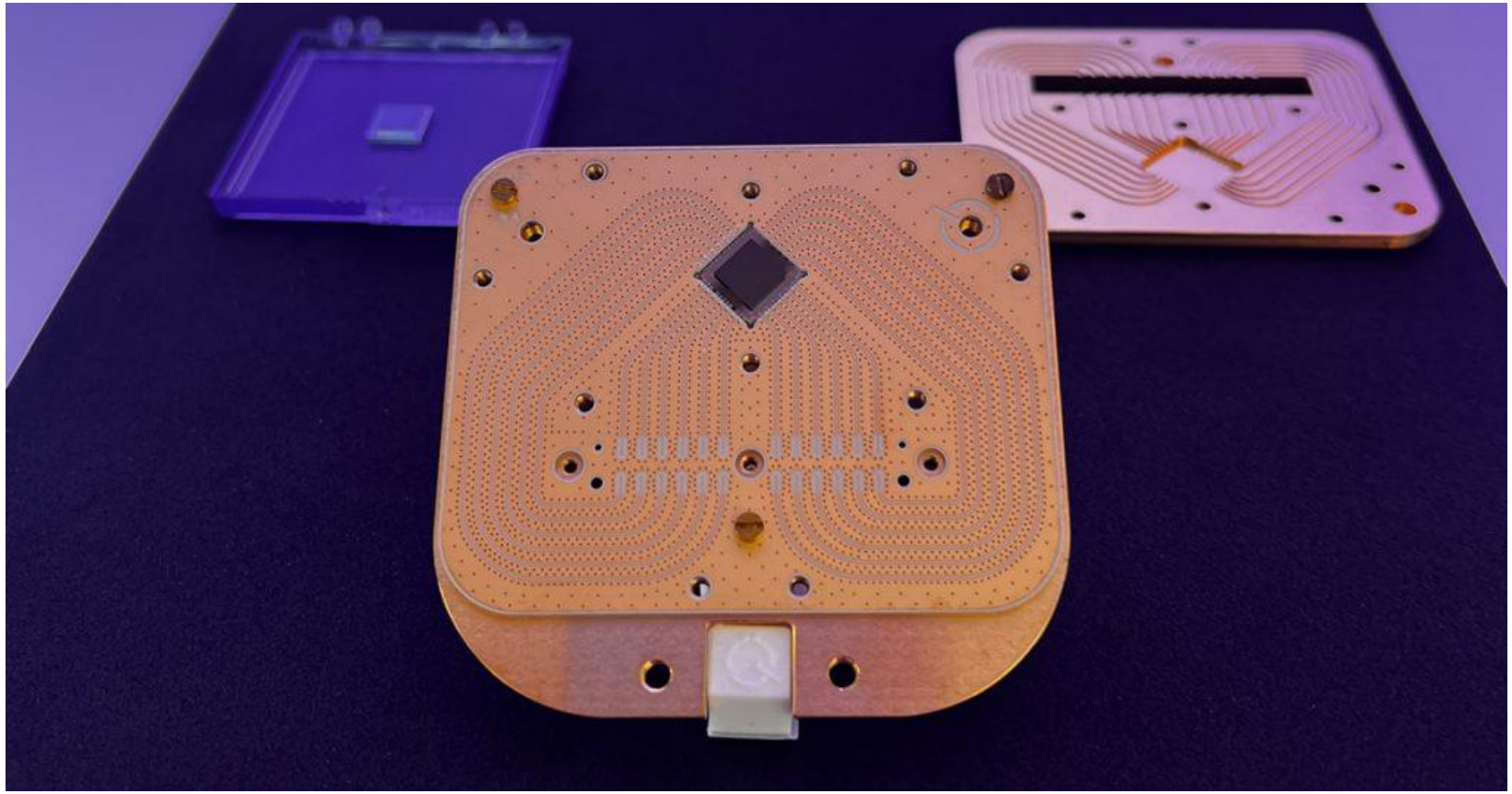
Small steps and quantum leaps – insights from DeiC's quantum activities

DeiC Conference 2025 – October 29, 2025



The new VLQ quantum computer contains 24 superconducting qubits in a star-shaped topology and will be available to users in Denmark!

Outline

1. **Introduction to DeiC's Quantum Department**

2. **Quantum Overviews, Guides, and Tutorials**
   a. DeiC's New Quantum Guide
   b. Quantum Stakeholder Overview
   c. Proof-of-concept Quantum Use Cases

3. **LUMI-Q Consortium + VLQ Access**

4. **Q-Access**
   a. Consulting Service and Office Hours
   b. Sandbox Access
   c. Calls for specialized Access
   d. VLQ Access

5. **Q-Competence**

6. **Q-Algorithm**

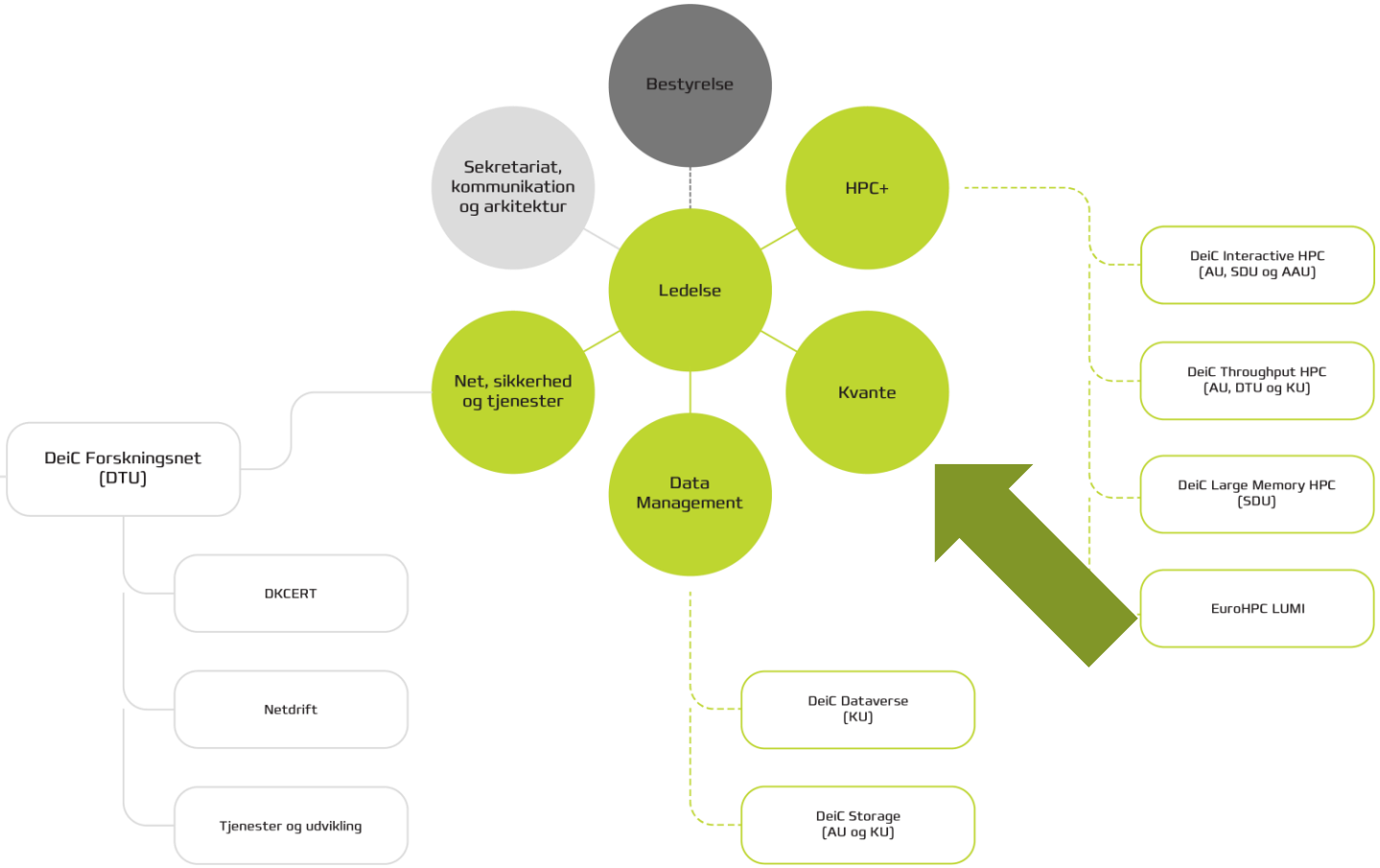
7. **Niels Bohr Quantum Summer School**

1. Introduction to DeiC's Quantum Department

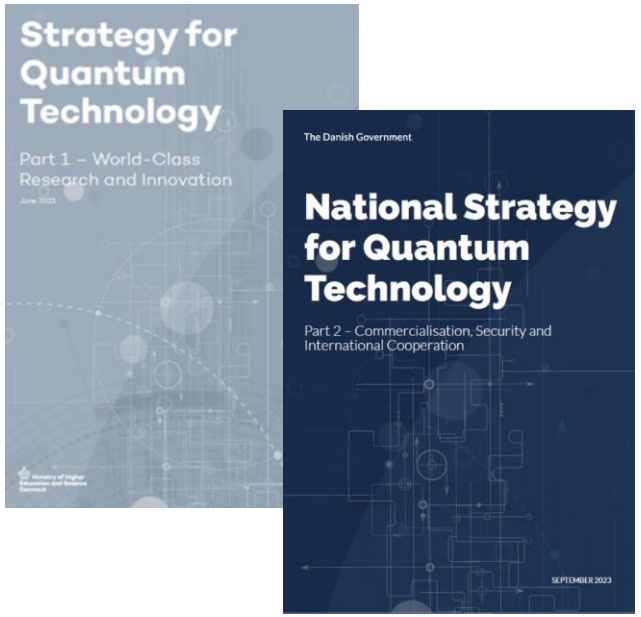
Overview of DeiC

The **Danish e-Infrastructure Consortium (DeiC)** develops and coordinates access to digital research infrastructure for Danish universities, enabling research and education at a high international level.

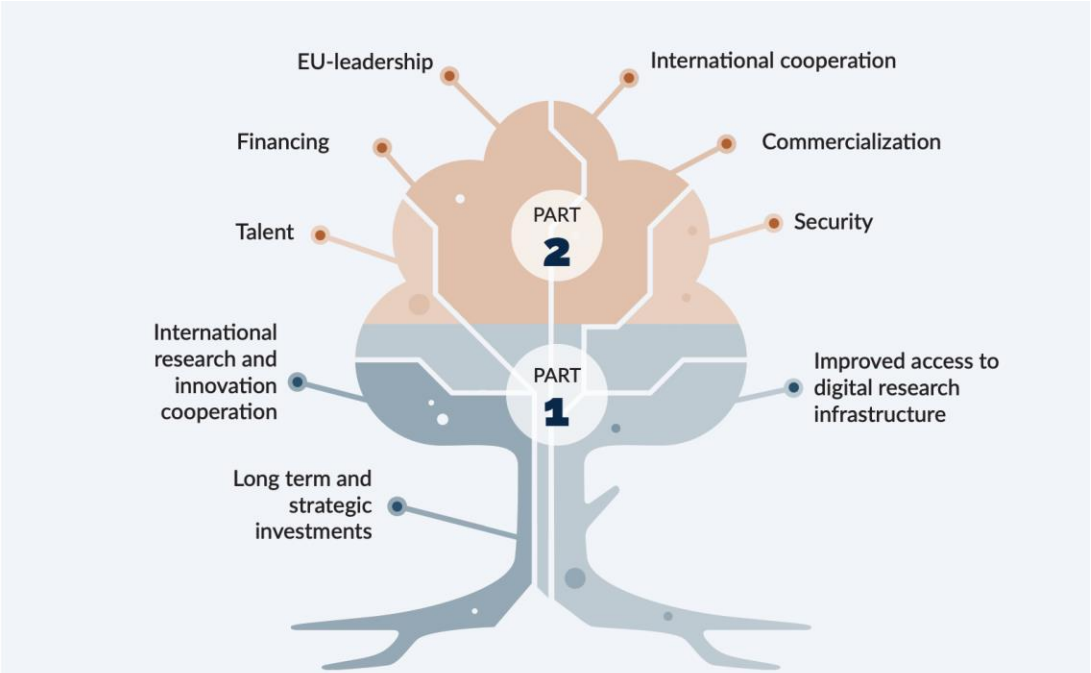
The research network is a high-speed network that connects Danish universities and research institutions.



Danish National Quantum Strategy



Link between Part 1 and Part 2



National Quantum infrastructure:
https://www.deic.dk/quantum-infrastructure

Grants and Funding:
https://www.deic.dk/da/quantum-technology/grants-and-funding

Strategy - part 1:

https://ufm.dk/en/publications/2023/strategy-for-quantum-technology-part-1-2013-world-class-research-and-innovation

Strategy - part 2:

https://eng.em.dk/publications/2023/national-strategy-for-quantum-technology

The Objective of the Strategy for Quantum Technology - Part 1

> Denmark aims to have one of the world's leading quantum research environments and to have the ability to effectively translate research into new, usable technology.

DeiC's Quantum Department

DeiC's Quantum Department is the newest department in DeiC, established as part of the implementation of the Danish government's national quantum strategy.

Initiatives

Q-Access

- Calls for specialized access to quantum computers.
- Sandbox access via Microsoft Azure for testing.
- Consulting service with quantum experts.
- Access to the new LUMI-Q VLQ quantum computer.
- Overviews, guides, and step-by-step tutorials.

Q-Competence

- Disseminate skills and increase understanding of the potential and risks of quantum technology.
- Financial support for developing quantum computing material and events.

Q-Algorithm

- DQA Academy to boost work in developing and testing quantum algorithms and the associated software stack.
- Scholarships for Ph.D. students and Postdocs.

Niels Bohr Quantum Summer School

Two-week summer school, for the next 4 years, for both Danish and international Ph.D. students to learn about quantum computing and attract talent to the quantum community in Denmark.

LUMI-Q

The LUMI-Q consortium set up a quantum computer called "VLQ," which has 24 superconducting qubits in a star-shaped topology. IQM in Finland is the hardware provider, and it is deployed in the Czech Republic at the IT4Innovations Centre at the Technical University of Ostrava.

DEIC QUANTUM DEPARTMENT: GOVERNANCE STRUCTURE & STRATEGIC ROADMAP FOR 2026

PURPOSE: TO VISUALIZE HOW DEIC BUILDS QUANTUM INFRASTRUCTURE

AVAILABLE ON DEIC'S WEBSITE FOR TRANSPARENCY AND KNOWLEDGE SHARING

LIVING WORKING DOCUMENT, UPDATED EVERY QUARTER

DeiC
DANISH eINFRASTRUCTURE CONSORTIUM

Strategic benchmark

Actively follow the development within quantum computing and algorithms and support the national development and future application in the field

Core initiatives	Core purpose	Regular internal meetings incl. i.a. the following governance bodies
DANISH QUANTUM ALGORITHM ACADEMY	Quantum algorithm and software development initiatives for academia and industry	Academy Council Evaluation committee
Q-COMPETENCE	Quantum competence-building educational activities for industry, public administration and research	Working group Evaluation committee
Q-ACCESS	Access to testing on quantum computing facilities at quantum computing and HPC facilities for universities, public administration and industry	Working group Evaluation committee POC @HPC department
NIELS BOHR QUANTUM SUMMER SCHOOL	Attract quantum talent to Denmark and foster a robust and innovative quantum sector	Steering committee Planning committee
LUMI-Q	Participate in the LUMI-Q consortium under EuroHPC JU, to establish a quantum computer	Steering committee
QUEX (QUANTUM EXCELLENCE CENTRE)	One-stop-shop for end-users of quantum technology, to take full advantage of emerging EuroHPC quantum computing infrastructure	Management committee
NORDIQUEST2	Nordic quantum corporation project on Q-oveview and quantum schools, through NeIC / NORFORSK	Procejctmanagement meetings

Cross-cutting:

University/DeiC Front Offices

Regular external meetings
incl. i.a. the following stakeholders
min. biannually

Cross-cutting:

Public organisations:

Ministry of Foreign Affairs (+ICDK's)

Danish Agency for Higher Education and Science

Danish Business Authority

Danish Defence (FE, FMI, FAK)
National Defence Technology Centre

PET (national security and intelligence service)

Innovation Fund Denmark

Independent Research Fund Denmark

LUMI-Q

QUEX

Danish Chips Competence Centre (DKCCC)

Private organisations:
Novo Nordisk Foundation

Confederation of Danish Industry

Quantum Denmark /DFM

Danish Quantum Community (DQC)

BII - DeepTech Lab/DIANA

Quantum computing companies

Current planned events and activities
some examples

Cross-cutting:

National events:
Digital Lead: Business casen for kvanteteknologi i 2025 - Del I

Social dinner for quantum community

Business Vejle paneldebat

Q-Access university roadshow visits

Sparrow Quantum networking event

Niels Bohr Quantum School incl. industry side event

Defence industy event at Precision Technic Defence

Cyber industry panel

Industryevent at the Confederation of Danish Industry (DI)

DeiC annual conference

International events:

QUEX internal kickoff (CPH)

QUEX external kickoff (Netherlands)

Ostrava / LUMIQ delegation trip

The European Quantum Technologies Conference 2025 (CPH)

2.Quantum Overviews, Guides, and Tutorials

DeiC's New Quantum Computing Guide

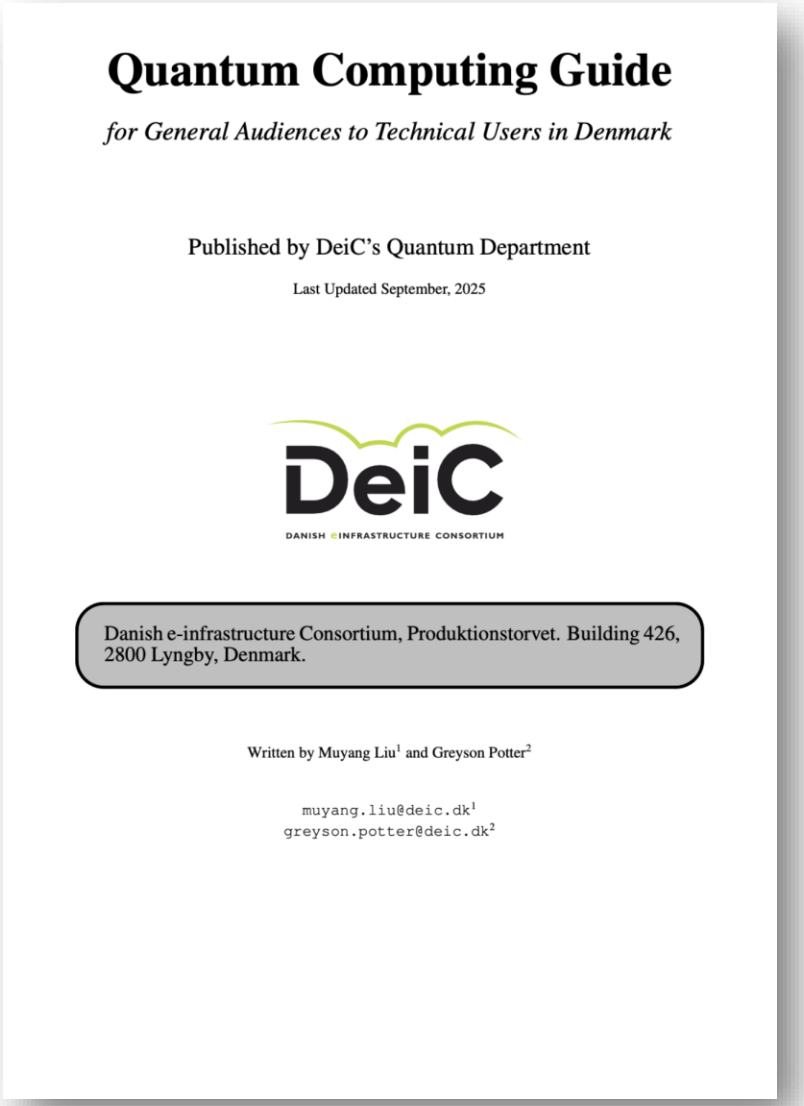
A clear, unified overview of quantum computing published by **DeiC's Q-Access team** to show:

- What resources exist (types, major providers, etc).
- How to get access.
- How quantum devices are benchmarked.
- Interdisciplinary Interfaces (e.g., the interface to AI)

The guide targets **multiple audience groups:**

- General audiences (policy makers, journalists, industry newcomers)
- Researchers and technical users
- Decision makers (funding, infrastructure)

The guide is a **living document** and will be updated regularly!



Quantum Computing Guide

for General Audiences to Technical Users in Denmark

Published by DeiC's Quantum Department

Last Updated September, 2025

DeiC

DANISH EINFRASTRUCTURE CONSORTIUM

Danish e-infrastructure Consortium, Produktionstorvet. Building 426, 2800 Lyngby, Denmark.

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greyson.potter@deic.dk[2]

Quantum Computing Guide – Navigation

Jump directly to what you need!

- Sec 1: Historical background and motivation
  - John Preskill: Quantum computing 40 years later
  - IBM: What is quantum computing?
- Sec 2: Quantum algorithms and their applications
  - Quantum Algorithm Zoo
- Sec 3-5: Practical access mode
  - DeiC Q-Access: Access to Quantum Computers
  - VLQ: the quantum computer of the LUMI-Q consortium
  - UCloud User Guide
  - Google Quantum AI: Choosing hardware for your qsim simulation
- Sec 6-7: Benchmarks, modalities and pricing
  - Deep Lall et al: A Review and Collection of Metrics and Benchmarks for Quantum Computers: definitions, methodologies and software
- Sec 8: EuroQHPC - an integration project
  - The European High Performance Computing Joint Undertaking: Quantum Computers
- Sec 9: Quantum Interface with AI
  - Jacob Biamonte et al: Quantum Machine Learning
  - Maria Schuld & Francesco Petruccione: Machine Learning with Quantum Computers
  - LUMI: From binary computing to quantum AI
- Appendix: Additional services and initiatives

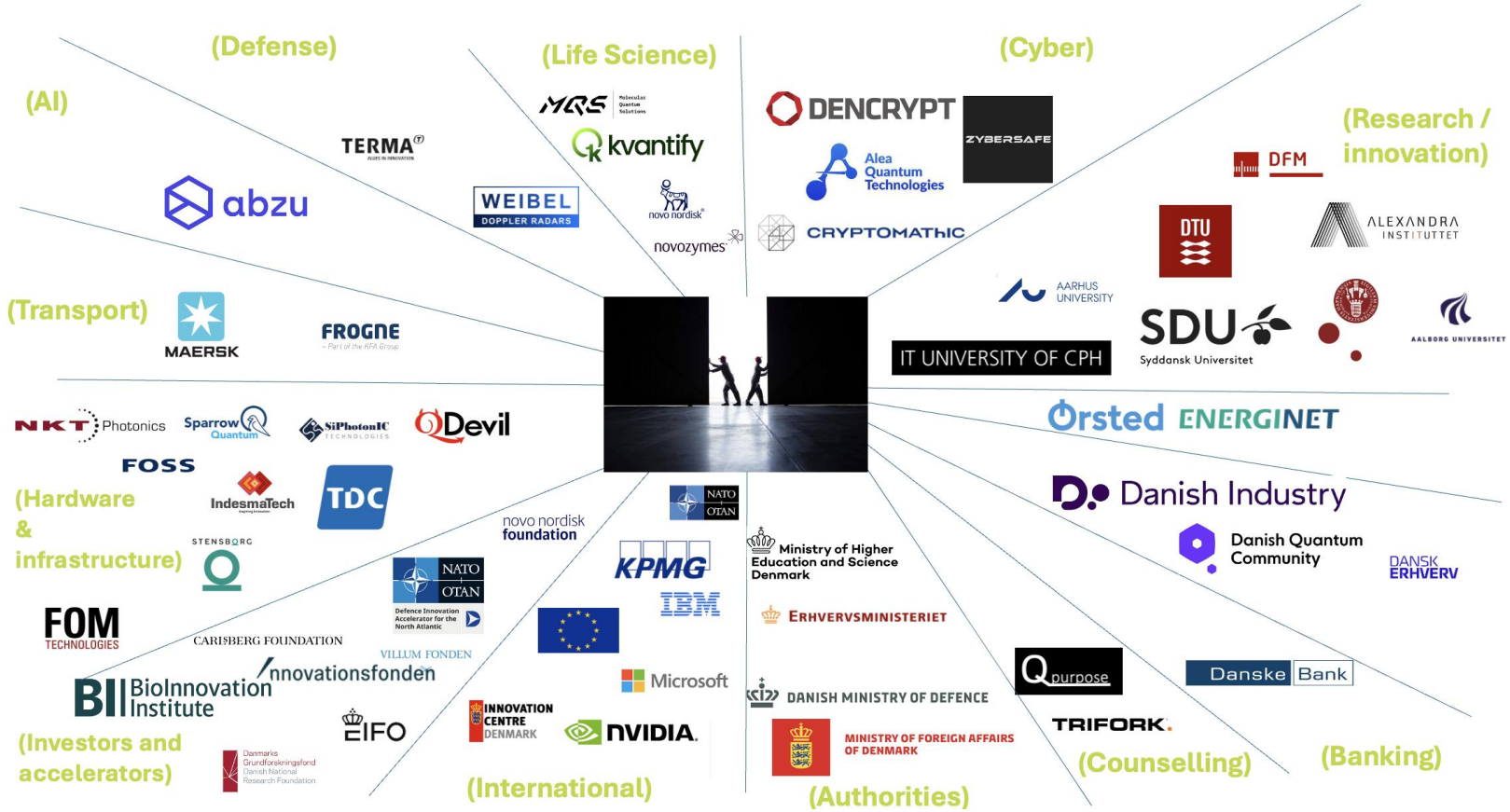
Quantum Computing Guide – Table of Contents

Contents

Overview of Quantum Stakeholders

Available in Danish and English

Goal: Understand the purpose and focus of the various Danish-based quantum actors, including how they are financed and how they each represent the Danish quantum effort in different ways.



Developing Proof-of-concept Use Cases

- We are currently in the **noisy intermediate-scale quantum (NISQ)** era, with QPUs not yet capable of **fault tolerance** or **quantum advantage**, but there are many algorithms with the great potential use cases.
- The most common class of NISQ algorithms are “variational algorithms” which leverage classical optimization of tunable parameters.
- DeiC is developing some simple **proof-of-concept use cases** (for both **academia and industry**) with **step-by-step explanations** of the thought process and implementation to help, especially Danish, users best utilize quantum computing resources.
- The three main areas for which DeiC is developing proof-of-concept use cases, and which seem the most promising, are **optimization, simulation, and machine learning.**

Optimization

From minimizing risk to maximizing throughput, optimizaiton problems are ubiquitous across many industries, espcially in *finance*, *logistics*, and *engineering*.

Simulation

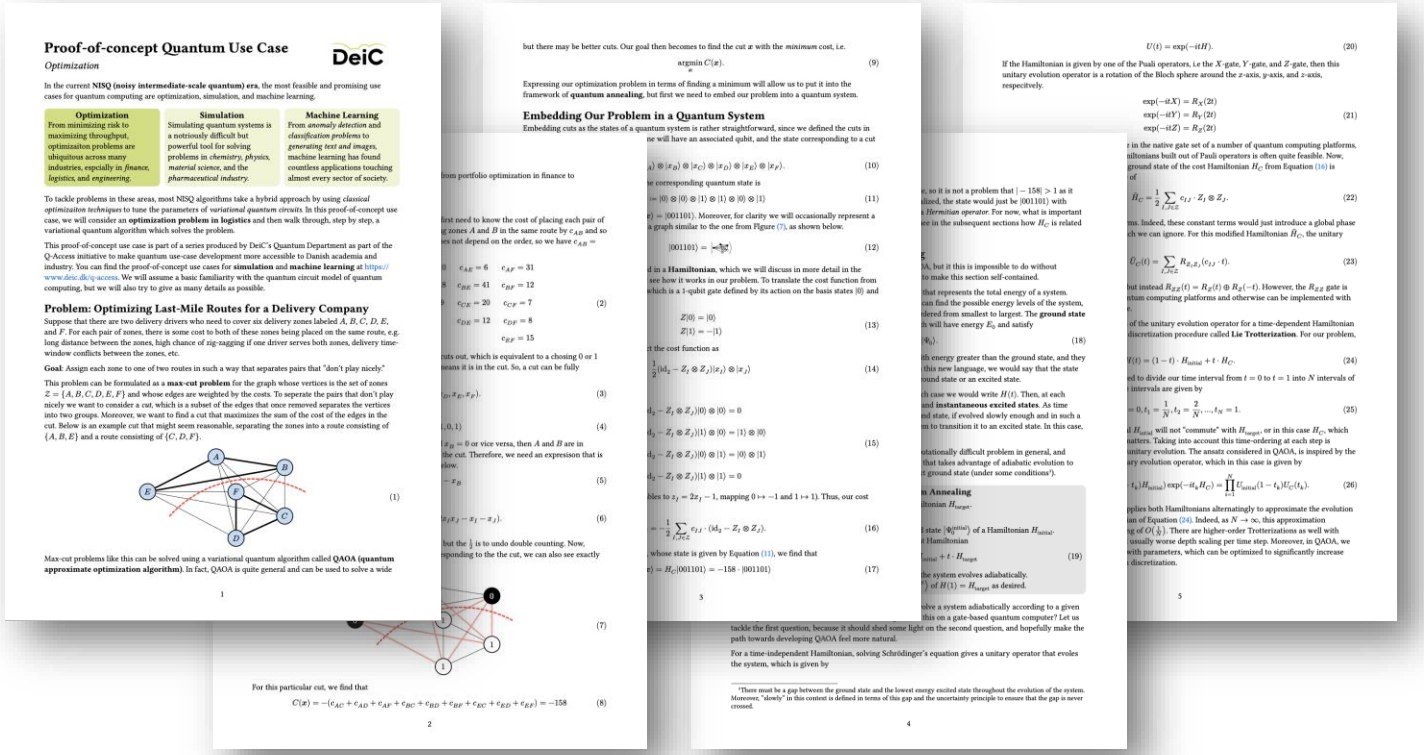
Simulating quantum systems is a notriously difficult but powerful tool for solving problems in *chemistry*, *physics*, *material science*, and the *pharmaceutical industry*.

Machine Learning

From *anomaly detection* and *classification problems* to *generating text and images*, machine learning has found countless applications touching almost every sector of society.

Proof-of-concept Use Case: Optimization

- Practically speaking, these proof-of-concept quantum use cases include a **step-by-step guide** starting from the problem description, then **formalizing and embedding the problem into a quantum system** and finally **describing and implementing a quantum algorithm to solve it**.
- The first proof-of-concept use case that DeiC has developed is in optimization.



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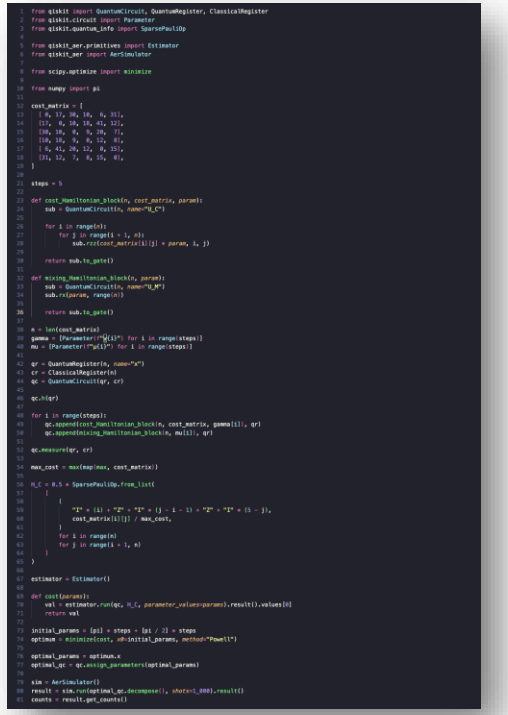


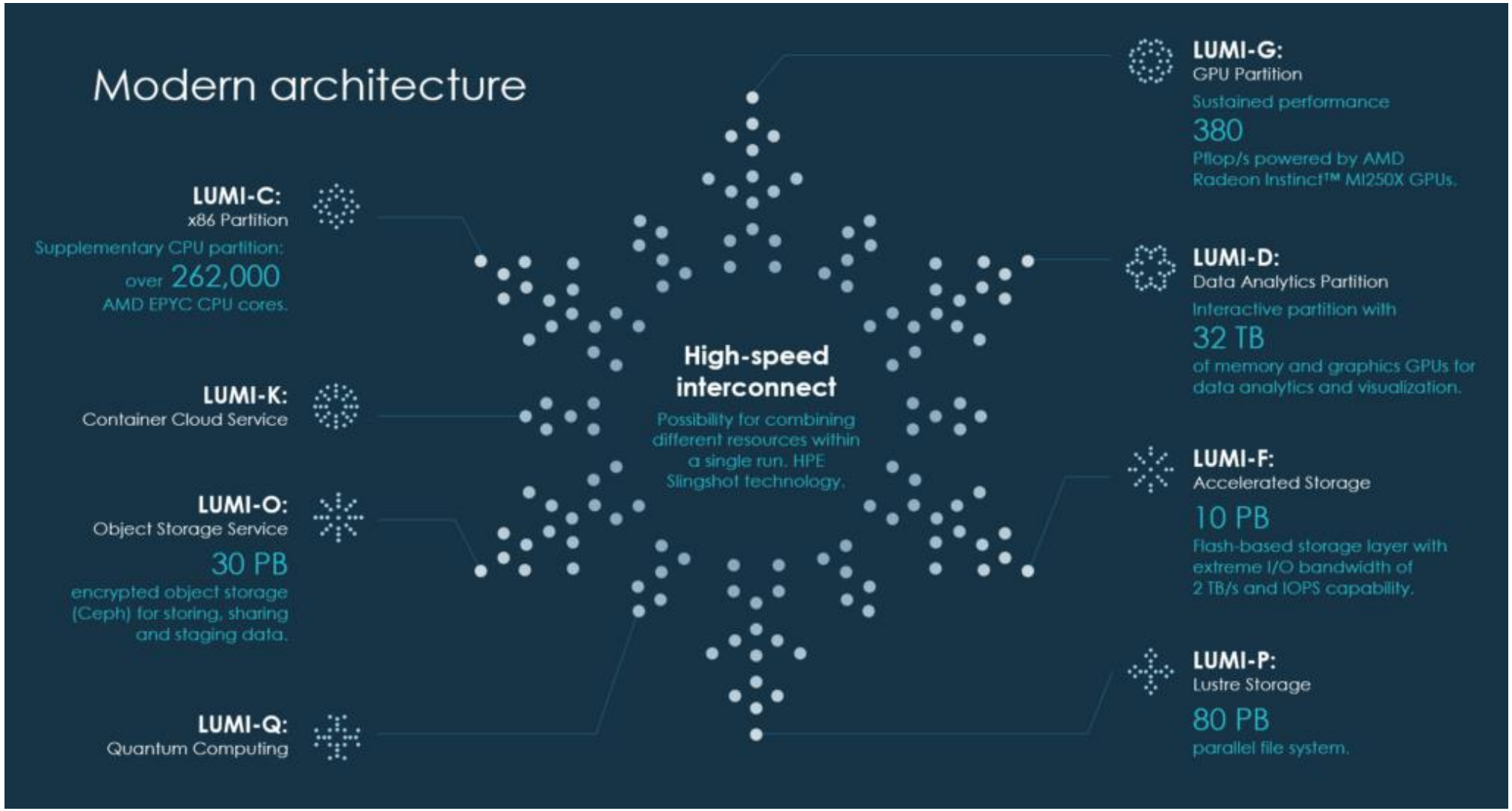
3. LUMI-Q Consortium and the New Quantum Computer “VLQ”

Overview of LUMI Consortium

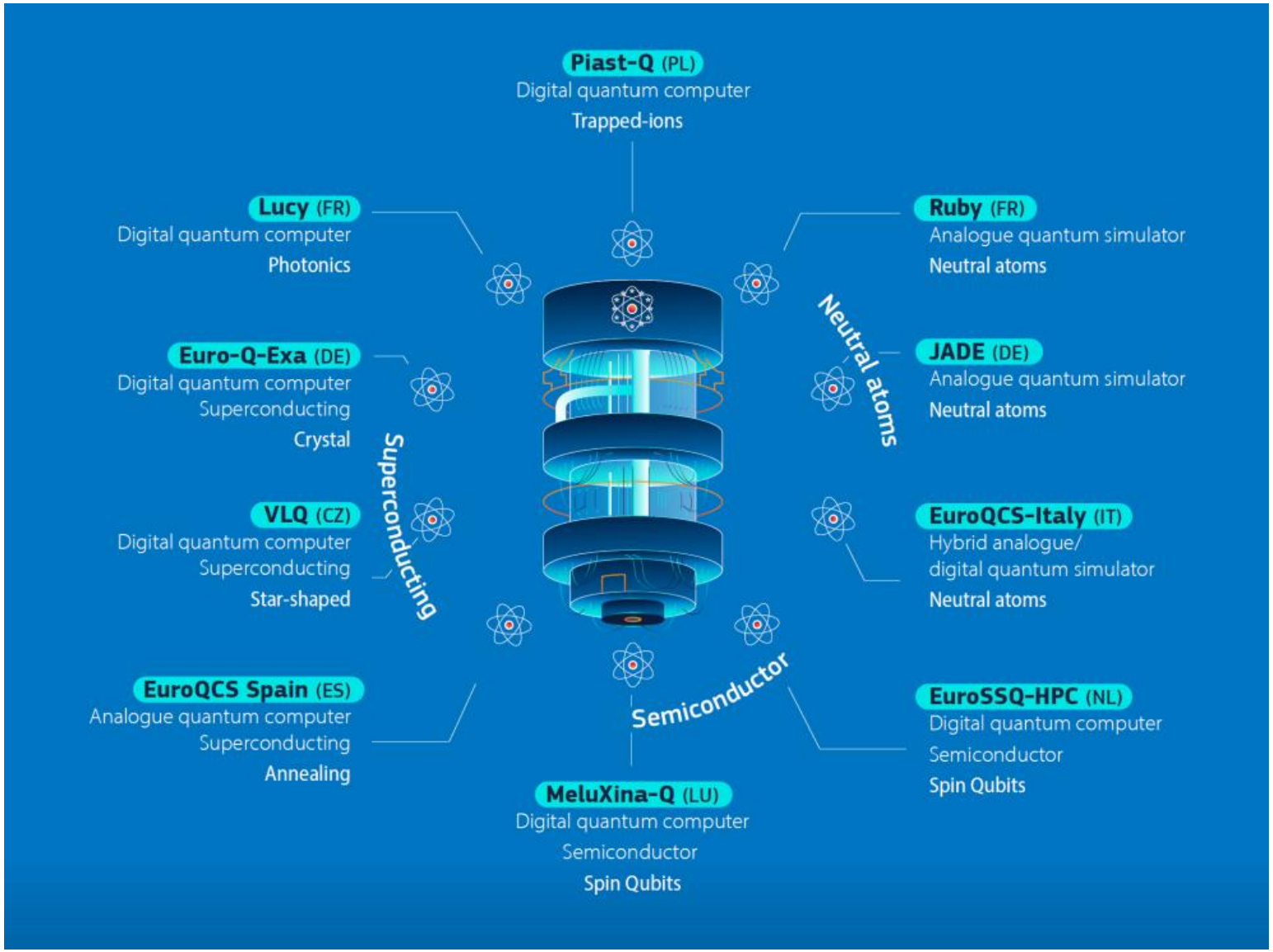
- The **European High-Performance Computing Joint Undertaking (EuroHPC JU)** has been pooling European resources to develop a variety of supercomputers for processing big data, based on competitive European technology.

- **LUMI**, which is in CSC's data center in Kajaani, Finland, is one such supercomputer and is hosted by the **LUMI consortium**.
- The **LUMI (Large Unified Modern Infrastructure) consortium** countries are Finland, Belgium, the Czech Republic, Denmark, Estonia, Iceland, the Netherlands, Norway, Poland, Sweden, and Switzerland.

Overview of LUMI Architecture



EuroHPC JU Quantum Computers



Overview of LUMI-Q

VLQ, the quantum computer of the LUMI-Q consortium, will provide a European-wide quantum computing environment **integrated with the EuroHPC infrastructure**. VLQ will allow the integration of the targeted EuroHPC quantum computer into EuroHPC supercomputer **KAROLINA** in Czechia, **LUMI** in Finland, and **EHPCPL** in Poland.

LUMI-Q CONSORTIUM MEMBERS

- Coordinator: VSB – Technical University of Ostrava, IT4Innovations National Supercomputing Center, Czechia
- CSC – IT Center for Science, Finland
- VTT Technical Research Centre of Finland Ltd, Finland
- Chalmers University of Technology, Sweden
- Danish e-Infrastructure Consortium (DeiC), Denmark
- Akademickie Centrum Komputerowe Cyfronet AGH, Poland
- Nicolaus Copernicus Astronomical Center, Poland
- Sigma2 AS, Norway
- Simula Research Lab, Norway
- SINTEF AS, Norway
- University of Hasselt, Belgium
- TNO Netherlands Organisation for Applied Scientific Research, the Netherlands
- SURF BV, the Netherlands

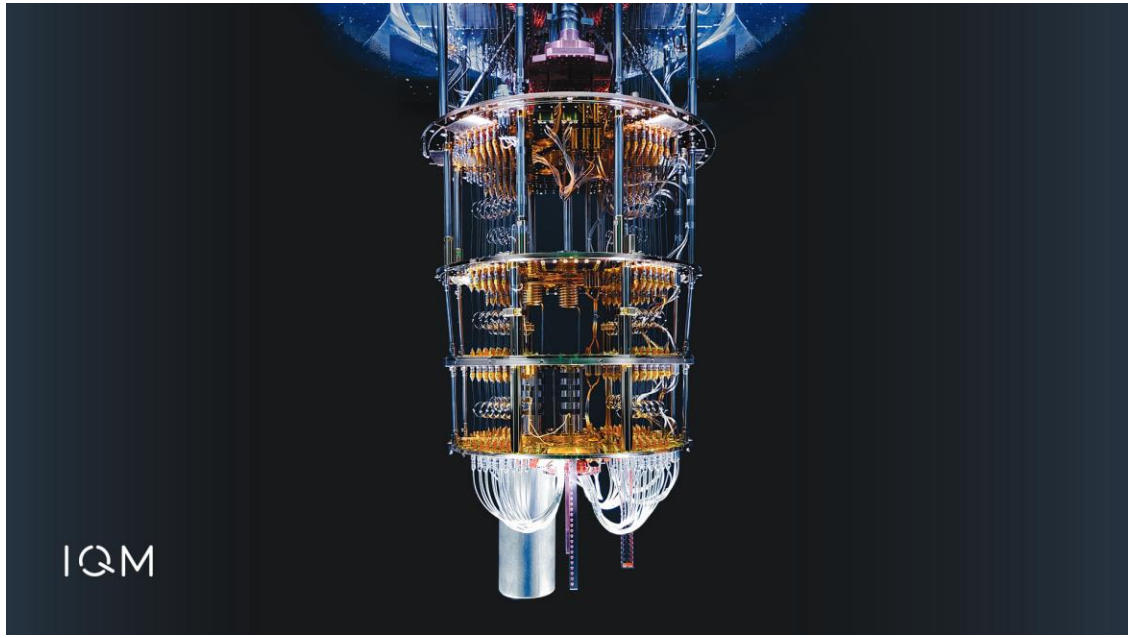
VLQ

ARCHITECTURE

- at least 24 physical qubits,
- the star-shape topology,
- the total cost of the system is EUR 5.0 million,
- integrated into the EuroHPC supercomputer KAROLINA,
- IQM Quantum Computers, supplier of systems,
- installation and commissioning will take place in 2025.

Overview of IQM

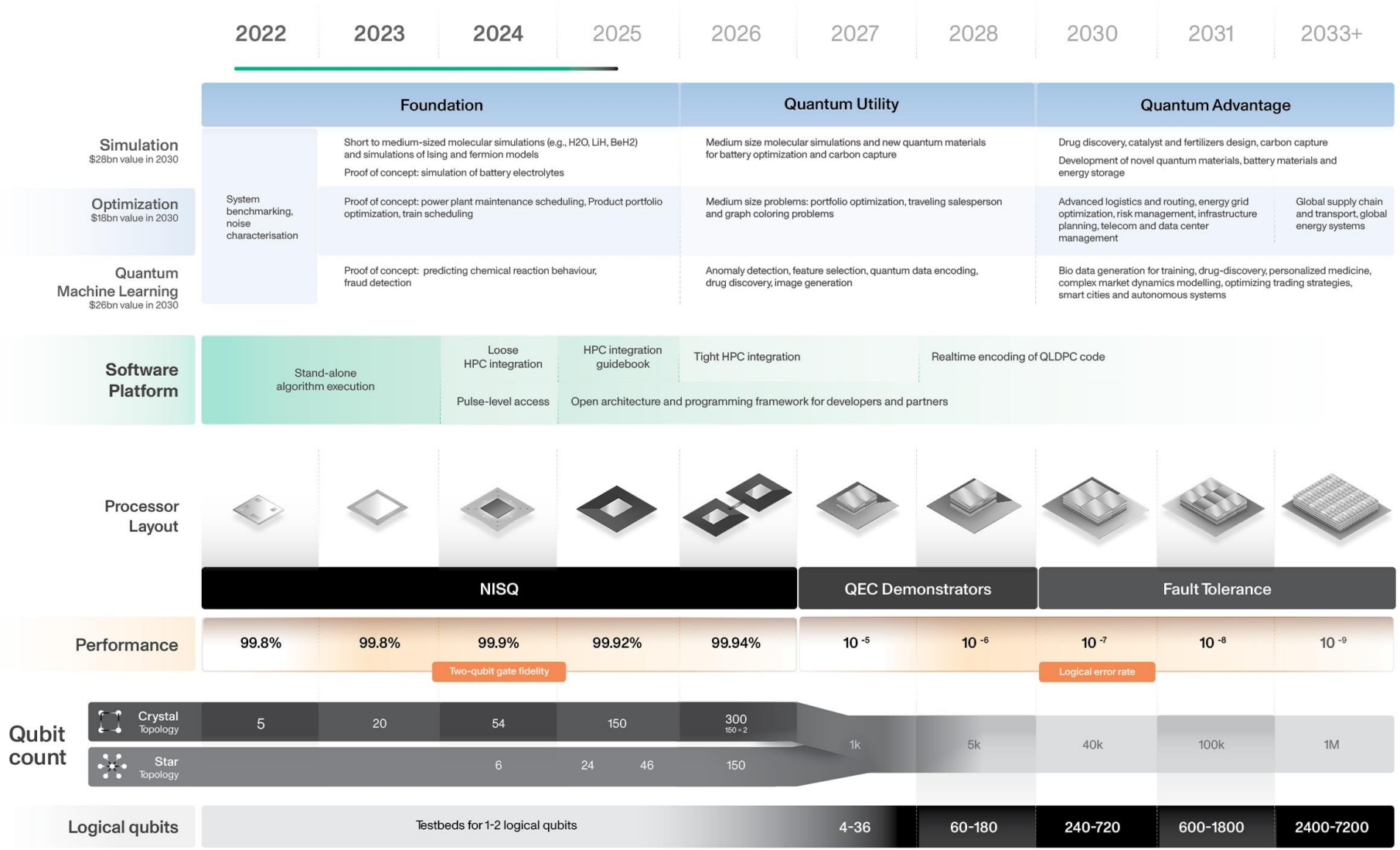
- IQM is the **leading European quantum hardware company in superconducting circuits**, headquartered in **Espoo, Finland**.
- IQM builds **superconducting full-stack quantum computers** with up to 150 high-fidelity qubits.
- Currently, IQM has **some*** QPU access available through AWS (Amazon Braket).



Industrial and Academic Customers

CINECA, LRZ, Oak Ridge National Laboratory, VTT, aws, Hewlett Packard Enterprise, Jülich Forschungszentrum, Eviden an atos business, Fondazione Links, VSB Technical University of Ostrava / IT4Innovations National Supercomputing Center, TSRI, 충북대학교

Overview of IQM



Overview of IT4I

- In the **Czech Republic**, **IT4I** is the leading research, development, and innovation centre active in the fields of HPC, QC, AI, and their application to other scientific fields, industry, and society.

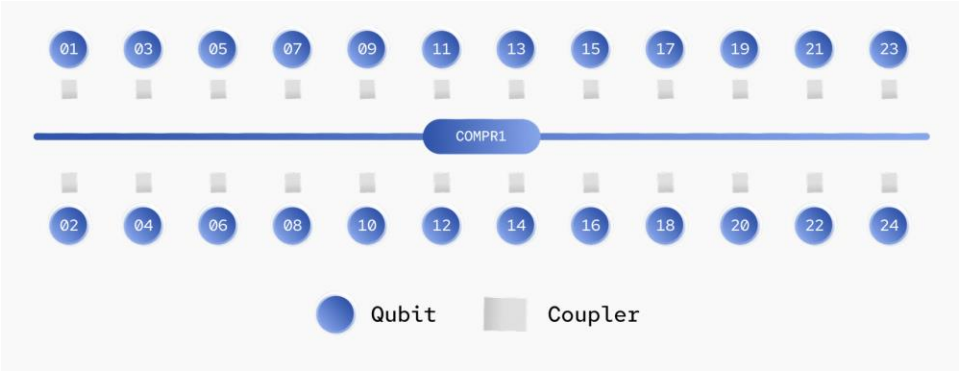
- IT4I operates the most powerful supercomputing systems in the Czech Republic, including **KAROLINA,** which are provided to Czech and foreign research teams from both academia and industry.

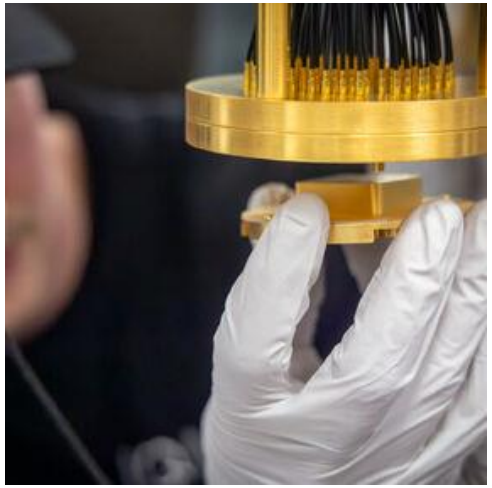
VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

PUT INTO OPERATION	summer 2021
THEORETICAL PEAK PERFORMANCE	15,690 Tflop/s
OPERATING SYSTEM	Rocky Linux 8.9
COMPUTE NODES	831
CPU	720x 2x AMD 7H12, 64 cores, 2,6 GHz, 92,160 cores in total 72x 2x AMD 7763, 64 cores, 2,45 GHz, 9,216 cores in total 72x 8x NVIDIA A100 GPU, 576 GPU in total 32x Intel Xeon-SC 8628, 24 cores, 2,9 GHz, 768 cores in total 36x 2x AMD 7H12, 64 cores, 2,6 GHz, 4,608 cores in total 2x 2x AMD 7452, 32 cores, 2,35 GHz, 128 cores in total
RAM PER COMPUTE NODE	256 GB / 1 TB (GPU) / 24 TB fat node 320 GB HBM2 (8 x 40 GB) GPU
ACCELERATORS	576x NVIDIA A100
STORAGE	30.6 TB / home (1.93 GB/s sequential write performance, 3.10 GB/s sequential read performance), 1,361 TB / scratch (NVMe, 730.9 GB/s sequential write performance, 1, 198.3 GB/s sequential read performance)

Hardware Details of VLQ

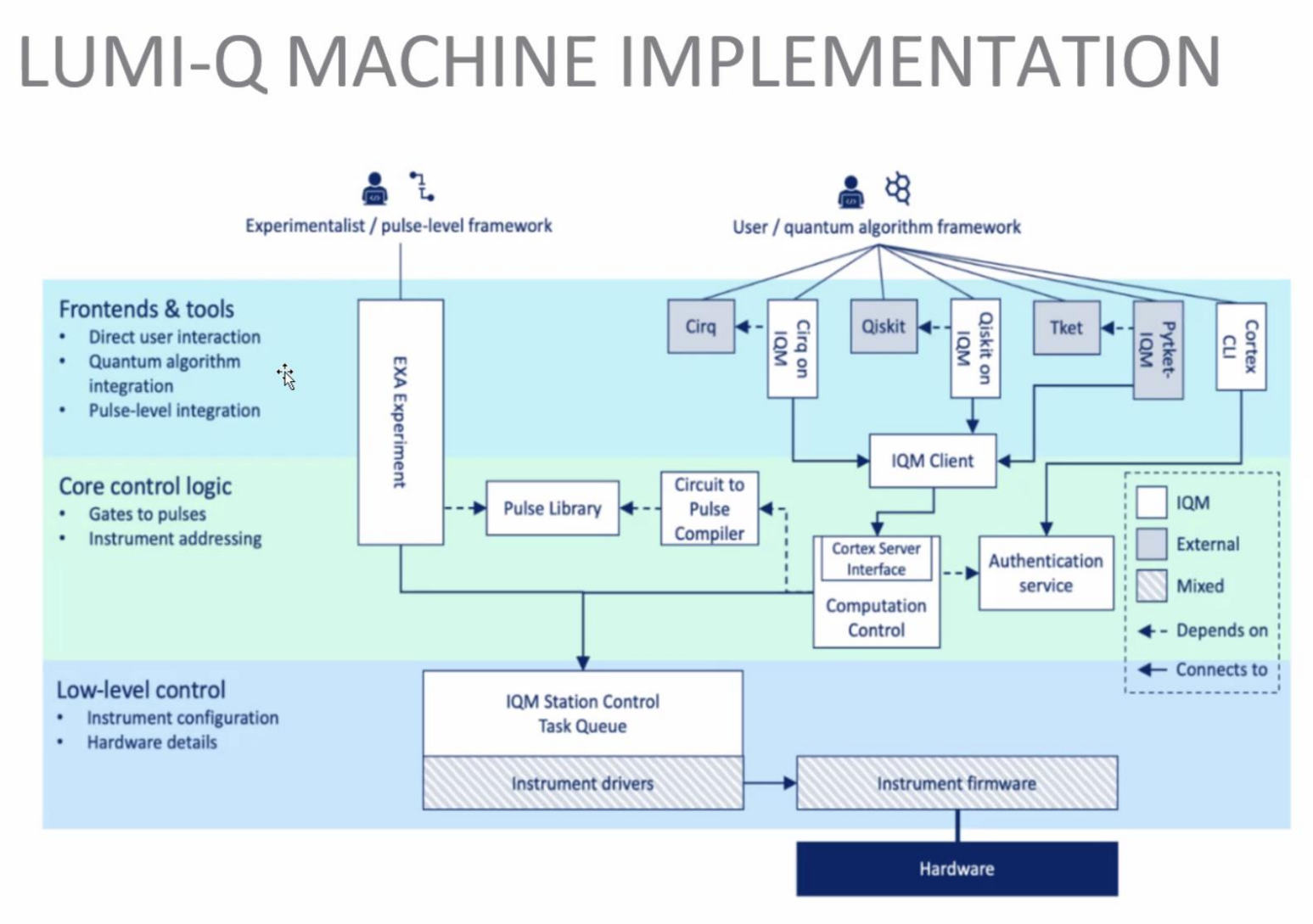
- VLQ's contains a 24-qubit QPU based on superconducting transmon qubits designed for cutting-edge quantum research that requires high connectivity.
- A central resonator hub connects a large number of qubits, optimizing connectivity for highly interactive quantum processes and dramatically reducing the number of SWAP operations needed.





Hardware Details of VLQ

Software Details of VLQ



Impact for Q-Access and Denmark

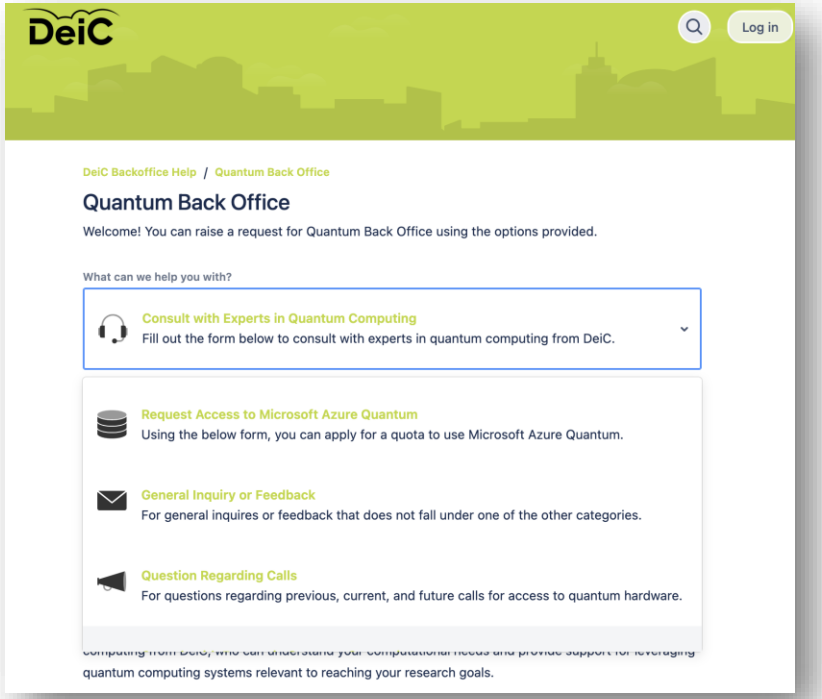
Summary

- LUMI-Q VLQ will be an **additional access option provided by Q-Access** to Danish academia.
- DeiC will provide **onboarding sessions and consulting** to help Danish academia and industry take full advantage of VLQ (in addition to what will be offered by IQM and IT4I).
- The **close HPC integration and pulse-level access** will open new possibilities for applications and diversify DeiC's Q-Access offering.
- There is **potential for Danish industry** to take advantage of LUMI-Q VLQ.
- DeiC is **developing proof-of-concept use cases** to showcase how to take advantage of quantum computers like VLQ!

4. Q-Access

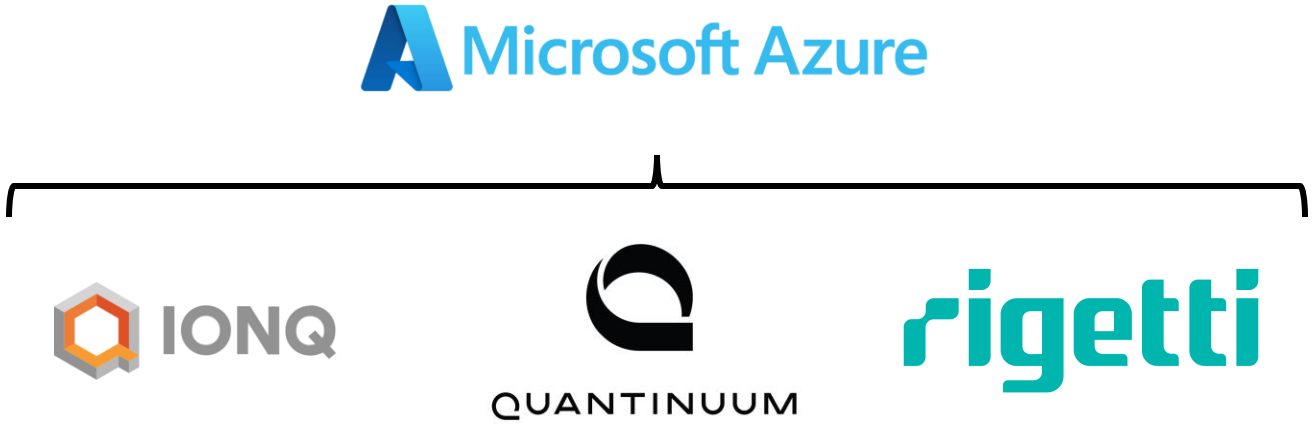
Consulting with Quantum Experts

- DeiC provides **consulting with experts in quantum computing**, who can understand your computational needs and provide support for leveraging quantum computing systems relevant to reaching your research goals.
- These services can be utilized by both universities, industry, and the public sector.
- These experts can provide advice and share technical expertise on porting and optimizing applications for quantum computing environments and offer guidance on software development as needed.
- DeiC is now offering **weekly Office Hours** as well to make it easier to drop in and ask questions.
- There are also **Jira Forms** for questions regarding calls, for general inquiry or feedback, and for requesting sandbox access to hardware!



Sandbox Access to Quantum Hardware

- Currently, sandbox access to Microsoft Azure for testing worth up to **25.000 DKK** can be applied for by filling out a simple form at: https://deic-backoffice.atlassian.net/servicedesk/customer/portal/3/group/4/create/35
- DeiC will evaluate and respond to your application within a week.
- Users can reapply after they use their allocated resources for a total of **100.000 DKK.**



- IBM and Amazon Braket sandbox access are currently under development. More details coming soon!
- This sandbox access can also be used in conjunction with Ucloud resources for testing hybrid algorithms.

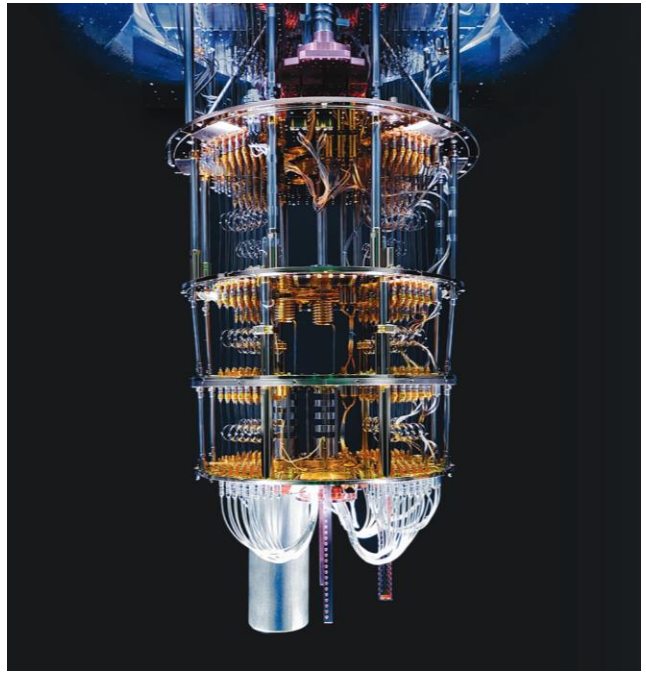
Calls for Specialized Access

- For access to specific quantum hardware and corresponding hardware-specific simulators via one of the calls for quantum access, there is a pool of **11.000.000 DKK**.

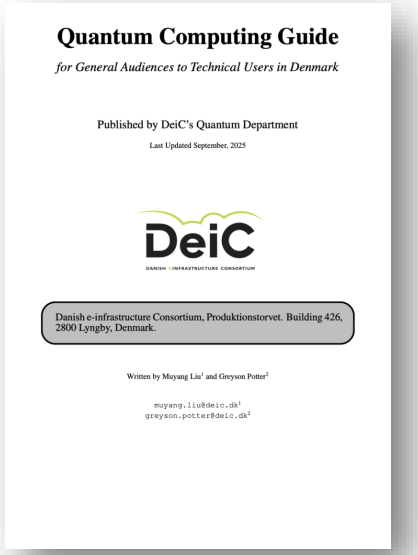
- See https://www.deic.dk/da/quantum-technology/grants-and-funding for active and previous calls!

Access to LUMI-Q VLQ and EuroHPC JU

- LUMI-Q VLQ will be an **additional access option provided by Q-Access** to Danish academia.
- DeiC will provide **onboarding sessions and consulting** to help Danish academia take full advantage of VLQ.
- The **close HPC integration and pulse-level access** will open new possibilities for applications and diversify DeiC's Q-Access offering.
- Direct access to the LUMI-Q VLQ quantum computer, through DeiC's participation in the LUMI-Q Consortium, will be available through a **call for applications in early 2026**.
- 50% of VLQ access will also be available through EuroHPC, along with the the other quantum computers partially financed by the EuroHPC Joint Undertaking.

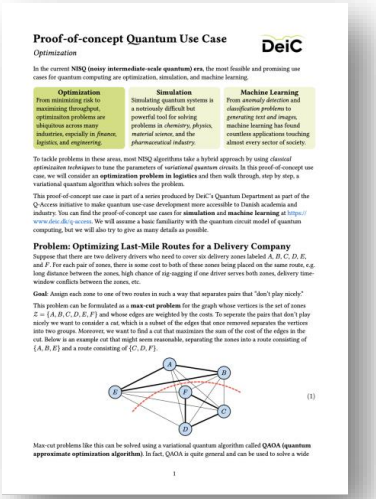


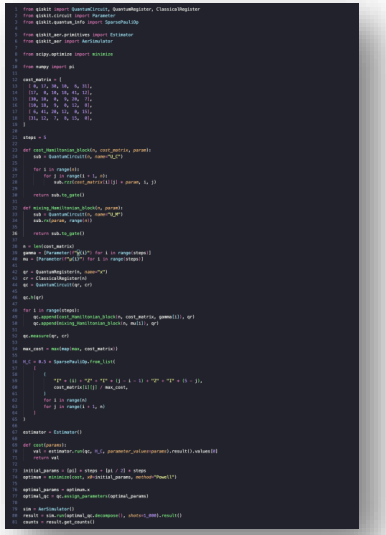
Guides and Tutorials



- Overview published by DeiC's Q-Access team to provide a clear and understandable description of the quantum computing resource available to users in Denmark as well as tutorials and guides of how to use them.
- Designed to be useful to both non-technical audiences (policymakers, journalists, and industry leaders) and professional quantum computing users both inside and outside Denmark.
- Begins with an introduction to quantum computing principles, followed by descriptions of different quantum devices, real-world applications, and tutorials for accessing and using resources.

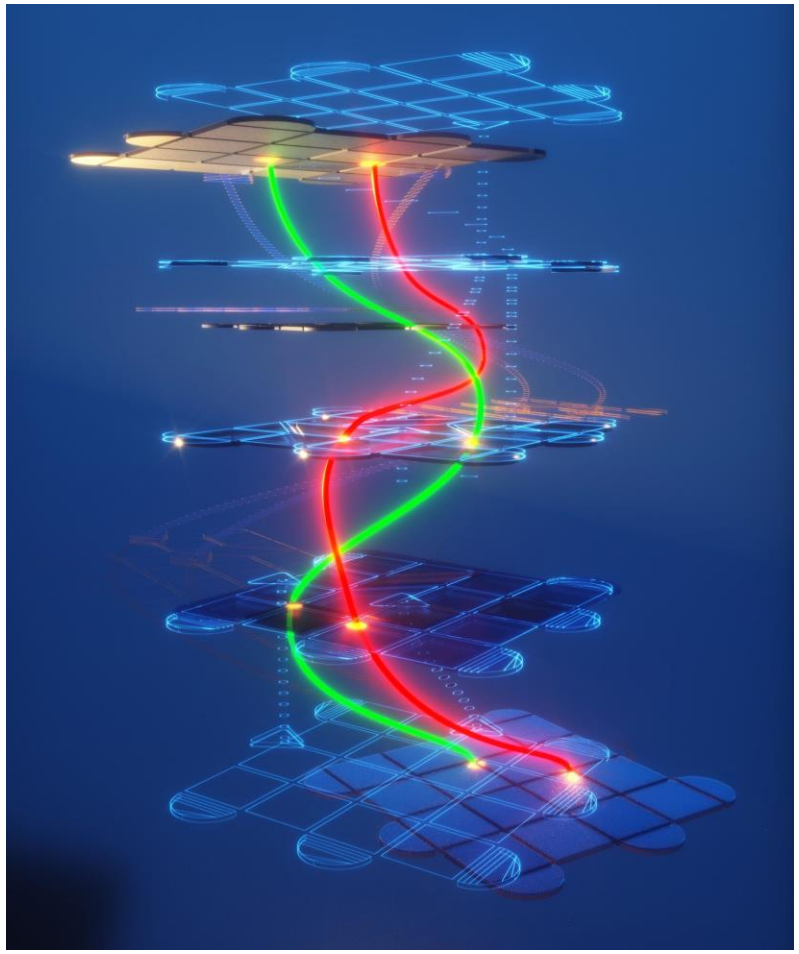
- DeiC is developing some simple **proof-of-concept use cases** (for both **academia and industry**) with **step-by-step explanations** of the thought process and implementation to help, especially Danish, users best utilize quantum computing resources.
- **Proof-of-concept use case for optimization is available**, with proof-of-concept use cases in simulation and machine learning coming by the end of 2025!





Q-Access – Next Steps

- Currently, DeiC's Quantum Department is on its **second roadshow to the Danish Universities!**
- Actively developing more **proof-of-concept use cases in simulation and machine learning** and working on **implementing them on a variety of platforms including VLQ**.
- Investigating further integrations with **HPC, UCloud, EuroHPC**, etc. and how to best utilize these in conjunction with quantum resources offered by DeiC.
- The **next call** for specialized access to quantum hardware (and hopefully VLQ coming) will be in **January 2026**.
- Continuing to investigate new access options for quantum hardware and ways to help Danish users get the most out of what is already offered!



5. Q-Competence

Q-Competence

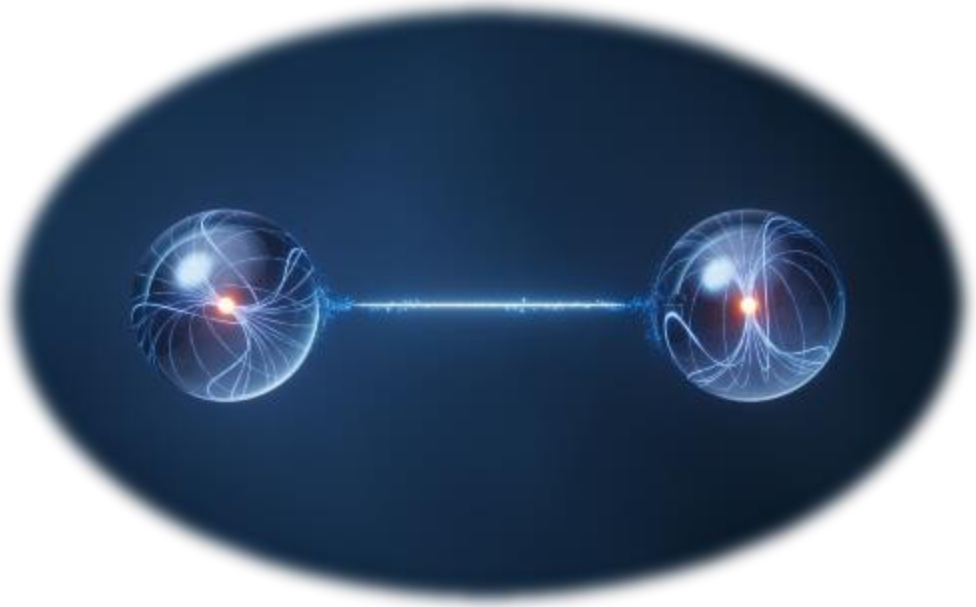
Missioned from the Danish National Quantum Strategy:

Build national competence by supporting educational activities related to quantum computing

All Danish public and private organisations can apply for financial support for their quantum educational projects!

Working group members

- Chairperson: *TBD, member from DeiC's board by DeiC's Board in Q4, 2025*
- AAU: Associate Professor Rolf Lyhneborg Lund
- SDU: Professor Jørgen Ellegaard Andersen
- KU: Associate Professor James Emil Avery
- DTU: Senior Researcher Mikkel Heuck
- Alexandra Instituttet: CSO Martin Møller
- DIREC: Director Thomas Riisgaard Hansen
- DeiC: Project Manager Dennis Lange Wollbrink
- DeiC: Quantum Consultant Maria Tammelin Gleerup
- DeiC: Head of Quantum Henrik Navntoft Sønderskov



Q-Competence

Where are we now?

- 2 calls for tender issued in Q4, 2024 and Q2, 2025
- 3 projects funded from the 1st call and 3 projects funded from 2nd call

Projects from 1st call

- Quantum Computing to Business (QC2B)
  PI Jørgen Ellegaard Andersen, Professor, Center for Quantum Mathematics, University of Southern Denmark

- Danish Quantum Integration Program (DQIP)
  PI Jacob Friis Sherson, Professor MSO, Dep. of Management, Aarhus University

- Training for Large-Scale Simulations of Quantum Systems
  PI Mark Kamper Svendsen, Assistant Professor, Niels Bohr Institute, University of Copenhagen

Stay tuned! Projects from 2nd call will be announced before end of 2025 when contracts are signed

Q-Competence – Next Steps

Next steps

- Announce 3rd call in Q1/Q2 2026
- Future calls may have thematic focuses - according to demand

More info

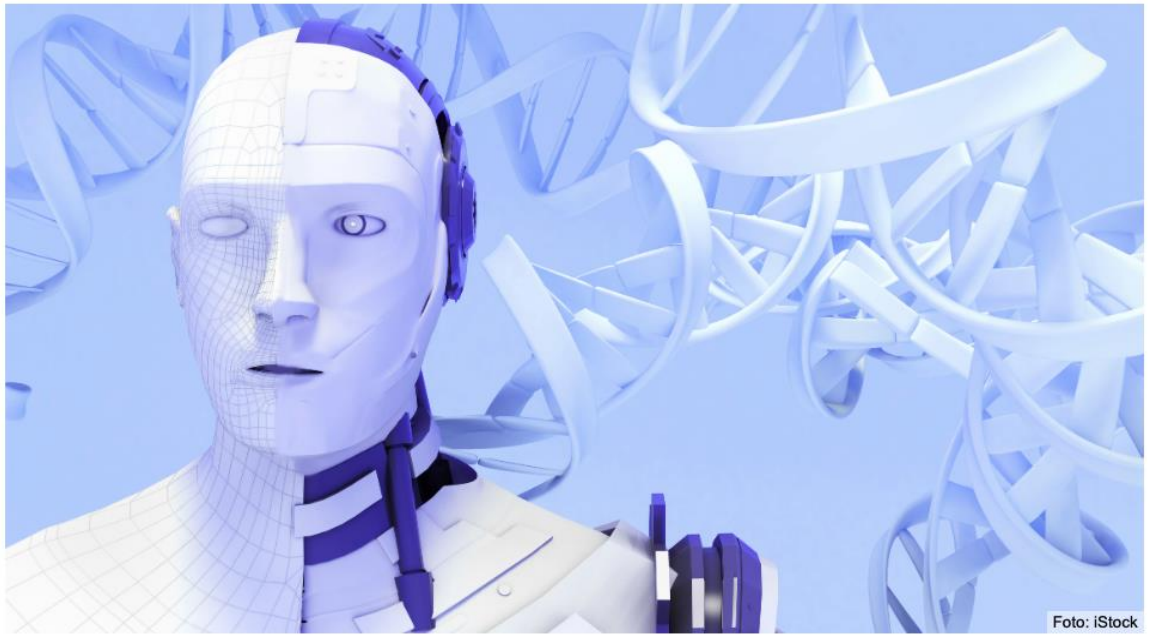
- https://www.deic.dk/da/q-competence
- https://deic.dk/da/quantum-technology/grants-and-funding
- https://deic.dk/en/news/2025-7-10/deic-contributes-to-securing-quantum-talent-in-denmark

DeiC Contributes to securing Quantum Talent in Denmark

DeiC is allocating DKK 6 million to three different educational initiatives focused on the use of quantum computers – benefitting businesses, researchers, and public administration alike.

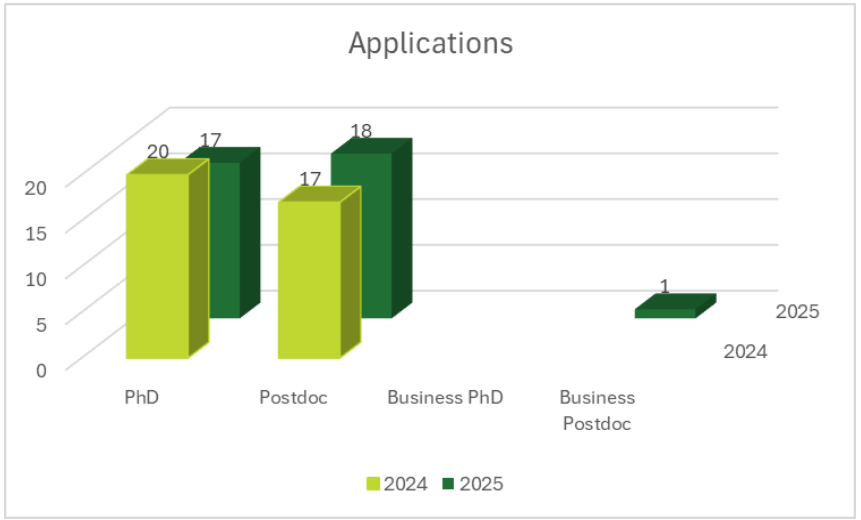
BY
Marie Charllotte Søbye

10/07/2025 12:07



6. Q-Algorithm

Q-Algorithm – a quantum excellence center for developing and testing algorithms



The Danish Quantum Algorithm Academy supports Danish quantum research by funding PhD and Postdoc positions (including industrial).
The goal is to build a competitive community in quantum algorithms and software. DQA Academy also hosts workshops, lectures, and events to foster collaboration and progress in the field, while also building an alumni network to keep past participants engaged.

Members of the Q Algorithm Academy:

Aalborg University: Professor Torben Larsen, Department of Electronic Systems
Alternate: Professor Rafal Wisniewski, Department of Electronic Systems

Aarhus University: Professor Jaco van de Pol, Department of Computer Science
Alternate: Professor Nikolaj Zinne, Department of Physics and Astronomy

Roskilde University: Teaching Associate Professor Sune Thomas Bernth Nielsen, Department of People and Technology
Alternate: Associate Professor Mads Rosendal, Department of People and Technology, Programming, Logic, and Intelligent Systems

University of Southern Denmark: Professor Jørgen Ellegaard Andersen, Department of Mathematics and Computer Science
Alternate: Professor Jacob Kongsted, Department of Physics, Chemistry and Pharmacy

Technical University of Denmark:
Associate Professor Sven Karlsson, Department of Applied Mathematics and Computer Science
University of Copenhagen
Associate Professor Michael Kastoryano, Department of Computer Science

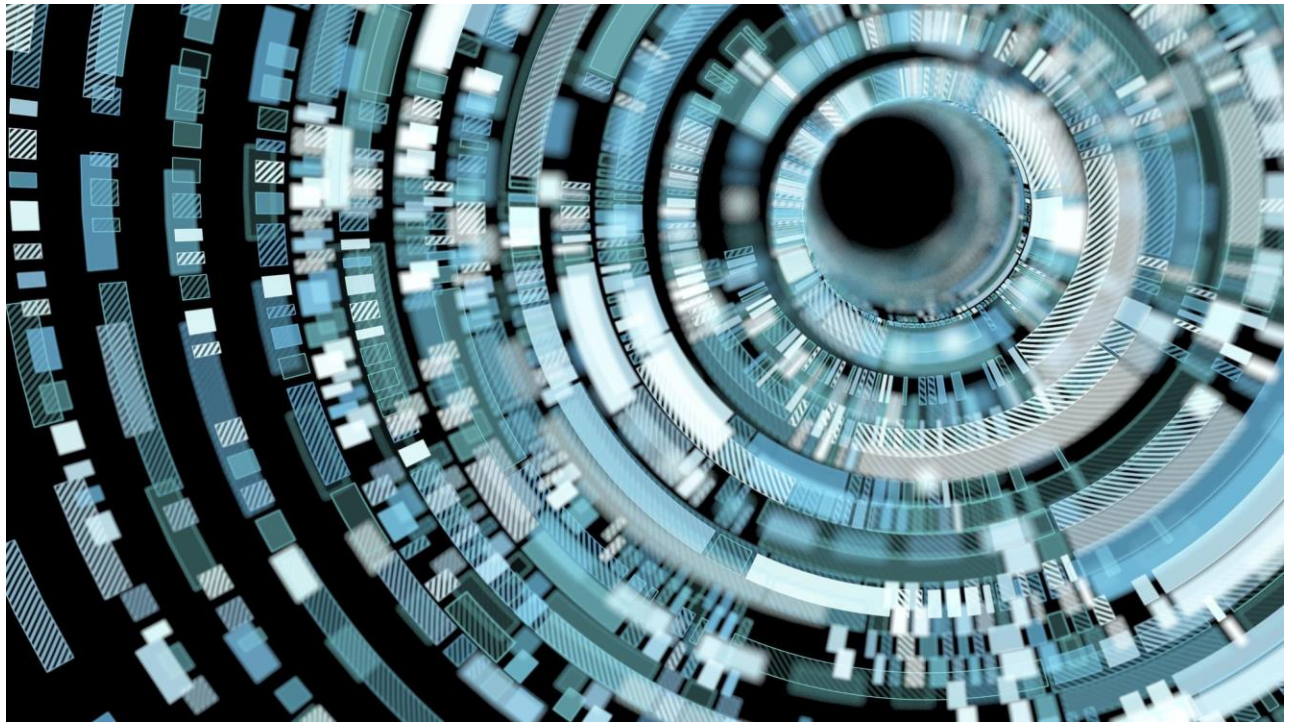
DeiC: Ex officio members: Head of Quantum Infrastructure, Henrik Navntoft Sønderskov, DeiC
Programme Coordinator, Louise Juel Broch, DeiC

Q-Algorithm – Next Steps

Next call will be announced in Q1 2026.

The academy is working on the following events:

- 12-12 Seminar for scholarship recipients in May 2026
- Delegation trip to London expected June 2026



7. Niels Bohr Quantum Summer School

Niels Bohr Quantum Summer School

The summer school directly aligns with Denmark's national quantum strategy, aiming to cultivate and attract more 'quantum talent' to strengthen Denmark's leadership in this cutting-edge field

DeiC

Coordinated by DeiC in collaboration with University of Copenhagen, University of Southern Denmark, Technical University of Denmark, Aalborg University, Aarhus University, Innovation Centre Denmark in Seoul, Tel Aviv, Munich, Boston and Silicon Valley.

Funding for 4 summer schools

2025: Niels Bohr Institute, University of Copenhagen
2026: Center for Quantum Mathematics, University of Southern Denmark, Odense
2027: DTU
2028: Aalborg University

The 2025 edition:

250 applications
70 students admitted + 14 on a waiting list
Some changes in the group underway due to world politics
Only 20 students from Danish universities!

➡ Quantumsummer.dk

➡ https://www.linkedin.com/company/niels-bohr-quantum-summer-school/

Thank you all for listening!

Stick around for Q&A!