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Simulating problems from high energy physics on quantum computers

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Gauge theories represent our most successful approach to describe natures fundamental forces. However, obtaining solutions using classical computational methods remains among some of the greatest challenges in physics, due to the inherent limitations of classical computers to simulate quantum properties, as well as the infamous sign-problem that plagues today's standard calculations based on Monte Carlo methods. Quantum technologies offer an exciting perspective to address such problems. This talk covers recent demonstrations of quantum simulations of 1D quantum electrodynamics on a trapped ion quantum computer [Martinez et al, Nature534, 516 [2016], Kokail et al, Nature 569, 355 (2019)]. Moreover, we show how quantum simulations of gauge theories can be extended to two spatial dimensions using current quantum hardware. In contrast to 1D QED, higher dimensions allow for non-trivial magnetic field effects, while at the same time, the Fermi statistics of the matter fields become important. Unlocking those effects imposes practical challenges, rendering quantum simulations beyond 1D inherently demanding. To tackle these difficulties, we introduce novel approaches to render near-term demonstrations possible.