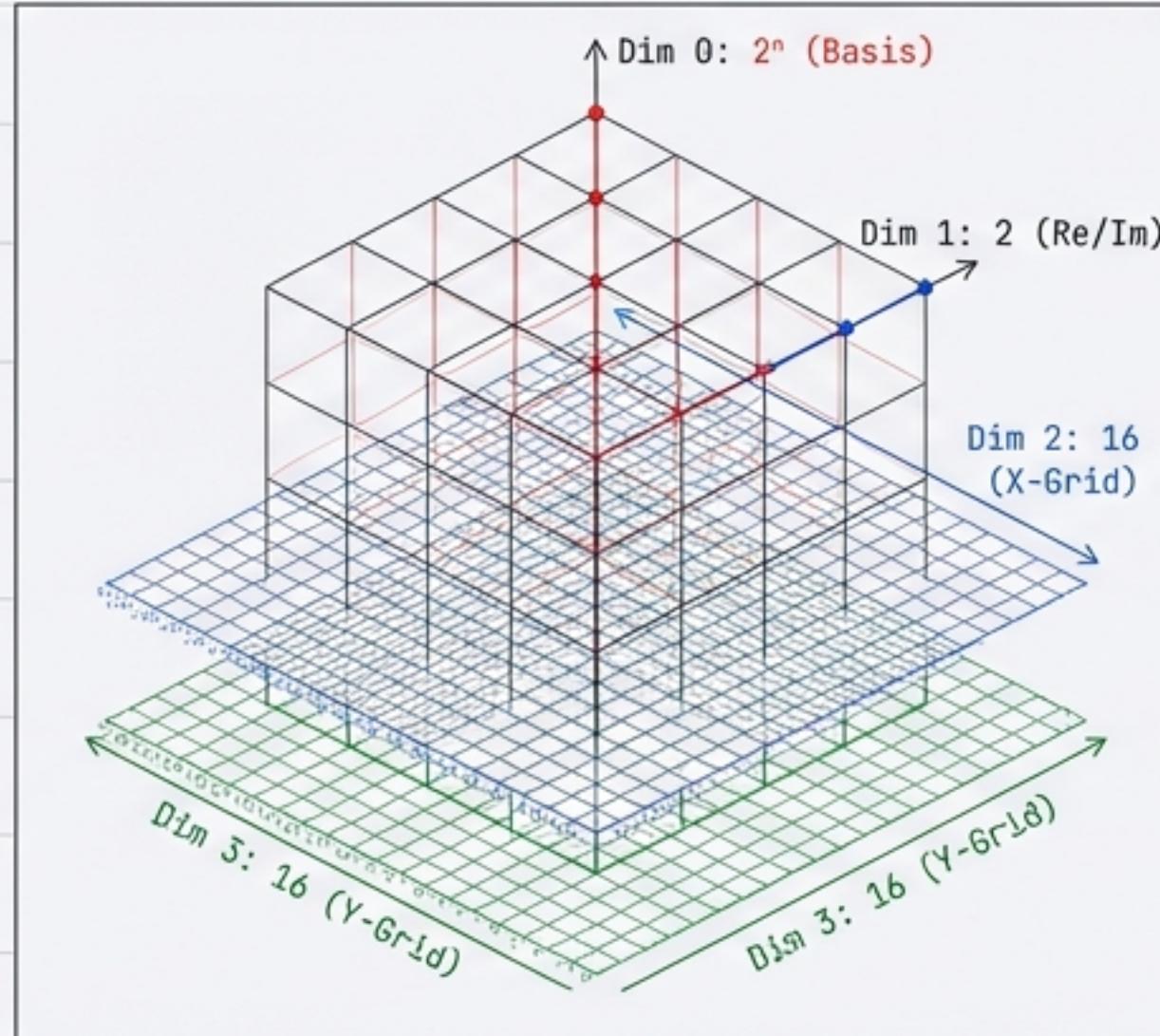


CONSTRAINT PRESERVATION IN NEURAL QUANTUM SIMULATION



An experimental analysis of collapse-free state evolution on classical hardware.

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STATUS: [VALIDATED](#)

THE PREMISE

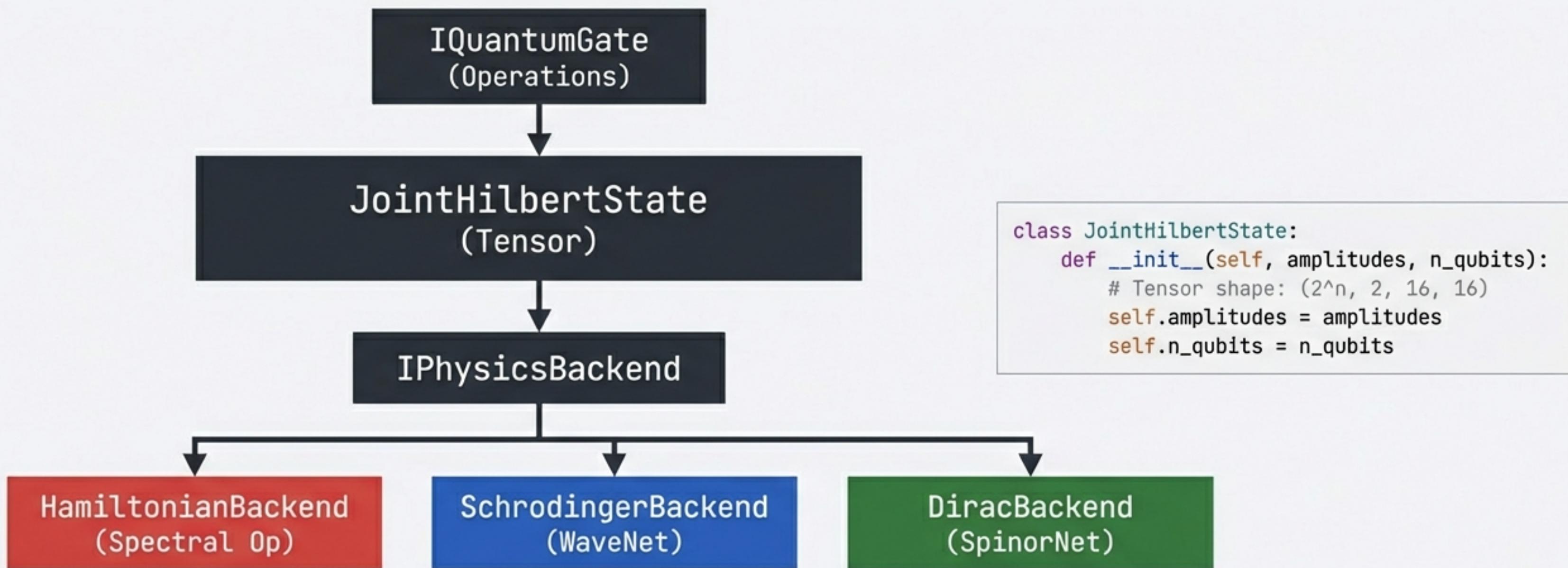
Standard simulation represents quantum states as scalar complex numbers. This experiment simulates amplitudes as 2D spatial wavefunctions evolved by neural physics backends. The hypothesis: hypothesis: Can **independent neural networks** preserve unitarity, phase, and entanglement without explicit enforcement?

THE METHODOLOGY

1. THREE **INDEPENDENT** BACKENDS
(Hamiltonian, Schrödinger, Dirac)
2. **NO** SHARED WEIGHTS
3. **NO** SHARED MEMORY
4. **NO** EXPLICIT CONSTRAINT LAYERS

This chapter is not about capability. It is about exposure.

SYSTEM ARCHITECTURE (SOLID)



Dependency Inversion ensures the simulator is agnostic to the physics engine.

EXPERIMENTAL CONSTRAINTS

The Clean Room Environment

PARAMETER	VALUE
SPATIAL GRID SIZE	16x16
HIDDEN DIMENSION	32
EXPANSION DIM	64
EXECUTION HARDWARE	CPU ONLY (Deterministic)
NOISE MODEL	NONE (Ideal)
INITIALIZATION	INDEPENDENT DISK CHECKPOINTS

ISOLATION PROTOCOL:

- Backends were loaded from **separate** disk checkpoints.
- **No shared** caches.
- **No** synchronized initialization beyond numerical libraries.
- **No mid-run** weight reloading.

BASELINE COHERENCE

Bell & GHZ State Generation

HAMILTONIAN

Bell State

$$P(|00\rangle) = 0.5000$$

$$P(|11\rangle) = 0.5000$$

$$\text{Entropy} = 1.0000 \text{ bits}$$

GHZ State

$$P(|000\rangle) = 0.5000$$

$$P(|111\rangle) = 0.5000$$

$$\text{Marginal } P(|1\rangle) = 0.5000$$

SCHRÖDINGER

Bell State

$$P(|00\rangle) = 0.5000$$

$$P(|11\rangle) = 0.5000$$

$$\text{Entropy} = 1.0000 \text{ bits}$$

GHZ State

$$P(|000\rangle) = 0.5000$$

$$P(|111\rangle) = 0.5000$$

$$\text{Marginal } P(|1\rangle) = 0.5000$$

DIRAC

Bell State

$$P(|00\rangle) = 0.5000$$

$$P(|11\rangle) = 0.5000$$

$$\text{Entropy} = 1.0000 \text{ bits}$$

GHZ State

$$P(|000\rangle) = 0.5000$$

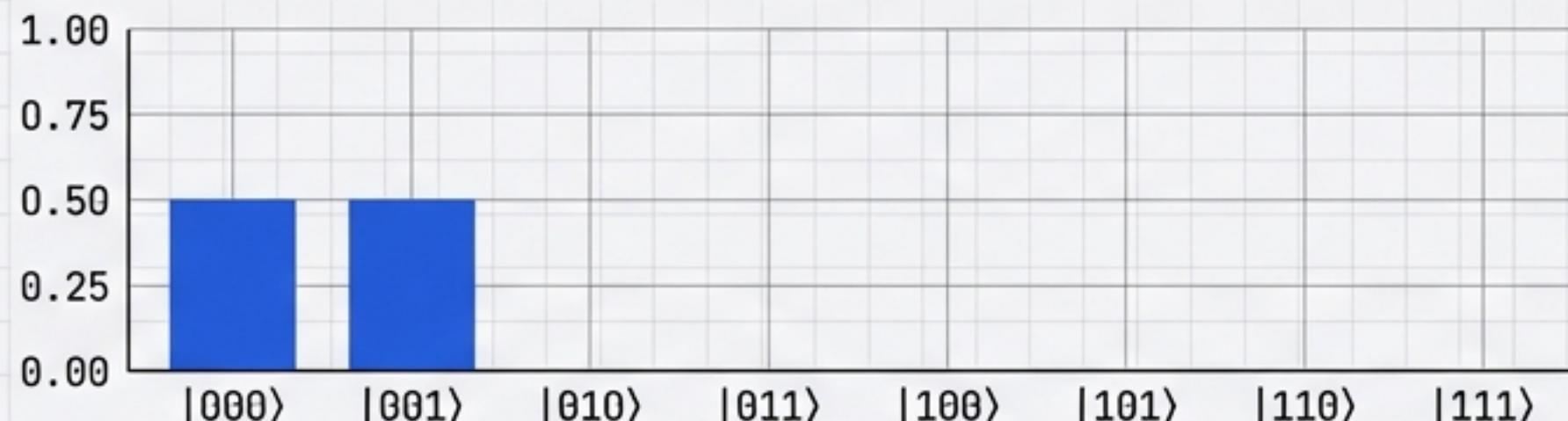
$$P(|111\rangle) = 0.5000$$

$$\text{Marginal } P(|1\rangle) = 0.5000$$

VERDICT: Perfect symmetry. Bloch vectors collapsed to origin. No backend bias.

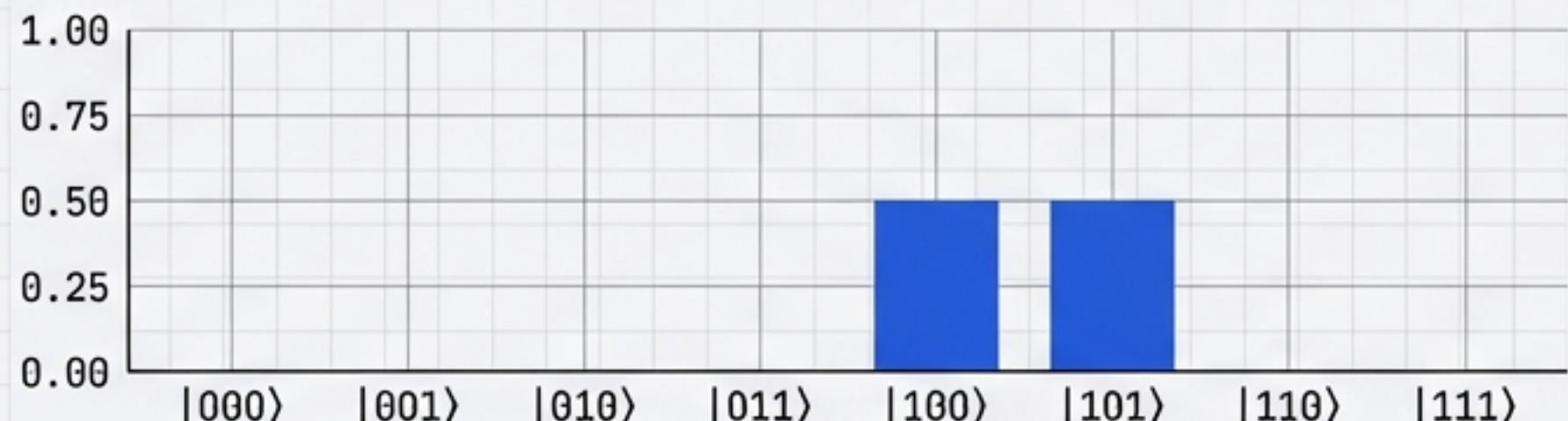
ORACLE LOGIC: DEUTSCH-JOZSA

CONSTANT ORACLE (Input $|0\rangle$)



Input register collapsed to $|0\rangle$. Ancilla (q2) in superposition.

BALANCED ORACLE (Input $|1\rangle$)



Qubit 0 flipped deterministically (Constructive Interference).

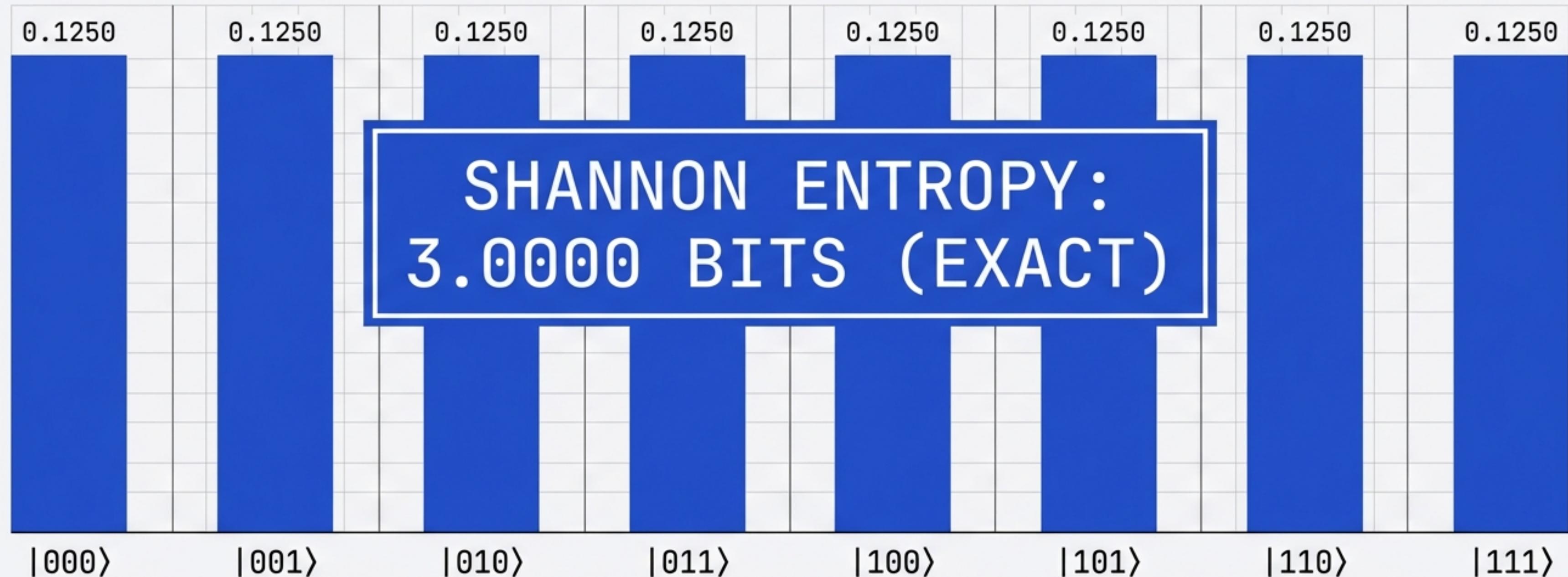
Analysis: System correctly encoded interference. No leakage observed.

Entropy = 1.0000 bits

Entropy = 1.0000 bits

THE ENTROPY TEST: QUANTUM FOURIER TRANSFORM

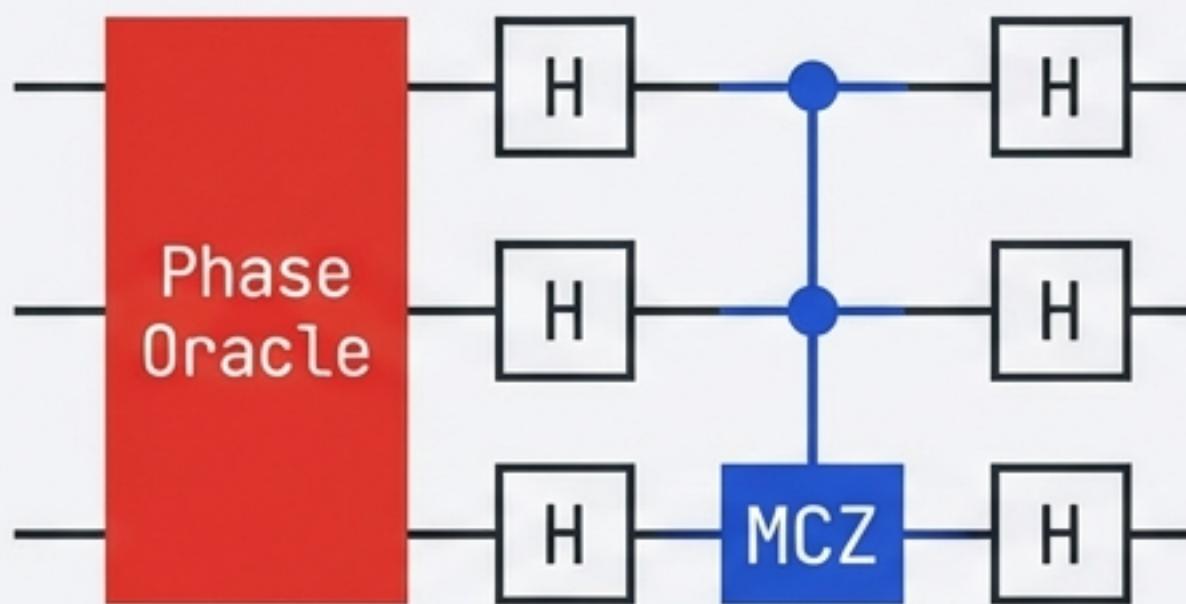
3-Qubit QFT on $|000\rangle$



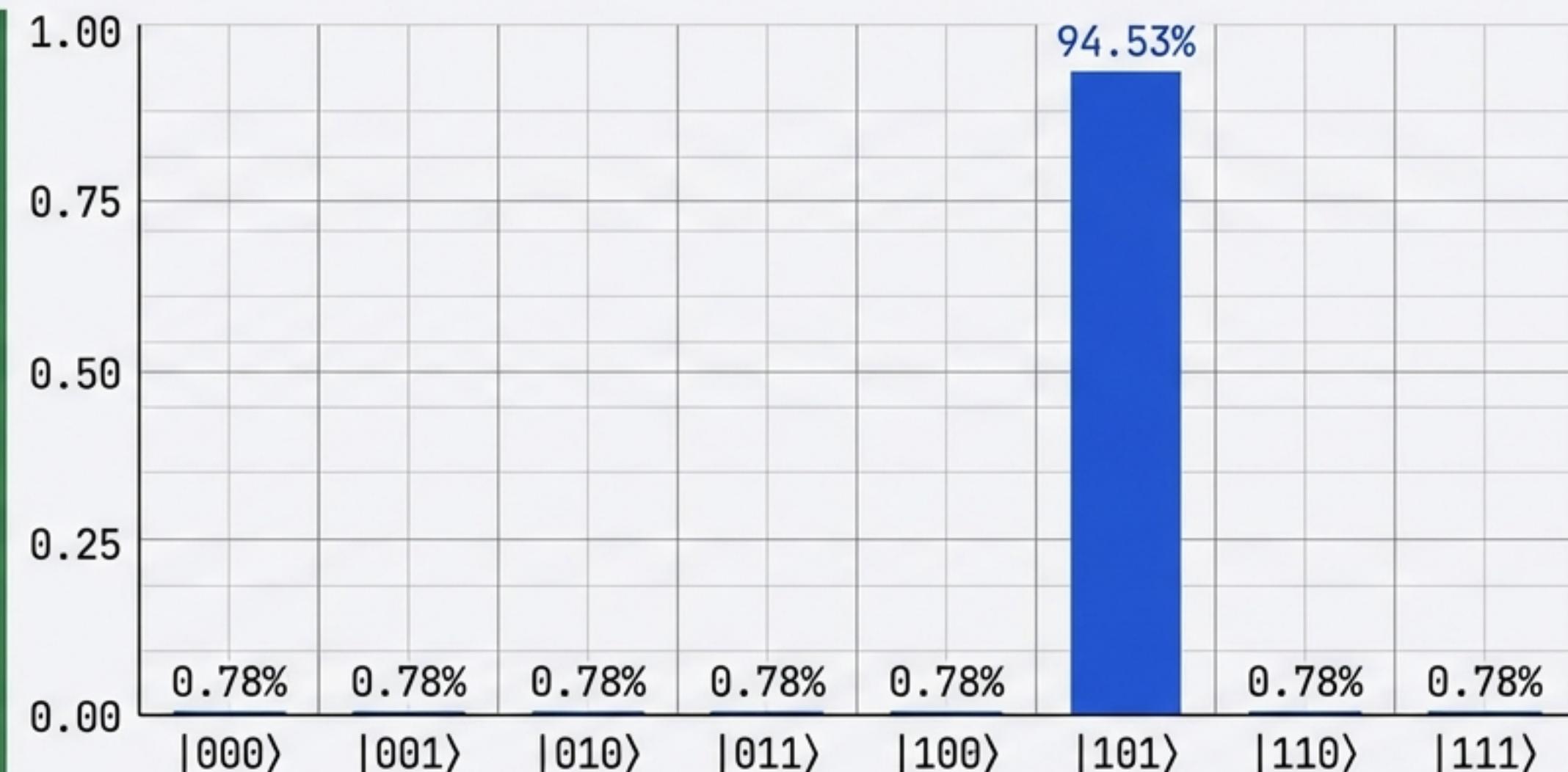
Simulators usually drift here. This system maintained perfect phase precision across the complex multi-qubit operation. No residual structure.

AMPLITUDE AMPLIFICATION: GROVER'S ALGORITHM

Phase Oracle + Diffusion
Operator (via MCZGate)



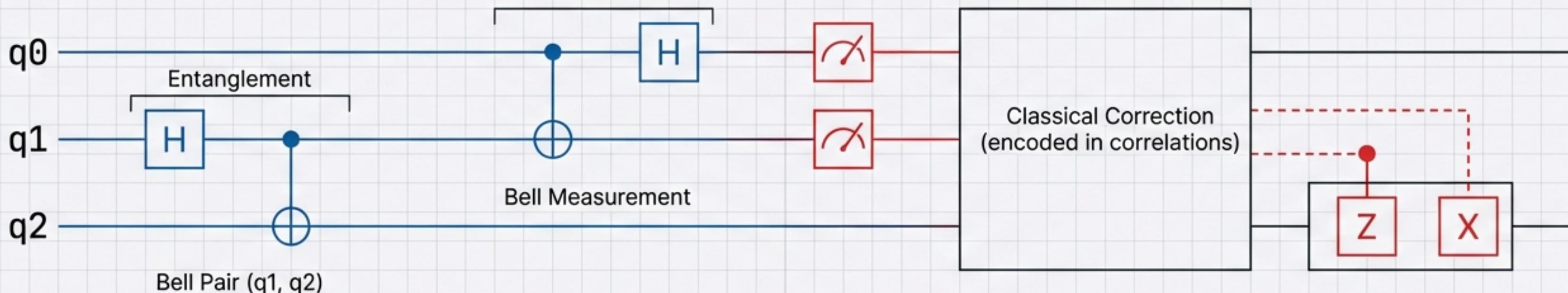
Inversion about the mean
Inversion about the mean
implemented via MCZ and H
gates.



Analysis:
Target: $|101\rangle$.
Result: The neural networks correctly implemented constructive and destructive interference to amplify the target state.

IMPLICIT INFORMATION TRANSFER: TELEPORTATION

State Transport $q_0 \rightarrow q_2$

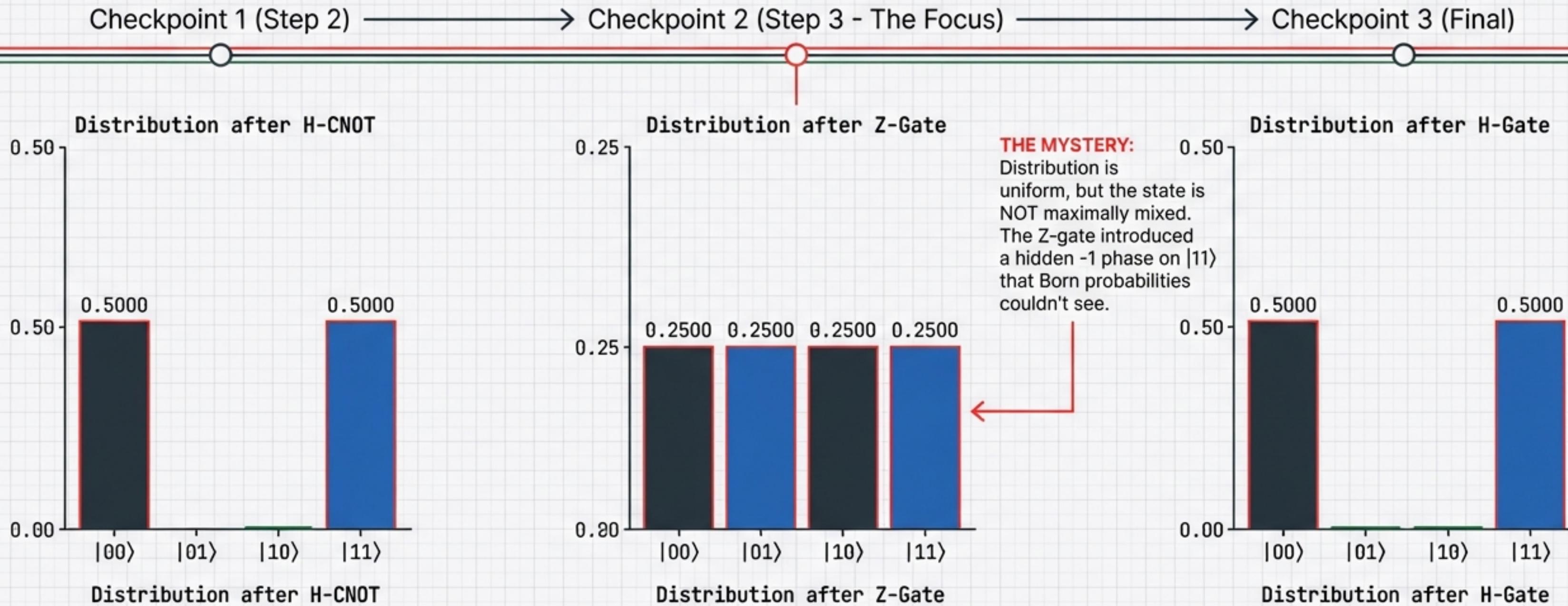


Metric	Value	Interpretation
Output Distribution	Spread (4 states)	2.8113 bits Entropy
Target (q2) $P(1\rangle)$	0.2500	Matches Source
Target (q2) $\langle Z \rangle$	+0.5000	Correlations Preserved

The simulator didn't 'cheat'. Classical correction was encoded implicitly in the joint state correlations.

THE INVISIBLE PHASE

Deep Dive: H-CNOT-Z-H Snapshot



“Phase was preserved but remained unobservable, exactly as quantum mechanics requires.”

PHASE COHERENCE & UNITARITY SUITE

Formal Verification

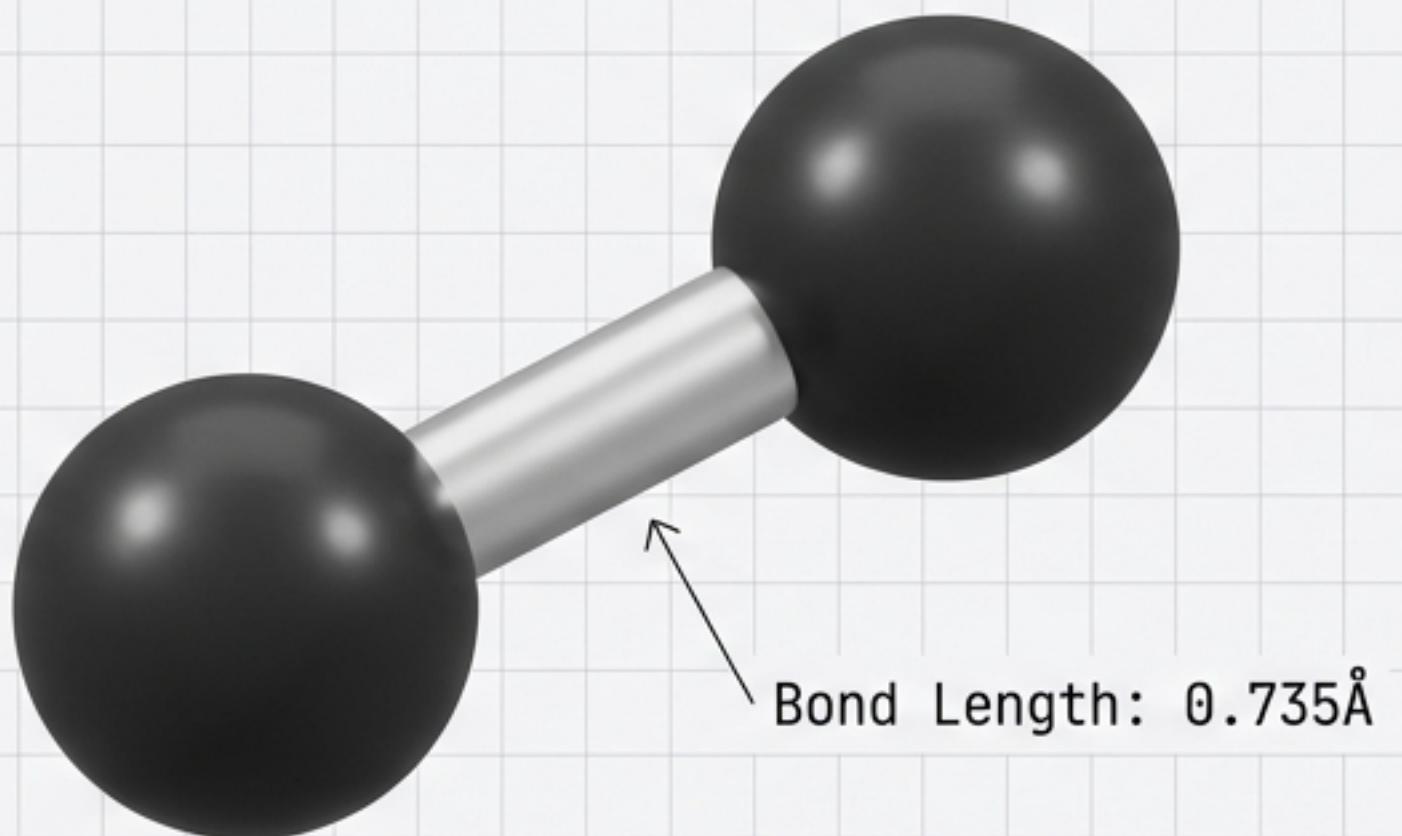
TESTS PASSED:
22 / 22

- ✓ $HZH = X$
- ✓ $H Rz(\pi) H = X$
- ✓ $HXH = Z$
- ✓ $XX = I$
- ✓ Norm Preservation (Sum = 1.0000000)
- ✓ Bell State Entropy (1.0000 bits)

Tests were executed as amplitude evolution followed by measurement. No symbolic substitution was used.

PHYSICAL SIMULATION: MOLECULAR HYDROGEN

The Boss Fight



TECHNICAL SPECIFICATIONS

Source Data: PySCF (STO-3G Basis)

Mapping: Jordan-Wigner Transform

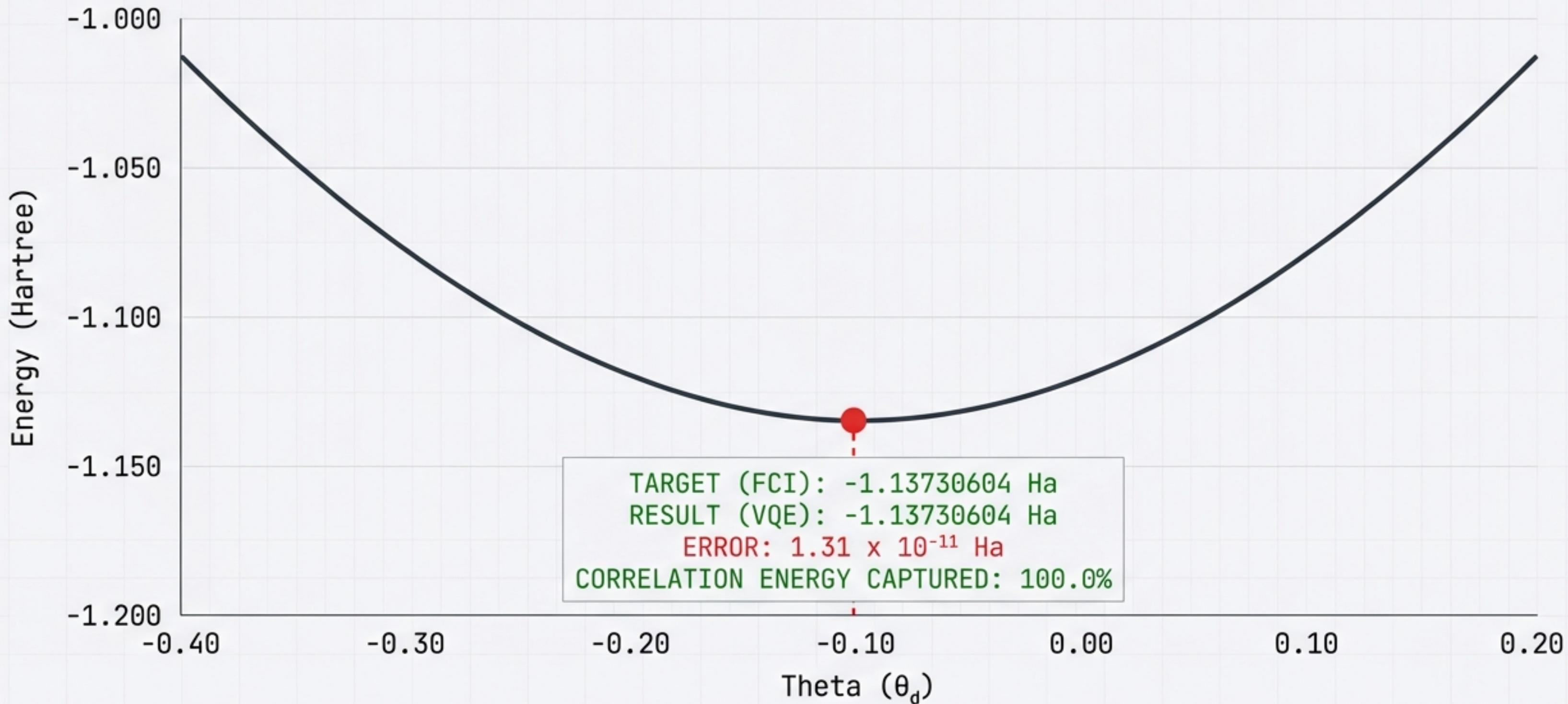
Hamiltonian: 14 Pauli Terms on 4 Qubits

Ansatz: UCCSD (Unitary Coupled Cluster)

Ground Truth (Hartree-Fock): -1.11699900 Ha

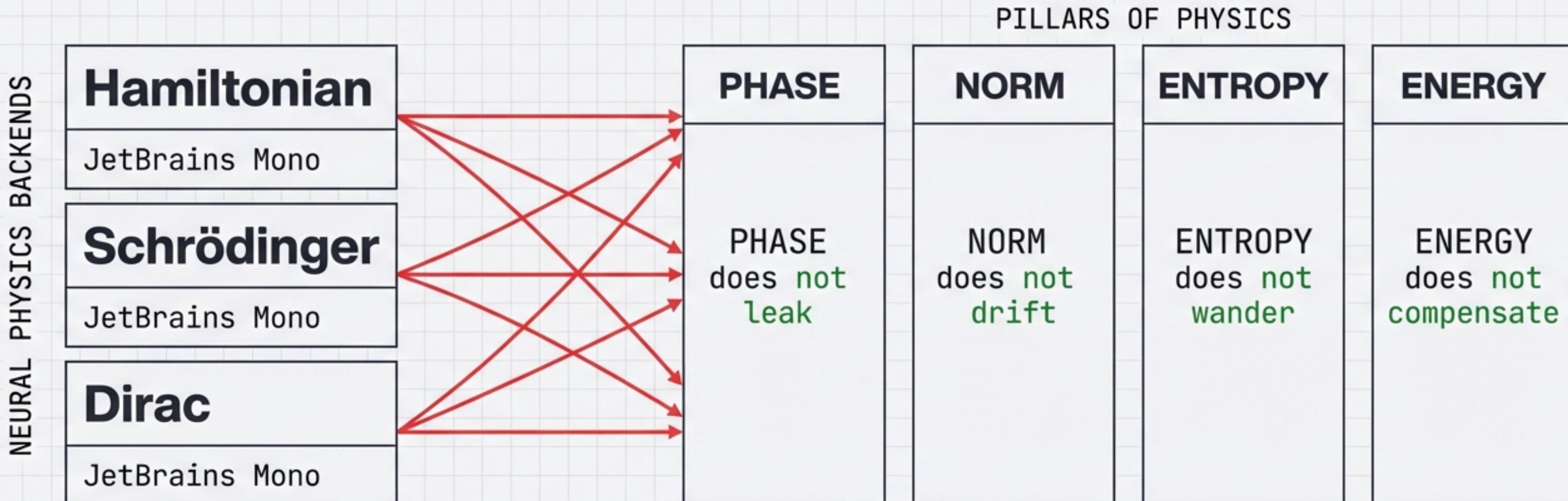
Ground Truth (FCI): -1.13730604 Ha

THE ENERGY LANDSCAPE



Note: Optimization proceeded without noise. The landscape was shallow, symmetric, and well-behaved.

THE VERDICT: A RULE-PRESERVING SYSTEM



Under controlled conditions, neural physics backends behave as rule-preserving systems rather than approximation engines.

TECHNICAL SPECIFICATIONS & REFERENCES

```
@dataclass
class SimulatorConfig:
    grid_size: int = 16
    hidden_dim: int = 32
    hamiltonian_checkpoint: str = 'weights/latest.pt
        h'
    schrodinger_checkpoint: str =
        'weights/schrodinger_crystal_final.pth'
    dirac_checkpoint: str =
        'weights/dirac_phase5_latest.pth'
    device: str = 'cpu'
```

Code Repository:
github.com/grisuno/QC

Data Object Identifier:
[10.5281/zenodo.18795538](https://doi.org/10.5281/zenodo.18795538)

Libraries:
PyTorch, OpenFermion,
PySCF