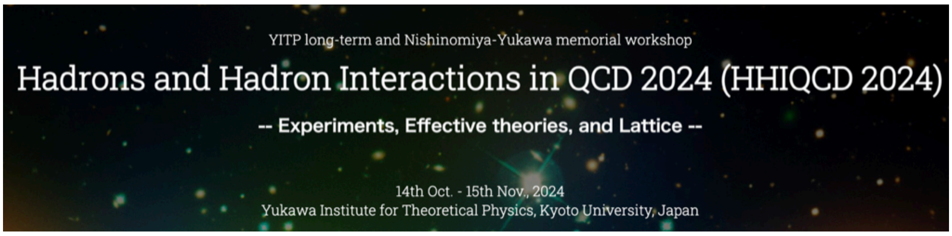

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Tensor Networks for Gauge Theories

Friday, November 1, 2024 2:00 PM (1 hour)

Gauge theories are fundamental to various areas of physics. In high-energy physics, the standard model, which is a gauge theory, explains three of the four fundamental forces of nature. While at high-energy scales quantum chromodynamics can be addressed perturbatively, this approach becomes ineffective at lower energies, necessitating nonperturbative techniques. This naturally leads to the development of lattice gauge theories, which provide a nonperturbative, gauge-invariant regularizations of quantum field theories. Significant progress has been made in studying these theories, particularly through Euclidean Monte Carlo simulations.

However, certain regimes remain challenging within this framework. Fermionic theories at finite density or with an odd number of fermion flavors can suffer from the sign problem, and computing real-time dynamics is difficult as Monte Carlo algorithms are typically formulated in Euclidean space-time. Recently, several approaches have been explored to overcome these issues. One prominent example is quantum simulation, where lattice gauge theory Hamiltonians are realized on quantum devices.

While the formulation in terms of Hamiltonians is not new, it had a rennaissance in recent years. It is not only well-suited for quantum devices; it also allows for the variational treatment of lattice gauge theories using methods from condensed matter physics. A notable family of ansatz states utilized in this context is tensor networks.

In this talk, I will present an overview of the current advancements in tensor network simulations of lattice gauge theories. The first part will provide a broad overview of tensor networks and the architectures currently in use. In the second part, I will focus on a specific ansatz known as Gauged Gaussian Projected Entangled Pair States (GGPEPS). GGPEPS allows for the construction of tensor network states that describe fermionic matter coupled to dynamical gauge fields with full gauge invariance. These states enable efficient contractions and numerical computations in arbitrary space dimensions, especially when combined with Monte Carlo techniques, and are sign-problem free. I will introduce the GGPEPS states, detail their construction and analytical properties, and demonstrate their numerical capabilities.

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