Evidence of collective excitations at low and medium spin in ^{59}Ni

S. S. Nayak[1,*], S. Basu[1,2], G. Mukherjee[1,2], S. Nandi[1,2], Shabir Dar[1,2], Sneha Das[1,2], S. Basak[1,2], Soumik Bhattacharya[1], D. Kumar[1,2], D. Paul[1], K. Banerjee[1,2], Pratap Roy[1,2], A. Sen[1], S. Manna[1,2], T. Ghosh[1,2], Samir Kundu[1,2], T.K. Rana[1,2], T. Bhattacharjee[1,2], R. Pandey[1], S.S. Alam[1], S. Bhattacharyya[1,2], C. Bhattacharya[1,2], S. Samanta[3], S. Das[3], S. Chatterjee[3], R. Raut[3], S. S. Ghugre[3], U. Datta[4], H. Pai[4], P. Das[4], A. Bhattacharyya[4], S. Sadhukhan[4], S. De[4], S. Malgope[4], S. Chattopadhyay[4], S. Rajbanshi[5], S. Das Gupta[6], P. Pallav[6], R. Banik[7], Md. A. Asgar[8], H. Ghosh[9], S. Ali[10]

[1]*Variable Energy Cyclotron Centre,1/AF Bidhannagar, Kolkata 700064, INDIA*
[2]*HBNI, Training School Complex, Anushaktinagar, Mumbai-400094, INDIA*
[3]*UGC-DAE CSR, Kolkata Centre, Kolkata 700098, INDIA*
[4]*Saha Institute of Nuclear Physics, 1/AF Bidhannagar,, Kolkata 700064, INDIA*
[5]*Department of Physics, Presidency University, Kolkata 700043, INDIA*
[6]*Victoria Institution (College), Kolkata, INDIA*
[7]*IEM, Kolkata, INDIA*
[8]*Prabhat Kumar College, Contai, INDIA*
[9]*IIEST, Shibpur, INDIA*
[10]*Government General Degree College at Pedong, Kalimpong, INDIA*
. * *email: ss.nayak@vecc.gov.in*

Introduction

The spectroscopic investigation of Ni (Z = 28) isotopes remains a subject of great interest in the contemporary experimental nuclear structure research. In doubly magic, self conjugate ^{56}Ni (N = Z = 28) nucleus, the protons and the neutrons occupy the single-particle levels up to $1f_{7/2}$, which comes down in energy due to spin-orbit interaction and forms the magic number at 28. In odd-A Ni isotopes, heavier than ^{56}Ni, the odd neutron would occupy the negative parity orbitals $2p_{3/2}$, $1f_{5/2}$ and $2p_{1/2}$. Consequently, the first few states in ^{57}Ni are experimentally found to be $3/2^-$, $5/2^-$ and $1/2^-$ [1]. The excited state, corresponding to the higher-lying, deformation driving positive-parity, $1g_{9/2}$ orbital is expected either at high excitation energy of the nucleus or if the nucleus has certain deformation. Rotational bands, which indicates deformed shape, based on this orbital are reported both in odd-Z and odd-N neighboring nuclei above N, Z = 28 [2]. On the other hand, deformed bands are also reported in ^{59}Cu [3] based on the $1f_{7/2}$ proton hole from below the Z = 28 core. Contribution of $1f_{7/2}$ neutron orbital has also been found in ^{58}Ni [4] for the states above 4^+ due to the breaking of ^{56}Ni core. The earlier works on ^{59}Ni identified the core breaking $1f_{7/2}$ hole states and $1g_{9/2}$ state [3] but no rotational bands are known based on these states. Highly deformed band structures are, however, reported in this nucleus at high excitation energies (more than 8 or 10 MeV) [5] having multi particle configuration. Recently, band-like structure at high excitation in ^{60}Ni [6] has been interpreted as possible chiral doublet bands [7]. In the present work, we have investigated the low and medium spin states in ^{59}Ni and reporting here the observation of rotational-like bands based on $1f_{7/2}$ neutron-hole configuration.

Experiment

The excited states in ^{59}Ni were produced using fusion evaporation reaction of α beam with an enriched (99.48%), self supporting, thick (18 mg/cm^2) ^{58}Ni target. The beam (47 and 50 MeV) was delivered from the K-130 cyclotron at VECC. The prompt gamma rays were detected using 12 Clover HPGe detectors (3 at 40°, 6 at 90° and 3 at 125°) and 3 $LaBr_3$(Ce) detectors. PIXIE–16 based digitizer was used for acquiring γ–γ coincidence (among clover detectors) data [8]. The recorded data were processed using the codes currently in development at VECC. The processed data were analyzed using Radware and INGASORT software. A total of ~ 2.0x10^9 γ–γ coincidence events (from clovers only) were collected in ~ 62 hours of beam-on-target time.

Analysis and Results

The calibration and gain matching of all the working crystals of the clovers from all the runs were made with the auto-calibration software developed at VECC using both in-beam γ-rays and ^{152}Eu source.γ–γ coincidence matrix, asymmetric matrices for DCO ratio and polarization asymmetry ratio measurements and γ–γ–γ coincidence cube were generated using the above mentioned code.

Several nuclei have been populated in the present work. However, the nucleus of interest could be cleanly selected by double-gating on known γ–rays from the γ–γ–γ cube. A representative double-gated spectrum is shown in Fig.1, which clearly shows the γ-peaks corresponding to ^{59}Ni transitions. Several new γ-rays have been identified in the present work.The spin-parity (J^{π}) of the higher-lying –ve and +ve parity states were not known from the previous work [3]. In this work, J^{π} of all these states have been firmly assigned from the DCO and polarization asymmetry ratio measurements. From these assignments and the newly identified γ-rays two –ve parity band structures, based on previously known core-excited configuration, have been assigned in ^{59}Ni for the first time.

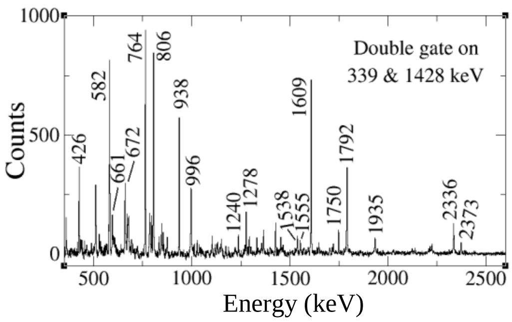

Fig.1 A double-gated γ-ray spectrum from γ–γ–γ cube. The γ-transitions from ^{59}Ni are marked.

Discussion and Summary

The higher lying -ve parity states above 3.5 MeV in ^{59}Ni are generated from 3 quasi-particle (qp) configuration involving $1f_{7/2}$ hole state due to core excitation.The excitation energy (E_x) vs. spin (I) for the newly identified 3-qp bands is plotted in Fig.2. The experimental points are well fitted by the rotational model formula, $E_x = (\hbar^2/2\mathcal{J})* I*(I+1)$, where $\mathcal{J}$ is moment of inertia. This indicates deformed structures in these bands. It can be seen that the curves are nearly parallel and the fitted moment of inertia parameter, A1 (= $\hbar^2/2\mathcal{J}$) is very similar for the two bands, signifying their identical nature. Connecting transitions between the bands are also observed, as expected for chiral doublet bands. The details of the measurements and new results will be presented.

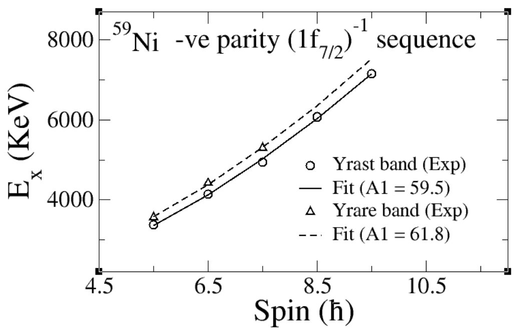

Fig.2 Excitation energy (E_x) vs. spin plot of the high-lying –ve parity bands in ^{59}Ni.

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