Isoscalar Giant Resonance for Nuclei with $A \geq 60$

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The locations of the isoscalar giant monopole resonance (GMR) and giant dipole resonance (ISGDR) are important because their energies can be directly related to the nuclear compressibility and from this the compressibility of nuclear matter ($K_{NM}$) can be obtained [1,2]. In the past few years, experiments with much improved peak to continuum ratio have been performed mostly in heavy nuclei $A \geq 90$ [3,4] as well as in light nuclei $A \leq 40$ [5-8]. Together with development of the multipole analysis program, high precision strength distributions of isoscalar multipoles in these nuclei have been obtained. The results of GMR strength distributions in heavy nuclei concluded the nuclear matter compressibility is $231 \pm 5$ MeV [3]. With the available of large amount of data in wide range of $A$ ($12 \leq A \leq 208$), we have also studied the mass dependence of GMR and the characteristic of GMR [3,8]. In heavy nuclei ($A \geq 110$), the shape of GMR strength distribution is typically symmetric (Gaussian like) [3], in $^{90}$Zr, the shape changes to mostly symmetric with a tail at high excitation side of the GMR [3]. This changes to asymmetric with a slower slope on the high excitation side of the peak in $^{58}$Ni and $^{40}$Ca and becomes fragmented in $A \leq 28$. The origin of this is not clear, it may be due to nuclear structure or some other effects. From our data, the transition from mostly symmetric to asymmetric shape occurs between $^{90}$Zr and $^{58}$Ni [10], however, between $40 \leq A \leq 90$, only one nucleus $^{58}$Ni has been thoroughly studied. Therefore, it is important to have more information in this region to study this interesting effect and the mass dependence of GMR. We have studied $^{46,48}$Ti, $^{56}$Fe, $^{60}$Ni, $^{64}$Ni and $^{64}$Zn recently, the preliminary result for the Ti isotopes has been reported [11] in a previous progress report. We will present preliminary results for $^{56}$Fe, $^{60}$Ni and $^{64}$Zn in this report.

![Figure 1](image-url)

Figure 1. Inelastic $\alpha$ spectra for $^{56}$Fe, $^{58,60}$Ni and $^{64}$Zn at $\theta_{avg}=1.1^\circ$. The solid lines show the continuum chosen for the analysis.
The experimental technique has been described thoroughly in Ref. [6] and is summarized briefly below. Beams of 240 MeV α particles from the Texas A&M K500 superconducting cyclotron bombarded self-supporting foils located in the target chamber of the multipole-dipole-multipole spectrometer. The horizontal acceptance of the spectrometer was 4 deg. and raytracing was used to reconstruct the scattering angle. The vertical acceptance was set at ± 2°. The focal plane detector measured position and angle in the scattering plane and covered from 47 to 55 MeV of excitation, depending on scattering angle. The out-of-plane scattering angle was not measured. Position resolution of approximately 0.9 mm and scattering angle resolution of about 0.09° were obtained. Cross sections were obtained from the charge collected, target thickness, dead time and known solid angle. The cumulative uncertainties in target thickness, solid angle, etc., result in about ±10% uncertainty in absolute cross sections. ²⁴Mg spectra were taken before and after each run with each target and the 13.85±0.02 MeV L=0 state was used as a check on the calibration in the giant resonance region.

Sample spectra obtained for ⁵⁶Fe, ⁵⁸,⁶⁰Ni and ⁶⁴Zn are shown in Fig. 1. The spectrum was divided into a peak and a continuum, where the continuum was assumed to have the shape of a straight lines at high excitation joining onto a Fermi shape at low excitation to model particle threshold effects. The multipole components of the giant resonance peak were obtained by dividing the peak into multipole regions (bins) by excitation energy and then comparing the angular distributions obtained for each of these bins to distorted wave born approximation (DWBA) calculations. Optical model parameters obtained for ⁵⁸Ni were used for ⁵⁶Fe, ⁶⁰Ni and ⁶⁴Zn calculations. The transition densities, sum rules, and DWBA calculation were discussed in Ref. [6]. Preliminary GMR strength distributions for ⁵⁶Fe, ⁵⁸Ni, ⁶⁰Ni

Figure 2. GMR strength distributions for ⁵⁶Fe, ⁵⁸,⁶⁰Ni and ⁶⁴Zn are shown by histogram. Error bars represent the uncertainty due to the fitting for angular distributions.
and $^{64}$Zn are shown in Fig. 2. More than 70% of GMR strength have been located in these nuclei and the experimental energies $(m_3/m_1)^{1/2}$ are labeled in Fig. 2.

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