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Quantum-centric Supercomputing for Physics Research

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The rise of parallel computing, in particular graphics processing units (GPU), and machine learning and artificial intelligence has led to unprecedented computational power and analysis techniques. Such technologies have been especially fruitful for theoretical and experimental physics research where the embarrassingly parallel nature of certain workloads —e.g., Monte Carlo event generation, detector simulations, workflows, and data analysis —are exploited to attain significant performance improvements. Despite these capabilities, there still exist an array of problems that are manifestly intractable with classical computation alone, or for which classical computation provides only approximate or inefficient solutions.

Quantum computing is able to give exponential gains in both time and space for certain classes of problems. However, quantum workloads require significant classical computing support for preprocessing, including optimization and compilation, and postprocessing. This naturally leads to the concept of Quantum-centric Supercomputing (QCSC): the integration of quantum computational devices and high performance computing (HPC) resources. QCSC will leverage quantum and classical computing devices to enable execution of parallel and asynchronous hybrid workloads, unlocking the potential for computations beyond what is currently possible. IBM Quantum is engaging with the scientific and HPC communities to deliver them unrivaled quantum computing capabilities that will play a central role in the most powerful supercomputing systems in the world.

In this talk, we will give a brief overview of IBM Quantum's development roadmap and show how QCSC naturally fits this vision. We will explore ways in which the physics community and computational scientists can benefit from QCSC, and detail use cases suitable for these integrated systems.

Significance

We will detail new technological developments from IBM Quantum which we believe physics research can benefit from. We hope to attract attention such that new collaborations can be built to expand the QCSC ecosystem; e.g., workflow management systems, programming models, use cases etc. Also, we want to engage with the physics research community, learn about their specific problems and what requirements they have from quantum, and how we can work together to bring useful quantum computing technologies to the community.

References

Quantum-centric Supercomputing for Materials Science: A Perspective on Challenges and Future Directions (arXiv:2312.09733)

Building Towards QCSC (https://www.youtube.com/watch?v=L5PwmFnHCBI)

Quantum-centric Supercomputing (https://www.simonsfoundation.org/event/quantum-centric-supercomputing/)

Experiment context, if any

ATLAS, CMS, DESI, DUNE, sPHENIX

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