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Publication Date

1966-01-27

UCRL-16686

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Berkeley, California

Submitted to Physical Review [illegible]

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AEC Contract No. W-7405-eng-48

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ASSOCIATION BETWEEN THE DIP IN THE $\pi^- p \to \pi^0 n$ HIGH-ENERGY ANGULAR DISTRIBUTION AND THE ZERO OF THE RHO TRAJECTORY*

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The angular distributions of $\pi^- p \to \pi^0 n$ near the forward direction have been measured by the Saclay-Orsay group at CERN at several momenta between 3 and 18 GeV/c.[1] The observed energy dependence gives important support to the hypothesis of Regge behavior controlled by the ρ trajectory. A dip at about $t = -0.6\ (\mathrm{GeV/c})^2$ together with a secondary maximum is a general feature of these distributions.

Figure 1 shows the angular distributions at 5.85, 9.8, 13.3, and 18.2 GeV/c. Phillips and Rarita fitted these distributions,[2] assuming that the amplitudes are dominated by a ρ Regge pole in the crossed channel, with the differential cross sections given by the expression

$$\frac{d\sigma}{dt}(s,t) = \frac{1}{\pi s}\left(\frac{M}{4k}\right)^2 \left[\left(1 - \frac{t}{4M^2}\right)|A|^2 + \frac{t}{4M^2}\left(s - \frac{s+p^2}{1 - \frac{t}{4M^2}}\right)|B|^2\right], \qquad (1)$$

where

$$A = C(t)\ \frac{1 - \exp(-i\pi\alpha)}{\sin \pi\alpha} \left(\frac{E}{E_0}\right)^{\alpha}$$ is the nonhelicity-flip amplitude

and

$$B = D(t)\ \frac{1 - \exp(-i\pi\alpha)}{\sin \pi\alpha} \left(\frac{E}{E_0}\right)^{\alpha-1}$$ is the helicity-flip amplitude.

The symbols s and t are the invariant squares of energy and momentum transfer, respectively, p and E are the incident pion momentum and total energy in the laboratory system, k is the center-of-mass momentum, M is the nucleon mass, and E_0 is a scale factor arbitrarily taken to be 1 BeV. The ρ trajectory is designated by $\alpha(t)$.

Phillips and Rarita parameterized $C(t)$ as $(2\alpha + 1)$ times the difference of two decreasing exponentials, while $D(t)$ was represented as α times such a difference. The trajectory $\alpha(t)$ was assigned the Pignotti form. They obtained a solution with $\alpha(0) = 0.540 \pm 0.002$ and $\alpha'(0) = 0.65 \pm 0.02$ from 75 data points with $\chi^2 = 144$. Assuming a linear trajectory, they found a less satisfactory fit with $\chi^2 = 175$ for $\alpha(0) = 0.530 \pm 0.003$ and $\alpha' = 0.47 \pm 0.02$. In both fits the value of $|t|$ where $\alpha(t)$ crosses zero is much larger than 0.6. In their solutions, the dip in the cross sections is explained by the change in sign of the difference of the two exponentials in the B amplitude (which is much larger than A), the position of the dip being near the position where the difference of the exponentials vanishes. At the same time, they pointed out the possibility that the dip might be associated with the vanishing of the factor $\alpha(t)$ in the

B amplitude. In fact, they noticed that if one assumes a linear trajectory that goes through the position of the ρ resonance and through $\alpha \approx 1/2$ at $t = 0$, this linear trajectory should go through $\alpha(t) = 0$ near $t = -0.6$. We proceeded to study this possibility using this idea as the ingredient, and have found a fit to the data, which is actually slightly better than the preferred fit of Phillips and Rarita.

As a preliminary to our analysis, the trajectory function $\alpha(t)$ was first studied by the so-called model-independent method, which has been used, for example, by Logan,[3] Höhler,[4] and others. The value of α at each t can be determined from the dependence of $d\sigma/dt$ on E, the incident-pion lab energy, since we have

$$\frac{d\sigma}{dt} = \left(\frac{E}{E_0}\right)^{2\alpha-2} F(t) .$$

A linear form for the trajectory gave a statistically adequate fit, as shown in Fig. 2 (Curve I) leading to $\alpha(0) = 0.56 \pm 0.03$ and $\alpha' = 0.81 \pm 0.08$. We thus chose a linear form to parameterize the trajectory in the following analysis.

For the residue functions $C(t)$ and $D(t)$ we chose forms based on L. L. Wang's analysis of the poles and zeros of the helicity amplitudes A and B, showing that there should be no poles beyond those at $\alpha = 1, 3, 5, \cdots$ in both amplitudes, while the kinematically required zeros occur at $\alpha = -1, -2, \cdots$, in both $C(t)$ and $D(t)$, and at $\alpha = 0$ in $D(t)$. The sequence of zeros at negative odd integers cancel out the spurious poles at these points in the function $[1 - \exp(-i\pi\alpha)]/\sin\pi\alpha$. The data in question will carry us near the point $\alpha = -1$ (see Fig. 2) but not near $\alpha = -2, -3, \cdots$, so in our parameterization we have included only the first zero of this sequence. In addition $D(t)$ must have a zero at $\alpha = 0$. It is possible that further (dynamical) zeros occur in the residue functions, but we have sought a "simple" fit where such complications are absent. Accordingly we chose the expressions

$$C(t) = (\alpha + 1)\, C_0 \exp(C_1 t)$$

and

$$D(t) = \alpha(\alpha + 1) D_0 \exp(D_1 t) ,$$

where C_0, C_1, D_0, and D_1 are adjustable constants. Note that these forms are somewhat different from those of Phillips and Rarita. In their parameterization there is an undesired zero at $\alpha = -1/2$ in A and poles at $\alpha = -1$ in both A and B amplitudes.

The data points for $|t| < 1.4 (\text{GeV}/c)^2$ at $p_\pi = 5.85$, 13.3, and 18.2 GeV/c and for $|t| < 0.8\ (\text{GeV}/c)^2$ at $p_\pi = 9.8$ GeV/c were included. With a total of 62 points,[5] the best solution we found had $\chi^2 = 98$. We did not include the normalization uncertainty, which would result in a lower χ^2 value. The values of the six adjustable parameters for our best solution are given in Table I, the corresponding fit being shown in Fig. 1.

Since both C_1 and D_1 are essentially consistent with zero, we made a search demanding that $C_1 = D_1 = 0$, and obtained a solution with the same χ^2 value.

Table I. Parameters for πN charge-exchange amplitudes.

$\alpha(0)$	0.56 ± 0.01	C_0	2.3 mb-GeV
		C_1	0.01 GeV^{-2}
α'	1.08 ± 0.03	D_0	38.9 mb-GeV
		D_1	0.01 GeV^{-2}

We feel this four-parameter fit is just an accident, however, since in the expression for the cross section an arbitrary exponential dependence on t has already been introduced through the choice of the value E_0. That is, if we were to choose a different value for E_0, the values of C_1 and D_1 would then be different from zero. Furthermore, there is no <u>a priori</u> reason to assume that the scale factor in the A amplitude should be the same as that in the B amplitude. Thus we feel six parameters are still needed.

Note that the trajectory parameters given in Table I are essentially compatible with values that we determined from the model-independent method. Figure 2 shows that $\alpha(t)$ should have a slight curvature, so that if we consider only small-momentum-transfer data points, we will get a higher value than 0.81 for the slope of the trajectory. In fact, the trajectory $\alpha(t) = 0.56 + 1.08t$ gives a satisfactory fit with $\chi^2 = 14$ for 14 points, i.e., $|t| < 0.8$. Incidentially, the trajectory given in Table I predicts $M_\rho \approx 640$ MeV, while the trajectory obtained by the model-independent method leads to $M_\rho \approx 740$ MeV.

To summarize, we find we can explain the dip at $t \approx -0.6\ (\text{GeV}/c)^2$ in terms of the necessary vanishing of the helicity-flip amplitude when the exchanged angular momentum passes through zero. If such is in fact the origin of this minimum in the angular distribution, one should expect to observe similar minima <u>at the same value of momentum transfer</u> in other reactions where the ρ trajectory plays a prominent role.

We are indebted to Professor Geoffrey Chew for his suggestions and advice on the present work. We especially thank Dr. William Rarita for his encouragement and many useful discussions. We would like to thank Mrs. Ling-Lie Wang for her discussion on the analysis of poles and zeros of the helicity amplitudes.

FOOTNOTES AND REFERENCES

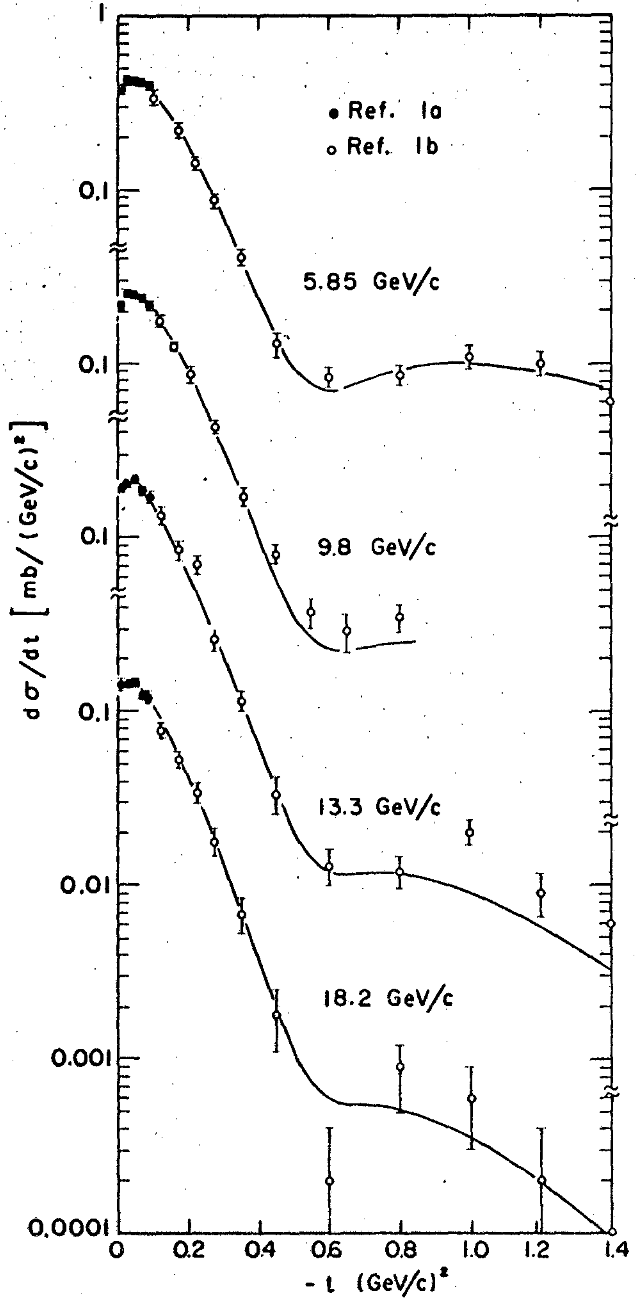
* This work was done under the auspices of the United States Atomic Energy Commission.

1. Saclay-Orsay Collaboration: (a) Phys. Rev. Letters 14, 763 (1965); (b) Phys. Letters 20, 75 (1966).
2. R. J. N. Phillips and W. Rarita, Phys. Rev. 139, B1336 (1965).
3. R. K. Logan, Phys. Rev. Letters 14, 414 (1965).
4. G. Höhler, J. Baacke, H. Schlaile, and P. Sonderegger, Phys. Letters 20, 79 (1966).
5. The 75 preliminary data points, which had been analyzed by Phillips and Rarita, were published later as 56 data points (see Ref. 1a). Thus the data analyzed in this paper cover a range slightly larger than the range in Ref. 2.

FIGURE CAPTIONS

Fig. 1. Differential cross sections of $\pi^- p \rightarrow \pi^0 n$ at four incident-pion momenta. The smooth curves are our best statistical fits.

Fig. 2. The ρ trajectory plotted as a function of t. Curve I = best linear fit to $\alpha(t)$ values determined by the model-independent method from data of Ref. 1a; $\alpha(t) = 0.56 + 0.81t$. Curve II: $\alpha(t) = 0.56 + 1.08t$.


● Ref. 1a
○ Ref. 1b
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9.8 GeV/c
13.3 GeV/c
18.2 GeV/c
1
0.1
0.1
0.1
0.1
0.01
0.001
0.0001
dσ/dt [mb/(GeV/c)²]
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0.2
0.4
0.6
0.8
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1.2
1.4
-t (GeV/c)²

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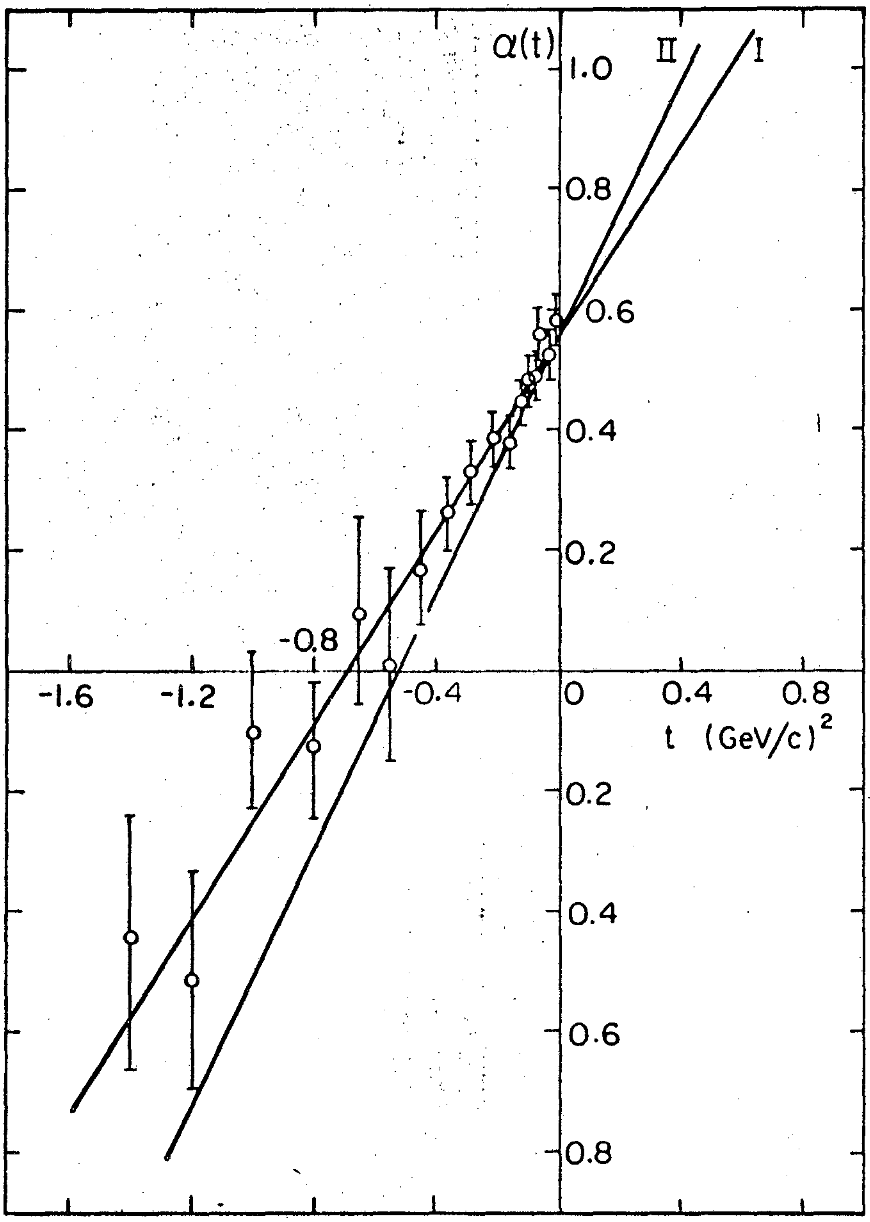

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