Are there Superdeformed states in ^{35}Cl?

Abhijit Bisoi[1], S. Ray[1], M. Roy Basu[2], Debasmita Kanjilal[1], Somnath Nag[3], K. Selva Kumar[3], A. Goswami[1], N. Madhavan[4], S. Muralithar[4], R. K. Bhowmik[4], S. Sarkar[5], M. Saha Sarkar[1*]
[1]*Saha Institute of Nuclear Physics, Bidhannagar, Kolkata - 700064, INDIA*
[2]*University of Calcutta, Kolkata - 700009, INDIA*
[3]*Indian Institute of Technology, Kharagpur-721302, INDIA*
[4]*Inter University Accelerator Centre, New Delhi - 110067, INDIA and*
[5]*Bengal Engineering and Science University, Shibpur, Howrah - 711103, INDIA*

Introduction

The nuclei in the neighbourhood of doubly closed ^{40}Ca usually exhibit characteristics of spherical single particle excitations. This feature is suitable for applications of spherical shell model in the *sd* shell. However, the spectroscopy of several nuclei in the mass region revealed deformed states (even superdeformation) at low-excitation energies, indicating that the nuclei near the closed shell with Z or N = 20 can easily lose spherical shape [1, 2]. Large-scale shell model calculations to interpret superdeformed band in ^{36}Ar[1] have provided a microscopic description of rotational motion in nuclei.

^{35}Cl is a stable nucleus in this mass region. We have studied this nucleus extensively by extending its level scheme and measuring the lifetimes of quite a few states using DSAM technique [3]. In that work we have pointed out that a few states have been observed whose lifetimes were estimated to be very short. But due to lower excitation energy of the compound nucleus populated, we could not investigate their nature conclusively. In a subsequent experiment, we have obtained relatively better data to proceed further. In this work we present our experimental and theoretical investigations of those short lived states and explain the origin.

The Experiment

High-spin states in ^{35}Cl have been populated through ^{12}C+^{28}Si (110 MeV) reaction in the inverse kinematics. The relevant details of the experiment have been discussed in Ref.[4]. Gamma - gamma coincidence measurement has been done using the multi-detector array of thirteen Compton suppressed Clover detectors (INGA setup) at Inter University Accelerator Centre (IUAC), New Delhi.

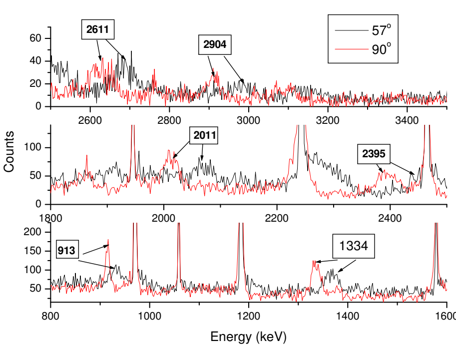

FIG. 1: The shifted and unshifted gamma peaks in 3163 keV gated spectra.

Results and Discussions

Two spectra from detectors at 90^o and 57^o (Fig. 1) generated by putting gates on the 3163 keV transition in ^{35}Cl show the six shifted peaks from around 900 keV to 3000 keV. The shifted and unshifted peak positions are marked in the figure. It clearly shows that the lifetimes of the corresponding states must be shorter than the characteristic stopping time of ^{35}Cl recoils in gold (Au) backing. The unshifted centroids of these gammas have been determined by plotting the centroids of

*Electronic address: maitrayee.sahasarkar@saha.ac.in

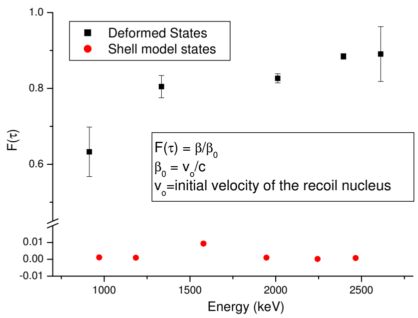

FIG. 2: Fractional Doppler shifts shown as a function of gamma energies.

the shifted peaks from spectra obtained from detectors at different angles as a function of cos θ. The regular ordering of these gammas provoked us to propose that they belong to a regular sequence of deformed states of a collective band. Due to the large Doppler shifts observed for these gammas (Fig.1), it was very difficult to generate spectra by putting gates on these gammas to show their mutual coincidence. So we have resorted to alternative means to establish their correlation. At first we conjectured that if these gammas belong to the same deformed band, they all should correspond to the same deformation. In order to determine the deformation of this proposed band, the residual Doppler shifts of the γs were measured. The average recoil velocity is expressed as a fraction of the initial recoil velocity to obtain $F(\tau)$. In Fig. 2, the fractional Doppler shifts $F(\tau)$ [1, 2] are plotted as a function of the γ -ray energies. The experimental $F(\tau)$ values are then compared with the calculated values based on known stopping powers. The comparison of the $F(\tau)$ values of these transitions with other single-particle transitions with similar spins and energies are shown in Fig.2.

Next we have done theoretical calculations using a version [5] of Particle Rotor Model, where the excitation energies of the core can be given as inputs. We have considered ^{35}Cl as a coupled system of superdeformed core of ^{36}Ar and a valence proton hole. We have taken the $\beta_2 \simeq 0.45$ as obtained from pre-

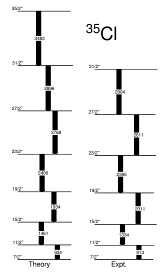

FIG. 3: The Particle Rotor Model results compared with the experimental spectra.

vious experiments on SD bands in ^{36}Ar [1]. The energies and lifetimes of these states have been calculated. The level spectra matches extremely well with our proposed band (Fig.3).

Conclusion

A sequence of gamma rays decaying from very short lived states manifested through their large Doppler shifts has been proposed to belong to a super deformed band having a deformation similar to that of a SD band in ^{36}Ar. Analysis of fractional Doppler shift has been done to assign deformation to this band. Theoretical studies using Particle rotor model exactly reproduces this band. Large scale shell model calculations will be done to identify the microscopic origin of these states.

Acknowledgments

The authors acknowledge the help from other INGA collaborators and the Pelletron staff of IUAC for their sincere help and cooperation.

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