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Quantum Computing and Quantum information in estimating EFTs from measurements.

In the quest for new physics at the LHC, Effective Field Theory (EFT) provides a robust framework for interpreting data. While classical machine learning is an excellent tool for isolating the effects of individual Wilson Coefficients in experimental data, it is limited in its ability to capture the underlying quantum correlations that these coefficients parametrize. This research proposes the use of aspects of Quantum Computing techniques, specifically Hamiltonian Learning and Quantum State Tomography into EFT measurements at the LHC.

In quantum chemistry, Hamiltonian Learning provides a way to directly learn the Hamiltonian from data, without the need for approximations like mean-field theories or perturbative methods. It can capture strongly correlated quantum phenomena that classical methods often approximate or simplify. Aspects of this Hamiltonian picture have been demonstrated to be beneficial for estimating the value of up to 8 Wilson coefficients including their quadratic contributions from data \[1\]. In quantum state tomography, a coupling of an arbitrary Hilbert operators coupling to the spin components of a multipartite final state can be completely characterised in given measurement basis by the density matrix \[2\] opening the door to learn such characterisations not through fitting differential distributions but directly using machine learning \[3\].

These techniques promise to provide a more direct and comprehensive understanding of the quantum phenomena parametrized by Wilson Coefficients, thereby enhancing the precision of EFT measurements. By integrating Quantum Computing into the EFT analysis pipeline, we aim to leverage the quantum native nature of the way these tools describe elementary processes to unlock new avenues for beyond-the-Standard-Model discoveries, offering a complementary approach to classical machine learning methods.

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