Exploring Scalar Non-Standard Interaction at DUNE and P2SO

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Introduction

- This work investigates the effects of off-diagonal SNSI parameters on the measurement of neutrino oscillation parameters in two long-baseline experiments: P2SO and DUNE.
- We focus on how SNSI impacts the determination of δ_{CP}, Δm^2_{31}, and θ_{23}. Additionally, we obtain bounds on the SNSI parameters.
- We also investigate how the new CP phase of SNSI parameters $\phi_{\alpha\beta}$ affect the sensitivity to unknowns of neutrino field in the DUNE and P2SO experiments.

Theoretical framework

- The effective Lagrangian in the presence of SNSI:

$$\mathcal{L} = \sum_{f,\alpha,\beta} \frac{y_f y_{\alpha\beta}}{m_\phi^2} (\bar{\nu}_\alpha \nu_\beta)(\bar{f} f) \quad (1)$$

- The effect of scalar NSI appears as an addition to the neutrino mass term.
- The corresponding Dirac equation, taking into account the effect of SNSI:

$$\bar{\nu}_\alpha [i\partial_\mu \gamma^\mu + (M_{\alpha\beta} + \frac{\sum N_f y_f y_{\alpha\beta}}{m_\phi^2})] \nu_\beta = 0 \quad (2)$$

With

$$\delta M = \frac{\sum N_f y_f y_{\alpha\beta}}{m_\phi^2}$$

- The effect of SNSI appears as a correction term:

$$\delta M = \sqrt{|\Delta m^2_{31}|} \begin{pmatrix} \eta_{ee} & \eta_{e\mu} & \eta_{e\tau} \\ \eta_{\mu e} & \eta_{\mu\mu} & \eta_{\mu\tau} \\ \eta_{\tau e} & \eta_{\tau\mu} & \eta_{\tau\tau} \end{pmatrix} \quad (3)$$

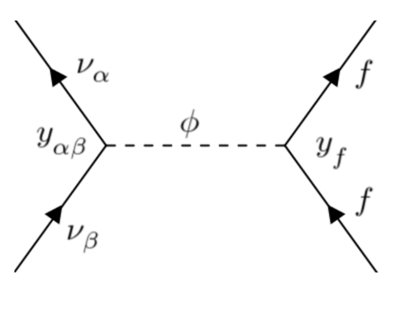

Fig. 1: Feynmann diagram contributing to SNSI.

Simulation Details

DUNE:

- Baseline Length: 1285 km.
- Earth matter density: 2.84 g/cm^3.
- Beam Power: 1.2 MW and will have a total exposure of 1.1×10^{21} protons on target (POT).
- Run time: 6.5 years for ν and 6.5 years for $\bar{\nu}$

P2SO: (Protvino to Super-ORCA)

- Baseline Length: 2595 km
- Beam Power: 450 KW and will have a total exposure of 4×10^{20} POT.
- Run time: 3 years for ν and 3 years for $\bar{\nu}$
- Earth matter density: $= 2.95\ g/cm^3$

The sensitivity is estimated in terms of χ^2.

$$\chi^2_{\rm stat} = 2\sum_{i=1}^{n} \left[N_i^{\rm test} - N_i^{\rm true} - N_i^{\rm true} \log\left(\frac{N_i^{\rm test}}{N_i^{\rm true}}\right)\right] \quad (4)$$

Results I

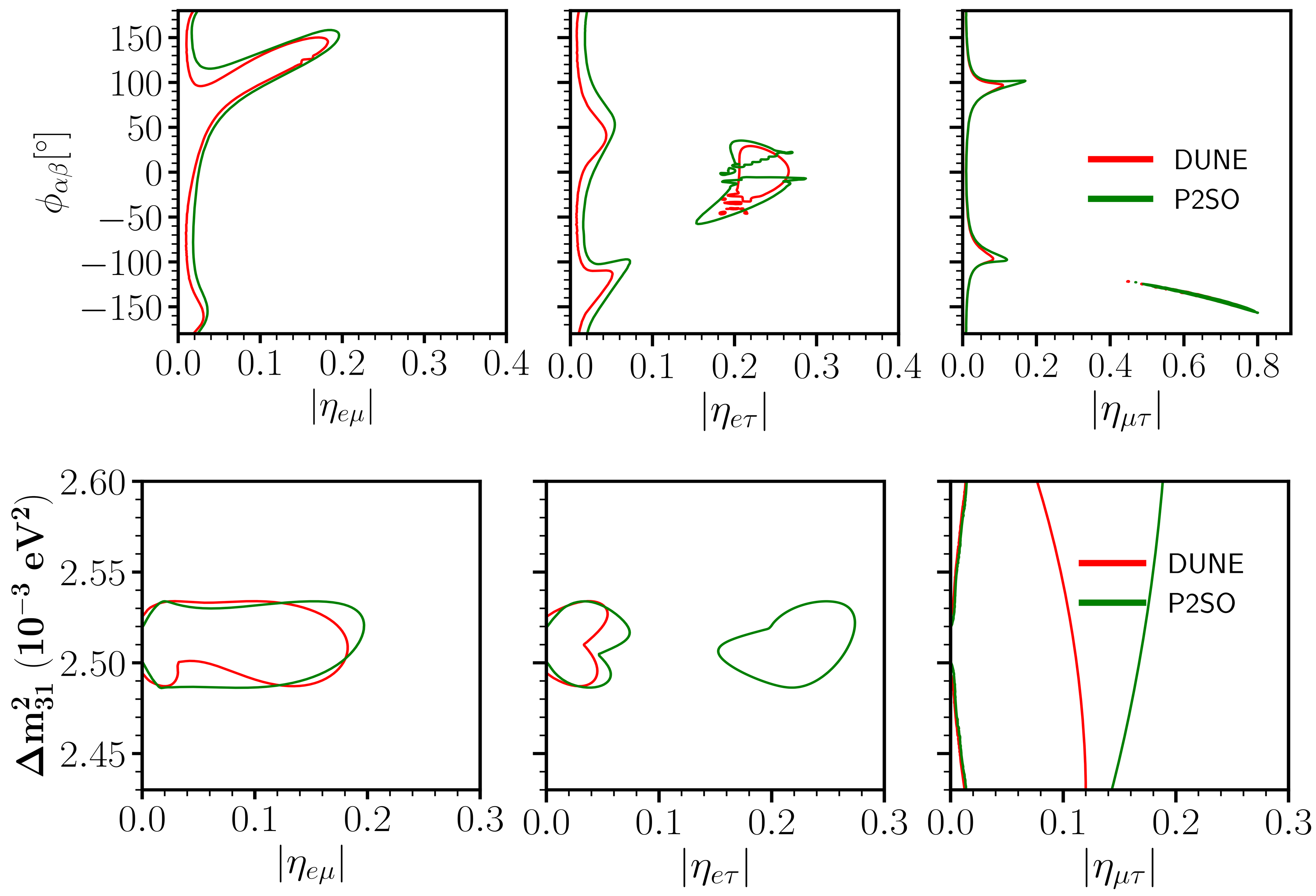

Fig. 1: Allowed parameter space between SNSI parameter $|\eta_{\alpha\beta}| - \phi_{\alpha\beta}$ (upper) and $|\eta_{\alpha\beta}| - \Delta m^2_{31}$(lower)

Results II

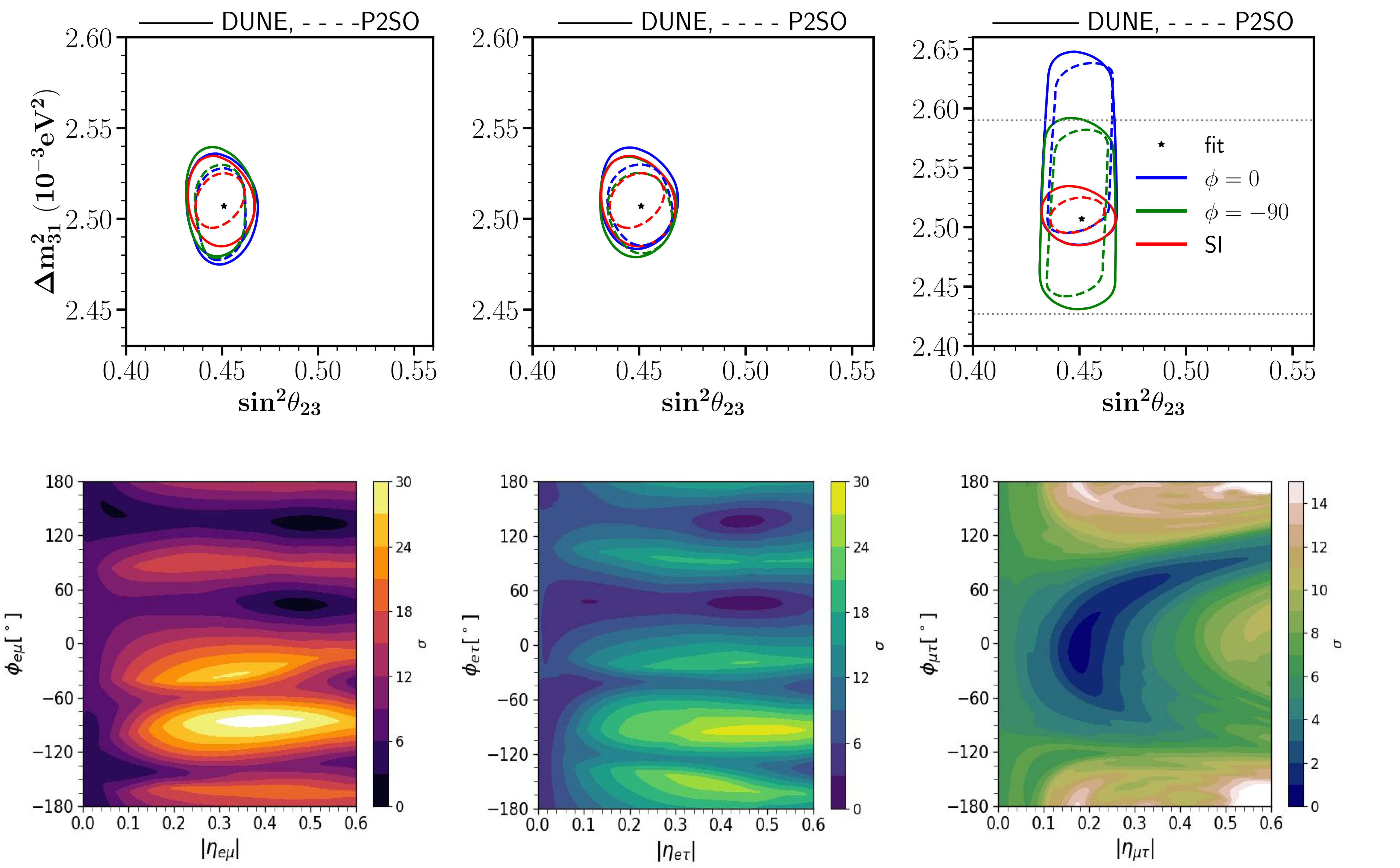

Fig. 2: Effect of SNSI parameters on $sin^2\theta_{23}$ and Δm^2_{31} (upper) and CP violation sensitivity as a function of $\eta_{\alpha\beta}$ and $\phi_{\alpha\beta}$ (lower)

Conclusion

- We obtain the bounds on the SNSI parameters and find that the bounds of $\eta_{e\mu}$ and $\eta_{e\tau}$ are stronger as compared to the bound of $\eta_{\mu\tau}$.
- We find that the parameter Δm^2_{31} has a non-trivial role while putting constraint especially for $\eta_{\mu\tau}$.
- Both DUNE and P2SO will be more sensitive to θ_{23} compare to Δm^2_{31}.
- We see for certain values of $\eta_{\alpha\beta}$ and $\phi_{\alpha\beta}$, the CPV sensitivity is almost lost.
- There is a significant contribution from $\phi_{\alpha\beta}$ in the measurement of other oscillation parameters.

Acknowledgement

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References

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