THE UNIVERSITY OF CHICAGO

Kavli Institute for Cosmological Physics at The University of Chicago

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

arXiv:1901.08094

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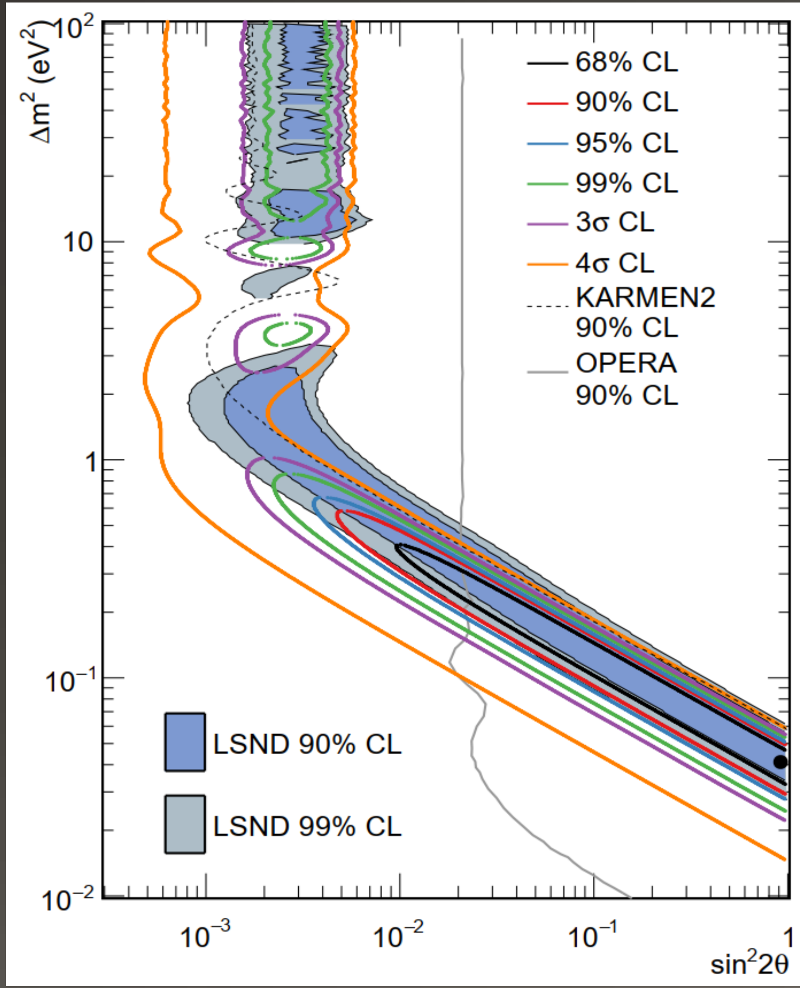
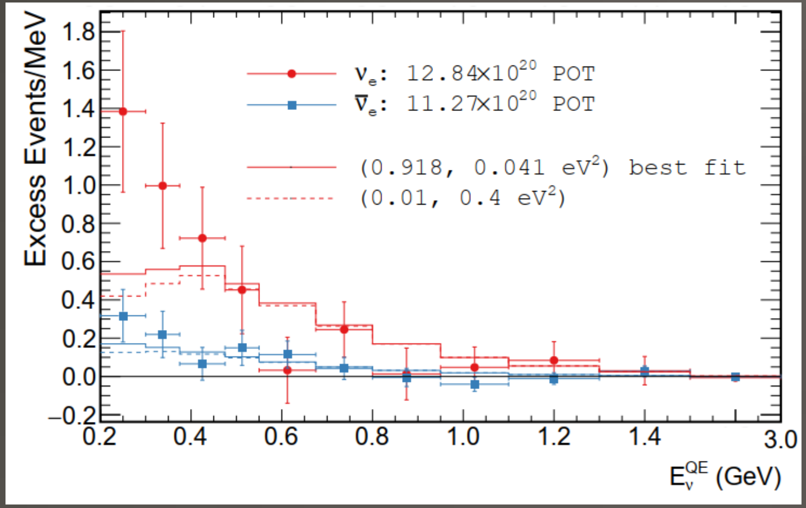
# LSND, and MiniBooNE Anomalies




Aguilar-Arevalo et. al. (MiniBooNE), arXiv: 1805.12028

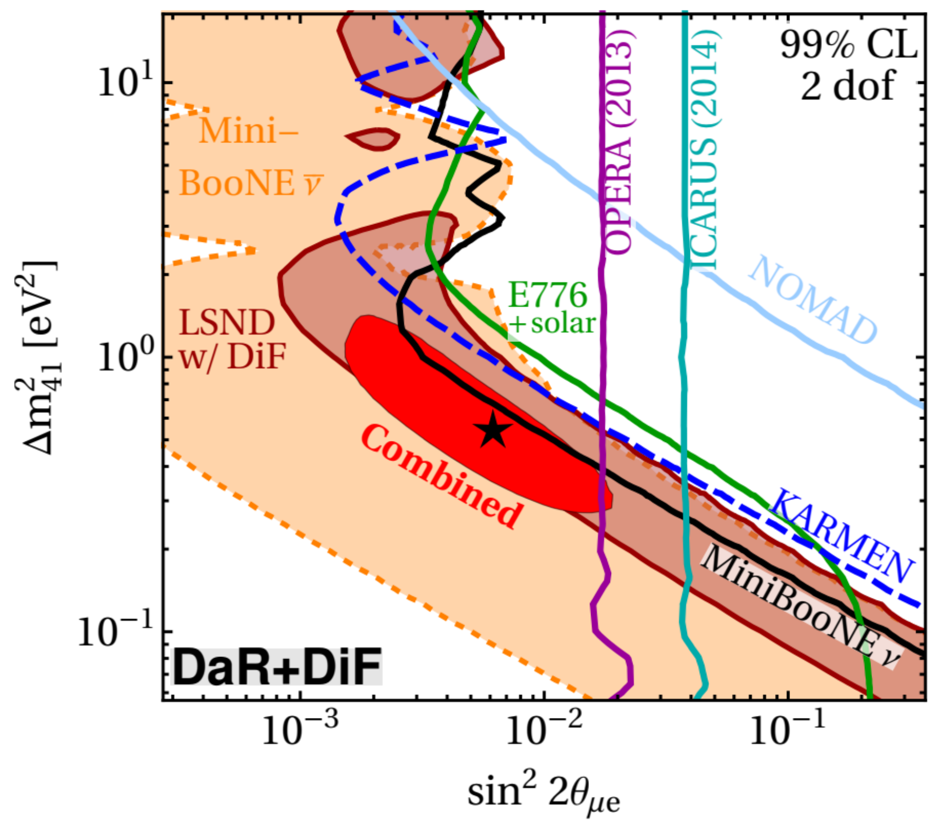



Aguilar-Arevalo et. al. (MiniBooNE), arXiv: 1805.12028

- 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 σ

# Sterile Neutrinos and SBL Oscillations

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



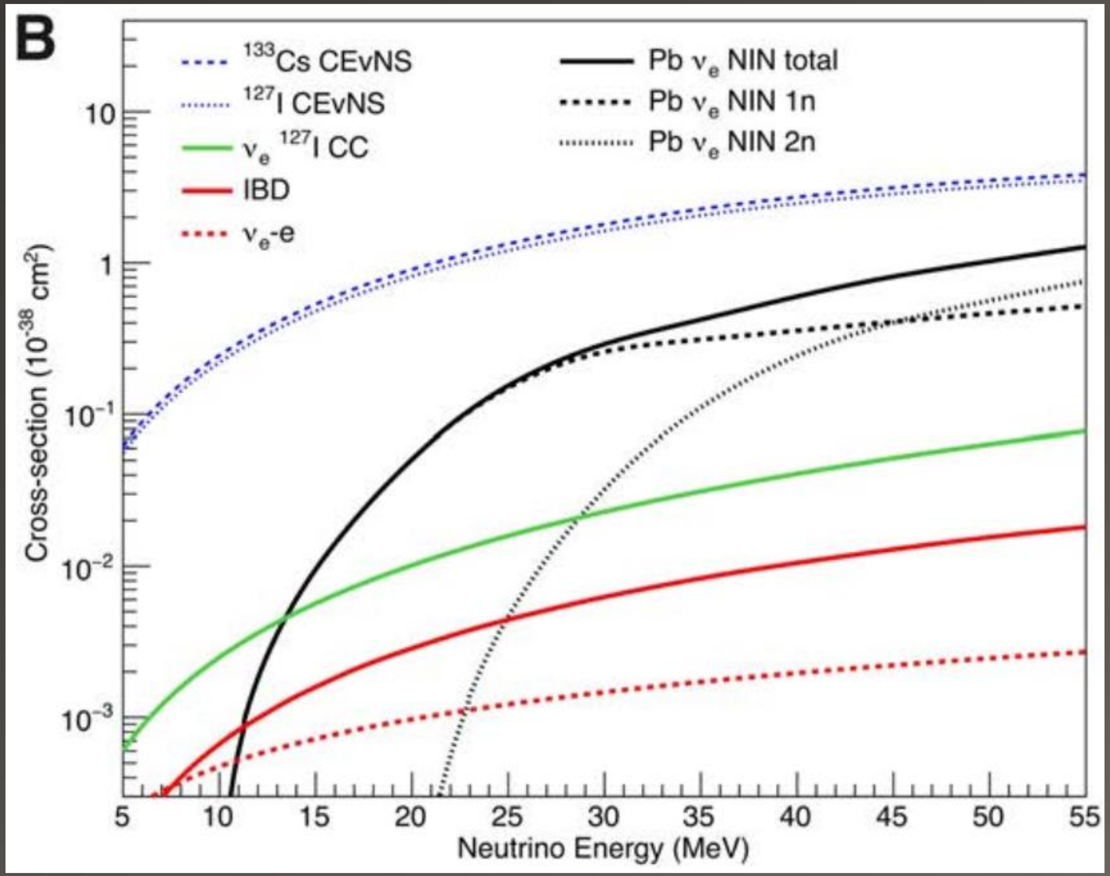

Dentler et. al. , arXiv: 1803.10661

- Short baseline: no SM neutrino oscillation
- Parameter space explored only through charged currents.
- Best global fit: $\Delta m^2_{41} \approx 0.5\ (\mathrm{eV}^2)$

$$\sin^2(2\theta_{\mu e}) \approx 6\times 10^{-3}$$

$$\sin^2(2\theta_{\mu e}) \equiv 4\,|U_{e4}|^2\,|U_{\mu 4}|^2$$

# Neutral vs Charged Currents



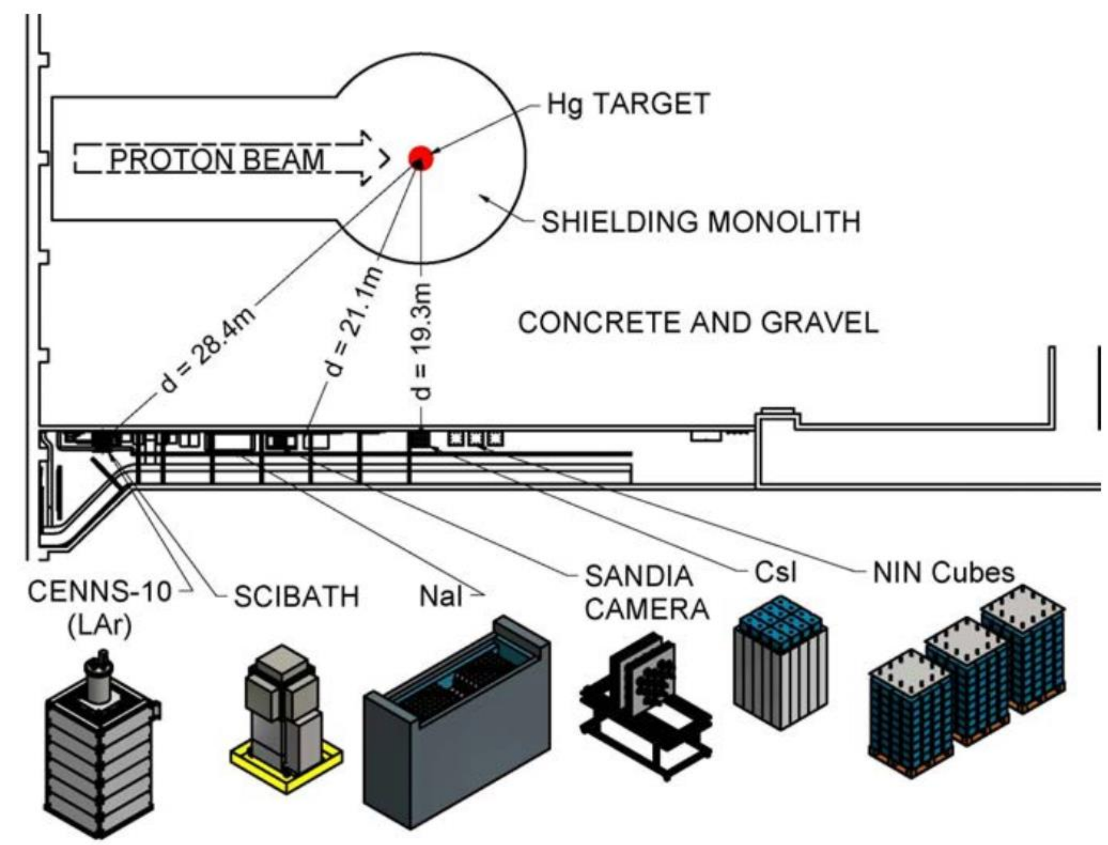

Akimov et. al. (COHERENT) , arXiv: 1708.01294

$$\left(\frac{d\sigma}{dE_T}\right)_{NC} \propto \frac{G_F^2 M}{4\pi} N^2$$

$$\left(\frac{d\sigma}{dE_T}\right)_{NC} \approx \mathcal{O}(10^2) \cdot \left(\frac{d\sigma}{dE_T}\right)_{CC}$$

- Smaller detector mass
- Very low background
- Flavor independent

# Proposed Measurement




ONL S.N.S. *schematic* - Akimov et. al. (COHERENT) , arXiv: 1708.01294

- 100 kg CsI over 10 years
- Baselines: 20 and 40 meters
- Pulsed π-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.

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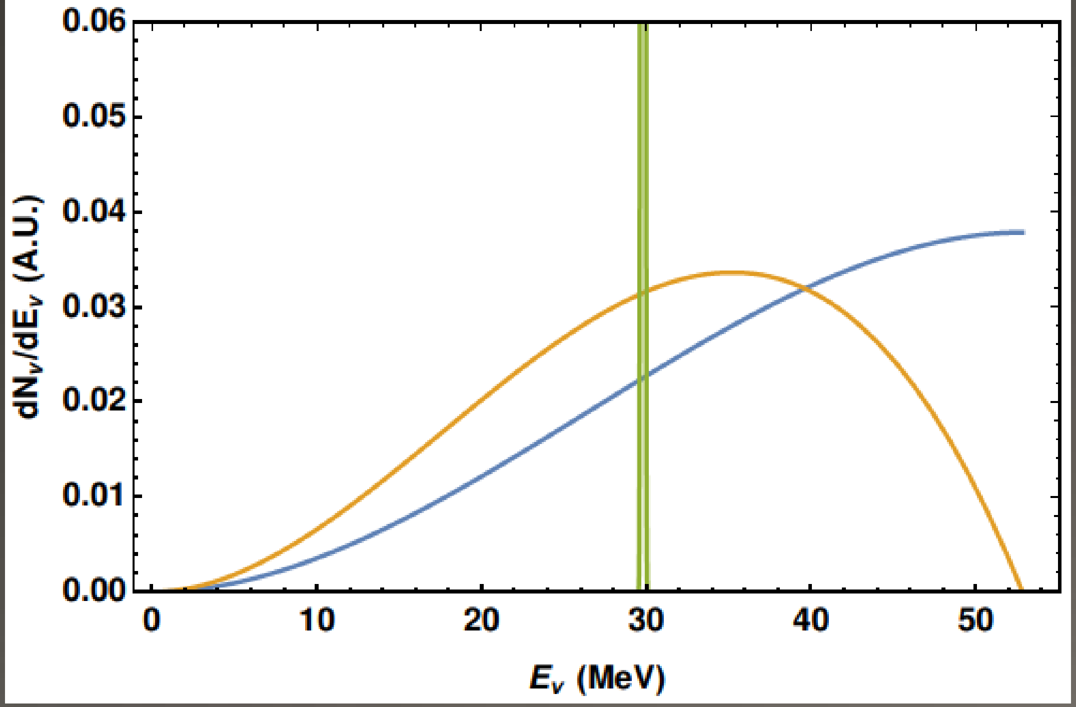
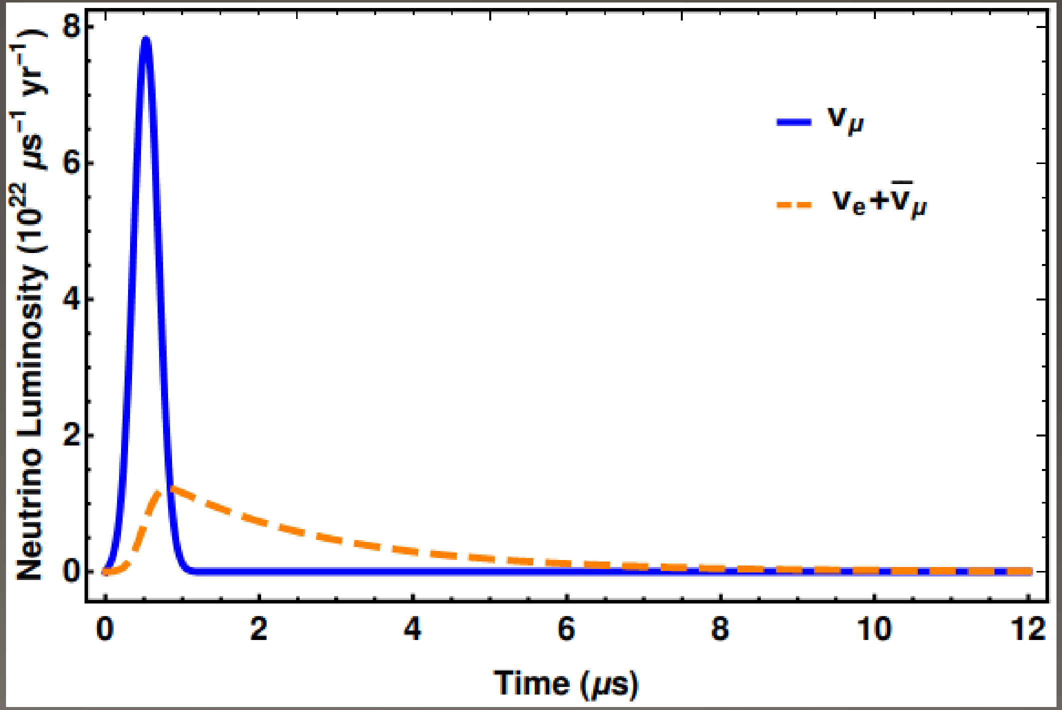
# Spallation π-DAR sources

~0.026 μs ~2.197 μs

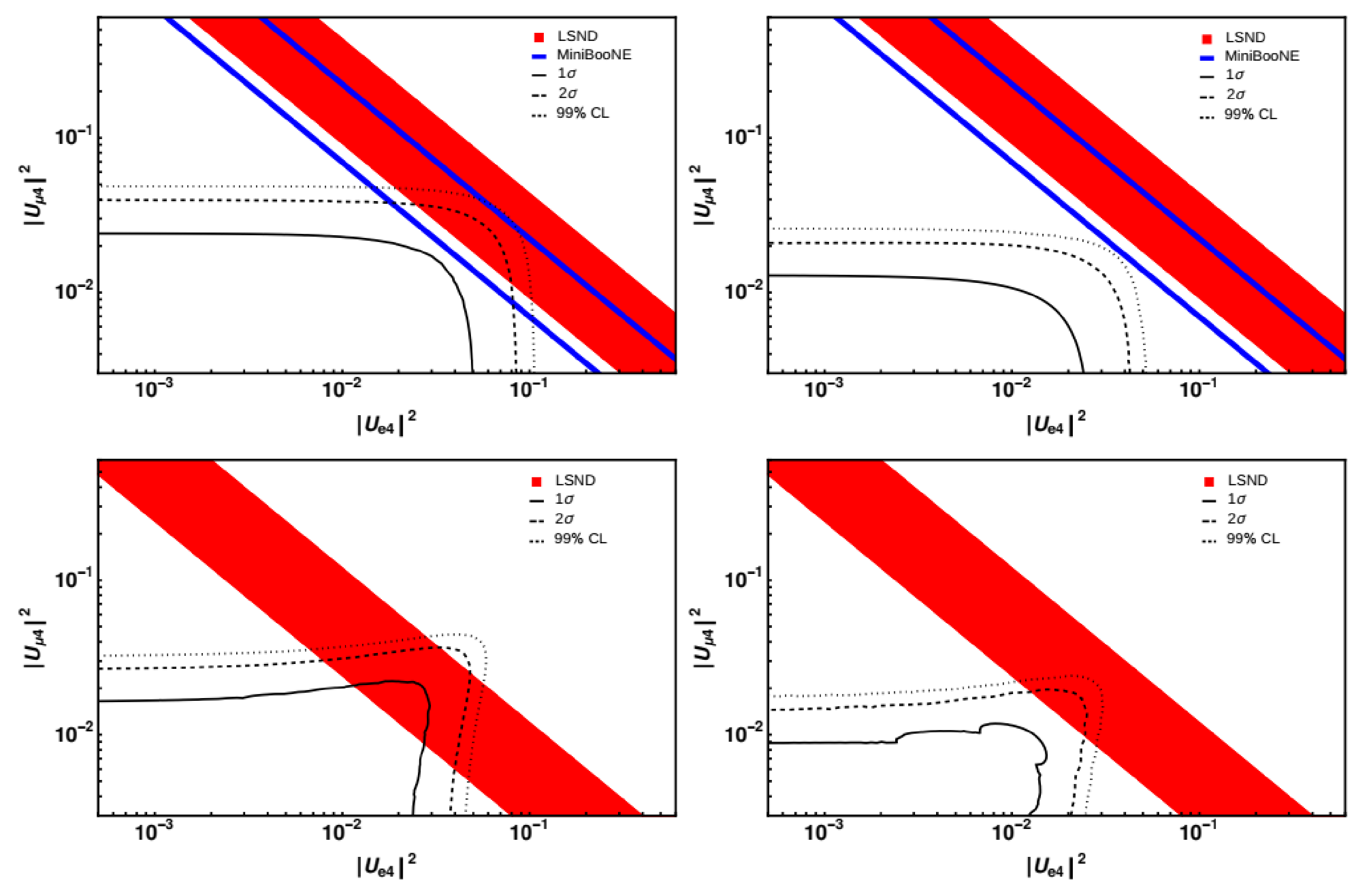
$$\pi^+ \rightarrow \mu^+ \nu_\mu \rightarrow e^+ \nu_e \overline{\nu}_\mu \nu_\mu$$




$$E_{\nu_\mu} \approx 30\text{MeV}$$

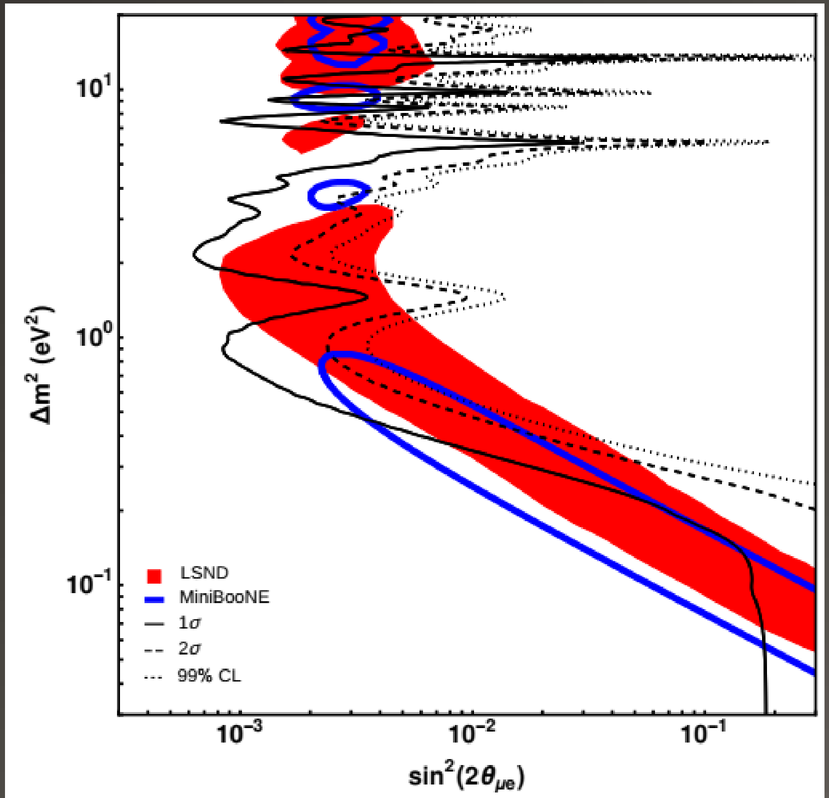
# The Importance of Timing



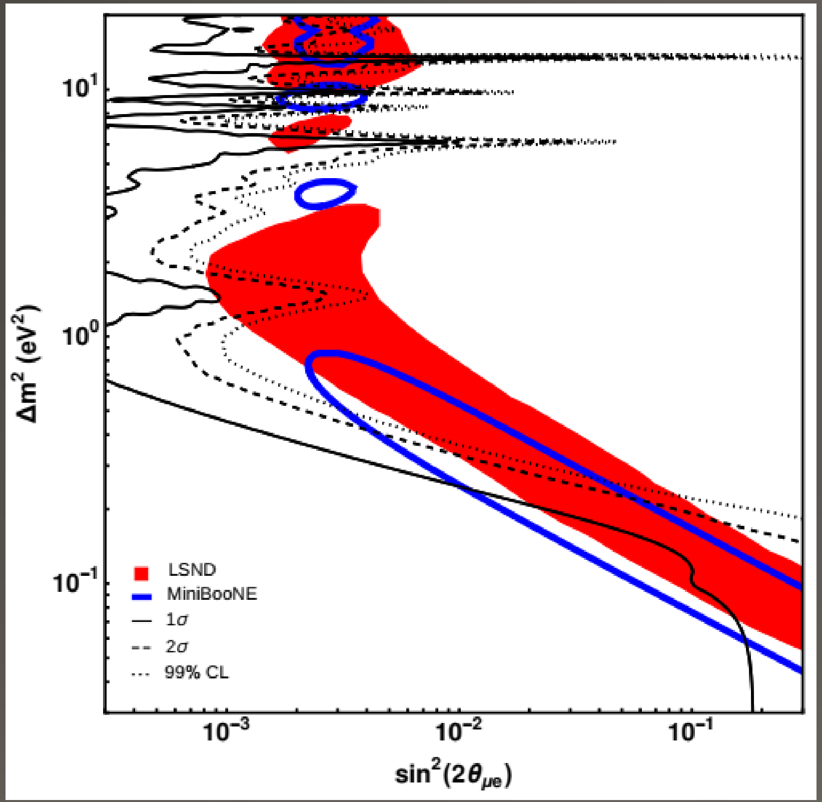

3 year total exposure @ 20 and 40 meters    10 year total exposure @ 20 and 40 meters

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

# Sensitivity to Sterile Neutrinos




3 year total exposure @ 20 and 40 meters




10 year total exposure @ 20 and 40 meters

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

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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# Summary

- 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 $|U_{e4}|^2$.
- 1000 kg y of CsI could probe the most of the best-fit parameter space.
- Small scale experiment probing “high” energy BSM physics.

# Extra Slide 1

| Experimental Parameter | Benchmark value |
|---|---|
| Total Systematic Uncertainty | 28% |
| $B_{ss}$ (Steady State Background) | Characterized -> Negligible (Timing helps a lot) |
| $B_{on}$ (Beam On Background) | $1.45 \times 10^{-10}$ counts/kg/μs (10x < than COHERENT) |
| $E_T$ threshold | Sigmoid: 0% @ 2.5 KeV and 100% @5.0 KeV |