Polarization of Protons in $C^{12}(d,p)C^{13}$†

R. G. ALLAS AND F. B. SHULL
Washington University, Saint Louis, Missouri

(Received September 22, 1961)

The measurement of polarization of protons from the $C^{12}(d,p)C^{13}$ ground-state reaction has been continued and extended to larger angles. The new values obtained are -42% at 42.5° (lab); -35.4% at 46°; -51.5% at 52°; -22.5% at 61.5°; -20% at 64.5°; -6% at 70°; $+35\%$ at 76°. The axis of quantization is taken as $\mathbf{n}=\mathbf{k}_d\times\mathbf{k}_p$.

AN argument due to Newns and Refai[1] leads one to expect that the polarization of protons from stripping reactions should change sign at the same angle as the (theoretical) stripping amplitude changes sign. An experiment measuring the polarization of protons from the $C^{12}(d,p)C^{13}$ ground-state reaction was carried out at this laboratory[2] for angles $\theta=15°$ (lab) to $\theta=60°$ (lab). The incident deuteron energy was $E_d=10$ Mev. The measurements were limited to 60° or less by the geometrical arrangement of the cyclotron research area. From the argument of Newns and Refai a change of sign of the proton polarization should be expected at around 60° (lab); however, the experiment failed to exhibit any such change of sign.

A change of sign of polarization with angle for the carbon reaction, was found, however, by Bokhari *et al.*,[3] for 8.9-Mev incident deuterons. A similar change of sign also has been found in the $Be^9(d,p)Be^{10}$ case.[4]

Since a later rearrangement of the cyclotron research area permitted the experiment to be carried to larger angles, it was thought worth while to investigate the carbon reaction to angles well past the stripping minimum and to see if a change of sign of polarization could be observed. The procedure used was essentially the same as in the previous experiment,[2] except that Ilford E-2 (100 μ) plates were found to be less sensitive to the general γ background, and thus were substituted for the previously used Ilford C-2 (100 μ) nuclear plates. An improved alignment technique used x-ray film to record the main proton beam and thus to test for proper centering in the polarimeter (see Fig. 2 of reference 2).

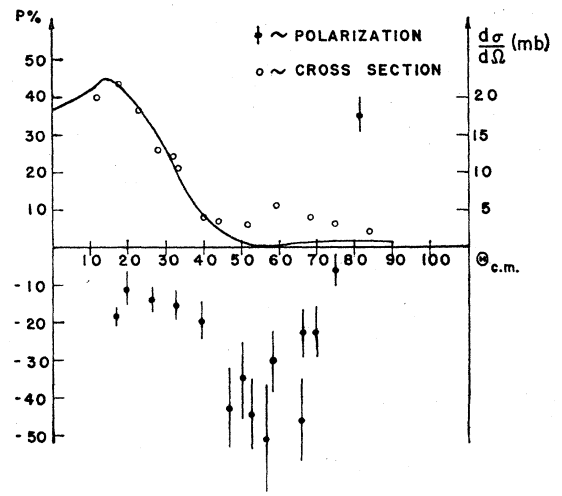

FIG. 1. Proton polarization in $C^{12}(d,p)C^{13}$. Incident deuteron energy $E_d=10$ Mev. The stripping cross section for $E_d=10.2$ Mev is taken from E. W. Hamburger, Phys. Rev. **123**, 619 (1961).

TABLE I. Present polarization measurements. Axis of quantization $\mathbf{n}=\mathbf{k}_d\times\mathbf{k}_p$. $E_d=10$ Mev.

θ (lab)	θ (c.m.)	L	R	P_1 (%)
42.5°	46.7°	112	62	−42.4±11.0
46.0°	50.1°	106	65	−35.4±10.5
52.0°	56.5°	120	68	−51.5±14.9
61.5°	66.3°	288	214	−22.5± 6.5
64.5°	69.9°	283	216	−20.0± 6.7
70.0°	75.0°	557	513	− 6.0± 4.7
76.0°	81.2°	355	580	+35.0± 4.7

Table I gives the polarization values and for convenience we include in Fig. 1 all of our measured polarizations to date at an incident deuteron energy $E_d=10$ Mev. For our previous results as well as a summary and references to other known polarization measurements for the carbon reaction we refer the reader to reference 2.

Note that the axis of quantization is defined as $\mathbf{n}=\mathbf{k}_d\times\mathbf{k}_p$ in accordance with the Basel convention. This convention is opposite to the one adopted in reference 2, and should be kept in mind when comparing results.

The new results substantiate the previously measured values in the region of overlap. There is, however, a sharp drop and a change of sign of polarization at considerably larger angles than the first minimum. This indicates that polarization is not primarily due to interference between the main undistorted direct amplitude and the smaller distorted waves as assumed by Newns and Refai, but that cross-terms between the distorted waves are at least of the same order of importance as cross-terms between the distorted and undistorted waves. The maximum as well as the angle of change of sign for polarization seem to have shifted to somewhat larger angles as compared with Bokhari's 8.9-Mev data.

Note added in proof: For completeness we include reference to a recent measurement reported by W. P. Johnson and D. W. Miller, Phys. Rev. **124**, 1190 (1961), who found a polarization of $32\pm5\%$ at angle 13.3° (c.m.) and $E_d=10.8$ Mev.

† This research was supported in part by the Air Force Office of Scientific Research Air Research and Development Command.

[1] H. C. Newns and M. Y. Refai, Proc. Phys. Soc. (London) **71**, 627 (1958).
[2] R. G. Allas and F. B. Shull, Phys. Rev. **116**, 996 (1959).
[3] M. S. Bokhari, J. A. Cookson, B. Hird, and B. Weesakul, Proc. Phys. Soc. (London) **72**, 88 (1958).
[4] R. G. Allas and F. B. Shull, Bull. Am. Phys. Soc. **6**, 24 (1961).