GDR FEEDING OF THE HIGHLY-DEFORMED BAND IN ^{42}Ca *

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The γ-ray spectra from the decay of the GDR in the compound nucleus reaction ^{18}O+^{28}Si at bombarding energy of 105 MeV have been measured in an experiment using the EUROBALL IV and HECTOR arrays. The obtained experimental GDR strength function is highly fragmented, with a low energy ($\approx$ 10 MeV) component, indicating a presence of a large deformation and Coriolis effects. In addition, the preferential feeding of the highly-deformed band in ^{42}Ca by this GDR low energy component is observed.

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1. Introduction

Change in nuclear shape from an oblate one with the spin parallel to the symmetry axis to an elongated prolate or triaxial one, accompanied by the collective rotation around the shortest axis, called Jacobi shape transition, has been predicted to appear in many nuclei at angular momenta close to the fission limit. The presence of elongated shapes has been indicated in the γ-decay of the Giant Dipole Resonance (GDR) in ^{46}Ti nucleus [1, 2]. In

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this article we show further observations which confirm this finding. The simulation of the GDR strength function based on the Lublin–Strasbourg Drop (LSD) model [3–5], when inserted into the statistical evaporation code CASCADE, results in a high-energy γ-spectrum very similar to the experimental one. The low energy component of the GDR strength function is interpreted as a result of both large deformation effects and Coriolis splitting of the GDR. Moreover, the low energy component of the GDR has been found to feed preferentially the highly-deformed band [6] in ^{42}Ca.

2. Jacobi shape transitions and Coriolis splitting of the GDR

The experiment [1, 2] was performed at the VIVITRON accelerator of the IReS Laboratory, in Strasbourg (France), using the EUROBALL IV Ge-array [7, 8] coupled to the BaF_2 HECTOR array [9]. The master trigger condition was highly selective — only the events having at least two Ge signals of EUROBALL, BGO-shield suppressed, and one high-energy γ-ray in BaF_2 detector of HECTOR were accepted. The ^{46}Ti compound nucleus was populated in the ^{18}O+^{28}Si reaction at 105 MeV bombarding energy. The excitation energy of the ^{46}Ti nuclei was 86 MeV and the maximum angular momentum, $\ell_{\rm max} \approx 35\hbar$.

The GDR spectrum measured by the HECTOR detector, gated on known well resolved low energy γ-ray transitions of ^{42}Ca detected in EUROBALL, is shown in Fig. 1(a). This gating condition, together with the highly selective master trigger condition, allowed to select high energy γ-rays coming from nuclei with the highest spins ($> 20\ \hbar$) and free from fission and direct reactions contaminations.

The high-energy γ-ray spectrum was analysed using a modified Monte-Carlo version of the statistical model code CASCADE [10, 11]. The GDR line shape given by the absorption cross-section extracted using the method described in *e.g.* Ref. [12] is shown in the inset to Fig. 1(a). The found strength function is split forming a narrow low-energy component around 10 MeV, and a broad structure ranging from 15 to 27 MeV. This splitting was interpreted [2] as the consequence of both the Jacobi shape transition in which an oblate nucleus with a non-collective rotation transforms (around spin $I = 28\hbar$) to a very elongated prolate one rotating collectively, and strong Coriolis effects which split the low energy component (at ≈ 13 MeV) by $2\omega_{\rm rot} \approx 6$ MeV (where $\omega_{\rm rot}$ is the rotational frequency) and shift a part of its strength down to ≈ 10 MeV. In fact, Ref. [2] presented the first clear observation of the Coriolis effects in hot nuclei.

In order to confirm this interpretation, in the following we compare the experimental spectrum with the calculated spectra in which the GDR strength function is simulated according to the theoretical predictions of the

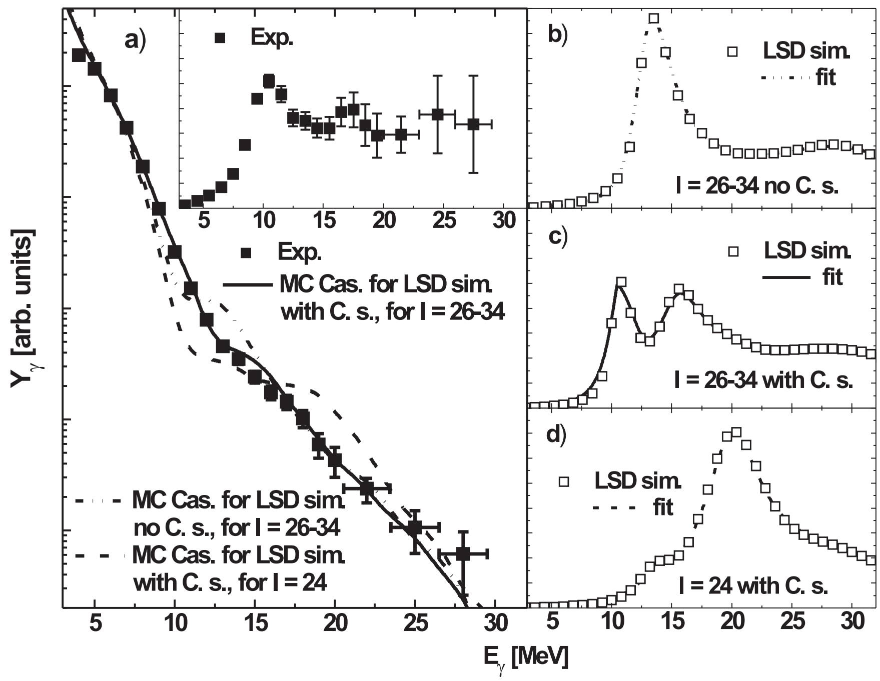

Fig. 1. (a) Full squares represent the experimental high energy γ-ray spectrum [1,2] compared to the spectra calculated using Monte Carlo Cascade code for GDR parameters obtained from the fit to the LSD model simulation [5] for spins indicated. In the inset the experimental GDR strength function is shown. Lines show the results of the CASCADE calculations with the GDR parameters fitted to the theoretical predictions shown in panels (a), (b) and (c); (b) Open squares represent theoretical simulation results (in the spin range from 26 to 34 $\hbar$) of the GDR line shape in ^{46}Ti, obtained from the thermal shape fluctuation model based on free energies from the LSD model calculations, in which the Coriolis splitting of the GDR components is not included. The dash-dotted line is the fit of simulated GDR line shape with a 5-component Lorentz function; (c) The LSD simulation results for the same spin range but including the Coriolis splitting of the GDR components (points) with the fit presented with solid line; (d) Similar to (c) but for $I = 24\ \hbar$. The dashed line shows the fit of simulated GDR line shape.

nuclear shape. The simulations are done using the method of the thermal shape fluctuations (*viz.* Ref. [13, 14] and references therein) based on the free energies from the newest version of the liquid drop model LSD [3], and on the microscopic single-particle spectra from the deformed Woods–Saxon Hamiltonian with the *universal* parameters. In the calculations [2, 5], we include the possibility of Coriolis splitting of the GDR strength function for a given spin and a deformation value. Thus, the GDR line shape consists in general of 5-Lorentzian parametrisation [15–17].

The results of the simulation for the spin region $I > 26\ \hbar$, where the Jacobi transition is predicted to occur, are presented as open squares in Fig. 1(b), 1(c) and denoted as "LSD sim". In Fig. 1(b) the Coriolis splitting of the GDR components was not included while it was done for calculations shown in Fig. 1(c). The latter are indeed similar to the experimental results for the GDR strength function (Fig. 1(a) — inset), and also exhibit the narrow 10 MeV component and a broad structure at higher energies. For comparison, the calculated GDR line shape for $I = 24\ \hbar$, *i.e.* in the region where the small oblate deformation is expected, is shown in Fig. 1(d).

The simulated GDR strength function can be used in the statistical model calculations. We have modified the Monte-Carlo version of the code CASCADE so that the GDR strength function is parameterised by 5 components; each defined by a GDR centroid, a width and a strength. Those 15 input parameters have been obtained by fitting the simulated GDR strength functions (Fig. 1(b), (c), (d)) with a 5-component Lorentz function which is shown in Fig. 1(b), (c) and (d) by dash-dotted, solid and broken lines, respectively.

The theoretical spectra resulting from the CASCADE calculations are shown also in Fig. 1(a) together with the experimental data. As can be seen, the calculations done for the spin range 26–34$\hbar$ taking into account the Coriolis splitting of the GDR components are in very good agreement with the experimental spectrum, while the one without Coriolis splitting assumption or the one for $I = 24\hbar$ are in full disagreement. This gives the additional confirmation of the observation of the Jacobi shape transition in the hot ^{46}Ti and the Coriolis splitting of the GDR.

In this context it is worth to mention that very large deformations of ^{46}Ti at high angular momenta were also suggested by the measured spectra of emitted α-particles [18].

3. The GDR feeding of various bands in ^{42}Ca

In addition, the GDR feeding of the normal-deformed bands and the highly-deformed (possibly super-deformed) collective band in ^{42}Ca [6] was investigated. To see how the different regions of high-energy γ-rays feed the discrete lines in ^{42}Ca residual nucleus, the gates (1 MeV wide) were set on the GDR spectrum and with such a condition the discrete line intensities were analysed. The three ratios between intensities of different discrete transition (normal deformed, highly-deformed and spherical) were taken into account. They are plotted as functions of the GDR energy in Fig. 2 after an arbitrary normalisation to 1 at 4.5 MeV.

As clearly seen, the ratio between γ-intensities from the highly-deformed (denoted as "hd") and normal-deformed ("nd") bands (solid points) shows a bump in the region 8–9 MeV. In this region the ratio is larger by a factor of 2 as compared to the low energy (statistical) region, and by a factor almost 4 as compared to the normal GDR region (>12 MeV). An enhancement, but smaller, is seen also in the ratio of the intensities of transitions within the "hd"-band and in the spherical ("spher") part of the level scheme (open squares), while there is no bump present in the "nd/spher" ratio case (open triangles). Considering that the gates were set on the raw spectrum, not corrected for the detector's response function, this 8–9 MeV bump corresponds to the 10 MeV low energy component of the GDR strength function shown in Fig. 1(a). This might indicate that the low energy component of the Coriolis split GDR in the *hot* compound nucleus ^{46}Ti feeds preferentially the highly-deformed (presumably super-deformed) band in the *cold* ^{42}Ca evaporation residue. Similar effect has been observed in the ^{143}Eu case [19]. This seems to confirm the old hypothesis [20] of a special role played by the low energy GDR component in feeding the super-deformed yrast structures.

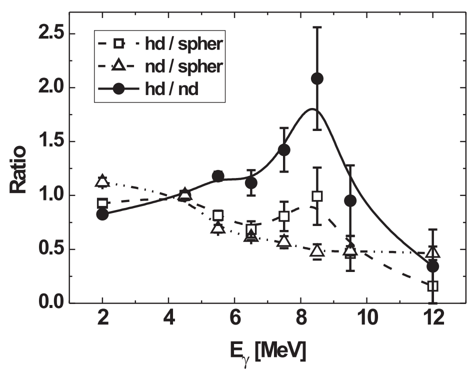

Fig. 2. The intensity ratios between gamma transitions proceeding within spherical (denoted as "spher"), normal deformed ("nd") and highly-deformed ("hd") bands as a function of the γ-ray energy from the GDR decay.

4. Summary

The high-energy γ-ray spectrum from the ^{46}Ti compound nucleus measured in coincidence with discrete transitions in the ^{42}Ca residues shows highly fragmented GDR strength function with a broad 15-25 MeV structure and a narrow low-energy 10 MeV component. This can be interpreted as the result of the Jacobi shape transition and strong Coriolis effects, seen experimentally for the first time. In addition, the low energy GDR component seems to feed preferentially the highly-deformed band in ^{42}Ca. This suggests that the very deformed shapes of hot compound nucleus, resulting from the Jacobi shape transition, persist in the entire evaporation process. Thus, the mechanism of the Jacobi shape transition might indeed constitute a gateway to the production of the very elongated, rapidly rotating and relatively cold nuclei, as advocated in Ref. [21].

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