



Neutrino Theory Overview

Shirley Li
Fermilab

Neutrino oscillation

Neutrino mass


Dirac vs. Majorana nature

Flavor structure

Mass origin

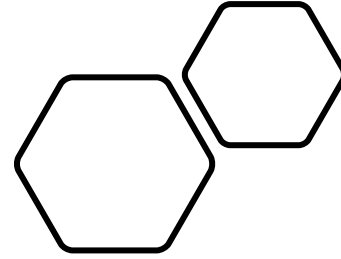
Matter-antimatter asymmetry



The background features decorative curved lines in shades of green and blue, positioned in the top-left and bottom-right corners. The text is centered in a dark blue, serif font.

Theme: theory supporting
experimental efforts

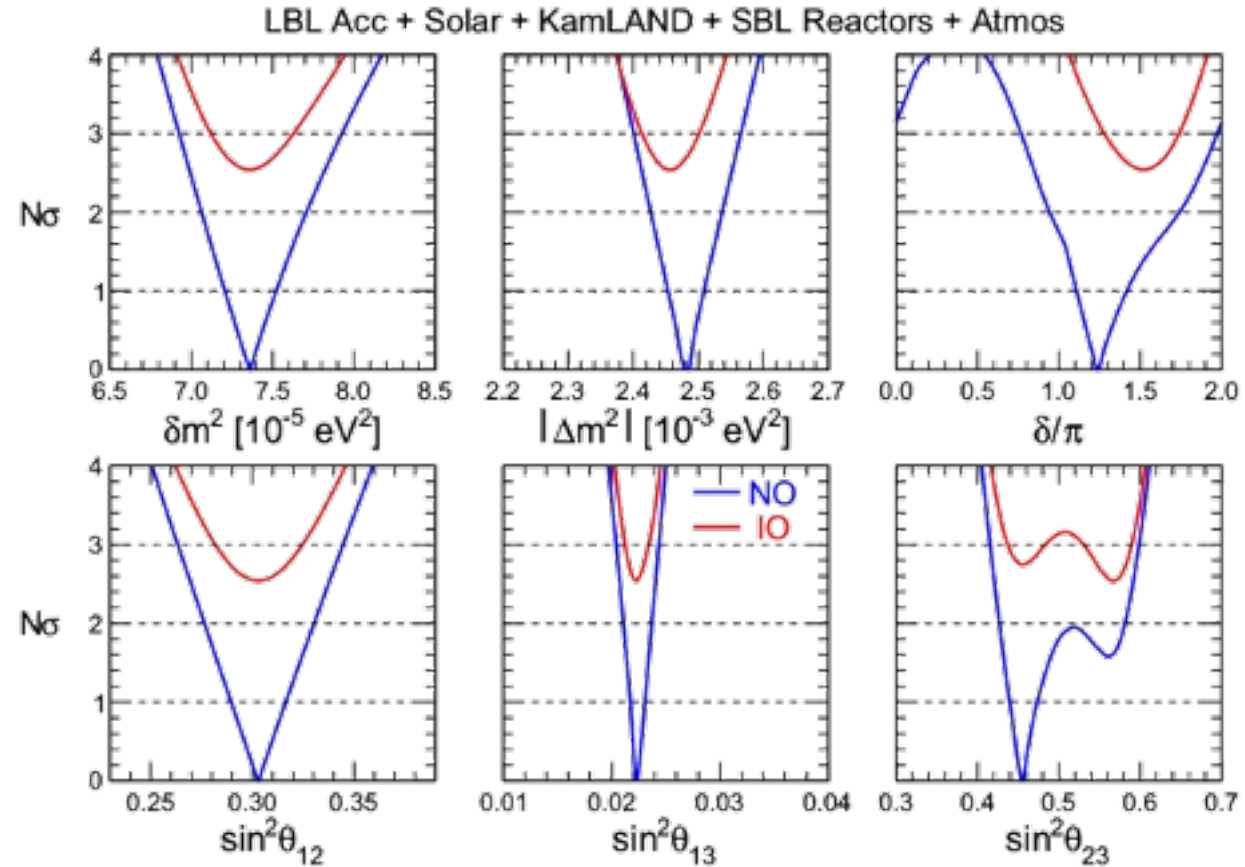
Neutrino oscillation



Global Fits of Three Flavor Oscillation

Capozzi et al, 2107.00532

Parameter	Ordering	Best fit	1σ range
$\delta m^2 / 10^{-5} \text{ eV}^2$	NO, IO	7.36	7.21 – 7.52
$\sin^2 \theta_{12} / 10^{-1}$	NO, IO	3.03	2.90 – 3.16
$ \Delta m^2 / 10^{-3} \text{ 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
$\Delta \chi^2_{\text{IO-NO}}$	IO-NO	+6.5	



Comparable results:

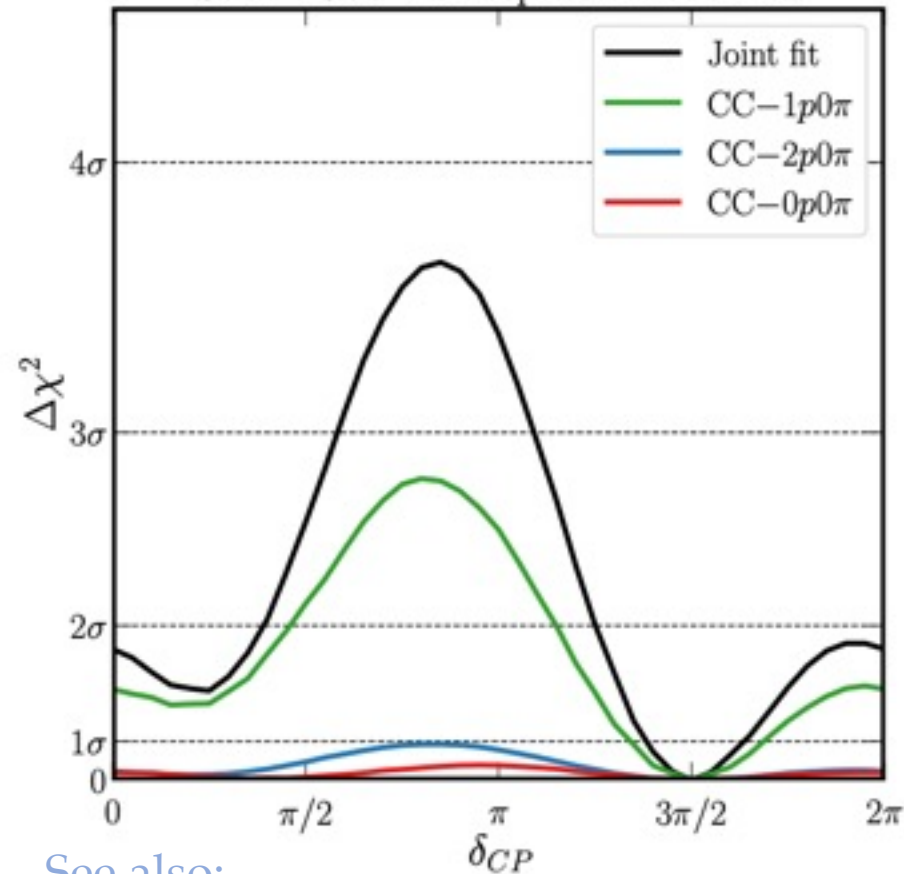
NuFIT 5.1 (2021), 2007.14792

Valencia: deSalas et al., 2006.11237

Sub-GeV Atmospheric Neutrinos

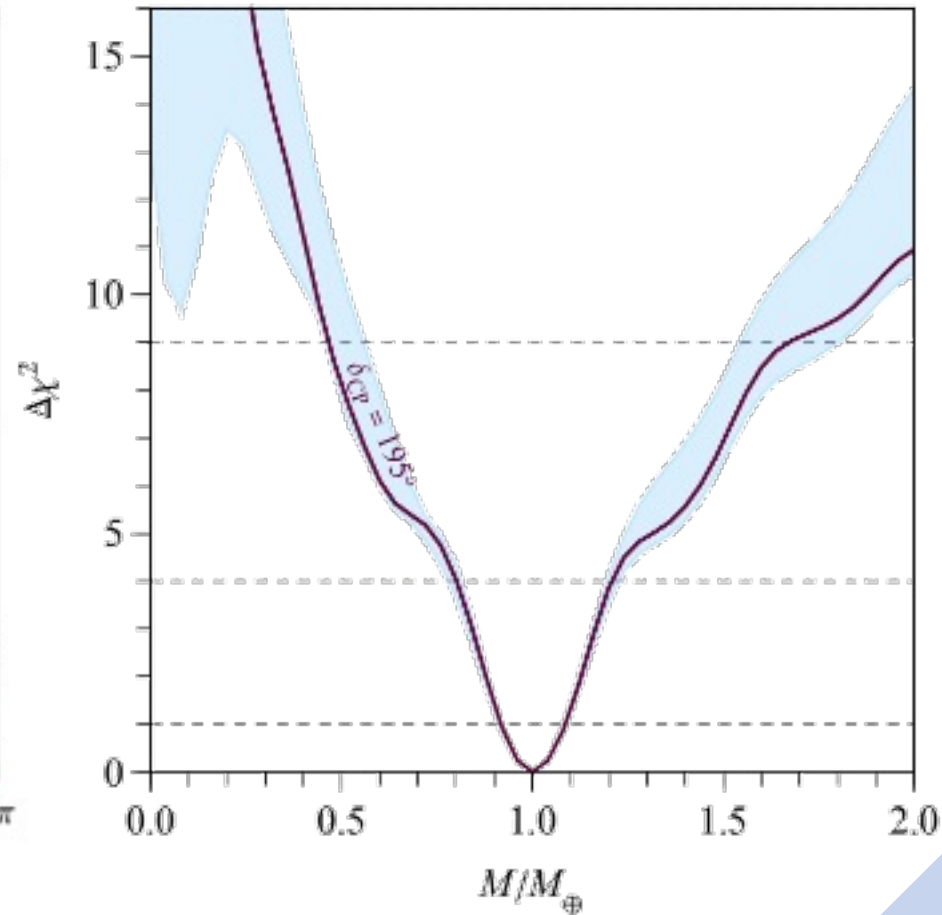
Kelly et al, 1904.02751, 2110.00003

Sub - GeV Atmospheric Neutrinos



See also:
Denton & Pestes, 2110.01148

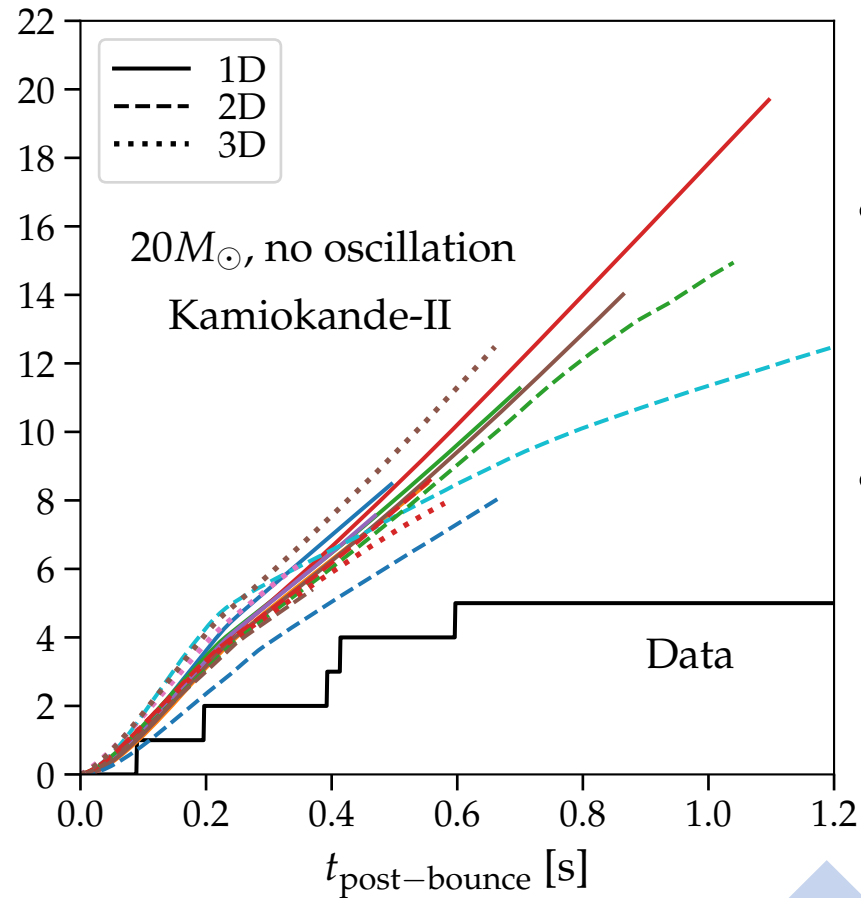
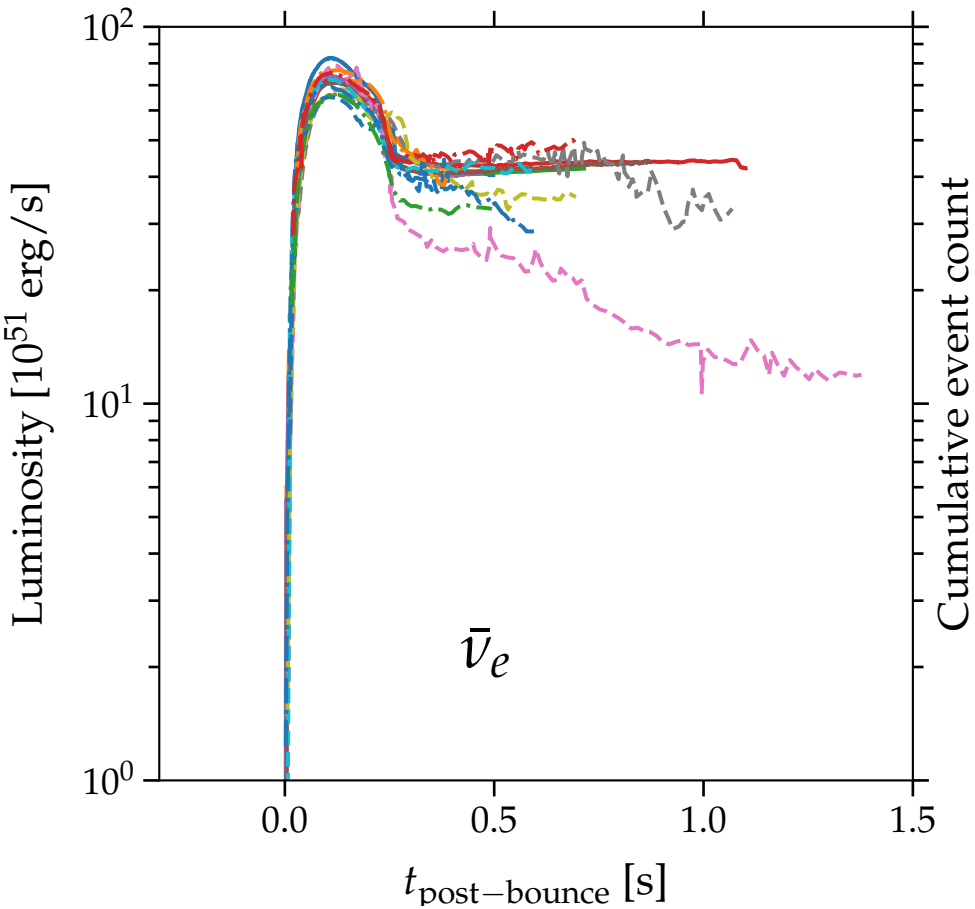
Normal Ordering



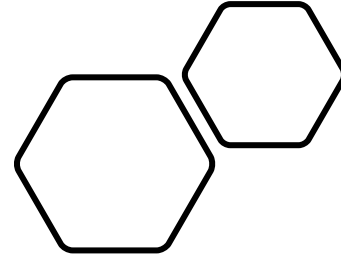
- Oscillation physics
- Earth tomography

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

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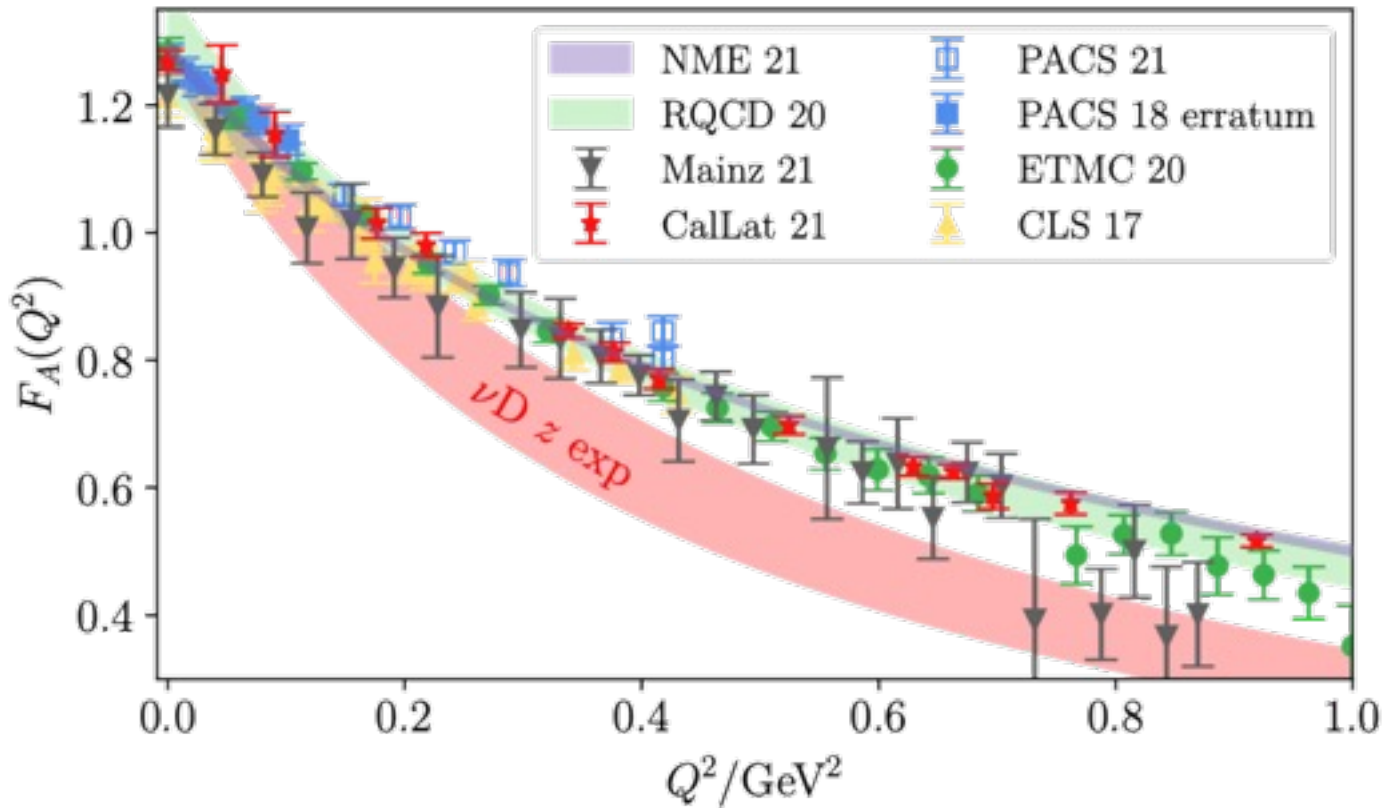
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Version: 1.0.0
Authors: Joshua Isaacson, William Jay, Alessandro Lovato,
Pedro A. Machado, Noemi Rocco
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Project goals:

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

Lattice Form Factors

Meyer, Walker-Loud, and Wilkinson, 2201.01839

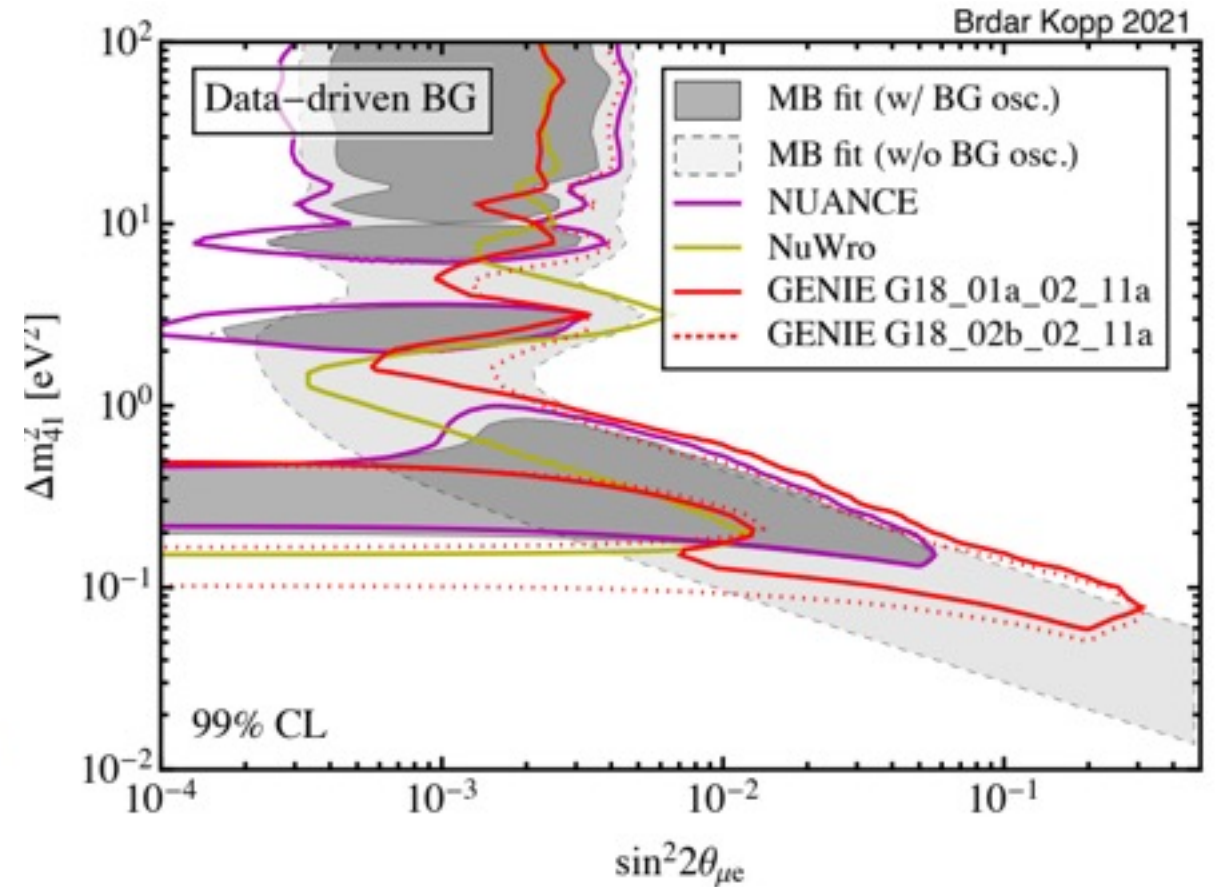
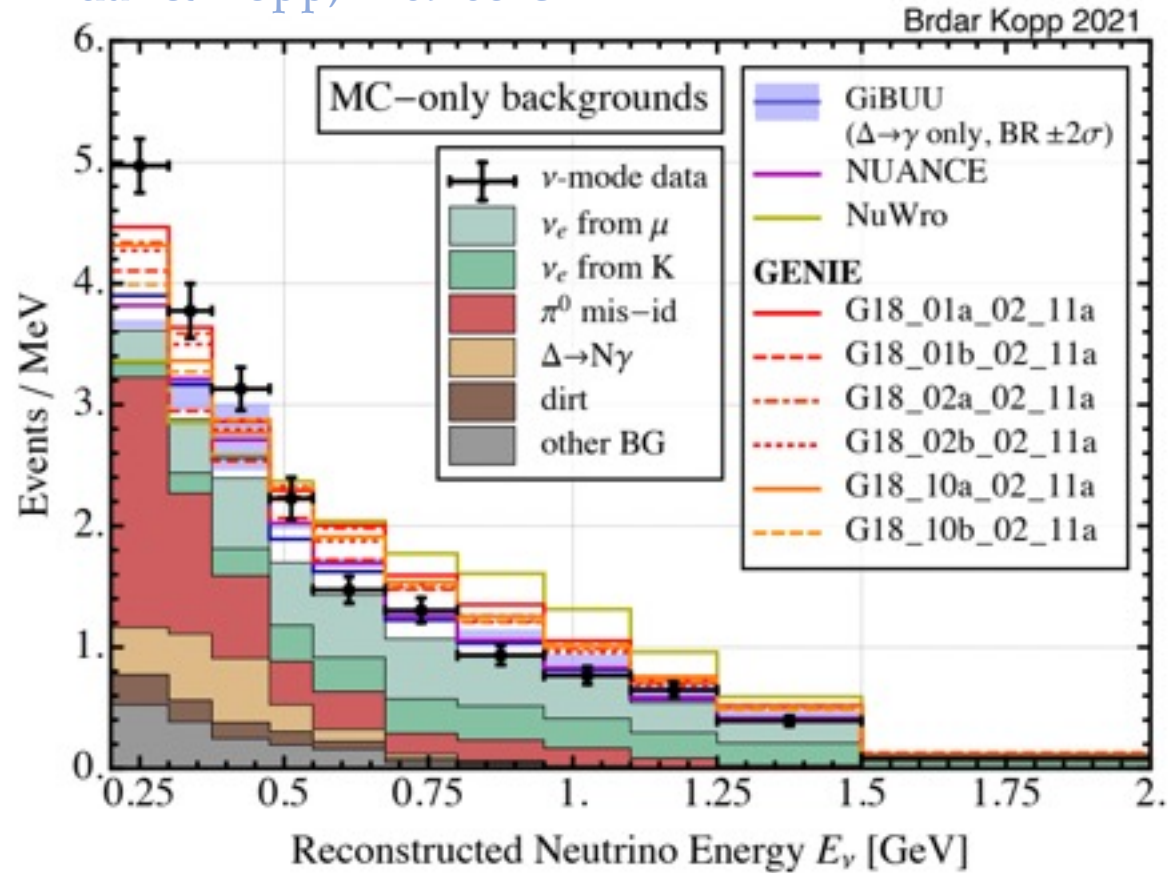


$$\langle N' | J_W^\mu | N \rangle \supset \bar{\mu}'_N \gamma^\mu \gamma^5 F_A \mu_N$$

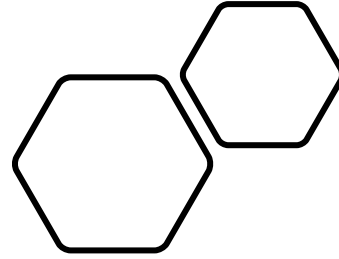
$$F_A(Q^2) = \frac{F_A(0)}{\left(1 + \frac{Q^2}{m_A^2}\right)^2}$$

Systematics for MiniBooNE Excess

Brdar & Kopp, 2109.08157

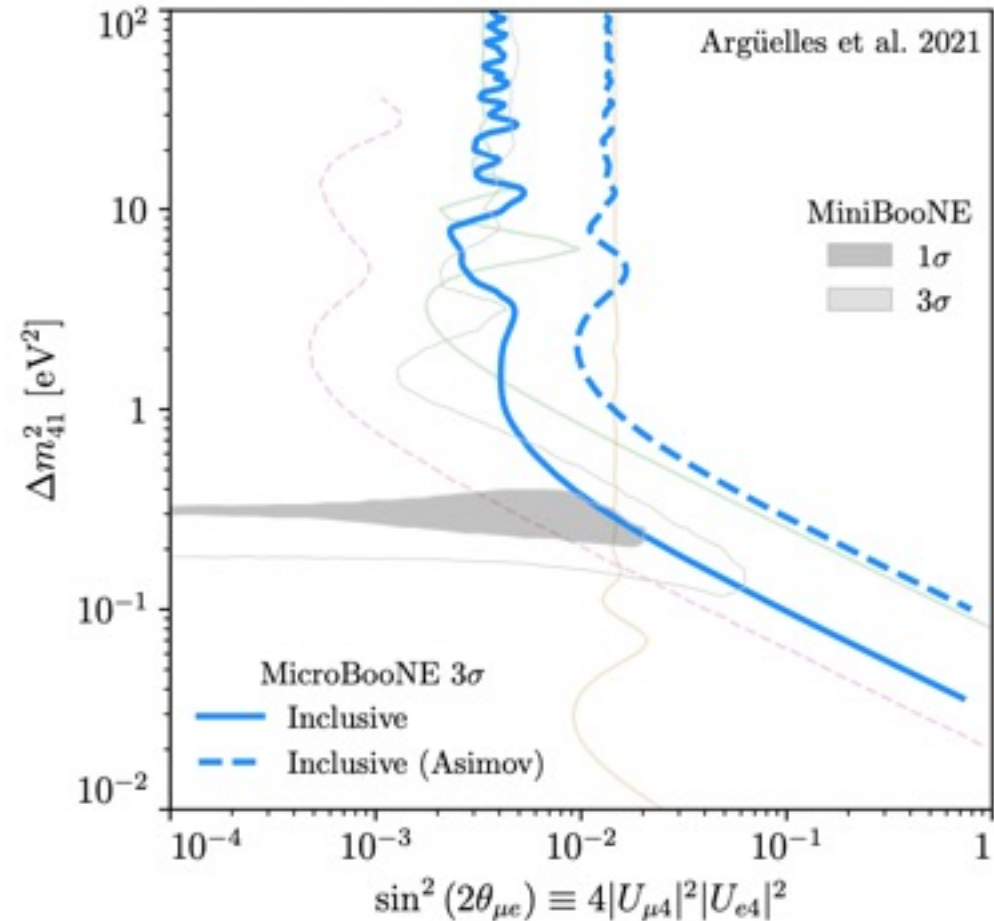
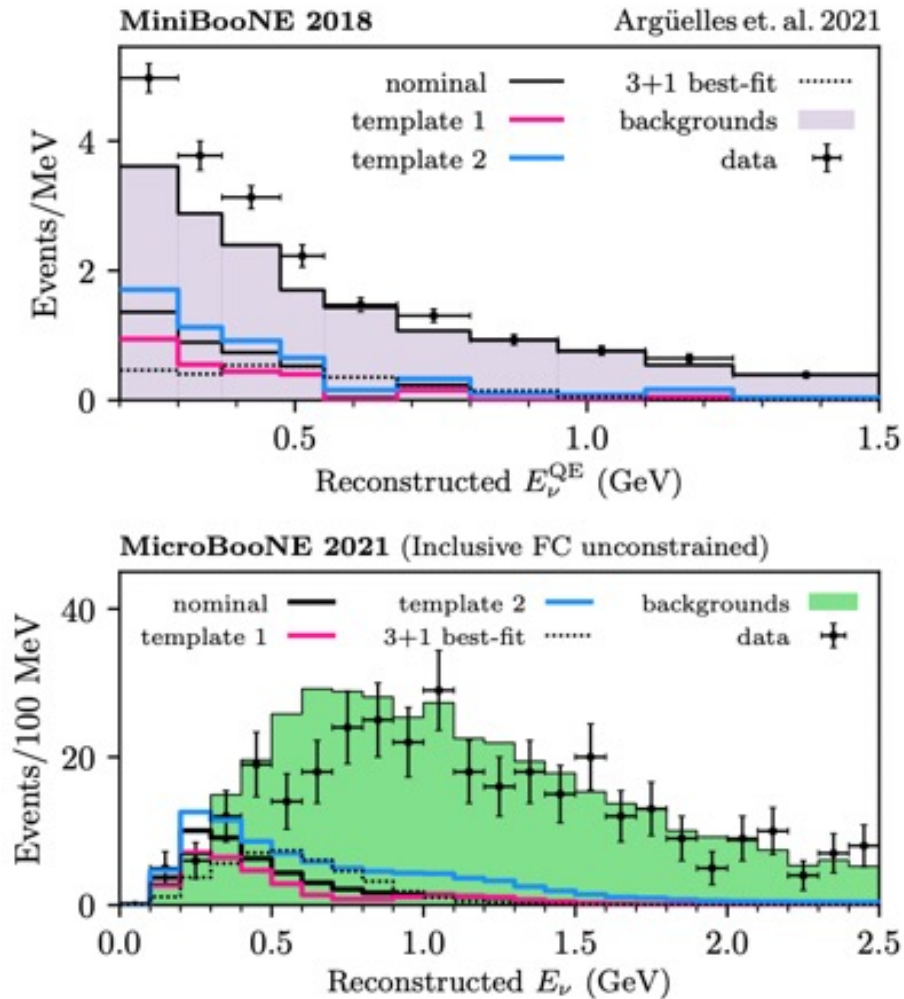


New Physics



Understanding MicroBooNE Results

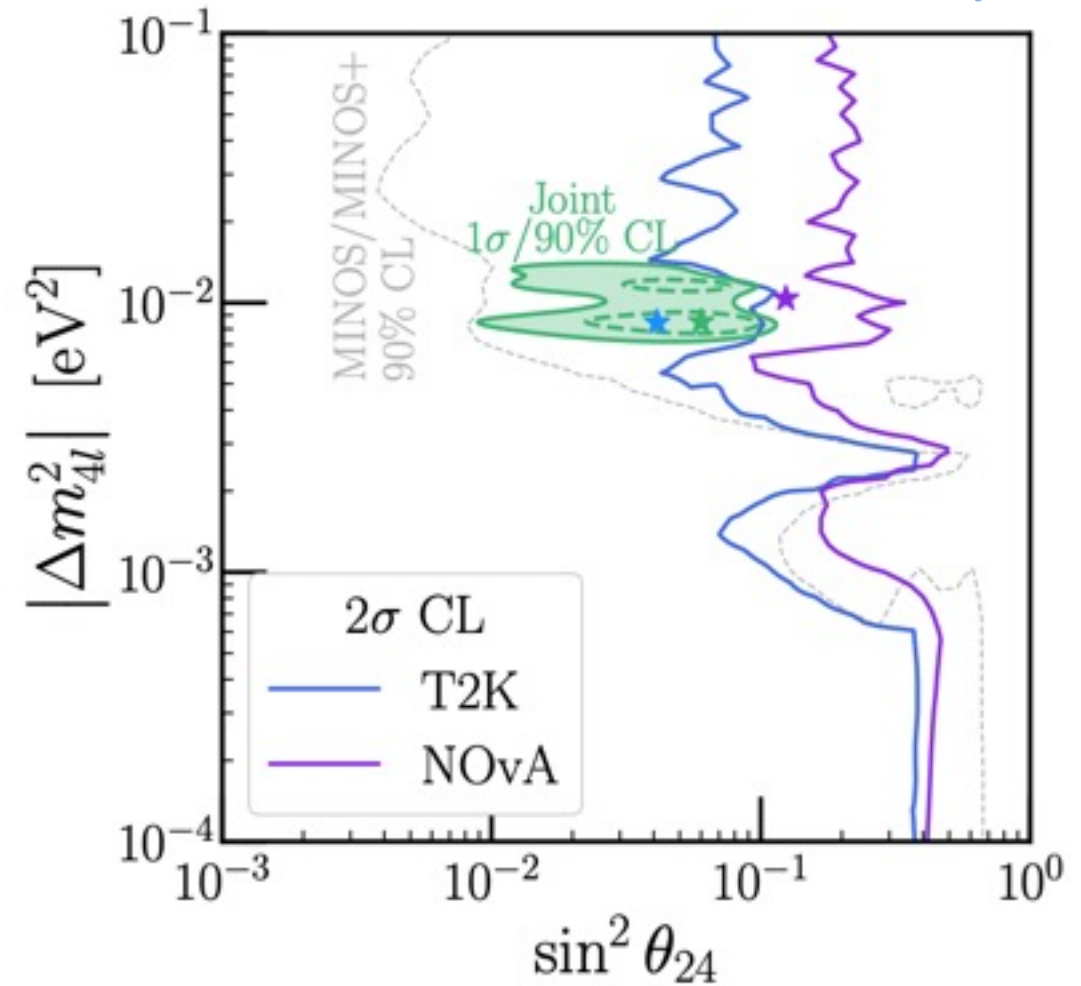
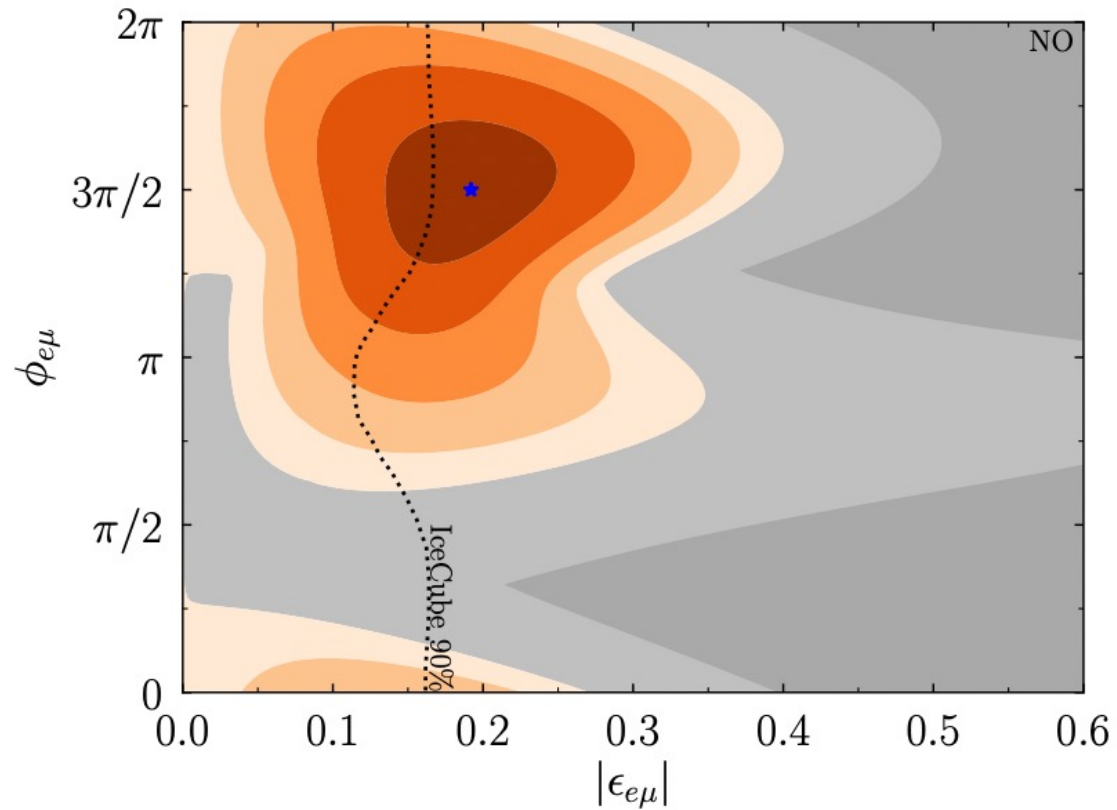
Argüelles et al., 2111.10359



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