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Application of Quantum Machine Learning to High Energy Physics Analysis at LHC using IBM Quantum Computer Simulators and IBM Quantum Computer Hardware

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Using IBM Quantum Computer Simulators and Quantum Computer Hardware, we have successfully employed the Quantum Support Vector Machine Method (QSVM) for a ttH (H to two photons), Higgs coupling to top quarks analysis at LHC.

We will present our experiences and results of a study on LHC high energy physics data analysis with IBM Quantum Computer Simulators and IBM Quantum Computer Hardware using IBM Qiskit. The work is in the context of a Qubit platform. Taking into account the limitation of a low number of qubits, the result expressed in ROC curve is comparable with the results using a classical machine learning method. This study is applied to a physics channel where Higgs-coupling-to–two-top-quarks (ttH), one of the flagship physics channels at LHC. Here ROC curve is defined as the Receiver Operating Characteristics curve on the plane of background rejection versus signal efficiency. At our current stage, with 5 qubits and 800 events we have reached AUC of 0.86, which is similar to the AUC of 0.87 from classical machine learning method (BDT), where AUC is the area under the ROC curve. By the time of the conference, we expect to have results performed by 20 qubits.

In addition, collaborating with IBM Research Zurich, we finished training with machine learning on the IBM Quantum Computer Hardware with 100 training events, 100 test events, and 5 qubits, again for ttH (H to two photons) analysis at LHC. Because of hardware access time and timeout limitations, we only finished a few iterations. By the time of the conference, we expect to perform the study on 20 qubits hardware with large number of iterations.

The work is performed with an international and interdisciplinary collaboration with high energy physicists (Physics Department, University of Wisconsin), computational scientists (Computing Science Department, University of Wisconsin and CERN openlab, IT Department), and quantum computing scientists (IBM Research Zurich).

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

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