MicroBooNE and SBND at Fermilab and IRIS

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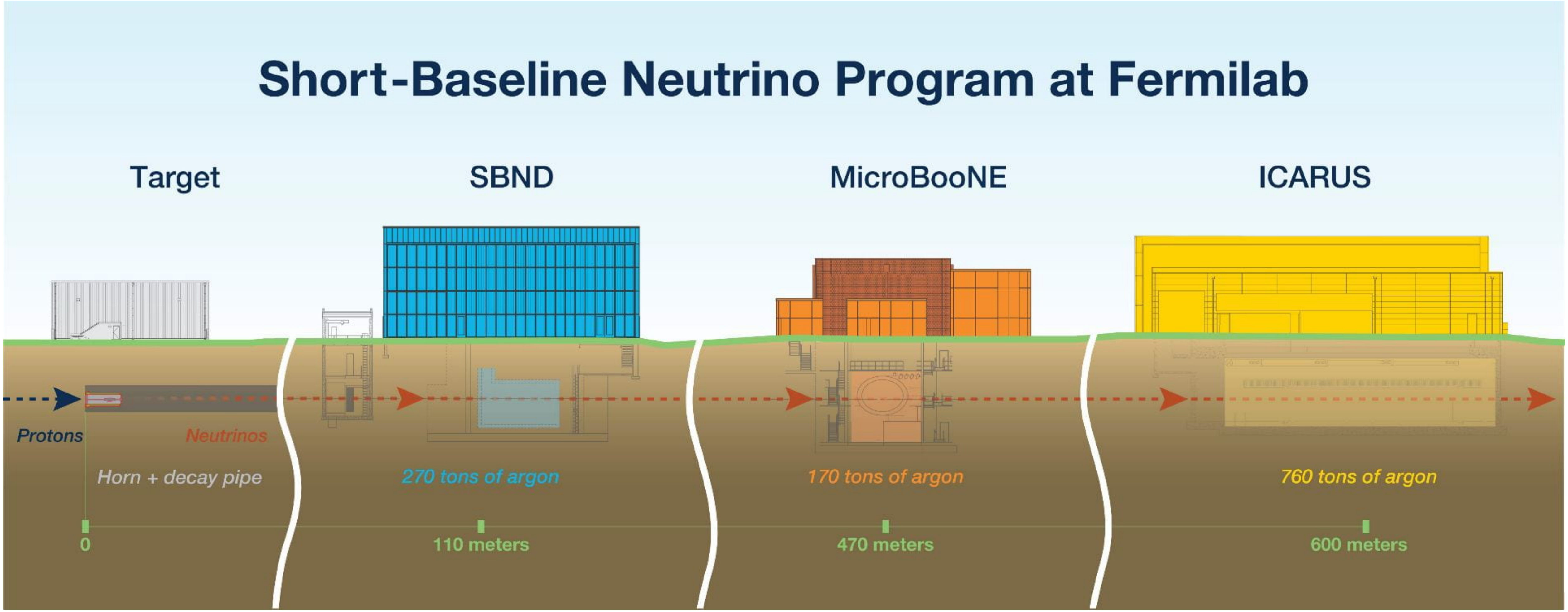
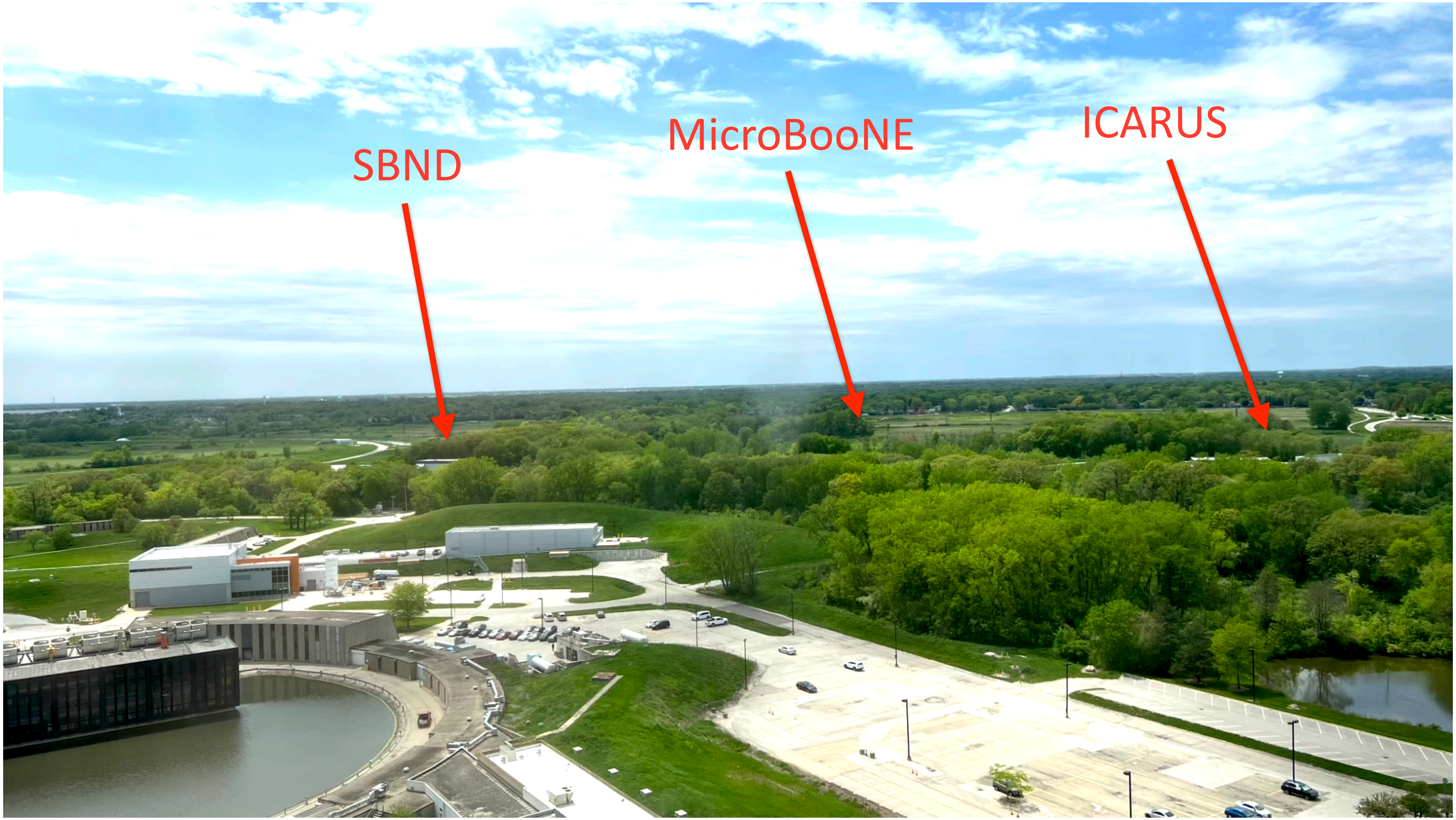
Fermilab's short baseline neutrino line

- Three neutrino detectors, mainly studying neutrino oscillations within the Fermilab site
- MicroBooNE ran 2015-21; SBND starting



Short Baseline neutrino line



MicroBooNE results

- This notable Nature paper from December has ruled out a fourth neutrino as an explanation for anomalous nu_e -> nu_mu mixing dating back to 1995.
- Ongoing work to measure cross-sections of various electron-neutrino and muon-neutrino processes
- All of these results included data processed on IRIS/GridPP capacity

Article

Search for light sterile neutrinos with two neutrino beams at MicroBooNE

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The existence of three distinct neutrino flavours, ν_e, ν_μ and ν_τ, is a central tenet of the Standard Model of particle physics[1,2]. Quantum-mechanical interference can allow a neutrino of one initial flavour to be detected sometime later as a different flavour, a process called neutrino oscillation. Several anomalous observations inconsistent with this three-flavour picture have motivated the hypothesis that an additional neutrino state exists, which does not interact directly with matter, termed as 'sterile' neutrino, ν_s (refs. 3–9). This includes anomalous observations from the Liquid Scintillator Neutrino Detector (LSND)[3] experiment and Mini-Booster Neutrino Experiment (MiniBooNE)[4,5], consistent with $\nu_\mu \to \nu_e$ transitions at a distance inconsistent with the three-neutrino picture. Here we use data obtained from the MicroBooNE liquid-argon time projection chamber[10] in two accelerator neutrino beams to exclude the single light sterile neutrino interpretation of the LSND and MiniBooNE anomalies at the 95% confidence level (CL). Moreover, we rule out a notable portion of the parameter space that could explain the gallium anomaly[6–8]. This is one of the first measurements to use two accelerator neutrino beams to break a degeneracy between ν_e appearance and disappearance, which would otherwise weaken the sensitivity to the sterile neutrino hypothesis. We find no evidence for either $\nu_\mu \to \nu_e$ flavour transitions or ν_e disappearance that would indicate non-standard flavour oscillations. Our results indicate that previous anomalous observations consistent with $\nu_\mu \to \nu_e$ transitions cannot be explained by introducing a single sterile neutrino state.

A broad experimental programme has shown that the three quantum-mechanical eigenstates of neutrino flavour, ν_e, ν_μ and ν_τ, are related to the three eigenstates of neutrino mass, ν_1, ν_2 and ν_3, by the unitary Pontecorvo–Maki–Nakagawa–Sakata (PMNS) matrix[11,12]. This mixing between flavour and mass states gives rise to the phenomenon of neutrino oscillation, in which neutrinos transition between flavour eigenstates with a characteristic wavelength in $L/E_\nu \propto (\Delta m_{ji}^2)^{-1}$, where L is the distance travelled by the neutrino, E_ν is the neutrino energy and $\Delta m_{ji}^2 = m_j^2 - m_i^2$ is the difference between the squared masses of the mass eigenstates ν_i and ν_j. The three known neutrino mass states give rise to two independent mass-squared differences and thus to two characteristic oscillation frequencies that have been well measured with neutrinos from nuclear reactors[13,14], the Sun[15], the atmosphere of Earth[16,17] and particle accelerators[18–20].

In apparent conflict with the three-neutrino model, several experiments during the past three decades have made observations that can be interpreted as neutrino flavour change with a wavelength much shorter than is possible given only the two measured mass-squared differences[3–9]. These observations are often explained as neutrino oscillations caused by at least one additional mass state, ν_4, corresponding to a mass-squared splitting of $\Delta m_{41}^2 \gtrsim 10^{-2}\ \mathrm{eV}^2$, which is much greater than the measured Δm_{21}^2 and Δm_{32}^2. New mass states would require the addition of an equivalent number of new flavour states, in conflict with measurements of the Z-boson decay width[21], which have definitively shown that only three light neutrino flavour states couple to the Z boson of the weak interaction. Therefore, these additional neutrino flavour states must be unable to interact through the weak interaction and are thus referred to as 'sterile' neutrinos. In this analysis, we focus specifically on light sterile neutrinos—those with masses below at least half the mass of the Z boson. It should be noted that the term 'sterile neutrino' has also been used to describe new particles, such as heavy right-handed lepton partners, that are potentially more massive than the Z boson. However, our study does not directly test these scenarios. The discovery of additional neutrino states would have profound implications across particle physics and cosmology, for example, on our understanding of the origin of neutrino mass, the nature of dark matter and the number of relativistic degrees of freedom in the early universe.

With the addition of a single new mass state ν_4 and a single sterile flavour state ν_s, the PMNS matrix becomes a 4 × 4 unitary matrix described by six real mixing angles θ_{ij} $(1 \le i < j \le 4)$. Oscillations driven by the two measured mass-squared splittings have not had time to evolve for small values of L/E_ν. The ν_μ to ν_e flavour-change probability, $P_{\nu_\mu \to \nu_e}$, and the ν_e and ν_μ survival probabilities, $P_{\nu_e \to \nu_e}$ and $P_{\nu_\mu \to \nu_{mu}}$, can then, to a very good approximation, be described by

$$P_{\nu_\mu \to \nu_e} = \sin^2(2\theta_{\mu e})\sin^2\left(\frac{\Delta m_{41}^2 L}{4E_\nu}\right), \quad (1)$$

$$P_{\nu_e \to \nu_e} = 1 - \sin^2(2\theta_{ee})\sin^2\left(\frac{\Delta m_{41}^2 L}{4E_\nu}\right), \quad (2)$$

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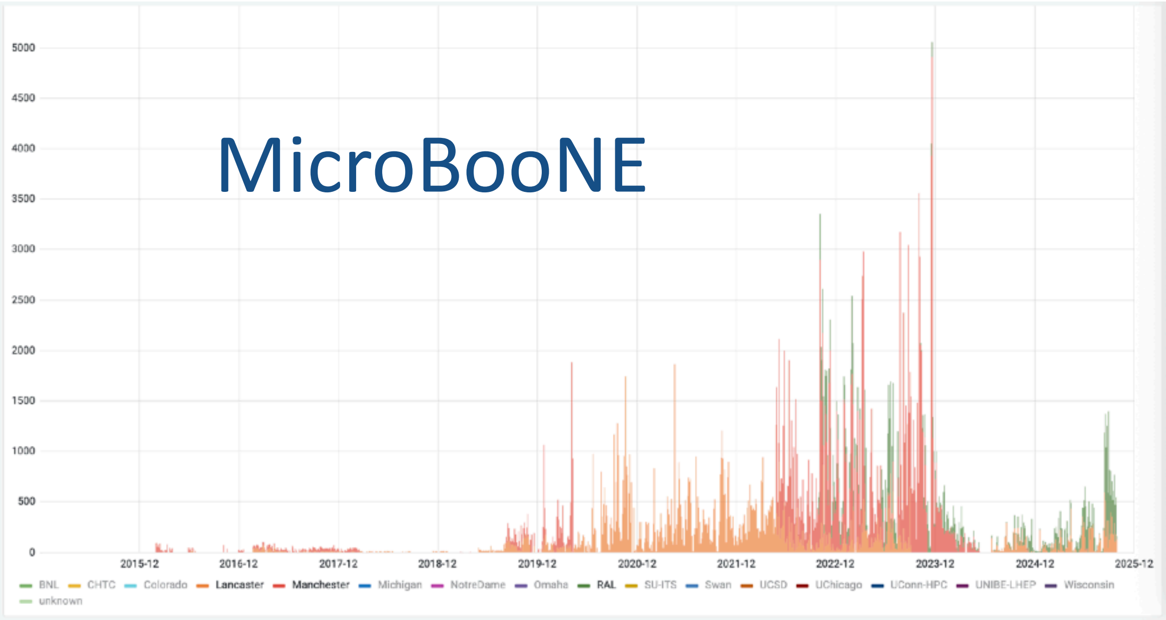
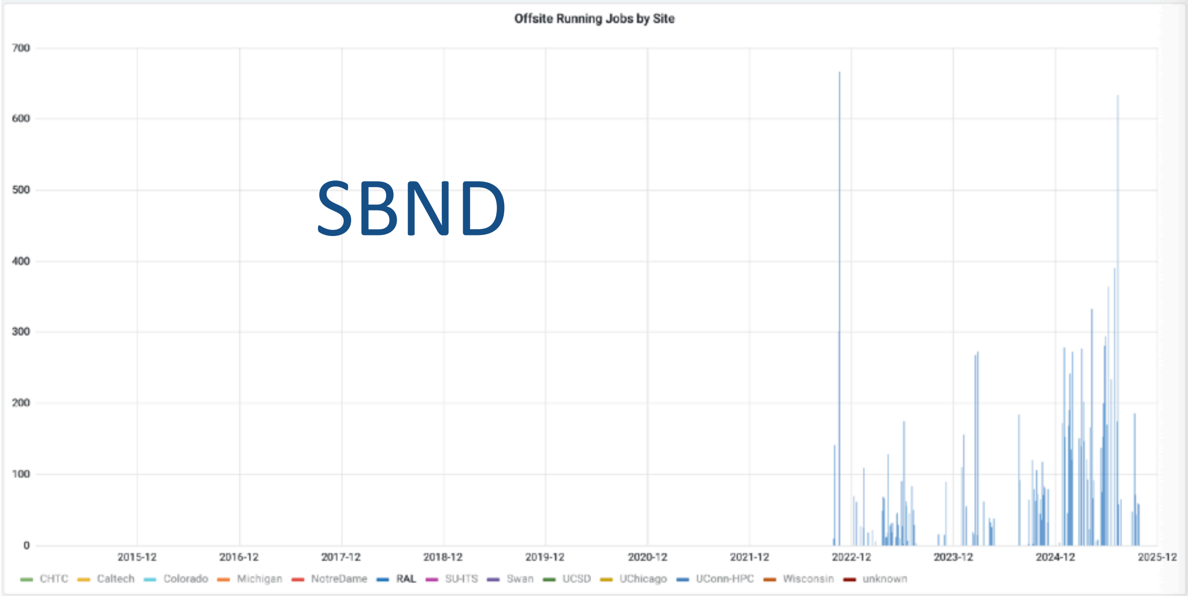
MicroBooNE and SBND in IRIS

- MicroBooNE and SBND operated as conventional grid experiments within the Fermilab VO, using GlideInWMS just like CMS and DUNE
- As such they are easy experiments for GridPP sites to support
- These charts show running jobs at UK sites for the two experiments from the Fermilab monitoring
  - 2019 and 2022 are when each really start using UK capacity
- You can see SBND is building up and MicroBooNE is winding down

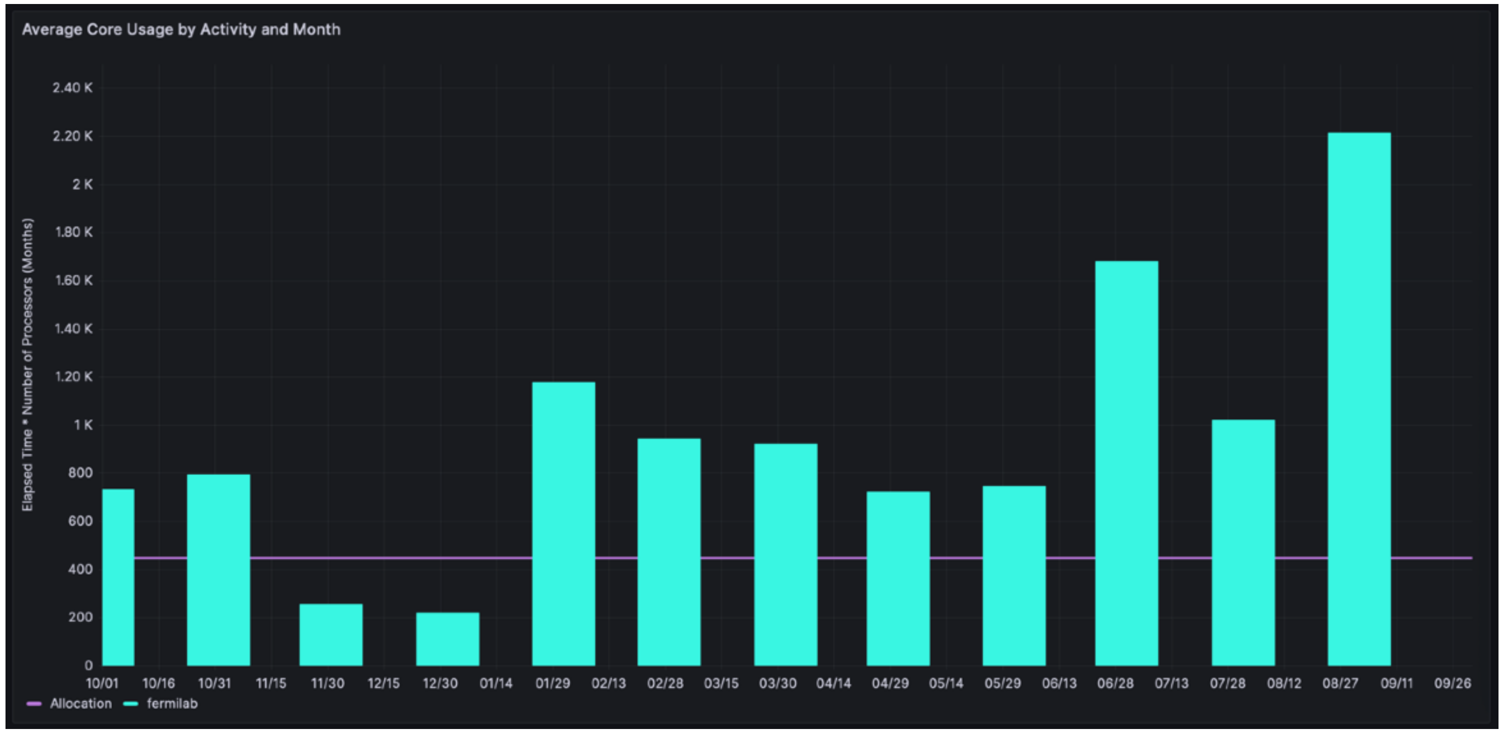




Backup

MicroBooNE + SBND request

- Combined MicroBooNE and SBND usage at IRIS sites last year vs 2025-26 MicroBooNE request



Year	GPU	Logical cores (MicroBooNE)	Logical cores (SBND)	Logical cores (Total)	Storage (Disk)	Storage (Tape)
2026-2027	-	580	1140	1720	-	-
2027-2028	-	460	1600	2060	-	-
2028-2029	-	-	1360	1360	-	-
2029-2030	-	-	2280	2280	-	-