Born-Rule Deviations under Finite-Time and Non-Equilibrium Conditions

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Abstract

> *In the FRC program, collapse arises by resonance phase-locking to pointer attractors and the Born rule emerges as a stationary equilibrium of microstates. This note analyzes when and how deviations from |alpha|^2 can appear: (i) finite locking time (truncated dynamics), (ii) biased or insufficiently mixed microstate ensembles (non-ergodicity), and (iii) non-stationary pointer coupling. It derives simple bias scalings, proposes falsifiable protocols to detect or rule out deviations, and provides toy simulations with code to reproduce the figures.*

1. Premise

In the FRC collapse picture ([[FRC-100-006]]), the Born rule is not a postulate but a **stationary equilibrium**: collapse proceeds by resonance phase-locking to pointer attractors, and sector frequencies settle to $|\alpha|^2$ when the microstate dynamics has fully mixed and locked. That derivation has a sharp corollary: whenever the equilibrium conditions are not met, small deviations from $|\alpha|^2$ become possible — and their structure identifies the mechanism. This note maps the deviation conditions.

2. Conditions for deviations

Three mechanisms can bias outcome frequencies away from $|\alpha|^2$:

Mechanism	Condition	Leading bias
Finite time	phase-locking completes on a timescale comparable to the sampling time T; sectors with slower attraction are under-represented	$\varepsilon \sim e^{-\kappa T}$
Non-ergodic ensembles	a skewed initial microstate density shifts sector frequencies until mixing erases the skew	$\mathcal{O}(\delta)$ in the skew δ
Non-stationary coupling	time-dependent pointer coupling $g(t)$ can temporarily favor sectors	suppressed by adiabatic ramps

3. Minimal drift picture

Let sector weights be $|\alpha|^2$ in equilibrium. A weak drift updates microstates toward their nearest sector; deviations arise when the drift/mixing dynamics is truncated or non-stationary. The three cases are modeled and the bias $\varepsilon(T,\delta,g)$ quantified in each.

4. Toy simulations (reproducible)

`code/100.006.002/make_figures.py` generates three fixed-seed figures:

1. **Bias vs. locking time T** — finite-time locking: mean absolute deviation from $|\alpha|^2$ decays with horizon T.
2. **Bias vs. ensemble skew δ** — non-ergodic ensembles: deviation grows with initial skew.
3. **Bias vs. coupling ramp** — non-stationary coupling: adiabatic ramps suppress the bias.

The script prints the measured mean deviations for each condition; figures are written to `artifacts/100.006.002/`.

5. Protocols and falsifiability

Each mechanism carries a protocol that can identify it — or rule it out — as the source of an observed deviation:

- **P-D1 (finite time):** repeat weak-then-strong measurement sequences with increasing horizon T; deviations should decay (exponential/overdamped) if finite-time bias is the cause.
- **P-D2 (non-ergodicity):** randomize microstate preparation to erase ensemble skew; residual deviations *falsify* non-ergodicity as the source.
- **P-D3 (non-stationarity):** use slow ramps for pointer coupling; deviations that vanish under adiabatic ramps identify non-stationarity as the source.

The logic runs in both directions: the protocols can detect a deviation mechanism, and null results under all three progressively confine any FRC-predicted deviation — or rule the deviation picture out for the tested regime.

6. Record

- Zenodo record: [10.5281/zenodo.17526499](https://doi.org/10.5281/zenodo.17526499) (published 2025-11-04; includes `FRC_100_006_002_Born_Rule_Deviation_Conditions.pdf` and `release.zip` with the figure code).

Connections

- [[FRC-100-006]] — Born rule from resonant equilibrium; the parent derivation whose failure modes are mapped here
- [[FRC-100-005]] — Thermodynamic consistency / boundary decision; the locking thermodynamics behind the finite-time scaling
- [[FRC-100-003]] — Collapse as open-system phase-locking; the two-stage dynamics being truncated at finite T
- [[FRC-566-001]] — Entropy–coherence reciprocity and UCC, the thermodynamic frame for equilibrium microstate statistics

References

1. Servat, H. *FRC 100.006 — Born Rule from Resonant Equilibrium*. DOI: 10.5281/zenodo.17438360.
2. Servat, H. *FRC 100.005 — Thermodynamic Consistency*. DOI: 10.5281/zenodo.17438231.
3. Servat, H. *FRC 566.001 — Reciprocity & UCC*. DOI: 10.5281/zenodo.17437759.