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Evaluating the Effects of Detector Modeling Uncertainties on Sterile Neutrino Oscillation Analysis with the ICARUS Detector

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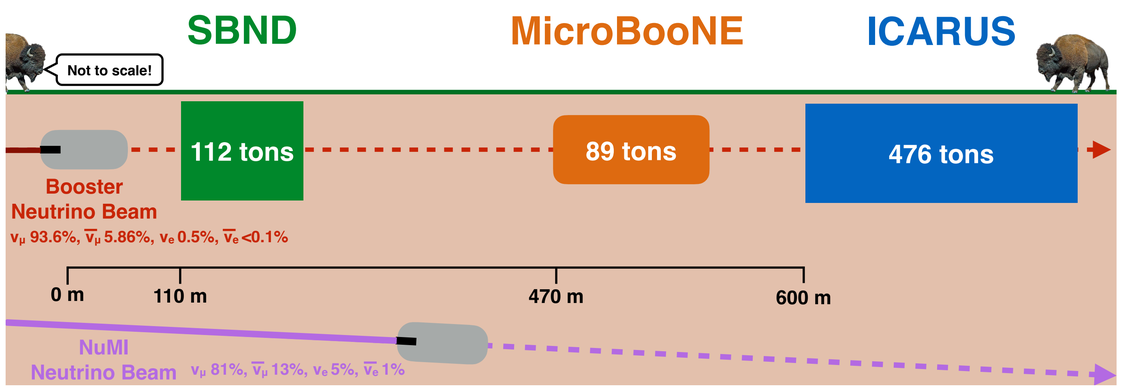
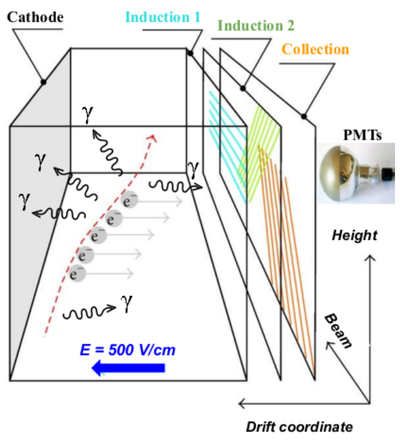
ICARUS and the SBN Program

- The Short Baseline Neutrino (SBN) Program is designed to definitively probe the sterile neutrino hypothesis of the MiniBooNE anomaly
- A near detector (SBND) and far detector (ICARUS) liquid argon time projection chamber (LArTPC) with the Booster Neutrino Beam (BNB) as a common beamline

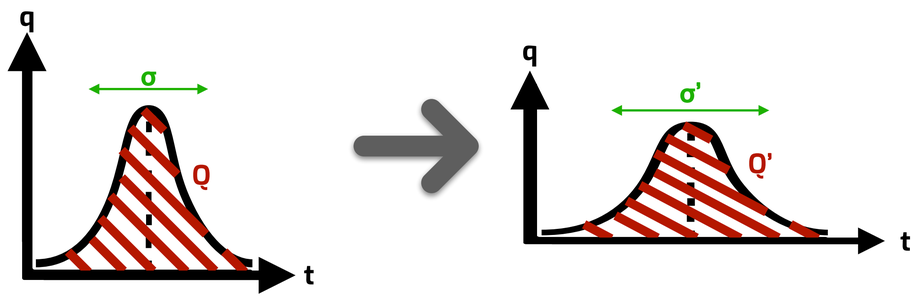


- ICARUS is a LArTPC detector with 476 tons active mass with two identical cryostats each with two TPCs divided by a central cathode
  - Instrumented with 360 PMTs coated with TPB for scintillation light detection
  - High-coverage cosmic ray tagger (CRT) to tag and remove cosmic ray backgrounds
- Commissioning began in 2020 and completed in 2022 with physics data-taking ongoing



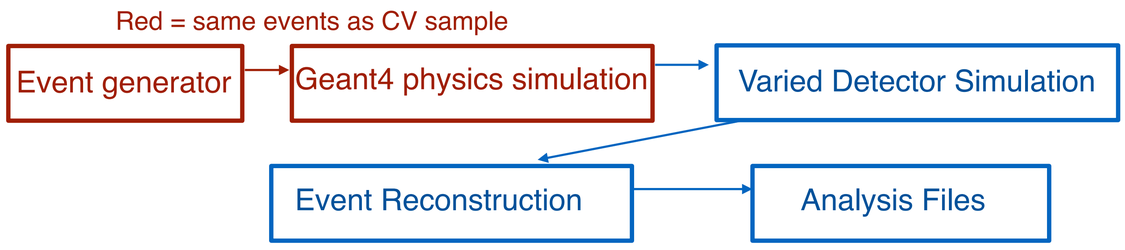
Detector Modeling Systematic Uncertainties

- Differences in the nominal and a modified simulation can be used to evaluate detector systematic uncertainties informed by calibrating the detector response
- Preliminary evaluation of detector modeling systematics focuses on uncertainties in the TPC signal model, the TPC noise model, the electron-ion recombination model, and the scintillation light model that go into the simulation



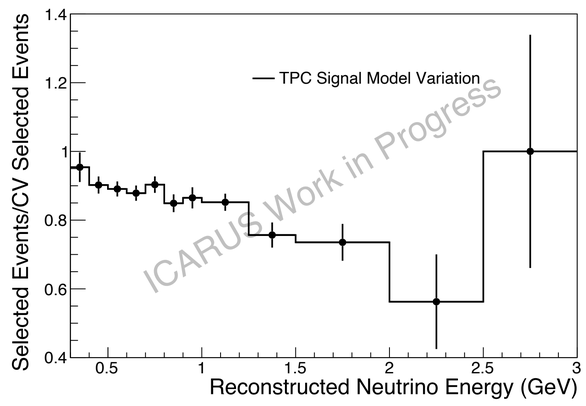
Generating Simulation Samples for Systematics

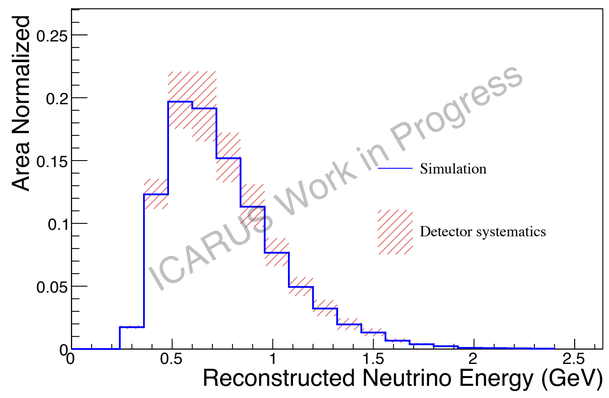
- The initial ICARUS analyses are applying a “detector variation” method running a common set of events through a modified detector simulation
- The same event selection analysis is applied to both the central value sample and the variation sample, representing the systematic effect of a given parameter
- The current variations represent a preliminary, conservative evaluation of the systematic effects

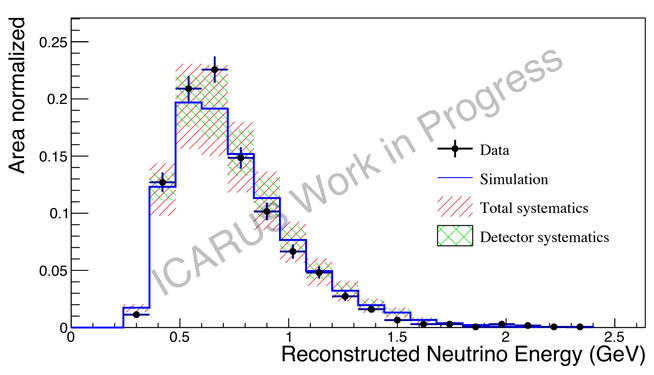


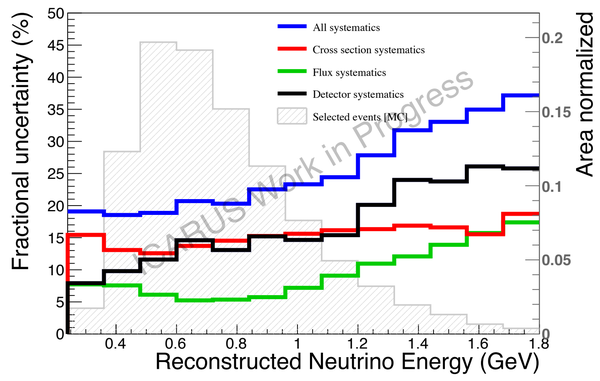
Evaluating Detector Modeling Uncertainties

- The ICARUS single-detector oscillation analysis searches for neutrino charged-current interactions consisting of a final state with 1 muon and any number of protons (1μNp) using the BNB beam
  - **See poster #51 for details of the event selection**
- The contribution of detector systematics to the overall uncertainty are evaluated by running the analysis event selection on both the central value and each variation sample
- The inputs are comparisons of the binned selected distributions between the central value and the different detector variation samples as either +1 or -1 sigma effects and extend to other values of sigma
- The contribution of each variation sample is evaluated by throwing a set of universes assuming a gaussian distribution and applying a shift and computing the 1-sigma error band for a given effect









Systematic	Change in selected events
TPC signal model	13.1%
TPC noise model	2.5%
Electron-ion recombination model	2.6%
Scintillation light model	< 1%
Total Detector	13.6%
Other Components (Flux+Cross-Section)	16.6%
Total Systematic Error	21.5%

Conclusions and Future Work

- This work represents a first, conservative estimate of the effects of detector modeling uncertainties
  - Work ongoing to improve upon the evaluations presented here towards a first sterile neutrino oscillation search with ICARUS and moving forward with SBN
- The methods developed for the SBN program to evaluate and reduce contributions to detector modeling uncertainties are extendable to the DUNE physics program
- Work ongoing and additional techniques are being explored in order to reduce the TPC signal model uncertainties
- Other possibilities include assessing the set of systematic variations with a single simulation sample

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