A Semi-Classical Description of the Shears Mechanism: Analysis of B(M1) and B(E2) Values.†

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The observation of cascades of magnetic dipole (M1) transitions in neutron-deficient Pb nuclei[1] has generated great interest in the nuclear structure community. These regular sequences of M1 transitions which show a rotational-like spectrum have been interpreted by S.Frauendorf[2] using the Tilted-Axis-Cranking (TAC) model. The total angular momentum is generated by aligning $h_{9/2}$ and $i_{13/2}$ protons and $i_{13/2}$ neutron-holes in a way that resembles the closing of a pair of shears, hence the name: *shears bands.* We present here a global analysis of the $B(M1)$ and $B(E2)$ values[3] in $^{198,199}Pb$, based on a schematic coupling of two long j-vectors ($\vec{j}_\pi$,$\vec{j}_\nu$). Defining θ_π and θ_ν as the angles of the proton and neutron spin vectors with respect to the total angular momentum, $\vec{I} = \vec{j}_\nu + \vec{j}_\pi$, the shears angle θ that corresponds to a given state in the band can be derived using the semi-classical expression: $cos\theta = \frac{\vec{j}_\nu \cdot \vec{j}_\pi}{|\vec{j}_\nu||\vec{j}_\pi|}$. Since the $B(M1)$ values are proportional to the square of the component of the magnetic moment perpendicular to the total angular momentum vector they should show a characteristic drop as the shears close (i.e. $\theta \approx 90^0 \rightarrow \theta \approx 0^0$). We find that this dependence is given by

$$B(M1) = \frac{3}{4\pi} g_{eff}^2 j_\pi^2 \frac{1}{2} sin^2\theta_\pi \quad [\mu_N^2] \qquad (1)$$

as a function of the proton angle, θ_π, where we have introduced an effective gyromagnetic factor, $g_{eff} = g_\pi - g_\nu$. From the measured $B(M1)$'s we derive a common $g_{eff} \approx 0.9$ for the different bands in $^{198,199}Pb$. This seems consistent with that expected for nuclei in this region where, for example, using the measured values for the configurations $(\pi h_{9/2} \otimes \pi i_{13/2})_{11^-}$ and $(\nu i_{13/2})^{-2}_{12^+}$ we estimate $g_{eff} \approx 1.12$. We can also derive a similar expression for $B(E2)$ values:

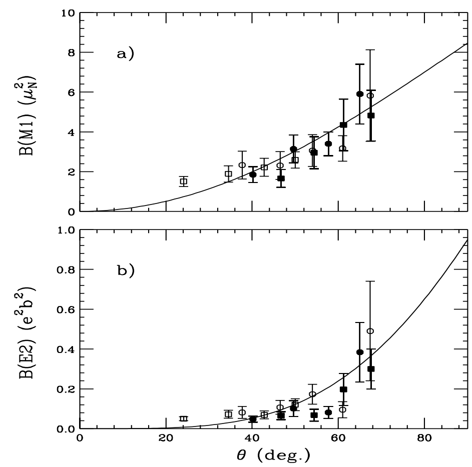

Figure 1: B(M1) and B(E2) values as a function of the shears angle. The lines are calculated with Eqs. (1) and (2).

$$B(E2) = \frac{5}{16\pi} (eQ)_{eff}^2 \frac{3}{8} sin^4\theta_\pi \quad [e^2b^2] \qquad (2)$$

in terms of $(eQ)_{eff} = e_\pi Q_\pi + (\frac{j_\pi}{j_\nu})^2 e_\nu Q_\nu$. The $B(E2)$'s also drop as the shears close and should go to zero because the charge distribution becomes symmetric around the rotation axis. The overall angle dependence is reproduced with an average $(eQ)_{eff} \approx 6.5eb$.

References

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