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

Invisibles18 Workshop, Karlsruhe

Ivan Esteban

Institute of Cosmos Sciences (ICCUB), University of Barcelona

In collaboration with M. C. Gonzalez-Garcia, M. Maltoni, I. Martinez-Soler and J. Salvado

Based on arXiv:1805.04530 [hep-ph]

4th September 2018

Introduction

- We only measure leptonic mixing angles and neutrino mass differences *indirectly*.
- How robust is the picture against New Physics?
- How much information on NP do neutrino oscillation experiments give us?

Framework

We consider neutral current NSI:

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

which modify the neutrino matter potential

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

Here, $\varepsilon_{\alpha\beta}(x) = \varepsilon^e_{\alpha\beta} + \varepsilon^p_{\alpha\beta} + \frac{N_n(x)}{N_e(x)}\varepsilon^n_{\alpha\beta}$.
We consider $\varepsilon^p_{\alpha\beta} \propto \varepsilon^n_{\alpha\beta}$.

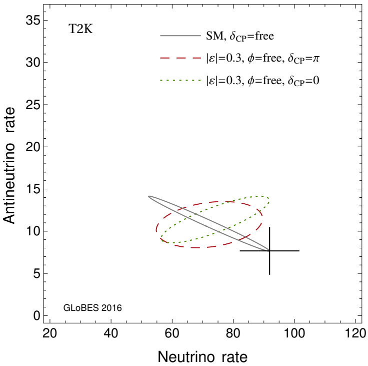
Degeneracies

- Generalized mass ordering degeneracy ($H \to H^*$)

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

"LMA-D" solution

- Poor determination of δ_{CP}

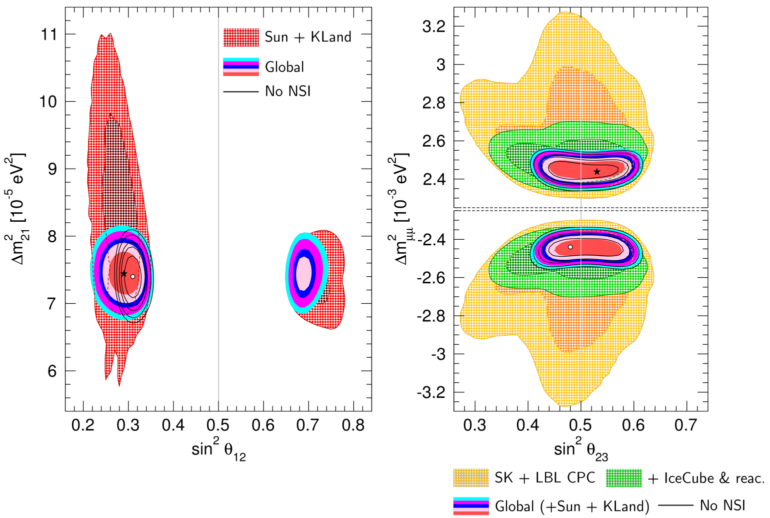


P. Coloma and T. Schwetz, "Generalized mass ordering degeneracy in neutrino oscillation experiments" , Phys. Rev. D **94** (2016) no.5, 055005 [arXiv:1604.05772 [hep-ph]].

D. V. Forero and P. Huber, "Hints for leptonic CP violation or New Physics?" , Phys. Rev. Lett. **117** (2016) no.3, 031801 [arXiv:1601.03736 [hep-ph]].

Results

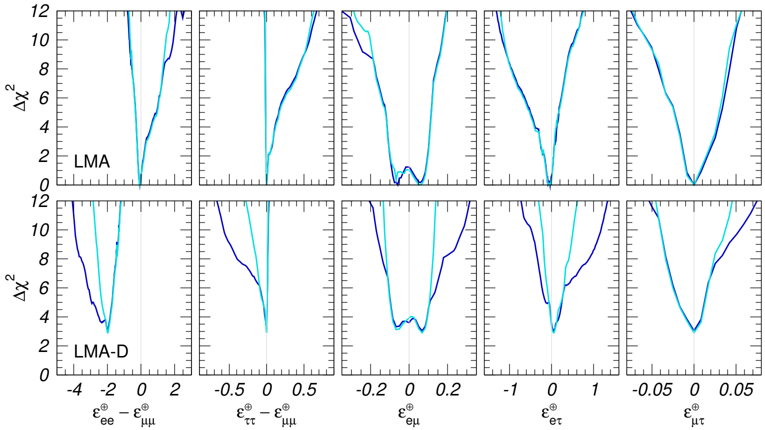
Robustness of oscillation parameters



Dotted: 90% CL, 3σ. Solid: 1σ, 90%, 2σ, 99%, 3σ.

Results

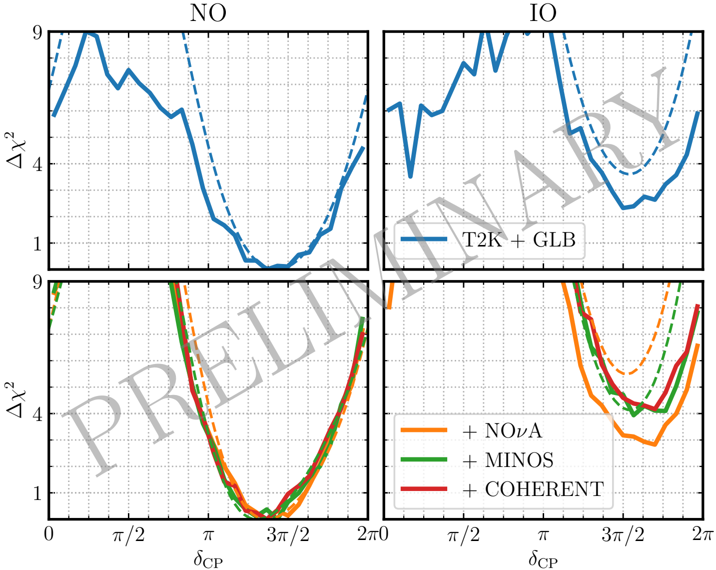
Matter potential in LBL experiments



Light blue: + COHERENT.

Implications

Maximum effect on δ_{CP} determination



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 protons and neutrons allows the LMA-D solution within $\sim 2\sigma$.

- Even though T2K loses sensitivity (~ 2 units in χ^2) to CP violation and the mass ordering, adding other experiments recovers the standard picture.

Backup

We allow admixtures of up and down quark NSIs

$$\varepsilon^e_{\alpha\beta} = 0$$

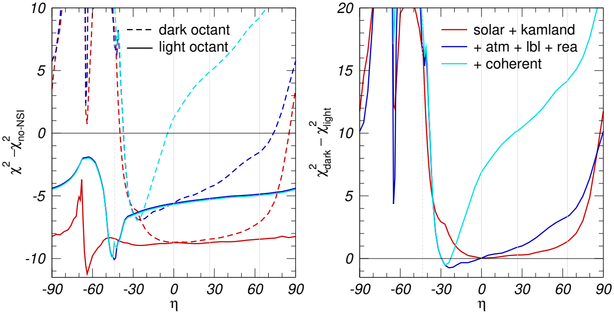
$$\varepsilon^p_{\alpha\beta} = \varepsilon^\eta_{\alpha\beta}\sqrt{5}\cos\eta$$

$$\varepsilon^n_{\alpha\beta} = \varepsilon^\eta_{\alpha\beta}\sqrt{5}\sin\eta$$

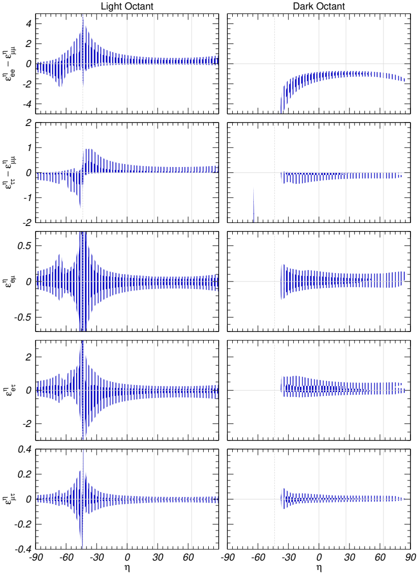
and so the combination that LBL experiments see is

$$\varepsilon^{\oplus}_{\alpha\beta} = \sqrt{5}\varepsilon^\eta_{\alpha\beta}(\cos\eta + Y_n\sin\eta)\,,$$

that vanishes for $\eta \sim -44^\circ$.



Backup



Light Octant
Dark Octant
$\epsilon^\eta_{ee} - \epsilon^\eta_{\mu\mu}$
$\epsilon^\eta_{\tau\tau} - \epsilon^\eta_{\mu\mu}$
$\epsilon^\eta_{e\mu}$
$\epsilon^\eta_{e\tau}$
$\epsilon^\eta_{\mu\tau}$
η
η