2 - 1 Research Progress of Nuclear Structure Research Group

Liu Minliang

The Group of Nuclear Structure Research at IMP has been working in the field of high-spin level structures via standard in-beam γ-ray spectrum. In order to explore the new high-spin physics in nuclei far from the valley of stability, we have recently completed the construction of a large-scale γ-ray detection array. This array consists of 15 HPGe, 9 Clover and 8 $LaBr_3$ detectors, providing excellent energy and timing resolution and high full-energy peak efficiency.

The first experiment was performed in 2017 at the TL2 beam line of HIRFL in Institute of Modern Physics, Chinese Academy of Sciences. High-spin states of ^{95}Tc have been populated by the ^{90}Zr (^{12}C, αp2n) fusion-evaporation reaction. The beam was delivered from the SFC. 15 HPGe, 7 Clover and 3 $LaBr_3$ detectors were available during the experiment. The use of Clover detectors facilitate the linear polarization measurement of γ ray[1,2], together with the angular distribution information, to firmly determine the level spin and parity. According to the measured γ rays, we have constructed a new level scheme for ^{95}Tc, which differs from the previous result[3] mainly by the level spins and parities for the Clover detectors added into the array.

In addition, we have performed another in-beam γ-ray experiment in INFN, Italy. The experiment aimed at the high-spin level structure of ^{130}Ba via the ^{122}Sn (^{13}C, 5n) fusion-evaporation reaction. The emitted γ rays, charged particles and neutrons were detected during the experiment. According to the particle-γ and $\gamma-\gamma$ coincidences as well as the angular distribution information, we have constructed a level scheme built up from the long-lived 8^- isomer in ^{130}Ba[4].

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2 - 2 Structure above *K*-isomer in ^{130}Ba

Guo Song[1], Qiang Yunhua[1], C. M. Petrache[2], Liu Minliang[1], Wang Jianguo[1], A. Astier[2], B.F. Lv[2], D. Bazzacco[3], G. de Angelis[3], Fang Yongde[1], Li Guangshun[1], Zheng Kuankuan[1], Li Ren[1], A.Goasduff[3], K. Hadynska[3], G. Jaworski[3], D. R. Napoli[3], M. Siciliano[3] and J. J. Valiente-Dobon[3]

([1]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730070, China;
[2]CSNSM, Universite Paris-Sud, CNRS-IN2P3, Universite Paris-Saclay, Orsay, France;
[3]INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy)

Isomeric I^π=8^- states have been observed in the even-even $N = 74$ nuclei ^{138}Gd[1], ^{136}Sm[2], ^{134}Nd[3], ^{132}Ce[4], ^{130}Ba[5], ^{128}Xe[6] with half-lives ranging from nanoseconds (Xe) to milliseconds (Ba, Ce). Rotational bands built on the K^π=8^- isomer were identified in all these isotones, with the exception of ^{130}Ba. The single-particle configuration of the isomers have been deduced from the $\Delta I = 2$ to $\Delta I = 1$ γ-ray intensity branching ratios, which allowed to extract the $(g_K - g_R)/Q_0$ values, and therefore the quasi-particle configuration of the state. A predominant ν $9/2^-[514]\otimes\nu$ $7/2^+[404]$ two-quasineutron structure has been deduced for the isomers with observed bands built on them. As Z increases across the $N = 74$ nuclei from ^{128}Xe to ^{138}Gd, the decreasing energy of the first excited 2^+ state indicates that the deformation increases. It might therefore be expected that the K-selection rule governing the E1

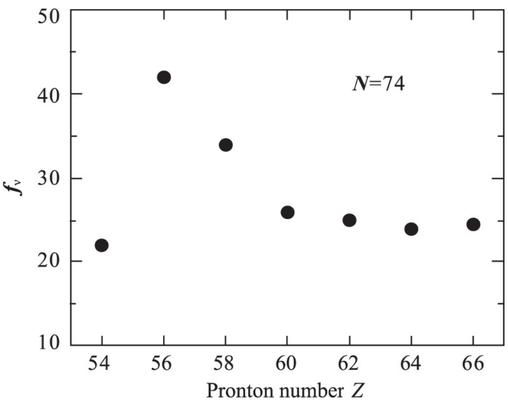

Fig. 1 The hindrance per degree of K forbiddenness f_ν for the transitions from the K^π=8^- state to the 8^+ member of the yrast band in the $N = 74$ isotones.

transition from the isomeric state should be more important for the heavier isotones, leading to a decrease in the transition rate of the E1 decay and a corresponding increase in the hindrance. This is opposite to what is observed for the sequence ^{130}Ba to ^{138}Gd (see Fig. 1)[7]. It is therefore proposed that the variation in the hindrance is due to a change in the underlying structure of either the isomeric states themselves or of the yrast states to which the isomer decays.

In this work, high-spin states of ^{130}Ba were populated through the ^{122}Sn(^{13}C, 5n)^{130}Ba reaction in INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy. ^{13}C beam with a beam energy of 65 MeV bombarded a stack of two self-supporting ^{122}Sn targets of 0.5 mg/cm^2. The emitted γ rays, charged particles and neutrons from the reaction products were detected by GALILEO+EUCLIDES+Neutron Wall setup. More than one billion triple coincidence events were collected.

By analyzing the data carefully, a new structure consisting 20 levels and 28 transitions was found (see Fig. 2). This structure was assigned to ^{130}Ba according to the following two experimental proofs. First, it cannot be observed in the data selected by charged particles. Second,by comparing the intensity difference between data in coincidence with no neutron and that with one neutron, similar trends were found between this structure and the known transition of ^{130}Ba. Since the transitions in this structure are not in coincidence with the transitions in ground band of ^{130}Ba, they are inferred to populate the known 8$^-$ isomer.

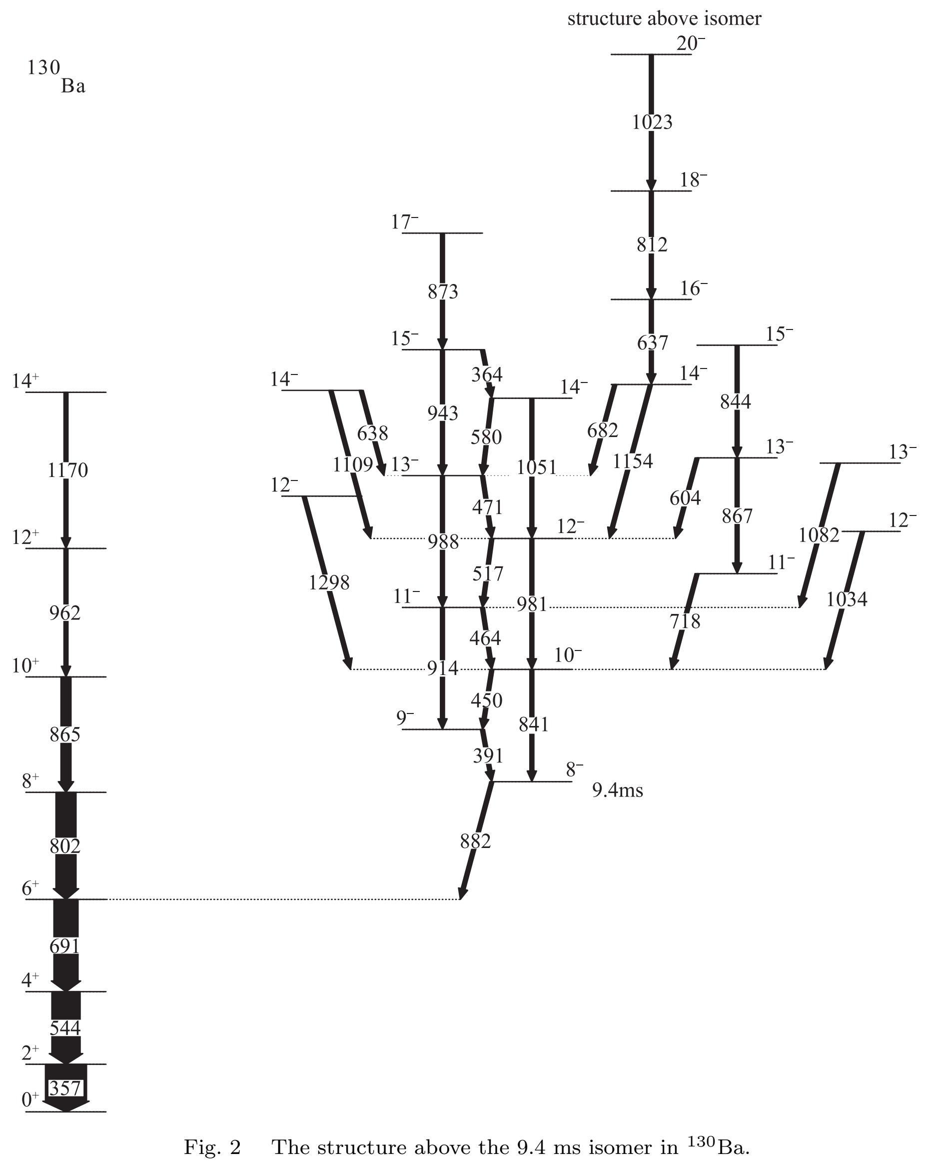

Fig. 2 The structure above the 9.4 ms isomer in ^{130}Ba.

In this structure there is a band built on ν 9/2$^-$[514]$\otimes\nu$ 7/2$^+$[404] configuration and two bands and four other levels populating it. Now Total Routhian Surface calculation is performing by our cooperative theorists. Experimental and theoretical results are expected to be published after a detailed discussion on the effects from deformation, bandbacking and possible configuration mixing.

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2 - 3 High Spin Level Scheme of ^{95}Tc

Zheng Kuankuan, Liu Minliang, Wang Jianguo, Guo Song, Qiang Yunhua, Li Guangshun, Fang Yongde, Zheng Yong and Zhou Xiaohong

High spin level structure of ^{95}Tc was reinvestigated via the ^{90}Zr(^{12}C, αp2n)^{95}Tc fusion-evaporation reaction using the incident beam energy of 78 MeV ^{12}C provided by the SFC of the Institute of Modern Physics (IMP), Chinese Academy of Sciences (CAS). The target was 1.82 mg/cm^2 ^{90}Zr on 8.23 mg/cm^2 natural lead backing. The emitted γ rays from the reaction products were detected by an multidetector array consisting of 15 HPGe detectors of which 8 HPGe detectors have Anti-Compton shieds, 7 Clover detectors placed in a plane perpendicular to the beam and 3 $LaBr_3$ detectors at 30° against the beam. The energy and efficiency calibrations were made using ^{60}Co, ^{133}Ba, and ^{152}Eu standard sources and the typical energy resolution is 2.0 to 2.5 keV at full width at half-maximum (FWHM) for a 1 332.5 keV γ ray of ^{60}Co. Events have been collected when at least two detectors are fired within the prompt coincidence time window of 100 ns. Under these conditions, a total of 3.5×10^6 coincidence events were recorded and the data were sorted into a symmetrized E_γ–E_γ matrix for subsequent off-line analysis.

In order to obtain angular distribution information of the emitted γ rays, two asymmetric coincidence matrices were constructed using the γ rays detected at all angles (as y axis) against those observed at 30° (or 150°) and 90° angles (as x axis), respectively. The ADO (γ-ray angular distribution from oriented nuclei) ratio[1] is defined as

$$R_{\mathrm{ADO}}(\gamma)=\frac{I_\gamma(30^\circ)}{I_\gamma(90^\circ)}=\frac{N_\gamma(30^\circ)/\epsilon_\gamma(30^\circ)}{N_\gamma(90^\circ)/\epsilon_\gamma(90^\circ)},$$

where I_γ is the intensity of γ ray in the respective angular obtained by the number N_γ and efficiency ϵ_γ. By setting gates on the y-axis with all the detectors, the γ ray intensities $I_\gamma(30^\circ)$ and $I_\gamma(90^\circ)$ were extracted from the coincidence spectra regardless of the multipole character of the gating transition. As shown in Fig. 1 stretched quadrupole transitions were adopted if $R_{\mathrm{ADO}}(\gamma)$ values were significantly larger than 0.9, and dipole transitions were assumed if $R_{\mathrm{ADO}}(\gamma)$'s were less than 0.9[2].

The use of Clover detectors facilitate linear polarization measurement which is crucial to determine the level parity from the electromagnetic nature of deexciting γ ray[3]. We also built two additional asymmetric coincidence matrices by the polarization-directional correlation from oriented nuclei (PDCO) method[4]. The so-called vertical PDCO matrix contained the events in which one of the γ rays was scattered inside the Clover detector in the direction perpendicular to the emission plane (those events were put on the x axis), whereas a coincident γ ray was registered in any detector (those events were put on the y axis). Again, the other, so-called horizontal PDCO matrix, contained the events in which one of the γ rays was scattered in the direction parallel to the emission plane (those events were put on the x axis), whereas a coincident γ ray was registered in any detector (those events were put on the y axis)[4]. By setting gates on the y-axis with all the detectors, the scattering γ ray numbers $N_\perp$ and $N_\parallel$ were extracted from the coincidence spectra regardless of the multipole character of the gating transition. In the experiment an asymmetry of Compton-scattered polarized photons was calculated from the expression[4,5]

$$A=\frac{(aN_\perp-N_\parallel)}{(aN_\perp+N_\parallel)},$$