Regge Behavior in $\pi^- p$ Charge-Exchange Process at the Region around $N(2190)$*

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An analysis based upon a Regge prediction indicates that the measured differential cross sections for the $\pi^- p$ charge-exchange process in the region of 2 GeV/c is consistent with the assignment of the $J=l-\frac{1}{2}$ state to $N(2190)$ resonance, and that there does not seem to exist a sign change in the pole residue associated with the spin-nonflip amplitude in the Regge term in the interval of t from 0 to 0.8. The data and the Regge prediction were in close agreement.

IT is of interest to investigate the validity of a Regge-pole model, in which the charge-exchange process is dominated by one-pole exchange, at lower momenta such as 2 GeV/c. The previous analysis[1] on the charge-exchange differential cross sections at this energy region indicated that the $N(2190)$ resonance has $J=l+\frac{1}{2}$ and had a poor agreement with a Regge-pole model around the region of the dip in the differential cross sections. However, a model-independent analysis[2] on the polarization data in $\pi^- p$ elastic scattering near 2 GeV/c yielded the assignment of $G_{7/2}$ to $N(2190)$. In particular, the associated Legendre-coefficient analysis provided strong evidence that $N(2190)$ is consistent with the $J=l-\frac{1}{2}$ state. It is advantageous to study the charge-exchange process at this energy region where the interference between the Regge term and the known resonances exists. Such an interference process can be used to test the sign of the Regge term.[3]

This paper compares the published experimental data[1] near 2 GeV/c to a prediction based upon a Regge-pole model. In particular, the data at 2.07 GeV/c, where the imaginary amplitude of $N(2190)$ is maximum and the real part is zero, were studied.

We begin with establishing the Regge parameters by fitting available differential cross section data[4] in charge exchange to a Regge-pole model at higher-energy region where the resonance effect can be neglected. Then, using those parameters, we calculate the Regge terms at 2.07 GeV/c. Resonant amplitudes in the direct channel are calculated at this energy by including: (i) those resonances used by Barger and Cline[5] in which the elasticity for $N(2190)$ was assumed to be 0.15; and (ii) only known resonances of $\Delta(1236)$, $\Delta(1924)$, $N(1518)$, and $N(2190)$. Since the most dominant resonance is $N(2190)$ at this energy, the above two cases make no significant difference in the analysis. Thus, we follow the discussion with the first case. The differential cross section is given by

$$(d\sigma/dt)(s,t)=(\pi/q^2)[|f(\text{nonflip})|^2+|g(\text{spin flip})|^2],$$

where q is the πN center-of-mass momentum,

$$f=f_{\text{Reg}}+f_{\text{Res}} \quad\text{and}\quad g=g_{\text{Reg}}+g_{\text{Res}}.$$

The amplitudes due to the exchange of the ρ Regge pole are given as[6]

$$f_{\text{Reg}}(s,t)=-(Mm/4\pi s^{\frac{1}{2}})F(s,t)b_1(t),$$
$$g_{\text{Reg}}(s,t)=(m/16\pi)F(s,t)[b_1(t)-\alpha(t)b_2(t)]\sin\theta,$$
$$F(s,t)=\left(\frac{1-e^{-i\pi\alpha(t)}}{\sin\pi\alpha(t)}\right)\left(\frac{s}{2Mm}\right)^{\alpha(t)},$$

where M=nucleon mass, m=pion mass, $\alpha(t)$=the trajectory of the ρ role$=0.58+1.00t$,[7] and $b_1(t)$, $b_2(t)$=the residues of the ρ Regge pole. To avoid a prejudice against the behavior of pole residues, $b_1(t)$ and $b_2(t)$ we performed a two-parameter search without functionalizing parameters. This was done by fitting data at small t intervals, where parameters were assumed to be constant. The fact that we can determine both the sign and magnitude of $b_1(t)$ at $t=0$ from the total cross section data gives a reliable starting point in the search. The sign of $b_2(t)$ near $t=0$ was determined from the polarization data[8] in $\pi^\pm p$ elastic scattering at high energies where the resonance effect is negligible. The experimental data[4] from $t=0$ to -1.0 were separated into eight small t intervals. After obtaining values of $b_1(t)$ and $b_2(t)$ uniquely at the first t interval, 0 to -0.1, these values were used as starting

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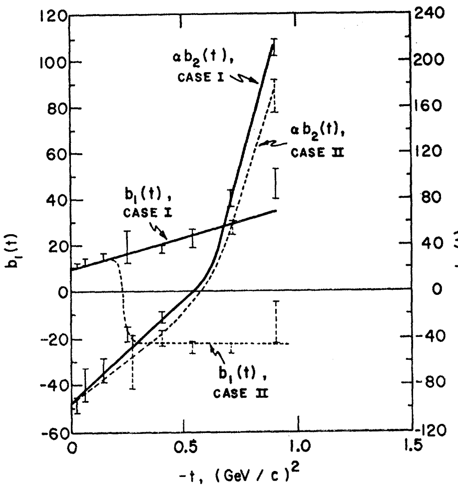

FIG. 1. Pole residues in charge-exchange process. Case I: obtained by the continuity condition. Case II: obtained by applying the crossover effect.

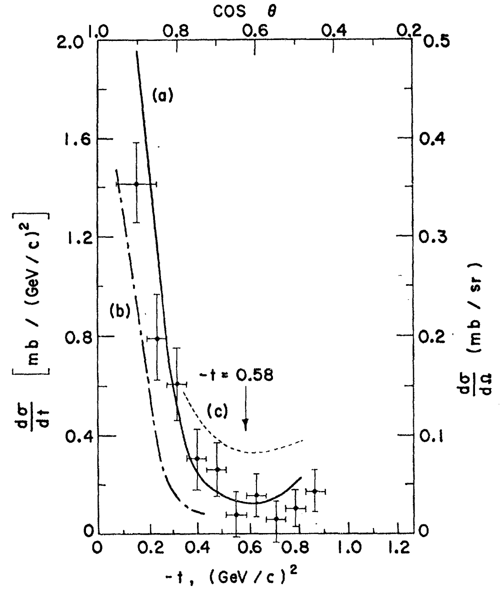

FIG. 2. Differential cross sections for $\pi^- p \to \pi^0 n$ at 2.07 GeV/c Experimental data: from Ref. 1. Curve A: computed with G_{72}. for $N(2190)$ and values given by Case I in Fig. 1. Curve B: computed with $G_{7/2}$ for $N(2190)$ and values given by Case II in Fig. 1. Curve C: computed with $G_{9/2}$ for $N(2190)$ and values given by Case I in Fig. 1.

values in the search at the second t interval. In a similar way, the search was conducted at the third t interval and so on. Both $b_1(t)$ and $\alpha(t)b_2(t)$ residues obtained by the above method are plotted with respect to t and are shown as Case I in Fig. 1. To check uniqueness of these solutions some limited random searches were made by varying starting guess values in the search, and solutions were screened by assuming a continuity condition of smoothness behavior of pole residues with respect to t. Final values were in agreement with those shown as Case I in Fig. 1. In this search, the sign flip of $b_1(t)$ proposed to explain the crossover effect[9] in πN elastic scattering was not obtained. By violating the above continuity condition at the region where the crossover takes place, we obtained another set of parameters, shown as Case II in Fig. 1.

Calculated cross sections using parameters of Case I by assuming $N(2190)$ with $G_{7/2}$ and with $G_{9/2}$ are shown as Curves A and B, respectively, in Fig. 2. Although there is not a remarkable difference between the two curves, the experimental data show that the $N(2190)$ is not inconsistent with $J=l-\frac{1}{2}$.

To test the validity of Cases I and II, we may conveniently compare two calculated cross sections at the region where the effect of $b_2(t)$ vanishes. Furthermore, the fact that the nonflip amplitude due to $G_{7/2}$ state, the most dominant resonance term at 2.07 GeV/c, has almost a local maximum at $t=-0.58$ makes the test ideal. The positive $b_1(t)$ gives a destructive interference, as shown in Curve A of Fig. 2; the negative $b_1(t)$ gives a constructive interference (Curve C). This effect is more remarkable if we assume the elasticity for $N(2190)$ as 0.25 instead of 0.15. Thus, Case I representing no sign change of $b_1(t)$ is preferred.

We conclude that the calculated differential cross section at low energy such as 2.07 GeV/c based upon the Regge-pole model gives a good agreement with the experimental data.

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