Leptonic CP is Majorana, not Dirac: a pre-registered neutrino-sector prediction set

($J_\ell = 0$, normal ordering, $m_{\beta\beta} \approx 2$–$3\,\mathrm{meV}$)

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Abstract

This short note pre-registers four linked, falsifiable neutrino-sector claims from the finite-QEC substrate programme, before the next generation of long-baseline and $0\nu\beta\beta$ data settles them. They follow from a single derivation chain, so they stand or fall together. **(1)** The leptonic *Dirac* CP phase is conserved: the Jarlskog invariant $J_\ell = 0$ and $\delta_{\mathrm{CP}} \in \{0, \pi\}$, because the PMNS mixing is the real error-correcting frame transport $U_{\mathrm{frame}} = \exp(\delta\, K_{R1}/3)$. **(2)** Leptonic CP violation is *Majorana*: it is carried by the discrete oriented-boundary sign pointer ωK_{R1} (eigenvalues $\{0, \pm\sqrt{3}\}$, diagonal in the mass basis), so it appears in $0\nu\beta\beta$ and leptogenesis, not in oscillations. **(3)** Normal ordering, with the neutrino spectrum fixed by the Koide circulant ($R_\nu = 1$, $\delta_\nu = 1/3$): $m = (0.79, 8.72, 50.2)\,\mathrm{meV}$ and $\sum m_\nu \approx 60\,\mathrm{meV}$. **(4)** The effective Majorana mass is $m_{\beta\beta} \approx 1.8\,\mathrm{meV}$ (or $3.1\,\mathrm{meV}$ for the opposite global orientation), inside a phase envelope $[0.7, 4.2]\,\mathrm{meV}$ — far below current (28–122 meV, KamLAND-Zen) and next-generation ($\sim$ 9–21 meV, LEGEND-1000/nEXO) reach. The set is consistent with all present data: NuFit-6.0 finds normal ordering compatible with CP conservation within 1σ (the strong $\delta_{\mathrm{CP}} \approx 270^\circ$ signal lives in the inverted ordering the framework excludes). It is falsified by: a high-significance nonzero long-baseline Dirac δ_{CP} in normal ordering; a $0\nu\beta\beta$ detection with $m_{\beta\beta} \gtrsim 10\,\mathrm{meV}$; an established inverted ordering; or $\sum m_\nu \gg 60\,\mathrm{meV}$. Numbers are frozen here as a dated claim; if data approach them the agreement is not to be reinterpreted as a fit, and if data exclude them the branch fails. Tier: conditional prediction (leading-order real frame transport, discrete-sign Majorana reading), not a locked result.

Plain summary

Neutrinos come in three types that mix as they travel, and the mixing may or may not treat matter and antimatter differently — "CP violation." Two separate kinds are possible: a *Dirac* kind that shows up in ordinary oscillation experiments, and a *Majorana* kind that only shows up if the neutrino is its own antiparticle, visible through the rare process of neutrinoless double-beta decay.

This note places a dated bet: in this framework the *oscillation* kind is switched off (the mixing pattern is built by a real "error-correcting" rotation, which cannot generate that phase), while *all* the CP violation sits in the Majorana kind. So long-baseline experiments should find no genuine Dirac CP violation in the (predicted) normal mass ordering, and the double-beta signal is fixed by the framework's neutrino masses to be tiny — about 2–3 thousandths of an eV, well below what even the next round of experiments can reach. Everything is written down in advance and is refutable: if oscillation data show clear Dirac CP violation, or if double-beta decay is seen at a much larger rate, or if the mass ordering turns out inverted, the prediction is wrong.

1 The predictions

All four follow from one chain (Section 2); they are one bet.

P1 — Leptonic Dirac CP is conserved.

$$\boxed{J_\ell = 0, \qquad \delta_{\rm CP} \in \{0, \pi\}} \tag{1}$$

The leptonic Jarlskog invariant vanishes: the framework's PMNS mixing is a real orthogonal matrix, so there is no Dirac (oscillation) CP violation.

P2 — Leptonic CP violation is Majorana. The CP content is the discrete oriented-boundary sign pointer ωK_{R1} (a Hermitian object with eigenvalues $\{0, \pm\sqrt{3}\}$, diagonal in the neutrino mass basis). Its phases are Majorana, so leptonic CP violation shows in $0\nu\beta\beta$ and in leptogenesis (the sign of the baryon asymmetry), not in oscillations.

P3 — Normal ordering, with a fixed spectrum. The neutrino Koide circulant ($R_\nu = 1$, $\delta_\nu = d/N = 3/9 = 1/3$) fixes the mass *ratios*; the atmospheric splitting Δm^2_{31} sets the scale:

$$\boxed{m_1 \approx 0.79\,\text{meV}, \quad m_2 \approx 8.72\,\text{meV}, \quad m_3 \approx 50.2\,\text{meV}, \quad \sum m_\nu \approx 60\,\text{meV}} \tag{2}$$

normal ordering. This is self-consistent: the same $\delta_\nu = 1/3$ gives $\Delta m^2_{21}/\Delta m^2_{31} = 0.030$ against the measured 0.0295.

P4 — The effective Majorana mass. With the real U_{ei} of P1 and the sign-pointer parities of P2 (the $(1,1,1)$ singlet mass eigenstate ν_2 is the reference; ν_1, ν_3 carry opposite CP parity, the choice fixed by the global orientation σ),

$$\boxed{m_{\beta\beta} \approx 1.8\,\text{meV}\ (\sigma = +) \quad \text{or} \quad 3.1\,\text{meV}\ (\sigma = -)} \tag{3}$$

with a full-phase envelope $[0.7, 4.2]$ meV (Fig. 1). With the same global orientation that fixes the CKM/baryon sign ($\sigma = +$), the value is ≈ 1.8 meV.

2 Framework origin, stated minimally

The framework encodes each fermion generation in a two-bit register (G_0, G_1); Rule R1 forbids the corner $(1,1)$, leaving the Boolean order ideal $\{00, 01, 10\}$ with the Hasse path e–τ–μ (τ central). Two objects live on this ideal. The symmetric edge covariance $K_{R1} = BB^\top$ sets the CP-even mass twist δ; the closed oriented boundary cochain Ω_{R1} (which satisfies $K_{R1}^2 = -3P_{\rm std}$, a complex structure on the mixing plane) is the CP-odd carrier.

Mixing (real). The PMNS matrix is the error-correcting recovery's coherent frame transport. The older one-generator shorthand $\exp(\delta K_{R1}/3)$ is now treated as an angle-reporting representative: it leaves $\theta_{23} = 45^\circ$ by construction. The current physical branch is the single-polar recovery

$$U_{\rm PMNS} = R_{23}(\pi/4) R_{12}(\pi/4) \exp[\delta A(a)], \qquad a = (-\tfrac{1}{2}, \tfrac{1}{2}, 1), \quad \delta = 2/9.$$

This gives $(\theta_{12}, \theta_{23}, \theta_{13}) \approx (32.2^\circ, 46.0^\circ, 8.9^\circ)$, or $\theta_{23} \simeq 45.9^\circ$ if normalized to the measured reactor angle. The prediction is therefore a near-maximal second-octant atmospheric angle, not the present high-octant central value near 49°. Being real, it carries $J_\ell = 0$ (P1).

CP (Majorana). The CP object is the passive syndrome record ωK_{R1}: Hermitian, eigenvalues $\{0, \pm\sqrt{3}\}$, diagonal in the DFT/mass basis — a discrete sign pointer, not a rotation, so it cannot change the angles and does not generate a Dirac phase. Its phases rephase the neutrino mass eigenstates: they are Majorana (P2).

Phase branch. The single magnitude is pinned to $\Phi = 1/3$: the faithful C_3 character $2\pi/3$ is a CP zero of the holonomy invariant $\sin(3\sigma\Phi)$, and the winding reading $2\pi/9$ gives the wrong neutrino mass-squared ratio (0.195 vs 0.0295); the raw defect fraction $d/N = 3/9 = 1/3$ survives and reproduces the ratio. The baryon-asymmetry sign $\text{sign}(\eta) = \text{sign}(J_{\text{quark}})$ is carried by the orientation σ and is independent of this magnitude.

Spectrum and $m_{\beta\beta}$. The neutrino Koide circulant fixes the spectrum (P3); $m_{\beta\beta} = \left|\sum_i U_{ei}^2 m_i e^{i\alpha_i}\right|$ then follows from the real U_{ei} and the sign-pointer Majorana parities (P4). The full derivation chain is in the framework's companion audit scripts (Section 3).

3 Rigidity and honest tier

The claims are *conditional-tier*, not locked. They rest on three stated premises, each a named audit script (all exit 0):

- the PMNS angles are the leading-order *real* single-polar frame-transport correction (`item87_frame_transport_lemma_closure.py`, `item87_theta23_theta13_single_polar_gate.py`, `item87_leptonic_dirac_cp_from_frame_transport.py`); a complex sub-correction, if one existed, could seed a small Dirac phase — none is produced by the current texture. The same branch predicts $\theta_{23} \simeq 45.9^\circ$–$46.0^\circ$, not a 49° atmospheric angle;
- the CP magnitude is pinned to $\Phi = 1/3$ (`item87_leptonic_dcp_branch_and_lift.py`, `item87_neutrino_phase_selection_audit.py`);
- the Majorana phases are read as the discrete CP-conserving sign pointer, and the $\sigma \to$parity assignment selects the 1.8 vs 3.1 meV branch (`item87_mbb_0nubb_prediction.py`).

The convention-free content that survives all three is: *normal ordering; no Dirac oscillation CP; leptonic CP is Majorana;* $m_{\beta\beta} \sim 2$–$3\,\text{meV}$*, below next-generation reach.* Do not rescale the neutrino spectrum, promote a small nonzero Dirac phase, or move Φ off 1/3 to accommodate future posteriors.

4 How the predictions fail

Any one of the following, established after this date, falsifies the set:

- **Dirac CP (P1).** A high-significance measurement of a nonzero leptonic Jarlskog / δ_{CP} clearly away from $\{0, \pi\}$ in *normal* ordering (DUNE, Hyper-Kamiokande, T2K, NOνA, JUNO) [1–3].
- **Ordering (P3).** An established *inverted* ordering — which also removes the $m_{\beta\beta}$ target and reinstates the $\delta_{\text{CP}} \approx 270^\circ$ preference the framework rejects.

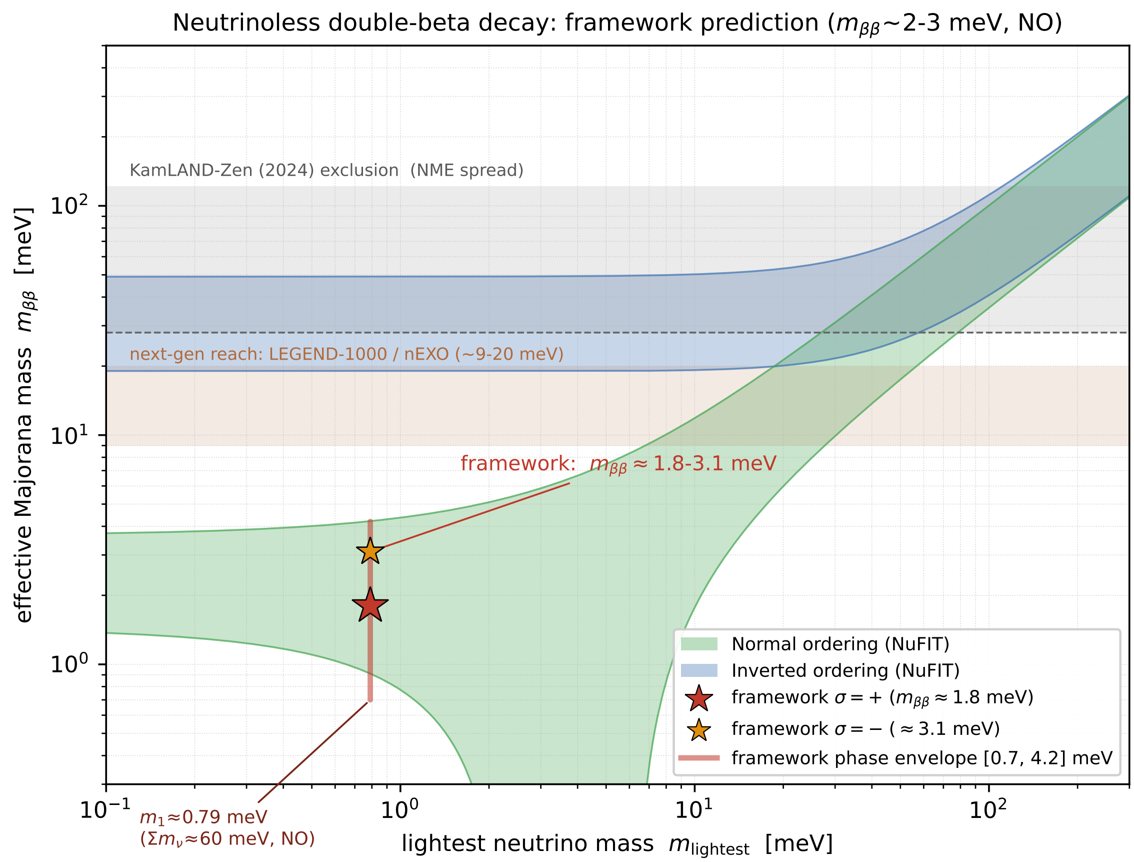

Figure 1: Effective Majorana mass $m_{\beta\beta}$ versus the lightest neutrino mass. Green/blue bands: the normal- and inverted-ordering regions allowed as the Majorana phases vary (NuFit-6.0 central mixing). Grey: the current KamLAND-Zen exclusion (nuclear-matrix-element spread); orange: the next-generation LEGEND-1000/nEXO reach ($\sim$ 9–21 meV). Stars: the framework prediction at $m_1 \approx 0.79$ meV — $m_{\beta\beta} \approx 1.8$ meV ($\sigma = +$) and 3.1 meV ($\sigma = -$) — with the red bar the full-phase envelope $[0.7, 4.2]$ meV. The prediction sits well below next-generation sensitivity: the framework expects *no* $0\nu\beta\beta$ signal in the coming round.

- $0\nu\beta\beta$ **(P4).** A detection with $m_{\beta\beta} \gtrsim 10$ meV under standard nuclear matrix elements [4–6] — incompatible with the predicted $\sim$ 2–3 meV (it would require inverted ordering or a much larger lightest mass).
- **Mass scale (P3).** A cosmological or laboratory $\sum m_\nu \gg 60$ meV, or a lightest mass $\gg$ 1 meV.

5 What would count as a positive result

Confirmation is cumulative, not a single number. Normal ordering established at high significance; δ_{CP} in normal ordering pinned near a CP-conserving value (0 or π) by DUNE/Hyper-K; and a $0\nu\beta\beta$ null through the $\sim$ 9–21 meV generation together would make the set a serious object. None of these alone proves the framework — normal ordering and small $m_{\beta\beta}$ are shared by many scenarios, and a CP-conserving δ_{CP} is one point in a prior-dependent posterior — but the *conjunction* of a hard Dirac-CP null with the fixed sub-threshold $m_{\beta\beta}$ is distinctive. Present data are already consistent: NuFit-6.0 finds normal ordering compatible with CP conservation within 1σ [7].

6 Pre-registered numerical targets

Quantity	Prediction	Ordering	Decisive experiment
J_ℓ (leptonic Jarlskog)	0	NO	DUNE, Hyper-K, JUNO
δ_{CP}	$\{0, \pi\}$	NO	DUNE, Hyper-K
Mass ordering	normal	–	JUNO, cosmology
m_1	$\approx 0.79\,\text{meV}$	NO	cosmology, β-decay
$\sum m_\nu$	$\approx 60\,\text{meV}$	NO	DESI/CMB-S4
$m_{\beta\beta}$	$\approx 1.8\text{–}3.1\,\text{meV}$	NO	LEGEND-1000, nEXO

7 Conclusion

The framework's leptonic CP is Majorana, not Dirac: the mixing angles are a real frame-transport rotation (Dirac $J_\ell = 0$), and CP violation sits in a discrete oriented-boundary sign pointer that feeds $0\nu\beta\beta$ and leptogenesis. The neutrino spectrum is fixed (normal ordering, $\sum m_\nu \approx 60\,\text{meV}$), and the effective Majorana mass is $m_{\beta\beta} \approx 2\text{–}3\,\text{meV}$, below next-generation reach. The set is consistent with present data and is refutable by the next decade of oscillation and double-beta measurements. It is recorded here, dated, as one bet on four fronts.

References

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