Neutron Lifetime from 5D Membrane Cosmology

WKB Tunneling, Brane-Soliton Structure, and the NJSR Framework

Paper 3 — NJSR Edition (Journal Version)

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with computational assistance from AI

Elastic Diffusive Cosmology Research

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"Jedenfalls bin ich überzeugt, daß der Alte nicht würfelt."
— Albert Einstein, letter to Max Born (4 Dec 1926) [3]

No — God plays with compass and triangles.
— Igor Grčman (author paraphrase)

Related Documents:
Elastic Diffusive Cosmology: Framework v2.0 (DOI: 10.5281/zenodo.18299085)
Companions:
A: *Effective Lagrangian* (DOI) · B: *WKB Prefactor* (DOI)
C: *5D Reduction* (DOI) · D: *Selection Rules* (DOI)
E: *Symmetry Ops* (DOI) · F: *Proton Junction* (DOI)
G: *Mass Difference* (DOI) · H: *Weak Interactions* (DOI)

Abstract

We present the **Neutron Junction-Slip Reduction (NJSR) framework** for computing particle lifetimes from 5D Elastic Diffusive Cosmology (EDC), with the neutron as the primary test case. The framework provides:

1. A WKB tunneling calculation with explicit prefactor $A_0 = (\omega_{\text{well}}/2\pi) \cdot R_{\text{det}} \cdot C_{\text{zero}}$

2. Brane-bound soliton structure for the electron ($Q = -1$ defect) with golden-ratio tail exponent $\varphi_{\text{tail}} = (1 + \sqrt{5})/2 \approx 1.618$

3. Determinant ratio $R_{\text{det}} = 0.63 \pm 0.10$ **[Dc]** from Gel'fand–Yaglom analysis (method-spread systematic)

4. Decay output classification (brane-bound vs bulk-escape) without Standard Model dynamics

Calibration statement: We calibrate a single barrier-height scale V_B to the measured free-neutron lifetime $\tau_n = 878.4 \pm 0.5\,\text{s}$ **[BL]**. All other outputs—the functional forms of $V(q)$ and $M(q)$ under

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stated ansätze **[Dc]**, the golden-ratio tail exponent φ_{tail} **[Dc]**, the determinant ratio R_{det} **[Dc]** (method-spread systematic), and 10/10 verification gates—are *not fitted* but follow from the reduction pipeline with V_B held fixed.

This is a journal-length version. For full forensic derivation chains, verification gates, and worked calculations, see the Companion Papers referenced in Section 13.

Guardrail: NJSR uses **5D EDC language only**—no V–A structure, no W boson, no CKM matrix. Standard Model observables serve as calibration benchmarks **[BL]**, not as inputs to the derivation.

Keywords: neutron lifetime, 5D membrane cosmology, WKB tunneling, brane soliton, golden ratio, EDC, determinant ratio

Contents

1 Introduction: Reading Physics from Both Sides of the Membrane

Most of modern particle physics is written in the language of a *closed* 3+1D world: we postulate fields, write a Lagrangian, fit parameters, and interpret experiments as interactions *within* that 4D arena. Elastic Diffusive Cosmology (EDC) deliberately changes the viewing geometry.

EDC treats our observed universe not as the full stage of reality, but as a *boundary* (or brane) embedded in a higher-dimensional plenum. The guiding idea is simple to state: *the equations we measure in 3D/4D are not necessarily the fundamental equations of nature; they may be effective projections of a deeper dynamics that lives in the bulk*. In the EDC book framework (Part I), the target is not to re-encode the Standard Model with new symbols, but to construct a mathematically controlled 5D membrane action that yields quantum and gravitational behavior as emergent, testable consequences.[1] [**?**]

1.1 A two-sided reading rule: Left side (5D cause) vs. right side (3D evidence)

To make this paper readable, we adopt a strict two-sided rule.

Left side (5D). On the left side of the membrane we describe *causes*: bulk geometry, junction constraints, and the membrane degrees of freedom. The objects we call "particles" on the right side are not taken as point-like primitives. Instead, they correspond to stable or metastable *geometric/topological configurations* of the membrane-bulk system (defects, junctions, winding, or trapped flux in the higher-dimensional description). This is the EDC ontological move: physics is encoded in geometry and boundary conditions, not in an a priori particle list.

Right side (3D/4D). On the right side we describe *evidence*: what detectors register. Accelerators, spectroscopy, and precision clocks do not look into the bulk; they see only the brane-projected signatures of bulk-membrane dynamics. The role of experiment is therefore diagnostic: it constrains which 5D hypotheses are viable, because only certain bulk geometries and junction laws can reproduce the observed right-side regularities.

This paper is written to keep that separation clear:

- The 5D construction is proposed as the *mechanism* (left side).

- The neutron lifetime is used as a *calibrated test observable* (right side).

1.2 Why the neutron: a metastable clock for bulk-to-brane dynamics

Among simple hadronic systems, the free neutron occupies a special conceptual role: it is not permanently stable, yet it is long-lived enough to be measured with high precision. In the EDC reading, this makes the neutron a natural "transition object": a metastable configuration that can relax from one geometric/junction state to another through a well-defined barrier in the reduced dynamics.

The key hypothesis of the present NJSR program is that the decay of a free neutron can be modeled as an effective one-dimensional collective coordinate q describing a bulk-to-brane reconfiguration mode at a junction/defect vertex. The 5D dynamics reduces to an effective action

$$S_{\text{eff}}[q] \;=\; \int dt \, \left(\tfrac{1}{2} M(q) \dot{q}^{\,2} - V(q) \right),$$

and the decay rate is controlled by semiclassical tunneling across the geometric barrier encoded in $V(q)$. The resulting lifetime is not inserted by hand; it becomes an output of the model once $M(q)$ and $V(q)$ are specified by the reduction and the boundary conditions.

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[1]This "build from a 5D membrane action" program is explicitly stated as the organizing aim of the EDC Part I book record.

1.3 Not "copying Standard Model numbers"

A frequent failure mode of alternative frameworks is accidental numerology: one can often engineer a new formula that reproduces a known constant without adding mechanistic explanatory power. EDC explicitly tries to avoid that trap by enforcing a directional logic:

bulk geometry and junction laws → *effective reduced dynamics* → *testable right-side observables*.

This philosophy is illustrated already in the companion report on particle geometry, where the fine-structure constant is presented as a derivation within a 5D membrane cosmology framework in a frozen-regime limit, with reproducibility comparisons and supplementary derivation indexing. [**?**] In the present paper we apply the same "geometry-first, evidence-second" logic to the neutron lifetime.

1.4 What the reader should expect

The main text is organized for comprehension rather than for forensic completeness. We begin with a narrative and a minimal set of definitions required to interpret the two-sided picture, then present the effective reduction and the decay-time prediction. All detailed derivation chains, lemma stacks, and audit artifacts are placed in appendices so that a skeptical reader can reproduce each step without forcing every reader to start with 100+ pages of intermediate algebra.

Epistemic labeling. Throughout, we maintain explicit epistemic tags for key statements: $[Der]$ for fully derived results within the declared model assumptions, $[Dc]$ for decisively constrained constructions that still contain modeling choices, $[P]$ for proposals, and $[I]$ for identified empirical inputs. This is a practical guardrail: it keeps the paper falsifiable, and prevents "model rhetoric" from blending into claims of established physics.

Navigation guide. The document is structured for different reading depths:

- **Main text** (∼25 pages): narrative, key results, and conclusions—sufficient for understanding the claim and its epistemic status.

- **Appendices** (∼110 pages): full forensic derivation chain, verification gates, and worked calculations—for readers who wish to audit every step.

- **Technical boxes**: self-contained derivations with explicit assumptions and status tags.

A skeptical reader should be able to verify any claim by tracing it to the relevant appendix; a casual reader can follow the main argument without drowning in algebra.

The matter-antimatter asymmetry (baryogenesis) remains one of the most profound unsolved problems in cosmology. The Standard Model combined with Big Bang cosmology predicts equal amounts of matter and antimatter should have been created, yet we observe a universe dominated by matter.

This paper proposes a geometric resolution within 5D Elastic Diffusive Cosmology (EDC), building on (i) the *EDC Theory Book* v17.49 [1] and (ii) the companion paper *Geometric Structure of Electron and Proton in 5D Membrane Cosmology* [2].

1.5 Program Scope and Contribution

This paper develops an **effective 1D collective-coordinate model** for particle creation and stability within EDC. The scope encompasses two interconnected phenomena:

1. **Matter-Antimatter Asymmetry:** We propose that cosmological particle creation draws energy from the 5D Plenum (INFLOW), eliminating the need for antimatter as a conservation partner. The Sakharov conditions are not required in this framework.

2. **Particle Stability Hierarchy:** The INFLOW/OUTFLOW mechanism provides a conceptual basis for understanding why some particles (proton, electron) are stable while others (neutron, muon) decay. Appendix A develops the neutron case as a worked example.

What this paper does:

- Establishes the INFLOW/OUTFLOW formalism (§4)

- Derives stability conditions under explicit assumptions A1–A6 (Appendix C)

- Constructs a computable 5D→1D reduction pipeline (Appendix)

- Demonstrates that verification gates pass for the effective model

What this paper does NOT do:

- Derive the effective potential $V(q)$ from the full 5D action (remains **[OPEN]**)

- Predict the neutron lifetime $\tau_n = 879\,\text{s}$ from first principles (remains **[OPEN]**)

- Compute the baryon-to-photon ratio $\eta \sim 10^{-10}$ (no quantitative prediction)

1.6 Roadmap of Evidence

The logical structure of this paper follows a claim→derivation→verification pattern:

1. **Claim C1:** INFLOW is energetically favored over OUTFLOW
   Derivation: §4, Appendix C (under A1–A6)
   Status: **[Dc]** (conditional on assumptions)

2. **Claim C2:** Cosmological creation does not require antimatter
   Derivation: §5 (5D current conservation)
   Status: **[Dc]** (follows from C1)

3. **Claim C3:** The 5D→1D reduction yields computable $V(q)$, $M(q)$
   Derivation: Appendix
   Verification: 10/10 gates pass (Table)

4. **Claim C4:** Neutron instability fits the INFLOW framework
   Derivation: Appendix A
   Status: **[P]** (conceptual fit; lifetime not derived)

1.7 From Baryogenesis to Stability: Why the Neutron is the First Quantitative Stress-Test

The EDC research program addresses three interlocking questions: (1) Why is there more matter than antimatter? (2) Why are protons and electrons stable while neutrons decay? (3) Can 5D geometry predict particle lifetimes quantitatively? This paper focuses on the third question, but the logical arc requires situating the neutron within the broader stability hierarchy.

Matter-Antimatter Resolution (EDC Theory Book v17.49). The INFLOW/OUTFLOW framework [1] proposes that cosmological particle creation draws energy from the 5D Plenum, eliminating the need for antimatter as a conservation partner. If correct, the Standard Sakharov conditions are not required (§5).

Reviewer Question: "Are These Defects Stable?" If matter consists of INFLOW defects and primordial antimatter never existed, a natural follow-up asks: *what sets the stability/metastability of these defects?* Why do protons appear absolutely stable ($\tau_p > 10^{34}$ yr) while free neutrons decay in 879 s?

Proton Stability (Paper 2 §5.2). The proton is modeled as a symmetric **Y-junction** in quark flux-tube space, with configuration space $S^3 \times S^3 \times S^3$ and geometric coefficient $C_p = (2\pi^2)^3$ [2]. This configuration minimizes energy analogously to the Steiner minimal tree (120° junctions). Paper 2 derives the prediction $m_p/m_e = 6\pi^5 = 1836.118$ with 0.002% agreement, establishing that the proton's Y-junction geometry is energetically optimal and thus stable.

Why Neutron Now? The **neutron** is the minimal metastable baryon—an *asymmetric* Y-junction with stored configurational energy $\Delta E_{\text{config}} > 0$. Unlike the proton, it can lower its energy by decaying to proton+electron+$\bar{\nu}_e$. Crucially, the neutron provides a clean observable: $\tau_n = 878.4 \pm 0.5\,\text{s}$ [5]. This makes the neutron the tightest calibration target for the effective 1D WKB pipeline developed in Appendix .

Why Not Electron? The electron belongs to the leptonic sector, which in EDC is a different topological class (point defect vs. flux-tube junction). The Y-junction / Steiner framework of Paper 2 does not directly apply. Electron stability is deferred to future work.

Why Not Deuteron/Helium? Multi-baryon systems (deuteron, ^{3}He, ^{4}He) require *nuclear binding*—a many-body interaction layer that involves the potential landscape of multiple defects. This is a distinct problem from single-particle metastability. Paper 3 deliberately restricts scope to the **single-coordinate WKB program**; nuclear binding is deferred.

Scope Statement. Paper 3 is the *first quantitative metastability test* within EDC. Proton stability (geometric optimality) is treated in Paper 2; the global 5D framework and epistemic taxonomy are documented in Book I [1]. Readers seeking background definitions should consult those references.

Scope & Limitations (Reviewer Note). This paper does **not** attempt nuclear binding (deuteron/helium) nor leptonic stability (electron/muon). It targets the **minimal metastable baryon**—the free neutron—as the first quantitative closure test of the 5D→1D effective model. For proton stability, see Paper 2 §5.2 (Y-junction geometry) [2]. For foundational definitions (Plenum, topological defects, epistemic tags), see Book I [1].

Reader Pointers.

- **5D framework:** Book I [1], Ch. 2 ($\mathcal{M}^5$, Plenum), Ch. 3 (membrane Σ^3)

- **Topological defects:** Book I [1], Ch. 4 (particle = pore)

- **INFLOW/OUTFLOW:** Book I [1], Ch. 5 (matter vs. antimatter)

- **Epistemic tags:** Book I [1], Appendix A ([P], [D], [Dc], [BL])

- **Proton Y-junction:** Paper 2 [2], §5.2 ($S^3 \times S^3 \times S^3$, Steiner)

- $m_p/m_e = 6\pi^5$**:** Paper 2 [2], §5.2–5.3 (0.002% agreement)

2 EDC Framework Review

2.1 5D Geometry

The EDC spacetime is a 5D manifold $\mathcal{M}^5$ with metric (see Book I [1], Ch. 2 for foundational definitions):

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu + d\xi^2 \tag{1}$$

where ξ is the compactified 5th dimension and $g_{\mu\nu}$ is the 4D metric on the membrane Σ^3 (Book I [1], Ch. 3).

2.2 Plenum Energy Fluid

The bulk contains an energy fluid (Plenum) with positive pressure (see Book I [1], Ch. 2 for Plenum postulates):

$$P_{\text{bulk}} = w\rho_{\text{P}}c^2, \quad w > 0 \tag{2}$$

This positive pressure drives energy flow toward the membrane.

2.3 Epistemic Status Tags

Throughout this paper, claims are tagged by derivation status (see Book I [1], Appendix A for the complete taxonomy):

Tag	Meaning
[P]	Postulated / phenomenological ansatz
[Dc]	Derived conditional on explicit assumptions
[D]	Definition (convention choice)
[M]	Mathematical identity or theorem
[I]	Identified / fit / empirical
[Cal]	Calibrated to data
[BL]	Baseline (experimental value, e.g., PDG)
[OPEN]	Unresolved / requires future work

Table 1: Epistemic status tags used in this paper.

2.4 Particle Classification: Where They Live

The EDC framework assigns particles to geometric configurations with specific brane vs. bulk localization properties. The following classification uses the canonical terminology from the Framework Reference Document v2.0 [13]:

Electron [Dc] Membrane-confined surface defect (brane-local). The electron is a simple vortex with winding number $W = -1$ around the compact dimension, configuration space B^3, and mass determined by flux-dominated boundary conditions. Fully localized on the brane.

Baryons (proton, neutron) [Dc] Y-junction / volume defects with bulk extension via flux tubes. The proton is a symmetric Y-junction ($S^3 \times S^3 \times S^3$ configuration space); the neutron is an asymmetric Y-junction with stored configurational energy. Flux tubes extend into the bulk but are confined by junction topology.

Neutrino [P] Partially bulk-coupled mode. Unlike charged leptons, the neutrino is postulated to have low brane confinement, coupling primarily through weak (junction-slip) interactions. Its bulk coupling enables escape during β-decay.

Antiparticles [Dc] Ledger partners for conservation closure. CPT symmetry requires opposite quantum numbers; antiparticles are brane-localized defects with opposite winding/charge. The "conservation ledger" tracks quantum numbers across brane and bulk channels—this is bookkeeping language, not a new physical law.

Key distinction: Charged leptons (e, μ, τ) are brane-confined; neutrinos are partially bulk-coupled **[P]**; baryons have Y-junction topology with flux-tube extensions. This classification determines decay channels and stability.

3 From 5D Action to Effective 1D Barrier: What is Derived vs What is Tested

Reduction Roadmap. The full 5D action contains four components:

$$S_{\text{5D}} = S_{\text{bulk}}[g_{AB}] + S_{\text{brane}}[\Phi, h_{\mu\nu}] + S_{\text{GHY}}[K] + S_{\text{Israel}}[\Delta K] \tag{3}$$

where S_{bulk} is the 5D Einstein-Hilbert action with cosmological constant, S_{brane} encodes membrane tension and matter fields, S_{GHY} is the Gibbons-Hawking-York boundary term ensuring a well-posed variational principle, and S_{Israel} enforces junction conditions across the brane. Under a collective-coordinate ansatz $q(t)$ representing the defect's "openness," dimensional reduction yields the effective 1D action:

$$S_{\text{eff}}[q] = \int dt \left(\frac{1}{2} M(q) \dot{q}^2 - V(q) \right) \tag{4}$$

where $M(q)$ is the effective mass (derived from kinetic terms) and $V(q)$ is the effective potential (derived from energy costs of membrane deformation). For explicit reduction steps, see Appendix .

Status Map. Table 2 summarizes the epistemic status of each component in the derivation chain, distinguishing what is rigorously derived versus what remains postulated or calibrated.

Quantity	Status	Source	Appendix
q collective coordinate	**[D]**	Geometric definition	App. D
$V(q)$ effective potential	**[Dc]**	5D reduction integral (under ansätze)	App.
$M(q)$ effective mass	**[Dc]**	5D kinetic term reduction	App.
Bulk metric g_{AB}	**[P]**	RS-type warped ansatz (choice)	App.
Brane profile $f(r; q)$	**[P]**	Gaussian ansatz (choice)	App.
WKB exponent B	**[D]**	Standard WKB from $V(q), M(q)$	App.
Prefactor A_0	**[P]**	Functional determinant (toy form)	App.
Exponent $p = 5/16$	**[I]**	Identified from scaling analysis	Main text §10
Sign $\delta S_{\text{INFLOW}} < 0$	**[Dc]**	Under assumptions A1–A6	App.
Amplitude V_B	**[OPEN]**	Calibration needed	—

Table 2: Status map: epistemic classification of key quantities in the 5D → 1D reduction. **[D]** = derived, **[Dc]** = derived conditional, **[P]** = postulated, **[I]** = identified/fit, **[OPEN]** = unresolved.

Calibration Ledger. To prevent ambiguity about "1 free parameter fitting 1 datum," we state explicitly:

- **Calibrated:** $V_B \to \tau_n$ **[Cal]**. The barrier-height scale is the *only* quantity fitted to the observed neutron lifetime.

- **Decisively constrained:** $V(q), M(q)$ functional forms under declared ansätze **[Dc]**—these shapes are not tuned once the ansätze are fixed.

- **Derived (conditional on BVP/E-L structure):** $\varphi_{\text{tail}} = (1 + \sqrt{5})/2$ **[Dc]**—emerges from asymptotic analysis of the soliton ODE, not fitted to data.

- **Derived (method-spread systematic):** $R_{\text{det}} = 0.63 \pm 0.10$ **[Dc]**—two independent methods yield a spread that we treat as systematic uncertainty, not as a second calibration knob.

- **Diagnostics/gates:** $V \geq 0$, $M \geq 0$, singularity handling, sensitivity gates **[Dc]**—pass/fail criteria that constrain but do not tune.

The key distinction: *once V_B is fixed*, the remaining outputs are determined by the reduction pipeline without additional degrees of freedom.

Forensic Audit Rule. Throughout this paper, we maintain a strict epistemic discipline: **the 5D action is the formal source of truth**; 1D effective models and their numerical implementations serve as validation layers. Any claim marked **[D]** must trace back to the action without calibration. Claims marked **[Dc]** or **[P]** are explicitly flagged as requiring future upgrade. Numerical gates (Table in Appendix) verify internal consistency but do not establish physical correctness.

4 INFLOW vs OUTFLOW Defects

This section summarizes the INFLOW/OUTFLOW framework established in Book I [1], Ch. 5 (see also §1.7 for context).

4.1 Definition

We define the energy flux in the ξ-direction:

$$J^\xi = T^\xi_\mu u^\mu \tag{5}$$

- **INFLOW:** $J^\xi > 0$ (energy flows from Plenum to membrane)

- **OUTFLOW:** $J^\xi < 0$ (energy flows from membrane to Plenum)

Canonical energy-exchange statement (Framework v2.0, Remark 4.5):

$$\nabla_A T^{AB}_{(5)} = 0 \, (A, B = 0, \ldots, 4), \qquad \nabla_\mu T^{\mu\nu}_{\text{brane}} = - J^\nu_{\text{bulk}\to\text{brane}} \, (\mu, \nu = 0, \ldots, 3).$$

Sign convention: $J^\nu_{\text{bulk}\to\text{brane}} > 0$ denotes bulk→brane (INFLOW).

This block is quoted verbatim from Framework v2.0, Remark 4.5; Framework remains the canonical source.

4.2 Stability Analysis

For coupling action:

$$S_{\text{coupling}} = \int d^4x \, d\xi \, J^A \partial_A \Phi \tag{6}$$

Under assumptions A1–A6 (see Appendix D), we derive **[Dc]**:

$$\delta S_{\text{INFLOW}} < 0 \quad \text{(energetically favored)} \tag{7}$$

$$\delta S_{\text{OUTFLOW}} > 0 \quad \text{(energetically suppressed)} \tag{8}$$

[Detailed derivation and assumption list in Appendix D]

KB-OPEN-009: Unresolved Sign Issue. The claim $\delta S_{\text{INFLOW}} < 0$ is currently **[Dc]** (derived conditional on assumptions A1–A6). A rigorous derivation from the full 5D action has not been completed. If the sign turns out to be reversed under proper calculation, the INFLOW/OUTFLOW framework would require fundamental revision. This is flagged as an open problem. See Roadmap (§10, Step 4) for upgrade path.

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5   Cosmological vs Local Creation

5.1   Cosmological Creation (Big Bang)

In an open 5D system:
$$\partial_A J^A = 0 \quad \Rightarrow \quad \partial_\mu J^\mu + \partial_\xi J^\xi = 0 \tag{9}$$

The Plenum flux $\Phi_\xi = \int d^3x \, \partial_\xi J^\xi$ compensates any 3D charge creation:
$$\Delta B_{\text{3D}} + \Phi_\xi = 0 \tag{10}$$

Result: Antimatter is *not required* for charge conservation because the Plenum provides compensation.

5.2   Local Creation (LHC)

In a closed 3D process with $\Phi_\xi \approx 0$:
$$\Delta B_{\text{3D}} = 0 \quad \Rightarrow \quad \text{particle} + \text{antiparticle pairs required} \tag{11}$$

6   Comparison with Sakharov Conditions

Condition	Standard	EDC	EDC Replacement
B violation	Required	Not required	Plenum reservoir **[OPEN]**
C and CP violation	Required	Not required	Asymmetric J^ξ sign **[Dc]**
Thermal non-equilibrium	Required	Not required	Cosmological INFLOW epoch **[P]**

Table 3: Sakharov conditions in EDC: "not required" shifts burden to Plenum properties. The EDC replacement requirements are flagged with their epistemic status.

7   Observational Consistency

The INFLOW/OUTFLOW framework is *consistent with* current observations, but these observations do not uniquely distinguish EDC from other baryogenesis scenarios:

1. **No primordial antimatter [P]**: The EDC framework proposes antimatter was never cosmologically created. AMS-02 has detected no primordial antihelium [6], consistent with this proposal. *Note: Standard cosmology with Sakharov mechanisms also predicts negligible primordial antimatter.*

2. **No annihilation gamma background:** Without primordial antimatter domains, no massive annihilation occurred. Fermi-LAT observes no excess at ~ 1 GeV [7, 8]. *Note: This is also consistent with standard baryogenesis.*

3. **LHC pair production:** Local processes must create pairs ($\Delta B = 0$). *Status: Confirmed experimentally.* This is required by both EDC and standard physics.

What Would Falsify This Framework:

- Detection of primordial antimatter (antihelium-3 or heavier) by AMS-02

- Evidence of annihilation gamma background from matter-antimatter domains

- Derivation showing $\delta S_{\text{INFLOW}} > 0$ from the full 5D action

8 Connection to Particle Stability

The INFLOW/OUTFLOW framework provides a conceptual basis **[P]** for understanding particle stability hierarchies. In particular, the neutron instability and its decay products are analyzed in Appendix A, connecting the matter-antimatter asymmetry to weak decay processes within the effective 1D model.

9 Future Work

1. Complete mathematical derivation of δS for INFLOW/OUTFLOW

2. Derive the origin of $P_{\text{bulk}} > 0$ from first principles

3. Connect to muon/tau lepton mass hierarchy

4. Investigate implications for dark matter candidates

10 Roadmap: From Effective Model to 5D Derivation

The current framework uses phenomenological parameters. A genuine 5D derivation would proceed as follows:

Step 1: Write Down Full 5D Action [Dc]

$$S_{\text{tot}} = S_{\text{bulk}}[g_{AB}] + S_{\text{membrane}}[\Phi, h_{\mu\nu}] + S_{\text{GHY}}[K] + S_{\text{defect}}[q] \tag{12}$$

with explicit functional forms for each term. *Status: bulk and membrane terms established in Book I; defect term requires topological specification.*

Step 2: Specify Defect Topology [OPEN] Define the map $\phi : S^2 \to \mathcal{M}^5$ characterizing the pore structure. This determines the winding number and energetic cost of the defect. *Status: not yet specified.*

Step 3: Perform KK Reduction to 1D [OPEN] Integrate out angular and transverse degrees of freedom to obtain:

$$S_{\text{eff}}[q] = \int dt \left(\frac{1}{2} M(q)\dot{q}^2 - V(q) \right) \tag{13}$$

The effective potential $V(q)$ should emerge from the reduction, not be postulated. *Status: ansatz used, not derived.*

Step 4: Verify $\delta S_{\text{INFLOW}} < 0$ from Full Action [OPEN] Currently claimed under assumptions A1–A6. A true derivation would show this sign follows from the action without additional postulates. *Status: claimed [Dc], needs upgrade to [D].* See KB-OPEN-009.

Step 5: Derive p from $\mathcal{M}^5$ Topology [OPEN] The suppression exponent $p = 5/16$ is currently **[I]** (identified via scoring). A derivation would connect p to the spectral dimension or Laplacian eigenvalues on the compactified space. *Status: identified, not derived.*

Step 6: Compute Observables Without Calibration [OPEN] A successful 5D derivation would predict:

- $\tau_n = 879$ s from EDC parameters alone (currently **[Cal]**)

- $V(q)$ functional form from topology (currently **[P]**)

- $\eta \sim 10^{-10}$ baryon asymmetry (currently no prediction)

What Would Count as a True 5D Derivation:

1. Compute $\tau = 879$ s from EDC parameters without calibrating V_B

2. Derive the functional form $V(q) = 16V_B q^2(1-q)^2 + Qq$ from the action

3. Show $p = 5/16$ follows uniquely from geometric constraints

4. Derive $\delta S_{\text{INFLOW}} < 0$ from the action (not assumptions)

10.1 Neutron Upgrade Roadmap: From 5D-Induced to 5D-Computed

The neutron decay calculation in Appendix A uses phenomenological potentials $V(q)$ and $M(q)$. Here we outline how these could, in principle, be computed from explicit 5D geometry.

Phase 1: Specify Computable 5D Setup [OPEN]

1. **[D] Choose bulk metric:** e.g., AdS$_5$ with $ds^2 = e^{-2|y|/\ell}(\eta_{\mu\nu}dx^\mu dx^\nu) + dy^2$ where ℓ is the AdS curvature radius. (Standard RS-type geometry.)

2. **[D] Define brane embedding:** Specify Σ^3 as a hypersurface with induced metric $h_{\mu\nu}$ and extrinsic curvature $K_{\mu\nu}$. (See Appendix .)

3. **[P] Choose defect ansatz:** Parameterize the pore profile as $\phi(r;q) = q \cdot f_0(r)$ where $f_0(r)$ is a fixed shape function and $q \in [0,1]$ is the collective coordinate. The functional form of f_0 determines $M(q)$ and $V(q)$ via the reduction integrals.

4. **[OPEN] Execute reduction integrals:** Evaluate

$$M(q) = \int_{\Sigma^3} d^3x \sqrt{h}\, g_{AB}\, \frac{\partial X^A}{\partial q}\frac{\partial X^B}{\partial q} \tag{14}$$

$$V(q) = S_{\text{brane}}[\phi(q)] - S_{\text{brane}}[\phi(0)] \tag{15}$$

for the chosen ansatz. *Status: not yet executed.*

Phase 2: Numerical Verification Gates [Dc] Before any $V(q)$, $M(q)$ can be used in WKB calculations, the following gates must pass:

- `Vq_positive_gate()`: $V(q) > 0$ for $q \in (0, q_{\text{max}})$

- `Mq_positive_gate()`: $M(q) > 0$ for all q

- `grid_refinement_gate()`: Integrals converge under mesh refinement

- `reparam_invariance_gate()`: WKB rate independent of coordinate choice

- `reduction_integral_nontrivial_gate()`: $V(q)$, $M(q)$ differ from historical model

- `historical_model_usage_gate()`: Default uses 5D-computed functions

- `vm_shape_sanity_gate()`: Boundary conditions and single-barrier shape

Status: All gates pass for Phase-1 ansatz. See code/neutron_wkb_sensitivity.py.

Phase-1 Closure Result [Dc]: In Phase-1 we close the reduction recipe in computable integral form under an explicit ansatz registry **[P]**. The resulting $V(q)$ and $M(q)$ are numerically evaluated from the integrals defined in Appendix and pass all refinement and reparameterization gates **[Dc]**. This demonstrates that the pipeline $5D \rightarrow (V(q), M(q)) \rightarrow B \rightarrow \tau$ is *executable*, not merely a narrative. However, this does **not** constitute a derivation of the bulk geometry or defect profile—those remain **[P]** (see Ansatz Registry, Appendix). Calibration of the overall scale V_B remains **[OPEN]** pending higher-principle input.

Phase-2 Prefactor Status [Dc]: Phase-2 replaces multiple historical prefactor choices (Fermi constant, attempt frequency) with a single 5D-motivated candidate A_0^{5D} **[Dc]**, computed from Gel'fand–Yaglom determinant ratios under transverse-mode assumptions **[P]**. The resulting prefactor passes finiteness and p-stability gates (see `code/neutron_wkb_sensitivity.py`). However, the exponent selection $p \in \{5, 6, 7\}$ remains prefactor-sensitive **[OPEN]** until the transverse sector is derived from the full 5D action rather than postulated.

Numerical Results Summary: Table 4 summarizes the key numerical outputs from the verification pipeline. These values are computed by running `code/neutron_wkb_sensitivity.py --no-phase3` and represent actual reduction integral outputs, not calibrated fits.

Quantity	Value	Status
Positivity & Shape Gates (Phase-1)		
$\min V(q)$, $q \in (0.01, 0.99)$	2.05×10^{-6}	PASS
$\min M(q)$, $q \in [0, 1]$	2.82×10^{-5} at $q = 0.53$	PASS
$V(q)$ peak location	$q = 0.52$ (single barrier)	PASS
Convergence & Invariance Gates (Phase-2)		
Grid refinement: I_{coarse} vs I_{fine}	rel. diff $< 2 \times 10^{-7}$	PASS
Reparam invariance: I_{orig} vs I_{trans}	rel. diff $< 4 \times 10^{-10}$	PASS
A_0^{5D} stability	max rel. diff $< 0.01\%$	PASS
WKB B integral stability	rel. diff $< 0.02\%$	PASS
Gate Summary		
Total gates executed	10	–
Gates passed	10	ALL PASS

Table 4: Numerical verification results from `neutron_wkb_sensitivity.py`. For detailed gate definitions and V/M comparison tables, see Appendix .

Phase-3 Computational Closure [Dc]: The computed profile $f^*(r; q)$ is now solved as a boundary value problem (BVP) using `scipy.integrate.solve_bvp`, reformulating the E-L equation as: $y = [f, f']$, with $f'(0) = 0$ (regularity) and $f(r_{\max}) = 0$ (Dirichlet). Gates 15–17 verify convergence ($\geq 4/5$ q-points), refinement stability ($N = 200 \rightarrow 800$, $< 2\%$), and solver consistency. This closes the computational pipeline; it does not fix the bulk geometry **[P]** or derive the scale V_B **[OPEN]**.

Phase-4: Full 5D Derivation Status. The target is to derive $S_{\text{eff}}[q] = \int dt \left(\frac{1}{2} M(q) \dot{q}^2 - V(q)\right)$ directly from the 5D action $S_{5D} = S_{\text{bulk}} + S_{\text{brane}} + S_{\text{GHY}}$ without phenomenological gluing. Three steps are required:

(i) **Bulk metric family**: Specify $g_{AB}(x, \xi; \theta)$ with warp factor $a(\xi; \theta)$ and boundary conditions at $\xi = 0$ (brane) and $\xi \rightarrow \infty$ (Plenum). Status: **[P]** (RS-type ansatz chosen).

(ii) **Brane embedding ansatz**: Define $X^A(\sigma^\mu; q)$ for defect with collective coordinate $q \in [0, 1]$. Status: **[P]** (Gaussian profile chosen).

(iii) **Second-order expansion [Dc]**: Expand $S_{5D}[q, \dot{q}]$ around static profile to $\mathcal{O}(\dot{q}^2)$, extracting $M(q)$ (supermetric) and $V(q)$ (static energy). Status: **[Dc] (completed under ansätze)**. See Appendix for the fully worked derivation.

Upgrade path: Steps (i)–(ii) remain **[P]**. Deriving the bulk metric and brane profile from EDC Plenum principles is **[OPEN]**.

Success Criterion (Full 5D): The upgrade from **[P]** to **[D]** is complete when $V(q)$ and $M(q)$ are computable from specified 5D geometry without fitting to the observed $\tau_n = 878.4\,\mathrm{s}$.

10.2 Post-calibration outputs with fixed V_B

Once the barrier-height scale V_B is fixed by matching $\tau_n = 878.4\,\mathrm{s}$, the framework produces constrained outputs *without further tuning*. These serve as discriminating constraints rather than additional fit parameters:

- **Profile-family sensitivity:** Switching from Gaussian to compact-support or exponential brane profiles (with V_B held fixed) yields τ_n variations that can be compared to experimental precision. Large deviations would falsify the profile choice.

- **Gate robustness:** The 10/10 verification gates (Table 4) must continue to pass under parameter perturbations; failure indicates model breakdown.

- **Golden-ratio stability:** The tail exponent $\varphi_{\text{tail}} = (1 + \sqrt{5})/2$ is insensitive to fit-range choices ($< 2\%$ variation over $r \in [2, 5]$ to $[3, 6]$), providing an internal consistency check independent of V_B.

These post-calibration diagnostics illustrate what "predictive once calibrated" means operationally: the single calibration point ($V_B \to \tau_n$) constrains the entire pipeline, and deviations in secondary outputs would signal model inconsistency rather than additional tuning opportunities.

11 Discussion

The neutron-lifetime calculation developed in this paper is part of a broader program: translating bulk hypotheses into right-side (detector-accessible) evidence, one observable at a time. Before concluding, we address a natural question that arises in any non-standard baryon-asymmetry narrative.

11.1 Antimatter in colliders as a boundary excitation: a two-sided EDC reading

A recurring objection to any non-standard baryon-asymmetry narrative is immediate: if the universe is matter-dominated, why do high-energy experiments routinely produce antimatter? EDC answers this by enforcing the same two-sided rule used throughout this paper: the *right side* (3D/4D) records detector-visible event topologies, while the *left side* (5D) supplies candidate mechanisms.

Right side (LHC facts). In proton–proton collisions, the detector-level statement is operational and model-agnostic: sufficiently energetic, localized interactions produce particle–antiparticle pairs, followed by rapid annihilation/decay in the laboratory environment. This observation does not, by itself, imply a primordial antimatter reservoir; it demonstrates that the accessible high-energy channel space includes configurations that register as "anti" quantum numbers in 3D observables.

Left side (EDC mechanism proposal) [P].   In EDC language, a collider event is a *strong, localized boundary forcing* of the brane. Such forcing is expected to excite short-lived, high-curvature boundary configurations and junction reconfigurations. The proposed interpretation is that what the detector labels as "antimatter" corresponds to a *localized counter-excitation* (a conjugate defect mode) in the bulk–brane configuration space, created in pairs due to boundary consistency and charge-conjugation of the effective 3D projection. In this view, collider antimatter is a *laboratory-produced boundary excitation*, not evidence for a globally symmetric matter–antimatter initial condition.

Relation to CP violation and baryogenesis [Dc]/[P].   EDC does not require that Standard-Model CP-violating mechanisms be false; rather, it shifts the logical emphasis. The global matter dominance is hypothesized to reflect a *directionality* (or boundary condition) of bulk-to-brane energy/flux organization, while CP-violation effects remain as effective right-side phenomenology of the brane-projected dynamics. At the present stage, this remains a constrained proposal: the paper does not derive the full collider production cross-sections or CP-odd observables from a 5D action. Instead, the claim is structural: laboratory antimatter can be consistently interpreted as a local, transient excitation channel without committing to a primordial antimatter inventory.

What would count as a discriminating test [P].   A falsifiable next step is to translate the qualitative "counter-excitation" picture into a quantitative mapping between bulk/brane parameters and right-side observables: e.g., scaling laws for pair-production yields under varying boundary forcing, or a constrained relation between effective defect/junction degrees of freedom and measured asymmetry patterns in specific channels. This paper focuses on a simpler diagnostic observable—the free neutron lifetime—as a first calibrated test of the reduction pipeline.

12   Conclusions

A two-sided result.   Elastic Diffusive Cosmology (EDC) is written under a disciplined reading rule: what we measure on the brane is the *right-side evidence*, while what we hypothesize in the bulk is the *left-side cause*. The value of this separation is not rhetorical. It prevents a familiar failure mode of alternative frameworks—relabeling known parameters—by enforcing a directional logic:

bulk geometry and junction laws $\rightarrow$ effective reduced dynamics $\rightarrow$ right-side observables.

Within that logic, the present work does not "translate" Standard Model numerics into new notation. It constructs a concrete effective description in which a precision observable, the free neutron lifetime, arises from a specific geometric barrier-crossing process in a collective coordinate q.

Why the neutron matters in this framework.   In conventional language the neutron is simply an unstable hadron. In the EDC reading it becomes more informative: a metastable configuration whose decay time functions as a macroscopic clock for microscopic reconfiguration. The neutron is therefore not merely "something that decays"—it is a transition object that tests whether the proposed bulk–membrane mechanism admits a controlled intermediate state and a controlled escape channel. The NJSR picture implemented here makes that statement technically sharp: the decay rate is governed by semiclassical tunneling (WKB) through a barrier encoded by an explicitly specified pair $\{V(q), M(q)\}$. The gates reported in this work (positivity of V, non-negativity of M, singularity handling, and sensitivity diagnostics) are not cosmetic checks; they are the minimal consistency requirements for treating neutron decay as a calculable barrier-crossing event rather than a postulated interaction vertex.

A cosmological implication (stated carefully).   A longstanding conceptual tension in early-universe storytelling is the apparent need to "explain" matter by balancing it against antimatter and then invoking

additional mechanisms to remove the unwanted half. EDC motivates a different framing: the first question is not "where did antimatter go?" but "which bulk–membrane configurations are dynamically stable, metastable, or forbidden?" In such a framing, a baryonic universe is not the leftover from a symmetric cancellation, but a reachable sector of configuration space. In that sense, the neutron is naturally interpreted as a *gateway configuration*: without an allowed metastable junction state that mediates transitions among stable bound states, the observed baryonic sector may not be dynamically reachable at all. This paper provides a concrete technical instance of that idea: the neutron lifetime becomes the timescale of a junction-slip event in the reduced dynamics. We stress that this is an interpretive implication of the model architecture, not a completed cosmological scenario; it should be read as a hypothesis to be refined and tested rather than as a claim of established early-universe history.

What has been achieved here. The main achievement of the present paper is to show that a neutron-lifetime calculation can be organized as an explicit, auditable pipeline:

- a well-defined effective one-dimensional coordinate q representing a reconfiguration mode,

- an effective action $S_{\text{eff}}[q] = \int dt \left(\frac{1}{2} M(q) \dot{q}^2 - V(q) \right)$ that encodes the barrier physics,

- a semiclassical decay estimate controlled by a WKB exponent and a tagged prefactor,

- and a reproducible numerical sensitivity layer with explicit "gates" that stress-test consistency.

This delivers more than a single number: it delivers a *diagnostic map* connecting assumptions to outputs. That structure is what enables falsifiability and targeted improvement.

Epistemic close (tags and next steps). We explicitly maintain epistemic tags to keep the paper falsifiable and to prevent "model rhetoric" from blending into claims of established physics. In the current implementation, the heavy-lift mathematics is an *effective 1D realization* with decisively constrained modeling choices: the 5D action (bulk+brane+GHY+Israel) is presently a *formal scaffold* rather than an input used end-to-end in the numeric pipeline, and certain elements (e.g. the prefactor A_0 and profile choices) remain **[Dc]** rather than fully **[D]**. Any external comparison baseline is **[BL]** and must remain segregated from derivation text. The next "true 5D step" is therefore unambiguous: derive $M(q)$ and $V(q)$ directly from the 5D action and junction conditions, replacing phenomenological gluing with a controlled reduction. With that upgrade, neutron lifetime would move from a consistency-oriented demonstration to a sharper discriminatory prediction of the underlying bulk geometry.

13   Companion Papers and Full Derivations

This journal-length paper presents the core narrative and key results. For full derivation chains, verification gates, and worked calculations, see the following companion documents:

Document	Title	Content
Framework v2.0	EDC Mathematical Framework	Complete 5D theory: mass formulas, α, Y-junction structure, SU(3) color. DOI: 10.5281/zenodo.18299085
Companion A	Effective Lagrangian L_{eff} from 5D Action	Complete derivation of $L_{\text{eff}}(q, \dot{q}) = \frac{1}{2}M(q)\dot{q}^2 - V(q)$ via Israel junction conditions, with $M(q)$ and $V(q)$ explicit forms. DOI: 10.5281/zenodo.18292841
Companion B	WKB Prefactor and Lifetime Calculation	Gel'fand–Yaglom determinant ratio $R_{\text{det}} = 0.63 \pm 0.10$, golden-ratio tail exponent $\varphi = 1.618...$, and 10/10 verification gates. DOI: 10.5281/zenodo.18299637
Companion C	5D Reduction Pipeline	Roadmap from brane-world action to 1D mechanics: bulk geometry, embedding, induced metric, extrinsic curvature, and assumption ledger. DOI: 10.5281/zenodo.18299751
Companion D	Selection Rules for β^- Decay	Topological necessity of neutral mode with $p^\xi \neq 0$; charge, winding, and momentum budget bookkeeping; antineutrino classification. DOI: 10.5281/zenodo.18299855
Companion E	Symmetry Layering and Defect Operations	Formal symmetry structure, process operators (Excitation, Relaxation, Merging), conservation ledger for β^- decay. DOI: 10.5281/zenodo.18300199

Table 5: Companion papers providing full derivation chains. These documents contain the forensic-level detail required for independent verification. Available at the Zenodo repository (DOI: 10.5281/zenodo.18262721).

Navigation guide:

- **This paper** ($\sim$25 pages): narrative, key results, and conclusions—sufficient for understanding the claim and its epistemic status.

- **Framework v2.0** (38 pages): complete EDC mathematical framework.

- **Companions A–E** ($\sim$50 pages total): full forensic derivation chain—for readers who wish to audit every step.

- **Full Paper 3** (147 pages): complete document with all appendices inline, available as `main_pathB.pdf` in the repository.

14 NJSR: Technical Summary

This section provides a condensed technical summary of the NJSR framework.

14.1 Language Guardrail

The NJSR framework uses **5D EDC language only**:

- No V–A structure (replaced by junction-slip topology)

- No W boson propagator (replaced by collective-coordinate tunneling)

- No CKM matrix (replaced by geometric phase factors)

Standard Model observables serve as calibration benchmarks **[BL]**, not as inputs.

14.2 Module Summary

The calculation pipeline consists of the following modules:

1. **5D Action** $\rightarrow$ collective coordinate q (Companion C: *5D Action Reduction Pipeline*)

2. **Dimensional reduction** $\rightarrow S_{\text{eff}}[q] = \int dt \left(\frac{1}{2} M(q) \dot{q}^2 - V(q) \right)$ (Companion A: *Effective Lagrangian*)

3. **WKB tunneling** $\rightarrow$ decay rate $\Gamma = A_0 e^{-2B}$ (Companion B: *WKB Prefactor*)

4. **Calibration** $\rightarrow V_B$ fitted to $\tau_n = 878.4\,\text{s}$ **[Cal]**

14.3 Key Results

1. Golden-ratio tail exponent: $\varphi_{\text{tail}} = (1 + \sqrt{5})/2$ **[Dc]**

2. Determinant ratio: $R_{\text{det}} = 0.63 \pm 0.10$ **[Dc]**

3. Verification gates: 10/10 passed **[Dc]**

4. Single calibration parameter: V_B **[Cal]**

14.4 Narrative Arc: Symmetry Through Saturation

The EDC program unfolds through three conceptual stages, each with distinct epistemic status:

Act I: (e, p) **Topology Distinction [Dc].** The electron and proton represent fundamentally different membrane defect classes. The electron is a surface defect (simple vortex, B^3 configuration space, winding $W = -1$); the proton is a volume defect (Y-junction, $S^3 \times S^3 \times S^3$ configuration space). This topological distinction yields the mass ratio $m_p/m_e = 6\pi^5$ (0.01% agreement) and explains why the electron is brane-confined while baryons have flux-tube extensions.

Act II: Muon as Higher-Overlap Generational Mode [P]. The muon is postulated to be a second-generation leptonic defect characterized by increased "overlap" with baryonic internal geometry. In this picture, the muon samples a larger portion of the Y-junction configuration space than the electron, yielding higher effective mass. The mass relation $m_\mu/m_e = \frac{3}{2}(1 + \alpha^{-1})$ (0.14% agreement) is consistent with this overlap interpretation, but the mechanism remains **[P]**—a conjecture awaiting derivation from the 5D action.

Act III: Tau and the Saturation Hypothesis [P]. The tau represents maximal leptonic overlap with baryonic geometry before topological instability sets in. The **Saturation Hypothesis [P]** proposes that no further stable lepton generation exists because the tau already saturates the available overlap regime. This is explicitly a conjecture: the "saturation" criterion has not been derived from the action, and the absence of a fourth generation is imposed, not proven.

Status summary: Act I is derived (**[Dc]**); Acts II and III are postulated (**[P]**) and require future derivation to upgrade their epistemic standing.

14.5 Strong-Sector Vocabulary

The Y-junction model provides natural mappings for strong-sector concepts (see [2] for detailed derivations):

- **Color (SU(3)):** The 8 gluon modes emerge from Y-junction arm permutation algebra **[Dc]**—the junction has $\mathbb{Z}_6$ symmetry generating 8 independent operations matching the 8 generators of SU(3).

- **Quarks:** Leg endpoints of the Y-junction; confined by infinite string energy **[P]**.

- **Spin, helicity, chirality:** Conserved quantities tracked via the conservation ledger **[BL]**. These are QFT inputs, not re-derived within EDC; ledger closure ensures consistency across decay channels.

14.6 Adopted Values

Quantity	Value	Status	Source
τ_n	$878.4 \pm 0.5\,\text{s}$	**[BL]**	PDG 2024
φ_{tail}	$1.618...$	**[Dc]**	Asymptotic ODE analysis
R_{det}	0.63 ± 0.10	**[Dc]**	Gel'fand–Yaglom
V_B	(calibrated)	**[Cal]**	Fitted to τ_n

Table 6: Key quantities and their epistemic status in the NJSR framework.

A Neutron Instability and Beta Decay (Summary)

The neutron is modeled as an asymmetric Y-junction in the 5D membrane framework. Unlike the proton (symmetric Y-junction, stable), the neutron has stored configurational energy $\Delta E_{\text{config}} > 0$ that can be released through a junction-slip transition.

The decay $n \rightarrow p + e^- + \bar{\nu}_e$ is interpreted as a collective-coordinate tunneling event where the asymmetric junction relaxes to the symmetric configuration while emitting brane-bound (electron) and bulk-escape (antineutrino) defects.

For full derivation: See Companion B (*WKB Prefactor and Neutron Lifetime Calculation*, DOI: 10.5281/zenodo.18299637) and the full Paper 3 Appendix A.

B Matter-Antimatter Asymmetry (Summary)

The INFLOW/OUTFLOW framework proposes that cosmological particle creation draws energy from the 5D Plenum, eliminating the need for antimatter as a conservation partner. Under assumptions A1–A6:

$$\delta S_{\text{INFLOW}} < 0 \quad \text{(energetically favored)} \tag{16}$$

$$\delta S_{\text{OUTFLOW}} > 0 \quad \text{(energetically suppressed)} \tag{17}$$

This replaces the Sakharov conditions with Plenum properties. The sign derivation remains **[OPEN]** pending a first-principles calculation.

For full derivation: See the full Paper 3 Appendix B.

C Mathematical Formalization (Summary)

The INFLOW/OUTFLOW formalism rests on assumptions A1–A6:

A1. Plenum has positive pressure: $P_{\text{bulk}} > 0$

A2. Energy conservation in 5D: $\nabla_A T^{AB} = 0$

A3. Membrane is a codimension-1 hypersurface

A4. Defects are localized perturbations of the membrane

A5. INFLOW defects have $J^\xi > 0$ (energy flows into membrane)

A6. OUTFLOW defects have $J^\xi < 0$ (energy flows out of membrane)

Canonical energy-exchange statement (Framework v2.0, Remark 4.5):

$$\nabla_A T^{AB}_{(5)} = 0 \ (A, B = 0, \ldots, 4), \qquad \nabla_\mu T^{\mu\nu}_{\text{brane}} = -J^\nu_{\text{bulk}\to\text{brane}} \ (\mu, \nu = 0, \ldots, 3).$$

Sign convention: $J^\nu_{\text{bulk}\to\text{brane}} > 0$ denotes bulk→brane (INFLOW).

This block is quoted verbatim from Framework v2.0, Remark 4.5; Framework remains the canonical source.

For full derivation: See the full Paper 3 Appendix C.

D   Collective Coordinate q: Geometric Definition (Summary)

The collective coordinate q is defined as the normalized "openness" of the junction defect:

$$q \equiv \frac{A_{\text{junction}}}{A_0} \tag{18}$$

where A_{junction} is the junction cross-sectional area and A_0 is a reference scale (electron Compton wavelength squared).

The range is $q \in [0, 1]$ where:

- $q = 0$: closed junction (stable proton)

- $q = 1$: fully open junction (decay threshold)

For full derivation: See Companion D (*Selection Rules for Neutron Beta Decay*, DOI: 10.5281/zenodo.18299855) and the full Paper 3 Appendix E.

Acknowledgments

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