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ORIGIN OF THE BACKBENDING IN $\pi h_{9/2}$ BAND OF ^{187}Ir

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Abstract. High-spin states of ^{187}Ir have been populated in the ^{176}Yb(^{15}N,$4n$) reaction and measured with the YRAST Ball spectrometer. Here we report the new γ rays associated with $\pi h_{9/2}$ yrast-band. The first backbending in this band was found at rotational frequency of $\hbar\omega \approx 0.40$ MeV. Two different scenarios were considered for explanation of this backbending suggesting alignment of an $h_{9/2}$ proton and $i_{13/2}$ neutron pair respectively.

1 Introduction

Nuclei with $Z \approx 82$ are well known for displaying textbook examples of shape coexistence. In nearly all instances, this competition has been between prolate and spherical shapes or prolate and oblate shapes. Recently, competition between three shapes (prolate, oblate, and spherical) has been found in ^{186}Pb [1], where in addition to the spherical ground state, excited 0^+ states associated with prolate and oblate shapes are observed at low energy (≤ 650 keV). Seewald *et al.* [2] measured spectroscopic quadrupole moments for a number of Ir isotopes using NMR technique. They extracted different quadrupole moments for 2^- isomeric state and 5^+ ground state of the ^{186}Ir.

The shape coexistence is an indication that the cores of these nuclei are "soft" with respect to deformation. One can thus expect significant changes in the nuclear shape to be caused by the occupation of high-j orbitals and aligned quasiparticles at high spins. Several open questions about collective behavior of these nuclei are still remain to be answered: (i) the role of individual proton and neutron orbitals in driving the nuclear nuclear shape (ii) the nature of the first yrast band crossing in $N \approx 106$ nuclei.

This paper reports on newly observed states of $\pi h_{9/2}$ band in ^{187}Ir. The excessive experimental information compared to the previous study of this nucleus performed by Kemnitz *et al.* [3] enable us to observe the first backbending at rotational frequency of $\hbar\omega \approx 0.38$ MeV. Aligned angular momenta of $\pi h_{9/2}$ bands in odd Ir isotopes with $N = 104-110$ was compared, and the difference in rotational behavior of lighter ^{181,183}Ir and heavier ^{185,187}Ir was discussed.

2 Experimental details

The experiment was performed with the tandem van de Graff accelerator at Wright Nuclear Structure Laboratory at Yale University. The main emphasis of this experiment

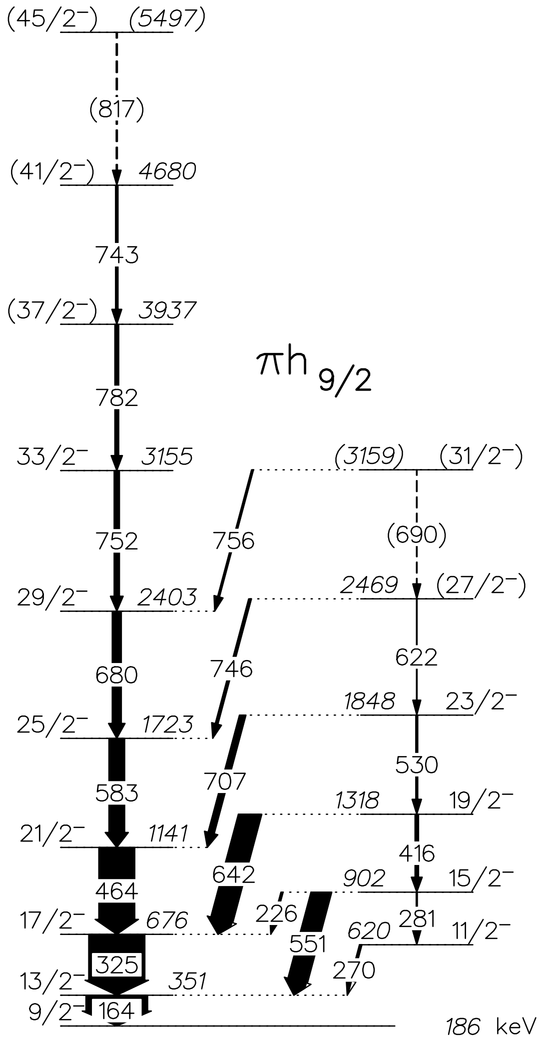

Figure 1. Partial level scheme showing $\pi h_{9/2}$ band deduced in present study.

was the search of chiral twin bands in ^{186}Ir, although several other channels had relatively large cross sections. High-spin states of ^{187}Ir were populated in the $4n$ channel of the fusion-evaporation reaction induced by beam of ^{15}N at 82 MeV energy. The target consisted of ^{176}Yb foil, which was 6.65 mg/cm^2 thick. Gamma rays were detected with the YRAST Ball array [4], which for this experiment consisted of 7 Clover detectors, 16 single-crystal Ge detectors, and three LEPS detectors. The detectors are situated around the target at different angles as described below: all clover detectors at 90°, three Ge detectors at 160°, eight at 126° and five at 50°. The trigger condition required a minimum of three coincident γ rays to hit clover or single Ge detector. The γ-γ-γ coincidence events were sorted in three dimensional histogram (cube) using the modified *incub8r* code from RADWARE package [5].

3 Results

In the previous study of ^{187}Ir [3] the $\pi h_{9/2}$ band has been established up to spin $I^\pi = 33/2^-$ for favorite and up to tentative spin (27/2$^-$) for unfavorite sequences. Now these sequences were extended up to (45/2$^-$) and (31/2$^-$) spins respectively. The level scheme for $\pi h_{9/2}$ band deduced in the present study is shown in Figure 1. Transitions were ordered on the basis of their coincidence relationship and their relative intensities. The arrow widths are proportional to the intensities of the corresponding transitions which are obtained in a fit with the *escl8r* program from RADWARE package [5]. Multipolarities for the new transitions observed in the present study were assigned assuming that rotational behavior of the band persist and in the level scheme spins of the corresponding levels are shown in parentheses.

4 Discussion

The origin of the first yrast-band crossing is still debated for $N \approx 106$ nuclei (see Carpenter *et al.* [6]). The last major attempt to clarify this issue was done by Carpenter *et al.* [6]. These authors carried out extensive set of calculation and concluded that two approaches could be applied to the problem.

In the first approach it is assumed that all the bands in $N \approx 106$ have similar deformations and therefore standard blocking arguments can be used. This leads to an interpretation in which $h_{9/2}$ protons play a crucial role at frequencies below 0.35 MeV. In the second approach the deformation of each band had been determined from cranking calculations. Since all band crossings are deformation dependent, a given band crossing may appear at very different frequencies depending on the deformation of the considered configuration and normal blocking arguments cannot be used. In this approach nearly all low-lying band crossings were explained as alignment of $i_{13/2}$ neutrons, the $h_{9/2}$ protons being involved only in exceptional cases.

The aligned angular momenta of ^{181,183,185,187}Ir are presented in Figure 2, where separate Harris parameters were used for different isotopes. What can be seen from a first glance is the apparent difference in rotational behavior of the $\pi h_{9/2}$ band in ^{181,183}Ir from one side and ^{185,187}Ir nuclei from the other. For the lighter Ir isotopes $\pi h_{9/2}$ band undergo crossing at rotational frequency of $\hbar\omega \approx 0.29$ MeV and gain alignment of $\Delta i \approx 7\hbar$, while for heavier Ir crossing is observed at $\hbar\omega \approx 0.38$ MeV and alignment gain after crossing is $\Delta i \approx 5\hbar$.

In the previous studies of ^{181}Ir and ^{183}Ir Dracoulis *et al.* [7] and Janzen *et al.* [8], interpreted the first backbending in the $\pi h_{9/2}$ band as an alignment of pair of $i_{13/2}$ neutrons. In the paper of Balabanski *et al.* [9] the band crossing of $\pi h_{9/2}$ band in ^{185}Ir was observed for the first time. These authors interpreted it as an alignment of pair of two $h_{9/2}$ protons on the base of blocking arguments. Additionally they assumed that $(\nu i_{13/2})^2$ crossing in $N = 108$ nuclei moves up significantly in rotational frequency due to reducing of neuron pairing resulting from the gap in the neutron single particle diagram at prolate deformations. Carpenter *et al.* [6] investigated aligned angular momentum of the yrast bands of even-even isotope chains of W, Os and Pt nuclei. They concluded that there is a large jump in the crossing frequency at which $(\nu i_{13/2})^2$ crossing occurs in the $N = 108$ W isotope. Nevertheless these authors on the base of TRS (total Routhian surface) and CSM (cranked shell model) calculations interpreted band crossing in ^{185}Ir as $(\nu i_{13/2})^2$ alignment.

Up to now gain of alignment in $\pi h_{9/2}$ band in ^{185}Ir and ^{187}Ir has not been discussed because the last transitions in the $\pi h_{9/2}$ band in these nuclei were not known. If the band crossing observed in ^{185}Ir and ^{187}Ir comes from alignment of $(i_{13/2})^2$ neutrons, one have to explain the difference in Δi with the ^{181}Ir and ^{183}Ir isotopes. One possible reason for this difference is the relative position of the neutron Fermi surface with respect to $i_{13/2}$ shell

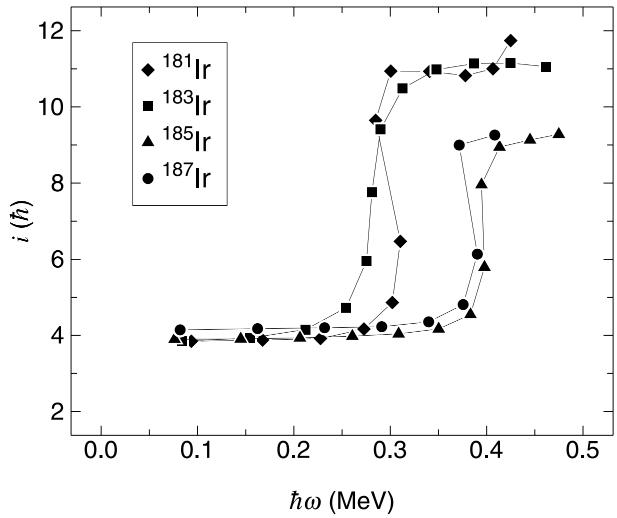

Figure 2. Aligned angular momenta for $\pi h_{9/2}$ band in $^{181-187}$Ir. Reference parameters and data for: ^{181}Ir $\Im_0 = 22$, $\Im_1 = 90$ [7]; ^{183}Ir $\Im_0 = 25$, $\Im_1 = 55$ [8]; ^{185}Ir $\Im_0 = 27$, $\Im_1 = 55$ [10]; ^{187}Ir $\Im_0 = 22$, $\Im_1 = 55$.

in lighter and heavier Ir isotopes. If it lies near the bottom of $i_{13/2}$ shell then the low-K orbitals from the same shell, are likely to align with increase of rotational frequency, which will result in larger gain of alignment Δi. Contrary, if the Fermi level resides away from the bottom of $i_{13/2}$ shell, then the neutrons from low-K orbitals are unlikely to align, which will result in less Δi. To confirm this qualitative conjecture further detailed theoretical calculation are necessary. It has to be mentioned however, that meaningful CSM (cranked shell model) calculation is difficult to be made, since they are sensitive to deformations and pairing, which are difficult to be determined for these nuclei.

The other scenario in which alignment in the ^{185}Ir and ^{187}Ir isotopes comes from alignment of $(\pi h_{9/2})^2$ seems to be more likely. In this case the difference in Δi between lighter and heavier Ir is natural, since two different alignment processes take place. The alignment of protons from the $h_{9/2}$ orbital is expected to be less than alignment of $i_{13/2}$ neutron pair. Another thing that supports this hypothesis is that the last transition in ^{181}Ir show upbend at the same rotational frequency at which the backbend is observed in ^{185,187}Ir. If we assume that this is the beginning of second alignment in the $\pi h_{9/2}$ band in ^{181}Ir it must come from $(\pi h_{9/2})^2$ since four quasineutron excitation will lie at higher excitation energy.

In the ^{183}Ir different behavior of $\pi h_{9/2}$ band was observed. In the studies of ^{181}Ir [7] and ^{183}Ir [8] the last transitions in $\pi h_{9/2}$ band were labeled as uncertain and it is not clear at this time which of those two patterns take place. Therefore continuation of the $\pi h_{9/2}$ band in Ir nuclei will be very important for understanding of band crossings in the odd Ir chain.

5 Conclusion

New high-spin states assigned to $\pi h_{9/2}$ band in ^{187}Ir was reported and the first backbending in the same band was observed at rotational frequency $\hbar\omega \approx 0.38$ MeV. The nature of this backbending could be either from alignment of pair of $i_{13/2}$ neutrons or $h_{9/2}$ protons. We present argument which supports both of the hypothesis. From the experimental data calculated gain of alignment after band crossing is $\Delta i \approx 5\hbar$ and differs from the alignment $\Delta i \approx 7\hbar$ in lighter ^{181,183}Ir.

Although this difference could be explained in case of $(\nu i_{13/2})^2$ alignment process the $(\pi h_{9/2})^2$ alignment is more likely. The later scenario is supported from the upbend observed in the ^{181}Ir at $\hbar\omega \approx 0.38$ MeV rotational frequency. However the last transition in ^{181}Ir is uncertain and $\pi h_{9/2}$ band have different behavior in ^{183}Ir. Therefore it is difficult to draw final conclusion at this time. More experimental work is needed in order to continue $\pi h_{9/2}$ band in ^{181}Ir and ^{183}Ir.

Acknowledgments

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