High Spin Spectroscopy of ^{168}Hf Nucleus

B.B. Sahu[1],* S.K. Singh[3], Z. Naik[2], S.K. Patra[3], and C.R. Praharaj[3]
[1]*Kalinga Institute of Industrial Technology (KIIT) University, Bhubaneswar-751 024, INDIA*
[2]*School of Physics, Sambalpur University, Jyotivihar, Sambalpur-768 019, INDIA and*
[3]*Institute of Physics, Sachivalaya Marg, Bhubaneswar-751 005, INDIA*

Introduction

Low-lying multiquasiparticle isomeric states are known in all of the heavy-, odd-, and even-mass hafnium isotopes. The search for the experimental signatures of triaxial nuclear shapes in the mass A∼160 region has drawn considerable interest in recent years. Indeed, high-spin triaxial strongly deformed (TSD) structures have been identified in several Lu (Z=71) isotopes. An extensive search for TSD bands in Hf (Z=72) nuclei has also been carried out, and a number of strongly deformed bands have been observed in ^{170}Hf [1], ^{171,172}Hf [2], ^{173,174}Hf [3, 4], and ^{175}Hf [5]. An extensive study of the normal deformed level structures of ^{168}Hf and the rotational properties of high K bands are studied systematically and is the subject of the article.

Theoretical Framework

A deformed shape such as one described by slater determinant of deformed orbits $\mid \Phi_K >$ is localized in angle and, by the uncertainty principle, is not a state of good angular momentum (J). Thus $\mid \Phi_K >$ does not have a unique J quantum number and is a superposition of various J states [6–8],

$$\mid \Phi_K >= \sum_I C_{IK} \mid \Psi_{IK} > . \qquad (1)$$

One needs to project out states of good angular momenta from the intrinsic state Φ_K with the Angular Momentum Projection operator,

$$P^{IM}_K = \frac{2I+1}{8\pi^2} \int d\Omega {D^I_{MK}}^*(\Omega) R(\Omega). \qquad (2)$$

In general two states $\mid \Psi^{JM}_{K_1} >$ and $\mid \Psi^{JM}_{K_2} >$ projected from two intrinsic configurations are not orthogonal to each other even if $\mid \Phi_{K_1} >$ and $\mid \Phi_{K_2} >$ are orthogonal. Thus, whenever necessary, we do band-mixing using the following equation:

$$\sum_{K'} (H^J_{KK'} - E_J N^J_{KK'}) C^J_{K'} = 0. \qquad (3)$$

Results and Discussion

The deformed HF orbits are calculated with a spherical core of ^{132}Sn, the model space spans the $2s_{1/2}$, $1d_{3/2}$, $1d_{5/2}$, $0g_{7/2}$, $0h_{9/2}$ and $0h_{11/2}$ orbits with single particle energies 3.654, 3.288, 0.731, 0.0, 6.46 and 1.705 MeV for protons and the $2p_{1/2}$, $2p_{3/2}$, $1f_{5/2}$, $1_{f7/2}$, $0h_{9/2}$ and $0i_{13/2}$ orbits with energies 4.462, 2.974, 3.432, 0.0, 0.686 and 1.487 MeV for neutrons, respectively. We use surface delta interaction [10] as the residual interaction among the active nucleons to obtain deformed single particle orbits. The interaction strength is taken as 0.3 MeV for p-p, n-n and n-p interactions.This interaction gives a good description of the systematics of deformations in this mass region. The calculated results are presented in Fig. 1.

The calculated results are depicted in Table I and the systematic agreement between calculated and experimental B(E2) values justifies that our calculations are able to describe the basic structure of this nucleus.

Conclusions

The neutron rotation-aligned (RAL) K=1^+ band is the yrast between $10\hbar$ and $18\hbar$. From

*Electronic address: bbsnou@gmail.com

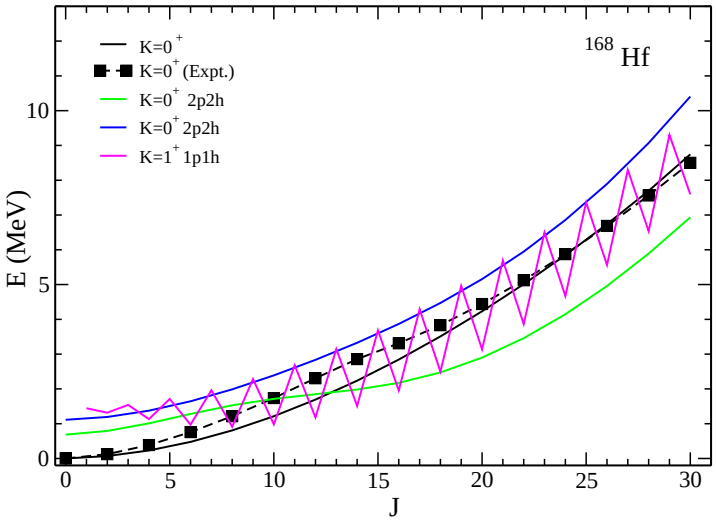

FIG. 1: Comparison of experimental spectra with deformed HF model results (Calc.) of ^{168}Hf. The experimental data are taken from [9].

TABLE I: Calculated reduced transition probabilities of ^{168}Hf with K=0$^+$ state. Experimental data are taken from [11].

Transition	B(E2: J→J-2) (e^2b^2)	B(E2: J→J-2) (e^2b^2)
J	Theory	Expt.
2^+	0.709	0.838± 0.035
4^+	1.011	1.152± 0.116
6^+	1.110	1.300± 0.127
8^+	1.157	1.398± 0.132
10^+	1.182	1.422± 0.216
12^+	1.195	1.780± 0.62
14^+	1.199	1.296± 278

20$\hbar$ upwards to 30$\hbar$, 2p2h K=0$^+$ band becomes yrast. We have calculated E2 and M1 matrix elements for various bands. We also have angular momentum projection results for the spectra and electromagnetic transitions for the (isomeric configurations) K=8$^-$(proton 1p1h), K=6$^-$(neutron 1p1h) and the 4-qp K=14$^+$ bands. We have identified the mechanism of 2p2h and 4p4h proton and neutron configuration mixings which gives a far more improved spectrum of the ground band. These will be presented latter.

Acknowledgments

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