Study of giant dipole resonance in hot rotating light mass nucleus ^{31}P[†]

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The Isovector Giant Dipole Resonance (GDR) is observed in all nuclei and is characterized by the resonance energy (E_G), width (Γ_G) and strength (S_G).1) Macroscopically, it is described as out-of-phase oscillation of proton and neutron fluids, while microscopically, it is a coherent excitations of one particle-one hole ($1p$-$1h$) configurations across one major shell. It can be built on the ground state as well as every excited states of atomic nucleus. The GDR built on the nuclear excited states is experimentally studied by two complementary methods, namely inelastic scattering reactions and fusion evaporation reactions.

In this report, a systematic study of the GDR parameters is presented in a very light mass nucleus ^{31}P by using fusion evaporation reactions. The compound nucleus (CN) ^{31}P was populated at three different excitation energies by using the α beam (E_{beam} = 28, 35, 42 MeV) from K-130 cyclotron at the Variable Energy Cyclotron Centre, Kolkata. The GDR and nuclear level density (NLD) parameters have been determined by simultaneous statistical model analysis of the high-energy γ ray and neutron spectra measured with the LAMBDA array2) and neutron time of flight detectors,3) respectively. The angular momentum (J) of the multiplicities with a multiplicity filter.4) The angular distribution of the high-energy γ rays has been performed to determine the bremsstrahlung component which is observed for the beam energies above ~10 MeV/nucleon. The estimation of the bremsstrahlung contribution is crucial for precise determination of the GDR parameters.

It was observed that the GDR remains very much collective in this light mass nucleus and the E_G remains roughly constant at around 17.5 MeV as the nuclear temperature (T) changes. In Fig. 1, the measured GDR widths are compared with the results of calculations within different models and plotted as a function of T. Panels (a) and (b) show that the thermal shape fluctuation model (TSFM)5) and the phenomenological thermal shape fluctuation model (pTSFM)6) (phenomenological version of TSFM) overpredict the measured widths. In panel (c) the calculations within the critical temperature included fluctuation model (CTFM)7) is presented. Within this model, the GDR width remains constant at the ground-state value up to a critical temperature due to the GDR induced fluctuation and increases thereafter. Interestingly, this model nicely reproduced the measured widths. The widths were also described quite well [panel (d)] by the results of calculations based on microscopic phonon damping model (PDM),8) according to which the GDR width arises owing to the coupling of the GDR state with the noncollective p-h, p-p and h-h configurations. The thermal paring gaps are found to vanish in the ranges of T and J considered in this experiment, therefore, have no effect on the measured GDR width in this light mass system. The present results establish the universality of CTFM and PDM in describing the GDR width as a function of temperature and angular momentum.

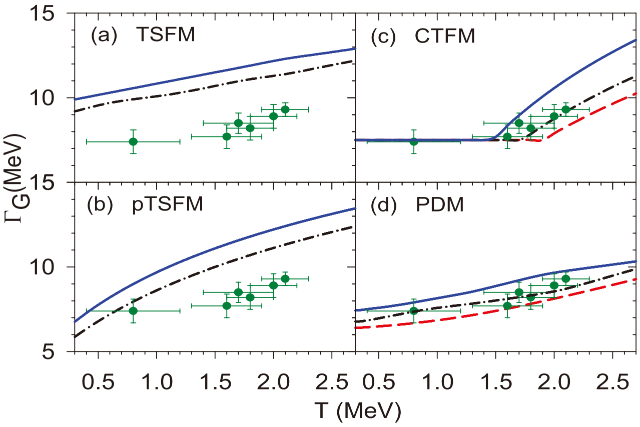

Fig. 1. Comparison of measured GDR width with the results of various model calculations as a function of T at $J = 11.5\ \hbar$ (black dot-dashed line) and $J = 15.5\ \hbar$ (blue solid line). The red long-dashed lines in panels (c) and (d) are the predictions at $J = 0\ \hbar$.

References

1) M. N. Harakeh, A. van der Would, *Giant Resonances: Fundamental high-Frequency mode of nuclear excitation* (Clarendon Press, Oxford, 2001).
2) S. Mukhopadhayay, *et al.*, Nucl. Instrum. Methods Phys. Res. A **582**, 603 (2007).
3) K. Banerjee, *et al.*, Nucl. Instrum. Methods Phys. Res. A **608**, 440 (2009).
4) Deepak Pandit, *et al.*, Nucl. Instrum. Methods Phys. Res. A **624**, 148 (2010).
5) Y. Alhassid, *et al.*, Phys. Rev. Lett. **61**, 1926 (1988).
6) Dimitri Kusnezov, *et al.*, Phys. Rev. Lett. **81**, 542 (1998).
7) Deepak Pandit, *et al.*, Phys. Lett. B **713**, 434 (2012).
8) N. Dinh Dang, *et al.*, Phys. Rev. Lett. **80**, 4145 (1998).

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