Giant resonances in ^{112}Sn

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The isoscalar giant quadrupole resonance and the giant monopole resonance in ^{112}Sn were identified at $E_x = 13.3 \pm 0.2$ MeV and 15.7 ± 0.3 MeV, respectively, using small angle inelastic scattering of 129 MeV alpha particles. The nuclear incompressibility parameters for the volume term ($K_{\rm vol}$), the surface term ($K_{\rm surf}$), and the symmetry term ($K_{\rm sym}$) were determined including ^{112}Sn.

The incompressibility of a nucleus (K_A) can be parametrized using the semiempirical mass formula as follows:[1,2]

$$K_A = K_{\rm vol} + K_{\rm surf} A^{-1/3} + K_{\rm sym}[(N-Z)/A]^2 + K_{\rm Coul} ,$$

where

$$K_{\rm Coul} = \frac{6Z^2e^2}{5r_c A^{4/3}}$$

with $r_c = 1.24$ fm. $K_{\rm vol}$ is usually interpreted as the incompressibility of nuclear matter ($K_{\rm nm}$), and K_A is obtained from the energy of the giant monopole resonance (GMR) as

$$E_m = \frac{\hbar}{r_0}\sqrt{K_A/m} ,$$

where m is the nucleon mass.[1,2] Utilizing this parametrization, $K_{\rm vol}$, $K_{\rm surf}$, and $K_{\rm sym}$ have been deduced from studies of the GMR systematics.[2] However, the absence of the GMR in light nuclei ($A < 64$) (Refs. 2 and 3) has limited the accuracy of those parameters. By studying the GMR over a series of isotopes to maximize the difference in $[(N-Z)/A]$, one may be able to better determine the symmetry parameter $K_{\rm sym}$. As the position of the GMR is affected by nuclear deformation,[4] a series of isotopes with spherical ground states would provide the best determination of $K_{\rm sym}$. The Sn isotopes are good candidates since a wide range of $[(N-Z)/A]$ is available with easy to fabricate and relatively inexpensive targets. Furthermore, from ^{112}Sn to ^{124}Sn the ground states appear to be spherical. Studies of the GMR in ^{116}Sn, ^{118}Sn, ^{120}Sn, and ^{124}Sn using 130 MeV alpha particles have already been reported.[2] We report here a study of the giant resonances in ^{112}Sn.

A beam of 129.1 MeV alpha particles, accelerated by the Texas A&M variable energy cyclotron, was used to bombard a self-supporting metal foil enriched to $>99.0\%$ in ^{112}Sn. Inelastically scattered alpha particles were detected with an 86 cm long resistive wire proportional counter backed by an NE102 scintillator placed in the focal plane of an Enge split-pole magnetic spectrograph. Considerable care was taken to minimize beam halo and slit scattering, especially for measurements at 0°. The detailed experimental setup and data analysis procedures are discussed in Ref. 5.

Angular distributions were taken over the range $\theta_{\rm lab} = 0°-7°$. Figure 1(a) shows energy spectra taken at 0° and 4°. After subtraction of the nuclear continuum, analyses were done by fitting two Gaussian components to the observed peak, and the results are shown in Fig. 1(b). Distorted-wave Born approximation (DWBA) calculations for quadrupole and monopole transitions were performed as described in Ref. 5. The observed angular distributions for the two components are shown in Fig. 2 together with the DWBA predictions for $L = 0$ and 2 transfer. The low-excitation component in the giant resonance peak is well fitted by the quadrupole calculation, and exhausts $57 \pm 20\%$ of the $E2$ energy weighted sum rule (EWSR). The high-excitation component is reasonably described by a monopole calculation exhausting $166 \pm 60\%$ of the $E0$

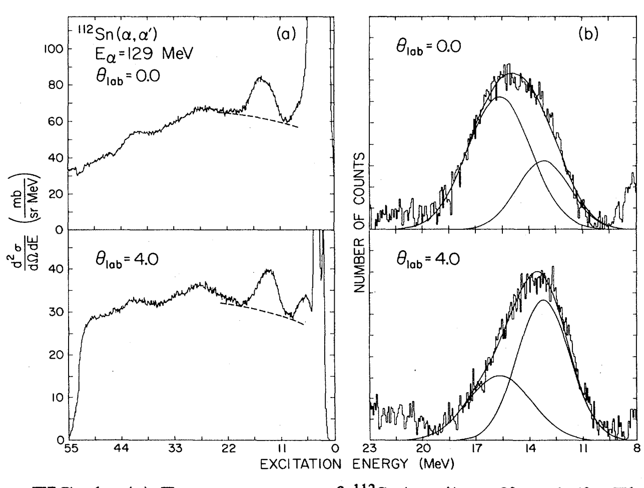

FIG. 1. (a) Energy spectra of ^{112}Sn(α,α') at 0° and 4°. The dashed line indicates the nuclear continuum assumed. (b) Portions of spectra at 0° and 4°, after subtraction of the nuclear continuum. The solid lines represent the fitted peaks and the sum.

EWSR. The uncertainties in the EWSR include the uncertainties in obtaining the cross section, in the background subtraction, peak decomposition, and normalization of DWBA predictions to the experimental data.

The positions and widths of the giant quadrupole resonance (GQR) and the GMR in the Sn isotopes are compared in Fig. 3. As expected, $EA^{1/3}$ and the widths remain constant within the errors. The strengths obtained for ^{112}Sn are reasonably consistent with those for the other Sn isotopes.

In addition to the above "single L" analysis for each peak, another fitting procedure whereby each peak was assumed to consist of several states with differing L values was carried out on ^{112}Sn. This multiple L analysis was motivated by two observations: (1) The GMR strength obtained for all the Sn isotopes (with the single L fit) is more than 1.5 times the EWSR, and (2) the peak to valley ratios in the experimental angular distribution are not nearly as large as predicted for a pure $L=0$ transfer, suggesting the presence of other processes. The angular distributions for both groups were fitted with a combination of L transfers using a least squares technique (see Ref. 6), and the results are shown by the dashed curves in Fig. 2. The best fit to the 15.7 MeV group was with $79\pm10\%$ $L=0$ EWSR, $29\pm4\%$ $L=2$ EWSR, and $3.6\pm1.0\%$ $L=4$ EWSR, while the best fit to the 13.3 MeV group

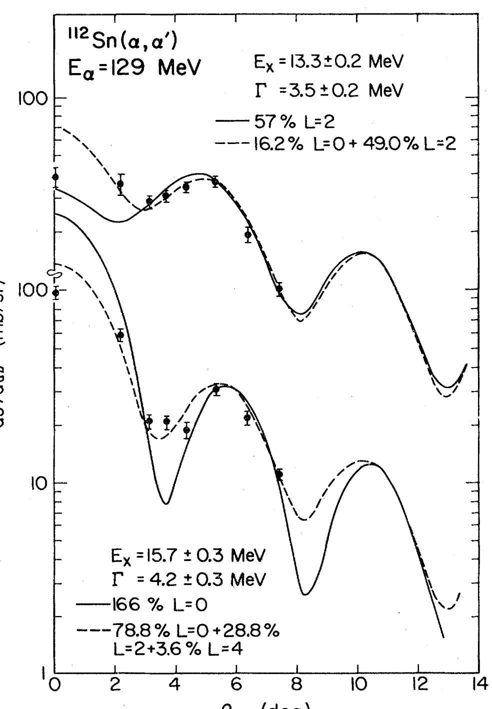

FIG. 2. Angular distributions obtained for the two components of the giant resonance peak. Error bars represent the statistical uncertainties obtained from the peak fitting. The solid lines are DWBA predications for the L transfer indicated. The dashed lines are the multiple L fits for different L transfers. Percentages of the respective EWSR are given.

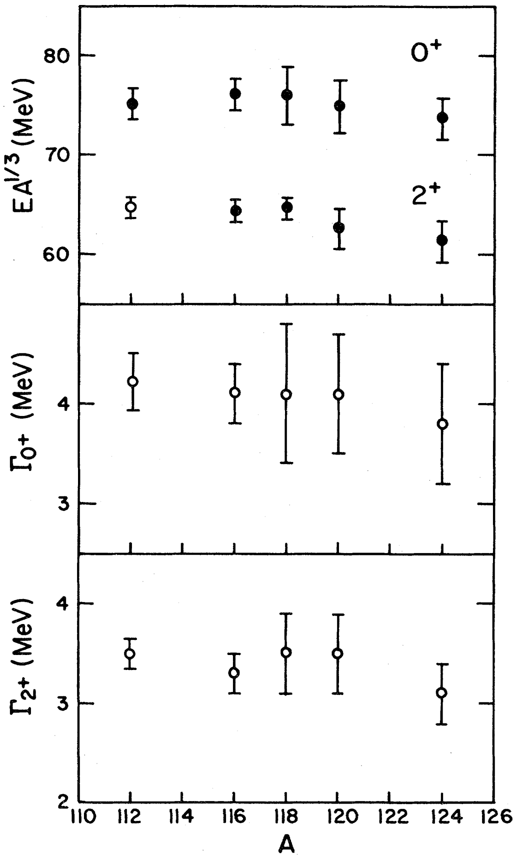

FIG. 3. Behavior of giant resonance parameters in Sn isotopes.

was with $16\pm5\%$ $L=0$ EWSR and $49\pm3\%$ $L=2$ EWSR. Inclusion of $L=4$ did not improve the fit to the 13.3 MeV group. The uncertainties quoted do not include systematic errors. These results suggest the existence of some concentrated $L=4$ strength in the GR region as predicted,[7] as well as some sharing of the GQR and GMR strength between the two groups. It must be kept in mind, however, that the peak to valley ratio in the angular distribution is affected strongly by almost any competing process which is not properly subtracted out, and it is not clear that the above multiple-L solution is unique. It is likely, however, that the actual amount of $L=0$ strength present is considerably less than that obtained with a pure $L=0$ fit.

A multiple L analysis of the data taken at Texas A&M for other nuclei is now underway, and possibly a consistent picture of the continuum which must be subtracted as well as the contributions of other multipolarities to each peak will emerge.

The values of K_{vol}, K_{surf}, and K_{sym} were extracted using the method described in Ref. 2 assuming that the GMR is located at 15.7 MeV, and the results are compared to that obtained without ^{112}Sn in Table I. The addition of K_A for ^{112}Sn changed each of the parameters somewhat, however, the uncertainties were not reduced significantly. A considerably more accurate determination of the energies of these states will be required for sig-

TABLE I. Incompressibility parameters.

	A[a]	B[b]
K_{vol}	221± 32	206± 35
K_{surf}	−398±135	−339±144
K_{sym}	−285±253	−133±286
x^2	1.02	0.99

[a]Used values for ^{64}Zn, ^{66}Zn, ^{90}Zr, ^{112}Sn, ^{115}In, ^{116}Sn, ^{118}Sn, ^{120}Sn, ^{124}Sn, ^{144}Sm, ^{197}Au, and ^{208}Pb.
[b]Without ^{112}Sn value.

nificant improvement in these uncertainties; the location of the GMR in light nuclei would particularly help. There is some question as to the proper form for this parametrization, and more complex forms have been proposed,[8] however, the data do not yet warrant introducing additional parameters.

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[1]J. P. Blaizot, D. Gogny, and B. Grammaticos, Nucl. Phys. A265, 315 (1976).
[2]D. H. Youngblood, P. Bogucki, J. D. Bronson, U. Garg, Y.-W. Lui, and C. M. Rozsa, Phys. Rev. C 23, 1997 (1981).
[3]D. Lebrun, M. Buenerd, P. Martin, P. de Saintignon, and G. Perrin, Phys. Lett. 97B, 358 (1980).
[4]U. Garg, P. Bogucki, J. D. Bronson, Y.-W. Lui, C. M. Rozsa, and D. H. Youngblood, Phys. Rev. Lett. 45, 1670 (1980).
[5]C. M. Rozsa, D. H. Youngblood, J. D. Bronson, Y.-W. Lui, and U. Garg, Phys. Rev. C 21, 1252 (1980).
[6]Y.-W. Lui, J. D. Bronson, D. H. Youngblood, Y. Toba, and U. Garg, Phys. Rev. C (to be published).
[7]K. Goeke and J. Speth, Annu. Rev. Nucl. Part. Sci. 32, 65 (1982).
[8]J. P. Blaizot, Phys. Rep. 64, 171 (1980).