# High Spin States and Shape Changes in the Transitional $^{185-190}$Ir Nuclei

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**Abstract**

We report new experimental data for the high spin structure of the $^{185-190}$Ir nuclei. These nuclei are located in a transitional region, where a prolate-to-oblate shape change has been observed. As a result, triaxial shapes are expected to stabilize in these nuclei. Triaxial-plus-rotor-calculations for the $\pi h_{9/2}$ bands in the odd-A Ir isotopes have been performed and compared with the experimental data. Chiral rotation, which results from the perpendicular coupling of an odd particle and an odd hole to the triaxial core, is reported for $^{188}$Ir.

## 1 Introduction

Since the discovery of the prolate-to-oblate shape change in the mass A~190 region [1,2], its understanding has been of primary physics interest. In an attempt to shed more light on the evolution of the nuclear structure along the Ir isotope chain in the transitional region we have studied the $\gamma$ decay of the $^{185-190}$Ir isotopes. Triaxial shapes are expected to stabilize as the neutron number increases. We have carried out triaxial-plus-rotor calculations for the $\pi h_{9/2}$ bands in the odd-Ir nuclei in order to extract the triaxiality parameter $\gamma$. Maximal triaxiality ($\gamma \approx -30°$) has been found for $^{189}$Ir.

For these nuclei the Fermi level is at the bottom of the $h_{9/2}$ and $i_{13/2}$ sub-shells for the protons and at the top of the $i_{13/2}$ sub-shell for the neutrons for these isotopes. Chiral rotations, resulting from the perpendicular coupling of the proton particle and the neutron hole to the triaxial core, has been predicted in $^{188}$Ir [3]. Evidence for chiral twin bands has been observed in this nucleus for the $\pi h_{9/2} \otimes \nu i_{13/2}$ configuration [4] and will be commented further in this report.

## 2 Experimental methods

High-spin states in the $^{185-190}$Ir nuclei were populated in fusion-evaporation and break-up reactions. The nuclear $\gamma$ decay has been detected with multidetector $\gamma$-ray spectrometers: the EUROBALL [5] at IReS, Strasbourg and the YRASTBall at WNSL, Yale University [6]. Details about the different experiments are presented in Table 1.

Particle-$\gamma$ coincidences have been used in oder to select the $^{189,190}$Ir reactions channels. The forward scattered $\alpha$ particles, which were produced in break-up reactions, were detected with an array of solar cells. The level schemes of these isotopes have been extended considerably. First $\gamma$ rays from an in-beam experiment have been detetermined for $^{190}$Ir. The data for the different isotopes will be published in detail elsewhere.

| Isotope | Reaction | Energy [MeV] | Spectrometer | Ref. |
|---|---|---|---|---|
| $^{185}Ir$ | $^{181}Ta(^{9}$Be,6n) | 55 | EUROBALL | |
| $^{186}Ir$ | $^{181}Ta(^{9}$Be,5n) | 55 | EUROBALL | |
| | $^{176}Yb(^{15}$N,5n) | 82 | YRASTBall | |
| $^{187}Ir$ | $^{176}Yb(^{15}$N,4n) | 82 | YRASTBAll | [7] |
| | $^{186}W(^{7}$Li,6n) | 52 | YRASTBall | |
| $^{188}Ir$ | $^{186}W(^{7}$Li,5n) | 52 | YRASTBAll | [4] |
| $^{189}Ir$ | $^{186}W(^{11}$B,$\alpha$4n) | 68 | YRASTBall | |
| $^{190}Ir$ | $^{186}W(^{11}$B,$\alpha$4n) | 68 | YRASTBall | |

Table 1: Experimental studies of the $^{185-190}$Ir.

## 3 Triaxial deformations in $^{185,187,189}$Ir

The level schemes of the odd-Ir isotopes have been extended considerably. First we studied the $\pi h_{9/2}$ bands in the odd-Ir isotopes, because a delayed band crossing has been repored in $^{185}$Ir [8]. Alignment plots for these bands are presented in Fig.1.

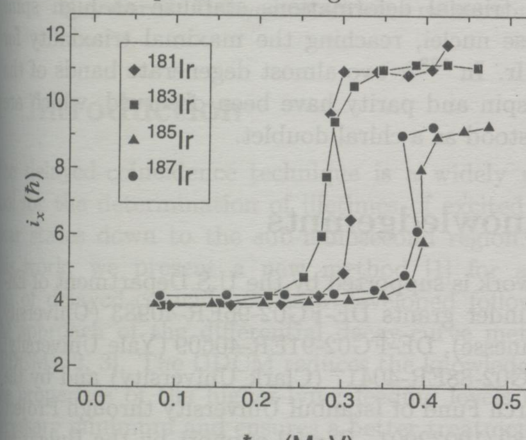


Figure 1: Aligned angular momenta for $\pi h_{9/2}$ bands in $^{181-187}$Ir.

The figure demonstrates that different band crossings take place below $N = 108$ (for $^{181,183}$Ir) and above it (for $^{185,187}$Ir). As mentioned, a delayed backbending was known in $^{185}$Ir [8], but in these experiments we have shown that for $^{185,187}$Ir also the alignment gain differs with $2\hbar$. This has been interpreted as due to the appearance of a shell gap for the neutrons above $N = 108$, which blocks the alignment of a $(\nu i_{13/2})^2$ pair [7]. As a result the secondary proton band crossing becomes possible (the $\pi h_{9/2}$ orbital is occupied and the backbending is due to the rotational alignment of a second pair of $\pi h_{9/2}$ protons). Cranking-shell model calculations indicate that for an axially symmetric nucleus the secondary band crossing has to occur at higher rotational frequencies. On other hand, it is well known, that the increase of the triaxial deformation would bring this band crossing down in rotational frequency. Therefore, we performed triaxial-plus-rotor calculations in order to extract the triaxiality parameter $\gamma$. The calculations demonstrate that the maximal possible deformation $\gamma = -31°$ is stabilized for $^{189}$Ir ($\epsilon_2 = 0.19$). The ASYRMO code has been used for these calculations; for more details see Ref. [9].

## 4 The $\pi h_{11/2} \otimes \nu i_{13/2}$ band in $^{186}$Ir

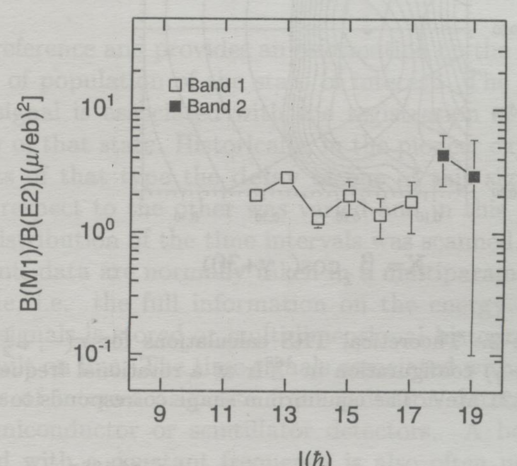


Figure 2: Experimental $B(M1)/B(E2)$ ratio for the $\pi h_{11/2} \otimes \nu i_{13/2}$ (Band 1) and for $\pi[h_{11/2}(h_{9/2})^2] \otimes \nu i_{13/2}$ (Band 2) in $^{186}$Ir

The $\pi h_{11/2} \otimes \nu i_{13/2}$ band in $^{186}$Ir is the only band with this structure, which is known in the doubly-odd Ir isotopes. Therefore, we studied it in some details. A band crossing has been established in this band for the highest known states. The rotational frequency of this crossing is lower, compared to that of the $\pi h_{9/2}$ bands in $^{185,187}$Ir and can be due to the rotational alignment of a $\pi h_{9/2}$ pair: a primary proton crossing, which is not blocked in this case. From the branching ratios of the intra-band and crossover transitions in this sequence we have extracted the experimental ratios of the reduced transition probabilities (B(M1)/B(E2) ratios), which are plotted on Fig.2. The data above the band crossing show an increase of the B(M1)/B(E2) ratios, which is consistent with the suggested proton crossing.

## 5 Chiral rotation in $^{188}$Ir

TRS (total routhian surface) calculations yield a triaxial minimum for the $\pi h_{9/2} \otimes \nu i_{13/2}$ configuration in $^{188}$Ir, as demonstrated in Fig.3. The triaxial shape stabilizes at $\beta_2 = 0.17$ and $\gamma = -31°$. This results is in agreement with the triaxial-plus-rotor calculations, which have been performed for the $\pi h_{9/2}$ bands in the odd-A Ir nuclei. The valence proton occupies the 1/2[541] orbital originating from $h_{9/2}$ sub-shell, while the valence neutron is at the top of the $\nu i_{13/2}$ sub-shell, which can be considered as a hole state in this high-$j$ orbital. The perpendicular coupling of the valence particle and hole to the triaxial core, provides a possibility for a spontaneous breaking of the chiral symmetry.

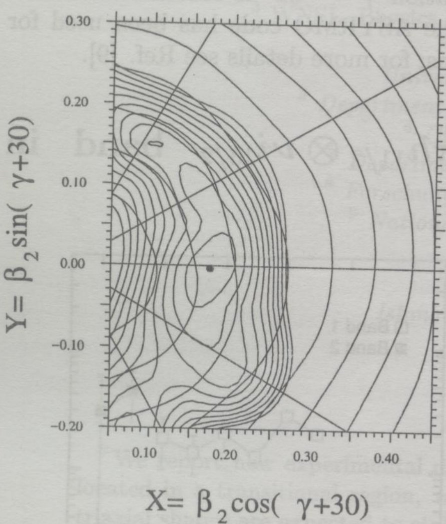


Figure 3: Theoretical TRS calculations for $\pi(-,+\frac{1}{2}) \otimes \nu(+,+\frac{1}{2})$ configuration in $^{188}$Ir at a rotational frequency $\hbar\omega$=0.21 MeV. The equilibrium shape corresponds to $\gamma = -31°$

We have studied the structure of $^{186,188}$Ir in order to find experimental evidence for the existence of chiral doublets bands. In $^{188}$Ir an almost degenerate structure of the same spin and parity has been established parallel to the yrast $\pi h_{9/2} \otimes \nu i_{13/2}$ band, which is built on the top of 4.2 ms isomer (see Fig.4). For more details see Ref. [4]. The detailed analysis of $^{186}$Ir did not reveal the existence of such structure. This might be related to the fact that the traxial deformation of the core in this case is less pronounced and the breaking of the chiral symmetry is less favored.

An interesting feature has been established in $^{188}$Ir: at higher spins an irregular structure becomes yrast, which decays to the $\pi h_{9/2} \otimes \nu i_{13/2}$ band. This is an indication that the triaxial structure compeates with single-patricle states and abrupt band-termination takes place. A similar irrregular structure has been also established in $^{186}$Ir, which decays in this case to the $\pi h_{11/2} \otimes \nu i_{13/2}$ band.

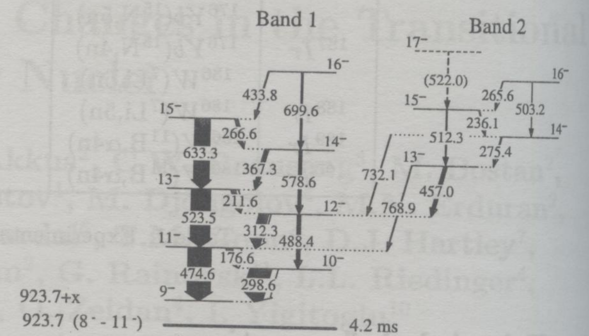


Figure 4: Partial level scheme of $^{188}$Ir, revealing the chiral twin bands in this nucleus

## 6 Summary

We have performed detailed studies of the transitional $^{185-190}$Ir isotopes, which demonastrate that considerable triaxial deformations stabilize at high spins in these nuclei, reaching the maximal triaxiality for $^{188,189}$Ir. In $^{188}$Ir two almost degenerate bands of the same spin and parity have been observed, which are understood as a chiral doublet.

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