Constraining Sterile Neutrino Interpretations of the LSND and MiniBooNE Anomalies with CEνNS Experiments

arXiv:1901.08094
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LSND, and MiniBooNE Anomalies

- LSND 2001: Excess in $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ appearance
- MiniBooNE 2018: Excess in $\overline{\nu}_\mu (\nu_\mu) \rightarrow \overline{\nu}_e (\nu_e)$ appearance
- Combined significance: 6.0 $\sigma$

Aguilar-Arevalo et. al. (MiniBooNE), arXiv: 1805.12028
Sterile Neutrinos and SBL Oscillations

\[ P_{\alpha \rightarrow e, \mu, \tau} = 1 - 4 |U_{\alpha 4}|^2 \left( 1 - \sum_{\beta=e, \mu, \tau} |U_{\beta 4}|^2 \right) \sin^2 \left( \frac{1.27 \Delta m^2 (eV^2) L(m)}{4E(MeV)} \right) \]

- Short baseline: no SM neutrino oscillation
- Parameter space explored only through charged currents.
- Best global fit: \( \Delta m^2_{41} \approx 0.5 \ (eV^2) \)
  \[ \sin^2 (2\theta_{\mu e}) \approx 6 \times 10^{-3} \]
  \[ \sin^2 (2\theta_{\mu e}) = 4 |U_{e4}|^2 |U_{\mu 4}|^2 \]
Neutral vs Charged Currents

\[
\left( \frac{d\sigma}{dE_T} \right)_{NC} \propto \frac{G_F^2 M}{4\pi} N^2
\]
\[
\left( \frac{d\sigma}{dE_T} \right)_{NC} \approx \mathcal{O}(10^2) \cdot \left( \frac{d\sigma}{dE_T} \right)_{CC}
\]

- Smaller detector mass
- Very low background
- Flavor independent

Akimov et al. (COHERENT), arXiv: 1708.01294
Proposed Measurement

- 100 kg CsI over 10 years
- Baselines: 20 and 40 meters
- Pulsed $\pi$-DAR spallation source (e.g. the Spallation Neutron Source)
- 1 GeV protons @ 60 Hz: $L_0 = 4 \times 10^{23}$ yr$^{-1}$
- Using timing and multiple baselines reduces uncertainties & increases sensitivity to short baseline oscillations.

Carlos Blanco @ PHENO 2019
Spallation $\pi$-DAR sources

$\pi^+ \rightarrow \mu^+ \nu_\mu \rightarrow e^+ \nu_e \bar{\nu}_\mu \nu_\mu$

$\approx 0.026 \mu s \quad \approx 2.197 \mu s$

$E_{\nu_\mu} \approx 30 \text{MeV}$
The Importance of Timing

- Timing information allows for separation of neutrino flavors.
- Upper frames: $\Delta m_{41}^2 = 0.55 \text{ eV}^2$
- Lower frames: $\Delta m_{41}^2 = 1.3 \text{ eV}^2$

3 year total exposure @ 20 and 40 meters  
10 year total exposure @ 20 and 40 meters
Sensitivity to Sterile Neutrinos

- Equal time of exposure at each baseline
- Exclude most of preferred parameter space @ 99% CL

3 year total exposure @ 20 and 40 meters
10 year total exposure @ 20 and 40 meters

Blanco, Hooper, Machado, arXiv:1708.01294
Future Prospects

• Bigger detector masses are possible since CsI is inexpensive.

• Cooling could give better performance.

• Higher flux sources decrease required exposure time.

• Considering sources with complementary neutrino flavor profiles.

• Similar setups/analysis could constrain NSI, DM, cross section uncertainties.
Acknowledgements

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LSND & MiniBooNE anomalies can be explained by sterile neutrinos.
CE $\nu$NS cross section is much higher than CCQE at MeV energies.
Pulsed Pion-DAR sources provide excellent timing and energy profiles.
Timing information gives important flavor discrimination.
Flavor discrimination could disentangle $|U_{\mu 4}|^2$ from $|U_{e 4}|^2$.
1000 kg y of CsI could probe the most of the best-fit parameter space.
Small scale experiment probing “high” energy BSM physics.
<table>
<thead>
<tr>
<th>Experimental Parameter</th>
<th>Benchmark value</th>
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<tr>
<td>Total Systematic Uncertainty</td>
<td>28%</td>
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<tr>
<td>$B_{ss}$ (Steady State Background)</td>
<td>Characterized -&gt; Negligible (Timing helps a lot)</td>
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<tr>
<td>$B_{on}$ (Beam On Background)</td>
<td>$1.45 \times 10^{-10}$ counts/kg/$\mu$s (10x &lt; than COHERENT)</td>
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<td>$E_T$ threshold</td>
<td>Sigmoid: 0% @ 2.5 KeV and 100% @5.0 KeV</td>
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