EPJ Web of Conferences **66**, 02020 (2014)
DOI: 10.1051/epjconf/ 20146602020

Giant Dipole Resonance decay of hot rotating ^{88}Mo

M. Ciemała[1a], M. Kmiecik[1], A. Maj[1], V.L. Kravchuk[2], F. Gramegna[2], S. Barlini[3], G. Casini[3], F. Camera[4]

for the HECTOR and GARFIELD collaborations

[1] Niewodniczański Institute of Nuclear Physics PAN, 31-342 Kraków, Poland
[2] INFN, Laboratori Nazionali di Legnaro, I-35020, Legnaro, Italy
[3] Dipartimento di Fisica and INFN Sez. di Firenze, Firenze, Italy
[4] Dipartimento di Fisica and INFN Sez. di Milano, Milano, Italy

Abstract. An experiment focusing on study of the properties of hot rotating compound nucleus of ^{88}Mo was performed in LNL Legnaro using ^{48}Ti beam at energies of 300 and 600 MeV on ^{40}Ca target. The compound nucleus was produced at the temperatures of 3 and 4.5 MeV, with angular momentum distribution with l_{max} > 60 ħ (i.e. exceeding the crtical angular momentum for fission). High-energy gamma rays, measured in coincidence with evaporation residues and alpha particles, were analyzed with the statistical model. The GDR parameters were obtained from the best fit to the data, which allowed investigating an evolution of the GDR width up to high temperatures.

1 Introduction

The study of Giant Dipole Resonance properties at high temperature and angular momentum is important for investigation of nuclear structure since it provides information on behavior of nuclei under extreme conditions. In particular, the change of the GDR width with angular momentum and temperature reflects the role played by quantal and thermal fluctuations in the damping of giant vibrations [1-7].

Recently the GDR width has been measured for several nuclei at different temperatures. The higher temperature region, up to 3.7 MeV, was investigated for ^{132}Ce showing the increase of GDR width as a function of temperature [8]. The essential in such measurements is proper determination of the nuclear temperature. In order to obtain this quantity it is important to know the precise excitation energy of the compound nucleus and consider preequilibrium emission that may occur at high energies.

Here results of new measurements of the GDR width for high temperature are presented for ^{88}Mo produced in fusion-evaporation reaction.

2 Experimental setup and data analysis

The decay of the ^{88}Mo compound nuclei has been studied in an experiment performed at the Tandem-

[a] Corresponding author: Michal.Ciemala@ifj.edu.pl

ALPI accelerator at the laboratory of LNL Legnaro using 300 and 600 MeV ^{48}Ti beam on a ^{40}Ca (500 μg/cm^2) target. The compound nucleus (CN) has been produced at 124 and 262 MeV excitation energy, corresponding to the average CN temperature of 3 and 4.5 MeV respectively. The high-energy gamma rays as well as charged particles were measured using the combined HECTOR [9] and GARFIELD [10] arrays. The GARFIELD detectors consisting of ΔE-E gaseous micro-strip and CsI(Tl) scintillation detectors were positioned at θ = 29° to θ = 82° and 2π in φ in the same gas volume. The 8 large volume BaF_2 HECTOR detectors were placed at backward angles. The phoswich [11] detectors were placed at forward angles to identify the evaporation residues, which provide possibility to select fusion-evaporation channel of the reaction. Schematic view of the experimental setup is presented in Fig. 1.

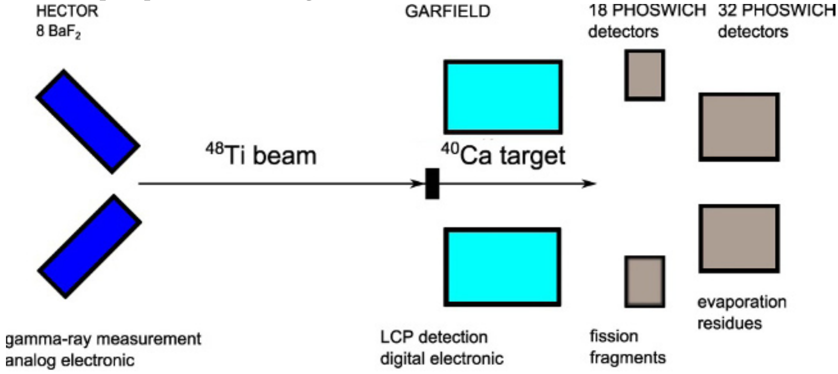

Figure 1 Schematic view of the experimental setup, which was composed of the large volume BaF_2 HECTOR array, GARFILED apparatus and a set of phoswich detectors.

To obtain GDR parameters such as centroid energy, strength and width (Γ_{GDR}), high-energy gamma-ray spectra, which were measured in coincidence with evaporation residues, were analyzed. In the analysis the GEMINI++ [12] Monte Carlo statistical model code with GDR emission enhancement [13] was employed. The high-energy gamma-ray spectra were fitted in the GDR region to obtain the GDR parameters. Both measured and calculated spectra are presented in Fig. 2 together with the extracted strength functions.

Apart from high-energy gamma rays, also charged particles have been measured allowing investigation of the preequlibrium process, which after analysis occurred not to be observed in the experiment.

3 The GDR width

Since GDR can be emitted at different decay steps, namely from nucleus characterized by different excitation energy, the temperature of nucleus at which the GDR is excited is not the same as for CN. Its values are calculated at each decay step using the formula:

$$T_{GDR} = [(E^* - E_{rot} - E_{GDR})/a(T)]^{1/2},$$

where E^* is the excitation energy, E_{rot} is the rotation energy and E_{GDR} is the energy of emitted gamma. The temperature of nuclei after gamma emission was estimated for both experimental cases using GEMINI++ calculations taking into account all experimental conditions. The obtained 2D distributions of nuclei temperature *versus* gamma-ray energy are presented in Fig. 3. Average temperatures of the nuclei, which decay by high-energy gamma rays, were estimated by gating on range of gamma-ray from 14 to 16 MeV on these distributions. As a result the calculated temperature values for beam energies 300 and 600 MeV respectively are $\langle T_{GDR} \rangle = 2.0^{+0.4}_{-0.7}$ and $3.1^{+0.6}_{-0.9}$ MeV.

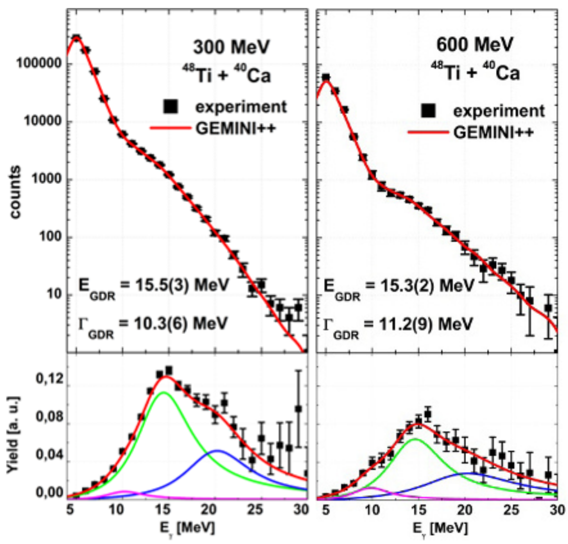

Figure 2 Upper panels: gamma rays spectra measured for 300 and 600 MeV beam energies compared to the GEMINI++ calculations. Bottom panels: GDR strength functions – red lines, with their three Lorentzian components (pink, green and blue lines) obtained from the best fit of the GDR part of gamma-ray spectra for both energies.

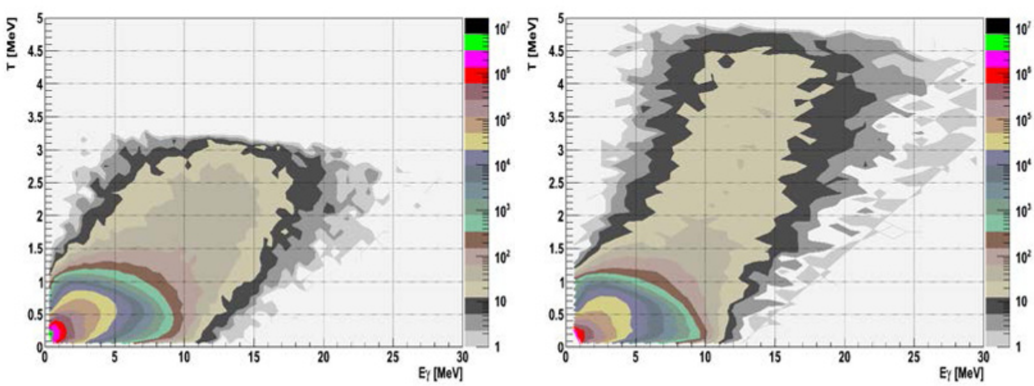

Figure 3 Distributions of nuclei temperature after gamma decay versus emitted gamma-ray energy, for 300 (left panel) and 600 MeV (right panel) beam energies.

The GDR widths were obtained as FWHM of the GDR strength functions (shown in the bottom panel of Fig. 2) for both experimental cases and found to increase from 10.3(6) MeV for 2 MeV temperature to 11.2(9) MeV at temperature equal to 3.1 MeV [14]. The measured values were compared to the theoretical predictions of the two models assuming that the damping of giant vibrations is caused by the different processes. One of the model, phonon damping model (PDM) [15,16] (Fig. 4a), describes the GDR width due to interaction of the GDR phonons with the particle – hole, particle – particle and hole – hole excitations. It predicts an increase of the GDR width up to certain value of temperature and then its saturation [14]. Another employed model was the recent version of the liquid drop model - LSD [17,18] (Fig. 4 b) with the thermal shape fluctuations anticipating the increase of the GDR width with temperature. The calculations were performed for Γ_0 = 6 MeV, which is GDR width at T_{GDR} = 0.

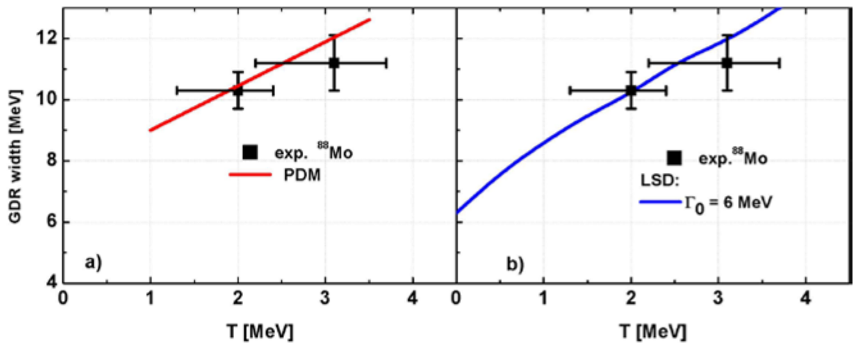

Figure 4 The temperature dependence of the GDR width obtained as FWHM of the strength function. The experimental values (points) are presented together with calculations based on PDM (a) and LSD + thermal fluctuations (b) models. The horizontal error bars indicate the standard deviations of the temperature distributions.

Both models predict that for ^{88}Mo in the investigated temperature region the GDR width increase is within the error bars of the increase obtained experimentally. It is observed quite good agreement between the measured values and the calculations based on PDM model as well as the LSD based results shown in Fig. 4. This may indicate that both models describe well the GDR width behavior. The GDR width increase with temperature can be explained due to phonon – single particle interaction or increased thermal shape fluctuations with temperature.

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