Neutrino Theory Overview

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Fermilab

- Neutrino oscillation
- Neutrino mass
- Dirac vs. Majorana nature
- Flavor structure
- Mass origin
- Matter-antimatter asymmetry

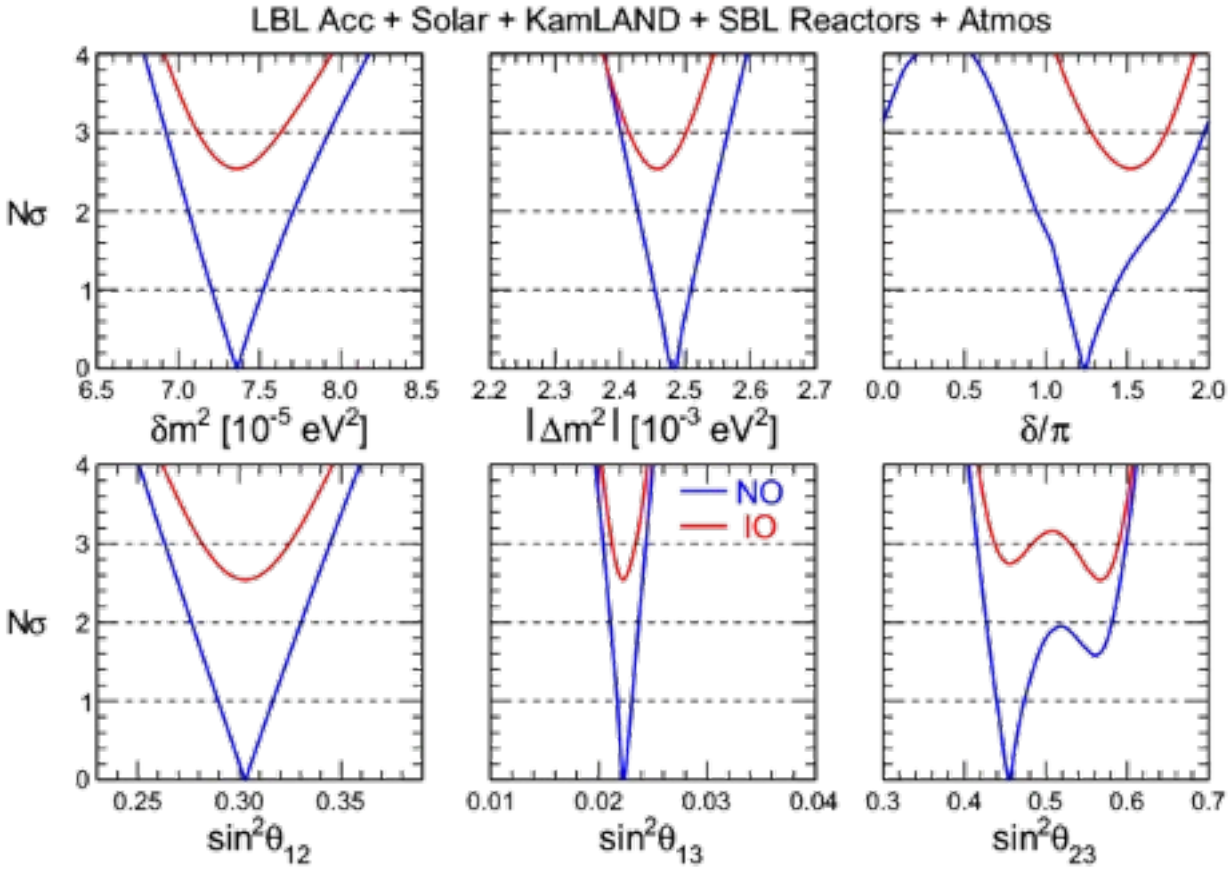
Theme: theory supporting experimental efforts

Neutrino oscillation

Global Fits of Three Flavor Oscillation

Capozzi et al, 2107.00532

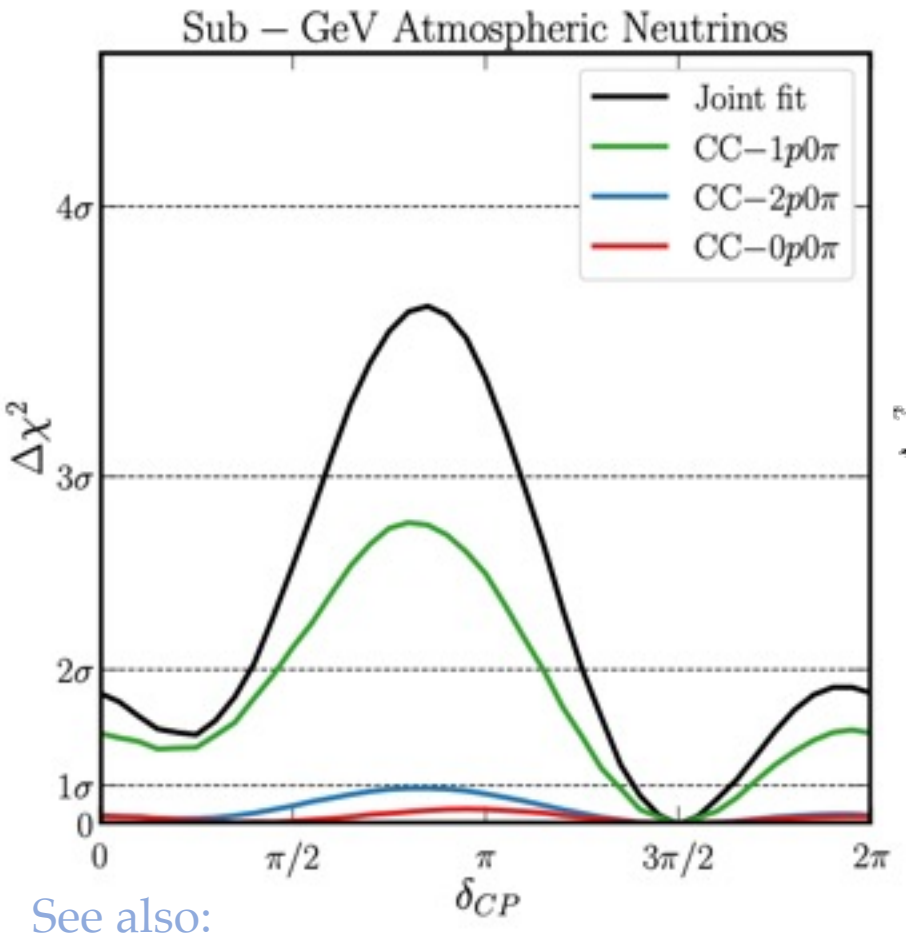
Parameter	Ordering	Best fit	1σ range
$\delta m^2/10^{-5}$ eV^2	NO, IO	7.36	7.21 – 7.52
$\sin^2\theta_{12}/10^{-1}$	NO, IO	3.03	2.90 – 3.16
$\lvert\Delta m^2\rvert/10^{-3}$ eV^2	NO	2.485	2.454 – 2.508
	IO	2.455	2.430 – 2.485
$\sin^2\theta_{13}/10^{-2}$	NO	2.23	2.17 – 2.30
	IO	2.23	2.17 – 2.29
$\sin^2\theta_{23}/10^{-1}$	NO	4.55	4.40 – 4.73
	IO	5.69	5.48 – 5.82
δ/π	NO	1.24	1.11 – 1.42
	IO	1.52	1.37 – 1.66
$\Delta\chi^2_{\mathrm{IO-NO}}$	IO−NO	+6.5	

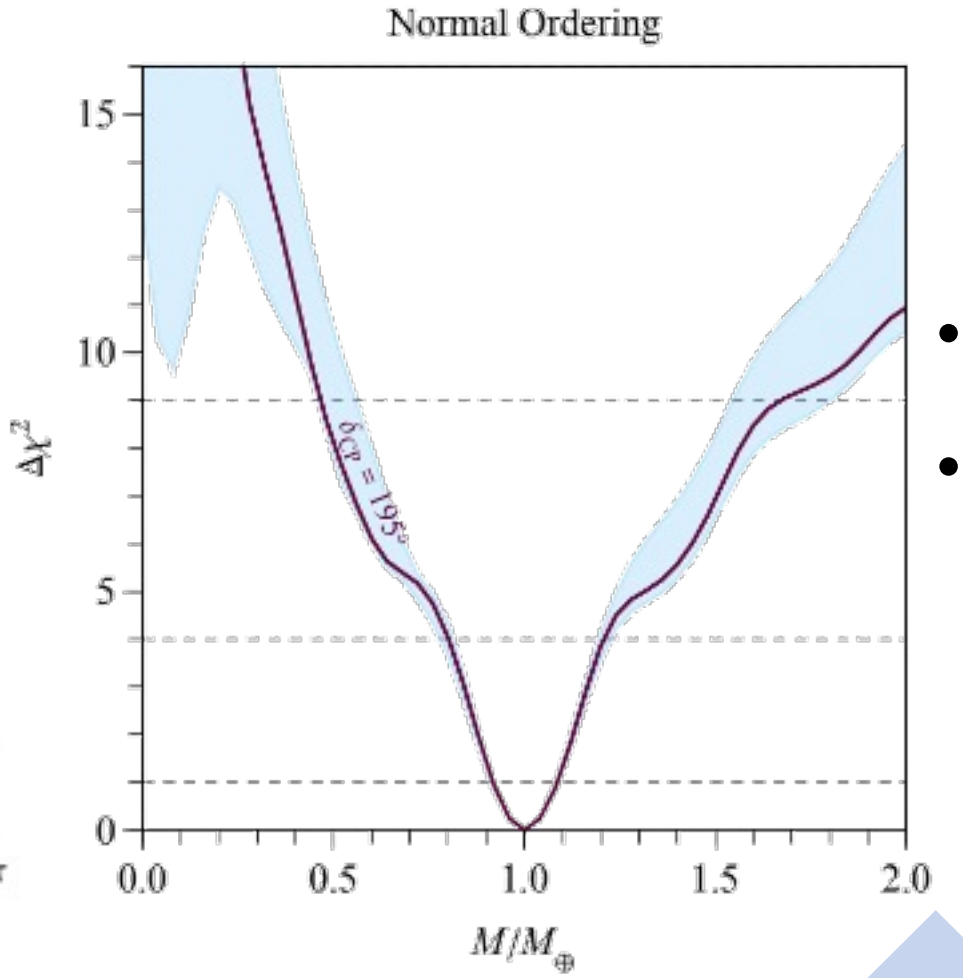


Comparable results:
NuFIT 5.1 (2021), 2007.14792
Valencia: deSalas et al., 2006.11237

Sub-GeV Atmospheric Neutrinos

Kelly et al, 1904.02751, 2110.00003



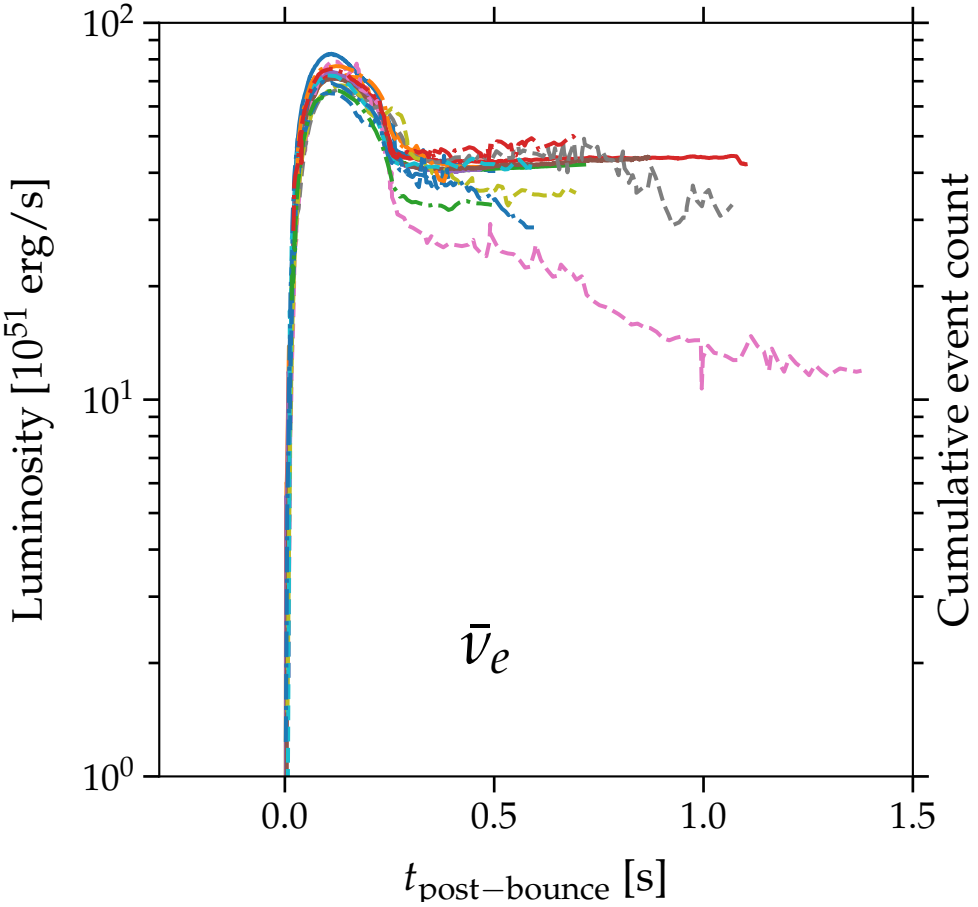


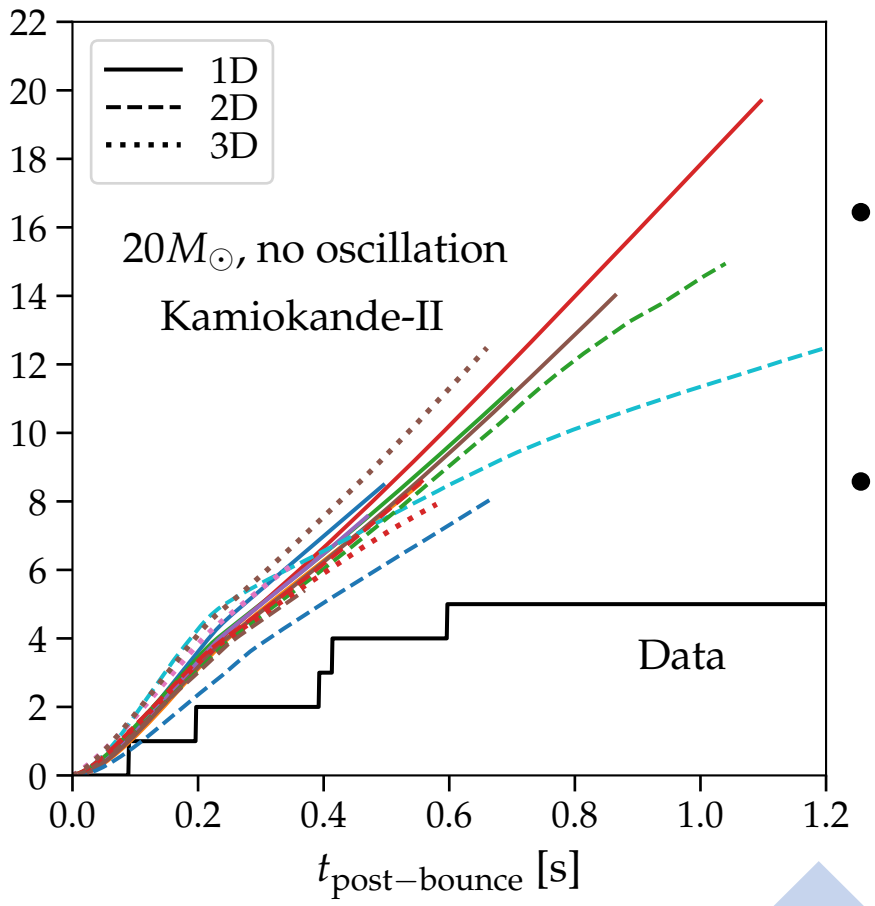
- Oscillation physics
- Earth tomography

See also:
Denton & Pestes, 2110.01148

Supernova Neutrinos

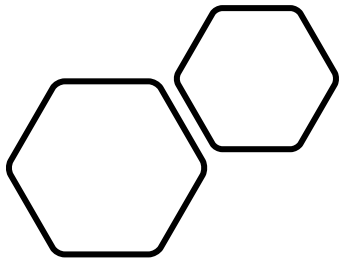
Li, Beacom, Roberts, and Capozzi, in prep





- Assess theory uncertainties
- Compare to 87A data

ν-A Cross-Sections



Achilles: A CHIcago Land Lepton Event Simulator

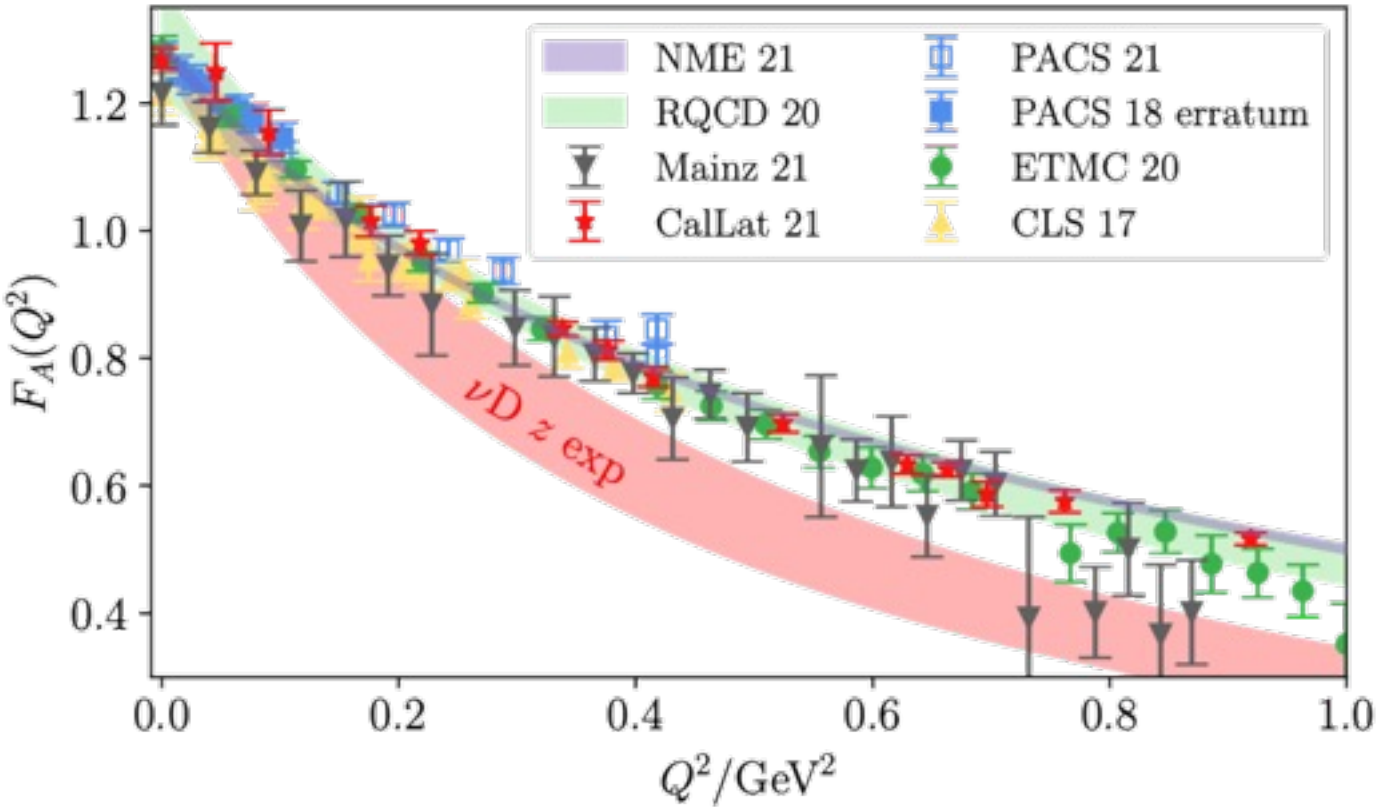
Isaacson, Höche, Jay, Lopez Gutierrez, Lovato, Machado, Rocco
2007.15570, 2110.15319, 2205.06378

Project goals:

- Theory driven
- Develop modular neutrino event generator
- Provide automated BSM calculations
- Evaluate theory uncertainties

Lattice Form Factors

Meyer, Walker-Loud, and Wilkinson, 2201.01839

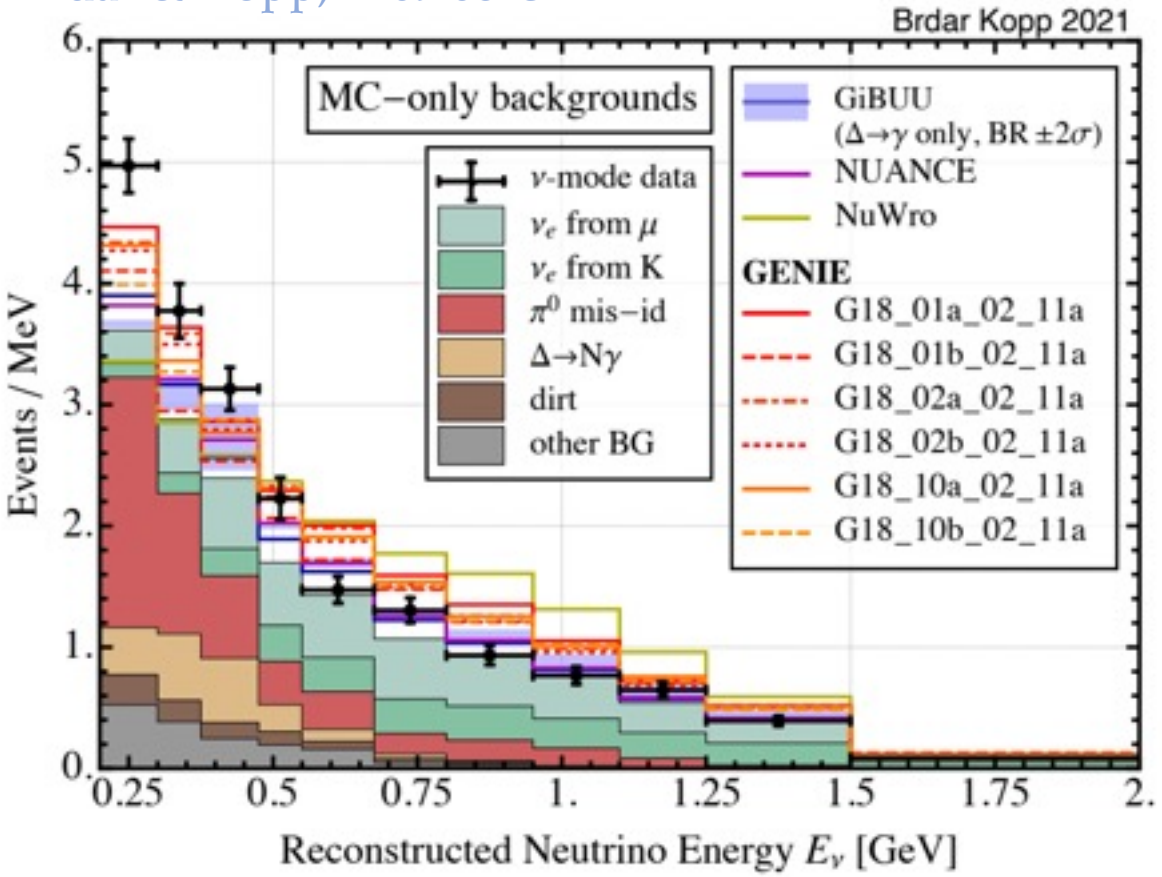


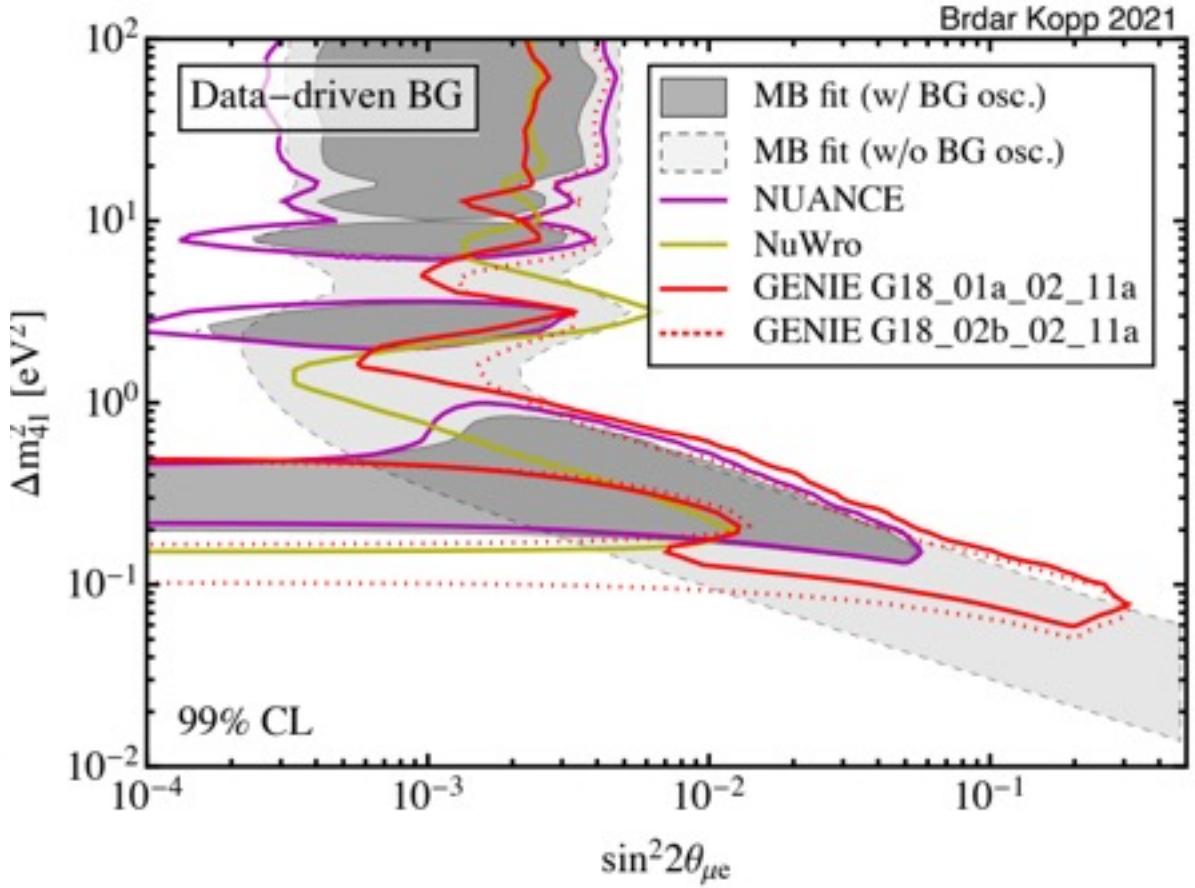
$$\langle N'|J_W^\mu|N\rangle \supset \bar{\mu}'_N \gamma^\mu \gamma^5 F_A \mu_N$$

$$F_A(Q^2) = \frac{F_A(0)}{\left(1+\frac{Q^2}{m_A^2}\right)^2}$$

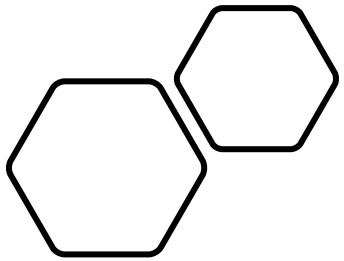
Systematics for MiniBooNE Excess

Brdar & Kopp, 2109.08157



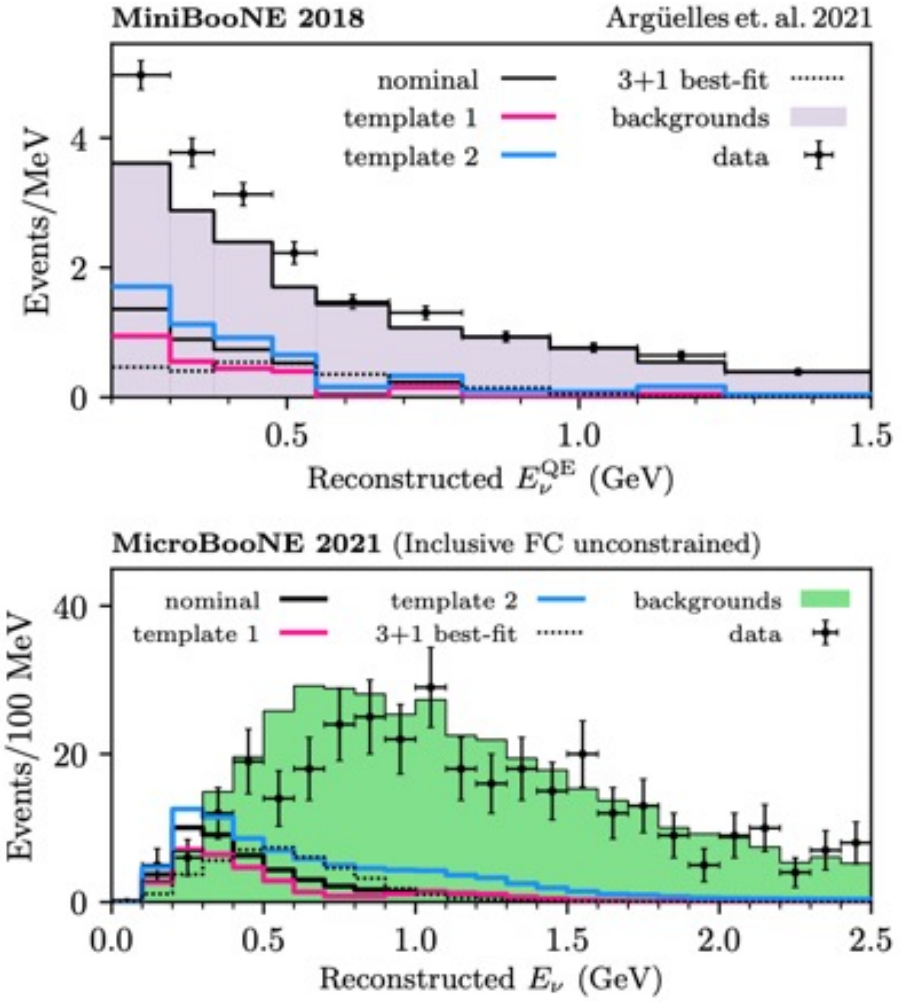


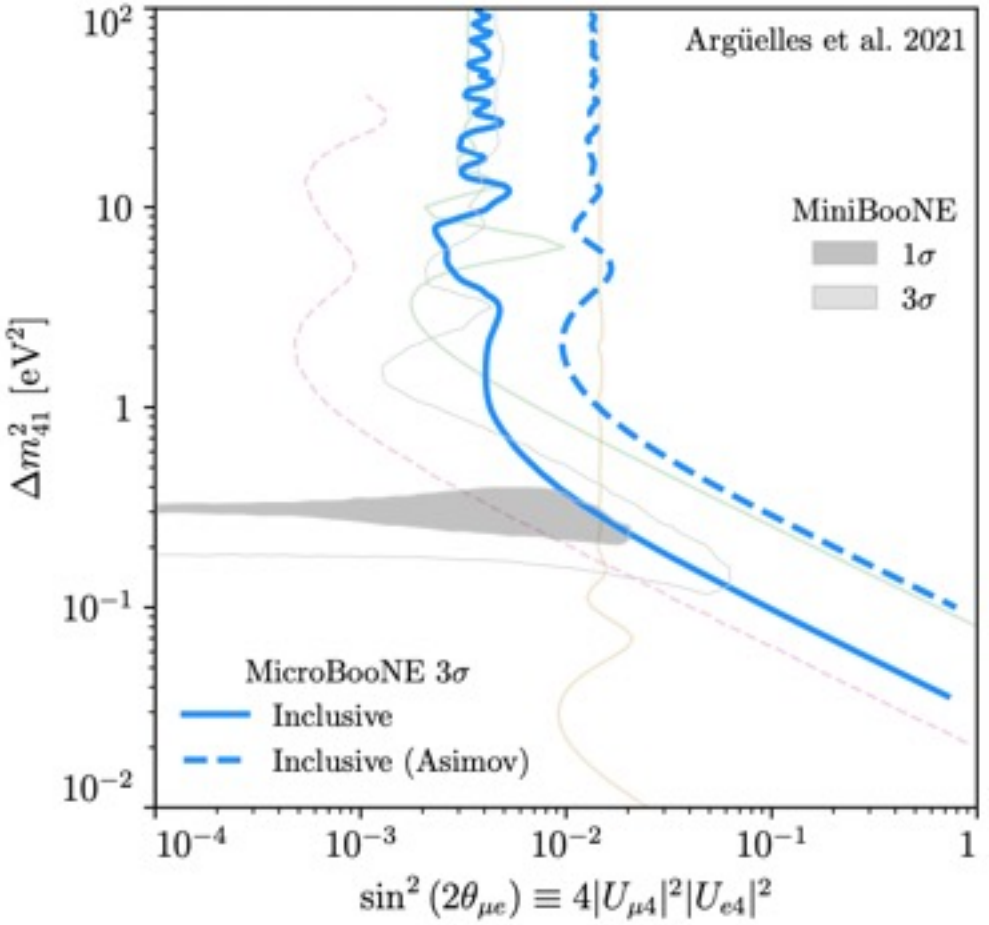
New Physics



Understanding MicroBooNE Results

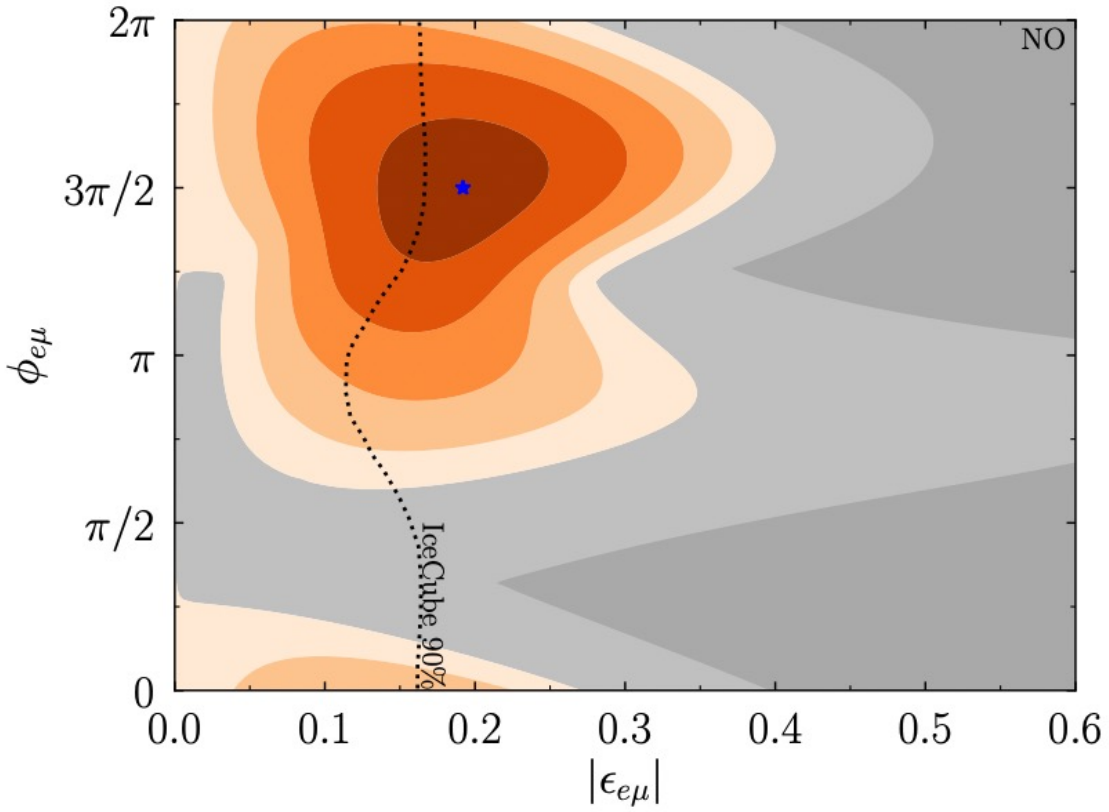
Argüelles et al., 2111.10359



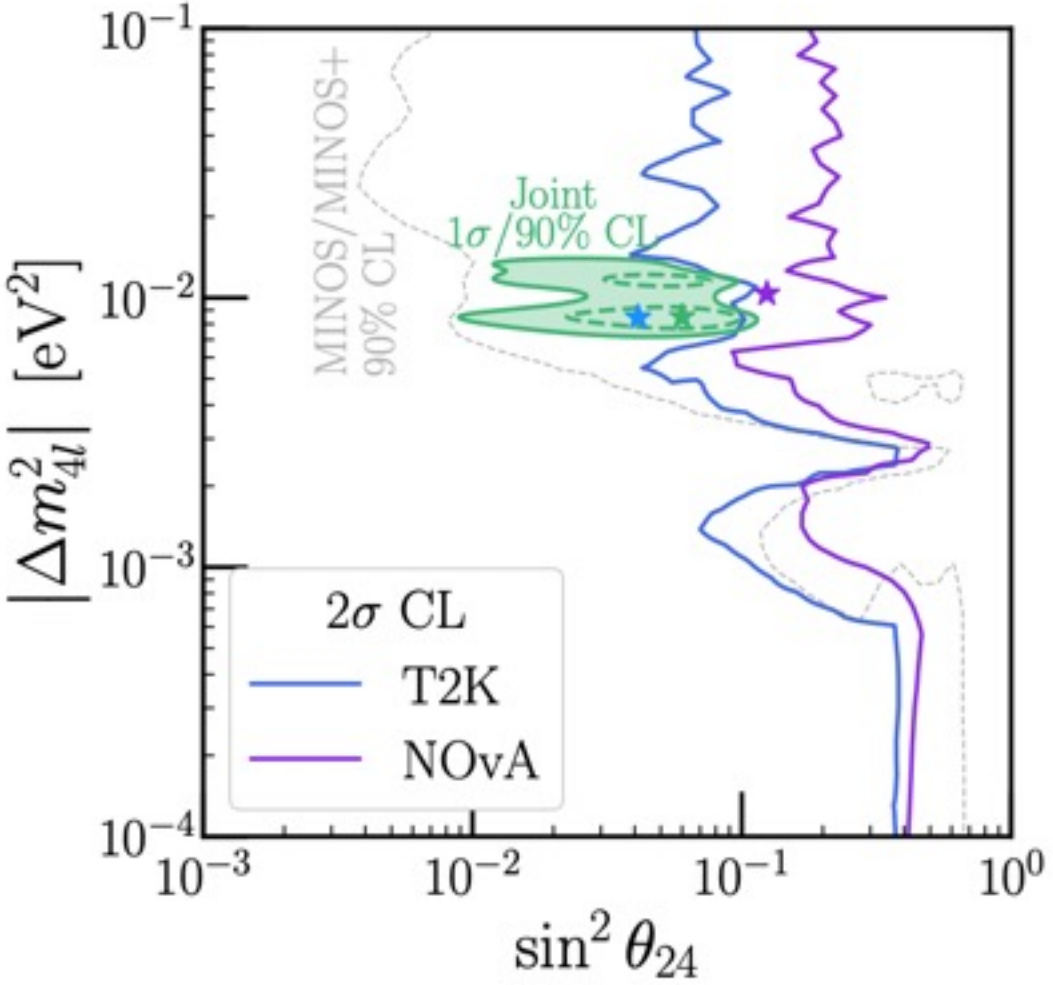


T2K-NOvA Tension

Denton, Gehrlein, Pestes, 2008.01110



de Gouvêa, Sánchez, Kelly, 2204.09130



Conclusions

- Many theory activities aiming to support experimental program
- Oscillation program – new sources, astrophysics
- Understanding neutrino-nucleus cross sections
- Exploring new physics