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Recent results from MiniBooNE:
update on oscillation studies and xsec measurements
Outline

- MiniBooNE experiment
- Beamline and detector
- Disappearance analysis overview and results
- Appearance analysis overview and results
- Axial anomaly studies
- Cross-section results
- Conclusions
MiniBooNE experiment

The primary goal of the experiment was to investigate the signal observed in LSND in terms of neutrino oscillations.

The first beam induced neutrino events were detected in 2002 (first anti-neutrino beam delivered in 2006).

Since then MiniBooNE obtained several interesting results both in oscillation and cross-section studies.
Beamline and detector

8 GeV protons from Fermilab booster

Be target and magnetic focusing horn

50-m decay pipe

~ 500 m of dirt

Disappearance analysis

Sample selection:
- two hit clusters separated in time: single muon + decay electron
- minimal hits in veto
- 1\textsuperscript{st} cluster – muon-like track
- 2\textsuperscript{nd} cluster – below decay electron energy
- fiducial volume, beam-coincidence and data-quality cuts

Appr. 25\% \mu\textsubscript{\nu} content in \nu\textsubscript{\mu} sample due to higher \pi^+ production at the target and higher \bar{\nu}\textsubscript{\mu} cross-section

Compare the difference between data and prediction to the error as a function of reconstructed neutrino energy

Where \chi^2(\Delta m^2, \sin^2\theta) is larger than \chi^2(90\% \text{ CL}) then that oscillation prediction is excluded at 90\% CL
Disappearance results

No $\nu$ or $\bar{\nu}$ disappearance at 90% CL

First antineutrino disappearance measurement between 0.1-10 eV$^2$

Work to fold in the data from SciBooNE detector (same flux, xsec)

Appearance analysis

- Geant4 is used to predict neutrino spectrum at detector location

- NUANCE generator is used to model neutrino interactions in the detector

- Geant3 is used to model propagation of final state particles inside the detector

- Track-based likelihood method is used for event reconstruction

- Hit topology and timing are used for particle identification (separate electrons from $\pi^0, \mu$)

- Reconstructed energy spectrum is fit for oscillations
Appearance results (neutrino mode)

- Analysis based on 6.46E20 POT
- No oscillations at LSND L/E region (> 475 MeV)
- Observed 3σ excess of events in low-energy region (< 475 MeV)

Phys. Rev. Lett. 102, 101802 (2009)
Low-energy excess

Anomaly Mediated Neutrino-Photon Interactions
Harvey, Hill, & Hill, arXiv:0905.029

CP-Violation 3+2 Model

Lorentz Violation

CPT Violation 3+1 Model

VSBL Electron Neutrino Disappearance

New Gauge Boson with Sterile Neutrinos
Axial anomaly

\[ \nu N \rightarrow \nu N\gamma \text{ and } \bar{\nu} N \rightarrow \bar{\nu} N\gamma \]

- Anomaly-mediated photon production
- Photon can be mis-identified as electron in MiniBooNE detector
- Studies are undergoing

arXiv:0905.029
Appearance results (anti-neutrino mode)

- Analysis based on 3.386E20 POT
- No low energy excess
- Currently work on combined $\nu - \bar{\nu}$ analysis
- More data will provide additional information

Cross-section results

- $\nu_\mu$ CC QE

- Based on 150K event sample

- First measurement of double-differential xsec on carbon

- Extracted axial mass from a “shape-only” fit of the $Q^2$ QE distribution: $M_A = 1.35 \pm 0.17$ GeV
Cross-section results

- First differential xsec measurement of NC $1\pi^0$ production
- Based on 21K ($\nu$) and 2.8K ($\bar{\nu}$) event samples
- Kinematics of this process are important for background studies in appearance experiments

**Phys.Rev.D 81, 013005 (2010)**
Cross-section results

• CC $\pi^+$ to QE xsec ratio measurement

• Based on 46K sample

• Observed (top) and FSI corrected (bottom) ratios

Cross-section results

- NC elastic xsec
- Based on 94.5K NC elastic candidates
- First measurement in $Q^2 < 0.4$ GeV$^2$

arXiv:0909.4617
Conclusions and future plans

• Collect more anti-neutrino data (approved for a new 5E20 POT - currently running) for updated anti-neutrino and joint neutrino-anti-neutrino analyses

• Integration of SciBooNE data (near detector)

• Further studies of low-energy excess (MicroBooNE)