The E(2) critical point description of the pairing phase transition in a two j-shell model

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Shortly after the development of the BCS theory of superconductivity [1], Bohr, Mottelson and Pines [2] suggested a pairing mechanism in the atomic nucleus analogous to that observed in superconductors to explain the gap observed in the intrinsic excitation spectra of nuclei. Since then a wealth of experimental data has been accumulated, supporting the important role played by nuclear "Cooper pairs" in modifying many properties such as deformation, moments of inertia, alignments, etc.

An early approach to describing pair correlations in nuclei was the development of a collective model by Bes and co-workers [3]. The variables in the model are a pair deformation α (which can be related to the gap parameter) and a gauge angle ϕ (which is the canonical conjugate to the particle-number operator N). The collective pairing Hamiltonian was derived in direct analogy to the Bohr collective Hamiltonian which describes the quadrupole degree of freedom for the nuclear shape [4]. The Bohr Hamiltonian has recently received renewed attention due to the suggestion that simple analytic approximations can be made to describe the critical point of the transitions between nuclear shapes[5-7]. These can then serve as new benchmarks against which nuclear properties can be compared.

In a recent Letter [8], we followed the ideas of Iachello to obtain an analytic solution of the collective pairing Hamiltonian corresponding to the critical point of the transition from a ‘‘normal’’ to a ‘‘superconducting’’ nucleus. Nuclei with two identical particles added or removed from a closed shell configuration should be close to the normal limit, where there is no static deformation of the pair field and the fluctuations of the field give rise to a pairing vibrational spectrum.

In this work we study the E(2) critical point symmetry on the basis of a simple microscopic model that takes into account the necessary ingredients. We consider nucleons moving in two single-j shells of degeneracy Ω interacting with a pairing force of strength G. The levels are separated by an energy ε. The control parameter, driving the system from the normal to the superconducting regimes is $x = G\Omega/2\varepsilon$. When x is small the pairing correlations are not strong enough to overcome the single particle splitting and the system is amenable of a description in terms of paring vibrations. As x is increased, it undergoes a transition to the superconducting regime, or pairing rotations.

We observe that the E(2) critical point corresponds, as expected, to x~1. The potentials in the pair deformation coordinate derived from the model are shown in Fig.1 and support the assumptions made in our macroscopic analysis [8].

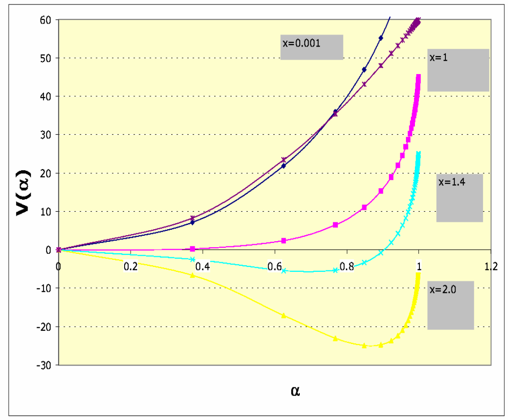

Fig. 1: Potential as a function of the “pairing deformation” α, shown for several values of the control parameter x.

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