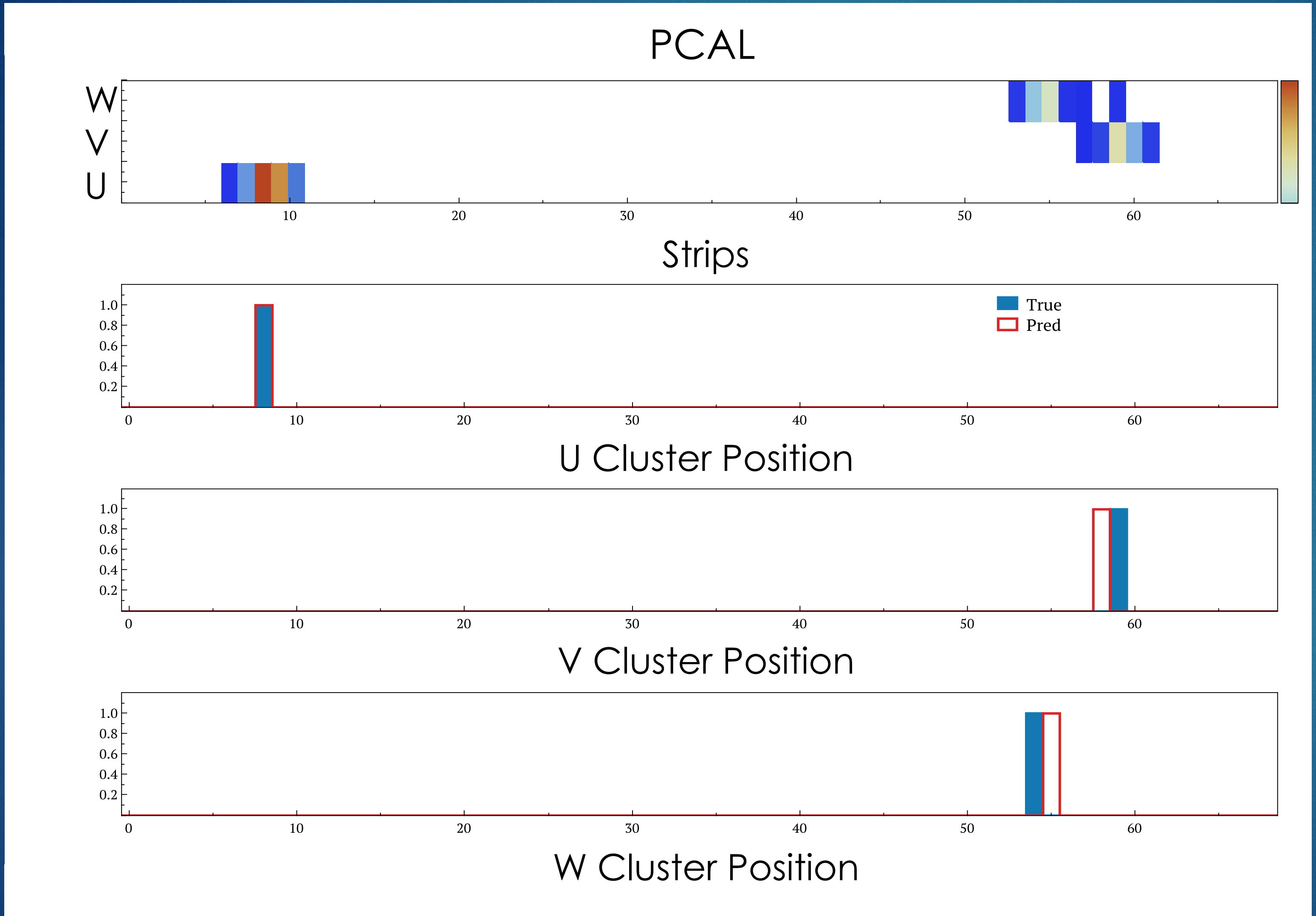
$$\text{Efficiency} = \frac{TP}{(TP+FN)} = \frac{\text{Number of EB e}^- \text{ \& trigger e}^-}{\text{Number of EB e}^-}$$

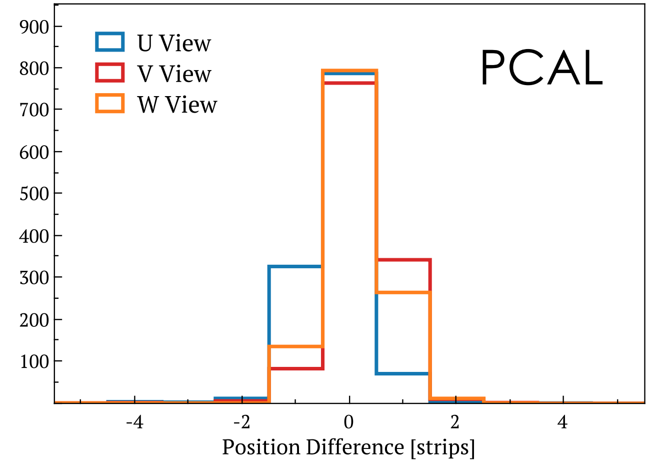
$$\text{Purity} = \frac{TP}{(TP+FP)} = \frac{\text{Number of EB e}^- \text{ \& trigger e}^-}{\text{Number of trigger e}^-}$$

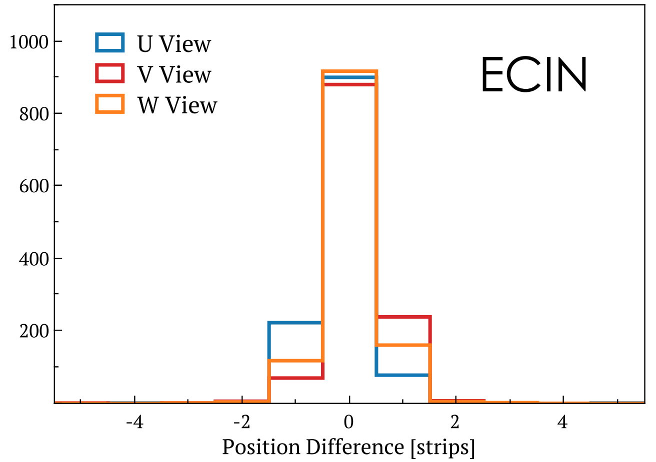
Track to ECAL Prediction

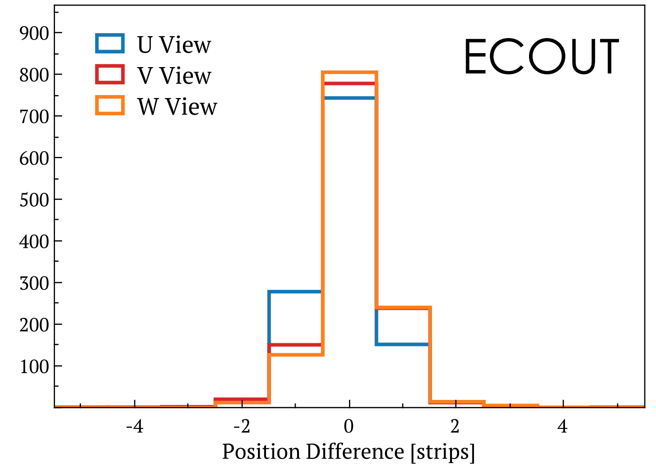
- Given a track, we can predict the position of an ECAL cluster.
- Input is average wire in each DC superlayer from track finding.
- Output is LU/LV/LW in each of PCAL/ECIN/ECOUT. Convert this to strips.
- Trained and tested on RG-D inbending.




PCAL
W
V
U
10 20 30 40 50 60
Strips
True
Pred
1.0 0.8 0.6 0.4 0.2
0 10 20 30 40 50 60
U Cluster Position
V Cluster Position
W Cluster Position

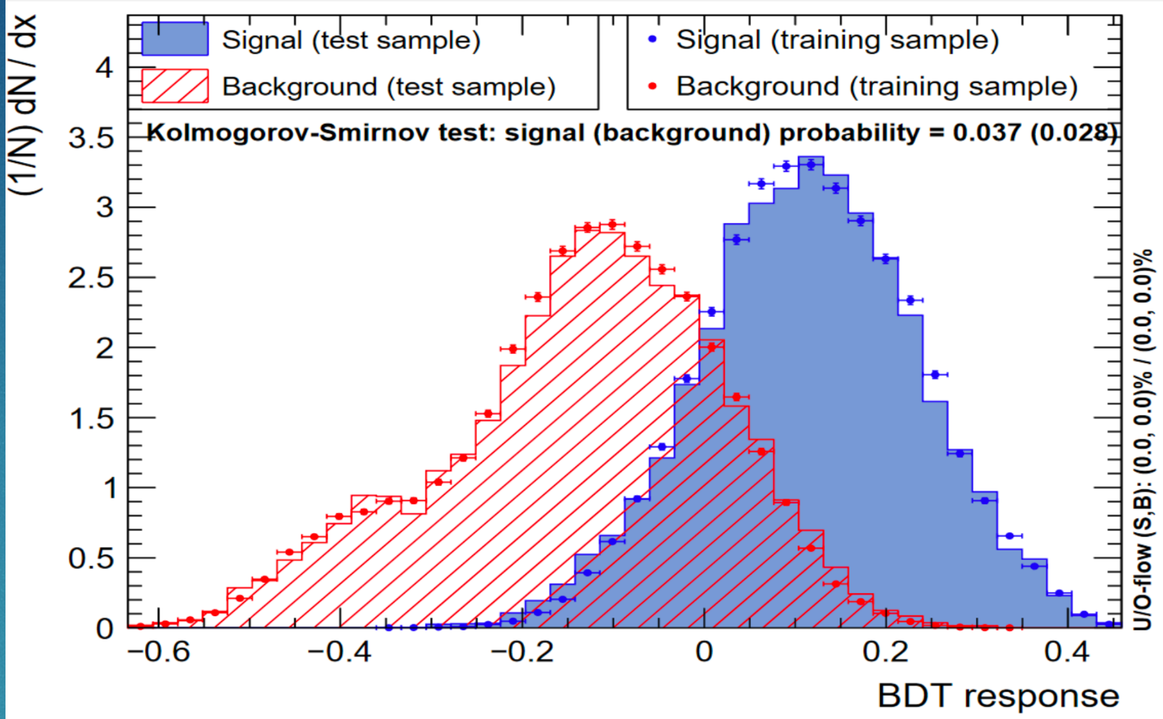

PCAL
U View
V View
W View
900 800 700 600 500 400 300 200 100
-4 -2 0 2 4
Position Difference [strips]


ECIN
U View
V View
W View
1000 800 600 400 200
-4 -2 0 2 4
Position Difference [strips]

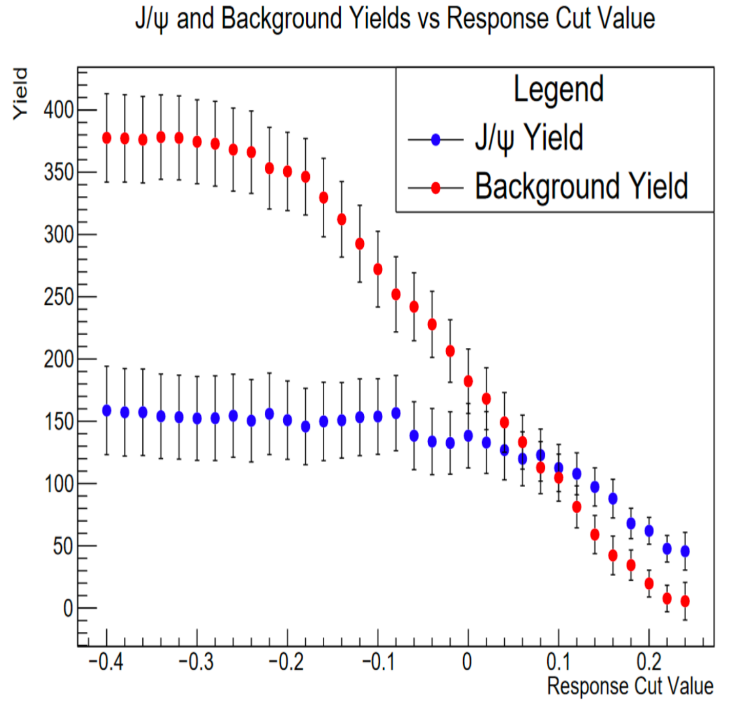

ECOUT
U View
V View
W View
900 800 700 600 500 400 300 200 100
-4 -2 0 2 4
Position Difference [strips]

Offline PID

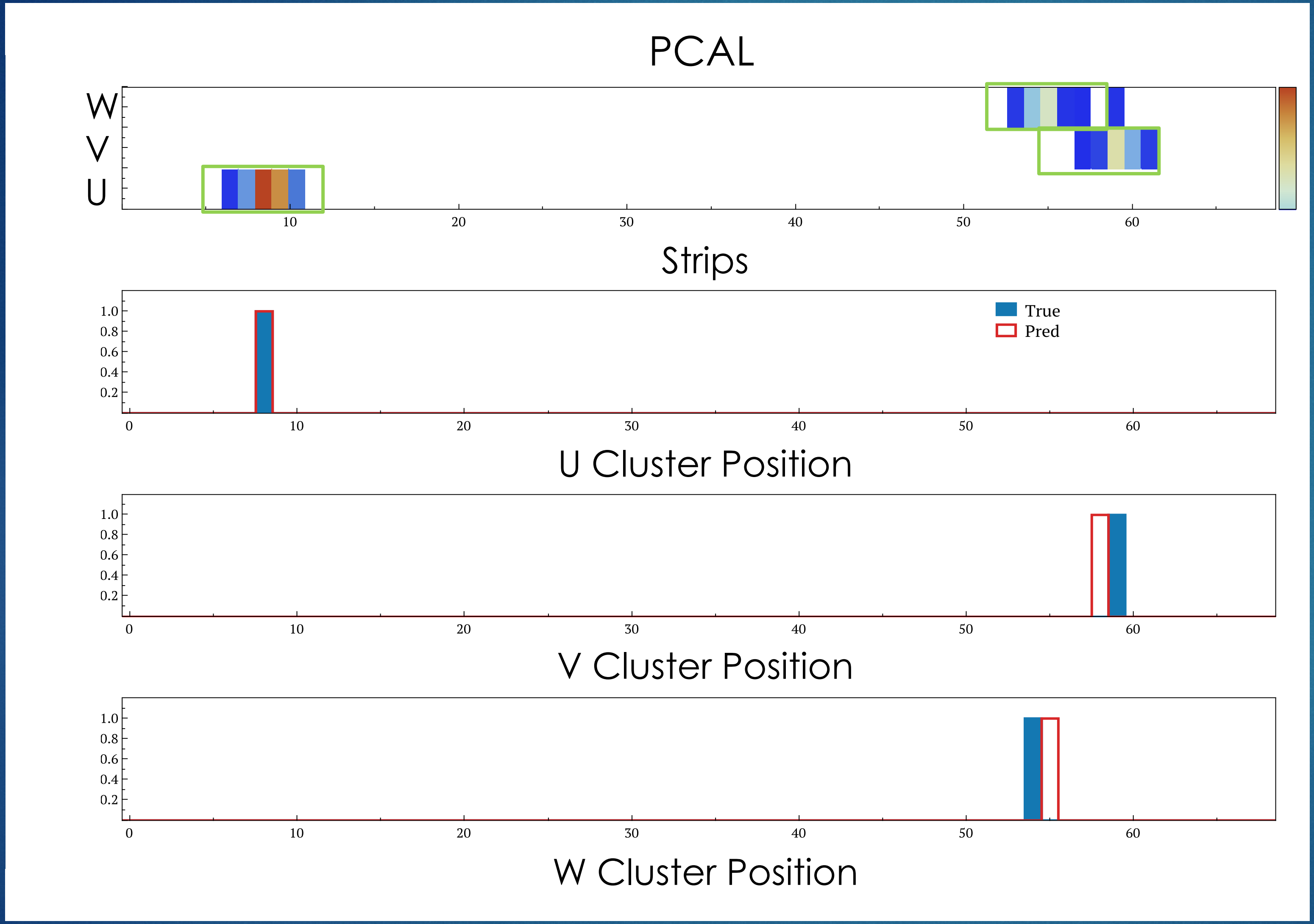
- Several analyses within the collaboration have used machine learning for PID:
  - Electrons & Positrons (see Thursday at 11am!)
  - Neutrons (see Friday morning and here)
  - Photons (see Thursday at 11am!)
  - Muons (see here)
- These rely on reconstructed quantities (eg energy deposition in the calorimeters) for a given reconstructed particle.
- Aim is to reproduce these offline analyses using raw information from ECAL and HTCC, for tracks ID by track finder.

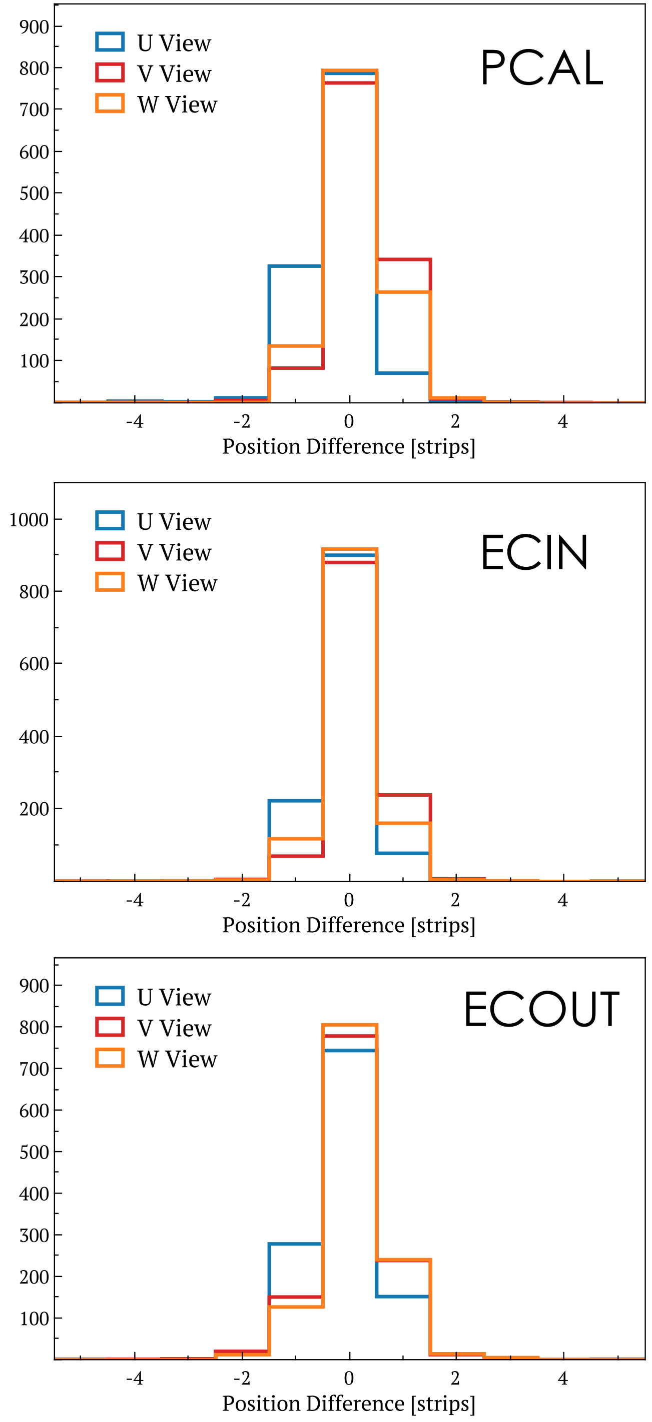


Muon ID



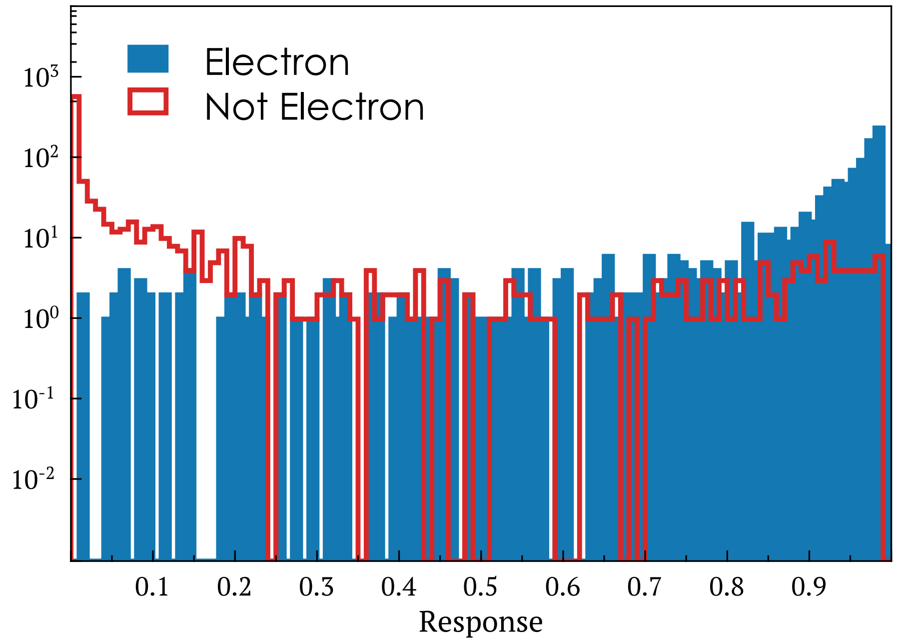
Sum ADCs in strips within +/- 3 of predicted strip.
Record the number of strips with non zero ADC.

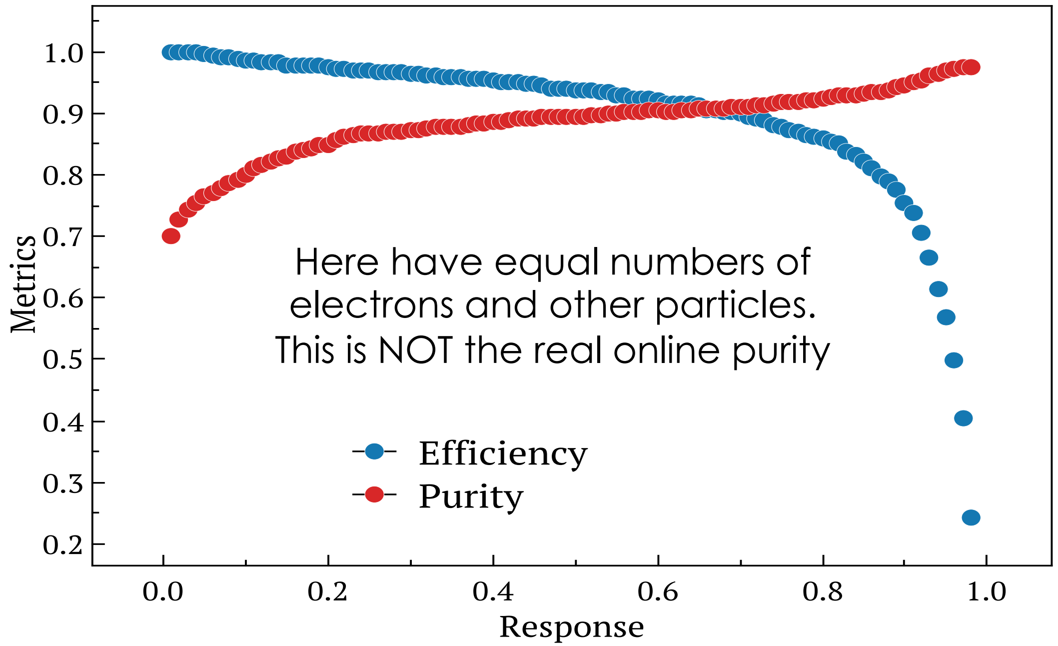




PID Prediction

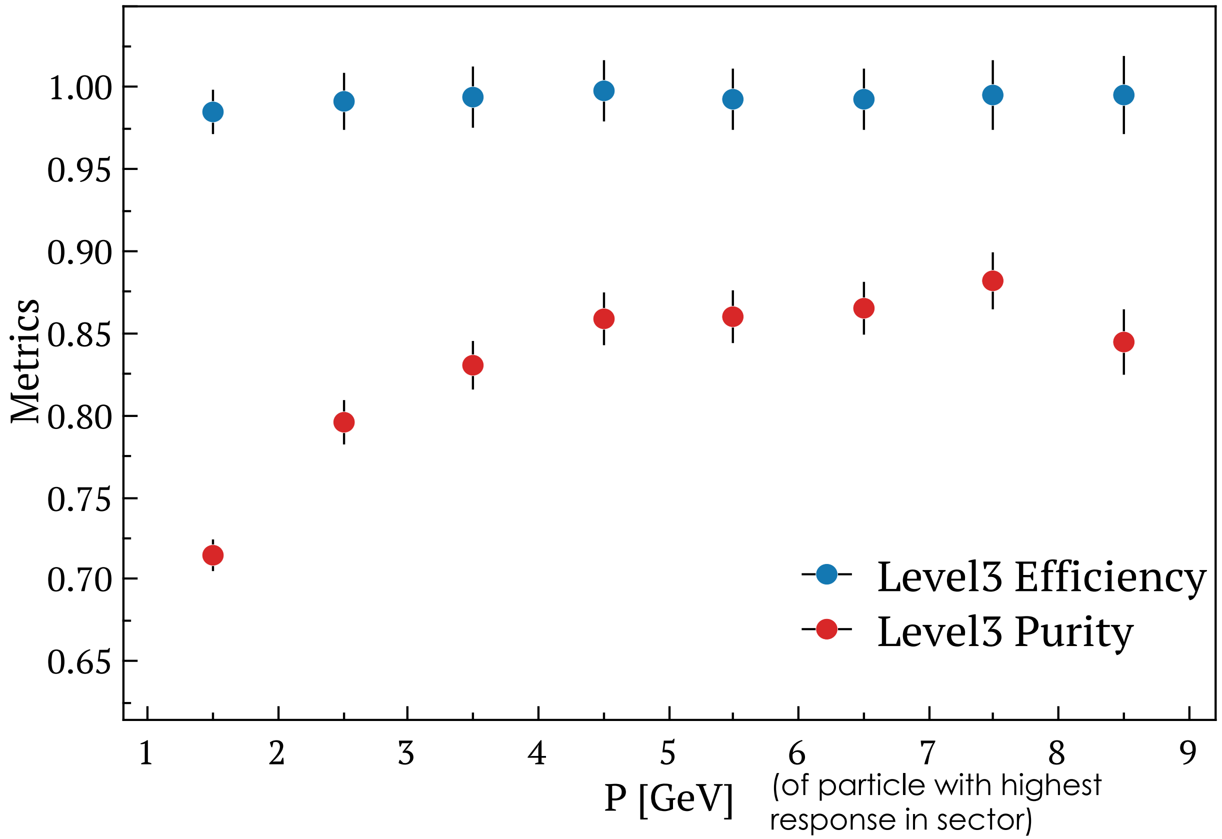
- Variables used for PID:
  - ADC, number of strips and LU/LV/LW in each layer of ECAL from cluster finder
  - Average wire position in each superlayer of DC from track finder
  - ADC in all HTCC PMTs in same sector as track
- Create training sample with particles IDed as electrons in the positive sample, and any other negative particle as the negative sample.
- In the future we'll expand this to multiple classes (eg muons).
- Use a "simple" neural network.





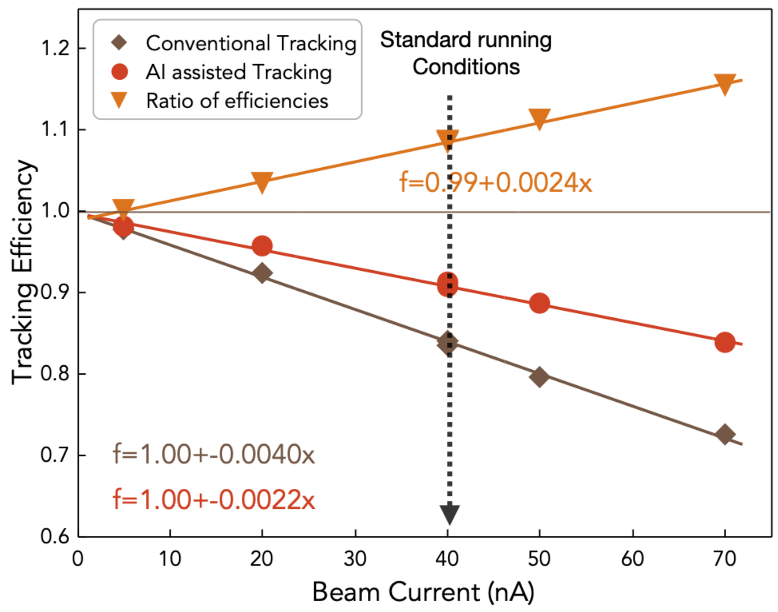
Putting it Together

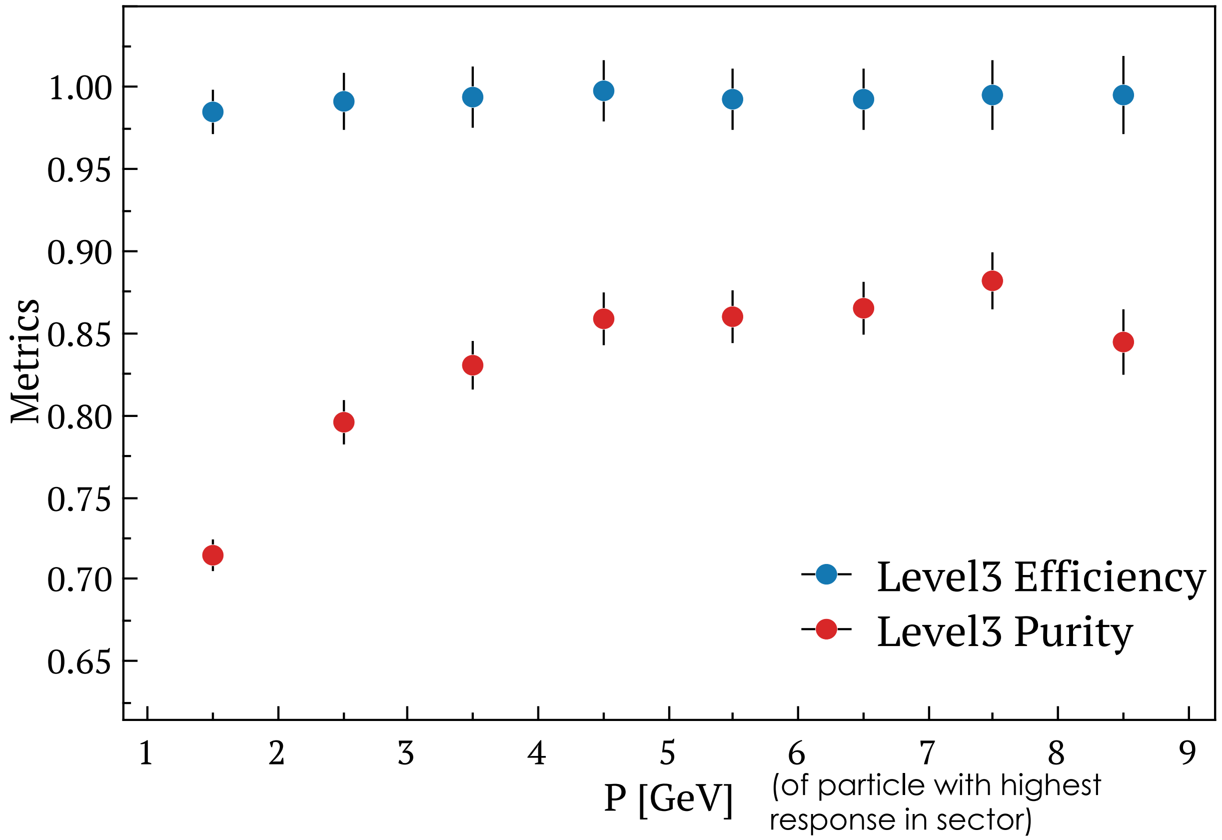
- We now put the entire chain together:
  - Conventional DC clustering (for now)
  - Track finding
  - Track to ECAL cluster finding
  - Electron PID
- Tests were made using RG-D inbending data taken at 100nA, cooked with conventional tracking.
- Level 1 trigger with DC roads on inbending data has purity ~50-60% and 100% efficiency.
- Metrics relative to level 1 trigger **AND** reconstruction + EB PID.



(of particle with highest response in sector)

AI tracking predicts more tracks than conventional, artificially decreases purity.





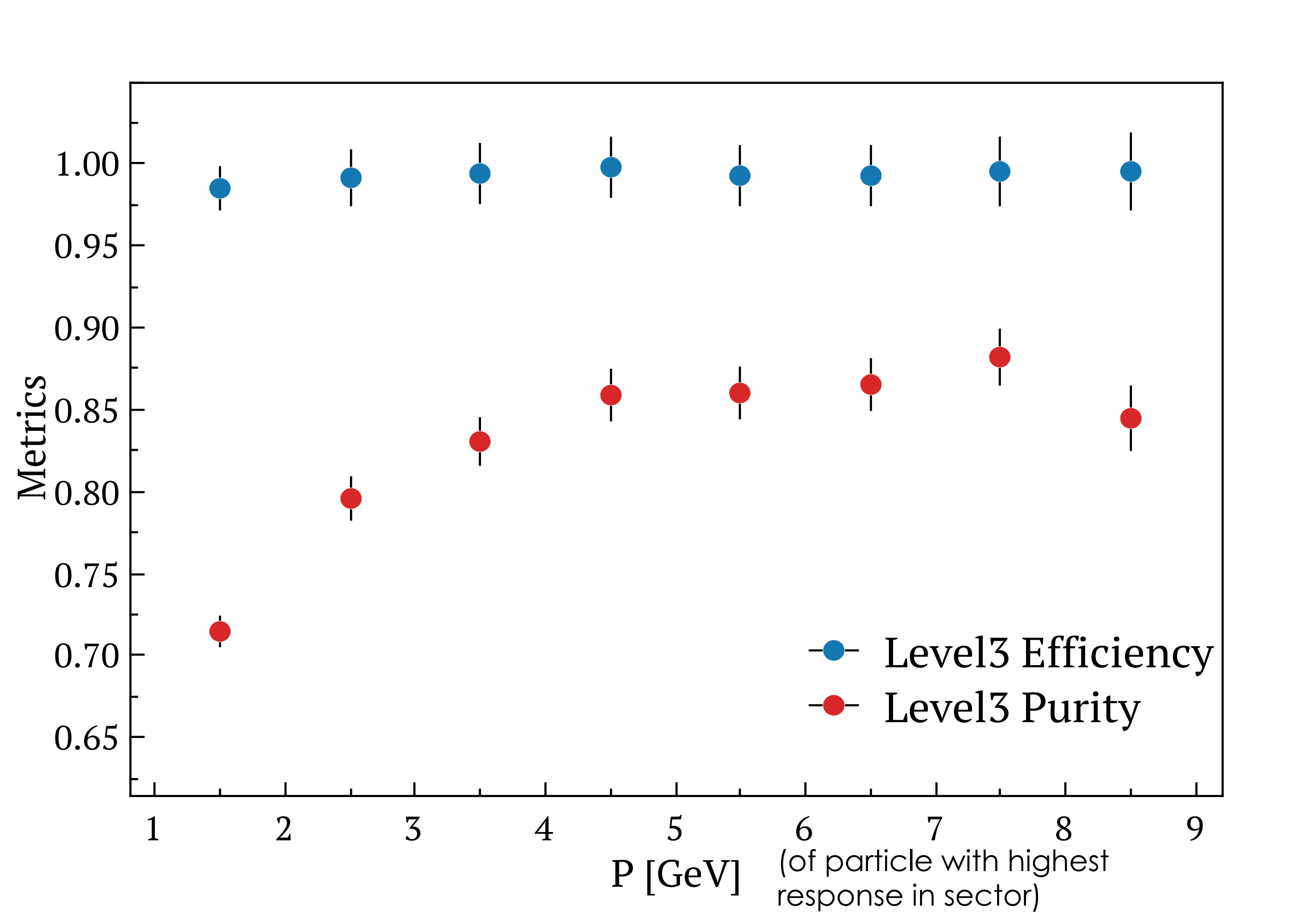
Key Takeaways

Now have ~100% efficient electron ID with purity of at least ~80% that can be deployed online.

The cut on the response can be tuned to attain a higher purity at a cost in efficiency.

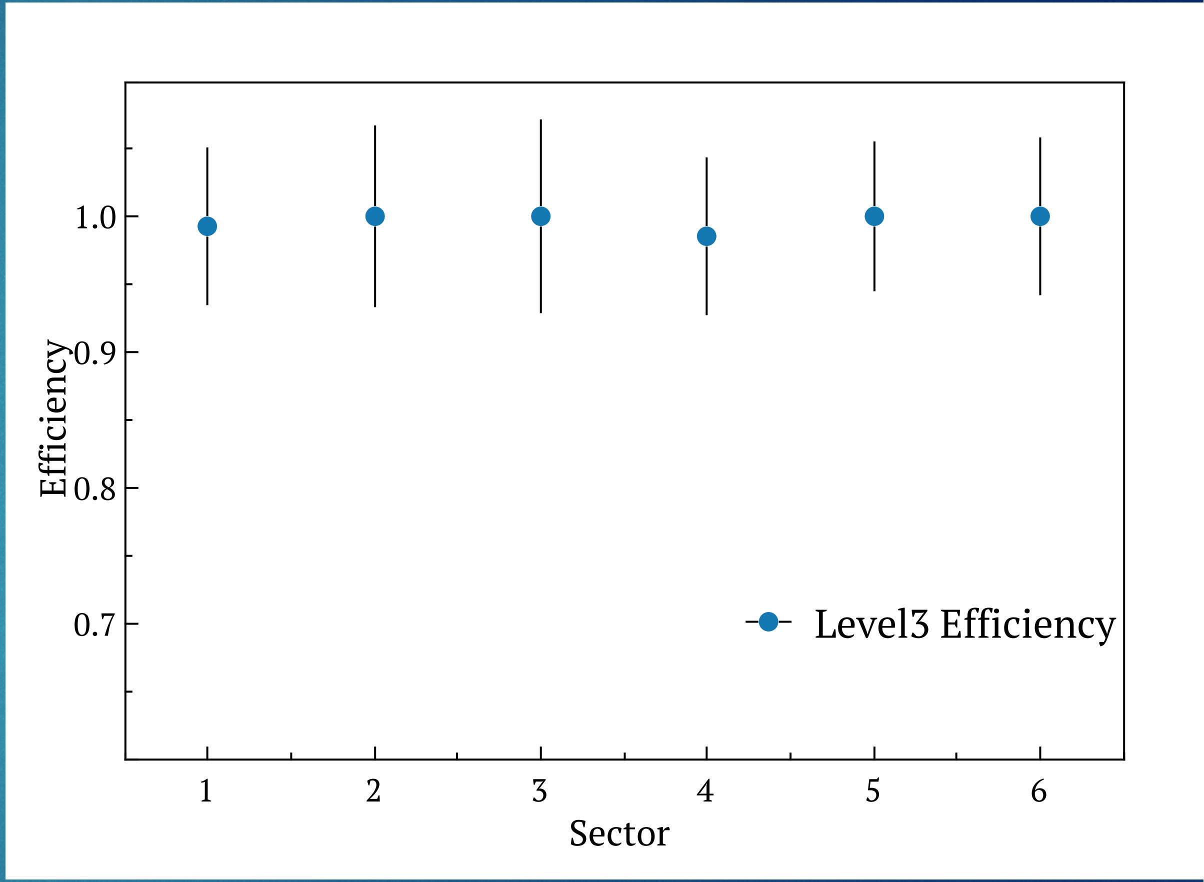
Almost ready to be implemented in online software.

Several potential applications, including triggering.



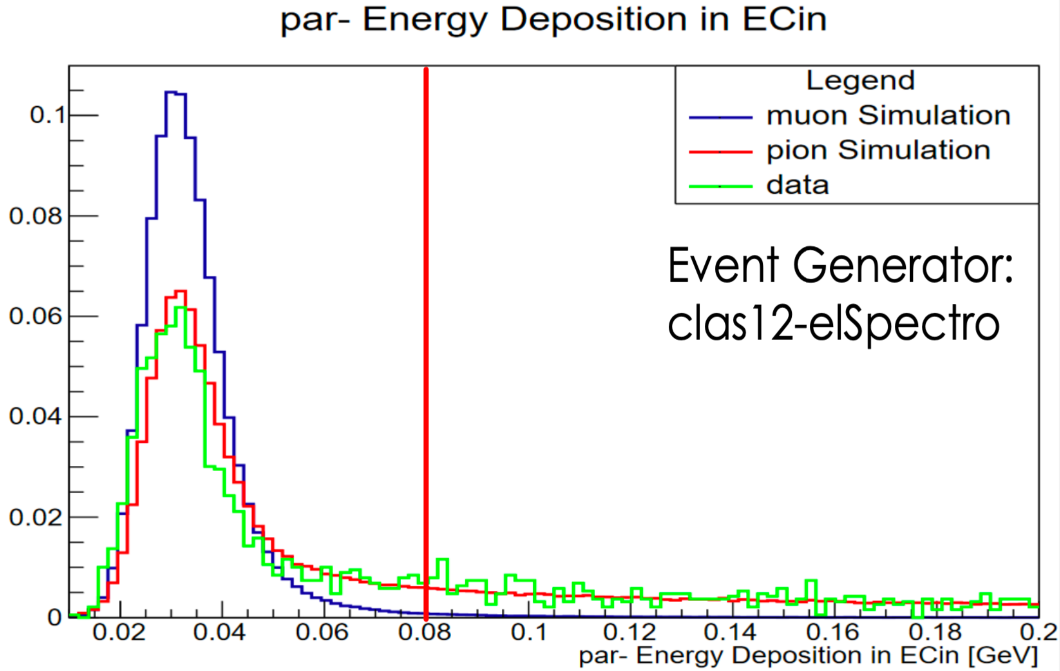
MesonEx Trigger

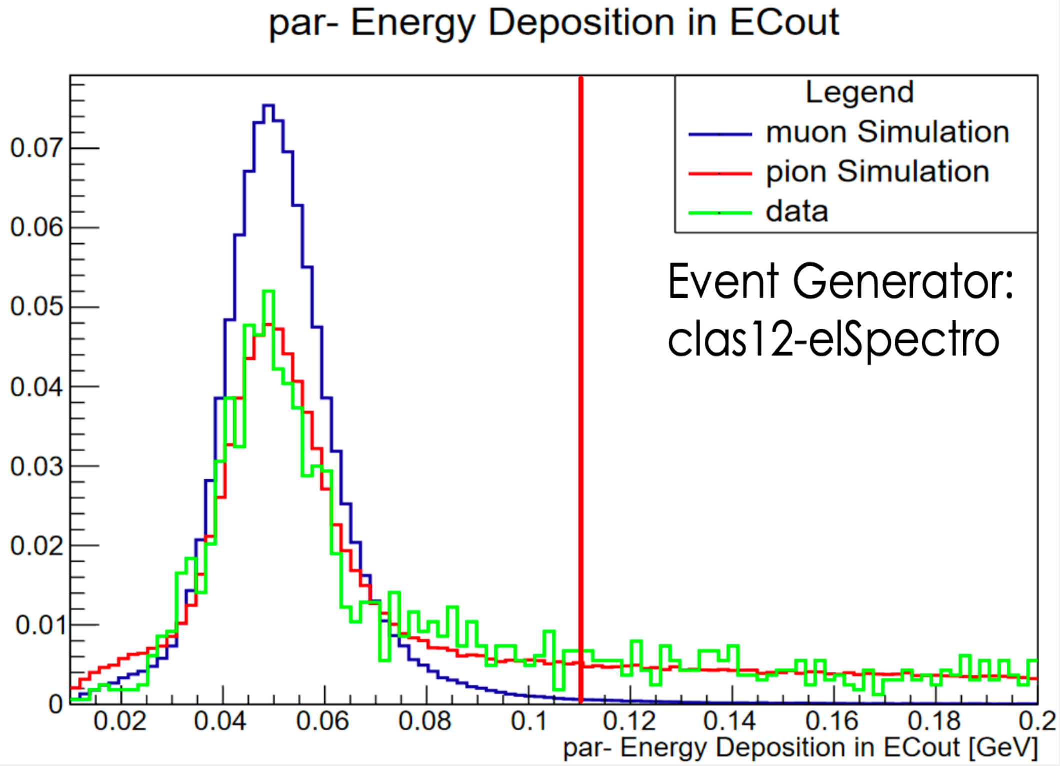
- The photoproduction (MesonEx) trigger requires one electron in the FT coupled to two charged hadrons in the FD.
- One limitation of the MesonEx trigger is that it cannot select events with two charged hadrons in the same sector.
- Online PID can be used by requiring:
  - Low electron PID response for negatively charged particles
- For reconstructed hadrons, require:
  - PID != |11|
  - Track χ^2 < 350 & 6 superlayers
  - $|V_z|$ < 20 cm
- Calculate efficiency based on events with two hadrons in same sector in reconstruction and as predicted by online PID.
- Purity not plotted here as it is meaningless given efficiency gain from AI tracking.



Other particle types

- Muons are in the conventional trigger. However, muons are typically hard to ID at CLAS12.
- This means it would be hard to create a good training sample. We could have a MIP trigger instead.
- To identify hadrons we need time of flight information. A possibility is using relative times between particles and with RF time.
- Lots to do and think about to expand online PID to other particle types!





Conclusion

- Developed online electron PID. This is beneficial for:
  - Improved triggering
  - Improved online analysis
  - Online preselection
- Next steps:
  - Refining metrics
  - Muon & hadron PID
  - Develop online clustering