Exchange-Degenerate Λ-Trajectory Interpretation of K^+p Backward Elastic Scattering Data*

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A baryon Regge exchange model for K^+p backward elastic scattering is constructed in accordance with the requirements of duality and the absence of $Y=+2$ baryons. The dominant exchange-degenerate amplitude is associated with the Λ_α (1115, $\frac{1}{2}^+$) and Λ_γ (1520, $\frac{3}{2}^-$) particles. Recent data on $d\sigma/du$ (K^+p) from 2 to 7 GeV/c are successfully reproduced.

NEW data on K^+p elastic scattering over the 2–7-GeV/c momentum range exhibit a backward peak with a rapid energy dependence.[1–6] Since the K^+p elastic amplitude has no prominent direct-channel resonances, we expect Reggeized baryon exchange to account for the backward peak down to rather low momenta.[7] To describe the present data on $d\sigma/du$ (K^+p), we propose a simple model based on the following assumptions: (i) Σ-exchange contributions can be neglected relative to Λ-exchange contributions; (ii) only exchanges of the leading Λ trajectories are important; (iii) the Regge amplitudes are exchange-degenerate, in accord with the duality principle[8] and the absence of prominent K^+p direct channel resonances. By the above arguments the dominant amplitudes will be associated with the $\Lambda_\alpha(1115,\frac{1}{2}^+)$ and $\Lambda_\gamma(1520,\frac{3}{2}^-)$ particles, which lie on a degenerate trajectory and have the same residue function. Quantitative fits are presented which reproduce the K^+p data with few parameters. Further tests of the model are proposed.

Hyperon exchange models for the K^+p amplitude are complicated by the numerous possibilities for Λ and Σ exchanges. However, the following considerations suggest that the Λ-exchange contributions will dominate in K^+p backward scattering.

(i) Coupling constants from dispersion relations give[9]

$$g_{p\Lambda K}^2 \gg g_{p\Sigma^0 K}^2.$$

(ii) Direct-channel resonance contributions to K^-p elastic scattering from $I=0$ resonances are appreciably larger than from $I=1$ resonances.

(iii) From the known residues of N_α and Δ_δ Regge exchanges in $\pi^\pm p$ backward scattering,[10] $SU(3)$ estimates for the residues of Λ_α, Σ_α, and Σ_δ exchanges in K^+p backward scattering give Λ_α amplitude $\gg \Sigma_\alpha$ or Σ_δ amplitudes.

(iv) The strong backward peak observed in data[11] on the reaction $K^-p\to\pi^0\Lambda_\gamma(1520,\frac{3}{2}^-)$ leads us to expect a significant contribution from Λ_γ exchange in $K^+p\to K^+p$.

Since the trajectory for $\Lambda_\beta(1405,\frac{1}{2}^-)$ is expected to lie about a unit below the Λ_α or Λ_γ trajectories,[12] the Λ_β-exchange contribution to K^+p scattering should die out extremely rapidly with energy. We therefore shall retain only Λ_α- and Λ_γ-exchange contributions in subsequent calculations. These trajectories are illustrated in Fig. 1.

The Regge plot of the Λ_α and Λ_γ particles[13] in Fig. 1 displays approximate exchange degeneracy for the trajectories. This degeneracy has been speculatively correlated with the nonexistence of K^+p direct-channel resonances through the duality principle.[14–16] In order that counterclockwise loops are not present in the Argand diagrams of the partial-wave decomposition

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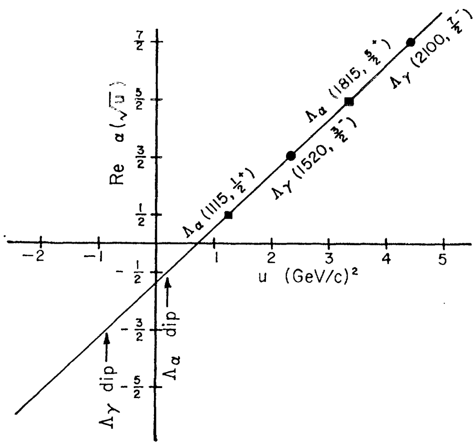

FIG. 1. Exchange degenerate $(\Lambda_\alpha,\Lambda_\gamma)$ Regge trajectory. The u positions of amplitude zeros at wrong-signature nonsense points are indicated by vertical arrows.

of the Regge exchange amplitude, the Λ_α and Λ_γ contributions must be exchange degenerate (by duality, counterclockwise loops would be associated with the existence of K^+p direct-channel resonances[14]). With this exchange-degenerate requirement, the u-channel amplitude for K^+p backward scattering has the form[17,18]

$$\tilde{f}_2(\sqrt{u},s)=\frac{1}{\Gamma(\alpha+\frac{1}{2})}\gamma\left(\frac{1+e^{-i\pi(\alpha-1/2)}}{\cos\pi\alpha}+\frac{1-e^{-i\pi(\alpha-1/2)}}{\cos\pi\alpha}\right)s^{\alpha-1/2},$$

where $\alpha(\sqrt{u})$ and $\gamma(\sqrt{u})$ denote the trajectory and residue, respectively. The first term above represents the Λ_α exchange, the second Λ_γ. The Λ_α amplitude vanishes at $\alpha=-\frac{1}{2}$ $(u\simeq+0.2)$ and the Λ_γ amplitude vanishes at $\alpha=-\frac{3}{2}$ $(u\simeq-0.8)$, as noted in Fig. 1. However, the sum of the two contributions is a smoothly varying function of u.

For data fitting we assume an approximately linear trajectory, as suggested by the Regge plot in Fig. 1. The residue is parametrized with a simple form consistent with the absence of $J^P=\frac{1}{2}^-$ and $J^P=\frac{3}{2}^-$ MacDowell reflected particles,[19]

$$\gamma(\sqrt{u})=\left(1+\frac{\sqrt{u}}{M_\Lambda}\right)\left(1+\frac{\sqrt{u}}{M_{Y_0*}}\right)\beta(u),$$

where $M_\Lambda\simeq1.115$ GeV and $M_{Y_0*}\simeq1.52$ GeV. For this residue structure, the u-channel amplitude is

$$\tilde{f}_2(\sqrt{u},s)=\frac{2\beta(u)}{\Gamma(\alpha+\frac{1}{2})\cos\pi\alpha}\left(1+\frac{\sqrt{u}}{M_\Lambda}\right)\left(1+\frac{\sqrt{u}}{M_{Y_0*}}\right)s^{\alpha-1/2}.$$

The fits to the 2–7-GeV/c data[1–6] are shown in Figs. 2 and 3. The $(\Lambda_\alpha,\Lambda_\gamma)$ trajectory was determined to be

$$\alpha=-0.72+1.01u$$

as compared with

$$\alpha=-0.7+0.96u$$

from the Regge spin-mass plot of particles in Fig. 1. The curves in Figs. 2 and 3 correspond to the residue parametrization (in GeV^{-1})[20]

$$\beta=9.1e^{2.1u}+3.1e^{-1.5u}.$$

The second term in β was needed to account for the tendency of the $d\sigma/du$ data to flatten at larger $|u|$. The model seems to provide a reasonable over-all description of the present K^+p data.

The measurement of $K^+n\to K^0p$, $K_2p\to K_1p$, or $K^+n\to K^+n$ backward scattering will provide a straightforward experimental test of the Λ-exchange dominance assumption of this model. We expect the

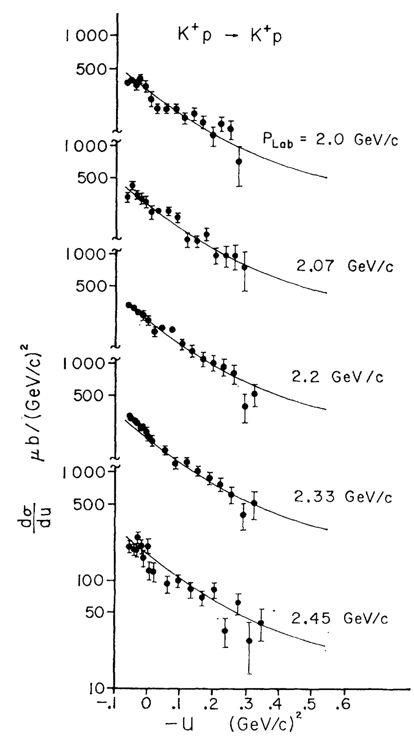

FIG. 2. Fitted curves for $d\sigma/du$ (K^+p) based on $(\Lambda_\alpha,\Lambda_\gamma)$ exchange-degenerate Regge model. Data from Ref. 3.

[17] The cross-section formulas for fermion Regge exchange are given in Ref. 12. The amplitude f_2 of Ref. 12 is related to $\tilde{f}_2$ by $f_2(\sqrt{u},s)=\tilde{f}_2(\sqrt{u},s)(E_u+M)/\sqrt{u}$. The units of s, t, and u are $(\mathrm{GeV}/c)^2$.

[18] Since we retain only the leading power in the Regge expansion, some question exists as to whether s^α or $(s-t)^\alpha$ represents the better approximation at low energies. We have tried both forms, with similar results for K^+p. Fits to the 3–7-GeV/c K^+p data were somewhat better with the $(s-t)^\alpha$ form, but fits to the more accurate 2–3-GeV/c data were better with the s^α form. Baryon-exchange calculations of $\bar{p}p\to K^-K^+$ at low energy are extremely sensitive to the choice of an energy-dependent factor.

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[20] For an $(s-t)^\alpha$ energy dependence (see Ref. 18), the fitted residue was $\beta=7.8e^{1.9u}+1.2e^{-1.7u}$. The parametric form for the residue is not well suited for extrapolation outside the u range considered in the data analysis.

following relations to hold:

$$\frac{d\sigma}{du}(K^+n\to K^0p)\approx\frac{d\sigma}{du}(K^+p\to K^+p),$$

$$\frac{d\sigma}{du}(K_2p\to K_1p)\ll\frac{d\sigma}{du}(K^+p\to K^+p),$$

$$\frac{d\sigma}{du}(K^+n\to K^+n)\ll 4\frac{d\sigma}{du}(K^+p\to K^+p).$$

The assumption of exchange degeneracy is somewhat more difficult to evaluate experimentally. The polarization is predicted to be zero in the exchange-degenerate limit, but polarization phenomena are typically sensitive to small background contributions. Finite-energy sum rules (FESR) for the u channel provide an alternative test of the exchange degeneracy, since the Λ_α and Λ_γ amplitudes can be separated through their opposite signature.[21] However, lack of information on the $\bar{p}p\to\bar{K}K$ channel will cause uncertainties in such FESR evaluations.

The absence of prominent resonances in the K^+p elastic channel makes it a particularly interesting reaction for phenomenological study. Our analysis indicates that Λ exchanges can account for the backward peak at intermediate energies. It will be of interest to see to what extent this model can account for K^+p backward scattering data below 2 GeV/c. At the same time, experiments above 7 GeV/c are highly desirable to determine if the measured energy dependence for $d\sigma/du$ (K^+p) remains compatible with the predictions from $(\Lambda_\alpha,\Lambda_\gamma)$ exchanges.

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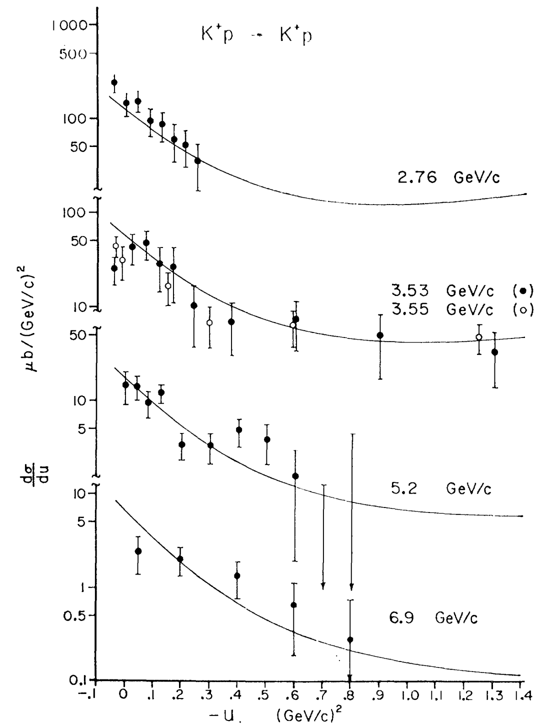

FIG. 3. Fitted curves for $d\sigma/du$ (K^+p) based on $(\Lambda_\alpha,\Lambda_\gamma)$ exchange-degenerate Regge model. Data from Refs. 1 (3.53 GeV/c), 2 (3.55 GeV/c), 4 (5.2 and 7.0 GeV/c), and 5 (2.76 GeV/c).