Quantum machine learning for charged particle tracking in high energy physics

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Tracking charged particles in high-energy physics experiments is one of the most computationally demanding steps in the data analysis pipeline. With the advent of the High Luminosity LHC era, which is expected to increase the number of proton-proton interactions per beam crossing by a factor of 3-5 (from 50 to 140-200 primary interactions per collision on average), the amount of data to be analysed will increase dramatically.

Currently the problem is being tackled using various algorithmic approaches. The best classical algorithms are local and scale worse than quadratically with the number of particle hits in the detector layers.

In this work, we investigate the possibility of using machine learning techniques in combination with quantum computing. In particular, we represent particle trajectories as a graph data structures and train a quantum graph neural network to perform global pattern recognition. We show recent results on the application of this method, with scalability tests for increasing pileup values. We discuss the critical issues and give an outlook on potential improvements and alternative approaches.

We also provide insights into various aspects of code development in different quantum programming frameworks such as Pennylane and IBM Qiskit, and also characterise the role of GPUs as computational accelerators in emulating quantum computing resources.