BNL LDRD Detector-II Weekly Meeting

Short Update on Muon ID Study

Jihee Kim (jkim11@bnl.gov)

Brookhaven National Laboratory

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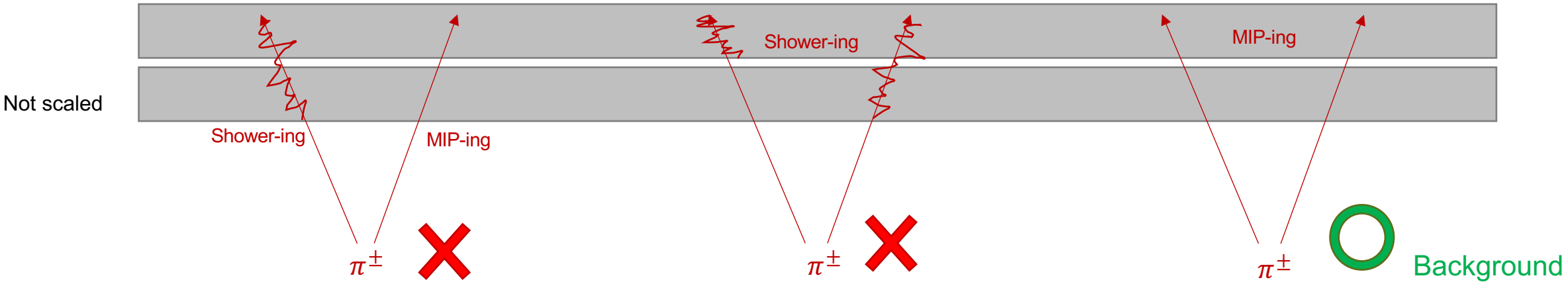
Approach – DIS Background

- Goal: estimation of background from DIS sample
  - $\pi^{\pm}$ can be background to $\mu^{\pm}$ when pions act like MIP

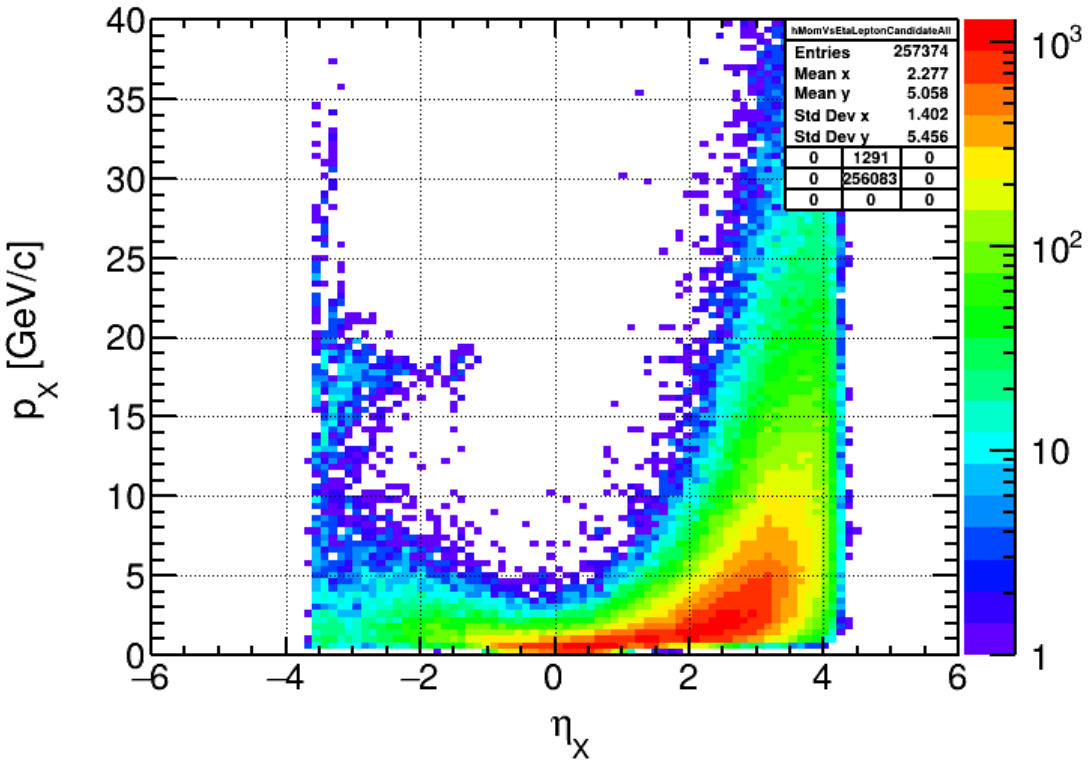


- Use tracker information to reconstruct invariant mass, but adding calorimeter information to determine if they are MIP-like particles

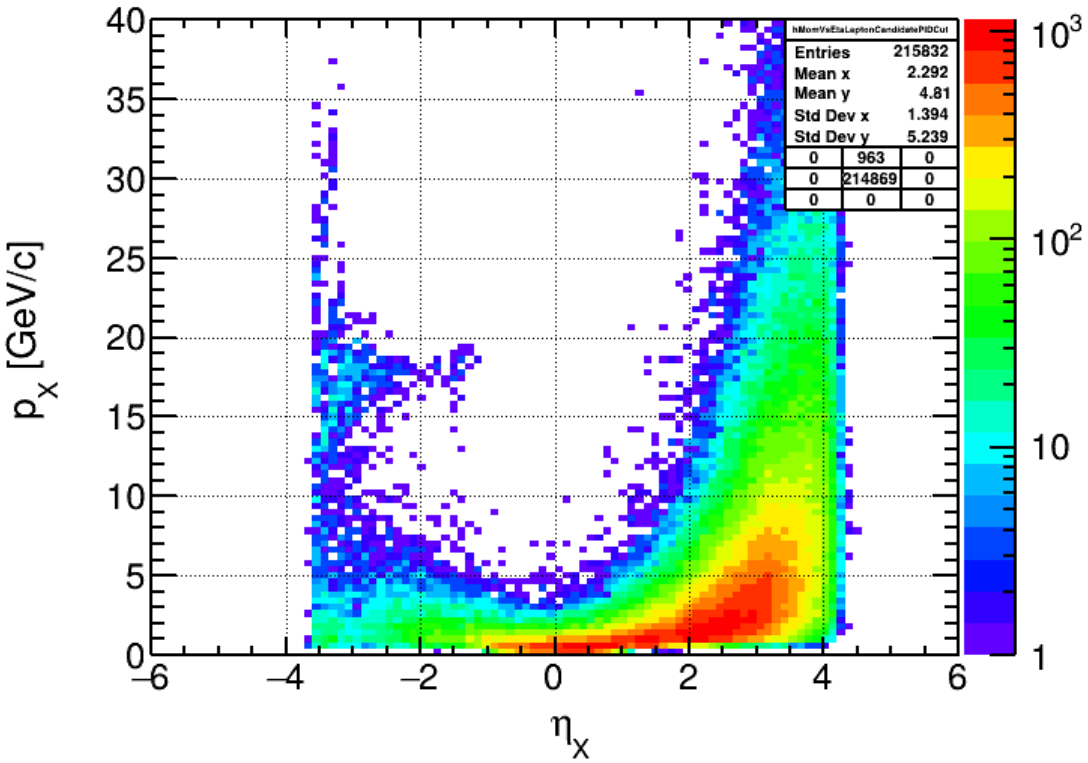
Two remaining particles within an 3-track event (removed scattered electron)

Kinematics – p vs η

All two remaining particles



All two remaining particles after PID cut



Many of particles going to forward region with higher momentum

Exercise for DIS Events

Input variables to determine $\mu^{\pm}/\pi^{\pm}$

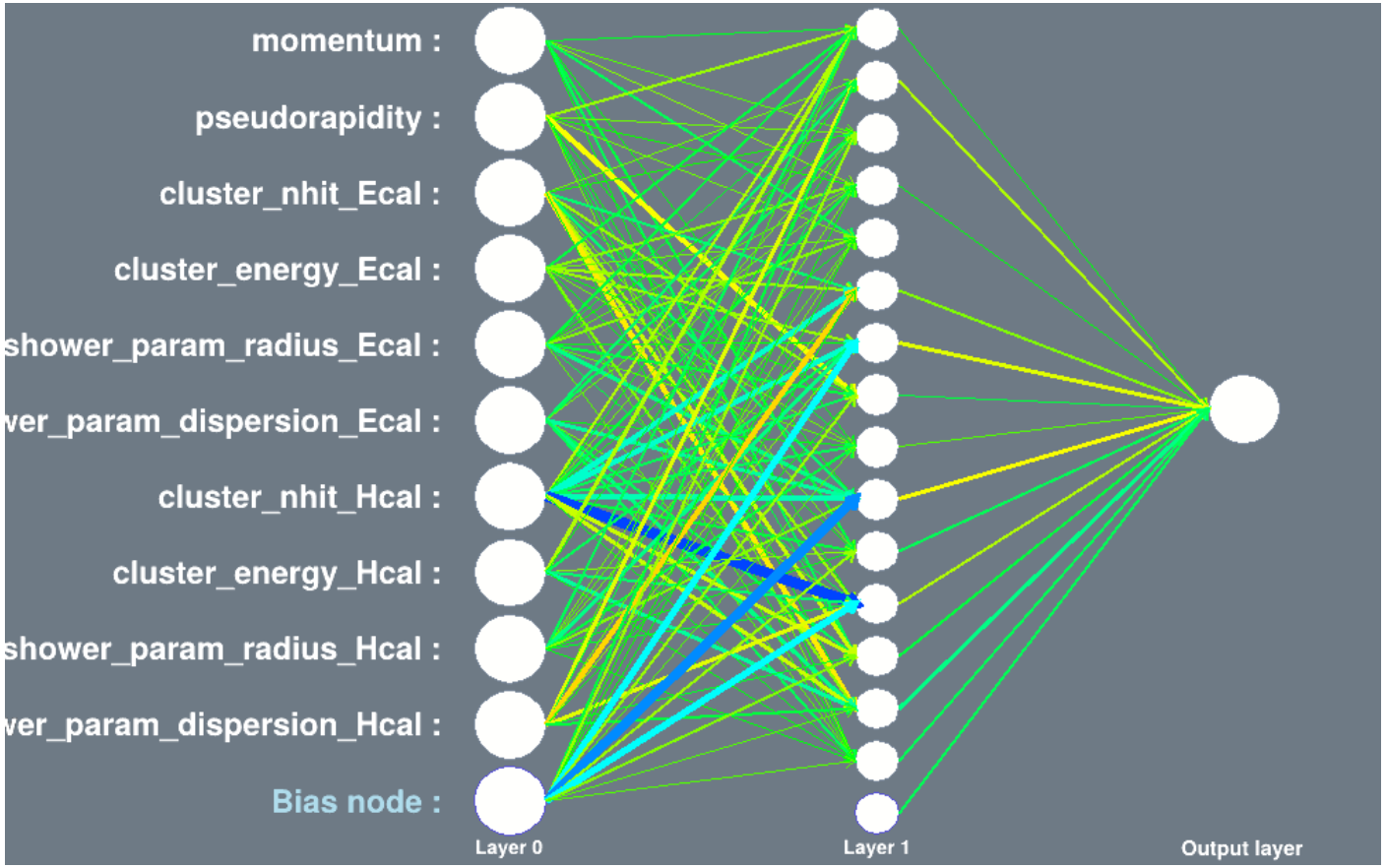
- Momentum
- Pseudo-rapidity
- Cluster information in both ECAL and HCAL
  - Number of hits
  - Energy
  - Cluster shape parameter radius
  - Cluster shape parameter dispersion (energy weighted radius)

Currently matched cluster with closest track, but

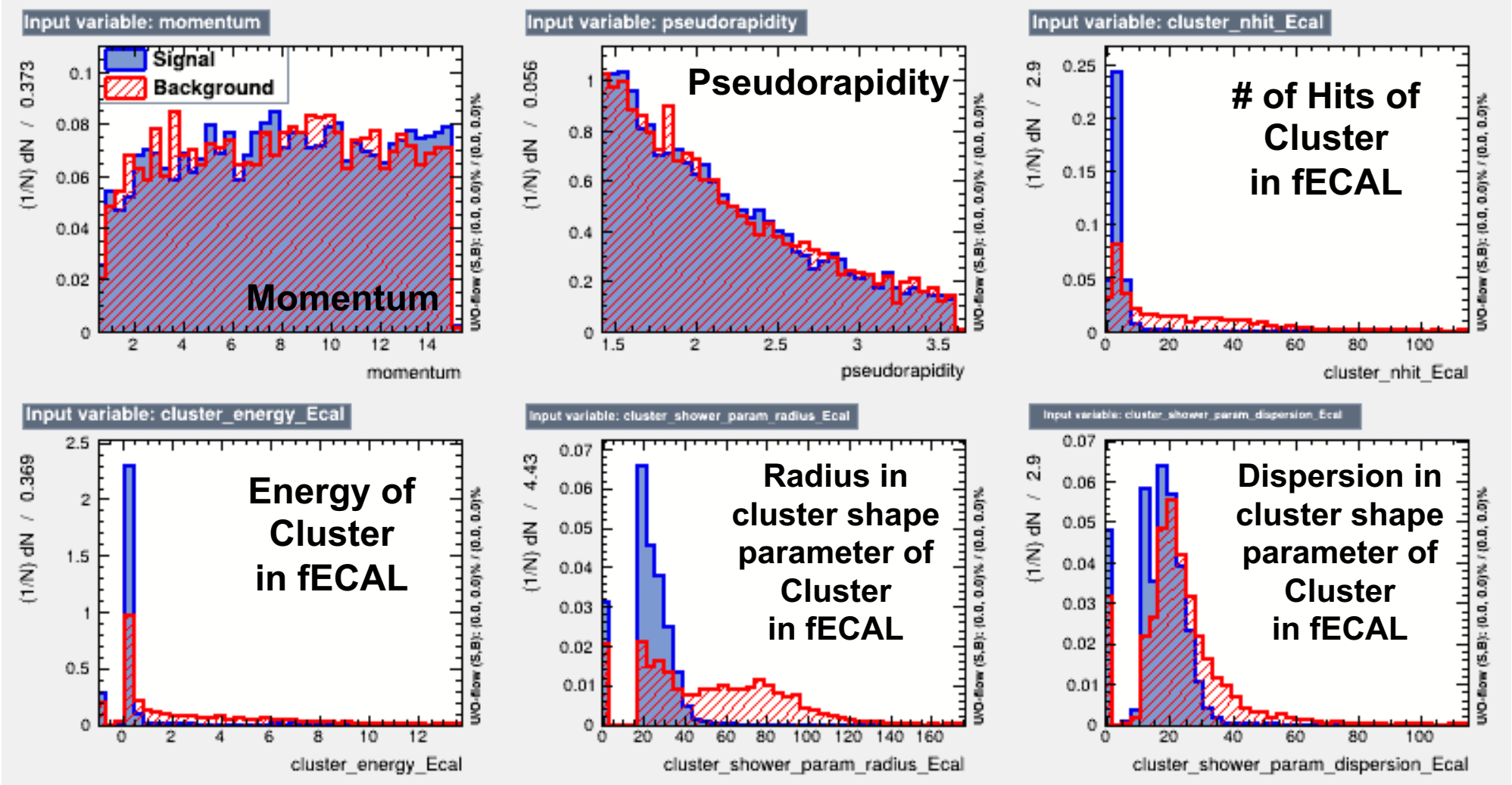
Talked to Derek Anderson about matching track projection to calorimeter cluster (WIP)

Input Variables

- Use TMVA: Toolkit for Multivariate Data Analysis with ROOT
  - Artificial Neural Networks (MultiLayer Perceptron)
- Default configuration
  - One hidden layer
  - N_{var}+5 neurons
- 10k events
  - 5k is used for training
  - Another 5k is used for testing
  - 9 inputs
- Lepton candidates (p, η)
- ECAL cluster (nhit, E, shape params)
- HCAL cluster (nhit, E, shape params)

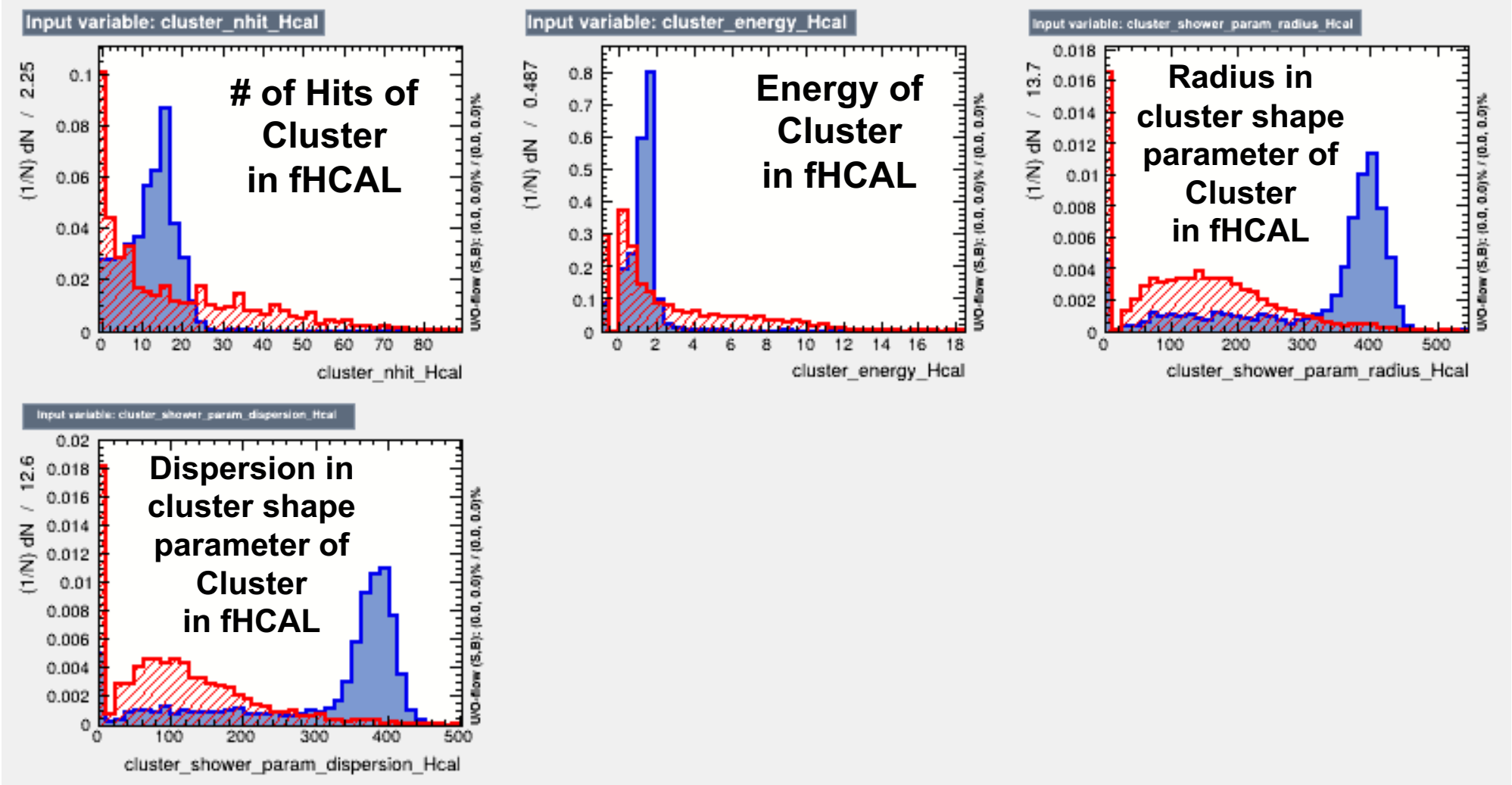


Input Distribution in Forward Region



Figures are normalized to show 1/N*dN/dx. So integral of histogram equals to 1.

Input Distribution in Forward Region



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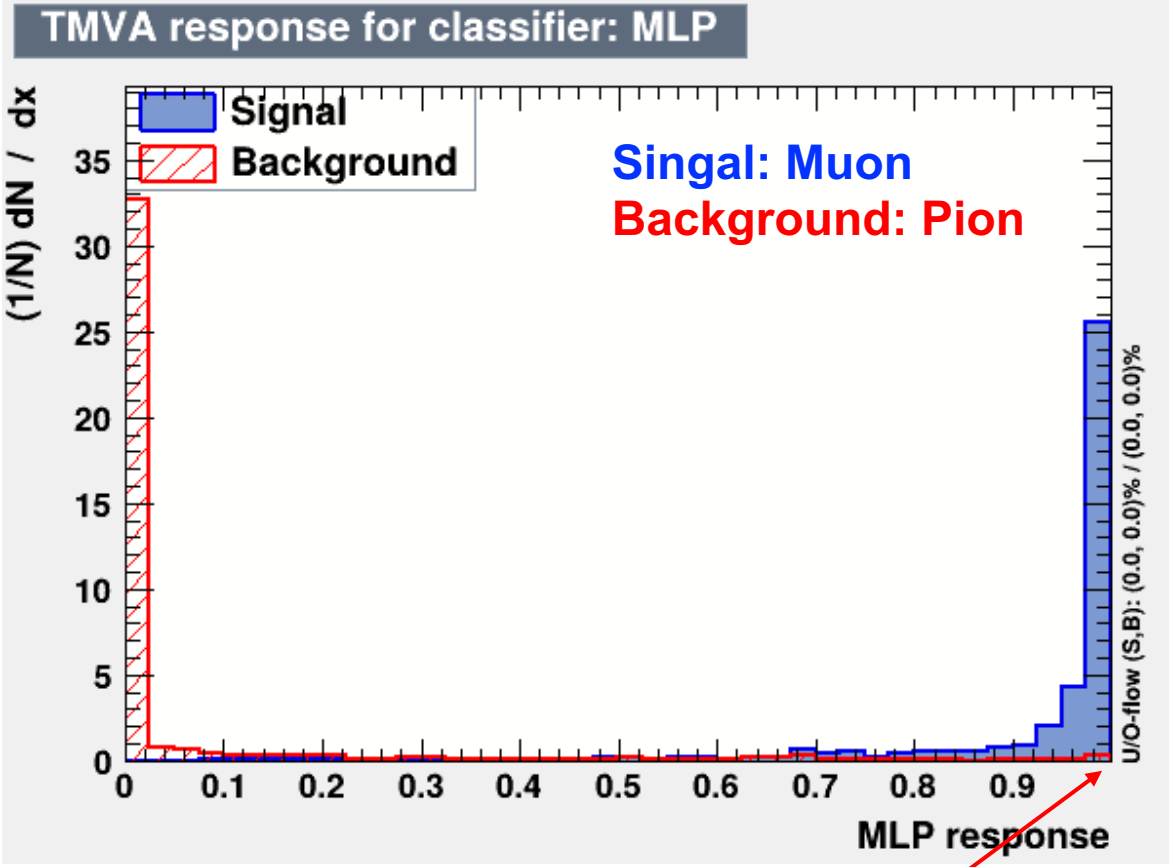
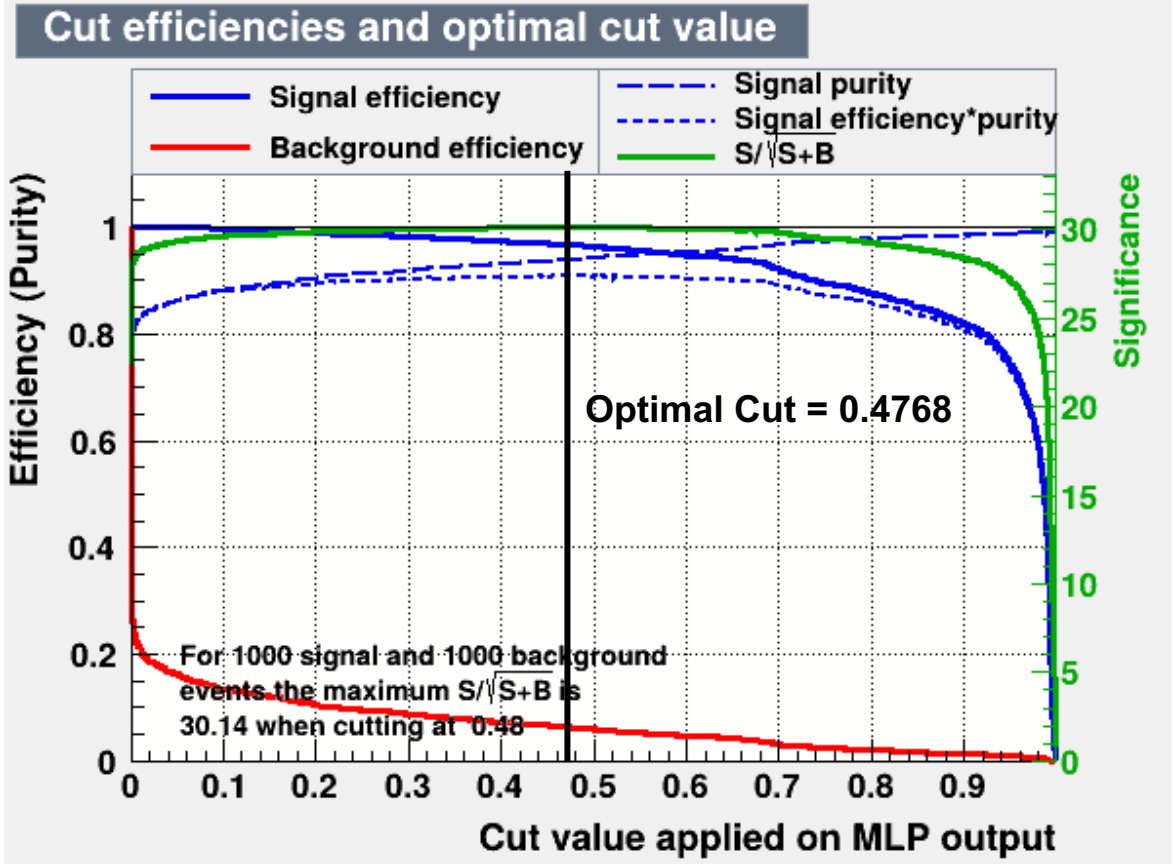
Signal/Background Efficiency



MIP-like background (pions)



$\varepsilon_{Bg} = 0.9676$ for $\varepsilon_{Sg} = 0.06299$

Results in Forward Region

Tested with ~1M muon and ~1M pion simulation samples

Momentum range: $0.1 < p < 15.0$

Rapidity range: $1.4 < \eta < 3.9$

Momentum [GeV/c]	Muon Efficiency	Background Rejection Efficiency	Mis-ID Efficiency
0.1 < p < 15.0	0.958879	0.804771	**0.195229**

where

Muon Efficiency: Muon to Muon = $\frac{N_{\mu\to\mu}}{N_{\mu}}$

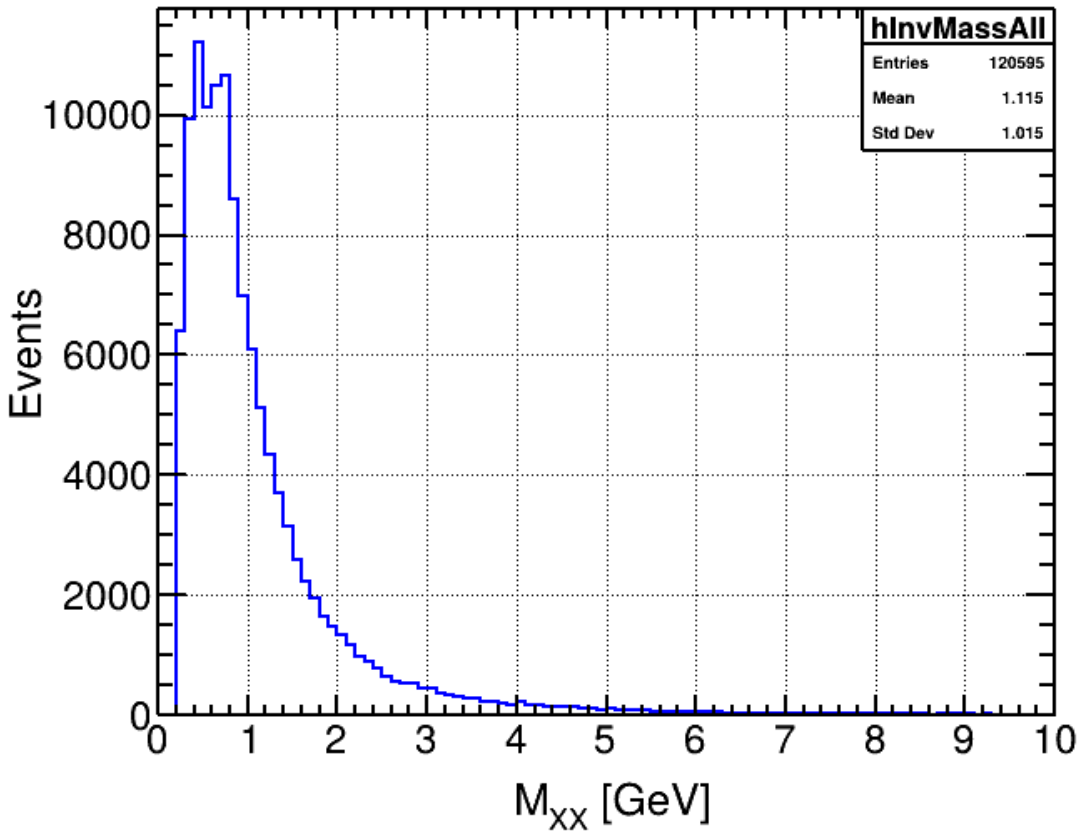
Background Rejection Efficiency: Pion to Pion = $\frac{N_{\pi\to\pi}}{N_{\pi}}$

Mis-ID Efficiency: Pion to Muon = $\frac{N_{\pi\to\mu}}{N_{\pi}}$

DIS Events in Forward Region

DIS sample

- 1M ep 18 GeV on 275 GeV with $Q^2_{min} = 1$
- Select events with 3 reconstructed tracks (which mimics exclusive channels)
- Exclude scattered e by TRUE ID
- Calculate M_{xx} using remaining 2 tracks (assuming muon mass, m_μ)



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- Select events with 3 reconstructed tracks (which mimics exclusive channels)
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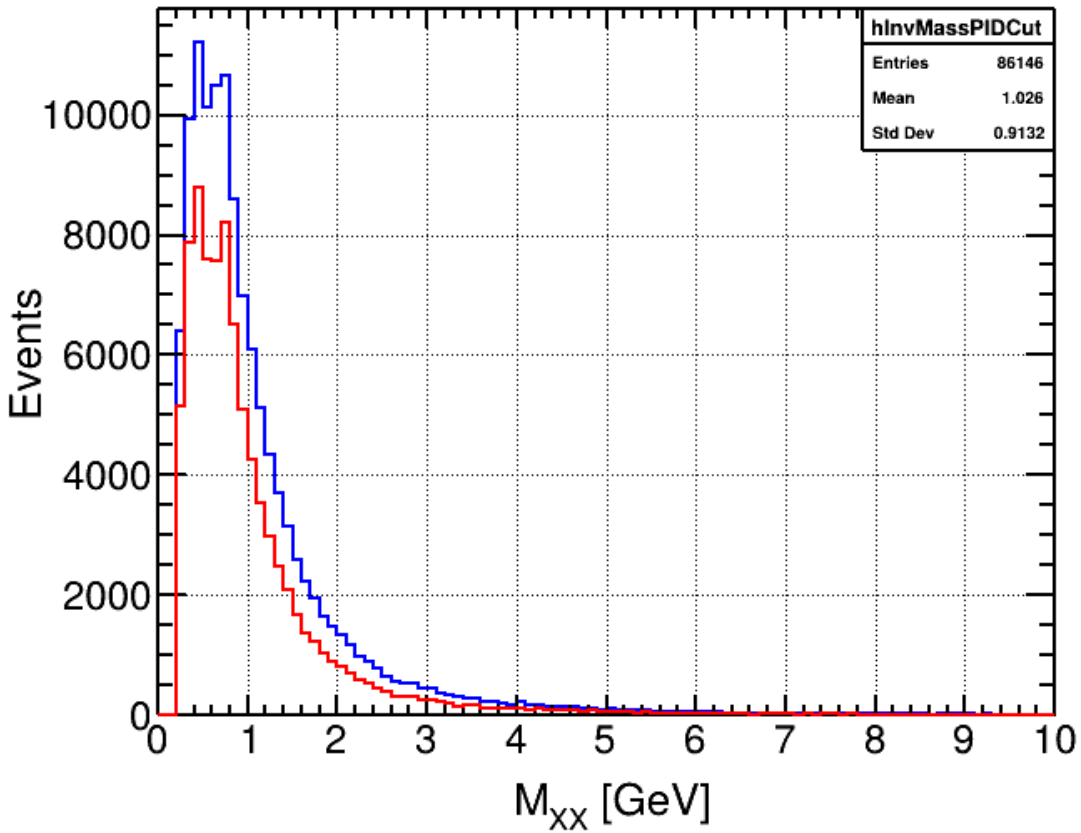
- Calculate M_{xx} using remaining 2 tracks (assuming muon mass, m_μ)
- Exclude p and $K^{\pm}$ by TRUE ID and Calculate M_{xx} using remaining 2 tracks (mostly pions)



Results in Forward Region

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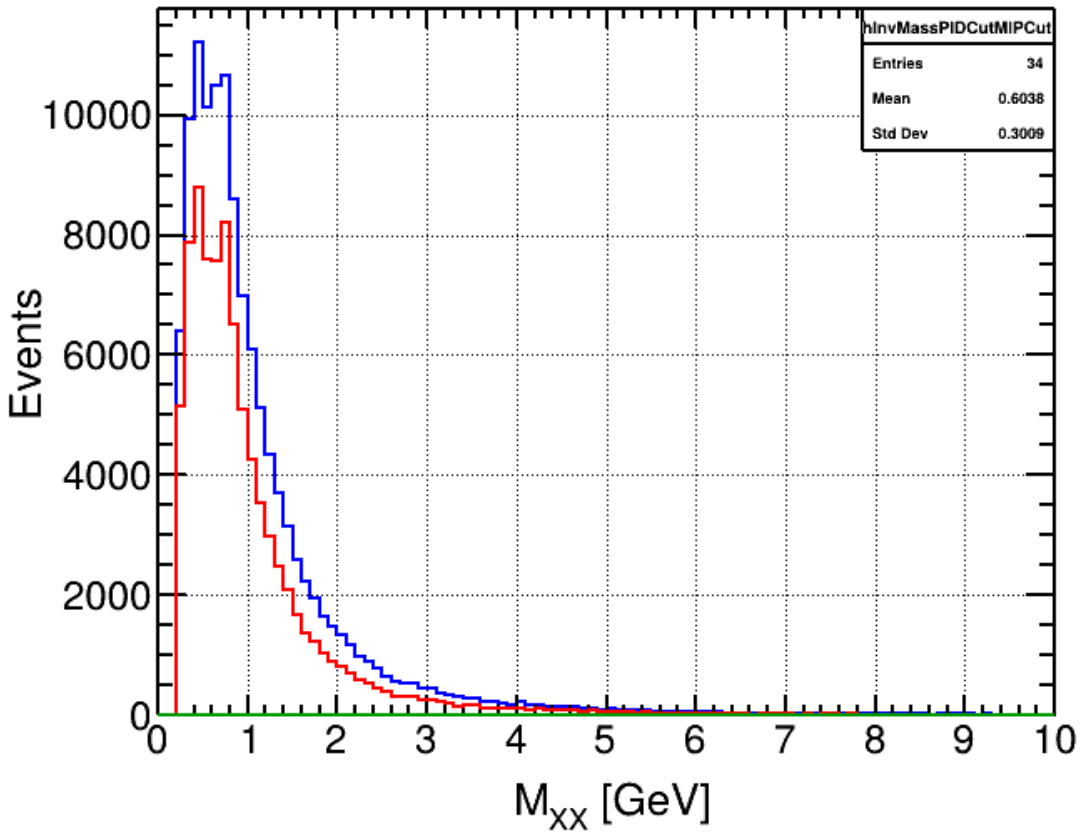
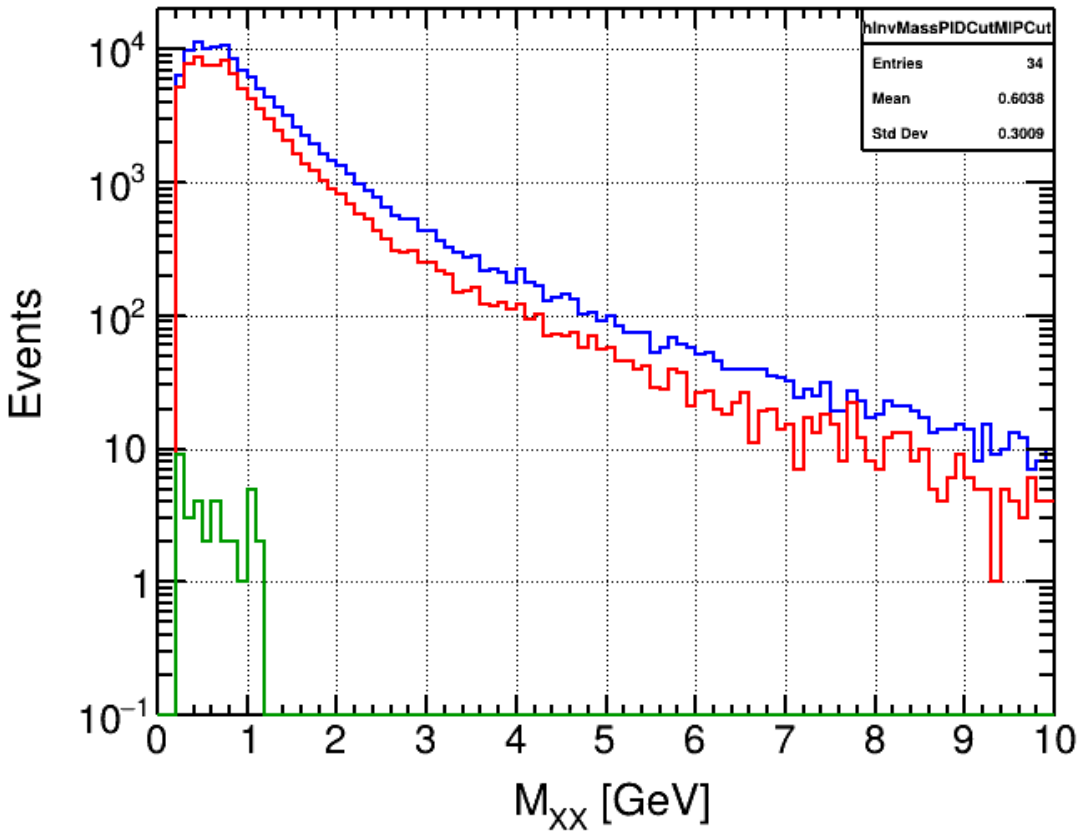
- Apply MIP-like cuts (not TMVA yet) based on input distributions of muons and pions and Calculate M_{xx} using remaining 2 tracks



Results in Forward Region

DIS sample

- 1M ep 18 GeV on 275 GeV with $Q^2_{min} = 1$
- Select events with 3 reconstructed tracks (which mimics exclusive channels)
- Exclude scattered e by TRUE ID
- Calculate M_{xx} using remaining 2 tracks (assuming muon mass, m_μ)
- Exclude p and $K^{\pm}$ by TRUE ID and Calculate M_{xx} using remaining 2 tracks
- Apply MIP-like cuts (not TMVA yet) based on input distributions of muons and pions and Calculate M_{xx} using remaining 2 tracks in Log scale



To-Do List

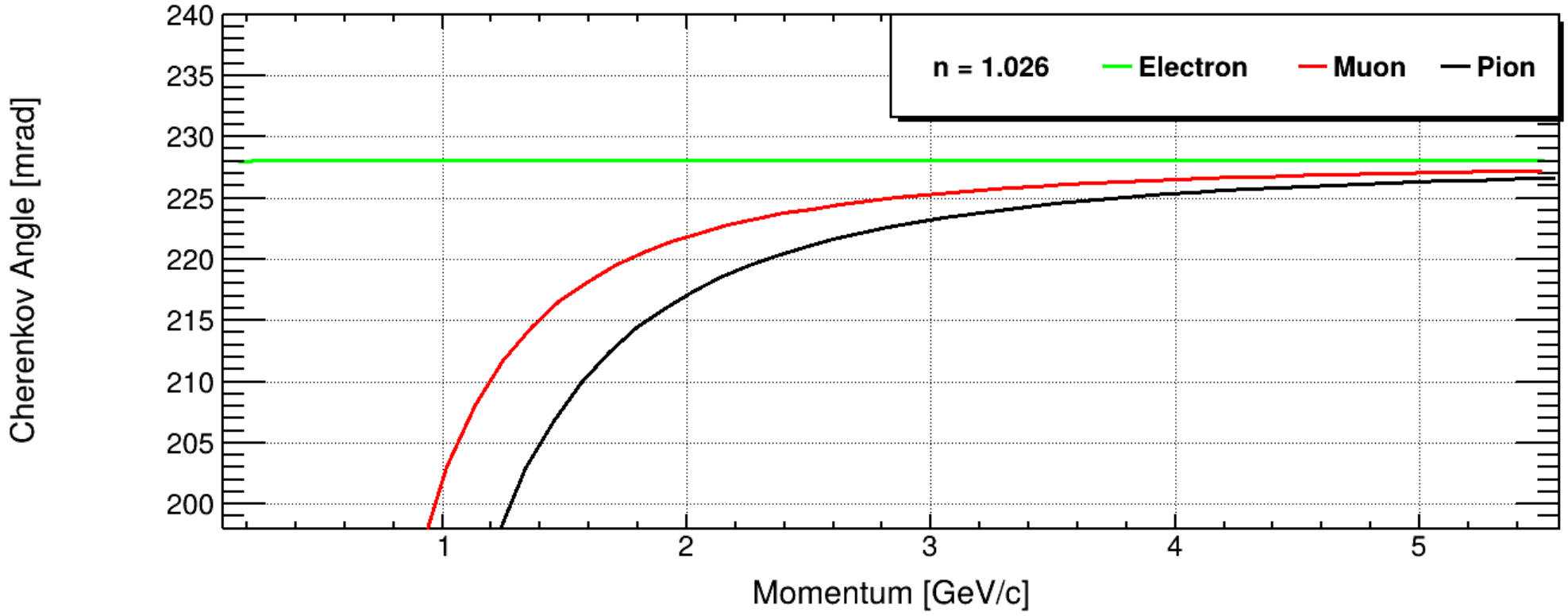
- Use TMVA on ep DIS events to estimate background
  - Evaluate in three rapidity regions (backward/central/forward)
  - Consider adding in reconstructed hit level information
  - Consider using PID look-up table information
  - Look at different Q^2_{min} values and beam configurations

- PID information
  - Evaluate dRICH gas performance in μ/π since so far dRICH aerogel performance is estimated
  - Possibly include PID information at analysis level?

Backup Slides

Estimate PID Performance

Based on $\theta^2 \sim 2(n-1) - \frac{m^2}{p^2}$ where n = 1.026 (dRICH)



Estimate PID Performance

▼ Muon and pion separation in Cherenkov Angle

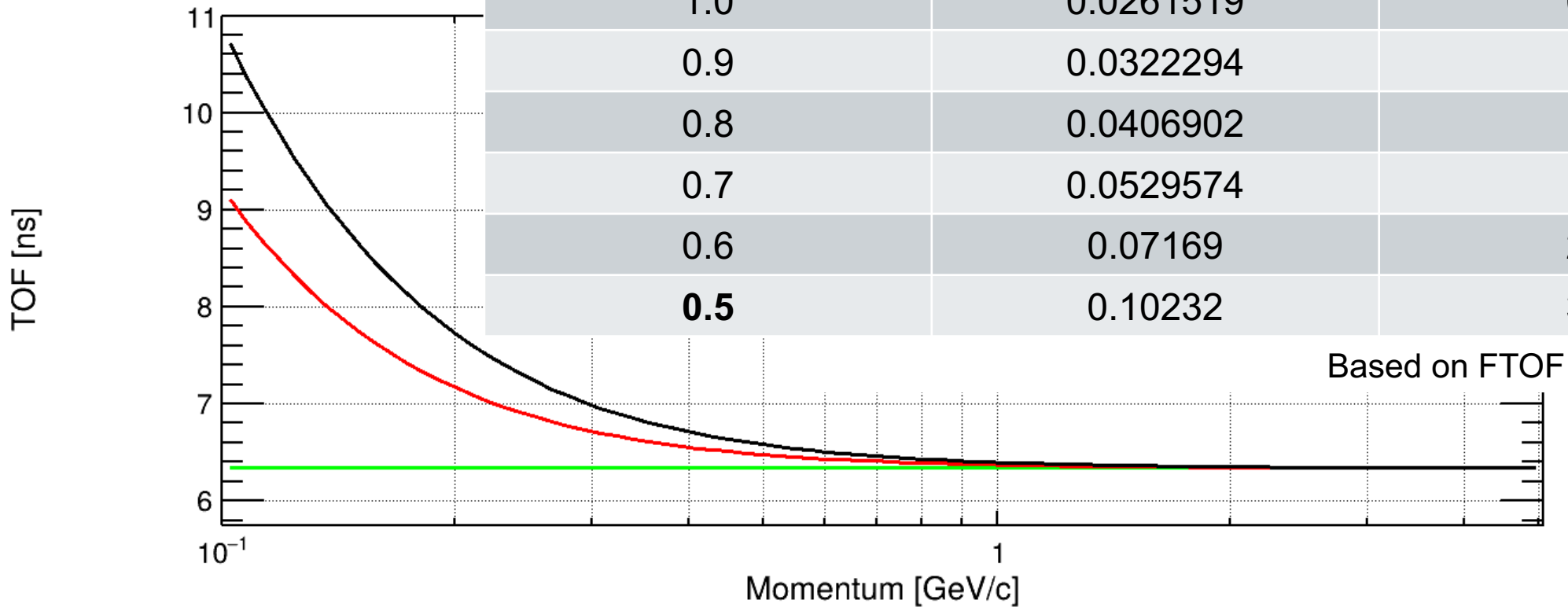
	n = 1.015	n = 1.026	n = 1.040
p = 1.5 GeV	12.1446 [mrad]	8.69475 [mrad]	6.83120 [mrad]
p = 2.0 GeV	6.42687 [mrad]	4.73642 [mrad]	3.76644 [mrad]
p = 2.5 GeV	4.00843 [mrad]	2.98872 [mrad]	2.38896 [mrad]
p = 3.0 GeV	2.74643 [mrad]	2.05997 [mrad]	1.65104 [mrad]
p = 3.5 GeV	2.00184 [mrad]	1.50669 [mrad]	1.20952 [mrad]

- In ePIC baseline aerogel refraction index ~ 1.019
- However, n = 1.026 performs better because of optical quality of material improvement (CLAS12 n = 1.019)
- Aerogel single photon resolution for 1.026 ~ 2.4 mrad (where for 1.019 ~ 3 mrad)
- With aerogel 1.026 we gain ~ 50 % more photons compared to 1.019
- Regarding ring (track-level) resolution, it depends on thickness optimization of aerogel (4 cm and 6 cm were studied). Resolution 0.5 mrad and given we can detect 15 photons

FTOF Performance – Time of Flight

Momentum [GeV/c]	Difference in TOF [ns]	Estimated σ Level
1.0	0.0261519	0.87
0.9	0.0322294	1.07
0.8	0.0406902	1.36
0.7	0.0529574	1.77
0.6	0.07169	2.39
0.5	0.10232	**3.41**

Based on FTOF resolution 30 ps



Assumed distance (straight from IP to FTOF plane; z_{min} = 185 cm and r_{max} = 60 cm)

PID Summary for Muon ID

dRICH n = 1.026	Difference in Cherenkov Angle [mrad]	Estimated σ Level
p = 1.5 GeV	8.69475	17.4σ
p = 2.0 GeV	4.73642	9.5σ
p = 2.5 GeV	2.98872	6σ
p = 3.0 GeV	2.05997	4.1σ
p = 3.5 GeV	1.50669	**3σ**
FTOF d = IP to FTOF plane	**Difference in TOF [ns]**	**Estimated σ Level**
p = 1.0 GeV/c	0.0261519	0.87σ
p = 0.8 GeV/c	0.0406902	1.36σ
p = 0.7 GeV/c	0.0529574	1.77σ
p = 0.6 GeV/c	0.07169	2.39σ
p = 0.5 GeV/c	0.10232	**3.41σ**

Upper limit (3σ separation)

- dRICH
  - μ/π up to 3.5 GeV/c
- FTOF
  - μ/π up to 0.5 GeV/c

dRICH could be helpful for low momentum (below 3.5 GeV/c)

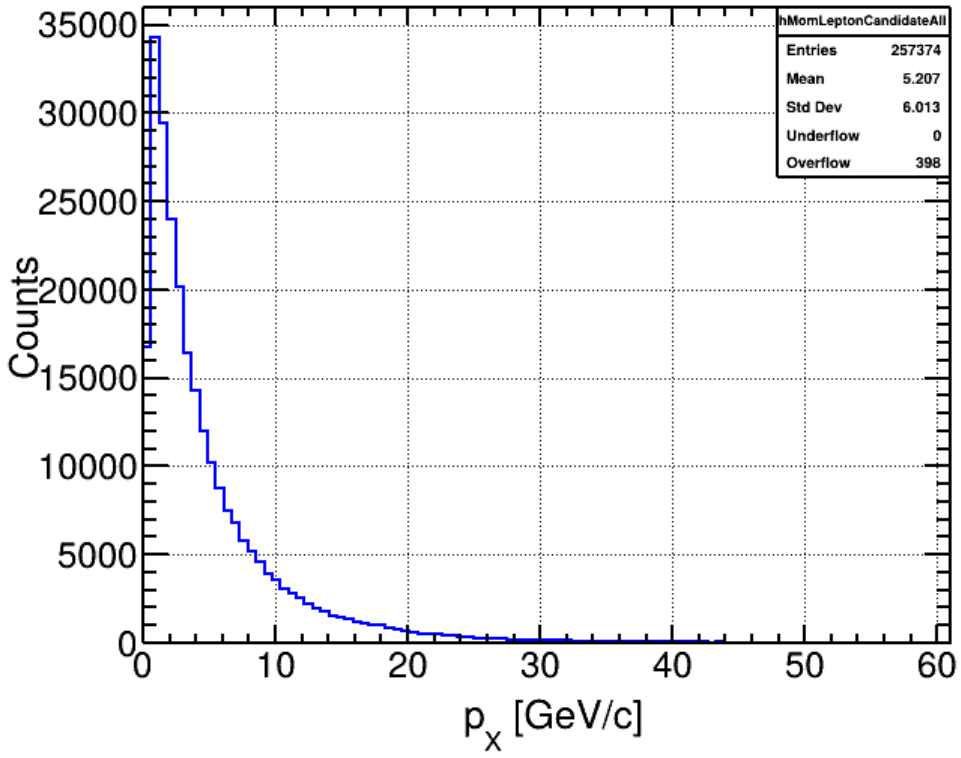
Need to think about

- Good enough momentum resolution at very low momentum
- How many low momentum muons/pions can travel beyond PID and reach up to forward calorimeter

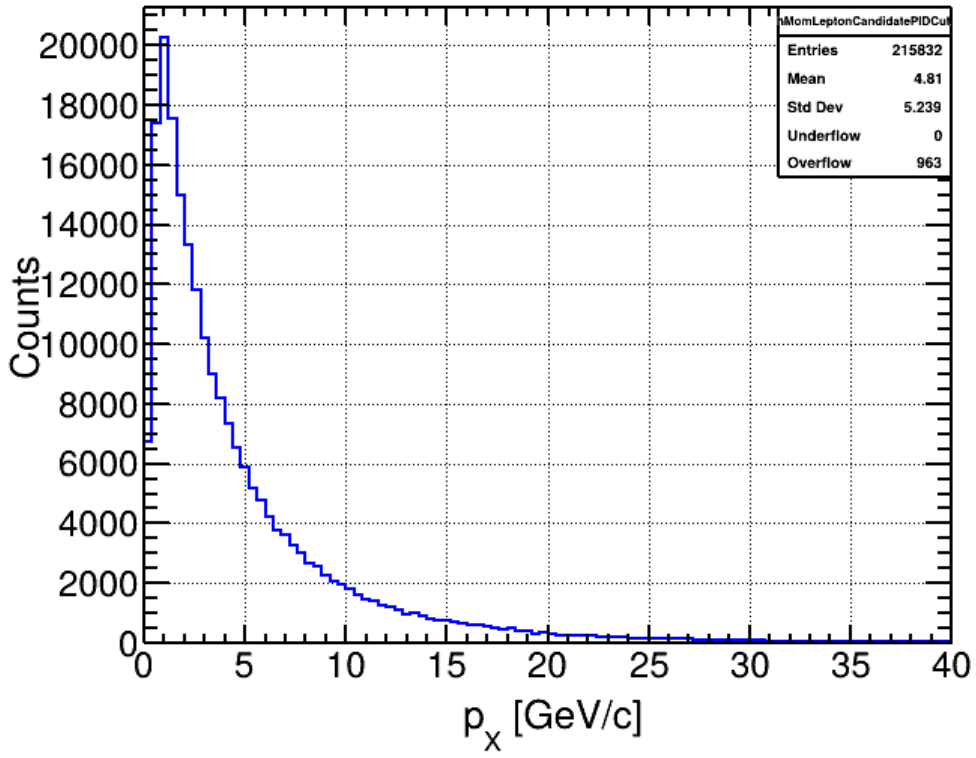
Two remaining particles within an 3-track event (removed scattered electron)

Kinematics – Momentum (p)

All two remaining particles



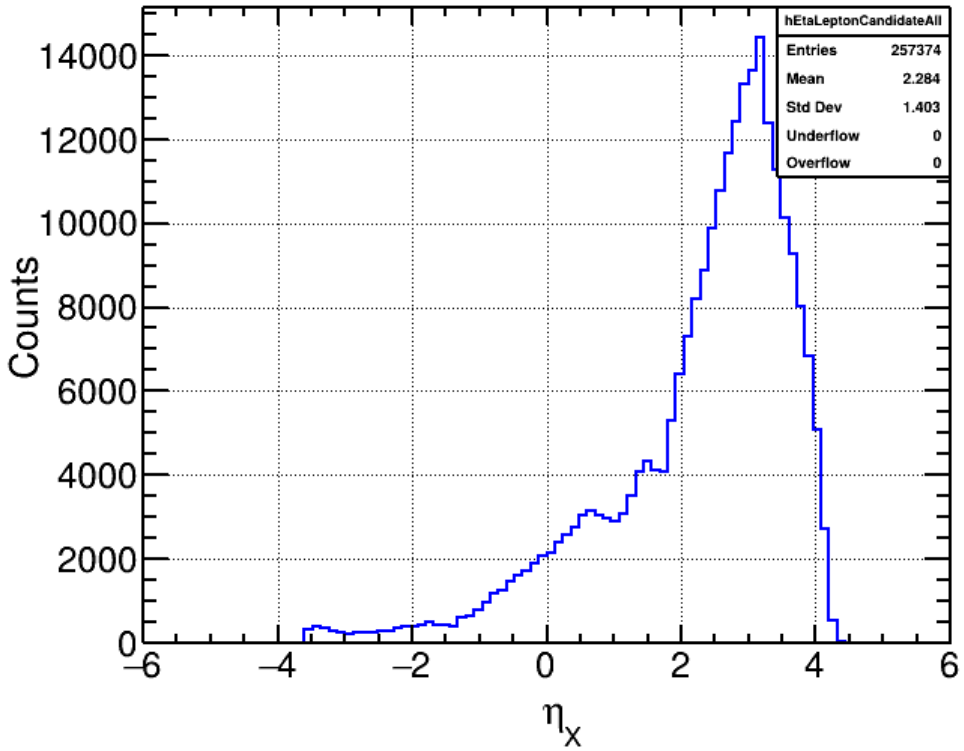
All two remaining particles after PID cut



Two remaining particles within an 3-track event (removed scattered electron)

Kinematics – Pseudo-rapidity (η)

All two remaining particles



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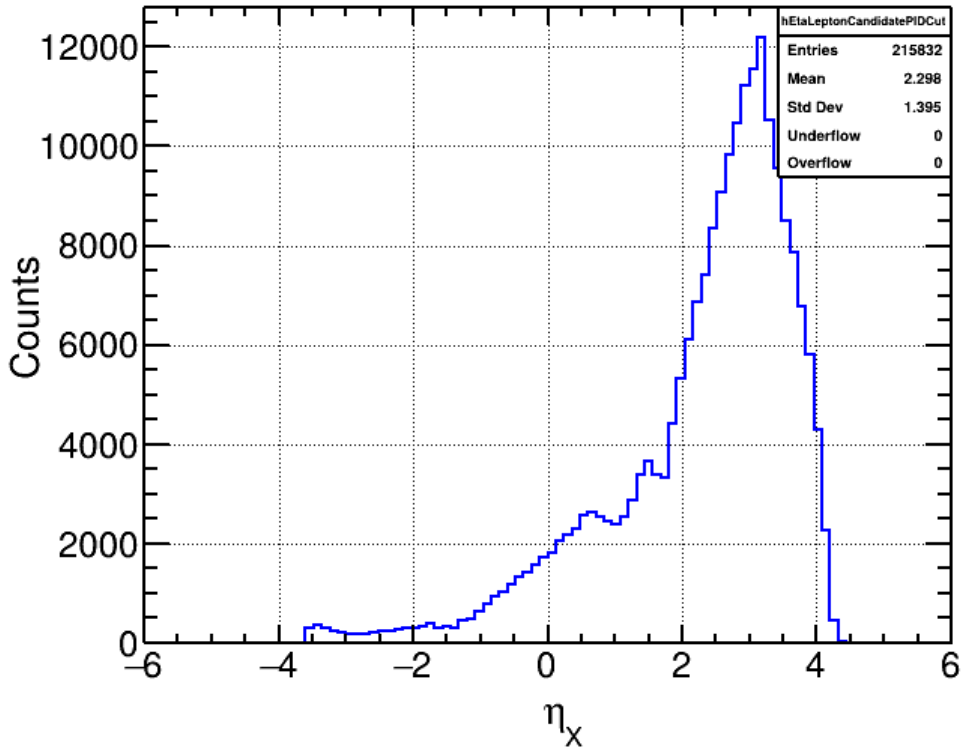

Many of particles going to forward region with higher momentum