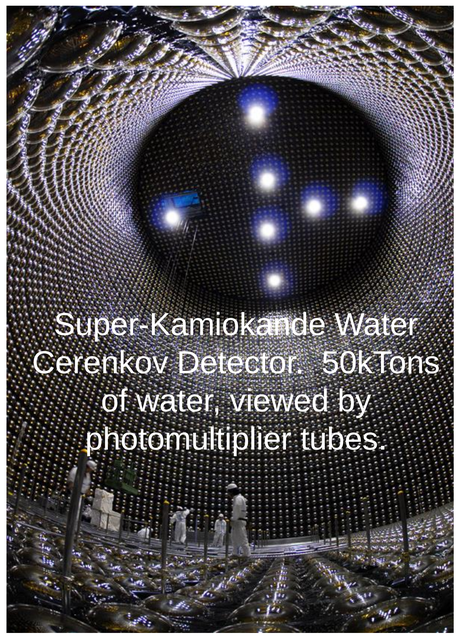
MINERvA: Bringing Neutrinos into Sharp Focus

MINERvA: Goals And Methods

Neutrino oscillations offer a chance to find a ***new source of matter-antimatter asymmetry***.

The Universe is matter-antimatter asymmetric. What caused this? Inquiring minds want to know.

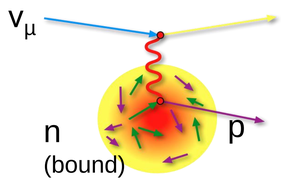


Water Cerenkov detectors can only see high velocity particles that exceed the speed of light in water. They miss a lot!

Neutrinos rarely interact, so neutrino oscillation experiments use massive nuclear targets with limited detection abilities. But these same detectors must be able to ***identify neutrino flavor*** and ***measure neutrino energy***.

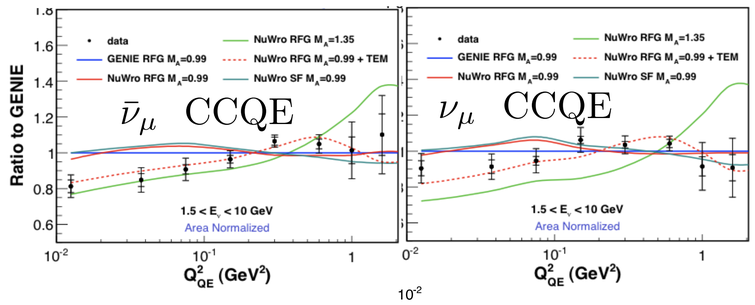
Quasi-Elastic Scattering

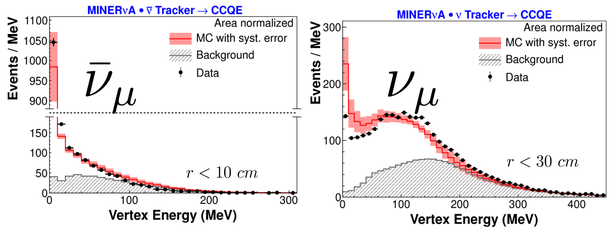
Phys Rev. Lett. 111, 002051 and 002052 (2013)



What is effect of nucleus?

Compare shape of $d\sigma/dQ^2$ to models

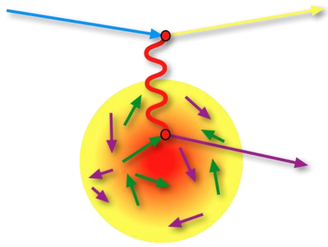




Look for energy near vertex consistent with extra nucleons *Data would prefer if 25±9% of events ejected initial state np pairs (final state nn or pp)*

Rate vs Q^2 and vertex energy hint at initial state correlated nucleons

Neutrinos Striking Nuclei



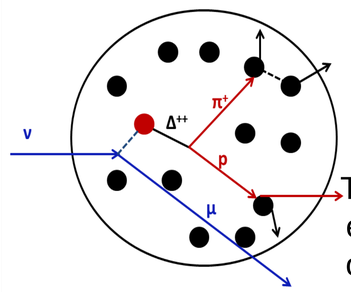
The nucleus is more than a collection of protons and neutrons.

At the transition between elastic and inelastic scattering, the nucleus behaves like a group of coupled springs.

Models are usually effective theories, rather than complete calculations. Data is needed to check and guide models.

Consider pion "resonant" production, $\nu_\mu p \to \mu^- \Delta^{++}$, $\Delta^{++} \to p\pi^+$. "Recipe" model:

1. $\nu_\mu p \to \mu^- \Delta^{++}$, on the bound proton
2. Δ^{++} and its decay products travel in nucleus

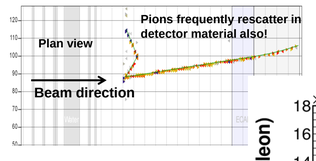


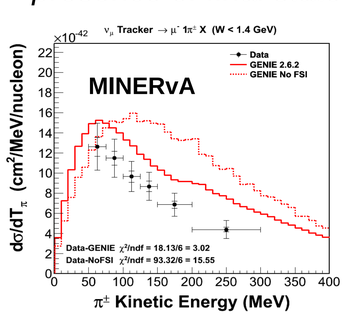
This neglects known effects (correlations of nucleons). ***Need data to know if it is good enough.***

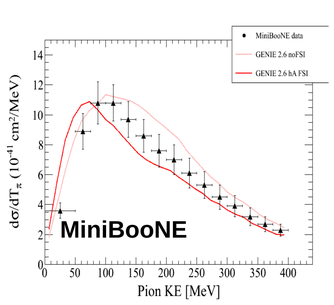
Pion Production

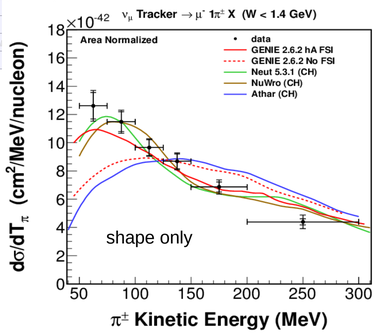
Do we correctly model nuclear rescattering, "final state interactions"?

Our data on pion momenta only agrees in the presence of final state rescattering



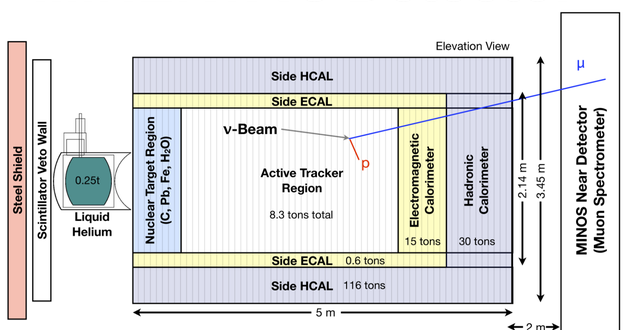


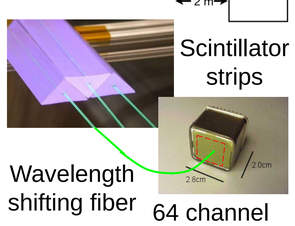




MiniBooNE's measurement sees more events, higher momenta and suggests less rescattering.

MINERvA's Detector

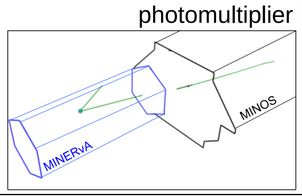




Scintillator strips

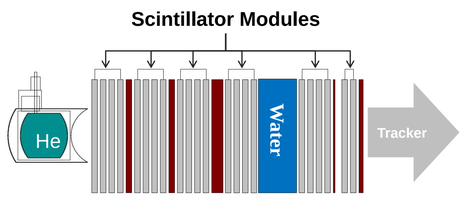
Wavelength shifting fiber

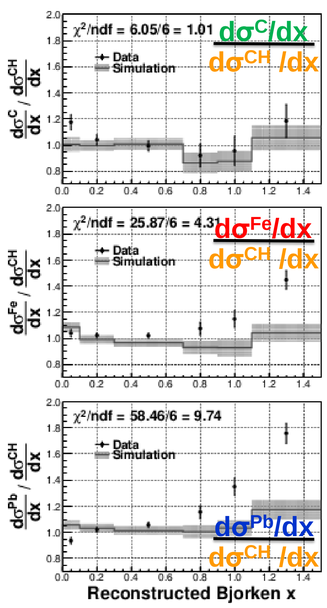
64 channel multi-anode photomultiplier

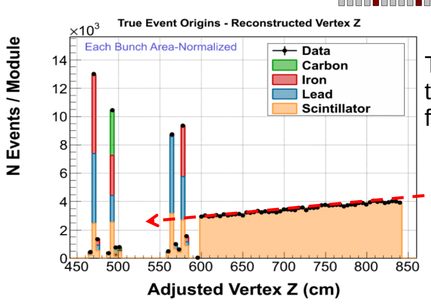


Reaction Rate Ratios on Nuclei

How are inclusive charged current reactions modified by nucleus?







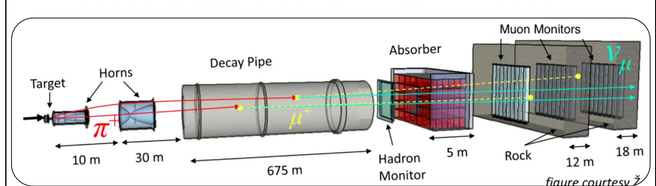
Targets are passive and there is contamination from nearby scintillator.

Use events in the tracker modules to estimate and subtract contamination from scintillator events

1. *At low x*, we observe a *deficit* that increases with the size of the nucleus.
2. *At high x*, we observe an *excess* that increases with the size of the nucleus.

These effects are not reproduced by current neutrino interaction models.

MINERvA's Beam



MINERvA uses the NuMI beam at Fermilab. Today's results from low energy beam; currently running in higher rate, higher energy beam (NOvA project).