# Comment on "Lack of evidence for a superdeformed band in $^{192}$Pb"

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(Received 12 October 1993)

This Comment examines the claim of a lack of evidence for a superdeformed band in $^{192}$Pb. We reaffirm the existence in our data of the superdeformed band in $^{192}$Pb.

PACS number(s): 21.10.Re, 23.20.Lv, 27.80.+w

Numerous superdeformed (SD) bands have been identified in the $A = 190$ region, including one which we identified and assigned to $^{192}$Pb [1]. Recently, Plompen *et al.* [2] questioned the evidence for this band based on data collected during a similar, but not identical, experiment. In this Comment we discuss the distinctions between these two experiments and the respective data analyses. We reaffirm the existence of the $^{192}$Pb SD band, and report briefly two results not found in our original publication. The reader is referred to Refs. [1,2] for details of the respective experiments.

A major difference between the two experiments is the number of events obtained in each data set, and the amount of information each data set contains on high multiplicity cascades like superdeformed bands. We collected $165 \times 10^6$ events, which included 14% with three Compton-suppressed germanium (CGS) detectors in coincidence (triples), and 1.2% quadruples. Unfolding these events to equivalent doubles events results in more than $200 \times 10^6$ doubles events in our experiment. This is to be compared to the $81 \times 10^6$ events accumulated in the experiment of Ref. [2]. As is pointed out in Ref. [2], the detector array used in that experiment has a somewhat better peak-to-total ratio than the HERA array ($\approx 0.63$ vs $\approx 0.52$). Nevertheless, the number of photopeak-photopeak coincidences in our data is approximately twice that of Ref. [2]. This higher number of photopeak-photopeak coincidences is important in identifying weakly populated SD bands.

Four additional factors contribute to a significant advantage for identifying weakly populated high multiplicity structures in our data set. First, we recorded all events in which two CSG detectors and at least six bismuth germanate (BGO) inner ball elements fired in coincidence. All events in which more than two CSG detectors fired were recorded, with no requirement on the number of inner ball elements firing. For the experiment of Ref. [2], events were recorded when at least two CSG detectors and two BGO inner ball elements fired in coincidence. These differing requirements enriched our data in high multiplicity events compared to those of Ref. [2]. Second, since our experiment used thin targets, the recoiling nuclei were outside the focal volume of the spectrometer after a few nanoseconds. Thus, our data contained significantly fewer events involving transitions in delayed coincidence compared to the experiment of Ref. [2]. As a result, prompt high multiplicity events were preferentially recorded in our data. Third, Doppler shift corrections were easily made to our data because we used thin targets. Shifted components of transitions several keV away from the SD band transitions were of no concern in the analysis of our data, as they were in Ref. [2] where a backed target was used. Fourth, our data contained no contribution from either Coulomb excitation of a backing foil or beta decay of residual radioactivities. Though difficult to quantify, these factors undoubtedly contribute to the cleanliness of our data and our ability to identify a SD band.

Considerable attention was paid to the fold distribution of the BGO inner ball in Ref. [2]. The conclusions drawn are in good agreement with our own evaluation of the fold distributions for the various nuclei, and the various structures within a given nucleus. However, contrary to the statement made in Ref. [2], no fold requirement beyond that at the time of data acquisition was imposed on our data for analysis of the SD band. The double-gated triples spectrum published in Ref. [1] had no inner ball fold requirement imposed at all. Higher fold requirements were only used to evaluate the population of various channels at high spin.

It is well known that many transitions in superdeformed bands are close in energy to more intense transitions in the normal structures. Therefore, we chose to publish a spectrum [1] obtained by using double gates on the triples and quadruples coincidence data as evidence for the SD band. To produce this spectrum, singly gated spectra were inspected for cleanliness, and only 24 of 36 pair combinations using the nine lowest energy SD band transitions were selected for the double gates. The spectrum showed only the SD band and low-lying transitions

 

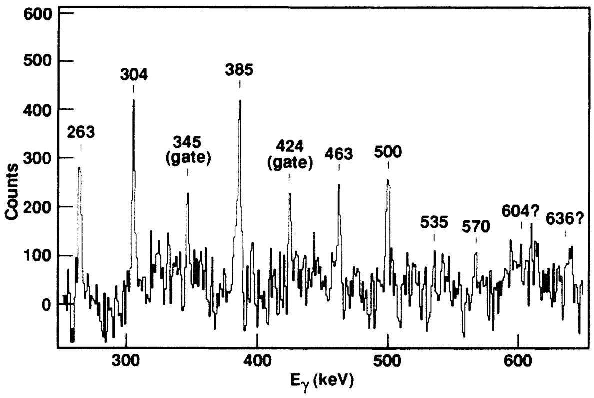


FIG. 1. Spectrum obtained with single gates on the clean SD band transitions at 345 and 424 keV in $^{192}$Pb. These data are from our original thin target experiment which used the $^{173}$Yb($^{24}$Mg,5$n$) reaction at 132 MeV. Clearly evident are all the SD band members through the 500-keV transition reported in Ref. [1].

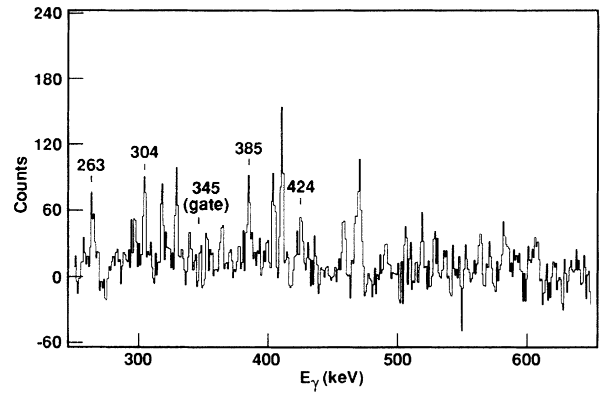


FIG. 2. Spectrum obtained with a single gate on the SD band transition at 345 keV. These data are from the $^{148}$Sm($^{48}$Ca, 4$n$) reaction at 205 MeV with a gold backed target. Although no longer completely clean, the SD band is still clearly observed; transitions above about 450 keV are expected to be significantly Doppler broadened or shifted.

in $^{192}$Pb. Table I in Ref. [2] enumerates many possible "contaminants" of the SD band transitions, suggesting that we confused these transitions with SD band members in our published spectrum. However, the gamma rays listed in that table are not relevant unless they contribute to our published spectrum. This is possible only if the gamma rays listed in this table meet our double-gate requirements and could therefore contribute to our published spectrum. The following observations can be made concerning the transitions in Table I of [2]: (1) the 345- and 424-keV transitions are not contaminated by Doppler-shifted transitions in our thin target data and gates on them produce clean SD band spectra; (2) many of the listed gamma rays are in different nuclei and thus cannot be in coincidence; (3) some of the gamma rays listed for the same nucleus (such as the 263.4- and 383.2-keV gamma rays in $^{190}$Hg) are not in the same cascade and so cannot be in coincidence; and (4) some transitions follow isomers with significant lifetimes. Transitions above and below these isomers are not in prompt coincidence in our thin target experiment since the recoiling nuclei leave the focal volume of the spectrometer. A critical examination of all pairs of contaminating transitions in Table I of Ref. [2], compared with the 24 SD gate pairs used to produce the published spectrum [1], reveals only one slight correspondence. The 263.4- and 388.6-keV transitions in $^{190}$Hg are in coincidence. However, the 388.6-keV transition is centered more than one full width at half maximum from our gate, and thus does not contribute measurably to our double-gated spectrum. If this gamma-ray pair did dominate the spectrum, other gamma rays in coincidence with both of them such as the 257.2-keV gamma ray should be evident in our spectrum, and they are not.

It is instructive to present our spectrum of the SD band obtained with single gates on the clean gamma rays at 345 and 424 keV in our thin target data with no fold condition beyond that at the time of data acquisition. This sum spectrum (Fig. 1) is comparable to many in the literature. Clearly evident are all the transitions in the SD band through the 500-keV gamma ray.

The experimental sensitivity was difficult to estimate in [1] because the level scheme of $^{192}$Pb was not well developed, although at least two isomers with half lives of 100 ns or more were known. Level structures above these isomers are now known [3], and we can estimate the cross section for population of this SD band to be $\approx$ 0.35% of the total $^{192}$Pb cross section in our data, including cascades that populate long-lived isomers ($\approx$ 0.21% of the $2^+ \to 0^+$ $^{192}$Pb transition when population of these isomers is excluded). This intensity for the SD band is at the sensitivity limit claimed in Ref. [2].

Finally, we have performed a preliminary second experiment on $^{192}$Pb using the $^{148}$Sm+$^{48}$Ca reaction at 205 MeV with a gold-backed target. The amount of data on $^{192}$Pb in this data set is about one half the amount of our first experiment. This experiment is similar to that of Ref. [2] (except for the projectile). These data have considerably more contamination due to the target backing. Nevertheless, a gate on the SD transition at 345 keV (no longer completely clean because of the backing) reveals the low-lying SD band members that we identified previously (Fig. 2). Transitions in the band above about 450 keV are not evident as peaks because of significant Doppler broadening or shifting.

In conclusion, we reaffirm the existence of the SD band in $^{192}$Pb and estimate its population at $\approx$ 0.35% of the $^{192}$Pb in our data set.

This work was supported in part by the U.S. Department of Energy under Contracts W-7405-ENG-48 (LLNL) and DE-AC03-76SF00098 (LBL), and in part by the U.S. National Science Foundation (Rutgers University).

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