Development of a joint oscillation analysis by the NOvA and T2K collaborations

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1 Introduction

The T2K [1] and NOvA [2] experiments study neutrino flavor oscillations over long baselines using relatively narrow-band beams of neutrinos and antineutrinos. Through measurements of $\nu_\mu \to \nu_\mu$ and $\nu_\mu \to \nu_e$ oscillation probabilities and their antineutrino counterparts, each experiment is setting new constraints on key parameters in the neutrino sector including:

- The CP-violating Dirac phase of the neutrino mixing matrix, δ_{CP}: $\sin\delta_{CP} \neq 0$ would indicate CP violation in neutrinos.
- The PMNS mixing angle θ_{23}: Current data suggests θ_{23} is near 45°, a noteworthy value given the μ/τ flavor symmetry it would imply. Increased precision is needed to resolve how far θ_{23} may lie from this "maximal mixing" value.
- The mass splitting Δm^2_{32}: Both experiments are making precise measurements of the magnitude of this splitting, however the sign of the splitting (*i.e.*, the "mass ordering" or "mass hierarchy") is unknown and is a major experimental target.

It has long been recognized that the different neutrino baselines of the experiments (NOvA at 810 km and T2K at 295 km) and the correspondingly different beam energies (NOvA near 2 GeV and T2K near 0.6 GeV) offer significant complementarity, most notably in how strongly the $\nu_\mu \to \nu_e$ and $\overline{\nu}_\mu \to \overline{\nu}_e$ rates depend on the mass ordering. Aspects of this complementarity can be seen in Figure 1, which shows a piece of the most recent T2K [3] and NOvA [4] results reported at the Neutrino 2020 conference. In the figure, preferences for all values of δ_{CP} are shown under both the normal ($\Delta m^2_{32}>0$) and inverted ($\Delta m^2_{32}<0$) neutrino mass ordering scenarios. The NOvA plot further splits the curves into upper ($\theta_{23}>45°$) and lower ($\theta_{23}<45°$) octant cases. The T2K curves show only a mild dependence on mass ordering, while the NOvA curves differ qualitatively between the two orderings. Each experiment prefers (at low significance) the normal mass ordering but at opposing δ_{CP} values. (Caution: the two panels use different conventions for the x-axis range.) For the inverted ordering, the experiments prefer similar values of δ_{CP}.

2 Joint Analysis

The T2K and NOvA collaborations have recently begun work towards a joint neutrino oscillation analysis using both experiments' data sets simultaneously, with the aim of enhancing the oscillation parameter

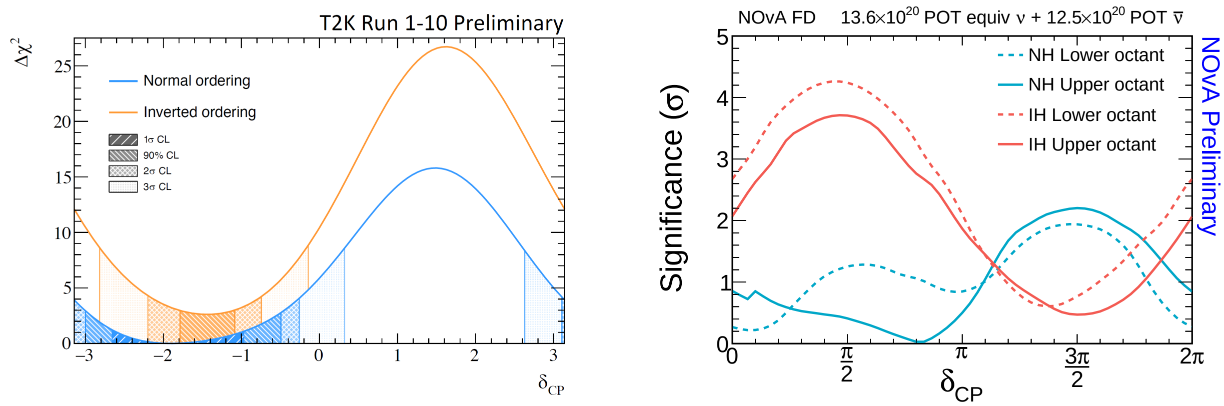

Figure 1: The relative preferences for values of δ_{CP} from the most recent T2K (left) and NOvA (right) oscillation analyses. Discussion in text.

measurements beyond what either collaboration can do individually. The benefits of this official joint analysis are manifold and go well beyond the raw oscillation parameter dependences.

- The direct complementarity between the experiments in oscillation parameter space can be exploited.
- Fully detailed likelihood functions for both experiments can be used.
- Appropriate methods for joint statistical inference can be brought to bear.
- Differences in the experiments' neutrino interaction models can be studied and, where required, reconciled.
- Systematic uncertainties can be correlated between the two experiments where appropriate.
- The substantially different approaches taken by T2K and NOvA for incorporating Near Detector data, estimating neutrino energies, and reducing the influence of systematic uncertainties can be studied deeply by experts from both experiments. This helps not only in producing a robust joint analysis but also in the continuing development of techniques for future long baseline experiments.

The projected timescale for a first NOvA-T2K joint analysis is 2021 - 2022.

References

[1] See the Snowmass 2021 LOI submitted by the T2K Collaboration, `https://snowmass21.org/loi`

[2] See the Snowmass 2021 LOI submitted by the NOvA Collaboration, `https://snowmass21.org/loi`

[3] P. Dunne on behalf of the T2K Collaboration, "Latest Neutrino Oscillation Results from T2K", The XXIX International Conference on Neutrino Physics and Astrophysics (Neutrino 2020), `https://conferences.fnal.gov/nu2020/`

[4] A. Himmel on behalf of the NOvA Collaboration, "New Oscillation Results from the NOvA Experiment", The XXIX International Conference on Neutrino Physics and Astrophysics (Neutrino 2020), `https://conferences.fnal.gov/nu2020/`