μ/π Separation from e$\longrightarrow\tau$ CLFV studies

Andrew Hurley

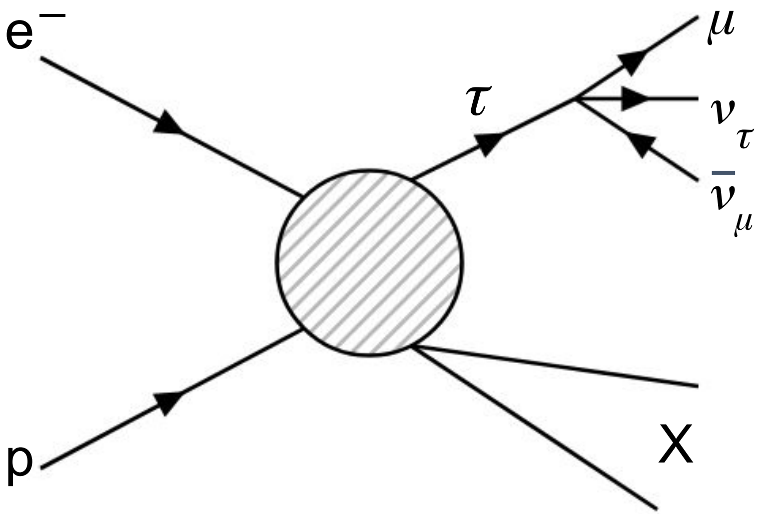
“1-prong” Muon Decay

$\tau \rightarrow \mu \bar{\nu}_{\mu} \nu_{\tau}$

Pros:
Suppression of SM background around $p^{\mu}_{t} > 15$ GeV

~17% branching ratio

Con: requires good muon identification

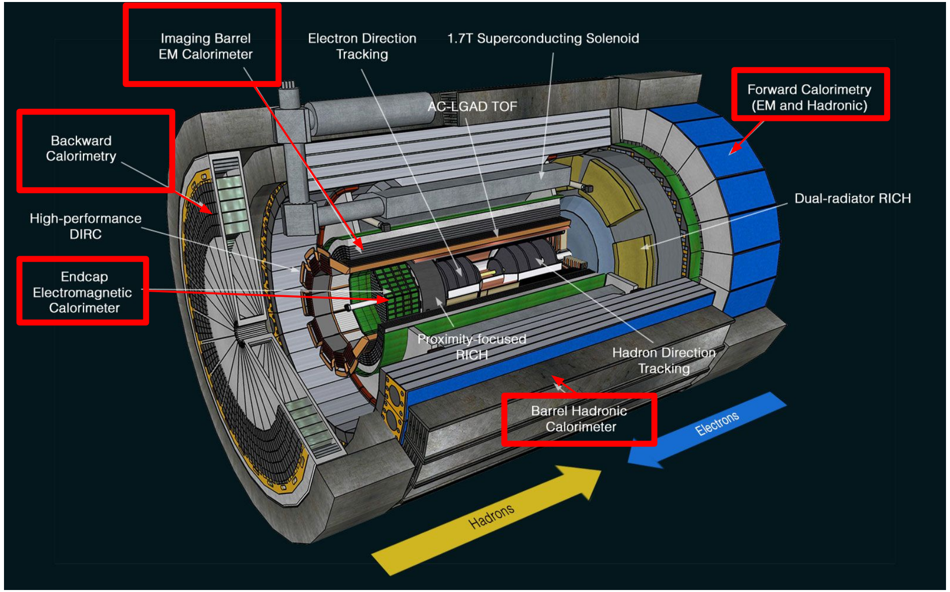


μ/π PID Separation Overview

University of Massachusetts Amherst

Detectors used for μ/π separation

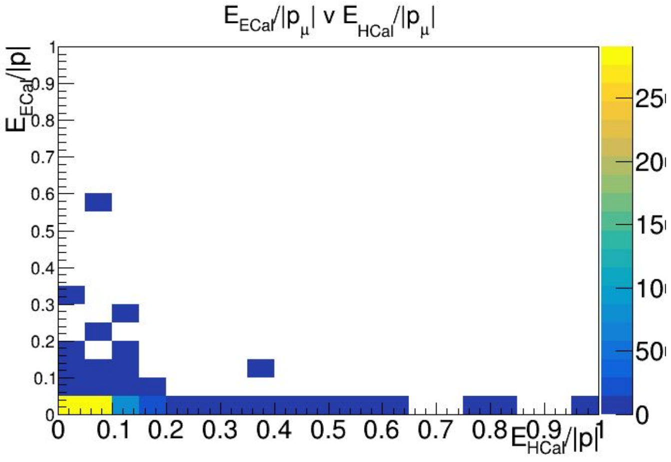
- Hadronic calorimeters (HCals) are a natural starting point for μ/π separation.
- Combining information from the electromagnetic calorimeters with the HCals improves μ/π separation in the following study.
- The following study focuses on the barrel region.
  - Near future plans to extend the study to the backward endcap.
  - Forward endcap μ-ID are ongoing elsewhere, but are not relevant to e$\rightarrow\tau$.



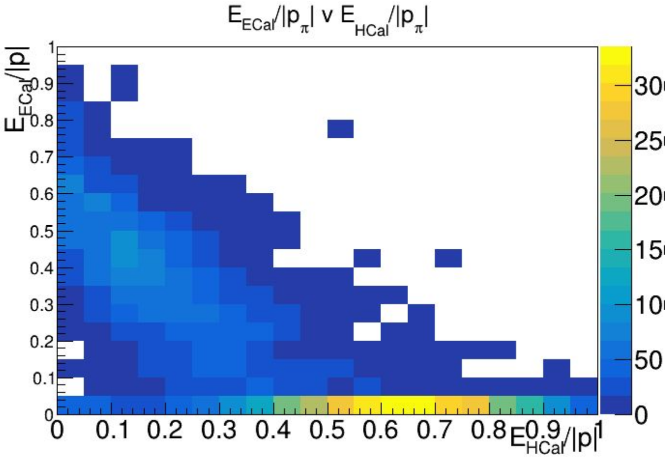
Using E/p in Both Barrel Calorimeters

University of Massachusetts Amherst

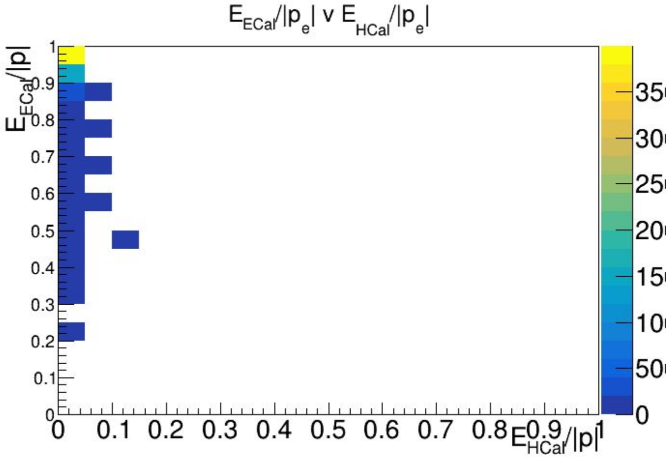
μ-



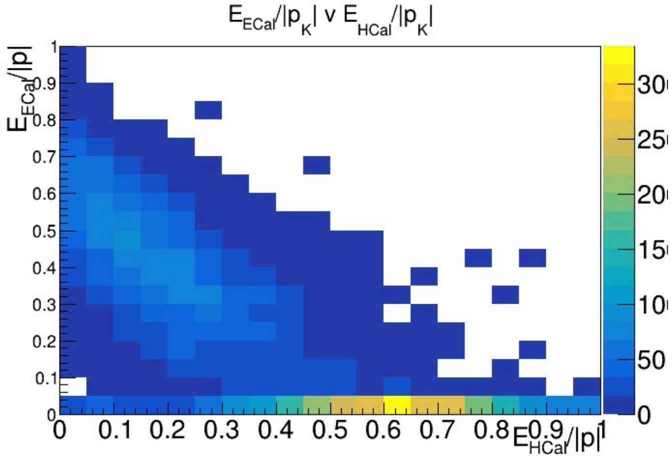
π-



e-



K-



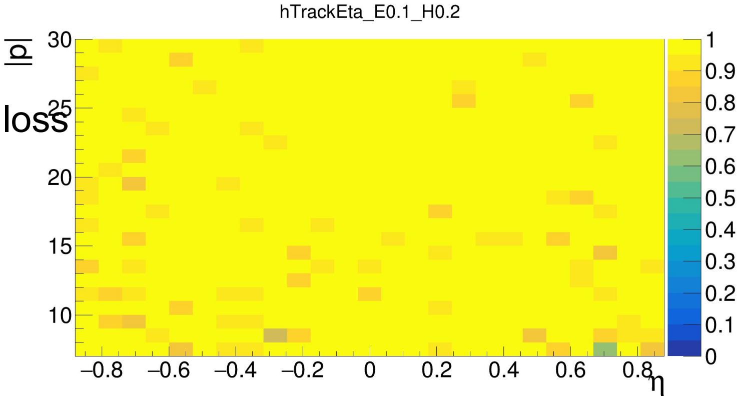
HCal E/p < 0.2 + ECal E/p < 0.1

University of Massachusetts Amherst

Z axis = events after combined E/p cut / events generated

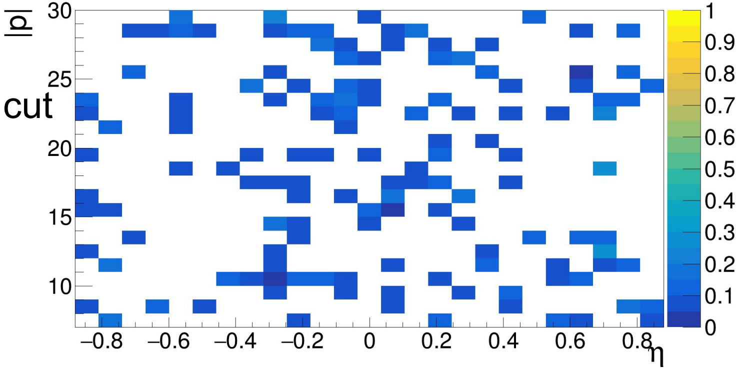
μ-

~1% loss



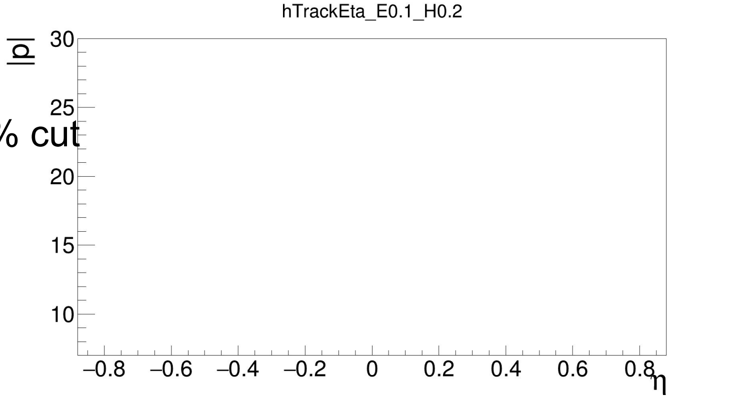
π-

98% cut



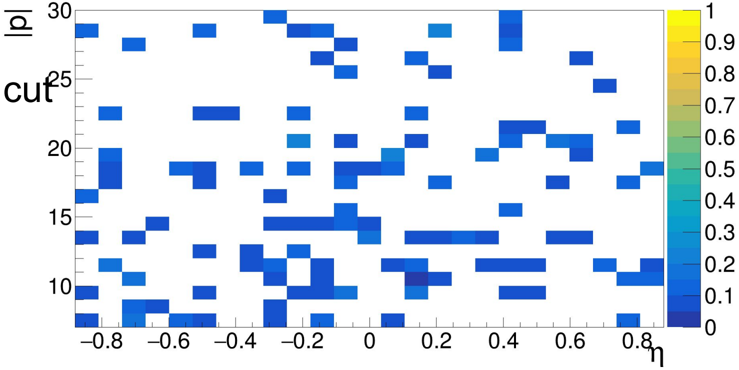
e-

>99% cut



K-

96% cut

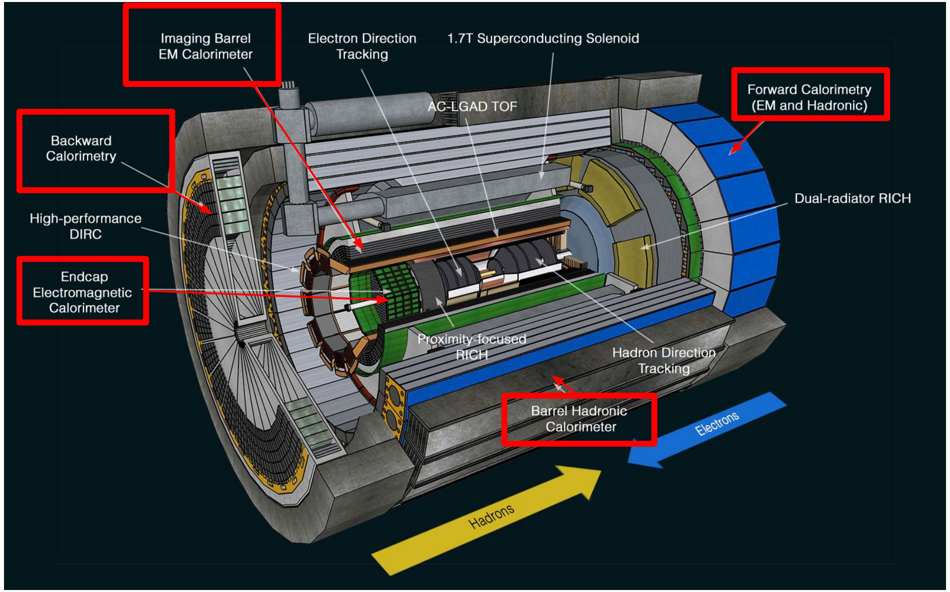


μ/π PID Study Data Set

University of Massachusetts Amherst

Simulation Details

- Single particle simulation using ddsim
  - 100K μ and π at each momentum and production angle:
    - $|p|$ = 1 to 15 GeV in 1GeV steps.
    - θ = 90° to 150° in 10° steps.
- Simulated in the ePIC detector
- Reconstructed using the EICrecon package



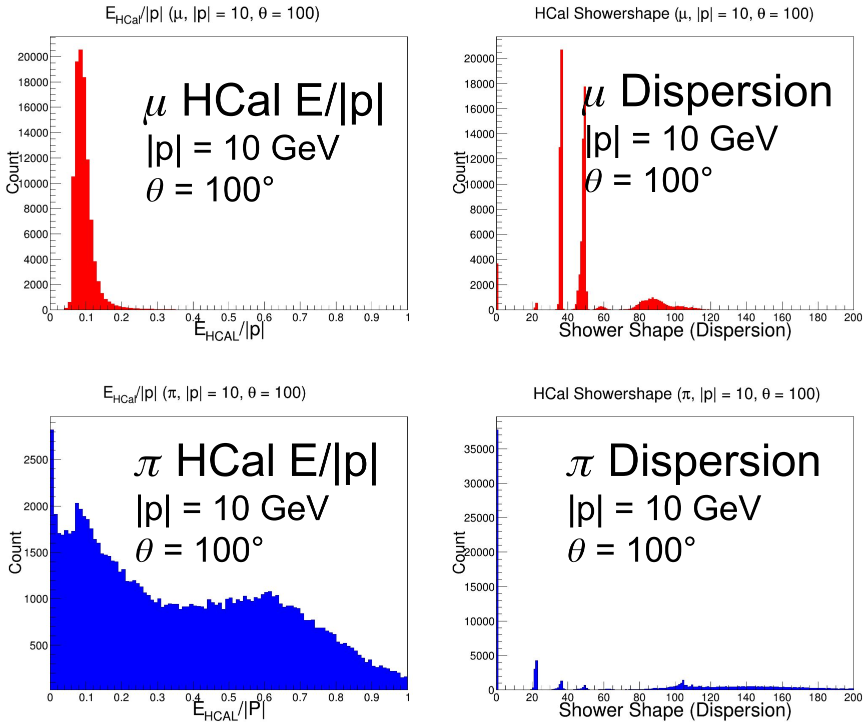
μ/π PID Values Used

University of Massachusetts Amherst

Reconstructed values used in this study

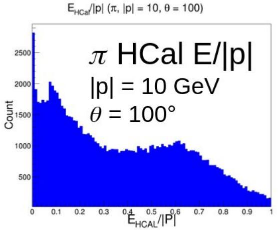
- ❖ Calorimeter $E_{cal}/|p|$ seems to be the most useful value in μ/π separation
- ❖ Dispersion (Energy weighted radius) improves separation somewhat.
  - ➢ Named 'Shower Shape' in the following slides.

Example Distributions



μ/π PID, Log-likelihood Approach

University of Massachusetts Amherst

- Using a log-likelihood reduces the PID separation to a single variable to which cuts can be tuned for any given analysis.
  - Easy to incorporate additional reconstruction values given sufficient data/simulation.
- Method:
  - Take distributions such as: 

and treat them as probability distributions

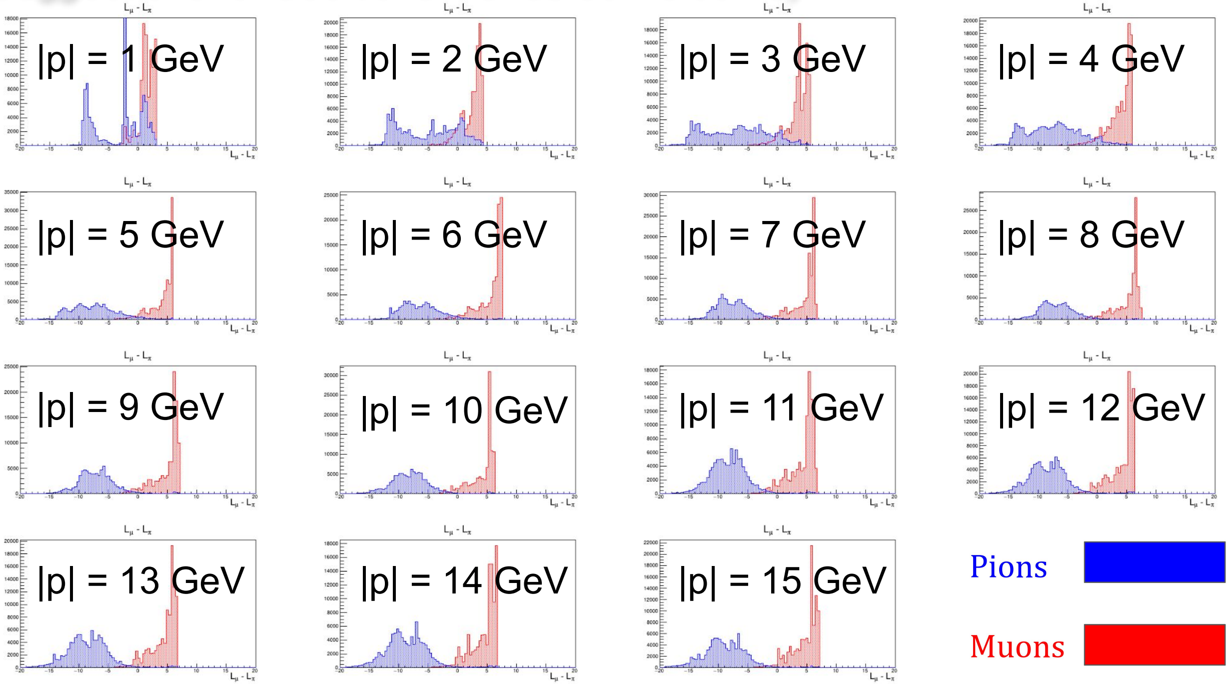
$P(q_{\pi,\text{HCal } E/|p|})$

  - Calculate the log-likelihood for each track:
    - $L_j = \ln(\mathcal{L}_j) = \ln(\Pi_i\, p(q_{ji})) = \Sigma_i \ln(p(q_{ji}))$.
    - where j is the PID hypothesis (μ or π in this case).
    - i is each reconstructed value used (e.g. HCal E/|p|).
    - $p(q_{ji})$ is the probability a track has a value q_{ji} for the given PID hypothesis and reconstructed variable.
  - Cut on the log-likelihood difference $L_\mu - L_\pi$

μ/π PID, Log-likelihood Example

University *of* Massachusetts Amherst

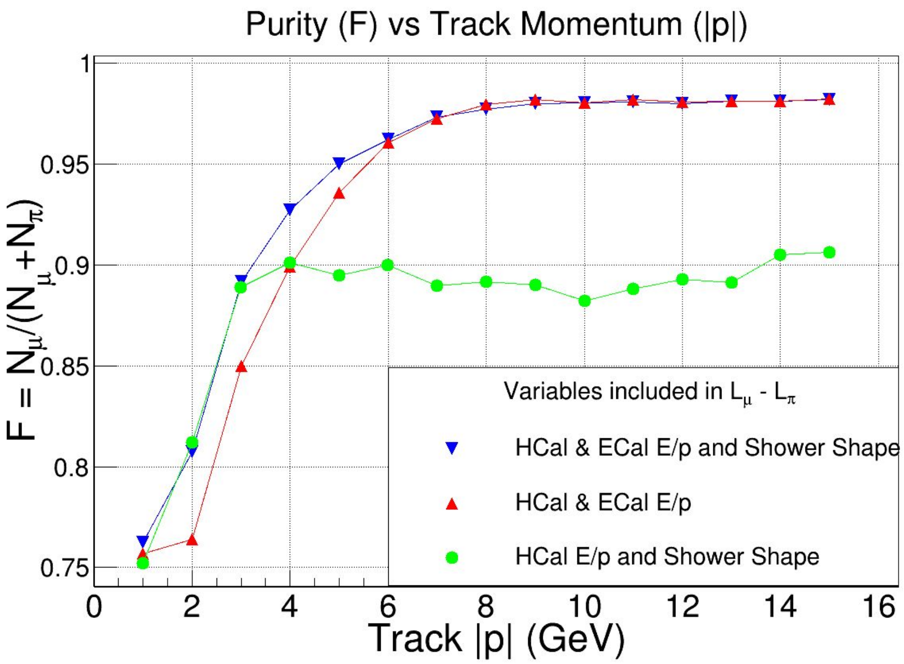
- $L_\mu - L_\pi$ for μ and π at θ = 90° with |p| = 1 GeV to 15 GeV in 1 GeV Steps.
- $L_\mu - L_\pi$ calculated using HCal E/|p|, HCal Shower Dispersion, ECal E/|p|, and ECal Shower Dispersion. (Suggestions for additional variables welcome)



μ/π PID, Log-Likelihood (cont.)

University of Massachusetts Amherst

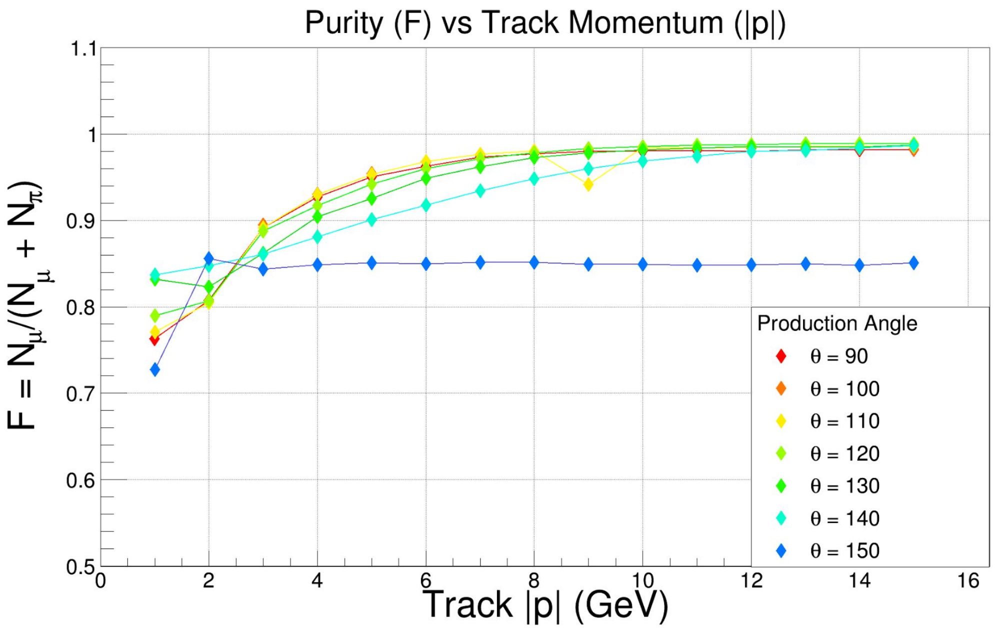
- Effect on L_μ - L_π calculated using different combinations of HCal E/|p|, HCal Shower Dispersion, ECal E/|p|, and ECal Shower Dispersion.
- Cut on L_μ - L_π > 0
  - Somewhat arbitrary. Cut can be tuned to balance purity and efficiency for individual analyses.
- Chose a purity ($N_\mu/(N_\mu+N_\pi)$) as a figure of merit to compare the following input value combinations:
  - HCal & ECal E/|p| and Shower Shape
  - HCal & ECal E/|p|
  - HCal E/|p| and Shower Shape



μ/π PID, Log-Likelihood (cont.)

University of Massachusetts Amherst

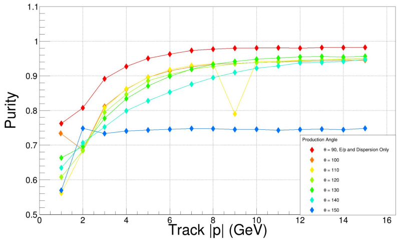
- $L_{\mu} - L_{\pi}$ calculated using HCal E/|p|, HCal Shower Dispersion, ECal E/|p|, and ECal Shower Dispersion.
- Now plotting the purity figure of merit for samples generated at different angles
  - 90° to 150° in 10° steps



Work to be done on μ/π separation

University of Massachusetts Amherst

- Extend study to other regions of the ePIC detector.
- Calorimeter shower profiles.
  - Shower Widths (2nd moments)



  - HCal hit Isolation cut
  - Hits or radius per layer
  - Other suggestions welcomed
- Including other PID detector signals.
- Implementing Machine Learning tools.
- Extending study to other regions of the ePIC detector.