


# IBM Quantum Research Updates: IBM Quantum Network


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**Improved nitrogen-fixation process** for creating ammonia-based fertilizer



**New catalysts** to make CO<sub>2</sub> conversion into hydrocarbons more efficient and selective



**Better financial models** to improve stability, predictability and growth of world economies



**New classes of antibiotics** to counter the emergence of multidrug-resistant bacterial strains

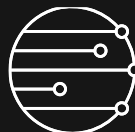
# The IBM Quantum Network:

A collaborative community of discovery

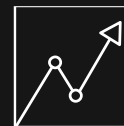
Educate and Train



Accelerate Research



Develop Applications



# IBM Quantum Network Today

**158 total**

13 industry partners

20 hubs

35 members

40 startups

50 academic members and partners

## Partners

Accenture

Amgen

BP

Boeing

Daimler

E.ON

ExxonMobil

Goldman Sachs

JP Morgan Chase

JSR Corporation

Paypal

Samsung Advanced Institute of Technology

Woodside Energy Ltd

## Hubs

Brookhaven National Lab

Bundeswehr University Munich

CERN Openlab

CSIC Spanish National Research Council

Cleveland Clinic Foundation

Fraunhofer

Iberian Nanotechnology Laboratory

KEIO University

Los Alamos National Laboratory

National Taiwan University

North Carolina State University

Oak Ridge National Lab

Pacific Northwest National Lab

Science & Technology Facilities Council, Daresbury

Sungkyunkwan University

United States Air Force Research Lab

University of Melbourne

University of Oxford

University of Sherbrooke

University of Tokyo

## Members

A\*STAR

Anthem

Archer Materials Limited

Argonne National Lab

Assured Information Security

Barclays Bank PLC

CMC Microsystems

Carnegie Mellon Software Engineering Institute

DIC Corporation

Deloitte

Delta Airlines

Fermi National Accelerator Laboratory

Flightprofler

GE Global Research

GRID Inc

General Atomics

Hitachi Ltd

III Taiwan

Industrial Technology Research Institute

Lawrence Berkeley National Laboratory

Lockheed Martin

Mitsubishi Chemical Corporation

Mitsubishi UFJ Financial Group

Mizuho Bank

Molecular Forecaster Inc

Sandia National Labs

Sony

Sumitomo Mitsui Trust Bank Limited

System Vertrieb Alexander GmbH

Toshiba

Toyota

TradeTeg Marketplace

United States Naval Research Laboratory

Wells Fargo

Yokogawa Electric Corporation

## Startups

1Qbit Systems

AIQTECH Inc

Agnostiq Inc

Aliro Quantum

Apply Science

Beit

Blueqat

Boxcat Inc

Cambridge Quantum Computing

Classiq

Coldquanta

Entropica Labs

Equal1

Horizon Quantum Computing

JoS Quantum

Keysight

Max Kelsen

Miraex

Multiverse Computing

NetraMark Corp

Nordic Quantum Computing Group

Opacity

Phasecraft

ProteinQure

Q Ctrl

QC Ware

Qedma Quantum Computing

Qu & Co

Quantifi

Quantum Machines

Qunays

Rahko

SoftwareQ

Solid State AI

SpinUp AI

Strangeworks

Super Tech Labs

Xanadu

Zapata Computing Inc

Zurich Instruments

## Academic

Aalto University

Boston University

Chalmers University of Technology

Cornell University

Duke University

EPFL

ETH Zurich

Florida State University

Georgetown

Georgia Institute of Technology

Hanyang University

Harvard

Johns Hopkins University

Korea Advanced Institute of Science and Technology

Korea University

Massachusetts Institute of Technology

National University of Singapore

Naval Postgraduate School

New Mexico State University

New York University

Northeastern University

Northwestern University

Pohang University of Science and Technology

Princeton University

Purdue University

Saarland University

Seoul National University

Stanford University

Stony Brook University

Turku University

University of Basque Country

University of Chicago

University of Colorado Boulder

University of Edinburgh

University of Georgia

University of Illinois at Urbana Champaign

University of Innsbruck

University of Madrid

University of Minho

University of Montpellier

University of New Mexico

University of Notre Dame

University of Southern California

University of Stuttgart

University of Tennessee

University of Washington

University of Waterloo

University of Witwatersrand Johannesburg

Virginia Tech

Yonsei University



# IBM Quantum Network: A Snapshot

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Over 300,000 users have...

Run over 700 Billion quantum circuits

1.4 Billion quantum circuits per day

using total 34 quantum computers  
deployed up to date

More than 150 Clients and Partners

Collaborating on 30+ applications

Over 400 contributors to Qiskit

Over 500 scientific papers so far

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# Business examples: quantum optimization

IBM Quantum



## JPMC: Option pricing for risk management

### Option Pricing using Quantum Computers

Nikitas Stamatopoulos<sup>1</sup>, Daniel J. Egger<sup>2</sup>, Yue Sun<sup>1</sup>, Christa Zoufal<sup>2,3</sup>, Raban Iten<sup>2,3</sup>, Ning Shen<sup>1</sup>, and Stefan Woerner<sup>2</sup>

<sup>1</sup>Quantitative Research, JPMorgan Chase & Co., New York, NY, 10017

<sup>2</sup>IBM Quantum, IBM Research – Zurich

<sup>3</sup>ETH Zurich

<https://arxiv.org/abs/1905.02666>



## Barclays: Managing transaction settlement

### Quantum Algorithms for Mixed Binary Optimization applied to Transaction Settlement

Lee Braine,<sup>1</sup> Daniel J. Egger,<sup>2</sup> Jennifer Glick,<sup>3</sup> and Stefan Woerner<sup>2,\*</sup>

<sup>1</sup>Barclays

<sup>2</sup>IBM Research – Zurich

<sup>3</sup>IBM T.J. Watson Research Center

<https://arxiv.org/abs/1910.05788>

# Business examples: quantum simulation

IBM Quantum



## Daimler: Design for Lithium-Sulfur Batteries

### Quantum Chemistry Simulations of Dominant Products in Lithium-Sulfur Batteries

Julia E. Rice,<sup>1</sup> Tanvi P. Gujarati,<sup>1</sup> Tyler Y. Takeshita,<sup>2</sup> Joe Latone,<sup>1</sup>

Mario Motta,<sup>1</sup> Andreas Hintennach,<sup>3</sup> and Jeannette M. Garcia<sup>1</sup>

<sup>1</sup>IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120, USA

<sup>2</sup>Mercedes Benz Research and Development North America, Sunnyvale, CA 94085

<sup>3</sup>Daimler AG (Mercedes-Benz Cars), Group Research, HPC G012-BB, 71034, Boeblingen, Germany

<https://arxiv.org/abs/2001.01120>

Energy of binary crystalline materials circuit.



## ExxonMobil: Reaction rates, entropies, heat capacities

### Computing thermodynamic observables on noisy quantum computers with chemical accuracy

Spencer T. Stober <sup>\*1</sup>, Stuart M. Harwood<sup>1</sup>, Donny Greenberg<sup>2</sup>, Tanvi P. Gujarati<sup>3</sup>, Sarah Mostame<sup>2</sup>, Sumathy Raman<sup>1</sup>, and Dimitar Tenev<sup>1</sup>

<sup>1</sup>ExxonMobil Corporate Strategic Research, Annandale, NJ 08801, USA

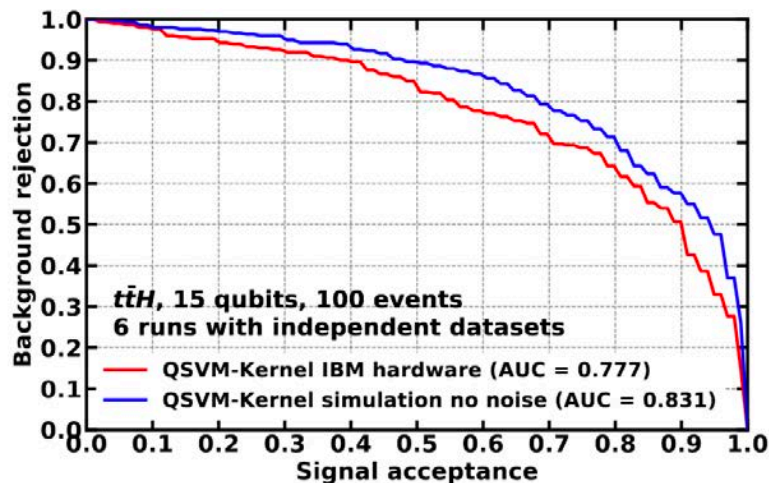
<sup>2</sup>IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA

<sup>3</sup>IBM Research Almaden, San Jose, CA 95120, USA

<https://arxiv.org/abs/2003.02303>

# Business example: quantum machine learning

## CERN: Classifying jet events



### Application of Quantum Machine Learning using the Quantum Kernel Algorithm on High Energy Physics Analysis at the LHC

Sau Lan Wu, Shaojun Sun, Wen Guan, Chen Zhou, Jay Chan, Chi Lung Cheng, Tuan Pham, Yan Qian, Alex Zeng Wang, and Rui Zhang  
*Department of Physics, University of Wisconsin, Madison WI, USA*

Miron Livny  
*Department of Computer Sciences, University of Wisconsin, Madison WI, USA*

Jennifer Glick  
*IBM Quantum, T.J. Watson Research Center, Yorktown Heights, NY, USA*

Panagiotis Kl. Barkoutsos, Stefan Woerner, and Ivano Tavernelli  
*IBM Quantum, Zurich Research Laboratory, Rüschlikon, Switzerland*

Federico Carminati and Alberto Di Meglio  
*CERN Quantum Technology Initiative, IT Department, CERN, Geneva, Switzerland*

Andy C. Y. Li, Joseph Lykken, and Panagiotis Spentzouris  
*Quantum Institute, Fermi National Accelerator Laboratory, Batavia, IL, USA*

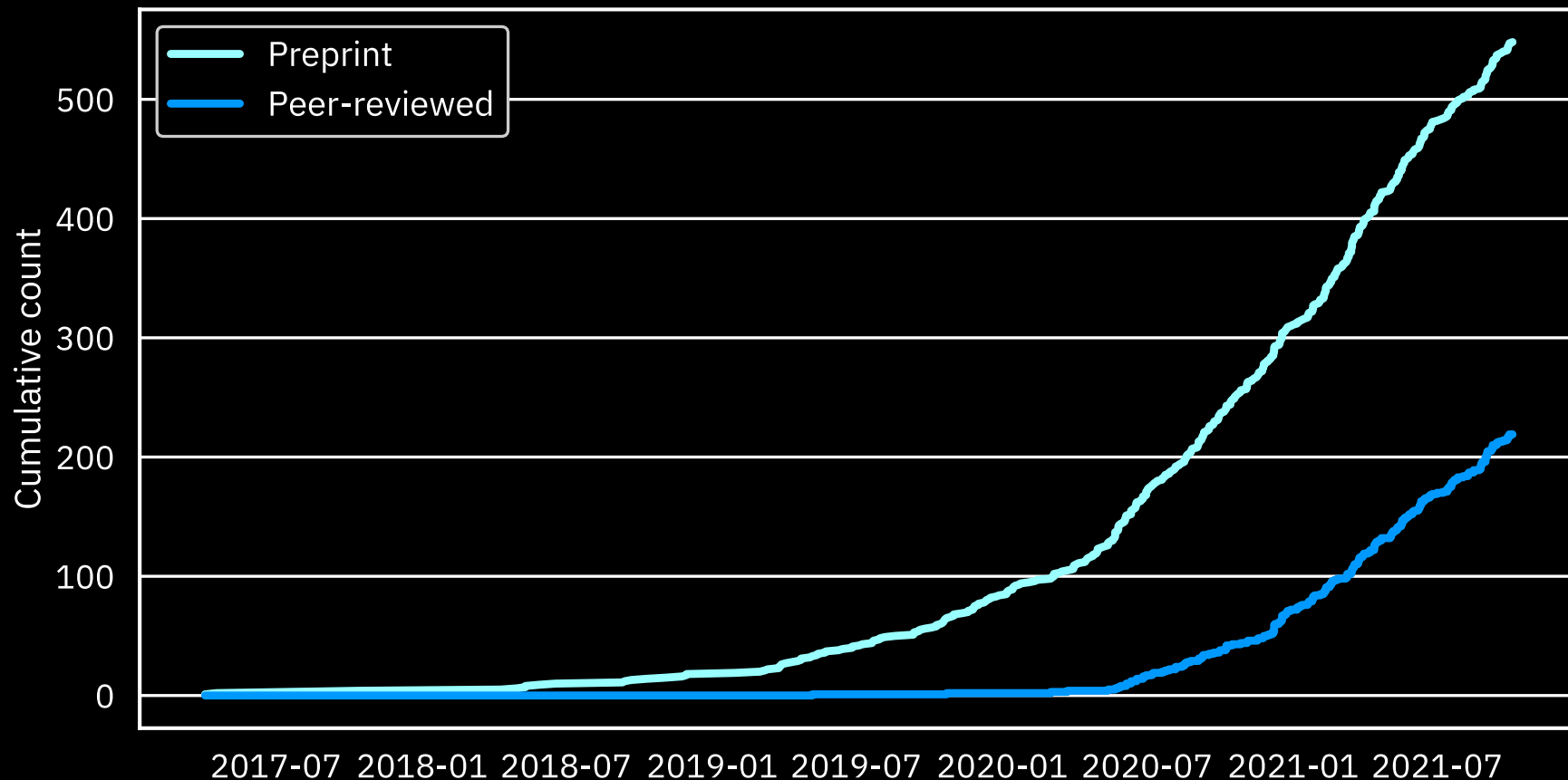
Samuel Yen-Chi Chen and Shinjae Yoo  
*Computational Science Initiative, Brookhaven National Laboratory, Upton, NY, USA*

Tzu-Chieh Wei  
*C.N. Yang Institute for Theoretical Physics, State University of New York at Stony Brook, Stony Brook, NY, USA*

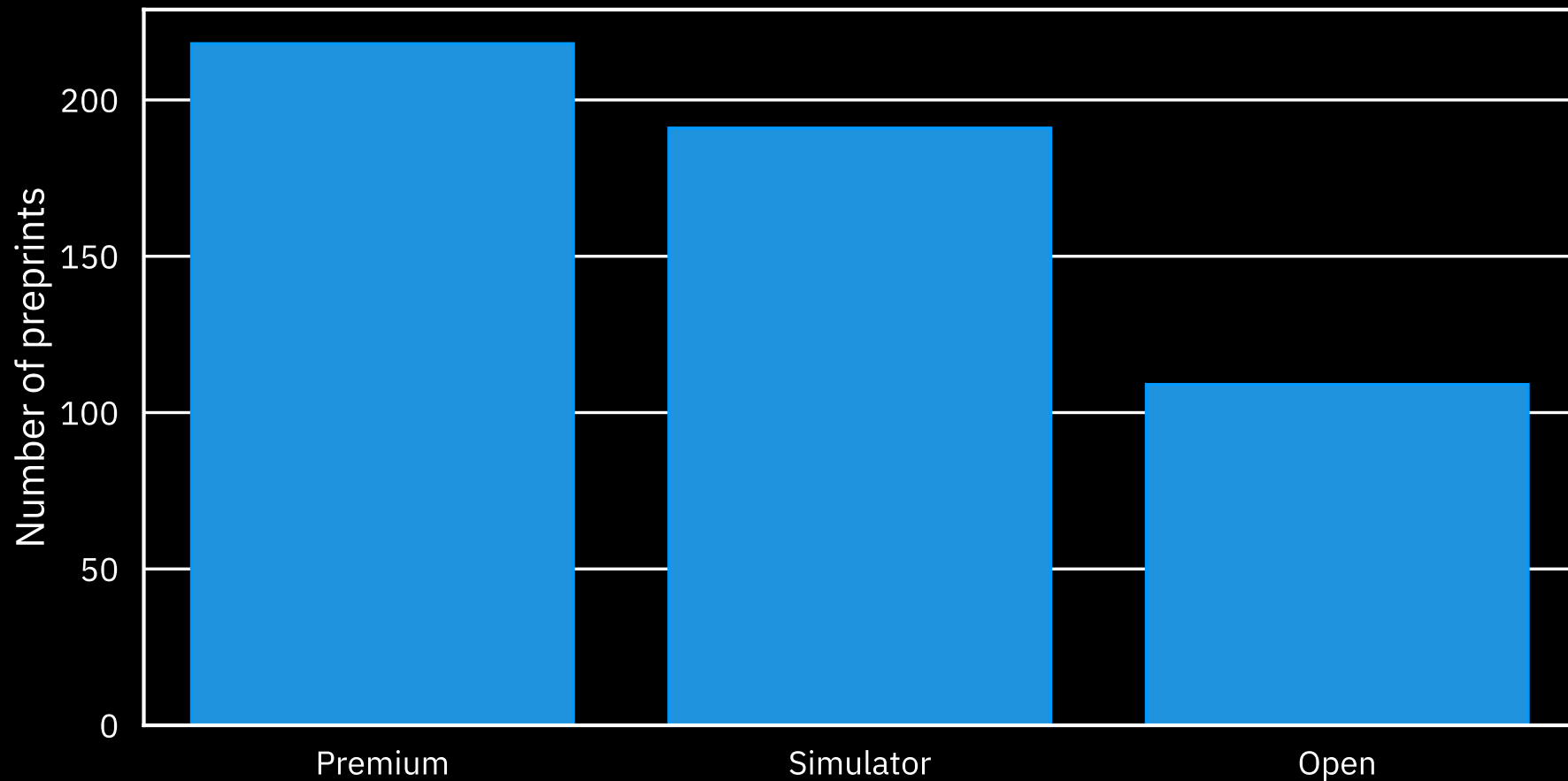
<https://arxiv.org/abs/2104.05059>

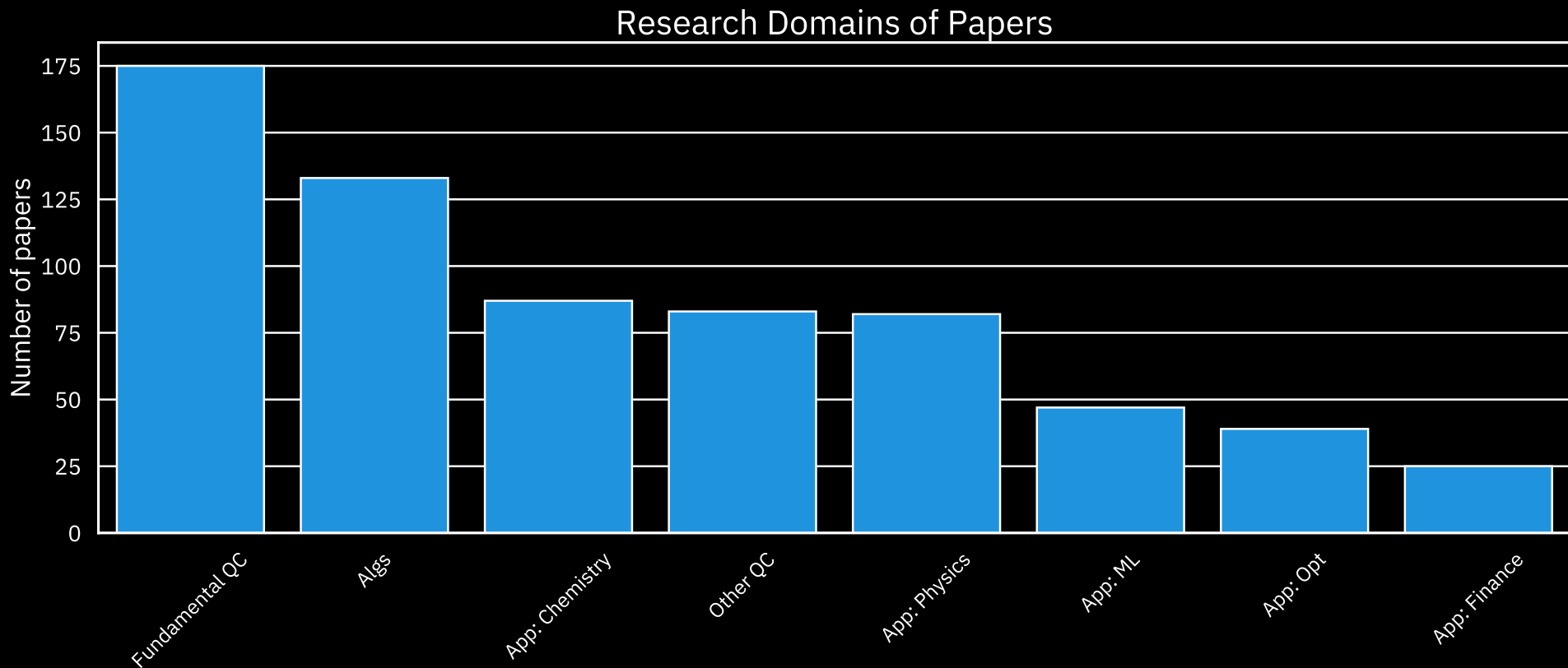


# The IBM Quantum Network: Accelerating Research



## Type of System Used





# IBM Quantum

<https://quantum-computing.ibm.com>