First Anti-Neutrino oscillation results from MiniBooNE

Žarko Pavlović
Los Alamos National Laboratory

DNP 2009, 10/16/09
LSND signal

- MiniBooNE designed to test LSND
- LSND observed excess of $\bar{\nu}_e$ in $\bar{\nu}_\mu$ beam
  $87.9 \pm 22.4 \pm 6.0 \ (3.8\sigma)$
- Assuming two neutrino oscillation:

$$P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) = \sin^2(2\theta)\sin^2 \left( \frac{1.27 \ L \ \Delta m^2}{E} \right)$$

$$= \ 0.245 \pm 0.067 \pm 0.045 \ %$$
• Within Standard Model 3 neutrino framework
LSND signal is not compatible with atmospheric and solar neutrino data

\[ \Delta m_{13}^2 = \Delta m_{12}^2 + \Delta m_{23}^2 \]

\[ \Delta m_{23}^2 = m_2^2 - m_3^2 \]

\[ \Delta m_{12}^2 = m_1^2 - m_2^2 \]
MiniBooNE

- Similar L/E as LSND
- MB detector:
  - 800 ton mineral oil Čerenkov detector
  - 12m diameter
  - 1280 inner PMT’s, and 240 outer veto PMT’s
- Focus either positive or negative mesons
- Collected & analysed:
  - $6.5 \times 10^{20}$ POT in neutrino mode
  - $3.4 \times 10^{20}$ POT in anti-neutrino mode
Neutrino events

- Čerenkov rings used to identify the products of $\nu$ interactions
- Looking for $\nu_e$ CCQE signal events
- Backgrounds:
  - Intrinsic $\nu_e$
  - Mis-identified events
- Use $\nu_\mu$ CCQE to constrain intrinsic $\nu_e$es
Neutrino run results

- No excess of events in signal region
- Ruled out 2ν oscillations as source of LSND signal (assuming no CP or CPT violation)

Neutrino run results

- Excess of events observed at low energy: \(128.8 \pm 20.4 \pm 38.3\) (3.0\(\sigma\))
- Shape not consistent with 2 \(\nu\) oscillations
- Magnitude consistent with LSND

Anti-Neutrino run

• Further insight in low energy excess
• Provides direct test of LSND
• Statistics low at present
  – First result with 3.4E20 POT
  – The total number of CCQEs down by order of magnitude compared to neutrino run
• Already have data corresponding to 4.86E20 POT
  – Approved for additional 5E20 POT run
• Same analysis as for neutrino mode with few checks
Antineutrino results

- No significant excess observed at either low or high energy
Limit from anti-neutrino run

- No significant excess observed at either low or high energy
- Assumes that neutrinos don't oscillate, only antineutrinos do
- Both LSND and null signal consistent with data at 90% CL
- Need more data
Low Energy Excess

- Preliminary results of the fits to $\nu$ and $\bar{\nu}$ data in low $E$ region
- Ignoring what we know about various backgrounds and looking only at how compatible two datasets are
- Preferred model: excess is due to neutrinos in the beam (no contribution from antineutrinos)

<table>
<thead>
<tr>
<th></th>
<th>Stat. Error Only</th>
<th>100% Correlated Syst. Error</th>
<th>Uncorrelated Syst. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same $\nu,\bar{\nu}$ NC</td>
<td>0.1%</td>
<td>0.1%</td>
<td>6.7%</td>
</tr>
<tr>
<td>NC $\pi^0$ scaled</td>
<td>3.6%</td>
<td>6.4%</td>
<td>21.5%</td>
</tr>
<tr>
<td>POT scaled</td>
<td>0.0%</td>
<td>0.0%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Bkgd scaled</td>
<td>2.7%</td>
<td>4.7%</td>
<td>19.2%</td>
</tr>
<tr>
<td>CC scaled</td>
<td>2.9%</td>
<td>5.2%</td>
<td>19.9%</td>
</tr>
<tr>
<td>Low-E Kaons</td>
<td>0.1%</td>
<td>0.1%</td>
<td>5.9%</td>
</tr>
<tr>
<td>$\nu$ scaled</td>
<td>38.4%</td>
<td>51.4%</td>
<td>58.0%</td>
</tr>
</tbody>
</table>

Maximum $\chi^2$ probability from fits to $\nu$ and $\bar{\nu}$ data in 200-475 MeV range
Conclusion

- MiniBooNE observes excess of low energy events in neutrino run consistent in magnitude with LSND signal, however energy shape not consistent with $2\nu$ oscillations.

- With $3.4 \times 10^{20}$ POT MiniBooNE does not observe low energy excess in anti neutrino data.

- High energy data consistent with both LSND best fit point and no oscillations.

- Collecting more anti-neutrino data (approved for a new $5 \times 10^{20}$POT run).