Particle Identification in the ND280 Electromagnetic Calorimeter

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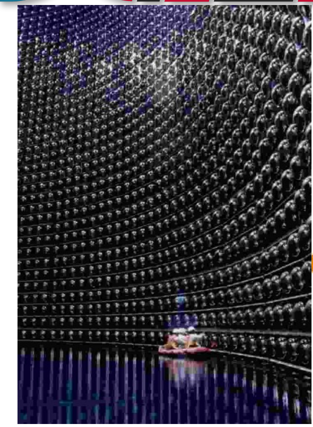
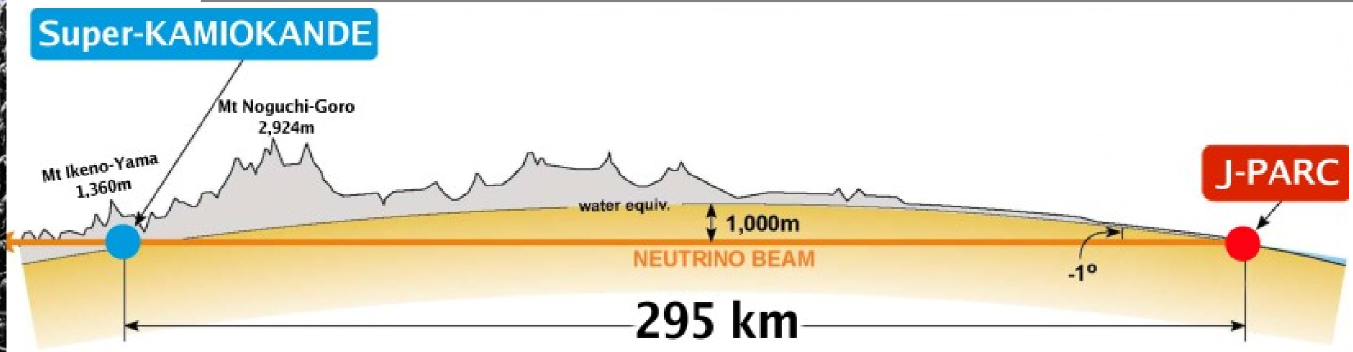
IOP HEPP 09

THE UNIVERSITY OF WARWICK

The T2K experiment

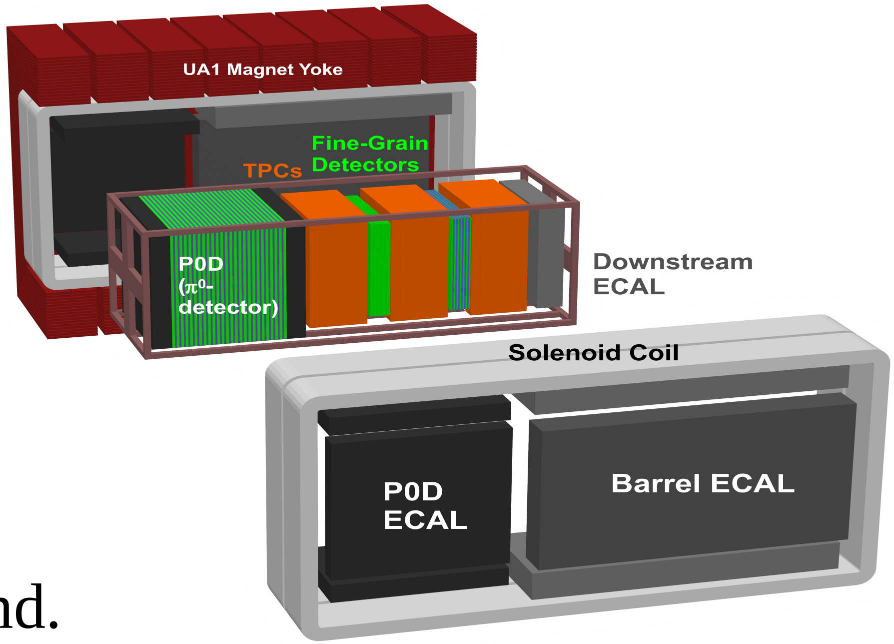




- T2K has a baseline of 295km.
- Muon neutrino beam generated at JPARC.
- Flux of muon and electron neutrinos measured at the ND280 detector.
- Muon neutrino disappearance and electron neutrino appearance measured at Super Kamiokande. θ_{13} search relies on electron neutrino appearance at far detector.
- Beam direction offset from far detector by 2 degrees.

ND280 Detector

- Located 280M from Proton target.
- FGD (Fine Grained Detector) and TPC (Time Projection Chamber) measure flux of muon and electron neutrinos close to source.
- P0D (Pi-0 Detector) measures the cross section of Pi0 production in water, as this is a Super-K background.



- **ECAL (Electromagnetic Calorimeter) tags and measures the energy of particles that escape the main volume of the detector.**
- Magnet, provides a magnetic field for charge and momentum measurements.

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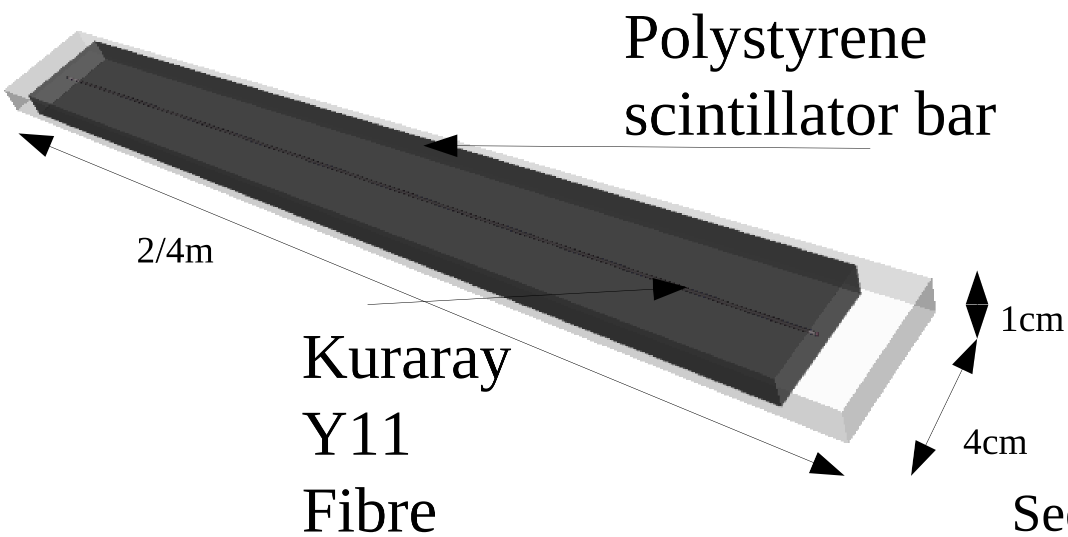
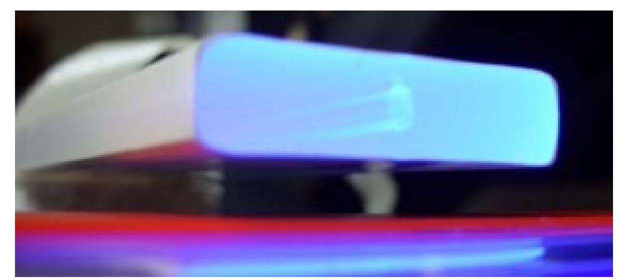
ND280 ECAL Design

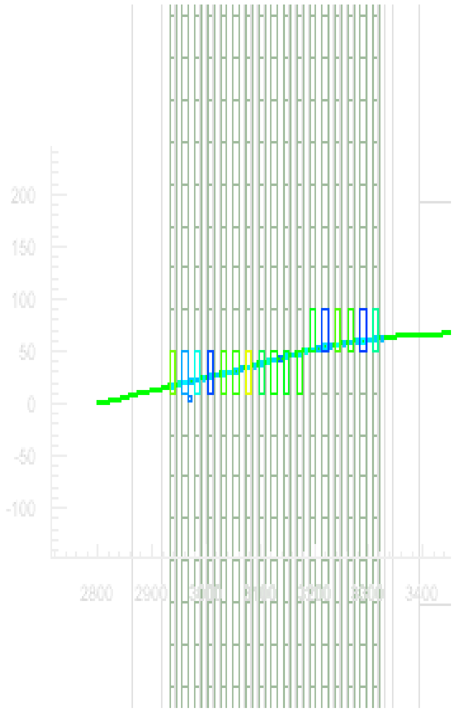
- The electromagnetic calorimeter is a lead/scintillator calorimeter.
- Contains and identifies particles that escape from the core of the detector and estimates the energy of charged particles.
- As it surrounds the core of the detector it can provide information to veto particles from outside such as cosmic particles.





See Gavin Davies talk, session 2C

Event Types

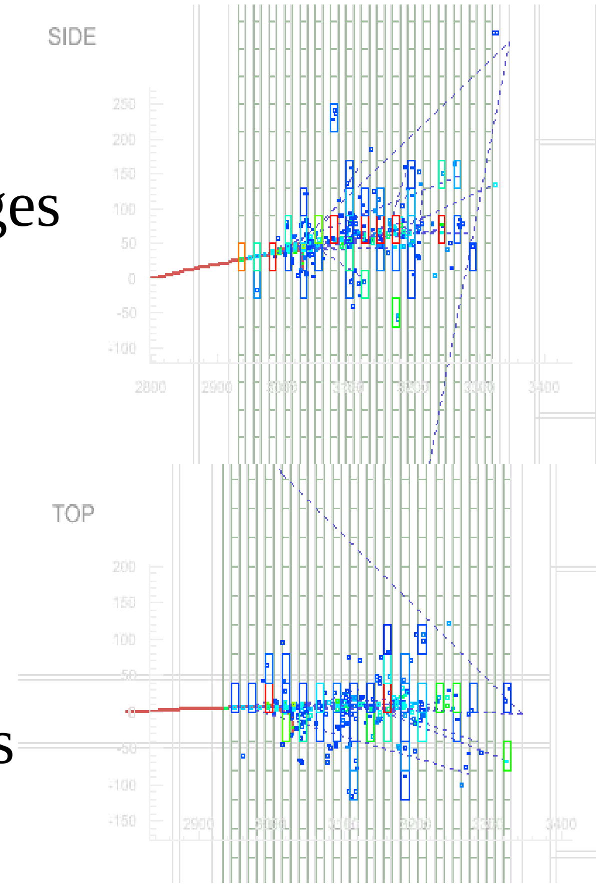


Track (left)

- Long, narrow cluster
- Narrow distribution of charges
- Charge distribution centred on MIP (Minimally Ionising Particle) energy deposit.

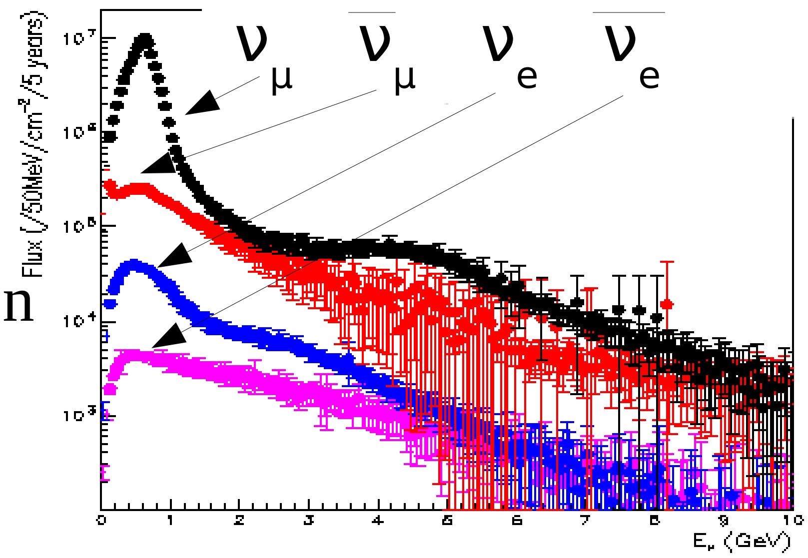
Shower (right)

- Wide cluster
- Large distribution of charges
- Electromagnetic shower converts rapidly on entering detector.



PID and the electron neutrino analysis

- The PID (Particle Identification) for the electromagnetic calorimeter is optimised to separate electrons and muons.



- Beam has an approximately 1% electron neutrino contamination due to kaon and muon decays.

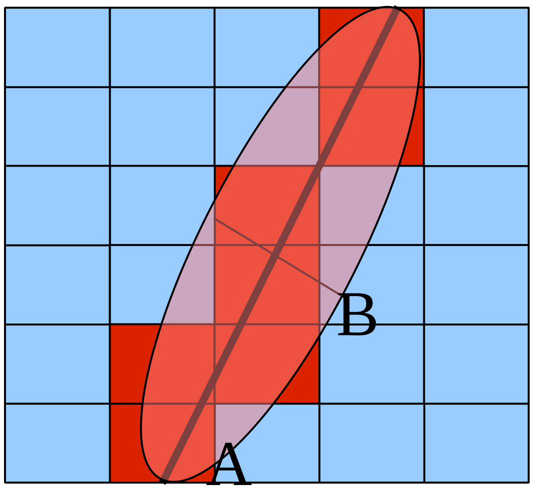
- Aim of electron neutrino study;
  - Measure the electron neutrino flux cross section with CCQE (Charged Current Quasi-Elastic) events - θ_{13} beam background.

- For the electron neutrino analysis a background acceptance of less 10^{-3} is required to give a signal to noise ratio of better than 1:1.

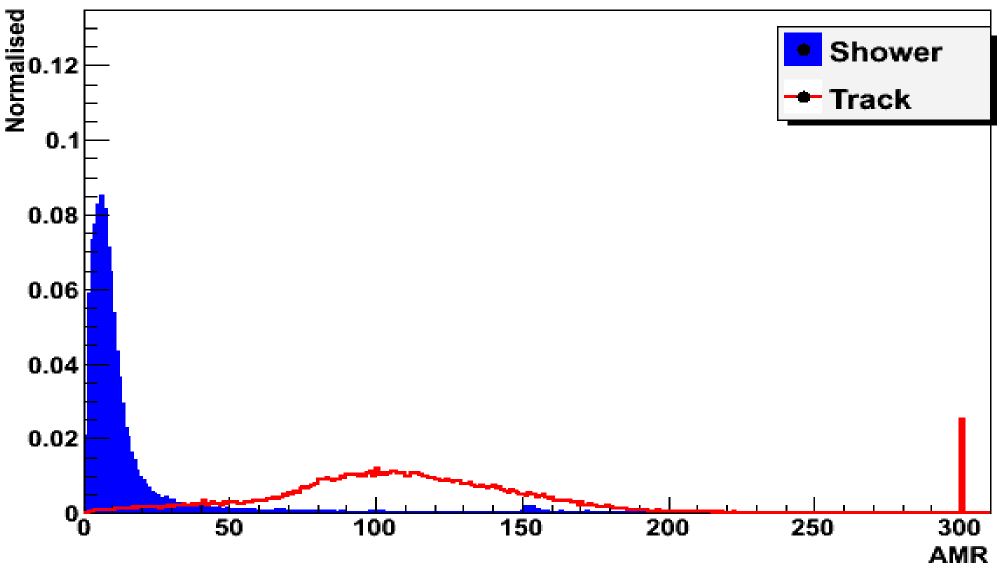
PID Variables - Example

AMR (Axis Max Ratio)

- Finds the 'longest' direction through the cluster using Principal Component Analysis.
- Then takes the ratio of this length to the orthogonal axis.
- This should be of order 1 for a shower but much larger for a track.



AMR = A/B

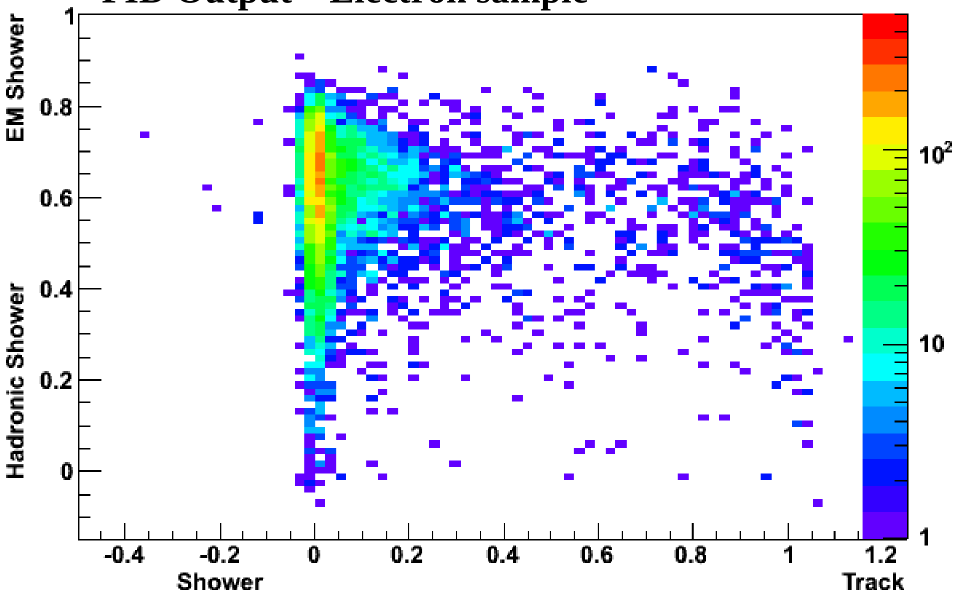


Neural Network Output - Track/Shower

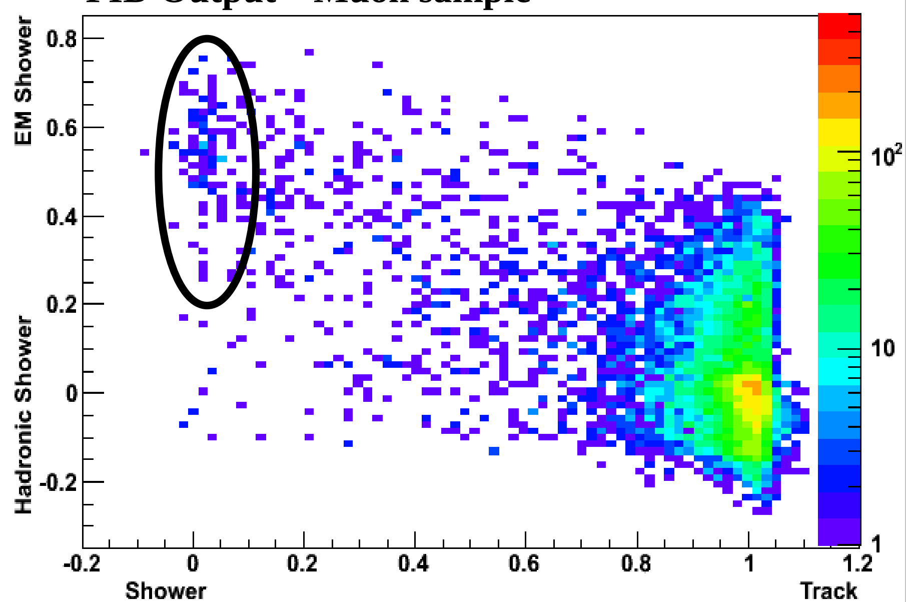
• Two neural nets are trained, one for the Track/Shower discrimination the other for EM/Hadronic shower discrimination.

• Stopping muons are often misidentified as showers.

PID Output – Electron sample



PID Output – Muon sample

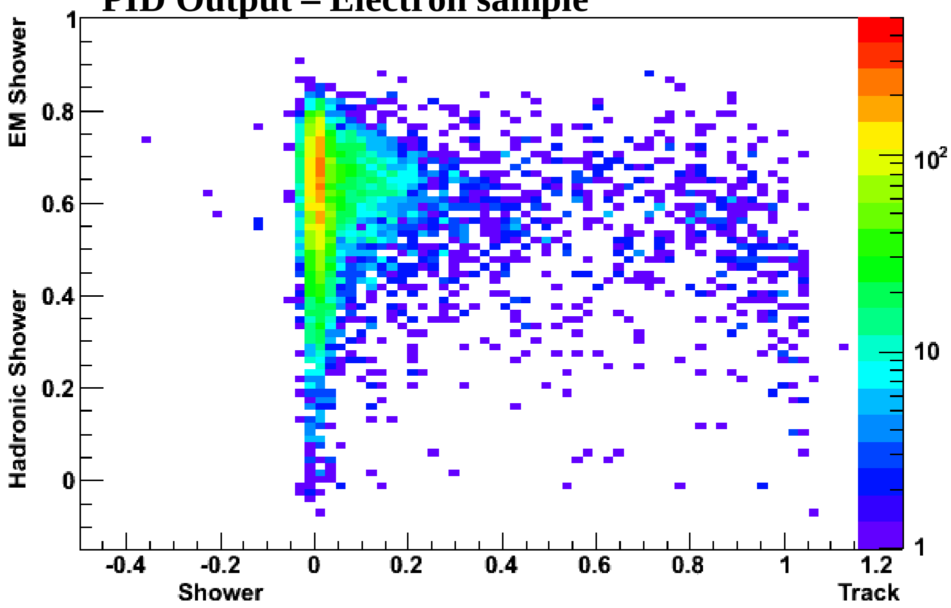


Neural Network Output - EM/Hadronic

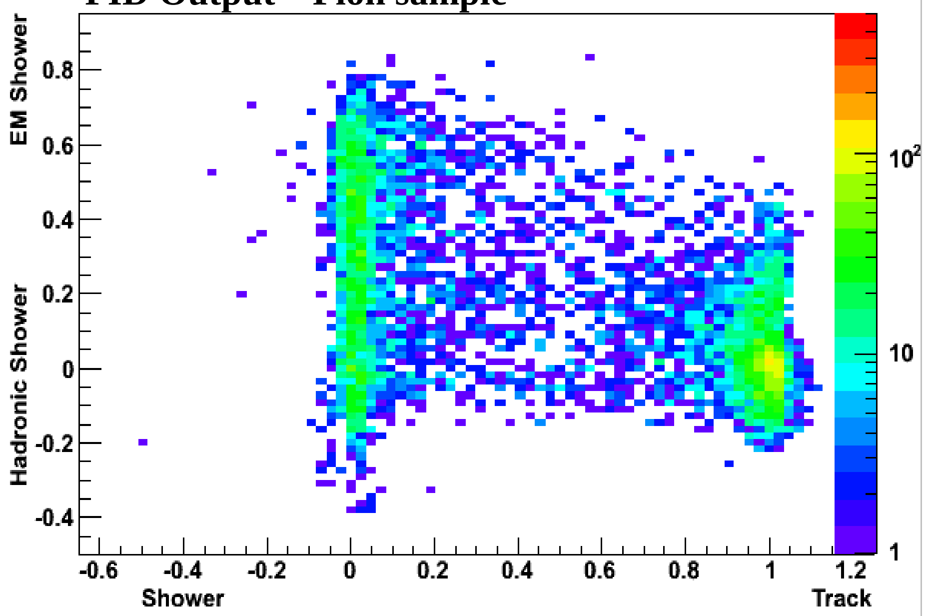
- MIP like pions are visible in the track-like region of the MLP output.

- Samples are less well separated than for Track/Shower identification as separating EM and Hadronic showers is more challenging.

PID Output – Electron sample



PID Output – Pion sample

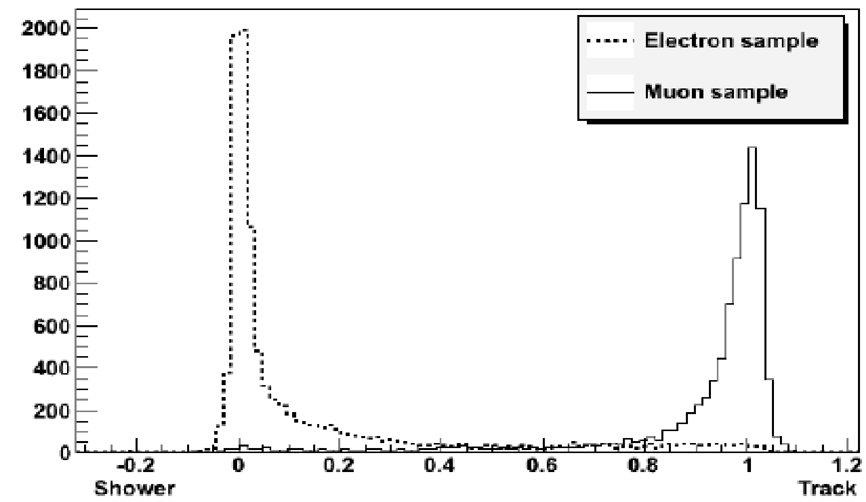


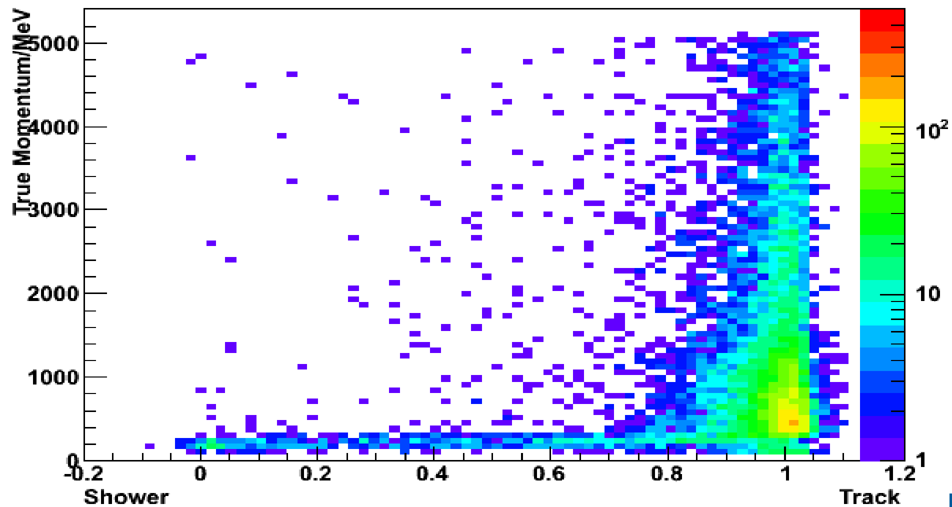
PID Performance – Track Shower

- Track vs. Shower discrimination tested with electron and muon MC samples.

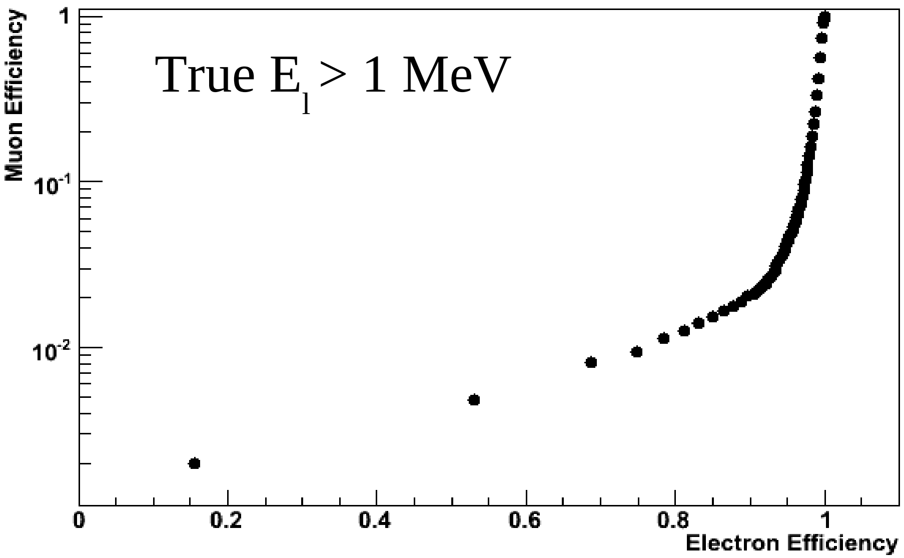
- Separation of electron and muon samples appear to be handled effectively by the network.

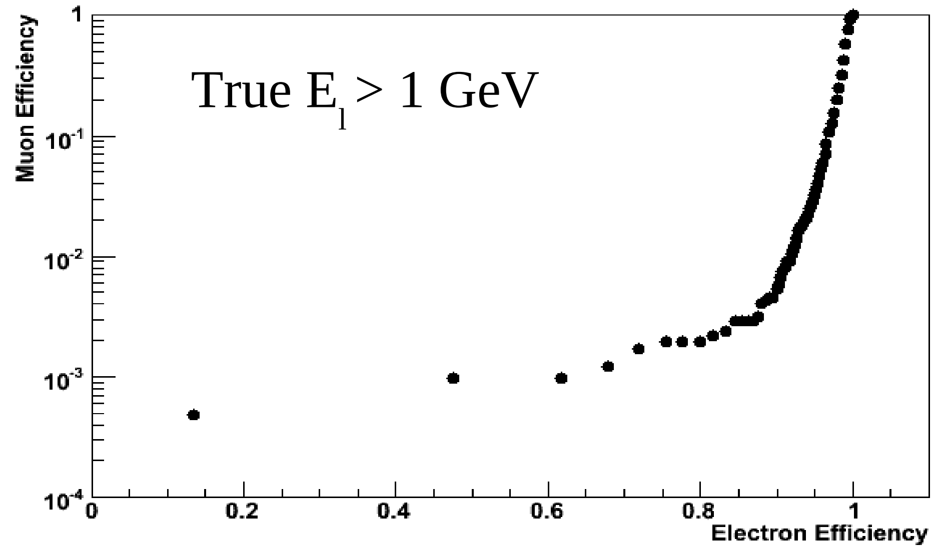
- The fraction of misidentified muons for a given energy increases with decreasing energy. This is due to stopping muons.





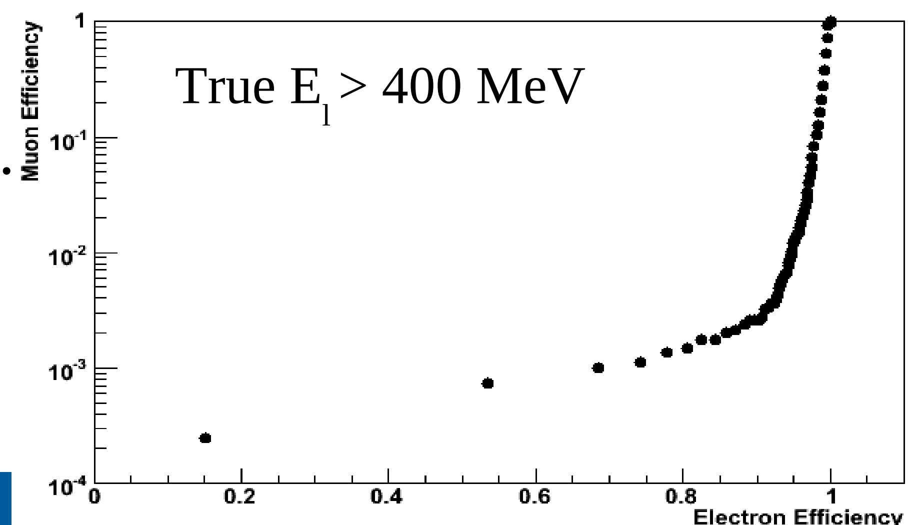
Track/Shower Performance





- Removing events below 400 MeV improves the performance of the PID.

- No obvious improvement in the higher 1 GeV energy cut.



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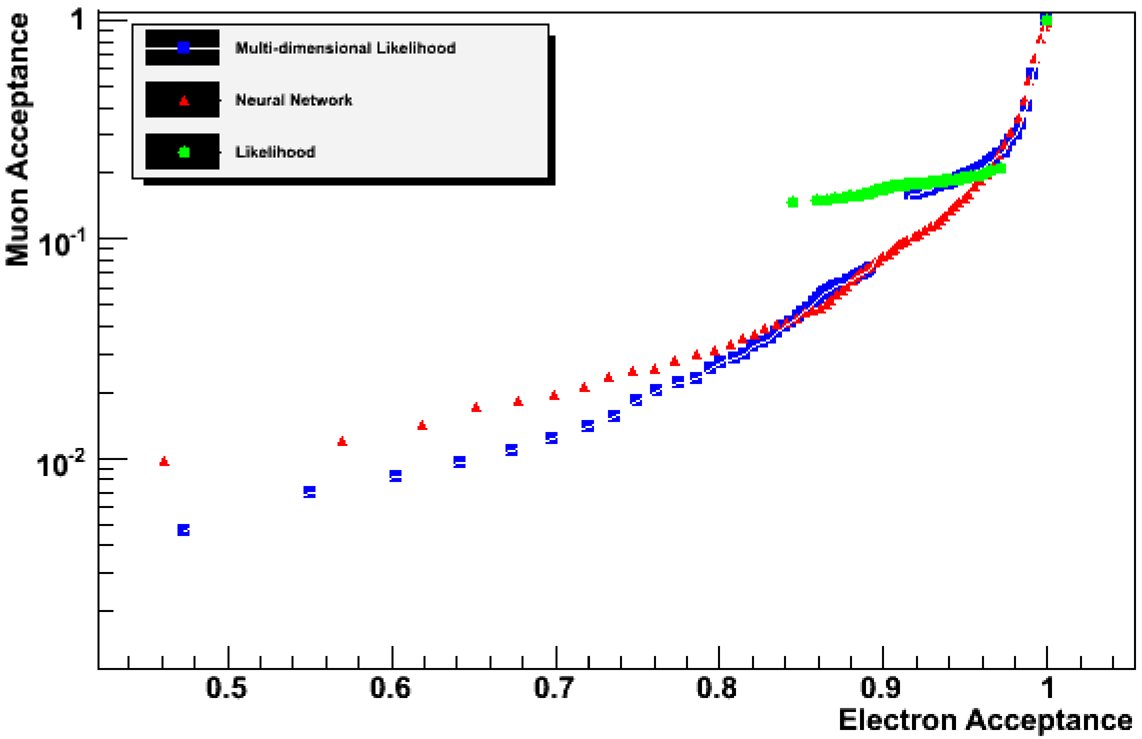
Comparison to likelihood techniques

- ANN and multi-dimensional likelihood have a similar performance.

- 1D likelihoods perform significantly worse as might be expected.



- Predicted PID performance over all energies gives an 80% electron acceptance for a 1% muon acceptance. Cutting at an output of 0.5.

Cosmic and Testbeam Data

• Final PID training will be with data from cosmic muons and a testbeam.

• Particularly pion events may not be well modelled at the T2K energy due to a lack of Hadronic interaction data.

• A cosmic run in March will be used to create a muon samples.

• Test beam at CERN is expecting to record approximately 500'000 and 500'000 electron events. This data will be used to train the EM and Hadronic shower hypotheses with real data.

• PID at the testbeam is carried out with TOF (Time Of Flight) and Cerenkov detectors.

Summary

• An artificial neural network has been designed to perform PID in the ND280 ECAL. From Monte Carlo studies a performance of 80% electron efficiency for 1% muon efficiency is predicted with the ECAL alone.

• New variables are being designed to improve the performance of the PID at low energy.

• Testbeam will be used to train final PID algorithm.

• Final variable selection will not be made until after this. Also decision trees and likelihoods will be implemented as its not apparent that neural net will still be optimum with more/different training data.

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