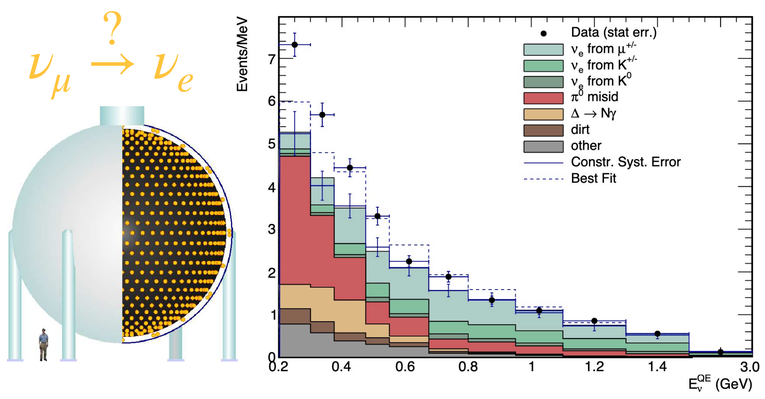
Did MicroBooNE kill MiniBooNE?

Ohana Benevides Rodrigues(IIT, Chicago), Matheus Hostert(Harvard U.), Kevin J. Kelly(Texas A&M), Bryce Littlejohn(IIT, Chicago), Pedro A.N. Machado(Fermilab), **Tao Zhou***(Texas A&M)

*: presenter (taozhou@tamu.edu)

— Based on arXiv: 2503.13594

eV-Scale Sterile Neutrinos



- MiniBooNE observed a significant excess (4.8σ) of electron-neutrino-like events.
- Not explained by conventional SM interactions or known backgrounds.
- Simplest interpretation: eV-scale sterile neutrinos driving short-baseline oscillations ($\nu_\mu \to \nu_e$).
- Connected to earlier LSND anomaly.
- Global fits show tension, but direct tests (like MicroBooNE) are crucial.

Short-Baseline Oscillations

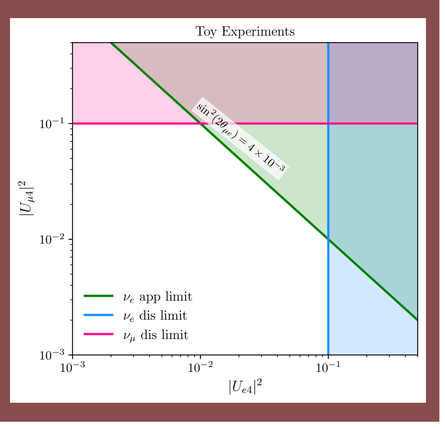
- **Appearance probability:**

$$P(\nu_\mu \to \nu_e) = \sin^2(2\theta_{\mu e})\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right), \text{where } \sin^2(2\theta_{\mu e}) \equiv 4\,|U_{e4}|^2\,|U_{\mu 4}|^2.$$

- **Disappearance probability:**

$$P(\nu_e \to \nu_e) = 1 - 4\,|U_{e4}|^2(1-|U_{e4}|^2)\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right)$$

$$P(\nu_\mu \to \nu_\mu) = 1 - 4\,|U_{\mu 4}|^2(1-|U_{\mu 4}|^2)\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right)$$

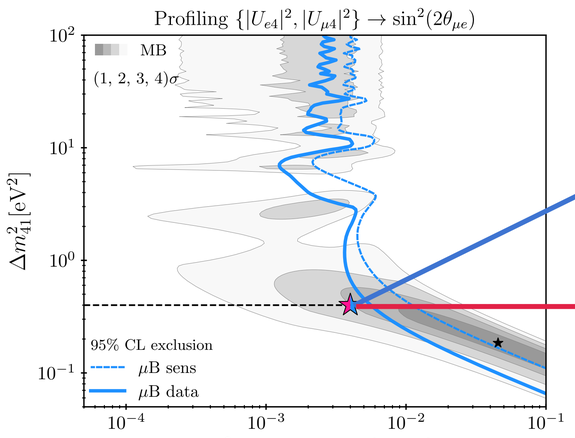


Degeneracies

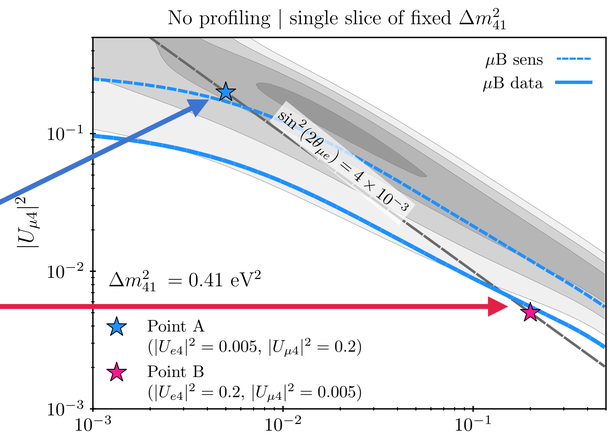
- Experiments are not sensitive to just one mixing parameter, but nontrivial combinations of them.
- BNB has intrinsic ν_e component (~ 0.5%), which is affected by $\nu_e \to \nu_e$ disappearance, controlled by $|U_{e4}|^2$.
- ν_μ control samples and induced backgrounds are affected by $\nu_\mu \to \nu_\mu$ disappearance, controlled by $|U_{\mu 4}|^2$.
- Nontrivial impact of oscillation on signal, control samples and background translate into different degeneracies in experiments.

Pitfall of Profiling

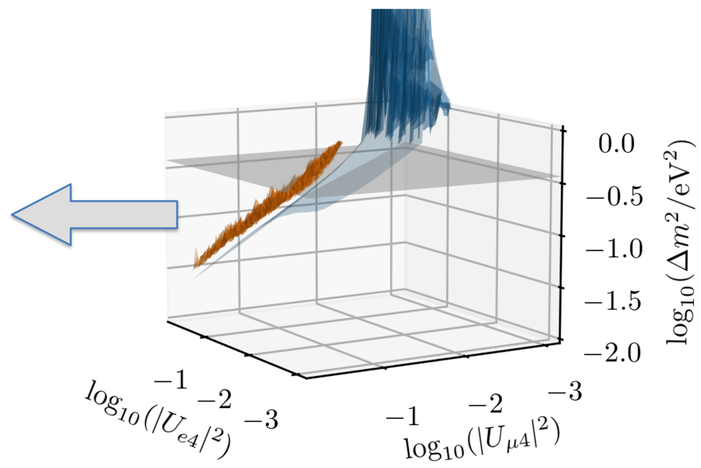
Standard 3+1 search (Weak constraint ❌)



A Slice of fixed Δm^2_{41} (Strong exclusion ✅)

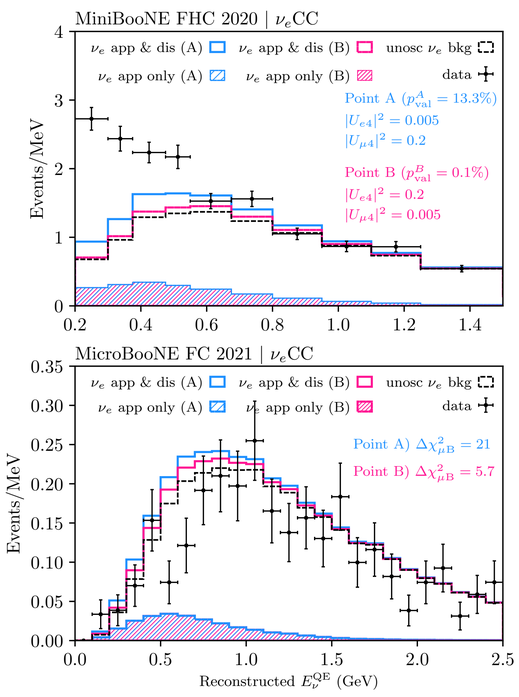


Actual 3D parameter space



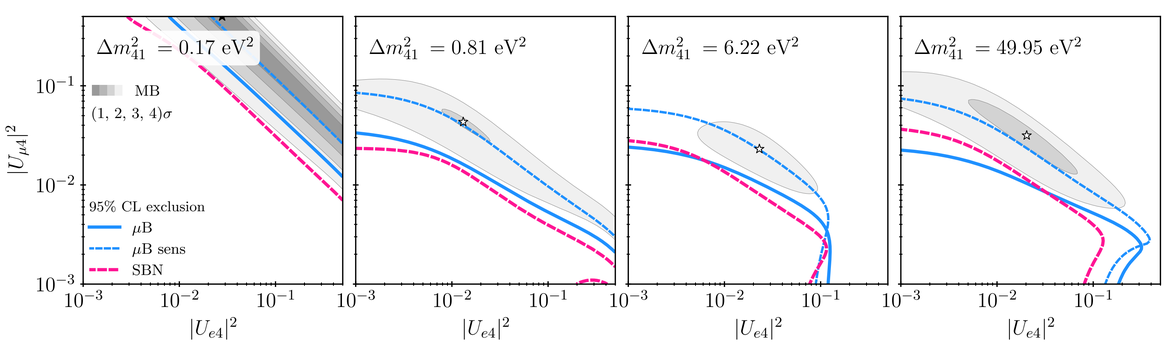
Event Rates

- Identical $\sin^2(2\theta_{\mu e})$ could produce distinct event rates given different combinations of $|U_{e4}|^2$ and $|U_{\mu 4}|^2$



- In a traditional 2-parameter search, MicroBooNE is still compatible with MiniBooNE in some space.
- We perform a full oscillation fit, recover significantly stronger constraints in the full parameter space.
- Profiling is **misleading and inaccurate**. It obscures important physical effects in experiments with significant neutrino-related background.

Slices of Parameter Space



Conclusions

- Answer to the title question: **Not yet! But we are close to the truth!**
- MicroBooNE **already** excludes MiniBooNE's 2σ region at > 2σ CL.
- Future SBN program will provide a robust test and significantly improve sensitivity, which is capable of excluding the 3σ region at more than 3σ level.