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High-order expansion around BCS theory: Superfluid phase of the attractive Hubbard model

G. Spada[a,b,c*], R. Rossi[d,e], F. Simkovic[f,g], R. Garioud[f,g], M. Ferrero[f,g], K. Van Houcke[b], et F. Werner[a]

a. Laboratoire Kastler Brossel, École Normale Supérieure - Université PSL, CNRS, Sorbonne Université, Collége de France, 75005 Paris, France
b. Laboratoire de Physique de l'École Normale Supérieure, ENS - Université PSL, CNRS, Sorbonne Université, Université de Paris, 75005 Paris, France
c. INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, 38123 Trento, Italy
d. Center for Computational Quantum Physics, The Flatiron Institute, New York, NY 10010, USA
e. Institute of Physics, École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland
f. CPHT, CNRS, École Polytechnique, Institut Polytechnique de Paris, 91128 Palaiseau, France
g. Collège de France, 11 place Marcelin Berthelot, 75005 Paris, France

* email : gabriele.spada@unitn.it

We demonstrate that summation of connected diagrams to high order on top of the BCS Hamiltonian is a viable generic unbiased approach for strongly correlated fermions in superconducting or superfluid phases. For the 3D attractive Hubbard model in a strongly correlated regime, we observe convergence of the diagrammatic series, evaluated up to 12 loops thanks to the connected determinant diagrammatic Monte Carlo algorithm. Our study includes the polarized regime, where conventional quantum Monte Carlo methods suffer from the fermion sign problem. Upon increasing the Zeeman field, we observe the first-order superconducting-to-normal phase transition at low temperature, and a significant polarization of the superconducting phase at higher temperature

[1] Spada et al. (2021) arXiv:2103.12038.

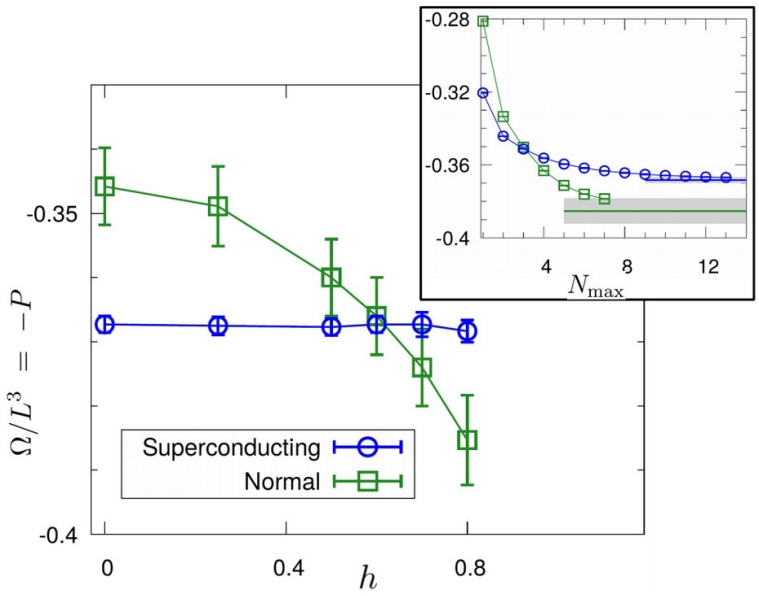

Figure 1: Grand-potential density vs. Zeeman field, at T = 1/16 ≈ T_c /4. Circles: superconducting phase, obtained by expanding around BCS mean-field theory. Squares: normal phase, obtained by expanding around the normal mean-field solution. The crossing between the curves signals the first-order phase transition. Inset: same quantity vs. truncation order N_{max}.