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Quantum entanglement in HWW decays

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We present a preliminary study of quantum entanglement in the $H \to WW^* \to e\nu\mu\nu$ channel using simulation data from the ATLAS experiment. Our study focuses on the dominant gluon-gluon fusion production mode of the Standard Model Higgs boson and its second-greatest decay channel at the Standard Model mass. Exploiting the scalar property of the Standard Model Higgs boson and the $V - A$ structure of weak interactions, we perform Bell tests using the CGLMP inequality via projective measurements of the final state leptons. At the truth level, we first analyze the ensemble averages and distributions of observables relevant to the entanglement study, then investigate the effects of experimental selections. In practical application, we must overcome the missing kinematic information due to neutrinos in the final state in order to reconstruct the rest frames of the Higgs and both W bosons. This study presents two approaches to reconstructing four-momenta of intermediate particles: an analytical approximation method and a neural network regression model. Our findings show that the neural network regression model significantly outperforms analytical approximations. Finally, we analyze the results of the entanglement observables calculated using predictions from the proposed neural network regression
model.

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