



Quantum Computing for NuMeriQS

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with the help of Emil Rosanowski (thanks!)

CRC Retreat, Kloster Steinfeld, 17.09.2025

Quantum computing: where do we stand?

Quantum hardware

Achievements

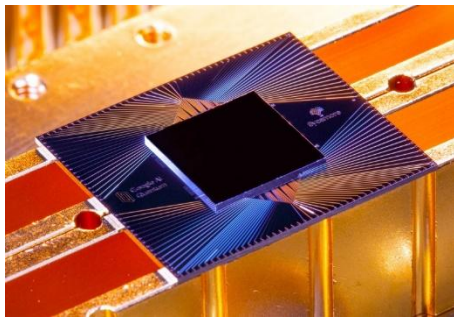
Quantum advantage: outperformed classical computers ¹

Exponential speedup of *specific* classical computations

Challenges

$\mathcal{O}(10 - 1000)$ qubits with $V_Q \leq 2^{21} \rightarrow$ increase size

Noise \rightarrow need quantum error mitigation / correction



Arute et al. (2019)



Zhong et al. (2020)

¹ Morvan et al. (2024), earlier claims by e.g. Arute et al. (2019), Zhong et al. (2020), Madsen et al. (2022) refuted by e.g. Liu et al. (2021), Oh et al. (2024)

Quantum algorithms

Potential future applications

Particle / condensed matter physics, quantum chemistry, ...

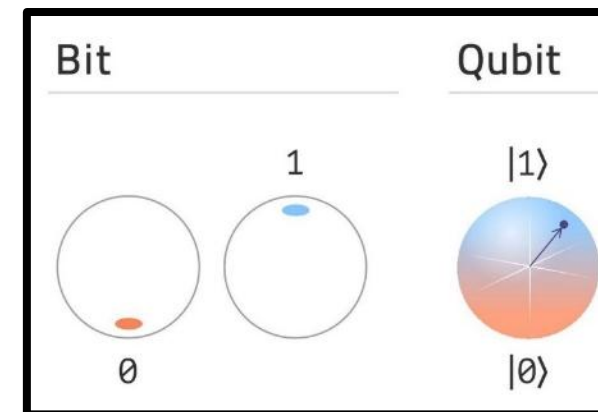
Challenges

New technology \rightarrow need fundamentally new algorithms

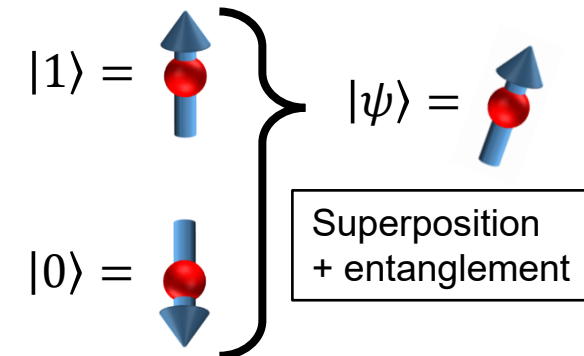
(see projects A04, C01, C03)

Competition \rightarrow classical algorithms quickly advance

(see David Luitz' talk on tensor networks)



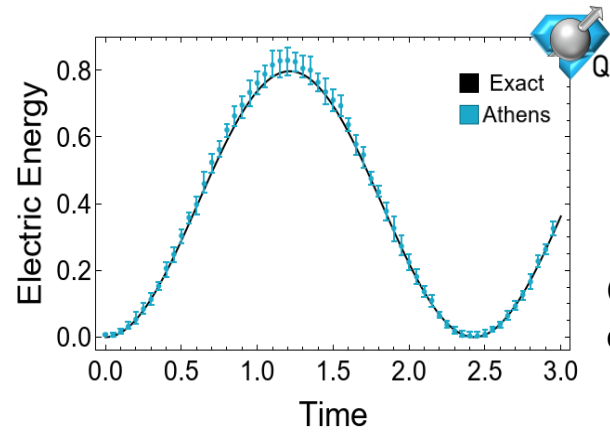
Astibuag (2022)



Which quantum systems have already been simulated?

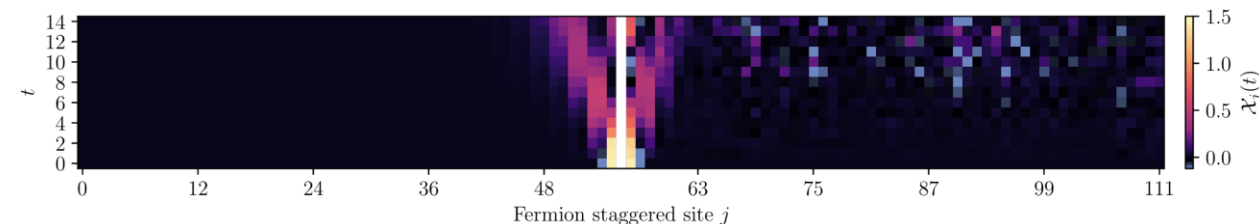
Real-time evolution

1+1D quantum electrodynamics (QED),¹ SU(2),² SU(3),³ ... 1+1D “baryon” masses⁵

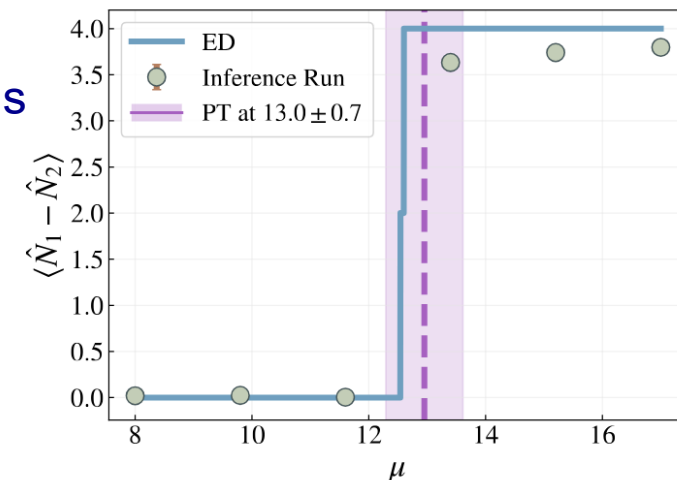
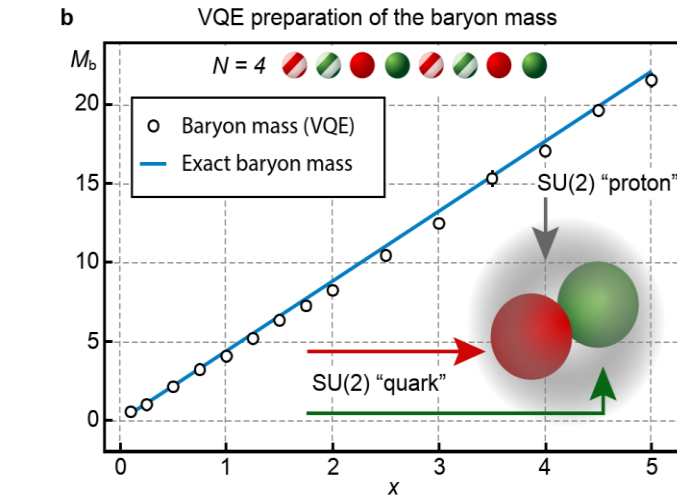


Ciavarella
et al. (2019)

1+1D QED with 1 fermion, on > 100 qubits⁴



2+1D QED with 2 fermions
at finite density⁶



¹ Klco et al. (2018), de Jong et al. (2021), ² Klco et al. (2019), ³ Ciavarella et al. (2019), ⁴ Farrell et al. (2024),

⁵ Atas et al. (2021), ..., ⁶ Rosanowski et al., manuscript in preparation, **part of project C01**

Survey: using quantum algorithms (QA) in NuMeriQS?

Current situation

Outlook

Are QA applied in your project?

- So far, only in C01 and C03
- A04 studies time evolution algorithms, applicable in principle to classical and quantum computers

Could your project benefit from incorporating QA?

- Yes for C01 and C03, potentially yes for A02
- Others: No clear benefits at this stage / unclear

Could your QA be useful to other NuMeriQS projects?

- QA exchange between C01 and C03
- A04 results could help in future projects?

Would you benefit from learning more about QA?

- Many wrote: eager to learn more
- Suggestion: join our new seminar series?

Seminar “Quantum Computing (QC) for Natural Sciences”

Overview

Content

Why?

- Bring together CRC researchers interested in QC
- Teach students the prospects and limitations of QC

When?

- WiSe 25/26, Fridays 10:15-11:45am @ HISKP SR I

How many students?

- ≤ 5 from MSc Chemistry and ≤ 15 from MSc Physics

What?

- 20 seminar talks by students about research papers, 30mins talk + 15mins questions
- Topics: foundations of QC, potential future applications in physics & chemistry, comparison to classical methods

Lecturers?

- Chemistry: **Kirchner**, Hansen
- Physics: **Funcke**, Kroha, **Luu**, **Ostmeyer**, Stollenwerk, **Urbach**

Interested in joining? Let me know!

Workshops, lectures, ...

Workshops



WORKSHOP HAMILTONIAN LATTICE GAUGE THEORIES: STATUS, NOVEL DEVELOPMENTS AND APPLICATIONS

September 1-5, 2025

ECT* Villa Tambosi, Villazzano



Organizers: Carsten Urbach
Karl Jansen
Randy Lewis
Giuseppe Magnifico
Simone Romiti
Enrique Rico Ortega

Main topics: - Efficient formulations of Lattice Gauge Theories for Hamiltonian Simulations
- Quantum Computing and applications for Lattice Gauge Theories
- Quantum Hardware for Lattice Gauge Theories
- Tensor Network States for Lattice Gauge Theories

ECT* Director: Prof. Ujjayjara van Kolck

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For the organization please contact: Susan Griesen - ECT* Secretariat - Villa Tambosi - Strada delle Tabacche 286 - 38123 Villazzano (Trento) - Italy | Tel: (+39-0461) 314722, E-mail: griesen@ectstar.it or visit <http://www.ectstar.eu>


Lectures

“Introduction to Quantum Computing”


- WiSe 25/26, Tuesdays 10-12 @ HS HISKP

“Lattice Field Theory – Hamiltonian and Lagrangian Methods” (tentative title...)

- SoSe 26, together with Simran Singh (Z02)

 Quantum Workshop DESY

May 12 – 14, 2025
DESY Zeuthen
Europe/Berlin timezone

Enter your search term 

Overview
Timetable
Contribution List

This event is a follow-up to the highly successful workshops held in October 2022 and October 2023 in Cyprus and will provide an opportunity for researchers related to CQTA and the ERA Chair QUEST and University of Bonn to come together and learn about the latest developments in various projects. Like the last years, the workshop will feature a range of presentations, discussions, and exchanges of results, techniques, and ideas. However, in 2025 we will meet at DESY.

 **Starts** May 12, 2025, 9:00 AM
Ends May 14, 2025, 9:00 PM
Europe/Berlin

 DESY Zeuthen
Seminar Room 5, Villa

Sign 2027 Workshop @ Bonn?

Seminars, journal clubs, ...

NuMeriQS seminars

Starting from WiSe 25/26

- Weekly theory seminars, Tuesday 3pm @ HS HSKP
- ~ 50% NuMeriQS-related talks by students & postdocs
- Talks about QC, tensor networks, machine learning, ...

Want to give a talk?

- Simran Singh will send around Google sheet soon

New mailing list ...

... for theoretical physics @ Uni Bonn

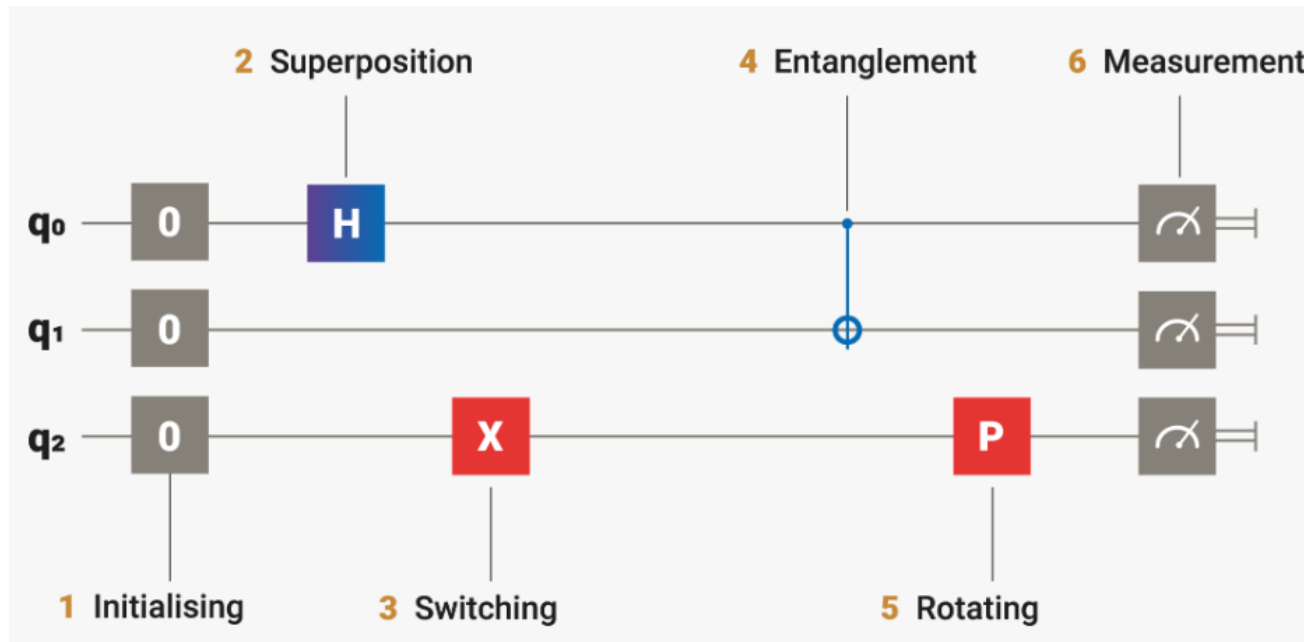
- Announcement of theory seminars, journal clubs, PhD and Master colloquia, discussion sessions, etc.
- Default members: HSKP Theory & PI Theory
- If you want to be added to the mailing list:



Backup: Content of “Seminar on Quantum Computing for Natural Sciences”

Learning the foundations of quantum computing

- Qubits, gates, superposition, entanglement, measurement, quantum noise, ...



$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \quad |1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$R_x(\theta_0) = \exp\left(-i\frac{\theta_0}{2}\sigma_x\right)$$

$$\langle\psi(\vec{\theta})|H|\psi(\vec{\theta})\rangle$$

Understanding the potential future applications (& limitations) of quantum computing for natural sciences

- Physics: real-time evolution, out-of-equilibrium dynamics, comparison to (classical) HMC & TN methods, ...
- Chemistry: FCI problem, NMR problem, comparison to (classical) CC or DFT methods, ...