Proton Study
At The T2K Near Detector ND280

UNIVERSITY OF LIVERPOOL

Michail Lazos

•Second generation long baseline neutrino experiment situated in Japan

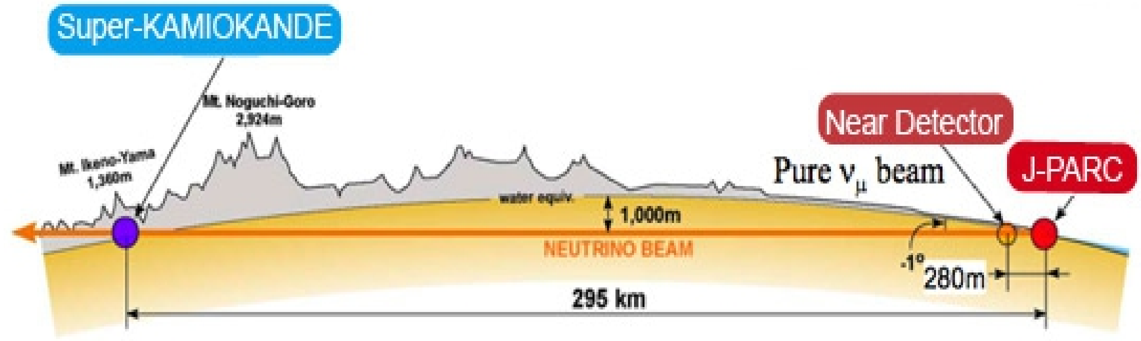
•Electron neutrino appearance

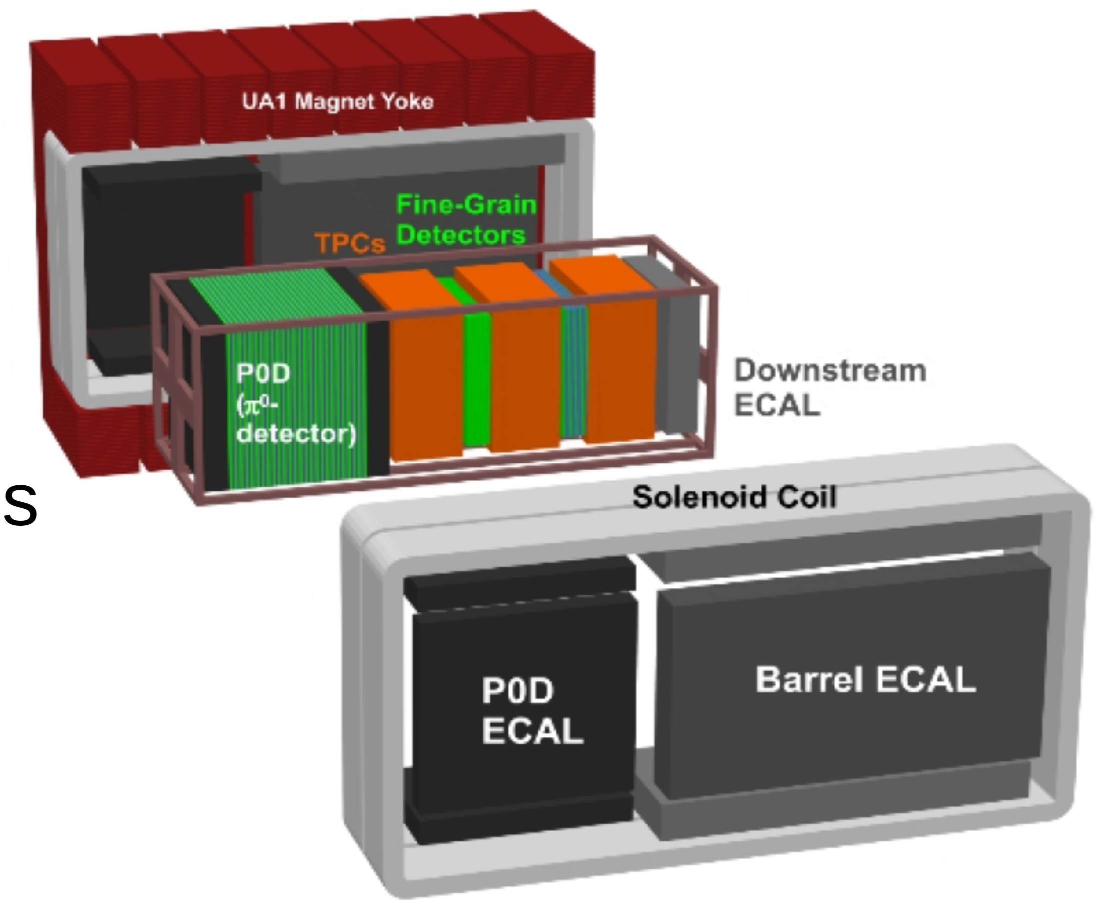
• Mixing angle θ_{13}

•Muon neutrino disappearance,

• Mixing angle θ_{23}

•ND280 measures various cross sections

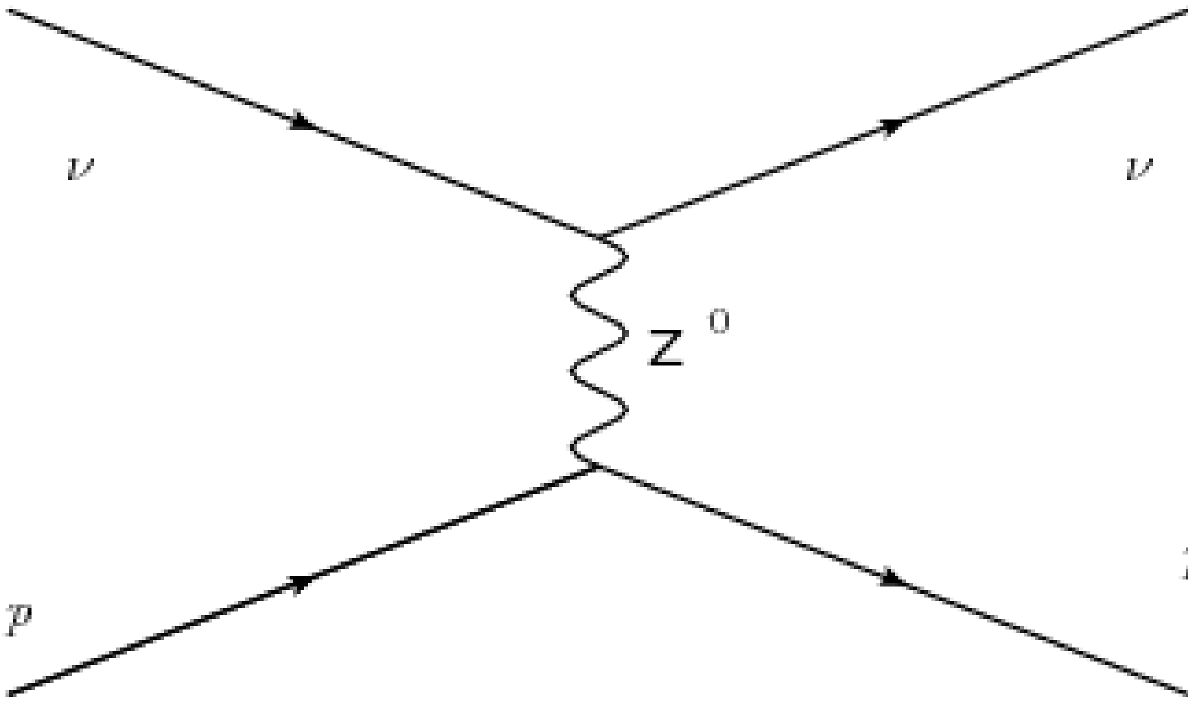




NCQES Neutrino Interaction

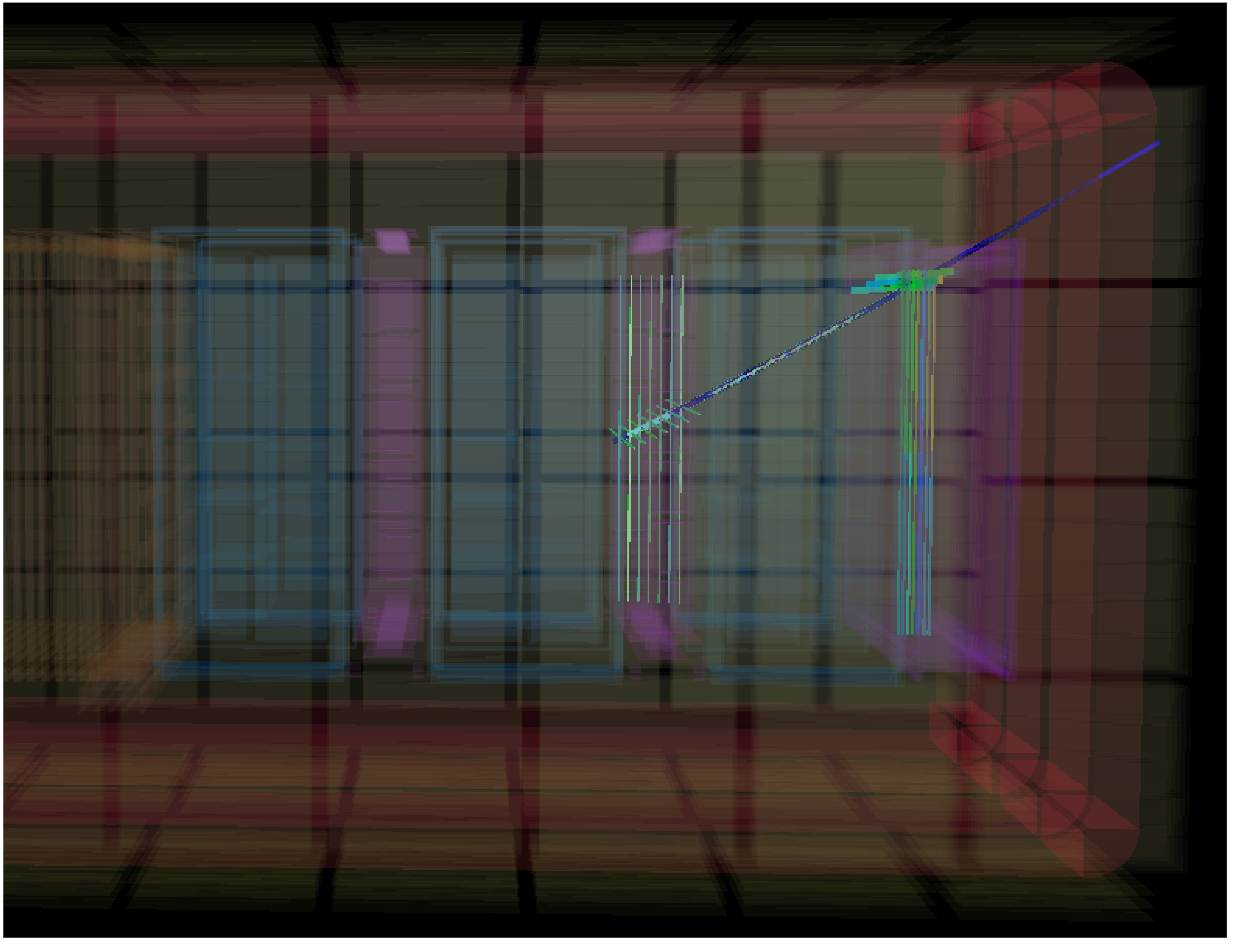
- Neutral Current Quasi Elastic cross section measurements
- Neutrino energy reconstruction

$$\nu + {}_{Z}N^{A} \dashrightarrow \nu + {}_{Z-1}N^{A-1} + p$$



Event selection FGD TPC

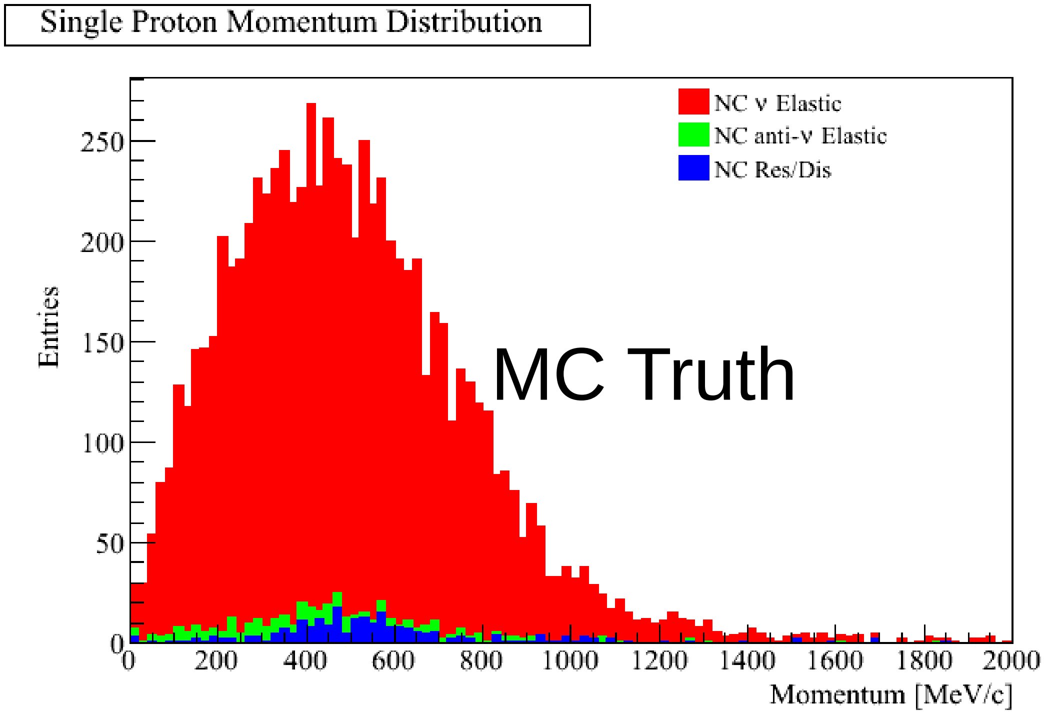
- Good tracking info
- Particle ID
  - TPC
  - ECAL

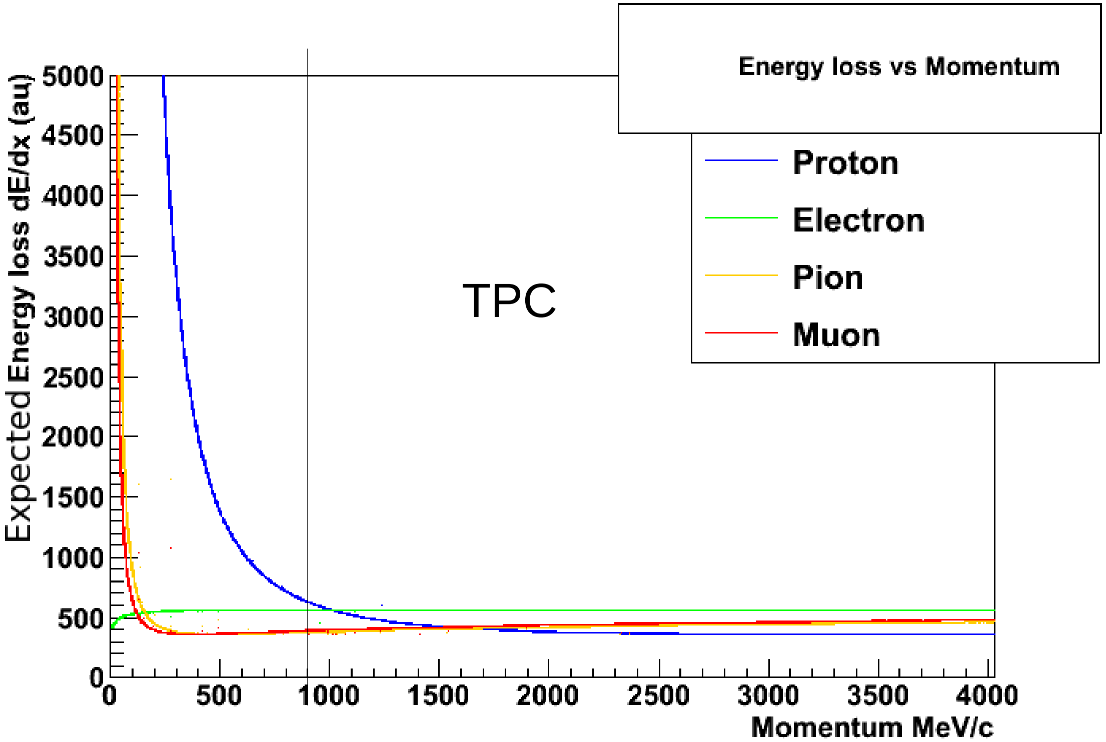


Single positive track
Events start in FGD
FGD->TPC->ECAL

Particle Discrimination Using dE/dx

- At high momentum it is very difficult to discriminate protons from μ and π
- This is what we measure on TPC
- Use the ECAL above 800 MeV/c to improve proton selection





Neural Network

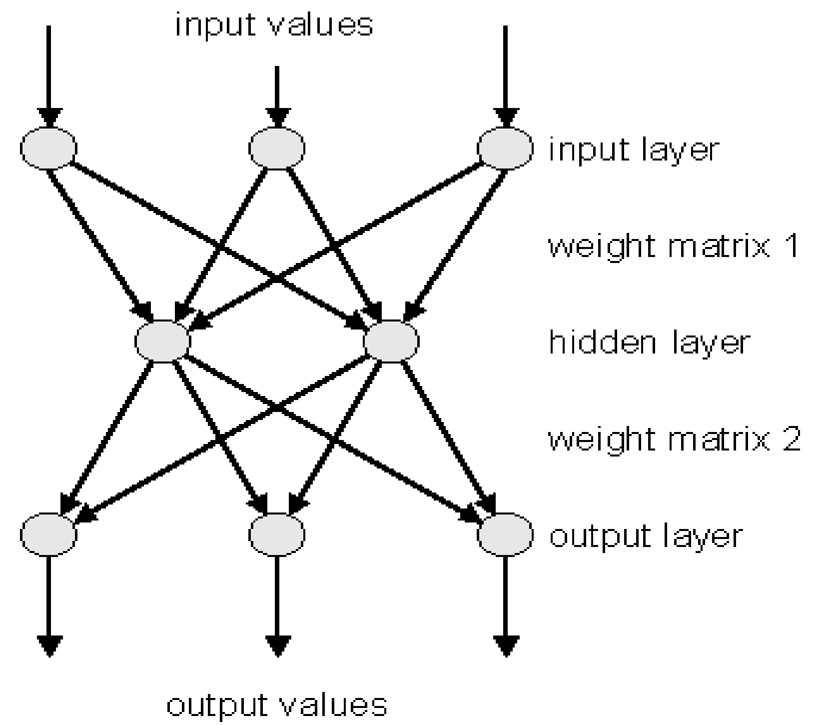
- Neural Network (NNA) to use ECAL variables
- 3 Momentum Regions

    p < 800 MeV/c, 800-1500 MeV/c and above 1500 MeV/c

- Particle Gun generated Monte Carlo were used for training and validation of the NNA
- NNA tested on Full ND280 Monte Carlo and Test Beam Data

Neural Network

- A neural network was designed to mimic a central nervous system
- Consist of sets of adaptive weights
- A linear set of sigmoid functions can approximate any continuous function

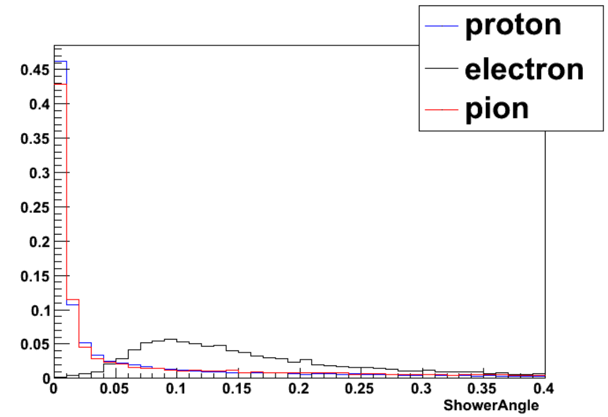


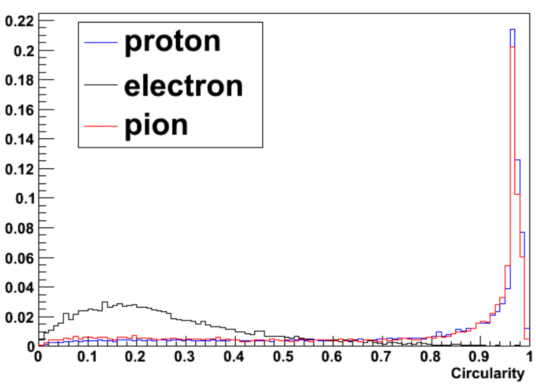
$$w_{ij}(t+1)=w_{ij}(t)+\Delta w_{ij}(t)$$

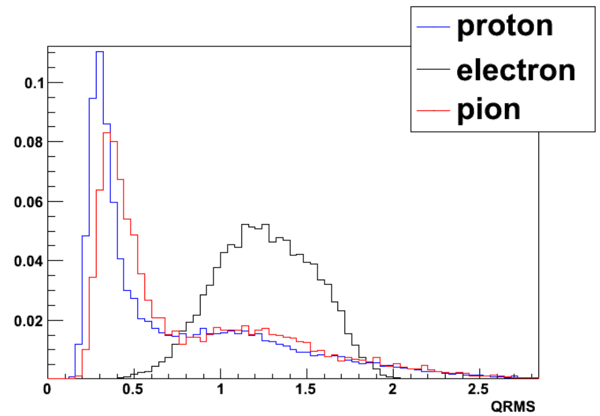
$$\Delta w_{ij}(t)=-\eta(d e_p / d w_{ij}+\delta)+\epsilon \Delta w_{ij}(t-1)$$

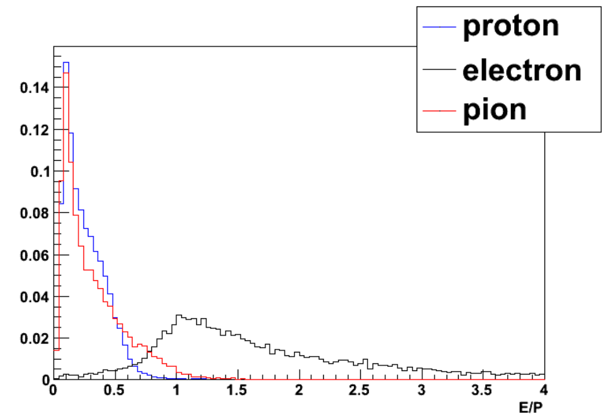
ECAL Variables

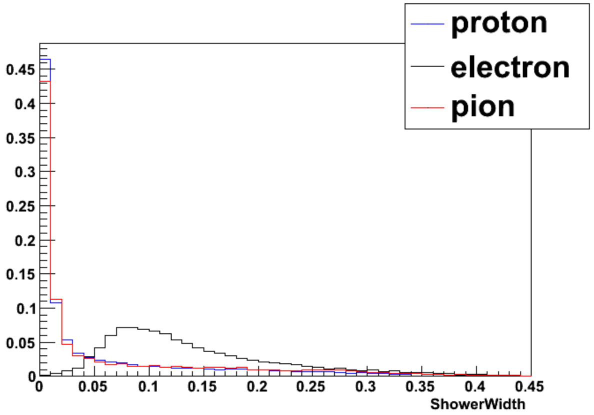
Inputs for the Neural Network

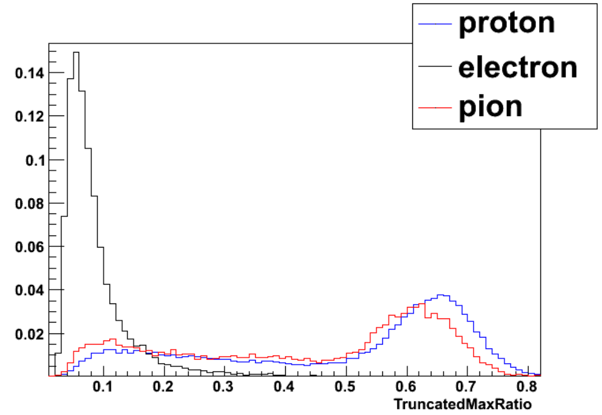


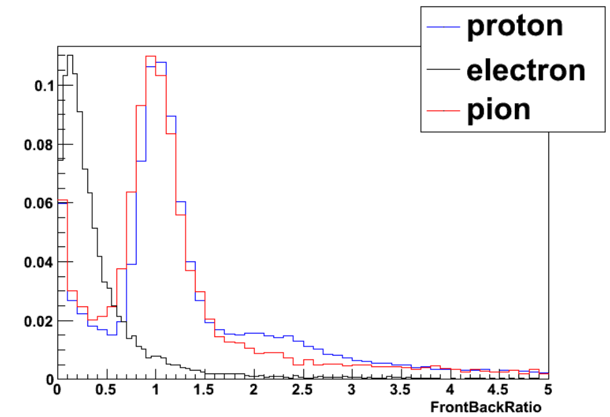






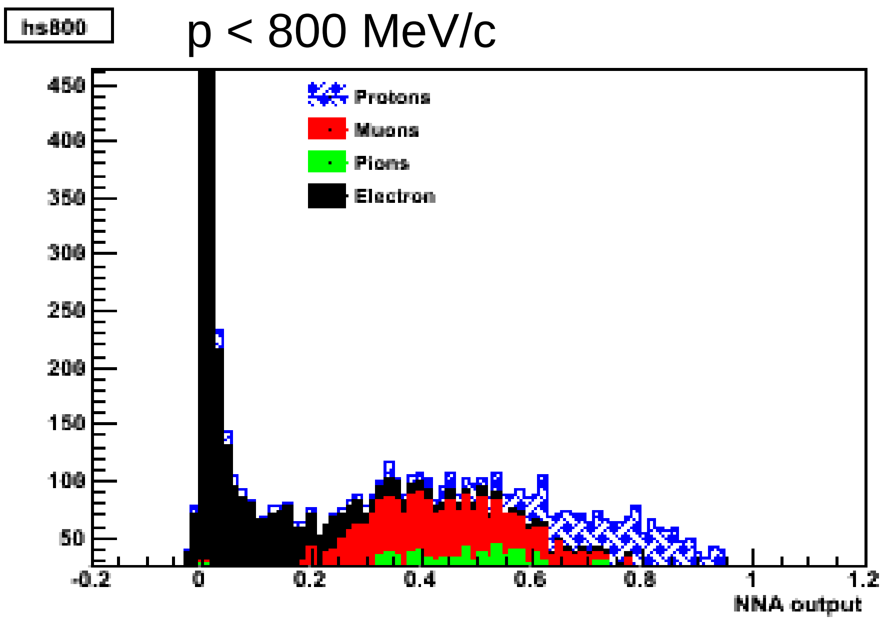




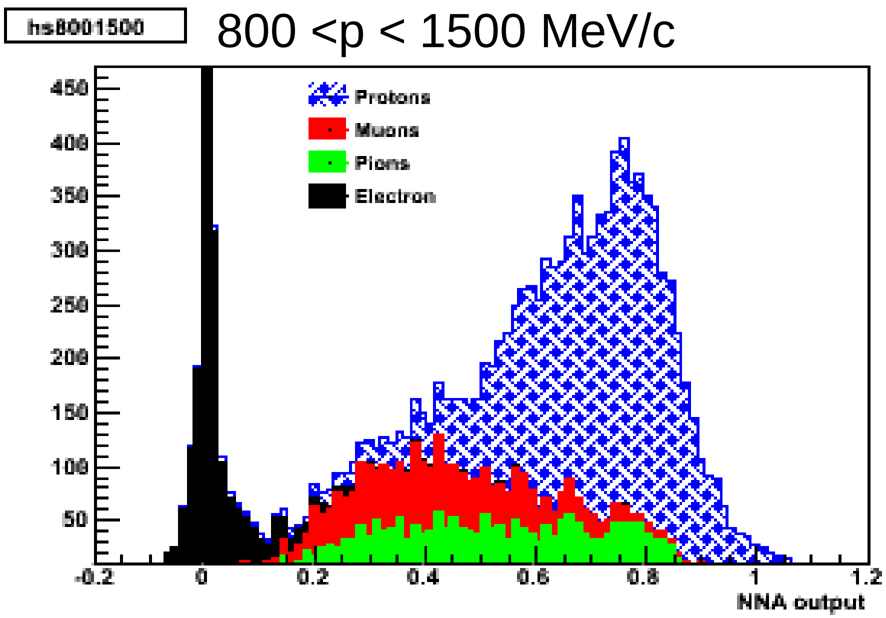


Neural Network Training

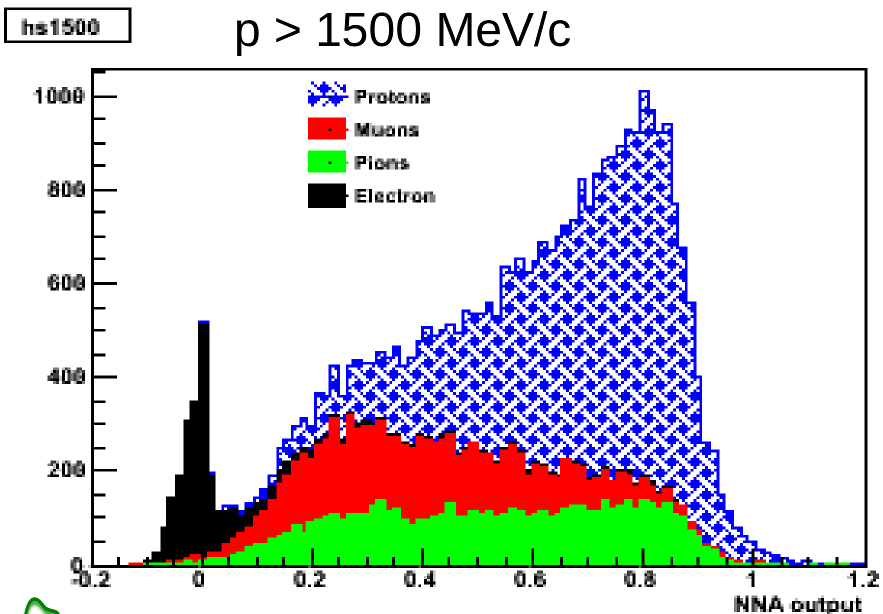
p < 800 MeV/c

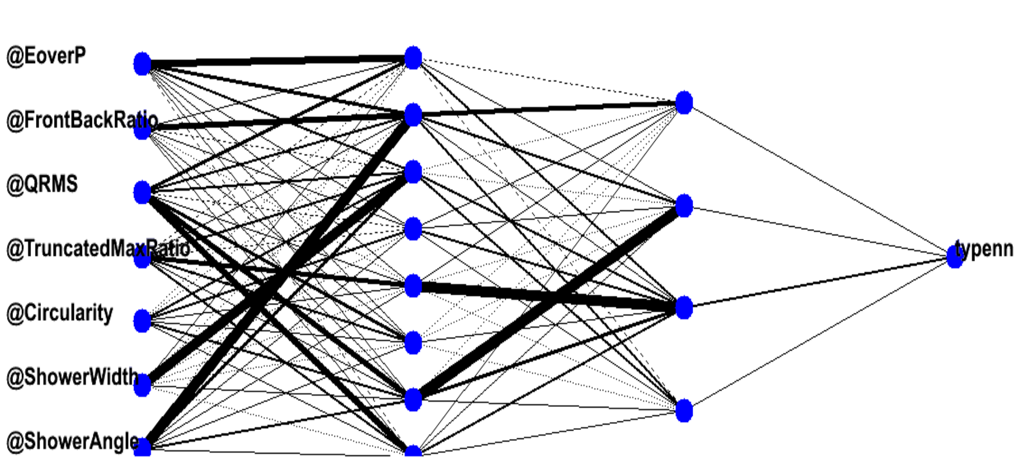


800 <p < 1500 MeV/c



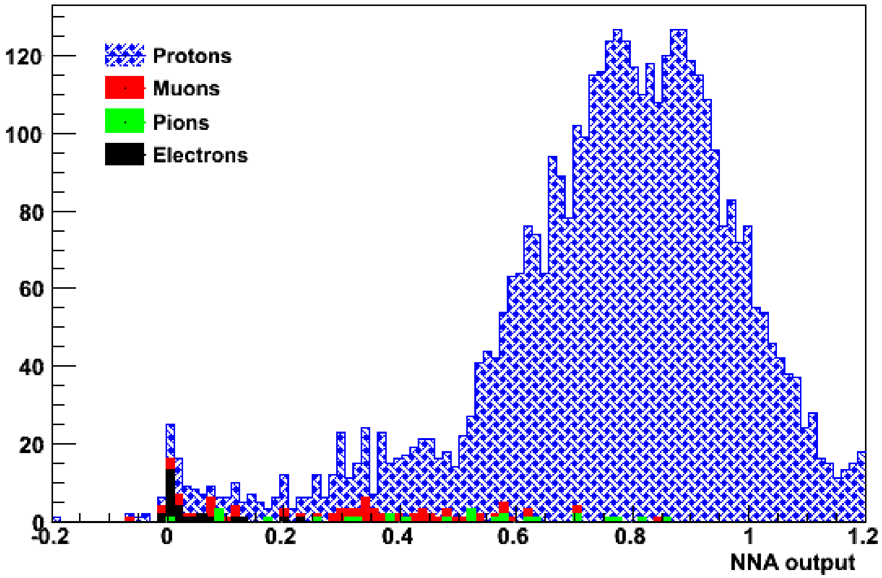
p > 1500 MeV/c



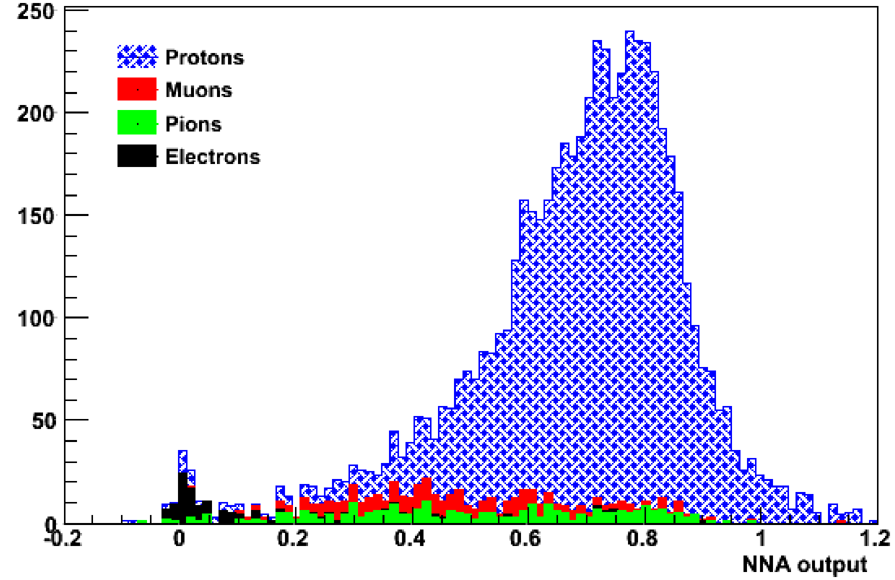


Full ND280 MC NNA Results

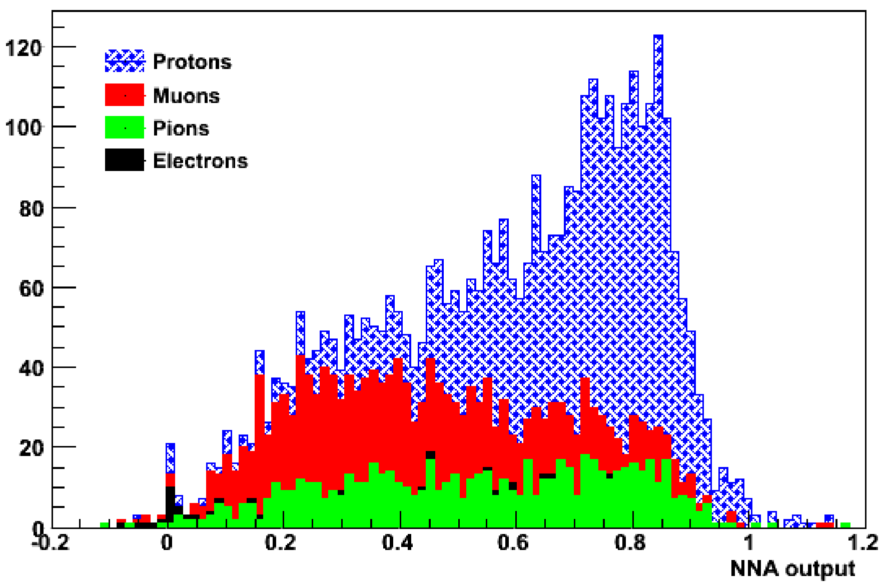
hs800 p < 800 MeV/c



hs8001500 800 < p < 1500 MeV/c



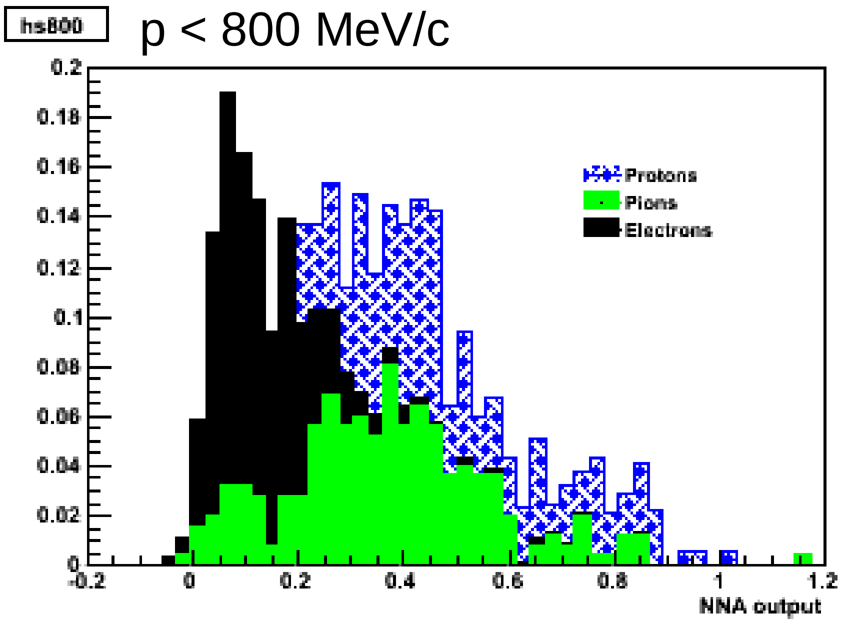
hs1500 p > 1500 MeV/c

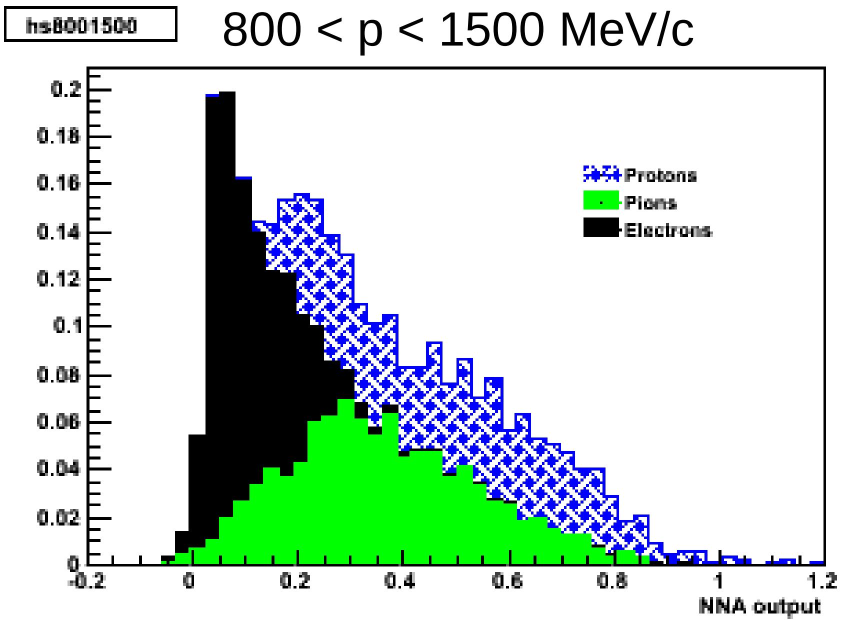


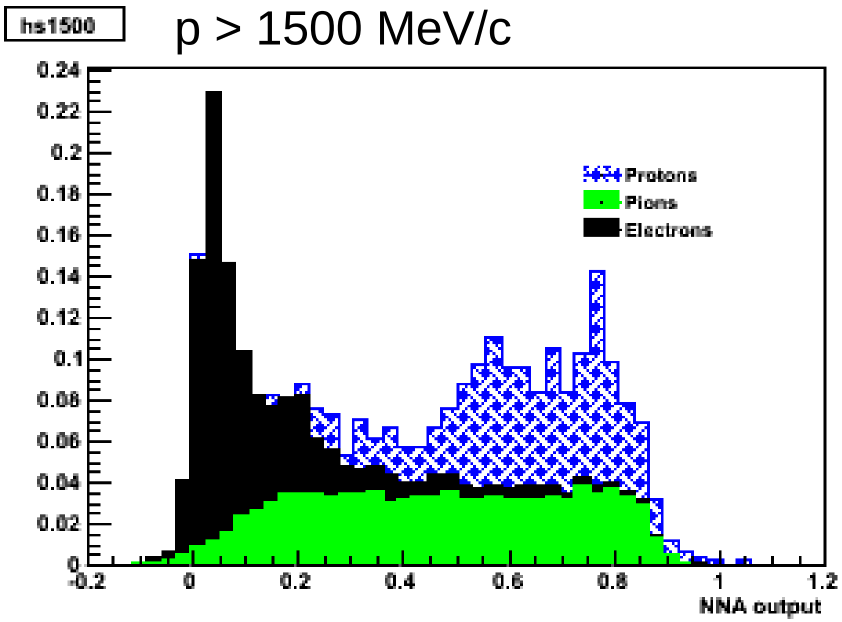
Performance on Full MC
Full track selection
TPC PID cut
(|proton pull| < 3)

$$pull = \frac{Expected\ dE/dx - Measured\ dE/dx}{\sigma}$$

Test Beam Results



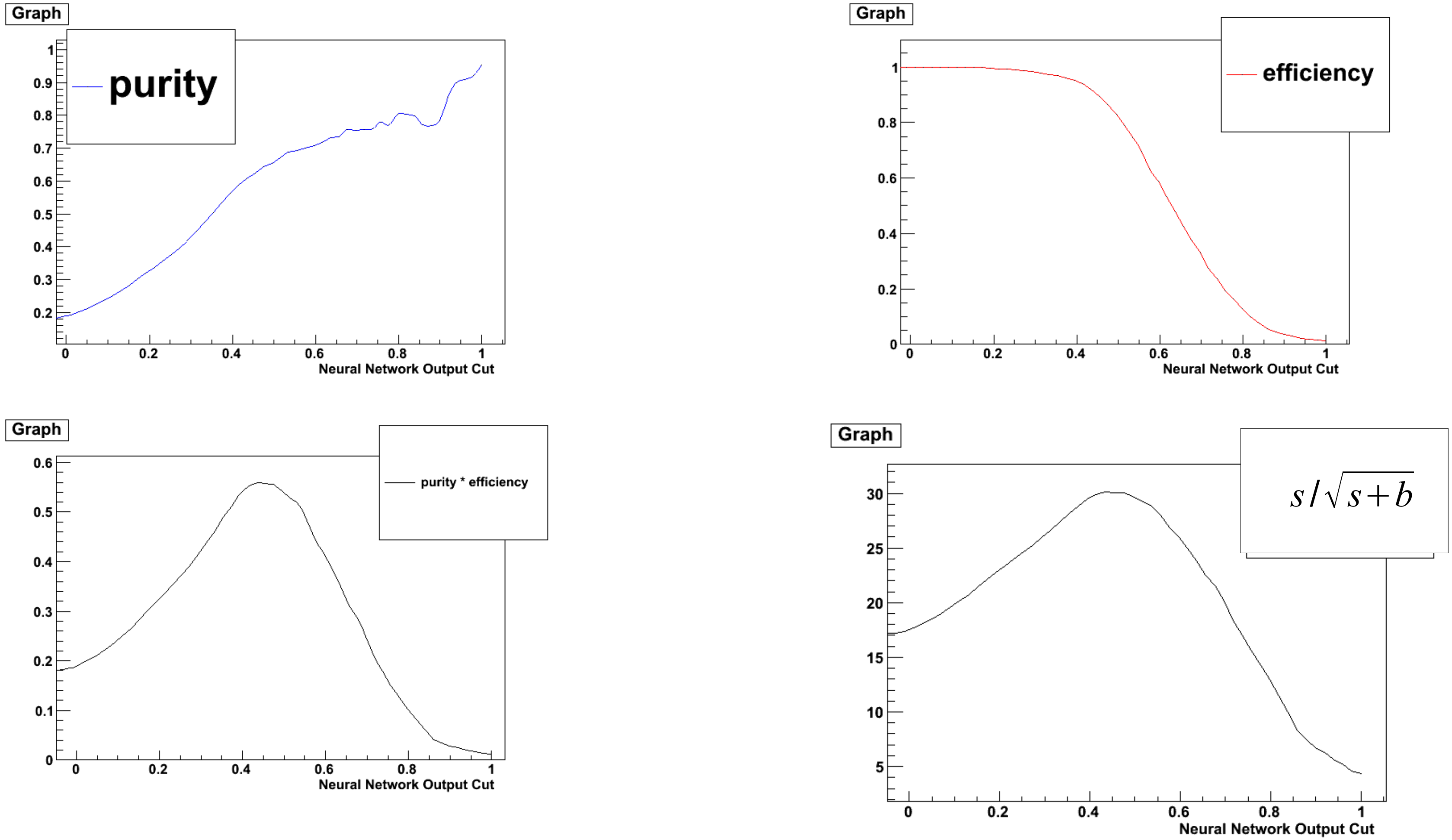




- Test Beam Data on CERN from DsEcal sub detector
- NNA results for 3 momentum regions
- NNA output
- Stack histogram normalised

Neural Network Results on MC

Statistical tests to quantify the NNA performance



Summary

- I extended the proton PID above 800 MeV/c using the neural network with the Electromagnetic Calorimeter

Future Work

- Finish the NNA (calculate systematics and run on data)
- Complete the proton selection
- Measure Neutrino NCQES cross section

Thank you for your attention.

Questions?

BACK UP SLIDES

- ECAL Variables for the Neural Network
  - MaxRatio
  - ShowerAngle
  - ShowerWidth
  - Circularity
  - TruncatedMaxRatio
  - QRMS
  - FrontBackRatio
  - Energy/P(momentum)

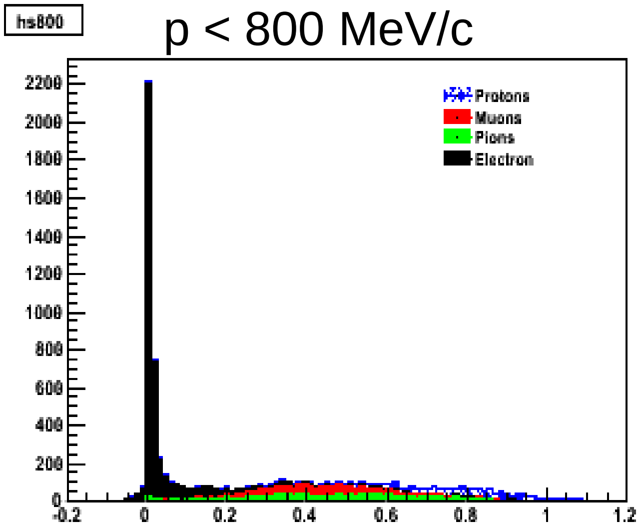
Full Spill MC Purity and Efficiency Using Only TPC

- |Proton Pull| < 3
- Momentum [0-800]
- Eff: 0.85   Pur: 0.91   Electrons : 75% Muons : 11% Pions : 14%
- Momentum [800-1500]
- Eff: 0.93   Pur: 0.57 Electrons : 75% Muons : 11% Pions : 8%
- Momentum [>1500]
- Eff:0.93   Pur: 0.13 Electrons : 92% Muons : 7% Pions : 1%

- |Proton Pull| < 3 |e mu pi pull| > 2
- Momentum [0-800]
- Eff:0.85   Pur: 0.99 Electrons : 46% Muons : 27% Pions : 42%
- Momentum [800-1500]
- Eff:0.533   Pur: 0.96 Electrons : 69% Muons : 6% Pions : 23%
- Momentum [>1500]
- Eff:0.13   Pur: 0.79 Electrons : 83% Muons : 10% Pions : 4%

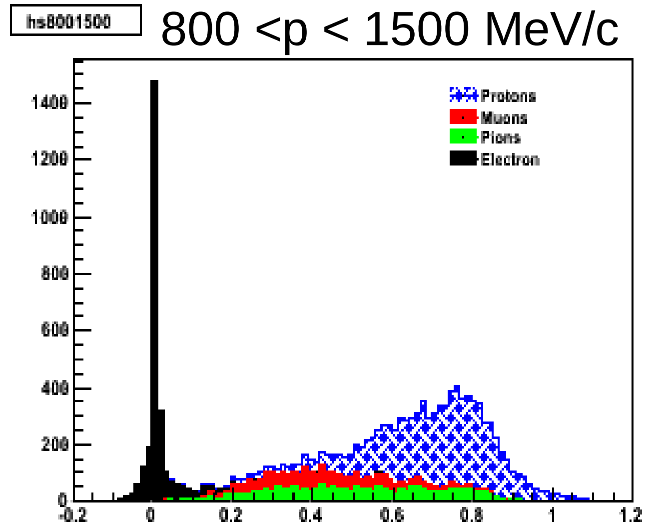
Neural Network Training

p < 800 MeV/c



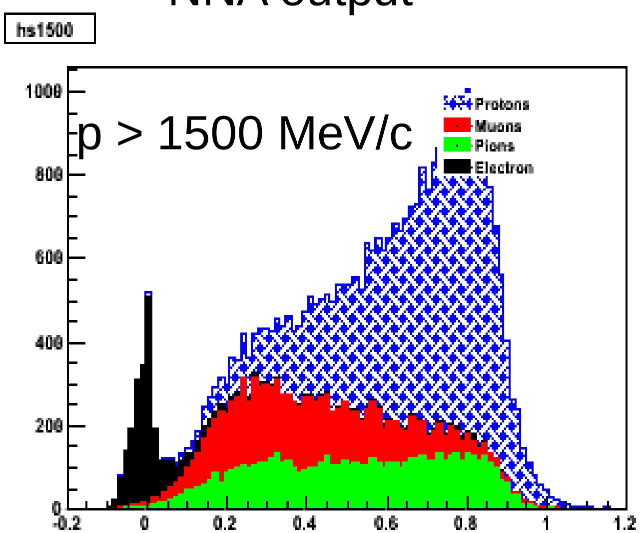
NNA output

800 <p < 1500 MeV/c

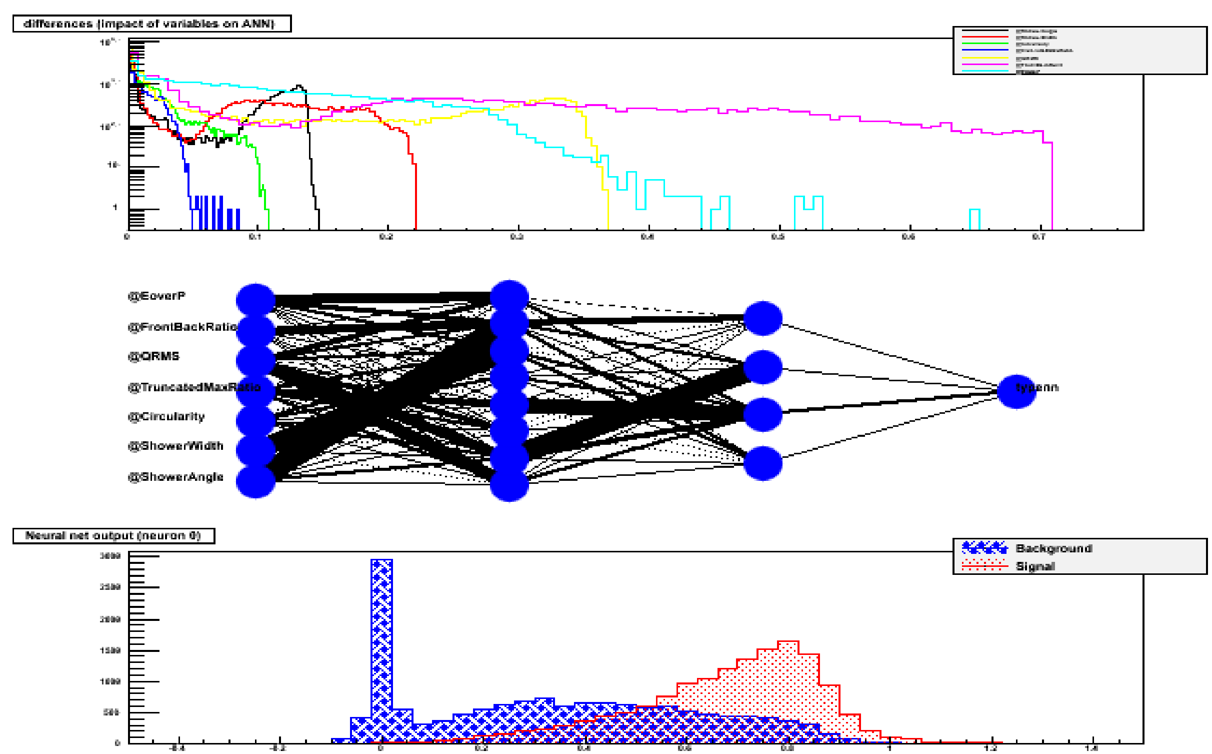


NNA output

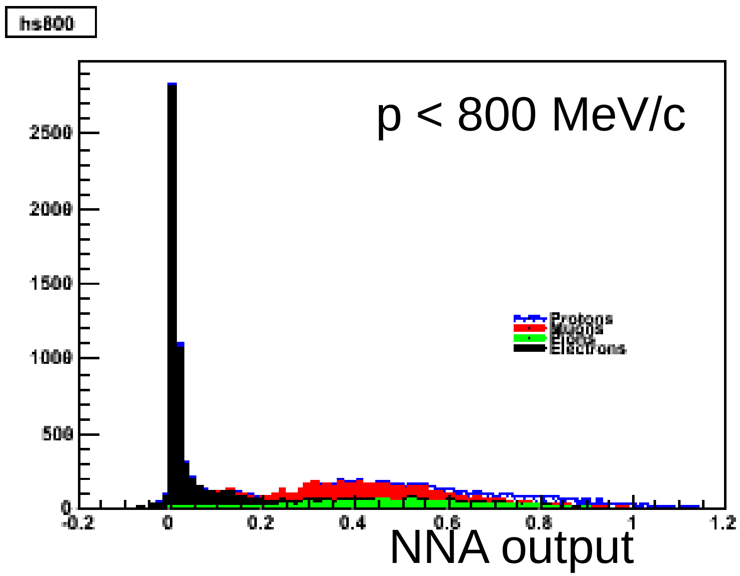
p > 1500 MeV/c

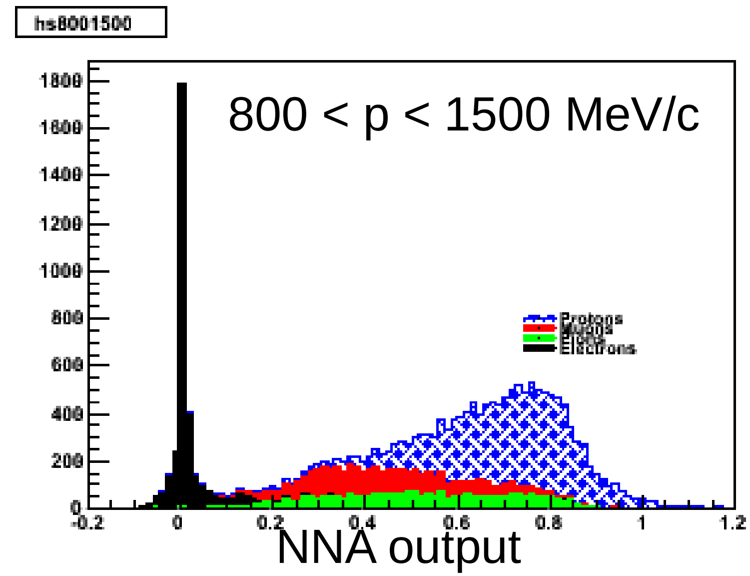


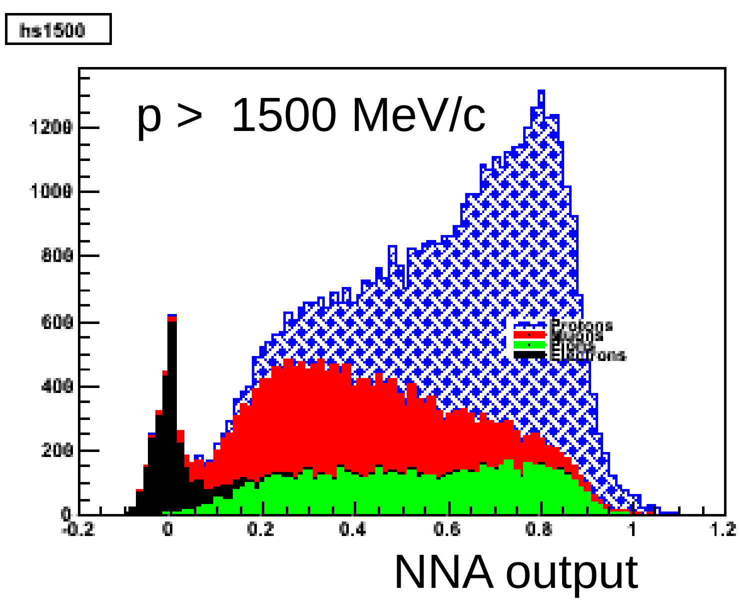
NNA output



Particle Gun NNA Results



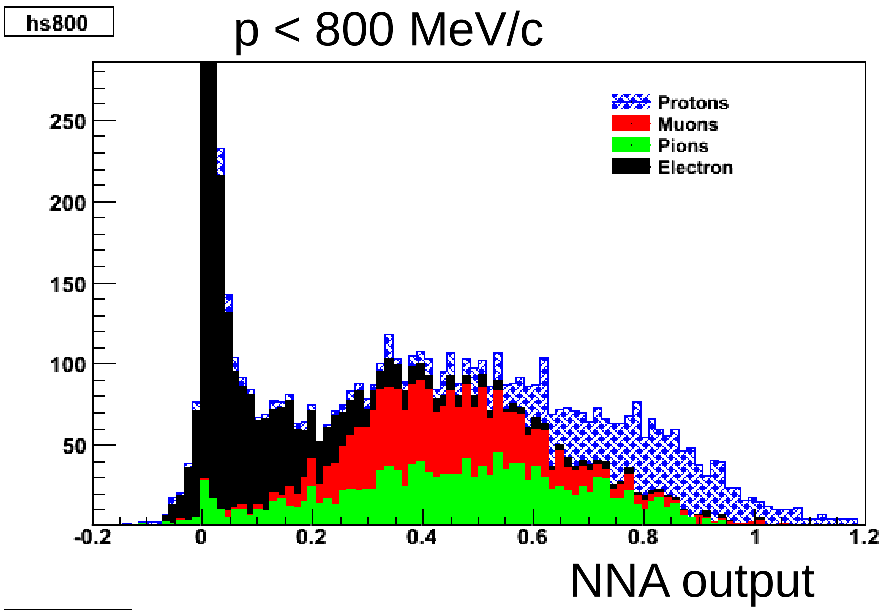


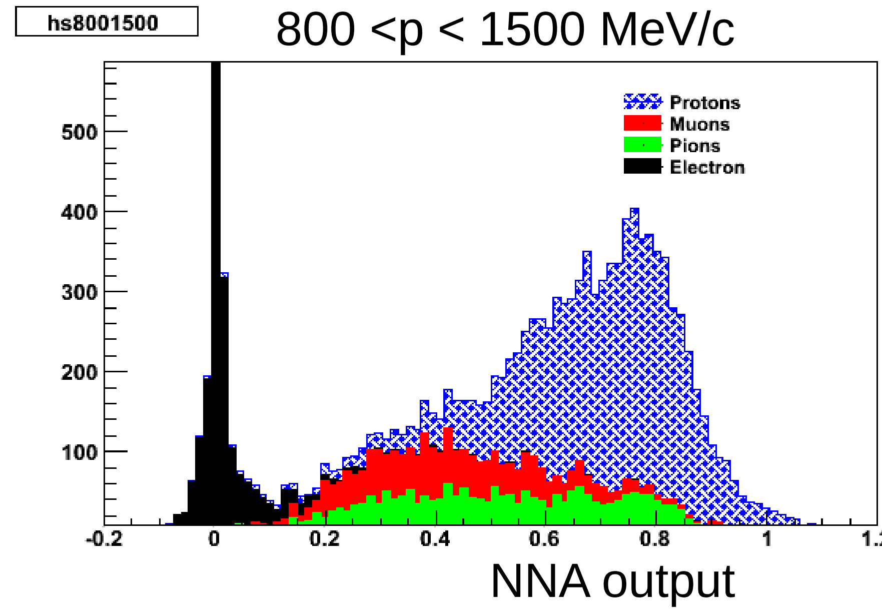


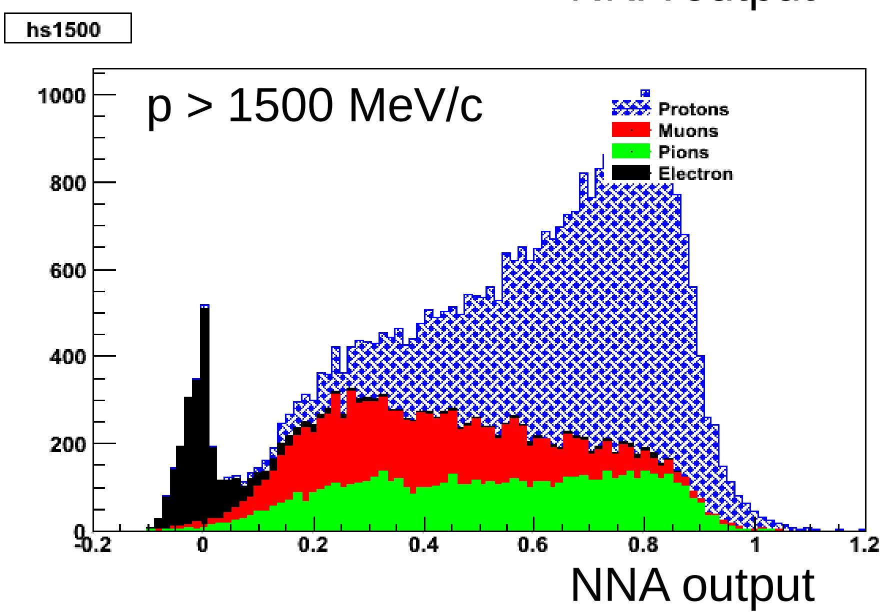
A different set of particle gun data files generated for NNA validation to test the NNA performance

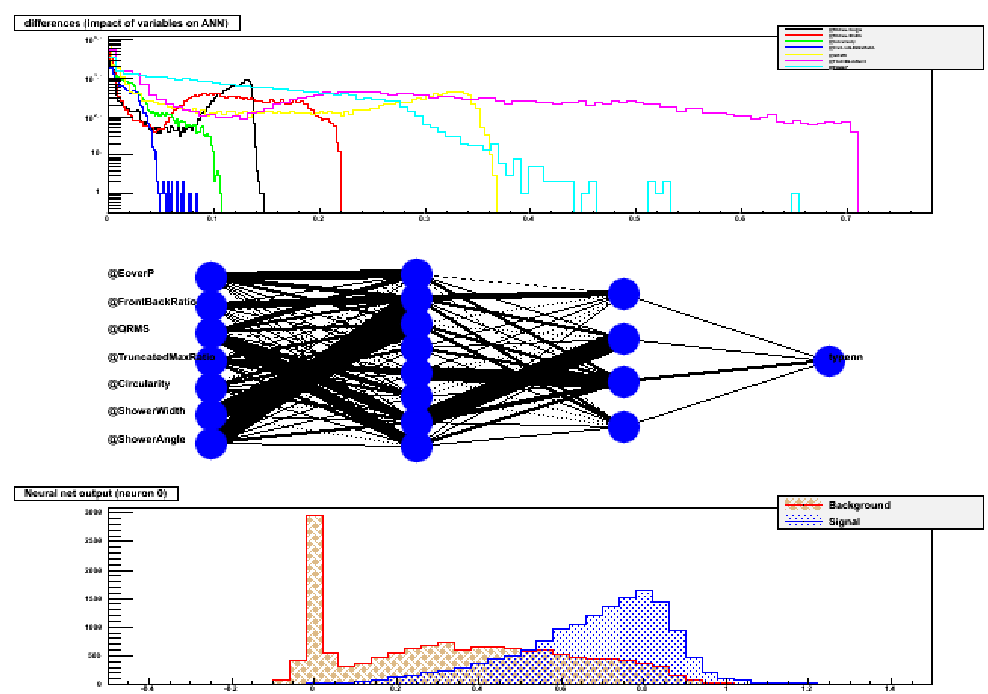
We test the ability of our NNA to discriminate between signal and background

Neural Network Training









Event selection FGD TPC

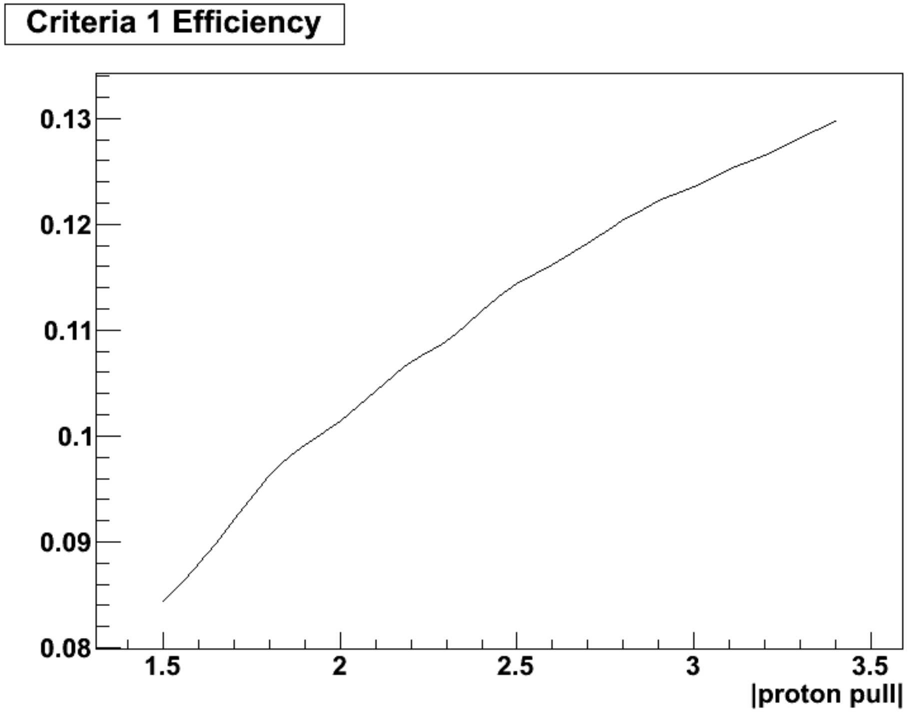
- Single positive track
- Events start in the FGD fiducial volume
- FGD ---> TPC ---> ECAL
- Good tracking info
- Particle ID
  - TPC
  - ECAL

Overview

- T2K and ND280 overview
- Proton PID physics motivation
- Steps of the analysis
- Results from MC and Test Beam Data files

Backup

- Criteria 1 : No restriction for e,μ,π pull
- Criteria 2 : |pull|>2.5 for e,μ,π



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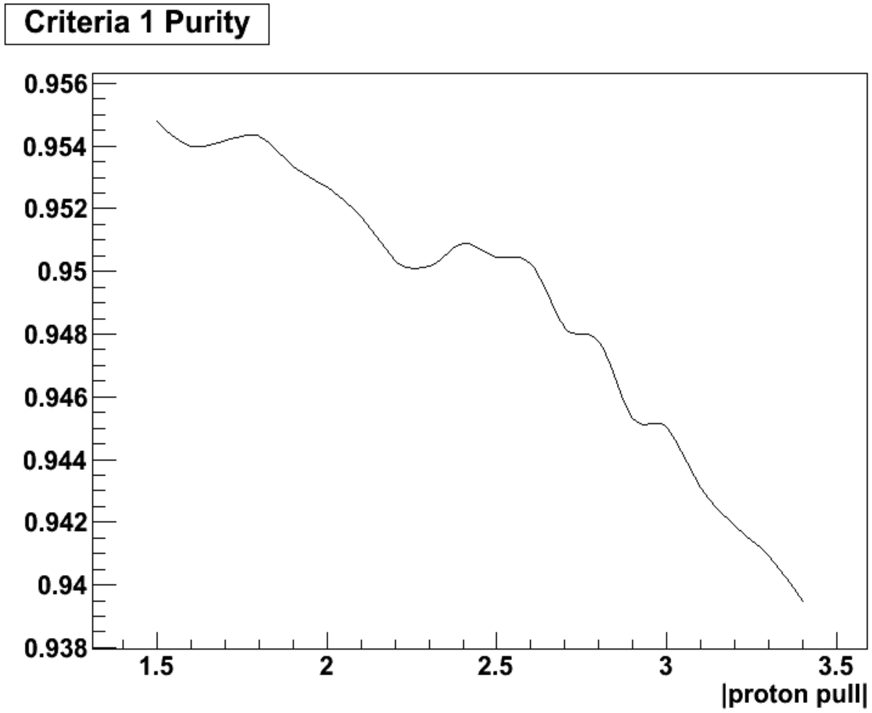
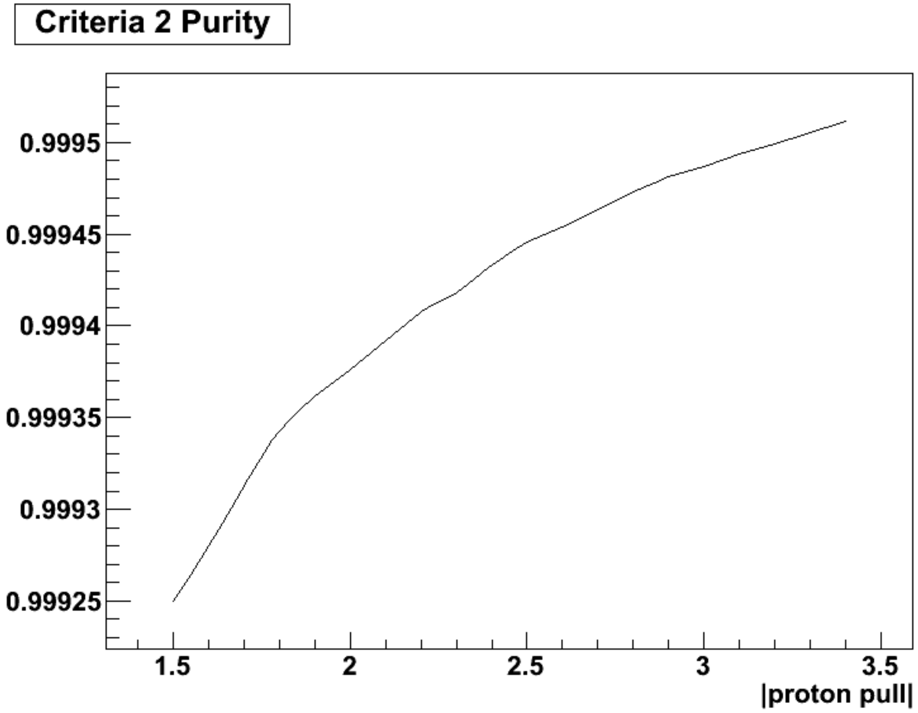
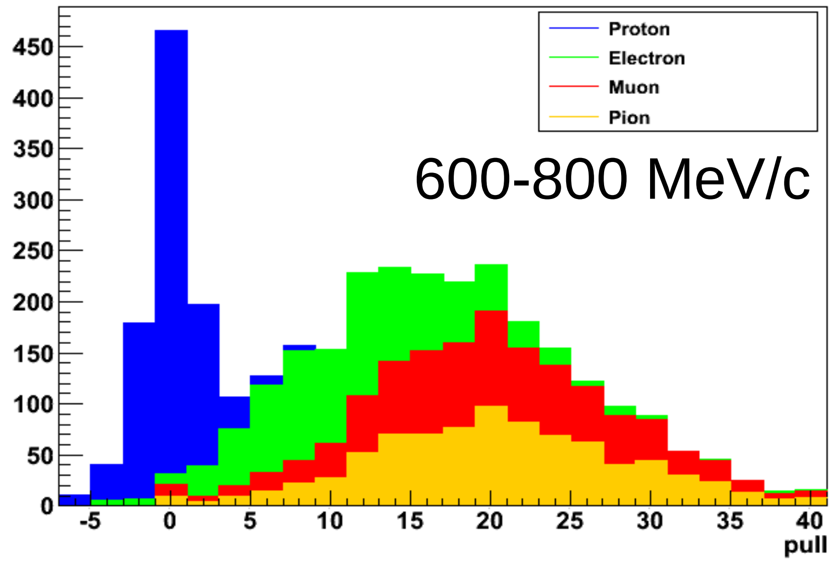


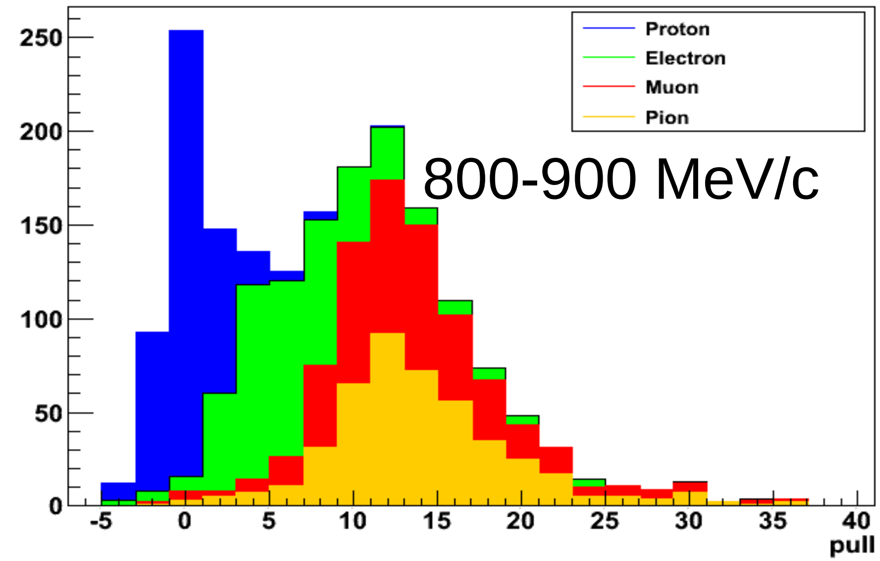


$$pull = \frac{Expected\ dE/dx - Measured\ dE/dx}{\sigma}$$

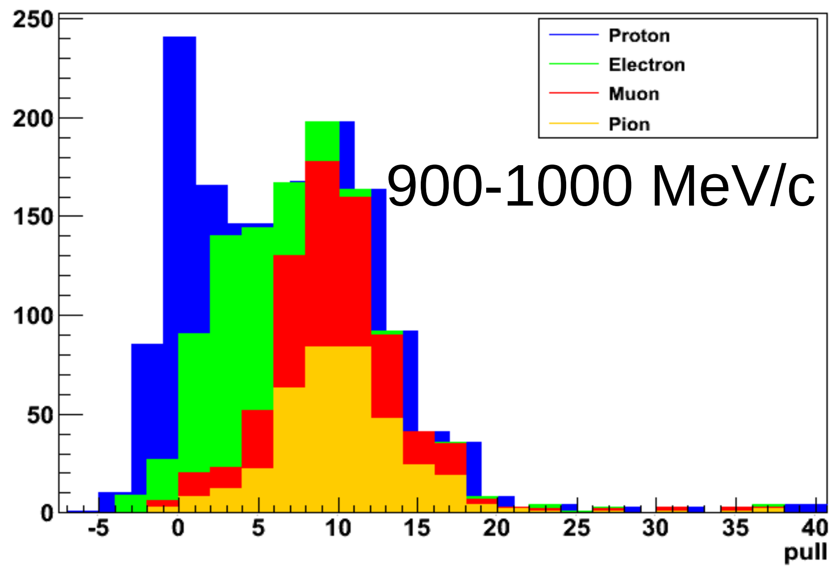
Pulls for momentum 600-800MeV/c proton hypothesis



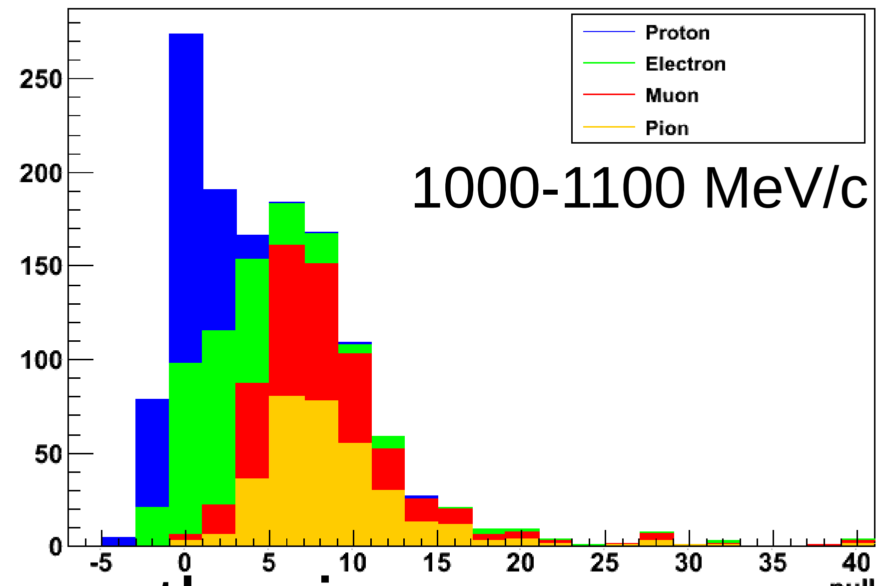
Pulls for momentum 800-900 MeV/c proton hypothesis



Pulls for momentum 900-1000 MeV/c proton hypothesis



Pulls for momentum 1000-1100 MeV/c proton hypothesis



Real proton hypothesis

Optimising The Pull

- Momentum region < 900 MeV/c
- Criteria 1 : No restriction for e,μ,π pull
- Criteria 2 : |pull|>2.5 for e,μ,π