Quantum Machine Learning Simulation of Higgs Boson Charge Parity Symmetry Violation

Braun, Lane (School: Beaverton Academy of Science and Engineering)

Simulations run on quantum computers are efficient tools to capture the quantum properties of fundamental particles more effectively than classical computers in high energy physics (HEP) simulations. However, current HEP simulations on quantum computers largely ignore the power of quantum neural networks (QNNs) to efficiently model the details of quantum systems. Here, I developed a QNN-based quantum simulation to model the charge parity symmetry (CP) quantum properties of Higgs bosons. I designed a quantum circuit for QNN-based simulation to run on currently-available quantum technology. The QNN was trained to reproduce probabilistic distributions of CP-sensitive statistics and recognize different levels of CP sensitivity depending on angles between Higgs decay products. QNN outputs were translated into tunable sampling distributions using the inherent randomness of quantum measurements. The QNN-based simulation readily reproduced the CP properties and statistical variability of Monte Carlo Higgs to two taus events. The quantum circuit design allowed the simulation to precisely model the mathematics of Higgs CP with very few qubits. The QNN accurately learned the correlation between Higgs decay product angles and CP sensitivity for most possible CP sensitivities. QNN sampling methods accurately captured the random statistical fluctuations in the training data. The results indicate that QNNs provide compact tools for developing fast, detailed quantum simulations for HEP to run on current and future quantum computers. These results can guide future QNN research and HEP simulation development as available quantum technologies and demand for computationally-intensive HEP simulations continue to grow.

Awards Won:

Third Award of $1,000