Nuclear collective excitations in hot and fast rotating nuclei

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One of the fascinating and extensively studied subjects in modern nuclear structure physics is the observation of giant dipole resonance (GDR) mode, which demonstrates a simple and well organized collective motion in complex many-body system like atomic nuclei. The phenomenon of GDR is very common one and it occurs in all nuclei. In liquid drop picture the resonance can be viewed as highly damped, small amplitude, high frequency, out of phase vibration of neutron and proton fluids in a spatial dipole pattern. The resonance is called 'giant' due to its large width in comparison to other known nuclear resonances and also due to the large cross section, implying that nearly all the nucleons participate in the vibration. The width of the resonance is related to the various damping mechanisms of the collective motion inside nuclear matter. The short lifetime of this resonance makes it an excellent probe to study the nuclear properties at extreme conditions, e.g. nuclear shapes and deformations at high temperature and angular momentum, fission time scale, isospin mixing, the ratio of nuclear shear viscosity to entropy volume density etc.

How GDR width depends on nuclear temperature (*T*) & angular momentum continues to remain prime focus for four decades in this field. The most widely accepted model for hot GDR is the thermal shape fluctuation model (TSFM) [1]. This model predicts the *J* dependence quite well. However, it deviates from the measured data at low as well as at high temperatures. Experimentally, the measurement of GDR width at low temperature (T <1.5 MeV) is also very challenging due to the difficulties in achieving low excitation energy. Traditional heavy ion fusion reactions are limited to higher temperature due to the presence of Coulomb barrier in the entrance channel and are always associated with broad J distributions. Inelastic scattering has been used as an alternative approach with the advantage that the angular momentum transfer will be relatively low, but the excitation energy windows are uncertain to about at least 10 MeV and hence, the estimated temperatures are less precise. Due to these reasons, very few and widely separated (~ 0.25 MeV) data points with large error bars are available using this method. At high temperature (T > 2.5 MeV), one of the open issues in this field is the saturation of GDR width. The experimental work done by O. Wieland et al [2], confirmed the monotonic increase of GDR width at least up to T~3.2 MeV and their data could be nicely reproduced by TSFM. However, recently M. Ciemala [3] et al suggested a possible onset of saturation of GDR width around T~3 MeV. The above results are contradictory in nature and deserve further investigation [4].

At VECC, an experimental program has been taken up to systematically investigate the above mentioned temperature regions. For studying low T region, a new experimental approach has been introduced for the first time and a series of experiments [5-8] have been carried out covering mass region A~30-210. These experiments have been performed using alpha beam from K-130 Cyclotron. The LAMBDA array [9] was used for the detection of high-energy gamma rays (typically in the range of 5 to 35 MeV). The Gamma Multiplicity filter array [10] was used to estimate the number of low energy discrete gamma rays which are emitted in coincidence with the high energy gamma rays and carry the required angular momentum (J) information. The neutron TOF array [11] was employed to measure the nuclear level density (NLD) parameter from the energy spectra of the evaporated neutrons in nuclear reactions which is very important for the statistical model calculation and also for the proper estimation of nuclear temperature (T). A typical experimental setup is shown in Fig.1.

Fig. 1 A typical experimental setup consisting of LAMBDA array along with ancillary detectors

The systematic trend of the data seems to disagree with the TSFM. The model predicts the gradual increase of GDR width from its ground state value whereas the measured GDR widths appear to remain constant at the ground state value up to certain temperature T_c (following an empirical relation 0.7 + 37.5/A) and increases thereafter. With the availability of new data at low temperatures, theoretical interest has also grown up. To explain the suppression of GDR width with respect to TSFM a new phenomenological model called critical temperature included fluctuation model (CTFM), has been proposed [8] which explains the measured data quite well. It should be highlighted that, by including the pairing fluctuation filed in the TSFM calculations, the GDR width has recently been fairly well described at T<1.5MeV in open-shell nuclei [12]. In addition, the measured data is well reproduced by the microscopic phonon damping model (PDM) [13,14].

To study the evolution GDR width at high temperature, recently the following experiment has been performed. A self-supporting 1 mg/cm^2 thick target of ^{58}Ni was bombarded with a pulsed ^{16}O beams of energies of 116,140 and 160 MeV to populate the compound nucleus ^{74}Kr* at excitation energies ~ 88, 107 and 123 MeV respectively. Data analysis is going on and a preliminary high energy gamma ray spectrum has been shown in Fig. 2. In this symposium, an overview of T & J dependence of GDR parameters and recent research activities at

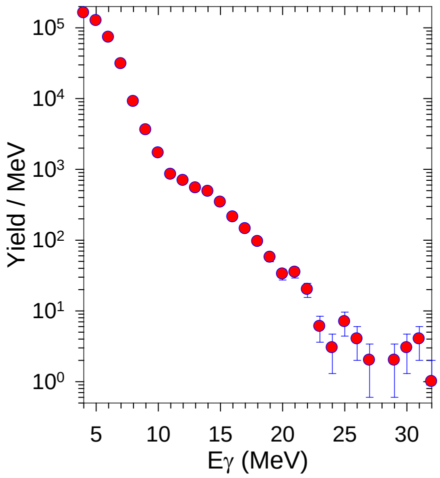

Fig. 2 Experimental high-energy γ-ray spectrum for the reaction ^{16}O (E_{Lab}=160 MeV) + ^{58}Ni → ^{74}Kr.

VECC in this direction along with new experimental results will be presented.

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