

Quantum Anticoncentration Has Limits

Free-fermion systems don’t spread probabilities exponentially — a key constraint for quantum advantage

Swipe for insights →

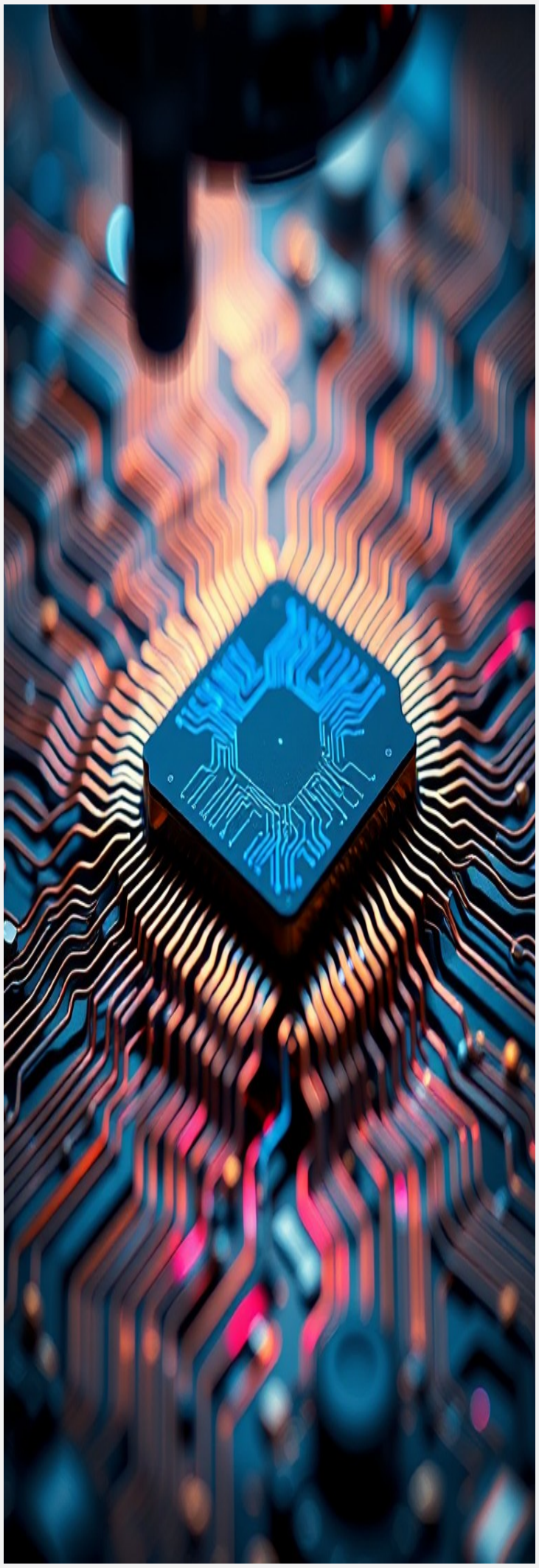
THE DATA

depths growing almost quadratically with system size

Circuit Depth for Convergence

For collision probability to converge in random matchgate circuits, depth must scale nearly quadratically with system size.

This finding reveals a fundamental bottleneck in using free-fermion systems for quantum advantage tasks like random circuit sampling. While Haar-random states anticoncentrate exponentially, fermionic Gaussian states only achieve polynomial anticoncentration. This means that even in idealized models, achieving full distributional spread requires depth that scales with the square of the system size.



Source: Guglielmo Lami · Published November 05, 2026
https://arxiv.org/abs/2611.05479

01

Polynomial Anticoncentration Is Not Enough

The paper establishes that free-fermion systems, despite being classically simulable in some regimes, still exhibit a form of anticoncentration — but only up to polynomial factors. This contrasts sharply with Haar-random quantum states, which anticoncentrate exponentially. This distinction is critical: exponential spreading is a hallmark of quantum computational supremacy, while polynomial spreading may not be sufficient to outperform classical simulation in practice.



02

Early Diffusion Precedes Slow Relaxation

The study identifies a two-phase dynamical behavior in random matchgate circuits: an early diffusive regime followed by a slow relaxation phase scaling as the square of system size. This implies that quantum systems built from fermionic modes may reach a metastable state quickly, but the final convergence to full randomness is prohibitively slow. For quantum algorithms relying on uniform sampling, this suggests a fundamental trade-off between speed and accuracy in fermionic architectures.

George Arnold Alexander III, MPA

MIT, Nvidia, Google, AWS & IBM-Trained. Cross-Domain Expert. Castor Venture Club.

Partner, ALEX Companies

Associate Broker, Alexander Tiffany Southwest, LLC dba ALEX.realestate, et al.

Texas License #574878-B · Texas Broker License #565194-BB

Broker · North Carolina License #367733

Independent Broker · Colorado License #II.100112456

Broker · Alabama License #000178406

george@alex.realestate · +1 713.918.9951

ALEX

ALEX Intelligence *deep intelligence*

ALEX Real Estate *genius real estate*

ALEX Advisory *uncontested strategy*

ALEX Cares *purposeful philanthropy*