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SEARCH FOR RARE SHAPE TRANSITION IN HOT ROTATING ^{188}Os NUCLEUS*

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We report on exclusive measurements of angular momentum gated high energy gamma rays from hot rotating ^{188}Os nucleus at two different beam energies. The spectra were measured at four different angles w.r.t. the beam direction for both beam energies. Statistical model fits to the spectra and the analysis of the anisotropy pattern for the high energy data ($E_{\rm beam} = 84$ MeV, corresponding to an effective compound nuclear temperature $T_{\rm eff} \sim 1.8$ MeV) seem to indicate a non-collective oblate shape for the compound nucleus. The shape at the lower beam energy (65 MeV) could not be determined unambiguously. The data for the higher beam energy is in qualitative agreement with our finite temperature potential energy surface (FTPES) calculations. We have observed significant enhancement in the high energy tail of the spectrum in the region of the IVGQR even after a very meticulous subtraction of the cosmic ray background. Further analysis is on to explain the excess counts in this region.

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1. Introduction

The search for nuclear shape transitions at finite temperature and angular momentum continues to be one of the more exciting and challenging aspects of Giant Dipole Resonance (GDR) decay studies in excited nuclei. The atomic nucleus is expected to undergo a variety of shape transitions with increasing temperature and angular momentum. Experimental confirmation of such shape transitions in hot rotating nuclei promises to open up new vistas in our efforts to understand the response of the nuclear many-body system at finite temperature and angular momentum. The selection

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of the nuclei to be studied and the region of phase space to be probed, are guided by the predictions of theoretical calculations, both microscopic and macroscopic. It is now well established, that all mean field calculations predict a transition temperature T_{c1}, at which the nucleus, irrespective of its ground state deformation, becomes spherical and on rotation becomes oblate, rotating about its symmetry axis [1]. A series of recent calculations by Goodman have resulted in prediction of a second transition temperature T_{c2}, where $T_{c2} > T_{c1}$, in some heavy nuclei [2]. According to these calculations the nucleus is expected to rotate about its symmetry axis with a prolate shape in a narrow region of the phase space demarcated by the two angular momentum dependent transition temperatures T_{c1} and T_{c2}.

Our previous measurements of phase space selected GDR gamma rays from ^{194}Au provided a definite indication of shape transition [3]. In particular, the reversal in the angular anisotropy pattern of the GDR gamma rays for the two different beam energies lent further credence to a possible shape transition. The conclusions drawn from the statistical model analysis of the GDR spectra, belonging to narrow domains of angular momentum and temperature, were also found to be in conformity with the angular anisotropy of the high energy gamma rays. This provided further impetus to carry out the investigations in other neighbouring nuclei. Here, we report on the measurements in ^{188}Os for which Goodman has predicted two transition temperatures and two consecutive shape transitions from collective oblate to non-collective prolate and then from non-collective prolate to non-collective oblate with increasing temperature and at finite angular momentum [2].

2. Experimental details

The ^{188}Os compound nucleus was populated by bombarding a 1.2 mg/cm^2, self-supporting ^{176}Yb target with ^{12}C beam of 84 and 65 MeV from the TIFR Pelletron. The selection of the beam energies was governed by theoretical calculations and the expectations to populate the compound nucleus in different regions of phase space corresponding to different shapes. The high energy gamma rays were measured in a close packed array of seven large hexagonal NaI(Tl) detectors. The array was kept at a distance of 80 cm from the target position for a clean n–γ separation. The pileup was rejected by zero-crossover technique. The array was surrounded by a plastic anti-coincidence shield for suppression of cosmic rays. The low energy discrete gamma rays were detected in a multiplicity filter of fourteen hexagonal NaI(Tl) detectors arranged in castle geometry. The high energy gamma rays were measured at four different angles (90°, 120°, 135°, 150°) w.r.t. the beam direction for both beam energies. The energy calibration was carried out by low energy sources for energies up to 4.443 MeV and by

$p(^{11}B,\ ^{12}C)\gamma$ reaction at $E_p = 7.2$ MeV. Special efforts were made to accurately estimate the remnant of the cosmic ray background in the spectra even after the rejection by the plastic anti-coincidence shield and the time gates. This was achieved by measuring the cosmic ray background without the beam for the same duration of the beam run and under exactly similar conditions of electronic gates and time windows.

TABLE I

The initial compound nucleus parameters for both beam energies.

E_{beam} MeV	E^* MeV	L_{max} $\hbar$	$\langle E_{\text{rot}}\rangle$ MeV	T_{eff} MeV
84	71	37	3.8	1.8
65	53	20	1.2	1.55

3. Analysis

The initial data reduction resulted in multiplicity fold gated gamma rays spectra for the two beam energies and for all the four angles. Two narrow windows, corresponding to 4–6 and 9–12 folds were chosen to extract the spectra from low and high spin regions of the distribution. The lowest folds of 1–3 were not considered to avoid spurious counts due to target contaminants. The spectra were analysed by fitting with statistical model calculations using a modified version of the code CASCADE [4]. The theoretical spectra were convoluted with the simulated response matrix for the detector array. The temperature dependence of the level density was calculated using the Ignatyuk/Reisdorf formalism [4]. The fits were carried out in an iterative manner considering spherical, prolate and oblate shapes and the GDR parameters were extracted from the best fits to the spectra. The best fits, obtained by chi-square minimisation and also visual inspection, seem to favour oblate shapes more over spherical or prolate shapes for the 84 MeV data. However, for the 65 MeV spectra, the shape could not be ascertained unambiguously from the statistical model fits. The value of the deformation parameter β obtained from these fits were used in the calculations to fit the angular anisotropy of the high energy gamma rays for the two beam energies. The amplitude of the anisotropy for 84 MeV was found to be less than that of 65 MeV. The anisotropy at 84 MeV could be reproduced assuming a non-collective oblate deformation with the β obtained from the statistical fit (see Fig. 1). This apparent consistency between the statistical model fit and the angular anisotropy is also in conformity with the theoretical prediction of a non-collective oblate shape beyond 1.6 MeV temperature [2].

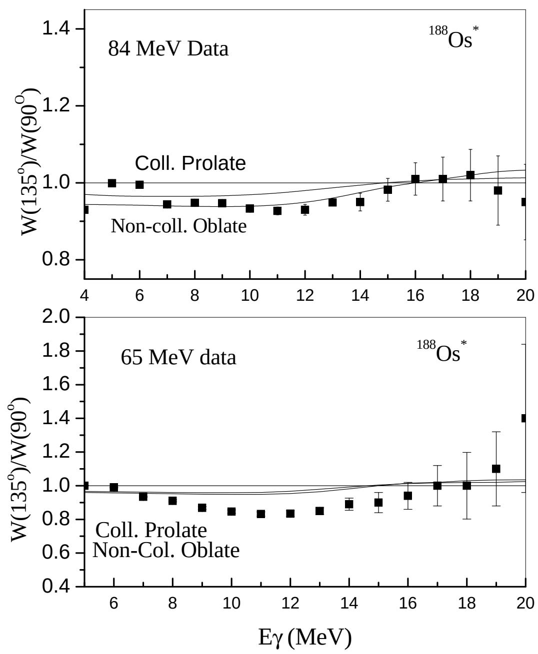

Fig. 1. Angular anisotropy plots for 84 and 65 MeV data for the low spin region corresponding to 4–6 folds. The solid lines are the theoretical calculations assuming non-collective oblate and collective prolate shapes.

We have also calculated the potential energy surfaces for ^{188}Os in small steps of temperature and angular momentum to span the relevant phase space. Our calculations also indicate the most probable shape to be oblate over most of the phase space. At this stage it should be emphasised that the analysis of both line shape and angular anisotropy of the spectra should take into consideration the presence of finite thermal and shape-orientation fluctuations at finite temperature and angular momentum. The presence of fluctuation leads to the extraction of only the effective shape of the nucleus from the GDR data. A necessary fuller analysis including fluctuation effects to have better understanding of the data is in progress and is to be reported elsewhere. Such an analysis may corroborate our preliminary conclusion on the high energy (84 MeV) data. It may also determine the effective shape and can account for the large anisotropy observed for the low energy (65 MeV) data. We have also made a serious attempt to search for the hitherto unobserved, IVGQR based on excited states. It is interesting to note that we have observed an excess yield of high energy gamma rays in the 18–26 MeV region after a meticulous subtraction of the cosmic ray contribution for both beam energies. Apart from the cosmic rays the Bremsstrahlung gamma rays may also mask the IVGQR gamma rays. While the Bremsstrahlung contribution at 84 MeV beam energy may be significant it is not expected to be so at 65 MeV. Further analysis of this portion of the spectrum is in progress and will be reported elsewhere.

As in [3] we would like to carry out the differential technique to measure the GDR gamma rays mostly from the compound nucleus [3, 5]. This is to be achieved by carrying out another set of measurements of spin gated GDR gamma rays and their angular anisotropy from the compound nucleus ^{187}Os at around 60 MeV excitation energy.

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