New results from the MiniBooNE experiment at Fermilab

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The MiniBooNE experiment has reported on May 30th, 2018, a significant excess of electron neutrino candidate events, ν_e, at 4.5σ, measuring in an electron appearance channel $\nu_\mu \to \nu_e$. Combining these data with the result in the anti-neutrino appearance channel $\overline{\nu}_\mu \to \overline{\nu}_e$, this corresponds to a 4.8σ excess with respect to the theoretical predictions assuming no neutrino oscillations at short baselines. This excess points in the same direction that the excess previously observed by the LSND experiment and their explanation may require new physics. When this result is included in the simplest non-standard scenario, the long-standing strong tension between the electron and muon disappearance channels on the one hand, and the appearance $\nu_\mu \to \nu_e$ on the other, still persists.

Neutrino masses represent one of the most promising open windows to prove for the existence of a more fundamental theory of Nature beyond the Standard Model (SM) of particle physics. The overwhelming experimental neutrino oscillation phenomena implies that, at least, two neutrinos are massive states. Thus, within the standard neutrino framework, a neutrino of a given flavor $(\nu_e, \nu_\mu, \nu_\tau)$ will propagate as a superposition of the three massive neutrino states (n_1, n_2, n_3), leading to a non-zero oscillatory probability of detecting the initial neutrino state at a distance L with a flavor different from the original one. In the two-family approximation this probability reads as

$$P = \sin^2(2\theta)\sin^2\left(\frac{\Delta m^2 L}{4E}\right), \tag{1}$$

where θ is the mixing angle between the two flavors, Δm^2 is the square mass difference and E is the energy of the neutrino.

The MiniBooNE experiment is a short-baseline accelerator neutrino experiment operating at Fermilab. It uses 8 GeV protons of the Fermilab Booster to produce a beam of ν_μ or $\overline{\nu}_\mu$. These neutrinos may oscillate when they travel the 541 m from the source to the MiniBooNE detector. The probability of detecting the ν_μ as ν_e (or the $\overline{\nu}_\mu$ as $\overline{\nu}_e$) at such distances within the standard 3ν framework is negligible. However, the MiniBooNE experiment has recently published its last analysis [1], and it reports a non-zero oscillation probability. MiniBooNE observes a total electron neutrino event excess in both neutrino and antineutrino running modes of 460.5 ± 95.8 events (4.8σ). Indeed, these results are consistent with the results of the LSND experiment [2–7]. The results are shown in Fig. 1.

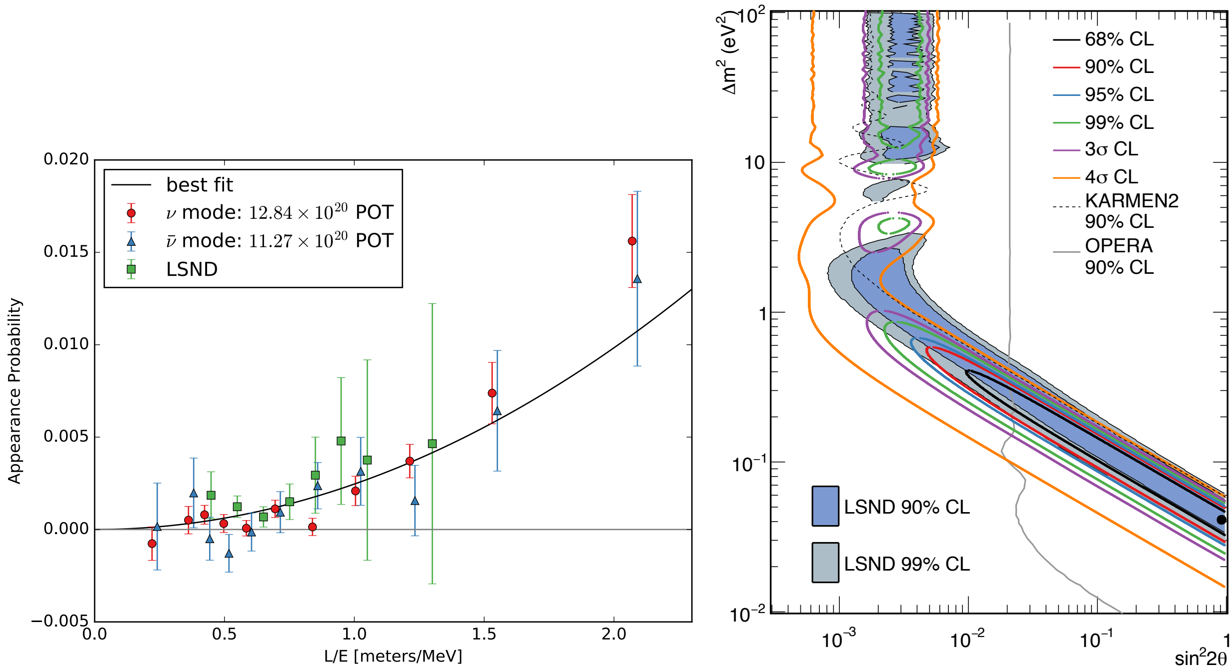

FIG. 1: Left panel: L/E distributions for the MiniBooNE data excesses in neutrino mode (red), antineutrino mode (blue) and L/E distribution from LSND (green). The solid curve shows the best fit to the LSND and MiniBooNE data assuming standard two-neutrino oscillations. Right panel: MiniBooNE allowed regions for a combined data sets of neutrino and antineutrino modes within a two-neutrino oscillation model. The black circle shows the MiniBooNE best fit point. Figures taken from [1].

Further studies such as the Short-Baseline Neutrino Oscillation Program that will take place in Fermilab could be able to further test this intriguing result.

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[3] **LSND** Collaboration, C. Athanassopoulos et al., "Evidence for $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillations from the LSND experiment at LAMPF", Phys. Rev. Lett. **77** (1996) 3082–3085, arXiv:nucl-ex/9605003 [nucl-ex].

[4] **LSND** Collaboration, C. Athanassopoulos et al., "Evidence for $\nu_\mu \to \nu_e$ neutrino oscillations from LSND", Phys. Rev. Lett. **81** (1998) 1774–1777, arXiv:nucl-ex/9709006 [nucl-ex].

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[nucl-ex].

[6] **LSND** Collaboration, C. Athanassopoulos et al., "Evidence for $\nu_\mu \to \nu_e$ oscillations from pion decay in flight neutrinos", Phys. Rev. **C58** (1998) 2489–2511, arXiv:nucl-ex/9706006 [nucl-ex].

[7] **LSND** Collaboration, A. Aguilar-Arevalo et al., "Evidence for neutrino oscillations from the observation of $\overline{\nu}_e$ appearance in a $\overline{\nu}_\mu$ beam", Phys. Rev. **D64** (2001) 112007, arXiv:hep-ex/0104049 [hep-ex].