Level structure of ^{159}Lu *

SHENG Hai-Qing(盛海清)[1] ZHAI Jian(翟健)[1] LI Xian-Feng(李险峰)[1;1)] MA Ying-Jun(马英君)[1]
ZHAO Yan-Xin(赵延新)[1] WANG Ya-Kun(王亚坤)[1] ZHAO Lei(赵磊)[1] ZHU Li-Hua(竺礼华)[2]
WU Xiao-Guang(吴晓光)[2] HE Chuang-Ye(贺创业)[2] LIU Yin(刘颖)[2]
HAO Xin(郝昕)[2] LI Xue-Qin(李雪琴)[2]

1 (Department of Physics, Jilin University, Changchun 130023, China)
2 (China Institute of Atomic Energy, Beijing 102413, China)

Abstract The high-spin states of ^{159}Lu were populated by fusion-evaporation reaction ^{144}Sm (^{19}F, 4n) with beam energy 106 MeV. A new level scheme was established, which consists of the yrast band with negative parity, the octupole vibration band based on the states and quasipartical band with positive parity. The high spin states of ^{159}Lu were discussed by systemic characteristics.

Key words high spin states, level scheme, octupole deformation

PACS 21.10.Hw, 21.10.Ma

1 Introduction

The even-N $Z = 71$ isotopes ^{161,163,165,167}Lu[1—4] and $N = 88$ isotones ^{155}Ho, ^{157}Tm[5] have all been well studied, with the first back-bending and signature splitting reported. The odd-Z nucleus ^{159}Lu lies in the transitional region from spherical nuclei to deformed nuclei, where nuclear shape is subject to change due to several factors, such as rotation of nucleus, alignment of paired nucleons and so on. It is of significance to study the high-spin states of ^{159}Lu to reveal systemic characteristics within isotopic and isotonic chains.

2 Experiment and results

The high-spin states of ^{159}Lu were populated by the fusion-evaporation reaction ^{144}Sm (^{19}F,4n) with beam energy 106 MeV provided by HI-13 tandem accelerator of CIAE in Beijing in Jan. 2007. The target, enriched in ^{144}Sm , consisted of self-supporting Sm foils of 1.2 mg·cm^{-2}.

The γ-γ coincidence events were recorded with an array of twelve Compton-suppressed HpGe detectors. Relative efficiency measurement of detectors and energy calibrations were carried out with the standard sources ^{152}Eu. Two matrixes were created for the determination of the coincidence relationships and angular-correlation information. The experiment results included transition energy, spin-parity assignments and DCO rations. Some of them listed in Table 1, grouped in sequences for $\pi = +$, $\pi = -$ and linking transitions.

The level scheme of ^{159}Lu was deduced by the present work in Fig. 1. The 426.0, 551.3, 642.0, 708.3 and 760.3 keV transitions are yrast and more intense than 529.4, 622.3 and 597.8 keV in Table 1. Studies of systematics indicate an energetic favoring of, and higher intensity in, the $\alpha = -1/2$ sequence for rotational bands based on the intrinsic $h_{11/2}$ quasiproton state. Thus, the sequence containing the stretched E2 transition 426.0, 551.3, 642.0 etc. keV, is assigned as $\alpha = -1/2$. Associating the 426.0 keV gamma ray with $15/2^- \rightarrow 11/2^-$ transition is consistent with the systematic of the transition of the $\alpha = -1/2$ sequence and energy splitting between signature partner bands in the $h_{11/2}$ sequences of neighboring Tb, Ho, Tm and Lu nuclei as illustrated in Refs [5, 6].

Received 3 September 2008
* Supported by National Natural Science Foundation of China (10475033, 10675053) and National Found for Fostering Talents of Basic Science (J0730311)
1) E-mail: lixf@jlu.edu.cn

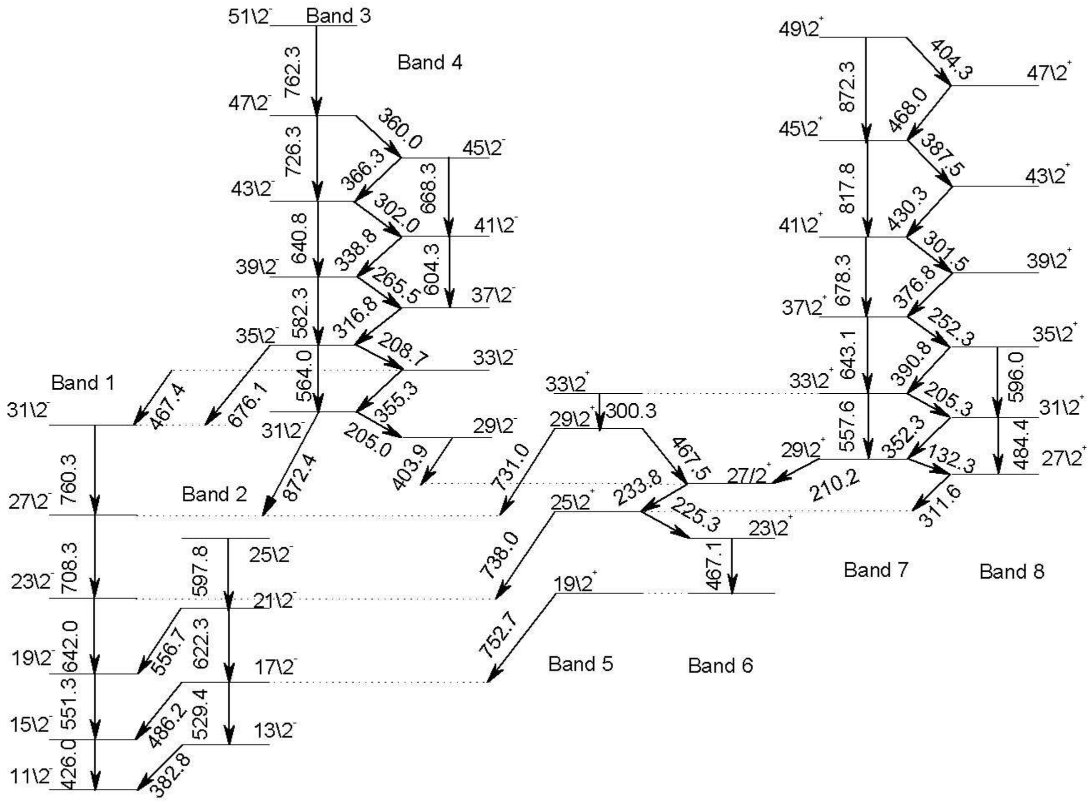

Fig. 1. The level schem of ^{159}Lu.

Table 1. Data for ^{159}Lu.

E/keV	I	R_{DCO}	I_i	I_j
π(−)				
426.0	1000(84)	1.00(10)	$15/2^-$	$11/2^-$
529.4	62(7)	0.98(10)	$17/2^-$	$13/2^-$
551.3	904(86)	1.02(11)	$19/2^-$	$15/2^-$
622.3	87(9)	1.04(13)	$21/2^-$	$17/2^-$
597.8	56(7)	0.97(15)	$25/2^-$	$21/2^-$
642.0	777(71)	1.02(14)	$23/2^-$	$19/2^-$
708.3	420(42)	1.04(13)	$27/2^-$	$23/2^-$
760.3	161(19)	1.02(12)	$31/2^-$	$27/2^-$
355.3	129(18)	0.97(10)	$33/2^-$	$31/2^-$
316.8	118(14)	0.64(9)	$37/2^-$	$35/2^-$
582.3	56(6)	1.03(15)	$39/2^-$	$35/2^-$
265.5	129(15)	1.03(12)	$39/2^-$	$37/2^-$
338.8	121(16)	0.78(11)	$41/2^-$	$39/2^-$
366.3	113(12)	0.73(10)	$45/2^-$	$43/2^-$
360.0	127(13)	0.72(12)	$47/2^-$	$45/2^-$
π(+)				
311.6	76(8)	0.76(10)	$27/2^+$	$25/2^+$
252.3	64(8)	0.64(11)	$37/2^+$	$35/2^+$
430.3	115(16)	0.66(9)	$43/2^+$	$41/2^+$
Linking				
731.0	107(18)	0.79(17)	$29/2^+$	$27/2^-$
738.0	178(21)	0.72(16)	$25/2^+$	$23/2^-$
752.7	42(7)	0.65(14)	$19/2^+$	$17/2^-$

Based on the arguments for assigning $I=11/2^-$ to the lowest level in band 1, together with the available angular correlation data in Table 1, high-spin states were observed up to $I=51/2^-$ in the negative parity decay sequences. At the same time, some new levels and γ-rays were set up by the present work.

The first irregularity to the regular pattern of increasing gamma ray energy with increasing spin occurs above $I = 31/2$. The sequence of levels at this discontinuity, is fixed by interconnected decays.

The spin and parity assignment for the decay sequence labeled 5 and 6 are based on the following arguments. The angular correlation ratios for the 731.0, 738.0 and 752.7 keV are all consistent with their being stretched dipole transition in Table 1. The nonobservation of transitions connecting a level of spin I in band 5 and 6 to one of $I-2$ in band 1 or 2 indicates that bands 5, 6 and band 1, 2 are of different parity. Opposite parity bands connected by $\Delta I=1$ E1 transitions give evidence for octupole correlations. Band 5 and 6 are tentatively interpreted as unstable octupole vibration states building on $h_{11/2}$ levels, consistently with the systematics of low-lying octupole bands in the $N=88$ isotones. The similar structure has been set up in $N=88$ ^{157}Tm[5]. Two shells, with opposite-parity and without neutron-rich[7, 8], lie close-together in the proton signal-partial spectrum, which leads to be softness with respect to octupole distortion. The octupole correlation occurs when high-j spherical sub shells which couple by the octupole component in an average field are relatively close to each other, which is the case for $i_{11/2}[660]1/2^+$ and $f_{11/2}3/2^-$ in ^{159}Lu.

From the level structure, ^{159}Lu has a band 2 besides yrast band, ^{157}Tm[5] and ^{155}Ho similarly with ^{159}Lu[6]. The large signature splitting has been observed between yrast band and partner band comparing to ^{161,163,165,167}Lu. The level structure of ^{159}Lu turns up prominent change, which indicates the configuration of the negative-parity band change from $h_{11/2}[514]9/2^-$ to $h_{11/2}$ $[523]7/2^-$. With the decreasing neutron number, the Fermi level in ^{159}Lu tends to closer to the $h_{11/2}$ $[523]7/2^-$ than the $h_{11/2}$ $[514]9/2^-$ Nilsson state.

3 Discussion

The states can be made clear in term of collective vibration involving configurations of vibration aligned quasiparticles with the cranked shell model in Fig. 2. The experiment alignments in ^{159}Lu are potted. The reference parameters ($J_0 = 12$ MeV$^{-1}\hbar^2$, $J_1 = 104$ MeV$^{-3}\hbar^4$) were choose to give zero alignment

for the first states in the ground band of the neighboring ^{158}Yb and ^{160}Hf even nuclei. In the negative parity states, band 1 and band 2 with aligned angular momentum of $2.9\hbar$ and $3.3\hbar$ (at rotational frequency $\hbar\omega = 0.24$ MeV) are interpreted as single quasiproton configurations $A_{\rm p}$ and $B_{\rm p}$, respectively. At $\hbar\omega = 0.34$ MeV, the $i_{13/2}$ neutron alignment occurs with band 3 and band 4 being interpreted as the $A_{\rm p}$AB and $B_{\rm p}$AB configurations, respectively. The increase in alignment of $9.4\hbar$ from band 1 (or 2) to 3 (or 4) is consistent with this interpretation. The neutron Fermi level of $N = 88$ nuclei lies well below the $vi_{13/2}$ [660]1/2 level, which is away from a pair of quasineutrons, so the first band-crossing frequency for nuclei with $N = 88$ is notably higher than other nuclei. It is consistent with the theory of CSM[9]. In addition, the crossing frequency value for $h_{11/2}$ based bands $\hbar\omega = 0.34$ MeV in ^{159}Lu and $\hbar\omega = 0.32$ MeV in ^{157}Tm, respectively, is higher than similar structure $\hbar\omega = 0.29$ MeV in ^{155}Ho[5], which fits in well with systematics of the first $i_{13/2}$ neutron deficient rare earth nuclei[10].

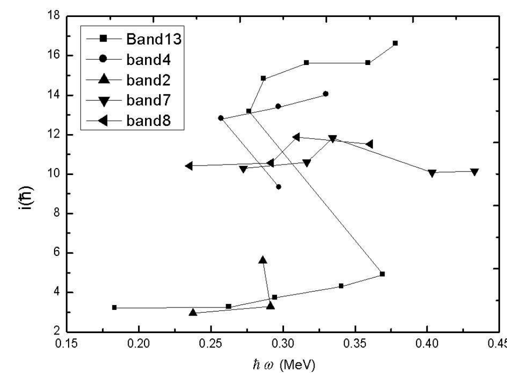

Fig. 2. Experimental alignment as a function of rotational frequency for the bands in ^{159}Lu.

4 Conclusion

The high-spin states of ^{159}Lu have been studied through the fusion-evaporation reaction ^{144}Sm (^{19}F, 4n), and the unstable octupole vibration band is reported for the first time in ^{159}Lu. At $\hbar\omega = 0.34$ MeV, the $i_{13/2}$ neutron alignment occurs with band 3 and band 4 being interpreted as the $A_{\rm p}$AB and $B_{\rm p}$AB configurations, respectively, which is consistent with the theory of CSM.

References

1 Bringel P et al. Eur. Phys. J A, 2005, **24**: 167—172
2 Jensen D R et al. Nucl. Phys. A, 2002, **703**: 3—44
3 Schõnwaer G et al. Phys. Letters B, 2003, **552**: 9—16
4 Yu C H et al. Nucl. Phys. A, 1990, **511**: 157-94
5 Johnson N R et al. Phys. Rev. C, 1995, **51**(3): 1234
6 MA Ying-Jun et al. J. Phys., 1995, **21**: 937—945
7 CHEN Yong-Jing et al. Chin. Phys. Lett., 2005, **22**(6): 1362
8 CHEN Y S, GAO Z C. Phy. Rev. C, 2000, **63**: 014314
9 Bengtsoon R et al. Nuclear Physics A, 1979, **327**: 139-71
10 Simpson J et al. J. Phys. G, 1991, **20**: 511