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Quantum Chebyshev Probabilistic Models for Fragmentation Functions

We propose a quantum protocol for efficiently learning and sampling multivariate probability distributions that commonly appear in high-energy physics. Our approach introduces a bivariate probabilistic model based on generalized Chebyshev polynomials, which is (pre-)trained as an explicit circuit-based model for two correlated variables, and sampled efficiently with the use of quantum Chebyshev transforms. As a key application, we study the fragmentation functions~(FFs) of charged pions and kaons from single-inclusive hadron production in electron-positron annihilation. We learn the joint distribution for the momentum fraction z and energy scale Q in several fragmentation processes. Using the trained model, we infer the correlations between z and Q from the entanglement of the probabilistic model, noting that the developed energy-momentum correlations improve model performance. Furthermore, utilizing the generalization capabilities of the quantum Chebyshev model and extended register architecture, we perform a fine-grid multivariate sampling relevant for FF dataset augmentation. Our results highlight the growing potential of quantum generative modeling for addressing problems in scientific discovery and advancing data analysis in high-energy physics.

Secondary track

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