Polarization Measurements of Negative Parity Band in ^{136}Ce

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1. Introduction

Linear polarization can help us distinguish between the electric and magnetic characteristics of gamma rays, decaying from oriented nuclear states. To investigate the linear polarization of gamma rays, one can analyze the asymmetry observed in parallelly and perpendicularly compton scattered events with respect to beam axis, in a particular plane. When electric transitions occur, there is a preference for scattering in the perpendicular direction, while magnetic transitions result in a preference for scattering in the parallel direction. Therefore, we can use a Clover detector as a polarimeter. In this setup, each crystal in the Clover acts as a scatterer, while the two adjacent crystals serve as absorbers. The main goal of this study is measurements of polarization for negative parity band of ^{136}Ce nucleus using the advanced Indian National Gamma Array (INGA) array setup at IUAC, New Delhi which are described in the next section.

Nuclei within the mass range of approximately A~135 have garnered significant interest from both experimental and theoretical perspectives, primarily because of their proximity to the shell closures at N = 82 and Z = 52. The study of angular momentum generation in these nuclei has been a longstanding area of fascination and holds a prominent position in the field of nuclear structure research due to its rich array of intriguing phenomena, including the presence of chiral partner bands [1-3] and wobbling bands [4-5]. Earlier studies focused on exploring the excited states of Cerium (Z=58, N=78) within this mass region, resulting in the identification of multiple bands [1,6-12].

A~135 under consideration, certain proton orbitals, specifically the $1g_{7/2}$, $2d_{5/2}$, and $1h_{11/2}$, as well as neutron hole orbitals, including the $1h_{11/2}$, $1g_{7/2}$, $2d_{3/2}$, and $3s_{1/2}$, are located near to the Fermi surface. These orbitals play a crucial role in shaping the bands and influencing the evolution of the nucleus's structure. Notably, the presence of the $1h_{11/2}$ orbital, which can drive shape changes and has negative parity, is significant for both protons and neutrons, encompassing a range of low-Ω and high-Ω configurations. This situation is expected to give rise to a variety of intriguing structural phenomena, as indicated in references [1] and [6-10].

In the present paper, we report our experimental polarization measurements for band B1 and B2 of ^{136}Ce [13] and discuss in result and discussion section.

2. Experimental Details

The ^{124}Sn (16O, 4n) ^{136}Ce fusion evaporation reaction was employed to access the excited states of 136Ce, with a beam energy of 90 MeV. The experiment was conducted at the Inter-University Accelerator Centre (IUAC) in New Delhi, utilizing a 1 mg-cm^{-2} isotopically enriched target. Detection of γ-rays emitted by the excited nucleus was achieved using the Indian National Gamma Array (INGA). Sixteen clover detectors were strategically positioned at various angles relative to the beam direction. The CAMAC-based data acquisition system recorded ~10^9 two-fold coincidence γ-events. Subsequent offline data analysis was performed using the computer programs INGASORT and RADWARE.

3. Results and Discussion

^{136}Ce have been populated by reaction ^{24}Sn (^{16}O, 4n)^{136}Ce@ 90MeV and asymmetry was determined from a matrix constructed with one axis corresponding to perpendicular or parallel scattered events in 90° detectors and other axis corresponding to the total energy in the other detectors. The gate is then set on the total energy and the asymmetry between the parallel and perpendicular scattering is determined.

Linear polarization was determined by establishing a connection between the polarization sensitivity Q(Eγ) [14] and the observed asymmetry, which is defined by the relation.

$$\Delta_{\text{asym}} = \frac{\left(a\left(\text{E}\gamma\right) N_{\perp} - N_{II}\right)}{\left(a\left(\text{E}\gamma\right) N_{\perp} + N_{II}\right)}$$

Figure.1 shows the decaying transition of bands B1 and B2 also the correction factor, a(Eγ) determined by liner fit as plotted in figure.2. The positive/ negative sign of the polarization asymmetry value (Δ_{asym}) implies the electric (E)/ magnetic (M) character for the stretched γ-ray transition.

Experimental polarization asymmetry results are tabled below

Eγ (keV)	(Δ_{asym})	E/ M
446	-0.042 ± 0.033	M1
664	0.054 ± 0.005	E1
722	0.205 ± 0.026	E2
806	0.153 ± 0.021	E2
840	0.107 ± 0.016	E2
971	0.019 ± 0.012	E2

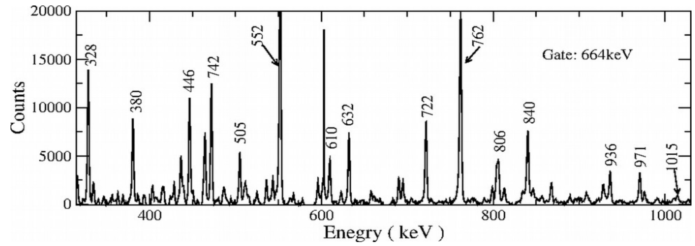

Fig.1: The coincidence energy gate on 664.2 keV, showing the decaying transitions of band B1 and B2 in ^{136}Ce.

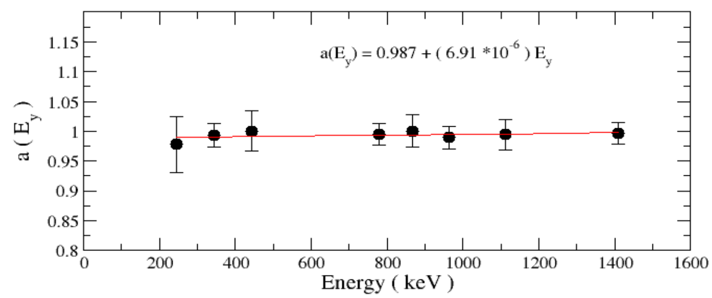

Fig.2: The geometrical asymmetry factor a(E γ) as a function of γ -ray energy.

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