Quantum noise and hardware limitations

Useful computation depends on reliability, connectivity and total resources, not just a qubit count.

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By the end, you'll be able to

- Distinguish finite-shot fluctuations from physical noise.
- Explain physical versus logical qubits without assuming a fixed overhead.

Noise is more than randomness

Even an ideal $|+\rangle$ preparation gives random Z outcomes. That is measurement statistics. Physical noise changes the preparation, evolution or readout relative to the ideal model.

Possible effects include decoherence, imperfect gates and readout errors. A single number rarely characterises all of them. A noise model must state which processes it approximates and which it excludes.

Connectivity changes the circuit

If a device only supports interactions between neighbouring qubits, an abstract two-qubit gate may require routing operations. SWAP gates can increase depth and the number of imperfect operations. Compilation quality therefore matters alongside the original algorithm.

Physical and logical qubits

A physical qubit is a hardware system. A logical qubit encodes information across physical resources using an error-correcting scheme. The overhead depends on the code, physical error rates, target logical reliability and the computation. There is no universal "one logical qubit equals 1,000 physical qubits" conversion.

The original introduction preserves a deliberately simplified resource example. Treat it as an illustrative assumption, not a current resource estimate or forecast.

A simple evidence exercise

Open BB84 in the experiment studio. With no adversary, increase the channel bit-flip probability. Then set it to zero and enable intercept–resend. Both can introduce disagreements. The toy model demonstrates why an observed error rate alone need not identify its cause.

This BB84 channel is not a general decoherence simulator. The foundation statevector tools remain ideal. A realistic noise study needs an explicit channel model, independent checks and careful interpretation.

Reference: Preskill — Quantum computing in the NISQ era and beyond.