FEEDING OF THE RESIDUAL STATES WITH GDR GAMMA DECAY STUDIED BY nuBALL COUPLED WITH PARIS*

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In the paper, experimental results of high-energy gamma GDR (Giant Dipole Resonance) decay from the ^{192}Pt compound nucleus associated with the $4n$ decay channel leading to the ^{188}Pt evaporation residue are presented. The measurement, which was performed with the use of coupled nuBall and PARIS arrays, aimed to investigate the link between deformation of a hot nucleus and different deformations of the residual states. The high-energy gamma rays from the GDR decay measured using the PARIS phoswiches provided information on compound nucleus properties, particularly on its effective shape. Discrete transitions in evaporation residues, measured by the nuBall array, were used to select the final products of specific deformations. As a result, the GDR strength functions measured for the particular decay paths were obtained.

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1. Introduction

The GDR has been proven to be a very good tool for the nuclear shape studies [1]. It is known that the properties, such as deformation, of a nuclear state on which GDR is built, are reflected by the GDR strength function. This was observed by studying the GDR excited in hot compound nuclei which decay to the ground states [2–4] and high-spin isomeric states in the final products [5, 6]. All the mentioned studies were based on coincidence measurements of high-energy and low-energy gamma-ray spectra enabling to obtain GDR strength functions corresponding to specific residual nuclei. The studies of giant resonance decay provided information on the relation between the properties of evaporation residues produced in compound nucleus decay and the characteristics of a hot compound nucleus. Particularly, it was shown that the shape of a hot nucleus may determine the deformation of the decay product. Such dependence was observed for the ^{46}Ti compound nucleus decay leading to ^{42}Ca residue in which preferential feeding of highly deformed band in ^{42}Ca by the low-energy part of GDR was evidenced [7]. A similar finding was reported for the ^{147}Eu compound nucleus decaying to deformed states of ^{143}Eu [8].

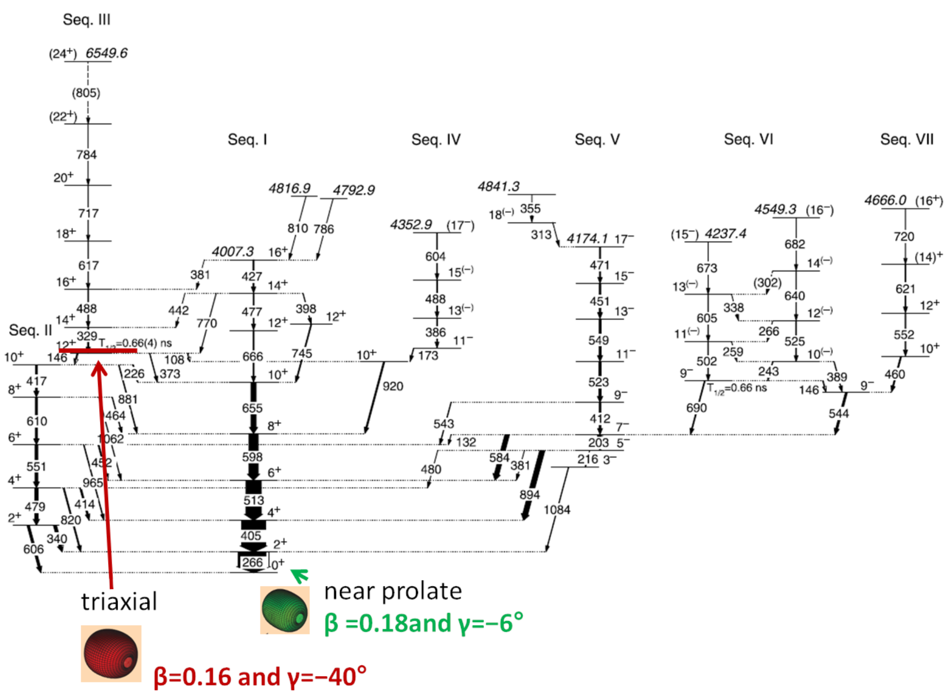

Fig. 1. Partial level scheme of the ^{188}Pt nuclei [9] with marked Yrast transitions corresponding to near prolate deformation, as well as band postulated by [9] to be triaxial.

Described below studies were motivated by observation that in the ^{188}Pt nuclei, the collective band built on the isomeric 12^+ state exhibits triaxial deformation, while the ground state has a prolate one [9, 10]. With the use of fusion–evaporation reaction, we investigated the case of ^{192}Pt compound nucleus and its $4n$ decay channel leading to ^{188}Pt residue. Measurement of high energy gamma rays in coincidence with the low-spin discrete transitions allowed to study the GDR built on states of certain deformation. With gates put on the Yrast band discrete transitions, we studied GDR for nuclei of prolate deformation, while for the GDR decay to the states characterized by triaxial deformation, we gated on the 329 keV transition which is feeding 12^+ isomer (see figure 1).

2. nuBall-PARIS experiment and data analysis

The experiment was performed in the IJCLab, Orsay, France, with the use of tandem providing ^{18}O beam at 90 MeV on the 1.5 mg/cm^2 thick ^{174}Yb target. The experimental setup contained the nuBall [11] array coupled to 33 phoswiches of the PARIS detector [12] in the wall-type geometry (see figure 2). Data were collected by triggerless DAQ with the use of FASTER digitizers [13]. During the process of the analysis events were created requiring at least one HPGe and one PARIS energy deposits within +300 and −100 ns time window with respect to the RF (signal from the pulsation system). From these events, gamma–gamma matrices were constructed with PARIS and HPGe energy deposits on their axis. To remove neutron and background contaminations, a narrow time gate for PARIS detectors (−3 ns to 1 ns with respect to RF) was used.

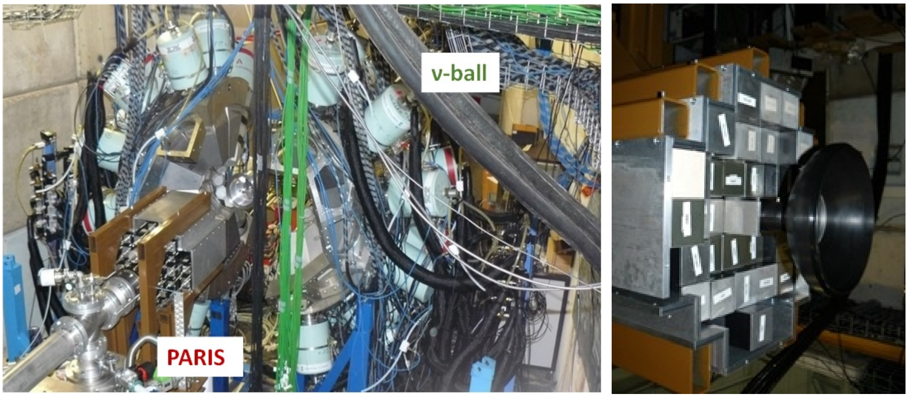

Fig. 2. Photo of the nuBall setup coupled with the PARIS array (left), view of the PARIS array in wall-type geometry used during the campaign (right).

The good selectivity of the discrete gamma-ray gating was checked by inspecting the shapes of high-energy gamma-ray spectra measured in coincidence with residue transitions. An example is shown in figure 3, where energy measured by PARIS is plotted while requiring ^{188}Pt (405 keV $4^+ \rightarrow 2^+$ transition) and ^{187}Pt discrete gamma ray (302 keV $17/2^+ \rightarrow 13/2^+$ transition). In the case of $5n$ (^{187}Pt) decay channel, huge suppression of the GDR energy range of the spectrum is visible compared to $4n$ (^{188}Pt) channel. This is due to the fact that in the case of GDR gamma decay, the remaining phase space limits the excitation energy and, in consequence, the evaporation of 5 neutrons is suppressed.

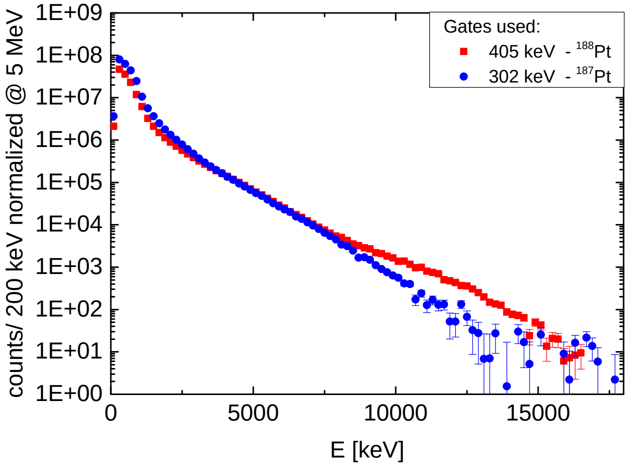

Fig. 3. (Colour on-line) Gamma-ray spectra measured by the PARIS detectors selected by gating on ^{188}Pt 405 keV $4^+ \rightarrow 2^+$ transition (red squares) and ^{187}Pt 302 keV $17/2^+ \rightarrow 13/2^+$ transition (blue circles).

The high-energy gamma-ray spectrum gated on 329 keV $14^+ \rightarrow 12^+$ transition above isomer was compared to GDR decaying to main band (gated on main band transition). As one can see in figure 4, they are statistically identical. This is contrary to our expectations to see a difference when we gate on the prolate shape band and triaxial isomer. The experimental spectra were compared to the calculated ones using the procedure described in Ref. [14]. Calculations were performed by the GEMINI++ statistical code [15] with the included description of gamma-ray decay of GDR [16] and assuming near prolate $\beta = 0.18$ and $\gamma = -6°$, and triaxial with $\beta = 0.16$ and $\gamma = -40°$ shapes, as the literature values of the deformation of ^{188}Pt residue bands [9]. The calculated spectra processed by the PARIS detector response matrix were compared to the experimental high-energy gamma-ray spectra selected by ^{188}Pt 405 keV $4^+ \rightarrow 2^+$ and 329 keV $14^+ \rightarrow 12^+$ transitions in HPGe. The results are shown in Fig. 5.

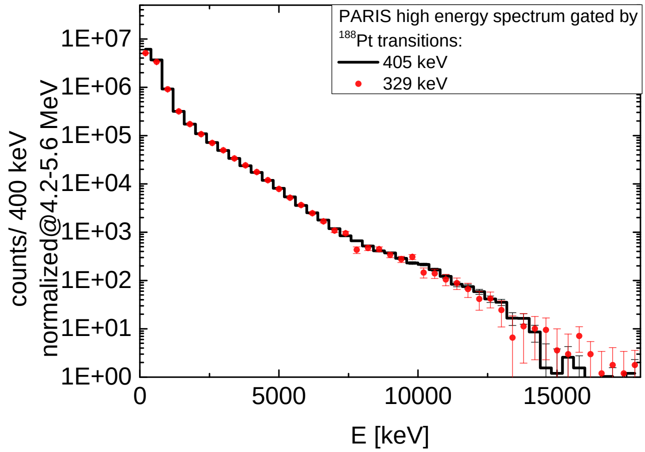

Fig. 4. High-energy gamma-ray measured by PARIS selected by ^{188}Pt 405 keV $4^+ \rightarrow 2^+$ transition (line) compared to data gated by 329 keV $14^+ \rightarrow 12^+$ transition (dots).

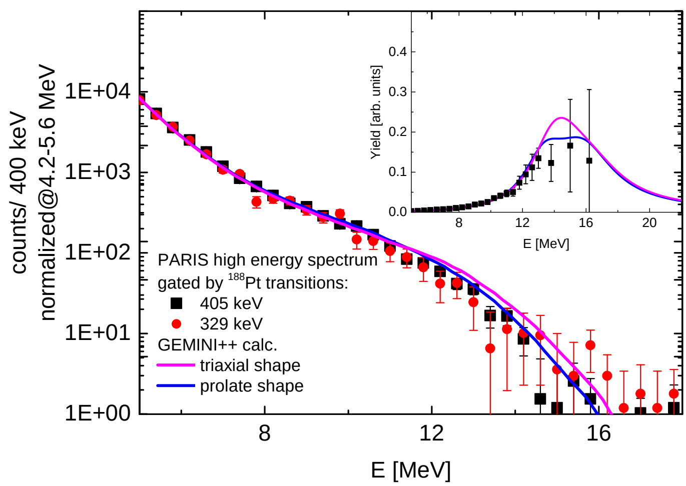

Fig. 5. (Colour on-line) The high-energy gamma-ray spectrum measured by PARIS with the simultaneous measurement of ^{188}Pt transitions in HPGe: 405 keV $4^+ \rightarrow 2^+$ (black squares) and 329 keV $14^+ \rightarrow 12^+$ (red dots) compared to the GEMINI++ calculations for the GDR strength function corresponding to the triaxial (pink/gray line) and prolate (blue/black line) shapes. Inset: the GDR strength functions used in GEMINI++ calculations, corresponding to the near triaxial and near prolate shapes, together with the linearized experimental GDR lineshape (black squares).

Despite limited statistics, experimental data agree rather well with the calculations performed with the assumed prolate shape (blue/black line in Fig. 5 and inset). This might suggest that either the assignment of the triaxial deformation for 12^+ isomer is wrong or the nucleus does not preserve the shape during the decay. However, it is worth to notice that no thermal shape fluctuations of the nucleus shapes were used for the above-mentioned GDR strength calculations. The addition of such fluctuations will be the next step of the further analysis of this dataset, and will allow to obtain the final result.

3. Summary and perspectives

Coupled together the PARIS and nuBall setup used in the experiment aiming to measure gamma decay of GDR from the hot compound nucleus ^{192}Pt shows very good selectivity which is achieved by coincidence measurement of GDR and discrete transitions from residues ^{187,188}Pt. The measured high-energy gamma-ray spectra from the GDR decay for ^{192}Pt to the states of various deformations of ^{188}Pt showed no difference. Statistical model calculations were performed for the GDR gamma decays for prolate and triaxial nuclear shapes. Better agreement to experimental data is obtained for the calculations assuming prolate-like shape of the nucleus. Before stating the final conclusion, thermal fluctuation of the nuclei shapes will be added to the calculations, which will be described in a forthcoming paper.

Recently, our group performed another experiment within the nuBall2 + PARIS campaign at IJCLab. It aimed at the measurement of high-energy gamma GDR decay from the ^{80}Sr compound nucleus leading to ^{76}Kr evaporation residue. In the ^{76}Kr nuclei, coexistence of the prolate and oblate shape bands is well known [18, 19] together with much higher statistics than in the ^{188}Pt case, which will allow to check the correlation between the compound nucleus GDR shape and deformation of the different bands. Hopefully, the results will shade more light on the problem of the GDR feeding of the residual states.

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