$^{16}O+^{8}Be$ breakup of ^{24}Mg via the $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$ and $^{12}C(^{24}Mg, ^{16}O^{8}Be)^{12}C$ reactions

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(Received 24 April 1998)

A study of the $^{12}C(^{20}Ne, ^{16}O\ ^{8}Be)^{8}Be$ and $^{12}C(^{24}Mg, ^{16}O\ ^{8}Be)^{12}C$ reactions has revealed $^{16}O+^{8}Be$ breakup occurring from specific states in the ^{24}Mg nucleus at high-excitation energies. A spin assignment has been determined for one of these states from an angular correlation measurement of the breakup fragments. In the ^{20}Ne beam reaction, states have been identified at 22.33, 22.96, 24.00, 24.43, 24.88, 25.53, 27.35, 27.97, 28.88, and 30.13 MeV, and in the ^{24}Mg beam reaction states have been identified at 20.58, 21.54, 22.70, and 24.31 MeV. The results have been compared with previous measurements of the $^{12}C+^{12}C$ breakup channel. [S0556-2813(98)03209-9]

PACS number(s): 25.70.Ef, 21.10.Re, 27.30.+t

I. INTRODUCTION

Following the initial observation of the $^{12}C+^{12}C$ molecular resonances by Almqvist *et al.* [1], many experiments have been performed in an attempt to establish a link between these resonances and states in ^{24}Mg and hence infer some cluster structure within that nucleus. One line of approach has been a study of the fission of ^{24}Mg into two ^{12}C nuclei in order to identify any correspondence with the scattering resonances and provide further insight into the structural properties of these states. Early studies used the electrofission of ^{24}Mg [2] and the inverse process of radiative capture [3]. Both these measurements revealed the existence of a series of states around an excitation energy of 22 MeV in the ^{24}Mg nucleus. However, these states did not appear to coincide with the resonances observed in the $^{12}C+^{12}C$ system. Inelastic scattering of alpha particles [4] and protons [5] have also been used to excite the ^{24}Mg nucleus in an attempt to probe these breakup states and, while these measurements removed the low multipolarity restriction of the electrofission and radiative capture measurements, the low detection efficiencies resulted in low breakup yields making interpretation difficult.

More recently, inverse kinematic reactions have provided a successful means of studying the $^{12}C+^{12}C$ breakup of states in ^{24}Mg by scattering a ^{24}Mg beam from a ^{12}C target (e.g. [6,7]). For example, a measurement of the $^{12}C(^{24}Mg, ^{12}C^{12}C)^{12}C$ reaction at 170 MeV indicated a series of states in ^{24}Mg displaying energy-spin systematics characteristic of a rotational band with large deformation [8]. Furthermore, the moment of inertia deduced from these measurements was close to that observed for the scattering resonances. While these breakup results suggest the existence of high lying excited states in ^{24}Mg with a pronounced $^{12}C+^{12}C$ cluster configuration, no definite association of these states with the scattering resonances was possible. However, the results from a recent high resolution measurement of the $^{12}C(^{24}Mg, ^{12}C^{12}C)^{12}C$ reaction [9] would suggest that the energies, spins and widths of the $^{12}C+^{12}C$ breakup states are in good agreement with those of the molecular resonances. This gives a strong indication that there is a direct relationship between these two phenomena.

Alongside the experimental evidence for the existence of highly deformed states in ^{24}Mg with a possible cluster structure, theoretical calculations also indicate that such structures may exist. Nilsson-Strutinsky calculations for the potential energy surface in ^{24}Mg predict the existence of several stable configurations at high deformation [10]. The cranked cluster model developed by Marsh and Rae [11] also predicts that a number of quasi-stable cluster configurations should exist in

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this nucleus and, on the basis of their deformation and shell model configuration, these cluster states have been associated with the minima in the Nilsson-Strutinsky calculations [12]. Cranked calculations suggest several of the minima that appear have moments of inertia consistent with that determined from the $^{12}C+^{12}C$ breakup results.

A study of the $^{12}C(^{20}Ne, ^{12}C^{12}C)^{8}Be$ reaction [13], using an alpha transfer process to excite the states of interest, revealed states in ^{24}Mg showing close agreement with those seen in the ^{24}Mg beam data. The selective nature of the transfer reaction suggests the association between these structures and the octupole stabilized prolate minimum predicted by the Nilsson-Strutinsky calculations, which has a dominant $4p$-$4h$ configuration in its wave function. This structure has a 3:1 axis deformation and in the cranked cluster model regime corresponds to an α-^{16}O-α configuration. Interestingly, this prolate configuration has been associated with the $^{12}C+^{12}C$ molecular resonances by several authors [11,14,15], supporting the view that the $^{12}C+^{12}C$ breakup reactions may be populating the same states seen in the $^{12}C+^{12}C$ scattering measurements.

If the prolate shape isomer is indeed responsible for the $^{12}C+^{12}C$ breakup yield, then theoretical models suggest similar yields should be observed in other breakup channels. For example, the oscillator model developed by Harvey [16] suggests that excited structures based on this configuration would be expected to break up into either the $^{12}C+^{12}C$ or $^{16}O+^{8}Be$ partitions, with both fragments in their ground states. In addition, time-dependent Hartree-Fock calculations [17,18] suggest the vibrational motion of a $^{12}C_{gs}+^{12}C(0_2^+)$ system gives rise to an α-^{16}O-α or ^{16}O-α-α configuration for a considerable portion of the time which would again enhance decay to the $^{16}O+^{8}Be$ channel. Observation of the same states breaking up into both the $^{12}C+^{12}C$ and $^{16}O+^{8}Be$ channels would, therefore, support the association of the breakup states with the deformed prolate structure. Furthermore, a study of the asymmetric fission channel allows the possible identification of any odd parity states in the rotational sequence which are forbidden to decay by symmetric fission and have therefore not been observed in earlier $^{12}C+^{12}C$ breakup measurements.

A measurement of the reaction $^{12}C(^{24}Mg, ^{16}O^{8}Be)^{12}C$ has previously been reported by Fulton *et al.* [19] and did indeed show breakup occurring from the excitation region of interest between 20–25 MeV. However, due to the rather poor resolution and detection efficiency, no evidence was seen in the $^{16}O+^{8}Be$ breakup yield for states similar to those seen in the $^{12}C+^{12}C$ channel. This measurement has therefore been repeated with an improved detection arrangement and, to complement this, a similar excitation region has also been studied using the alpha transfer reaction, $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$.

II. EXPERIMENTAL PROCEDURE

The first experiment was carried out at the Nuclear Structure Facility at Daresbury using a 170 MeV ^{24}Mg beam to study the $^{12}C(^{24}Mg, ^{16}O^{8}Be)^{12}C$ reaction. The second experiment was performed using a 160 MeV ^{20}Ne beam from the 88-Inch Cyclotron at the Lawrence Berkeley Laboratory to study the $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$ reaction. The detection arrangements used were identical in both experiments.

In order to reconstruct events with three-body final states, it is necessary to obtain position and energy information for two of the three final-state particles. To detect and identify the ^{16}O nuclei, three heavy ion detector telescopes were employed. Each telescope consisted of three silicon surface barrier detectors; a relatively thin ΔE passing detector (30 μm), an intermediate thickness E detector (300 μm), and a final stopping detector (2000 μm). The stopping detectors were thick enough to stop alpha-particles passing through the telescopes and could therefore be used in the offline analysis to eliminate pile-up events involving alpha particles (of which there was a very high flux). The ΔE and E detectors were position sensitive in one dimension, with orthogonal axes so as to determine both in-plane and out-of-plane position information. The three telescopes were mounted in a vertical arrangement to provide coverage for both in-plane and out-of-plane coincidences. In both experiments, the two telescopes mounted above and below the horizontal scattering plane were angled at 10° to the horizontal plane such that all three telescopes were an equal distance from the target (120 mm). In this configuration the solid angle subtended by each telescope was 6.94 msr.

In order to detect the two alpha particles from the breakup of $^{8}Be_{g.s.}$, a 1000 μm thick silicon strip detector was situated on the other side of the beam axis. This detector consisted of sixteen position sensitive strips formed on a single silicon slice, with the horizontal and vertical dimensions of each strip being 50 mm and 3 mm, respectively. Using resistive charge division in the horizontal plane, signals were taken from both ends of each strip. These signals then provided the energy and in-plane position information for each incident alpha-particle. The vertical position of the strip in the array provided the out-of-plane position information for each detected alpha particle. A sheet of 175 μm thick mylar absorber was mounted in front of this detector to prevent the damaging flux of elastically scattered beam particles from entering the detector. This detector was also situated 120 mm from the target position giving a solid angle of 170 msr.

In order to obtain the energy and position response of the heavy ion telescopes, a grid consisting of accurately positioned holes was placed in front of each telescope and elastically scattered ions of known energy were recorded through each hole. This technique also enabled estimates of the energy and position resolutions to be determined. The ^{16}O energy resolution of the heavy ion telescopes was 400 keV and 550 keV for the ^{24}Mg and ^{20}Ne beam experiments, respectively, whilst the in-plane and out-of-plane position resolutions were estimated to be $\approx$ 0.6 mm.

The energy calibration of the alpha detector was obtained using known states in ^{20}Ne observed in the $^{12}C(^{20}Ne, ^{16}O\alpha)^{12}C$ reaction, which was recorded simultaneously with the data of interest. In both experiments, the energy resolution of each strip in the alpha detector was between 300 and 500 keV for single alpha particle events. The position response of the strips in the alpha detector was assumed to be linear and the in-plane position resolution for a single alpha particle was estimated to be about 0.5 mm. The out-of-plane position resolution was governed by the height of the strips, which was 3 mm.

In the first experiment, data were obtained for one set of

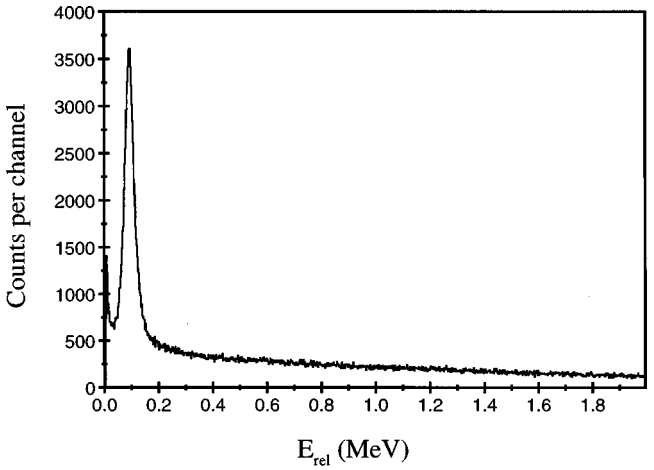

FIG. 1. Reconstructed relative energy spectrum for coincident alpha particles in the strip detector. The peak at 92 keV signifies the breakup from $^{8}Be_{g.s.}$ events.

detector angles, 11.0° and 18.0° for the heavy ion telescopes and strip detector, respectively. Natural carbon targets of both 200 μg cm^{-2} and 400 μg cm^{-2} thickness were used during this experiment, and the accumulated beam charge for the two targets was 1.23 mC and 5.57 mC, respectively, after accounting for the dead-time of the data acquisition hardware.

In the second experiment, the strip detector was situated at 21.0°, but data were taken at two angle settings of the heavy ion telescopes, namely 15.5° and 12.0°. A natural carbon target of thickness 240 μg cm^{-2} was used, and the accumulated beam charge, after accounting for dead-time, was 2.58 mC at the 15.5°/21.0° setting, and 1.64 mC at the 12.0°/21.0° setting. The uncertainty in the accumulated beam charge is estimated to be about 25% due to an intermittent hardware malfunction.

III. ANALYSIS

The analysis of the data from both experiments followed an identical procedure. The heavy ion telescopes provide the necessary particle identification to distinguish the ^{16}O nuclei of interest in the breakup channel and also yield the energy and angle information for each incident ion. The relative energy of the alpha particles from the ^{8}Be decay is obtained from the energies and angles of two coincident alpha particles in the strip detector, after a correction has been made for the energy loss in the mylar absorber. Figure 1 shows the reconstructed relative energy spectrum for coincident alpha particles during the $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$ experiment. The Q-value for $^{8}Be_{g.s.}$ breakup into two alpha particles is 92 keV and $^{8}Be_{g.s.}$ events can, therefore, be selected by applying a software gate on the peak at 92 keV in the relative energy spectrum.

By obtaining the energy and angle information of the $^{16}O+^{8}Be$ breakup fragments, conservation of momentum then gives the kinematic information on the unobserved recoil nucleus. The total energy in the exit channel E_{tot} is the sum of the measured ^{16}O and ^{8}Be energies and the calculated recoil energy and this gives a measure of the Q value for a particular reaction.

Only coincidences involving the middle of the three

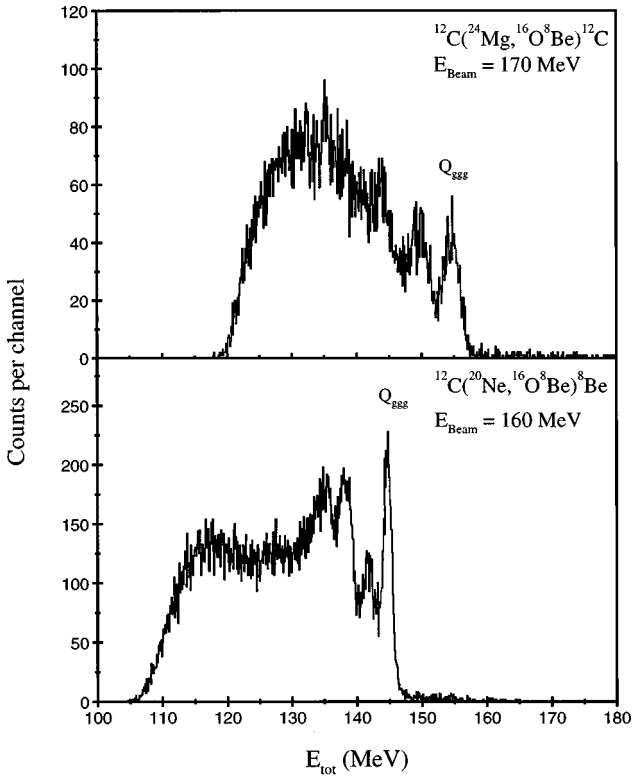

FIG. 2. Total energy spectra for coincident $^{16}O+^{8}Be$ nuclei from the $^{12}C(^{24}Mg, ^{16}O\ ^{8}Be)^{12}C$ and the $^{12}C(^{20}Ne, ^{16}O\ ^{8}Be)^{8}Be$ measurements. The peaks labeled Q_{ggg} correspond to all three particles being emitted in their ground states.

heavy-ion telescopes will be presented here because the statistics in the other two telescopes were rather poor. Figure 2 shows typical E_{tot} spectra obtained from the $^{12}C(^{24}Mg,^{16}O^{8}Be)^{12}C$ and $^{12}C(^{20}Ne,^{16}O^{8}Be)^{8}Be$ reactions. The peaks labeled Q_{ggg} correspond to all three final state particles emitted in their ground states and subsequent lower-energy peaks correspond to excitation of one or more of the fragments. Q_{ggg} events are selected in software and the relative energy of the two detected breakup fragments is reconstructed to give a measure of the excitation in the ^{24}Mg nucleus.

Figure 3 shows the reconstructed excitation spectra obtained from both reactions. The dotted lines on this figure are detection efficiency curves which have been calculated using a Monte Carlo simulation, taking into account angle coverage and energy detection thresholds, and requiring that the two alphas from the ^{8}Be breakup arrive in different strips on the strip detector. The simulation assumes an exponential falloff of the primary reaction cross section with center-of-mass scattering angle and isotropic distributions for the ^{24}Mg and ^{8}Be breakup. It should be noted that while the variation of the calculated efficiency with excitation is rather insensitive to these assumptions, the absolute value of the efficiency is not, and hence the cross sections for different reactions and different angle settings cannot be compared. However, as a guide to the order of magnitude, the Monte Carlo simulations indicate a detection efficiency of around 1% at the peak of the curve for both of the reactions studied.

The energy centroids and widths (FWHM) of the peaks in Fig. 3 are shown in Tables I and II and have been obtained

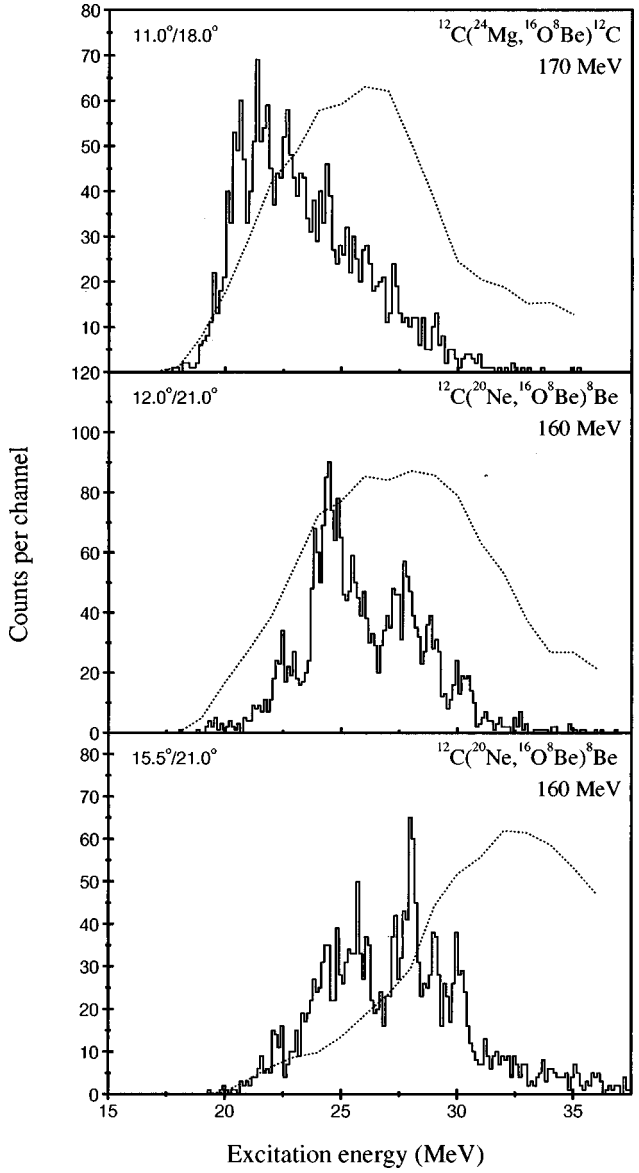

FIG. 3. ^{24}Mg excitation spectra for the ^{12}C(^{24}Mg, ^{16}O^{8}Be)^{12}C and ^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be reactions at two different angle settings, after gating on the Q_{ggg} peaks of the corresponding E_{tot} spectra. The dotted lines show the relative coincidence detection efficiency as a function of excitation, calculated using a Monte Carlo simulation, as described in the text.

from a Gaussian peak fitting routine [20]. In addition to the random error quoted on the excitation energy, all centroids are subject to an additional uncertainty of approximately 250 keV due to systematic uncertainties in the absolute excitation energy scale. Using a Monte Carlo computer code to simulate the breakup process, the excitation energy resolution is estimated to be ≈450–550 keV. Since the measured widths are considerably greater than the simulated resolution, these measured widths may represent the natural widths of the states. However, it is more likely that some or all of these states are multiplets.

Information on the spin of the breakup states can be obtained from the angular correlation of the breakup fragments [21]. This angular correlation can be expressed in terms of the center-of-mass scattering angle θ^* of the excited ^{24}Mg nucleus and the breakup angle ψ, being the angle between the beam axis and the relative velocity vector of the breakup fragments. For ^{24}Mg nuclei scattered at $\theta^*=0°$, and with a spinless recoil nucleus, conservation of J_z determines that only the $m=0$ substate can be populated for any state of spin J, where the beam direction is taken as the quantization axis. If the breakup fragments also have zero spin, the distribution of the breakup yield as a function of ψ is then represented by the square of a Legendre polynomial of order J. A measure of the periodicity of the minima at $\theta^*=0°$ then identifies the spin of the state.

Away from $\theta^*=0°$, the restriction on populating $m=0$ substates is removed and the angular correlation becomes more complicated. However, if, as in these measurements, the breakup fragments are restricted by the detector arrangement to be emitted approximately in the primary scattering plane, some simplicity in the correlation is retained. Specifically, while the dependence of the yield on ψ is no longer a squared Legendre polynomial of order J, it still oscillates with the same periodicity, but with the phase shifted in proportion to the value of θ^*. Hence the angular correlation takes the form of a series of diagonal ridges in the θ^*-ψ plane whose minima at the $\theta^*=0°$ axis coincide with those of a squared Legendre polynomial of order J. A derivation of this behavior is given in Ref. [21]. By projecting the data back along the ridges onto the $\theta^*=0$ axis, the spin of the state can be determined by comparing the position of the minima in the projected data with squared Legendre polynomials of various orders.

TABLE I. Excitation energies for the states identified in the ^{12}C(^{20}Ne,^{16}O^{8}Be)^{8}Be reaction. The energy centroids, associated errors and widths (FWHM) have been extracted using a Gaussian peak fitting routine [20]. Each peak is subject to an additional systematic uncertainty of ~250 keV. Using a Monte Carlo computer code to simulate the reaction, the excitation energy resolution for each state is estimated to be ≈450–550 keV.

E_x (MeV)	Error ΔE_x (keV)	Measured width (keV)
22.33	28	620
22.96	53	840
24.00	40	750
24.43	24	800
24.88	24	550
25.53	70	600
27.35	28	700
27.97	25	900
28.88	30	920
30.13	36	1080

TABLE II. States identified in the ^{12}C(^{24}Mg,^{16}O^{8}Be)^{12}C reaction. Using a Monte Carlo computer code, the experimental resolution is estimated to be ≈450 keV. For details, see caption for Table I.

E_x (MeV)	Error ΔE_x (keV)	Measured width (keV)
20.58	40	1050
21.54	46	1320
22.70	64	1450
24.31	115	1800

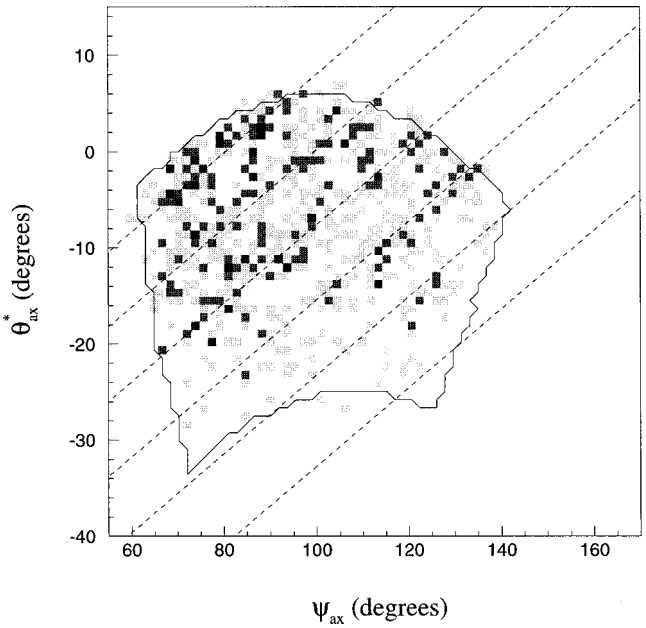

FIG. 4. Angular correlation for the state identified at 24.43 MeV in the $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$ reaction. The solid line indicates the calculated region of phase space accessible, whilst the dashed lines indicate the expected positions of ridges in the angular correlation for a $J=9$ state.

It has also been shown [22,21] that the gradient of the ridges in the θ^*-ψ plane is given by

$$\frac{d\theta^*}{d\psi}=\frac{J}{l_f}, \tag{1}$$

provided that θ^* is small and $J \ll l_f$, where l_f denotes the dominant partial wave in the exit channel. If J is determined from the periodicity of the ridges, a value for l_f can then be obtained from the gradient.

Figure 4 shows the two dimensional angular correlation for the state identified at 24.43 MeV in the $^{12}C(^{20}Ne,^{16}O^{8}Be)^{8}Be$ reaction, with data from the two angle settings combined. In this plot, instead of using a spherical polar coordinate system, we have used the so-called ''axial'' coordinate system in which the angles θ^* and ψ are projected into the horizontal scattering plane to give θ^*_{ax} and ψ_{ax}. It has been shown by Freer [23] that for detector geometries of the kind employed in these measurements, the axial coordinate system enhances the ridge structure in the correlation. The solid line around the data shows the calculated boundary of the θ^*-ψ acceptance for the two angle settings combined, based on the energy and angle thresholds of the detectors. The dashed lines indicate the expected positions of the ridges in the correlation, based on a spin assignment of $J=9$, $l_f=22$.

The corresponding projection along the ridges onto the $\theta^*_{ax}=0$ axis is shown in Fig. 5. There is some uncertainty in the true angle of the ridges, and hence the angle which should be used for projecting the data. The angle we used in this case was that which provided the optimum peak-to-valley ratio in the projection. The projection has been overlaid with squared Legendre polynomials of various orders and on this basis it can be seen that the most suitable spin

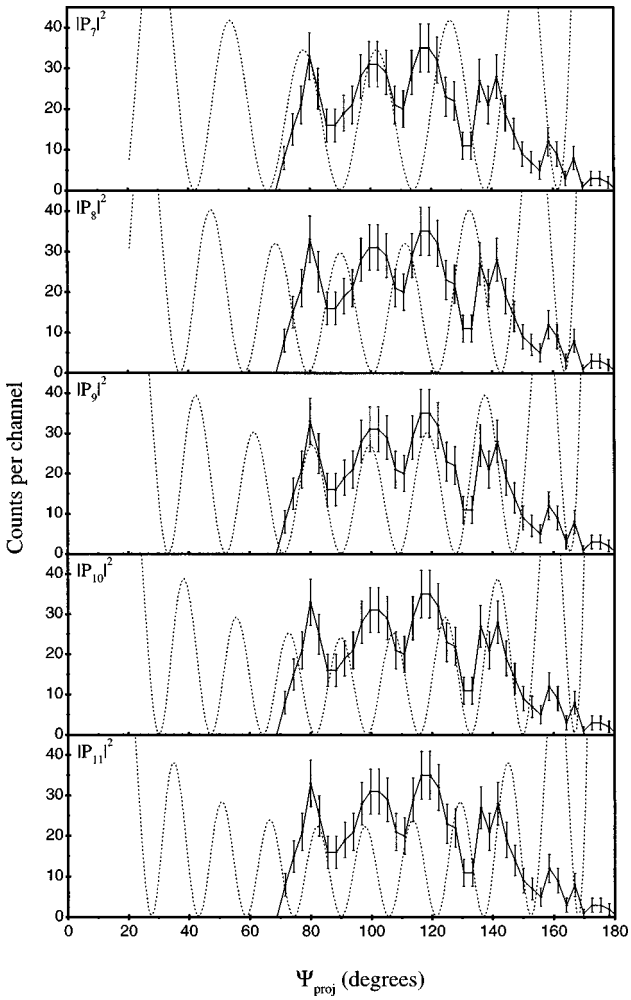

FIG. 5. Projection of the angular correlation data onto the $\theta^*_{ax}=0$ axis for the state at 24.43 MeV identified in the $^{12}C(^{20}Ne, ^{16}O^{8}Be)^{8}Be$ reaction. The projection is overlaid with squared Legendre polynomials of various orders as indicated in the figure. On this basis the most suitable spin assignment for this state is $J=9$.

assignment for this state is $J=9$. Based on the angle used to project the data, this assignment implies a value for l_f of 22. If we assume a stretched configuration such that $l_i=l_f+J$, where l_i denotes the dominant partial wave in the entrance channel, we obtain a value for l_i of 31. This is somewhat smaller than the value of the grazing l predicted by optical model calculations using potential parameters obtained by fitting to elastic scattering data at $E_{cm}=23.3$ MeV [24] and $E_{cm}=146.3$ MeV [25]. However, both potentials indicate that a wide spread of partial waves is active in the surface region, with $T(l)$ falling from 0.9 to 0.1 over the range $l \sim 30-40$. Hence, a value of 31 for the dominant l in this reaction is not inconsistent with these calculations.

Unfortunately, the angular correlations for the other peaks observed in the two reactions studied do not have sufficiently well-defined ridge structure to allow definite spin assignments to be made. One likely reason for this is that the observed peaks are composed of two or more states of different spins, and hence the structure in the angular correlation is washed out.

IV. DISCUSSION

Figure 3 shows the reconstructed excitation spectra obtained from the $^{16}O+^{8}Be$ breakup measurements. The breakup is seen to occur from a series of discrete states in the range 20–30 MeV excitation in the ^{24}Mg nucleus. The excitation energies of the individual states identified in the two reactions are shown in Tables I and II. An interesting feature of the breakup yields is that the $^{12}C(^{20}Ne,^{24}Mg^{*})^{8}Be$ reaction is seen to populate states towards slightly higher excitation energies than the $^{12}C(^{24}Mg,^{24}Mg^{*})^{12}C$ reaction. This may be explained by angular momentum matching favoring the population of higher-energy states by alpha transfer. The unfortunate consequence of this is that the region of overlap in excitation energy observed with the two entrance channels is too small to allow a direct correspondence to be made between the individual states identified in each case. A similar problem was encountered in previous measurements of the $^{12}C+^{12}C$ channel [8,13].

The results from those measurements are shown in Fig. 6, for comparison with the present measurements. In the absence of spin assignments, it is difficult to make a definitive statement about the similarity of the states observed in the two decay channels. The $^{16}O+^{8}Be$ channel appears to have a larger density of states than the $^{12}C+^{12}C$ channel, but this may be a result of the fact that observation of breakup states with odd spin is not possible in the $^{12}C+^{12}C$ measurements due to the symmetry of the final $^{12}C+^{12}C$ system, whereas both odd and even spin states may contribute to the asymmetric breakup yield. This hypothesis is supported by the observation of a $J=9$ state in the present work.

In an additional measurement of the $^{12}C(^{20}Ne,^{12}C^{12}C)^{8}Be$ reaction carried out at a beam energy of 300 MeV [26], no breakup yield was observed from states above $\sim$ 33 MeV excitation in the ^{24}Mg nucleus, despite the higher energy and angular momentum introduced into the system. The cessation of the yield in the $^{12}C+^{12}C$ breakup measurements was, therefore, thought to arise from the termination of the rotational band associated with these states. Interestingly, the breakup yield in the $^{12}C(^{20}Ne,^{16}O^{8}Be)^{8}Be$ reaction dies away at a similar excitation energy as in the $^{12}C(^{20}Ne,^{12}C^{12}C)^{8}Be$ reaction despite the efficiency for detection remaining high in this region in both cases.

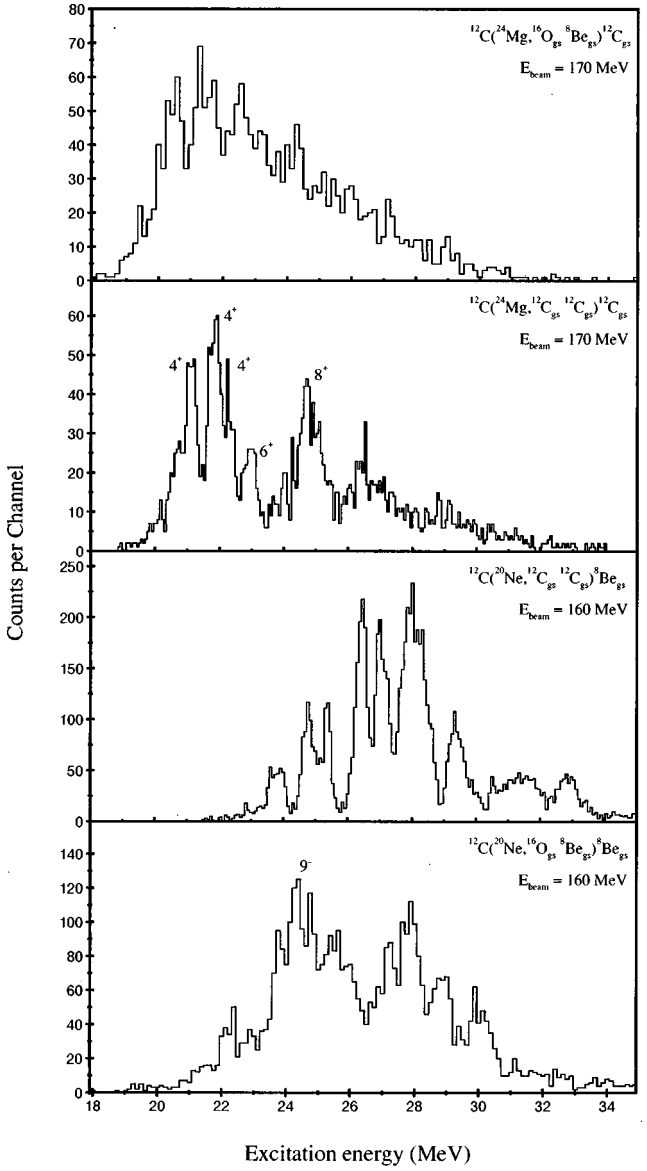

FIG. 6. Comparison of breakup states observed in various reactions, as indicated in the figure. The data for the $^{12}C(^{20}Ne,\ ^{16}O^{8}Be)^{8}Be$ reaction is the combined data from both the angle settings used in the present work.

V. SUMMARY

Two reactions have been studied to look for $^{16}O+^{8}Be$ breakup of highly excited deformed states in ^{24}Mg. In the reaction $^{12}C(^{24}Mg,^{16}O^{8}Be)^{12}C$, breakup has been observed from a series of states in the range 20–25 MeV excitation, with individual states identified at 20.58, 21.54, 22.70, and 24.31 MeV. The alpha transfer reaction $^{12}C(^{20}Ne,^{16}O^{8}Be)^{8}Be$ has revealed breakup occurring from a slightly higher excitation region in the ^{24}Mg nucleus, with states identified at 22.33, 22.96, 24.00, 24.43 24.88, 25.53, 27.35, 27.97, 28.88, and 30.13 MeV. The angular correlation of the breakup fragments has been used to obtain a spin assignment of $J=9$ for the state at 24.43 MeV.

The previously measured $^{12}C+^{12}C$ breakup states have been associated with a highly deformed α-^{16}O-α structure in ^{24}Mg with a dominant $4p$-$4h$ configuration. Theoretical calculations based on the cranked cluster model [11] suggest this structure would readily breakup into $^{16}O+^{8}Be$ fragments, and time-dependent Hartree-Fock calculations [17,18] also suggest the importance of this channel. The present data show that breakup is indeed observed in the $^{16}O+^{8}Be$ channel, but the lack of spin assignments precludes any direct comparison with the $^{12}C+^{12}C$ breakup results. The single spin assignment which has been possible in this study is for a state with $J=9$. If the same states are being observed in both breakup channels, then measurements of this kind offer the possibility of investigating odd spin members of the ^{24}Mg molecular band.

ACKNOWLEDGMENTS

This work was supported by NATO research Grant No. D890066 and by the U.S. Department of Energy under Contract No. DE-AC 03-765 F00098. C. D. Jones, S. P. Fox, M. J. Leddy, J. T. Murgatroyd, and J. S. Pople acknowledge the support of SERC.

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