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Simulating Particle Scattering with Digital Quantum Computers

Particle scattering is a cornerstone of high-energy physics, providing deep insights into the structure and dynamics of matter. However, simulating this real-time, nonperturbative dynamic process remains a major challenge for classical methods: Monte Carlo techniques suffer from sign problems, while tensor network approaches are limited by rapid entanglement growth. Quantum computing offers a promising path to overcome these barriers.

In this talk, I will present our recent progress on simulating particle scattering using digital quantum computers. First, I will introduce a method we developed for constructing accurate meson wave packets in a (1+1)D lattice gauge theory, enabling high-accuracy simulations of meson scattering dynamics. Our classical simulations reveal rich nonperturbative phenomena, including new particle production, long string formation, and string breaking.

Second, I will present our recent hardware implementation of fermion scattering in the (1+1)D Thirring model using IBM quantum devices with 40 and 80 qubits. By combining tensor network-based circuit optimization with error mitigation techniques, we achieve experimental results that closely match ideal simulations, clearly capturing transmitted and reflected scattering phenomena.

Together, these results demonstrate the feasibility and scalability of quantum approaches to particle scattering, and point toward broader applications in lattice gauge theory and real-time quantum dynamics.

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