Causal Budget Framework, Part 2: Exploring the Double-Slit Experiment

Introduction: From Wave Cells to Measured Events

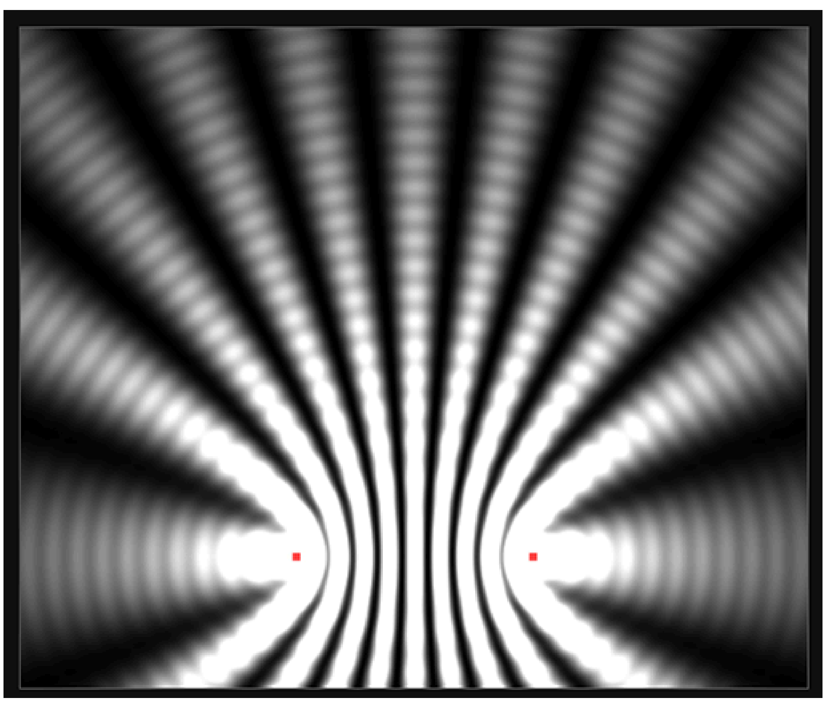
In **Part I**, the Causal Budget Framework (CBF) showed how to reproduce quantum-like wave behavior using only cellular automata style components:

1. **Wave cells** that expand using a discrete Huygens rule.
2. A **budget constraint** $C = T + M = 1$ that governs motion versus maintenance.
3. A **computational substrate** with spacing a and tick rate τ that sets the physical scale.

With just these rules, wave cells naturally curve around obstacles and diffract through openings. Photons arise as wavefronts with $M = 0$, matter as bound systems with $M > 0$.

One of the most revealing tests of any microphysical model is the double-slit experiment.
Below is an interference pattern generated directly by CBF's wave cell rules:

Figure 1. CBF-generated double-slit interference pattern, showing curved phase fingers and asymmetric healing fronts.



This post explains **why** patterns like this emerge, what they tell us about measurement, and why interference alone is not the full story. The following sections show how absorber atoms briefly store pieces of the particle's wavefront, how many candidate events accumulate, and why the eventual detection requires a global decision-making process beyond any strictly local cellular automaton.

Atomic Pollination

As a particle's wavefront grows and spreads, it reaches many potential absorber atoms at once. In the usual textbook treatment of quantum mechanics, this is summarized as a single stochastic detection event that produces one outcome. In CBF, the process is more detailed and more physical: **many atoms can interact with the wavefront before collapse is decided**.

Each wave cell carries phase, direction, and energy tags. As the wavefront sweeps across the environment, these tagged cells arrive at different atoms in the barrier, detector, or surrounding medium. Because collapse is not instantaneous in CBF, absorber atoms do not decide immediately. Instead, they enter a period of **pollination**.

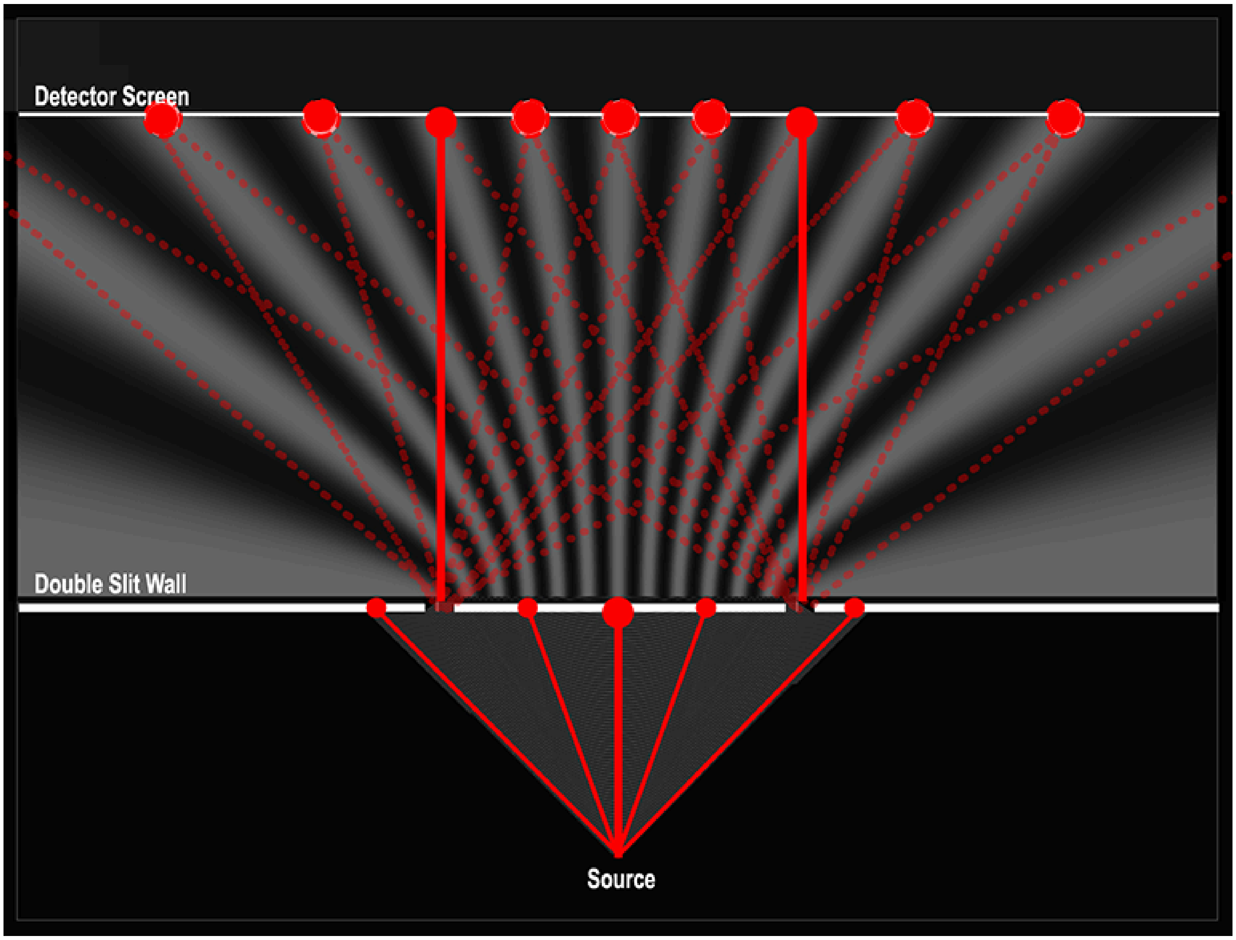
During pollination:

- wave cells from a single particle can reach **hundreds or thousands of atoms**
- each atom temporarily absorbs phase and direction information
- none of the atoms commit yet
- the system collects proposals from all potential absorbers

Every atom becomes a candidate, holding a small fragment of the particle's wavefront information. The collapse does not occur until enough information has arrived for the system to choose a single consistent outcome. The winning atom becomes the final collapse site, and the remaining atoms release their unused proposals.

This turns the familiar picture of "a wave that spreads, then a sudden dot on the screen" into a computational workflow. The wave spreads and **pollinates** many atoms, which accumulate partial information, and collapse happens only after the field has explored the available paths. Diffraction, interference, and tunneling then become simple consequences of how this pollination phase distributes wave cells across different atoms in space.

Figure 2. Atomic pollination in the double-slit setup.
As the particle's wavefront passes through both slits, many atoms across the detector screen and barrier absorb partial wave information (shown as red candidates).
The **dotted red lines** mark diffracted and interference-shaped proposals, while the **solid red lines** show the earliest, direct arrivals that would occur even without interference.
Each red dot represents a temporary proposal for a possible collapse event before a single winner is eventually selected.



Particles vs Atoms

In CBF, particles and atoms play very different roles.

A **particle** is a distributed wavefront made of many wave cells. It carries phase, momentum direction, and timing information, but it does *not* have a fixed location. It only provides a **probability distribution** of where a collapse *could* occur.

An **atom**, by contrast, is a discrete absorber. It has a physical location, a set of internal states, and the ability to commit an event. Atoms are where collapses happen. During pollination, each atom temporarily stores the tagged information arriving from the wavefront, but none of them acts until the system selects a final winner.

This distinction is essential:

- **Particles provide possibilities.**
- **Atoms provide actual outcomes.**

Interference patterns reflect how particles distribute possibilities. The final dot on the screen reflects which atom's history becomes real.

Events as the Only Reality

Despite all the complexity of wave propagation and pollination, **the only things we ever observe are events**.

We do not see the particle's wavefront. We do not see the atom storing temporary proposals. We only see the **final committed interaction**: a single atom absorbing the incoming energy.

In CBF, an **event** is the moment the system chooses one absorber among many candidates. Everything else such as wave spreading, pollination, and proposals are invisible bookkeeping that determines *where* the next real event can happen.

This viewpoint matches physical reality:

- every detection is a point-like event,
- every measurement corresponds to a commit,
- and every "particle path" is inferred only after the fact from the pattern of events.

Events are the atomic units of observable reality.

Event Delay (Commit Delay)

Pollination does not produce an immediate winner. Even atoms that receive early proposals must wait for the wavefront to unfold across all viable paths.

This creates a **commit delay**.

During this delay:

- many atoms hold partial information,
- the system compares phase, timing, and geometric consistency,
- and only after the full set of proposals is evaluated does one absorber commit.

This explains why collapse appears instantaneous from the outside but is preceded by a hidden competition internally.

The earliest-arriving atoms (those along the solid red lines in Figure 2) do *not* automatically win. They merely enter the candidate pool first. Interference, path differences, and phase relationships can shift the final outcome toward atoms reached later by more favorable proposals.

The commit delay is therefore the bridge between:

- **local CA wave propagation**, and
- **the global selection of a single, consistent event**.

Invalid Events and Pruning

During pollination, many atoms receive partial wave information, but only one can commit.
The remaining proposals (often hundreds or thousands of them) must be removed in a way that keeps the universe consistent. This requires a **pruning** step.

Pruning eliminates all losing candidates:

- atoms release their temporary phase and direction tags
- no energy is transferred
- the particle's wavefront resets for the next tick

These invalid proposals do not simply vanish without consequence. Even though they never become real events, they leave **subtle informational traces** in the surrounding field, shaping how future wavefronts propagate. The details of these traces, and their surprising physical implications, will be explored in a later post.

Pruning is therefore the mechanism that prevents contradictory outcomes and ensures that one, and only one, atom becomes real in each interaction.

Wavefront Reset After Measurement

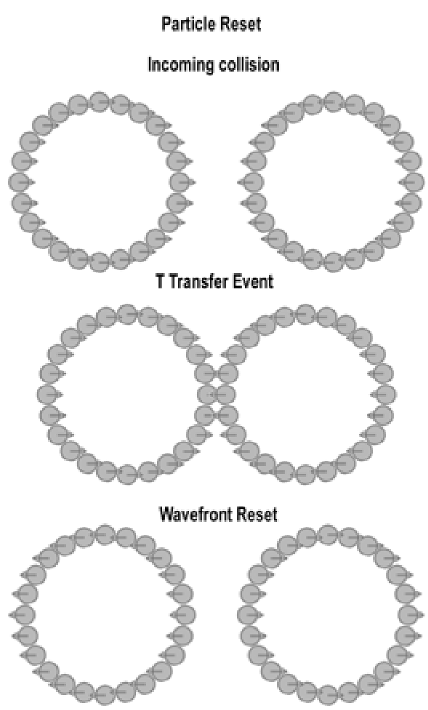
In CBF, a collapse ends the particle's uncommitted futures. Once a single absorber commits, the particle's probability field no longer continues forward from any other location.

For **particle–particle** interactions (reflection, scattering), a new outgoing wavefront naturally forms according to the propagation rules.

For **particle–atom** interactions, the particle's probability field terminates at the commit site. No further propagation occurs unless the atom later emits or scatters radiation according to ordinary physical processes.

The reset reflects the completion of the particle's current propagation cycle, not the creation of a new photon or electron. It explains why interference disappears after a measurement: once a commit occurs, the remaining unchosen possibilities are no longer active, and the particle's future evolution begins only from the committed event.

Figure X. Particle–particle wavefront reset in CBF.
Two incoming particles (top) collide and exchange translation share during the T-transfer event (middle). After the interaction, both particles propagate away with freshly reset wavefronts (bottom), reflecting the new momentum configuration.



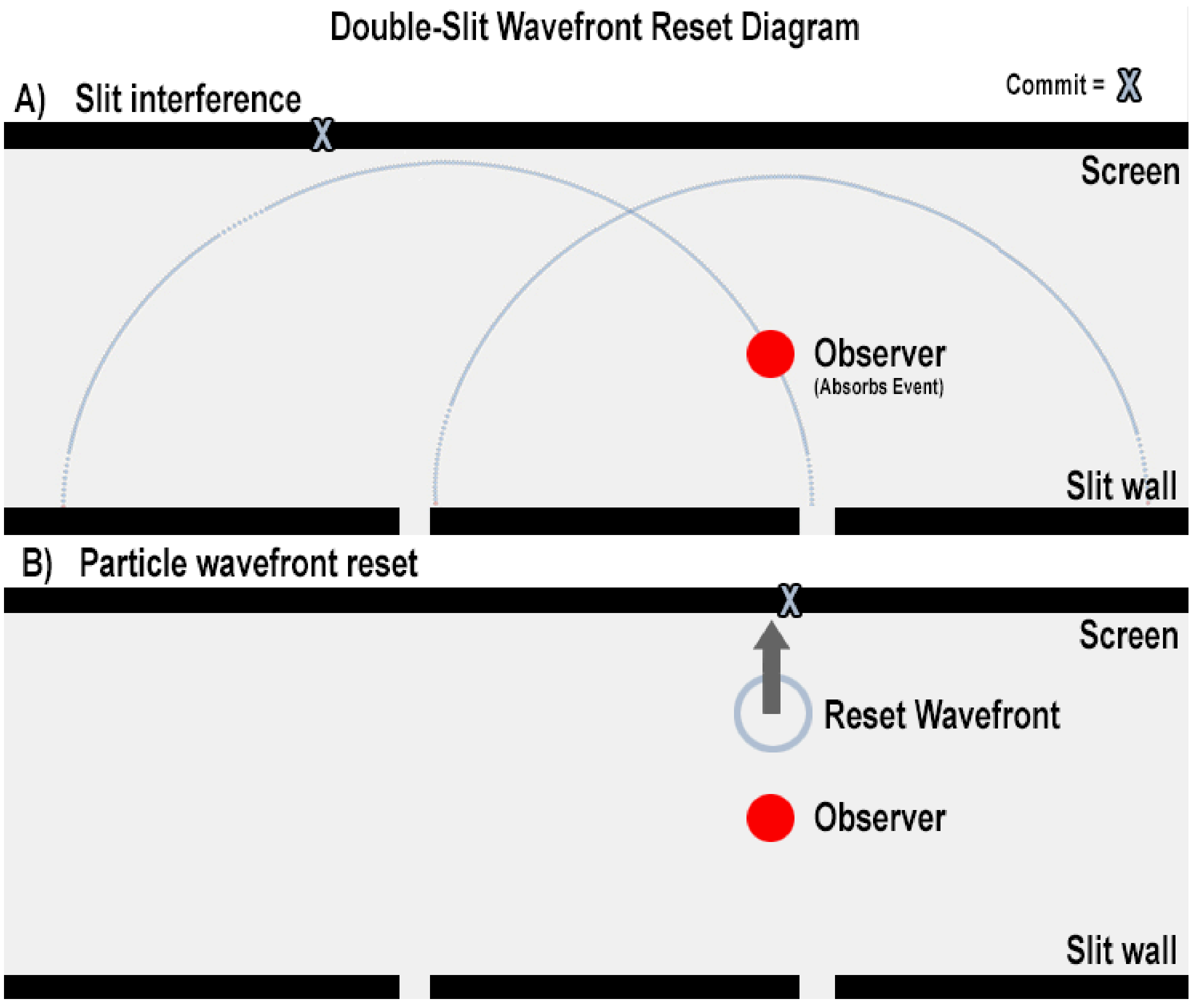
Early Collapse and the Quantum Dot Scenario

Wavefront reset also explains what happens in double-slit experiments where a weak detector or quantum dot sits near one of the slits. The interference pattern begins to form, but the quantum dot occasionally commits early, before the full pollination process is complete.

When this early commit occurs, the wavefront is reset immediately, and the particle continues from the commit site as a single, non-interfering emission. On the detector screen, these events appear as straight-line hits coming from one slit instead of an interference fringe.

In CBF, this happens because the premature commit prunes all unchosen paths and collapses the developing interference structure. What remains is a clean, single-slit propagation from the moment of early collapse.

Figure X. Early collapse in the double-slit experiment.
(A) Interference is forming, and the commit (marked by **X**) would normally occur at a location on the screen consistent with two-slit interference.
(B) A premature detection near one slit commits early, resetting the wavefront at that point and producing a single-slit style propagation toward the screen.



What Is a Measurement?

In CBF, a measurement the moment when one absorber atom wins the competition among all the pollinated candidates. This winning interaction becomes a **commit**: a final, discrete event that anchors the particle's history to a specific place and time.

Before the commit, the particle exists only as a distributed wavefront carrying phase and timing information. After the commit, all unused proposals are pruned and the old wavefront is invalidated.

A measurement, in this sense, is nothing more than **the system choosing one consistent outcome**. The rules of propagation determine which atoms receive proposals, and the commit mechanism determines which proposal becomes real.

What Is an Observer?

A surprising conclusion emerges from the pollination process: every atom acts as an observer.

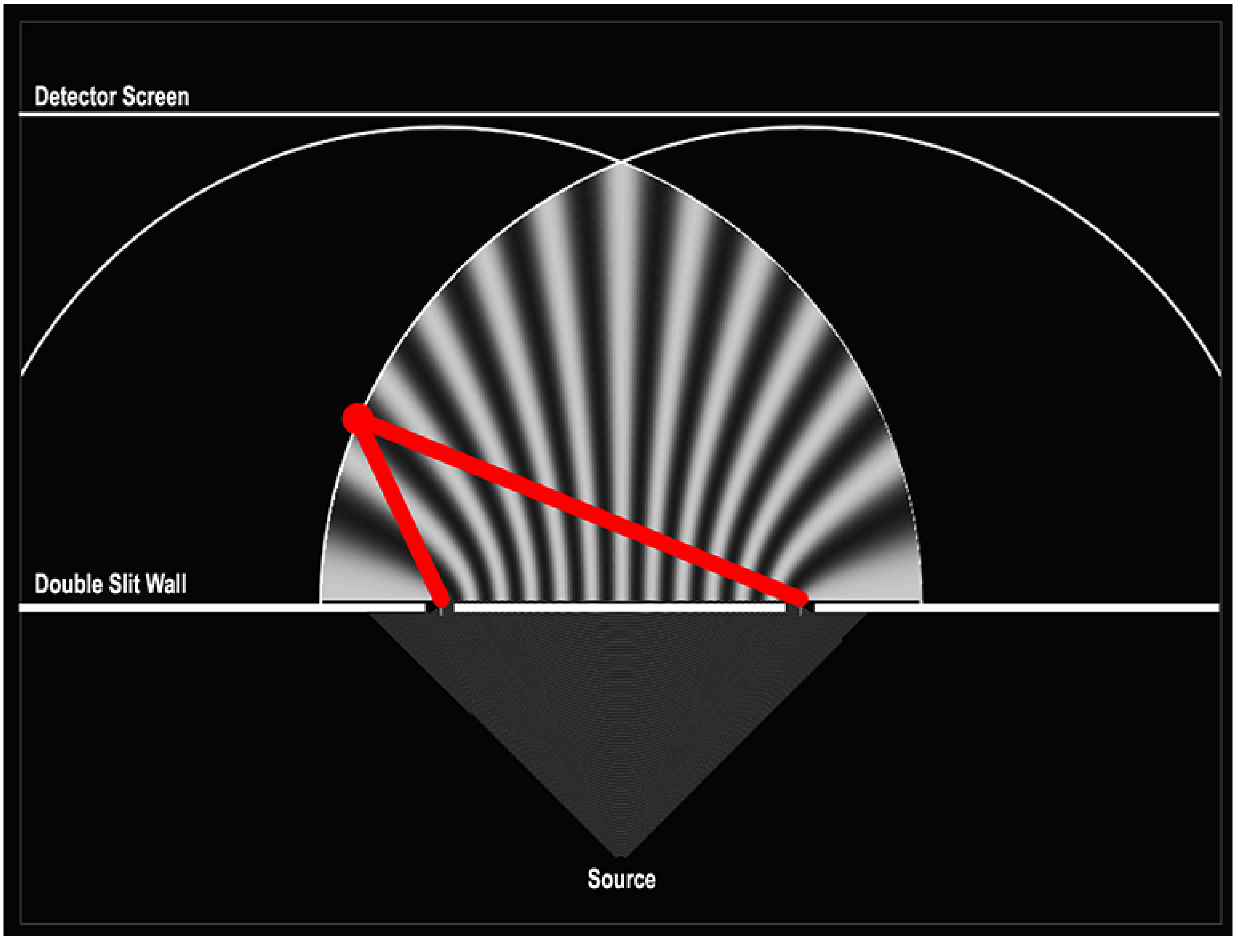
Any atom that receives a proposal from a wavefront is "observing" the particle in the CBF sense. It temporarily stores phase, direction, and timing tags, and participates in the competition to become the collapse site. No special equipment or consciousness is required.

An observer is therefore **any physical system capable of holding a proposal**. The interference pattern is shaped by the distribution of which atoms receive proposals, and collapse is determined by which atom commits. Observation is not tied to human measurement devices, but to the local physics of interaction.

How Interference Fingers Form

The alternating bright and dark "fingers" in the double-slit pattern arise naturally in CBF from differences in travel time. Each slit produces an expanding hemispherical wavefront, and wave cells from the two slits wash over each other and reach the detector with different path lengths and phases.

Figure 3. Interference geometry.
Wave cells from the left and right slits reach different points on the screen with unequal travel times, creating alternating constructive and destructive arrival phases.



When the incoming proposals arrive **in phase**, the atom at that location is more likely to commit, producing a bright finger. When they arrive **out of phase**, proposals cancel statistically and commits are rare, forming a dark region. The gray-scale background in the image is not a single moment in time, but a **time-integrated map** of where collapses *would have occurred* if the system committed at each location along the way.

Crucially, interference in CBF does not require two slits. It arises from **diffraction**, which occurs whenever a particle's wavefront bends and spreads around an edge. A single slit also introduces travel-time differences across its diffracted wavefront, and therefore produces a broad interference envelope on its own.

Fundamental Observations

The double-slit experiment reveals several unavoidable requirements for quantum measurement that extend beyond what local cellular automaton rules can provide.

Coordination Across Space

During pollination, a single particle creates hundreds or thousands of proposals scattered across potentially vast distances. These proposals must be:

- **Held simultaneously** across the entire interaction region
- **Compared for phase relationships** between widely separated locations
- **Coordinated for timing** despite different path lengths and arrival times
- **Resolved to a single winner** from among all competing candidates
- **Instantly prune all losing proposals** throughout the affected space to maintain consistency

Wave cells in a cellular automaton are a closed local system. They cannot know about distant proposals, compare timing across large separations, or coordinate simultaneous pruning of far-away candidates. Something globally organized is occurring here. Other supporting evidence includes gravitational effects (how does the Moon know the Earth exists) and quantum entanglement (particles at any distance are somehow tied together).

CBF calls this global layer the **Event Ledger**, and it becomes the key to understanding Special and General Relativity in later discussions.

Conclusion

The double-slit experiment in CBF transforms from a mysterious quantum phenomenon into a detailed computational process. Wave cells expand through Huygens-style rules, pollinate hundreds of atoms with tagged proposals, and create interference patterns through phase relationships and timing differences. The eventual detection represents a single committed event selected from many candidates.

This analysis reveals that quantum mechanics emerges naturally from cellular automaton rules, but only when supported by a global coordination system. Local wave propagation creates the possibilities; the Event Ledger selects the realities.

The pollination process, commit delays, and pruning requirements demonstrated here are not unique to the double-slit experiment. They represent the fundamental computational architecture underlying all quantum measurements, from particle detection to atomic transitions to field interactions.

CBF suggests that the universe operates as a vast computational network, where local cellular automaton rules generate possibilities and a global Event Ledger selects consistent realities. The double-slit experiment provides the first clear glimpse into this deeper computational architecture of physical reality.

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