In beam Spectroscopy of Negative Parity States in ^{135}Pr

Ritika Garg[1],* S. Kumar[1], Mansi Saxena[1], Savi Goyal[1], Davinder Siwal[1], Sunil Kalkal[1], S. Verma[1], S. Mandal[1], R. Singh[1], S. C. Pancholi[1], R. Palit[2], Deepika Choudhury[3], A. K. Jain[3], S. S. Ghugre[4], G. Mukherjee[5], R. Kumar[6], S. Muralithar[6], R. K. Bhowmik[6], and R. P. Singh[6]

[1]*Department of Physics and Astrophysics, University of Delhi, Delhi - 110007, INDIA*
[2]*Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*
[3]*Department of Physics, Indian Institute of Technology, Roorkee - 247667, INDIA*
[4]*UGC - DAE Consortium for Scientific Research, Kolkata, INDIA*
[5]*Physics Group, Variable Energy Cyclotron Centre, Kolkata - 700064, INDIA and*
[6]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

Introduction

In the early 1990's, a new mode of nuclear excitation was discovered. A long and regular sequences of states of fixed parity I^{π}, $(I+1)^{\pi}$, $(I+2)^{\pi}$, . . . connected by strong $\delta I = 1$, M1 transitions (with B(M1) values of several μ^2_{prep}) and relatively weak crossover E2 transitions were observed [1]. It was suggested by Frauendorf *et al.* that these sequences (bands) offer a new type of nuclear rotation called magnetic rotation (MR). In this rotation, proton holes/particles and neutron particles/holes are aligned perpendicular to each other as a shear and produce higher angular momentum in a way that resembles the closing of the blades of a pair of shears. In special cases the band continues its MR character after the band crossing from one configuration to another (known as MR band crossing). In the mass A = 135 region, such crossing of MR bands have been explored in ^{137}Pr nuclei [2]. We report here ^{135}Pr nuclei that has not been explored for MR. The high spin spectroscopy of ^{135}Pr nuclei has been studied earlier by using 6 Ge detectors [3]. The level scheme is known to about 6 MeV of excitation energy and tentatively upto 43/2 $\hbar$ of angular momentum.

*Electronic address: ritikagarg25@yahoo.co.in

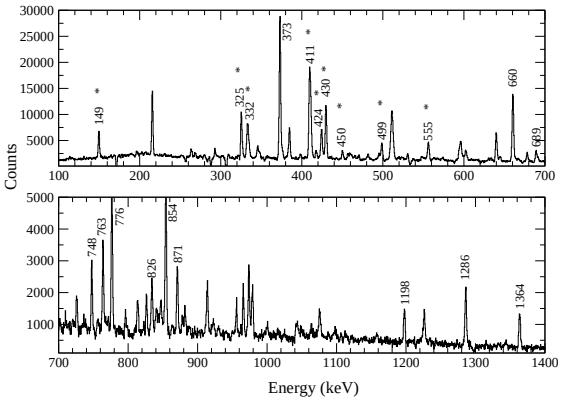

FIG. 1: Sum (430 keV + 332 keV) gate spectrum.

Experimental Details

The high spin states in ^{135}Pr were populated by the reaction ^{123}Sb(^{16}O,4n)^{135}Pr using a ^{16}O beam of 82 MeV from the pelletron accelerator of Inter University Accelerator Centre (IUAC), New Delhi. The target consisted of a 800 μg/cm^2 ^{123}Sb with 10 mg/cm^2 ^{197}Au backing. The $\gamma-$rays were detected using Indian National Gamma Array (INGA) during the second campaign. The array consisted of 15 Compton suppressed clover HPGe detectors placed at 148°, 123°, 90°, 57°, 32° with 4, 2, 4, 2 and 3 detectors respectively. The list mode data was taken in triple and higher fold. A total of about 300 million events were recorded in the experiment. The

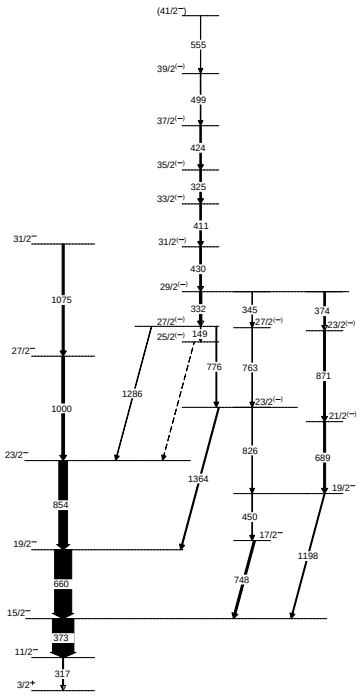

FIG. 2: Partial level scheme for the negative parity band in ^{135}Pr.

excitation function was performed by taking the detector at 90° using 4 MeV step (lab. energy between 70-82 MeV). The data was sorted using INGASORT program to produce symmetrised E_γ-E_γ matrices.

The level scheme for the negative parity states of ^{135}Pr obtained from the present work is shown in Fig.2. This is constructed on the basis of coincidence relation of $\gamma-\gamma$ and intensity balance. The DCO ratios listed in Table 1 have been calculated from the asymmetric matrix with one axis corresponding to 90° and the other axis corresponding to 148°.

In the upper panel of Fig.1, the sequence of 149-, 325-, 332-, 411-, 424-, 430-, 499- and 555 keV γ-ray (labeled by asterisk (*)) constitute a dipole band on the basis of R_{DCO} value given in Table 1. In the lower panel of Fig.1, all the other connecting transitions with the ground band are shown. In order to assign the spins of the dipole band, R_{DCO}

TABLE I: Energy, DCO ratio and multipolarity of the transitions of ^{135}Pr deduced from the present work. D stands for dipole and Q for quadrupole.

Eγ	R_{DCO}	Multipolarity
149	1.50(4)^b	D
325	1.31(4)^b	D
332	0.54(2)^a	D
345	1.19(6)^b	D
411	1.46(4)^b	D
424	1.21(5)^b	D
430	0.51(1)^a	D
499	1.16(6)^b	D
763	0.51(2)^b	Q
776	1.31(6)^a	Q
871	2.89(14)^b	D+Q
1286	1.06(4)^a	Q
1364	0.82(4)^a	Q

^{a}From quadrupole gate.
^{b}From dipole gate.

of 1286-, 1364- and 776-keV has been used. Our analysis show that these transitions are quadrupole in nature and leads to the assignment of spins of the dipole band. The character of this band resembles the negative parity band of ^{137}Pr[2]. Thus, we believe that this band has magnetic nature and need to do theoretical calculations using TAC to undestand its nature. Polarization analysis is in progress to assign parities.

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References

[1] Hubel H., *et al.*, Progress in Particle and Nuclear Physics **54**, 1 (2005).
[2] Agarwal P., *et. al.*, Phys. Rev. C **76**, 024321 (2007).
[3] Semkow T. M., *et al.*, Phys. Rev. C **34**, 523 (1986).