No Dice, Niels: Deterministic Quantum Statistics from Null-Shell Causality

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"God does not play dice," Einstein objected to quantum indeterminacy. This paper examines how quantum probability may emerge from deterministic, time-symmetric causal processes. Within the null-shell causality framework of *Einstein's Big Toe*, the Born rule is shown to follow geometrically once amplitude squaring is assumed: two-boundary null-contact structure fixes the $\cos^2$ detection law with no adjustable parameters. Introducing a natural symmetry threshold at $T_{\text{crit}} = 0.5$ converts the continuous coupling into discrete yes/no outcomes, providing a fully deterministic version of the theory. Bell correlations arise from boundary-conditioned phase selection where both retarded (past) and advanced (future) null contacts participate. The model is retrocausal in a kinematic sense—future settings constrain which past emissions complete—but it preserves locality and no-signaling. Apparent randomness reflects epistemic ignorance of absorber boundary conditions rather than ontological chance.

I. INTRODUCTION

Copenhagen quantum mechanics treats measurement outcomes as intrinsically probabilistic. Einstein maintained that probability should arise from hidden causal structure, famously declaring that "God does not play dice." In the *null-shell causality* framework [1], all interactions occur at lightlike contact between worldlines. Each observable event is a completed two-way transaction between emission and absorption that respects time symmetry.

Here we outline a two-level account. First, given amplitude squaring, Born statistics follow directly from null-shell geometry with no free parameters. Second, an optional threshold criterion transforms the continuous weighting into deterministic single-event dynamics while leaving ensemble results unchanged. The apparent stochasticity of quantum mechanics is then epistemic: it arises from ignorance of absorber microstates, not from indeterministic law.

Scope. The analysis employs the time-symmetric two-boundary framework encoded in a Fokker-type direct action [1–4], where interactions are supported on null separation $(x-y)^2 = 0$. Section II develops the geometric and deterministic models. Section III contrasts them with other retrocausal interpretations. Section IV discusses testability and conceptual implications.

II. FROM GEOMETRIC STATISTICS TO DETERMINISTIC EVENTS

A. Continuous two-boundary weighting and the Born rule

For a photon traversing emitter $\to$ polarizer (axis θ) $\to$ absorber, let λ_e and λ_a denote the emission and absorption polarization phases. The retarded and advanced legs contribute $\cos(\lambda_e - \theta)$ and $\cos(\theta - \lambda_a)$ respectively, giving joint amplitude

$$\mathcal{A}(\lambda_e, \theta, \lambda_a) = \cos(\lambda_e - \theta)\cos(\theta - \lambda_a), \tag{1}$$

and corresponding weight

$$W(\lambda_e, \theta, \lambda_a) = \big|\cos(\lambda_e - \theta)\cos(\theta - \lambda_a)\big|^2. \tag{2}$$

Averaging over uniformly distributed absorber orientations $\lambda_a \in [0, 2\pi)$ yields

$$P_{\text{det}}(\theta|\lambda_e) \propto \int_0^{2\pi} W(\lambda_e, \theta, \lambda_a)\, d\lambda_a = \cos^2(\lambda_e - \theta)\int_0^{2\pi} \cos^2(\theta - \lambda_a) d\lambda \tag{3}$$

so that after normalization

$$P_{\text{det}}(\theta|\lambda_e) = \cos^2(\lambda_e - \theta). \tag{4}$$

Born's rule (Malus's law) therefore follows from null-shell geometry once amplitude squaring is accepted. This "continuous-weight" version is fully deterministic at the ensemble level but leaves individual events unresolved until absorber boundary conditions are known.

B. Optional deterministic partition: the 0.5 threshold

A discrete, fully deterministic version is obtained by introducing a binary partition of coupling strength:

$$\text{Detection occurs} \iff \big|\cos(\lambda_e - \theta)\cos(\theta - \lambda_a)\big| > T_{\text{crit}}. \tag{5}$$

Each event's outcome is then fixed by $(\lambda_e, \theta, \lambda_a)$; ensemble randomness arises solely from unobserved λ_a.

The value $T_{\text{crit}} = 0.5$ provides a symmetric division of normalized coupling:

1. **Midpoint symmetry:** $|\mathcal{A}| \in [0, 1]$; 0.5 partitions "more aligned" from "less aligned," preserving isotropy.

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2. **Two-gate logic:** Requiring each causal leg to be "more open than closed," $|\cos| > 1/\sqrt{2}$, gives product threshold $(1/\sqrt{2})^2 = 0.5$.

3. **Statistical consistency:** Averaging over uniform λ_a recovers Eq. (4) exactly—a result that can be verified by direct integration or numerically. Threshold values $T \neq 0.5$ produce angular dependence distinct from $\cos^2$, making 0.5 the unique choice consistent with empirical data.

This threshold is thus the simplest deterministic discretization consistent with experiment. Its deeper derivation from the action principle remains open.

C. Bell correlations from boundary-conditioned phase selection

For a polarization singlet, partners have phases $(\lambda, \lambda + \pi/2)$. Analyzers at a and b produce local amplitudes

$$\mathcal{A}_A(\lambda, a) = \cos(\lambda - a), \tag{6}$$
$$\mathcal{A}_B(\lambda, b) = \sin(\lambda - b). \tag{7}$$

Concurrent completion on both arms yields

$$W_{AB}(\lambda|a, b) = \cos^2(\lambda - a)\sin^2(\lambda - b), \tag{8}$$

and the setting-dependent hidden-variable density

$$\rho(\lambda|a, b) = \frac{W_{AB}(\lambda|a, b)}{\int_0^{2\pi} W_{AB}(\lambda'|a, b)\, d\lambda'}. \tag{9}$$

Local outcomes follow deterministic signs,

$$A(a, \lambda) = \mathrm{sgn}[\cos(\lambda - a)], \qquad B(b, \lambda) = -\,\mathrm{sgn}[\cos(\lambda - b)], \tag{10}$$

giving correlation

$$E(a, b) = \int_0^{2\pi} \rho(\lambda|a, b) A(a, \lambda) B(b, \lambda) d\lambda = -\cos\bigl(2(a - b)\bigr), \tag{11}$$

which reproduces the quantum prediction ($S = 2\sqrt{2}$ for CHSH settings).

Bell's assumptions. Bell's theorem presumes measurement independence, $\rho(\lambda)$ independent of (a, b). In the null-shell framework $\rho(\lambda|a, b)$ depends on both settings because advanced analyzer legs contribute to transaction completion. This relaxes measurement independence while preserving locality and no-signaling: single-arm marginals remain $P_A(\pm|a) = P_B(\pm|b) = 1/2$. Retrocausality here is geometric rather than dynamical.

III. RELATION TO OTHER RETROCAUSAL INTERPRETATIONS

The model shares features with the transactional interpretation [5], the two-state-vector formalism [6], and retrocausal models of Price and Wharton [7, 8]. Null-shell causality differs by grounding these ideas in an explicit direct-action principle with null-contact geometry. It replaces stochastic collapse with deterministic phase-matching and derives the setting-dependent distribution (9) from two-boundary coupling itself rather than postulating retrocausality.

IV. IMPLICATIONS AND TESTABILITY

Determinism and locality. Individual outcomes are fixed by local phase alignment once absorber microstates are specified. All interactions occur at null separation; retrocausality acts as a boundary constraint, not as a signal channel.

Differential prediction under absorber bias. Standard quantum mechanics treats detector absorbers as unpolarized. If absorber orientations λ_a are partially aligned by external fields, the threshold model predicts a small, angle-dependent modification of detection rates while leaving correlations $E(a, b)$ unchanged. Careful modeling of such anisotropic absorbers could empirically distinguish the boundary-condition picture from conventional treatments.

Other probes. Time-asymmetric absorber environments (e.g. one-way optical cavities) may suppress advanced-leg formation, and realistic detector-saturation modeling should change absolute counts without altering normalized correlations.

V. CONCLUSION

Within null-shell causality, Born statistics arise geometrically from two-boundary coupling, and a simple symmetric threshold yields complete microscopic determinism. Bell correlations follow from boundary-conditioned phase selection, giving a local, time-symmetric, and no-signaling account of quantum phenomena. Quantum probability is therefore epistemic: ignorance of absorber microstates masquerades as randomness.

Nature does not play dice—she enforces geometry. The dice Einstein rejected are the shadows of half-known boundary conditions.

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