BCS-type theory in canonical ensembles

H. Nakada

Department of Physics, Chiba University, Chiba 263-8522, Japan

While various types of phase transitions (for increasing or decreasing temperature) are well established in infinite systems, it has been argued that there is no phase transition in finite systems, washed out by quantum fluctuations. Taking the superfluid-to-normal transition as an example, we here investigate the following two fundamental problems: (i) what roles conservation laws play, which is negligible in infinite systems but significant in finite systems, and (ii) how ‘phase transition’ develops as the particle-number increases.

Nuclear structure at finite temperature is useful in describing statistical properties of nuclei (e.g. level density), and therefore is significant in theoretical estimate of nuclear reaction rates in stars as well as in reactors. It has been pointed out that the superfluid-to-normal transition occurs at relatively low temperature ($T_c \approx 0.5$ MeV), in the finite-temperature BCS or HFB approximation for nuclei [1]. Efforts have been made to find remnant of the transition [2]. A new device called ultrasmall metallic grain [3] is another example of finite number-conserving system in which superconductivity has been found at low temperature. It may provide a good tool to investigate the above problems (i) and (ii) by experiments.

We have derived variational equations [4] after particle-number projection [5] in the finite-temperature BCS theory, for the first time. These equations almost as simple as in the usual BCS theory. Although this approximation does not include all the quantum fluctuations, it will be useful to pin down effects of the conservation laws, since it selectivity takes account of the fluctuation attached to the particle-number conservation. Moreover, this theory enables us to interpret the results in relatively simple language. Some results of numerical calculations will be presented, which give insights to the above problems (i) and (ii).

References