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TWO BODY CHANNELS IN THE INTERACTIONS OF 3, 3.5 and 5 GeV/c POSITIVE KAONS ON HYDROGEN : Possibility of Regge-pole Exchange

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In a systematic study of two body and quasi two body reactions in hydrogen, occurring in the Saclay 81 cm bubble chamber exposed, at CERN, to K^+ mesons of 3, 3.5 and 5 GeV/c, it was found that the bulk of the reactions occur as :

1)	$K^+p \rightarrow K^+p$		
2)	$K^+p \rightarrow K^{*+}p$	$K^{*+} \rightarrow \begin{cases} K^o\pi^+ \\ K^+\pi^o \end{cases}$	(+)
3a)	$K^+p \rightarrow K^o\, N^{*++}$	$N^{*++} \rightarrow p\pi^+$	
3b)	$\rightarrow K^+\, N^{*+}$	$N^{*+} \rightarrow \begin{cases} p\pi^o \\ n\pi^+ \end{cases}$	(+)
4a)	$K^+p \rightarrow K^{*o}\, N^{*++}$	$K^{*o} \rightarrow \begin{cases} K^+\pi^- \\ K^o\pi^o \end{cases}$	
4b)	$\rightarrow K^{*+}\, N^{*+}$	$K^{*+} \rightarrow \begin{cases} K^o\pi^+ \\ K^+\pi^o \end{cases}$	$N^{*+} \rightarrow \begin{cases} p\pi^o \\ n\pi^+ \end{cases}$

Detailed discussions of these reactions are given elsewhere[1][2][3].

In Fig. 1 the variations of the cross section for reactions (1 - 4b) are given as a function of the centre of mass energy(++). The values outside our interval of energy are taken from other sources[4]. The curves are hand drawn and should only be considered as giving an illustration of the variations of the cross sections. It is seen that in each resonance channel, the cross section goes rapidly through a maximum and then drops rather slowly. The interesting question of whether or not they tend towards an asymptotic limit remains open until higher energy experiments are performed. The data presently available is not in contradiction with a positive answer to this question. One may recall that, as far as elastic scattering is concerned, the results at 5 GeV/c are already very close to the high energy limit[1].

The K^*N and N^*K cross sections, as well as the total cross sections for $KN\pi$ final states are shown on Fig. 1a. One sees that,

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(+) These channels have only been studied at 3.5 GeV/c. They have been analysed at 3 GeV/c by the Stockholm group, whom we thank for communication of their results.

(++) Undetectable final states such as $K^+\pi^o n\pi^+$ have been taken into account by use of isospin invariance.

whereas the $KN\pi$ total cross section is dominated up to 1.2 GeV/c by the N^*K system, the fraction of quasi two body inside the $NK\pi$ final state drops at higher momenta. The same remark applies to the K^*N^* channel inside the $KN\pi\pi$ final state Fig. 1b.

The comparison between the sum of the cross sections for reactions (1), (2), (3) and (4) to the total cross section can be seen on Fig. 1c. We note that the remaining non-accounted for cross section reaches 10 mb at 5 GeV/c. Although some new resonances appear or may appear between 3 and 5 GeV/c, such as the $K^*(1400)$ or the controversial $K\pi\pi$ ($\sim$1300)[5], their production cross section, of the order of 100 μb, seems to be too small to take care of all this difference. One may then conclude that as the energy increases, true three (or more) body channels are an important part of the K^+p interactions.

The distributions of the momentum transfer squared, t, for the four channels are shown on Fig. 2 for $t \leqslant 1$ $(\mathrm{GeV/c})^2$. The bulk of the events for the reactions (1 - 4) are found in this momentum transfer region. The differential cross sections are plotted on a logarithm scale, and each distribution is rather well approximated by straight lines, i.e. $d\sigma/dt \sim e^{-At}$. Table I gives a summary of the slopes A for reactions (1 - 4) for the three K^+ incoming momenta.

Also shown on Fig. 2 are the predictions of the peripheral model corrected for absorption, assuming that reactions (2) and (3) are dominated by vector meson exchange and that reaction (4) is dominated by pion exchange. These assumptions being suggested by the experimental decay angular distributions[2][3]. There is clear evidence for the well known fact[7] that the experimental cross sections are lower than the predicted ones for increasing energy, especially in the case of vector meson exchange.

We should remark that according to the coherent Droplet Model[6] the expected slopes A for the quasi two body reactions (2 - 4b) should be identical to the slope obtained for the elastic scattering (reaction (1)). As can be seen on Fig. 2 and Table I this is not the case for reaction (4) which is known to be dominated by pion exchange.

Another striking feature is the energy dependence of the slopes which, for all four reactions, show a small but systematic increase with energy. In particular this effect is beyond any doubt for elastic scattering where a reasonable explanation[1b] can be obtained from the Regge-pole model proposed by Phillips and Rarita[8].

In view of this and of other recent successes[8][9] of the Regge-pole approach, we show on Fig. 3b the α vs t, Chew Frautschi, plot for reactions (1 - 4). We express the dependence of the differential cross section on the K^+ laboratory momentum in the form[*]

$$\frac{d\sigma}{dt} = F(t)\, P_K^{2\alpha(t) - 2} ,$$

where $F(t)$ is some function of t alone and $\alpha(t)$ is the trajectory. This dependence for reactions (1 - 4) is shown on Fig. 3a for fixed values of t. The experimental points were fitted by least square to straight lines whose slopes are $2\alpha(t) - 2$.

It is interesting to verify if the trajectories are compatible with the nature of the exchanged particle as deduced from the study of the decay angular distributions in the peripheral model.

Except for the case of the elastic scattering, the statistical errors are too large to draw firm conclusions from the so determined trajectories (which also are not necessarily straight lines). Nevertheless we can note that : i) the elastic scattering trajectory goes roughly through the Pomeranchuk pole; ii) the K^*N and N^*K trajectories are not too far from the ω or ρ pole, as expected from the decay distributions which imply vector meson exchange (of course some admixture of A_2 exchange is also possible); iii) the pion pole, which on Fig. 3 seems to lie far from the K^*N^* trajectory is actually less than 1.5 standard deviations from it and the slope of the trajectory is within the errors compatible with the slope one might expect for a π trajectory ($\sim .5\ (\mathrm{GeV}/c)^{-2}$).

(*) This form is equivalent, as far as the determination of α is concerned, to the usual form $d\sigma/dt \sim s^{2\alpha - 2}$ when P_K is large enough. Even though this is not quite true at our lower momenta, the deviations are negligible compared to our statistical errors.

In conclusion the four reactions examined are all characterized by strongly peripheral production, they exhibit a shrinking which, within statistics, may be qualitatively described by the simplest Regge-pole exchange model.

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FIGURE CAPTIONS

Fig. 1. Cross sections for various final states of the K^+p interaction at several energies. The values of the cross sections are deduced from the data given in the references by multiplying the quoted ratio of each individual reaction to the total cross section, by the total cross section exhibited in Fig. 1c. The curve (σ_{tot}) was adapted to the data of counter experiments quoted in Ref. 1b.. (Although it shows a bump it was drawn before the latest results of Cool et al[10] were available). The hand drawn curves are an artist's smoothing procedure such that the sum of all curves for 2, 3 ... n body final states yields the total cross section curve. The circled points correspond to estimates reported without quoted errors.

Fig. 2. Differential production cross sections as a function of t, the momentum transfer squared, for reactions (1 - 4b) at the three incident K^+ momenta of 3, 3.5 and 5 GeV/c. The second row, K^*p, corresponds to reaction $K^+p \to K^*p$, $K^* \to K^o\pi^+$, the third row to reaction $K^+p \to N^*K^o$, $N^* \to p\pi^+$ and the fourth row to reaction $K^+p \to K^*N^*$, $K^* \to K^+\pi^-$, $N^* \to p\pi^+$.

Fig. 3. a) Plots of $d\sigma/dt$ vs $P_{K\ lab}$ for the reactions considered in Fig.2. The published data at 1.96 and 2.3 GeV/c[4] have been used (except for the K^*N^* reaction) to reduce the errors in the determination of the slopes Fig. 3b.

b) Chew Frautschi, α vs t plot for the reactions shown in Fig.2. The experimental points are fitted by a least square to the straight lines shown. The values of the slopes are given in Table II.

TABLE I

Slope A for $\frac{d\sigma}{dt} \sim e^{-At}$

Reaction	t Interval $(GeV/c)^2$	Slope A $(GeV/c)^{-2}$ 3.0 GeV/c	3.5 GeV/c	5.0 GeV/c
$K^+p \to K^+p$	0.04 - 1.03	3.85 ± 0.17	3.80 ± 0.14	4.63 ± 0.20
$\to K^{*+}p$	0.05 - 1.00	3.6 ± 0.4	3.2 ± 0.3	4.2 ± 1.1
$\to K^0N^{*++}$	0.05 - 1.00	3.2 ± 0.6	3.5 ± 0.5	4.1 ± 0.7
$\to K^{*0}N^{*++}$	0.1 - 0.35	7.1 ± 1.1	8.2 ± 1.2	10.3 ± 2.3

TABLE II

$$\alpha(t) = \alpha(0) + \alpha'.t$$

Reaction	$\alpha(0)$	$\alpha'(GeV/c)^{-2}$
$K^+p \to K^+p$	0.89 ± 0.15	0.92 ± 0.17
$\to K^{*+}p$	0.26 ± 0.27	0.80 ± 0.47
$\to K^0N^{*++}$	0.40 ± 0.22	1.72 ± 0.33
$\to K^{*0}N^{*++}$	0.60 ± 0.42	3.78 ± 2.33

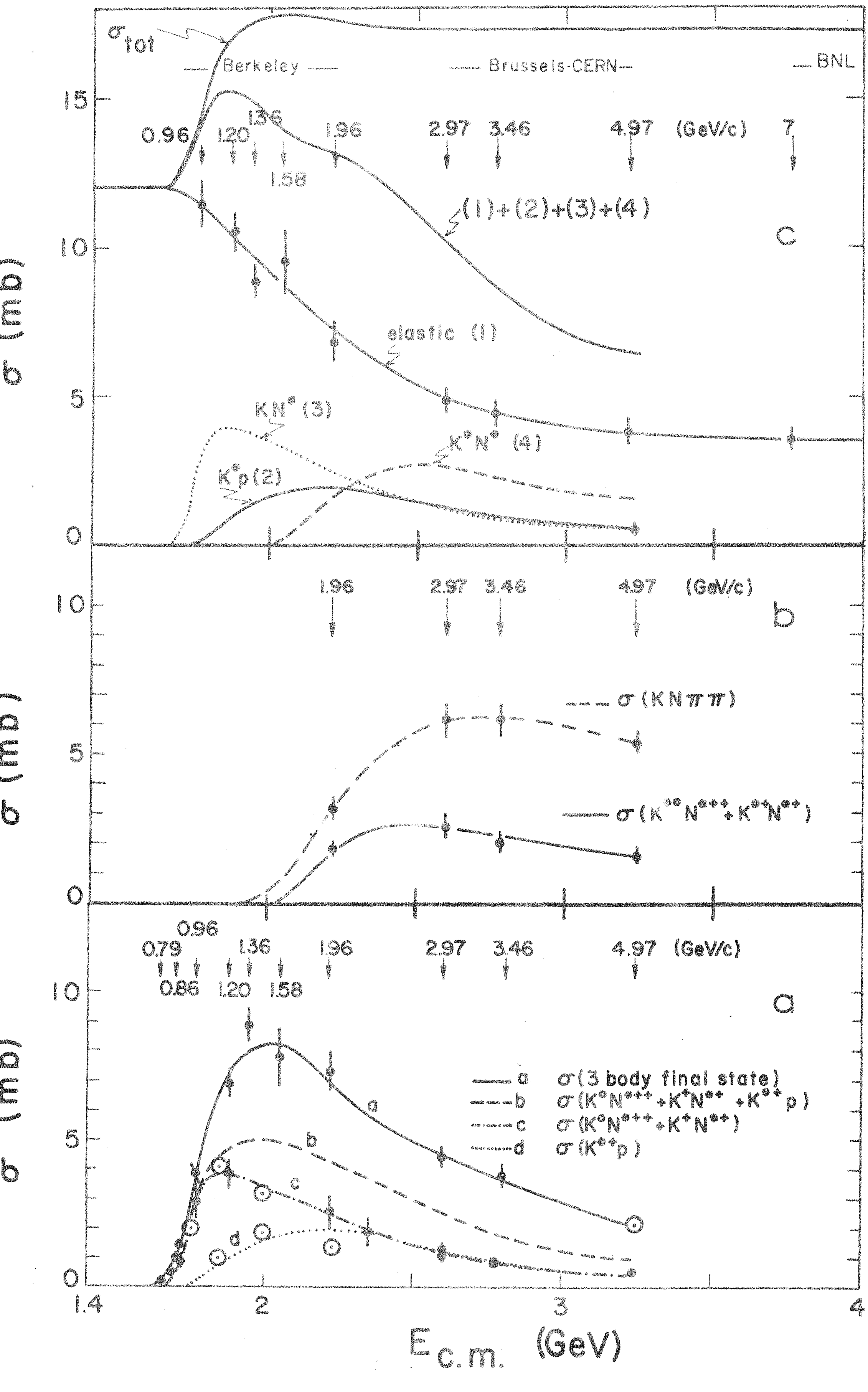

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Fig.1

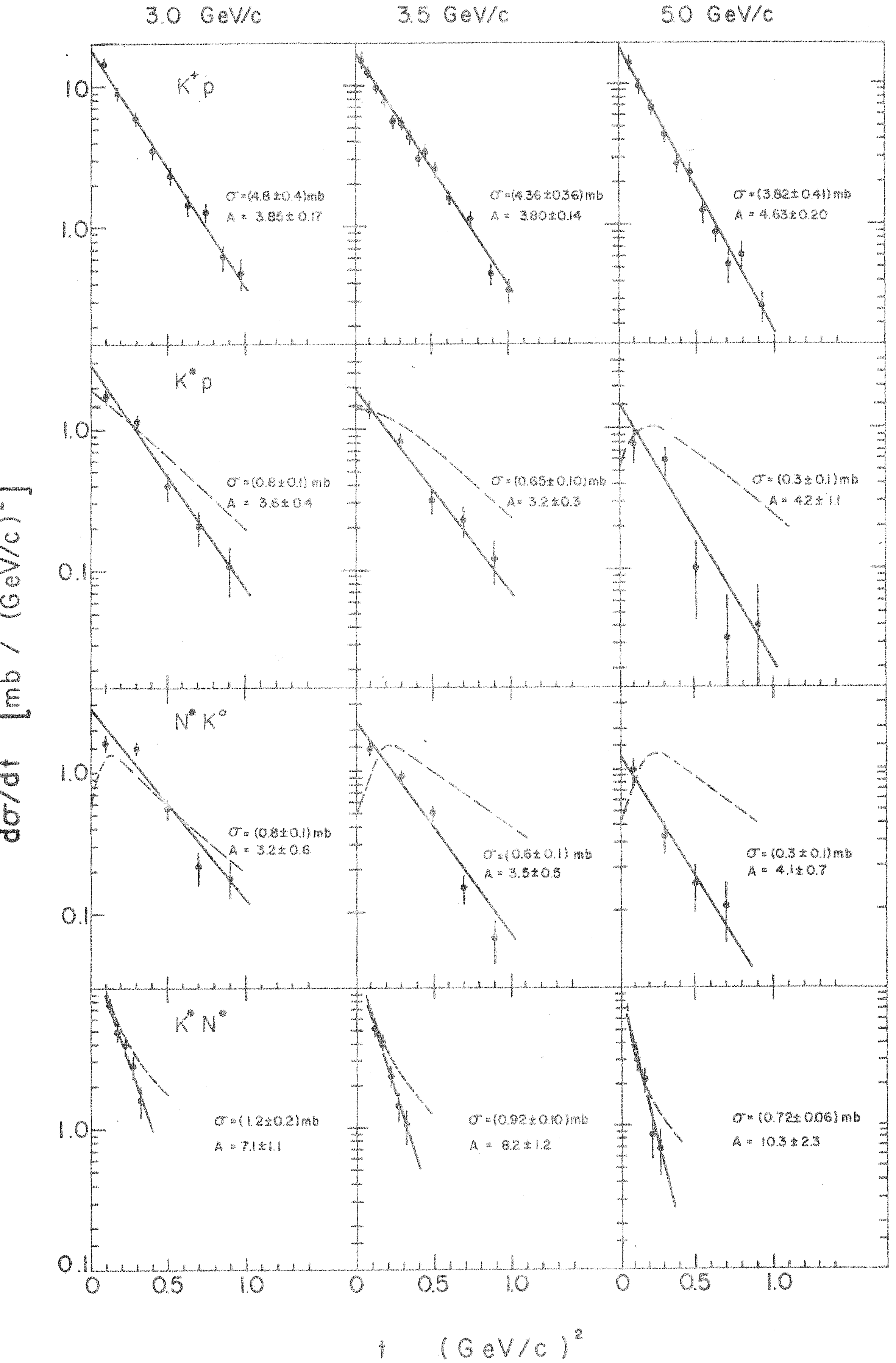

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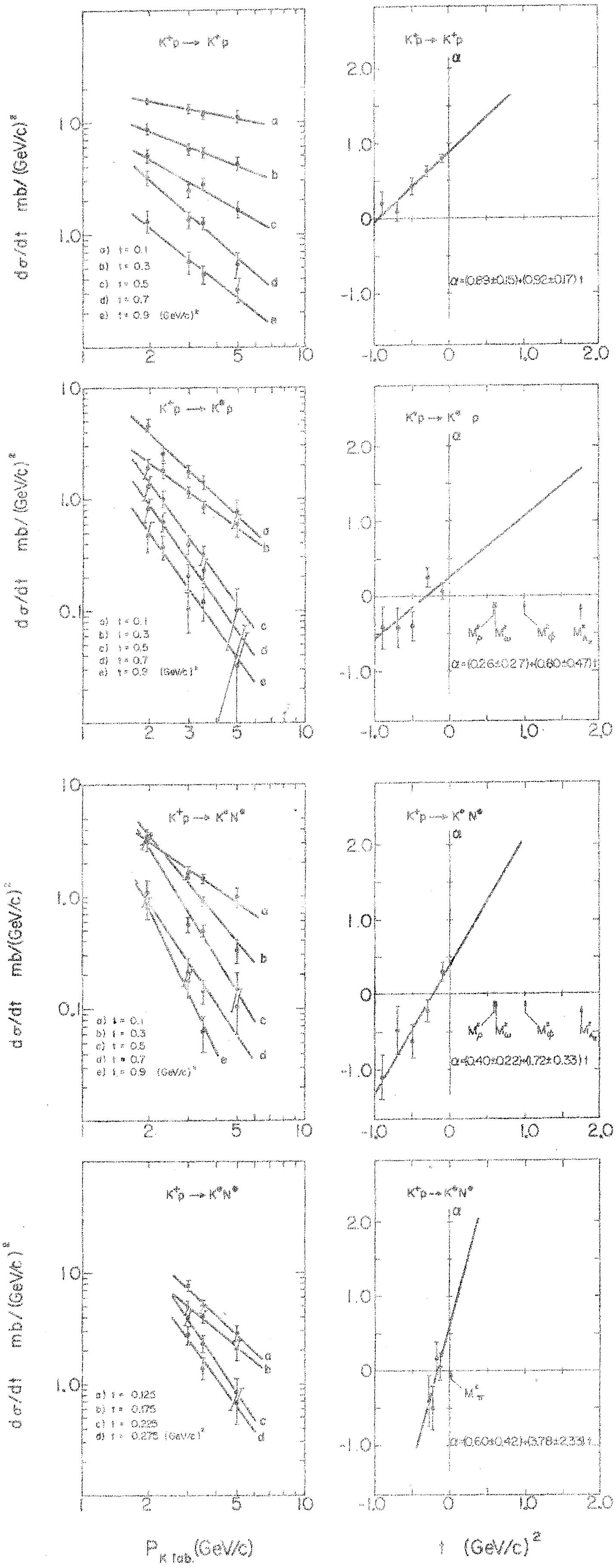
Fig. 2



a b

Fig. 3

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