Neutrino Cross Section Measurements from MiniBooNE

Geoffrey Mills for the MiniBooNE Collaboration
Los Alamos National Laboratory, Los Alamos, NM 87544 USA (mills@lanl.gov)

Neutrino Cross Sections and Neutrino Oscillations

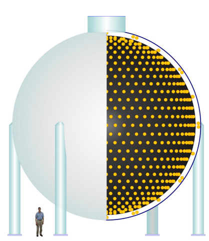
Neutrino interactions are important to understand for precise measurements of neutrino oscillation parameters. In many cases the uncertainty in neutrino-nucleus cross sections are one of the dominant sources of systematic errors.

In MiniBooNE the most prevalent processes are Charged Current (CC) and Neutral Current (NC) interactions in the quasi elastic (QE) and single pion (1π) channels. Thus CCQE, NCQE, CC1π, and NC1π in their various forms make up most of MiniBooNE's neutrino events.

The measurement of neutrino cross sections requires four ingredients:

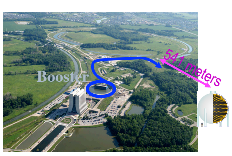
1. **The number of targets (in MiniBooNE the targets are the molecules of mineral oil which are chains of CH_2 primarily) which is given by the mass of the mineral oil.**
2. **The flux of neutrinos (in MiniBooNE the neutrinos are produced by 8 GeV protons impinging on a beryllium target, which produces pions and kaons that decay into neutrinos). The flux is predicted by a GEANT4 simulation and uses as input measurements made by the HARP Experiment at CERN, PS-214.**
3. **The number of neutrino interactions observed by the detector in the various channels of interest (CCQE, NCQE, CC1π, and NC1π) which requires taking data!**
4. **The efficiency and purity of the neutrino events recorded by the detector in each of the observed channels. This is calculated with a GEANT3 detector simulation coupled with the NUANCE event generator.**

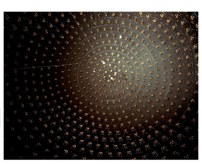
The MiniBooNE Detector



The MiniBooNE Detector

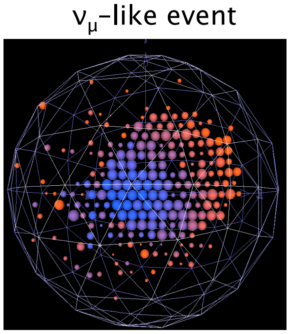
- 541 meters downstream of target
- 3 meter overburden
- 12 meter diameter sphere
  (10 meter "fiducial" volume)
- Filled with 800 t of pure mineral oil (CH_2)
  (Fiducial volume: 450 t)
- 1280 inner phototubes,
- 240 veto phototubes



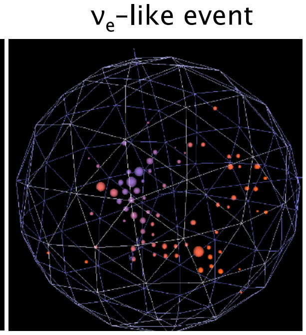


CCQE Event Displays

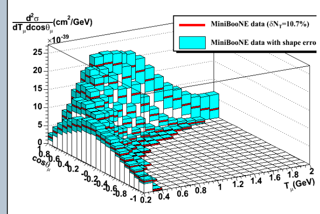
ν_μ-like event

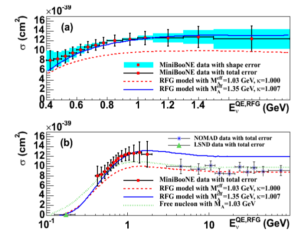


ν_e-like event



The Charged Current Quasi Elastic Channel (CCQE)





Theoretical approaches for the large cross section and harder Q^2 spectrum

Martini et al.,PRC80(2009)065501
Carlson et al.,PRC65(2002)024002

RPA formalism
SRC+MEC

The presence of a polarization cloud (tensor interaction) surrounding a nucleon in the nuclear medium contribute large 2p-2h interaction. Since MiniBooNE counts multi nucleon emission as CCQE, 2p-2h interaction is counted as CCQE and it enhances CCQE more than 40%.

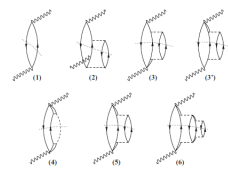
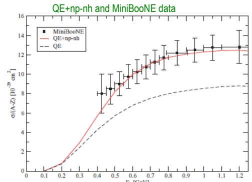
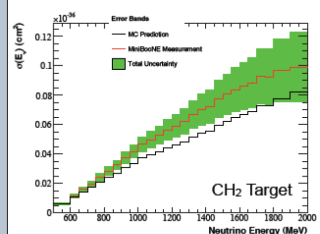


FIG. 1. Feynman graphs of the partial polarization propagators.

QE+np-nh and MiniBooNE data



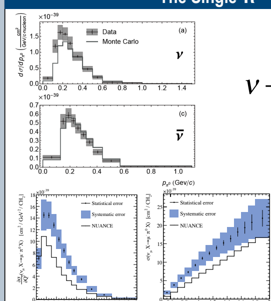
The Charged Current Single π⁺ Channel (CCπ⁺)



CCπ⁺ total cross section

$$\nu_\mu + p(n) \to \mu + \Delta^{+(+)} \to \mu + p(n) + \pi^+$$
$$\nu_\mu + A \to \mu + A + \pi^+$$

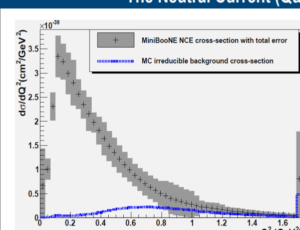
The Single π⁰ Channel (NCπ⁰ and CCπ⁰)



$$\nu + N \to \nu + N + \pi^0$$

$$\nu + N \xrightarrow{\Delta} \mu + N' + \pi^0$$

The Neutral Current (Quasi) Elastic Channel (NCE)



$$\nu + N \to \nu + N$$
$$(\nu + {}^{12}C \to \nu + X)$$

References

MiniBooNE cross section papers and students:

1. charged current quasielastic (CCQE) cross section measurement
   by Teppei Katori, PRD81(2010)092005
2. neutral current elastic (NCE) cross section measurement
   by Denis Perevalov, paper in preparation
3. neutral current p^o production (NCp^o) cross section measurement (n and anti-n)
   by Colin Anderson, PRD81(2010)013005
4. charged current single pion production (CCp^+) cross section measurement
   by Mike Wilking, paper in preparation
5. charged current single p^o production (CCp^o) measurement
   by Bob Nelson, paper in preparation
6. improved $CC1p^+$ simulation in NUANCE generator
   by Jarek Novak
7. CCp^+/CCQE cross section ratio measurement
   by Steve Linden, PRL103(2009)081801
8. anti-nCCQE measurement
   by Joe Grange, paper in preparation