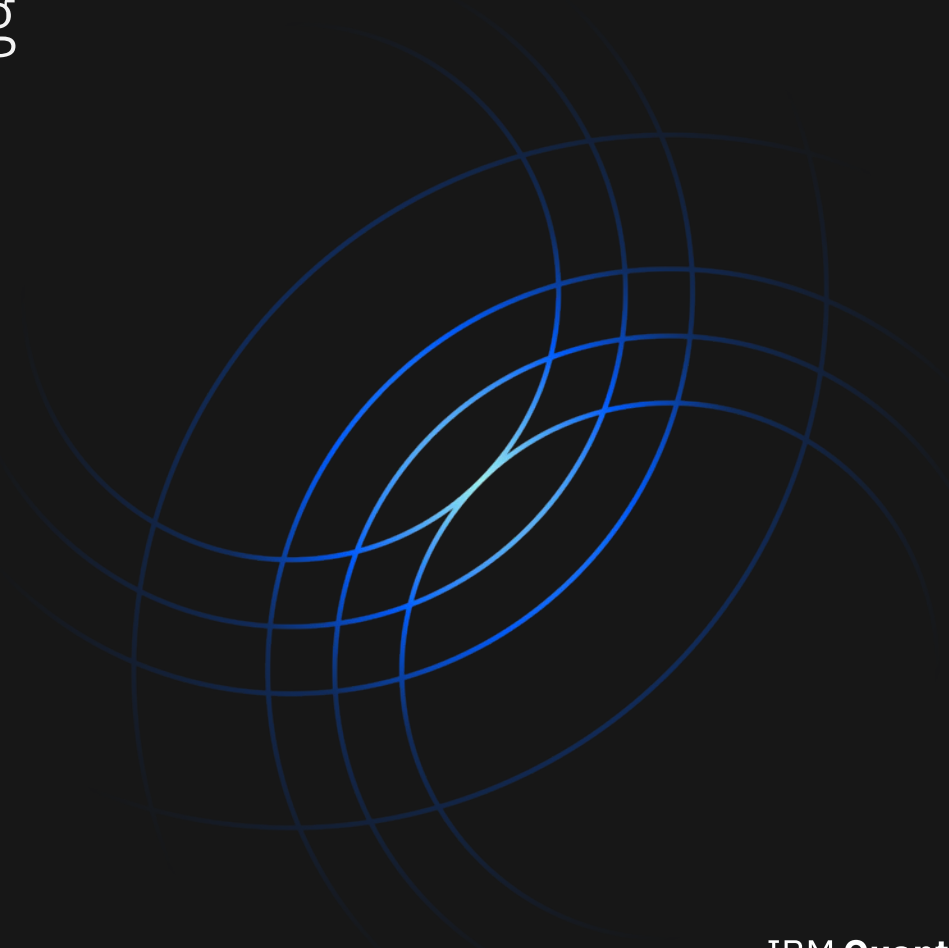
IBM Quantum Computing

Federico Mattei
IBM Quantum Ambassador



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IBM **Quantum**

A path towards quantum advantage

„IBM's point of view and goal is a computational quantum advantage, where a computational task of business or scientific relevance can be performed more ***efficiently****, cost-effectively, or accurately using a quantum computer than with classical computations alone.“*

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Performance =

Scale — Number of qubits — 433 qubit

\+ Quality — Circuit fidelity — 512 QV

\+ Speed — Circuit execution speed — 15.700 CLOPS

Qiskit – Open-Source SDK

High level applications

- Qiskit Nature
- Qiskit Finance
- Qiskit Optimization
- Qiskit Machine Learning

Low level applications

Qiskit

- Qiskit Metal
- Qiskit Dynamics
- Qiskit Experiments

Core Capabilities

- Qiskit Terra

Simulator

- Qiskit Aer

Hardware providers

- IBM
- AQT
- IonQ
- ...

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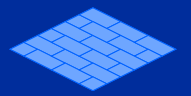
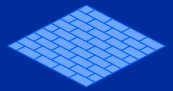
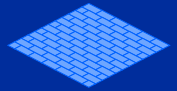
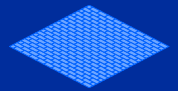
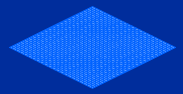
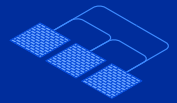
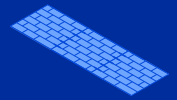
Development Roadmap

Executed by IBM
On target

IBM Quantum

	2019	2020	2021	2022	2023	2024	2025	Beyond 2026
	Run quantum circuits on the IBM cloud	Demonstrate and prototype quantum algorithms and applications	Run quantum programs 100x faster with Qiskit Runtime	Bring dynamic circuits to Qiskit Runtime to unlock more computations	Enhancing applications with elastic computing and parallelization of Qiskit Runtime	Improve accuracy of Qiskit Runtime with scalable error mitigation	Scale quantum applications with circuit knitting toolbox controlling Qiskit Runtime	Increase accuracy and speed of quantum workflows with integration of error correction into Qiskit Runtime
Model Developers					Prototype quantum software applications → Quantum software applications		Machine learning | Natural science | Optimization	
Algorithm Developers		Quantum algorithm and application modules			Quantum Serverless			
		Machine learning | Natural science | Optimization			Intelligent orchestration	Circuit Knitting Toolbox	Circuit libraries	
Kernel Developers	Circuits		Qiskit Runtime					
				Dynamic circuits	Threaded primitives	Error suppression and mitigation		Error correction
System Modularity	Falcon 27 qubits	Hummingbird 65 qubits	Eagle 127 qubits	Osprey 433 qubits	Condor 1,121 qubits	Flamingo 1,386+ qubits	Kookaburra 4,158+ qubits	Scaling to 10K-100K qubits with classical and quantum communication
					Heron 133 qubits x p	Crossbill 408 qubits		



IBM **Quantum** – On the cloud since May 2016

Over 500,000 registered users

More than 25 quantum computing systems on the IBM Cloud, and written over

2000+ scientific and research papers.

IBM Quantum Network members worldwide
> 220 Worldwide

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Strategic partnerships to accelerate regional quantum ecosystems

IBM Quantum

IBM Quantum datacenter in NY

Fraunhofer
Jan 2021

University of Tokyo
July 2021

Cleveland Clinic
1Q23

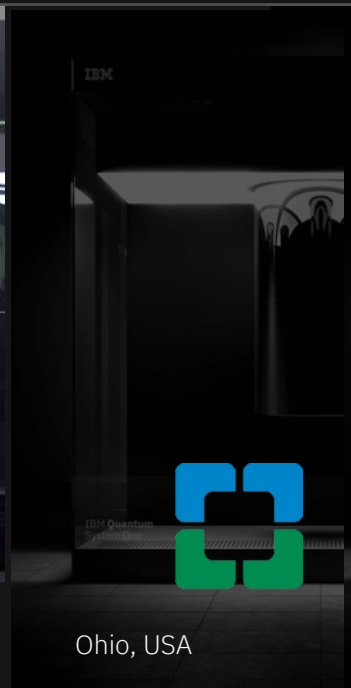
Yonsei University
Projected 2023

Quebec
Projected 2023

New York, USA

Ehningen, Germany

Shin-Kawasaki, Japan



Ohio, USA

Seoul, South Korea

Bromont, Canada

Mercedes-Benz

Quantum Computing for Materials Discovery and Manufacturing Optimization

Mercedes-Benz and IBM have recently published a series of papers demonstrating progress toward using quantum computers to model material systems including Lithium-sulfur that are relevant to advancing the performance of batteries. The teams have also demonstrated applications in manufacturing defect analysis and product recommendation.

“Developing and perfecting these hypothetical batteries could unlock a billion-dollar opportunity.”

Benjamin Boeser
[Former] Director of Innovation Management, Silicon Valley at Mercedes-Benz R&D North America

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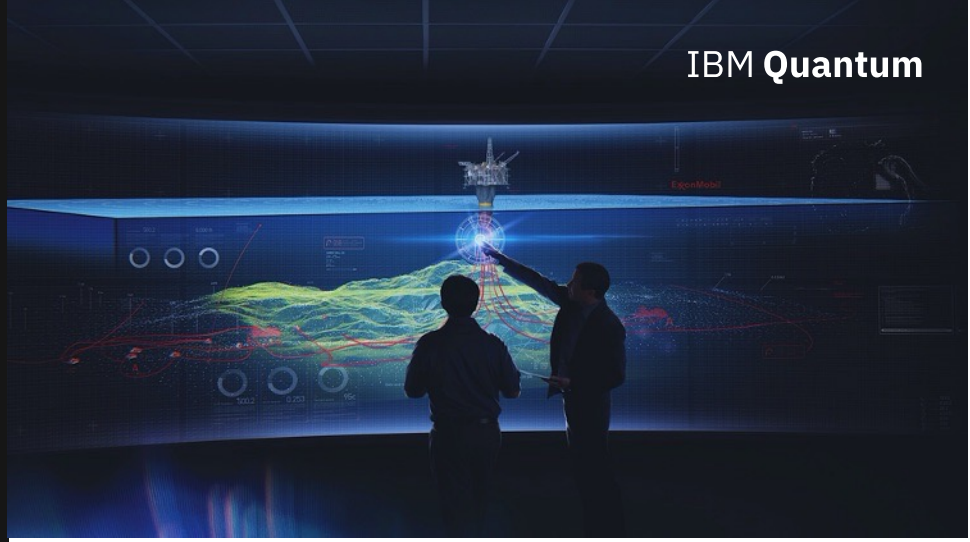
ExxonMobil



Quantum Computing as a Tool for Chemistry and Engineering

Working together, ExxonMobil and IBM recently demonstrated advancements in using quantum computers to accurately calculate thermodynamic observables, demonstrating how quantum can be the next generation tool for chemists and chemical engineers developing advanced energy solutions.

"We know in our bones that there are huge global challenges that we will tackle in the foreseeable future. When quantum computing scales to become utterly disruptive, we'll be ready."

Dr. Vijay Swarup
ExxonMobil Vice President of Research and Development

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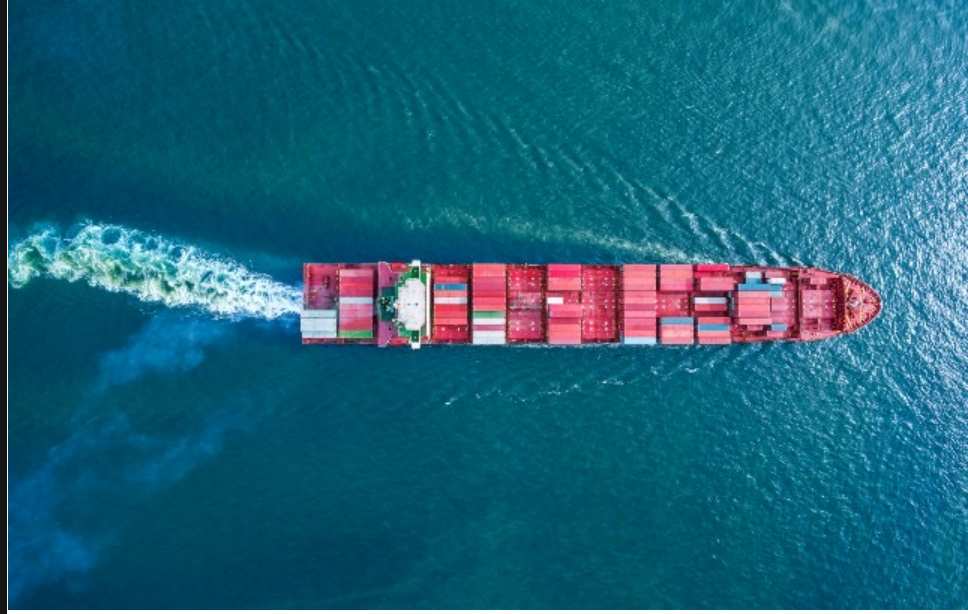
ExxonMobil

Maritime Routing's Mind-Boggling Math

In 2021 more than 500 LNG (liquified natural gas) ships are used to transport critical fuel supplies across the oceans. Together, they make thousands of journeys per year to destination ports where the LNG is deployed to power critical infrastructure.

Finding optimal routes for a fleet of such ships can be a mind-bendingly complex optimization problem.



Quantum computers take a new approach to addressing this sort of complexity, with the potential to find solutions that classical supercomputer alone cannot handle. Industry leaders like Exxon are getting involved now to explore how blending classical and quantum computing techniques might solve big, complex, pressing global challenges.

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JP Morgan Chase

Quantum Computing for the Financial Services Industry

Recently, JPMC and IBM used Quantum Amplitude Estimation, a Monte Carlo-like sampling algorithm, to compute European option pricing, pricing path depend options, showing a quadratic speed-up versus a classical Monte Carlo approach.

European derivative pricing on a Quantum computer implements the Black-Scholes model using a Quantum Machine Learning Algorithm, namely a quantum Generative Adversarial Network (qGAN). The qGAN utility loads the log-normal probability distribution and models the spot price of an asset underlying a European call option.

The resulting model can then be integrated into a Quantum Amplitude Estimation based algorithm to evaluate the expected payoff.

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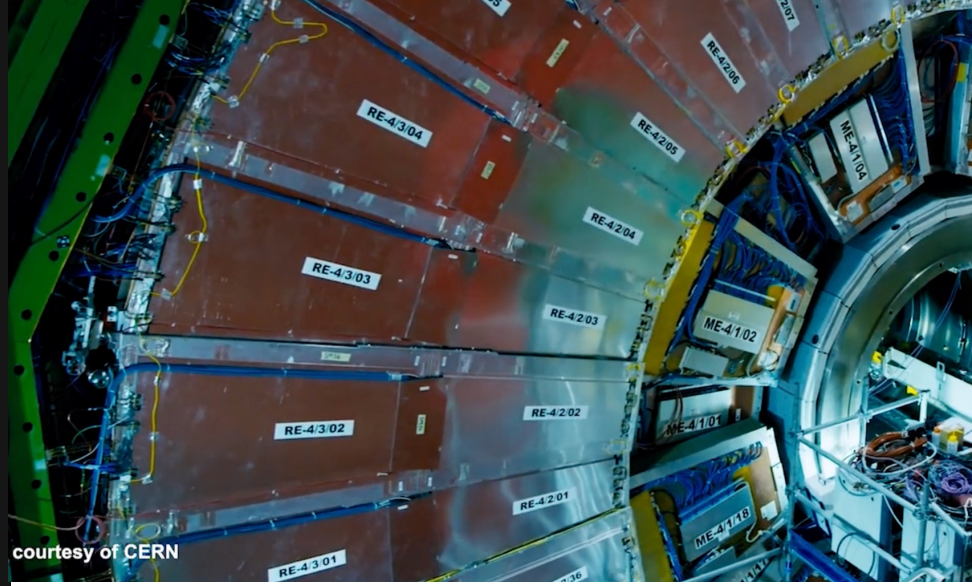
CERN

Quantum Machine Learning to understand what sews the universe together

CERN's partnership with IBM Quantum seeks new ways of finding patterns in data of the Large Hadron Collider. A recent collaboration with IBM scientists involves the detection and analysis of the Higgs boson, a recently discovered particle that helps explain the origin of mass. Sifting through raw data to find occurrences of Higgs behavior is a knotty problem that stretches classical computers to their limit.



"Quantum computing may play a significant role in (...) exploring the many open questions related to issues such as dark matter, dark energy, (...) and more."

Alberto Di Meglio
Head of CERN openlab

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Mitsubishi Chemical, JSR and Keio University

Exploring new forms of light with Quantum Computing

A Japanese research partnership comprising corporate teams from industrial chemists Mitsubishi Chemical and JSR Corporation, and academics from Keio University, have joined the IBM Quantum Network. Their mission is to collaborate with IBM scientists to create a new breed of disruptively efficient OLED materials — flexible, scalable and able to produce more (and more visually appealing) light with far less energy.

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