A Data Driven Method of Background Estimation at NOνA

DPF Meeting 2013, Santa Cruz, CA

Kanika Sachdev

University of Minnesota

For the NOνA Collaboration

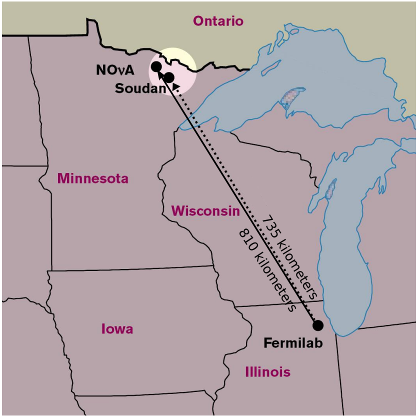
August 16th, 2013

Outline

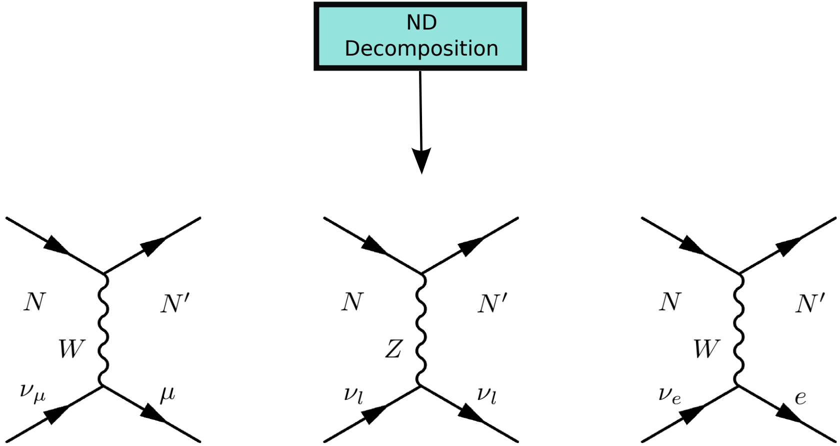
- Oscillation analysis at NOνA
- Muon Removed Charged Current (MRCC) – A data driven method of background estimation
- Summary

Oscillation Analysis

- NOνA can observe oscillations in two channels using a predominantly ν_μ beam:
  - ν_μ disappearance
  - ν_e **appearance**
- We have a two detector configuration
  - The Near Detector (ND), 1km from the target, used to measure composition of the un-oscillated beam
  - Far Detector (FD), 810km from the source, observes the oscillated beam

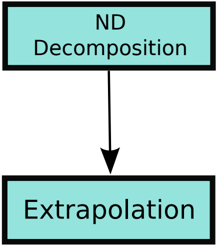


Oscillation Analysis

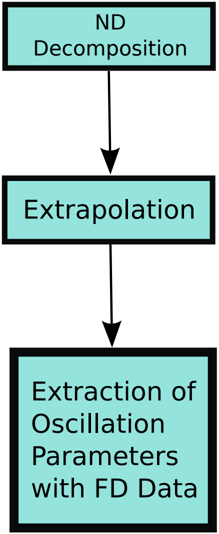


ν_μ Charged Current | Neutral Current | ν_e Charged Current

Oscillation Analysis

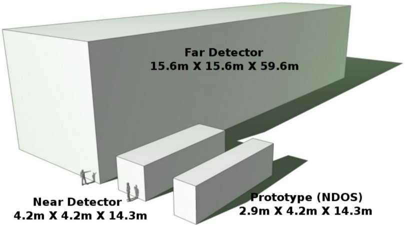


Oscillation Analysis



The Near Detector

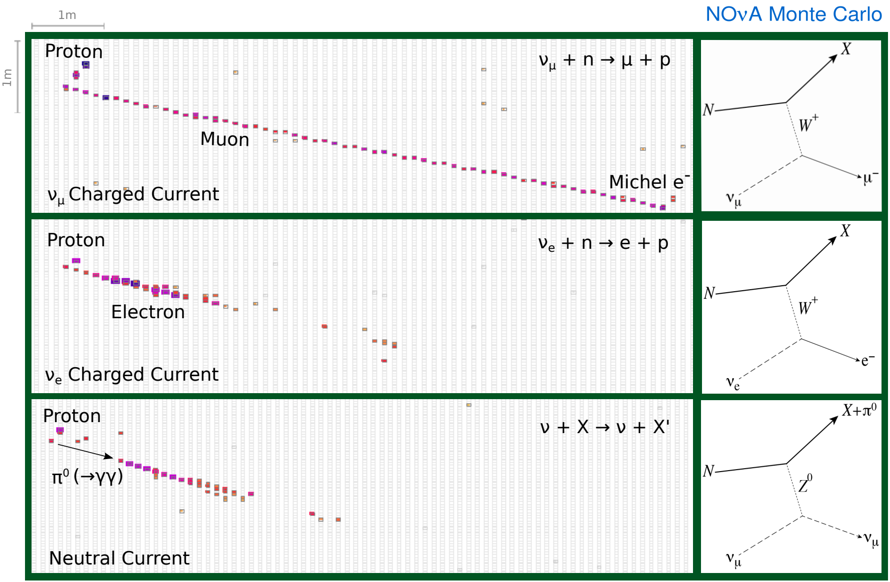
- Functionally identical to the FD (14kt), though much smaller at 300 tons
- The environment is quite different from the FD
  - Underground – small cosmic background
  - Very intense neutrino beam
  - Line source at ND vs point source at the FD
  - Decomposition and background estimation methods exploit these features of the ND



Near Detector And ν_e Appearance Analysis

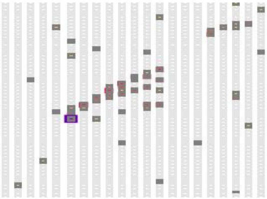
* There is no ν_e appearance signal in the Near Detector
* Anything our ν_e PIDs select as "signal" in the ND, is background
* Near Detector provides a "background only" sample for ν_e appearance analysis that can be extrapolated to the FD

Event Topologies At NOνA

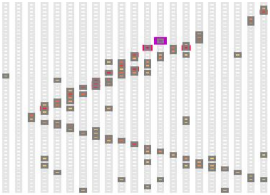


Muon Removed Charged Current (MRCC)

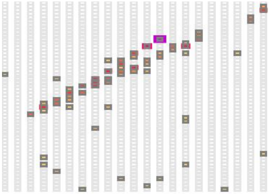
- Muon Removed Charged Current events are ν_μ CC interactions where the muon is removed from the event
- MRCC events give us a well-understood sample of hadronic showers
- Muon removal can be performed on Monte Carlo as well as data
- ν_μ CC events without the muon look a lot like Neutral Current events, which are the main background to the ν_e analysis



NC



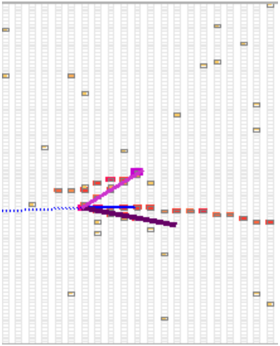
CC



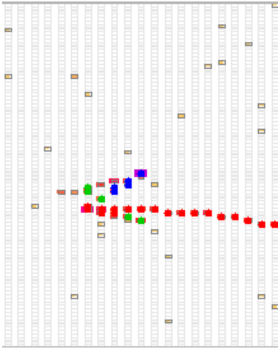
MRCC

MRCC Event Construction

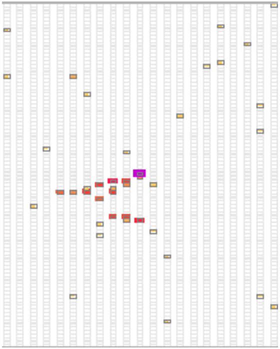
- The muon track is selected using the muon PID (see **Michael Baird's** talk on ν_μ analysis at NOνA)
- The hits that belong to the muon track are removed from the event



Monte Carlo Truth



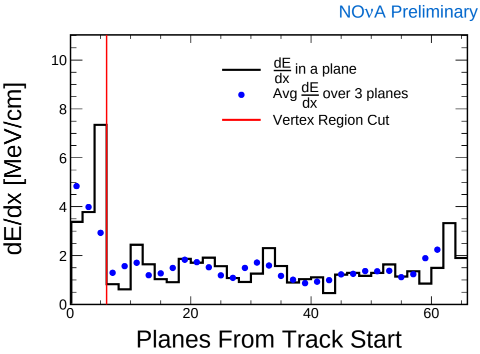
Track Reconstruction



Simple Muon Removal

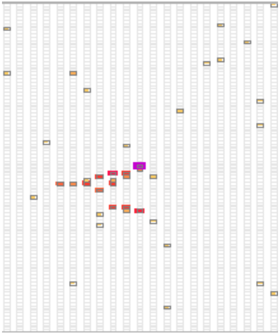
Separating Muon Energy And Hadronic Energy

- To avoid removing extra energy from event, muon tracks must be "cleaned up"
- We define a "vertex region" starting from the interaction vertex where its very likely that the muon shares hits with hadronic energy
- If dE/dx falls to levels consistent with muon energy deposition, and stays there for the next few planes, vertex region is over.

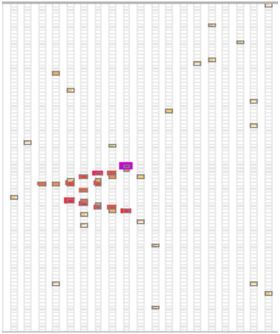


Muon Removal with CleanUp

* In the vertex region, instead of removing all energy in a cell, only 1 MIP is removed (the characteristic energy deposited by a minimum ionizing particle like muon).



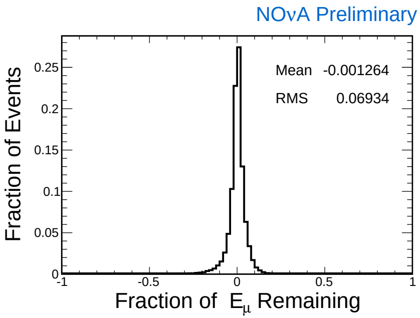
Simple
Muon Removal

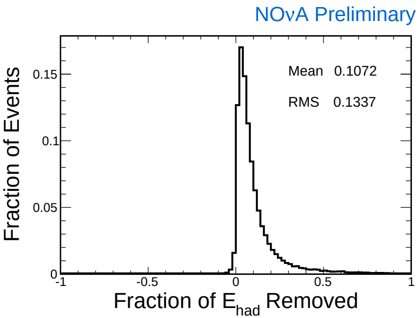


Muon Removal
with CleanUp

Muon Removal Performance

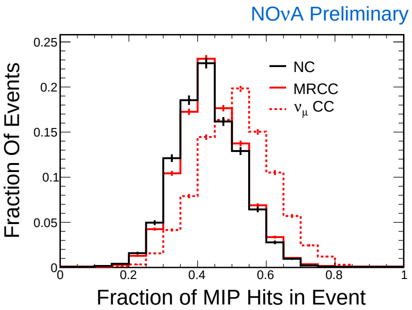
* If muon removal is perfect, all of muon energy from the event should be removed and none of the energy from hadrons should be removed

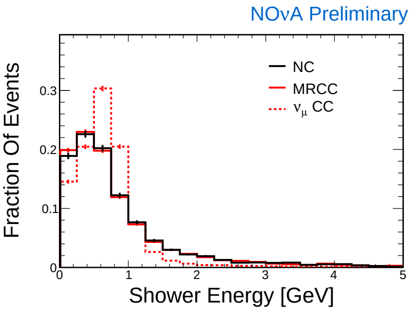




MRCC Similarity To Neutral Currents

- We have done several checks to test the likeness of MRCC events to NC events
- MRCC and NC samples look similar in low as well as high level variables





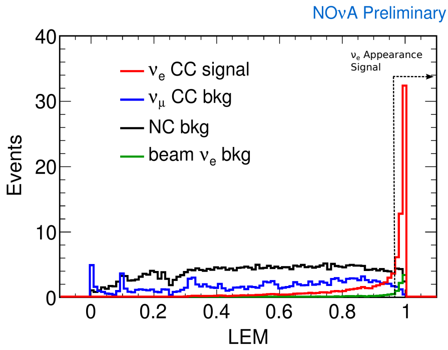
MRCC Analysis Flow

- The NC background estimation is done bin by bin:

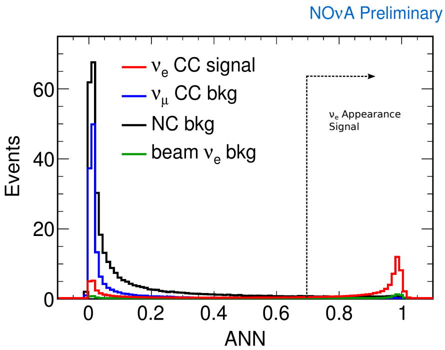
$$NC^{BG} = \frac{NC^{MC}}{MRCC^{MC}} \times MRCC^{Data}$$

- Many systematic effects cancel in the ratio, resulting in a more accurate estimate of background
- Uncertainties on neutrino cross-section parameters are large – therefore data-driven methods are important
- MRCC gives us one such handle
- CC hadronic showers are, however, different from NC hadronic showers
- Systematic effects accounted for include parameters like axial mass M_a, non-resonance background cross-sections, pion mean-free path etc

The Background We Are Trying To Predict Is Small...

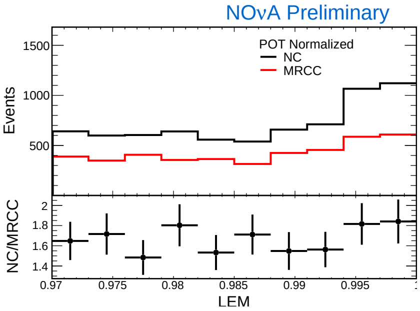


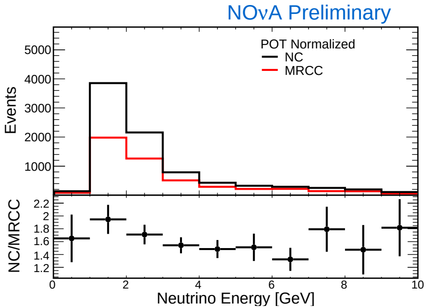
Library Matching based ν_e PID



ANN based ν_e PID uses shower shape variables

Computing The Ratio



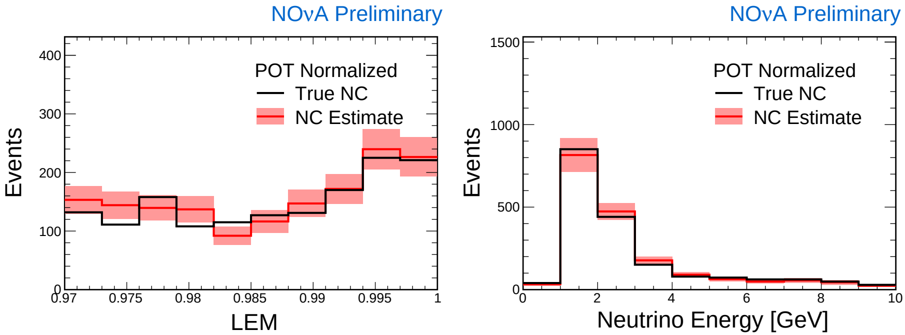


The error bars include statistical error and systematic error due to uncertainty on modelling parameters

Performance Of The MRCC Method

- Using the computed ratios, we can predict the NC background in data
- To see the performance of the method, we used a statistically independent set of Monte Carlo as pseudo-data
- The data set is equivalent to 2.2 E19 POT which amounts to ~2 weeks of Full Near Detector data at 700kW

Estimation Of Neutral Current In Pseudo-Data



The error bands include statistical error and systematic error due to uncertainty on modelling parameters

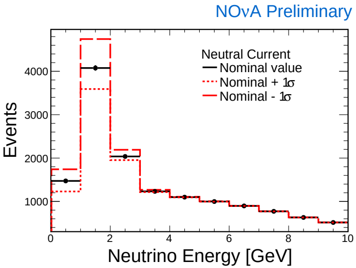
Summary

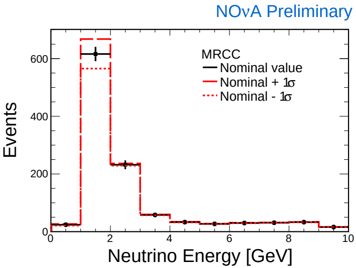
* We have multiple Near Detector background estimators in the works
* Muon Removed Charged Current is a data driven method of estimating neutral current rates in Near Detector
* The method gives results consistent with Monte Carlo truth
* Can estimate NC background to 10% error with <1 month of full Near Detector data
* We are excited to see it applied to our data!

Back Up

Examples Of Systematic Effects

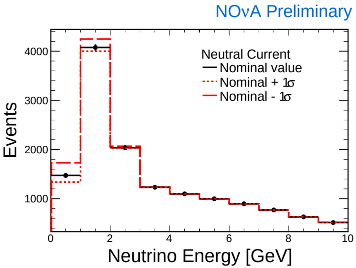
* Effect of changing the axial mass in resonance interactions on NC and MRCC samples

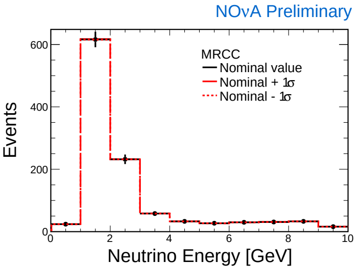




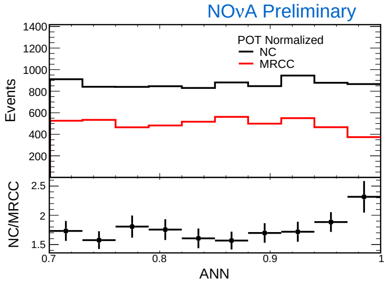
Examples Of Systematic Effects

* Effect of changing the axial mass in elastic Neutral Current interactions on NC and MRCC samples

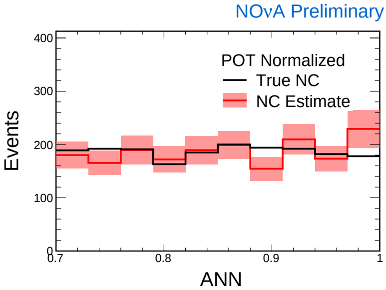




NC Background Prediction ANN ν_e PID Bins



Ratio NC/MRCC computed in ANN ν_e PID bins



NC Background prediction in ANN ν_e PID using MRCC