Quantum Computing at the Utility Scale and Beyond

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With a multitude of quantum demonstrations on 100+ qubits, quantum computing is now firmly in the era of utility where quantum computers can serve as a scientific tool to explore a new scale of problems that classical methods may not be able to solve. This scale, combined with advances in algorithms, is fundamental to enabling quantum advantage; the point where quantum computers can faithfully run one of more tasks providing business or scientific value with more accuracy, efficiently, or cost-effectiveness than with classical computation alone.

In this talk, we will highlight the progress in both quantum hardware and software that allow for computing observables on ~100 qubits within a reasonable time-budget on present-day devices. We then turn to the IBM Quantum roadmap, and how the technological improvements therein open up new opportunities not only for large-scale applications utilizing error-mitigation, but also pave the way toward future error corrected systems within the next decade.

References

[1] T. Ichikawa, H. et. al., "A comprehensive survey on quantum computer usage: How many qubits are employed for what purposes?" *arXiv:2307.16130*, 2023.

[2] E. Bäumer, V. Tripathi, D. S. Wang, P. Rall, E. H. Chen, S. Majumdar, A. Seif, and Z. K. Minev, "Efficient Long-Range Entanglement using Dynamic Circuits," *arXiv:2308.13065*, 2023.

[3] E. H. Chen, G.-Y. Zhu, R. Verresen, A. Seif, E. Bäumer, D. Layden, N. Tantivasadakarn, G. Zhu, S. Sheldon, A. Vishwanath, S. Trebst, and A. Kandala, "Realizing the Nishimori transition across the error threshold for constant-depth quantum circuits," *arXiv:2309.02863*, 2023.

[4] R. C. Farrell, M. Illa, A. N. Ciavarella, and M. J. Savage, "Scalable Circuits for Preparing Ground States on Digital Quantum Computers: The Schwinger Model Vacuum on 100 Qubits," *arXiv:2308.04481*, 2023.

[5] "Quantum Simulations of Hadron Dynamics in the Schwinger Model using 112 Qubits," *arXiv:2401.08044*, 2024.

[6] O. Shtanko, D. S. Wang, H. Zhang, N. Harle, A. Seif, R. Movassagh, and Z. Minev, "Uncovering Local Integrability in Quantum Many-Body Dynamics," *arXiv:2307.07552*, 2023.

[7] T. Yasuda, Y. Suzuki, T. Kubota, K. Nakajima, Q. Gao, W. Zhang, S. Shimono, H. I. Nurdin, and N. Yamamoto, "Quantum reservoir computing with repeated measurements on superconducting devices," *arXiv:2023.06706*, 2023.

[8] H. Yu, Y. Zhao, and T.-C. Wei, "Simulating large-size quantum spin chains on cloud-based superconducting quantum computers," *Phys. Rev. Res.*, vol. 5, p. 013183, Mar 2023

Figures

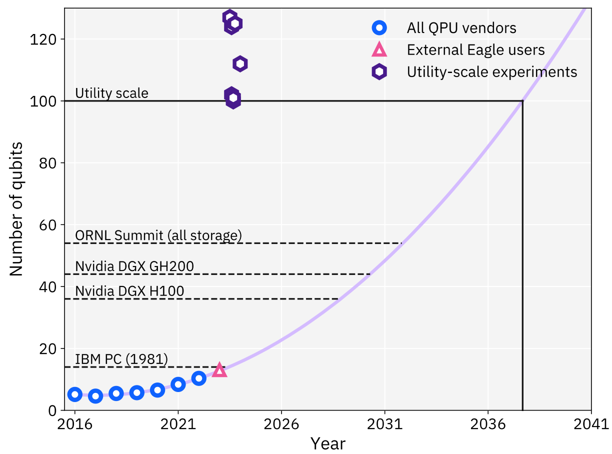

Figure 1: Estimated mean number of qubits used on all cloud-accessible modalities of quantum processing units (QPU) as a function of year (circles) [1], along with IBM Quantum data for its external users using 127-qubit Eagle processors in 2023 (triangle). The shaded region is an extrapolation from a quadratic fit to the data for all QPU vendors Dashed lines indicate the number of qubits that can be brute-force simulated using the indicated classical simulation hardware. Solid-line highlights the 100-qubit boundary for quantum utility that comes in 2038 at the current rate of progress. Utility scale experiments (hexagons) [2], [3], [4], [5], [6], [7], [8], utilizing 100+ qubits overlaid on top of the present-day trend.