Spectroscopy of ^{67}Zn using Digital INGA at VECC

A. Sharma[1],* S. Kundu[1], Pankaj K. Giri[1], S. S. Ghugre[1], S. S. Nayak[2], S. Basu[2], S. Pal[2], S. Das[2], S. Dar[2], S. Paul[2], A. Pal[2], S. Basak[2], G. Mukherjee[2], S. Bhattacharyya[2], and R. Raut[1]
[1] *UGC-DAE CSR, Kolkata Centre, Kolkata 700098, INDIA and*
[2] *Variable Energy Cyclotron Centre, Kolkata 700064, INDIA*

Introduction

Nuclear structure pursuits in the vicinity of the doubly-magic ^{56}Ni-core have several underlying impetuses. The corresponding nuclei provide a testing ground for the shell model calculations wherein it is possible to probe the significance of core-broken configurations following the excitations across the Z,N = 28 closure. The latter is the lowest magic number emerging from the inclusion of $l.s$ coupling in the shell model Hamiltonian and the core is expected to be less stable against excitations (from the $f_{7/2}$ orbital). It has indeed been suggested [1] that the complete description of the excitation schemes of these nuclei, within the shell model framework, would necessitate inclusion of the complete fpg ($f_{7/2}$, $p_{3/2}$, $f_{5/2}$, $p_{1/2}$, $g_{9/2}$) orbitals in the model space while incurring larger dimensionality in the resulting calculations. The associated impediments are often countered with appropriate truncation schemes that also caters to our understanding of the pertinent orbitals and the particular excitations impacting the level structure of these nuclei at least at low and moderate energies. There have also been developments of different interaction Hamiltonians for shell model calculations in this region and a number of recent [2, 3] spectroscopic investigations have reported a comparison between these, in the context of reproducing the experimental data (level energies, branching ratios). Such exercises are envisaged to further contribute to the refinements in the model parameters towards better representing the measurements. These nuclei, around the Ni-core, have also been observed to exhibit varied excitation phenomena subject to the occupancy of particular orbitals and/or changing number of valence nucleons outside the Ni-core. For instance, the $g_{9/2}$ orbital is a deformation driving one and its occupation could lead to collective bands as have indeed been observed [4, 5] in different nuclei in this region. In addition, there have also been observations [6] of shears mechanism in the level structures of some of these nuclei. The myriad possibilities underlying the nuclear excitations around the Ni-core warrant sustained spectroscopic endeavours that would identify the evolving level structures of these systems through changing energy and angular momentum. The data will not only facilitate constraining the model calculations but also aid our understanding of the microscopic origins of the aforementioned excitation phenomena.

The present study is particularly directed at the level structure investigation of ^{67}Zn ($Z = 30, N = 37$) nucleus. The previous studies ([8], for example) on the structure of the nucleus, principally, were more than a couple of decades earlier and using modest experimental setups that limited the observations on its excitation scheme. The present endeavour is the maiden instance of spectroscopic investigation of the nucleus using a large high resolution γ-ray detector array.

Experiment and Data Analysis

The excited states of the ^{67}Zn nucleus was populated using the ^{65}Cu(α,pn) reaction at E$_{lab}$ = 30 MeV. The corresponding reaction channel was one of the less dominant (Fig. 1)

*Electronic address: anils051299@gmail.com

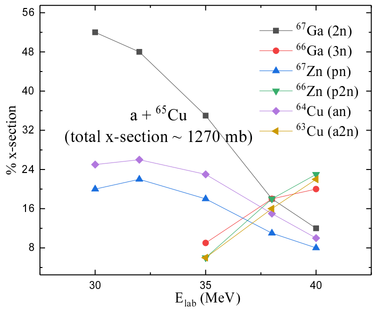

FIG. 1: Calculated excitation functions of different channels following the α + ^{65}Cu reactions.

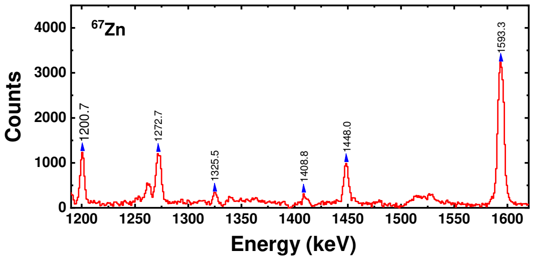

FIG. 2: Part of the γ-ray spectrum corresponding to gate set on the 1549 keV transition of the ^{67}Zn nucleus.

ones, as per the predictions of the statistical model calculations using the PACE [9] code. The target was a self supporting foil of natural Cu (^{63}Cu $\sim$ 69.1% and ^{65}Cu $\sim$ 30.9%) of thickness 8.9 mg/cm^2. The α-beam at 30 MeV was delivered by the Room Temperature Cyclotron (RTC) at VECC, Kolkata. The Indian National Gamma Array (INGA) setup therein was used as the detection system. The same consisted of eleven Compton suppressed HPGe clover detectors positioned at 40^o (2 detectors), 90^o (6 detectors) and 125^o (3 detectors) during the experiment. The pulse processing and data acquisition system was that based on 12-bit 250 MHz PIXIE-16 digitizers from XIA LLC, USA and running on a firmware conceptualized by the UGC-DAE CSR, Kolkata Centre [10]. Data was principally acquired subject to the validation of an event trigger that corresponded to a coincidence multiplicity of $\geq$ 2. The acquired data has been sorted into symmetric and angle-dependent γ-γ matrices using the IUCPIX [10] codes. The matrices are being analyzed using the RADWARE [11] package.

Preliminary Observations and Outlook

The data analysis exercise is in the preliminary stage and currently in progress. However, observation of γ-rays of energies $\sim$ 1.5 MeV in the coincidence spectra, of the ^{67}Zn nucleus, is noteworthy. The ^{67}Zn nucleus has two protons and nine neutrons outside the ^{56}Ni-core. The particle configurations in the lower excitation regime presumably correspond to occupation of the $f_{5/2}, p_{3/2}, p_{1/2}$ orbitals. At increased excitations, the occupancy of the $g_{9/2}$ orbital is predicted and may be indicated by the aforementioned high energy transitions. Large basis shell model calculation shall be carried out as a part of the present study and the same is expected to validate the proposition.

SK acknowledges financial support from the UGC, under the NETJRF scheme.

References

[1] C. Chiara *et al.* Phys. Rev. C 85, 024309 (2012).

[2] S. Samanta *et al.* Phys. Rev. C 97, 014319 (2018) and Phys. Rev. C 97, 014315 (2019).

[3] S. Chatterjee *et al.* Phys. Rev. C 107, 024312 (2023).

[4] Bhattacharya *et al.* Phys. Rev. C 107, 054311 (2023).

[5] D. Ayangeakaa et al. Phys. Rev. C 105, 054315 (2022).

[6] Lin *et al.* Phys. Rev. C 107, 014307 (2023).

[7] Hu *et al.* Phys. Rev. C 104, 064325 (2021).

[8] G. F. *et al.* Nucl. Phys. A 280, 161 (1977).

[9] Tarasov *et al.* Nucl. Instr. Meth. Phys. Res. B 266, 4657 (2008); Gavron, Phys. Rev. C 21, 230 (1980).

[10] S. Das *et al.*, Nucl. Instr. Meth. Phys. Res. A**893** 138(2018).

[11] D. C. Radford, Nucl. Instr. Meth. Phys. Res. A**361** 306(1995).