Atos Quantum Program

04-03-2021

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.

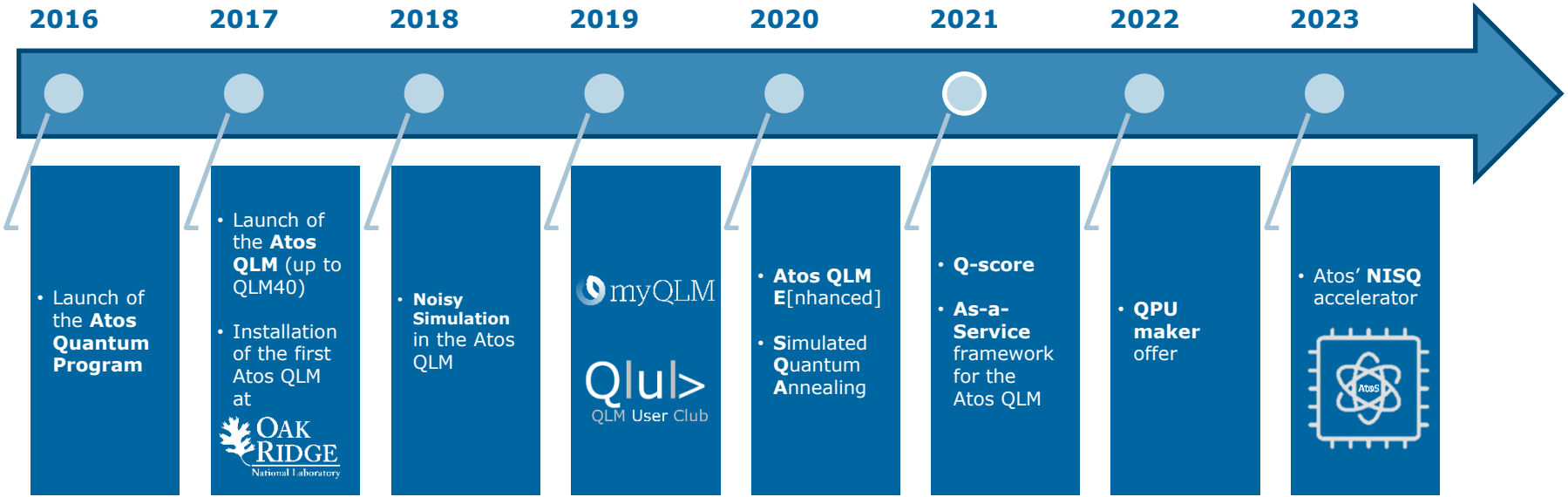
- Artur Ekert (Hughes Medal)
- Alain Aspect (Wolf Prize)
- Serge Haroche (Nobel Prize)
- Daniel Esteve
- David Di Vincenzo

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 Variational Algorithms, one of the most promising application areas for NISQ computing
5. **Quantum Safe Cryptography**
   Preparing the cryptographies and hardware security modules, resistant to quantum computer attacks

The road to quantum-accelerated HPC



Atos QLM positioning

A hardware-agnostic approach to Quantum Computing

Quantum Simulator

Quantum Annealing	Super-conducting	Trapped ions	Topological qubits	Photons	Silicon qubits	Misc.
D-Wave	IBM	IONQ	Microsoft	Hewlett Packard Enterprise	intel	QDTI
Limited to optimization algorithms	intel	AQT	NOKIA	XANADU	cea	PASQAL
	Google	universität innsbruck	QuTech	UNIVERSITY OF OXFORD	NOKIA	
	rigetti	Honeywell		ORCA Computing	NTT	
	QCI OQC					
	QuTech UCSB					
	IQM					

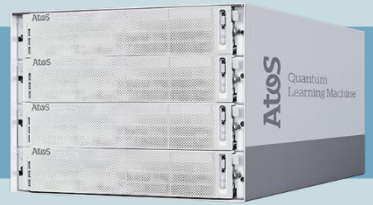
Atos Quantum

A universal gateway to quantum technologies

1 Atos Quantum Learning Machine

On-Premise solution

- Advanced simulation
  - Noise modelling
  - Optimization
  - Quantum annealing
- Multi-tenancy
- Scalability: 40 qubits
- Performance
  - Optional GPU acceleration



2 myQLM

Universal programming environment

Desktop solution

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

Interoperability

Proprietary programming frameworks

Universal front-end for quantum technologies

Any Quantum Computing hardware

- Superconducting
- Trapped ions
- Rydberg atoms
- ...

3 Center of Excellence in Advanced Computing

- Training
- Consulting
- Proof of Concept

Quantum Computing
2020 product highlights

Quantum Annealing

New approach to quantum simulation soon available in the Atos QLM:

- Fully **tunable**
- Highest **efficiency**
- Greatest **scalability**

D-Wave The Quantum Computing Company™

Suited for **combinatorial optimization** problems

myQLM

Atos' quantum programming environment is now available:

- **Free** download:
- **Community support**
- Articles & Tutorials

GitHub Medium slack binder

Learn more:
https://atos.net/myqlm

QLM E[nhanced]

GPU-accelerated quantum simulation:

- Up to **12x**
- Up to **30 qubits**
- **Noisy** & **noiseless** simulations

Optimized for research on near-term **variational algorithms**

A broad range of services based on the Atos QLM

Beginner

Quantum Computing Basics

½ day

A comprehensive approach to quantum computing

Intermediate

QLM Fast Start

2 days

Quick knowledge ramp-up on the Atos QLM appliance

Comes by default with every Atos QLM sold

Advanced

Decoding quantum algorithm

2 → 5 days

Principles and building steps of a specific quantum algorithm

Expert

Proof of Concept

1 → 8 months

Study the feasibility of quantum implementation relative to the customer's use cases

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

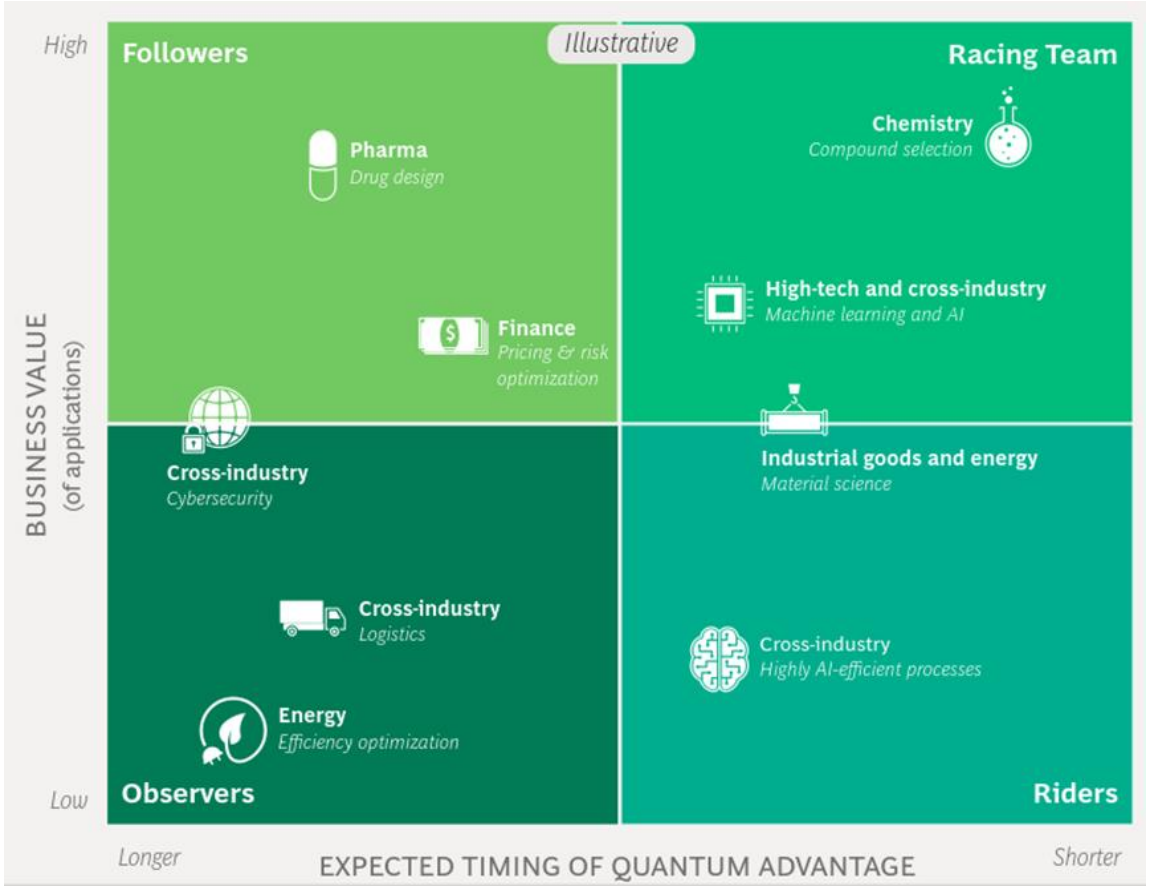
Resources & Services

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

Health & Life Sciences

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

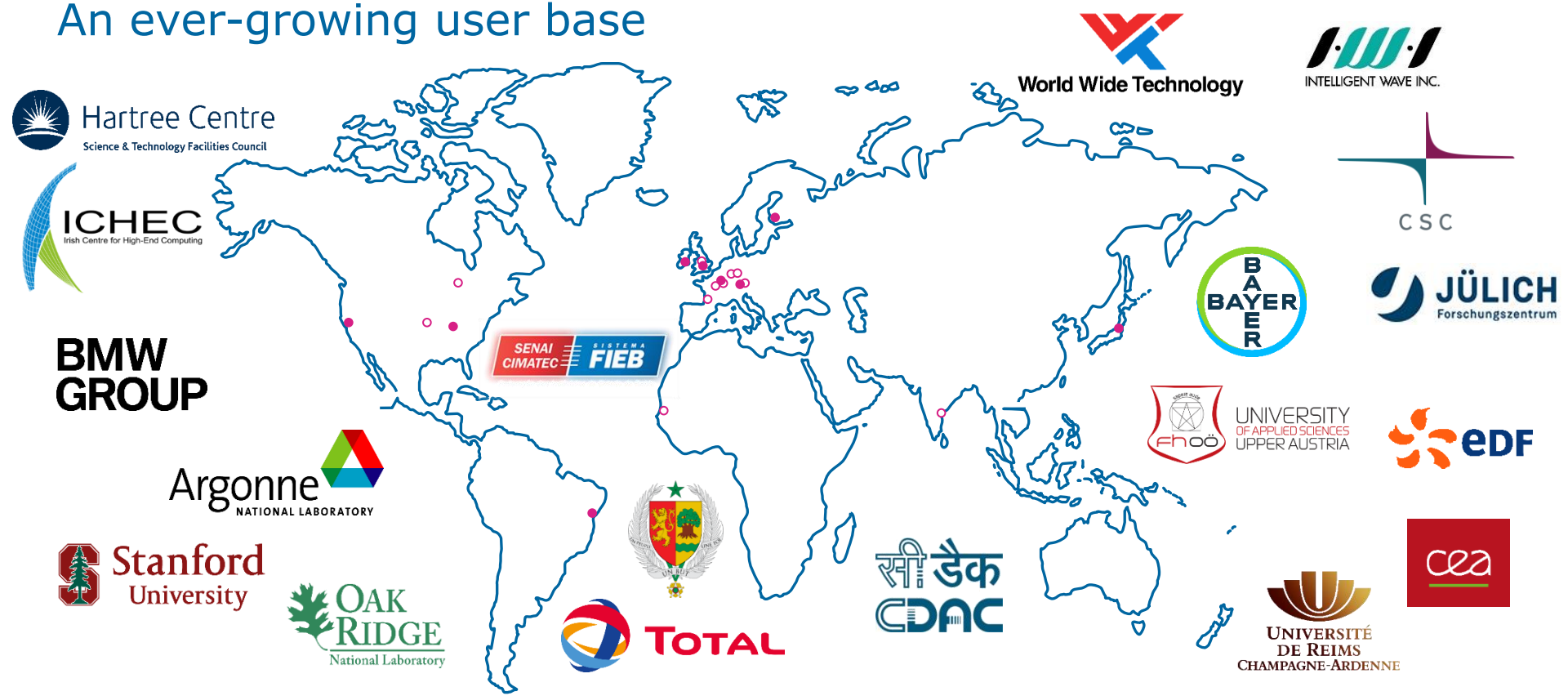
Expected timing of Quantum Advantage



Source: BCG analysis

Atos Quantum

An ever-growing user base



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

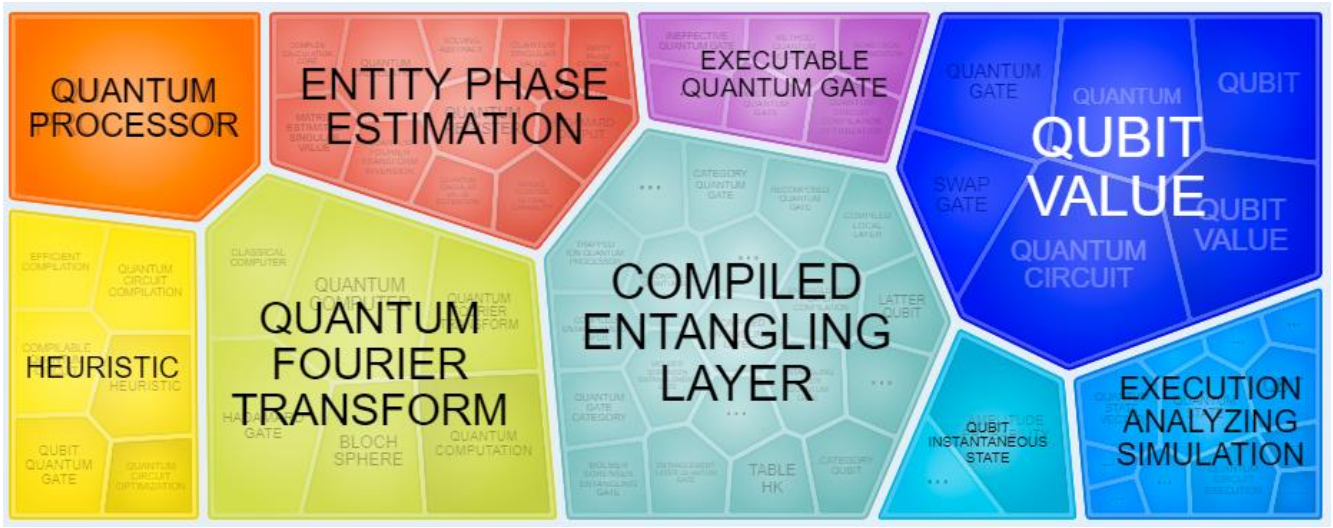
Leader of the Atos QLM User Club

Will organize user group meetings

Will be the link between users and the Atos organization

The Atos Quantum Program

Patent production



- A portfolio of 18 patent families (inventions)
- 50 patents total with a first patent in 2016

Atos Quantum

A major actor in international research initiatives

Next Generation Architectures

Front-end for trapped ions

Tomography

Mitigation tricks

Member of the user board

Leader of applications

MIS problems

Atos Quantum

A major actor in French national research programs

Next Generation Architectures

NASNIQ

Industrial co-funded chair between Atos & ANR

Jan. 2018 +4Y

Project scope: Fundamental research on hybrid qubits NV-centers coupled to superconducting qubits

Computational architecture
Noise models

Quantronics lab.

Atos Quantum

A major actor in international research on Quantum algorithms

Quantum Algorithms

QUANTERA

QuantAlgo

project

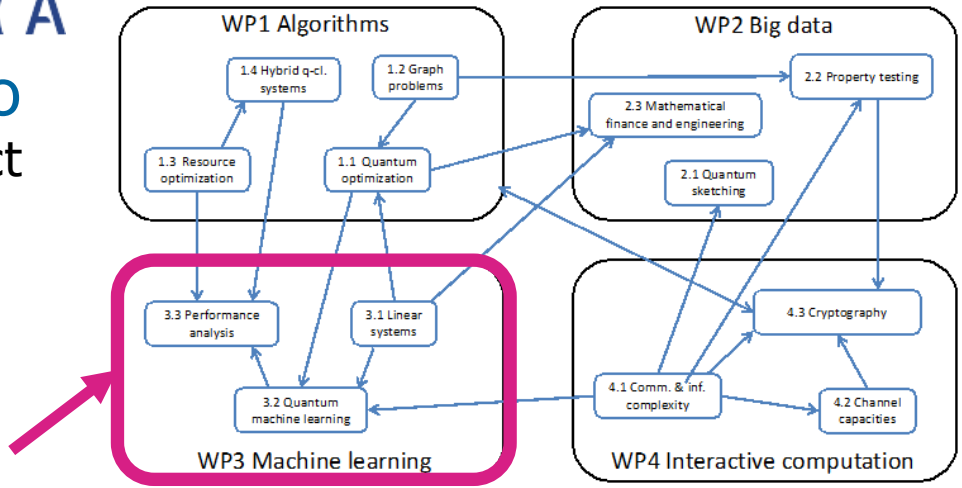
Atos

Leader of

Work Package 3 on

Quantum Machine Learning

Exploration of real use cases



ULB

UNIVERSITY OF CAMBRIDGE

QuSoft

Research Center for Quantum Software

CWI

Centrum Wiskunde & Informatica

INSTITUT DE RECHERCHE EN INFORMATIQUE FONDAMENTALE

Atos Quantum

A major actor in French national research programs

Quantum Algorithms

Dec. 2017 + 4Y

SoftQPro

projects scope:
theory of quantum programming languages

algorithms
implementation
industrial
exploitation

Atos

AGENCE NATIONALE DE LA RECHERCHE
ANR

QuData

Dec. 2018 + 3Y

project scope:
Quantum algorithms for Big Data

Atos

assessment of
industrial use
cases
numerical
simulation

LABORATOIRE DE RECHERCHE EN INFORMATIQUE

Loria
Laboratoire lorrain de recherche en informatique et ses applications

list
ceatech

INSTITUT
DE RECHERCHE
EN INFORMATIQUE
FONDAMENTALE

LaBRI

PARIS
SORBONNE
UNIVERSITÉ

Atos Quantum

Our R&D team supervises PhD students

Quantum Algorithms

INSTITUT DE RECHERCHE EN INFORMATIQUE FONDAMENTALE

Industial PhD thesis on **Algorithms for Quantum Machine Learning**

September 2016 +4Y

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

Classification of the MNIST data set with quantum slow feature analysis *– Phys Rev A 2020*
I. Kerenidis and A. Luongo

Atos Quantum

Our R&D team supervises PhD students

Quantum Algorithms

CentraleSupélec

université PARIS-SACLAY

Industrial PhD thesis on **Numerical techniques for quantum circuits generation**

October 2016 +4Y

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

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

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

<NE|AS|QC>
NExt ApplicationS of Quantum Computing

Quantum Applications

Boosting practical applications of Quantum Computing in the NISQ era

- QUANTUM FLAGSHIP complementary call
- Objectives
  1. Develop 9 industrial and financial use cases with a practical quantum advantage for NISQ machines.
  2. Develop open source NISQ programming libraries for industrial use cases, with a view to facilitate quantum computing experimentation for new users.
  3. Build a strong user community dedicated to industrial NISQ applications.
  4. Develop software stacks and benchmarks for the Quantum Technology Flagship hardware platforms.

<NE|AS|QC>
Practical use cases

Quantum Applications

Chemistry

UC7 ▶ CO2 recapture

UC8 ▶ Drug discovery

TOTAL · HQS · ICHEC Irish Centre for High-End Computing · AstraZeneca

Machine Learning & Optimisation

UC1 ▶ Reinforcement learning for hydrocarbon well optimization

UC9 ▶ HPC mesh segmentation

UC3 ▶ Hard optimization problems for smart-charging of electric vehicles

UC5 ▶ Financial applications

TOTAL · EDF · HSBC · Universiteit Leiden · UNIVERSITÉ DE LORRAINE · CESGA Centro de Supercomputación de Galicia

Symbolic AI and graph algorithmics

UC2 ▶ Quantum natural language processing (QNLP)

UC4 ▶ Quantum probabilistic safety assessment (QPSA)

UC6 ▶ Quantum rule-based systems (QRBS) for breast cancer detection

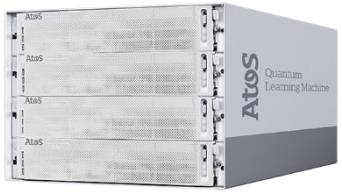
TILDE · ICHEC Irish Centre for High-End Computing · EDF · UNIVERSIDADE DA CORUÑA · Universiteit Leiden · CESGA Centro de Supercomputación de Galicia

<NE|AS|QC>
Overview of the project structure

Quantum Applications

Atos QLM

Enabling research since 2017



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

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

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

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

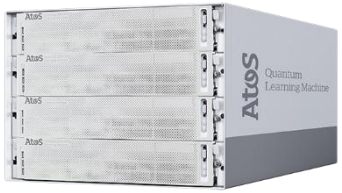
Function Maximization with Dynamic Quantum Search – *QTOP 2019*
C. Moussa, H. Calandra, and T. S. Humble

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

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

Atos QLM

Enabling research since 2017



Quantum CNOT Circuits Synthesis for NISQ Architectures Using the Syndrome Decoding Problem – *Rev Comp 2020*
T. G. de Brugière, M. Baboulin, B. Valiron, S. Martiel, and C. Allouche

Running large quantum circuits on small quantum computers – *Bull APS 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 – *Bull APS 2020*
B. Marchand, F. Serret, and T. Ayral

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

Classification of the MNIST data set with quantum slow feature analysis – *Phys Rev A 2020*
I. Kerenidis and A. Luongo

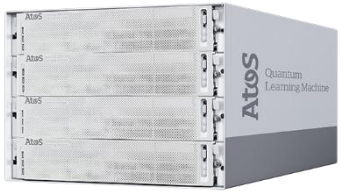
Quantum Divide and Compute: Hardware Demonstrations and Noisy Simulations – *IVLSI 2020*
T. Ayral, F.-M. L. Régent, Z. Saleem, Y. Alexeev, and M. Suchara

To quantum or not to quantum: towards algorithm selection in near-term quantum optimization – *QST 2020*
C. Moussa, H. Calandra, and V. Dunjko

Solving optimization problems with Rydberg analog quantum computers: Realistic requirements for quantum advantage using noisy simulation and classical benchmarks – *Phy Rev A 2020*
M. F. Serret, B. Marchand, and T. Ayral

Atos QLM

Enabling research since 2017



Considering decoherence errors in the simulation of quantum circuits using decision diagrams – *ICCAD39 2020*
T. Grurl, J. Fuß, and R. Wille

Stochastic Quantum Circuit Simulation Using Decision Diagrams – *arXiv 2020*
T. Grurl, R. Kueng, J. Fuß, and R. Wille

Practical Quantum Computing: Solving the Wave Equation Using a Quantum Approach – *ACM Transactions on QC 2021*
A. Suau, G. Staffelbach, and H. Calandra

Benchmarking quantum co-processors in an application-centric, hardware-agnostic and scalable way – *arXiv 2021*
S. Martiel, T. Ayral, and C. Allouche

Thank you

For more information please contact:

Xavier GEOFFRET
Global Presales for Quantum Projects
M+ 33 6 87715757
xavier.geoffret@atos.net

Sabine KERAVEL
Atos QLM Product Manager
M+ 33 6 42973634
sabine.keravel@atos.net