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A STUDY OF THE SLOPE-MASS CORRELATION IN THE LOW MASS $K\pi\pi$ SYSTEM*

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ABSTRACT

The shape of the four-momentum transfer t' distribution in the reactions $K^{\pm}p \to K^{\pm}\pi^{+}\pi^{-}p$ at 13 GeV/c is studied for various partial waves as a function of the $K\pi\pi$ mass. Strong variation of the slope with effective mass is observed for the dominant $J^P = 1^+$ waves. For natural parity exchange it is found that, for $K\pi\pi$ masses up to 1.6 GeV, the slope of the t' distribution is decreasing with increasing spin of the excited system, $B_{0^-} > B_{1^+} > B_{2^+}$.

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In the production of low mass diffractive objects it is well known that the shape of the four-momentum transfer distribution strongly depends on the mass of the produced system [1,2]. The experimental differential cross sections are usually well described in the small t' region by the exponential function

$$\frac{d\sigma}{dt'} = Ae^{Bt'} \quad . \tag{1}$$

Near threshold the value of the slope B is usually much higher than the slope of elastic scattering processes and then decreases with increasing mass of the excited system.

The idea of geometrical scaling and the success of the "b universality" hypothesis in describing pp interactions at high energies [3,4] has created a picture of diffractive processes in which all the contributing partial waves have a universal impact parameter distribution, or, in other words, their amplitudes may be parametrized as

$$T^{i}_{\Delta\lambda}(s,t') = A_i(s)J_{\Delta\lambda}(R\sqrt{-t'})e^{\frac{b}{2}t'} \quad . \tag{2}$$

Individual amplitudes have no slope-mass correlation. The variation of the overall t' distribution with mass is explained in such a picture by the increasing contribution of helicity flip amplitudes with increasing mass [5].

In contrast, reggeized Deck model calculations [6] present the slope-mass correlations for individual partial waves as a consequence of the doubly peripheral structure in the momentum transfer of the Deck diagrams. Absorptive effects enhance the correlation by sharpening the distribution $d\sigma/dt'$ near threshold [7].

In this paper we present results on the slope-mass correlation of the individual partial waves contributing to the reactions

$$K^{\pm}p \rightarrow K^{\pm}\pi^{+}\pi^{-}p \qquad (3)$$

at 13 GeV/c for $K\pi\pi$ mass < 1.6 GeV and $|t'| \leq 0.6$ $(\text{GeV}/c)^2$. In addition we shall examine how the slope parameter, B, depends upon the quantum numbers involved: total spin, helicity, orbital angular momentum, or the final-state isobar. The experiment was performed with a magnetic spectrometer at SLAC using rf separated kaon beams at 13 GeV/c and is described in refs. [8,9,10]. The details of the partial wave analysis and main results of the study of mass distributions are published in refs. [9,10,11]. The cross sections of some of the important partial waves are presented in table 1 for $K\pi\pi$ mass intervals of 120 MeV and compared to the total $K\pi\pi$ cross section.

The partial wave analysis was performed in the t channel coordinate system. Subsequently spin density matrix elements were transformed to the s channel in each of the mass and t' intervals, permitting simultaneous study of the t' distributions in both s and t channels.

The s channel t' distributions for some representative partial waves are presented in fig. 1 for the mass interval 1.36 - 1.48 GeV. These, as well as all other t' distributions, are well described by the exponential formula

$$\left(\frac{d\sigma}{dt'}\right)_i = A_i |t'|^M \exp\,(B_i t') \ . \qquad (4)$$

Here i denotes the partial wave quantum numbers $J^P M^\eta$ and isobar in the final state; M describes the helicity flip at the kaon vertex. When the helicity flip at the proton vertex is zero, M is equal to $\Delta\lambda$, the net helicity flip of the reaction.* The lines shown in fig. 1 correspond to fits with equation (4). For all the partial waves in all mass bins, no significant structure is observed in the t' range

* We note that all 0^- waves are well described by a single exponential function, i.e., equation (4) with M = 0, which indicates that the contribution of proton helicity flip is small, at least for these waves.

studied except for the dip at $t' = 0$ for waves with $M \geq 1$. As a consequence fits with the parametrization of equation (2) indicate R values smaller than 0.6 fermi for all dominant partial waves. This may be contrasted with the measured value of R for proton diffraction, which is ~ 1 fermi [1,4].

In fig. 2 we present the slope B of the $1^+K^*\pi$ waves in both s and t channels. As can be seen, for both K^+ and K^- beams the value of B decreases rapidly as the $K\pi\pi$ mass increases from 1.0 to 1.6 GeV. The $1^+K^*\pi$ contribution is dominant for the $K\pi\pi$ mass range studied. Therefore, its mass dependence is largely responsible for the overall t' behavior, despite the fact that the t' dependence of other waves is drastically different (see fig. 1). For comparison the bands in fig. 2 represent the slope-mass dependence in the K^+p and K^-p total $K\pi\pi$ cross section. It is interesting to note that the slope for the $1^+1^+K^*\pi$ wave shows the same trend as that of $1^+0^+K^*\pi$ wave. However, the values differ by about 2 units for most of the mass bins studied. This observation is in disagreement with the predictions of the "b universality" model [3] in which waves with different M values should have the same slope. A similar but weaker slope-mass correlation is also present in the $1^+K\rho$ and $1^+K\epsilon$ waves.

The obvious difference between the K^+ and K^- slope-mass dependence shown in fig. 2 may be related to the existence of a $1^+0^+K^*\pi$ resonance near 1.4 GeV [10,12] and to the development with mass of a crossover effect [9] in the $K^\pm$ t' distributions.

In fig. 3 we compare the t channel slopes of the 0^- and $2^+1^+K^*\pi$ partial waves with that of $1^+0^+K^*\pi$. The mass range of the 2^+1^+ wave is too small for a conclusion on any mass dependence. It is evident, however, that the $0^-K^*\pi$ wave is strikingly more peripheral than either 1^+0^+ or 2^+1^+ $K^*\pi$ waves throughout our mass region. A similar observation was made for K^- data by Otter et al. [12]. Although measurements in the low mass region are difficult due to the small 0^- cross section, our results for the $0^- K^*\pi$ wave indicate a slope-mass correlation in the K^-p data but a rather flat dependence in the K^+p data. Although the difference between 0^- and 1^+ slopes may be partly related to the existence of the pseudoscalar meson at about 1.4 GeV [11], high values of the slope for all 0^- waves at all masses indicate a more general nature of this observation.

The significant difference in the slope values for the 0^- and 1^+ waves is not confined to the $K^*\pi$ final state. To illustrate this we plot in fig. 4 the values of the t channel slopes fitted with the formula (4) for various partial waves in the mass interval 1.36 - 1.48 GeV. For a given spin, $K^*\pi$ and $K\epsilon$ waves differ in the value of the orbital angular momentum L. The clustering of slope values for a given spin presented in fig. 4 indicates that the value of the slope depends only weakly on L, M, or isobar of the partial wave, but rather depends primarily on the total spin of the meson system, i.e., $B_{0^-} > B_{1^+} > B_{2^+}$.

The slope-mass correlation of the dominant S wave ($1^+0^+K^*\pi$ in our case) was obtained in reggeized Deck model calculations by Berger and Pirilä [7]. Their calculations are in rough agreement with the shape and the absolute values of the $1^+0^+K^*\pi$ slopes in the mass region studied. This model, however, encounters serious difficulties with high values of B for the 0^- waves at higher $K\pi\pi$ masses, and more sophisticated calculations are needed to accomodate this result.

In the study of the t' distributions of the individual partial waves in the low mass $K\pi\pi$ system we have made the following observations:

a) the partial wave data are well described by the exponential function $\sim |t'|^M e^{Bt'}$;

b) the dominant partial wave $(1^+0^+K^*\pi)$ exhibits strong slope-mass correlation which is responsible for the behavior of the overall t' distribution;

c) waves with different M values at the meson vertex (different net helicity flip) have different slope values;

d) 0^- waves are much more peripheral than 1^+ waves even at large $K\pi\pi$ masses;

e) at a given $K\pi\pi$ mass the slope for $\eta = +1$ depends mainly on the total spin of the meson system, namely $B_{0^-} > B_{1^+} > B_{2^+}$.

These observations are in disagreement with the geometrical "b universality" model and indicate that the spin of the excited system and not the net helicity flip of the amplitude is the controlling factor of the four momentum transfer distributions. The reggeized Deck model with absorptive corrections gives a better representation of the data, although here the crucial issue of explaining the mass dependence of the nondominant partial waves remains unresolved.

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References REFERENCES

[1] D.W.G.S. Leith, Diffractive processes, SLAC Summer Institute in Particle Physics, SLAC-PUB-1526 (1975).

[2] D.R.O. Morrison, Rapporteur's talk at Int. Conf. on Elementary Particle Physics, Kiev, 1970.

[3] S. Humble, Nucl. Phys. B76 (1974) 137 and B86 (1975) 285.

[4] H. I. Miettinen, Talk at Int. Conf. on High Energy Physics, Palermo, 1975 (CERN TH2072).

[5] G. Kane, Acta Phys. Pol. B3 (1972) 845.

[6] E. L. Berger, "A critique of the reggeized Deck model," Daresbury study meeting, February 1975.

[7] E. L. Berger and P. Pirilä, Phys. Rev. D 12 (1975) 3448.

[8] G. W. Brandenburg et al., to be submitted to Nucl. Instrum. Methods.

[9] G. W. Brandenburg et al., Phys. Rev. Lett. 36 (1976) 706.

[10] G. W. Brandenburg et al., Phys. Rev. Lett. 36 (1976) 703.

[11] G. W. Brandenburg et al., Phys. Rev. Lett. 36 (1976) 1239.

[12] G. Otter et al., Nucl. Phys. B106 (1976) 77.

Figure Captions

1. Four momentum transfer distributions for the total $K^+\pi^+\pi^-$ cross section and selected partial waves presented in the s channel for the $K^+\pi^+\pi^-$ mass interval 1.36 - 1.48 GeV.

2. Mass dependence of the slope parameter for the $1^+K^*\pi$ waves in t and s channels of the reaction (3). The shaded bands represent the slope of the total $K\pi\pi$ differential cross section for $|t'| < 0.1 (\mathrm{GeV}/c)^2$.

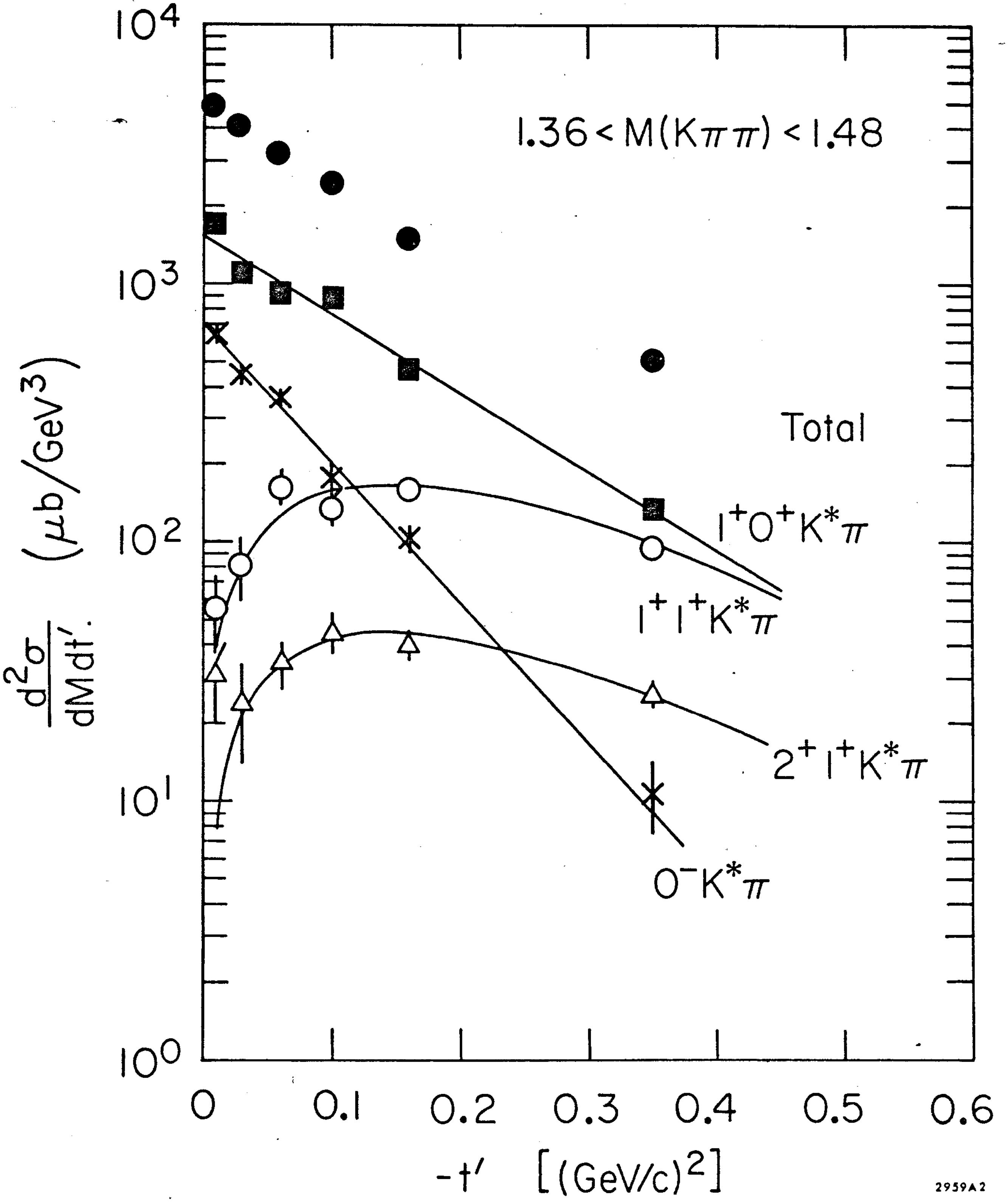
3. Mass dependence of the slope parameter for the 0^-, 1^+0^+, and 2^+1^+ $K^*\pi$ waves in the t channel.

4. Comparison of the slope parameters for the principal partial waves in the t channel for $1.36 < \mathrm{Mass}\ (K\pi\pi) < 1.48$ GeV.

Table 1

Partial cross sections for principal partial waves for $|t'| < 0.6 (GeV/c)^2$ in μb

Mass	Wave	$0^- K^* \pi$	$0^- K \rho$	$0^- K \epsilon$	$1^+ K^* \pi$	$1^+ K \rho$	$1^+ K \epsilon$	$2^+ K^* \pi$	Total $K^\pm \pi^+ \pi^-$
1.00 - 1.12	K^+	0.75 ± 0.21	0.30 ± 0.13	3.20 ± 1.92	10.26 ± 1.17	1.44 ± 0.72	3.00 ± 0.91	0.09 ± 0.06	18.58 ± 2.01
	K^-	0.60 ± 0.17	0.10 ± 0.07	1.50 ± 1.15	9.66 ± 1.15	1.42 ± 0.70	2.39 ± 0.97	0.06 ± 0.06	17.73 ± 1.33
1.12 - 1.24	K^+	3.89 ± 0.61	0.29 ± 0.20	2.31 ± 1.68	43.55 ± 2.74	6.41 ± 1.55	4.67 ± 1.24	0.26 ± 0.14	62.67 ± 2.65
	K^-	2.87 ± 0.53	0.31 ± 0.20	2.28 ± 1.74	43.19 ± 3.05	5.76 ± 1.80	3.64 ± 1.26	0.19 ± 0.14	56.93 ± 2.50
1.24 - 1.36	K^+	7.24 ± 0.97	0.58 ± 0.35	5.76 ± 2.36	43.70 ± 2.81	23.81 ± 2.94	8.46 ± 1.79	0.98 ± 0.34	99.62 ± 3.43
	K^-	6.02 ± 0.84	0.66 ± 0.40	6.61 ± 2.27	40.91 ± 2.91	18.70 ± 2.70	7.51 ± 1.91	0.46 ± 0.27	88.09 ± 3.71
1.36 - 1.48	K^+	6.56 ± 0.78	1.98 ± 0.48	8.20 ± 1.62	31.63 ± 1.87	8.81 ± 1.57	9.86 ± 1.50	3.66 ± 0.43	79.84 ± 2.25
	K^-	5.81 ± 0.76	1.33 ± 0.40	6.26 ± 1.42	35.51 ± 2.09	6.60 ± 1.36	8.43 ± 1.55	3.80 ± 0.58	74.52 ± 2.16
1.48 - 1.60	K^+	3.12 ± 0.53	3.35 ± 0.67	6.50 ± 1.25	8.22 ± 1.09	4.64 ± 1.31	8.23 ± 1.48	0.84 ± 0.31	39.42 ± 1.90
	K^-	2.71 ± 0.59	1.82 ± 0.58	4.54 ± 1.14	7.83 ± 1.13	4.08 ± 1.08	8.75 ± 1.64	1.39 ± 0.42	33.89 ± 1.98



1.36 < M(Kππ) < 1.48
Total
1+0+K*π
1+1+K*π
2+1+K*π
0−K*π
d²σ/dMdt′ (μb/GeV³)
10⁴
10³
10²
10¹
10⁰
0
0.1
0.2
0.3
0.4
0.5
0.6
−t′ [(GeV/c)²]
2959A2

Fig. 1

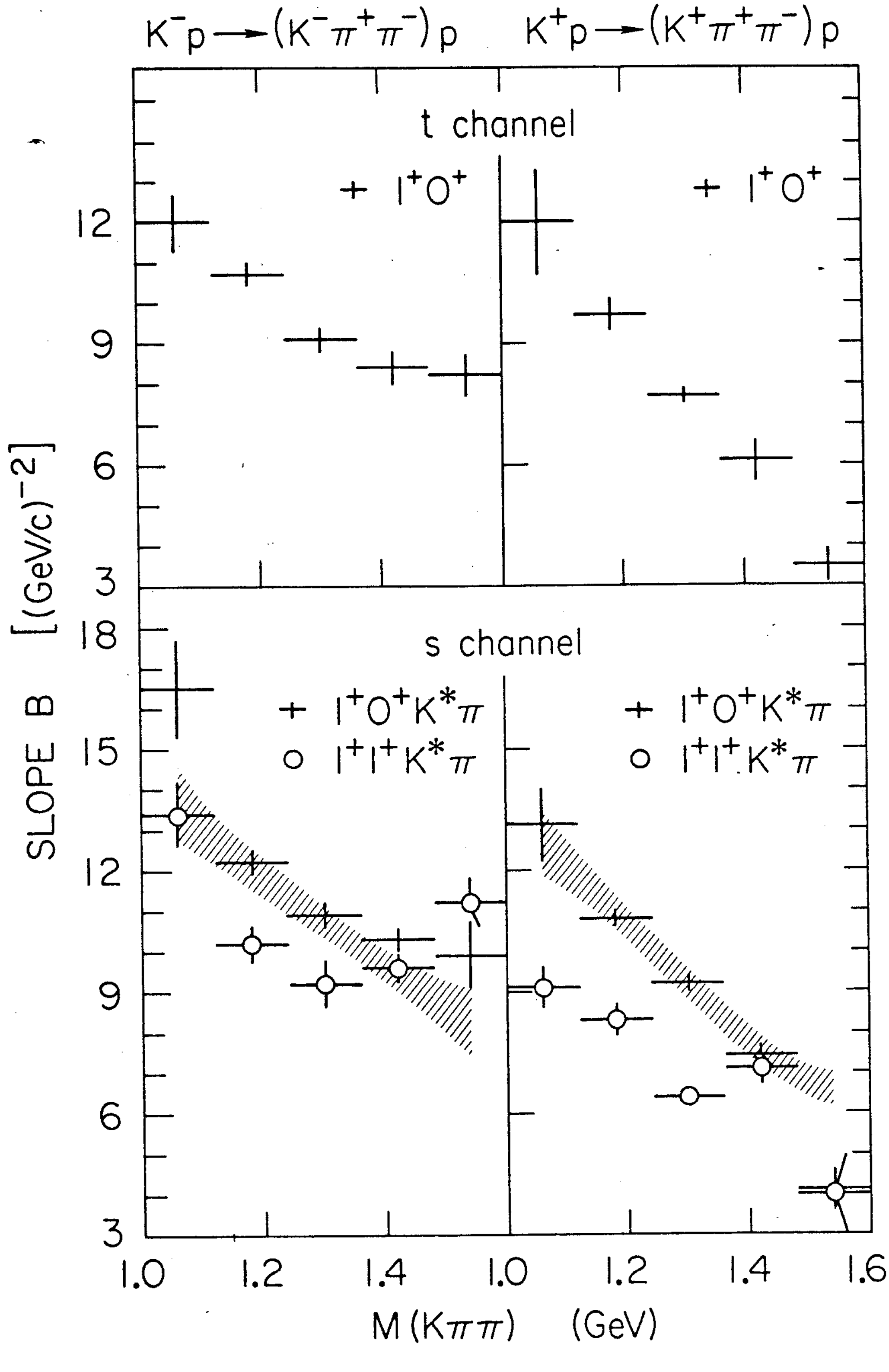
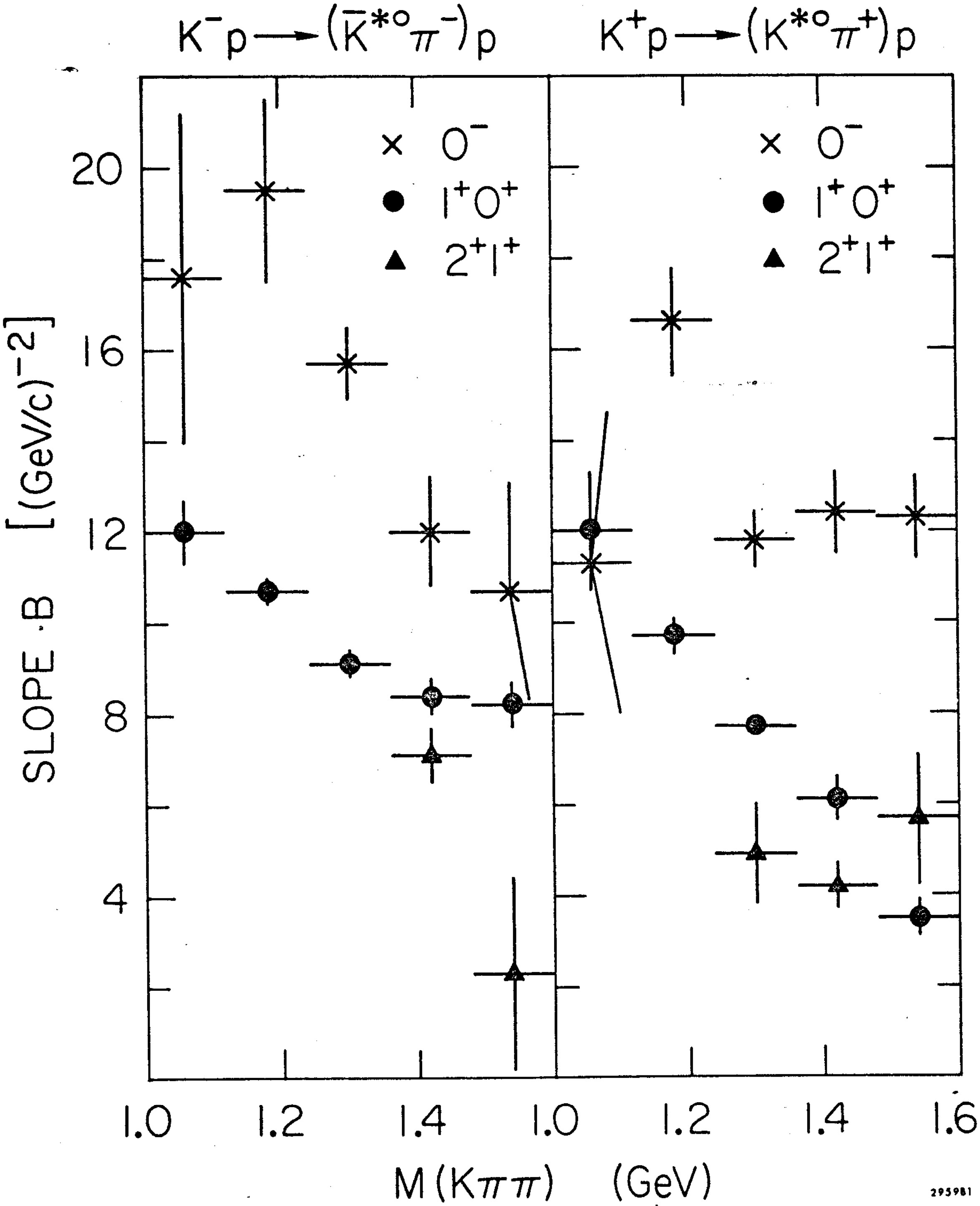
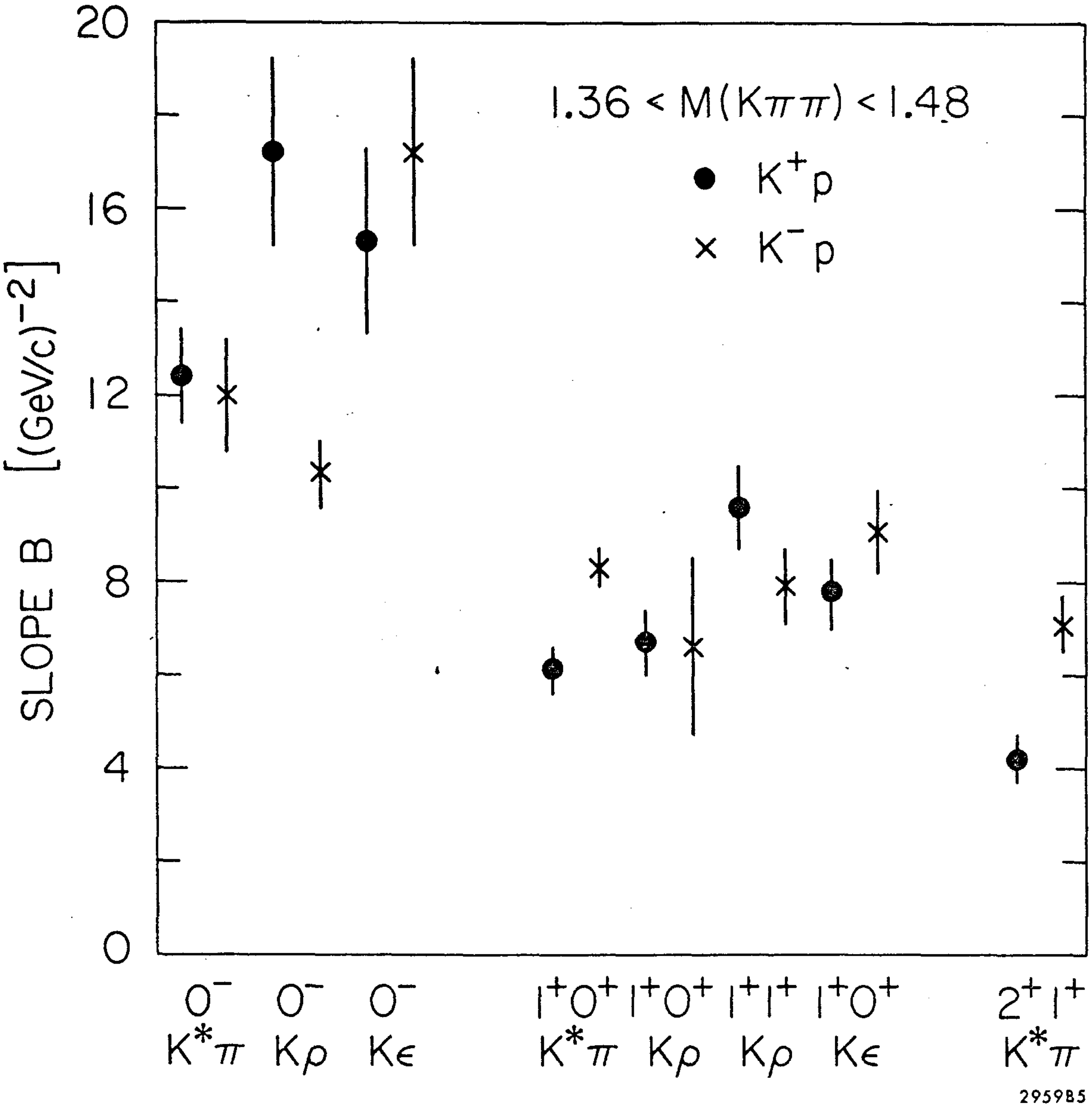

$K^-p \to (K^-\pi^+\pi^-)p$
$K^+p \to (K^+\pi^+\pi^-)p$
t channel
1^+0^+
1^+0^+
s channel
$1^+0^+K^*\pi$
$1^+1^+K^*\pi$
$1^+0^+K^*\pi$
$1^+1^+K^*\pi$
SLOPE B $[(GeV/c)^{-2}]$
3
6
9
12
15
18
1.0
1.2
1.4
1.6
$M(K\pi\pi)$ (GeV)
295984

Fig. 2



K⁻p ⟶ (K̄*⁰π⁻)p
K⁺p ⟶ (K*⁰π⁺)p
× 0⁻
● 1⁺0⁺
▲ 2⁺1⁺
SLOPE · B [(GeV/c)⁻²]
20
16
12
8
4
1.0
1.2
1.4
1.6
M(Kππ) (GeV)
295981

Fig. 3



1.36 < M(Kππ) < 1.48
K⁺p
K⁻p
SLOPE B [(GeV/c)⁻²]
20
16
12
8
4
0
0⁻ K*π
0⁻ Kρ
0⁻ Kε
1⁺0⁺ K*π
1⁺0⁺ Kρ
1⁺1⁺ Kρ
1⁺0⁺ Kε
2⁺1⁺ K*π
2959B5

Fig. 4