# Nuclear Structure Studies in the Vicinity of the "Island of Inversion "

S.S. Bhattacharjee[1], R. Chakrabarti[1], R. Bhattacharjee[1], R. Raut[1], S.S. Ghugre[1],* A.K. Sinha[1], S. Saha[2], J. Sethi[2], T. Trivedi[2], and R. Palit[2]
[1] UGC-DAE Consortium for Scientific Research, Kolkata Centre, Kolkata-700098. and
[2] Tata Institute of Fundamental Research, Mumbai - 400005.

## Introduction

Nuclear structure studies of the neutron-rich nuclei are being zealously pursued in recent years. The impetus of such endeavours lies in the very different structural characteristics of these nuclei, compared to those around the line of $\beta$-stability. The region of neutron-rich isotopes of Na, Mg and Ne with N$\sim$20 and $Z\sim$10 referred as the "island of inversion" has been probed in several of the aforesaid efforts to investigate the interesting structural changes stemming out of large neutron-proton asymmetry. The intriguing observations in the neutron-rich nuclei at the island of inversion appear to undermine the conventional spherical shell model approach, deployed for structural interpretations of nuclei in the proximity of the $\beta$-stability line. These observations include large ground state deformations, anomalous binding energies, large B(E2) values and low-lying first excited states, all implicative of the disappearance of the N=20 magic number, beyond the purview of the *sd* shell model calculations. The observations at the island of inversion have been ascribed to an "inverted" level structure with the intruder states, normally expected to be higher in excitation, falling below the "normal" *sd* states [1].
The region between the line of $\beta$-stability and island of inversion couch the signatures of evolving nuclear structure from stable to neutron-rich nuclei. This include nuclei with $Z$ near the bottom of the *sd* shell and N near the top of the shell, that represents a highly transitional region from nuclear structure perspectives. Probing the structure of these nuclei is expected to aid the understanding of the boundaries of the island of inversion as well as facilitate testing of the relevant theoretical models [2]. One of such nucleus is $^{26}$Mg ($Z$=12). The nucleus has not been studied in the recent years and complete structural information is in requirement [3]. Immense scope of modifying and/or extending the level scheme alongwith conclusive spin-parity assignments exist in the light of modern large gamma detector arrays and state-of-the-art pulse processing and data acquisition systems, as has been pursued in the present work.

## Experiment and Data Analysis

The $^{26}$Mg nucleus was populated using $^{18}$O($^{13}$C,$\alpha n$) reaction at $E_{lab}$ = 30 MeV. The target-projectile combination and the beam energy was chosen from the predictions of statistical model calculations carried out using the PACE4 code. The $^{13}$C beam was provided by the 14UD pelletron at Pelletron Linac Facility, Mumbai. The neutron-rich $^{18}$O target was prepared by heating a 50 mg/cm$^2$ thick Ta foil in an atmosphere of oxygen, enriched to 99.999% in $^{18}$O, to form $Ta_2O_5$. The $^{18}$O equivalent thickness was estimated to be $\sim$ 1.6 mg/cm$^2$ on either sides of the Ta foil. The emitted $\gamma$-rays were detected using the Indian National Gamma Array (INGA), currently stationed at the Pelletron Linac Facility, Mumbai. During the experiment, INGA consisted of 15 Compton suppressed Clover detectors, 3 at 40$^o$, 2 at 65$^o$, 4 at 90$^o$, 2 at -65$^o$, 2 at -40$^o$ and 2 at -23$^o$. The signals from the array were processed and recorded in a digital signal processing based data

*Electronic address: ssg@alpha.iuc.res.in

acquistion system DGF Pixie-16. The data was acquired under the condition that two or more crystals should fire in coincidence for generating the event trigger. The data was in the list mode format with an event-by-event record of the identity of the firing clover crystal, energy deposited in the crystal and the corresponding time stamp. ROOT based data inspection and pre-sorting routines are being developed. The acquired data was checked for the multiplicity pattern based on the condition that consecutive events would be considered as coincident events if the time difference between them is $\leq$ 20 ns. In the present experiment it was observed that for a given data file, $\sim$ 50% events consisted of crystals of the same clover, $\sim$ 30% events were singles (one crystal firing) and $\sim$ 20% events consisted of crystals from different clovers (good events). In view of the high energy gamma rays, a fourth order polynomial plus the conventional *sqrt* term was used as the calibration function. The data has been sorted into symmetric $\gamma - \gamma$ matrix using the program Marcos and being analyzed using RADWARE [4]. It has been noted that the Marcos program incorporates only the good clover-clover coincident events in the matrix, while rejecting the singles and the events consisting of crystals of the same clover. Angle dependent asymmetric $\gamma - \gamma$ matrices would be constructed for extracting the directional correlations and polarization asymmetry of the emitted $\gamma$-rays, inorder to assess their multipolarity and electromagnetic character for eventual assignment of spin-parity to the excited states. The singles (single crystal and single clover) events can be used for extracting the angular distribution of the emitted $\gamma$-rays, further facilitating the spin-parity assignments.

## Results and Outlook

Fig. 1 illustrates the coincidence $\gamma$-spectrum with gate set on the ground state transition 1808 keV of the $^{26}$Mg nucleus. New $\gamma$-transitions have been observed and efforts to include them in the level scheme is in progress. The large number of detectors in INGA distributed over different available angles is expected to facilitate conclusive spin-parity assignments to the level scheme. Apart from $^{26}$Mg, the nuclei $^{28}$Si and $^{29}$Si have also been populated in the present experiment. These nuclei also represent the transitional character of the region in the vicinity of the island of inversion and would be pursued to investigate the evolving structure, as discussed at the onset.

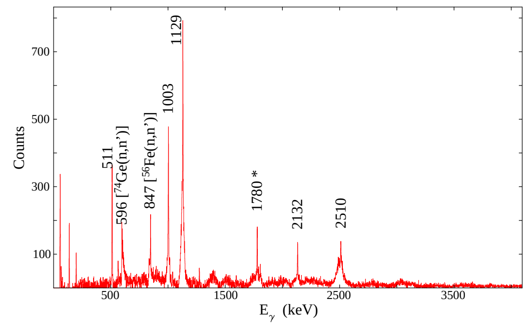


FIG. 1: Coincidence $\gamma$-spectrum with gate on the g.s. transition of $^{26}$Mg, 1808 keV.

## Acknowledgements

The authors thank all the participants of the INGA collaboration. We are thankful to Mr. J.P. Greene (Argonne National Laboratory) for $^{18}$O target. The support from Mr. Kausik Basu (UGC-DAE CSR), Mr. B.S. Naidu (TIFR), Mr. R. Donthi (TIFR) and the staff at the Pelletron Linac Facility, Mumbai is deeply appreciated.

## References

[1] P.C. Bender *et al.*, Phys. Rev. C **80**, 014302(2009).
[2] R. Chakrabarti *et al.*, Phys. Rev. C **80**, 034326(2009).
[3] F. Glatz *et al.*, Z. Phys. A **324**, 187(1986).
[4] D.C. Radford, Nucl. Instr. Meth. Phys. Res. A **361**, 297(1995).