

# **HPC+QC, NordQuEst and the Future of Quantum Computing**

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# Why do we need quantum computers ?

→ We need QC for **exponential speed-up** to solve **hard problems** (only approximately!) **with finite resources** (time, memory).  
(to reduce energy consumption, if nothing else ...)

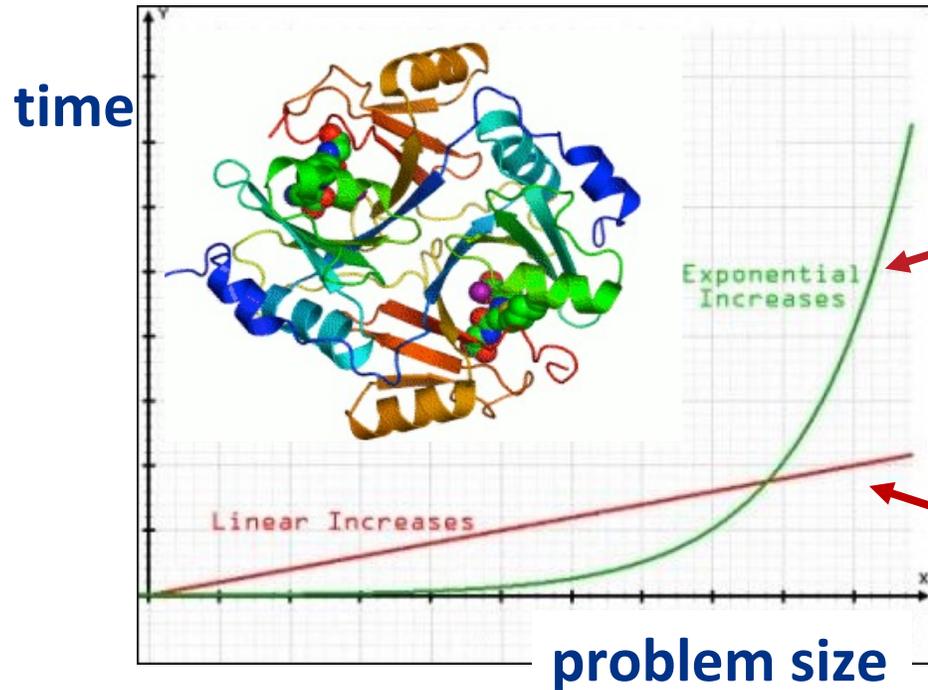
The original “killer application”: **Shor’s algorithm for factorisation** (1995)

Today, the typical killer applications are “use cases”:

- **Quantum Chemistry** – designing **enzymes and catalysers**; pharma
- **Materials science** – describing **strong electron correlations**; new materials
- **Optimization** - **logistics, scheduling, big data, machine learning, ....**

# Quantum Advantage

Quantum computers offer, in principle,  
**exponential speed-up** for certain classes of **hard problems**

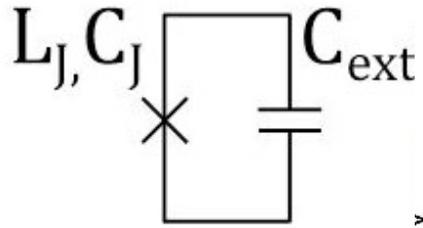


TTS for a HPC:  
Grows exponentially

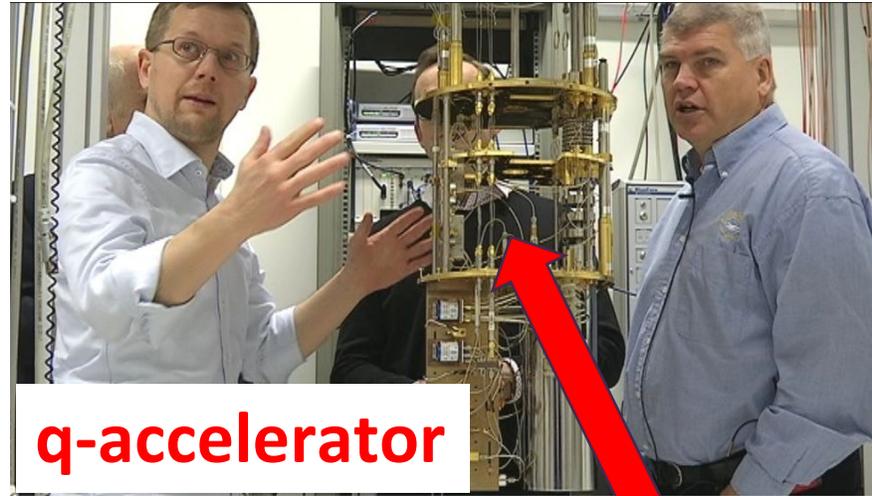
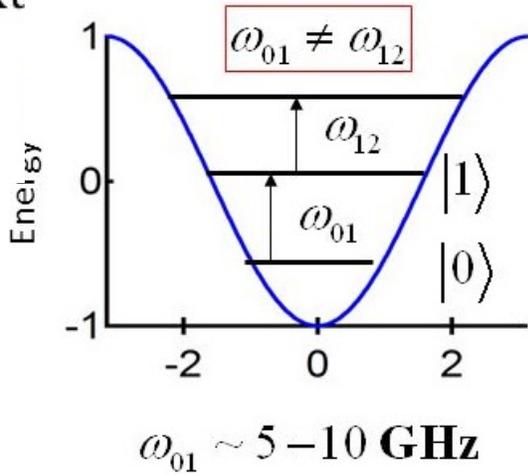
TTS for a quantum  
computer:  
Grows  
linearly/polynomially

No Quantum Advantage

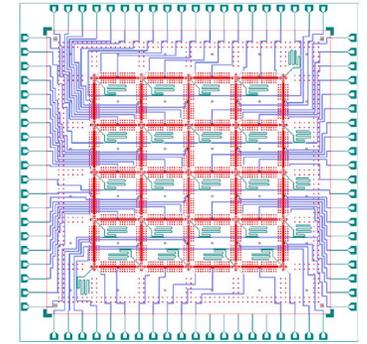
# HPC+QC = Classical computer + q accelerator



1 Qubit



q-accelerator

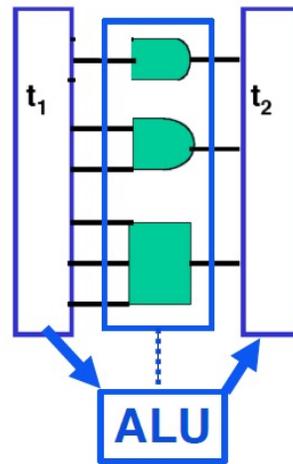


25 qubits



CC: Classical gates

C-register state    C-register state

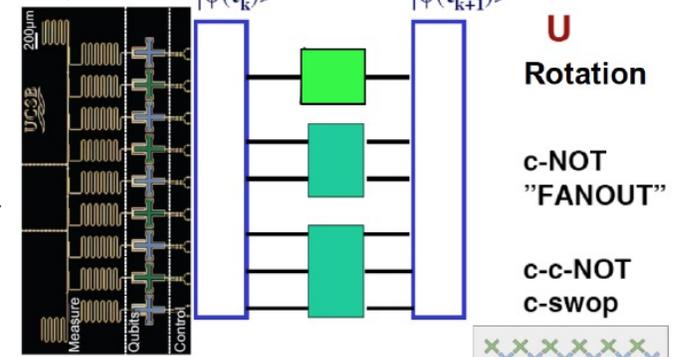


Computing **FROM/TO** memory  
The memory is the storage

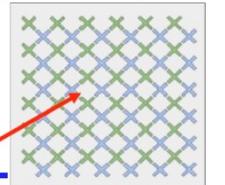
FANOUT  
NOT,  
AND,  
OR,  
NAND,  
NOR, ...

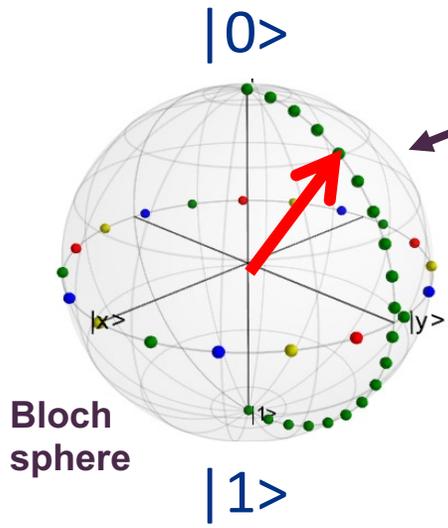
QC: Quantum gates

Q-register state    Q-register state



Computing **IN** memory  
The memory is the computer



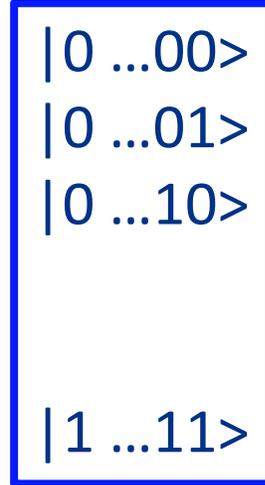


$$a|0\rangle + b|1\rangle$$

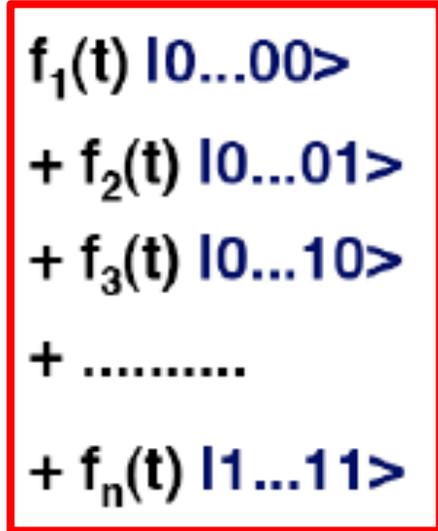
**Qubit**  
 0 and 1  
 Vector addition  
**Superposition!**

**Parallellism!!**

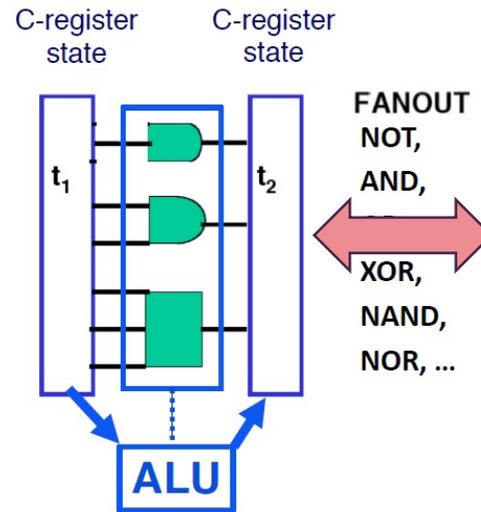
One single memory configuration at any given time  $t$



**Superposition & Entanglement**  
**→ Quantum Advantage**

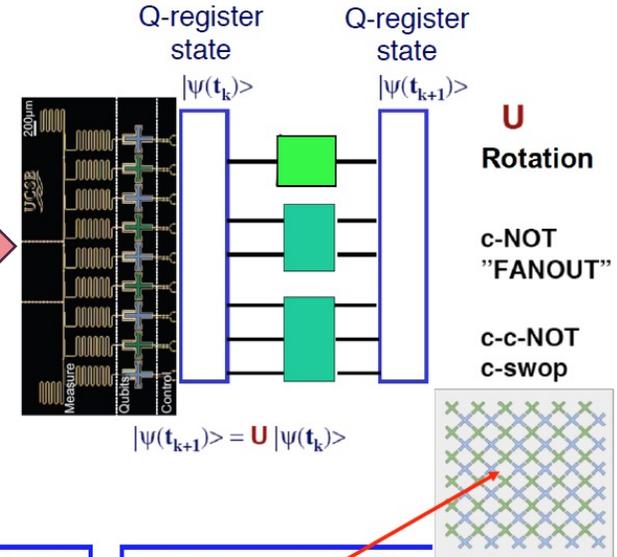


**CC: Classical gates**



Computing **FROM/TO** memory  
 The memory is the storage

**QC: Quantum gates**



Computing **IN** memory  
 The memory is the computer

# History of QC-projects with superconducting circuits

SQUBIT (2000-2002)

SQUBIT-2 (2002-2004)

EuroSQUIP (2005-2008)

SOLID (2009-2012)

ScaleQIT (2013-2016)

.... Q-Flagship .....

OpenSuperQ (2018-2022)

OpenSuperQPlus (2022-2026)

OpenSuperQPlus100 (2023-2026 (-2029))

1999 - Nakamura, Pashkin, Tsai:  
1st demo of superconducting qubit

Coordinated by Göran Wendin,  
Chalmers

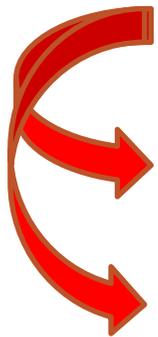
Coordinated by Frank Wilhelm-Mauch,  
Jülich  
100q+ QPU by 2025; (1000q+ by 2029)

NordlQuEst (2022-2025)

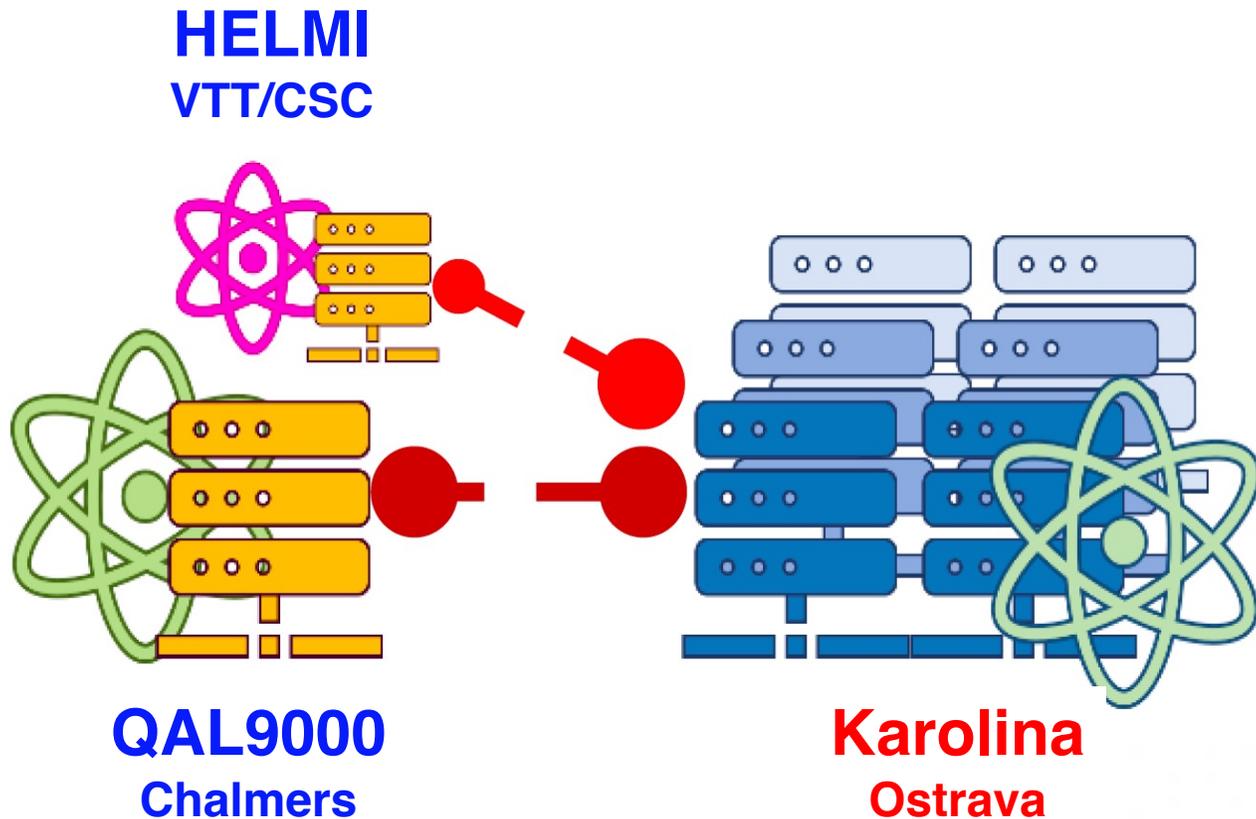
NeIC, NordForsk

LUMI-Q (2023-2026)

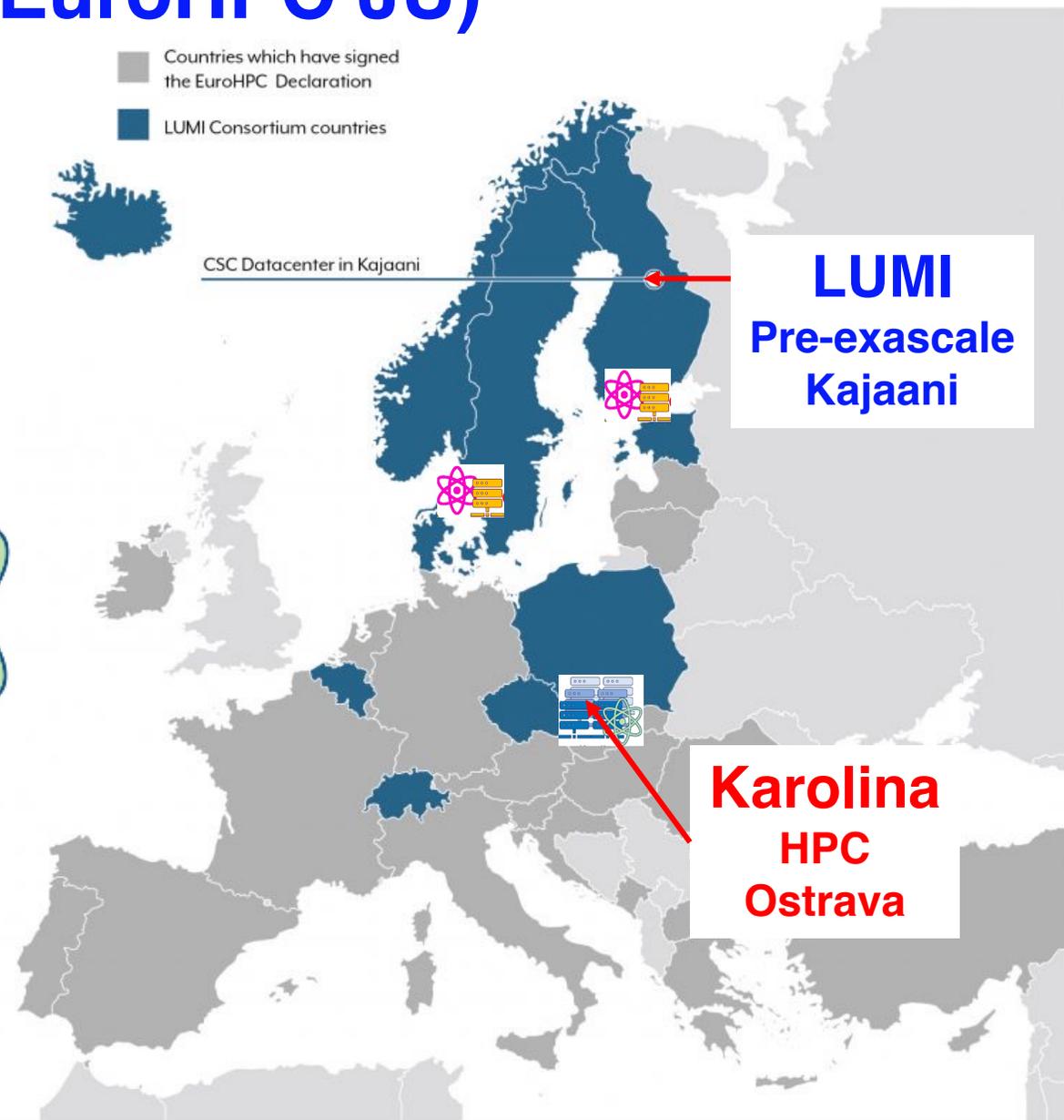
EuroHPC Joint Undertaking  
HPC+QC European ecosystem  
QPU procurement



# LUMI-Q (2023-2026 ....; EuroHPC JU)



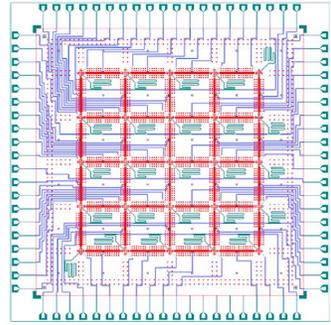
**Integrated and distributed  
HPC+QC hybrid computing**



# NordiQuEst HPC+QC hybrid ecosystem



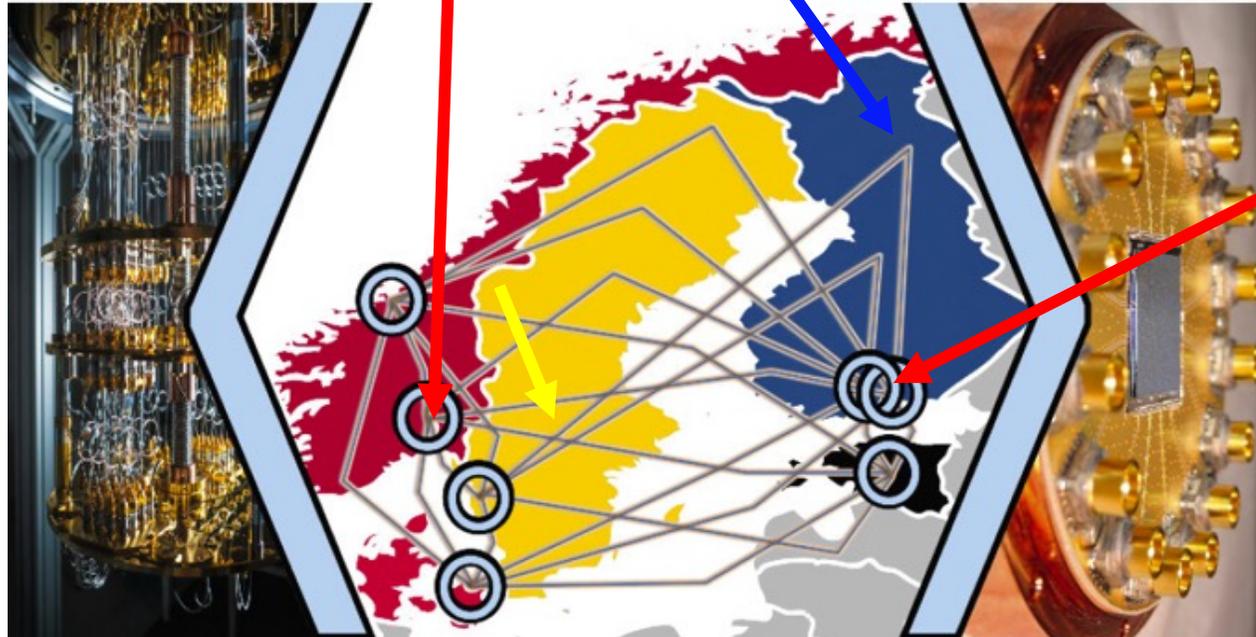
NeIC = Nordic  
e-Infrastructure  
Collaboration



2022-2025

LUMI pre-exascale HPC in Kajaani

Chalmers QPU:  
QAL 9000



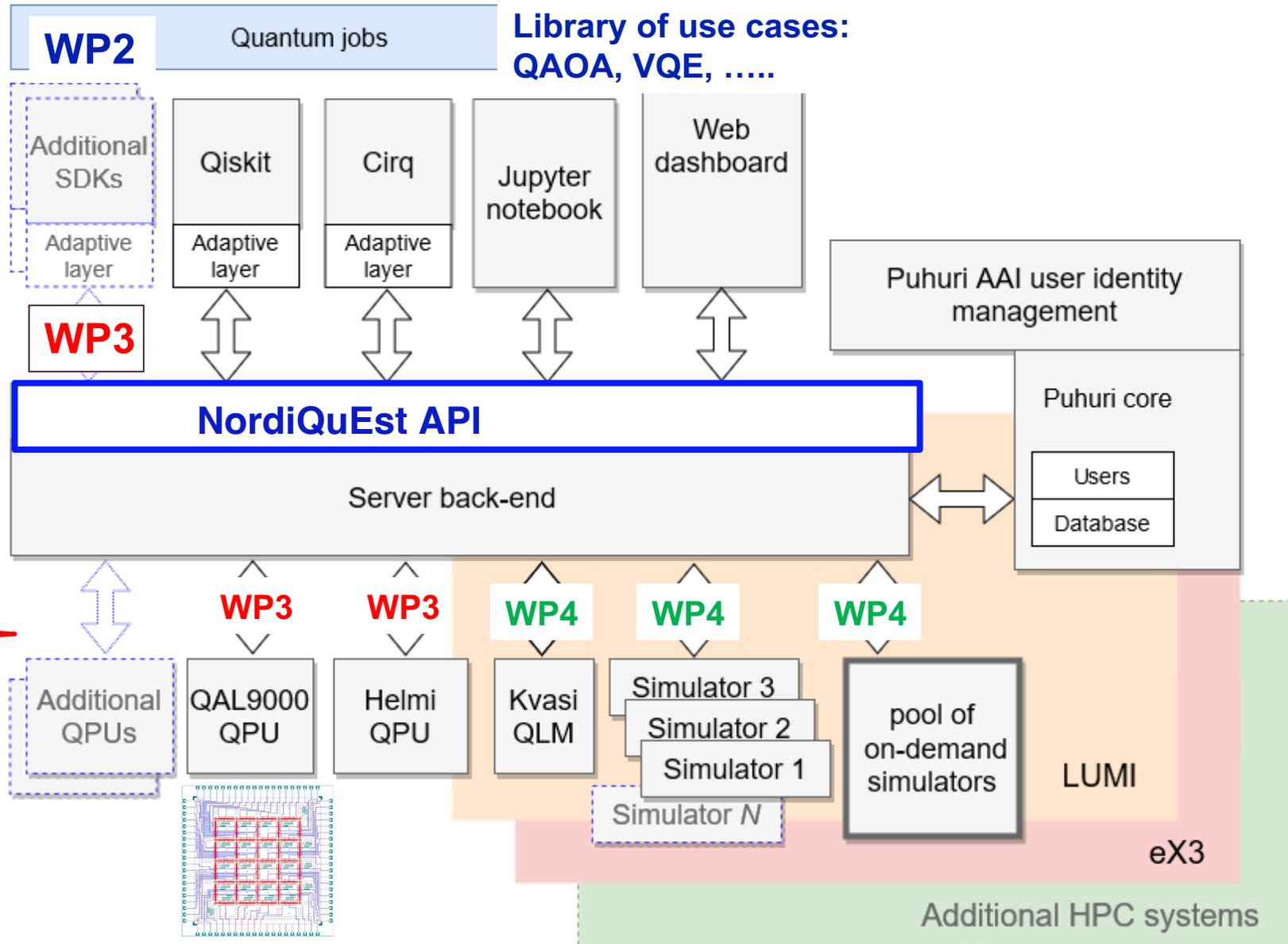
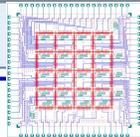
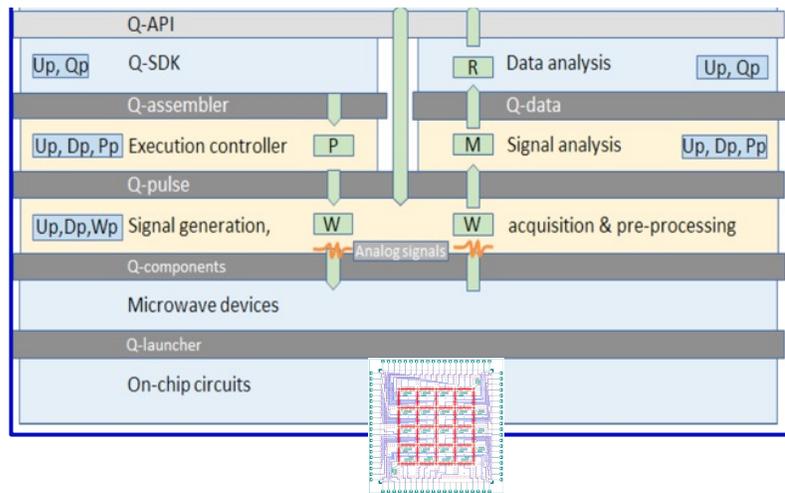
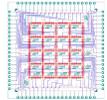
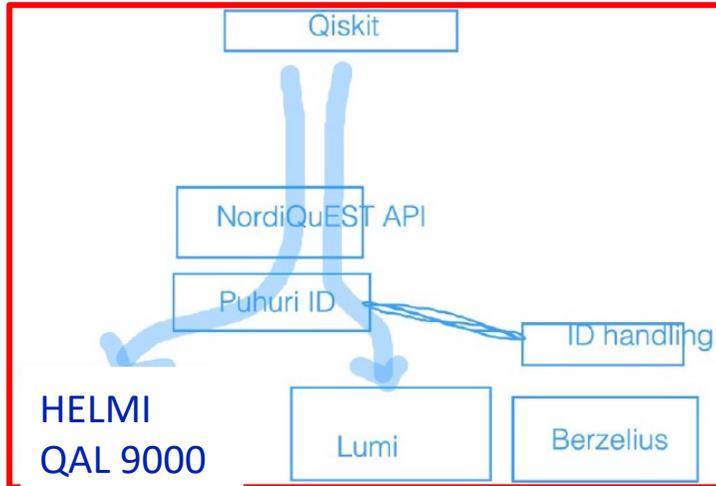
VTT QPU:  
HELMI

According to plans:  
25 qubits by 2023  
50 qubits by 2025

Accessible for users via  
a LUMI's Puhuri portal

NordiQuEst =  
Nordic-Estonian Quantum Computing e-  
Infrastructure Quest – NeIC/NordForsk

# NordiQuEst in a nutshell

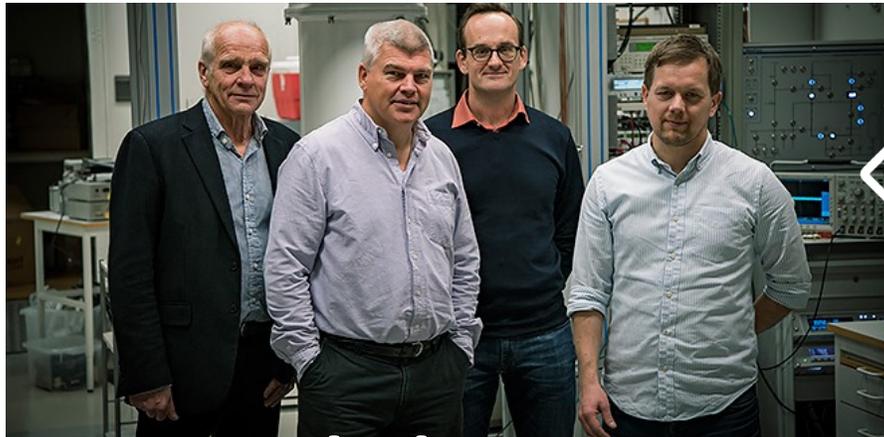


# Sweden's quantum technology programme

## Wallenberg Center for Quantum Technologies

**WACQT, 2018-2029** MC2, Chalmers U of Tech, Sweden

**12 years, 150 M€**

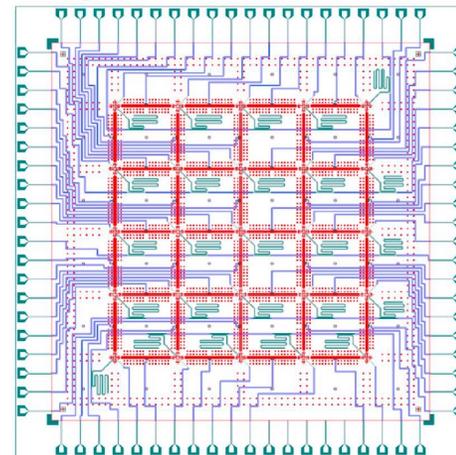


**Mission: to build a quantum processor  
with 100+ superconducting qubits by 2029**

<https://www.chalmers.se/en/centres/wacqt/Pages/default.aspx>



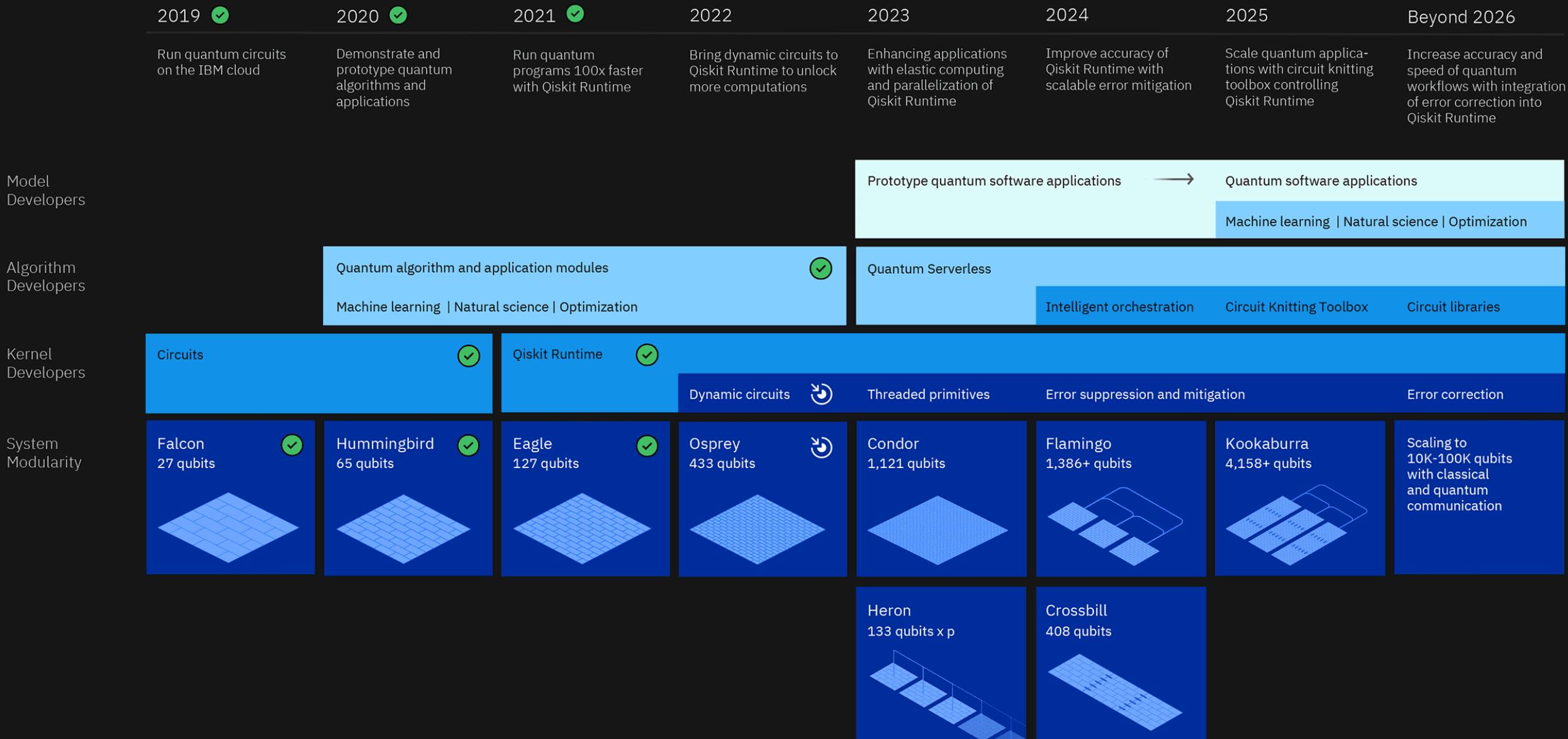
**Cryostat  
≈ 10 mK**



**25q Transmon chip under testing**



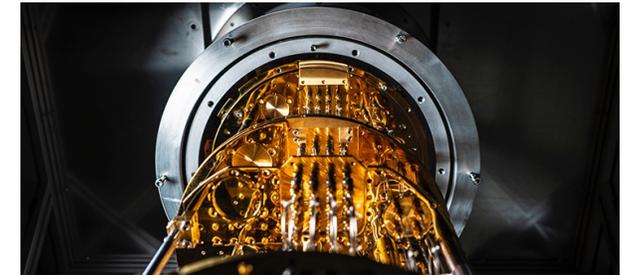
# The Future of Quantum Computing ??



**Thanks for your attention!**  
**Questions?**  
**Comments??**



**WACQT**



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



The OpenSuperQ project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820363.