Improving Non-Unitary Limits on the Tau Row Matrix Elements Using Tau Neutrino Appearance

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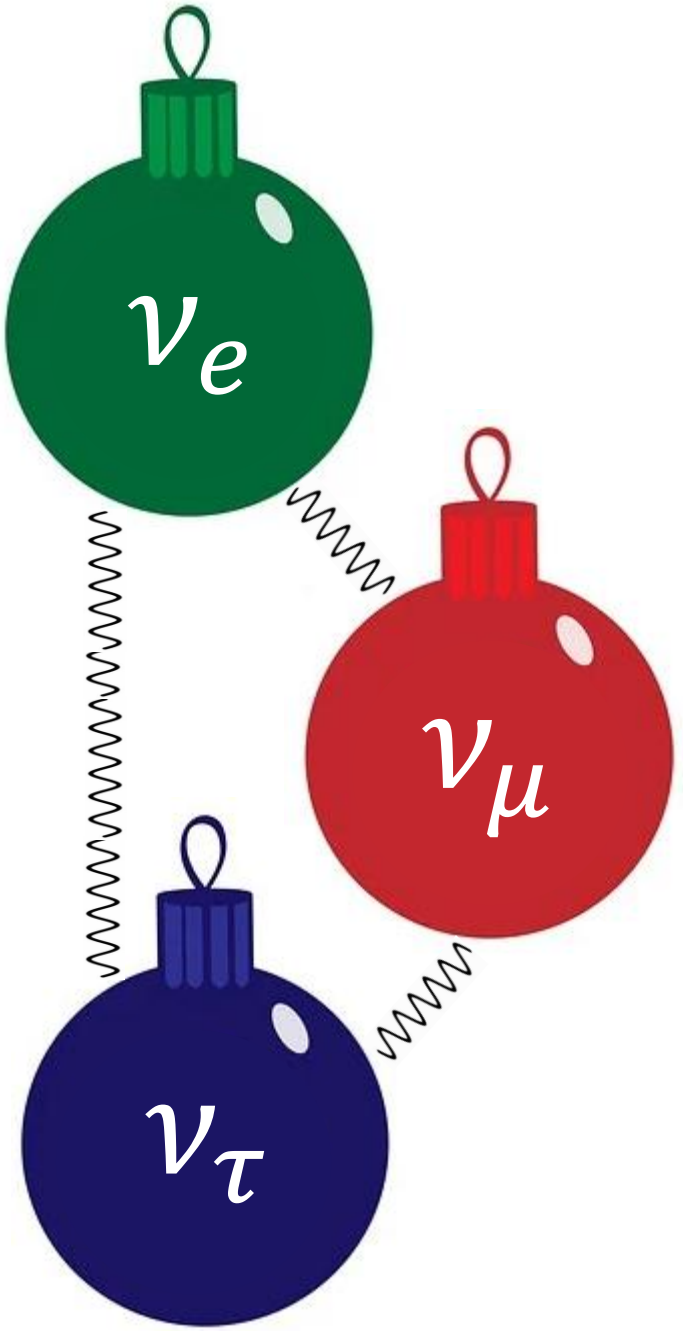
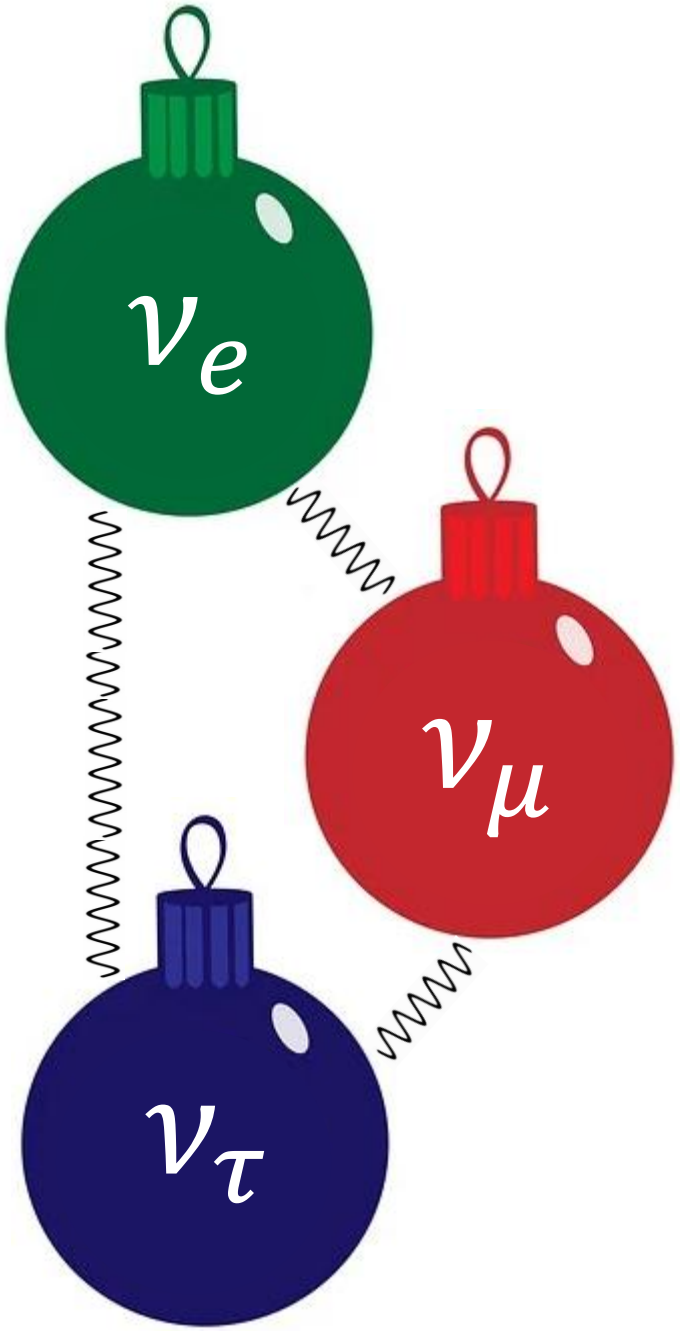


PMNS Matrix Limits

$$|U_{PMNS}|_{3\sigma\ (with\ unitarity)}^{w/o\ unitarity} =$$

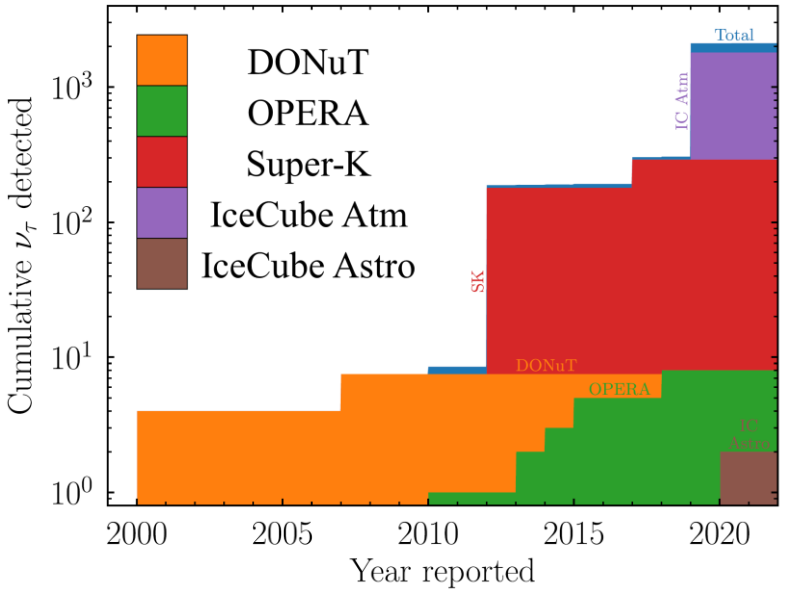
0.76→0.85 (0.79→0.85)	**0.50→0.60** (0.50→0.59)	**0.13→0.16** (0.14→0.16)
0.21→0.54 (0.22→0.52)	**0.42→0.70** (0.43→0.70)	**0.61→0.79** (0.62→0.79)
0.18→0.58 (0.24→0.54)	**0.38→0.72** (0.47→0.72)	**0.40→0.78** (0.60→0.77)

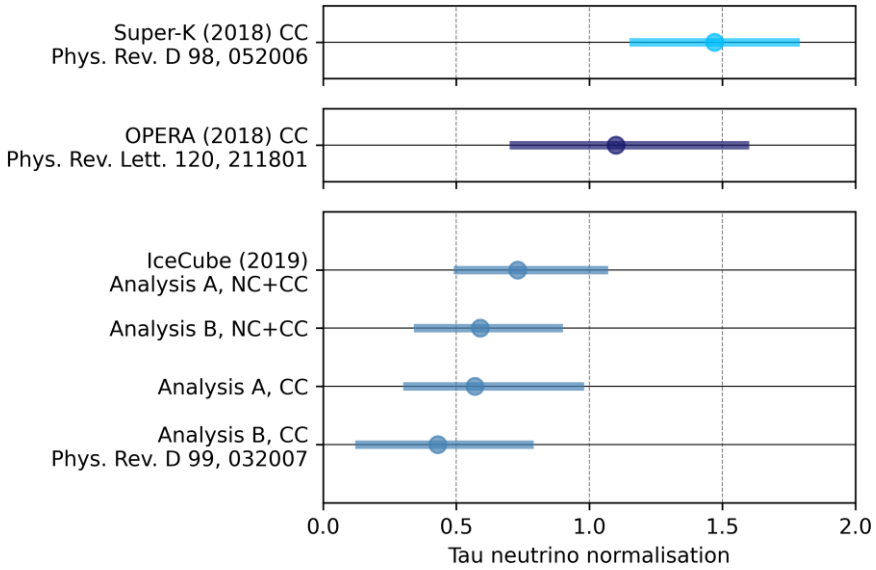
Best fit [1] limits for tau <u>without</u> unitarity constraint are poor



[1] Parke, S. and Ross-Lonergan, M. *Phys. Rev. D* 93, 113009 (2016) arXiv:1508.05095 [hep-ph]

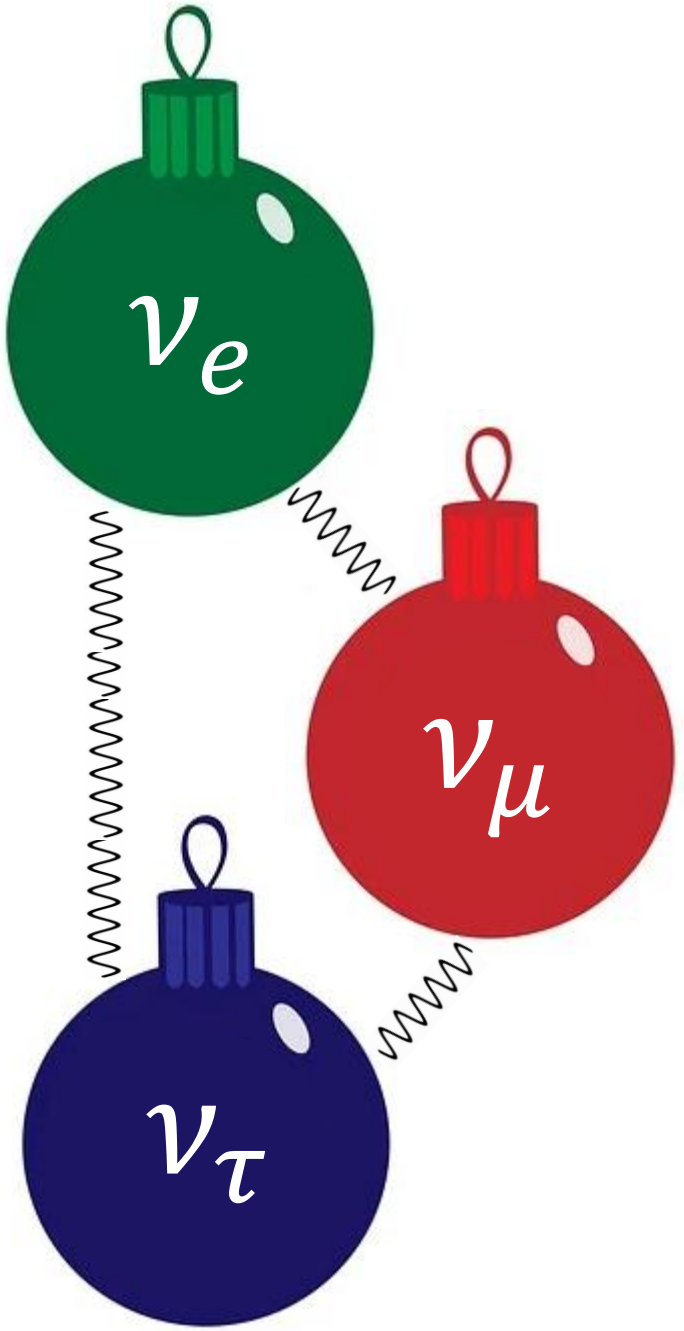
Tau Neutrinos Measured in Experiments





Measuring more and more tau neutrinos over the years [2]

But they do not always agree with predictions…



[2] R. Mammen Abraham *et al. J. Phys. G* **49** (2022) 110501 [2203.05591].

What can we do?

Come find out at EX-25!

Hint: it does not interact with Standard Model forces

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MATRIX ELEMENTS WITHOUT UNITARITY

The PMNS matrix, U_{PMNS}, governs neutrino mixing,

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}U_{e1} & U_{e2} & U_{e3}\\ U_{\mu1} & U_{\mu2} & U_{\mu3}\\ U_{\tau1} & U_{\tau2} & U_{\tau3}\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}.$$

We can measure the elements from oscillation experiments and normally constrain them with unitarity; without unitarity, the constraints are poor.

Limits on the PMNS matrix elements at 3σ from [1].

$$|U_{PMNS}|^{w/o\ unitarity}_{3\sigma\ (with\ unitarity)} =$$

0.76→0.85 (0.79→0.85)	0.50→0.60 (0.50→0.59)	0.13→0.16 (0.14→0.16)
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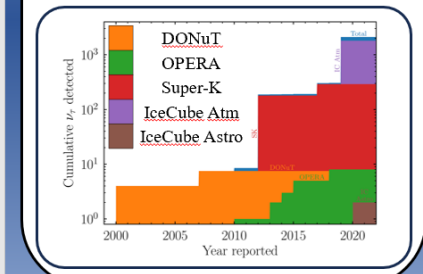
TAU NEUTRINO SOURCES

Tau neutrinos are one of the least studied particles in the Standard Model due to difficult detection signatures. Only ~2000 ν_τ total have been observed at a few experiments [2].

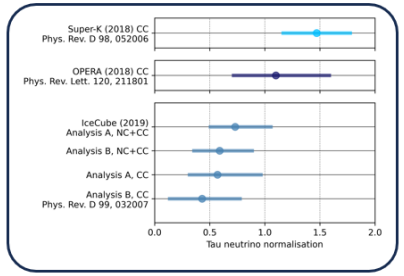


TAU NEUTRINO NORMALISATION

There are tensions in the number of tau neutrinos measured versus the number expected between different experiments,

$$N_\tau = \frac{\phi^{meas}_{\nu_\tau}}{\phi^{theo}_{\nu_\tau}}.$$

Sterile ν could possibly resolve high and low energy regimes.



REFERENCES

[1] S. Parke, M. Ross-Lonergan. *Phys. Rev. D* **93** (2016) 113009 [1508.05095].
[2] R. Mammen Abraham *et al. J. Phys. G* **49** (2022) 110501 [2203.05591].