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Quantum error mitigation for Fourier moments computation

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Hamiltonian moments in Fourier space—expectation values of the unitary evolution operator under a Hamiltonian at various times—provide a robust framework for understanding quantum systems. They offer valuable insights into energy distribution, higher-order dynamics, response functions, correlation information, and physical properties. Additionally, Fourier moments enable the computation of arbitrarily complex polynomial transformations of the Hamiltonian, which have numerous applications, such as estimating ground state energy.

In this talk, we will discuss methods for reliably computing the first moments of a nuclear effective field theory using current quantum processors. We will delve into how echo-verification and noise renormalization techniques can be effectively employed within Hadamard test protocols, utilizing control reversal gates to avoid directly controlling the time evolution. These techniques, combined synergistically with purification and error suppression methods, significantly enhance the capabilities of current quantum processors. Our analysis, conducted using noise models, shows a substantial reduction in noise strength by two orders of magnitude. Additionally, quantum circuits involving up to 266 CNOT gates across five qubits achieve high accuracy with these methodologies when executed on IBM superconducting quantum devices.

Finally, we will see how noise renormalization techniques can be utilized to observe correlation decay across a quantum phase transition in one-dimensional spin chains, in alignment with the predictions of the Kibble-Zurek mechanism.

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Author: KISS, Oriel Orphee Moira (Universite de Geneve (CH))

Co-authors: ROGGERO, Alessandro (University of Trento); Dr GROSSI, Michele (CERN)

Presenter: KISS, Oriel Orphee Moira (Universite de Geneve (CH))

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