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Quadrupole moments of superdeformed bands in ^{193}Tl

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Abstract. Lifetimes of states in the two strongest superdeformed (SD) bands in ^{193}Tl were measured using the Doppler-shift attenuation method. The reaction ^{176}Yb(^{23}Na,6n)^{193}Tl at a beam energy of 129 MeV was used and γ-rays were detected by the Gammasphere array. Quadrupole moments of 18.3(10) eb and 17.4(10) eb were extracted for SD bands 1 and 2, respectively, using the fractional Doppler-shifts of the SD transitions. The previously reported linking transitions of these SD bands to normal deformed near yrast levels could not be confirmed. No other candidates for linking transitions could be established.

PACS. 21.10.Re Collective levels – 21.10.Ky Electromagnetic moments – 27.80.+w $190 \leq A \leq 219$

Today more than 100 superdeformed (SD) bands are known in the mass-190 region in various neutron deficient Au, Hg, Tl, Pb, Bi, and Po isotopes [1,2]. Only in a few cases, namely ^{194}Hg [3,4] and ^{194}Pb [5,6] were the excitation energy and spins of SD states established by the observation of linking transitions from the low spin SD states to near yrast normal deformed (ND) states. Due to the lack of knowledge of these basic observables the single-particle structure of most SD bands is assessed on the basis of their dynamic moment of inertia [7,8] and the transition quadrupole moment of the SD transitions. While the SD quadrupole moments in the Pb and Hg isotopes have been systematically studied [9–16], little information is available for SD bands in odd-Z nuclei. A recent work by Reviol et al. [17] has provided the first measurement of the quadrupole moments in the strongest SD band in ^{191}Tl.

In this short note we present the first measurement of the average quadrupole moment of the two strongest SD bands in ^{193}Tl [18] by means of the Doppler-shift attenuation method (DSAM). The observation [19] of magnetic dipole (M1) crossover transitions between these SD bands identified them as signature partners. The $\pi i_{13/2}$ single-particle structure of these bands was determined by measuring the B(M1)/B(E2) ratios and extracting the g-factor for the SD states by assuming a deformation of 19 (2) eb [19]. The measured quadrupole moments in these two SD bands presented in this work confirms their single-particle assignment.

Recently the observation of high energy linking transitions has been reported [20], which connect the two strongest SD bands in ^{193}Tl to the near yrast ND levels. The data from the present experiment could not confirm these transitions.

The reaction ^{176}Yb(^{23}Na,6n)^{193}Tl was used to populate high-spin states in ^{193}Tl. The 129 MeV ^{23}Na beam was delivered by the 88-Inch cyclotron of the Lawrence Berkeley National Laboratory. The target consisted of approximately 1 mg/cm^2 of isotopically enriched Yb on a 10 mg/cm^2 Au backing in which the recoiling nuclei were stopped. About 10^9 four-fold and higher γ-ray coincidences were detected by the Gammasphere array [21], which at the time of the experiment comprised 100 individually Compton-suppressed large volume HPGe detectors. Figure 1 shows triple gated spectra of the two strongest SD bands in ^{193}Tl obtained in the present experiment. The Gammasphere detectors can be grouped in 17 rings, where all detectors of a given ring have the same angle with respect to the beam axis. A total of 60 detectors in 10 of these rings [5 at 17.3°, 5 at 31.7°, 5 at 37.4°, 10 at 50.1°, 5 at 58.3°, 5 at 121.7°, 10 at 129.9°, 5 at 142.6°, 5 at 148.3°, and 5 at 162.7°] provide sufficient Doppler-shift for an analysis in this DSAM experiment. Double gated spectra for each of these 10 rings were sorted in the off-line analysis with gates on uncontaminated transition energies in SD band 1 and 2, respectively. The other known SD bands in this nucleus [22] had insufficient statistics for a

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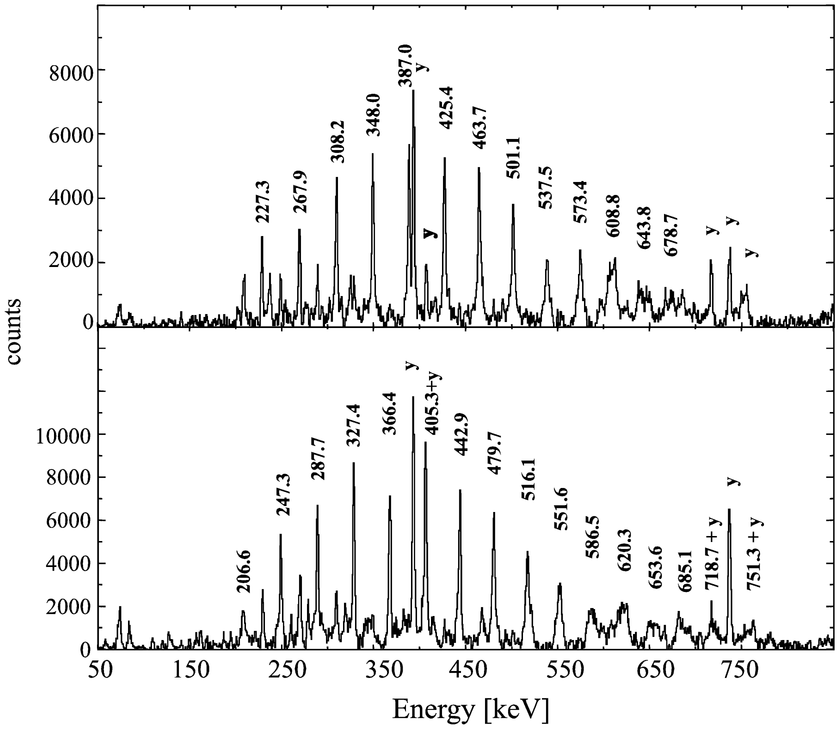

Fig. 1. Spectra of SD band 1 and 2 in ^{193}Tl obtained from quadruple coincidences with gates placed on any clean combination of three SD transition energies. The transitions above 550 keV are very broad due to the different Doppler-shifts for the various Gammasphere detector rings

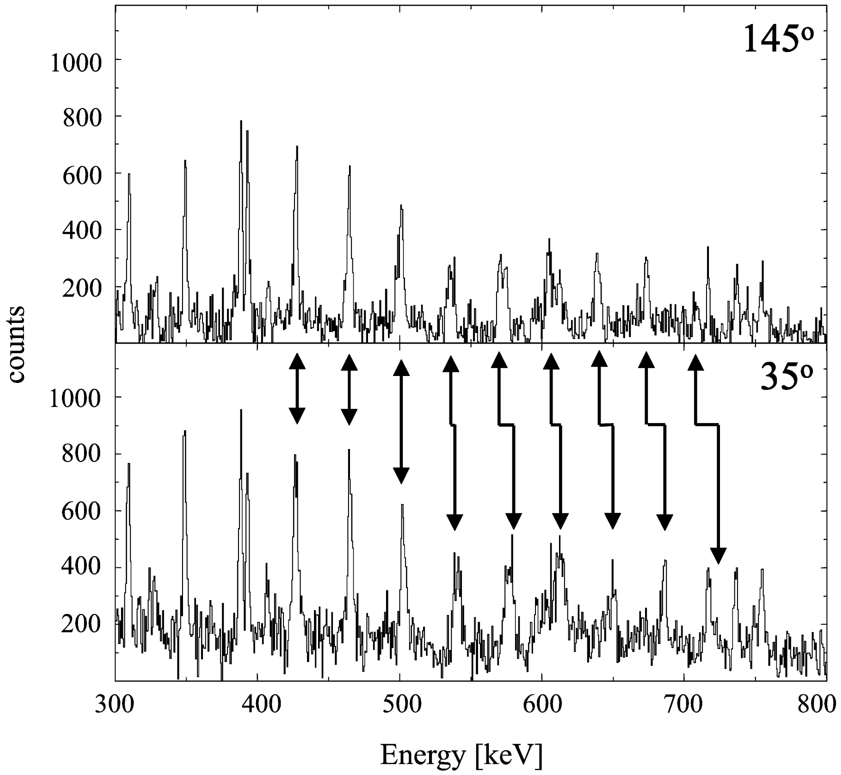

Fig. 2. Spectra of SD band 1 in ^{193}Tl for the combination of detector rings at 31.7° and 37.4° (a) and 142.6° and 148.3° (b). The spectra were obtained by placing double gates on all uncontaminated pairs of transitions in SD band 1. The Doppler shifts of the higher lying transitions in the SD band are indicated

lifetime analysis. Figure 2 shows spectra of SD band 1 at two different detector angles showing the varying Doppler-shifts for the SD transitions.

Fractional Doppler-shifts F(τ) were deduced from the centroid shifts of the SD transitions, where F(τ) is the ratio of the average recoil velocity v(τ) at which a state decays and the initial velocity $v_0=0.015 \cdot c$. The experimental F(τ) curves (see Fig. 3) were compared to theoretical F(τ) curves, which were calculated under the assumption of a rotational cascade with a constant quadrupole moment Q_0 and a sidefeeding of each level by a rotational cascade of five transitions with a quadrupole moment Q_{sf}, which was also assumed to be constant along the band. The experimental sidefeeding intensities were used in the

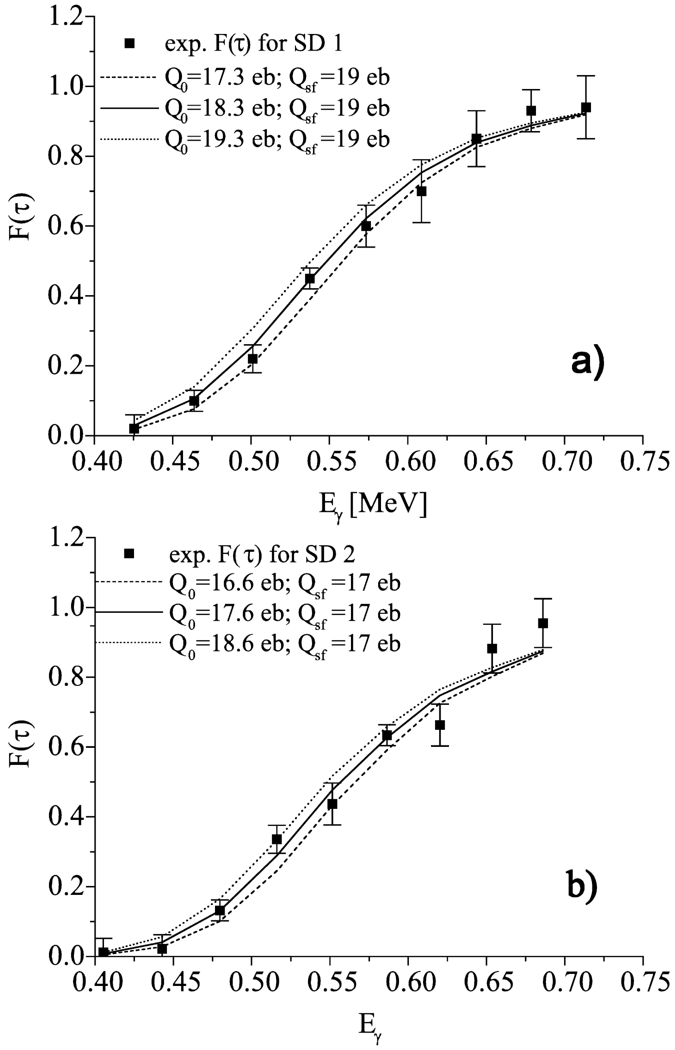

Fig. 3. Experimental F(τ) curves for SD bands 1 (a) and 2 (b) in ^{193}Tl. The calculated F(τ) curves for quadrupole moments leading to the best fit of the data are also shown. Values of Q_0=18.3(10) eb and Q_{sf}= 19(7) eb for SD band 1 and Q_0=17.4 (10) eb and Q_{sf}=17(2) eb for SD band 2 were obtained. For details on the calculations see text

calculations. The stopping of the recoiling nuclei was modelled using the electronic stopping powers by Northcliff and Schilling [23] and the theory of Lindhard *et al.* [24] for the treatment of the nuclear component of the stopping. A χ^2-minimization fit of the calculated curves was performed and the curves for the best fit are also displayed in Fig. 3. Quadrupole moments Q_0 of 18.3(10) eb and 17.4(10) eb and sidefeeding quadrupole moments of 19(5) eb and 17(2) eb were determined for SD bands 1 and 2, respectively. The large uncertainty in the sidefeeding quadrupole moments reflect that the F(τ) curves were fairly insensitive to the sidefeeding quadrupole moment because only the transitions near the top of the band exhibit large sidefeeding and their F(τ) values are rather uncertain and are also above the region that is most sensitive to the quadrupole moments. A reasonably accurate lineshape analysis could not be performed due to insufficient statistics and problems with contaminated transitions.

SD band 1 and 2 in ^{193}Tl are thought to be built on the $\pi i_{13/2}$ orbital [19]. This assignment is based on the measurement of B(M1)/B(E2) ratios and the subsequent determination of the g factor for the SD bands [19]. This analysis was based on the assumption of a quadrupole moment of 19(2) eb [19] which is, within the uncertainties, in agreement with the experimental quadrupole moments form the present work. The assignment of the $\pi i_{13/2}$ orbital can therefore be confirmed.

Recently, linking transitions between SD band 1 and 2 and the normal deformed near yrast states in ^{193}Tl were reported [20]. In the current experiment a similar amount of data as in [20] was taken. Due to the use of a backed target in the present experiment a better peak-to-background ratio was expected for the linking transitions, since these transitions would be emitted from stopped nuclei and no Doppler broadening would occur. Figure 4a and b show the same energy range as Fig. 1a and 1b of [20] for a triple gated spectrum of SD bands 1 and 2 using approximately the same binning as in [20]. The spectra obtained in this work show no evidence for the previously reported linking transitions at 3113 keV for SD band 1 and at 3046 keV and 3134 keV for SD band 2. No conclusive evidence for other linking transitions could be obtained from the present data set.

Comparing the results on linking transitions in ^{194}Pb between a thin-target experiment [5] with EUROGAM II [25] and a backed target experiment [6] with Gammasphere leads us to conclude that we would have expected to see the reported linking transitions in our data, if the reasonable assumption is made that the population of the SD bands is of the same order in the two reactions.

In summary, quadrupole moments of 18.3(10) eb and 17.4(10) eb were measured in a DSAM experiment for SD band 1 and 2 in ^{193}Tl, respectively. The quadrupole moments confirm the assignment of the $\pi i_{13/2}$ orbital to these bands on the basis of the B(M1)/B(E2) ratios measured by Bouneau et al. [19]. The previously reported [20] linking transitions from the two SD bands were not observed in the present experiment. No other candidates for linking transitions could be established.

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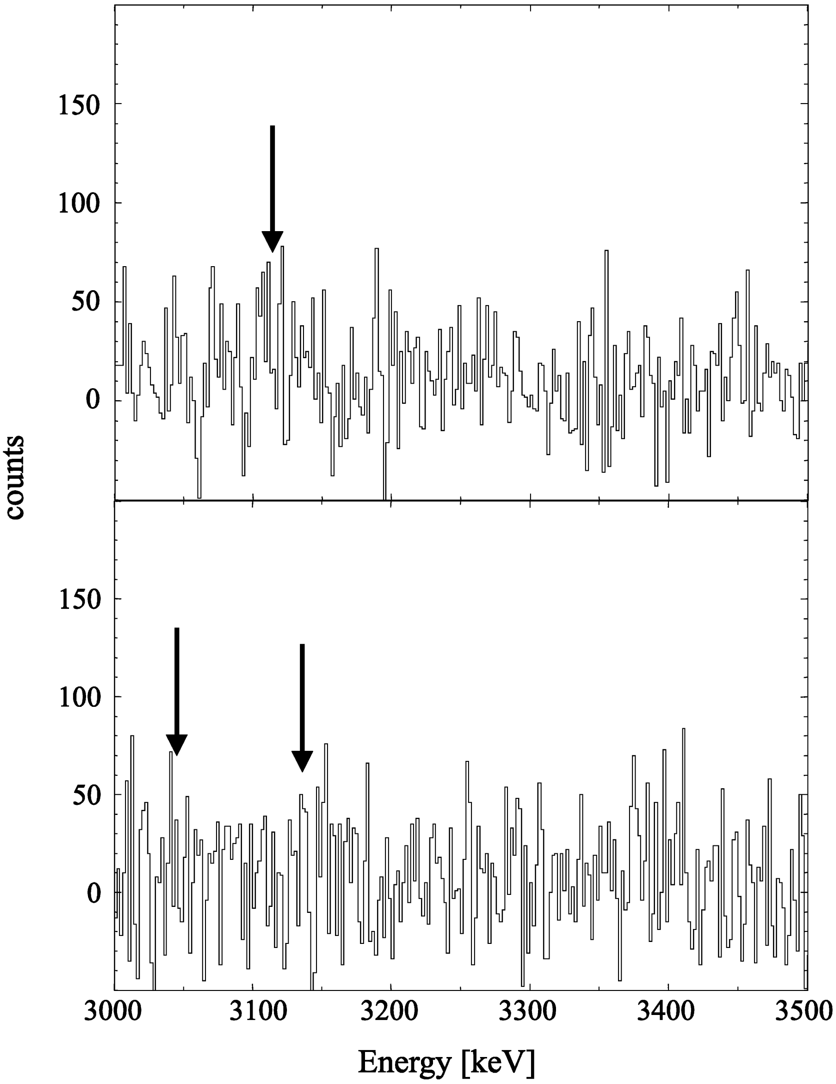

Fig. 4. Sum of triple gated spectra on the transitions of SD band 1 (a) and SD band 2 (b). The energy range and binning is chosen about equal to that of Figure 1 in [20]. The arrows indicate the positions of the linking transitions proposed in [20]. Apparently these transitions were not confirmed in the present experiment despite the fact that the peaks should exhibit no Doppler-broadening, leading to an improved peak-to-background ratio

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