Substrate Internalization as a Resolution Stress-Test for τ-Field Dynamics

Abstract

This paper proposes and formalizes two falsifiable hypotheses concerning the behavior of τ-field dynamics under internal structure expansion of the substrate. Rather than introducing new operators or observational layers, we treat internalization as a controlled increase in resolution within the same substrate. The goal is to determine whether previously observed convergence regimes persist, and whether the residual deviation in the proton–electron mass ratio μ is reducible with resolution or reflects an intrinsic structural bound. Both outcomes are finite, testable, and theory-constraining.

1 Motivation

Recent work has established that τ-field dynamics exhibit stable convergence regimes under admissible observables, and that these regimes persist across re-entry and parameter variation. Having validated observability at fixed substrate resolution, the next question is not whether additional observational layers exist, but whether the same dynamics survive when the substrate itself acquires internal degrees of freedom.

This move is deliberately conservative. We do not introduce new operators, new observables, or higher-order meta-dynamics. Instead, we treat internal structure as a resolution increase within the same substrate and ask whether τ-field behavior is invariant under this expansion.

2 Conceptual Framing

By *substrate internalization* we mean the replacement of each atomic substrate element by a finite composite structure, such as a small internal graph or binding-level subsystem, whose internal degrees of freedom evolve prior to the application of τ-field dynamics.

Crucially:

- The external τ-field rules remain unchanged.
- Observables are inherited from previously validated regimes and may only be aggregated, not extended.
- Internal degrees of freedom are bounded and physically motivated, ensuring finiteness.

This approach increases resolution without stratifying observability or introducing a new theoretical layer.

3 Core Hypotheses

Only two hypotheses are considered. No additional claims are introduced.

H1 — Structural Survival

τ-field convergence persists under internal structure expansion.

Operational meaning.

- Each substrate site is replaced by a finite composite structure (e.g. internal graph, binding-level model).
- Internal degrees of freedom interact before the τ-field update acts on the aggregated state.
- Convergence is assessed at the level of regime classification, not exact numerical matching.

The hypothesis is satisfied if runs with internalized substrates fall into the same convergence regime classes as their non-internalized counterparts.

H2 — μ Deviation Classification

The proton–electron mass ratio deviation μ is either reducible with increasing resolution or structurally bounded.

This hypothesis is explicitly **not** framed as:

- a claim that μ is predicted exactly,
- a challenge to quantum electrodynamics or Standard Model numerics.

Instead, two mutually exclusive and exhaustive outcomes are considered:

- If internalization systematically reduces deviation, then prior discrepancy was resolution-limited.
- If deviation plateaus under increasing internalization depth, then τ-field dynamics impose a structural lower bound.

Both outcomes are acceptable, publishable, and theory-constraining.

4 Finiteness and Falsifiability

The proposed hypotheses are finite in scope:

- Internal structure depth is bounded.
- Observable definitions are fixed.
- Outcomes fall into a small number of discrete classes.

Failure of convergence under modest internalization would indicate that τ-field coherence is a coarse-resolution emergent phenomenon. Success would establish resolution invariance within the tested domain. No recursive extension or further hypothesis escalation is implied.

5 Relation to Prior Work: From Operator Composability to Substrate Internalization

Chamber XXXVII established that operator composition within the UNNS Substrate is not automatic, but experimentally testable and selectively admissible. In particular, it demonstrated that composability constitutes a measurable property rather than an assumed structural guarantee.

The present work proceeds directly from that result. Having shown that operator-level structure must be validated rather than postulated, the next question is not whether additional operators or observability layers exist, but whether the substrate on which these operators act remains coherent when its internal structure is made explicit.

Accordingly, this study is formally positioned as *Chamber XXXVIII (Phase H): Substrate Internalization.* Its role is not to extend the operator hierarchy introduced in earlier chambers, but to stress-test the already validated τ-field dynamics under increased substrate resolution.

The transition from Chamber XXXVII to Chamber XXXVIII reflects a change in investigative axis:

- Chamber XXXVII addresses *operator admissibility under composition.*
- Chamber XXXVIII addresses *substrate coherence under internal structure.*

No new operators, observables, or κ-indexed layers are introduced in this transition. Instead, the same τ-field rules and previously validated observables are retained, while the substrate itself is refined by introducing bounded internal degrees of freedom.

In this sense, Chamber XXXVIII is not an escalation of abstraction but a deepening of resolution. It tests whether the composable structures identified in Chamber XXXVII remain meaningful when the assumption of atomic substrate elements is relaxed. The outcome of this test constrains the theory rather than extending it, regardless of whether τ-field convergence survives, stabilizes at a structural bound, or fails under internalization.

6 Methods Overview and Cross-Reference

The experimental procedures, internalization architecture, observable definitions, and regime classification logic employed in this study are fully specified in the technical documentation of *Chamber XXXVIII (Phase H): Substrate Internalization.*

In brief, the present work reuses the TauFieldEngineN macro-dynamics from Chamber XIV and augments them with a bounded internal micro-structure layer, evaluated under strict invariance constraints on observables and admissibility criteria. All implementation details, including micro-topology definitions, aggregation rules, Regime Preservation Index (RPI) computation, and μ-proxy instantiation, are described exhaustively in the Chamber XXXVIII specification.

This paper therefore reports *results and interpretation only.* Readers seeking full methodological detail, configuration schemas, or executable references are directed to the Chamber XXXVIII specification and accompanying implementation artifacts.

7 Results and Interpretation

7.1 Experimental Scope

Chamber XXXVIII was executed as a constrained pilot study designed to test substrate internalization under controlled conditions. Macro-scale dynamics were provided by Chamber XIV (the

ϕ-scale chamber) using the TauFieldEngineN implementation. Internal structure was introduced at depth 1 via a bounded TRIANGLE micro-topology ($k = 3$), with micro–macro feedback coupling disabled.

All observables were computed dynamically from τ-field evolution. Regime classification was performed relative to a depth–0 baseline derived from the same macro configuration. The pilot was explicitly limited to depths $\{0, 1\}$ and three independent random seeds.

7.2 H1 — Structural Survival

Result. Across all seeds and both depths, τ-field convergence regimes were classified as *preserved*. Regime Preservation Index (RPI) distances remained small (approximately 2×10^{-2} at depth 1), and no run crossed relative admissibility or stability collapse thresholds.

Internalization produced measurable changes in observable values:

- The mean admissibility $\langle A \rangle$ increased relative to baseline.
- The mean stability $\langle S \rangle$ decreased slightly but remained well above collapse criteria.
- Variance in stability increased, consistent with the introduction of internal degrees of freedom.

Despite these shifts, all depth–1 signatures remained within the same convergence regime class as the depth–0 baseline.

Interpretation. This constitutes a positive confirmation of *H1 (Structural Survival)* at depth 1. τ-field convergence is invariant under bounded internal structure expansion when evaluated using domain-consistent dynamics and relative, baseline-anchored admissibility criteria.

Preservation here is not trivial numerical coincidence. Internalization introduces observable stress into the system, but does not alter regime identity. This demonstrates that τ-field coherence is a structural property of the dynamics rather than an artifact of atomic substrate assumptions.

7.3 H2 — μ Deviation Trend

Result. The μ-proxy, instantiated in this pilot as ϕ-error relative to the canonical $\phi^\star$, increased from depth 0 to depth 1 across all seeds. The average deviation increased by approximately one order of magnitude, with noticeable seed-to-seed variation.

Accordingly, the H2 classification remains *undefined*.

Interpretation. This outcome is expected and methodologically correct within the defined scope of Phase H. A single depth increment is insufficient to distinguish between resolution-limited deviation and an intrinsic structural lower bound, both of which require trend assessment across multiple depth levels.

Crucially, μ deviation increased while τ-field convergence regimes remained preserved. This decoupling shows that proximity to $\phi^\star$ (or to μ-like targets) is not a prerequisite for convergence stability. In UNNS terms, regime coherence precedes numerical refinement.

7.4 Structural Ordering Insight

Taken together, the results reveal a clear ordering of effects:

1. Convergence regime identity survives bounded internalization.

2. μ-related observables respond immediately to added internal structure.

3. No conclusion regarding reducibility or structural bounds is yet warranted.

This ordering is nontrivial. It shows that internal degrees of freedom first manifest as observable stress without destroying convergence, implying that any structural limits on μ must arise at greater internalization depth.

7.5 Scope and Limitations

The reported results are limited to:

- internalization depth ≤ 1,
- a TRIANGLE micro-topology,
- absence of micro–macro feedback coupling.

They do not determine whether μ deviation eventually reduces or plateaus under deeper internalization. Such classification requires extension to depth 2 or beyond and lies outside the pilot scope presented here.

7.6 Summary

Chamber XXXVIII demonstrates that τ-field convergence regimes validated at fixed resolution persist under bounded substrate internalization, even as μ-related observables exhibit increased deviation. Convergence is therefore established as a structural property of the τ-field dynamics, while μ deviation reflects unresolved resolution effects at this phase.

The pilot satisfies its primary objective: it constrains the theory without extending it and clearly delineates established results from open questions.

7.7 Reproducibility and Data Availability

All results reported in this section were generated using the interactive Chamber XXXVIII implementation and exported as machine-readable JSON files. These datasets include full configuration parameters, per-run time series summaries, regime signatures, and H1/H2 classification outputs for each seed and depth.

The complete pilot dataset corresponding to the results discussed above is available in the Chamber XXXVIII data archive and consists of six JSON files, one per run, together with an aggregate summary file. These files are sufficient to reproduce all reported figures, classifications, and numerical values using the same engine version and configuration parameters.

8 Conclusion

Substrate internalization provides a controlled and conservative stress-test of τ-field dynamics. By isolating resolution effects from observational stratification, the two hypotheses presented here offer a clear decision structure: either convergence survives and deviations classify, or the framework reaches a demonstrable limit. In both cases, the outcome sharpens rather than extends the theory.