Les ressources quantiques sur les plateformes de calcul en France: vue d'un utilisateur

Webinaire RI3, 12 juin 2026

Bogdan Vulpescu

Service Calcul et Données

Laboratoire de Physique de Clermont Auvergne

Le vulgarisateur expert ⇒ https://www.oezratty.net/wordpress/

L’œil attentif et vigilant de Olivier Ezratty sur son blog et dans son livre accessible « Understanding Quantum Technologies », 2025 (mis à jour, > 1500 pages)

Opinions Libres

le blog d'Olivier Ezratty

Home Archives Publications Podcasts Videos Blog About Recherche

Decode Quantum à l'envers avec Sébastien Marie de Matmut

Publié le 25 mai 2026 - Commenter -

Post Share

Dans cet épisode 86 de **Decode Quantum**, nous accueillons **Sébastien Marie**, CIO/CTO de Matmut mais nous faisons les choses à l’envers puisque c’est lui qui nous interviewe, **Fanny Bouton** (OVHcloud) et moi-même. Pour une fois, nous sommes de l’autre côté du micro.

Nous passons en revue la raison de notre entrée dans l’écosystème du quantique, comment cela s’est passé, les rencontres à commencer par les premières avec Alain Aspect, puis Daniel Estève et Maud Vinet, Jean-Christophe Gougeon de Bpifrance, Christophe Jurczak de Quantonation, Pascale Senellart, Neil Abroug à l’époque de la DGE, nos parcours en parallèle, Fanny Bouton à l’AID puis chez OVHcloud, et moi-même, auteur d’**Understanding Quantum Technologies**, enseignant, puis cofondateur de la **Quantum Energy Initiative** avec Alexia Auffèves et Robert Whitney, et maintenant impliqué à différents niveaux dans la Commission Européenne.

[...]

Actualités quantiques d'avril 2026

Publié le 4 mai 2026 et mis à jour le 9 mai 2026 - Commenter -

Post Share

Nous voici dans le 80ième épisode de Quantum, le podcast et la newsletter de l’actualité quantique en France et dans le monde. 80, mazette ! On avait démarré il y a presque 7 ans, en septembre 2019.

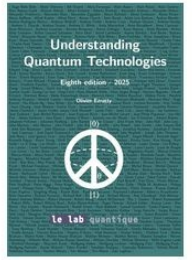
Fanny Bouton et moi-même couvrons d’abord l’actualité française avec l’inauguration de l’ordinateur quantique photonique Lucy de Quandela au TGCC du CEA, la conférence Pasqal Thoughts avec un point sur leurs deux qubits logiques, quelques nouveautés scientifiques et un changement de direction, une journée sur la photonique au Collège de France, la journée quantique organisée par l’AID à l’école Polytechnique, et la roadmap de C12.

Last posts / derniers articles

- Decode Quantum à l’envers avec Sébastien Marie de Matmut
- Actualités quantiques d’avril 2026
- Actualités quantiques de mars 2026
- How to compare logical qubits?
- Decode Quantum with Christian Weedbrook from Xanadu
- Actualités quantiques de février 2026
- Actualités quantiques de janvier 2026
- Actualités quantiques de décembre 2025
- Back from the Q2B Santa Clara 2025
- Actualités quantiques de novembre 2025

Free downloads

Understanding Quantum Technologies 2025, a free 1,522 pages ebook about all quantum technologies (computing, telecommunications, cryptography, sensing):



Understanding Quantum Technologies 2025 Key takeaways, a 38 pages version with key takeaways from the eponymous book.

Une classification des processeurs quantiques

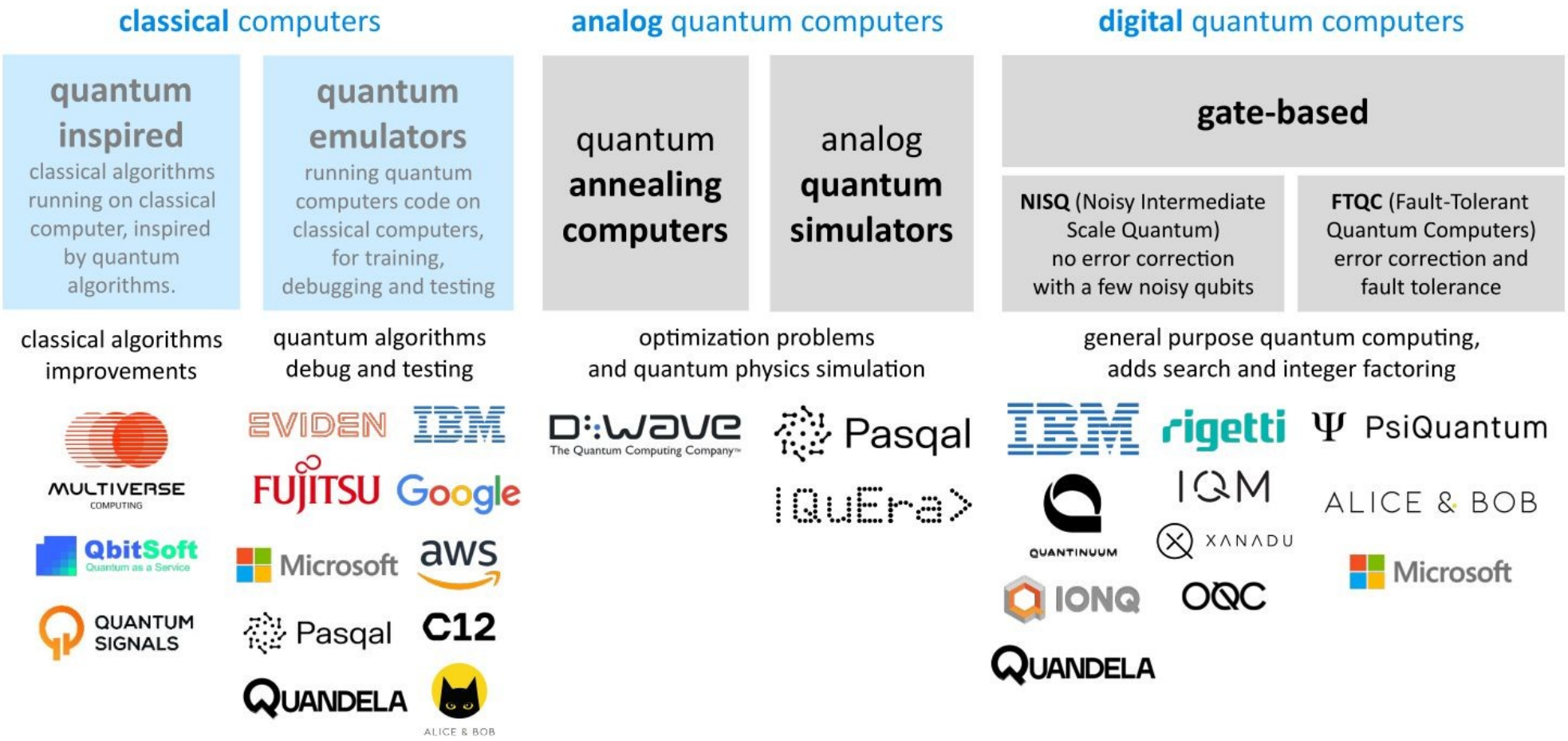
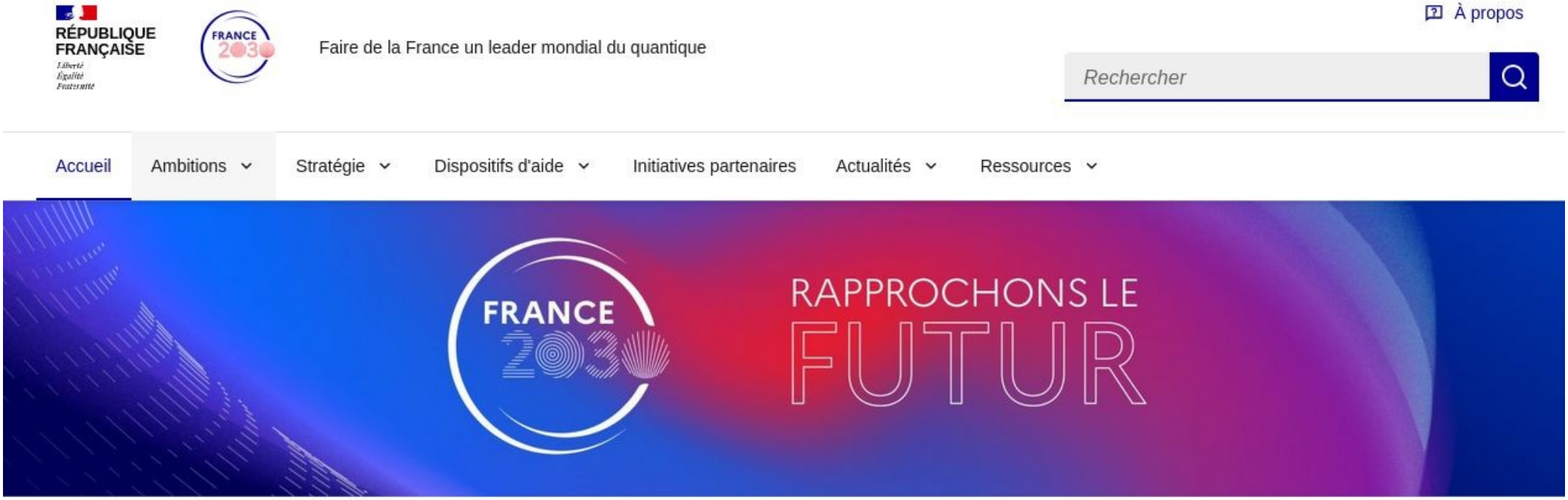


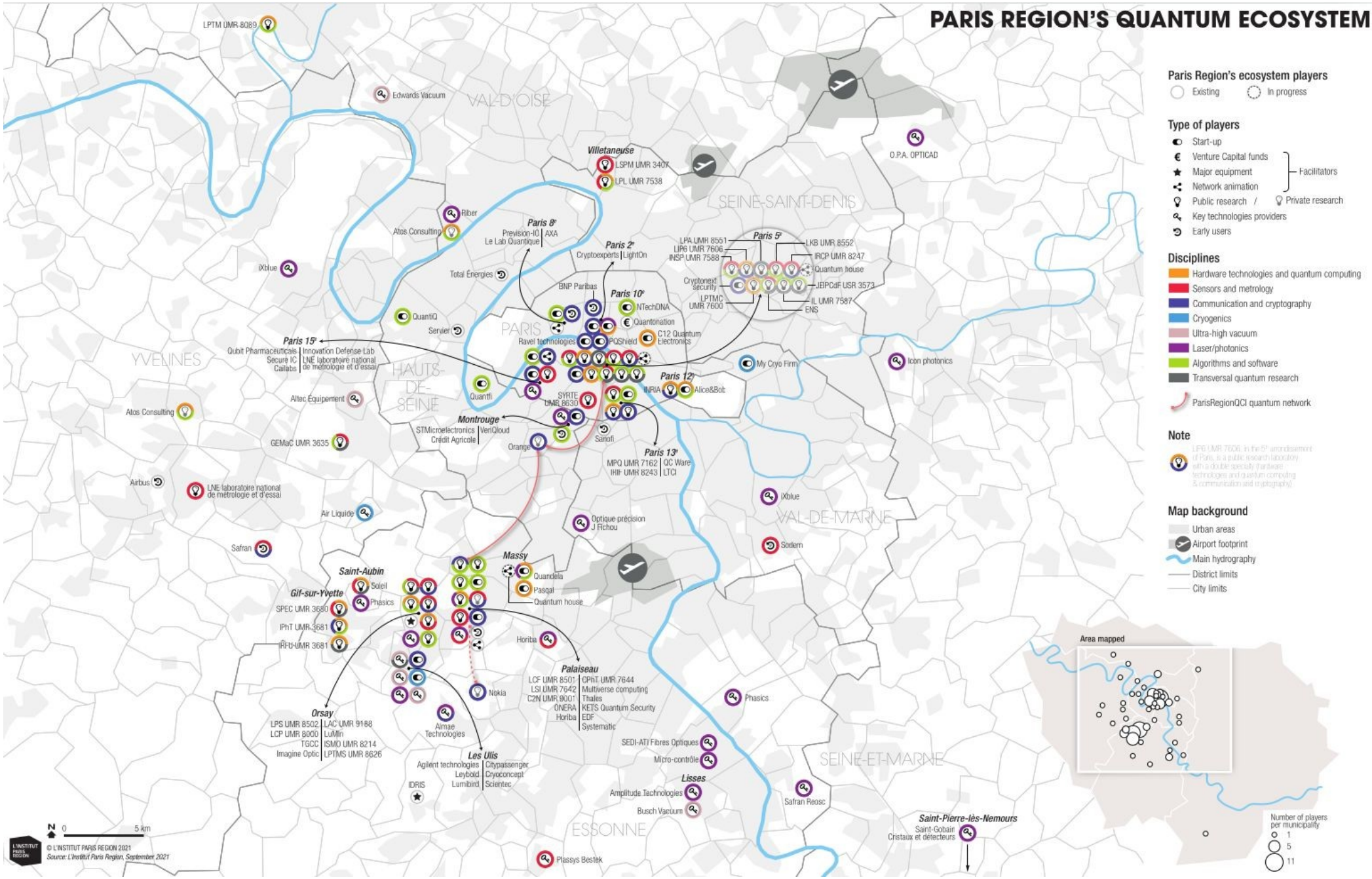
Figure 225: The different computing paradigms with gate-based quantum computers, analog quantum computers (grey), and classical systems for code emulation or quantum inspired tensor network-based solutions (in blue). © Olivier Ezratty, 2022-2025.

Vue d’en haut ⇒ https://quantique.france2030.gouv.fr/



La Stratégie Nationale Quantique

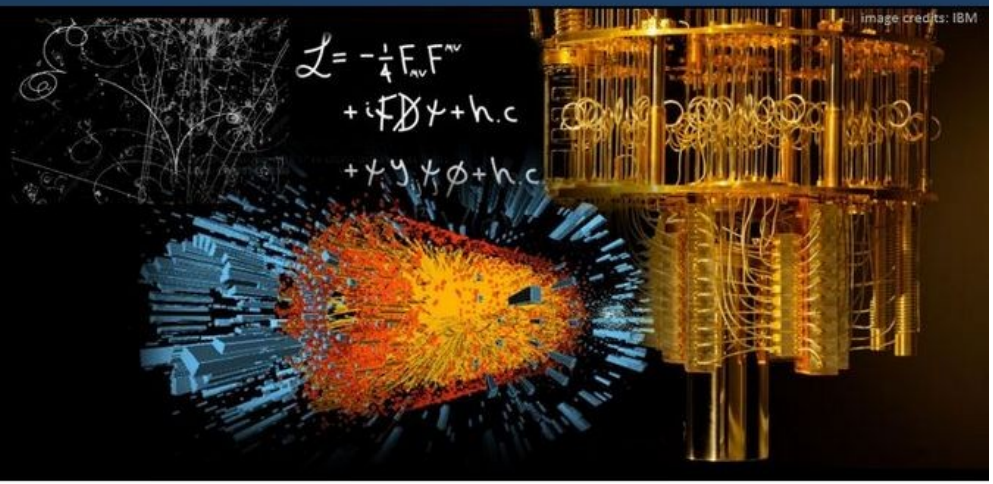
Avec un investissement gouvernemental d’un milliard d’euros entre 2021 et 2025, la Stratégie Nationale Quantique porte l’ambition française de devenir un acteur incontournable des technologies quantiques. En unissant les efforts de l’État, des startups, des industriels et des investisseurs privés, la stratégie nationale quantique vise à consolider le leadership français et à catalyser l’avènement de leaders industriels de stature mondiale d’ici la fin de la décennie.



Septembre 2021, institutparisregion.fr

Vue de l'IN2P3 ⇒ https://qc.pages.in2p3.fr/web/ (01.2021 -?)

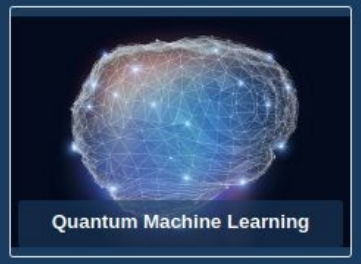
QC2I: Quantum Computing for the two Infinites



QC2I is a computing project supported by IN2P3, the French national nuclear and particle physics institute. Its goal is to explore the possible applications of the emerging quantum computing technologies to particles and nuclear physics problems as well as astrophysics. The main tasks are:

- to identify, within IN2P3, scientists/engineers/technicians who are interested in using quantum technologies,
- to facilitate the access and training on quantum computers,
- to identify milestones applications for nuclear/particle physics and astrophysics,
- to design dedicated algorithms and proof of principle applications.

The project action has three main directions: **Prepare the Quantum Computing Revolution** (PQCR), **Quantum Machine Learning** (QML), **Complex Quantum Systems Simulation** (CQSS, **until end of 2022**)



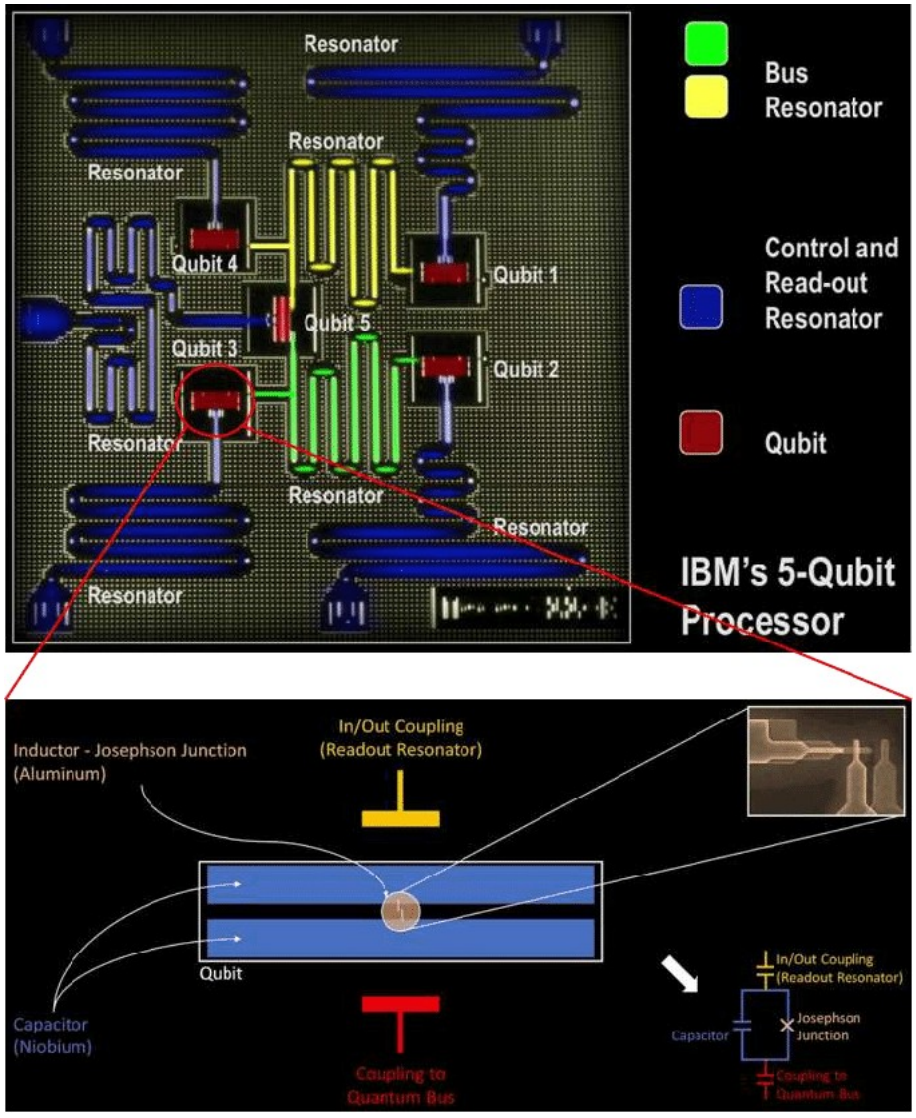
Le qubit : élément de base de l’informatique quantique

Démo ⇒ https://javafxpert.github.io/grok-bloch/

La programmation des circuits quantiques

Démo ⇒ https://quantum.cloud.ibm.com/composer

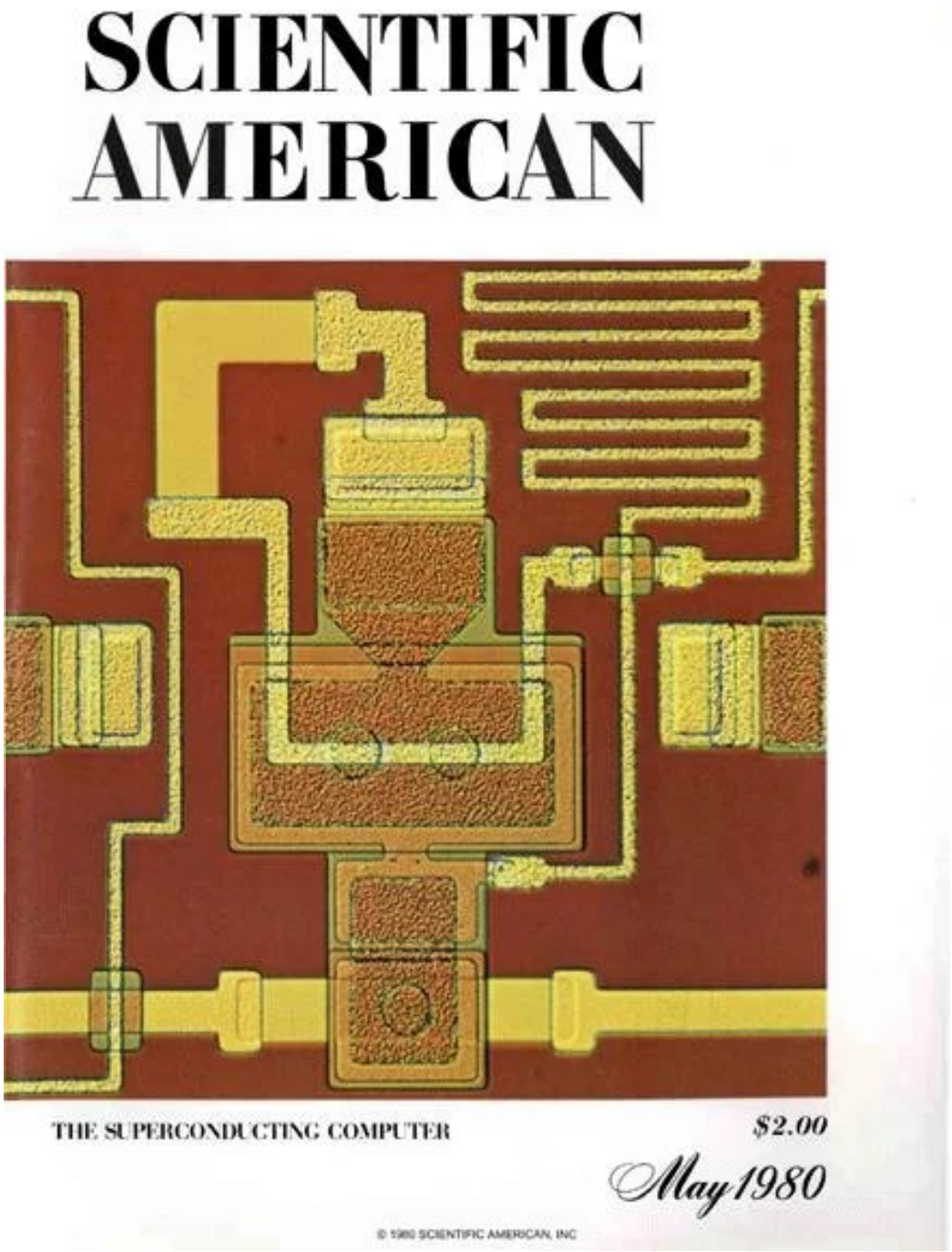
Qubits supraconducteurs



https://quantumzeitgeist.com/top-superconducting-quantum-computing-companies/ (QPU à portes)

- IBM Quantum
- Google Quantum AI
- Rigetti Computing
- IQM Quantum Computers
- Alice & Bob
- SeeQC
- QuantWare
- Anyon Systems

Atomes artificiels (macroscopiques) avec circuits Josephson



Un vieux rêve : l'ordinateur supraconducteur

Une application de la jonction Josephson (1974, l'effet tunnel des paires Cooper) ⇒ un commutateur commandé par un champ magnétique (un magnétomètre)

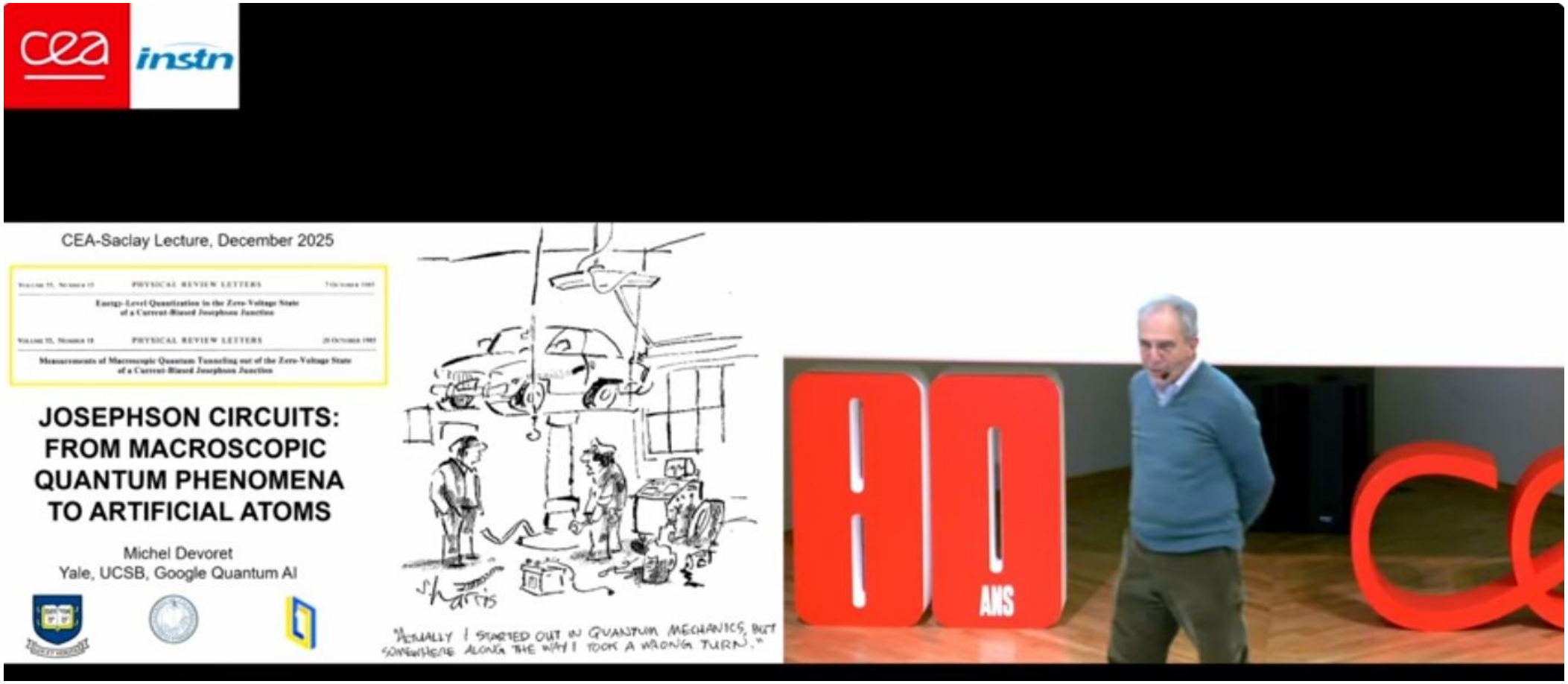
Deux ou plusieurs jonctions Josephson ⇒ SQUID = Superconducting Quantum Inteference Device

… mais les promesses (x 50) ont été vite dépassées par le progrès fait dans les circuits intégrés en technologie TTL, etc.

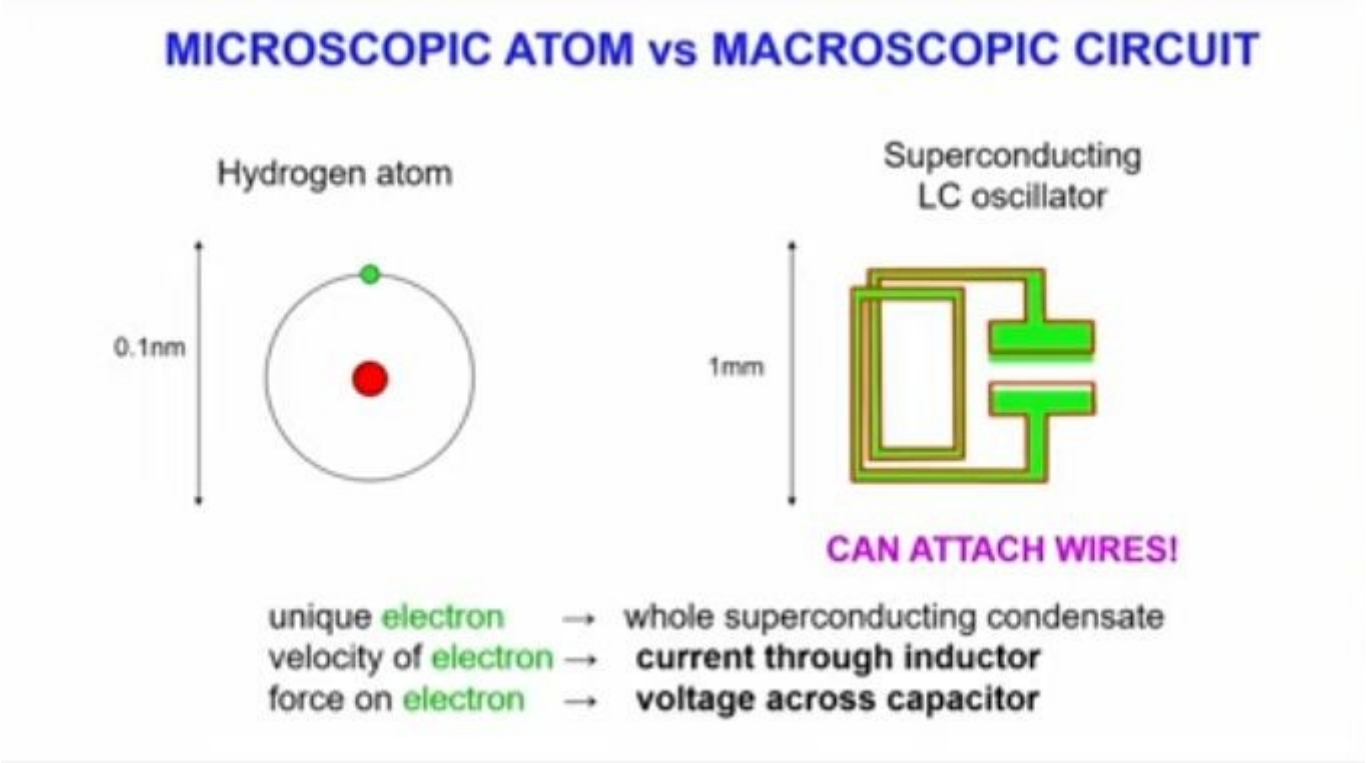
Michel Devoret (prix Nobel de physique 2025)

Conférence exclusive

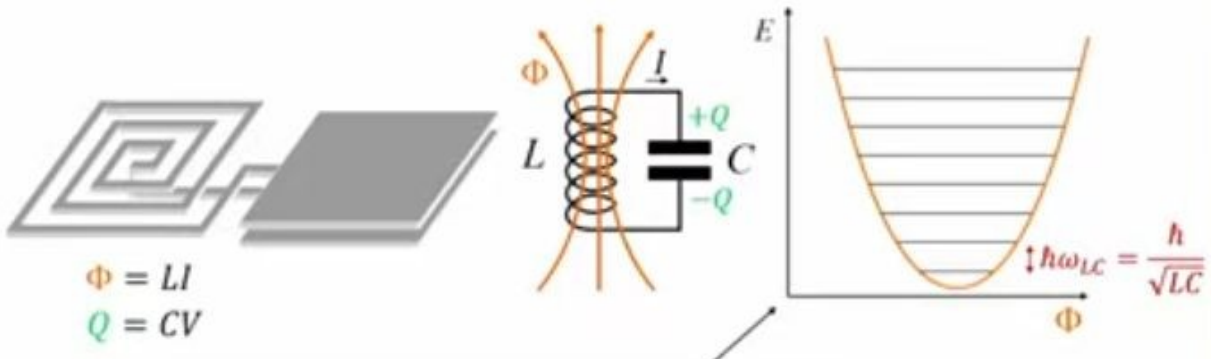
https://www.youtube.com/watch?v=yxECzgPtd1k



Source : capture d’écran https://www.youtube.com/watch?v=yxECzgPtd1k

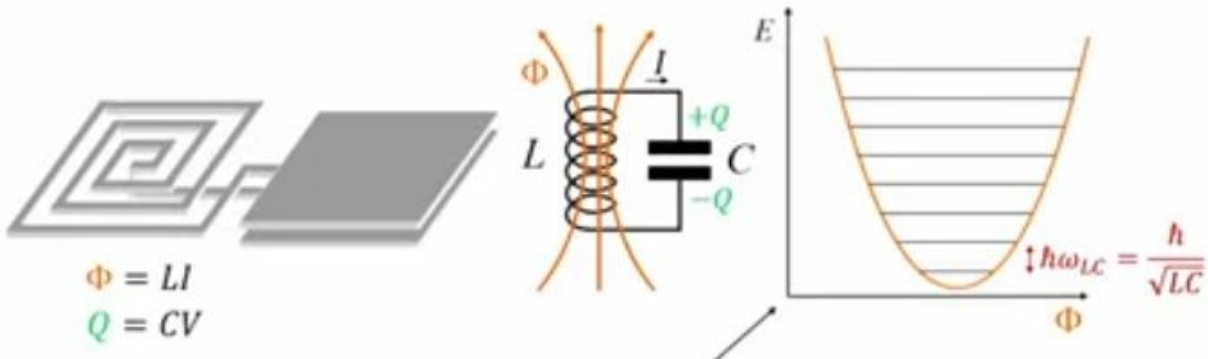


SUPERCONDUCTING LC CIRCUIT AS A QUANTUM HARMONIC OSCILLATOR



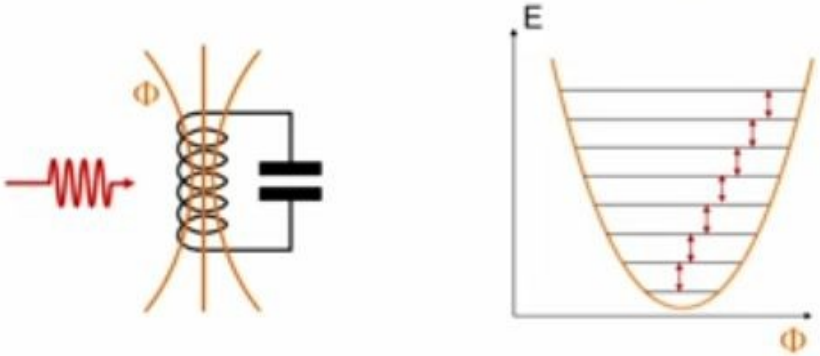
Leggett's hypothesis: $\left[\hat{\Phi}, \hat{Q}\right] = i\hbar\hat{1}$

SUPERCONDUCTING LC CIRCUIT AS A QUANTUM HARMONIC OSCILLATOR



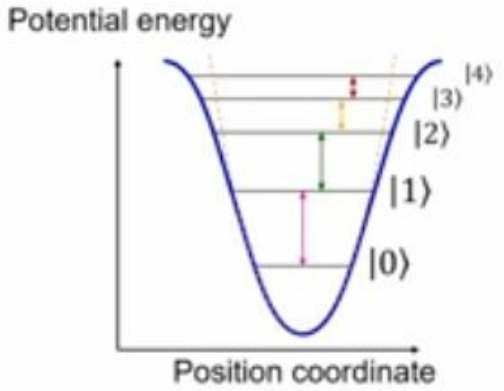
Leggett's hypothesis: $[\hat{\Phi}, \hat{Q}] = i\hbar\hat{1}$

CAVEAT: THE QUANTUM STATES OF A PURELY LINEAR CIRCUIT CANNOT BE FULLY CONTROLLED!



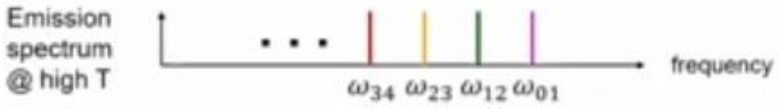
NO STEERING TO AN ARBITRARY STATE IF SYSTEM PERFECTLY LINEAR

NEED NON-LINEARITY TO FULLY REVEAL QUANTUM MECHANICS

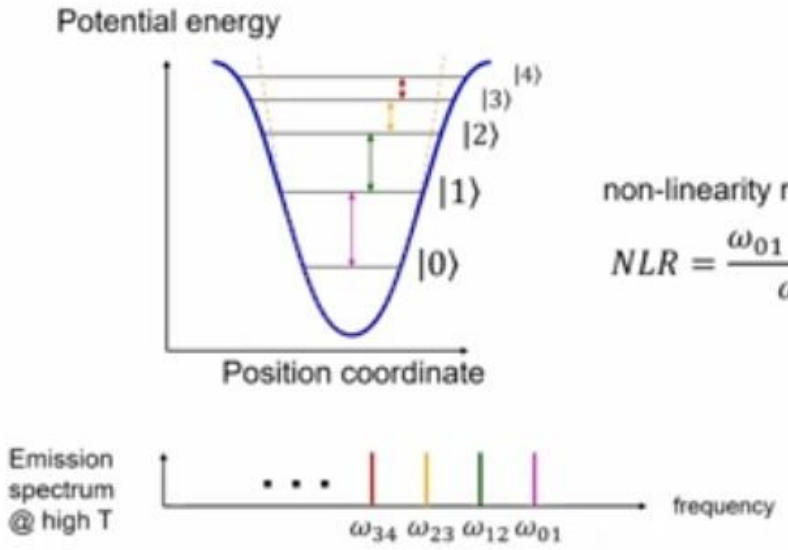


non-linearity ratio:

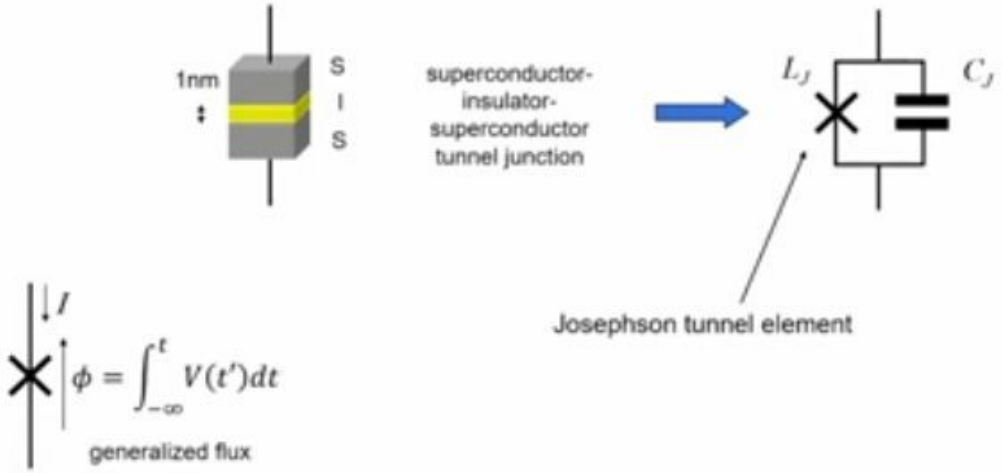
$$NLR = \frac{\omega_{01} - \omega_{12}}{\omega_{01}}$$



NEED NON-LINEARITY TO FULLY REVEAL QUANTUM MECHANICS



A NON-LINEAR INDUCTANCE WITH NO FUNDAMENTAL DISSIPATION: THE JOSEPHSON TUNNEL ELEMENT



Energy-Level Quantization in the Zero-Voltage State of a Current-Biased Josephson Junction

John M. Martinis, Michel H. Devoret,[a] and John Clarke
Department of Physics, University of California, Berkeley, California 94720, and Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, California 94720
(Received 14 June 1985)

We report the first observation of quantized energy levels for a macroscopic variable, namely the phase difference across a current-biased Josephson junction in its zero-voltage state. The position of these energy levels is in quantitative agreement with a quantum mechanical calculation based on parameters of the junction that are measured in the classical regime.

Measurements of Macroscopic Quantum Tunneling out of the Zero-Voltage State of a Current-Biased Josephson Junction

Michel H. Devoret,[a] John M. Martinis, and John Clarke
Department of Physics, University of California, Berkeley, California 94720, and Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, California 94720
(Received 26 July 1985)

The escape rate of an underdamped ($Q \approx 30$), current-biased Josephson junction from the zero-voltage state has been measured. The relevant parameters of the junction were determined *in situ* in the thermal regime from the dependence of the escape rate on bias current and from resonant activation in the presence of microwaves. At low temperatures, the escape rate became independent of temperature with a value that, with no adjustable parameters, was in excellent agreement with the zero-temperature prediction for macroscopic quantum tunneling.

Les qubits supraconducteurs sur IBM Quantum Platform

Démo ⇒ https://quantum.cloud.ibm.com/

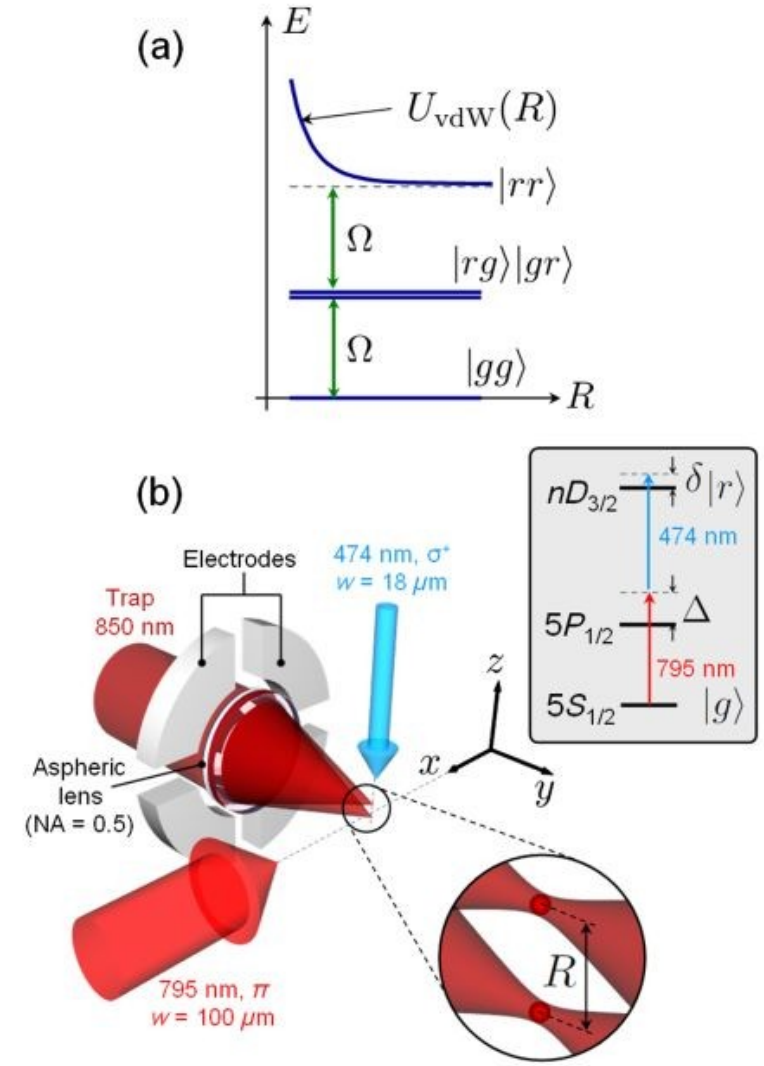


FIG. 1 (color online). (a) Principle of the Rydberg blockade. The single-atom Rabi frequency is Ω. (b) Experimental setup. Two single atoms are trapped in microscopic optical traps separated by R. Eight electrodes (four of which, facing the ones displayed here, are not shown) provide electric field control. Inset: two-photon excitation scheme (the intermediate-state detuning is $\Delta \simeq 2\pi \times 740$ MHz).

Qubits avec des atomes neutres

(ou atomes froids, ou atomes Rydberg)

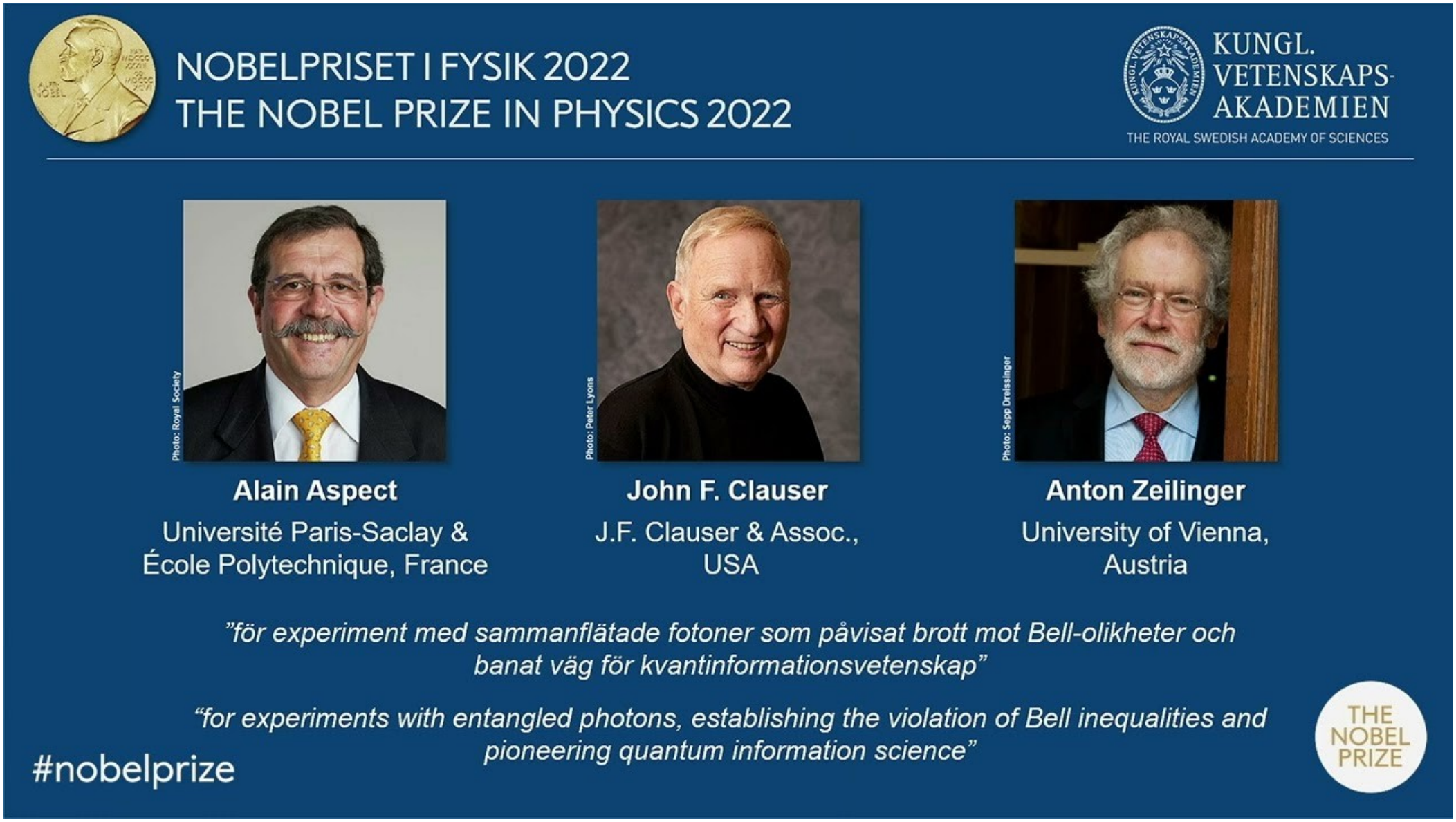
Le *White paper* de Pasqal,

Henriet et al., https://arxiv.org/abs/2006.12326

⇒ applications :

- simulation quantique (analogue)
  - systèmes de spins
  - physique de la matière condensée
  - chimie quantique
  - théorie de jauge sur réseau
- méthodes variationnelles
  - problèmes d'optimisation combinatoire
  - équation différentielles non-linéaires
  - machine learning

Fin du débat sur les inégalités de Bell … et le start-up Pasqal



PASQAL Ruby @ GENCI/TGCC (CEA) depuis décembre 2025 ;

Via le programme **HQI** (*France Hybrid HPC Quantum Initiative*), dans le cadre du projet européen **HPCQS** (*High Performance Computer - Quantum Simulator Hybrid*), https://www.hpcqs.eu/

Atos/Eviden/Bull QLM Qaptiva infrastructure

Vidéos :

https://www.canal-u.tv/chaines/genci/webinaires-quantiques

Démo ⇒ https://pulserstudio.pasqal.cloud/

Démo ⇒ Ruby @ TGCC

Qubits avec des photons

VOLUME 73, NUMBER 1 PHYSICAL REVIEW LETTERS 4 JULY 1994

Experimental Realization of Any Discrete Unitary Operator

Michael Reck and Anton Zeilinger
Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, A–6020 Innsbruck, Austria

Herbert J. Bernstein and Philip Bertani
Hampshire College and ISIS, Amherst, Massachusetts 01002
(Received 11 February 1994)

An algorithmic proof that any discrete finite-dimensional unitary operator can be constructed in the laboratory using optical devices is given. Our recursive algorithm factorizes any $N \times N$ unitary matrix into a sequence of two-dimensional beam splitter transformations. The experiment is built from the corresponding devices. This also permits the measurement of the observable corresponding to any discrete Hermitian matrix. Thus optical experiments with any type of radiation (photons, atoms, etc.) exploring higher-dimensional discrete quantum systems become feasible.

Qubits = photons sur des modes spatiaux

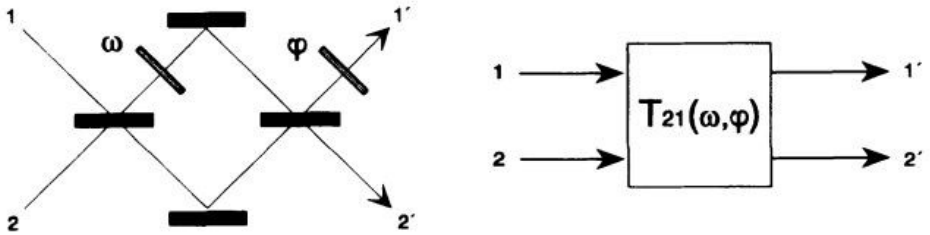


FIG. 1. A Mach-Zehnder interferometer can be used instead of a variable reflectivity beam splitter as the basic building block of any $N \times N$ unitary matrix. On the left is one experimental realization of the device using two 50:50 beam splitters, two mirrors, and two phase shifters. The Mach-Zehnder interferometer can be represented by the abstract four-port device on the right. Two parameters (ϕ, ω) of the transformation T are set in the device.

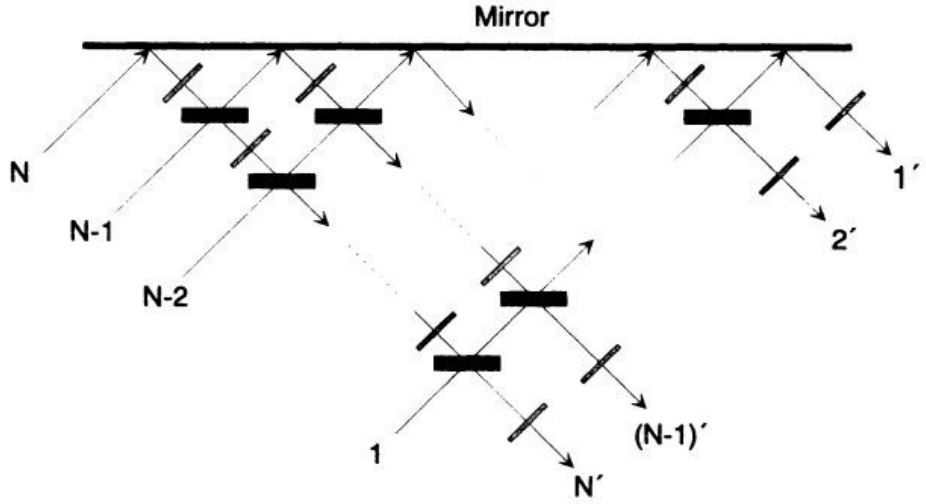


FIG. 3. A triangular array of beam splitters implements any $N \times N$ unitary matrix as an optical multiport. The beams are solid lines. A suitable beam splitter is at each crossing point of the beams. Phase shifters are at one input of each beam splitter and at the outputs $(1', \ldots, N')$ of the multiport. Each diagonal row of beam splitters performs a transformation reducing the effective dimension of the Hilbert space by one.

QUANDELA Lucy @ GENCI/TGCC (CEA), depuis avril 2026 ; dans le cadre du projet EuroQCS France (*European Quantum Computing & Simulation Infrastructure*)

Démo ⇒ https://hub.quandela.com/

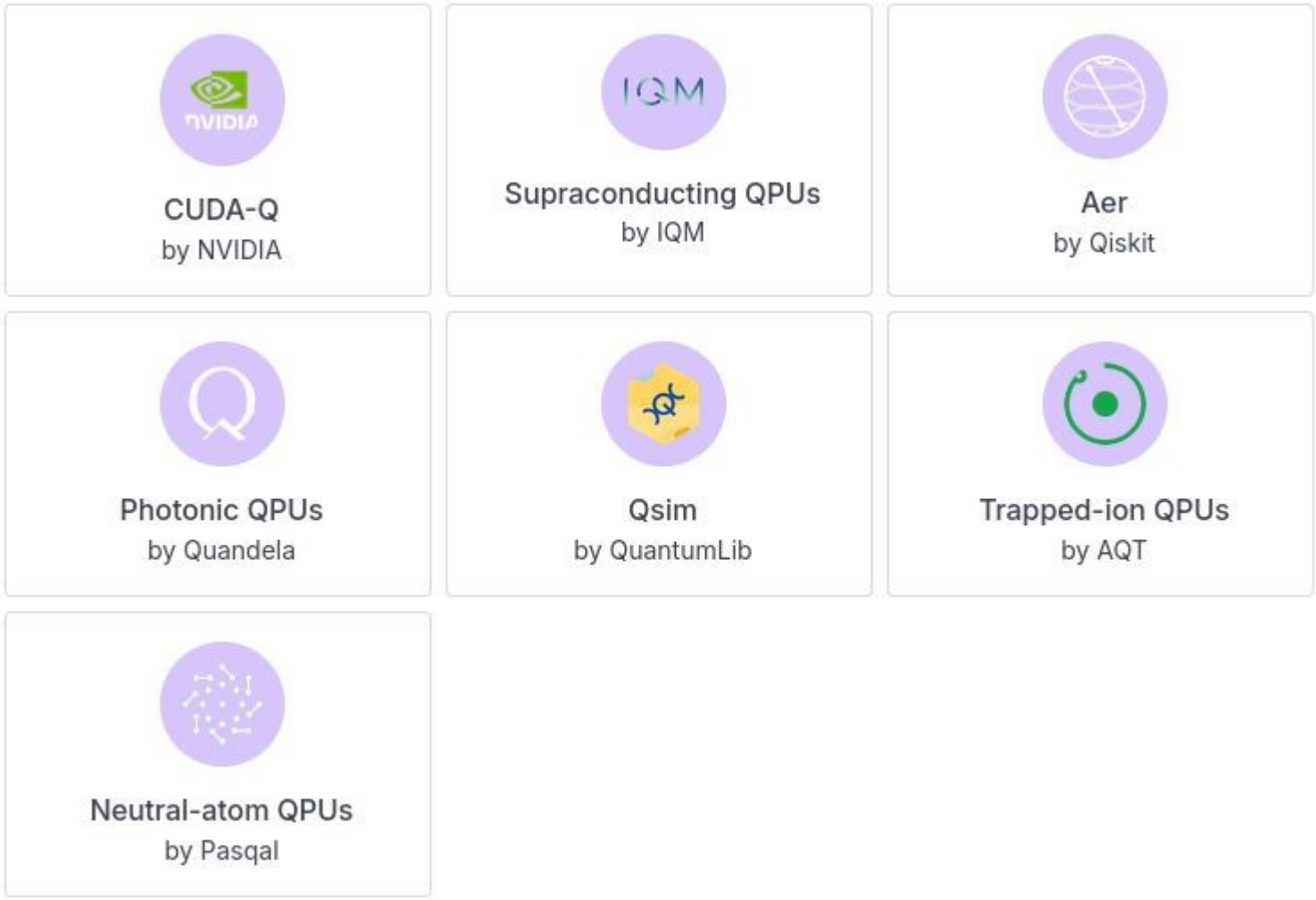
https://cloud.quandela.com/

https://training.quandela.com/catalog

https://training.quandela.com/virtual-lab

https://training.quandela.com/composer

Scaleway : le cloud souverain



CUDA-Q (NVIDIA)

As-You-Go offers | Bookable offers SOON | Emulated offers

A GPU-based emulated QPU mimics the behavior of a real quantum computer, such as entanglement and superposition. It is on-purpose to explore or test quantum algorithms.

Name	Price (excl. tax.)	Emulation backend	Estimated max qubits*
EMU-CUDAQ-64C-512M	€3.3/hour	cudaq	34
OUT OF STOCK EMU-CUDAQ-8B300SXM	€60/hour Billed per min	cudaq	38
EMU-CUDAQ-4H100SXM	€11.61/hour Billed per min	cudaq	35
EMU-CUDAQ-H100	€2.52/hour Billed per min	cudaq	33
EMU-CUDAQ-2H100SXM	€6.018/hour Billed per min	cudaq	34
EMU-CUDAQ-8H100SXM	€23.028/hour Billed per min	cudaq	36

Qiskit Aer

EMU-AER-32C-256M	€1.65/hour	aer	33
OUT OF STOCK EMU-AER-8L40S	€11.2/hour Billed per min	aer	36
EMU-AER-2H100	€5.04/hour Billed per min	aer	34
OUT OF STOCK EMU-AER-2L40S	€2.8/hour Billed per min	aer	34
EMU-AER-H100	€2.52/hour Billed per min	aer	33
EMU-AER-16C-128M	€0.82/hour	aer	32
OUT OF STOCK EMU-AER-4L40S	€5.6/hour Billed per min	aer	35
EMU-AER-64C-512M	€3.3/hour	aer	35
EMU-AER-2L4	€1.5/hour Billed per min	aer	33

Qsim (QuantumLib)

EMU-QSIM-32C-256M	€1.65/hour	qsim	34
EMU-QSIM-8C-64M	€0.41/hour	qsim	32
EMU-QSIM-8H100SXM	€23.028/hour Billed per min	qsim	36
EMU-QSIM-64C-512M	€3.3/hour	qsim	35
EMU-QSIM-L40S	€1.4/hour Billed per min	qsim	32
EMU-QSIM-4H100SXM	€11.61/hour Billed per min	qsim	34
EMU-QSIM-H100	€2.52/hour Billed per min	qsim	33
EMU-QSIM-16C-128M	€0.82/hour	qsim	33

QuantumLib :
a library for representing and reasoning about quantum computing in the **Coq proof assistant**.

Name	Price (excl. tax.)	QPU model	Max photons
QPU-BELENOS-12PQ	€0.3/circuit €0.000001/shot	mosaiq-12	12
IN MAINTENANCE QPU-ALTAIR-10PQ	€0.3/circuit €0.000001/shot	mosaiq-10	10
IN MAINTENANCE QPU-ASCELLA-6PQ	€0.3/circuit €0.000001/shot	mosaiq-6	6

Quandela

Name	Price (excl. tax.)	QPU model	Max atoms
IN MAINTENANCE QPU-FRESNEL-100PQ	€3.3333/shot	orion-beta	100
IN MAINTENANCE QPU-DISTRIQ-100PQ	€3.3333/shot	orion-beta	100

Pasqal

Name	Price (excl. tax.)	QPU model	Max qubits
QPU-EMERALD-54PQ	€0.25/circuit €0.0014/shot	crystal-54	54
QPU-GARNET-20PQ	€0.22/circuit €0.0012/shot	crystal-20	20
QPU-SIRIUS-24PQ	€0.2/circuit €0.00075/shot	star-24	16

IQM (supercond.)

https://iqm.tech

Name	Price (excl. tax.)	QPU model	Max atoms
IN MAINTENANCE QPU-IBEX-12PQ	€0.3/circuit €0.021/shot	ibex-q1	12

AQT (ions piègés)

https://www.aqt.eu/

Machine Learning avec MerLin (Quandela)

https://merlinquantum.ai/

https://www.scaleway.com/en/docs/quantum-computing/how-to/use-merlin/

https://github.com/merlinquantum/reproduced_papers

Use MerLin for Photonic Quantum Machine Learning

Reviewed on February 24, 2026

MerLin is a Photonic Quantum Machine Learning Framework developed by Quandela. It brings quantum computing capabilities to AI practitioners through easy-to-use PyTorch integrations, adding quantum wizardry to your AI toolkit with no extensive quantum expertise required.

It is designed to feel familiar to PyTorch users while unlocking the potential of quantum computing. Under the hood, it leverages photonic quantum computing—a cutting-edge approach using single-photons that's hardware-aware and prepares your models for real quantum processors.

Scaleway offers access to Quandela's QPUs and emulated QPUs via its Quantum as a Service (QaaS) offer. This allows you to run your MerLin-based quantum circuits on real photonic quantum processors or emulators directly from your Python code.

[1]:
```
import os
import torch
import perceval.providers.scaleway as scw
```

[2]:
```
from merlin.builder.circuit_builder import CircuitBuilder
from merlin.algorithms import QuantumLayer
from merlin.core.merlin_processor import MerlinProcessor
```

[3]:
```
PROJECT_ID = os.environ.get("SCW_PROJECT_ID", [redacted])
SECRET_KEY = os.environ.get("SCW_SECRET_KEY", [redacted])
PLATFORM_NAME = "EMU-SAMPLING-L4"  ## EUR 1.125/hour, billed per minute
```

[4]:
```
# Define a simple circuit builder
b = CircuitBuilder(n_modes=4)
b.add_rotations(trainable=True, name="theta")
b.add_angle_encoding(modes=[0, 1], name="px")
```

[4]:
```
<merlin.builder.circuit_builder.CircuitBuilder at 0x796d35445a90>
```

[5]:
```
# 1. Open a Scaleway session
with scw.Session(platform_name=PLATFORM_NAME, project_id=PROJECT_ID, token=SECRET_KEY) as session:

    # 2. Bind the session to the MerlinProcessor
    proc = MerlinProcessor(session=session)

    # 3. Create a Quantum Layer
    q_layer = QuantumLayer(
        input_size=2,
        builder=b,
        n_photons=2
    ).eval()

    # 4. Run inference
    X = torch.rand(4, 2)
    result = proc.forward(q_layer, X, nsample=100)

    print(f"Input shape: {X.shape}")
    print(f"Output shape: {result.shape}")
```

```
Input shape: torch.Size([4, 2])
Output shape: torch.Size([4, 6])
```

Software :

perceval

+

torch

+

merlinquantum

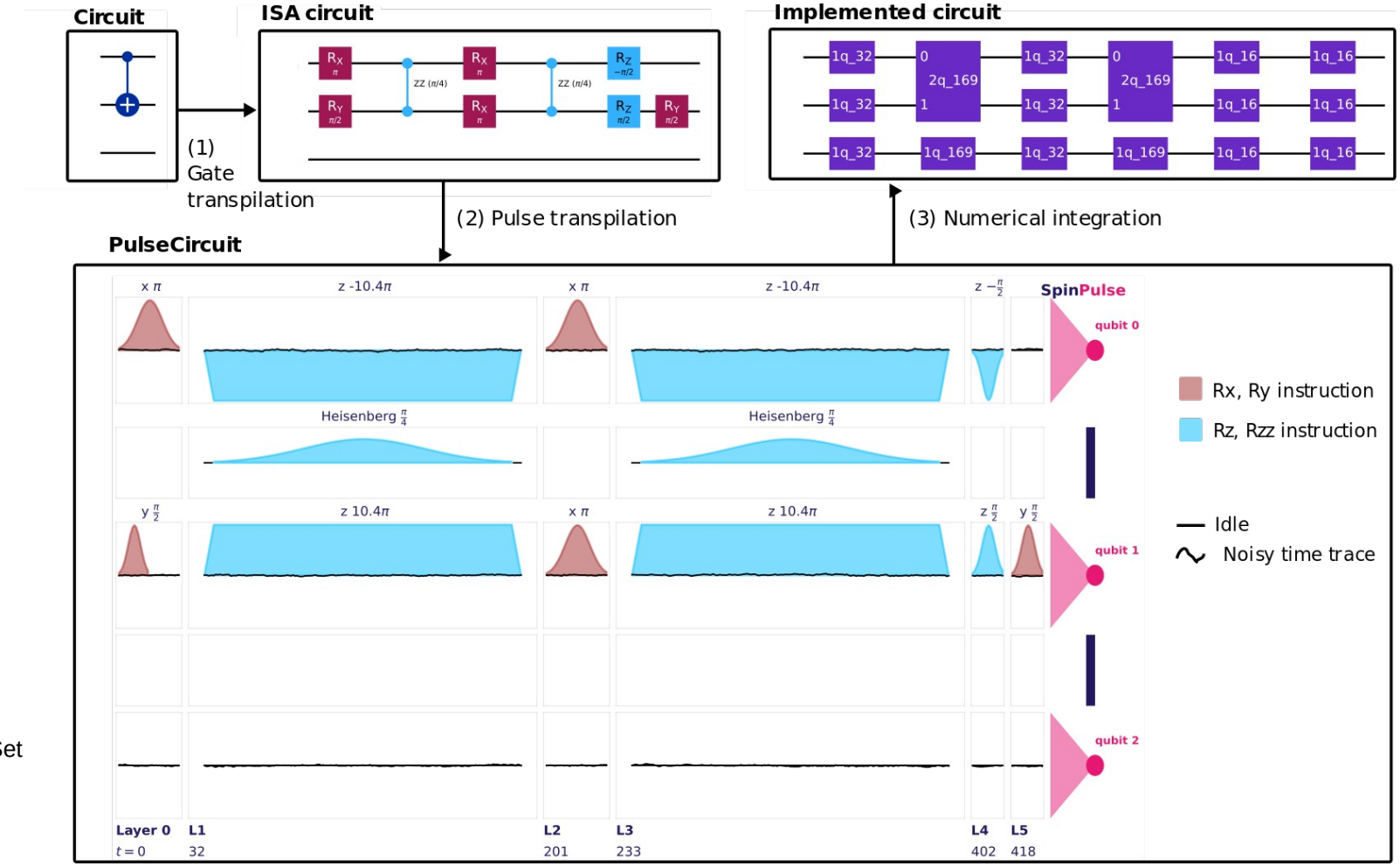
Démo

Qubits avec les spins (des électrons) : SpinPulse/Quobly

https://quobly-sw.github.io/SpinPulse/

https://github.com/quobly-sw/SpinPulse

https://arxiv.org/pdf/2601.10435



ISA = Instruction Set Architecture

quobly's edge: semiconductor industry to disrupt Quantum Computing market

10m^2 quantum computer compatible with HPC and data centers for pervasive hybrid quantum-classical computing

1,000x faster, **100x** smaller, **100x** cheaper

Quantum computing future depends on technology's ability to scale the number of qubits at a competitive cost: Quobly leverages the billions of dollars invested in the semiconductor industry.

quobly

Voir aussi le tutoriel QC2I sur les spins en champ magnétique:

26, 28 oct. 2021, https://indico.in2p3.fr/event/25426/

Démo ⇒ spin-pulse

Simulations avec

MIMIQ/QPerfect

- émulateurs performants

⇒ 1024 qubits

https://qperfect.io/

https://docs.qperfect.io/

https://mimiq.qperfect.io

https://arxiv.org/abs/2504.14027

Cloud trial access ⇒ 11 mai

Quantanium is MIMIQ's **local statevector simulator** — it runs entirely on your own machine, with no internet connection needed.

How Quantanium works

A statevector simulator represents a quantum state as a complex vector of 2^n amplitudes (where n is the number of qubits). It applies quantum gates as exact matrix multiplications on this vector.

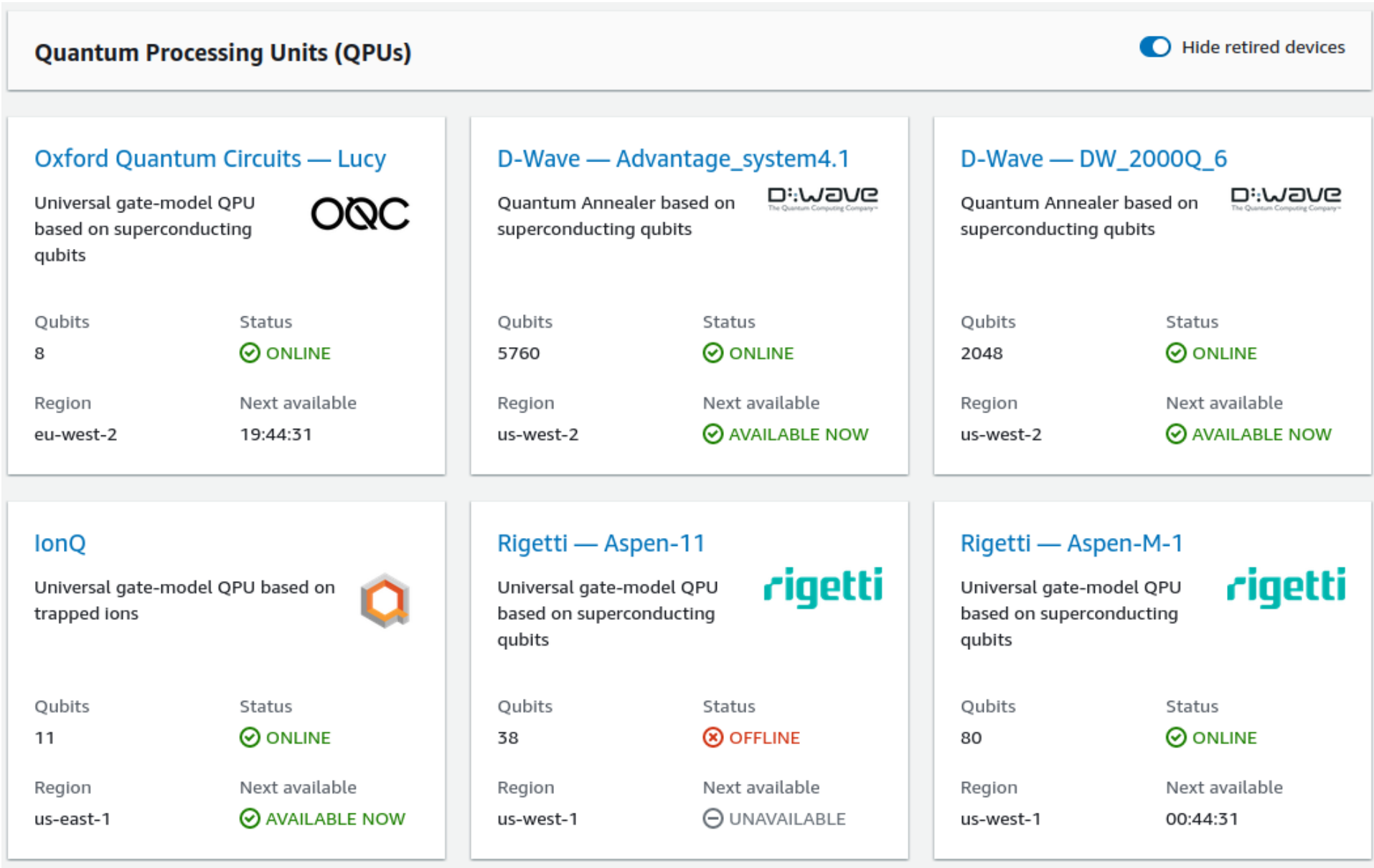
Property	Value
Simulation method	Exact statevector
Qubit limit	~25–30 qubits (RAM-limited)
Noise support	Full noise channel simulation
Connection	None — runs fully offline
Use case	Development, debugging, education

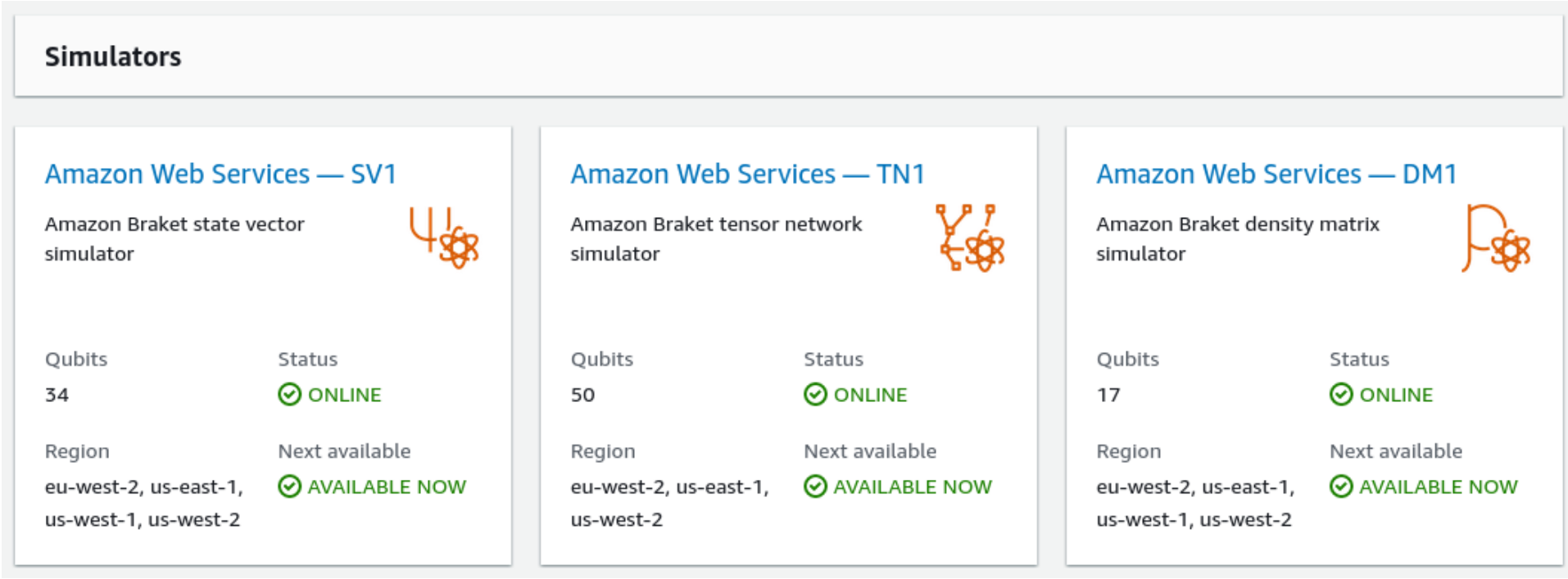
Quantanium vs MIMIQ Cloud ¶

	Quantanium (local)	MIMIQ Cloud
Qubits	~25–30	Hundreds+
Speed	Fast for small circuits	HPC-accelerated
Internet	Not required	Required

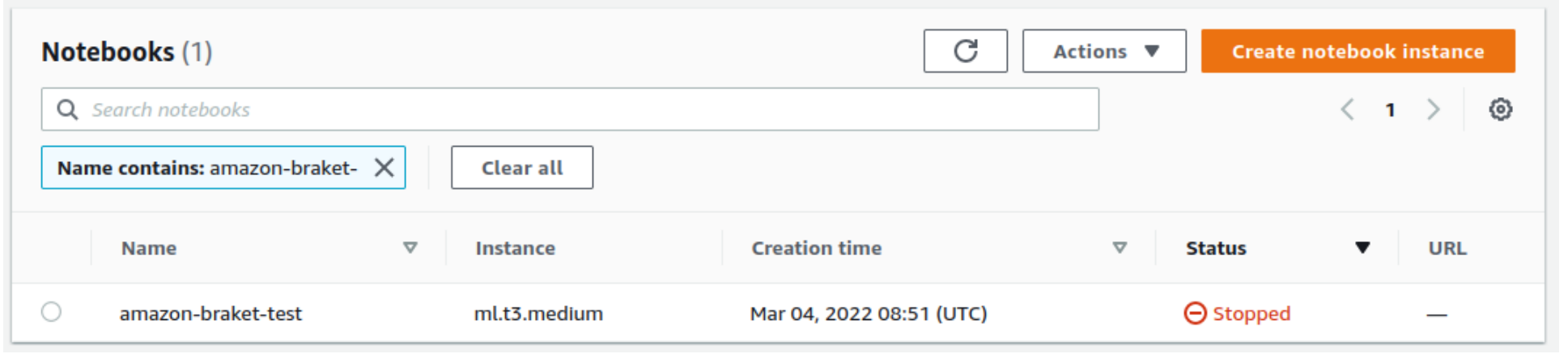
Démo ⇒ mimiq-ide

Ressources sur AWS, 02.2022 → 04.2023

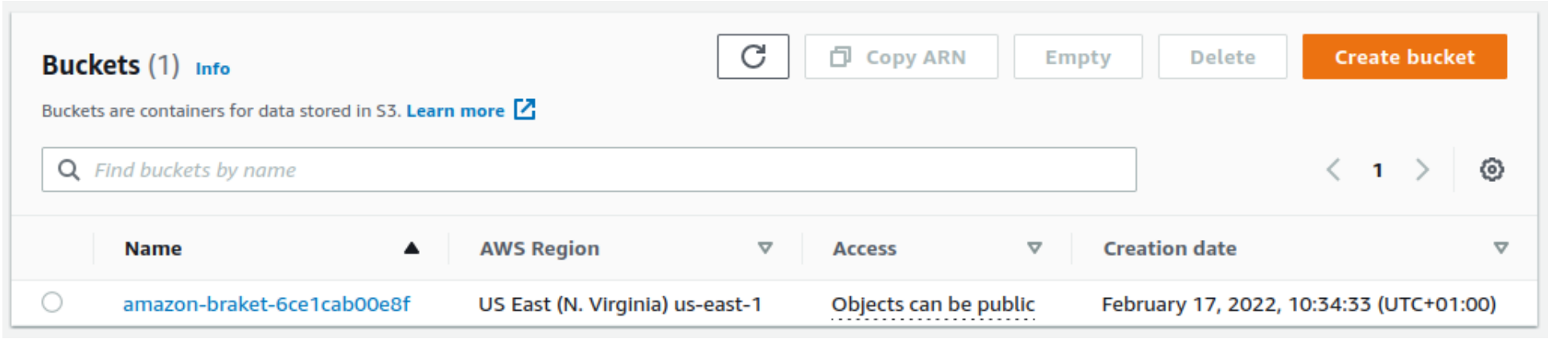


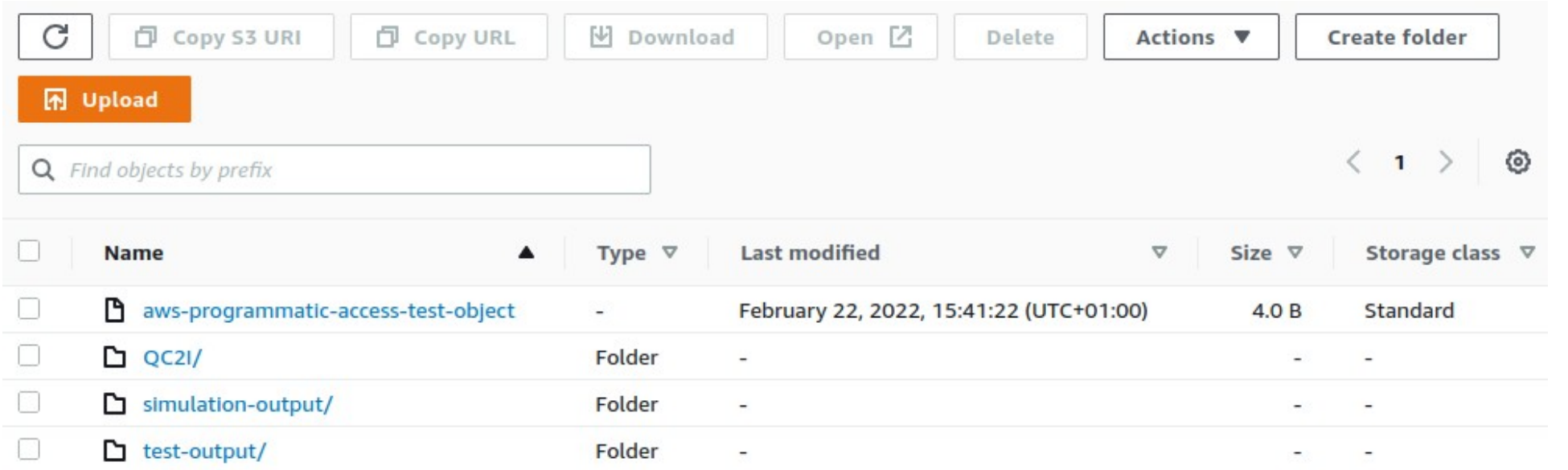


Instance pour les Notebooks Jupyter



Stockage sur S3

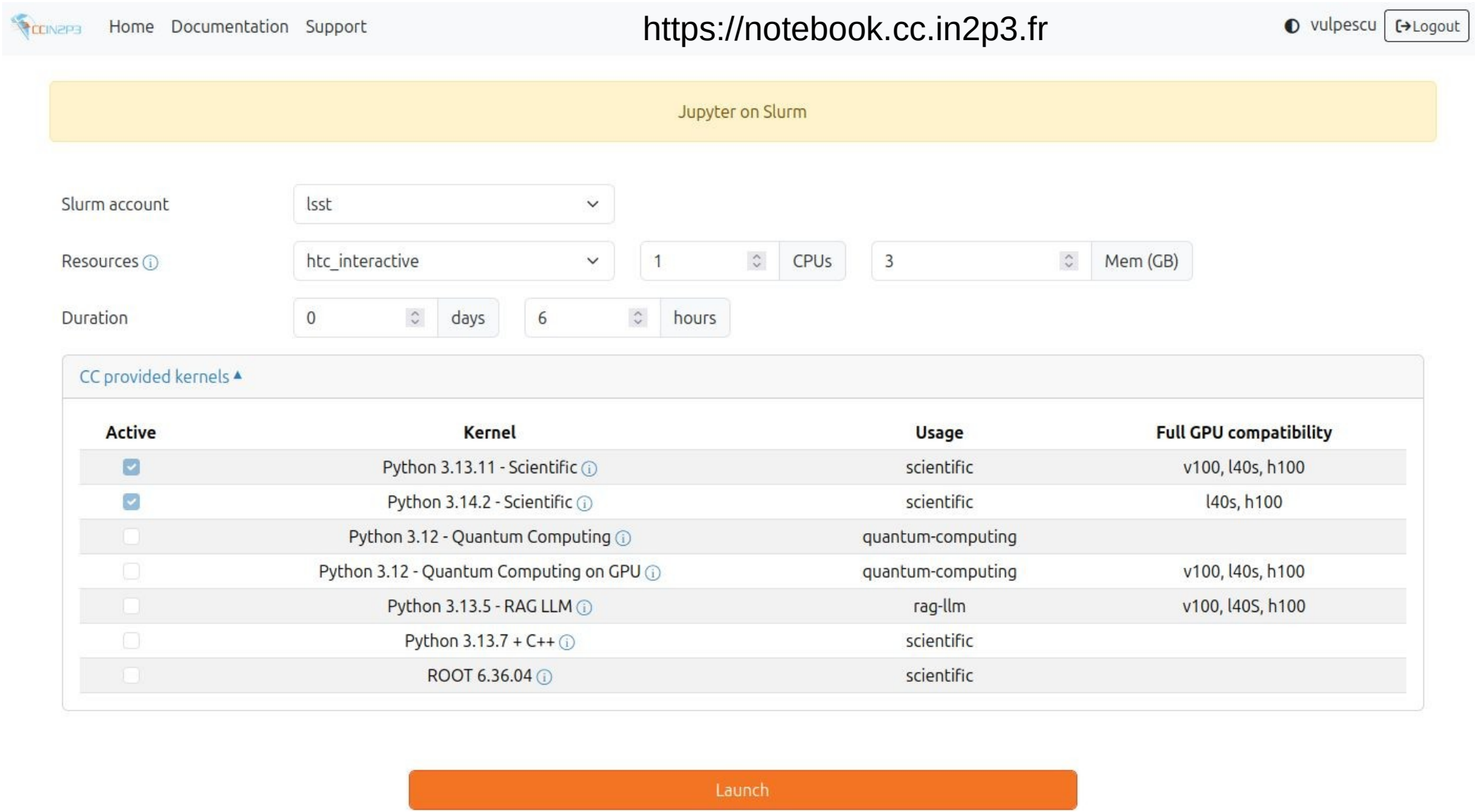




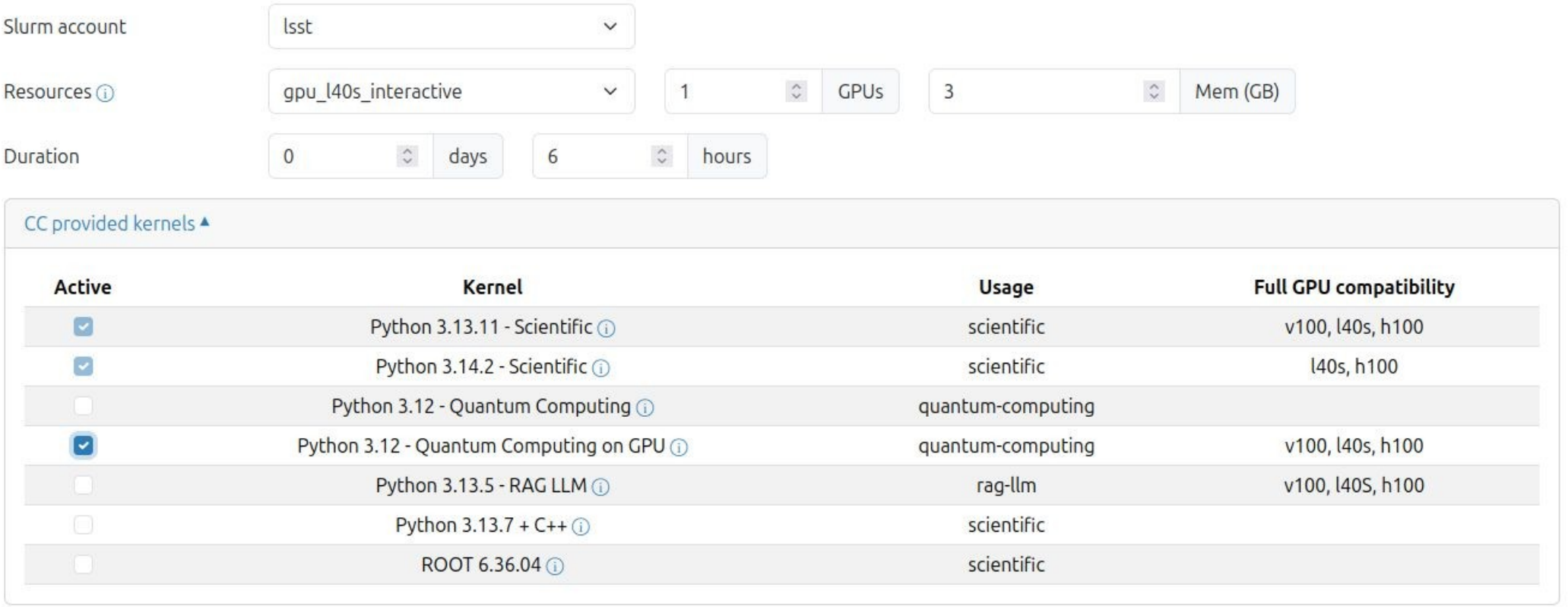
… difficultés sur le mode de facturation ...

Qiskit sur la plateforme jupyter @ CCIN2P3 :

depuis 01.2022 (merci Sébastien), mise à jour 10.2025 avec GPU version (merci Sybille)



Pour la version GPU il faut commencer par choisir une ressource avec GPU :

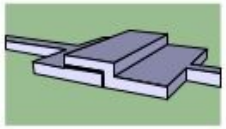
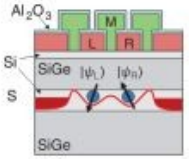
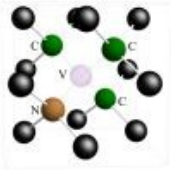
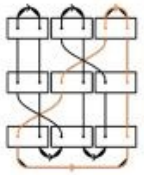
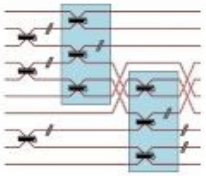


Example :

GHZ_CPU ⇒ 9.53 a.u. ± 0.29 a.u.

GHZ_GPU 6.72 a.u. ± 0.59 a.u.

Et la consommation ? (encore Olivier Ezratty)

	atoms		electron superconducting loops & controlled spin				
							
qubit type	**trapped ions**	**cold atoms**	**supercond.**	**silicon**	**NV centers**	**Majorana**	**photons**
cryogeny	300 W-6 kW	7-10 kW (2)	16-105 kW	12 kW	< 1 kW	16 kW	3 kW
vacuum pumps[1]	ultra-vacuum	ultra-vacuum	vacuum	vacuum	vacuum	vacuum	vacuum
qubits gate controls	<1.4 kW ions heating, lasers, micro-aves generation, CMOS readout electronics	1.8 kW atoms heater, lasers, control (SLM, AOD), readout sensor + electronics	from 20 mW to 100 W / qubit depending on architectures with micro-wave generation outside or inside the cryostat		N/A	<25 mW / qubit	300 W for photons sources and detectors, qubit gates controls
computing	300 W	300 W	<1 kW	<1 kW	<1 kW	<1 kW	700 W
# qubits used	24	100/256 (1) - 300-1000 (2)	53-433	12	<10	N/A	20
total	**2 kW** (5)	**3** (1)-**20 kW** (2)	**25-140 kW** (3)	**21 kW**	**N/A**	**N/A**	**4 kW** (4)

[1] : fixed energetic cost, for prepping stage

typical configurations for Pasqal and QuEra (1), neutral atoms with 4K pump/chamber cooling (2), Google Sycamore with 53 qubits, and guestimate for IBM System 2 with its KIDE cryostat (3), Quandela/QuiX (4), AQT (5) rough estimates for others

Figure 282: Rough estimations of current quantum computers total power and decomposition. It is too early to extrapolate these numbers to useful QPUs in the FTQC regime where several orders of magnitude more physical qubits will be necessary and their related control electronics and, sometimes, cryogenic resources. You must also consider the difference in speed of operations between these QPU and their qubit connectivity, which affects the circuit run times, and thus, their energy efficiency.

Merci de votre attention