

# Quantum @ NERSC



Quantum for Science Day 2022

Katie Klymko, Daan Camps  
Advanced Technologies Group  
October 24, 2022

# Quantum@LBNL

## Advanced Quantum Testbed

Irfan Siddiqi, David Santiago, Kasra Nowrouzi, Ravi Naik, Monica Hernandez, Christopher Spitzer, Anastasiia Butko, Gang Huang, Yilun Xu, ...

## Quantum Algorithms

Bert de Jong, Roel Van Beeumen, Wim Lavrijsen, David Williams-Young, Chao Yang, Talita Perciano, Lin Lin, ...

## Quantum @ NERSC



Nick Wright



Katie Klymko



Daan Camps



Neil Mehta



Brandon Cook



Brian Austin



Jan Balewski



Richard Gerber

- Quantum benchmarking
- Large-scale simulations for QIS
- Algorithm development
- Hardware evaluation

## Quant-Net @ ESNet

Inder Monga, Ezra Kissel, Alp Sipahigil, Hartmut Häffner, Mariam Kiran, ...

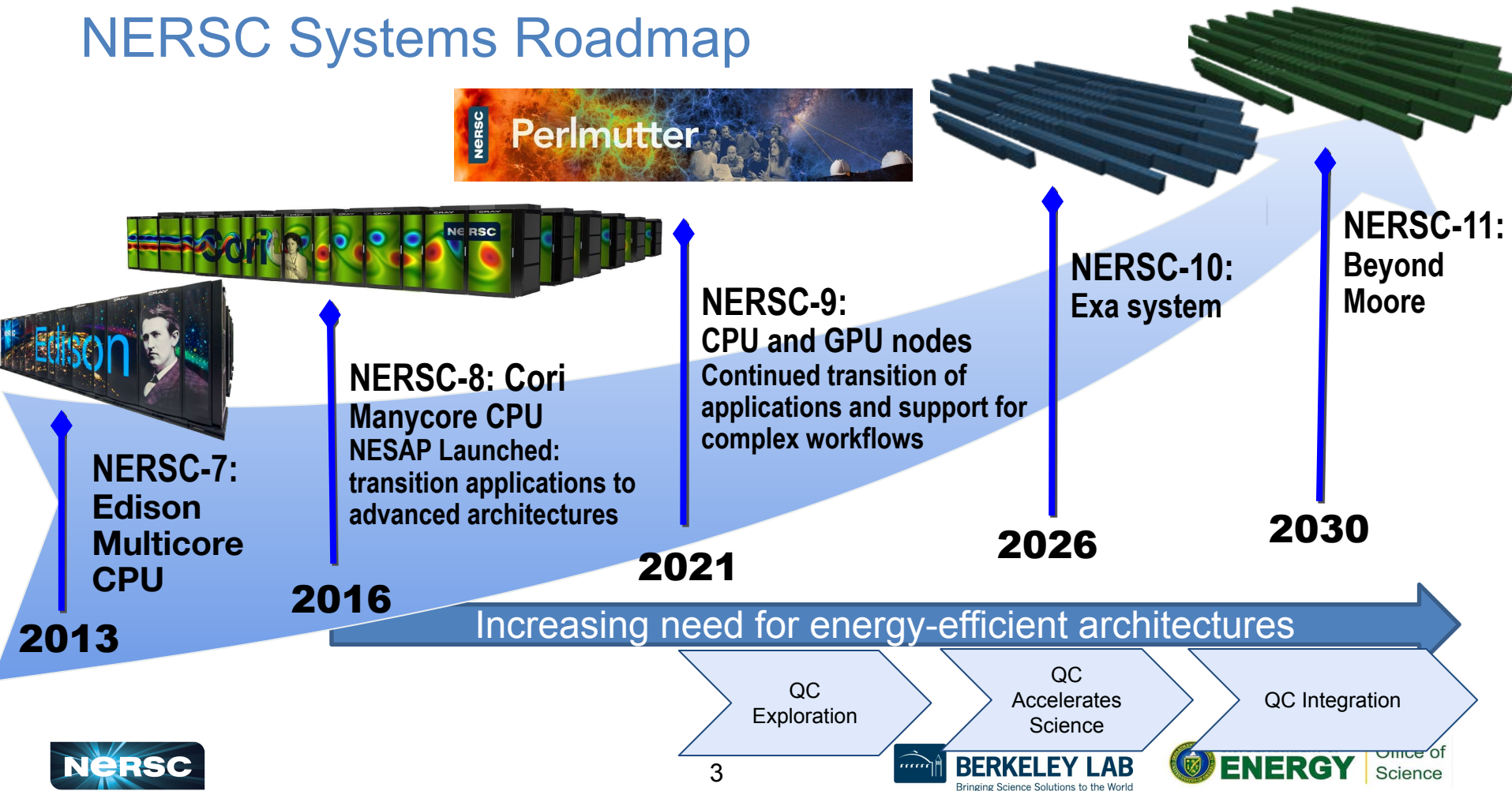
## Quantum Compilers

Costin Iancu, Ed Younis, Wim Lavrijsen, ...

## High Energy Physics

Christian Bauer, Benjamin Nachman, ...

# NERSC Systems Roadmap



# NERSC Quantum Computing Roadmap

2022	2022-2024	2024-2028	2028-203?
<ul style="list-style-type: none"><li>• <b>Ramp up</b> engagement with QIS community</li><li>• Director's Discretionary Reserve Call for quantum information science (QIS) on <b>Perlmutter</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Engage</b> with quantum hardware companies</li><li>• Enable <b>user access</b> to quantum hardware</li><li>• <b>Development</b> of hybrid algorithms</li><li>• Identify <b>opportunities</b> for quantum accelerated HPC codes</li><li>• <b>Benchmarking</b> quantum hardware</li></ul>	<ul style="list-style-type: none"><li>• <b>Integration</b> of near-term (NISQ) quantum hardware becoming standard</li><li>• <b>Users</b> requesting both classical and quantum resources</li></ul>	<ul style="list-style-type: none"><li>• <b>High-performing quantum hardware</b> becoming available</li><li>• <b>Full integration</b> with traditional HPC</li><li>• Users <b>routinely</b> solve problems using quantum hardware !</li></ul>

Optimal integration of classical and quantum processors is an open area of research

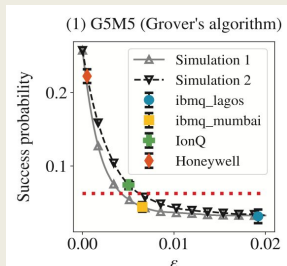
# QIS@Perlmutter 2022: Overview

- In the fall of 2021, we issued an open **call for proposals** to conduct research using NERSC's **Perlmutter** supercomputer in the area of **quantum information science** (QIS). Proposals were evaluated based on their scientific merit, readiness for Perlmutter, and ability to benefit from Perlmutter's resources
- **250k+ GPU node hours** from the NERSC Director's Reserve for AY22 were awarded to 16 groups from national laboratories, academic institutions, and industry
- Users have access to NVIDIA's **cuQuantum SDK** for state vector and tensor network simulation



# QIS@Perlmutter: Early Science Results

PI: Kwangmin Yu (BNL)



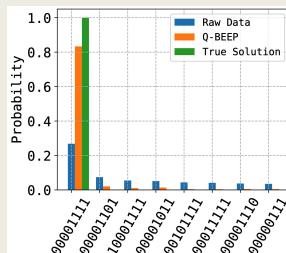
**Grover search on NISQ devices**

Zhang et al., 2022 EPL 140 18002

Park et al., arXiv:2207.14464

more coming later!

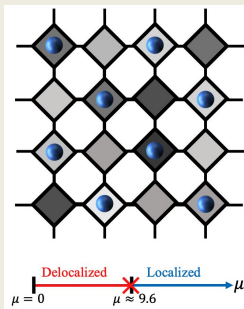
PI: Ang Li (PNNL)



**Bayesian error mitigation**

Stein et al., arXiv:2207.07237

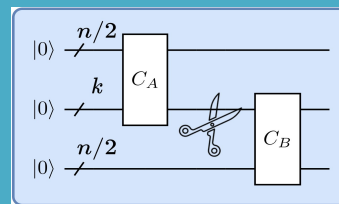
PI: Lindsay Bassman  
Ofelie (LBNL)



**Boson Localization**

arXiv:2210.08386

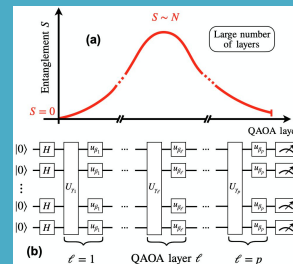
PI: Lee J. O'Riordan (Xanadu)



**Fast quantum circuit cutting**

Lowe et al., arXiv:2207.14734

PI: Matt Reagor (Rigetti)



**Entanglement Barrier in QAOA**

arXiv:2206.07024,

arXiv:2206.06348

# QIS@Perlmutter in 2023 and onwards

- Given the great success of the QIS@Perlmutter '22 program, we are open to support more research projects in QIS in 2023 and beyond!
- If you are interested in getting access to GPU time on Perlmutter to pursue a quantum information project, please reach out to us! We are open to support new startup awards
- By the end of today, you will have learned how to efficiently simulate quantum systems on Perlmutter using NVIDIA's cuQuantum SDK

# Outline for the rest the day



**Don't hesitate to reach out to us!**

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[dcamps@lbl.gov](mailto:dcamps@lbl.gov)

Advanced Quantum Testbed (AQT) @ LBL	Kasra Nowrouzi (LBL)	9:00 AM (15 min)
Bridging HPC and Quantum Computing	Panel	9:15 AM (45 min)
Coffee Break		10:00 AM (20 min)
Hamiltonian Simulation via Qubitization using a Tensor Network Quantum Simulator	Nathan Fitzpatrick (Quantinuum)	10:20 AM (20 min)
GPU-Accelerated Quantum Circuit Simulations with QCLAB++	Roel Van Beeumen (LBL)	10:40 AM (20 min)
Large-scale Hybrid Quantum Workflows with PennyLane	Lee J. O'Riordan (Xanadu)	11:00 AM (20 min)
Quantum Computing Systems and Results for Hybrid Quantum-Classical Algorithms	Matt Reagor (Rigetti)	11:20 AM (20 min)
Lunch Break		11:40 AM (40 min)
Simulating quantum systems with Qiskit Dynamics	Dan Puzzuoli (IBM)	12:20 PM (20 min)
Parallel GPU Quantum Circuit Simulations on Qiskit Aer	Jun Doi (IBM)	12:40 PM (20 min)
Tutorial- introduction to cuQuantum and QODA	Jin-Sung Kim and Pooja Rao (NVIDIA)	1:00 PM (120 min)
Closing remarks		3:00 PM (5 min)

