Event Density and Quantum Behavior: Participation, Discreteness, and Relational Becoming

Abstract
Quantum mechanics is unmatched in predictive power yet unsettled in meaning. Competing interpretations disagree on what is real, what is fundamental, and what a quantum state represents. The Event Density (ED) framework offers a different foundation. ED begins not with wavefunctions, particles, or fields, but with micro‑events — the atomic units of becoming — and the participation relations that weave them into coherent structures. At microscopic scales, ED is granular, fluctuating, and relationally rich. Quantum behavior emerges naturally from this architecture: superposition reflects coexisting participation channels; interference reflects relational timing; entanglement reflects shared participation bandwidth; decoherence reflects participation thinning; and measurement is the structural commitment of a micro‑event to a single stable channel. The wavefunction becomes a coarse‑grained summary of participation structure rather than a physical object. Quantum dynamics arise from the evolution of participation geometry, and relativistic constraints emerge from participation limits and micro‑event discreteness. This paper develops the ED account of quantum behavior and shows that the same primitives — micro‑events, ED gradients, and participation — unify quantum, relativistic, classical, and cosmological phenomena. ED provides the ontology that quantum mechanics has always lacked.

1. Introduction

1.1 The Challenge of Quantum Foundations
Quantum mechanics is empirically flawless yet conceptually fractured. Competing interpretations disagree on what is real, what is fundamental, and what a "quantum state" even is. Wavefunctions are treated as physical fields, epistemic summaries, or abstract probability amplitudes. Measurement is alternately a physical collapse, an observer‑dependent update, or a branching of worlds. Entanglement is described as nonlocal correlation, nonclassical information, or a mysterious holistic property.

These disagreements arise because quantum theory lacks an ontology.
It describes how systems behave, not what they are.

The Event Density framework offers a different starting point. ED begins with micro‑events — the atomic units of becoming — and the participation structure that relates them. From these primitives, quantum behavior is not added; it is forced. Superposition, entanglement, decoherence, and measurement all emerge as structural consequences of how micro‑events are produced and integrated.

Quantum mechanics becomes the large‑scale summary of a deeper relational ontology.

1.2 The ED Perspective
In ED, the universe is not made of particles or fields. It is made of micro‑events — discrete acts of becoming — and the participation relations that weave them into coherent structures. At microscopic scales, ED is not smooth. It is granular, fluctuating, and relationally rich. Participation bandwidth varies across systems, and micro‑event production rates differ based on local ED.

Quantum behavior arises from this micro‑scale structure:

- Superposition reflects multiple participation channels coexisting.

- Interference reflects relational timing between micro-events.
- Entanglement reflects shared participation bandwidth.
- Decoherence reflects participation thinning.
- Measurement reflects a reconfiguration of participation structure.

Nothing collapses.
Nothing branches.

Nothing is indeterminate in itself.

Quantum phenomena are the visible consequences of how becoming is shared.

1.3 Aim of the Paper

This paper develops the ED account of quantum behavior. We show that:

- micro-events are the fundamental units of discreteness
- participation is the relational substrate underlying all quantum processes
- the wavefunction is a coarse-grained summary of participation structure
- entanglement is shared becoming, not nonlocal influence
- decoherence is the thinning of participation channels
- measurement is a structural reconfiguration, not a dynamical collapse
- quantum dynamics arise from ED evolution
- relativistic quantum behavior follows from participation limits and micro-event discreteness

The goal is not to reinterpret quantum mechanics but to ground it.

ED provides the ontology that quantum theory has always lacked.

This paper completes the micro-scale half of the ED program. Together with Papers 6–8, it shows that the same primitives — micro-events, ED gradients, and participation — govern both the smallest and largest scales of the universe.

2. Micro-Events as Fundamental Units of Becoming

2.1 Discreteness as Ontological, Not Epistemic

Quantum mechanics begins with discreteness — quantized energy levels, discrete measurement outcomes, indivisible quanta of action. But in standard formulations, this discreteness is treated as a mathematical artifact or a measurement effect. The underlying ontology remains ambiguous.

In ED, discreteness is not a feature of measurement.
It is a feature of reality itself.

A micro-event is the smallest possible act of becoming. It is not a particle, not a field excitation, not a collapse, and not a point in spacetime. It is the primitive unit of change. Everything that exists is built from micro-events and the participation relations that connect them.

Discreteness is therefore not imposed by quantization rules.

It is the natural consequence of ED’s atomic structure of becoming.

2.2 Micro-Events Are Not Particles

Particles are coarse-grained summaries of micro-event patterns. A particle is what a stable, self-reinforcing participation structure looks like when viewed at macroscopic scales. Micro-events are the underlying reality:

- They do not have trajectories.
- They do not have persistent identity.
- They do not occupy points in space.
- They do not move.

A particle “moving” is a sequence of micro-events whose participation structure shifts across regions. Motion is the migration of becoming, not the translation of a persistent object.

This resolves wave–particle duality cleanly:

- The “wave” is the participation structure.
- The “particle” is the micro-event discreteness.
- There is no duality — only two coarse-grainings of the same ontology.

2.3 Local ED Determines Micro-Event Production

Just as cosmic ED determines the rate of becoming at large scales, local ED determines the micro-event production rate at small scales. Regions with higher ED produce micro-events more rapidly; regions with lower

ED produce them more slowly. This production rate governs:

- the stability of quantum states
- the coherence of participation structures
- the bandwidth available for entanglement
- the susceptibility to decoherence

Quantum behavior is therefore not universal.
It is contextual, because ED is contextual.

A system’s quantum properties reflect the ED environment in which its micro-events are produced and integrated.

2.4 Micro-Events as the Source of Quantum Phenomena

Every quantum phenomenon traces back to micro-events. A micro-event is discrete, but not committed to any particular participation channel until the surrounding structure forces a stable configuration. Before commitment, multiple participation channels coexist; after commitment, only one remains.

This single architectural feature generates the full quantum repertoire:

- Superposition arises because micro-events are not committed to a single participation channel.
- Interference arises from relational timing between uncommitted micro-events.
- Entanglement arises when multiple regions share the same uncommitted participation bandwidth.
- Decoherence arises when micro-event production cannot sustain fine-grained uncommitted channels.
- Measurement arises when a micro-event becomes committed to a single stable participation structure.

Quantum mechanics is therefore not a theory of waves or particles.

It is a theory of how micro-events become committed.

3. Participation as the Relational Substrate

3.1 Participation Defined

In ED, micro-events do not exist in isolation. They exist in relation. Participation is the structure that determines how micro-events in one region are integrated by micro-events in another. It is not a force, not a field, and not an exchange of information. It is the relational fabric that allows becoming to be shared.

Participation answers the question quantum mechanics leaves open:

What does it mean for two systems to “interact,” “correlate,” or “cohere”?

In ED, it means:

- micro-events in one region are integrated into the becoming of another
- the bandwidth of this integration varies
- the structure of this bandwidth determines what is possible

Participation is the substrate beneath superposition, entanglement, interference, and measurement.

3.2 Participation Bandwidth

Participation is not binary. It has bandwidth — a measure of how richly two regions can integrate each other’s micro-events. High bandwidth means:

- many micro-events are mutually integrated
- relational timing is precise
- fine-grained structure is preserved

Low bandwidth means:

- fewer micro-events are integrated
- relational timing becomes coarse
- fine-grained structure is lost

Bandwidth determines:

- how stable a quantum state is
- how long coherence can be maintained
- how strongly two systems can be entangled
- how quickly decoherence occurs

Quantum behavior is therefore not universal.
It depends on the participation environment.

3.3 Participation Structure Determines What Exists

In ED, existence is relational. A system “exists” for another system only to the extent that their micro-events participate. If participation bandwidth is high, the systems share a rich relational structure. If bandwidth is low, they barely register each other.

This resolves several quantum puzzles:

- Why superpositions persist in isolation but collapse when measured
- Why entanglement is strong within a system but fragile with the environment
- Why classical objects appear definite
- Why quantum systems appear indefinite

The answer is always the same: Participation structure determines what is real for whom.

3.4 No Hidden Variables

Participation is not a hidden variable. It is not a supplement to quantum mechanics. It is the ontological substrate that quantum mechanics is summarizing. There is no deeper deterministic state beneath the wavefunction. The wavefunction is the coarse-grained description of participation.

This avoids the usual pitfalls:

- No superluminal influences
- No nonlocal signaling
- No collapse postulate
- No branching worlds
- No epistemic vs. ontic ambiguity

Participation is relational, not mechanical.

It is structural, not dynamical.

It is the architecture beneath quantum behavior.

3.5 Participation and "Not Committed" Micro-Events

A micro-event is not committed to any particular participation channel until the structure forces it. Before commitment:

- multiple channels coexist
- relational timing is distributed
- participation bandwidth is shared across possibilities

After commitment:

- one channel becomes stable
- the others dissolve
- the system's relational structure becomes definite

This is the ED foundation of:

- superposition
- interference
- entanglement
- measurement

Quantum behavior is not mysterious.
It is the natural consequence of uncommitted micro-events embedded in a structured participation network.

4. Quantum States as Participation Structures

4.1 The Wavefunction as a Summary, Not a Substance

In standard quantum mechanics, the wavefunction is treated ambiguously: sometimes as a physical field, sometimes as a probability distribution, sometimes as a bookkeeping device. This ambiguity is the root of many interpretational problems.

In ED, the wavefunction is none of these.
It is a coarse-grained summary of participation structure.

A quantum state encodes:

- which participation channels are available
- how strongly each channel is supported
- the relational timing between micro-events
- the bandwidth distribution across possibilities

The wavefunction is not a physical object.
It is the mathematical shadow of the underlying participation network.

4.2 Amplitudes as Participation Weights

The magnitude of a wavefunction amplitude corresponds to the participation weight of a channel — how much bandwidth is allocated to that relational possibility.

High amplitude → strong participation

Low amplitude → weak participation

Zero amplitude → no participation channel exists

This reframes quantum probabilities:

- They are not epistemic ignorance.
- They are not intrinsic randomness.
- They are the statistical expression of participation weights across uncommitted micro-events.

The Born rule becomes a structural fact about how participation bandwidth distributes across channels.

4.3 Phase as Relational Timing

Phase is one of the most mysterious features of quantum mechanics. It has no classical analogue, yet it determines interference, coherence, and the stability of quantum states.

In ED, phase is simply relational timing between micro-events.

Two channels with aligned timing reinforce each other.
Two channels with misaligned timing interfere destructively.

Interference is not a wave phenomenon.
It is a timing phenomenon in the participation network.

This makes interference inevitable and intuitive:

- It arises whenever uncommitted micro-events share participation bandwidth.
- It disappears when participation thins or commitment occurs.

4.4 Superposition as Coexisting Participation Channels
Superposition is not a physical object being in multiple states.
It is the coexistence of multiple uncommitted participation channels.

Before commitment:

- micro-events integrate across several channels
- relational timing is distributed
- participation bandwidth is shared
- no single structure dominates

After commitment:

- one channel becomes stable
- the others dissolve
- the system becomes definite

Superposition is therefore not a mystery.
It is the natural state of uncommitted micro-events embedded in a rich participation structure.

4.5 Collapse as Structural Reconfiguration
In ED, nothing collapses dynamically.
There is no physical process that destroys a wavefunction.

What happens is simpler and more architectural:

- A micro-event becomes committed.
- Participation bandwidth reorganizes.
- Only one channel remains stable.
- The wavefunction's "collapse" is the coarse-grained description of this reconfiguration.

Collapse is not a physical event.
It is a change in participation structure.

This resolves the measurement problem without adding mechanisms, observers, or branching worlds.

4.6 The Quantum State Is Not the System
In ED, the quantum state is not the system itself.
It is the participation profile of the system — the relational structure through which its micro-events can become.

This distinction is crucial:

- The system is micro-events.
- The quantum state is the structure of their possible commitments.

- Measurement is the moment when one commitment becomes stable.

Quantum mechanics describes the geometry of possibility, not the ontology of reality.

ED provides the ontology: micro-events and participation.

4.7 Environmental Decoherence vs. the Quantum–Classical Transition
In standard quantum mechanics, all physical systems—from electrons to buckyballs to viruses to dust motes—are assumed to obey the same Schrödinger equation. Under this assumption, every system is fundamentally quantum, and classical behavior arises only because the environment interacts with the system and gradually destroys phase coherence. This process is known as **environmental decoherence**, and it produces the familiar **smooth decay curves** measured in cavity-QED experiments (Haroche), molecular interferometry (Zeilinger, Arndt), and related platforms.

Environmental decoherence is smooth because it is caused by **many small, independent interactions** with the environment. Each interaction carries away a tiny amount of phase information, so the loss of coherence accumulates gradually. These curves answer the question: **How fast does the environment destroy coherence?**

However, these measurements do **not** probe the **quantum–classical transition**. They do not test whether a system of a given **internal complexity** can in principle sustain superposition. They only test how quickly coherence is eroded once it exists.

The ED framework identifies a different axis entirely: **superposition capacity as a function of internal event density**.

This axis has never been measured, because in standard QM the question itself does not arise. If all systems obey the same Schrödinger equation, then internal complexity cannot limit superposition, and there is no reason to look for such a boundary.

Thus, the field has only ever measured:

> **How fast coherence decays** (environmental decoherence)

and has never measured:

> **Whether coherence is possible at all** (the ED transition)

The ED prediction is that the true quantum–classical transition is a **sharp structural boundary**, not a smooth environmental decay.

5. Entanglement as Shared Becoming

5.1 Entanglement Is Not a Correlation
In standard quantum mechanics, entanglement is often described as a correlation stronger than any classical correlation. But this description is misleading. Correlations describe relationships between outcomes.

Entanglement describes a relationship between becoming.

In ED, entanglement is not a correlation.
It is shared participation bandwidth.

Two systems are entangled when their micro-events are not independent — when they draw from the same participation structure and therefore share the same uncommitted channels. Before commitment, their becoming is partially fused.

Entanglement is therefore not mysterious.
It is the natural consequence of shared relational structure.

5.2 Shared Participation Bandwidth
When two regions share participation bandwidth:

- micro-events in one region integrate micro-events in the other
- relational timing becomes coupled
- uncommitted channels span both systems
- commitment in one region constrains commitment in the other

This is the ED foundation of entanglement.

The key point is architectural: Entangled systems do not have separate participation structures.
They share one.

5.3 Why Entanglement Is Nonlocal but Not Mysterious
Quantum mechanics treats entanglement as nonlocal because measurement outcomes are correlated across spacelike separations. ED reframes this cleanly:

- The participation structure is nonlocal.
- The micro-events are local.
- Commitment is local.
- The consequences of commitment reflect the structure, not a signal.

Nothing travels faster than light.
Nothing influences anything at a distance.

The structure was already shared.

This resolves the tension between entanglement and relativity without adding hidden variables or modifying quantum theory.

5.4 Bell Correlations as Participation Geometry
Bell inequalities constrain classical models of correlation. Their violation is often taken to imply nonlocality or the failure of realism. In ED, Bell correlations arise from the geometry of participation:

- uncommitted micro-events share channels
- relational timing spans both systems
- commitment in one region selects a channel that already spans both
- the statistics reflect the structure of the shared bandwidth

Bell violations are therefore not paradoxical.

They are the statistical signature of shared becoming.

No superluminal influence is required.
No hidden variables are invoked.
No collapse propagates across space.

The geometry of participation does all the work.

5.5 Entanglement Swapping and Teleportation as Participation Re‑Routing

Quantum information protocols often appear magical: entanglement swapping, teleportation, dense coding. In ED, these are straightforward consequences of how participation structures can be reconfigured.

- Entanglement swapping occurs when two participation networks merge and re‑route their shared bandwidth.
- Teleportation occurs when commitment in one region forces a channel selection in a shared participation structure that spans multiple regions.
- Dense coding exploits the fact that shared participation bandwidth carries relational structure, not information in the classical sense.

These protocols do not move particles or signals.
They reorganize participation geometry.

5.6 Entanglement Ends When Commitment Occurs

Entanglement persists only while micro‑events remain not committed.

Once commitment occurs:

- the shared channels dissolve
- the participation structure becomes local
- entanglement ends

This is not collapse.
It is the natural consequence of commitment selecting a single stable channel.

Entanglement is therefore not fragile because of noise or measurement.
It is fragile because commitment is inevitable once participation bandwidth thins or structure becomes too complex to maintain coherence.

6. Decoherence as Participation Thinning

6.1 Decoherence Is Not Collapse

In standard quantum mechanics, decoherence is often described as the process by which quantum systems “lose coherence” due to environmental interaction. But this description is incomplete. Decoherence explains why interference disappears, but not why outcomes become definite.

In ED, decoherence is not collapse.
It is participation thinning.

A system decoheres when its participation bandwidth becomes too thin to sustain fine‑grained uncommitted channels. The system does not collapse; it simply loses the structural capacity to maintain multiple coexisting possibilities.

Decoherence is therefore not a dynamical process.
It is a structural transition in the participation network.

6.2 Fine‑Grained Participation Requires Bandwidth

Quantum coherence requires:

- precise relational timing
- shared participation bandwidth
- stable uncommitted channels
- low structural complexity

These conditions are fragile. As soon as the environment begins integrating the system's micro‑events, the available bandwidth is redistributed:

- timing becomes coarse
- channels lose definition
- uncommitted structure dissolves

This is decoherence:
the loss of fine‑grained participation due to bandwidth dilution.

6.3 The Environment as a Participation Sink

The environment is not a source of noise.
It is a participation sink.

When a system interacts with its environment:

- the environment integrates the system's micro‑events
- the system integrates the environment's micro‑events
- participation bandwidth is spread across many degrees of freedom
- fine‑grained channels cannot be maintained

This is why decoherence is effectively irreversible.

Once bandwidth is diluted across a vast environment, it cannot be re‑concentrated.

The environment does not "measure" the system.
It absorbs its participation structure.

6.4 Classicality as Thick Participation

Classical behavior emerges when participation bandwidth is:

- thick
- stable
- highly redundant
- dominated by committed channels

In this regime:

- micro‑events commit rapidly
- uncommitted channels are short‑lived
- relational timing is coarse
- structure is robust

Classical objects are not quantum systems that have "collapsed."
They are systems whose participation structure is too thick and too committed to support quantum behavior.

Classicality is therefore not an approximation.
It is a participation regime.

6.5 Why Decoherence Precedes Commitment

Decoherence does not produce definite outcomes.
It produces structural instability in uncommitted channels.

Commitment occurs only when:

- one channel remains structurally stable
- all others have thinned beyond viability
- the participation network can no longer support coexistence

Thus:

- Decoherence removes the capacity for superposition.
- Commitment selects a single stable channel.

These are distinct architectural steps, not a single process.

6.6 Decoherence Timescales Are Participation Timescales

Decoherence timescales vary dramatically across systems.

In ED, this variation is not mysterious. It reflects:

- local ED
- micro‑event production rate
- participation bandwidth
- environmental coupling
- structural complexity

Systems with high ED and low environmental coupling maintain coherence longer.
Systems with low ED or high complexity decohere rapidly.

Decoherence timescales are therefore participation timescales.

6.7 Decoherence Is the Gateway to Measurement

Decoherence prepares the system for measurement by:

- thinning uncommitted channels
- reducing participation bandwidth
- isolating a single structurally stable channel

Measurement is not decoherence.
Measurement is commitment.

But decoherence is the architectural precondition for commitment.
It is the moment when the system's participation structure becomes fragile enough that a single channel can dominate.

7. Measurement as Participation Reconfiguration

7.1 Measurement Is Not a Dynamical Process

In standard quantum mechanics, measurement is treated as a special kind of physical process — a collapse, a projection, a branching, or an update of knowledge. Each interpretation adds machinery to explain why measurement is different from ordinary evolution.

In ED, measurement is not a special process.
It is a structural reconfiguration of participation.

A measurement occurs when:

- decoherence has thinned the participation structure
- only one channel remains structurally viable
- a micro-event becomes committed
- the participation network reorganizes around that commitment

No collapse.
No branching.
No observer dependence.

Measurement is the moment when becoming selects a stable channel.

7.2 Why Outcomes Are Discrete

Outcomes are discrete because micro-events are discrete.
A micro-event cannot partially commit.

It cannot distribute its becoming across multiple channels once commitment occurs.
It must select a single, definite participation structure.

This discreteness is ontological, not epistemic.

It is not imposed by measurement.
It is built into the atomic structure of becoming.

Quantum discreteness is therefore not mysterious.
It is the visible consequence of micro-event commitment.

7.3 Why Outcomes Are Definite

Definiteness arises because commitment is structurally irreversible.

Once a micro-event commits:

- the uncommitted channels dissolve
- the participation network thickens around the committed channel
- the system becomes robust and classical
- the environment reinforces the same structure repeatedly

This is why measurement outcomes are definite:

Commitment selects a single channel, and classical thickening locks it in.

There is no need for collapse postulates or observer-centric rules.
Definiteness is the natural consequence of the participation architecture.

7.4 The Born Rule as Participation Statistics
The Born rule is not a fundamental axiom.
It is the statistical expression of participation weights.

Before commitment:

- each channel has a participation weight (amplitude squared)
- these weights reflect how much bandwidth supports each possibility
- commitment selects a channel with probability proportional to its weight

The Born rule is therefore not mysterious.
It is the natural statistical outcome of:

- uncommitted micro-events
- distributed participation bandwidth
- structural commitment

Quantum probabilities are participation probabilities.

7.5 Measurement Devices as Participation Amplifiers
A measurement device is not a classical object that "forces" collapse.

It is a participation amplifier:

- it couples strongly to the system
- it rapidly redistributes participation bandwidth
- it accelerates decoherence
- it isolates a single stable channel
- it thickens the committed structure into a macroscopic record

Measurement devices are engineered to:

- thin uncommitted channels
- force commitment
- amplify the committed channel into classical stability

This is why measurement outcomes are robust and repeatable.

7.6 No Observer Dependence
In ED, measurement does not depend on:
- consciousness
- knowledge
- observation
- awareness
- information acquisition

Measurement is a structural transition, not a psychological one.
An observer is just another participation structure.

Their presence or absence does not change the mechanism.
This resolves the observer paradox cleanly:

Measurement is commitment, not observation.

7.7 Measurement as the Completion of the Decoherence Sequence
The full ED sequence is now clear:

Quantum coherence
 Thin, fine-grained participation; multiple uncommitted channels.

Decoherence
 Participation thinning; fine-grained channels lose definition.

Commitment
 A micro-event selects a single structurally stable channel.

Classical thickening
 The committed channel becomes dense, redundant, and robust.

Measurement is step 3 — the moment of commitment.
Decoherence prepares it; classicality follows from it.

This resolves the measurement problem without collapse, branching, or hidden variables.

8. Quantum Dynamics From ED

8.1 Dynamics Without a Wavefunction
Quantum mechanics begins with a wavefunction and then prescribes how it evolves. ED begins deeper: with micro-events and participation structure. The wavefunction is not fundamental; it is a summary of how participation channels evolve over time.

Thus, quantum dynamics are not laws imposed on a state.

They are the coarse-grained behavior of a relational network of becoming.

The Schrödinger equation, the path integral, and unitarity all emerge from:

- the evolution of participation bandwidth
- the evolution of relational timing
- the evolution of uncommitted channels
- the constraints imposed by micro-event discreteness

Quantum dynamics are the shadow of ED evolution.

8.2 Schrödinger Evolution as Smooth Participation Change

The Schrödinger equation describes how a quantum state evolves smoothly and reversibly. In ED, this corresponds to:

- gradual shifts in participation weights
- continuous evolution of relational timing
- redistribution of bandwidth across uncommitted channels
- no commitment occurring

As long as:

- participation remains thin
- channels remain uncommitted
- environmental coupling is weak

the system evolves smoothly and reversibly.

This is why Schrödinger evolution breaks down during measurement: Measurement is commitment, not smooth evolution.

8.3 Path Integrals as Participation Histories

The path integral formulation of quantum mechanics sums over all possible histories. In ED, this is not a mathematical trick. It is a literal description of how uncommitted micro-events behave.

Before commitment:

- multiple participation channels coexist
- each channel corresponds to a possible relational history
- micro-events integrate across all viable channels
- relational timing determines interference between histories

The path integral is therefore the mathematical encoding of: All uncommitted participation histories contribute to becoming.

Commitment selects one.
The others dissolve.

8.4 Unitarity as Conservation of Participation Bandwidth

Unitarity — the conservation of total probability — is a structural fact in ED. It arises because:

- participation bandwidth is conserved during uncommitted evolution

- micro‑event production is locally regulated by ED
- no channel gains or loses bandwidth except through structural redistribution

As long as no commitment occurs, the total participation weight remains constant.
Unitarity is therefore not a postulate.

It is the conservation law of uncommitted participation.

8.5 Why Unitarity Breaks During Measurement
Measurement is commitment.
Commitment is structurally irreversible.
Irreversibility breaks unitarity.

This is not a contradiction.
It is the architectural distinction between:

- uncommitted evolution (unitary)
- commitment (non‑unitary)
- classical thickening (irreversible)

Quantum mechanics conflates these regimes.

ED separates them cleanly.

8.6 Quantum Fields as Participation Networks
Quantum field theory treats particles as excitations of fields. ED reframes this:

- A “field” is a stable participation network.
- A “particle” is a pattern of micro‑event commitments within that network.
- A “mode” is a structured participation channel.
- A “vacuum fluctuation” is micro‑event production in a low‑ED regime.

QFT’s infinities and renormalization problems arise because it treats the field as fundamental. ED avoids these pathologies because:

- micro‑events are discrete
- participation bandwidth is finite
- ED regulates production rates
- no continuum fields exist at the ontological level

Quantum fields are emergent relational structures, not fundamental entities.

8.7 Dynamics Are Participation Geometry
The deepest insight of this section is architectural:

Quantum dynamics are the evolution of participation geometry.

- Schrödinger evolution = smooth redistribution of participation
- Path integrals = coexistence of uncommitted histories
- Unitarity = conservation of participation bandwidth
- Measurement = commitment

- Classicality = thickening of the committed structure

Quantum mechanics is the mathematical language of this geometry.
ED is the ontology that makes the geometry real.

9. Relativistic Quantum Behavior

9.1 The Usual Tension: Relativity vs. Quantum Mechanics

Relativity and quantum mechanics are often portrayed as fundamentally incompatible:

- Relativity demands locality and causal structure.
- Quantum mechanics exhibits nonlocal correlations and entanglement.
- Relativity treats spacetime as continuous.
- Quantum mechanics requires discreteness and superposition.
- Relativity has no measurement problem.
- Quantum mechanics is defined by it.

This tension arises because both theories lack an underlying ontology.
They describe behavior, not becoming.

ED resolves the tension by providing the shared substrate beneath both.

9.2 Participation Limits as the Source of Causal Structure

Relativity's causal structure — light cones, horizons, simultaneity constraints — emerges from participation limits.

Participation cannot exceed:

- the local micro‑event production rate
- the ED gradient between regions
- the relational timing constraints imposed by the participation network

These limits produce:

- causal cones
- invariant speeds
- horizon behavior
- relativistic time dilation

Causality is not a geometric constraint.
It is a participation constraint.

This is why entanglement does not violate relativity: entanglement is shared structure, not influence.

9.3 Micro‑Event Discreteness and Lorentz Invariance

A common worry is that discreteness breaks Lorentz invariance.
In ED, it does not.

Micro‑events are discrete, but:

- they are not embedded in a background spacetime
- they do not occur “at points”
- they do not form a lattice
- they do not define a preferred frame

Lorentz invariance emerges because:

- participation structure is relational
- micro‑event production rates transform consistently
- ED gradients determine effective geometry
- no absolute background exists

Discreteness and Lorentz symmetry coexist because both arise from the same relational substrate.

9.4 Entanglement Across Horizons

Entanglement across horizons — Rindler horizons, black hole horizons, cosmological horizons — is often treated as paradoxical. ED makes it straightforward:

- participation structure can span a horizon
- micro‑events cannot
- commitment is always local
- the consequences of commitment reflect the shared structure, not a signal

Thus:

- entanglement persists across horizons
- measurement does not transmit information
- no causal paradox arises

This ties directly back to Paper 6 (horizons as decoupling surfaces) and Paper 8 (cosmic participation gradients).

9.5 Relativistic Quantum Fields as Participation Networks

Relativistic quantum field theory (QFT) treats fields as fundamental and particles as excitations. ED reframes this:

- A “field” is a relativistically consistent participation network.
- A “particle” is a pattern of micro‑event commitments within that network.
- A “mode” is a stable participation channel.
- Vacuum structure reflects micro‑event production in a low‑ED regime.

Relativistic invariance arises because:

- participation limits enforce causal structure
- micro‑event discreteness regulates divergences
- ED gradients define effective geometry

QFT’s infinities and renormalization issues disappear because ED never assumes a continuous field with infinite degrees of freedom.

9.6 Why ED Avoids the Measurement–Relativity Paradox

The measurement problem becomes acute in relativistic settings:

- When does collapse occur?
- In which frame?

- How does collapse propagate?
- Does collapse violate causality?

ED dissolves the paradox:

- Measurement = commitment (local).
- Commitment does not propagate (structural).
- Entanglement is shared structure (nonlocal but not influential).
- Relativity constrains participation, not collapse.

There is no collapse wave.
There is no preferred frame.
There is no conflict.

9.7 The Unified Picture

Relativistic and quantum behavior are not separate regimes.
They are two aspects of the same participation architecture:

- Quantum behavior = thin, fine-grained, uncommitted participation.
- Relativistic behavior = constraints on participation imposed by ED gradients.
- Classical behavior = thick, committed participation.

The three regimes form a single continuum:

- Thin → Uncommitted → Quantum
- Constrained → Relational → Relativistic
- Thick → Committed → Classical

ED provides the ontology that unifies them.

10. Consequences and Outlook

10.1 ED as a Unified Quantum Ontology

Quantum mechanics has always lacked an ontology. It describes how systems behave, not what they are. ED fills this gap by grounding quantum behavior in:

- micro-events — the atomic units of becoming
- participation — the relational substrate
- uncommitted channels — the source of superposition
- commitment — the source of discreteness and definiteness
- bandwidth — the measure of relational capacity
- thickening — the emergence of classical stability

With these primitives, quantum phenomena are not added; they are forced.
Superposition, interference, entanglement, decoherence, and measurement all arise as structural consequences of how becoming is shared.

Quantum mechanics becomes the mathematical summary of ED's relational architecture.

10.2 Resolution of Foundational Puzzles

ED dissolves the major conceptual puzzles of quantum theory:

Wave–particle duality

There is no duality. Micro-events are discrete; participation is extended.

Superposition

Coexisting uncommitted participation channels.

Interference

Relational timing between uncommitted channels.

Entanglement

Shared participation bandwidth, not nonlocal influence.

Decoherence

Participation thinning, not collapse.

Measurement

Commitment followed by classical thickening.

Born rule

Participation weights.

Relativity tension

Participation limits enforce causal structure; commitment is local.

These are not interpretive choices.

They are architectural consequences of ED's ontology.

10.3 The Micro–Macro Continuum

Paper 9 completes the micro-scale half of the ED program.

Together with Papers 6–8, a single continuum emerges:

Quantum:

Thin, fine-grained, uncommitted participation.

Relativistic:

Participation constrained by ED gradients.

Classical:

Thick, committed participation.

These are not different domains of physics.
They are different participation regimes of the same ontology.

ED unifies:

- quantum behavior
- relativistic structure

- classical stability
- cosmological evolution

all through the same primitives.

10.4 Toward Paper 10

With the quantum architecture now complete, the next step is to explore the emergence of spacetime and information from ED. Paper 10 will develop:

- classical spacetime as a thick participation manifold
- information as constraints on participation structure
- entropy as the distribution of commitment histories
- geometry as the large-scale summary of ED gradients
- causal structure as participation limits
- the arrow of time as the asymmetry of commitment

Paper 10 will close the loop: From micro-events to spacetime, from participation to geometry, ED becomes the ontological foundation of physics.