A Joint Search for Muon Neutrino Disappearance with the Short-Baseline Neutrino Program Using the SPINE Deep Learning-Based Reconstruction Package

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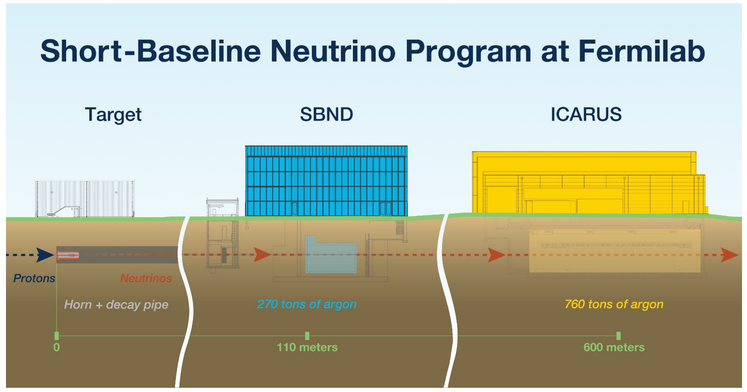
The Short-Baseline Neutrino Program

The Short-Baseline Neutrino (SBN) Program at Fermilab aims to discover or exclude eV-scale sterile neutrinos through a dedicated multi-detector configuration.

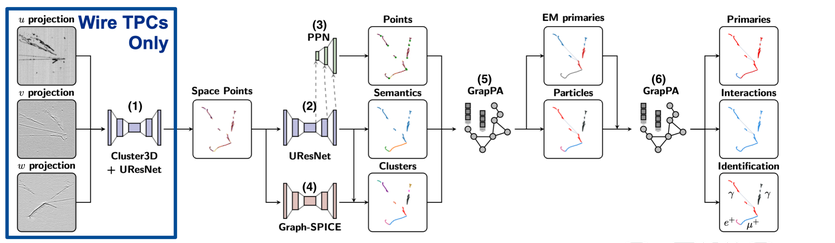
Sampling the Booster Neutrino Beam (BNB) simultaneously with a near detector (SBND) and a far detector (ICARUS) leads to a strong constrain on the flux and cross section systematic uncertainties.



The SPINE Reconstruction

Convolutional Neural Net (CNN)

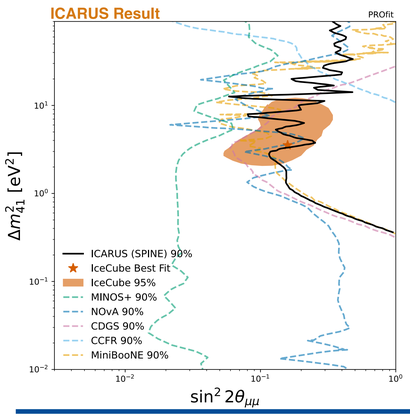
Graph Neural Net (GNN)

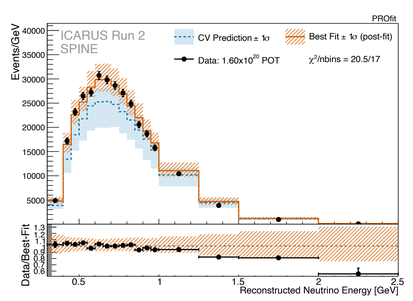


SPINE employs a series of neural networks to perform successively higher-level reconstruction tasks: CNNs for point-level features and GNNs for particle-level features. This delivers high selection efficiency, high selection purity, and excellent energy resolution, which together sharpen oscillation sensitivity.

SPINE Github!

Beginning at the Far Detector (ICARUS)

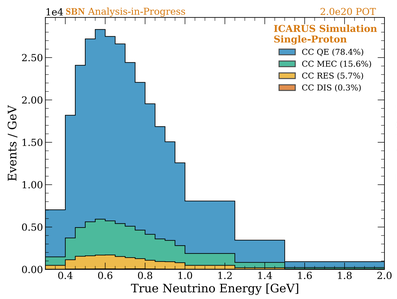


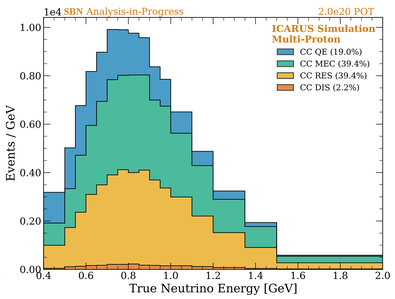


arXiv:2603.22557

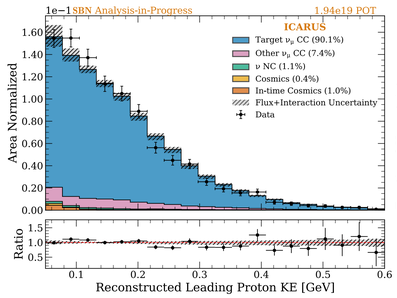
Previous ICARUS-only results are highly limited by systematics

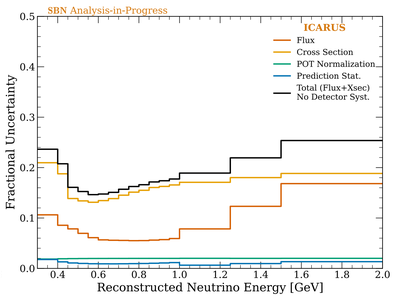
ICARUS Selection Performance





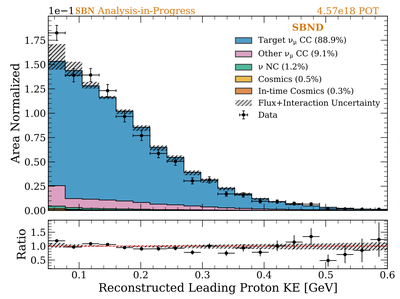
The SPINE selection isolates the $1\mu Np0\pi$ target topology with ~90% purity and ~80% efficiency. As a single-detector measurement, the result is limited by flux and cross section systematics, which dominate the uncertainty budget across the full energy range.

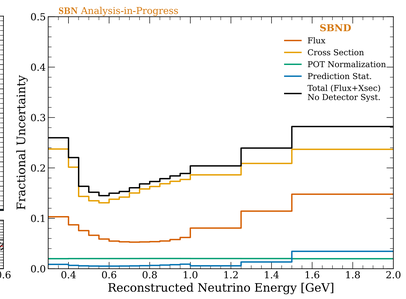




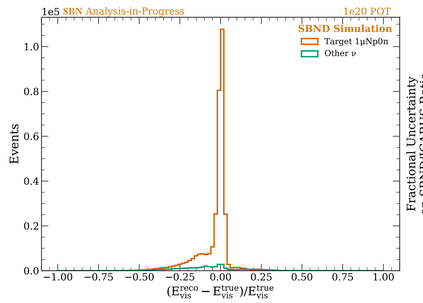
Adding the Near Detector (SBND)

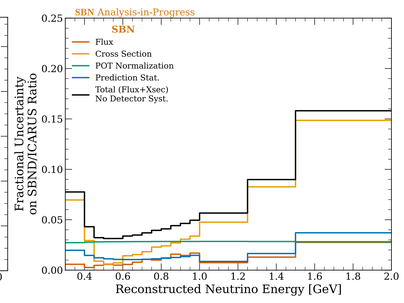
The same selection is used at SBND and achieves similar selection purity and selection efficiency to ICARUS — ideal for preserving correlated systematic uncertainties.





The impact of including the near detector can be seen in the near/far ratio: the correlated systematics that limited the single-detector measurement are constrained.





These results establish the SPINE-based selection for SBN's first joint oscillation analysis — the next step toward realizing the ultimate goal of the SBN Program.

Acknowledgements

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