Sterile Neutrino Search using ν_e Appearance with the NOvA ND

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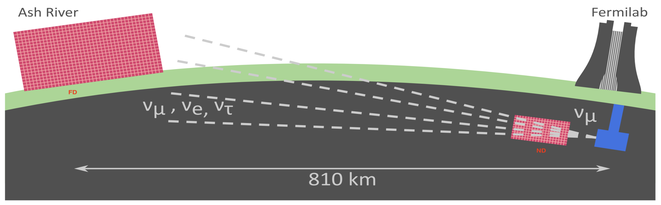
FERMILAB-POSTER-26-0052-PPD

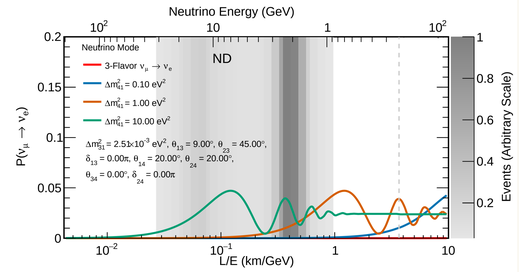
NOvA Experiment

- NOvA is a long-baseline oscillation experiment using Fermilab's NuMI beam.
- Near Detector (ND) at 1 km and Far Detector(FD) at 810 km.
- Searches for beyond-standard-model physics, including sterile neutrinos.



Sterile Neutrino

- NOvA sterile-neutrino searches have mainly used NC disappearance and ν_μ disappearance channels.
- The ν_e appearance channel provides a complementary probe, motivated by anomalies in the electron-neutrino sector.

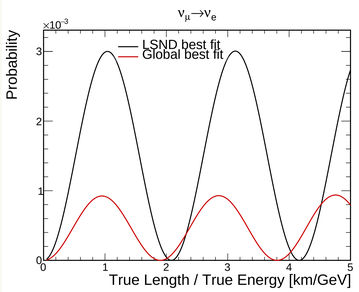


Oscillation probabilities for different Δm^2_{41} values.

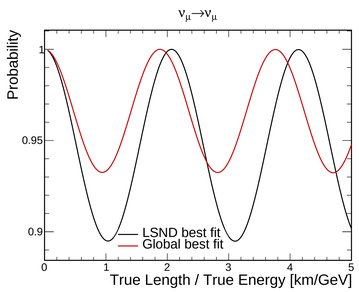
- In a 3+1 model, a new mass state introduces oscillations driven by Δm^2_{41}.

3+1 Short-Baseline Oscillation Probability

$$P^{\mathrm{SBL,3+1}}_{\mu e} = \sin^2 2\theta_{\mu e} \sin^2\left(1.27\frac{\Delta m^2_{41} L}{E}\right) \qquad P^{\mathrm{SBL,3+1}}_{\mu\mu} = 1 - \sin^2 2\theta_{\mu\mu} \sin^2\left(1.27\frac{\Delta m^2_{41} L}{E}\right)$$



Appearance: $P_{\mu e}(L/E)$

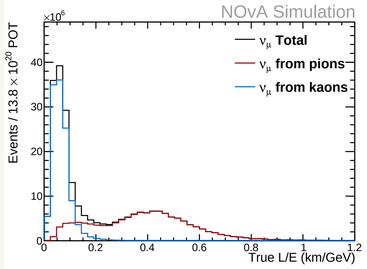


Disappearance: $P_{\mu\mu}(L/E)$

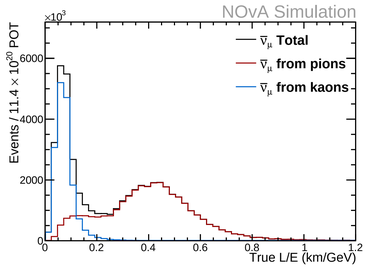
LSND best fit: $\Delta m^2_{41} = 1.20\ \mathrm{eV}^2$, $\sin^2 2\theta_{\mu e} = 0.003$ [1]; global best fit: $\Delta m^2_{41} = 1.32\ \mathrm{eV}^2$, $\sin^2 2\theta_{\mu e} = 0.000924$ [2].

NOvA ND L/E Coverage for Short-Baseline Sterile Searches

Broad spread in L/E up to $\sim 1\ \mathrm{km/GeV}$ provides sensitivity to short-baseline oscillations driven by $\Delta m^2_{41} \sim 1\ \mathrm{eV}^2$.



FHC ν_μ L/E distribution



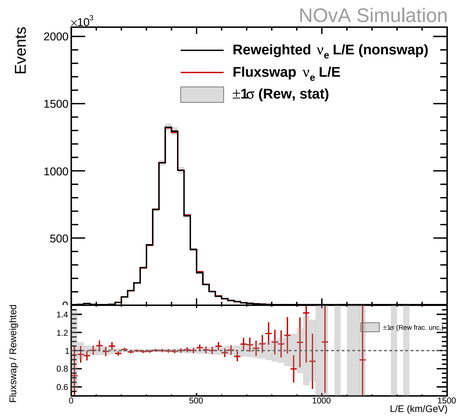
RHC $\bar{\nu}_\mu$ L/E distribution

FD Validation of Reweighting Method

Motivation: FD ν_e appearance analyses use samples in which the ν_μ and ν_e flavours are switched to model the appearance prediction. Since producing these samples is computationally intensive in ND, we are developing a faster reweighting approach using the nominal sample.

Reweighting technique: A one-dimensional weight in true L/E is derived from the ratio of the FD reference sample to the standard prediction and applied to the standard simulated sample.

- Closure test performed at the FD, where a ν_e appearance study sample is available.
- Reweighted standard prediction is compared to the FD reference sample.
- The validated method is then applied at the ND.



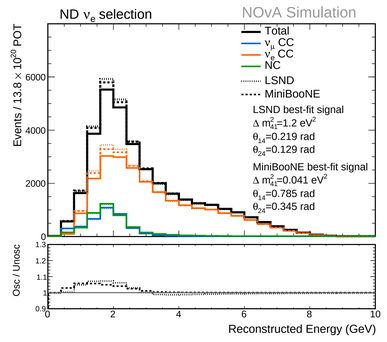
Comprehensive strategy to improve limits!

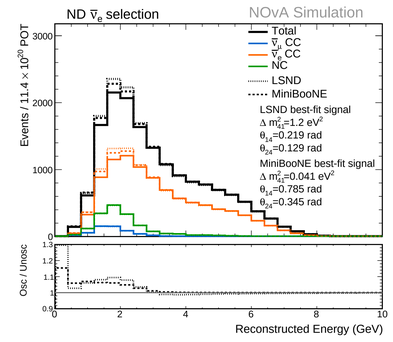
Improving our L/E resolution
See Jessica's poster (#206)

Additional samples for disambiguating oscillations and systematic effects
See Adam's poster (#194)

ND ν_e and $\bar{\nu}_e$ Spectra : Technical Demonstration

- ND ν_e and $\bar{\nu}_e$ spectra are compared with unoscillated and LSND/MiniBooNE sterile benchmark predictions [1, 3].
- Technical demonstration using a preliminary selection; optimization is ongoing.

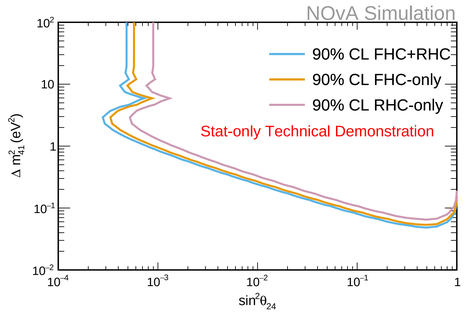




ND Sterile Sensitivity: Technical Demonstration

Short-baseline sensitivity using ν_μ and ν_e samples in FHC and RHC beam modes.

- Projected 90% C.L. sensitivity in the $(\sin^2\theta_{24},\ \Delta m^2_{41})$ plane.
- Comparison of FHC+RHC, FHC-only, and RHC-only shows the benefit of combining beam modes.
- Sensitivity shown for statistical uncertainties only.



Acknowledgment and References

This poster was prepared by the NOvA Collaboration using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, Office of High Energy Physics HEP User Facility. Fermilab is managed by Fermi Forward Discovery Group, LLC, acting under Contract No. 89243024CSC000002.

[1] A. Aguilar et al., DOI 10.1103/PhysRevD.64.112007 (2001).
[2] M. H. Moulai et al., DOI 10.1103/PhysRevD.101.055020 (2020).
[3] A. A. Aguilar-Arevalo et al., DOI 10.1103/PhysRevLett.110.161801 (2013).

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