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# EXCITED STATES IN $N^{14}$ FROM $C^{12}$ + d REACTIONS

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Deuteron elastic scattering and (d, $p_o$) and (d, n) reactions have been studied by several authors [1,5] and strong resonances corresponding to the excited states in $N^{14}$ have been observed. The $B^{10}(\alpha, p)N^{13}$ reaction [6] and the $C^{13}(p,p)C^{13}$ [1], $C^{13}(p,n)N^{13}$ [1] and $C^{13}(p,\gamma)N^{14}$ [1] reactions have also been studied to obtain the levels in $N^{14}$. In this note we present the results for $C^{12}(d,d)C^{12}$, $C^{12}(d,p_o)C^{13}$, $C^{12}(d,p_1)C^{13*}$, $C^{12}(d,p_2)C^{13*}$ and $C^{12}(d,p_3)C^{13*}$ reactions to obtain the levels in $N^{14}$ from 11-15 MeV excitation. This is a part of a programme that has been undertaken at Saclay (i) to obtain the energy levels in $N^{14}$ from various possible reactions and (ii) to study the mechanism of the reactions which have the same "composite" system, namely, $N^{14}$. It is hoped that such a study would also yield information regarding "cluster" states in light nuclei.

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The excitation curves for the above mentioned reactions have been studied at two angles, 143.5° and 155° in the laboratory system, for deuteron energies from 0.9 to 5.0 MeV. The targets used were self supporting carbon targets having a thickness corresponding to 5-10 μgm/cm$^2$. Carbon build up on the target was kept below 5% during the whole period for the measurement of one excitation curve, by a liquid air trap before the target and also by allowing the beam to fall on the target only during measurement. Solid state detectors having a resolution of around 50 to 60 keV were used to detect the reaction products and a fixed counter at 90° served as monitor.

Figs. 1 and 2 show the excitation curves for all the above reactions at the two laboratory angles of 143.5° and 155°. $C^{12}(d, p\gamma)C^{13}$ have been studied by Fintz et al[7] by observing $\gamma$-rays from the various levels in $C^{13}$. Their excitation curves appreciably differs from ours, and we see more resonances possibly due to the use of thinner targets by us and better resolution as obtained from solid state detectors.

In table 1 we list all the levels of $N^{14}$ obtained in the present work. The levels which are designated as broad may possibly have more than one level and their energy determination is hence not very accurate. In fig. 3 we present a comparison of our results with those from Ajzenberg-Selove and Lauritsen [1] as well as the levels obtained by the Strasbourg group [7].

One sees from figs 1 and 2 that there is a large resonant contribution in deuteron reactions with $C^{12}$ even at 5 MeV.

Similar trends have been observed in $He^3$ reactions with $C^{12}$ [8] where broad resonances in the **elastic** scattering as well as in the $(He^3, \alpha)$ and $(He^3, n)$ reactions have been noted. Since in this nucleus the p subshell gets filled, it is possible that due to lack of losely coupled surface nucleons, the incident particle tends to form compound system and hence the relative contribution of resonance mechanism compared to direct interactions gets enhanced.

It is surprising that the resonances seem to get "washed out" in the $(d, p_o)$ reaction at high energies. Since this reaction has positive Q-value of about 2.7 MeV, this effect might be related to the energy of the emergent proton with respect to the Coulomb barrier. Further work is being done now to study this in detail.

Recently Picard et al [9] have observed strong backward peaks in $C^{12}(d, \alpha)B^{10}$ reactions which they explain as due to heavy particle stripping and they give qualitative arguments to show that this reaction does not proceed through compound system. This might indicate the presence of losely coupled alpha particles in $C^{12}$ which get stripped in the $(d, \alpha)$ reaction. Further work in this direction might yield information on the alpha structure of $C^{12}$.

Table 1

Excited states in $N^{14}$ from $C^{12}$ + d reactions

| $C^{12}(d,d)$ | $C^{12}(d,p_0)$ | $C^{12}(d,p_1)$ | $C^{12}(d,p_2)$ | $C^{12}(d,p_3)$ | Remarks |
|---|---|---|---|---|---|
| | | 11.243 | | | |
| | 11.277 | | | | |
| 11.387 | 11.387 | 11.387 | | | |
| | | 11.484 | | | |
| 11.505 | 11.505 | 11.505 | | | |
| | | 11.682 | | | broad** |
| | 11.802 | 11.802 | | | |
| | | | 11.825 | | |
| 11.844 | | | 11.844 | | |
| | 12.036 | | | | ?* |
| | | 12.078 | | | ?** |
| | | | | 12.171 | ?* |
| 12.392 | 12.392 | | 12.392 | 12.392 | * |
| | | | 12.441 | | |
| | | | 12.475 | | |
| | | | 12.559 | 12.559 | |
| 12.582 | 12.582 | | | | |
| 12.672 | | | 12.672 | 12.672 | |
| | | | | 12.732 | |
| 12.763 | | | | 12.763 | |
| | 12.778 | | | | ?* |
| 12.799 | | | 12.799 | 12.799 | |
| | | | 12.854 | 12.854 | ?*broad** |
| 12.913 | 12.913 | | | 12.913 | |
| 12.968 | | 12.968 | | | ?* |
| 13.140 | | | 13.140 | 13.140 | |
| | | | 13.192 | | |
| | | | | 13.217 | |
| | | 13.284 | | | broad** |
| | | 13.428 | | | broad** |
| | | | 13.554 | | |
| | | | 13.580 | | |
| | | | 13.605 | | ?* |
| | | 13.663 | | 13.663 | broad** |
| | | | 13.824 | | |
| | | | 13.926 | 13.926 | ?*broad** |
| | | | 14.030 | 14.030 | broad** |
| | | 14.102 | | | broad** |
| | | | 14.187 | | broad** |

* These levels are not very definite.

** These levels are very broad and may be composed of more than one level. The energies quoted are the energies corresponding to the maxima in the excitation curves.

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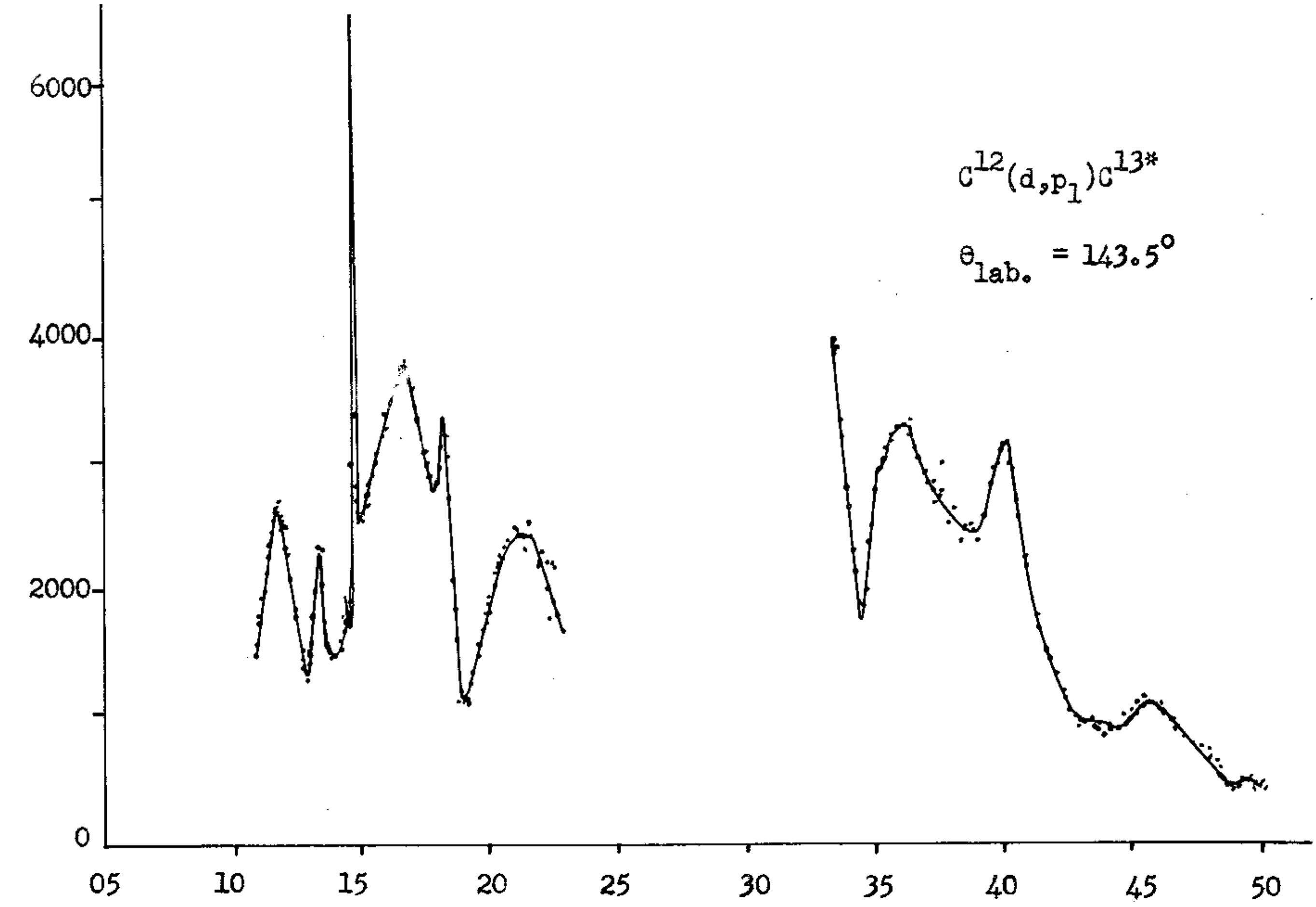


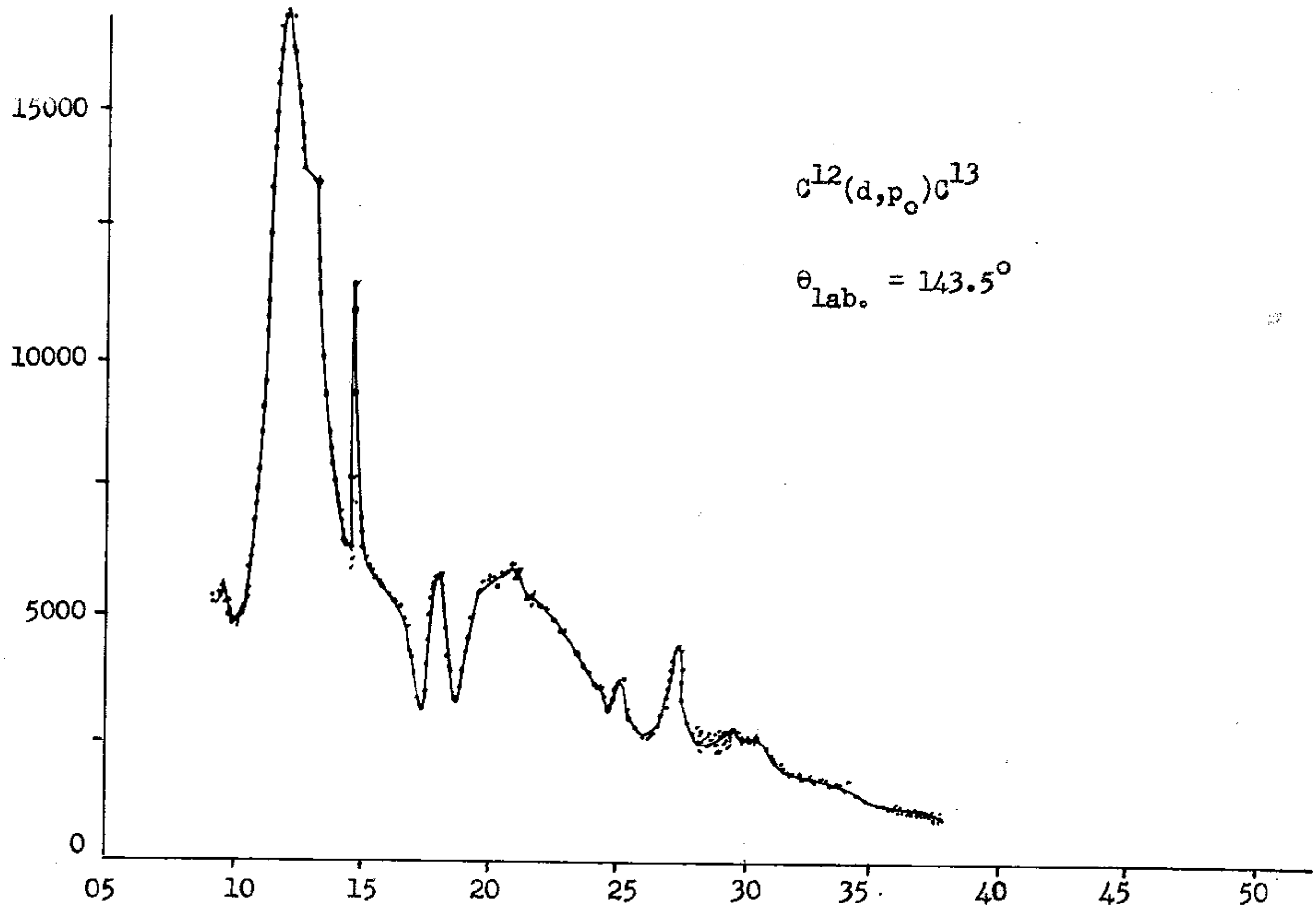


Fig. 1a - Excitation curves of $C^{12}$ + d reaction for the laboratory angle 143.5°.

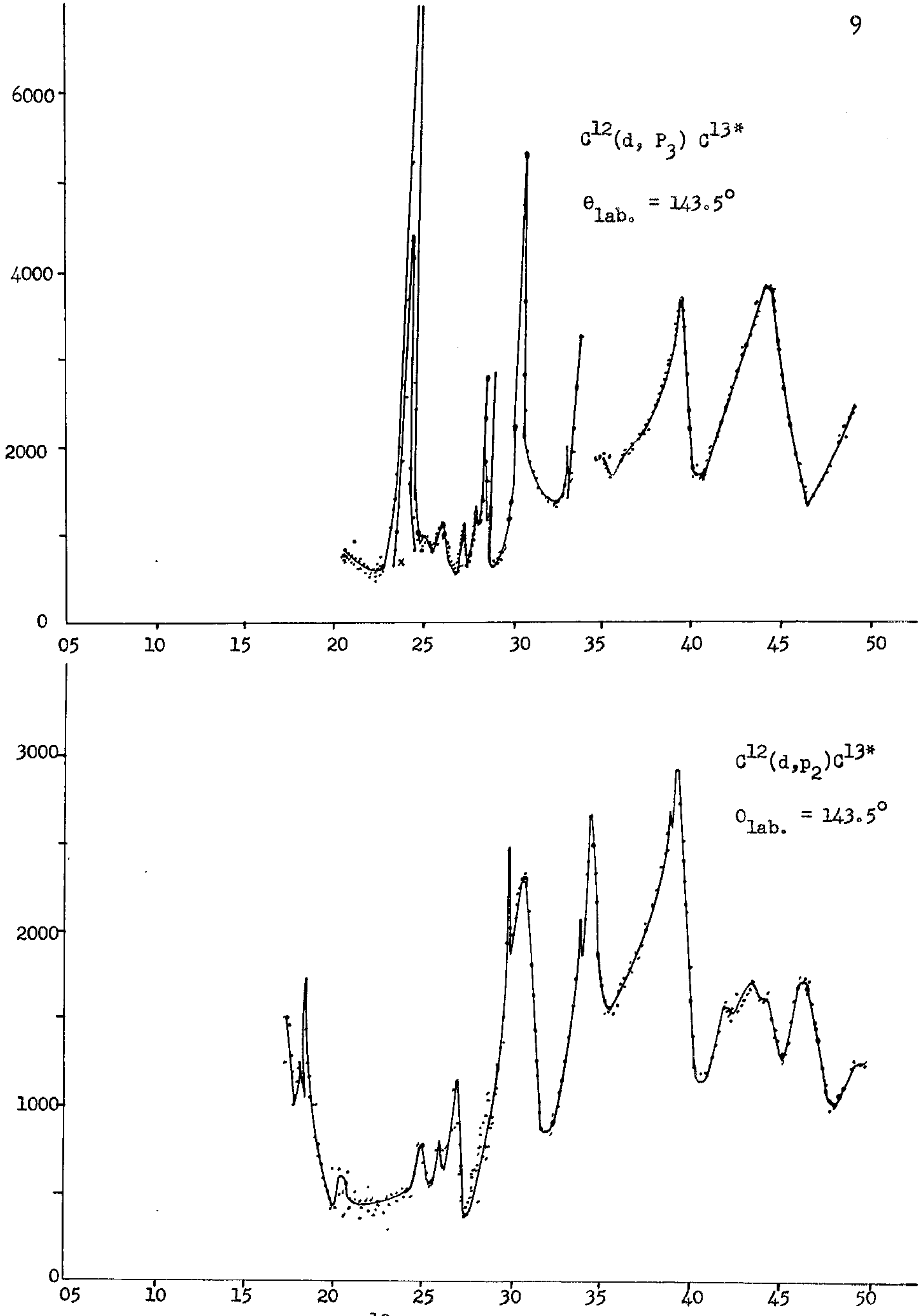


Fig. 1b - Excitation curves of $C^{12}$ + d reaction for the lab. angle 143.5°.

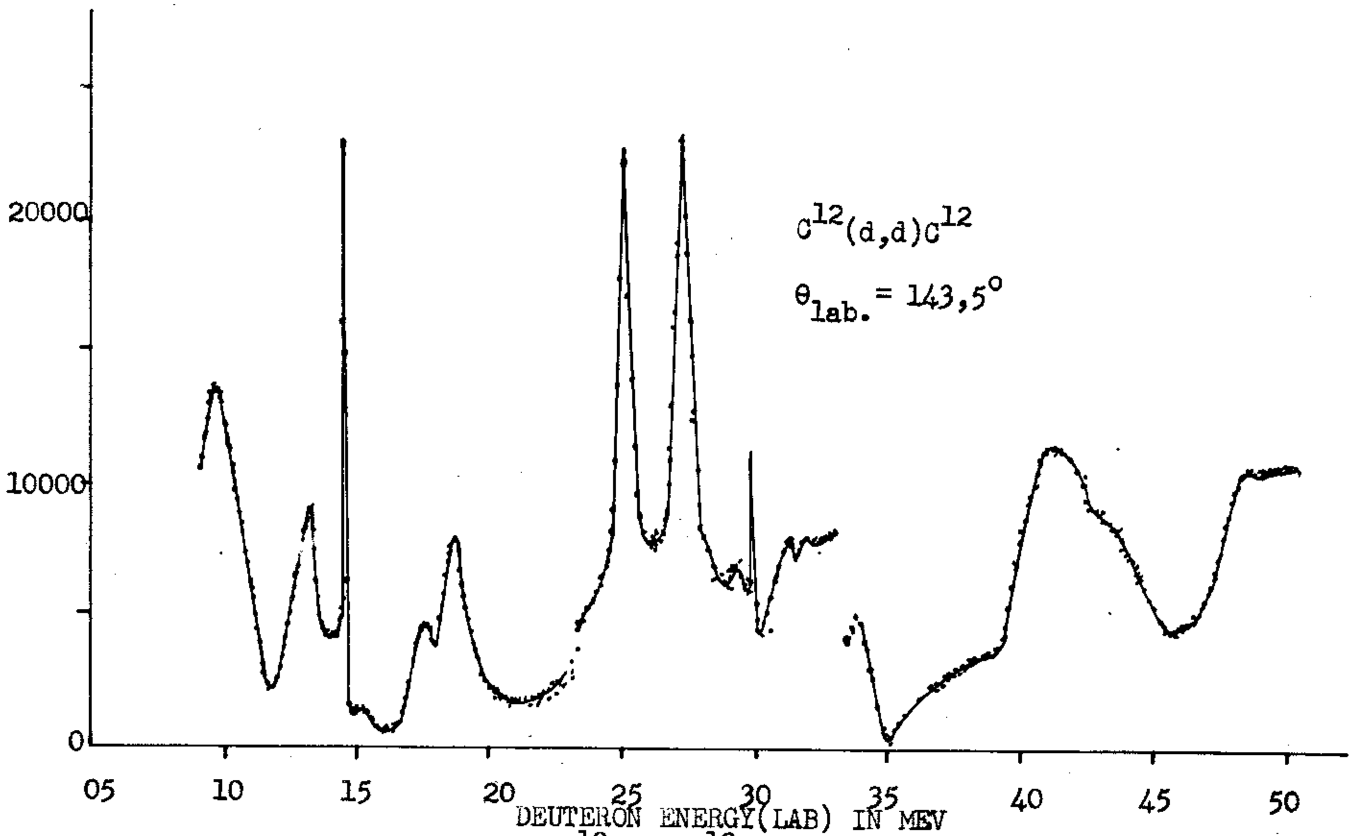


Fig. 1c - Excitation curve of $C^{12}(d,d)C^{12}$ for the laboratory angle 143.5°.

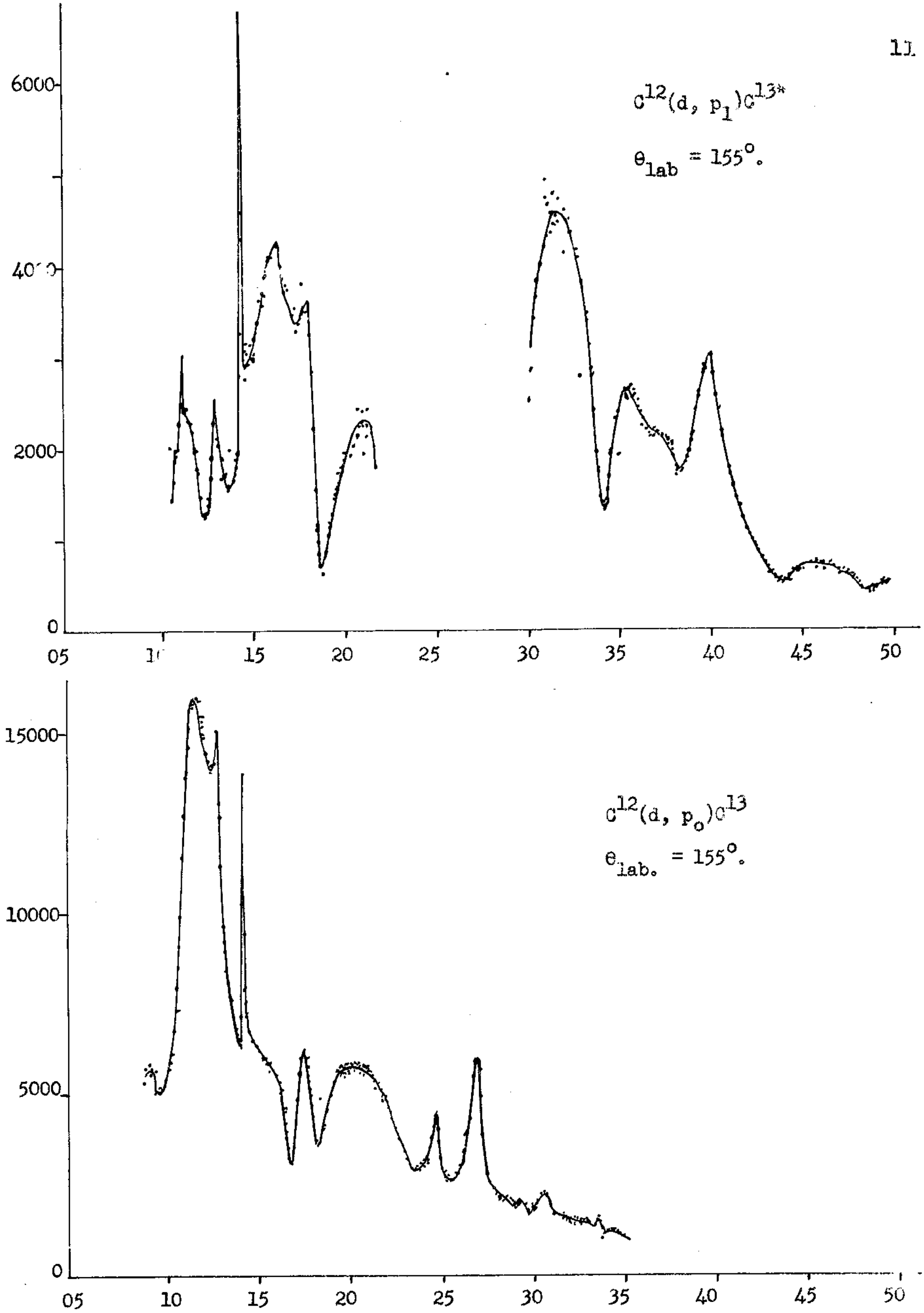


Fig. 2a - Excitation curves of $C^{12}$ + d reaction for the laboratory angle 155°.

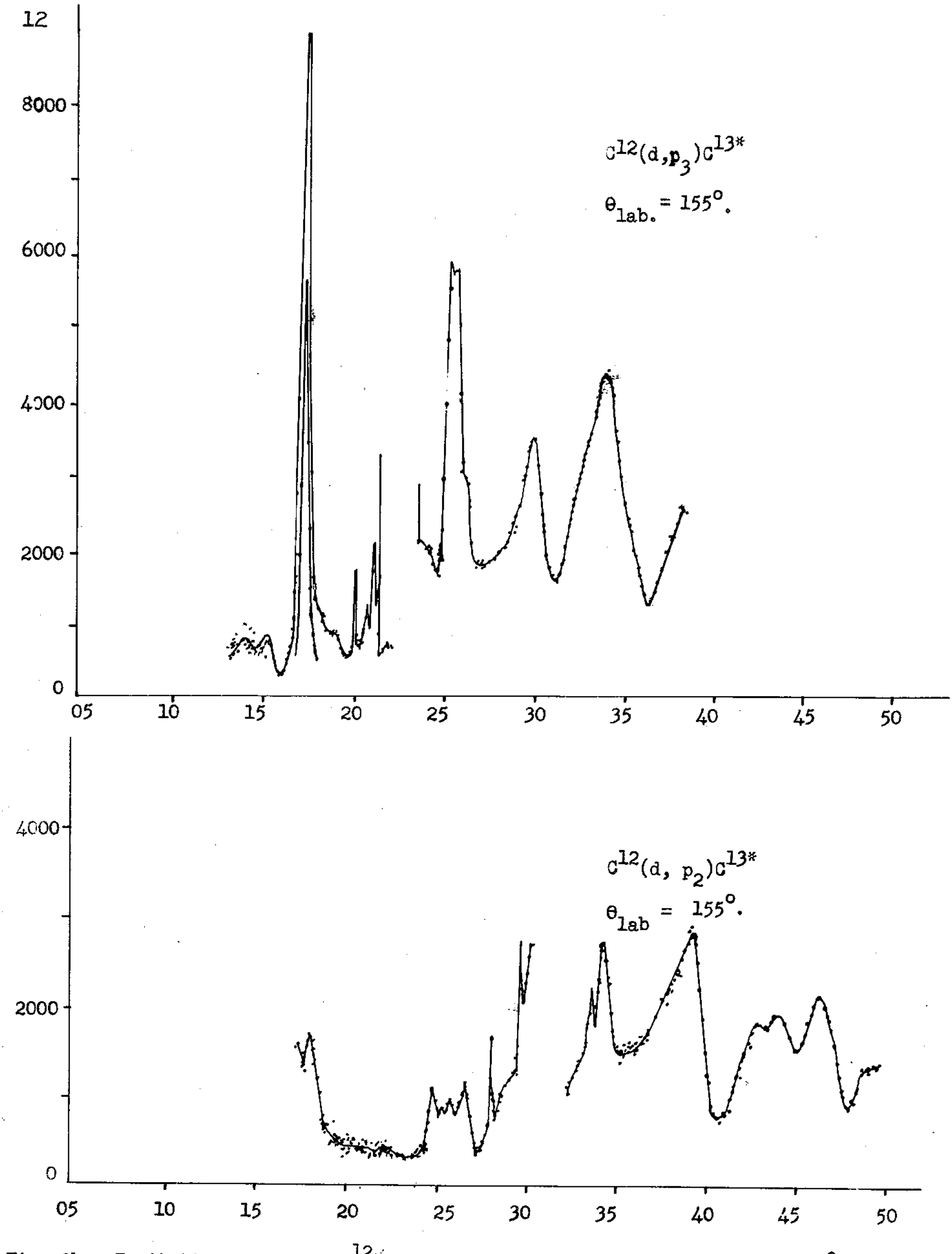


Fig. 2b - Excitation curves of $C^{12}$ + d reaction for the laboratory angle 155°.

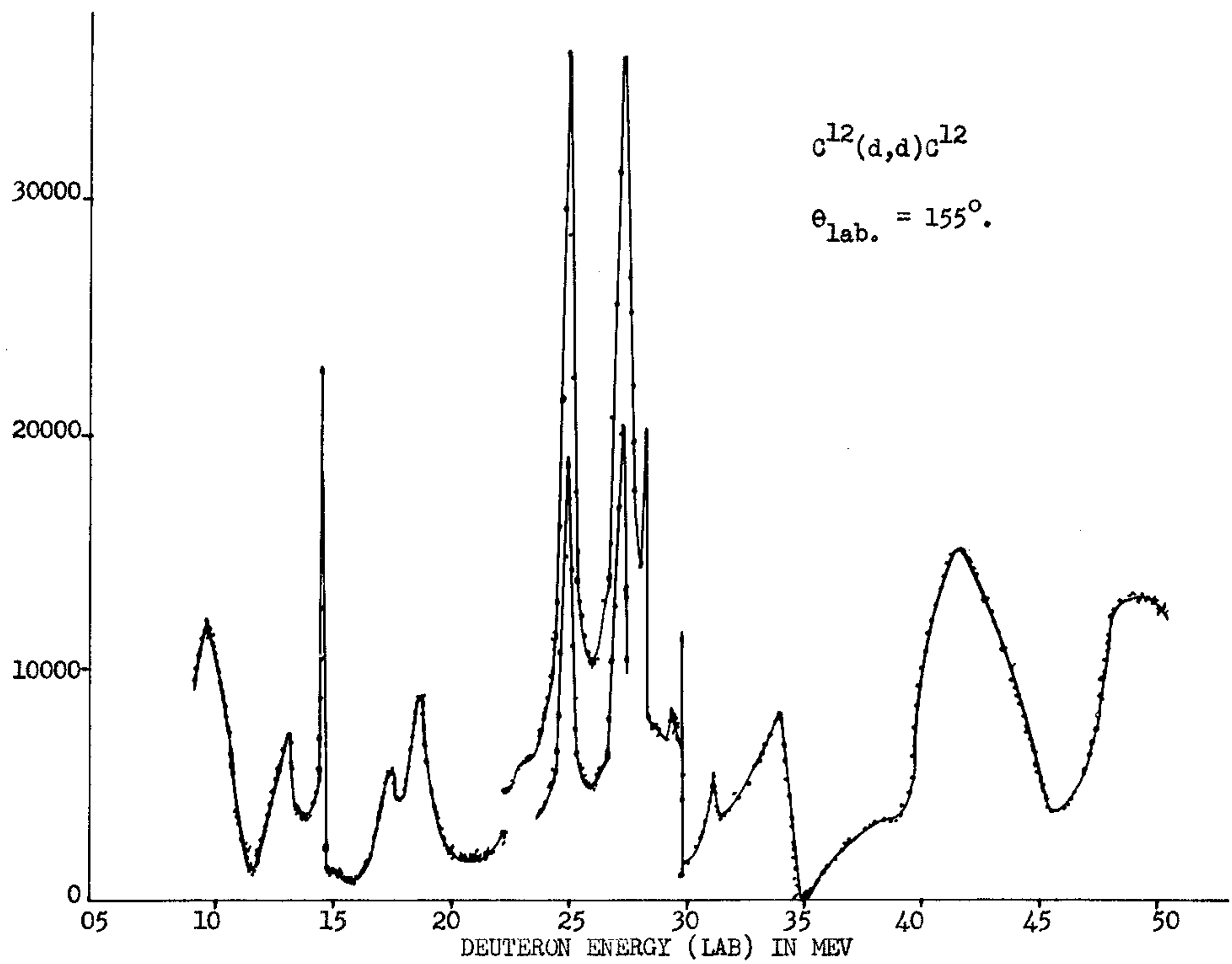


Fig. 2c - Excitation curve of $C^{12}(d,d)C^{12}$ for the laboratory angle 155°.

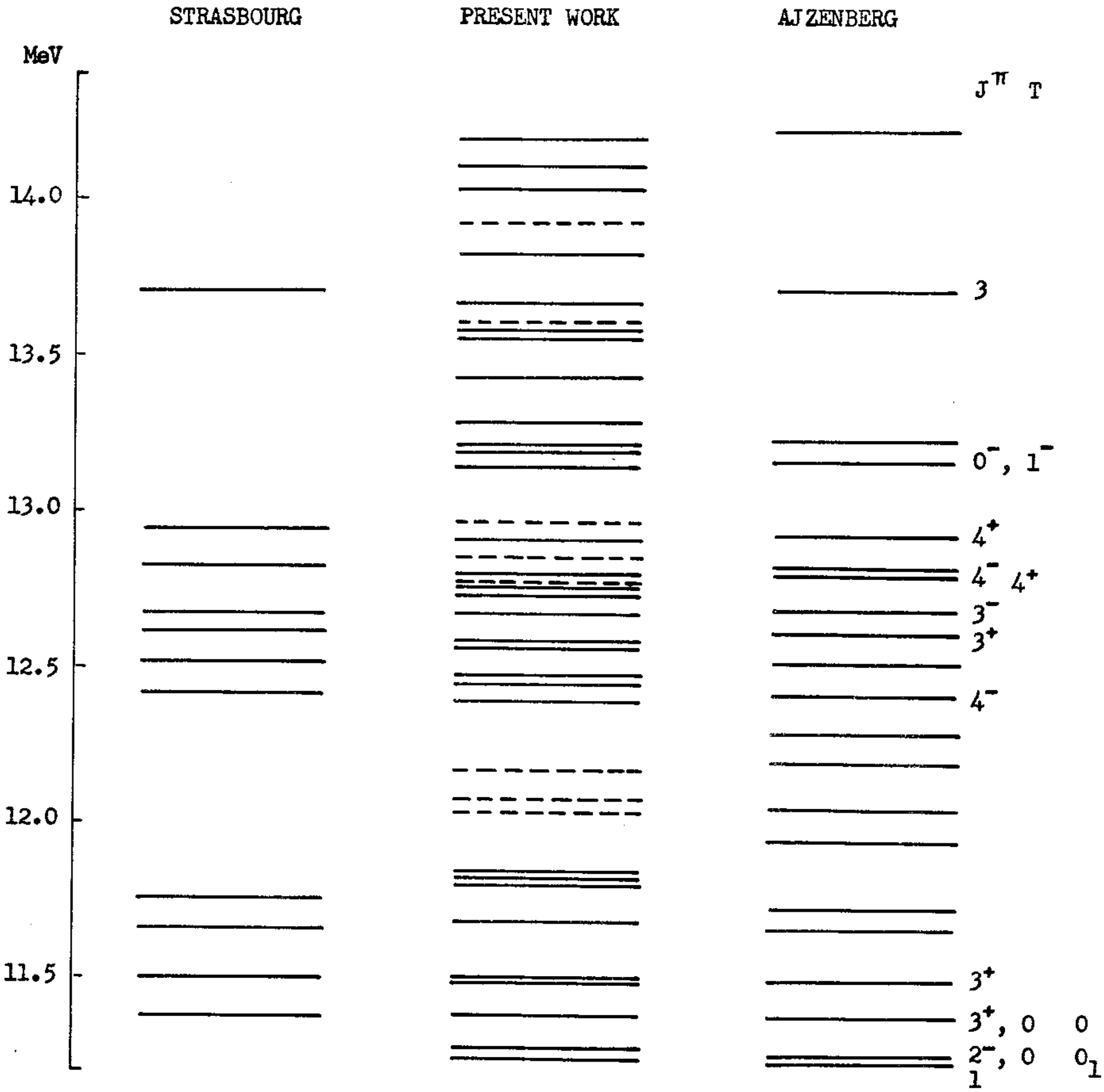


Fig. 3 - Comparison of the excited states in $N^{14}$ from all existing data with present work.