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Search for γ rays from the quasimolecular $^{12}C + ^{12}C$ system

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An upper limit (three standard deviations) of 8×10^{-6} has been determined for the branching ratio of gamma to particle decay of the 14^+ resonance at $E_{c.m.}=25.2$ MeV in the $^{12}C + ^{12}C$ system. This limit is a factor of $2-3$ lower than theoretically expected for an interpretation of the intermediate structure resonances as quasimolecular states in ^{24}Mg, making this hypothesis unlikely. The experimental limit is consistent with an interpretation of these structures as shape resonances in a direct reaction process.

[NUCLEAR REACTIONS $^{12}C + ^{12}C$ elastic and inelastic scattering; measured ^{12}C-^{12}C coincidences, ^{12}C-^{12}C-γ triple coincidences; deduced upper limit on γ decay of $^{12}C + ^{12}C$ resonances.]

I. INTRODUCTION

Pronounced structures in the excitation functions for the $^{12}C + ^{12}C$ elastic and inelastic scattering and various reaction channels have been interpreted using two opposing hypotheses. In the one case, the observed structures are explained in a simple direct reaction model[1] as arising from the dominance of certain partial waves; in the other case, these structures are related to the existence of quasimolecular excitations[2-4] corresponding to strongly deformed rotational states in ^{24}Mg.

It should be possible to differentiate between these two views by measuring the branching ratio for an $E2$ transition between two quasimolecular rotational states. The ratio of the radiative decay to the two body decay (elastic and inelastic channels) will be larger if a relatively long-lived quasimolecular state exists compared to the ratio for a direct reaction process with only shape resonances. The radiative process we have in mind is indicated schematically in Fig. 1. Suppose one bombards ^{12}C by ^{12}C at the c.m. energy corresponding to the 14^+ resonance. If a quasimolecular state exists the radiative decay will have an energy approximately equal to the energy difference between the 12^+ and 14^+ ion-ion potentials at the separation distance where this energy is a minimum. The absolute value of the radiative width will be determined by the quadrupole moment of the dinuclear system at this separation. The shape of the dinuclear system shown in Fig. 1 is based on the calculations of Chandra and Mosel.[5]

Even with the enhancement of the radiation width due to the large decay energy (6–7 MeV) and the large quadrupole moment of the dinuclear system, the radiative width is expected to be much smaller than the particle decay width of a possible

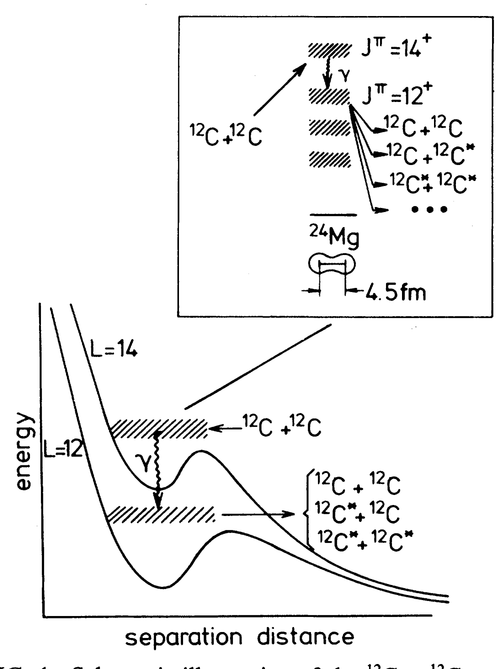

FIG. 1. Schematic illustration of the $^{12}C + ^{12}C$ potential and the emission of a quasimolecular γ ray. The theoretically predicted (Ref. 5) shape of the quasimolecular configuration is indicated in the inset.

quasimolecular state. For purposes of orientation we will estimate the branching ratio for radiative decay, $\Gamma\gamma/\Gamma_{tot}$, for the two cases of quasimolecular state formation and of direct shape resonances. The radiative width for the dinuclear system has been calculated as detailed in Sec. IV, and is found to be 7×10^{-6} MeV. For the assumption of the existence of quasimolecular resonances we take $\Gamma_{tot}\approx0.3$ MeV from the analysis of Cosman *et al.*[6] For the case of shape resonances we estimate Γ_{tot} from the width of the gross structure shape resonances, $\Gamma=2.5$ MeV.[4] The branching ratio is therefore expected to be 2×10^{-5} for quasimolecular states and 2×10^{-6} in the absence of a quasimolecular enhancement. One notes that these branching ratios differ by an order of magnitude for the two models so that a measurement of the branching ratios could provide a crucial distinction between the two models.

II. EXPERIMENTAL METHOD

The observation of these rare events of interest requires an experimental arrangement with an optimized detection effeciency which allows a kinematically complete and redundant identification of all reaction products in order to eliminate various sources of background. The charge and energy of the reaction products, as well as their position in θ and ϕ, are measured in coincidence using two position sensitive gas ΔE, solid state E telescopes subtending angles in the laboratory system $30^\circ\leq\theta_L\leq50^\circ$. Coincident γ rays are detected in a 25.4 cm$\times$25.4 cm NaI crystal positioned 10 cm away from the target (Fig. 2). Singles, twofold, and threefold coincidences have been stored on magnetic tape event by event. In the off-line analysis, in addition to the usual time and $\Delta E/E$ particle identification constraints, all events have been checked for coplanarity and momentum conservation, utilizing the position and energy information provided by the particle detectors. In particular, tails in the response function of the particle detectors were effectively reduced by requiring that the Q value determined from the two particle energies agrees with the Q value derived from the energy of one particle and the angles of the two outgoing carbon nuclei.[7]

In the given geometry the peak-to-total ratio for the detection of 4.4 MeV γ rays is 60%. The absolute photopeak efficiency ϵ_γ, including the geometrical solid angle, is 4%, determined from the ratio of C + C + γ to C + C coincidences

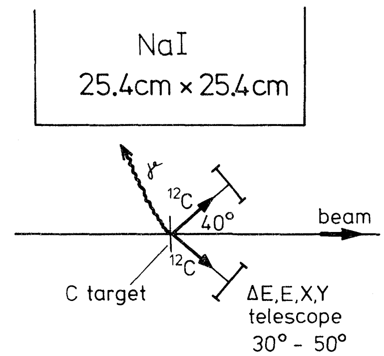

FIG. 2. Detector configuration used in the experiment.

corresponding to the excitation of one of the C nuclei to the 2^+ states at 4.44 MeV. The efficiency $\epsilon_C(Q)$ for detecting the two outgoing C nuclei in coincidence depends on the reaction Q value. The geometry of the two particle detectors is optimized for a Q value of -7 MeV. It drops by a factor of 1.6 for Q values of -15 and 0 MeV as determined by a Monte Carlo simulation, assuming a $1/\sin\theta_{c.m.}$ angular distribution of the C nuclei. Only the relative variation of the particle detection efficiency with the Q value enters in the analysis discussed in Sec. IV.

Isotopically enriched ^{12}C targets of 30 $\mu g/cm^2$ thickness were irridiated with ^{12}C beams of 50 nA provided by the Seattle FN-tandem accelerator. Count rates were 6 kHz in the particle telescope and 8 kHz above 1 MeV in the NaI detectors. At these rates 70 C + C coincidences and six triple coincidences were recorded per second, on the average.

III. EXPERIMENTAL RESULTS

At a bombarding energy of 50.4 MeV a total of 1.2×10^7 carbon-carbon twofold coincidences and 1×10^6 C + C + γ triple coincidences have been accumulated. The distribution of the C + C + γ coincidences is shown in Fig. 3 in a scatter plot of events as a function of γ-ray energy and the reaction Q value, inferred from the summed energy of the two carbon ions. In addition, the γ and particle spectra resulting from a projection of the coincidence data on either side are also shown. Two groups of events with $Q=-4.44$ and -8.88 MeV are apparent, corresponding to the excitation of one or both ^{12}C ions to the 2^+ state at 4.44 MeV in the decay of the state at $E_{c.m.}=25.2$ MeV. Owing to Compton scattering and pair production the

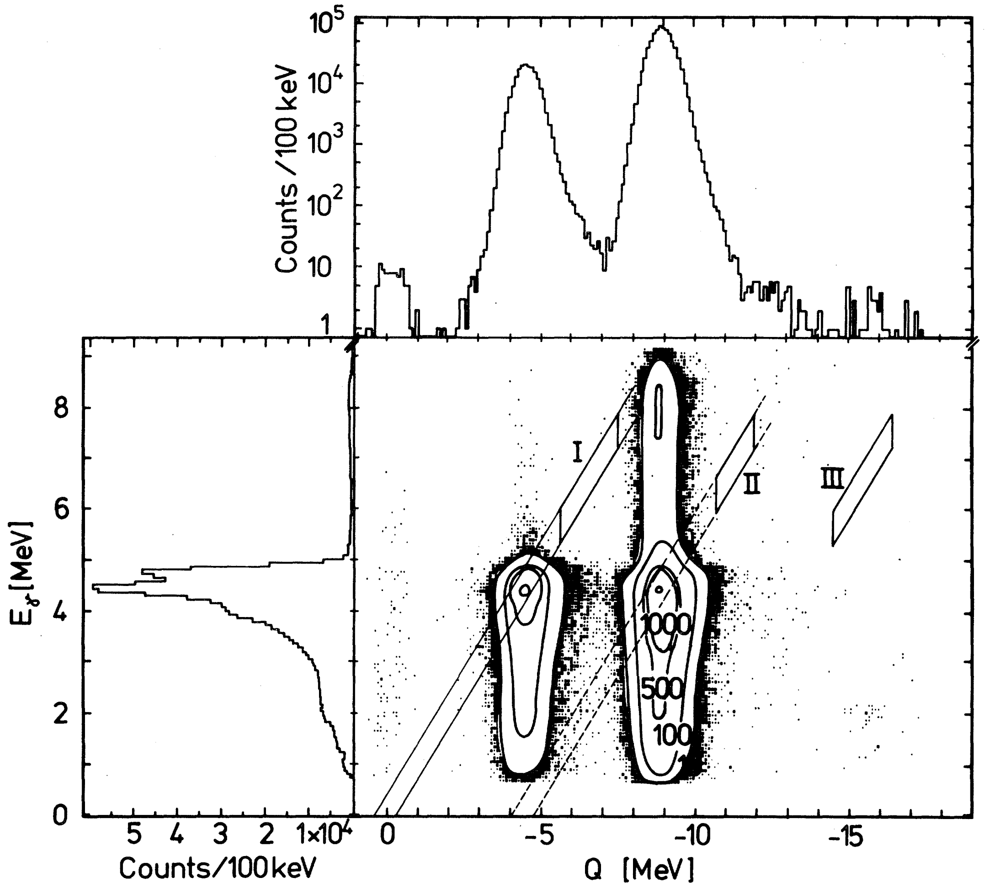

FIG. 3. Scatter plot of γ-ray energy vs the reaction Q value for $^{12}C + ^{12}C$ at a bombarding energy of 50.4 MeV. Small squares correspond to one event, big squares to $\geq$ two events. Contour lines for intensities of 10, 100, 1000, and 5000 counts are indicated. The two straight lines limit the region of events for which the total energy observed in the γ-ray and particle detectors agree within the resolution with the bombarding energy. The dashed lines correspond accordingly to the case that one of the 4.4 MeV γ rays, emitted from the excited ^{12}C nuclei, escapes detection. The boxes labeled I–III limit the areas where quasimolecular γ rays are expected, accompanied by none, single, or double excitation of the two C nuclei, respectively.

registered γ-ray energies are spread over a large energy range. The strong intensity at $E_\gamma = 4.44$ MeV for $Q = -8.88$ MeV corresponds to the detection of only one of the two emitted 4.44 MeV γ rays. Events for which the observed energy in particle and γ detectors is equal to the beam energy within the particle energy and photo peak resolution of (including Doppler shift and single escape peak) 900 keV and 1 MeV, respectively, will fall between the two straight lines shown in Fig. 3. Events beyond this limit are attributed to pileup or chance coincidences. If one of the C nuclei is excited to the 2^+ state and its γ decay escapes detection the events will fall between the two dashed lines.

The events of interest are expected in regions I, II, or III, respectively, depending on whether the supposed quasimolecular γ decay is accompanied by none, single, or double excitation of the C nuclei. The investigated range of γ-ray energies from 5.6 to 7.5 MeV includes possible decays of the 14^+ resonance at $E_{c.m.} = 25.2$ MeV, our bombarding energy, to the 12^+ resonance with fragmented strength[8] at 19.3 and 18.0 MeV. The corresponding particle Q-value ranges are 5.6–7.5, 10.7–11.9, and 14.5–16.4 MeV. For the simultaneous excitation of one of the C nuclei, a narrower Q value bin has to be considered because of residual tails in the particle energy spectra. The amount of tailing has been determined by assuming that all events in the lower part of Fig. 3 ($E_\gamma < 5$ MeV), not concentrated at $Q = -4.4$ and -8.9 MeV are due to tails in the response functions of the particle detector. The five counts with $E_\gamma \geq 5.2$ MeV and $-7.5 \leq Q \leq -5.5$ MeV are also accounted for by energy tails. No events are found in the regions I—III.

Events with $E_\gamma \approx 7-9$ MeV observed close to Q values of -12.7 and -12.1 MeV, respectively, are not related to the decay of quasimolecular states since their yield increases "off resonance" at a bombarding energy of 54.0 MeV. These counts are attributed to decays of excited states in ^{12}C, which have known, although extremely small, branching ratios for γ decay. The 1^+ state at 12.71 MeV decays with a probability of 3×10^{-3} via an 8.27 MeV γ ray to the 2^+ state at 4.44 MeV. The 0^+ state at 7.65 MeV decays with a probability of 4.1×10^{-4} via a cascade of a 3.21 MeV γ ray and a 4.44 MeV γ ray. Events close to $Q=-12.1$ MeV are ascribed to the simultaneous excitation of the 4.44 and 7.65 MeV states. The coincident detection of two out of the three resulting γ rays will lead to events in the energy range of 7 to 9 MeV.

Events with $(E_\gamma, Q) = (2.0 \text{ MeV}, -15.8 \text{ MeV})$ and $(3.1 \text{ MeV}, -16.9 \text{ MeV})$ arise from the $^{12}C(^{12}C,^{11}C)^{13}C$ reaction populating the lowest lying excited states in ^{11}C and ^{13}C, respectively. The yield of this reaction in Fig. 3 is strongly suppressed by the tight momentum constraints used in the data analysis.

In all cases the observed number of counts is reproduced within a factor of 2 using the known detection efficiencies and intensities in the particle-particle coincidence spectrum shown in Fig. 4. In this spectrum the population of excited states in the outgoing reaction products is only seen to the extent that they decay by electromagnetic transitions and not by particle emission, since two-body kinematics are required.

The number of random events in Fig. 3 has been estimated by setting the appropriate gates in the time spectra and by normalizing to the number of γ rays observed in chance coincidence with the two elastically scattered carbon nuclei. For $E_\gamma \geq 5.2$ MeV and $-7.5 < Q < -5.6$ MeV we expect 0.6 chance coincidences, and for $E_\gamma \geq 5.2$ MeV and $Q < -10.0$ MeV we expect 0.3 chance coincidences; i.e., the contribution of random events is negligible.

Summarizing this section, it has been demonstrated that the events shown in the two dimensional scatter plot of Fig. 3 are quantitatively understood. In regions I—III no events are observed which can be interpreted as decays of quasimolecular states in ^{24}Mg.

IV. ANALYSIS OF THE DATA

In this experiment ^{12}C-^{12}C coincidences were measured for elastic scattering and for inelastic scattering corresponding to single and mutual excitation of the 2^+ state over the range $\theta_{c.m.}=90° \pm 20°$. Furthermore, double-differential cross sections were measured corresponding to ^{12}C-^{12}C-γ coincidences for $\theta^{\gamma}_{lab}=90°\pm45°$ and $\theta^{^{12}C}_{c.m.}=90°\pm20°$. The NaI detector subtended a conical acceptance area centered at $\theta^{\gamma}_{lab}=90°$, with a half-angle of 45°; the angular ranges quoted above in the c.m. system depend slightly on the reaction Q value for kinematic reasons. The $\pm20°$ quoted above are typical values but in the analysis the actual Q-value dependences were used throughout. The ^{12}C-^{12}C-γ coincidences were sensitive to preparticle γ emission as well as ^{12}C-^{12}C-γ arising from ^{12}C-^{12}C inelastic scattering.

In the analysis that follows we will want to use expressions dependent on the angle-integrated cross section. To obtain quantities proportional to the angle-integrated cross sections we must divide the observed yields by detection efficiencies which depend on the nature of the angular distributions. We have assumed for simplicity the gamma ray distribution is isotropic, since the gamma detector subtends a large solid angle and the radiation pattern for quadrupole radiation is not highly directional. The particle distribution has been assumed

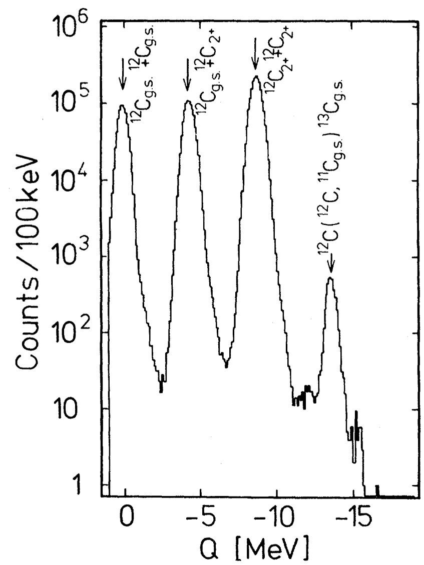

FIG. 4. The Q-value spectrum for the $^{12}C + ^{12}C$ reaction at a bombarding energy of 50.4 MeV.

to be of the form $1/\sin\theta_{\text{c.m.}}$, which corresponds to the expected envelope of the differential cross section for decaying states of high spin. We have made a few sample calculations of the possible error introduced by this assumption, and find that for various assumed angular distributions an error of less than 10% is introduced. In order to make comparisons with theoretical expectations, we have to make the further assumption that all of the observed yield is due to an isolated resonance of a single spin and that there is no nonresonant background. The data of Refs. 3 and 4 suggest that this assumption is qualitatively correct for the elastic and double excitation exit channels at $E_{\text{c.m.}}=25.2$ MeV, where the resonant yield is dominant. This assumption cannot be justified for the single excitation channel.

We will use the above assumptions to estimate upper limits on the branching ratio $(\Gamma_\gamma/\Gamma_{\text{tot}})^{14^+}$ for the decay of the 14^+ resonance by γ emission to the 12^+ resonance relative to all other decay branches. The ratio $(\Gamma_\gamma/\Gamma_{\text{tot}})^{14^+}$ can be related to the number of C-C coincidences by recognizing that

$$N^i_{\text{C-C-}\gamma}\sim\epsilon_\gamma\epsilon_{\text{C}}(\tilde{Q}_i)\left[\frac{\Gamma_{\text{C}}}{\Gamma_{\text{tot}}}\right]^{14^+}\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}\left[\frac{\Gamma_i}{\Gamma_{\text{tot}}}\right]^{12^+} \tag{1}$$

and

$$N^i_{\text{C-C}}\sim\epsilon_{\text{C}}(Q_i)\left[\frac{\Gamma_{\text{C}}}{\Gamma_{\text{tot}}}\right]^{14^+}\left[\frac{\Gamma_i}{\Gamma_{\text{tot}}}\right]^{14^+}, \tag{2}$$

so that

$$\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}=\frac{\sum_i N^i_{\text{C-C-}\gamma}/\epsilon_\gamma\epsilon_{\text{C}}(\tilde{Q}_i)}{\sum_i N^i_{\text{C-C}}/\epsilon_{\text{C}}(Q_i)}\times\left[\frac{\Gamma_{\text{C}}+\Gamma_{2^+}+\Gamma_{2^+2^+}}{\Gamma_{\text{tot}}}\right]^{14^+}\left[\frac{\Gamma_{\text{tot}}}{\Gamma_{\text{C}}+\Gamma_{2^+}+\Gamma_{2^+2^+}}\right]^{12^+}. \tag{3}$$

Hereby, ϵ_γ and $\epsilon_{\text{C}}(Q)$ are the gamma ray photopeak efficiency and the Q value dependent efficiency for coincident C nuclei, respectively, as introduced above. The index i characterizes the state of excitation of the outgoing C nuclei:

$$\Gamma_i=\Gamma_{\text{C}},\ \Gamma_{2^+},\ \text{or}\ \Gamma_{2^+2^+}\ , \tag{4}$$

for none, single, or double excitation of the C nuclei, respectively. The corresponding reaction Q values are Q_i—and for the additional emission of a quasimolecular γ ray—$\tilde{Q}_i$, with $\tilde{Q}_i=Q_i-E_\gamma$. Expression (3) can be simplified to

$$\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}=\sum_i\frac{N_{\text{C-C-}\gamma}}{\epsilon_\gamma\epsilon_{\text{C}}(\tilde{Q}_i)}\sum_i\frac{\epsilon_{\text{C}}(Q_i)}{N^i_{\text{C-C}}} \tag{5}$$

if one assumes $(\Gamma_{\text{C}}+\Gamma_{2^+}+\Gamma_{2^+2^+})/\Gamma_{\text{tot}}$ is approximately the same at the 12^+ and 14^+ resonances as has been shown by Cormier *et al.*[4]

First we consider γ rays from 6.3–7.5 MeV. Assuming one detected C + C + γ coincidence and inserting the observed particle-particle coincidence yields, $N_{\text{C}}=2.35\times10^6$, $N_{2^+0^+}=2.92\times10^6$, and $N_{2^+2^+}=6.45\times10^6$, we obtain from Eq. (5) with $\epsilon_\gamma=4\%$

$$\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}\leq1.9\times10^{-6}\ . \tag{6}$$

For the full γ-ray energy range of 5.6–7.5 MeV only the information of regions I and III in Fig. 3 can be used. For the branching ratio we obtain in this case

$$\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}\leq2.4\times10^{-6}\ . \tag{7}$$

If one restricts the analysis to those reaction channels which show the most pronounced resonance type structures in the excitation function, i.e., the inelastic excitation of one or both C nuclei, one obtains accordingly by considering only regions II and III

$$\left[\frac{\Gamma_\gamma}{\Gamma_{\text{tot}}}\right]^{14^+}\leq2.7\times10^{-6}\ . \tag{8}$$

Independent of the particular estimates of Eqs. (6)–(8), we derive an upper limit on the branching ratio for the searched for γ decay of the 14^+ resonance of 8×10^{-6}, at the level of three standard deviations.

This experimental result has to be compared with theoretical estimates. If a quasimolecular dinuclear system exists the radiative width can be calculated within the rotational model from the theoretically predicted shape. From the work of Chandra and Mosel[5] an electric quadrupole moment of this 24 nucleon configuration of $Q=1.8$ b is deduced, compared to a quadrupole moment of $Q_{\text{g.s.}}=0.74$ b (Ref. 9) for the ground state of ^{24}Mg. Ragnarsson *et al.*[10] also find a quadrupole moment $Q_{20}=1.82$ b for the minimum in the potential energy surface of ^{24}Mg which they associate with ^{12}C + ^{12}C resonances.[11] The experimentally observed excitation energies and spins of the supposed quasimolecular resonances are consistent with an interpretation as a rotational band[3] with a moment of inertia $2\theta/\hbar^2=10$ MeV^{-1}. Assuming rigid rotation this moment of inertia provides a lower limit of 1.4 b for the quadrupole moment of the dinuclear system. If one assumes $\theta/\theta_{\text{rig}}=0.8$, as found experimentally for strongly deformed fission isomeric states in the actinide region,[12] the observed moment of inertia implies a quadrupole moment of 1.9 b, in good agreement with the above theoretical predictions.

For $E_\gamma=6$ MeV and a quadrupole moment of 1.8 b one obtains

$$\Gamma_\gamma=7 \text{ eV}$$

from

$$\Gamma_\gamma=\hbar T_\gamma , \qquad (9)$$

$$T_\gamma=1.22\times10^{13}\,[E_\gamma\,(\text{MeV})]^5\,B(E2)(e^2\text{b}^2) , \qquad (10)$$

(Ref. 13) using

$$B(E2, I\rightarrow I-2)=\tfrac{15}{32}e^2{Q_0}^2\frac{I(I-1)}{(4I^2-1)} . \qquad (11)$$

The calculations of Chandra and Mosel[5] as well as Ragnarsson *et al.*[10,11] indicated that the ^{24}Mg quasimolecular configuration is triaxial. This asymmetry in nuclear deformation leads to a fragmentation of the $K=0$ strength and will, in general, modify the transition probabilities that are derived for a symmetric rotor. A detailed calculation shows that the γ width for transitions between $K=0$ components is reduced by 25% if the theoretically predicted nonaxiality [$Q_{22}=-0.28$ b (Ref. 10)] is taken into account.

To determine the branching ratio for γ decay one has to divide the radiative width by the total width. As discussed in the Introduction, $\Gamma_{\text{tot}}=0.3$ MeV and $\Gamma_{\text{tot}}=2.5$ MeV are used for the assumption of the existence of quasimolecular or shape resonances, respectively, leading to branching ratios of 1.8×10^{-5} and 2.1×10^{-6}.

We have also considered the possibility of a fractionation of the 14^+ and 12^+ states due to residual interaction. Although such a fragmentation would reduce the $B(E2)$ value for the decay from any one fragment it is expected that such an interaction would also affect the overlap with the C + C channel, i.e., reduce the carbon width accordingly. Hence, the branching ratio $\Gamma_\gamma/\Gamma_{\text{tot}}$ remains approximately unchanged even if we sample only one of the 14^+ states at the given bombarding energy (energy spread ≈ 50 keV in the c.m. system due to energy losses in the target). The γ-ray energy window allowed for in the experiment is broad enough to cover transitions to 12^+ states fragmented over an energy interval of ≈ 2 MeV; hence, we expect to be sensitive to the sum rule strength of the 12^+ state.

The experimentally determined upper limit (three standard deviations) of 8×10^{-6} is more than two times smaller than the branching ratio expected in the case of a quasimolecular dinuclear system. Although the deduction of this branching ratio from the experimental data is based on certain assumptions we feel that the discrepancy by at least a factor of 2 does not support the interpretation of the observed resonances as quasimolecular states, whereas an interpretation as shape resonances in a direct reaction process is fully consistent with the experimental result.

It is illustrative to formulate our experimental result in terms of the lifetime of the dinuclear system, independent of involved analyses to determine the width of resonance structures. From the reliably estimated partial width for γ decay of $\Gamma_\gamma\approx5.5$ eV, corresponding to a partial lifetime of 1.2×10^{-16} s, and the experimentally found upper limit of $\Gamma_\gamma/\Gamma_{\text{tot}}\leq 8\times10^{-6}$, a lifetime of $\leq 1\times10^{-21}$ s, twice the collision time of 5×10^{-22} s,[14] can be deduced for the dinuclear configuration. In comparison, the time for a full rotation of a nucleus with a moment of inertia of 10 MeV^{-1} and spin 14^+ is 1.3×10^{-21} s, i.e., the colliding C nuclei do not find time enough to form a longer-lived, rotating quasimolecular configuration.

It can, however, not be excluded that the nonobservation of a quasimolecular γ ray is due to a sudden change of shape of the dinuclear system with increasing spin, although the apparent moment of inertia does not indicate a dramatic variation. Such a "giant backbending" has been predicted[15] to occur at sufficiently high spins when nuclei become triaxial before fissioning. A shape change would reduce the overlap of the wave functions and consequently also change the probability for an electromagnetic transition. Such an effect would, of course, be an interesting phenomenon of its own.

Blair and Sherif[16] have recently performed a DWBA calculation of the yield of $E2$ nuclear bremsstrahlung emitted in the collision of two carbon nuclei. For a given choice of optical potential, they calculate the elastic cross section and the bremsstrahlung cross section accompanying processes where the two carbons are left in their ground state. This model does not assume any resonant behavior beyond the shape resonances associated with the optical potential. The bremsstrahlung yield at our bombarding energy comes predominantly from the decay with $l_f=12$ in the exit channel as expected, although an important contribution from $l_f=14$ is also observed. They find a branching ratio of 1×10^{-6} for the bremsstrahlung to elastic cross section ratio, integrated over a γ-ray energy interval of 2 MeV and integrated over the angular range covered by the particle detectors. This can be compared directly to our ratio of threefold events in region I to twofold elastic yield, corrected for detection efficiencies,

$$\frac{\sigma_{\text{C-C-}\gamma}}{\sigma_{\text{C-C}}}=\frac{N_{\text{C-C-}\gamma}}{\epsilon_\gamma \epsilon_{\text{C}}(\tilde{Q}_{\text{C}})}\frac{\epsilon_{\text{C}}(Q_{\text{C}})}{N_{\text{C-C}}}\ ,$$

for which we obtain an upper limit of 6×10^{-6}. This is consistent with the value obtained by Blair and Sherif.

An experimental verification of this theoretical prediction requires an improvement of the sensitivity by at least an order of magnitude. This seems feasible with the use of a crystal ball, allowing for a 4π detection of the γ rays. Bremsstrahlung emitted in the collision of two colliding heavy ions should be observable for any target-projectile combination, independent of the nuclear structure of the dinuclear system.

V. CONCLUSION

The search for the γ decay of the 14^+ resonance at $E_{\text{c.m.}}=25.2$ MeV in the $^{12}C+{}^{12}C$ system has provided an upper limit (three standard deviations) of the 8×10^{-6} for the probability of this decay mode. This result does not support an interpretation of the 14^+ resonance as a quasimolecular configuration of the 24 nucleon system, since in this case a branching ratio for gamma to particle decay of 1.8×10^{-5} is expected. To rule out this interpretation at a still higher confidence level an experiment with a considerably improved sensitivity is required, which seems feasible with new γ-ray detector systems currently under construction. The present experimental limit is consistent with the hypothesis that the structures, observed in the excitation function for the $^{12}C+{}^{12}C$ elastic and inelastic scattering, are associated with shape resonances in a direct reaction process.

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