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Artikel: Polarisation of 9 MeV protons elastically scattered by C, Mg and Al

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Polarisation of 9 MeV Protons Elastically Scattered by C, Mg and Al

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The polarisation measurements were made using a double scattering technique in which 9.6 MeV protons from the Birmingham 60″ cyclotron were scattered first by the target and then by helium. Using the known polarisation properties of helium [1] [1]), a measurement of the asymmetry after double scattering gives the polarisation of the protons elastically scattered by the target.

The general arrangement is shown in figure 1. The overall angular definition for scattering by the first target was $\pm 3°$; the target was set to give optimum resolution at each angle of scattering and adjusted so as to present a 1 MeV thickness to the incident beam. The polarisation of protons scattered from helium shows two peaks in this energy region, one of negative sign at about 70° and one of positive sign at about 120°. Photographic plates were used to record the doubly scattered protons and it was arranged that scattering at both 70° and 120°, from helium, was recorded simultaneously. Since the sign of the polarisation differs for the two peaks, they should produce opposite asymmetries. This was a valuable check on the geometrical alignment of the apparatus. A diagram of the helium chamber is shown in figure 2. The direction of the beam through the helium was recorded on a photographic plate at the

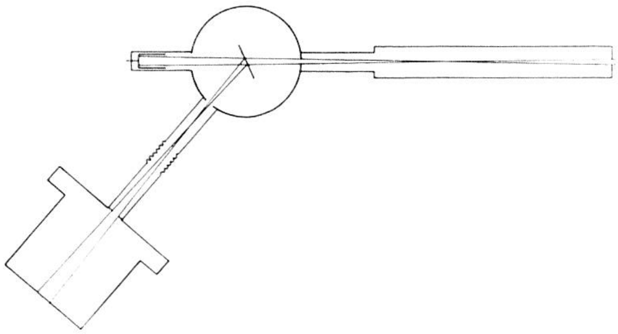


Figure 1

[1]) Numbers in brackets refer to References, page 331.

end of the chamber and background plates were placed adjacent to the recording plates (Ilford El).

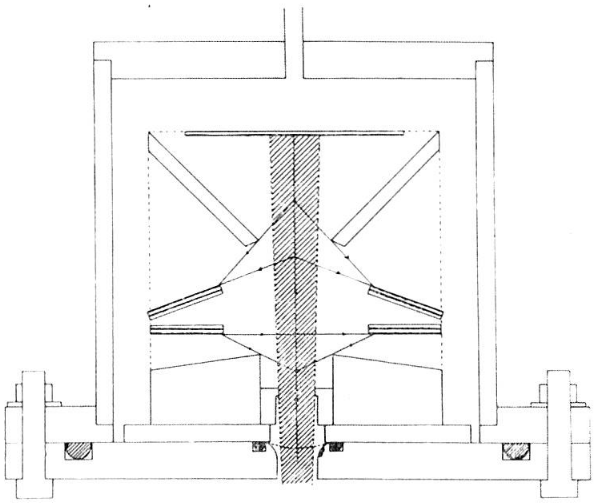


Figure 2

Large solid angles of acceptance were used for the helium scattering corresponding to a range of scattering angles. The distribution of scattering angles corresponding to those tracks used in the asymmetry measurement could be determined from the track orientation and hence, knowing the variation of polarisation with angle of scatter in helium, a mean value for the polarisation of the second scattering could be obtained. Range criteria were used to select the elastically scattered particles. Figure 3 shows the projected range distribution for doubly scattered protons, using Mg and a scattering angle of 60° for the first target. The

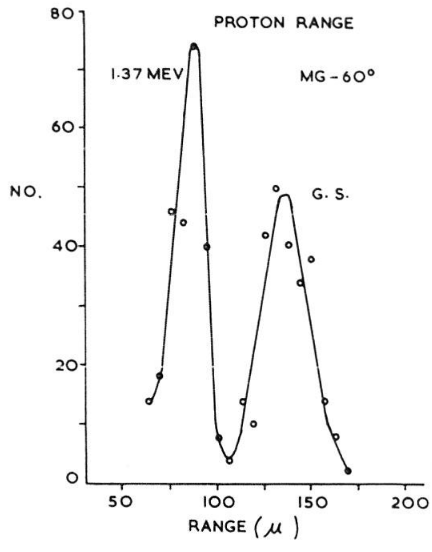


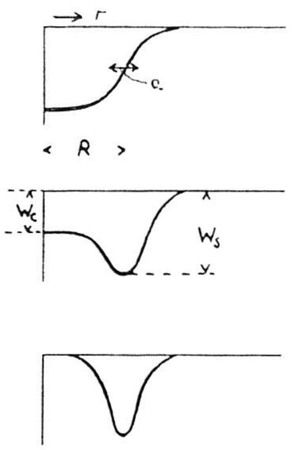
Figure 3

two groups of figure 3 correspond to elastic scattering and to inelastic scattering from the first level at 1.37 MeV excitation. These are clearly resolved and hence the measurements give polarisation for pure elastic scattering without contamination from inelastic groups.

Results

In all three cases studied, C, Mg and Al, elastic scattering angular distributions were also obtained using the same target thickness and an attempt has been made to fit the data with an optical model analysis. The optical model programme was made available by Mr. B. Easlea of University College, and used on the University of London Mercury Computer. The potential used in the calculations is shown in figure 4 and has a Saxon-Woods form factor, a real spin orbit term of surface form with both surface and volume imaginary potentials. The imaginary potential is specified by the magnitudes at $r = 0$ and $r = R$, W_c and W_s respectively.

$$V(r) = V_{coul.} + Vf(r) + iWg(r) + \sigma . L V_s h(r)$$



$$f(r) = \frac{1}{1 + \exp\left(\frac{r-R}{a}\right)}$$

$$R = r_0 A^{\frac{1}{3}}$$

$$g(r) = b f(r) + c f'(r)$$

$$h(r) = \frac{1}{r}\left|f'(r)\right|$$

Figure 4

The sign convention used for the polarisation is that $\boldsymbol{K}_{\text{in}} \wedge \boldsymbol{K}_{\text{out}}$ is positive.

Carbon

The results for carbon are shown in figure 5. At three angles two points are shown for the polarisation. In each case one of these was taken using forward scattering from helium with a negative polarisation and the other using backward scattering with a positive polarisation. The agreement of these pairs of points indicates the absence of geometrical asymmetries.

The optical model predictions shown in figure 5 (full line) are typical of the results obtained from a number of runs. In all cases the model predicted a negative peak in the polarisation around 60° which was not present experimentally and the cross sections predicted were too low to fit the experimental data.

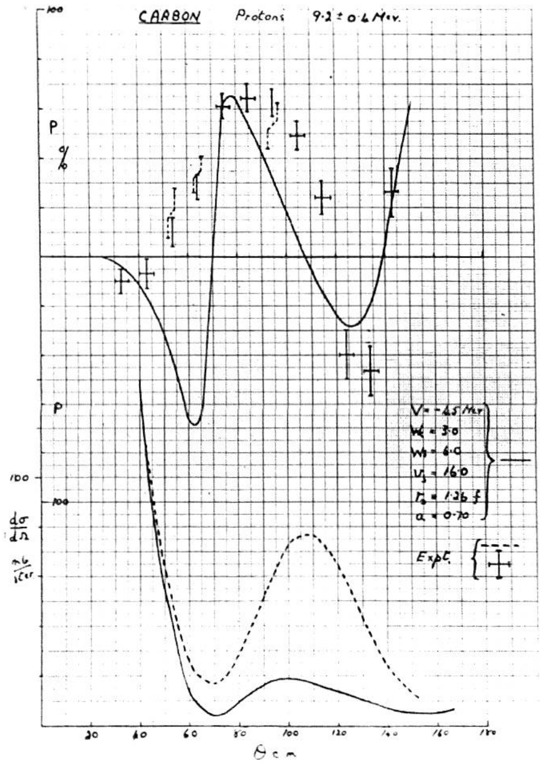


Figure 5

HIRD [2] hasobserved variations of the polarisation with energy around 9 MeV in the scattering from carbon at 40°. Nevertheless, the shape of HIRD's polarisation angular distribution at 8.2 MeV and ROSEN's [3] at 10 MeV is very similar to the present results. Variations with energy have also been observed in the elastic scattering cross sections for carbon at backward angles [4] which have been attributed to compound nucleus effects but the magnitude of the effects is insufficient to explain the present discrepancy between the model and experiment. One can only conclude that the model as used here is unsatisfactory for carbon in the 10 MeV region.

Magnesium

The elastic scattering cross section angular distribution from magnesium varies markedly with energy around 9 MeV [5]. This is shown in figure 6 where angular distributions are given at five energies between

7.86 and 9.55 MeV. In the present measurements a target thickness of 1 MeV was used so that an experimental average was taken in the energy range 8.6–9.6 MeV. Work by MATSUDA *et al.* [6] has shown that the pattern of the 9.55 MeV curve of figure 6 persists at higher energies and EASLEA [7] has been able to fit the 9.55 MeV data and the higher energy data with the present optical model programme. The fit at 9.55 MeV is shown in figure 7. The departure at backward angles can reasonably be explained in terms of a compound elastic contribution.

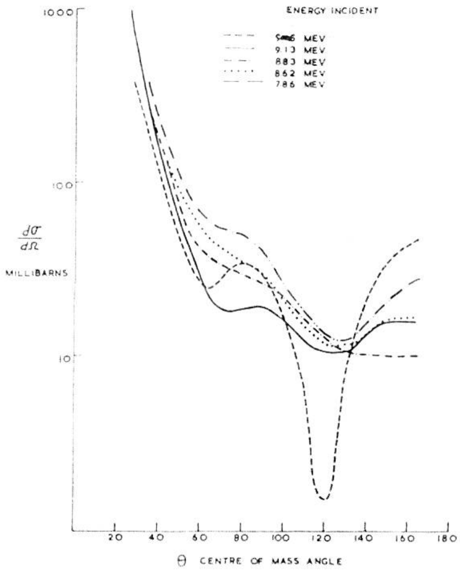


Figure 6

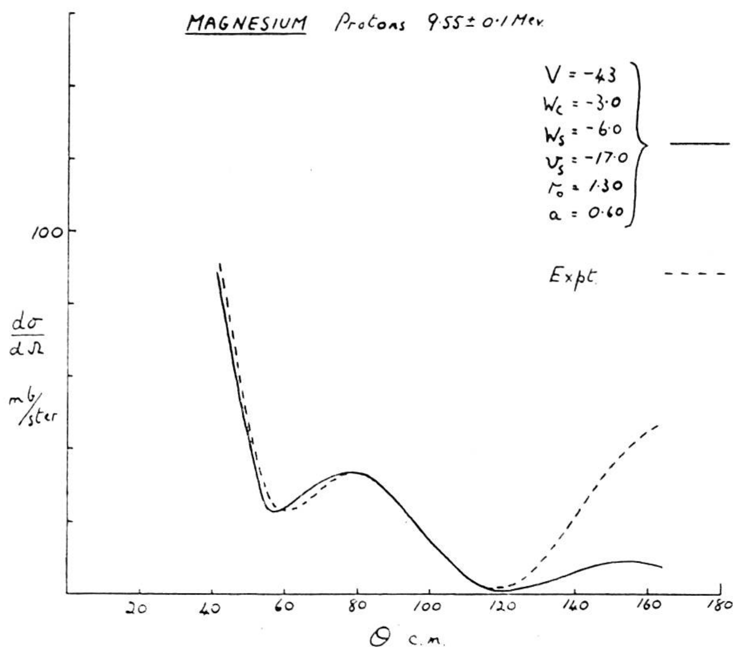


Figure 7

Since the optical model predictions vary slowly with energy, one would not expect a fit to the lower energy data of figure 6 or to the elastic scattering cross sections at 9.1 MeV with a 1 MeV thick target. This is in fact found and must be attributed to some additional process occurring which is not included in the model. The present polarisation and cross section data together with the optical model fits are shown in figure 8. Although, as anticipated, one is not getting a fit to the elastic scattering, the polarisation is reasonably well represented by the model. This polarisation data is very similar in shape to that obtained by ROSEN [3] at 10 MeV; thus in going from 10 MeV to 9.1 MeV the measured polarisation changes little, whereas the cross section angular distribution shows a marked change. One can fit the cross section and the polarisation data at 10 MeV with an optical model but at 9.1 MeV one only fits the polarisation data. This is a surprising result, since, whether the additional elastic scattering process occuring in Mg at about 9 MeV, is polarised or not, one would expect the observed polarisation to change due to its presence.

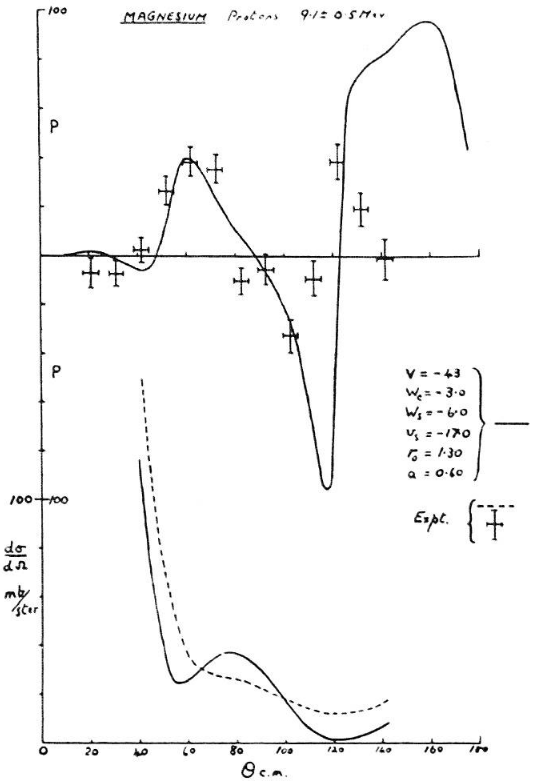


Figure 8

Aluminium

The elastic scattering cross section angular distributions from Al are known to vary smoothly and slowly with energy in the range 7.8–9.6 MeV [8]. It is reasonable therefore to expect a fit to the data with an optical model analysis. The cross section and polarisation data obtained in the present experiments are shown in figure 9. Apart from one point (51°) which may be in error experimentally, the polarisation data is well represented by the model and a reasonable representation is made of the cross section data. The departure at backward angles might reasonably be attributed to a compound elastic contribution since such effects are known to occur in this energy region [9].

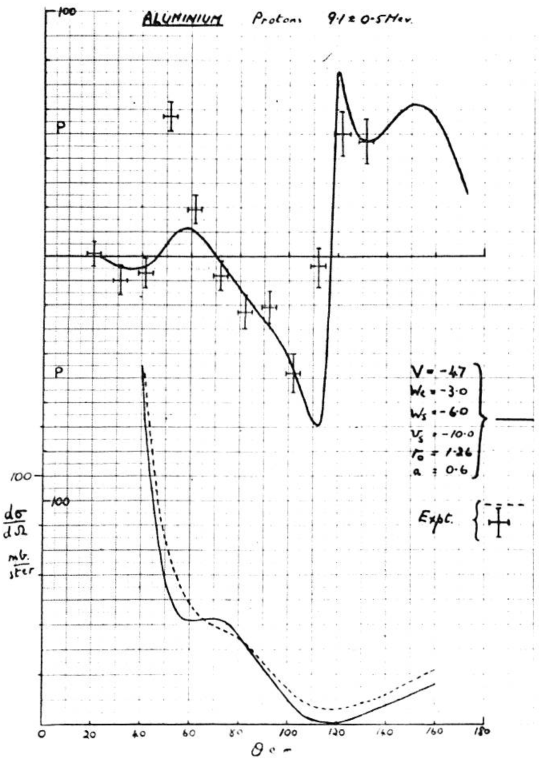


Figure 9

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