New search for a sterile neutrino at MicroBooNE with BNB and NuMI beams

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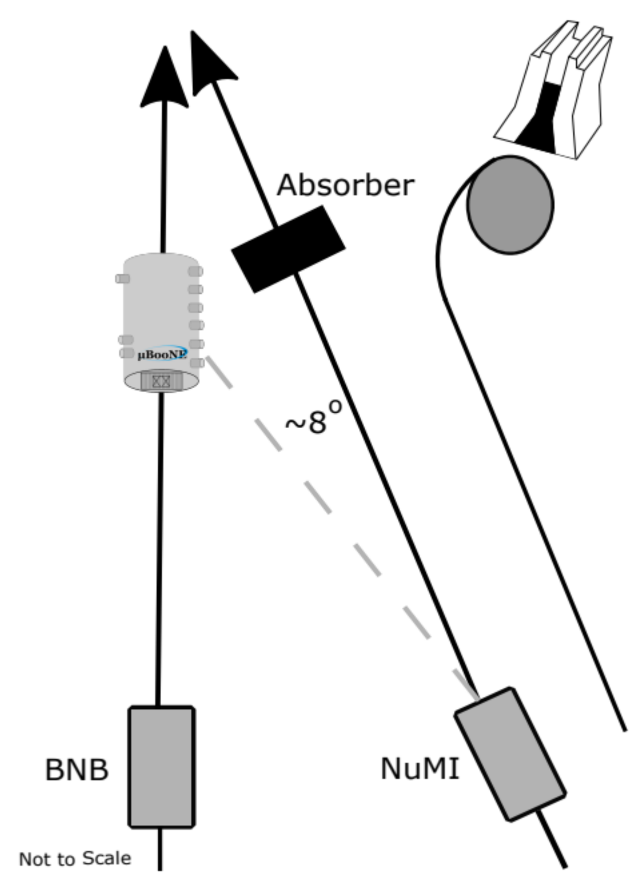
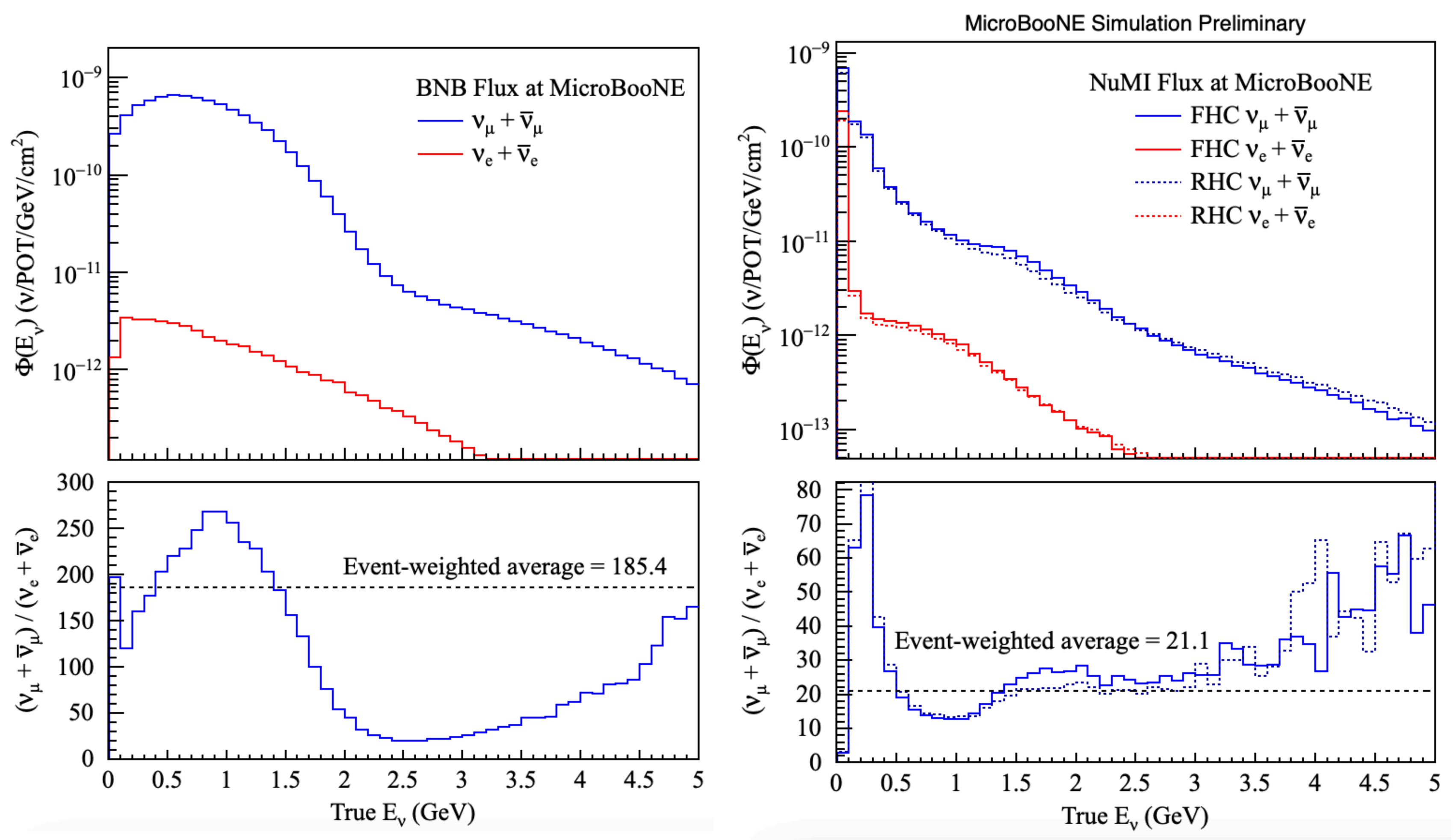
On behalf of the MicroBooNE Collaboration

MicroBooNE Experiment



- A 85 ton active-mass liquid-argon TPC
- Two neutrino beams: BNB (on-axis) and NuMI (off-axis)
- On-axis Booster Neutrino Beam (BNB) at a baseline of ~470 m with mean neutrino energy at 800 MeV
- Off-axis Neutrino from the Main Injector (NuMI) beam at a baseline of ~680 m with neutrinos up to a few GeV



- Beam intrinsic muon neutrinos (ν_μ) and electron neutrinos (ν_e): significant difference in the ν_μ/ν_e ratio in BNB and NuMI [1,2]

Sterile Neutrino Search

- The existence of a light eV-scale sterile neutrino has been postulated to explain several experimental anomalies.
- 3 active + 1 sterile neutrino framework (3+1 oscillation)

$$P_{\nu_\alpha \to \nu_\beta} = \delta_{\alpha\beta} + (-1)^{\delta_{\alpha\beta}} \cdot \sin^2 2\theta_{\alpha\beta} \cdot \sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right)$$

$$\begin{aligned}
\sin^2 2\theta_{ee} &= \sin^2 2\theta_{14} \\
\sin^2 2\theta_{\mu\mu} &= 4\cos^2\theta_{14}\sin^2\theta_{24}\left(1-\cos^2\theta_{14}\sin^2\theta_{24}\right) \\
\sin^2 2\theta_{\mu e} &= \sin^2 2\theta_{14}\sin^2\theta_{24} \\
\sin^2 2\theta_{es} &= \sin^2 2\theta_{14}\cos^2\theta_{24}\cos^2\theta_{34} \\
\sin^2 2\theta_{\mu s} &= \cos^4\theta_{14}\sin^2 2\theta_{24}\cos^2\theta_{34}
\end{aligned}$$

This analysis involves three independent oscillation parameters $(\Delta m^2_{14}, sin^2\theta_{14}, sin^2\theta_{24})$ *, fixing* θ_{34} *at zero [3].*

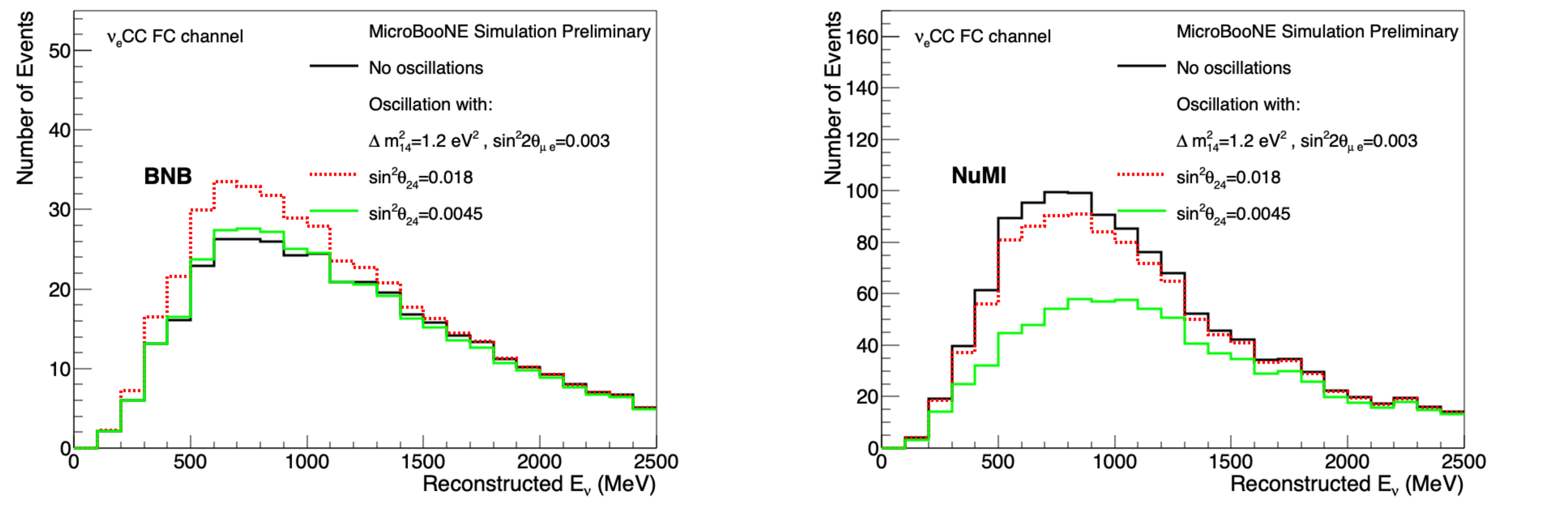
Cancellation between ν_e disappearance and appearance oscillations

- Cancellation between ν_e disappearance and ν_μ to ν_e appearance oscillations leads to a degeneracy in the oscillation parameters. Expected degeneracy to be at $\sin^2\theta_{24} \sim 0.005$ for the BNB.
- The degeneracy can be mitigated by using both BNB and NuMI because of different beam intrinsic ν_e/ν_μ ratios.

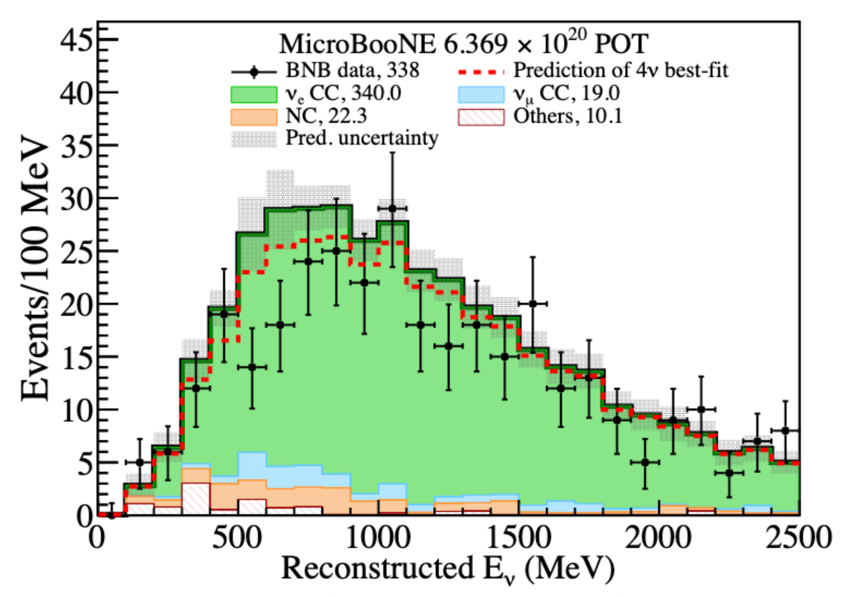
$$N_{\nu_e} = N_{\text{intrinsic}\ \nu_e} \cdot P_{\nu_e \to \nu_e} + N_{\text{intrinsic}\ \nu_\mu} \cdot P_{\nu_\mu \to \nu_e}$$

$$= N_{\text{intrinsic}\ \nu_e} \cdot \left[1 + (R_{\nu_\mu/\nu_e} \cdot \sin^2\theta_{24} - 1) \cdot \sin^2 2\theta_{14} \cdot \sin^2\Delta_{41}\right]$$

where R_{ν_μ/ν_e} *beam intrinsic* ν_μ *and* ν_e *ratio*



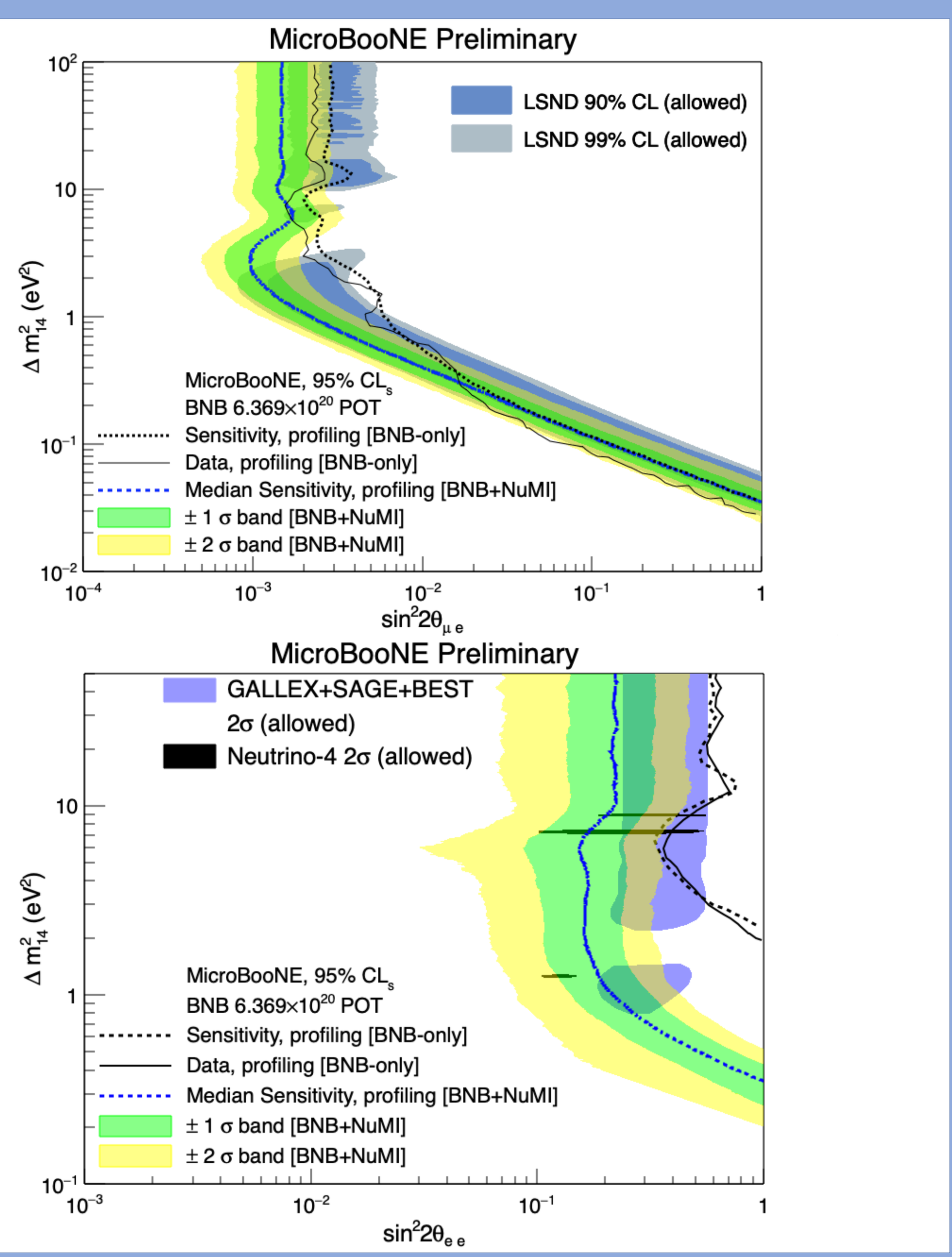
Results of 3+1 oscillation analysis



- The best-fit value from BNB data on the 7 channels is:

$(\Delta m^2_{14}, sin^2\theta_{14}, sin^2\theta_{24}) = (1.295\ eV^2, 0.936, 0)$,
with $\chi^2/NDF = 86.62/179$

- The BNB result is consistent with the 3-neutrino hypothesis at 0.80σ. Exclusion limits is placed on the sterile neutrino parameter space
- The addition of NuMI alongside BNB both increases the overall sensitivity and breaks the degeneracy considerably



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[1] Abratenko, P., et al. "First constraints on light sterile neutrino oscillations from combined appearance and disappearance searches with the MicroBooNE detector." Physical review letters 130.1 (2023)

[2] Supporting Public Notes: MICROBOONE-NOTE 1129-PUB and MICROBOONE-NOTE1132-PUB

[3] *Aartsen, M. G., et al. "Searching for eV-scale sterile neutrinos with eight years of atmospheric neutrinos at the IceCube Neutrino Telescope." Physical Review D 102.5 (2020)*

*All the data or MC samples correspond to BNB run1-3 period with 6.4×10[20] POT, NuMI run1-3 period with 1.054×10[21] POT