OAK RIDGE National Laboratory

Quantum Computing Codesign for High-Energy Physics

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Growing the adoption of quantum computing for high-energy physics research will require interdisciplinary coordination

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Quantum Computing for High-Energy Physics

- Today, this topic supports a broad scope of loosely related activities and exploratory techniques
  - Modeling and Simulation
  - Detection and Classification
  - Data Analysis and Machine Learning
- In the future, we expect growth and discovery as the technology and methods become more sophisticated
  - Growth in accessibility, controllability, capacity, fidelity, and programmability
  - Advances in theory, modeling, algorithms, analysis, awareness

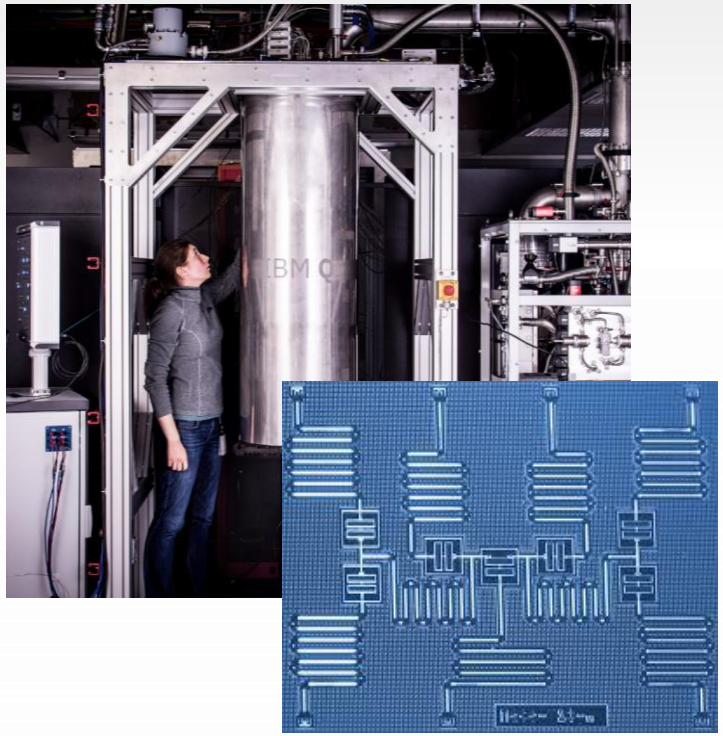
OLCF Quantum Computing User Program

D-Wave

- DW special-purpose annealing systems provides 2048 qubits

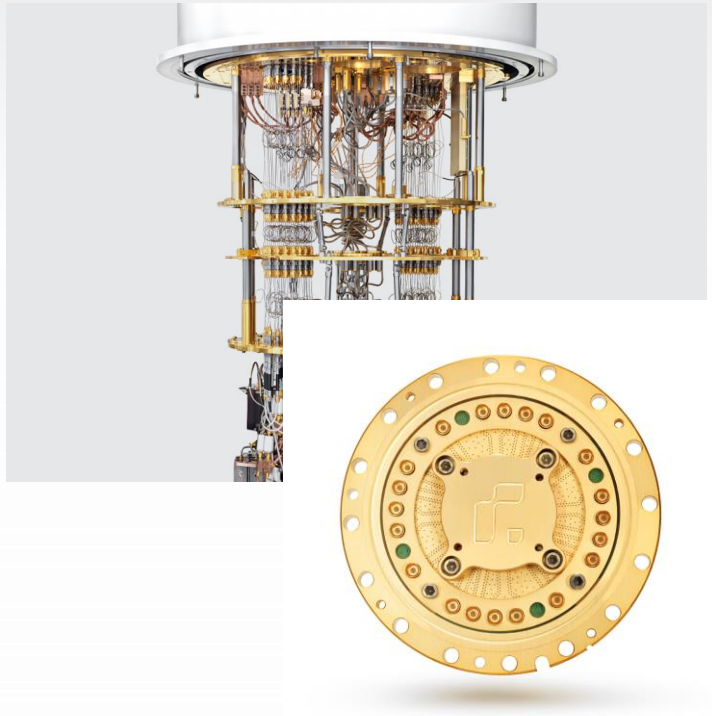
IBM

- IBM general-purpose gate system provides 53 qubits



Rigetti

- Rigetti general-purpose gate system provides 31 qubits



Changing Challenges and Emerging Opportunities

- Fast-paced changes in QC over the next 10 years will shift priorities for technology development
  - Examples: analog versus digital simulation, gate versus pulse control, error correction versus coherence, time versus fidelity
  - Where will returns on these investments appear?
  - Chemistry? Optimization? Fault-tolerance?
- Emerging priorities for the HEP community will both compete and complement these alternatives
  - Example: HEP-focused specializations of hardware, software, and algorithms for "quantum advantages"
  - Hope for these advantages require further analysis

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- Quantum computing co-design leverages HEP science needs to develop functionality and performance
  - Co-design is a paradigm for interdisciplinary research coordination that uses feedback to make progress
  - Example: tailoring quantum software stacks to specialized hardware for simulating quantum field theories
- These collaborative efforts establish responsibilities and agreement on shared scientific priorities
  - Computational partnerships may be tailored to both short-term and long-term priorities, opportunities

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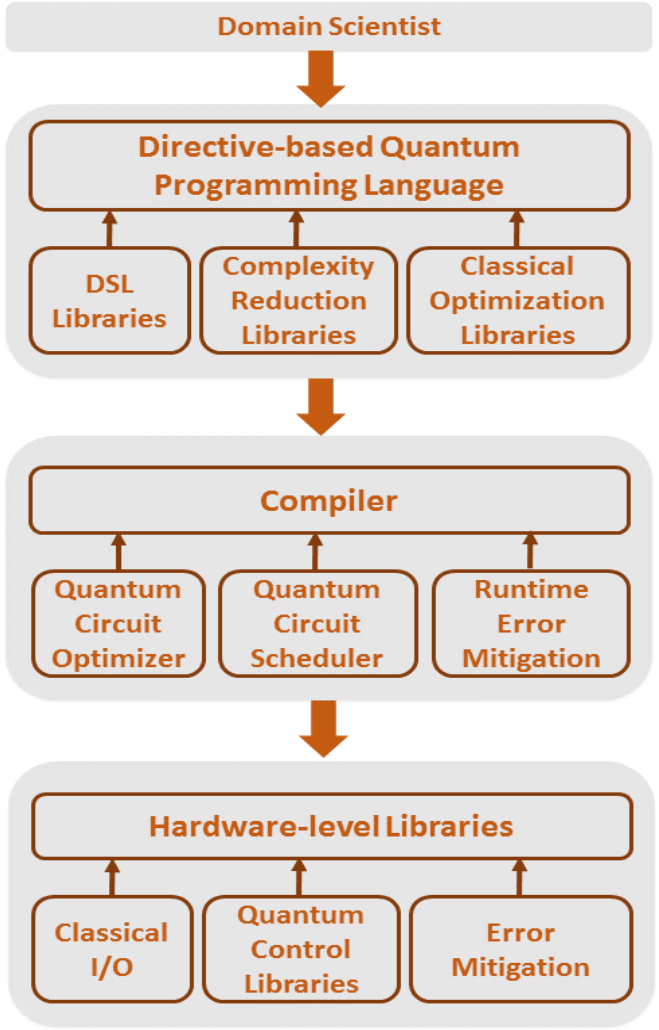

- Interdisciplinary Priorities
  - Use Cases and Requirements
  - Quantum Algorithms
  - Accelerated Applications
  - Software and Interfaces
  - Communication and Controls
  - Hardware Requirements
  - Systems and Networks
  - Metrics and Benchmarks
  - Verification and Validation
  - Infrastructure