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Teaching an LLM Agent to Calibrate a Superconducting Cavity

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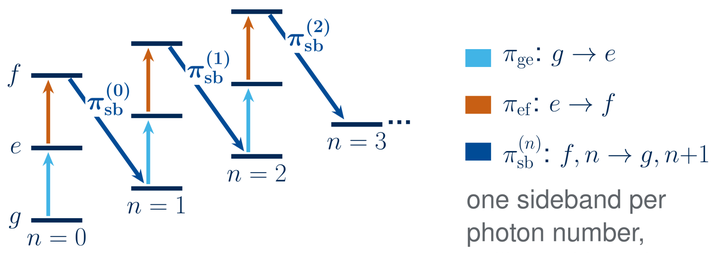
Our goal: an AI agent that, at the expert's request, takes over routine calibration of bosonic cavity systems by choosing the next experiment and its settings, and learns from the expert's corrections, while it only proposes and never changes the device itself.

1 Why automate cavities

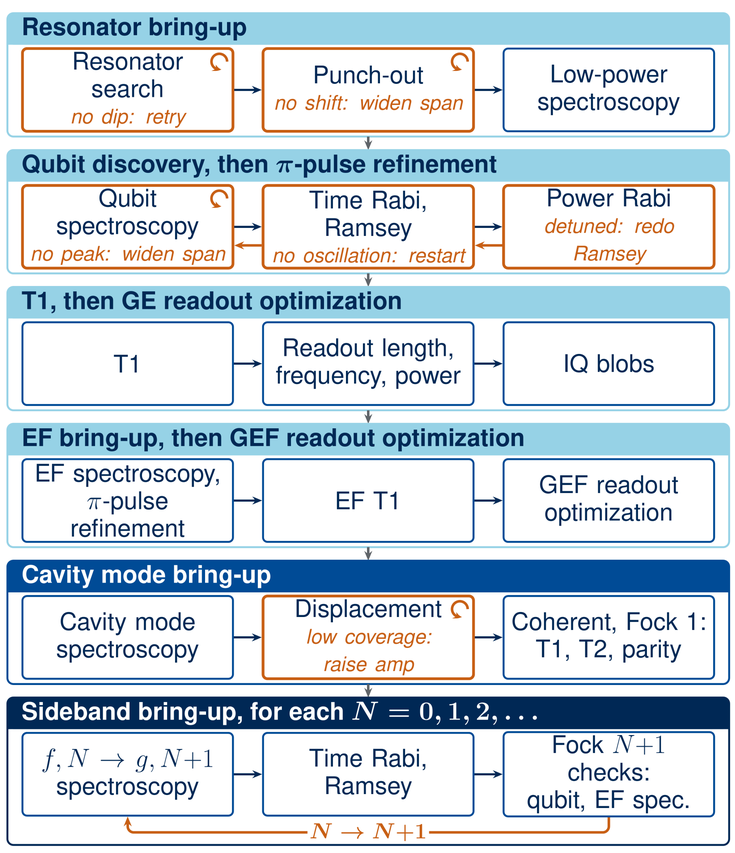
Cavities are bosonic quantum systems holding photons for tens of ms [1]. Arrays for computing [2,3] and dark-matter searches [4,5] multiply calibrations [6] that already stop scaling by hand [7,8].

Scales worst, and needs automation: sideband pulses. They serve several protocols, mainly active reset, and each photon number needs its own sideband, calibrated in order [1], on top of SNAP and displacements [15–17].



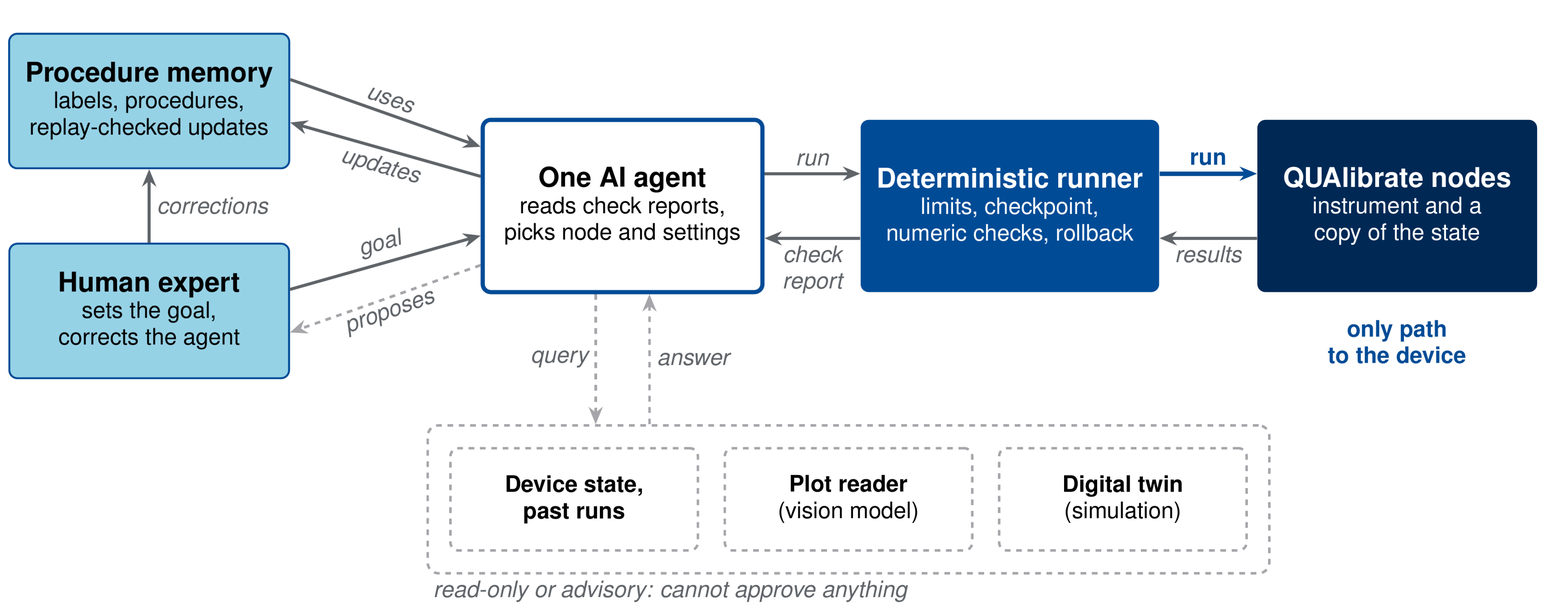
2 QUAlibrate for cavities

We extended QUAlibrate [13] to cavities: unattended bring-up of a 3D SRF cavity [14], with adaptive retries (orange). **Why graphs are not enough:** retries cover only failures we foresaw; anything unexpected stops the run and waits for an expert [8,9]. The agent is meant to take that step.



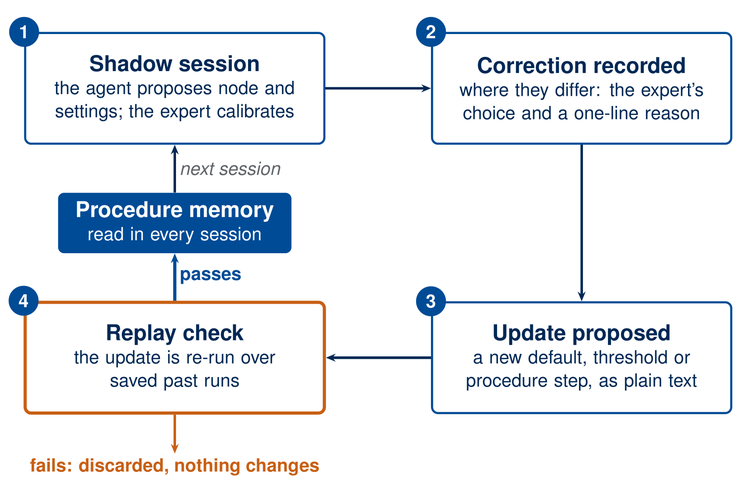
3 Our architecture: the agent only proposes

Plain code executes. Only numeric checks can approve a write.



Why this split: the agent is the one part whose judgement nobody can audit, so it is the one part that cannot write. Hard-coded safety checks, each able to block a run, will stand between a proposal and a write.

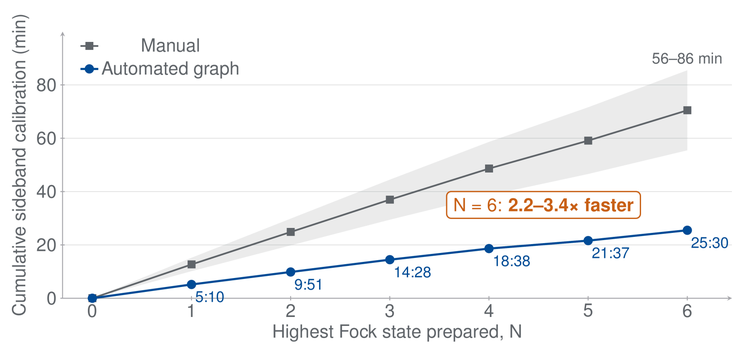
4 Teaching the agent



No weights change: what it learns is text you can read. Planned next (8).

5 Automation already pays off

Our sideband graph (2) on the real cavity, up to Fock state 6, against a typical manual pace.



6 What is new

UNTIL NOW	OUR DESIGN
Fixed node graphs [13,14] cannot adapt to unexpected failures	**Picks the next node and its settings (3)**
AI agents calibrate qubits and ions [8–10,18], not bosonic cavity modes	**A cavity and its ancilla transmon**
Safety gates check commands, not results [18]; vision models over-report success [11,12]	**Only numeric checks on results can approve a write (3)**

7 Takeaways

- Calibrating many cavity modes by hand does not scale; sideband pulses are the bottleneck (1).
- Our automated sideband calibration is already 2.2–3.4× faster than by hand, which adds about 5–10 min per Fock level (5).
- The AI agent will only suggest the next measurement, never change the device itself (3).
- Values will be saved only after a numeric check, so a bad guess costs time, not a calibration (3).
- The agent will learn from expert corrections, each tested on past runs first (4).

8 Next steps

- Run the agent on top of our QUAlibrate graphs, starting with sidebands (2).
- Add a numeric check to every node (3).
- Teach it from logged expert sessions (4).
- Compare it with hand calibration and fixed graphs on hardware.
- Scale to multi-mode cavity arrays (1).

[1] T. Kim *et al.*, arXiv:2506.03286 (2025). [2] D. Venturelli *et al.*, arXiv:2506.05608 (2025). [3] S. Zhu *et al.*, arXiv:2608.21733 (2026). [4] B. Freiman *et al.*, arXiv:2510.26754 (2025). [5] A. V. Dixit *et al.*, Phys. Rev. Lett. 126, 141302 (2021). [6] A. M. Souza *et al.*, arXiv:2606.03815 (2026). [7] J. Kelly *et al.*, arXiv:1803.03226 (2018). [8] H. Xu *et al.*, arXiv:2606.22376 (2026). [9] S. Cao *et al.*, Patterns 6, 101372 (2025). [10] S. Li *et al.*, arXiv:2603.08801 (2026). [11] A. Tripathy and A. Krishnan, arXiv:2607.03193 (2026). [12] S. Cao *et al.*, arXiv:2604.25884 (2026). [13] QUAlibrate documentation, qualibrate-docs.quantum-machines.co. [14] L. Bove *et al.*, Quantum Machines blog, quantum-machines.co/resources/blog/automating-superconducting-cavity-calibration-qualibrate (2026). [15] S. Krastanov *et al.*, Phys. Rev. A 92, 040303(R) (2015). [16] R. W. Heeres *et al.*, Phys. Rev. Lett. 115, 137002 (2015). [17] T. Fösel *et al.*, arXiv:2004.14256 (2020). [18] D. Wang *et al.*, arXiv:2606.27231 (2026).

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Cavity bring-up
blog post [14]

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