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Quantum Machine Learning for HEP Detectors Simulations

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Quantum Machine Learning is among others the most promising applications on near-term quantum devices which possess the potential to combat problems faster than traditional computers. Classical Machine Learning (ML) is taking up a significant role in particle physics to speed up detector simulations. Generative Adversarial Networks (GANs) have scientifically proven to achieve a similar level of accuracy compared to Monte Carlo -based simulations while decreasing the computation time by orders of magnitude. In this research we are going one step further and apply quantum computing to GAN-based detector simulations. Given the practical limitations of current quantum hardware in terms of number of qubits, connectivity, and coherence time, we perform initial tests with a simplified GAN model running on quantum simulators. The model is a classical-quantum hybrid ansatz. It consists of a quantum generator, defined as a parameterised circuit based on single and two qubit gates, and a classical discriminator network. Our initial qGAN prototype focuses on a one-dimensional toy-distribution, representing the energy deposited in a detector by a single particle. It employs three qubits and achieves high physics accuracy thanks to hyper-parameter optimisation. Furthermore, we study the influence of real hardware noise for the quantum ML GAN training. A second qGAN is developed to simulate 2D images with a 64-pixel resolution, representing the energy patterns in the detector. Different quantum ansatzes are studied. We obtained the best results using a tree tensor network architecture with six qubits. Additionally, we discuss challenges and potential benefits of quantum computing as well as our plans for future development.

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