Signature dependent structure for [642]5/2$^+$ configuration in ^{167}Yb?

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Introduction

For a deformed (axially symmetric) rotating nucleus, the signature (α) and parity (π) are the only good quantum numbers. A rotational band, based on a particular Nilsson configuration has two partners, e.g with α=+1/2 and α= -1/2 for an odd-A nucleus. In general, both the signature partner bands for a well deformed nucleus have same structure. However, recently, it has been reported that the two signature partner bands in ^{167}Yb nucleus based on [642]5/2$^+$ Nilsson configuration posses different deformations [1]. It has been reported that the B(E2) values, obtained from the lifetime measurements, for the favoured (α = +1/2) signature partner are larger than the unfavoured (α = -1/2) one, signifying larger deformation for the α = +1/2 partner. This effect increases with spin or rotational frequency indicating signature dependent shape evolution in this nucleus. The particle plus triaxial rotor model (PTRM) calculations failed to account for the observed differences. Larger contribution from low-Ω orbitals in the wave function has been attributed as the possible reason for larger deformation of the favoured band.

Signature dependent shape evolution was predicted earlier from the Total Routhian Surface (TRS) calculations for the nuclei in A = 130 mass region [2]. It has been shown that the α = +1/2 and α = -1/2 signatures induce different shape evolution, particularly in the deformation parameter γ.

In this work, the proposed signature dependent shape driving effect of the [642]5/2$^+$ Nilsson configuration has been studied in ^{167}Yb.

Method

The TRSs are calculated, in the present work, using the Hartee-Fock-Bogoliubov code of Nazarewicz et al. [3]. A deformed Woods-Saxon potential and a pairing interaction was used with Strutinsky shell corrections method. The energies are calculated in the β_2-γ deformation mesh points and were minimized in β_4 at each value of the mesh points. These are calculated at different rotational frequencies $\hbar\omega$ and for different configurations. Typical TRS plots in the β_2-γ deformation mesh are shown in Fig. 1. In this figure, the TRS plots for both favoured (α = +1/2) and unfavoured (α = -1/2) signatures in [642]5/2$^+$ parentage are shown at the rotational frequency of $\hbar\omega$ = 0.11 MeV. The equipotential lines in this figure are separated by 300 keV. The figure indicates that both the signature partners have well defined minimum corresponding to very stable prolate deformation with β_2 ~ 0.27.

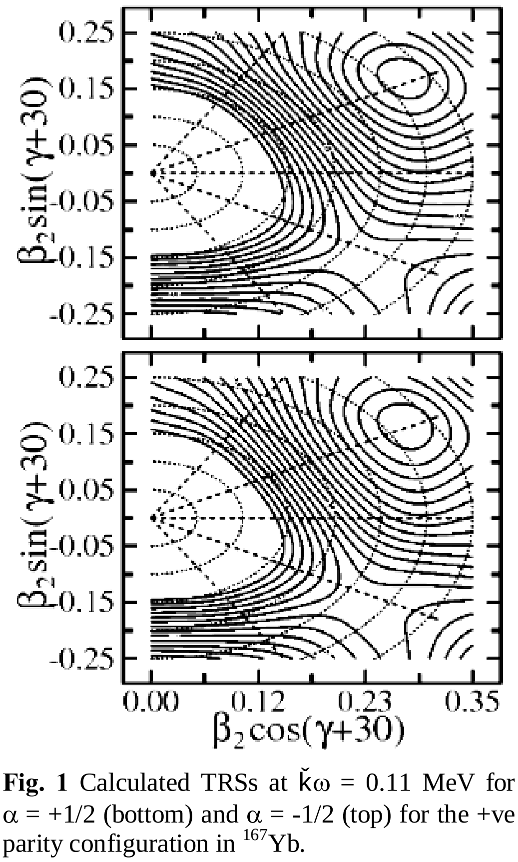

Fig. 1 Calculated TRSs at $\hbar\omega$ = 0.11 MeV for α = +1/2 (bottom) and α = -1/2 (top) for the +ve parity configuration in ^{167}Yb.

Results and Discussion

From the TRS calculations at different $\hbar\omega$, the β_2 and γ values corresponding to the minimum for each of those have been obtained. The calculated quadrupole moments (Q_t) are deduced from these β_2 and γ values using the standard formulae [4]. The experimental Q_t values are obtained from the measured B(E2) values reported in Ref. [1].

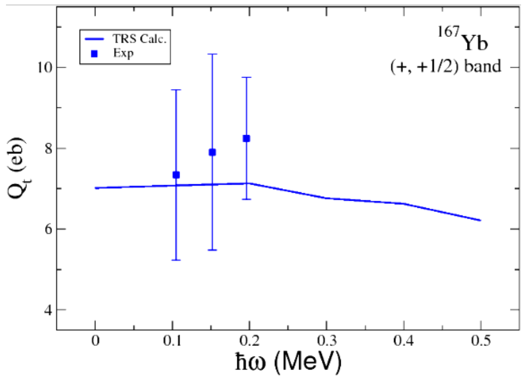

Fig. 2 Experimental and calculated transition quadrupole moments (Q_t) for the favoured signature partner of the +ve parity band in ^{167}Yb.

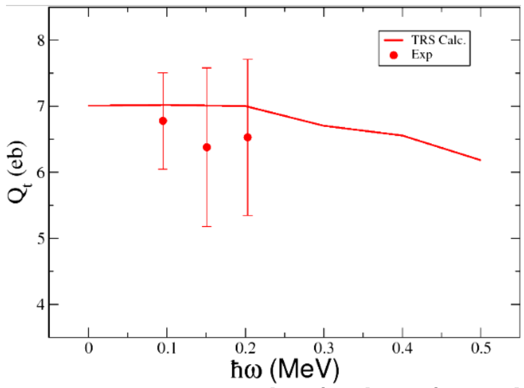

Fig. 3 Same as Fig. 1 but for the unfavoured signature partner.

The Q_t values are related to the structure of a nucleus. The calculated and experimental Q_ts for the favoured and the unfavoured signature partners of $[642]5/2^+$ band in ^{167}Yb are compared in Fig. 2 and 3, respectively. It can be seen that the calculated Q_t values match well with the experimental ones, within the uncertainties. However, the experimental values have large error bars. The Increase in the observed value of B(E2)s claimed in Ref. [1] for the favoured band cannot be justified within the uncertainties. The calculated Q_t values remain almost constant over the rotational frequency range for which experimental data are available. After that the calculated values tend to decrease with $\hbar\omega$.

The kinematic moment of inertia ($J^{(1)}$) for the two signature partners are also obtained from the experimental level scheme of ^{167}Yb and are plotted in Fig. 4. The $J^{(1)}$ values are related to the deformation. It can be seen from this figure that the $J^{(1)}$ values of ^{167}Yb decrease with $\hbar\omega$ for both the signature partners in the above configuration. They start to increase again after $\hbar\omega \sim 0.25$ MeV where there is a band crossing.

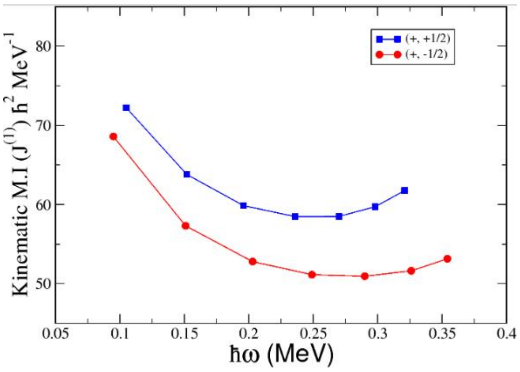

Fig. 4 Experimental kinematic moments of inertia for the two signature partners of the +ve parity band in ^{167}Yb.

Conclusions

In conclusion, the TRS calculations suggest that the two signature partners of the $[642]5/2^+$ orbital have quite similar structure and structural evolution with rotational frequency, unlike in the A = 130 region. The calculated quadrupole moments agree well within the present uncertainties in the experimental values for both the signature partners. More precise data are required in future.

References

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