Neutron pickup at high energies

from P. E. Hodgson

THERE have been many studies of nucleon transfer reactions at low energies (5 to 50 MeV) and these have given much information on the single particle states of nuclei (see for example, *Nature*, **254**, 18; 1975; **256**, 615; 1975). Very few analyses have been made at higher energies, partly because it is then difficult to resolve the final states and partly because it is thought unlikely that such studies could give any information that could not be obtained from the technically much easier studies at lower energies.

In 1974 a group working at the Saturne synchrotron (*Phys. Lett.*, **52B**, 57) published the results of their measurements of the ^{12}C(p,d)^{11}C neutron pickup reaction at 700 MeV. These data were remarkable because the energy resolution was sufficient to resolve several states of ^{11}C, and thus provided the only stripping or pickup data available above 200 MeV.

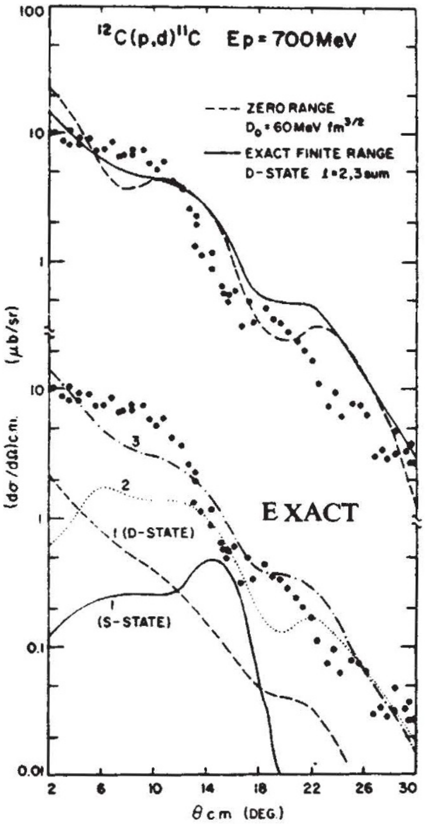
The group made a preliminary analysis of their data using the distorted wave formalism, with the zero-range approximation for the neutron–proton force. At high energies, however, the momentum transfers are large, and this invalidates the approximation. They also ignored the D-state component of the deuteron wave function, although this is expected to contribute strongly at high energies. In spite of this, they found that the overall shape of the differential cross section is given quite well by their calculation, as shown in the figure, but the absolute magnitude is wrong by a factor of two.

In the past few years computer programs using a finite range neutron–proton force have been developed, mainly to analyse heavy ion reactions. Rost and Shepard (*Phys. Lett.*, **59B**, 413; 1975) have now used one of these programs to analyse the ^{12}C(p,d)^{11}C data, and have also included the effect of the D-state of the deuteron.

As shown in the figure, they found that the theory then gives a cross-section in good agreement with the experimental data, both in absolute magnitude and in overall shape. As expected the contribution of the D-state is dominant, so the previous agreement in shape must be largely fortuitous. It is thus very important for reactions of deuterons at high energies to use an accurate deuteron wavefunction, and the results can themselves provide information about that wavefunction.

This conclusion is reinforced by studies of the contribution of the S-state component of the deuteron wavefunction. Rost and Shepard used an S-state waveform calculated from the Reid soft-core potential, that has been obtained by fitting a large body of nucleon–nucleon and deuteron data. Calculations with the Hulthèn wavefunction, a simple analytical function widely used at low energies, gave cross sections completely in disagreement with the experimental data.

This work shows the value of repeating familiar analyses at substantially higher energies, whenever it is practicable to do so.



Differential cross section for the ^{12}C(p,d)^{11}C reaction at 700 MeV compared in the top section with zero-range and exact finite-range distorted wave calculations. The zero-range curve has been arbitrarily divided by two to fit the data. The lower section shows the individual cross sections for the S-state L=1 and the D-state L=1,2,3 contributions.

decaying Molniya satellite, entirely on the basis of visual observations from Britain. Brookes presented the results of his first orbit determination, of Cosmos 373 (1970–87A) at 25 epochs between 1971 and 1975: this orbit, at inclination 62.9°, is closer to the critical inclination of 63.4° than any other orbit that has been accurately analysed, and he has determined the oscillation in perigee height caused by odd zonal harmonics in the geopotential as 59 km —the largest value yet established. D. G. King-Hele (Royal Aircraft Establishment, Farnborough) described new results obtained by himself and D. M. C. Walker in determining the atmospheric rotation rate from orbital analysis; the variations with height and local time have now been separated, and three curves of the variation of rotation rate with height were shown, for average local time, for evening (18–24 h) and morning (4–12 h).

The afternoon session began with an excellent presentation by J. Eady (Ordnance Survey) of the work of the Hewitt Camera at Malvern, owned and operated by the Ordnance Survey. He commended the beautiful design of this accurate camera, a great tribute to the skill of the late Mr Hewitt, and looked forward to its increased use with a second observing team. The session continued with a succession of short contributions on topics connected with satellite observing. D. A. Richards (University College of Wales, Aberystwyth), offered some thoughtful comments on the slower time response of the eye in poor light, and demonstrated how the eyes see the linear swing of a pendulum as an ellipse if the light to one eye is reduced by a filter. The other contributions, to flash through them even more rapidly than they were presented included a kaleidoscope of satellite shapes (J. A. Pilkington); an experimental demonstration of flash behaviour with satellite models (M. D. Waterman); recent work on radio tracking of satellites at Kettering and associated stations (G. E. Perry); the telemetry of Soviet navigation satellites (C. D. Wood); a possible explanation of the break-up of the Pageos balloon and several other US satellites (R. D. Eberst); the US Navy satellite tracking network (D. G. King-Hele); an analysis of a lengthy questionnaire on observing previously completed by the participants (M. D. Waterman); and a film of the Apollo–Soyuz Mission.

Apart from the formal presentations the meeting was intended to allow the visual observers to meet the new university researchers; to introduce the latter to some of the problems of observing; and to allow the volunteer visual observers to meet each other, to renew their enthusiasm, and to see how their unpaid work was utilised by the scientists. The subsequent comments of the participants suggested that these aims were fully achieved. □