Sterile Neutrino Oscillation Searches using the PRISM Technique within VALOR at SBND

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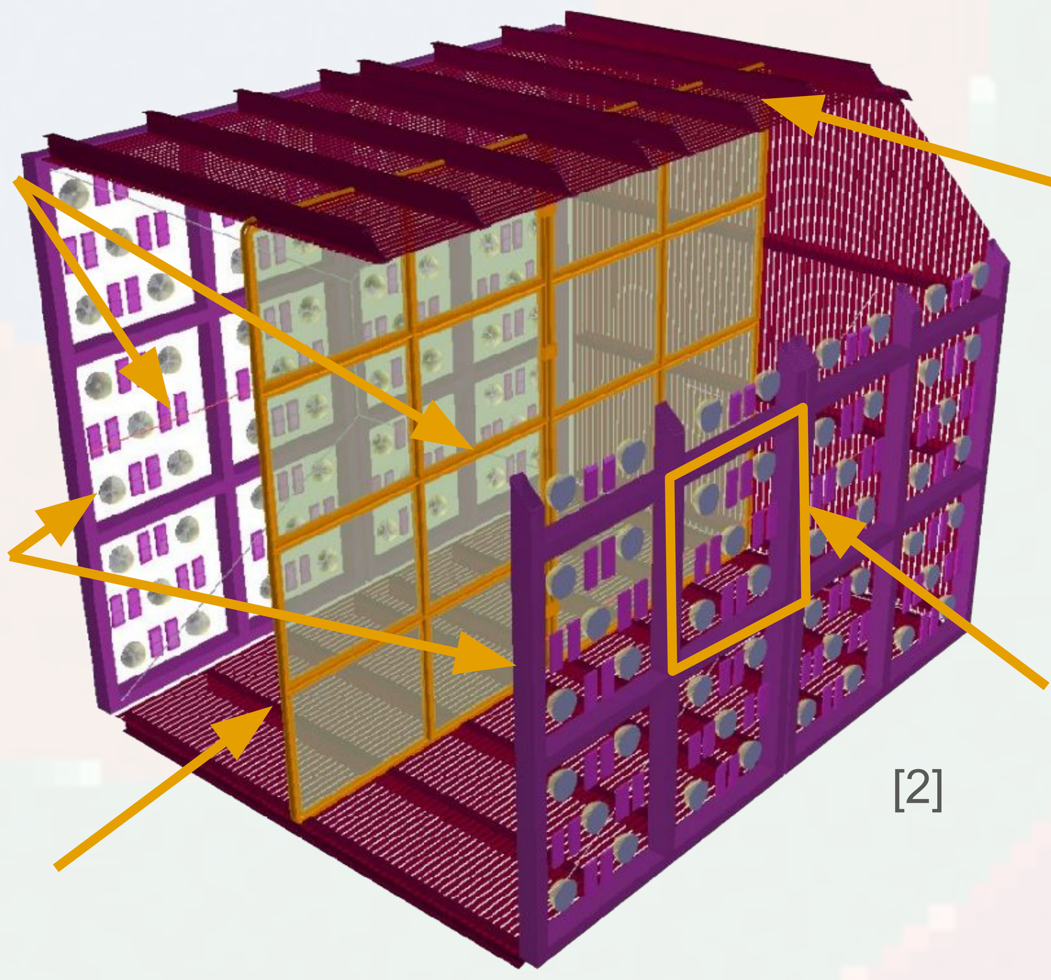
SBND Physics

SBND is one of 3 detectors along a ν_μ beam at Fermilab [1] forming the Short-Baseline Neutrino programme. This has the aims of:

- ❖ Searching for sterile neutrinos
- ❖ Studying neutrino-argon interactions
- ❖ Searching for new physics

Oscillation searches at SBND:

- ❖ Will measure about 2 million neutrino-argon interactions each year → largest dataset
- ❖ Short baseline of 110m → sensitive to very fast oscillations
  - ➢ Large squared mass splittings, in the region of prior hints



SBND has recently completed the filling with LAr stage and is currently in the commissioning/calibrations stage.

VALOR Neutrino Fitting Framework

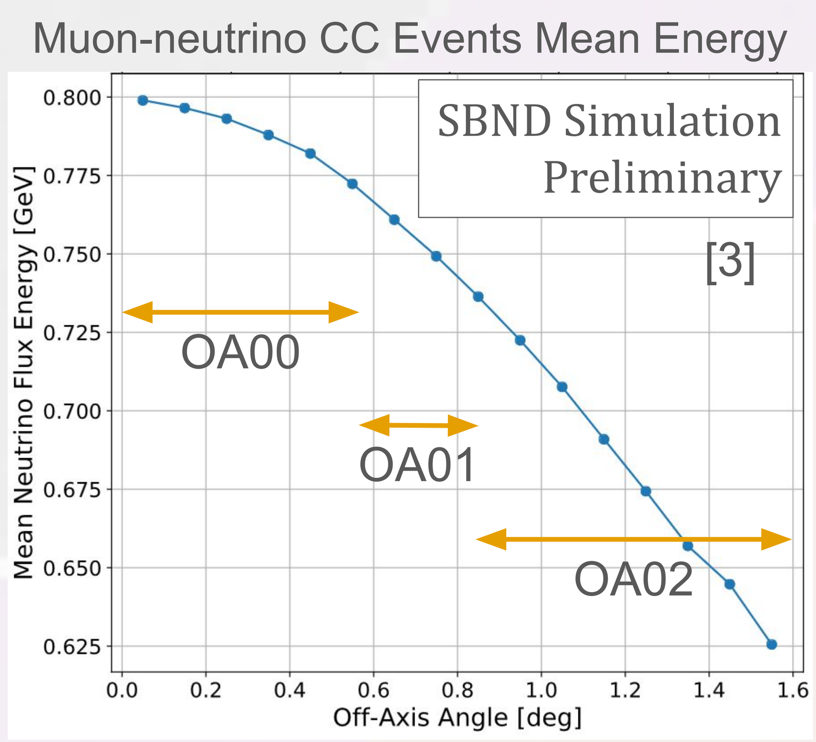
VALOR simultaneously fits for oscillation and systematic parameters.

- ❖ Capable of complex fits using combinations of oscillation channels and inclusive or exclusive samples
- ❖ Unique granularity by defining systematics by reaction mode
- ❖ Obtains explicit systematic constraints

Use post fit parameters to inform targeted modifications to the analysis:

- ❖ Improve interaction systematic constraints → exclusive and semi-exclusive topologies
- ❖ Improve flux systematic constraints → off-axis bins (PRISM)

The PRISM Concept



The PRISM concept uses measurements from multiple off axis (OA) locations. These samples have different energy spectra and compositions. Moving off axis:

- ❖ Ratio of muon to electron neutrinos decreases
- ❖ Electron neutrino energy spectrum is constant
- ❖ Muon neutrino energy spectrum has decreased mean (shown)

Motives for using PRISM:

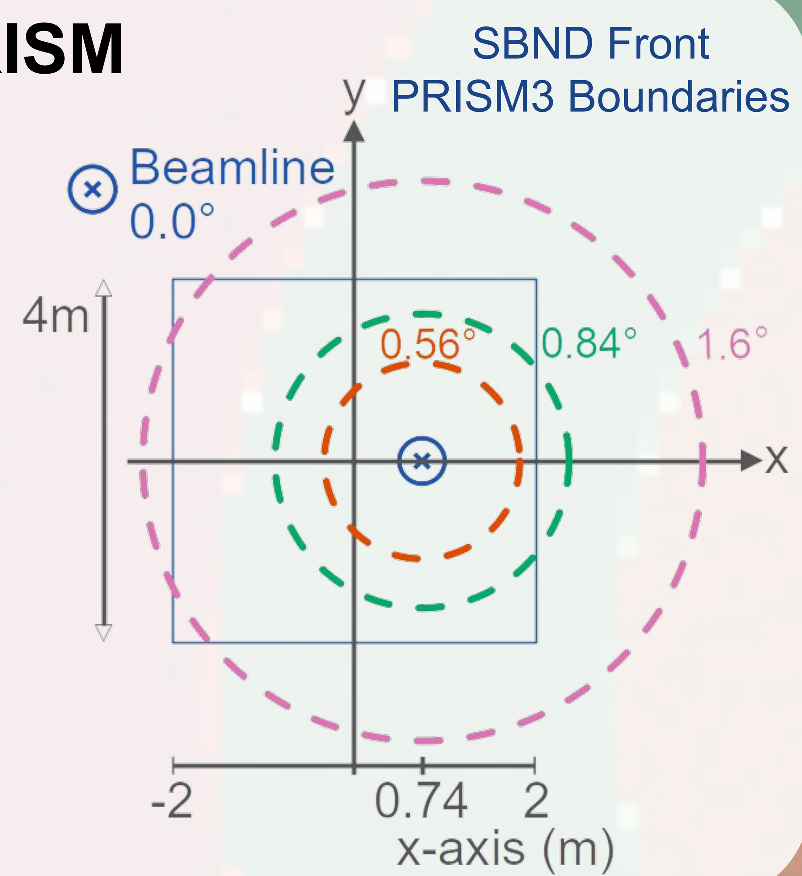
- ❖ Improved systematic constraints and degeneracy resolution
  - ➢ Differing energy in each sample
    - ▪ The observables are not the same in each sample
    - ▪ Extra observable → more handles on the systematics
- ❖ Enhanced oscillation sensitivity

SBND-PRISM

- ❖ Sees up to 1.6° off axis (OA)
  - ➢ 74cm OA
  - ➢ Close to target
- ❖ Systematics still dominate
  - ➢ Statistics large in OA samples

SBND: standard whole detector approach, integrated across all off axis angles.

PRISM3: splitting SBND into 3 angular bins with ~equal statistics (shown)



[1] Acciarri R, et al. Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in them Fermilab Booster Neutrino Beam. 2015.

[2] Jones R. Status of the Short-Baseline Near Detector at Fermilab. ICHEP 2022.

[3] Del Tutto M., et al. SBND-PRISM: Sampling Multiple Off-Axis Fluxes with the Same Detector. APS April Meeting 2021.

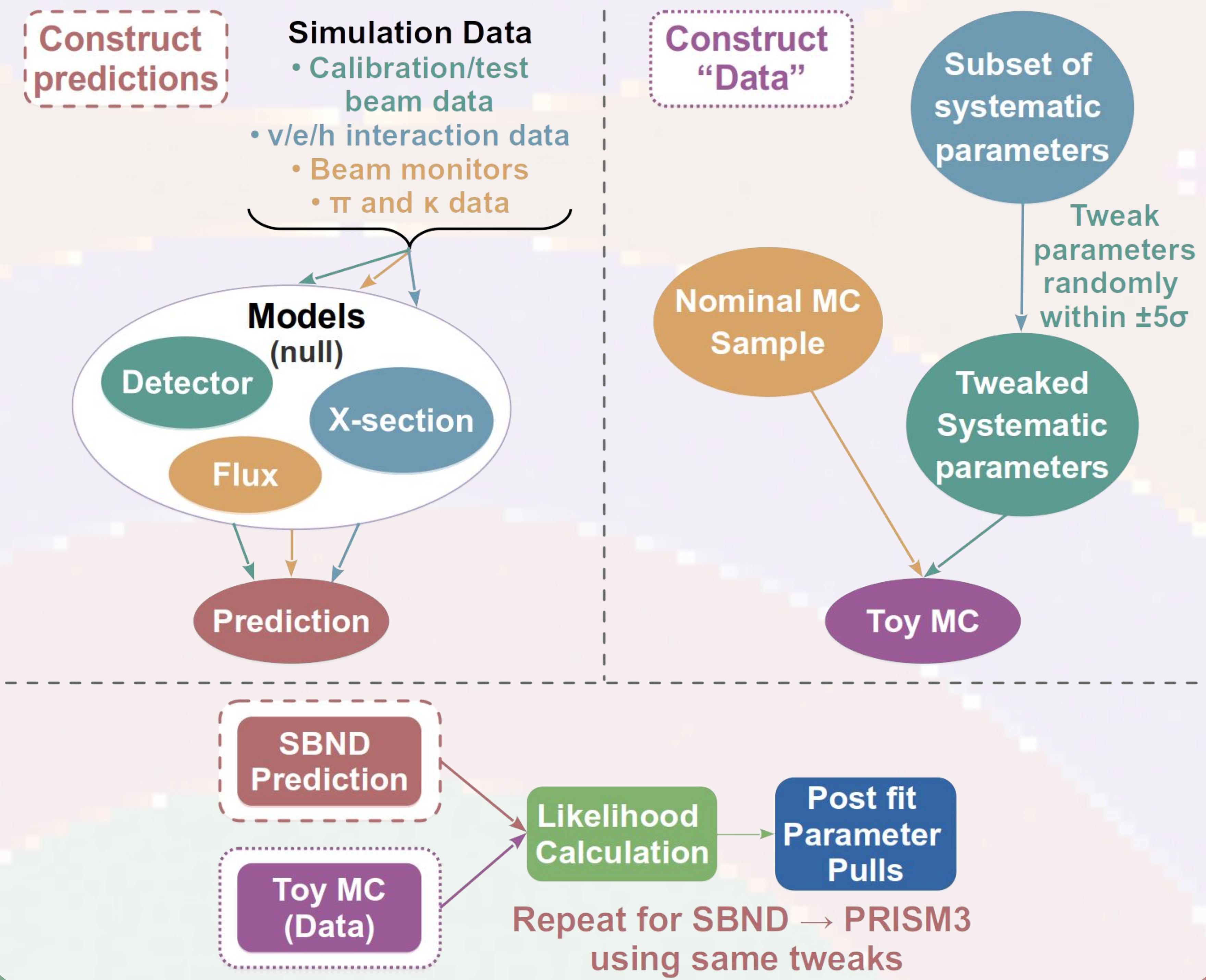
Improvements with PRISM

Test if analysis is capable of correctly determining applied tweaks to a subset of dominant parameters by assigning:

- ❖ Appropriate parameter pulls
- ❖ Sensible corresponding uncertainties

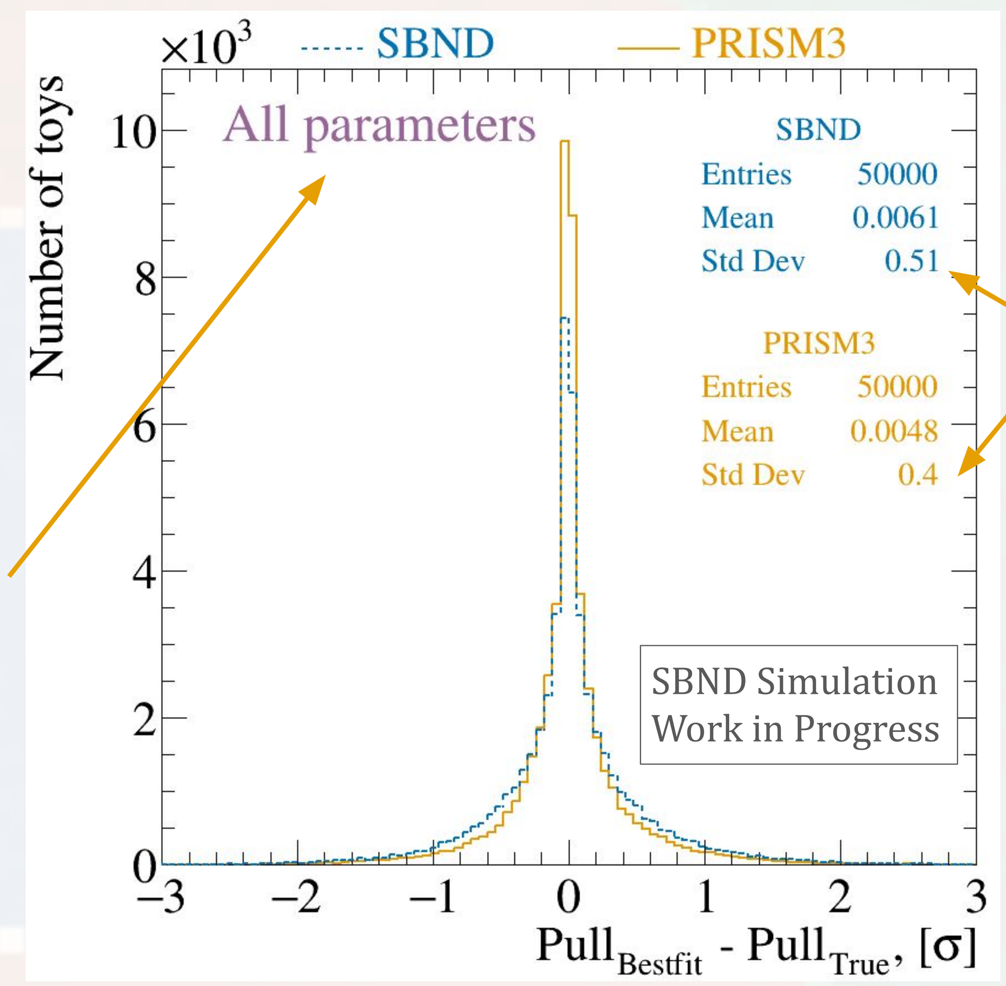
Compare results from inclusive fits under the no-oscillation hypothesis using PRISM3 and standard SBND.

Repeat the following for 5,000 sets of tweaked parameters:



Comparison of Postfit Parameter Pulls

- ❖ SBND gives correct pull **81%** of the time
- ❖ PRISM3 gives correct pull **88%** of the time



Using SBND-PRISM has been demonstrated to consistently improve systematic constraints for a variety of dominant parameters.