

IS THERE EVIDENCE FOR THE EXISTENCE OF THE 14^+ -MEMBER AT 39 MEV
OF THE ^{24}Mg QUASIMOLECULAR BAND?

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Near 39 MeV excitation in ^{24}Mg in the total reaction cross section of $^{12}\text{C}+^{12}\text{C}$ appears a broad structure with a width of 2.5 MeV and ≈ 200 mb height¹. What is its structure and is it entirely due to the $l=14$ -partial wave? We investigated the ^{24}Mg continuum by the reactions pointed out in Fig. 1, where their unexpected selectivity in total angular momentum is displayed as calculated by the Hauser-Feshbach model (HF). Note the lack of contribution to low spin states (0-6). The strong dependence of the cross section (esp. $^{12}\text{C}(^{12}\text{C},\alpha_2)^{20}\text{Ne}_{4^+}$) on the yrast cutoff favors an yrast spin of 14 by comparison with experiment². The small number of contributing partial waves corresponds to an unexpected large coherence angle for the ^{12}C -reactions ($\theta_c(\alpha_0) \approx 55^\circ$, $\theta_c(^8\text{Be}_0) > 63^\circ$ (HF)). Whereas a crosscorrelation

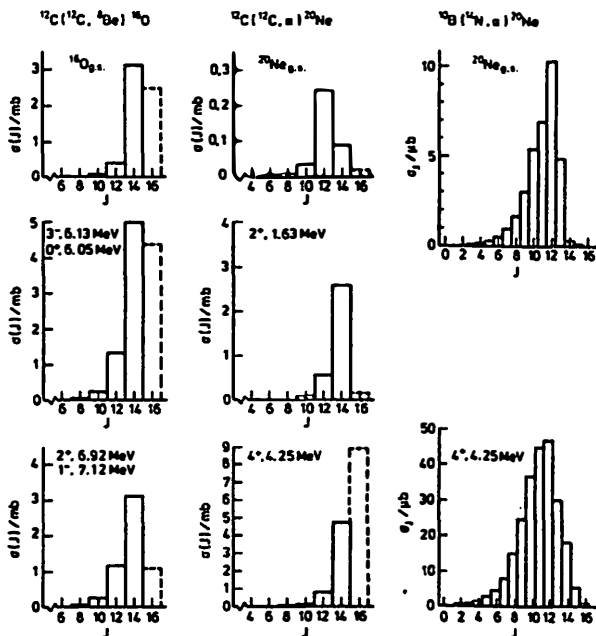


Fig. 1: Partial cross section $\sigma(J)$ of different reactions calculated by the HF-model

function i.e. of the diff cross sections for the 8 different exit channels exhibits some correlation, there is no statistically significant resonance effect in the deviation function. On the other hand, a simultaneous fit like that in Fig. 2 with 3 resonant Breit-Wigner terms within the resonance region (Tab. I) indicates a possibly correlated structure. From this fit, ratios of reduced width are obtained (Tab. II) dependent on the assumed resonance spin J . Whereas the $^8\text{Be}_0$ - α_0 -ratio would be

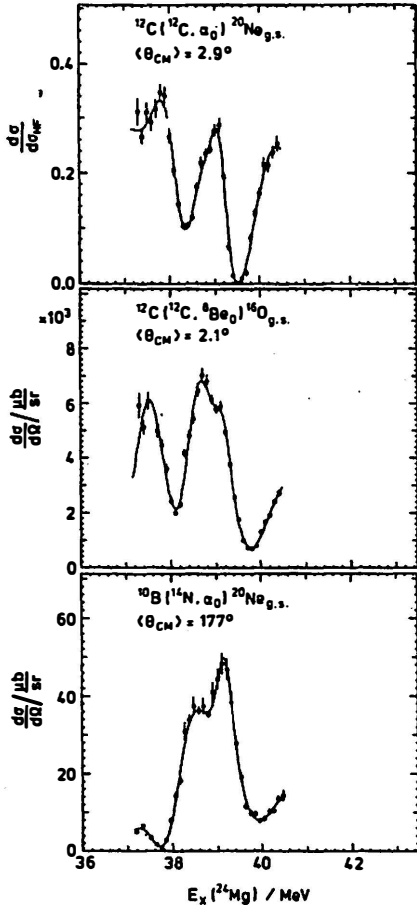


Fig. 2: Simultaneous fit to selected excitation functions

Tab. I: Resonance-parameters (Fig. 2)

$E_x(^{24}\text{Mg})/\text{MeV}$	$\Gamma_{\text{tot}}/\text{keV}$
38.19(1)	893(31)
38.73(1)	977(30)
39.15(1)	607(18)

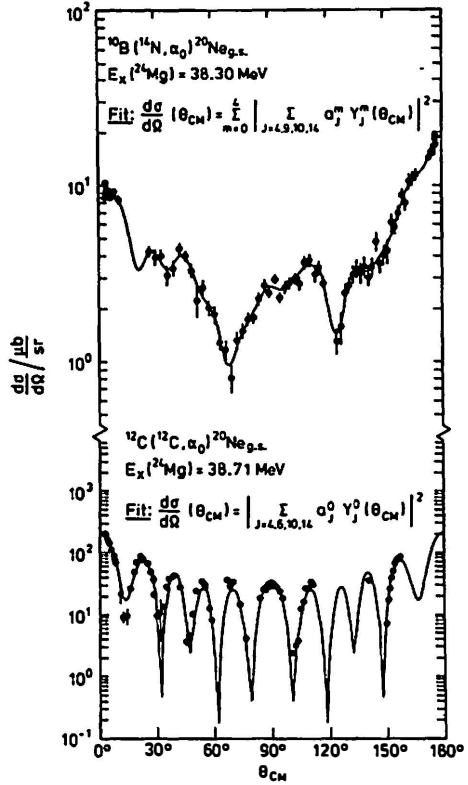


Fig. 3: Fit to angular distributions with a restricted number of 4 contributing total angular momenta J

Tab. II: Ratios of reduced width for assumed spin J (Fig. 2)

J	$\gamma_{\text{BeO}}^2 / \gamma_{\alpha\text{O}}^2$	$\gamma_{^{10}\text{B}^{14}\text{N}}^2 / \gamma_{^{12}\text{C}}^2$
4	50	≥ 1.2
10	40	≥ 10
14	19	$\geq 220 (!)$

($r_0 = 1.50$ fm for penetrabilities)

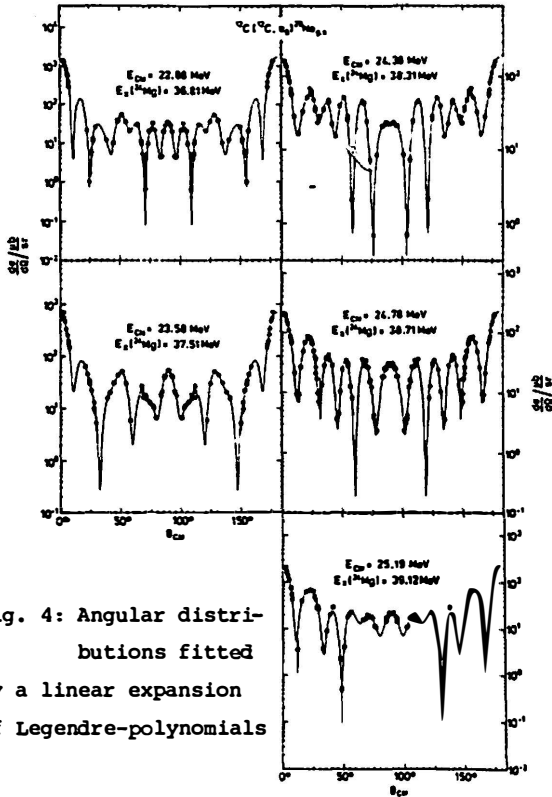


Fig. 4: Angular distributions fitted by a linear expansion of Legendre-polynomials

expected the $^{10}\text{B}^{14}\text{N}-^{12}\text{C}$ value contradicts a $J=14$ -assumption. The reason for this large value is the fact that only one of the 21 subchannels of $^{10}\text{B}_3 + ^{14}\text{N}_1+$ contributes at $\theta_{\text{CM}}=177^\circ$.

The combination of spins 4,9,10,14 yields the best fit to the unexpectedly structured $^{10}\text{B}(^{14}\text{N},\alpha_0)$ angular distribution by the expression given in Fig. 2 (upper part). However, because of many contributing components (aligned channel spin assumed) this selection of spins should not be taken too seriously. Spins $J=4$ and 10 are necessary to fit the two pronounced minima. The same fitting procedure

indicates for $^{12}\text{C}(^{12}\text{C},\alpha_0)^{20}\text{Ne}$ (Fig. 2, bottom) a main contribution of $J=10$ instead of 14.

To verify this, the five angular distributions shown in Fig. 4 are fitted by a real Legendre-polynomial expansion $\sum_{L=0}^{28} b_L P_L(\cos(\theta))$. The $2^{2 \cdot \max L - 1} = 64$ possible combinations of the complex expansion $|\sum_{L=0}^{14} a_L P_L(\cos(\theta))|^2$ are calculated from the b_L for each angular distribution by a program written by W. Bickel³⁾. The "Shortest Path"-method^{3,4)} allows to determine the most probable combinations of scattering amplitudes out of the 64. The corresponding cross sections σ_J^{exp} are displayed in Fig. 5 for the 5 angular distributions of Fig. 4 compared with the predictions of Hauser-Feshbach calculations σ_J^{HF} .

Note i) the contribution of $\sigma_{J=12}^{\text{exp}}$ is entirely overestimated by $\sigma_{J=12}^{\text{HF}}$, which should be the main contribution (Fig. 1),

ii) the experimental total cross section $\sum_J \sigma_J^{\text{exp}}$ clearly exhibits a resonance in the expected region (indicated by an arrow in Fig. 5),

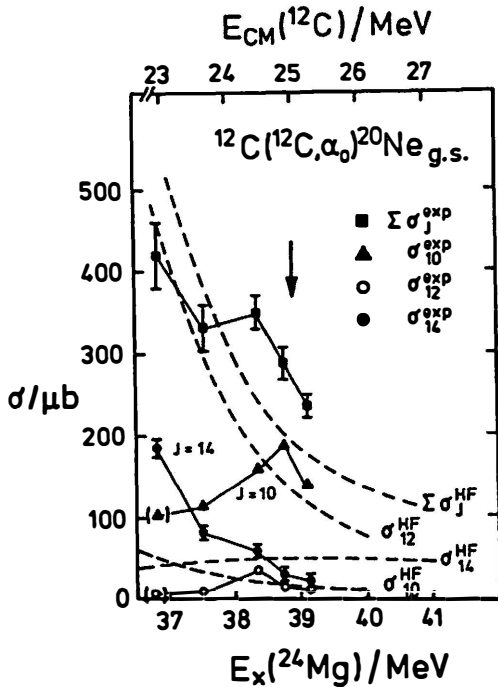


Fig. 5: Analysed partial cross sections from angular distributions of Fig. 4 compared with HF-predictions

On the contrary, the HF-model predicts an almost pure $P_{\ell=14}^2$ angular distribution (Fig. 1). A phase-shift analysis of $^{12}\text{C} + ^{12}\text{C}$ elastic scattering⁶⁾ also gives no evidence for a dominant J=14-contribution.

In summary $\ell=10$ carries up to 65 % of the $^{12}\text{C}(^{12}\text{C},\alpha_0)^{20}\text{Ne}$ total reaction cross section (Fig. 5).

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iii) instead of $\sigma_{J=14}^{\text{exp}}$, which decreases with energy according to the total cross section $\sum_J \sigma_J^{\text{HF}}$, the $\sigma_{J=10}^{\text{exp}}$ component is responsible for the structure in the resonance region (Fig. 2), very much underestimated by $\sigma_{J=10}^{\text{HF}}$. The $^{12}\text{C}(^{12}\text{C},\alpha_0)^{20}\text{Ne}$ g.s. reaction is able to populate J=14 states, as can be recognized by the $\sigma_{J=14}^{\text{exp}}$ contribution already at $E_x(^{24}\text{Mg}) \sim 37$ MeV. Moreover, this reaction of only α nuclei has been regarded up to now to be a good candidate for observing quasimolecular structure.

A reanalysis (Legendre-polynomial fit) of the $^{12}\text{C}(^{12}\text{C},^8\text{Be}_0)^{16}\text{O}$ g.s. angular-distribution measurements of ref. 5 yields no J=14 contribution at all, but the data are not sufficient for a precise statement.