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Multiple quantum phase transitions in the Zr isotopes

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Abstract

Quantum Phase transitions (QPTs) are currently a topic of great interest in nuclear physics [1]. In this field, most of the attention has been devoted to shape phase transitions in a single configuration (denoted Type I), described by a single Hamiltonian, $\hat{H}(\xi) = (1-\xi)\,\hat{H}_1 + \xi \hat{H}_2$, where ξ is the control parameter inducing the transition. A different type of phase transitions (denoted Type II) occurs when two configurations coexist [2]. In this case, the quantum Hamiltonian has a matrix form [3], with entries: $\hat{H}_A(\xi^A)$, $\hat{H}_B(\xi^B)$, $\hat{W}(\omega)$, where the index A, B denotes the two configurations and $\hat{W}$ denotes their coupling. As the control parameters (ξ_A, ξ_B, ω) are varied, the separate Hamiltonians $\hat{H}_A$ and $\hat{H}_B$ can undergo shape-phase transitions of Type I, and the combined Hamiltonian can experience a Type-II crossing of configurations A and B. In most cases, the separate QPTs are masked by the strong mixing between the two configurations. In the present contribution, we focus on the zirconium isotopes, which have been recently the subject of several experimental [4] and theoretical [5, 6] investigations. We show that these isotopes are exceptional, in the sense that the crossing is abrupt, the separate normal and intruder configurations retain their purity, hence exhibit pronounced individual shape evolutions. This results in an intricate interplay of multiple QPTs [7], with configuration-interchange and ground state shapes changing from spherical to prolate-deformed and finally to γ-unstable. Evidence for this scenario is provided by a detailed comparison with the experimental data for the entire chain of $_{40}$Zr isotopes, from neutron number 52 to 70, using the interacting boson model with configuration mixing.

References

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