Invisible neutrino decay at KM3NeT-ORCA

(Not on behalf of KM3NeT)

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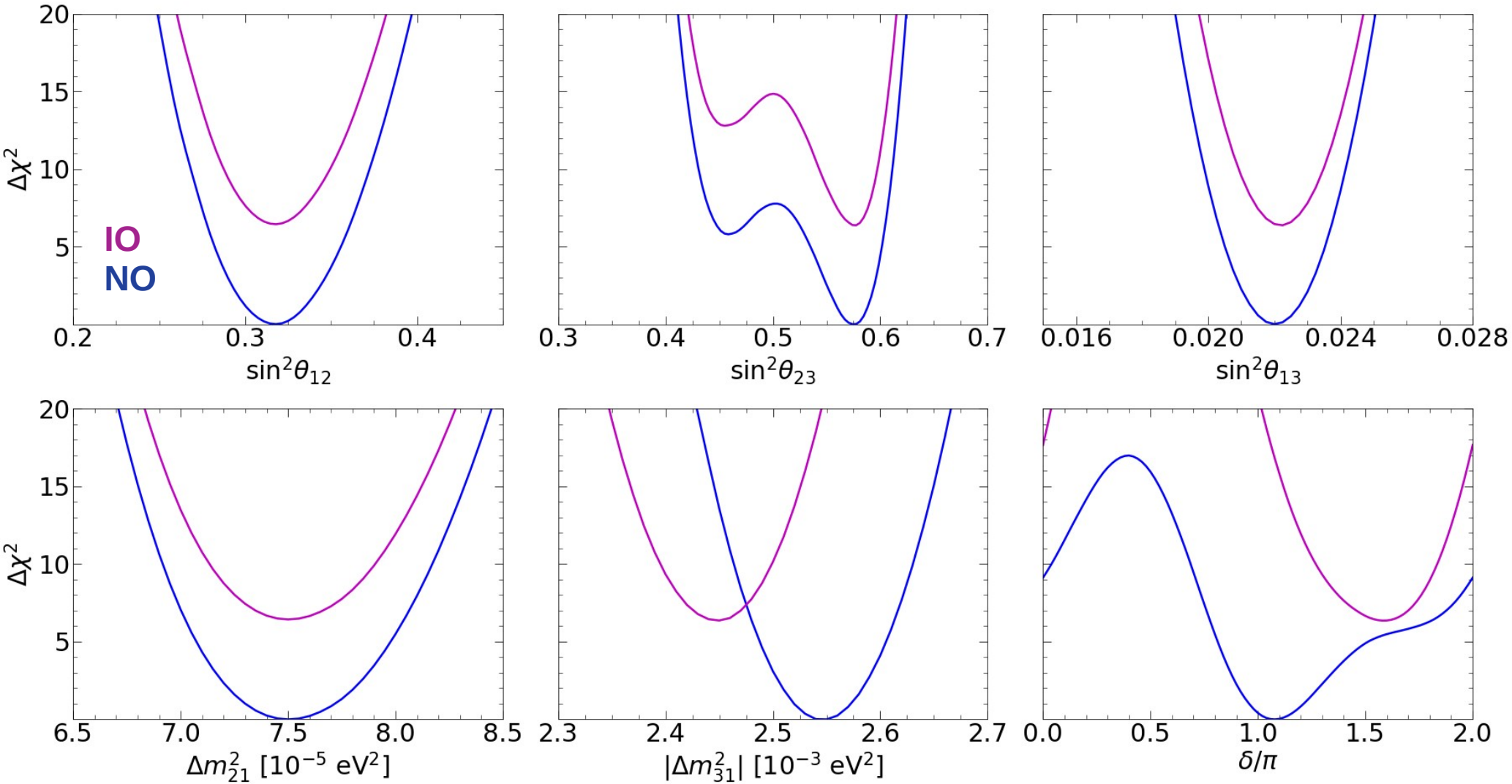
SEZIONE DI TORINO

Three-neutrino oscillations



Valencia - Global Fit, 2006.11237, JHEP 2021

Neutrino decay

New physics can worsen the determination of standard oscillation parameters

Neutrino decay has been proposed as a solution to the atmospheric and solar problems

Disfavored now, but can still appear at subleading level

Decay is predicted in some theories, e.g. Majoron model

$$\nu_i \to \nu_j + J$$

If the decay product is an active (sterile) neutrino, we talk about visible (invisible) neutrino decay

Invisible neutrino decay

We will focus on $\nu_3 \to \nu_4 + J$

We assume the sterile neutrino does not mix, such that

$$\begin{pmatrix} \nu_\alpha \\ \nu_s \end{pmatrix} = \begin{pmatrix} U & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_k \\ \nu_4 \end{pmatrix}$$

Neutrino oscillations are then described by

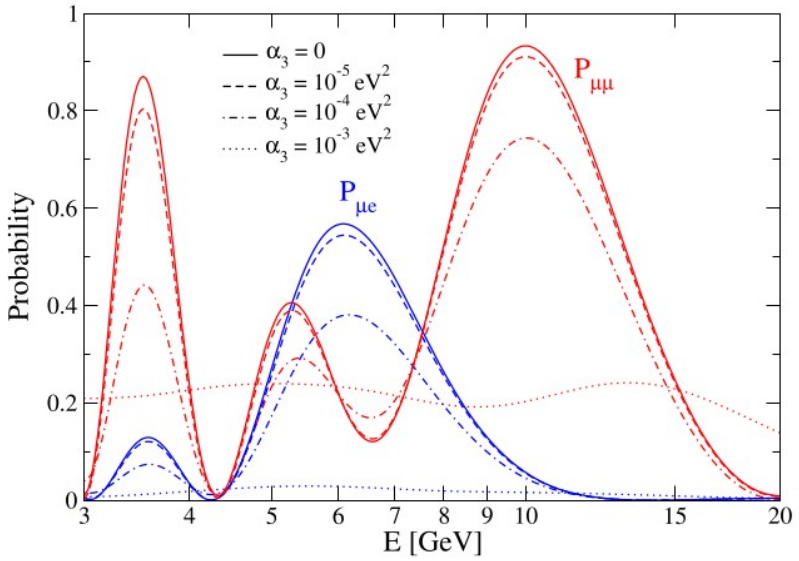
$$H = \frac{1}{2E}\left[H_0 + H_m + H_D\right]$$

$$H_D = U \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -i\alpha_3 \end{pmatrix} U^\dagger$$

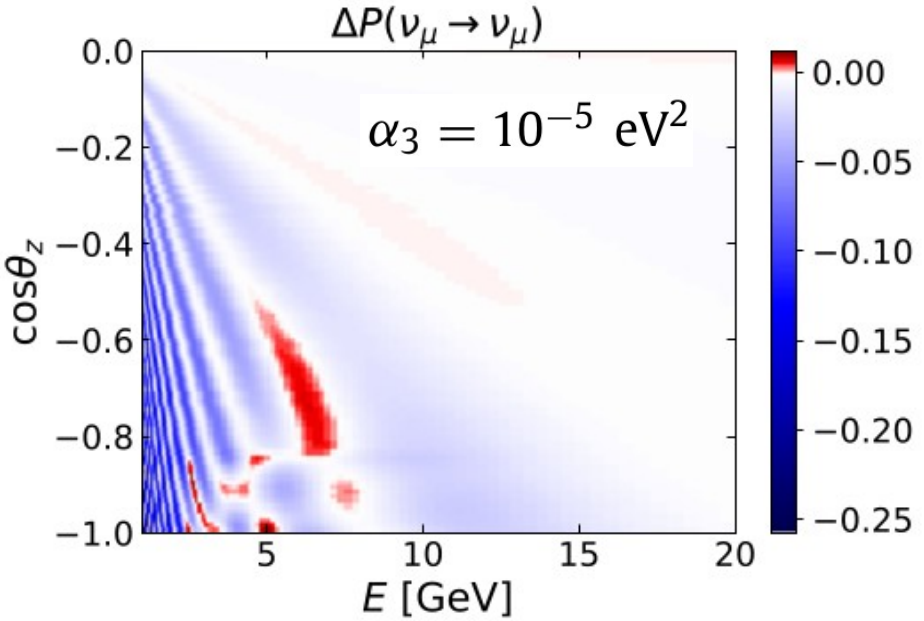
$$\alpha_3 = m_3/\tau_3$$

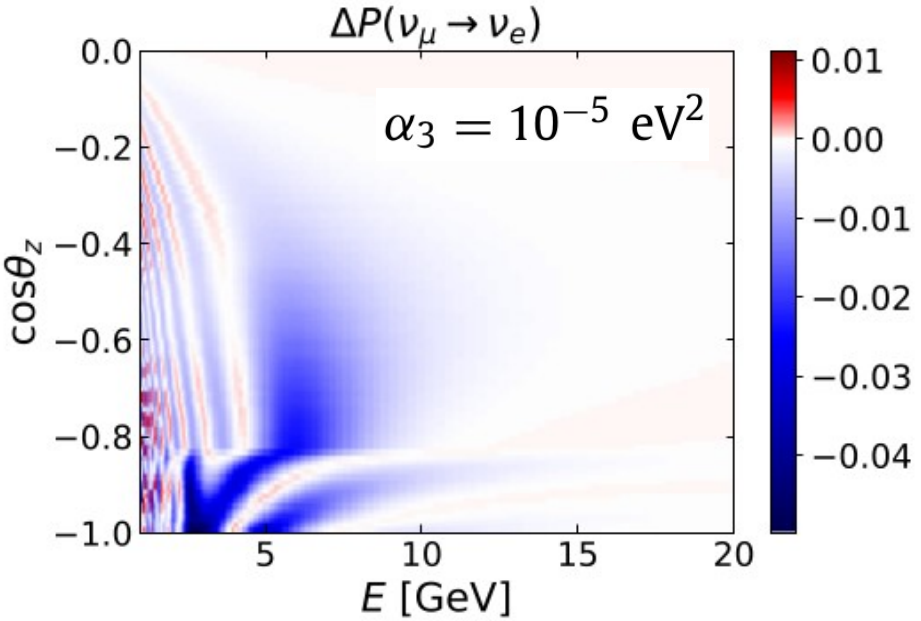
Oscillation probability

Neutrino oscillations get flattened in presence of neutrino decay



de Salas, Pastor, Ternes, Thakore, Tórtola, 1810.10916, PLB 2019





Simulation

Simulate full atmospheric signal at ORCA

Simulated spectrum — Fake data — Systematic uncertainties

$$\chi^2 = \min_{\vec{\epsilon}} \left\{ \sum_{i,j} \left(\frac{N_{ij}(\sin^2\theta_{23}, \Delta m^2_{31}, \alpha_3; \vec{\epsilon}) - N_{ij}^{\mathrm{dat}}}{\sqrt{N_{ij}^{\mathrm{dat}}}} \right)^2 + \sum_k \left(\frac{\epsilon_k - \mu_k}{\sigma_k} \right)^2 \right\}$$

Includes particle identification (CC/NC, Tracks/Showers), detector resolution/response

Many sources of systematic uncertainties are included (flux, detector and energy calibration)

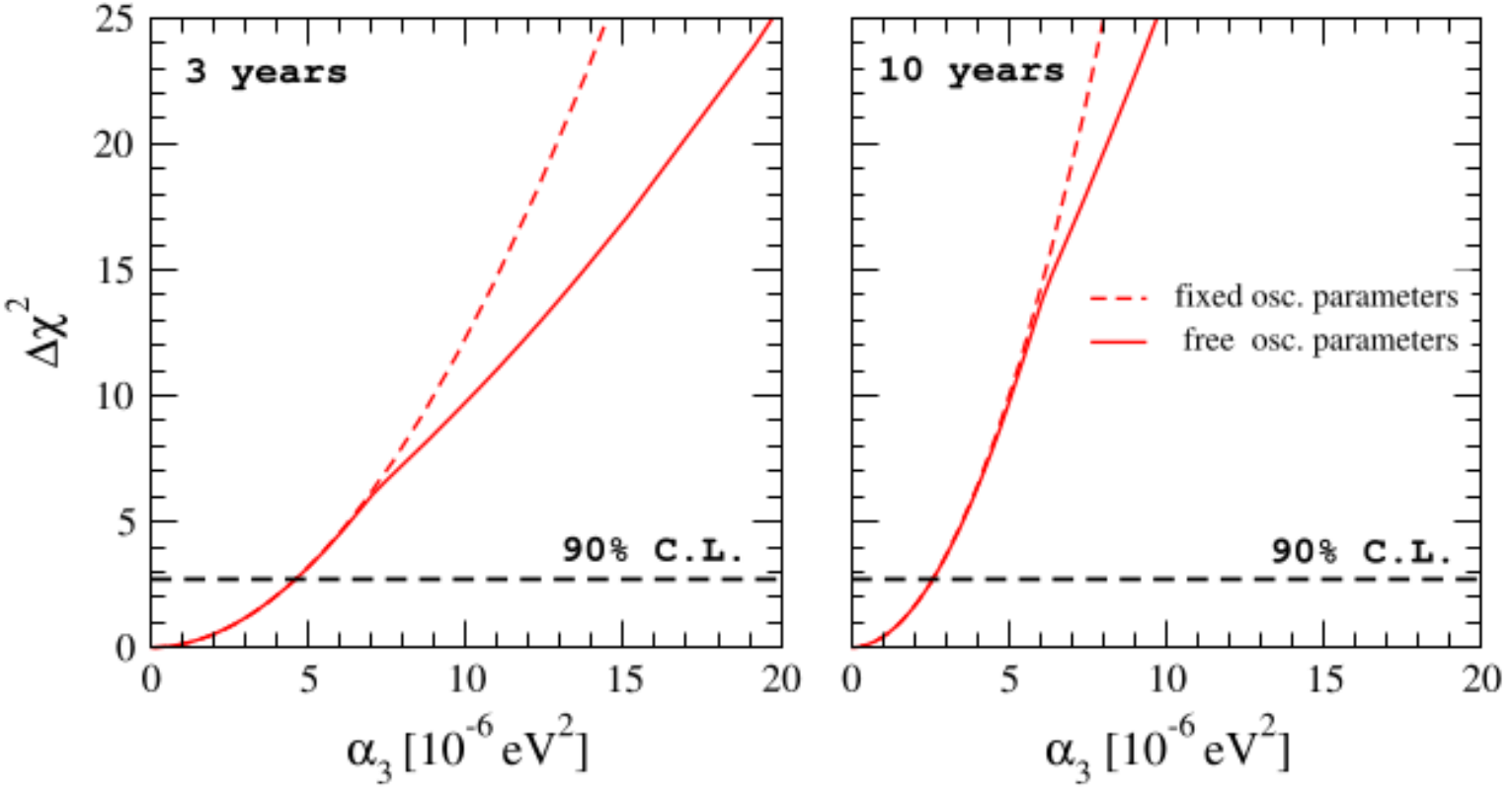
All technical information has been extracted from (9m spacing):

KM3NeT collaboration, 1601.07459, JPG 2016

ORCA sensitivity

ORCA can set strong bounds on the decay constant

The determination is mostly independent of the standard parameters



de Salas, Pastor, Ternes, Thakore, Tórtola, 1810.10916, PLB 2019

Comparison with other bounds

ORCA, our analysis:

Time	α_3 [eV^2]	τ_3/m_3 [s/eV]
3 years	$< 4.6 \times 10^{-6}$	$> 1.4 \times 10^{-10}$
10 years	$< 2.6 \times 10^{-6}$	$> 2.5 \times 10^{-10}$

de Salas, Pastor, Ternes, Thakore, Tórtola, 1810.10916, PLB 2019

DUNE (7 years): $\tau_3/m_3 \gtrsim 5.1 \times 10^{-11}$ s/eV

Ghoshal, Giarnetti, Meloni, 2003.09012, JPG 2021

See talk by D. Meloni

JUNO (5 years): $\tau_3/m_3 \gtrsim 9.1 \times 10^{-11}$ s/eV

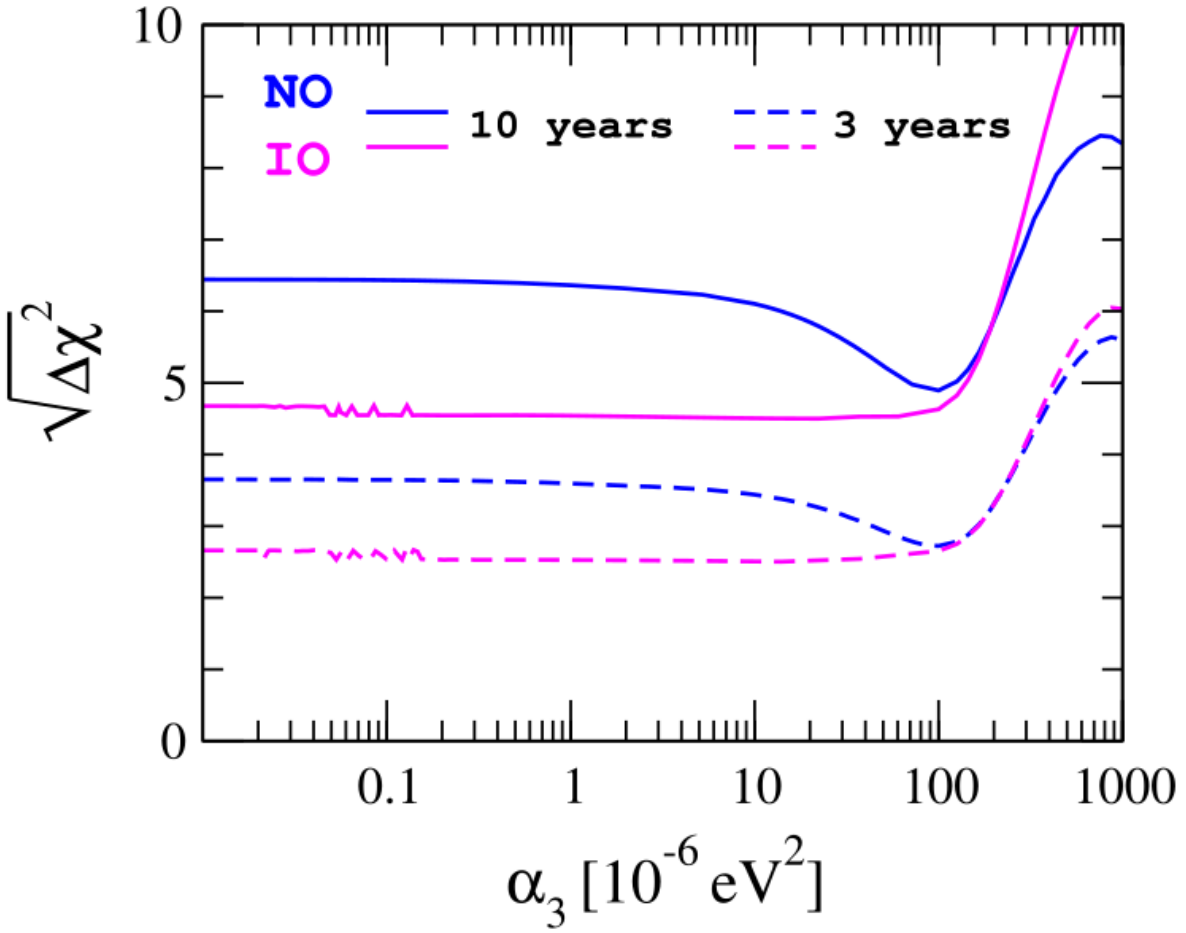
Abrahao, Minakata, Nunokawa, Quiroga, 1506.02314, JHEP 2015

INO (10 years): $\tau_3/m_3 \gtrsim 1.5 \times 10^{-10}$ s/eV

Choubey, Goswami, Gupta, Lakshmi, Thakore, 1709.10376, PRD 2018

Neutrino mass ordering

Neutrino decay does not affect the mass ordering sensitivity



de Salas, Pastor, Ternes, Thakore, Tórtola, 1810.10916, PLB 2019

Conclusions

The precise measurement of neutrino oscillation parameters can be more difficult if new physics is present

ORCA is a very good suited next generation neutrino oscillation experiment to search for invisible neutrino decay of υ_3

The measurement of the neutrino mass ordering at ORCA is robust against invisible neutrino decay

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Long live the neutrino