K^-p BACKWARD SCATTERING FROM 1 TO 2.5 GeV/c*

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Elastic scattering of K^- mesons from protons in the backward direction has been measured to high accuracy in the momentum interval from 1.0 to 2.5 GeV/c. The cross sections exhibit a very fast decrease as a function of energy given by $d\sigma/du \sim s^{-10}$. The data can be fitted either by a superposition of the known resonant amplitudes in the K^-p system, or by postulating the existence of a Z^* Regge trajectory.

In a recent paper[1] we reported on K^+p backward elastic-scattering data obtained with high statistical accuracy at the Brookhaven alternating gradient synchrotron (AGS). In this Letter we present preliminary results on backward elastic scattering of K^- mesons on protons in the same momentum region.[2] As before, the angular region covered was from $\cos\theta_{\text{c.m.}} = -1.00$ to -0.70. The partially separated beam of the Brookhaven AGS was used, with an average yield of 6×10^3 K^- mesons/10^{12} interacting protons and $\Delta p/p = \pm1\%$; the π/K ratio varied from 3 to 8. The experimental apparatus is described in Ref. 1. Suffice it to say here that wire spark chambers were used to detect both the incoming and the scattered K mesons as well as the outgoing proton. In addition, forward-going protons with laboratory angles less than 10° were momentum analyzed by passing through a No. 48D48 magnet. The only experimental difference between the K^+ and K^- scattering is that in the present case the primary beam is dispersed in the opposite direction from the recoil proton.[1] This feature reduced the accidental trigger rate and also permitted us in some cases to measure the elastic scattering at exactly 180°. This was achieved by triggering only on a forward proton (without requiring a backward-scattered track) and performing a missing-mass analysis.

Data taking, processing, and analysis were nearly identical to those previously described.[1] The K^-p cross sections, however, are typically smaller than the corresponding ones for K^+p by a factor 5-10. The additional constraint provided by the measurement of the proton momentum for the small-angle events was, therefore, essential to this experiment; the inelastic background was thus reduced to the level of 10^{-31} cm^2/sr.

Figure 1 shows the measured angular distributions. Each of these distributions contains between 500 and 1000 elastic events; the errors shown are purely statistical. An additional uncertainty of ±7% may exist in the relative normalization of the distributions taken at different momenta. The unpublished bubble-chamber data of Lynch et al.[3] are also indicated in the figure. One notices the following main features of the data: (1) There is a backward dip at all energies and the cross section drops off smoothly[4] towards 180°; (2) the general behavior of the backward angular distribution is the same throughout the entire momentum range explored; and (3) the 180° cross section decreases very rapidly with increasing K^- laboratory momentum.

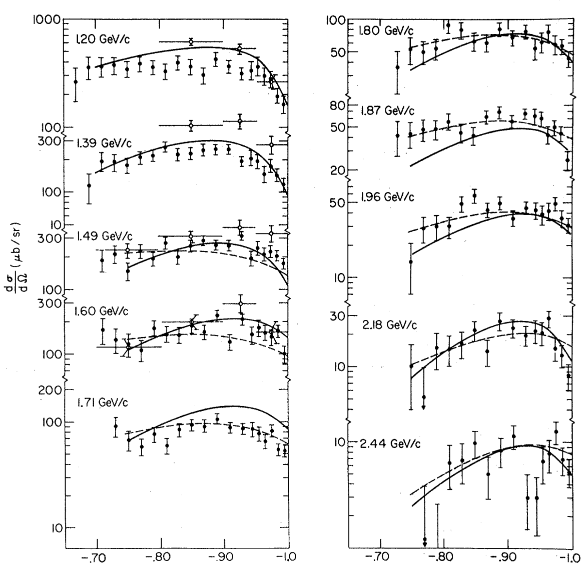

FIG. 1. The differential cross section for elastic scattering of K^- on protons in the backward direction. The solid curves are the results of a direct-channel resonance fit, whereas the dashed curves are from a Regge-pole exchange fit. Data from Ref. 3 are indicated by the open circles.

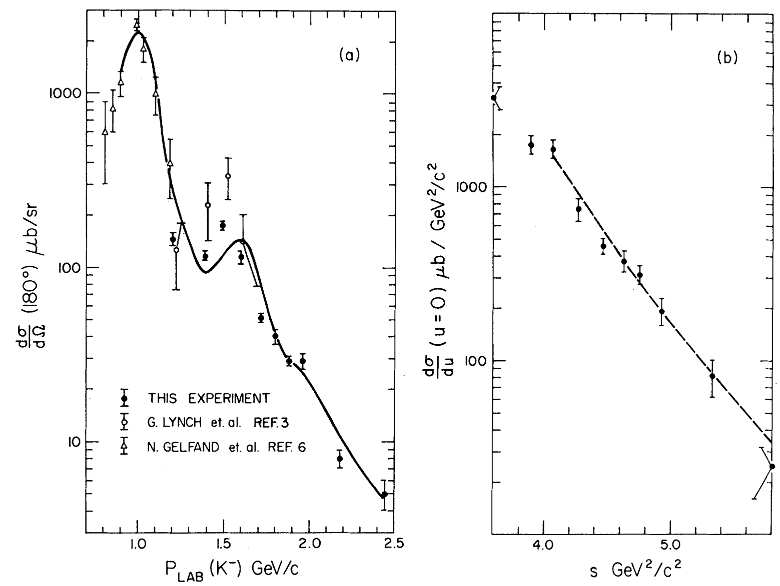

FIG. 2. The backward differential cross section as a function of energy. (a) $d\sigma/d\Omega$ at 180°. The solid curve is the result of the resonance fit. Data from Refs. 3 and 6 are included. (b) $d\sigma/du$ at $u=0$. The dashed curve is the result of the Regge fit.

In Fig. 2 we show as a function of incident momentum the behavior of the cross section $d\sigma/d\Omega$ at 180° and of $d\sigma/du$ at $u=0$. The cross section drops faster than any other known elastic backward cross section at comparable energies; $d\sigma/du$ at $u=0$ has approximately an s^{-10} dependence. It is customary to justify this decrease by the absence of Regge trajectories with quantum numbers appropriate for a u-channel exchange.[5] In this case the s-channel contribution must be entirely responsible for the backward cross section.

To test this hypothesis we have attempted a fitting to our data including the lower energy points of Gelfand et al.[6] by a pure resonance model without background.[7] The parameters for the many known $S=-1$, $B=1$ resonances were taken from the Rosenfeld tables[8] as indicated in Table I. The masses and widths were kept constant and only the elasticities were allowed to vary within reasonable limits, the best-fit values being indicated in column 5 of the table. For the higher mass resonances, which have been seen only as total cross-section bumps, the bracketed spin and parity assignments of column 2 of the table have been assumed.

The results of this fitting procedure are shown by the solid curves in Figs. 1 and 2(a) and are in qualitative agreement with the data.[9] The fitted elasticities are in good agreement with the Rosenfeld values[8] except for the five resonances in the mass region 1.65-1.82 GeV.[10] We wish to stress that acceptable fits can also be found using different spin and parity assignments for the high-mass resonances and that inclusion of background terms can modify the elasticity assignments obtained. We can, however, safely conclude that direct-channel effects alone can reproduce the behavior of the backward K^-p cross sec-

Table I. The resonance parameters used for the resonance fit in Figs. 1 and 2(a). The last column gives the accepted values for the elasticities from Ref. 8. Bracketed values in the second column designate spin and parity assignments assumed in this fit.

ISOSPIN	J^P	MASS (Gev)	WIDTH (Gev)	ELASTICITY	ELASTICITY FROM REF. 8
0	3/2-	1.519	0.016	0.27	0.45
1	3/2-	1.660	0.050	0.12	small
0	1/2-	1.670	0.018	0.41	0.14
0	3/2-	1.690	0.045	0.70	0.20
1	5/2-	1.767	0.095	0.19	0.46
0	5/2+	1.816	0.090	0.99	0.65
0	5/2-	1.860	0.090	0.09	0.08
1	5/2+	1.930	0.100	0.07	0.10
1	7/2+	2.030	0.120	0.16	0.10
0	7/2-	2.100	0.140	0.30	0.30
1	(7/2+)	2.250	0.200	0.15	0.10
0	(9/2-)	2.350	0.210	0.04	0.06
1	(9/2+)	2.455	0.140	0.07	0.03
1	(11/2-)	2.595	0.140	0.02	0.04

tion.

An alternative explanation of the rapid decrease of $d\sigma/du$ at $u=0$ would be the exchange of a Z^* trajectory with a very low intercept at $u=0$. Evidence for this possibility comes from the smooth behavior of the backward differential cross section and the fact that the data for $d\sigma(\bar{p}p \to K^+K^-)/du$ can be satisfactorily predicted[11] from our $d\sigma(K^-p \to pK^-)/du$ on the basis of a crossing relation derived by Barger and Cline[12] on the assumption of a Reggeized Z^* exchange.

Since the differential cross section near 180° exhibits a turnover, we have fitted our data by an odd-signature Regge exchange term of the form[12]

$$\frac{\gamma}{\Gamma(\alpha+\frac{1}{2})}\frac{1-i\exp(-i\pi\alpha)}{\cos\pi\alpha}\left(\frac{s}{s_0}\right)^{\alpha-1/2}. \qquad (1)$$

All kinematic factors, which are quite important at these energies, were included in the calculation. An acceptable fit was found using the parameters $\alpha=-3.73+1.1u$, and $s_0=0.05$ $(\mathrm{GeV}/c)^2$.[13] This is indicated by the dashed curves in Figs. 1 and 2(b).

The possibility of explaining the data in terms of a Regge cut is rather remote. Michael[14] has estimated the contribution of successive K^* and Δ exchange and finds that the calculated cross section is 1-2 orders of magnitude too low and has the wrong energy dependence.[15]

In conclusion, we note that either the direct-channel resonance model or the Regge-pole exchange model can give satisfactory fits to our data.[16] Support for the first approach comes from the lack of any known Z^* resonances, while the latter hypothesis is considered because of the success of the crossing-symmetry results referred to above.[11,12]

We are indebted to the many people who made this experiment possible. We wish to thank the AGS staff, the operating and experimental support group, and in particular Dr. G. K. Green, Dr. J. Sanford, Mr. J. Spiro, Mr. W. Walker, and Mr. T. Blair. The continued support and advice of Dr. R. L. Cool has been greatly appreciated. The Brookhaven Central Scientific Computing Facility has given us invaluable assistance, and the same is true of the technical and support personnel at Brookhaven and Rochester; in particular, we thank Mr. J. Fuhrman, Mr. J. Sanders, and Mr. J. Gatz. Dr. B. McDaniel, Dr. C. Delorme, and Mr. A. Entenberg have helped us at various stages of this experiment.

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[1]A. S. Carroll, J. Fischer, A. Lundby, R. H. Phillips, C. L. Wang, F. Lobkowicz, A. C. Melissinos, Y. Nagashima, C. A. Smith, and S. Tewksbury, Phys. Rev. Letters 21, 1282 (1968).

[2]These data are available in tabular form on request from the authors.

[3]G. Lynch, private communication; see also L. W. Alvarez, in Proceedings of the International Conference on Instrumentation for High Energy Physics, Stanford, 1966 (International Union of Pure and Applied Physics and U. S. Atomic Energy Commission, Washington, D. C., 1966), pp. 271-295. In spite of the relatively large errors of the bubble-chamber data, they seem to indicate that our data are systematically lower by 30-40 %. We are presently investigating possible sources of such a discrepancy which nevertheless does not affect the main conclusions reached in this Letter.

[4]In view of the limited angular range explored in this experiment we cannot confirm the dip at fixed $u=-0.3$ (and associated with a zero in the polarization) reported by C. Daum, P. Erné, J. P. Lagnaux, J. C. Sens, and F. Udo, Nucl. Phys. B6, 273 (1968).

[5]See for example, G. Bellettini, in Proceedings of the Fourteenth International Conference on High Energy Physics, Vienna, Austria, September 1968 (CERN Scientific Information Service, Geneva, Switzerland, 1968), p. 339.

[6]N. M. Gelfand et al., Phys. Rev. Letters 17, 1224 (1966); W. R. Holley et al., Phys. Rev. 154, 1273 (1967). Only the data in the interval $-1.0 \leq \cos\theta^* < -0.7$ were used in the fit.

[7]For a detailed description of the expressions used see, e.g., A. S. Carroll et al., Phys. Rev. Letters 20, 607 (1968). A similar fit to lower energy data was done by S. Minami, Phys. Rev. 155, 1678 (1967).

[8]Particle Data Group, Rev. Mod. Phys. 41, 109 (1969).

[9]We have not fitted the total cross section or K^-p charge-exchange data; however our fit is in good agreement with the backward charge-exchange data at 1.2, 1.5, and 1.7 GeV/c.

[10]Abnormal elasticities had to be chosen to fit the large peak in $d\sigma/d\Omega$ (180°) at $p_{\mathrm{LAB}} \sim 1$ GeV/c. This may be due to the absence of background terms in our fit, or to the existence of additional resonances in this mass region.

[11]B. C. Barish, H. Nicholson, J. Pine, A. V. Tollestrup, J. K. Yoh, C. Delorme, F. Lobkowicz, A. C. Melissinos, Y. Nagashima, A. S. Carroll, and R. H. Phillips, Phys. Rev. Letters, to be published.

[12]V. Barger and D. Cline, Phys. Letters 25B, 415 (1967).

[13]Equally good fits can be found by replacing s by $s-M^2-u^2$, or by replacing $1/\Gamma(\alpha+\frac{1}{2})$ by $(\alpha+\frac{7}{2})$ with only slightly different parameters. We also note that while the value for s_0 seems low, for linear u dependence of α, this is equivalent to using $s_0=1.0$ $(\mathrm{GeV}/c)^2$ and multiplying γ by $\exp(\lambda u)$, where $\lambda=3.3$.

[14]C. Michael, Phys. Letters 29B, 230 (1969).

[15]The energy dependence will be given by $\alpha_{\rm eff}=\alpha_N+\alpha_K-1$. Even taking the lowest trajectories, N_γ and $K^*(890)$, one would get $\alpha_{\rm eff}=-2.1$, which is much larger than the required $\alpha_{\rm eff}\sim-4$.

[16]While the two models predict similar cross sections, they have quite different amplitudes. All acceptable resonance fits to K^-p scattering have a large spin-flip amplitude whose vanishing at 180° causes the backward dip. On the other hand, in any single-trajectory Regge model without $\sqrt{u}$ terms in the residue function, the spin-nonflip amplitude dominates because of kinematic factors. The dip at 180° is caused by the nonsense wrong-signature zero in the Regge amplitude.

PHOTOPRODUCTION OF $K^+\Lambda$ AND $K^+\Sigma^0$ FROM HYDROGEN AT BACKWARD ANGLES*

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We have investigated photoproduction of $K^+\Lambda$ and $K^+\Sigma^0$ from hydrogen at 4.3 GeV and for u values between -0.2 (GeV/c)^2 and -0.7 (GeV/c)^2. The data were consistent with a smooth decrease in $d\sigma/du$ towards larger negative u values. The K^+ backward photoproduction cross sections appear to be closely similar to the observed cross section for backward π^+ photoproduction. The ratio of Σ^0/Λ is about 1.7, which rules out pure decuplet exchange in this region of u. The results are consistent with the SU(3) prediction.

At high energies the large-angle photoproduction of K^+ is expected to be dominated by u-channel exchange of baryons with hypercharge $Y=0$. In contrast to π photoproduction, there are no large-angle data available for K^+ photoproduction above 1.5 GeV. We report here the results of a

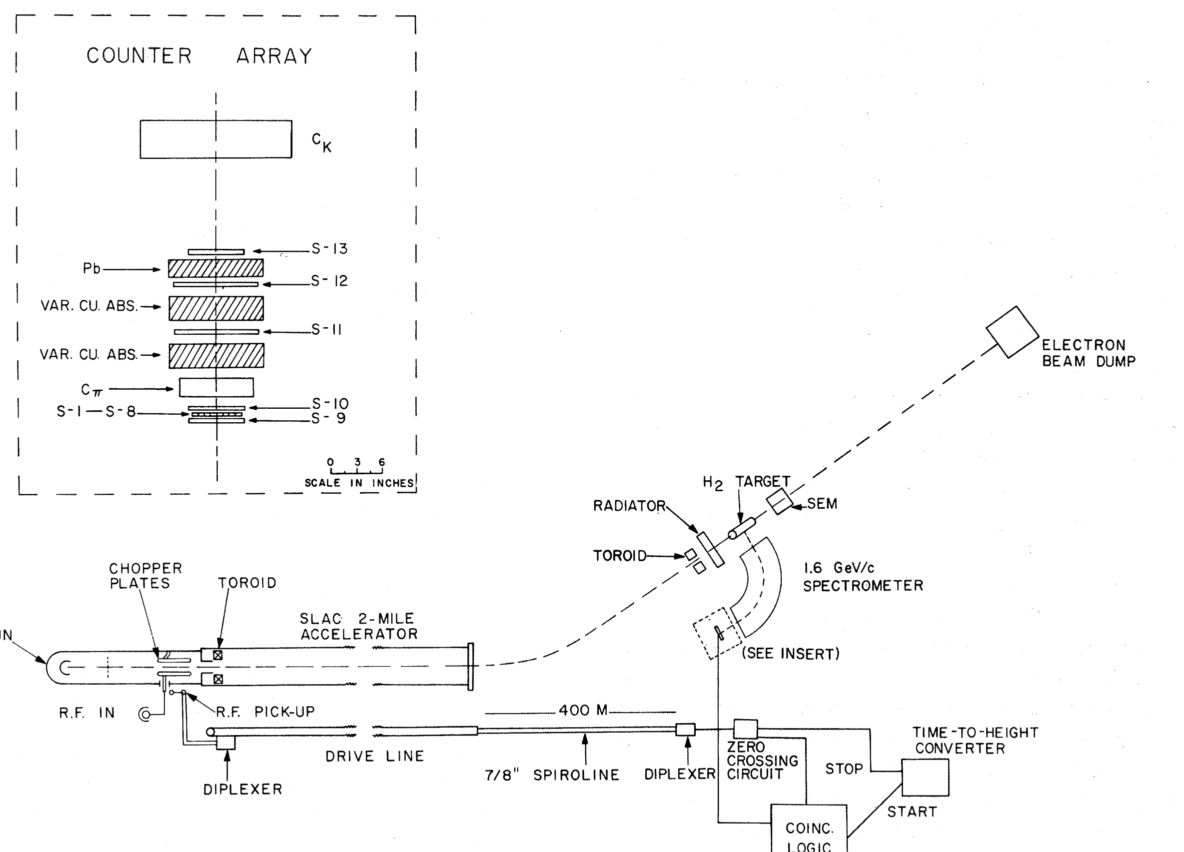

FIG. 1. The experimental setup including the time-of-flight system. The counter system is shown in the insert.