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*Short note*

# Spin and parity values of states of dipole bands in $^{194}$Pb

M. Kaci[1,2], M-G. Porquet[1], Ch. Vieu[1], C. Schück[1], A. Astier[3], F. Azaiez[2], C. Bourgeois[2], I. Deloncle[1], J.S. Dionisio[1], J. Duprat[2], F. Farget[4,a], B.J.P. Gall[1,5], L. Han[5], A. Korichi[2,1], Y. Le Coz[3,b], M. Pautrat[2], N. Perrin[2], D. Santos[4], H. Sergolle[2]

[1] CSNSM, IN2P3-CNRS, F-91405 Orsay Campus, France
[2] IPN, IN2P3-CNRS, F-91406 Orsay Cedex, France
[3] IPN Lyon, IN2P3-CNRS, F-69622 Villeurbanne, France
[4] ISN, IN2P3-CNRS, 38026 Grenoble, France
[5] IReS, IN2P3-CNRS, F-67037 Strasbourg, France

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**Abstract.** Spin and parity values of the states of two dipole bands in $^{194}$Pb have been determined from internal conversion and linear polarisation measurements. The multiparticle configurations assigned previously to these dipole bands are discussed within these results.

**PACS.** 23.20.Nx Internal conversion and extranuclear effects – 21.10.Hw spin, parity, and isobaric spin – 27.80.+w $190 \leq A \leq 219$

Numerous dipole bands have been observed in neutron deficient lead isotopes, from A=192 to 202[1]. For A≤197, most of the known dipole bands have been connected to the low-lying states enabling their excitation energy to be known. However, the spin values of their states have been only determined from DCO ratios or angular distribution analyses, and therefore parity is not known. The M1 multipolarity of the transitions belonging to these bands has been first suggested from the intensity balance within the bands and has been confirmed later by the measurement of internal conversion in $^{199}$Pb[2] and $^{195}$Pb[3]. In $^{194}$Pb, two dipole bands have been observed and their linking transitions to the yrast states well established[4,5]. We report here on the measurements of spin and parity of the states of these bands and we discuss their configurations, previously assigned[5] from the comparison of the excitations observed in the isotones, $^{194}$Pb and $^{192}$Hg.

Excited states in $^{194}$Pb have been populated using the $^{182}$W($^{16}$O,4n) reaction at a bombarding energy of 95 MeV. The beam was provided by the MP Tandem of Orsay. Runs have been performed using two different self-supported $^{182}$W targets oriented at 30° with regard to the beam axis, with respective thickness 500 $\mu$g/cm$^2$ and 250 $\mu$g/cm$^2$. The electron spectrometer, consisting of a Kleinheinz magnetic lens, with a transmission T=(4.11±0.15)x10$^{-2}$, coupled to a 4mm-thick Si(Li) detector, was oriented at 90° with respect to the beam direction[6]. The limits of the variable magnetic field inside the lens was chosen for detecting electrons in the energy range [40-700 keV]. A clover detector, consisting of four closely packed germanium detectors[7,8], located in front of the magnetic lens, has been used to detect the $\gamma$-rays emitted in the reaction and to perform linear polarization measurements. Six fast $BaF_2$ scintillators, surrounding the target, have been used as trigger. The electron and $\gamma$ spectra have been incremented when at least one $BaF_2$ scintillator fired in prompt coincidence with either one of the germaniums of the clover detector or with the Si(Li) detector.

Figure 1 shows an example of an electron spectrum obtained with the 250 $\mu$g/cm$^2$ target. The internal conversion coefficients, $\alpha_{exp}$, in the K and/or L subshells, have been normalized to reproduce theoretical values of known E1 (442 keV) and E2 (609 keV) transitions of $^{194}$Pb[9]. The linear polarization values given in table 1, $P_{exp} = (1/Q)A_{exp}$, have been extracted using the sensitivity Q values determined from known transitions of $^{194}$Pb[9] and the curve given in[8].

The multipolarity of the 515 keV dipole transition, which connects band 1 to the known $I^\pi$=15$^-$ state, has been measured to be M1 (with a small E2 admixture). The magnetic character of this transition is also confirmed by the negative value of the linear polarisation. The spin and the parity of the first state of band 1, located at 4963 keV, is then $I^\pi$=16$^-$. The decay out of band 2 is very frag-

[a] present adress: GSI, 64291 Darmstadt, Germany
[b] present address: DAPNIA, CEA, 91190 Gif/Yvette, France

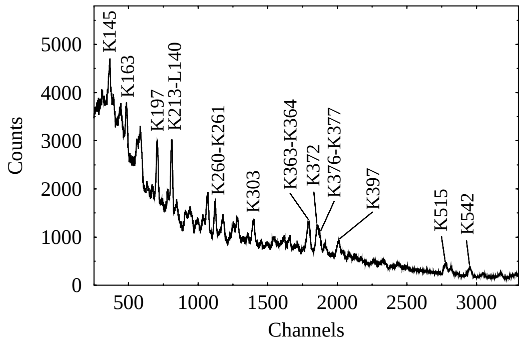


**Fig. 1.** Electron spectrum measured using the 250 $\mu$g/cm$^2$ target

mented and its decay intensity spreads over many different states. The 140 keV transition, which has been found to link band 2 to known states[3] has been analyzed from the data obtained with the thin target. The M1 (+E2) multipolarity of this transition has been extracted from its K-line ($E_e$=52 keV), thanks to the very low threshold of our apparatus. It is worth noting that its L-line could not be analyzed because it is obscured by the intense K-line of the 213 keV transition of $^{193}$Pb, also produced in the reaction. Thus, the spin and the parity values of the band-head of band 2 located at 4376 keV, has been measured to be $I^\pi$=13$^+$.

Moreover, the M1 multipolarity of the stretched dipole transitions belonging to the two dipole bands are well established up to spin 23$\hbar$. The negative values of the linear polarisation also confirms their magnetic character. The spin and parity values for the states of the two bands are given in table 1.

Configurations associated to the two dipole bands have been already proposed from the comparison of the excitations in the two isotones $^{194}$Pb and $^{192}$Hg[5], corresponding to slightly deformed nuclei with oblate deformation. The present measurements of spin and parity of the band heads support the previously assigned configurations, in which angular momenta of protons and neutrons are coupled perpendicularly : $\{(\pi h9/2\pi i13/2)_{K=11^-} \otimes (\nu i13/2)^2_{J=12^+}\}I^\pi$= 16$^-$ and $\{(\pi h9/2\pi i13/2)_{K=11^-} \otimes (\nu p3/2$ or $f5/2\nu i13/2)_{J=7^-}\}I^\pi$=13$^+$, respectively. It is worth noting that a crossing has been observed in band 2 between spin I=20-22$\hbar$, which corresponds to the breaking of a $(\nu i13/2)^2$ pair. Moreover the extension of the two bands to higher spin than previously known[10,3] exhibits clearly a crossing on the top of band 1 while the transition energies of band 2 continue to be regularly spaced from spin I=22$\hbar$ up to the highest spin observed (I=33$\hbar$). Such a behaviour is expected from the number of aligned i13/2 neutrons involved in these structures. It is interesting to notice that the same behaviour occurs also in $^{192}$Hg for the positive parity band and the negative parity bands, respectively, which have also been recently extented to higher spin[11]. This means that even at higher spin than previously established[5,12], the excitations of neutrons in $^{192}$Hg and $^{194}$Pb remain very similar.

**Table 1.** Linear polarisation, $P_{exp}$, and internal conversion coefficients, $\alpha_{exp}$, measured for the transitions of the dipole bands and for some other transitions involved in their decay

| $E_\gamma$(keV) | $P_{exp}$x10$^2$ | $\alpha_{exp}$x10 | Mult. | $I_i^\pi \rightarrow I_f^\pi$ |
|---|---|---|---|---|
| **Band1** | | | | |
| 119 | | 4.7±0.9$^{b)}$ | M1 | $17^- \rightarrow 16^-$ |
| 145 | | 4.5±0.5$^{b)}$ | M1 | $18^- \rightarrow 17^-$ |
| 197$^{a)}$ | | 7.9±0.9 | M1+E2 | $19^- \rightarrow 18^-$ |
| 260$^{a)}$ | -65±11 | 5.4±0.5 | M1 | $20^- \rightarrow 19^-$ |
| 336 | -46±12 | 2.0±0.5 | M1 | $21^- \rightarrow 20^-$ |
| 376$^{a)}$ | -23±13 | 1.9±0.5 | M1 | $22^- \rightarrow 21^-$ |
| 417 | | 1.1±0.3 | M1 | $23^- \rightarrow 22^-$ |
| **Band2** | | | | |
| 130 | | 5.3±0.9$^{b)}$ | M1 | $14^+ \rightarrow 13^+$ |
| 137 | | 8.5±1.3$^{b)}$ | M1 | $15^+ \rightarrow 14^+$ |
| 163 | | 16±5 | M1 | $16^+ \rightarrow 15^+$ |
| 303$^{a)}$ | | 2.1±0.5 | M1+E2 | $17^+ \rightarrow 16^+$ |
| 377$^{a)}$ | -23±13 | 1.9±0.5 | M1 | $19^+ \rightarrow 18^+$ |
| 363$^{a)}$ | -38±8 | 2.0±0.6 | M1 | $20^+ \rightarrow 19^+$ |
| 397 | -48±9 | 1.7±0.5 | M1 | $18^+ \rightarrow 17^+$ |
| 228 | | 5.6±0.8 | M1 | $23^+ \rightarrow 22^+$ |
| 261$^{a)}$ | -65±11 | 5.4±0.5 | M1 | $21^+ \rightarrow 20^+$ |
| **Others** | | | | |
| 140 | | 1.1±0.3 | M1+E2 | $13^+ \rightarrow 12^+$ |
| 326 | +24±4 | 0.5±0.1 | E2 | $18^- \rightarrow 16^-$ |
| 364$^{a)}$ | -38±8 | 2.0±0.6 | M1 | $13^- \rightarrow 12^-$ |
| 372 | -26±4 | 2.3±0.5 | M1 | $16^- \rightarrow 15^-$ |
| 442 | +27±14 | 0.09±0.02 | E1 | $15^- \rightarrow 14^+$ |
| 515 | -19±9 | 0.81±0.05 | M1+E2 | $16^- \rightarrow 15^-$ |
| 542 | -20±10 | 0.56±0.05 | M1+E2 | $12^- \rightarrow 11^-$ |
| 609 | | 0.17±0.05 | E2 | $15^- \rightarrow 13^-$ |
| 659 | | 0.15±0.05 | E2 | $18^+ \rightarrow 16^+$ |
| 906 | +38±19 | | E2 | $13^- \rightarrow 11^-$ |

a) Doublets
b) From L-lines. The other values of $\alpha_{exp}$ are from K-lines

In conclusion, we have established through conversion electron as well as linear polarization measurements the M1 multipolarity of the transitions within two dipole bands in $^{194}$Pb. Some transitions connecting these two bands to known low-lying states have been also measured. This has allowed us to determine for the first time the spin and parity values of the states of such bands. These results support the configurations which had been previously assigned to these two dipole bands.

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