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Short note

The γ-decay of the GDR built on superdeformed states in ^{143}Eu

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Abstract. A search for the γ decay of the Giant Dipole Resonance built on superdeformed (SD) nuclear configurations of ^{143}Eu was made, using the reaction ^{110}Pd(^{37}Cl, $4n$)^{143}Eu at 165 MeV. Eight large BaF_2 scintillators and the NORDBALL array were used to measure high and low-energy γ-rays. The γ-spectrum gated by transitions populated by the SD states shows an excess yield at 7-10 MeV compared to the spectrum gated by transitions not populated by SD states. The comparison with statistical model predictions indicates that this excess most probably is due to γ-ray emission of the GDR built on superdeformed states.

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One of the important problems not yet understood concerning superdeformed nuclei is how these nuclear configurations are populated. It has been suggested [1] that the rather intense population of superdeformed bands (of the order of 1%) is connected to the E1 cooling of the nucleus that is expected to be enhanced due to the large splitting of the GDR strength function [2,3] and to the level density of the superdeformed states.

In this paper we discuss the first experiment aiming at searching for a signal from the γ-decay of the GDR in the superdeformed ^{143}Eu. This nucleus is characterized by a very intense continuum of E2 type that was found to originate from superdeformed configurations and to have a decay path feeding only particular intense low-spin states [4]. At low spins, due to the coexistence of both normally deformed, almost spherical, (ND) and triaxially deformed (TD) shapes [5,6], this nucleus has a very complex and irregular level scheme and it becomes superdeformed (SD) at high spins.

Both the SD yrast band and the excited SD states forming the E2 continuum follow decay routes leading to low spin states of the spherical shape only (ND). It is therefore expected that one should see the γ-decay of the GDR built on superdeformed states by comparing the high-energy γ-spectrum gated by low spin ND transitions (populated partly by the SD decay) with that gated by low spin TD transitions (not populated by the SD decay).

The experiment was performed at the Tandem Laboratory of the Niels Bohr Institute in Denmark. The 165 MeV ^{37}Cl beam impingued on two stacked targets of ^{110}Pd (97.3% pure and 510 and 550μ g/cm^2 thick). The compound nucleus ^{147}Eu was formed at an excitation energy E^*= 79 MeV. The maximum angular momentum is predicted to be 62$\hbar$ by the the Swiatecki model [7] and 68 $\hbar$ by the model of Winther, in which the excitation of collective modes is taken into account in the formation process [8].

A particular configuration of the NORDBALL detector array consisting of 17 HPGe detectors, a multiplicity filter (30 small BaF$_2$'s) covering $\approx 2\pi$ and 8 large volume BaF$_2$ detectors of the HECTOR [9] array was used. The BaF$_2$ detectors were calibrated using the 15.1 MeV γ transition from the reaction ^{11}B + D $\rightarrow$ ^{12}C* + n.

The two high-energy γ-spectra, one gated by ND transitions and the other by TD transitions and associated to the fold interval 6-10 measured with the multiplicity filter ($< I > \approx 45\ \hbar$), are compared in Fig. 1. They are different in the region $7 < E_\gamma < 10$ MeV. This difference should not be related to population of different spin regions. In fact, the two types of transitions have very similar fold distributions (cf. [10]).

The ratio of the ND gated to the TD gated spectra of Fig. 1, displayed in Fig. 2a, shows some excess (of the order of 15 to 35 %) in the region where one expects to find the low energy component (dipole vibration along the symmetry axis) of the GDR built on a superdeformed configuration [2,3].

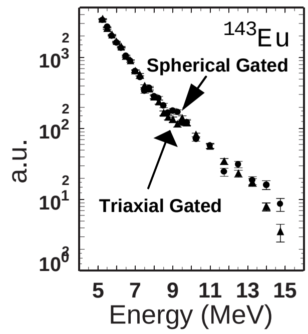

Fig. 1. High energy γ-ray spectra measured with the BaF_2 detectors in coincidence with ND transitions fed by SD decay (*filled circles*) and in coincidence with TD transitions not fed by SD decay (*filled triangles*)

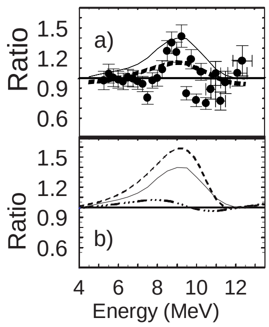

Fig. 2. a Ratio between the two spectra of Fig. 1. The curves are the statistical model calculations described in the text, one for $a_{SD} = a_{ND}$ =A/8 MeV^{-1} (*dashed line*) and the other for a_{SD} = A/10 MeV^{-1} and a_{ND} = A/8 MeV^{-1} (*full drawn line*). **b** The calculation shown with the *full drawn line* in **a** is compared with two predictions obtained by lowering (*dotted-dashed line*) and raising (*dashed line*) the particle binding energy by 2 MeV

Statistical model predictions of the ratio spectrum were also obtained. We denote with $Y_{ND}(E_\gamma)$ the calculation correponding to the normally deformed nucleus and with $Y_{SD}(E_\gamma)$ the calculation corresponding to the superdeformed configuration.

The $Y_{ND}(E_\gamma)$ yield was obtained assuming that the GDR strength function is a a single Lorentzian with centroid E_{GDR}= 15 MeV and width Γ_{GDR} varying, with increasing excitation energy, from 5 to 8 MeV. The $Y_{SD}(E_\gamma)$ yield was obtained in the same way as the $Y_{ND}(E_\gamma)$ yield, with the exception that in the angular momentum region $40\hbar < I < 55\hbar$ and for energy U above yrast in the interval U = 0-15 MeV, the GDR strength function was assumed to be a superposition of two Lorentzian functions. In particular, for the dipole vibration along the symmetry axis we have used $E_{GDR(low)}$ = 9.5 MeV and $\Gamma_{GDR(low)}$ = 2.5 MeV , and 33% of the energy weighted sum rule strength (EWSR), and for the dipole vibrations perpendicular to the symmetry axis $E_{GDR(Hi)}$ = 18.5 MeV and $\Gamma_{GDR(Hi)}$ = 6.5 MeV , and 66% of the EWSR.

Using the calculated $Y_{ND}(E_\gamma)$ and $Y_{SD}(E_\gamma)$ yields and assuming that 40 % of the total decay flux passes through the superdeformed states [4], we have calculated the ratio:

$$Y_{ratio}(E_\gamma) = \frac{0.4 \times Y_{SD}(E_\gamma) + 0.6 Y_{ND}(E_\gamma)}{Y_{ND}(E_\gamma)}. \quad (1)$$

Since the E1 decay depends on the density of states, the ratio spectrum was calculated for two different sets of values for the levels density parameters a_{SD} and a_{ND} [1]. In Fig. 2a, the calculation corresponding to $a_{SD} = a_{ND}$ = A/8 MeV^{-1} (dash-line) is shown in comparison with the data and with a calculation with a_{SD} = A/10 MeV^{-1} and a_{ND} = A/8 MeV^{-1} (full drawn line). The magnitude of the measured yield lies between the two predictions.

It is important to stress that the transition probability for the E1 decay for the SD nucleus is a factor of 4 to 10 larger (depending on the assumed value for the superdeformed level density) than that of the ND nucleus and yet, the enhancement in the total ratio spectrum, that receives contributions from all the decay steps of the compound nucleus, is much smaller (only of the order of 15 to 35 %).

A feature of the calculated ratio in the GDR region is that it increases smoothly with E_γ and then it falls off more rapidly. This reflects the fact that at E_γ larger than the particle binding energy E_b the γ-spectrum is dominated by the decay at high excitation energy, where the E1 strength function associated to the two different gates is the same. To illustrate this effect we have made two additional calculations, one in which we have decreased (dotted-dashed line in Fig. 2b) and the other in which we have increased (dashed line in Fig. 2b) the E_b values by 2 MeV. Indeed, the shape and also the intensity of the ratio are different, with very small values in the case of loosely bound nuclei.

To conclude, the comparison of the measured ratio between ND and TD gated spectra with calculations gives indications of the existence of the γ-decay of GDR built on a superdeformed configuration. We note also that the sensitivity to the neutron binding energy confirms, for the first time, similar binding at high spin SD, as at I=0. However, results from new measurements providing more firm conclusions are desirable. In particular, our calculation shows that gating with superdeformed yrast transitions is expected to give a ratio two times larger than the present analysis using continuum states.

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