REACTION $He^3(d,p)He^4$ WITH A POLARIZED TARGET*

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Careful measurements of the angular distribution of differential cross section[1] and proton polarization[2] in the reaction $He^3(d,p)He^4$ for deuteron energies above a few MeV have been made, but so far these data have not been accurately described by existing stripping theories[3]. This Letter reports new data on the reaction $He^3(d,p)He^4$ in which a polarized He^3 target was used. These preliminary results indicate that such measurements provide significant information concerning direct-interaction mechanisms since it has been shown that the assumptions of conventional stripping theories preclude[4] the simultaneous fitting of our data and the proton-polarization data.[2]

Figure 1 shows the geometry of our measurement. The He^3 target polarization is perpendicular to the reaction plane. Proton emission to the left (or right) is said to occur when $\vec{k}_d \times \vec{k}_p$ is parallel (or antiparallel) to the He^3 target polarization. The quantity which contains the physical information obtained in this experiment is

$$A_{LR}(\theta) = q^{-1}[\sigma_L(\theta) - \sigma_R(\theta)]/[\sigma_L(\theta) + \sigma_R(\theta)], \quad (1)$$

where $\sigma_L(\theta)$ and $\sigma_R(\theta)$ are the differential cross sections for the production of protons at the angle θ to the left and right, respectively, and q is the target polarization. $A_{LR}(\theta)$ is simply the left-right counting asymmetry that will be observed in an experiment with a target of 100% polarization ($q = 1$).

The target polarization (typically ≈15%) is produced by optical pumping[5] in a thin-walled

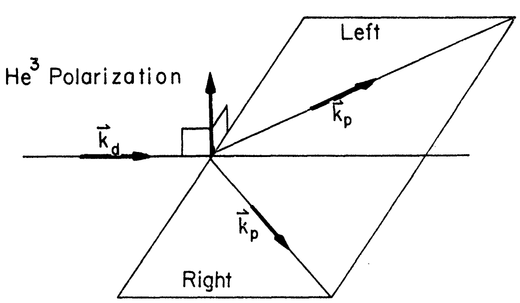

FIG. 1. Geometry of reaction, showing the direction of the incoming deuteron beam, the orientation of the He^3 polarization, and our convention for emission of protons to the right and left in the reaction plane.

(≈0.020-in.) Pyrex bulb filled to approximately 3-mm-Hg pressure and equipped with 0.000 35-in.-thick aluminum end windows to allow the deuteron beam to enter and exit. The energetic ($Q = +18.35$ MeV) protons from the reaction pass through the glass walls and are detected in symmetrically placed counter telescopes which can be set anywhere in the interval 30° to 150° with respect to the beam direction.

The target polarization is determined from measurements of the optical-absorption characteristics of the optically pumped He^3 gas. These characteristics are related to the polarization by an expression derived by Colegrove, Walters, and Schearer.[5] However, parameters in their Eq. (9) depend on the relative illumination by the He^4 pumping light of the various He^3 spectral lines involved in the optical pumping process. The nature of the pumping light is known only accurately enough to establish well-defined limits on the target polarization, the ratio of maximum to minimum polarization being 1.35. These limiting cases are discussed by Colegrove, Walters, and Schearer,[5] and Greenhow,[6] respectively.

In determining $A_{LR}(\theta)$ the maximum value of target polarization was always assumed. Thus, it is possible that the values of $A_{LR}(\theta)$ reported here should be multiplied by a factor as large as 1.35.

The measured values of $A_{LR}(\theta)$ are displayed in Fig. 2. In the data taken at 6- and 10-MeV deuteron energy, the errors are primarily due to counting statistics; the uncertainty in the 8-MeV data, taken prior to improvements in our optical measurements, is largely due to estimated experimental uncertainty in determining the target polarization. The effect of finite angular resolution was estimated to be negligible with respect to corrections to the scattering angle (<1°) and to the magnitude of $A_{LR}(\theta)$ (<1%).

Also plotted in Fig. 2 are smooth curves representing the measurements by Brown and Haeberli of the polarization, $P(\theta)$, of the protons in the reaction $He^3(d,p)He^4$ with unpolarized beam and target.[2] Two features of the data are apparent: (1) The magnitude of $A_{LR}(\theta)$ and $P(\theta)$ are very nearly equal when they are

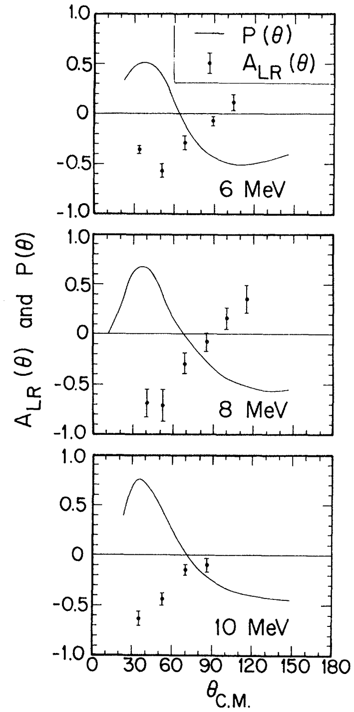

FIG. 2. The measured values of $A_{LR}(\theta)$ plotted versus center-of-mass angle. Error flags indicate precision of the measurements and do not include a possible systematic correction described in the text. The solid curves represent $P(\theta)$, measured by Brown and Haeberli (reference 2).

both large and one has the approximate result $A_{LR}(\theta) \approx -P(\theta)$. (2) $A_{LR}(\theta)$ crosses through zero at a distinctly different angle than $P(\theta)$ does.

Several conclusions can be drawn: (1) It is clear that the expression $A_{LR}(\theta) = -\frac{1}{3}P(\theta)$ obtained by Tanifuji in the previous Letter (case I)[4] is not satisfied. This expression is shown to be quite generally true on the basis of conventional direct-interaction theories in which one neglects consideration of (a) the D-state admixture in the deuteron, (b) simultaneous spin-flip of the proton and the target nucleus, (c) knock-out processes, and (d) recoil effects. (2) Tanifuji's cases II, III, or IV describe the data qualititatively in that they predict $A_{LR}(\theta) = -P(\theta)$. This may be reasonably interpreted as requiring a tensor interaction that will produce simultaneous spin-flips of both the proton and the He^3. (3) However, $A_{LR}(\theta)$ and $P(\theta)$ have zeros at different angles, and in those angular regions where either is near zero the approximate relation $A_{LR}(\theta) \approx -P(\theta)$ is not valid. This indicates that none of the cases examined by Tanifuji are adequate to describe the data quantitatively. (4) It appears that interactions more complex than are ordinarily used should be incorporated into the theory of deuteron stripping as applied to the reaction $He^3(d,p)He^4$ and that conventional calculations of polarization in other stripping reactions should be re-examined.

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