Quantum Computing @ CINECA

AI and Future – 15/05/2025

Daniele Ottaviani

CINECA QUANTUM COMPUTING LAB

Cineca Quantum Computing Lab

Teaching, Outreaching and Dissemination

CINECA ACADEMY

European and National projects

⟨HPC|QOS⟩

Fondazione ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

EuroQHPC-I

QUANTUM COMPUTING AND SIMULATION CENTER

QEC-QEA

QUANTUM COMPUTING LAB

Quantum Computing Resources

Cloud QC

D-Wave The Quantum Computing Company

?

PASQAL

Hybrid HPC-QC System

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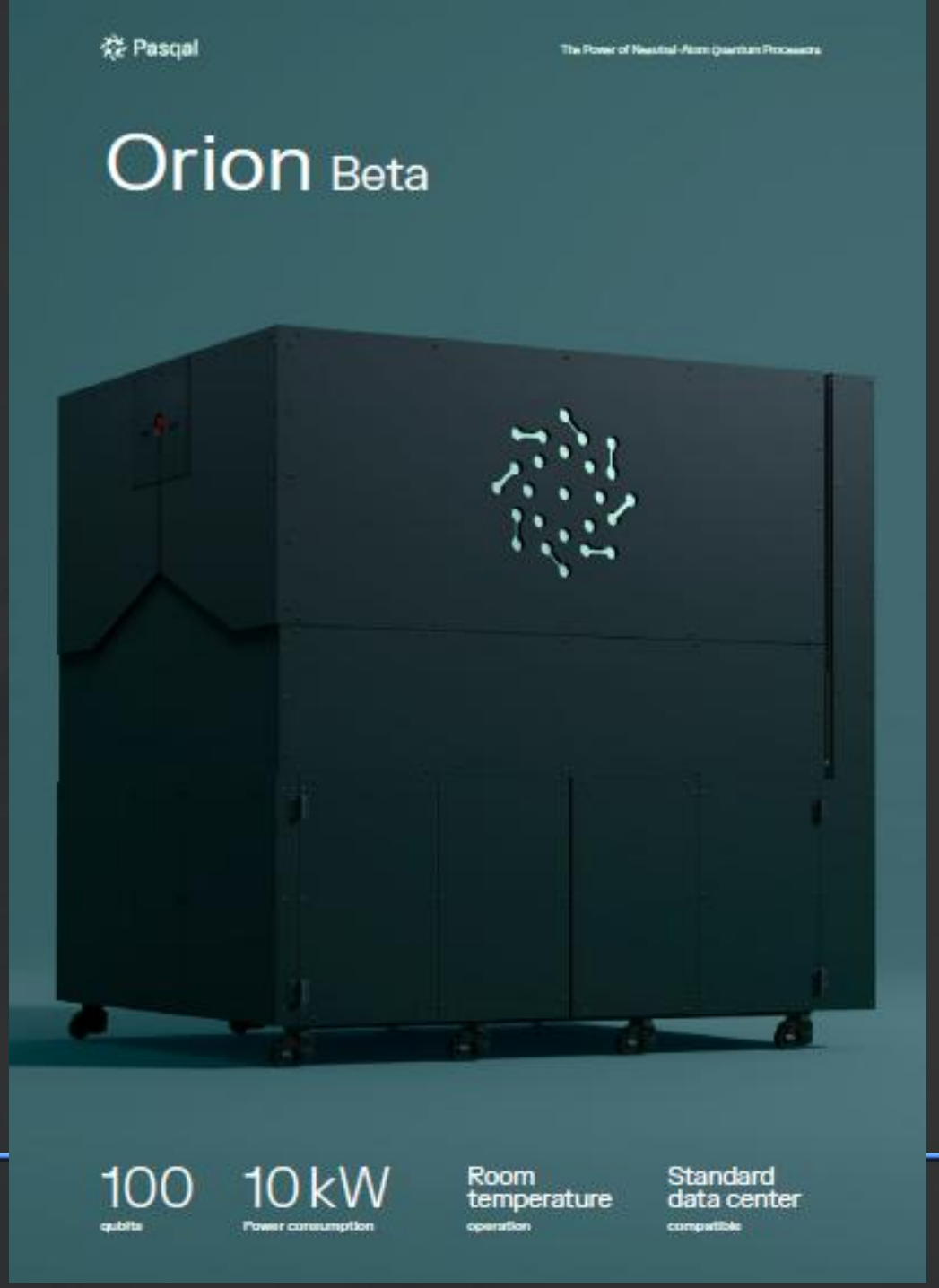
EuroQCS-Italy

- To be installed at Bologna DaMa Technopole in Q2 2026
- 140 qubits analog quantum simulator
- Customizable qubit topology
- Upgrade to a mixed analog/digital system in Q4 2026



Quantum «EDU»

- Superconducting Digital Quantum Computer
- 54 qubits
- 90 couplers
- Delivery in Q4 2025

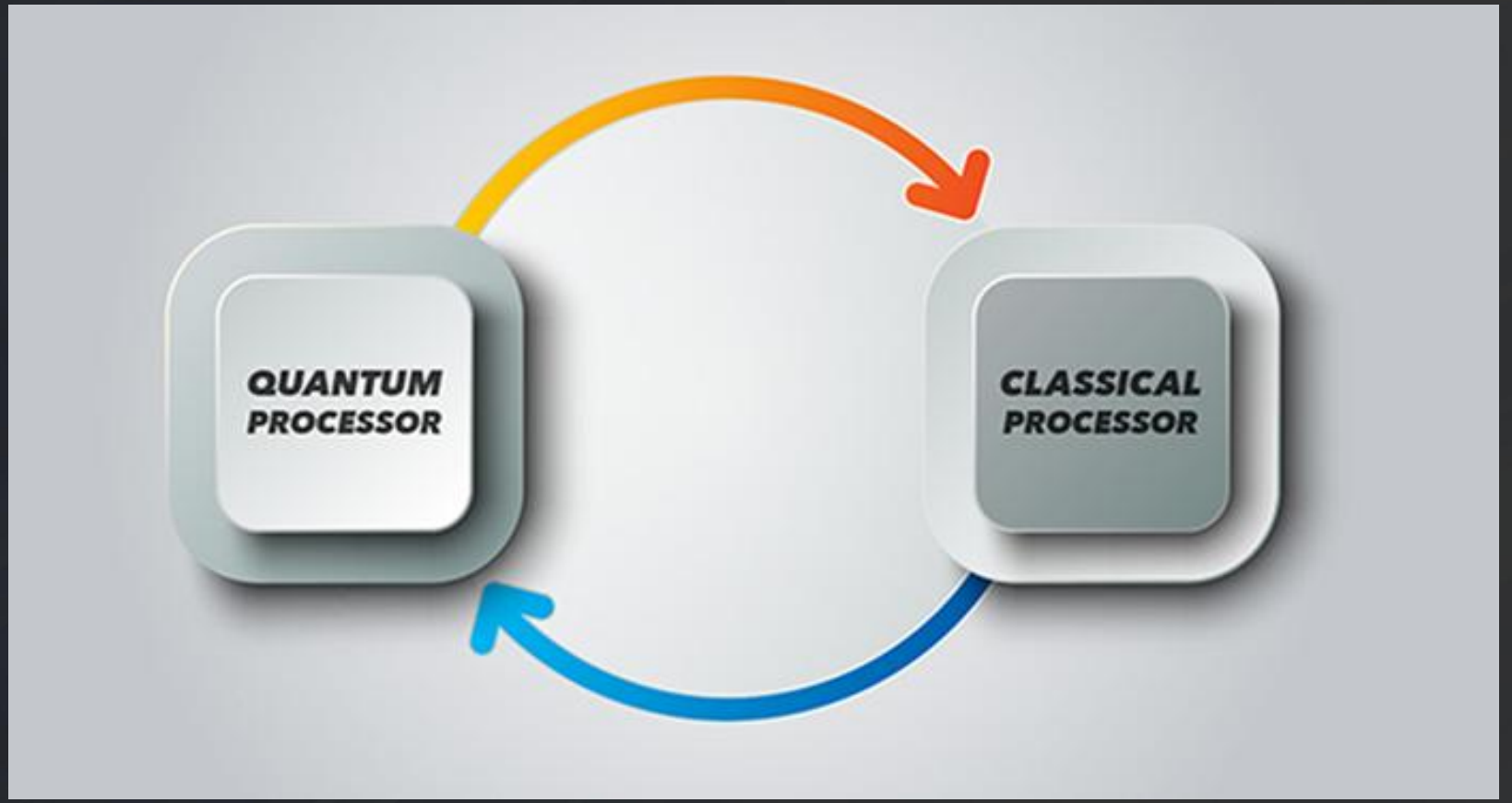
Cineca to house Italy's most powerful quantum computer IQM Radiance 54

17/03/2025 3 min. read

- IQM Radiance 54-qubit full-stack superconducting quantum computer will be integrated into Leonardo, one of the world's fastest supercomputers in Bologna, Italy.
- Cineca intends to use the system for optimisation of quantum applications, quantum cryptography, quantum communication and artificial intelligence quantum algorithms.
- IQM Radiance 54-qubit quantum computer is scheduled for delivery and installation in Q4 2025. The system will be the first and most powerful on-prem quantum computer in Cineca.

NISQ Quantum Computer

- Not able to run complex quantum computing algorithms
- Able to be used as HPC accelerators (like GPUs)

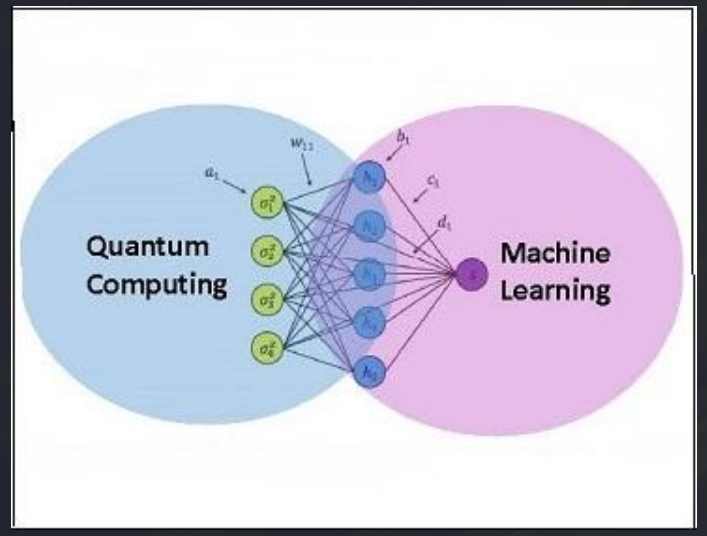


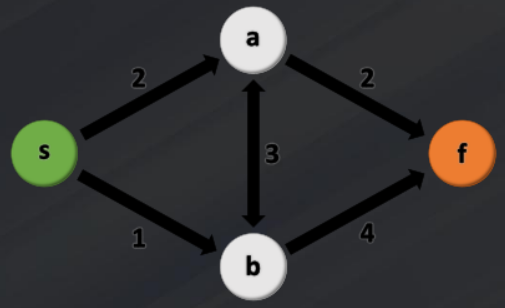
Quantum Computing and Simulations

Neutral Atom devices can natively realize quantum spin Hamiltonians
Digital superconducting devices can natively implement fast quantum algorithms

QUANTUM MATTER
NUCLEAR PHYSICS
MANY-BODY DINAMICS
OPTIMIZATION
QUANTUM CHEMISTRY
MACHINE LEARNING

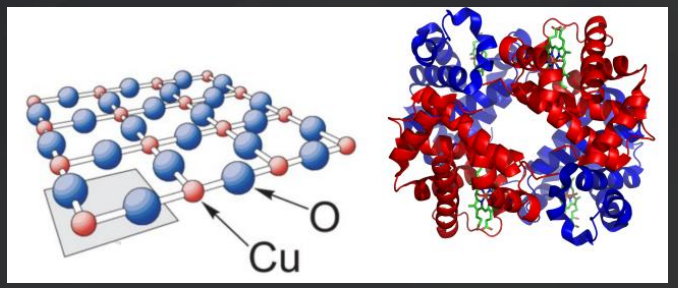
Quantum Machine Learning





Solving QUBO problems

Simulation of active site of proteins



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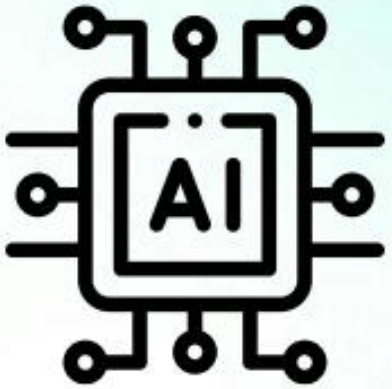
Quantum AI: a Two-Way Street



AI for Quantum Computing

Key to scale up systems

- Automatic calibration of multiple parameters
- Reduce the overhead of error mitigation
- AI enhanced decoders and transpilers for error correction

Quantum Computing for AI

Key to enhance certain tasks (forecasting, classification and generative) and to optimize training.

On-Premise QC

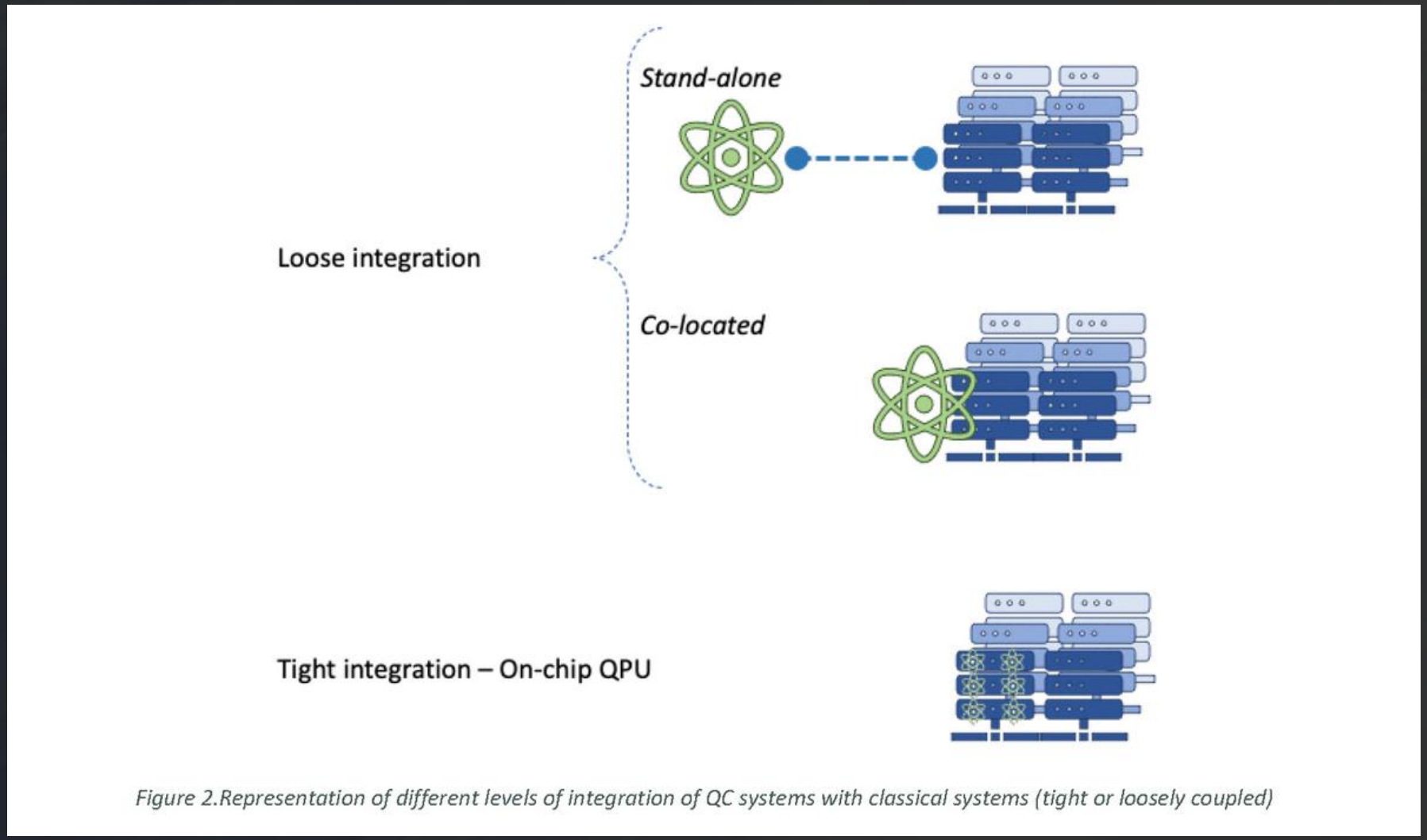
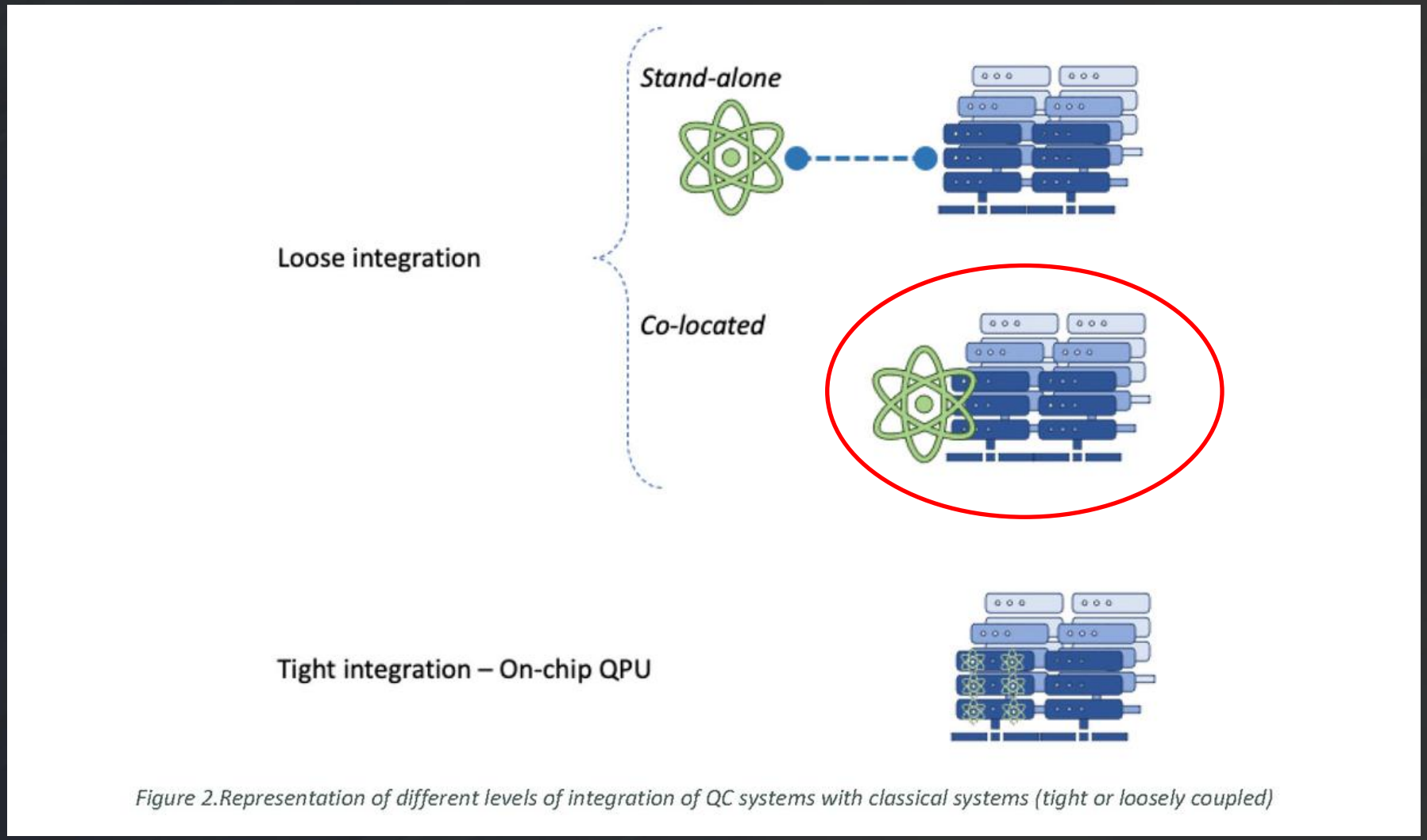


Figure 2.Representation of different levels of integration of QC systems with classical systems (tight or loosely coupled)

ETP4HPC White Paper: < QC | HPC > Quantum for HPC → https://www.etp4hpc.eu/white-papers.html#quantum

On-Premise QC



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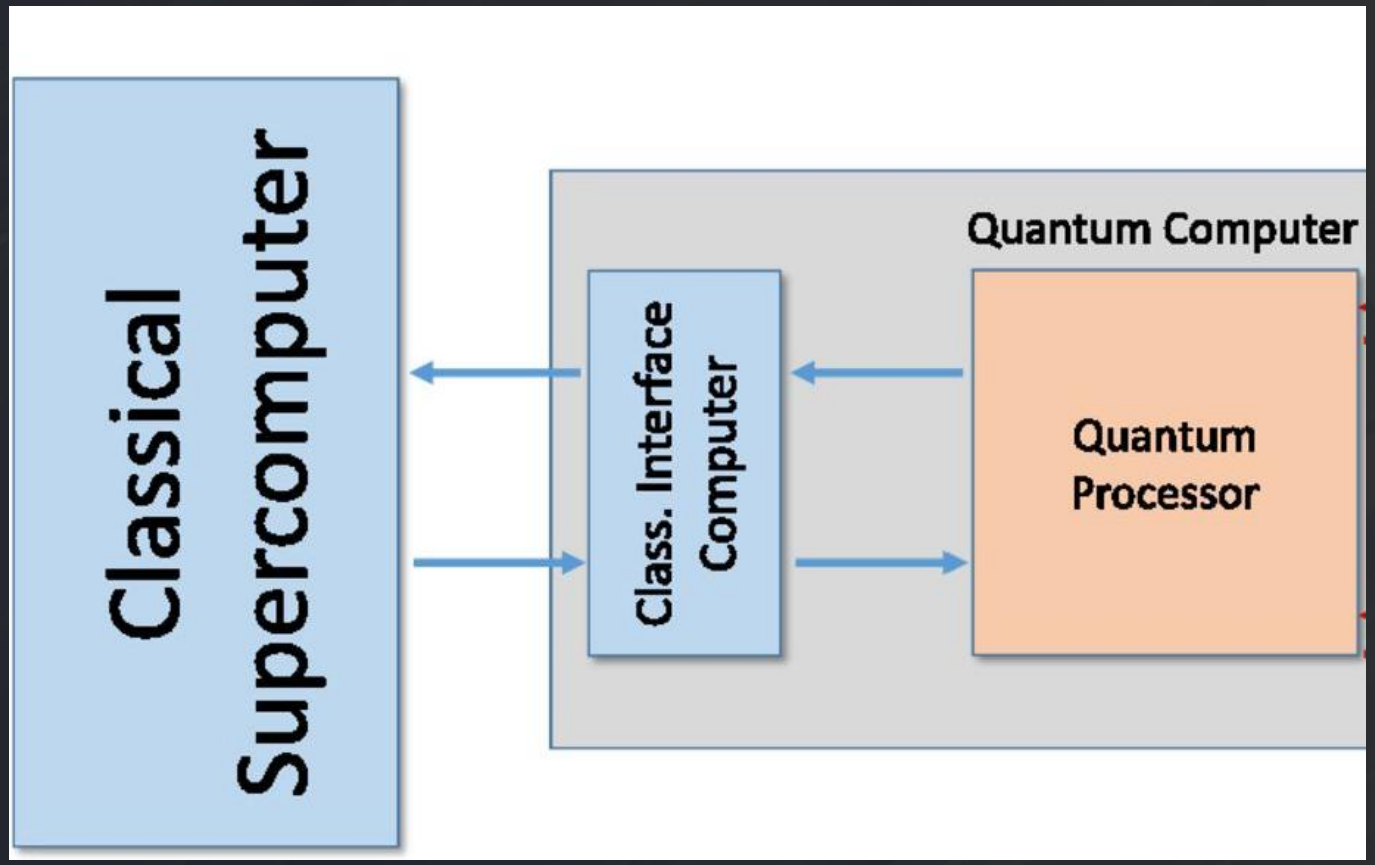
The Hardware part

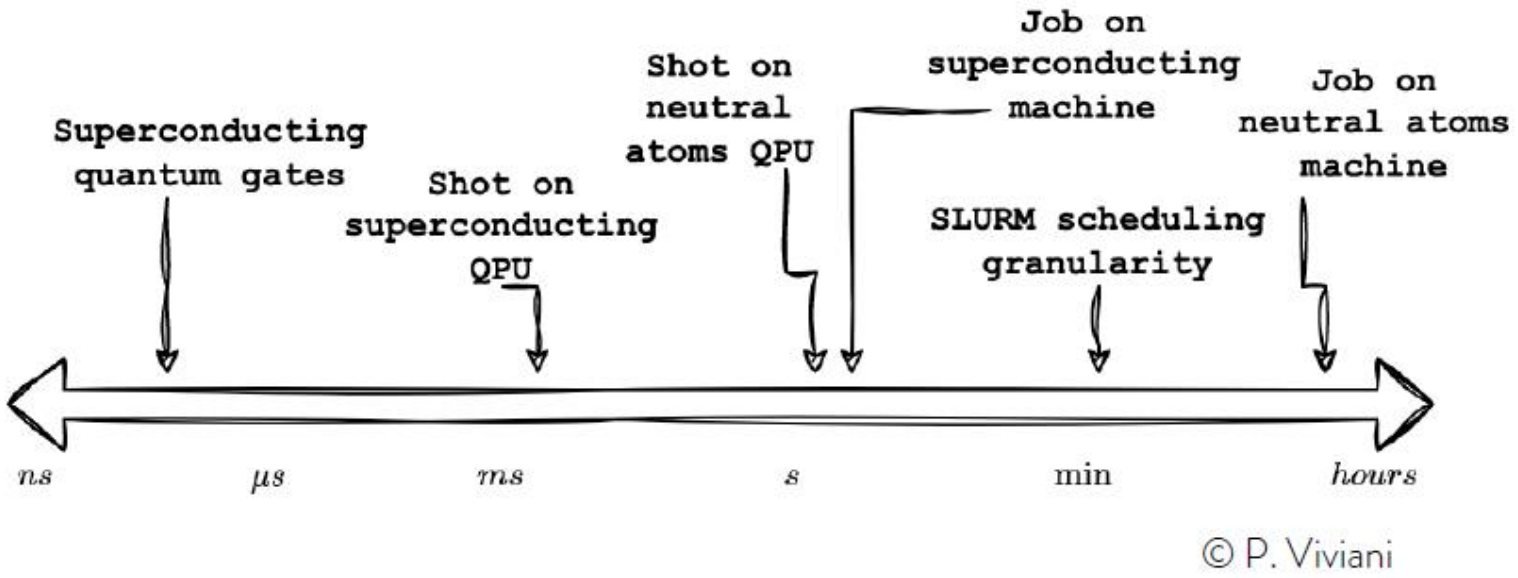


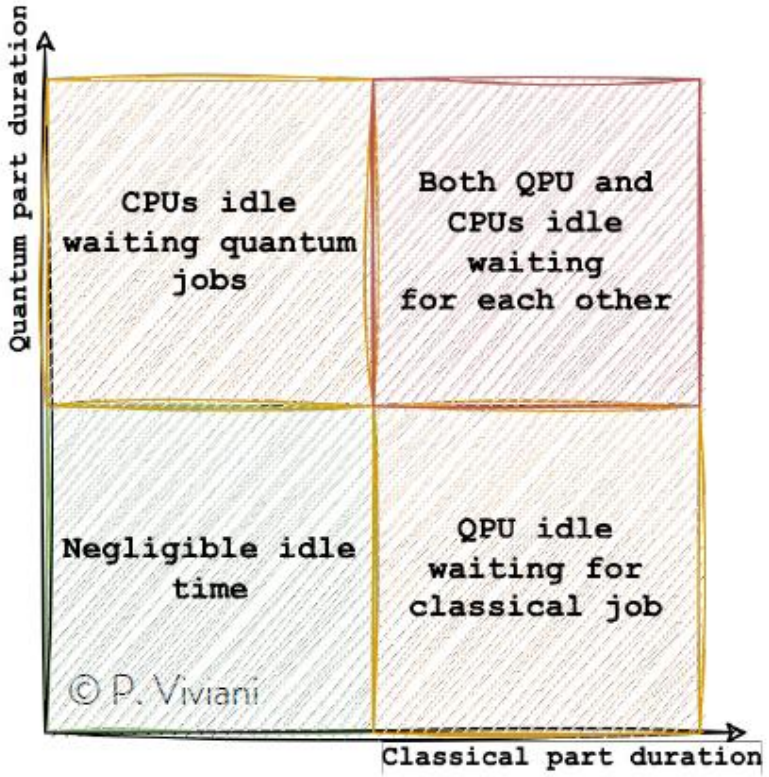
- Beginners: Connecting the qc to a node
  - A commercial qc usually is set up to be connected to a classic computer via an Ethernet cable – easy part!
- Advanced: Hijack the connection
  - To achieve a tighter connection and eliminate unnecessary latencies, one could also consider connecting the HPC node directly to the QPU (without going through the control computer present in the QC)
  - This means installing firmware and operating systems for the QC on the HPC node, making it a de facto control system for the QPU

The Software part

- Beginners: Use the QC without HPC
  - Usually the vendors that produce QC also develop SDKs that can talk to the control computer and consequently to the QPU
  - Installing and using such software is step 0 for integration
- Advanced: Use the QC as a part of an HPC job
  - SDKs provided by vendors often do not include the use of MPI and/or CUDA to take advantage of HPC
  - One solution might be to explore existing software (Nvidia CUDA Quantum, Eviden Qaptiva etc.)
  - Or work with the vendor to write a custom SDK

The Middleware part



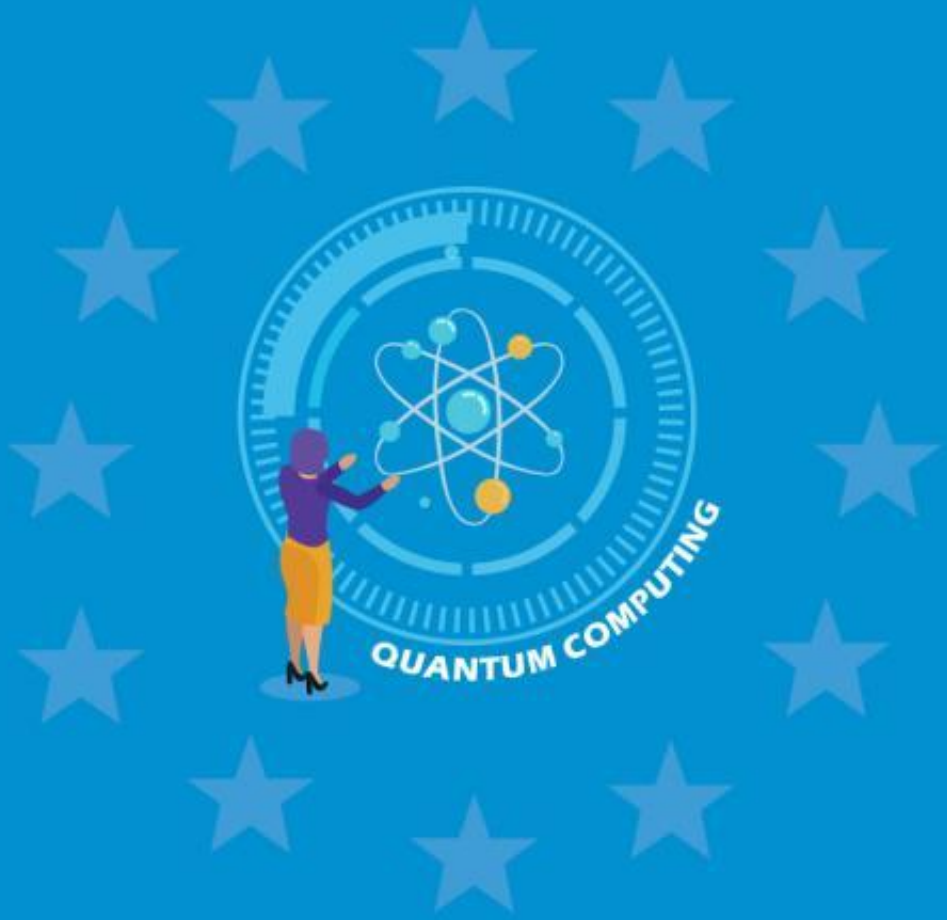


Co-scheduling of hybrid jobs can excessively block quantum or classical resources

EuroHPC
Joint Undertaking

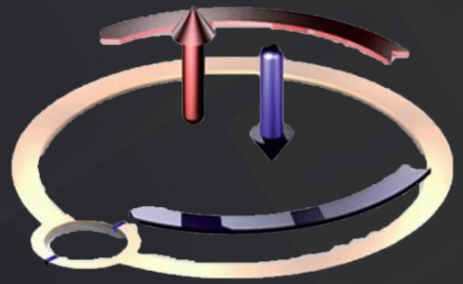
The EuroHPC JU has selected six sites across the European Union to host and operate the first EuroHPC quantum computers in:

- Czechia
- France
- Germany
- Italy
- Poland
- Spain

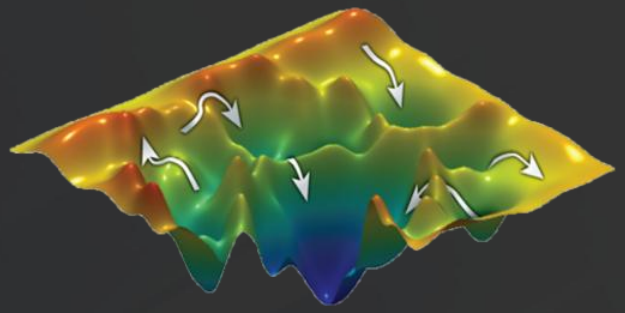


EuroQHPC-I

EuroQCS Italy

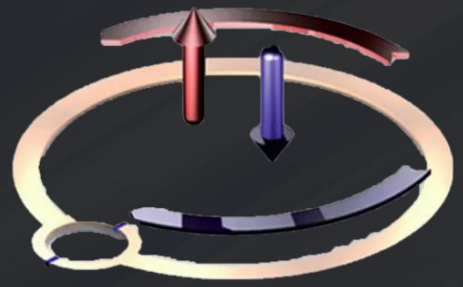


LUMI-Q

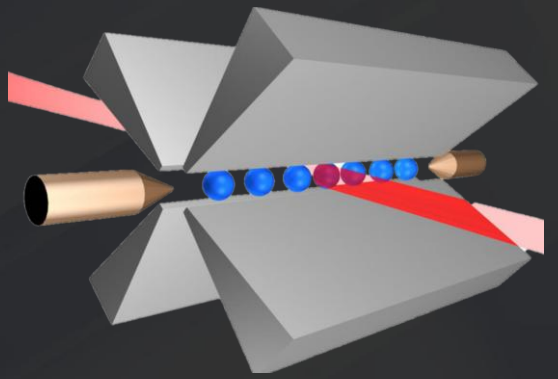


EuroQCS Spain

EuroQCS France



Euro-Q-Exa



EuroQCS Poland

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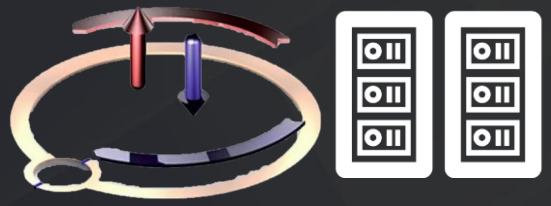
EuroQCS Italy



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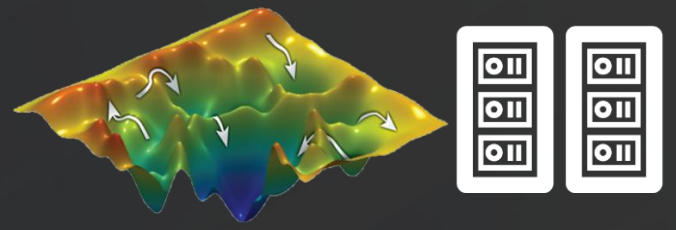
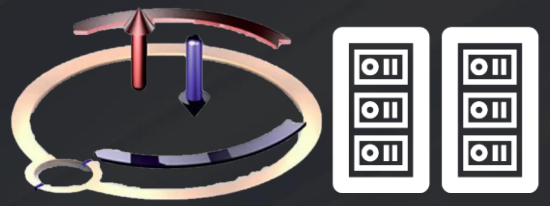


EuroQCS Spain

EuroQCS France



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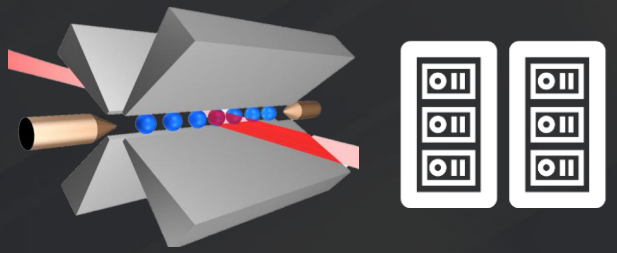

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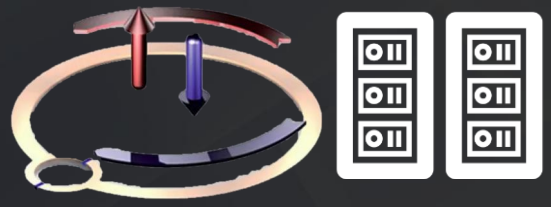

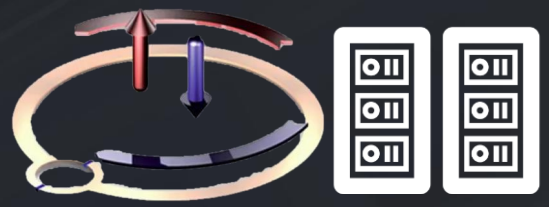

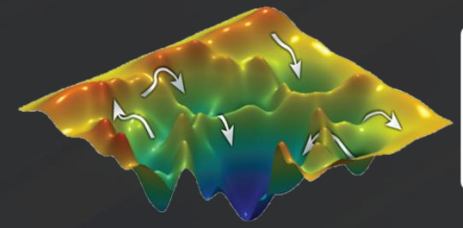

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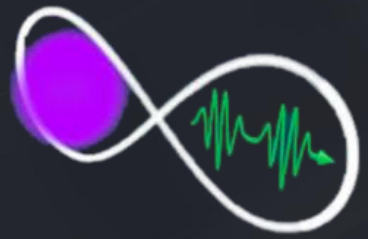
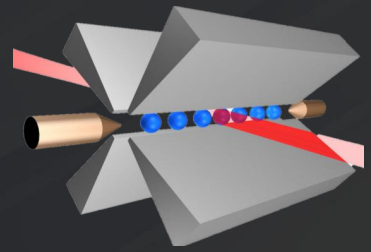
Joint Undertaking





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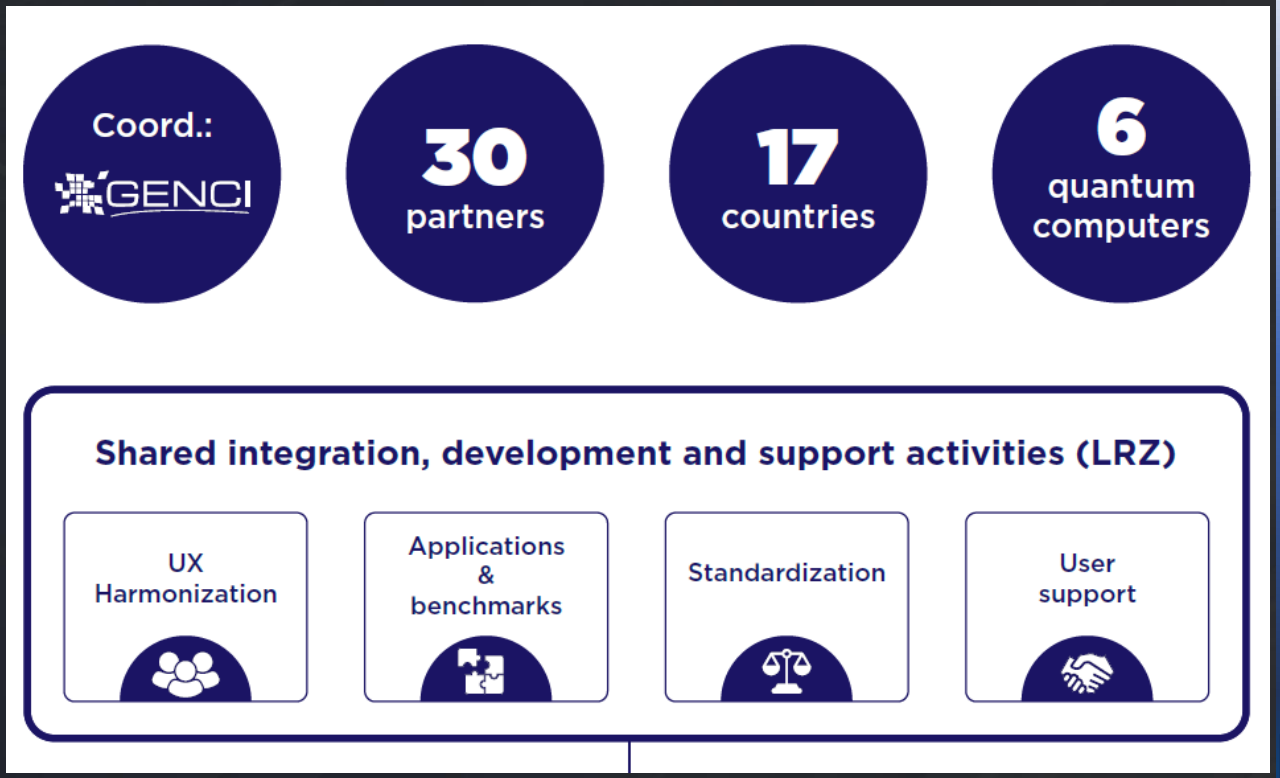

- 4 years project
- Start: 01/03/2025
- 6 WPs (one for each HE) +
- 1 Management WP (Genci) +
- 1 Shared WP (LRZ)
- Our effort:
  - 156 PM in total (WP6 + WP2 + WP1)

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Ljubljana, Slovenia

arnes
povezujemo znanje

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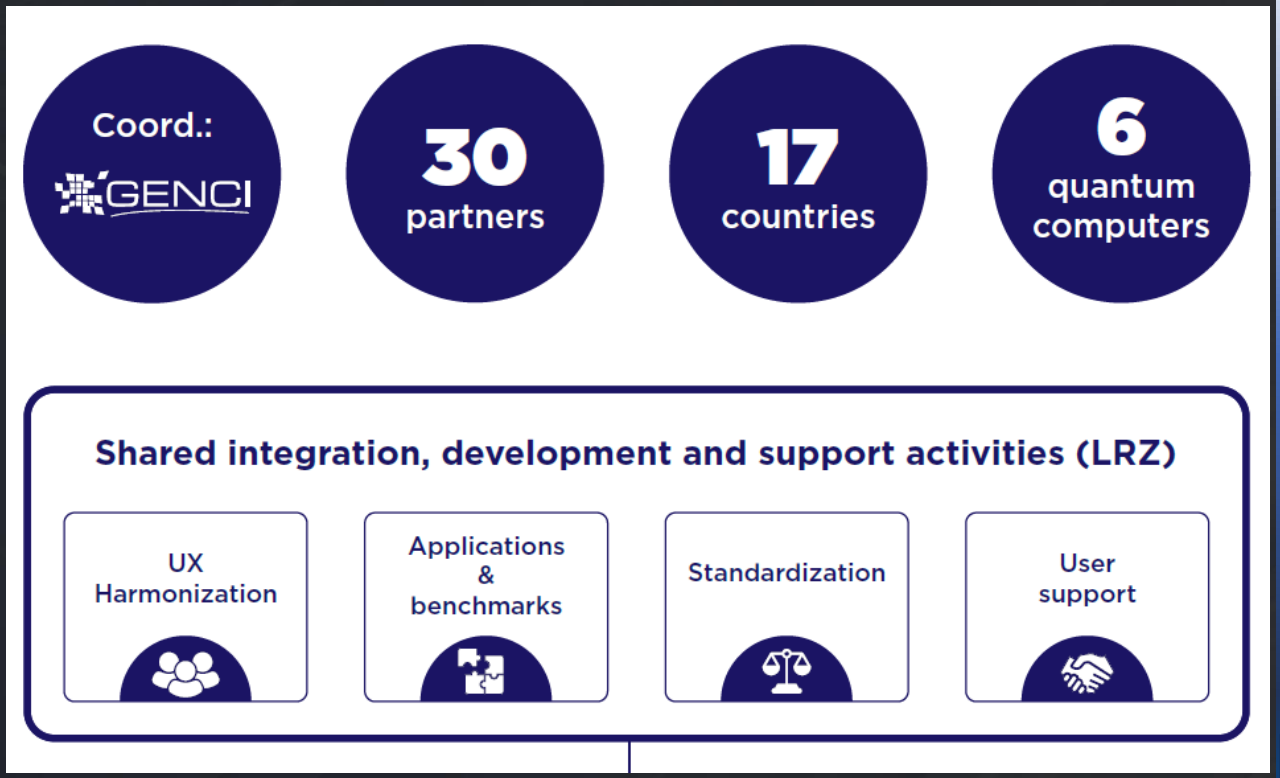

OUR WP6 OBJECTIVES

- **Integration** of **neutral atoms** quantum computer (mixed digital/analog usage) with **Leonardo supercomputer**
- Integration of a **cloud quantum computing service** into our HPC service
- **Interface** and **software stack** development
- Development of **HPC-QC test libraries**

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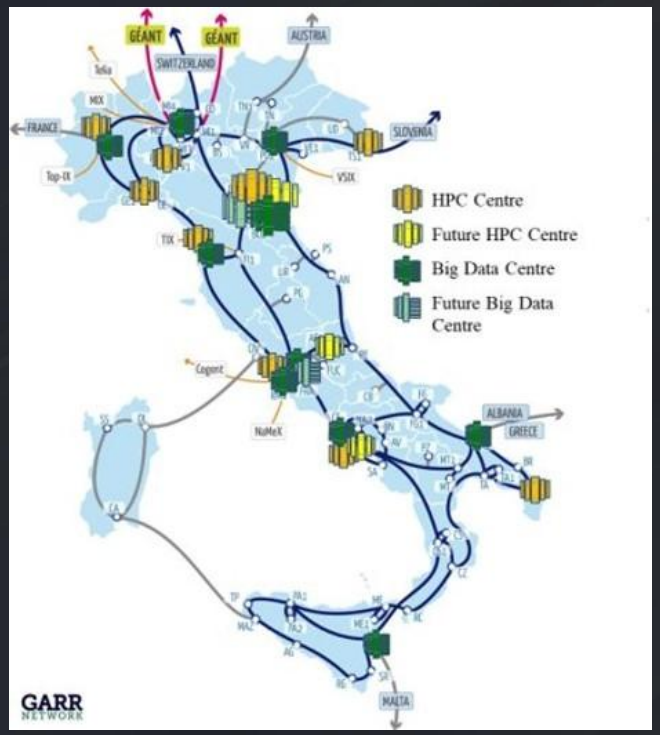
Italian and European QC Environment



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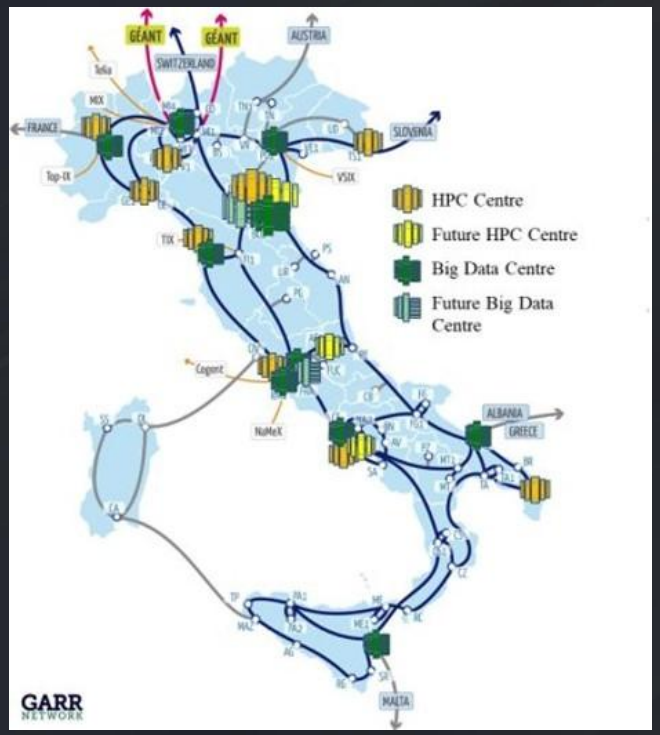

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EuroHPC Joint Undertaking

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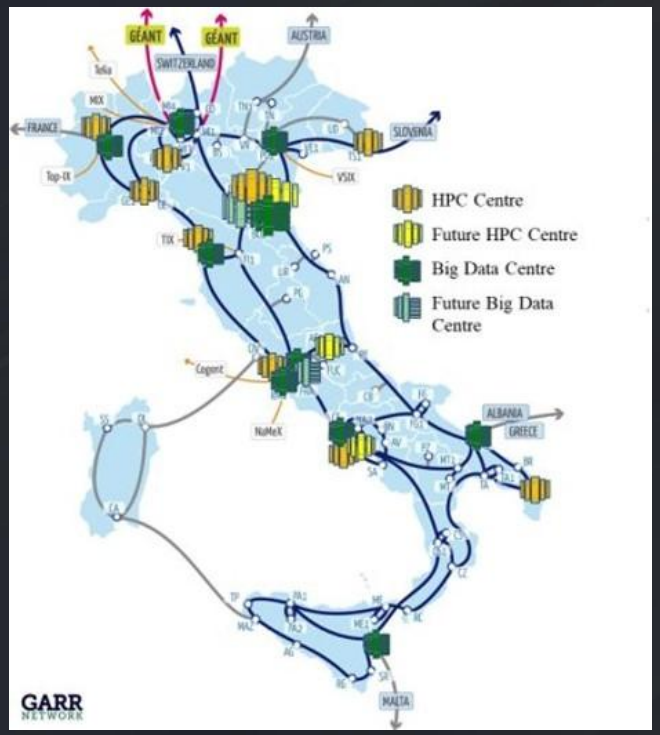

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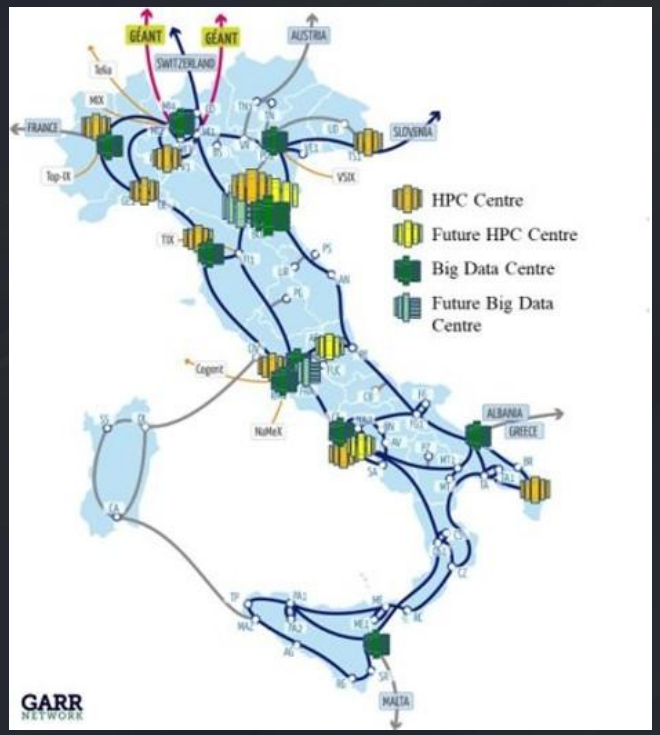

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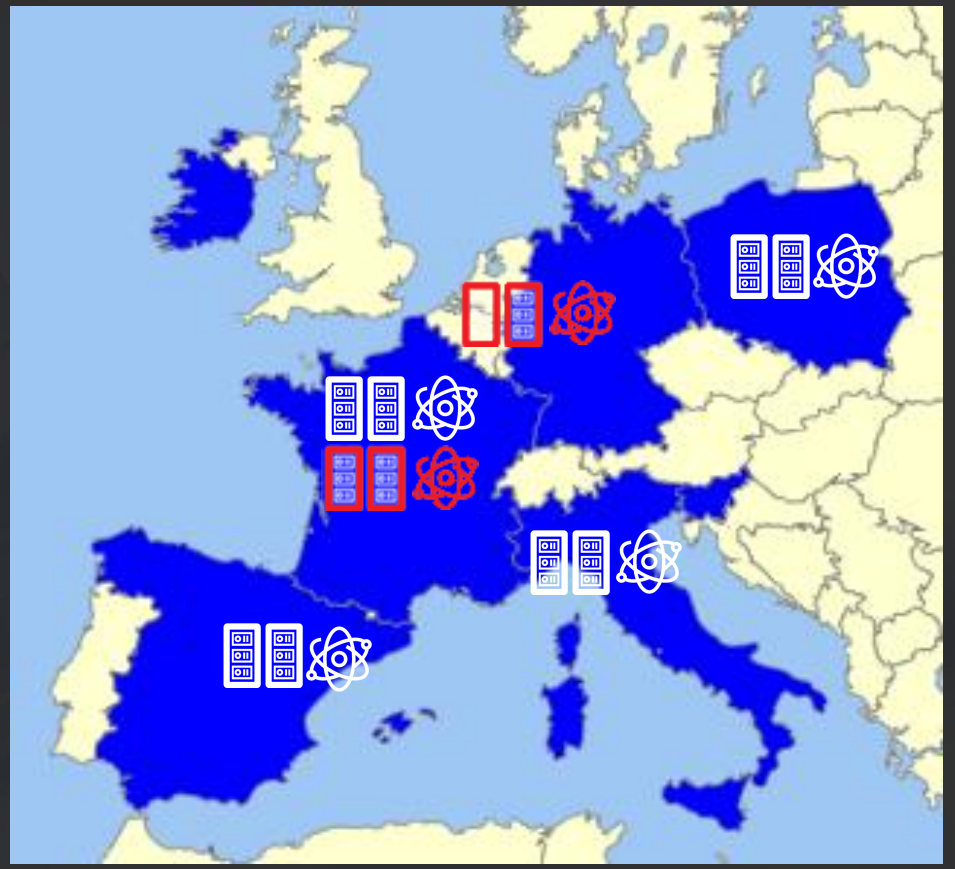

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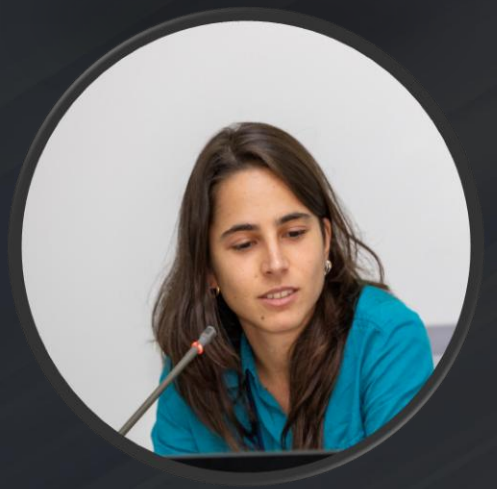
Daniele Ottaviani

Sara Marzella

Anita Camillini

Vito Palmisano

Francesco Finelli



Francesca Gebbia

Jonathan Frassineti

Antonio Costantini

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Thank You!

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