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Quantum anomaly detection in the latent space of proton collision events at the LHC

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Exploring innovative methods and emerging technologies holds the promise of enhancing the capabilities of LHC experiments and contributing to scientific discoveries. In this work, we propose a new strategy for anomaly detection at the LHC based on unsupervised quantum machine learning algorithms. To accommodate the constraints on the problem size dictated by the limitations of current quantum hardware we develop a classical autoencoder. The designed quantum models, an unsupervised kernel machine and two clustering algorithms, are trained to detect new-physics events in the latent representation of LHC data generated by the autoencoder. The performance of the quantum algorithms is assessed on different new-physics scenarios and its dependence on the dimensionality of the latent space and the size of the training dataset is studied. For kernel-based anomaly detection, we identify a regime where the quantum model significantly outperforms its classical counterpart. An instance of the kernel machine is implemented on a quantum computer to verify its suitability for available hardware. We demonstrate that the observed consistent performance advantage is related to the inherent quantum properties of the circuit used.

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