PASQAL

Quantum computing with Neutral Atoms
Achieving Tangible Results

PASQAL
www.pasqal.com

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Technical Business Developer
Expert in Quantum Solutions Development

40 Years of History for Neutral Atoms

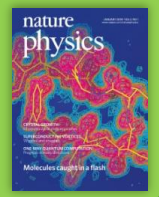
1981

Bell's inequalities violation by Prof. A. Aspect

2001

First single atom in an optical tweezer by G. Reymond

2009



First Rydberg blockade by Prof. A. Browaeys

2016

Simulation with 30 qubits by T. Lahaye & Prof. A. Browaeys

2018

Simulation with 49 qubits, 3D and 72 atoms in tweezers by T. Lahaye & Prof. A. Browaeys

2019

Founding of Pasqal by T. Lahaye, Prof. A. Browaeys, G. Reymond, C. Jurczak

PASQAL

2021

Simulation with 196 qubits Quantum Advantage by T. Lahaye & Prof. A. Browaeys

2022

1st use case implementation with up to 60 qubits with real world data

PASQAL

PASQAL in a few numbers

30+

CLIENTS
2 QPUs provided via HPCQS
Activities in 11 countries, and engagements with top cloud distributors

40

YEARS
History in quantum technologies

100+

QUBITS
Available through the Cloud or on premise

210+

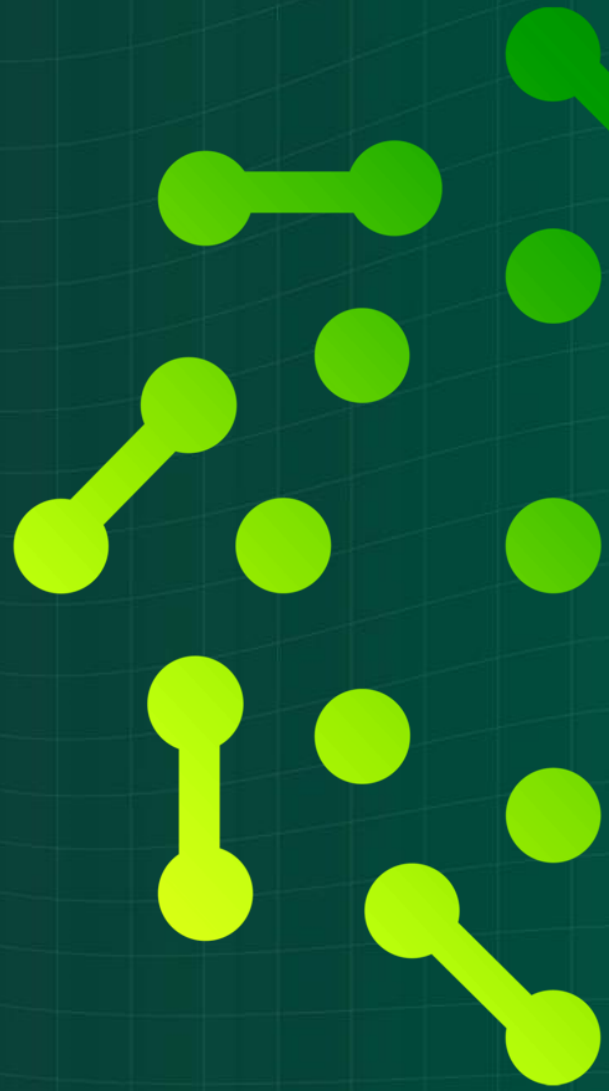
EMPLOYEES
19 nationalities

30+

PATENTS & APPLICATIONS
800+ publications

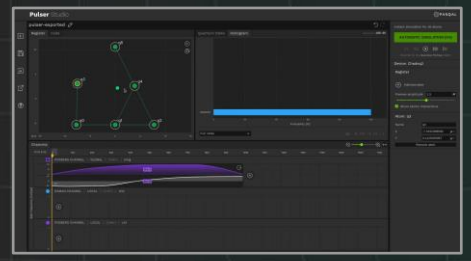
FULL-STACK

QUANTUM HARDWARE AND SOFTWARE TODAY
Practical Advantage

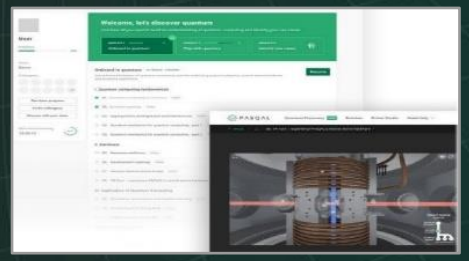


PASQAL has market-ready technology and use case implementations

APPLICATIONS



Pulser Studio offers zero code programming



Quantum Discovery provides a quantum learning platform

HARDWARE

QPU works at room temperature and standard environment, consuming low energy

Software & Applications

- Turnkey Solutions + Coding Environment (including Pulser, Pulser Studio, Qubec, and Quantum Discovery)

Middleware

- Hardware accelerated quantum libraries
- Machine Learning
- Optimization
- Simulation
- Differential Equations

Hardware

Quantum Hardware

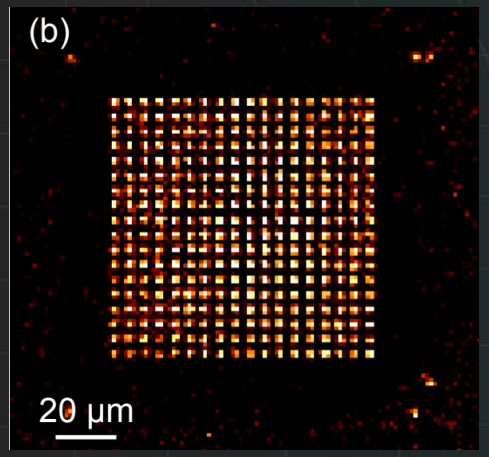
- Quantum registers
- Electronics
- Laser control
- Room temperature
- Ultra-high vacuum

Sample Customers & End-users

BMW *Crédit Agricole CIB* ***EDF***

CINECA *GENCI* *Jülich* *Saudi Aramco*

Neutral Atoms Drive Our Quantum Technology



Laser

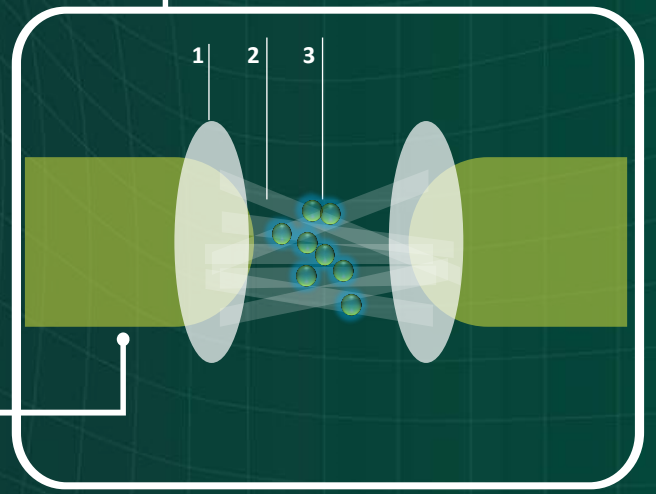
Vacuum chamber

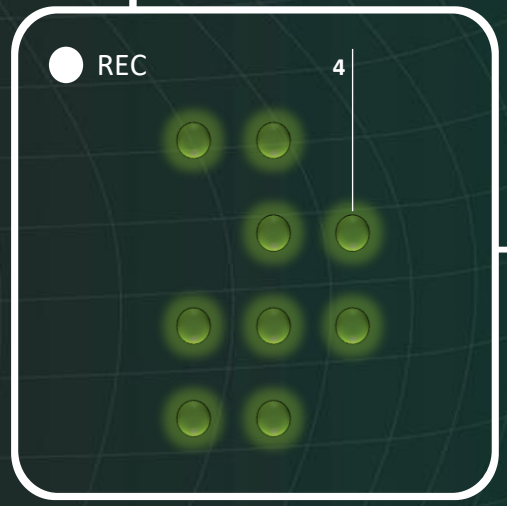
SLM
Spatial Light Modulator

Dichroic mirror

Camera
The mirror sends the reflection back to the camera, and therefore the image of what is happening in the vacuum chamber

Zoom optical clamp





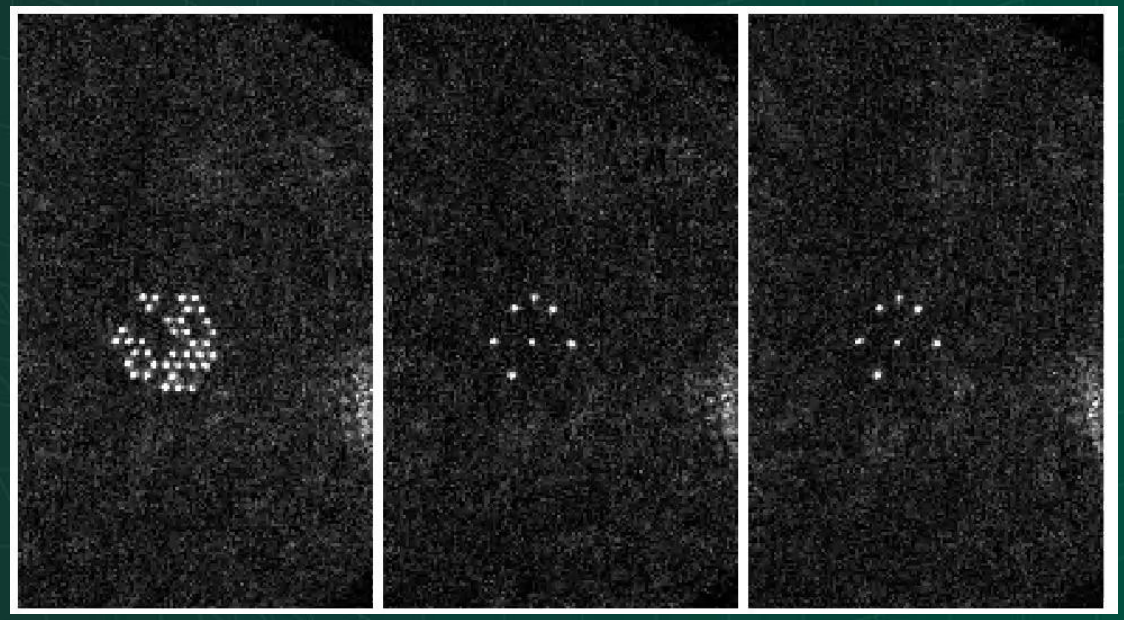
Zoom laser pattern:
Atoms trapped in laser beams

4| The light points come from photons emitted by the trapped atoms

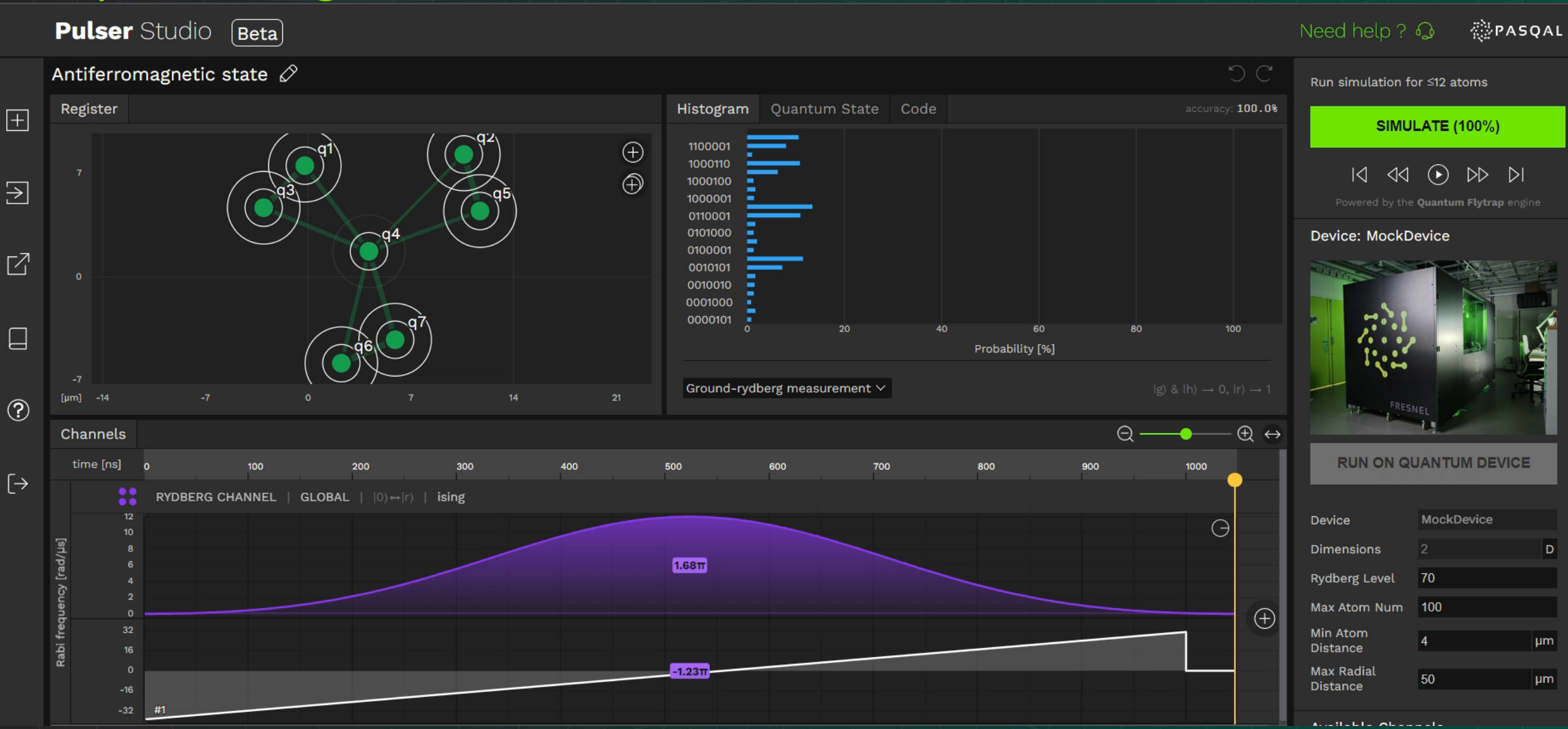
1| Lense allows the laser beam to be divided into several beams called “optical tweezers”
2| Multiple optical tweezers
3| Trapped rubidium atoms (1 atom = 1 qubit)

How does one make qubits out of atoms?

1. **We need to identify a $|0\rangle$ and a $|1\rangle$ state**
   - Ground states and hyper-excited Rydberg states of Rubidium atoms
2. **We need to be able to address transition between $|0\rangle$ and $|1\rangle$ states**
   - Laser beams
3. **We need to know where the atoms are**
   - Optical tweezers
4. **We need to be able to produce entanglement between the atoms**
   - Rydberg blocade
5. **We need to be able to measure the system**
   - Fluorescence imaging



Implementing on a neutral atoms based device



https://pulserstudio.pasqal.cloud/

Native implementation of graph problems – combinatorial optimization

What are 'graphs'?

- Mathematical structures to model objects and relations between them
- Made up of vertices (also called nodes or points) connected by edges (also called links or lines).

Combinatorial Problems

- The cost/duration/price of some process can be calculated easily/cheaply for a configuration of a graph. The problem: there are combinatorially many such graphs, which one is 'best'?
  - With only 50 variables we have $2^{50} \approx 1$ quadrillion possible bitstrings: impossible to check all
  - Quantum Computing aims to solve such problems much faster using superpositon+interference[1]

Find an itinerary which visits every location while minimizing total distance

Find bipartition z that maximizes the number of edges which are "cut" (one vertex in each set)

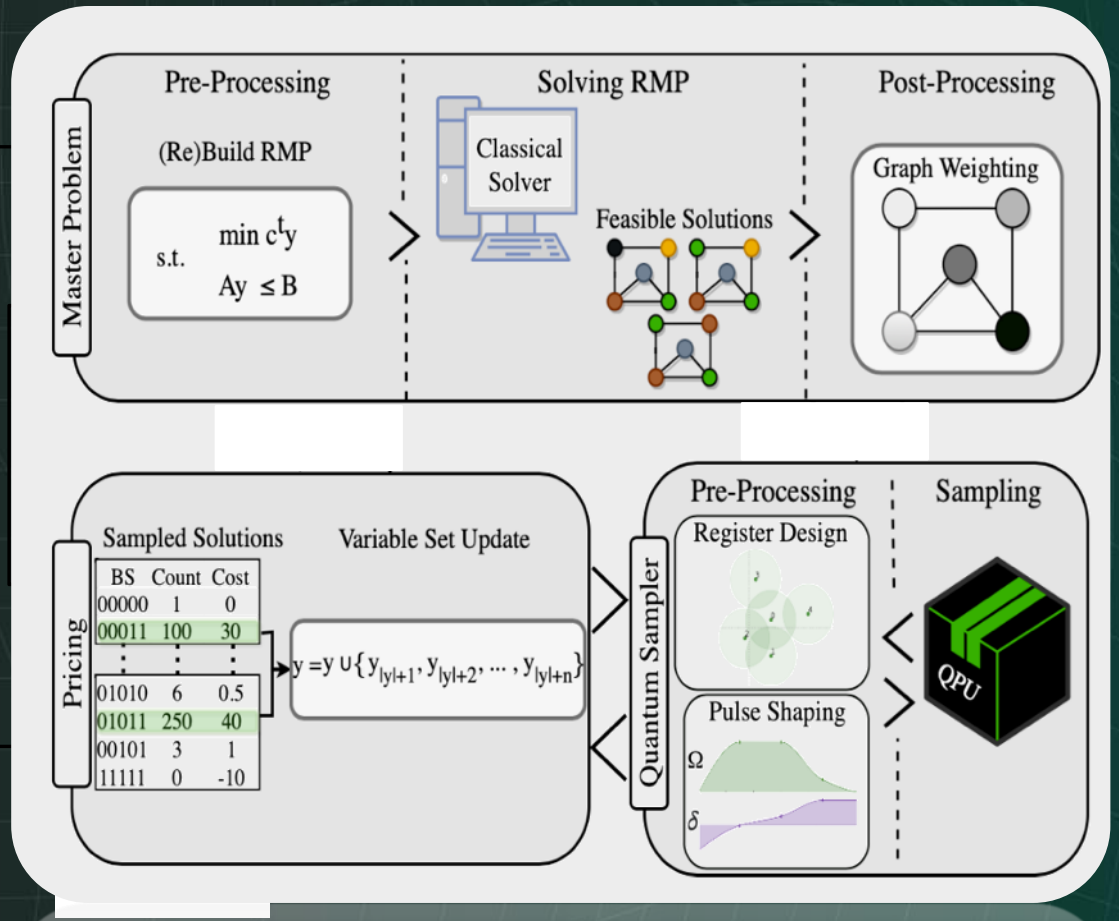
Find the largest set z of vertices subject to constraint that no two are adjacent

[1] PASQAL et al. "Qualifying quantum approaches for hard industrial optimization problems. A case study in the field of smart-charging of electric vehicles" https://arxiv.org/abs/2012.14859

Hybrid methods are the driver for short term implementations

Based on PASQAL's recently proposed[1] proprietary quantum method for solving graph coloring problems

An overview of the hybrid column generation framework for solving hard combinatorial problems



Classical Computer

- Finds the best coloring with the current set of elements (variables)
- Provides instances to the pricing routine
- Runs the Atom Register and Pulse Sequence design algorithms

Quantum Computer

- Samples good solutions for each pricing sub-problem
- Provides new elements to the RMP as new variables

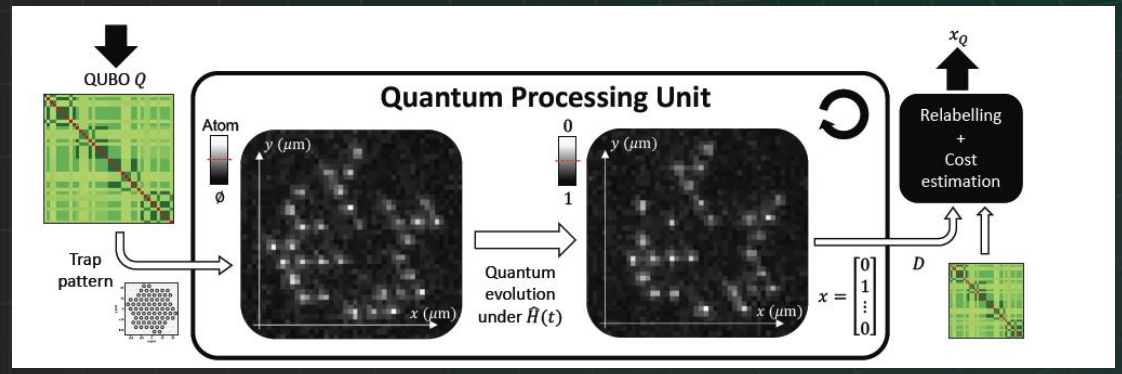
QPU : Quantum Processing Unit; RMP : Reduced Master Problem; BS: Bitstring

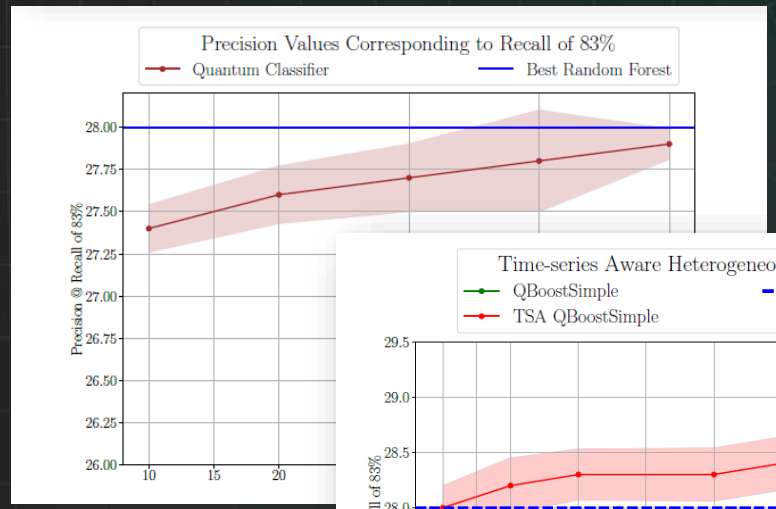
[1]: PASQAL et al. "A quantum pricing-based column generation framework for hard combinatorial problems" (https://arxiv.org/abs/2301.02637)

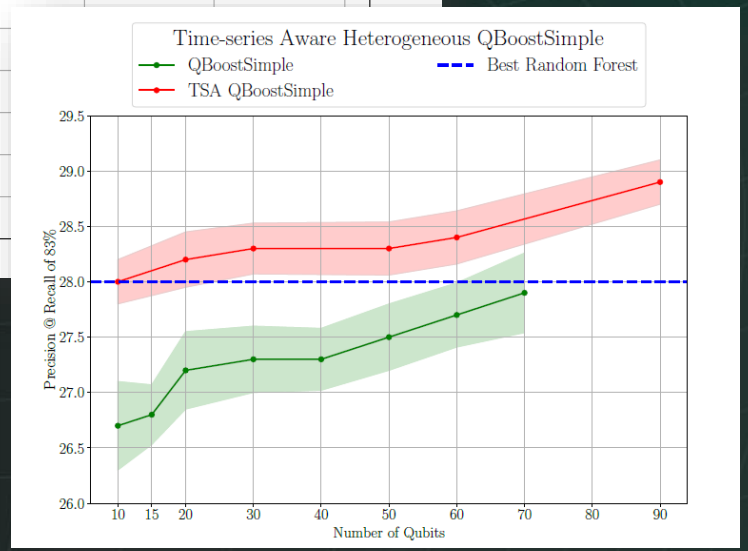
Please note that PASQAL has filed a patent application for this quantum method

Quantum Optimization for credit risk for fallen angels

Quantum optimization for predicting credit risk for fallen angels







Method

- **QBoost-based** hybrid quantum-classical algorithm trained on PASQAL's 50-qubit quantum processing unit
- Constructed a **strong binary classifier** via **Quadratic Unconstrained Binary Optimization** of the weak Decision Tree classifier ensemble
- **Random Graph Sampling**: a proprietary algorithm to speed up neutral atom QC by randomly sampling partial solutions, then reconstructing together for the complete solution
- Distinct advantages of the quantum approach over the classical approach from the **imbalanced dataset & expansive solution space**

Results

96% fewer initial learners

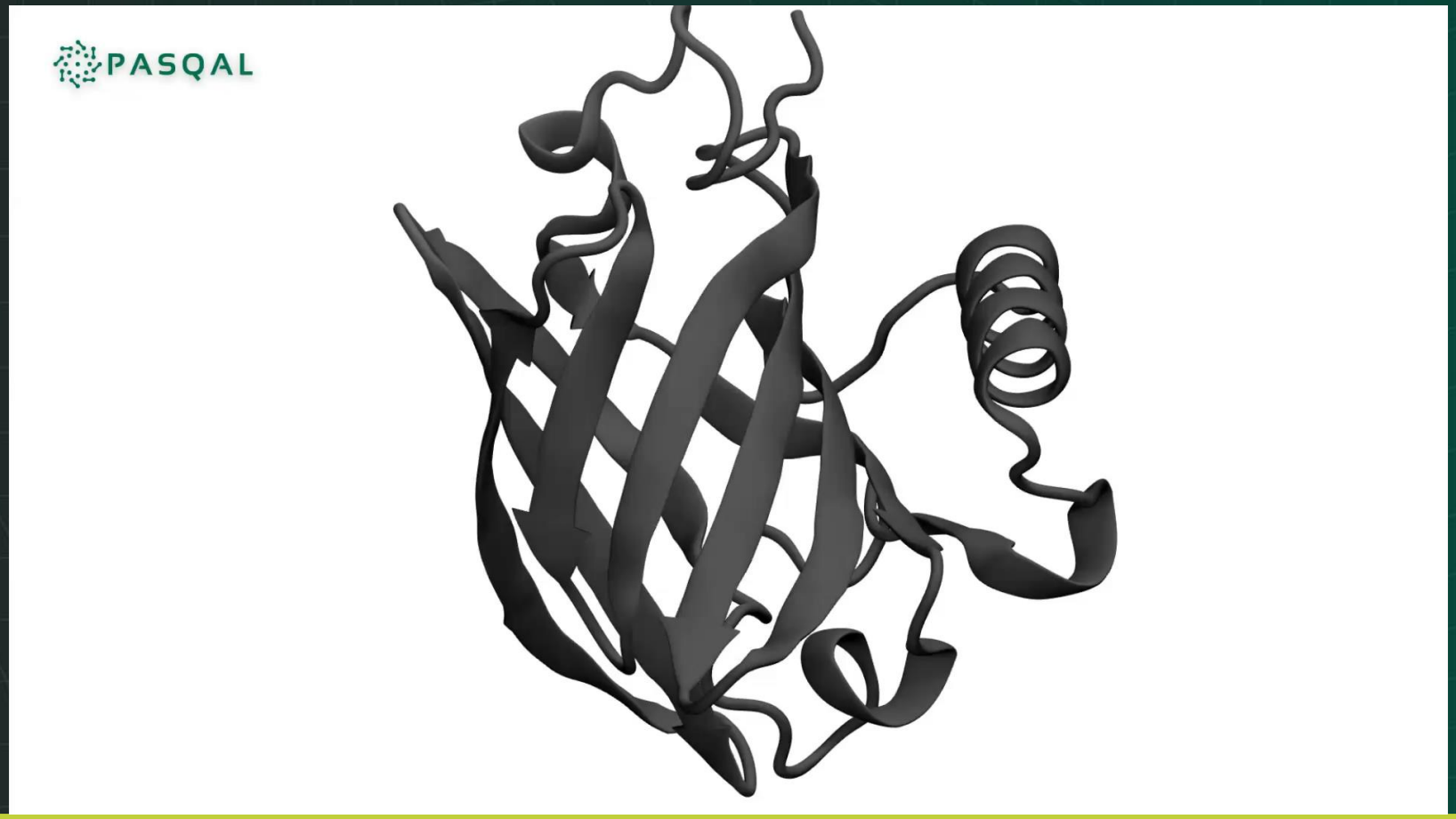
Quantum approach achieved the same level of precision and recall value as classical solution while using **a much simpler model**

- **Concrete advantage over classical benchmark** shown from simulation w/ additional flavor of qubit interaction on ~90 qubits (on roadmap by 2024)

PASQAL has contributed in paving the way for quantum machine learning in the financial sector

Scan QR code to read our blog post

PASQAL's recent results in drug discovery



PASQAL has successfully implemented a novel algorithm tackling a critical molecular biology problem in drug discovery in collaboration with **Qubit Pharmaceuticals.**

Scan QR code to read our blog post

Pasqal's Quantum Computers Facilitate a Sustainable Tomorrow

Higher Efficiency QPUs than Classical CPUs

Energy efficient

One QPU consumes the equivalent of 4 hair dryers

Faster Algorithms[1] Reduces Energy Consumption

98%

Faster on Ising Model[1]

Massive Energy Use Cases

UN SDG Positioning

Electrification, Food and Forestry, Industrial Operations, Decarbonize Energy, Ramp Carbon Markets[2]

[1] Reflects savings from just one 8-hour runtime on a Pasqal QPU over one 14-day runtime on traditional methods
[2] McKinsey, Quantum Computing Just Might Save the Planet, May 2022

The Blaise Pascal [re]Generative Quantum Challenge

PASQAL's sustainability-focused hackathon attracted more than 800 candidates with 75 proposals from over 25 countries.

This challenge was launched in collaboration with Blaise Pascal Advisors, GENCI, Capgemini and Michelin.

2023 WINNING PROJECTS

1st PLACE

Neutral Atom Renewable Energy Forecasting

Improving Renewable Energy Forecasting with Neutral Atom Reservoir Computing

by Naomi Mona Chmielewski, Leo Monbroussou and Ulysse Remond

2nd PLACE

Neutrogen: Unlocking data driven applications

Optimally embedding neutral atoms for any data-driven application

by Maria Demidik, Cenk Tuysuk, Manuel Rudlph, Giorgio Fecellli and Ravi Kumar

3rd PLACE

Molecular Docking with Neutral Atoms

Enhancing drug discovery pipelines to find a sustainable alternative to Paclitaxel

by Victor Onofre, Noe Bosc-Haddad and Mathieu Garrigues

Towards Regenerative Quantum Computing with proven positive sustainability impact

SCAN ME

FRANCE HYBRID HPCQUANTUM INITIATIVE

JÜLICH Forschungszentrum

PASQAL

#QEI the quantum energy initiative

Blaise Pascal Advisors

gesda

GENCI Le calcul intensif au service de la connaissance

EDF

COP28 UAE