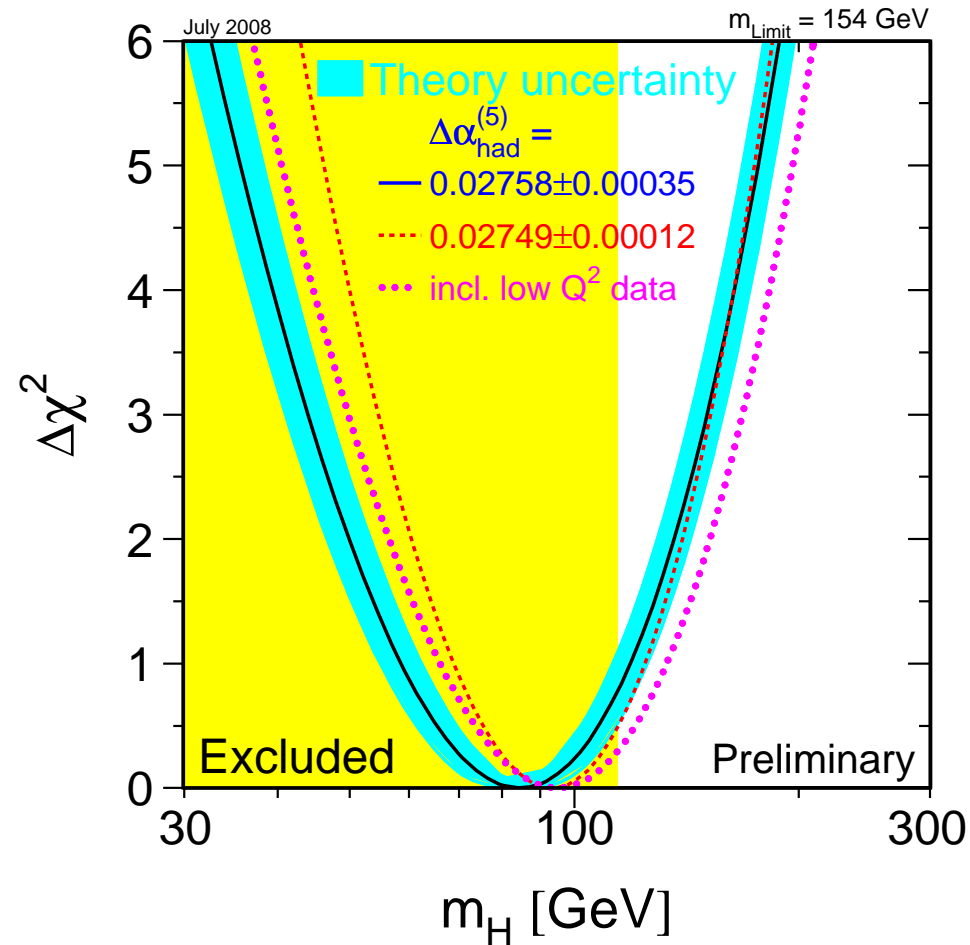


# $W + 4\tau$ NMSSM Higgs Search

Soft Electrons

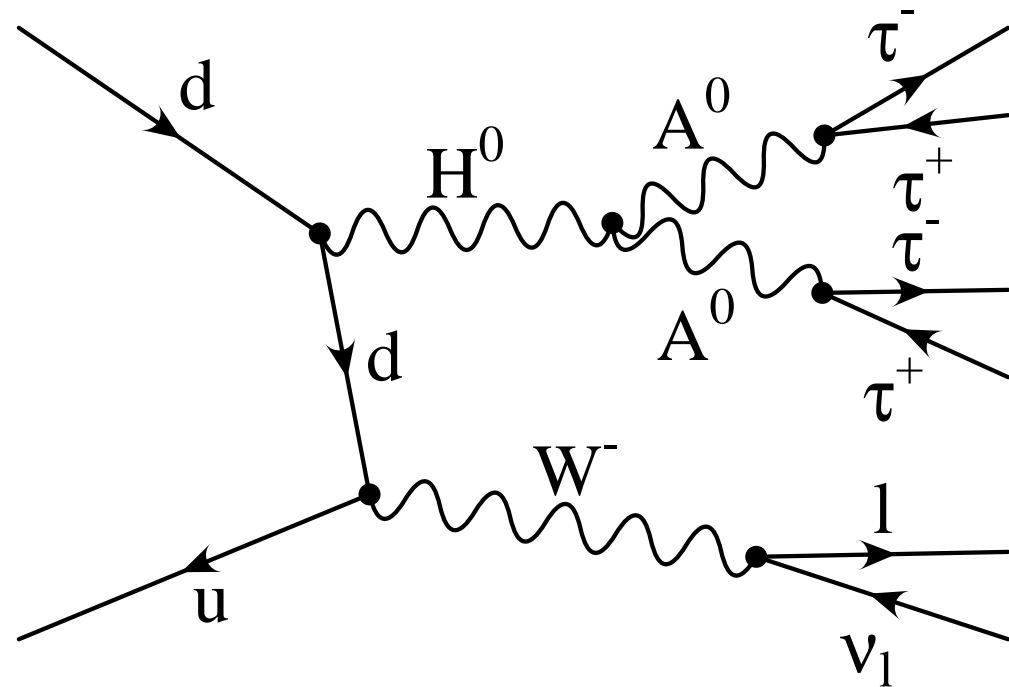


Henry Frisch, Dan Krop, Carla Pilcher, Scott Wilbur

*University of Chicago*

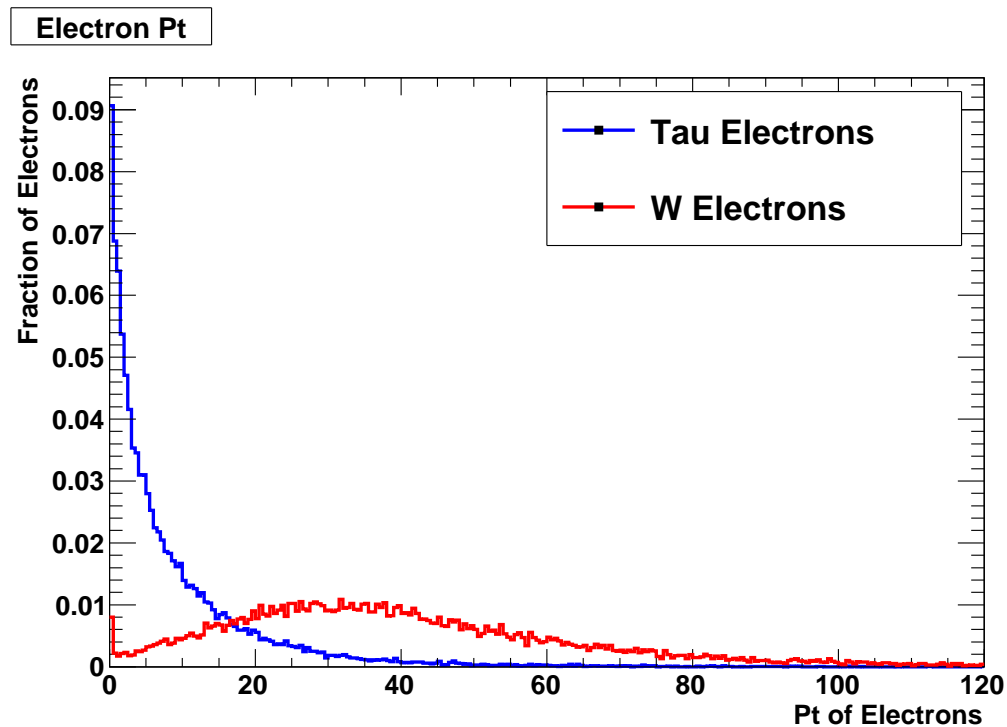
# $W + 4\tau$ NMSSM Higgs Search

- Searching in the  $W + H$  channel
- Our signal MC is  $W + H$  production with  $W$  decaying leptonically
- Currently only examining signal; background comes later
- Principal background expected to be  $W + \text{jets}$



# Soft Electrons

- $\tau$  decays to  $e$  18% of the time
- With four  $\tau$ s, 55% of events will have at least one  $\tau \rightarrow e$
- In this model, ( $m_H = 90$  GeV,  $m_{A^0} = 9$  GeV) electrons from taus are very soft
  - $W$  electrons peak at 30 GeV
  - $\tau$  electrons have median of 5 GeV



# Why a Soft Electron ID?

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- The standard electron ID is only good for  $P_t > 20$ , according to the Lepton Working Group
- The standard electron ID only finds 1.2% of events after requiring a hard lepton and  $\cancel{E}_t$ . (Compared to 55% of events which should have a soft electron)
- I will describe a likelihood-based soft electron identifier based on the  $b$ -group's soft electron tagger. (Note 7121)
- This soft electron ID finds 25% of the events after the other cuts. (losses are from detector coverage)

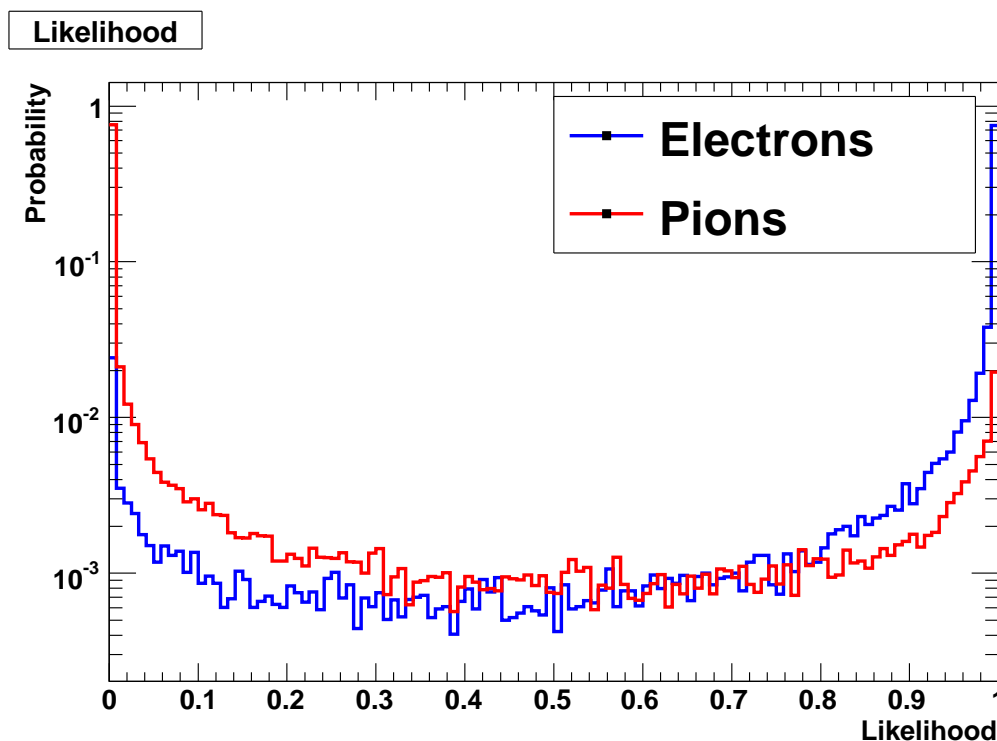
# Description of Soft Electron ID

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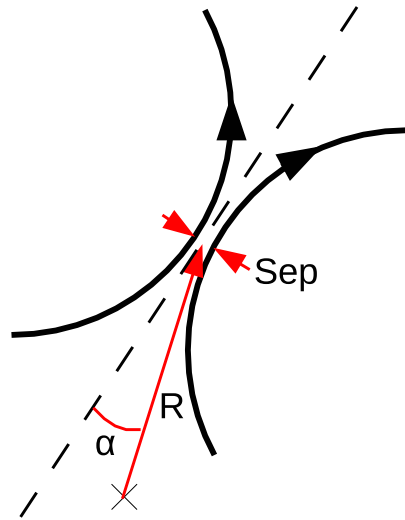
- Choose a track to tag
- Require  $P_t > 1$ , 20 stereo and 20 axial COT hits, and fiducial to CES and CPR
- Extrapolate track to CPR, CES, and calorimeter
  - Pions are MIPs, so they will produce smaller showers in each of these layers, which will be detectable in many ways.
- Look at discriminating variables:
  - $E_{Had}/E_{EM}$
  - $E_{EM}/p$
  - $E_{CES}/p^*$
  - $E_{CPR}/p^*$
  - CES  $\chi_S^2, \chi_W^2$
  - CES  $\Delta x, \Delta z$
  - CES  $E_S/E_W$
  - CES  $N_S$  and  $N_W$  vs.  $P_t$

# Description of Soft Electron ID

- For each variable  $x_i$ , get signal ( $S_i$ ) and background ( $B_i$ ) likelihoods
  - Discriminating variable PDFs are calibrated with data: conversions and  $K_s^0$ s.
- Calculate total signal and background likelihoods:  $S = \prod_{i=1}^n S_i$ ,  $B = \prod_{i=1}^n B_i$
- Calculate final likelihood:  $\mathcal{L} = \frac{S}{S+B}$

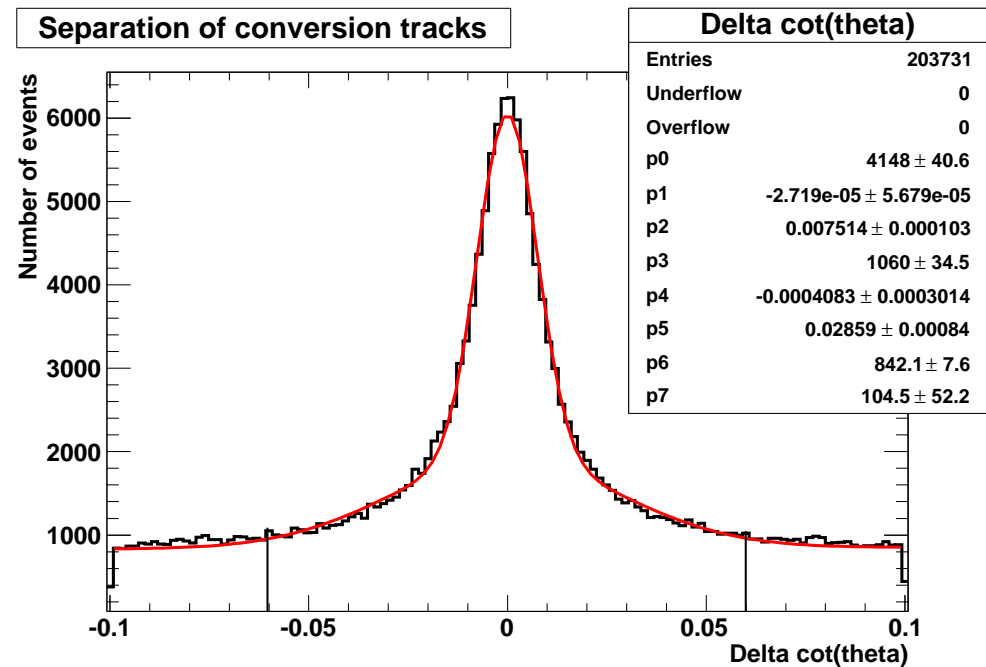


# Selection of Signal Sample

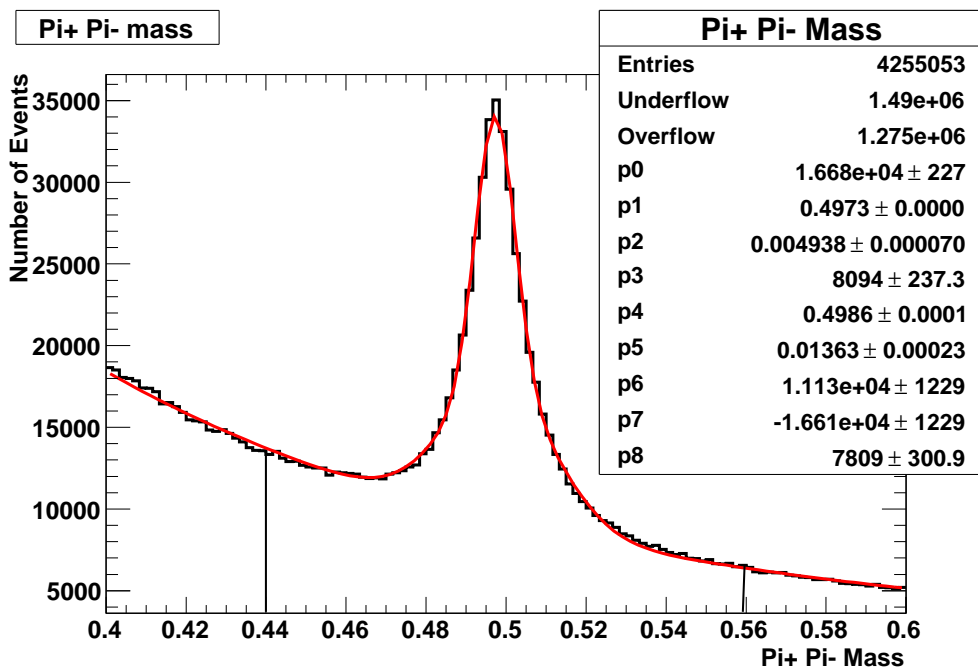


- Use 8 GeV electron trigger
- Find opposite-charge pairs of tracks
- $|Sep| < .5$  cm,  $R > 10$  cm

- Parameterize  $\Delta \cot(\theta)$  distribution
- Use sideband of distribution to subtract background
- Use softer conversion leg. Harder leg is trigger-biased.

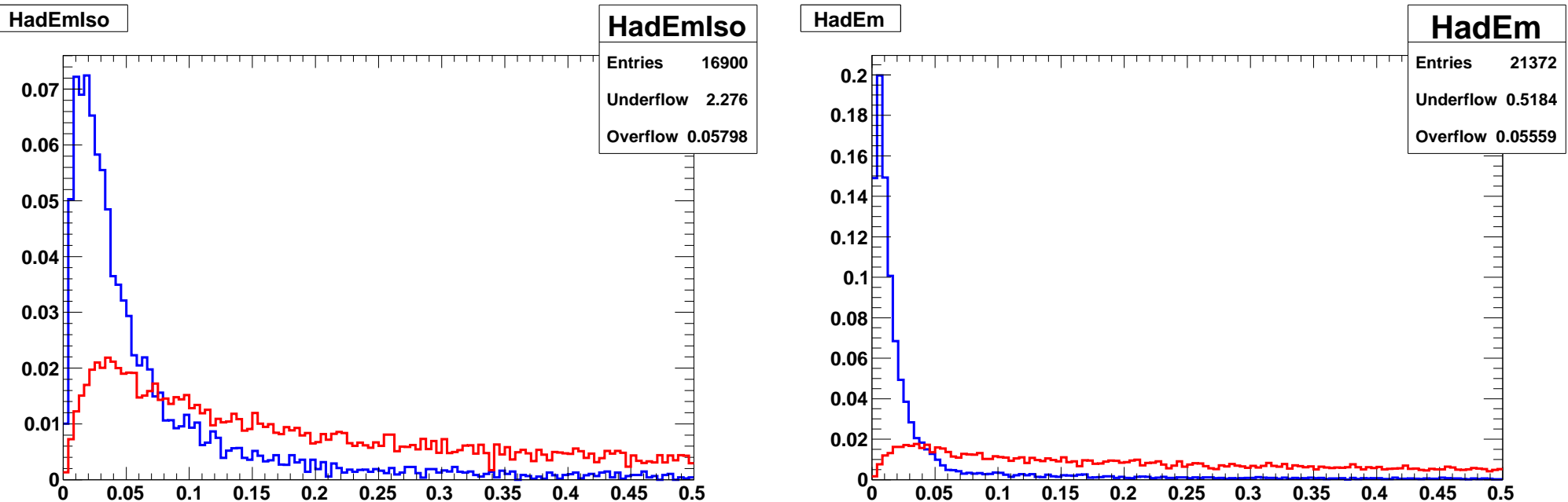


# Selection of Background Sample



- Use the Jet20 trigger
- Find opposite-charge pairs of tracks
- Require 20 stereo and 20 axial hits in COT
- Require  $d_0 > 0.01$  cm on one track
- Use the CTVMFT secondary vertex fitter to fit the decay vertex
- Require  $P_t(K_s^0) > 0.5$  and  $\cos(\alpha) > 0.99$
- Parameterize  $K_s^0$  mass peak
- Use sideband of distribution to subtract background

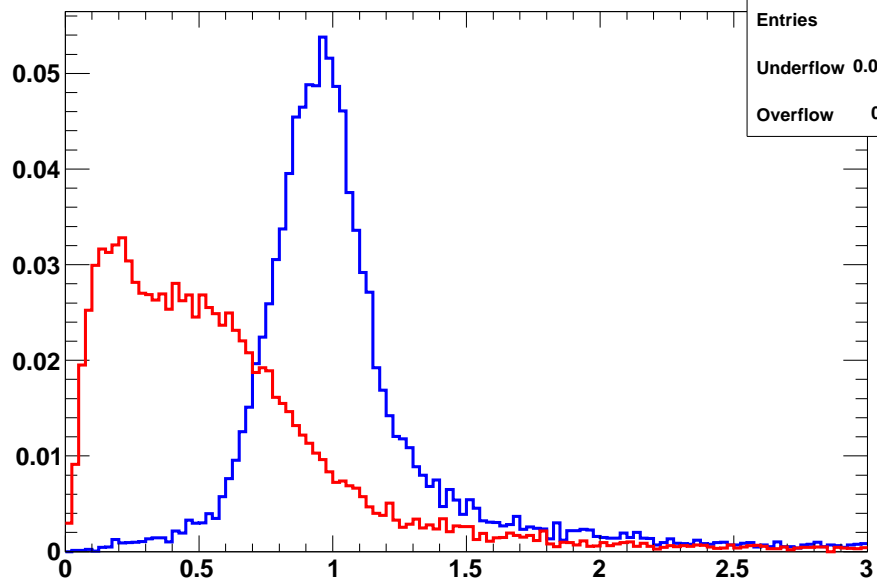
# Discriminating Variables



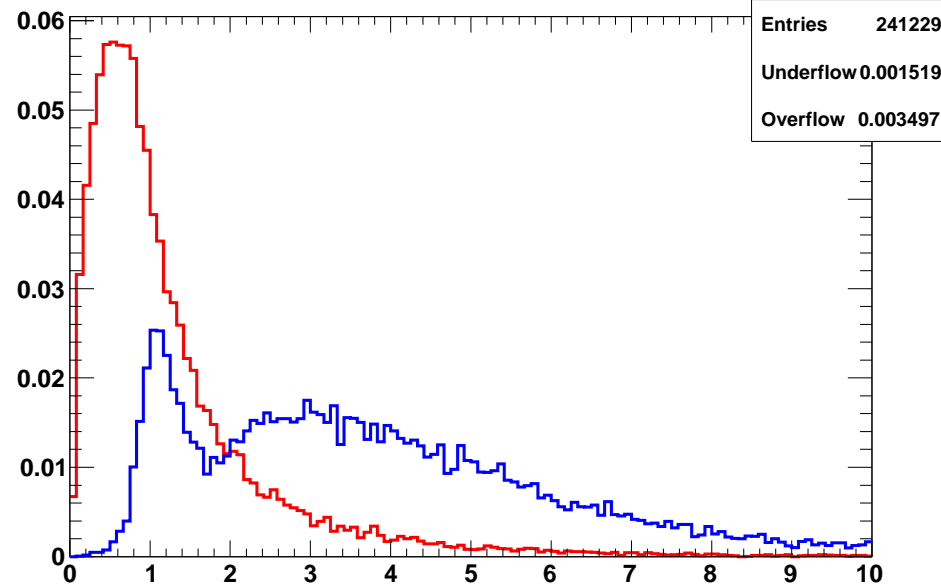
- Two calorimeter towers are used to calculate  $E_{Had}/E_{EM}$ . Different distributions are used based on whether the track is isolated. (whether it's the only track pointing to those two towers)
- Electrons tend to cluster more toward 0, as they don't make it into the hadronic calorimeter.

# Discriminating Variables

EmEOverPiso

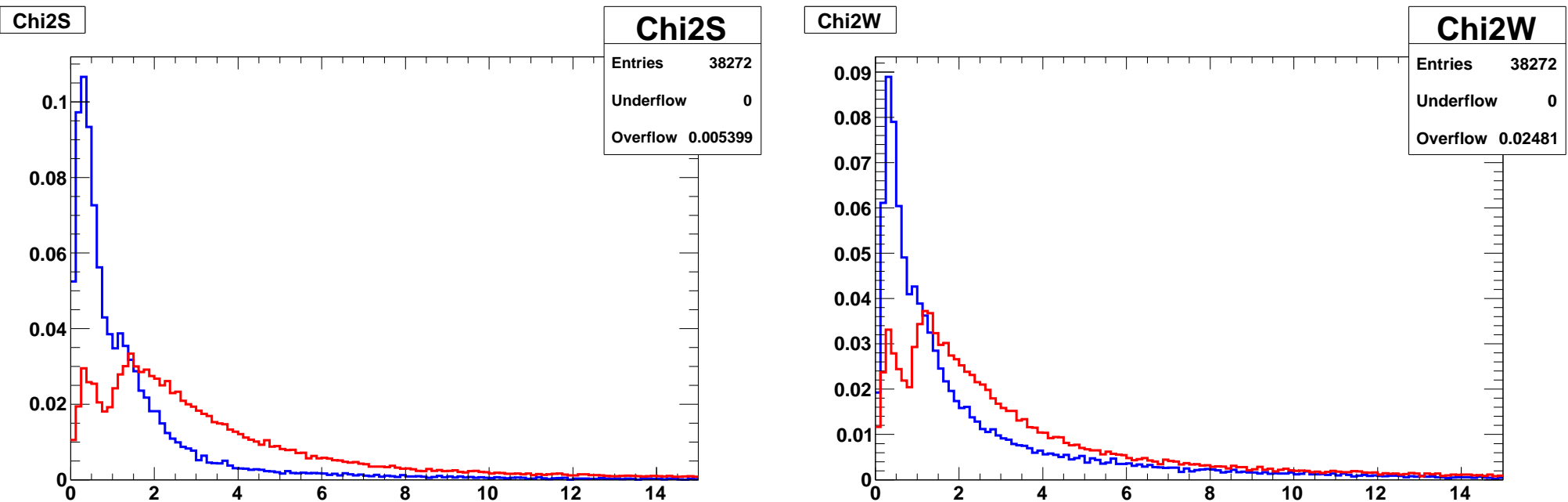


EmEOverP



- Two calorimeter towers are used to calculate  $E_{EM}/P$ . Different distributions are used based on whether the track is isolated.
- Electrons tend to cluster near 1, as most of their energy is deposited in the EM calorimeter.

# Discriminating Variables

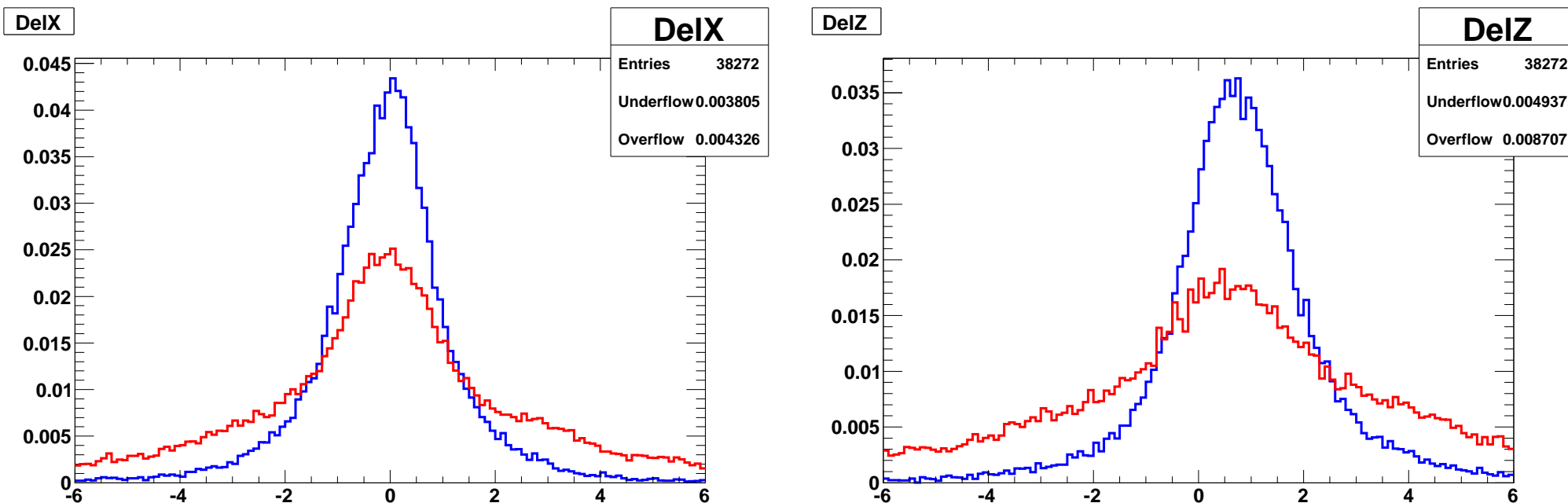


- The  $\chi^2$  of the nearest strip cluster and the nearest wire cluster in the CES are corrected for track momentum based on Note 1432:

$$\chi_{corr}^2 = \chi^2 \times \begin{cases} 0.1792 \times 2.11^{\ln P_t} & \text{if } P_t > 10 \\ P_t/10 & \text{if } P_t < 10 \end{cases}$$

- Pions tend to have higher  $\chi^2$ s, as their smaller showers don't fit the shower profile well.

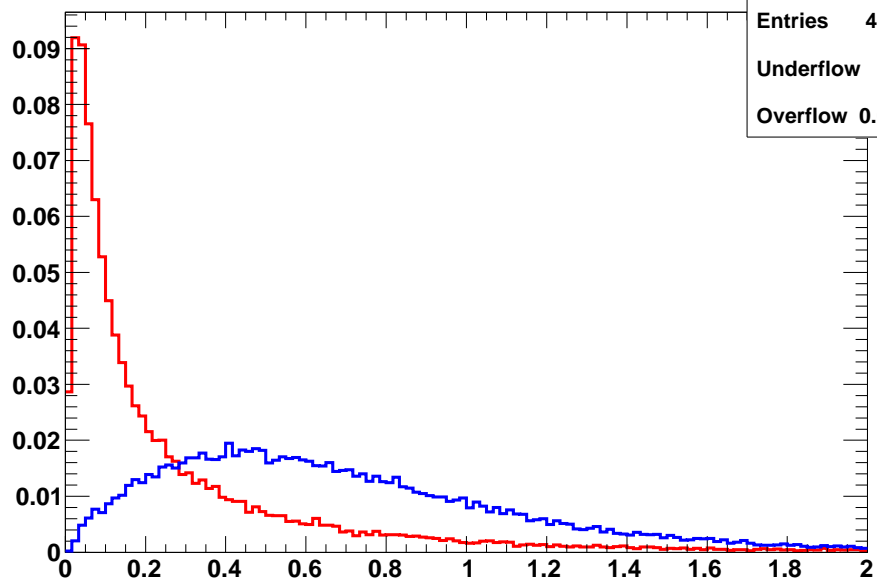
# Discriminating Variables



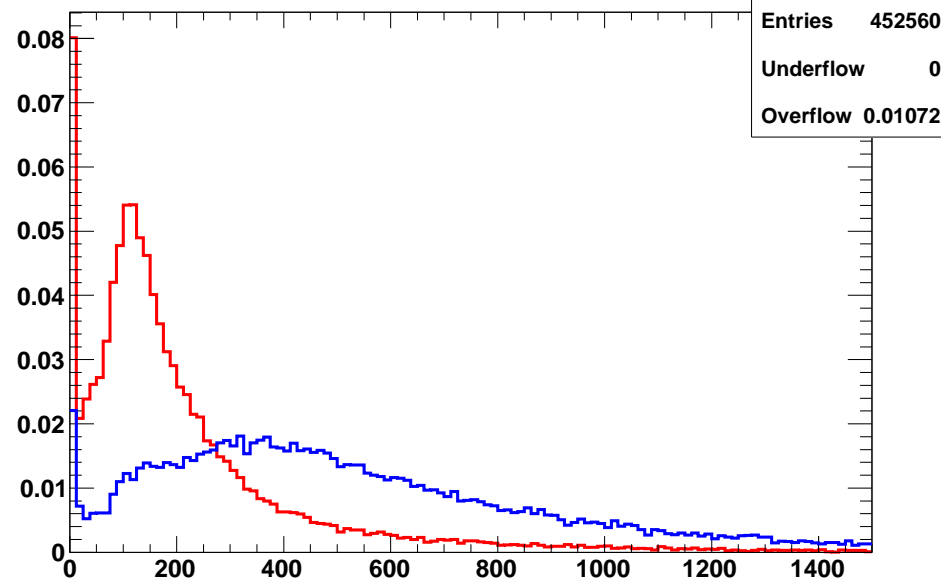
- Since electron showers are fitted better than pion showers, they correlate better with the extrapolated position of the track.

# Discriminating Variables

CesWireCorr

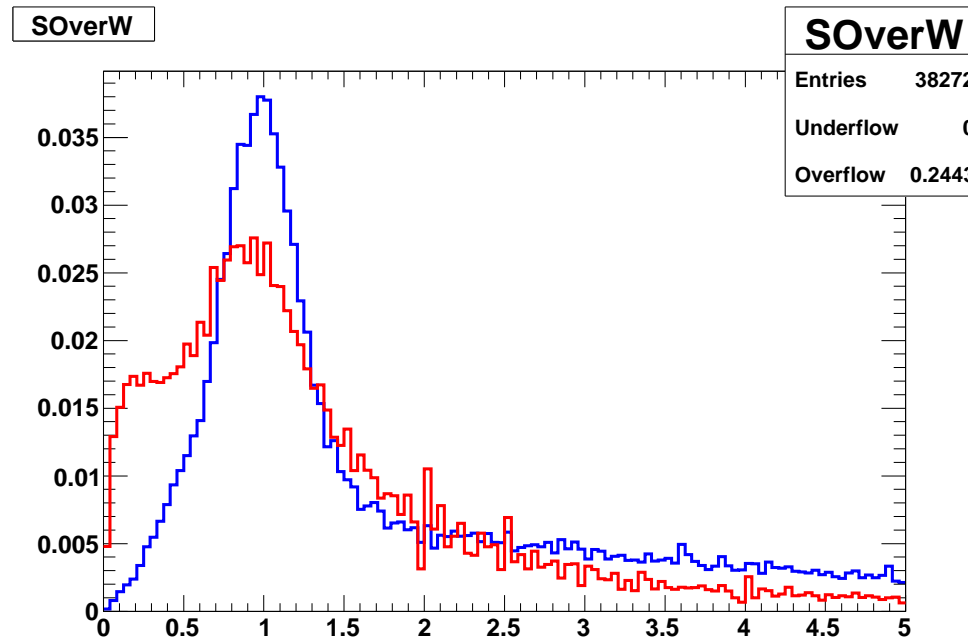


CprCorr



- The energy deposited in the CES and CPR is corrected for the momentum of the track.
- Pions tend to create smaller showers than electrons.

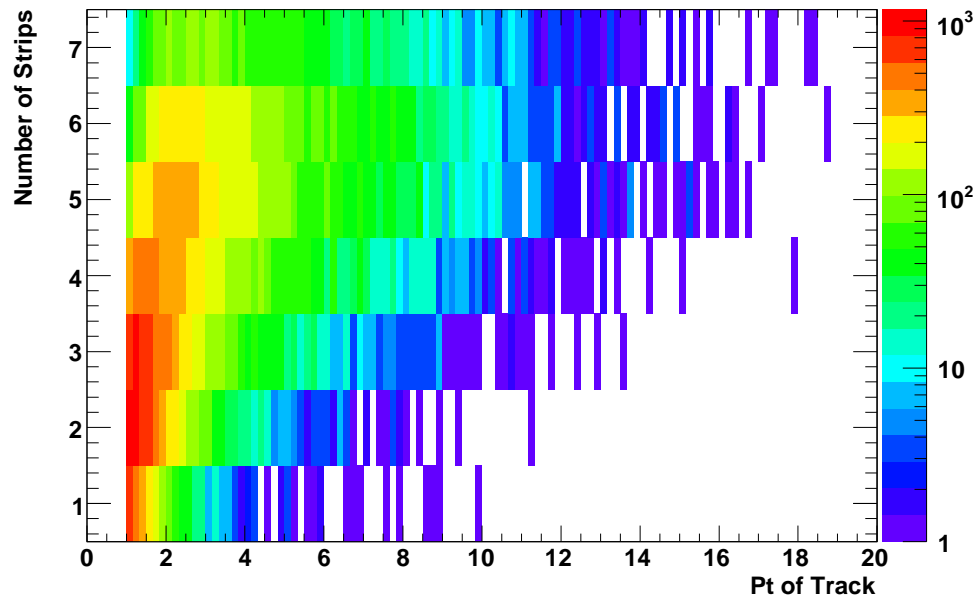
# Discriminating Variables



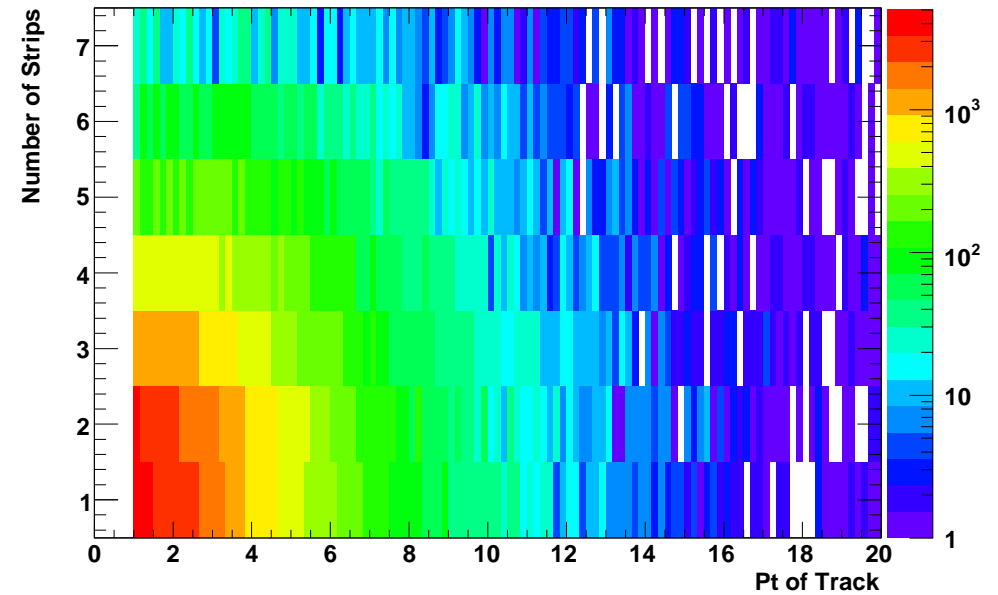
- CES strips and wires see the same avalanche charge, so

# Discriminating Variables

NS vs Pt (Electrons)



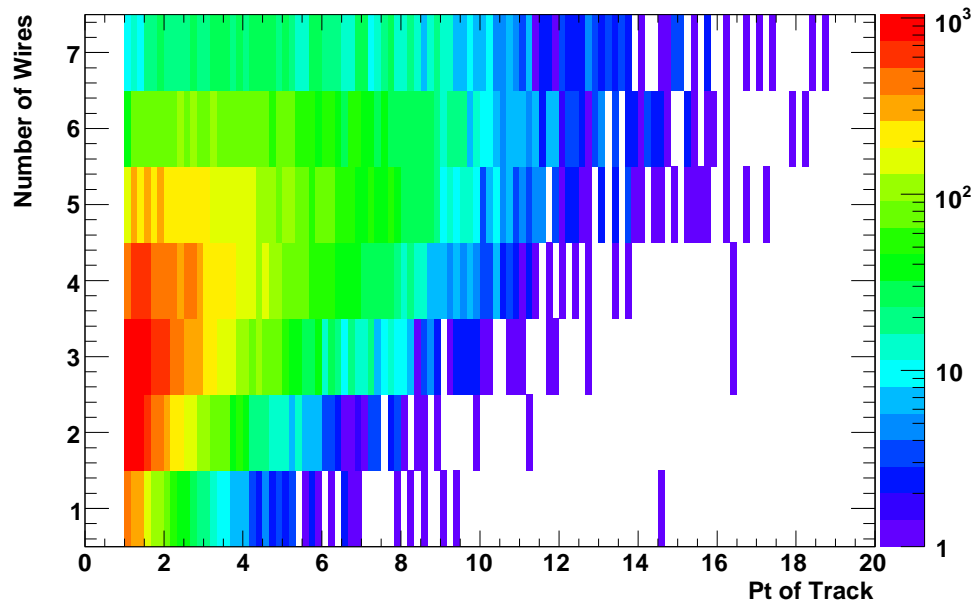
NS vs Pt (Pions)



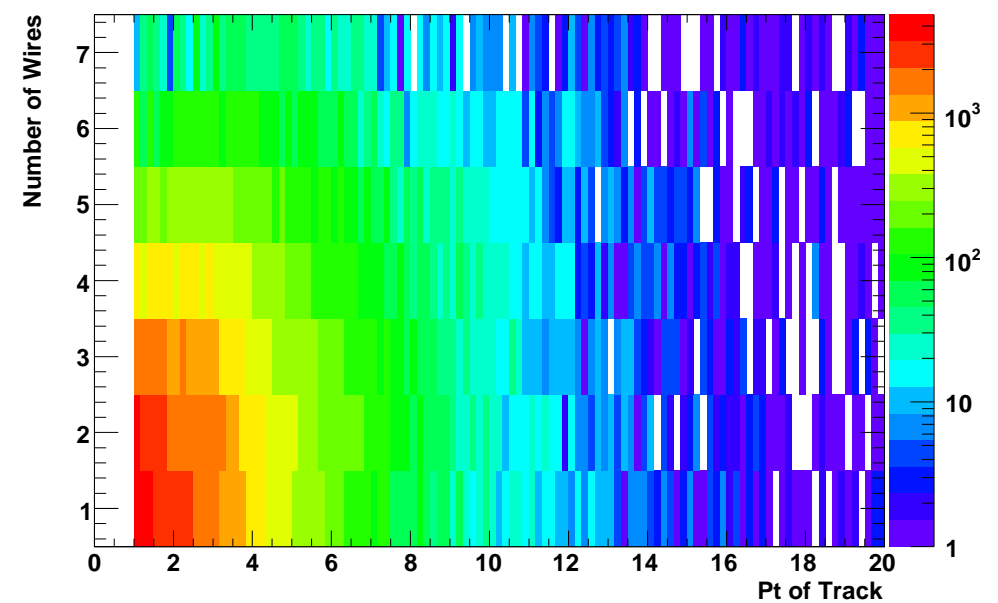
- Pions' showers are smaller and likely to hit fewer CES strips at higher  $P_t$ .

# Discriminating Variables

NW vs Pt (Electrons)



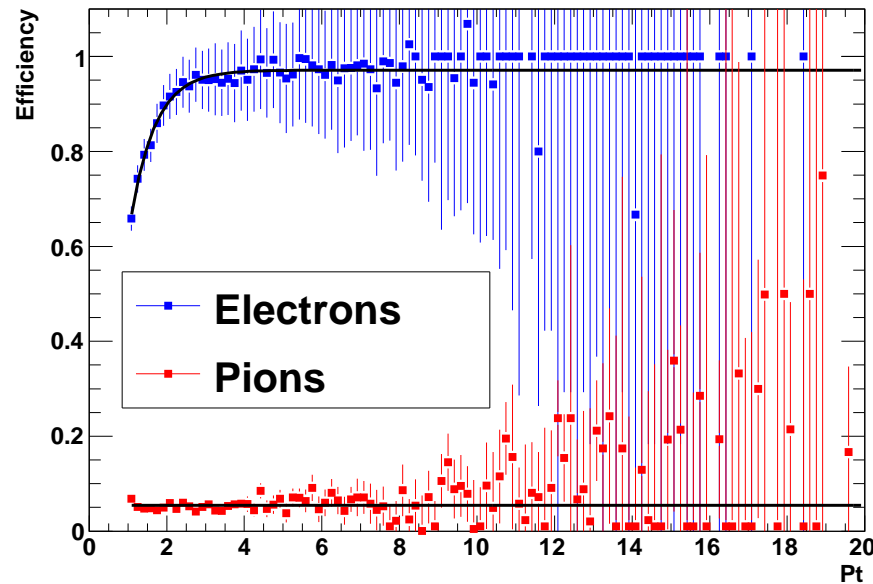
NW vs Pt (Pions)



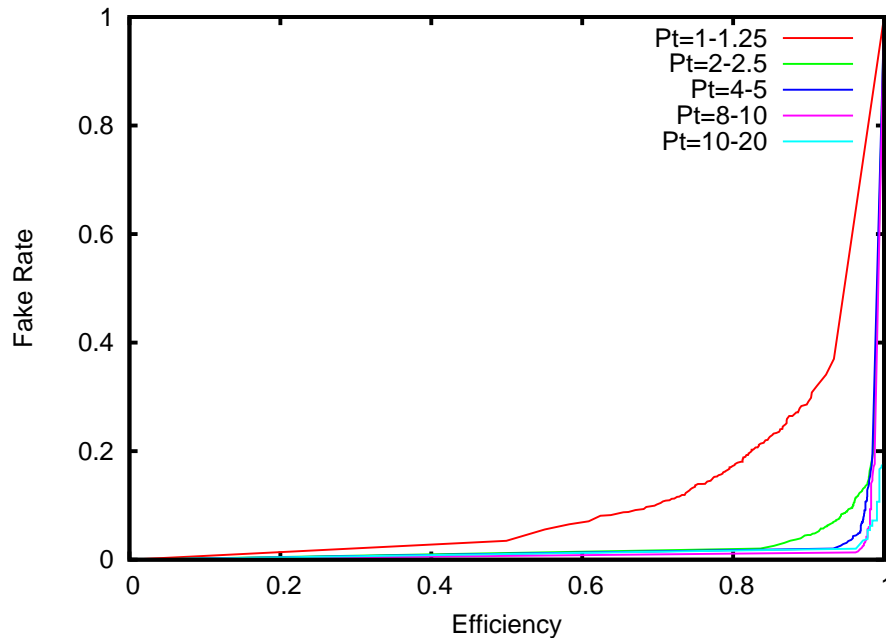
- Pions' showers are smaller and likely to hit fewer CES wires at higher  $P_t$ .

# Performance of ID Algorithm

Pt Efficiency



- Excellent separation between electrons and pions
- For example, 95% efficiency with 5% fake rate for 2 GeV tracks
- Can adjust likelihood cut to get different efficiency / fake rate



# Performance of ID Algorithm in This Sample

- Trigger on  $W$ : Require a hard lepton ( $P_t > 20$ ) and  $\cancel{E}_t > 15$
- After these cuts, the soft electron ID finds 25% of the remaining events
- Bottom line: With  $m_H = 90$  GeV,  $m_{A^0} = 9$  GeV:
  - Our MC gives a 70 fb production cross-section (forcing the  $W$  to decay leptonically)
  - Running the analysis code on the MC sample gives us 21 events expected in  $3 \text{ fb}^{-1}$ .

