Possibility of nuclear structure effects on ISGMR in low- and medium-mass nuclei

Krishichayan[1,2]*, Y.-W. Lui[2], J. Button[2], and D.H. Youngblood[2]
[1]Dept. of Pure & Applied Physics, Guru Ghasidas University, Bilaspur - 495009, C.G., INDIA
[2]Cyclotron Institute, Texas A&M University, College Station, TX 77843, USA
* email: krishichayan@gmail.com

Introduction

The giant resonances (GR) are small amplitude collective modes of excitations of nuclei and have been extensively studied since the discovery of the isovector giant dipole resonance (IVGDR) by Baldwin and Klaiber [1] over a wide mass region. The study of the isoscalar giant monopole resonance (ISGMR), identified in 1977 [2], in which protons and neutrons in a nucleus move in-phase and oscillate with spherical symmetry, is important as it provides information about finite nuclear incompressibility, K_A, from which the incompressibility of infinite nuclear matter, K_{NM}, can be obtained [3]. The incompressibility of finite nucleus is related to the GMR energy by $K_A = [M/\hbar^2]\langle r^2\rangle E_{GMR}^2$ where in the scaling model $E_{GMR} = (m_3/m_1)^{1/2}$ and $m_k = \Sigma(E_n - E_0)k|\langle 0|r^2|n\rangle|^2$ is the kth moment of the strength distribution. There are, in general, two approaches to relate finite nucleus incompressibility, K_A, to infinite nucleus incompressibility, K_{NM}. In the semi-empirical (macroscopic) approach, which is similar to the semi-empirical mass formula, K_A is expressed as a Leptodermous ($A^{-1/3}$) expansion to parameterize K_A into volume, surface, symmetry, and Coulomb terms. K_{NM} is identified with the volume term as $K_{NM} = \lim_{A\to\infty} K_A = K_{vol}$ (valid in scaling model only). In the microscopic approach, strength function of the ISGMR is carried out using fully self consistent mean-field based random-phase approximation (RPA), with specific interactions [4] and comparing with the experimental data. The values of K_{NM} are then deduced from the interaction that best reproduced the experimental data. With the availability of a large amount of giant resonance data from 240-MeV α inelastic scatterings, Texas A&M group has studied the ISGMR in large number of nuclei in different mass region with $12 \leq A \leq 208$. It has been reported that the monopole strength in heavier (spherical) nuclei is concentrated in a mostly symmetrical peak, and in light nuclei the strength is located either in a peak with significant tailing to the high energy side or with obvious broad components above the main peak [5,6]. The origin of this behaviour is not clear and it could be due to the effects of nuclear structure or some other effects.

Experimental details and results

A beam of 240-MeV α-particles from Texas A&M K500 superconducting cyclotron, after passing through a beam analysis system, bombarded self-supporting targets (varying from ^{12}C to ^{208}Pb) located in the scattering chamber of the multipole-dipole-multipole (MDM) spectrometer. The experimental details are given in Ref. [7]. The horizontal acceptance of the spectrometer was 4° and the vertical acceptance was set at ±2°. Ray tracing was used to reconstruct the scattering angle. Scattered particles entering the MDM spectrometer were momentum-analyzed and measured by a 60 cm long focal plane detector, which consisted of four resistive wire proportional counters to measure position, as well as an ionization chamber to provide ΔE and a plastic scintillator behind the ionization chamber to measure the energy deposited and provided a fast timing signal for each event. A position resolution of ~ 0.9 mm and scattering angle resolution of ~ 0.09° were obtained. The out–of-plane scattering angle was not measured. At $\theta_{spec} = 0°$, runs with an empty target frame had an α-particle rate approximately 1/2000th of that with a target in place, and α particles were uniformly distributed in the spectrum.

As seen in Fig.1, in ^{208}Pb, ^{144}Sm, and ^{116}Sn, ISGMR strength distribution is concentrated in what appears to be one symmetric peak (with Gaussian-like shape). This is the case with all heavy nuclei (A ≥ 100). In ^{60}Ni, the ISGMR is asymmetric with a slower slope on the high excitation side of the peak whereas in nuclei with A ≤ 28 the ISGMR becomes fragmented. The structure of the ISGMR in ^{40,48}Ca are quite complex, with multiple components. In ^{90}Zr [8], the shape changes to mostly symmetric with a tail on the high excitation side of the ISGMR, as seen in Fig.1. As we have seen from our data, the

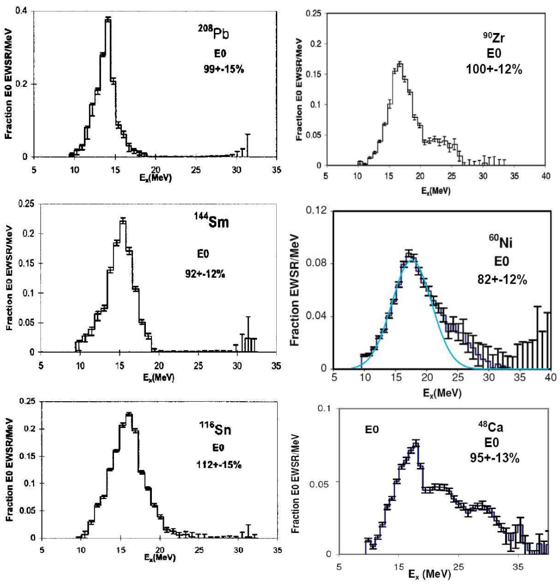

Fig. 1 E0 strength distributions for nuclei in different mass region. Data taken from Refs.[6,8,9]

transition from mostly symmetric to asymmetric shape occurs at ^{90}Zr region. Fig.2 shows the ISGMR strength distribution in ^{90,92}Zr and ^{92}Mo nuclei. As we see from Fig. 2, the upper peak of ^{90}Zr at E_x = 24.9 MeV contains about 22% of the E0 EWSR (Energy Weighted Sum Rule) while the lower narrow peak contains the bulk of the E0 strength. However the additions of two nucleons (protons or neutrons) to ^{90}Zr results in a very different picture. In ^{92}Zr the higher peak at E_x = 25.5 MeV contains 38% and the narrow peak 62% of the E0 EWSR. On the other hand, in ^{92}Mo, the higher peak contains 65% of the E0 EWSR while only 42% is located in the narrow lower peak. Detailed experimental analysis as

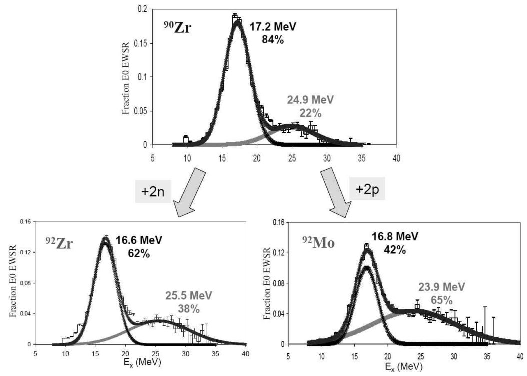

Fig. 2 ISGMR strength in Zr and Mo nuclei. The centroids and E0 EWSR strengths of the two components obtained with collective model transition densities are shown.

well as theoretical approaches to understand the anomalous behaviour of ISGMR shape will be discussed in detail.

References

[1] G.C. Baldwin and G.S. Klaiber, Phys. Rev. 71, 3 (1947).

[2] D.H. Youngblood, C.M. Rozsa, J.M. Moss, D.R. Brown, and J.D. Bronson, Phys. Rev. Lett. 39, 1188 (1977).

[3] J.P. Blaizot, J.F. Berger, J. Decharge, M. Girod, Nucl. Phys. A 591, 435 (1995).

[4] S. Shlomo, V. M. Kolomietz, and G. Colo, Eur. Phys. J. A30, 23 (2006) and references therein.

[5] D.H. Youngblood, Y.-W. Lui, Y. Tokimoto, H.L. Clark, B. John, Phys. Rev. C68, 057303 (2003)

[6] Y.-W. Lui, D.H. Youngblood, S. Shlomo, X. Chen, Y. Tokimoto, Krishichayan, M. Anders, and J. Button, Phys. Rev. C83, 044327 (2011).

[7] D.H. Youngblood, Y.-W. Lui, and H.L. Clark, Phys. Rev. C60, 014304 (1990).

[8] D.H. Youngblood, Y.-W. Lui, B. John, Y. Tokimoto, H.L. Clark, and X. Chen, Phys. Rev. C69, 054312 (2004).

[9] D.H. Youngblood, Y.-W. Lui, H.L. Clark, B. John, Y. Tokimoto, and X. Chen, Phys. Rev. C69, 034315 (2004); Y.-W. Lui, D.H. Youngblood, H.L. Clark, Y. Tokimoto, and B. John, Phys. Rev. C73, 014314 (2006).