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THE $^{27}Al(p,\alpha)^{24}Mg$ REACTION STUDIED WITH A 30-MeV AVF CYCLOTRON

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Introduction

A study of nuclear excitation functions with high energy resolution reveals many fluctuations. According to the statistical theory of nuclear reactions [1] these fluctuations are related to the properties of the compound nucleus formed during the reaction. For instance, the width Γ of the fluctuations is a direct measure for the lifetime of the compound nucleus.

The statistical theory can be applied to a measured excitation function if the following conditions are satisfied:

i) The excitation energy of the compound nucleus is so high that $\Gamma >> D$, where D is the level distance of the compound nucleus. For proton excited reactions this means that $E_p > 7$ MeV.

ii) The energy resolution ΔE is less than Γ. Characteristic values of Γ are 50 keV in the mass region around A = 28 to 5 keV in the mass region around A = 50.

iii) The excitation function is measured in energy steps smaller than Γ.

Up till now this kind of experiments has been performed exclusively with tandem accelerators (with one exception [2]), which means that the proton energy is restricted to about 12 MeV. Extension of these measurements to higher energies can give valuable information, for instance about the energy dependence of Γ.

Many fluctuation experiments leading to the compound nucleus ^{28}Si have been performed, as is illustrated in figure 1 [2-4]. The explicit aim of the present experiment was to get an overlap in excitation energy with the $^{12}C(^{16}O,\alpha)^{24}Mg$ experiment [4] which means that the excitation function should be measured from 11 to about 20 MeV. The energy resolution should be 10 to 20 keV and the step size about 25 keV. It is an extension of the work of Allardyce et.al. who measured the $^{27}Al(p,\alpha)^{24}Mg$ reaction in the range E_p = 9 to 12 MeV [3].

Experimental arrangement

Figure 2 shows the experimental arrangement. The cyclotron is the 30 MeV prototype developed at the Philips Laboratories [5]. It has a pole diameter of 130 cm, protons can be accelerated from 3 to 30 MeV.

The extracted beam is focused by means of a triplet of quadrupoles on the entrance slit of a 60° analyzing magnet. This beam has an energy spread of about 50 keV FWHM. The analyzed beam has a calculated energy spread of 10 to 15 keV in the energy range 11 to 20 MeV. Under normal running conditions about 200nA analysed beam was focused by means of a doublet on the target. This is about 3% of the internal cyclotron beam. No attempts were made to maximize this number.

The magnetic field of the analyzing magnet was monitored with a calibrated Hall probe with an accuracy better than $1 : 5.10^3$.

The beam current was limited because of insufficient shielding around the exit slit and the Faraday cup in which the beam was dumped. The beam was focused to a 3 mm diameter spot in the centre of a small 25 cm diameter scattering chamber. Around this central spot there was a much larger one, presumably due to slit-scattered particles. This scattered beam had an intensity of about 5% of the beam in the central spot which was too small to effect the results of the measurements.

The α-particles were detected with 4 surface barrier counters at respectively 60°, 90°, 138° and 160° to the beam direction. Their thickness was just sufficient to stop the α-particles completely while the protons and the other reaction products lose only part of their energy.

The excitation function was measured in 25 keV steps. Such an energy change was brought about in the following way:
The magnetic field of the analyzing magnet was adjusted to its new value. Due to the energy spread of the beam this resulted sometimes already in a sufficient beam current on the target. More often however it was necessary to shift the energy of the cyclotron beam by changing the R.F.-frequency roughly proportional to the change in momentum required. The current through the main coil was than adjusted for optimum target beam current. The outer concentric coil was used as well for fine adjustment of themain magnetic field as for keeping the direction of the extracted beam constant. This whole procedure took about 1 to 2 minutes which may be compared with a measuring time of 10 to 15 minutes.

Only once every MeV it turned out to be necessary to readjust all the settings of harmonic coils, concentric coils and quadrupoles. This took about 30 to 60 minutes. Most of this time was used for realignment of the external beam.

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Results

Figure 3 shows the spectrum of α-particles detected with the 138° counter at 19.7 MeV. The α_o, α_1, α_{2+3}, α_4 and α_5 peaks can be clearly distinguished. The background is presumably due to pile-up of scattered protons.

Up till now the α_o and α_1 excitation functions have been analyzed. Figure 4 shows the α_o excitation function from 11 to 19.7 MeV at 138°. The interval from 11.3 to 12 MeV of this excitation function was used for a relative energy calibration by comparing the shape of the excitation function with the one measured with a tandem accelerator by Allardyce et.al. [3].

Especially in the energy range below about 16 MeV the fluctuations can be seen clearly. From the analysis of several excitation functions we tentatively conclude that Γ does not increase with energy over the range studied in this experiment. The measured value of 50 keV is considerably smaller than the value of 110 keV found in the $^{12}C(^{16}O,\alpha)^{24}Mg$ reaction for similar excitation energies [4]. This discrepancy is presumably due to angular momentum effects.

Conclusion

It is our experience that such an AVF cyclotron is a very suitable tool for high resolution nuclear physics experiments.

Acknowledgements

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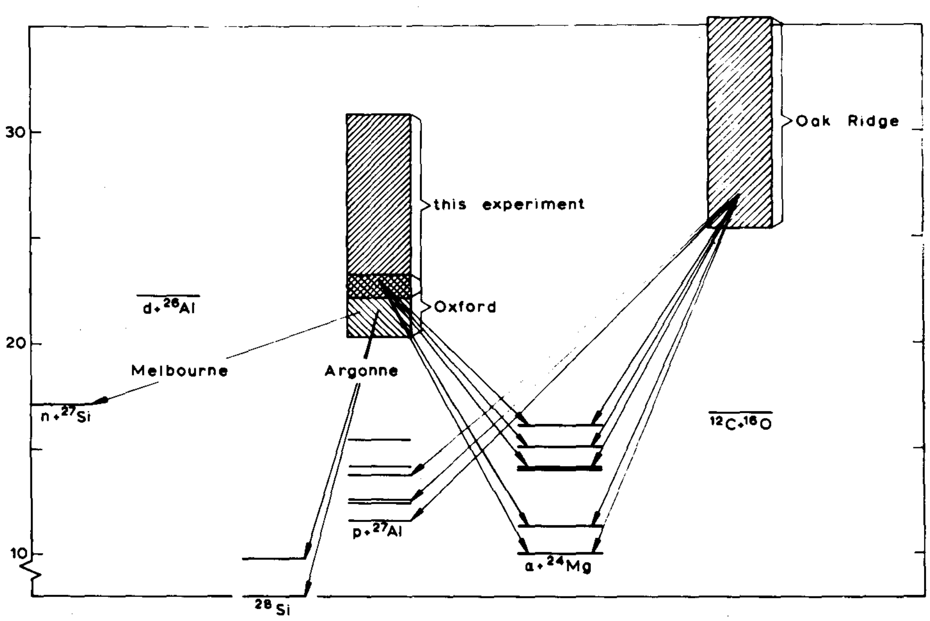

Fig. 1. Survey of fluctuation experiments with ^{28}Si as compound nucleus.

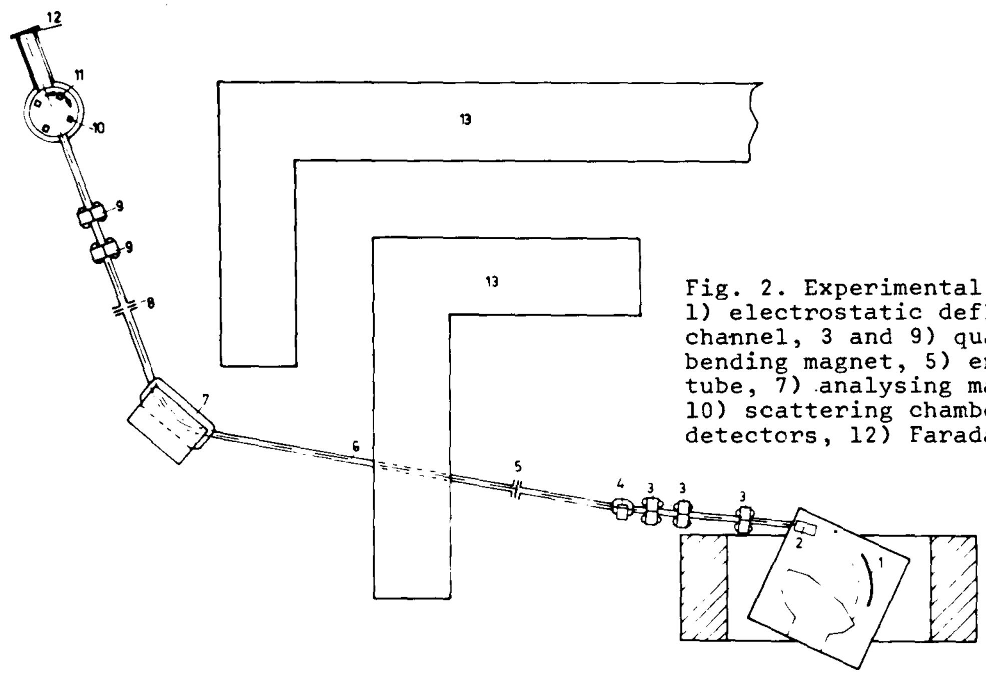

Fig. 2. Experimental arrangement: 1) electrostatic deflector, 2) magnetic channel, 3 and 9) quadrupole magnets, 4) bending magnet, 5) entrance slit, 6) beam tube, 7) analysing magnet, 8) exit slit, 10) scattering chamber, 11) solid state detectors, 12) Faraday cup

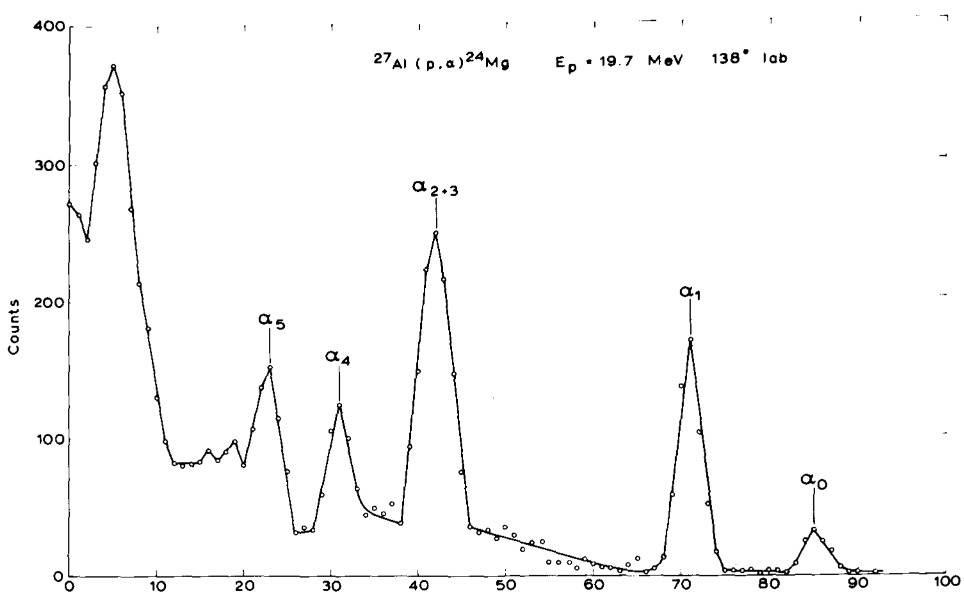

Fig. 3. Spectrum of α-particles detected at 138° to the beam direction. The energy of the incident protons in 19.7 MeV. The background is presumably due to pile up of scattered protons.

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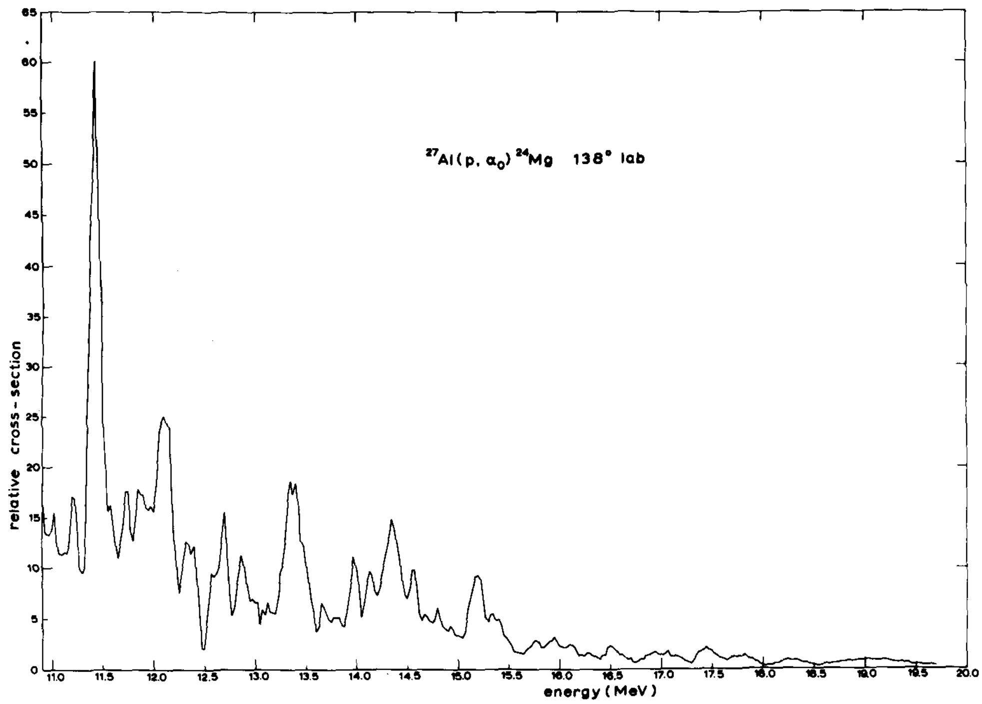

Fig. 4. The α_0 excitation curve measured at 138° to the beam direction from 11 to 19.7 MeV.

DISCUSSION

POLLOCK: How long did it take to change energy between steps?

HAGEDOORN: We made 25-kV steps in about 10 seconds, if we were lucky, one minute if a bit unlucky. It took less time to vary the energy than to read out the data from the 400-channel analyzer.