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Application of Quantum Machine Learning to HEP Analysis at LHC using Quantum Computer Simulators and Quantum Computer Hardware – Challenges and Opportunities

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Machine learning enjoys widespread success in High Energy Physics (HEP) analysis at LHC. However the ambitious HL-LHC program will require much more computing resources in the next two decades. Quantum computing may offer speed-up for HEP physics analysis at HL-LHC, and can be a new computational paradigm for big data analysis in High Energy Physics.

We have successfully employed Variational Quantum Classifier (VQC) method, Quantum Support Vector Machine Kernel (QSVM-kernel) method and Quantum Neural Network (QNN) method for two LHC flagship analyses: ttH (Higgs production in association with two top quarks) and H->mumu (Higgs decay to two muons, the second generation fermions).

We will present our experiences and results of a study on LHC High Energy Physics data analysis with IBM Quantum Simulator and Quantum Hardware (using IBM Qiskit framework), Google Quantum Simulator (using Google Cirq framework), and Amazon Quantum Simulator (using Amazon Braket cloud service). The work is in the context of a Qubit platform. Taking into account the present limitation of hardware access, different quantum machine learning methods are studied on simulators and the results are compared with classical machine learning methods (BDT, classical Support Vector Machine and classical Neural Network). Furthermore, we do apply quantum machine learning on IBM quantum hardware to compare performance between quantum simulator and quantum hardware.

The work is performed by an international and interdisciplinary collaboration with the Department of Physics and Department of Computer Sciences of University of Wisconsin, CERN Quantum Technology Initiative, IBM Research Zurich, Fermilab Quantum Institute, BNL Computational Science Initiative, State University of New York at Stony Brook, and Quantum Computing and AI Research of Amazon Web Services.

This work pioneers a close collaboration of academic institutions with industrial corporations in a High Energy Physics analysis effort.

Though the size of event samples in future HL-LHC physics and the limited number of qubits pose some challenges to the Quantum Machine learning studies for High Energy Physics, more advanced quantum computers with larger number of qubits, reduced noise or close to noiseless quantum simulators and improved running time (as envisioned by IBM and Google) may outperform classical machine learning in both classification power and in simulations.

Although the era of efficient quantum computing may still be years away, we have made promising progress and obtained preliminary results in applying quantum machine learning to High Energy Physics. A PROOF OF PRINCIPLE.

Is this abstract from experiment?

No

Name of experiment and experimental site

N/A

Is the speaker for that presentation defined?

Yes

Details

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