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HIGHER SUPERDEFORMED BAND MEMBERS IN ^{190}Hg: EVIDENCE FOR A BAND INTERACTION?

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Abstract: The superdeformed band of ^{190}Hg has been traced up to a frequency $\hbar\omega \geq 0.4$ MeV by combining data from several experiments. A distinct change in the slope of the dynamic moment of inertia $J^{(2)}$ vs $\hbar\omega$ is observed at $\hbar\omega = 0.32$ MeV. This result is interpreted as evidence for a band interaction at the highest frequencies. Possible interpretations are reviewed.

The evolution of the dynamic moment of inertia $J^{(2)}$ as a function of rotational frequency for superdeformed (SD) bands in the mass A = 150 region is characterized by pronounced isotopic and isotonic variations[1] attributed to differences in the occupation of specific high-N intruder orbitals[2]. In contrast, the vast majority of the SD bands in the mass A = 190 region displays the same smooth and rather pronounced increase of $J^{(2)}$ with $\hbar\omega$[1]. The occupation of specific high-N intruders cannot account for this rise[1,3-5] in $J^{(2)}$. The results of lifetime measurements[6] rule out the possibility that a change in deformation with $\hbar\omega$ causes this increase. It has been suggested that quasiparticle alignments and the resulting changes in pairing play an essential role[4-8]. Calculations using the cranked Woods-Saxon Strutinsky model (CSM) with pairing are able to account for the 40 % rise in $J^{(2)}$ observed for $0.12 \leq \hbar\omega \leq 0.40$ MeV in ^{192}Hg by the combined alignment of a pair of N = 6 ($i_{13/2}$) protons and a pair of N = 7 ($j_{15/2}$) neutrons[6]. These calculations predict that, after the quasiparticle alignments have taken place, $J^{(2)}$ will exhibit a downturn with increasing $\hbar\omega$ and will approach the static moment of inertia $J^{(1)}$.

We have recently reported on a new investigation[9] of ^{192}Hg, in which the SD band was extended to higher frequencies. As can be seen from figure 1, $J^{(2)}$ rises with $\hbar\omega$ over the entire frequency range and there is no sign of the predicted downturn. Thus, the data at high rotational frequencies lead one to question the validity of the calculations as well as of the proposed interpretation.

In order to assess whether this result is unique, i.e. whether (for example) the SD band in ^{192}Hg has a peculiar behavior because of the "doubly magic" SD character of this nucleus[1], we have now performed a similar study for ^{190}Hg. It has been noted[10] that CSM calculations for this nucleus indicate that the interaction strength between the ground state and the aligned configurations is much weaker in ^{190}Hg than in $^{192,194}Hg$ and, hence, alignment effects should result in more distinct variations of $J^{(2)}$.

Coincidence data obtained with the $^{160}Gd(^{34}S, 4n)$ reaction at three beam energies (159, 162, 165 MeV) were used. The experimental details can be found in ref. 10. In the analysis, a coincidence matrix was constructed from signals recorded in 12 Compton suppressed Ge detectors. Events corresponding to high-multiplicity cascades in ^{190}Hg were enhanced by careful gating on the γ-ray multiplicity and sum-energy recorded in the 50 element inner array of the Argonne Notre Dame BGO γ-ray facility. The gates were adjusted at each beam energy, in order to reflect corresponding changes in input angular momentum and excitation energy. The final matrix obtained in this way contained 3.5×10^7 events.

The spectrum obtained by adding the cleanest coincidence spectra (gates placed on the 360, 443, 483 and 558 γ rays) is shown in fig. 2. The SD band and the yrast transitions reported earlier[10] are clearly visible. From the data we were able to establish more precisely the energy of the 727 keV transition and add three new γ rays with energies of 756, 784 and 812 keV. These three transitions correspond to intensities of 15, 12 and 5% of the most intense transition in the SD band.

The behavior of the dynamic moment of inertia $J^{(2)}$ at high rotational frequency in the ^{190}Hg SD band is also presented in fig. 1. It can be seen that two markedly different slopes in $J^{(2)}$ are present. At frequencies $\lesssim$ 0.32 MeV, there is a smooth rise with a slope similar to that of ^{192}Hg. However, for the higher frequencies, a clear upbend in the data points is observed and, as a result, the $J^{(2)}$ values for ^{190}Hg become even larger than those for ^{192}Hg. Such a change in slope is very similar to those seen in many rotational bands at normal deformation and strongly suggests the presence of a crossing between the SD "ground state" band and another band.

A comparison between the data and the results of CSM calculations is presented in figure 3a. The solid line in the figure represents the result of a calculation with the reduced neutron pairing gap and the increased proton pairing

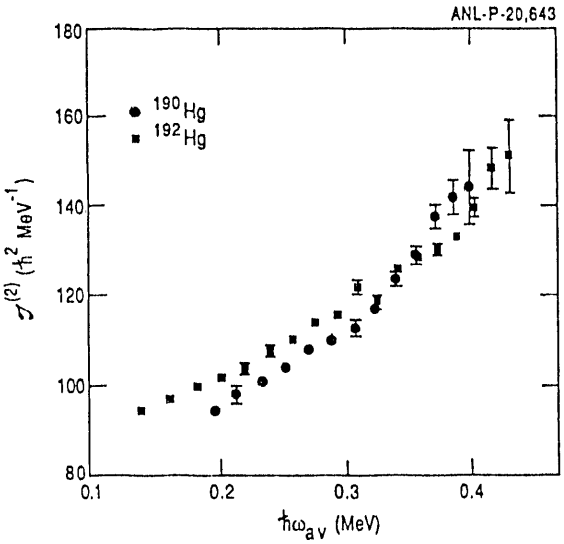

Fig. 1

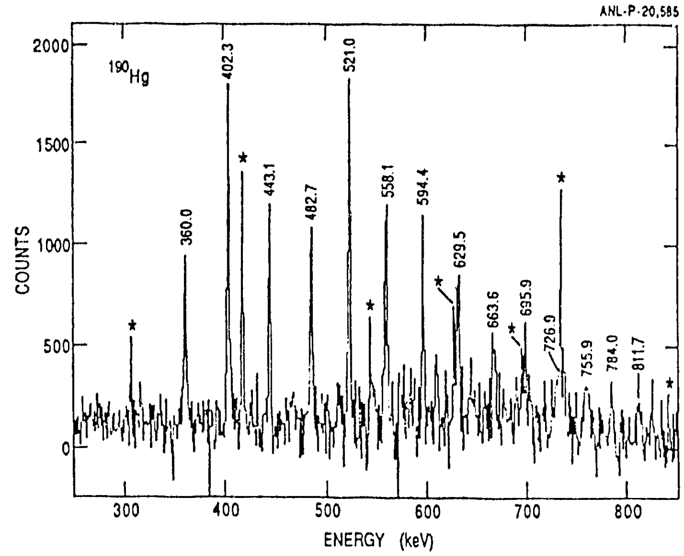

Fig. 2

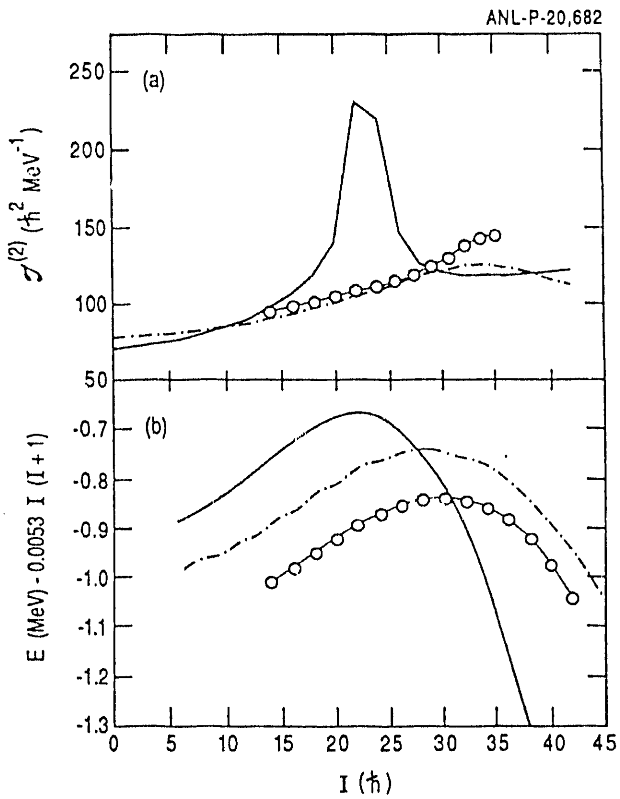

Fig. 3

Fig. 1: Dynamic moments of inertia $J^{(2)}$ vs $\hbar\omega$ for the latest data sets on the SD bands in ^{190}Hg and ^{192}Hg.

Fig. 2: Spectrum of the SD band in ^{190}Hg. Known yrast transitions associated with the decay out of the SD band are marked with a *.

Fig. 3: Comparison for the moments of inertia (a) and the energies with respect to a reference (b) between the data on ^{190}Hg (open circles) and CSM calculations with (i) reduced neutron pairing and enhanced proton pairing (solid line) and (ii) with a shifted aligned $\nu(j_{15/2})^2$ configuration and an increased interaction strength (dashed line).

gap used to reproduce the moments of inertia in $^{192,194}Hg$ (see ref. 7 for details). This calculation shows a sharp rise in the moment of inertia brought about mainly by the relatively weak interaction strength (~ 100 keV compared to ~ 500 keV in $^{192,194}Hg$) between the ground state and the aligned $\nu(j_{15/2})^2$ SD band. This sharp rise is not present in the data. In figure 3b the calculations and the data are presented with a reference subtracted. At the highest spins (or frequencies) the data exhibit a downward slope which can be interpreted as a crossing with a configuration having larger aligned angular momentum. The comparison between data and calculations then suggests that the alignment process is (1) delayed in frequency and (2) occurs with a larger interaction strength than predicted. There is at present no satisfactory explanation for these observations. However, some possible interpretations are worth discussing.

Within the CSM, variations of several parameters which influence the evolution of $J^{(2)}$ with $\hbar\omega$ have been explored. Neither the small changes in the deformation parameters β_2 and β_4 allowed by the lifetime measurements[10] nor the introduction of a static octupole deformation as suggested in ref. 11 result in significant changes in $J^{(2)}$ with $\hbar\omega$. In ref. 10 it was proposed that a strong residual neutron-proton (np) interaction may be present which would result in a lowering in energy of the yrast SD configuration with respect to all other orbitals and would shift the interaction frequency and modify the interaction strength. A motivation for this approach comes from the fact that delays in frequency, changes in interaction strength and/or non-observation of expected alignments have been reported in some nuclei with normal deformation when intruder configurations are involved[12]. Furthermore, for the SD configuration discussed here, the protons and the neutrons occupy the same number of intruder orbitals which could result in an enhanced np interaction. The dashed lines in figs. 3a and 3b are the result of a calculation where this possibility has been "simulated" by artificially shifting up the aligned $(\nu j_{15/2})^2$ band by 350 keV relative to the yrast band while keeping the interaction strength between the two crossing bands to a value of the order of 200-400 keV. Clearly, this calculation comes closer to the data. It is hoped that detailed calculations will further explore this suggestion.

In most CSM calculations which attempt to reproduce the evolution of $J^{(2)}$ with $\hbar\omega$ in the A = 190 region, the most critical parameter appears to be the monopole pairing strength. However, this strength has thus far mainly been used as a parameter for which a detailed microscopic treatment is not yet available.

Pairing is sensitive to the overlap between orbitals of interest. At very large deformation, states originating from different shells approach the Fermi surface, and these states should have a reduced pairing interaction. If the monopole pairing strength is reduced, higher order corrections such as quadrupole pairing may become important. Efforts to explore this possibility are currently under way for the SD nuclei[13,14], and preliminary calculations of quadrupole pairing in the $\nu j_{15/2}$ system result in a higher crossing frequency. Here too a more definite conclusion is still lacking.

To summarize, recent analysis of data on the SD bands of ^{192}Hg and ^{190}Hg has shown that the dynamic moments of inertia $J^{(2)}$ are not reproduced well by the available calculations. Two suggestions for possible explanations of the deviations were briefly discussed: a strong neutron-proton interaction and/or higher order corrections to the pairing field. It is, of course, also possible that neither of these effects will provide a satisfactory account of the data and the fascinating possibility that these data will require the introduction of "new physics" may still have to be contemplated.

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