Isoscalar giant dipole resonance for several nuclei with \( A \geq 90 \)


Although evidence for the isoscalar giant dipole resonance (ISGDR) in \(^{208}\text{Pb}\) has been reported by several groups [1-4], details of the ISGDR were not known until recent years [5,6]. In 2001, Clark et al. [5] reported that the isoscalar E1 strength distribution in \(^{90}\text{Zr}\), \(^{116}\text{Sn}\) and \(^{208}\text{Pb}\) consisted of two components, containing a total of more than 100\% energy-weighted sum rule (EWSR). This discovery confirms the predictions from microscopic calculation that there are two components in E1 distribution, however, the large difference in the energy of the ISGDR between the experiment and theory was puzzling. The discrepancy found later [7] in the formula for the ISGDR transition density given by Harakeh and Dieprink [8] reduced the E1 EWSR strength located in those nuclei to \( \sim 40\% \). This suggests that there could be some missing E1 strength in the higher excitation region and a re-investigation of the E1 strength distribution with more sensitive data to the ISGDR angular distribution is necessary.

In these measurements, the horizontal and vertical acceptance of the spectrometer was set to minimize spurious scattering in the spectra and ray tracing was used to reconstruct the scattering angle. The focal plane detector contains two parts: the horizontal part covered approximately 50 MeV of excitation and measured position and angle \( \theta \) in the scattering plane, and the vertical part measured the out-of-plane scattering angle \( \phi \) [9]. The experimental technique has been described thoroughly in Ref. [10]. Sample spectra for \(^{144}\text{Sm}\) at \( \theta_{\text{avg}} = 0.4^\circ \) and \( 0.9^\circ \) are shown in Fig. 1. The giant resonance peak can be seen extending up past \( E_x = 35 \) MeV with excellent peak to continuum ratio. The spectrum was divided into a peak and a continuum where the shape of the continuum was described in detail in Ref. [7]. The multipole decomposition analysis and the DWBA calculations were described in detail in Ref. [7,10].

The E1 strength distributions obtained for \(^{90}\text{Zr}\), \(^{144}\text{Sm}\) and \(^{208}\text{Pb}\) are shown in Fig. 2. There are two components in each distribution, a broad component at \( E_x \sim 125 \text{MeV}/A^{1/3} \) containing approximately 70\% of the E1 EWSR and a narrower component at \( E_x \sim 74 \text{MeV}/A^{1/3} \) containing 11 to 28\% of the E1 EWSR. Two calculated Gaussian peaks are superimposed on each distribution. The estimated uncertainty in

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**Figure 1.** Inelastic alpha spectra for \(^{144}\text{Sm}\) at \( \theta_{\text{avg}} = 0.4^\circ \) and at \( 0.9^\circ \). The solid lines show the continuum chosen for the analysis.
each centroid is about 0.6 MeV. With the new data, the high energy component is much stronger than the low energy component and extends to higher excitation energy. The centroids of the high energy components are about 1 to 2 MeV higher than those given in Ref. [8].

The centroid energies for both components are compared to the calculated values of Colo et al. [20,23] in Table I. The centroids of the upper component are about 1 MeV less than the theoretical values in $^{208}$Pb and $^{144}$Sm and about 2.7 MeV lower than the predicted value in $^{90}$Zr. The calculated centroids of the lower component locate 2-3 MeV below the experimental values in $^{208}$Pb and $^{90}$Zr and it is in good agreement with the experimental value in $^{144}$Sm. The experimental E1 strength distributions were converted to ISGDR response functions and are shown with the calculation from Colo et al. for $^{144}$Sm is shown in Fig. 3.

![Figure 2](image1.png)

**Figure 2.** ISGDR strength distributions for $^{90}$Zr, $^{144}$Sm and $^{208}$Pb are shown by the histogram. Error bars represent the uncertainty due to the fitting of the angular distributions. The solid lines are Gaussian peaks calculated with parameters labeled near the peak.

![Figure 3](image2.png)

**Figure 3.** E1 response functions obtained from two different experiments, the dark color histogram is from experiment without measuring vertical angle and the light color histogram is from experiment with vertical angle information. The solid line is the calculation from Colo et al. [11].

The dark color data are from experiment without vertical angle information and the light blue data are from recent experiment with vertical angle information. The present results are in closer agreement with calculated values on the two components of the E1 distribution. However, the splitting of the ISGDR from the present data is still 3-5 MeV less than that predicated in calculations.
**Table 1.** Comparison of centroids to Colo et al., [11, 12] calculations.

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\(^a\)Ref. 12

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**References**