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Investigating the Structure of ^{128}I

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Abstract. A series of nuclear spectroscopy experiments aiming at the study of the ^{128}I isotope were made. This nucleus was obtained in fusion-evaporation reaction of ^{7}Li projectile at 23, 26 and 27 MeV with a ^{124}Sn target, using either continuous and pulsed beam. The composite gamma array dedicated for nuclear spectroscopy measurements, which was recently developed at the Tandem Laboratory from Bucharest, consisting of eight large volume HPGe and five $LaBr_3$ scintillator detectors was used, combined with neutron and charged particles detectors. A preliminary level scheme for ^{128}I nucleus was obtained, with new information regarding high spin levels.

1 Introduction

The high spin structure of the iodine nuclei, when approaching the $N = 82$ shell closure, is insufficiently studied. Concerning the structure of the ^{128}I nucleus, the record from the ENSDF database [1] is primarily based on two studies: a (p,n) experiment of Burde et al. [2] and an extensive study of Sakharov et al. that uses the (n,γ), (d,p) and (d,t) reactions to populate excited states in the ^{128}I nucleus [3]. These experiments established the level scheme at low excitation energies, as well as the spin and parities of the first few states. However, no experiment using heavy ion induced reactions for studying ^{128}I was done up till now. Consequently, the information regarding the high spin states of this isotope are completely missing. In all double-odd iodine nuclei, 10^+ states which are built on the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration are expected. Such positive parity states were tentatively assigned in the $^{116-128}$I nuclei and rotational bands buit above this state were observed [4–14]. Also, bands built on a 7^- state, having $\pi g_{7/2} \otimes \nu h_{11/2}$ or the $\pi d_{5/2} \otimes \nu h_{11/2}$ configuration, were observed.

In the present work, the high-spin states of ^{128}I were produced in the ^{124}Sn(^{7}Li,3nγ)^{128}I fusion-evaporation reaction. Two γ-ray spectroscopy experiments were conducted, the first one using a continous beam, and, in the second measurement, in order to clean up the spectra from the important β-decay contribution, the beam was pulsed to give 1 ns wide pulses, 200 ns appart. A search for

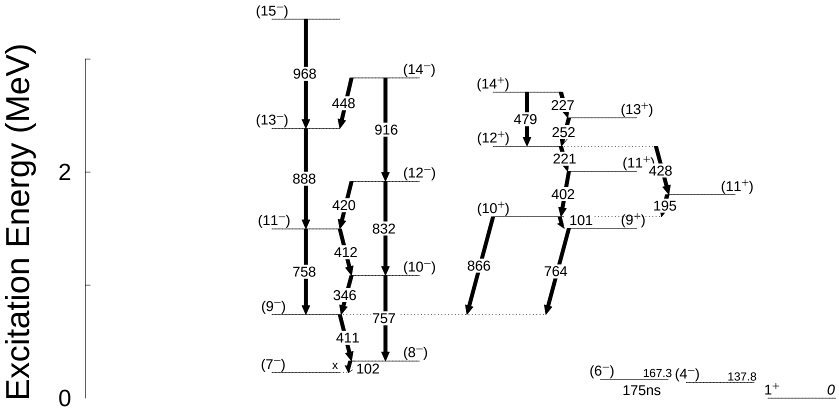

Figure 1. High-spin level scheme of ^{128}I deduced from the present work.

isomeric states was also done. The experimental setup, installed at the Bucharest Tandem accelerator, consists of a HPGe detector array (seven detectors, having an overall absolute efficiency ≈0.7%) and a $LaBr_3$ detector array (five detectors, with excellent time resolution, 100 to 300 ps depending on the crystal size) dedicated for fast timing measurements. In-beam measurements of γ-γ coincidences and γ-ray angular distributions as well as γ-timing were performed to further determine the level energies, the γ-ray multipolarities and the lifetimes. The trigger condition for the acquisition system was: (at least two Ge detectors) OR (at least one HPGe detector AND at least two $LaBr_3$ detectors), which fire in coincidence. The last condition was imposed by the lifetime measurement technique detailed in [15].

2 Results

The data recorded in list mode consists in time and energy signals for each of the HPGe and $LaBr_3$ detectors. The recorded γ-γ and γ-γ-γ coincidence data were sorted into two and three-dimensional matrices, respectively. Figure 1 shows the high-spin level scheme of ^{128}I derived from the data recorded during the present experiment. Fourteen new levels were added and the lifetimes of two states were estimated. These levels could be arranged into two band-like structures as shown in Figure 1. The absolute excitation energy of these levels (their connection to the well known low-lying levels) could not be established in these experiments. Relative spin values of the levels were determined from DCO (Directional Correlations from Oriented states) ratio values, while the absolute spin and parity values were tentatively proposed on the basis of the similarity with the band structures known in the ^{122,124,126}I isotopes (Figures 2 and 3).

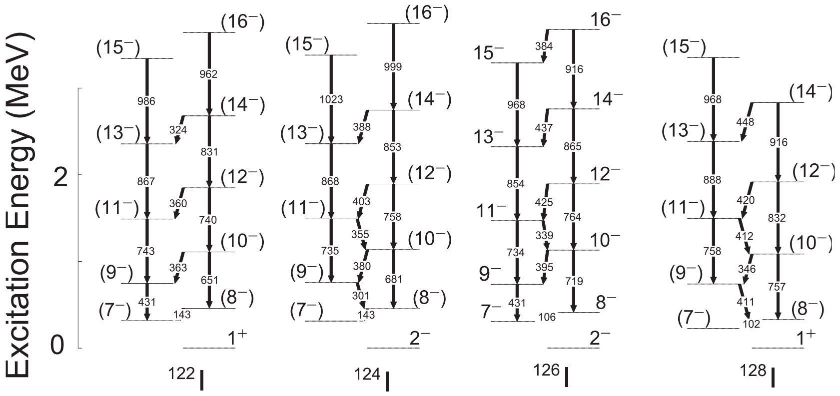

Figure 2. Systematics of the levels in the negative-parity bands built on a 7^- state resulting from $\pi g_{7/2} \otimes \nu h_{11/2}$ or $\pi d_{5/2} \otimes \nu h_{11/2}$ configurations in the odd-odd $^{122-128}$I.

In ^{128}I the (8^-) and (10^+) decay by emmiting γ transitions of almost equal energy. Employing the fast timing method [15], time spectra were obtained for both states which decay by the 101 and 102 keV γ-rays. Figure 4a partially shows the energy projection of a $\gamma\gamma\Delta$t cube constructed for the $LaBr_3$:Ce detectors, gated by two transitions (832 keV and 758 keV) detected in the HPGe detectors and selecting the π=- band. The time spectra of the 101 keV transition was obtained from gating on two gamma rays in the $\gamma\gamma\Delta$t cube constructed for the $LaBr_3$:Ce detectors, already gated by the HPGe detectors (Figure 4b). The two gates are the transitions which populate and depopulate de (8^-) state. The time spectrum clearly shows an exponential tail revealing a decay time longer than the width of the prompt coincidence spectrum, which was determined from gating on the background near the 102 keV peak. The fit to the experimental data provides a a value $T_{1/2}$=2.47$\pm$0.13 ns for the (8^-) state. A similar analysis was performed for determining the lifetime of the (10^+) state and a time spectrum

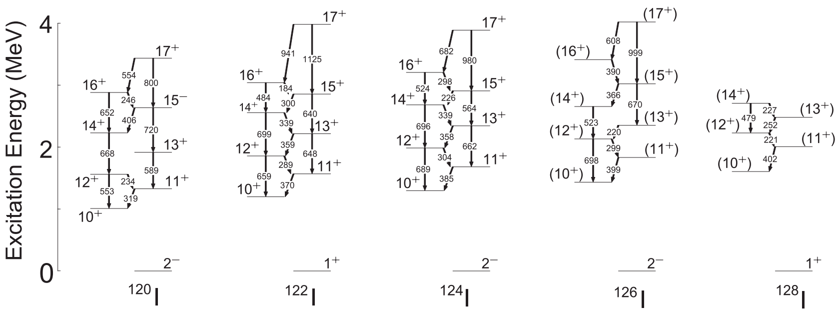

Figure 3. Systematics of the levels in the positive-parity $\pi h_{11/2} \otimes \nu h_{11/2}$ bands in the odd-odd $^{120-128}$I.

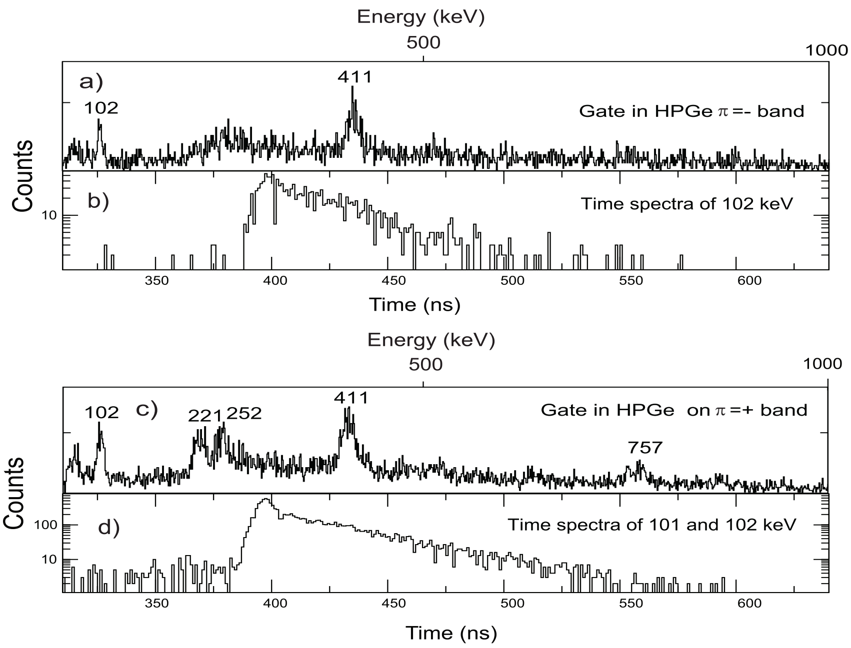

Figure 4. (a) The energy projection of a $\gamma\gamma\Delta$t cube constructed for the $LaBr_3$:Ce detectors, gated by the transitions 832 keV and 758 keV detected in the HPGe detectors, which select the π=- band; (b)Time spectra of 101 keV transition; (c) The energy projection of a $\gamma\gamma\Delta$t cube constructed for the $LaBr_3$:Ce detectors, gated by the transitions 402 keV and 428 keV detected in the HPGe detectors, which select the π=+ band; (d)Time spectra of 101 keV and 102 keV transitions.

for both 101 keV and 102 keV transitions was obtained (Figure 4d). The time spectrum reveals two clearly different structures which support the existence of the 102 doublet (Figure 4c).

The 101 keV transition from the positive parity band is a fast transition having a lifetime shorter than 100 ps (less than the resolution of the method for these energies), suggesting that 101 kev is a fast M1 transition which connects states of the $\pi h_{11/2} \otimes \nu h_{11/2}$ multiplet. The results were also confirmed by the DCO ratio values.

3 Conclusion

The structure of doubly odd ^{128}I was investigated using in-beam γ-spectroscopy of the ^{124}Sn(^{7}Li, 3nγ)^{128}I fusion-evaporation reaction. A positive parity collective band was established for which the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration was suggested. A negative parity band built on a 7^- state having the $\pi g_{7/2} \otimes \nu h_{11/2}$ or the $\pi d_{5/2} \otimes \nu h_{11/2}$ configuration was observed for the first time. The fast timing method was employed for lifetime measurements and time spectra were obtained for both states which decay by the 101 and 102 keV γ-rays.

Acknowledgements

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