
Atos
Quantum
Learning
Machine
Trusted partner for your Digital Journey
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Quantum computing – a promise

Quantum computing relies on one promise:

Quantum computing is based on the promise that, when quantum computers are available, it will be possible to solve some complex problems faster than the current most powerful HPC systems.

It will **massively reduce the complexity** of some problems currently intractable to classical computers…

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A brief story of quantum computing

1981: First basic model of a quantum computer
R. Feynman

1994: Quantum algorithm development to factorize large numbers. *P. Shor*

2017: Atos introduced Quantum Learning Machine

Today: Simulation
- Learning systems
- NISQ prototypes

~ 2023: Physical qubits
NISQ devices era (Noisy Intermediate-Scale Quantum)
- Quantum accelerator industrialization
- Atos NISQ introduction

2035+: Logical qubits
- *FTQC (Fault Tolerant Quantum Computers)*

Discovery phase | NISQ era | FTQC era

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Quantum computing – a few fundamental notions

QUANTUM BIT "QUBIT"

- ✓ **Basic unit** of quantum information
- ✓ **Two-state** quantum-mechanical system
- ✓ In QC, the **computational power** of a system is expressed in # of qubits
- ✓ **N qubits ➔** 2^N information

STATE SUPERPOSITION and MEASUREMENT

Qubits can be in **superposed |0> and |1> states**

When measured, they **collapse** to one of the states: |0> or |1>

N-qubit system ➔ 2^N states

QUANTUM ENTANGLEMENT

Entangled qubits have their states in **interaction** with each other. They cannot be described independently of the state of the others

q_0

Measurement of a single qubit will influence the entangled system as a whole!

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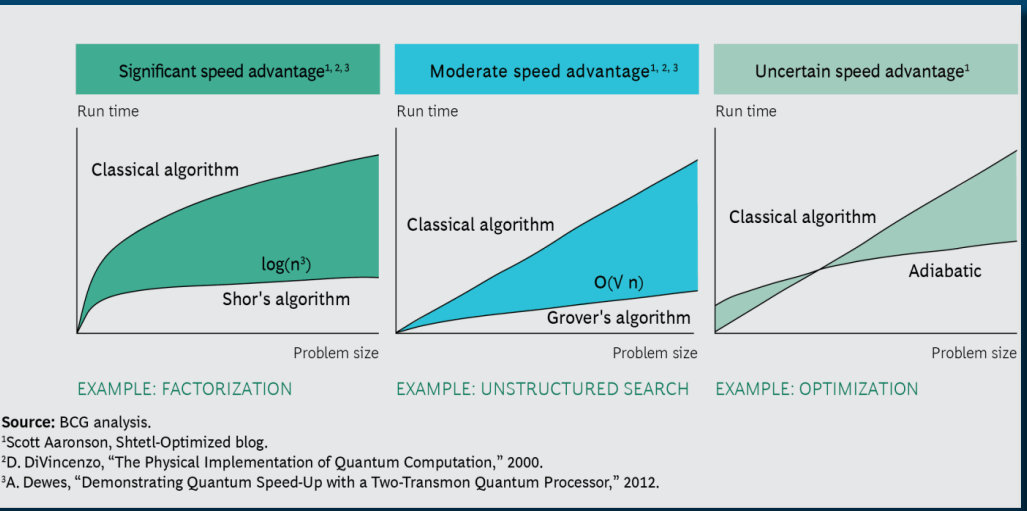
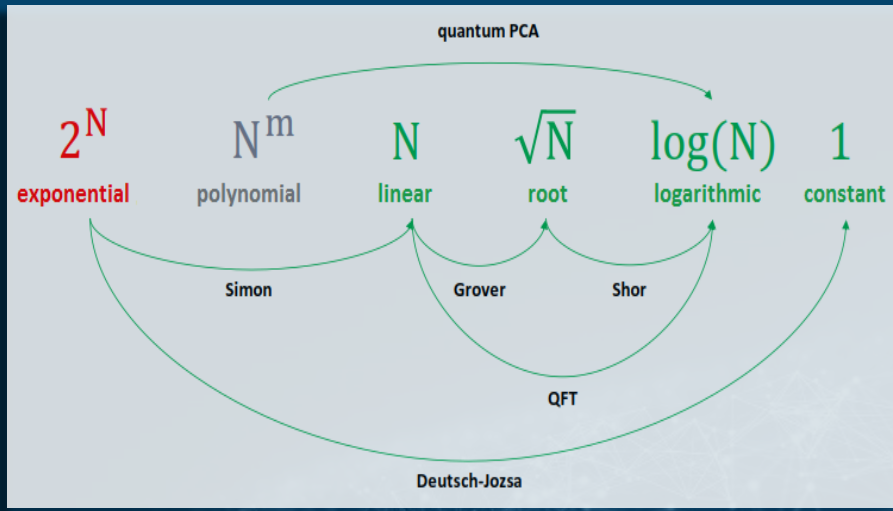
Quantum computing acceleration

- We see quantum computing as an accelerator of classical computing



Source: BCG analysis.
[1]Scott Aaronson, Shtetl-Optimized blog.
[2]D. DiVincenzo, "The Physical Implementation of Quantum Computation," 2000.
[3]A. Dewes, "Demonstrating Quantum Speed-Up with a Two-Transmon Quantum Processor," 2012.



It is unlikely classical computing will be replaced any time soon by quantum computing…

Why investing in quantum computing now?

Quantum computing is an opportunity, now available for businesses…

Artificial Intelligence created an unprecedented competitive gap on the market

Quantum Computing: when QPUs are available, organizations with the greatest expertise may get an order-of-magnitude edge

Investing in **Quantum Computing** is urgent

- Access existing commercial quantum **simulation** capabilities,
- Test newly available hardware **platforms**, and software **applications**,
- Develop new **algorithms**

To create competitive advantage

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Quantum Computing applications

Numerous cross-industry impacts

Manufacturing

Public Sector & Defense

Financial Services & Insurance

Telecom, Media & Technology

Resources & Services

Healthcare & Life Sciences

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Quantum Computing applications

Numerous cross-industry impacts

Manufacturing

- Autonomous vehicle
- Logistics
- Supply chain
- Software validation
- Batteries
- Polymers

Public Sector & Defense

- Neural networks
- Process optimization
- Cryptanalysis
- Material science
- Nanotechnologies

Financial Services & Insurance

- Fraud detection
- Trading strategies
- Market simulation
- Portfolio optimization
- Risk assessment
- Cryptocurrency

Telecom, Media & Technology

- Personalized content
- 5G antenna location
- Chip layout optimization
- Post-quantum cryptography

Resources & Services

- Smart grids
- Flight scheduling
- Oil well optimization
- Yield management
- Cybersecurity
- Carbon dioxide capture

Healthcare & Life Sciences

- Genomics
- Virtual screening
- Protein folding
- Drug discovery
- Personalized medicine

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Quantum Computing Applications

	Machine Learning	Combinatorial Optimization	Security	Chemistry
Public Sector & Defense	Neural networks	Process optimization	• Cryptanalysis • Quantum key distribution	• Materials science • Nanotechnologies
Manufacturing	• Traffic simulation • E-charging station and parking search • Autonomous driving	• Logistics (scheduling, planning, production distribution routing) • Supply chain	• Software validation • Verification and fault analysis	• Batteries • Polymers • Catalysts, enzyme design
Resources & Services	• Smart grids • Energy management • Network design	• Yield management • Flight scheduling • Oil well optimization	Cybersecurity	• Carbon dioxide capture • Lubricants
Healthcare & Life Sciences	• Personalized medicine • Genomics	• Virtual screening • Clinical trial database search	Post-quantum cryptography	• Molecular modeling • Protein folding • Drug discovery
Financial Services & Insurance	• Fraud detection • Trading strategies • Asset pricing • Market simulation	• Portfolio optimization • Risk assessment	Cryptocurrency	
Telecom, Media & Utilities	Personalized content	• 5G antenna location • Chip layout optimization	Post-quantum cryptography	

And many more to come…

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Chemistry

One of today's most active application area!

Chemistry

GOAL

Compute the exact energy of large molecules

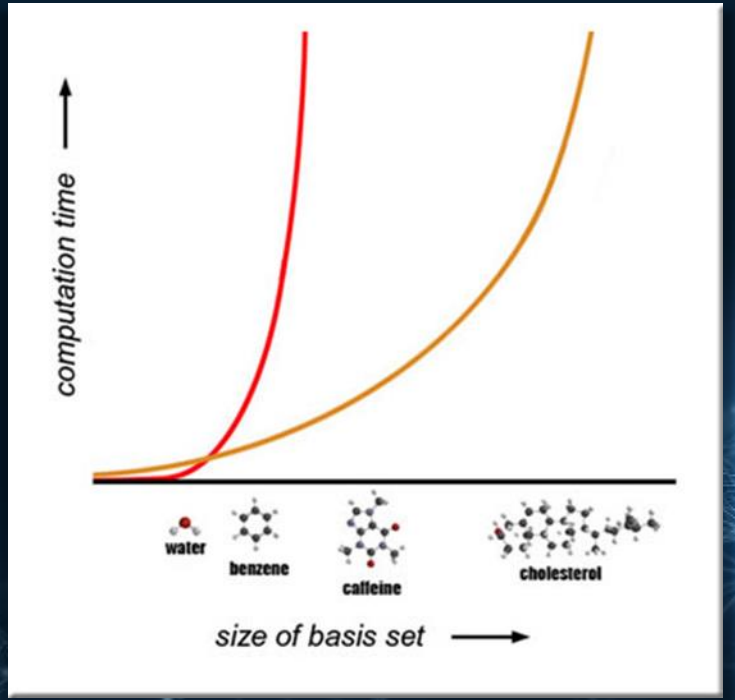
- This is intractable today
- Cost: 2 qubits per orbital even without error correction!

STAR ALGORITHMS

Variational Quantum Algorithms (VQE and derivatives)

IMPACT

New discovery and energy savings in synthesis for fertilizers, lubricants, …



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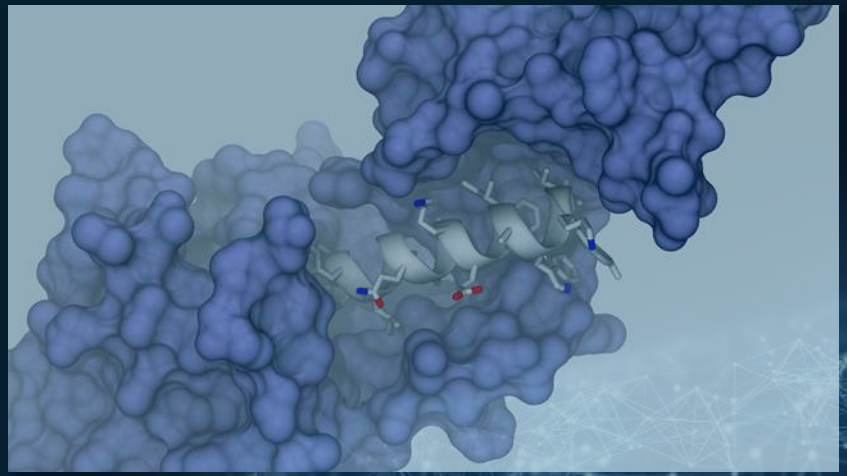
Pharmaceuticals

GOAL

Predict and simulate the exact protein folding

Proteins exist in an astronomical number of possible arrangements.



IMPACT

Enable revolutionary new applications in pharmaceuticals, genetic engineering and personalized medicine

e.g: Improve the treatment of Alzheimer's-, Parkinson's disease and Cancer

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Cryptography

TODAY/PAST (pre-quantum)

- After RSA768 in 2010, RSA795 in 2019, RSA829 is the factorization world record (2,700 years of cores on tens of thousands powerful machines running NFS, in 2020)

21403246502407449612644230728393335630086147151447550177977549208814180234471401366433455190958046796109928518724709145876873962619215573630474547705208051190564931066876915900197594056934574522305893259766974716817380693648946998715784949759374979377
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- comp[RSA1024] ≅ comp[RSA829] * 10^{57}

This exponential complexity is the keystone of RSA crypto algorithm (and almost all asymmetric algos)

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```
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33372027594978156556226010605355114227940760344767554666784520987023841729210037080257448673296881877565718986258036932062711
```

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TOMORROW (post-quantum)

Shor Algorithm: polynomial time
RSA-768 : almost instantaneous by using a quantum computer with several thousands logical Qubits
comp[RSA1024] < comp[RSA829] * 2

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Critical risk (very high impact, low prob.) for IT security everywhere

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Finance

Finance

GOAL

Help investment professionals and financial institutions optimize returns while minimizing risk by analyzing an unimaginable range of scenarios

STAR ALGORITHMS

- Black-Scholes differential equation is a derivative from Schrödinger's equation
- Quantum Random Walker

IMPACT

- Optimization of trading strategies
- Portfolio optimization (optimization under constraints)
- Improved fraud detection

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Oil Prospection

GOAL

Solve Partial Differential Equations with an exponential speed-up

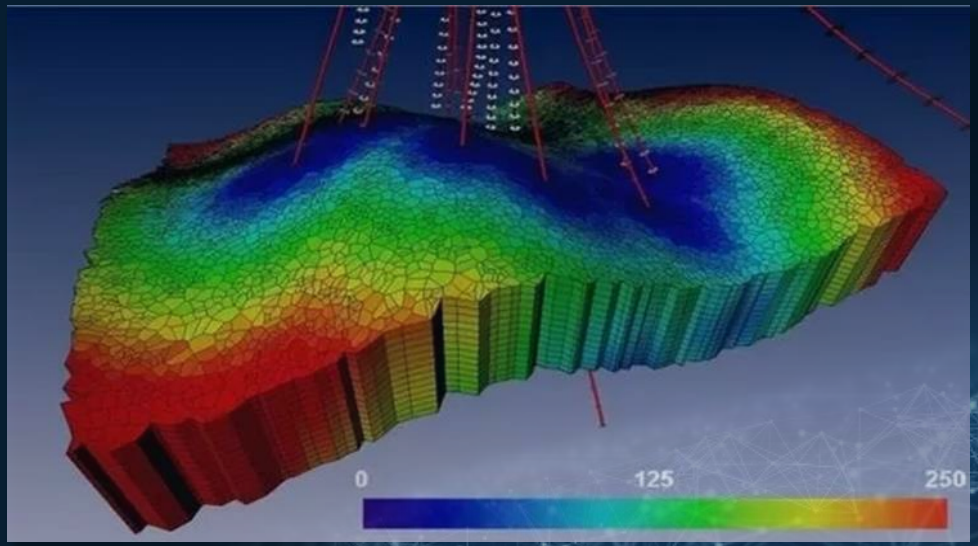
STAR ALGORITHMS

HHL, the matrix inversion algorithm

IMPACT

Unprecedented performance and accuracy for

- Oil well optimization
- Seismic simulation



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Combinatorial Optimization

Example of the Travelling Salesman problem

Combinatorial Optimization

What is the shortest path to travel to x cities?

- 14 cities = 10^11 possible routes ➔ 100s (1GHz computer)
- 22 cities = 10^19 possible routes ➔ 1,600 years (1GHz computer)
- 28 cities … ➔ Longer than the lifetime of the universe

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Combinatorial Optimization

Combinatorial Optimization

GOAL

Solve NP-hard problems with an exponential speedup

STAR ALGORITHMS

QAOA, the Quantum Approximate Optimization Algorithm

IMPACT

Direct applications to:

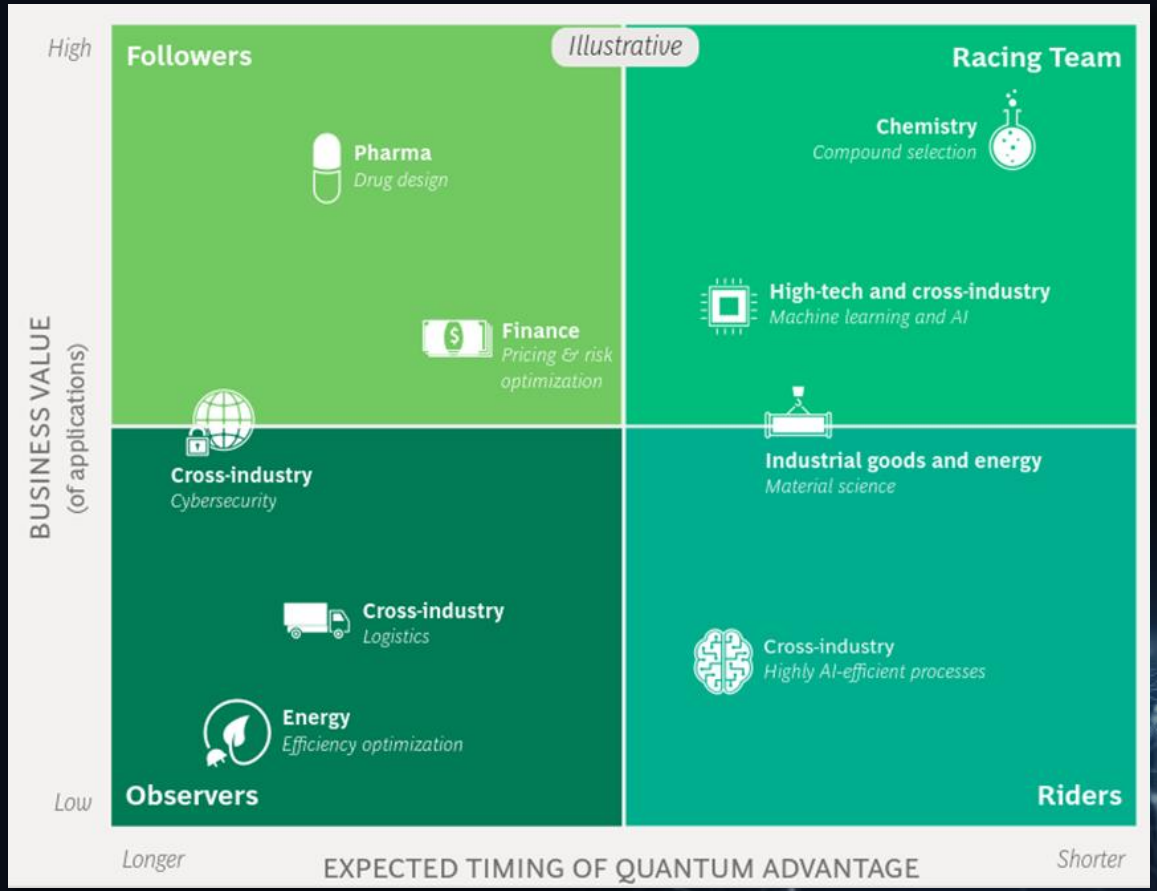
- power management
- supply chain optimization
- optimization of industrial processes
- flight scheduling

Machine Learning

- **Quantum Machine Learning (QML)** is among the most active research areas

- Theoretical works have proven exponential speedup in several key applications:
  - **Train neural networks** of a complexity intractable to current supercomputers
  - Most statistical learning techniques have **a quantum counterpart with an exponential speedup**

Expected timing of Quantum Advantage



Source: BCG analysis

Quantum Computing market

Operating income (low forecasts)

2-5

$billions – 2023-2025

Source: BCG

Top Quantum Computing investors

China

3 Billion USD over five years

Source: BCG

United States

1.275 Billion USD over five years

Source: Forbes

India

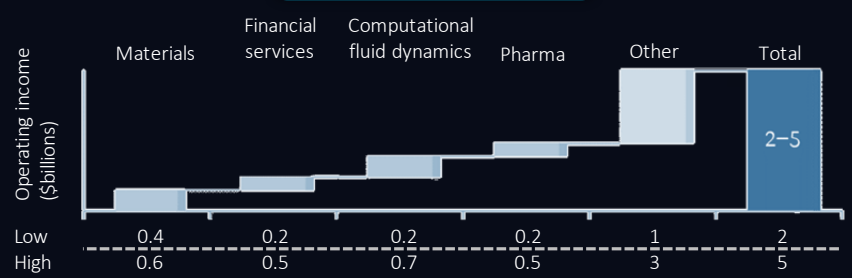
1.2 Billion USD over five years

Europe

1.1 Billion USD over five years

NISQ era - Value creation

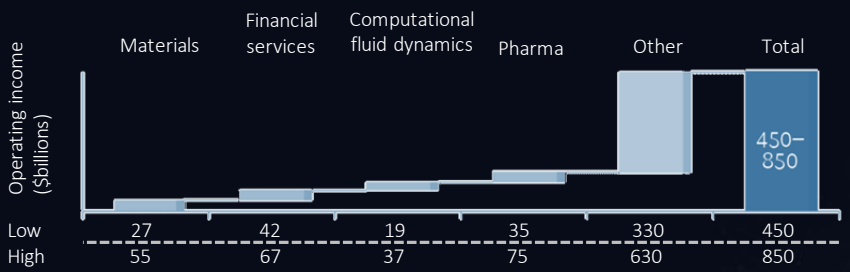
Error mitigation (~3-5 years)



Source: BCG

FTQC era - Value creation

Modular architecture (~20+ years)



Source: BCG

Quantum Computing Key Players

Company – Headquarters	Qubits technology
IBM – Armonk, NY.	Superconducting Qubits
Google – Mountain View, CA.	Superconducting Qubits
Microsoft – Redmond, WA.	Majorana fermions
intel – Santa Clara, CA.	Superconducting Qubits
Honeywell – Charlotte, NC.	Trapped ions

Quantum Computing expected phases - Example of business impact

NISQ era (3-5 years) Error mitigation	Material simulations that reduce expensive and time-consuming trial-and-error lab testing
FTQC era (20+ years) Modular architecture	De novo drug design with large biologics that have minimal off-target effects

Source: BCG

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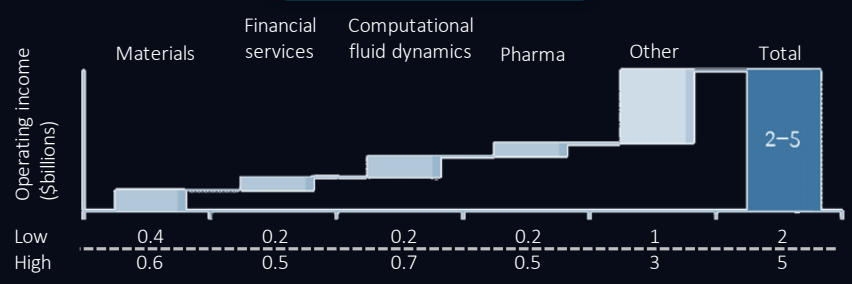

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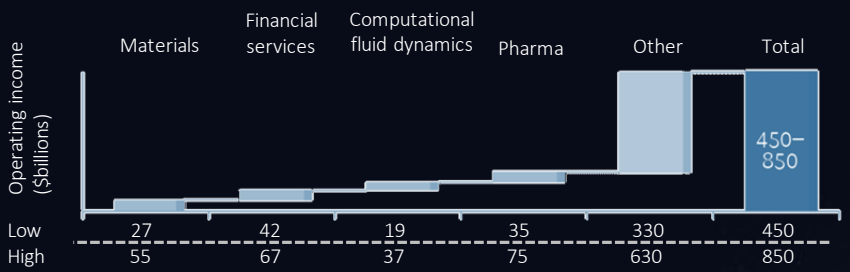

Source: BCG

Funding for Quantum Computing Startups

	Total fundings – USD millions	Qubits technology
D-Wave	D-Wave Systems - 250	Quantum annealing
Rigetti	Rigetti Computing - 119	Superconducting qubits
PsiQuantum	PsiQuantum - 65	Photonic
Silicon Quantum Computing	Silicon Quantum Computing, AUS - 60	Silicon qubits
Cambridge Quantum Computing	Cambridge Quantum Computing, UK - 50	Photonic

Source: BCG

Quantum Computing expected phases - Example of business impact

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Source: BCG

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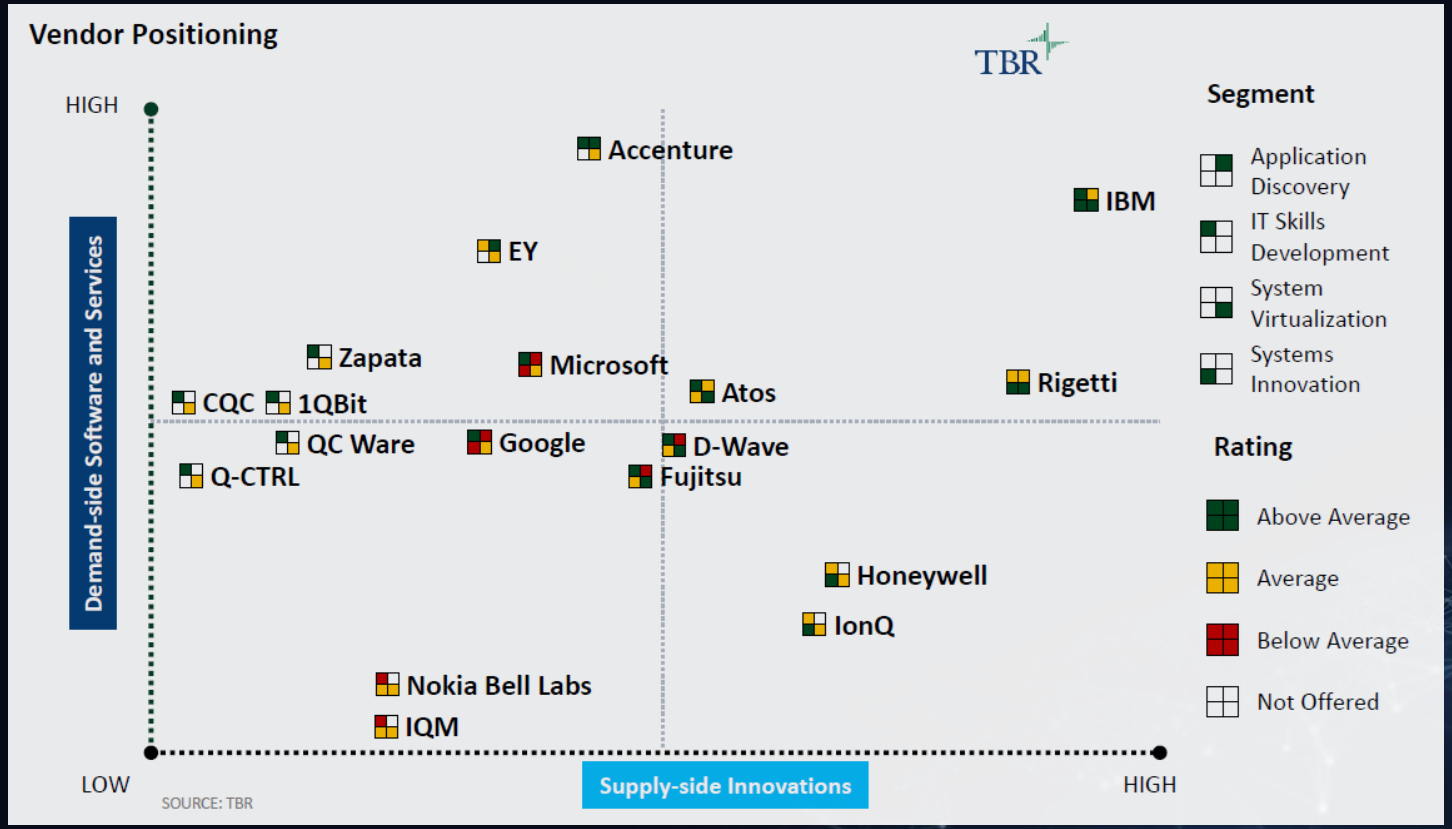
Providing end-to-end solutions for the quantum era



Atos Quantum Program

Help people **learn,**
experiment with quantum computers,
develop applications and algorithms,

without the need to wait for quantum machines to be physically available…

Atos Quantum program

- Monitored by a top-class scientific advisory board

Atos has its quantum activities watched by the most renowned scientists in this field.

- Artur Ekert (Hughes Medal)
- Alain Aspect (World Prize)
- Serge Haroche (Nobel Prize)
- Daniel Esteve
- David Di Vincenzo

Atos Quantum program

► A global strategy

1	Quantum Programming Platform	Complete programming and simulation environment for quantum software/hardware developers and for education/training
2	Quantum Expert Consulting Services	Assisting our customers in discovering Quantum Computing, detecting relevant use cases, assessing quantum implementation benefits on the QLM simulator
3	New Generation Architectures	Designing the new quantum-powered accelerators for supercomputers or hybrid systems
4	Quantum Algorithms	Atos' own research, focused on Quantum Machine Learning, one of the most promising application areas of QC
5	Quantum Safe Cryptography	Preparing the cryptographies and hardware security modules, resistant to quantum computer attacks

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Atos QLM positioning

A hardware-agnostic approach to Quantum Computing

Quantum Simulator

Quantum Annealing

D-Wave — The Quantum Computing Company™

Limited to optimization algorithms

Superconducting qubits

IBM, intel, Google, rigetti, QCI, OQC, UCSB, IQM

Trapped ions

IONQ, AQT, universität innsbruck, Honeywell

Topological qubits

Microsoft, NOKIA, Delft University of Technology

NV centers

cea, QDTI

Silicon qubits

intel, cea, NOKIA, NTT

Photons

Hewlett Packard Enterprise, XANADU, University of Oxford

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Quantum Computing Programming environment

Quantum computing hardware manufacturers have created their **own proprietary programming** software and standards, based on their qubits technology

Atos offers a **universal programming environment** to avoid the vendor lock-in

Atos Quantum Program added value

Universal programming environment

myQLM

- Freeware
- Entry-level simulation
- Open-source plugins
- Scalability: ~20 qubits

Interoperability

Qiskit ProjectQ Cirq rigetti

Proprietary programming

Atos QLM

- Multi-tenancy
- Advanced simulation
  - Noise modelling
  - Optimization
- Scalability: 41 qubits
- Performance

Atos
Center of Excellence in Performance Programming

Consulting Services

Any Quantum Computing hardware

QPU — Superconducting: IBM, rigetti, D-Wave, intel, Google, IQM

QPU — Trapped ions: IONQ, universität innsbruck, AQT, Honeywell

Silicon qubits, Photonic, Majorana fermions: Microsoft, Silicon Quantum Computing, Cambridge Quantum Computing

...

What are the possible ways to use the Atos QLM?

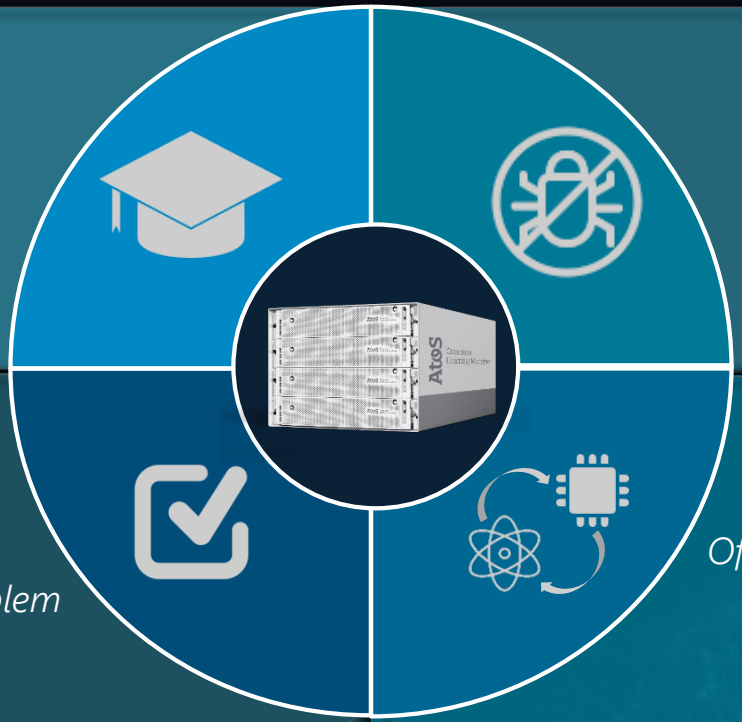
► A multi-purpose system

LEARN

Get acquainted with Quantum Computing

TEST

Conceive new programs …
… and debug them



OPTIMIZE

Select the best quantum technology to solve your problem

RUN HYBRID CODE

Off-load the quantum-accelerable parts to the simulated QPU

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What is the Atos Quantum Learning Machine?

- A complete programming environment and a quantum processor emulator

PROGRAMMING

AQASM
Assembly language to build quantum circuits

pyAQASM
Python extension to AQASM

CIRC
Binary format of quantum circuits

QLIB
AQASM & pyAQASM libraries

Cirq ProjectQ rigetti Qiskit

OPTIMIZATION

PBO
Pattern based optimizer

NNIZER
Topology constraint solver

CIRCUIT OPTIMIZER
Generic circuit optimizer

SIMULATION

NOISELESS
Simulation modules

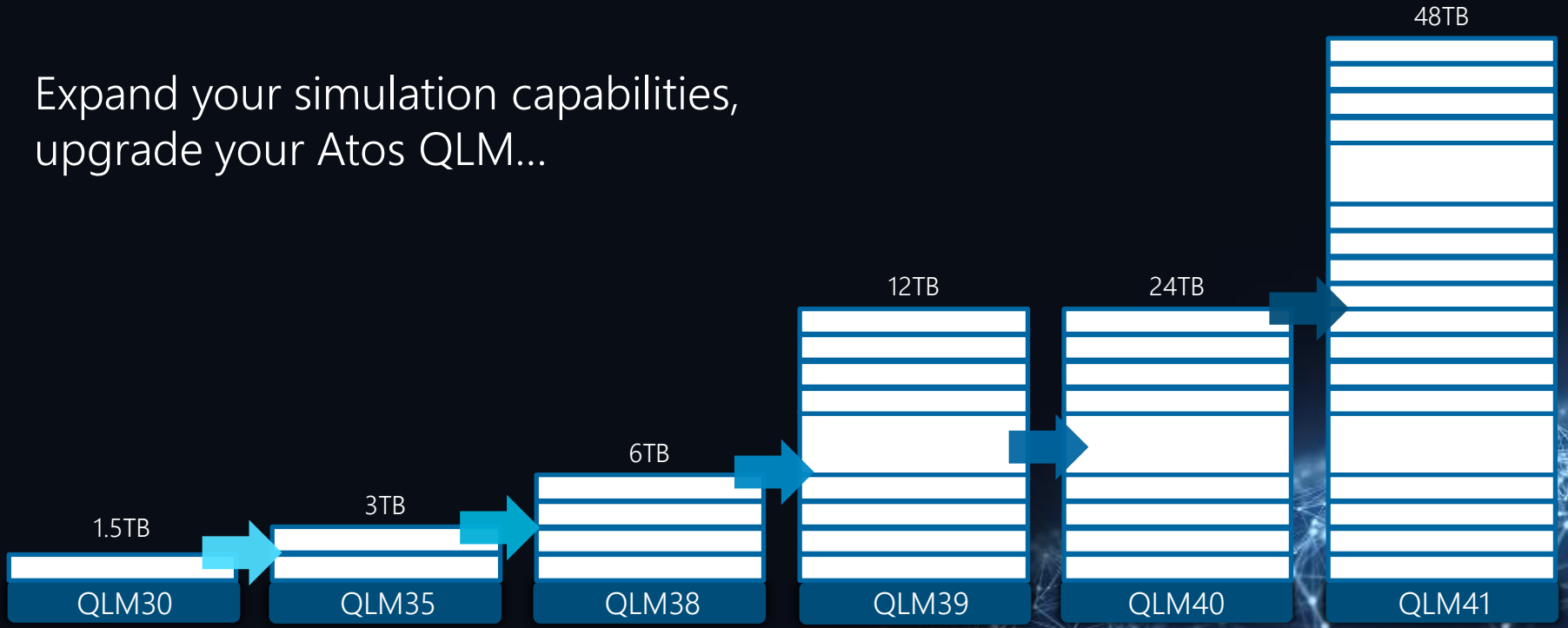
NOISY
Physical Noise models

Atos

A highly scalable and modular simulator

- Upgrade your Atos QLM to suit your simulation needs

Expand your simulation capabilities,
upgrade your Atos QLM…

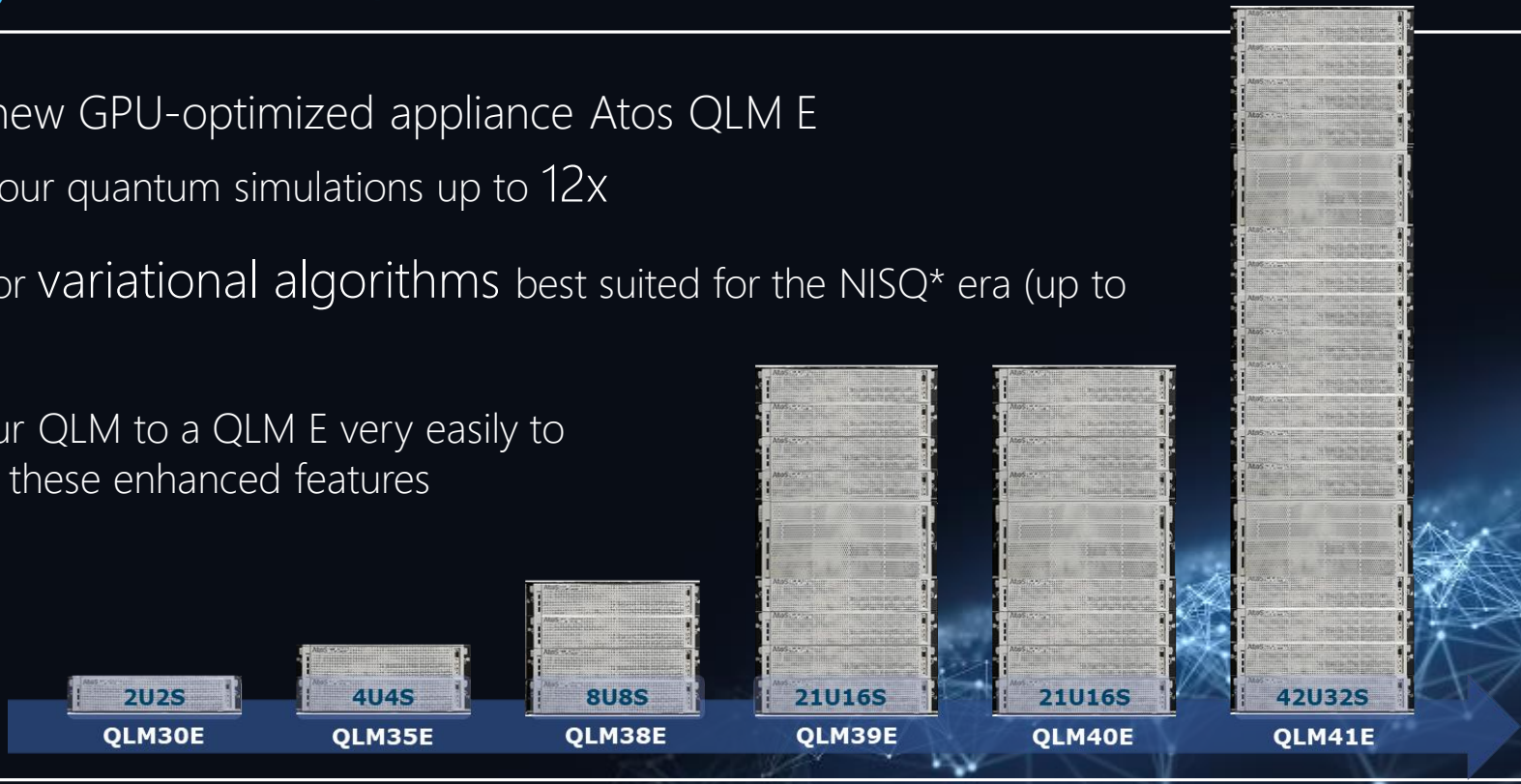


Atos QLM E[nhanced]

► Accelerating research in the NISQ era

Discover the new GPU-optimized appliance Atos QLM E

- Accelerate your quantum simulations up to 12x
- Optimized for variational algorithms best suited for the NISQ* era (up to 30 qubits)
- Upgrade your QLM to a QLM E very easily to benefit from these enhanced features



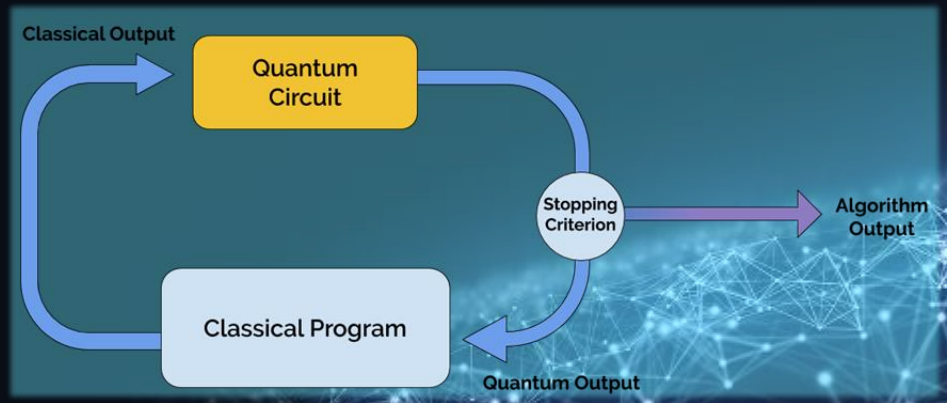
*NISQ = Noisy Intermediate-Scale Quantum

Atos QLM E[nhanced]

► Accelerating research in the NISQ era

- Quantum Approximate Optimization Algorithm
- Variational Quantum Eigensolver / Variational Imaginary Time Evolution
- Variational Quantum Factoring
- Variational Quantum Classifier
- …

Variational algorithms will be the first to be implemented on NISQ* devices



*NISQ = Noisy Intermediate-Scale Quantum

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COMING SOON: Simulated Quantum Annealing

Atos' Quantum Annealing Simulator

Available to solve real-world production problems

Fully tunable
all variables are accessible

Highest efficiency
unrivaled precision and speed

Greatest scalability
emulate more than 40,000 perfect spins in a few seconds

- Portfolio optimization
- Protein folding
- Automotive/ aeronautic design
- Grid management
- Traffic optimization
- Navigation
- Airline scheduling
- Yield management
- Supply chain optimization

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Why the Atos QLM?

► Key benefits

1 Hardware Agnostic

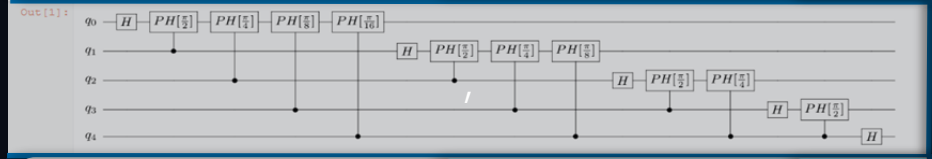
- Avoid the lock-in
- Evaluate your code vs several HW

2 Scalable & Futureproof

- Up to 41 qubits (worst case simulation)
- Hybrid quantum-classical simulations

3 A user-friendly framework

- Jupyter Notebooks library
- Integrated Quantum Algorithms & QLIB



4 Interoperability kit

- Use interoperability with Qiskit or ProjectQ
- Develop your own connectors

5 Noisy Simulation

- Evaluate the impact of quantum noise on your simulation's results

Expand your Quantum Programmer Community with myQLM

Available for FREE to ALL Atos QLM customers

Scientists: You are currently using the Atos QLM and you want to prepare your code and run them on your laptop?

Students: You want to start programming Quantum algorithms using the same framework as your professors?

Tech enthusiasts: You want to discover Quantum programming using an accessible and user-friendly environment?

Atos

myQLM

- An accessible approach to quantum simulation

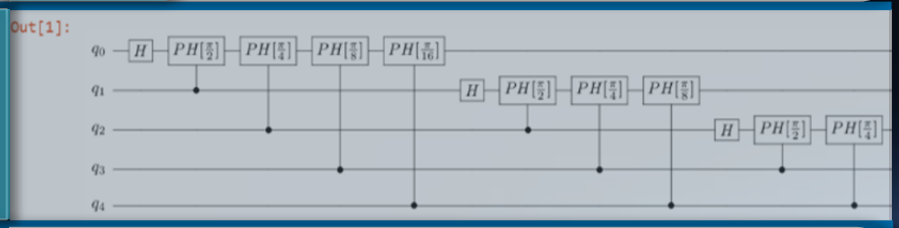
```
In [1]: from qat.lang.AQASM import Program
        from qat.lang.AQASM.qftarith import QFT
        from qat.lang.AQASM.oracles import StatePreparation
        from demo_init import prepare_ft_signal
```

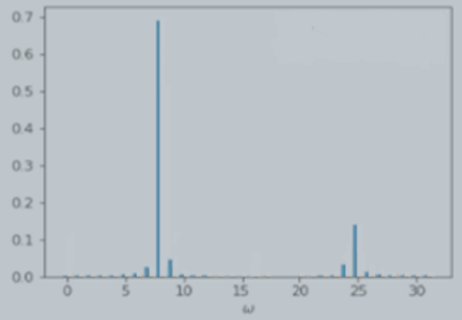
1

Write your code in AQASM or PyAQASM

Visualize your quantum circuits

2





3

Simulate them on your laptop or on a real QLM

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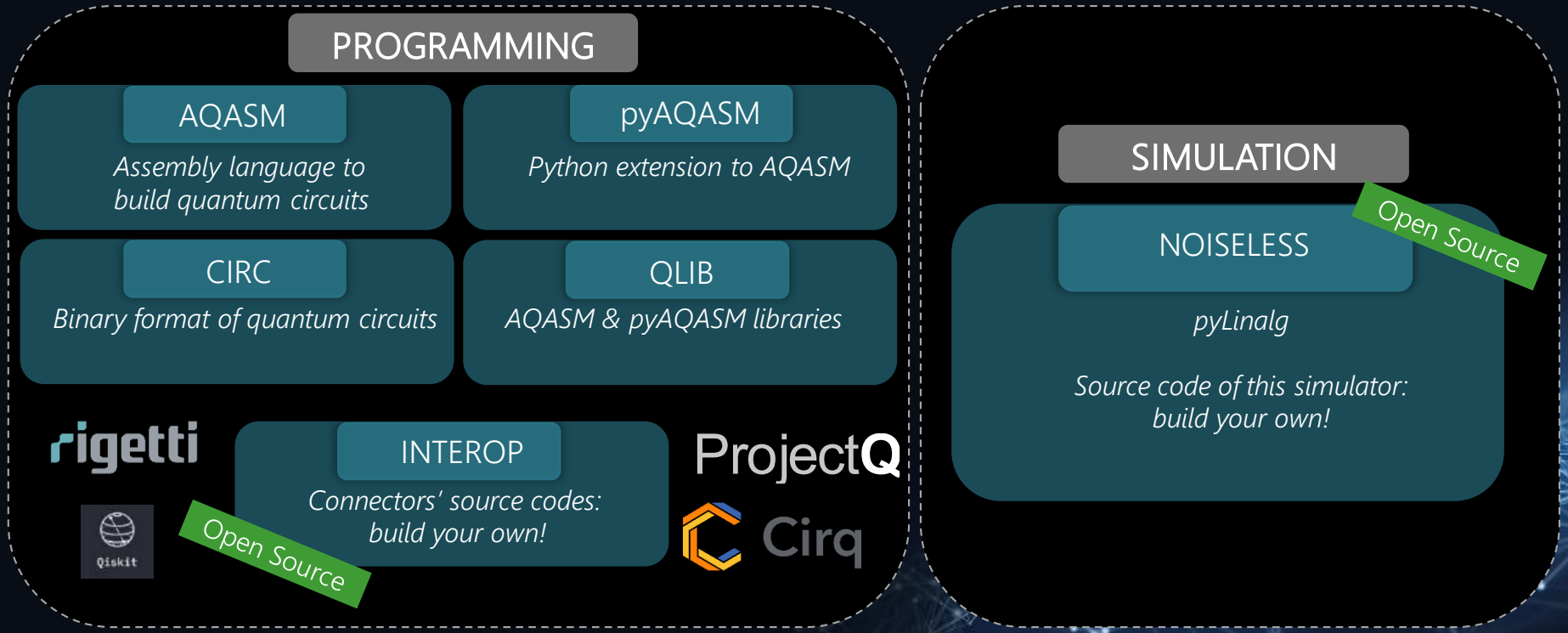
What functionalities are included in myQLM?

- The programming environment of the Atos QLM with open source simulators



Atos

Upgrade from myQLM to advanced simulators

- Features comparison

	Features	myQLM freeware	Atos QLM appliance	Atos QLM E[nhanced] appliance
PROGRAMMING	pyAQASM/AQASM/CIRC formats	✓	✓	✓
	Custom gates	✓	✓	✓
	QLIB libraries	✓	✓	✓
	Interoperability kit – open source	✓	✓	✓
PRE-/POST-PROCESSING	Custom plugins	✓	✓	✓
	Gate set rewriter	X	✓	✓
	Topology constraints solver	X	✓	✓
	Circuit Optimizer	X	✓	✓
SIMULATION	Simulation capabilities	Up to 20 qubits	Up to 41 qubits	Up to 41 qubits
	Simulation performances	★	★★★	★★★★
	PyLinalg – open source	✓	✓	✓
	Advanced noiseless simulators	X	✓	✓
	Noisy simulators	X	✓	✓
	Acceleration up to 12x	X	X	✓
SERVICES	Training	Self-training	Instructor-led	Instructor-led
	Support	Community	Subscription	Subscription
	Consulting	On demand	On demand	On demand

Atos

A broad range of services based on the Atos QLM

1	Quantum Computing Basis	BEGINNER ½ day	A comprehensive approach to quantum computing
2	Atos QLM Fast Start	INTERMEDIATE 2 days	Quick knowledge ramp-up on the Atos QLM appliance
3	Decoding of quantum algorithm	ADVANCED 2 days	Principles and building steps of a specific quantum algorithm
4	Proof of Concept	BUSINESS + EXPERTS 5 days → 8 months	Study the feasibility of quantum implementation relative to the customer's use cases

Atos

Included in the Atos QLM offer: the Fast Start program

- Hands on the Atos QLM

Center for Excellence in Performance Programming

GOALS

- provide a quick **knowledge ramp-up** on the QLM appliance
- ensure that developers and end-users will be **autonomous** to exploit the Atos QLM capabilities to run their own quantum algorithms

AGENDA

1. Discover the Atos QLM
2. Develop & Simulate
3. AQASM & pyAQASM
4. Compile & Execute

REQUIREMENTS

- ✓ **Required level:** Beginner to intermediate
- ✓ **Included :** Quantum Computing Basis
- ✓ **Duration :** 2 days
- ✓ **Users:** max. of 5 users
- ✓ **Location:** on customer site

Atos

The Atos QLM User Club

- Building on existing synergies around the Atos QLM

TOTAL & OAK RIDGE National Laboratory

started collaborating early on Quantum Computing-related research topics

They co-signed a QLM-based research article:

Function Maximization with Dynamic Quantum Search

Charles Moussa[1,2][0000−0002−5387−564X] and Henri Calandra[3], and Travis S. Humble*[2][0000−0002−9449−0498]

[1] TOTAL American Services Inc., Houston, Texas USA
[2] Oak Ridge National Laboratory, Oak Ridge, Tennessee USA
[3] TOTAL SA, Courbevoie, France

Atos

The Atos QLM User Club

► Launched in December 2019

QLM User Club

Join the Atos QLM user community

- Get the **latest updates** on the Atos Quantum program
- **Meet** other Atos QLM users and **share** tips
- Provide Atos **feedback** on the features and build the future of the Atos QLM
- Explore contributions to the **myQLM** open source project

Henri CALANDRA & Travis HUMBLE

TOTAL — OAK RIDGE National Laboratory

Presidents of the Atos QLM User Club

Will send the invitations for user group meetings

Will be the voice of users

Andy GRANT

Atos

Leader of the Atos QLM User Club

Will organize user group meetings

Will be the link between users and the Atos organization

Atos

The Atos QLM User Club

- Events

Qlu|>
QLM User Club

At HPC events

June

ISC High Performance
The HPC Event.

First meeting @ISC20 in June 2020 !

November

SC20
Atlanta, GA | more than hpc.

At Atos QLM customers' premises

Atos

From a disruptive innovation to a commercial success

- They chose the Atos Quantum approach

Atos QLM: enabling research since 2017

Reuse method for quantum circuit synthesis – *AMMCS 2017*
Allouche C, Baboulin M, Goubault de Brugière T, Valiron B

Quantum classification of the MNIST dataset via Slow Feature Analysis – *Phys Rev A 2020*
Kerenidis I, Luongo A

Electron-Phonon Systems on a Universal Quantum Computer – *Phys Rev Lett 2018*
A. Macridin, P. Spentzouris, J. Amundson, and R. Harnik

Digital quantum computation of fermion-boson interacting systems – *Phys Rev A 2018*
A. Macridin, P. Spentzouris, J. Amundson, and R. Harnik

q-means: A quantum algorithm for unsupervised machine learning – *NIPS 2019*
Kerenidis I, Landman J, Luongo A, Prakash A

Synthesizing Quantum Circuits via Numerical Optimization – *ICCS 2019*
Goubault de Brugière T, Baboulin M, Valiron B, Allouche C

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Atos QLM: enabling research since 2017

Function Maximization with Dynamic Quantum Search – *QTOP 2019*
C. Moussa, H. Calandra, and T. S. Humble

Practical implementation of a quantum backtracking algorithm – *Sofsem 2020*
S. Martiel, M. Remaud

Methods for Classically Simulating Noisy Networked Quantum Architectures – *QST 2019*
I. Vankov, D. Mills, P. Wallden, and E. Kashefi

To quantum or not to quantum: towards algorithm selection in near-term quantum optimization – *arXiv 2001.08271*
C. Moussa, H. Calandra, and V. Dunjko

Quantum circuits synthesis using Householder transformations – *CPC 2020*
T. Goubault de Brugière, M. Baboulin, B. Valiron, and C. Allouche

Running large quantum circuits on small quantum computers – *ISVLSI 2020*
F.-M. Le Régent, T. Ayral, Z. H. Saleem, Y. Alexeev, and M. Suchara

Assessing the potential of Rydberg atoms for adiabatic quantum computing of an NP-hard problem– *arXiv 2006.11190*
B. Marchand, F. Serret, and T. Ayral

Atos

BAYER & RWTH AACHEN UNIVERSITY

Center for Excellence in Performance Programming

Proof of Concept in the pharmaceutical industry

➔ **Demonstrate** that Quantum can either **tackle problems** that **traditional** computing cannot solve or prove that it is **exponentially faster**

➔ **Goal:** evaluate the use of Quantum Computing in **research and analysis of human disease patterns**

BAYER & RWTH WITH ATOS
FOR
JOINT COOPERATION TO ACCELERATE MEDICAL RESEARCH USING QUANTUM COMPUTING

Atos

Proof of Concept in the pharmaceutical industry

BAYER	Atos	RWTH AACHEN UNIVERSITY
Project driver and evaluation	• Propose and implement **quantum algorithm** corresponding to proposed problem • Evaluate QC approach	• Agree on **problem translation** suited for quantum algorithm • Compare classical machine learning algorithm with **Atos quantum implementation**

Study of disease propagation mechanisms

1 Observed morbidities

2 Patient clustering depending on observed morbidities

Quantum-accelerated clustering

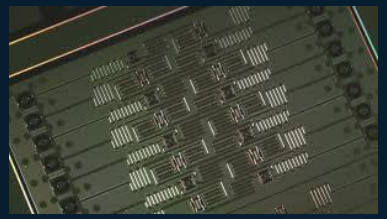
3 Underlying relationship between morbidities

- ➔ Development of new diagnostic methods
- ➔ Improved therapy of complex multifactorial diseases

BAYER & RWTH AACHEN UNIVERSITY

Study of disease propagation mechanisms

- Targeting **an algorithm suited for Noisy Intermediate-Scale Quantum (NISQ) devices**
  - to be less sensitive to noise/quantum errors
  - to exploit near term quantum devices



- Since quantum speed-up is only expected for larger problems than current use cases, **focus on the qualitative benefit of quantum algorithm approach**

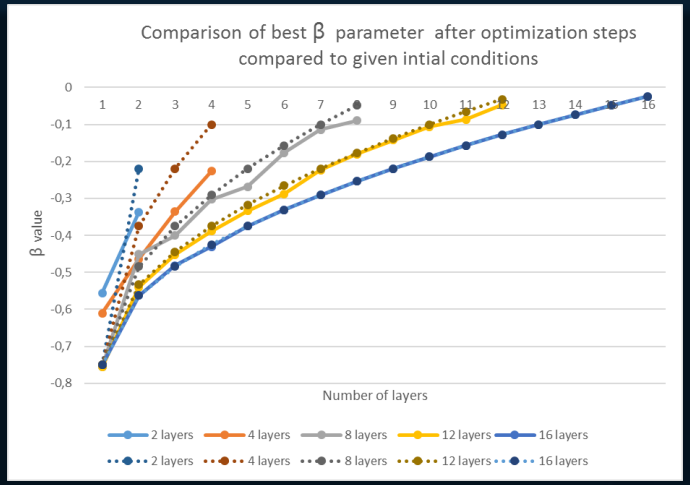
Hierarchical clustering approach

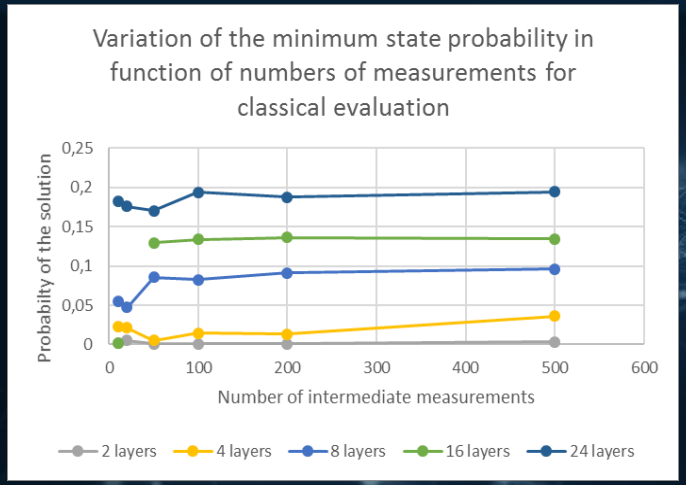
- **Combinatorial optimization** through the **Quantum Approximate Optimization Algorithm (QAOA)**, hybrid classical-quantum algorithm

Atos

Hybrid classical-quantum approach

- Defining pre-processing of the data with **medical data analysis expert** (Aachen)
- Atos Quantum Learning Machine is crucial for **studying parameters effects** and get improved results





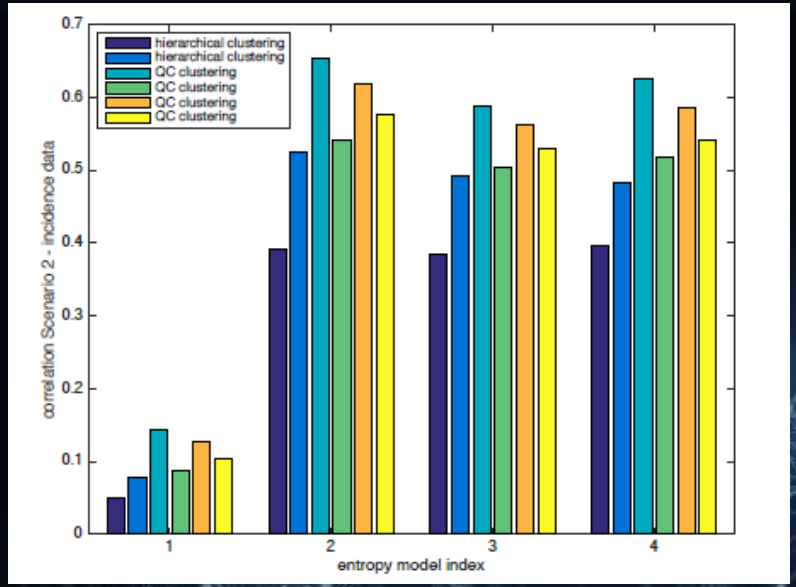
BAYER & RWTH AACHEN UNIVERSITY

Results

1. Leads to groups of diseases with **minimum correlation between groups**

2. Groups used to estimate the evolution of co-morbidities

3. QC – based clusters exhibit significantly ($p<.01$) **superior performance compared to classical clustering**



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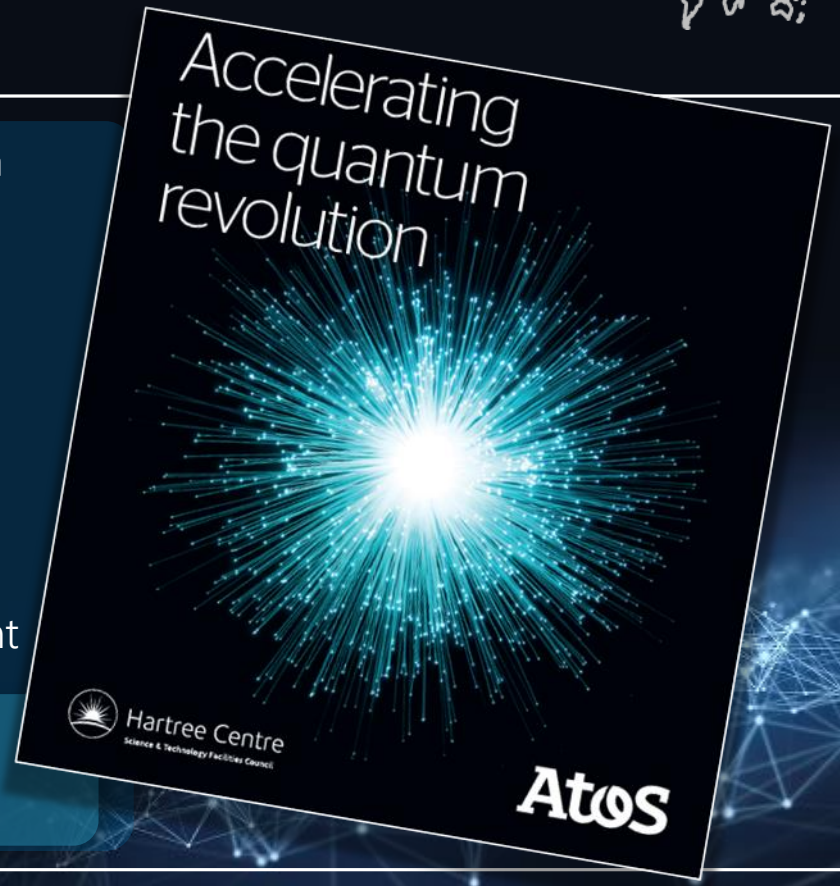
Hartree Centre
Science & Technology Facilities Council

Quantum Learning-as-a-Service

1. Work with STFC and Industry to **develop quantum algorithms** in a technology agnostic way
2. Develop a **library of quantum algorithms**
3. Training and knowledge transfer **workshops** on QLM using CEPP services
4. Provide **access to the QLM**
   - PaaS model
   - Quantum consulting
   - Expertise for quantum algorithm development

➔ Already a successful initiative: many prospects and an ongoing PoC



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Hartree Centre
Science & Technology Facilities Council

▶ Quantum Learning-as-a-Service

- ✓ Bought a QLM38 in 2019
- ✓ Established a Quantum-Learning-as-a-service (QLaaS) business around the QLM
- ✓ Have gathered major British industries interests

Hartree Centre
Science & Technology Facilities Council
&
ROLLS ROYCE

"Quantum Algorithms for Aerospace Applications

*"The **Quantum Learning Machine** will provide a platform on which we can **develop new quantum algorithms** with potential impacts across our business. We have a long track-record of successful collaborations with the Hartree Centre and with the support of Atos we look forward to research that takes us in new and exciting directions."*

Leigh Lapworth, Head of Computational Sciences – Rolls-Royce

Atos

Argonne NATIONAL LABORATORY

► Providing external research teams access to the Atos QLM

"Argonne [...] has an on-premise Atos QLM-35 quantum simulator, a state-of-the-art environment capable of simulating quantum algorithms using up to 35 qubits"

Fermilab

Digital quantum computation of fermion-boson interacting systems – 2018
Macridin A, Spentzouris P, Amundson J, Harnik R

Electron-Phonon Systems on a Universal Quantum Computer – 2018
Macridin A, Spentzouris P, Amundson J, Harnik R

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OAK RIDGE National Laboratory

► Our customers are our best promoters

"The Atos Quantum Learning Machine provides a unique platform for testing new quantum programming ideas"

***Travis Humble**, ORNL's Quantum Computing Institute Director*

Atos

Thank you

Jan Wender
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