Giant dipole resonance in hot rotating nuclei†

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Experimental observations on the dependence of the width of giant dipole resonance (GDR) on temperature (T) and angular momentum (J), covering a wide range of T, J and nuclear systems, can be summarized as follows. The GDR width is rather insensitive to the change of T up to $\sim$ 1 MeV and increases rapidly up to a moderate T of $\sim$ 2.5 MeV. At higher T, there are claims of observing a saturation of the GDR width. This observation has, however, been questioned in some works which have emphasized the need for a better characterization of the excitation energy E_X (i.e. T and J) of the source in the data analysis. The reanalysis of the data after taking into account the pre-equilibrium (PEQ) effects in the mass asymmetric channel, has shown a monotonic increase of the width at least up to $T \sim 3.5$ MeV.

On the other hand a recent experiment in a mass symmetric channel, which shows negligible PEQ effects, has suggested the GDR width saturation at $T \sim$ 3 MeV. This highlights the need to resolve this important issue in future experiments. At still higher T, the other observed phenomenon is the quenching of the GDR strength. In this regime again, various authors use a saturated GDR width in the data analysis. The GDR quenching has been related to the competition between the equilibration time for the excitation of GDR and the lifetime of the nucleus or the transition of the hot nucleus to a chaotic regime. In this regard, an interesting suggestion has been made on the relation of the vanishing of the collective vibration and the liquid to gas phase transition in nuclear systems. As for the J-dependence the GDR width, the disentangling of the J-effect from the T-effect is made mostly in the moderate T-regime. The GDR width weakly depends on J up to a certain value and increases at higher J. This value of J depends on the nuclear mass number, being, for example, $J \sim 30\hbar$ for A $\sim$ 110. In heavier nuclei (A $\sim$ 180) the width is roughly constant up to the highest measured $J \sim 50\hbar$.

Among several theoretical approaches to calculating the GDR strength function, the microscopic-macroscopic thermal-shape fluctuation model (TSFM) has been most widely employed in comparisons with experimental data. The J-dependence of the width is reasonably well explained by the model. Here the contribution to the width at low J comes from thermal shape fluctuations. The T dependence of the width is not very well reproduced by this model, particularly at low T. An improvement in this model, by including pairing fluctuations, is able to describe the GDR width at low T. The macroscopic collisional damping model (CDM) predicts a monotonic increase of width with T but does not address the J-dependence. The experimental data at high T do not agree with the CDM predictions.

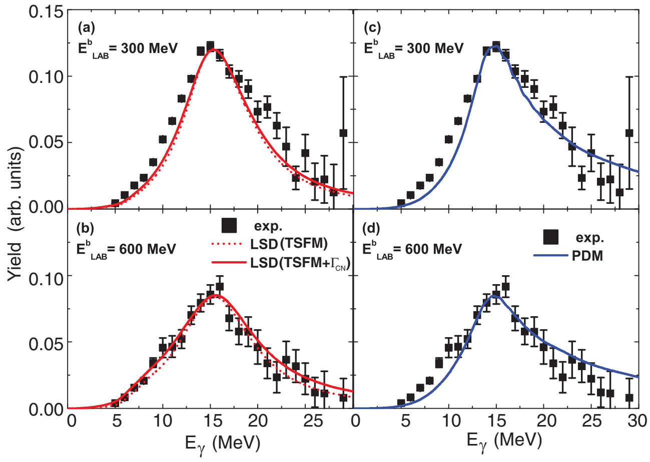

Fig. 1. Experimental and theoretical GDR strength functions in ^{88}Mo at beam energies of 300 MeV (E_X = 123.8 MeV) [(a) and (c)] and 600 MeV (E_X = 260.7 MeV) [(b) and (d)]. Results of Lublin-Strasbourg Drop model (LSD) based on TSFM (including the contribution of the evaporation width Γ_{CN}) and PDM calculations are shown by continuous lines. Dashed lines are LSD results without Γ_{CN} contribution.

The microscopic models, which go beyond the finite-temperature random-phase approximation (FT-RPA), have shown that the GDR spreading width $\Gamma^{\downarrow}$, which arises because of coupling to 2 particle - 2 hole configurations, is almost temperature-independent. Among the various microscopic models the phonon-damping model (PDM)[1)] is the most successful one [Figs. 1 (c) and 1 (d), where E_x in (c) corresponds to the mean temperature T_{ev} = 2 MeV of nuclei in the evaporation process after the emission of GDR γ-ray, whereas T_{ev} = 3.1 MeV in (d)]. The results of the PDM calculations including pairing fluctuations agree with the T-dependence of the observed widths at low and moderate T. It predicts the width's saturation as well as the quenching of the GDR γ-ray yield at very high T.

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Reference

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