Properties of the $\nu 7/2^-[503](f_{7/2})$ band in ^{185}Pt*

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Abstract: High-spin states in ^{185}Pt have been reinvestigated via the reaction ^{173}Yb(^{16}O, 4n) at a beam energy of 90 MeV. The previously known band based on the $\nu 7/2^-[503](f_{7/2})$ Nilsson orbital has been extended to higher spin states. Properties of the $\nu 7/2^-[503](f_{7/2})$ band have been discussed with an emphasis on the evolution of configuration while increasing the spin.

Key words: high-spin state, configuration mixing, Fermi surface

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1 Introduction

In the $A\approx180$ region, the neutron and proton Fermi surfaces are among high-Ω orbitals, therefore the presence of high-K bands near the yrast line would be expected [1]. For the odd-neutron Os-Pt nuclei with mass number around 180, the lowest negative-parity bands can be based on the Nilsson orbitals having the parentage of either "$\nu f_{7/2}$" or "$\nu h_{9/2}$". Furthermore, there may be mixing between neutron Nilsson states having the same angular momentum projections, Ω, on the nuclear symmetry axis. Negative-parity bands with pure configurations of $\nu 7/2^-[503]$ and $\nu 7/2^-[514]$ have been reported in ^{187}Pt [2] and ^{183}Pt [3], respectively. Therefore, the spectroscopic information in ^{185}Pt becomes of particular interest for probably revealing configuration mixing phenomenon as it lies between the two nuclei ^{187}Pt and ^{183}Pt. The present work aims at extending the level scheme of ^{185}Pt to higher spin states via heavy-ion induced reactions and studying the structural properties of the negative-parity band. Prior to the present work, high-spin states of ^{185}Pt were reported in the literature [4].

2 Experimental procedure and results

In order to obtain information about the excited states in ^{185}Pt, we have carried out a standard in-beam γ-ray spectroscopy experiment at the Japan Atomic Energy Agency (JAEA). A 2.1 mg/cm^2 isotopically enriched ^{173}Yb foil with a 7.0 mg/cm^2 Pb backing was bombarded by a ^{16}O beam delivered from the JAEA tandem accelerator. γ-γ-t coincidence measurement was performed at the beam energy of 90 MeV, at which energy the yield of ^{185}Pt was large. The GEMINI [5] γ-ray detector array was used. At the time of this experiment, the array consisted of 13 HPGes with BGO anti-Compton shields. Six of the detectors had an efficiency of 40% and the others had 70% relative to $3'' \times 3''$ NaI. The energy calibration was made by using ^{133}Ba and ^{152}Eu standard sources both before and after the experiment. The typical energy resolution was about 2.0–2.4 keV at FWHM

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for the 1332.5 keV line of ^{60}Co.

Data were recorded in an event-by-event mode, requiring the simultaneous firing of at least two detectors within 200 ns. The coincidence data were sorted into a 4 k×4 k matrix for off-line analysis. To obtain the multipolarity information of emitting γ rays, the detectors were divided into 3 groups positioned at 40° (140°), 58° (122°), and 90° with respect to the beam direction. A nonsymmetrized matrix with detectors at θ_2=90° against those at θ_1=40° (140°) was constructed so that the DCO (Directional Correlations of γ rays de-exciting the Oriented states) ratios could be extracted using the method described in Ref. [2].

The previously known $\nu 7/2^-[503](f_{7/2})$ band [4] in ^{185}Pt has been extended and is shown in Fig. 1. The spins and parities for the known low-lying states were adopted from the previous work [6], and these values were used as references for the spin and parity assignments of the higher spin states. Prior to this work, the two signatures were known up to $27/2^-$ and $29/2^-$ states, respectively [4]. In the present study, one signature was extended to the $35/2^-$ state and the other one was extended to a tentative state of $33/2^-$.

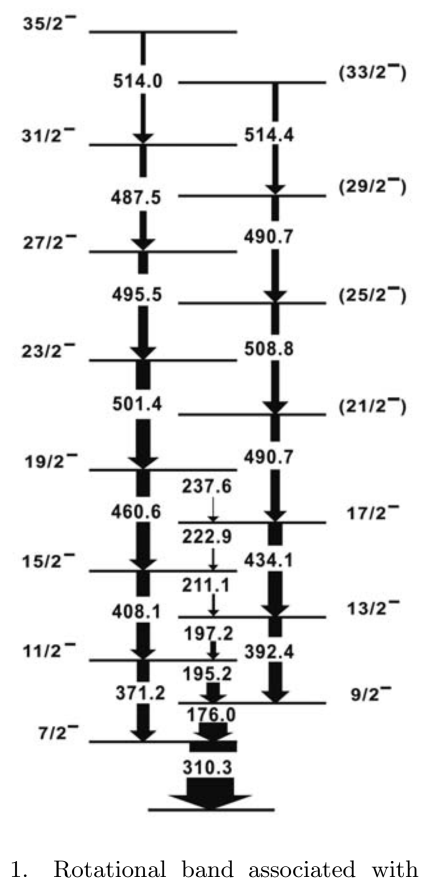

Fig. 1. Rotational band associated with the $\nu 7/2^-[503](f_{7/2})$ configuration in ^{185}Pt.

Furthermore, compared with the level scheme in Ref. [4], transitions between the two signatures above the 237.6 keV γ ray were not observed in the present experiment and the observed intensities have necessitated a reordering of the earlier reported sequences. Consequently, we interchanged the ordering of the 495.5 and 501.4 keV transitions according to the γ-ray relative intensities. To illustrate the quality of the data and highlight some important features of the level scheme, examples of γ-ray coincidence spectra are given in Figs. 2–3. The coincidence spectra gated on the 487.5 and 514.0 keV transitions (Fig. 2) illustrate the extensions of the band, and γ rays in this band can be clearly seen. The spectra gated on 310.3 and 176.0 keV transitions (Fig. 3) indicate the ordering of 501.4 and 495.5 keV γ rays in the decay paths, and the intensity arguments of the two transitions are clearly shown. A new 514.4 keV transition has been found in coincidence with 490.7 and 508.8 keV as well as other low-lying transitions of this band. However,

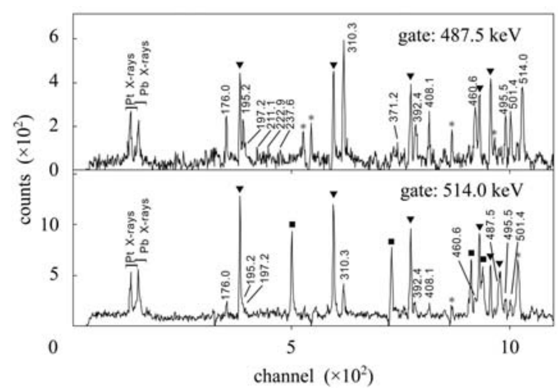

Fig. 2. Coincidence spectra gated on the 487.5 and 514.0 keV γ rays. The triangles and squares indicate contaminations from ^{186}Pt and another rotational band of ^{185}Pt, respectively. The asterisks indicate other contaminations.

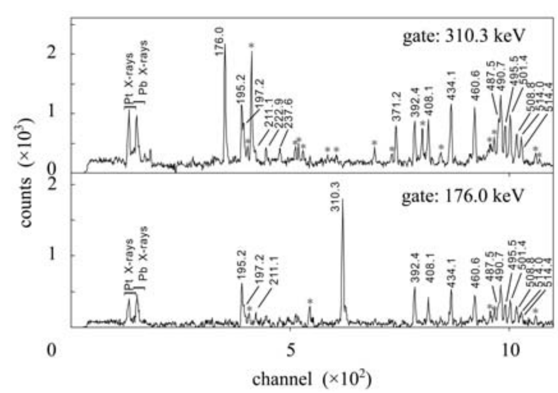

Fig. 3. Coincidence spectra gated on the 310.3 and 176.0 keV γ rays. The asterisks indicate contaminations.

this assignment is not conclusive due to the presence of 514.0 keV transition in the other signature. Therefore, we tentatively assigned 514.4 keV γ ray as $33/2^- \rightarrow 29/2^-$ transition.

The experimental γ-ray branching ratios $\lambda = T_\gamma(I \rightarrow I-2)/T_\gamma(I \rightarrow I-1)$ were extracted in the present work to deduce the reduced transition probability ratios. Here, $T_\gamma(I \rightarrow I-2)$ and $T_\gamma(I \rightarrow I-1)$ represent the γ-ray intensities of the ΔI=2 and ΔI=1 transitions, respectively. These intensities were measured from the coincidence spectra gated on the transition above the level of interest. The ratios of the reduced transition probabilities have been deduced according to the formula [7]

$$\frac{B(\mathrm{M1}; I \rightarrow I-1)}{B(\mathrm{E2}; I \rightarrow I-2)} = 0.697 \frac{[E_\gamma(I \rightarrow I-2)]^5}{[E_\gamma(I \rightarrow I-1)]^3 \lambda(1+\delta^2)} \left(\frac{\mu_\mathrm{N}^2}{\mathrm{e}^2\mathrm{b}^2}\right),$$

where E_γ are the γ-ray energies in MeV, δ corresponds to the E2/M1 mixing ratio in the ΔI=1 transition, and $E_\gamma(I \rightarrow I-2)$ and $E_\gamma(I \rightarrow I-1)$ are the ΔI=2 and ΔI=1 transition energies, respectively. The value δ=0 has been used in the present analysis because it has hardly any effect on the deduced ratios.

3 Discussion

Information about the structure of the rotational band can be obtained by comparing the theoretical B(M1)/B(E2) values with the experimental ones. The theoretical B(M1)/B(E2) ratios have been estimated using the semiclassical formula [8, 9]

$$\frac{B(\mathrm{M1}; I \rightarrow I-1)}{B(\mathrm{E2}; I \rightarrow I-2)} = \frac{12}{5Q_0^2 \cos^2(\gamma + 30^\circ)} \left[1 - \frac{K^2}{(I-1/2)^2}\right]^{-2} \frac{K^2}{I^2} \times \left\{(g_1 - g_\mathrm{R})\left[(I^2-K^2)^{1/2} - i_1\right]\right\}^2 \left(\frac{\mu_\mathrm{N}^2}{\mathrm{e}^2\mathrm{b}^2}\right).$$

In the formula, Q_0 is the intrinsic quadrupole moment in units of eb, K is the nominal band head, γ represents the degree of triaxiality, i_1 denotes aligned angular momentum for the strongly coupled particle, and g_1 and g_R refer to the gyromagnetic factors for the corresponding Nilsson orbital and collective rotation, respectively. Fig. 4 shows the calculated B(M1)/B(E2) values till the band crossing and the experimental data whatever available for ^{187}Pt, ^{185}Pt, and ^{183}Pt. The parameters used in the calculations are presented in Table 1. It should be pointed out that the Nilsson labels associated with each configuration are strictly valid only at $\hbar\omega$=0 MeV. For convenience, each band is labeled with Nilsson notation, although it is recognized that rotational perturbations may lead to configuration mixing. As illustrated in Fig. 4, the experimental values of ^{187}Pt and ^{183}Pt can be well reproduced by the configurations of $\nu 7/2^-[503](f_{7/2})$ and $\nu 7/2^-[514](h_{9/2})$, respectively. However, for the case of ^{185}Pt, the experimental observations are in close agreement with the predicted values associated with the $\nu 7/2^-[503](f_{7/2})$ configuration in the low spin states. As the nucleus rotates faster, the experimental values gradually become reasonably consistent with the calculated values associated with the $\nu 7/2^-[514](h_{9/2})$ configuration. Similar results were found for the negative-parity bands in the corresponding isotones of ^{181}Os [10], ^{183}Os [1] and ^{185}Os [11], where the calculated g-factor values were compared with the experimental data. Therefore, we propose that there be mixing between the two configurations in the negative-parity band of ^{185}Pt and that the dominant component changes from

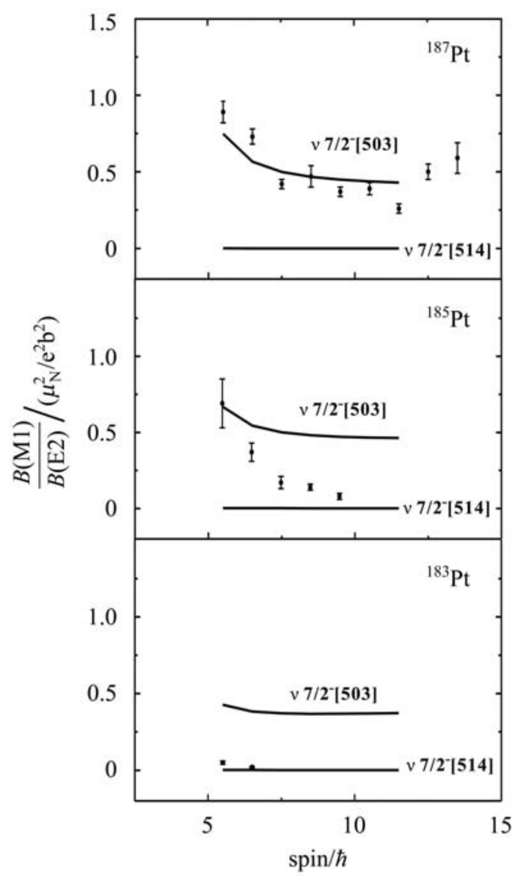

Fig. 4. Comparison of the experimental and calculated B(M1)/B(E2) ratios for the negative-parity bands in ^{187,185,183}Pt. The experimental data sources are: ^{187}Pt [2], ^{185}Pt [this work], ^{183}Pt [3].

Table 1. Parameters used in the calculations of $B(\mathrm{M1})/B(\mathrm{E2})$ ratios.

nucleus	configuration	g_R	g_1	Q_0	γ	K	i_1
^{187}Pt	$\nu 7/2^-[503]$	0.25[a]	−0.34[b]	5.70[a]	0	3.5	0.5[c]
	$\nu 7/2^-[514]$	0.25[a]	0.26[b]	5.70[a]	0	3.5	0.5[c]
^{185}Pt	$\nu 7/2^-[503]$	0.30[b]	−0.34[b]	5.67[a]	0	3.5	1.0[d]
	$\nu 7/2^-[514]$	0.30[b]	0.26[b]	5.67[a]	0	3.5	1.0[d]
^{183}Pt	$\nu 7/2^-[503]$	0.30[b]	−0.34[b]	6.00[b]	0	3.5	1.5[e]
	$\nu 7/2^-[514]$	0.30[b]	0.26[b]	6.00[b]	0	3.5	1.5[e]

*The data sources are: (a) Ref. [11], (b) Ref. [1], (c) Ref. [2], (d) Ref. [4], (e) Ref. [3].

$\nu 7/2^-[503](f_{7/2})$ to $\nu 7/2^-[514](h_{9/2})$ while increasing the spin. In order to confirm such a suggestion, particle-rotor model calculations of the wave function evolution are needed.

To interpret this property, one can consider the change of the neutron Fermi surface while increasing the mass number. In the nuclei of N=107 (^{185}Pt and ^{183}Os), both $\nu 7/2^-[503](f_{7/2})$ and $\nu 7/2^-[514](h_{9/2})$ orbitals get closer to the Fermi surface. This is supported by the systematics of the Nilsson single-particle states in the $N = 107$ isotones [12], as shown in Fig. 5. The level spaces of the bandhead energies between $\nu 7/2^-[503](f_{7/2})$ band and $\nu 7/2^-[514](h_{9/2})$ band are minimized at ^{185}Pt (with 140 keV) and ^{183}Os (with 120 keV). This maximizes the possibility of configuration mixing between the two Nilsson orbitals while increasing the spin in ^{185}Pt and ^{183}Os.

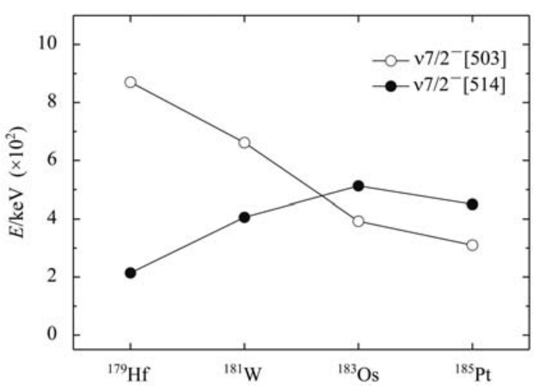

Fig. 5. Systematics of the Nilsson single-particle states in the N=107 isotones [12]. The data sources are ^{179}Hf [13], ^{181}W [14], ^{183}Os [1], ^{185}Pt [6].

4 Summary

High-spin states in ^{185}Pt have been reinvestigated via the ^{173}Yb(^{16}O, 4n)^{185}Pt fusion-evaporation reaction. The previously known band based on $\nu 7/2^-[503](f_{7/2})$ Nilsson orbital has been extended to higher spin states. From the comparison of the theoretical $B(\mathrm{M1})/B(\mathrm{E2})$ values with the experimental ones, configuration evolution from $\nu 7/2^-[503](f_{7/2})$ Nilsson orbital to $\nu 7/2^-[514](h_{9/2})$ Nilsson orbital while increasing the spin has been proposed in ^{185}Pt. In contrast, the lowest negative-parity bands in ^{187}Pt and ^{183}Pt were suggested to be based on rather pure $\nu 7/2^-[503](f_{7/2})$ and $\nu 7/2^-[514](h_{9/2})$ configurations, respectively. Similar results were found for the corresponding bands in respective isotones of ^{181}Os, ^{183}Os and ^{185}Os. This phenomenon can be understood by the change of the neutron Fermi surface while changing the neutron number.

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