JÜLICH Forschungszentrum | JÜLICH SUPERCOMPUTING CENTRE

# QUANTUM INFORMATION PROCESSING

## SIMULATION ON/OF QUANTUM COMPUTERS


- **High performance computing for simulating quantum computers up to 48 qubits**
- **Modeling and simulation of physical models of multi-qubit systems**
- **Development of algorithms and prototype applications**
- **Modular quantum-HPC hybrid computing**

### Panel Simulating quantum computers

Development of software to
- validate designs of quantum processors
- investigate the performance of quantum algorithms

Our emulator JUQCS – Jülich Universal Quantum Computer Simulator – achieved a world record of simulating 50 qubits on JUPITER, Europe's first exascale supercomputer

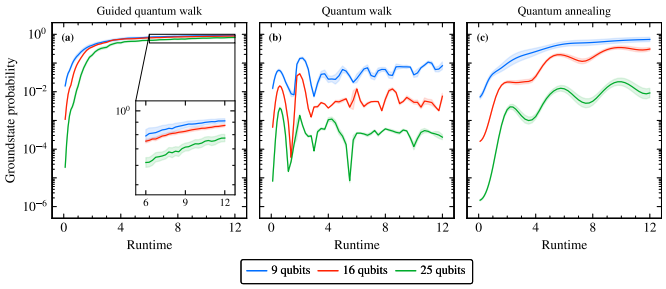
H. De Raedt et al., **arXiv:2511.03359** (2025)
H. De Raedt et al., **Comp. Phys. Comm**. 237, 47-61 (2019)
D. Willsch et al., **Comp. Phys. Comm**. 278, 108411 (2022)
F. Arute et a., **Nature** 574, 505–510 (2019)


*Benchmarking Google's quantum processor Sycamore*

### Guided Quantum Walk

New quantum optimization algorithm bridging quantum walk (QW) and quantum annealing (QA) algorithms.

S. Schulz et al., **Phys. Rev. Research** 6, 013312 (2024)




*Performance comparison of the GQW (a), the QW (b), and QA (c) as a function of the total evolution time T on traveling salesperson problem instances with N = 9, 16, 25 qubits.*

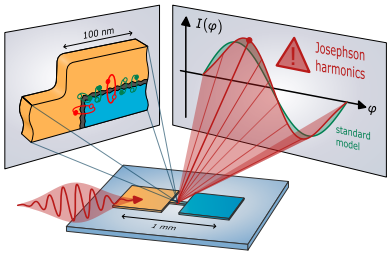
### Modeling & simulating superconducting qubits

The standard Josephson junction model – in use for over 15 years – fails to accurately describe energy spectra of state-of-the-art superconducting qubits.

A new Josephson harmonics model yields orders of magnitude better agreement with experiments.

Engineering Josephson harmonics in future transmon qubits can reduce errors by an order of magnitude.

D. Willsch et al., **Nature Physics** 20, 815 - 821 (2024)

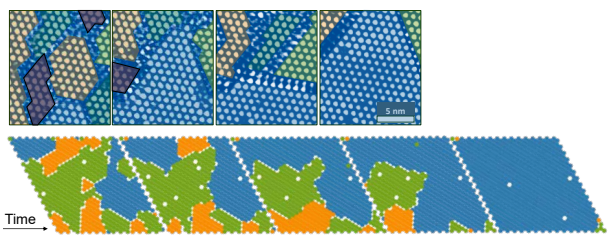



*Spectroscopy experiments (bottom) show deviations from the sinusoidal current-phase relation (green curve) of the standard Josephson junction model (right). New understanding of junction physics (left) and HPC simulations led to the Josephson harmonics model (right, red curve).*

### Quantum domain reconfiguration dynamics in a 2D electronic crystal and a quantum annealer

Reproducing the time evolution and temperature dependence of domain reconfiguration, the quantum annealer confirms that pink noise governs both experimental and simulated dynamics, offering a new approach to studying non-equilibrium quantum many-body systems.

J. Vodeb et al., **Nature Communications** 15, 4836 (2024)




*Top: STM measurements showing domain reconfigurations in 1T-$TaS_2$.*
*Bottom: Emulation of the STM measurement process on a quantum annealer.*

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