

LOOKING FOR THE ISOSCALAR GIANT DIPOLE RESONANCE IN INELASTIC α SCATTERING AT AND NEAR 0°

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We have undertaken a detailed investigation of the isoscalar giant dipole resonance (ISGDR) in ^{208}Pb with a view to obtaining conclusive evidence for its existence via measurements at very small angles. The ISGDR is best described as a “hydrodynamical density oscillation”, meaning a state in which the volume of the nucleus remains constant and the energy of the state is in the form of a compression wave oscillating back and forth through the nucleus (the “squeezing mode”).¹ It is a second-order effect (in the first order, the isoscalar dipole mode corresponds to the spurious center-of-mass motion!). In addition to being of substantial intrinsic interest as an exotic mode of collective oscillation, it also has importance in that it provides a direct measurement of the nuclear compressibility. The excitation energy of the ISGDR, as given by the scaling model is:

$$E_x = \sqrt{\frac{7}{3} \cdot \frac{K_a + \frac{27}{25}\epsilon_F}{3m\langle r^2 \rangle}}$$

where K_a is the compressibility of the nucleus and ϵ_F is the Fermi energy. Of course, the most common and well-known experimental determination of the nuclear compressibility has been achieved via the excitation energies of the giant monopole resonance (GMR), the systematics of which are already quite well established. There have been some concerns, however, about the extraction of the nuclear compressibility of infinite nuclear matter from the available GMR data.² A detailed and systematic investigation of the ISGDR would provide additional information on the compressibility of nuclei, leading, it is hoped, to a more precise determination of the compressibility of nuclear matter.

The evidence for this resonance has been rather sparse so far. Indications for this resonance have been reported in inelastic scattering experiments at forward angles on ^{208}Pb and ^{144}Sm .³⁻⁵ However, this resonance lies very close in energy to the high-energy octupole resonance (HEOR) and unambiguous identification of the ISGDR is possible only

at angles near 0° because any appreciable differences in the angular distributions of the two resonances appear only at those angles. Using an alpha probe near 0° has the added advantages that the isoscalar nature of this reaction leads to only these two giant resonances, which are dominant in the spectrum at the excitation energies of interest. Also near 0° the cross sections are at their maxima. The situation, thus, is quite similar to that of the GMR more than a decade ago: unambiguous evidence for GMR could be established only by measurements at the smallest angles where the GMR angular distribution differs substantially from that of the giant quadrupole resonance (GQR), which lies at an excitation energy close to the GMR.

Fig. 1 shows the expected inelastic α scattering angular distributions for the ISGDR and HEOR in ^{208}Pb over the angular range 0° – 7° . By utilizing the 2° angular acceptance of the K600 spectrometer, and making software cuts in the spectra from 0° to 1° and from 1° to 2° , it is possible to use the “difference-of-spectra technique” which has been very effectively used in detailed investigations of the GMR.⁶ When properly normalized, the difference of these two cut spectra would show little contribution from the octupole resonance, which has a roughly flat distribution over this angular range, or from the background. In principle, this would yield a spectrum that is a lucid picture of the desired ISGDR.

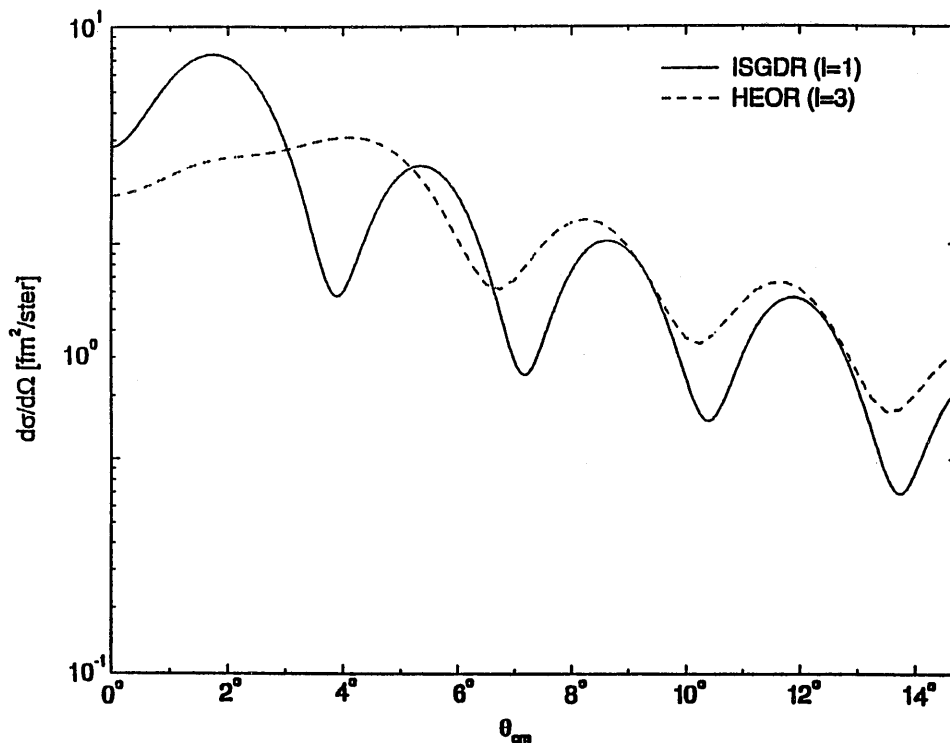


Figure 1. Shown are results of DWBA calculations for the HEOR and ISGDR angular distributions in $^{208}\text{Pb}(\alpha, \alpha')$ at 200 MeV incident energy.

We have made (α, α') measurements at the IUCF K600 spectrometer at very small angles (including 0°) to study the ISGDR in ^{208}Pb . Data have been obtained at 0° – 2° , as well as at 4° , 5° , 6° , 7° , 8° and 10° , with an energy resolution of approximately 100 keV. The non-zero angle measurements were taken using the newly commissioned septum magnet.

Fig. 2 shows the 0° – 2° spectrum. A broad “bump”, most likely comprised of the ISGDR and the HEOR, is clearly visible above background. Detailed data analysis is presently in progress with a view to disentangling the two resonances using the “difference-of-spectra” technique mentioned above. Preliminary results do seem to indicate the presence of the ISGDR: the centroid of the “bump” in the “subtracted spectrum” is almost 1 MeV higher than that in the full 0° – 2° spectrum. This is consistent with the expectation that the component of the “bump” associated with the HEOR (which has an excitation energy lower than that of the ISGDR)^{3–5} is substantially removed in the subtracted spectrum.

In the same experiment, data were also obtained, albeit with lesser statistics, on ^{120}Sn ; a detailed analysis will follow completion of the analysis of the ^{208}Pb data. Further experiments are planned to establish the efficacy of this technique in studying the ISGDR in detail.

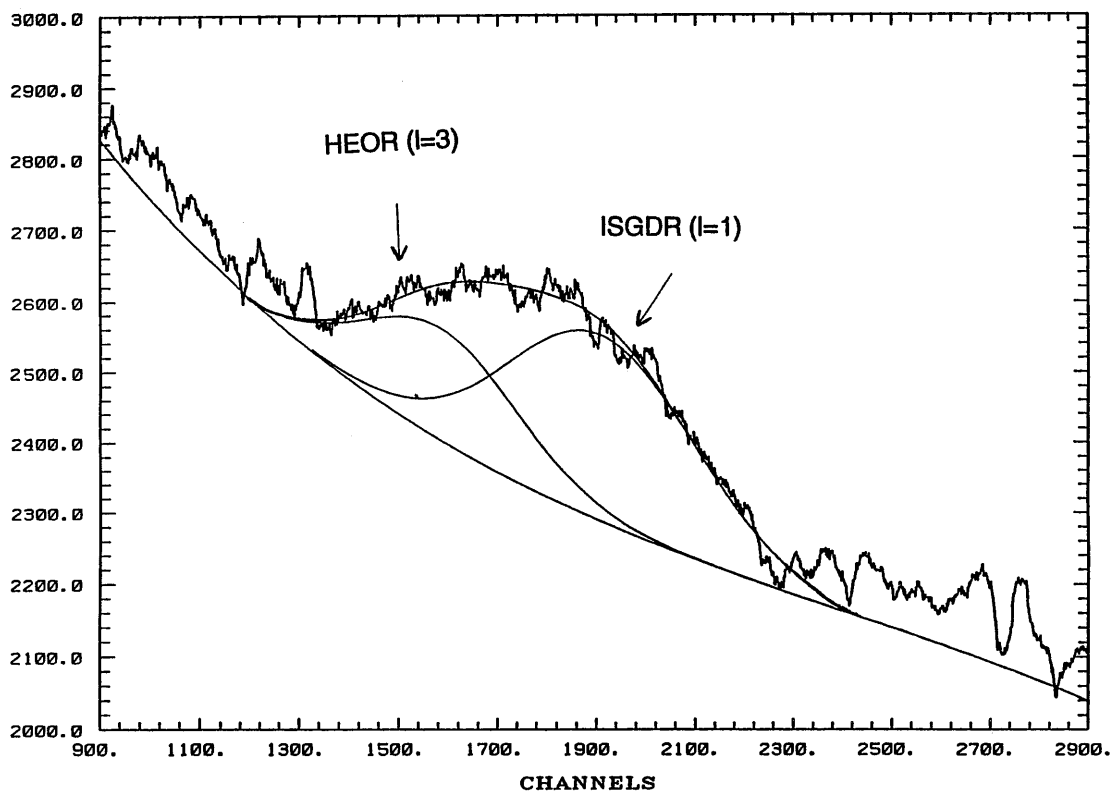


Figure 2. Measured 0° – 2° momentum spectra of $^{208}\text{Pb}(\alpha, \alpha')$ at 200 MeV incident energy are displayed. The solid lines show fits to the data indicating the possible positions of the HEOR and ISGDR. See text for details.

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