Call 2021
Final Evaluation

QUANTERA
DECADE OF IMPACT 2016-2026

HQCC

Hybrid Quantum Classical Computation

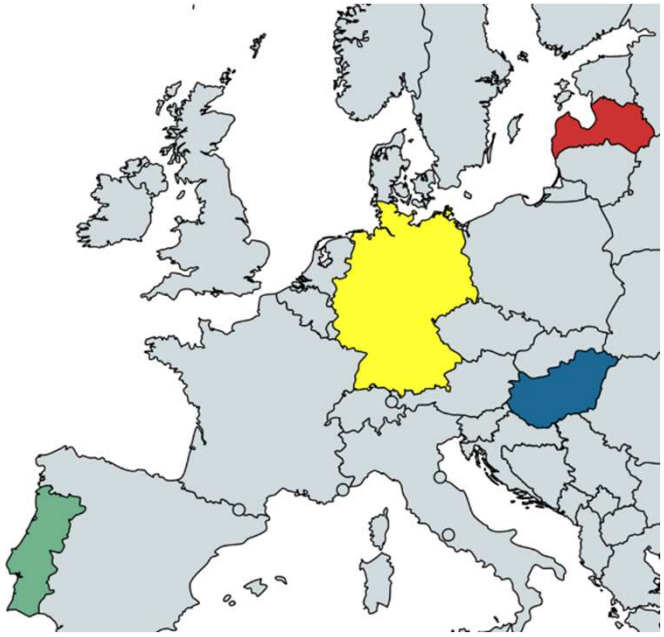
Andris Ambainis

Website: https://hqcc.lu.lv

COLLABORATION (overview)

PARTNERS:

- University of Latvia (Latvia);
- Free University of Berlin (Germany);
- Portuguese Quantum Institute (Lisbon, Portugal);
- Wigner Institute (Budapest, Hungary).



COLLABORATION (overview)

GEOGRAPHICAL BREADTH
4 countries, 3 of them Widening

VARIETY OF SECTORS, DISCIPLINES – All academic, variety of backgrounds (computer science, physics, mathematics)

QUALITY OF COOPERATION – 4 consortium meetings, regular Zoom calls, 3 bilateral collaborations leading to papers

SUCCESS STORY (highlights)

CHALLENGE – putting hybrid computation on a solid theoretical basis

SOLUTION – algorithms, lower bounds, complexity, learning theory, in collaboration between computer scientists and physicists

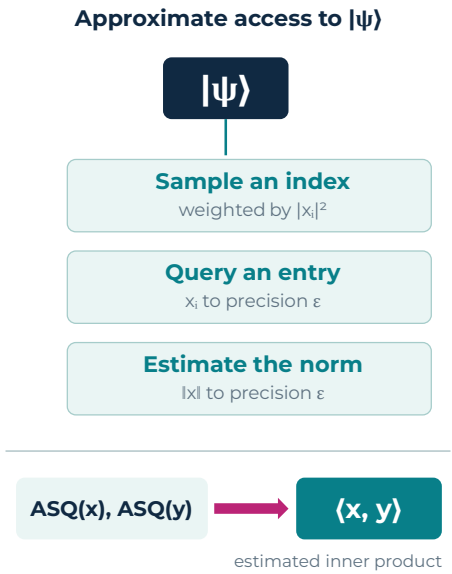
QUANTUM-ENCODED DATA (highlight)

MODEL: Approximate sample-and-query (ASQ) access describes how to work with quantum-encoded data.

IMPLEMENTATION: An n-qubit state provides this access with O(n) extra gates and O(log n) extra depth.

APPLICATION: Distributed inner-product estimation gains polynomial improvements in sample and computational complexity.

Murça, Faehrmann & Omar, An access model for quantum encoded data, Quantum 10, 2028 (2026).



TRAINING DESPITE BARREN PLATEAUS (highlight)

METHOD: Batched line search takes finite steps in directions chosen from subsets of circuit parameters.

SCALE: Numerical simulations trained 21-qubit circuits with 15,000 entangling gates.

APPLICATION: The strategy also improved quantum gate synthesis compared with gradient-based methods.

Nádori et al., Batched Line Search Strategy for Navigating through Barren Plateaus, Quantum 9, 1841 (2025).



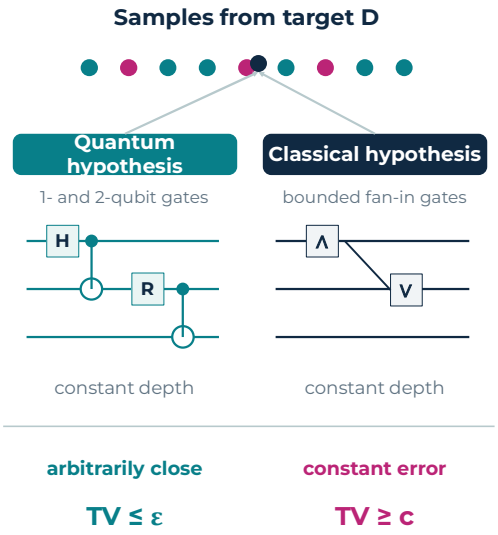
LEARNING WITH SHALLOW CIRCUITS (highlight)

SETTING: Target distributions generated by constant-depth quantum circuits.

RESULT: Shallow quantum circuit hypotheses learn them arbitrarily well. Constant-depth, bounded-fan-in classical hypotheses remain a constant total-variation distance away.

SCOPE: The separation is unconditional within these restricted hypothesis classes.

Pirnay, Jerbi, Seifert & Eisert, An unconditional distribution learning advantage with shallow quantum circuits, arXiv:2411.15548.



SCIENTIFIC OUTPUTS

PUBLICATIONS AND PRESENTATIONS: 48 publications, 16 presentations to various audiences

Highlights: 4 papers in Nature Communications, 2 in Nature Physics, 2 in Nature Reviews Physics

THESES DEFENDED: 2 Ph.D., 1 B.Sc. thesis

IMPACT (potential users)



RELEVANT **INDUSTRY BRANCH:** HPC centres, quantum software



KEY COMMERCIALLY RELEVANT **APPLICATIONS:** optimization, machine learning, chemical simulation, adapting quantum algorithms to existing hardware



EXISTING/POTENTIAL **END USERS:** automotive, logistics, pharmaceutical



COOPERATION WITH THE **QUANTUM FLAGSHIP** OR OTHER QUANTUM INITIATIVES: flagship projects Millenion, PASQUANS2, joint workshop with QuantERA project QOPT, future European Quantum Academy

WHAT'S NEXT

Research on hybrid computation will continue, mainly with national funding

Directions for collaboration:

- Query algorithms in hybrid model (Latvia - Budapest);
- Small depth quantum circuits (Budapest - Berlin);
- Quantum encoded data (Berlin – Lisbon).