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ON THE ANGULAR DISTRIBUTION AND THE POLARIZATION OF THE DEUTERON IN THE REACTION P t P-\*D t it1""

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ON THE ANGULAR DISTRIBUTION AND THE POLARIZATION OF THE DEUTERON IN THE REACTION  $P + P \rightarrow D + \pi^+$ 

> K. M. Watson and C. Richman July 12, 1951

> > Berkeley, California

- 15 A.M.

ON THE ANGULAR DISTRIBUTION AND THE POLARIZATION OF THE DEUTERON IN THE REACTION  $P + P \rightarrow D + \pi^+$ 

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#### K. M. Watson and C. Richman

#### Radiation Laboratory, University of California Berkeley, California

#### July 12, 1951

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Cross sections at several angles for the reaction  $P + P \longrightarrow \pi^{+} P$  have been measured<sup>1,2,3</sup>. For energies not too far above threshold (i.e., for those at which the cross sections have been measured) and in the center-of-mass frame of reference there is reason to believe<sup>4,5</sup> that only orbital S- and P-states of the meson with respect to the deuteron contribute appreciably to the cross section.

There will be no S- and P-wave interference in the differential cross section, so for the moment we can restrict our considerations to just the contribution from meson P-waves. Combining the intrinsic angular momentum of the deuteron with the P-wave orbital motion, we obtain a total angular momentum j = 0, 2 (j = 1 is forbidden by parity considerations if the meson is assumed to be pseudoscalar, in accord with present evidence). These values of j arise from the  $\begin{bmatrix} 1 & 1 \\ 0 & 2 \end{bmatrix}$  states, respectively, of the initial p-p system.

The wave functions for the orbital motion of the meson will then be described by the spherical harmonics  $\gamma_{1}^{\mu}(\theta, \phi)$ 

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(1)

(with the polar axis defined by the proton beam direction) and those of the internal coordinates of the deuteron by  $\sum_{1}^{A} (\mu=1, 0, -1)$ . Then the linear combinations of these,  $Q_0$  and  $Q_2^0$ , which transform as a scalar and as the spherical harmonic  $\sum_{2}^{0}$  will arise from the  $\sum_{1}^{1} (\mu=1, 0, -1)$ .

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The asymptotic form of the outgoing wave will be proportional

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$$\begin{bmatrix} \mathbf{q} & \mathbf{r} \\ \mathbf{q} & \mathbf{r} \end{bmatrix} \begin{bmatrix} \mathbf{q} & \mathbf{\gamma} & \mathbf{q}^0 \\ \mathbf{q} & \mathbf{\gamma} & \mathbf{q}^0 \end{bmatrix}$$

where q is the meson momentum and  $\eta$  is a parameter. Writing  $\eta = \epsilon^{i\sigma}$ , the resulting angular distribution of the mesons will be

$$F(\theta) = 1 + \frac{\varepsilon^2}{2} + \sqrt{2} \varepsilon \cos \sigma + 3 \cos^2 \theta (\frac{\varepsilon^2}{2} - \sqrt{2} \varepsilon \cos \sigma)$$
(2)

Including an arbitrary amount of contribution to the cross section from mesons in S-states, we arrive at the following generalization of the cross section given previously<sup>4</sup>:

$$d\sigma = \sigma_0 \frac{d\Lambda}{4\pi} \left[ 1 + a \frac{q^2}{\mu^2 c^2} F(\theta) \right] , \qquad (3)$$

where  $F(\theta)$  is given by Eq. (2) and  $\mu$  is the mass of the meson.

Near threshold it is assumed that a is a constant and that  $\sigma_0$  is just q (from the phase space factor) times a constant.

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Integrating, we obtain the total cross section

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$$\sigma = \sigma_0 \left[ 1 + a(1 + \epsilon^2) \frac{q^2}{\mu^2 c^2} \right] , \qquad (4)$$

which is of the specific form given previously<sup>4</sup>, with  $a(1 + \epsilon^2) \equiv b$ . We see that  $\epsilon^2$  represents the relative amounts of  ${}^{1}S_{0}$  and  ${}^{1}D_{2}$  contribution of the initial p-p system to the P-wave partial cross section.

The approximate value, b = 8, was deduced earlier<sup>4</sup>. This value is consistent with the observed angular distribution<sup>3</sup>, which however implies that b cannot be much less than 8. From the experimental cross sections<sup>3</sup>, it would then follow that at 340 Mev  $\mathbf{\sigma}_{0} \simeq 5(10)^{-29} \text{ cm}^{2}$ . The observed angular distributions are consistent with a pure cos<sup>6</sup>  $\theta$ , dependence from the meson P-states, which would imply cos  $\mathbf{\sigma}_{-} = -1$ ,  $\boldsymbol{\varepsilon}_{-}^{2} = 2$  (the quoted experimental errors imply that these relations are also quite approximate). Of more positive significance is the conclusion from the observed angular asymmetry that the large contribution from the  ${}^{1}D_{2}$  state of the initial protons implies, independently of a specific model, that non-central interactions are involved (since the deuteron is mostly in an S-state).

Eq. (1) suggests that the deuterons observed at an angle  $(\textcircled{\bullet}, \oiint)$  may be polarized. Indeed, the direction of the polarization is given by the average values of the components of

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intrinsic angular momentum of the deuteron, which are  $J_x = -R \sin \phi$ ,  $J_y = R \cos \phi$ ,  $J_z = 0$  (i.e., at right angles to the plane defined by the direction of the protons and the deuterons).

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The degree of polarization (considering just the P-wave component of the cross section), R' (0 4 R' 4 1), is given by the numerical magnitude of

$$R = 3\sqrt{2} \mathcal{E} \sin \sigma \cos \Theta \sin \Theta \left[ F(\Theta) \right]^{-1},$$
(5)

where F is given by Eq. (2). R vanishes for a pure  $\cos^2 \theta$  angular distribution.

The detection of this polarization, if non-vanishing, would appear feasible. The beam of deuterons produced is more intense than the accompanying meson beam<sup>8</sup>, which has been used to study meson scattering<sup>9</sup>. A possible means of detection would be by means of (d, p) scattering, the polarization effects of which have been used by Wouters<sup>10</sup> to measure polarization in (n, p) scattering.

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