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Quantum-assisted generative AI for simulating high-energy calorimetry

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The quest towards probing the Higgs field in the High luminosity Large Hadron Collider (LHC) comes with many great challenges. In particular, the need to speed up the particle-detector simulations poses a roadblock, as projections show millions of CPU-years required to create simulated datasets. To tackle the problem of simulating particle-calorimeter interactions in the ATLAS detector at LHC we have developed a quantum-assisted deep generative model by combining quantum simulations with deep learning. In particular, we utilize D-wave's Zephyr quantum annealer (QA) topology as a latent space prior using a variational autoencoder. We propose a robust method to generate conditioned samples using the quantum annealer leveraging flux bias to effectively increase the magnitude of the self-fields-to-interaction-energy ratio in the QA. We further propose a new, fast and robust method to estimate the effective inverse temperature in QAs. To benchmark our framework we use the CaloChallenge dataset, which has served as a catalyst for generative AI in high-energy calorimetry simulations. We compare our framework with 17 other frameworks which use generative AI and show that our framework is among the fastest and best in quality. The speed-up is three to six orders of magnitude compared to first-principles simulations used at CERN. We further assess the computational efficiency of our model in comparison to state-of-the-art generative models and first-principles approaches, demonstrating its potential for significantly accelerating high-energy physics simulations.

Keyword-1

quantum annealers

Keyword-2

high-energy physi

Keyword-3

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