The decay of high energy GDR γ-rays from ^{32}S nucleus

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Clustering is one of the most fundamental aspects of nuclear many-body dynamics, which exist simultaneously with the formation of a mean-field [1]. It is now well accepted that α-clustering occurs in self conjugate nuclei, that is nuclei with *N* =*Z*, which have an equal number of protons and neutrons. Owing to this cluster formation, strongly deformed states are formed at higher angular momenta (J). The relation between the superdeformed band of ^{32}S and ^{16}O +^{16}O molecular band was studied recently and was found that superdeformed band members of ^{32}S have a considerable amount of the ^{16}O+^{16}O component [2]. The giant dipole resonance (GDR) is one of the best probes to study these deformations at excited states via the splitting of the GDR lineshape [3]. But, the statistical decay of the GDR from self-conjugate nuclei built on highly excited states, when populated by T=0 reaction channel, is hindered since decays from T=0 to T=0 states are isospin forbidden. The transitions from T=0 to T=1 states are allowed, but there are not many T=1 final states available to be populated by the GDR decays. However, the yield of high-energy γ-rays from N=Z compound nuclei increases in the presence of isospin mixing [4]. The GDR decay from ^{32}S was studied earlier in the reaction ^{20}Ne + ^{12}C at 145 and 160 MeV incident energies [5]. However, the data was analysed without considering the isospin effect in the statistical CASCADE calculation. Hence, the data have been reanalyzed using a modified version of CASCADE in which isospin quantum number is taken into account.

Recently, the isospin mixing at lower excitation energy was estimated in ^{32}S at E* = 30 MeV in the reaction ^{4}He+ ^{28}Si [6]. The Coulomb spreading width (Γ↓), which mixes the T=0 and T=1 states, was estimated to be Γ↓= 13 keV. The GDR centroid energy E_{GDR} and width Γ_{GDR} was extracted as 17.5 MeV and 7.5 MeV, respectively. It has been seen experimentally and justified theoretically that the Coulomb spreading width remains constant with excitation energy [7]. Hence, using this value, the ^{32}S data at higher angular momenta were reanalyzed to extract the GDR parameters.

It is now well known that the GDR width increases with excitation energy due to thermal fluctuations and angular momentum induced deformation but the E_{GDR} remains constant [8]. Hence, the ^{32}S data formed in the reaction ^{20}Ne + ^{12}C was tried to fit with E_{GDR} = 17.5 MeV, larger width Γ_{GDR} = 13 MeV and Γ↓= 13 keV. It can be seen, even in the high-energy gamma ray spectra, that the data cannot be explained using a single Lorentzian in the statistical model calculation (Fig 1 left panel). A second component in the higher energy region is evident in the high energy gamma ray spectra. The bremsstrahlung slope was estimated from the bremsstrahlung systematic. Hence, the data were analysed considering two lorentzian functions for the GDR in CASCADE. However, it was not possible to fit the data with Γ↓= 13 keV as arbitary strength function (more than 300% of TRK sum rule) was required for the higher GDR component. Even for Γ↓= 100 keV (which corresponds to large mixing) around 200% of TRK sum rule was required for the second component. Therefore, the data were analysed using Γ↓= 100 MeV (which should correspond to full mixing) and is shown in Fig 1 (right panel). Interestingly, for 100 MeV mixing the GDR parameters were similar with those obtained from the normal CASCADE [5]. The strength function required for 100 MeV mixing was also found to be ~ 100 % as required by TRK sum rule. The linearised GDR spectrum for E_{lab} = 145 MeV is shown in Fig 2 (upper panel) using the quantity $F(E_\gamma) * Y_{exp}/ Y_{cas}$ where Y_{exp} and Y_{cas} are the experimental gamma yield and CASCADE prediction, respectively.

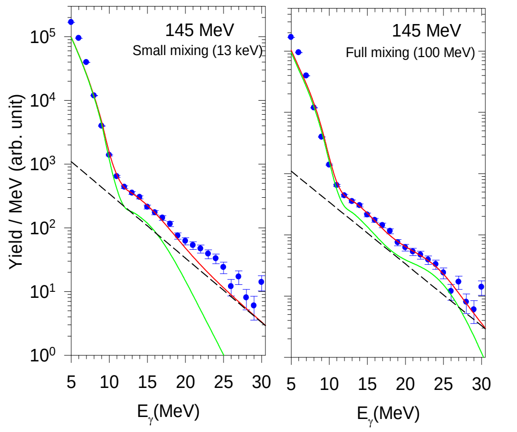

Fig.1. The experimentally measured γ-ray spectrum (filled circles) from ^{32}S at E_{lab} = 145 MeV. The CASCADE predictions using different mixing and GDR strength function is also shown along with the bremsstrahlung component (dashed lines).

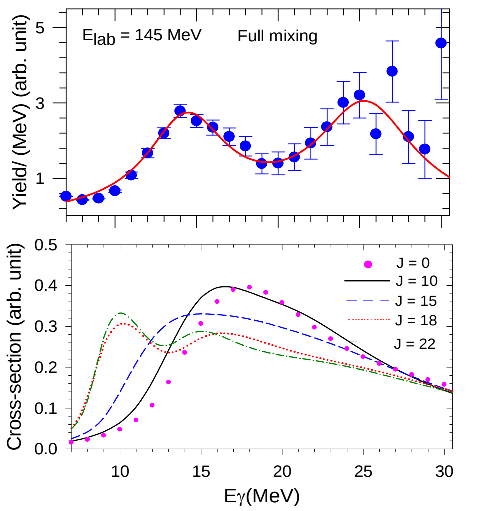

Fig.2. The linearized experimental GDR strength function (filled circles) ^{32}S (upper panel). The evolution of GDR lineshape with angular momentum for ^{32}S nucleus at T = 2.8 MeV generated using TSFM (lower panel).

$F(E_\gamma)$ is the GDR strength function used in the CASCADE calculation. Interestingly, similar results were also obtained for E_{lab} = 160 MeV.

A theoretical calculation was performed to generate the GDR lineshape under the framework of thermal shape fluctuation model [TSFM] [5]. The calculations were performed at different angular momenta and T = 2.8 MeV (extracted from the experimental excitation energy) [5]. The shape evolution as a function of J is shown in Fig 2 (bottom panel.) It can be clearly seen that considering mean field picture only, it is not possible to explain the data ^{32}S at high J.

Thus, it is observed that the high energy γ-ray spectra data from ^{32}S at higher angular momentum cannot be explained using a single Lorentzian function and small isospin mixing with reasonable GDR strength functions. On the other hand, the high energy γ-ray spectrum from ^{32}S is indeed suppressed due to isospin symmetry when populated via different reaction channel ^{4}He + ^{28}Si (i.e. at low J) and can be explained using a single Lorenztian strength function. As it appears, the two GDR component obtained at higher angular momenta is for very deformations (β-0.76) and could be due to orbiting or clustering. The result seems to be consistent with the recent macroscopic-microscopic model which shows cluster formation in microscopic density distributions resembling ^{16}O+^{16}O configuration in ^{32}S at higher angular momentum [9]. It would have been interesting to generate the GDR lineshape considering the splitting due to clustering, recently done for ^{12}C and ^{16}O [10], but is beyond the scope of present work.

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References

[1] W. von Oertzen et al., Physics. Reports 432 (2006) 43.
[2] M. Kimura et al., Phys. Rev. C 69 (2004) 051304 (Rapid).
[3] J. J. Gaardhoje, Ann. Rev. Nucl. Part. Sci. 42 (1992) 483.
[4] M. N. Harakeh Phys. Lett. B 176 (1986) 297.
[5] Deepak Pandit et al, Phys. Rev. C 81 (2010) 061302 (Rapid).
[6] Debasish Mondal et al, DAE Symp. on Nucl. Phys. 58 (2013) 52.
[7] H. L. Harney et al., Rev. Mod. Phys. 58, (1986) 607.
[8] Deepak Pandit et al., Phys. Lett. B 713 (2012) 434 and references therein.
[9] T. Ichikawa et al, Phys. Rev. C 83 (2011) 054319.
[10] W. B. He et al, PRL 113 (2014) 032506.