

The Ruby Quantum Computer @ TGCC

Deploying a Cold Atom QPU in an HPC Centre

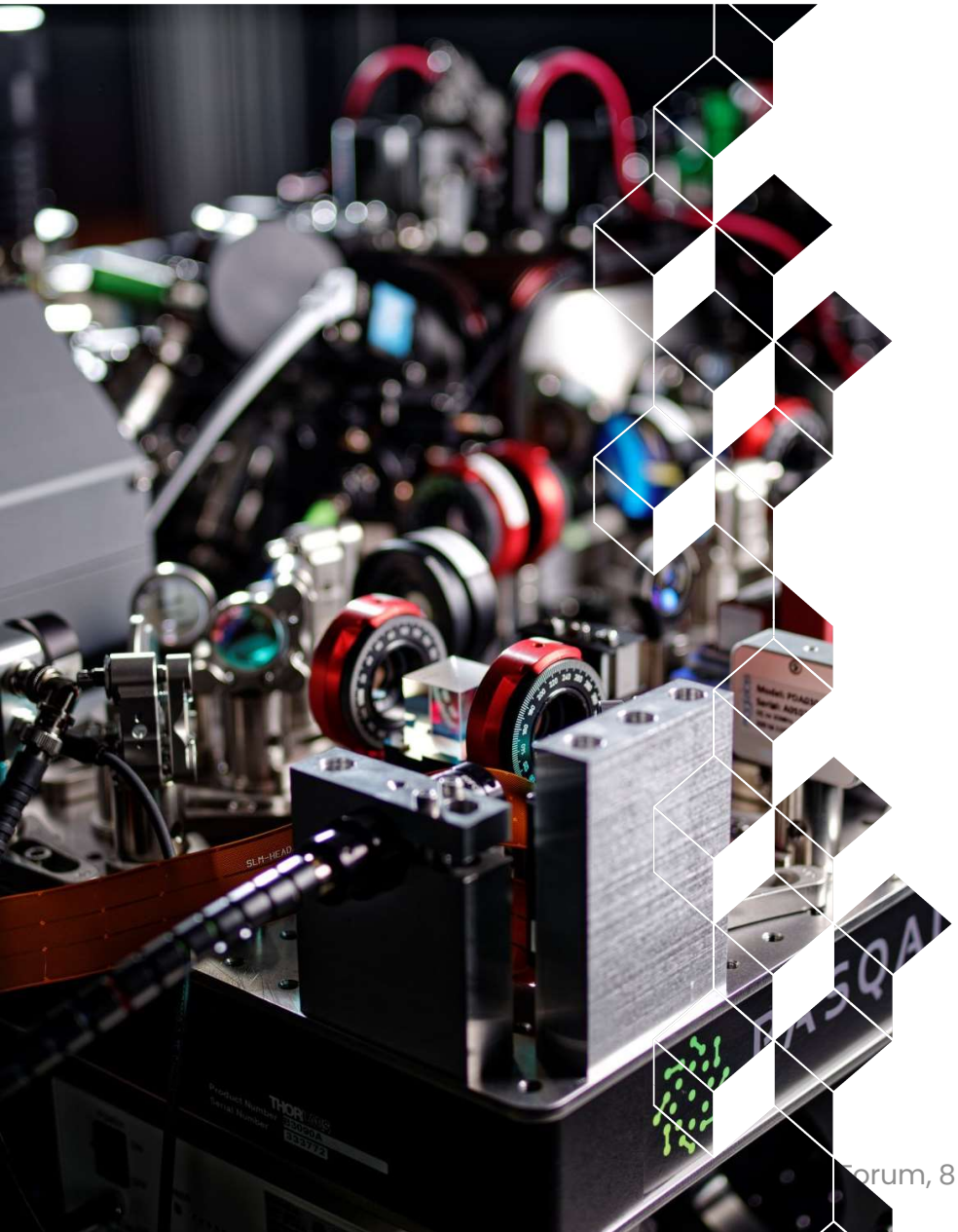
HPC User Forum, Paris, 8 October 2025

Dr. Eng. Jean-Philippe NOMINE

jean-philippe.nomine@cea.fr

Dr. Eng. Philippe DENIEL

philippe.deniel@cea.fr



HQI and TGCC at TGCC

Pasqal technology

Integration

The story in short...



cofunding



RUBY



hosting





CEA operates supercomputing centres

HPC services for Research, Industry, Defense

4 computing centres

Two facilities

TERA+EXA

Four large systems

DEFENSE



EXAI-HE
104 PFLOPS

2024, BullSequana XH3000, Nvidia GH200, BXI V2

EXA-HF
36 PFLOPS

2021, BullSequana XH2000, AMD Milan, BXI V2

TERA-1000-2
25 PFLOPS

2017, Intel KNL+BXI v1.2

TGCC

DEFENSE INDUSTRY



CCMD-A
2 PFLOPS

2022, BullSequana XH2000, AMD Milan, BXI V2

RESEARCH



JOLIOT-CURIE ROME
12 PFLOPS

2019, BullSequana XH2000, AMD Rome, IB HDR

JOLIOT-CURIE SKL
6.6 PFLOPS

2017, Sequana X1000, Intel SKL, IB EDR, ATOS QLM 40

INDUSTRY (20 PARTERS)



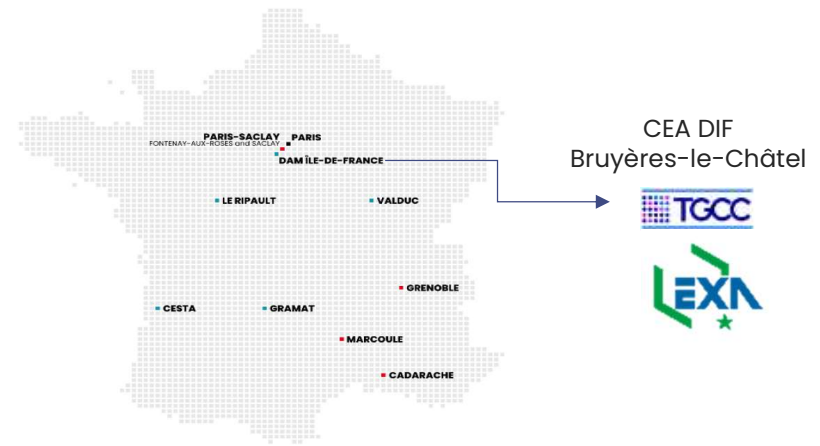
TOPAZE-CPU
5 PFLOPS

2021, BullSequana XH2000, AMD Rome, IB HDR

TOPAZE-GPU
6 PFLOPS

2023, BullSequana XH2000, Nvidia A100, IB HDR

One team designing facilities and their infrastructures, co-designing supercomputers parts in relationship with technology suppliers/vendors, operating supercomputers, delivering related services, giving a full vision of a wide range of computational needs!



TGCC: national centre for QC (and EU exascale)



ON-GOING EVOLUTIONS
QUANTUM COMPUTING
EXASCALE



2025: Pasqal's RUBY cold-atom and Quandela's LUCY photonic quantum computers at TGCC
 w/ Qaptiva/QLM emulator and front-end to supercomputers

EuroHPC
 Joint Undertaking

The EuroHPC JU has selected the Jules Verne Consortium to host and operate in France the 2nd EuroHPC exascale supercomputer.

Jules Verne consortium:

- > Hosting Entity
- > Hosting Site
- > (NL) Partner

Alice Recoque in 2027
 Procurement on-going
 Infrastructure ready



EXASCALE @ TGCC

We are ready to welcome Alice!



EuroHPC
Joint Undertaking



Adapting CEA's TGCC for Exascale computing

Warm Water DLC

End 2023 - Mid 2025

- Environmental impact analysis
- Installation of dry adiabatic cooling towers
- New facility room for pumps, controllers...
- Noise-damping wall



Computer rooms adaptation

End 2023 - End 2024

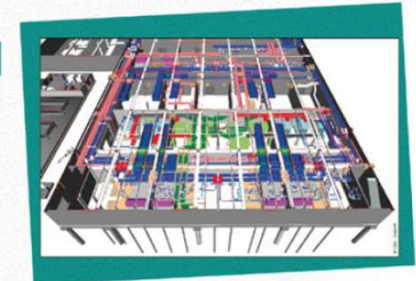
- Electrical and cooling interfaces
 - Security systems (monitoring, alarm, fire extinguishing)
 - Local reinforcement of the floor
- 2025 - 2027
- Dismantling of previous generation of supercomputers



Increased electrical & cooling power

Mid 2024 - Mid 2025

- 6 x 4.2 MVA electrical transformers
- 2 x 1.2 MVA UPS
- Air handling system



Concrete slab reinforcement

End 2023 - Q3/2024

- Metal frame to sustain the computer room floor
- 67 micro-piles to sustain the frame



Quantum Computing: HQI is QC part of French National Quantum Strategy



A scalable and open platform



Training



HLST



Houses of Quantum

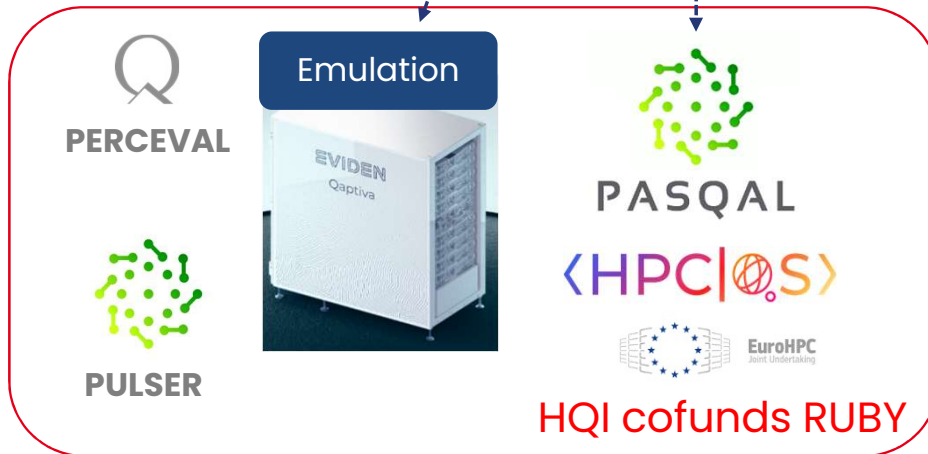


Joliot-Curie supercomputer

then EuroHPC and Jules Verne Consortium to acquire/operate Alive Recoque supercomputer



Shared software stack



QUANDELA
HPCQS-France

QPU#3





HPCQS EuroHPC project cofunds RUBY (as well as twin QPU JADE in Juelich)

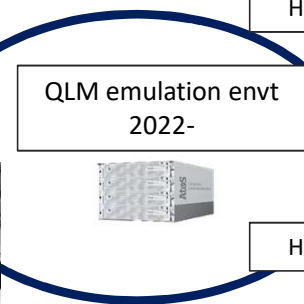


<HPC|QS>



HPCQS brings together leading quantum and supercomputer experts from science and industry from six European countries. Copyright : HPCQS

Foundations of a hybrid Quantum-HPC European Infrastructure 2x100+ qubits



HPCQS system#1



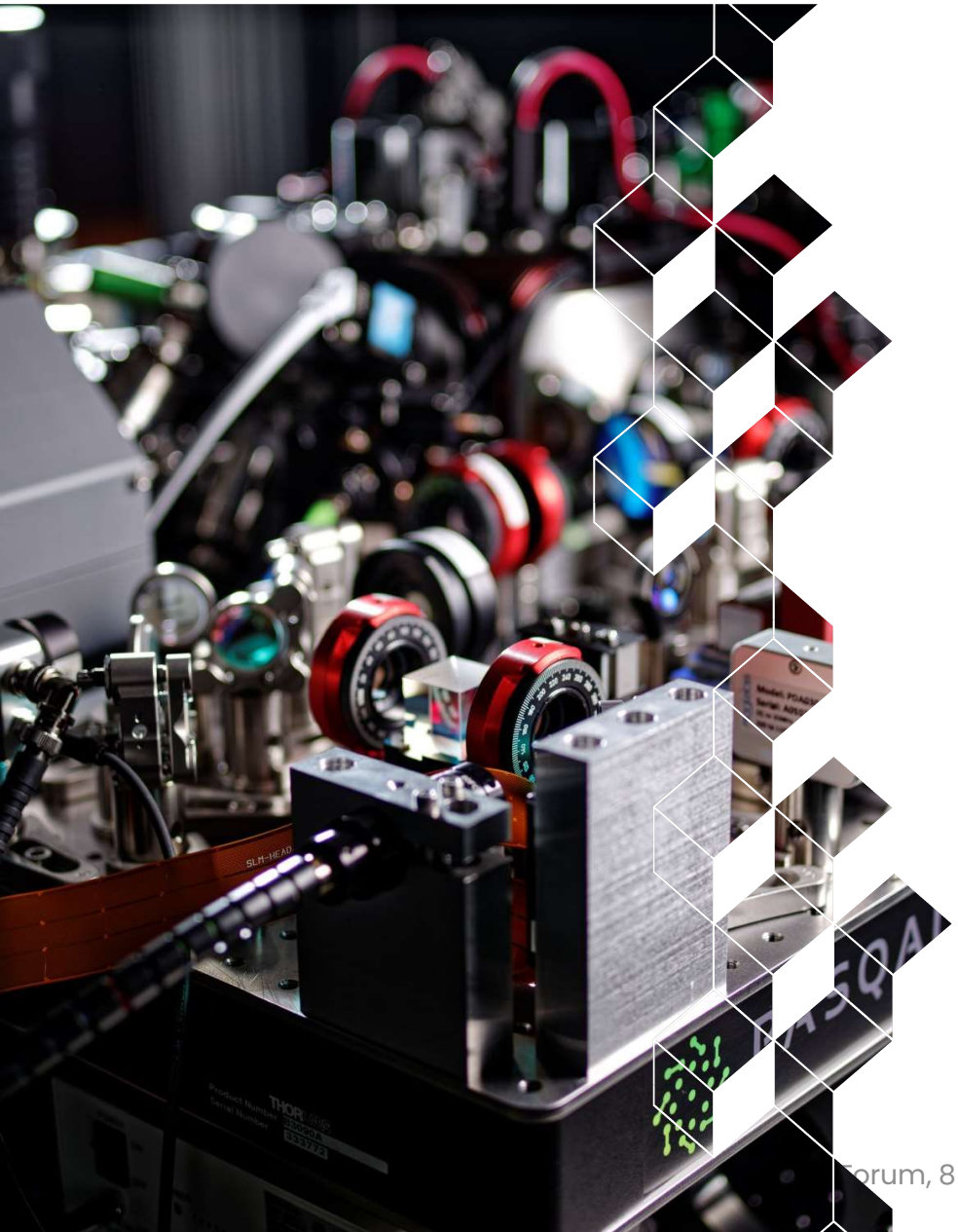
HPCQS system#2



EuroHPC HPCQS project – 2021-2025

<https://www.hpcqs.eu/>





HQI and TGCC at TGCC

Pasqal technology

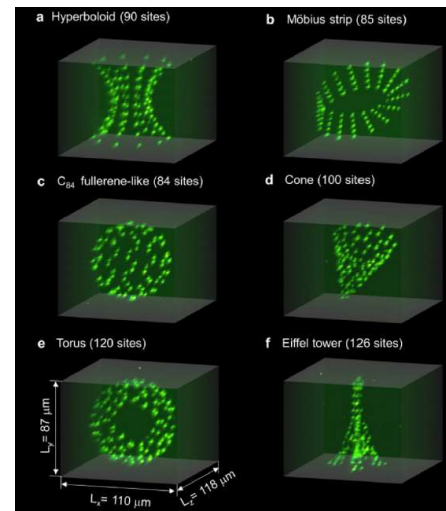
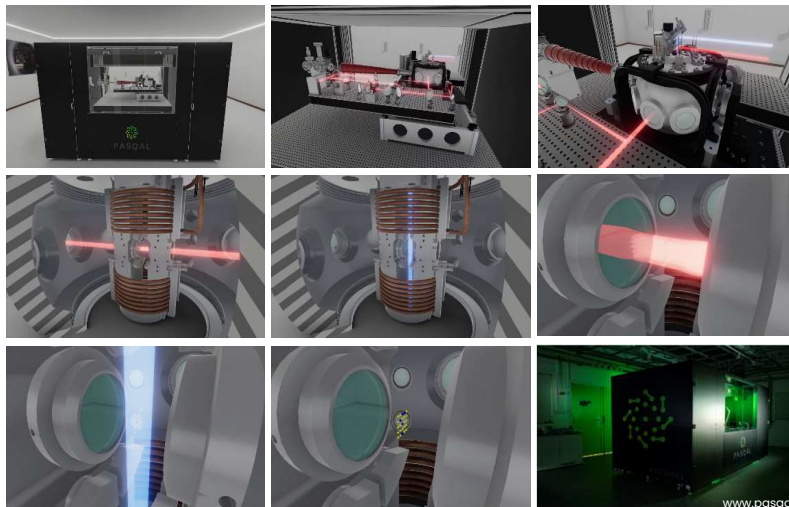
Integration



The Pasqal Device

Pasqal is a French company whose product is an analogic quantum computer*

- The QC is using Rydberg Blockade to perform computation
 - They use cold atoms emitted in a void chamber to implement qubits
 - Lasers are used for
 - Fine positioning of the atoms (optical tweezers)
 - Exciting the atoms and trigger the Rydberg Blockade



* Very recent breakthrough: first logical qubits successfully prepared on a Pasqal platform

Rubidium Atom



Pasqal implements qubits with Rubidium atoms (Rb)

- Rubidium is monovalent
- The Rubidium atom is rather big
 - The electron can be « far » from the kernel

For a Rb atom

- Excited state (noted $|1\rangle$) where the electron is far from the kernel
- Unexcited state (noted $|0\rangle$) where the electron is close to the kernel

Rydberg Blockade

- When atoms are close enough (Rydberg radius), they can't be both excited at the same time, due to Coulomb interaction
- Only states $|01\rangle$ and $|10\rangle$ are possible and any superpositions of them

TABLEAU PÉRIODIQUE DES ÉLÉMENTS

Masses atomiques: 55.845, 26
 Numéro atomique (nombre de protons dans le noyau): 26
 Symbole chimique: Fe
 Nom: fer

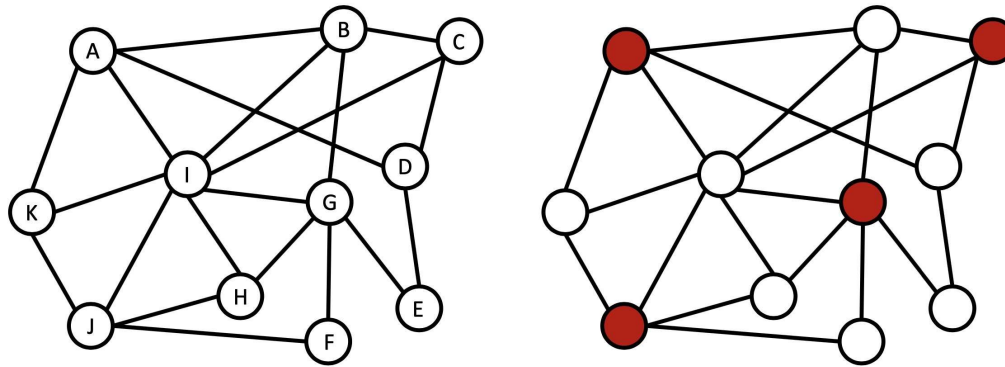
Source: IUPAC, Wikimedia Commons

Possible use: Rydberg Blockade and MIS problem



Atoms build a Unitary Disk Graph whose radius is the Rydberg radius

- Atoms are vertices
- Entanglements are edges
- Since no two connected / entangled atoms can't be excited at the same time, the final state of the set of atoms, after Rydberg Blockade, is a superposition of solutions of MIS



MIS is NP-Complete, any NP problem can be reduced to MIS, and the transformation is P

And also: Hamiltonian simulation...

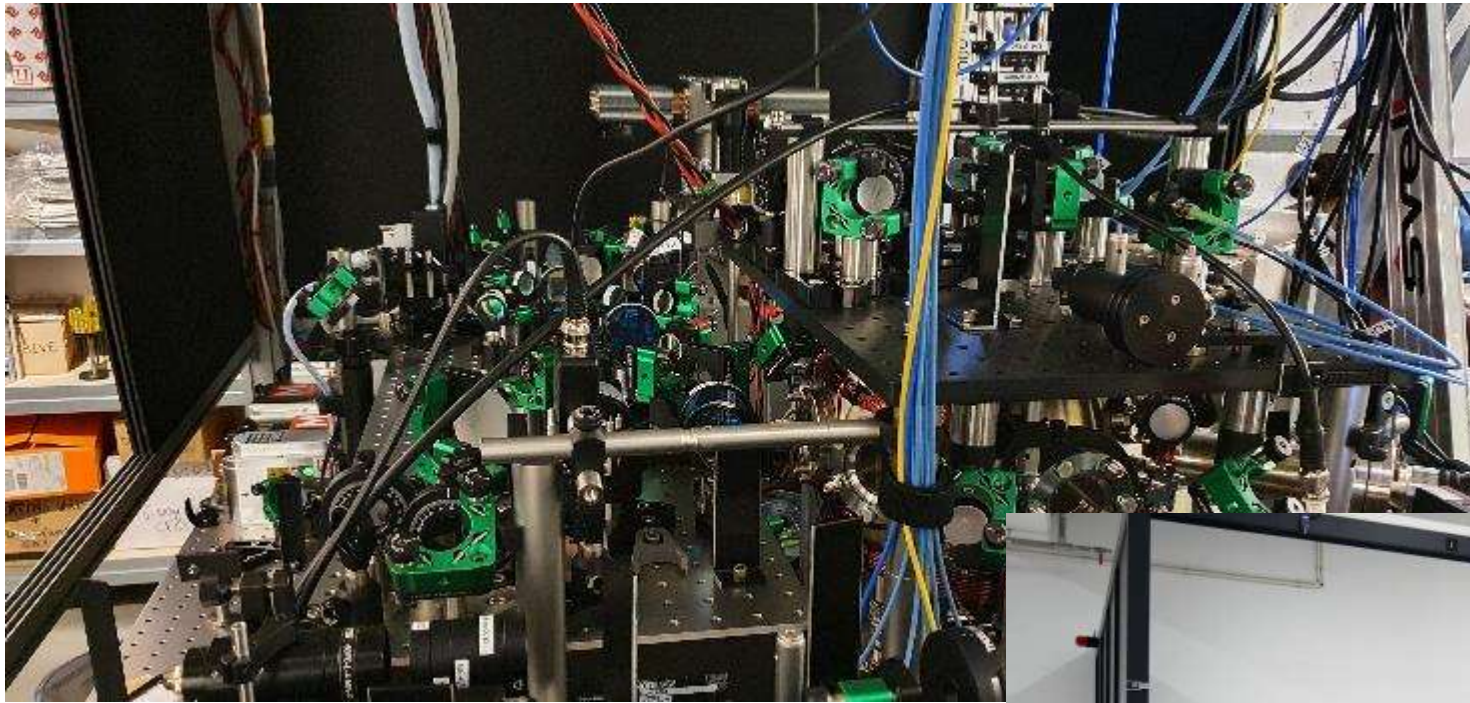
Want to learn more?

<https://www.pasqal.com/>

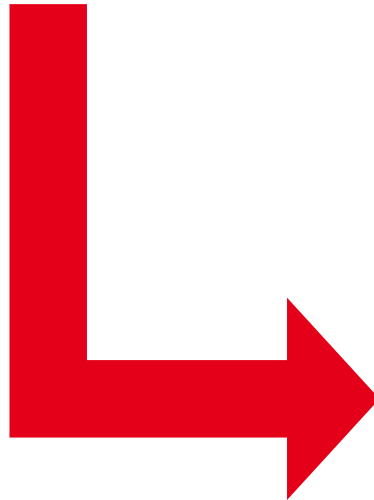


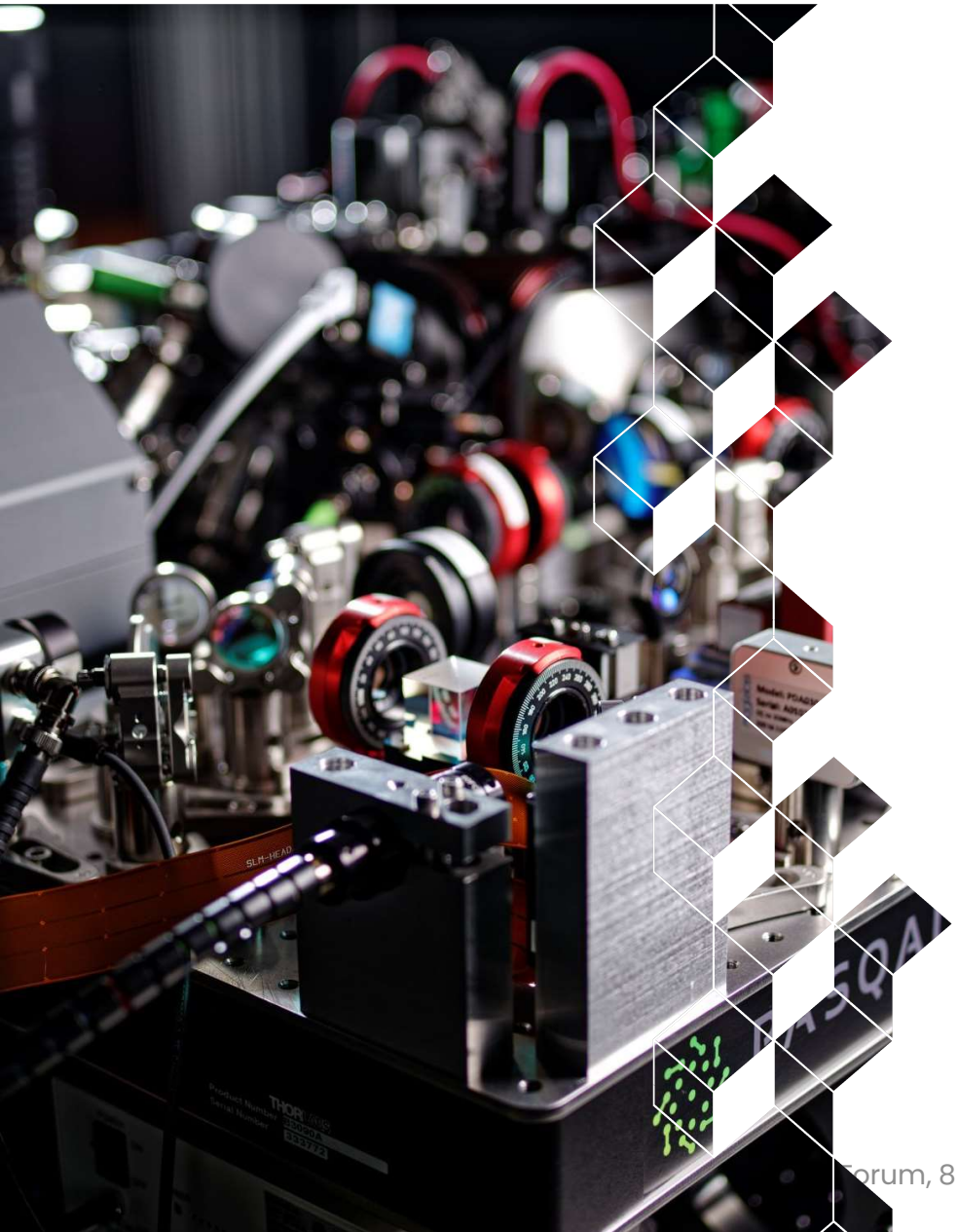
The screenshot displays the Pasqal website interface. At the top, there is a navigation bar with the Pasqal logo, a search bar, and links for Technology, Solutions, Resources, About Us, and Contact. Below the navigation bar, there is a 'Filter by:' section with a dropdown menu. The 'Source' filter is expanded, showing a list of sources with checkboxes: ACM, Advanced Quantum Technologies, APL Quantum, APS, Arxiv, Astrophysics Data System, AVS Quantum Science, Cryogenics, IEEE, Machine Learning: Science and Technology, Nature, Nature Physics, Nature review physics, New Journal of Physics, Physical Review A, Physical Review Applied, Physical Review Letters, Physical Review Research, Physical Review X, Quantum, Quantum Technology, Scientific Reports, SciRate, and The European Physical Journal A. The 'Year Published' filter is also visible at the bottom of the filter section. The main content area shows a list of research papers, each with a title, a date, and a share icon. The papers listed are:

- Attributed-graphs kernel implementation using local detuning of neutral-atoms Rydberg Hamiltonian (SEP 11, 2025)
- Hybrid Quantum-Classical Branch-and-Price Method for the Vertex Coloring Problem (AUG 26, 2025)
- A Scalable Heuristic for Molecular Docking on Neutral-Atom Quantum Processors (AUG 25, 2025)
- Quantum Optimization on Rydberg Atom Arrays with Arbitrary Connectivity: Gadgets Limitations and a Heuristic Approach (AUG 8, 2025)
- Enhancing the Performance of Quantum Neutral-Atom-Assisted Benders Decomposition (JUL 22, 2025)
- A Framework for Quantum Advantage – IBM & Pasqal paper (JUN 26, 2025)
- Rydberg blockade mechanism through the lens of graph theory: characterization and applications (JUN 17, 2025)



From the lab
to the
computing centre



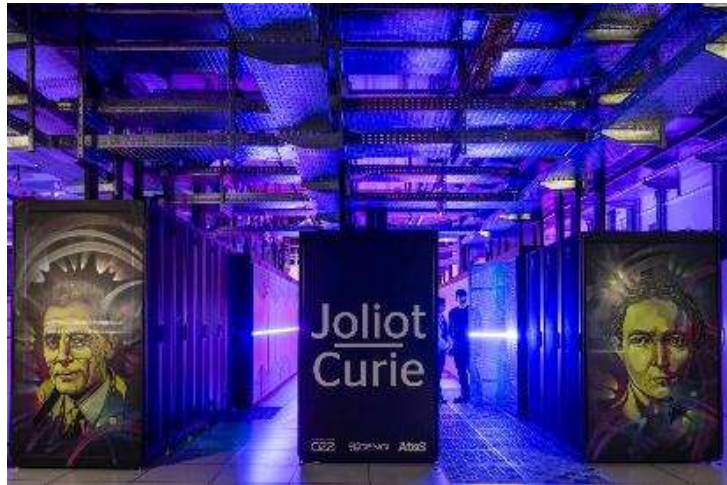


HQI and TGCC at TGCC

Pasqal technology

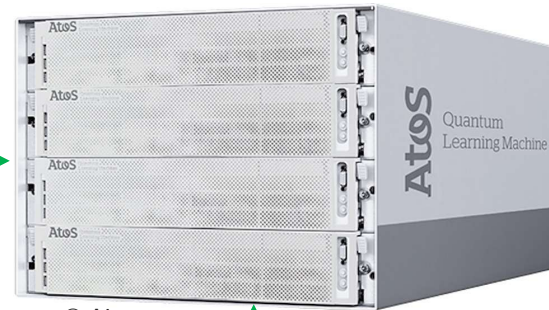
Integration

Ruby@TGCC



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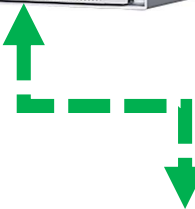
Joliot-Curie machine room



© Atos

Qaptiva (QLM)

- Emulator
- Front end



Quantum Room

Modest requirements :
a few kW, some air conditioning



Different than HPC rooms
(small, «quiet » room)

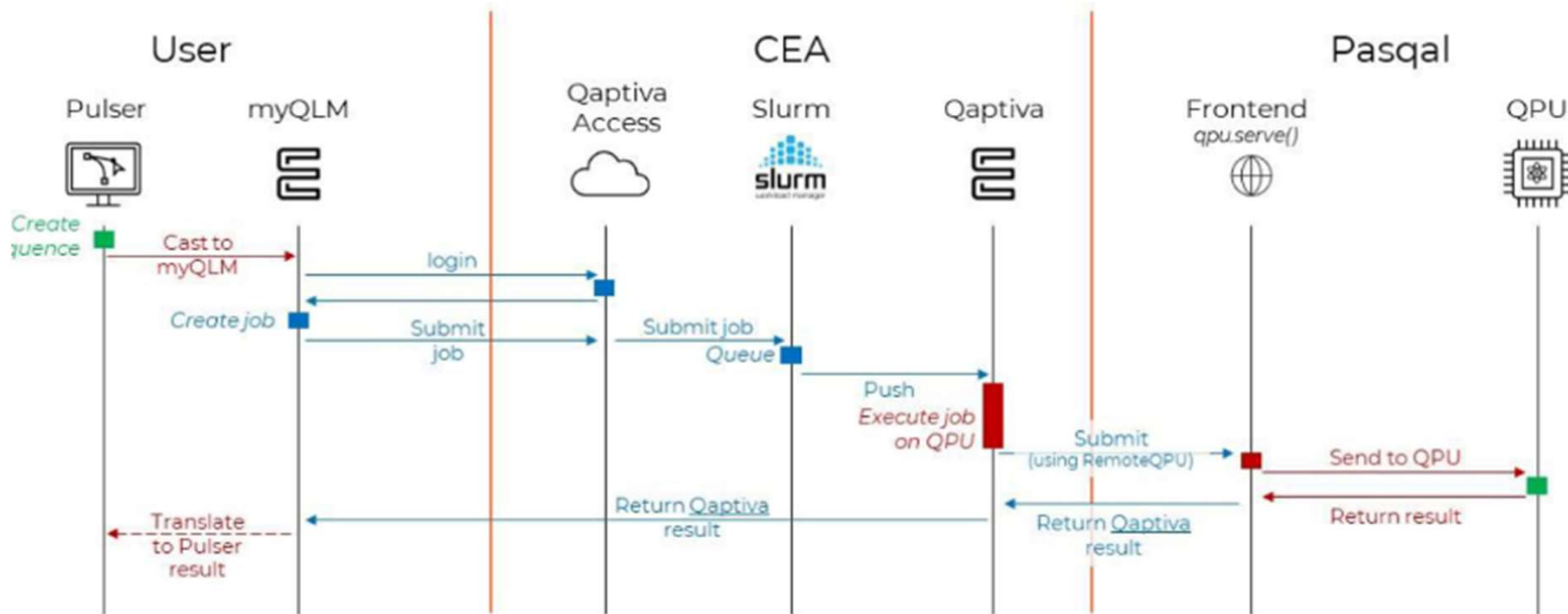
Easier works than
infrastructure adaptation
for Alice Recoque...



Pasqal / Qaptiva integration

The Ruby system is accessed via the Qaptiva which operates as a proxy

- Qaptiva deals with Authentication, Accounting and Scheduling
- It provides an unified programming frontend to end-users
- The QC are protected / isolated in a specific and dedicated network private zone



Pulser/QLM code sample



```
import numpy as np
from pulser import Pulse, Register, Sequence
from pulser.devices import AnalogDevice
from pulser.waveforms import CustomWaveform
from pulser_simulation import QutipEmulator

from pulser_myqlm import IsingAQPUPU

# Pulser Sequence (find more at https://pulser.readthedocs.io/)

device = AnalogDevice
register = Register.square(2, 5, None)
seq = Sequence(register, device)
seq.declare_channel("ryd_glob", "rydberg_global")
duration = 100
seq.add(
    Pulse(
        CustomWaveform([ti / duration for ti in range(duration)]),
        CustomWaveform([1 - ti / duration for ti in range(duration)]),
        0,
    ),
    "ryd_glob",
)
seq.add(Pulse.ConstantPulse(20, 1, 0, 0), "ryd_glob")
seq.add(Pulse.ConstantPulse(20, 1, 0, np.pi / 2), "ryd_glob")

# Draw the Sequence
seq.draw(draw_phase_curve=True)

# Simulate the Sequence using Pulser
sim = QutipEmulator.from_sequence(seq, with_modulation=True)
res = sim.run().sample_final_state(2000)
print("Pulser Result obtained with pulser_simulation for 2000 samples:")
print(res, "\n")
print("Converted into MyQLM Result:")
print(IsingAQPUPU.convert_samples_to_result(res), "\n")
print(
    "Expressed as a dictionary of (state: probability): ",
    {
        sample.state: sample.probability
        for sample in IsingAQPUPU.convert_samples_to_result(res)
    },
    "\n",
)
)
```

```
# Convert the Sequence to a Job
job = IsingAQPUPU.convert_sequence_to_job(seq, nbshots=0, modulation=True)

# Simulate the Job using pulser_simulation
aqpup = IsingAQPUPU.from_sequence(seq, qpu=None)
result = aqpup.submit(job)
print(
    "MyQLM Result obtained using IsingAQPUPU with pulser-simulation with "
    "default number of samples (2000):"
)
print(result, "\n")
print(
    "Expressed as a dictionary of (state: probability): ",
    {sample.state: sample.probability for sample in result},
    "\n",
)

print("Converted into a Pulser Result:")
print(IsingAQPUPU.convert_result_to_samples(result), "\n")

# Simulate the Job using AnalogQPU
try:
    from qlmaas.qpus import AnalogQPU

    analog_qpu = AnalogQPU()
    aqpup = IsingAQPUPU.from_sequence(seq, qpu=analog_qpu)
    results = aqpup.submit(job)
    # Display the results once they have run on AnalogQPU
    print("Results obtained with AnalogQPU: ", results.join())
    print(
        "Expressed as a dictionary of (state: probability): ",
        {sample.state: sample.probability for sample in results},
        "\n",
    )
except ImportError:
    print("Can't import AnalogQPU, check connection to Qaptiva Access.")
```

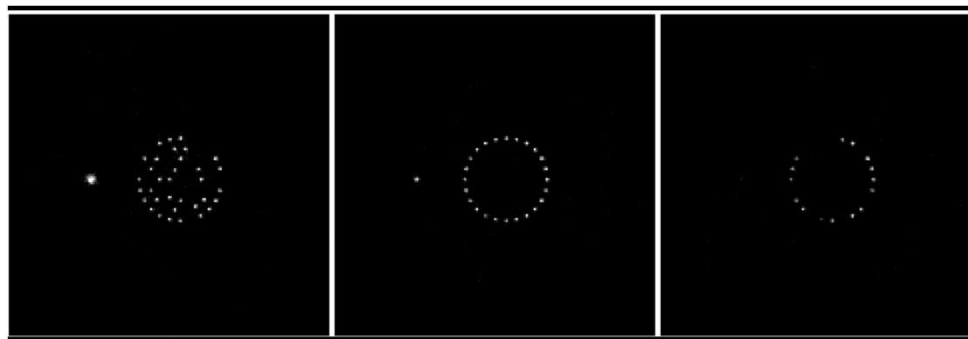


Ruby : the Pasqal system at TGCC

- Ruby is connected to TGCC network since July 17th 2025
- Accessible via Qaptiva Access
- Acceptance tests are almost complete

The first user computation was a benchmark from French project BACQ

- Developed by CEA/IPHT



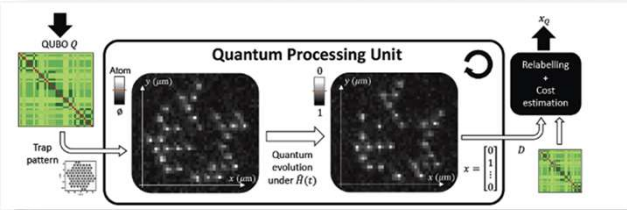
Next... use cases & end users

<https://www.pasqal.com/>



Ready to welcome scientific and industrial use cases, like some explored by Pasqal and partners already

Predicting fallen angels in finance with quantum computers



Pasqal and EDF pave the way to optimize energy management for EV Smart Charging with neutral atom quantum computing

21 JANUARY 2025



in X

Pasqal and Thales Successfully Solve Satellite Planning Challenges with Neutral-Atom Quantum Computing

17 MAY 2024



in X

Coming next: the Lucy system from Quandela



The Lucy system will be delivered in October 2025

- It's based on Linear Optics with 12 photons shot in 24 fibers
- The technology is **very** different from Pasqal
- The system is made of 2 racks...
- The system is built at Quandela facility in Massy near Paris
- To be shipped/installed October 2025

