A Search for Sterile Neutrinos at the NOνA Far Detector

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Abstract

We measured things. And searched for other things. Here is what we found, please let me graduate.

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This is the dedication.

Acknowledgments

These people were cool.

1

A Brief History of Neutrinos

1.1 Introduction

The neutrino was first postulated by Wolfgang Pauli as a possible explanation for the continuous spectrum of electrons emitted from nuclear β decay [1]. This decay was originally thought to be the emission of an electron from an atom, resulting in a different nucleus, via the process,

$$N \to N' + e \tag{1.1}$$

where N and N' are the parent and daughter nuclei, respectively. In a two body decay such as this, the momenta and energies of the outgoing particles are exactly constrained. Pauli's new particle explained the continuous spectrum of electron energy via a modified decay process:

$$N \to N' + e + \nu \tag{1.2}$$

where ν is the outgoing neutral particle. Pauli's original proposal called the new particle the neutron, but this name was later used to name the massive neutral nucleon discovered by Chadwick in 1932 [2]. Three years after Pauli's idea, Fermi proposed a model for nuclear β decay that included the new particle, which he coined the neutrino, or little neutral one [3].

1.2 First Detection of Neutrinos

Twenty years passed from Fermi's model proposal before neutrinos were discovered experimentally. Reines and Cowan made the discovery by placing a detector near a nuclear reactor as a source of neutrinos and observing inverse β decay [4, 5]. The neutrinos observed were anti-electron neutrinos, thus the following was the observed process.

$$p + \bar{\nu}_e \rightarrow n + e^+. \tag{1.3}$$

Fred Reines earned the Nobel Prize in Physics in 1995 for the detection of the neutrino.

In 1962, the muon neutrino was discovered at Brookhaven National Laboratory using the first neutrino beam [6] in a scheme still used in neutrino experiments today. The beam was generated by colliding protons with a target, producing pions that decayed into muons and muon neutrinos. The resultant beam then passed through thick steel, absorbing everything but the neutrinos. Leon Lederman, Melvin Schwartz, and Jack Steinberger won the Nobel Prize in Physics in 1988 for the discovery of the muon neutrino.

The last generation of neutrino, the tau neutrino, was discovered at Fermilab by the DONUT collaboration in 2000 [7].

1.3 First of Evidence of Oscillations

1.4 Possible Evidence of Sterile Neutrinos

The number of active neutrinos is constrained by measurements of the width of the Z boson. LEP has measured the number of active neutrinos to be 2.984 ± 0.008 [8], so the discoveries of the ν_e, ν , and ν

leave no room for new active neutrinos.

2

Theory of Neutrino Oscillations

2.1 Standard 3-Flavor Oscillations

2.2 Matter Effects

2.3 Sterile Neutrinos

2.4 Current Measurements

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The NOνA Experiment

3.1 Introduction

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Experiment Simulation

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Event Reconstruction

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Neutral Current Disappearance Analysis

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Analysis Results and Systematic Errors

8.1 Fitting Method

8.2 Systematic Errors

8.3 Results

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Conclusions and Future Improvements

9.1 Conclusions

The results of this analysis are consistent with no sterile neutrinos.

9.2 Future Improvements

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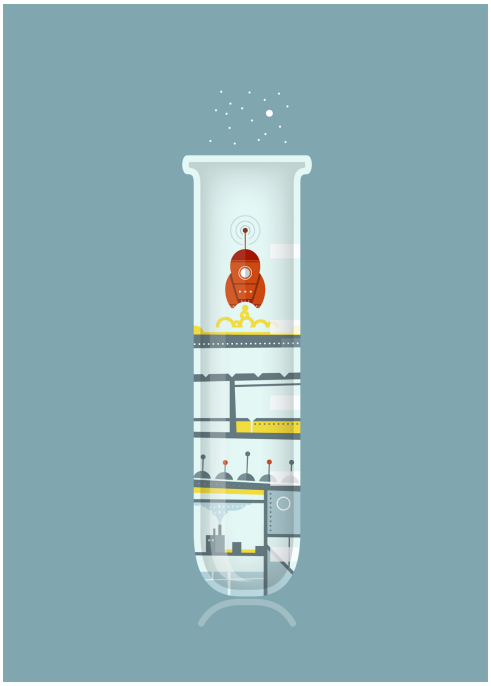

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