Neutron as Excited 5D Junction

in Elastic Diffusive Cosmology

(Companion N to Paper 3: NJSR Edition)

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Repository: github.com/igorgrcman/elastic-diffusive-cosmology

(Public artifacts for this paper are in the `edc_papers` folder.)

Related Documents:

Neutron Lifetime from 5D Membrane Cosmology (DOI: 10.5281/zenodo.18262721)

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)

This: N: *Neutron Junction* (DOI)

Abstract

We establish the neutron as an **excited 5D junction state** within Elastic Diffusive Cosmology (EDC). The neutron shares the same three-arm junction topology as the proton (Companion F), but is displaced from the local Steiner minimum—the universal 120° optimum in the tangent metric. This excitation couples to the bulk-facing side of a thick brane, pumping energy into brane-layer modes. The observer-side frozen projection boundary then organizes the released energy into allowed weak-channel outputs ($e^- + \bar{\nu}_e$).

Calibration boundary: The neutron lifetime $\tau_n \approx 879\,\mathrm{s}$ is treated as a **baseline observable** **[BL]**, not as a prediction of this companion. The lifetime value enters only as a phenomenological check; no parameters are fitted to it here.

Epistemic status: The junction postulate is **[P]** (inherited from Companion F). Given this postulate, the neutron's excited nature is **[P]**, while the Steiner relaxation mechanism is **[Dc]**. The thick-brane pumping and frozen projection remain **[OPEN]** at the microphysics level.

Contents

Cornerstone: Neutron in EDC

In the EDC program, the neutron is modeled as an excited 5D junction state: the same three-arm junction core as the proton, but displaced from the local Steiner minimum (the universal 120° optimum in the tangent metric). This excitation couples to the bulk-facing side of a thick brane, pumping energy into brane-layer modes. The observer-side frozen projection boundary then organizes the released energy into allowed weak-channel outputs (e.g., e^- and $\bar{\nu}_e$), while overall bulk–brane conservation remains anchored to Framework v2.0, Remark 4.5.

Epistemic status:

- 120° as local optimum: **[Der]**/**[Dc]** (geometric, from Companion F)
- Neutron = excited junction: **[P]** (object assumption)
- Thick-brane pumping + frozen output mapping: **[P]**/**[OPEN]**

1 Motivation and Scope

1.1 The Gap: Neutron Object Model

Companion F establishes the proton as a Y-junction in 5D—a three-arm flux-tube network meeting at 120° angles (Steiner configuration). Companion G derives the neutron-proton mass difference from $\mathbb{Z}_6$ symmetry breaking. Companion H describes weak interactions as junction transitions mediated by thick-brane microphysics.

What is missing: A clear statement of *what the neutron is* as a 5D object, analogous to Companion F's treatment of the proton.

1.2 Purpose of This Companion

This document provides the **neutron backbone**:

1. Define the neutron as an excited 5D junction state **[P]**
2. Show that instability arises from displacement from Steiner minimum **[Dc]**
3. Connect junction oscillation to thick-brane energy pumping **[P]**/**[OPEN]**
4. Describe the frozen projection boundary as organizing outputs **[Dc]**/**[P]**
5. Identify the bridge to Paper 3's WKB treatment **[OPEN]**

1.3 What This Companion Does NOT Do

- Does NOT derive the lifetime $\tau_n \approx 879\,\mathrm{s}$ from first principles (remains **[Cal]** via Paper 3's WKB barrier)
- Does NOT derive the V–A structure of weak interactions (Standard Model input **[BL]**)
- Does NOT derive the thick-brane coupling constant (remains **[OPEN]**)

1.4 Epistemic Hierarchy

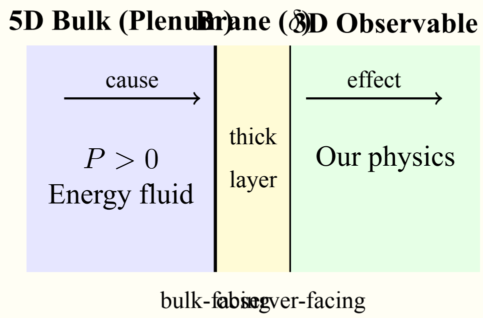
Level	**Content**	**Status**
Inherited	Baryon = 3-arm junction in 5D bulk	**[P]** (from F)
Inherited	Equal tensions $\Rightarrow 120^\circ$ angles	**[Der]** (from F)
Postulate	Neutron = excited (non-Steiner) junction	**[P]**
Definition	Collective coordinate $q = \lvert\hat{e}_1 + \hat{e}_2 + \hat{e}_3\rvert/3$	**[Def]**
Consequence	Excitation carries geometric energy	**[Dc]**
Model	Ring mode + 3 springs (heuristic)	**[I]**/**[P]**
Open	Thick-brane pumping mechanism	**[OPEN]**
Open	WKB–damping bridge	**[OPEN]**

2 Thick-Brane Setting

This section summarizes the thick-brane framework established in Companion H. The brane is not a mathematical surface but a **finite-thickness layer** with distinct bulk-facing and observer-facing boundaries.

2.1 The Brane as "Glass Window"

Conceptual Picture [P]



Key idea: The brane has TWO sets of boundary conditions:

- **Left (bulk-facing):** BC toward 5D bulk (Plenum, energy fluid)
- **Right (observer-facing):** BC toward 3D observable universe (our physics)

Physics in 5D is the **cause**; 3D observations are the **effect**.

2.2 Bulk–Brane Energy Exchange

Remark 2.1 (Canonical reference [BL]). *See Framework v2.0, Remark 4.5 for the canonical bulk–brane conservation statement and sign convention ($J^{\nu}_{bulk\to brane} > 0$ = INFLOW).*

The thick-brane allows energy to flow from bulk structures (junctions) into brane-localized modes, which then appear as observable particles on the 3D side.

2.3 Frozen Projection Boundary

Definition 2.1 (Frozen Projection **[Dc]**/**[P]**). *The* ***frozen projection boundary*** *is the observer-facing interface where:*

1. *High-frequency bulk modes are adiabatically eliminated ("frozen")*
2. *Only allowed channels (selection rules) can carry energy to 3D*
3. *Acts as a* ***one-way valve****: INFLOW allowed, OUTFLOW suppressed*

For neutron decay, this boundary organizes the released junction energy into the β^- channel: $e^- + \bar{\nu}_e +$ recoil.

3 Neutron as Excited Junction: Ontology

3.1 Same Topology, Different State

Postulate 1 (Neutron as Excited Junction **[P]**). *In 5D EDC, the neutron is a three-arm flux-tube junction with the* ***same topological structure*** *as the proton, but in an* ***excited state****—displaced from the Steiner minimum.*

	Proton	Neutron
Topology	Y-junction (3 arms)	Y-junction (3 arms)
Arm angles	120° (Steiner)	$\neq$ 120° (excited)
Energy state	Ground state (minimum)	Metastable (excited)
Stability	Stable	Unstable ($\tau \approx 879$ s)
Charge (Q)	+1	0

3.2 Collective Coordinate

Definition 3.1 (Collective Coordinate q **[Def]**). *Let $\hat{e}_i$ ($i = 1, 2, 3$) be the unit tangent vectors at the junction. The collective coordinate measuring departure from Steiner symmetry is:*

$$\boxed{q \equiv \frac{1}{3} |\hat{e}_1 + \hat{e}_2 + \hat{e}_3|} \tag{1}$$

Proposition 3.1 (Range and Interpretation **[Der]**). *The collective coordinate satisfies:*

- $q = 0$*: Steiner configuration (*$\hat{e}_1 + \hat{e}_2 + \hat{e}_3 = 0$*)* $\Rightarrow$ ***proton***
- $q = 1$*: Maximal asymmetry (all arms parallel)* $\Rightarrow$ *unphysical limit*
- $0 < q < 1$*: Excited states, including **neutron***

Proof. For unit vectors summing to zero (Steiner), $|\sum \hat{e}_i| = 0$, hence $q = 0$. For all parallel, $|\sum \hat{e}_i| = 3$, hence $q = 1$. Intermediate configurations give $0 < q < 1$. □

Remark 3.1 (Neutron value of q **[I]**/**[OPEN]**). *Based on $\mathbb{Z}_6$ symmetry arguments (Companion G), the neutron corresponds to approximately:*

$$q_n \approx \frac{1}{3} \quad \textit{(or equivalently, half-Steiner displacement)} \tag{2}$$

*The precise value and its derivation from first principles remain **[OPEN]**. Current estimates give $q_n \approx 0.31$ from phenomenological matching.*

3.3 Energy from Displacement

Lemma 3.2 (Geometric Excitation Energy **[Dc]**). *Any displacement from the Steiner minimum ($q = 0$) carries positive geometric energy:*

$$E_{geom}(q) = E_0 + \kappa_q\, q^2 + O(q^4) \tag{3}$$

where $\kappa_q > 0$ is the stiffness of the junction against asymmetric deformations.

Proof. The Steiner point is a local minimum of the total weighted length (Companion F, Theorem 4.1). Near a minimum, the energy expands as a positive-definite quadratic form to leading order. □

Corollary 3.3 (Instability **[Dc]**). *The neutron ($q_n > 0$) has higher energy than the proton ($q = 0$). This energy difference drives relaxation toward the Steiner minimum.*

4 Mechanics Picture: Ring + 3 Springs

4.1 Heuristic Model

To build intuition for the junction dynamics, we introduce a mechanical analogy.

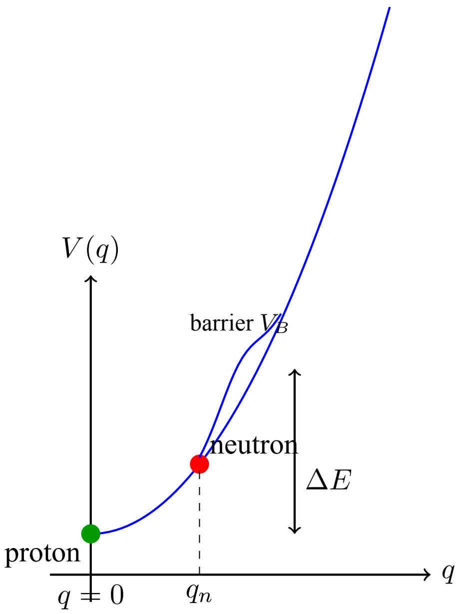
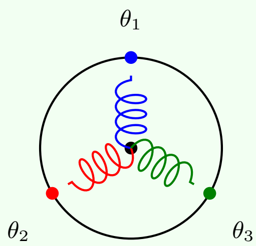


Figure 1: Schematic potential $V(q)$ for the junction coordinate. The proton sits at $q = 0$ (Steiner minimum); the neutron at $q_n > 0$ (metastable excited state). A barrier V_B separates neutron from proton, determining the tunneling lifetime.

Mechanical Analogy [I]/[P]

Ring + 3 Springs Model:
Consider a circular ring of radius R with three springs attached at angles $\theta_1, \theta_2, \theta_3$, each pulling toward the center with spring constant k. The springs represent flux-tube tensions; the ring represents a collective constraint.



Interpretation:

- Equilibrium: $\theta_1 = \theta_2 = \theta_3 = 120^\circ$ (proton)
- Excited: angles deviate, springs store extra energy (neutron)
- Ring constraint couples all three modes (collective dynamics)

4.2 Three-Mode Decomposition

The junction has three angular degrees of freedom $(\theta_1, \theta_2, \theta_3)$ subject to $\theta_1 + \theta_2 + \theta_3 = 2\pi$. This leaves two independent modes:

Definition 4.1 (Mode Decomposition **[Def]**)**.**

$$q = \textit{(collective asymmetry)} = \frac{1}{3}|\hat{e}_1 + \hat{e}_2 + \hat{e}_3| \qquad \text{(radial)}$$

$$\perp_1, \perp_2 = \textit{(transverse modes)} \qquad \text{(angular)}$$

The collective coordinate q measures overall departure from Steiner; the transverse modes $\perp_{1,2}$ describe shape distortions at fixed q.

Remark 4.1 (Effective 1D dynamics **[I]**)**.** *For slow (adiabatic) relaxation, the transverse modes equilibrate quickly, and the effective dynamics is one-dimensional in q. This justifies the 1D WKB treatment in Paper 3.*

4.3 Linearized Oscillation

Near the metastable neutron configuration $q = q_n$, the dynamics linearizes to:

$$\ddot{q} + 2\gamma\dot{q} + \omega_0^2(q - q_n) = 0 \tag{4}$$

where:

- ω_0 = natural frequency (junction stiffness) **[P]**
- γ = effective damping (energy loss to brane modes) **[OPEN]**

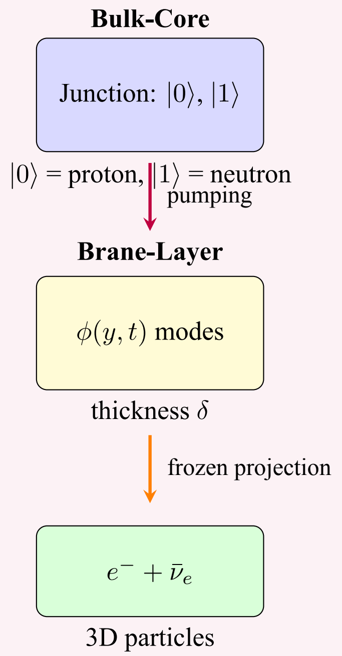
Remark 4.2 (Not a Standard Model oscillator **[I]**)**.** *Equation (4) is a* ***mechanical linearization*** *around a geometric minimum—not a quantum field theory oscillator. It captures the qualitative behavior: the junction oscillates around its metastable position while losing energy to the brane.*

5 Pumping and Dissipation Pathway

5.1 Bulk-Core to Brane-Layer Coupling

As the junction oscillates/relaxes, it couples to modes within the brane layer:

Energy Pathway [P]/[OPEN]



Mechanism (schematic):

1. Neutron junction relaxes: $q_n \to 0$ (toward proton)
2. Relaxation couples to brane-layer fields: $\mathcal{L}_{\text{int}} \sim g \cdot q(t) \cdot \phi(y = -\delta/2, t)$
3. Brane modes cascade to observer-facing boundary
4. Frozen projection selects allowed outputs: $e^- + \bar{\nu}_e$ + recoil

5.2 Coupling Structure

Postulate 2 (Bulk-Brane Coupling **[P]**). *The junction coordinate q couples linearly to brane-layer modes ϕ at the bulk-facing boundary:*

$$\mathcal{L}_{int} = g\, q(t)\, \phi(y = -\delta/2, t) \tag{5}$$

*where g is an effective coupling constant (dimensions and magnitude **[OPEN]**).*

Remark 5.1 (Coupling derivation **[OPEN]**). *The coupling Eq. (5) is postulated based on locality (junction at bulk-facing boundary) and linearity (leading-order expansion). A first-principles derivation from the 5D action remains open.*

5.3 Conservation Ledger

Remark 5.2 (Energy closure **[BL]**). *Energy released by junction relaxation ($\Delta E = E(q_n) - E(0) \approx \Delta m_{np}c^2 \approx 1.293$ MeV) is transferred to brane modes and ultimately to 3D particles. Total energy is conserved via Framework v2.0, Remark 4.5.*

6 Frozen Projection Boundary

6.1 One-Way Valve Mechanism

Proposition 6.1 (Asymmetric Flow **[Dc]**/**[P]**). *The frozen projection boundary acts as a* ***one-way valve****:*

- ***INFLOW*** *(bulk $\to$ brane): spontaneously allowed*

- ***OUTFLOW*** *(brane $\to$ bulk): energetically/kinematically suppressed*

Physical interpretation: The boundary condition at the observer-facing side "freezes" high-energy bulk modes, preventing their re-excitation from the 3D side. This is analogous to decoherence: environmental tracing eliminates coherent bulk superpositions.

6.2 Selection Rules

The frozen boundary imposes selection rules on which decay products can emerge:

1. **Charge conservation:** $Q_{\text{in}} = Q_{\text{out}}$ (neutron: $0 \to +1 + (-1) + 0$)
2. **Lepton number:** $L_e : 0 \to 0 + 1 + (-1) = 0$ (✓)
3. **Energy threshold:** $\Delta E > m_e c^2$ required for electron emission
4. **Momentum matching:** recoil absorbed by proton

Remark 6.1 (V–A structure [BL]). *The $V - A$ (vector minus axial-vector) structure of weak interactions is **not derived here**—it is input from Standard Model phenomenology. EDC provides the energy release mechanism; the detailed interaction vertex is inherited.*

7 Beta$^-$ Channel as Observer-Facing Output

7.1 Decay Process Mapping

5D (Cause)		3D (Effect)
Junction relaxes: $q_n \to 0$	$\Rightarrow$	$n \to p$
Energy pumped to brane: $\Delta E \approx 1.293$ MeV	$\Rightarrow$	Kinetic energy of products
Brane modes organize via selection rules	$\Rightarrow$	$e^- + \bar{\nu}_e$ emission

7.2 Why Electron and Antineutrino?

Remark 7.1 (Channel selection [Dc]/[P]). *The frozen boundary's selection rules (charge, lepton number, energy threshold) determine that:*
- *A charge -1 lepton must be emitted (to conserve Q)*
- *The lightest such lepton is e^- (muon would require $\Delta E > 105$ MeV)*
- *Antineutrino carries lepton number -1 (to conserve L_e)*

*This is **not** a derivation of why weak interactions exist, but an explanation of why β^- is the allowed channel given the EDC framework.*

7.3 Suppressed Channels

- $n \to p + \mu^- + \bar{\nu}_\mu$: Forbidden by $m_\mu > \Delta E$
- $n \to p + \gamma$: Suppressed (no photon channel in lowest-order weak)
- $n \to p + e^- + e^+ + \nu_e + \bar{\nu}_e$: Phase space suppressed

8 Observable Benchmarks (No Fitting)

This section lists observable quantities and their status in the EDC neutron model. **No parameters are fitted in this companion.**

Observable	**Value**	**Status**	**Notes**
Neutron lifetime τ_n	879.4 ± 0.6 s	[BL]	PDG 2024
Mass difference Δm_{np}	1.293 MeV	[BL]	CODATA
Q-value ($n \to p + e + \bar{\nu}$)	0.782 MeV	[BL]	Kinematic endpoint
Proton recoil	$\sim$ keV	[BL]	Small due to mass ratio
Δm_{np} from $\mathbb{Z}_6$ breaking	1.30 MeV	[Dc]	Companion G
$q_n \approx 1/3$	identified	[I]	Half-Steiner
Barrier height V_B	~ 2.6 MeV	[Cal]	Fitted to τ_n (Paper 3)

Remark 8.1 (Lifetime is NOT predicted **[Cal]**)**.** *The neutron lifetime $\tau_n \approx 879$ s is reproduced in Paper 3 via WKB tunneling through a barrier V_B. However, V_B is **calibrated** to match τ_n, not derived from first principles. A first-principles derivation of V_B (or equivalently, the attempt frequency Γ_0) remains **[OPEN]**.*

9 Open Problems and Research Roadmap

9.1 Critical Open Problems

1. **Derive V_B from 5D action [OPEN]**
   - Current status: $V_B \approx 2.6$ MeV is calibrated (Paper 3)
   - Goal: Show V_B emerges from junction geometry + brane tension
   - Would upgrade τ_n from **[Cal]** to **[Der]**
2. **WKB–Damping Bridge [OPEN]**
   - Paper 3 uses WKB tunneling through $V(q)$
   - This companion uses damped oscillator + pumping
   - Goal: Show equivalence in appropriate limits
3. **Thick-brane coupling g [OPEN]**
   - Postulated in Eq. (5)
   - Need: derive from 5D action or constrain from observables
4. **Precise value of q_n [I]/[OPEN]**
   - Currently: $q_n \approx 1/3$ from $\mathbb{Z}_6$ symmetry arguments
   - Alternative: $q_n \approx 0.31$ from phenomenology
   - Need: reconcile or derive from first principles

9.2 Important (For Completeness)

- Derive factor $12 = \mathbb{Z}_6 \times \mathbb{Z}_2$ connecting 70 MeV and 5.856 MeV scales
- Derive $S/\hbar = 60 \approx 12\ln(1/\alpha) + 1$ (currently **[I]**)
- Connect neutrino emission to ξ-wave dynamics

9.3 Already Resolved (Documented Elsewhere)

Problem	Solution	Document
Frozen criterion from action	Two routes (instanton + topological)	Paper 2
$120°$ Steiner angles	Variational derivation	Companion F
Δm_{np} from geometry	$\mathbb{Z}_6$ symmetry breaking	Companion G
Weak channel selection rules	Thick-brane microphysics	Companion H

10 Summary and Epistemic Classification

10.1 Main Results

1. **Neutron ontology**: Same Y-junction as proton, but excited (displaced from Steiner) **[P]**
2. **Collective coordinate**: $q = |\hat{e}_1 + \hat{e}_2 + \hat{e}_3|/3$ measures asymmetry **[Def]**
3. **Instability**: $q_n > 0$ implies higher energy than proton ($q = 0$) **[Dc]**
4. **Relaxation pathway**: Junction $\to$ brane modes $\to$ 3D particles **[P]**/**[OPEN]**
5. **Frozen projection**: Organizes outputs into allowed channels **[Dc]**/**[P]**

10.2 Epistemic Classification Table

Claim	Tag	Ref	Notes
Baryon = 3-arm junction	**[P]**	F, Post. 1	Inherited
$120°$ Steiner optimum	**[Der]**	F, Thm. 4.2	Variational
Neutron = excited junction	**[P]**	Post. 1	This paper
Collective coordinate q	**[Def]**	Def. 3.1	Definition
Excitation $\Rightarrow$ instability	**[Dc]**	Lem. 3.2	From minimum property
Ring + springs (heuristic)	**[I]**/**[P]**	§4	Mechanical analogy
Thick-brane pumping	**[P]**/**[OPEN]**	Post. 2	Mechanism open
Frozen projection output	**[Dc]**/**[P]**	Prop. 6.1	From H + Paper 2
$\tau_n \approx 879$ s	**[BL]**	PDG	Observable
V_B barrier height	**[Cal]**	Paper 3	Fitted to τ_n
$q_n \approx 1/3$	**[I]**	Rem. 3.1	From $\mathbb{Z}_6$ pattern

10.3 Calibration Boundary

This companion has zero calibrated parameters.

The neutron lifetime τ_n enters only as a baseline observable [BL] for consistency checks. The barrier height V_B that determines τ_n via WKB is calibrated in Paper 3, not here. All geometric results (q definition, Steiner instability, relaxation direction) are parameter-free consequences of the junction postulate.

Cornerstone Statement

Neutron Geometry: The Excited Junction Foundation

Given the junction postulate (baryons = 3-arm flux-tube networks in 5D, from Companion F):

1. The neutron is an **excited** junction state (displaced from Steiner) **[P]**
2. Excitation carries geometric energy that drives relaxation **[Dc]**
3. The collective coordinate $q = |\hat{e}_1 + \hat{e}_2 + \hat{e}_3|/3$ quantifies asymmetry **[Def]**
4. Relaxation pumps energy into thick-brane modes **[P]**/**[OPEN]**
5. Frozen projection organizes output into $e^- + \bar{\nu}_e$ **[Dc]**/**[P]**

This is the geometric foundation for the neutron in 5D EDC.

The neutron is not a "different animal" from the proton—it is the **same 5D object** in an excited state, destined to relax toward the Steiner minimum.

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