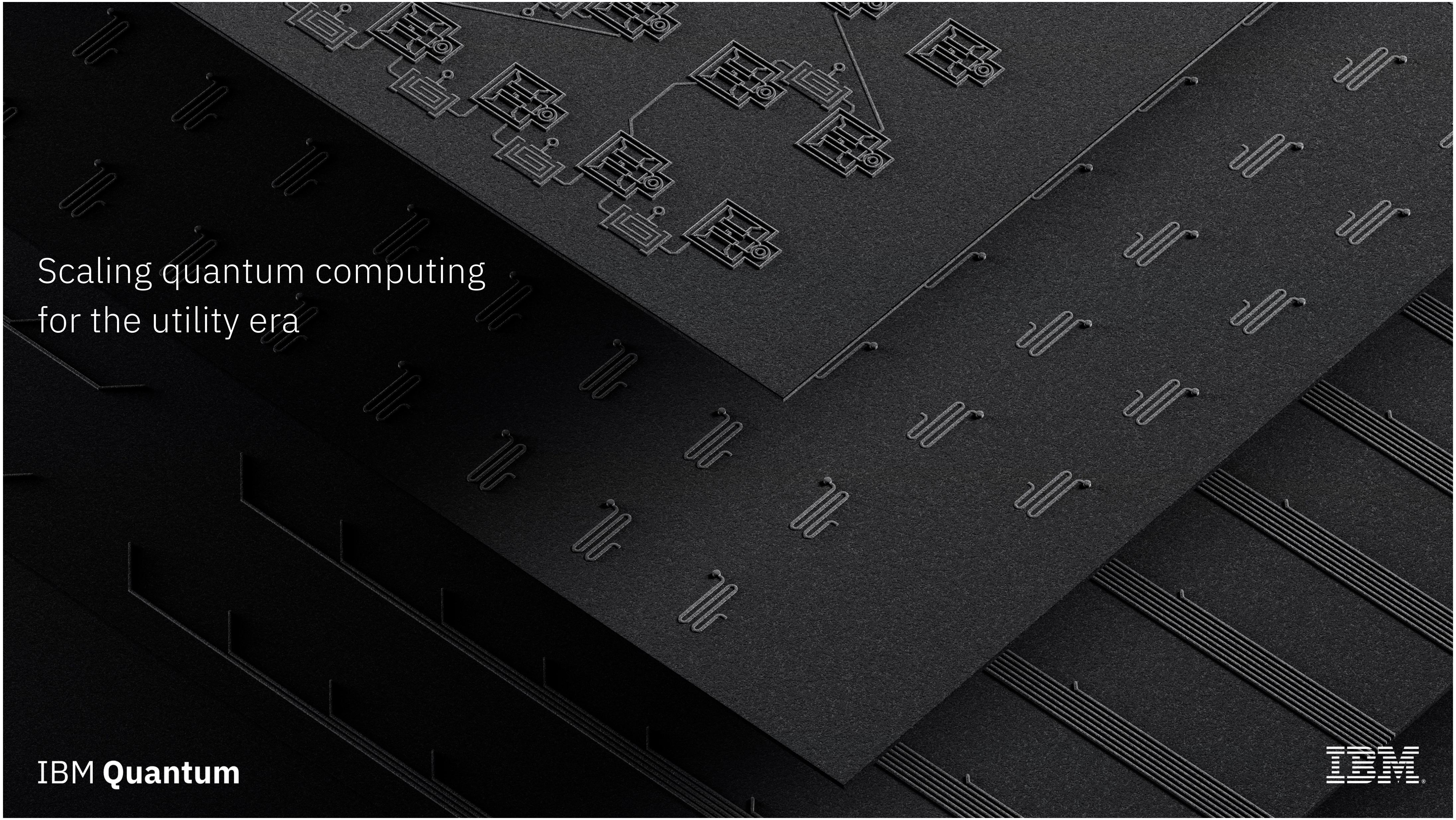

Scaling quantum computing
for the utility era
IBM Quantum
IBM

IBM Research

3000
Researchers

77
Years

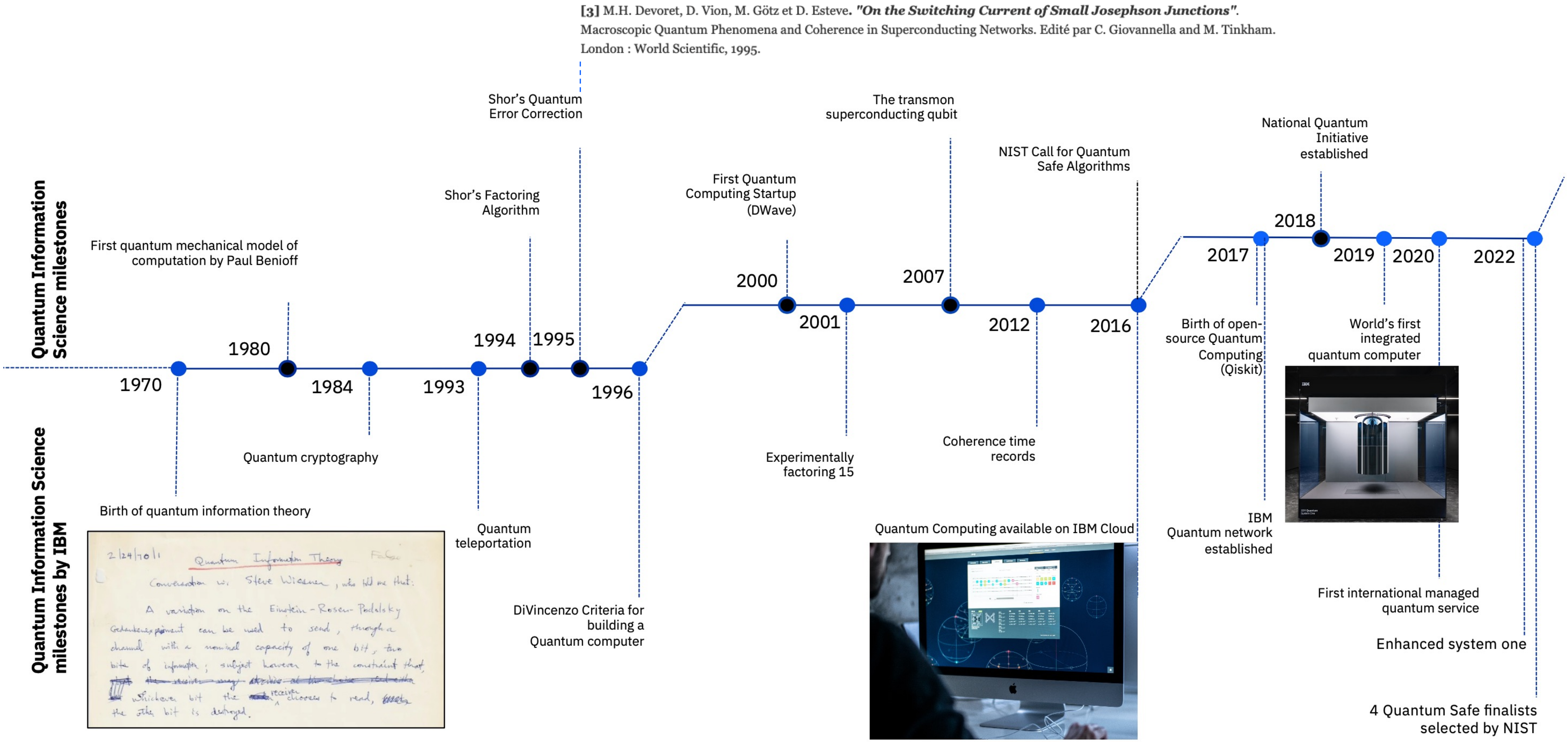
6
Nobel Laureates

10
Medals of Technology

5
National Medals of Science

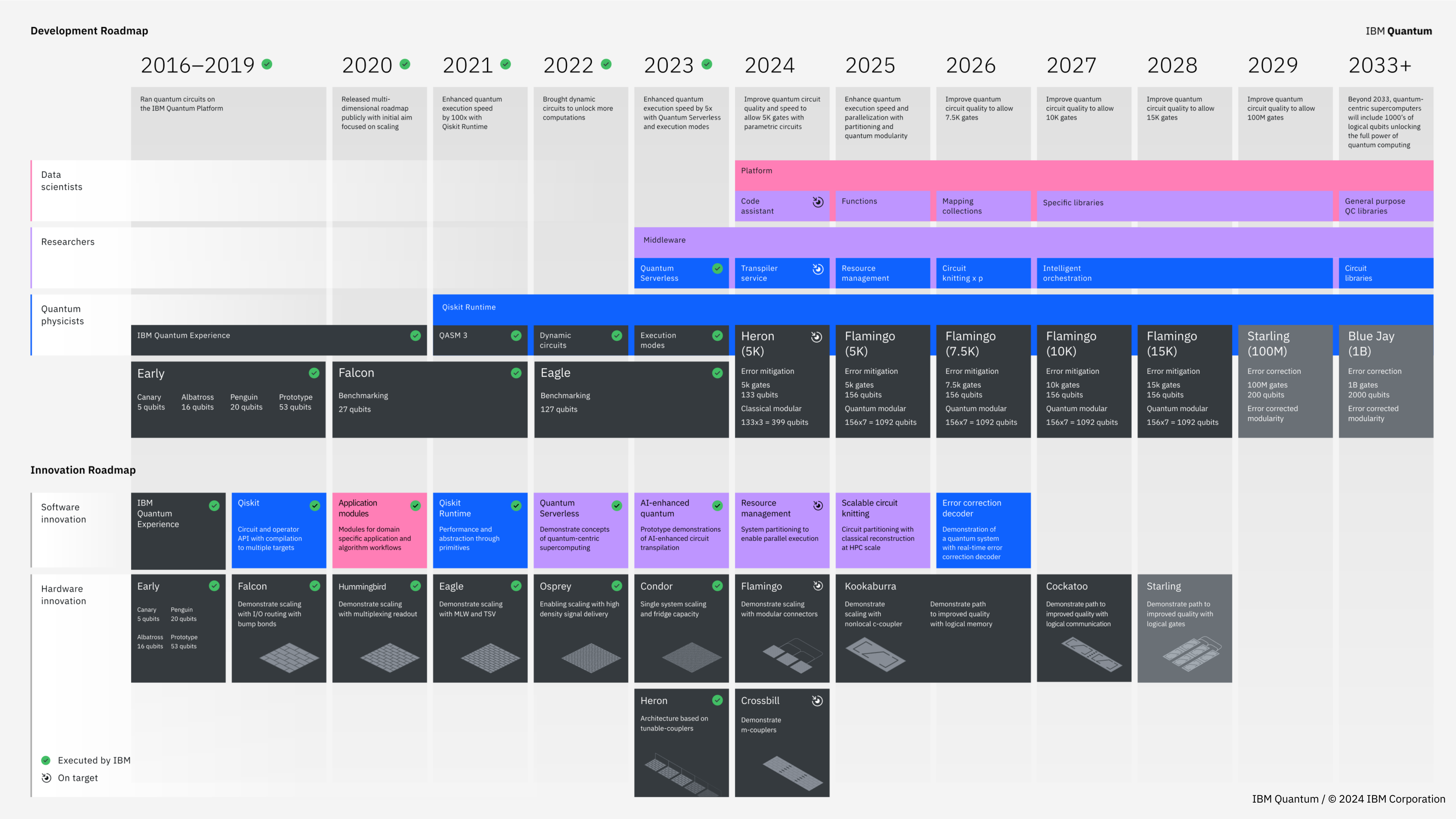
6
Turing Awards

Quantum timeline



From hardware, to software, and of course adoption, « scale » must be a global approach

New Development & Innovation Roadmap →


Development Roadmap
IBM Quantum
2016–2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2033+
Ran quantum circuits on the IBM Quantum Platform
Released multi-dimensional roadmap publicly with initial aim focused on scaling
Enhanced quantum execution speed by 100x with Qiskit Runtime
Brought dynamic circuits to unlock more computations
Enhanced quantum execution speed by 5x with Quantum Serverless and execution modes
Improve quantum circuit quality and speed to allow 5K gates with parametric circuits
Enhance quantum execution speed and parallelization with partitioning and quantum modularity
Improve quantum circuit quality to allow 7.5K gates
Improve quantum circuit quality to allow 10K gates
Improve quantum circuit quality to allow 15K gates
Improve quantum circuit quality to allow 100M gates
Beyond 2033, quantum-centric supercomputers will include 1000's of logical qubits unlocking the full power of quantum computing
Data scientists
Platform
Code assistant
Functions
Mapping collections
Specific libraries
General purpose QC libraries
Researchers
Middleware
Quantum Serverless
Transpiler service
Resource management
Circuit knitting x p
Intelligent orchestration
Circuit libraries
Quantum physicists
Qiskit Runtime
IBM Quantum Experience
QASM 3
Dynamic circuits
Execution modes
Heron (5K)
Error mitigation
5k gates
133 qubits
Classical modular
133x3 = 399 qubits
Flamingo (5K)
Error mitigation
5k gates
156 qubits
Quantum modular
156x7 = 1092 qubits
Flamingo (7.5K)
Error mitigation
7.5k gates
156 qubits
Quantum modular
156x7 = 1092 qubits
Flamingo (10K)
Error mitigation
10k gates
156 qubits
Quantum modular
156x7 = 1092 qubits
Flamingo (15K)
Error mitigation
15k gates
156 qubits
Quantum modular
156x7 = 1092 qubits
Starling (100M)
Error correction
100M gates
200 qubits
Error corrected modularity
Blue Jay (1B)
Error correction
1B gates
2000 qubits
Error corrected modularity
Early
Canary 5 qubits
Albatross 16 qubits
Penguin 20 qubits
Prototype 53 qubits
Falcon
Benchmarking
27 qubits
Eagle
Benchmarking
127 qubits
Innovation Roadmap
Software innovation
IBM Quantum Experience
Qiskit
Circuit and operator API with compilation to multiple targets
Application modules
Modules for domain specific application and algorithm workflows
Qiskit Runtime
Performance and abstraction through primitives
Quantum Serverless
Demonstrate concepts of quantum-centric supercomputing
AI-enhanced quantum
Prototype demonstrations of AI-enhanced circuit transpilation
Resource management
System partitioning to enable parallel execution
Scalable circuit knitting
Circuit partitioning with classical reconstruction at HPC scale
Error correction decoder
Demonstration of a quantum system with real-time error correction decoder
Hardware innovation
Early
Canary 5 qubits
Penguin 20 qubits
Albatross 16 qubits
Prototype 53 qubits
Falcon
Demonstrate scaling with I/O routing with bump bonds
Hummingbird
Demonstrate scaling with multiplexing readout
Eagle
Demonstrate scaling with MLW and TSV
Osprey
Enabling scaling with high density signal delivery
Condor
Single system scaling and fridge capacity
Flamingo
Demonstrate scaling with modular connectors
Kookaburra
Demonstrate scaling with nonlocal c-coupler
Demonstrate path to improved quality with logical memory
Cockatoo
Demonstrate path to improved quality with logical communication
Starling
Demonstrate path to improved quality with logical gates
Heron
Architecture based on tunable-couplers
Crossbill
Demonstrate m-couplers
Executed by IBM
On target

IBM **Quantum**

Development roadmap: Hardware

	2016–2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2033+
	Ran quantum circuits on the IBM Quantum Platform	Released multi-dimensional roadmap publicly with initial aim focused on scaling	Enhanced quantum execution speed by 100x with Qiskit Runtime	Brought dynamic circuits to unlock more computations	Enhanced quantum execution speed by 5x with quantum serverless and execution modes	Improve quantum circuit quality and speed to allow 5K gates with parametric circuits	Enhance quantum execution speed and parallelization with partitioning and quantum modularity	Improve quantum circuit quality to allow 7.5K gates	Improve quantum circuit quality to allow 10K gates	Improve quantum circuit quality to allow 15K gates	Improve quantum circuit quality to allow 100M gates	Beyond 2033, quantum-centric supercomputers will include 1000's of logical qubits unlocking the full power of quantum computing
Data scientists						Platform						
						Code assistant	Functions	Mapping collections	Specific libraries			General purpose QC libraries
Researchers					Middleware							
					Quantum Serverless	Transpiler service	Resource management	Circuit knitting x p	Intelligent orchestration			Circuit libraries
Quantum physicists			Qiskit Runtime									
	IBM Quantum Experience		QASM 3	Dynamic circuits	Execution modes	Heron (5K) Error mitigation 5k gates 133 qubits Classical modular Up to 133x3 = 399 qubits	Flamingo (5K) Error mitigation 5k gates 156 qubits Quantum modular Up to 156x7 = 1092 qubits	Flamingo (7.5K) Error mitigation 7.5k gates 156 qubits Quantum modular Up to 156x7 = 1092 qubits	Flamingo (10K) Error mitigation 10k gates 156 qubits Quantum modular Up to 156x7 = 1092 qubits	Flamingo (15K) Error mitigation 15k gates 156 qubits Quantum modular Up to 156x7 = 1092 qubits	Starling (100M) Error correction 100M gates 200 qubits Error corrected modularity	Blue Jay (1B) Error correction 1B gates 2000 qubits Error corrected modularity
	Early Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	Falcon Benchmarking 27 qubits		Eagle Benchmarking 127 qubits								

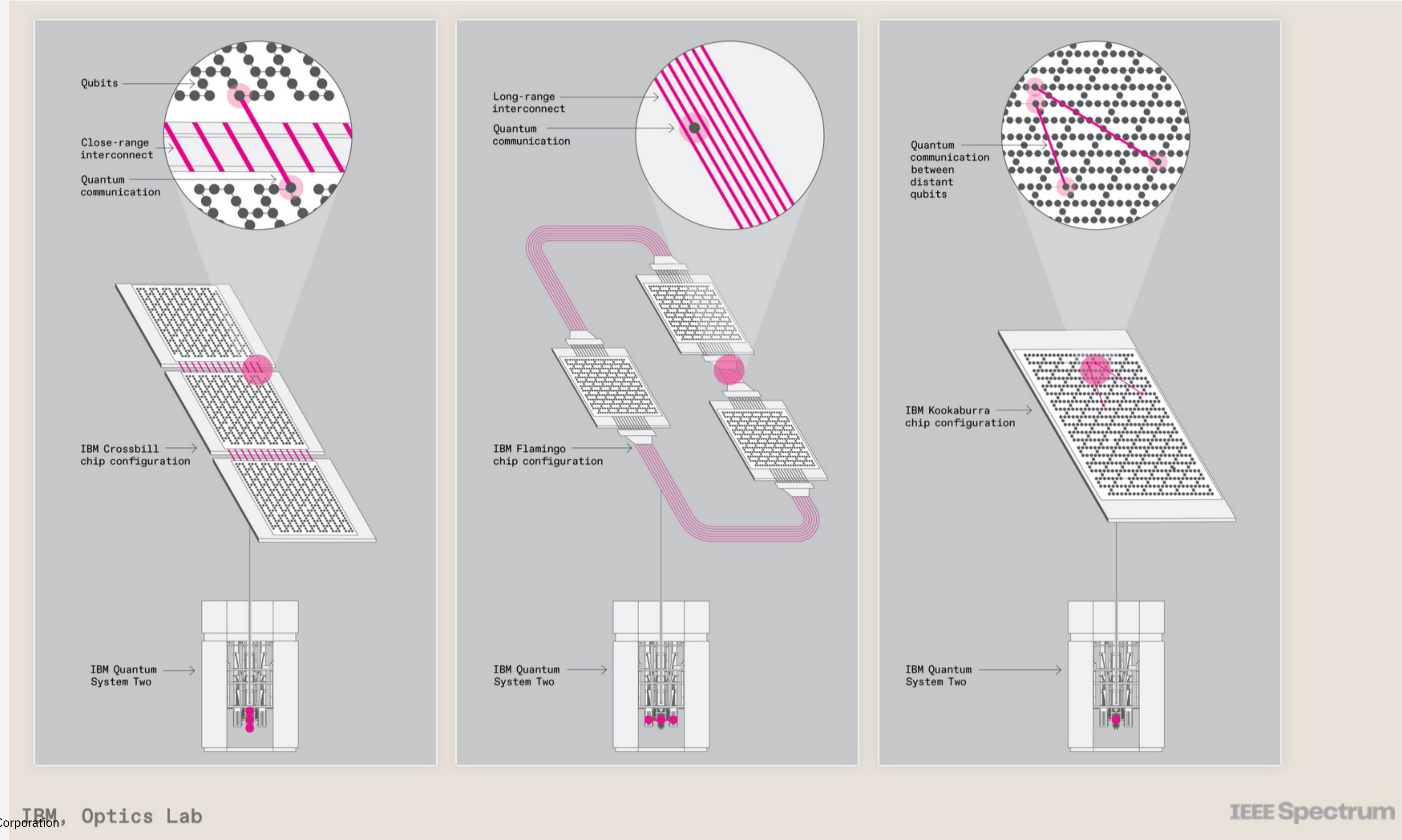
Innovation roadmap: Hardware

	2016–2019 ✓		2020 ✓	2021 ✓	2022 ✓	2023 ✓	2024	2025	2026	2027	2028	2029
	Ran quantum circuits on the IBM Quantum Platform		Released multi-dimensional roadmap publicly with initial aim focused on scaling	Enhanced quantum execution speed by 100x with Qiskit Runtime	Brought dynamic circuits to unlock more computations	Enhanced quantum execution speed by 5x with quantum serverless and execution modes	Improve quantum circuit quality and speed to allow 5K gates with parametric circuits	Enhance quantum execution speed and parallelization with partitioning and quantum modularity	Improve quantum circuit quality to allow 7.5K gates	Improve quantum circuit quality to allow 10K gates	Improve quantum circuit quality to allow 15K gates	Improve quantum circuit quality to allow 100M gates
Software innovation	**IBM Quantum Experience** ✓	**Qiskit** ✓ Circuit and operator API with compilation to multiple targets	**Application modules** ✓ Modules for domain specific application and algorithm workflows	**Qiskit Runtime** ✓ Performance and abstraction through primitives	**Quantum Serverless** ✓ Demonstrate concepts of quantum-centric supercomputing	**AI-enhanced quantum** ✓ Prototype demonstrations of AI-enhanced circuit transpilation	**Resource management** (on target) System partitioning to enable parallel execution	**Scalable circuit knitting** Circuit partitioning with classical reconstruction at HPC scale	**Error correction decoder** Demonstration of a quantum system with real-time error correction decoder			
Hardware innovation	**Early** ✓ Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	**Falcon** ✓ Demonstrate scaling with I/O routing with bump bonds	**Hummingbird** ✓ Demonstrate scaling with multiplexing readout	**Eagle** ✓ Demonstrate scaling with MLW and TSV	**Osprey** ✓ Enabling scaling with high density signal delivery	**Condor** ✓ Single system scaling and fridge capacity	**Flamingo** (on target) Demonstrate scaling with modular connectors	**Kookaburra** Demonstrate scaling with nonlocal c-coupler	Demonstrate path to improved quality with logical memory	**Cockatoo** Demonstrate path to improved quality with logical communication	**Starling** Demonstrate path to improved quality with logical gates	
						Heron ✓ Architecture based on tunable-couplers	**Crossbill** (on target) Demonstrate m-couplers					

✓ Executed by IBM

On target

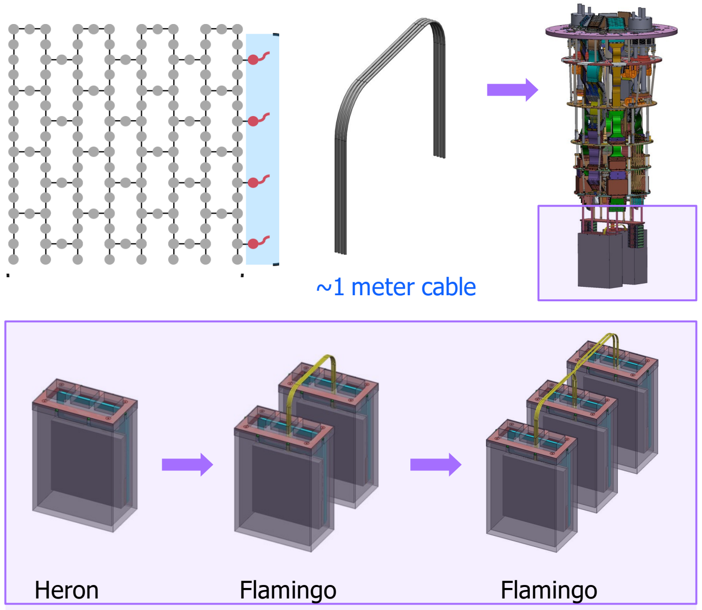
Innovation roadmap: Hardware



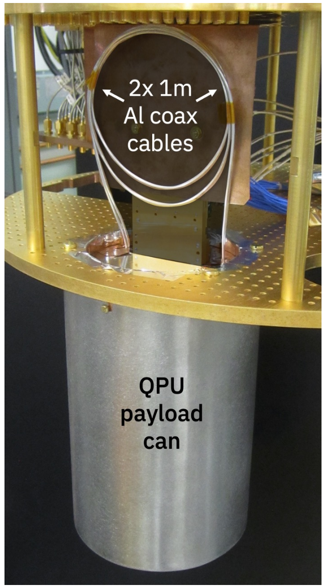
Innovation roadmap:
Hardware

Flamingo

Heron platform + *l-coupler* gate + *l-coupler* cable

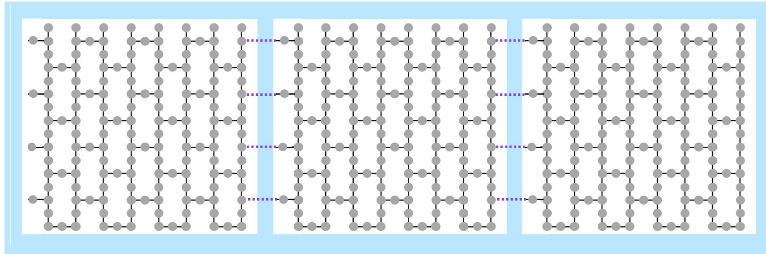


L-coupler demonstrated in 2023 with internal quality factor exceeding the required 95% state transfer fidelity.

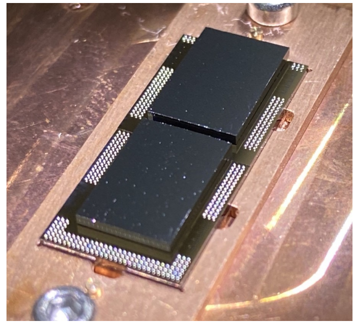


Crossbill

Heron platform + *m-coupler bus* + *m-coupler packaging*



Qubit chiplets within a multi-chip module



IBM Research technology schematic

IBM Quantum: the path to Blue Jay system

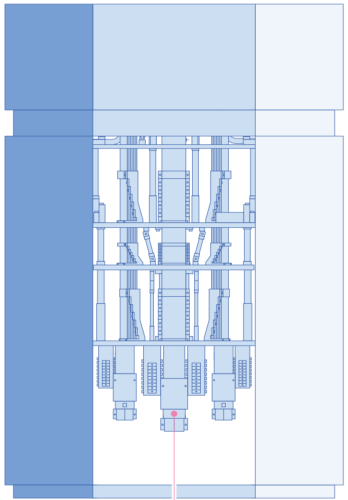
Abstract

Scaling to achieve universal quantum computation.

Development team

IBM Quantum
Yorktown Heights, NY

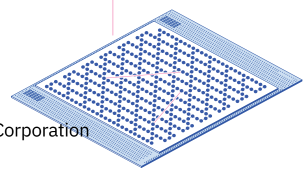
2026



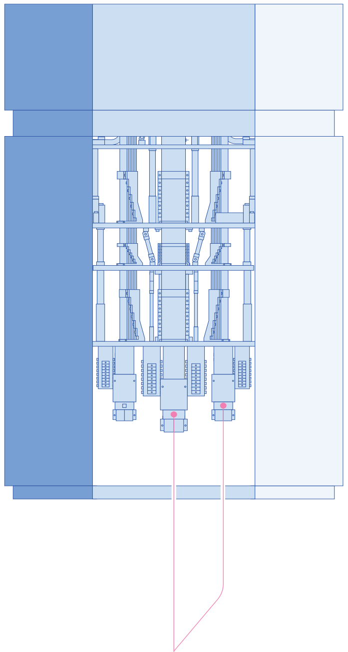
Kookaburra system

Logical memory

→ C-coupler
→ Degree 6 gates
→ 1,200 control lines



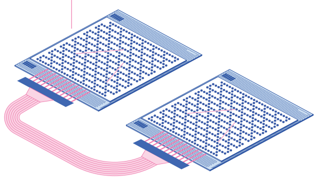
2027



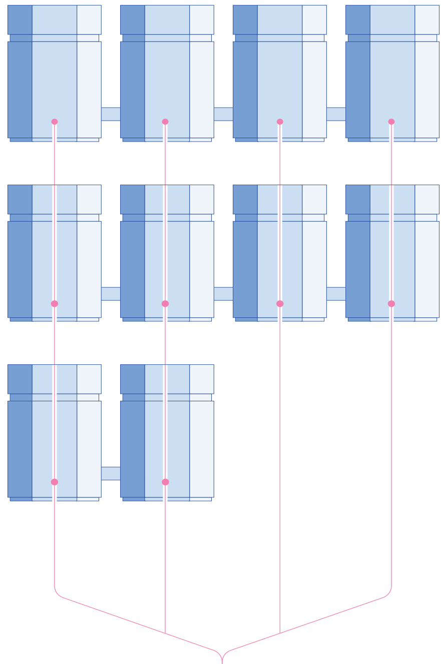
Cockatoo system

Logical operations

→ L-coupler
→ Logical commiunication
→ 3,600 control lines



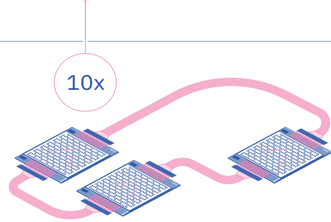
2029



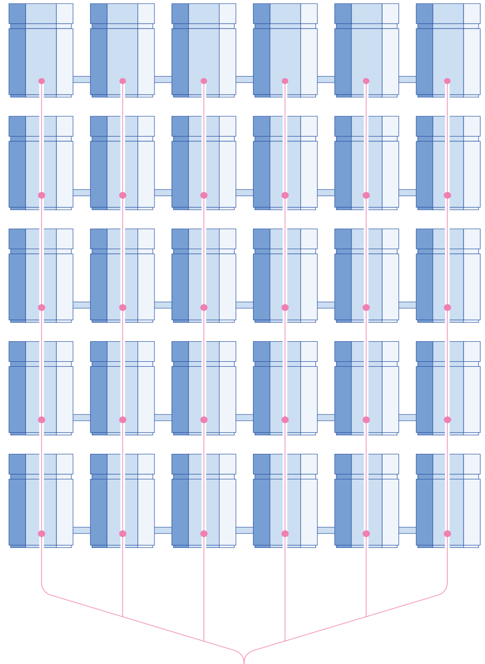
Starling system

100 million gates

→ Gen-3 flex
→ FPGA control
→ Universal computation
→ 40K control lines



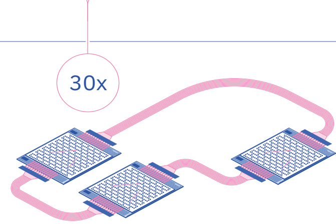
2033



Blue Jay system

1 billion gates

→ Gen-4 flex
→ ASIC control
→ Universal computation
→ 400K control lines



Performant quantum systems

The tools of utility

IBM Quantum systems give access to scale, quality and speed around the clock.

Availability

Seven utility-scale quantum systems (with more to come) for parallel workflows and advanced algorithms.

Reliability

Unparalleled reliability with >95% uptime across the fleet of quantum processors

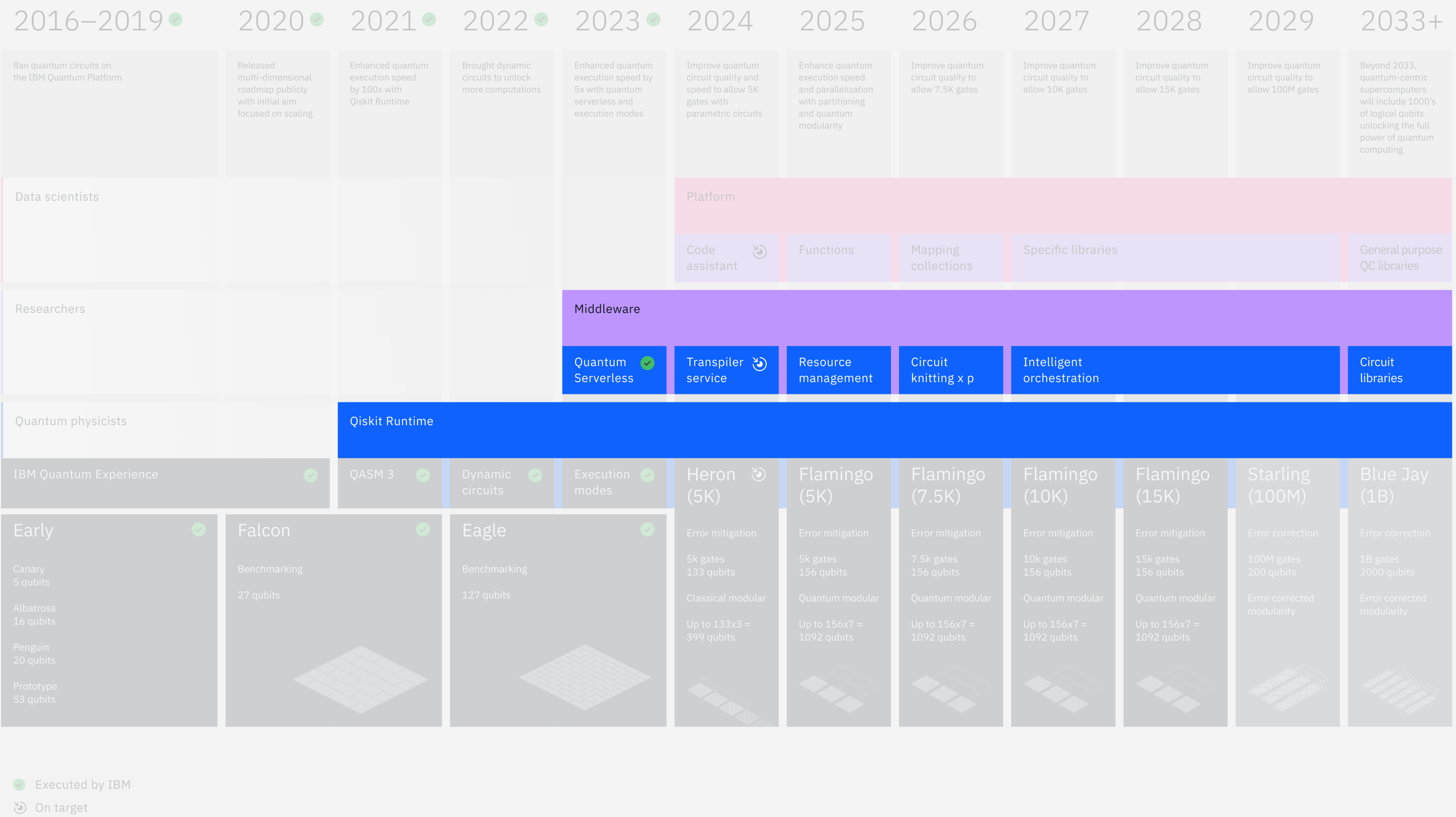
Stability

Unmatched stability; 2Q gate error fluctuations no larger than ~10^{-3} over timescales measured in months.*

* Median 2Q gate errors measured over all accessible Eagle processors from July 20 to September 20, 2023.

Development roadmap: Execution and Orchestration

IBM **Quantum**



Quantum Centric Supercomputing vision

- Based on **open-source** software and services
- Compatible with **major cloud providers**
- Seamless workflow orchestration: complexity **simplified**

User

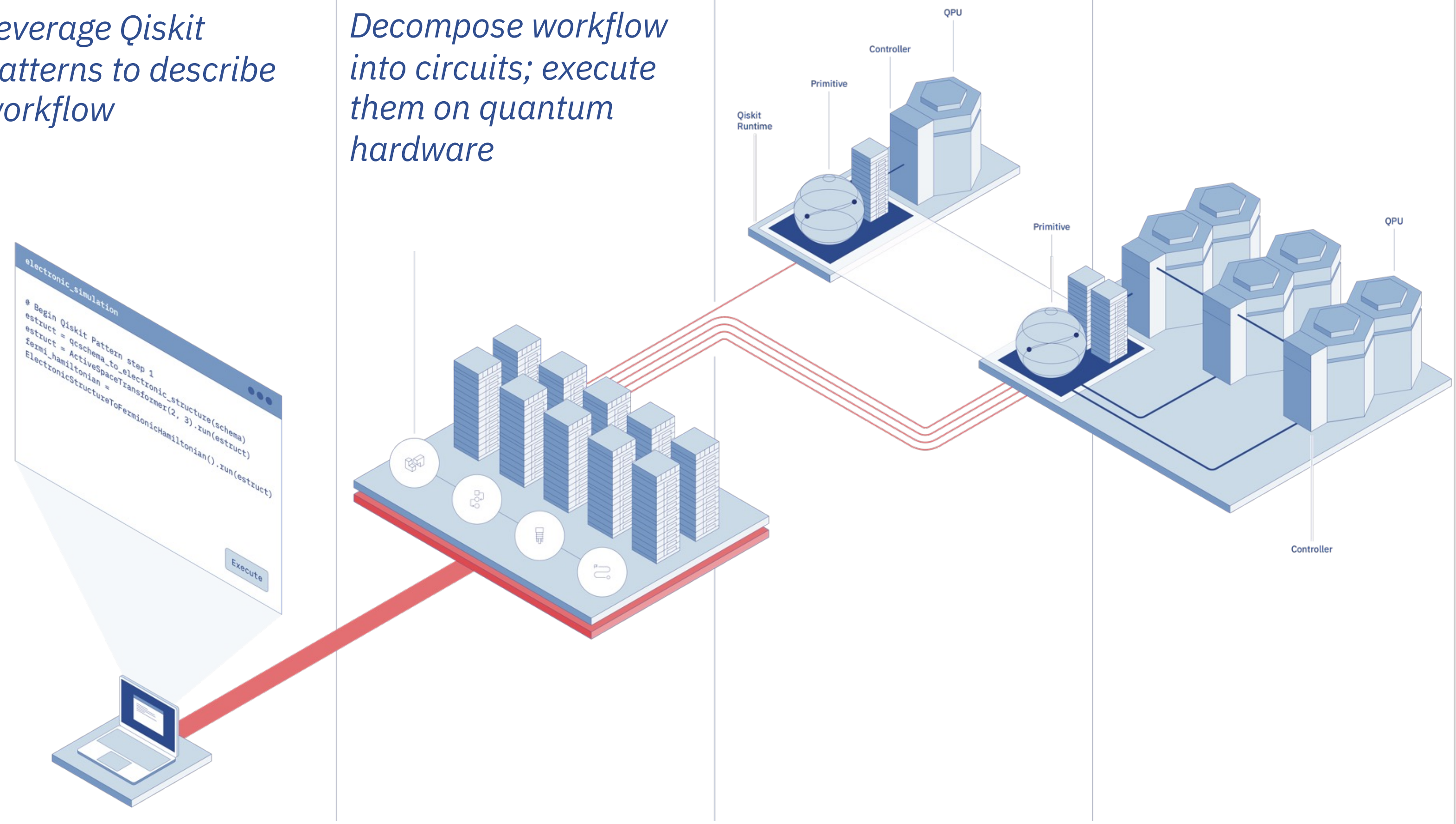
Leverage Qiskit Patterns to describe workflow

Quantum Serverless

Decompose workflow into circuits; execute them on quantum hardware

Single node

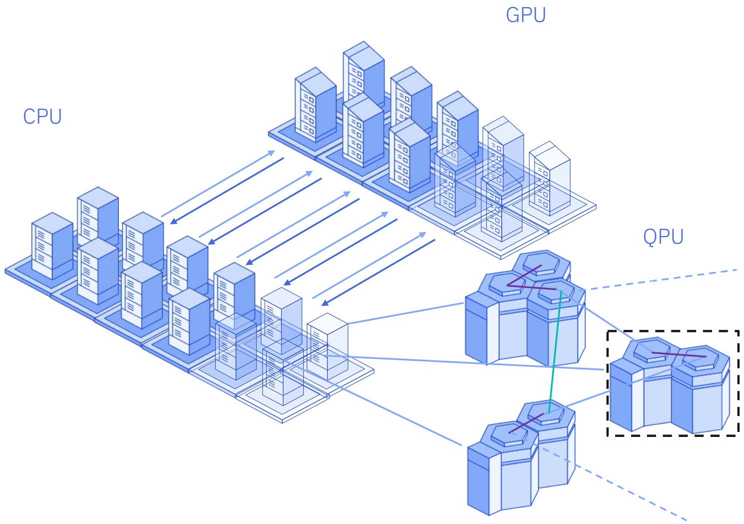
Multi-node



IBM **Quantum** RIKEN

University of Colorado **Boulder**

Quantum-centric supercomputing: a new computational framework

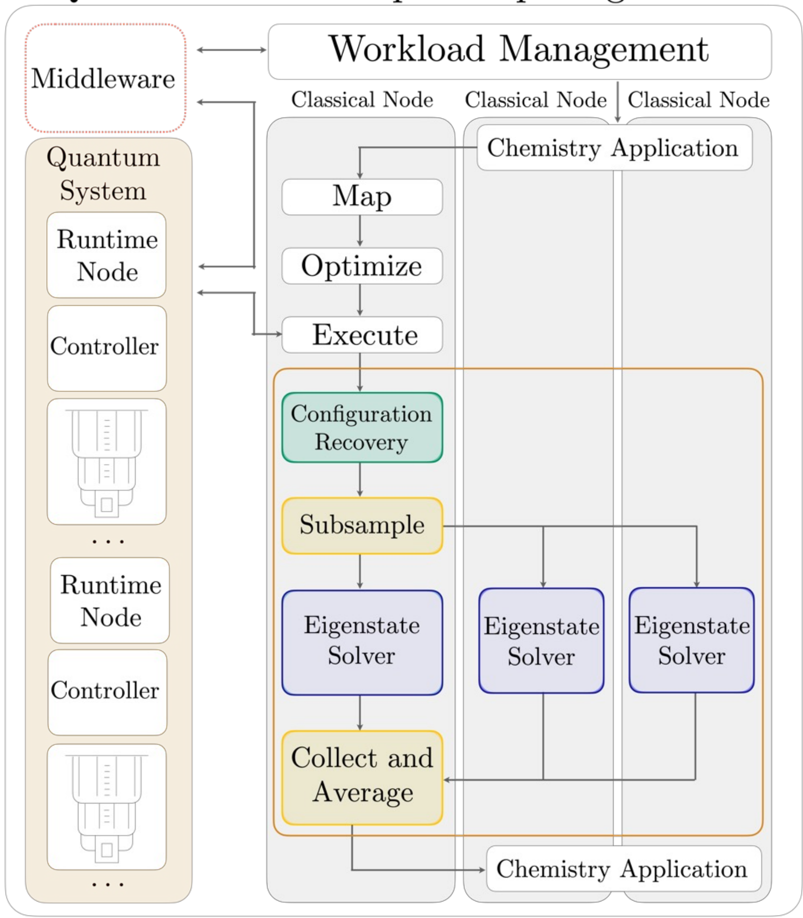


77 qubits
10570 quantum gates
3590 two-qubit gates

富岳
Fugaku

1600 nodes @
32 GB
1024 GB/s
48 cores

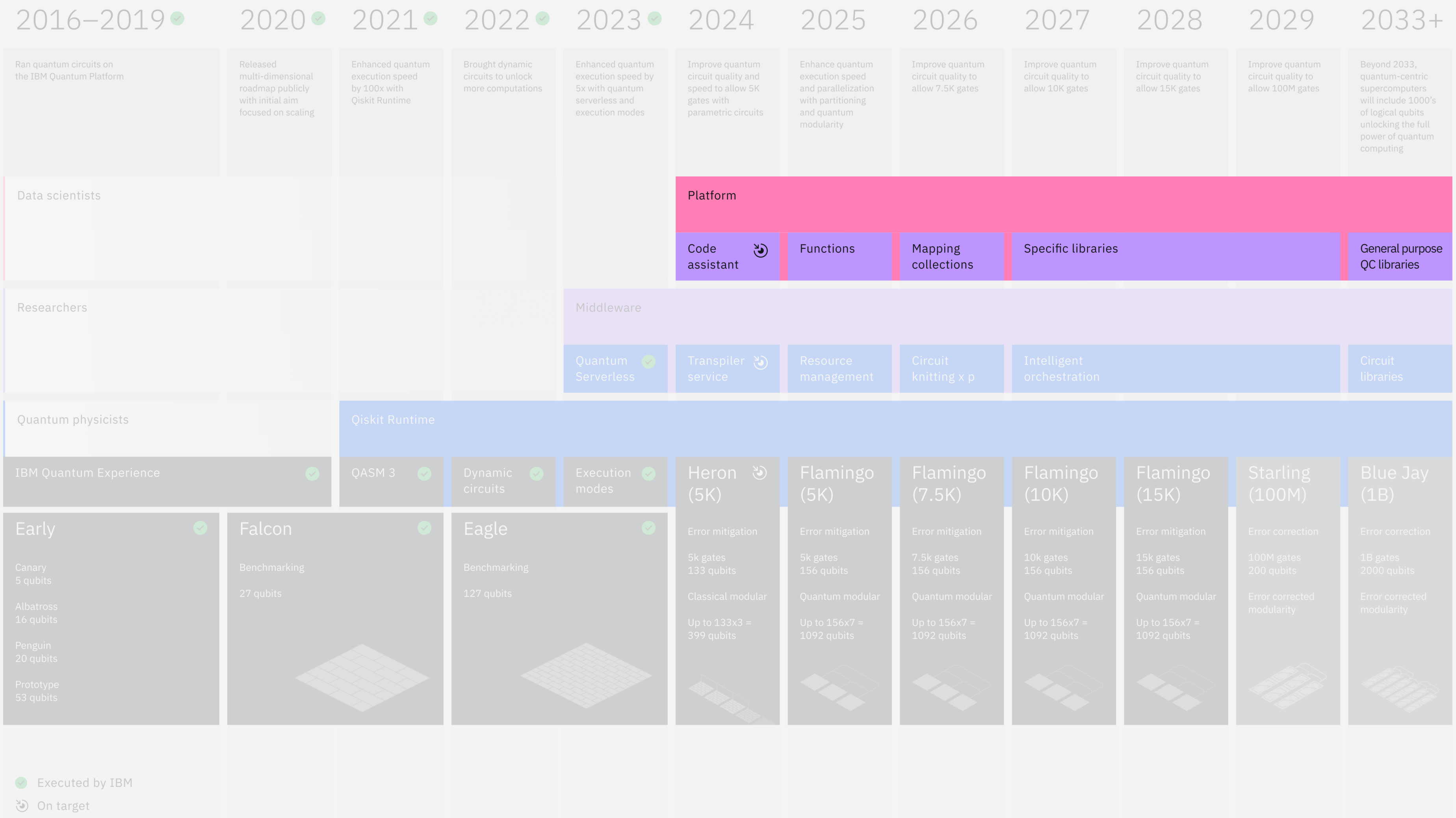
Quantum-centric Supercomputing Cluster



arXiv:2405.05068

IBM **Quantum**

Development roadmap: Software



Scalable quantum software

The tools of utility

Qiskit

Circuit Toolkit

Efficient construction and manipulation of quantum circuits

Operator toolkit

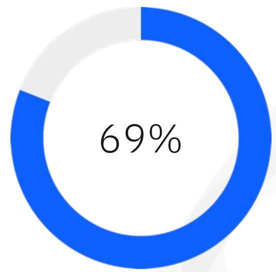
Tools for building and evaluating quantum operators

Transpiler

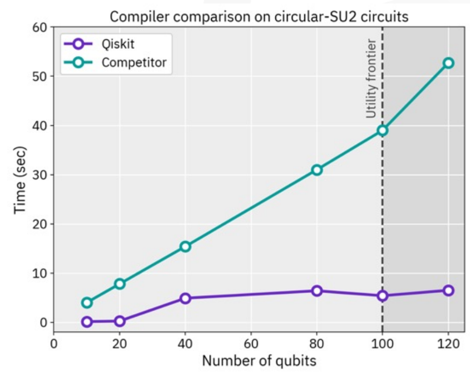
Abstract to logical circuit transformation and optimization

Primitives

Simple interface for quantum circuit execution



SDK preferred by 69% of quantum programmers.*



The lingua franca of quantum computing; write once and execute quantum circuits on 9+ different hardware manufacturers

- Alpine Quantum
- AWS Braket
- Azure Quantum
- IBM Quantum
- IonQ
- IQM
- Quantinuum
- Rigetti
- Alice & Bob

* Unitary Fund Survey, 2023.

From a framework to tools and services

IBM **Quantum**

Qiskit Pattern

*Framework for **showing** how to build algorithms that leverage quantum by stacking capabilities across four steps.*

Step 1 (map)

```
def map_problem(...):
    return abs_circs
```

Step 2 (optimize)

```
def optimize(abs_circs):
    return isa_circs
```

Step 3 (execute)

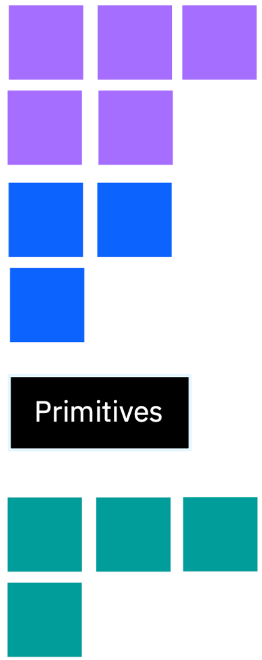
```
res =
Sampler().run(isa_circs)
```

Step 4 (postprocess)

```
def postprocess(res):
    return solution
```

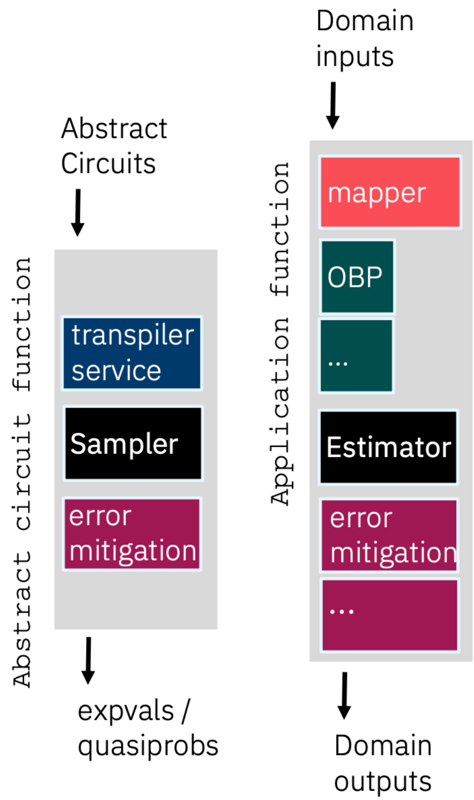
Building Blocks

*Tools or services that perform **tasks within a step** (and can be composable with others).*



Functions

***Utility-scale service** that runs the quantum sub-task of a larger workflow for a variety of inputs.*



Qiskit Patterns

Qiskit Patterns can be composed from reusable building blocks allowing for **code reuse and simplification**

Tailoring Patterns is a simple replacement of blocks with IBM Quantum defined components, or those of 3rd-parties

Maximizes **compatibility**, with existing software ecosystems for easier acceleration of workflows

Step 1 - Map

- `qcschema_to_electronic_structure`
- `ActiveSpaceTransformer`
- `ElectronStructureToFermion`
- `JordanWignerMapping`
- `EfficientSU2`

Step 2 - Optimize

- `Passmanger_optimization_level3`
- `DynamicalDecoupling`

Step 3 - Execute

- `RuntimeInit`

`SPSA optimization`

- `EstimatorCostFunction`

Step 4 – Post-process

- `return res.fun`

Step 1

- `qcschema_to_electronic_structure`
- `ActiveSpaceTransformer`
- `ElectronStructureToFermion`
- `BravyiKitaevMapping`
- `UCCSD`

Step 2

- `Passmanger_optimization_level3`
- `DynamicalDecoupling`

Step 3

- `RuntimeInit`

`SPSA optimization`

- `EstimatorCostFunction`

Step 4

- `return res.fun`

Step 1

- `qcschema_to_electronic_structure`
- `ActiveSpaceTransformer`
- `ElectronStructureToFermion`
- `BravyiKitaevMapping`
- `UCCSD`

Step 2

- `Passmanger_optimization_level3`
- `DynamicalDecoupling`

Step 3

- `RuntimeInit`

`L-BFGS-B optimization`

- `EstimatorCostFunction`

Step 4

- `return res.fun`

Innovation roadmap: Execution & Software

IBM Quantum

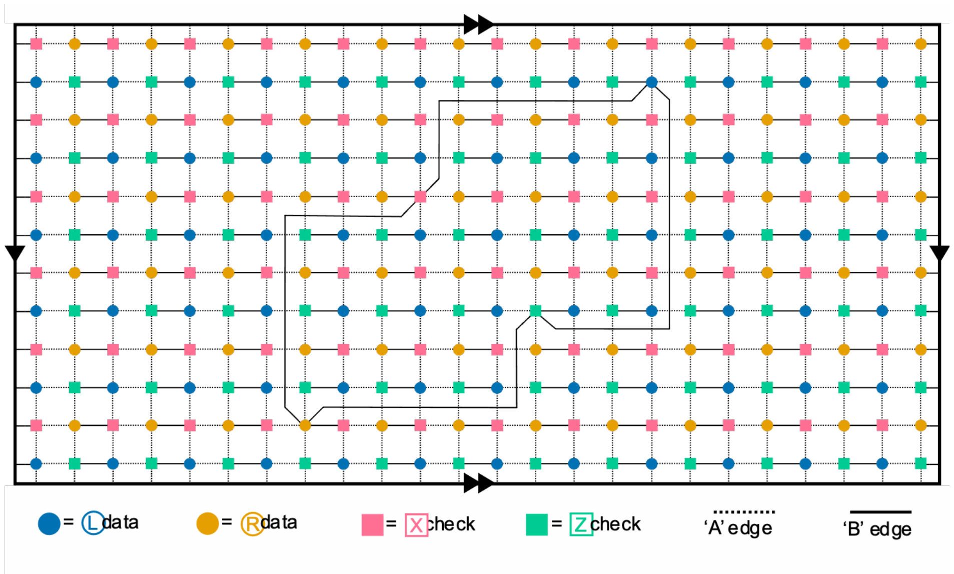
	2016–2019 ✓		2020 ✓	2021 ✓	2022 ✓	2023 ✓	2024	2025	2026	2027	2028	2029
	Ran quantum circuits on the IBM Quantum Platform		Released multi-dimensional roadmap publicly with initial aim focused on scaling	Enhanced quantum execution speed by 100x with Qiskit Runtime	Brought dynamic circuits to unlock more computations	Enhanced quantum execution speed by 5x with quantum serverless and execution modes	Improve quantum circuit quality and speed to allow 5K gates with parametric circuits	Enhance quantum execution speed and parallelization with partitioning and quantum modularity	Improve quantum circuit quality to allow 7.5K gates	Improve quantum circuit quality to allow 10K gates	Improve quantum circuit quality to allow 15K gates	Improve quantum circuit quality to allow 100M gates
Software innovation	**IBM Quantum Experience** ✓	**Qiskit** ✓ Circuit and operator API with compilation to multiple targets	**Application modules** ✓ Modules for domain specific application and algorithm workflows	**Qiskit Runtime** ✓ Performance and abstraction through primitives	**Quantum Serverless** ✓ Demonstrate concepts of quantum-centric supercomputing	**AI-enhanced quantum** ✓ Prototype demonstrations of AI-enhanced circuit transpilation	**Resource management** (on target) System partitioning to enable parallel execution	**Scalable circuit knitting** Circuit partitioning with classical reconstruction at HPC scale	**Error correction decoder** Demonstration of a quantum system with real-time error correction decoder			
Hardware innovation	**Early** ✓ Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	**Falcon** ✓ Demonstrate scaling with I/O routing with bump bonds	**Hummingbird** ✓ Demonstrate scaling with multiplexing readout	**Eagle** ✓ Demonstrate scaling with MLW and TSV	**Osprey** ✓ Enabling scaling with high density signal delivery	**Condor** ✓ Single system scaling and fridge capacity	**Flamingo** (on target) Demonstrate scaling with modular connectors	**Kookaburra** Demonstrate scaling with nonlocal c-coupler	Demonstrate path to improved quality with logical memory	**Cockatoo** Demonstrate path to improved quality with logical communication	**Starling** Demonstrate path to improved quality with logical gates	
						Heron ✓ Architecture based on tunable-couplers	**Crossbill** (on target) Demonstrate m-couplers					

✓ Executed by IBM

On target

Low-overhead fault-tolerant quantum computing

Gross code
(example from bivariate bicycle family)



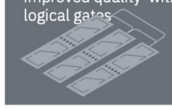
gross (noun): an aggregate of a dozen dozen things

Logical communication between memory blocks

Cockatoo

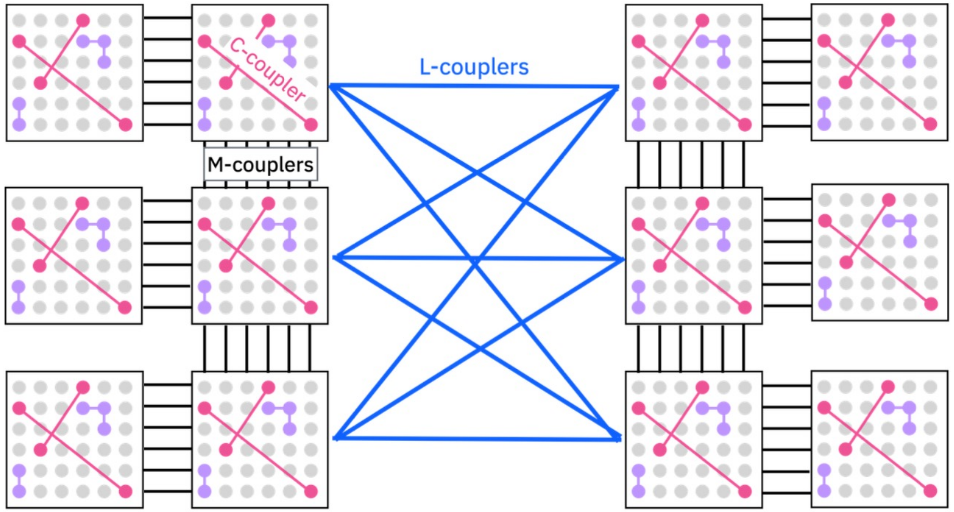
Demonstrate path to improved quality with logical communication

Starling



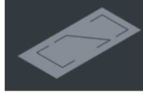
Demonstrate path to improved quality with logical gates

New innovations required: c-couplers, which are non-local connections, and 6-way connectivity



C-coupler

Kookaburra

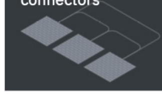


Demonstrate scaling with nonlocal c-coupler

Demonstrate path to improved quality with logical memory

L-coupler

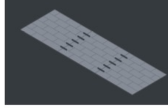
Flamingo



Demonstrate scaling with modular connectors

M-coupler

Crossbill



m- coupler

The continuous path from utility to quantum error correction

"Coming together is a beginning; keeping together is progress; working together is success." - Henry Ford

Hardware ecosystem development

IBM Intends to Partner with Fermilab’s SQMS Center to Advance Critical Quantum Information Science Initiatives

IBM plans to join Fermilab’s SQMS Center to further accelerate critical technologies and applications of superconducting quantum systems and expand quantum workforce development programs.

Jul 18, 2024

2024/06/17

AIST and IBM partner for the industrialization of the next generation quantum computing

On May 10, 2024, the National Institute of Advanced Industrial Science and Technology (AIST) and International Business Machines Corporation (IBM) signed a Memorandum of Understanding (MOU) for research cooperation to strengthen collaboration for the industrialization of quantum technology. To stimulate the quantum hardware and component industry, AIST and IBM will work together to promote the development of next-generation quantum computers and their supply chain. Japanese industry involvement in the procurement of quantum hardware parts for the development of future quantum computing systems is expected, and supplier development will also be promoted through this effort. We also believe that by promoting the use of quantum computing in industry, we can accelerate the growth of the quantum industry in Japan. We will help foster a large community for the development of industry use cases focused on business impact.

The enhanced collaboration between the two institutions in industrialization efforts for quantum technology, which will be increasingly in demand, will promote the development of next-generation devices and supply chains, as well as market creation through industrial use case development.

AIST Create the Future, Collaborate Together

G-QuAT

IBM

39 “Quantum Innovation Centers”, 8 with Dedicated Service

Americas

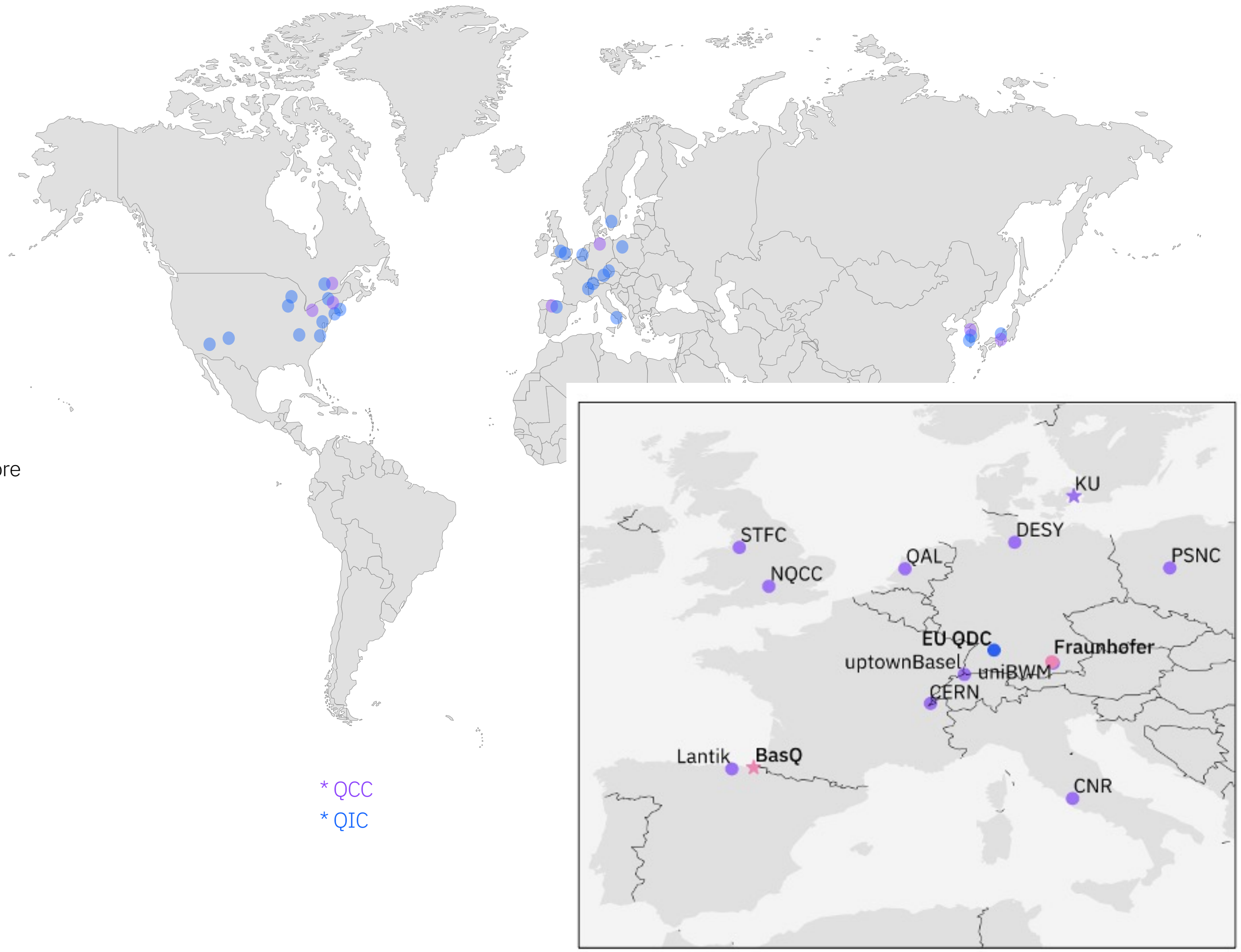
Air Force Research Lab
Arizona State University
Chicago Quantum Exchange
Cleveland Clinic Foundation
IBM-HBCU Quantum Center
IBM-Illinois DA Inst – UIUC
Los Alamos National Lab
North Carolina State University
Oak Ridge National Lab
PINQ²
Rensselaer Polytechnic Institute
Université de Sherbrooke
University of Rhode Island
University of Southern California

Europe, Middle East & Africa

BasQ (Ikerbasque)
CERN
Consiglio Nazionale delle Ricerche
DESY
Fraunhofer
Lantik
National Quantum Computing Centre
PSNC
Quantum Application Lab
QuantumBasel
STFC/ Hartree Centre
UniBW Munich
University of Copenhagen
University of Witwatersrand
WACQT

Asia Pacific

IIT Madras
Keio University
Korea Quantum Computing
National Taiwan University
National University of Singapore
RIKEN
Sungkyunkwan University
University of Melbourne
University of Tokyo
Yonsei University



IBM Quantum Network : 250+ members to date

Current as of 2024-06-26 12:39:37

1Qbit Systems
Accelequant
Adam Mickiewicz University
Agnostiq Inc
Alabama A&M University
Alabama State University
Albany State University
Algorithmiq Oy
Aliro Quantum
American Express
Anaqor
AngelQ
Ansys Inc
Applied Quantum Computing
Aqarios
Argonne National Lab
Arizona State University
Assured Information Security
Banco Bilbao Vizcaya Argentaria
Banco Bradesco
Basque Center for Climate Change
Basque Center for Neuroscience (Achucarro)
Basque Center on Cognition, Brain and Language
Beit
Biofisika Institute
BlueQubit
Boeing
Bosch
BosonQ Psi
Boston University
Bowie State University
Brookhaven National Lab
Bundeswehr University Munich
CERN
CIC energiGUNE
CMC Microsystems
Cambridge Quantum Computing
Capgemini SE
Carnegie Mellon Software Engineering Institute
Case Western Reserve University
Center for Cooperative Research for Biosciences
Center for Cooperative Research in Biomaterials
Center for Theoretical Physics Polish Academy of Sciences
Centrum Wiskunde & Informatica
Chicago Quantum Exchange
Clark Atlanta University
Classiq
Cleveland Clinic Foundation
Cleveland State University
ColibriTD
Consiglio Nazionale delle Ricerche - Istituto di calcolo e reti ad alte prestazioni
Coppin State University
Cornell University
Credit Mutuel
Czech Technical University in Prague
DIC Corporation
DNeuro.ai
Delaware State University
Dell Technologies
Deloitte
Deutsches Elektronen Synchrotron
Dillard University
Doosan Group
Dow Chemical Company
E.ON
ETH Zurich
EY Global
Entropica Labs
Erste Group Bank AG
ExxonMobil
Fachhochschule Nordwestschweiz
Fermi National Accelerator Laboratory
Florida A&M University
Fraunhofer
Fraunhofer members
GE Global Research
General Atomics
George Mason University
Georgia Institute of Technology
Global Data Quantum
Good Chemistry
HQS Quantum Simulations
HSBC
Haiqu
Hampton University
Hanlim Pharm
Harvard University
Hitachi Ltd
Howard University
Hydro-Quebec
Hyundai Motor Company
IBM-HBCU Quantum Center - Howard University
IBM-Illinois Discovery Accelerator Institute - University of Illinois Urbana Champaign
III Taiwan
ITRI Taiwan
Ikerbasque Foundation
Ikerbasque members
Indian Institute of Technology Madras
Industrial Technology Research Institute
Infleqtion
Institute of Theoretical and Applied Informatics Polish Academy of Sciences
Instituto Nazionale di Fisica Nucleare
Israel Aerospace Industries
Istituto Italiano di Tecnologia
JSR Corporation
Jij Inc.
JoS Quantum
Johns Hopkins University
KEIO University
KPMG
Kent State University
Kipu Quantum
Knolls Atomic Power Laboratory
Korea Advanced Institute of Science and Technology
Korea Quantum Computing Corporation
Korea University
Kyunghee University
LG ELECTRONICS, INC
LTIMindtree
Lantik SA
Lantik members
Lawrence Berkeley National Laboratory (Berkeley Lab)
Lawrence Livermore National Laboratory
Lehigh University
Lockheed Martin
Los Alamos National Laboratory
Max Kelsen
Mitsubishi Chemical Corporation
Mitsubishi UFJ Financial Group
Mizuho Bank
Moderna
Mondragon Unibertsitatea
Morehouse College
Morgan State University
Multiverse Computing
National Energy Technology Laboratory
National Institute for Nuclear Physics
National Quantum Computing Centre
National Taiwan University
National University of Singapore
Naval Air Warfare Center Aircraft Division
Naval Air Warfare Center Weapons Div.
Naval Information Warfare Center Atlantic Command
Naval Information Warfare Center Pacific Command
Naval Surface Warfare Center
Netherlands Organization for Applied Scientific Research
Netherlands eScience Center
New Mexico State University
New York University
Norfolk State University
North Carolina AT State University
North Carolina Central University
North Carolina State University
Northeastern University
Northwestern University
OESIA
OVH Groupe SA
Oak Ridge National Lab
Pacific Northwest National Lab
Perimeter Institute for Theoretical Physics
Phasecraft
Plateforme d'Innovation Numerique et Quantique
Polymat
Poznan Supercomputing and Networking Center
Prairie View AM University
PricewaterhouseCoopers
Purdue University
Q-Ctrl
QAI Ventures
QC Design
QC Ware
QCENTROID
QEDMA Quantum Computing
QbitSoft
Qognitive
Qruise GmbH
Quanscient
Quantagonia
Quantum Algorithms Institute
Quantum Application Lab
Quantum MADS
Quantum South
Quantum Technology Foundation of Thailand
QuantumBasel
QuantumNET
QubitSolve Inc
Qunasys
Qunova Computing
RIKEN National Research and Development Agency
Rensselaer Polytechnic Institute
Riverlane
SK Inc. C&C
STFC Hartree Centre (UKRI)
Sandia National Labs
School of Engineering, Zürcher Hochschule für Angewandte Wissenschaften
Seoul National University
SeoulTech
SoftBank
Sony
South Carolina State University
Southern University and A&M College
Spelman College
Stellenbosch University
Stony Brook University
Strangeworks
Sumitomo Mitsui Trust Bank Limited
Sungkyunkwan University
Suntory
Super Tech Labs
Surf
System Vertrieb Alexander GmbH
T-Systems International GmbH
TECNALIA Research & Innovation
Technical University of Denmark
Tecnologico de Monterrey
Tekniker
Tennessee State University
Texas Southern University
The University of Texas at San Antonio
Tokyo Electron Limited
Tokyo University of Agriculture and Technology
Toppan Inc
Toshiba
Toyota
Truist Financial Corp
Tuskegee University
Ulsan National Institute of Science and Technology
United States Air Force Research Lab
United States Naval Postgraduate Military University
United States Naval Research Laboratory
United States Naval Undersea Warfare Center
Universite de Sherbrooke
University of Amsterdam
University of Applied Sciences and Arts Northwestern Switzerland
University of Chicago
University of Colorado Boulder
University of Copenhagen
University of Deusto
University of Georgia
University of Kansas
University of Maryland
University of Melbourne
University of Rhode Island
University of Saskatchewan
University of South Carolina
University of Southern California
University of Southern Denmark
University of Sydney
University of Tennessee
University of Tokyo
University of Toronto
University of Washington
University of Waterloo
University of Wisconsin
University of Witwatersrand Johannesburg
University of the District of Columbia Community College
University of the Virgin Islands
Vicomtech
Virginia Tech
Virginia Union University
Vodafone Group
Volkswagen
WACQT
Wells Fargo
Woodside Energy Ltd
Xavier University of Louisiana
Yokogawa Electric Corporation
Yonsei University
Zapata Computing Inc
qBraid Co

Application use cases

Together, stronger

IBM Quantum is not in this alone. Working groups bring together the best industry pioneers and scientists in their field to accelerate our path to achieving Quantum Advantage by 2025 across several domain areas:

Optimization

July 19–20, Zurich

UKRI:STFC
E.On
Fraunhofer
Los Alamos

Quantum Optimization: Potential, Challenges, and the Path Forward
https://arxiv.org/abs/2312.02279

Materials and HPC

April 17–18, Chicago

Riken
Univ. Tokyo
Univ. Chicago
Oak Ridge Nat. Labs

Quantum-centric Supercomputing for Materials Science: A Perspective on Challenges and Future Directions
https://arxiv.org/abs/2312.09733

High energy physics

November 2–3, Geneva

CERN
DESY
PSNC
Univ. Tokyo

Quantum Computing for High-Energy Physics: State of the Art and Challenges. Summary of the QC4HEP Working Group
arXiv:2307.03236

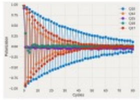
Healthcare and life sciences

April 13–14, Cleveland

Cleveland Clinic
Univ. Toronto
Univ. Chicago
Yonsei Univ

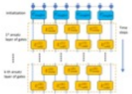
Towards quantum-enabled cell-centric therapeutics
arXiv:2307.05734

If you build it, they will come...

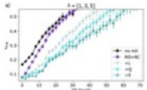


Characterizing quantum processors using discrete time crystals
arXiv:2301.07625
80 qubits / 7900 CX gates
simulation

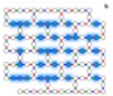
Evidence for the utility of quantum computing before fault tolerance
Nature, 618, 500 (2023)
127 qubits / 2880 CX gates
simulation



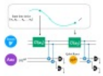
Simulating large-size quantum spin chains on cloud-based superconducting quantum computers
Phys. Rev. Research 5, 013183 (2023)
102 qubits / 3186 CX gates
simulation



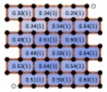
Best practices for quantum error mitigation with digital zero-noise extrapolation
arXiv:2307.05203
104 qubits / 3605 ECR gates
tools



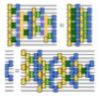
Uncovering Local Integrability in Quantum Many-Body Dynamics
arXiv:2307.07552
124 qubits / 2641 CX gates
simulation



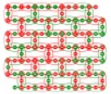
Quantum reservoir computing with repeated Measurements on superconducting devices
arXiv:2310.06706
120 qubits / 49470 gates + meas.
simulation



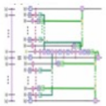
Realizing the Nishimori transition across the error threshold for constant-depth quantum circuits
arXiv:2309.02863
125 qubits / 429 gates + meas.
simulation



Scalable Circuits for Preparing Ground States on Digital Quantum Computers: The Schwinger Model Vacuum on 100 Qubits
PRX Quantum 5, 020315 (2024)
100 qubits / 788 CX gates
simulation

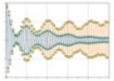


Scaling Whole-Chip QAOA for Higher-Order Ising Spin Glass Models on Heavy-Hex Graphs
arXiv:2312.00997
127 qubits / 420 CX gates
optimization

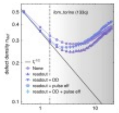


Efficient Long-Range Entanglement using Dynamic Circuits
arXiv:2308.13065
101 qubits / 504 gates + meas
tools

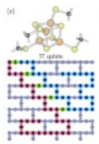
Quantum Simulations of Hadron Dynamics in the Schwinger Model using 112 Qubits
arXiv:2401.08044
112 qubits / 13,858 gates
simulation



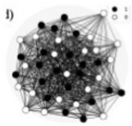
Unveiling clean two-dimensional discrete time quasicrystals on a digital quantum computer
arXiv:2403.16718
133 qubits / 15,000 CZ gates
simulation



Benchmarking digital quantum simulations and optimization above hundreds of qubits using quantum critical dynamics
arXiv:2404.08053
133 qubits / 1440 CX gates
simulation



Chemistry Beyond Exact Solutions on a Quantum-Centric Supercomputer
arXiv:2405.05068
77 qubits / 3590 CZ gates
simulation

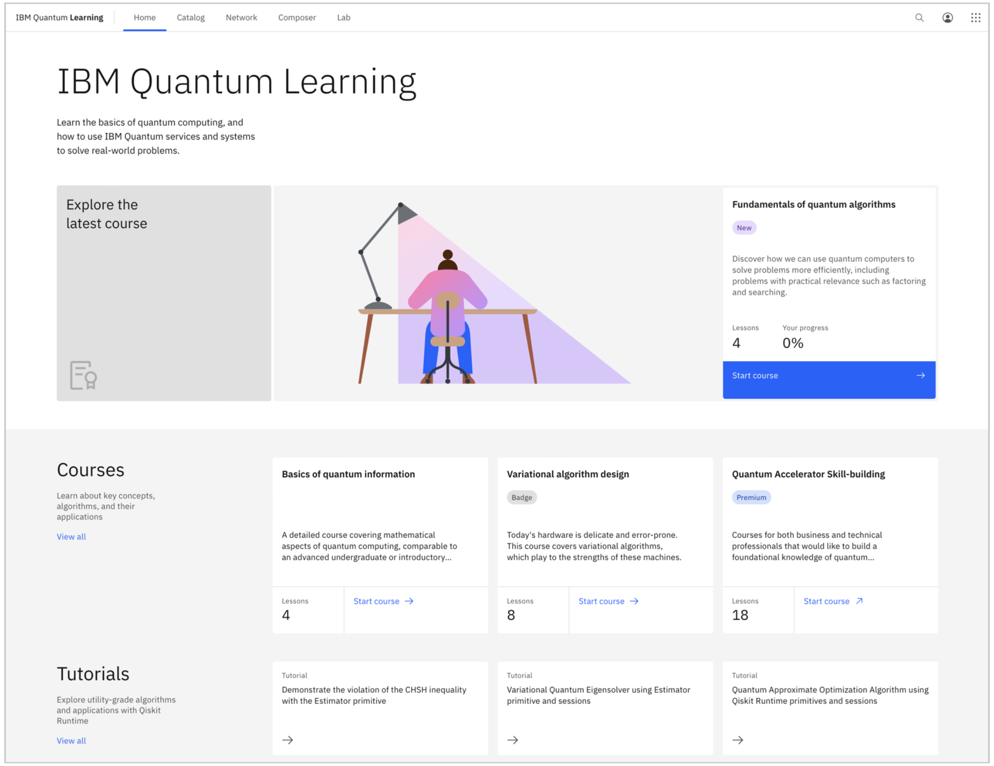


Towards a universal QAOA protocol: Evidence of quantum advantage in solving combinatorial optimization problems
arXiv:2405.09169
109 qubits / 21,200 gates
optimization

Education

IBM Quantum Learning – the home to learn, experiment, and prototype quantum algorithms and applications

- University-level Courses
- Tools
- Tutorials
- Guides



Workforce Development: Community driven

Spring

IBM Quantum Challenge

Qiskit Global Summer School

Summer

IBM Quantum Internships

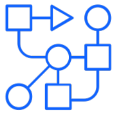
Qiskit Fall Fest

Fall

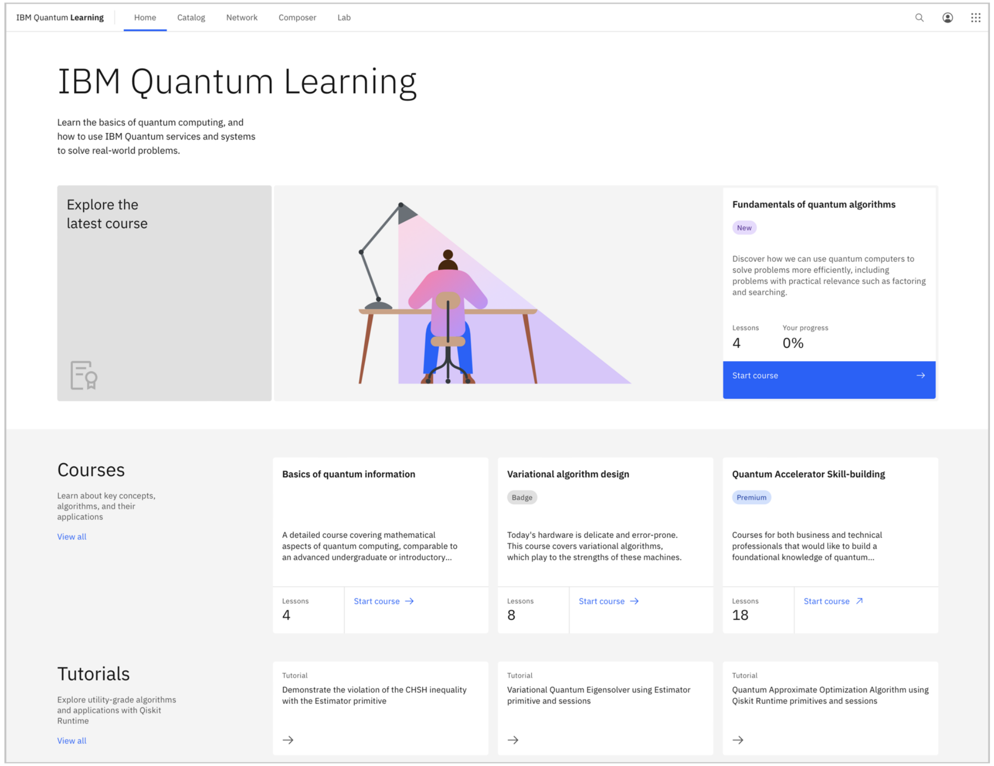
Advocate Mentorship Program

Winter

Workforce Development



Education



In summary

Deliver our technical roadmap on hardware, orchestration, and software layers

Contribute to the development of enabling technology ecosystems

Empower people around the world to use and advance quantum knowledge

Collaborate with partners in industry, academia, and government to develop quantum usage