

How to set up In-House Quantum Computer Infrastructure

Integrating quantum computers at the Juelich Supercomputing Center

05.11.2026 I David Rabanus | d.rabanus@fz-juelich.de | 2nd Slovenian Quantum Computing Forum

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WHY WOULD YOU WANT A QUANTUM COMPUTER?

Because Quantum Computing promises...

...to solve some of our toughest problems



Drug design



Materials design



Supply chain logistics



Traffic optimization



Energy grid management



Vegetation evolution, climate change

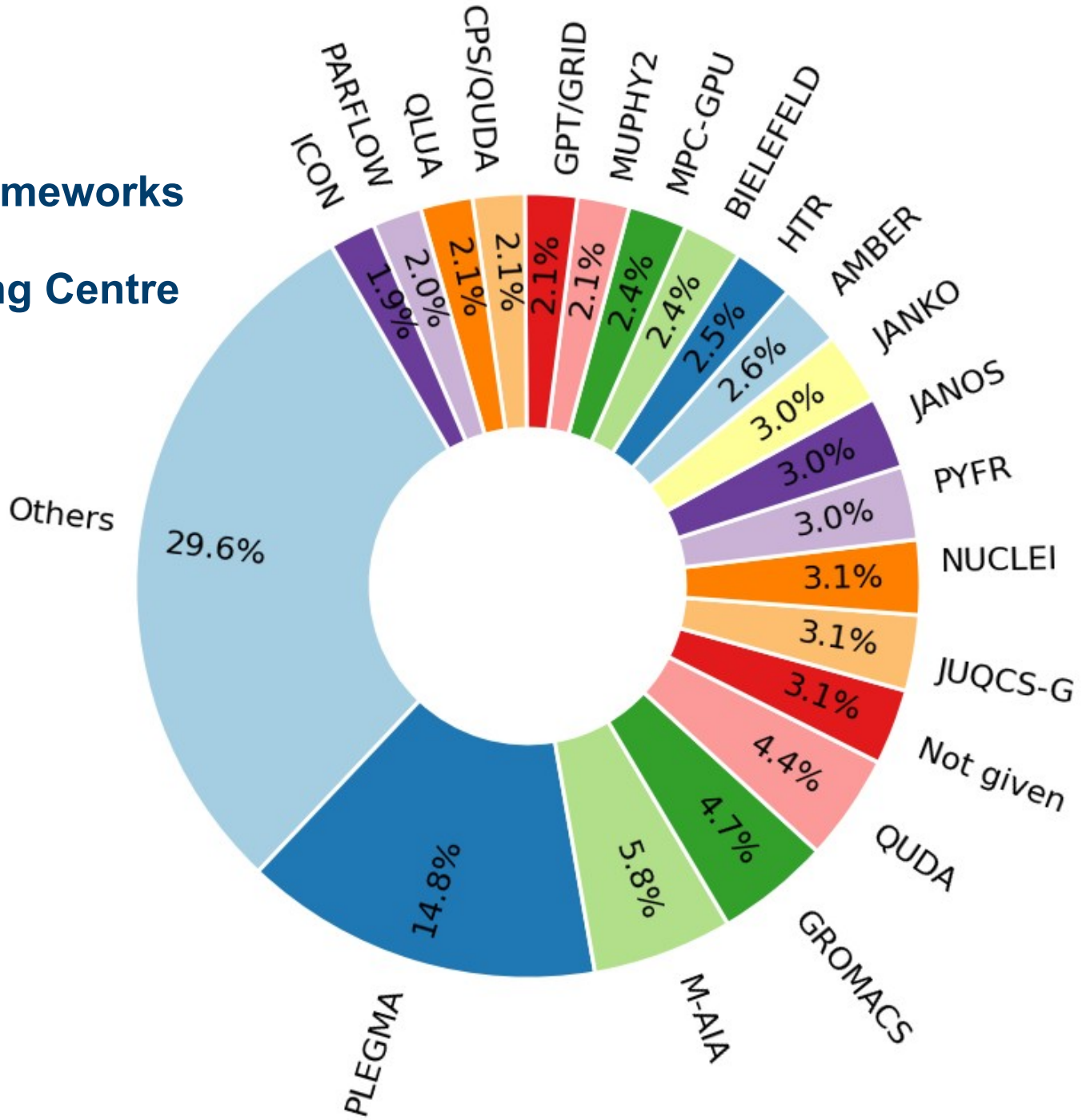


Human brain functionality - neural networks

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Deployed:

Classical compute frameworks at the Jülich Supercomputing Centre



Proposals for compute frameworks at the Juelich Supercomputing Centre

#	Software	Description	Typical Use Cases
1	AMBER	Molecular dynamics for biomolecules	Protein folding, drug design
2	Arbor	Neuroscience spiking network simulator	Brain modeling
3	BIELEFELD	Lattice QCD simulation framework	Quantum Chromodynamics research
4	Chroma	Lattice QCD large-scale simulations	Hadron structure, quantum physics
5	CPS/QUDA	Lattice QCD GPU library	Quantum chromodynamics on GPU
6	DynQCD	Dynamical fermion lattice QCD code	Particle physics simulations
7	GPT/GRID	Grid lattice QCD solver	Gauge field simulations
8	GROMACS	Molecular dynamics package	Biophysics, chemistry

#	Software	Description	Typical Use Cases
9	HTR	Hypersonic reacting flows simulator	Aerospace, combustion research
10	ICON	Climate and weather simulation model	Weather forecasting, climate
11	JANOS	HPC framework for multiphysics	Engineering simulations
12	JANKO	HPC framework for materials science	Material simulations
13	JUQCS-G	Quantum computer simulator with GPU	Quantum algorithm prototyping
14	M-AIA	AI/ML framework for scientific computing	Machine learning workloads
15	MMoCLIP	Multimodal contrastive learning	Vision-language AI models
16	MPC-GPU	GPU-based multiphysics simulations	Fluid dynamics, robotics

Proposals for compute frameworks at the Juelich Supercomputing Centre

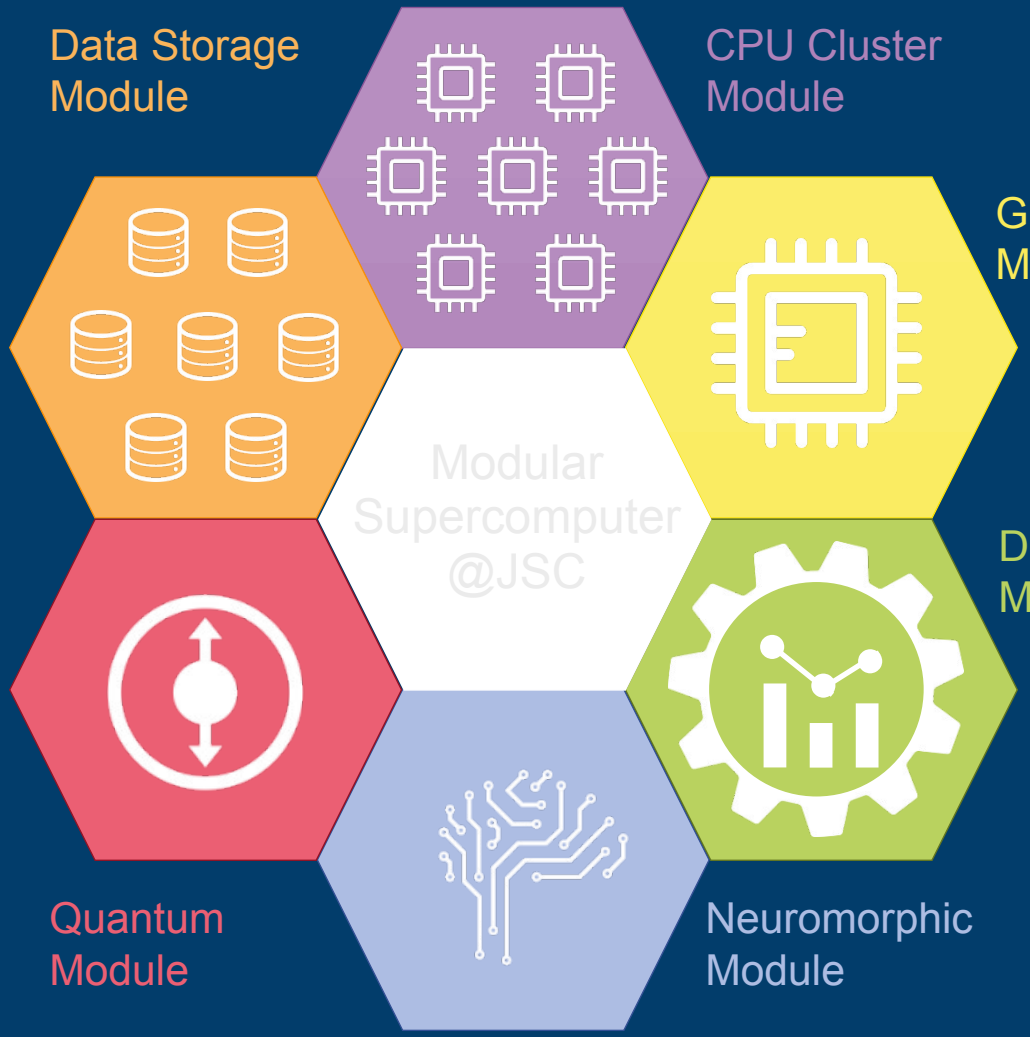
#	Software	Description	Typical Use Cases
17	MUPHY2	Multiphysics for complex fluids	Biophysics, plasma simulation
18	NAStJA	Lattice QCD analysis software	High-precision QCD analysis
19	NEKRS	GPU spectral element solver	Incompressible flows, CFD
20	NLP (Megatron)	Large-scale transformer NLP training	Natural language processing
21	NUCLEI	Nuclear structure and reaction model	Nuclear physics
22	PARFLOW	Parallel groundwater flow solver	Hydrology, environment modeling
23	PIConGPU	Particle-in-cell plasma simulations	Plasma physics, astrophysics
24	PLEGMA	HPC framework for quantum materials	Multiscale simulations
25	PYFR	Python high-order CFD solver	Turbulence, aerodynamics
26	QUANTUM ESPRESSO	Plane-wave DFT electronic structure package	Materials science, quantum chemistry
27	QUDA	GPU library for lattice QCD	Lattice QCD GPU acceleration
28	SOMA	Simulation environment for neuromorphic apps	Brain-inspired computing

JSC's Quantum Computing Strategy

Modular HPC and QC integration

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- Pushing for the tightest possible integration of quantum computers into the HPC environment
- Modular supercomputing architecture is ideal for integrating quantum computing capabilities into HPC workflows

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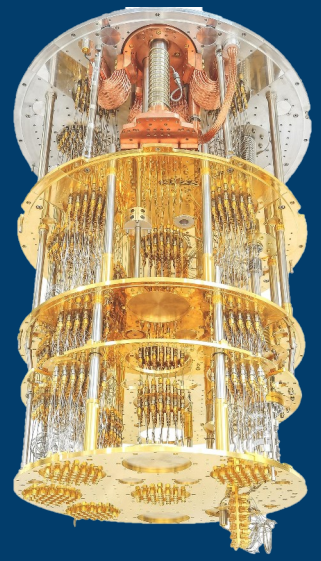
NOW THAT THIS WISH IS ESTABLISHED: WHAT'S NEEDED?

Quantum Computing

What is needed?

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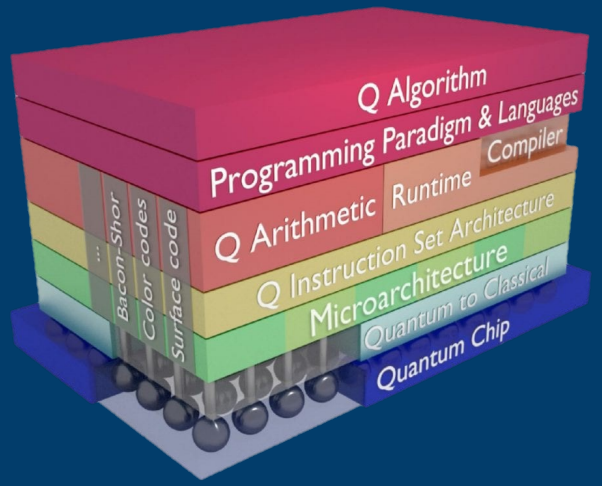
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Quantum computer hardware

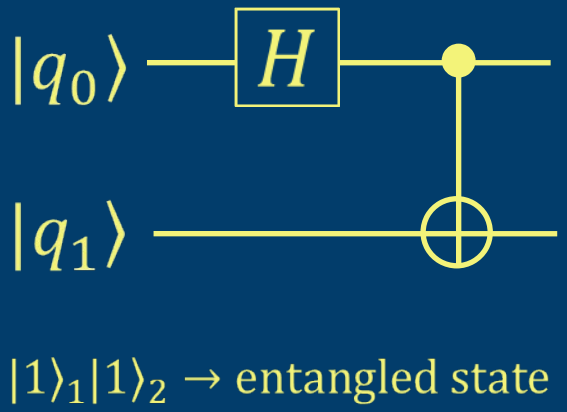
Quantum processor/chip



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Quantum software stack

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



Quantum algorithms

Sequence of controlled one- and two-qubit operations



Use cases & access

Quantum computer user infrastructure

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What is JUNIQ?

Juelich UNified Infrastructure for Quantum computing

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JUPSI D-Wave JADE Pasqal JION eleQtron JIQCER-5 IQM JAQUI-5 ARQUE SYSTEMS

JSC's Quantum Computing Strategy

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Four Pillars

WORLD-RECORD

I. Modeling and emulation (since 2004)

II. Provision of QC systems (since 2016)

III. HPC-QC integration (since 2017)

IV. Creation of a quantum computing user infrastructure (since 2016)



JUNIQ – Jülich UNified Infrastructure for Quantum computing



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QUANTUM COMPUTING HARDWARE: A PLETHORA OF PLATFORMS

A multitude of quantum computing platforms

Strengths, weaknesses and application domains

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	Key Strengths	Main Challenges	Representative Players	Best Fit For
Superconducting	• Very fast gates • Mature and available	• Cryogenics required • Noise and calibration	IBM, Google, IQM	• NISQ apps • Optimization • Simulation
Trapped Ions	• High fidelity • Long coherence times	• Slow gates; • Complex optical components	IonQ, Quantinuum	• Chemistry • Quantum simulation
Neutral Atoms	• Flexible connectivity • Promising large-scale analog systems	• Still maturing • Complex optical components	Pasqal, QuEra	• Optimization, • Quantum simulation
Photonic	• Low decoherence • Networking-friendly • Room-temperature	• Loss and deterministic gates are hard	Quandela, Orca	• Quantum machine learning • Communication • Sampling
Semiconductor Spin	• Compact • CMOS-compatible • Potential for mass manufacturing	• Fabrication variability • Precision control challenges	Intel, Arque	• Long-term scalable digital QC
Quantum Annealing	• Many qubits • practical for optimization heuristics	• Not universal	D-Wave, Qilimanjaro	• Discrete optimization • Quantum simulation
Topological	• Potentially noise-resistant • Strong fault-tolerance promise	• Highly experimental	Microsoft, academic labs	• Future fault-tolerant QC



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JSC's Quantum Computing Strategy

Provision and integration strategy

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Analog quantum computers

D-Wave



Quantum annealer

4400+
superconducting
flux qubits
Hosting since 2021

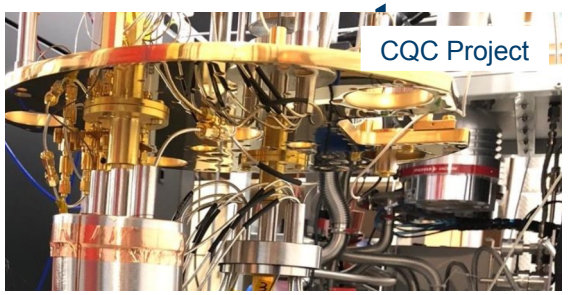
Pasqal



Quantum simulator

140+ neutral atom
qubits
Hosting since 2025

Digital quantum



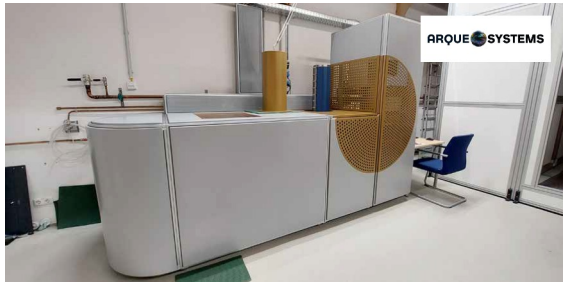
5 superconducting qubits
Hosting since 2023



4 trapped ion qubits
Hosting since 2026



5 superconducting qubits
Hosting since 2023



5 semiconducting qubits
Coming 2026

Further Systems: SOLID

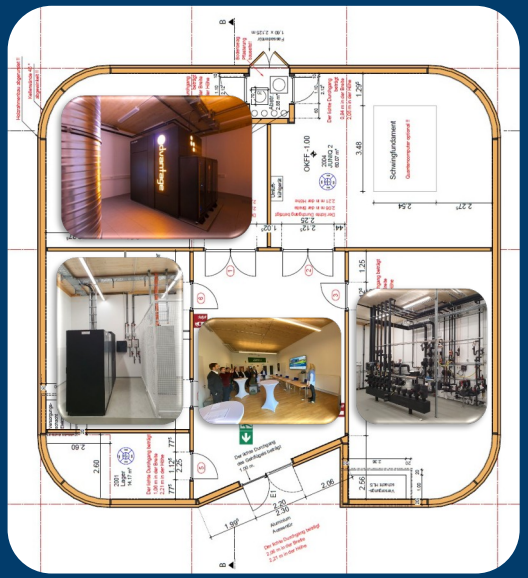
A multitude of quantum computing platforms

…but what are the site requirements to host one?

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	Cryogenic solid-state QPUs	Atomic QPUs	Photonic QPUs	Room temp. solid-state QPUs
Example platforms	**Superconducting** (IBM, Google, IQM,…). **Semiconducting** (Intel, Arque,…)	**Trapped-ion** (Quantinuum, eleQtron,…). **Neutral-atom** (Pasqal, Quera,…)	**Photonic** (Orca, Quandela,…)	**NV-centre** (XeedQ, Quantum Brilliance,…)
Operating temperature	**A few mK**	Room temp. **Extremely low drift!** (<0.3K/h)	Room temp. / 3-4K	Room temp. **Moderate drift (<2K/12h)**
Support infrastructure	UPS. **Powerful cryostat! --> N2 and He supply.**	UPS. Vibration isolation (e.g. floating optical table).	UPS. Sometimes small cryostat needed --> **He supply.**	UPS. **Vibration isolation** (e.g. dampers)
Power consumption	10-25kW	2-7kW	2-6kW	7kW
Lab environment	Air/liquid cooling. O2 monitoring.	**Clean room** reqs. (protects optical elements). **Thermal + humidity stabilization**. **Laser protection** (if >5mW in free space).	Air conditioning. Generally **low reqs.**	Air/liquid cooling. Generally **low reqs**.



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D-Wave The Quantum Computing Company™ **Advantage**

Cooling system

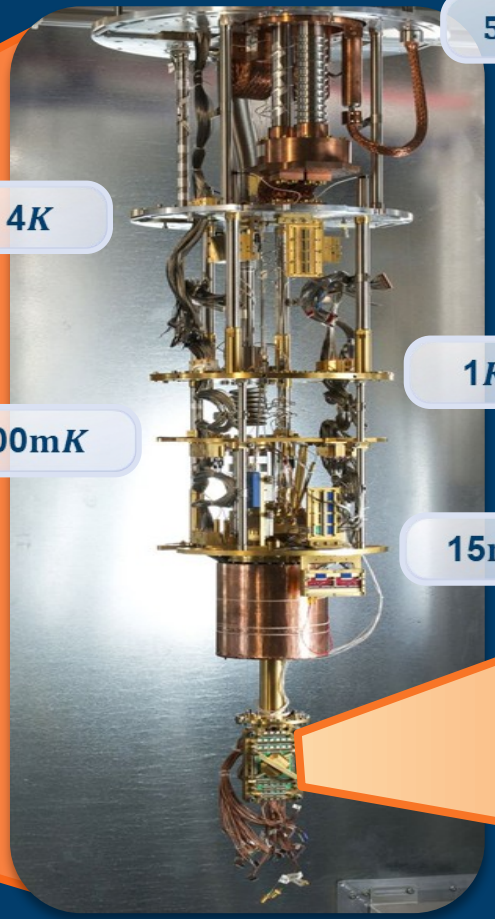
25kW power consumption

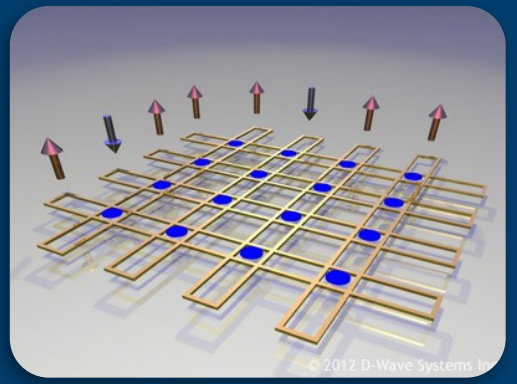
Quantum Processing Unit

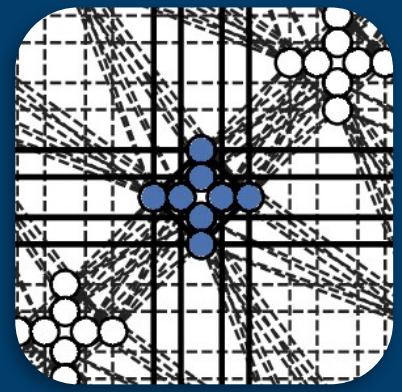
5640 superconducting qubits

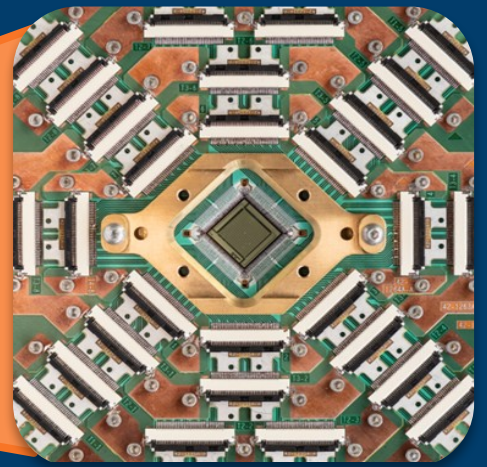
Pegasus topology with 40.484 couplers











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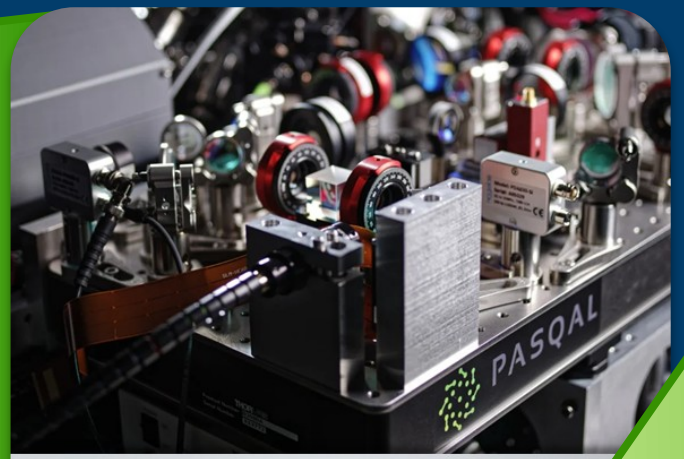
PASQAL **Fresnel**

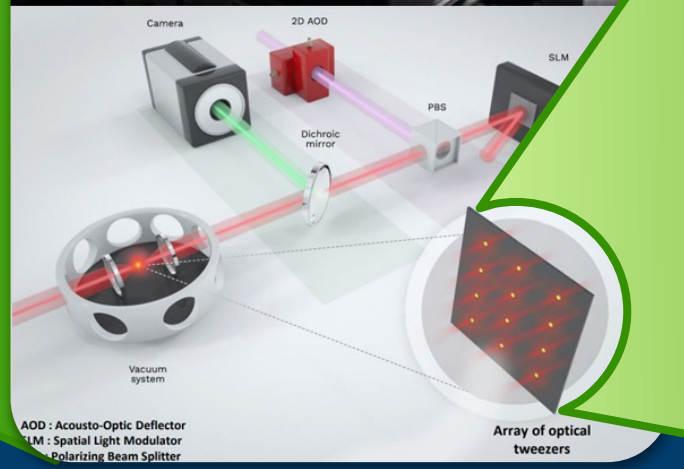
Quantum **P**rocessing **U**nit

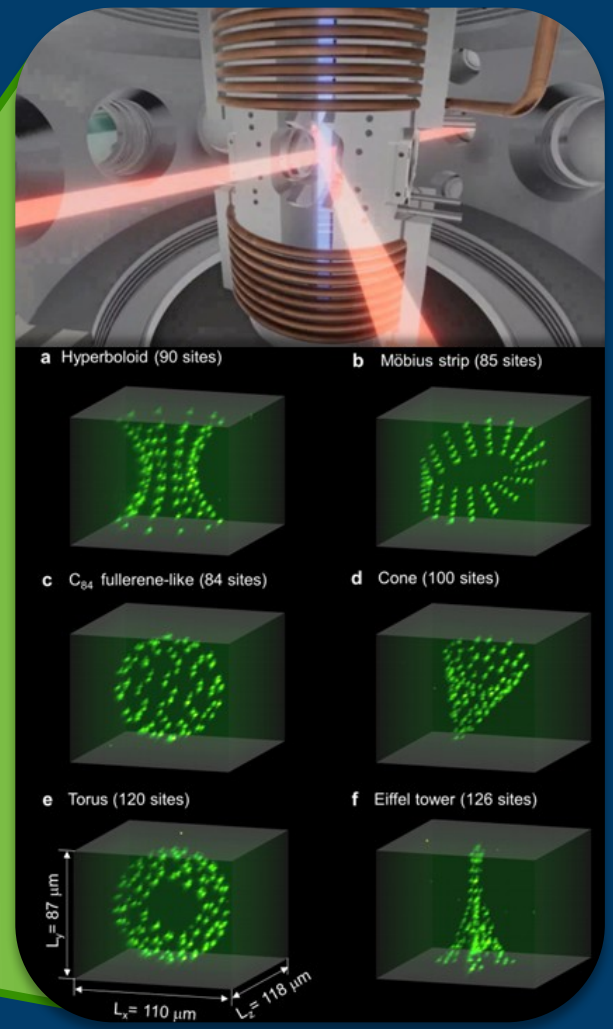
Quantum **R**egister

100 Rydberg atoms trapped in a 3D lattice









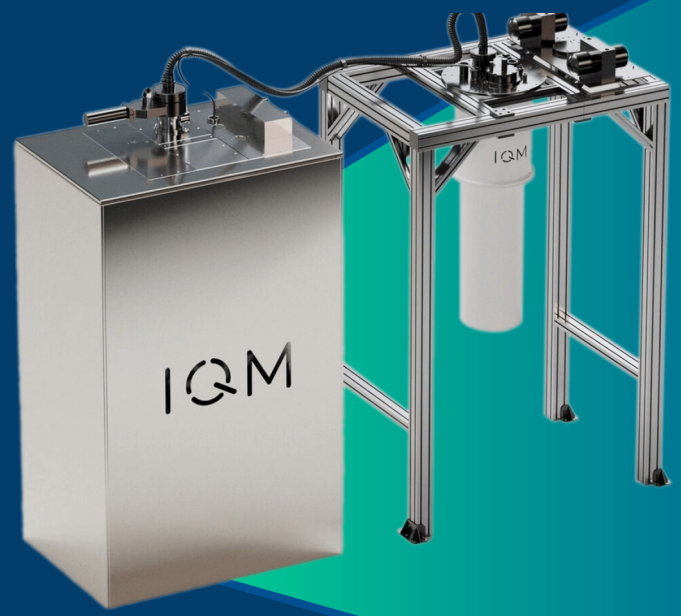
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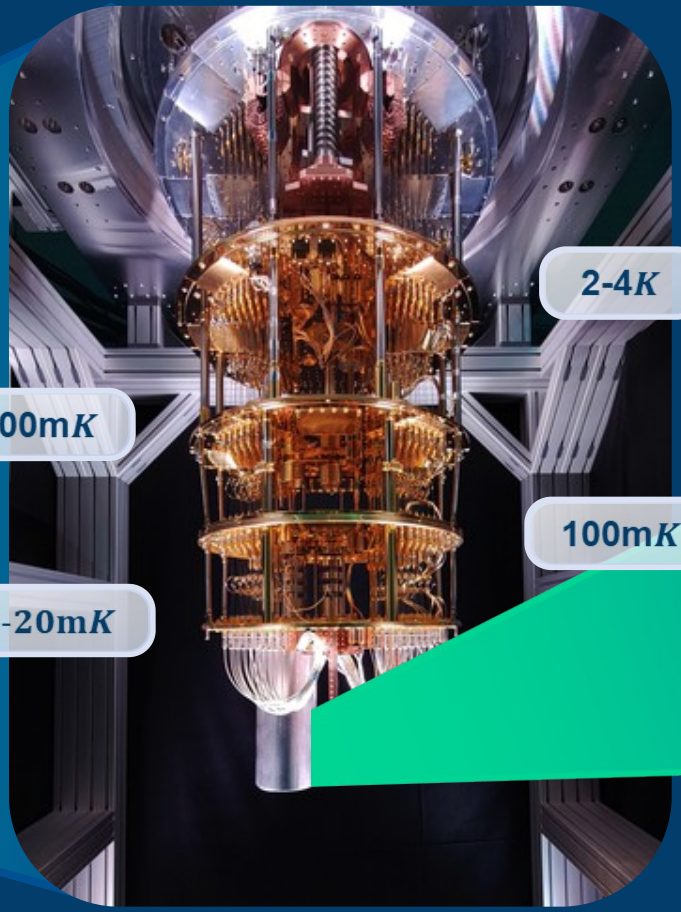
IQM Spark

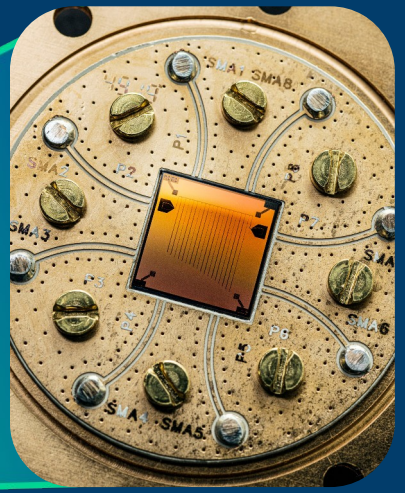
Cooling system

Quantum Processing Unit

5 superconducting qubits







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eleQtron

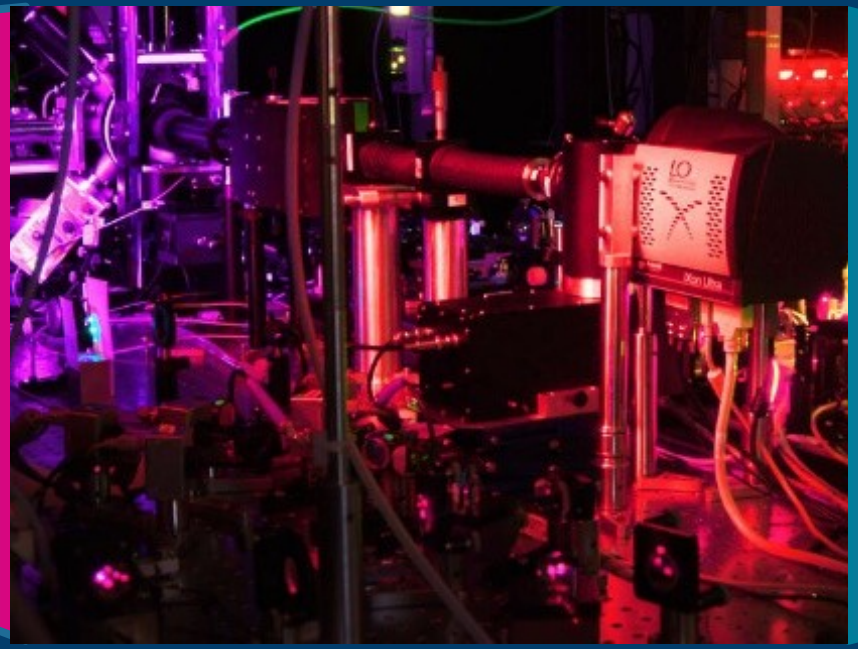
Quantum Processing Unit

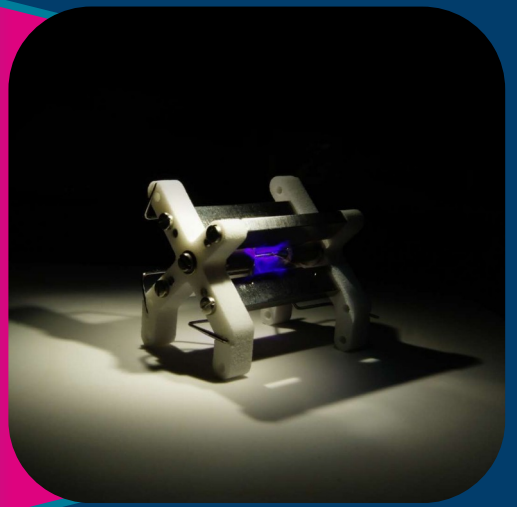
Linear ion trap

Quantum Register

20-30 trapped ion qubits controlled with MAGIC technology







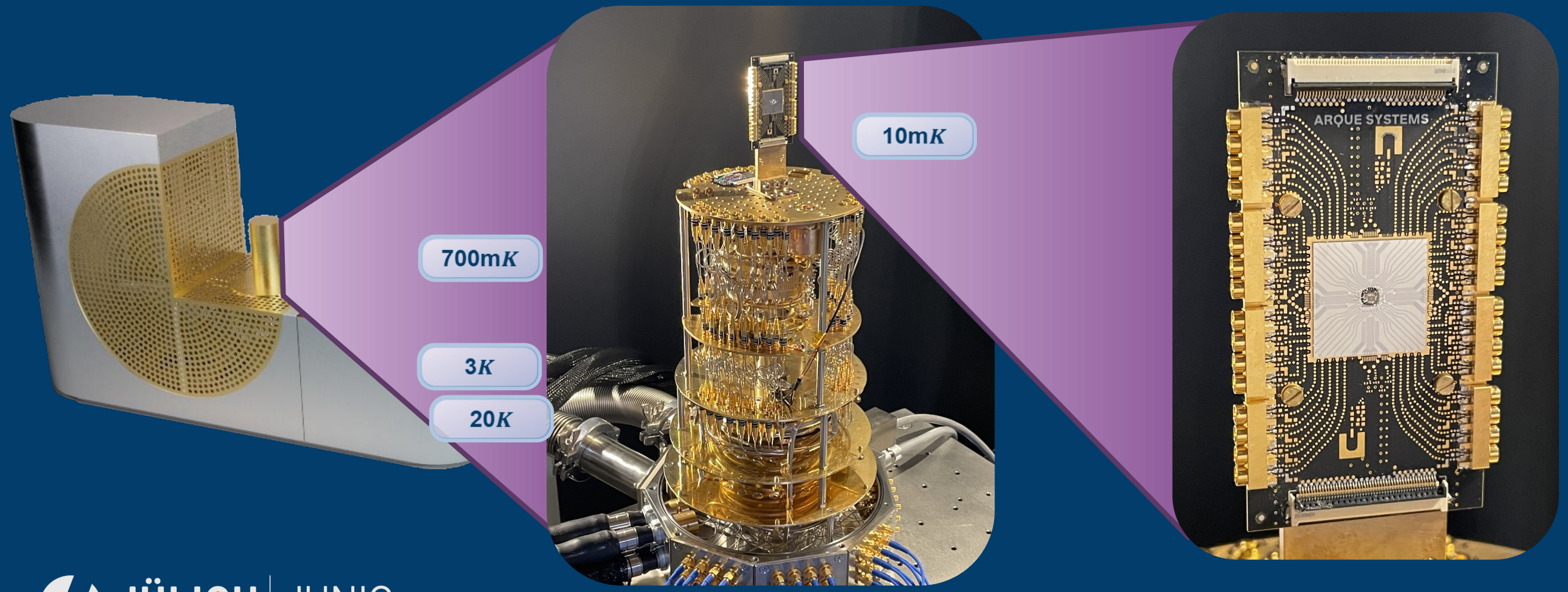
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ARQUE SYSTEMS

Cooling system

Quantum Processing Unit

5 electron-spin qubits



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INTEGRATING QUANTUM COMPUTERS INTO HIGH PERFORMANCE COMPUTING SYSTEMS

JSC's Quantum Computing Strategy

Pillar III: HPC-QC integration

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For practical quantum computing …



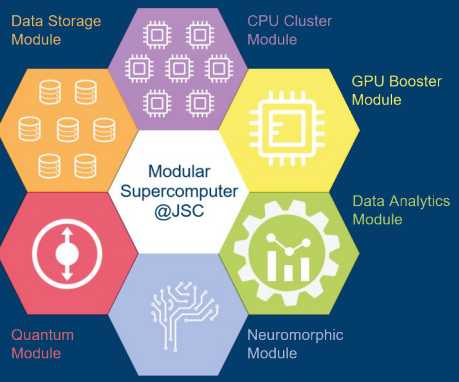
the best of both computer technologies must be combined

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HPC-QC integration models

Different QPU access models for different integration levels

QPU access model	Integration mode	QPU scarcity	Advantages	Disadvantages	Example	Compatibility
Cloud access	None	1 QPU / many HPC centers	No integration work Required on HPC Center.	**Scheduler on cloud-sided impedes real HPC workloads.**	Qiskit Leap²	N/A
HPC system-global	"Flexible"	Few (diverse) QPUs per 1 HPC center	Supports HPC workloads **Allows QPU-sharing**	Scheduling is tricky (HPC vs QC job timescales, resource sharing).	JÜLICH Forschungszentrum | JUNIQ QUANTUM USER FACILITY	Can support cloud access too
HPC node local	"Fixed"	Many QPUs per 1 HPC center	**Highest performance potential** Delegates scheduling issues.	Assumes QPUs are widely available resources (like GPUs) No QPU sharing.	NVIDIA CUDA QUANTUM	None



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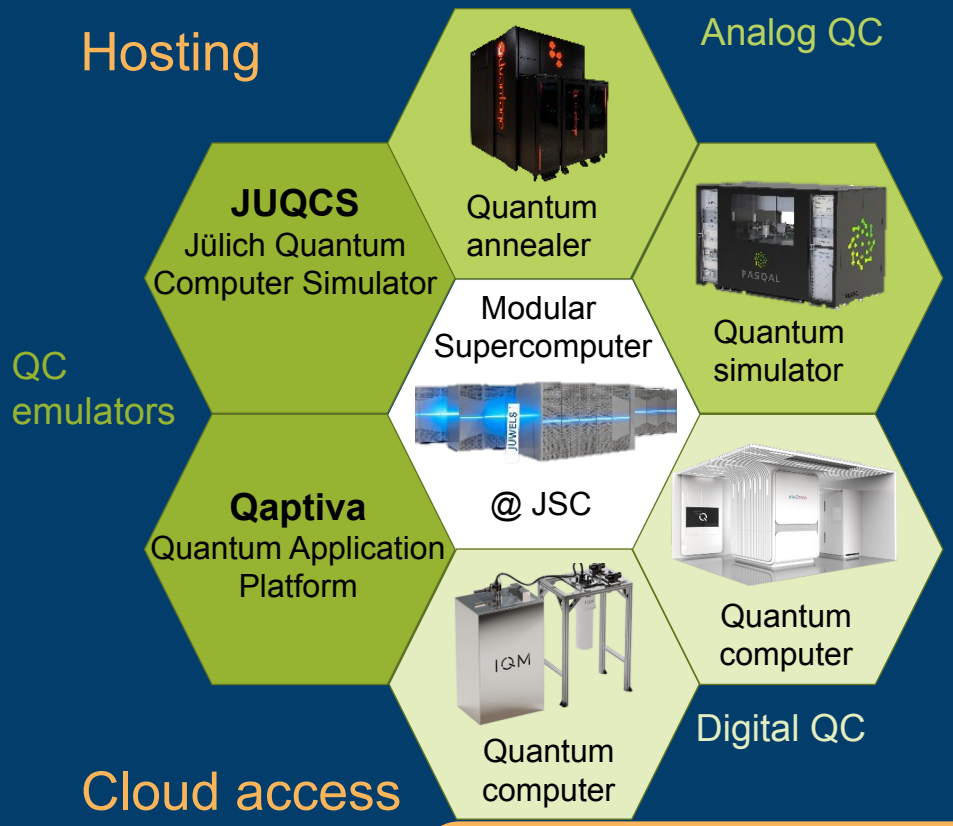
USER FACILITY

JSC's Quantum Computing Strategy

Creation of a quantum computing user infrastructure - JUNIQ

Bundesministerium für Bildung und Forschung

Ministerium für Kultur und Wissenschaft des Landes Nordrhein-Westfalen



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

Rolling call for peer-reviewed access:

https://www.fz-juelich.de/en/jsc/systems/quantum-computing/juniq-facility/access-service-and-support

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LLview-quantum

Continuous benchmarking of QPUs

LLview:

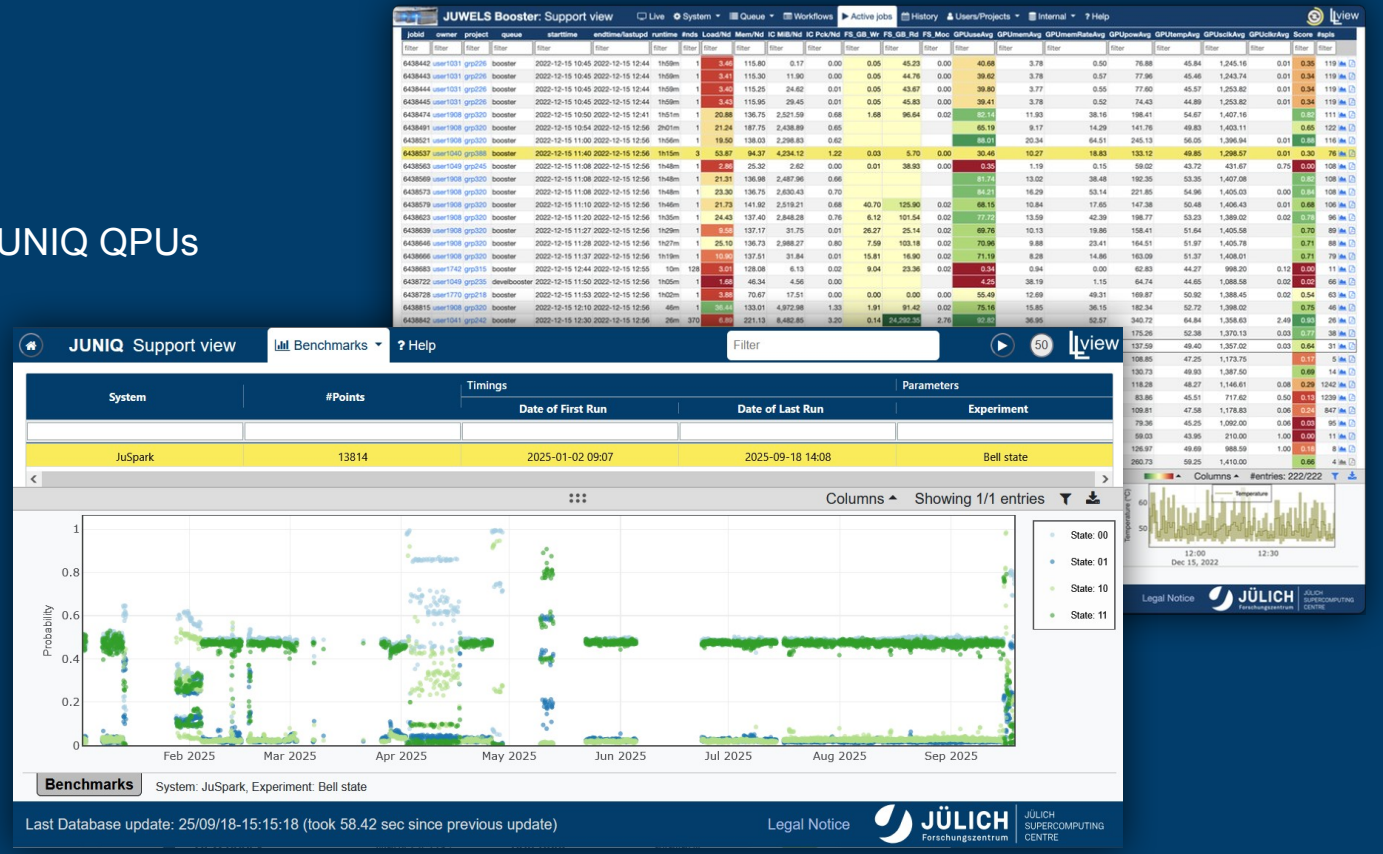
- Tool for HPC system monitoring and job reporting
- Currently being extended for continuous benchmarking of JUNIQ QPUs

Supported benchmarks (so far):

- Digital (IQM Spark) – Bell state
- Q. annealer (D-Wave JUPSI) – Ferromagnetic state
- Q. simulator (Pasqal JADE) – Antiferromagnetic state
- Multimodal: Volumetric approach w/ adiabatic protocols

Next steps:

- Extending benchmark suite
- Implementing HPCQC job-reporting (include timings, QPU usage, etc.)



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