High spin structure of ^{55}Cr in deformed Hartree-Fock and Angular Momentum Projection model

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Introduction

Study of chromium isotopes (Z=24), becomes important as these are expected to undergo rapid changes in nuclear shape and related excitation modes throughout the isotopic chain due to the contiguity of magic number at Z=20, 28 [1]. The isotope ^{48}Cr is a well-deformed nucleus with significant collective behaviour [2]. Further increasing the neutrons, more and more neutrons get occupied to $0f_{5/2}$ and $1p_{3/2}$ orbitals. This affects the shell structure significantly and lead to a more unusual shell structure, particularly when neutrons get occupied in $0g_{9/2}$ [1].

In ^{55}Cr, involvement of the $0g_{9/2}$ orbital in higher spin bands may lead to unexpected shell structure like ^{48}Cr. For getting a detailed picture about the decoupled $0g_{9/2}$ band, appropriate microscopic model is required. Experimentally three bands has been observed with high spin upto J=$25/2^+$ with energy 7.430MeV in [3]. In the present work the spectrum of ^{55}Cr has been investigated using our quantum mechanical model known as deformed Hartree-Fock (HF) and Angular Momentum Projection (J Projection) model. A comparative study has been done among our result, experimental data and other theoretical data. Along with this some structural properties like magnetic dipole and quadrupole quadrupole moment have been reported.

Theoretical Framework

We have used deformed HF and J projection model in this work, with axial symmetry of the HF field. Deformed HF orbits (prolate or oblate) are obtained from the self-consistent solution of the HF equation by iteration. The surface delta interaction with strengths $V_{pp} = V_{np} = V_{nn}$= 0.5 MeV is taken as two-body residual interaction among active nucleons. The prolate solution is favoured from oblate solution by 4.331MeV energy, thus resulting prolate HF orbits of protons and neutrons are presented in Fig.1 and this HF solution is used further for J projection study. The model space used are $1p_{1/2}$, $1p_{3/2}$, $0f_{5/2}$, $0f_{7/2}$ and $0g_{9/2}$ with spherical single-particle energies 2.132, 0.0, 2.138, -3.97 and 5.450 MeV for protons and 2.0, 0.0, 1.637, -4.04, 5.204 Mev for neutrons. To calculate the spectra and other spectroscopic properties (like transition matrix elements) we need states of good J. The good J states of a given intrinsic state are obtained by performing J Projection. The J projection operator is [4–6]:

$$P^{JM}_{K} = \frac{2J+1}{8\pi^2}\int d\Omega\ D^{J\,*}_{MK}(\Omega)\ R(\Omega) \quad (1)$$

where $R(\Omega)$ is the rotation operator and Ω stands for the Euler angles (α, β, γ).

The energies and electromagnetic transition operators are calculated by finding out their matrix elements which consists of integration over Euler angles. Reduced matrix elements of tensor operator T^L of rank L are given by,

$$\langle \Psi^{J_1}_{K_1} ||\ T^L\ || \Psi^{J_2}_{K_2}\rangle = \frac{1}{2}\frac{(2J_2+1)(2J_1+1)^{1/2}}{(N^{J_1}_{K_1K_1}N^{J_2}_{K_2K_2})^{1/2}} \sum_{\mu\nu} C^{J_2LJ_1}_{\mu\nu K_1}\int_0^\pi d\beta\ \sin(\beta) d^{J_2}_{\mu K_2}(\beta) \langle \phi_{K_1}|T^L_\nu e^{-i\beta J_y}|\phi_{K_2}\rangle \quad (2)$$

where T^L is an electromagnetic operator (E2, M1 etc). Here $N^J_{K_1K_2}$ is the normalisation constant [4–6].

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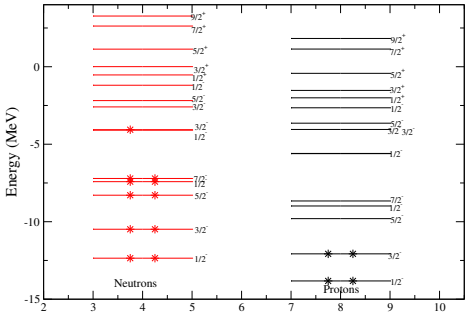

FIG. 1: HF Orbit for ^{55}Cr, particle occupied upto Fermi surface are shown by *.

Results and discussions

In ^{55}Cr isotope, three one quasiparticle bands with bandhead K=$9/2^+$, K=$5/2^-$, K=$3/2^-$ has been experimentally reported. We have studied these spectrum by considering intrinsic states with K=$1/2^+$, K=$1/2^-$, K=$3/2^-$. These one quasiparticle states and corresponding rotational aligned band with 3 quasiparticles are constructed by considering suitable particle excitation near the Fermi surfaces. The band mixed spectrum of these bands with their experimental counterpart are shown in Fig.2. The band based on K=$3/2^-$ is the ground band as per the experiment. However our theory gives band with K=$1/2^-$ as the lowest band (There is a uncertainty of 0.5 MeV on bandhead calculation in our model). Using the pesent model we have predicted high spin states upto J=$31/2^-$, J=$31/2^-$, J=$37/2^+$ for configuration K=$3/2^-$, K=$1/2^-$, K=$1/2^+$ respectively. These bands have been experimentally observed upto J=$19/2^-$, J=$25/2^-$, (J=$33/2^+$) for the corresponding bands resprctively.

The RAL mixed results agrees well with corresponding experimental level spacings and excitation energies. We have also shown the unfavoured signature partners of these bands in Fig.2. The deformation for K=$3/2^-$ is 0.308 and for K=$1/2^-$ is 0.312 and for K=$1/2^+$ is 0.327. The magnetic moment of the bandhead is lying between -0.151μ_N to 2.061μ_N. So far our knowledge is concerned these values are not known experimentally.

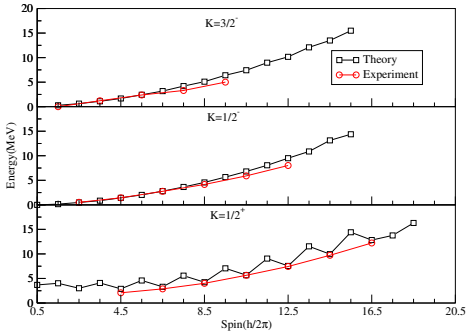

FIG. 2: Comparision of experimental (as given in [3]) and theoritical spectrum (band mixed).

Conclusion

Our predictions are in reasonably good agreement with the experiment. We predict both the signature partner of the bands while experimentally only one branches are observed. Along with available spectrum, we have predicted spectra for few more configurations and Q_0, μ_N values of all bands for future reference. We have compared our results with experimental data and with other theoretical models where data are available.

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