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Quantum Generative Modeling for Calorimeter Simulations in Noisy Quantum Device

Quantum generative modeling provides an alternative framework for simulating complex processes in high-energy physics. Calorimeter shower simulations, in particular, involve high-dimensional, stochastic data and are essential for particle identification and energy reconstruction at experiments such as those at the LHC. As these simulations increase in complexity—especially in large-scale analyses—classical methods become increasingly demanding, making them a natural candidate for quantum approaches. This work investigates the use of parameterized quantum circuits on Noisy Intermediate-Scale Quantum (NISQ) devices to generate calorimeter-like images, assessing their viability for future applications.

The Quantum Angle Generator (QAG) is introduced as a variational quantum model designed for image generation. An extensive hyperparameter study is conducted, along with a comprehensive comparison against classical generative models, to evaluate relative performance and limitations within this domain.

A key component of the study is the evaluation of robustness to hardware noise. The QAG's ability to adapt to realistic noise conditions is tested through both simulation and deployment on actual quantum devices. Results show that models trained directly on hardware can internalize device-specific noise characteristics, maintaining stable performance even under substantial noise and calibration drift. These findings support the feasibility of near-term quantum generative models for practical use in high-energy physics simulations.

Significance

References

https://inspirehep.net/literature/2785240

Experiment context, if any

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