Neutrino Sector Predictions from the Bilateral Crossing Geometry

Inverted Mass Ordering, Zero Lightest Mass,
and the PMNS Parameters as Falsifiable Predictions

Updated April 2026 with JUNO First Results (November 2025)

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Abstract

We state the complete neutrino sector predictions of the bilateral crossing framework as a self-contained falsifiable package. The framework predicts: inverted mass ordering with $m_3 = 0$ exactly; the neutrino Koide value $K_\nu = 1/2$ (confirmed at 0.001% against current IO oscillation data); $\sum m_i \approx 99.9$ meV; and four PMNS parameters all within 3.5% or 1σ of observation. All predictions follow from the geometry of $S^3 \times \mathbb{CP}^2$ without free parameters.

November 2025 update: JUNO published first results after 59 days of operation, measuring solar oscillation parameters with record precision. The mass ordering has not been determined; the decisive measurement requires ∼6.5 years of full exposure (∼2031–2032). The global preference for normal ordering remains at 1.5–2σ — not decisive. The bilateral prediction of inverted ordering is not yet falsified.

If JUNO confirms normal ordering the neutrino sector is falsified. If JUNO confirms inverted ordering with $m_3 \to 0$ the framework gains a major confirmation.

Contents

1 Introduction

The bilateral crossing framework [1] derives the Standard Model from the geometry of $S^3 \times \mathbb{CP}^2$. The neutrino sector predictions follow from two inputs: the identification of the third neutrino with the τ_0 massless state, and the volume of $\mathbb{CP}^2$ as the neutrino Koide value.

The neutrino mass ordering is the sharpest falsifiable prediction of the bilateral framework. If JUNO confirms normal ordering, the neutrino sector is falsified and the revision required will be precisely located. The current experimental situation is described in Section 7. All predictions stand unchanged.

2 The τ_0 Massless Condition

Definition 2.1 (τ_0 Massless State)**.** *The crossing point τ_0 carries no rest mass by Axiom A3: it is the crossing event itself, dimensionless, not a stable propagating state.*

Prediction 1 ($m_3 = 0$)**.** *The third neutrino mass eigenstate has exactly zero mass: $m_3 = 0$. This is a precise prediction, not an approximation.*

3 Inverted Mass Ordering

Prediction 2 (Inverted Ordering)**.** $m_3 < m_1 < m_2$ *with* $m_3 = 0$.

Given $m_3 = 0$ and PDG 2024 IO mass splittings:

$$m_3 = 0, \quad m_1 = 49.5 \text{ meV}, \quad m_2 = 50.3 \text{ meV}.$$

4 The Neutrino Koide Value

Prediction 3 (Neutrino Koide Value)**.** $K_\nu = \text{Vol}(\mathbb{CP}^2)/\pi^2 = 1/2$.

Table 1: Neutrino Koide value: prediction vs. IO oscillation data.

Quantity	Value	Note
K_ν (predicted)	0.500000	from $\text{Vol}(\mathbb{CP}^2)$
K_ν (IO data)	0.500007	
Deviation	0.001%	not a fit

The complete Koide algebra: $K_\nu : K_{\text{eg}} : K_{\text{down}} : K_{\text{up}} = 1/2 : 2/3 : 3/4 : 4/(3\varphi)$.

5 The Sum of Neutrino Masses

Prediction 4 (Sum of Masses)**.** $\sum m_i = 49.5 + 50.3 + 0 \approx 99.9$ *meV.*

Consistent with the Planck bound $\sum m_i < 120$ meV (95% CL). Will be tested by CMB-S4 and Simons Observatory to $\sim$ 20–30 meV precision.

6 The PMNS Mixing Parameters

Prediction 5 (PMNS Parameters)**.**

$$\begin{aligned}\theta_{12} &= \pi/3 - \arctan(1/2) = 33.43^\circ,\\ \theta_{13} &= \arcsin(1/\sqrt{42}) = 8.88^\circ,\\ \theta_{23} &= \arctan(7/6) = 49.40^\circ,\\ \delta_{\mathrm{CP}} &= 3\pi/2 = 270^\circ.\end{aligned}$$

Table 2: PMNS predictions vs. observation (IO, PDG 2024).

Parameter	Formula	Predicted	Observed	Deviation
θ_{12}	$\pi/3 - \arctan(1/2)$	33.43°	$33.41^\circ \pm 0.75$	0.07%
θ_{13}	$\arcsin(1/\sqrt{42})$	8.88°	$8.58^\circ \pm 0.11$	3.5%
θ_{23}	$\arctan(7/6)$	49.40°	$49.5^\circ \pm 1.1$	0.20%
δ_{CP}	$3\pi/2$	270°	$282^\circ \pm 28$	0.4σ

7 JUNO Update: First Results (November 2025)

7.1 What JUNO Has Measured

JUNO began data taking 26 August 2025 and published first physics results 18 November 2025 [3] after 59.1 days of operation.

JUNO measured solar oscillation parameters with record precision:

$$\sin^2\theta_{12} = 0.3092 \pm 0.0087, \quad \Delta m^2_{21} = (7.50 \pm 0.12) \times 10^{-5}\ \mathrm{eV}^2,$$

improving on all previous measurements by factors of 1.6 and 1.8. These results confirm a 1.5σ tension between reactor and solar θ_{12} measurements. **The results were presented assuming normal ordering. The mass ordering has not yet been determined.**

7.2 Updated Timeline

The mass ordering sensitivity requires the full Δm^2_{31}-driven interference pattern. Reaching 3σ sensitivity requires approximately 6.5 years of full-power exposure [4]. The decisive determination is expected around **2031–2032**, not 2027 as previously stated. A combined analysis with T2K and NOvA may yield 3σ sensitivity earlier ($\sim$2026–2028).

7.3 Status of the Bilateral Prediction

The bilateral prediction of inverted ordering with $m_3 = 0$ is **not yet falsified**. Current situation (April 2026):

- T2K + NOvA + atmospheric: 1.5–2σ preference for normal ordering. Non-decisive.
- JUNO first results: analysed under normal ordering assumption; ordering determination pending.

- Global fit NuFIT 6.1 (incorporating JUNO): non-decisive preference for normal ordering.

The trend toward normal ordering is noted honestly. If this preference reaches $\geq 3\sigma$ before the full JUNO determination, the bilateral neutrino sector will be under serious pressure. The prediction stands as stated; the framework does not adjust in response to non-decisive data.

7.4 The Δm^2_{21} Measurement

JUNO measured $\Delta m^2_{21} = 7.50 \times 10^{-5}$ eV^2. This is consistent with current IO oscillation data within uncertainties. The Koide value confirmation ($K_\nu = 0.500007$, deviation 0.001%) is not materially affected by the JUNO measurement.

8 Summary of Predictions

Table 3: Complete neutrino sector predictions (April 2026).

Prediction	Value	Observation	Status
Mass ordering	Inverted	Slight NO preference	Not falsified
m_3	0 (exact)	< 0.45 eV	Consistent
K_ν	1/2	0.500007 (IO)	0.001%
$\sum m_i$	99.9 meV	< 120 meV	Consistent
θ_{12}	33.43°	$33.41^\circ \pm 0.75$	0.07%
θ_{13}	8.88°	$8.58^\circ \pm 0.11$	3.5%
θ_{23}	49.40°	$49.5^\circ \pm 1.1$	0.2%
δ_{CP}	270°	$282^\circ \pm 28$	0.4σ
JUNO decisive test			$\sim$2031–2032

9 Conclusion

The bilateral framework makes seven independent falsifiable neutrino predictions, all from $S^3 \times \mathbb{CP}^2$ geometry without free parameters. The sharpest is inverted ordering with $m_3 = 0$.

JUNO published first results in November 2025 with world-record precision on solar parameters, but has not determined the ordering. The decisive determination requires $\sim$6.5 years of full exposure ($\sim$2031–2032). The prediction stands. If JUNO confirms normal ordering, that prediction fails. If JUNO confirms inverted ordering with $m_3 \to 0$, the framework gains its strongest confirmation.

References

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