

A ROTATIONAL BAND IN  $^{24}\text{Mg}$  AT HIGH ENERGIES OF EXCITATION:  
A ROTATION-VIBRATION COUPLING

F. Coçu, N. Cindro\*, J. Uzureau, Z. Basrak\*, M. Cates,  
J.M. Fieni, E. Holub\*, Y. Patin and S. Plattard

Service de Physique Nucléaire, C.E. Bruyeres-le-Chatel,  
France

\* and Institute "Rudjer Bošković", Zagreb, Yugoslavia

Several recent experiments<sup>1-4)</sup> have provided new information on spins and parities of resonances in  $^{24}\text{Mg}$  at high energies of excitation. In the present work, we investigate the  $^{12}\text{C}(^{12}\text{C},\alpha)^{12}\text{C}$  reaction in the range of  $6.6 < E_{\text{cm}} < 15$  MeV and

report three new resonances at  $E_{\text{cm}} = 6.6, 8.05, 8.85, 11.2$  and  $13.75$  MeV, to which we assign  $J^\pi$  values. Combining these results with the data from previously reported measurements and the results of other authors, we attempt a unified picture of the resonances in  $^{24}\text{Mg}$ .

The present experiment was performed using the FN tandem accelerator of the CE Bruyeres-le-Chatel.  $\alpha$  particles from the  $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$  reaction were momentum-

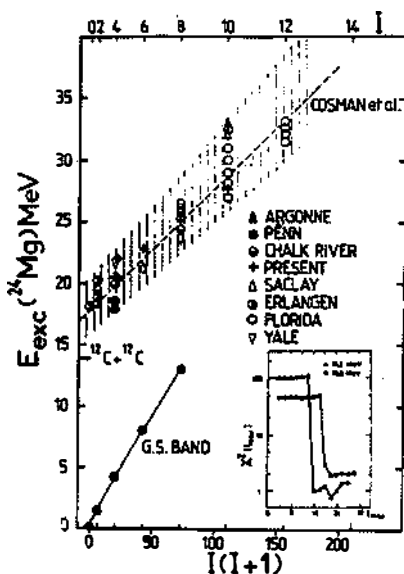


Fig.1. Resonances in  $^{12}\text{C} + ^{12}\text{C}$  plotted in an  $E_{\text{exc}}(^{24}\text{Mg})$  vs. measured spin diagram. Insert: Plot of  $\chi^2_{\text{max}}$  vs.  $l_{\text{max}}$  for the 11.2 and 13.75 MeV angular distributions.

analyzed in a split-pole magnetic spectrograph and detected in a position-sensitive Si detector. From the correlated maxima in the excitation functions of transitions leading to natural-parity states in  $^{20}\text{Ne}$  and the relative smallness of the  $2^-$  excitation function at very forward angles, several c.m. energies were selected as likely candidates for resonances and ground-state  $\alpha$ -angular distributions were measured on and off these energies. These angular distributions were compared with pure  $P_L^2(\cos\theta)$  shapes; moreover, an analysis in terms of  $\chi^2$  vs.  $l_{\text{max}}$  using the expansion of  $\sigma(\theta)$  in Legendre polynomials was performed. Should the distribution correspond to a pure resonance of given angular momentum  $I$ , the value of  $\chi^2(l_{\text{max}})$  should drop sharply when  $l_{\text{max}} = 2I$  (see insert in Fig. 1). From the combined analyses we conclude that the resonances at  $E_{\text{cm}} = 6.6, 8.05, 8.85, 11.2$  and  $13.75$  MeV had  $J^\pi$  values of  $(4^+), (4^+), 6^+, 8^+$  and  $10^+$ , respectively.

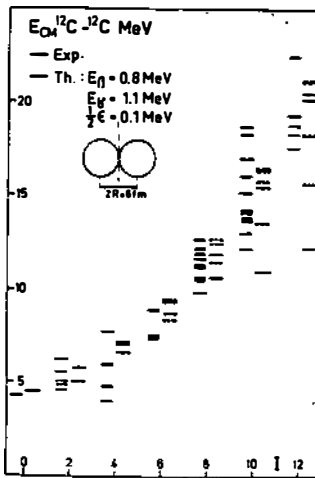


Fig. 2. Comparison of experimental and calculated resonance spectra (rotation-vibration model, no coupling).

Fig. 1 shows the present results together with the results of some earlier measurements plotted vs.  $I(I+1)$ . Two features of this plot strike the eye: (i) all the measured values lie on a fairly straight line and (ii) resonances of the same  $J^\pi$  appear to be grouped within a few MeV.

As discussed earlier<sup>5)</sup>, the above features indicate the presence of a collective rotational band at high energies of excitation in  $^{24}\text{Mg}$ . The grouping of resonances of the same  $J^\pi$  into clusters is suggestive of fragmenting

of wide shape-resonances (a few MeV) into narrower ones (a few hundred keV). In order to account for this behaviour, we have applied the first-order rotation-vibration model<sup>6)</sup>, where the energy spectrum is given by

$$E_{IKn_2n_0} = [I(I+1) - K^2] \frac{1}{2}\epsilon + (\frac{1}{2}|K| + 1 + 2n_2)E_\gamma + (n_0+1)E_\beta$$

with  $n_0 = n_2 = 1$ . The parameter  $\frac{1}{2}\epsilon = \hbar^2/2\mathcal{I}$  is determined from the average slope in fig. 1. We take  $E_\beta = 0.8$  MeV (an arbitrary but reasonable value); then, fixing the bandhead near the experimental value of  $E_{cm} = 4.2$  MeV, we obtain  $E_\gamma = 1.1$  MeV. Thus, the ratio  $E_\gamma/E_\beta$  appears as the only free parameter in the calculation. Figure 2 shows that the calculated and experimental spectra are in fair agreement. It is hoped that inclusion of the rotation-vibration coupling would improve the above picture, giving, in particular, the width of the resonances.

#### References

- 1) K.A. Erb et al., Phys. Rev. Lett. 37 (1976) 670.
- 2) H.T. Fortune et al., Phys. Lett. 63B (1976) 403;  
H.T. Fortune et al., Phys. Rev. C14 (1976) 1271.
- 3) Z. Basrak et al., Phys. Lett. 65B (1976) 119.
- 4) W. Galster et al., Phys. Rev. C15 (1977) 950.
- 5) N. Cindro et al., Proc. Int. Conf. on Resonances in Heavy Ion Reactions, Hvar 1977, to be published.
- 6) See, e.g., J. Eisenberg and W. Greiner, Nuclear Theory, Vol. 1, p. 149, North Holland, Amsterdam, 1975.