Benchmarking quantum processors with the randomized measurement toolbox

Quantum Benchmark Reims

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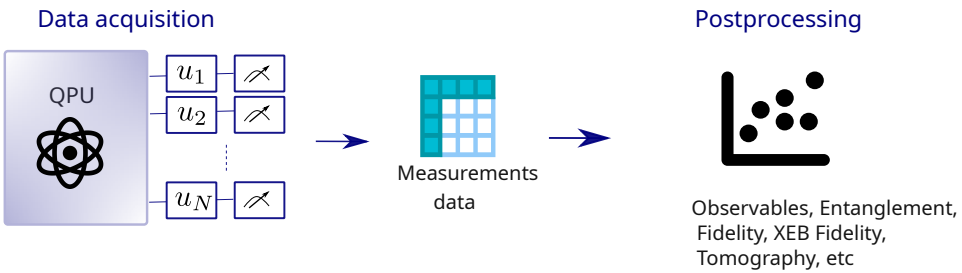
Benchmarking with the randomized measurement toolbox

A *single* measurement procedure for measuring *many* physical properties (!!)



The measurement settings $u_1, \ldots, u_N$ are chosen at random, independent of the quantity of interest

Benchmarking with the randomized measurement toolbox

A universal measurement toolbox

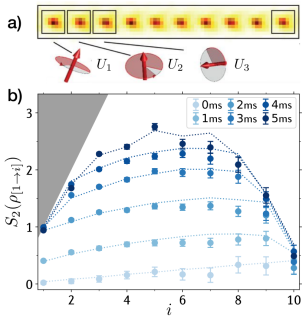
- Rigourous performance guarantees.
- Gives access to any observable, measures entanglement, fidelities, etc
- Deep connections with state-tomography (SPAM robust), Hamiltonian learning, error-mitigation, randomized benchmarking, etc
- Routinely used in companies (Google, IBM, etc) and univ. labs.

The randomized measurement toolbox A. Elben, S. T. Flammia, H.-Y. Huang, R. Kueng, J. Preskill, B. V, P. Zoller, Nature Physics Review (2023).

Verifying entanglement

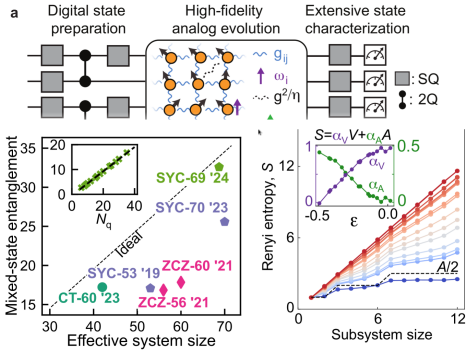
Trapped ions

(Brydges et al Science 2019 & follow-ups)



Google

(arxiv:2405.17385 & previous works)

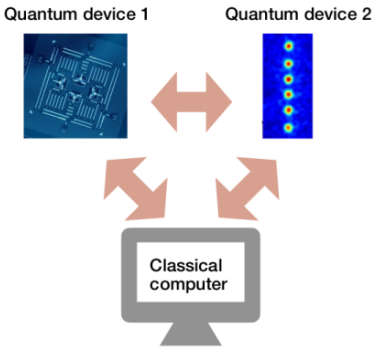


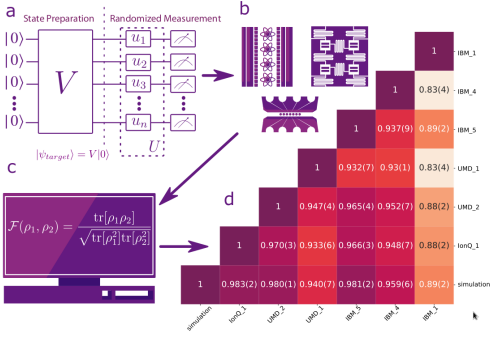
See also works by IBM & IonQ

Reminder: Entanglement = quantum advantage over tensor-network simulations

Measuring fidelities & Cross-Platform verification

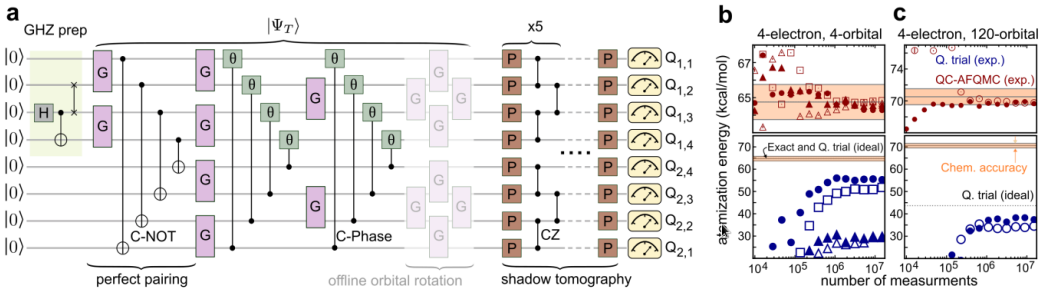
- Direct fidelity estimation (Flammia, Poulin, . . . , 2013)
- X-Platform verification (Elben et al PRL 2020, Exp: UMD& IonQ Nat. Comm. 2022)





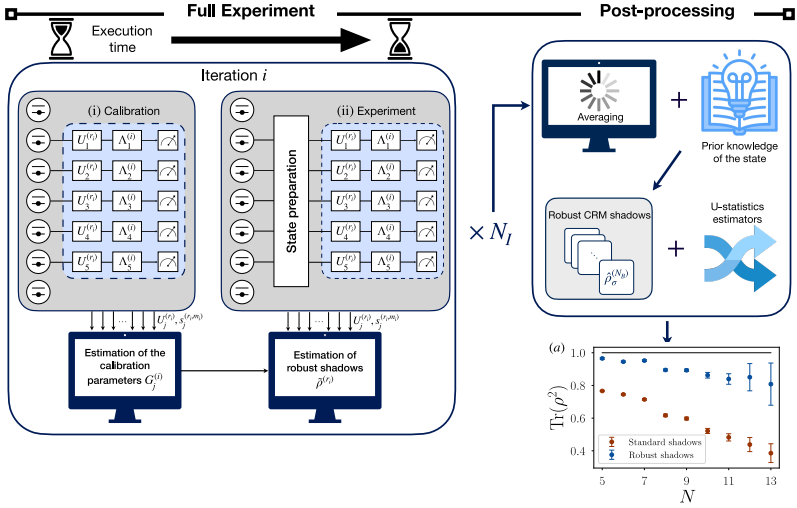
Measurement subroutines in quantum optimization

- Classical shadows framework (Huang et al, Nature Physics 2020)
- Example: Quantum chemistry calculation (Huggins et al (Google), Nature 2022)

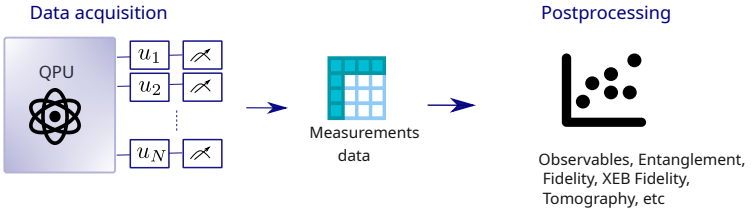


Application to Quantum Error Mitigation

Example: Vitale et al (arXiv:2307.16882, collaboration with IBM)



A software library based on the randomized measurement toolbox?



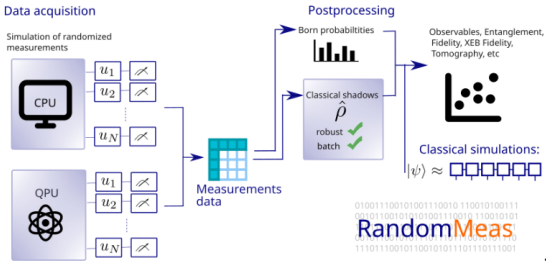
We would like to propose

- One open-source software library for all randomized measurement protocols: calibration, estimators, bootstrapping, etc
- Practical use-case tutorials based on simulated/measured data.
- A tensor-network backend for flexible high-speed postprocessing & benchmarking the protocols 

RandomMeas: The randomized measurements toolbox in julia

This package presents efficient routines for testing and postprocessing randomized measurements, in order to estimate physical properties in quantum computers.

RandomMeas relies heavily on ITensors. Some examples use the packages PastaQ and MAT



Pre-release: https://github.com/bvermersch/RandomMeas.jl

Thank you

Review: *The randomized measurement toolbox* A. Elben, S. T. Flammia, H.-Y. Huang, R. Kueng, J. Preskill, B. V, P. Zoller, Nature Physics Review (2023).