

# $\gamma$ -ray spectroscopy of $^{56}\text{Fe}$

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## Introduction

In recent decades, there have been various experimental and theoretical efforts to study the level structure of  $^{56}\text{Fe}$ . One interesting aspect of  $^{56}\text{Fe}$  is its proximity to the spherical region of nickel isotopes. Studying nuclei near the doubly closed-shell nucleus  $^{56}\text{Ni}$  is particularly intriguing because  $^{56}\text{Ni}$  has a soft core, and its neighboring nuclei may exhibit shape co-existence between prolate and oblate configurations. Theoretical studies based on the Hartree-Fock model [1] and nuclear shell model [2] suggest that  $^{56}\text{Fe}$  show shape co-existence at low excitation energies, although clear experimental evidence is lacking. Additionally,  $^{58}\text{Fe}$ , a close neighbor of  $^{56}\text{Ni}$ , features several bands, including a  $\gamma$ -vibrational band associated with triaxial deformation, which has not yet been identified in  $^{56}\text{Fe}$ . Although theoretical models predict the existence of triaxiality in  $^{56}\text{Fe}$ , this has not been experimentally confirmed.

Most experimental studies of  $^{56}\text{Fe}$  have utilized heavy-ion reactions, which do not populate the non-yrast states. However, alpha-induced reactions could enhance the likelihood of identifying  $\gamma$ -vibrational bands and provide further insights into the nuclear structure of  $^{56}\text{Fe}$ .

## Experimental Details

In the present work the excited states of  $^{56}\text{Fe}$  were populated via alpha induced reaction  $^{55}\text{Mn}(\alpha, p2n)^{56}\text{Fe}$  at a beam energy of 37 MeV. The alpha beam was delivered by K-130 cyclotron at VECC, Kolkata. A compound of  $\text{MnO}_2$  of thickness  $\sim 6 \text{ mg/cm}^2$  on a Mylar backing of  $0.5 \text{ mg/cm}^2$  served the purpose of target. The prompt  $\gamma$ -rays emitted from the de-excited nuclei were detected using Indian National Gamma Array (INGA), which consists of 11 Compton Suppressed (CS) clover HPGe detectors and 1 LEPS detector at three different angles. 6 CS-clover detectors were placed at  $90^\circ$ , 2 CS-clovers and the LEPS at  $40^\circ$  and 3 CS-clovers at the backward ( $125^\circ$ ) angle with respect to the beam axis. A PIXIE-16 based digital data acquisition system, was

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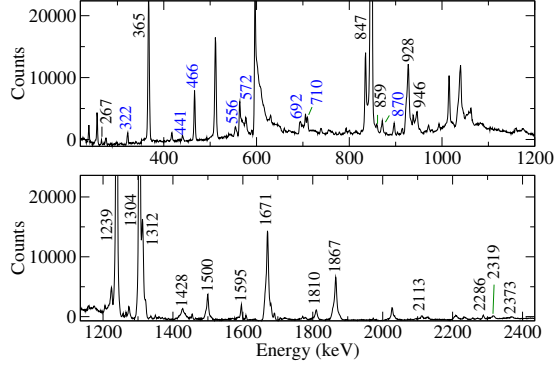


FIG. 1: Sum-gated  $\gamma$ -ray spectrum with gates on the two intense lowest transitions 847 keV and 1239 keV of  $^{56}\text{Fe}$ . The new  $\gamma$ -ray transitions are marked in blue colour.

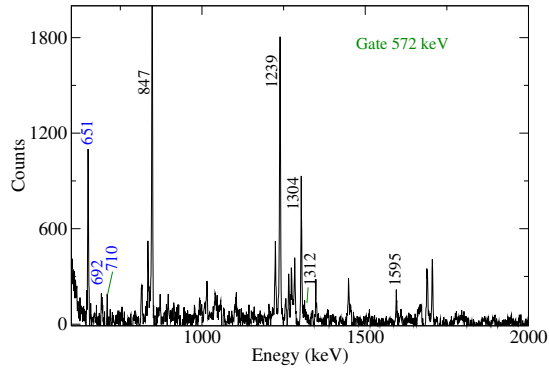


FIG. 2: Coincidence spectra with gate on 572 keV. The new transitions are marked with blue colour.

employed to record the time stamped  $\gamma$ -events in single and co-incidence modes [3]. The detailed experimental procedure is given by S. Basu *et al* [4]. Offline data sorting and analysis were carried out using BiNDAS, INGA-SORT [5] and RADWARE [6] analysis packages.

## Results and Discussion

From the present analysis, several new  $\gamma$ -ray transitions have been observed on the basis of coincidence relationship between the  $\gamma$ -rays as obtained from the  $\gamma$ - $\gamma$  symmetric matrix. Fig. 1 shows the coincidence spectrum corresponding to sum gate of two intense tran-

sitions, 847 ground state transition ( $2^+$  to  $0^+$ ) and 1239 keV ( $4^+$  to  $2^+$ ) transition. Figure 2 shows the  $\gamma$ -ray spectrum gated by the 572 keV transition, a newly observed transition at the 1239 keV gate. This work also provides evidence that some levels are connected by stretched E2 transitions, indicating the presence of a coupled band structure. The level structure has been refined by reordering the 2657 keV and 3122 keV levels based on the observed  $\gamma$ -rays, 1810 keV ( $2^+$  to  $2^+$ ), 2276 keV ( $4^+$  to  $2^+$ ) and 466 keV ( $4^+$  to  $2^+$ ) transitions. To assign the spin-parity of the states, the directional correlation of oriented states (DCO) ratio and polarization asymmetry of the decaying  $\gamma$ -rays have been determined using two asymmetric  $\gamma$ - $\gamma$  matrices.

## Summary

In the present study, several new  $\gamma$ -ray transitions and energy levels have been assigned to the  $^{56}\text{Fe}$  nucleus. The existing level scheme has been updated to incorporate these new findings, and evidence for a gamma-vibrational band has been observed. Ongoing research is focused on comparing these  $\gamma$ -vibrational bands across different iron isotopes, as well as other nuclei in a similar region of the nuclear chart.

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