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0^+ states in Deformed Nuclei

A. Aprahamian

Nuclear Science Laboratory, University of Notre Dame, Notre Dame, IN 46556 USA

Abstract

The 1975 Nobel prize in Physics was awarded to Bohr, Mottelson, and Rainwater for the discovery of the connection between nucleon motion and the emergent collective behavior. Bohr-Mottelson-Rainwater described nuclei geometrically as a shape and the oscillations of the nucleus around that shape. The lowest lying shape effecting oscillations or vibrations would be quadrupole ($\lambda = 2$) in nature, resulting in two types of vibrations in deformed nuclei: β with oscillations along the symmetry axis ($\mathrm{K}^\pi = 0^+$) and γ breaking axial symmetry with a projection of $\mathrm{K}^\pi = 2^+$ on the symmetry axis. The γ vibration seems to be well characterized as the first $\mathrm{K}^\pi = 2^+$ (2^+_γ) band and exhibits a systematic behavior across the region of deformed nuclei with typical $B(E2; 2^+_\gamma \to 0^+_{g.s.})$ values of a few Weisskopf units (W.u.). Today, over forty years later, the existence and characterization of the low-lying β vibration however still remains an open question in nuclear structure. This is due to a large extent to the lack of sufficient experimental data on the identification and characterization of 0^+ excitations in deformed nuclei and to some extent due to the interpretation of what is expected of a β vibration. In well-deformed regions of nuclei, excitations built on a deformed ground state have traditionally been described in terms of quadrupole excitations leading to the decades-old classifications of the first excited 0^+ bands as single-phonon β-vibrational excitations. However, the discussion in recent years has focused on a debate about the absence or lack of a ($\mathrm{K}^\pi = 0^+$) β vibration with a multitude of possible interpretations. $\mathrm{K}^\pi = 0^+$ bands in deformed nuclei show widely varying levels of collectivity for the first excited 0^+ states. This paper will report on new lifetime measurements of excited states in the ^{156}Gd nucleus. The Gd isotopes lie in a well deformed region of the chart of nuclides with the ratio of the first two excited states $4^+/2^+$ ($\mathrm{R}_4/2$) vary from 3.0 to 3.3 from ^{154}Gd to ^{160}Gd where numerous 0^+ states have been identified in each isotope. We have been measuring lifetimes of low-lying excited states of K^π=0^+ bands including the $0^+, 2^+, 4^+$ states in this region of deformation and will present our results along with expected levels of collectivity.

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