Microscopic description of quantum phase transitions in nuclei*

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Quantum phase transitions in nuclei have been the subject of a number of recent theoretical and experimental studies. They occur between systems characterized by different ground-state shapes. Most of these investigations are based on phenomenological models and use either an algebraic or a geometric framework. A phase transition is then accessed by variation of a control parameter and at the critical point of a phase transition new symmetries with analytic solutions are found. It is an important question, to what extent such model are justified by a microscopic description the nuclear system. To answer this question we use covariant density functional theory, that provides a unified description of bulk properties (masses, density distributions, radii) and strength functions of collective excitations. In principle such microscopic theories are based on the mean field approximation which has the advantages to include on one side global effective nuclear interactions allowing the treatment of arbitrarily heavy systems, and to allow on the other side an intuitive picture of intrinsic shapes. However, it is well known that the mean field approximation breaks down in transitional nuclei, where configuration mixing and fluctuations connected with broken symmetries play an important role. Therefore a theory is developed which uses the relativistic Generator Coordinate Method to perform configuration mixing calculations of angular momentum and particle number projected wave functions. At present three-dimensional applications of this method require a extreme numerical effort. Therefore, for the study of triaxial shapes a five dimensional Bohr Hamiltonian is derived by constrained self-consistent relativistic mean-field calculations and the resulting spectra are used to study spectra of nuclei in the Rare Earth and Actinide region. This method provides a microscopic theory of quantum phase transition in finite nuclei. It can be compared with experimental spectra and with phenomenological models. It allows to calculated the behavior of characteristic physical quantities and the study them as a function of the control parameter, the number of nucleons in the region of quantum phase transitions.

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