Exploring high spin structure in ^{88}Zr

S. Saha[1],* R. Palit[1],† P. Singh[1], J. Sethi[1], S. Biswas[1], D. Choudhury[1], P. C. Srivastava[2], D. C. Biswas[3], C. Ghosh[1], H. C. Jain[1], S. Mukhopadhyay[3], L. S. Danu[3], A. Asgar[4], G. Mukherjee[4], R. Raut[5], S. S. Ghugre[5], A. K. Sinha[5], S. K. Tandel[6], and S. Muralithar[7]

[1]*Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*
[2]*Department of Physics, Indian Institute of Technology, Roorkee-247667, India*
[3]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[4]*Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata 700064, India*
[5]*UGC-DAE Consortium for Scientific Research, Kolkata Centre, Kolkata 700098, India*
[6]*UM-DAE Centre for Excellence in Basic Sciences, Mumbai 400098, India and*
[7]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

Introduction

High spin spectroscopy of nuclei near shell closure remains a subject of current interest in nuclear physics. Recently, a number of interesting phenomena, like the evolution of collectivity in spherical nuclei, has been observed in doubly closed nuclei at high spin which indicates multiple particle hole excitation across the shell closure [1]. The states contributed by configurations involving excitations of nucleons to orbitals across the shell gap can also provide valuable insight into the effects of these orbitals on driving deformation in nuclei. The nuclei around ^{90}Zr having Z=40 sub-shell closure and N=50 major shell closure are good candidates where cross shell excitation can be observed at high spin [2, 3]. With this motivation, high spin states of ^{88}Zr were populated using ^{30}Si beam and ^{65}Cu target at 137 MeV.

Experimental Technique

Excited states of ^{88}Zr were produced by bombarding ^{30}Si beam from TIFR-BARC Pelletron-Linac facility at 137 MeV on a thin self supported foil of ^{65}Cu of 850 μg/cm^2 thickness. The target was sufficiently thin so that the recoil compound nucleus can fly

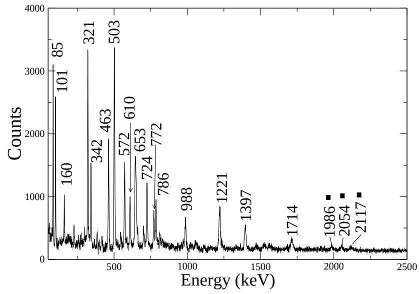

FIG. 1: A sum of double gated spectrum generated from $\gamma-\gamma-\gamma$ cube data with gates on 572, 988, 724, 610, 786, 85, 100 and 1221 keV transitions. The new transitions have been marked with filled boxes.

through it. The γ-rays emitted in the reaction have been measured with the Indian National Gamma Array (INGA) at TIFR. The INGA array is a Compton suppressed clover detector array with a provision of placing 24 clovers at angles with three detectors each at 23°, 40°, 65°, 115°, 140°, 157° and six detectors at 90° with respect to the beam direction. Two and higher fold clover coincidence events were recorded in a fast digital data acquisition system based on Pixie-16 modules of XIA LLC [4]. The Doppler shifted γ-rays from the recoiling compound nucleus were corrected for respective shifts at different angles according to the formula: $E_\gamma = E_0(1+\beta cos\theta)$
where, E$_\gamma$ is the Doppler shifted γ-ray emitted

*Electronic address: `sudiptajit@tifr.res.in`
†Electronic address: `palit@tifr.res.in`

from a recoil moving with a velocity v incident at an angle θ with respect to the beam direction and $\beta = \frac{v}{c}$. The data sorting routine "Multi pARameter time-stamped based COincidence Search program (MARCOS)" developed at TIFR was used for gain matching and Doppler correction and to generate $E_\gamma - E_\gamma$ matrix and $E_\gamma - E_\gamma - E_\gamma$ cube which were later converted to radware format and the analysis was done using Radware package [5].

Results and Discussion

In our previous measurement, high spin states in ^{88}Zr were observed up to an excitation energy of 10559 keV using ^{13}C + ^{80}Se reaction [3]. The motivation of the present experiment is to probe further high energy and spin states of the nucleus. However, the intensity of the γ-rays become weaker as higher angular momentum states are being explored. Hence, to extend the level scheme analysis was carried out using different sum of double gates on cube data. Various combination of double gates on transitions of the previously established level scheme were used to place the newly observed γ-rays in the level scheme. In the present analysis, all previously assigned γ-rays have been reconfirmed and 5 new γ-rays have been observed. All of these transitions have been assigned in the negative parity part of the level scheme. A new crossover γ-ray of 1115 keV has been observed decaying from a level of $18^-\hbar$ spin and 9594 keV energy to $16^-\hbar$ spin and 8477 keV energy. This crossover transition has now confirmed our previous rearrangement of 342-773 keV and 463-653 keV γ-ray sequences [3]. Another, γ-ray of 545 keV energy has also been observed to be decaying to the level of 8477 keV energy and $16^-\hbar$ spin. At further high spin three high energy γ-rays of $\sim$ 2 MeV energy have been observed. One of these γ-rays, of 2054 keV energy is found to be decaying to 9915 keV $19^-\hbar$ state and the other two with 2117 keV and 1986 keV energies decay to the 10559 keV level. The high energy γ-rays with energies 1986, 2054 and 2117 keV have been shown in Fig. 1.

In the present experiment the reaction that has been chosen to populate the high spin states of ^{88}Zr is a more symmetric one than the ^{13}C + ^{80}Se reaction. The grazing angular momentum for this reaction is $\sim$ 60 $\hbar$ which is $\sim$ 30 $\hbar$ higher than the previous measurement. However, surprisingly the level scheme could not be extended beyond $\sim$ 22 $\hbar$. Recently, a similar situation has been reported in ^{88}Y nucleus where even after $>$ 40 $\hbar$ angular momentum was imparted on the compound system transitions were not observed from states with spin beyond $\sim$ 20 $\hbar$ [6]. Further, in our measurement the observation of several high energy γ-rays at high spin indicates fragmentation of intensity at high energies as a possible reason for not observing further high spin states. However, the existence of high spin isomers cannot also be ruled out. The third possibility could be that, at this energy particle decay modes are predominant hindering γ-decay channels. The interesting outcome of our measurement has opened up the possibility of finding sudden shape transition at high spin which may provide the answer to the highly fragmented decay path at high spin.

Acknowledgments

We gratefully acknowledge the INGA collaboration for making the detectors available and all the staff of the Pelletron Linac Facility at Mumbai for smooth functioning of the accelerator. This work was partially funded by the Department of Science and Technology, Government of India (No. IR/S2/PF-03/2003-I).

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