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Quantum computing for particle physics applications

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The original idea that a quantum machine can potentially solve many-body quantum mechanical problems more efficiently than classical computers is due to R. Feynman who proposed the use of quantum computers to investigate the fundamental properties of nature at the quantum scale. In particular, the solution of problems in electronic structure, many-body physics, and high energy physics (just to mention a few) is a challenging computational task for classical computers as the number of needed resources increases exponentially with the number of degrees of freedom. More recently, the possibility to obtain quantum speedup for the solution of classical optimization problems became also an active field of research in, for instance, statistical physics, classical optimization, machine learning and finance. Thanks to the recent development of quantum technologies, we have now the possibility to address these classes of problems with the help of quantum computers. To achieve this goal, several quantum algorithms able to best exploit the potential quantum speedup of state-of-the-art, noisy, quantum hardware have been proposed.
After a short introduction on the state-of-the-art of digital quantum computing from a hardware and software prospective, I will present applications for the solution of problems in many-body and high energy physics, focusing on those aspects that are relevant to achieve quantum advantage with near-term and fault tolerant quantum computers. In particular, I will discuss applications on the classification of high-energy scattering events using quantum machine learning algorithms [1], as well as the development of quantum algorithms for the study of static and dynamic properties of lattice gauge models [2,3].

[1] S.L .Wu, et al. "Application of quantum machine learning using the quantum kernel algorithm on high energy physics analysis at the LHC ", Physical Review Research 3, 033221 (2021)
[2] S.V. Mathis, G. Mazzola, I. Tavernelli, "Toward scalable simulations of lattice gauge theories on quantum computers", Physical Review D 102, 094501 (2021)
[3] G. Mazzola, S.V. Mathis, G. Mazzola, I. Tavernelli, "Gauge-invariant quantum circuits for U(1) and Yang-Mills lattice gauge theories", Physical Review Research 3, 043209,(2021).

In-person participation

Yes

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