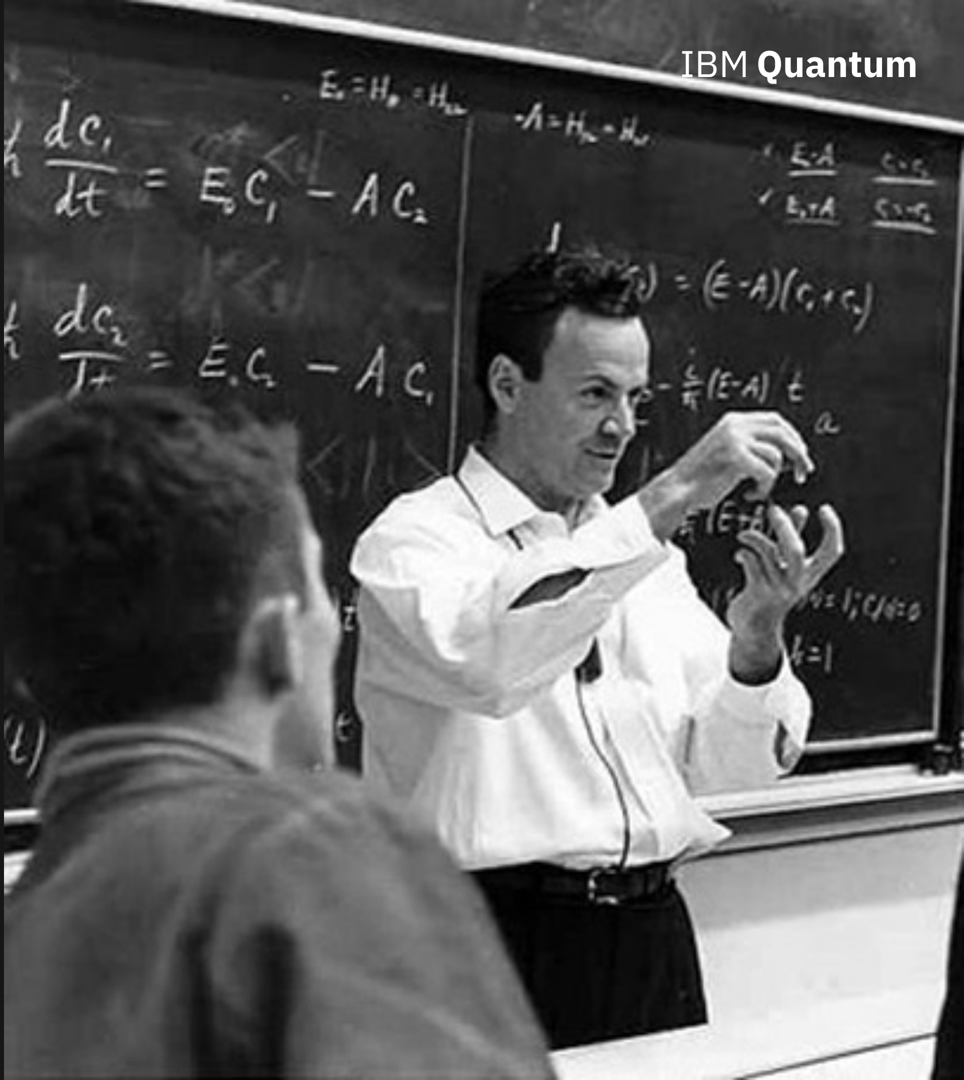
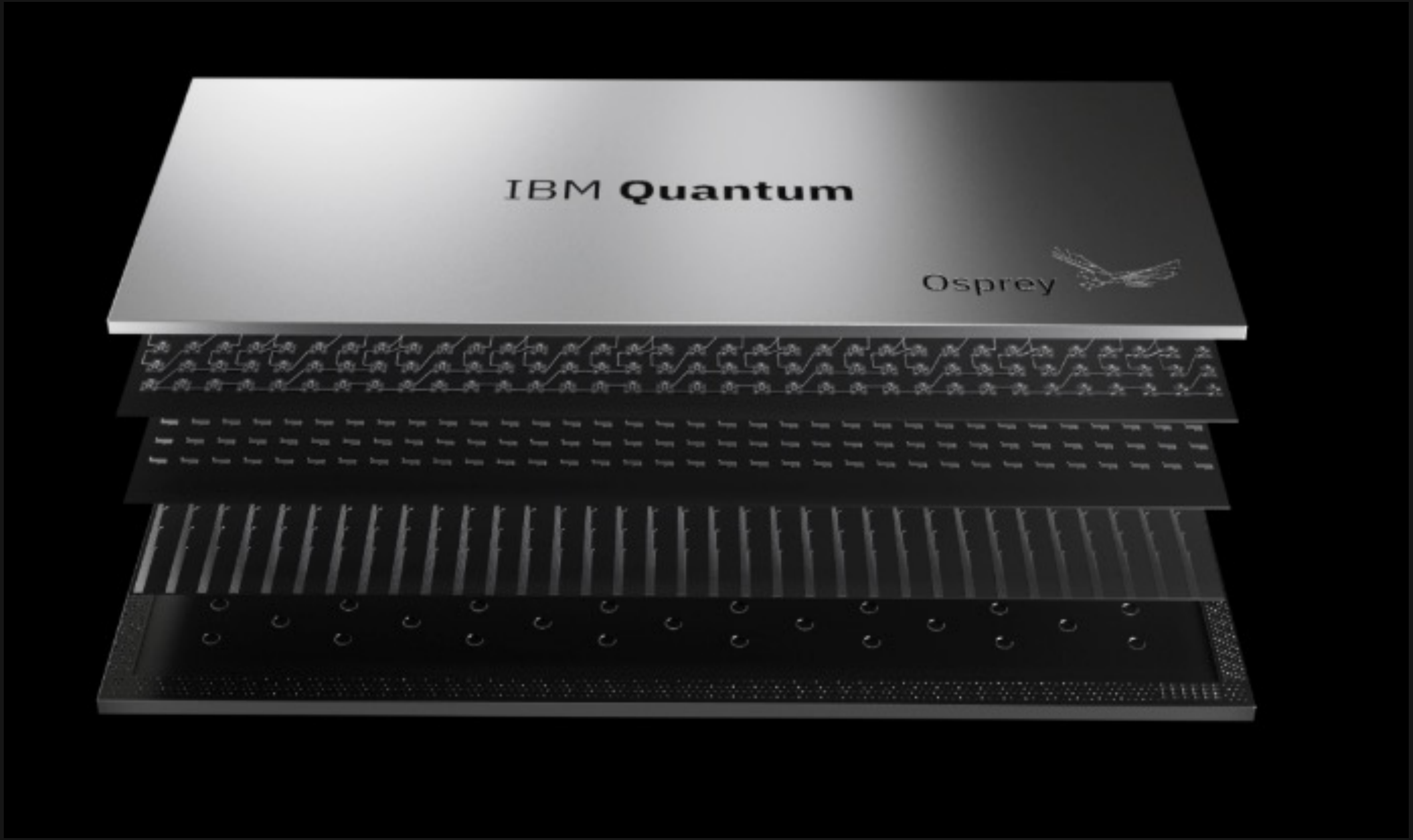
“I’m not happy with all the analyses that go with just the classical theory, because nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical ...”

Richard P. Feynman
Department of Physics,
California Institute of Technology

International Journal of Theoretical Physics,
Vol 21, Nos. 6/7, 1982




IBM Quantum
Osprey

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

Over 400,000 registered users have run …

over 2 TRILLION hardware quantum circuits in total, and users run …

over 4 BILLION hardware quantum circuits on a typical day on …

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

1500+ scientific and research papers.

Feuille de route de développement | Réalisé par IBM ✓ En cible

IBM Quantum

2019 ✓	2020 ✓	2021 ✓	2022 ✓	2023	2024	2025	Beyond 2026
Exécuter des circuits quantiques sur IBM Cloud	Démontrer et prototyper des algorithmes et des applications quantiques	Exécuter des programmes quantiques 100 fois plus rapidement avec Qiskit Runtime	Apporter des circuits dynamiques à Qiskit Runtime pour déverrouiller plus de calculs	Optimisation des applications grâce à la parallélisation et à la puissance de calcul flexible de Qiskit Runtime	Améliorer la précision de Qiskit Runtime avec atténuation évolutive des erreurs	Passer à l'échelle les applications quantiques avec une décomposition des circuits complexes via l'outillage de Qiskit Runtime	Augmenter la précision et la vitesse des flux de travail quantiques grâce à l'intégration de la correction d'erreur dans Qiskit Runtime

Développeurs de modèles

- Prototypes d'applications logicielles quantiques → Applications logicielles quantiques
- Apprentissage Automatique | Optimisation | Sciences naturelles

Développeurs d'algorithmes

- Algorithme quantique et modules d'applications ✓
  - Apprentissage Automatique | Sciences naturelles | Optimisation
- Quantum Serverless
  - Orchestration intelligente
  - Primitives de decomposition des circuits
  - Librairies de circuits

Développeurs de noyaux

- Circuits ✓
- Qiskit Runtime ✓
  - Circuits dynamiques ✓
  - Primitives filetées
  - Suppression et atténuation des erreurs
  - Correction d'erreurs

Systèmes modulaires

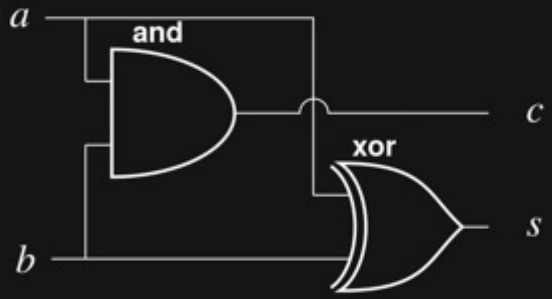
- Falcon ✓ 27 qubits
- Hummingbird ✓ 65 qubits
- Eagle ✓ 127 qubits
- Osprey ✓ 433 qubits
- Condor 1,121 qubits
- Flamingo 1,386+ qubits
- Kookaburra 4,158+ qubits
- Mise à l'echelle vers 10K-100K qubits incluant la communication entre classique et quantique
- Heron 133 qubits x p
- Crossbill 408 qubits

Bits and classical logic circuits

0

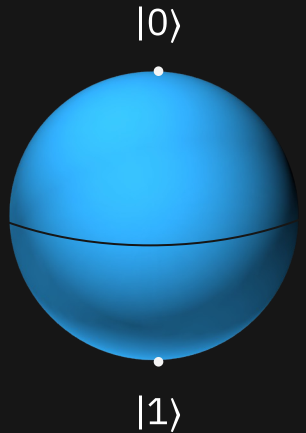
1

A bit is a controllable classical object that is the unit of information

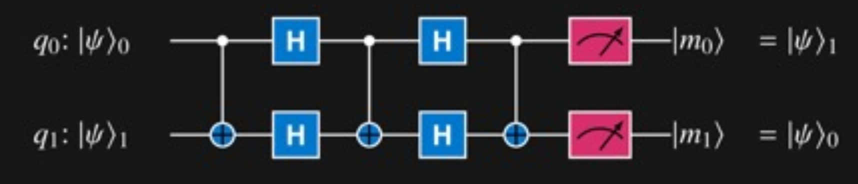


A classical logic circuit is a set of gate operations on bits and is the unit of computation

Quantum bits (qubits) and quantum circuits



A quantum bit or qubit is a controllable quantum object that is the unit of information



A quantum circuit is a set of quantum gate operations on qubits and is the unit of computation

Exponential growth

$$2^3$$

1 qubit – 2 quantum state dimensions

$$a\,|0\rangle + b\,|1\rangle$$

where *a* and *b* are complex numbers.

2 qubits – 4 quantum state dimensions

$$a\,|00\rangle + b\,|01\rangle + c\,|10\rangle + d\,|11\rangle$$

where *a, b, c,* and *d* are complex numbers.

3 qubits – 8 quantum state dimensions

$$a\,|000\rangle + b\,|001\rangle + c\,|010\rangle + d\,|011\rangle +$$
$$e\,|100\rangle + f\,|101\rangle + g\,|110\rangle + h\,|111\rangle$$

where *a, b, … , g,* and *h* are complex numbers.

We now have **eight** items of numeric data.

Exponential growth

$$2^n$$

n qubits – 2^n quantum state dimensions.

$2^{10} = 1{,}024$

$2^{20} = 1{,}048{,}576$

$2^{50} = 1{,}125{,}899{,}906{,}842{,}624$

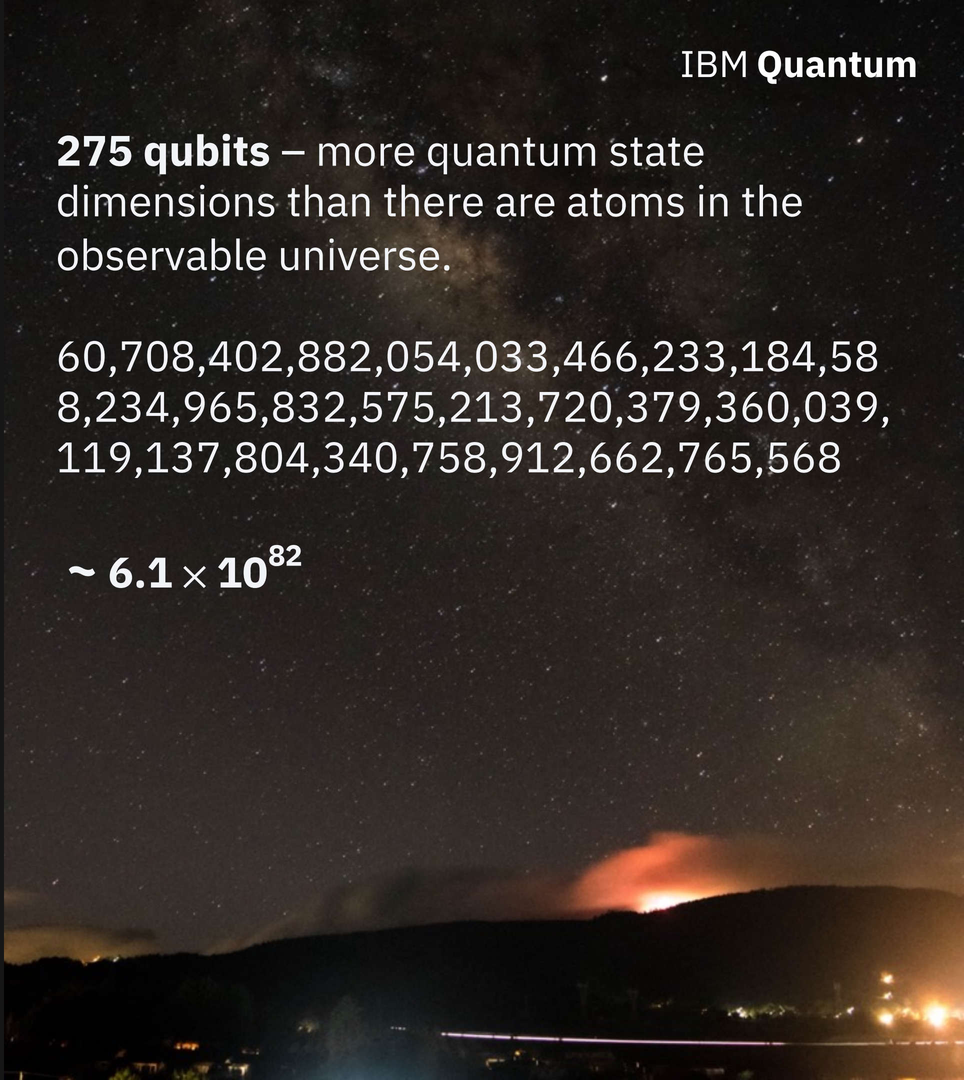
$2^{65} = 36{,}893{,}488{,}147{,}419{,}103{,}232$

$2^{127} = 170{,}141{,}183{,}460{,}469{,}231{,}731{,}687{,}303{,}715{,}884{,}105{,}728$

Exponential growth

IBM **Quantum**

$$2^{275}$$



275 qubits – more quantum state dimensions than there are atoms in the observable universe.

60,708,402,882,054,033,466,233,184,58
8,234,965,832,575,213,720,379,360,039,
119,137,804,340,758,912,662,765,568

$\sim \mathbf{6.1 \times 10^{82}}$

IBM Quantum Network Today

212 total

18 industry partners

24 hubs

56 members

49 startups

65 academic members and partners

Current as of 2022-10-24 19:00:08

Partners

BP
Boeing
Bosch
Capgemini SE
Credit Mutuel
Daimler
E.ON
Erste Group Bank AG
ExxonMobil
Goldman Sachs
HSBC
JP Morgan Chase
JSR Corporation
LG Corporation
Samsung Advanced Institute of Technology
Tokyo Electron Limited
Wells Fargo
Woodside Energy Ltd

Hubs

Arizona State University
Brookhaven National Lab
Bundeswehr University Munich
CERN Openlab
Cleveland Clinic Foundation
Deutsches Elektronen Synchrotron
Fraunhofer
KEIO University
Korea Quantum Computing Corporation
Lantik SA
Los Alamos National Laboratory
National Taiwan University
North Carolina State University
Oak Ridge National Lab
Pacific Northwest National Lab
Poznan Supercomputing and Networking Center
Quebec PINQ2
Science and Technology Facilities Council Daresbury
Sungkyunkwan University
United States Air Force Research Lab
University of Melbourne
University of Sherbrooke
University of Tokyo
Yonsei University

Members

Amgen
Anthem
Argonne National Lab
Assured Information Security
CMC Microsystems
Carnegie Mellon Software Engineering Institute
Consiglio Nazionale delle Ricerche - Istituto di calcolo e reti ad alte prestazioni
DIC Corporation
Fermi National Accelerator Laboratory
Fidelity Investments
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Fraunhofer members
GE Global Research
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Hitachi Ltd
III Taiwan
Industrial Technology Research Institute
Istituto Italiano di Tecnologia
Lawrence Berkeley National Laboratory (Berkeley Lab)
Lockheed Martin
Mitsubishi Chemical Corporation
Mitsubishi UFJ Financial Group
Mizuho Bank
Molecular Forecaster Inc
National Institute for Nuclear Physics
RIKEN National Research and Development Agency
Sandia National Labs
Sony
Sumitomo Mitsui Trust Bank Limited
System Vertrieb Alexander GmbH
TNO
Toshiba
Toyota
Toyota Central RD Labs
United States Naval Research Laboratory
Yokogawa Electric Corporation

Startups

1Qbit Systems
AIQTECH Inc
Agnostiq Inc
Aliro Quantum
Applied Quantum Computing
Apply Science
Beit
Blueqat
Boxcat Inc
Cambridge Quantum Computing
Classiq
ColdQuanta
Entangled Networks Ltd.
Entropica Labs
Equal1
HQS Quantum Simulations
Horizon Quantum Computing
JoS Quantum
Keysight
Kipu Quantum
Max Kelsen
Menten AI
Miraex
Multiverse Computing
NetraMark Corp
Nordic Quantum Computing Group
Opacity
Phasecraft
ProteinQure
Q-Ctrl
QC Ware
QEDMA Quantum Computing
Qu & Co
Quantfi
Quantum MADS
Quantum Machines
Quantum South
Quantum Technology Foundation of Thailand
Qunasys
Rahko
SoftwareQ
Solid State AI
SpinUp AI
Strangeworks
Super Tech Labs
Xanadu
Zapata Computing Inc
Zurich Instruments
qBraid Co

Academic

Aalto University
Boston University
Bowie State University
Centrum Wiskunde & Informatica
Chalmers University of Technology
Clemson University
Cornell University
ETH Zurich
Florida State University
Georgia Institute of Technology
Hampton University
Hanyang University
Harvard University
Howard University
Indian Institute of Technology - Madras IIT
Johns Hopkins University
Korea Advanced Institute of Science and Technology
Korea University
Maastricht University
Massachusetts Institute of Technology
Morehouse College
Morgan State University
National University of Singapore
Netherlands Organization for Applied Scientific Research
Netherlands eScience Center
New Mexico State University
New York University
North Carolina AT State University
Northeastern University
Northwestern University
Pohang University of Science and Technology
Prairie View AM University
Princeton University
Purdue University
Saarland University
Seoul National University
Southern University and A&M College
Stanford University
Stony Brook University
Surf
Swiss Federal Institute of Technology Lausanne
The University of Texas at Austin
Turku University
Tuskegee University
Ulsan National Institute of Science and Technology
United States Naval Postgraduate Military University
University of Amsterdam
University of Basque Country
University of Chicago
University of Georgia
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University of Minho
University of Montpellier
University of New Mexico
University of Oxford
University of South Carolina
University of Southern California
University of Tennessee
University of Washington
University of Waterloo
University of Witwatersrand Johannesburg
University of the District of Columbia Community College
Virginia Tech

Quantum applications span three general areas

Simulating Quantum Systems	Artificial Intelligence	Optimization / Monte Carlo
Quantum chemistry Material science High energy physics	Better model training Pattern recognition Fraud detection	Portfolio optimization Risk analysis Loans & credit scoring Monte Carlo-like applications

Quantum applications span three general areas

Simulating Quantum Systems		Artificial Intelligence	Optimization / Monte Carlo	
Improved battery materials	Accelerated Diagnosis	Fraud detection	Irregular Operations	Freight Forecasting
Manufacturing defect identification	Genomic Analysis	Risk analysis	Network Optimization	Irregular Operations
Semiconductor materials	Chemical product design	Options pricing	Product Portfolio Optimization	Fabrication Optimization
Chemical property prediction	Catalyst discovery	Derivatives Pricing	Process Planning	Manufacturing Supply Chain
Drug Discovery	Chemical process optimization	Investment Risk Analysis	Quality Control	Fluid Dynamics
Protein Structure Predictions	High energy physics classification	Portfolio Management	Vehicle Routing	
Disease Risk Predictions	Transaction classification	Transaction Settlement	Raw materials shipping	
	Product recommendation	Finance Offer Recommender	Refining Processes	
		Credit/Asset Scoring	Seismic imaging	
		Airline Scheduling	Disruption Management	

and many more …

IBM and partners working to perform complex scenario simulations

Number of simulations are reduced today, impacting assumptions and estimation accuracy

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.

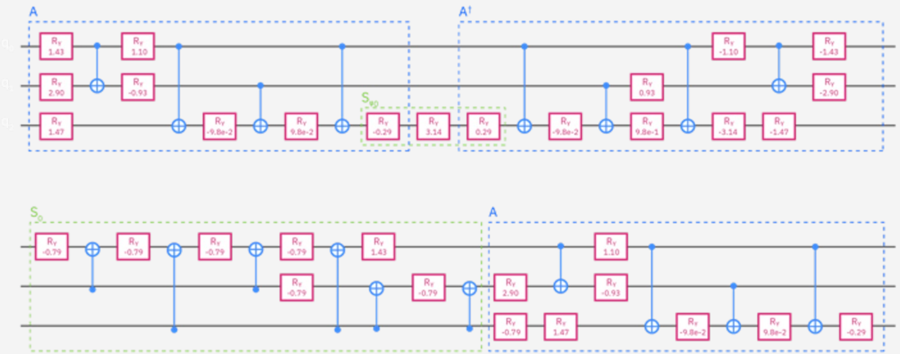
JP Morgan Chase

IBM **Quantum**

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 circuit



IBM **Quantum**

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