Measurement of gated γ-ray angular distribution coefficients for ^{139}Pm

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Introduction

^{139}Pm, belongs to $A \sim 140$ mass region, known for γ-soft behaviour and display various structural features similar to neighbouring odd-proton nuclei belonging to the same mass region.

The present work focuses on the estimation of angular distribution coefficients of a few transitions belonging to ^{139}Pm. These transitions were previously established [1, 2] and found to decay from a positive parity dipole sequence to the decoupled $h_{11/2}$ band. These coefficients were not reported in earlier works [1–4] and are very essential for the determination of the multipolarity of a γ-transition decaying from a rotationally aligned state. These coefficients are also very crucial for determining the mixing ratio of higher-order multipolarities.

Experimental Details

The details o the experiment, target and data analysis procedure is described in ref. [2, 5]. For present analysis additionally, angle-dependent 4096×4096 matrices with a 0.5 keV channel dispersion were created from gain-matched energy spectra to extract energy and intensity data. These matrices were formed by projecting a single detector on one axis and remaining all detectors on the other. To determine angular distribution coefficients, stretched quadrupole γ-gated spectra at 466 keV and 751 keV were generated using these matrices, isolating the relevant γ-transitions of the ^{139}Pm nucleus. The angular distribution is described by the following relation:

$$W(\theta) = 1 + A_2 P_2(\cos\theta) + A_4 P_4(\cos\theta) \quad (1)$$

where A_2 and A_4 are angular distribution coefficients, which are calculated by the relations:

$$A_2 = \alpha_2 A_{2,\mathrm{max}} \quad (2)$$

$$A_4 = \alpha_4 A_{4,\mathrm{max}} \quad (3)$$

Here, α_2 and α_4 are attenuation coefficients, determined using the value of σ/J from existing data (where σ belongs to degree of alignment and J is the spin). The terms $A_{2,\mathrm{max}}$ and $A_{4,\mathrm{max}}$ are the angular distribution coefficients for completely aligned nuclei, and they are expressed as:

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$$A_k^{\max} = \frac{1}{1+\delta^2}\left[B_kF_k(L_1L_1)\right.$$
$$\left. + 2\delta B_kF_k(L_1L_2) + \delta^2 B_kF_k(L_2L_2)\ \right] \quad (4)$$

where δ is the mixing ratio, and $B_kF_k(L_mL_n)$ are coefficients tabulated in the Yamazaki table [6].

Results and Discussions

The angular distribution of some of the transitions in ^{139}Pm is shown in Figure 1, along with the fitted curve using equation (1).

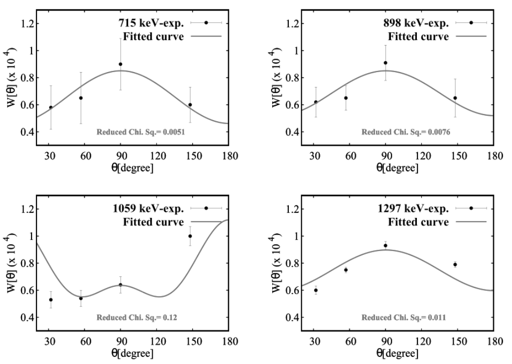

FIG. 1: The angular distribution of some band 8 transitions in ^{139}Pm, along with the fitted curve.

Table I lists the obtained values of the angular distribution coefficients. These values clearly indicate the dipole nature of the transitions with energy 715 keV, 898 keV, and 1297 keV, as shown in Figure 2. However, The data is insufficient to estimate 1059 keV's nature. It was previously reported as a ΔI = 0 transition [1, 2].

E_γ **(keV)**	A_2/A_0	A_4/A_0
715	-0.359 ± 0.105	–
898	-0.298 ± 0.125	–
1059	0.336 ± 0.686	0.383 ± 1.145
1297	-0.251 ± 0.141	–

TABLE I: Tabulated angular distribution coefficients A_2 and A_4.

The multipolarity and mixing ratios were calculated for each transition, revealing that the band 8 transitions are predominantly quadrupole in nature, confirming E2 transitions as expected for the aligned rotational band.

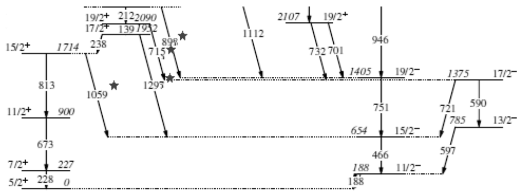

FIG. 2: Partial level scheme of ^{139}Pm taken from ref. [2], the transitions of interest are marked with asterisk.

Conclusion

In summary, we have measured the angular distribution coefficients for band 8 transitions in ^{139}Pm. The results support the quadrupole nature of these transitions, providing additional confirmation of E2 transitions. These findings contribute to a better understanding of the nuclear structure in the $A \approx 140$ mass region, particularly regarding the shape coexistence phenomena and the evolution of nuclear shapes with increasing spin.

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References

[1] Zhang et al., Phys. Rev. C **84**, 031302(R) (2011).
[2] Tiwary et al., Physica Scripta May 27, 2019.
[3] F. R. Xu et al., Nucl. Phys. A, **462**, 604 (1987).
[4] A. K. Dhal et al., Nucl. Phys. A, **818**, 208 (2009).
[5] Tiwary et al., Vacuum, **205**, 111461 (2023).
[6] Yamazaki, Nucl. Data Sect. A, **3**, 1 (1967).