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Publication Date
1963-12-16

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Berkeley, California

For Phys. Rev. Letters

UCRL-11164

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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ABSTRACT

It is shown that the existing high energy data for the np charge exchange differential cross section in the forward direction and the difference between np and pp total cross sections can be simultaneously explained in terms of two Regge trajectories. The two trajectories are the ρ and the R (using the notation of Pignotti in the preceding paper). The R has parity and G parity opposite to ρ but the same isotopic spin. These two sets of quantum numbers in the crossed channel are the only possible ones with non vanishing contribution to the processes in question. The conjecture of real analyticity of the generalized coupling constants together with the existing data require the existence of an R trajectory. In fitting the experimental data the intercepts are

$$\alpha(0) = 0.57 \pm 0.1 \quad \text{and} \quad \alpha_R(0) = 0.31 \pm 0.05 .$$

ZERO-ENERGY INTERCEPTS OF THE ρ AND R TRAJECTORIES, THE pn CHARGE-EXCHANGE SCATTERING, AND THE DIFFERENCE IN pp AND np TOTAL CROSS SECTIONS*

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The np charge-exchange experiment of Palevsky et al[1] has received considerable attention from numerous authors. By assuming that only the ρ trajectory in the t channel is dominant, Muzinich has obtained a rough fit to the narrow forward peak of the differential charge-exchange cross section at 2.85-BeV laboratory energy. However, Phillips subsequently showed that ρ exchange alone cannot explain simultaneously the energy dependence of $(\sigma_{pp} - \sigma_{np})$ and $d\sigma_{c.e.}(t=0)/d\Omega$.[3] He has also shown that experimental results contradict the real analyticity of the generalized coupling constants introduced by Gell-Mann[4] and by Gribov and Pomeranchuk.[5] Taking what amounts to a combination of a Reggeized pion and a Reggeized ρ, Islam and Preist have obtained a reasonable fit to the differential charge-exchange np cross section at 2.04 BeV.[6] However, their solution does not remove the difficulties pointed out by Phillips, because the pion contribution vanishes in the forward direction. The purpose of this letter is to show that by introducing the R trajectory of Pignotti,[7] we can explain the data and at the same time obtain the intercept values $\alpha(t=0)$ of the ρ and R trajectories. We shall also see that a second ρ trajectory, instead of R, does not suffice.

The possible quantum numbers of the particles which can be exchanged in the t channel for nucleon-nucleon scattering (s channel) have been tabulated by Muzinich.[8] It can be shown that of these twelve sets of quantum numbers only two give a nonvanishing contribution to the forward direction in the charge-exchange process. The two are

(i) ρ trajectory with $I = 1$, $G = +1$, $P = -1$, and $\tau = -1$

and

(ii) R trajectory with $I = 1$, $G = -1$, $P = +1$, and $\tau = +1$,

where I is the isospin, G is the G parity, P is the parity and $\tau = (-1)^J$ is the signature.

We define a general two-pole, $I = 1$ amplitude A at $t = 0$ as

$$A = -\beta_1 \frac{(2\alpha_1+1)}{\sqrt{s}} P_{\alpha_1}(-z) \frac{(1+\tau_1 e^{-i\pi\alpha_1})}{\sin \pi\alpha_1} - \beta_2 \frac{(2\alpha_2+1)}{\sqrt{s}} P_{\alpha_2}(-z) \frac{(1+\tau_2 e^{-i\pi\alpha_2})}{\sin \pi\alpha_2} . \quad (1)$$

Here the Regge parameters β_1, β_2, α_1, and α_2 are evaluated at $t=0$, and we have $Z = (m + T)/m$ and $s = 4m^2 + 2mT$, where T is the laboratory kinetic energy. Writing $\beta = Be^{i\pi\alpha}$, we have

$$A = -B_1 \frac{(2\alpha_1+1)}{\sqrt{s}} P_{\alpha_1}(z) \frac{(1+\tau_1 e^{-i\pi\alpha_1})}{\sin \pi\alpha_1} - B_2 \frac{(2\alpha_2+1)}{\sqrt{s}} P_{\alpha_2}(z) \frac{(1+\tau_2 e^{-i\pi\alpha_2})}{\sin \pi\alpha_2} , \quad (2)$$

where now B_1 and B_2 are real. The differential charge-exchange cross section in the forward direction is given by

$$d\sigma_{c.e.}(t=0)/d\Omega = |A|^2 , \tag{3}$$

where Ω is the center-of-mass solid angle, and from the optical theorem we have

$$D\sigma \equiv \sigma_{pp} - \sigma_{np} = \frac{4\pi}{p} \text{ Im } A , \tag{4}$$

where $p = (2mT)^{1/2}$. From Eqs. (2), (3), and (4), the four real parameters α_1, B_1, α_2, and B_2 can be fitted to the available experimental data of Palevsky et al.[1] and Diddens et al.[9]

Two solutions can be considered:

(1) One possibility is that both trajectories considered have the same quantum numbers as ρ. In this case the amplitude can be written as

$$A = -B_\rho \frac{(2\alpha_\rho+1)}{\sqrt{s}} P_{\alpha_\rho}(z) \frac{(1-e^{-i\pi\alpha_\rho})}{\sin \pi\alpha_\rho} - B_{\rho'} \frac{(2\alpha_{\rho'}+1)}{\sqrt{s}} P_{\alpha_{\rho'}}(z) \frac{(1-e^{-i\pi\alpha_{\rho'}})}{\sin \pi\alpha_{\rho'}} \tag{5}$$

To explain the positive sign of $D\sigma$ between T=1 and T=7 BeV, we must take B_ρ and $B_{\rho'}$ to have opposite signs (B_ρ positive and $B_{\rho'}$ negative). This contradicts the real analyticity of the generalized coupling constants (see the arguments of Phillips[3]). However, the argument here does not deny existence of a ρ' trajectory. We shall return to this point later.

(2) The second possibility is to take a combination of the ρ trajectory [with the set of quantum numbers (i)] and the so called R trajectory [with the set of quantum numbers (ii)]. The R trajectory was proposed by Pignotti[7]

in connection with SU(3) symmetry and the bootstrap mechanism. Here we point out that, aside from the SU(3) implications, it is the only other trajectory that contributes to np charge-exchange cross sections in the forward direction and, consequently, to $D\sigma$ through the optical theorem. In this case, the amplitude A is

$$A = B_\rho \frac{(2\alpha_\rho+1)}{\sqrt{s}} P_{\alpha_\rho}(z) \frac{(1-e^{-i\pi\alpha_\rho})}{\sin \pi\alpha_\rho} - B_R \frac{(2\alpha_R+1)}{\sqrt{s}} P_{\alpha_R}(z) \frac{(1+e^{-i\pi\alpha_R})}{\sin \pi\alpha_R} \qquad (6)$$

a combination that is particularly suitable. As pointed out by Chew,[10] because ρ and R have opposite signatures we can fit the $D\sigma$ data taking B_ρ and B_R both positive provided that we have $\alpha_\rho > \alpha_R$. We should notice that experimentally $D\sigma$ is negative at low energies, becomes positive for laboratory momenta between 1.2 and 8 BeV/c, and then appears to become negative again.[9] Using Eqs. (3), (4), and (6), we vary the four parameters to fit simultaneously the $d\sigma_{c.e.}(t=0)/d\Omega$ data of Palevsky et al.[1] and the $D\sigma$ data of Diddens et al.[9]

The four parameters were fitted by numerical calculation with the help of the IBM 7094 computer of the Lawrence Radiation Laboratory. The results are:

$$\alpha_\rho = 0.57 \pm 0.1 \qquad \alpha_R = 0.31 \pm 0.05$$
$$B_\rho = 0.8 \pm 0.2 \qquad B_R = 1.8 \pm 0.4 \qquad (7)$$

The result for α_ρ is in fair agreement with the arguments of reference 11.

Figure 1 shows the result of our fit $d\sigma_{c.e.}(t=0)/d\Omega$. The point at 710 MeV is from the charge-exchange experiment by Larsen.[12] We have not used this point in fitting the parameters. Figure 2 shows the fit to $D\sigma$ of Diddens et al.[9]

In this solution we have neglected the data below 2 BeV. To fit the $D\sigma$ data below 2 BeV, we would have to consider at least a third trajectory, a ρ' . This we have not done so far, one reason being that at these energies one may question the idea that the Regge poles of the t channel are dominant. The second reason for ignoring these low-energy points is that a third trajectory would allow a total of six parameters, and the present data are not sufficient for such an elaborate calculation. We could, of course, include $\sigma_{\bar{p}p} - \sigma_{pp}$ data as well; but then we should also have to include the ω trajectory. Such a possibility is subject to future investigation.

Finally, we remark that any future charge-exchange experiment should be valuable to our understanding of these trajectories. In particular, the measurement of high-energy pion-nucleon charge exchange should be encouraged. Because of G-parity conservation, the R trajectory would be absent here and, if the energy is high enough, the ρ alone should suffice.

ACKNOWLEDGMENTS

The author is indebted to Professor G. F. Chew for numerous helpful suggestions and encouragements. Thanks are also due to Drs. E. Leader and V. Teplitz and Mr. A. Pignotti for helpful discussions.

FOOTNOTES AND REFERENCES

* Work done under the auspices of the U. S. Atomic Energy Commission.

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FIGURE LEGENDS

Fig. 1. The differential charge-exchange cross section in the forward direction vs laboratory energy.

Fig. 2. The difference between pp and pn total cross sections vs laboratory energy.

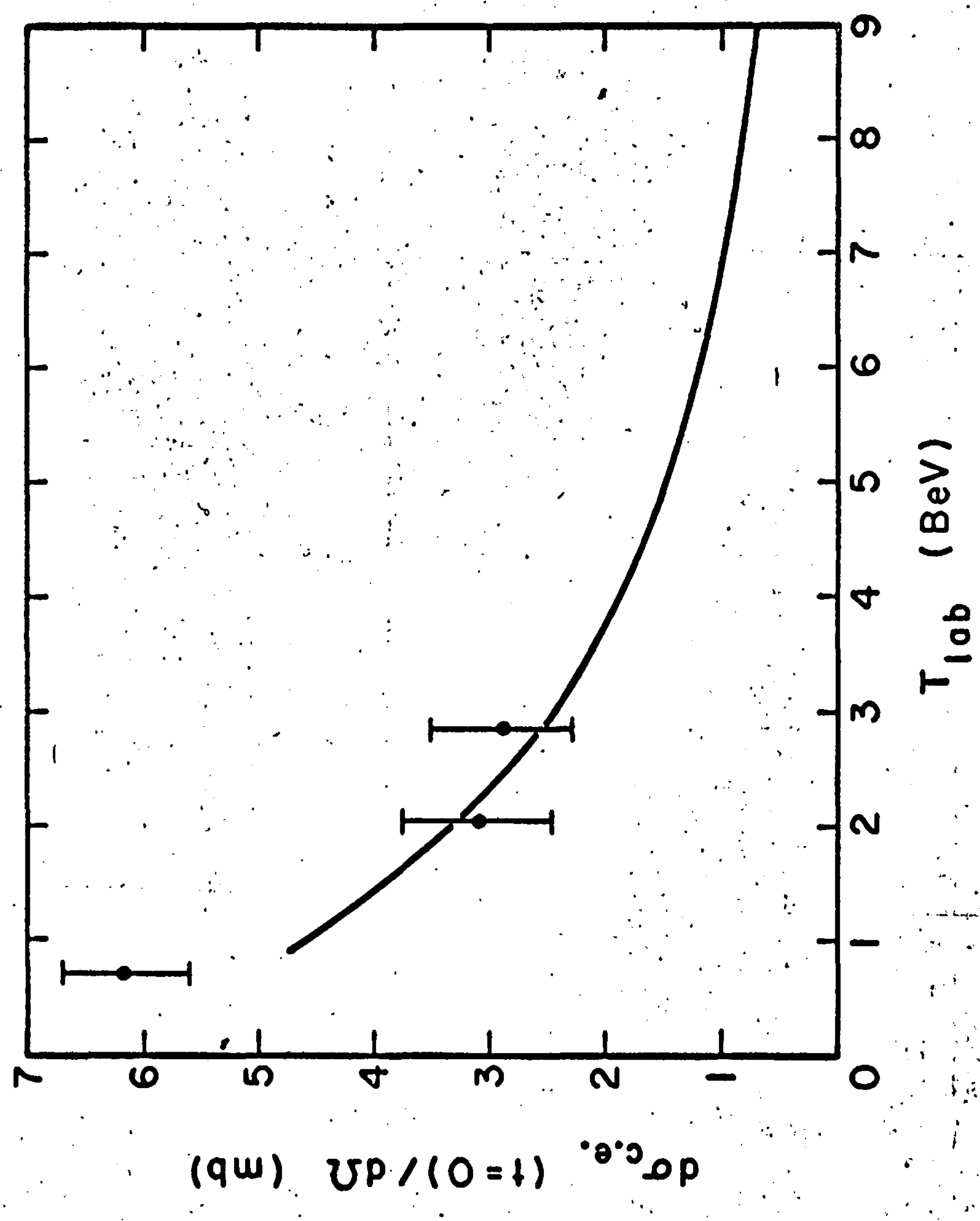

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Fig. 1

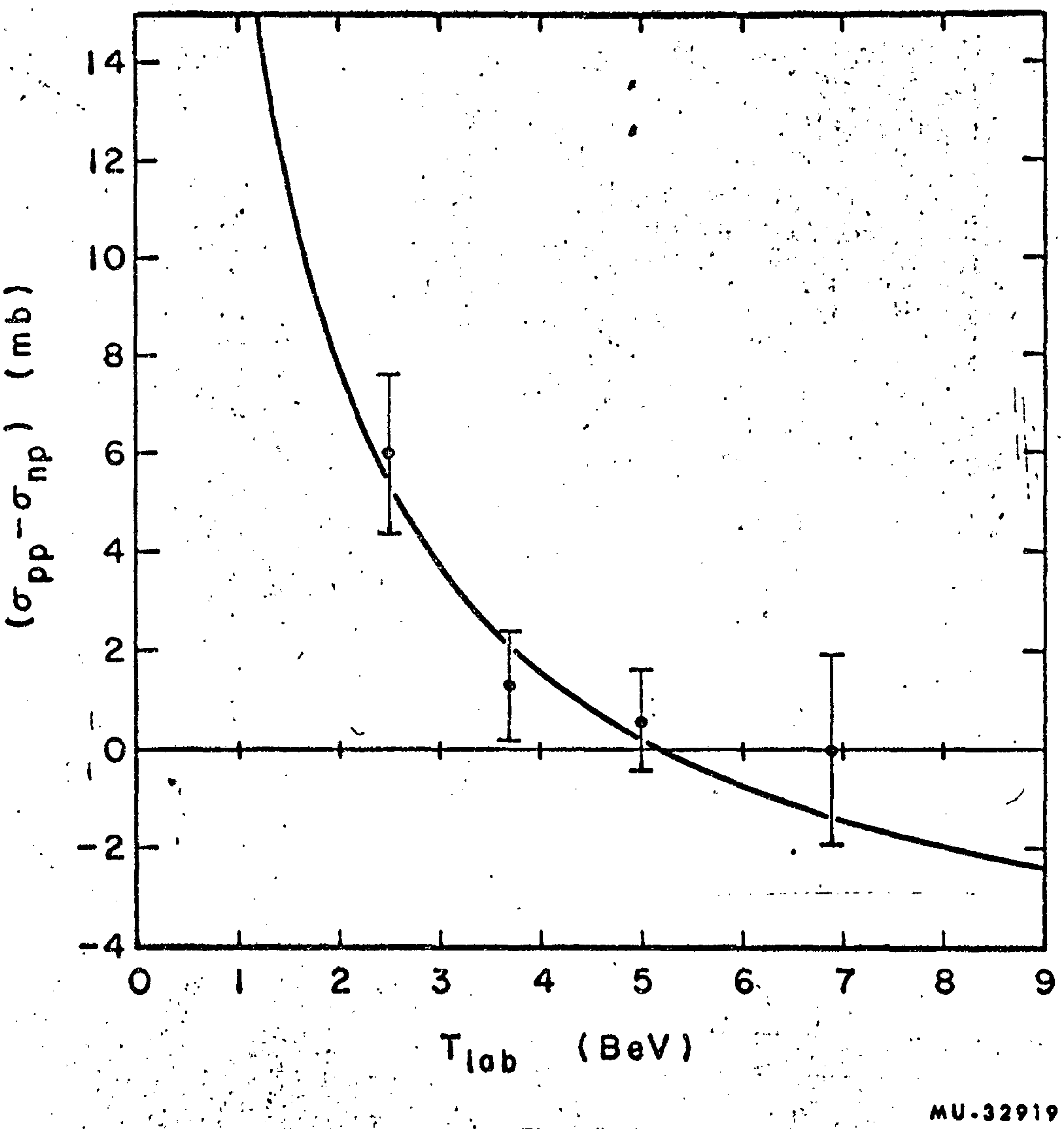

Fig. 2