A SEMIEMPIRICAL PREDICTION OF THE OCCURRENCE OF RESONANCES IN HEAVY ION REACTIONS

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In this contribution we propose a semiempirical prediction of the occurrence of resonances in heavy ion reactions, based on an estimate of their spreading width. This calculation is applied to s-d nuclei from A=24 to 32.

Our main assumptions are (i) the resonances are associated with simple configurations leading to rotational-like bands; (ii) the experimental observation of resonances is related to the spreading width $\Gamma^{\downarrow}$ of such configurations $\Gamma^{\downarrow}=2\pi|\langle e\ell|V|CN\rangle|^2\rho(E_x,J)$ estimated uwing existing models of nuclear level density and neglecting the influence of the matrix element.

Our method consists in determining the regions of observed resonances in nuclear systems in the E_x vs. J(J+1) plane. Such regions are well defined in ^{24}Mg and ^{28}Si; indications about resonances and their spins exist also in ^{29,30}Si. The densities corresponding to medians of these regions are first fitted by a Fermi gas expression with a=0.12 A and $\sigma^2=1.2\ \mathcal{J}_{rigid}\cdot T/\hbar^2$. In this way a constant density line in the E_x vs. J(J+1) plane was determined for each system (fig. 1). Fig. 2 shows that the so obtained values of ρ^F_{line} for ^{24}Mg and ^{28,29,30}Si lie on an exponential line. We assume that this line defines values of ρ^F_{line} for all neighbouring nuclei. In this way one maps regions in the E_x vs. J(J+1) planes where resonances are to be expected, unless structure effects prevent the possibility of their observation.

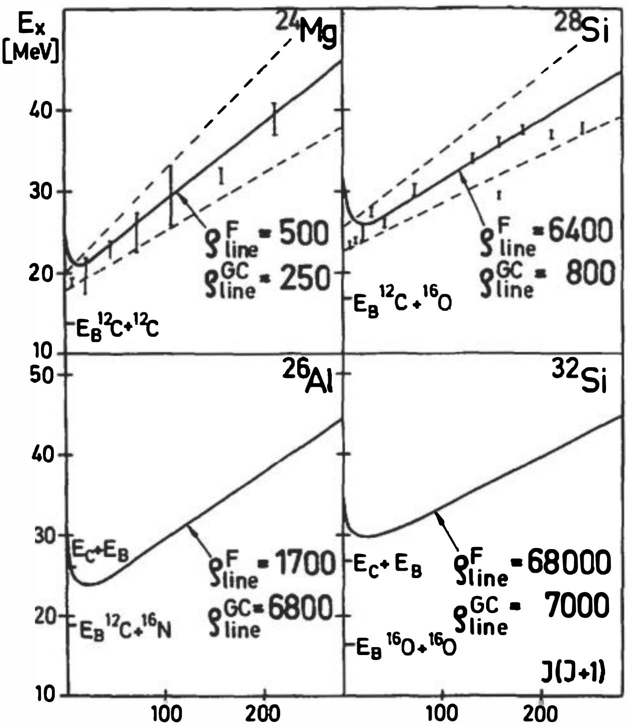

Fig. 1

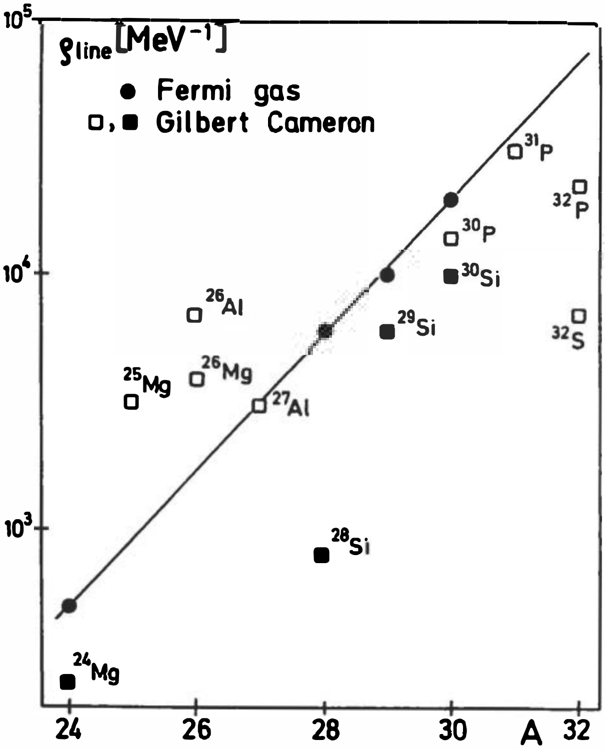

Fig. 2

To take structure effects into account, we performed a calculation of level densities based upon the Gilbert-Cameron model with $\underline{a} = \underline{a}_{obs}$ and the above value of σ^2. The squares in fig. 2 correspond to values of ρ^2_{line} obtained by fitting the medians of previously mapped "resonant" regions with the second model. The results show that (i) the values of ρ^{GC}_{line} for ^{24}Mg and ^{28,29,30}Si (full squares) are substantially smaller (factor of 2 or more) than the corresponding Fermi gas values; (ii) in other systems there is a twofold effect: in some (^{32}P, ^{32}S) the level densities ρ^{GC}_{line} are lowered, while in others (^{25,26}Mg, ^{26,27}Al, ^{30,31}P) they are increased or virtually not changed with respect to ρ^{F}_{line}. We expect that for nuclei with $\rho^{GC}_{line} \ll \rho^{F}_{line}$ the estimated value of $\Gamma^{\downarrow}$ associated with the resonances will be considerably smaller than for nuclei with $\rho^{GC}_{line} \gtrsim \rho^{F}_{line}$. Consequently, the experimental observation of resonances in the former is more likely than in the latter nuclei.

Other physical quantities capable of influencing the experimental occurrence of resonances (<el|V|CN>, number of open channels) will be discussed in a forthcoming paper.

EVIDENCE FOR A NON-STATISTICAL POPULATION OF HIGH SPIN STATES IN ^{24}MG VIA THE $^{12}C(^{13}C,n)$ REACTION +)

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Our earlier measurements of the $^{12}C(^{13}C,n)^{24}Mg$ reaction at e.g. $E_{c.m.}$= 14.4 MeV yielded strong excitation of states between E_x= 20.15 and 21.2 MeV in ^{24}Mg which due to a Hauser-Feshbach analysis were likely candidates to have spins $J \geq 10$ [1]. When the incident energy was raised to $E_{c.m.}$= 19.2 MeV the decrease of the yield of states at E_x= 20.80 and 21.00 MeV, however, turned out to be considerably larger than expected from the corresponding Hauser-Feshbach predictions. Further neutron time-of-flight measurements of this reaction have been performed with incident energies between $E_{c.m.}$= 13.4 and 15.3 MeV to check whether this behaviour may be caused by resonances in the $^{12}C+^{13}C$ system. The spectra have been taken at a flight path of 4m and angles of $\Theta \doteq 0^o$ and 180^o using large efficiency neutron counters. The 180^o data were obtained by interchanging target and projectile. Spectra observed at $E_{c.m.}$ = 14.71 MeV are shown in fig. 1. In the range of presently studied projectile energies we found no indications of isolated resonances. However, forward-backward asymmetries are present and clearly demonstrated at certain excitation energies in ^{24}Mg when the spectra at 0^o and 180^o, converted to double differential c.m.cross sections, were subtracted from each other. At the excitation energies marked in fig. 2 the asymmetry change as a function of the incident energy shows structures which have widths of

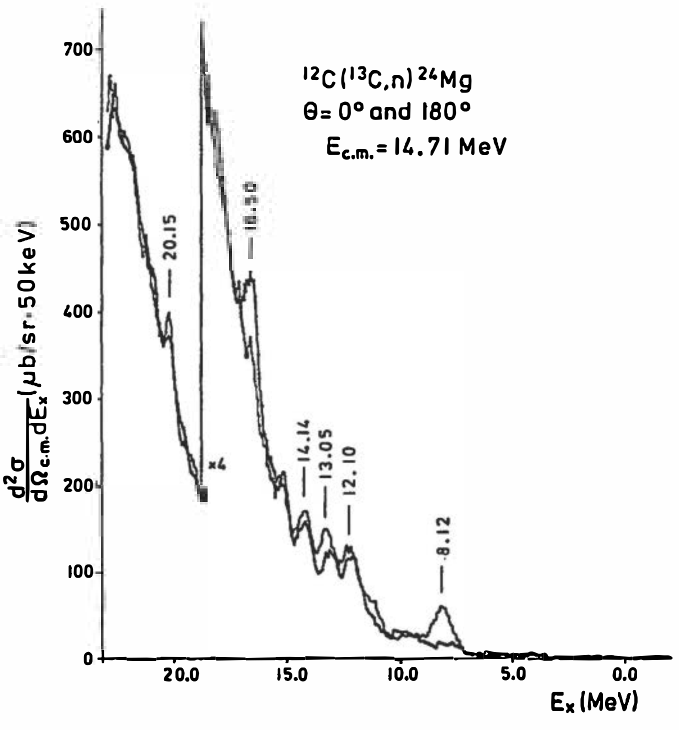

Fig. 1. Double differential cross sections obtained from the neutron time-of-flight spectra are plotted versus the excitation energy in ^{24}Mg. The histogram plot shows data at 180^o.

$\Gamma_{c.m.} \geq 300$ keV. This limit is about twice the coherence width expected for the ^{25}Mg compound nucleus at an excitation energy around 31 MeV we are here dealing with. Two explanations may be given for this non-statistical behaviour. It is caused either by a few overlapping resonances of opposite parity or a direct multi-nucleon transfer. The rather constant backward peaking of the 8.12 MeV, 6^+ and the 20.2 MeV, possibly 10^+ state in ^{24}Mg for the examined projectile energy range of $\Delta E_{c.m.} = 1.2$ MeV seems to make the latter possibility the more probable one. An interesting consequence then would be that these states have a large ^{12}C parentage. As our preliminary calculations with the finite range DWBA code LOLA show, the excitation of the 8.12 MeV state cannot be explained, however, by a simple cluster transfer of ^{12}C in the lowest 0^+ state into the p and sd shells.

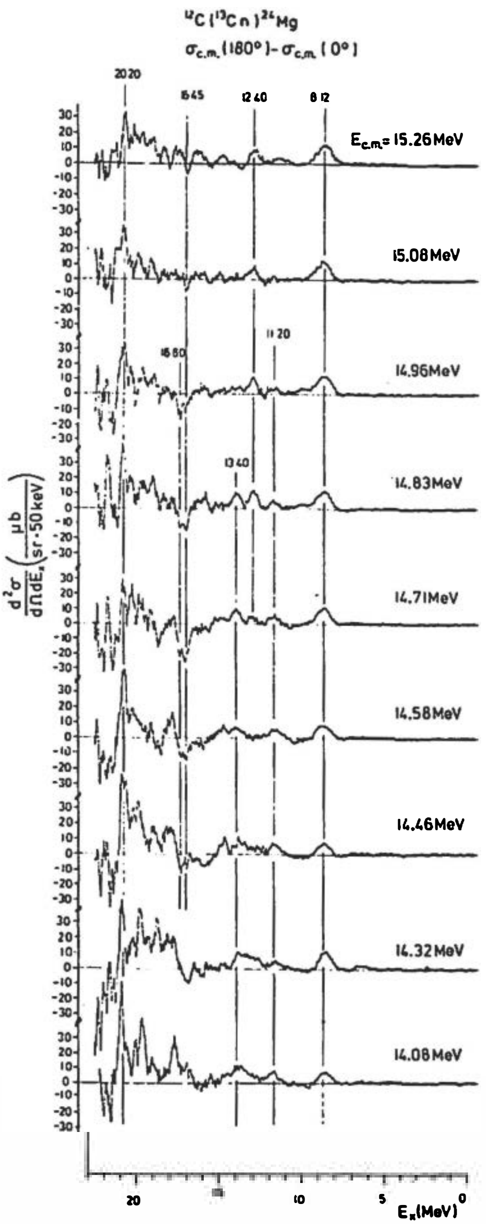

Fig. 2. Difference of the spectra shown in fig. 1 as well as of those obtained at other indicated incident energies.

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1) Annual report of the Beschleunigerlaboratorium der Universität und der Technischen Hochschule München (1974)p.80 and (1976)p.36, and W.Assmann et al.,Verh. DPG(VI) 12, 997 (1977).