Excitation of ^{24}Mg states through the interaction of 85 MeV ^{16}O ions with ^{12}C and ^{24}Mg targets

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The decay of ^{24}Mg at high excitation energies has been investigated by the interaction of a ^{16}O beam with ^{24}Mg and ^{12}C targets. Coincident heavy-ion–heavy-ion detection allowed for the study of the ^{12}C-^{12}C and ^{16}O-^{8}Be decay modes of ^{24}Mg. No evidence for these processes was found in the interaction of the beam with the ^{24}Mg target. The ^{12}C-^{12}C relative energy spectra measured via the ^{16}O+^{12}C reaction provide indication for the excitation of a few selected ^{24}Mg states around 30 MeV. Spins as high as $12\hbar$, deduced from the angular correlations, are consistent with a quasimolecular nature of these states.

I. INTRODUCTION

The existence of resonant states at high excitation energies (20–40 MeV) in ^{24}Mg is well documented and is known to influence a variety of reactions [1]. It is also known that different entrance channels may lead to the excitation of different states in ^{24}Mg [2–6].

In an attempt to understand this point better, two measurements in the reaction ^{12}C(^{24}Mg,^{12}C^{12}C)^{12}C have been performed recently [7,8] with the aim of studying the decay of the formed ^{24}Mg excited states into two ^{12}C fragments. In both experiments a ^{24}Mg beam was used to bombard a ^{12}C target. The laboratory energies were 375 MeV in Ref. [7] and 180 MeV in Ref. [8]. The spectra of the relative energy of the two emitted ^{12}C ions showed that the process takes place essentially through the excitation of selected states of ^{24}Mg presumably formed by inelastic scattering. These states were suggested to have low spin [7] and compared favorably to those seen in the radiative capture [4] of ^{12}C+^{12}C and the electrofission [5] of ^{24}Mg. On the other hand, they did not show a clear-cut correspondence to the resonances previously observed [1] in ^{12}C+^{12}C scattering.

The possibility that ^{12}C-^{12}C molecular resonances can be excited as a final-state interaction (FSI) of a three-body process has also been investigated via the ^{16}O+^{12}C reaction. Indeed, structure in the single α spectra from this reaction studied at different energies [9–12] has been interpreted as due to the excitation of ^{24}Mg states, in some cases related to the well-known resonances observed in several exit channels of the ^{12}C+^{12}C reaction [1]. This interpretation was supported by the finding that similar structures were also observed in other reactions such as ^{16}O(^{16}O,α)^{28}Si and ^{16}O(^{20}Ne,α)^{32}S. It was tempting to relate this evidence to the well-known appearance of structures in the excitation functions of the ^{12}C+^{12}C, ^{16}O+^{12}C, and ^{20}Ne+^{12}C systems which were interpreted as due to the formation of quasimolecular states in ^{24}Mg, ^{28}Si, and ^{32}S, respectively. In this picture, the lack of structure in the α spectra from the ^{13}C(^{16}O,α)^{25}Mg and ^{14}N(^{16}O,α)^{26}Al reactions is also consistent with the absence of resonances in the ^{12}C+^{13}C and ^{12}C+^{14}N excitation functions, which, if present, could have been related to the formation of quasimolecular states in ^{25}Mg and ^{26}Al.

On the other hand, different interpretations have also been proposed to explain the single α spectra from the ^{12}C(^{16}O,α) reaction, namely, the projectile breakup and the α decay of ^{20}Ne produced as the result of an α transfer from the target to the projectile [13,14]. The role of a compound-nucleus mechanism, leading to normal ^{24}Mg states after α evaporation, was also evidenced by other inclusive experiments [15,16].

The mechanism of the above reactions can be better investigated by coincidence experiments, since if quasimolecular states of ^{24}Mg are indeed excited in the reaction, they are expected to have large widths for decaying into the ^{12}C-^{12}C channel. Since the work of Wieland *et al.* [17], searches for the α-heavy-ion and heavy-ion–heavy-ion FSI have been performed by detecting coincident α-^{12}C, α-^{16}O, and ^{12}C-^{12}C pairs produced in the ^{16}O+^{12}C reaction [17–24] and measuring their relative energy spectra. The main conclusion of these exclusive experiments was that the process is dominated by the sequential α decay of inelastically scattered ^{16}O ions [18–22] or ^{20}Ne ions produced by an α transfer mechanism [20–22]. Only in particularly favorable detection geometries evidence was found for a mechanism proceeding through the excitation of ^{24}Mg states and the decay into the ^{12}C-^{12}C channel [23,24]. Due to the small cross section of the latter process with respect to the other competing mechanisms of α production, the only quantitative information on these states deduced from coincidence experiments is reported by Lazzarini *et al.* [24]. Their cross-correlation analysis between the ^{12}C+^{12}C+α coincidence data and the known excitation function of ^{12}C+^{12}C elastic and inelastic scattering indicates the formation and ^{12}C-^{12}C decay of four ^{24}Mg states in the range of 25–35 MeV of excitation energy.

As seen from the above discussion, in spite of the relative abundance of experiments, the actual mechanism of the excitation and the decay of ^{24}Mg states at high energies presents many unknowns. Hence the present experiment was devised with the aim of studying the excitation of ^{24}Mg via the inelastic scattering of ^{16}O and its decay into the ^{12}C-^{12}C and ^{16}O-^{8}Be channels. However, as we shall discuss later, additional data were also obtained on the ^{16}O+^{12}C interaction due to the presence of a large carbon buildup in the ^{24}Mg target. Preliminary results of the analysis of these data have been reported in Ref. [25].

II. THE EXPERIMENT

A beam of 85-MeV ^{16}O ions was provided by the SMP tandem accelerator of the Laboratorio Nazionale del Sud, Catania, and focused, after careful collimation, onto a self-supported 250-μg/cm^2-Mg target, enriched to 99.8% in ^{24}Mg, placed at the center of a standard reaction chamber. The beam spot size on the target was about 1×2 mm^2.

The detection setup is sketched in Fig. 1. It consisted of three heavy-ion telescopes (A,B,C) and one split detector for ^{8}Be (D). Each telescope consisted of a longitudinal field ionization chamber followed by a silicon position-sensitive detector (PSD), with a depletion depth of 500 μm. Two of them (B,C) were mounted with axes at 27° on opposite sides with respect to the beam direction and the third one (A) was mounted at 52°. Rectangular slits on the PSD's restricted their polar and azimuthal angular acceptances to about 11° and 2°, respectively, but only horizontal-position information was provided by these detectors. The fourth detector (D) consisted of a rectangular silicon PSD, 600 μm thick, horizontally split into two parts separated by 1 mm. Its center was placed at $-55°$ in the reaction plane in such a way that the resulting average azimuthal angle of these two PSD's was $+2.5°$ and $-2.5°$, respectively. The polar angular opening of the split detector was about 22°. The measurement of the energies and polar angles of the coincident particles in these two detectors, together with the assumption of a given value for the masses and of average out-of-plane angles, allows for the determination of their relative energy. With this technique, it is possible to identify the α-particle pairs emitted in the decay of ^{8}Be, and, hence, measure the energy and position of the primary ^{8}Be ions. Due to its closely packed geometry, the system has a much lower efficiency for the detection of α particles from the decay of ^{8}Be excited states than for those from the ground state.

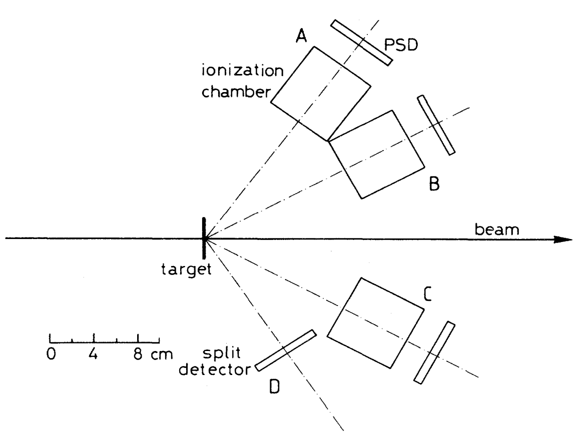

FIG. 1. Sketch of the experimental setup.

The time signals from any pair of PSD's were sent to time-to-amplitude converters (TAC's), whose standard outputs were used as a general trigger for computer acquisition. For each coincidence between any two of the heavy-ion telescopes seven digitized analog signals ($\Delta E,E$ and position for both telescopes and time difference) were stored on tape in event-by-event mode and then analyzed off line. An event due to coincidence between the ^{8}Be detector and one of the three heavy-ion detectors consisted of eight signals ($\Delta E,E$ and position for the heavy-ion telescope, two energy and two position signals for the ^{8}Be detector and time difference).

The calibration of the detectors was performed in preliminary runs by using α particles from a ^{241}Am source and ^{16}O ions scattered from a thin gold target at different beam energies. The calibration was also checked at the end of the experiment.

III. DATA ANALYSIS

In the off-line analysis of the data the number of random coincidences was reduced by selecting only the events falling under the time peak in the TAC spectra. The particle energies were corrected event by event for energy losses in the target, in the ionization-chamber windows, and in the dead layers of the silicon detectors. The thresholds of detectors A, B, and C, due to the ΔE and window thickness, were about 20 MeV for ^{12}C ions. However, in the analysis somewhat higher, angle-dependent thresholds had to be used, due to difficulties in the fast timing for particles hitting the central region of PSD's.

Preliminary runs had shown a carbon buildup on the target, presumably due to leakage of isobutane from the ionization chambers. A backscattering analysis of the target showed that the carbon buildup at the end of the experiment was about 60 μg/cm^2. A procedure [26] was then used to discriminate between the coincidences produced by the interaction of ^{16}O on different target nuclei. According to this procedure, coincidences are reported in an E_3 versus p_3^2 plot. Here E_3 and p_3 are the energy and momentum of the undetected third particle, respectively, and are deduced independently from conservation laws [26]. As seen in Fig. 2, events from three-body reactions, corresponding either to different residual nuclei (and thus to different targets) or to different Q values, fall on different straight lines. The slope $(1/A_3)$ of each line gives the mass A_3 of the undetected particle and its intersection with the E_3 axis $(-Q)$ gives the Q value of the corresponding reaction. Thus in the plot it is possible to identify events due to reactions on different targets.

In this way it is possible to analyze separately the contributions of the reactions induced by ^{16}O on the two main components (^{24}Mg and ^{12}C) of the target. Both components can in principle lead to the coincident detection of ^{12}C-^{12}C and of ^{16}O-^{8}Be produced in the decay of highly excited ^{24}Mg nuclei.

In the data analysis, the mass number of all the carbon ions detected in coincidence was assumed to be 12. The validity of such assumption was verified *a posteriori*, by an inspection of the obtained Q spectra. Indeed, reactions leading to coincidences of carbon isotopes other than ^{12}C have much more negative Q values, with both the ^{12}C and ^{24}Mg target, and would be easily identified on the Q spectra. Similar arguments hold for the assignment of mass 16 to the $Z=8$ ions detected in coincidence with ^{8}Be.

IV. RESULTS AND DISCUSSION

The first striking results of the above analysis applied to the present experiment is that essentially all the observed ^{12}C-^{12}C and ^{16}O-^{8}Be coincidences come from the interaction of the beam with ^{12}C, while practically no contribution from the ^{16}O+^{24}Mg reaction was observed. In fact, the events tend to align along the lines corresponding to the reactions on ^{12}C [solid lines in Figs. 2(a) and 2(b)], while no clear indication of reactions induced on ^{24}Mg (dashed lines) is present. The lowest lines correspond to the emission of all particles in their ground state; upper lines correspond to the emission of one or both of the detected ions in their first excited states (4.44 MeV for ^{12}C and 6.1 MeV doublet for ^{16}O).

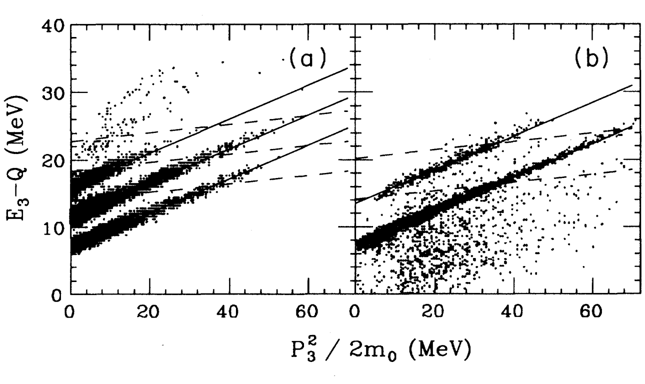

FIG. 2. Scatter plot of the ^{12}C-^{12}C (a) and ^{16}O-^{8}Be (b) coincidence yield (see text for the definition of the coordinates). Coincidences produced in the interaction of ^{16}O with ^{12}C and ^{24}Mg are expected to fall around the solid and dashed lines, respectively.

^{16}O on the ^{24}Mg target

Our experimental setup was optimized for detecting a process leading to ^{24}Mg states around 30 MeV of excitation. Nevertheless, we did not observe such a process. At least two reaction mechanisms can be expected to produce the ^{12}C+^{12}C+^{16}O final state, namely, the inelastic scattering and the transfer of two α particles (or a ^{8}Be nucleus) from the ^{24}Mg target to the projectile leaving an ^{16}O residual nucleus. However, in the present experiment the ^{16}O scattering angle covers the range from $+155°$ to $-155°$ in the center of mass, with a maximum efficiency at 180°. Thus the inelastic-scattering process is not supposed to give an important contribution at these very backward angles. Hence, from our results one can conclude that either the excited ^{24}Mg nucleus has a small probability of being formed in a ^{8}Be transfer or that it decays preferentially into channels not detected in the present experiment.

^{12}C-^{12}C from the ^{12}C target

The analysis of the ^{12}C-^{12}C coincidences entirely attributed to the ^{16}O+^{12}C interaction was performed in a standard way, by deducing the three-body Q spectrum for the coincidences between $Z=6$ ions in each pair of the detectors, A, B, and C. Figure 3 shows these Q spectra for coincidences A-C (a) and B-C (b). The coincidence in detectors B and C fall under three well-separated Q peaks, close to the expected values of -7.16, -11.60, and -16.04 MeV, which correspond to final states involving all the combinations of ^{12}C (g.s.) and ^{12}C(2^+).

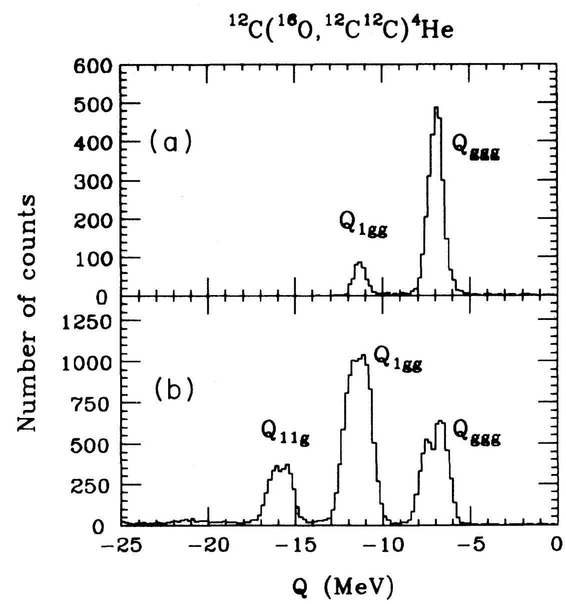

FIG. 3. Q spectra of the ^{12}C-^{12}C coincidences in detectors A-C (a) and B-C (b) from the ^{16}O+^{12}C interaction.

These peaks are labeled Q_{ggg}, Q_{1gg}, and Q_{11g}, respectively. Detection of ^{12}C-^{12}C coincidences is kinematically forbidden for the detector pair *A-B*, while the absence of the less energetic peak in the *Q* spectrum of the detector pair *A-C* is due to the energy thresholds.

For each peak in the *Q* spectra the relative energies between any two of the three final particles were deduced. Figure 4 shows the matrices $E_{12}-E_{2\alpha}$ and $E_{1\alpha}$-$E_{2\alpha}$ for the Q_{ggg} peak. Here 1 and 2 refer to the ^{12}C ions detected, respectively, in telescopes *B* and *C*. Due to different thresholds introduced in the off-line analysis the $E_{1\alpha}$-$E_{2\alpha}$ matrix is not symmetric, in spite of the geometric symmetry of the detectors.

In this representation, the grouping of data along a line perpendicular to the E_{ij} axis provides evidence for a reaction proceeding through the formation of the $(i+j)$ intermediate nucleus at a given excitation energy, followed by the decay into particles *i* and *j*. We recall that the excitation energy E^* of this nucleus is simply given by the sum of the relative energy E_{ij} and the separation energy of the decay products *i* and *j*. The latter is 13.92 and 7.16 MeV for the ^{12}C+^{12}C and ^{12}C+α systems, respectively. Figure 4 clearly shows that most of the ^{12}C-^{12}C yield comes from the deexcitation of ^{16}O discrete states into the ^{12}C+α system.

To obtain the relative energy spectra, shown in Figs. 5, 6, and 7 for each one of the three *Q* peaks, the matrices were projected on the axes. Because of the different thresholds on detectors *B* and *C*, information from $E_{1\alpha}$ and $E_{2\alpha}$ spectra is not equivalent. Nevertheless, in both spectra a peaking is visible at about 4 MeV [Figs. 6(a) and 7(a)], corresponding to the excitation of a few levels in ^{16}O around 11 MeV. The preferential excitation of these states has been observed already in other ^{16}O breakup experiments (see, e.g., Refs. [17, 20, and 22]).

Even if the reaction is dominated by the breakup of the projectile, it is possible to see in the matrix of Fig. 4(a) a trend of data at high $E_{2\alpha}$ to align on vertical lines. Obviously, when all the data are projected on the E_{12} axis, the presence of such events is completely covered by the breakup contribution. To highlight this yield we selected on the $E_{1\alpha}$-$E_{2\alpha}$ matrix the events with both of these relative energies larger than 11 MeV [$E^*(^{16}\text{O}) > 18$ MeV ap-

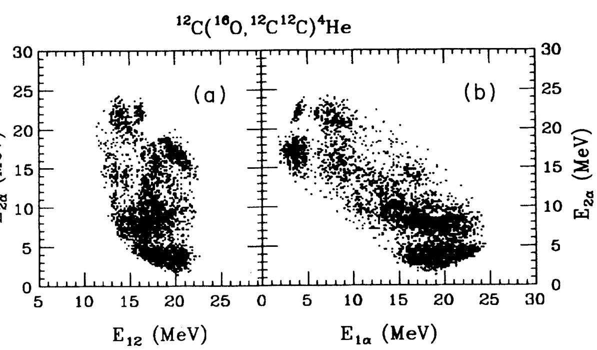

FIG. 4. $E_{12}-E_{2\alpha}$ (a) and $E_{1\alpha}-E_{2\alpha}$ (b) matrices for ^{12}C-^{12}C coincidences falling under the Q_{ggg} peak (detectors *B-C*).

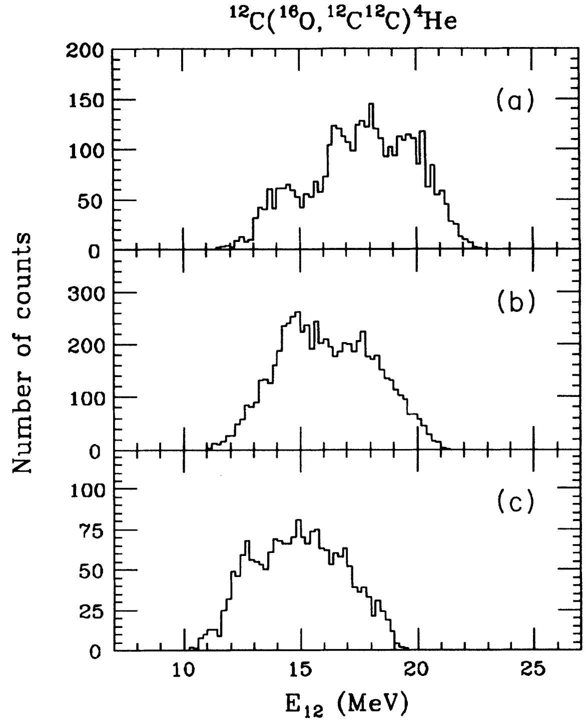

FIG. 5. E_{12} relative energy spectra deduced from ^{12}C-^{12}C coincidences by gating in turn on each one of the three *Q* peaks of Fig. 3(b); (a) Q_{ggg}, (b) Q_{1gg}, (c) Q_{11g}.

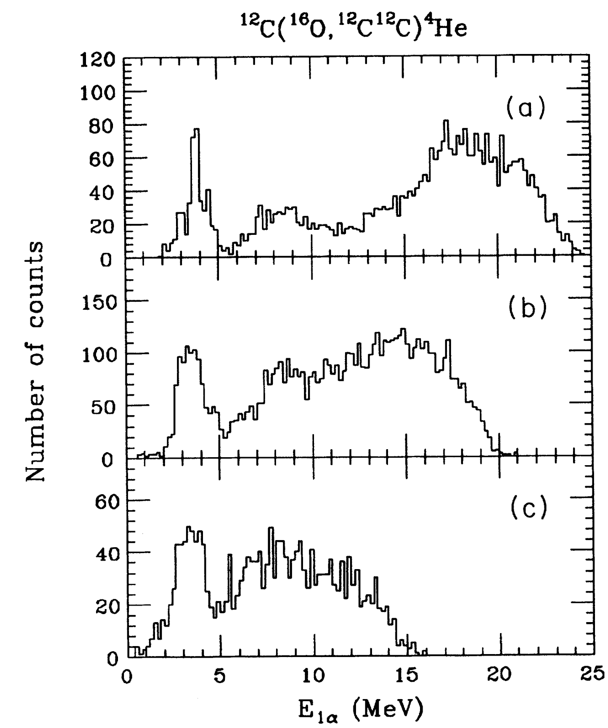

FIG. 6. $E_{1\alpha}$ relative energy spectra deduced from ^{12}C-^{12}C coincidences by gating in turn on each one of the three *Q* peaks of Fig. 3(b): (a) Q_{ggg}, (b) Q_{1gg}, (c) Q_{11g}.

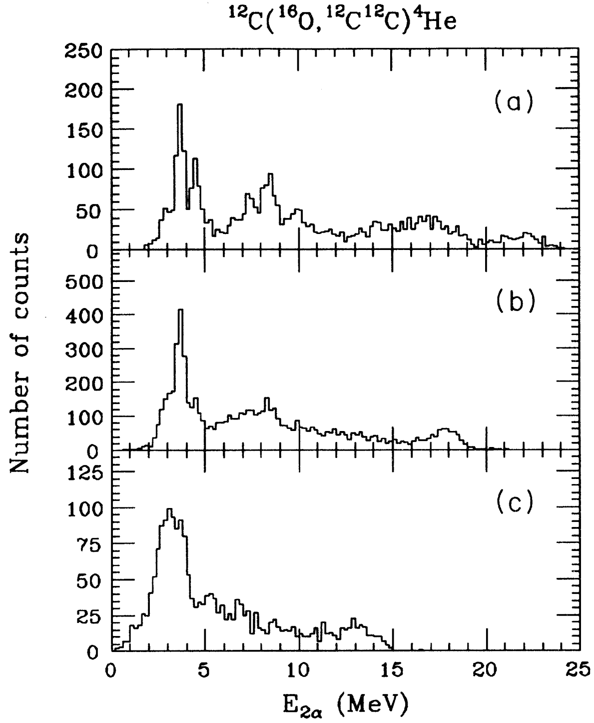

FIG. 7. $E_{2\alpha}$ relative energy spectra deduced from ^{12}C-^{12}C coincidences by gating in turn on each one of the three Q peaks of Fig. 3(b): (a) Q_{ggg}, (b) Q_{1gg}, (c) Q_{11g}.

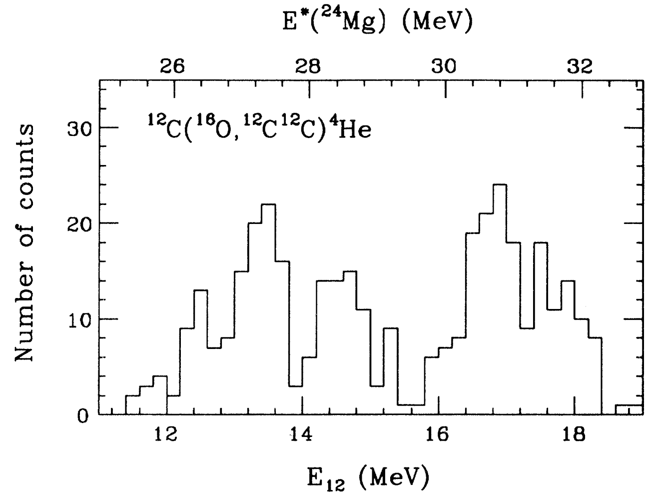

FIG. 8. Projection of a selected portion of the E_{12}-$E_{1\alpha}$ matrix on the E_{12}-axis, for the Q_{ggg} peak. In the upper scale the corresponding excitation energies in ^{24}Mg are reported.

proximately], thus excluding the strongest contributions from the ^{12}C-α FSI. Figure 8 shows the projection of these data on the E_{12} axis. The main feature of this spectrum is the presence of a few peaks which can be attributed to the formation and decay of selected ^{24}Mg states at excitation energies of 26.3, 27.3, 28.4, 29.2, 30.7, and 31.6 MeV (see Table I). Checks were made to be sure that the overall features of the E_{12} projection are not affected by the particular choice of the thresholds. Increasing the thresholds on $E_{1\alpha}$ and $E_{2\alpha}$ has the only effect of gradually cutting the highest energy peaks.

The peak energies, whose uncertainty is estimated to be $\pm$200 keV, are to be compared with the ones previously found in the same reaction. Lazzarini *et al.* [24] report four peaks at 25.2, 28.8, 30.2, and 33.2 MeV, which do not overlap well with our findings. On the other hand, in the inclusive experiment of Stwertka *et al.* [16], some α peaks from the interaction of ^{16}O with ^{12}C were interpreted as due to the formation of ^{24}Mg states at about 20, 21, 26, and 29 MeV. Only the last two values are in the range of the present investigation and are in agreement with our results.

Assuming that for each peak one single value of the angular momentum J is dominating, this value can be obtained by following the procedure reported in Ref. 27, taking into account the fact that all the involved particles have zero spin. The double differential cross section, expressed as a function of θ^*, the c.m. angle of ^{24}Mg, and of ψ, the angle formed by the relative ^{12}C-^{12}C velocity with the beam axis, shows ridges in the θ^*-ψ plane. The slope of these ridges and their spacing in the ψ direction depend on the spin J of the intermediate state. In addition, the cross section as a function of ψ at $\theta^*=0°$ should be simply proportional to the square of the Legendre polynomial of order J. In order to get information on J from the experimental data, one can average the double-differential cross section along lines parallel to the ridges. The resultant cross section can be presented as a function of ψ_0, the value of ψ at $\theta^*=0°$. Its comparison with the squared Legendre polynomials of various orders allows the determination of the spin J.

Obviously, this analysis needs a wide ψ range covered by the experiment. In our case this condition is better satisfied for the two peaks at the highest energies where the data extend over a ψ range from about 70° to 110°.

Figure 9 shows that the best reproduction of the oscillations of the data for the peak at $E^*(^{24}\text{Mg})=30.7$ MeV is given by $J=12$, which can be taken as a measure of the spin of this state. The uncertainty on this value is mainly

TABLE I. Resonances observed as ^{12}C-^{12}C FSI in the ^{16}O+^{12}C interaction compared with selected ^{24}Mg states found in various exit channels of the ^{12}C+^{12}C reaction.

Present work $E^*(^{24}\text{Mg})$ (MeV)	^{12}C+^{12}C reactions $E^*(^{24}\text{Mg})$ (MeV)	J	Ref.
26.3	26.26	8	28
	26.21		29
27.3	27.27	10	28
	27.33		30
28.4	28.26	10	28
(29.2)	29.25	10	28
30.7	30.35	10	28
31.6	31.68	12	28
	31.80		31

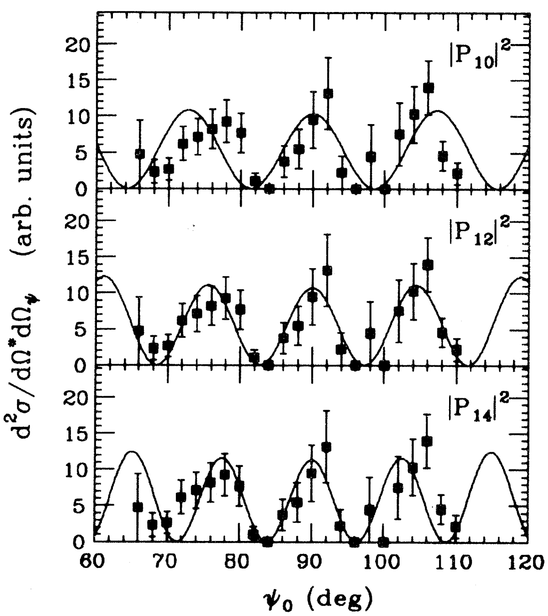

FIG. 9. Double-differential cross section for the 30.7-MeV state in ^{24}Mg (obtained after averaging along axes parallel to the ridges in the θ^*-ψ plane, see text), compared with squared Legendre polynomials of different orders.

due to poor statistics which prevents an unambiguous determination of the slope of the ridges, and is estimated to be ± 2 units.

The same procedure applied to the structure centered at $E^*(^{24}\text{Mg}) = 31.6$ MeV leads again to a spin assignment of 12 ± 2. The assignment of the same spin value to both states is further supported by the very similar slopes of the ridges in the two cases.

For the peaks at lower energies, the angular range covered by the data was not large enough to show more than one or two oscillations. Thus the above analysis would not be meaningful.

A comparison can be made with the existing data on the ^{24}Mg states excited in the interaction between two ^{12}C nuclei [28–31]. The energies of the states found in the present work agree fairly well with those of some of the levels reported in the literature (see Table I). A correspondence can even be found for the small peak at 29.2 MeV of excitation energy, which is statistically less meaningful. For states in this region of excitation energy in ^{24}Mg spins around 10 units have been measured, which compares well with our assignment of $J = 12\pm 2$ to the states at 30.7 and 31.6 MeV.

The data corresponding to the other peaks of the Q spectrum (Fig. 4) as well as those coming from detectors A-C, do not show any evidence for contributions from the ^{12}C-^{12}C FSI. In these cases, from the relative energy spectra, one can conclude that only mechanisms involving excitation and decay of ^{16}O are responsible for the ^{12}C-^{12}C coincidence yield.

^{16}O-^{8}Be from the ^{12}C target

Recently, population of ^{24}Mg states followed by the decay into the ^{16}O-^{8}Be channel has been observed in the interaction of a ^{24}Mg beam with a ^{12}C target [32]. Comparison of the strength for this and the ^{12}C-^{12}C channel indicates a dominance of the ^{16}O-^{8}Be cluster configuration in ^{24}Mg at excitation energies around 20–25 MeV.

The present setup kinematically allows ^{16}O-^{8}Be coincidences only in the B-D detector pair. Figure 10 shows the spectrum of the relative energy between the particles hitting in coincidence the two parts of the detector D. In this analysis mass 4 was assumed for the detected particles. The peak corresponding to two α particles produced in the decay of the ^{8}Be ground state clearly shows up around the known value of 92 keV. From the events falling under this peak which are in coincidence with $Z = 8$ ions detected in B, the Q spectrum of Fig. 11 is obtained. In this spectrum, apart of the background due to the simultaneous detection in D of particles other than α from ^{8}Be decay, two peaks can be observed which are attributed to the reaction leading to the formation of the ground state (Q_{ggg}) and the doublet of ^{16}O around 6 MeV (Q_{1gg}). Contributions from higher levels of ^{16}O can fall in the tail of the Q_{1gg} peak.

With the same procedure described in the previous section, the relative energy spectra were deduced for all the combinations of particles in the final state by gating in turn on each one of the peaks in the Q spectrum. They are shown in Figs. 12, 13, and 14, the ^{16}O being labeled as particle 1 and the ^{8}Be as particle 2. The ^{24}Mg excitation energy spanned by our detection geometry is higher than in the case of ^{12}C-^{12}C coincidences, ranging from 33 to 43 MeV. This is mainly due to the larger angle between counters B and D with respect to counters B and C and to the energy thresholds.

Both data and Monte Carlo simulation show that ^{24}Mg nuclei, eventually formed in the reaction and leading to the ^{16}O(g.s.)-^{8}Be and ^{16}O(6.1 MeV)-^{8}Be coincidences detected in our experimental setup, are emitted into cones around 4° in the laboratory system, with full widths of 8° and 5°, respectively. These forward angles should still be favorable for detecting decay products from a

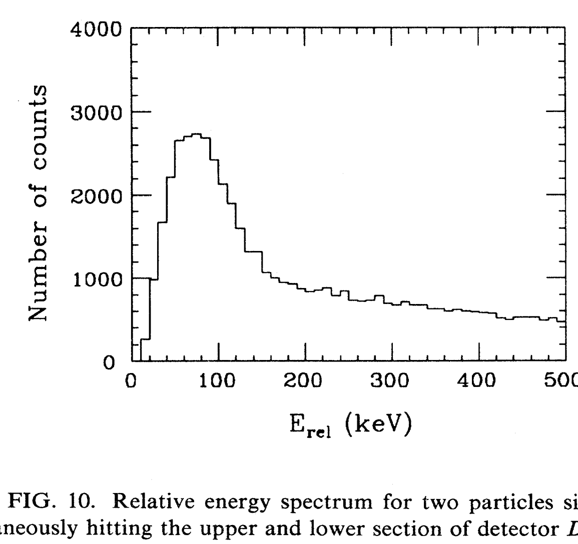

FIG. 10. Relative energy spectrum for two particles simultaneously hitting the upper and lower section of detector D, assuming mass 4 for both of them.

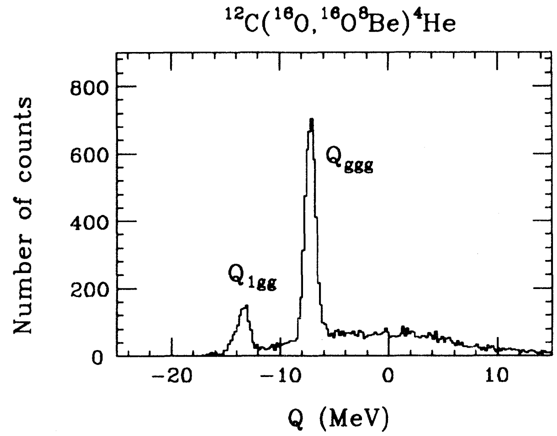

FIG. 11. Q spectrum of ^{16}O-^{8}Be coincidences in detectors B-D from the ^{16}O+^{12}C interaction.

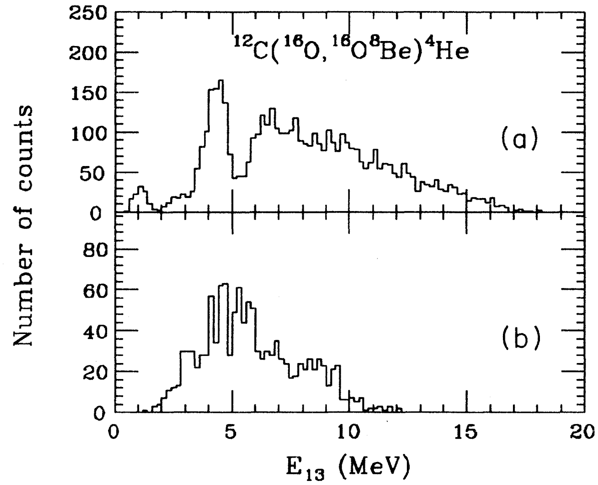

FIG. 13. $E_{1\alpha}$ relative energy spectra deduced from ^{16}O-^{8}Be coincidences by gating in turn on each one of the two Q peaks of Fig. 11: (a) Q_{ggg}, (b) Q_{1gg}.

^{24}Mg formed in a ^{8}Be transfer process from the target to the projectile. Nevertheless, no contribution from this or other mechanisms producing ^{24}Mg can be deduced by looking at the relative energy spectra. The reaction appears to be dominated by different processes such as the target excitation and decay into the α-^{8}Be system [peaks in $E_{2\alpha}$ spectra, Figs. 14(a) and 14(b)] or the formation and α decay of ^{20}Ne [peaks in $E_{1\alpha}$ spectra, Figs. 13(a) and 13(b)]. ^{12}C states close to 7.4 and 9.6 MeV which are known to have large widths for α decay, are excited in combination with the ^{16}O in its ground and first-excited states.

The $E_{1\alpha}$ spectrum for the Q_{ggg} peak [Fig. 13(a)] clearly shows the deexcitation of states in ^{20}Ne around 5.7 and 9 MeV, and also provides evidence for higher states, whose identification is made difficult by the overlapping of the α-^{8}Be FSI contribution. Contributions from states close to 9 MeV have been already observed in ^{16}O-α coincidence experiments (see, for example, Refs. [20] and [22]). States close to 5.7 MeV cannot easily be observed by detection of the decay products (^{16}O and α), because of their small relative energy (about 1 MeV). Evidence for excitation and α decay of a state at 5.62 MeV has been provided by the experiment on the ^{12}C(^{12}C,$\alpha\alpha$)^{16}O reaction reported in Ref. [33]. The $E_{1\alpha}$ spectrum for the Q_{1gg} peak [Fig. 13(b)] probably contains a contribution from a process of α emission from a ^{20}Ne leaving an ^{16}O*, but it is strongly influenced by the α-^{8}Be FSI.

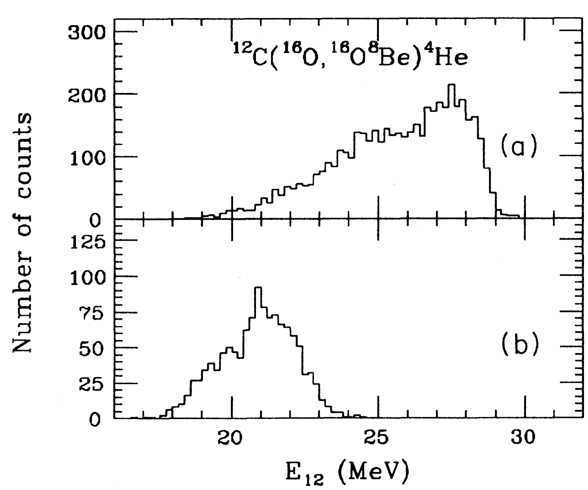

FIG. 12. E_{12} relative energy spectra deduced from ^{16}O-^{8}Be coincidences by gating in turn on each one of the two Q peaks of Fig. 11: (a) Q_{ggg}, (b) Q_{1gg}.

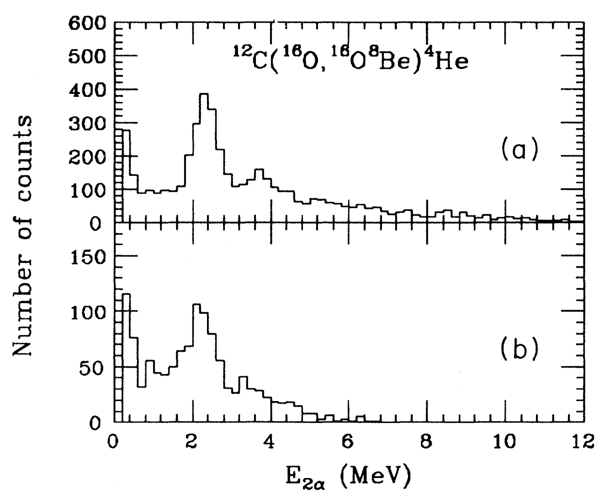

FIG. 14. $E_{2\alpha}$ relative energy spectra deduced from ^{16}O-^{8}Be coincidences by gating in turn on each one of the two Q peaks of Fig. 11: (a) Q_{ggg}, (b) Q_{1gg}.

V. CONCLUSIONS

The present experiment did not show any contribution to the ^{12}C-^{12}C or the ^{16}O-^{8}Be coincident yields due to the interaction of the ^{16}O beam with the ^{24}Mg target. On the other hand, a few ^{24}Mg states around 30 MeV, decaying into the ^{12}C-^{12}C channel, have been found to be excited via the $^{12}C(^{16}O,^{12}C^{12}C)^{4}He$ reaction. Since our setup does not allow for the detection of the decay of these states through the ^{16}O-^{8}Be channel, nothing can be said about the branching ratio of the competing ^{12}C-^{12}C and ^{16}O-^{8}Be exit channels. No evidence for ^{16}O-^{8}Be decay of ^{24}Mg at excitation energies higher than 30 MeV has been found in the present experiment.

The spin of two of the observed states, at energies of 30.7 and 31.6 MeV, measured through the ^{12}C-^{12}C angular correlations, was found to be 12 ± 2. This is in agreement with previous findings and supports the hypothesis that these states have a quasimolecular nature.

[1] See, for instance, N. Cindro, Riv. Nuovo Cimento, **4**, 1 (1981); K. A. Erb and D. A. Bromley, in *Treatise on Heavy-Ion Science,* edited by D. A. Bromley (Plenum, New York, 1985), Vol. 3; N. Cindro, Ann. Phys. (Paris) **13**, 289 (1988), and references therein.

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