SECTION 9 — MANY-BODY AND MULTI-PARTICLE TUNNELING IN CUWF

Quantum tunneling becomes substantially more intricate when more than one particle is involved. In standard quantum mechanics, many-body tunneling is typically modeled by extending the wavefunction into a higher-dimensional configuration space and applying the same probabilistic barrier-penetration formalism used for single-particle systems. Although this approach is computationally effective, it does not by itself supply a physical mechanism explaining why correlated particles tunnel together, why tunneling may be enhanced in pairs or clusters, how entanglement affects barrier crossing, or why collective tunneling can appear to exceed single-particle expectations.

Within the Chayut Universe Wave Function (CUWF), these phenomena are reinterpreted through deterministic multi-particle entropic geometry. The many-body problem is not treated as a collection of independently tunneling objects, but as a collective collapse-node structure defined by a shared entropic landscape. Tunneling in such systems therefore occurs when a joint collapse node becomes unstable, the composite wave continues through a collective entropic peak, and a new admissible multi-particle node is re-instantiated beyond the barrier.

9.1 Why Many-Body Tunneling Requires a Distinct Framework

In standard quantum mechanics, an N-particle system is represented by a configuration-space wavefunction $\Psi_{total}(x_1, x_2, \ldots, x_N)$ evolving over an effective potential surface $V(x_1, x_2, \ldots, x_N)$. This formalism can reproduce many-body tunneling probabilities, but it leaves unresolved the physical basis of cooperative barrier crossing.

Three conceptual difficulties are especially important. First, correlated tunneling is computed, but not physically explained: a pair may tunnel together in the mathematics, yet the mechanism by which the pair acts as a single unit is left implicit. Second, entanglement-assisted tunneling can be represented in the formalism, but the geometric reason for the enhancement is not made explicit. Third, collective tunneling can occur even when no individual particle would have an admissible classical pathway, and the cooperative origin of this behavior remains conceptually obscure.

CUWF addresses these issues by replacing the probability-amplitude picture with a shared entropic-geometry picture. What tunnels is not a set of independently propagating particles, but a collective collapse-node configuration sustained by the structure of the composite wave.

9.2 Composite Structural Entropy for Multi-Particle Systems

For N interacting particles, CUWF represents the total wave as a composite structure on the Fundamental Wave Basin (FWB):

$$\Psi_{total}(\mathbf{X}, t) = \Sigma_i \Psi_i(x_i, t) + \Sigma_{ij} \Psi_{int}(i, j) + \Psi_{FBW}(\mathbf{X}, t)$$

$$S_{total}(\mathbf{X}, t) = S[\Psi_{total}(\mathbf{X}, t)]$$

Here $\mathbf{X} = (x_1, x_2, \ldots, x_N)$ denotes the collective configuration coordinate. A collective collapse node exists only when the composite entropy field possesses a joint entropic minimum. In the simplest form, this requires

$$\partial S_{total} / \partial x_i = 0 \quad \text{for all } i,$$

$$\text{Hessian}(S_{total}) > 0.$$

These conditions mean that the particles do not occupy merely neighboring minima, but a shared minimum in the collective entropic landscape. This provides a deterministic explanation for pair tunneling, co-tunneling, and cluster tunneling: the collective node remains admissible where individual nodes would not.

9.3 Collective Collapse Nodes in Many-Body Entropic Geometry

A many-body collapse node N_multi exists at a configuration $\mathbf{X}$_A when the composite entropic curvature is positive-definite. Denoting the curvature operator by the Hessian of S_total, the stability condition may be written schematically as

$$C_{S,total} = \text{Hessian}(S_{total}) > 0.$$

This condition has three important consequences. First, the system collapses as a unit: the many-body node is a single geometric structure, not N unrelated particle nodes. Second, instability is collective: if the curvature becomes indefinite along any essential degree of freedom, the admissibility of the entire node is lost. Third, re-instantiation is also collective: after the barrier, the new node forms at the next collective entropic minimum rather than through N separate post-barrier events.

The post-barrier location of the many-body node may therefore be expressed as

$$\mathbf{X}_B = \arg\min_{\mathbf{X}} S_{total}(\mathbf{X}, t + \Delta t).$$

Correlated tunneling thus emerges naturally from collective entropic geometry rather than from an unexplained probabilistic coincidence.

9.4 Pair Tunneling, Entangled Tunneling, and CUWF Predictions

In CUWF, entangled particles may be understood as sharing a coupled entropic structure. Because their admissibility is determined by the composite wave rather than by isolated particle states, entangled systems can form deeper or more robust collective minima than comparable uncorrelated systems.

This leads to several qualitative predictions. Pair tunneling can exceed single-particle tunneling because the collective entropic curvature may remain positive over a wider approach region. Entangled tunneling is governed by collective admissibility: if a shared collapse-node minimum exists, the correlated system tunnels as a unit; if it does not, the joint event fails. Re-instantiation beyond the barrier preserves entanglement because entanglement resides in the continuous composite wave, not in the transient node. More generally, clusters supported by shared entropic minima may tunnel collectively, offering a deterministic interpretation of phenomena such as pair tunneling and other forms of cooperative barrier crossing.

9.5 Collective Barrier Formation and Multi-Particle Tunneling

A many-body barrier arises when the composite structural entropy increases and the curvature of the collective entropic landscape ceases to support a joint minimum. In schematic form, the barrier condition is

$$S_{total,inside} > S_{total,before},$$

$$\text{eigenvalues}[\text{Hessian}(S_{total,inside})] \text{ not all positive.}$$

Under these conditions, the collective node cannot persist. The many-body tunneling process therefore follows the same three-phase logic established for the single-particle case, but now in collective form: joint node destabilization, wave-only propagation of the composite state, and joint node re-instantiation beyond the barrier.

In compact notation, the process may be written as

$$N_A^{(multi)} \longrightarrow \emptyset \longrightarrow N_B^{(multi)}.$$

This should not be interpreted as N independent tunneling events, but as a single collective restructuring of the composite wave.

9.6 Experimental Signatures of Multi-Body CUWF Tunneling

The many-body extension of CUWF yields several experimentally meaningful signatures. First, partial collapse should not be stably detectable inside the barrier: if the collective node fails, the admissibility of the joint structure is lost rather than only a subset of it. Second, pair or cluster tunneling enhancements should reflect collective entropic geometry rather than mere probabilistic reinforcement. Third, momentum structure should be preserved at the level of the composite wave, implying that post-barrier cluster behavior reflects pre-barrier wave organization rather than newly generated node dynamics. Fourth, phase continuity should remain rigid across correlated subsystems because continuity resides in the shared wave. Finally, Hartman-like behavior in collective tunneling receives the same interpretation as in the single-particle case: node traversal time is not fundamental because node transport does not occur.

9.7 Summary of Section 9

Section 9 extends the CUWF account of tunneling from the single-particle case to many-body and multi-particle systems. In this extension, collapse nodes become collective geometric structures defined by a shared entropic minimum; correlated tunneling arises from collective admissibility rather than probabilistic coincidence; collapse and re-instantiation occur as joint events; and entanglement remains anchored in the composite wave rather than in transient node identity.

The result is a deterministic interpretation of many-body tunneling that preserves the central CUWF principle established throughout Paper A-6: tunneling is not traversal through a forbidden region, but the restructuring of wave-supported collapse across an entropic barrier.

This completes the CUWF tunneling framework for Paper A-6.