π^+- PROTON SCATTERING CROSS SECTIONS BY CHEW-LOW EXTRAPOLATION*

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The π^+-p interaction cross section has been determined up to the 1-2 Bev region by many workers.[1,2] A new method recently suggested by Chew and Low[3] allows one to infer the total π^+-p cross section at various energies by measuring the process $p+p \rightarrow p+n+\pi^+$ at a specific laboratory energy. In particular, consider the diagram of Fig. 1(a). In this diagram one of the protons emits a π^+ meson which then scatters on the other proton; the pion emitter recoils as a neutron. The basic physical principle in the Chew-Low technique is related to the location and residue of a pole in the transition amplitude of the process $p \rightarrow n+\pi^+$. This pole is located in the nonphysical region of negative kinetic energy of the recoiling spectator neutron. The value of the residue at this pole is shown to be directly related to the pion-proton cross section at a given pion-proton Q value. The value of this application of the Chew-Low technique to measure π^+-p cross sections is not in the actual measurement of the cross sections but rather as a test of the technique itself.

Chew and Low suggest the construction of the function

$$F(w^2, p^2) = 2\pi\left(\frac{M_1}{M_2}\right)^2 \frac{q_{1L}{}^2(p^2 - p_0{}^2)^2}{[\frac{1}{4}w^4 - \frac{1}{2}w^2(M_1{}^2 + \mu_2{}^2) + \frac{1}{4}(M_1{}^2 - \mu_2{}^2)^2]^{1/2}} \frac{\partial^2\sigma(pn\pi^+)}{\partial p^2 \partial w^2},$$

where w is the total energy of the proton and pion in their c.m. system and is related to their Q value by $w = Q + M_1 + \mu_2$, p is the neutron recoil momentum, M_1 is the proton mass, M_2 is the neutron mass, μ_2 is the π^+ mass, q_{1L} is the laboratory momentum of the incident proton, and

$$p_0{}^2 = -(M_2/M_1)[\mu_2{}^2 - (M_2 - M_1)^2].$$

For any fixed value of w^2, $\partial^2\sigma(pn\pi^+)/\partial p^2 \partial w^2$ has a second order pole at $p^2 = p_0{}^2$ and the value of the residue at this pole is just $F(w^2, p_0{}^2)$. Thus a plot of $F(w^2, p^2)$ vs p^2 extrapolated to $p^2 = -\mu_2{}^2$ (assuming $M_1 = M_2$) will yield the residue which is related to the cross section in the following manner:

$$F(w^2, -\mu_2{}^2) = -2f^2\sigma_{\pi^+p}(Q),$$

where f is the pion-nucleon coupling constant and $f^2 \approx 0.08$. It should also be noted that the diagram of Fig. 1(b) is also possible in π^+ production. This process competes with that of Fig. 1(a) and will provide background to the process of interest; however, this background should not affect the value of the residue $F(w^2, -\mu_2{}^2)$, where $w = Q + M_1 + \mu_2$ is for π^+-p only.

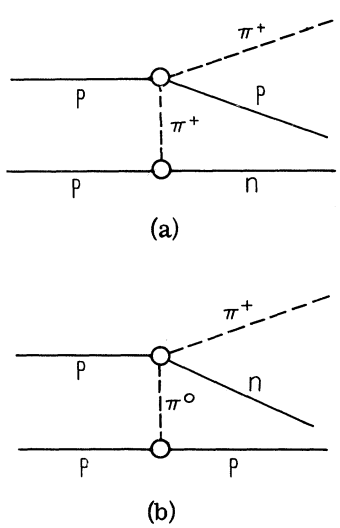

FIG. 1. Feynman diagrams considered in the Chew-Low analysis of $p+p \rightarrow p+n+\pi^+$.

The 20-inch liquid hydrogen bubble chamber of the Brookhaven Cloud Chamber group was exposed to a beam of 2.85-Bev protons from the Cosmotron. 790 examples of $p+p \rightarrow p+n+\pi^+$ have been identified in the analysis to date.[4] Each event was considered to be a possible candidate for the process of Fig. 1(a). Since the laboratory system and the rest system of the incident proton are completely equivalent in the proton-proton collision, the event was treated in that system in which the neutron momentum was lower. Since one must determine accurately the value of $F(w^2,p^2)$ near $p^2=0$ to perform the extrapolation into the unphysical region of p^2, it is advantageous to select low neutron momenta.

Because of the extreme reduction of statistics by the $\partial^2\sigma(pn\pi^+)/\partial p^2\partial w^2$ factor of $F(w^2,p^2)$, the final analysis was considered to be lacking sufficient statistics to measure more than two cross sections at different values of Q over rather wide intervals in p^2 and w^2. The two intervals selected were for $62 \leq Q \leq 226$ Mev where the π^+-p cross section peaks in the 3/2, 3/2 resonance at 154 Mev to about 200 mb, and $226 < Q \leq 793$ Mev where the π^+-p cross section falls from about 100 mb to 20 mb. The Chew-Low technique should measure some average cross section over each of these intervals. The results of this analysis are shown in Fig. 2.

Although the statistics make the extrapolation uncertain, on the basis of the least-squares linear and quadratic extrapolations shown in Fig. 2 the following conclusions seem to be justified: (a) One can clearly detect the difference between the cross section for the region $62 \leq Q \leq 226$ Mev and that which is found with the data in the region $226 < Q \leq 793$ Mev, and in addition these cross sections have approximately the correct relative magnitude. (b) The data are consistent with the fact that $\partial^2\sigma(pn\pi^+)/\partial p^2\partial w^2$ must stay positive definite at least through $p^2=(p^2)_{\rm min}\approx 0.005$ (Bev/c)^2.

So far as we know, this is the first Chew-Low extrapolation attempt, outside the deuteron case, where the answer has been known; in addition, it is felt that if a resonance exists in the π,π case which is as large as the 3/2, 3/2 π^+-p resonance, such an extrapolation should detect it.

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[1]S. J. Lindenbaum, Annual Review of Nuclear Science (Annual Reviews Inc., Palo Alto, California, 1957), Vol. 7.

[2]J. C. Brisson, J. Detoef, P. Falk-Vairant, L. van Rossum, G. Valladas, and L. C. L. Yuan, Phys. Rev. Letters 3, 561 (1959). (Recent measurements in the region 382-872 Mev.)

[3]G. F. Chew and F. E. Low, Phys. Rev. 113, 1640 (1959).

[4]G. A. Smith, H. Courant, E. Fowler, H. Kraybill, J. Sandweiss, and H. Taft, Proceedings of the Tenth Annual Rochester Conference on High-Energy Nuclear Physics (to be published).

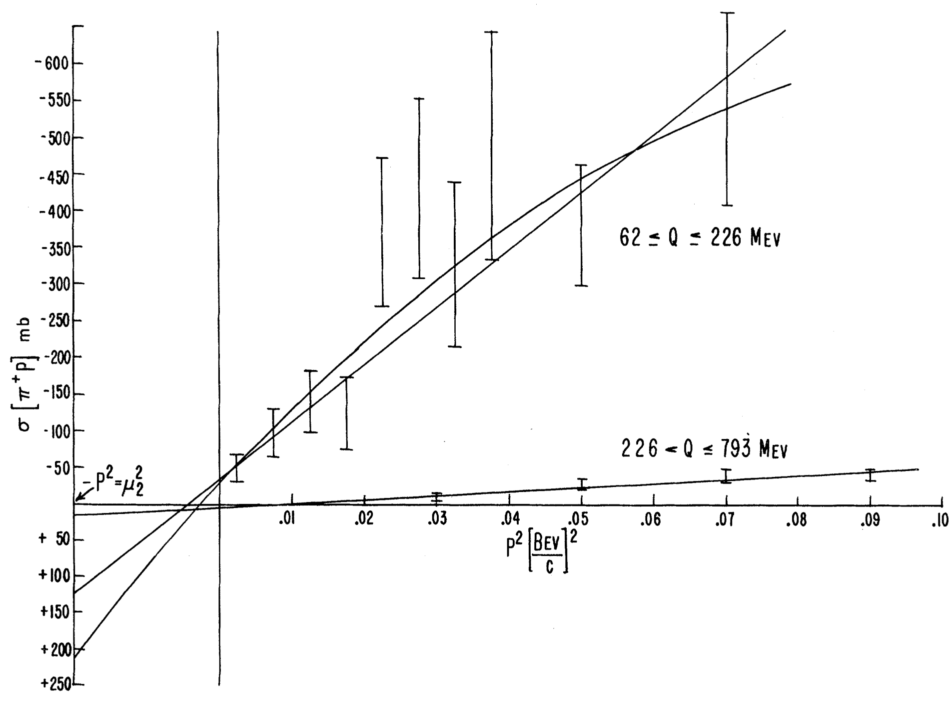

FIG. 2. Chew-Low plot with linear and quadratic least-squares extropolation.