Isoscalar E0, E1 and E2 Strength in ^{28}Si

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In an earlier report[1], evidence was presented for the location of approximately half of the E0 and 1/3 of the E2 sum rule strength in ^{28}Si. Unfortunately in order to extract information about K_{NM}, essentially all of the E0 strength must be located. Thus we report here a further study of ^{28}Si where data were obtained with considerably better statistics, the folding model was used to obtain multipole strengths, and a new analysis procedure [2] was used which treats the continuum in a more consistent manner and allows extraction of multipole distributions with much better resolution Inelastic scattering of 240 MeV α particles particles from the Texas A&M K500 superconducting cyclotron were used to excite giant resonances and they were detected over the angle range from 0^{o} to 7^{o}. The experimental technique has been described thoroughly in Ref. 1 and 2.

A sample spectrum obtained is shown in Fig. 1. The giant resonance peak can be seen extending up past E_x = 35 MeV. The spectrum was divided into a peak and a continuum where the continuum was assumed to have the shape of a straight line at high excitation joining onto a fermi shape at low excitation to model particle threshold effects[2]. The multipole components of the giant resonance peak were obtained[2] by dividing the peak into multiple regions (bins) by

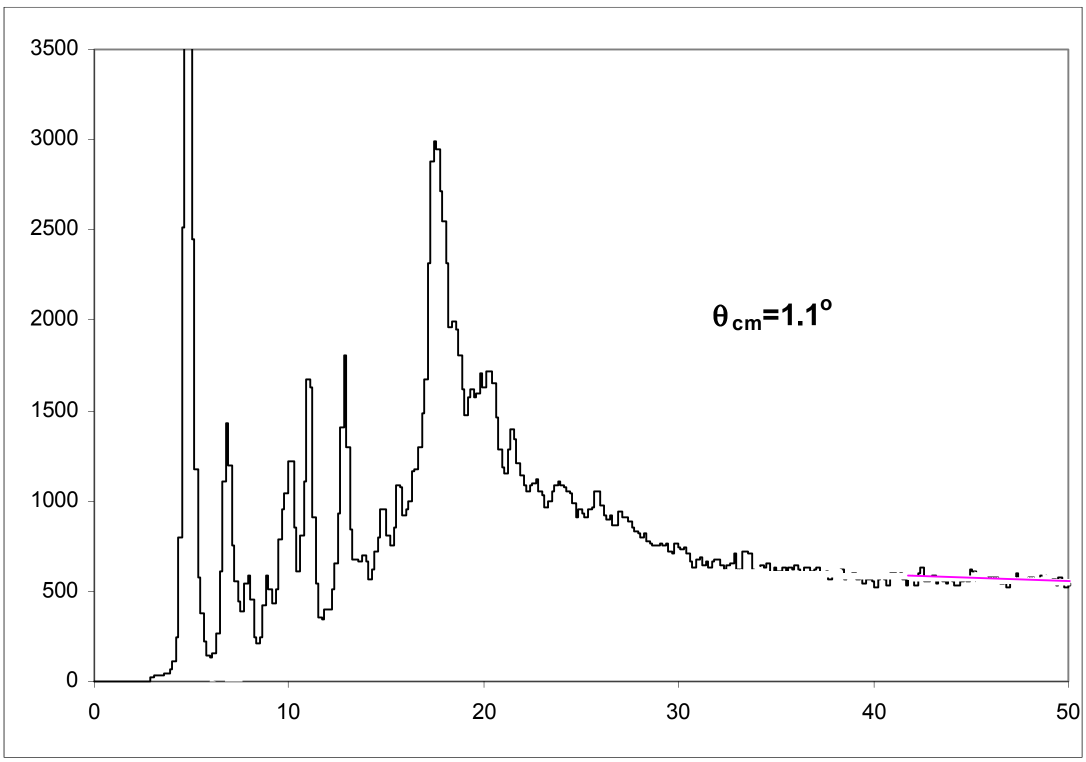


Figure 1: Inelastic α spectrum of ^{28}Si obtained with the spectrometer at 0^{o}. The thick line shows the continuum chosen for the analysis

excitation energy and then comparing the angular distributions obtained for each of these bins to distorted wave Born approximation (DWBA) calculations to obtain the multipole components.

For this work we have used density dependent

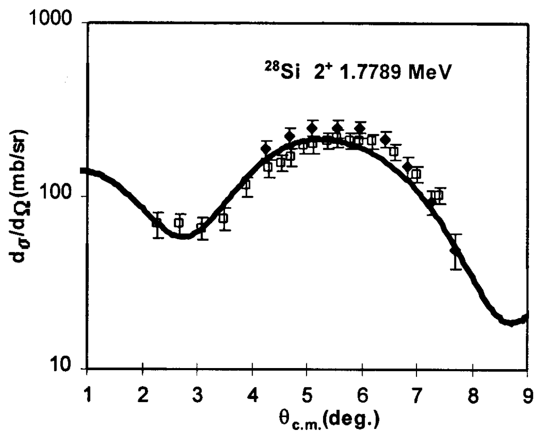
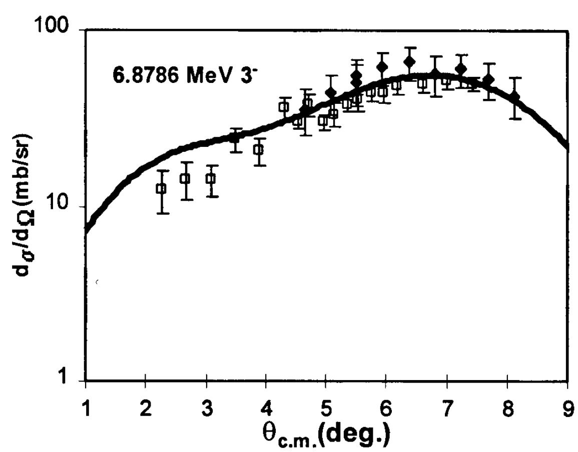


Figure 2: (a) Angular distribution of the differential cross section for inelastic α scattering to the 1.7789 MeV 2^+ state in ^{28}Si plotted versus average center-of-mass angle. The solid line shows an L=2 DDWS calculation.



(b) Angular distribution of the differential cross section for inelastic ∀ scattering to the 6.8786 MeV 3^- state in ^{28}Si plotted versus average center-of-mass angle. The solid line shows an L= 3 DDWS calculations for B(EL)= 0.00457 e3fm6.

single folding with a Woods-Saxon imaginary term (DDWS) which was shown by Satchler and Khoa[3] to give excellent results for low lying states in ^{58}Ni excited by 240 MeV inelastic α MeV scattering. Folding parameters, given in Table 1, were obtained by fitting the elastic scattering data reported in Ref. 1. DDWS calculations for the 1.7789 MeV 2^+ and 6.8786 MeV 3^- states in ^{28}Si using electromagnetic B(EL) values from the NNDC[5] are shown superimposed on data we obtained for those two

Table 1: Folding model and Fermi parameters used.

V (MeV)	W (MeV)	R_i (fm)	a_i (fm)	R_c (fm)	c (fm)	a (fm)
44.0	32.5	4.303	0.687	3.970	3.155	0.623

Table 2: Multipole parameters obtained for ^{28}Si.

	m_1/m_0 (MeV)	RMS width (MeV)	%EWSR	Ratio def.pot./folding
E0	21.25±0.38	6.4±0.6	81±10	1.17
E2	18.54±0.25	4.7±0.6	68±9	1.24
E1 (T=0)	19.15±0.60	6.9±0.70	44±10	1.37

states in Fig. 3. The agreement is excellent.

A sample of the angular distributions obtained for the giant resonance(GR) peak and the continuum are shown in Fig. 3. Fits to the angular distributions were carried out with a sum of isoscalar 0^+, 1^-,2^+, 3^-, and 4^+ strengths. The isovector giant dipole resonance (IVGDR) contributions are small, but were calculated from the known distribution[6] and held fixed in the fits. Sample fits obtained, along with the individual components of the fits, are shown superimposed on the data in Fig. 3.

The (Isoscalar) E0, E1, and E2 multipole distributions obtained are shown in Fig. 4 and the results are summarized in Table 2. The strength distributions obtained in Ref. 1, normalized by the difference between the folding and deformed potential calculations (used in ref. 1) are shown superimposed. Also shown is the E0 strength distribution obtained from the fits to the continuum. It can be seen in Fig. 4 that the E0 strength obtained from the fits to the continuum contains about 6% of the E0 EWSR and, while the uncertainties are large, no contribution to E0 strength is seen above E_x=27 MeV. The E0 distribution shown in the top panel in Fig. 4 includes both the peak and continuum contributions and corresponds to 82$\pm$12% of the E0 EWSR compared to 54$\pm$6% reported in Ref. 1. The additional strength comes from the use of folding, the strength seen at low excitation (below the threshold of the measurement reported in Ref.1), the inclusion of continuum strength (it was not included in ref. 1), and the strength seen above E_x=35 MeV where the much better statistics of this measurement improved the analysis.

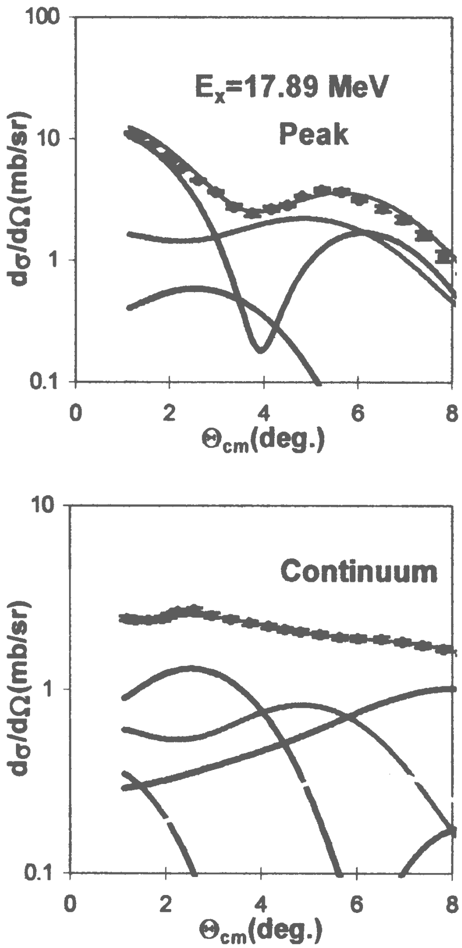


Figure 3: Angular distributions of the GR peak and the continuum for inelastic α scattering from ^{28}Si obtained for the bin having E_x=17.89 MeV. Thin lines show the fits and the broad line shows the E0 contribution. Contributions of the other multipoles are shown as hatched lines. When not shown, errors are smaller than the data points.

The E2 strength observed corresponds to 65$\pm$10% of the E2 EWSR with a centroid of 18.54 MeV. Previous studies[1,9] identified approximately 32$\pm$5% of the EWSR strength centered around 19.0 MeV. In this measurement, additional E2 strength was identified below the threshold of the measurement reported in ref. 1 and from 25<E_x<35 MeV. Renormalizing the Ref. 1 results by the deformed potential/folding model cross section ratio would increase the strength reported in Ref. 1 to 40$\pm$6%.

Isoscalar E1 strength corresponding to 44$\pm$10% of the E1 EWSR was identified with a centroid of 19.15 $\pm$ 0.60 MeV and an RMS width of 6.9 MeV. Generally the distribution is in excellent agreement with the renormalized distribution from Ref. 1. Additional strength is seen in this measurement below the threshold of Ref. 1. In addition to the deformed potential/folding correction in Table 2, the calculation for E1 cross section used in Ref. 1 was a factor of 1.87 too high due to a numerical error, so that the E1 strength reported in Ref. 1 was in error by a factor of 1.87.

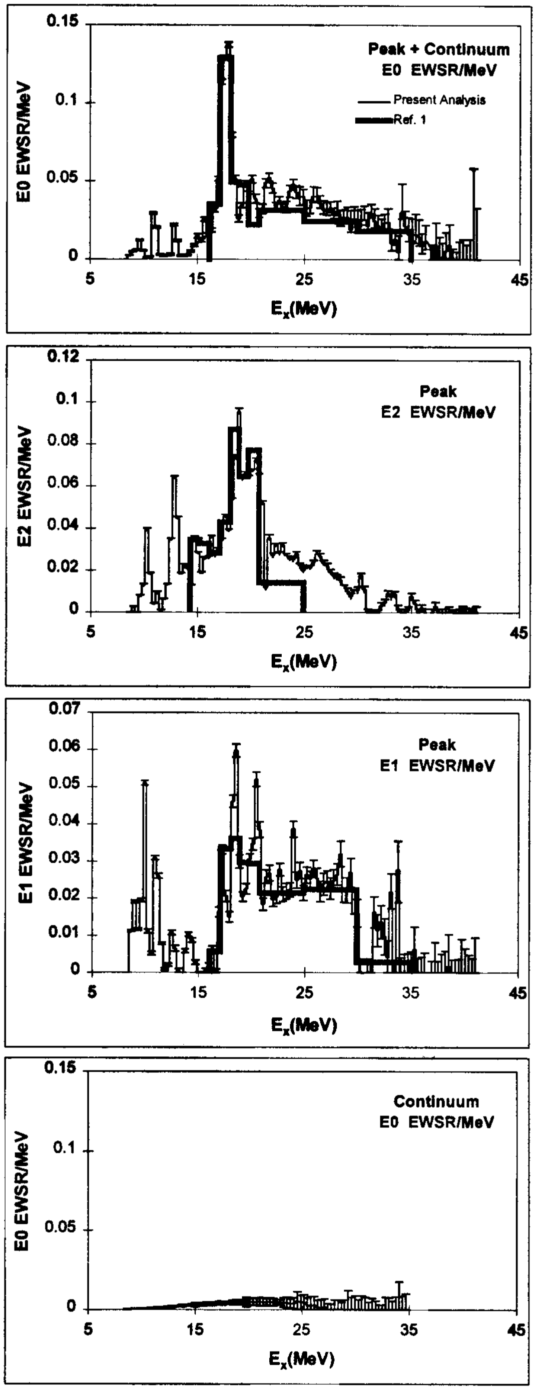


Figure 4: Strength distributions obtained are shown by the histograms. Error bars represent the uncertainty due to the fitting of the angular distributions. The thick lines show the distributions reported in Ref. 1, renormalized by the deformed potential to folding ratio.

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