# ML 2025

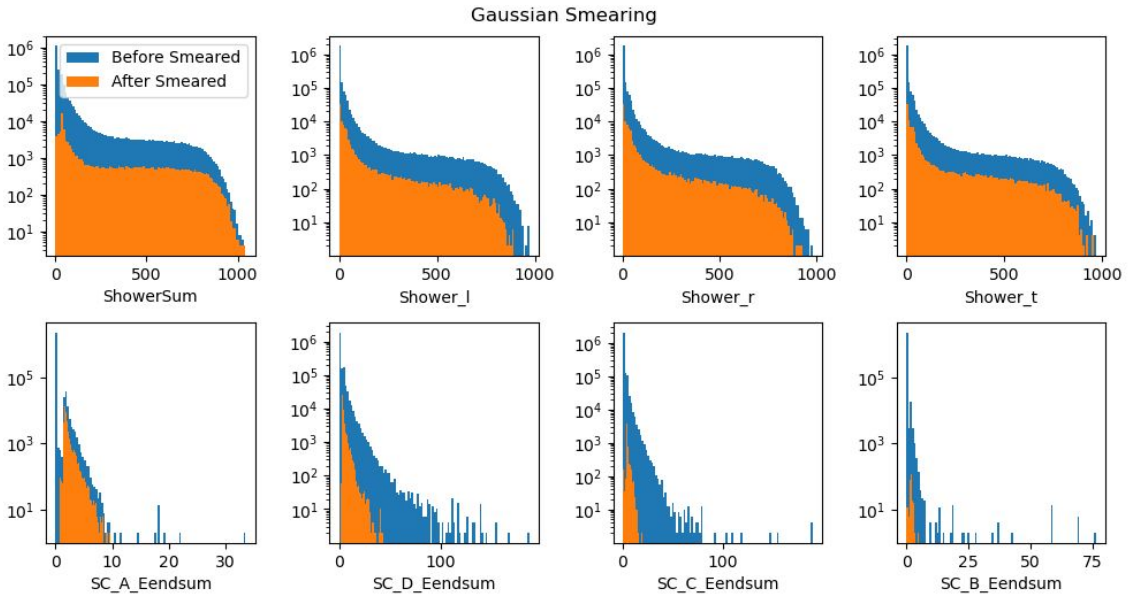
By Mohhamed Rafi

# TOC

- Model Development
  - Simulation Smearing
  - Full PID model trained on simulated events + bkg events.
- Beam Test Comparison
  - Beam Test Scaling for #4779
  - First look at results at PID model

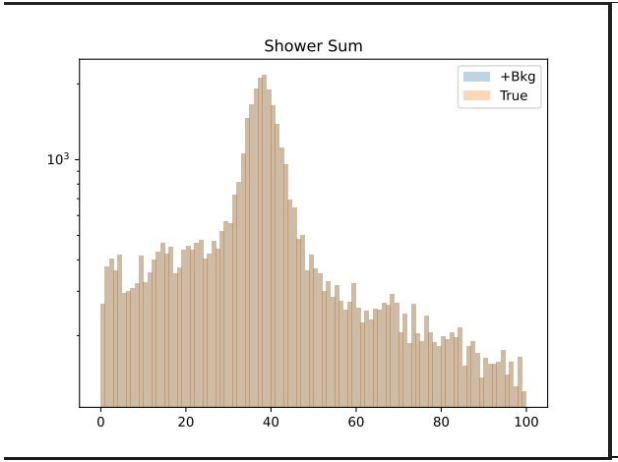
# Simulation Smearing

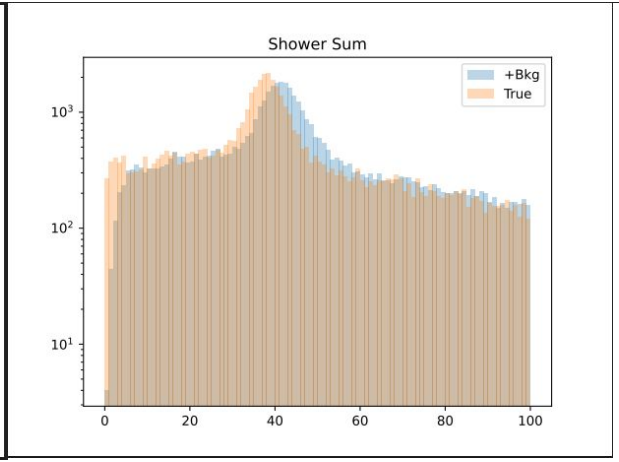
- Simulation needs smearing due resolution effects not being properly modeled. Simulation is smeared before used to train model.
  - Shower Sum, and Scints are smeared based on Darren's report on the scaling between beam test data and model.

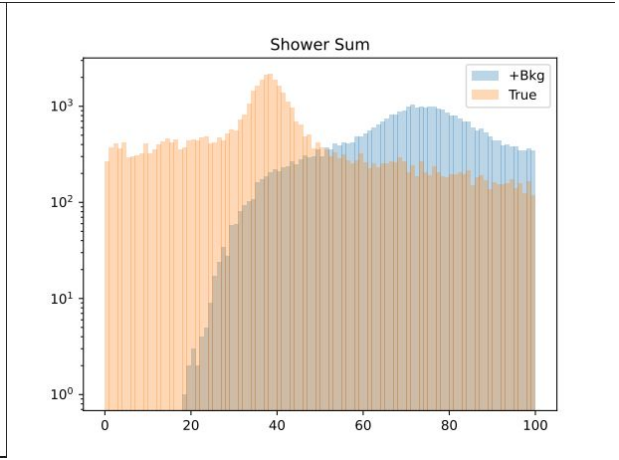


# Bkg Mixing, Results

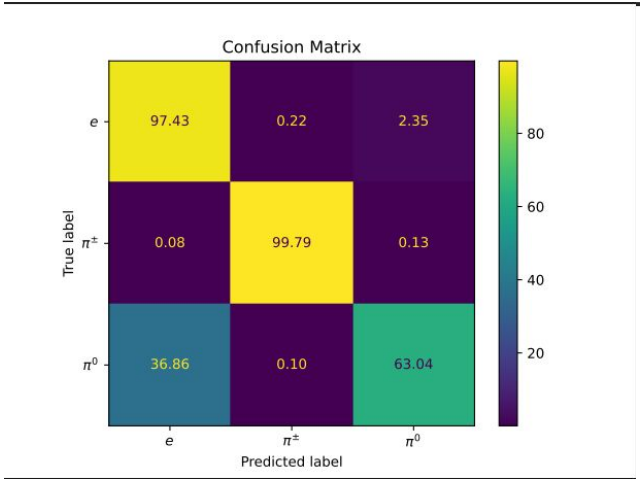
- Simulation is mixed with BeamOnTarget background events.
  - Using sampling method where background events are randomly sampled with various amount of mixing (Darren's Method).
  - Background is also smeared with the same smearing as simulation.
  - Models are trained on a Trigger 2 Cut and Shower Sum > 0.5 and LASPD > 0.1

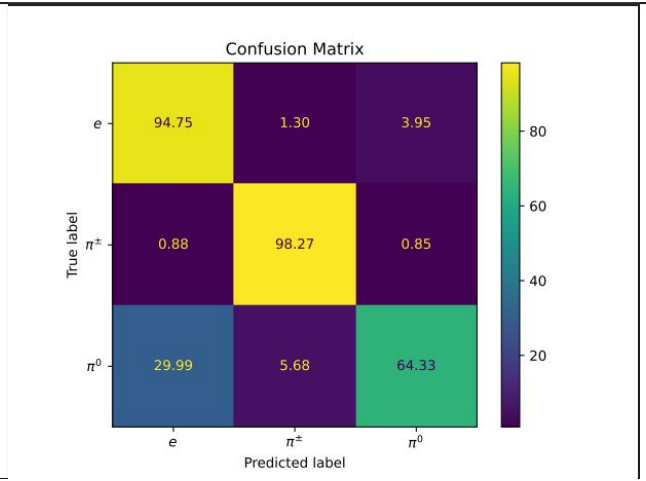


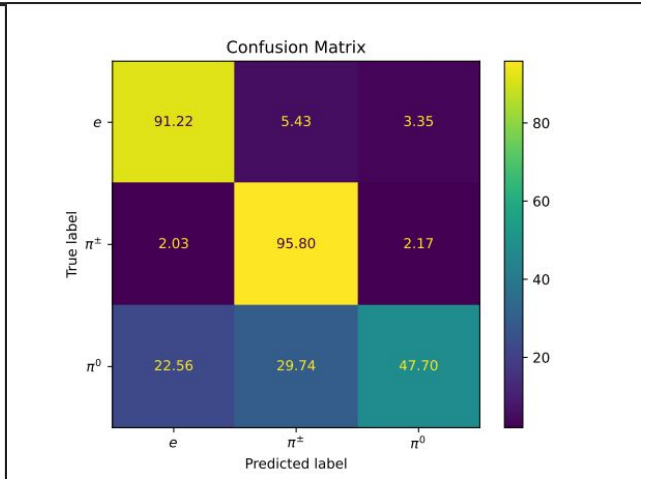



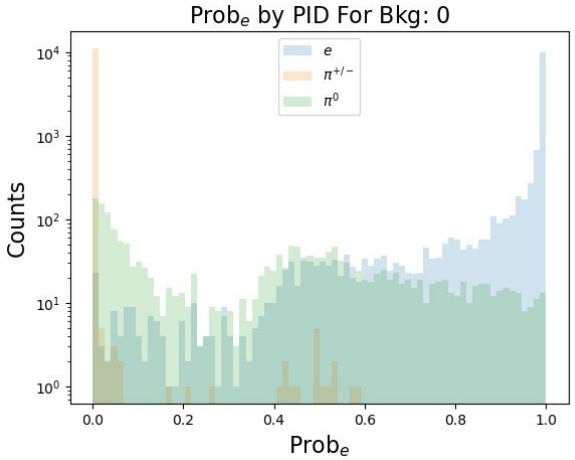
# Confusion Matrices

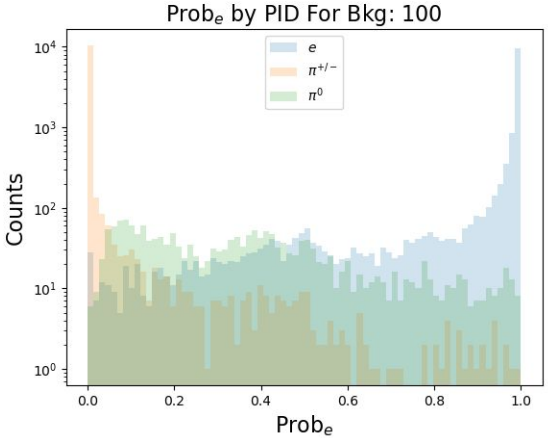


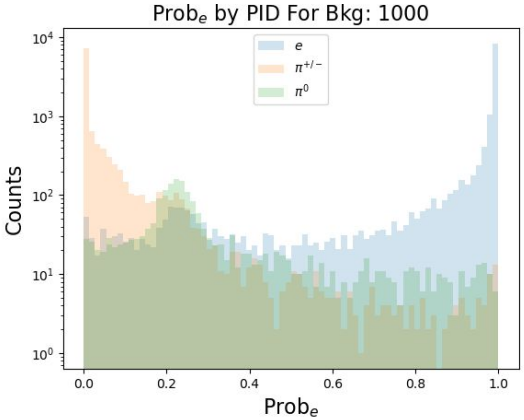



# Prob. Dists


Prob$_e$ by PID For Bkg: 0
$e$
$\pi^{+/-}$
$\pi^0$
Counts
Prob$_e$

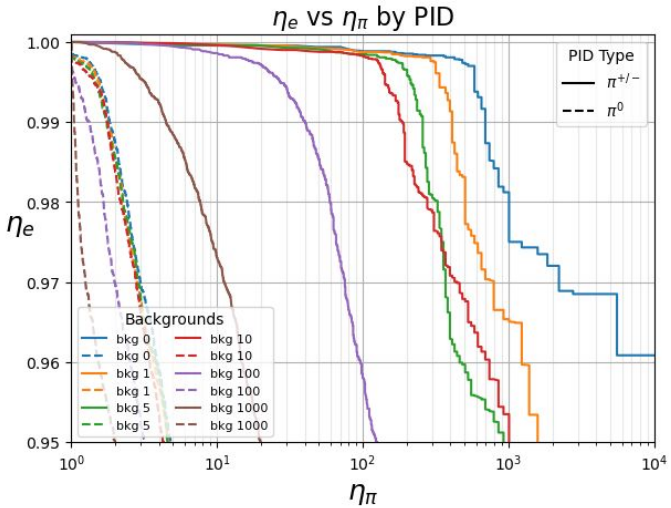

Prob$_e$ by PID For Bkg: 100
$e$
$\pi^{+/-}$
$\pi^0$
Counts
Prob$_e$


Prob$_e$ by PID For Bkg: 1000
$e$
$\pi^{+/-}$
$\pi^0$
Counts
Prob$_e$

# Model Comparisons

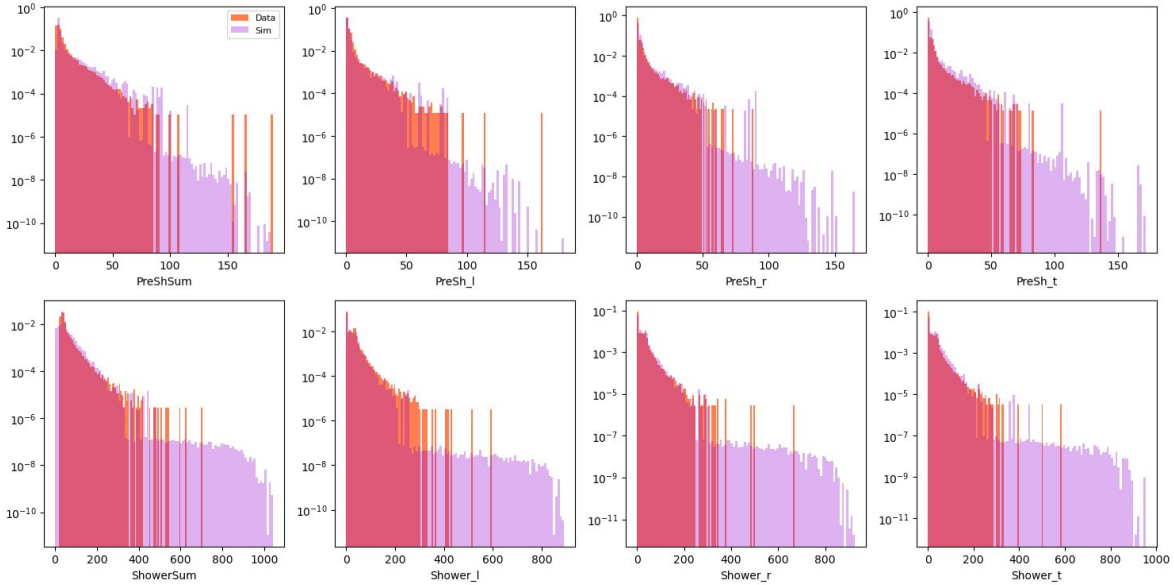
Electron Efficiency and Pion Rejection Table

| Bkg # | Electron Efficiency | Pion Rejection |
|---|---|---|
| 0 | 0.9743 | 0.9445 |
| 1 | 0.9658 | 0.9508 |
| 5 | 0.9618 | 0.9548 |
| 10 | 0.9603 | 0.9554 |
| 100 | 0.9475 | 0.9479 |
| 1000 | 0.9122 | 0.9492 |



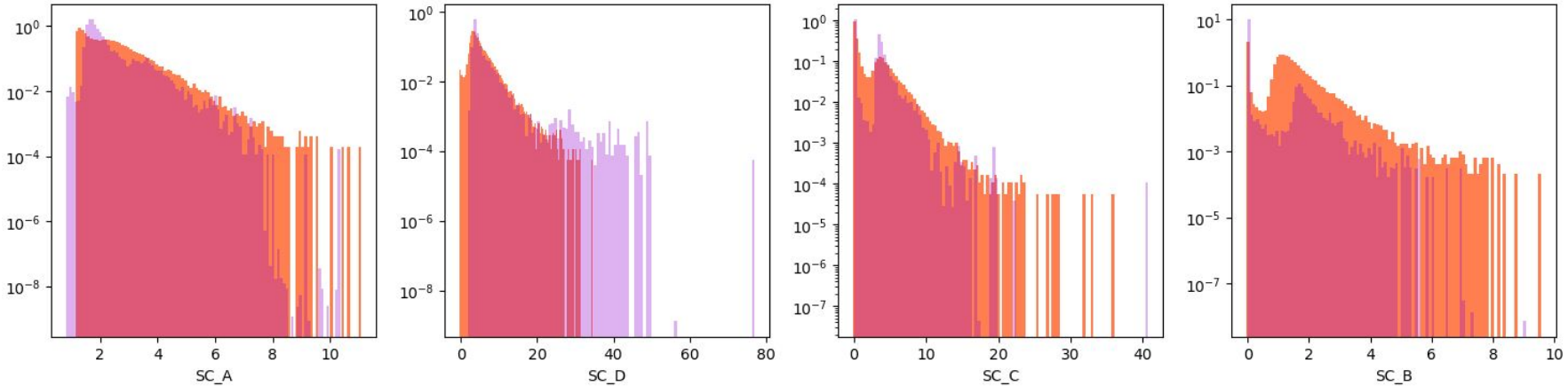
# Model On Beam Test Data

- Beam Test Scaled



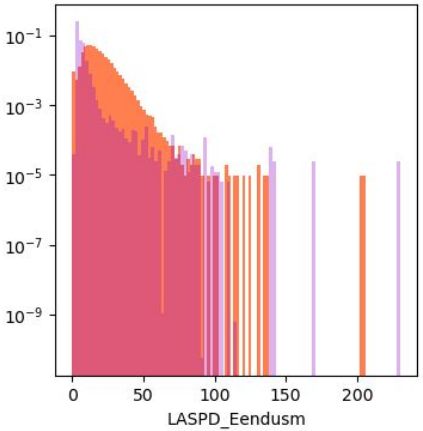
# Scint. Dist

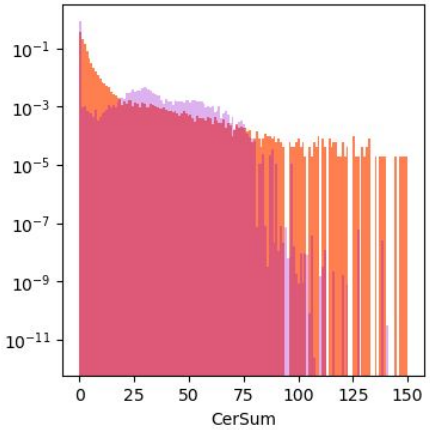
- SC A & B
  - Scaled using conversion values provided by Ye Tien but no additional smearing or MIP shifts were applied. Manually adjusted scaling values to match simulation.
- SC C & D
  - Scaled and shifted using values provided by Darren

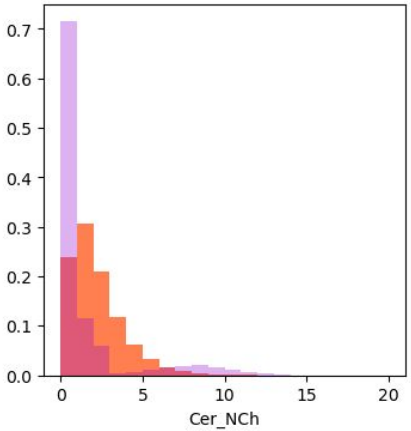


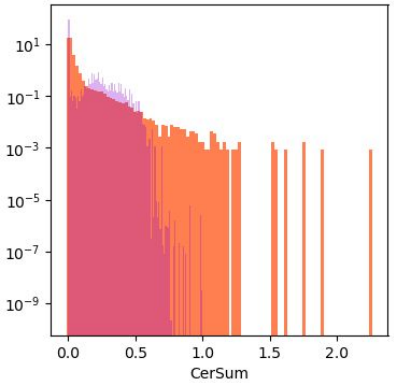
# LASPD & Cher Sum Dist.

- LASPD
  - Scaled using conversion values for LASPD_t and LAPSD_b and summed together.
- Cher. has issues
  - Individual channels are scaled, and then summed together for A,B,C,D.
  - But not properly scaled, so a MinMaxScaler transforms it outside the bounds of the model input.

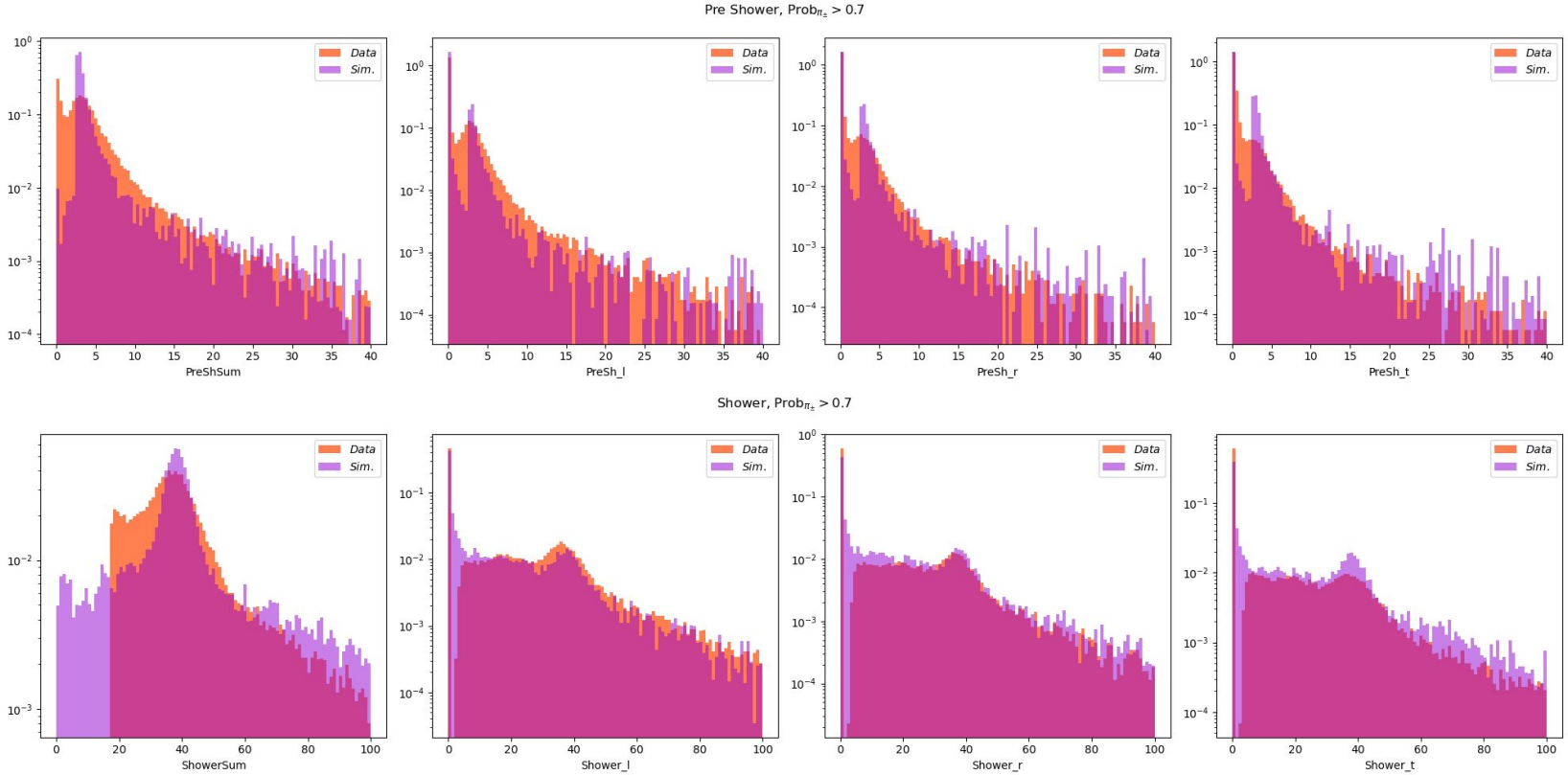


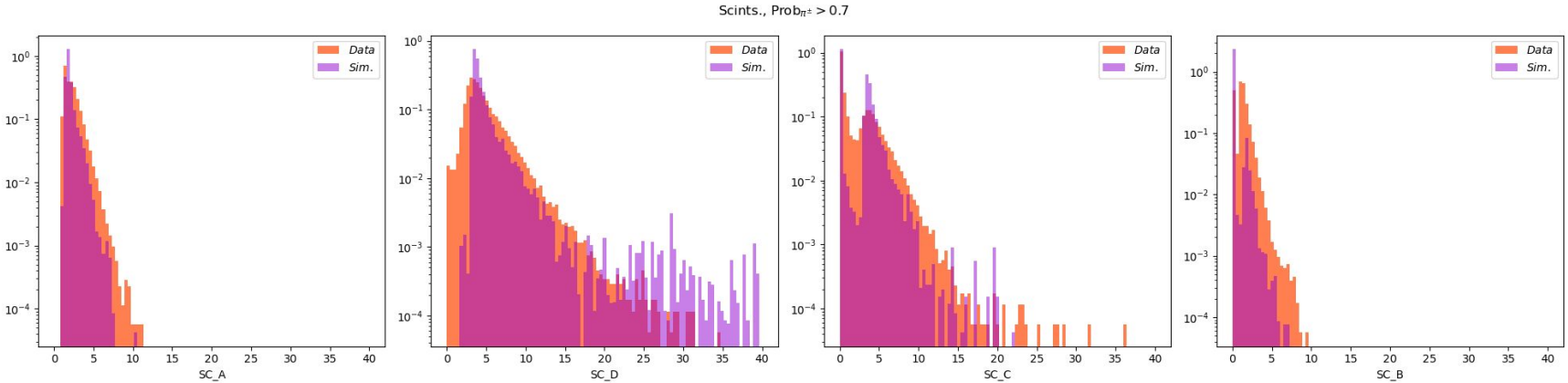



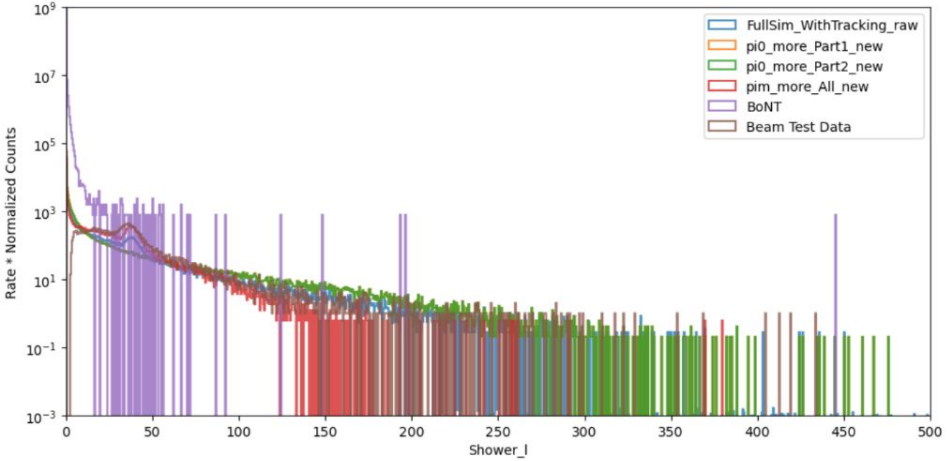



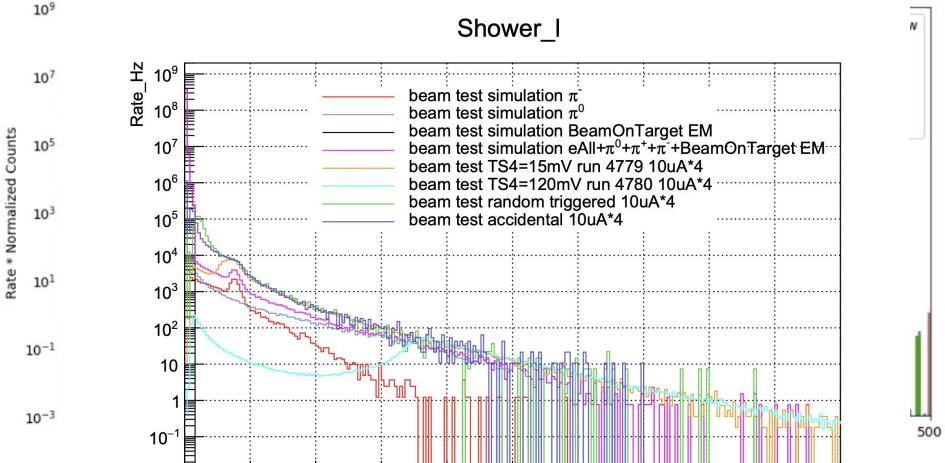
# Full ML-PID Results

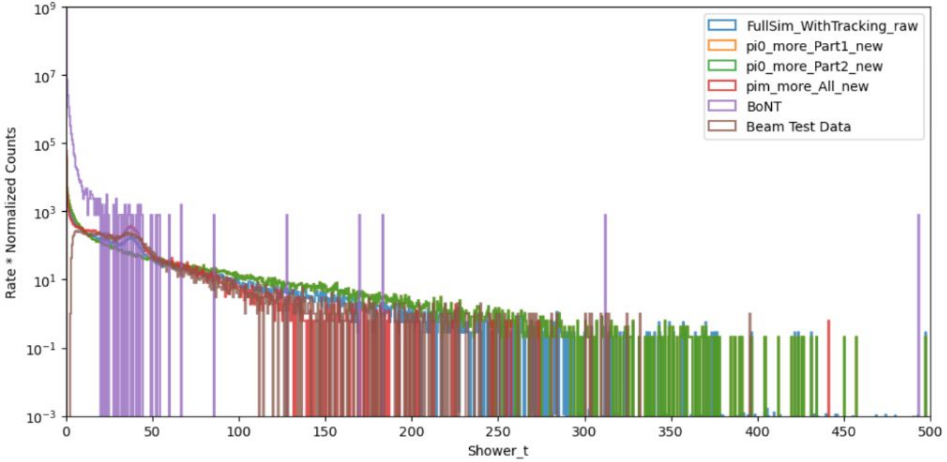


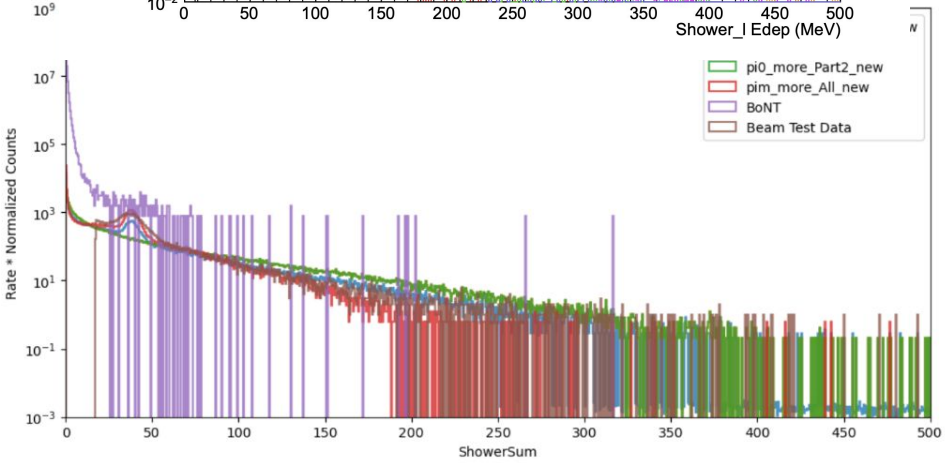
# Scints. Dist

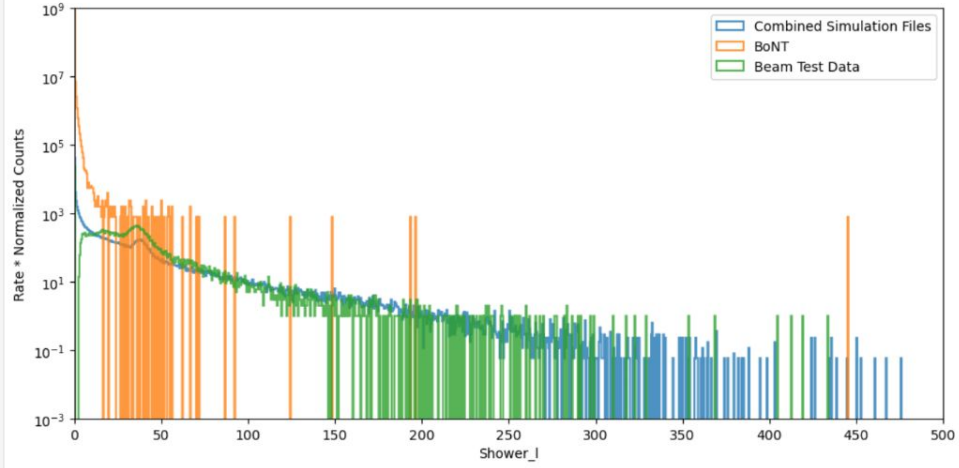


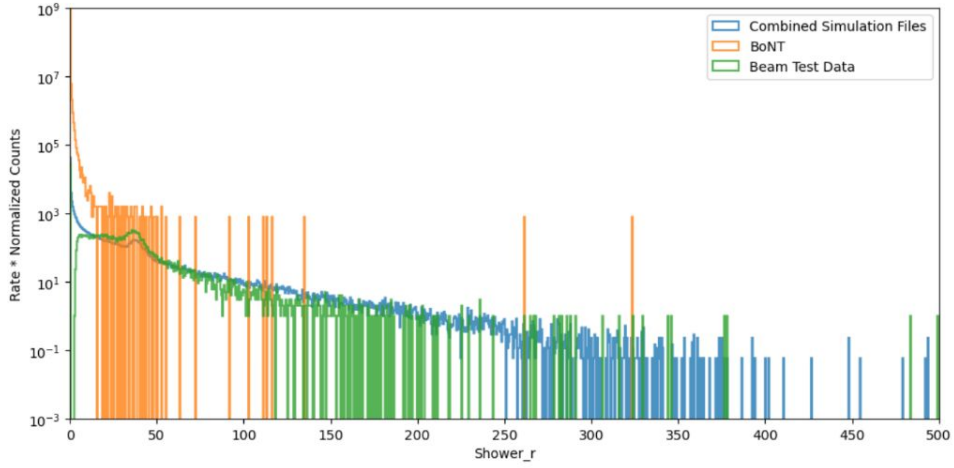

FullSim_WithTracking_raw
pi0_more_Part1_new
pi0_more_Part2_new
pim_more_All_new
BoNT
Beam Test Data
Rate * Normalized Counts
Shower_l

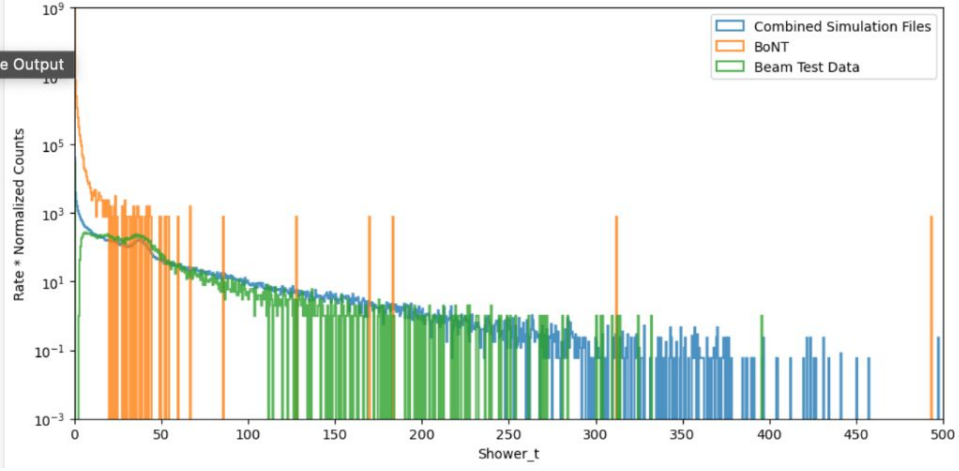

Shower_l
beam test simulation π⁻
beam test simulation π⁰
beam test simulation BeamOnTarget EM
beam test simulation eAll+π⁰+π⁺+π⁻ +BeamOnTarget EM
beam test TS4=15mV run 4779 10uA*4
beam test TS4=120mV run 4780 10uA*4
beam test random triggered 10uA*4
beam test accidental 10uA*4
Rate_Hz
Shower_l Edep (MeV)

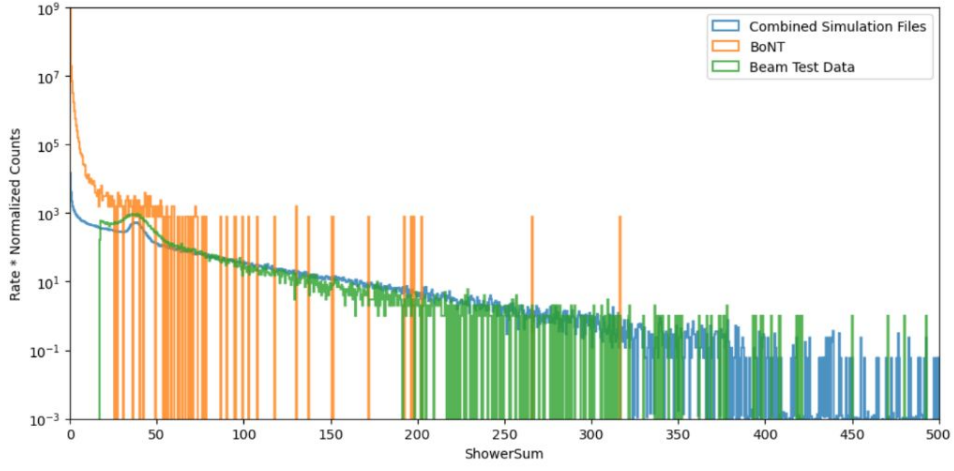

FullSim_WithTracking_raw
pi0_more_Part1_new
pi0_more_Part2_new
pim_more_All_new
BoNT
Beam Test Data
Rate * Normalized Counts
Shower_t

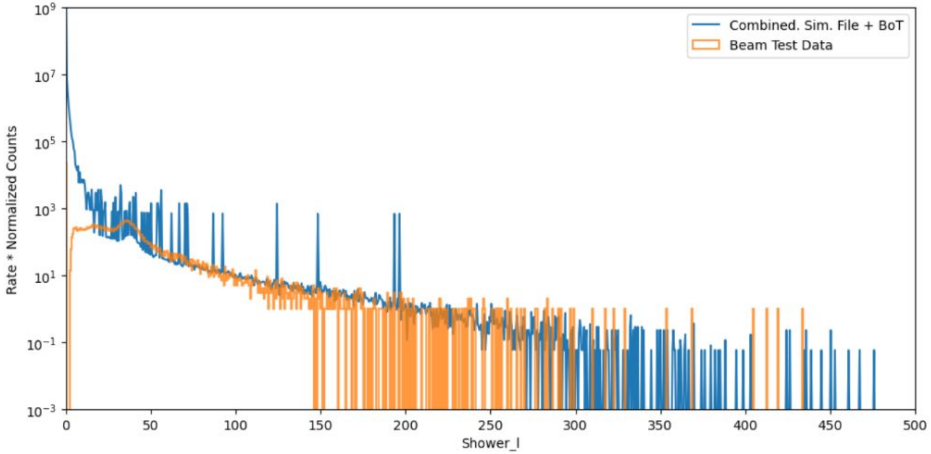

pi0_more_Part2_new
pim_more_All_new
BoNT
Beam Test Data
Rate * Normalized Counts
ShowerSum

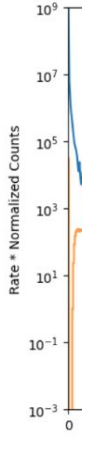

Combined Simulation Files
BoNT
Beam Test Data
Rate * Normalized Counts
Shower_l

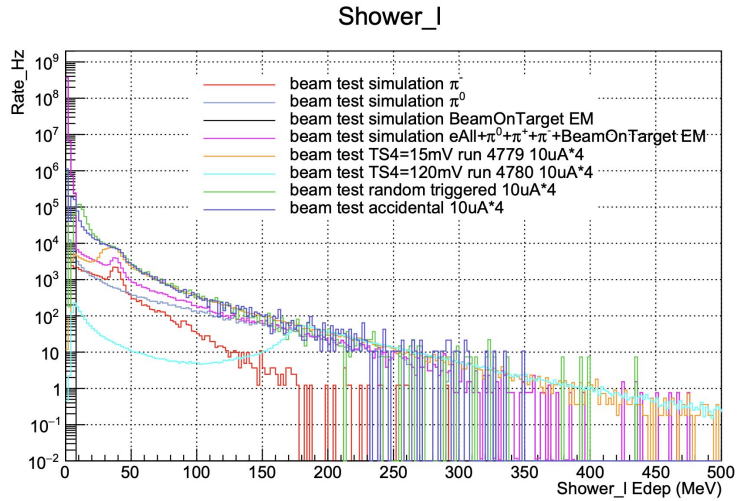

Combined Simulation Files
BoNT
Beam Test Data
Rate * Normalized Counts
Shower_r

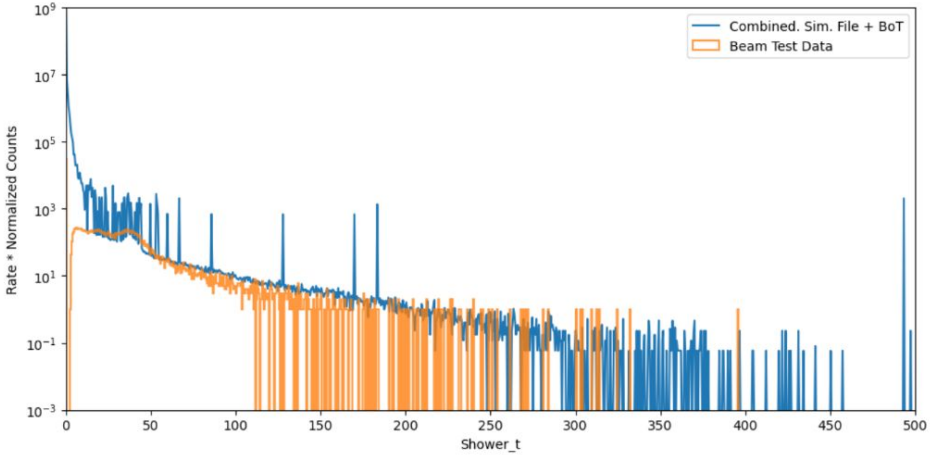

Combined Simulation Files
BoNT
Beam Test Data
Rate * Normalized Counts
Shower_t

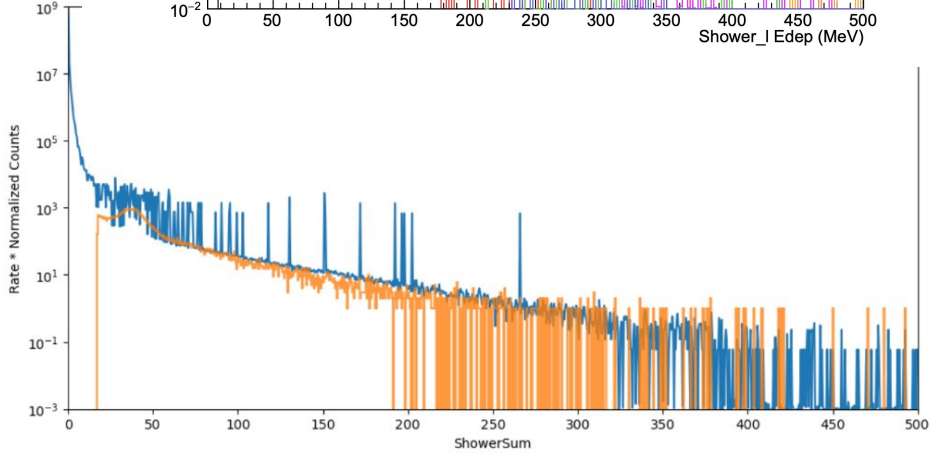

Combined Simulation Files
BoNT
Beam Test Data
Rate * Normalized Counts
ShowerSum


Combined. Sim. File + BoT
Beam Test Data
Rate * Normalized Counts
Shower_l


Rate * Normalized Counts


Shower_l
Rate_Hz
beam test simulation π
beam test simulation π0
beam test simulation BeamOnTarget EM
beam test simulation eAll+π0+π+π +BeamOnTarget EM
beam test TS4=15mV run 4779 10uA*4
beam test TS4=120mV run 4780 10uA*4
beam test random triggered 10uA*4
beam test accidental 10uA*4
Shower_l Edep (MeV)


Combined. Sim. File + BoT
Beam Test Data
Rate * Normalized Counts
Shower_t


Rate * Normalized Counts
ShowerSum

# ML/Classical First Look

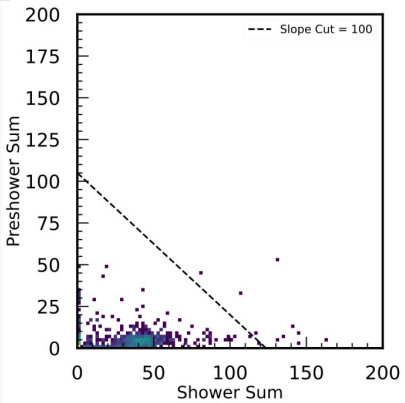
## Classical Cuts

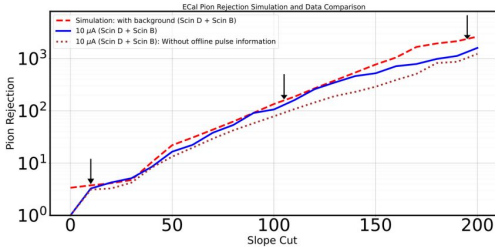
### PID Performance

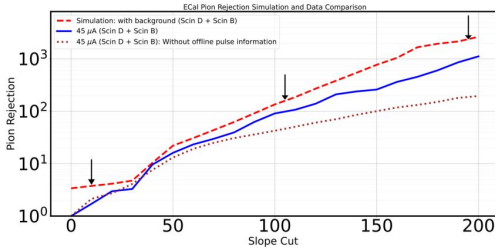
Charged Pion Samples: TS2 events with:

- CerSum<100
- SC-C>500
- LASPD-T(B)>10

A “slope cut” is then applied to study pion rejection of ECal




- Arrows in the figure correspond to a 95% electron efficiency for electrons in ranges of (0-1], (1-2], and (2-3] GeV, as determined by simulation
- The three curves are: simulation, data with waveform “cleaning”, and data without waveform “cleaning”

## ML-PID Model

Electron Efficiency and Pion Rejection Table (for p values in (0, 1)] GeV)

| Bkg Sampling Ratio | Electron Efficiency | $\pi^{\pm}$ Rejection | $\pi^0$ Rejection |
|---|---|---|---|
| 3 | 0.981 | 1435.4533 | 1.9891 |
| 13 | 0.9559 | 406.8513 | 2.0262 |

Electron Efficiency and Pion Rejection Table (for p values in (1, 2)] GeV)

| Bkg Sampling Ratio | Electron Efficiency | $\pi^{\pm}$ Rejection | $\pi^0$ Rejection |
|---|---|---|---|
| 3 | 0.9824 | 756.2336 | 2.1737 |
| 13 | 0.9727 | 187.9972 | 2.242 |

Electron Efficiency and Pion Rejection Table (for p values in (2, 3)] GeV)

| Bkg Sampling Ratio | Electron Efficiency | $\pi^{\pm}$ Rejection | $\pi^0$ Rejection |
|---|---|---|---|
| 3 | 0.9883 | inf | 2.0908 |
| 13 | 0.988 | 187.8234 | 2.187 |