WIN 2025

June 10th 2025

Alleviating the T2K and NOνA tension with source NSI

Check our paper: arXiv:2310.18401

Collaborators:

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O. L. G. Peres

F. F. Rodrigues

R. R. Rossi

E. S. Souza

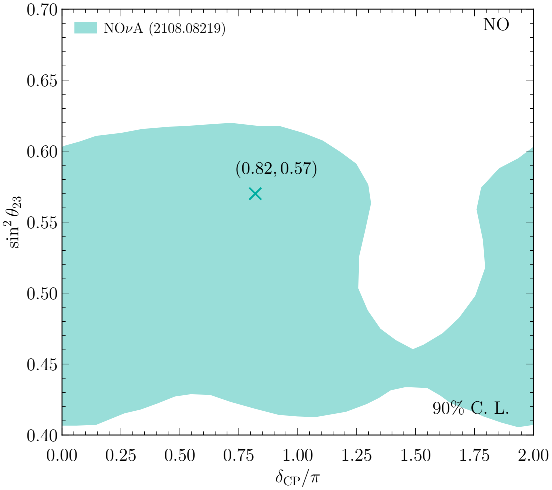
(pronouns: He/Him/His)

Pedro Pasquini

GEFAN
Grupo de Estudos em Física e Astrofísica de Neutrinos

UNICAMP

The T2K & NOνA Tension!



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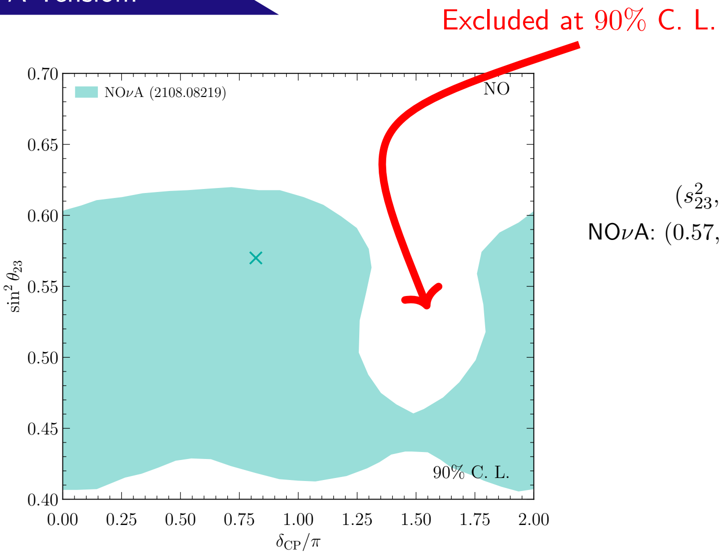

(s^2_{23}, δ_{CP})

NOνA: $(0.57, 0.82\pi)$

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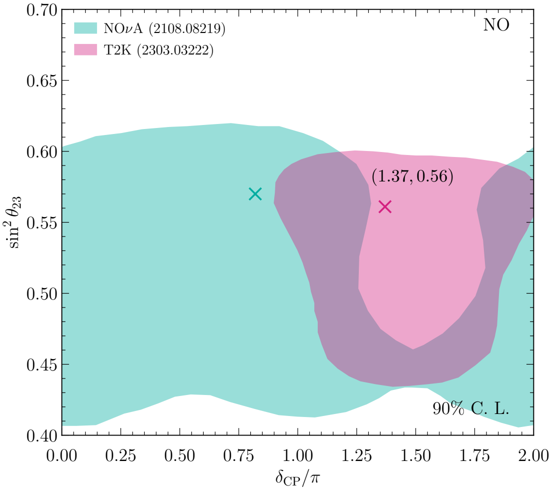

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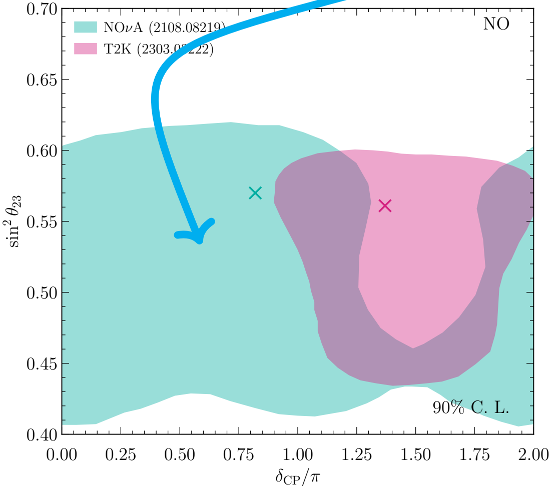

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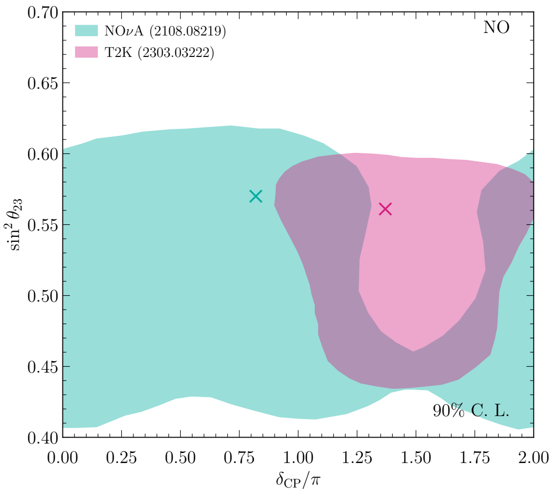

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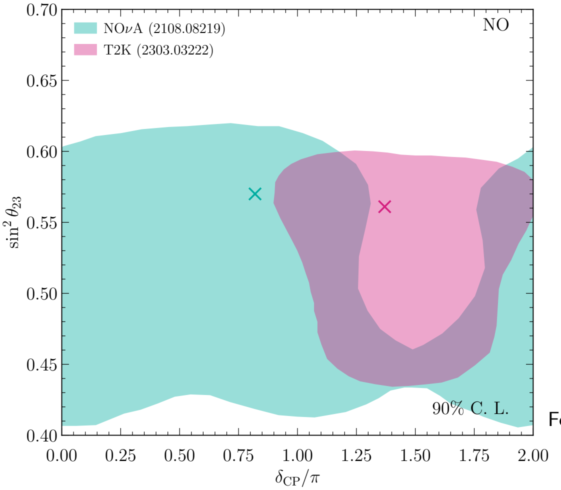

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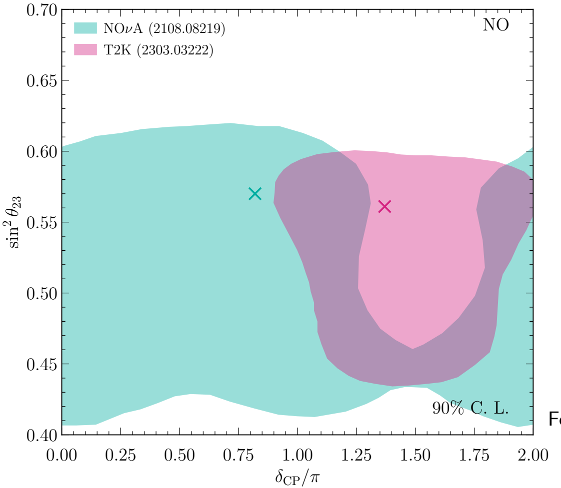

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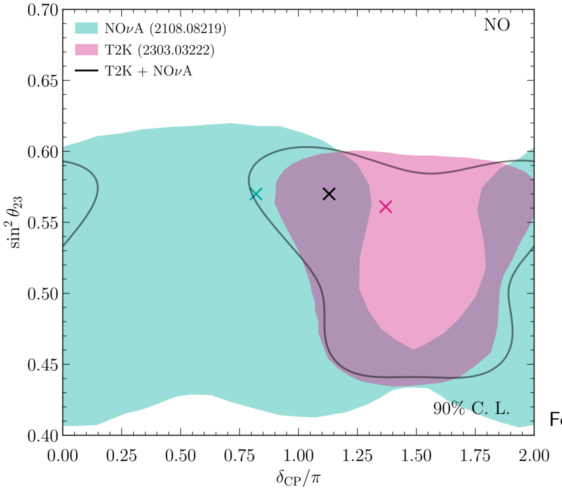

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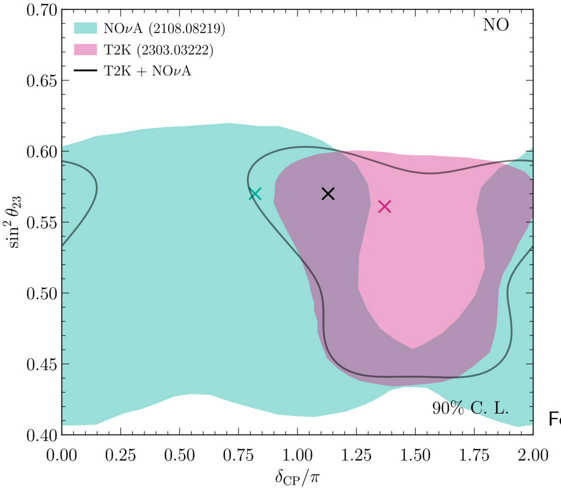

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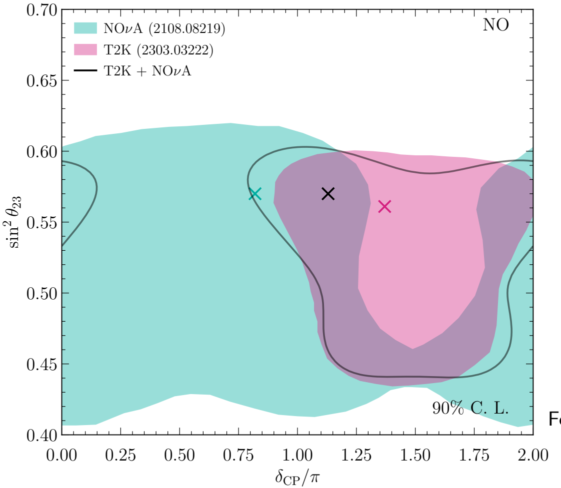

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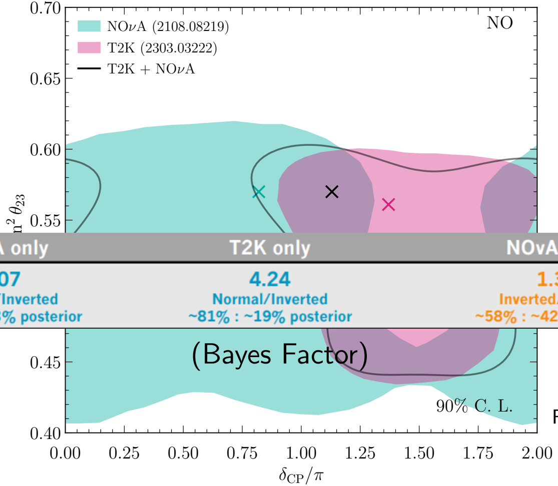

NOvA only	T2K only	NOvA+T2K
2.07	4.24	1.36
Normal/Inverted	Normal/Inverted	Inverted/Normal
~67% : ~33% posterior	~81% : ~19% posterior	~58% : ~42% posterior

(Bayes Factor)

$(s^2_{23}, \delta_{\rm CP})$

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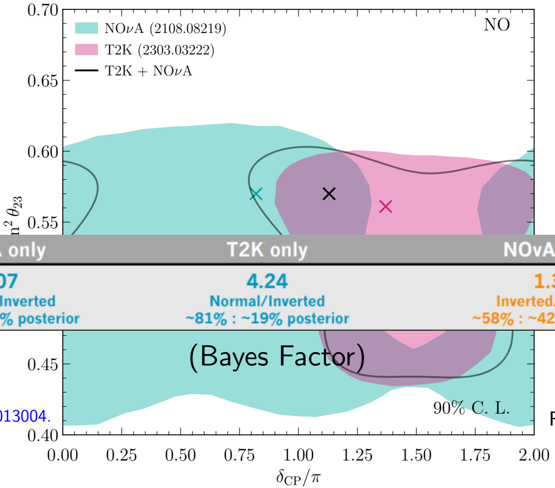
Also note by
I. Esteban et al. JHEP **09** (2020), 178
& K. Kelly et al. PRD **103** (2021) no.1, 013004.



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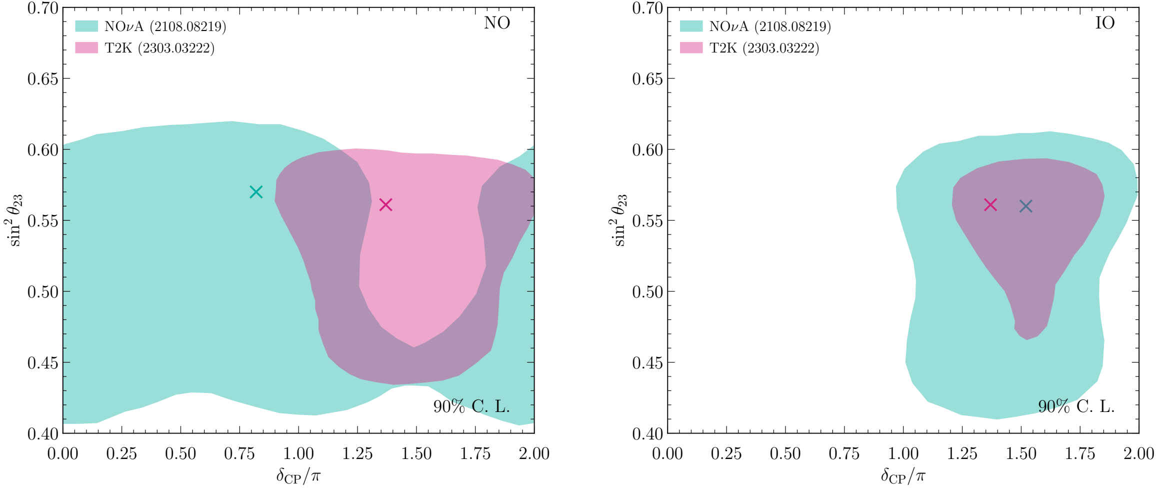
The T2K & NOνA Tension!

Intuitive?



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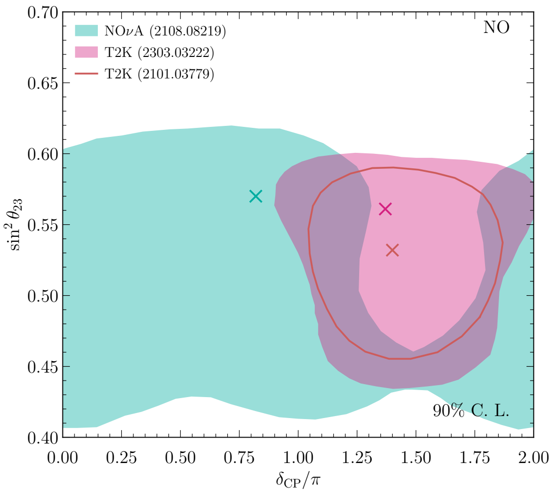

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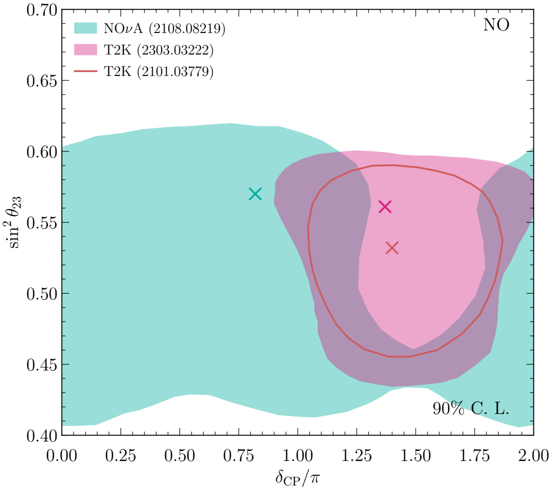

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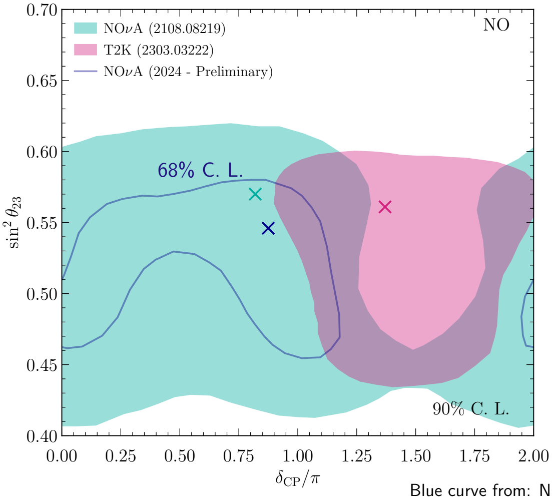

Blue curve from: NOvA PPC2024 proceedings

<u>Also curious</u> :

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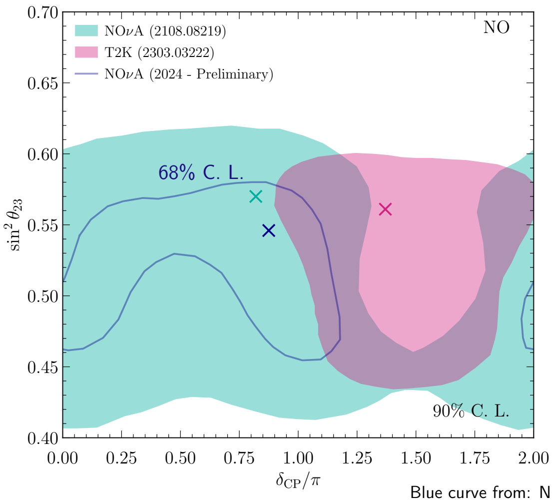

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I won't discuss the Preliminary data...

Blue curve from: NOvA PPC2024 proceedings

It is possible to reduce tension!

Tension: Apparent excess in ν_e sample

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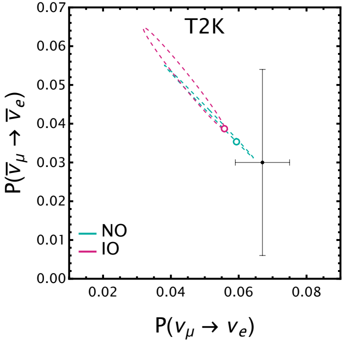

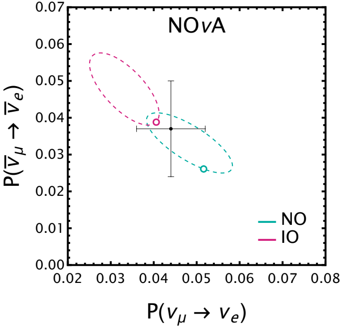

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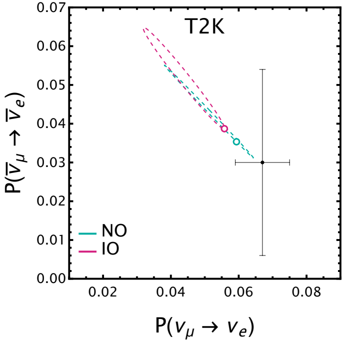

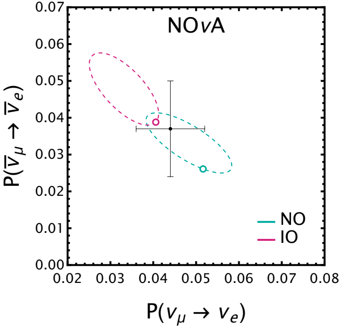

T2K has a large excess $\to$ NO and $\delta_{\text{CP}} \approx -90°$

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Tension: Apparent excess in ν_e sample

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Explanation:

$\Rightarrow$ Decrease $P(\nu_\mu \to \nu_e)$ (and also helps increase $P(\overline{\nu}_\mu \to \overline{\nu}_e)$)

$\Rightarrow$ Preferably: act differently for T2K and NOνA (Matter effect? Baseline? Energy?)

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Attempts to reduce the tension:

Non-Standard interaction (matter): P. Denton et al. PRL **126** (2021) no.5, 051801, S. Chatterjee et al. PRL **126** (2021) no.5, 051802, and R. Majhi et al. EPJC **82** (2022) no.10, 919

Non-unitarity (matter+ baseline): Pedro Pasquini et al. Eur. Phys. J. C **81** (2021) no.5, 444

Lorentz Invariance Violation (energy): U. Rahaman EPJC **81** (2021) no.9, 792

Sterile neutrinos (baseline): A. de Gouvêa et. al.PRD **106** (2022) no.5, 055025

New idea: NSI at source

This talk: We checked if pseudo-scalar NSI at source could reduce the tension

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Suppose a model produces an effective interaction

$$\mathcal{L} = \sqrt{2} G_{\mathrm{F}} V_{ud}^{\mathrm{CKM}} \epsilon_{\alpha\beta} \left(\overline{u}\gamma_5 d\right) \left(\overline{\ell}_\alpha P_L \nu_\beta\right)$$

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No detection/propagation change!

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Neutrino Process	NSI Matching with EFT
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$\Rightarrow$ Easier to avoid constraints

$\Rightarrow$ has extra CP-phases

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$\delta_{\rm CP} - \phi$ correlation

We showed - first time perturbation for source NSI :

$\delta_{\rm CP} - \phi$ correlation

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$$P_{\mu e}^{\rm NSI} = 4\frac{s_{13}^2 s_{23}^2}{(1-r_a)^2}\sin^2\frac{(1-r_a)\Delta L}{2} + \frac{8J_r r_\Delta}{r_a(1-r_a)}\cos\left(\delta_{\rm CP} + \frac{\Delta L}{2}\right)\sin\frac{r_a\Delta L}{2}\sin\frac{(1-r_a)\Delta L}{2}$$

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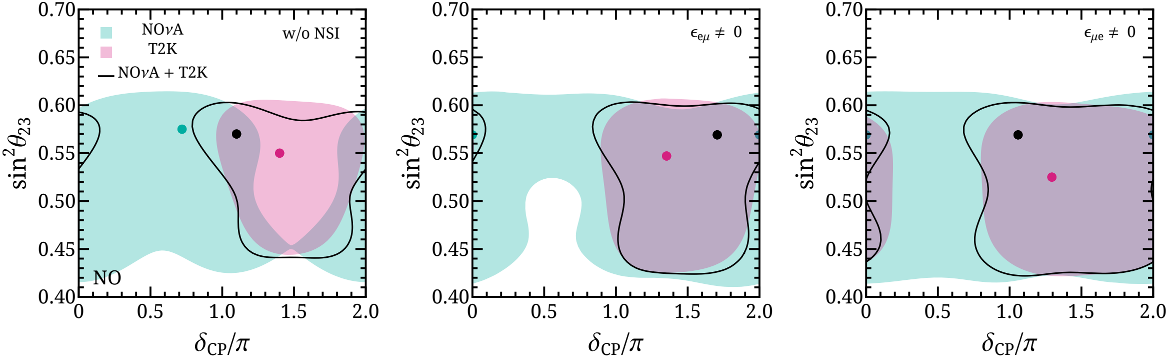
NSI at source reduces tension!



Plots from Pedro Pasquini et al. arXiv:2310.18401

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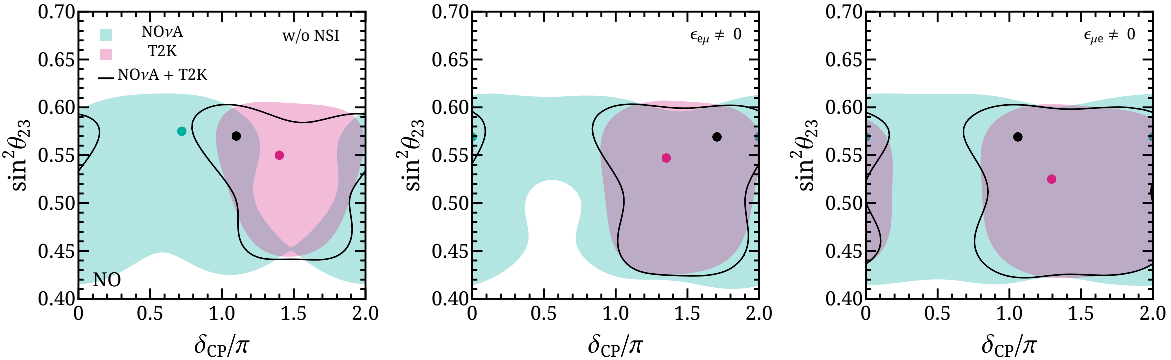

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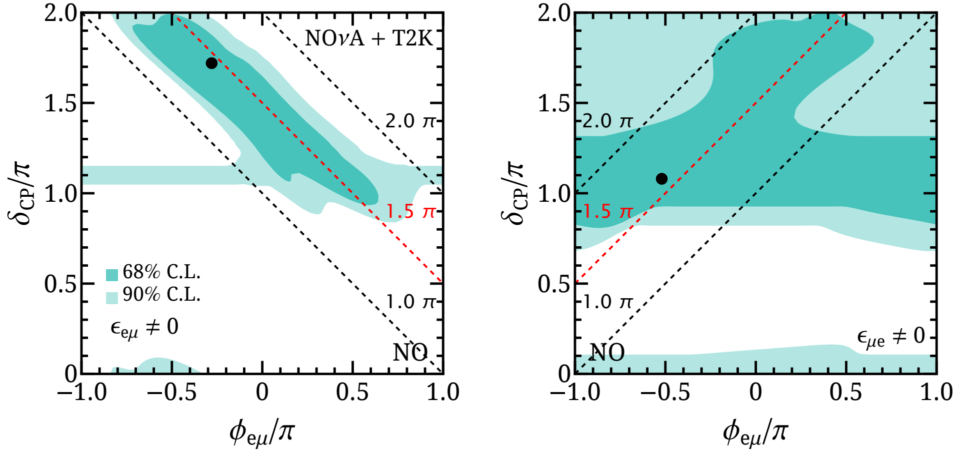
<u>Best Fits:</u>

$$|\epsilon_{e\mu}| = 7.2 \times 10^{-4},\ \delta_{CP} = 1.74\pi,\ \arg[\epsilon_{e\mu}] = -0.32\pi$$
$$|\epsilon_{\mu e}| = 1.1 \times 10^{-3},\ \delta_{CP} = 1.08\pi,\ \arg[\epsilon_{\mu e}] = -0.49\pi$$

Effect of the $\delta_{CP} \mp \phi$ correlation

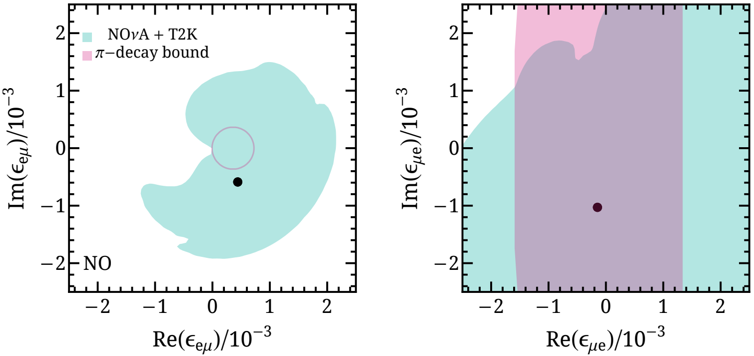


From Pedro Pasquini et al. arXiv:2310.18401

Clear correlation: $\delta_{CP} - \phi_{e\mu}$ and $\delta_{CP} + \phi_{\mu e}$

Other constraints

We are still working on combining all...



From $\pi \to \ell\nu$ universality

see M. Guzzo et. al PRD **107** (2023) no.9, 095037

From Pedro Pasquini et al. arXiv:2310.18401

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⇒ T2K and NOνA has a tension for quite some time!

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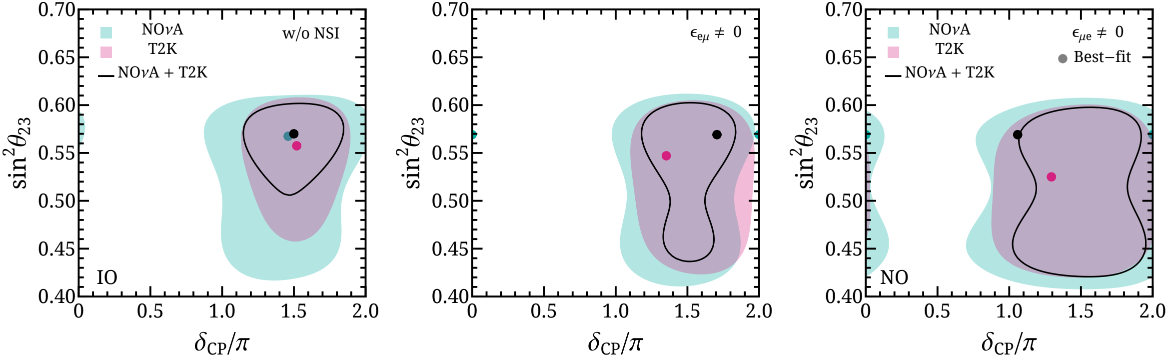
Many thanks!

Any questions?

Work suppoerted by FAEPEX grant number 2404/25 FAEPEX/UNICAMP

Backup Slides

Inverted ordering plots



Statistic test tables

Preliminary!!

$\chi^2_{\min}$	Standard Osc.		$\epsilon_{e\mu}$		$\epsilon_{\mu e}$	
	NO	IO	NO	IO	NO	IO
NOνA	51.8	52.5	48.4	50.4	51.3	51.6
T2K	107.2	109.2	106.3	107.6	106.5	106.8
NOνA + T2K	165.9	163.9	161.4	161.0	165.2	162.4
$\chi^2_{\mathbf{PG}}$ / $\mathbf{N_{par}}$	7.0 / 4	2.2 / 4	6.7 / 6	3.0 / 6	7.4 / 6	4.0 / 6
p_{PG}-value	14%	70%	35%	81%	28%	68%