Simone Montangero
Padua University

Dipartimento di Fisica e Astronomia Galileo Galilei
INFN Istituto Nazionale di Fisica Nucleare
Università degli Studi di Padova

https://www.supercomputing-icsc.it

ICSC Founding Members: a public private partnership

25

Universities

12

Research Institutions

15

Strategic private partners

Public Research Institutions Founding Members: a pervasive initiative throughout Italy

National Institutions

INFN Istituto Nazionale di Fisica Nucleare
CINECA
ENEA
Consiglio Nazionale delle Ricerche
INGV
Consortium GARR
INAF ISTITUTO NAZIONALE DI ASTROFISICA

Hub Only

UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
UNIVERSITÀ DI PARMA
OGS

Private Founding Members: strategic players for digital transformation

eni
LEONARDO
Terna Driving Energy
sogei
autostrade per l'italia
ENGINEERING THE DIGITAL TRANSFORMATION COMPANY
FINCANTIERI
HUMANITAS RESEARCH HOSPITAL
UPMC LIFE CHANGING MEDICINE
FERROVIE DELLO STATO ITALIANE
UnipolSai ASSICURAZIONI
ThalesAlenia Space a Thales / Leonardo company
INTESA SANPAOLO

Highly-qualified group of large leading companies covering most of the strategic industrial sectors involved by digital transformation at the national level

fondazione innovazione urbana

Strategic partner to implement and develop the digital twin pilot case of an urban complex system

iFAB INTERNATIONAL FOUNDATION BIG DATA & ARTIFICIAL INTELLIGENCE FOR HUMAN DEVELOPMENT

Industry-driven not-for-profit international organization aimed at: (1) aggregating companies, including SMEs, to engage with ICSC through a structured partnership, (2) funding research and innovation projects, (3) promoting the Big Data Technopole

The ICSC will include ten **thematic Spokes** and one ***Infrastructure* spoke**

EDUCATION & TRAINING, ENTREPRENEURSHIP, KNOWLEDGE TRANSFER, POLICY, OUTREACH

1 FUTURE HPC & BIG DATA

2 FUNDAMENTAL RESEARCH & SPACE ECONOMY

3 ASTROPHYSICS & COSMOS OBSERVATIONS

4 EARTH & CLIMATE

5 ENVIRONMENT & NATURAL DISASTERS

6 MULTISCALE MODELING & ENGINEERING APPLICATIONS

7 MATERIALS & MOLECULAR SCIENCES

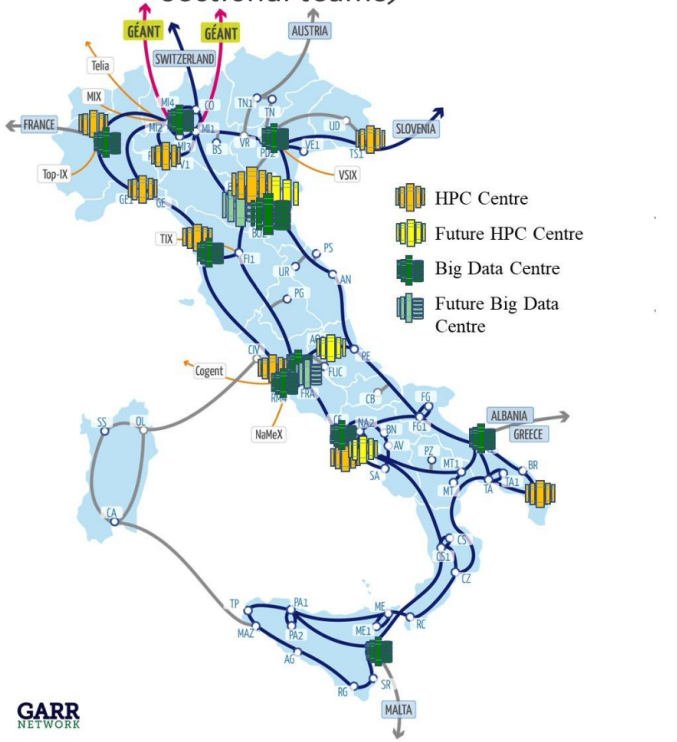
8 IN-SILICO MEDICINE & OMICS DATA

9 DIGITAL SOCIETY & SMART CITIES

10 QUANTUM COMPUTING

0 SUPERCOMPUTING CLOUD INFRASTRUCTURE

equipped with high-level teams of experts integrating the Spokes working groups (mixed cross-sectional teams)



ICSC: Main figures over the next 3 years

1575

Personnel shared by partners

250+

New researchers

300+

New PhDs

40 ME

Open calls

Sustainable & Well balanced (territory, gender, age, size)

40 ME

Innovation grants

SPOKE 10
QUANTUM COMPUTING

Istituzione leader

POLITECNICO MILANO 1863

Istituzione co-leader

UNIVERSITÀ DEGLI STUDI DI PADOVA

ENTI Partecipanti

CINECA
Consiglio Nazionale delle Ricerche
INAF ISTITUTO NAZIONALE DI ASTROFISICA
INFN Istituto Nazionale di Fisica Nucleare
ISTITUTO ITALIANO DI TECNOLOGIA
SAPIENZA UNIVERSITÀ DI ROMA
UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
Università di Catania
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
UNIVERSITÀ DI PISA
UNIVERSITÀ DI PAVIA

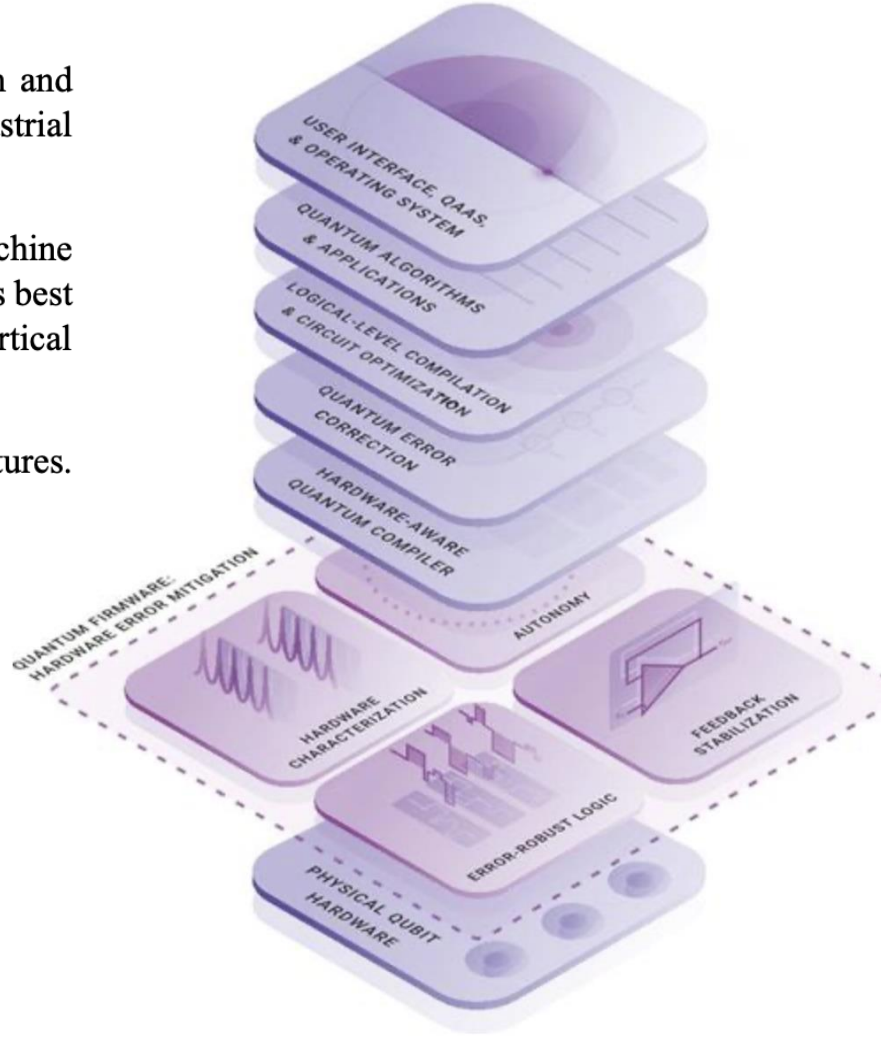
Privati Partecipanti

enel
iFAB INTERNATIONAL FOUNDATION BIG DATA AND ARTIFICIAL INTELLIGENCE FOR HUMAN DEVELOPMENT
INTESA SANPAOLO
sogei
ThalesAlenia Space a Thales / Leonardo company

Layer 1. Applications. High-level quantum applications for the solution of special-purpose research and industrial use cases (chemistry, biology, high energy and condensed matter physics, data-science. industrial optimization, etc.).

Layer 2. Algorithms. General purpose algorithms (e.g., linear algebra, variational eigensolvers, machine learning, hard optimization, etc.). The research challenge is to identify general-purpose library algorithms best suited to be accelerated on near-term quantum computers and that can be used as building blocks for vertical applications.

Layer 3. Emulation. Software for the emulation on classical computers of particular quantum architectures. Benchmarking and verification of quantum computations.



Layer 4. Compilation. Tools for compilation and optimization of algorithms. Toolchains for hw/sw codesign of special-purpose quantum accelerators.

Layer 5. Firmware. Low-level software for the physical operation of specific quantum computers: control of physical operations, optimization of the operations, measurement protocols, scheduling of the operations, automatic calibration, etc.

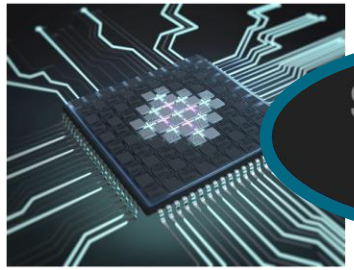
Layer 6. Hardware. Quantum computer hardware components. Here, the research challenge is to play a role in the international production chain.

Spoke 10 – Quantum Computing

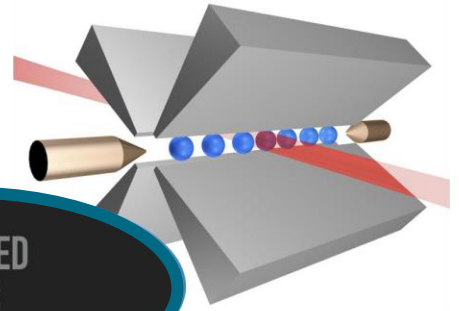
WP1. Software (Leader: INFN): Development and application of high-level quantum software for algorithms solving general purpose problems, scientific and industrial applications: T1.1 New algorithms (Pavia, Bologna, IIT, Catania, CINECA, CNR, Pisa, Sapienza, Bari, Polimi, Padova); T1.2 Applications and use cases (IIT, Bologna, CINECA, CNR, INAF, INFN, Pavia, Pisa, Bari, Bicocca, Polimi, Padova)

WP2. Mapping, compilation and quantum computing emulation (Leader: CINECA): Development of software toolchain for compilation, benchmarking, verification, emulation of quantum computers and algorithms: T2.1 Mapping and compilation (Bologna, CNR, Pisa, Polimi); T2.2 Emulation (CINECA, INAF, Bari, Padova)

WP3. Firmware and hardware platforms (Leaders: CNR, Catania): Development of low-level software for the physical operation of quantum computers. Development and support of the quantum computer hardware chain: T3.1 Photonic (Sapienza, CNR, Bicocca, Pavia, Napoli); T3.2 Superconducting circuits (Napoli, INFN, Bicocca, CNR, Catania); T3.3 Atoms (CNR, Padova); T3.4 Ions (Padova, CNR); T3.5 Models and firmware (Catania, Polimi, Bari, Padova, Bicocca, CNR, Pisa)

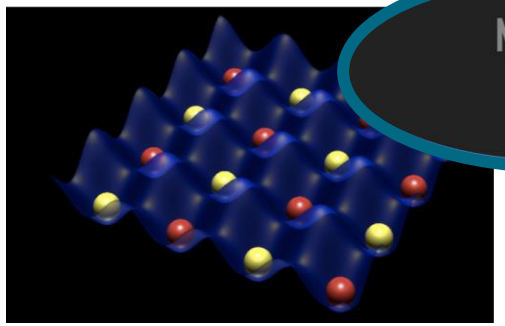


SUPERCONDUCTING CIRCUITS

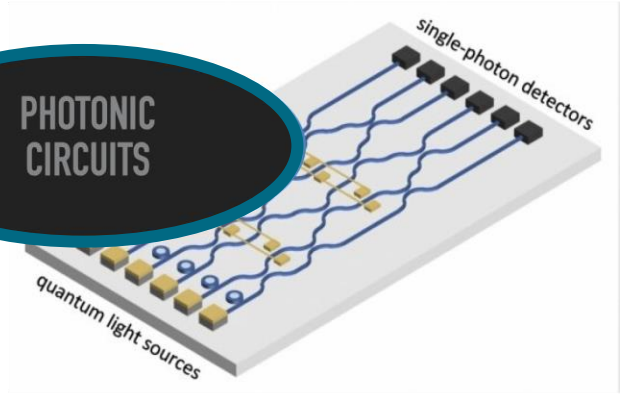


TRAPPED IONS

Physical systems



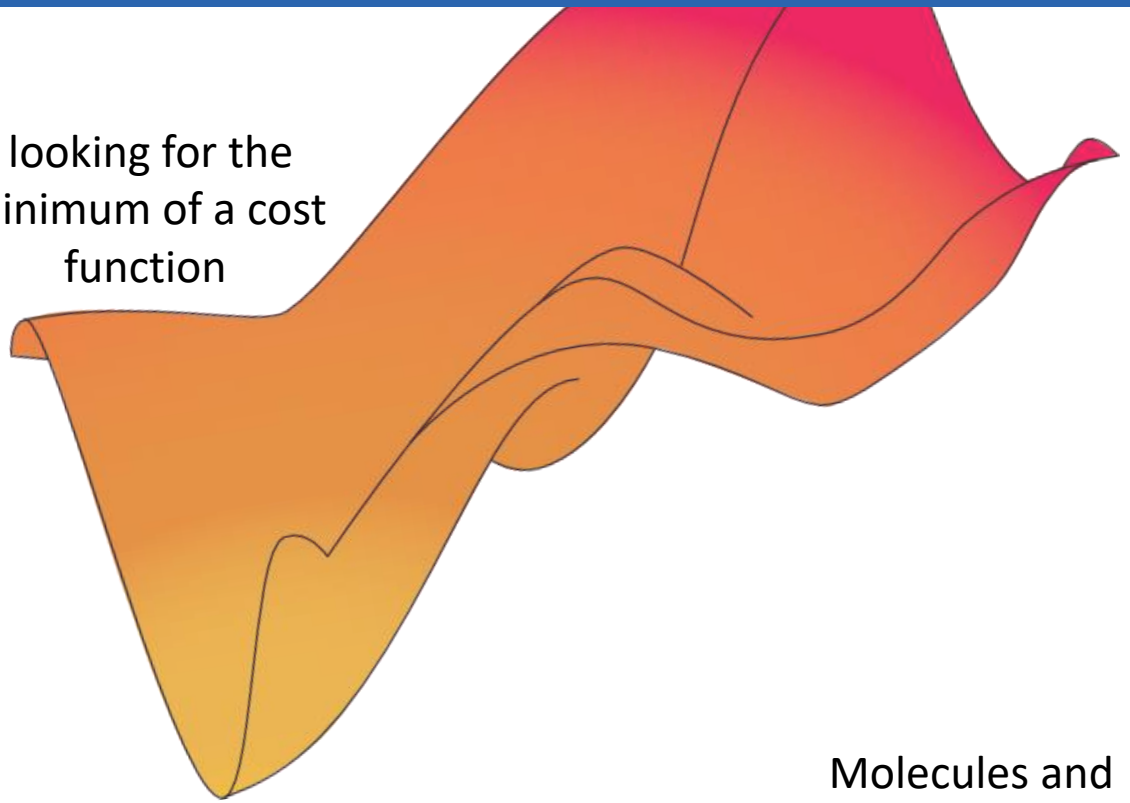
NEUTRAL ATOMS



PHOTONIC CIRCUITS

Earth Observation

looking for the minimum of a cost function



Machine Learning

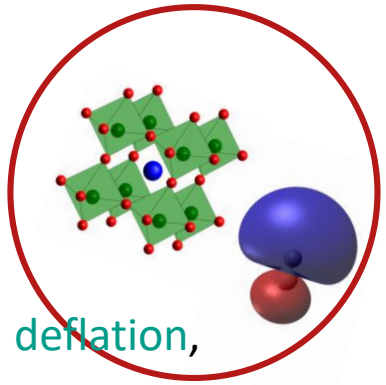
Combinatorial optimization problems

(QAOA, quantum annealing, …)

Traffic

Portfolio optimization

Molecules and Materials



(VQE, quantum deflation, …)

Results WP1: Algorithms and Applications

- **Quantum Machine Learning**
- Quantum Applications in Science and Technology
- Quantum Simulation and Modeling
- Hybrid Quantum-Classical Systems and Applications

- Desing and preliminary implementation of quantum machine learning algorithms (e.g., quantum neural networks, variational algorithms, and specific problem-solving algorithms)
  - (Bicocca, Catania, Cineca, Infn, Napoli, Pavia, Pisa, Polimi, Sapienza)

Results WP1: Algorithms and Applications

- Quantum Machine Learning
- **Quantum Applications in Science and Technology**
- Quantum Simulation and Modeling
- Hybrid Quantum-Classical Systems and Applications

- Practical application of quantum computing in various specific fields such as image classification, particle tracking, bio-inspired optimization techniques, classical fluids, and N-body simulations, among others.
  - (Cineca , IIT, INAF, INFN, Napoli, Pavia, Sapienza)

Results WP1: Algorithms and Applications

- Quantum Machine Learning
- Quantum Applications in Science and Technology
- **Quantum Simulation and Modeling**
- Hybrid Quantum-Classical Systems and Applications

- Preliminary application of quantum computing for simulations of quantum electrodynamics, quantum thermodynamics and other quantum systems.
  - (Bari, Catania, Pisa)

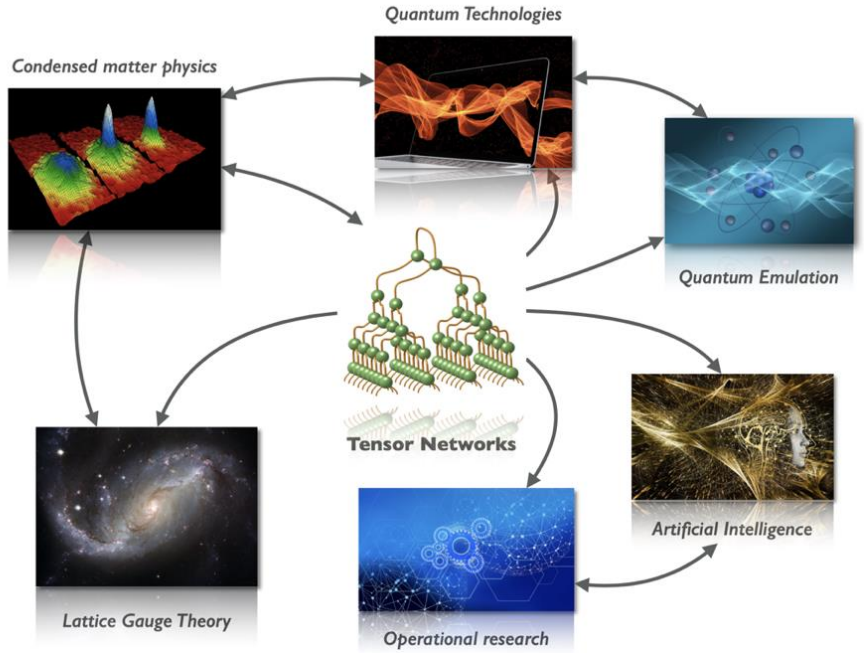
Results WP1: Algorithms and Applications

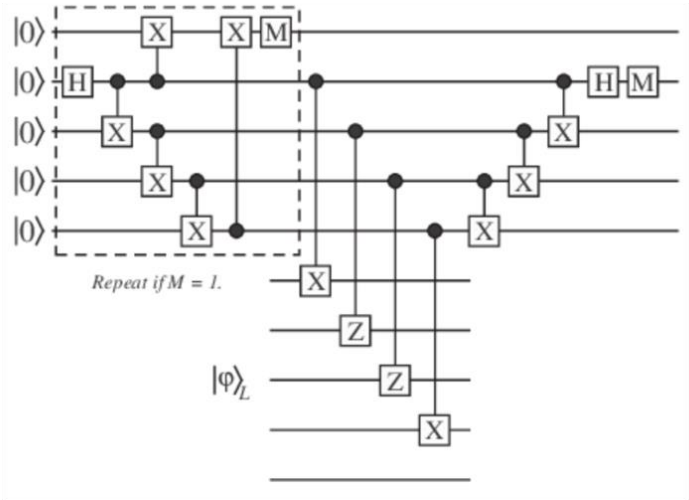
- Quantum Machine Learning
- Quantum Applications in Science and Technology
- Quantum Simulation and Modeling
- **Hybrid Quantum-Classical Systems and Applications**

- Integration of quantum and classical computing systems. This includes the development of hybrid infrastructures, benchmarking, and comparative studies of quantum and classical algorithms, and the exploration of hybrid quantum-classical algorithms for specific problem-solving
  - (Cineca, Catania)

Results WP2: Compilers, Emulators and Benchmarks

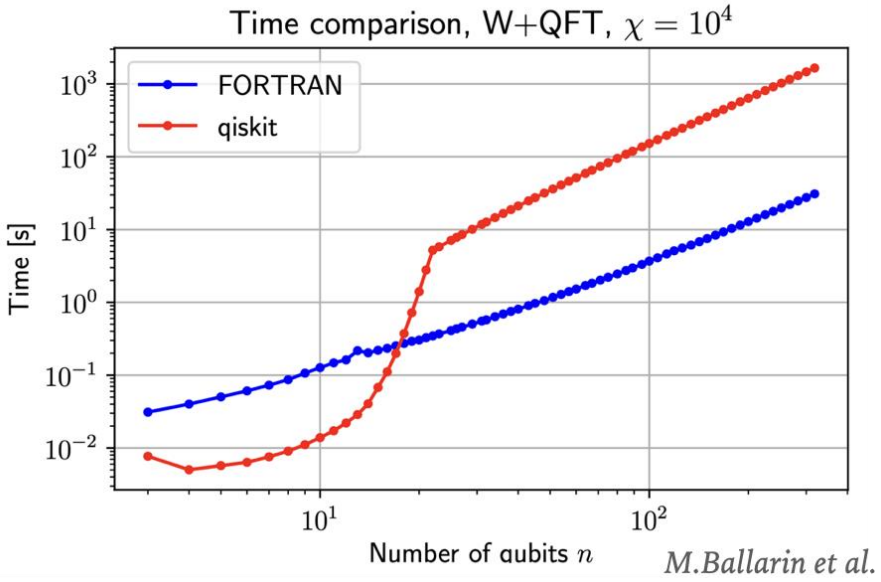
- Quantum Simulations and Emulation
- Quantum Benchmarks





HPC e Quantum Computing

Un binomio sempre più concreto



www.quantumtea.it

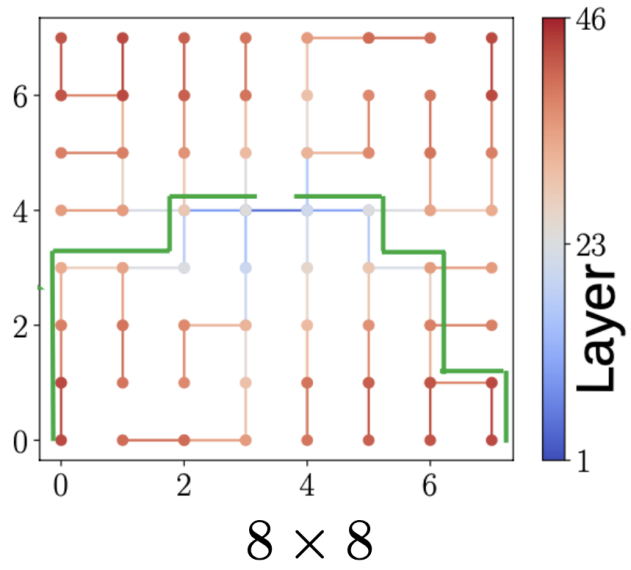
ABOUT APPLICATIONS PLATFORMS PUBLICATIONS PEOPLE RUNNING Q.TEA PARTNERS EVENTS CONTACTS

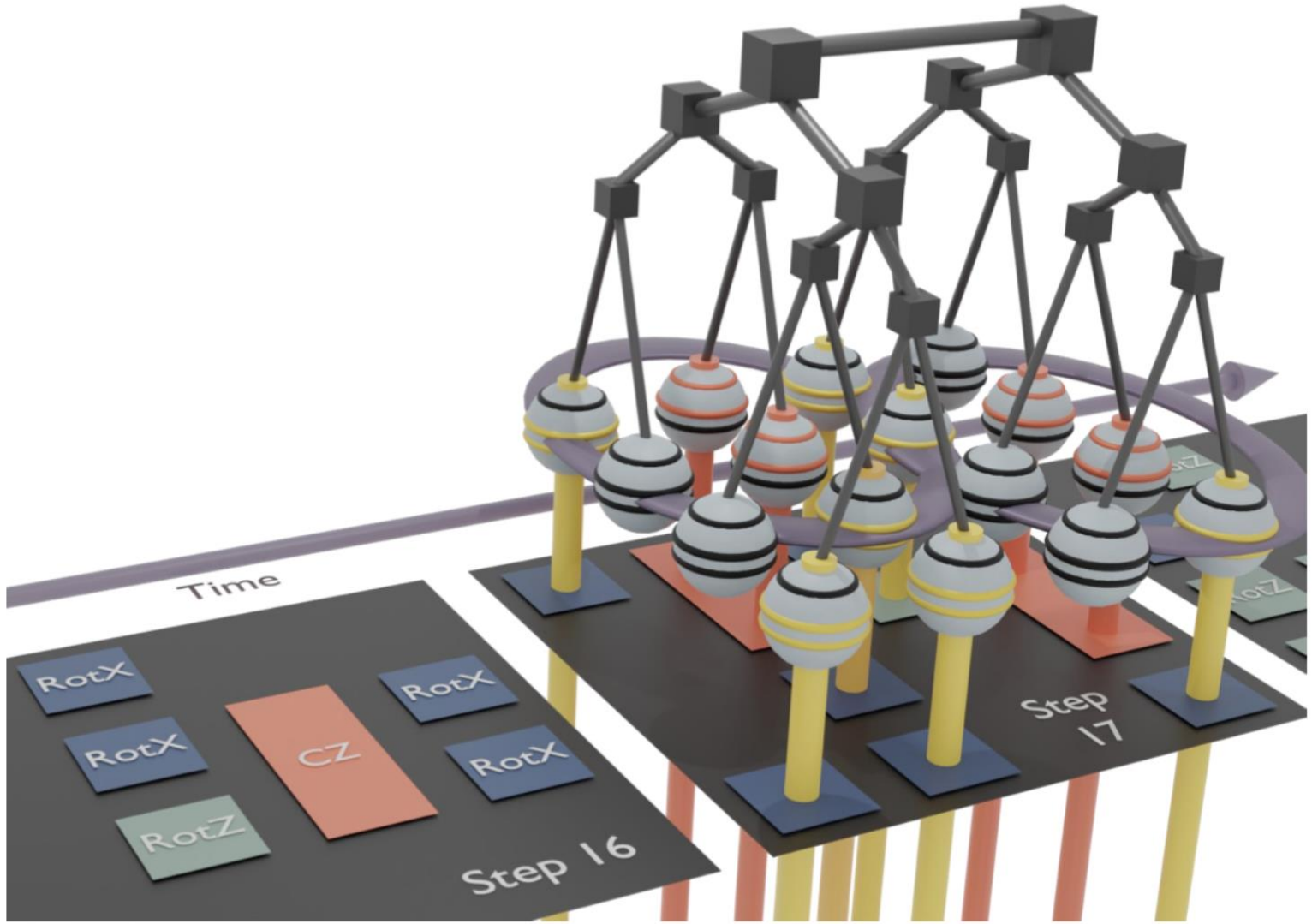
About

The Quantum TEA combines a suite of applications using tensor network methods to simulate quantum systems and solve machine learning tasks.

VIEW MORE

Digital twin of a
Rydberg atom quantum computer





T. Felser, S. Notarnicola, S. Montangero PRL (2021)
D. Jaschke et al arxiv:2210.03763

Results WP2: Compilers, Emulators and Benchmarks

- Quantum Simulations and Emulation
- **Quantum Benchmarks**

- Desing of an evaluation infrastructure for the comparative benchmarking of quantum algorithms against classical ones
  - (Padova, Polimi)

Results WP3: Firmware and Hardware

- Superconducting Systems
- Photonic Systems

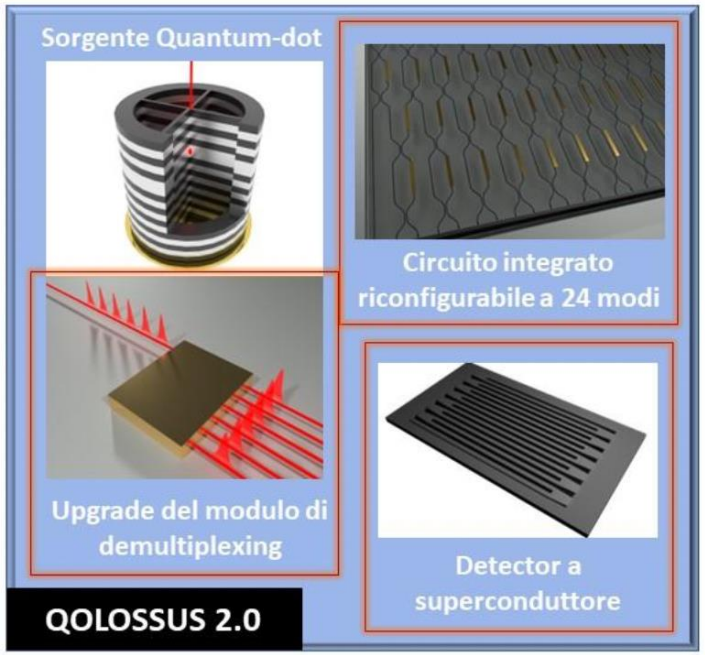
Results WP3: Firmware and Hardware

- **Superconducting Systems**
- Photonic Systems

- Design and simulation of 2D and 3D superconducting qubits, fabrication techniques, control and readout mechanisms using advanced technologies like FPGA boards, and development of prototype quantum processors. Characterization of multi-qubit arrangements and development of innovative read-out devices.
  - (Bicocca, INFN, Napoli)

Results WP3: Firmware and Hardware

- Superconducting Systems
- **Photonic Systems**



- Development of photonic quantum sampling architectures, and creation of software tools for simulating photonic systems while considering real-world imperfections.
  - (Bicocca, Sapienza)

Y1 key results

WP1: Algorithms and Applications

- Identification of target application domains and design of the necessary quantum algorithms

WP2: Compilers, Emulators and Benchmarking

- Tensor network emulator for 100+ qubits
- Design of a bechmarking methodology and platform for the comparative evaluation of quantum algorithms

WP3: Firmware and Hardware

- Implementation of a platform with 5+ qbits
- Design of a photonic sampling machine with 5+ photons and 24+ modes

Innovation Projects: overview

- 1,7/1,8 M€ funding (2,2 M€ cost)

- 8 projects
  - 5 internal
  - 2 in cooperation with other Spokes (2, 3 and 5)
  - 1 coordinated by Spoke 3

Innovation Projects: partners

Public partners (9)

- IFAB
- INFN
- Istituto Italiano di Tecnologia
- Politecnico di Milano
- Roma Sapienza
- Università di Bari
- Università di Bologna
- Università di Milano Bicocca
- Università di Padova

Private partners (8)

- ENI
- IFAB
- Intesa Sanpaolo
- Leonardo
- Società Autostrade
- SOGEI
- Thales Alenia Space
- UnipolSai

Innovation Projects: list

- Molecular Energy Landscapes with Quantum Computing
- Fraud Detections
- Quantum Credit Scoring
- Quantum Algorithms for the Solution of Differential Equations
- Cybersecurity and Combinatorial Optimization
- Scale up Quantum Optimization Algorithms for Aerospace & Telco Applications
- Quantum algorithm for the Detection of the Optimal Maximal Clique
- Serial Code Porting on HPC & Quantum Architectures

Thank you!

Open calls for projects with partners outside the center in January 2024!