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Quantum anomaly detection in the latent spaces of high energy physics events

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We developed supervised and unsupervised quantum machine learning models for anomaly detection tasks at the Large Hadron Collider at CERN. Current Noisy Intermediate Scale Quantum (NISQ) devices have a limited number of qubits and qubit coherence. We designed dimensionality reduction models based on Autoencoders to accommodate the constraints dictated by the quantum hardware. Different designs were investigated, such as convolutional and Sinkhorn Autoencoder architectures, that can compress HEP data while preserving the class structure of the original dataset. The quantum algorithms are trained to identify anomalies in the latent spaces generated by the Autoencoders. A collection of results for a quantum classifier and a set of quantum anomaly detection algorithms is presented. Our study is supported by a performance comparison to the corresponding classical models.

Significance

In our work, as well as in other studies addressing classification tasks in HEP, no significant difference in performance between quantum and classical ML models has been observed. Classical ML and deep learning approaches typically outperform quantum algorithms when one allows the size of the training dataset or the number of model parameters to increase beyond the limits of both current quantum hardware and quantum simulation software on classical devices. We believe that these results can stimulate fundamental research towards quantum machine learning or hybrid quantum-classical algorithm design that would manifest interesting behaviour that cannot be replicated by classical models.

References

Experiment context, if any

CMS

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