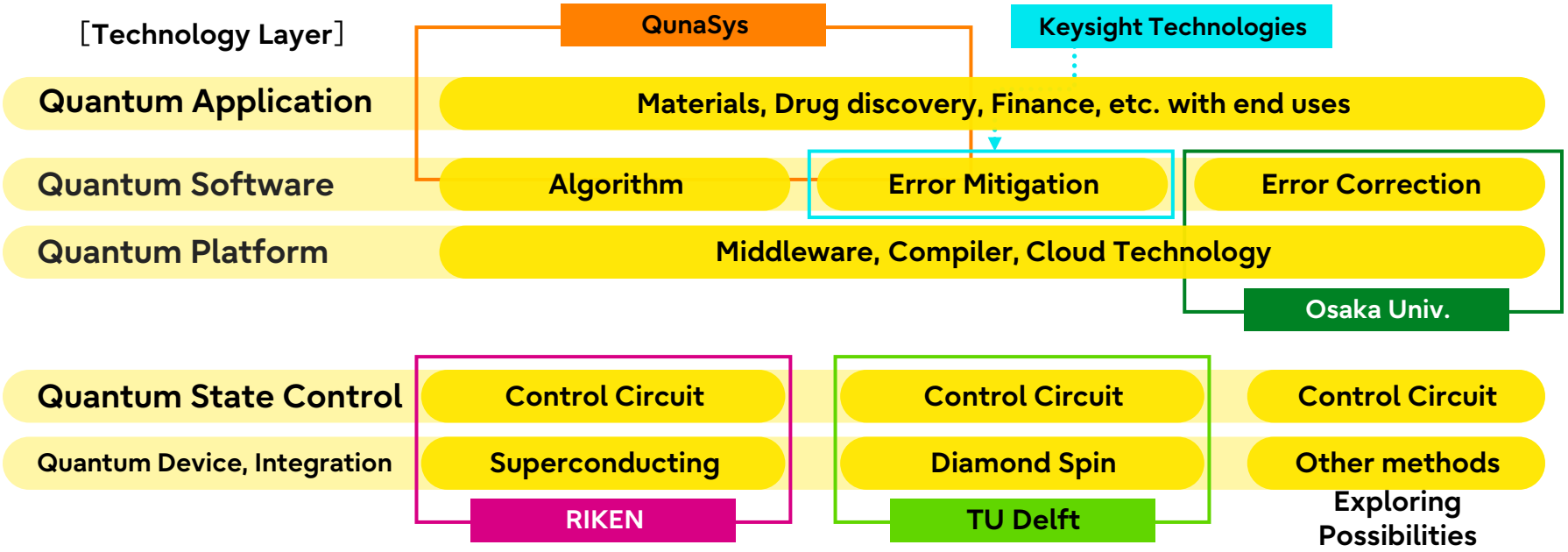
Fujitsu Hybrid Quantum Computing Platform

Quantum Laboratory
Fujitsu Research, Fujitsu Limited

Fujitsu's Strategy for Quantum Computing

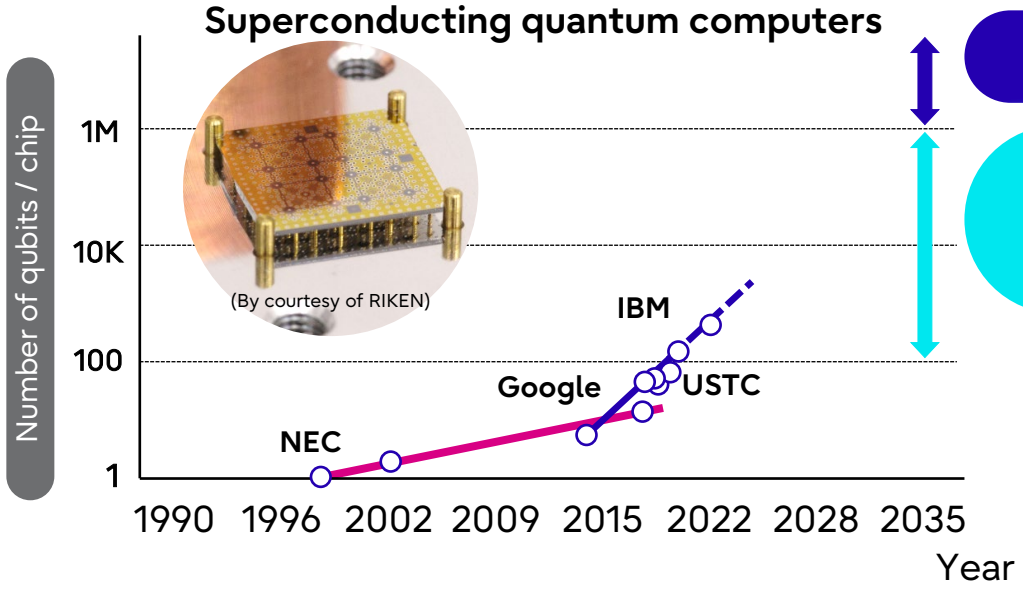
- Cover all the technology layers with the world's leading research institutions
- Put emphasis on software technologies, while working on several types of hardware
- Develop applications with end users by using a newly-developed quantum simulator



Background and Challenges

Current quantum computers have problems with qubit errors and cannot perform large-scale computations accurately.

- Current quantum computers are small-scale and cannot eliminate errors due to noise.
- Experts anticipate that the realization of a practical fault-tolerant quantum computer that can provide reliable, accurate results, will take a decade or longer



Fault-tolerant quantum computers (~1 million bits or more)

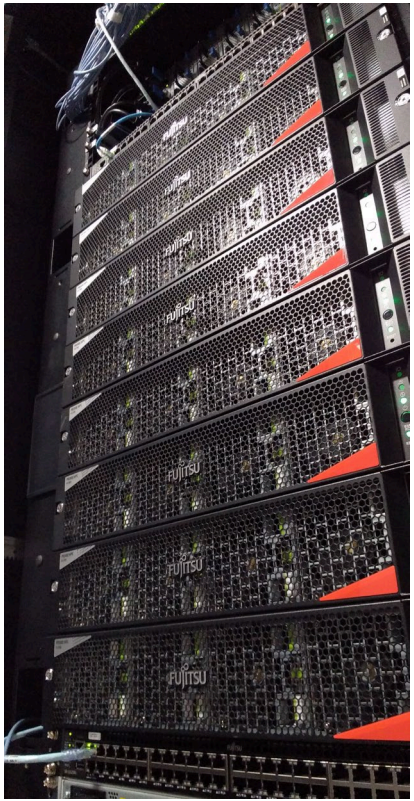
Current NISQ* computers
Expect to be useful in limited applications
*NISQ : Noisy Intermediate-Scale Quantum

"A full-fledged quantum computer, with 1000 logical qubits, might end up containing many millions of physical qubits",
Adrian Cho, Science, 2020/7/9

Quantum Computer Simulator

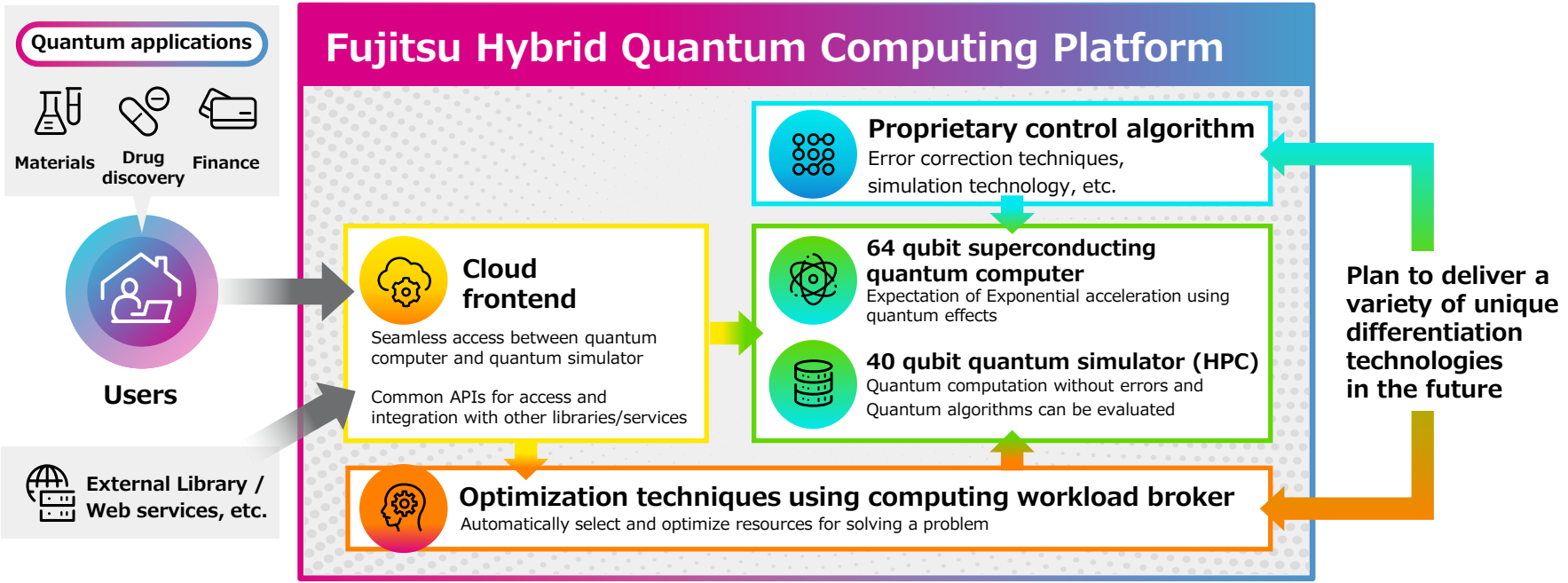
FUJITSU

- **The world largest-class quantum computer simulator as a permanent dedicated system**
  - Qulacs (state vector simulator) on FX700 cluster
  - Continuous enhancement
    36qubits (64 nodes: FY21) → 40qubits (1024 nodes: FY23)
- **Collaboration with customers**
  - Material (Fujifilm), Finance (Mizuho-DL Financial Technology)
  - **Quantum challenge**: Application discovery with universities and companies around the world (US, Europe, Asia and Oceania)
- **Research on new-type simulators for larger scale**
  - **Tensor Network simulator** with Barcelona Supercomputing Center
  - **Decision Diagram simulator** with the University of Tokyo



Fujitsu Hybrid Quantum Computing Platform

- Seamless operation between quantum computer and quantum simulator
- Development of computational methods that take advantage of both quantum computers and quantum simulators



Introduction of a 64-qubit superconducting quantum computer at RIKEN RQC-Fujitsu Collaboration Center

～Half-size mock-up of dilute refrigerator for superconducting quantum computer

Release of a 64-qubit System (Oct. 5, 2023)

RIKEN QUANTUM COMPUTING

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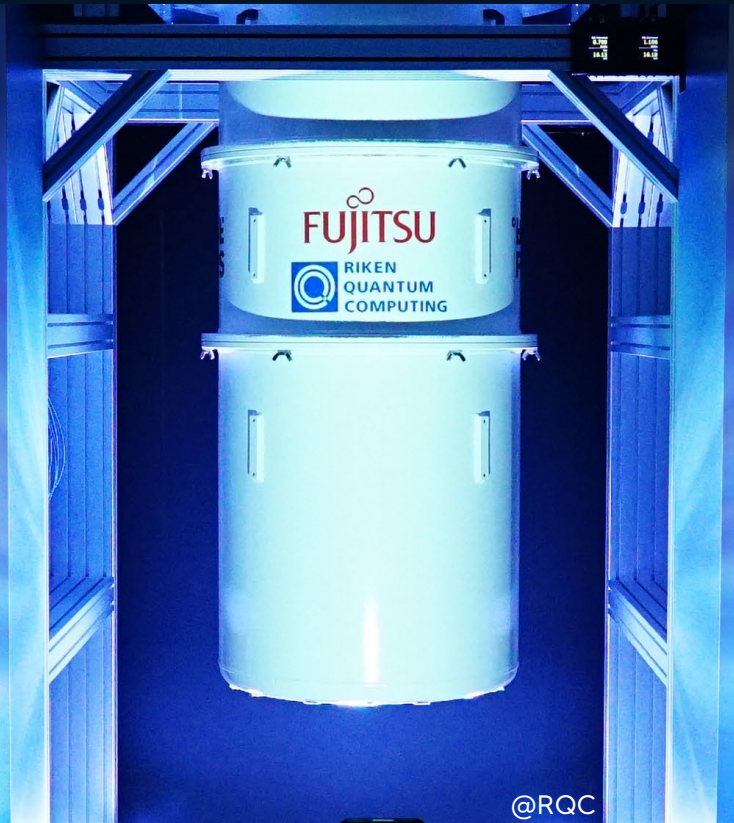
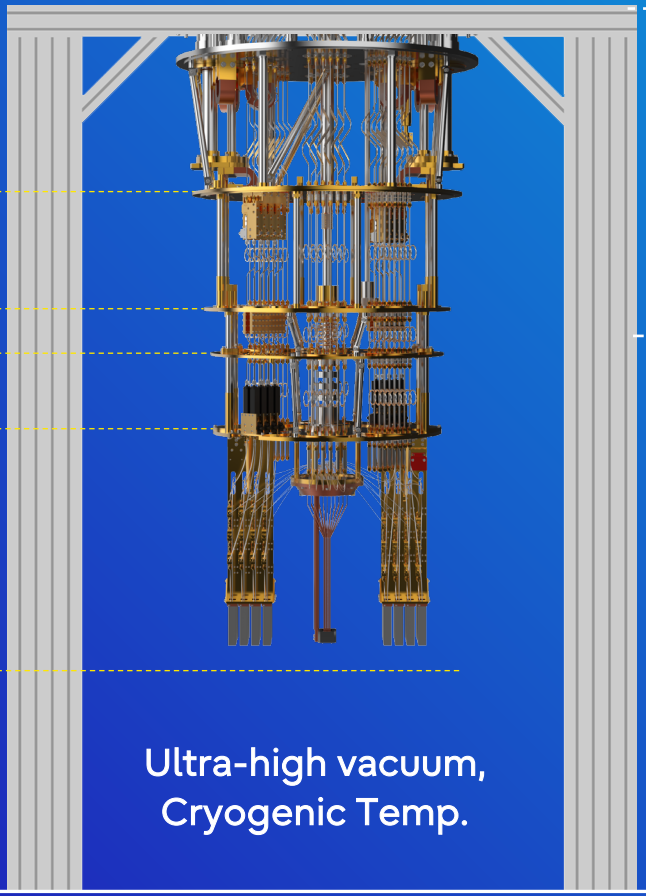
- Collaboration with Prof. Nakamura

- Developed Japan's second domestic quantum computer at RIKEN RQC-Fujitsu Collaboration Center
- Plan to develop applications with end users mainly in the industry using this system





Colder than outer space

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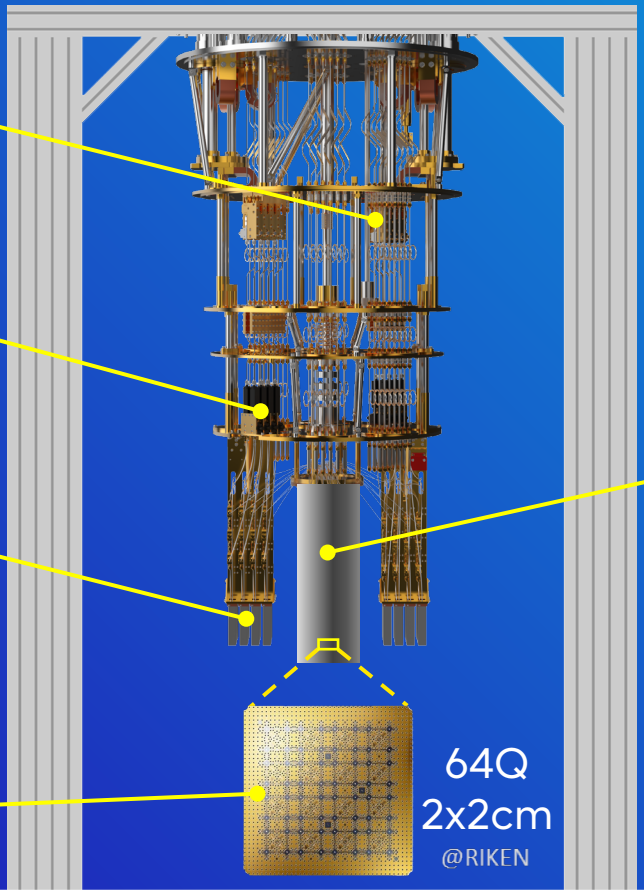
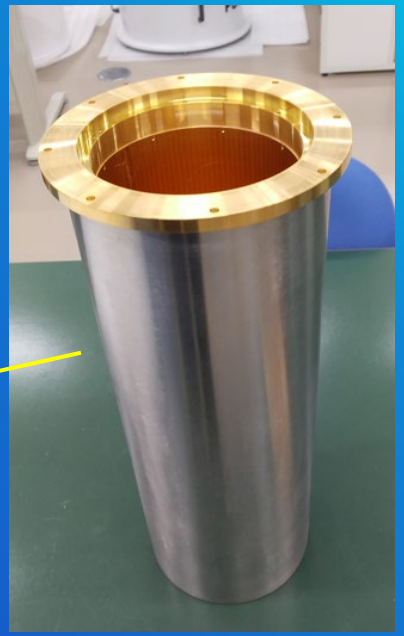
HEMT Amplifier

Low pass filter

Josephson Parametric Amplifier

Qubit chip



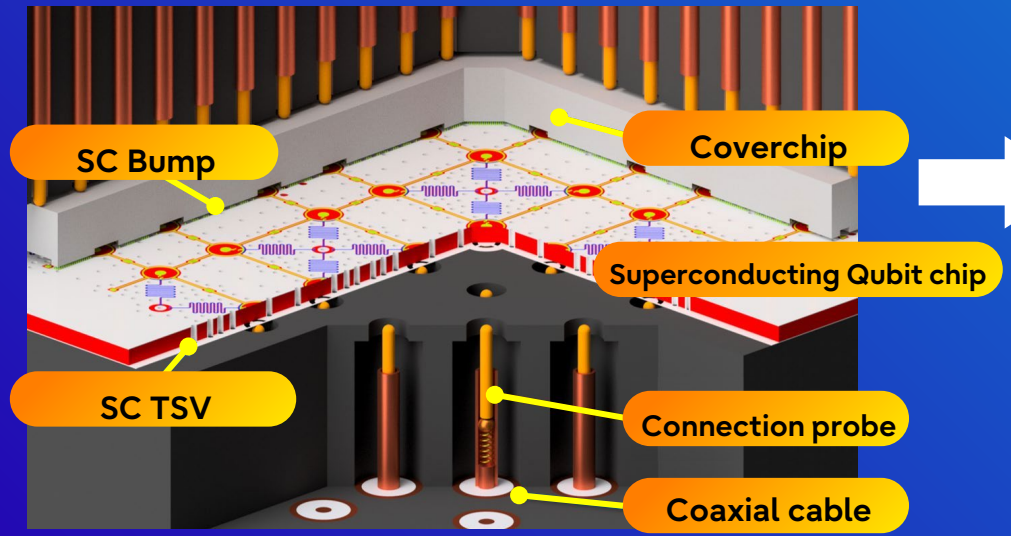


Electrical-magnetic Shield

Superconducting Qubit chip

RIKEN QUANTUM COMPUTING FUJITSU

3D contact to Superconducting qubits



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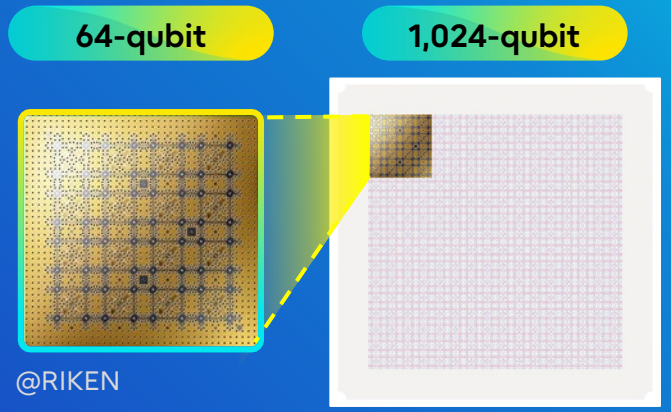

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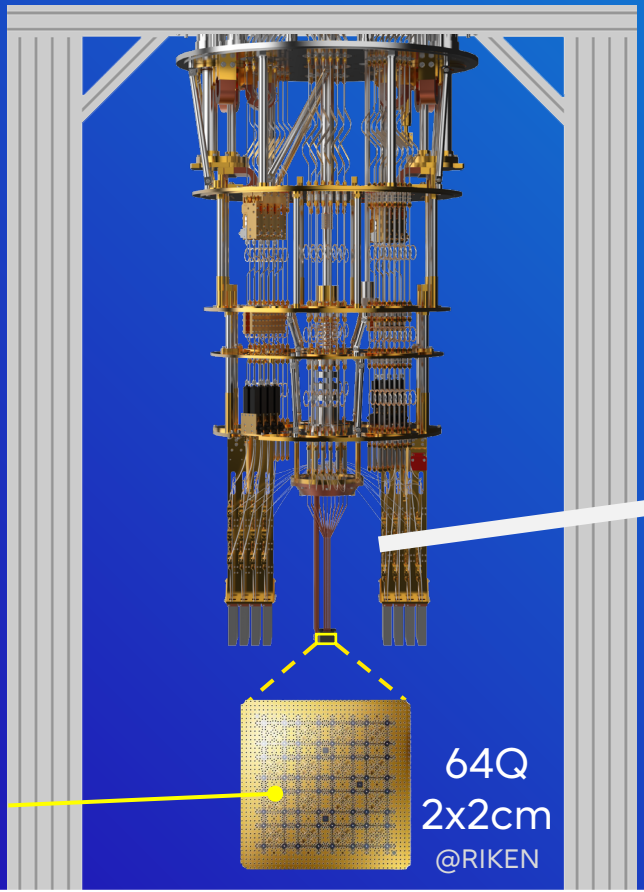
Can scale up by tiling basic units

Technological strength

3D contact structure



Qubit chip

64Q
2x2cm
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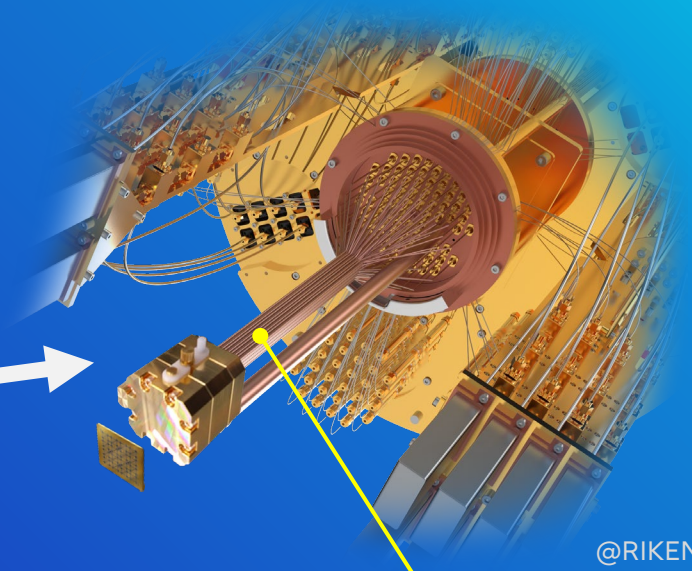

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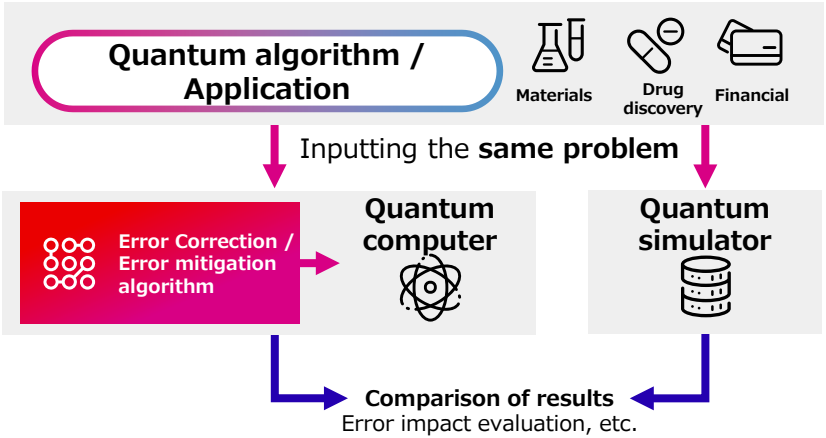
Wiring to the qubit

Platform Utilization Approach

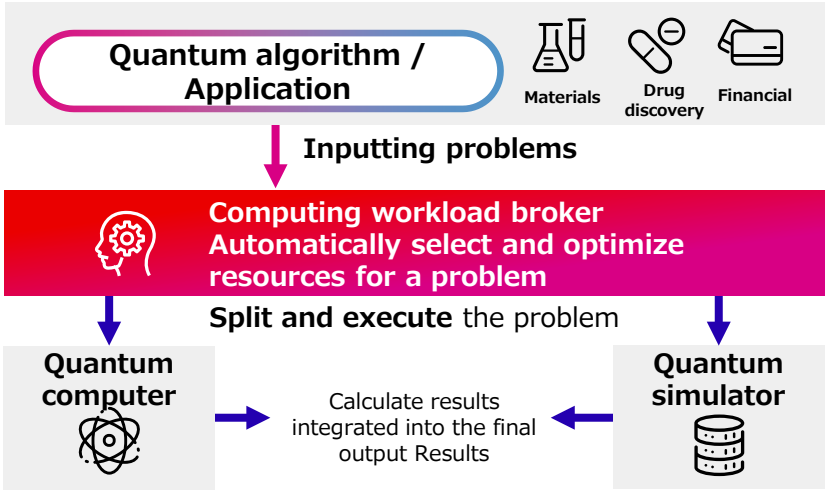
1 Accuracy evaluation of quantum algorithms

- Input the same problem for a quantum computer and quantum simulator
- Evaluate the impact of qubit errors by comparing results
- Expected use for algorithm development of quantum error mitigation and error correction



2 Hybrid algorithm development of quantum computer /simulator

- Split the same problem by condition (Speed priority, accuracy priority, etc.)
- Execution assigned properly to quantum computer and the simulator for a split problem



Development of Applications

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- Fujitsu is already working with customers to develop pioneering quantum applications using quantum simulators
- We plan to accelerate collaboration research using this platform and expand the search for practical hybrid quantum applications in various fields such as materials, finance, and drug discovery.

FUJIFILM

MITSUBISHI CHEMICAL GROUP

TOKYO ELECTRON

Mizuho–DL Financial Technology

About the Future

To release large-scale simulators and actual machines successively in order to solve societal problems

2023.7 To release a high-speed and large-scale 40 qubit quantum simulator

2023.10 To release a superconducting quantum computer (64 qubits) at the RIKEN RQC- Fujitsu Cooperation Center

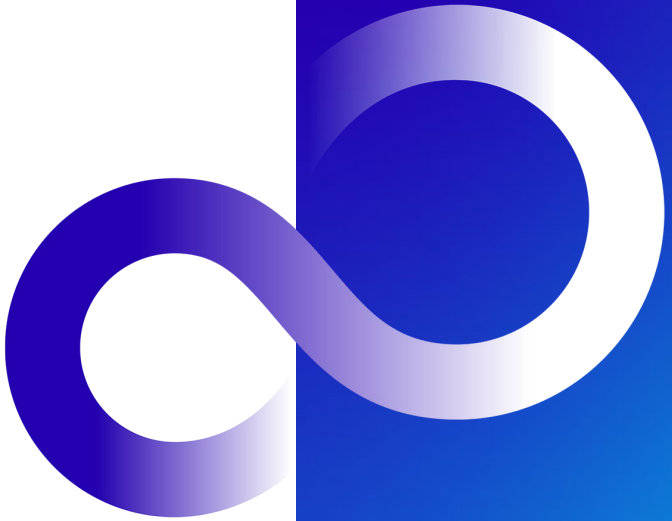
Fault-Tolerant Quantum Computer

FY2025 To release of a larger-scale superconducting quantum computer (256 qubits), and implement the error correction

FY2026~ To release a superconducting quantum computer with >1000 qubits

FY 2020 — 2030

Thank you



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Use Case with Cooperative Calculation of Quantum Computing and High Performance Computing

Use Case: Quantum Chemistry Computation

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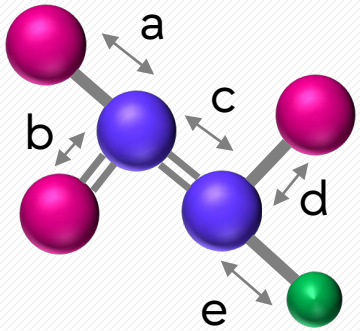
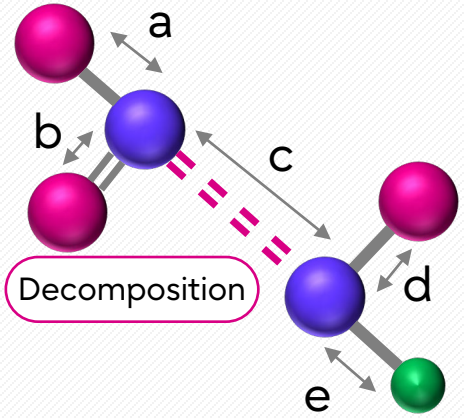
- **Analysis of molecular structures, material properties, and reactivity by calculating the behavior of atoms and electrons**

Identification of the molecular structure



Understand the shape of molecules, the angle of connections, and other structures by calculating the distance and angle between each atom

Analysis of reactivity



Understand the ease of chemical reactions and how they work, such as how much energy is needed to decompose

The basic quantum chemical calculation is the energy calculation of the target molecule

Size of Molecules and Errors in Quantum Computing

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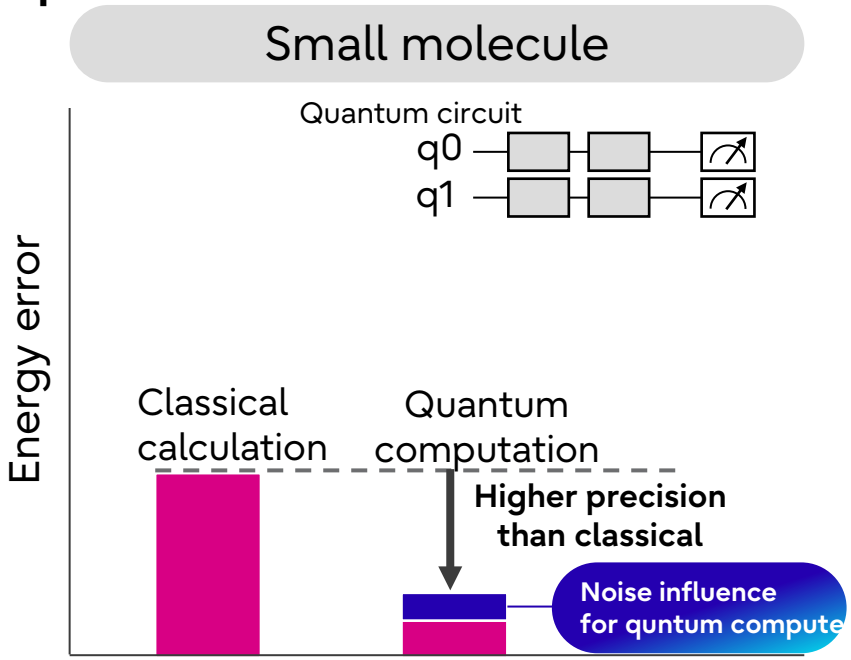
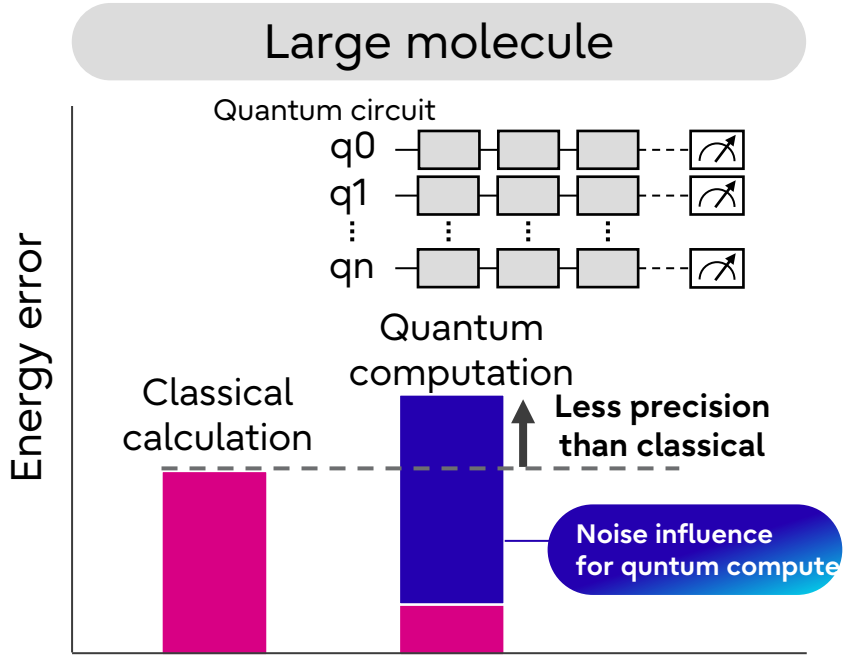
Quantum algorithms have the potential to surpass accuracy by classical algorithms. However, when the molecule is large, the noise effects can make it less precise than the classical one.





Use Case of the Hybrid Platform

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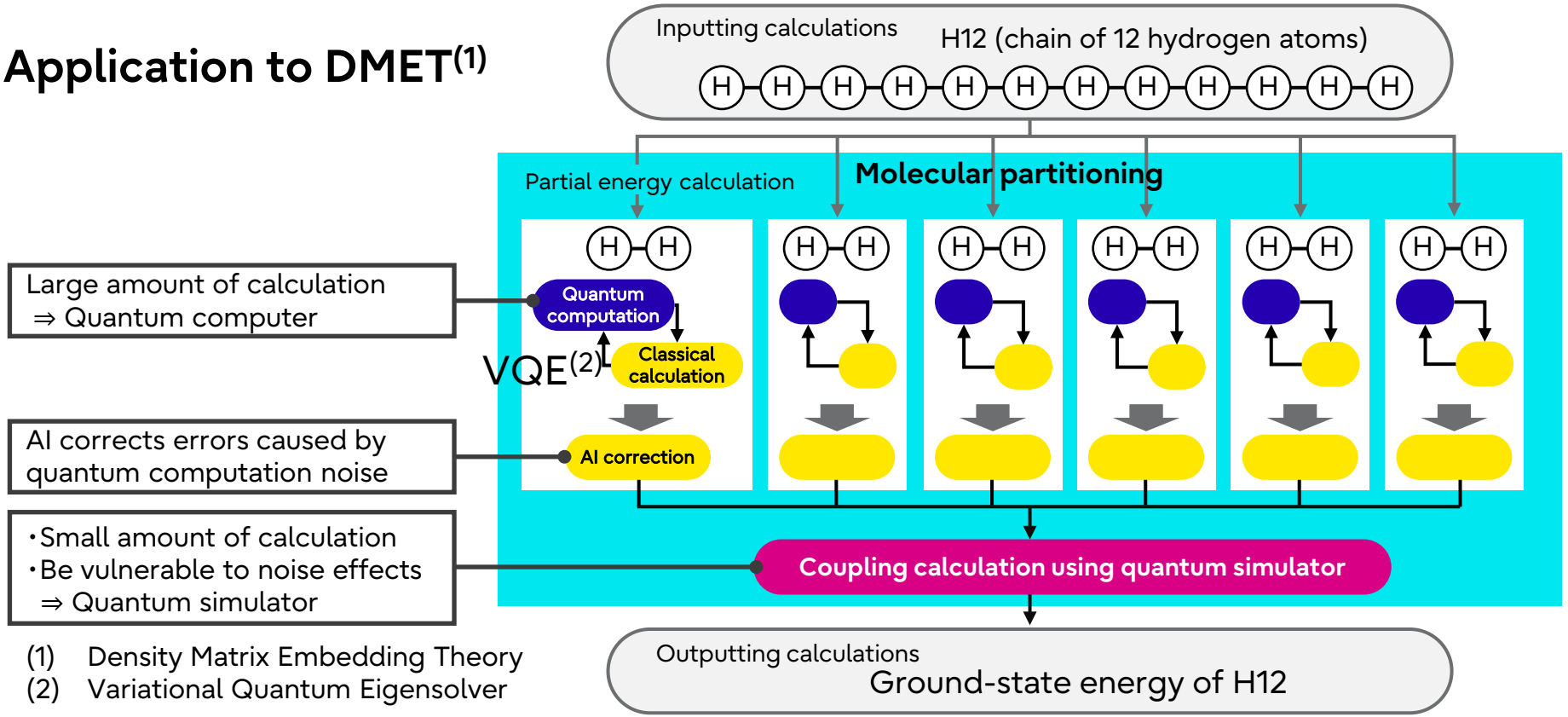
Application to DMET(1)



(1) Density Matrix Embedding Theory
(2) Variational Quantum Eigensolver

Results by Hybrid Quantum Algorithm

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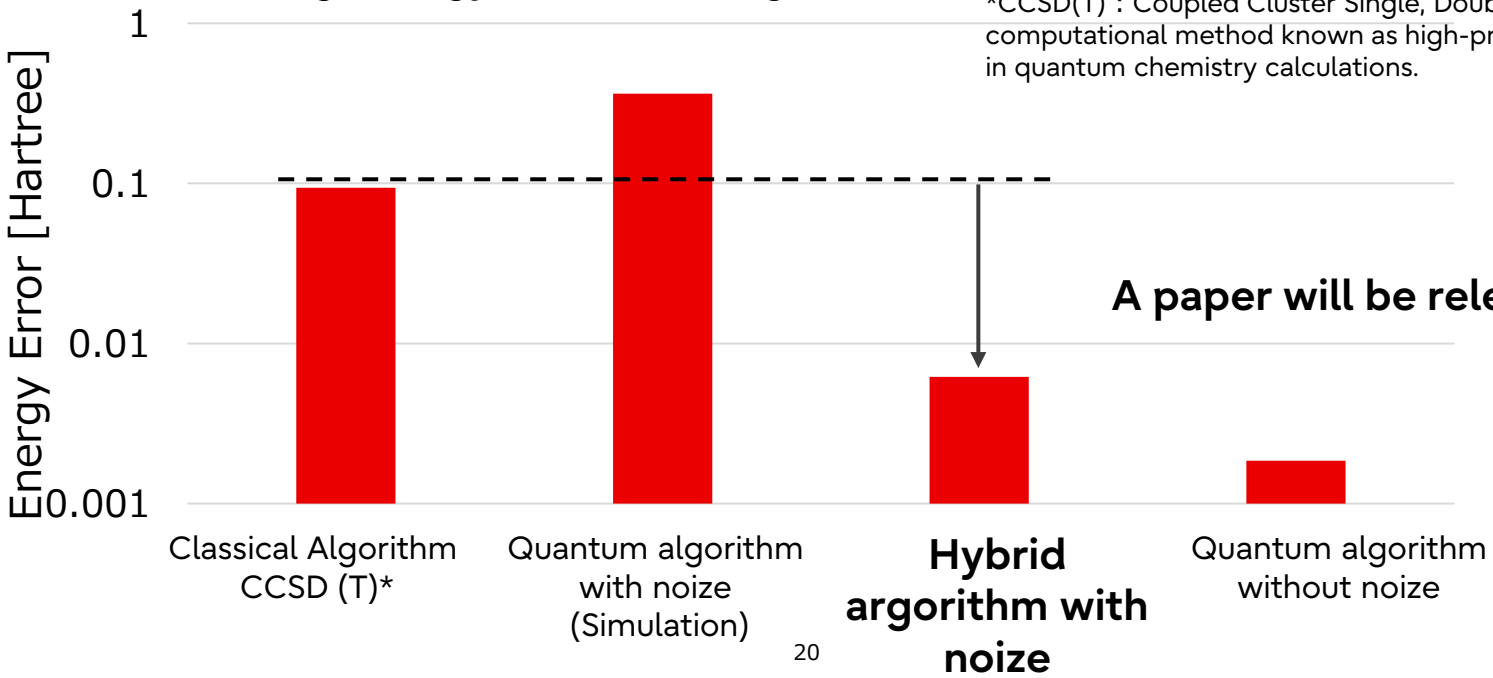
By a hybrid algorithm between a real quantum machine and a simulator, the accuracy of the calculation of H12 surpasses that of the classical approximation.

Error in binding energy (@bond length of 2.5 Å)



*CCSD(T) : Coupled Cluster Single, Double, (and Triple), a computational method known as high-precision computing in quantum chemistry calculations.