AI/ML for PID in the Charged Pion Polarizability Experiment at JLAB

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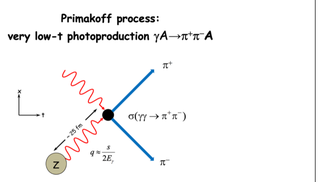
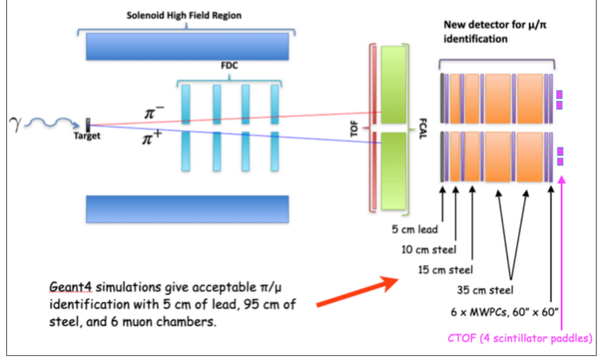
Pion Polarizability

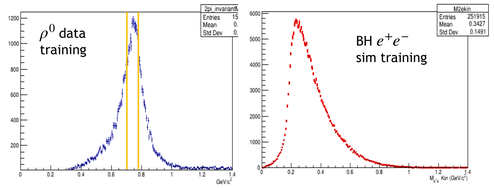
- Charged pion polarizability (CPP) is an important experimental test point for low-energy QCD. Measuring polarizability is as fundamental a test as measuring magnetic moments.
- Hall D at JLAB: photo-production facility.
- CPP: Try to select Primakoff pions.





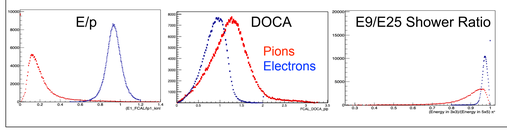
Training/Validation of e/π MLP neural nets (TMVA)

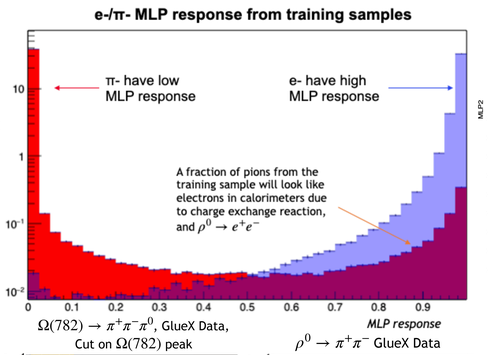
- 2 MLPs: one for e-/π-, one for e+/π+.
- Train on GlueX ρ^0 pions (700 MeV < W < 770 MeV) and *simulated* Bethe-Heitler electron pairs.

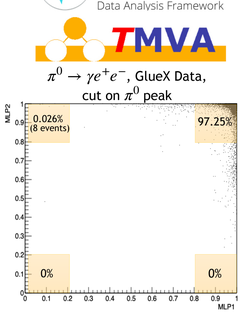


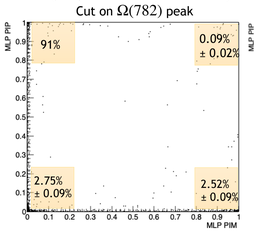
Calorimetry Based Training Variables

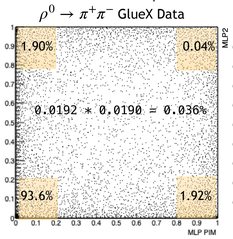
- Shower Energy/Track Momentum (E/p)
- Distance of Closest Approach (DOCA) (L from shower centroid to track proj.)
- E9/E25 Shower Ratio—energy deposited in 3x3 grid of crystals/E in 5x5 grid—a mea--sure of shower width

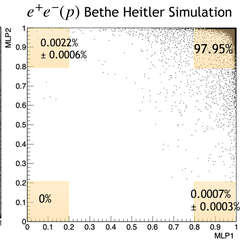








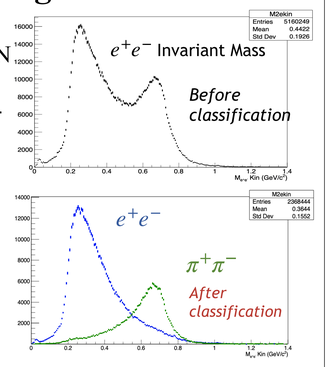




- Use $\pi^0 \to \gamma e^+e^-$ and $\omega(782) \to \pi^0\pi^+\pi^-$ reactions as a way to test performance of the neural nets, as well as new e^+e^- simulation and $\rho^0 \to \pi^+\pi^-$ files.

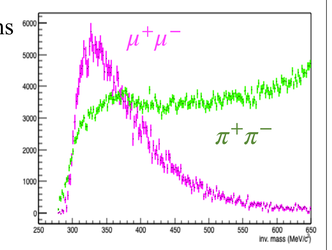
Testing e/π nets on GlueX data before CPP running

- While testing the μ/π NN before CPP running was impossible (MWPCs ne--eded to be installed) e/π testing was possible on GlueX data
- Result of classifier cut $MLP_{1,2} < 0.2$, $MLP_{1,2} > 0.8$

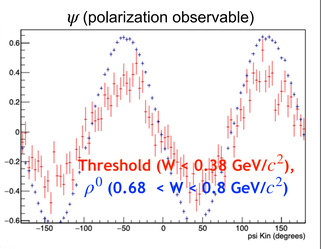


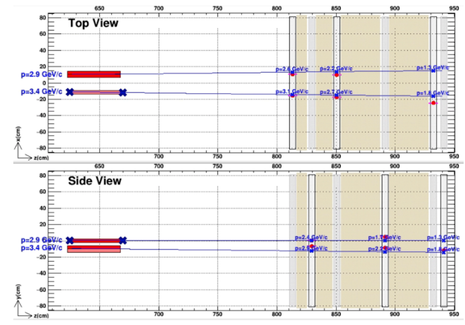
Real Time Data Monitoring in CPP

- Both the muons and pions are subjected to the e/π neural net, with a model cut < 0.35.
- Then further cuts are applied:
  $MLP < 0.2$
  $MLP > 0.8$



- Can monitor polarization of the photon beam with selected pions.
- Can also infer what fraction of p-wave and s-wave is in data. Only ρ^0 produces a signal in this observable, so a reduced peak indicates presence of Primakoff events.

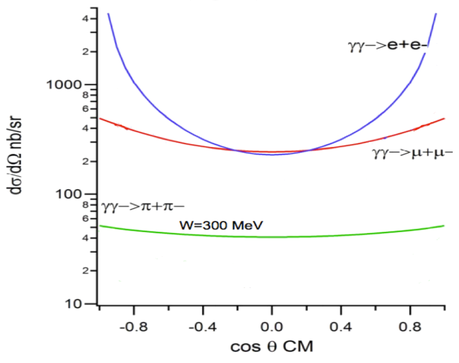




- Individual tracks can be viewed in real time monitoring plots, with the momentum and projection to the face of each wire plane.

Electron and Muon Backgrounds

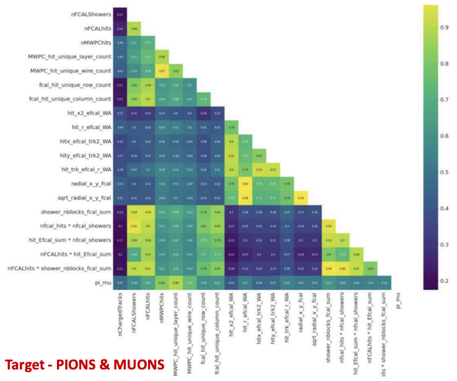
- $\mu^+\mu^-$ and e^+e^- (background) are produced ~10x more than $\pi^+\pi^-$ (signal)



- e/π: separation achievable using calorimeter features, already available at GlueX.
- μ/π: 6 multi-wire proportional ch--ambers (MWPCs) were built and installed to use as input features for μ/π neural net.
- Lead absorbers are placed between the MWPCs. Muons pass out the back, pions interact with lead.

Preliminary μ/π MLP neural net used in Data Monitoring (Tensorflow Lite)

- Train on simulated primakoff + ρ^0 pions, and simulated muons



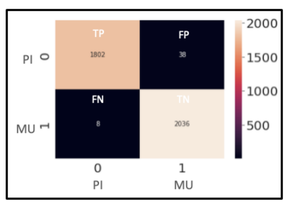
Classification report

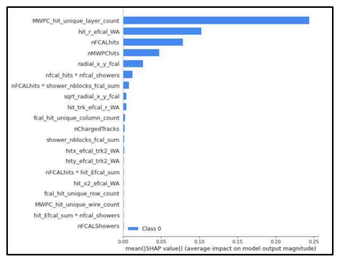
	precision	recall	f1-score	support
0.0	0.96	0.93	0.94	2055
1.0	0.93	0.96	0.94	1939
accuracy			0.94	3994
macro avg	0.94	0.94	0.94	3994
weighted avg	0.94	0.94	0.94	3994

CORRELATION PLOT

Steps to calculate correlation

- **Step 1**: Find the mean of **x**, and the mean of **y**
- **Step 2**: Subtract the mean of x from every x value (call them "**a**"), and subtract the mean of y from every y value (call them "**b**")
- **Step 3**: Calculate: **ab**, **a²** and **b²** for every value
- **Step 4**: Sum up **ab**, sum up **a²** and sum up **b²**
- **Step 5**: Divide the sum of ab by the square root of [(sum of a²) × (sum of b²)]





SUMMARY PLOT