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re:Invent

QCM301

Exploring quantum computing today with Amazon Braket

Eric Kessler, PhD

Sr. Product Manager, Science
Amazon Braket
AWS

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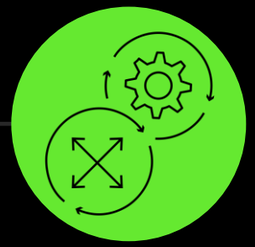
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Agenda



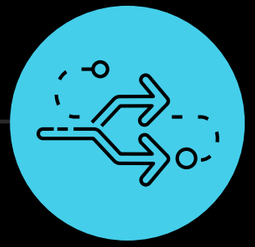
Amazon Braket

GET STARTED WITH QUANTUM COMPUTING



Hybrid quantum computing

TRAIN YOUR QUANTUM CIRCUIT LIKE A NEURAL NET



Tensor network simulation

TEST NEW CIRCUIT CLASSES



Why now?

The field is advancing rapidly

- Technology milestones are being achieved
- Increasing choice of competing technologies
- Government initiatives stimulate activity

Starting now allows customers to

- Understand the long-term transformative potential
- Plan ahead, manage risk, and identify opportunities and threads
- Learn new skills, build expertise, and collect resources
- Develop new algorithms and IP

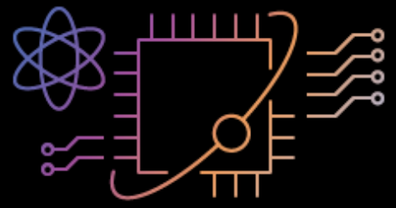
Democratizing quantum computing



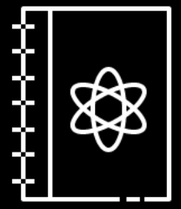
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Amazon Braket

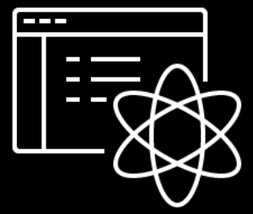


A fully managed service that makes it easy for scientists and developers to experiment with quantum computing



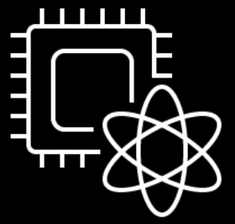
Build

Fully managed development environment



Test

High-performing circuit simulators



Run

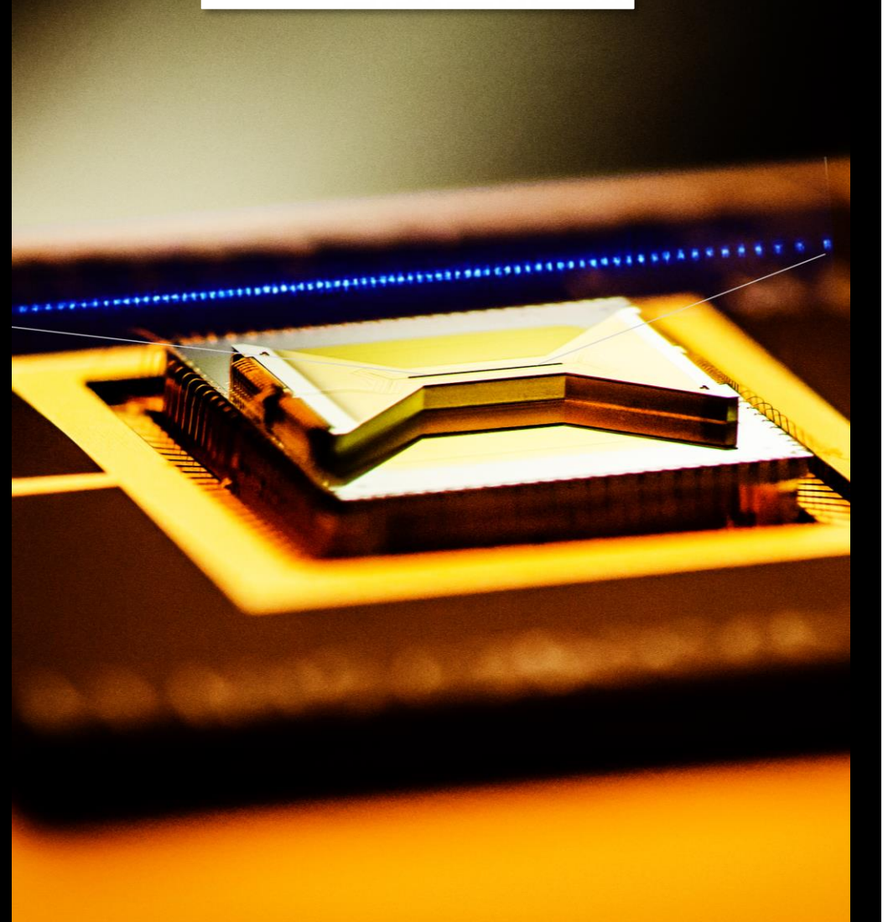
Secure, on-demand access to quantum hardware

Choice of quantum hardware technology

D-Wave
The Quantum Computing Company™



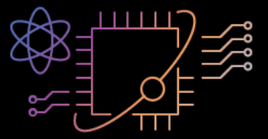
IONQ



rigetti



Available on-demand on AWS



D-Wave — The Quantum Computing Company™

IONQ

rigetti

D-Wave — Advantage_system1.1

Quantum Annealer based on superconducting qubits

Qubits	Status
5760	ONLINE
Region	**Next available**
us-west-2	AVAILABLE NOW

IonQ

Universal gate-model QPU based on trapped ions

Qubits	Status
11	ONLINE
Region	**Next available**
us-east-1	AVAILABLE NOW

Rigetti — Aspen-8

Universal gate-model QPU based on superconducting qubits

Qubits	Status
31	ONLINE
Region	**Next available**
us-west-1	AVAILABLE NOW

Democratize quantum computing and accelerate innovation

VOLKSWAGEN GROUP

"For the first time, Amazon Braket makes it possible to address and use quantum computers of different service providers via a standardized programming interface."

- Florian Neukart, Director of Advanced Technologies and IT Strategy, Volkswagen Group of America

FCAT FIDELITY CENTER for APPLIED TECHNOLOGY

"[With Amazon Braket] we're able to research the strengths of different quantum backends, build hybrid classical-to-quantum, and quantum-to-quantum workflows."

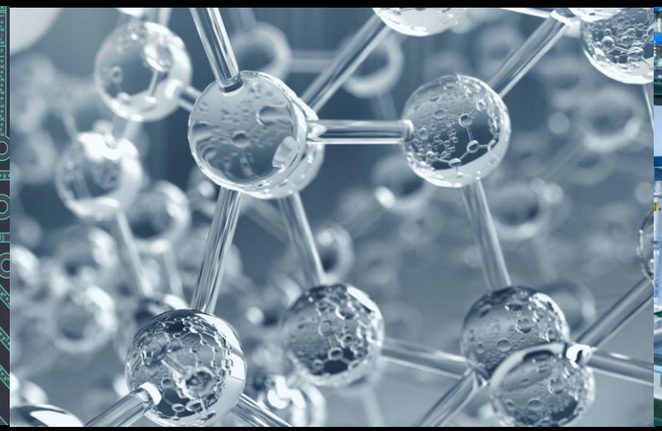
- Adam Schouela, Head of Emerging Technology at the Fidelity Center for Applied Technology

UNIVERSITY OF WATERLOO | IQC Institute for Quantum Computing

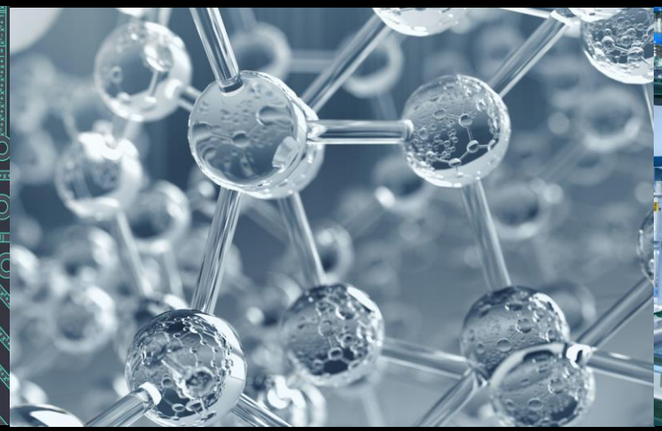
"A quantum computing service, like Amazon Braket, that offers ready access to multiple hardware devices enables quantum readiness and agility."

- Michele Mosca, Full Professor at the University of Waterloo

Quantum algorithms exceed the capabilities of today's devices

Cryptography	Physics/Chemistry	Material Science	Optimization
			
Break 2048 RSA	Simulate FeMoco	Simulate High-T superconductors	Scheduling, ranking, learning

Quantum algorithms exceed the capabilities of today's devices

Cryptography	Physics/Chemistry	Material Science	Optimization
			
Break 2048 RSA	Simulate FeMoco	Simulate High-T superconductors	Scheduling, ranking, learning
~ 10M qubits*	~ 100K qubits*	~ 100K qubits*	~ 1M qubits*

*For qubits with 0.1% error rate

Learning quantum machines



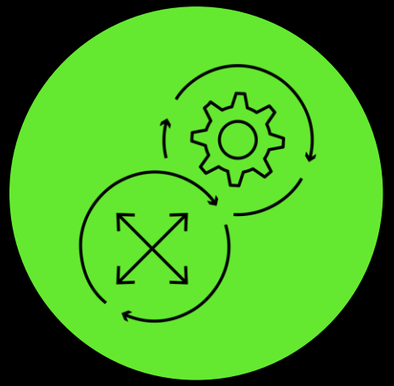
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Hybrid methods promise near-term applications

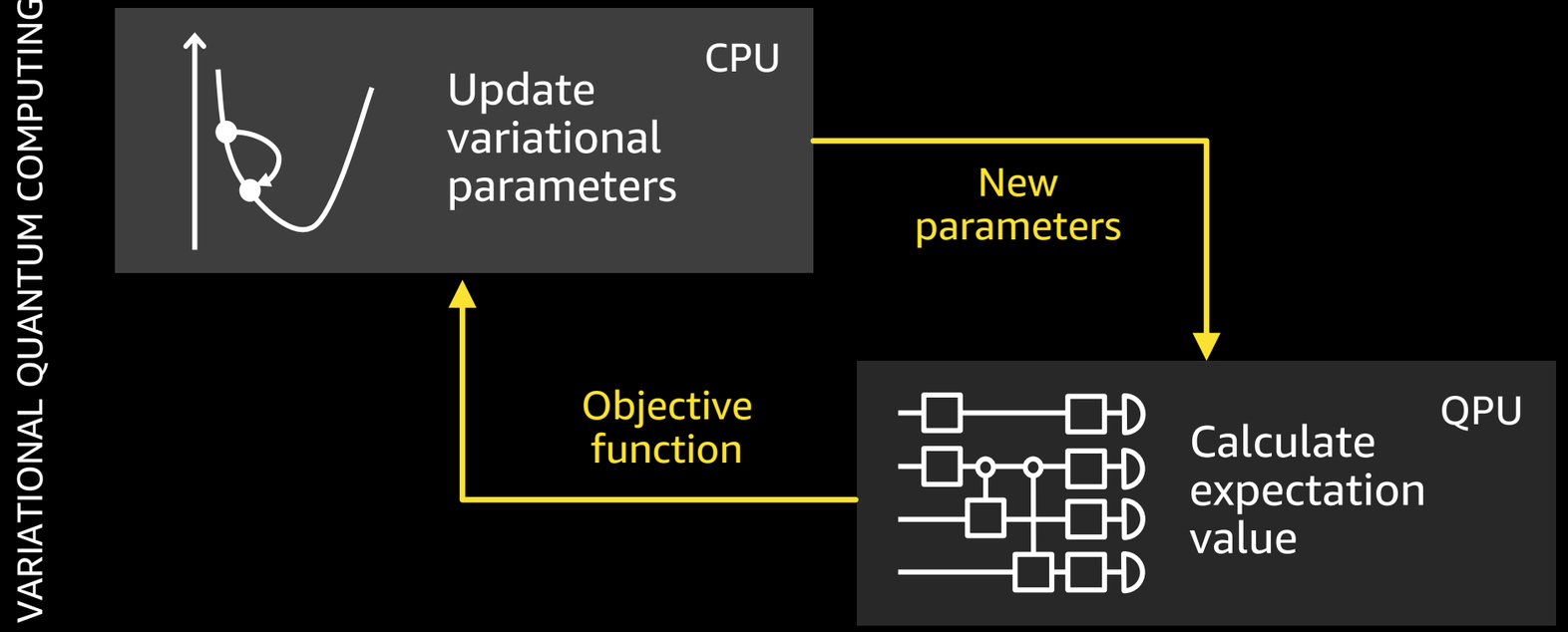
Noisy Intermediate Scale Quantum (NISQ)

Hybrid algorithms use fewer qubits and shorter circuits

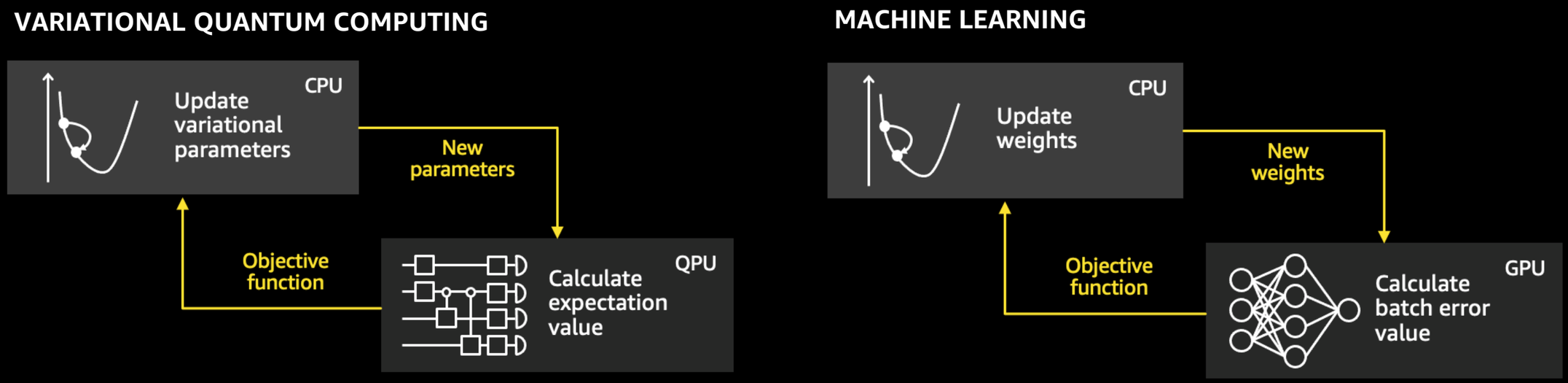


Hybrid algorithms

QUANTUM COMPUTERS AS CO-PROCESSORS



Self-learning quantum algorithms



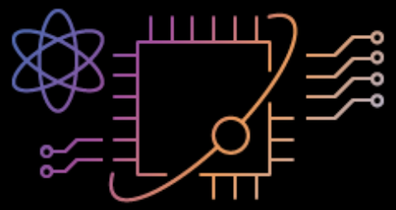
Insights from ML to supercharge near-term quantum computing

- Adoption-led innovation: Build and test heuristic approaches
- Differentiable programming and sophisticated optimization strategies paved the way for the success of neural nets
- Mature end user libraries make it easy and intuitive to build, train, and experiment

Introducing PennyLane on Amazon Braket

TRAIN YOUR QUANTUM CIRCUIT LIKE A NEURAL NETWORK

PENNY LANE



Bringing machine learning tools to quantum computing

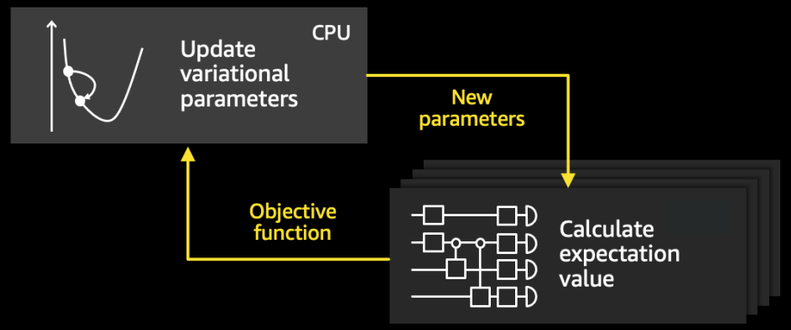
- Get started with *quantum differentiable programming*
- Use familiar ML tools including PyTorch and TensorFlow
- Build hybrid quantum-classical models

Easy to use and high-performing

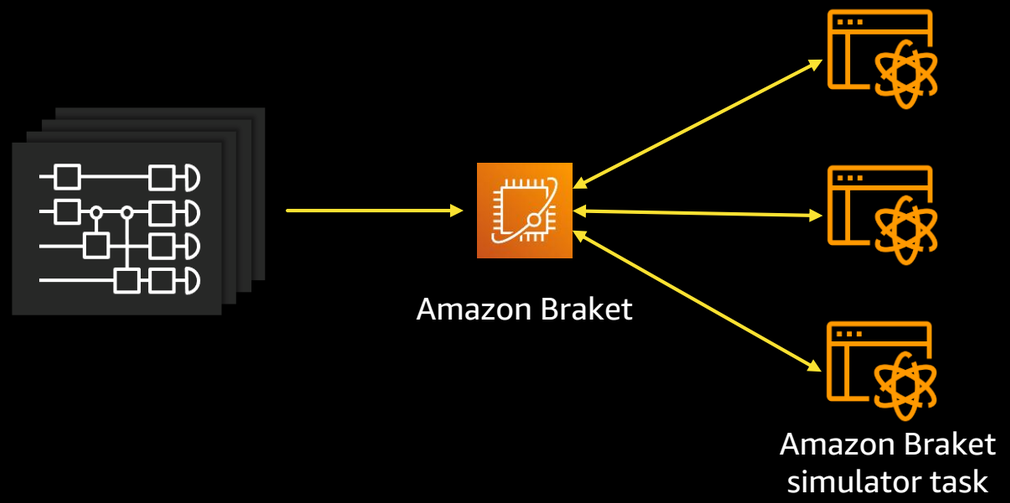
- Get started quickly with pre-configured Amazon Braket notebooks and tutorials
- Access application libraries for chemistry, optimization, and ML
- Train 10x faster on Amazon Braket simulators

Train 10x faster on Amazon Braket simulators

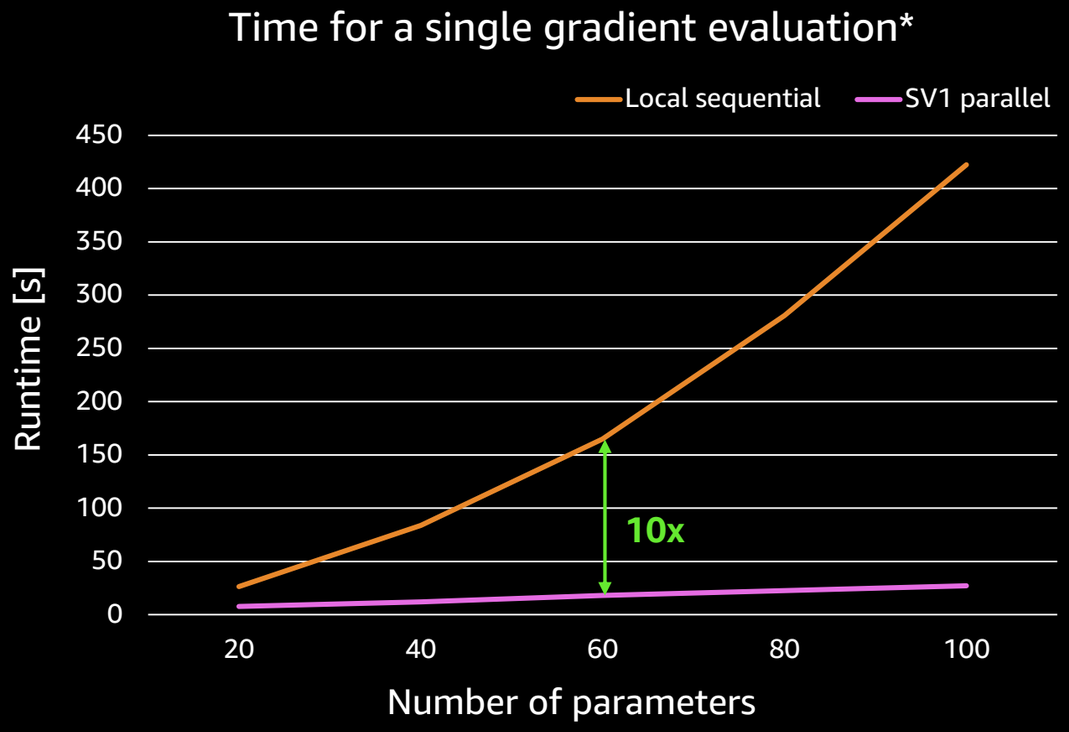
VARIATIONAL ALGORITHMS REQUIRE MANY CIRCUIT EXECUTIONS AT EVERY STEP



PARALELLIZE CIRCUIT EXECUTIONS WITH AMAZON BRAKET SIMULATORS



10x FASTER TRAINING TIMES ACCELERATING ALGORITHM RESEARCH AND TUNING



*20 qubits, local simulation on m5.12xl EC2 instance using PennyLane local simulator

Simulating quantum circuits is hard



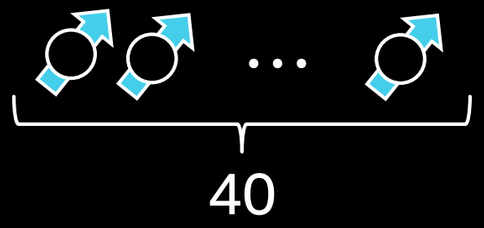
Classical bits: 00 or 01 or 10 or 11
Quantum bits: 00 and 01 and 10 and 11



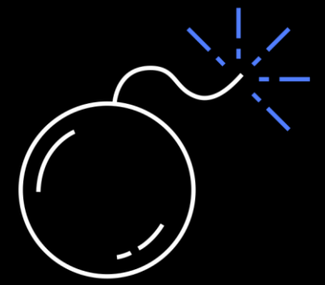
4 numbers to describe the system



8 numbers to describe the system



2^{40} numbers to describe the system



Exponential memory requirements

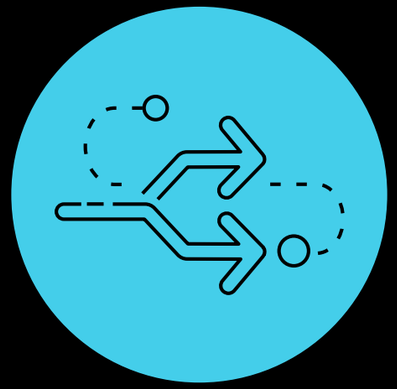
The unreasonable effectiveness of tensor networks



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Introducing: Managed tensor network simulation with TN1



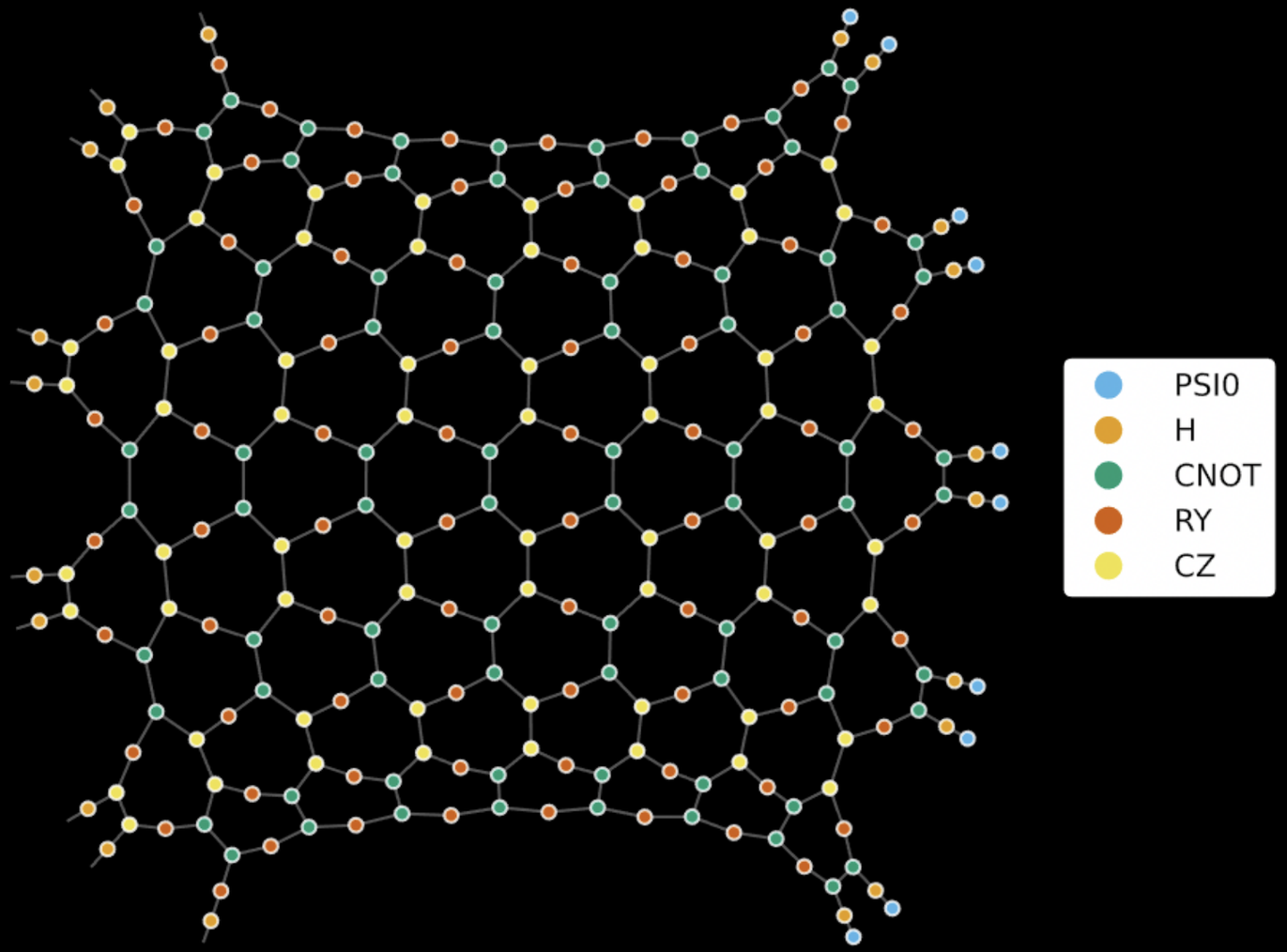
Tensor network simulation

You don’t need the full state vector to get the results that matter

There is more than one way to simulate a circuit. Let’s find the best one

Special circuit structure makes it easier to simulate a circuit

What makes simulation hard?



Entanglement **determines the hardness of a circuit**

Entanglement **spread is slowed down by**

› Local gates

› Sparse circuits

› Weakly interacting groups of qubits

TN1 detects and exploits circuit structure

Large-circuit simulation with TN1

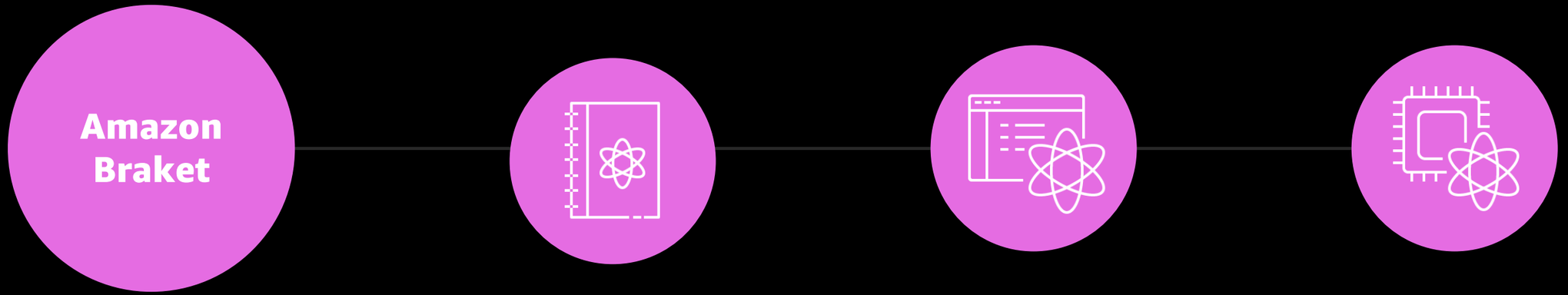


TN1 runtimes follow the true *hardness* of the circuit

- Simulate up to 50 qubits
- Faster runtimes than SV1 for large, structured circuits
- *Rehearsal* determines whether circuit can be simulated

Accelerate research of hardware-specific algorithms

Accelerating the innovation cycle with Amazon Braket



Build

Get started quickly with a fully managed development environment

NEW! Build variational algorithms with familiar ML tooling

NEW! Access application libraries for chemistry, ML, and optimization

Test

Use fully managed simulators to test and fine-tune your algorithm

NEW! 10x faster training through optimized parallel execution

NEW! Test new algorithm classes with tensor network simulations

Run

Secure and on-demand access to quantum computers

NEW! Control the physical allocation of qubits in your algorithms

Thank you!



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