EuroQHPC-Integration

Towards a pan-European hybrid HPC-QC platform

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GENCI

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LRZ/TUM/MQV

A bit of context on the EuroHPC Quantum Computing initiative…

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Two pilot systems acquired for the HPCQS project

2 **100+-qubit quantum simulators** acquired in the context of ⟨HPC|QS⟩

GENCI/CEA **RUBY**

FZJ **JADE**

15 **partners** in total

6 **countries** involved

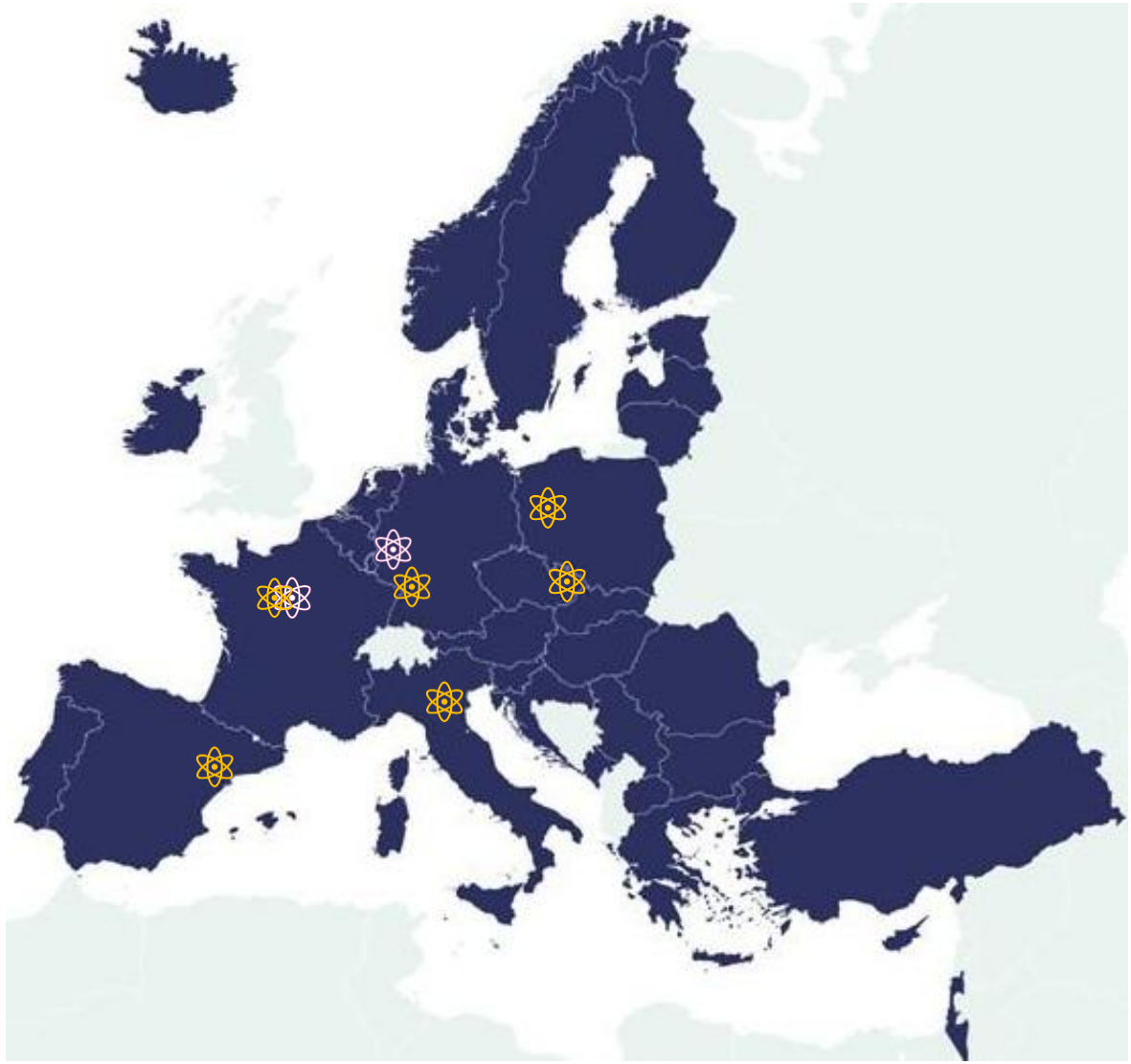
THE EUROHPC QUANTUM COMPUTING INITIATIVE

Six additional quantum computers acquired

6 **10+-qubit quantum computers** acquired through a call for expression of interest (CEI)

30 **partners** in total

17 **countries** involved



EuroQCS-France
GENCI/CEA

Euro-Q-Exa
LRZ

EuroQCS-Italy
CINECA

Lumi-Q
IT4I @ VSB

EuroQCS-Poland
PSNC

EuroQCS-Spain
BSC-CNS

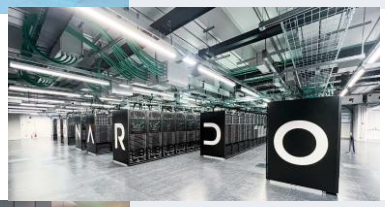
THE EUROHPC QUANTUM COMPUTING INITIATIVE

Six additional quantum computers acquired

EuroQCS-France GENCI/CEA	**LUCY**	Photonic quantum computer	QUANDELA	
Euro-Q-Exa LRZ		Superconducting qubits		IQM
EuroQCS-Italy CINECA		Neutral atoms	PASQAL	
Lumi-Q IT4I @ VSB	**VLQ**	Superconducting qubits with a star-shaped topology		IQM
EuroQCS-Poland PSNC	**PIAST-Q**	Trapped ions	AQT	
EuroQCS-Spain BSC-CNS	**MN-ONA**	Quantum annealer		QILIMANJARO QUANTUM TECH

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Seven different flavors of HPC-QC infrastructures

EuroQCS-France GENCI/CEA	**LUCY**	Photonic quantum computer	QUANDELA	 
Euro-Q-Exa LRZ		Superconducting qubits	IQM	
EuroQCS-Italy CINECA		Neutral atoms	PASQAL	
Lumi-Q IT4I @ VSB	**VLQ**	Superconducting qubits with a star-shaped topology	IQM	
EuroQCS-Poland PSNC	**PIAST-Q**	Trapped ions	AQT	
EuroQCS-Spain BSC-CNS	**MN-ONA**	Quantum annealer	QILIMANJARO QUANTUM TECH	

How are these centers collaborating on HPC-QCS integration?

THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project

Coordinated by GENCI

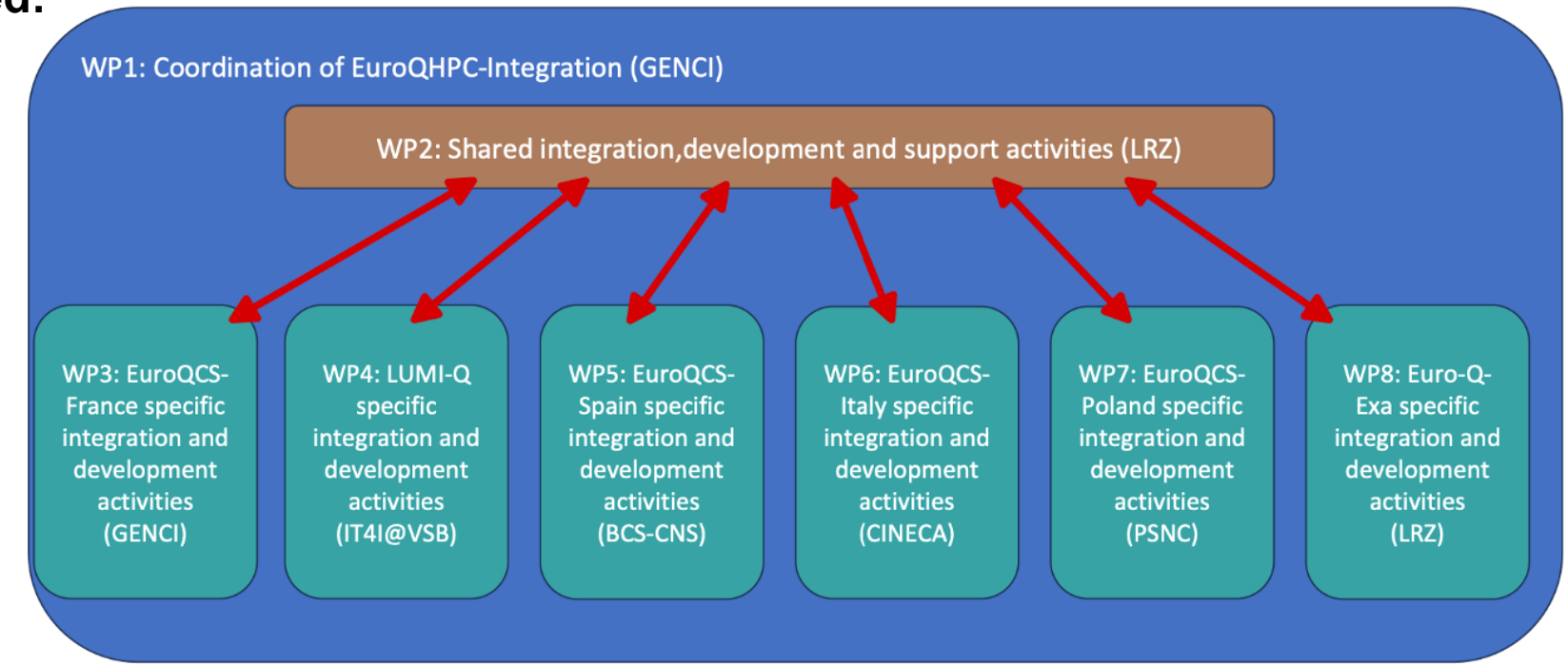
Partners & affiliated entities involved:
all partners from the initial
six grant applications to
EUROHPC-22-CEI-QC-01

Duration: 48 months

Budget: €15M

Goal: harmonize the respective
HPC-QC integration strategies
for all EuroHPC quantum devices,
connect to the work carried out
within ⟨HPC|QS⟩

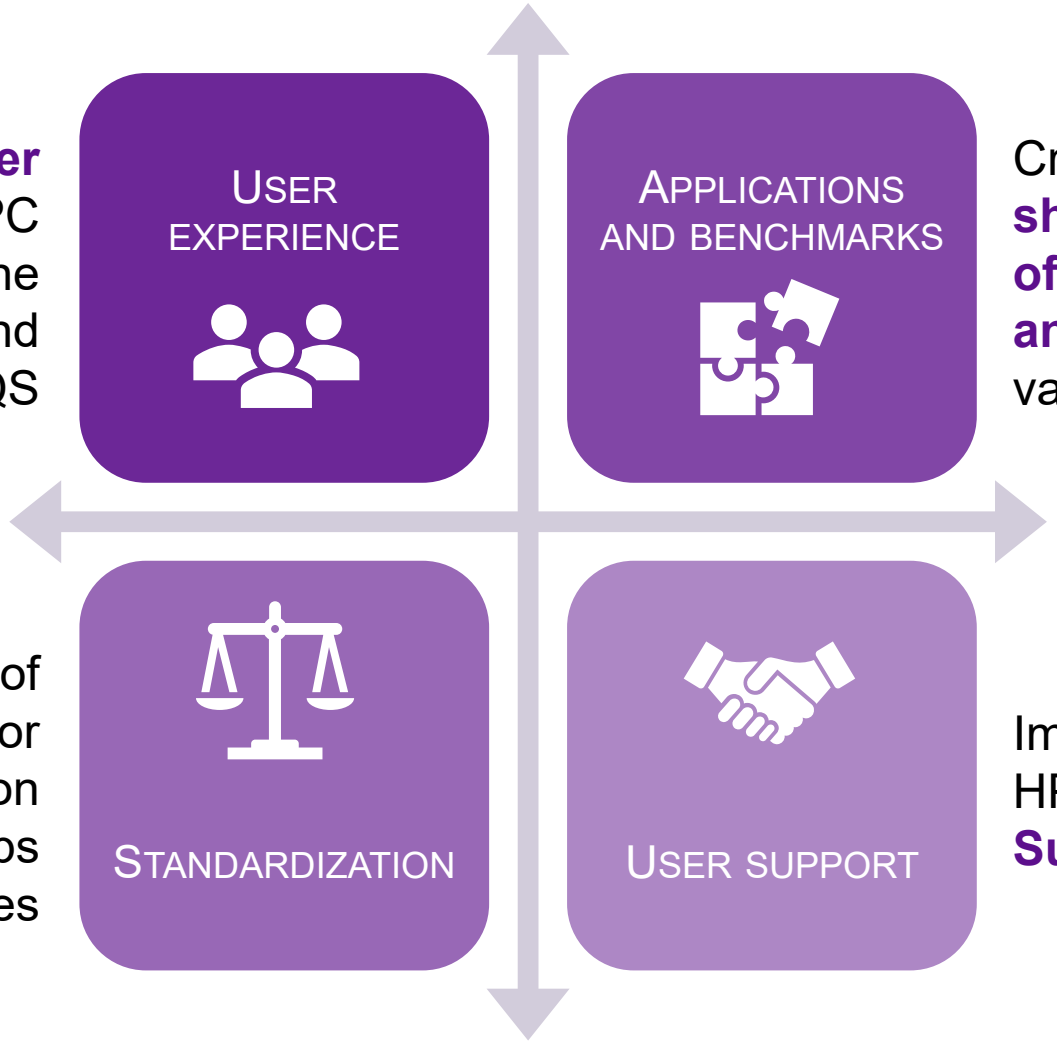
Status:
Signature of the Grant Agreement
First technical coordination starting!



THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project: topics addressed in WP2

Harmonization of the user experience for the EuroHPC quantum systems across the six Hosting Entities and HPCQS



Creation of a repository of **shared collection of proof-of-concept applications and benchmarks** running on various hybrid systems

Collaboration with/Creation of **standardization bodies** for key interfaces and participation in relevant working groups and committees

Implementation of an HPC-QC **Technical Support Team**

USER EXPERIENCE

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Towards a Unified User Experience Across Centers and Communities

🚀 **Harmonize the user experience** between the 7 HPC-QCS platforms

EUExchange with the ⟨HPC|QS⟩ and **EuroHPC Federation of Resources** projects

🎯 Seeking a **unified/federated access** to EuroHPC HPC-QCS resources

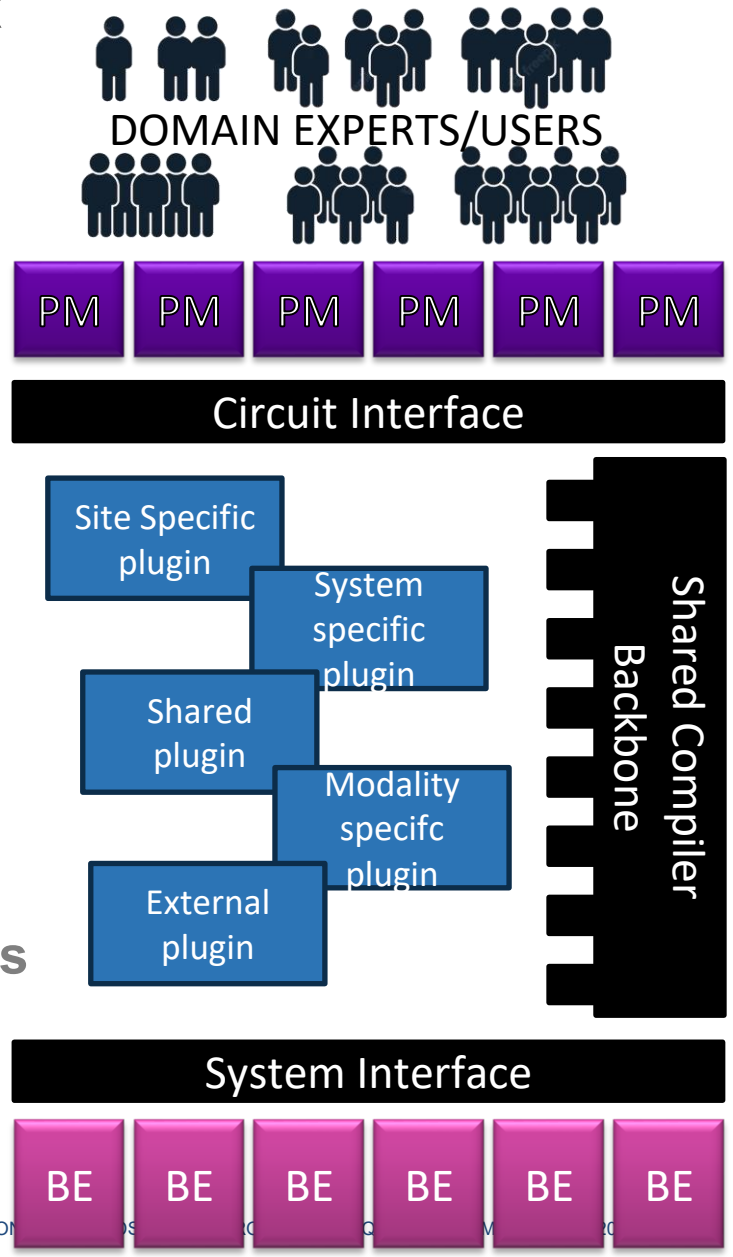
🎯 Towards the use of **common tools** and **system environments**

- Efficient **Co-scheduling** of HPC and QCS resources
- Hardware-agnostic **programming** environments
- **Reporting** the use of resources (time, performances, energy consumption) / **metrics**
- Deployment of **European tools** and **abstraction libraries**

User Experience

THE EUROHPC QUANTUM COMPUTING INITIATIVE

The Technical Vision Towards a Shared Software Stack



EuCompare and share **local developments**

Vision: shared core infrastructure that is adjustable to site requirments to support sharing of local developments

🎯 Central: shared **interfaces** and **representations**

- Towards **common programming models** and **abstractions**
- **Support/Backends** for all EuroHPC systems
- **Merging functionality** (e.g., compiler passes)

APPLICATIONS AND BENCHMARKS

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Comparing Experiences and Helping Communities

🚀 Creation of a **shared repository** of **proof-of-concept applications** and **benchmarks** running on all involved architectures

🎯 End-users will assess **various QPUs** and **coupling strategies** with HPC systems

🎯 **Finding the best fit between algorithms, workflows and hardware technologies**

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Enabling Practical Use On and Across All Sites

🚀 Implementation of a shared HPC-QCS **Technical Support Team** (TST)

🤝 By pooling existing resources from each proposals and creating a **distributed workforce** that will collaborate in sharing best practices and experience

EU Liaise with existing **Applications Support Teams (AST)** set up by EuroHPC

🎯 **Support and train** end-users to use the various QCS systems exposed by EuroHPC

🎯 Collaborate in **peer reviewing** the projects submitted to access the EuroHPC HPC-QCS platforms

STANDARDIZATION

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Defining Shared Interfaces Across the EU Communities (and Beyond)

🚀 Feedback to standardization efforts

💡 As we are jointly moving forward with the HPC-QCS integration in Europe, it's crucial our experience and learnings are integrated in standards

🎯 Liaise with existing **standardization bodies** and participate in **relevant working groups** and/or **support grass-root standardization efforts**

IEEE QUANTUM

CEN CENELEC Focus Group on Quantum Technologies

QUANTUM|FRANCE 2030 BACQ MetriQs-France

THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project : the EuroQCS-France-specific WP (WP3)

- **Project management**
- **Hosting entity** of the second EuroHPC JU exascale system (Alice Recoque)
- **Interface** with the French and European quantum ecosystems

- Deployment of **software environment** coupled with Joliot-Curie
- **Emulation environments**
- Deployment of **extra emulators or QPU-specific environments**

- Quantum-HPC **workflow** design pattern
- Quantum-HPC **programming models and abstractions**
- Dynamic QC **resource management and scheduling**

- **Earth observation** use cases
- Exploration of **distributed quantum computing**
- Members in advisory committee of the **Open Quantum Institute**

- Coordinator of the **HPCQS** project, Hosting Entity of the JADE neutral-atom system
- Extensive expertise in **HPC-QC integration**

THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project : the EuroQCS-France-specific WP (WP3)

LUCY – 12 photonic qubits

- Single-photon-powered quantum computer;
- Provided by Quandela (FR) and Attocube (DE);
- **Access to a remote QPU** from March 15th, 2025 through the Joliot-Curie supercomputer;
- **Installed at TGCC on Oct. 15th** in the same room as the HPCQS Ruby device (neutral-atom system provided by Pasqal);
- Available early 2026
- Should be upgraded to a 24-qubit system

Check out the video of Lucy's installation at TGCC here !

THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project : the EuroQCS-France-specific WP (WP3)

❑ SYSTEM-LEVEL INTERFACE AND SOFTWARE STACK DEVELOPMENTS

- **Interface and software stack development,** integration of some of the components of HPCQS
- Extension of the **resource allocation system** developed in HPCQS

❑ NON-LOCAL IMPLEMENTATIONS OF QUANTUM FUNCTIONS

- Exploration of **distributed quantum computing** (on various algorithms)

❑ HYBRID HPC-QC PROGRAMMING ENVIRONMENT DEVELOPMENTS

- Development of a **system software** by re-using and extending HPCQS and open-source software frameworks
- Implementation of **extensions within the Julia language framework**

❑ VALIDATION AND BENCHMARK OF THE HPC-QC SOFTWARE STACK

- Run the common benchmark applications to **validate the specific EuroQCS-France HPC-QC integration**

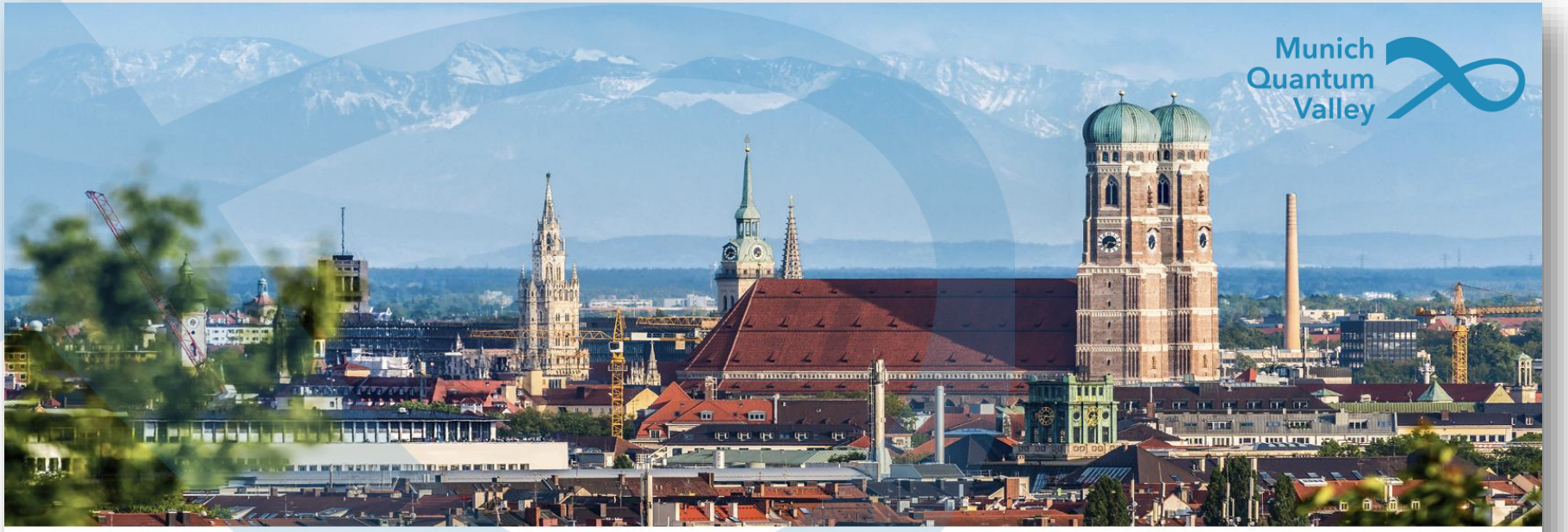
THE EUROHPC QUANTUM COMPUTING INITIATIVE

The EuroQHPC-Integration project : the Euro-Q-Exa specific WP (WP8)

MUNICH QUANTUM VALLEY

Tasks:

- Bringup of Euro-Q-Exa systems
- Integration into compute eco-system
- Software-stack with well-defined interfaces
- User support and Guidance for industry and academia



The primary goal of the Munich Quantum Valley initiative is **developing and operating competitive quantum computers** in close cooperation with strong industry partners and visionary start-ups and making them available for a broad range of applications.

Superconducting. Ion. Neutral Atom. Quantum-HPC.

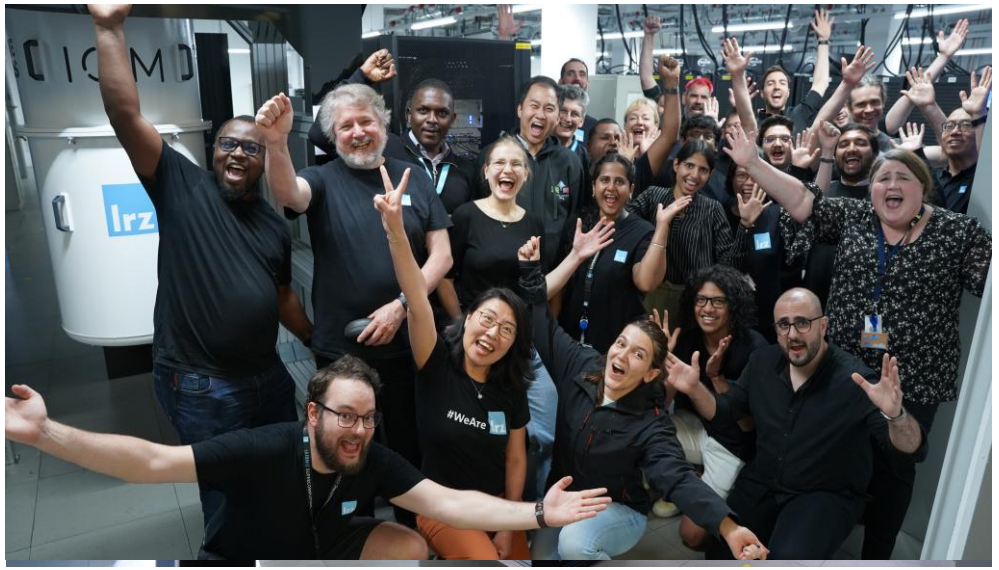
EURO-Q-EXA IN THE QUANTUM COMPUTING INITIATIVE

The (Euro)-Q-Exa Series of Systems

🚀 Starting point: **German Demonstrator Q-Exa**
20 Qubits IQM SC System
Status: up and running

🎯 **Euro-Q-Exa System 1**
54 Qubits IQM SC System
Status: under acceptance, coming soon

🎯 **Euro-Q-Exa System 2**
150 Qubits IQM SC System
Status: to be delivered 2026

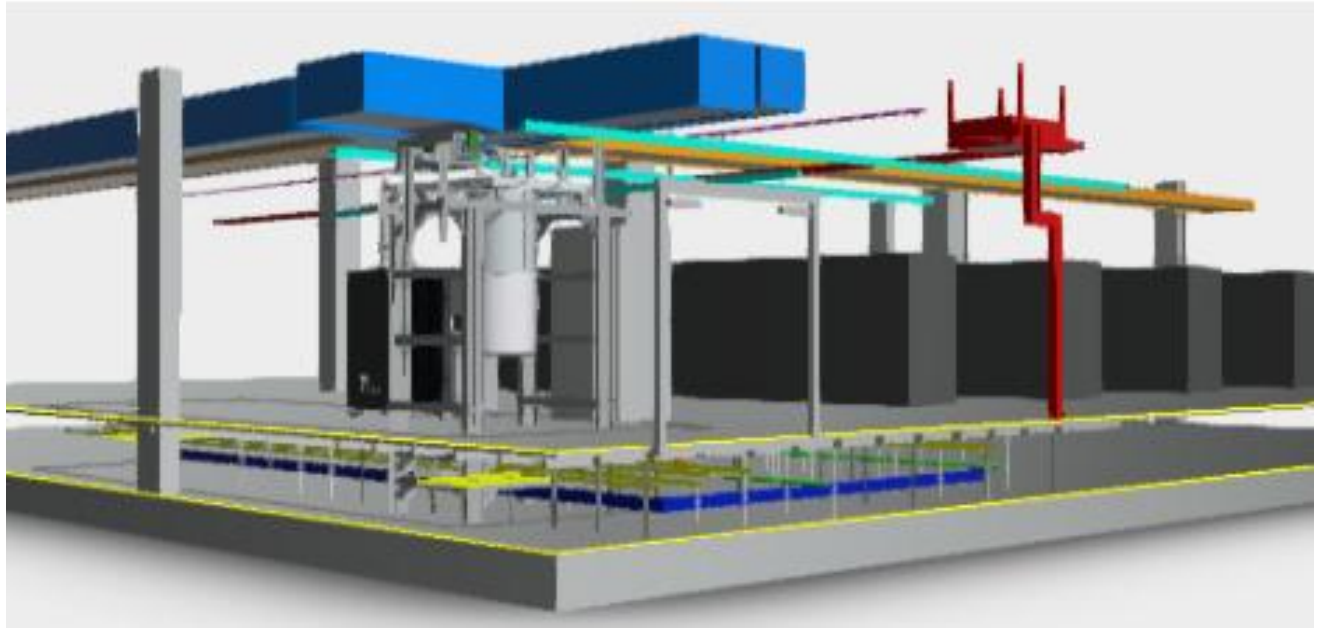


EURO-Q-EXA IN THE QUANTUM COMPUTING INITIATIVE

Integrating Euro-Q-Exa into the LRZ/MQV Eco-System

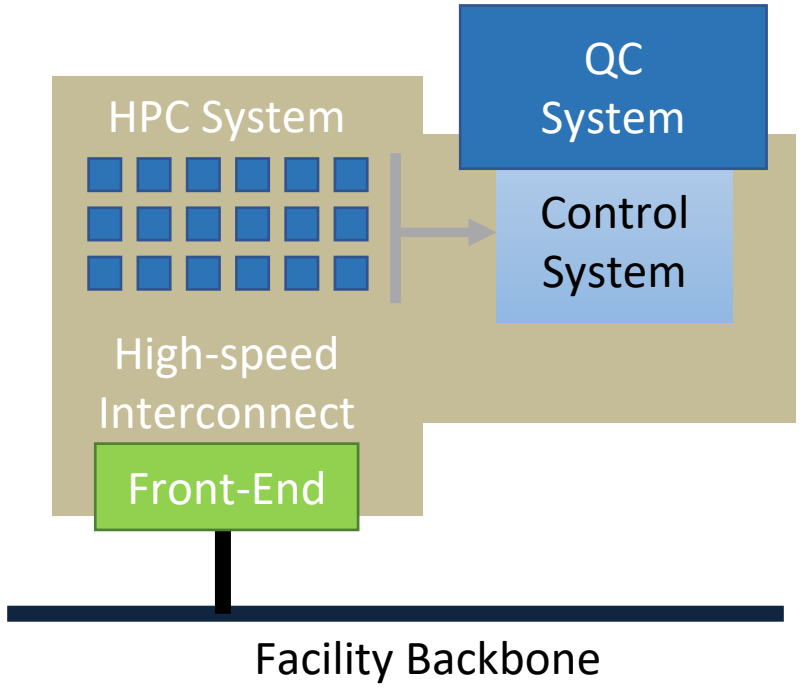
🎯 Physical Integration:

- ➢ On the machine floor at LRZ
- ➢ Integrated into the infrastructure



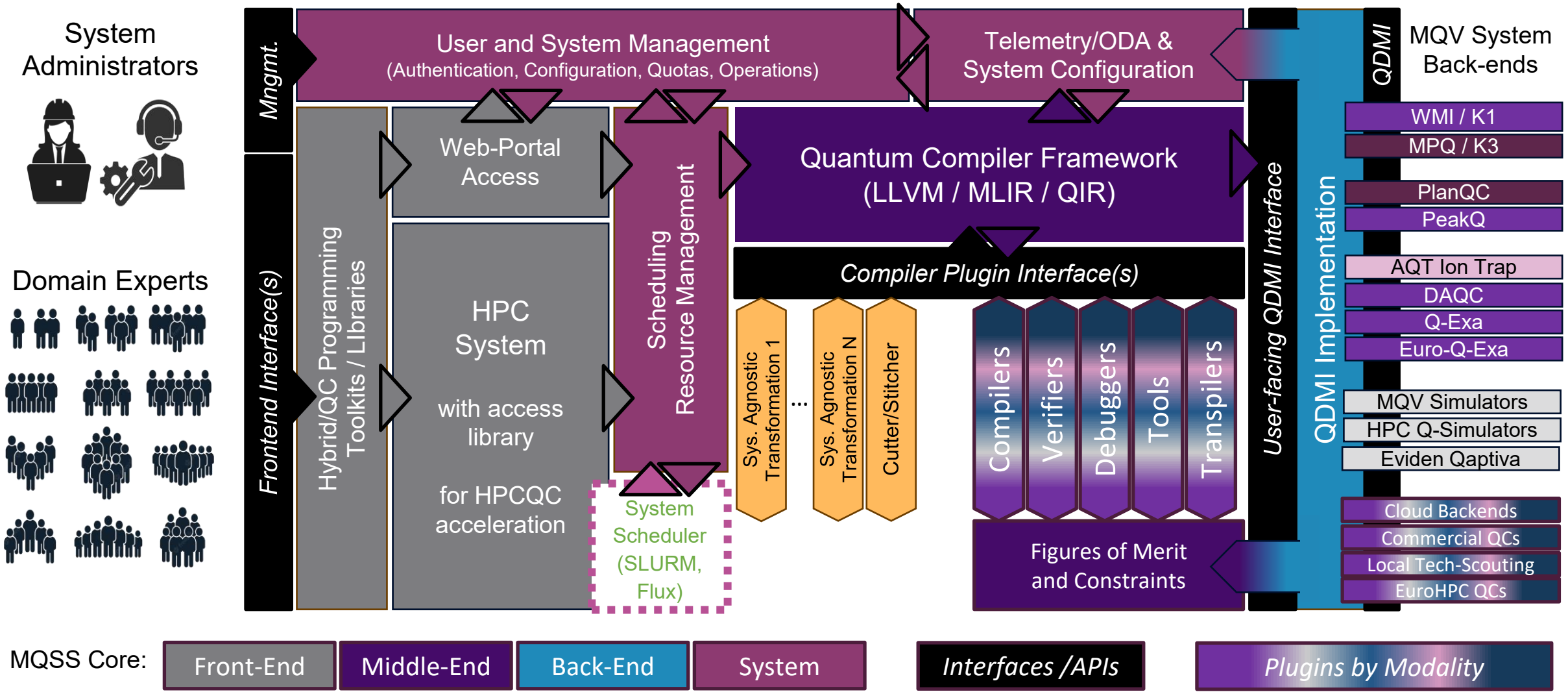
🎯 Software Integration:

- ➢ Closely connected to HPC
- ➢ Front-Ends part of HPC
- ➢ Use of HPC for QC Stack



EURO-Q-EXA IN THE QUANTUM COMPUTING INITIATIVE

Building a Compatible Stack with Clear Interfaces

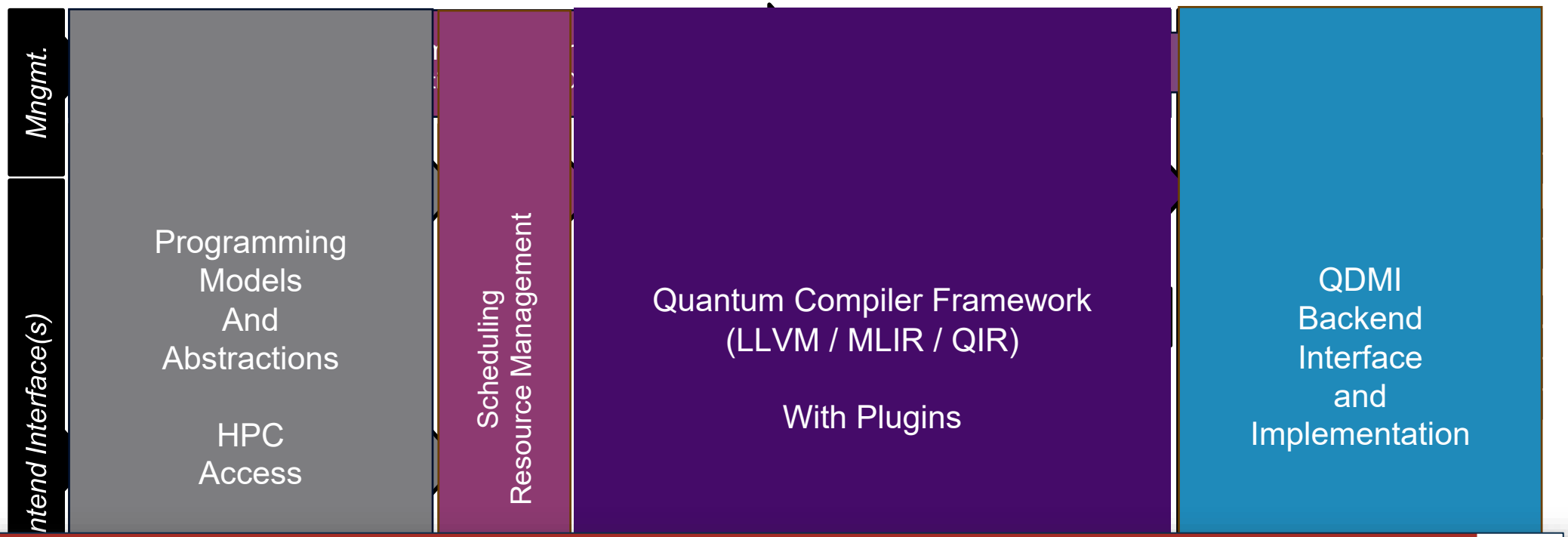


EURO-Q-EXA IN THE QUANTUM COMPUTING INITIATIVE

Building a Compatible Stack with Clear Interfaces

System Administrators

Domain Experts



arXiv > quant-ph > arXiv:2509.02674

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Quantum Physics

[Submitted on 2 Sep 2025]

The Munich Quantum Software Stack: Connecting End Users, Integrating Diverse Quantum Technologies, Accelerating HPC

Lukas Burgholzer, Jorge Echavarria, Patrick Hopf, Yannick Stade, Damian Rovara, Ludwig Schmid, Ercüment Kaya, Burak Mete, Muhammad Nufail Farooqi, Minh Chung, Marco De Pascale, Laura Schulz, Martin Schulz, Robert Wille

THE EUROHPC QUANTUM COMPUTING INITIATIVE

And the The EuroQHPC-Integration project

WHERE DO WE STAND WITH SYSTEMS?

EuroQCS-France
GENCI/CEA

Euro-Q-Exa
LRZ

EuroQCS-Italy
CINECA

Lumi-Q
IT4I @ VSB

EuroQCS-Poland
PSNC

EuroQCS-Spain
BSC-CNS

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Two EuroHPC quantum computers have already been inaugurated !

PIAST-Q – June 23rd, 2025

PCSS

VLQ – September 23rd, 2025

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

The Latest Additions to the Hosting Entities selected by EuroHPC

EUROSSQ-HPC

MELUXINA-Q

THE EUROHPC QUANTUM COMPUTING INITIATIVE

Bringing Together the European HPC-QCS User and System Eco-Systems

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EuroQHPC-I