The expansion of a JUNIQ universe

KRISTEL MICHIELSEN

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

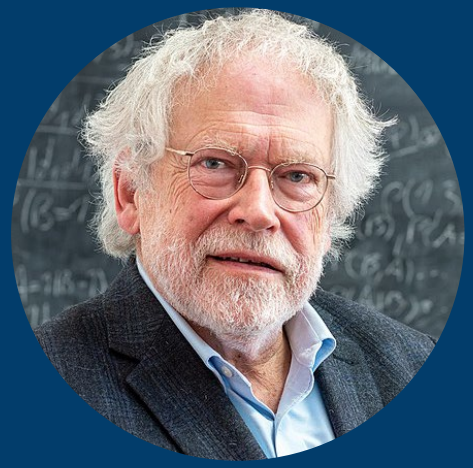
Quantum Information Processing in Europe

Long tradition of excellence in quantum research

The Nobel Prize in Physics 2022

Alain Aspect
Université Paris-Saclay
Paris, France
École Polytechnique
Palaiseau, **France**

John F. Clauser
J.F. Clauser & Assoc.
CA, **USA**



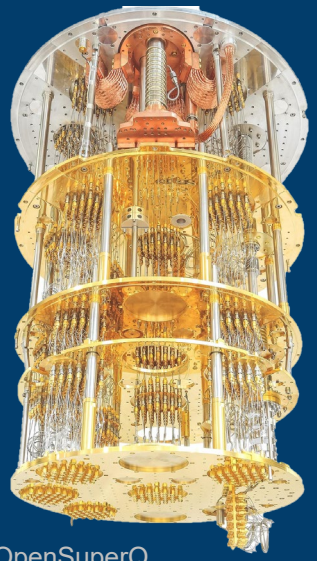
Anton Zeilinger
University of Vienna
Vienna, **Austria**

"for experiments with **entangled** photons, establishing the violation of Bell inequalities and pioneering quantum information science"

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

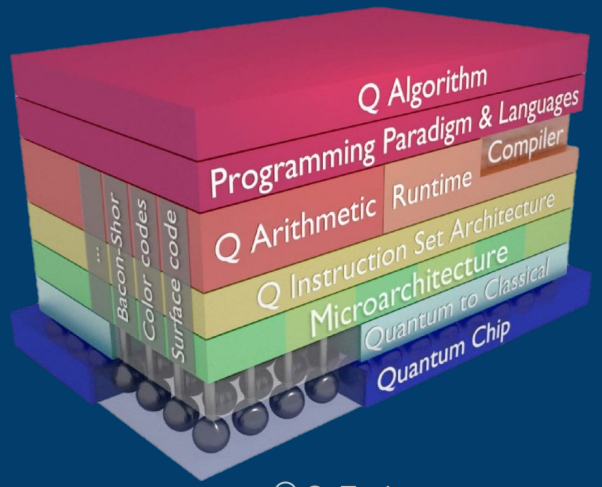
Quantum Computing

What is needed?



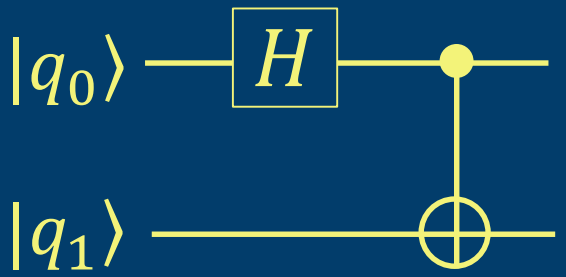
© OpenSuperQ

Quantum computer hardware
Quantum processor/chip

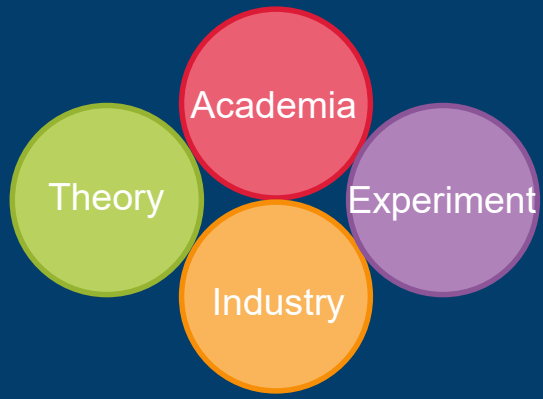


© QuTech

Quantum software stack
Quantum control, quantum error correction, compiler, user interfaces, …



Quantum algorithms
Sequence of controlled one- and two-qubit operations



Collaboration

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

JSC's Quantum Computing Strategy

Four Pillars

- Modeling and emulation strategy
- Provision strategy
- HPC-QC integration strategy
- Creation of a quantum computer user infrastructure

Jülich Supercomputing Centre (JSC)

Jülich UNified Infrastructure for Quantum computing (JUNIQ)

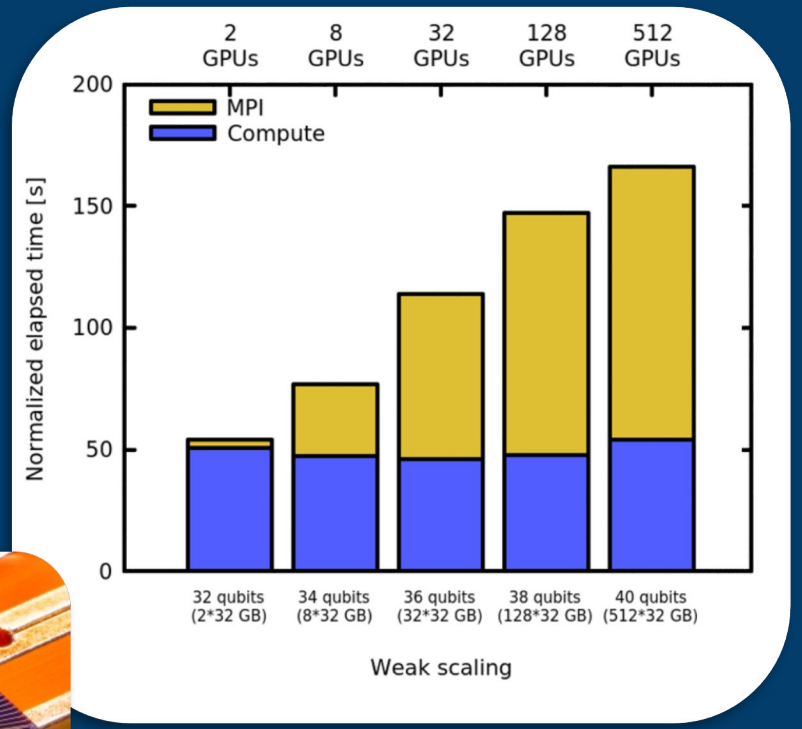
JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

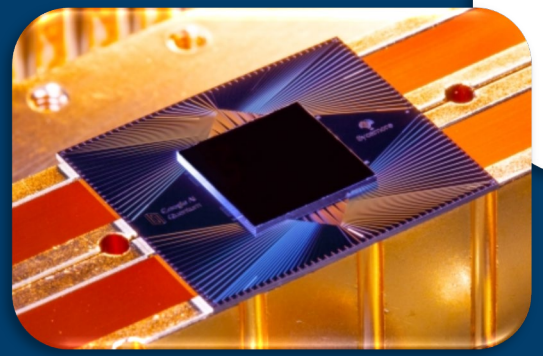
Pillar I: Modeling and Emulation

Development of theoretical tools to

- validate designs of physically realizable quantum processors
- investigate the implementation and performance of quantum algorithms on physically realizable quantum computers

Jülich Universal Quantum Computer Simulator (JUQCS)

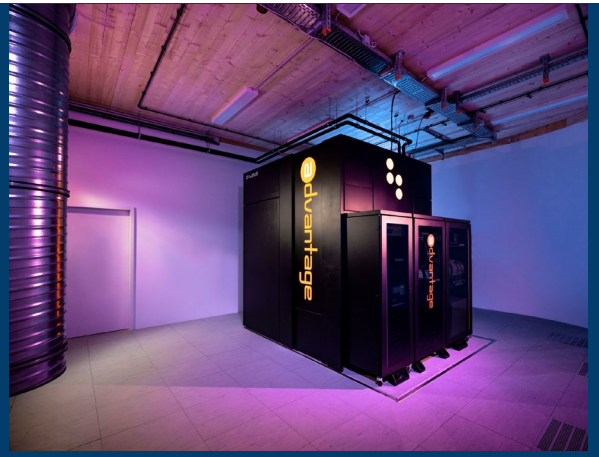


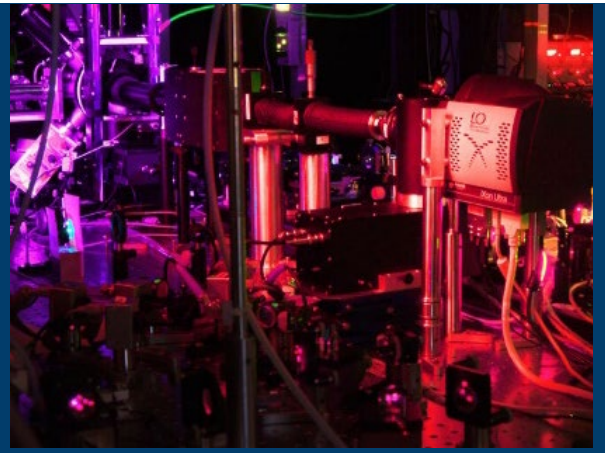


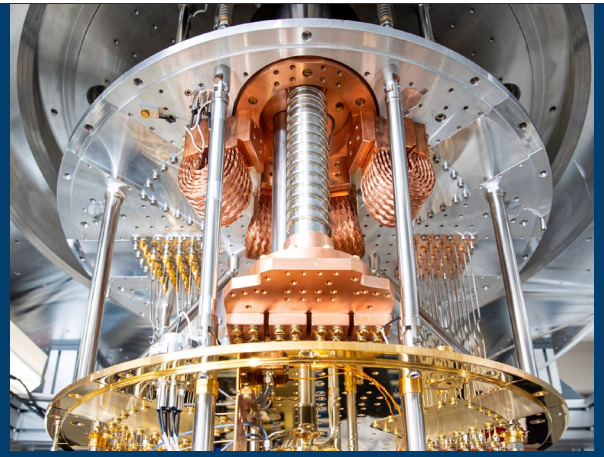
Benchmarking Sycamore (quantum supremacy)

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

Pillar II: Provision Strategy







Quantum annealer

Analog quantum computer
5000+ superconducting qubits

Quantum simulator / computer

Analog /digital quantum computer
100+ neutral atom qubits

Quantum computer

Digital quantum computer
10+ trapped ion qubits, 25+ superconducting qubits, ...

HOSTING of pilot production systems …
REMOTE ACCESS to the respective lab for hardware-software co-design

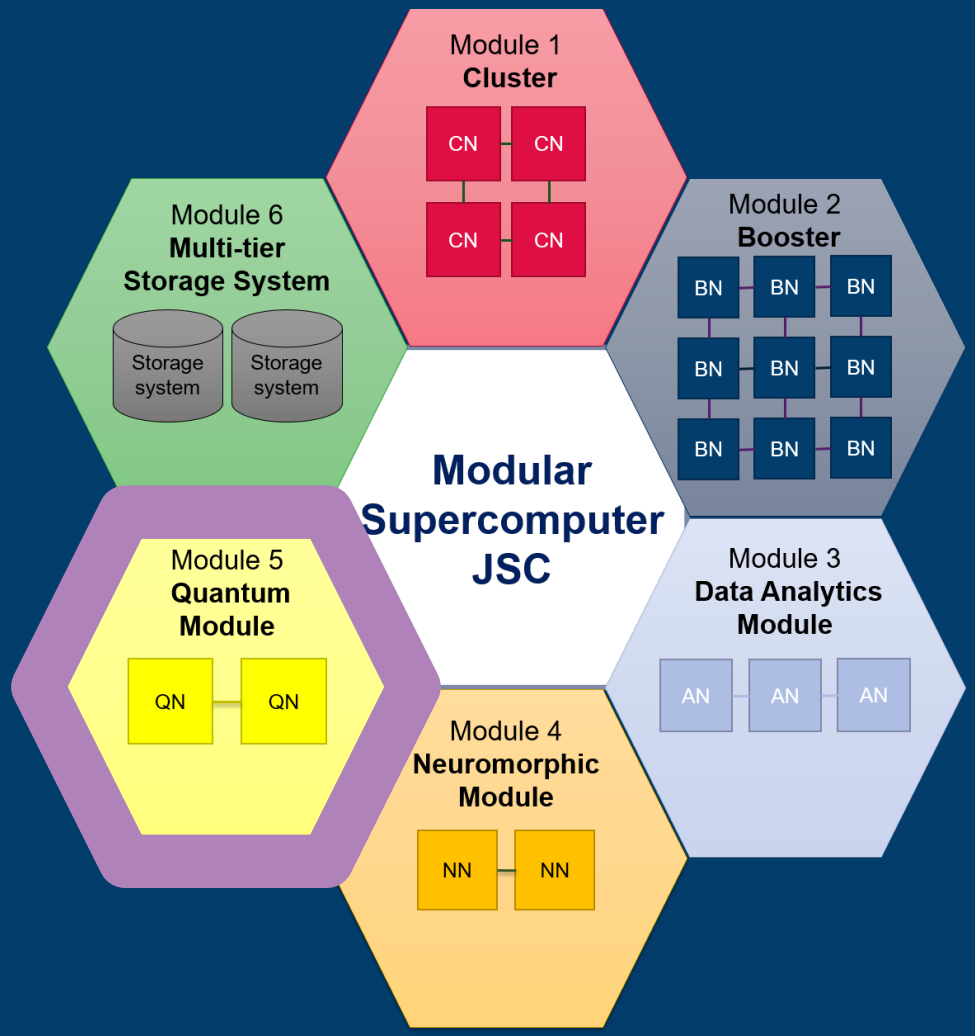
JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

Pillar III: HPC-QC Integration

Practical Quantum Computing

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

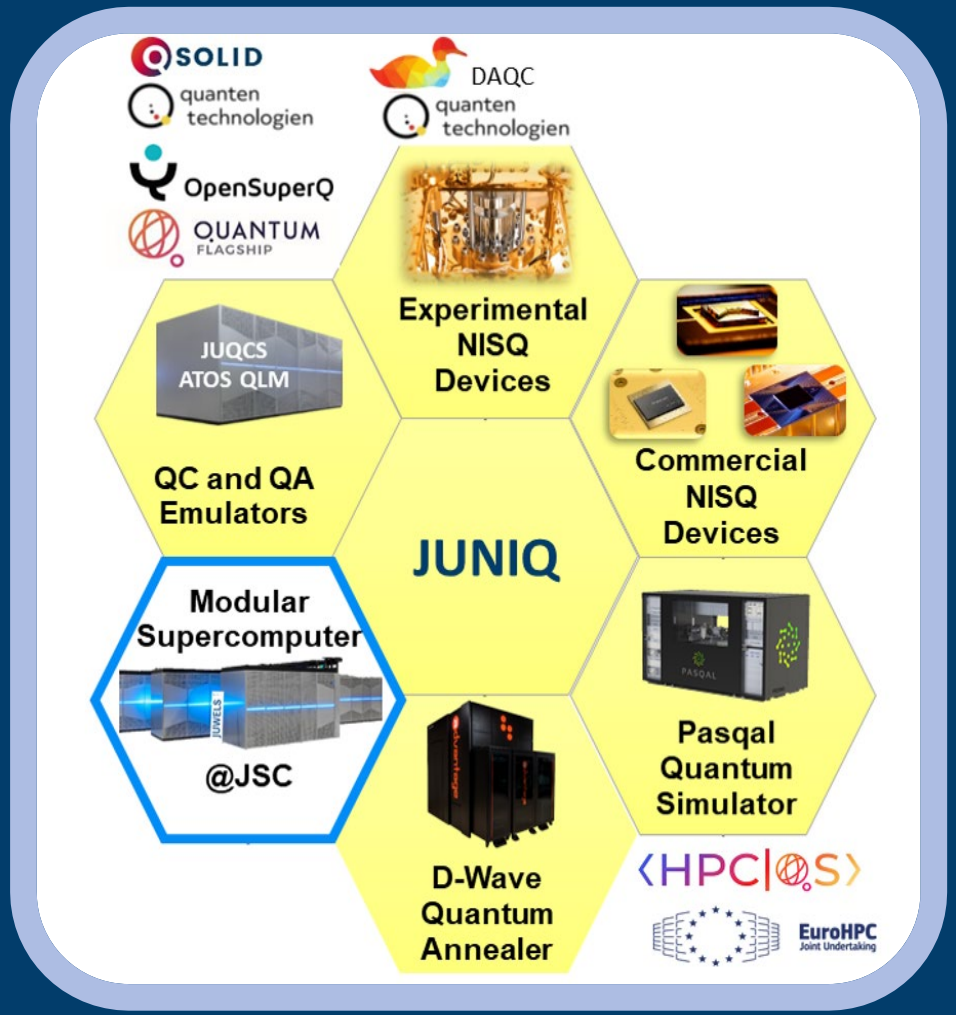
Pillar III: HPC-QC Integration



- Pursue the tightest integration of quantum computers into HPC
- The Modular Supercomputing Architecture (MSA) allows functional parallelism at system level
- MSA is ideal to integrate quantum computer functionality into HPC workflows

JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

Pillar IV: JUNIQ

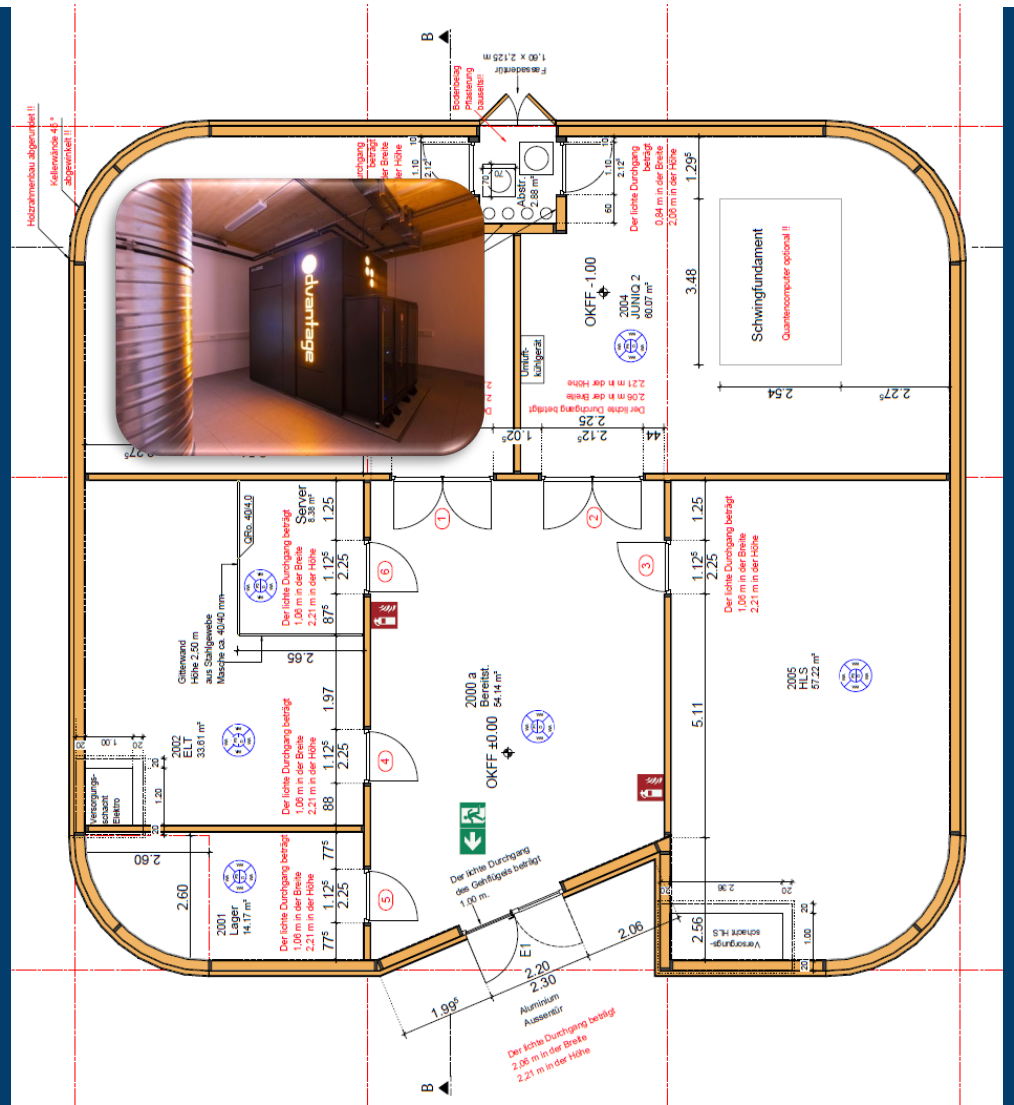


1. QC user facility for science and industry
2. Installation, operation and provision of QCs
3. Unified portal for access to QC emulators and to QC devices at different levels of technological maturity (QC-PaaS)
4. Development of algorithms and prototype applications
5. Services, training and user support
6. Modular quantum-HPC hybrid computing

https://www.fz-juelich.de/ias/jsc/juniq

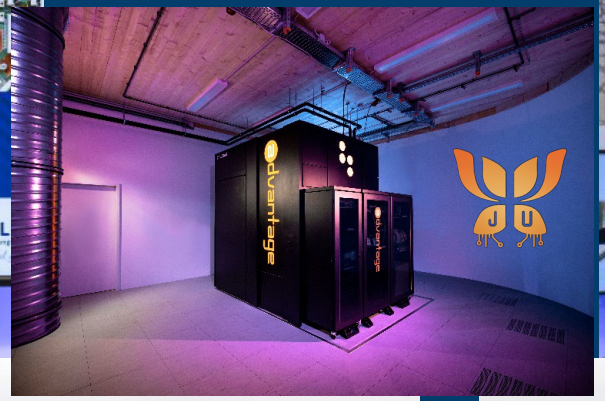
JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

JUNIQ Building built in 2020 - 2021



JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

JANUARY 17, 2022: LAUNCH of JUPSI



JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY

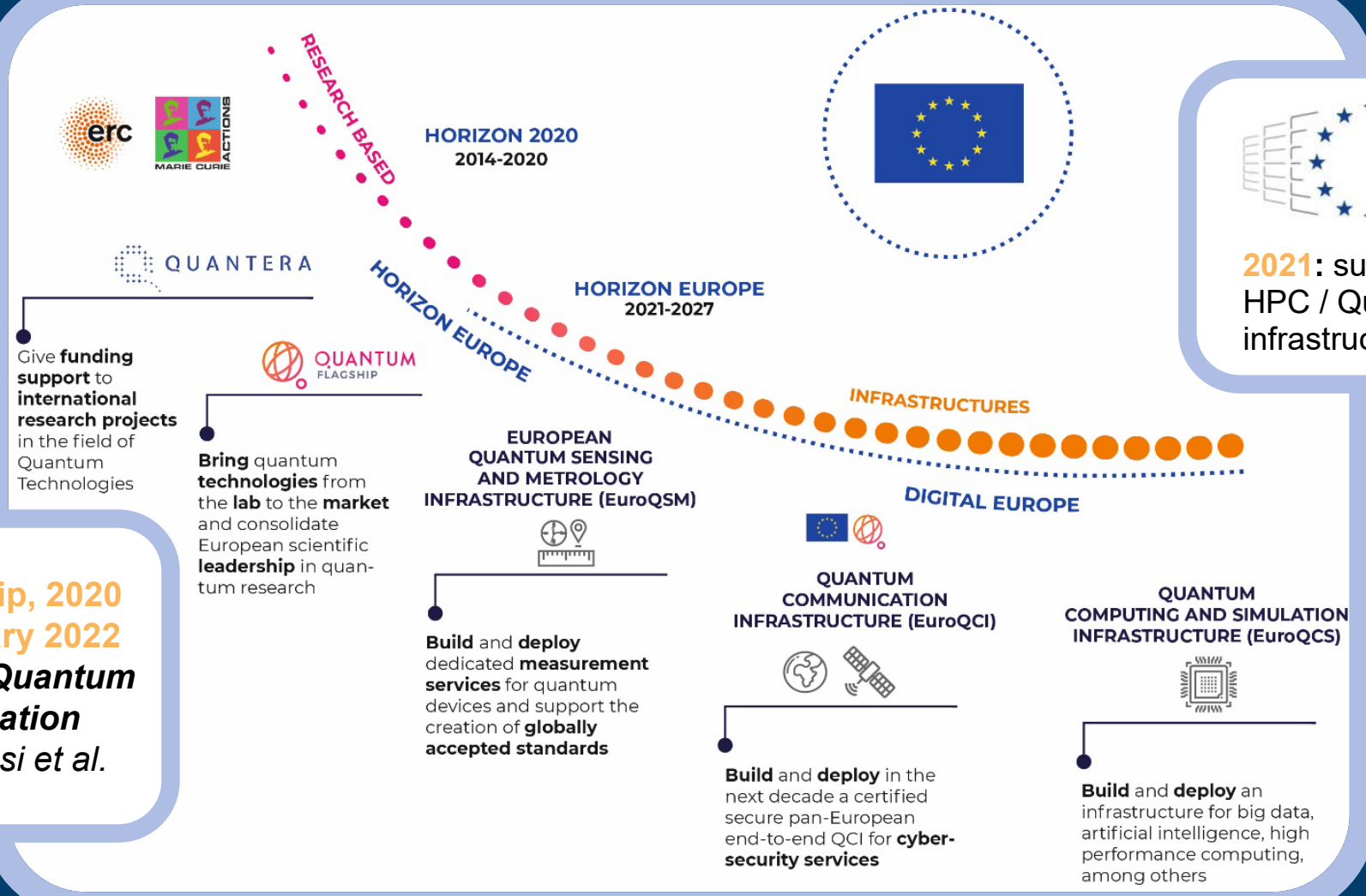
First European Hybrid HPC/Quantum Computing Infrastructure

2019

EuroQCS

JUNIQ - Jülich UNified Infrastructure for Quantum computing, Germany

From Vision to Reality – The EU's Commitment



EuroHPC Joint Undertaking

2021: support for the first hybrid HPC / Quantum computing infrastructure in Europe

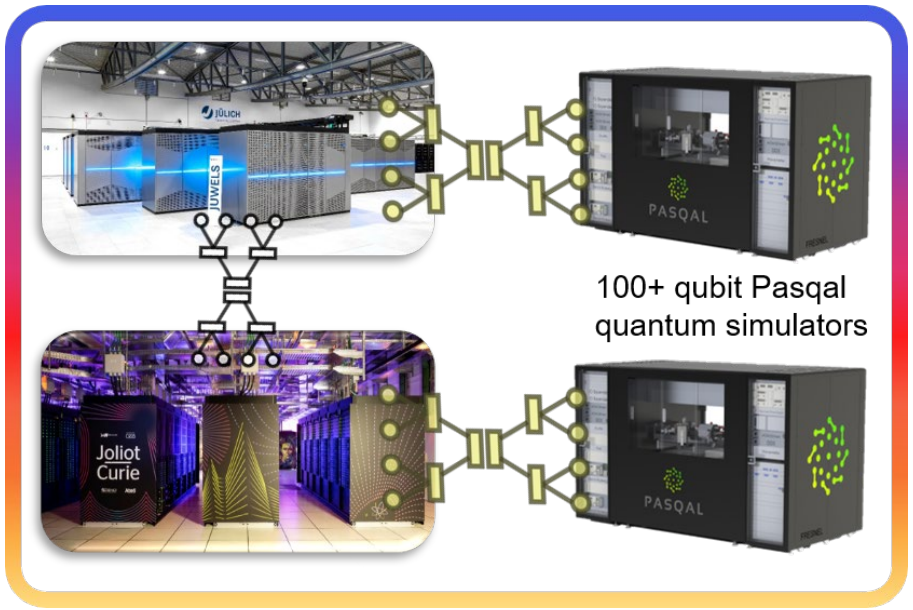
⟨HPC|QS⟩

SRA Quantum Flagship, 2020
White paper, 2 February 2022
EuroQCS: European Quantum Computing and Simulation Infrastructure, *D. Binosi et al.*

Duration and Partners

- December 1st 2021 - November 30th, 2025
- Coordinator: Forschungszentrum Jülich GmbH
- 15 partners + 3 linked 3rd parties from 6 countries

Project Aim



HPC-QS Integration – Main Technical Components

- **Quantum Learning Machine QLM®** by ATOS
  - Programming environment
  - Access to quantum computing backends the quantum simulator

- **Modular Supercomputing Architecture**
  - For lowest latency integration of the quantum simulator
  - Developed in the series of EU-funded DEEP Projects
  - Based on ParTec's **ParaStation Modulo®** middleware suite

ParaStation MODULO

ParTec Modular Supercomputing

HPC-QS Integration – Full Hybrid Software Stack

- Technical libraries and tools

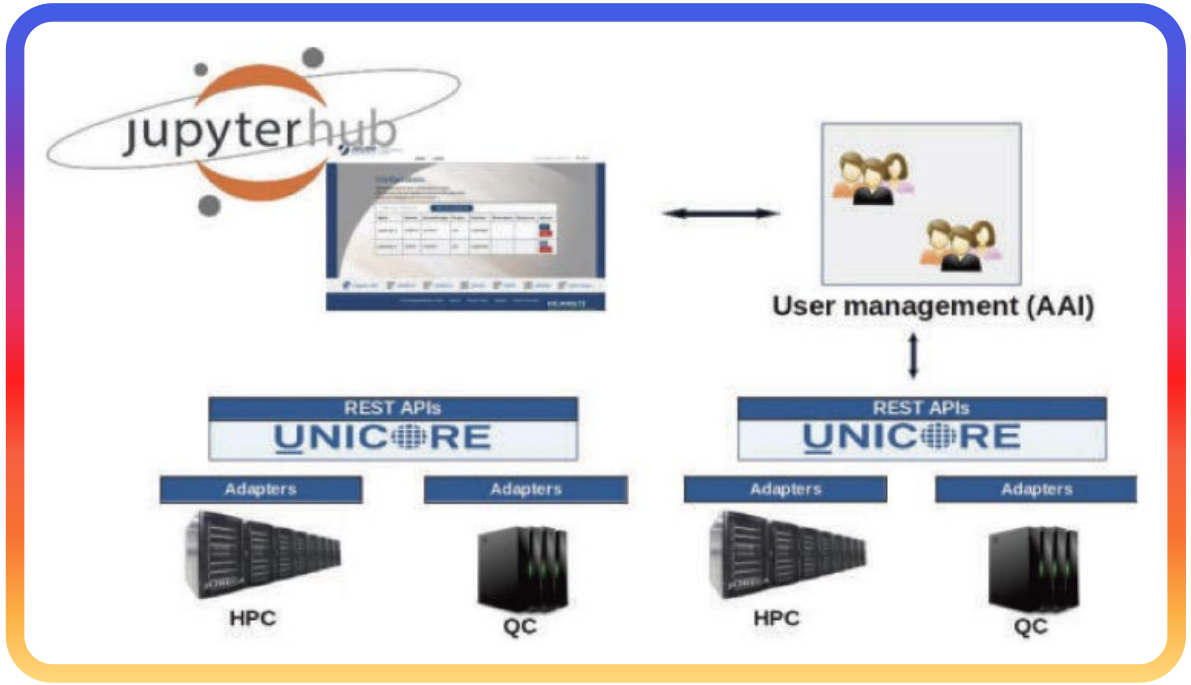
- Benchmarking and certification/performance analysis

- Compilers

- Cloud access

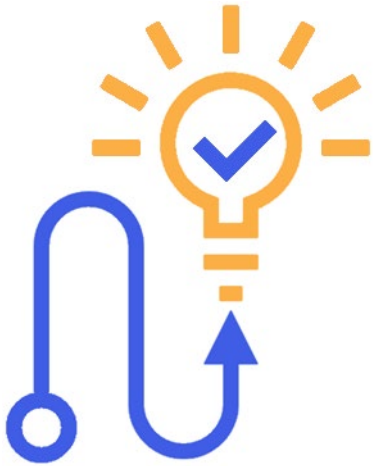
HPC-QS Integration – Access

- Portal-based access in form of a QS-PaaS under European legislation
  - Based on QC-PaaS pilot implementation of JUNIQ
  - Based on JupyterHub technology
  - Joined with a HPC-PaaS via an end-to-end safe UNICORE implementation
  - FENIX like authentication and authorization infrastructure services



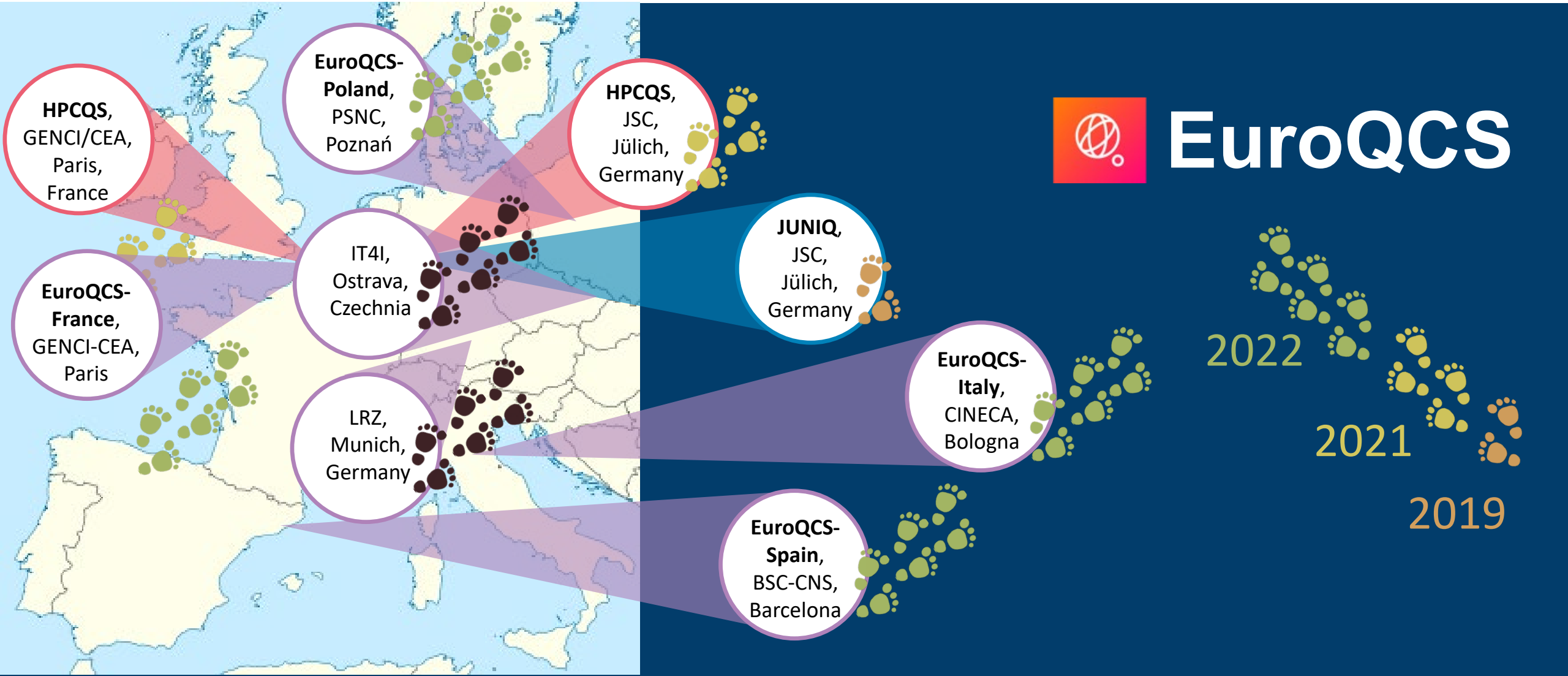
Use Case and Training

- Co-design of hardware and software
  - Investigation of applications in terms of use cases
  - Use cases: machine learning and scientific simulations, featuring the Variational Quantum Eigensolver (VQE) and the Quantum Approximate Optimization algorithm (QAOA)

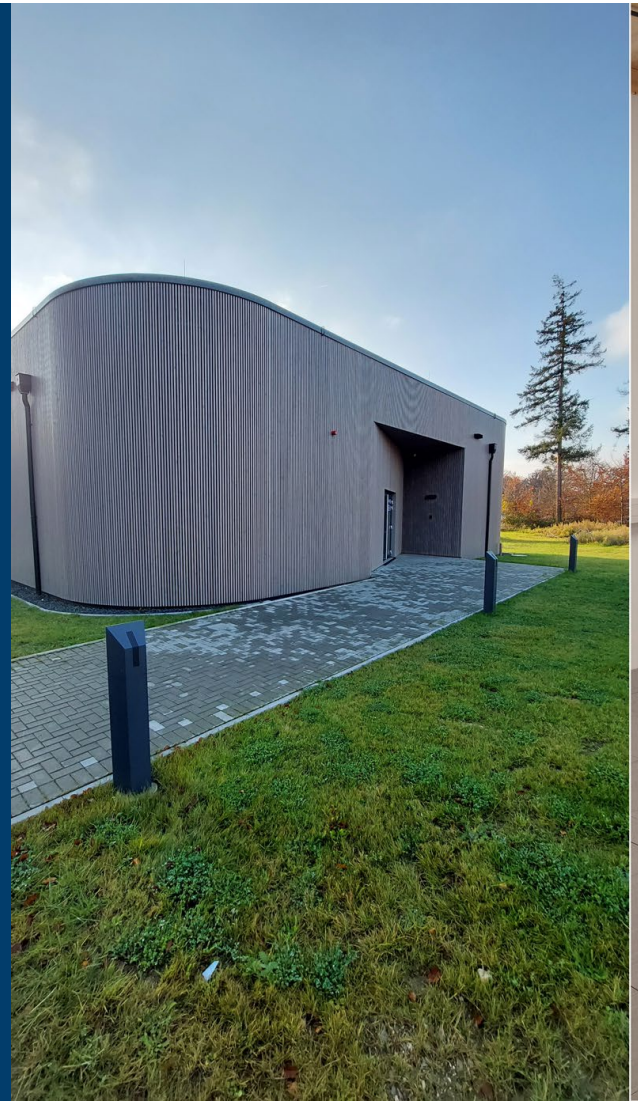


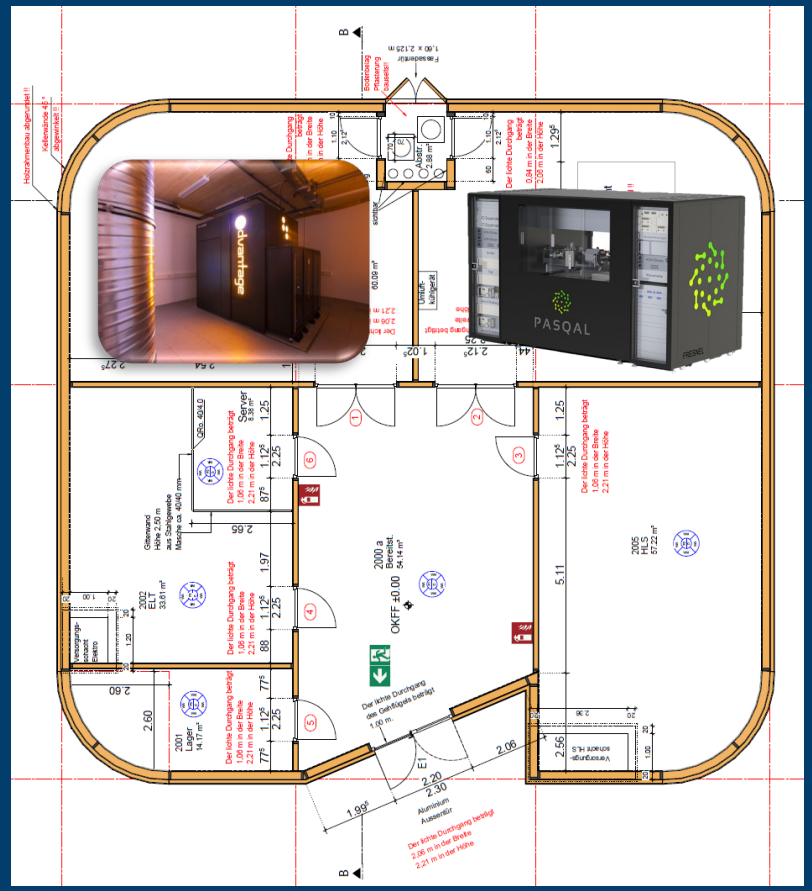
- Training material, user guides and courses
  - For scientific and industrial user needs

Hybrid HPC/Quantum Computing Infrastructures



Expectations for December 2023

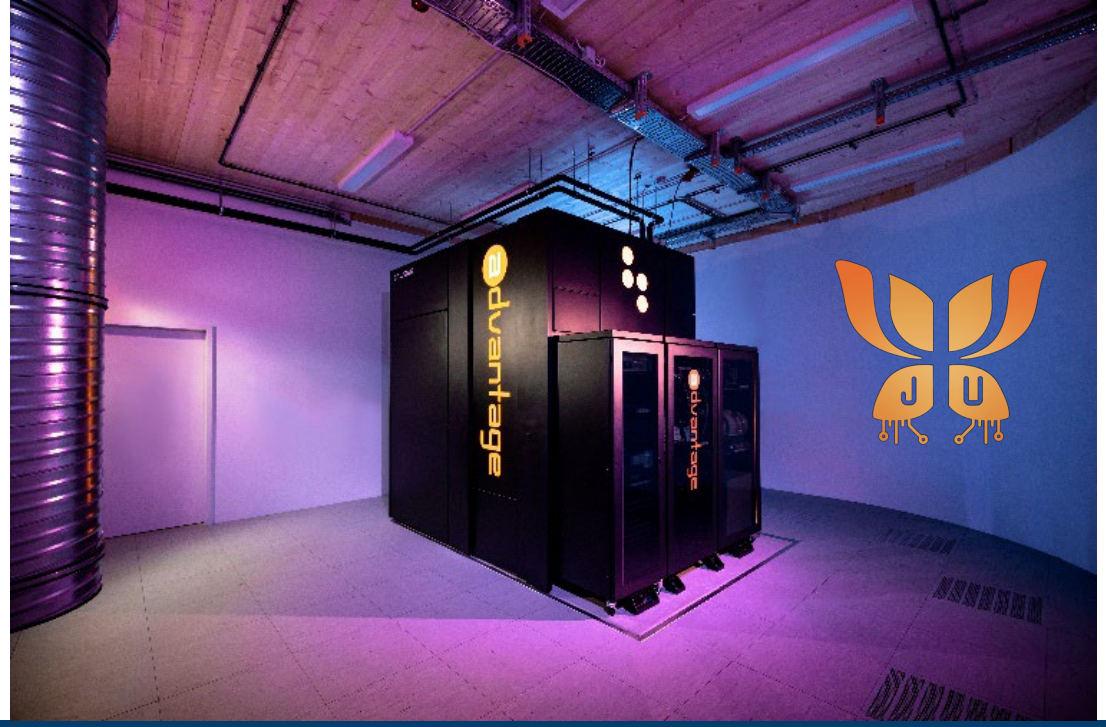




Michael Bresser

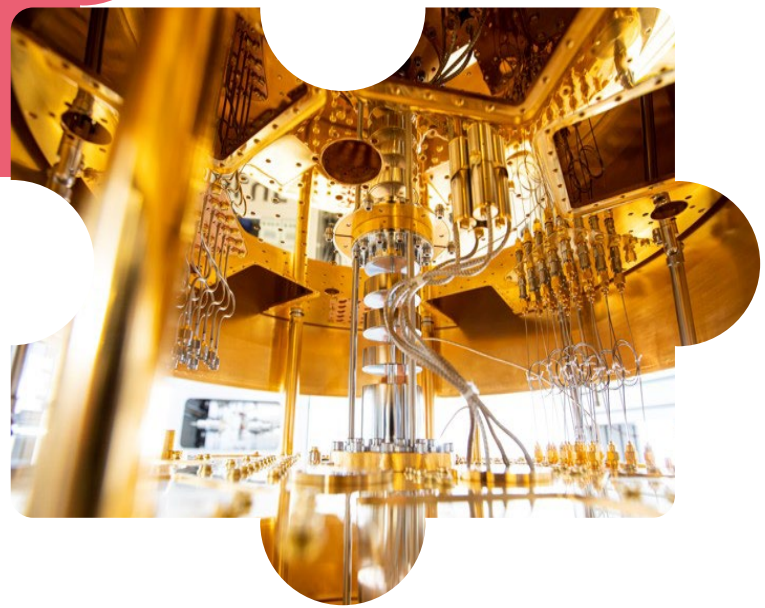
JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY


JUNIQ
2022



Solving the Tail Assignment Problem on the D-Wave Quantum Annealer

TSRC Workshop | June 13, 2022 | KRISTEL MICHIELSEN



Member o

NIQ

SER FACILITY