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Track reconstruction for future colliders with quantum algorithms

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Tracking is one of the most crucial components of reconstruction in the collider experiments. It is known for high consumption of computing resources, and various innovations have been being introduced until now. Future colliders such as the High-Luminosity Large Hadron Collider (HL-LHC) will face further enormously increasing demand of the computing resources. Usage of cutting-edge artificial intelligence will likely be the baseline at the HL-LHC, but the rapid development of quantum algorithms and hardware could bring in further paradigm-shifting improvement to this challenge. The track reconstruction can be considered as a quadratic unconstrained binary optimization (QUBO) problem. The Quantum Approximate Optimization Algorithm (QAOA) is one of the most promising algorithms to solve such combinatorial problems and to seek for a quantum advantage in the era of the Noisy Intermediate-Scale Quantum computers. It is found that the QAOA shows promising performance both in simulator and hardware from Origin Quantum. It demonstrated itself as one of the candidates for the track reconstruction using quantum computers. Ongoing studies with other quantum algorithms will also be presented.

Significance

QAOA had not been successfully implemented in the track reconstruction in previous studies in our field. Another important implementation is a theoretically robust method considered for the first time regarding the sub-QUBO method (an approach to split the QUBO into small subsets to match with the available number of qubits). Other sub-QUBO methods (e.g. qbsolv used in D-Wave) are empirical and do not have a theoretical foundation to guarantee quasi-optimal solutions. Lastly, the work utilizes a quantum hardware from Origin Quantum, the first practical quantum computer in China.

References

Previous results: https://arxiv.org/abs/2310.10255 (accepted as a peer-reviewed conference paper at IC2023, published through Springer CCIS)

Experiment context, if any

This work uses a public dataset from the TrackML Challenge intended for the HL-LHC.

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