Definitive Signatures of Shape Isomerism and Shape Coexistence in E0 isomers

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INTRODUCTION

The search for new signatures of specific phenomena, especially those based on simple observables, is a continuing research goal in nuclear physics. The phenomena of shape isomerism and shape coexistence are unique in nuclei, in the realm of finite many-body quantum systems. Low lying excited 0^+ states are associated with either changes in pair-correlated structure or, changes in deformation (shape) relative to the ground state. The probability of shape coexistence is more, when a shape isomeric state is identified in the excited 0^+ state. The large values of E0 transition strengths are considered to be a compelling spectroscopic fingerprint of shape coexistence in nuclei since it is consistent with changes in the shape[1]. Another quantity which could determine shape coexistence, is the reduced transition strength [B(E2: $2_1^+ \rightarrow 0_2^+$) and B(E2: $0_2^+ \rightarrow 2_1^+$)] which may be linked to deformation variation of first excited 2_1^+ state and lowest excited 0_2^+ state. The correlation between the monopole transition strength $\rho^2(E0)$ and the reduced transition strength B(E2) depends on the mixing of two different configurations.

In this presentation, we consider lowest 0^+ isomers, which are divided into three different half-life ranges viz. $>$ 10 ns, 10 ns to 1 ns, and 1 ns to 100 ps. As mentioned in Ref. [2, 3], out of total 2620 isomers having half-life $>$ 10 ns only fifteen isomers have 0_2^+ spin whereas only ten and sixteen 0_2^+ isomers with half life in the range of 10 ns to 1 ns, and 1 ns to 100 ps are reported respectively. The comparative study of these isomers in terms of monopole transition strength $\rho^2(E0)$, reduced transition strength B(E2), hindrance factor and other qunatities shed light on a new concept of E0 isomers. In particular, the variation of E2 hindered factor F_w as a function of nucleon number discriminates the shape isomers from the E0 isomers throughout the nuclear chart.

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DISCUSSION

To study the important physical observables affected by shape coexistence, we have used an average pairing energy (=$12/\sqrt{A}$) of the 0_2^+ isomers as a function of proton and neutron number. It is observed that nearly all the 0_2^+ isomers lie below or close to the pairing line except six. These six isomers lying in the half life range of less than 10 ns, are most likely collective in nature, hence excluded from the present study.

It is known that the shape coexistence of 0_2^+ isomer can be correlated with the size of the E0 matrix element. The monopole operator connecting $J \rightarrow J$ state is described in terms of the deformation parameters β and γ as,

$$m(E0) = (\frac{3Z}{4\pi})[\frac{4\pi}{5} + \beta^2 + (\frac{5\sqrt{5}}{21\sqrt{\pi}})\beta^3 \cos\gamma] \quad (1)$$

. This formula is based on the expression of E0 transition operator for a deformed uniformly charged nucleus [5]. In the limit of simple two-state mixing between configurations with deformations β_1, γ_1, β_2, and γ_2, the resulting monopole strength is given by

$$\rho^2(E0) = (\frac{3Z}{4\pi})^2 \times a^2(1-a^2)[(\beta_1^2 - \beta_2^2) + (\frac{5\sqrt{5}}{21\sqrt{\pi}})(\beta_1^3 \cos\gamma_1 - \beta_2^3 \cos\gamma_2)]^2 \quad (2)$$

where Z is the atomic number, β_1 is axial deformation of the first state, β_2 is axial deformation of the second state, γ_1 is non-axial deformation

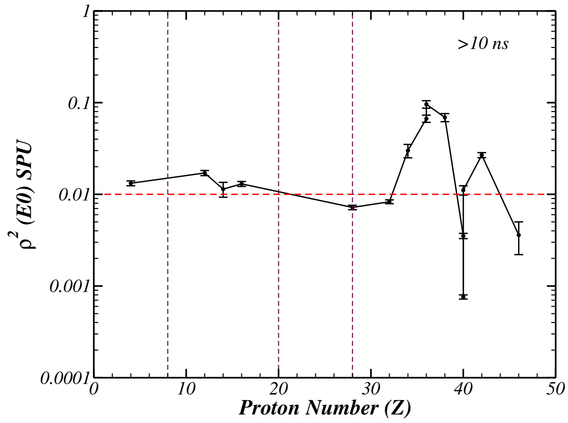

FIG. 1: Monopole transition strength $[\rho^2(E0)]$ vs. the proton number (Z) for > 10 ns 0_2^+ isomers.

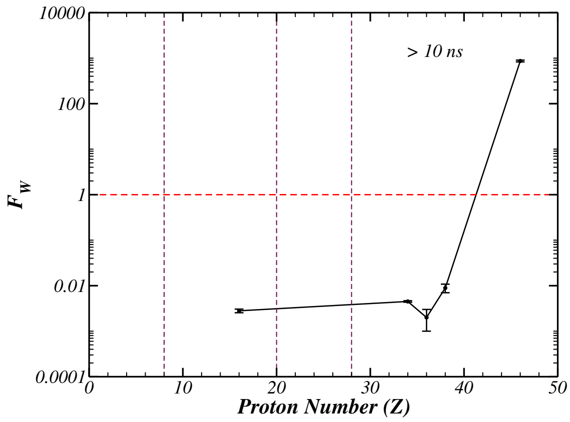

FIG. 2: Variation of E2 hinderance factor F_w vs. the proton number (Z) for > 10 ns 0_2^+ isomers.

of the first state, γ_2 is non-axial deformation of the second state, and a^2 is the mixing amplitude of two different configurations.

The variation of $\rho^2(E0)$ for 0_2^+ isomeric nuclei having half-life > 10 ns as a function of proton number is shown in Fig. 1. It is observed that the values of $\rho^2(E0)$ for ^{96,98}Zr and ^{102}Pd isotopes lie much below 0.01 indicating that these isomers are unlikley to be shape isomers. However, in the plot of Fig. 2, it is noticed that although the hindrance factor (F_w) of ^{96,98}Zr isotopes are lower than 1.0, the F_w for ^{102}Pd nucleus lies above unity. This anomaly in the hindrance factor suggests that ^{102}Pd nucleus is one of the exceptional nuclei in which 0_2^+ state is established to be a shape isomer in spite of having lower $\rho^2(E0)$ value, whereas ^{96,98}Zr isotopes are classified as E0 isomers. From these figures it is evident that $\rho^2(E0)$ is not the only defining quantity for shape isomers. There are other contributing factors which might also define a shape isomer and thus can be used to differentiate between shape isomers and E0 isomers. Such description of shape coexistence, shape isomer and E0 isomer in other half-life region, based on various contributing factors, shall be presented in detail.

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