SLAC-PUB-1014
(TH) and (EXP)
February 1972

OBSERVATION OF A CROSSOVER IN THE DIFFERENTIAL CROSS SECTIONS FOR Q MESON PRODUCTION*

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ABSTRACT

A crossover is observed in the differential cross sections for the inelastic processes $K^o p \rightarrow Q^o p$ and $\bar{K}^o p \rightarrow \bar{Q}^o p$, from $K_L^o p$ data in the momentum range from 4 to 12 GeV/c. This phenomenon is evidence that Regge, in addition to Pomeron, exchanges contribute to Q meson production.

(Submitted to Phys. Rev. Letters.)

*Work supported by the U. S. Atomic Energy Commission.

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One of the well known features of elastic scattering is the "crossover" phenomenon where the differential cross sections for the reactions $Xp \rightarrow Xp$ and $\bar{X}p \rightarrow \bar{X}p$ (X is π^+, K^+, or p) have different forward slopes but become equal in magnitude in the vicinity of $-t \sim 0.2\ GeV^2$.[1] The crossover effect recently has been interpreted as a sensitive probe of the Regge exchange contribution to the elastic scattering amplitude.[2]

In this letter we report the first experimental observation of the crossover phenomenon in inelastic reactions. A K^o_L beam (with equal components of K^o and $\bar{K}^o$ mesons) has been used to obtain a precise comparison of the Q^o and $\bar{Q}^o$ differential cross sections free from problems of relative normalization. The reactions studied are

$$K^o p \rightarrow Q^o p \quad , \qquad (1)$$

and

$$\bar{K}^o p \rightarrow \bar{Q}^o p \quad , \qquad (2)$$

where Q ($\bar{Q}$) represents the wide $K\pi\pi$ mass enhancement centered near 1300 MeV and observed previously in many $K^{\pm}p$ experiments.[3] The data from reactions (1) and (2) are selected from the final state

$$K^o_L p \rightarrow K^o_S p \pi^+ \pi^- \quad , \qquad (3)$$

as observed in the SLAC 40-inch hydrogen bubble chamber. The Q region is defined by $1100 < M(K\pi\pi) < 1500$ MeV. The Q^o ($\bar{Q}^o$) events are selected by requiring $860 < M(K^o_S\pi^+) < 920$ MeV ($860 < M(K^o_S\pi^-) < 920$ MeV). Events in the K*(890) overlap are excluded and the $\Delta^{++}(1236)$ signal is removed by requiring $M(p\pi^+) > 1340$ MeV. With these selections the contamination from K*(1420) events in the Q region is less than 5%. The present results are based on approximately 400 events each for $Q^o p$ and $\bar{Q}^o p$ over the momentum range from 4 to 12 GeV/c. A more complete description of reaction (3) is presented elsewhere.[4]

The differential cross sections for reactions (1) and (2) are presented in Fig. 1.[5] The data are plotted versus $t' = t - t_{min}$, where $|t_{min}|$ is the minimum momentum transfer squared to the proton for a given $K\pi\pi$ mass. Both reactions are well described by fits to a single exponential of the form $\frac{d\sigma}{dt'} = \left(\frac{d\sigma}{dt'}\right)_0 \exp(Bt')$. Neither reaction shows a forward turnover.[6] The slopes of the forward peaks are quite different from each other, with $B = 5.9 \pm 0.5$ GeV^{-2} for Q^0p and $B = 9.7 \pm 0.7$ GeV^{-2} for $\bar{Q}^0p$. The crossover position is $-t' = 0.13 \pm 0.03$ GeV^2. We have also examined the slope parameters as a function of beam momentum and find that they are consistent with being independent of energy. We note that these features of Q production are in qualitative agreement with Kp elastic scattering data. In particular, for the momentum interval 5 - 10 GeV/c elastic K^+p and K^-p differential cross sections have slopes $B \sim 5.5$ and 7.5 GeV^2, respectively,[7] and a crossover point near $-t \sim 0.2$ GeV^2.

It is generally believed that the Pomeron contribution to elastic scattering is the same for $Xp \rightarrow Xp$ and $\bar{X}p \rightarrow \bar{X}p$. Assuming that this is also the case for "diffraction-dissociation" processes, one expects identical differential cross sections for $K^0p \rightarrow Q^0p$ and $\bar{K}^0p \rightarrow \bar{Q}^0p$. In contradiction to this prediction, the data in Fig. 1 exhibit significantly different slopes. In analogy to $K^{\pm}p$ elastic scattering we interpret this difference as arising from a Regge exchange contribution to the Q production amplitude.

To test this hypothesis we employ the procedure of Davier and Harari[2] to obtain an estimate for the magnitude of the Regge exchange amplitude to Q production. It is assumed that the Pomeron contribution to Q and $\bar{Q}$ production is purely imaginary and that duality constrains the Regge contribution to the exotic $Kp \to Qp$ process to be predominantly real. Writing the Pomeron amplitude as P and the Regge amplitude as R, we have (neglecting terms in R^2):

$$\frac{d\sigma}{dt'}(Qp) = \sum_\lambda |P_\lambda|^2 \quad ,$$

$$\frac{d\sigma}{dt'}(\bar{Q}p) = \sum_\lambda |P_\lambda + R_\lambda|^2 \simeq \sum_\lambda \left(|P_\lambda|^2 + 2P_\lambda \, \mathrm{Im}\, R_\lambda\right) \, ,$$

where the symbol λ represents all possible helicities. In the analysis of elastic scattering by Davier and Harari the assumption of s channel helicity conservation reduces the above summation to a single term. However, in diffraction dissociation, s channel helicity is not conserved at the meson vertex.[4,8] Therefore in Q and $\bar{Q}$ production the above summations involve several s channel helicities and we cannot extract individual Regge amplitudes without polarization information at the baryon vertex. In order to obtain an estimate of the Regge contribution, we define the average:

$$\langle \mathrm{Im}\, R \rangle \equiv \frac{\sum_\lambda P_\lambda \, \mathrm{Im}\, R_\lambda}{\left[\sum_\lambda |P_\lambda|^2\right]^{\frac{1}{2}}} = \frac{\frac{d\sigma}{dt'}(\bar{Q}p) - \frac{d\sigma}{dt'}(Qp)}{2\left[\frac{d\sigma}{dt'}(Qp)\right]^{\frac{1}{2}}}$$

This amplitude,[9] evaluated from the experimental data, is displayed in Fig. 2. The curve in Fig. 2 is taken from the exponential fits shown in Fig. 1 (Ref. 10):

$$\langle \mathrm{Im}\, R \rangle = \frac{1.36 \exp(9.7\, t') - 0.83 \exp(5.9\, t')}{2\left[0.83 \exp(5.9\, t')\right]^{\frac{1}{2}}} \ \mathrm{mb}^{\frac{1}{2}}\, \mathrm{GeV}^{-1} \quad .$$

From the preceding analysis we observe

a. $|\langle \mathrm{Im}\, R \rangle|^2 / |P|^2 \sim 0.11$ at $t'=0$ for our mean beam momentum ~ 7 GeV/c. This can be compared to the ratio of ~ 0.14 obtained for $K^{\pm}p$ elastic data at 5 GeV/c;[2]

b. $|\langle \mathrm{Im}\, R \rangle|^2 \sim 0.4$ mb/GeV^2 at $t'=0$ when corrections are made for the unobserved decay modes of the neutral Q meson.[5] The Regge contributions to neutral Q production are expected to be predominantly isoscalar (ω^o, f^o). For comparison, the reaction $K_L^o p \rightarrow K_S^o p$, which is dominated by ω^o exchange, has a forward differential cross section ~ 0.3 mb/GeV^2 at 7 GeV/c.[11] Other Regge exchange reactions, such as $\pi^- p \rightarrow \pi^o n$ (Ref. 12) (charge exchange) or $\pi N \rightarrow \Sigma K$ (Ref. 13) (hypercharge exchange), also have similar values for the forward differential cross section over the range 5-10 GeV/c;

c. the integral, $\int dt' |\langle \mathrm{Im}\, R \rangle|^2 \sim 30\ \mu$b. Therefore we expect that Q production in charge or hypercharge exchange channels will have cross sections on the order of 30 μb in the momentum range 5 - 10 GeV/c.

In summary we observe a crossover in the differential cross sections for $K^o p \rightarrow Q^o p$ and $\bar{K}^o p \rightarrow \bar{Q}^o p$. In analogy with elastic scattering, we interpret the crossover as the result of a significant Regge contribution to the Q production amplitude.

We thank F. Gilman, R. Cashmore, and M. Davier for interesting discussions. We are grateful for the assistance given to us by R. Watt and the crew of the SLAC 40-inch bubble chamber and by J. Brown and the scanning and measuring staff at SLAC.

References and Footnotes

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2. M. Davier and H. Harari, Phys. Letters 35B, 239 (1971).

3. For example, see the review: A. Firestone, Experimental Meson Spectroscopy, ed. Baltay and Rosenfeld (Columbia University Press, New York, 1970); p. 229.

4. G. Brandenburg et al., to be published.

5. The ordinate scale of Fig. 1 is determined for neutral Q's decaying into $K_S^o \pi^+ \pi^-$, where all decay modes of the K_S^o are included. When all other possible decay modes of the Q^o (or $\overline{Q}^o$) are considered, the cross sections are increased by a factor ~ 5. The exact correction factor is $18/(4-\alpha)$ where α is the branching ratio $K\rho/(K\rho + K^*\pi)$.

6. The data for $|t'|$ less than 0.02 GeV^2 are not shown in Fig. 1 since, for part of the momentum region studied, the recoil protons in this t' interval are unobservable in the hydrogen bubble chamber.

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9. One may interpret $\langle \mathrm{Im}\, R \rangle$ as being approximately the helicity nonflip t channel Regge amplitude since t channel helicity is nearly conserved and there is no evidence for a forward turnover in the differential cross section for diffraction dissociation processes.

10. Over the t' range studied, we note that an almost indistinguishable curve is obtained using the parameterization form of Ref. 2: $\langle \mathrm{Im}\, R \rangle = 0.3 \exp(0.7\, t')\, J_0(6.5\sqrt{-t'})\ \mathrm{mb}^{\frac{1}{2}}\ \mathrm{GeV}^{-1}$. As cautioned in the text, the factor of 6.5 GeV^{-1} cannot be simply interpreted as an interaction radius.

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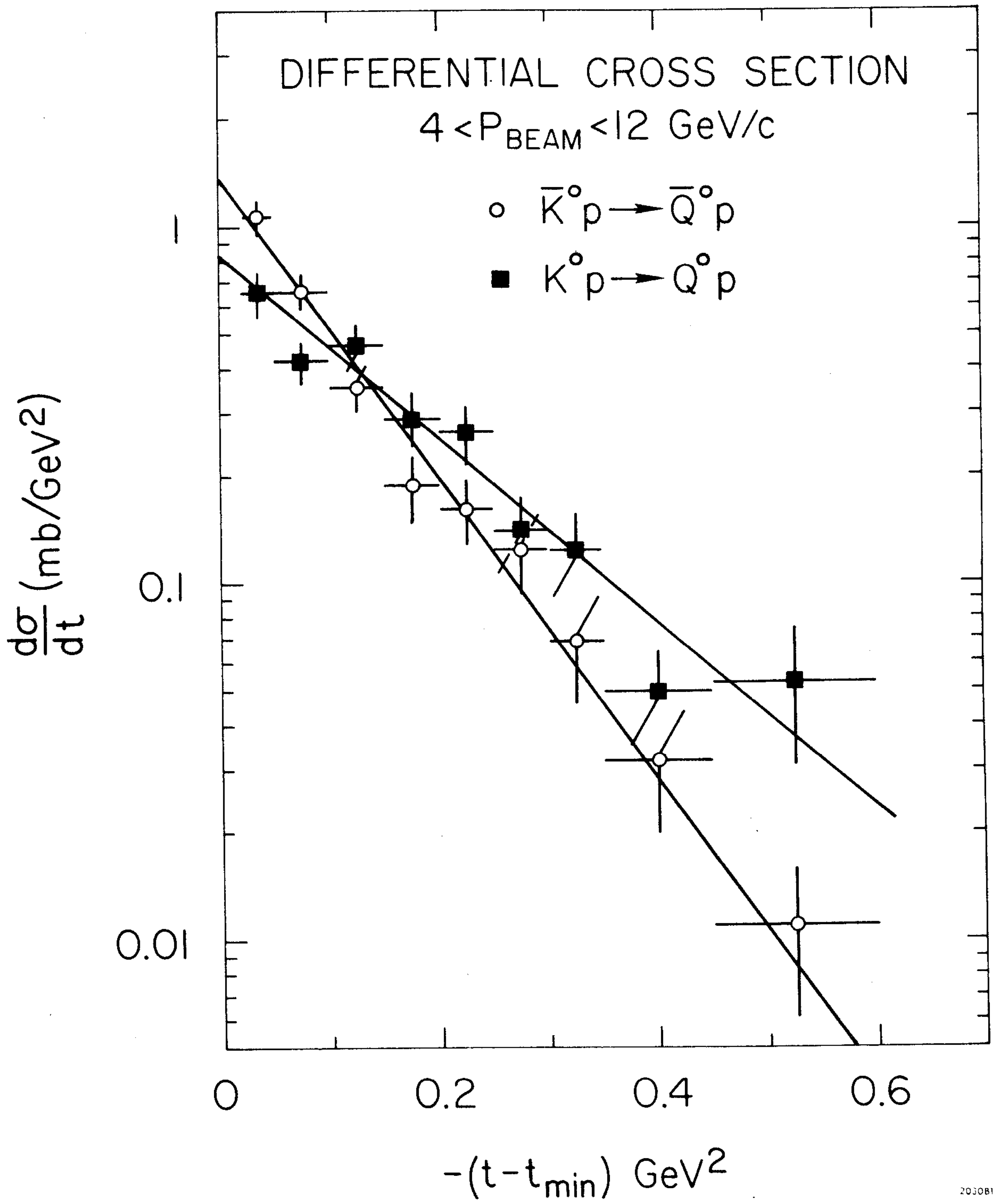
Figure Captions

1. Differential cross sections for $K^o p \rightarrow Q^o p$ (♦) and $\bar{K}^o p \rightarrow \bar{Q}^o p$ (◊) over the momentum range 4 to 12 GeV/c. The scale of the ordinate is determined for neutral Q mesons decaying into $K_S^o \pi^+ \pi^-$. The curves result from the following exponential fits: $\frac{d\sigma}{dt'}(Q^o p) = 0.83 \exp(5.9\, t')\ \mathrm{mb/GeV}^2$, and $\frac{d\sigma}{dt'}(\bar{Q}^o p) = 1.36 \exp(9.7\, t')\ \mathrm{mb/GeV}^2$.

2. $\langle \mathrm{Im}\, R \rangle$ determined from the difference between the $Q^o p$ and $\bar{Q}^o p$ differential cross sections (see text). The curve is obtained from the exponential fits shown in Fig. 1.



DIFFERENTIAL CROSS SECTION
4 < P_BEAM < 12 GeV/c
○ K̄°p → Q̄°p
■ K°p → Q°p
dσ/dt (mb/GeV²)
1
0.1
0.01
0
0.2
0.4
0.6
-(t-t_min) GeV²
2030B1

Fig. 1

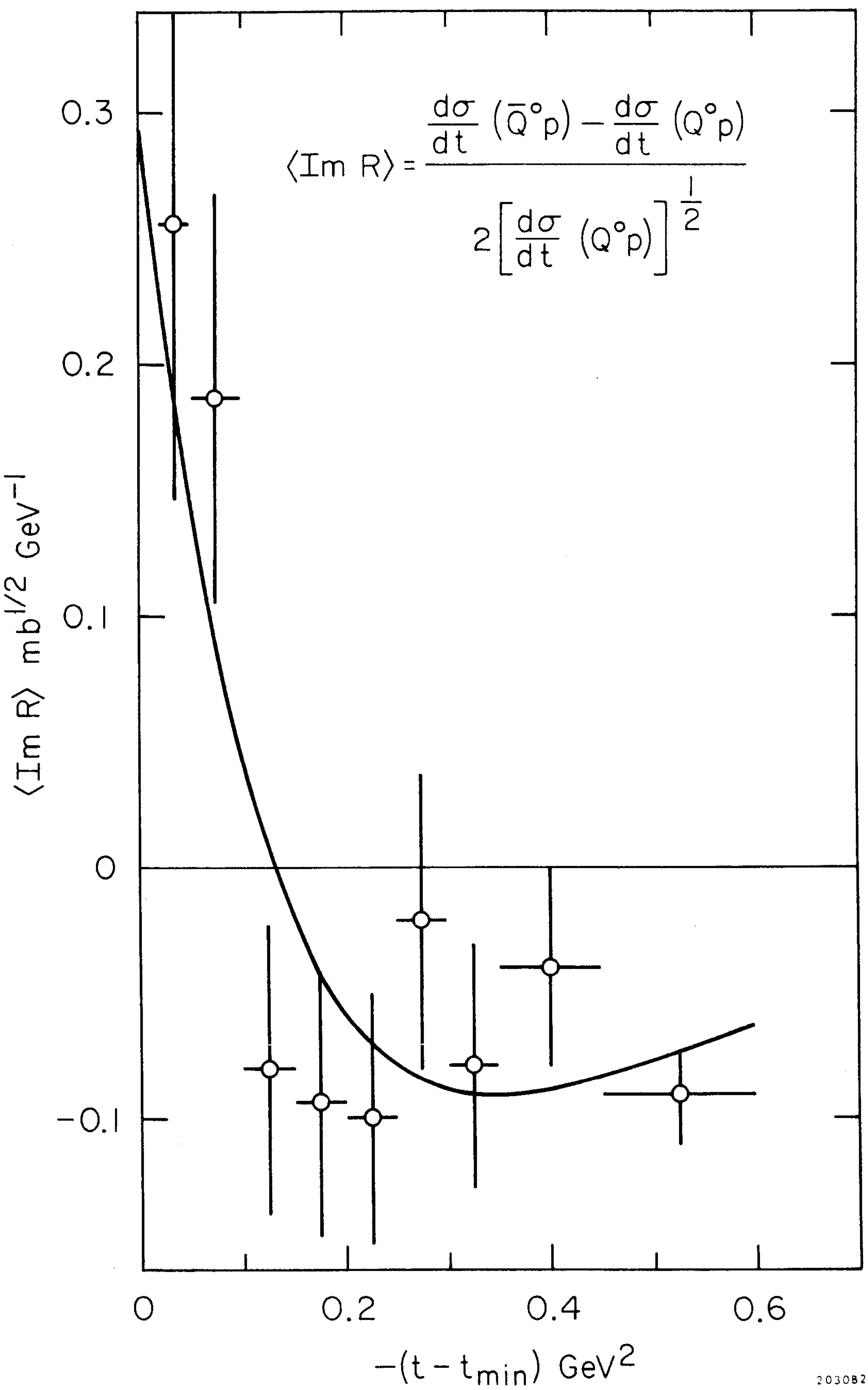

0.3
0.2
0.1
0
-0.1
$\langle \mathrm{Im}\, R \rangle$ mb$^{1/2}$ GeV^{-1}
$\langle \mathrm{Im}\, R \rangle = \dfrac{\frac{d\sigma}{dt}(\bar{Q}^{\circ}p) - \frac{d\sigma}{dt}(Q^{\circ}p)}{2\left[\frac{d\sigma}{dt}(Q^{\circ}p)\right]^{\frac{1}{2}}}$
0
0.2
0.4
0.6
$-(t - t_{min})$ GeV^2
203082

Fig. 2