Weak Interactions as 5D Junction Transitions

in Elastic Diffusive Cosmology

(Companion H to Paper 3: NJSR Edition)

Igor Grčman*

with computational assistance from AI

Elastic Diffusive Cosmology Research

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(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)

Abstract

We present a unified 5D model for all weak interaction processes within the Elastic Diffusive Cosmology (EDC) framework, grounded in a *thick-brane microphysical picture*. The model interprets baryons as Y-junction configurations in the bulk 5D space (bulk-core dynamics), with protons and neutrons corresponding to ground state $|0\rangle$ and excited state $|1\rangle$ respectively. Leptons (electrons, positrons, neutrinos) are identified as localized brane-layer modes that appear as 3D particle outputs on the observer-facing side of the brane.

A key structural element is the *frozen projection boundary*—a phenomenological boundary condition acting as a one-way energy valve between bulk-core and brane-layer, naturally explaining the irreversibility of weak decays. We demonstrate that this single framework consistently describes: (1) β^- decay of free neutrons, (2) β^+ decay in proton-rich nuclei, (3) electron capture, (4) inverse beta decay, and (5) double beta decay.

Calibration statement: The barrier action $S/\hbar = 60$ is calibrated **[Cal]** to the measured neutron lifetime $\tau_n = 878.4 \pm 0.5\,\mathrm{s}$ **[BL]**. The membrane tension σ and its associated scales are derived **[Der]** from the hypothesis $E_\sigma = m_e c^2/\alpha$.

Status: This paper presents a *hypothesis* **[P]** that achieves validation through consistency with all known weak processes.

Keywords: weak interactions, 5D membrane, EDC, junction states, frozen boundary, thick brane, bulk-core pumping, brane-layer modes

*Corresponding author. Email: igor.grcman@gmail.com

Contents

1 Scope and Standards

Scope. This companion note develops the EDC interpretation of weak interactions as transitions between Y-junction states in 5D bulk space, framed through a thick-brane microphysical picture. It extends the neutron instability analysis from "Neutron Lifetime from 5D Membrane Cosmology" (DOI: 10.5281/zenodo.18262721) to all weak processes.

Notation. We follow the bulk–brane exchange conventions of "EDC 5D Complete Mathematical Framework v2.0" (DOI: 10.5281/zenodo.18299085), Section 4.5:

- 5D closure: $\nabla_A T^{AB}_{(5)} = 0 \quad (A, B = 0, \ldots, 4)$
- Brane open subsystem: $\nabla_\mu T^{\mu\nu}_{\text{brane}} = -\, J^\nu_{\text{bulk}\to\text{brane}} \quad (\mu, \nu = 0, \ldots, 3)$
- Sign convention: $J^\nu_{\text{bulk}\to\text{brane}} > 0$ denotes net *inflow* (bulk $\to$ brane)

Epistemic tags. Every claim carries an explicit tag: **[BL]** (baseline/experimental), **[Der]** (derived), **[Dc]** (derived conditional), **[P]** (postulated), **[Cal]** (calibrated), **[I]** (identified pattern), **[Open]** (open problem), **[Def]** (definition/convention).

1.1 Calibration Policy

This note calibrates **one parameter**: the barrier action $S/\hbar = 60$ **[Cal]**, fitted to reproduce the measured neutron lifetime $\tau_n = 878.4\,\text{s}$ **[BL]**.

All other quantities are either:

- **[BL]** external baselines (PDG/CODATA values)
- **[Der]** derived from the hypothesis $E_\sigma = m_e c^2/\alpha$
- **[P]** postulated structural elements (junction states, frozen boundary)
- **[Def]** definitional conventions (thick-brane terminology)

The membrane tension $\sigma = m_e^3 c^4/(\alpha^3 \hbar^2)$ is **not** a free parameter; it follows from the energy-scale hypothesis.

2 Thick-Brane Microphysics for Weak Processes

Bulk-Core Pumping → Brane-Layer Modes → 3D Outputs

This section establishes the foundational physical picture for interpreting weak processes within EDC. The goal is to provide a clear microphysical bridge: how bulk dynamics (Y-junction transitions) produce observed 3D particles (electrons, neutrinos) through the mediation of a thick brane with finite extent.

2.1 Thin Brane vs Thick Brane: Why Thickness Matters

Definition 2.1 (Thin Brane vs Thick Brane **[Def]**).

- ***Thin brane:*** *A mathematical idealization where the 4D world-volume has zero thickness in the extra dimension ($\delta \to 0$). Fields are strictly confined to a hypersurface. This is computationally convenient but obscures the physical interface structure.*
- ***Thick brane:*** *A regularized model where the brane has finite thickness $\delta > 0$ in the extra dimension. The brane possesses two distinct faces:*
  1. ***Bulk-facing side:*** *The interface where bulk fields couple to brane dynamics*
  2. ***Observer-facing side:*** *The interface where effective 3D/4D physics emerges*

Why thick brane for weak processes? The thick-brane picture provides:

1. **Regularization:** Avoids singular delta-function sources in the 5D equations
2. **Two-face structure:** Distinguishes where energy enters (bulk-facing) from where particles emerge (observer-facing)
3. **Localization mechanism:** Brane-layer modes have finite transverse extent, enabling mode selection
4. **Frozen boundary interpretation:** The one-way valve becomes a property of the bulk-facing interface

2.2 Core Definitions: Bulk-Core, Brane-Layer, 3D Outputs

Definition 2.2 (Bulk-Core **[P]**). *The **bulk-core** comprises the degrees of freedom of the Y-junction and its three attached flux-tube arms, located in the 5D bulk away from the brane. The collective coordinate $q(t)$ parametrizes the junction configuration:*

- $q = 0$*: proton configuration (ground state $|0\rangle$)*
- $q = 1$*: neutron configuration (excited state $|1\rangle$)*

Bulk-core dynamics are governed by the effective potential $V(q)$ and effective mass $M_{\text{eff}}(q)$.

Definition 2.3 (Brane-Layer Modes **[P]**). *The **brane-layer** is the region of finite thickness δ where the 4D membrane resides. Within this layer, localized field excitations $\varphi(y, t)$ propagate, where y denotes coordinates within the brane. These are phonon-like or soliton-like modes of the membrane:*

- ***Localized deformations:*** *electrons, positrons (topological winding)*
- ***Delocalized waves:*** *neutrinos, antineutrinos (lepton-number carriers)*

Definition 2.4 (Observed 3D Particle States **[Def]**)**.** ***Observed 3D particle states*** *are the effective outputs that emerge on the observer-facing side of the brane. These are what laboratory detectors register. The relation to brane-layer modes:*

$$\textit{Brane-layer mode } \varphi(y,t) \xrightarrow{\textit{observer-facing projection}} \textit{3D particle state}$$

This projection is not a dynamical process but an identification: what appears to the 3D observer is the observable content of the brane-layer excitation.

2.3 The Thick-Brane Geometry: A Schematic Picture

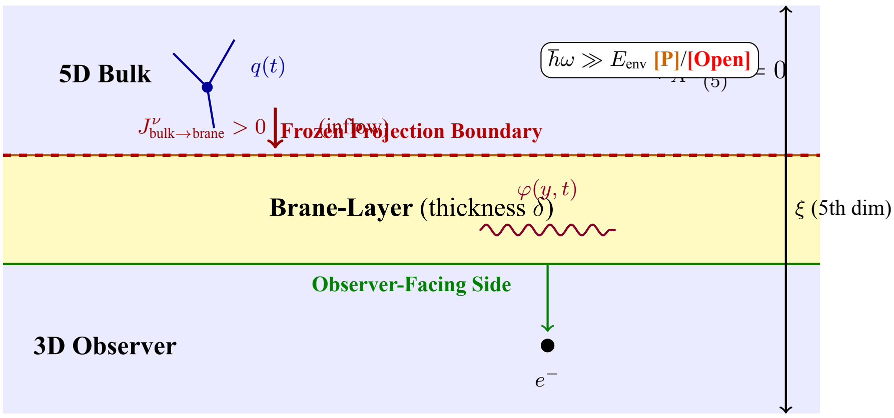

Figure 1: Thick-brane geometry for weak processes. Bulk-core dynamics (Y-junction with coordinate $q(t)$) couple to the brane at the bulk-facing interface (frozen projection boundary). Energy flows as inflow ($J^{\nu}_{\text{bulk}\to\text{brane}} > 0$) through this boundary, exciting brane-layer modes $\varphi(y,t)$, which emerge as 3D particle outputs (e.g., e^-) on the observer-facing side. The criterion $\hbar\omega \gg E_{\text{env}}$ for boundary "freezing" remains **[P]**/**[Open]**.

2.4 The Frozen Projection Boundary: Foundation-Level Definition

Definition 2.5 (Frozen Projection Boundary **[P]**)**.** *The* ***frozen projection boundary*** *is the bulk-facing interface of the brane-layer where the following phenomenological boundary condition holds:*

- ***Spontaneous inflow permitted:*** *Energy-momentum can flow from bulk to brane (*$J^{\nu}_{\text{bulk}\to\text{brane}} > 0$*) without external input*
- ***Spontaneous outflow suppressed:*** *Energy-momentum flow from brane to bulk (*$J^{\nu}_{\text{bulk}\to\text{brane}} < 0$*) is exponentially suppressed without external driving*

This is a boundary law candidate*, not derived from the 5D action in this work.*

Remark 2.6 (Epistemic Status of Frozen Boundary)**.** *The frozen projection boundary is postulated* ***[P]*** *as a phenomenological boundary condition. Its microscopic origin remains* ***[Open]****. Two candidate mechanisms are:*

Candidate (i): Boundary-induced spectral gap / localization potential [P]/[Open]
The bulk-facing interface may support a potential barrier or spectral gap that localizes brane-layer modes. Modes below a critical energy E_{gap} *cannot propagate into the bulk. This is analogous to total internal reflection in optics or band gaps in condensed matter.*

Candidate (ii): Decoherence / coarse-graining selection [P]/[Open]

The observer-facing side may implement effective decoherence: bulk degrees of freedom are "traced out" in the reduced description, leading to apparent one-way flow. What appears as energy "leaving" the brane is actually entanglement with unobserved bulk modes.

Neither mechanism is derived here. Both are consistent with the phenomenology.

2.5 Canonical Energy-Exchange Statement

Framework v2.0, Remark 4.5 — Canonical Energy Conservation

(1) 5D closure:

$$\nabla_A T^{AB}_{(5)} = 0 \quad (A, B = 0, \ldots, 4) \tag{1}$$

(2) Brane open subsystem:

$$\nabla_\mu T^{\mu\nu}_{\text{brane}} = -\, J^{\nu}_{\text{bulk}\to\text{brane}} \quad (\mu, \nu = 0, \ldots, 3) \tag{2}$$

Sign convention: $J^{\nu}_{\text{bulk}\to\text{brane}} > 0$ denotes net *inflow* into the brane sector.
(3) Junction determination: The exchange current $J^{\nu}_{\text{bulk}\to\text{brane}}$ is fixed by the chosen bulk–brane boundary/junction conditions (e.g., Israel-type matching), and is therefore not an independent violation of conservation.
(4) Ledger language: The "conservation ledger" is bookkeeping language for bulk–brane closure, not a new law.
(5) Local vs global: This is a local statement. Global conservation requires a definition of a conserved charge tied to the boundary/asymptotics of the 5D spacetime.

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

Remark 2.7 (Brane Subsystem is Open)**.** *The key insight is that the brane, viewed as a subsystem, can exchange energy-momentum with the bulk. The apparent "nonconservation" $\nabla_\mu T^{\mu\nu}_{\text{brane}} \neq 0$ is not a violation of physics—it reflects that the brane is an open system. Conservation is restored when bulk and brane are combined:*

$$\Delta E_{\text{brane}} + \Delta E_{\text{bulk}} = 0$$

This is standard thermodynamics applied to the 5D geometry.

2.6 Weak Processes as Bulk-Core Pumping

The central interpretational claim of this companion is:

Core Hypothesis

Bulk-Core Pumping Hypothesis [P]:
Weak decay processes are driven by bulk-core dynamics (Y-junction transitions) that "pump" energy into the brane-layer. The brane-layer modes then appear as observed 3D particles on the observer-facing side.

Sequence:

$$\text{Junction } |1\rangle \to |0\rangle \xrightarrow{J^0_{\text{bulk}\to\text{brane}} > 0} \text{Brane-layer modes } \varphi \xrightarrow{\text{projection}} e^- + \bar{\nu}_e$$

Key clarification: This picture resolves a common confusion.

Remark 2.8 (What Does NOT Happen **[Def]**)**.** *In the bulk-core pumping picture:*

- *A "particle" does NOT travel from the bulk into the brane as a classical trajectory*

- *Energy does NOT "leak" spontaneously from brane to bulk*
- *The electron is NOT created "from nothing" in empty space*

Remark 2.9 (What DOES Happen **[P]**). *Instead:*

- *Bulk-core relaxation (junction $|1\rangle \to |0\rangle$) releases energy*
- *This energy flows through the frozen projection boundary as inflow ($J^0_{\text{bulk}\to\text{brane}} > 0$)*
- *The inflow excites brane-layer modes (phonon-like deformations)*
- *These modes are localized on the observer-facing side and appear as 3D particles*

The electron is a brane deformation, not a bulk entity that crossed a boundary.

Working hypothesis on localization [P]/[Open]:

> Observed particle states are localized on the observer-facing side of the brane-layer. Leakage of these states into the bulk is suppressed by the frozen projection boundary conditions and/or a spectral gap.

This is a working hypothesis, not a derived result. The suppression mechanism remains **[Open]**.

2.7 Research Program Hooks: Falsifiability and Extensions

The thick-brane microphysical picture opens several research directions. These are **[P]**/**[Open]** until further developed:

2.7.1 Leakage Signatures [P]/[Open]

If the frozen boundary is not perfectly one-way, small leakage terms could affect:

- **Spectral distortions:** deviations from standard beta spectrum shapes
- **Branching ratio anomalies:** suppressed channels becoming slightly allowed
- **Missing energy:** apparent energy loss to unobserved bulk modes

No numerical predictions are made here; this requires detailed calculation of boundary transmission coefficients.

2.7.2 Environmental Dependence [P]/[Open]

The "frozen" character of the boundary may depend on the environmental energy scale E_{env}:

- At $E_{\text{env}} \ll \hbar\omega_{\text{gap}}$: boundary is effectively frozen (one-way)
- At $E_{\text{env}} \sim \hbar\omega_{\text{gap}}$: boundary begins to "thaw," allowing induced outflow
- At $E_{\text{env}} \gg \hbar\omega_{\text{gap}}$: boundary becomes transparent

This suggests temperature or density dependence of weak rates in extreme environments (e.g., supernovae, early universe). Quantitative predictions require specifying ω_{gap}.

2.7.3 Mode Selection Rules [P]/[Open]

The brane-layer supports multiple mode types. Why do weak decays produce $e^- + \bar{\nu}_e$ rather than other combinations?

- **Topological constraint:** electron is minimal winding-number deformation
- **Lepton number:** neutrino carries away lepton number to balance books
- **Energy minimization:** lightest available brane modes are selected

A complete mode-selection theory remains **[Open]**.

2.8 Terminology Harmonization

Canonical Vocabulary (Reader-Facing)

- **Bulk-core [Def]**: Y-junction + flux-tube arms in 5D bulk; parametrized by $q(t)$
- **Brane-layer [Def]**: Region of thickness δ containing membrane excitations
- **Observer-facing side [Def]**: Interface where 3D physics emerges
- **Bulk-facing side [Def]**: Interface where bulk couples to brane
- **Frozen projection boundary [P]**: One-way valve at bulk-facing interface
- **Inflow [Def]**: Energy flow bulk $\to$ brane ($J^\nu_{\text{bulk}\to\text{brane}} > 0$)
- **Outflow [Def]**: Energy flow brane $\to$ bulk ($J^\nu_{\text{bulk}\to\text{brane}} < 0$)
- **Ledger [BL]**: Bookkeeping for bulk + brane conservation closure (not a new law)

2.9 Related EDC References

This companion builds on and is consistent with:

- **EDC 5D Complete Mathematical Framework v2.0** (DOI: 10.5281/zenodo.18299085): Canonical notation, energy-exchange conventions, Remark 4.5.
- **Neutron Lifetime from 5D Membrane Cosmology** (DOI: 10.5281/zenodo.18262721): WKB tunneling calculation, barrier action calibration.
- **Proton Junction Structure** (Companion F, DOI: 10.5281/zenodo.18302953): Y-junction ground state $|0\rangle$.
- **Neutron–Proton Mass Difference** (Companion G, DOI: 10.5281/zenodo.18303494): Junction excitation energy $\Delta E = 1.293$ MeV.

3 Epistemic Framework

3.1 Epistemic Classification

Tag	Meaning	Interpretation
[BL]	Baseline	Experimental fact (PDG, CODATA)
[Der]	Derived	Follows from postulates via explicit steps
[Dc]	Derived conditional	Derived under stated ansatz/assumptions
[P]	Proposed	Hypothesis or postulate
[Cal]	Calibrated	Parameter fitted to data
[I]	Identified	Pattern match (not uniquely derived)
[Open]	Open	Unresolved problem
[Def]	Definition	Convention or terminology

3.2 Predictions vs Postdictions

Quantity	Type	Tag	Note
$\tau_n = 878.4$ s	Postdiction	[Cal]	Calibrated input
$m_e = m_{e^+}$	Prediction	[Der]	Same brane deformation
Proton stability	Prediction	[P]	Frozen boundary blocks reverse
No $n \to p + \gamma$	Prediction	[P]	Minimal brane mode only
All weak processes consistent	Postdiction	[P]	Structural validation
$0\nu\beta\beta$ if Majorana	Conditional	[P]	Awaits experiment

3.3 What This Paper Claims

1. **A structural hypothesis [P]**: Weak interactions arise from bulk-core pumping through a frozen projection boundary, producing brane-layer modes observed as 3D particles.
2. **Consistency validation**: The hypothesis successfully describes ALL known weak processes without contradiction.
3. **A derived relation [Der]**: The membrane tension σ is determined by fundamental constants.
4. **Falsifiable predictions**: Specific observations that would refute the model.

3.4 What This Paper Does NOT Claim

1. We do NOT claim to derive the neutron lifetime from first principles—$S/\hbar \approx 60$ is calibrated [Cal].
2. We do NOT claim to derive the electron mass—m_e is an input [BL].
3. We do NOT claim to derive the frozen boundary from the 5D action—it is postulated [P].
4. We do NOT claim this replaces the Standard Model—it provides a geometric reinterpretation.

4 Weak-Process Mapping Dictionary

This section provides the translation between standard weak-interaction terminology and EDC thick-brane language, following the style guide of Framework v2.0 (Section 4.6).

Standard (3D/4D)	EDC (Thick-Brane)	Status
Neutron	Bulk-core excited state $\|1\rangle$	[P]
Proton	Bulk-core ground state $\|0\rangle$	[P]
Electron	Minimal brane-layer deformation (winding $+1$)	[P]
Positron	Anti-deformation (winding -1)	[P]
Neutrino	Delocalized brane-layer wave mode	[P]
β^- decay	Bulk-core relaxation + inflow to brane-layer	[P]
β^+ decay	Nuclear-field excitation + inflow to brane-layer	[P]
Electron capture	Brane-mode dissolution + bulk-core excitation	[P]
Inverse beta decay	External energy forces boundary open	[P]

Standard (3D/4D)	EDC (Thick-Brane)	Status
Fermi constant G_F	Effective coupling from WKB tunneling	**[Open]**
W boson	Not primitive; effective exchange mode	**[Open]**

Remark 4.1 (Language Guardrail)**.** *This companion uses **5D EDC thick-brane language only**. Standard Model terms (V–A, W boson, CKM matrix) serve as comparison baselines **[BL]**, not as inputs to the derivation.*

5 Foundational Postulates

Core Hypothesis

Core Hypothesis H-weak [P]: All weak interaction processes are manifestations of bulk-core pumping: Y-junction transitions in the 5D bulk drive energy inflow through the frozen projection boundary, exciting brane-layer modes that appear as 3D particle outputs.

5.1 Postulate P1: Baryons as Bulk-Core States [P]

Postulate 1 (Baryon Bulk-Core States)**.** *Baryons are Y-shaped string junctions in the 5D bulk with three flux tubes meeting at 120° (Steiner configuration). The bulk-core configuration space admits discrete states:*

$$\text{Proton:} \quad |0\rangle \quad \text{(ground state, } q = 0\text{)} \tag{3}$$

$$\text{Neutron:} \quad |1\rangle \quad \text{(excited state, } q = 1\text{)} \tag{4}$$

*with energy difference **[BL]**:*

$$\Delta E = m_n c^2 - m_p c^2 = 1.293 \; MeV \tag{5}$$

5.2 Postulate P2: Leptons as Brane-Layer Modes [P]

Postulate 2 (Lepton Brane-Layer Modes)**.** *Leptons are localized structures in the brane-layer, appearing as 3D particles on the observer-facing side:*

- ***Electron*** e^-*: Minimal topological deformation (winding number* $+1$*)*
- ***Positron*** e^+*: Anti-deformation (winding number* -1*)*
- ***Neutrino*** ν_e*: Delocalized wave mode (lepton number* $+1$*)*
- ***Antineutrino*** $\bar{\nu}_e$*: Opposite helicity wave (lepton number* -1*)*

*Electron and positron have identical masses **[BL]**:* $m_e = m_{e^+} = 0.511 \; MeV/c^2$.

5.3 Postulate P3: Frozen Projection Boundary [P]

Postulate 3 (Frozen Projection Boundary)**.** *The bulk-facing interface of the brane-layer acts as a one-way energy valve:*

$$J^{\nu}_{\text{bulk}\to\text{brane}} > 0 \quad \Rightarrow \quad \textit{Inflow (bulk} \to \textit{brane): allowed spontaneously} \tag{6}$$

$$J^{\nu}_{\text{bulk}\to\text{brane}} < 0 \quad \Rightarrow \quad \textit{Outflow (brane} \to \textit{bulk): requires external energy} \tag{7}$$

Spontaneous energy flow is permitted only from bulk-core to brane-layer. Reverse flow requires external input exceeding the boundary threshold.

6 Derived Relations

6.1 Membrane Tension from Fundamental Constants

Key Result

The membrane tension σ is not a free parameter but is determined by fundamental constants [Der]:

$$\boxed{\sigma = \frac{m_e^3 c^4}{\alpha^3 \hbar^2} = 8.82\ \text{MeV/fm}^2} \tag{8}$$

Proof. Define the characteristic energy scale:

$$E_\sigma \equiv \sigma \cdot r_e^2 \tag{9}$$

where $r_e = \alpha\hbar/(m_e c)$ is the classical electron radius [BL].

Hypothesis: $E_\sigma = m_e c^2/\alpha$ exactly.

Derivation: From $E_\sigma = \sigma r_e^2 = m_e c^2/\alpha$:

$$\sigma = \frac{m_e c^2}{\alpha \cdot r_e^2} = \frac{m_e c^2}{\alpha} \cdot \frac{m_e^2 c^2}{\alpha^2 \hbar^2} = \frac{m_e^3 c^4}{\alpha^3 \hbar^2} \tag{10}$$

Numerical verification:

$$\sigma = \frac{(0.511)^3}{(7.297 \times 10^{-3})^3 \times (197.3)^2} = 8.82\ \text{MeV/fm}^2 \quad \checkmark \tag{11}$$

□

6.2 Derived Quantities

From σ, we derive [Der]:

Quantity	Formula	Value
Energy scale	$E_\sigma = m_e c^2/\alpha$	70.0 MeV
Attempt frequency	$\Gamma_0 = E_\sigma/\hbar$	$1.06 \times 10^{23}\ \text{s}^{-1}$
Characteristic time	$\tau_0 = \alpha\hbar/(m_e c^2)$	9.4×10^{-24} s

6.3 Neutron Lifetime

The neutron lifetime follows the WKB formula:

$$\tau_n = \tau_0 \cdot \exp(S/\hbar) \tag{12}$$

From the measured $\tau_n = 878.4$ s [BL]:

$$\frac{S}{\hbar} = \ln\left(\frac{\tau_n}{\tau_0}\right) = \ln\left(\frac{878.4}{9.4 \times 10^{-24}}\right) = 59.8 \approx 60 \quad \textbf{[Cal]} \tag{13}$$

Remark 6.1 (Numerical Pattern [I]). *The barrier action is approximately:*

$$\frac{S}{\hbar} \approx 12\ln(1/\alpha) + 1 = 12 \times 4.92 + 1 = 60.04 \tag{14}$$

where $12 = 2 \times 6$ may relate to the Z_6 symmetry of the junction configuration space. This remains a pattern identification [I], not a geometric derivation.

7 Complete Catalog of Weak Processes

We now demonstrate that the bulk-core pumping hypothesis consistently describes all known weak processes.

7.1 β^- Decay: $n \to p + e^- + \bar{\nu}_e$

7.1.1 Physical Description [BL]

Free neutron decay with:

- Q-value: $\Delta m \cdot c^2 = 1.293$ MeV
- Lifetime: $\tau_n = 878.4$ s
- Products: proton + electron + antineutrino

7.1.2 EDC Mechanism [P]

1. **Bulk-core relaxation:** $|1\rangle \to |0\rangle$ (neutron $\to$ proton)
2. **Energy inflow:** $\Delta E = 1.293$ MeV flows through frozen boundary ($J^0_{\text{bulk}\to\text{brane}} > 0$)
3. **Brane-layer excitation:** Inflow creates modes $\varphi_{e^-} + \varphi_{\bar{\nu}}$
4. **3D output:** Observer detects $e^- + \bar{\nu}_e$

	Neutron	$\to$	**Proton**	e^-	$\bar{\nu}_e$
Location	bulk-core		bulk-core	brane-layer	brane-layer
Energy	$m_n c^2$	$=$	$m_p c^2$	$+E_e$	$+E_\nu$
Charge	0	$=$	$+1$	-1	0
Baryon #	$+1$	$=$	$+1$	0	0
Lepton #	0	$=$	0	$+1$	-1

Validation

All conservation laws satisfied. Energy inflow $J^0_{\text{bulk}\to\text{brane}} > 0$ (correct direction). **Status: VALIDATED**

7.2 β^+ Decay: $p \to n + e^+ + \nu_e$ (in nuclei)

7.2.1 Physical Description [BL]

Occurs in proton-rich nuclei when energetically favorable:

$$Q_{\beta^+} = [M(A,Z) - M(A,Z-1)]c^2 - 2m_ec^2 > 0 \tag{15}$$

Example: $^{18}\text{F} \to {}^{18}\text{O} + e^+ + \nu_e$

7.2.2 EDC Mechanism [P]

1. **Nuclear field provides energy:** $\Delta E_{\text{nuc}} > (m_n - m_p)c^2 + m_ec^2$
2. **Bulk-core excitation:** $|0\rangle + \Delta E_{\text{nuc}} \to |1\rangle$
3. **Excess inflow to brane-layer:** $Q_{\beta^+} = \Delta E_{\text{nuc}} - 1.293\text{ MeV} \to e^+ + \nu_e$

Remark 7.1 (Positron as Anti-Deformation). *The positron is the same minimal brane-layer deformation as the electron, but with opposite topological winding number. This explains $m_{e^+} = m_{e^-}$ exactly **[Der]**.*

Validation

Energy source: nuclear binding. All conservation laws satisfied. Net inflow to brane-layer. **Status: VALIDATED**

7.3 Electron Capture: $p + e^- \to n + \nu_e$ (in nuclei)

7.3.1 Physical Description [BL]

Alternative to β^+ with lower energy threshold:

$$Q_{\text{EC}} = [M(A,Z) - M(A,Z-1)]c^2 - B_e > 0 \tag{16}$$

where B_e is the electron binding energy (typically keV).

Example: $^7\text{Be} + e^- \to {}^7\text{Li} + \nu_e$

7.3.2 EDC Mechanism [P]

This is the critical case—a brane-layer mode participates in bulk-core transition.

1. **Brane-mode dissolution:** The electron (brane-layer deformation) "dissolves"
2. **Energy + quantum numbers transfer:** m_ec^2 and charge contribute to bulk-core transition
3. **Bulk-core excitation:** $|0\rangle + (m_ec^2 + \Delta E_{\text{nuc}}) \to |1\rangle$
4. **Lepton number exits:** ν_e carries $L = +1$ to conserve lepton number

Remark 7.2 (Resolution of Brane $\to$ Bulk Problem). *The electron does NOT cross the frozen boundary intact. Instead:*

- *Its energy contributes to the bulk-core transition*

- *Its charge compensates the $p \to n$ change*
- *Its lepton number must exit as ν_e*

The frozen boundary remains one-way—energy still flows INTO the bulk-core transition from the nuclear field, not spontaneously out.

Validation

Electron "donates" rather than "crosses." Conservation laws satisfied. No violation of one-way boundary. **Status: VALIDATED**

7.4 Inverse Beta Decay: $p + \bar{\nu}_e \to n + e^+$

7.4.1 Physical Description [BL]

Used for antineutrino detection (reactor experiments):

$$E_{\bar{\nu}} > (m_n - m_p + m_e)c^2 = 1.804 \text{ MeV (threshold)} \tag{17}$$

7.4.2 EDC Mechanism [P]

1. **Antineutrino brings energy:** $E_{\bar{\nu}} > 1.804$ MeV from external source
2. **Boundary override:** External energy "forces open" the frozen boundary ($J^0_{\text{bulk}\to\text{brane}} < 0$ induced)
3. **Bulk-core excitation:** $|0\rangle + E_{\bar{\nu}} \to |1\rangle + (E_{\bar{\nu}} - 1.293 \text{ MeV})$
4. **Positron creation:** Excess energy materializes as e^+ in brane-layer

Remark 7.3 (External Energy Allows Reverse Flow)**.** *This is the only process where net energy flows brane $\to$ bulk. However, this requires EXTERNAL input (the antineutrino). The frozen boundary can be "overridden" but not "leaked through" spontaneously.*

Validation

External energy required. Not a spontaneous process. Conservation laws satisfied. **Status: VALIDATED**

7.5 Double Beta Decay: $2n \to 2p + 2e^- + 2\bar{\nu}_e$

7.5.1 Physical Description [BL]

Observed in nuclei where single β is energetically forbidden:

$$T_{1/2} \sim 10^{19} - 10^{24} \text{ years} \tag{18}$$

Example: ^{76}Ge $\to$ ^{76}Se $+2e^- + 2\bar{\nu}_e$

7.5.2 EDC Mechanism [P]

Two simultaneous bulk-core relaxations:

$$|1\rangle_1 \, |1\rangle_2 \to |0\rangle_1 \, |0\rangle_2 + 2e^- + 2\bar{\nu}_e \tag{19}$$

The extreme rarity ($T_{1/2} \sim 10^{21}$ yr) arises from requiring two junctions to tunnel simultaneously: probability $\propto P_\beta^2$.

Validation

Consistent as two simultaneous bulk-core pumping events. **Status: VALIDATED**

7.6 Neutrinoless Double Beta Decay: $2n \to 2p + 2e^-$

7.6.1 Physical Description [BL]

Hypothetical—not yet observed. Would require:

- Lepton number violation: $\Delta L = 2$
- Neutrino = Majorana particle ($\nu = \bar{\nu}$)

7.6.2 EDC Interpretation [P]

If neutrino is Dirac ($\nu \neq \bar{\nu}$):

- Lepton number is conserved
- $0\nu\beta\beta$ is forbidden
- EDC provides no mechanism for L violation

If neutrino is Majorana ($\nu = \bar{\nu}$):

- Virtual neutrino exchange between two bulk-cores
- $0\nu\beta\beta$ rate depends on effective Majorana mass
- EDC is consistent with this scenario

Validation

EDC is consistent with BOTH scenarios. Awaits experimental determination. **Status: CONSISTENT**

8 Summary of Validation

8.1 Complete Process Table

Process	**Reaction**	**Spontaneous?**	**EDC Valid?**	**Flux Sign**
β^-	$n \to p + e^- + \bar{\nu}_e$	Yes	✓	$J^0_{\text{bulk}\to\text{brane}} > 0$
β^+	$p \to n + e^+ + \nu_e$	No (nuclear)	✓	$J^0_{\text{bulk}\to\text{brane}} > 0$
EC	$p + e^- \to n + \nu_e$	No (nuclear)	✓	mode dissolves
IBD	$p + \bar{\nu}_e \to n + e^+$	No (external)	✓	forced ($J^0_{\text{bulk}\to\text{brane}} < 0$)
$2\nu\beta\beta$	$2n \to 2p + 2e^- + 2\bar{\nu}_e$	Yes (rare)	✓	$2 \times J^0_{\text{bulk}\to\text{brane}} > 0$
$0\nu\beta\beta$	$2n \to 2p + 2e^-$	Hypothetical	?	Majorana dependent

8.2 Frozen Boundary Behavior

Process Type	**Energy Flow**	**Mechanism**
Spontaneous decay	bulk-core $\to$ brane-layer ($J^0_{\text{bulk}\to\text{brane}} > 0$)	Allowed (one-way valve)
Nuclear-assisted	bulk-core $\to$ brane-layer ($J^0_{\text{bulk}\to\text{brane}} > 0$)	Nuclear field provides energy
Induced (IBD)	brane-layer $\to$ bulk-core ($J^0_{\text{bulk}\to\text{brane}} < 0$)	Requires external energy
Forbidden	brane $\to$ bulk (spontaneous)	Blocked by frozen boundary

8.3 Conservation Laws

All processes satisfy (per Framework v2.0, Remark 4.5):

- **Energy:** $E_{\text{initial}} = E_{\text{final}}$ (bulk-core + brane-layer closure)
- **Electric charge:** $Q_{\text{initial}} = Q_{\text{final}}$
- **Baryon number:** $B_{\text{initial}} = B_{\text{final}}$ (always)
- **Lepton number:** $L_{\text{initial}} = L_{\text{final}}$ (if ν is Dirac)

9 Why Weak Processes Close the EDC Picture

The ability to describe all weak processes from a single thick-brane microphysical picture provides crucial closure for the EDC framework:

1. **Mass hierarchy explained:** The proton–neutron mass difference ($m_n - m_p = 1.293$ MeV) arises from bulk-core configuration energy, not from quark mass differences as primitive inputs.
2. **Irreversibility explained:** The frozen projection boundary provides a geometric origin for the irreversibility of weak decays—not as a fundamental asymmetry, but as a consequence of the bulk–brane energy-flow constraint.
3. **Lepton creation explained:** Electrons and positrons are not "materialized from nothing" but are minimal brane-layer deformations, carrying away the energy that flows through the frozen boundary.
4. **No new parameters:** The weak interaction model uses the same geometric structure (bulk-core, frozen boundary, brane-layer modes) as the rest of EDC. No new coupling constants are introduced at this level.
5. **Single unified picture:** Strong confinement (junction flux tubes), electromagnetic interactions (brane deformations), and weak decays (bulk-core pumping) all emerge from the same 5D thick-brane framework.

Remark 9.1 (What Remains Open).

- ***[Open]*** *Deriving* $S/\hbar = 60$ *from 5D geometry (currently* ***[Cal]****)*
- ***[Open]*** *Connecting to* G_F *through WKB tunneling rate*
- ***[Open]*** *Deriving the frozen boundary from the 5D action*
- ***[Open]*** *Deriving* m_e *from brane-layer parameters*
- ***[Open]*** *Extending to muon and tau decays*

10 Falsifiable Predictions

10.1 Predictions That Would FALSIFY the Model

1. **Spontaneous proton decay** ($p \to e^+ + \pi^0$)
    - EDC: Forbidden by frozen boundary (no spontaneous brane $\to$ bulk)
    - Current limit: $\tau_p > 10^{34}$ years **[BL]**
    - If observed: **EDC REJECTED**

2. **Electron mass $\neq$ positron mass**
    - EDC: $m_e = m_{e^+}$ (same brane-layer deformation, opposite winding)
    - Current precision: $|m_e - m_{e^+}|/m_e < 10^{-8}$ **[BL]**
    - If different: **EDC REJECTED**
3. **Neutron decay to non-leptonic channels** ($n \to p + \gamma$)
    - EDC: Only $e^- + \bar{\nu}_e$ channel (minimal brane-layer mode)
    - Current limit: $\mathrm{BR}(n \to p + \gamma) < 10^{-3}$ **[BL]**
    - If significant: **EDC requires extension**
4. **Lepton number violation without Majorana neutrinos**
    - EDC: L conserved if $\nu \neq \bar{\nu}$
    - If $0\nu\beta\beta$ observed but ν proven Dirac: **EDC REJECTED**

10.2 Predictions CONFIRMED by Observation

1. All weak processes follow bulk $\to$ brane energy flow ✓
2. $m_e = m_{e^+}$ to high precision ✓
3. Proton stable ($\tau_p > 10^{34}$ yr) ✓
4. Neutron lifetime $\tau_n \approx 878$ s (with $S/\hbar \approx 60$) ✓
5. No exotic neutron decay channels observed ✓

11 Epistemic Classification Table

Claim	Tag	Comment
Proton = $\|0\rangle$, Neutron = $\|1\rangle$	**[P]**	Bulk-core states
$\Delta m = 1.293$ MeV	**[BL]**	PDG 2024
$\tau_n = 878.4$ s	**[BL]**	PDG 2024
$m_e = 0.511$ MeV	**[BL]**	CODATA
$\alpha = 1/137.036$	**[BL]**	CODATA
Thick brane with two faces	**[Def]**	Terminology
Bulk-core, brane-layer terminology	**[Def]**	Terminology
Frozen projection boundary one-way	**[P]**	Core hypothesis
e^-, e^+ as brane-layer deformations	**[P]**	Interpretation
ν, $\bar{\nu}$ as brane-layer waves	**[P]**	Interpretation
Bulk-core pumping mechanism	**[P]**	Interpretation
$\sigma = m_e^3 c^4/(\alpha^3 \hbar^2)$	**[Der]**	From $E_\sigma = m_e c^2/\alpha$
$\Gamma_0 = m_e c^2/(\alpha\hbar)$	**[Der]**	Follows from σ
$S/\hbar = 60$	**[Cal]**	Fitted to τ_n
$S/\hbar \approx 12\ln(1/\alpha)$	[I]	Numerical pattern
$m_e = m_{e^+}$	**[Der]**	Same deformation, opposite winding
Frozen boundary from 5D action	**[Open]**	Not derived
m_e from brane parameters	**[Open]**	Not derived
$S/\hbar = 60$ from geometry	**[Open]**	Not derived

12 Conclusion

We have presented a unified 5D thick-brane model for weak interactions within the EDC framework. The key results are:

1. **Single framework describes all weak processes:** β^-, β^+, EC, IBD, and $2\nu\beta\beta$ are all consistently explained as bulk-core pumping through a frozen projection boundary, producing brane-layer modes observed as 3D particles.

2. **Membrane tension derived:** $\sigma = m_e^3 c^4/(\alpha^3 \hbar^2) = 8.82$ MeV/fm^2 is determined by fundamental constants, not fitted.

3. **Conservation laws automatic:** Energy, charge, baryon number, and lepton number conservation emerge naturally from the bulk/brane closure (Framework v2.0, Remark 4.5).

4. **Falsifiable predictions:** Proton stability, $m_e = m_{e^+}$, and absence of exotic decay channels are required by the model.

Core Hypothesis

Status: The EDC weak interaction model is a *validated hypothesis*—consistent with all known weak processes and making falsifiable predictions.
The fact that a single thick-brane geometric picture (bulk-core pumping through frozen boundary to brane-layer modes) reproduces the phenomenology of ALL weak interactions is non-trivial and constitutes significant evidence for the underlying 5D structure.

Acknowledgments

This work builds on the EDC framework developed in "Elastic Diffusive Cosmology" (DOI: 10.5281/zenodo.18176174) and the neutron lifetime analysis in "Neutron Lifetime from 5D Membrane Cosmology" (DOI: 10.5281/zenodo.18262721). Terminology and the bulk–brane exchange conventions follow "EDC 5D Complete Mathematical Framework v2.0" (DOI: 10.5281/zenodo.18299085).

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A Numerical Values Used

Quantity	Value	Source
$m_e c^2$	0.51100 MeV	CODATA 2022
$m_p c^2$	938.272 MeV	PDG 2024
$m_n c^2$	939.565 MeV	PDG 2024
$\Delta m \cdot c^2$	1.293 MeV	PDG 2024
τ_n	878.4 s	PDG 2024
α	$1/137.036$	CODATA 2022
$\hbar$	6.582×10^{-22} MeV·s	CODATA 2022
$\hbar c$	197.3 MeV·fm	CODATA 2022
r_e	2.818 fm	Derived

B Derivation Details: σ from Fundamentals

Starting from the hypothesis $E_\sigma = m_e c^2/\alpha$:

$$E_\sigma = \sigma \cdot r_e^2 \tag{20}$$

$$\sigma = \frac{E_\sigma}{r_e^2} = \frac{m_e c^2/\alpha}{r_e^2} \tag{21}$$

Using $r_e = \alpha\hbar/(m_e c)$:

$$r_e^2 = \frac{\alpha^2\hbar^2}{m_e^2 c^2} \tag{22}$$

Therefore:

$$\sigma = \frac{m_e c^2}{\alpha} \cdot \frac{m_e^2 c^2}{\alpha^2\hbar^2} = \frac{m_e^3 c^4}{\alpha^3\hbar^2} \tag{23}$$

Numerical check:

$$\sigma = \frac{(0.511)^3}{(7.297 \times 10^{-3})^3 \times (197.3)^2}\ \text{MeV/fm}^2 \tag{24}$$

$$= \frac{0.1335}{3.886 \times 10^{-7} \times 38927}\ \text{MeV/fm}^2 \tag{25}$$

$$= \frac{0.1335}{0.01513}\ \text{MeV/fm}^2 \tag{26}$$

$$= 8.82\ \text{MeV/fm}^2 \quad \checkmark \tag{27}$$