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ANALYSIS OF MESON-BARYON SCATTERING PROCESSES RELATED BY SU(3) IN A UNITARIZED VENEZIANO MODEL*

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ABSTRACT

We extend a previously developed eikonal-like model to analyze meson-baryon scattering. Unitarity is partly described by introducing all the coupled two-particle channels which are related to each other by the requirements of SU(3), duality, factorization and absence of exotics. The Pomeron is interpreted as the manifestation of multiparticle unitarity rather than as a t-channel Regge exchange. With a small number of parameters we are able to obtain good agreement with data on twelve processes. One parameter, the F/D ratio for t-channel spin flip coupling, is shown to play a crucial role in understanding the differing behaviors of various cross sections and polarizations.

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I. INTRODUCTION

It is now generally accepted that the Regge-pole model for strong interactions has to be extended to include cuts in order to explain some features of high energy scattering. In a previous paper[1] (referred to hereafter as I) we developed a model designed to incorporate into the Veneziano model corrections due to unitarity while preserving a number of desirable features of the original amplitude. Such a course led naturally to a generalized form of eikonal model for multiparticle reactions, described in a subsequent paper[2] (referred to hereafter as II). The indications were that Regge cuts played an important role not only in elastic scattering but also in production processes.

In I spin was treated in a simplified manner; the generalization to include spin being described in II. In this paper we study the particular case of meson-baryon scattering in an attempt to understand the large amount of existing data for elastic and two-body inelastic reactions.

In contrast to usual Regge models we do not have a Pomeranchuk trajectory in the t-channel; instead we interpret the "Pomeron" as a manifestation of multiparticle unitarity. This point of view is similar to that of the absorption model and leads, in the case of particles with spin, to a natural explanation of conservation of s-channel helicity at high energies, as explained in II.

We include all two-body final states which couple to the initial state and consider pseudo-two-body states to be, in reality, three (or more) body final states. Our description of $2 \rightarrow 2$ body scattering is then corrected for two-body unitarity by the inclusion of these coupled channels and furthermore we can make predictions for each of them in turn. Multiparticle unitarity is, of course, described via the absorptive corrections. Proper treatment of the coupled two-body channels becomes increasingly important at lower energies. In this paper we shall simultaneously describe $\pi^{\pm}p$, $K^{\pm}p$ elastic scattering and eleven other processes which are coupled to them.

In order to describe all these processes without introducing a vast number of parameters we can relate them all by SU(3) symmetry. Furthermore, we can do this within a framework which is automatically consistent with the requirements of duality, factorization and absence of exotics. The method for doing this has been developed by Harari[3] and Rosner[4] and we simply employ the Lagrangian written down by Rosner for the (s, t) and (u, t) terms. Although the expressions for the A' and B amplitudes (proportional to the t-channel non-flip and flip amplitudes) appear to be very similar, they in fact differ since they involve different F/D ratios. For the A' amplitude universality requires F=1 (where F+D=1) for the vector coupling, and exchange degeneracy implies the same result for the tensor coupling. However the F/D ratio for the spin-flip is certainly different from the non-flip value and one of the consequences of this analysis will be a determination of F_B. In fact it turns out that F_B plays an important role in explaining the differing behaviors of the various differential cross sections and polarizations. We shall see that those reactions which show a dip in the forward cross section are independent of $F_{A'}$ and F_B. Those which do not dip are such that the amplitudes A' and B depend on $F_{A'}$ and F_B in a manner which tends to reduce the importance of the B amplitude for that value of F_B determined by our analysis. This same value of F_B also explains the "mirror symmetry" observed in π^+p and π^-p polarizations.

In Section II we describe the model for $PB \rightarrow P'B'$ and in Section III we enlarge upon the preceeding discussion concerning the F/D ratios. Finally, in Section IV we compare our results on differential cross sections and polarizations with the experimental data on twelve reactions. On the whole the fits are good particularly when one considers that we have not resorted to the use of contrived residue functions. Our ambition here is to understand all the reactions in a simultaneous analysis rather than to treat each one separately and with a special set of parameters for each individual process.

II. THE MODEL

We begin by writing Veneziano amplitudes for A' and B amplitudes for meson-baryon ($PB \to P'B'$) scattering, which are proportional to the t-channel spin non-flip and spin-flip amplitudes. We write

$$
\begin{aligned}
A'_{st}(s,t) &= \gamma^{st}_{A1} \frac{\Gamma(1-\alpha_s)\,\Gamma(1-\alpha_t)}{\Gamma(1-\alpha_s-\alpha_t)} + \gamma^{st}_{A2} \frac{\Gamma(1-\alpha_s)\,\Gamma(2-\alpha_t)}{\Gamma(1-\alpha_s-\alpha_t)} \\
B_{st}(s,t) &= \gamma^{st}_{B1} \frac{\Gamma(1-\alpha_s)\,\Gamma(1-\alpha_t)}{\Gamma(2-\alpha_s-\alpha_t)} + \gamma^{st}_{B2} \frac{\Gamma(1-\alpha_s)\,\Gamma(2-\alpha_t)}{\Gamma(2-\alpha_s-\alpha_t)}
\end{aligned}
\tag{1}
$$

The first term determines the leading Regge behavior and the second corresponds to a so-called "satellite" term. Similar terms are written for A'_{ut}, B_{ut} and A'_{su}, B_{su}. We shall be interested in only the asymptotic region of large s and small t so that the (s,u) terms can be safely discarded. In principle there is no reason for choosing only two terms in Eq. (1); simplicity requires us to take as few terms as possible. For the complete amplitudes we have, in the asymptotic region;

$$
\begin{aligned}
A'(s,t) &= \left\{\left[\gamma^{st}_{A1} + \gamma^{st}_{A2}(1-\alpha_t)\right] e^{-i\pi\alpha_t} + \left[\gamma^{ut}_{A1} + \gamma^{ut}_{A2}(1-\alpha_t)\right]\right\} s^{\alpha_t} \\
B(s,t) &= \left\{\left[\gamma^{st}_{B1} + \gamma^{st}_{B2}(1-\alpha_t)\right] e^{-i\pi\alpha_t} + \left[\gamma^{ut}_{B7} + \gamma^{ut}_{B2}(1-\alpha_t)\right]\right\} s^{\alpha_t-1}
\end{aligned}
\tag{2}
$$

In every process the γ^{st} and γ^{ut} are given in terms of just four constants γ_{A1}, γ_{A2}, γ_{B1}, γ_{B2} and the two SU(3) parameters $F_{A'}$ and F_B which determine the F/D ratios. Depending upon the particular process, the t-channel Regge trajectory will be either the exchange degenerate (E.X.D.) ρ-f-ω-A_2 trajectory or the EXD K*-K** trajectory or the EXD ϕ-f' trajectory which are parameterized as

$$\begin{aligned} \rho\text{-f-}\omega\text{-}A_2 &: \quad \alpha_t = 0.9t + 0.48 \\ K^*\text{-}K^{**} &: \quad \alpha_t = 0.9t + 0.30 \\ \phi\text{-f}' &: \quad \alpha_t = 0.9\, t + 0.06 \end{aligned} \tag{3}$$

The s-channel helicity amplitudes are given, in the asymptotic region, by

$$\begin{aligned} F_{++}(s,t) &= (4\pi W)^{-1}\left[mA' + \left(EW-m^2-\frac{s}{2}\right)B\right]\cos\frac{\theta}{2} \\ F_{+-}(s,t) &= (4\pi W)^{-1}\left[EA' + \left(Wm-Em-\frac{sE}{2m}\right)B\right]\sin\frac{\theta}{2} \end{aligned} \tag{4}$$

and the corresponding Bessel transforms are given by

$$F_{+\pm}(s,b) = (2p^2)^{-1}\int QdQ\, J_{0\atop 1}(bQ)\, F_{+\pm}(s,t) \tag{5}$$

The usual parity conserving amplitudes are $f_\pm(s,b)$ where

$$f_\pm(s,b) = F_{++}(s,b) \pm F_{+-}(s,b) \tag{6}$$

and it is these amplitudes to which it is most convenient to apply the unitarity corrections.

In the spinless case we introduced the inelasticity parameter $\eta(b)$ which was parameterized according to the usual absorption model by

$$\eta(b) = 1 - C\exp(-b^2/R^2) \tag{7}$$

It was shown in I and II that, given the Regge amplitude R(s,b) for scattering of spinless particles, one can write the unitarity corrected amplitude H as

$$H(s,b) = \frac{i}{2p}(1-\eta)\left[1 - ipR(1-ipR)^{-1}\right] + \eta R(1-ipR)^{-1} \qquad (8)$$

This form of H(s,b) has the following properties:

(a) $S^{\dagger}S = \eta^2$ + terms which $\rightarrow 0$ as $s \rightarrow \infty$, where S is the $2 \rightarrow 2$ S matrix.

(b) A consistent procedure exists for transferring s-channel poles of the Veneziano amplitude for multiparticle scattering on to the second sheet.

(c) In the limit $\eta \rightarrow 1$ (elastic limit), (8) reduces to Lovelace's[5] K-matrix interpretation of the Veneziano amplitude at low energies.

By interpreting the term $\frac{i}{2}(1-\eta)$ as the "Pomeron", P, it was shown in I that H can be expanded in the form

$$pH = P + iPR - PR^2 + R + iR^2 + \ldots$$

which displays the eikonal-like structure of the model. One should note that the P-R cut is weaker than that in the usual eikonal models.[6]

In the case of meson-baryon scattering we write Eq. (7) for both the corrected f_+^c and f_-^c amplitudes:

$$f_{\pm}^{c}(s,b) = \frac{i}{2p}(1-\eta^{\pm})\left[1 - ipf_{\pm}^{R}(1-ipf_{\pm}^{R})^{-1}\right] + \eta f_{\pm}^{R}(1-ipf_{\pm}^{R})^{-1} \qquad (7)$$

where $f_{\pm}^{R}$ denotes the amplitudes obtained from Eq. (6) when Regge amplitudes are used for A' and B. As pointed out in II one should take $\eta^{+}=\eta^{-}=\eta$. Consequently the "Pomeron" couples only to the corrected helicity amplitude F_{++}^{c} and not to F_{+-}^{c}. I.e., at high energies we have conservation of s-channel helicity, a result for which there is an increasing amount of evidence.[7] The final amplitudes $F^{c}_{+\pm}(s,t)$ are then given by

$$F^{c}_{+\pm}(s,t) = (2p^2)\int bdb\, J_0\,(b\sqrt{-t})\; F^{c}_{+\pm}(s,b) \quad .$$

1

We now discuss the more general case when we include all the coupled two-body channels. In our previous expressions the amplitudes $F_{+\pm}$, $f_{\pm}$ etc. all become matrices and η (now a diagonal matrix) represents the corrections due to multiparticle unitarity. To be specific, in our analysis we have considered four different initial states $\pi^{\pm}p$, $K^{\pm}p$, together with all the coupled two-body states, giving 15 reactions:

$K^-p \rightarrow K^-p$	$K^+p \rightarrow K^+p$	$\pi^+p \rightarrow \pi^+p$	$\pi^-p \rightarrow \pi^-p$
$\rightarrow \bar{K}^o n$		$\rightarrow K^+\Sigma^+$	$\rightarrow \pi^o n$
$\rightarrow \pi^-\Sigma^+$			$\rightarrow K^o\Sigma^o$
$\rightarrow \pi^o\Sigma^o$			$\rightarrow \eta^o n$
$\rightarrow \pi^o\Lambda$			$\rightarrow K^o\Lambda$
$\rightarrow \eta^o\Sigma^o$			
$\rightarrow \eta^o\Lambda$			

for which there is data on all but three. In order to compute the full matrices, however, we have to calculate the matrix elements of all of the above 15 states to every other coupled state thus making it necessary to evaluate 47 reactions altogether. By SU(3) symmetry, however, all these processes are related to one another. Moreover, since we also wish to be consistent with duality, factorization and absence of exotics we apply the method developed by Rosner for calculating any given process $PB \rightarrow P'B'$ in terms of the (s,t) and (u,t) terms of Eq. (2). We can then describe all of our 47 processes in terms of one set of parameters γ_{A1}, γ_{A2}, γ_{B1}, γ_{B2} plus the parameter corresponding to the F/D ratio for the B amplitude. As mentioned in Section I the F/D ratio for A' is determined by universality plus exchange degeneracy. The full table of coefficients, γ, for all the processes is given in the appendix.

III. ROLE OF THE F/D RATIO

In this section we consider certain features of a theory, such as our model, in which the contributions from various Regge-pole exchanges are consistent with duality. As mentioned earlier we have six parameters to describe the Regge amplitudes; γ_{A1} and γ_{A2} are the residues associated with the A' amplitude, γ_{B1} and γ_{B2} those with the B amplitude. In addition we have $F_{A'}$ and F_B the two SU(3) parameters determining the F/D ratios for the A' and B amplitudes. (Normalized according to F+D=1.)

From the appendix we see that the π^+p and π^-p elastic B amplitudes are given by

$$\begin{aligned} B(\pi^+p) &\propto (2F_B-1)\, e^{-i\pi\alpha_t} + \left[2+2(2F_B-1)\right] \\ B(\pi^-p) &\propto \left[2+2(2F_B-1)\right] e^{-i\pi\alpha_t} + (2F_B-1) \end{aligned} \tag{10}$$

From Eq. (4) we see that B contributes to the leading behavior of F_{+-} at high energy but not to that of F_{++}. That is, apart from the "Pomeron" term, only the A' Regge amplitude contributes to F_{++}. This contribution turns out to be small (a fact necessary to explain the dip in K^-p elastic scattering) compared with the Pomeranchuk. The polarization, which is given by

$$\text{Pol.} \propto \left[\text{Im}\,(F_{++})\;\text{Re}\,(F_{+-}) - \text{Re}\,(F_{++})\;\text{Im}\,(F_{+-})\right] \tag{11}$$

therefore gets most of its contribution from the first term, as the Pomeron is purely imaginary. Since the π^+p and π^-p elastic polarizations are very nearly mirror reflections of one another, it follows that $\text{Re}\,(F_{+-})$ must be odd under charge conjugation, i.e., it must be dominated by ρ exchange. Both A' and B contribute to F_{+-} but again we assume the A' part to be small. We can immediately arrange for the B amplitude to be dominated by ρ exchange by choosing $F_B \approx \frac{1}{4}$ so that by Eq. (10) we have

$$\begin{aligned} B(\pi^+ p) &\propto \frac{1}{2}\left(1-e^{-i\pi\alpha_t}\right) \\ B(\pi^- p) &\propto -\frac{1}{2}\left(1-e^{-i\pi\alpha_t}\right) \end{aligned} \tag{12}$$

Thus within the framework of duality and SU(3) we see that F_B is fairly well determined by basic features of the experimental data. The fits we have obtained to the data indicate a value of F_B=0.3 which is consistent with the above remarks. Note however that "mirror symmetry" cannot occur in $K^{\pm}p$ scattering since the proportions of ρ, f, ω, A_2 exchange are independent of F_B.

With the values of $F_{A'}$=1 (universality + EXD) and $F_B=\frac{1}{4}$ it is of interest to study the relative behaviors of the forward dips which occur in some inelastic reactions. We consider ten inelastic processes and list the corresponding ratios of the SU(3) $F_{A'}$ factor for A' divided by the SU(3) F_B factor for B and also the corresponding proportions of the Regge-pole exchanges calculated with these values of $F_{A'}$ and F_B.

Process	A'/B ratio	Regge contributions	
$K^- p \to \bar{K}^0 n$	1	A'	$(A_2-\rho)$
		B	$(A_2-\rho)$
$K^- p \to \pi^- \Sigma^+$	-2	A'	(K^*+K^{**})
		B	$-1/2(K^*+K^{**})$
$K^- p \to \pi^0 \Lambda$	2	A'	$-\sqrt{3}/2(K^*+K^{**})$
		B	$-\sqrt{3}/4(K^*+K^{**})$

$K^-p \to \eta^o\Sigma^o$	-2	A'	$1/(2\sqrt{3})$ (K**-3K*)
		B	$-1/(4\sqrt{3})$ (K**-3K*)
$K^-p \to \eta^o\Lambda$	2	A'	1/2 (K**-3K*)
		B	1/4 (K**-3K*)
$\pi^-p \to \pi^o n$	1	A'	$\sqrt{2}\rho$
		B	$\sqrt{2}\rho$
$\pi^-p \to K^o\Sigma^o$	-2	A'	$-1/\sqrt{2}$ (K*+K**)
		B	$1/(2\sqrt{2})$ (K*+K**)
$\pi^-p \to \eta^o n$	1	A'	$\sqrt{2}/3\ A_2$
		B	$\sqrt{3}/3\ A_2$
$\pi^-p \to K^o\Lambda$	2	A'	$-\sqrt{6}/2$ (K**-K*)
		B	$-\sqrt{6}/4$ (K**-K*)
$\pi^+p \to K^+\Sigma^+$	-2	A'	(K**-K*)
		B	-1/2 (K**-K*)

It is precisely those processes with an A'/B SU(3) factor of 1 (i.e., those processes independent of the F/D ratio) which exhibit dips in the forward direction. It also happens that these reactions involve ρ and A_2 exchange — as opposed to f or ω exchange. The presence or absence of forward dips can be understood in the following way. In the high energy region we have $F_{++} \propto A'$ and $F_{+-} \propto A' - (s/2m)B$ where the main contributions are from Regge pole terms. If the exchanged Regge poles couple strongly to B and relatively weakly to A' then B will dominate in the near-forward direction and produce a dip. However for those processes for which the A'/B SU(3) factor is greater than 1, the effect is much reduced and it becomes impossible for F_{+-} to dominate; consequently the dip fails to appear. It is thus crucial that the exchanged Regge poles couple more strongly to B than to A' and that F_B is near to $\frac{1}{4}$. (If F_B=1 then all the above reactions would have forward dips.)

Note that we cannot arrange for the ρ to couple purely to F_{+-}, as has been suggested[8] in order to explain the pattern of forward dips, since then A' would vanish asymptotically for <u>all</u> the inelastic processes. It is thus <u>not</u> true that ρ-A_2 exchange will always be associated with forward dips. For instance in the unrealizable reaction $\pi^- \Sigma^+ \to \pi^0 \Sigma^0$ the A'/B SU(3) factor is 4 (for $F_{A'}$=1 and $F_B = \frac{1}{4}$) and the t-channel is pure ρ exchange. Our model would therefore predict <u>no</u> forward dip, with such a large factor enhancing the A'. It should also be noted that the f and ω are not constrained to couple only to F_{++}, which has also been suggested.[8] This is apparent for example in the reaction $\pi^- \Sigma^+ \to \pi^- \Sigma^+$ which has an equal mixture of ρ and f in both the A' and B amplitudes. It is interesting to note that every inelastic reaction involving K**-K* exchange also has an SU(3) A'/B factor greater than one. I.e., in such cases the B amplitude is relatively suppressed to the point where no dip results. It is therefore true to say that K*-K** exchange reactions never exhibit forward dips.

To summarize, the presence or absence of dips in the forward direction we believe to be a natural consequence of a value of F_B near to $\frac{1}{4}$, rather than due to a contrived mechanism in which ρ, A_2 prefer to couple to F_{+-} and f, ω to F_{++}.

IV. COMPARISON WITH EXPERIMENT

In comparing to experiment we choose the trajectories as in Ref. 1. In addition to the six parameters ($\gamma_{A1}\gamma_{A2}\gamma_{B1}\gamma_{B2}$, $F_{A'}$ and F_B) mentioned previously we also have the parameters R and C which describe the inelasticity function $\eta(b)$ according to Eq. (7). These correspond to the radius of interaction and degee of absorption which characterize our "Pomeron" contribution.† In contrast

† We take the absorption parameters to be the same for any set of coupled two-body states, e.g., for π^+p and $K^+\Sigma^+$, as we must in order to guarantee correct time reversal symmetry.

to the other parameters, R and C are allowed to vary with the beam energy and with the nature of the initial state. In the tables below we give the resulting values of R and C which correspond to our best fits at three energies. The average error on each number is about fifteen percent.

TABLE 1

Values of R^2 in GeV^{-2}

P_{LAB} \ INITIAL STATE	π^+p	π^-p	K^+p	K^-p
3 GeV	7.2	8.0	7.5	15.1
5.5 GeV	12.2	11.9	8.5	10.3
10 GeV	10.5	10.5	10.1	9.5

TABLE 2

Values of C

P_{LAB} \ INITIAL STATE	π^+p	π^-p	K^+p	K^-p
3 GeV	.83	.91	.87	.40
5.5 GeV	.67	.83	.71	.55
10 GeV	.65	.65	.70	.54

At high energies the radius of interaction tends to a value of $R \simeq 0.6$ fermi for all the reactions. Since $F_{A'}$ is fixed to be 1 in our model we have five remaining variables which are determined, from our fits to the data, to be:

$$F_B = 0.32 \qquad \gamma_{A1} = -8.0\ \text{GeV}^{-1} \qquad \gamma_{B1} = -59.7\ \text{GeV}^{-2}$$

$$\gamma_{A2} = \ 3.7\ \text{GeV}^{-1} \qquad \gamma_{B2} = -53.2\ \text{GeV}^{-2}$$

The values of the γ_i indicate the stronger coupling of all the Regge exchanges to the t-channel spin-flip amplitude and F_B is close to 1/4, as discussed in Section III. The signs of the γ_B are necessarily as given in order that the π^+p, π^-p polarizations be of the correct sign.

Figures 1 and 2 show the results for the differential cross sections (DCS) for $K^{\pm}p$, $\pi^{\pm}p$ elastic scattering. The structure which appears near t=-0.9 becomes a pronounced dip as the beam momentum is lowered. In our model this dip arises from interference between the "Pomeron" P, the Regge term R and the P-R cut in the A' amplitude. The DCS for the coupled two-body inelastic reactions are shown in Figs. 3, 4 and 5. The tendency for some of these to dip in the forward direction illustrates the discussion in Section III concerning the value of F_B. The well-known dip in π^-p charge-exchange arises from the nonsense zero inherent in Veneziano type residue functions. This zero is partially filled in by the cut contributions. Figure 6 illustrates the polarizations for the elastic reactions and two inelastic reactions near 5.5 GeV. We do not obtain the large polarization in π^+p and π^-p near the forward direction but the general qualitative agreement is good. In particular, the "mirror symmetry" discussed in Section III is apparent. Our results for K^-p elastic scattering polarization shows the features which have been observed in detailed experiments below 3 GeV, namely a gradual increase and subsequent rapid fall, becoming negative near t=-0.9. Like almost all absorption-like models we obtain a negative spike for $\pi^-p \rightarrow \pi^0 n$ at -t=0.5, where the dip in the DCS occurs. The polarization for $\pi^+ p \to K^+ \Sigma^+$ although showing the correct qualitative behavior is too small. This reaction and the "line reversed" reaction $K^- p \to \pi^- \Sigma^+$ are of particular relevance in any model, such as ours, which insists on exact exchange degeneracy. A pure pole model with K*-K** exchange degeneracy necessarily requires $d\sigma/dt\ (K^- p \to \pi^- \Sigma^+) = d\sigma/dt\ (\pi^+ p \to K^+ \Sigma^+)$ which is violated by a factor of 2, the larger cross section being $K^- p \to \pi^- \Sigma^+$. One might hope to rectify this situation by including cuts, the requirement being that the absorption for $K^- p$ coupled channels be somewhat less than that for $\pi^+ p$ coupled channels. Our parameter C, characterizing the absorption, does turn out to be less for $K^- p$ than for $\pi^+ p$ but not enough so; the difference in the Regge character of the two reactions, $K^- p \to \pi^- \Sigma^+$ being pure real and $\pi^+ p \to K^+ \Sigma^+$ being pure rotating phase, appears to cancel the former effect. This same sort of difficulty was encountered by Michael[9] and by Meyers *et al.*[10] It would thus appear that either additional freedom must be allowed in the Regge residues, (i.e., additional satellites) or that some violation of exact exchange degeneracy ... and/or SU(3) symmetry must be allowed. Attempts to improve the overall quality of our theoretical curves by the former method are under way.

APPENDIX

Here we list the SU(3) coefficients for the 47 processes coupled to $\pi^{\pm}p$, $K^{\pm}p$, calculated according to Rosner's Lagrangian. The first factor is the coefficient for the (s, t) term and the second for the (u, t) term. The former has always an associated factor $e^{-i\pi\alpha_t}$ while the latter is real. The values of F will be different for the A' and B amplitude (see Section II). Here $\mathscr{F}$=2F-1, where F+D=1 and ρ means the EXD ρ-f-ω-A_2, etc.

Process	(s, t) factor	(u, t) factor	t EXD trajectory type
$K^-p \to K^-p$	$2+2\mathscr{F}$	0	ρ
$K^-p \to \bar{K}^0 n$	2	0	ρ
$K^-p \to \pi^-\Sigma^+$	0	$2\mathscr{F}$	K*
$K^-p \to \pi^0\Sigma^0$	0	$-2\mathscr{F}$	K*
$K^-p \to \pi^0\Lambda$	0	$-1/\sqrt{3}\,(2+\mathscr{F})$	K*
$K^-p \to \eta^0\Sigma^0$	$2/\sqrt{3}\mathscr{F}$	$-1/\sqrt{3}\mathscr{F}$	K*
$K^-p \to \eta^0\Lambda$	$2/3\,(2+\mathscr{F})$	$-1/3\,(2+\mathscr{F})$	K*
$\bar{K}^0 n \to \bar{K}^0 n$	$2+2\mathscr{F}$	0	ρ
$\bar{K}^0 n \to \pi^-\Sigma^+$	0	0	ρ
$\bar{K}^0 n \to \pi^0\Sigma^0$	0	$-\mathscr{F}$	K*
$\bar{K}^0 n \to \pi^0\Lambda$	0	$1/\sqrt{3}\,(2+\mathscr{F})$	K*
$\bar{K}^0 n \to \eta^0\Sigma^0$	$-2/\sqrt{3}\mathscr{F}$	$1/\sqrt{3}\mathscr{F}$	K*
$\bar{K}^0 n \to \eta^0\Lambda$	$2/3\,(2+\mathscr{F})$	$-1/3\,(2+\mathscr{F})$	K*
$\pi^-\Sigma^+ \to \pi^-\Sigma^+$	$2+\mathscr{F}$	0	ρ
$\pi^-\Sigma^+ \to \pi^0\Sigma^0$	$-(1+\mathscr{F})$	$1+\mathscr{F}$	ρ
$\pi^-\Sigma^+ \to \pi^0\Lambda$	$1/\sqrt{3}\,(1-\mathscr{F})$	$-1/\sqrt{3}\,(1-\mathscr{F})$	ρ
$\pi^-\Sigma^+ \to \eta^0\Sigma^0$	$1/\sqrt{3}\,(1+\mathscr{F})$	$1/\sqrt{3}\,(1+\mathscr{F})$	ρ

Process	(s,t) factor	(u,t) factor	t EXD trajectory type
$\pi^- \Sigma^+ \to \eta^o \Lambda$	$-1/\sqrt{3}\ (1-\mathcal{F})$	$-1/\sqrt{3}\ (1-\mathcal{F})$	ρ
$\pi^o \Sigma^o \to \pi^o \Sigma^o$	$1+\mathcal{F}$	$1+\mathcal{F}$	ρ
$\pi^o \Sigma^o \to \pi^o \Lambda$	0	0	
$\pi^o \Sigma^o \to \eta^o \Sigma^o$	0	0	
$\pi^o \Sigma^o \to \eta^o \Lambda$	$1/3\ (1-\mathcal{F})$	$1/3\ (1-\mathcal{F})$	ρ
$\pi^o \Lambda \to \pi^o \Lambda$	$1/6\ (2+7\mathcal{F})$	$1/6\ (2+\mathcal{F})$	ρ
$\pi^o \Lambda \to \eta^o \Sigma^o$	$1/3\ (1-\mathcal{F})$	$1/3\ (1-\mathcal{F})$	ρ
$\pi^o \Lambda \to \eta^o \Lambda$	0	0	
$\eta^o \Sigma^o \to \eta^o \Sigma^o$	$1/3\ (1+\mathcal{F})$	$1/3\ (1+\mathcal{F})$	ρ
	$4/3\mathcal{F}$	$4/3\mathcal{F}$	ϕ
$\eta^o \Sigma^o \to \eta^o \Lambda$	0	0	
$\eta^o \Lambda \to \eta^o \Lambda$	$1/18\ (2+7\mathcal{F})$	$1/18\ (2+7\mathcal{F})$	ρ
	$4/9\ (2+\mathcal{F})$	$4/9\ (2+\mathcal{F})$	ϕ
$K^+ p \to K^+ p$	0	$2+2\mathcal{F}$	ρ
$\pi^- p \to \pi^- p$	$2+2\mathcal{F}$	$2\mathcal{F}$	ρ
$\pi^- p \to \pi^o n$	$-\sqrt{2}$	$\sqrt{2}$	ρ
$\pi^- p \to K^o \Sigma^o$	$-\sqrt{2}\mathcal{F}$	0	K*
$\pi^- p \to \eta^o n$	$\sqrt{2}/3$	$\sqrt{2}/3$	ρ
$\pi^- p \to K^o \Lambda$	$-\sqrt{2}/3\ (2+\mathcal{F})$	0	K*
$\pi^o n \to \pi^o n$	$1+2\mathcal{F}$	$1+2\mathcal{F}$	ρ
$\pi^o n \to K^o \Sigma^o$	$-\mathcal{F}$	0	K*
$\pi^o n \to \eta^o n$	$-1/\sqrt{3}$	$-1/\sqrt{3}$	ρ
$\pi^o n \to K^o \Lambda$	$-1/2\sqrt{3}\ (1+2\mathcal{F})$	0	K*
$K^o \Sigma^o \to K^o \Sigma^o$	$2\mathcal{F}$	$1+\mathcal{F}$	ρ
$K^o \Sigma^o \to \eta^o n$	$1/\sqrt{3}\mathcal{F}$	$-2/\sqrt{3}\mathcal{F}$	K*

Process	(s,t) factor	(u,t) factor	t EXD trajectory type
$K^o\Sigma^o \to K^o\Lambda$	0	$1/\sqrt{3}\ (-1+\mathscr{F})$	ρ
$\eta^o n \to \eta^o n$	$1/3\ (1+2\mathscr{F})$	$1/3\ (1+2\mathscr{F})$	ρ
$\eta^o n \to K^o\Lambda$	$-1/3\ (2+\mathscr{F})$	$2/3\ (2+\mathscr{F})$	K^*
$K^o\Lambda \to K^o\Lambda$	$2/3\ (2+\mathscr{F})$	$1/3\ (1+5\mathscr{F})$	ρ
$\pi^+ p \to \pi^+ p$	$2\mathscr{F}$	$2+2\mathscr{F}$	ρ
$\pi^+ p \to K^+\Sigma^+$	$2\mathscr{F}$	0	K^*
$K^+\Sigma^+ \to K^+\Sigma^+$	$2\mathscr{F}$	$2+2\mathscr{F}$	ϕ, ρ

REFERENCES

1. J. F. Gunion, R. G. Roberts, Report No. UCSD 10P70-73, University of California, San Diego (1970).
2. J. F. Gunion, R. G. Roberts, Report No. UCSD 10P70-74, University of California, San Diego (1970).
3. H. Harari, Phys. Rev. Letters 22, 563 (1969).
4. J. Rosner, Phys. Rev. Letters 22, 689 (1969).
5. C. Lovelace, Proc. Conf. on $\pi\pi$ and $K\pi$ Interactions, Argonne (1969).
6. S. Frautschi, B. Margolis, Nuovo Cimento 56A, 1155 (1968);
   C. B. Chiu, J. Finkelstein, Nuovo Cimento 57A, 649 (1968), ibid 59A, 92 (1969);
   R. C. Arnold, Phys. Rev. 153, 1523 (1968);
   R. C. Arnold, M. L. Blackmon, Phys. Rev. 176, 2082 (1968).
7. J. Ballam et al., Phys. Rev. Letters 24, 969 (1970);
   F. J. Gilman, J. Pumplin, A. Schwimmer, L. Stodolsky, Phys. Letters 37B, 287 (1970).
8. R. Odonico, A. Garcia, C. A. Garcia-Canal, Phys. Letters 32B, 375 (1970).
9. C. Michael, Nucl. Phys. B13, 644 (1969).
10. C. Meyers, Y. Noirot, M. Rimpault, Ph. Salin, University of Bordeaux preprint (1970).
11. M. N. Focacci et al., Phys. Letters 19, 441 (1968). (3 GeV)
12. J. Mott et al., Phys. Letters 23, 171 (1966). (5.5 GeV)
13. J. Orear et al., Phys. Rev. Letters 21, 387 (1968). (5.8 GeV)
14. M. Aderholz et al., Phys. Letters 24, 434 (1967). (10 GeV)
15. J. Debaisieux et al., Nuovo Cimento 43, 142 (1966). (3 GeV)
16. W. DeBaere et al., Nuovo Cimento 45, 885 (1966). (5 GeV)

17. K. J. Foley et al., Phys. Rev. Letters 11, 503 (1963). (6.8, 9.8 GeV)

18. C. T. Coffin et al., Phys. Rev. 159, 1169 (1967). (3, 4 GeV)

19. K. J. Foley et al., Phys. Rev. Letters 11, 425 (1963). (6.8, 10.8 GeV)

20. S. Brendt et al., Phys. Rev. Letters 10, 413 (1963). (10 GeV)

21. J. Orear et al., Phys. Letters 28, 61 (1968). (9.7 GeV)

22. P. Astbury et al., Phys. Letters 23, 396 (1966). (5, 9.5 GeV)

23. D. D. Reeder, K.V.L. Sarma, Phys. Rev. 172, 1566 (1968); private communication from J. Loos, University of Illinois. (5.5 GeV)

24. See Ref. 23, communication from D. Hodge, University of Wisconsin. (5.5 GeV)

25. S. M. Pruss et al., Phys. Rev. Letters 23, 189 (1969). (5 GeV)

26. A. V. Stirling et al., Phys. Rev. Letters 14, 763 (1965). (5.9, 9.8 GeV)

27. O. I. Dahl et al., Phys. Rev. 163, 1430 (1967). (4 GeV)

28. O. Guisan et al., Phys. Letters 18, 200 (1965). (5.9, 9.8 GeV)

29. A. Abashian et al.; see J. Kirz, Review talk Int. Conf. High Energy Collisions, Stony Brook, N. Y. (1969), p. 59. (10 GeV)

30. M. A. Wahling, I. Manelli, Phys. Rev. 168, 1515 (1968). (10 GeV)

31. R. J. Esterling et al., paper submitted to the Vienna Conf. on High Energy Physics (1968);
see Review talk by Belletini. (5.15 GeV)

32. M. Borghini et al., reported by D.R.O. Morrison, Lund Conference (1969). (6 GeV)

FIGURE CAPTIONS

1. K^-p and K^+p elastic D.C.S. at 3, 5.5 and 10 GeV. Data from Refs. 11, 12, 13, 14, 15, 16, 17, 18.

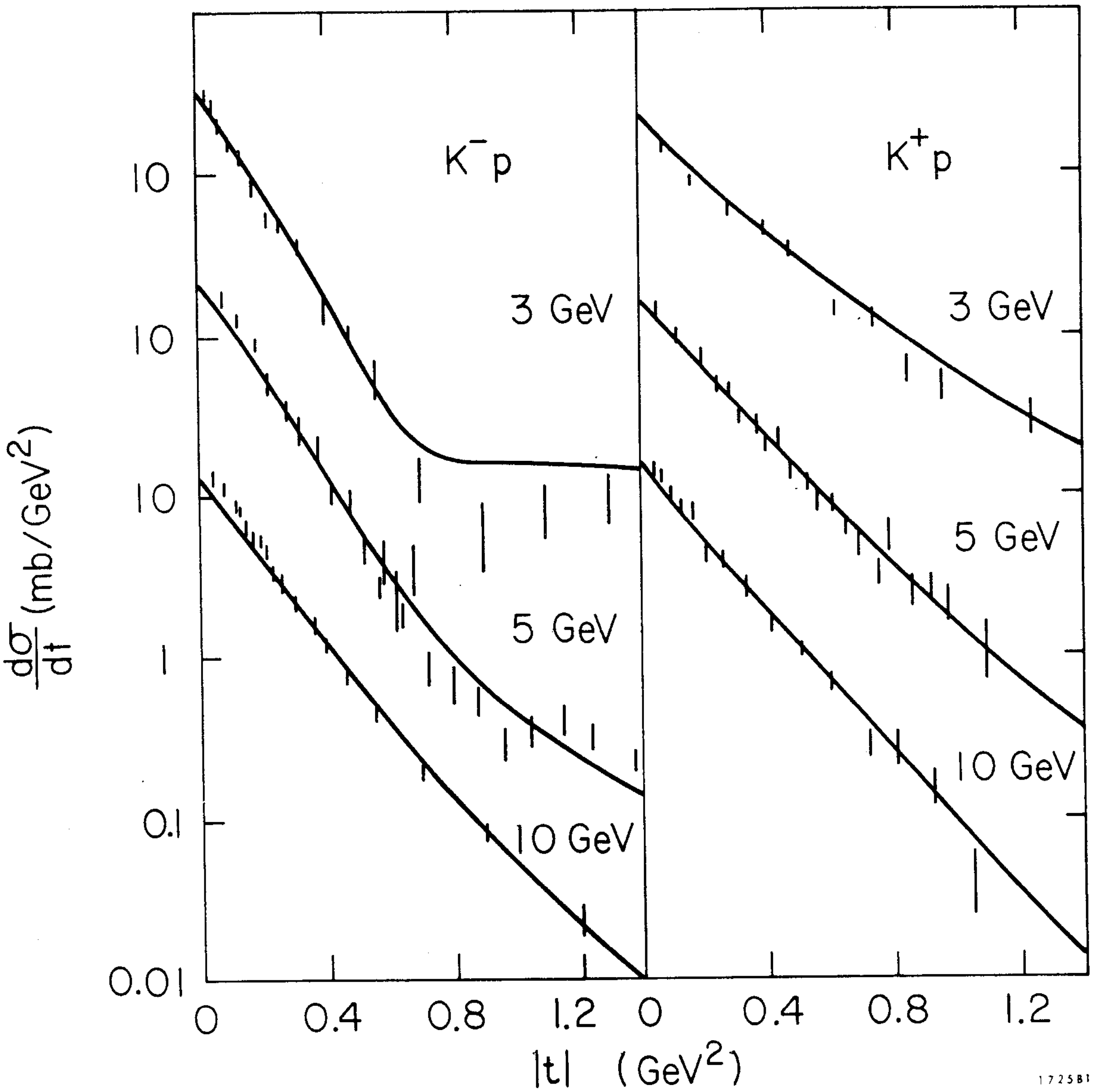
2. π^+p and π^-p elastic D.C.S. at 3, 5.5 and 10 GeV. Data from Refs. 12, 13, 18, 19, 20, 21.

3. Inelastic D.C.S. at 5.5 GeV. (a) $K^-p \to \bar{K}^on$, (b) $K^-p \to \pi^-\Sigma^+$, (c) $K^-p \to \pi^o\Lambda$, (d) $\pi^+p \to K^+\Sigma^+$. Data from Refs. 22, 23, 24, 25.

4. Inelastic D.C.S. at 5.5 GeV. (a) $\pi^-p \to \pi^on$, (b) $\pi^-p \to K^o\Sigma^o$, (c) $\pi^-p \to \eta^on$, (d) $\pi^-p \to K^o\Lambda$. Data from Refs. 26, 27, 28.

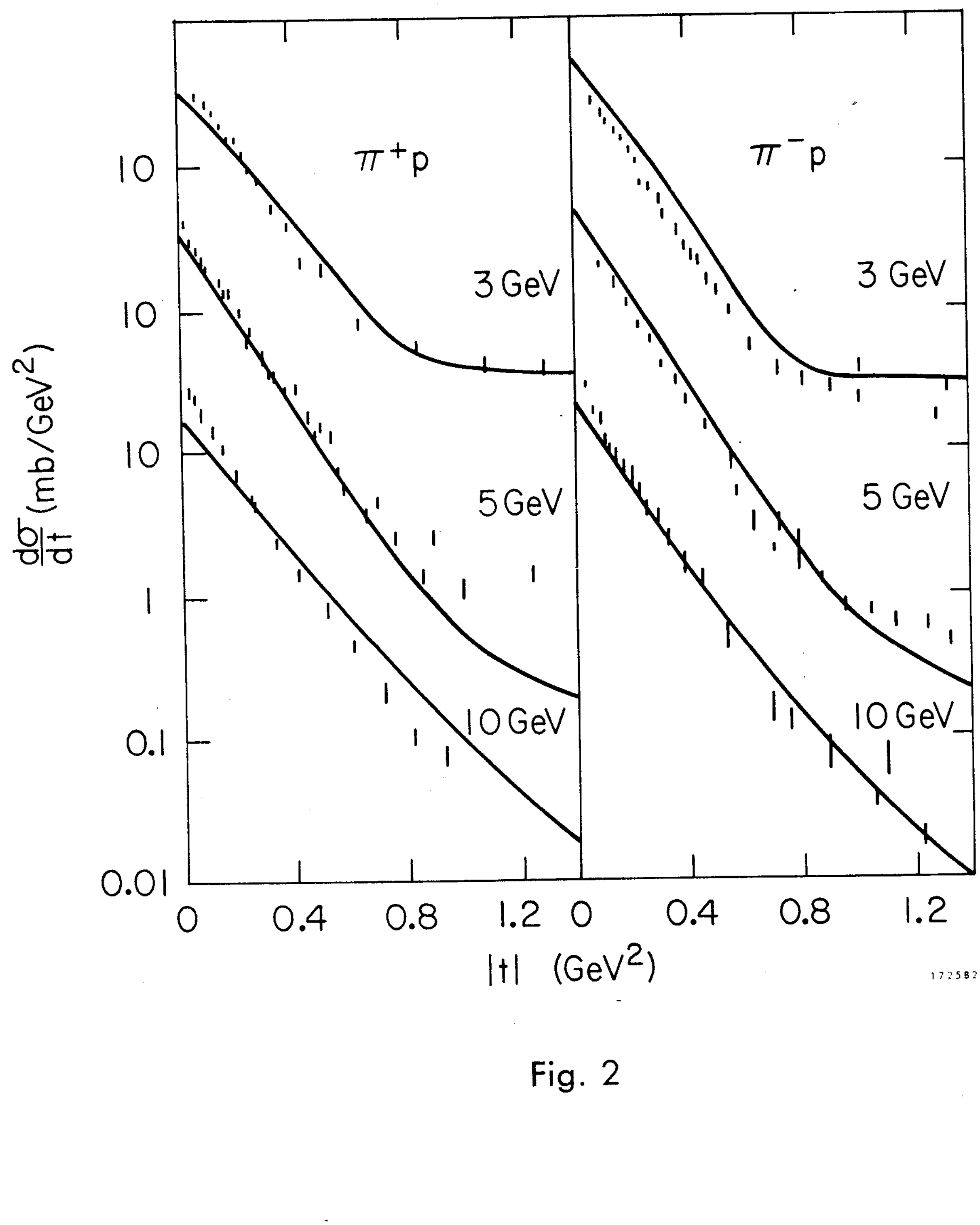
5. Inelastic D.C.S. at 10 GeV. (a) $K^-p \to \bar{K}^on$, (b) $\pi^+p \to K^+\Sigma^+$, (c) $\pi^-p \to \pi^on$ (d) $\pi^-p \to \eta^on$. Data from Refs. 22, 26, 28, 29, 30.

6. Polarizations at 5.5 GeV. (a) π^+p elastic, (b) π^-p elastic, (c) $\pi^+p \to K^+\Sigma^+$, (d) K^+p elastic, (e) K^-p elastic, (f) $\pi^-p \to \pi^on$. Data from Refs. 25, 31, 32, 33.



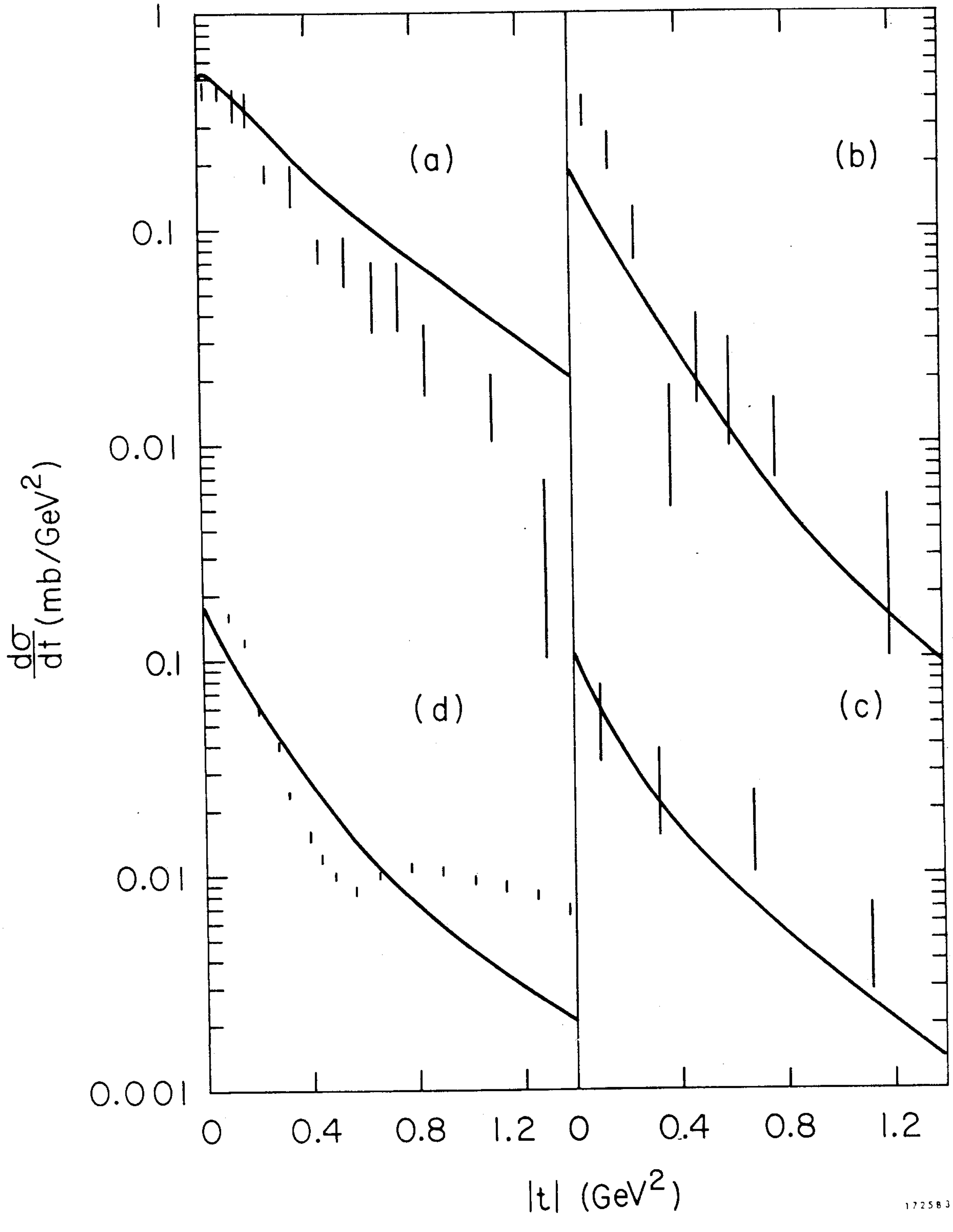
K⁻p
K⁺p
3 GeV
5 GeV
10 GeV
3 GeV
5 GeV
10 GeV
10
10
10
1
0.1
0.01
dσ/dt (mb/GeV²)
0
0.4
0.8
1.2
0
0.4
0.8
1.2
|t| (GeV²)
1725B1

Fig. 1



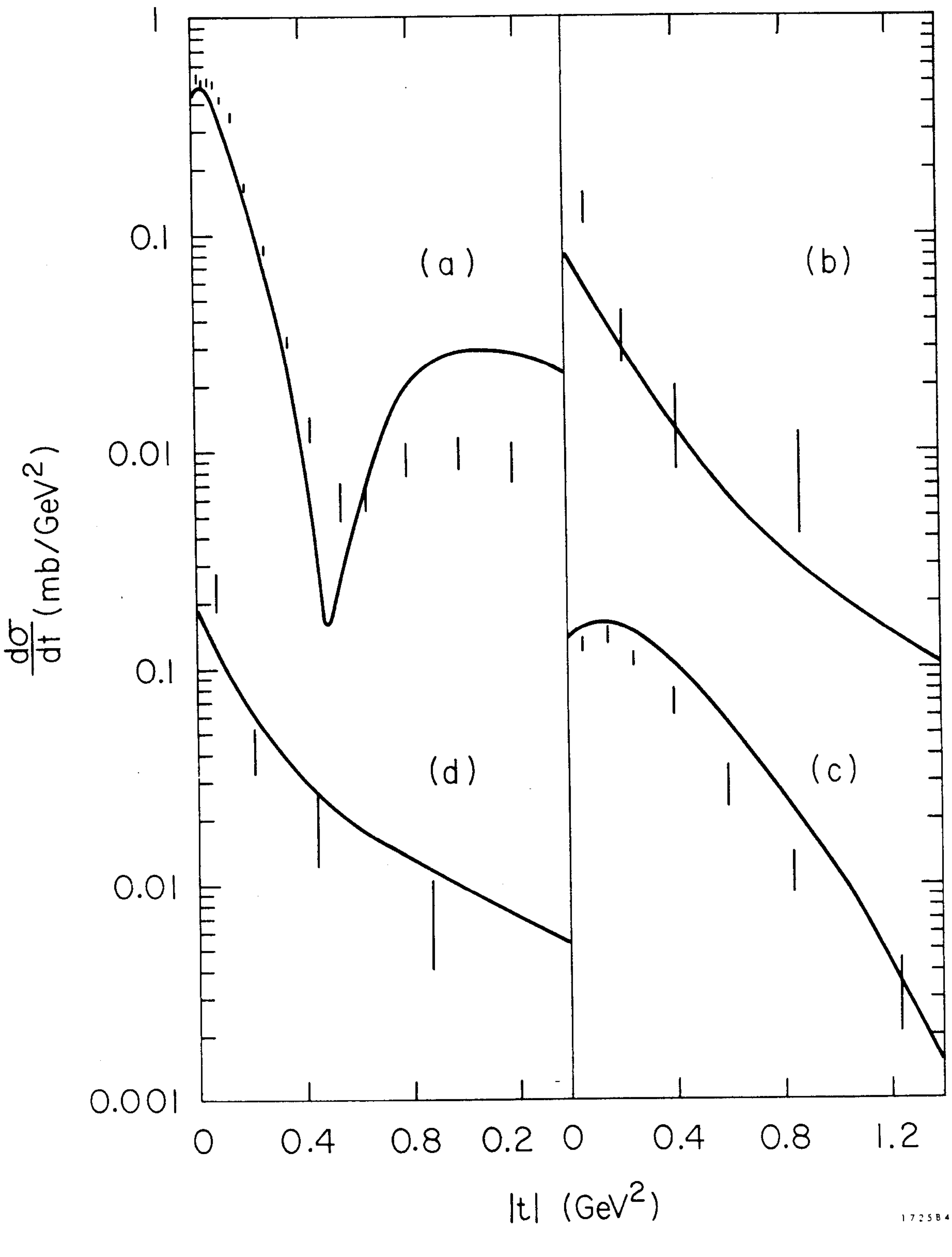
$\pi^+ p$
$\pi^- p$
3 GeV
5 GeV
10 GeV
10
10
10
1
0.1
0.01
0
0.4
0.8
1.2
$\frac{d\sigma}{dt}$ (mb/GeV^2)
|t| (GeV^2)
1725B2

Fig. 2



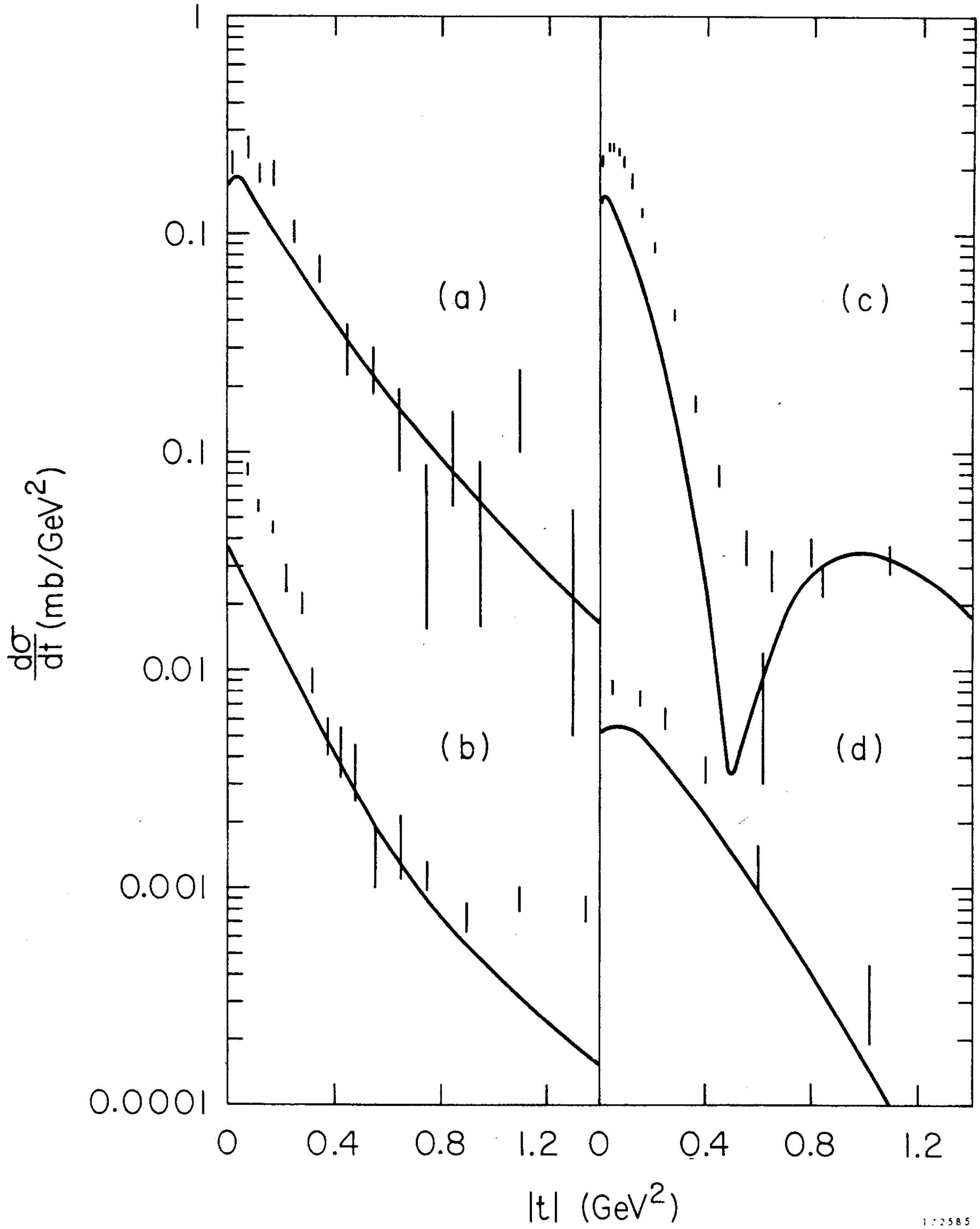
1
0.1
0.01
0.1
0.01
0.001
(a)
(b)
(c)
(d)
$\frac{d\sigma}{dt}$ (mb/GeV^2)
0
0.4
0.8
1.2
|t| (GeV^2)
172583

Fig. 3



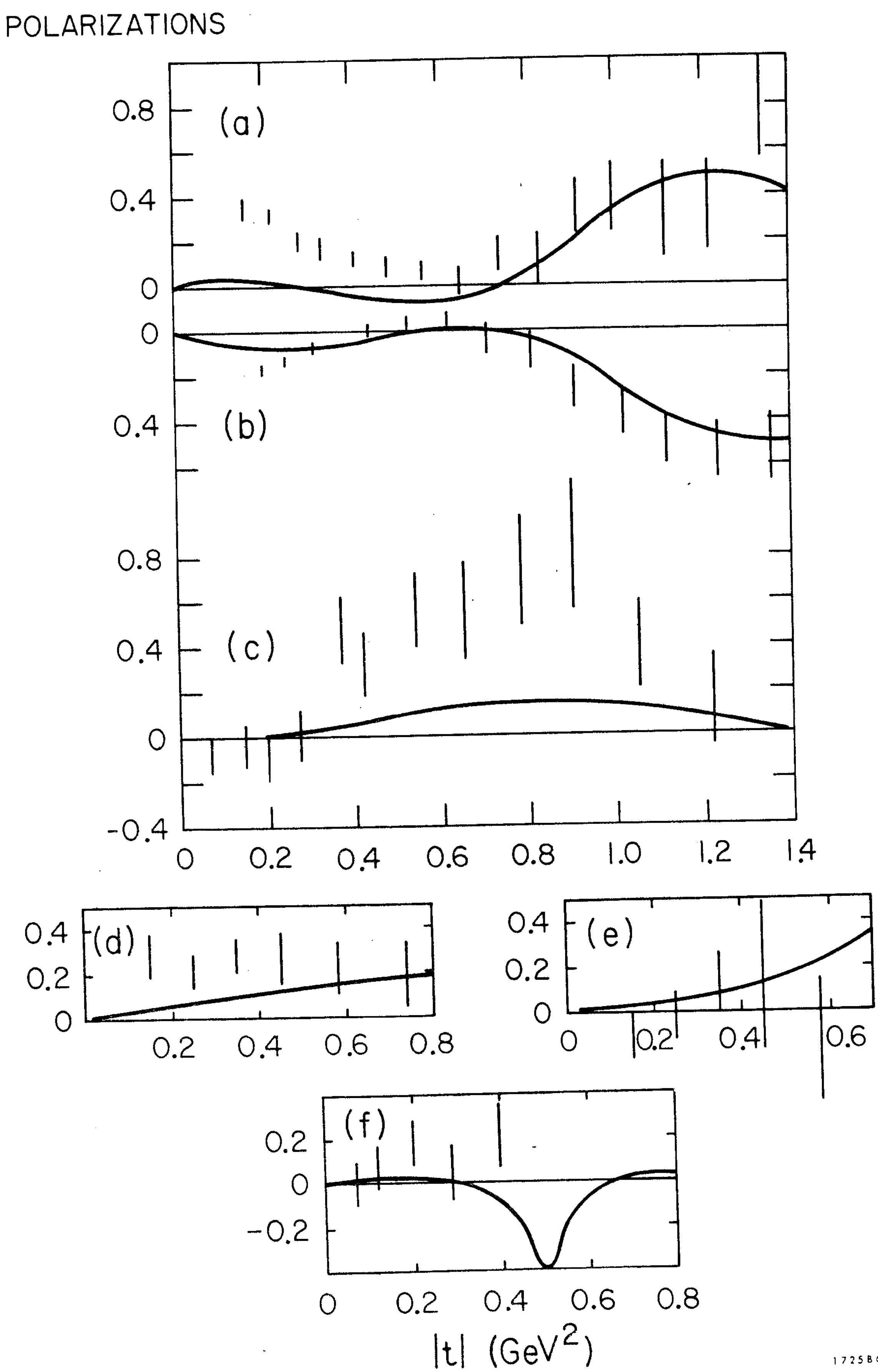
$\frac{d\sigma}{dt}$ (mb/GeV^2)
1
0.1
0.01
0.1
0.01
0.001
(a)
(b)
(c)
(d)
0
0.4
0.8
0.2
0
0.4
0.8
1.2
|t| (GeV^2)

Fig. 4



1
0.1
0.1
0.01
0.001
0.0001
(a)
(b)
(c)
(d)
dσ/dt (mb/GeV²)
0
0.4
0.8
1.2
0
0.4
0.8
1.2
|t| (GeV²)

Fig. 5



POLARIZATIONS
0.8
0.4
0
(a)
0
0.4
(b)
0.8
0.4
(c)
0
-0.4
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0.4
0.2
0
(d)
0.2
0.4
0.6
0.8
0.4
0.2
0
(e)
0
0.2
0.4
0.6
0.2
0
-0.2
(f)
0
0.2
0.4
0.6
0.8
|t| (GeV^2)
1725B6

Fig. 6