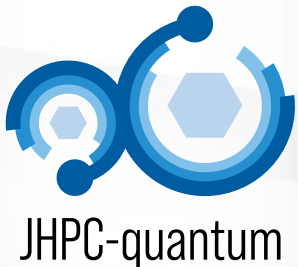


# Needs for Benchmarks towards Utility-scale QC-HPC hybrid computing

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**RIKEN Center for Computational Science (R-CCS)**



# Supercomputer "Fugaku" at R-CCS (2021~)



神戸ポートアイランド



RIKEN Center for Computational Science (R-CCS)



**432 racks**  
**158,976 general-purpose manycore processors Fujitsu A64FX, 7 Million Cores**

**Half exaflops in DP**  
**1 Exaflops in SP!**

**Very power-efficient system with 20MW power-consumption!**

**The Public Service has started from March, 2021**

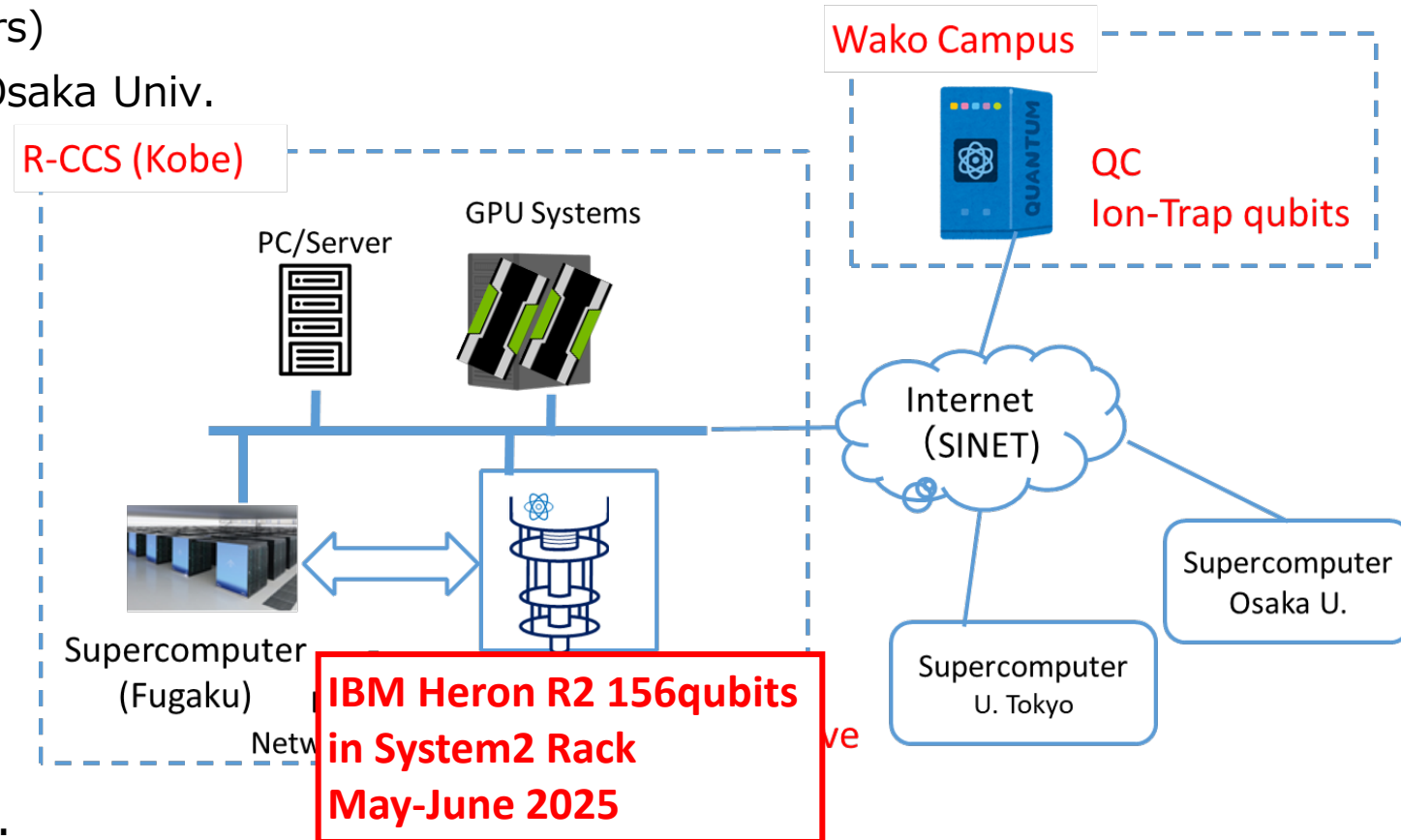


- **NEDO-funded project: “Research and Development of quantum-supercomputers hybrid computing platform for exploration of uncharted computable capabilities”**

- Project Period: Nov 2023 – Oct 2028 (5years)
- Members: RIKEN, Softbank, U. Tokyo and Osaka Univ.

## ● Missions

- Research and development of **quantum HPC hybrid system software** for the integration of quantum computers and supercomputers (HPC)
- **JHPC Quantum quantum-supercomputer hybrid platform** is being built to execute QC-HPC hybrid applications with two types of quantum computers, **IBM** and Quantinuum, installed on-premises in RIKEN (R-CCS and Wako), and **Fugaku** and other HPCs.



- Aiming to Demonstrate the superiority (and “Quantum Utility” ) of **quantum HPC hybrid applications** against existing applications only by supercomputers, and research of advanced internet technology to deploy the quantum HPC hybrid applications as **a service in the post-5G era.**

**IBM kobe was just  
installed in R-CCS in  
June!**



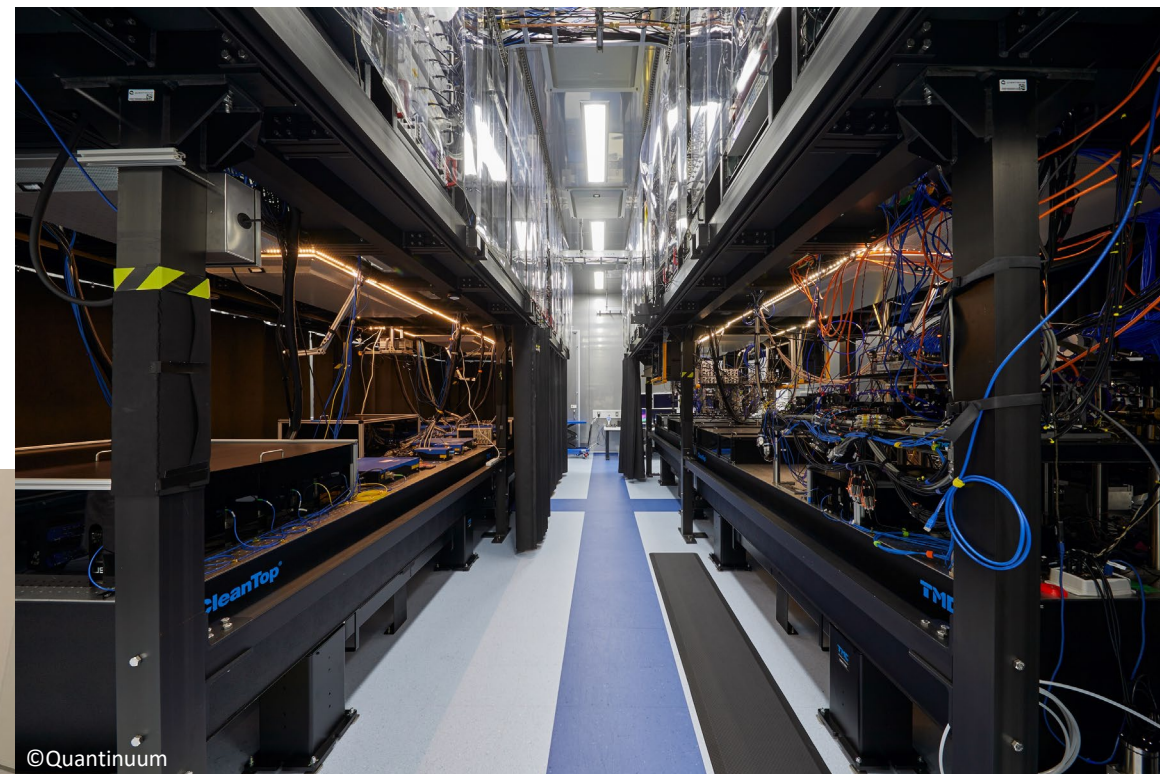
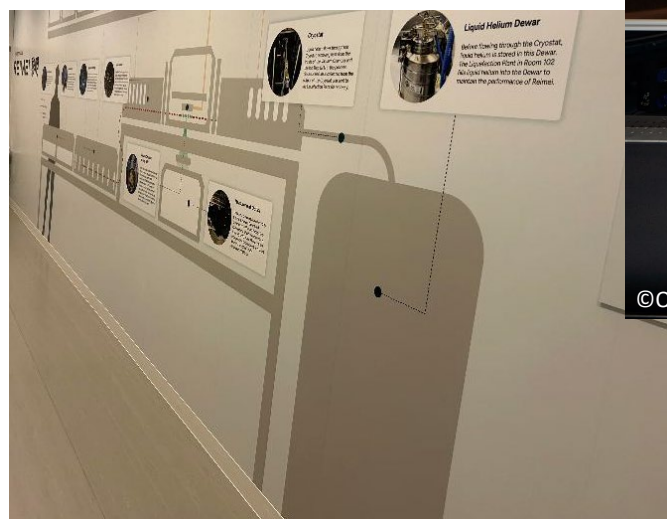
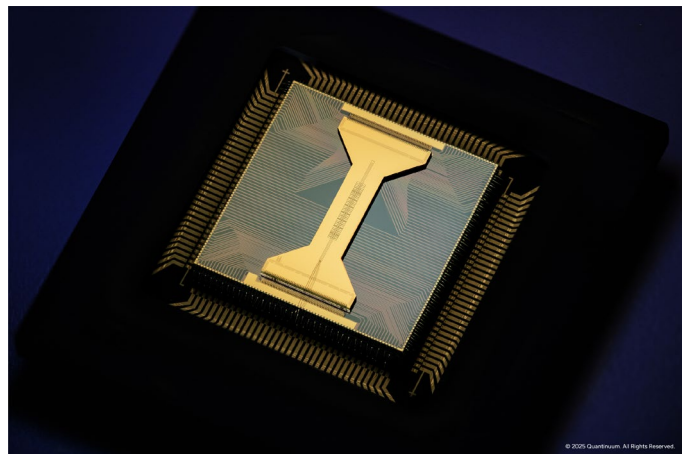


# "Remei" Quantinuum Trapped-Ion Quantum Computer

初  
明

QUANTINUUM  
REIMEI

Quantinuum Trapped-Ion Quantum Computer H1  
(20 qubits) was installed in Wako Campus, Japan  
and is operated since Feb, 2025



# JHPC Quantum Programming models and environment for QC-HPC hybrid applications

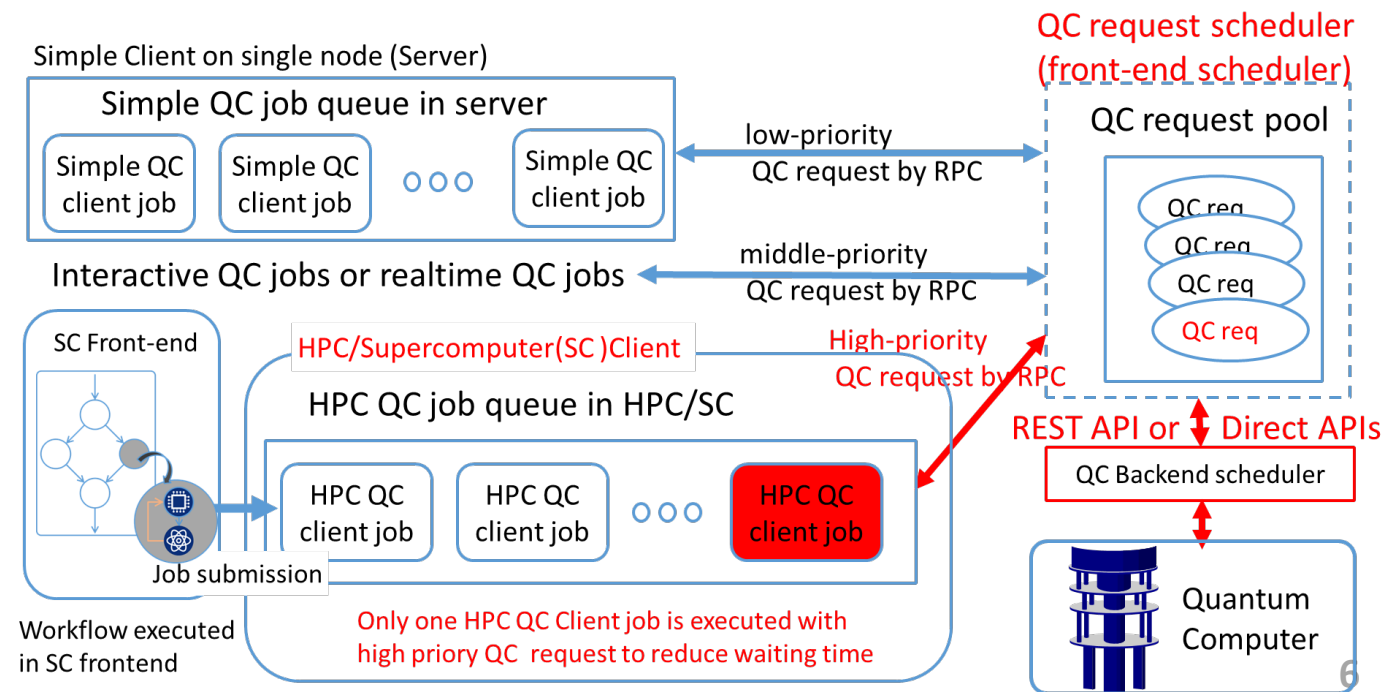
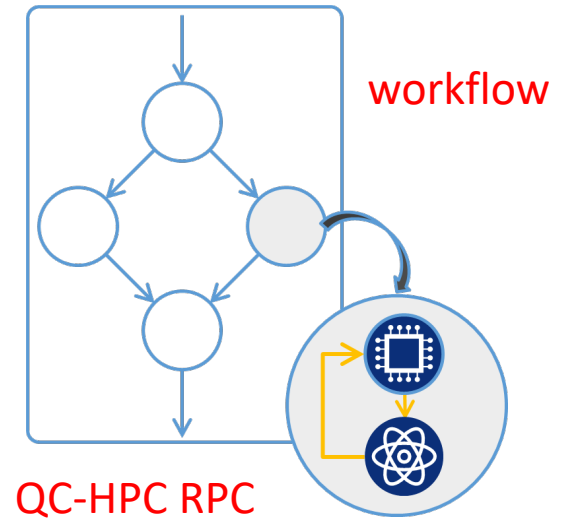
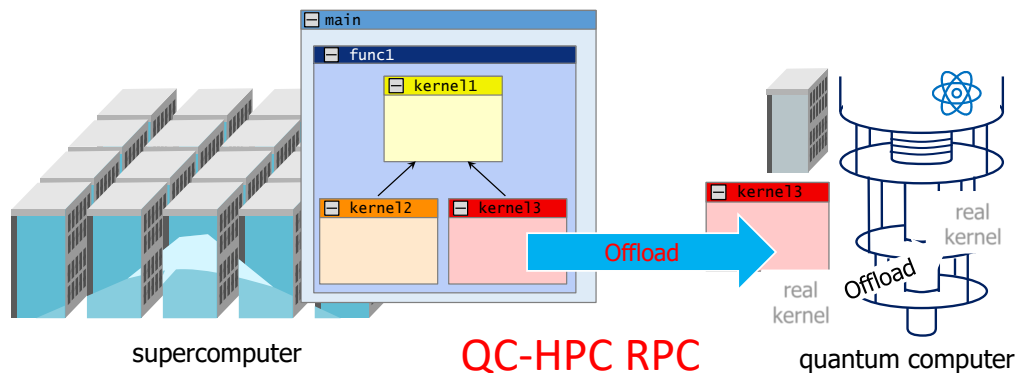
(0) Running Qiskit program on a single node as in “Cloud”

(1) Loosely-coupled independent programs by workflow tools

- Workflow tools: Tierkreis (Quantinuum), Prefect, Xcryption

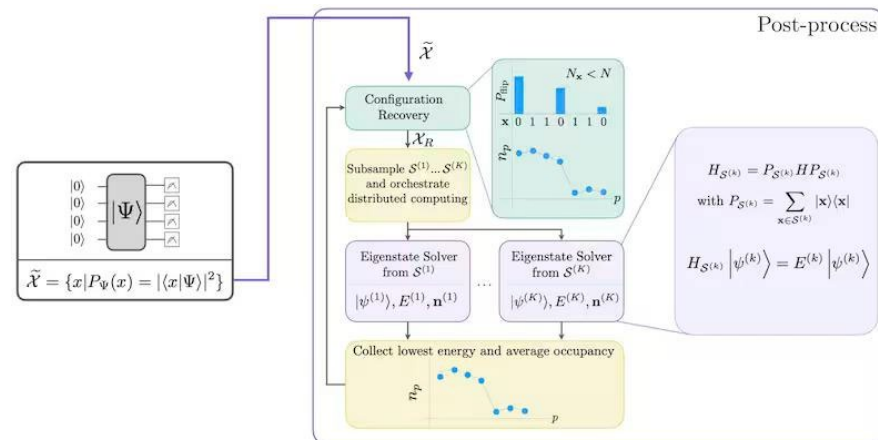
(2) Tightly-coupled QC and HPC in one HPC program by **offloading of QC computation using (asynchronous) RPC** (remote procedure call)

- SQC APIs (our C APIs) – low-level APIs in C
- RPC requests from HPC are executed with high-priority by our RPC scheduler



- **QCSC “Quantum-Centric Supercomputing” with IBM**
- **Sample-Based Quantum Diagonalization**

- “a classical post-processing technique which acts on samples obtained from a quantum circuit after execution on a QPU. It is useful for finding eigenvalues and eigenvectors of quantum operators, such as the Hamiltonian of a quantum system, and uses quantum and distributed classical computing together.” (from IBM web site)



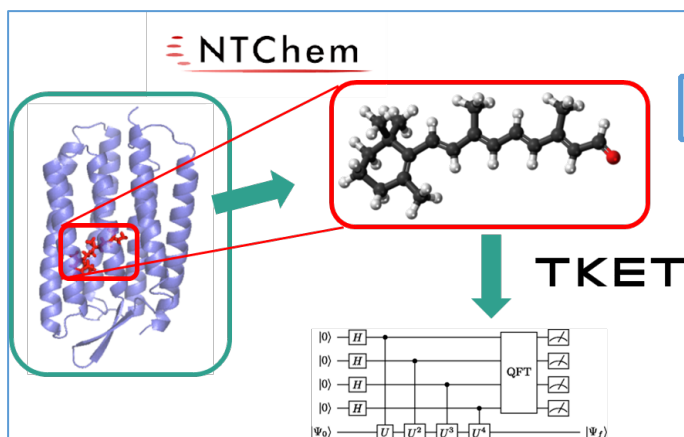
<https://docs.quantum.ibm.com/guides/qiskit-addons-sqd>

- We already demonstrated to incorporate quantum computations of chemistry in a quantum-centric supercomputing architecture, using up to **6400 nodes of the supercomputer Fugaku** to assist a **Heron superconducting quantum processor**. J. Robledo-Moreno et al., arXiv:2405.05068
  - Simulation of the active-space electronic structure of [2Fe-2S] and [4Fe-4S] clusters, using 58, 45 and 77 qubits respectively, with quantum circuits of up to 10570 (3590 2-qubit) quantum gates.
  - In this study, calculations are performed on a supercomputer using quantum computer results
- 
- Nest step: we are working on:
    - Iterative calculations with **tight integration by exchanging data at run-time, and overlapping quantum and HPC**
    - Using larger number of nodes of Fugaku and on-premise quantum computing

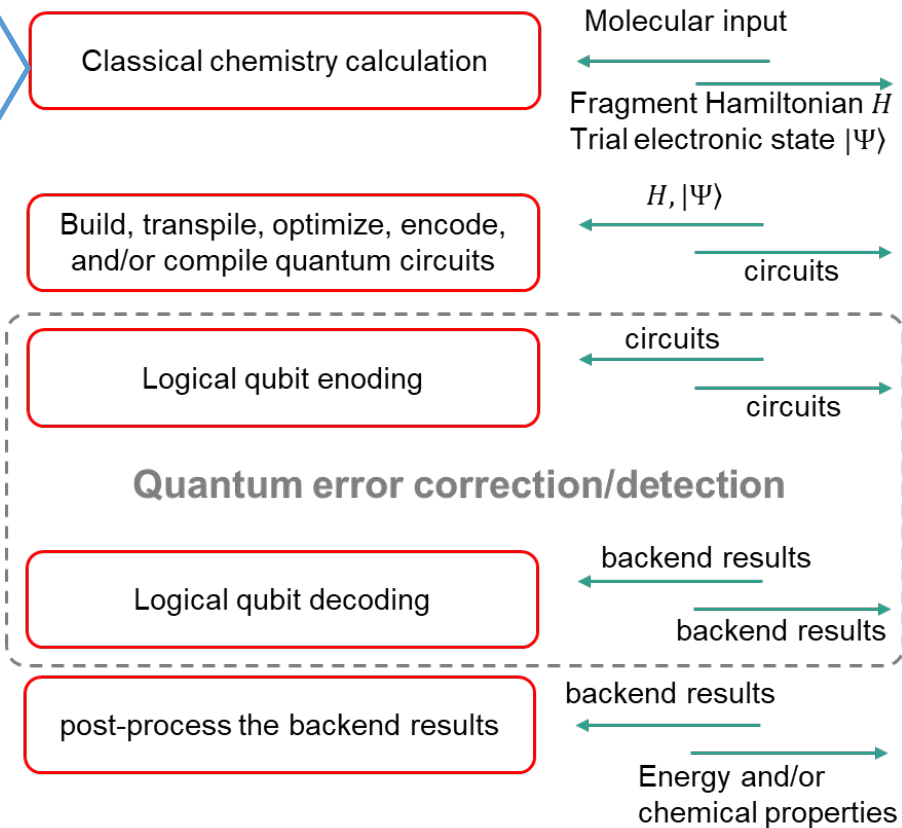


# Full-stack QC-HPC hybrid computing system for biomolecular chemistry problems

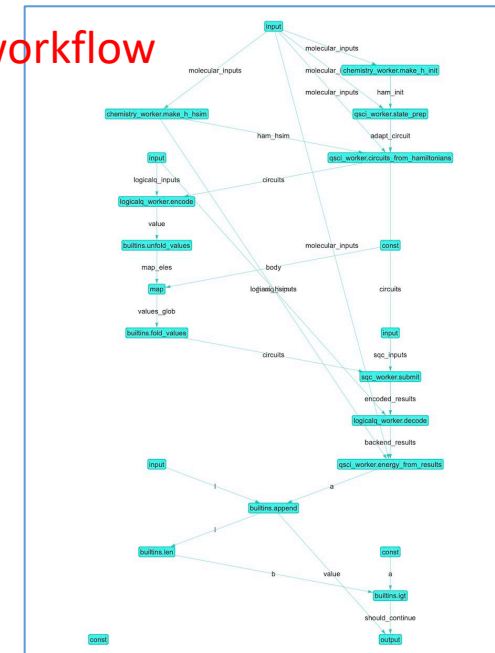
- A project with **Quantinuum** using loosely coupled **Tierkreis** workflow programming model



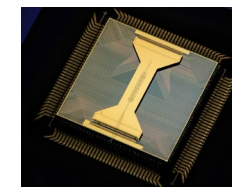
**HPC**



**Tierkreis workflow**



**Molecular input**



SYSTEM MODEL

**H1**

This work was presented in the workshop, ISC25, Hamburg, Germany



# Needs for Benchmarks for Utility-scale QC/HPC hybrid computing

- Regarding benchmarking Utility-scale QC/HPC hybrid computing, we need to take following two programming models into account.
- **Loosely-coupled QC-HPC workflow programs**
  - Possible metrics:
    - Latency and Throughput of “massive” Quantum computing jobs
    - Control capability and expressiveness
- **Tightly-coupled QC-HPC task-based programs**
  - Possible metrics:
    - Performance, wall-clock time, speedup by overlapping QC computing
    - Control capability and expressiveness