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S-WAVE PIONS IN THE REACTION  $p + p \rightarrow \pi^+ + d$

Frank S. Crawford, Jr., and M. Lynn Stevenson

May 2, 1957

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In their phenomenological analysis of the reaction



Gell-Mann and Watson<sup>1</sup> use for the c. m. differential cross section the expression

$$4\pi \frac{d\sigma}{d\Omega} = a\eta + \beta\eta^3 \frac{X + \cos^2\theta}{X + 1/3}, \quad (2)$$

where  $\eta$  is the pion c. m. momentum in units  $m_\pi c$ , and  $a$ ,  $\beta$ , and  $X$  are constants. The first term,  $a\eta$ , is supposed to arise from S-wave pions, and the second from P-wave pions.

Integration of Eq. (2) yields the total cross section

$$\sigma = a\eta + \beta\eta^3. \quad (3)$$

Lichtenberg has recently made a theoretical calculation<sup>2</sup> of the differential cross section for Reaction (1) at energies near threshold. As a result he concludes that Expressions (2) and (3) are not appropriate for a phenomenological analysis, and that more suitable expressions are

$$4\pi \frac{d\sigma}{d\Omega} = \left(\frac{p_0}{p}\right)^3 \left[ a'\eta + \beta'\eta^3 \frac{X' + \cos^2\theta}{X' + 1/3} \right], \quad (2)'$$

$$\sigma = \left(\frac{p_0}{p}\right)^3 \left[ a'\eta + \beta'\eta^3 \right]. \quad (3)'$$

<sup>1</sup>This work was done under the auspices of the U. S. Atomic Energy Commission.

<sup>2</sup>M. Gell-Mann and K. M. Watson, Ann. Rev. Nuclear Sci. 4, 219 (1954).

<sup>3</sup>D. B. Lichtenberg, Phys. Rev. 105, 1064 (1957).

where  $p$  is the relative incident proton momentum in the cm system,  $p_0$  is the value of  $p$  at threshold, and  $\alpha'$ ,  $\beta'$ , and  $\chi'$  are new constants.

Lichtenberg points out that the  $p^3$  dependence in Eq. (3)' has the effect of making the P-wave production rise less rapidly than  $\eta^3$ . Consequently a pure P wave may seem like a mixture of S and P waves if analyzed according to Eq. (3), instead of the more appropriate Eq. (3)'. Lichtenberg concludes that the amount of S wave is poorly known, and that "a rough estimate indicates that  $(\alpha'/\beta') \sim 0.03$ ."

Our experimental differential cross-section measurements are at present the only published results that determine directly the amount of S wave in Reaction (1), through measurement of the momentum dependence fairly near threshold.<sup>3</sup> A least-squares fit of our data<sup>4</sup> to Eq. (2) yielded<sup>3</sup>

$$\alpha = (0.138 \pm 0.015) \text{ millibarn,}$$

$$\beta = (1.01 \pm 0.08) \text{ millibarns,}$$

$$\chi = 0.082 \pm 0.034,$$

$$\alpha/\beta = 0.137 \pm 0.025.$$

In the light of Lichtenberg's remarks we have reanalyzed our data in terms of Eq. (2)'. We find

$$\alpha' = (0.125 \pm 0.017) \text{ millibarn,}$$

$$\beta' = (1.40 \pm 0.10) \text{ millibarns,}$$

$$\chi' = 0.13 \pm 0.03,$$

$$\alpha'/\beta' = 0.090 \pm 0.016.$$

We see that the S-wave contribution,  $\alpha'$ , is still clearly present, although reduced in comparison with the P wave, under the new analysis.

<sup>3</sup>Frank S. Crawford, Jr., and M. Lynn Stevenson, Phys. Rev. 97, 1305 (1955).

<sup>4</sup>Table I of Reference 3.