little phase variation is observed between $1^+ K^*\pi$ waves and the structureless $0^- 0^+ K^*\pi$ wave[9] as expected of "Deck" mechanisms.[6]

The large increase in statistics of the present experiment has allowed a partial-wave analysis to be performed in much finer mass intervals, revealing distinct structure heretofore undetected. In particular, intensity and phase variations with widths $\lesssim 200$ MeV have been observed. These effects may be interpreted as due to the existence of two 1^+ mesons Q_1 and Q_2, in accord with the multiplet structure implied by the quark model. These states would presumably be mixtures of Q_A and Q_B, the octet partners of the A_1 and B.

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†Now at Physics Department, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

‡Now at Physics Department, Carleton University, Ottawa, Ont., Canada K15 5B6.

§Now at Physics Department, Oxford University, Oxford, England.

‖ Now at Laboratoire de l'Accelerateur Lineaire, Orsay, France.

¶Now at Physics Department, Michigan State University, East Lansing, Mich. 48823.

**Now at TRIUMF, University of British Columbia, Vancouver, B. C., Canada V6T 1W5.

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Production Properties of Q Mesons in $K^{\pm}p \to K^{\pm}\pi^+\pi^- p$ at 13 GeV*

G. W. Brandenburg,† R. K. Carnegie,‡ R. J. Cashmore,§ M. Davier,‖ W. M. Dunwoodie, T. A. Lasinski, D. W. G. S. Leith, J. A. J. Matthews,¶ P. Walden,** S. H. Williams, and F. C. Winkelmann‡

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

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The momentum transfer (t') dependence of the $J^P = 1^+$ $K^*\pi$ and ρK partial waves in the $K^{\pm}\pi^+\pi^-$ system is presented. The production of the Q_1 meson ($m \sim 1300$ MeV), which has a large ρK decay mode, obeys approximate s-channel helicity conservation. In contrast the production of the Q_2 meson ($m \sim 1400$ MeV), which decays predominantly to $K^*\pi$, satisfies approximate t-channel helicity conservation. Furthermore the $Q_1^{\pm}$ production distributions are virtually identical, whereas the $Q_2^{\pm}$ distributions exhibit a distinct crossover for $|t'| \sim 0.18$ GeV^2.

In the previous Letter,[1] the results of a partial-wave analysis investigating the spin and parity structure of the $K\pi\pi$ system were presented as a function of mass for the reactions

$$K^{\pm}p \to K^{\pm}\pi^+\pi^- p \qquad (1)$$

at 13 GeV. Definite structure was observed in the intensity and phase variation of the 1^+ partial waves and was interpreted as evidence for the existence of the two strange 1^+ Q mesons expected from the quark model. The Q_1 meson at ~ 1300 MeV was observed to have a large ρK decay, while the Q_2 meson at ~ 1400 MeV decays predominantly to $K^*\pi$. In addition, a large low-mass peak in the 1^+ $K^*\pi$ system near 1200 MeV was ascribed to a "Deck" mechanism.

In this Letter the t' dependence of the partial waves associated with these structures in the mass spectrum is presented. The production properties are studied in three regions: Region (I),

$$1.16 < m(K\pi\pi) < 1.28 \text{ GeV},$$

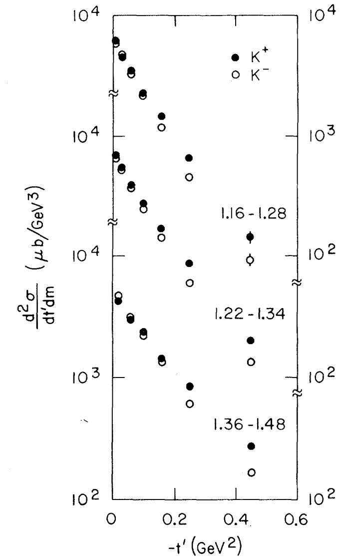

FIG. 1. Total differential cross sections for the indicated $K\pi\pi$ mass regions (GeV).

Region (II),

$$1.22 < m(K\pi\pi) < 1.34 \text{ GeV},$$

and Region (III),

$$1.36 < m(K\pi\pi) < 1.48 \text{ GeV},$$

in order to emphasize the "Deck" aspects of the data (I), the lower mass resonance Q_1 (II), and the upper resonance Q_2 (III).

The data were obtained using a wire spark-chamber spectrometer system[1,2] in an experiment in which rf-separated 13-GeV $K^\pm$ beams were incident on a 1-m liquid hydrogen target. The spectrometer measured the forward mesons from Reactions (1), and K/π identification was achieved by means of a multicell Cherenkov counter. The spectrum of missing mass opposite the reconstructed $K\pi\pi$ system shows a clean proton peak, and events of Reactions (1) are selected by requiring $0.74 < MM < 1.10$ GeV. In order to minimize the relative normalization uncertainty associated with possible changes in the characteristics of the apparatus, periods of K^+ and K^- data collection were interleaved. In addition the large samples of $K^\pm \to \pi^\pm\pi^+\pi^-$ beam decays obtained under the trigger conditions for Reactions (1) permit detailed studies of apparatus efficiency effects and yield a direct measurement of the K^+/K^- relative normalization which is uncertain to $\pm 2\%$.

To determine the production properties of the two Q mesons and the Deck background, a partial-wave analysis of the $K\pi\pi$ system has been performed as a function of t' for each of mass Regions (I), (II), and (III). The partial-wave notation is that of Ref. 1. Each wave is labeled by J^PM^η Iso, where J^P is the $K\pi\pi$ spin and parity, M the magnetic substate, η the exchange naturality, and Iso denotes the isobar ($K^*, \rho, \kappa, \epsilon$). The production cross sections were measured by util-

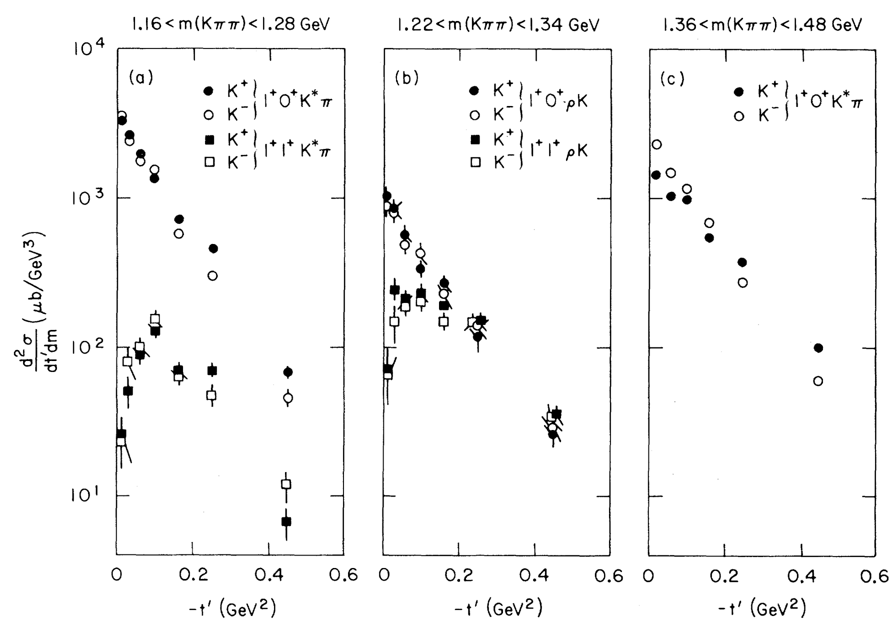

FIG. 2. The principal 1^+ t-channel partial waves as a function of t' for (a) the low-mass "Deck" region for 1^+ $K^*\pi$, (b) the Q_1 region for 1^+ ρK, and (c) the Q_2 region for 1^+0^+ K^* (1^+1^+ $K^*\pi$ is negligibly small).

TABLE I. The 1^+0^+ $K^*\pi$ parameter values from fits of $A\exp(bt')$ to the data with $|t'|<0.6$ GeV^2.

$\Delta m(K\pi\pi)$ (GeV)	Beam	A (mb/GeV^3)	b (GeV^{-2})	χ^2
1.16 – 1.28	K^+	3.39 ± 0.11	8.8 ± 0.2	20
	K^-	3.47 ± 0.12	9.9 ± 0.3	25
1.22 – 1.34	K^+	2.89 ± 0.09	7.9 ± 0.2	4.4
	K^-	3.01 ± 0.10	9.5 ± 0.3	3.1
1.36 – 1.48	K^+	1.60 ± 0.06	6.1 ± 0.2	7.2
	K^-	2.67 ± 0.09	8.6 ± 0.2	5.3

TABLE II. The 1^+ ρK parameter values from fits of $A|t'|^M\exp(bt')$ to the data in the region $1.22<m(K\pi\pi)<1.34$ GeV for $|t'|<0.6$ GeV^2.

Wave	Beam	A[a]	b (GeV^{-2})	χ^2
1^+0^+ ρK	K^+	1.00 ± 0.08	8.3 ± 0.6	6.7
	K^-	0.90 ± 0.08	7.7 ± 0.6	3.0
1^+1^+ ρK	K^+	6.70 ± 0.64	9.9 ± 0.5	8.9
	K^-	5.25 ± 0.68	9.6 ± 0.7	5.3

[a] Units mb/GeV^3 for 1^+0^+ and mb/GeV^5 for 1^+1^+.

izing the wave set and solutions of Ref. 1 in discrete t' bins. The parameters of three mass bins of Ref. 1 within each of Regions (I), (II), and (III) were used as starting points for the likelihood fits. In general the fitting procedure converged to the same parameter values in a given region and t' bin; in particular, this was true for various starting points within the K^- ambiguous region,[1] $1.14 \leq m(K\pi\pi) \leq 1.25$ GeV.

The differential cross sections for Reactions (1) are shown in Fig. 1 for Regions (I)–(III). The K^- distribution is always steeper than the K^+, and for both K^+ and K^- the differential cross section becomes less steep with increasing mass. There is no obvious crossover in Regions (I) and (II), although one may exist in Region (III). All distributions exhibit significant curvature.

The t-channel production distributions for the 1^+ $K^*\pi$ waves in Regions (I) and (III) and for the 1^+ ρK waves in Region (II) are shown in Fig. 2. The individual partial-wave t' distributions are, for the most part, well described by the form $A\exp(bt')$ with the parameters given in Tables I and II; this is in contrast with the t' dependence of the total cross sections.[3] The $M=1$ waves for both $K^*\pi$ and ρK exhibit a forward turnover, which is characteristic of amplitudes involving one unit of net helicity change.

There is a dramatic change in the production of the 1^+ $K^*\pi$ system as the $K\pi\pi$ mass increases from 1.22 to 1.42 GeV [Figs. 2(a) and 2(c)]. The amount of 1^+1^+ $K^*\pi$, already small compared to 1^+0^+ $K^*\pi$ in Region (I), decreases with mass; that is, t-channel helicity conservation is a better approximation at higher $K\pi\pi$ mass. For the 1^+0^+ $K^*\pi$ wave, the K^- slopes (Table I) are larger than the K^+; however, the difference in slope increases with mass, contrary to the prediction of "Deck" models.[4] While no crossover is evident in Region (I) or Region (II) (not shown), a clear K^+,K^- crossover is observed in Region (III) at $t'\sim 0.18$ GeV^2. This crossover implies the presence of $C=+1$ *and* $C=-1$ exchange contributions in the production of the 1^+ $K^*\pi$ system in the Q_2 region.

The production of the 1^+ ρK system associated with the Q_1 meson [Fig. 2(b)] presents a striking contrast to that of 1^+ $K^*\pi$. The 1^+1^+ ρK and 1^+0^+ ρK waves are of comparable strength in the t channel for $t' \gtrsim 0.10$ GeV^2. However, in the s-channel system (Fig. 3), the 1^+1^+ ρK wave is only ~10% of the 1^+0^+ ρK in intensity, indicating approximate s-channel helicity conservation.[5,6] In addition the $K^\pm$ differential cross sections are the same within error (Table II). This last observation implies that for each nucleon helicity state either the ρK system is produced by pure charge-conjugation exchange ($C=+1$ or $C=-1$)

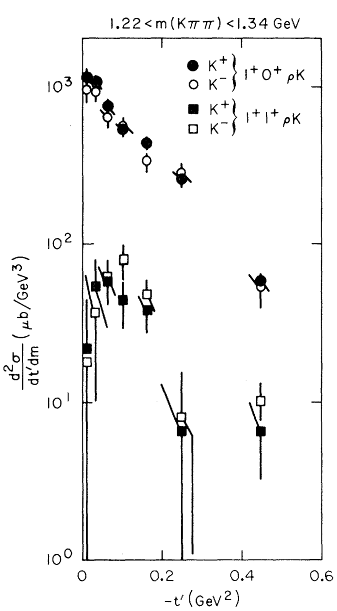

FIG. 3. The t' dependence of the 1^+ ρK system in the s channel, obtained by transformation of the t-channel data.

or the $C=\pm 1$ contributions are 90° out of phase. However, the relative phase of the ρK system with respect to the 1^+0^+ $K^*\pi$ wave is essentially the same[1,7] for K^+ and K^-. With the assumptions that 1^+0^+ $K^*\pi$ in Region (II) is produced predominantly by $C=+1$ exchange and nucleon helicity nonflip, it may be inferred that the ρK system is also produced by $C=+1$ exchange for the nucleon nonflip amplitude.

In summary, the production properties of the 1^+ $K\pi\pi$ system change dramatically as $m(K\pi\pi)$ increases from 1.2 to 1.5 GeV. For the 1^+ $(K^*\pi)^\pm$ systems, the slope difference increases, t-channel helicity conservation becomes a better approximation, and a crossover develops with increasing $K\pi\pi$ mass. These features are inconsistent with the predictions of a π-exchange "Deck" mechanism.[4] Rather they are more probably associated with the fact that in Region (III), the $K^*\pi$ amplitude involves both Q_2 and "Deck" contributions. In contrast the 1^+ $(\rho K)^\pm$ systems at ~1.3 GeV exhibit approximate s-channel helicity conservation and the nucleon helicity-nonflip amplitude corresponds mainly to $C=+1$ exchange. These contrasting production features of the 1^+ ρK and 1^+ $K^*\pi$ systems are strongly correlated with the structure observed in the mass spectra of Ref. 1. Thus, they underscore the interpretation of the 1^+ $K\pi\pi$ system in terms of two distinct axial-vector states, the $Q_1(1300)$ and $Q_2(1400)$ mesons.

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†Now at Physics Department, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

‡Now at Physics Department, Carleton University, Ottawa, Ont., Canada K1S 5B6.

§Now at Physics Department, Oxford University, Oxford, England.

‖Now at Laboratoire de l'Accelerateur Lineaire, Orsay, France.

¶Now at Physics Department, Michigan State University, East Lansing, Mich. 48823.

**Now at TRIUMF, University of British Columbia, Vancouver, B. C., Canada V6T 1W5.

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