NEW PHYSICS FROM OSCILLATIONS AT THE DUNE NEAR DETECTOR AND THE ROLE OF SYSTEMATIC UNCERTAINTIES

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THEORETICAL FRAMEWORK

The simplest extension able to account for the light neutrino masses and leptonic mixing observed in neutrino oscillation experiments, consists in the addition of singlet fermions (sterile ν's) to the SM field content. In all generality the full mixing matrix can be written as:

$$\mathcal{U} = \begin{pmatrix} N & \Theta \\ R & S \end{pmatrix}$$

where N is a 3×3 non-unitary matrix corresponding to the PMNS active-light sub-block.

PARAMETRIZATION

Deviations from unitarity can be parametrised as [3-5]:

$$N = (I - T)U$$

$$T = \begin{pmatrix} \alpha_{ee} & 0 & 0 \\ \alpha_{\mu e} & \alpha_{\mu\mu} & 0 \\ \alpha_{\tau e} & \alpha_{\tau\mu} & \alpha_{\tau\tau} \end{pmatrix}$$

In terms of the $\mathcal{U}$ elements

$$\alpha_{\beta\beta} = \frac{1}{2}\sum_{i=4}^{n} |\mathcal{U}_{\beta i}|^2$$

$$\alpha_{\gamma\beta} = \sum_{i=4}^{n} \mathcal{U}_{\gamma i}\mathcal{U}^*_{\beta i}$$

NON-UNITARITY

- New $\nu's$, too heavy to be produced
- Strong contraints from precision EW and flavour searches [6-7]
- Non-zero probability of observing flavour transitions at zero distance

$$P_{\mu e}(L=0) = |\alpha_{\mu e}|^2$$
$$P_{\mu\tau}(L=0) = |\alpha_{\tau\mu}|^2$$

STERILE ν OSCILLATIONS

- New $\nu's$, light enough to be kinematically produced in the ν beam
- Unitarity is effectively restored in EW and flavour observables (bounds from oscillations) [2]

We consider the case of the 3+1 scenario. The oscillation probabilities at the ND are given by:

$$P_{\gamma\beta} = 4\,|\mathcal{U}_{\beta 4}|^2\,|\mathcal{U}_{\gamma 4}|^2 \sin^2\left(\tfrac{\Delta m^2_{41} L}{4E}\right)$$
$$P_{\beta\beta} = 1 - 4\,|\mathcal{U}_{\beta 4}|^2\left(1 - |\mathcal{U}_{\beta 4}|^2\right)\sin^2\left(\tfrac{\Delta m^2_{41} L}{4E}\right)$$

AVERAGE-OUT REGIME

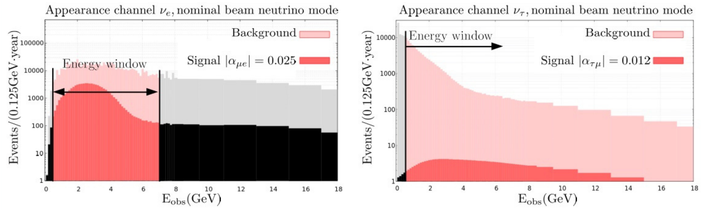
In the averaged-out regime $\left(\Delta m^2_{41} L/E \gg 1\right)$ the oscillations are too fast to be distinguished at the detector, and we find

$$P_{\mu e} = 2\,|\mathcal{U}_{\mu 4}|^2\,|\mathcal{U}_{e4}|^2 = 2\,|\alpha_{\mu e}|^2$$
$$P_{\mu\tau} = 2\,|\mathcal{U}_{\mu 4}|^2\,|\mathcal{U}_{\tau 4}|^2 = 2\,|\alpha_{\tau\mu}|^2$$

Factor 2 difference between Non-Unitarity and average out sterile scenarios. Non-Unitarity stemming from heavy new physics and averaged-out sterile neutrinos are indistinguisable at the ND.

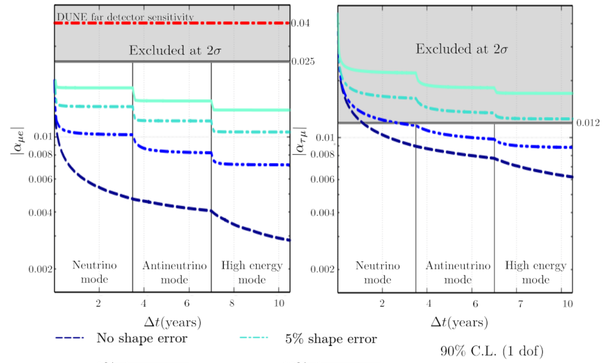
RESULTS

EXPECTED NUMBER OF EVENTS



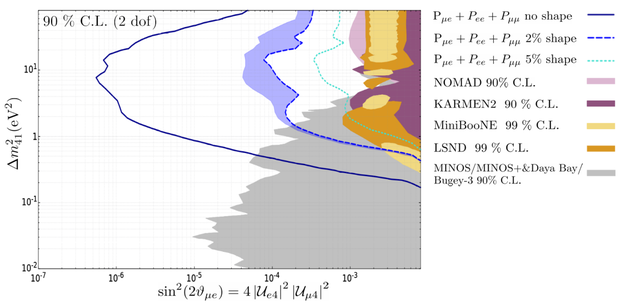
- Sensitivity driven by differences in the spectra

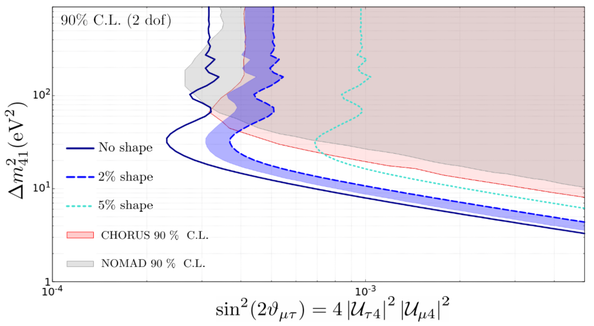
NON-UNITARITY & AVERAGE-OUT REGIME



- The shape uncertainty has large impact on the sensitivity. In the literature, most phenomenological studies for near detectors only consider normalization systematics, giving very impressive but unrealistic results.
- Despite this, we still find improvement with respect to the present bounds.
- See Ref. [1] for further details

STERILE ν OSCILLATIONS





CONCLUSION

Our results show that the potential of the DUNE ND to constrain new physics scenarios affecting oscillations at short baselines is severely limited by shape uncertainties. This stresses the importance of a joint experimental and theoretical effort to improve our understanding of neutrino nucleus cross sections, as well as hadron production uncertainties and beam focusing effects. Nevertheless, even with our conservative and more realistic implementation of the systematic uncertainties, an improvement over current bounds is generally expected.

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