Short-Baseline Neutrino Program

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Outline

Overview of SBN

- Three neutrino detectors at Fermilab [Machado *et al.* 2019]
- Short-baseline
- Currently ongoing
- Motivated by LSND and MiniBooNE results
- Precursor to DUNE

Outline

Neutrino Oscillations

- Freely-travelling neutrinos can oscillate in flavor [Bellini *et al.* 2014]
- Oscillation is characterized by the PMNS matrix
- Oscillation probability depends on neutrino energy and distance travelled

$$|U| = \begin{bmatrix} |U_{e1}| & |U_{e2}| & |U_{e3}| \\ |U_{\mu 1}| & |U_{\mu 2}| & |U_{\mu 3}| \\ |U_{\tau 1}| & |U_{\tau 2}| & |U_{\tau 3}| \end{bmatrix} = \begin{bmatrix} 0.803 \sim 0.845 & 0.514 \sim 0.578 & 0.142 \sim 0.155 \\ 0.233 \sim 0.505 & 0.460 \sim 0.693 & 0.630 \sim 0.779 \\ 0.262 \sim 0.525 & 0.473 \sim 0.702 & 0.610 \sim 0.762 \end{bmatrix}$$

[1]

[1] 3σ ranges of November 2022, From Wikipedia

Sterile Neutrinos

Sterile Neutrinos

How can sterile neutrinos actually be observed?

Detecting Sterile Neutrinos

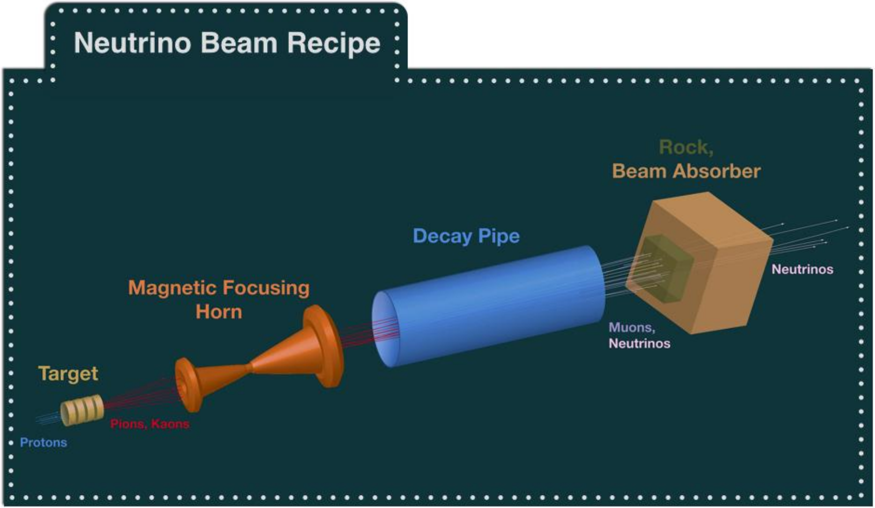
- LSND and MiniBooNE data seems to show anomalies (3-4 σ) [Machado *et al.* 2019]
- Anomalies could be explained by a fourth, heavy ν
- Null results from other experiments complicate things

Other Goals of SBN

- Better understanding of neutrino-nucleus interactions [Machado *et al.* 2019]
- Serve as precursor to DUNE
- Milli-charged particles?
- Dark matter candidates?
- Other beyond-the-Standard-Model physics?

Outline

Making a ν_μ beam

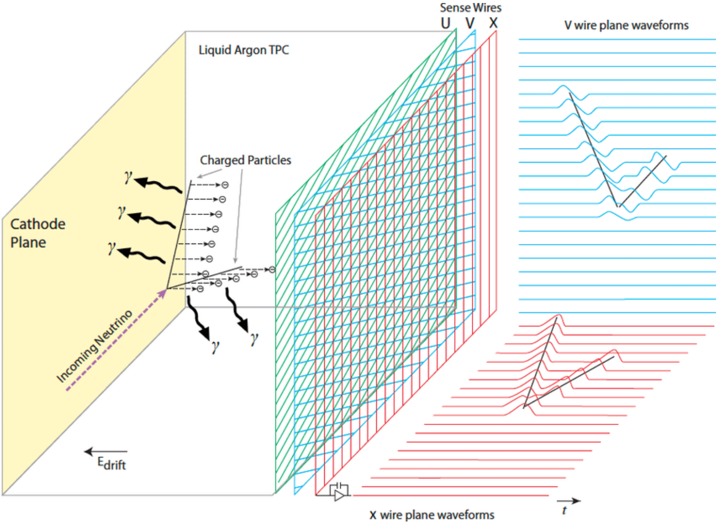


Miceli 2014

Liquid Argon Time Projection Chambers (LArTPCs)

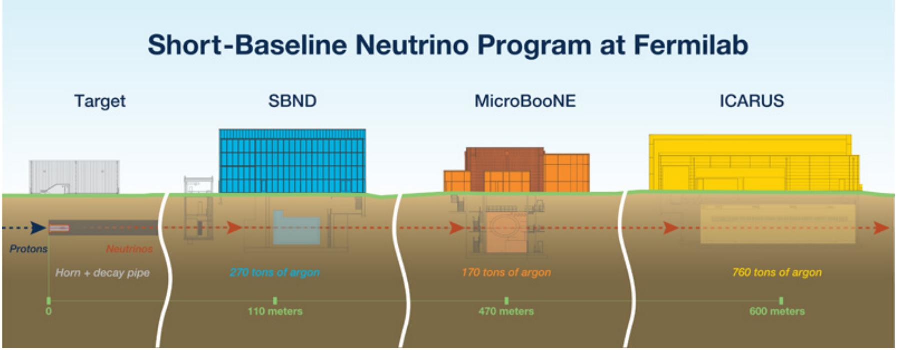
- A bubble chamber filled with liquid argon [Gamez 2018]
- Charged particles ionize argon, neutral particles don't (but can decay / interact)
- Electrode planes and photosensors allow 3-D reconstruction

Liquid Argon Time Projection Chambers (LArTPCs)



Abi *et al.* 2020

The SBN Detectors



Short-Baseline Neutrino Program at Fermilab 2019

Outline

Example of an Event

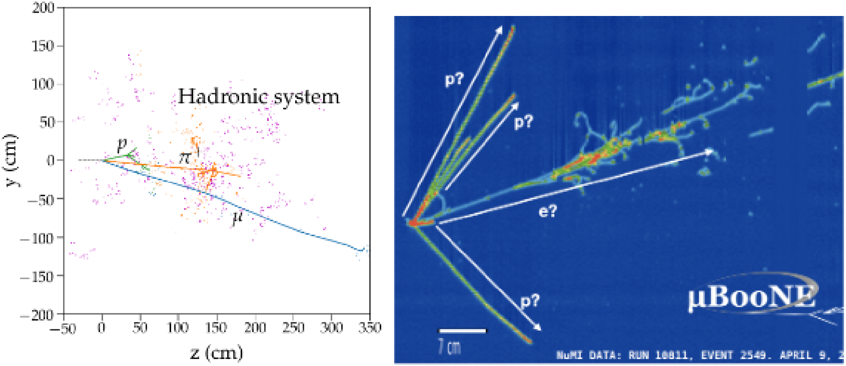


Figure: LEFT: A 4 GeV ν_μ simulated event in liquid argon.

RIGHT: Example of a candidate neutrino interaction in the MicroBooNE detector, displaying electromagnetic activity. [Caratelli *et al.* 2022]

Some Analysis Notes

- Analysis involves measurement of neutrino flavor rates at each SBN detector
- Powerful algorithms reconstruct particle flavor [Caratelli *et al.* 2022]
- LArTPC technology allows improvement over previous experiments [Machado *et al.* 2019]
- Background includes cosmic rays, solar neutrinos
- Having three (almost identical) detectors reduces systematic uncertainties

Outline

In Summary

- Neutrinos are a promising sector for new physics
- Both a discovery and a precision machine
- Why I like SBN
- What I found challenging about SBN

References I

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[2] G. Bellini, L. Ludhova, G. Ranucci, and F. L. Villante, "Neutrino oscillations," *Advances in High Energy Physics*, vol. 2014, pp. 1–28, 2014, ISSN: 1687-7365. DOI: 10.1155/2014/191960. [Online]. Available: http://dx.doi.org/10.1155/2014/191960.

[3] T. Miceli, *How to make a neutrino beam*, Dec. 2014. [Online]. Available: https://www.fnal.gov/pub/today/archive/archive_2014/today14-12-11_NutshellReadMore.html.

References II

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[7] D. Caratelli *et al.*, “Low-energy physics in neutrino lartpcs,”, 2022. arXiv: 2203.00740 [physics.ins-det].