# High-spin states in $^{128}$I*

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**Abstract** The high-spin states in $^{128}$I have been studied by using in-beam $\gamma$-ray spectroscopy with the $^{124}$Sn($^7$Li, 3n)$^{128}$I reaction at beam energies of 25, 28 and 42 MeV. A new level scheme including 20 new levels and 27 new $\gamma$-transitions for $^{128}$I has been established preliminarily.

**Key words** high spin state, level scheme, doubly odd nucleus

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## 1 Introduction

The iodine nuclei ($A$ ~120—130), which lie in the transitional region between the primarily spherical $_{50}$Sn nuclei and the well-deformed $_{57}$La and $_{58}$Ce nuclei, are expected to inherit features from both the regions and display rich information on nuclear structure. They exhibit softness with respect to the triaxiality parameter $\gamma$, sensitivity to the shape polarizing effects of the valence quasiparticles, and, as a consequence, coexistence of different shapes and collective bands based on intrinsic states with different shapes and deformations[1, 2]. For example, based on previously experimental and theoretical research, the band termination has been observed in odd-$A$ $^{113-123}$I nuclei[3] and odd-odd $^{120,122,124}$I nuclei[4—6] at higher spin region; the coexistence of prolate ($\gamma = 0°$) and oblate ($\gamma = -60°$) has been observed in odd-odd $^{121,125}$I nuclei[1] at lower spin region, and the evidence of chirality has been observed in $^{118}$I[7]. Many physical connotations have been revealed from these features. These features may be still exist with the increasing neutron number. But there are no enough experimental evidences, especially in $^{128}$I. Low-lying states in $^{128}$I were studied with reactions: (n,$\gamma$)[8] and (p,n)[9]. But the information of high-spin states in $^{128}$I is very shortage. The purpose of the present study is to explore the high-spin states features in $^{128}$I by heavy-ion fusion-evaporation reaction.

## 2 Experimental details and data analysis

The high-spin states in the doubly odd nucleus $^{128}$I were populated via the heavy-ion fusion-evaporation reaction $^{124}$Sn($^7$Li, 3n)$^{128}$I at beam energies of 25 and 28 MeV with beams provided by HI-13 tandem accelerator of China Institute of Atomic Energy, and studied by in-beam $\gamma$-ray spectroscopic method with a detector array consisting of 14 BGO-Compton-suppressed HPGe detectors. The target was an enriched self-supporting $^{124}$Sn metallic foil of 4.6 mg/cm$^2$ thickness. A total of $3.45\times10^7$ $\gamma$-$\gamma$ coincidence events was accumulated. The Ge detec-

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tors were calibrated for energy and efficiency using the standard energy calibration $\gamma$ lines from decay of $^{133}$Ba, and $^{152}$Eu radioactive sources. The recorded $\gamma$-$\gamma$ coincidence data were sorted, event by event, into a two-dimensional $E_\gamma - E_\gamma$ matrix. Background-subtracted coincidence spectra were generated and intensity analysis was performed using the PC-base computer program RADWARE.

It is very important to identify and assign the observed unknown $\gamma$-rays to $^{128}$I due to the shortage of the level scheme of $^{128}$I. This was done based on the difference of populated intensity ratio of different nucleus at different beam energies. The reaction cross section calculated by PACE2 is shown in Fig. 1. As is evident from Fig. 1, the major evaporation residues were determined to be $^{127}$I and $^{128}$I at the beam energies of 25 and 28 MeV, but there is no $^{128}$I at 42 MeV. It is worth pointing out that the reaction cross section of $^{128}$I is greater than that of $^{127}$I at beam energy of 25 MeV, but it is contrary for the case of 28 MeV. This is in coincidence with the experimental data (see Fig. 2).

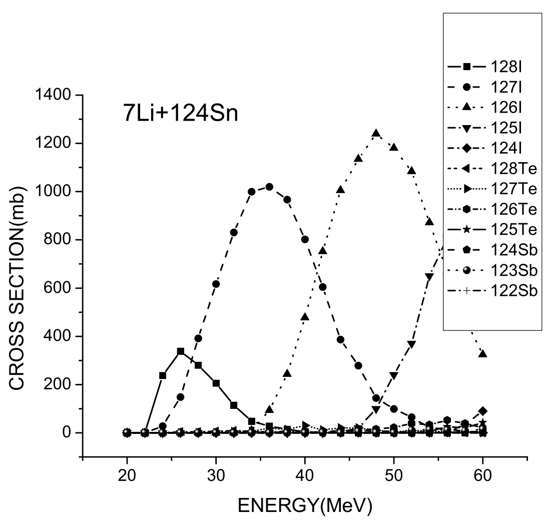


Fig. 1. The reaction cross section calculated by PACE2.

In other words, the observed unknown $\gamma$-rays could be identified and assigned to $^{128}$I with this feature. For instance, the intensities of observed unknown 102, 402.5, 411, 757 keV $\gamma$-rays, and known 490.2, 549.8, 658.8 keV $\gamma$-rays belonging to $^{127}$I, obtained from 25 and 28 MeV total projection spectra respectively (see Fig.2), were normalized to the intensity of known 659 keV $\gamma$-ray respectively, the result is shown in Fig. 3. The ratios of the unknown $\gamma$-rays at 25 MeV are greater than that of 28 MeV. But the ratios of the known $\gamma$-rays, including 659 keV, are very closely or equal at the two beam energies. It is clear that the above-mentioned unknown $\gamma$-rays are likely belonging to $^{128}$I.

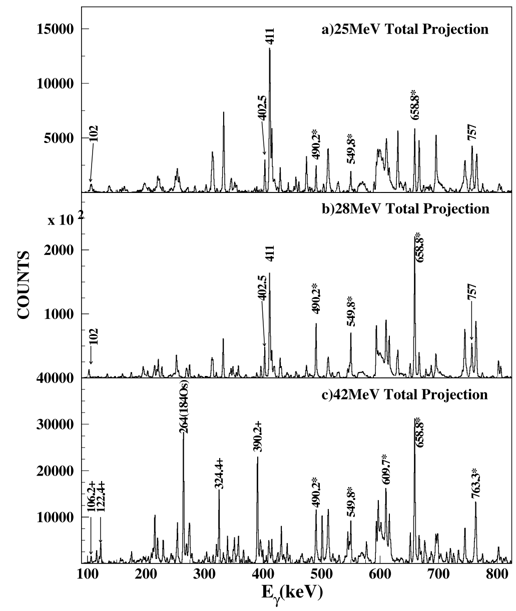


Fig. 2. The total projections at the beam energies of 25, 28 and 42 MeV. The $\gamma$-rays marked with '*' are belonging to $^{127}$I. The $\gamma$-rays marked with '+' are belonging to $^{126}$I. The unknown 102, 402.5, 411, 757 keV $\gamma$-rays could not be observed in the 42 MeV total projection spectrum.

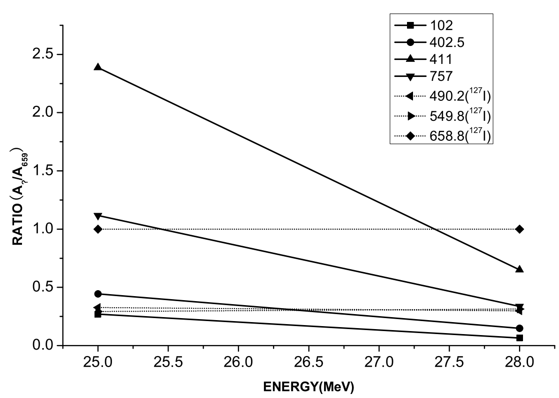


Fig. 3. The ratios of $A_\gamma/A_{659}$ ($A$=Peak Area).

In addition, the energy of 102 keV $\gamma$-transition is in coincidence with previously data[7, 8] within error limit. As shown in Fig. 4 a), the above-mentioned unknown $\gamma$-rays could be observed in the coincidence spectrum gated on the 102 keV transition. From the coincidence relationships and the ratios of $A_\gamma/A_{659}$ (see Fig. 3), a conclusion can be drawn that the above-mentioned unknown $\gamma$-rays are highly likely belonging to $^{128}$I. As is evident from Fig. 4 b), c) and d), such a 102 keV $\gamma$-transition could be observed in

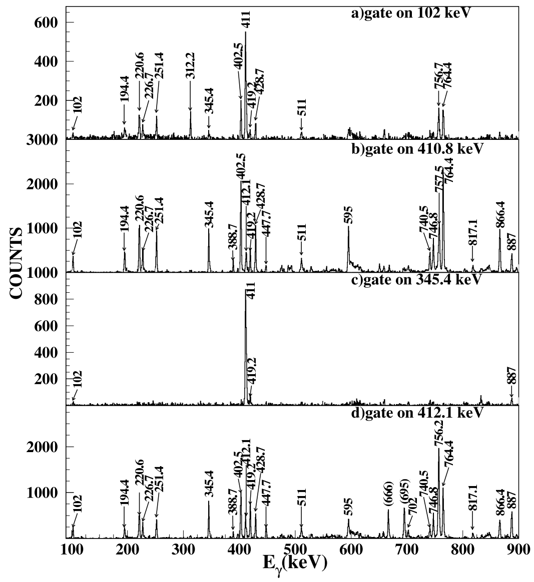


Fig. 4. Representative $\gamma$-$\gamma$ coincidence spectra showing transitions in $^{128}$I, with a) gated on the 102 keV transition, b) gated on the 410.8 keV transition, c) gated on the 345.4 keV transition, d)gated on the 412.1 keV transition, the 666 and 695 keV transitions from $^{126}$Te.

the coincidence spectra gated on the 410.8, 345.4 and 412.1 keV $\gamma$-transitions. It is noted that a doublet 411 keV $\gamma$-transition (see Fig.4 a)) could be separated into a 410.8 keV $\gamma$-transition and a 412.1 keV $\gamma$-transition, and a doublet 756.7 keV $\gamma$-transition (see Fig.4 a)) could be separated into a 756.2 keV $\gamma$-transition and a 757.5 keV $\gamma$-transition. As shown in Fig.4 b), c) and d), the 757.5 keV $\gamma$-transition could only be observed in the coincidence spectrum gated on the 410.8 keV $\gamma$-transition; the 756.2 keV $\gamma$-transition could only be observed in the coincidence spectrum gated on the 412.1 keV $\gamma$-transition, but both of these two $\gamma$-transitions could not be observed in the coincidence spectrum gated on the 345.4 keV $\gamma$-transition. The level scheme of doubly odd $^{128}$I, deduced from the present work preliminarily, is shown in Fig. 5. The placement of $\gamma$-transitions in the level scheme is based on their intensities, energy sums, and coincidence relationships.

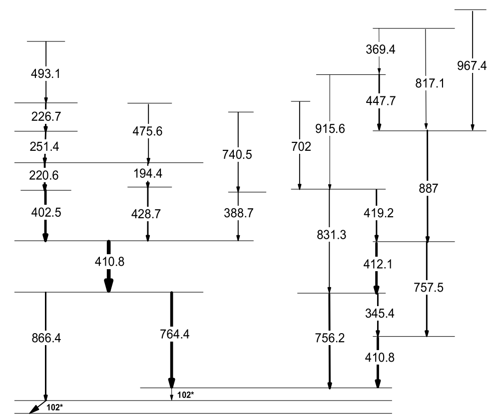


Fig. 5. Partial level scheme of $^{128}$I deduced from the present work.

## 3 Summary

The high-spin states in the doubly odd $^{128}$I have been populated via the heavy-ion fusion-evaporation reaction $^{124}$Sn($^{7}$Li, 3n)$^{128}$I. From the present investigation, the new level scheme of $^{128}$I including 20 new levels and 27 new $\gamma$-transitions has been established preliminarily for the first time. The works to obtain information on $\gamma$-ray multi-polarities deduced from directional correlation (DCO) ratios etc. having been carried out.

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