(with $F_{1\omega NN}$, $F_{2\omega NN}$ the electric and anomalous magnetic couplings, respectively, and $|f_{\omega\pi\gamma}|^2$ proportional to the decay rate $\omega\rightarrow\pi\gamma$). A comparison with Eqs. (1) through (4) near the pole then yields the following for the fixed residues β_1 and β_2:

$$\beta_1 \approx \frac{\frac{1}{2}F_{1\omega NN}f_{\omega\pi\gamma}}{4-m_\omega^2/M^2} \approx -0.155\ \mathrm{BeV}^{-3}, \qquad (9)$$

$$\beta_2 \approx \beta_1/M \approx 1.65\ \mathrm{BeV}^{-4}, \qquad (10)$$

where we have taken the values for the relevant elementary particle couplings from H. Abarbanel, C. Callan, and D. Sharp, Phys. Rev. 143, 1225 (1966); we chose $\epsilon_\omega = \partial\alpha_\omega(t)/\partial t \approx 1$. Since the anomalous magnetic moment couplings are small, we have neglected terms $\propto F_{2\omega NN}$ for this rough calculation.

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FURTHER EVIDENCE FOR BARYON EXCHANGE FROM K^+p BACKWARD ELASTIC SCATTERING*

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We have studied K^+p elastic scattering near the backward direction at a beam momentum of 3.5 GeV/c. In addition to providing evidence for baryon exchange, the experimental results show a possible turnover of the angular distribution for positive values of u which is interpreted in terms of a Reggeized baryon exchange model. We have made a comparison of K^+p, π^+p, and π^-p backward scattering within the framework of SU(3) which leads to predictions concerning other, as yet unmeasured, K^+N processes.

Backward peaks in meson-baryon scattering processes have been observed for several reactions in the past few years.[1] It is well known that such peaks can result from at least two distinct physical mechanisms: (a) the exchange of baryons in the u channel and (b) the excitation of high-spin baryon resonances in the direct or s channel.[2] In general both processes may be expected to contribute thus complicating the analysis. In order to separate these contributions unambiguously it is necessary to study processes in which one or the other mechanism is expected to be absent. For the reasons given below we believe that the process $K^+p\rightarrow pK^+$ is relatively free of the effects of direct-channel resonances and, therefore, the study of backward scattering relates directly to the question of baryon exchange. In this note we present evidence for a relatively large cross section for backward K^+p elastic scattering thus indicating the presence of baryon exchange in this process.

K^+p elastic scattering has been studied in the angular region $-0.5 \leq \cos\theta \leq -1$, using film from an exposure of the Brookhaven National Laboratory 80-inch bubble chamber to a 3.53-BeV/c K^+ beam.[3] The exposure yielded 0.196 μb/event. Events of two types were distinguished on the scanning table according to the following criteria:

(1) A two-pronged interaction in which one track made an angle greater than 90° with the beam track. The other track must then have been on the opposite side of the beam at an angle less than the maximum kinematically allowed for backward elastic scattering. In general the kaon could be distinguished from pions by ionization.

(2) A two-pronged interaction in which a minimum ionizing track had a projected angle be-

tween 45° and 90° with respect to the beam track. The other track was again required to be on the opposite side of the beam and less than the kinematic limit. These requirements result in a bias against detecting events for which the normal to the plane of production was nearly perpendicular to the line of sight. For these events the angles appear foreshortened and the ionization appears greater than minimum.

Of the 1350 events which were found and measured, 45 satisfactorily fit the hypothesis of large-angle Kp elastic scattering.[4] None of these had fits to πp elastic scattering. These events were corrected for scanning efficiency and for the azimuthal bias. The latter correction was obtained by adjusting to isotropy the azimuthal distribution of the production plane for the 1350 measured events as a function of the center-of-mass scattering angle. The corrected angular distribution is shown in Fig. 1. In addition, various other K^+p and K^-p cross-section data are plotted in Fig. 1.[5-7]

In order to interpret the backward peak in

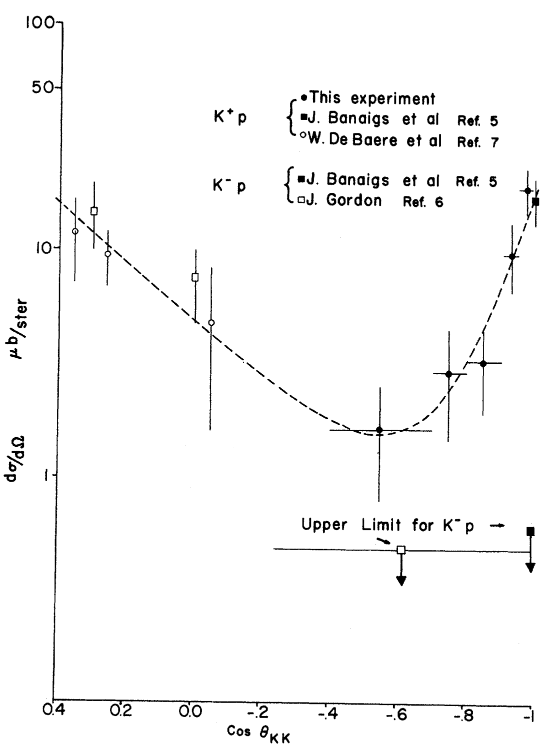

FIG. 1. Differential cross section for K^+p elastic scattering near $\cos\theta = -1$ measured in this experiment and reported in Ref. 5. This graph also shows the present upper limits on the differential cross section for K^-p elastic scattering in the backward hemisphere. The dashed curve is drawn to guide the eye.

K^+p elastic scattering it is useful also to consider K^-p backward elastic scattering. For K^+p and K^-p scattering near 180° there are at least two mechanisms that are expected to be important: (1) Exchange of $Y=0$ and $Y=+2$ baryon states, respectively, in the u channel, (2) excitation of $Y=+2$ and $Y=0$ baryon states, respectively, in the s channel. At present there are many well-known $Y=0$ states with low mass. Furthermore, recent K^-n and K^-p total-cross-section measurements have suggested the existence of high-mass $Y=0$ states.[8] The situation is less clear regarding $Y=+2$ states. Although none have been definitely established, recent K^+p total-cross-section measurements have indicated the possible existence of a few such states.[9] However, if $Y=+2$ states do exist, the total-cross-section measurements limit their elasticities to values much less than those of the $Y=0$ states of similar masses.[8,9] Thus if direct channel effects are important in the K^+p and K^-p systems at the laboratory momentum of 3.5 BeV/c, it is to be expected that the cross section in the backward hemisphere for K^-p will be larger than that for K^+p. On the other hand, if baryon exchange is dominant at this momentum and if no $Y=+2$ states exist or their coupling to the $\bar{K}N$ system is very small, the K^+p cross section near 180° should be larger than that for K^-p scattering. Also in Fig. 1 is plotted the upper limit for the K^-p elastic-scattering cross section in the backward hemisphere for the laboratory beam momentum of ~3.5 BeV/c.[5,6,10] On the basis of this graph the following two conclusions seem appropriate: (1) $d\sigma(K^+p)/d\Omega \gg d\sigma(K^-p)/d\Omega$ for $-0.5 < \cos\theta < -1$ resulting from the exchange of $Y=0$ baryons in the u channel. (2) The $Y=0$ and $Y=+2$ baryon resonances in the direct channel make a negligible contribution to $K^\pm p$ elastic scattering in the backward hemisphere at this momentum.

It is amusing to note that near 90° the K^-p and K^+p cross sections have a similar magnitude again suggesting the dominance of a meson-exchange contribution (the P, P', and R contribution) over the direct-channel contribution. It would seem that even at this low momentum the meson and baryon exchange amplitudes dominate the large-momentum-transfer K^+p and K^-p elastic-scattering amplitude, thus suggesting that a high-statistics comparison of these reactions will be useful. In addition if backward peaks are to be interpreted within the framework of an optical model,[11] it seems remarkable that such a difference between K^+p and K^-p backward scattering should exist.

Figure 2 shows the corrected differential cross section ($d\sigma/du$) as a function of u. For comparison the differential cross sections for π^-p and π^+p backward elastic scattering at the same laboratory momentum are shown.[12] There are two important considerations to be made: (1) The average cross sections for $\pi^\pm p$ and K^+p elastic scattering near $u=0$ satisfy the following relation:

$$\frac{d\sigma(\pi^+p)}{du} > \frac{d\sigma(K^+p)}{du} > \frac{d\sigma(\pi^-p)}{du}. \qquad (1)$$

(2) Within the limited statistics of this experiment the momentum-transfer distribution turns over near $u \geq 0$.

Relation (1) can be understood on the basis of a model of baryon exchange incorporating SU(3) symmetry for the $\bar{B}BM$ vertices.[13] Assuming that N_α exchange and Δ_δ exchange dominate

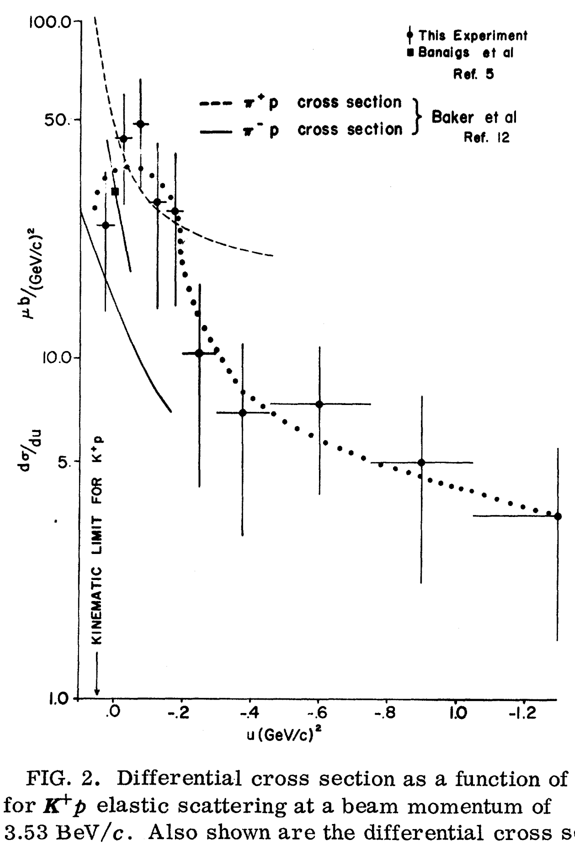

FIG. 2. Differential cross section as a function of u for K^+p elastic scattering at a beam momentum of 3.53 BeV/c. Also shown are the differential cross sections for π^+p and π^-p near $u=0$ for beam momentum of 3.55 GeV/c (Ref. 12). The dotted line is drawn through the K^+p data points to guide the eye.

the π^+p and π^-p elastic-scattering amplitudes, respectively, it is possible to estimate, within the frame work of SU(3) symmetry, the individual contributions of Λ_α, Σ_α, Σ_δ exchange to the K^+p elastic-scattering amplitude. In this model, if only Σ_δ contributes to K^+p and only Δ_δ to π^-p the following cross-section equality is predicted:

$$\frac{d\sigma(K^+p)}{du} = \frac{1}{36}\frac{d\sigma(\pi^-p)}{du}, \qquad (2)$$

in contradiction with relation 1. Therefore, the contribution of Σ_δ to K^+p scattering is negligible. If the exchange of the α trajectory dominates both K^+p and π^+p scattering, an F/D ratio of $\frac{2}{5}$ leads to the following approximate equality[13]:

$$\frac{d\sigma(\pi^+p)}{du} \sim 4\frac{d\sigma(K^+p)}{du}, \qquad (3)$$

which is not in disagreement with the results presented in Fig. 2 at least for $u \gtrsim 0$. In this case the contribution of Σ_α exchange to K^+p scattering is negligible compared with Λ_α. An immediate consequence of this model is the prediction that

$$\frac{d\sigma(K^+p \to pK^+)}{du} \gg \frac{d\sigma(K^+n \to nK^+)}{du}. \qquad (4)$$

This relation should also hold if a sizable fraction of the K^+p amplitude comes from a singlet contribution such as the exchange of the trajectory containing the $Y_0^*(1520)$. Thus relation (4) is almost model independent and should provide a good qualitative test for the usefulness of SU(3) in the description of baryon-exchange reactions.

The K^+p momentum-transfer distribution shown in Fig. 2 does not seem to rise as fast near $u \gtrsim 0$ as the π^+p momentum-transfer distribution and, in fact, there is a possible turnover or flattening of the cross section.[14] It is interesting to speculate on the possible nature of this turnover. It is now well known that a dip occurs in the angular distribution for π^+p back scattering at $u \sim -0.15$.[15] The origin of this dip is presumably due to the N_α trajectory passing through the nonsense spin value of $-\frac{1}{2}$.[16] A simple-minded straight-line extrapolation of the N_α trajectory from the region $u>0$ indicates that the trajectory should intersect $\alpha=-\frac{1}{2}$ near $u \sim -0.15$. Correspondingly, if the Λ_α trajectory dominates K^+p back scattering, an extrapolation of the Λ_α trajectory indicates that a dip will occur for positive u values somewhere between $u \sim +0.1$ and $u = +0.2$. If the trajectory curves slightly with decreasing u, the dip might occur closer to $u = 0$. Such a zero in the amplitude near $u = 0$ could cause the turnover or flattening of the K^+p angular distribution. Observation of such a turnover with good statistics for different laboratory momenta would constitute further evidence for the validity of the Reggeized baryon-exchange model.

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NEW STRUCTURES IN THE K^-p AND K^-d TOTAL CROSS SECTIONS BETWEEN 2.4 AND 3.3 GeV/c *

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Small structures observed in K^-p and K^-d total-cross-section measurements are interpreted as indications for two new $I = 1$ resonances at c.m. energies of 2455 ±10 and 2595 ±10 MeV.

The K^-p and K^-d total cross sections have been measured with increased precision and resolution in the momentum interval 2.45 to 3.30 GeV/c using a partially separated K^- beam at the Brookhaven alternating-gradient synchrotron (AGS).[1] Data were obtained at momentum intervals of 50 MeV/c with $\Delta p/p = \pm 0.75\,\%$. The statistical standard deviations are approximately ±0.25% for hydrogen and ±0.15% for deuterium. The experimental arrangement was the same as that which was previoulsy described.[2] The beam flux was approximately constant at 10^4 K^- for 10^{12} circulating protons.

In Figs. 1(a) and 1(b) the measured cross sections are plotted versus the laboratory momentum. The data below 2.45 GeV/c of Cool et al.[3] are also shown. The error bars represent statistical errors only. It is estimated that an over-all systematic error of less than ±1% is present in the absolute cross-section