High Energy Physics and Nuclear Physics

Volume 19, Number 4

Lifetime Measurement of the 16^+ Yrast State in ^{128}Ce

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The high-spin states in ^{128}Ce were populated with the reaction ^{100}Ru(^{32}S,2p2n)^{128}Ce at an incident energy of 141 MeV. The lifetime of the 16^+ state was measured by using the Doppler shift attenuation method. The corresponding *B*(*E*2) value is compatible with the rotational value of theoretical calculation.

Key words: high-spin state, Doppler shift attenuation method, level lifetime, *B*(*E*2) value

1. INTRODUCTION

Lifetime measurements for the yrast band of ^{128}Ce up to a 14^+ state were performed by Wells et al. [1] Their result indicated that the *B*(*E*2) values of the yrast transitions are compatible with rigid rotor value within experimental error. It can be seen that ^{128}Ce and ^{130}Ce have similar rotation characteristics by a comparison of the reduced transition probabilities for these two nuclei. However, the lifetime of the 16^+ yrast state of ^{130}Ce shows a reduction in collectivity [2]. To see if this behavior occurs in ^{128}Ce we have measured the lifetime of the 16^+ yrast state for ^{128}Ce by using the Doppler shift attenuation method (DSAM) in association with the γ–γ coincidence technique including selection of γ ray multiplicity.

2. EXPERIMENTAL METHOD

The experiment was carried out at the HI-13 tandem accelerator of the China Institute of Atomic

Received on December 21, 1994. Supported by the National Natural Science Foundation of China.

Energy, Beijing. High-spin states of ^{128}Ce were populated through the reaction $^{100}Ru(^{32}S, 2p2n)^{128}Ce$ using the 141 MeV ^{32}S beam bombardment on isotope ^{100}Ru target with a thickness of 950 $\mu g/cm^2$. The recoiling nuclei were decelerated and stopped in a gold backing 18 mg/cm^2 thick. The γ rays were detected by a multidetector array comprising six high-purity germanium (HPGe) detectors with bismuth geminate (BGO) Compton suppression devices. The γ ray multiplicity was simultaneously recorded in a filter consisting of 14 independent BGO scintillation detection elements close to the reaction chamber to eliminate the low multiplicity background associated with coulomb excitation and radioactive decay. The HPGe detectors of 15% to 30% relative efficiency and having a 1.9 to 2.1 keV energy resolution were located at a distance of 17 cm from the target and positioned at angles of $\pm 28°$, $\pm 90°$, and $\pm 143°$ vis-à-vis the beam direction, respectively. The ^{60}Co and ^{152}Eu standard sources were used to determine energy calibration. Only the coincidence events involving at least two HPGe detectors and one BGO element of the filter being simultaneously triggered were recorded in list mode and stored on magnetic tapes. A total of approximately 30×10^6 coincidence events were accumulated in the experiment.

3. RESULTS

To perform the Doppler shift attenuation analysis, the event-by-event data were sorted into an angle-dependent, two-dimensional matrix. This matrix contained 28° events sorted against events at all the other angles. The 28° spectra projected from the matrix were used to analyze the line shape of the γ rays. The level scheme of the yrast band in ^{128}Ce is shown in Fig. 1. The coincidence spectra

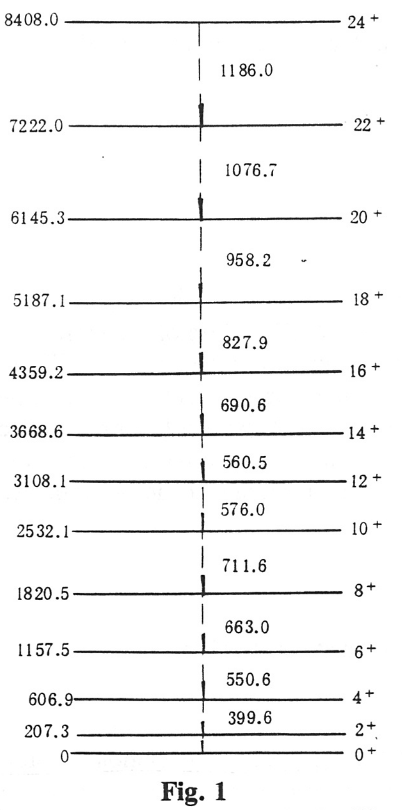

Fig. 1
Level scheme of the yrast band in ^{128}Ce.

Table 1
Lifetime and $B(E2)$ values obtained from present work.

E_X(keV)	I^π	E_γ(keV)	τ(ps)	$B(E2)$(e^2b^2)	$B(E2)/B(E2)_{rot}$
4359.2	16^+	690.6	0.53 ± 0.03	0.98 ± 0.06	1.2 ± 0.1
5187.1	18^+	827.9	<0.93	>0.23	>0.3

gated with all the yrast transitions below the 16^+ state were added together to give the best possible statistical accuracy. The resulting sum spectrum is displayed in Fig. 2.

The Doppler-broadened line shapes were analyzed with the computer program GNOMON [3]. As for the stopping power of the recoiling nuclei in the Ru-Au target, we adopted the semiempirical expression proposed by Ziegler, Biersack, and Littmark [4] for the electronic part and that proposed by Kalbitzer and Oetzmann [5] for the nuclear part. The angular straggling of recoiling ions caused by nuclear collisions during the slowing-down process was treated according to Blaugrund approximation [6]. The velocity distribution of the recoiling nuclei as a consequence of multiparticle evaporation was considered by using a Gaussian distribution function. The energy loss of the beam and the recoiling nuclei in the target were considered by dividing the target into eight thin layers with equal thickness. It is assumed that for each layer, the stopping of the beam occurred in the preceding layers and the stopping of the recoiling nuclei in all remaining layers or in the backing. In the analysis of line

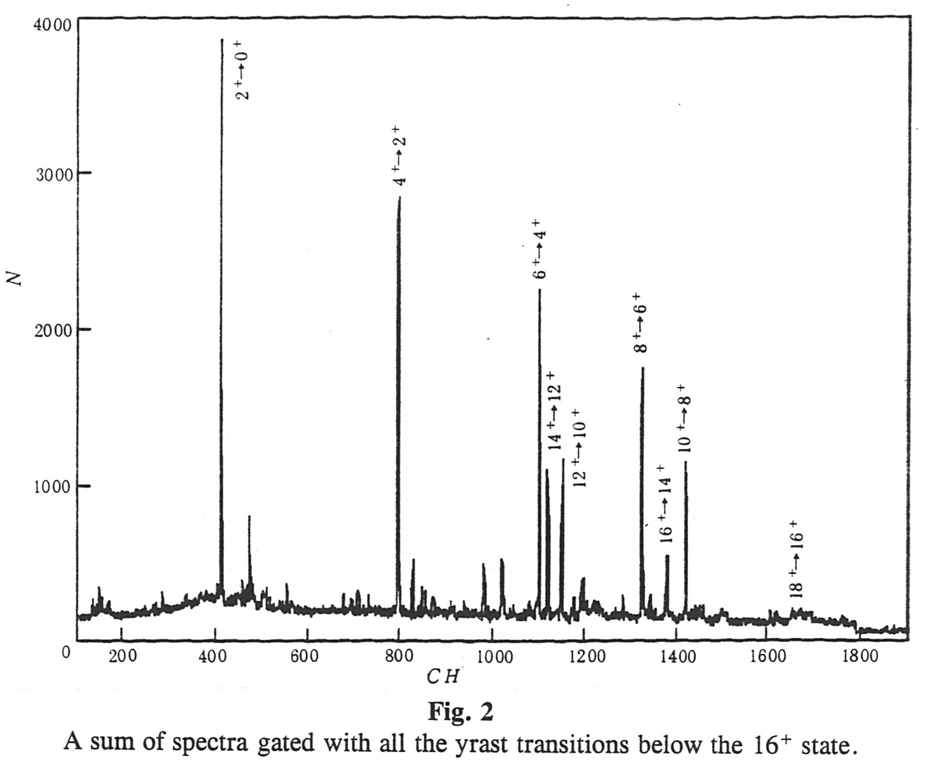

Fig. 2
A sum of spectra gated with all the yrast transitions below the 16^+ state.

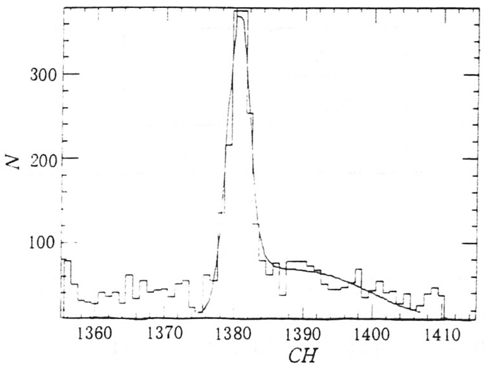

Fig. 3
The Doppler-broadened line shape of the 691 keV $16^+ \to 14^+$ transition.
The smooth curve is a fit with the computer program GNOMON.

shapes, the corrections for the finite solid angle and the finite energy resolution of the Ge detector were made. In addition, it is necessary to take into consideration the influences of feeding from higher levels above the state being studied and side feeding into each level. The side feeding intensities were determined on the basis of relative intensities of the yrast transitions. The side feeding intensity for a given level was taken to be the increase in intensity of that level compared with the preceding one (i.e., any increase in intensity was assumed to be due to unobserved side feeding). The level lifetime was calculated with a series that assumed side feeding numerous times until the best fit to the line shape was obtained. In the present work it was found that introducing a single side-feeding component was sufficient to describe the line shape and that no further long-lived component was required. The measured and fitted line shape for the 691 keV $16^+ \to 14^+$ transition is shown in Fig. 3. The result obtained from the present measurement is presented in Table 1.

4. DISCUSSION

As the neutrons, which are evaporated from the reaction ^{100}Ru(^{32}S, 2p2n)^{128}Ce, bombard the Ge detectors, the 691 keV γ rays will be emitted due to (n,n′) excitation of the 691 keV 0^+ state in ^{72}Ge; thus the analysis of the Doppler-broadened line shape for the 691 keV transition of ^{128}Ce would be seriously disturbed in a single spectrum. As we applied γ-γ coincidence measurement and used gated spectra to perform the Doppler shift attenuation analysis, the effect resulting from the background γ rays of 691 keV was eliminated and the confidence level of the experimental result was improved.

For the convenience of evaluating the collectivity of ^{128}Ce with increasing angular momentum, the experimental $B(E2)$ values deduced from the measured lifetimes were normalized to the rigid rotor $B(E2)_{\rm rot}$ values based on the transition probability of $2^+ \to 0^+$ yrast transition, that is, they were expressed in the ratio $B(E2)/B(E2)_{\rm rot}$. The rotational value $B(E2)_{\rm rot}$ can be derived from the relation

$$B(E2)_{\rm rot} = \frac{\langle I020 \mid I-20 \rangle^2}{\langle 2020 \mid 00 \rangle^2} B(E2,\ 2 \to 0)_{\rm exp}$$

where $B(E2,\ 2\to 0)_{\rm exp}$ is an experimental $B(E2)$ value of the $2^+ \to 0^+$ yrast transition. The normalized $B(E2)$ value of 1.2 for the 16^+ state of ^{128}Ce given in Table 1 is compatible with the rotational value of 1.0 from theoretical calculation.

An upper limit of lifetimes is also given for the 18^+ state. Since there is no information about the feeding delay above the 828 keV transition, an effective lifetime not corrected for feeding that fits the line shape best is presented. We attempted to measure lifetimes of higher spin states; however, statistics and signal-background ratios were too poor to perform a meaningful Doppler shift attenuation analysis.

5. SUMMARY

The high-spin states of ^{128}Ce were populated with the fusion evaporation reaction $^{100}Ru(^{32}S,2p2n)^{128}Ce$ at a beam energy of 141 keV. The lifetime of the 16^+ state was measured by using the Doppler shift attenuation method. The corresponding $B(E2)$ value indicates a symmetric rotor behavior. In addition, an upper limit of lifetime for the 18^+ state is presented.

ACKNOWLEDGMENT

We would like to thank the staff of the HI-13 tandem accelerator crew at the CIAE for providing a quality beam. We are also grateful to Mr. Xu Guoji for his help in making the targets.

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