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TrackHHL: A Quantum Aomputing Algorithm for Track Reconstruction at the LHCb

As the high-luminosity LHC era approaches, high-energy physics requires increasingly efficient computational methods for event reconstruction. We present a novel approach to charged particle track reconstruction using the LHCb Vertex Locator as a case study. The method relies on minimizing an Ising-like Hamiltonian via matrix inversion, where classical solutions achieve state-of-the-art reconstruction efficiency but suffer from poor time complexity. To address this, we explore the Harrow-Hassidim-Lloyd (HHL) quantum algorithm, which promises exponential speedup in the number of input hits.

In this work, we propose a one-bit precision version of the HHL algorithm. By restricting quantum phase estimation (QPE) to a single bit, we significantly reduce the circuit depth while retaining sufficient information for track reconstruction. This simplification enables a novel post-processing scheme, where event Primary Vertices (PVs) are estimated first, followed by track reconstruction using an Adaptive Hough Transform. The reduced precision addresses HHL's readout limitations and brings the algorithm closer to near-term quantum hardware implementation.

Our findings demonstrate that one-bit HHL can serve as a practical stepping stone for quantum-enhanced particle track reconstruction, showcasing its potential for tackling the computational challenges of the next generation of high-energy physics experiments.

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Short summary

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