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Hybrid quantum graph neural networks for 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.
As we approach the High Luminosity LHC era, with an estimate increase in the number of proton-proton interactions per beam collision by a factor 3-5 (from 50 to 140-200 primary interactions per collision on average), particle tracking will become even more problematic due to the massive increment in the volume of data to be analysed.

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. Promising results are coming from global approaches. In particular, among these, we are investigating the possibility of using machine learning techniques in combination with quantum computing.

In our work we represent charged particle tracks as a graph data structure, and we train a hybrid graph neural network composed of classical and quantum layers. We report recent results on the use of these technologies, with emphasis on the computational aspects involved in the code development within different programming frameworks, such as Jax, Pennylane and IBM Qiskit.

We give an outlook on the expected performance in terms of accuracy and efficiency, and also characterise the role of GPUs as computational accelerators in the emulation of quantum computing resources.

Primary authors: CAPPELLI, Laura (INFN Ferrara); ARGENTON, Matteo (INFN and University of Ferrara)

Co-authors: Dr BOZZI, Concezio (INFN Ferrara); Dr CALORE, Enrico (INFN Ferrara); Prof. SCHIFANO, Sebastiano Fabio (University of Ferrara and INFN); Dr AMITRANO, Valentina (INFN Ferrara)

Presenter: ARGENTON, Matteo (INFN and University of Ferrara)

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