Abstract

In sterile neutrino (3+1) parameterisation, we observe that sterile phases (\(\theta_{14}, \theta_{24}\)) are always together in oscillation probability, even when the MSW effect is considered. We see that the difference between the sterile phases has a more dominating effect over event rates compared to small variations due to changes in individual values. In this work, we show the value of sterile phase difference (\(\delta_{14} - \delta_{24}\)) least effects the parameter degeneracy resolution of \(\delta_{14}, \theta_{24}\) at NOvA. We find the value of sterile phase difference that will give a greater chance at sterile neutrino discovery.

Introduction

- LSND and MiniBooNE have experimental results which could be interpreted as due to a new neutrino with a mass \(\sim 1\, eV\).
- As the LEP experiment limits no: of active neutrino flavors to 3, the new neutrino must be a sterile (No weak interaction) neutrino.
- Sterile neutrino introduces new parameters to be measured which increases the degrees of freedom and will affect degeneracy resolution capabilities of detectors.

(3+1) Sterile Neutrino Model

- We worked on one sterile neutrino model (3+1). The 3+1 model parameterisation is
  \[ U_{PMNS} = R_{12}(\theta_{23})R_{14}(\theta_{14}, \delta_{14}) \rho_{14}R_{12}(\theta_{13}, \delta_{13})U_{PMNS}. \]  
- We see that addition of one sterile neutrino introduces 3 new mixing angles and 2 new CP-phases.
- Measuring these new parameters is important for the study of sterile neutrinos.
- Short baseline(SBL) experiments give good bounds on sterile mixing angles, while long baseline (LBL) experiments explore CP phases. Combining both gives us better measurements.
- \(P_{\mu e}\) for LBL experiments in 3+1 model is expressed as sum of the four terms
  \[ P_{\mu e}^{\text{true}} \equiv P_1 + P_2(\delta_{13}) + P_3(\theta_{13} - \delta_{13}) + P_4(\theta_{13} - (\delta_{14} - \delta_{24})). \]  
- The first two terms give ordinary CP violation, the last two terms of equation give the sterile CP phase dependence terms.
- Here we observe that \(\delta_{13}\) and \(\delta_{24}\) are always together in form of \(\delta_{14} - \delta_{24}\). That implies that in vacuum case, individual values of \(\delta_{14}\) and \(\delta_{24}\) do not matter, only the difference \(\delta_{14} - \delta_{24}\) matters as shown in below figure 1.

Results

- We used GLoBES (General Long Baseline Experiment simulator [1, 2]) to simulate the data for NOvA.
- In this work, we try to see which value of \(\delta_{14} - \delta_{24}\) least effects the parameter degeneracy of resolution of \(\delta_{14}, \theta_{24}\).
- We use latest NOvA Best fit values [3] as true values for this analysis
- For sterile mixing angles, we take upper bounds given in NOvA neutral current analysis paper. [4]
  \[ \theta_{14} = 10^\circ; \theta_{24} = 20.8^\circ; \theta_{13} = 31.2^\circ. \]
- We explore allowed regions in \(\sin^2 2\theta_{23}\)-\(\delta_{12}\) plane from NOvA simulation data with different runtimes and different values of \(\delta_{14}\) and \(\delta_{24}\) considering latest NOvA results as true values.

Conclusion and Future Work

- We plot test values for both NH-HO and NH-LO, of 3 and 3+1 neutrino models for NOvA[3+4] run-time.
- We see that for both NH-HO and NH-LO case, \(\delta_{14} - \delta_{24} = 180\) has highest sensitivity to parameter degeneracy.

Acknowledgments

- I would like to thank my supervisor Prof. Bindu A. Bambah, SSP, UOH, India for invaluable guidance.
- My sincere gratitude to Fermilab organizing committee, Chicago, United States, for inviting me to 53rd Annual Users Meeting and giving me this golden opportunity to present this poster.

References


Figure 1: \(P_{\mu e}\) for NOvA for various \(\delta_{14} - \delta_{24}\) at 1.5 GeV for vacuum case(left) and matter case (right).

- We plotted bands for different \(\delta_{14} - \delta_{24}\) values while changing the individual values of \(\delta_{14}\) and \(\delta_{24}\) in figure 2. We observe small variations due to individual values of \(\delta_{14}\) and \(\delta_{24}\) at all energies.

Figure 2: \(P_{\mu e}\) for NOvA under matter effects for different energies

Figure 3: Bi-event plot when \(\theta_{12}\) = 0 for different values of \(\delta_{14} - \delta_{24}\)

Figure 4: The contours of this figure are plotted for 90% C.L regions. We take NH-HO (NH-LO) as true values for left(right) case.

Figure 5: Measurement capacity of \(\delta_{14}\) for different values of \(\delta_{24}\) and \(\delta_{14} - \delta_{24}\).