Study of Quasi-elastic Scattering in the NOvA Near Detector Prototype

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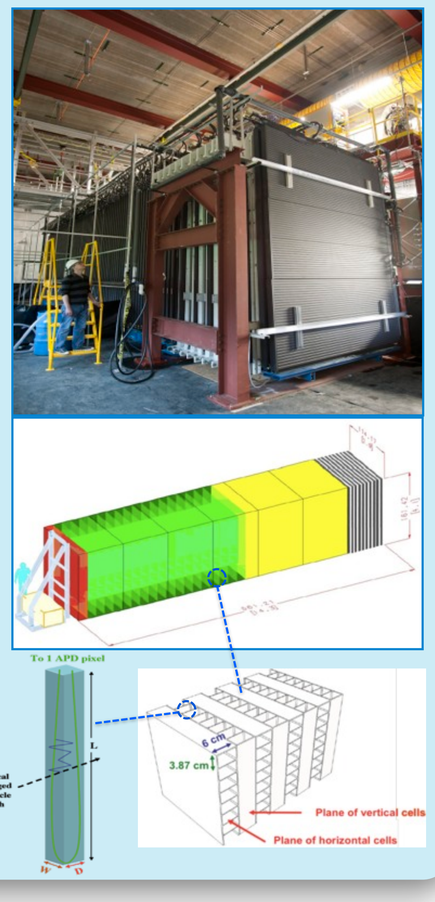
For the NOvA Collaboration

NOvA Near Detector Prototype

NOvA is a 14 kton long-baseline neutrino oscillation experiment now being assembled in northern Minnesota.

- The prototype is a 222 ton detector located on the surface at Fermilab.
- The prototype collected data for more than one year in the NuMI neutrino beam using a partially instrumented detector, 110 mrad off-axis.



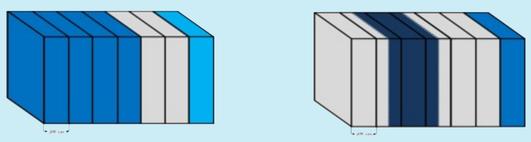
Detector Components

- Detector structure is PVC modules each of which has 32 cells.
- Each cell contains a looped wavelength shifting fiber readout by a pixel of a 32 channel Avalanche Photo-Diode (APD) array.
- Each module is filled with liquid scintillator.

Detector Prototype

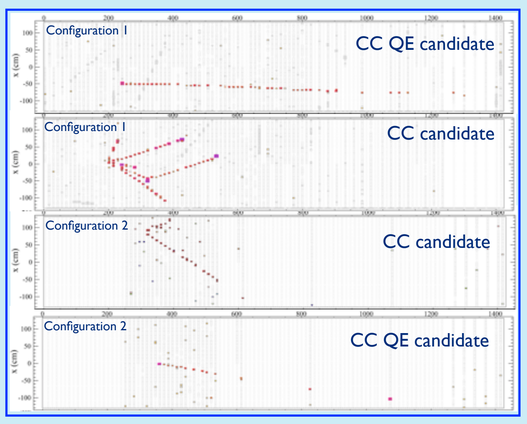
Two Detector configurations

Configuration 1 | Configuration 2



- Fully instrumented
- Mostly instrumented
- Partially instrumented
- Uninstrumented

Event Topology (Data)



Quasi-elastic Selection

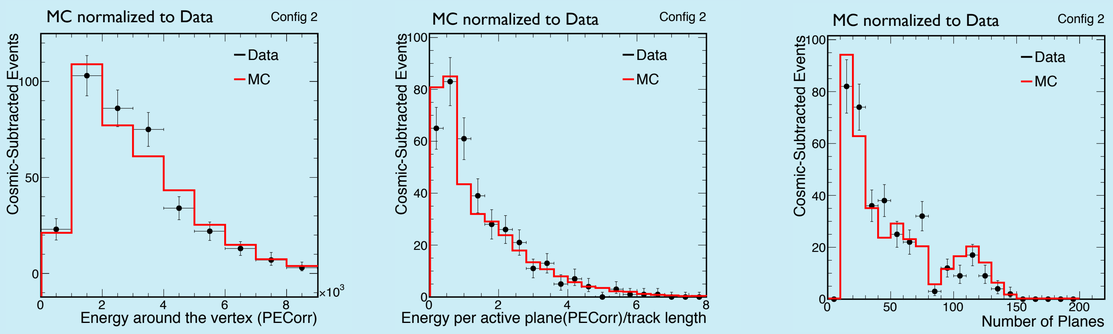
Quasi-elastic (QE) candidate pre-selection cuts:

- Event within 10 microsecond beam spill
- Interaction point 50cm from the edge of the detector
- One and only one reconstructed track
- The slope of the tracks is not near vertical (cosmic rejection)
- Track does not exit the detector

Quasi-eleastic interaction identification using a k Neural Network (kNN) algorithm with three input quantities shown below

NOvA Preliminary

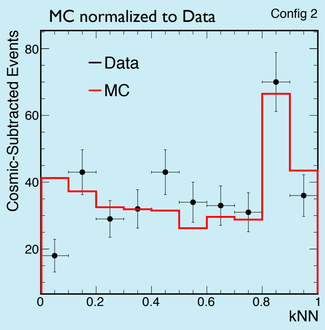
Energy around the vertex | Energy per plane per track length | Number of planes



Beam candidates after cosmic background subtraction and Monte Carlo simulation for preselected events

- **kNN selection:**

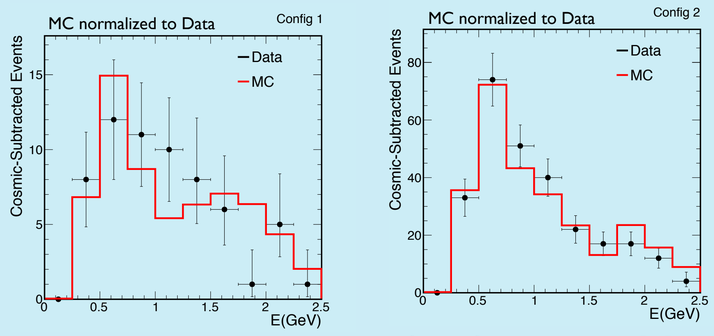
For kNN>0.3, events have 65% purity and 85% efficiency for the partially instrumented detector for both configurations.



Preselected events

Neutrino Energy and Q^2 Distribution

- Neutrino energy is reconstructed from the length of the track and its angle from the beam direction
- Neutrino energy for ν_μ CC QE selected events after cosmic background subtraction



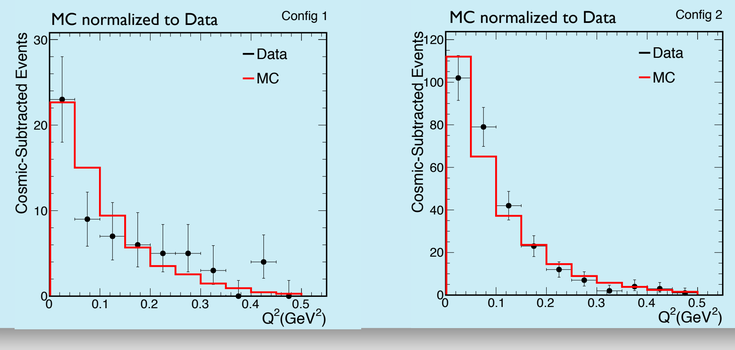
Energy is estimated using

$$E_\nu = \frac{2(M')E_\mu - ((M')^2 + m_\mu^2 - M_p^2)}{2[(M') - E_\mu + \sqrt{E_\mu^2 - m_\mu^2}\cos\theta_\mu]}$$

where M' is the adjusted neutron mass

$$M' = M_n - E_B \quad and \quad E_B = 25MeV$$

- Four momentum transfer for ν_μ CC QE selected events after cosmic background subtraction

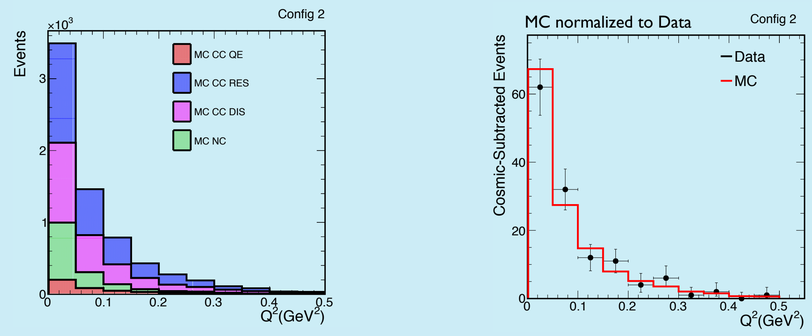


Four momentum transfer is estimated using

$$Q^2 = -m_\mu^2 + 2E_\nu(E_\mu - \sqrt{E_\mu^2 - m_\mu^2}\cos_\mu)$$

Study of Background

- Background dominated data with two reconstructed tracks from the interaction is used to cross check the Monte Carlo for background events.
- Each track has a minimum of four hits in each view.
- Longest track used to determine the energy and four momentum transfer

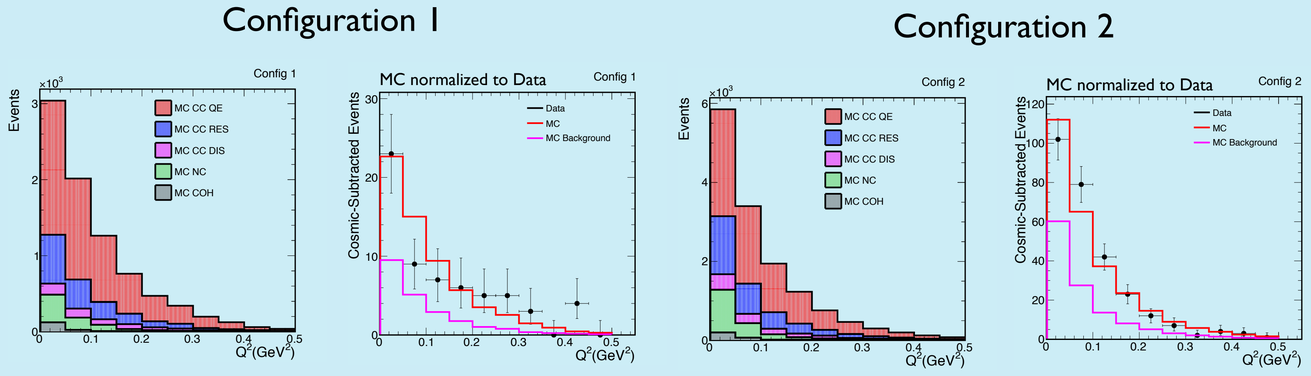


- Background data agrees well with MC simulations

Q^2 Distribution and Background

- Comparison of ν_μ CC QE selected data and Monte Carlo for both detector configurations

Configuration 1 | Configuration 2



For ν_μ CC QE selected events after cosmic background subtraction and MC simulation. The red curve is the total Monte Carlo prediction and the pink curve is the MC background prediction.

Summary

- Quasi-elastic studies using the data from the Near Detector Prototype will be limited by statistics.
- We continue to study neutrino data from the Near Detector Prototype to test analysis procedures for NOvA.
- NOvA will begin taking data with a partially constructed Far Detector early in 2013. The detector construction will be completed in early 2014.