Neutrino Oscillations: Global Fit and implications on DM searches

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COST Action
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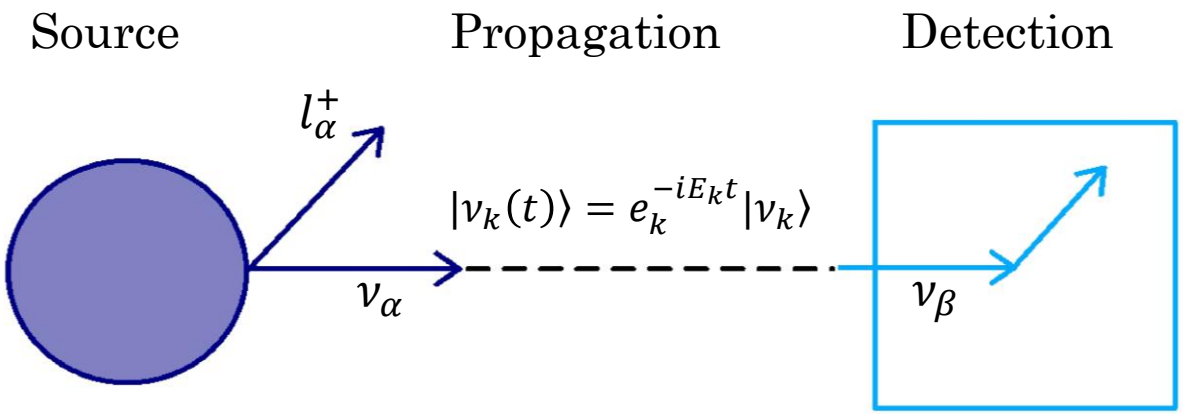
Neutrino Oscillations

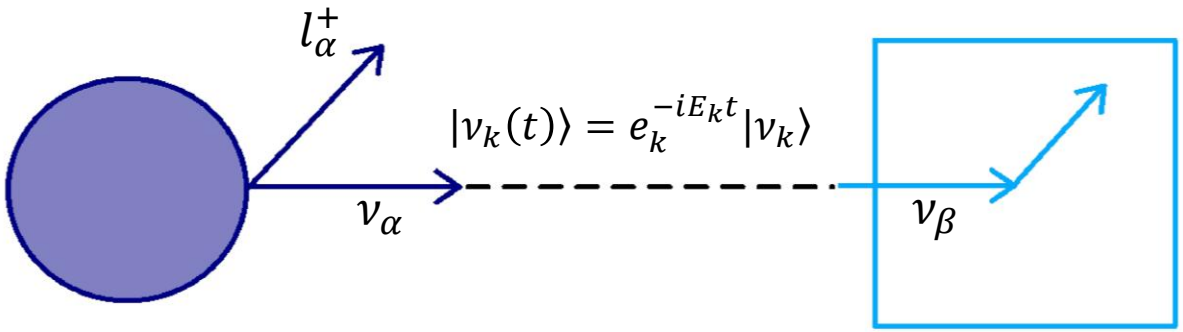


$$|\nu_\alpha\rangle = \sum_k U_{\alpha k}^* \, |\nu_k\rangle$$

$$\langle \nu_\beta | \nu_\alpha(t) \rangle = \sum_k U_{\alpha k}^* U_{\beta k} e^{-iE_k t}$$

Neutrino Oscillations

Source Propagation Detection



$$P(\alpha \to \beta; E, L) = \sum_{k,l} U^*_{\alpha k} U_{\beta k} U_{\alpha j} U^*_{\beta j} e^{i\frac{\Delta m^2_{kj}}{2E}L}$$

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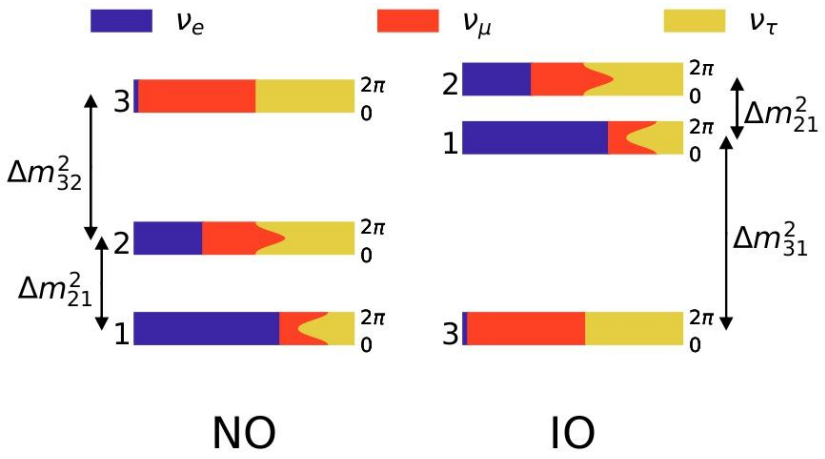
Neutrino Oscillations

- Neutrino mixing matrix
  (for Majorana neutrinos: +2-CP phases)

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\boldsymbol{P(\alpha \to \beta; E, L) = \sum_{k,l} U^*_{\alpha k} U_{\beta k} U_{\alpha j} U^*_{\beta j} e^{i\frac{\Delta m^2_{kj}}{2E}L}}$$

- Mass splitting:



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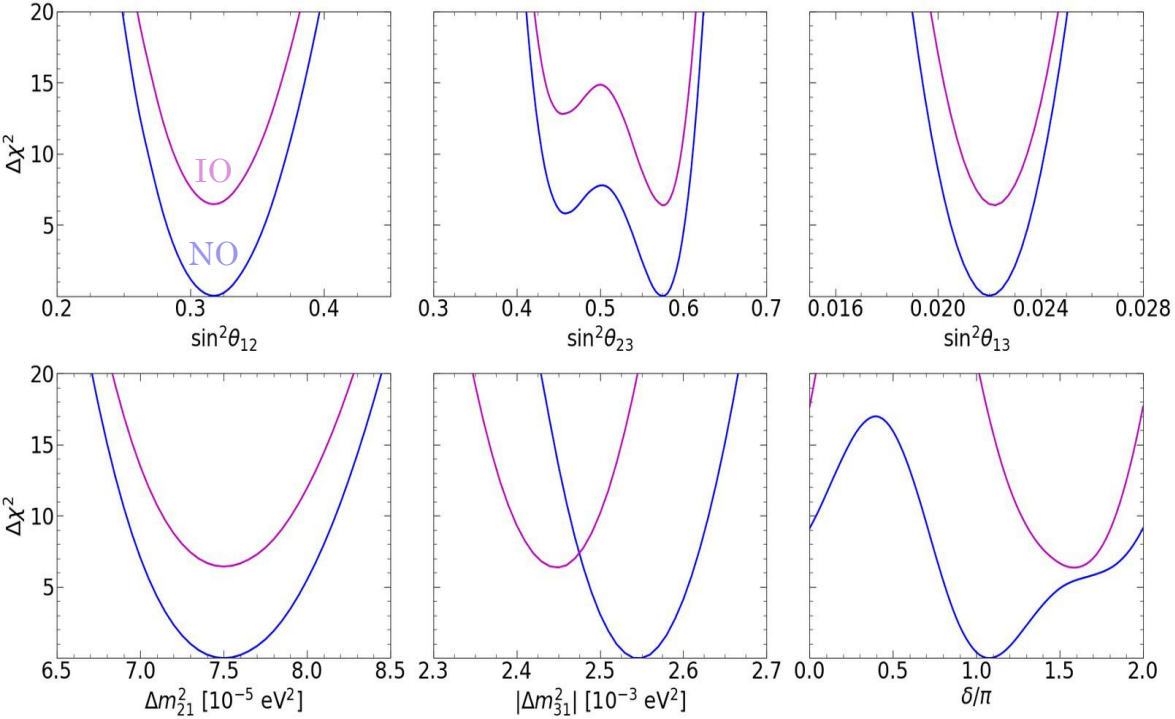
Neutrino Oscillations

- Different experiments are sensible to different parameters
- Combination of datasets enhances sensitivity

Global fit of neutrino oscillation data

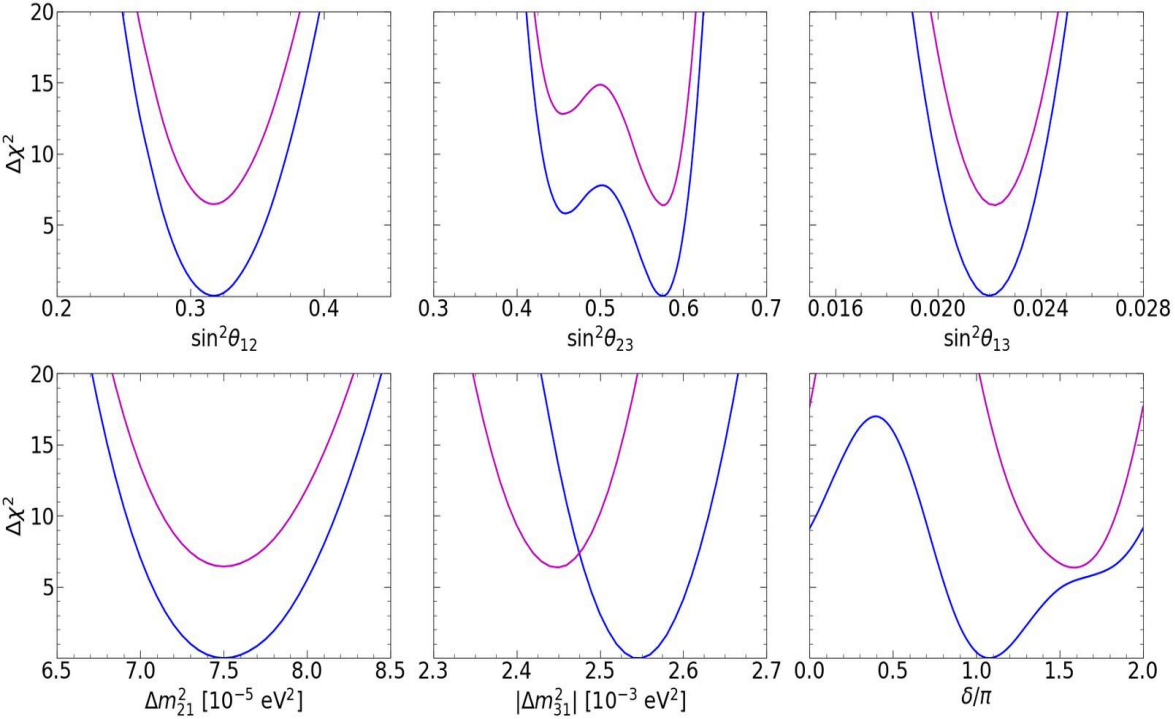


parameter	best fit $\pm 1\sigma$	2σ range	3σ range
$\Delta m^2_{21}[10^{-5}\text{eV}^2]$	$7.50^{+0.22}_{-0.20}$	7.12–7.93	6.94–8.14
$\lvert\Delta m^2_{31}\rvert[10^{-3}\text{eV}^2]$ (NO)	$2.55^{+0.02}_{-0.03}$	2.49–2.60	2.47–2.63
$\lvert\Delta m^2_{31}\rvert[10^{-3}\text{eV}^2]$ (IO)	$2.45^{+0.02}_{-0.03}$	2.39–2.50	2.37–2.53
$\sin^2\theta_{12}/10^{-1}$	3.18 ± 0.16	2.86–3.52	2.71–3.69
$\sin^2\theta_{23}/10^{-1}$ (NO)	5.74 ± 0.14	5.41–5.99	4.34–6.10
$\sin^2\theta_{23}/10^{-1}$ (IO)	$5.78^{+0.10}_{-0.17}$	5.41–5.98	4.33–6.08
$\sin^2\theta_{13}/10^{-2}$ (NO)	$2.200^{+0.069}_{-0.062}$	2.069–2.337	2.000–2.405
$\sin^2\theta_{13}/10^{-2}$ (IO)	$2.225^{+0.064}_{-0.070}$	2.086–2.356	2.018–2.424
δ/π (NO)	$1.08^{+0.13}_{-0.12}$	0.84–1.42	0.71–1.99
δ/π (IO)	$1.58^{+0.15}_{-0.16}$	1.26–1.85	1.11–1.96

Valencia - Global Fit, 2006.11237, JHEP 2021

Neutrino Oscillations

GOAL: update the global fit



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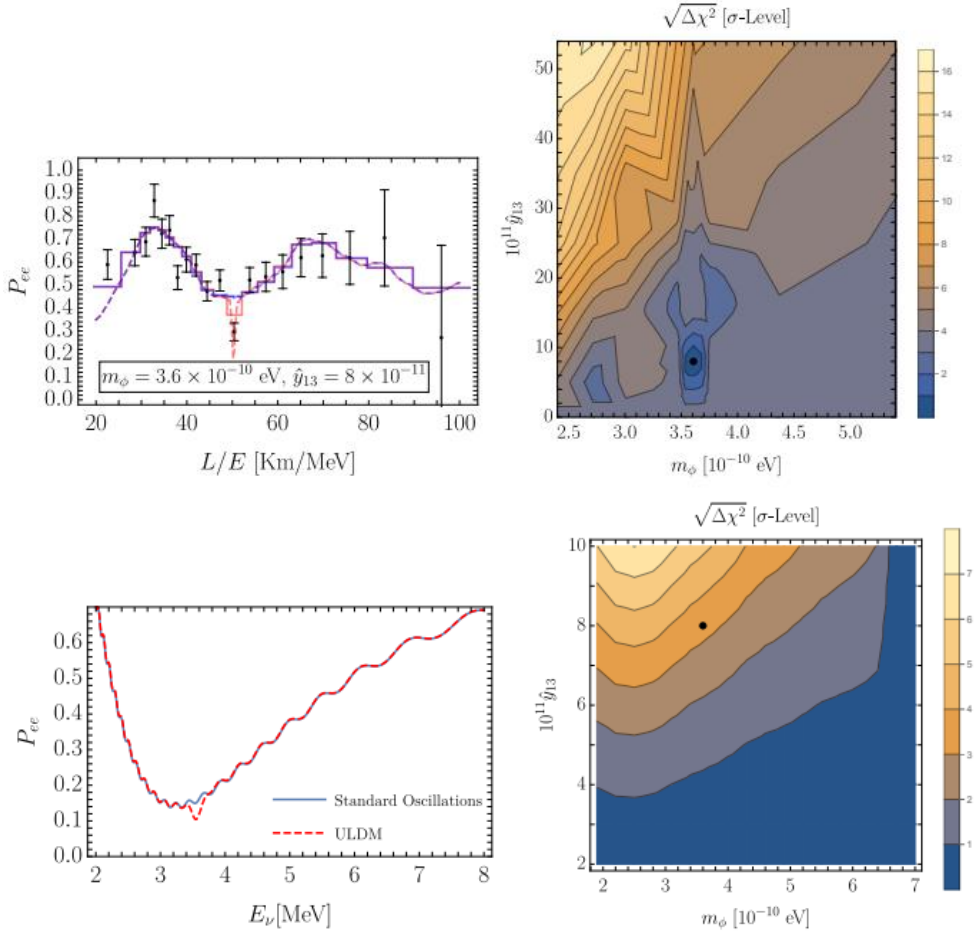
Neutrino-DM connections

If:

- Dark Matter is composed by ultra light particles
- they interact with neutrinos

Neutrino oscillations are expected to be damped through interactions with DM

GOAL: apply the framework introduced for the Global Fit to study Neutrino-DM interactions



Losada et al., 2205.09769, JHEP 2023
Top: KamLAND
Bottom: JUNO

Thanks for the attention!

Back up slides

Experiments and parameters

Parameter	Main contribution from	Other contributions from
Δm^2_{21}	KamLAND	SOL
$\lvert\Delta m^2_{31}\rvert$	LBL+ATM+REAC	-
θ_{12}	SOL	KamLAND
θ_{23}	LBL+ATM	-
θ_{13}	REAC	(LBL+ATM) and (SOL+KamLAND)
δ	LBL	ATM
MO	(LBL+REAC) and ATM	COSMO and $0\nu\beta\beta$

- In the simpler 2ν oscillation case:

$$P_{\alpha\beta} = \sin^2 2\theta \sin^2\left(\frac{\Delta m^2 x}{4E}\right)$$

with

$$\frac{\Delta m^2 x}{4E} = 1.267\left(\frac{\Delta m^2}{eV^2}\right)\left(\frac{\mathrm{x}}{m}\right)\left(\frac{\mathrm{MeV}}{E}\right)$$

- Study of
  - Appearance channel $\nu_\alpha \rightarrow \nu_\beta$
  - Disappearance channel $\nu_\alpha \rightarrow \nu_\alpha$

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