# Spectroscopy of low lying states in $^{150}$Pm

A. Pal[1, 2,*], S. Basak[1, 2], D. Kumar[1, 2], A. Saha[3], S. S. Alam[4], D. Banerjee[5], A. Adhikari[6], A. Gupta[6], A. Das[6], Y. Sapkota[6], A. Bisoi[6],S. Sharma[7#], S. Das[7$] , S. Samanta[8$$], S. Chatterjee[8,] S. Das[8] and T. Bhattacharjee[1, 2]

[1]*Variable Energy Cyclotron Centre, Kolkata – 700 064, INDIA,* [2]*HBNI, Mumbai-400 094 INDIA*
[3]*ICFAI University, Agartala, Tripura – 799 210, INDIA*
[4]*Government Degree College, Chapra, West Bengal – 741 123, INDIA*
[5]*RCD-BARC, Variable Energy Cyclotron Centre, Kolkata – 700 064, INDIA*
[6]*Indian Institute of Engineering Science and Technology, Howrah - 711103, INDIA*
[7]*SINP, Kolkata – 700 064, INDIA,* [8]*UGC-DAE-CSR, Kolkata – 700 098, INDIA*
*Present add. # Manipal Inst. of Tech., Manipal, Karnataka. $ Brainware Univ., Kolkata (WB), $$ The Hebrew University of Jerusalem, Israel.*
** email: ag.pal@vecc.gov.in*

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## Introduction

Nuclear structure studies of nuclei in the transitional mass region of mass number A = 150 are challenging yet extremely important. Even with advancements in state of the art experimental facilities and data analysis techniques, this domain remains very poorly studied. These features are amply illustrated in the structural information of Pm ($Z$ = 61) isotopes, especially for the odd-odd nuclei. Spectroscopic information about the excited states in the odd-odd nucleus $^{150}$Pm is very scanty. The Evaluated Nuclear Structure Data File (ENSDF) database [1] specifies only a ground state of possible spin and parity $1^-$ beta decaying with a half-life of 2.68 hours [2].

This nucleus lies in a very interesting transitional region, which exhibits exotic phenomenon like quantum shape phase transition (QPT) and shape co-existence. It is in the middle of the 50–82 proton shell (Z = 61) and near the N = 90 neutron number (N = 89). The N = 90 nuclei in Sm-Gd region are well known for the observation of quantum shape phase transition from spherical to well deformed rotor as well as coexistence of different shapes [3]. Its structure is very important for the study of nuclear quantum phase transitions.

Other important aspects about the knowledge of the excited states in $^{150}$Pm is that they are intermediate states in the double β decay of $^{150}$Nd to $^{150}$Sm which can either be neutrinoless ($0\nu\beta\beta$) or with the emission of 2-neutrino ($2\nu\beta\beta$). The possible measurement of such decay would confirm that neutrinos are Majorana rather than Dirac particles and settle the long-standing debate. It is therefore of major interest to have a detailed knowledge of the excited states of $^{150}$Pm.

## Experiment

The low lying excited states of $^{150}$Pm were populated through $^{150}$Nd(p,nγ)$^{150}$Pm reaction using proton beam of two different energies, 8 MeV & 9 Mev, delivered from K-130 cyclotron at VECC, Kolkata. These energies were chosen such as to keep the contribution of the (p, 2n) channel as small as possible. The decaying γ-rays from the excited states were detected using multi-detector INGA setup comprising of six Compton suppressed clovers [125°(2), 90°(3), 40°(1)] and one LEPS. The data were recorded in list mode using PIXIE-16 digitizers. The raw data were sorted using the program IUCPIX [4] to generate γ–γ matrix, which were subsequently analyzed using the program INGASORT [5].

## Analysis, Results and Discussion

The main challenge faced in the analysis was the assignment of very close lying γ lines to $^{150}$Pm after correctly considering the transitions of $^{149}$Pm. Therefore, the level scheme, shown in Fig. 1 has been developed analysing the yield ratios along with γ–γ coincidence analysis. The yield ratio (as shown in Fig. 2) was calculated using the following equation from both singles and coincidence data.

$$Yield\ Ratio = \frac{N\ (8\ MeV)}{N_{norm}\ (9\ MeV)}$$

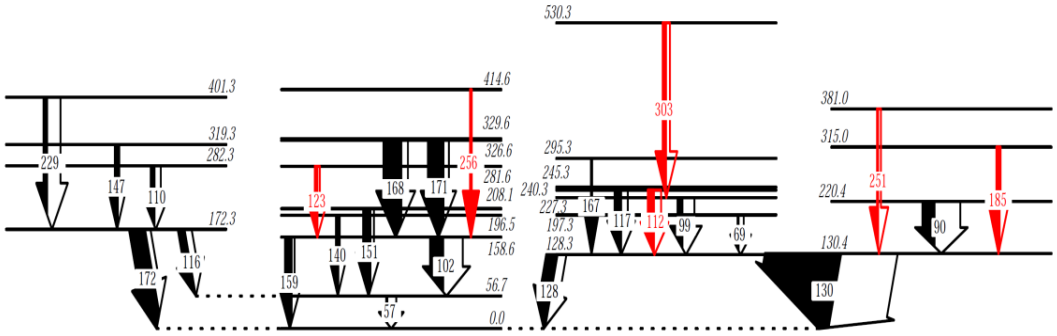


*Fig. 1: The level scheme of $^{150}$Pm as observed in the present analysis. The lines shown in red are new transitions in addition to verifying the proposed gamma lines in Ref. [2].*

Where, $N_{norm}$ (9 MeV) = F * N(9 MeV) and N(9 MeV) and N(8 MeV) are the areas under a particular γ peak observed in the experiment. F is defined as the normalizing factor [N(8 MeV)/N(9 MeV)] for the strong transitions (115 keV or 211 keV) of $^{149}$Pm that was observed in $\beta^-$ decay of $^{149}$Nd [1]. It is observed that the yield ratios of all the transitions belonging to $^{149}$Pm were close to one and those of $^{150}$Pm are greater than one.

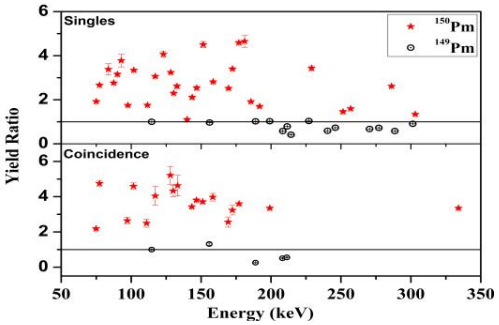


*Fig 2: Yield Ratio plot for the γ-rays using singles & coincidence data*

The γ–γ coincidence analysis was performed by sorting the data in symmetric matrices for both 8 and 9 MeV data. Few coincidence spectra relevant to the level scheme of $^{150}$Pm are shown in Fig. 3. The relative intensities of the transitions were determined for the first time in the present work considering the added intensities of the transitions decaying to ground state as 100%. The spin-parity assignment is difficult, as the multipolarity for none of the transitions is yet known. A detailed angular distribution measurement would be necessary for this purpose. The shell model calculation considering $^{132}$Sn as core is in progress to interpret the observed level scheme.

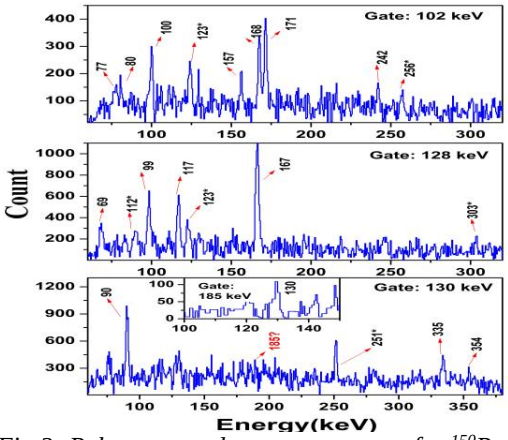


*Fig 3: Relevant gated energy spectrum for $^{150}$Pm showing new γ-lines maked with *.*

## Acknowledgement

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