The "pair" current is suppressed, so we get just the "$\omega\pi$" exchange current of Ref. 6, the only parameter of the theory being F_ω. The net effect is to drop g_T' from Eq. (3), giving rise to a unique relation for λ in terms of ζ. To see whether this model makes sense, it is necessary to evaluate g_T from the current (10). We are unable to do this fully satisfactorily, but we can get an order-of-magnitude idea by saturating the matrix element of Eq. (10) by nucleon intermediate states alone.[6,17] The results depend rather sensitively on the cutoff mass M used in the πNN and ωNN form factors. For a common mass $M = 0.9$ GeV (1 GeV), we obtain a ratio $\lambda/\xi = 4.90$ MeV (-4.02 MeV) which agrees in sign and in order of magnitude with the empirical value -1.6 ± 0.5 MeV. In view of our ignorance on the contributions from other intermediate states, this may not be too significant; however, the rough agreement suggests that this simple one-parameter model is not utterly absurd.

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*Permanent address: Department of Physics, University of Tokyo, Tokyo, Japan.

†Permanent address: Institut de Physique Nucléaire, Université Claude Bernard, Lyon I, France, and Institut National de Physique Nucléaire et de Physique des Particules, 69621 Villeurbanne, France.

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Quadrupole Moment of the Second 2^+ State of ^{184,186}W†

J. J. O'Brien, J. X. Saladin, C. Baktash, and J. G. Alessi

Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania 15260

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We have performed a thick-target particle-γ coincidence experiment to measure $q(2^{+\prime})$, the quadrupole moment of the second 2^+ state, of ^{184,186}W. We have also determined $q(2^{+\prime})$ of ^{186}W by an independent method involving particle spectroscopy. Neither the rotation-vibration nor the asymmetric rotor model can explain the results. Kumar-Baranger calculations agree with the trend.

Much systematic information has now been obtained on the spectroscopic quadrupole moment of first excited nuclear states via the reorientation effect. Little is known of the higher-lying states, since such experiments require high-precision measurements which become more difficult with increasing excitation energy. It is of interest to extend these measurements to higher-lying collective levels which are not members of the ground-state band and whose nature is less well understood. ^{186}W and ^{184}W each have a second 2^+ state, at 737 and 904 keV, respectively, of a collective nature. In the simplest collective models, these states would be interpreted either as γ vibrations built on an axially symmetric ground state or as band heads of $K=2$ bands of an asymmetric rotor. Both models predict a $2^{+\prime}$ quadrupole moment substantially larger than that predicted by Kumar and Baranger calculations. To determine the nature of these $2^{+\prime}$ states we have performed a series of experiments to measure their quadrupole moments. We have developed a method whereby the required information is obtained from the de-excitation γ rays. Thick targets of natural isotopic abundances are used and so measurements may be made on several isotopes simultaneously. One then has a high degree of confidence in the relative quadrupole moments extracted.

Experimentally, a tungsten target thick enough to stop the beam (250 mg/cm^2) was bombarded, first with 13.5-MeV α particles, then with 54-MeV ^{16}O ions. γ rays emitted at 55° to the beam direction were detected in coincidence with backscattered particles using a Ge(Li) detector with nominal active volume of 66 cm^3 (see spectrum in Fig. 1). The geometry of the experiment was not changed when the projectile type was changed. Thus accurate knowledge of factors such as the Ge(Li) efficiency, detector solid angles, etc., was not required. The γ-ray energy, particle energy, and timing information were logged on tape, event by event. These data were analyzed off-line to extract the coincident γ-ray spectra and, also, to determine the contributions of γ rays in random coincidence. The latter was typically a 15% subtraction. To monitor the integrated beam on target we used the coincidence γ-ray yields of the 2^+ to 0^+ transitions.

The yield of γ rays in coincidence with backscattered particles was calculated using the semiclassical code of Winther and de Boer and integrated over the effective target thickness. The matrix elements $\langle 0^+ \| \mathfrak{M}(E2) \| 2^+ \rangle$ and $\langle 0^+ \| \mathfrak{M}(E4) | \times | 4^+ \rangle$ were taken from the literature.[1,2] From these values all the other $E2$ and $E4$ matrix elements connecting the first four members of the ground-state band were calculated, using the rigid-rotor model. The matrix element $\langle 0^+ \| \mathfrak{M}(E2) | \times | 2^{+\prime} \rangle$ and the ratio of $B(E2; 0^+ \to 2^{+\prime})$ to $B(E2; 2^+ \to 2^{+\prime})$ were taken from Baktash *et al.*[3] and Milner *et al.*[4] The calculation also requires the stopping power of the target material.[5] In the projectile energy range 0.1 to 1 MeV the stopping powers were modified to fit the data of Ziegler and Chu[6] in the manner proposed by Guidry *et al.*[7] Corrections were applied for γ-ray absorption in the target and for the finite solid angle subtended by the Ge(Li) detector. A quantum mechanical correction was obtained by comparing the full quantum

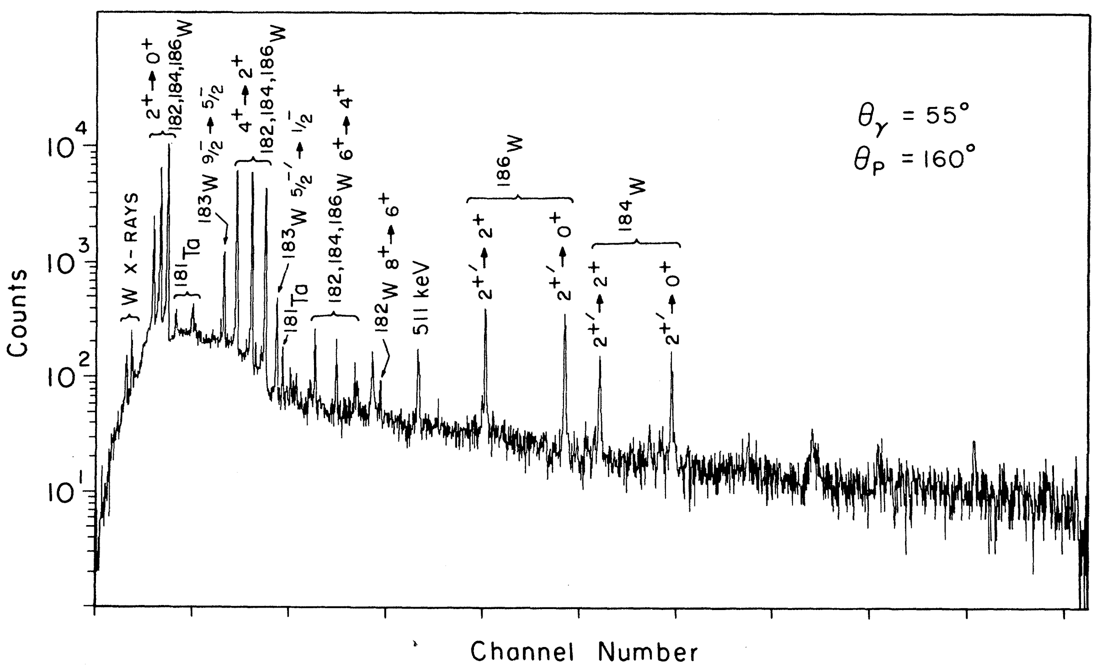

FIG. 1. Spectrum of γ rays in coincidence with backscattered particles.

TABLE I. $q(2^{+\prime})$ in electron barns.

	$\mathrm{sgn}P_4$	^{184}W	^{186}W
Particle-γ	−	$0.1^{+0.4}_{-0.3}$	1.1 ± 0.3
Coincidence	+	$-2.6^{+0.5}_{-0.4}$	$-0.8^{+0.5}_{-0.4}$
Particle	−		1.6 ± 0.5
Spectroscopy	+		1.1 ± 0.9
Adopted value	−	$0.1^{+0.4}_{-0.3}$	1.3 ± 0.3
McGowan *et al*	−		0.74 ± 0.42

[a]Result of Ref. 12.

mechanical code AROSA[8] with the semiclassical results.

In a second experiment, particles scattered elastically and inelastically from a thin enriched ^{186}W target (10–20 μg/cm^2) were analyzed. This method has been reported previously.[9] With ^{16}O projectiles, six spectra of varying resolution and total number of counts were obtained. The energy separation of the $2^{+\prime}$ and 6^+ states is 71 keV. These peaks could not be resolved. According to semiclassical calculations, the 6^+ peak should be about 10% of the $2^{+\prime}$ peak. The counts attributed to the $2^{+\prime}$ peak were adjusted accordingly. Results from the various spectra were combined to obtain the final estimate of $q(2^{+\prime})$. The major sources of uncertainty are the low statistics of the ^{16}O data and the difficulties in separating the peaks.

The experimental results are presented in Table I. As the relative signs of the $E2$ matrix elements connecting the 0^+ to $2^{+\prime}$ and 2^+ to $2^{+\prime}$ states are not known, there is an ambiguity in the quadrupole moments extracted. This is usually discussed in terms of the sign of P_4, which is the product of the four matrix elements $\langle 0^+ \| \mathfrak{M}(E2) \| 2^+\rangle$, $\langle 0^+ \| \mathfrak{M}(E2) \| 2^{+\prime}\rangle$, $\langle 2^+ \| \mathfrak{M}(E2) \| 2^+\rangle$, and $\langle 2^+ \| \mathfrak{M}(E2) \| 2^{+\prime}\rangle$. Quadrupole moments were determined for both signs of P_4.

In the case of ^{186}W, where we have data on the ratio of the $2^{+\prime}$ to the 2^+ excitation cross section and on the $2^{+\prime}$ to the elastic cross section, one may determine both $q(2^{+\prime})$ and P_4, if the 2^+ state is assumed to be a rotational state built on a prolate intrinsic shape. The results of the two experiments are consistent only when P_4 is chosen to be negative, as is expected theoretically. This should be contrasted with the work of Baker *et al.*[10] in ^{194}Pt, where the sign opposite to the theoretical prediction was found. The present result has the virtue of being model independent, the only assumption being on the nature of the 2^+

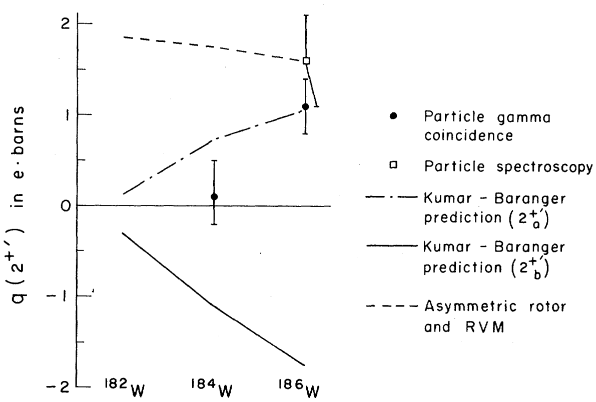

FIG. 2. Experimental values of $q(2^{+\prime})$, for P_4 negative, and the model predictions. Kumar-Baranger calculations predict two $2^{+\prime}$ states (see text).

state. With this choice of P_4, the values of $q(2^{+\prime})$ obtained from the two experiments are in good agreement.

The striking feature of the data is the rapid drop in the value of $q(2^{+\prime})$ in going from ^{186}W to ^{184}W. The predictions of the asymmetric rotor model (ARM) and the rotation-vibration model (RVM) are very similar for this state. ARM predicts the quadrupole moment of the $2^{+\prime}$ state to be equal in magnitude but opposite in sign to that of the 2^+ state, while according to RVM $q(2^{+\prime})$ is approximately $-0.98q(2^+)$. Both ARM and RVM predict P_4 to be negative and $q(2^{+\prime})$ to increase slowly with decreasing mass for the tungsten isotopes. This is in marked contrast with the experimental results, as is seen in Fig. 2.

Kumar and Baranger[11] predict two $2^{+\prime}$ states beyond the first excited state for the tungsten isotopes, referred to here as $2_a^{+\prime}$ and $2_b^{+\prime}$. P_4 is negative for both. The predictions of this calculation for $B(E2)$ values and $q(2^{+\prime})$ are compared with experiment in Table II. While the numerical agreement is not as good as would be desired, one is tempted to associate the experimental results with the $2_a^{+\prime}$ state. In particular, $q(2_a^{+\prime})$ is opposite in sign to $q(2^+)$ and decreases with decreasing mass in going from ^{186}W to ^{184}W to ^{182}W. In the present experimental arrangement, Doppler broadening of the $2^{+\prime}$ γ rays prevented us from measuring $q(2^{+\prime})$ of ^{182}W.

The $2^{+\prime}$ states of ^{184}W and ^{186}W appear quite different in nature. Both nuclei have ground-state bands which are well described by the rigid-rotor model. Hence both nuclei are believed to be well deformed in the ground state. The $2^{+\prime}$ state of ^{184}W has a quadrupole moment close to zero,

TABLE II. Comparison of the two $2^{+\prime}$ states of Kumar and Baranger with experimental results. Values of $B(E2; 2^+ \to 2^{+\prime})$ were derived from $B(E2; 0^+ \to 2^{+\prime})$, using the branching ratios of Ref. 4.

	$2_a^{+\prime}$	$2_b^{+\prime}$	Expt.
	^{184}W		
$B(E2; 0^+ \to 2^{+\prime})$	0.085	0.135	0.138
$B(E2; 2^+ \to 2^{+\prime})$	0.176	0.007	0.050
$g(2^{+\prime})$	0.736	−1.097	0.1
	^{186}W		
$B(E2; 0^+ \to 2^{+\prime})$	0.154	0.083	0.139
$B(E2; 2^+ \to 2^{+\prime})$	0.302	0.002	0.064
$g(2^{+\prime})$	1.053	−1.735	1.3

which implies that its average deformation is small. This is in contrast with ^{186}W where the $2^{+\prime}$ state is well deformed. Two-neutron-transfer reactions have previously provided evidence of the coexistence of nearly spherical and deformed nuclear states in regions of the periodic table where a rapid shape transition occurs. Excited states of such small deformation have not previously been found in permanently deformed nuclei.

The calculations of Kumar and Baranger fit the trend of the present data quite well. For the tungsten isotopes, this calculation predicts a strong coupling between the β and γ bands. In this model, this is the source of the reduced value of $q(2^{+\prime})$. This strong coupling is also supported by the large $B(E2)$ values connecting the β and γ bands in ^{184}W.

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High-Spin States in ^{183}Ir and ^{185}Ir Nuclei: Is the Breaking of a Few Pairs of Nucleons Responsible for the Backbending Effect in the Osmium Region?*

S. André, J. Genevey-Rivier, and J. Treherne
Institut des Sciences Nucléaires, 38044 Grenoble, France

and

J. Jastrzebski, R. Kaczarowski, and J. Łukasiak
Department of Physics, Institute for Nuclear Research, 05-400 Swierk, Poland
(Received 1 November 1976)

High-spin levels of the rotation-aligned bands built on the $h_{9/2}$ subshell in ^{183}Ir and ^{185}Ir have been populated by $(\alpha, 6n\gamma)$ and $(\alpha, 4n\gamma)$ reactions. In ^{183}Ir a rapid increase in the apparent moment of inertia has been observed at high spins. The implication of this result for the interpretation of backbending phenomena in even nuclei in this mass region is discussed.

The anomalies exhibited by the nuclear moment of inertia of many deformed nuclei at high rotational velocities has been described by two competing microscopic models: the Coriolis antipairing[1,2] and the rotational alignment model.[3] Although the possibility that both effects contribute to the backbending phenomena cannot be excluded,[4] it seems now that the decisive contribu-