

The interaction matrix elements are

$$\begin{aligned}
 & \langle jLJM|H_Q|j'LJ'M' \rangle \\
 &= f_2 (-1)^{J'+j'} \begin{Bmatrix} j & L & J \\ L & j' & 2 \end{Bmatrix} \hat{L} \hat{L}' \begin{pmatrix} L & 2 & L' \\ 0 & 0 & 0 \end{pmatrix} \delta_{JJ'} \delta_{MM'} \\
 & \times \langle L|\alpha(R_c)|L' \rangle \sum_{l's'} a_{l's}^j a_{l's'}^{j'} \tilde{j} \tilde{j}' (-1)^{l+j'+s} \begin{Bmatrix} l & j & s \\ j' & l' & 2 \end{Bmatrix} \langle j|\alpha(r_{\text{ph}})|j' \rangle \tilde{l} \tilde{l}' \\
 & \times \left[(-1)^{l_2+l'} \tilde{l} \tilde{l}' \begin{pmatrix} l_1 & 2 & l'_1 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} l_1 & l & l_2 \\ l' & l'_1 & 2 \end{pmatrix} \delta_{l_2 l'_2} \right. \\
 & \left. + (-1)^{l_1+l_2+l+l_2} \tilde{l}_2 \tilde{l}'_2 \begin{pmatrix} l_2 & 2 & l'_2 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} l_2 & l & l'_1 \\ l' & l'_2 & 2 \end{pmatrix} \delta_{l_1 l'_1} \right] \delta_{ss'}, \quad (3)
 \end{aligned}$$

where the angular momentum coupling coefficients are written as 3- j - and 6- j -symbols, l_1 and l_2 are the orbital angular momenta of the hole and the particle of the original unperturbed particle-hole excitation, and f_2 is a constant whose value is unknown. The factors $\langle L|\alpha(R_c)|L' \rangle$ and $\langle j|\alpha(r_{\text{ph}})|j' \rangle$ specify the radial dependence of the interaction. The matrix elements are evaluated in terms of a parameter Q given by

$$Q = f_2 \langle L|\alpha(R_c)|L' \rangle \langle j|\alpha(r_{\text{ph}})|j' \rangle, \quad (4)$$

which is regarded as a measure of the strength of the interaction. Each particle-hole state has been expanded as

$$|j \rangle = \sum_{l's} a_{l's}^j |lsj \rangle, \quad (5)$$

where the coefficients $a_{l's}^j$ are the elements of eigenvectors of each particle-hole state, and the $|lsj \rangle$ are the unperturbed particle-hole configurations in LS coupling.

Each matrix is diagonalized, for various values of Q , to give eigenvalues and eigenvectors. The dipole strength of each eigenstate is then found for comparison with the experimental giant resonance data. The energy range 20–26 MeV is concentrated upon here in the determination of the best value of the parameter Q , as in this region the structure of the cross section is well determined. Examination of cross sections for $^{12}\text{C}(\gamma, n)$ reactions and for proton capture by ^{11}B suggests that the main giant resonance peak for ^{12}C can be regarded as containing two component levels, separated by ~ 1 MeV and with the larger component at the lower energy. A second main peak of the dipole strength should be found at an energy of 25.5 MeV.

Results

Using the particle-hole data of Seaborn and Cooper (1971), we find that, for $Q = 12$ MeV, the dipole strength distribution has three peaks with the required energy spacing and in reasonably good agreement with the relative strengths required. After an energy adjustment of almost 2 MeV for all the peaks, the structure predicted

for $Q = 12$ MeV is that shown in Fig. 1. The (γ, n) cross sections as given by Cook *et al.* (1966) and Firk *et al.* (1963) are also shown. The distribution of dipole strengths resulting from the calculation fails to account for the strengths of the peaks seen experimentally at 27.5 MeV and 29.5 MeV.

In the 30–35 MeV region the effect of the major peaks in the giant resonance on the energies and wavefunctions of states appears to be marginal, with very little transfer of strength into the higher energy region occurring. Thus the calculation is unable to predict structure in this region to allow us to distinguish between the different energy assignments tried for the higher 2^+ rotational level. Finally, we note that the particle-hole data of Gillet and Vinh-Mau (1964) give dipole strength distributions of quality inferior to those of Seaborn and Cooper (1971).

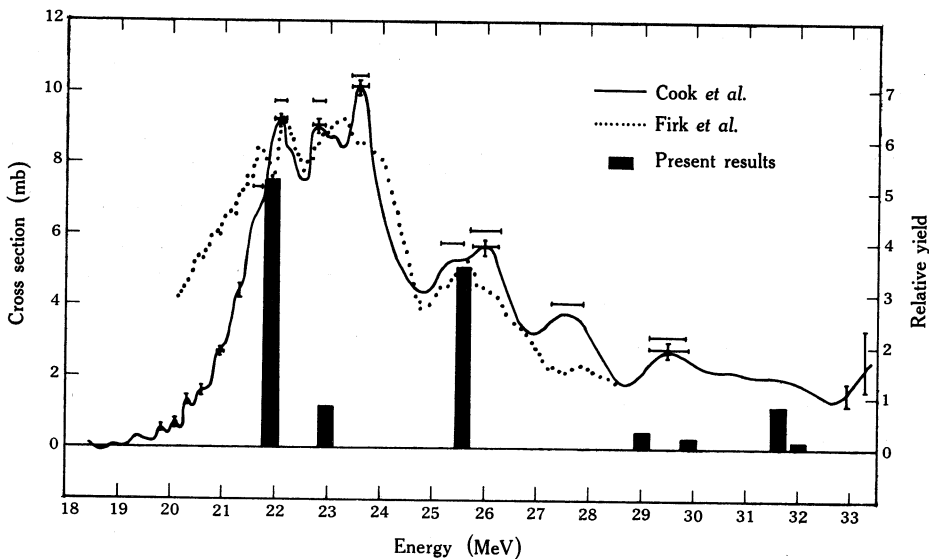


Fig. 1. Comparison of our predicted structure for the giant resonance of ^{12}C with experimental data. The present collective correlations calculation is based on the particle-hole data of Seaborn and Cooper (1971), using 10.3 MeV energy assignment for the higher 2^+ rotational level, for $Q = 12$ MeV. The data of Cook *et al.* (1966) are the CLSR output for the reaction $^{12}\text{C}(\gamma, n)^{11}\text{C}$ with $\Delta E = 125$ keV, while those of Firk *et al.* (1963) are neutron time-of-flight relative yields.

Discussion

The use of a rotator description for the low-lying levels of the nuclear core in a collective correlations calculation for ^{12}C does predict more dipole states in the giant resonance than do the particle-hole calculations. As expected, these states are at least slightly shifted in energy by the coupling process, the extent to which this occurs in a particular case being related to the strength of the coupling. The model does produce some redistribution of the dipole strength from the original particle-hole states. It is interesting to note that the value of 12 MeV for the strength parameter Q which gives the most satisfactory results for this calculation is very close to the value $Q = 10$ MeV selected by Dracoulis (1970) for best results from his calculation for ^{16}O .

However, the calculation fails to transfer strength to the extent expected. Dracoulis (1970) noted that, while he could produce good agreement in position and strength

for the two main peaks of the ^{16}O giant resonance, the calculation did not transfer enough strength to the other peaks. This failure is even more marked in the case of ^{12}C , suggesting a limitation inherent in the model as such. To achieve larger transfer of absorption strength to the higher energy dipole states would require a much larger value of Q than was used, but the use of such a value would destroy the agreement in the energies of the dipole states.

It may be noted that a constant value of Q is assumed in this calculation, but this is a simplification, as the definition of Q given in equation (4) contains a factor $\langle j|\alpha(r_{\text{ph}})|j'\rangle$. Correct accounting for such a factor would require a different value for each particle-hole state, and consequently different values of Q within the energy matrix. However, the transfer of absorption strength from the main peak (22 MeV) to the satellite peak at 25.5 MeV suggests that the value of Q used is not too far wrong. It would appear therefore that this calculation makes too weak a coupling between the ground state of ^{12}C and its 7.65 MeV state, thus inhibiting the transfer of absorption strength, or else it suffers (at higher energies) from neglect of the one particle-one hole $3\hbar\omega$ excitations. This unsatisfactory redistribution of absorption strength means that the present method is not satisfactory for examining the proposed rotational band of states built on the 7.65 MeV level in ^{12}C .

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