Quantum AI

Hardware Experiment Proposal Guidance

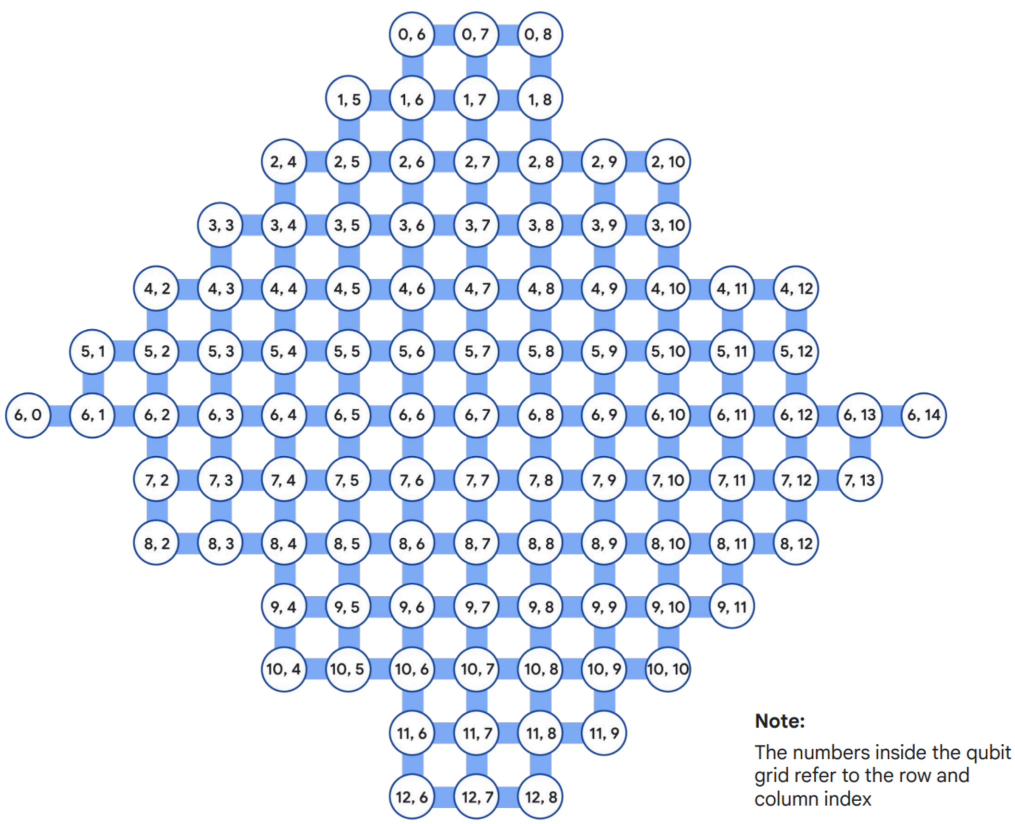
Published Dec 1, 2025

This document contains additional technical guidance for UK researchers expressing their interest in running an experiment on Google quantum hardware through the National Quantum Computing Centre (NQCC). Proposals are evaluated on technical feasibility and potential scientific impact. Please note that this guidance complements guidance available on the relevant NQCC webpages and may be subject to change.

Experiment boundary conditions

Experiments must be executable on a processor with the following specifications:

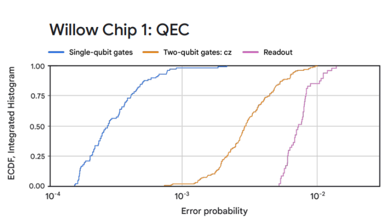
Willow Qubit Grid

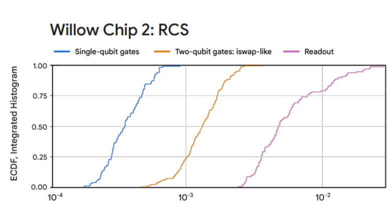


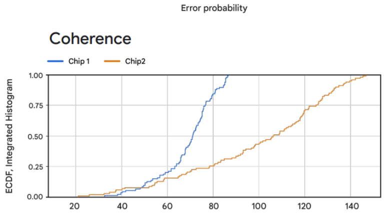
Willow System Metrics	
Number of qubits	105
Average connectivity	3.47 (4-way typical)
Quantum Error Correction (Chip 1)	
Single-qubit gate error[1] (mean, simultaneous)	0.035% ± 0.029%
Two-qubit gate error[1] (mean, simultaneous)	0.33% ± 0.18% (CZ)
Measurement error (mean, simultaneous)	0.77% ± 0.21% (repetitive, measure qubits)
Reset options	Multi-level reset (|1⟩ state and above) Leakage removal (|2⟩ state only)
T_1 time (mean)	68 µs ± 13 µs[2]
Error correction cycles per second	909,000 (surface code cycle = 1.1 µs)
Application performance	$\Lambda_{3,5,7} = 2.14 \pm 0.02$
Random Circuit Sampling (Chip 2)	
Single-qubit gate error[1] (mean, simultaneous)	0.036% ± 0.013%
Two-qubit gate error[1] (mean, simultaneous)	0.14% ± 0.052% (iswap-like)
Measurement error (mean, simultaneous)	0.67% ± 0.51% (terminal, all qubits)
Reset options	Multi-level reset (|1⟩ state and above) Leakage removal (|2⟩ state only)
T_1 time (mean)	98 µs ± 32 µs[2]
Circuit repetitions per second	63,000
Application performance	103 qubits, depth 40, XEB fidelity = 0.1%
Estimated time on Willow vs. classical supercomputer	5 minutes vs. 10^{25} years

[1] Operation errors measured with randomized benchmarking techniques and reported as "average error"
[2] Chip 1 and 2 exhibit different T_1 due to a tradeoff between optimizing qubit geometry for electromagnetic shielding and maximizing coherence

Full Distributions







The information above matches that in the spec sheet published on the Google Quantum AI website in November 2024. Noisy simulations can be executed on a virtual Willow processor using the Quantum Virtual Machine.

Additional Constraints:

- Adaptive quantum circuits (those with mid-circuit measurements and classical feedback) are not supported.
- Experiments demonstrating error correcting codes are not supported.
- Experiments should not contain mid-circuit measurements while trying to preserve the coherence of other qubits on the same readout line (readout lines run diagonally from the bottom left to upper right of the chip). However, reset gates are allowed.
- Operating the device in analog mode is experimental, and proposals requiring this will face a higher threshold for acceptance.
- Two-qubit gates other than CZ and CPhase are experimental, and proposals requiring them will face a higher threshold for acceptance.
- Experiments should be designed to run within a day assuming that we can run 63,000 shots per second and 60 distinct circuits per second.
- Circuits should not be much deeper than those in our previous papers (see the references below).
- Measuring higher transmon levels (e.g. the $|2\rangle$ state) is not supported
- Experiments involving measurement-based quantum computation may be limited by the following considerations:
  - Readout lines run diagonally across the chip (i.e. such that in the diagram on page 2 of the spec sheet, row+col = const). Measuring any qubit on a readout line dephases the whole readout line. This is why in Google's error correction experiments (e.g. this one), the data and measure qubits are on separate readout lines.
  - Measurements are comparatively slow (600 ns), compared to gates (~35 ns). Measurement-based quantum computation must be designed with this in mind.
  - We do not currently support feedforward (also known as feedback or adaptive circuits - conditioning gates on the results of mid-circuit measurements).

Prior examples of successful research projects

For examples of successful research projects meeting the experiment boundary conditions and constraints above, please refer to the following recent papers:

1. Will, M., Cochran, T.A., Rosenberg, E. *et al*. Probing non-equilibrium topological order on a quantum processor. *Nature* **645**, 348–353 (2025). https://doi.org/10.1038/s41586-025-09456-3
2. Cochran, T.A., Jobst, B., Rosenberg, E. *et al*. Visualizing dynamics of charges and strings in (2 + 1)D lattice gauge theories. *Nature* **642**, 315–320 (2025). https://doi.org/10.1038/s41586-025-08999-9
3. Hou, W., Garratt, S.J., Eassa, N.M., *et al.* Machine learning the effects of many quantum measurements. arXiv:2509.08890 (2025).
4. Gyawali, G., Kumar, S., Lensky, Y.D., *et al*., Observation of disorder-free localization using a (2+1)D lattice gauge theory on a quantum processor. arXiv:2410.06557 (2025).