Study of nuclear structure in odd-odd ^{122,124}I

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Introduction:

The structure of the Iodine nuclei in A ~ 120-130 region is guided by the presence of shape driving orbitals in N/Z = 50 - 82 subshell space. At low spin, three extra proton particles occupy $\pi d_{5/2}$, $\pi g_{7/2}$ orbitals and the neutron hole occupies the $\nu h_{11/2}$, $\nu s_{1/2}$ and $\nu d_{3/2}$ orbitals. Band structures based on these orbitals have been observed in these nuclei through various spectroscopic investigations [1]. The Iodine nuclei lie in between the vibrational Te and deformed Xe and thus carry extreme importance to study the shape transitions, diverse shape effects and their coexistence. Investigations have revealed $\pi g_{9/2}$ hole collectivity in the odd-A and odd-odd Iodine nuclei, originated from the excitation of a $1g_{9/2}$ proton across the Z = 50 closed shell and that has been interpreted in terms of proton-hole quadrupole-core coupling [2,3]. The odd-odd iodine nuclei are also known to have a variety of states with lifetimes varying from ~ps to ms range [1]. These nuclei are of particular importance for studying the p-n residual interaction associated with the available single particle orbitals occupying the same subshell space for both protons and neutrons. Experimental data on the heavier odd-odd nuclei (A > 120) has been very scanty and specially the information on ^{124}I nucleus is limited to proton induced measurements with a few Ge(Li) detectors [4]. A preliminary data exist in literature that focuses lifetime measurement in ~ns range using pulsed beam technique [5]. In none of the ^{122,124}I nuclei, the lifetimes ~ps have been measured for the low lying levels. In the present work, the in-beam γ-spectroscopic measurement on low to moderate spin states of ^{122,124}I has been reported. The possibility of lifetime measurement in the picosecond range with the use of triple gamma coincidence with Clover and $CeBr_3$ detectors in case of in-beam measurements have also been explored.

Experiment:

The excited states of ^{122,124}I nuclei were populated by using ^{nat}Sb(α, xn) reaction with 40 MeV alpha beam from K = 130 cyclotron at VECC, Kolkata. The 7mg/cm^2 target was prepared with centrifuge technique on a 500 μg/cm^2 thick mylar backing. The γ–rays were detected and characterized with an array of six Compton suppressed Clover Ge detectors (VENUS) [6] coupled to an ancillary array of six fast timing $CeBr_3$ detectors [7], configured in median plane geometry, as shown in Fig. 1. The six Clover Ge detectors were kept at angles of 45°, 90°, 150°, 210°, 270° and 305° with respect to the beam direction and at a distance of 26cm from the target position. The $CeBr_3$ detectors were kept at a distance of 11cm from the target and the corresponding angles with respect to the beam direction were 32^o, 126^o, 231^o, 248^o, 291^o and 337^o. The preamplifier pulses from the Clover detectors have been processed by using Mesytec sixteen channel shaper and discriminator module whereas discrete NIM based pulse processing electronics were used for the $CeBr_3$ detectors. Timing data were gathered from both type of detectors in order to measure level lifetimes as well as to select prompt and delayed γ coincidences. A newly developed VME system with CAEN VME controller, 13 bit Mesytec ADCs and LAMPS DAQ software were used for acquisition of zero suppressed list mode data. The data from the Clover detectors were collected with a master trigger of M_γ (Clover) $\geq$ 1 and M_γ (Clover) $\geq$ 2 in order to study the angular distribution and γ–γ coincidence respectively for the development of level scheme. For the measurement of level lifetime of the low lying excited states, data were gathered with two types of MASTER trigger, viz., $M_\gamma(CeBr_3) \geq 2$ in double coincidence mode and [$M_\gamma(CeBr_3) \geq 2$ **.AND.** $M_\gamma(\text{Clover}) \geq 1$] in triple coincidence mode. The data with the first type of trigger has been used to measure the level lifetimes of a few strongly populated low lying levels in ^{122,124}I nuclei, using Generalized Centroid Difference (GCD) technique [8]. Data gathered with the second type of trigger was used to study the feasibility and future design of the ps timing experiments with γ tagging with the Clover HPGe detectors using prompt in-beam γ spectroscopy at VECC, Kolkata. Data were also gathered with the standard sources of ^{152}Eu and ^{133}Ba, both in singles and coincidence mode, in order to determine the efficiency of the array as well as the prompt time calibration curve.

Data Analysis and Results:

Data were sorted using the LAMPS, INGASORT and Radware software packages. A γ–γ matrix has been formed to study the coincidence relationships among the detected γ transitions using data from Clover HPGe detectors. In order to study the DCO (Directional Correlation from Oriented states) ratio, a matrix has been formed using the data from two backward Clover Ge detectors at 150° and 210^{o} in y-axis and other two Clover Ge detectors at 90° along the x-axis. Matrix has also been formed to study the IPDCO (Integrated Polarization from Directional Correlation of Oriented states) ratio by using the parallel and perpendicular scattering of γ-rays observed in the 90° detectors. The added spectrum, corresponding to the gates of three low lying transitions in ^{124}I, obtained from the γ–γ coincidence matrix has been shown in Fig. 1. Several new transitions have been observed that can be placed in the level scheme of ^{124}I. The γ–γ coincidence, angular distribution, DCO and IPDCO analysis are in progress. For the lifetime measurement with GCD technique, the prompt calibration curve has been generated from the data taken with standard sources. The centroid differences corresponding to different excited levels are being determined to measure the lifetimes.

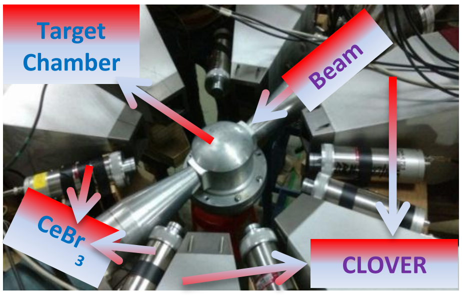

Fig. 1: The array used in the present experiment where two types of detectors are indicated with arrows along with other relevant details.

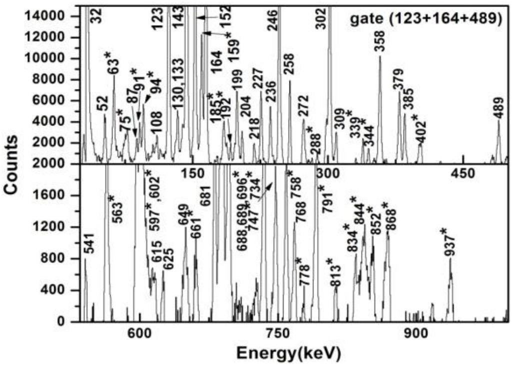

Fig. 2: The added gate corresponding to low lying transitions in ^{124}I nucleus. The new γ-rays observed are marked with asterisk (*).

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References:

[1] ENSDF data file: www.nndc.bnl.gov/ensdf.
[2] M. A. Quader et al., PR**C30**, 1772(1984).
[3] P. Van Isacker et al., NP **A292**, 125 (1977).
[4] J. Burde et al., Nucl. Phys. **A385**, 29 (1982).
[5] C. B. Moon et al., JKPS **59**, 1525(2011).
[6] Soumik Bhattacharya et al. submitted to DAE Symp. Nucl. Phys. 2016
[7] S. S. Alam et al. submitted to DAE Symp. Nucl. Phys. 2016.
[8] S. S. Alam et al., DAE Symp. Nucl. Phys. **60**, 270 (2015) and references therein.