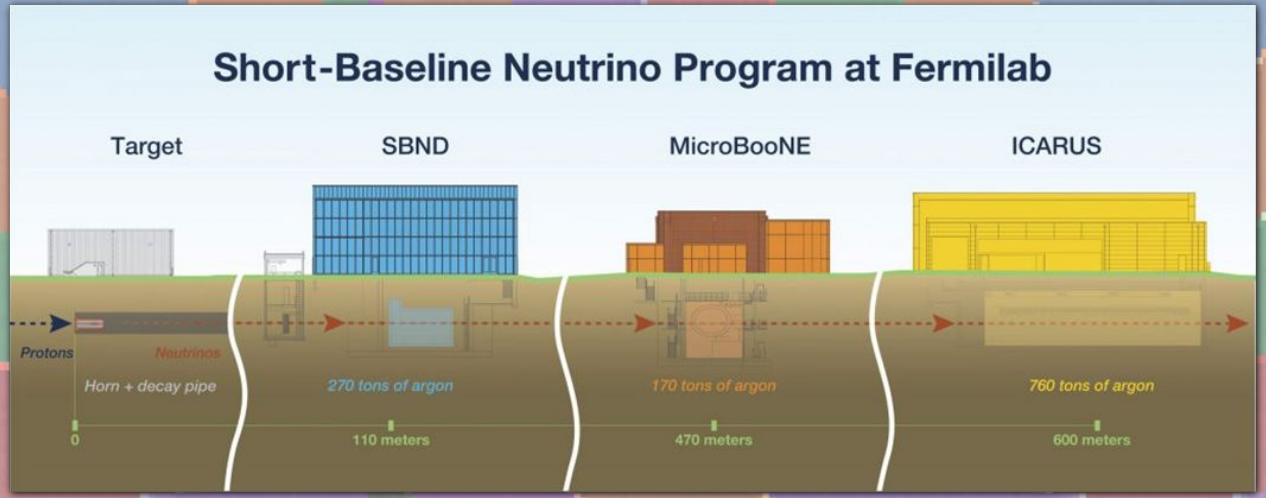
Sterile Neutrino Search:
SBND-PRISM

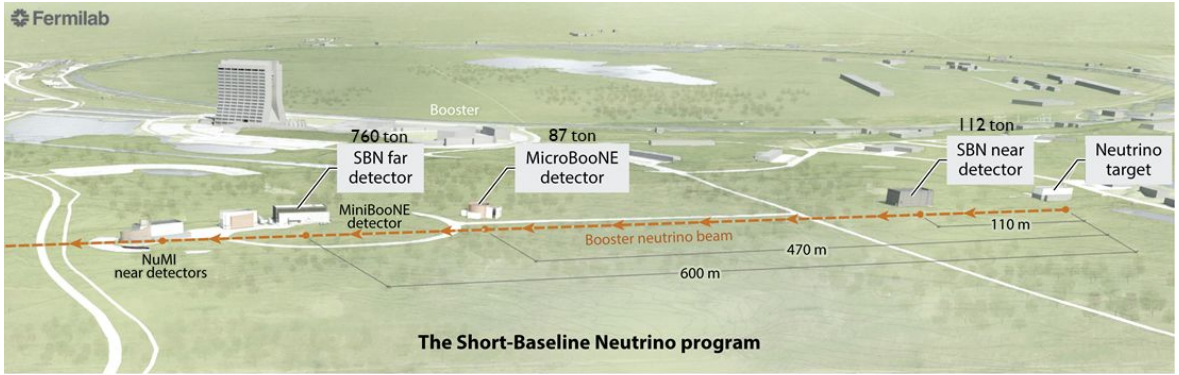
Beth Slater

HEP Christmas Meeting: May 2023



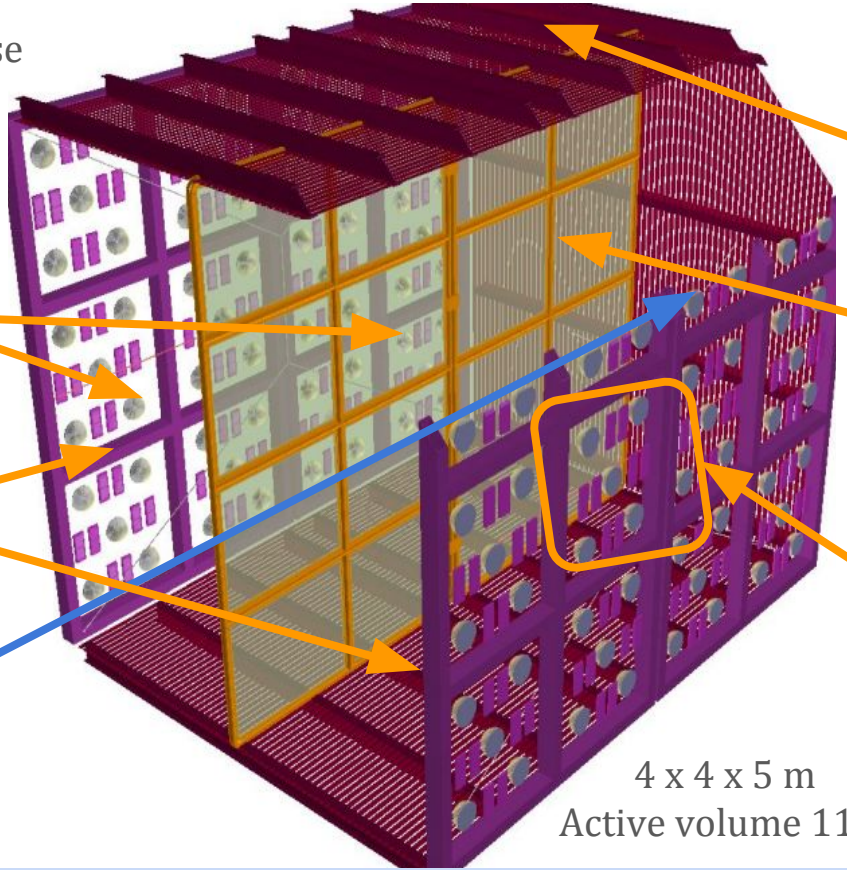
Short Baseline Neutrino (SBN) Programme

- 3 liquid argon TPC detectors along the neutrino beam
- Physics aims:
  - Searching for sterile neutrinos: $\Delta m^2_{41} \sim 1 eV^2$
  - Studying neutrino-argon interactions
    - ~2 million/year in SBND alone
  - BSM searches
    - see arXiv:1903.04608



Short Baseline Near Detector (SBND)

SBND in commissioning phase
ICARUS already taking data



Field Cage

Two
back-to-back TPC
volumes

Common Cathode

Anode plane
assembly

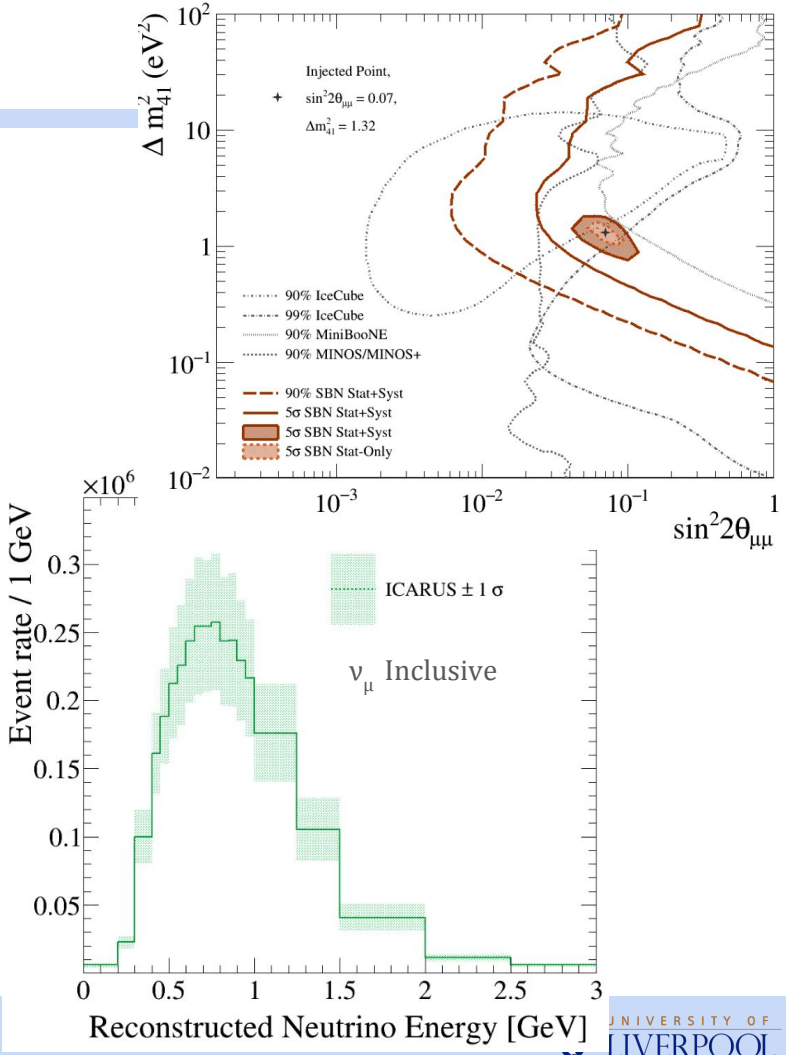
Photon detection
system: PMTs and
X-ARAPUCA

Beamline
~74cm off-axis

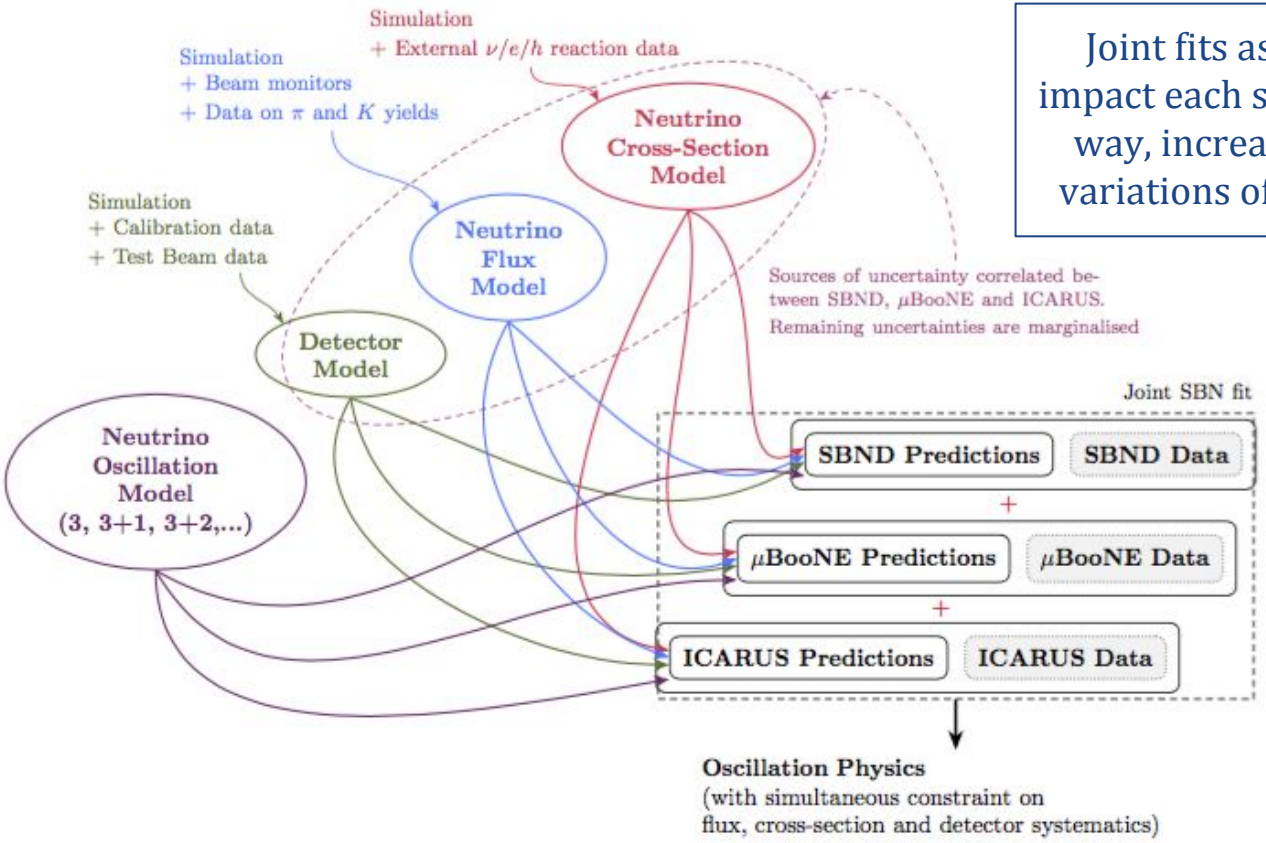
4 x 4 x 5 m
Active volume 112t

Role of SBN

- Investigate parameter space favoured by previous measurements
- Signal will manifest via oscillations
- Our predictions have uncertainties ~30%
  - Too large to search for new physics
  - Current flux and x-section systematics
- SBND reduces uncertainty to enable new physics searches
- My plan is to use muon neutrino inclusive samples



VALOR: Analysis Strategy

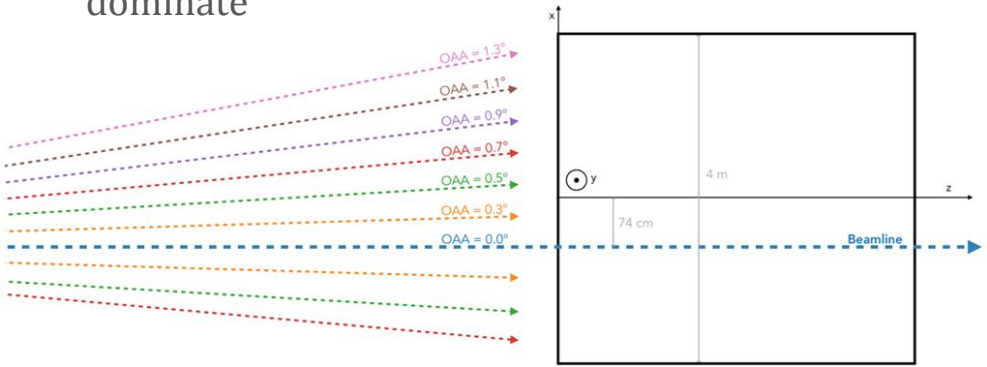


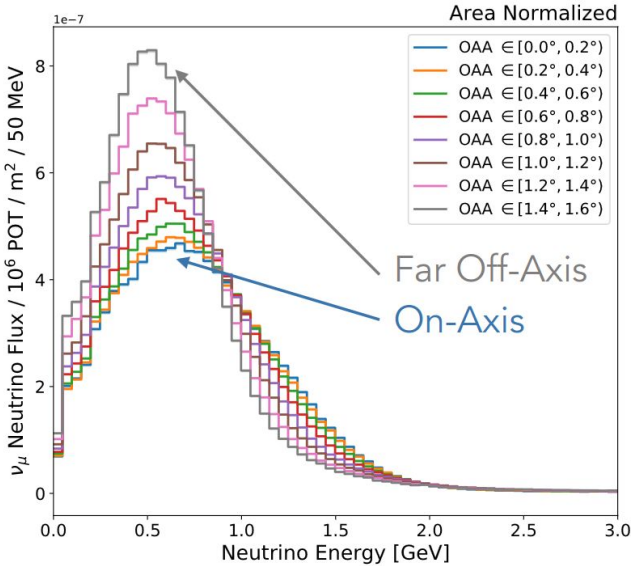
Joint fits as systematics will impact each sample in a different way, increasing sensitivity to variations of those parameters

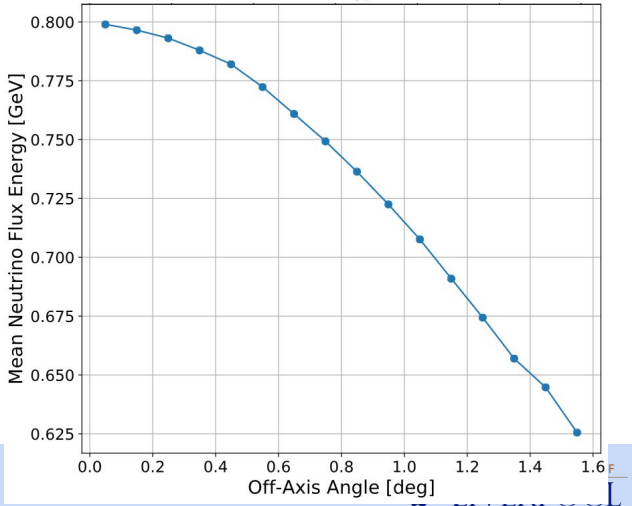
- Joint fits matching prediction to data
- Simulation data informs models
- Models used to generate predictions
- Obtain explicit systematic constraints

SBND-PRISM

- Takes measurements at different locations in the detector
- Use different samples to constrain oscillation
  - Different energy spectra/composition
  - Sensitive to different sources of systematics
- SBND (110m baseline) split into 8 bins (8 samples)
  - The statistics in each bin are still large so the systematics dominate

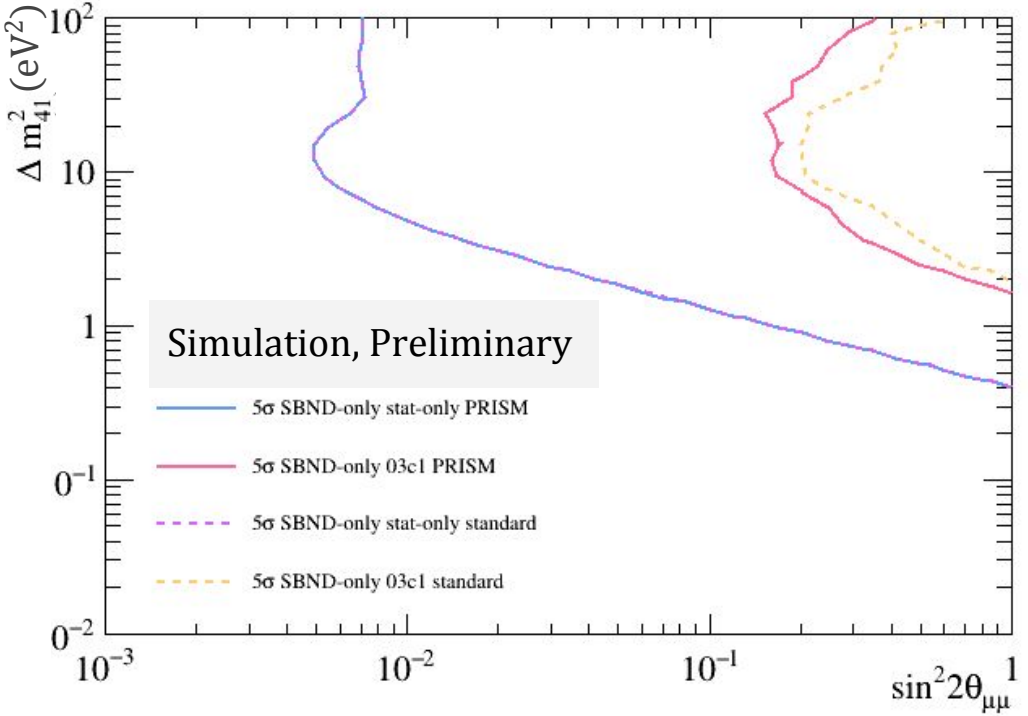






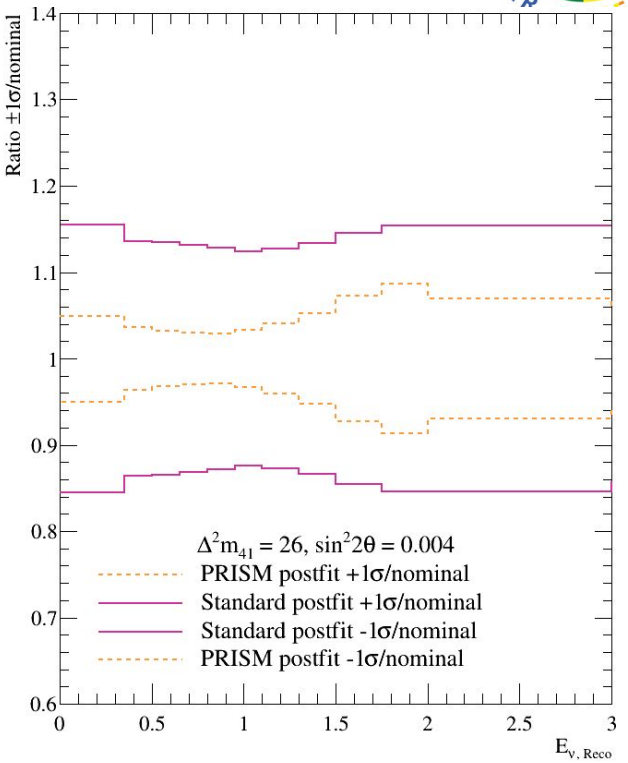
Sensitivity Studies: Muon Neutrino Disappearance

- Worsening is less when using PRISM as opposed to standard analysis when including systematics
- PRISM means that oscillation signals are less likely to be hidden when systematic uncertainties are included



Reduction in Systematic Uncertainties

- Initial studies with PRISM show postfit error reduction from ~15% to ~5% level
  - Increases oscillation sensitivity
- Further work to exploit the PRISM capabilities ongoing



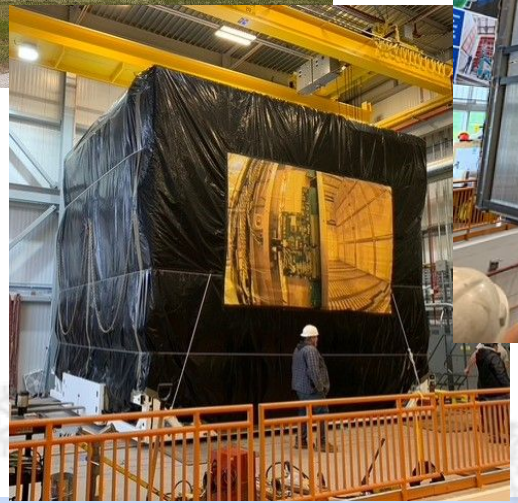
Overview

- SBN programme should improve understanding of sterile hypothesis
- SBND will have excellent statistics as the event rate is high
  - Used to constrain systematic uncertainties
- I am investigating the use SBND-PRISM
  - Currently implemented with 8 bins for all 3 oscillation channels available
  - Should improve systematic constraints for the whole programme

Next Steps

- Investigate the use of PRISM with only 3 off-axis samples
  - Improve computing efficiency
- Investigate different exclusive fits within VALOR-PRISM
- Mock data studies
  - Currently in collaboration with UTA to produce relevant mock data samples
- LTA at Fermilab
  - Start at the end of the month
  - Will work on trigger commissioning (exact details to be decided there)
- Thesis
  - 2-3 months muon neutrino physics quality data
  - First numu CC studies in SBND, SBND-fits to constrain systematics, first attempts at using PRISM

Any Questions?



Oscillation Analysis Strategy

- Use data from SBND, MicroBooNE and ICARUS to measure oscillations
- SBN will be sensitive to the parameter space ($\sin^2 2\theta$, Δm^2) favoured by previous measurements at the 5σ confidence level
  - Focused on the LSND/MiniBooNE anomalies
- SBND will be essential in reducing uncertainties
- Use VALOR neutrino fitting framework to calculate sensitivity
  - Jointly fit many kinematic distributions (eg different detectors, different off axis angles)
  - Float systematics so predictions match the data
  - Obtain explicit constraints on systematics
- Using all detectors improves the sensitivity to oscillations (rather than individually)
  - PRISM method further improves sensitivity and could be used for SBND-only studies

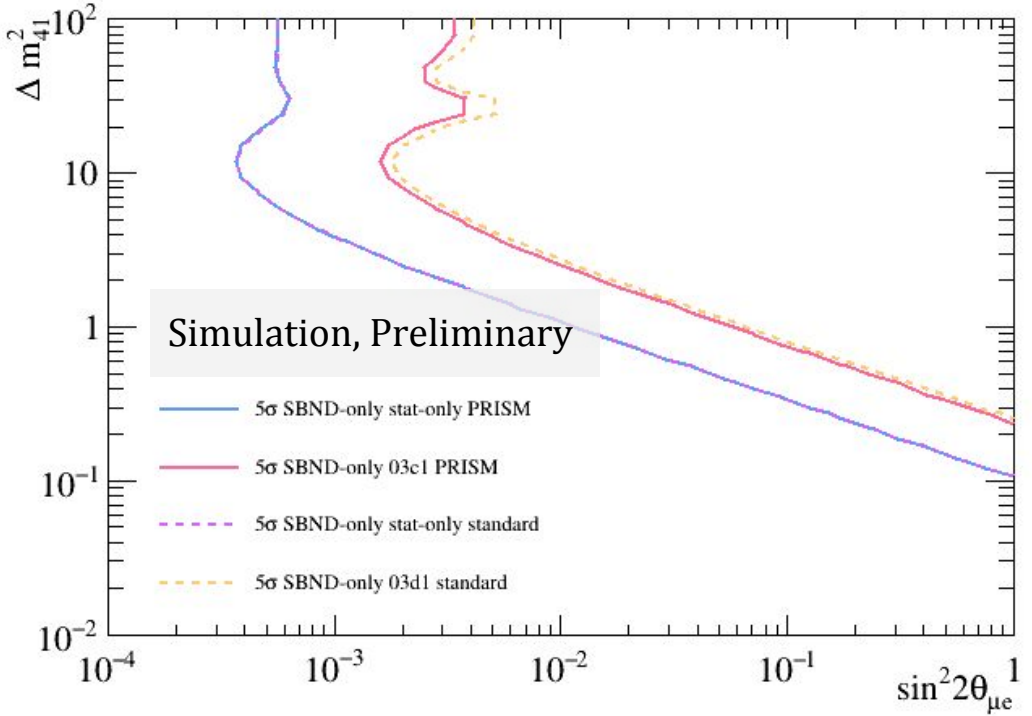
Oscillation Analysis: Sensitivity Studies

- Try to fit prediction with oscillation to data without
- Jointly fit SBND, MicroBooNE and ICARUS data
  - 3 samples
- On parameter space, split grid up and calculate χ^2_0 at every point
- Float any included systematics within $\pm 5\sigma$ of their limits
- Apply profiling and minimise the binned-likelihood (χ^2)
  - Includes penalty terms to penalise the fit increasingly with larger systematic pulls
- Plot contours of constant χ^2_{critical} on the parameter space
  - Exclusion curves
  - Allowed regions

Sensitivity Studies: Electron Neutrino Appearance

- SBND-only
- Exclusion limits when looking as statistics-only show no difference between standard analysis and PRISM (as expected)
- See improvement using PRISM when looking at full exclusion limits (including statistics and systematics)

Take note of change in x-axis limits



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