Searching for Sterile Neutrinos at the STS with CEvNS

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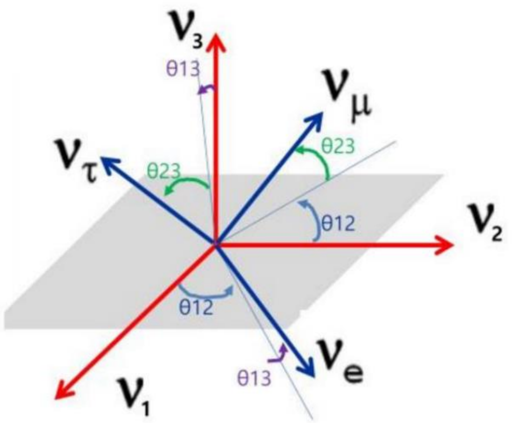
Neutrino mixing

- Neutrino mass and flavor eigenstates are not identical → so we expect flavor oscillations in a propagating neutrino flux

$$P(\nu_\alpha \to \nu_\beta) = \left| \sum_{i=1}^{N_\nu} U_{i\alpha}^\dagger U_{\beta i} e^{-im_i^2 L/2E} \right|^2$$



Parameterized by PMNS matrix

$$U = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix}$$

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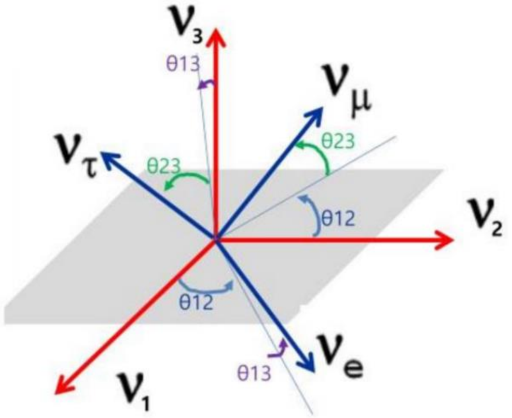

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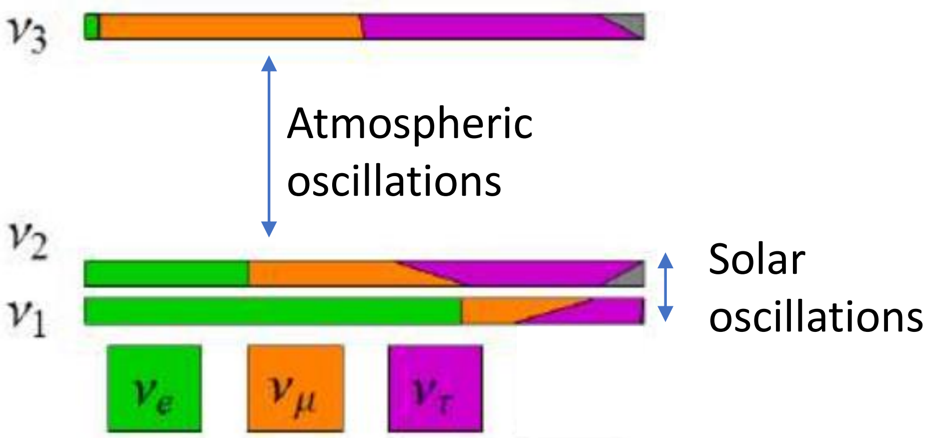
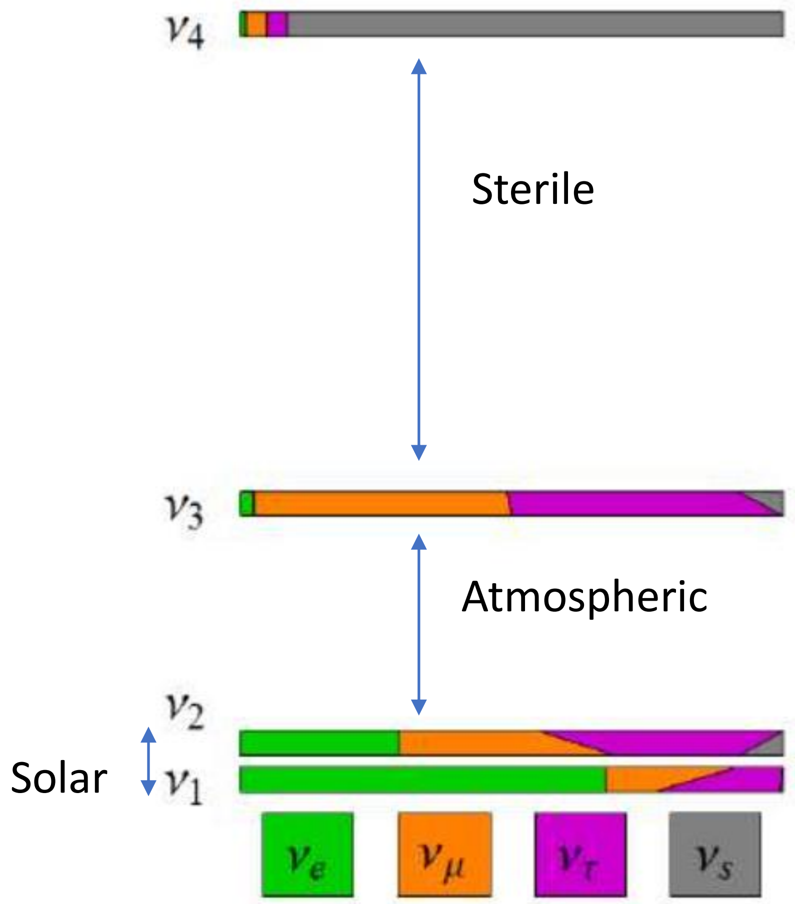
- Known three flavors oscillate at two different mass splittings, Δm^2_{ij}
  - Solar oscillations with Δm^2_{21} = 7.5e-5 eV^2
    - SNO, SK, KamLAND
  - Atmospheric oscillations with Δm^2_{32} = 2.6e-3 eV^2
    - SK, MINOS, NOvA, IceCube, T2K, DUNE, HK, others

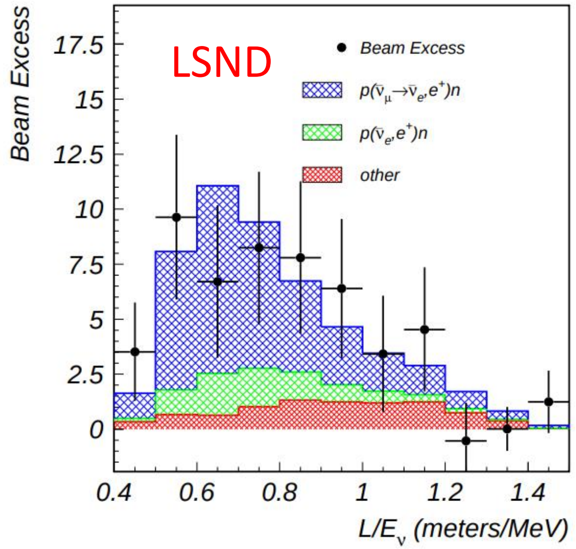


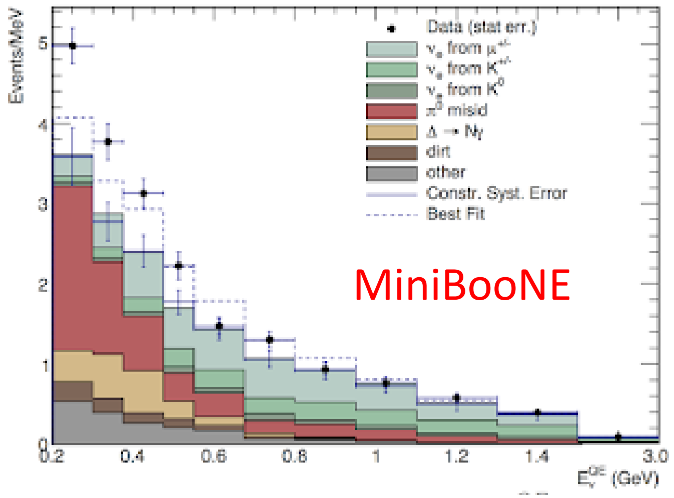
Expanding model to include four neutrinos

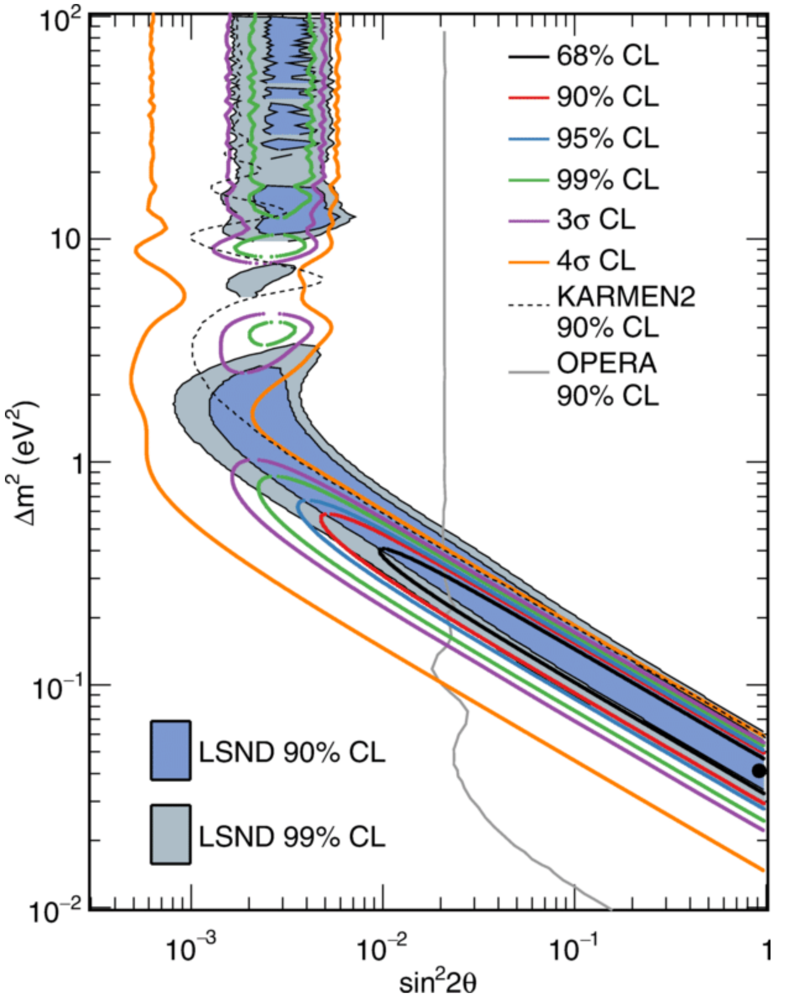
- ❑There could be an additional neutrino eigenstate, otherwise unobservable, that could mix with the standard-model neutrinos
- ❑Could not interact with weak force given Z^0 width observed by LEP
  - So, we call this new particle a “sterile” neutrino
- ❑But, we would see their oscillation effects



Evidence for sterile neutrinos







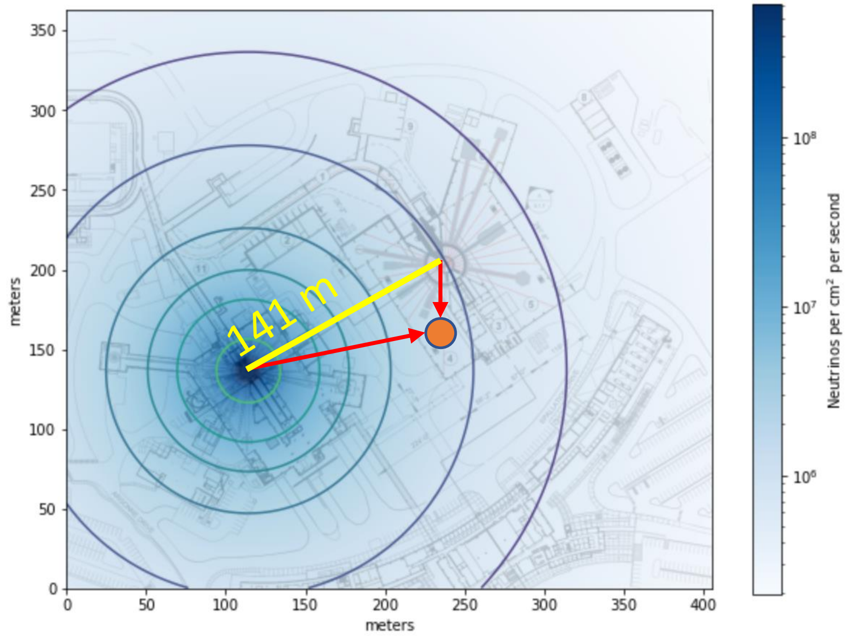
- There have been some observations which are consistent with the sterile neutrino hypothesis
  - LSND: $\bar{\upsilon}_\mu \to \bar{\upsilon}_e$
  - MiniBooNE: $\upsilon_\mu \to \upsilon_e$ and $\bar{\upsilon}_\mu \to \bar{\upsilon}_e$
  - Reactor experiments: $\bar{\upsilon}_e \to \bar{\upsilon}_e$
- But, many subsequent searches found no evidence for sterile neutrino oscillations, must test conclussively

Searching for steriles with CEvNS detectors

- COHERENT would search for υ_μ and υ_e disappearance
  - $P(\upsilon_\mu \to \upsilon_\mu) = 1 - \sin^2 2\theta_{23} \sin^2 \frac{1.27\Delta m^2_{31} L}{E} + 2\sin^2 2\theta_{23} \sin^2\theta_{24} \sin^2 \frac{1.27\Delta m^2_{41} L}{E} - \sin^2 2\theta_{24} \sin^2 \frac{1.27\Delta m^2_{41} L}{E}$
  - $P(\upsilon_e \to \upsilon_e) = 1 - \sin^2 2\theta_{13} \sin^2 \frac{1.27\Delta m^2_{31} L}{E} - \sin^2 2\theta_{14} \sin^2 \frac{1.27\Delta m^2_{41} L}{E}$
  - Need to test disappearance at 5-10% to test MiniBooNE/LSND parameter space
- CEvNS experiments are small and compact, you can have multiple detectors testing oscillations at multiple baselines (or a moving detector)
  - Moving detectors also possible to correlate systematic uncertainties
- Spallation neutrino fluxes include a monoenergetic flux of υ_μ, ideal for extracting survival probability at that energy
- Multiple flavors in our flux so we directly test different angles in mixing angles
- Well understood xsec and flux shape – big problems for MiniBooNE and LSND

Sterile neutrinos at the STS

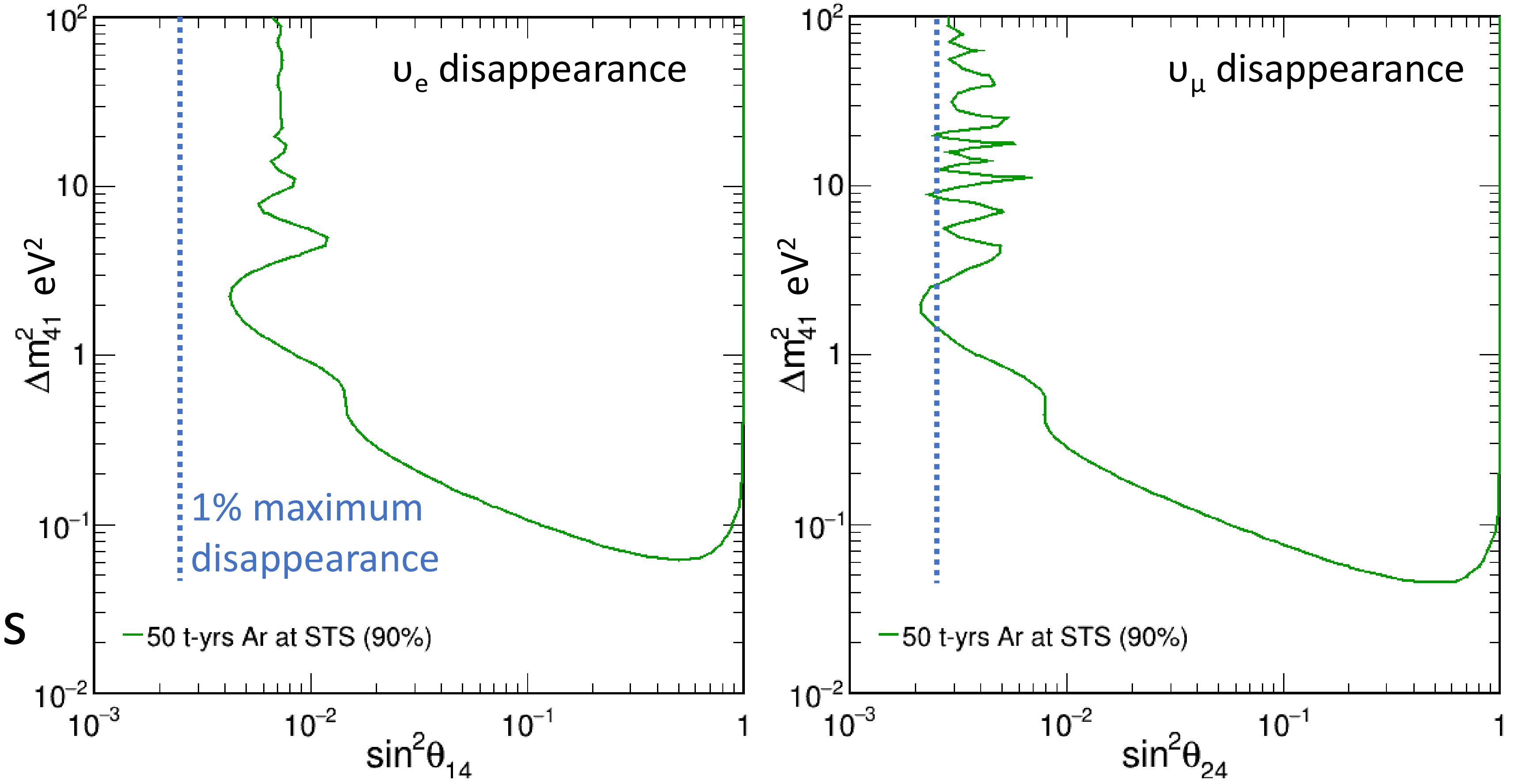
- FTS/STS gives us a very unique opportunity
- As soon as the STS begins delivering beam, any detector at either target will receive beam from both targets
  - This is a fantastic opportunity for people interested in sterile neutrinos
  - Analyze neutrinos on two different baselines with the same detector – very correlated systematics



- A 10-t argon CEvNS detector will be massive enough to see neutrinos from each target so that we can study oscillations from both baselines
  - Assume L_{STS} = 20 m and L_{FTS} = 121 m
  - Include 1% flux uncertainty due to differences in π production on Hg/W

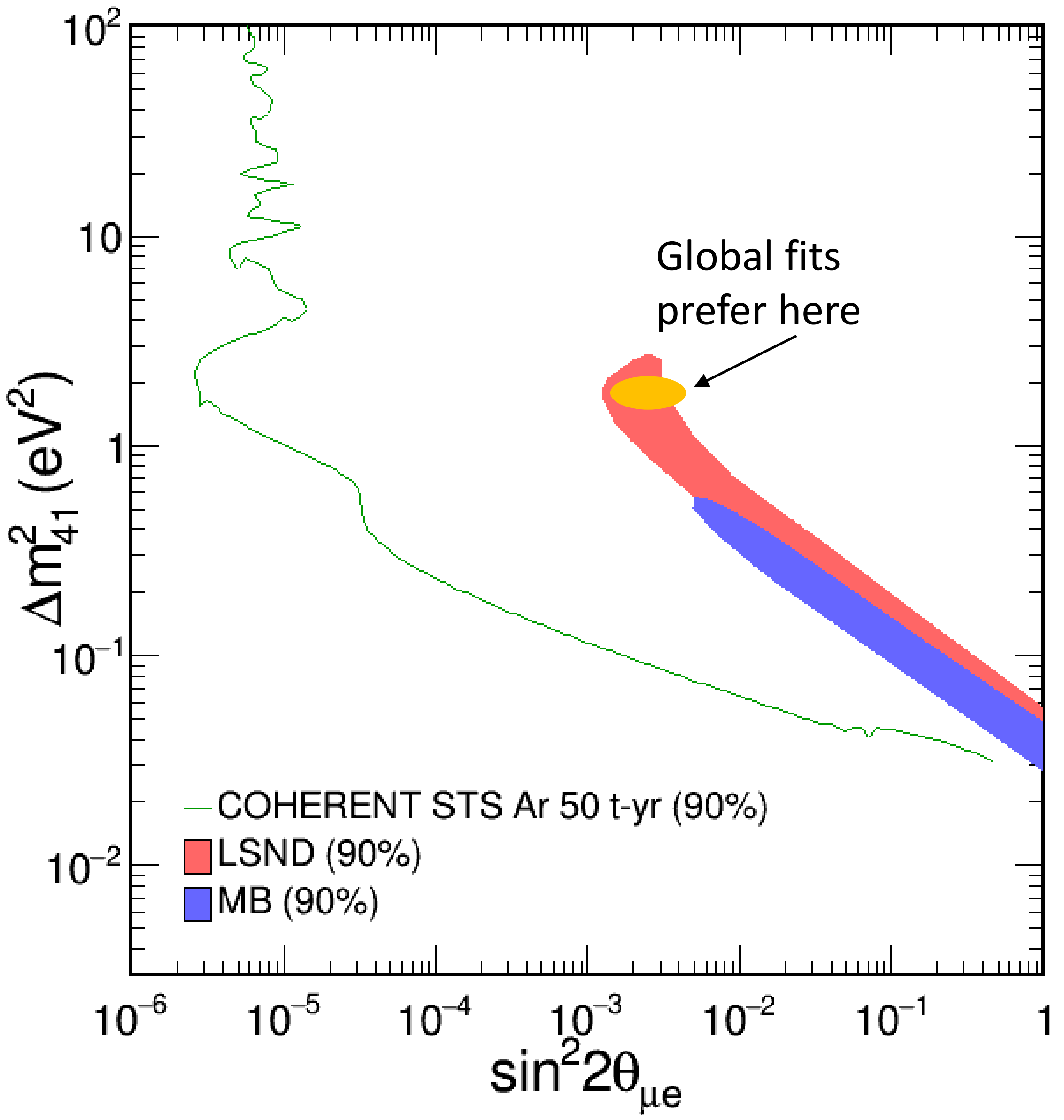
Searching for neutrino

- Similar sensitivity to υ_μ / υ_e disappearance
  - Sensitivity to υ_e not so common, though many can look at υ_μ
- Contours roughly map to 1% disappearance which is achievable with CEvNS experiments



Comparison to past data

- ❑Our direct observables are the disappearance channels, but we can make this sensitivity onto the appearance channel where the LSND/MiniBooNE anomoly arose
- ❑We can very efficiently test the parameter space favored by the SBL experiments with a very different detection strategy
  - Near global best fit, we can test mixing angles three orders of magnitude below best fit to sterile data



Summary

- The sterile neutrino anomaly first observed by LSND and MiniBooNE is not totally resolved, more data is needed to conclusively test hypothesis
- CEvNS experiments show great potential due to intense, well-understood flux with multiple detectors and datasets
- Building the STS gives us fantastic opportunity to study oscillations from two baselines with a single detector
- We will test anomaly up to three orders of magnitude below parameters preferred by LSND / MiniBooNE