Online Electron Reconstruction at CLAS12

RICHARD TYSON

GAGIK GAVALIAN

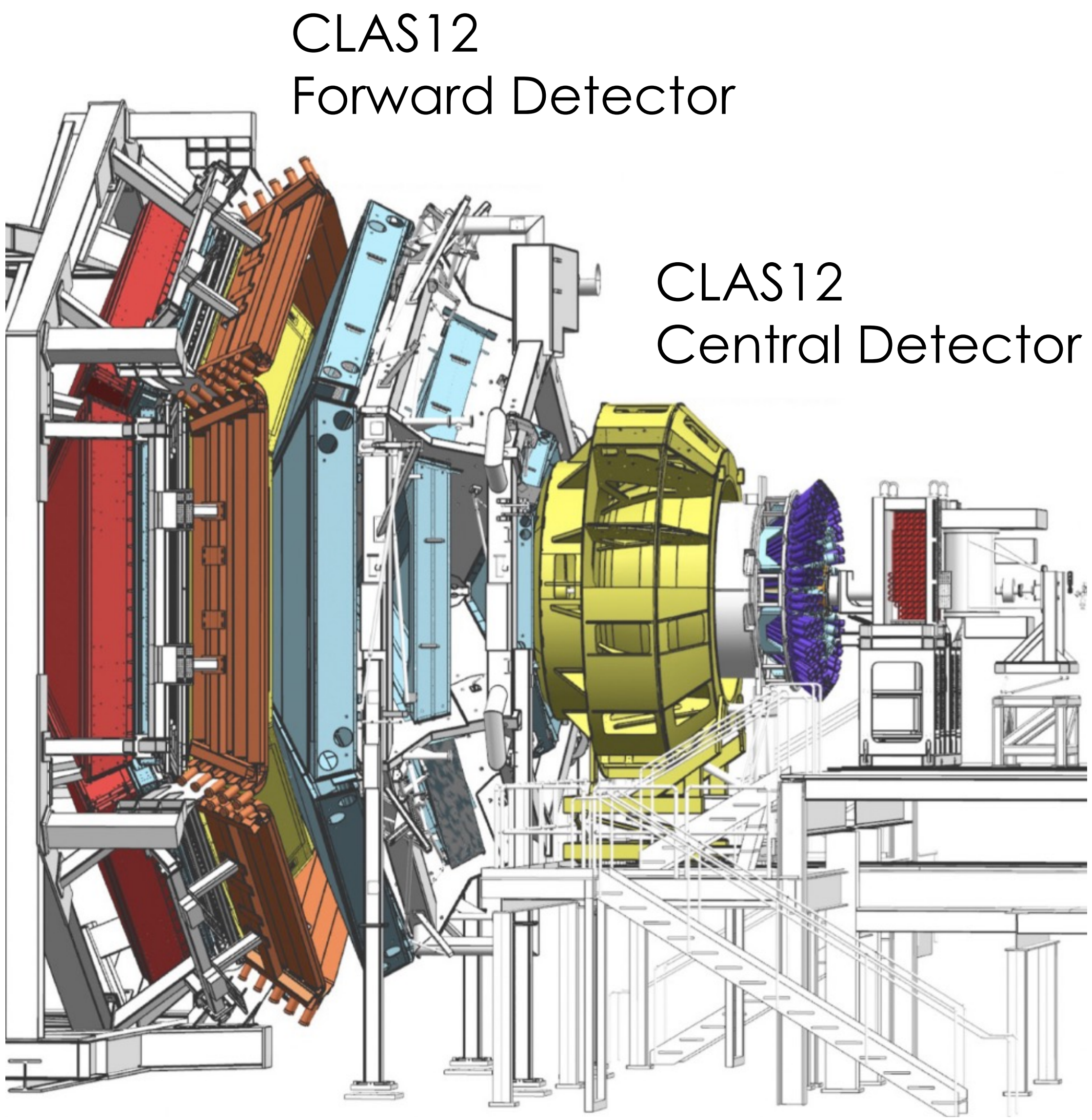
Jefferson Lab
Thomas Jefferson National Accelerator Facility

JLab

- The Thomas Jefferson National Accelerator Facility (JLab) is located in Newport News, Virginia.
- The Continuous Electron Beam Accelerator Facility (CEBAF) produces a 12 GeV electron beam.
- The CEBAF Large Acceptance Spectrometer (CLAS12) is located in Hall B.

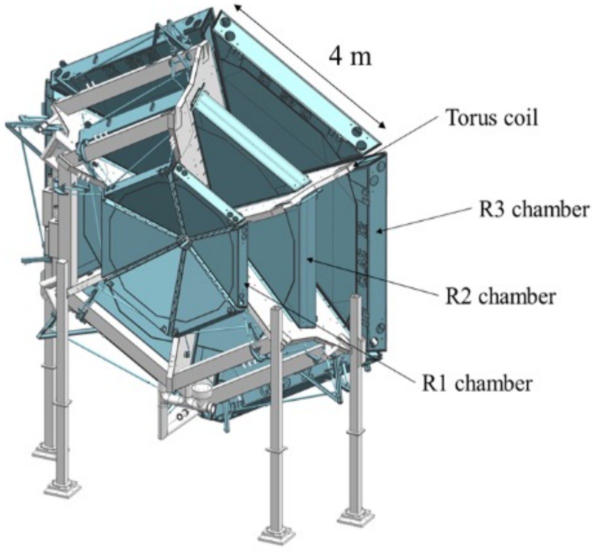
The CLAS12 Detector

- Large acceptance spectrometer with >100k readout channels.
- An electron trigger is used to flag events relevant to the CLAS12 experimental program.
- In 2018:
  - 500 MB/s data rate (after trigger)
  - 95% livetime
  - 2pB of recorded data
- This talk is mostly concerned with the Forward Detector where electrons are detected.



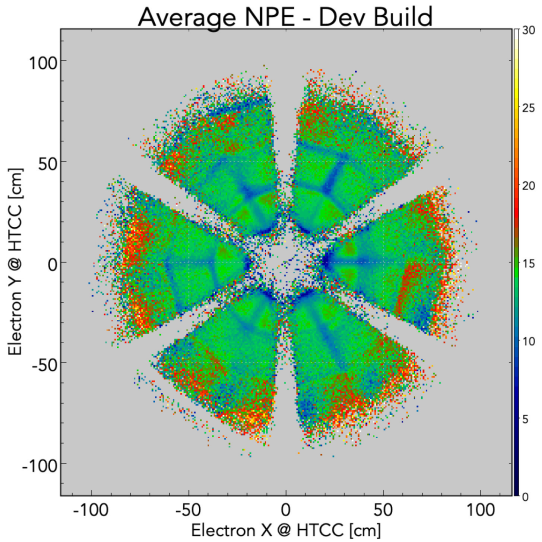
Electron ID

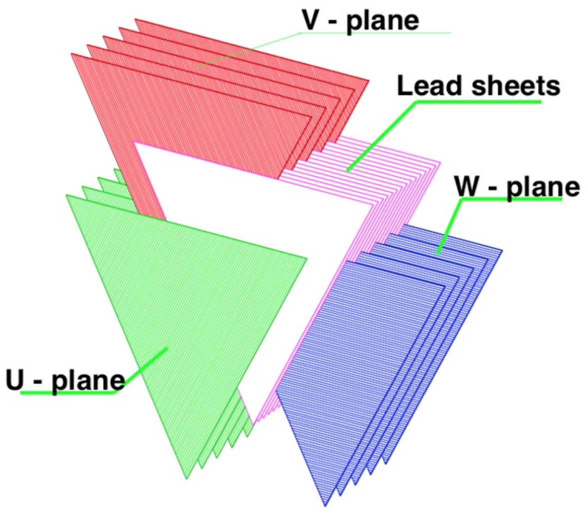
- The CLAS12 Forward Detector is composed of 6 sectors.
- The DC is composed of 6 superlayers in 3 regions with 6 layers and 112 wires per layer in each sector.
- The ECAL (PCAL/Ecin/ECout) has three layers with three views (U/V/W).
- The HTCC has 8 mirrors in each sector. Veto detector, should only fire for electrons.
- Electrons ID in the Forward Detector:
  - One track in the DC matched to
  - Cluster in ECAL with high energy deposition
  - Cluster in the HTCC.



Drift Chambers (DC)

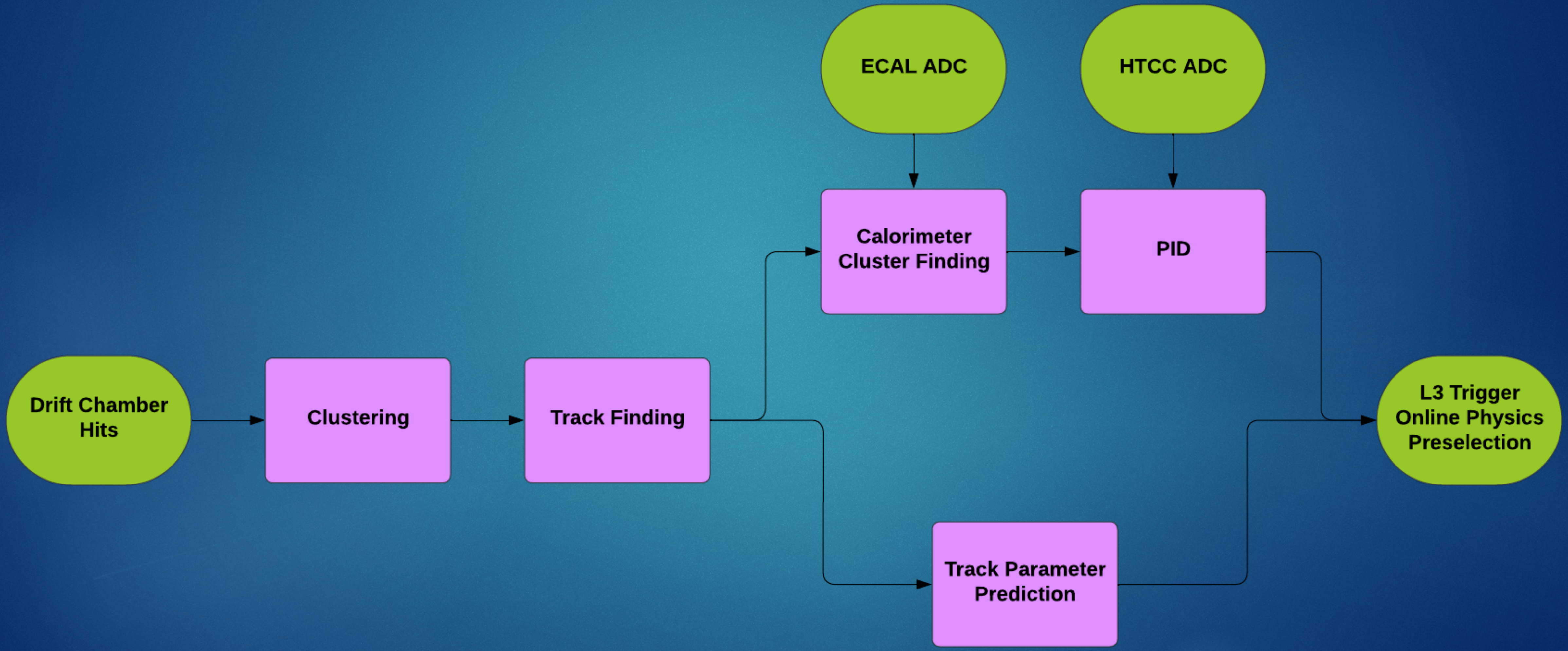
High Threshold Cherenkov Counter (HTCC)



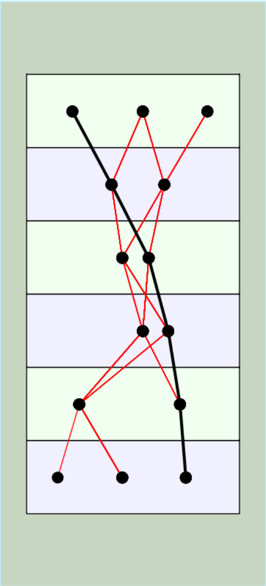


Electromagnetic Calorimeters (ECAL)

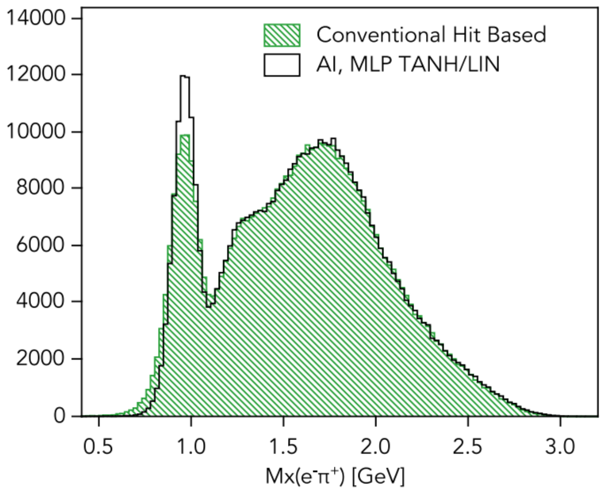
Online Reconstruction



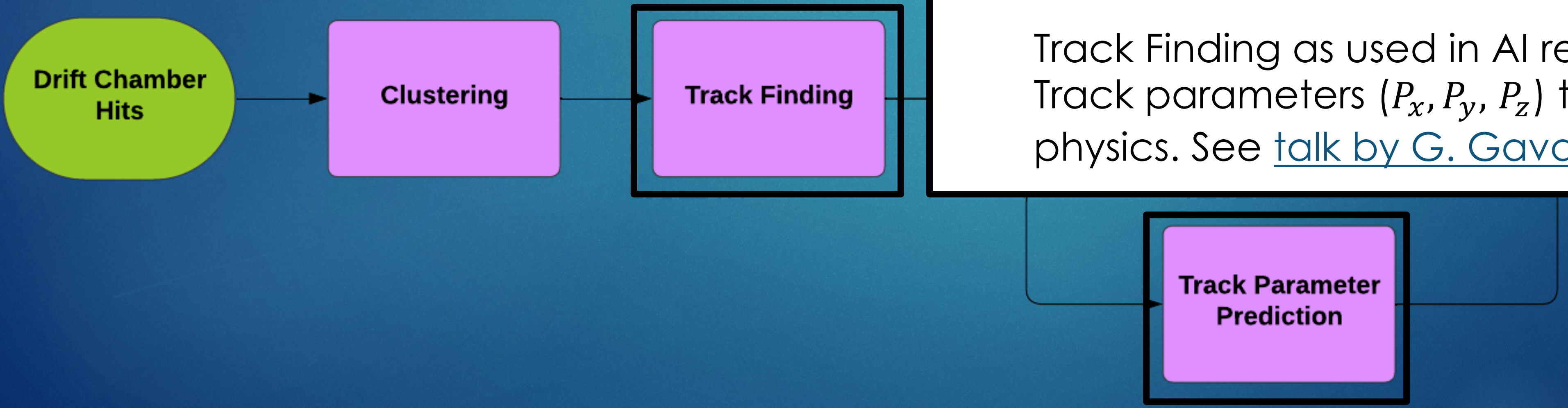
Online Reconstruction



$$ep \rightarrow e^{-} n \pi^{+}$$



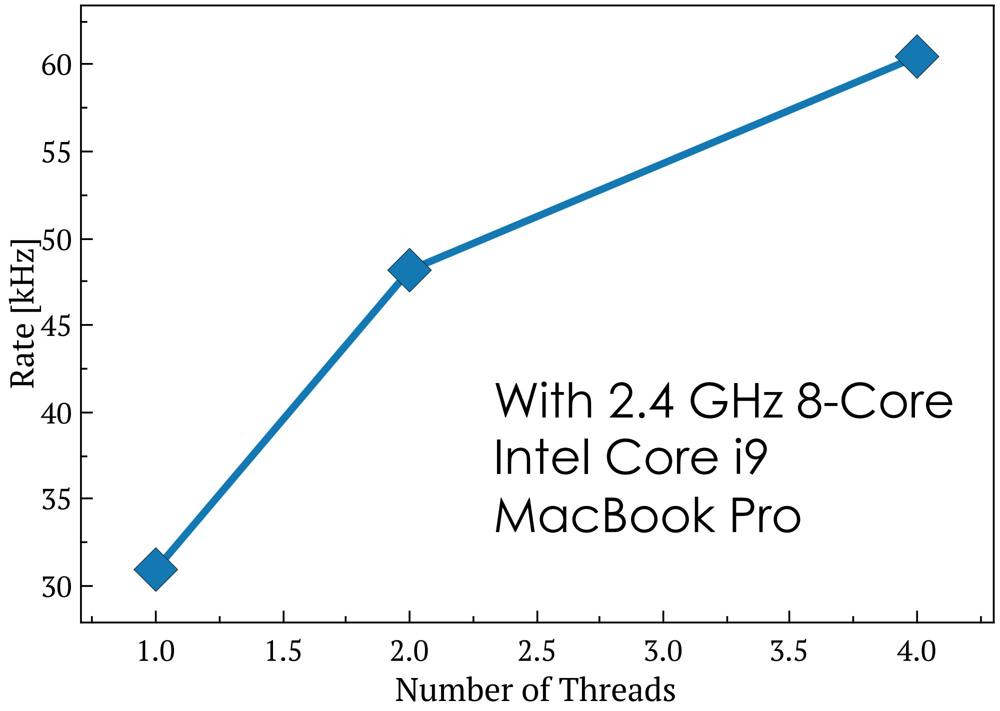
Track Finding as used in AI reconstruction. Track parameters (P_x, P_y, P_z) then used for physics. See talk by G. Gavalian.

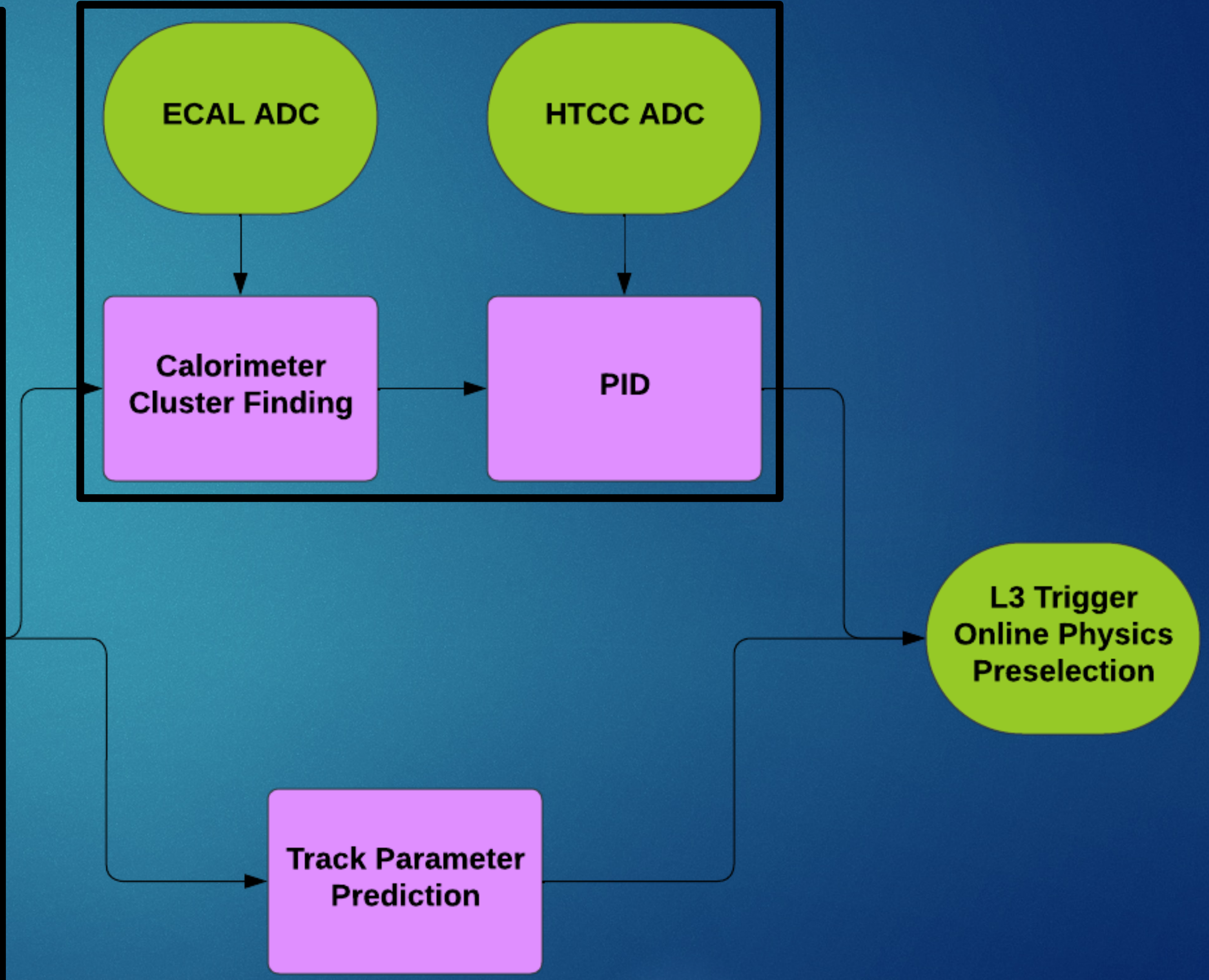


Online Reconstruction

Subject of this talk.

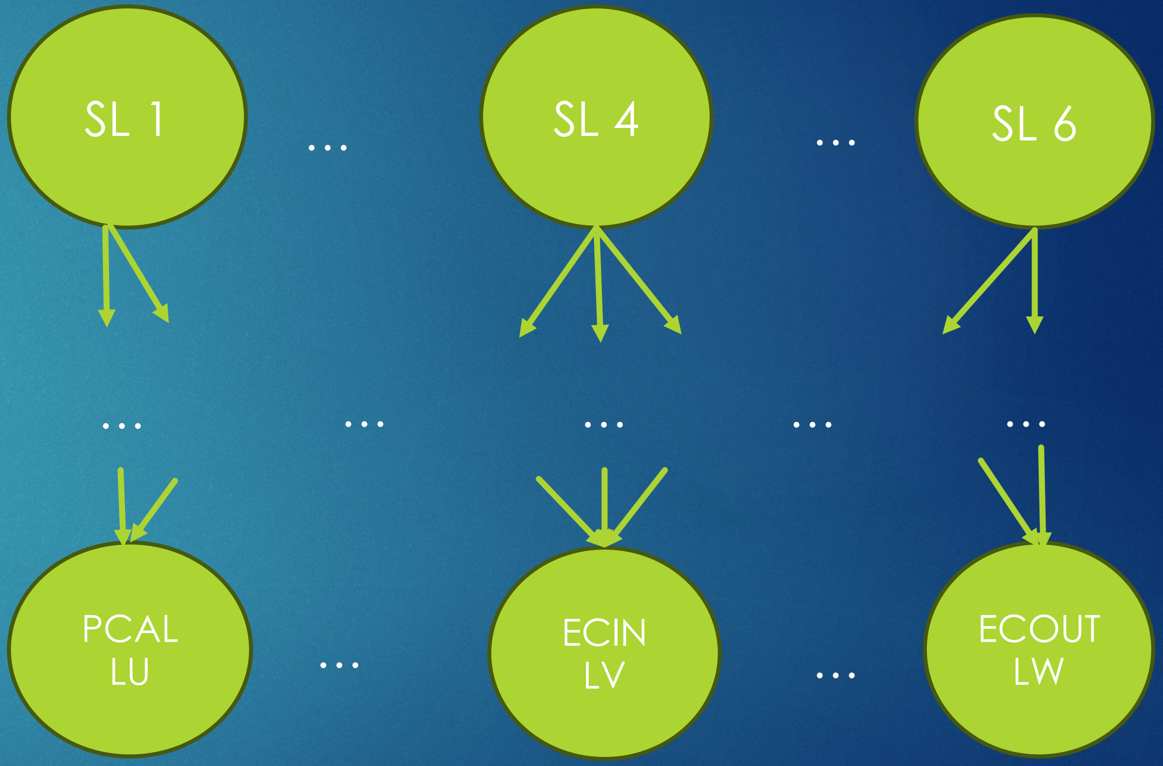
Aim is to combine tracking information to ECAL and HTCC to ID electrons

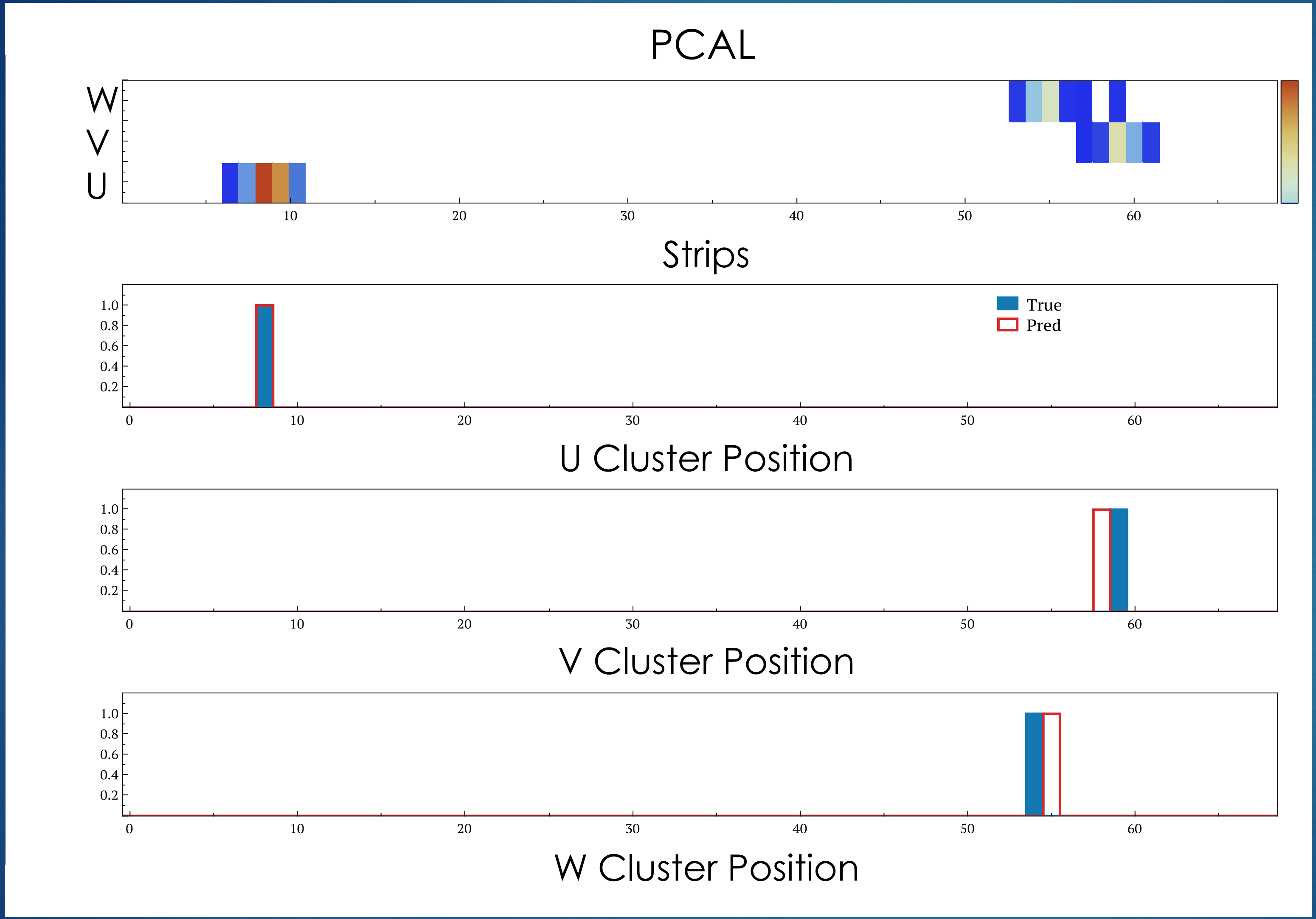


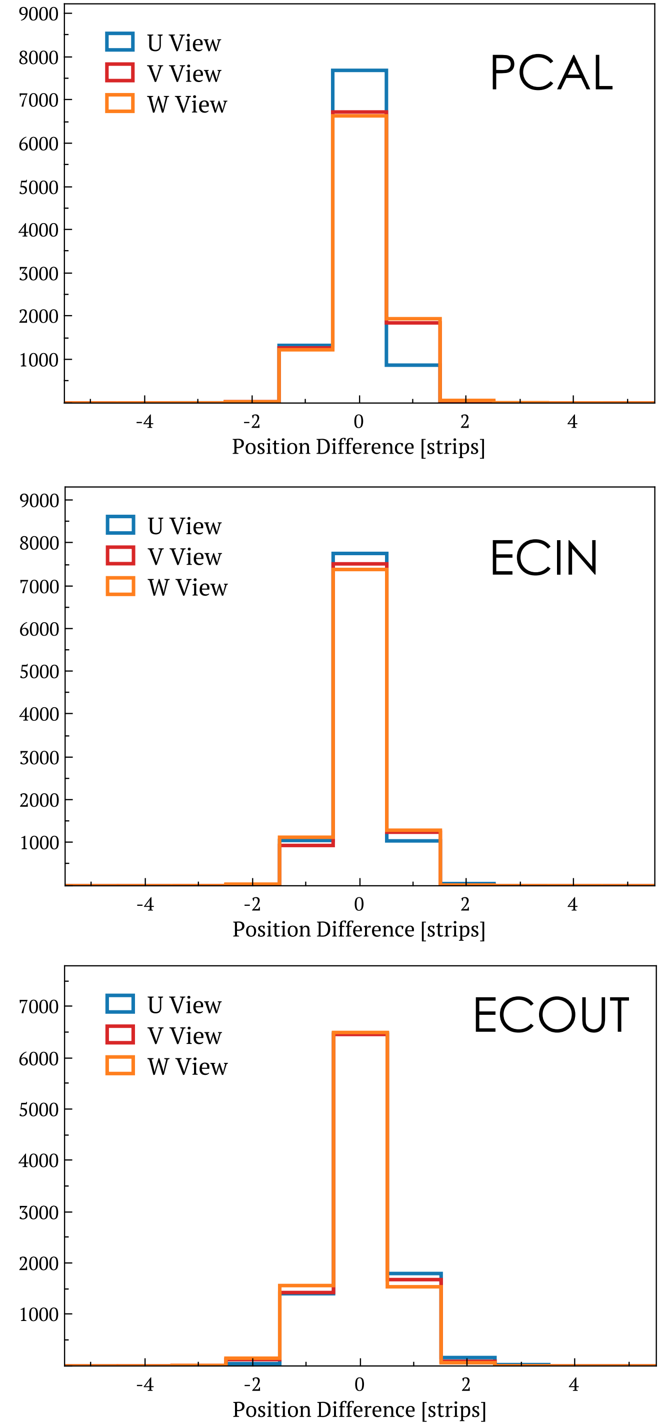


Track to ECAL Prediction

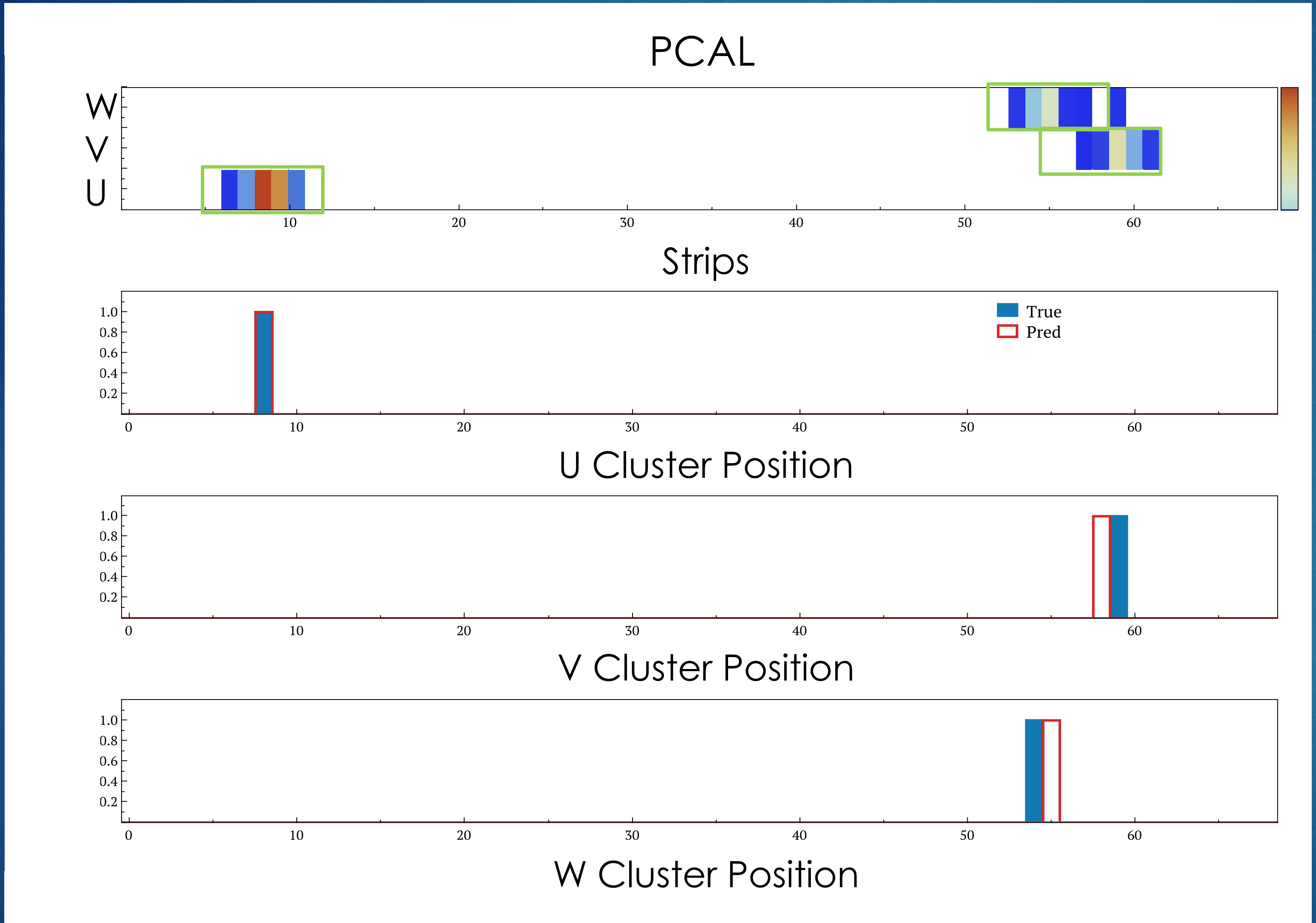
- Given a track, we can predict the position of an ECAL cluster.
- Input is average wire in each DC superlayer from track finding.
- Output is LU/LV/LW in each of PCAL/ECIN/ECOUT. Convert this to strips.

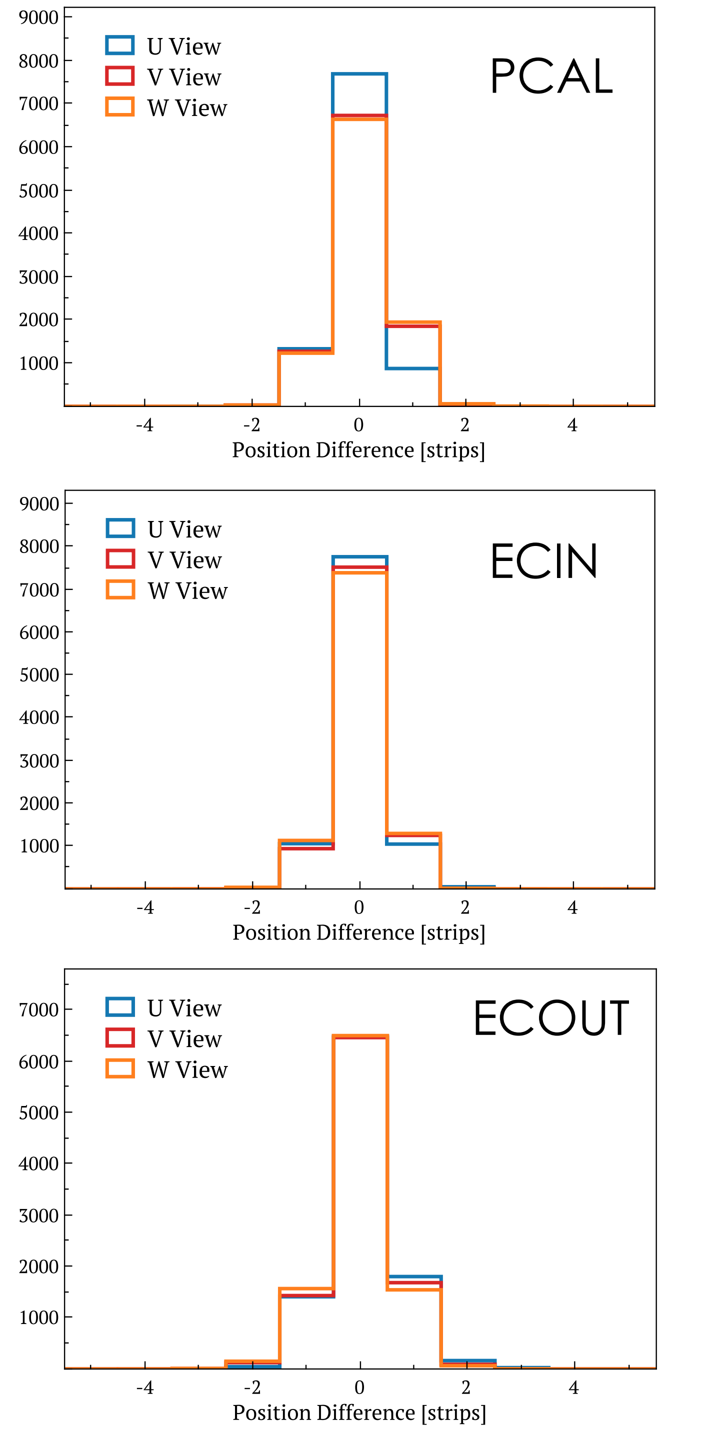



PCAL
W
V
U
Strips
True
Pred
U Cluster Position
V Cluster Position
W Cluster Position


U View
V View
W View
PCAL
Position Difference [strips]
U View
V View
W View
ECIN
Position Difference [strips]
U View
V View
W View
ECOUT
Position Difference [strips]

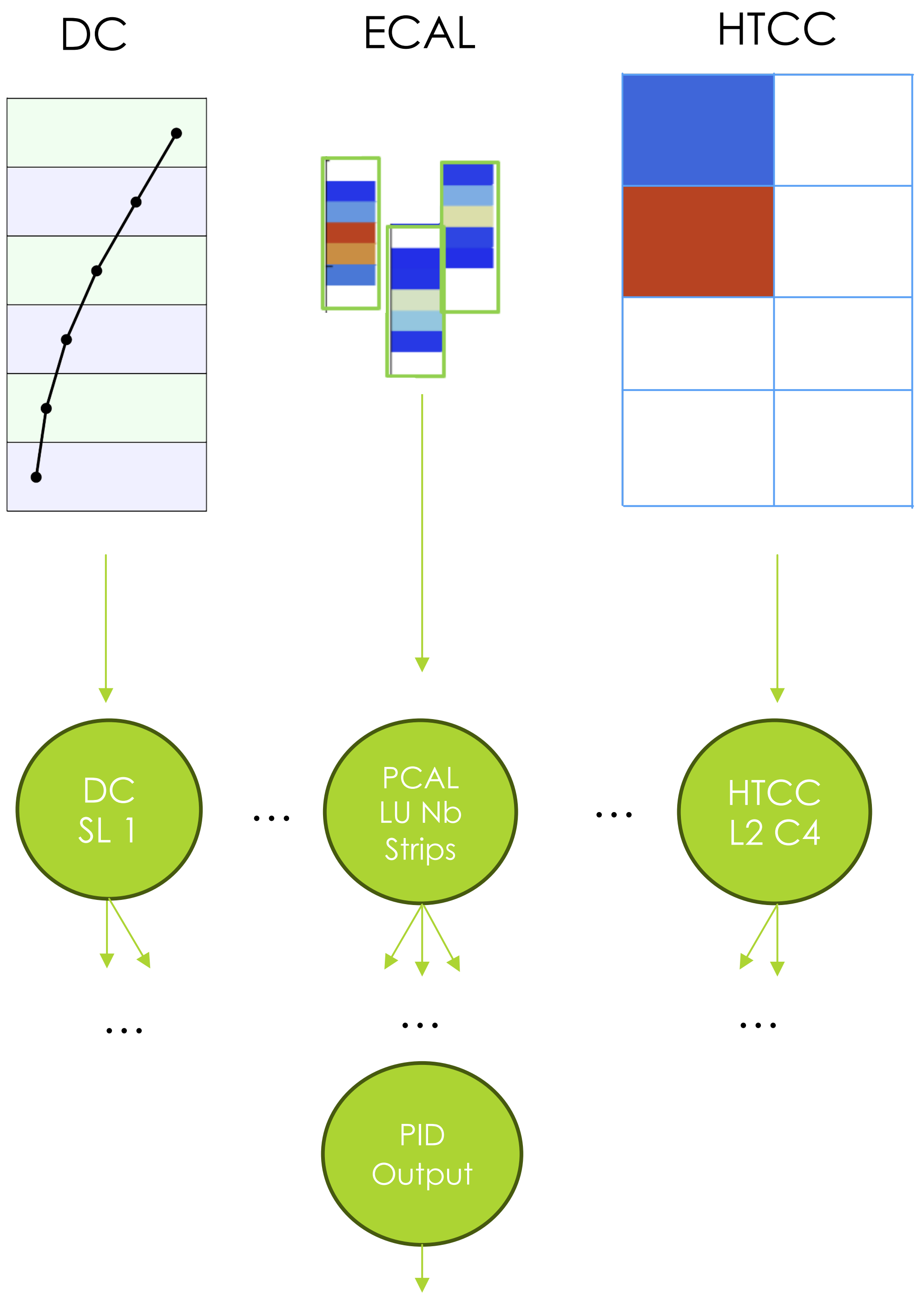
Sum ADCs in strips within +/- 3 of predicted strip.
Record the number of strips with non zero ADC.





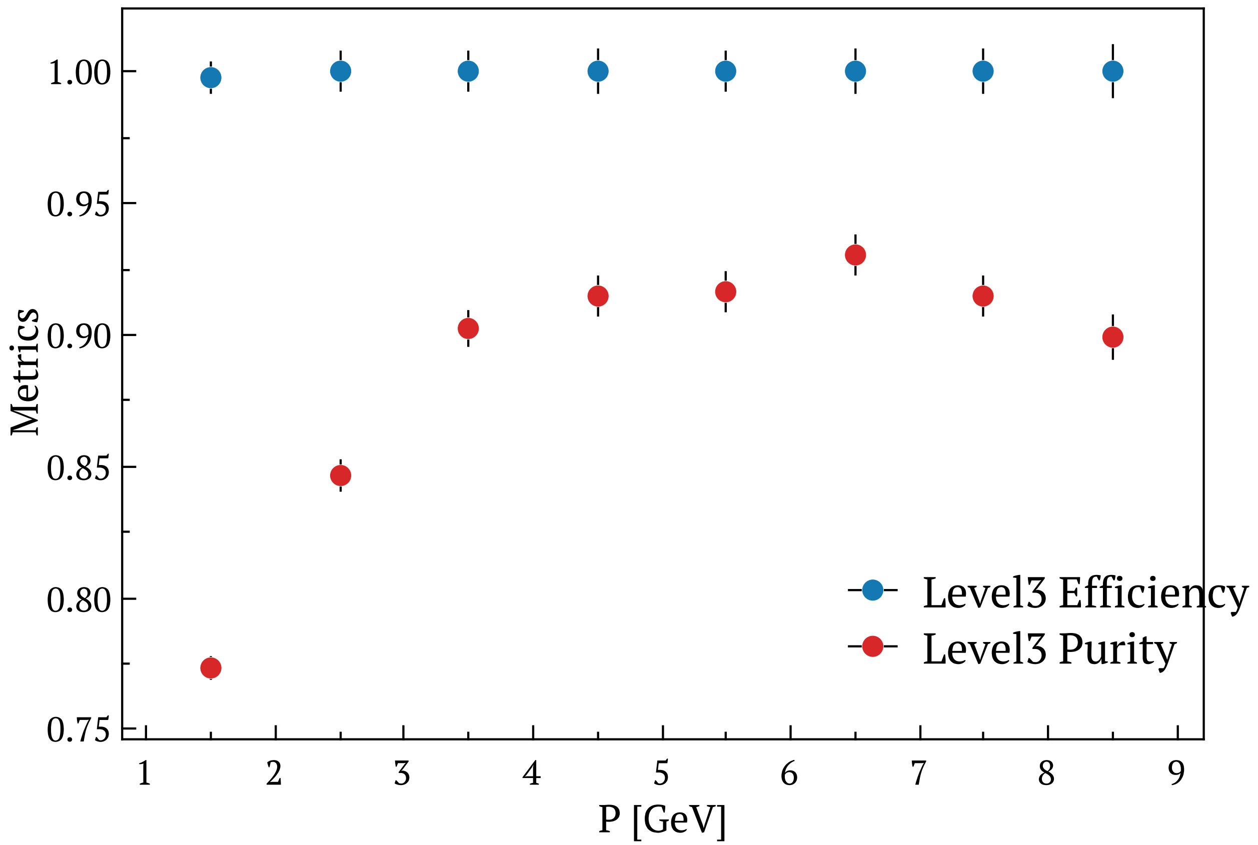
Adding HTCC Information

- The HTCC has 8 PMTs in each sector.
- This is sufficiently few numbers to pass directly to a network responsible for identifying electrons.
- We add the track average wire position in each layer.
- This allows to correlate the direction of the track to the position of hits in the HTCC.
- The network is then able to ID tracks as electrons or not in the same sector as a hit in the HTCC.



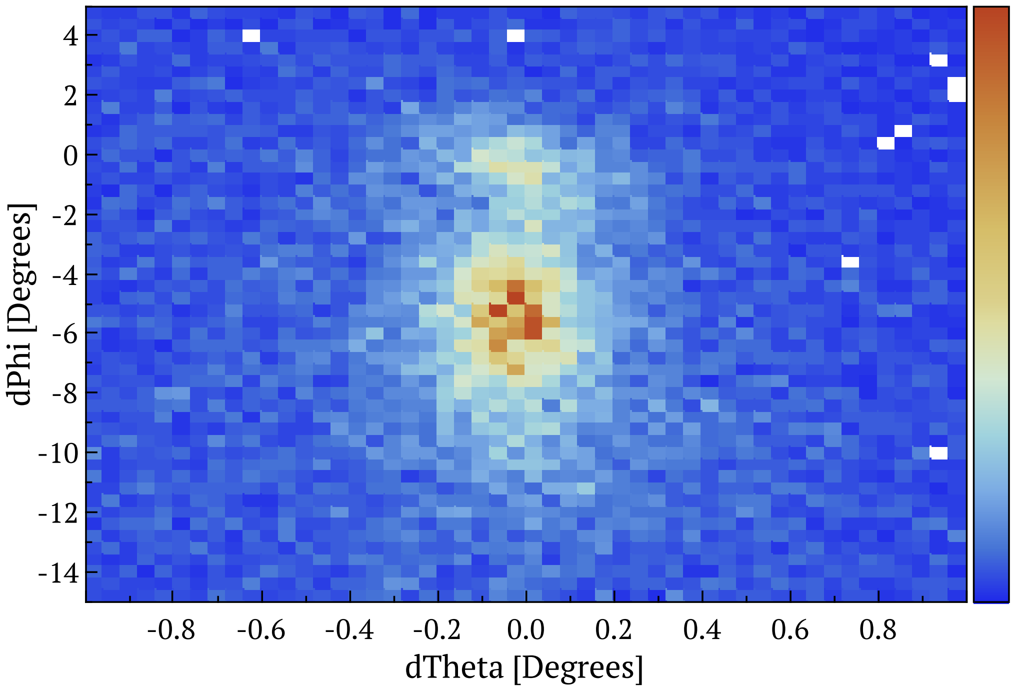
Putting it Together

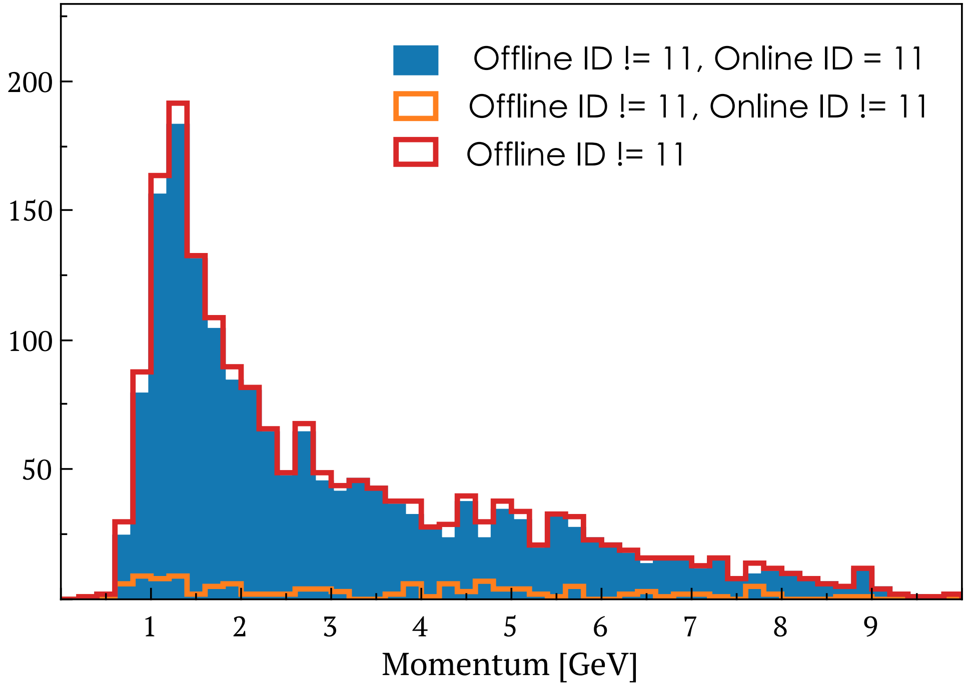
- We now put the entire chain together:
  - Conventional DC clustering (for now)
  - Track finding
  - Track to ECAL cluster finding
  - Electron PID
- Use true online rate of negative particles and proportion of non electrons to electrons.
- Only consider tracks that appear online and offline – impurity reported here is only due to electron ID.



Low momentum?

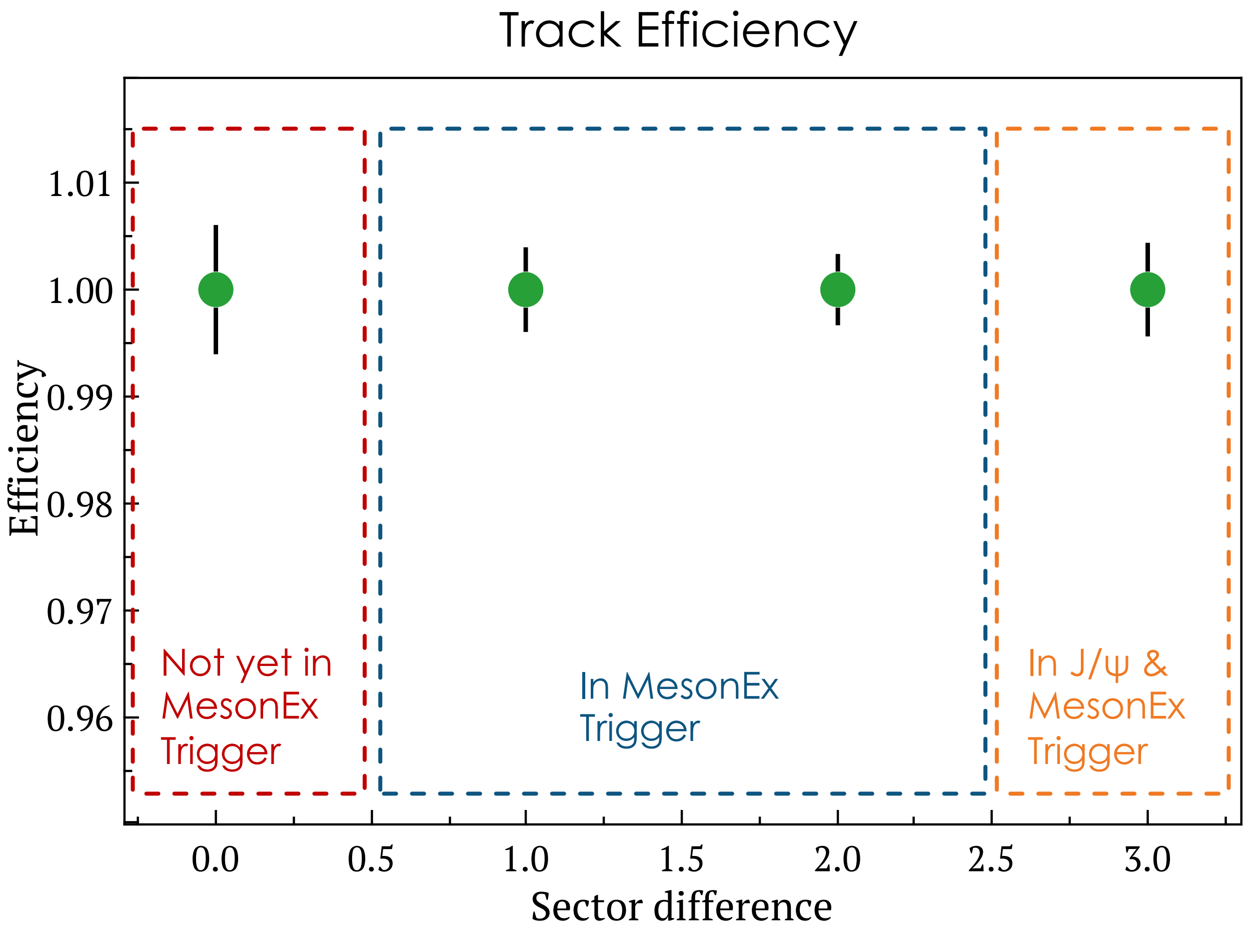
- Calculate metrics relative to offline electron PID, misses electrons at low momentum.
- Good way to identify true electrons is by looking at negative tracks in small angular distance from photons.
- Signature of photons radiated by electrons passing through material between target and detector.
- Online PID recovers most electrons missed by offline PID – artificially decrease purity at low momentum.





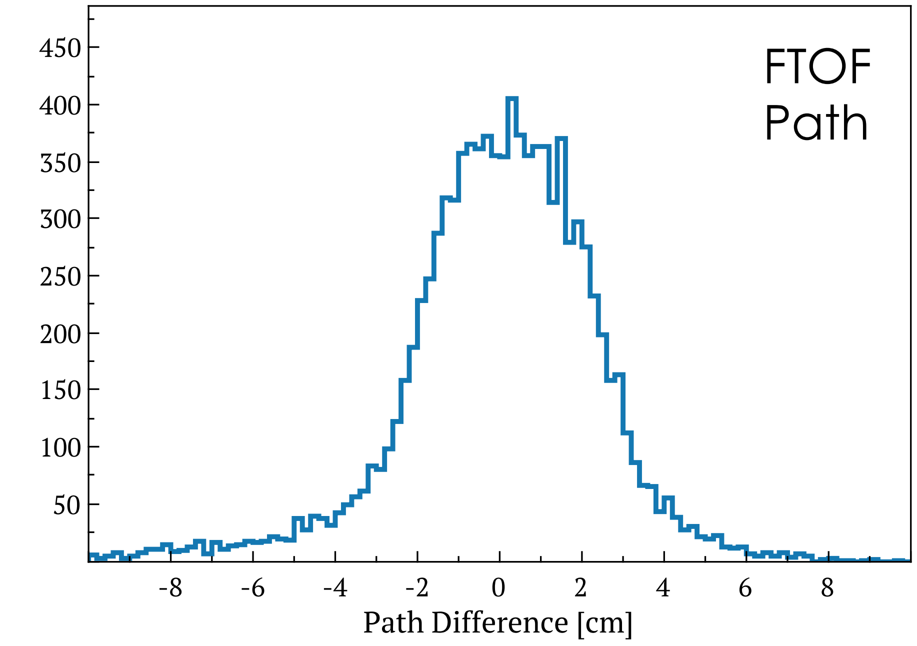
Triggering on Hadrons

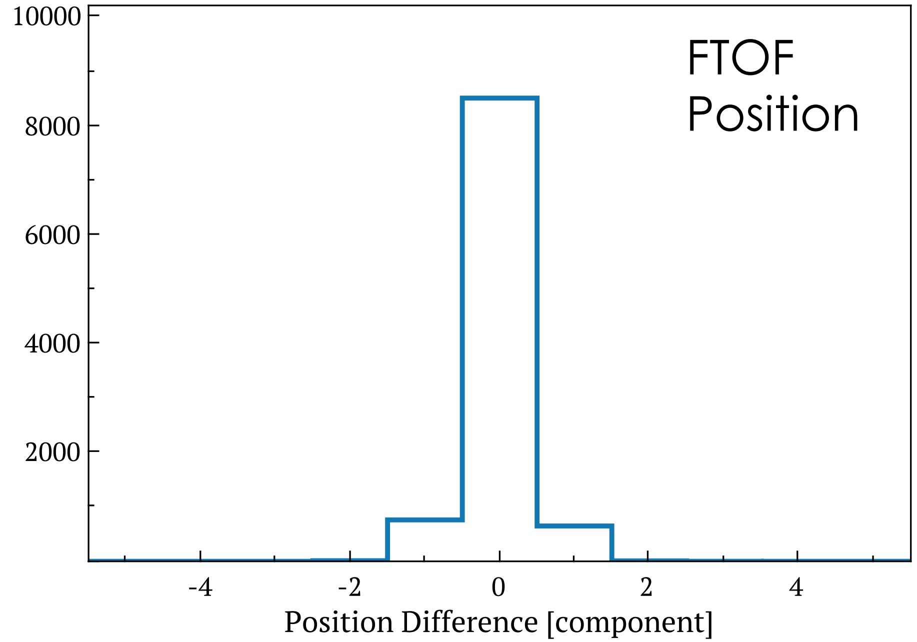
- CLAS12 Trigger system also triggers on hadron tracks:
  - "MesonEx" trigger – two hadron tracks
  - "J/ψ" trigger – mips in opposite sectors
- MesonEx trigger limited as it cannot identify events with two tracks in the same sector.
- Hadrons can be identified online as non electrons (ie high response).
- Efficiency calculated for events where offline has two hadrons at given sector difference.
- Take ratio of the subset of these events where online also has two hadrons at same sector difference.



Other particle types

- To identify hadrons we need time of flight information from the Forward Time of Flight detector (FTOF).
- Given a track we can predict path and position of clusters in FTOF.
- We can then use our electron PID to get a start time for the event, and calculate β for hadron identification.



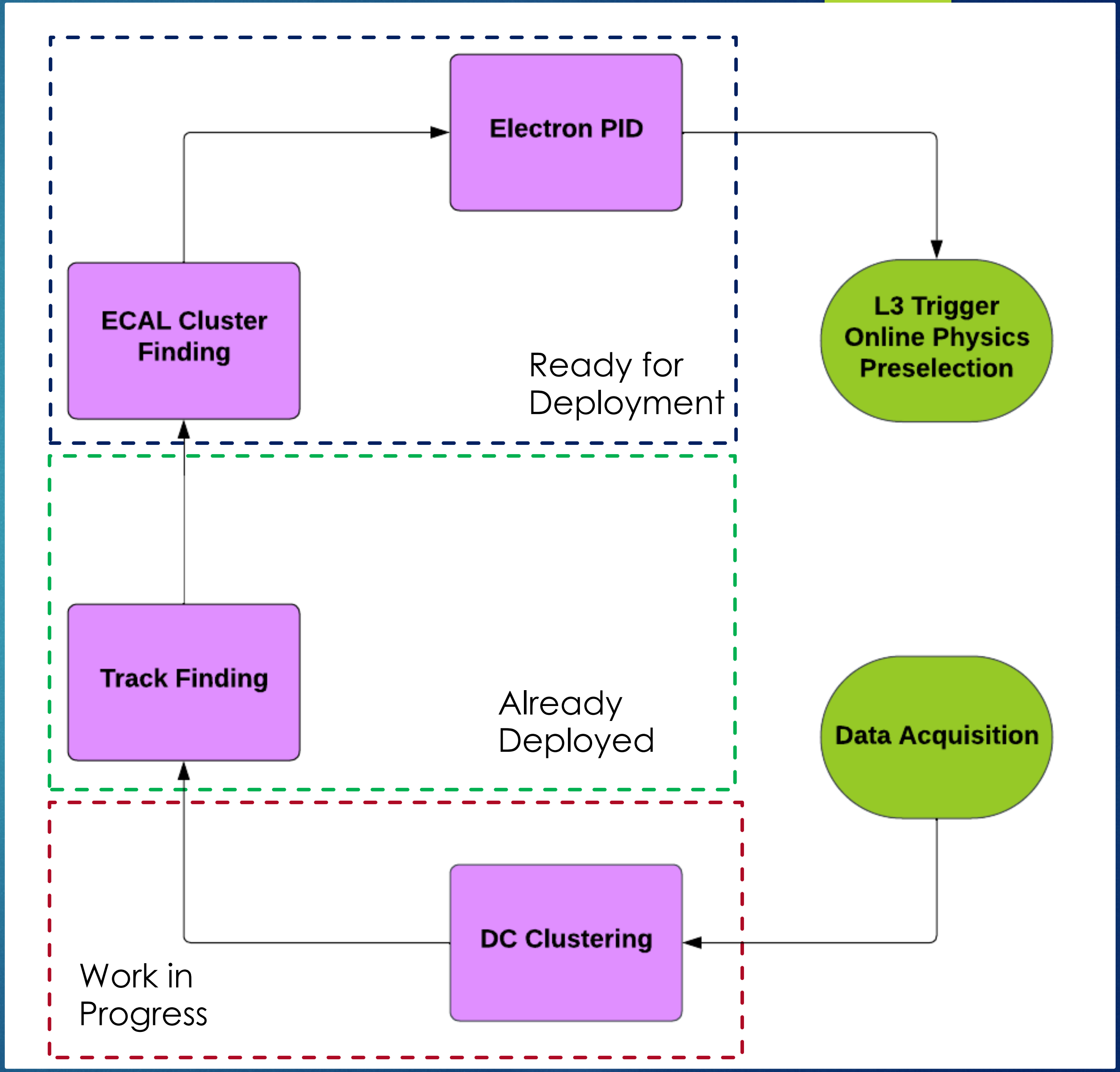


Conclusion

- Developed online electron PID. This is beneficial for:
  - Improved triggering
  - Improved online analysis
  - Online preselection

- Electron PID is 100% efficient with high purity.

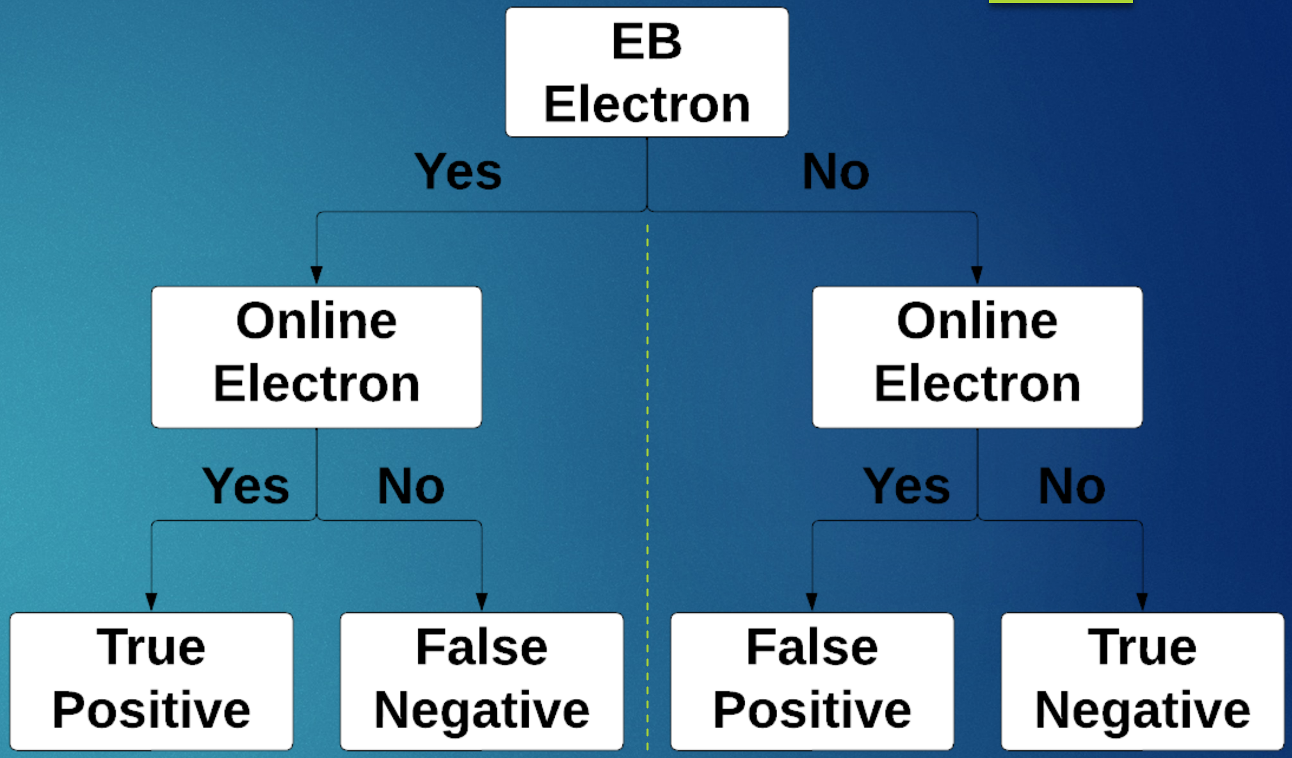
In 1M Hipo Events	Inbending (RG-D 18326)	Outbending (RG-D 18777)
Number of events with L1 trigger bit (DC roads)	400 592	944 204
Number of events with online e^-	166 324	743 651
Ratio	0.42	0.79
Data Reduction (1- Ratio)	58 %	21 %



Backup Slide

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



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

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

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.