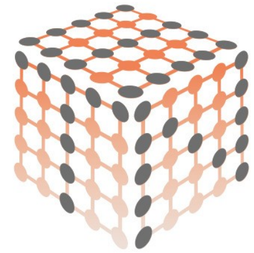
Call 2021
Final Evaluation

QUANTERA
RESEARCH FUNDERS FOR QUANTUM TECHNOLOGIES

QUANTERA
DECADE OF IMPACT 2016-2026



T-NiSQ

Tensor Networks in Simulation of Quantum Matter

T-NiSQ

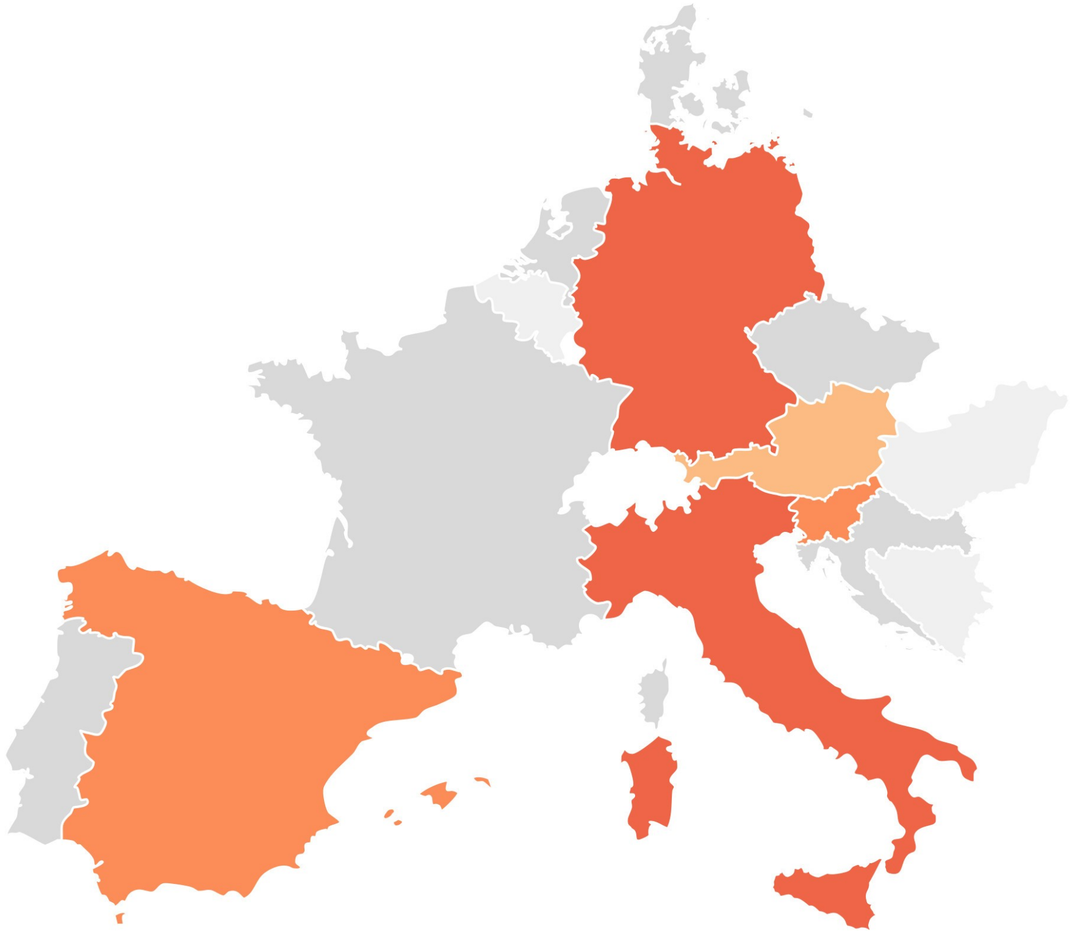
Tensor Networks in Simulation of Quantum Matter

Website: https://t-nisq.pd.infn.it/

COLLABORATION (overview)

GEOGRAPHICAL BREADTH

6 Partner Institutions in
5 Different EU countries



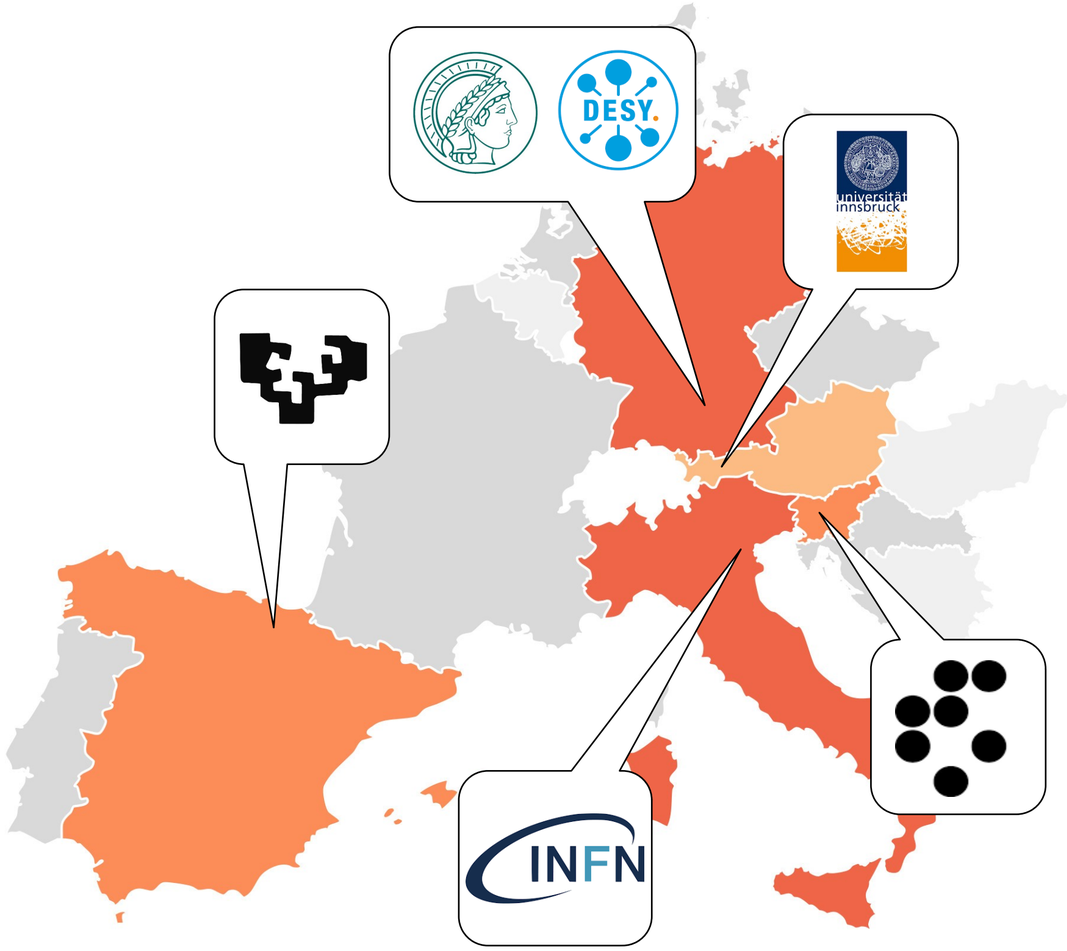
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COLLABORATION (overview)

GEOGRAPHICAL BREADTH

6 Partner Institutions in
5 Different EU countries

- **Padova (UNIPD)**
- **Bilbao (UPV/EHU)**
- **Innsbruck (UIBK)**
- **Zeuthen (DESY)**
- **Garching (MPQ)**
- **Ljubljana (IJS)**

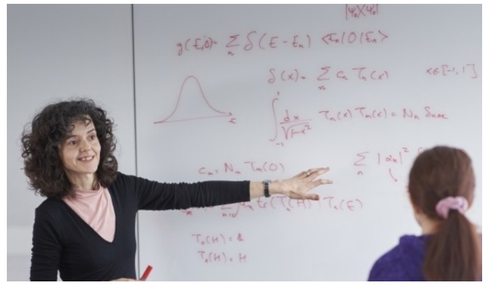


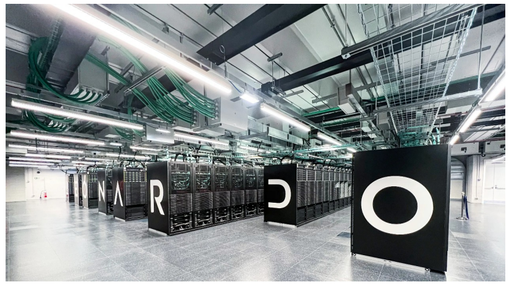
T-NiSQ

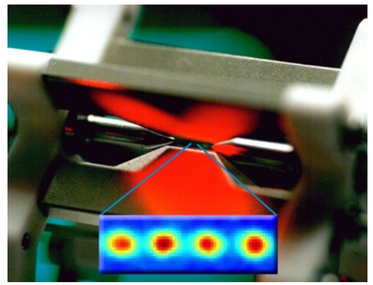
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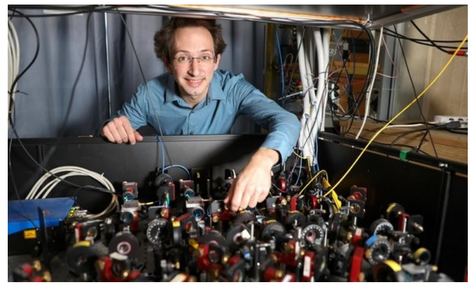
VARIETY OF SECTORS, DISCIPLINES

- Theoretical Physics
  Quantum Information Theory, Classical Simulations
- Experimental Physics
  Trapped Ion Quantum Processing, Quantum Simulations







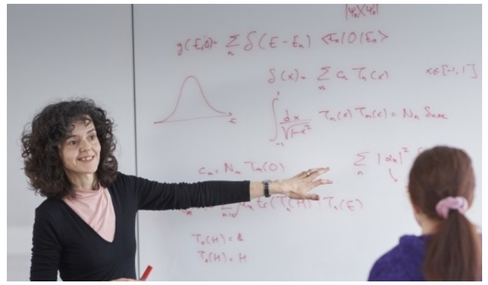


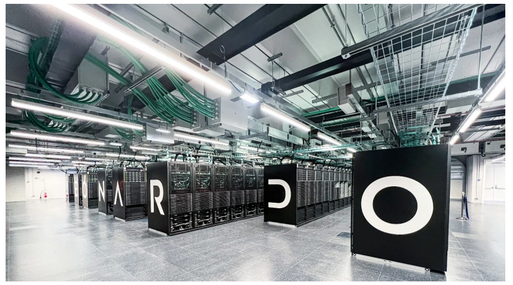
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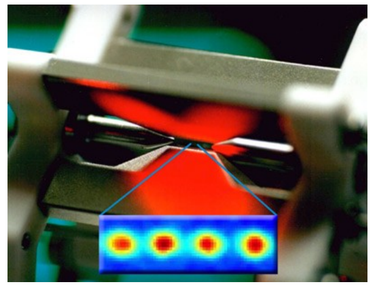
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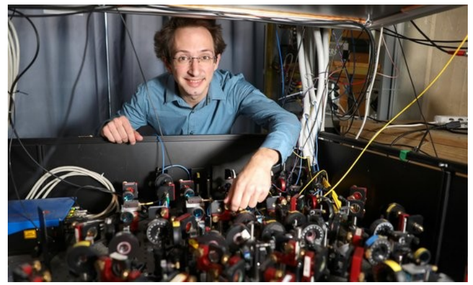
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QUALITY OF COOPERATION

Feedback, Experimental Data

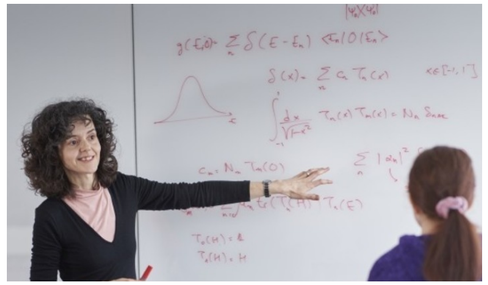
Theory **Experiment**

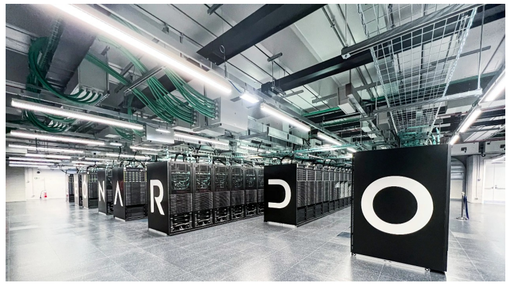
Proposal, Design, Postprocess, Benchmarking

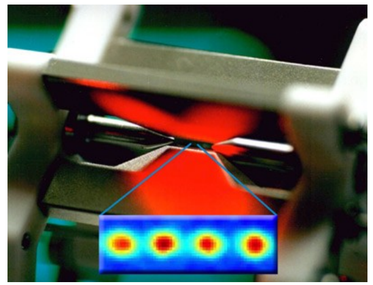
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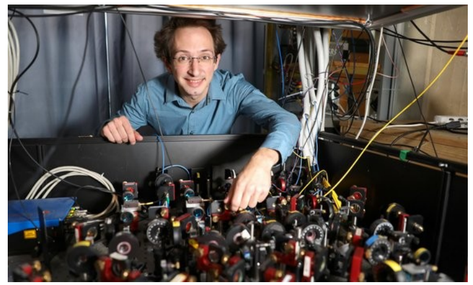
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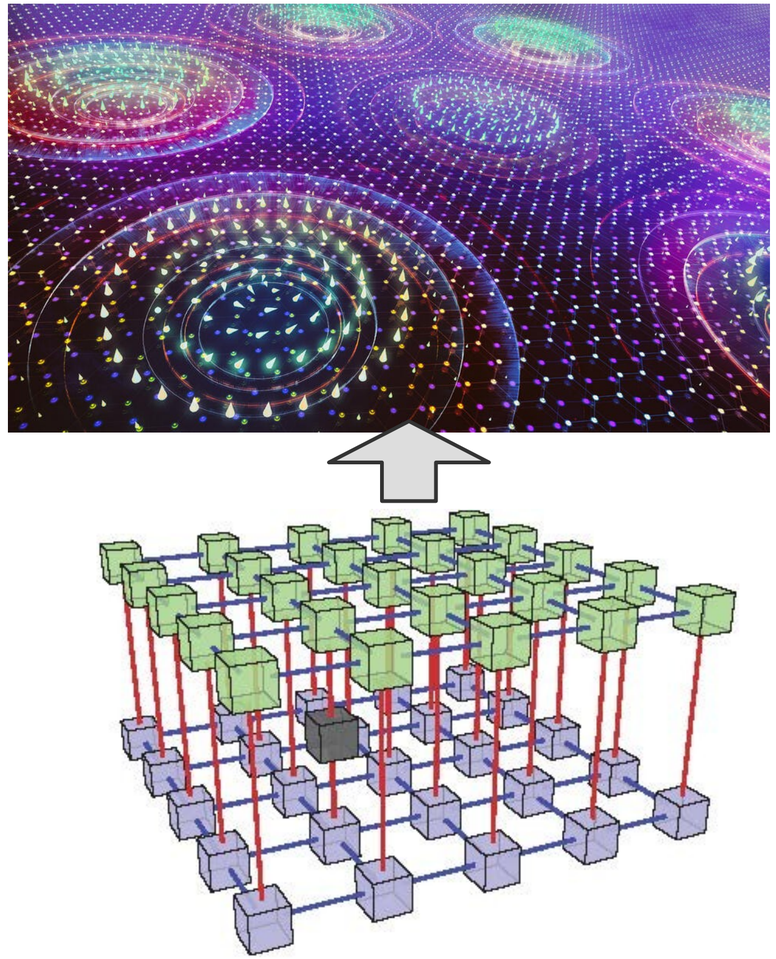
QUALITY OF COOPERATION

- **<u>Joint</u> Papers: > 5** joint publications (more after project end)
- **Human Resource Mobility:** 3 exchange PhD students/PostDocs

SUCCESS STORY (highlights)

CHALLENGE –

Enhance our understanding of quantum matter by means of *Tensor Networks*

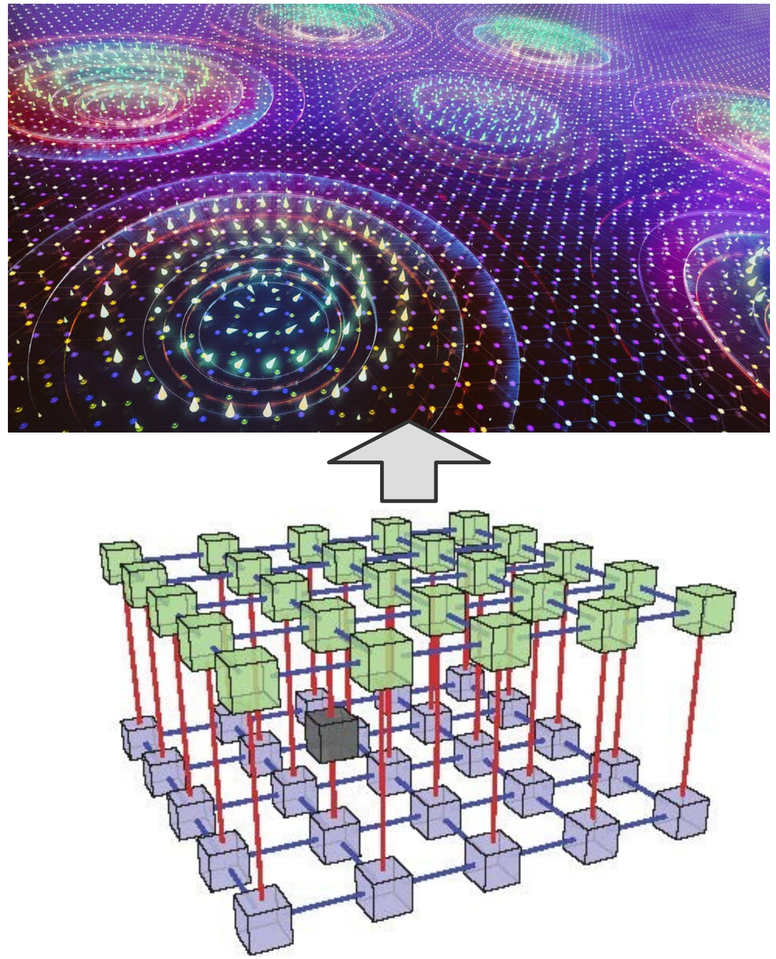


@ Courtesy of Quanta Magazine

SUCCESS STORY (highlights)

CHALLENGE –

Enhance our understanding of quantum matter by means of *Tensor Networks*



SOLUTION –

- Software Development and Classical simulation **(WP1)**
- Comparison with Trapped-Ion quantum processor **(WP2)**
- Analog Quantum Simulation **(WP3)**

@ Courtesy of Quanta Magazine

T-NiSQ

SUCCESS STORY (highlights)

PLANNED (AND UNPLANNED) OUTCOMES

Several scientific breakthroughs, all objectives have been achieved

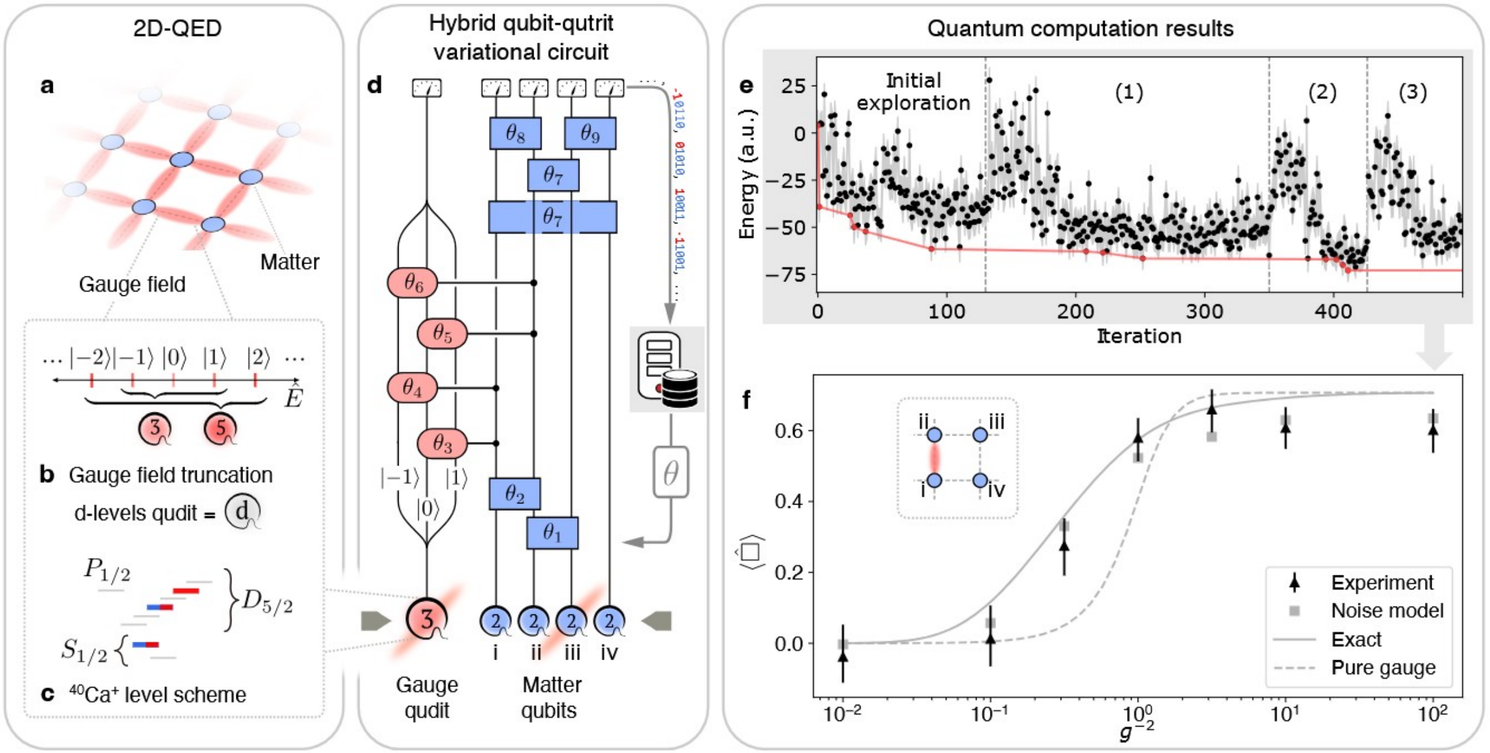
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SUCCESS STORY (highlights)

PLANNED (AND UNPLANNED) OUTCOMES

Several scientific breakthroughs, all objectives have been achieved

Just a few Highlights



Digital Quantum Simulation of two-dimensional lattice gauge theories

using hybrid ion-qubit ion-qudit system

M. Meth *et al.*; Nature Physics **21**, 570-576 (2025)

SUCCESS STORY (highlights)

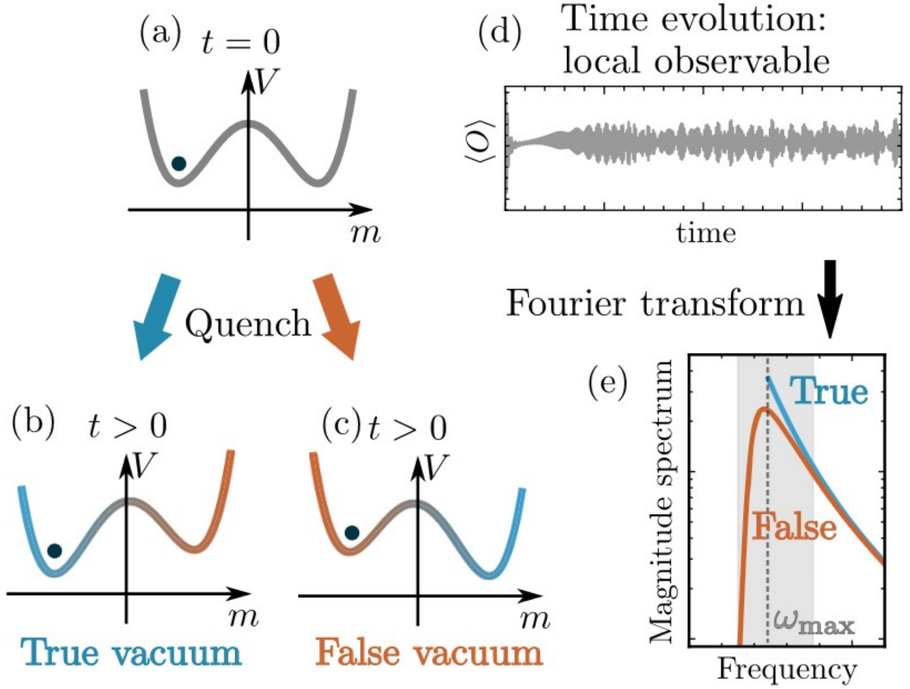
General diagnostics strategy to distinguish a **true vacuum** from a long-lived metastable state (**false vacuum**)

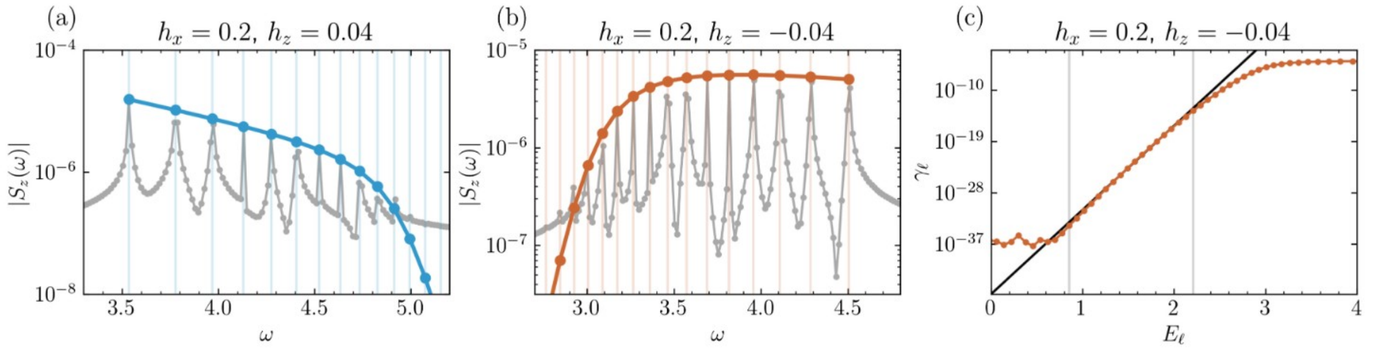
(1) Quench the system

(2) Probe a local observable in time

(3) Analyze the magnitude spectrum

...no need to go to decay times!





G. Lagnese, *et al.*; PRL **133**, 240402 (2024)

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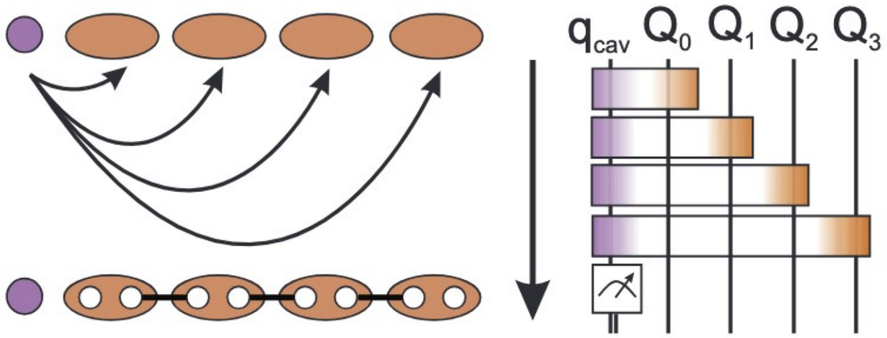
SUCCESS STORY (highlights)

Preparation of the Affleck-Kennedy-Lieb-Tasaki (AKLT) state in trapped ion qutrits.

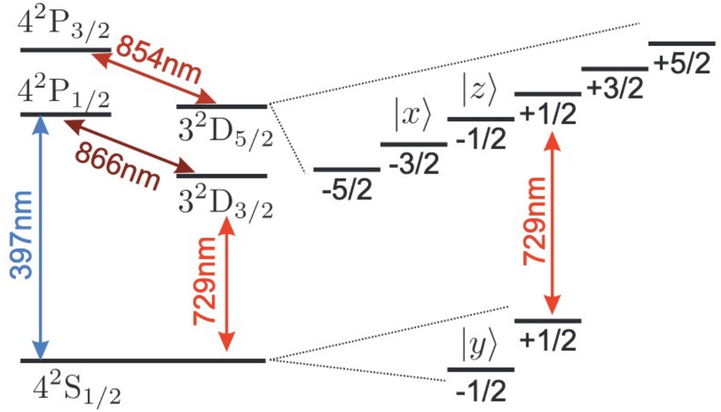
(1) Requires a single ancilla ion qubit

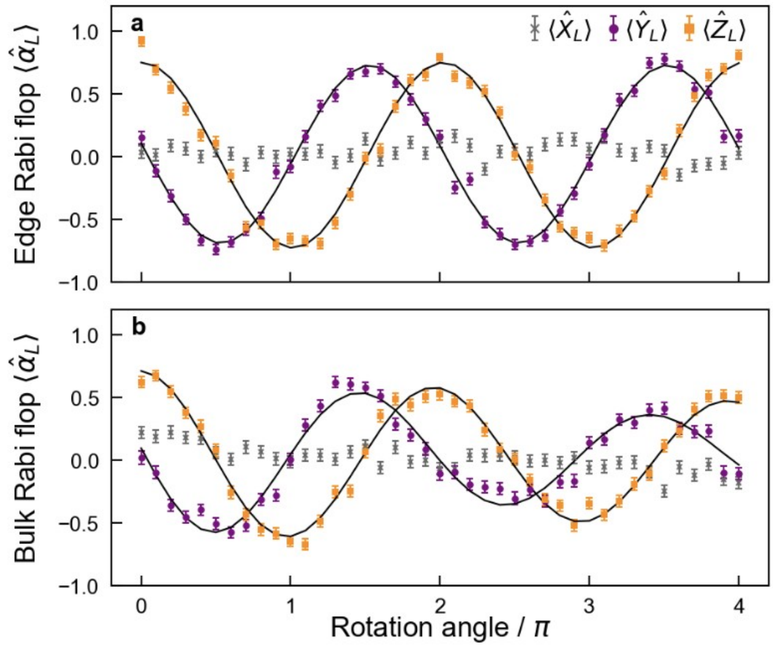
(2) Only a linear number of 2-ion gates.

Tensor Network-based Circuit



C.L. Edmunds, *et al.*; PRX Quantum **6**, 020349 (2025)





SUCCESS STORY (highlights)

ADDRESSING SUGGESTIONS

Emerged in the evaluation process:

***Evaluator**: A direct cooperation with industry was not reported. However, industry relevant output was identified.*

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SUCCESS STORY (highlights)

ADDRESSING SUGGESTIONS

Emerged in the evaluation process:

***Evaluator**: A direct cooperation with industry was not reported. However, industry relevant output was identified.*

→ Due to the temporary nature of the consortium we had to establish relationship with industy as single units instead.

***Example:** UNIPD (Node 1) has now active collaboration with ESA, Italian Railways, Qruise, Tensor Solutions, and QuEra.*

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SUCCESS STORY (highlights)

ADDRESSING SUGGESTIONS

Emerged in the evaluation process:

***Evaluator**: No patent applications were reported.*

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SUCCESS STORY (highlights)

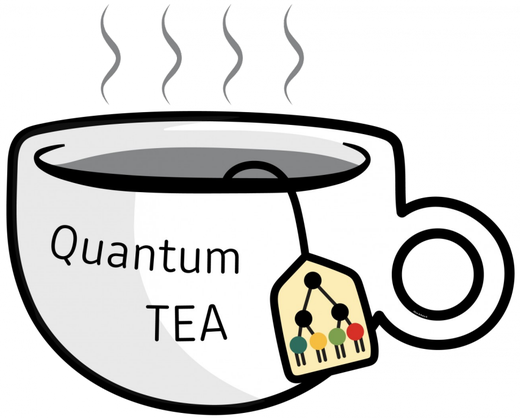
ADDRESSING SUGGESTIONS

Emerged in the evaluation process:

***Evaluator**: No patent applications were reported.*

→ We decided to embrace the **OPEN SCIENCE** policy promoted by the European Union and release our *IP Software as open source*

***Example:** The QuantumTEA Tensor Network software*



https://www.quantumtea.it/

T-NiSQ

SCIENTIFIC OUTPUTS

PUBLICATIONS AND PRESENTATIONS

More than **60** peer-reviewed papers in international scientific journals

Additional **30** released preprints at the moment of reporting

Countless presentations, mostly invited-speaker scientific talks

SCIENTIFIC OUTPUTS

PUBLICATIONS AND PRESENTATIONS

More than **60** peer-reviewed papers in international scientific journals

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Countless presentations, mostly invited-speaker scientific talks

THESES SPONSORED BY THE PROJECT

3 PhD Theses fully funded by T-NiSQ

6 more PhD Thesis involved in the T-NiSQ project

10 jobs created within the T-NiSQ framework

IMPACT (potential users)

RELEVANT INDUSTRY BRANCH

Logistics, Applied Information Science, Applied Material Science…

T-NiSQ

IMPACT (potential users)

RELEVANT INDUSTRY BRANCH

Logistics, Applied Information Science, Applied Material Science…

KEY COMMERCIALLY RELEVANT APPLICATIONS

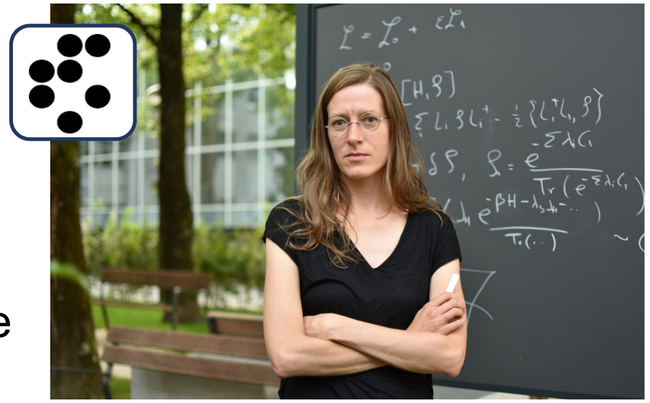
Correlated multivariate optimization strategies (*e.g. Kubo*), based on Tensor Networks.

General benchmarking tools for NIST Programmable Quantum Devices

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IMPACT (RRI Aspects)

GENDER: Interview with Zala Lenarčič (IJS) in a reportage of women coordinators of QuantERA projects



OPEN SCIENCE: All preprints, data, and software made available in easy-access repositories.

SCIENCE EDUCATION: Two PhD Summer schools, quantum education initiatives in High Schools



PUBLIC ENGAGEMENT: Four single-day public events (exhibitions) celebrating Quantum Technologies for the general public. Several divulgation interviews.

QUANTERA

RESEARCH FUNDERS FOR QUANTUM TECHNOLOGIES

T-NiSQ

Co-funded by
the European Union