The University of Manchester

Sterile Neutrino Global Fits to Neutrino Oscillation Data

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A quick outline

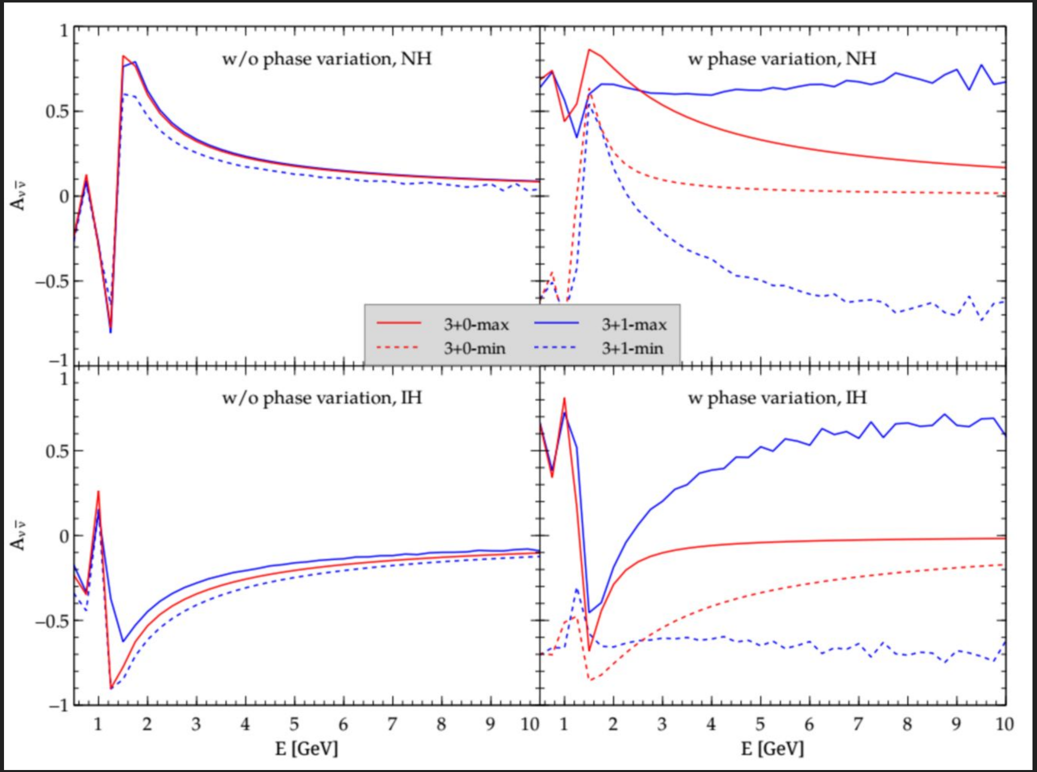
- Why are sterile neutrinos important?
- What are sterile neutrinos in the first place?
- Review of the current status of global fits.
- Difficulties in the interpretation of these fits.
- The short baseline program and how it will be a big help.

Why are sterile neutrinos important?

Finding evidence to prove or disprove the existence of sterile neutrinos is critical to studying CP violation in long baseline experiments.

Even a single sterile neutrino can drastically affect sensitivity at long baselines.

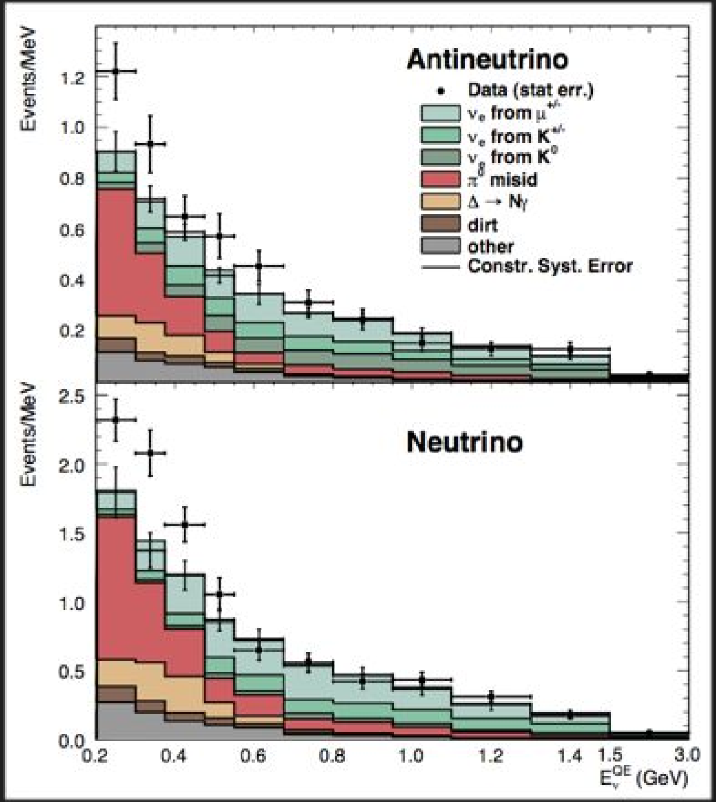
Like in DUNE.



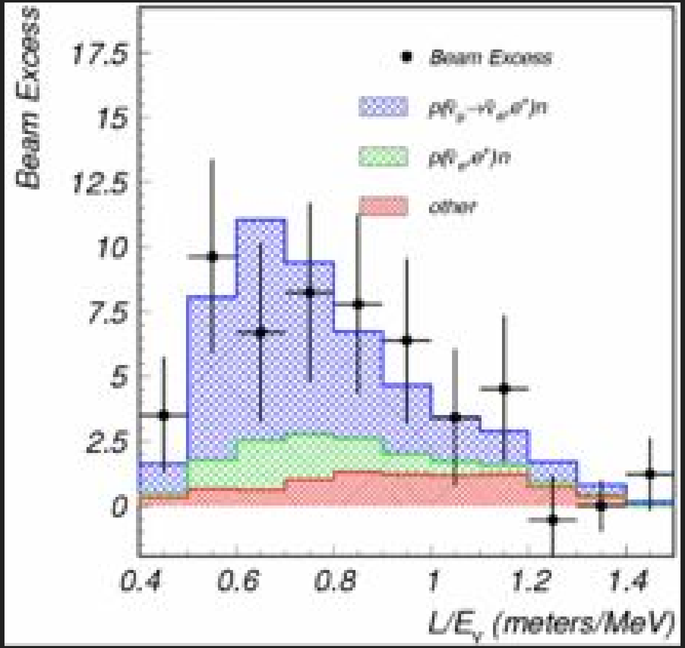
JHEP 1511 (2015) 039

Sterile neutrino hints from short-baseline experiments

MiniBooNE



LSND



Phys. Rev. Lett. 110, 161801 (2013)
Phys. Rev. D 64, 112007 (2001)

Sterile Neutrinos

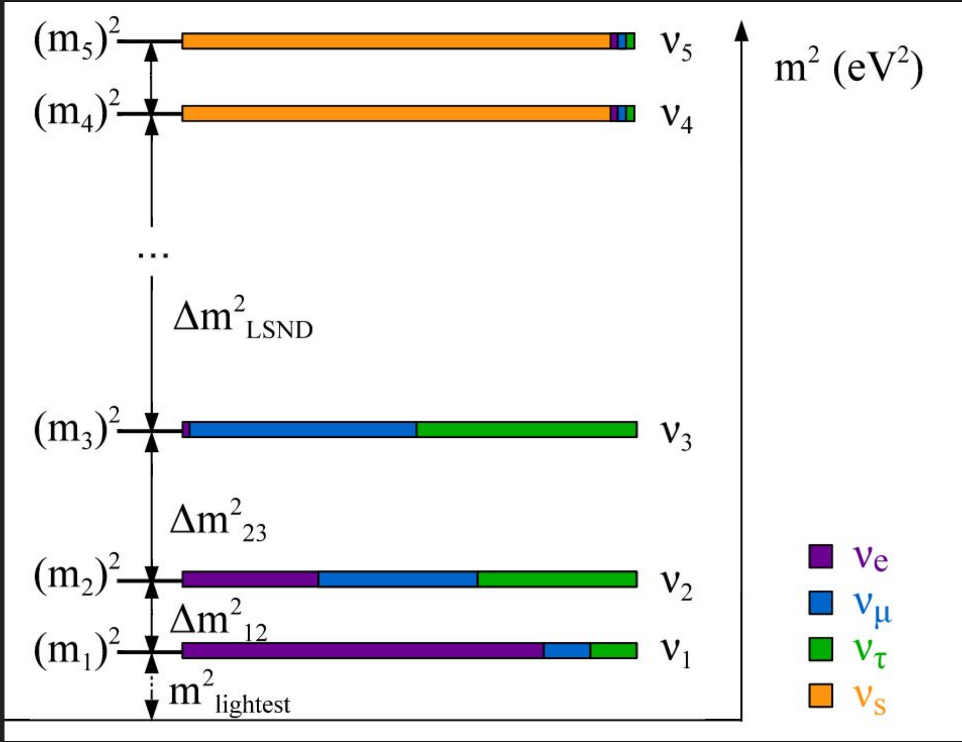
One possible explanation for these low-energy anomalies is that muon neutrinos (and antineutrinos) are oscillating through additional, mostly sterile states into electron neutrinos (and antineutrinos)

$$\nu_\mu \rightarrow ? \rightarrow \nu_e$$

3+N

Neutrinos exist as a superposition of the three known mass states as well as potential sterile states, the proportions of which can be seen in the relative sizes of the colored bars.

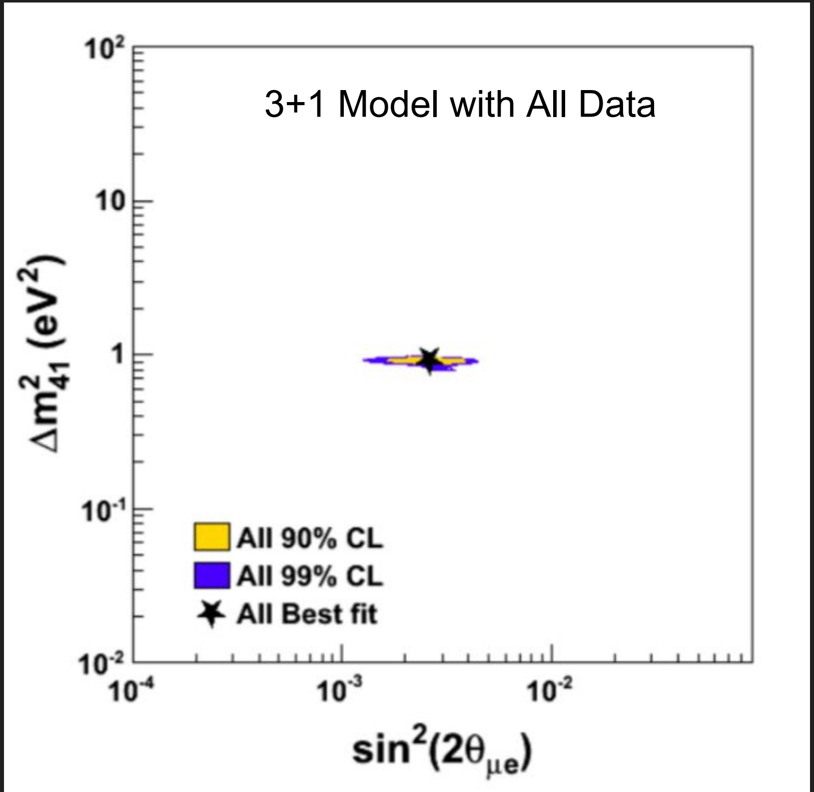
$$|\nu_\alpha\rangle = \sum_{i=0}^{N} U_{\alpha i}|\nu_i\rangle$$



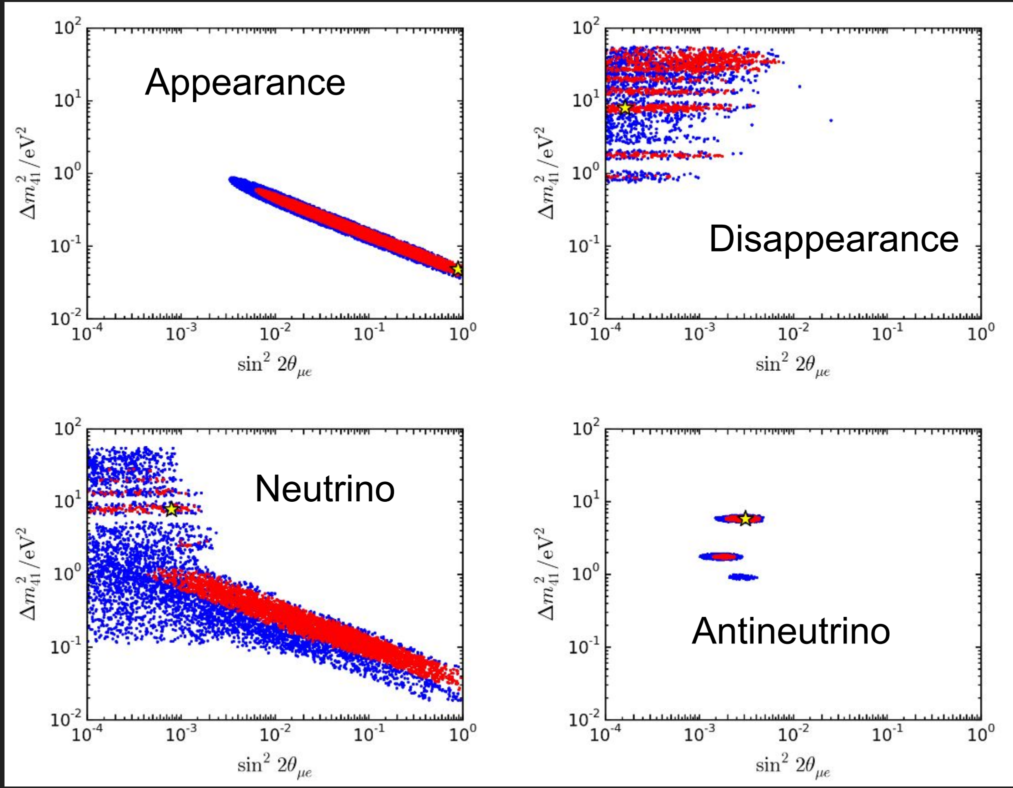
Global fits

Data from several different oscillation experiments are combined in fits, including appearance and disappearance, neutrino and antineutrino, reactor and beam, as well as several different baselines.

One can assemble a hypothetical oscillation hypothesis assuming some 3+N oscillation and compare it against observed data to see how well it matches.



Adv.High Energy Phys. 2013 (2013) 163897



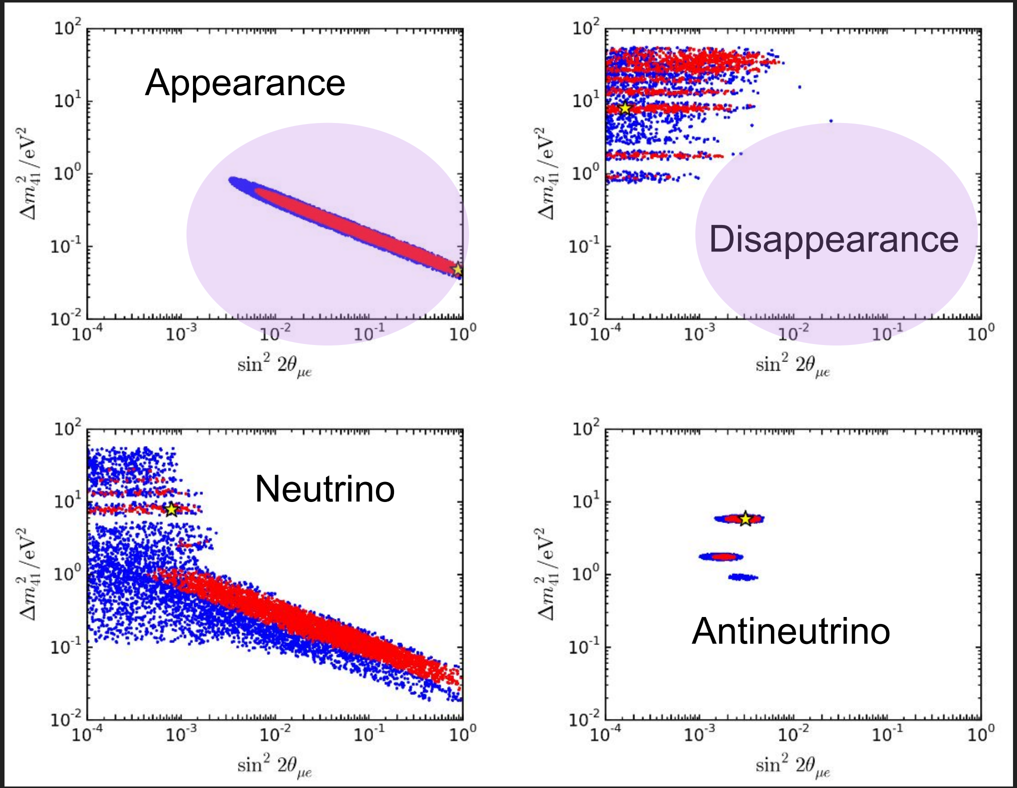
3+1 Global Fit

We can see how the global fit point is plotted for different sets of data to examine how different channels affect the fitting.

Global fits are typically measured and interpreted by looking at their χ^2 and their parameter goodness of fit, which is a metric of compatibility between data sets.

Conrad et al, arXiv:1602.00671 [hep-ph]

3+1 Global Fit



We can see some stark disagreement between the appearance and disappearance channels as well as between the neutrino and antineutrino channels.

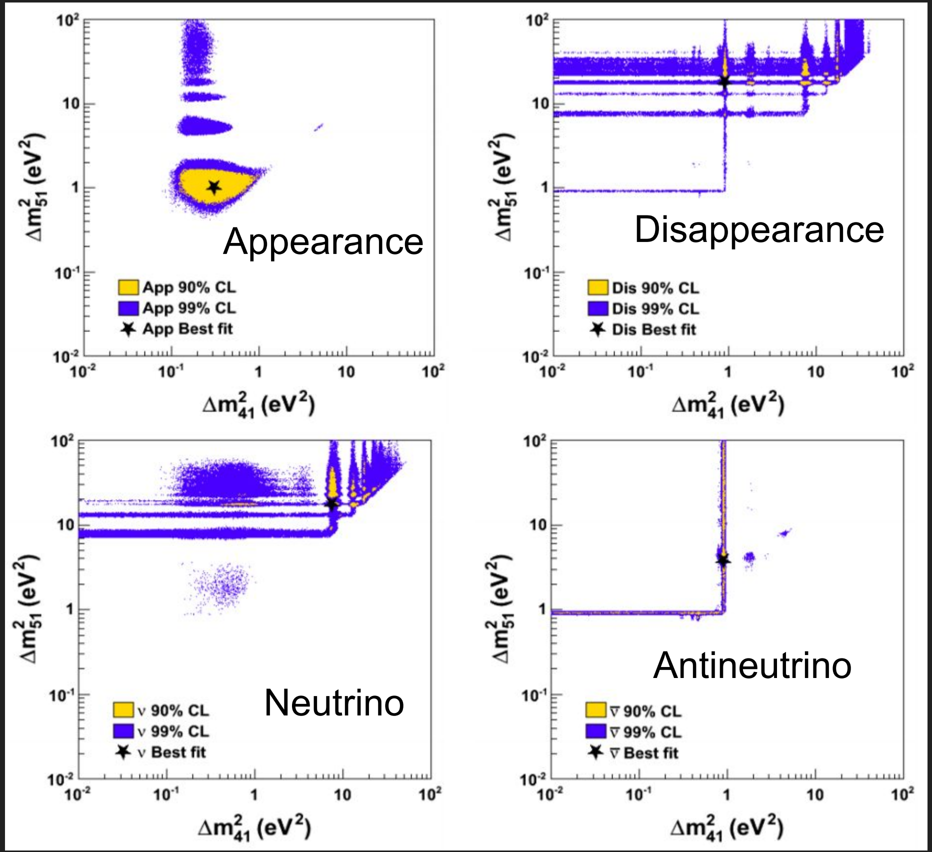
This isn’t great, so let’s try adding another sterile.

	χ^2(dof)	PG
App:	87.8 (87)	12%
Dis:	128.2 (147)	28%
App vs Dis:		.013%

Conrad et al, arXiv:1602.00671 [hep-ph]

3+2 Global Fits

The 3+2 model means we're introducing a CP violating term, which allows for neutrino-antineutrino asymmetry.



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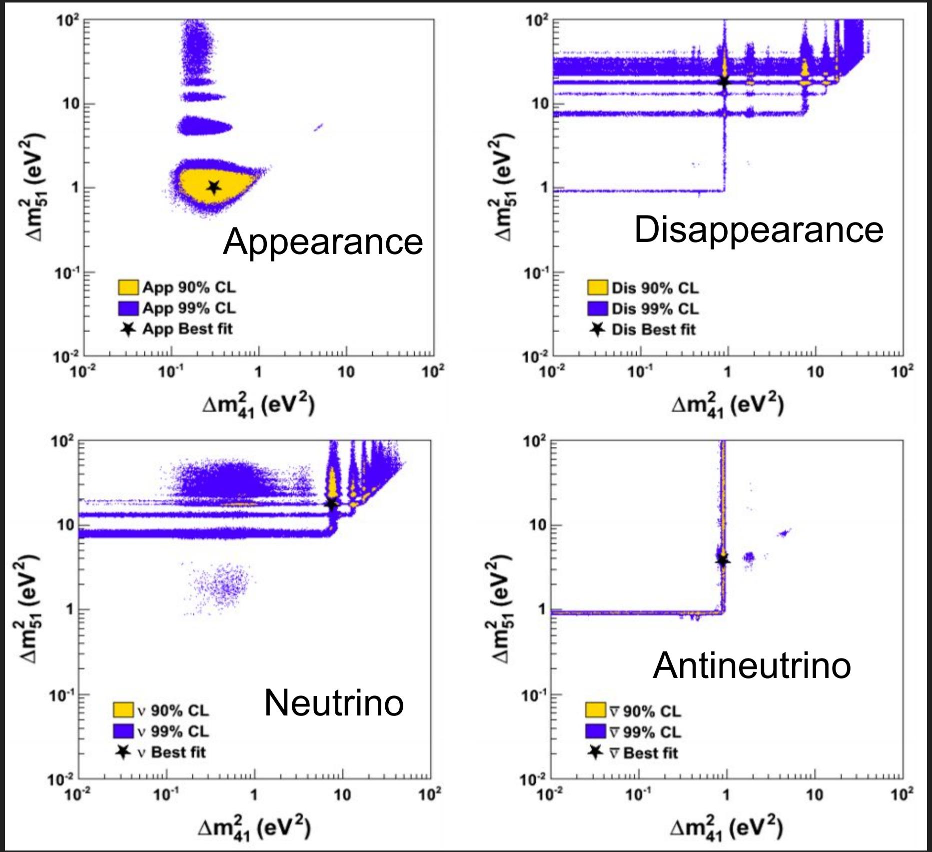
3+2 Global Fits

At least now we have SOME agreement, but it’s still not great.

What if we added just one more sterile?

	χ^2(dof)	PG
App:	75.0 (85)	90%
Dis:	122.6 (144)	43%
App vs Dis:		.0082%



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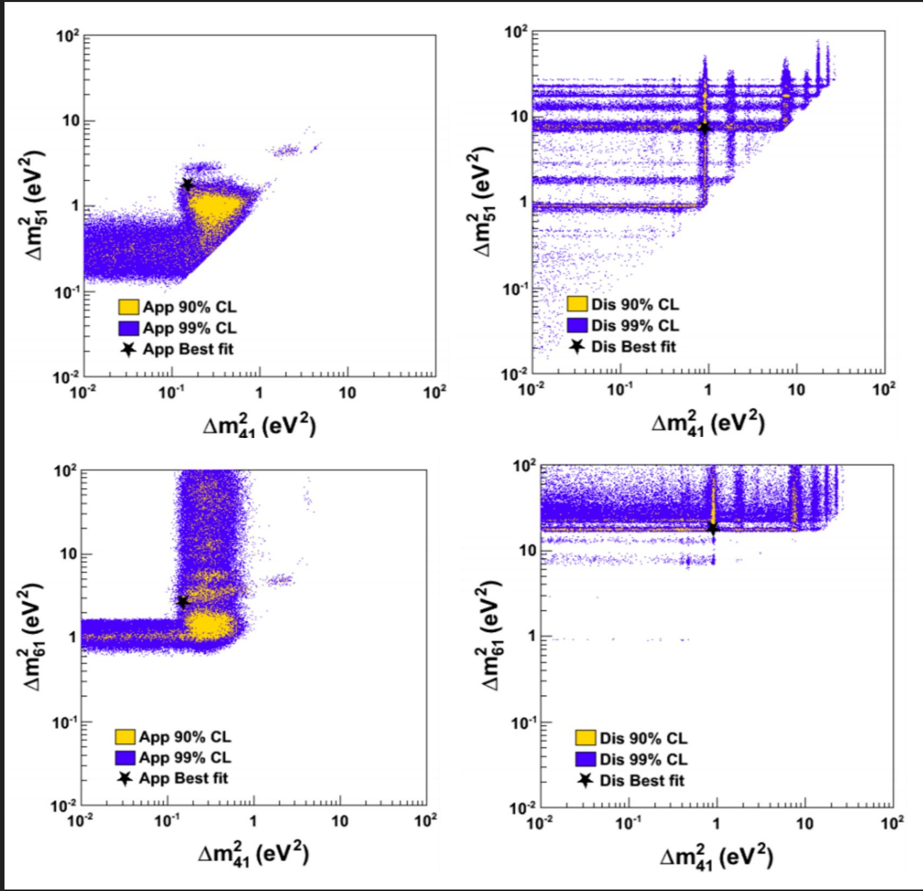
Appearance Disappearance



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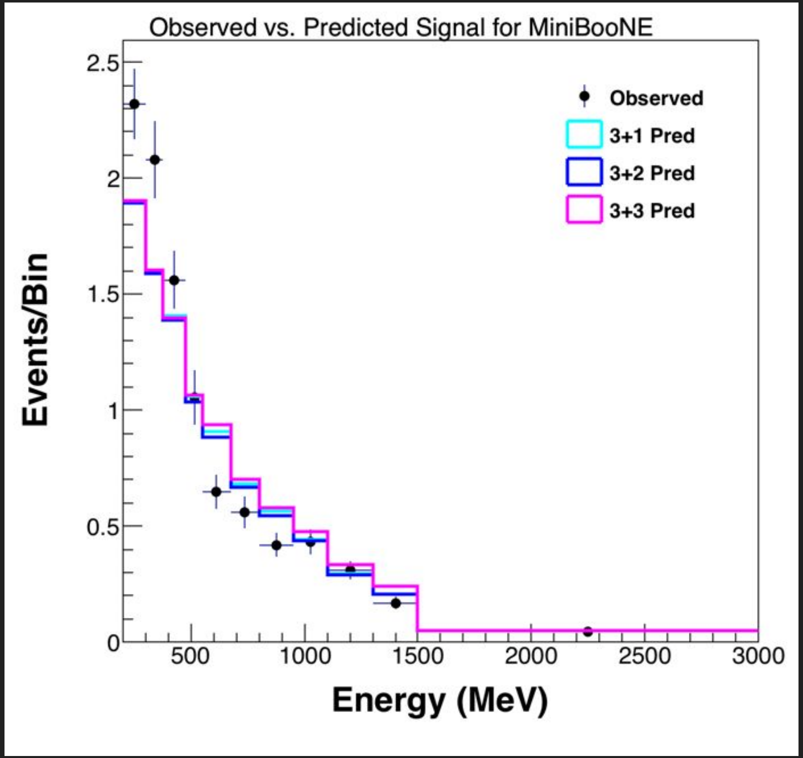
3+3 Global Fit

3+3 fits appear to be markedly more compatible!

And yet, still quite lacking, and it reveals some of the obstacles in interpreting global fits.

	χ^2(dof)	PG
App:	70.8 (81)	100%
Dis:	120.3 (144)	90%
App vs Dis:		.0081%

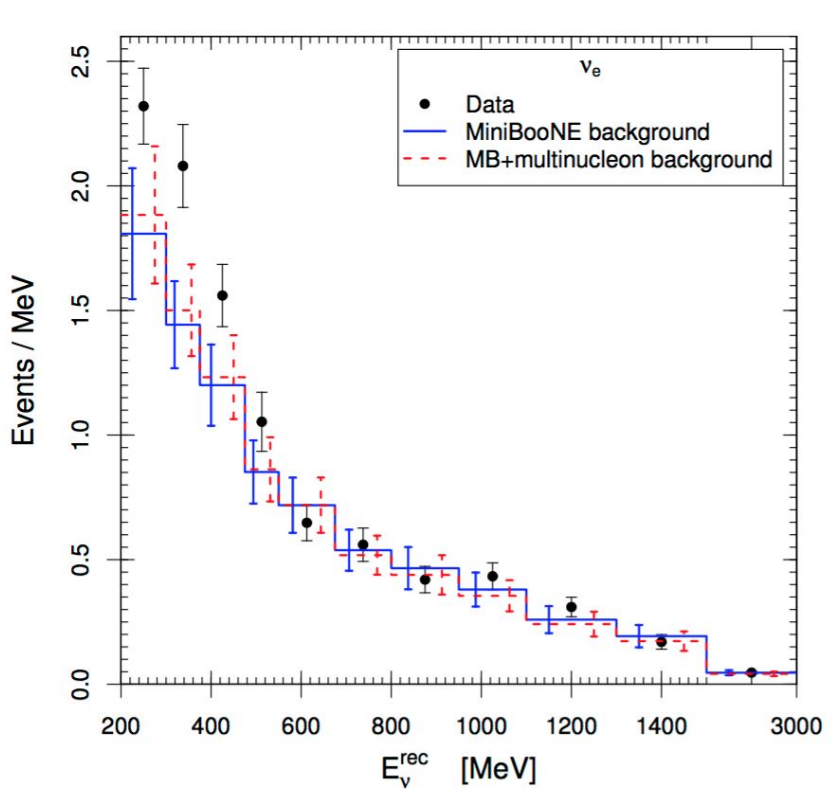
The trouble with interpreting these



Even if one sees a great χ^2 for the global best fit - meaning a set of oscillation parameters that agrees reasonably well with all the data has been found, it could still fail to adequately describe individual data sets.

And that's what we see here! The global best fits for 3+1, 3+2 and 3+3 models all fail to capture the excess.

The MiniBooNE Low Energy Excess



A lot of this tension seems to stem from the MiniBooNE low E anomaly.

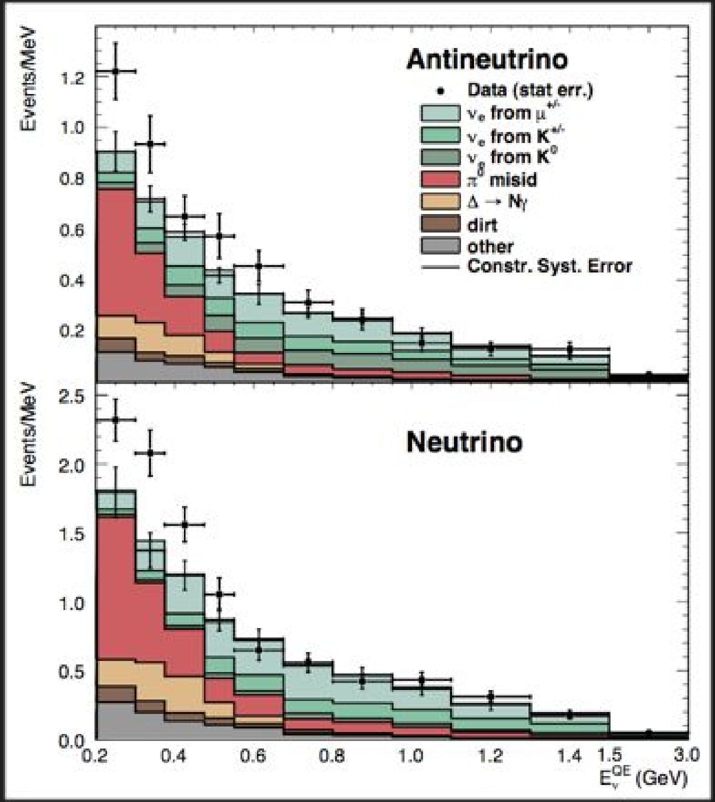
Ericson, M. *et al* interpreted this as the low E excess not being caused by oscillation but perhaps by mis-reconstructed energy due to nuclear effects.

arXiv:1602.01390 [hep-ph]

What we don’t know

Understanding this excess is key to being able to successfully determine the presence of sterile neutrinos.

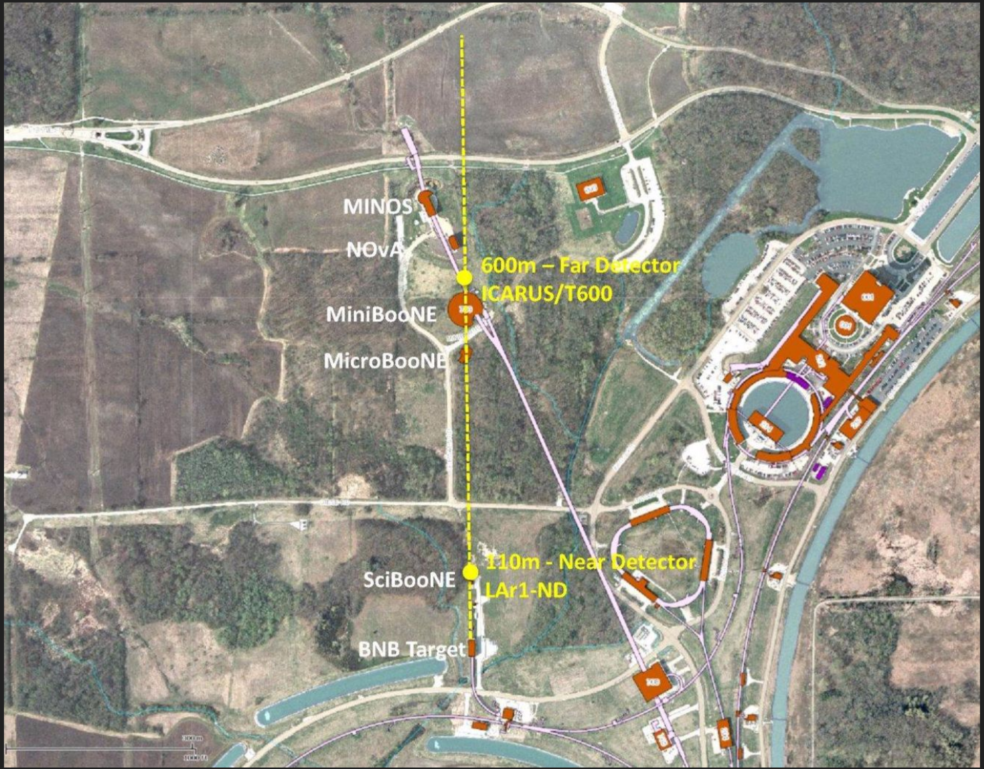
One way one can do this is by better understanding our uncertainties. The cross section and flux, for example, are incredibly hard to estimate. Greater knowledge of the content of our neutrino beam, would provide far more robust energy reconstruction and uncertainty estimation.



The SBN Program

The Short Baseline Neutrino program at Fermilab plans to pair a near detector with two other LArTPC detectors further down the beamline.

A detector very near to the start of the beam will give us an unprecedented picture of the beam flux to help us constrain our uncertainties in detectors down the line.

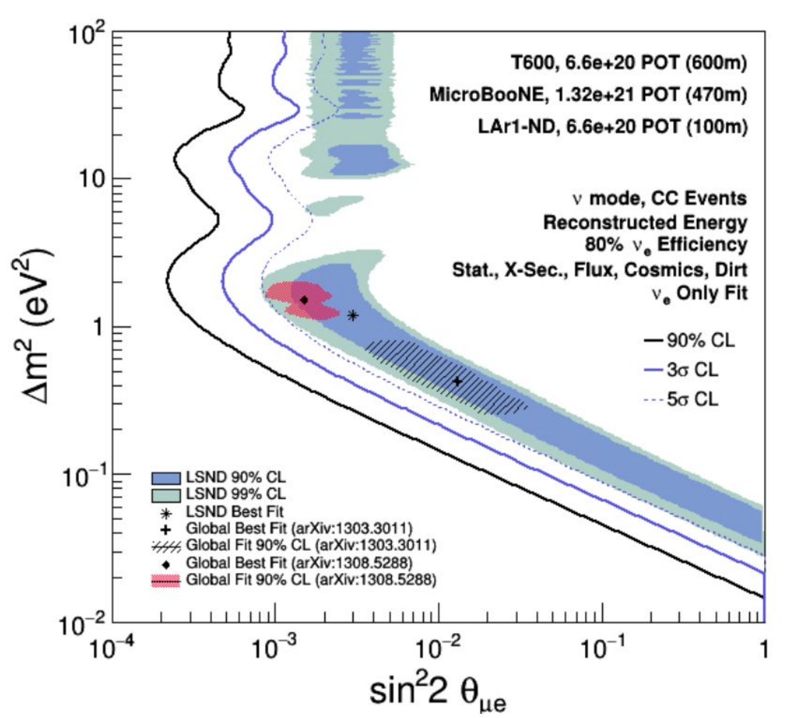


arXiv:1503.01520 [physics.ins-det]

The SBN Program

Since this set of detectors shares the same neutrino source as MiniBooNE, it will allow us to address the excess as well as the sterile neutrino interpretation.

From these curves, one can see that SBN can test the 3+1 interpretation to 5σ and investigations of 3+2 and 3+3 sensitivities are underway. Global fits allow us to constrain the broad parameter space and strengthen our sensitivities.



arXiv:1503.01520 [physics.ins-det]

In conclusion

- Sterile neutrinos provide an interesting explanation for the short baseline anomalies.
- Understanding the presence of sterile neutrinos will be vital in studies of CP violation at long baselines.
- Global fits are a way to explore this interpretation, but have so far been unconvincing in explaining the low energy excess in MiniBooNE while respecting the disappearance constraints.
- The SBN program will help resolve this tension by constraining beam uncertainty and testing the 3+1 interpretation with high sensitivity.
- Global fits will be important in future in constraining the parameter space for 3+N oscillations to increase detector sensitivity in searches for sterile neutrinos.