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DEEXCITATION OF SUPERDEFORMED BANDS IN THE NUCLEUS ^{151}Tb*

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The aim of this work is to get more informations about the decay-out of superdeformed bands. One of the best candidates in the mass $A \simeq 150$ region for that kind of research is the nucleus ^{151}Tb. From previous works, it has been established that the first excited band goes lower in frequency than the band SD(1) [2], and it is the only known case in that mass region. One way to investigate these different behaviours, is to perform measurements of the average entry spin. The nucleus ^{151}Tb has been populated via the fusion-evaporation reaction ^{130}Te(^{27}Al,6n)^{151}Tb at a beam energy of 155 MeV. This experiment has been performed at the Vivitron facility accelerator in Strasbourg using the Eurogam II spectrometer, consisting of 54 Germa nium detectors. It came out of this study, that the band SD(2) and band SD(3) feed the normal deformed well 9$\hbar$ lower than the band SD(1). For the moment, it is not possible to explain the observed shell structure effects and to conclude about the statistical decay-out. The analysis is still under progress.

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1. Introduction

Since the discovery of the first superdeformed (SD) band in the mass A≃150 region [1], many other SD bands have been found in different nuclei. At the moment over 50 SD bands are known in that region, but therefore no linking transitions between the first and the second well of deformation have been observed, except for the nucleus ^{143}Eu [2] where there are some canditates. The situation is quite different in other mass regions, for instance the A≃190 mass region where linking transitions have been found in the nuclei ^{194}Hg [3] and ^{194}Pb [4] and have been placed in the level scheme. The determination of the linking transitions and their nature is very important for the calculation of spins and excitation energies of SD bands. Since these transitions have not been established yet, we propose to get futher informations of the decay mechanism by investigating the average entry spins. Among the eight SD bands known in the nucleus ^{151}Tb [5], there is one band, namely the first excited band (labelled band 2), which exhibits a very interesting feature. Indeed band 2 is going lower in frequency than the band SD (1) (Fig. 1). That is why the nucleus ^{151}Tb is thought to be a particularly good case to look at shell structure effects in the decay-out. The configurations of those bands are based on the orbitals $j_{15/2}$ for neutrons and $i_{13/2}$ for protons.

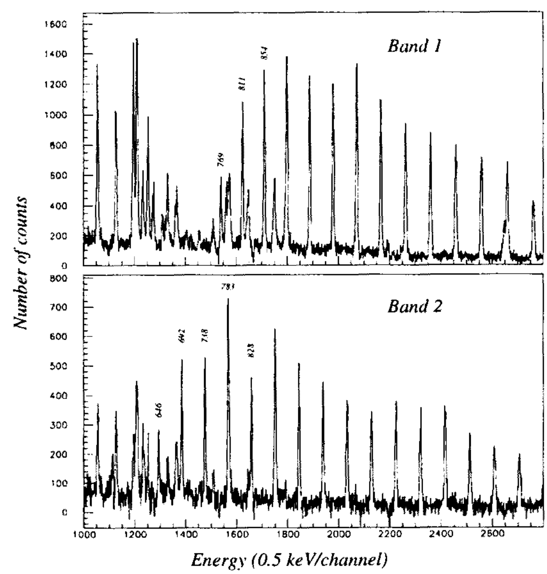

Fig. 1. Spectrum of the band SD(1) and the first excited band, three conditions gated.

2. Experiment

The nucleus ^{151}Tb was populated through the fusion-evaporation reaction ^{130}Te(^{27}Al,6n)^{151}Tb at a beam energy of 155 MeV. This experiment has been performed at the Vivitron accelerator at CRN Strasbourg. The target consisted of 500 μg/cm^2 of ^{130}Te. In order to prevent the sublimation of target matter under beam, a layer of gold 180 μg/cm^2 was evaporated onto. The gamma-ray energies were measured with the spectrometer Eurogam phase II. This array consisted of 30 large germanium detectors at backward and forward angles, and of 24 clover detectors at the angle around 90^o relative to the beam axis. Coincidence events were only recorded when the number of Ge detectors fired was greater than 7 unsuppressed, and 3 suppressed. A total of 1.6×10^9 raw events were collected. After gain matching and time filtering the number of clean events was about 1.3×10^9 ($M\gamma \geq 3$).

3. Analysis

Several methods have been tested, and the one chosen relies on a gate-combine technique, which allows a direct measurement of peak areas of the lines fed by the SD band and the states below. The method combines two gate files, one containing the gate on the last transitions of the plateau (d_{i+1}), the other file containing gates on energies belonging to the alimentation and the plateau (minus the last transition) (Fig. 2). One requires at least one gate fired in the first gate file and two gates fired in the second file to store the event in a one dimensional spectrum. One can easily measure the contribution of the first deexcitation transition by replacing the gate on (d_{i+1}) by a gate on that line. One can obtain, in that way, the contribution of the fed ND states for each transition of deexcitation (d_i). But at each step, the statistics decrease drastically. So it was only possible for the SD(1) band to get the contribution of each d_i.

The background subtraction has to be done very safely, thus in this analysis we used the Palameta-Waddington method [6], but for a one dimensional spectra. Two background gate files were created by setting gates just beside the SD peaks. We combined the two gate files and the two background gate files to build up the background spectra. The different combinations used were $b_i \otimes [b_j, b_k]$, $p_i \otimes [b_j, b_k]$ and $b_i \otimes [p_j, p_k]$ where p_i symbolises the gate on a SD peak and b_i symbolises the gate set beside a SD peak (indice i indicates a gate in the first file and j,k indicate gates in the second file). A resulting background subtracted spectrum is shown in Fig. 3, the last gated energy (d_{i+1}) of the plateau has disappeared in the spectrum as expected.

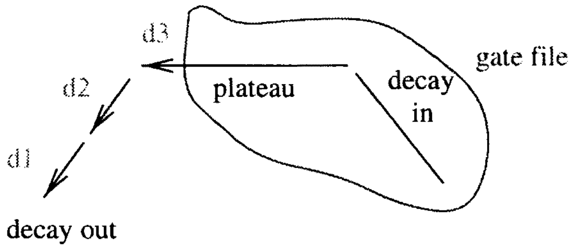

Fig. 2. Schematic view of the intensity pattern of a SD band. One gate file involves the plateau (minus the last transition) and the decay in, the other file contains one gate on the deexcitation line or on the last transition of the plateau.

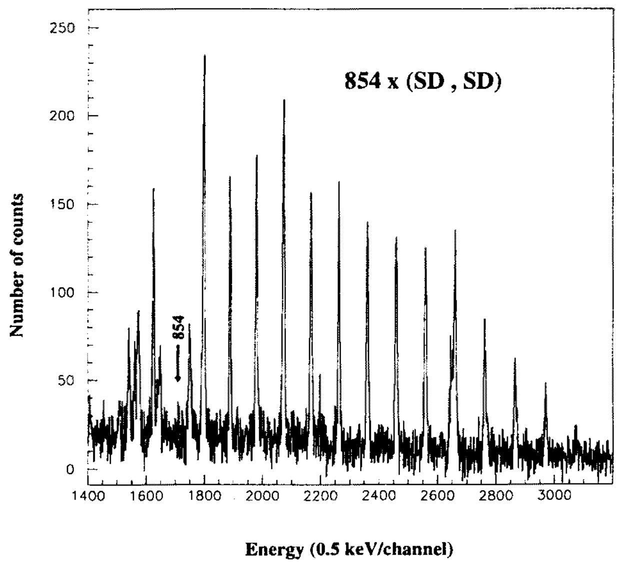

Fig. 3. Background subtracted spectrum, for the SD(1) band. The gate, contained in the first gate file, has been set on the last transition of the plateau (854 keV). The corresponding peak disappears as expected.

4. Results

A $\gamma-\gamma-\gamma$ analysis of the normal decay has confirmed the purious of the published level scheme [7]. Using the method describe above, we obtained a value of $30.6\hbar$ for the average entry spin of band 1. The spread in spin of the ND states fed by the SD band is rather large, about $7\hbar$ (69/2 to 55/2). We also measured the contribution of each deexcitation line in the feeding of those ND states. A summary of those results is shown in Table I, with the

TABLE I

Proportion of alimentation of the ND state by the SD(1) band, with the proton and the neutron configurations for every fed ND states.

State	Feeding %			Configuration	
	d_1	d_2	d_3	neutron	proton
$69/2^+$	0	2 ± 2	3 ± 3	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$d_{5/2}^{-2}\, h_{11/2}^3$
$67/2^-$	0	0	8 ± 2	$f_{7/2}\, h_{9/2}\, i_{13/2}^2$	$d_{5/2}^{-2}\, h_{11/2}^3$
$63/2^-$	8 ± 3	0	0	$f_{7/2}\, h_{9/2}^2\, i_{13/2}$	$g_{7/2}^{-1}\, h_{11/2}^2$
$61/2^+$	0	7 ± 5	19 ± 9	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$d_{5/2}^{-2}\, h_{11/2}^3$
$59/2^-$	1.5 ± 0.5	4 ± 2	0	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$g_{7/2}^{-1}\, h_{11/2}^2$
$57/2^-$	2 ± 1	10 ± 8	0	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$d_{5/2}^{-1}\, h_{11/2}^2$
$55/2^+$	5 ± 2	0	0	$f_{7/2}^2\, i_{13/2}$	$d_{5/2}^{-1}\, h_{11/2}^2$

corresponding proton and neutron configurations. The distribution in spin for the fed ND states is rather uniform, except for the $61/2^+$ state where the feeding is around 26%. For the moment there is no explanation for that phenomena. If we measure the average entry spin for every SD state involved in the decay-out, we find $28.8\hbar$, $29.9\hbar$ and $30.8\hbar$ respectively for the energies 769 keV, 811 keV and 854 keV, the average difference between two lines is only about $1\hbar$. The decay-out intensity distribution of the fed ND states is quite different since for the first transition of deexcitation, there is a strong feeding of the states $61/2^+$, while this distribution is quite larger for the other deexcitation transitions. This phenomena can be related to the fact that the difference in excitation energy between the SD states and ND states raise up when the SD energies of the decay-out decrease.

Another point to mention is the loss of about 30(5)% of the intensity of the SD band in the entry spin region. Therefore the total intensity of the band is gain back at low lying states ($19/2^-$ and $15/2^+$ respectively 18(4)% and 13(2)%). The loss could be due to unknown states through which a part of the SD intensity "floats". This states could be collective as in the nucleus ^{152}Dy where about 20% of the SD(1) intensity goes through oblate states. But these states have not been observed yet in ^{151}Tb.

TABLE II

Proportion of alimentation of the ND state by the SD(2) and SD(3) bands, with the proton and the neutron configurations for every fed ND states.

State	Feeding %		Configuration	
	B2	B3	neutron	proton
$47/2^-$	23 ± 5	27 ± 17	$f_{7/2}^2\, i_{13/2}^2$	$h_{11/2}$
$45/2^+$	17 ± 6	13 ± 15	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$h_{11/2}$
$41/2^+$	18 ± 9	26 ± 20	$f_{7/2}^2\, h_{9/2}\, i_{13/2}$	$h_{11/2}$
$39/2^+$	16 ± 10	7 ± 7	$(f_{7/2}^3)_{15/2}\, h_{9/2}$	$(3^- \otimes h_{11/2})_{15/2}$
$37/2^+$	19 ± 8	2 ± 2	$f_{7/2}^3\, i_{13/2}$	$h_{11/2}$
$35/2^+$	0	2± 2	$\left[(f_{7/2}^3)_{11/2}\, h_{9/2}\right]_{10}$	$(3^- \otimes h_{11/2})_{15/2}$
$31/2^+$	12 ± 6	0	$\left[(f_{7/2}^3)_{7/2}\, h_{9/2}\right]_{8}$	$(3^- \otimes h_{11/2})_{15/2}$

The results for the SD(2) and SD(3) bands are summarised in Table II. As seen for the band SD(1), they are only a few specific ND states fed by the SD bands. Mostly of them have positive parity (70% of the intensity of SD bands). For the moment it is not quite understood why those states are preferentialy fed. The two bands, SD(2) and SD(3), have the same average entry spin ($43/2\hbar$). Their configurations, in terms of intruder obitals, are identical ($\pi 6^4 \nu 7^2$). The energies of those bands are similar to those of the band SD(1) of ^{152}Dy . The average entry spin for this nucleus is $21\hbar$, this value could be compare to value obtained for band 2 and band 3. It seems that flat orbitals should not play an important role in the spin entry region and maybe in the mechanism of the decay-out. The value of the average spin entry for band 2 and band 3 lies about $9\hbar$ lower than the value of the band SD(1). The additional proton in the intruder orbital N=6 ($\pi 6^4$ seems to block the decay-out of the SD band and bring the rotatiting nucleus lower in spin.

5. Conclusion

In this work, we have measured with higher precision the average entry spin for band 1 and band 2 than established previously [5] with a focus on the determination of the proportion of feeding in the ND states for each step of deexcitation in band 1. We have also been able to investigate the average entry spin for band 3. The technique of background subtraction was properly developped to allow the accurate measurement. Nevertheless we were not able to explain clearly the observed shell structure effects. But it seems that parity of the fed ND states influence the decay-out of SD bands. Indeed the additional proton in the intruder orbitale $N = 6$ seems to play an important role by blocking somehow the deexcitation. A measurement of statistical decay-out is under progress and should bring some more informations of the way of deexcitation for the SD band in the nucleus ^{151}Tb. The new array of detector build up at Legnaro, namely Euroball, should provide a gain of factor ten in statistics. Following the results reported here, a new investigation with this measurement should be able to approach the goal to determine the linking transitions.

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