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Some applications of machine learning and quantum computing in jet reconstruction

To enhance the scientific discovery power of high-energy collider experiments, we propose and realize the concept of jet-origin identification that categorizes jets into five quark species (u, d, s, c, b), five antiquarks, and the gluon. Using state-of-the-art algorithms and simulated $\nu\nu H$, $H \longrightarrow jj$ events at 240 GeV center-of-mass energy at the electron-positron Higgs factory, the jet-origin identification simultaneously reaches jet flavor tagging efficiencies ranging from 67% to 92% for bottom, charm, and strange quarks and jet charge flip rates of 7%–24% for all quark species. We apply the jet-origin identification to Higgs rare and exotic decay measurements at the nominal luminosity of the Circular Electron Positron Collider and conclude that the upper limits on the branching ratios of $H \longrightarrow ss$, uu, dd and $H \longrightarrow sb$, db, uc, ds can be determined to 0.02%–0.1% at 95% confidence level. The derived upper limit for $H \longrightarrow ss$ decay is approximately 3 times the prediction of the standard model, which improves by more than a factor of 2 upon previous studies.

Exploring the application of quantum technologies to fundamental sciences holds the key to fostering innovation for both sides. In high-energy particle collisions, quarks and gluons are produced and immediately form collimated particle sprays known as jets. Accurate jet clustering is crucial as it retains the information of the originating quark or gluon and forms the basis for studying properties of the Higgs boson, which underlies the mechanism of mass generation for subatomic particles. For the first time, by mapping collision events into graphs—with particles as nodes and their angular separations as edges—we realize jet clustering using the Quantum Approximate Optimization Algorithm (QAOA), a hybrid quantum-classical algorithm for addressing classical combinatorial optimization problems with available quantum resources. Our results, derived from 30 qubits on quantum computer simulator and 6 qubits on quantum computer hardware, demonstrate that jet clustering performance with QAOA is comparable with or even better than classical algorithms for a small-sized problem. This study highlights the feasibility of quantum computing to revolutionize jet clustering, bringing the practical application of quantum computing in high-energy physics experiments one step closer.

Secondary track

T15 - Quantum technologies in HEP (special topic 2025)

Author: ZHOU, Chen (Peking University)

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