DUNE AS AN ULTRALIGHT DARK MATTER DETECTOR

Poster based on [4]

can probe **ultralight scalars** via signal **time modulation** and **distorted neutrino oscillations**.

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Ultralight scalars and neutrino oscillations

Dark matter might be a scalar with a mass much below the eV scale, (**Fuzzy Dark Matter**).
Its coupling to neutrinos would induce time dependencies on the masses and mixing angles [1,2].

$$\theta_{ij}(t) = \theta_{ij} + \eta\cos(m_\phi t),$$

$$\Delta m^2_{ij}(t) \equiv m^2_i(t) - m^2_j(t) \simeq \Delta m^2_{ij}\left[1 + 2\eta\cos(m_\phi t)\right]$$

The period of the modulation is related to the mass of the scalar

$$\tau_\phi \equiv \frac{2\pi}{m_\phi} = 0.41\left(\frac{10^{-14}\ \mathrm{eV}}{m_\phi}\right)\ \mathrm{s}.$$

Three regimes can be identified.

A **TIME MODULATION** of the signal can be measured when the **period of the modulation** is between the running time of the experiment and the event rate, and if the **number of events** is large enough.

For a smaller modulation period, the time variation of signal would be **averaged**, leading to **DISTORTED NEUTRINO OSCILLATIONS.**

The distortion expected is similar to the effect of having a finite **energy resolution**.

As the modulation period gets closer to the **time of flight** of the neutrino, the changes of the oscillation parameters have to be treated **at the Hamiltonian level [3]**.

These **DYNAMICAL Distorted Neutrino Oscillations** can be understood in terms of a modified matter potential.

For even smaller values of the modulation period, the sensitivity is lost and the standard picture is recovered.

REFERENCES:
[1]A. Berlin; Phys. Rev. Lett. 117, 231801 (2016)
[2] G. Krnjaic, P. A. N. Machado, L. Necib; Phys. Rev. D 97, 075017 (2018).
[3] V. Brdar, J. Kopp, J. Liu, P. Prass, X.-P. Wang ;(Phys. Rev. D 97, 043001 (2018).
[4]A. Dev, P. A. N. Machado, P. Martínez-Miravé. Work in progress; arXiv:2006.xxxxx.

In DUNE, for a modulating Δm^2_{31}

In this case, the position of the minima and maxima of the oscillation probability changes with time, leading to a time modulation of the signal. For a very fast modulation, the effect would be averaged and the signal would be distorted.

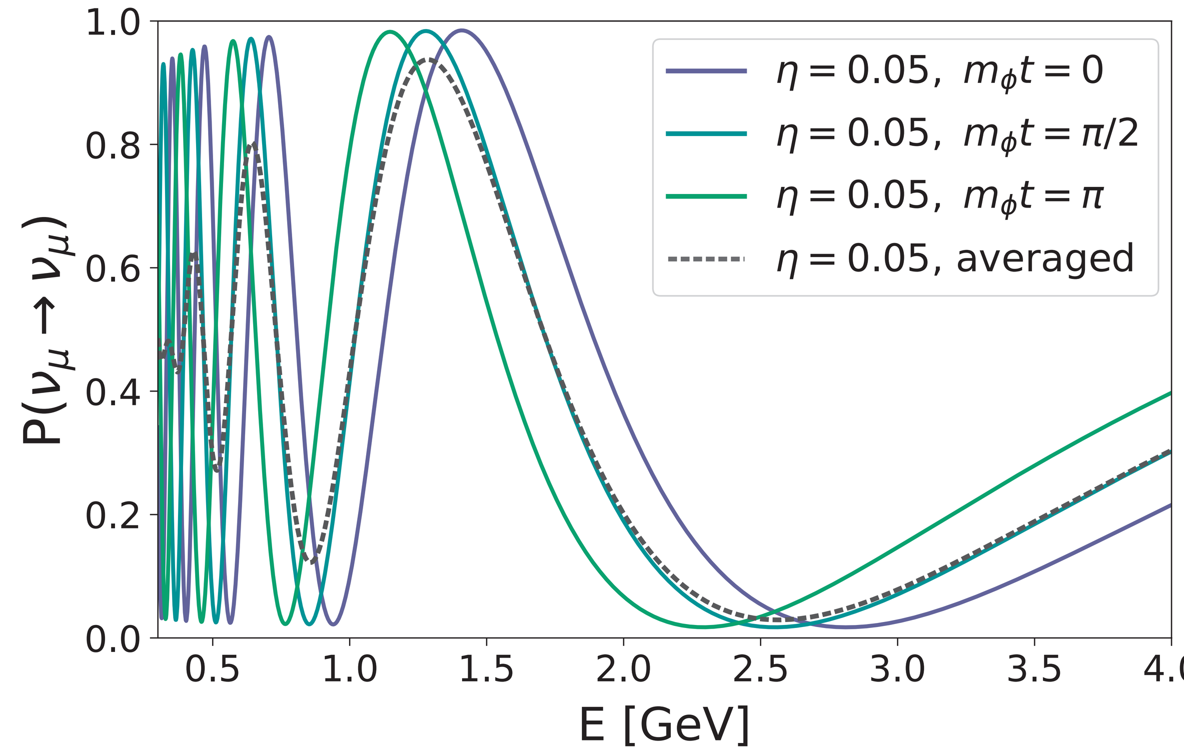

FIG I. Disappearance probability for ν_μ for different values of $m_\phi t$ and also in the averaged case (dashed).

Searches for signal time dependencies can be conducted using the **Lomb Scargle periodogram** (LS), for masses between ~ 10^{-20} - 10^{-22} eV. For more technical and experimental details, see [4].

The excellent energy resolution allows to look for Distorted Neutrino Oscillations too and set constraints on the oscillation amplitude η, for masses $m_\phi \sim 10^{-13}$ - 10^{-20} eV.

Conclusion

Combining the Lomb Scargle approach (LS) with searches for Distorted Neutrino Oscilaltions allows to cover almost ten orders of magnitude in masses and a large range of modulation amplitudes.

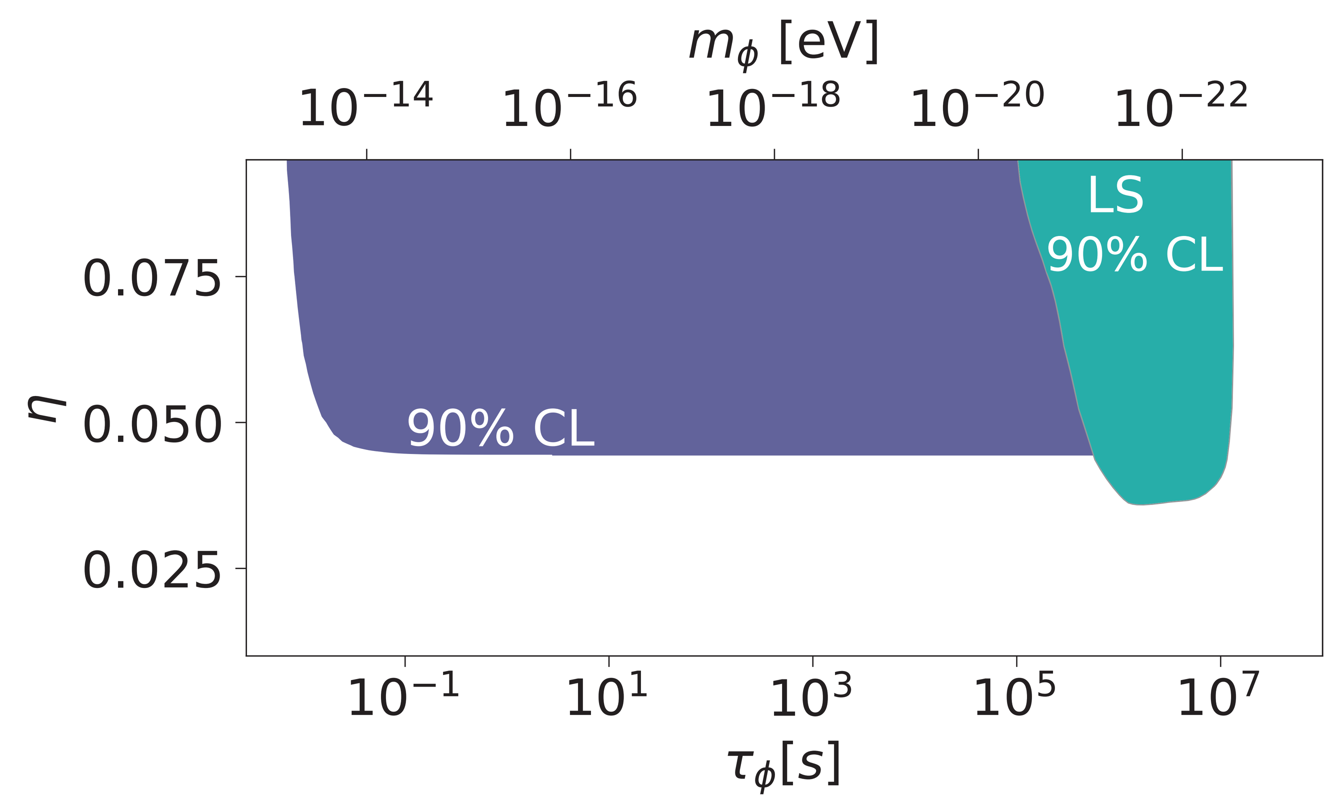

FIG II. DUNE sensitivity (90% C.L.) to ultralight scalars via modulation of the mass splitting Δm^2_{31}.