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Diagrammatic Monte Carlo for Structure and Reaction Calculations

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The ab initio calculation of optical potentials, grounded in the microscopic Hamiltonian, and the consistent evaluation of cross sections requires accounting for high-order virtual excitations, whose number grows factorially with perturbative order. This limitation has long hindered ab initio calculations of scattering observables, which instead rely on phenomenological models of optical potentials that are inconsistent with the structure part of the calculation [1].
Diagrammatic Monte Carlo (DiagMC) offers a powerful way to tackle this challenge, as it can efficiently capture high-order excitations through a stochastic sampling. The method has already showed remarkable success in condensed matter physics [2, 3], where it enables the resummation of contributions in infinite systems at finite temperature.
I will present the first application of DiagMC to a problem of relevance to nuclear structure: the pure pairing Richardson model. Our results exceed the accuracy of the state-of-the-art ADC(3) approximation by including diagrams up to eighth order in the ladder expansion [4].
Work is ongoing to extend this approach to realistic Hamiltonians. This development will pave the way for the calculation of reliable optical potentials with minimal phenomenological input, strengthening the predictive power of nuclear reaction studies with radioactive ion beams. The challenges and progress in the applications of DiagMC to realistic nuclear models will be discussed.

[1]: Idini, A. et al., Ab Initio Optical Potentials and Nucleon Scattering on Medium Mass Nuclei, Phys. Rev. Lett. 123, 092501 (2019).
[2]: Van Houcke, K. et al., Feynman diagrams versus Fermi-gas Feynman emulator, Nat. Phys. 8, 366–370 (2012).
[3]: Van Houcke, K. et al., Diagrammatic Monte Carlo algorithm for the resonant Fermi gas, Phys. Rev. B 99, 035140 (2019).
[4]: SB et al., Diagrammatic Monte Carlo for Finite Systems at Zero Temperature, Phys. Rev. Lett. 134, 182502 (2025).

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