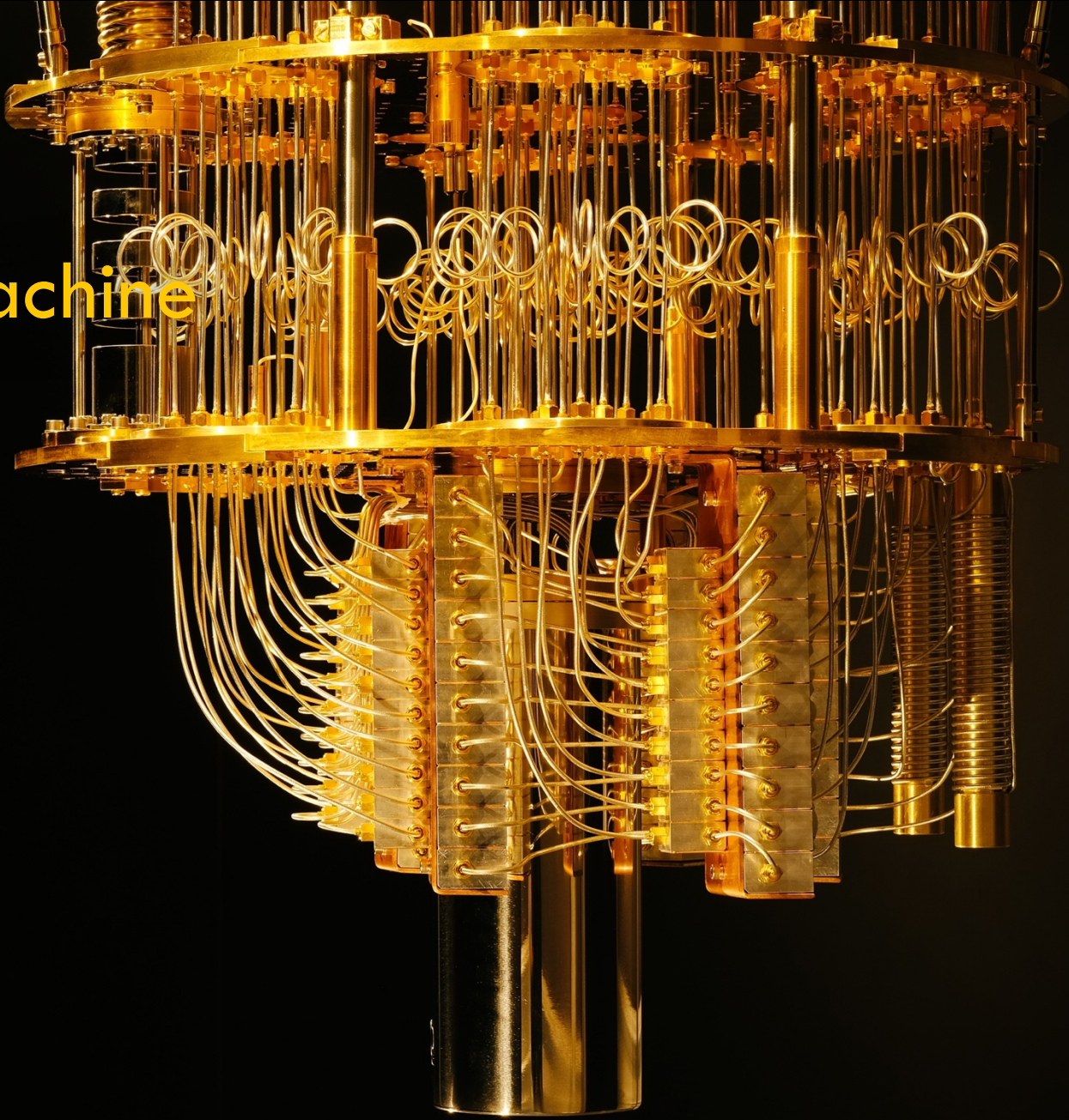
Quantum Computation for Machine Learning, AI, and Optimization

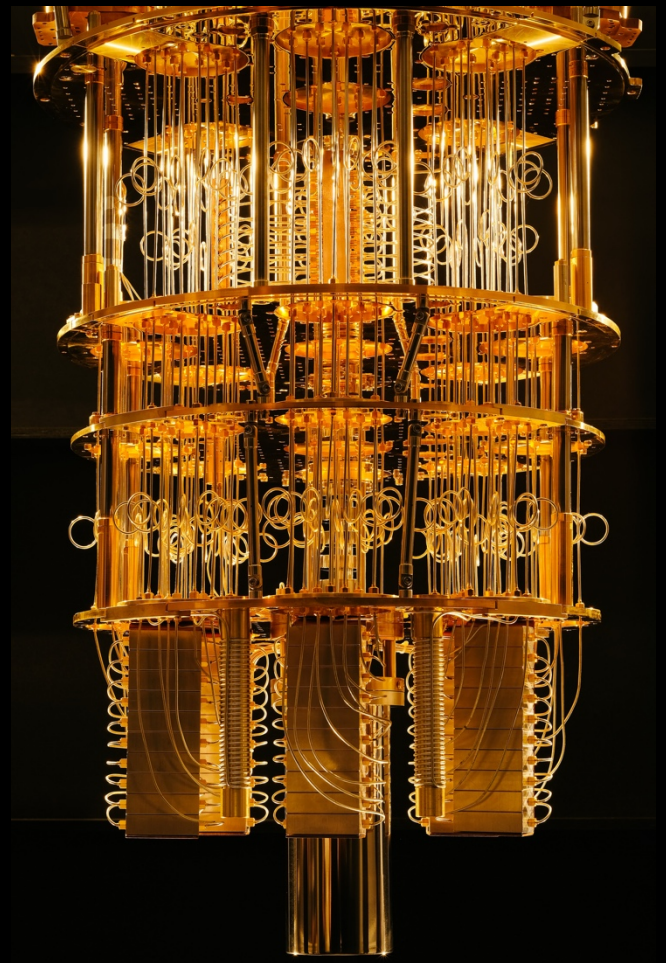


Zlatko K. Minev, Ph.D.

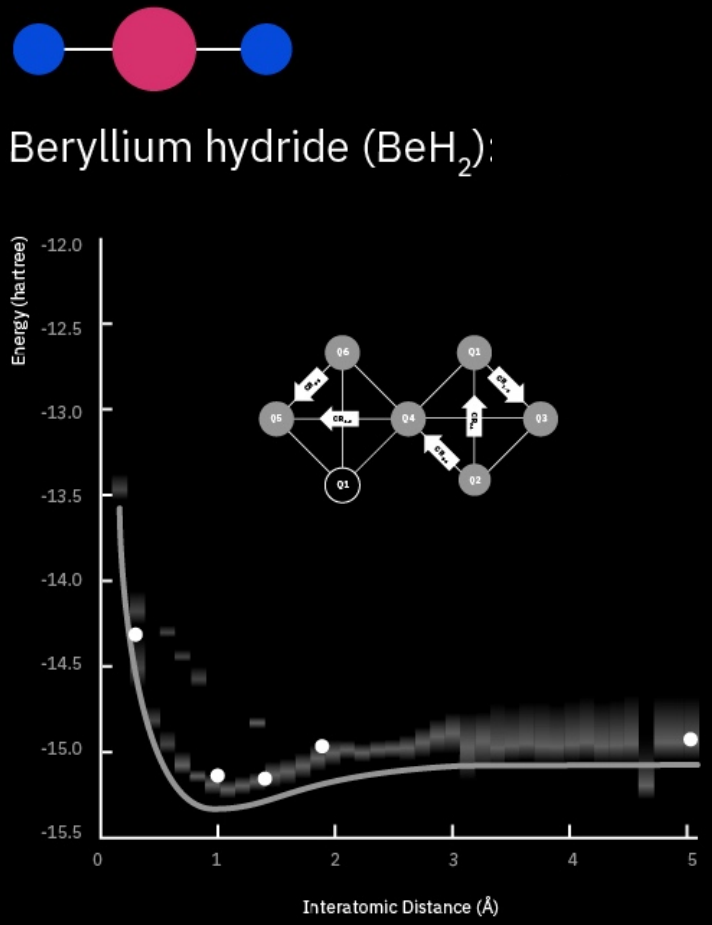
IBM Quantum @ TJ Watson

Experimental Superconducting Quantum Computing

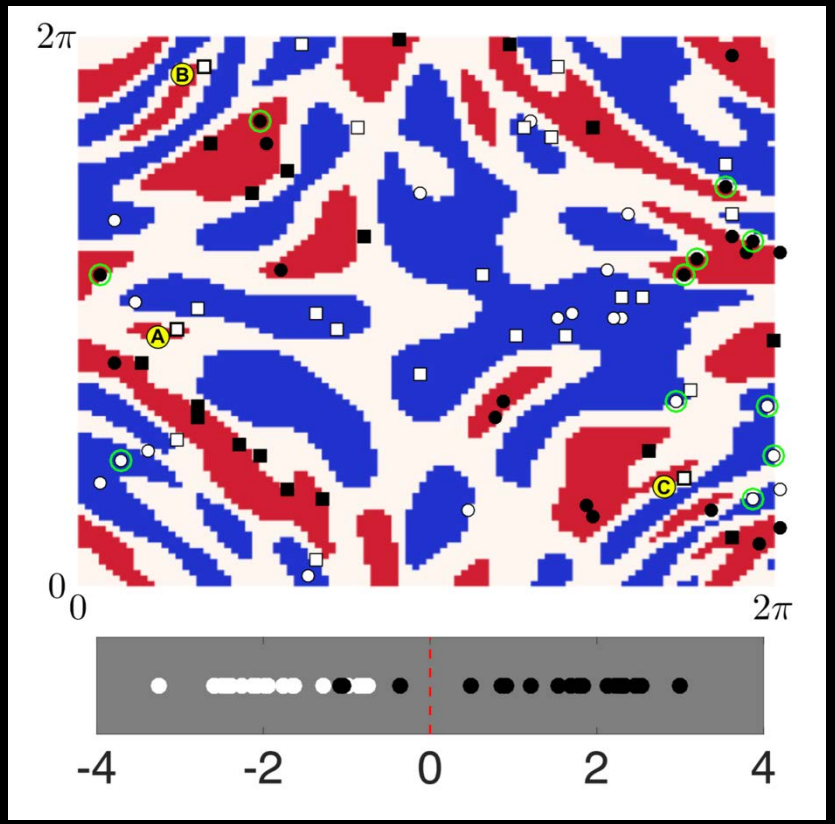
Hardware



Chemistry



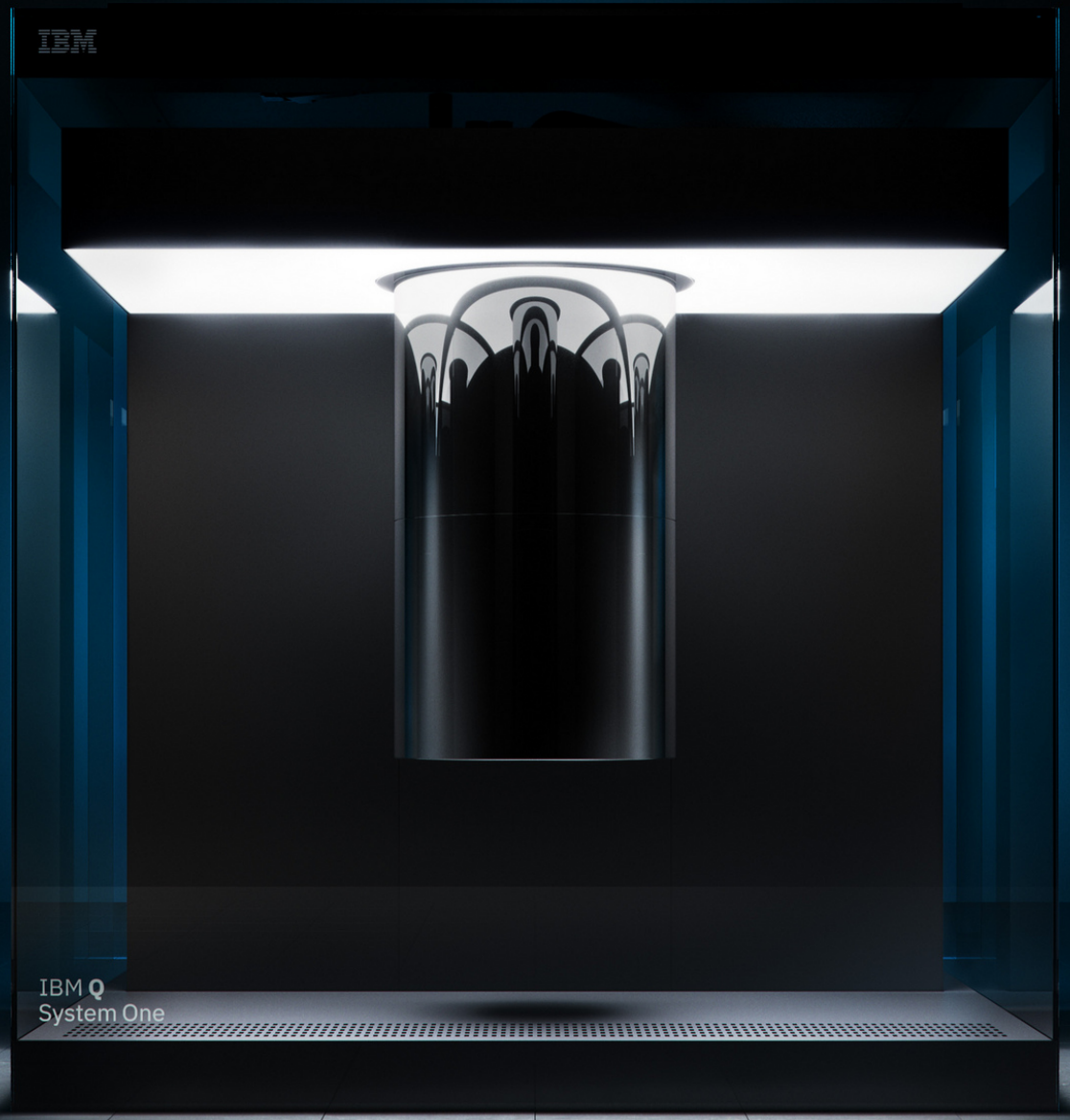
Machine Learning

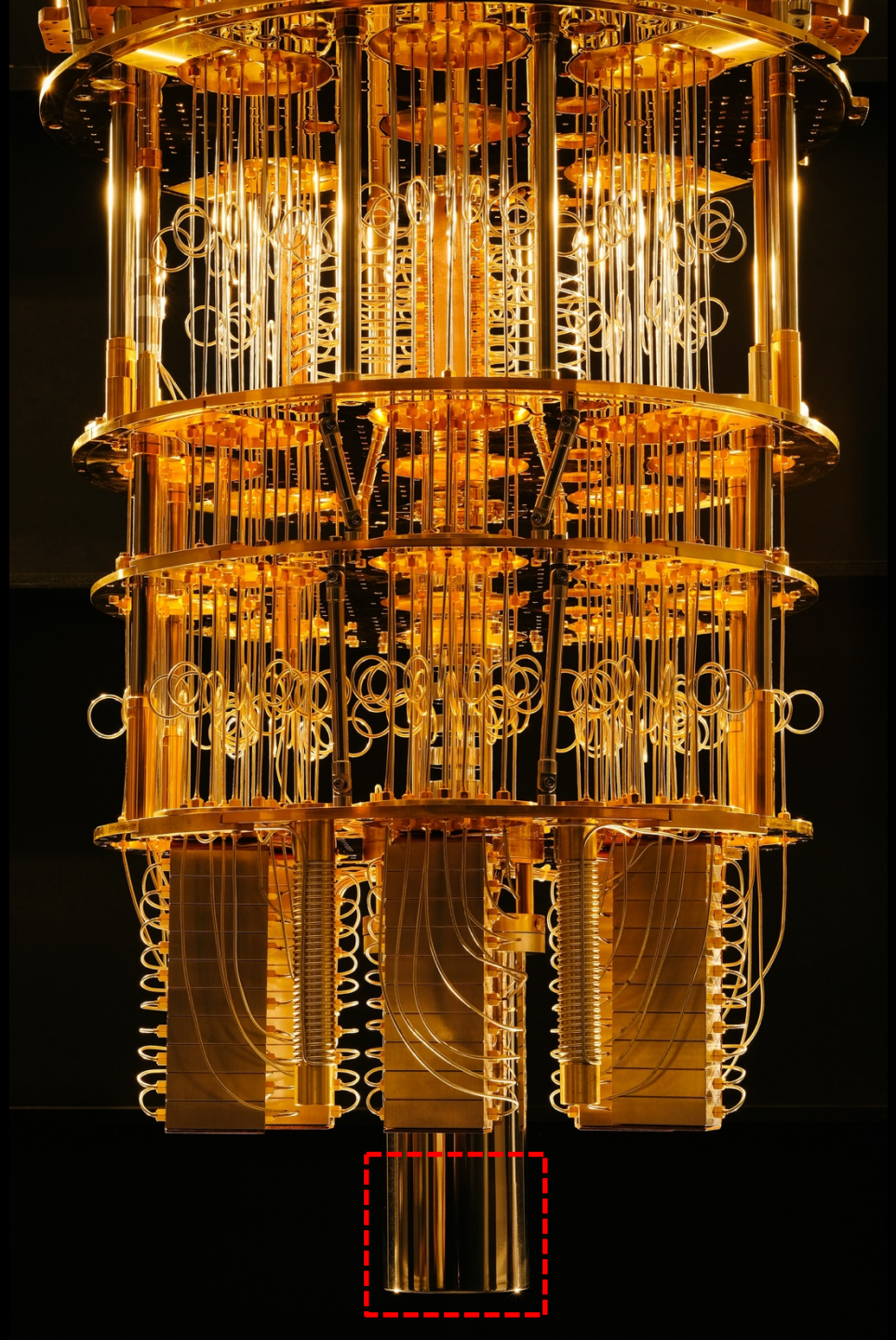


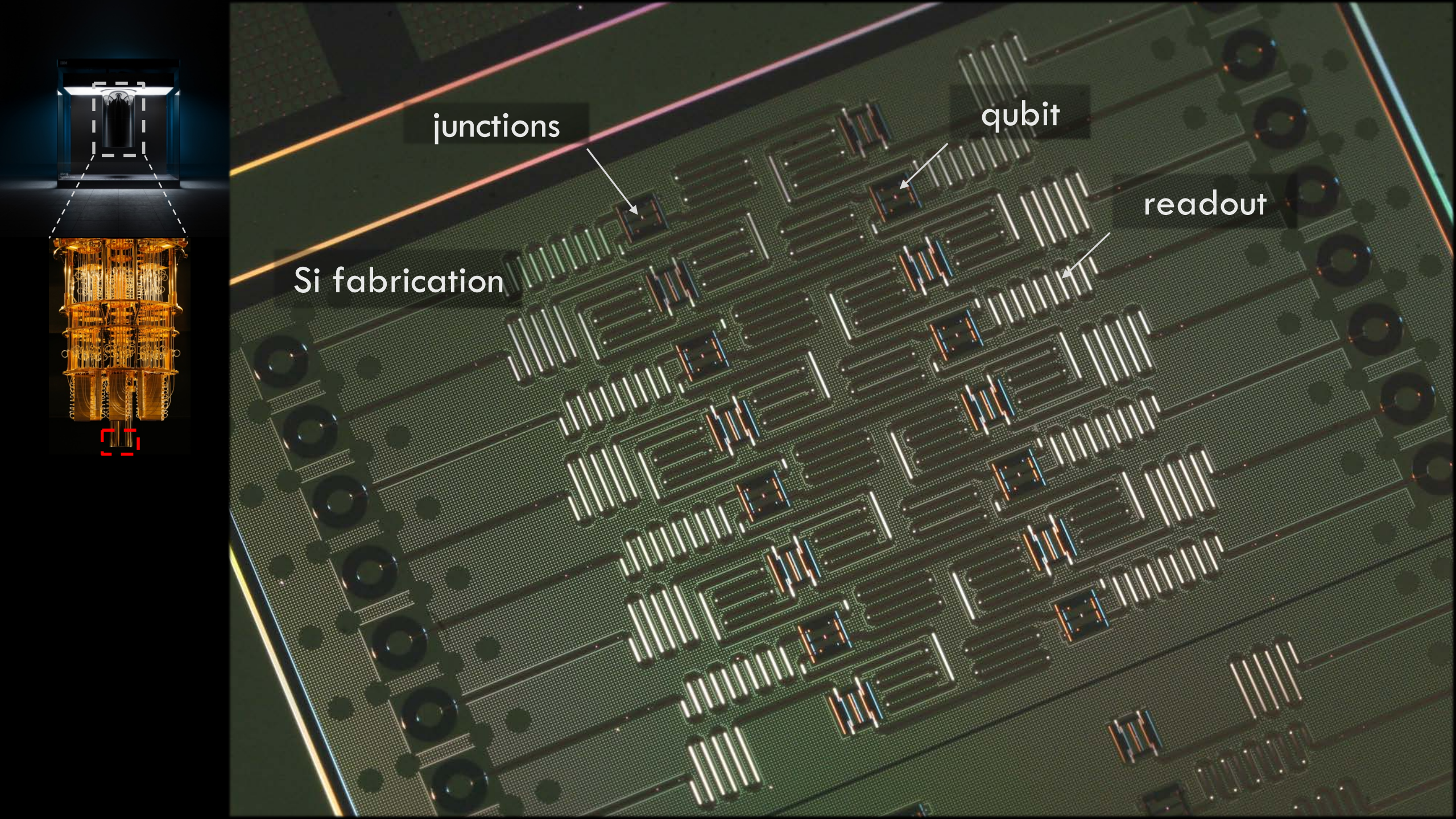
Cloud-based quantum computing

What does today's hardware look like?

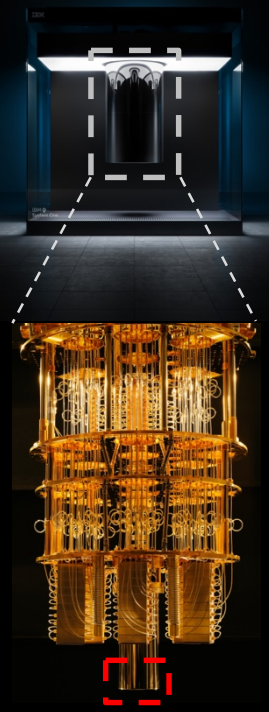
Commercial cloud service

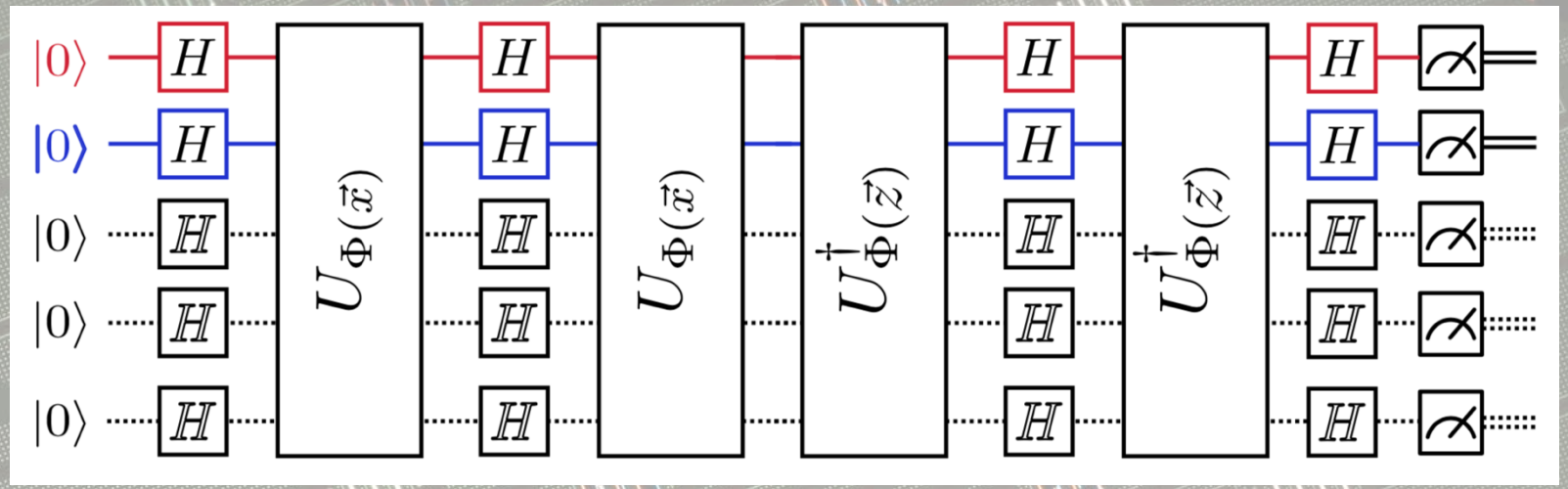





junctions
qubit
readout
Si fabrication

From chip to algorithm





Quantum Applications

Possible application areas for quantum computing

We believe the following areas might be useful to explore for the early applications of quantum computing:

Chemistry

Material design, oil and gas, drug discovery

Artificial Intelligence

Classification, machine learning, linear algebra

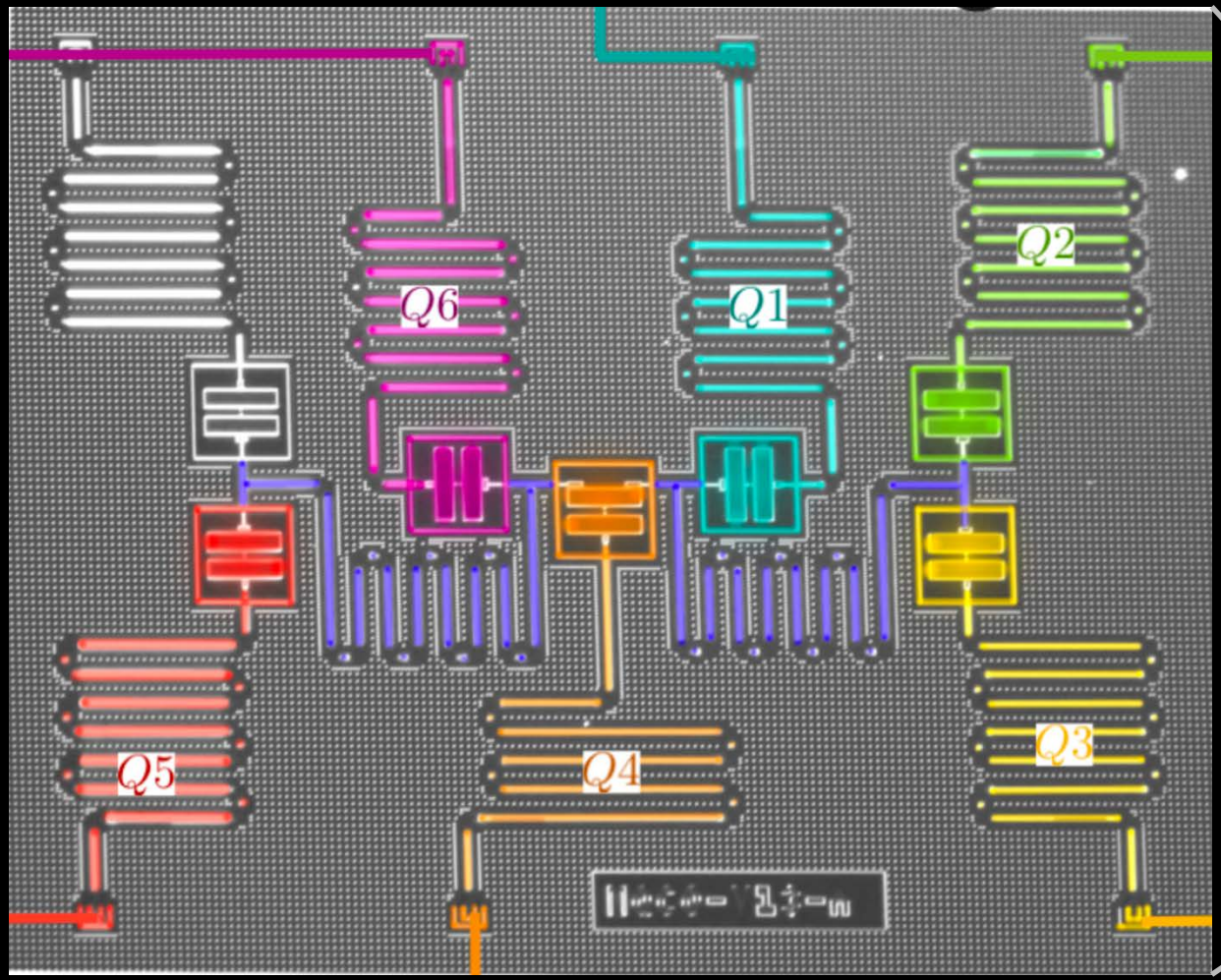
Optimization

Portfolio optimization, scenario analysis, pricing

Letter article for *Nature*

Experimental Results

Computing the ground state energy for small molecules



A. Kandala, et al. (IBM) Nature **549**, 242, 2017

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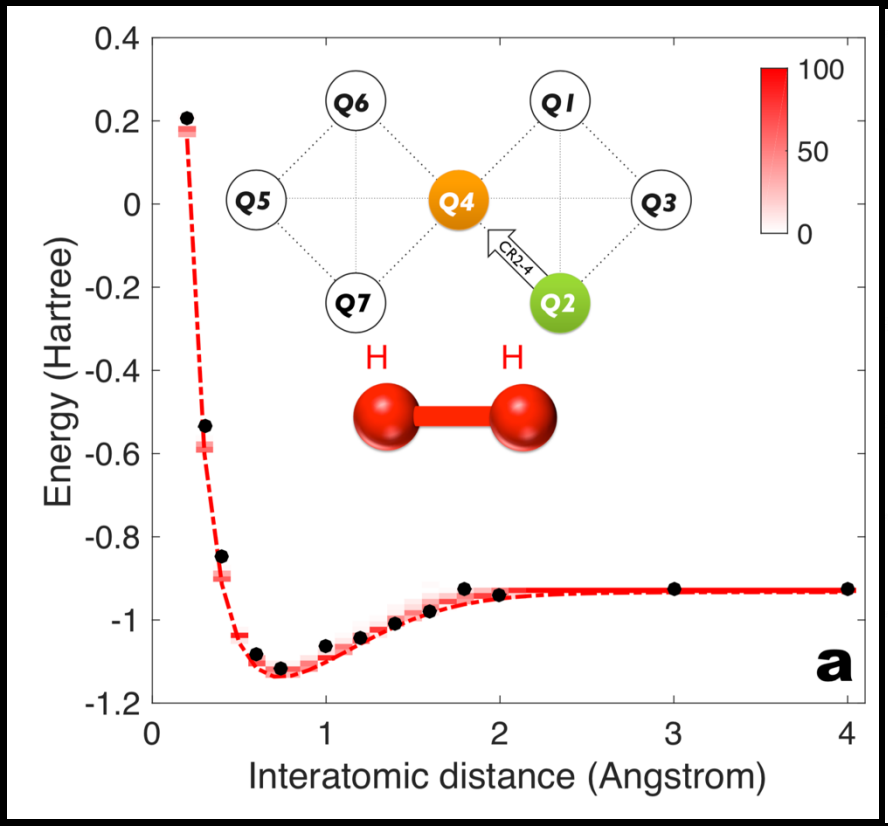
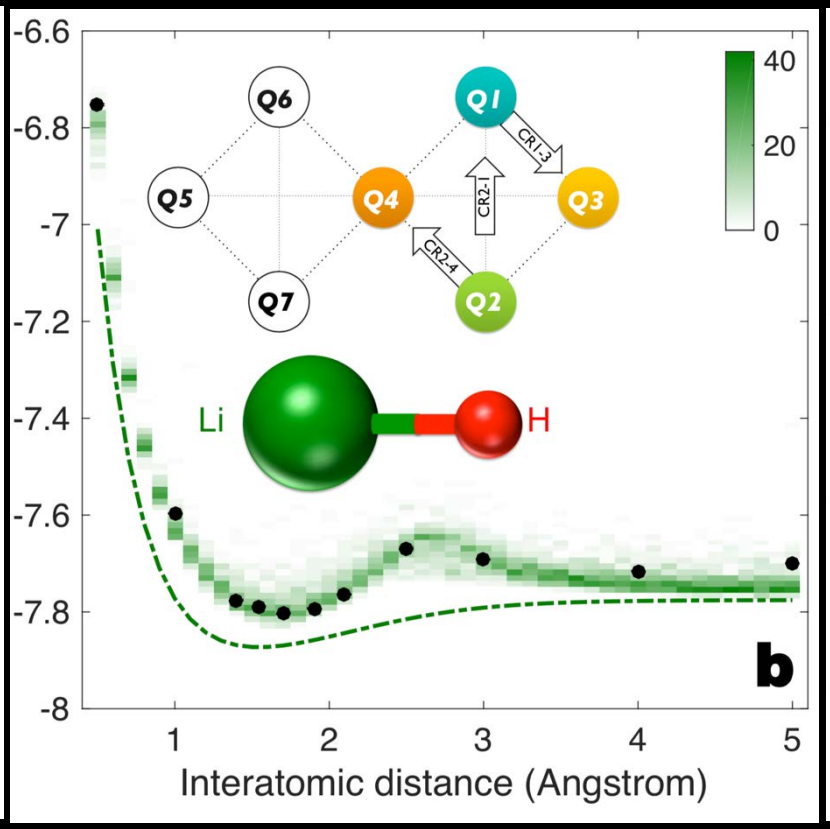
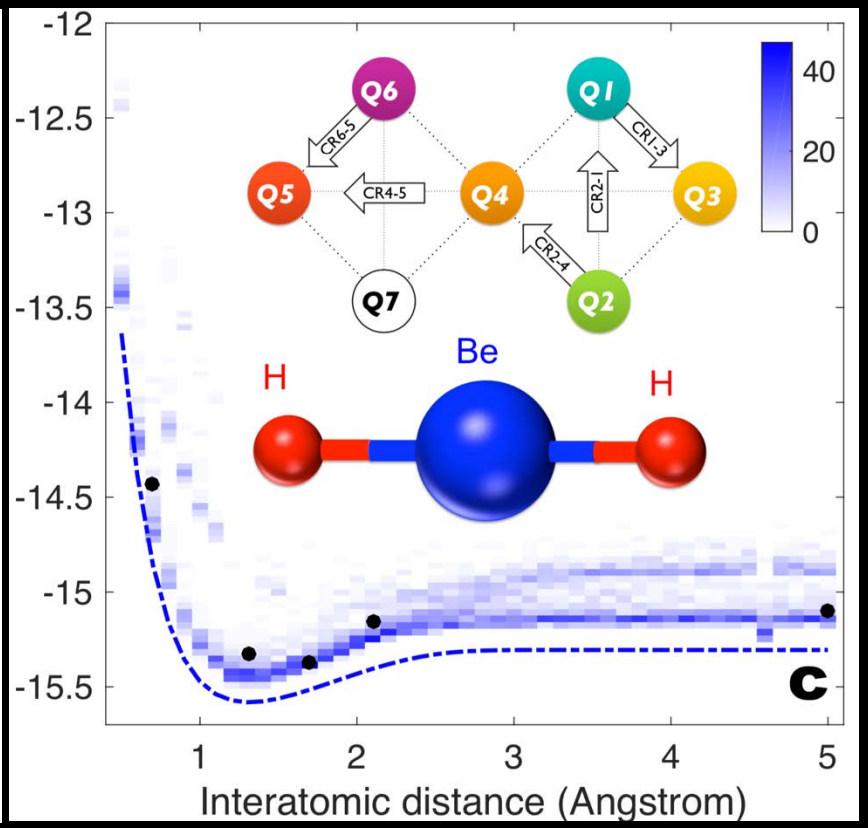
Experimental Results

Computing the ground state energy for small molecules



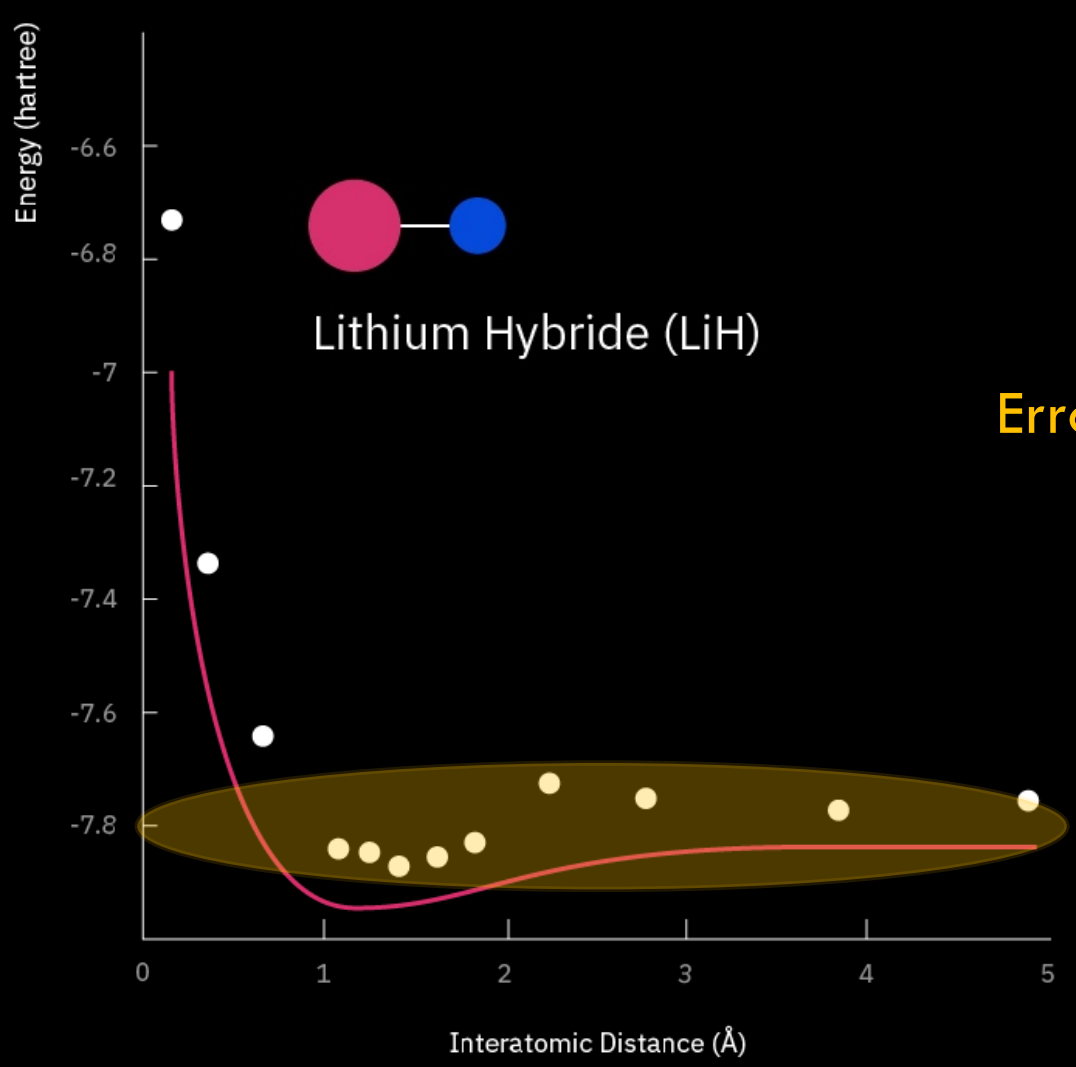




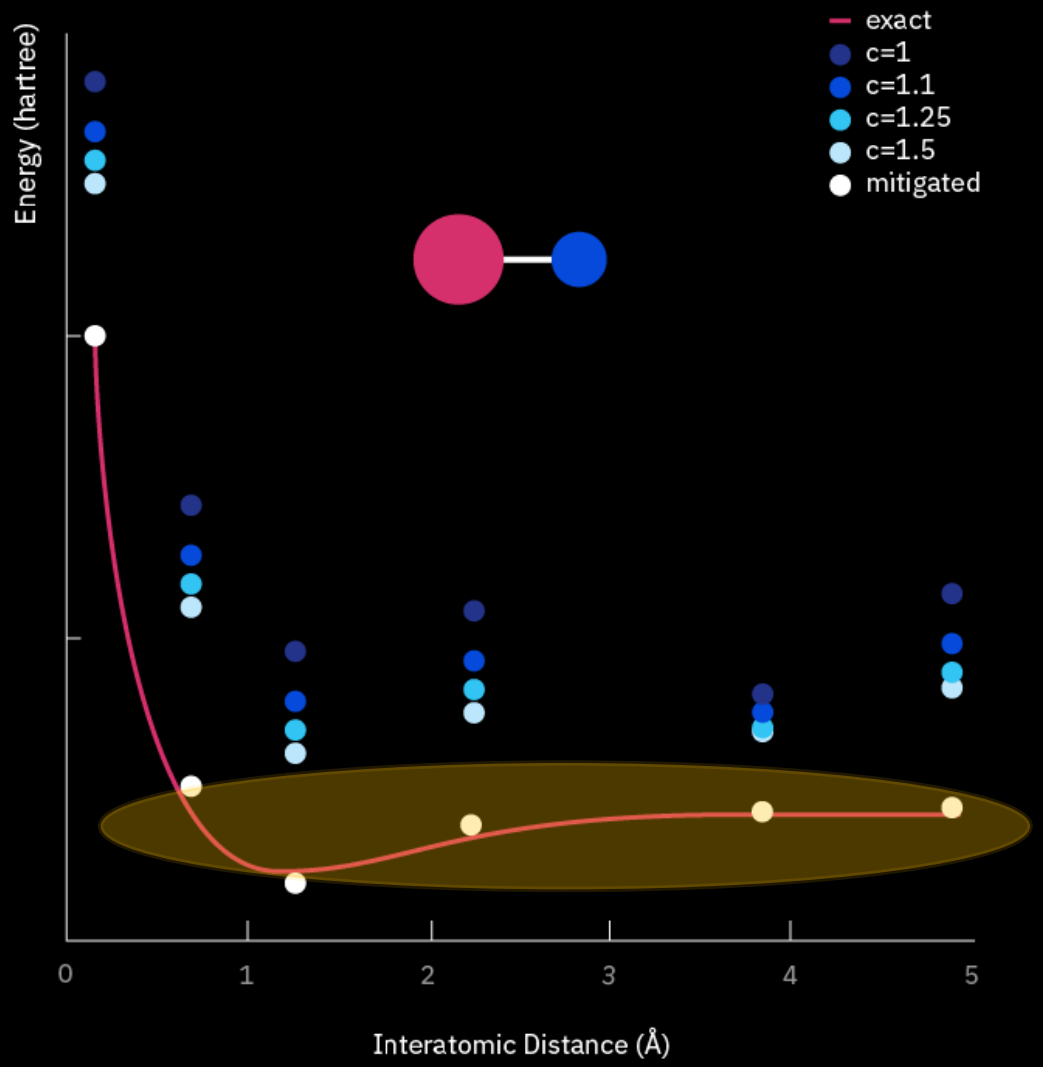
A. Kandala, et al. (IBM) Nature **549**, 242 (2017)

Error mitigation: improving accuracy

Recovering correct result in the presence of noise



Error mitigation



Nature **549,** 242 (2017)

Nature **567,** 491 (2019)

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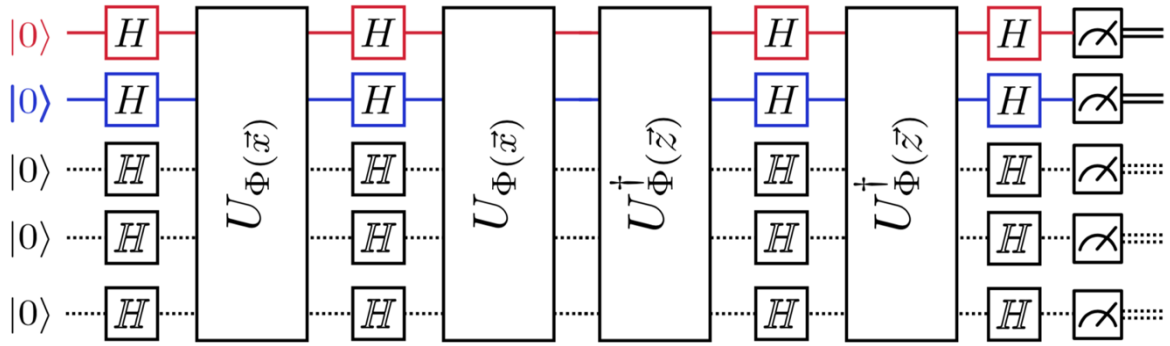
Quantum Machine Learning

Example: Support Vector Machines (SVM)

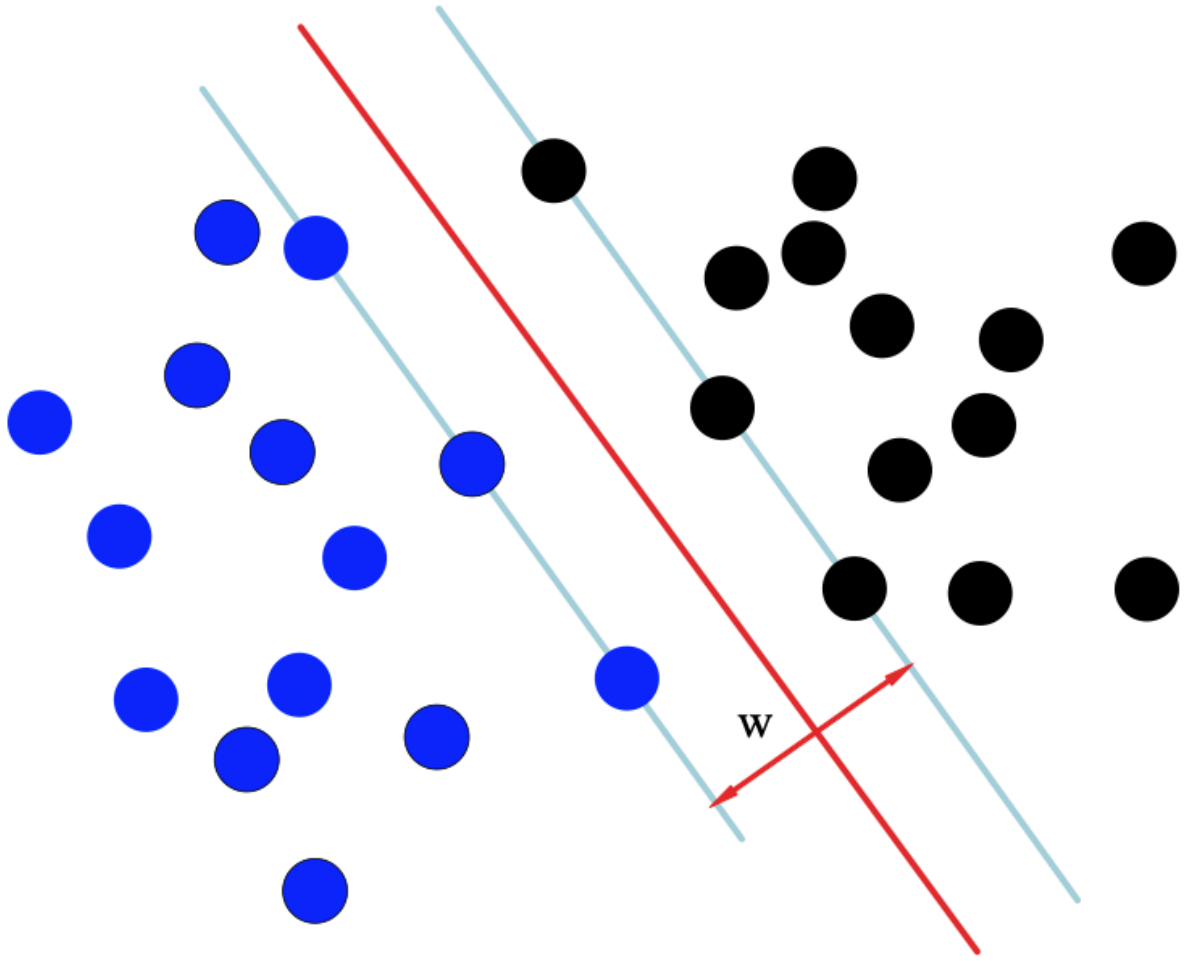
IBM *Nature* **567**, 209 (2019)

Classical vector $\vec{x}$ is encoded into the exponentially-large quantum state space.

Quantum short depth circuits as classifiers



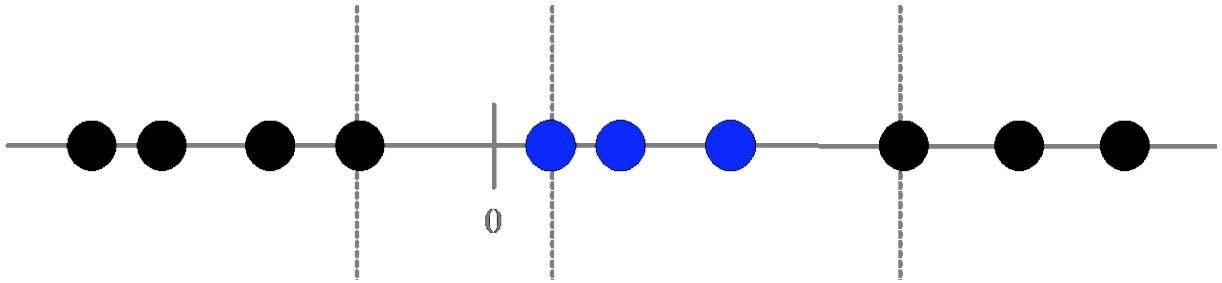
Classical Computing: SVM Classification

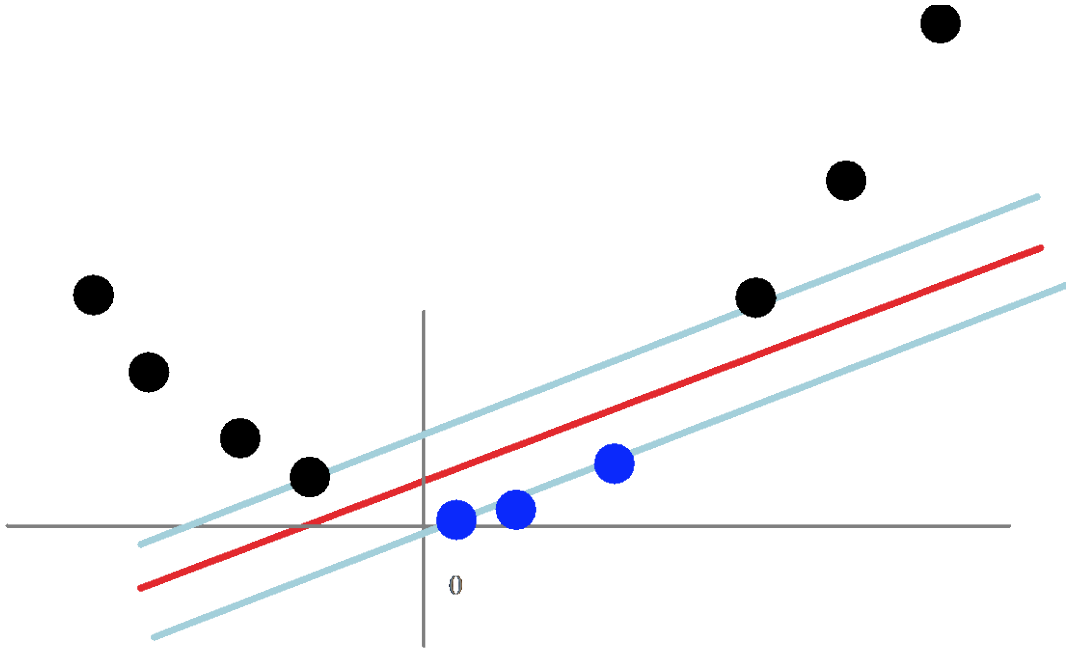


Classical Computing: Feature Space

Data that is *not* linearly separable may become linearly separable by increasing dimensionality.

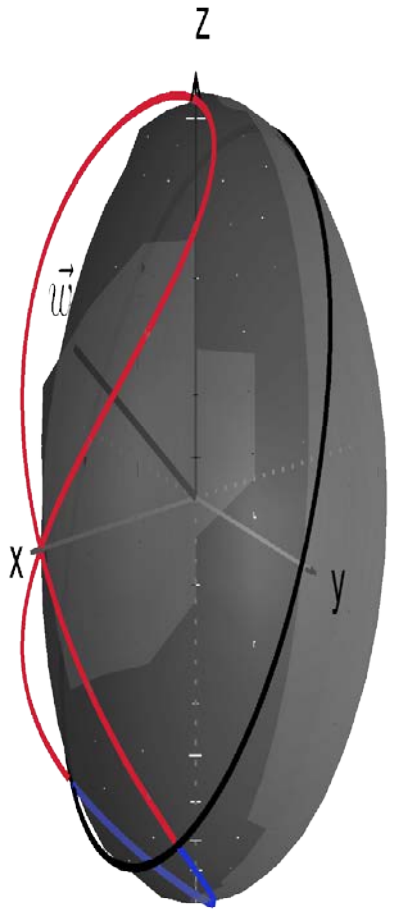
Non-linear classification at cost of dimensionality

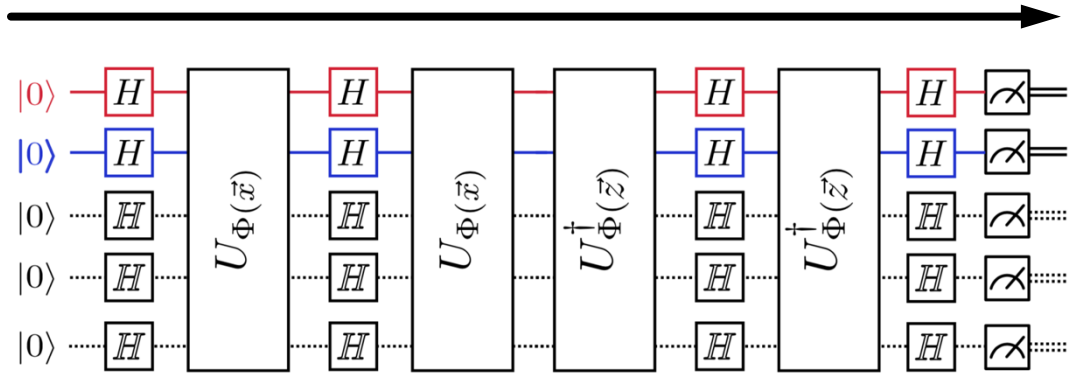




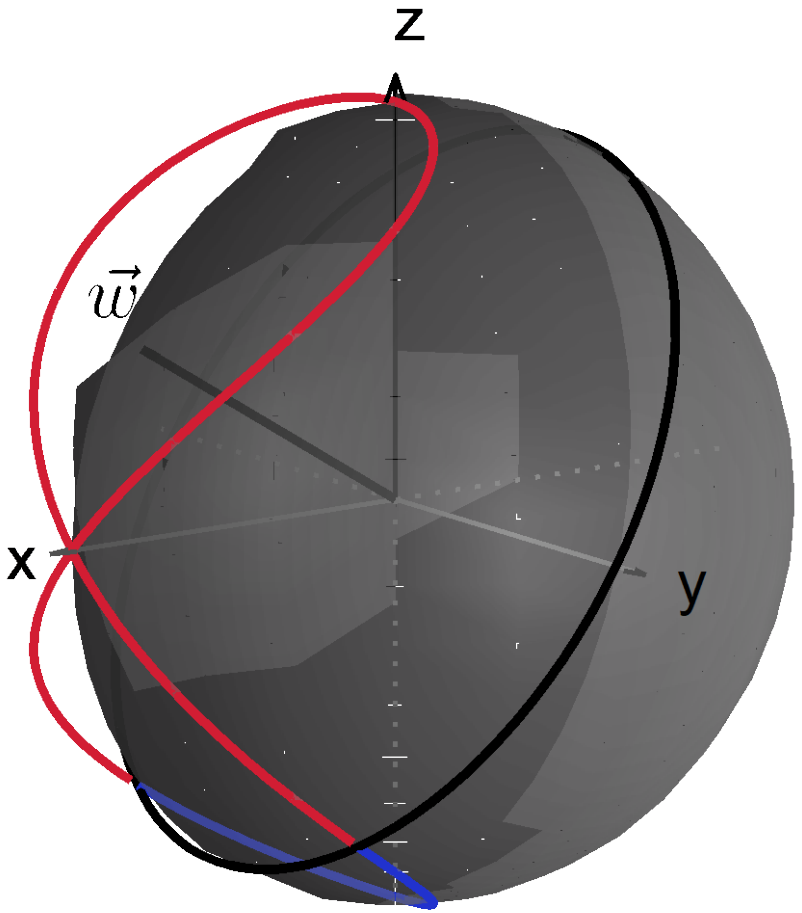
Quantum-Enhanced Feature Space

Classical Classified Data





Quantum state space



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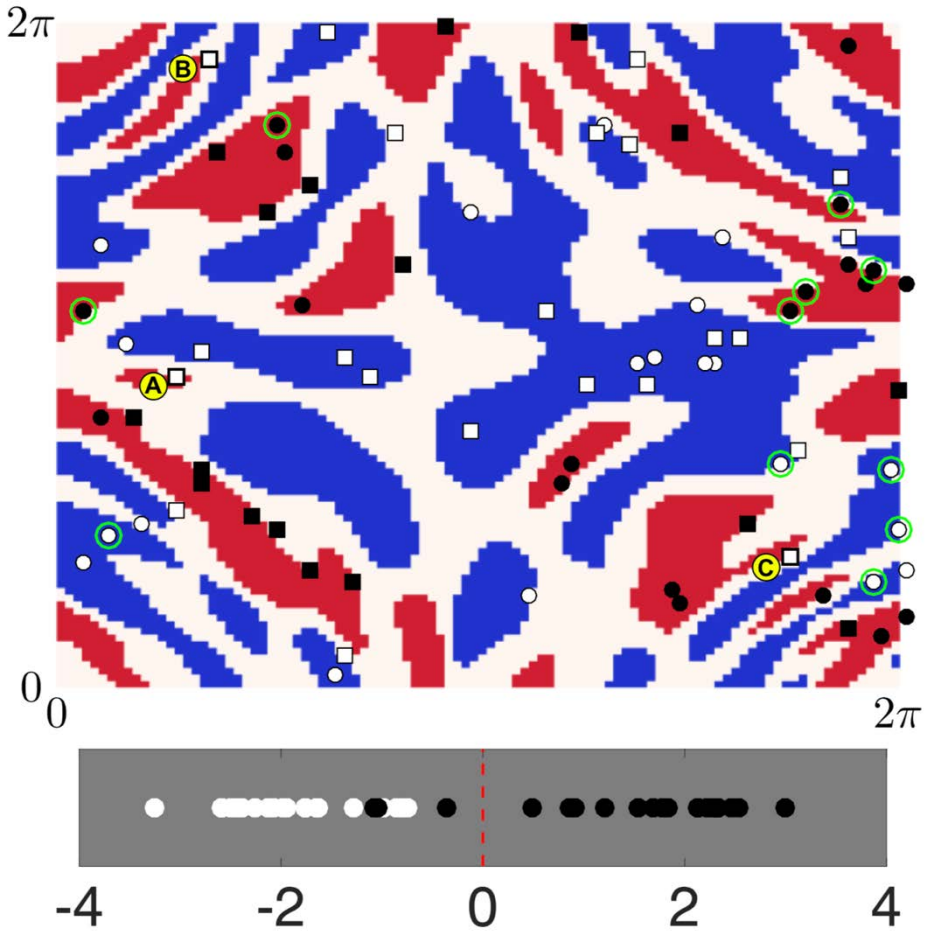
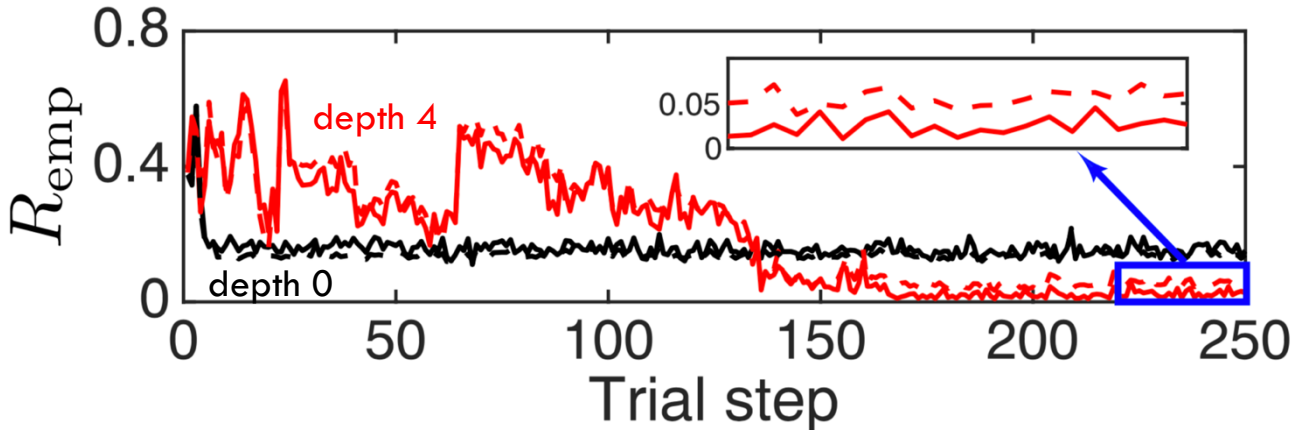
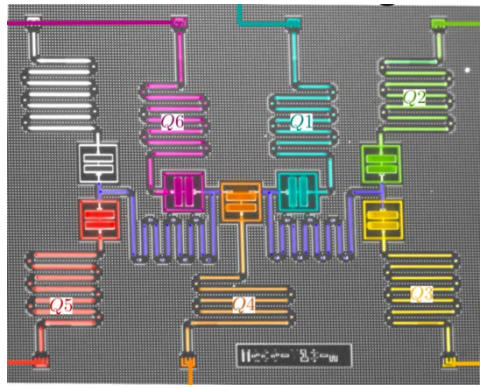
Quantum-Enhanced Feature Space

Classical Classified Data



Training classifier in quantum state space





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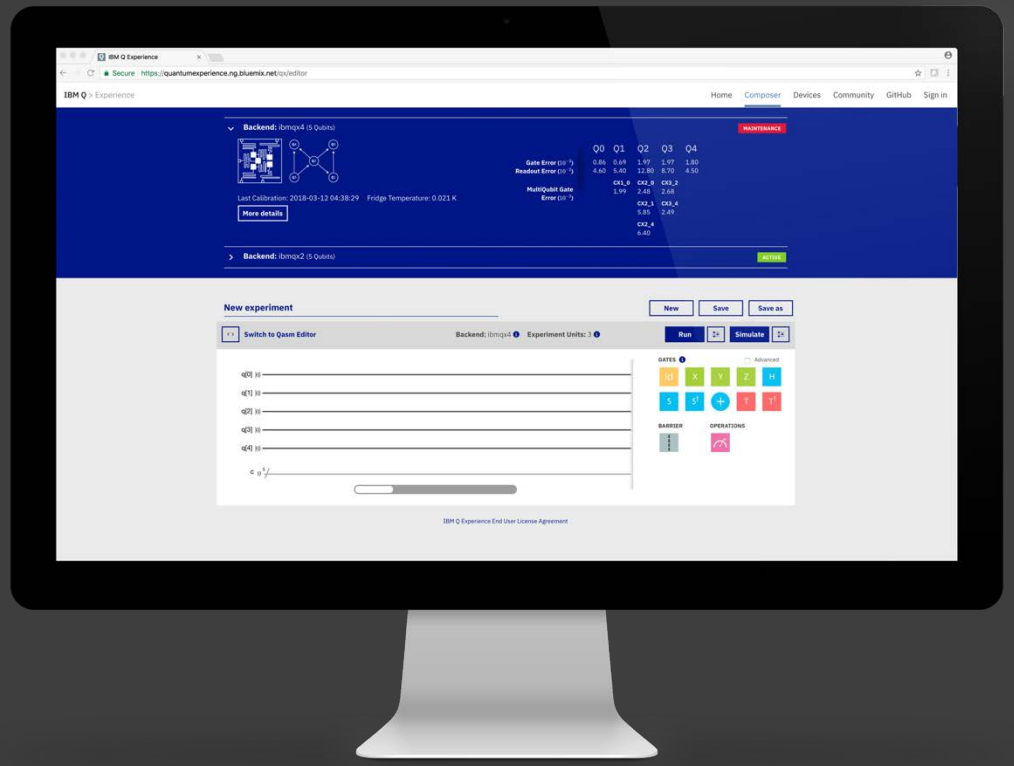
How to start using quantum computers?

Qiskit

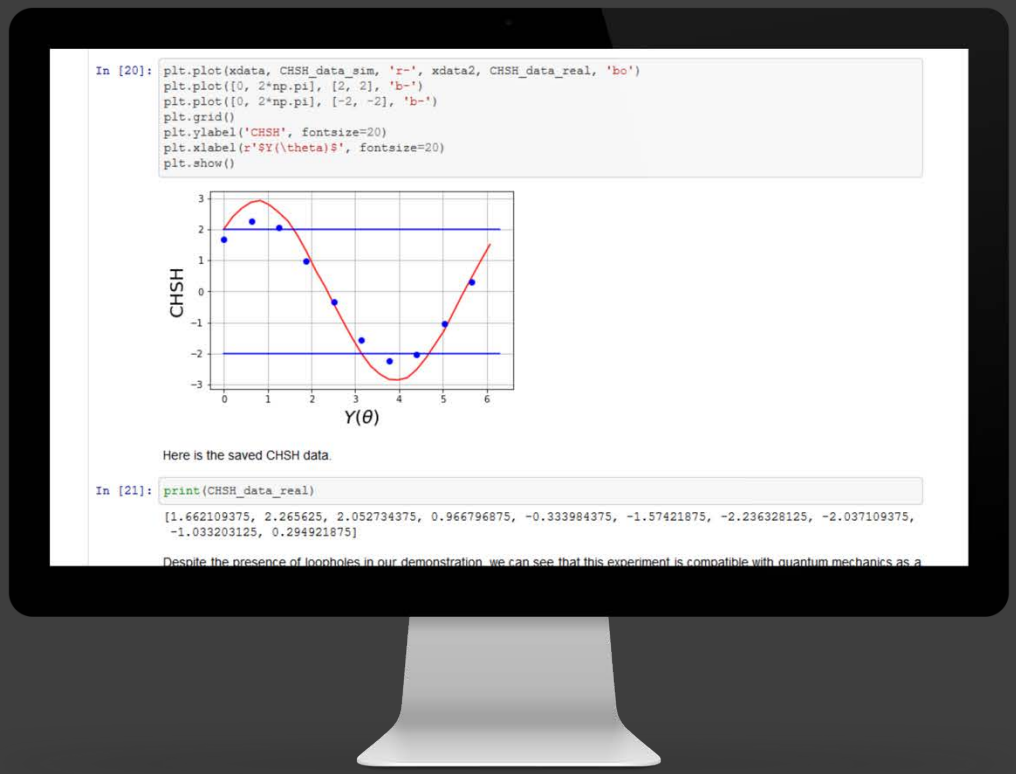
Quantum Community

IBM Q Experience



- Open to public for research and education
- Access via IBM Cloud

QISKit.org



Software kit for short depth quantum circuits
and building near term applications and experiments on quantum computers.

Quantum Computing

IBM Technical Presentation

Thank you!

Zlatko K. Minev, Ph.D.