TIM Braids and Framed Memory: Canonical Topology, Degenerate State Structure, and a Universal Closure-Scaled Map to First-Generation Electroweak Quantum Numbers

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Abstract

We study a minimal three-ribbon TIM braid kinematics model equipped with an explicit slot-based framed sector. The model distinguishes unreduced braid history from canonical braid topology and exhibits nontrivial framed remnants even when topological braid content cancels. We first define the discrete braid/framing rules, verify basic braid consistency, classify short-word closure sectors, and introduce a simple relaxation layer showing that framed remnants can be metastable or topology-sensitive. We then construct a Garside-style normalization pipeline for B_3 in order to separate macroscopic braid topology from history-dependent framed memory. A computational sweep over admissible B_3 histories up to fixed length reveals large framed/topological degeneracy, frequent identity-sector memory, and recurrent low-rank remnant families. Motivated by this structured state space, we define a universal closure-scaled framing map in which electroweak quantum numbers are assigned by linear projections of the framing vector scaled by the maximum cycle length of the closure permutation. Under this single calibrated map, the computed database contains exact first-generation Standard Model electroweak quantum numbers, with fractional quark charges emerging mechanically from the $c = 3$ closure sector and the Gell-Mann–Nishijima relation holding identically. We emphasize that this establishes a particle-dictionary correspondence within the model, not yet a derivation of gauge dynamics, confinement, spin/statistics, or a physical mass spectrum.

Contents

1 Introduction

The purpose of this paper is not to claim a derivation of the Standard Model from first principles. Instead, the goal is narrower and more disciplined: to test whether a minimal three-ribbon braid/framing system can support a nontrivial and computationally explicit particle dictionary. The idea of encoding particle quantum numbers in braided topological structures has precedent, notably in the preon-braid model of Bilson-Thompson [4, 5]. The present approach differs in its emphasis on computational classification, explicit slot-based framing dynamics, and a universal closure-scaled mapping derived from the cycle structure of the trace-closure permutation.

The central structural issue is that topological braid content and internal framed memory need not coincide. In the TIM setting studied here, a braid history may reduce topologically while still leaving a nonzero residual framed state. This immediately suggests that a useful model must track at least two distinct layers:

(i) canonical braid topology, which captures macroscopic topological content, and

(ii) unreduced framed history, which captures internal path-dependent memory.

The paper develops this point in stages. First, we define a minimal slot-based framed-transfer law on B_3. Second, we classify short words and closure sectors, showing partial decoupling between topology and framed residuals. Third, we introduce a normalization layer and a computational sweep, which together reveal a large and structured state space. Finally, we show that this state space supports a universal closure-scaled mapping to electroweak quantum numbers. Under that map, exact first-generation Standard Model quantum numbers occur in the database.

The main result is therefore a *particle-dictionary result*: a single universal map yields exact first-generation electroweak quantum numbers in a minimal three-ribbon braid/framing model. The present work does *not* yet derive gauge interactions, confinement, spin/statistics, or a calibrated physical mass spectrum.

2 Minimal three-ribbon braid/framing model

2.1 State variables

We work with three ribbons and three ordered slots. The underlying algebraic structure is the three-strand braid group B_3 [2, 3]. The instantaneous state consists of:

- a permutation shadow $P = [p_0, p_1, p_2]$, specifying which ribbon occupies each slot;
- a slot-based framing vector $f = (f_0, f_1, f_2)$.

The initial state is taken to be

$$P = [0, 1, 2], \qquad f = (0, 0, 0).$$

The braid generators are σ_k^s with $k \in \{1, 2\}$ and $s = \pm 1$. Here k specifies which adjacent slot pair is crossed, and s gives the sign of the crossing.

2.2 Slot-based framed-transfer law

For a generator σ_k^s:

1. identify the active slots $k - 1$ and k;
2. update slot framings by

$$f_{k-1} \leftarrow f_{k-1} + s, \qquad f_k \leftarrow f_k - s;$$

3. swap the slot occupancies $p_{k-1} \leftrightarrow p_k$.

This rule is intentionally minimal. It is local, depends only on the currently active slot pair, and conserves the total framed charge

$$Q_{\text{tot}} = \sum_i f_i.$$

If the system starts at $Q_{\text{tot}} = 0$, then Q_{tot} remains zero for all braid histories.

> *Design choice.* The framing update acts on *slot positions*, not on ribbon labels. An alternative ribbon-tracking rule — in which framing increments follow individual ribbons through permutations — produces a braid invariant: topologically equivalent words always yield identical framing. The slot-based rule, by contrast, is deliberately history-dependent: the framing output depends on the *ordering* of crossings, not only on the braid class. This is essential for the model, since it is precisely this history dependence that generates the decoupling between canonical topology and framed memory.

2.3 Topological and framed layers

The model keeps two layers separate:

- **Raw braid history**: the full sequence of generators used to compute framed evolution;
- **Topological normalization**: a reduced braid representative used to identify macroscopic braid content.

This separation is essential. The raw history governs framed memory, whereas the normalized form captures macroscopic topology. One of the main results of the paper is that these two layers are not interchangeable.

3 Consistency check

A basic braid-consistency check is provided by the same-sign Yang–Baxter relation:

$$\sigma_1^+\sigma_2^+\sigma_1^+ \sim \sigma_2^+\sigma_1^+\sigma_2^+.$$

Under the slot-based framed-transfer rule, both words produce the same permutation and the same framed output:

$$P = [2, 1, 0], \qquad f = (2, 0, -2).$$

Thus the minimal rule is compatible with this elementary braid consistency test.

4 Short-word closure classification and framed residual sectors

4.1 Closure conventions

To analyze closed states, we use trace closure. In this setting:

- the cycle structure of the final permutation determines the number of closed components;
- the full braid word determines the knot/link topology;
- component framing labels are defined as sums of slot framings carried by the slots in the corresponding cycle.

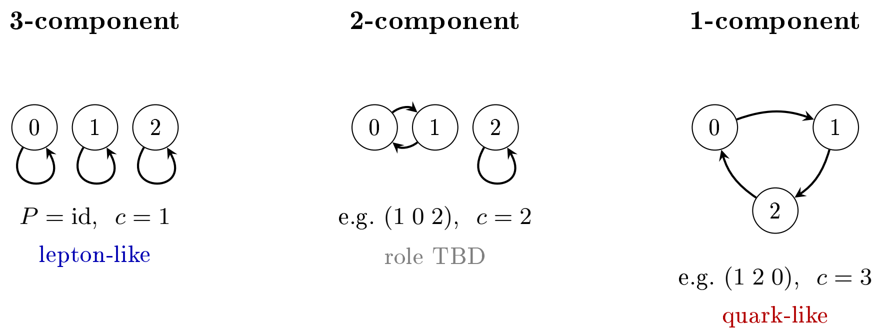

Figure 1: The three closure types of B_3 trace closure, determined by the cycle structure of the final permutation P. The maximum cycle length c is the closure-scaling parameter used in the universal quantum-number map.

4.2 Identity-sector examples

Several short words reduce topologically to identity while leaving nonzero framed residuals. Representative examples are shown in Table 1.

Table 1: Representative identity-sector residuals.

Word	Length	Residual framing
$\sigma_1^+\sigma_1^-$	2	$(2, -2, 0)$
$\sigma_2^+\sigma_2^-$	2	$(0, 2, -2)$
$\sigma_1^+\sigma_2^+\sigma_2^-\sigma_1^-$	4	$(4, -2, -2)$
$\sigma_1^+\sigma_1^-\sigma_2^+\sigma_2^-$	4	$(2, 0, -2)$
$\sigma_1^+\sigma_2^-\sigma_2^+\sigma_1^-$	4	$(0, -2, 2)$

These examples show that topological cancellation does not force framed cancellation.

4.3 Non-identity closure examples

Representative non-identity closures include:

- σ_1^+, yielding a 2-component unlink with $f = (1, -1, 0)$;
- $\sigma_1^+\sigma_2^+$, yielding a 1-component unknot with $f = (2, -1, -1)$;
- $\sigma_1^+\sigma_2^+\sigma_1^+$, yielding a Hopf-link sector with $f = (2, 0, -2)$.

A key structural lesson already appears here: the same or similar framed residuals can occur in distinct topological environments.

4.4 Decoupling statement

The short-word analysis supports a partial decoupling between closure topology and internal framed-memory sector:

- topologically trivial closures can carry nonzero framed memory;
- nontrivial closures can carry zero or nonzero component framing labels;
- the framing vector alone does not determine the topological sector.

This is the core Project 3 foundation for everything that follows.

5 Relaxation, metastability, and topology-coupled destabilization

5.1 Toy framing energy

To explore whether framed residuals can persist dynamically, we introduce a toy energy

$$E = \sum_i f_i^2.$$

This is not a physical rest-mass functional. It is used only as an internal ranking and relaxation diagnostic.

5.2 Model D: threshold-trapped remnants

Under a threshold rule with cutoff $T = 2$, moves are allowed only if $|f_i| > 2$. The state

$$(4, -2, -2)$$

then relaxes to

$$(2, 0, -2),$$

reducing the toy energy from 24 to 8. The state $(2, 0, -2)$ does not further discharge under this rule and therefore acts as a trapped remnant.

This shows that framed memory is not merely a static combinatorial label; persistence depends on dynamics.

5.3 Model E: topology-coupled threshold lowering

To model simple environment sensitivity, we define an effective threshold

$$T_{\text{eff}} = T_{\text{base}} - \lambda \sum |\text{Lk}(C, X)|.$$

Here $T_{\text{base}} = 2$, and Lk is the pairwise linking number between closed components.

In a Hopf-link-like environment with $\lambda = 1$, the remnant

$$(2, 0, -2)$$

can fully discharge, while the same state remains trapped in the unlink vacuum. Thus topology can catalyze framed decay.

5.4 Interpretation

The Project 3 dynamical message is modest but important:

- kinematic state existence and dynamical survival are different questions;
- some framed states are vacuum-stable or metastable;
- linked environments can destabilize states that survive in the unlink vacuum.

This provides a first selection layer beyond pure state counting.

6 Why canonicalization is needed

The examples above already show that raw history and topology should not be conflated. To make this precise, we require a normalization scheme for B_3.

6.1 Preliminary normalization and its failure

A first attempt at normalization uses:

- the braid relation $\sigma_1\sigma_2\sigma_1 = \sigma_2\sigma_1\sigma_2$;
- adjacent inverse cancellation;
- extraction of $\Delta = \sigma_1\sigma_2\sigma_1$.

However, this preliminary scheme is path-dependent when negative generators interact with Δ. Different reduction orders can produce different outputs. Therefore the naive scheme is not canonical.

6.2 Inverse-aware extension

The ambiguity can be resolved locally by introducing sign-aware Δ interaction rules, including:

$$\sigma_1^- \Delta \to \Delta \sigma_2^-,$$
$$\sigma_2^- \Delta \to \Delta \sigma_1^-,$$

together with adjacent dissolution rules such as

$$\Delta \sigma_1^- \to \sigma_1^+ \sigma_2^+.$$

These rules repair the local failures of the preliminary scheme.

6.3 Garside-style shift

A stronger approach, following the classical framework of Garside [1] (see also [6, 7]), is to eliminate negative generators systematically:

$$\sigma_1^- \to \Delta^{-1}\sigma_1^+\sigma_2^+,$$
$$\sigma_2^- \to \Delta^{-1}\sigma_2^+\sigma_1^+.$$

After commuting Δ^{-1} factors to the left and extracting positive Δ factors from the remaining tail, one obtains representatives of the form

$$\Delta^p W,$$

with W positive.

6.4 Left-greedy factorization

To make the positive tail deterministic, we use a left-greedy factorization into simple braids of B_3 [1, 7]. This aligns the normalization layer with the standard Garside left normal form structure.

6.5 Meaning for the present paper

Canonicalization gives a macroscopic braid representative. But the framed output of the canonical word generally differs from the framed output of the raw history. Therefore:

> canonical topology and framed memory are distinct observables and must be tracked independently.

This point is central to the logic of the combined Project 3 / Project 4 manuscript.

7 Computational sweep and empirical state-space structure

7.1 Sweep protocol

A computational sweep was performed over admissible B_3 histories up to maximum length

$$L_{\max} = 10.$$

The alphabet is

$$\{\sigma_1^+, \sigma_1^-, \sigma_2^+, \sigma_2^-\},$$

with immediate adjacent inverses discarded during generation.

The admissible word count at each length satisfies $N(L) = 4 \cdot 3^{L-1}$, giving a total through $L_{\max}$ of $2(3^{L_{\max}} - 1)$. For $L_{\max} = 10$ this yields

$$N = 2(3^{10} - 1) = 118{,}096$$

admissible raw histories, confirmed exactly by the pipeline.

For each history:

1. the raw framed output is computed using the slot-based rule;
2. a canonical braid representative is computed via the normalization layer.

7.2 Main empirical observations

The sweep reveals the following structural facts:

- Of the 324 raw words that reduce topologically to identity, 284 (87.65%) carry nonzero framed residuals.
- Across the sweep, 9,196 distinct canonical forms occur.
- Of these, 6,048 canonical classes (65.7%) host multiple framed states.
- The sweep produces 221 distinct framed vectors, and 213 of them occur in multiple canonical sectors.
- The recurrent remnant $(2, 0, -2)$ appears 1,890 times.

These observations show that the state space is both large and highly degenerate. This is precisely the kind of structure needed before a particle-dictionary question even becomes meaningful.

7.3 Minimal disagreement lengths

Two mismatch scales are especially informative:

- $\mathrm{MDL}_{\mathrm{rep}} = 1$: the raw framed output can already differ from that of the canonical representative at length one;
- $\mathrm{MDL}_{\mathrm{top}} = 3$: the first nontrivial braid-equivalent mismatch appears at length three.

Thus the divergence between raw framed history and canonical topology is not a high-complexity accident; it appears almost immediately.

8 Project 3 to Project 4 handoff

The Project 3 part of the program establishes the structural foundation for Project 4:

- topological normalization and framed memory are distinct layers;
- the same framed residual can occur in different topological sectors;
- canonicalization is required to separate macroscopic braid content from history-dependent framed output;
- relaxation dynamics supply a first selection layer beyond pure kinematics.

This makes the next question sharply defined:

> Can the structured framed state space produced by Project 3 support a disciplined particle dictionary?

Project 4 begins exactly there.

9 A universal closure-scaled framing map

9.1 Closure-cycle scaling hypothesis

Let c denote the maximum cycle length of the trace-closure permutation (see Figure 1). In the present B_3 setting:

- $c = 1$ corresponds to the 3-component sector;
- $c = 3$ corresponds to the 1-component sector.

In the current dictionary:

- the 3-component sector hosts lepton-like states;
- the 1-component sector hosts quark-like states.

The sweep also contains a 2-component sector with $c = 2$ (arising from transposition permutations). Under the universal map this sector produces quarter-integer values of T_3 and half-integer values of Q. Its physical interpretation remains open and is deferred to future work.

This is a dictionary assignment, not yet a derivation of physical confinement.

9.2 Universal electroweak projections

Using a single calibration anchor,

$$e_L \leftrightarrow (-2, 2, 0) \quad \text{in the } c = 1 \text{ sector},$$

we define the universal closure-scaled map

$$Q = \frac{f_0}{2c}, \tag{1}$$

$$T_3 = \frac{f_0 - f_2}{4c}, \tag{2}$$

$$Y = \frac{f_0 + f_2}{2c}. \tag{3}$$

9.3 Gell-Mann–Nishijima identity

Under (1)–(3),

$$\begin{aligned} T_3 + \frac{Y}{2} &= \frac{f_0 - f_2}{4c} + \frac{1}{2}\left(\frac{f_0 + f_2}{2c}\right) \\ &= \frac{f_0 - f_2}{4c} + \frac{f_0 + f_2}{4c} \\ &= \frac{2f_0}{4c} = \frac{f_0}{2c} = Q. \end{aligned}$$

Hence

$$Q = T_3 + \frac{Y}{2}$$

holds identically. In this model, it is an algebraic consequence of the closure-scaled framing projections, not an independently imposed condition.

10 Exact first-generation quantum-number matches

10.1 Dictionary result

The current Project 4 database contains exact first-generation Standard Model electroweak quantum numbers under the universal closure-scaled map. The matched states are listed in Table 2.

Table 2: Exact first-generation electroweak quantum-number matches under the universal closure-scaled framing map.

State	Sector	c	f	Q	T_3	Y	E
ν_{eR}	3-comp (lepton-like)	1	$(0,0,0)$	0	0	0	0
e_L	3-comp (lepton-like)	1	$(-2,2,0)$	-1	$-1/2$	-1	8
ν_{eL}	3-comp (lepton-like)	1	$(0,2,-2)$	0	$+1/2$	-1	8
e_R	3-comp (lepton-like)	1	$(-2,4,-2)$	-1	0	-2	24
u_L	1-comp (quark-like)	3	$(4,-2,-2)$	$+2/3$	$+1/2$	$+1/3$	24
d_L	1-comp (quark-like)	3	$(-2,-2,4)$	$-1/3$	$-1/2$	$+1/3$	24
d_R	1-comp (quark-like)	3	$(-2,4,-2)$	$-1/3$	0	$-2/3$	24
u_R	1-comp (quark-like)	3	$(4,-8,4)$	$+2/3$	0	$+4/3$	96

10.2 Strength of the result

This is the strongest claim supported by the current analysis:

> Under one universal map and one calibration anchor, the TIM database contains exact first-generation Standard Model electroweak quantum numbers.

This is stronger than a loose analogy and weaker than a full particle derivation. It is exactly a particle-dictionary result.

10.3 What is structurally significant

Several nontrivial features emerge immediately:

1. **Fractional quark charges emerge mechanically.** The values $\pm 1/3$ and $\pm 2/3$ are not inserted case by case. They arise automatically because the 1-component sector carries $c = 3$.

2. **The same formula covers leptons and quarks.** No separate quark formula is introduced. The only difference is the closure-cycle scale c.

3. **Doublet degeneracies appear in the toy energy.** In the toy metric $E = \sum_i f_i^2$,

$$E(e_L) = E(\nu_{eL}) = 8, \qquad E(u_L) = E(d_L) = 24.$$

   This is not yet a derivation of weak isospin dynamics, but it is a clear structural pattern.

4. **The recurrent remnant family reappears in the dictionary.** The state family containing previously identified trapped remnants now intersects exact right-handed fermion assignments. This does not prove physical identity, but it shows that the Project 3 remnant basin is structurally relevant for Project 4.

11 Dictionary matching versus dynamical survival

11.1 Important distinction

The particle dictionary and the dynamical selection problem are not the same. The Project 4 universal map establishes exact quantum-number matching. It does *not* yet establish a final physical particle spectrum.

11.2 Current stability status

The current stability filter confirms that this distinction matters. In the presently available Model E outputs:

- some matched lepton-like states are vacuum-stable or metastable;
- some matched quark-like states decay under the current relaxation rule;
- exact quantum-number matching therefore precedes full dynamical selection.

So the proper interpretation is:

> the database contains the correct electroweak quantum numbers under a universal map, but the final physically surviving spectrum still depends on a separate dynamical layer.

12 Interpretation boundary

To keep the manuscript properly scoped, we state clearly what has and has not been established.

12.1 Established in this paper

This paper establishes:

- a minimal three-ribbon braid/framing model with explicit slot-based framed dynamics;
- a canonicalization layer that separates macroscopic braid topology from framed history;
- a computationally classified state space with large framed/topological degeneracy;
- a universal closure-scaled framing map under which exact first-generation electroweak quantum numbers occur in the database.

12.2 Not yet established

This paper does *not* yet establish:

- a derivation of gauge-boson dynamics;
- a derivation of QCD confinement;
- a spin/statistics mechanism;
- a calibrated physical mass spectrum;
- higher-generation organization;
- a final stability-selected particle spectrum.

13 What is still missing for exact quantitative predictions

The present framework has reached the level of structured kinematic classification plus an initial particle dictionary. Exact quantitative particle predictions still require additional bridges:

1. a full particle dictionary beyond first-generation electroweak charges;
2. a physical energy functional replacing the toy metric $E = \sum_i f_i^2$;
3. a dimensional calibration scale;
4. a unique physical closure/embedding prescription;
5. a sharper dynamical selection and decay framework;
6. a spin/statistics mechanism;
7. interaction rules and effective couplings;
8. a precise vacuum definition;
9. recovery of known low-energy symmetry structure;
10. a falsification protocol strong enough to reject over-flexible mappings.

These are the natural next Project 4 workstreams.

14 Discussion

The combined Project 3 / Project 4 program now supports a coherent narrative.

Project 3 showed that framed memory and braid topology are distinct layers and that the model supports a large, structured, and dynamically nontrivial state space. Project 4 then asked whether that state space can be mapped to physical quantum numbers in a disciplined way. The answer is yes at the level of first-generation electroweak quantum numbers.

The most striking structural point is that fractional quark charges arise mechanically from the closure-cycle scaling factor $c = 3$. This does not yet amount to confinement physics, but it is precisely the kind of nontrivial emergent arithmetic that makes the model worth taking seriously as a structured particle-dictionary framework. Compared to the Bilson-Thompson preon model [4, 5], which assigns quantum numbers by manually decorating individual ribbon twists, the present approach derives quantum numbers from a single closure-scaled map applied uniformly across the state space. The fractional charges are not encoded in the ribbon structure *a priori*; they emerge from the permutation cycle length at closure.

At the same time, caution is essential. The present paper is strongest when read as a theory-plus-computation study of how a minimal braid/framing model can support exact electroweak quantum-number matching without yet claiming full Standard Model derivation.

15 Conclusion

We have presented a combined Project 3 / Project 4 manuscript built around a minimal three-ribbon TIM braid/framing model. The main results are:

- topological normalization and framed memory are distinct and must be tracked independently;
- the model supports identity-sector memory, nontrivial remnant structure, and topology-sensitive relaxation;
- the computational sweep reveals a large and highly degenerate state space;
- a universal closure-scaled framing map yields exact first-generation Standard Model electroweak quantum numbers in the computed database.

This establishes a nontrivial particle-dictionary correspondence within the TIM framework. The next major task is to determine whether the dictionary states can be promoted into a physically selected spectrum through improved dynamics, symmetry analysis, and a physically motivated energy functional.

Acknowledgment of scope

The present manuscript is intentionally scoped as a disciplined structural result. It is not a claim of complete unification and should be read as a foundation for sharper future tests.

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