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Author

Flores-Maldonado, Victor.

Publication Date

1966-04-04

UCRL-16799

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Ernest O. Lawrence Radiation Laboratory

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Submitted for publication to Physical Review Letters UCRL-16799

UNIVERSITY OF CALIFORNIA
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AEC Contract No. W-7405-eng-48

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The sharp forward peak observed at high energy p-n charge-exchange scattering[1,2] has so far eluded a theoretical explanation. Various attempts based on π and ρ exchange models[3,4] and on π and ρ exchange with absorption[5,6] have been unsuccessful. We propose here an explanation based on the Regge Pole Theory with exchange of the ρ and R trajectories. The other known possible candidate, the π trajectory, does not contribute in the forward direction[7] and it lies lower than ρ and R. We are concentrating on large energies and small angles and disregarding the π contribution.

The amplitude for p-n charge-exchange scattering, A(pn ch ex), is related by general isotopic spin arguments to the difference between the amplitudes for p-p scattering, A(pp), and p-n scattering, A(pn), in the form

$$A(\text{pn ch ex}) = A(\text{pn}) - A(\text{pp}) . \qquad (1)$$

The $\sigma(pn) - \sigma(pp)$ total cross section difference is very small at high energies,[8,9] and in fact, becomes zero at about $9 (\text{Gev})^2$ according to recent measurement of $\sigma(pn)$ and $\sigma(pp)$.[10] The optical theorem, Eq. (1), and this result imply that $\sigma(\text{pn ch ex}) = 0$ at this energy. This conclusion is general, that is, not based on any model.

In the Regge Pole Theory the information regarding the real and imaginary parts of the amplitude for each pole contribution is contained in the so-called signature factor ζ_p, which can be factored out. Because of the spin $\frac{1}{2}$ of the nucleons there are five amplitudes, but three of these become zero in the forward direction and the remaining two become identical at $t = 0$. Each may be written in the ρ and R model as

$$\phi_i(\text{pn ch ex}) = \phi_i(s,t)\left[\zeta_\rho(t)\, g_\rho(t)\left(\frac{2s}{4m^2-t} - 1\right)^{\alpha(\rho,t)} + \zeta_R(t)\, g_R(t)\left(\frac{2s}{4m^2-t} - 1\right)^{\alpha(R,t)}\right], \quad (2)$$

where

$$\zeta_\rho = \frac{1}{2}\left\{i + \tan\left[\frac{\pi}{2}\,\alpha(\rho,t)\right]\right\}, \qquad \zeta_R = \frac{1}{2}\left\{-i + \cot\left[\frac{\pi}{2}\,\alpha(R,t)\right]\right\},$$

$\alpha(t)$ is the trajectory, and t the 4-momentum invariant.

At energies above $7.5(\text{Gev})^2$ the imaginary part of the amplitude is very small in the forward direction, and this must be the case near $t = 0$. In this region the amplitude consists mainly of its real part, which in the present model becomes

$$\phi_i(\text{pn ch ex}) \approx f_i(s,t)\left\{\tan\left[\frac{\pi}{2}\,\alpha(\rho,t)\right] + \cot\left[\frac{\pi}{2}\,\alpha(R,t)\right]\right\}. \quad (3)$$

We propose to explain the forward peak by a combination of two factors. (a) We assume that $\alpha_\rho(0) > 0.5$ and that the slope of ρ is large, and that $\alpha_R(0) < 0.5$ and that the slope of R is small. Then $\tan\left[\frac{\pi}{2}\alpha(\rho,t)\right]$ is a fast decreasing function for small angles while $\cot\left[\frac{\pi}{2}\alpha(R,t)\right]$ is slow increasing. (b) In addition $g_\rho(t)$ is assumed to decrease faster than $g_R(t)$ (or vice versa). These two conditions are sufficient to accentuate the forward p-n charge-exchange peak so as to agree with experiments.[1,2] The mechanism described is independent of the energy, therefore the peak should be observed at very high energies. This is in agreement with the fact that at 8.0(GeV/c)^2, which is the highest energy at which experiments have been done, the peak has the same slope observed previously at 3.0 GeV/c .[1] This mechanism depends only on the fact that the difference $\sigma(pn) - \sigma(pp)$ is small. The ρ and R model account for this and for the intersection of $\sigma(pn)$ and $\sigma(pp)$.

The conditions imposed on the trajectories are in agreement with determinations in connection with π-N scattering[11,12] and with the general N-N scattering problem.[13]

In $\bar{p}$-n charge-exchange scattering the amplitude becomes

$$\phi_i(\bar{p}n\ \text{ch ex}) = \phi_i(s,t)\left[\zeta_\rho(t)\, g_\rho(t)\left(\frac{2s}{4m^2-t} - 1\right)^{\alpha(\rho,t)} - \zeta_R(t)\, g_R(t)\left(\frac{2s}{4m^2-t} - 1\right)^{\alpha(R,t)}\right] . \quad (4)$$

The ρ and R model implies no corresponding intersection of $\sigma(\bar{p}p)$ and $\sigma(\bar{p}n)$. This seems to be in agreement with experiment, although present $\sigma(\overline{p}n)$ determinations are subject to large errors. The calculated charge-exchange differential cross sections at 3.0 Gev/c are shown in Fig. 1. The trajectories assumed in these calculations are $\alpha(\rho,t) = 0.60 + 0.87t$ and $\alpha(R,t) = 0.35 + 0.35t$, with residue functions as shown in Fig. 2. An equally good experimental fit of p-n is also obtained when $g_R(t)$ decreases faster than $g_\rho(t)$. Nevertheless, we prefer the first choice since this seems to agree better with the general behavior of residues of even and odd signature trajectories found in Ref. 13. Further evidence in support of the choice of a ρ residue function that is fast decreasing at small angles comes from independent work on π-N scattering.[16]

In contrast to the p-n case, the $\overline{p}$-n differential cross section has a smaller forward slope, since here the imaginary part of the amplitude has a forward peak that the real part tends to cancel. This is in agreement with a few recent $\overline{p}$-n differential cross-section measurements at 3.0 and 3.6 Gev/c.[14] Here again a π exchange model with absorption[15] seems unsuccessful, since it predicts again a sharp peak at very small angles. In the range of energies above 7.5 $(\mathrm{GeV})^2$ the ρ and R model gives $\overline{p}$-n charge-exchange total cross sections larger than for p-n, in which actually the cross section becomes zero at the $\sigma(pn)$ and $\sigma(pp)$ intersection.

Experimental p-n and $\overline{p}$-n charge-exchange measurements at energies in the neighborhood of the $\sigma(pn)$ and $\sigma(pp)$ intersection will be helpful in the investigation of the charge-exchange amplitudes. Finally we point out that our choice of residue functions predicts a crossover point for the p-n and $\bar{p}$-n charge-exchange differential cross sections that should be observed experimentally.

In conclusion, the present calculations seem to constitute further theoretical evidence in support of the role of the R and ρ trajectories in charge exchange scattering.

We are grateful to Professor Geoffrey F. Chew for encouragement, to Mr. Thomas Clements for programming assistance, and to Professor Burton J. Moyer for the hospitality of the Physics Department, University of California, Berkeley.

FOOTNOTES AND REFERENCES

* Visiting scientist, on leave of absence from Instituto Politécnico Nacional and Comisión Nacional de la Energía Nuclear of Mexico.

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FIGURE CAPTIONS

Fig. 1. Calculated p-n and $\bar{p}$-n charge-exchange differential cross sections at 3.0 GeV/c .

Fig. 2. The ρ and R most important residue functions near the forward direction, used in the calculations of p-n and $\bar{p}$-n charge-exchange differential cross sections.

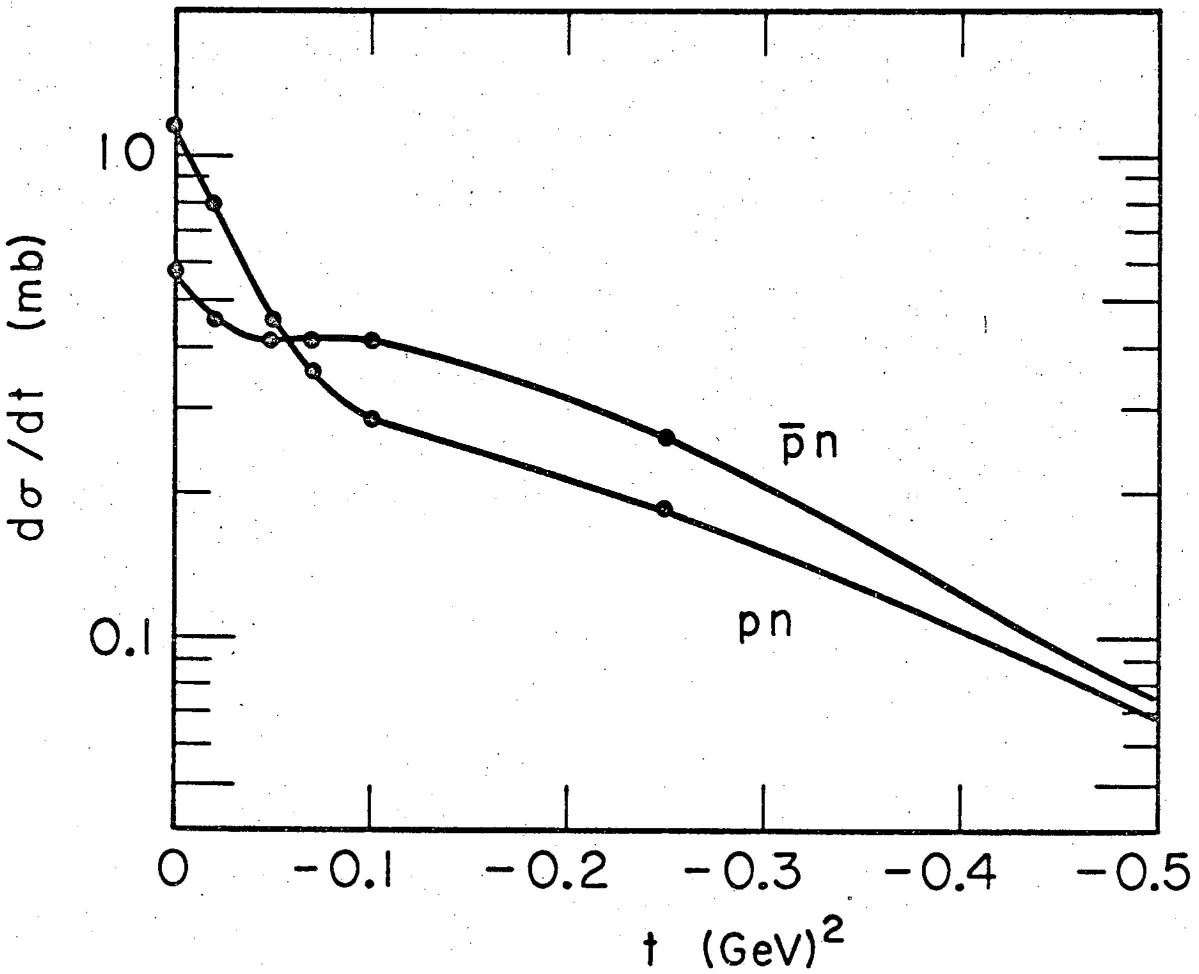

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Fig. 1.

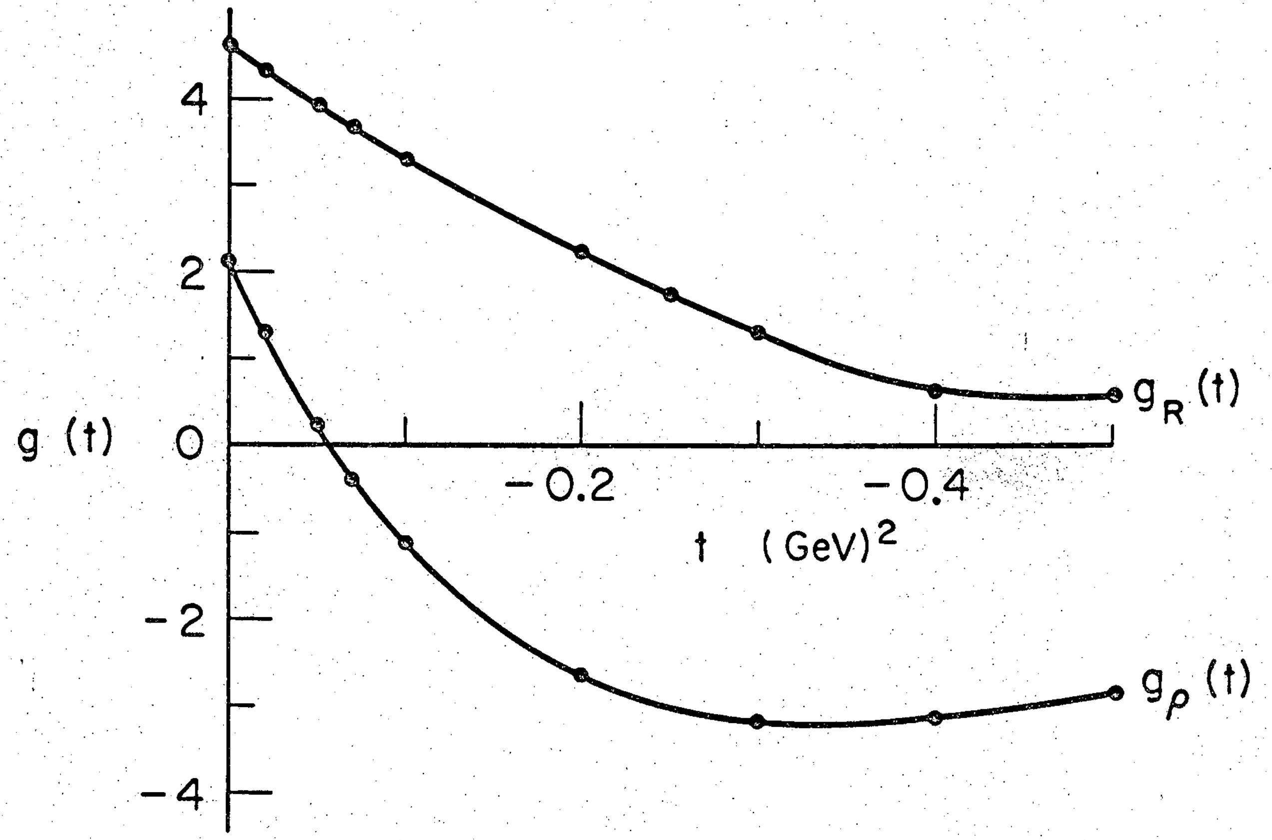

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Fig. 2.