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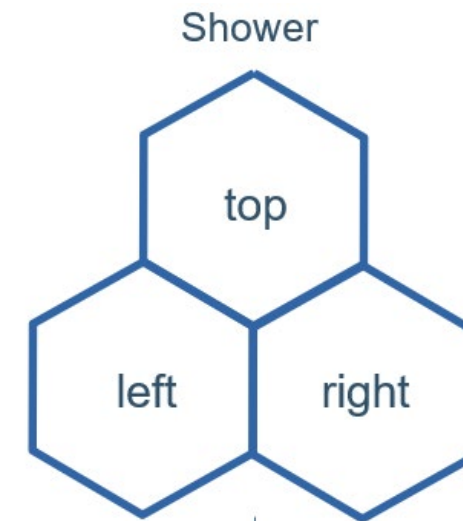
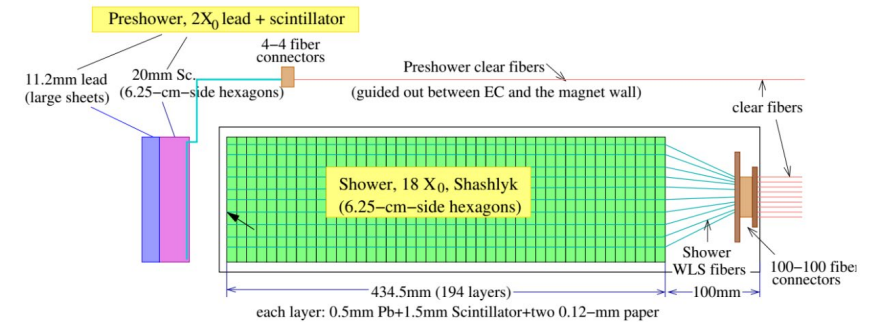
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Introduction (Pencil Simulation Study)

- SoLID detector responses include,
 - Electromagnetic Calorimeter (ECal)
 - Cherenkov Detector
 - Scintillators
 - Gas Electron Multipliers
- The Pencil Beam simulates thin beams of e^- (11), π^- (-211), and gamma photons (22), shot through the center of the detector set-up.

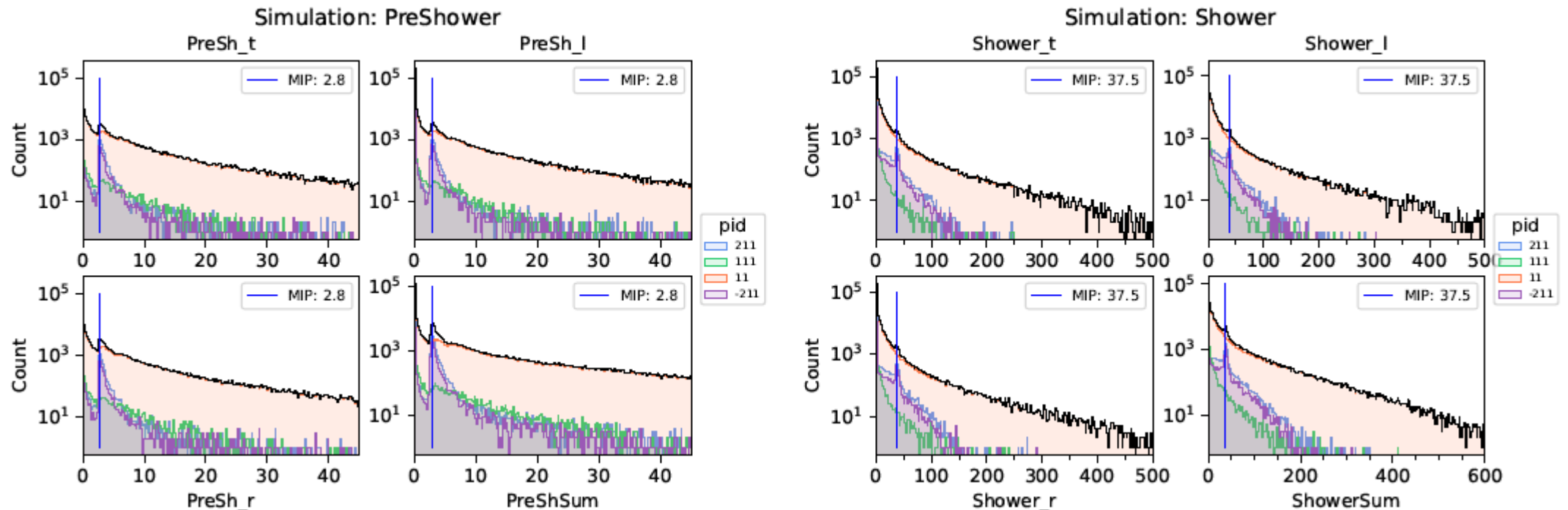
Detector Signal: ECal

- ECal signals include PreShower, Shower modules.
- PreShower are 2cm thick scintillators (followed by $2X_0$ of lead).
- Pre/Shower modules include a top, left, and right triangular pattern.
- Primary response of an Ecal signal analysis is locating the Minimally-Ionizing Particle (MIP) peaks.



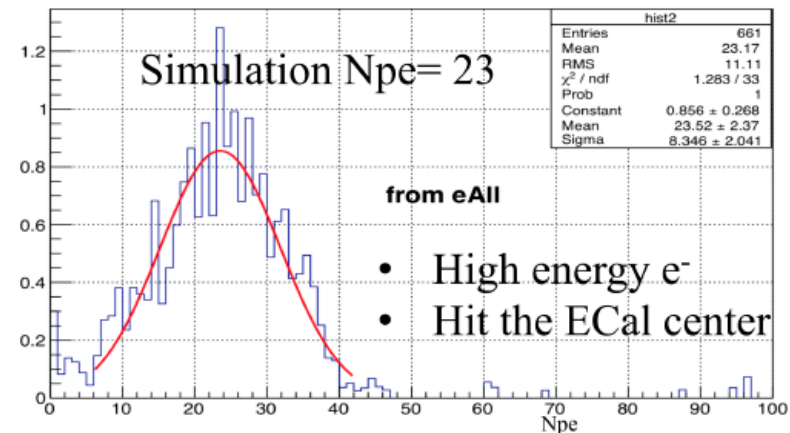
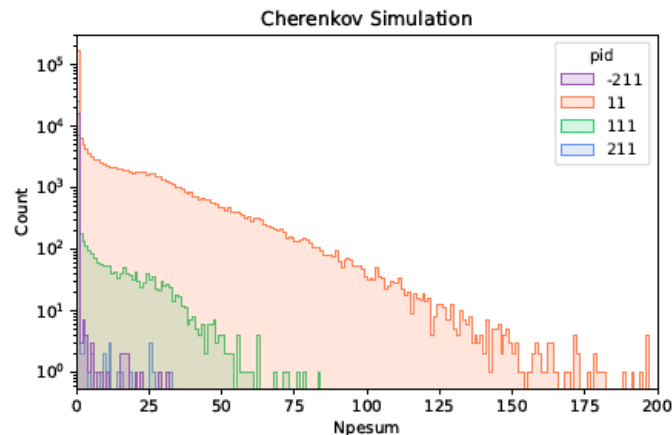
ECal Signals

- ECal Analysis by Darren shows MIP peaks at 2.8 MeV in PreShower and 37.5 MeV in the Shower.



Cherenkov Detector Signals

- When a charge particle passes through a Cherenkov Detector, they emit Cherenkov light. Photo-multiplier tubes would measure the number of photo-electrons (N_{PE}) from a charged particle.
- π^- , π^+ should be zero (excluding δ -electrons) in N_{PE} since we are using CO₂, while π^0 can decay into two gammas which can produce $e^- e^+$ pairs,



Scintillators Signals

- MIP peaks can be seen in Scintillators (SC_{A,B,C}) and Large Angle Scintillating Pad Detector (LASPD)
- SC_B is placed behind the ECal so pions create signals (high energy e leaking through the ECal).
- LASPD is useful for gamma-rejection (?)
- Multiple MIP peaks can be correlated to different decay chains that produce multiple particle final states.

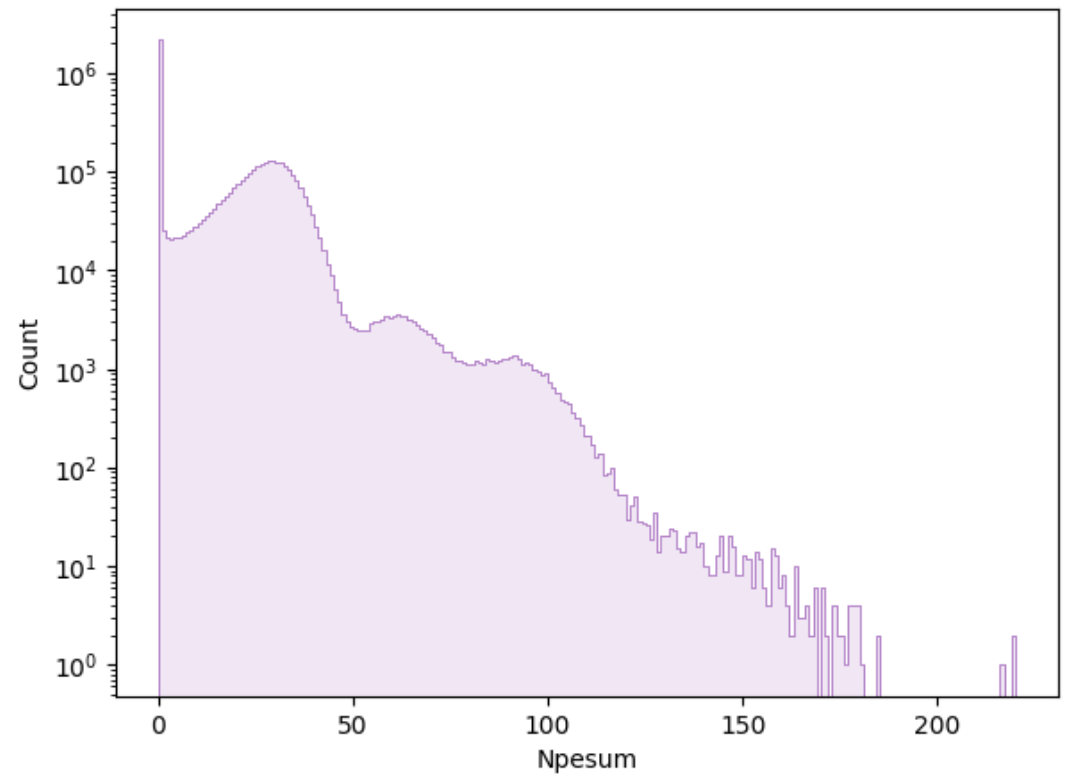
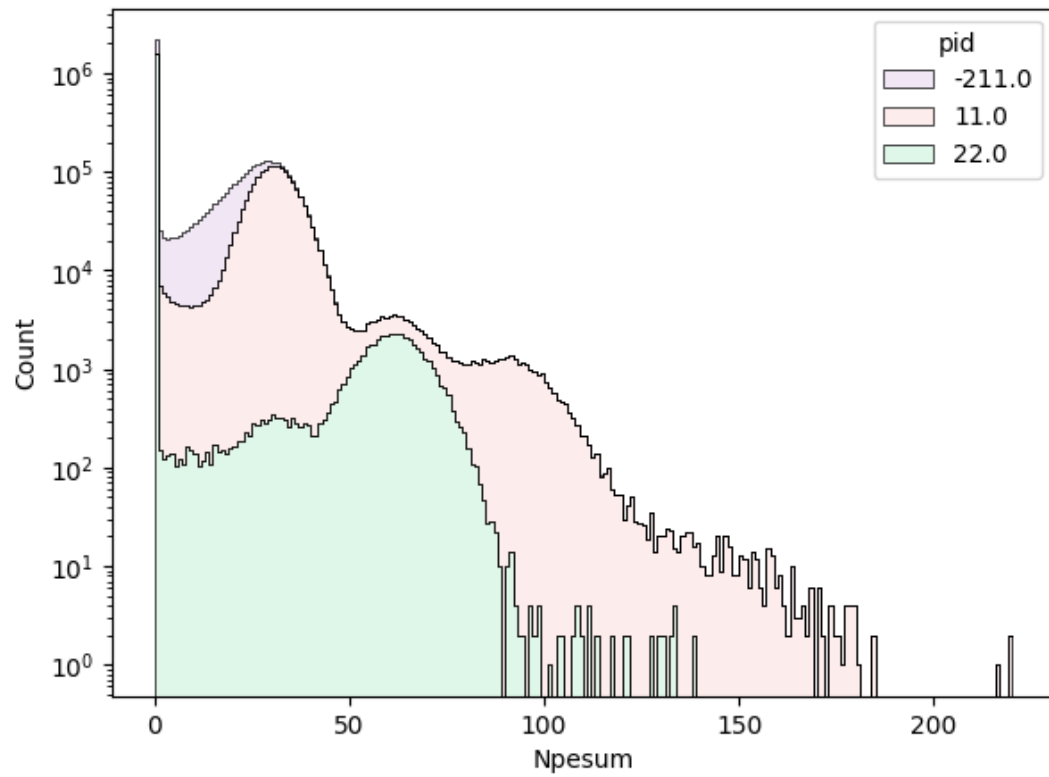
Table of Pencil Simulation “Features”

Column (Variable Name)	What It Measures?	ECal Analysis	Cherenkov Analysis	Scintillator Analysis
vx,vy,vz	Particle Velocity			
px,py,pz,p	Particle Momentum		Npesum	
pid	True PID			
PreShP	Pre Shower Momentum ?			
PreShP_e	Pre Shower Momentum Energy?			
PreShPx,PreShPy,PreShPz	Pre Shower Momentum			
PreShTheta	?			
PreSh_Sum, PreSh_l, PreSh_r, PreSh_t	Pre Shower Energy Deposit	Hist		
Shower_l,Shower_r,Shower_t,Shower_Sum	Shower Energy Deposit	Hist		
SC*_Endsum	Scintillators Energy Deposit			Hist
SPD_P,SPD_Eendsum	?			
LASPD_Endsum	LASPD Energy Deposit			Hist
Npesum	Number of Photoelectrons		Hist, NCh, P	
Theta			Npesum	
NCh	Number of Triggered Channels?			
Notes		Pencil Sim showed MIP peaks 2.8, 37.5 MeV for Pre/Shower	Varying features in Npesum vs P space, Npe hist will show varying peaks depending on decay channel, Npe vs NCh is another space to look at.	Depending on decay channel or multiple particle final state, we can see multiple MIP peaks. Particles will correlate to the number of MIP peaks depending on the decay process

Replication of Pencil Beam - Cherenkov Study

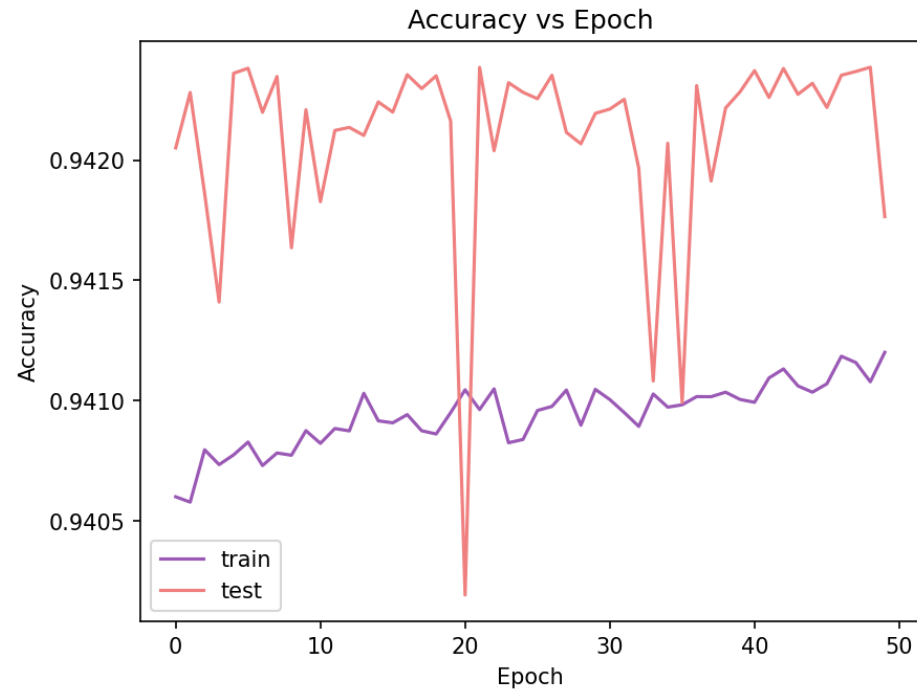
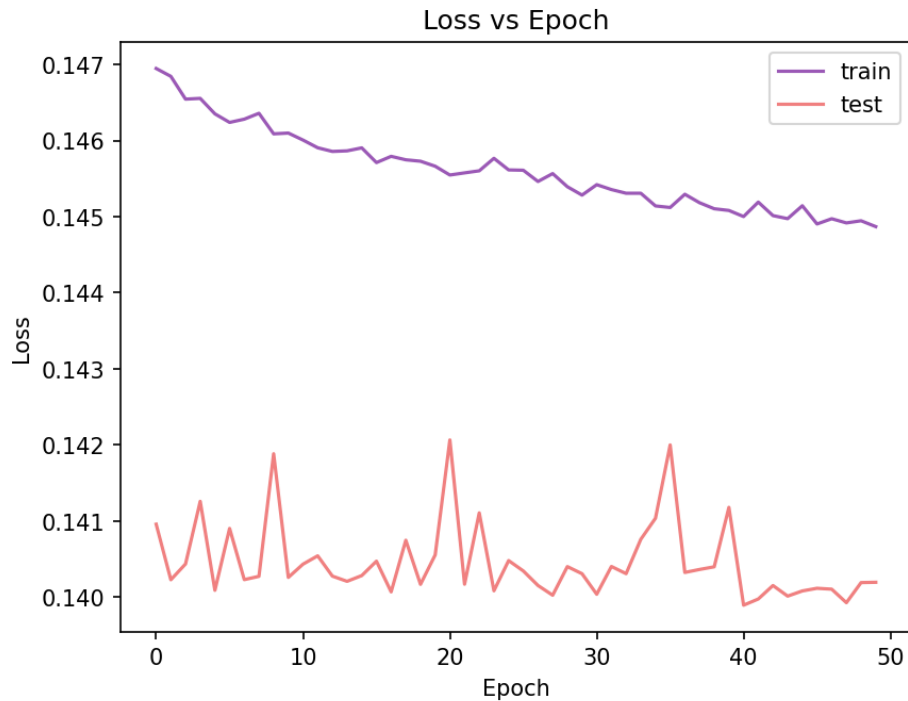
- I tried reproducing the pencil cher. results by
 - Selecting p, Npesum, NCh columns for π^- , e.
 - Without any cuts to momentum.
 - Training Darren's model based on those columns.
 - Looking at Loss/Accuracy vs Epoch, Confusion Matrix, and Location of Mislabeled particles in Npesum histogram.

Dist. Of Pencil Data

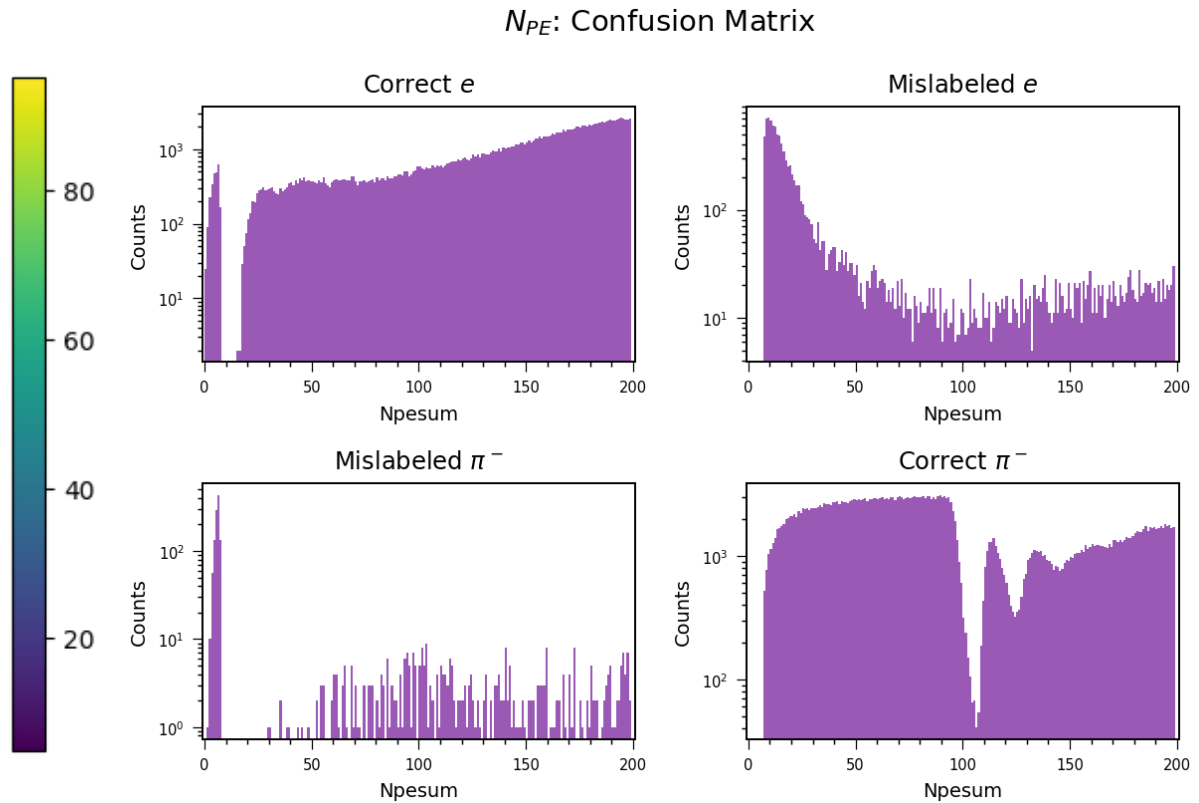
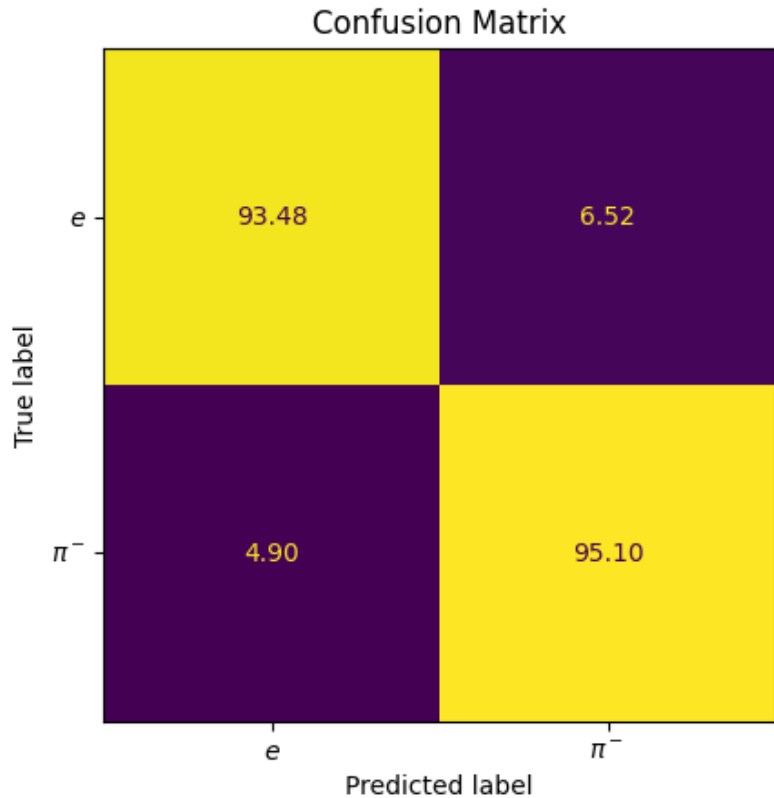


Model Metrics

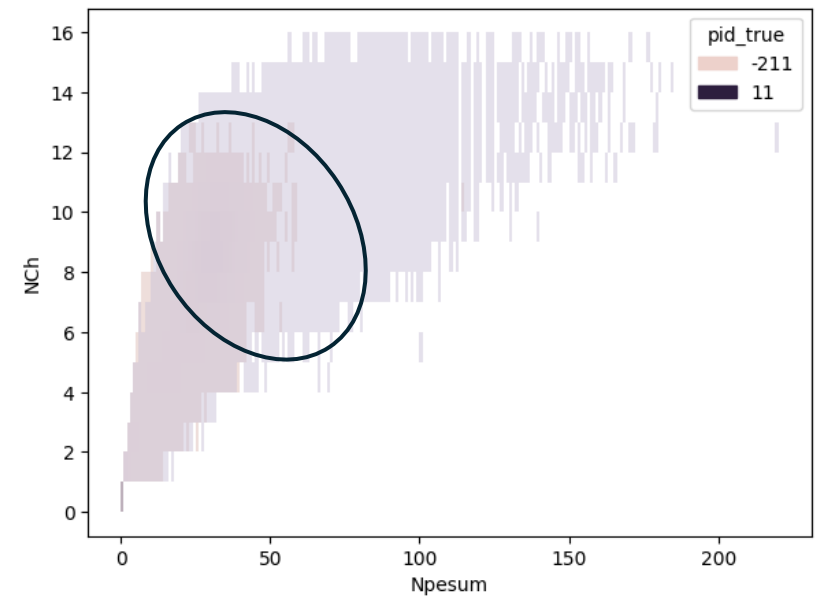
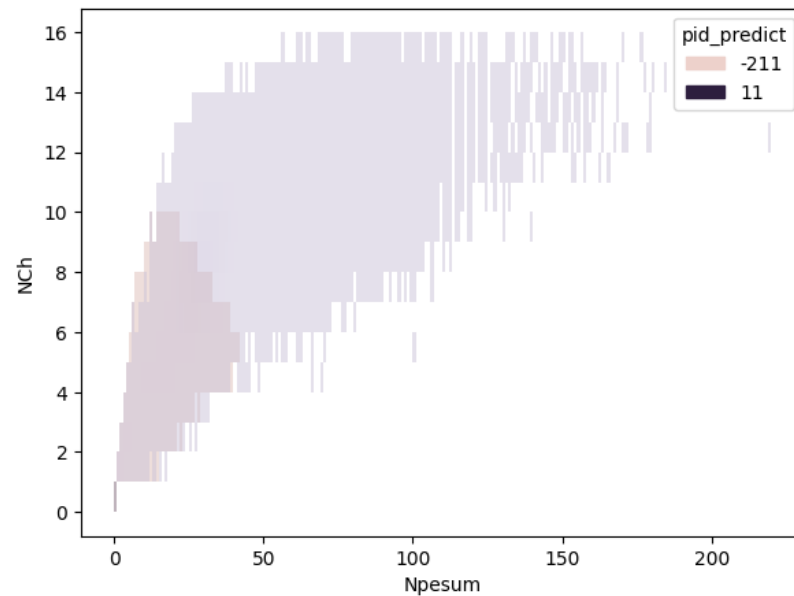
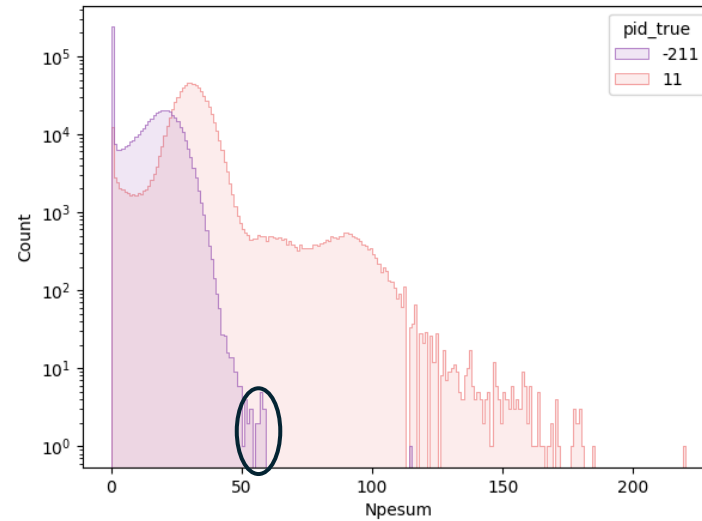
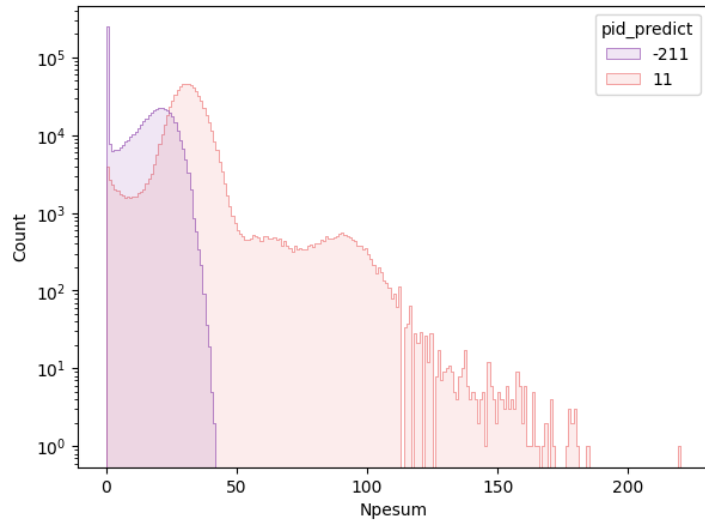
- Trained over 50 Epochs without any early stopping conditions to see accuracy/loss plateau. (When adding early stopping, we stop at the 7th epoch and recover some true probability)



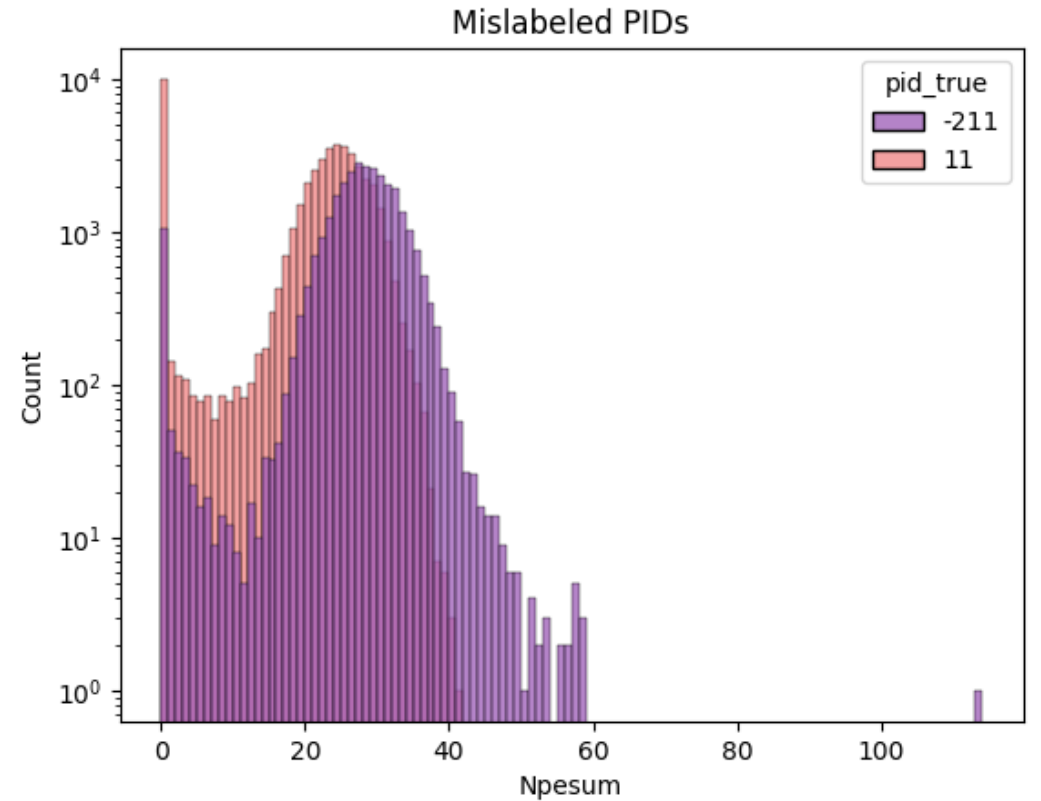
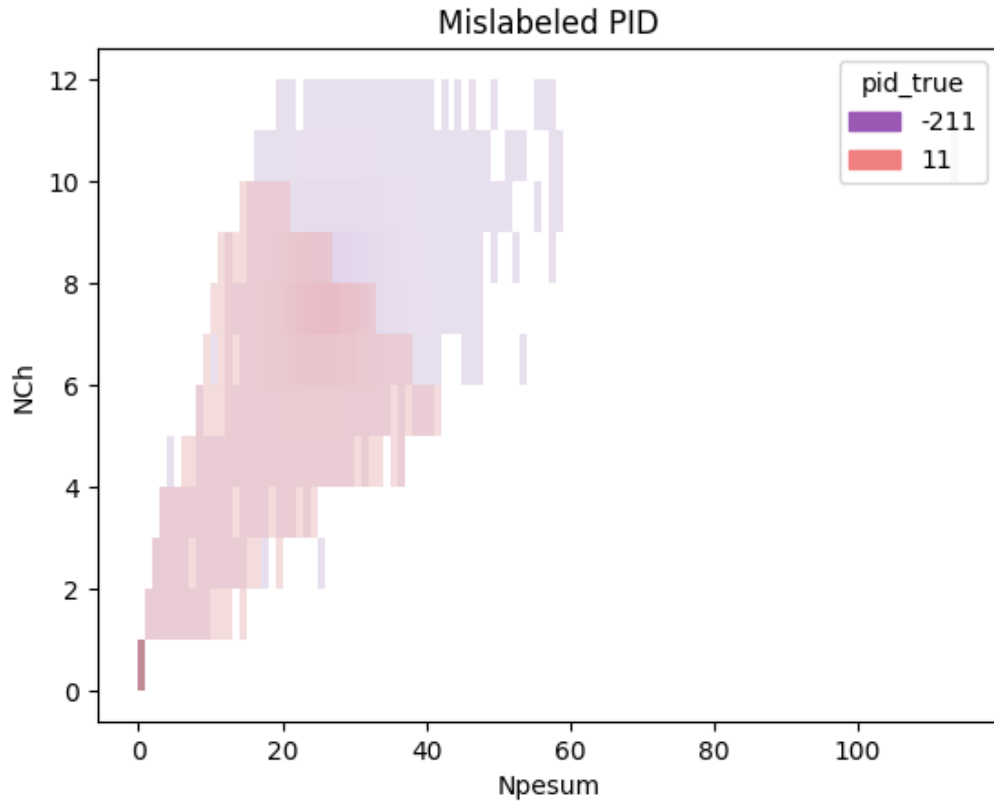
Confusion Matrix



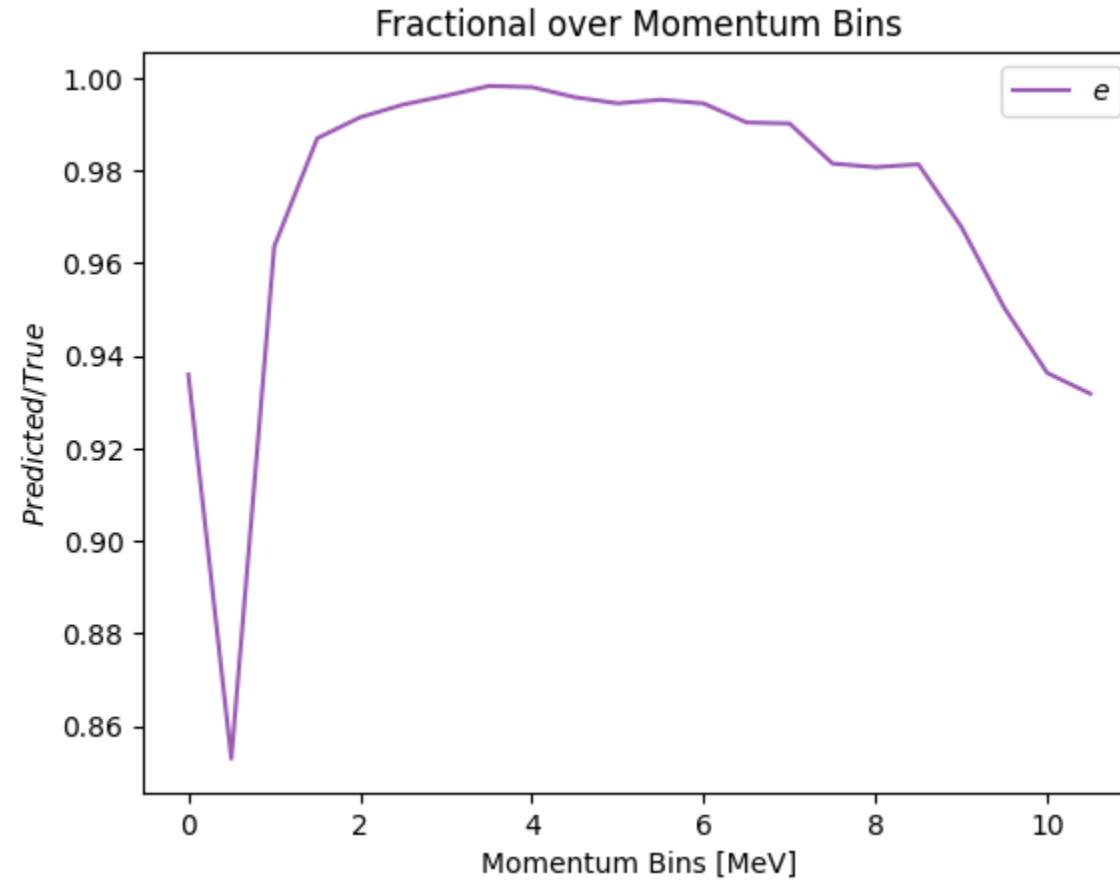
Comparing Predicted PIDs vs True PIDs



Location of Mislabeled PIDs



Electron/Pion Prediction Fraction



Summary (June 24)

- Pencil Beam Analysis of Cherenkov ML (Done-ish)
 - I need to figure out to plot ν_e vs ν_{π^-} (relevant metric).
 - Do a combined classification with the ECal by including relevant ECal Columns (Basically recreate the Baseline):
 - Cher columns are: Npesum, NCh, p
 - ECal columns are: PreShSum, PreSh_*, ShowerSum, Shower_*
- Baseline model on Full Simulation (Potential Next Step?)