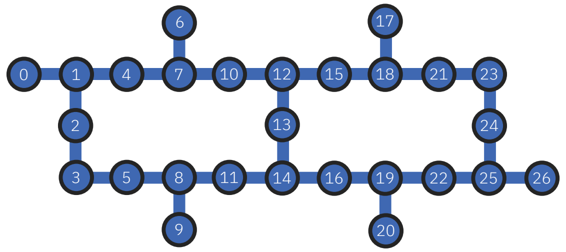
IBM Quantum System One at Ehningen Germany

The IBM quantum computer at Ehningen is a System One device, the world's first integrated gate-based quantum computer system. Use is exclusive to Fraunhofer and its partners. It has a modular, compact design and has been optimized for stability and auto-calibration, yielding a reliable, high-quality quantum system for continuous use. Its design includes includes a 2.7m by 2.7m encasement of 1.27 cm thick borosilicate glass forming a sealed, airtight enclosure. Independent aluminum and steel frames decouple the system's cryostat, control electronics, and exterior casing, helping to isolate the system components for improved performance. Its high precision electronics and quantum firmware allows the control of large numbers of qubits.

The quantum system at Ehningen has the following specs:

- Number of qubits: 27 (see qubit connectivity map)
- Coherence time ≈ 150 us
- Single qubit gate error ≈ 0.025%
- Two qubit gate error ≈ 0.7%
- Operation time of 2 qubit gate ≈ 300ns for CNOT
- Quantum Volume: QV 64

Connectivity of the 27-qubit system at Ehningen



Security and Privacy

The IBM Quantum System One at Ehningen (Germany) is operated under German law, European and German data protection regulations apply.

- No user or project data or results processed within the IBM Quantum System One at Ehningen will be stored or processed outside the territory of Germany.
- Exclusive German cloud infrastructure providing local end-to-end flow of quantum workloads, data and user information in Germany using state-of- the-art data protection technology.
- Fraunhofer administered and managed access control (authentication and user authorization exclusively done by Fraunhofer).
- Any intellectual property rights generated remain solely with the party who has developed them.

To learn more about quantum computing at Fraunhofer visit:
https://www.fraunhofer.de/en/quantumcomputing

For more information and inquiries about access, please contact the Central office Fraunhofer Competence Network Quantum Computing
Geschaeftsstelle-QC@fraunhofer.de

In cooperation with:
Fraunhofer

Pulse Tube Coolers
These coolers provide the first stage of cooling, by utilizing a thermodynamic cycle to extract heat and cool this stage to 4 Kelvin.

Superconducting Coxial Lines
To minimize energy loss, part of the coaxial lines that carry the output readout signals from the qubits are made out of superconductors.

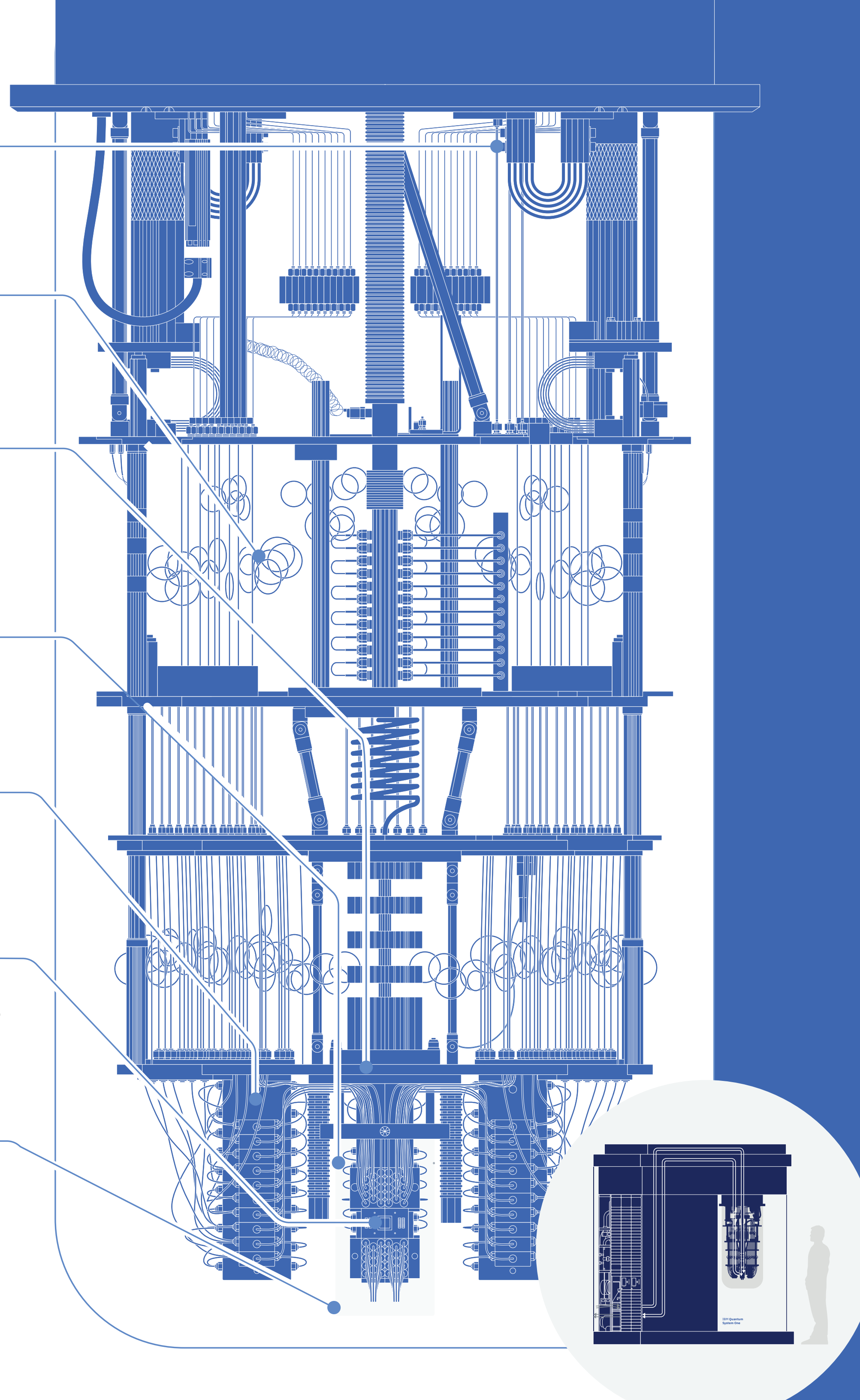
Mixing Chamber
The mixing chamber at the lowest part of the refrigerator provides the necessary cooling power to bring the quantum processor and associated components to a temperature of 15 mK – colder than outer space.

Cryogenic Isolators
Cryogenic isolators enable qubit signals to go in one direction while preventing noise from compromising qubit quality.

Quantum Limited Amplifiers
Quantum limited amplifiers that are cooled to 15 mK capture and amplify quantum processor readout signals while minimizing noise.

Quantum Processor Chip
Superconducting qubits connected to microwave resonators process quantum information and send the computation outcomes back through the system via microwave signals.

Cryoperm Shield
The quantum processor sits inside a shield that protects it from electro-magnetic radiation in order to preserve the quality of quantum operation.



IBM Quantum System Operation

To run a quantum program on a quantum processor, a user, from a normal computer, uses Qiskit to compose their problem in the language of a quantum circuit — a computational routine consisting of coherent quantum operations on quantum data, such as that held in qubits, and concurrent real-time classical computation.

This set of instructions, in the form of classical information, is submitted via the cloud to the quantum system control electronics and executed in the form of microwave signals. These signals are input to the cryostat and attenuated (to reduce noise) to reach the quantum chip, composed of superconducting transmon qubits, at the heart of a dilution refrigerator operating at 15 mK. The pulses implement the instructions sent by the user, manipulating the qubits to process information by leveraging quantum principles such as interference and entanglement to perform the computation. Once the instructions are completed, the microwave signals are amplified and travel back up the cryostat, to be packaged as classical information and returned via the cloud to the user to view the solution to their problem. Visit the demo: https://www.ibm.com/events/activations-quantum/
Learn more about quantum computing through Qiskit and IBM Education resources. Visit also our Qiskit YouTube channel or visit: https://qiskit.org/learn

Quantum Computing

Quantum computing holds the promise of solving entirely new categories of problems that are beyond the reach of today's most powerful supercomputers. This new computing paradigm codifies information in quantum bits, or qubits, and leverages unique phenomena found in the quantum world to process information in a fundamentally different way than classical computers.

A quantum computer is a highly intricate machine where thousands of meticulously engineered components have to work together flawlessly in extreme temperatures within astonishing tolerances. Qubits are extremely sensitive to the slightest vibration or fluctuation in temperature or electromagnetic environment, losing their fleeting quantum properties within microseconds.

Performance requires three critical attributes: Scale, Quality, and Speed. For scale, progress is measured through the number of qubits in IBM systems. With quality, IBM introduced quantum volume (QV), a holistic metric meant to measure the performance of the overall quantum system. The QV metric quantifies the largest random circuit of equal width (number of qubits) and depth (number of operations) that the computer successfully implements, essentially indicating the relative complexity of a problem that can be solved by the quantum computer. QV increases with better qubit fidelities, richer connectivity, larger gate sets, and larger number of qubits. For Speed IBM introduces Circuit Layer Operations Per Second (CLOPS), a metric correlated with how fast a quantum processor can execute circuits, specifically, the metric measures the speed the processor can execute layers of a parameterized model circuit of the same sort used to measure QV. IBM has published an aggressive roadmap that shows how the IBM Quantum team will continue to improve the performance of quantum computing systems by pushing on all three areas. This demonstrates IBMs commitment to offering a scalable system.

IBM offers broad access to the world's most powerful integrated quantum computing systems for business and science through a fleet of quantum systems accessible through the cloud.

In cooperation with:

IBM **Quantum** Fraunhofer