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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 the 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 a ROC curve is comparable with the results using a classical machine learning method. This study is applied to a Higgs-coupling-to–two-top-quarks (ttH) physics analysis, one of the flagship physics channels at the LHC. Here the ROC curve is defined as the Receiver Operating Characteristics curve in the plane of background rejection versus signal efficiency. At our current stage, with 5 qubits and 800 events, we have reached an AUC of 0.86, which is similar to the AUC of 0.87 from a classical machine learning method (BDT), where the AUC is the area under the ROC curve. By the time of the conference, we expect to have results with 20 qubits.

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

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

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

Authors: CHAN, Jay (University of Wisconsin Madison (US)); GUAN, Wen (University of Wisconsin (US)); SUN, Shaojun (University of Wisconsin Madison (US)); WANG, Alex Zeng (University of Wisconsin Madison (US)); WU, Sau Lan (University of Wisconsin Madison (US)); ZHOU, Chen (University of Wisconsin Madison (US)); Prof. LIVNY, Miron (University of Wisconsin-Madison); DI MEGLIO, Alberto (CERN); CARMINATI, Federico (CERN); Dr BARKOUTSOS, Panagiotis (IBM Research Zurich); Dr TAVERNELLI, Ivano (IBM Research Zurich); Dr WOERNER, Stefan (IBM Research Zurich); Dr ZOUFAL, Christa (IBM Research Zurich)

Presenter: ZHOU, Chen (University of Wisconsin Madison (US))

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