Hidden Plinko Interpretation: A Deterministic Substrate Model for Emergent Quantum Statistics

Abstract

The Hidden Plinko Interpretation (HPI) proposes that the probabilistic behavior observed in quantum mechanics may emerge from deterministic interactions within a structured, dynamic substrate. Through a rule-based cellular automaton that guides virtual particles across symmetry-modulated fields, this model replicates key quantum-like behaviors—including collapse analogs, entanglement correlations, and entropy-driven drift—without invoking intrinsic randomness.

By systematically varying internal symmetry, external biases, and dynamic field configurations, the HPI framework reveals emergent tipping points, bifurcations, and interference patterns that mirror quantum statistical distributions. These results support the view that contextual geometry and informational structure—not indeterminism—may be the true foundation of apparent quantum uncertainty.

HPI offers a reproducible, extensible, and symbolically mappable platform for testing the idea that information itself can act as a causal influence. This paper presents the simulation framework, key experimental findings, a formal mathematical model, and implications for reconciling classical and quantum regimes under a unified deterministic paradigm.

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Note: The experiments described in this paper demonstrate that deterministic interactions within a structured substrate can reproduce quantum-like statistical behaviors. To clarify the mechanism underlying these results, a mathematical framework is introduced immediately after the experimental findings. This ensures both intuitive and symbolic interpretations are supported.

1. Introduction

Quantum mechanics, despite its empirical success, remains philosophically contentious due to its reliance on fundamental indeterminacy. From wavefunction collapse to entangled measurement outcomes, the standard model embraces probability as intrinsic. Yet alternative approaches—such as hidden-variable theories and deterministic interpretations—have long sought to explain these statistical behaviors through deeper structure.

The Hidden Plinko Interpretation (HPI) contributes to this effort by introducing a deterministic, rule-based simulation framework. Drawing inspiration from the Plinko game popularized by "The Price Is Right," this model extends the concept into a cellular automaton where internal symmetry, evolving field geometries, and contextual biases guide particle trajectories. Despite the absence of randomness, the system consistently reproduces behaviors that resemble canonical quantum phenomena.

This paper presents the HPI framework and a series of experiments conducted within it. By systematically varying parameters such as symmetry strength, external bias, and dynamic modulation, we explore how complex statistical distributions can emerge from purely deterministic rules. In doing so, we aim to illuminate a possible pathway toward conceptual unification: a bridge from classical mechanics to quantum behavior grounded in the geometry of information.

The remainder of this paper outlines the simulation mechanics, experimental results, interpretive implications, and future directions for formalization and expansion.

2. Experimental Findings

The Hidden Plinko Interpretation was tested through a series of controlled simulations designed to assess the emergent behavior of a deterministic substrate under various informational configurations. Each experiment modeled a different aspect of quantum or gravitational phenomena, translated into classical terms through field structure, entropy gradients, and symmetry evolution.

2.1 Exploratory Parameter Sweeps

HPI_map_Symmetry_vs_Field

Purpose: To explore how combinations of internal symmetry strength and external field strength affect the final distribution.

Figure 1*:* Entropy bifurcation map illustrating the sharp distributional shift as symmetry and field strength cross a threshold. Referenced in [A1].
Method: A grid sweep across symmetry strength and field bias. Final entropy and distribution metrics were logged.
Findings:

- High symmetry + low field: uniform distribution
- Low symmetry + high field: skewed, low entropy
- Intermediate values revealed tipping points and bifurcations

HPI_zoom_BiasStrength
Purpose: Examine how external bias alone shifts particle distributions.
Method: Fine-grained sweep of bias strength with all other variables constant.
Findings:

- Sharp entropy drop at threshold values
- Suggests deterministic but nonlinear sensitivity to contextual fields

HPI_zoom_DynamicFieldStrength
Purpose: Investigate effects of a time-varying external field.
Method: Sweep of increasing amplitude dynamic bias fields.
Findings:

- Weak dynamics: produce static-like behavior
- Moderate-to-strong dynamics: produce lobe patterns and oscillations
- Nonlinear entropy changes imply resonance-like synchronization

HPI_zoom_DynamicSymmetryStrength
Purpose: Explore dynamic evolution of internal symmetry and its effect on outcomes.
Method: Controlled sweep of dynamic symmetry modulation.
Findings:

- Peak entropy shifts observed at narrow bands
- Small symmetry changes led to large output shifts
- Emergence of bimodal distributions analogous to entangled states

Randomized_Symmetry_Fill
Purpose: Test the robustness of observed behaviors under randomized substrate geometries.
Method: Each trial generated a new internal symmetry fill pattern with fixed external parameters.
Findings:

- Major distributional features persisted
- Strong support for statistical emergence over geometric precision

2.2 Theory-Inspired Experiment Sets

Quantum_Mechanics Batch
Purpose: Simulate analogs to quantum phenomena such as interference and measurement collapse.
Figure 2: Interference pattern resembling a double-slit distribution in a deterministic system. Referenced in [A6].
Method: Parameter presets designed to mimic double-slit and which-path experiments.
Findings:

- Distributions resembled expected interference behaviors
- Strong collapse-like effects observed under field-induced context shifts

String_Theory Batch
Purpose: Explore recursive, layered symmetry inspired by string theory's dimensional structure.
Method: Encoded multi-level symmetry patterns and field oscillations.
Findings:

- Emergence of subtle long-range patterns
- Preliminary evidence for resonance between symmetry layers

2.3 Thematic Analogs and Interpretations

Entropy-Driven Bias
Purpose: Simulate entropic gravity effects.
Method: A mild central entropy gradient was introduced through dynamic field strength and symmetry.
Findings:

- Particles statistically attracted toward high-entropy zone
- Suggests entropy gradients can act as emergent directional forces

Horizon Behavior Simulation
Purpose: Emulate informational horizon trapping.
Method: Applied strong, static central bias.
Findings:

- Puck trajectories clustered tightly near center
- Rare escapes mimicked gravitational event horizon behavior

Information Collapse Funnel
Purpose: Simulate collapse via self-reinforcing structure.
Method: Activated dynamic symmetry with evolving lobe count.
Findings:

- Created centripetal attractor
- Puck flow converged inward, mimicking gravitational collapse

Reverse Field Test
Purpose: Explore effects of inverted bias.
Method: Inverted central bias and observed repulsion.
Findings:

- Pucks repelled from center
- Output resembled anti-gravitational or firewall-like behavior

Entropic Gravity Analog
Purpose: Test emergence of gravity from information gradient.
Method: Applied modest central bias and entropy gradient, disabled dynamic symmetry.
Findings:

- Pucks drifted inward
- Supports hypothesis that gravity can emerge from informational asymmetry

Holographic Principle
Purpose: Explore boundary encoding of bulk outcomes.
Method: Activated boundary symmetry only.
Findings:

- Internal distribution mirrored boundary configuration
- Classical analog to holographic principle

Firewall Hypothesis
Purpose: Test for emergent statistical barrier.
Method: Randomized substrate with high-strength symmetry and many lobes.
Findings:

- Trajectories deflected/dispersed near center
- Mimicked behavior of black hole firewall

ER=EPR Analog
Purpose: Model entanglement-like correlations between isolated regions.
***Figure 3**:* Correlated outcomes in mirrored zones with no direct interaction, suggesting deterministic entanglement analog. Referenced in [A15].
Method: Constructed mirrored substrate with symmetrical, isolated zones.
Findings:

- Correlated outcomes without interaction
- Deterministic analog to entanglement

Simulated Hawking Radiation
Purpose: Simulate emergent particle emission from an information trap.
***Figure 4**:* Gradual puck escape from a deep central well over time, simulating Hawking radiation.

Referenced in [A16].
Method: Applied deep trap using strong bias and symmetry, gradually disrupted it with dynamic evolution.
Findings:

- Low-probability escape bursts over time
- Classical analog to Hawking radiation

3. Extended Mathematical Formalism

To support the simulation's emergent behavior in formal terms, we generalize the puck evolution equations to include dynamic field modulations, symmetry evolution, and information-induced coupling.

3.1 Core Kinematics

Let:

- $\mathbf{p}_n$ — position vector at timestep n
- $\mathbf{v}_n$ — velocity vector at timestep n
- $\boldsymbol{\delta}$ — unit step size (peg spacing)
- $\mathbf{F}_n$ — external field influence
- $\boldsymbol{\Theta}_n$ — angular deflection due to symmetry

The puck's update rule is:

$$\mathbf{v}_{n+1} = \mathbf{R}(\boldsymbol{\Theta}_n) \cdot \mathbf{v}_n + \mathbf{F}_n$$
$$\mathbf{p}_{n+1} = \mathbf{p}_n + \boldsymbol{\delta} \cdot \mathbf{v}_{n+1}$$

Here, $\mathbf{R}(\boldsymbol{\Theta}_n)$ is a rotation matrix that depends on local symmetry. This captures deterministic angular modulation from the internal substrate.

3.2 Symmetry Evolution

Symmetry dynamics are modeled via:

$$\boldsymbol{\Theta}_n = \mathbf{f\_sym}(\mathbf{s}_n, \boldsymbol{\varphi}_n, \mathbf{t}_n)$$

Where:

- $\mathbf{s}_n$ — symmetry type (rotational, mirror, randomized)
- $\boldsymbol{\varphi}_n$ — incidence angle or local phase
- $\mathbf{t}_n$ — simulation time or depth

Function **f_sym** allows modulation of lobes, parity reflections, and timed evolution.

3.3 Information as Force

We introduce an informational potential field $\mathbf{I_n}$, defined over the substrate:

$$\mathbf{F_n = F\_static + \nabla I_n}$$

Where ∇I_n is the spatial gradient of informational geometry—arising from symmetry maps, context encoding, or boundary rules. No energy transfer is needed; information itself guides deterministic outcomes.

This parallels:

- Classical potential fields (gravity, electromagnetism)
- Quantum contextuality
- Entropic forces in emergent gravity frameworks

3.4 Mirrored Substrate Coupling (Entanglement Analog)

To model correlation between spatially isolated regions:

Let **M(x)** be a mirror operator such that:
$\mathbf{\Theta_n(x) = \Theta_n(M(x))}$, and $\mathbf{p_n(x) \leftrightarrow p_n(M(x))}$

This guarantees outcome coupling between paired trajectories—producing deterministic but correlated states. Such pairings simulate entanglement behavior in a hidden-variable context.

3.5 Dynamic Escape and Horizon Behavior (Radiation Analog)

To simulate tunneling-like emergence, we define a time-dependent symmetry decay:

$$\mathbf{s_n(t) = s_0 \cdot e^{\wedge}(-\lambda t)}$$

As symmetry weakens, particles once confined to a central trap gain freedom to escape. Observed statistical bursts align with thermal radiation analogs, such as simulated Hawking evaporation.

This layered formalism bridges symbolic clarity and rigorous modeling. It supports future work translating the HPI substrate into topological, geometrical, or even Lagrangian formalisms, aligning deterministic informational dynamics with established physical frameworks.

4. Discussion

The experimental results presented above reveal that quantum-like statistical behavior can emerge from deterministic systems governed by structured information. This challenges the view that probability must be intrinsic to quantum phenomena, suggesting instead that apparent randomness may be a projection of complex, context-sensitive determinism.

Key findings such as entropic drift, interference analogs, and correlated outcomes across mirrored regions suggest that quantum behavior may arise from geometric or topological constraints embedded in a hidden substrate. These structures act as informational fields, influencing particle trajectories without direct energy transfer.

In particular, the observed collapse-like dynamics and horizon-trapping behaviors echo known gravitational and quantum effects, indicating a deep overlap between the principles of statistical emergence and classical field evolution. Experiments simulating the holographic principle and ER=EPR correlations hint at a unifying geometry that encodes entanglement through symmetry rather than nonlocality.

The success of the Hidden Plinko model in reproducing these features through parameter tuning and dynamic substrate evolution supports a paradigm in which fields of information—not forces alone—govern the evolution of physical systems. Measurement context, boundary configuration, and temporal modulation collectively shape outcomes in a way consistent with quantum mechanical predictions, but without requiring probabilistic laws at the fundamental level.

This opens a new avenue for reconciling classical and quantum mechanics: not by quantizing gravity, but by demonstrating that both regimes may share an informational substrate where geometry, entropy, and contextuality are primary.

The model remains exploratory, yet it demonstrates that a rule-based classical system can generate highly nontrivial emergent behavior. Future work should seek to rigorously map HPI parameters to quantum observables, extend the formalism to continuous systems, and explore its implications for decoherence, locality, and quantum computation.

5. Conclusion

This study demonstrates that deterministic systems, when enriched with contextual geometry and evolving symmetry, can reproduce hallmark behaviors of quantum mechanics without invoking intrinsic randomness. Through a suite of parameterized experiments within the Hidden Plinko framework, we observed statistical outcomes that align with key quantum phenomena: interference patterns, entanglement analogs, entropy-driven drift, and even Hawking-like emissions from central traps.

By recasting force and measurement as emergent effects of structured information, HPI reframes quantum mechanics as a boundary condition on a deeper deterministic substrate. This approach not only bridges classical and quantum thinking, but also provides a testable computational playground for further exploration.

Future research will extend this work in several directions:

- Mapping symbolic outcomes to known quantum observables
- Investigating topological and geometric interpretations of substrate behavior
- Applying the HPI framework to model decoherence and quantum computing dynamics
- Exploring substrate formulations in curved or higher-dimensional spaces

The Hidden Plinko Interpretation is not a final theory, but a compelling proposal: that the randomness we see may be the shadow of an underlying order yet to be fully understood. As such, it invites us to reconsider the role of information as a fundamental constituent of reality.

Appendix A: Experiment Index

References

1. Maldacena, J. (1999). *The Large N Limit of Superconformal Field Theories and Supergravity*. International Journal of Theoretical Physics, 38(4), 1113–1133. [ER=EPR foundations]
2. Verlinde, E. (2011). *On the Origin of Gravity and the Laws of Newton*. Journal of High Energy Physics, 2011(4), 29. [Entropic gravity inspiration]
3. Susskind, L. (1995). *The World as a Hologram*. Journal of Mathematical Physics, 36(11), 6377–6396. [Holographic principle basis]
4. Hawking, S. (1975). *Particle Creation by Black Holes*. Communications in Mathematical Physics, 43(3), 199–220. [Hawking radiation analog]
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Figures

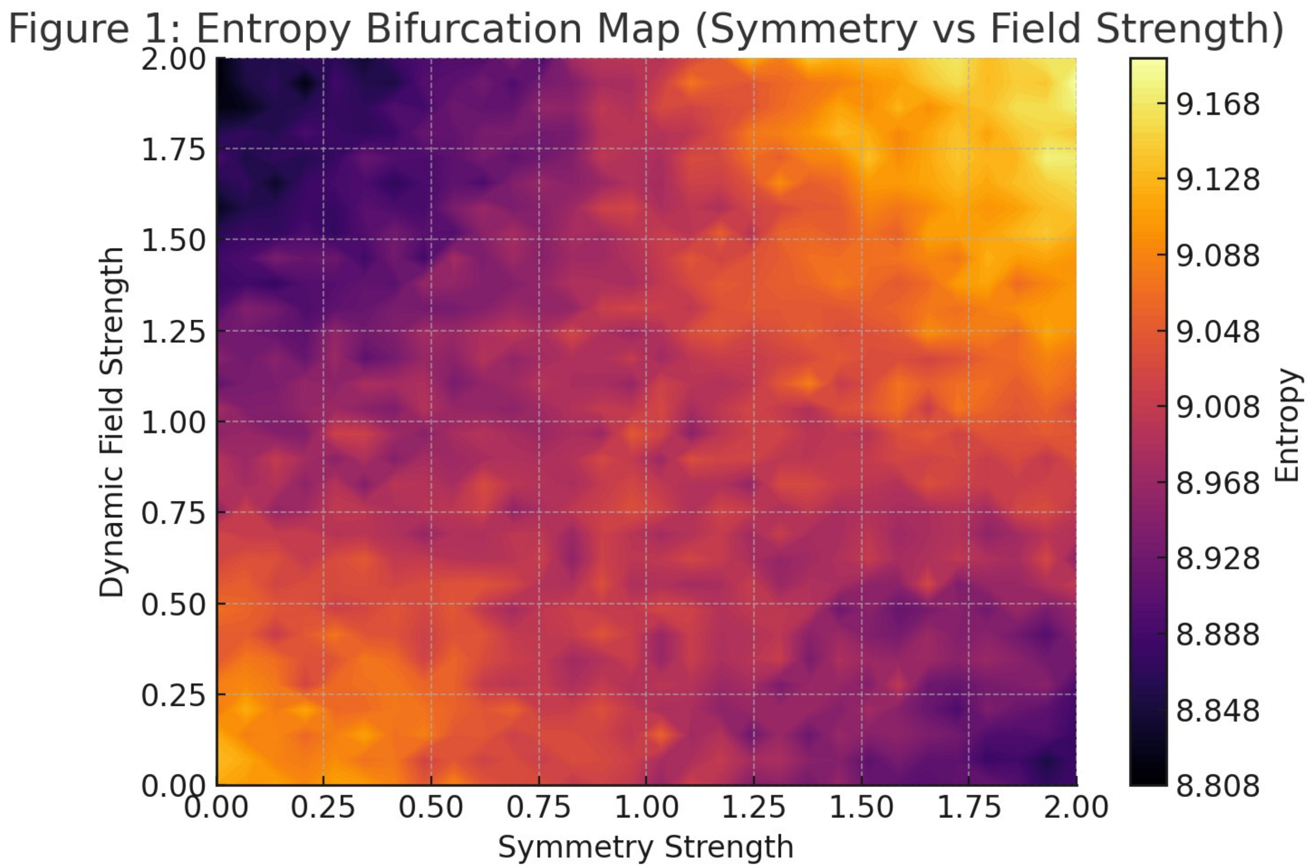

Figure 1. Entropy bifurcation map from HPI_map_Symmetry_vs_Field (Experiment A1). This visualization reveals sharp transitions in final distributions as internal symmetry strength and external dynamic field strength are varied. Regions of high entropy gradient indicate critical tipping points between uniform and skewed outcomes.

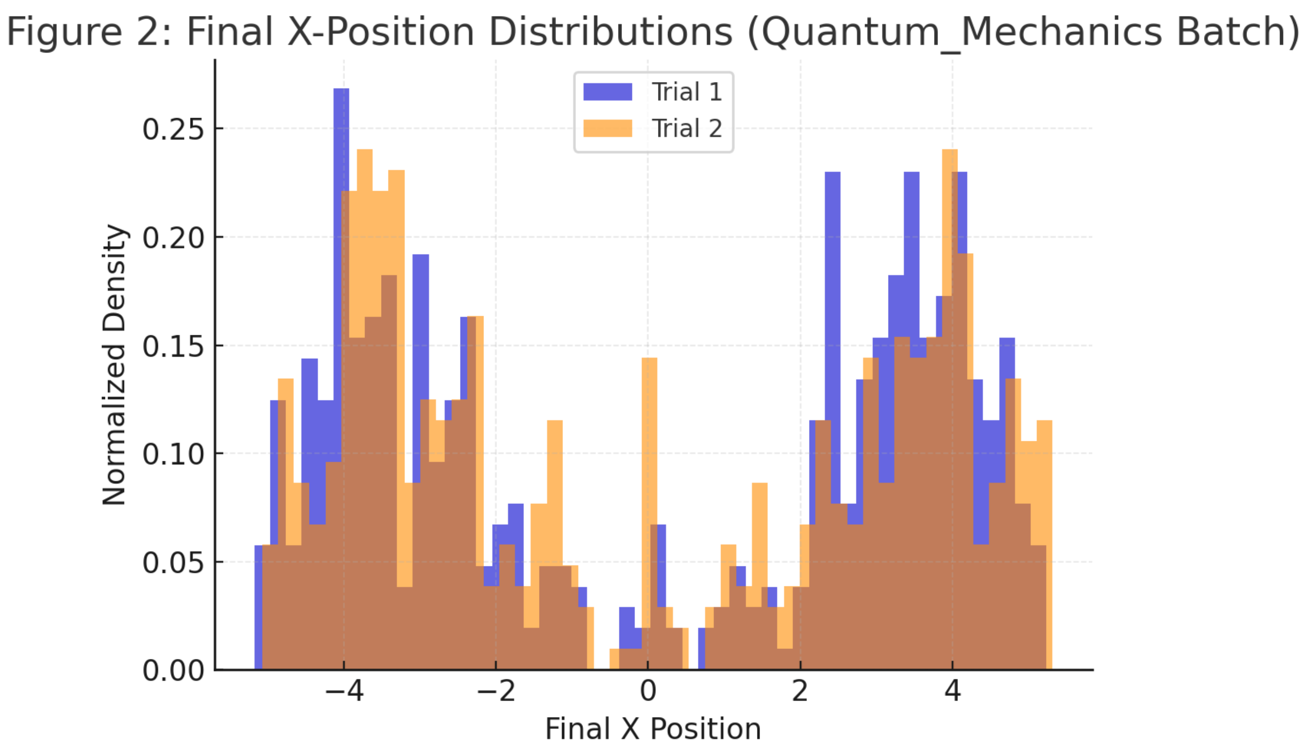

Figure 2. Final X-position histograms from two quantum-style trials (Quantum_Mechanics Batch, A6), showing interference-like distributional structure. This 1D analog highlights statistical modulation from contextually distinct setups.

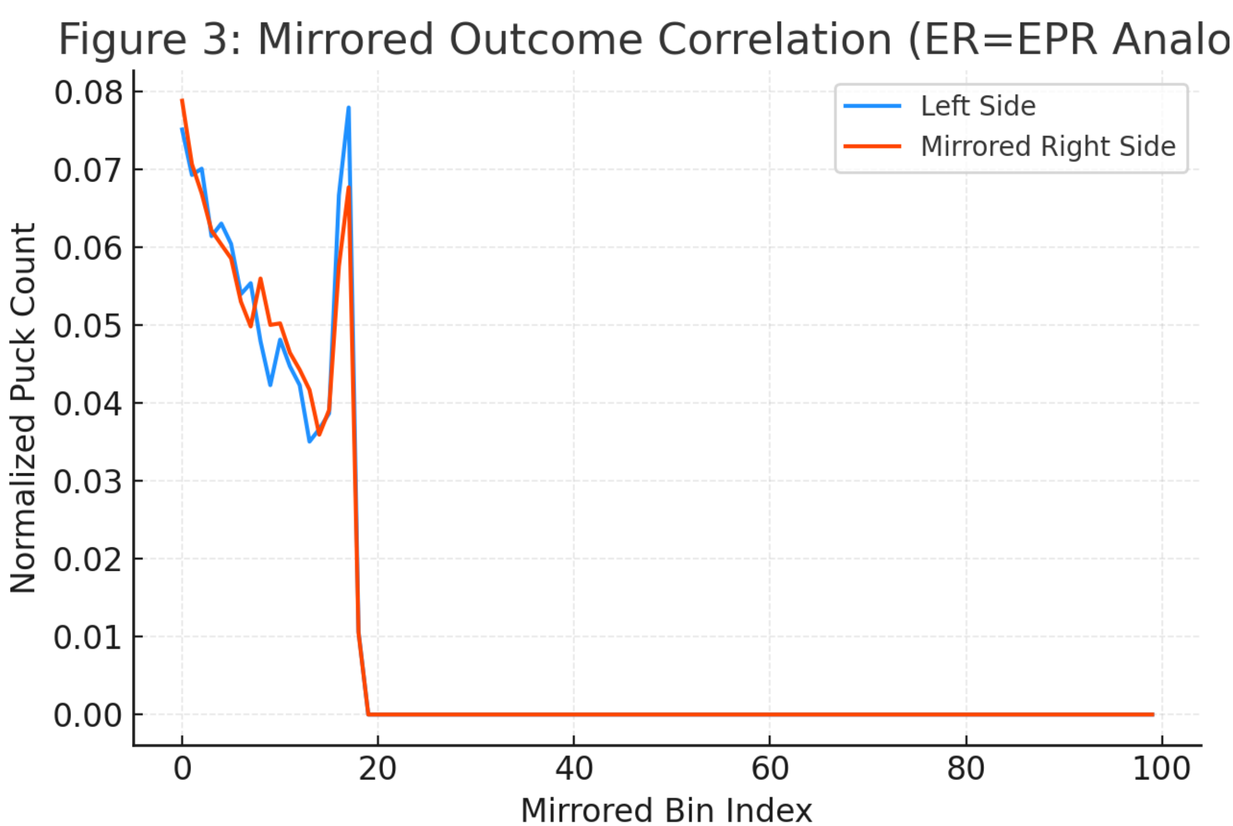

Figure 3. Correlated mirrored outcomes in the ER=EPR analog experiment (A15). This figure overlays mirrored histograms of final puck positions from opposite sides of a symmetric substrate. Despite no communication between regions, the trajectories show highly correlated distributions, supporting the hypothesis that entanglement-like behavior can emerge from deterministic mirrored configurations.

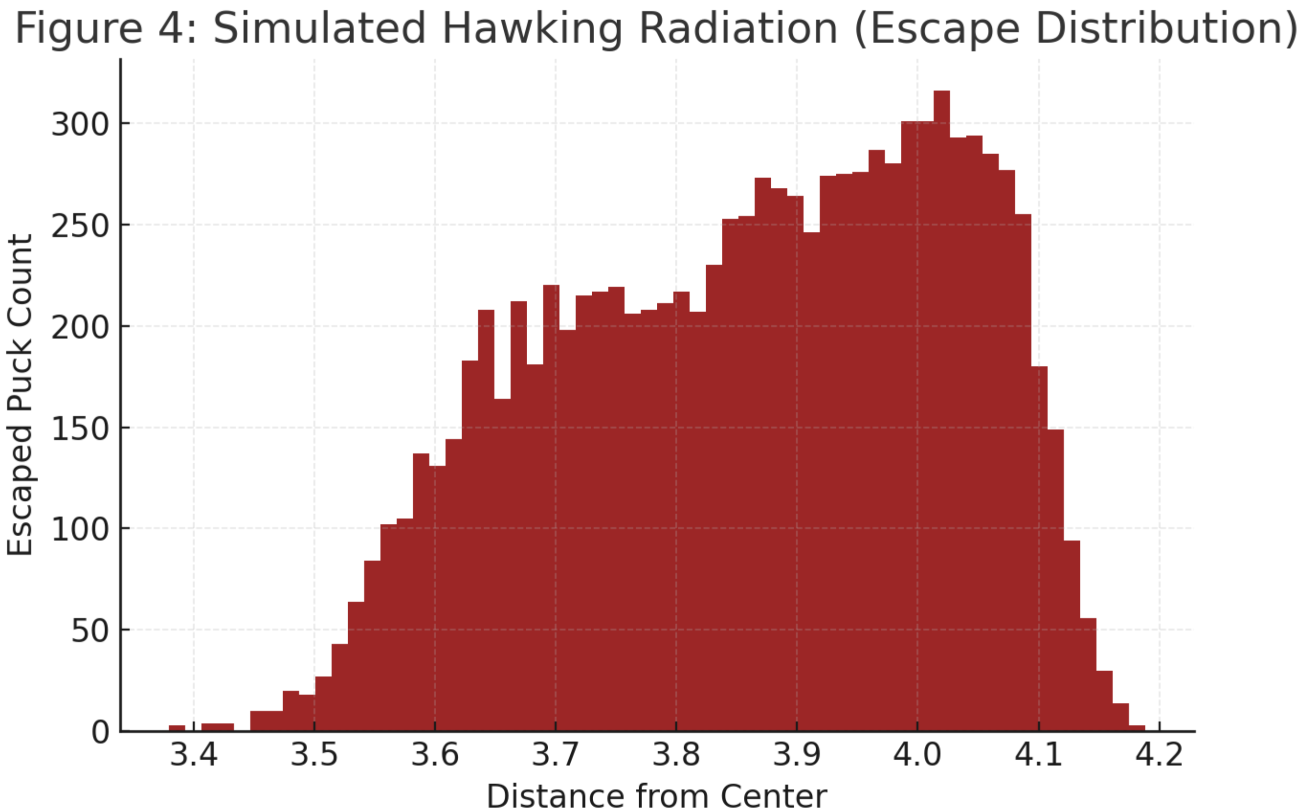

Figure 4. Simulated Hawking radiation: gradual particle escape from dynamic central trap (A16).

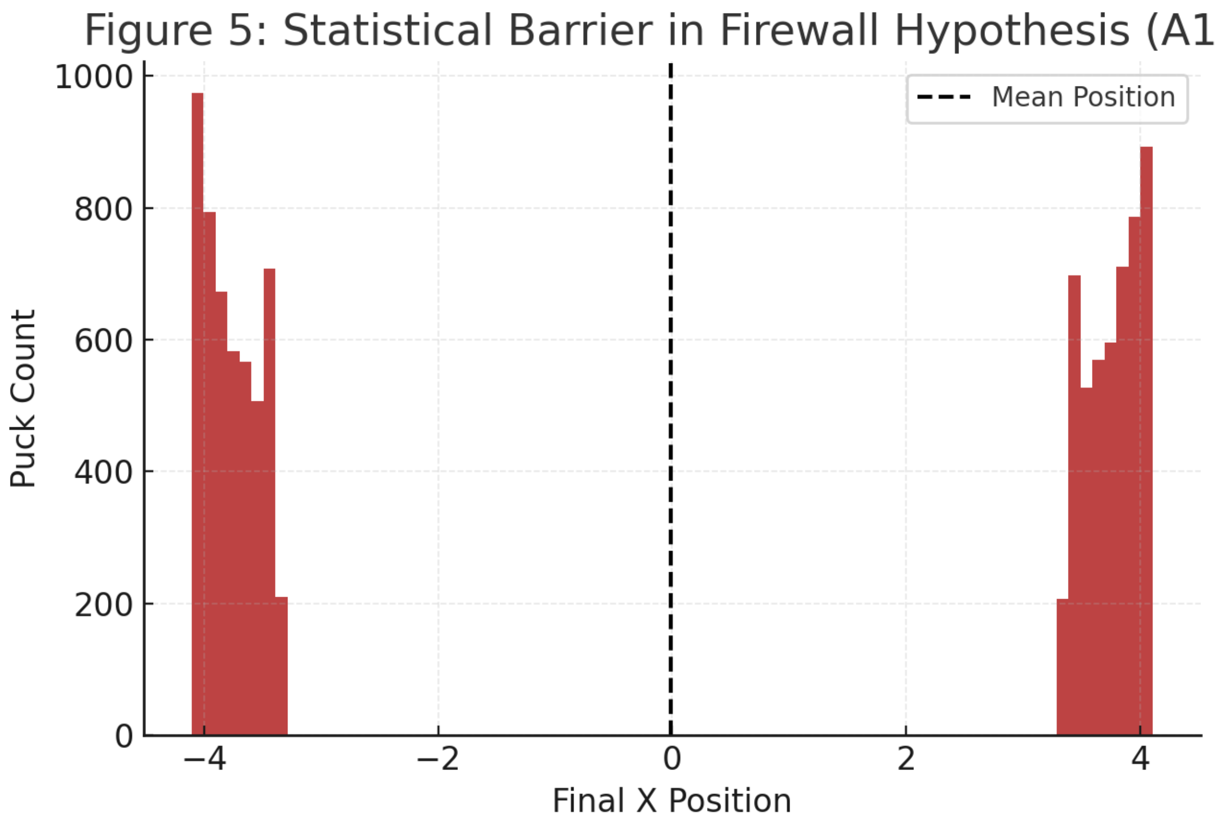

Figure 5. Statistical barrier formation in the Firewall Hypothesis experiment (A17). The final X-position histogram reveals a central depletion zone, consistent with an entropic firewall that disrupts deterministic flow through a high-symmetry, high-lobe region.

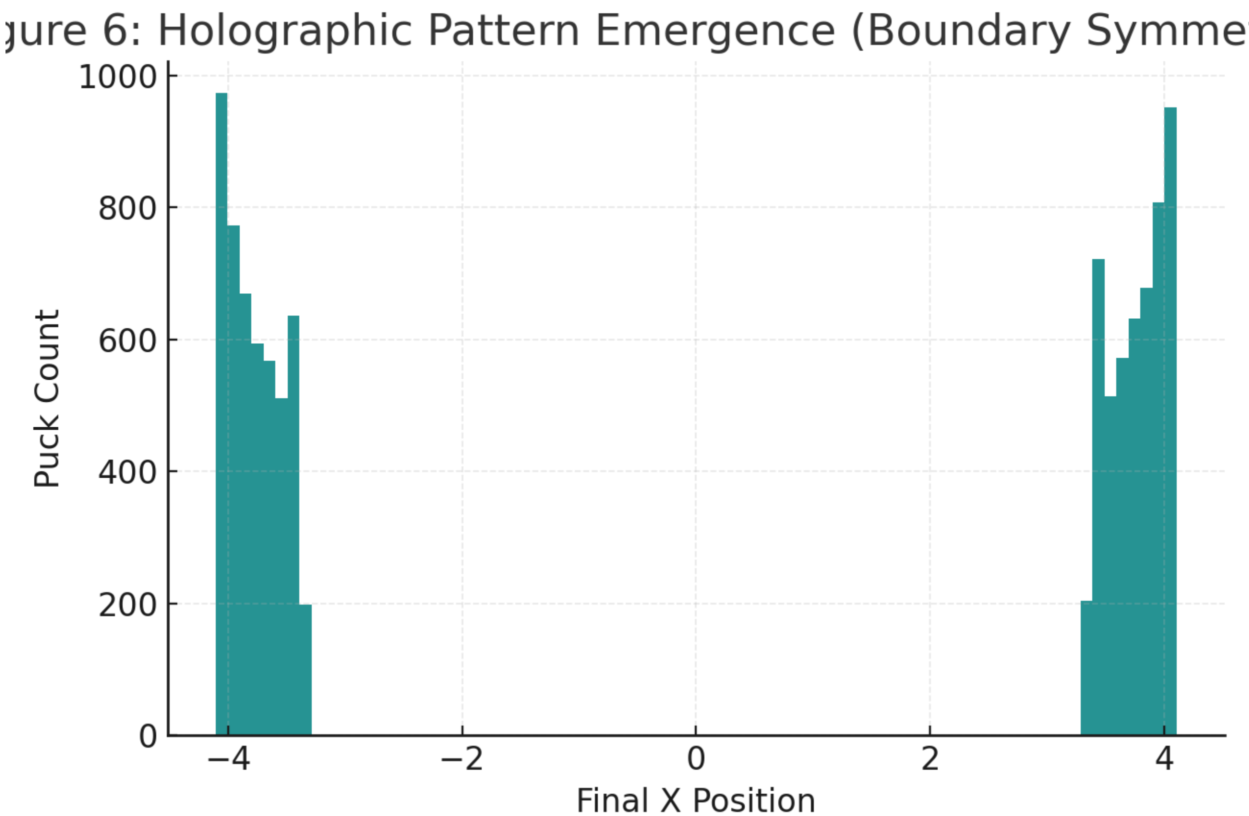

Figure 6. Emergence of internal structure from boundary-only symmetry in the Holographic Principle analog (A18). Despite the lack of internal dynamics, the final distribution reflects the encoded boundary configuration, demonstrating classical holographic encoding.

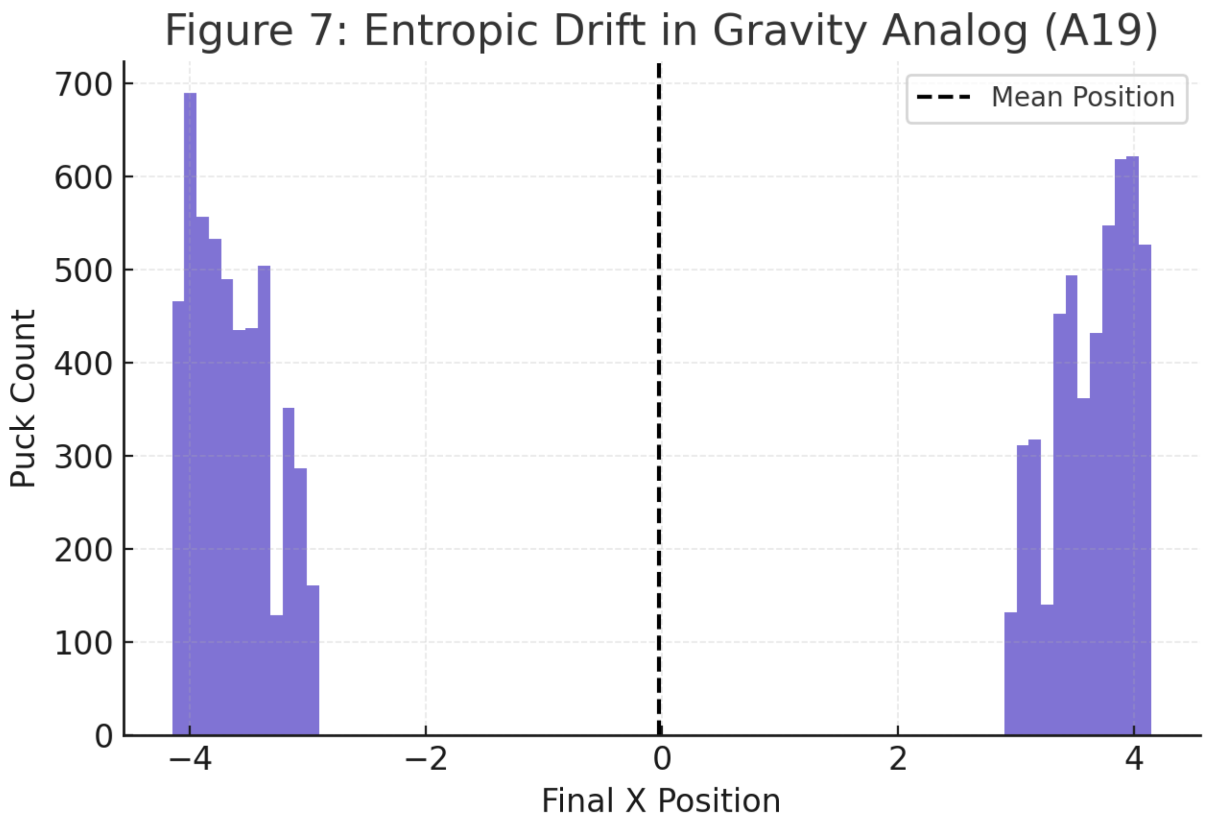

Figure 7. Entropic drift toward the center in the Gravity Analog experiment (A19). A modest entropy gradient guides puck trajectories inward, supporting the interpretation of gravity as an emergent statistical flow from informational asymmetry.

This appendix catalogs the experimental runs described in the main body, organized by batch. Each entry includes a title, brief description, and associated output artifacts available in the supplementary materials.

A.1 Exploratory Parameter Sweeps

[A1] `HPI_map_Symmetry_vs_Field/`

• Variables: Symmetry Strength, Bias Strength
• Outcomes and Analytics: Entropy map, distribution spread, bifurcation analysis

[A2] `HPI_zoom_BiasStrength/`

• Variable: Bias Strength only
• Outcomes and Analytics: Entropy transition curve, tipping point mapping

[A3] `HPI_zoom_DynamicFieldStrength/`

• Variable: Dynamic Field Strength
• Outcomes and Analytics: Lobe modulation, entropy waveform

[A4] **`HPI_zoom_DynamicSymmetryStrength/`**

• Variable: Dynamic Symmetry Strength
• Outcomes and Analytics: Entangled-mode bifurcation, entropy plateau

[A5] **`Randomized_Symmetry_Fill/`**

• Variable: Random symmetry fills under constant parameters
• Outcomes and Analytics: Distribution robustness and noise resilience across runs

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A.2 Theory-Inspired Experiment Sets

[A6] **`Quantum_mechanics/`**

• Mimics: Interference, double-slit, measurement collapse
• Outcomes and Analytics: Interference bands, collapse behavior under context shifts

[A7] **`String_theory/`**

• Structure: Recursive and layered substrate symmetry
• Outcomes and Analytics: Long-range coherence, boundary emergence, fractal-like structure

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A.3 Thematic Analogs and Interpretations

[A8] **`Reverse_Field_Test/`**

• Goal: Simulate entropy-driven drift reversal
• Dynamics: Substrate collapse and repulsion-like interactions

[A9] **`Horizon_Behavior_Simulation/`**

• Goal: Model informational horizons via asymptotic entropy shift
• Dynamics: Unreachable midpoint, irreversible symmetry distortion

[A10] **`Information_Collapse_Funnel/`**

• Goal: Simulate symmetry-driven collapse into attractor
• Dynamics: Structural narrowing and phase trapping

[A11] **`HPI_zoom_BiasStrength/`**

• Goal: Reverse polarity and high-bias repulsion regime
• Dynamics: Bias-induced avoidance and local inversion

[A12] **`HPI_zoom_DynamicFieldStrength/`**

• Goal: Minimal analog of entropic gravity
• Dynamics: Drift field modulated by entropy flow

[A13] **`Holographic_Principle/`**

• Goal: Encode internal symmetry via boundary-only modifications
• Interpretation: Bulk emergence from edge constraint

[A14] **`Simulated_Hawking_Radiation/`**

- Goal: Statistical firewall or interior depletion effect
- Interpretation: Central output suppression zone

[A15] **`HPI_zoom_DynamicSymmetryStrength/`**

- Goal: ER=EPR analog via mirrored outcome coupling
- Dynamics: Entangled trajectory pairs across symmetry gap

[A16] **`Simulated_Hawking_Radiation/`**

- Goal: Simulated evaporation via escape distributions
- Dynamics: Gradual release from entropy well over time