Rotation-particle coupling and the triaxiality in ^{167}Lu

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Introduction

The study of shape of nuclei is an important and interesting subject in the area of nuclear physics. The changes in shape with atomic number provide rich information about the interplay between collective and underlying shell structure of nuclei. Nuclei in the region of $70 \leq Z \leq 80$ and $82 \leq N \leq 126$ exhibit interesting features related to shape change from spherical to prolate and then oblate [1]. We study an odd-proton system ^{167}Lu, which lies in the range of Z and N mentioned above and find this nucleus as triaxial in shape. The modified particle-rotor model (MPRM) calculations [2] are performed to study the negative parity yrast band in ^{167}Lu.

Formalism

In microscopic rotation-particle coupling, the wave function of an odd-A nucleus with the odd particle at position $\vec{r}$, and orientation of rotor at ω, is given by

$$\Psi_{IM}(\vec{r},\omega) = \sum_{ljR\tau} \frac{\phi^I_{ljR\tau}(r)}{r} |ljR\tau, IM\rangle, \quad (1)$$

where (I, M) and K are quantum numbers in laboratory frame and center of mass frame, respectively. Labels (l, j, Ω) are related to the particle and (R, K_R, M_R) correspond to the rotor [2]. Quantities $\phi^I_{ljR\tau}(r)$ and $|ljR\tau, IM\rangle$ are the radial and angular parts of the wave function, respectively.

The total Hamiltonian reads as

$$H = H_{\text{avg}} + H_{\text{pair}} + H_{\text{rot}} \ , \quad (2)$$

where H_{avg} corresponds to the intrinsic energy of the odd particle. The pairing interaction is given by H_{pair}, and H_{rot} is the rotor Hamiltonian.

The matrix element of H_{rot} can be written in K representation [2] by utilizing the experimental rotor energies E_{TRi} and the calculated wave functions $c^{Ri}_{K_R}$ as

$$\begin{aligned} &\langle lj\Omega_{p'}K', IM|H_{\text{rot}}|lj\Omega_p K, IM\rangle \\ &= \sum_{R,K_R,K'_R} A^{IK'}_{j\Omega'_p,RK'_R} \sum_i c^{Ri}_{K'_R} E_{TRi} c^{Ri}_{K_R} A^{IK}_{j\Omega_p,RK_R} \\ &= W^{K'K}_{j\Omega_{p'}\Omega_p} \ . \end{aligned} \quad (3)$$

Here, the amplitude $A^{IK}_{j\Omega_p,RK_R}$ enables the transformation of the wave function from R representation to K representation and vice versa. The matrix element of the total Hamiltonian H can be written as

$$\begin{aligned} \langle q'K', IM|H|qK, IM\rangle &= \epsilon_q \ \delta_{K'K}\delta_{q'q} \\ &+ \sum_{lj\Omega_{p'}\Omega_p} W^{K'K}_{j\Omega_{p'}\Omega_p} \\ &\times \int dr \ f_{uv} \ \phi^{IK'*}_{lj\Omega_{p'}}(r) \ \phi^{IK}_{lj\Omega_p}(r) \ , \end{aligned} \quad (4)$$

where q defines particle state and ϵ_q is the quasiparticle energy. The quantity f_{uv} is used to transform the matrix element from single-particle states to quasiparticle states.

Quantity E_{TRi} correspond to the measured energies. The missing data and eigen vectors $c^{Ri}_{K_R}$ are obtained from a variable moment of inertia (VMI) approach with the stiffness parameter C and ground state moment of inertia $\mathcal{I}_0$ [2–4].

Result and discussions

Both ^{167}Lu and its core (^{166}Yb) lie near the β-stability region, where we have enough

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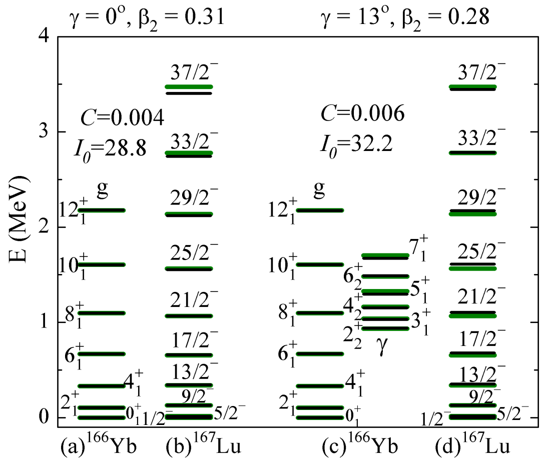

FIG. 1: (a) and (c): Rotational spectrum of ^{166}Yb. (b) and (d): The negative parity yrast band of ^{167}Lu. Theoretical results of (a) and (b) assume axial symmetry whereas triaxiality ($\gamma = 13°$) is considered in the cases (c) and (d). Green lines correspond to the experimental spectrum (^{166}Yb data from Ref. [7]) and the black lines represent our calculated results.

data to investigate their structural properties. ^{166}Yb is predicted to be triaxially deformed [5, 6] because of the occurrence of a gamma-band along with the ground-band. The gamma-band of ^{166}Yb appears at very high in energy compared to the ground band, thus the nucleus has a low triaxial deformation ($\gamma \sim 12.5°$ [5]).

In Fig. 1(a), the ground-band of ^{166}Yb is presented at $\gamma = 0°$. At $\gamma = 0°$ the gamma-band appears at infinite energy and even-angular-momentum states are observed in the ground band. The negative parity yrast band of ^{167}Lu, built on $I^{\pi} = 1/2^{-}$ is presented in Fig. 1(b) at $\gamma = 0°$ and the choice of $\beta_2 = 0.31$ leads to the best fitting with the data. The rotational energy calculations of ^{167}Lu involve single-particle energies, wave functions and also the rotor ^{166}Yb states at the given deformation. In Figs. 1(a) and (b), axial symmetry is assumed for ^{166}Yb and ^{167}Lu, and in Fig. 1(c) and (d), the bands are presented at triaxial deformation $\gamma = 13°$. The gamma band of ^{166}Yb is approximately 1 MeV higher in energy than the ground band. Thus a low $\gamma = 13°$ is required to obtain the best fit simultaneously for the ground and gamma bands. In Fig. 1(d), ^{167}Lu spectrum is presented at $\gamma = 13°$ and $\beta_2 = 0.28$. The γ value is constrained by the rotor ^{166}Yb and the β_2 corresponds to the best fitting of the spectrum with the measured data.

From Fig. 1, It can be concluded that ^{167}Lu is a triaxially deformed nucleus since the best agreement with the data is obtained both for ^{167}Lu and its core ^{166}Yb when the triaxial deformation is considered. The negative parity yrast band of ^{167}Lu is built on $1/2^{-}$, which has predominant contributions from the admixture of $h_{9/2}$ and $f_{7/2}$ orbitals.

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