



Simulating Subatomic Physics on a Quantum Frequency Processor

Pavel Lougovski

Oak Ridge National Laboratory

Photonics is at the forefront of quantum computing and simulations. It enabled a host of pioneering demonstrations of the variational quantum eigensolver (VQE) algorithm, of molecular vibronic spectra and dynamics simulations, and of experimental Hamiltonian learning. It offers a versatile platform to process quantum information with low noise in a multitude of encodings, ranging from spatial or polarization degrees of freedom, to temporal modes. We discuss how frequency encoding, where qubits are represented by photons in narrow frequency bins, can be utilized for simulating complex many-body quantum phenomena in nuclear physics and quantum field theory. Using an all-optical quantum frequency processor, the ground-state energies of light nuclei including the triton, ${}^3\text{He}$, and the alpha particle are computed. Complementing these calculations and utilizing a 68-dimensional Hilbert space, our photonic simulator is used to perform sub-nucleon calculations of the two-body and three-body forces between heavy mesons in the Schwinger model. This work is a first step in simulating subatomic many-body physics on quantum frequency processors---augmenting classical computations that bridge scales from quarks to nuclei.