The Transition from Vibrational to Rotational Regimes in the Pairing Phase

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Pair correlations in electron motion are directly related to macroscopic phenomena such as superconductivity. The concepts that were developed to describe such correlations found immediate application in nuclear physics and provided a key to understanding the excitation spectra of even-A nuclei, odd-even mass differences, rotational moments of inertia, and a variety of other phenomena. An early approach to describing pair correlations in nuclei was the development of a collective model by Bès and co-workers [1]. 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. 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 [2]. These can then serve as new benchmarks against which nuclear properties can be compared.

This contribution describes our efforts to develop a critical-point description of the transition from a "normal" to a "superconducting" nucleus. Some of our initial work on this topic was published recently [3]. Analytical solutions of the collective pairing Hamiltonian can be found by using simple approximations to the potential in the limits of harmonic vibrations (zero deformation of the pair field corresponding to normal behavior), deformed rotation (static deformation of the pair field corresponding to superconducting behavior) and at an intermediate transitional point. In the latter situation the potential is approximated as an infinite square well. The eigenvalues are expressed in terms of the zeros of Bessel functions of integer order. Comparison to the pairing bands based on the Pb isotopes suggests that this description may provide a simple approach to explaining the observed anharmonicities of the pairing vibrational structure around ^{208}Pb (see Figure 1).

We have tested the collective solutions by comparison to the results obtained from exact solution of a two-level model. We have assumed particles moving in two levels of identical pair-degeneracy Ω separated by an energy ε with G as the strength of the pairing interaction. By using the ratio $G\Omega/\varepsilon$ as a control parameter we can describe the full transition from harmonic vibration ($G\Omega/\varepsilon \rightarrow 0$) to deformed rotation ($G\Omega/\varepsilon \rightarrow \infty$). We find a phase-transitional behavior and that the eigenvalues and matrix elements at the critical-point are in excellent agreement with those from the collective critical-point description.

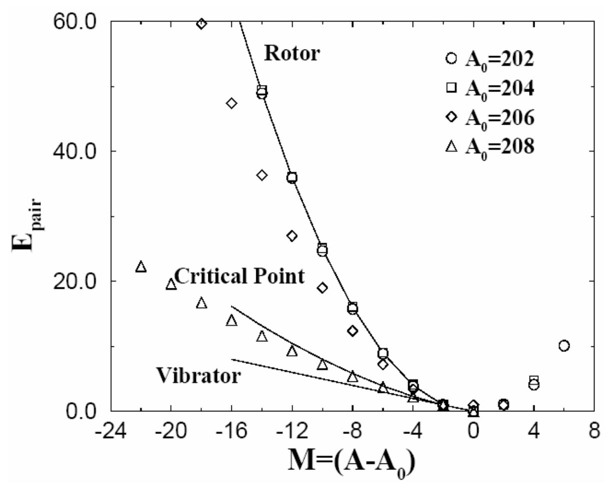

Fig. 1: Plots of the empirical neutron pair energies for the sequence formed by the 0^+ ground-states of the Pb isotopes using as a reference ^{202}Pb (open circles), ^{204}Pb (open squares), ^{206}Pb (open diamonds), and ^{208}Pb (open triangles). For comparison are shown the expectations of the pure vibrator, pure deformed rotor, and the critical-point description (solid lines).

REFERENCES

[1] D. R. Bès, R. A. Broglia, R. P. J. Perazzo, and K. Kumar, Nucl. Phys. **A143**, 1 (1970).

[2] F. Iachello, Phys. Rev. Lett. **85**, 3580 (2000), ibid. **87**, 052502 (2001), ibid. **91**, 132502 (2003).

[3] R. M. Clark, A. O. Macchiavelli, L. Fortunato, R. Krücken, Phys. Rev. Lett. **96**, 032501 (2006).