Non-standard Neutrino Interactions and Robustness of Neutrino Parameters in Oscillation Experiments

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Based on arXiv:1805.04530 [hep-ph]

Motivation

- Leptonic mixing angles and neutrino squared mass differences are measured *indirectly* through neutrino oscillations.
- Is the picture robust against New Physics?
- How much **new** information on New Physics do neutrino oscillation experiments give us?

Framework

- We consider neutral current NSI

$$\mathcal{L} = -2\sqrt{2}G_F \sum_{f,\alpha,\beta} \varepsilon^f_{\alpha\beta}(\bar{\nu}_\alpha \gamma_\mu P_L \nu_\beta)(\bar{f}\gamma^\mu f)\,. \qquad (1)$$

- These modify the matter potential:

$$H_{\text{mat}} = \sqrt{2}G_F N_e(x) \begin{pmatrix} 1+\varepsilon_{ee}(x) & \varepsilon_{e\mu}(x) & \varepsilon_{e\tau}(x) \\ \varepsilon^*_{e\mu}(x) & \varepsilon_{\mu\mu}(x) & \varepsilon_{\mu\tau}(x) \\ \varepsilon^*_{e\tau}(x) & \varepsilon^*_{\mu\tau}(x) & \varepsilon_{\tau\tau}(x) \end{pmatrix}, \qquad (2)$$

with $\varepsilon_{\alpha\beta}(x) = \varepsilon^e_{\alpha\beta} + \varepsilon^p_{\alpha\beta} + \frac{N_n(x)}{N_e(x)}\varepsilon^n_{\alpha\beta}$. For simplicity, we set $\varepsilon^e_{\alpha\beta} = 0$ but consider admixtures of $\varepsilon^u_{\alpha\beta}$ and $\varepsilon^d_{\alpha\beta}$.

Degeneracies

- Generalized mass ordering degeneracy (LMA-D): $H \longrightarrow -H^*$ [1-3]

$$\begin{aligned} \Delta m^2_{31} &\longrightarrow -\Delta m^2_{32} \\ \theta_{12} &\longrightarrow \pi/2 - \theta_{12} \\ \delta_{\text{CP}} &\longrightarrow \pi - \delta_{\text{CP}} \\ [\varepsilon_{ee}(x) - \varepsilon_{\mu\mu}(x)] &\longrightarrow -[\varepsilon_{ee}(x) - \varepsilon_{\mu\mu}(x)] - 2 \\ [\varepsilon_{\tau\tau}(x) - \varepsilon_{\mu\mu}(x)] &\longrightarrow -[\varepsilon_{\tau\tau}(x) - \varepsilon_{\mu\mu}(x)] \\ \varepsilon_{\alpha\beta}(x) &\longrightarrow -\varepsilon^*_{\alpha\beta}(x) \qquad (\alpha \neq \beta) \end{aligned} \qquad (3)$$

- Poor determination of CP violation [4].

Data analysed

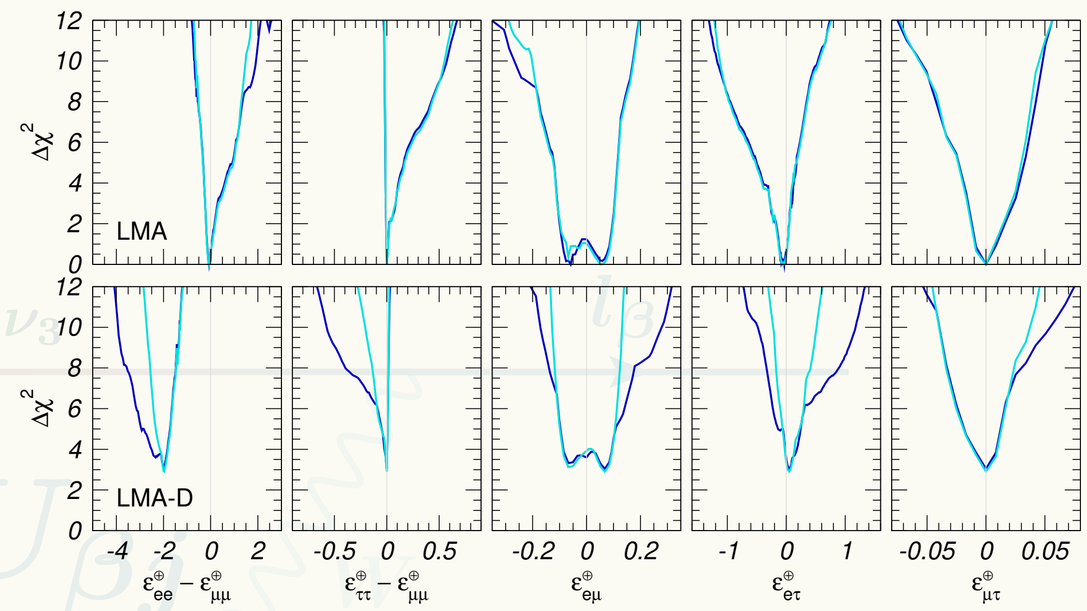
- Solar neutrinos & KamLAND
- Super-Kamiokande, IceCube & DeepCore atmospheric neutrino data
- MINOS, NOνA disappearance, T2K disappearance
- Reactor neutrino data

Conclusions

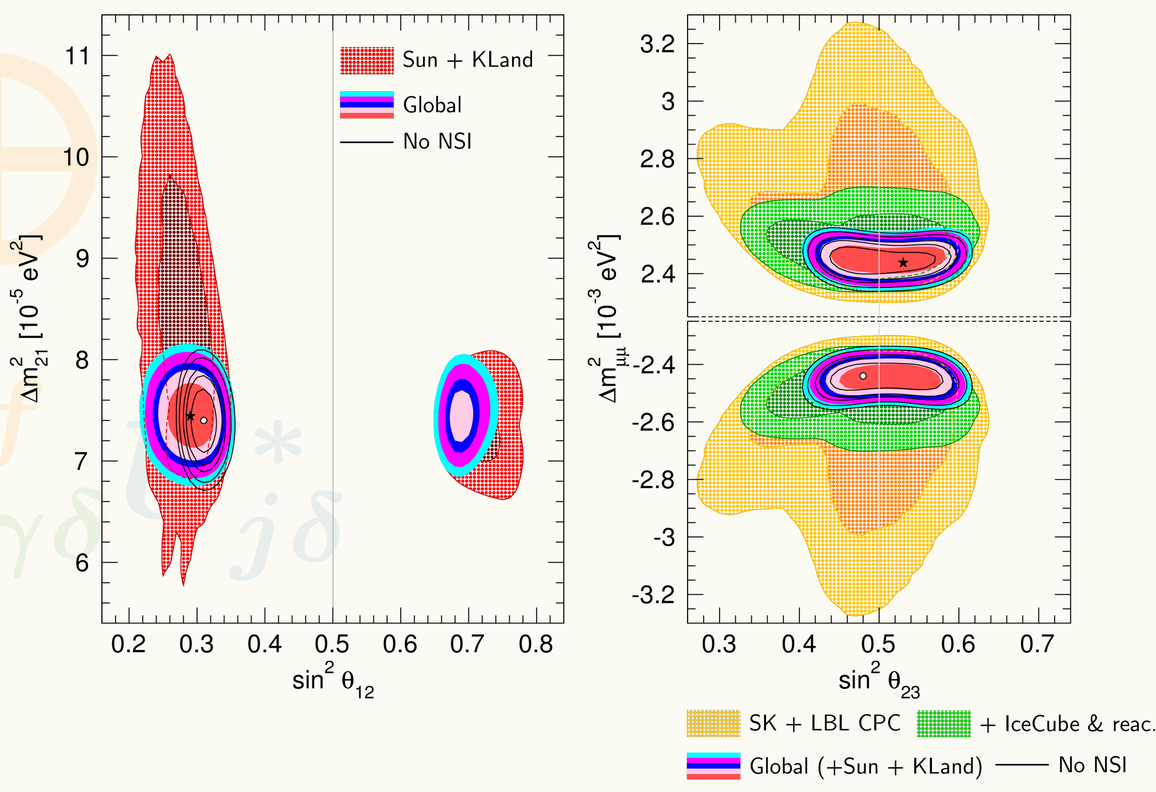
- The combination of experiments with different baselines, matter properties, energies and oscillation channels makes the standard picture *very robust*, except for θ_{12}.
- Marginalization over admixtures of NSI with up and down quarks allows the LMA-D solution within $\sim 3\sigma$.
- Even though T2K loses sensitivity ($\sim$ 2 units in χ^2) to CP violation and the mass ordering, adding other experiments recovers the standard picture.

Results: matter potential in LBL experiments

Light blue: + COHERENT.

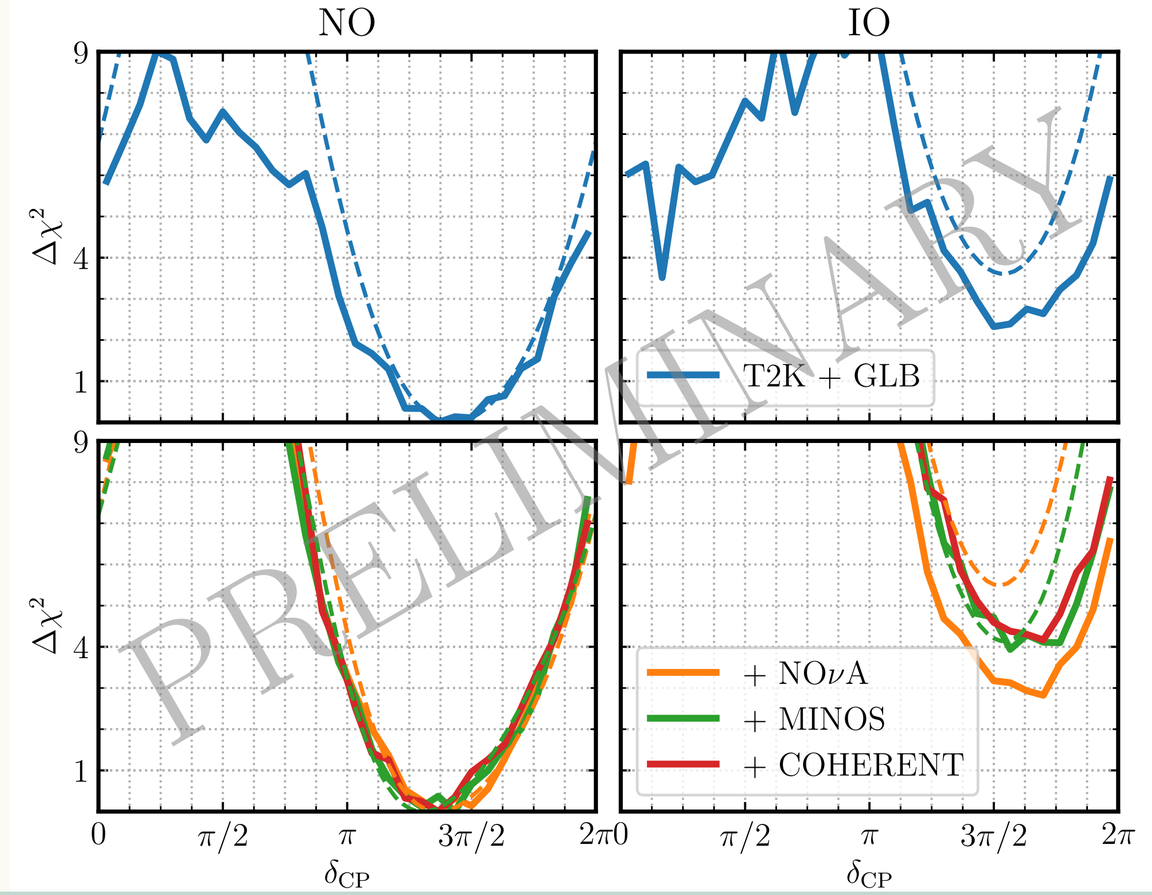


Results: robustness of oscillation parameters



Implication: maximum effect on δ_{CP} determination

We considered the *full* NSI parameter space, and included LBL appearance experiments. The dashed lines show the results without NSI.



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