Quantum error correction below the threshold

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Quantum error correction (QEC) is critical for achieving useful quantum computers, since it allows us to combine many noisy physical qubits into one high-quality logical qubit with exponentially decreasing logical error rate. In this talk, we will discuss Google's latest error correction results where we achieved below threshold performance in surface codes up to distance 7 [1], as well as color codes [2] and dynamic codes [3] up to distance 5. In the case of the surface code, we show that increasing the distance by 2, reduces errors by a factor of 2.14. Additionally, we report the ability to decode these QEC experiments in real-time for up to 1 million rounds. Finally, we present a 10,000x reduction in the rare correlated errors by measuring the repetition code in the very low error regime. Ultimately, our results show device performance that, if scaled, could realize the operational requirements of large scale fault-tolerant quantum algorithms.

References

[1] Quantum error correction below the surface code threshold, Google Quantum AI, Nature (2025)
[2] Scaling and logic in the color code on a superconducting quantum processor, N. Lacroix, A. Bourassa, et.al., arXiv 2412.14256 (2024)
[3] Demonstrating dynamic surface codes, Google Quantum AI, arXiv 2412.14360 (2024)

Figures

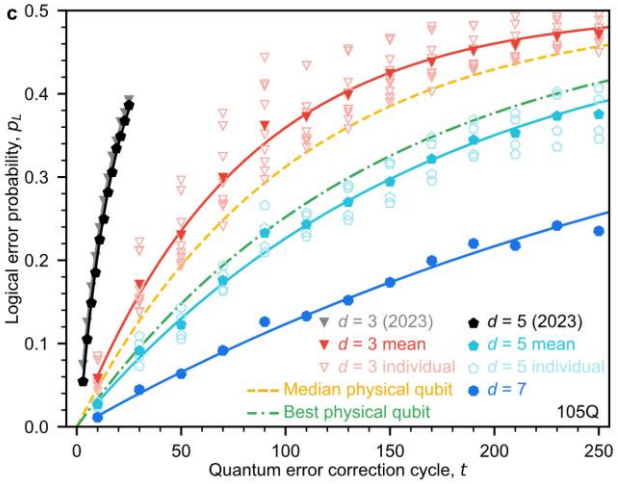

Figure 1: Logical error probability, p_L, vs number of error correction cycles, for a range of surface code memory experiments [1].

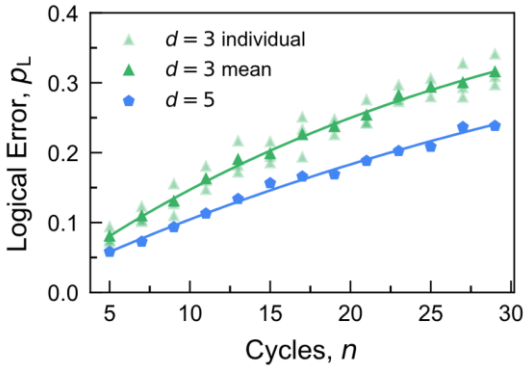

Figure 2: Logical error probability, p_L, vs number of error correction cycles, for color codes with distance 3 and 5 [2].