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Triple Regge analysis of inclusive Λ production in $K^+ p$ and $\pi^+ p$ interactions at 250 GeV/c

EHS/NA22 Collaboration

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Abstract. A triple Regge analysis is performed of inclusive Λ production in the proton fragmentation region of $K^+ \rightarrow \Lambda + X$ and $\pi^+ \rightarrow \Lambda + X$ at 250 GeV/c. Slope and intercept of the leading strange meson trajectory are determined. The results obtained here are compared with those of other experiments.

Inclusive Λ production has been studied in the framework of the triple Regge model in the proton fragmentation region of pp [1–4], $\pi^- p$ [5], $K^- p$ [6–8] and $K^+ p$ interactions [9, 10]. However, in only few of these experiments the data have been analysed at large enough energies and with sufficient statistics.

In this paper we apply the triple Regge analysis to the reactions

$$K^+ p \rightarrow \Lambda + X \quad (1)$$

$$\pi^+ p \rightarrow \Lambda + X \quad (2)$$

at 250 GeV/c, the highest beam momentum so far reached for positive meson-proton collisions.

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The data presented here come from the NA22 experiment performed at CERN. In this experiment the European Hybrid Spectrometer (EHS) is equipped with the Rapid Cycling Bubble Chamber (RCBC) as a vertex detector and exposed to a 250 GeV/c tagged, positive, meson enriched beam. In data taking, a minimum bias interaction trigger has been used. The experimental set-up and the trigger conditions are described in [11].

The properties of inclusive Λ production in reactions (1) and (2) (for reaction (2) on part of the statistics) have been analysed in detail in our previous publication [12], where the data are also compared with the results at

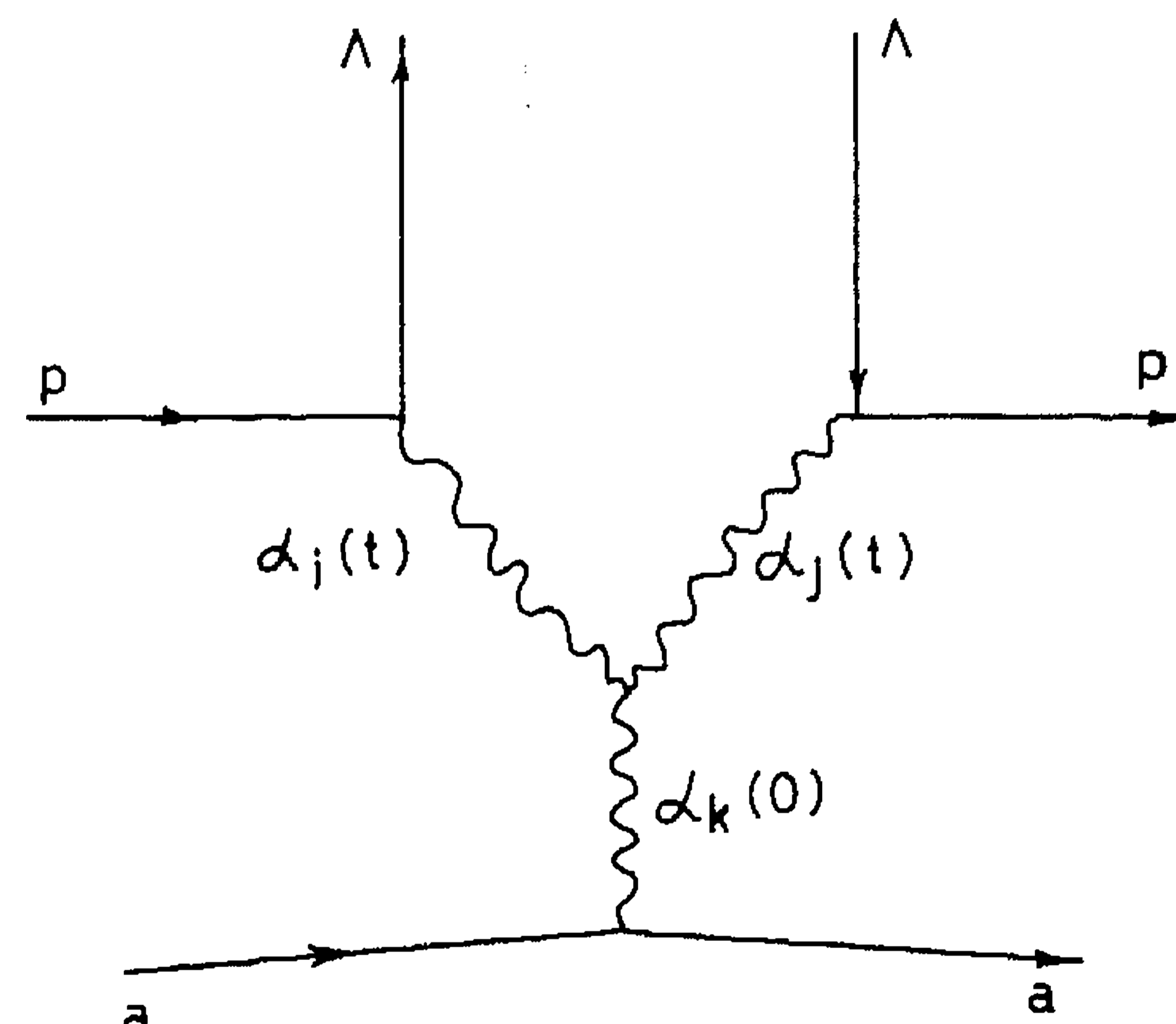


Fig. 1. The triple-Regge diagram for the inclusive reaction $a + p \rightarrow \Lambda + X$

lower energies. Here, we selected a sample of unambiguously identified 3 C-fit Λ decays according to the criteria described in [12]. As in [12], no attempt has been made to remove Λ 's originating from Σ^0 decay.

The cross section for the inclusive reaction $b \xrightarrow{a} c$ can be written in the triple Regge limit of large $s=(p_a+p_b)^2$, $M^2=(p_a+p_b-p_c)^2$ and small $t=(p_b-p_c)^2$, M^2/s as

$$\frac{d^2\sigma}{dt d(M^2/s)} = \sum_{ijk} G_{ijk}(t) s^{\alpha_k(0)-1} (M^2/s)^{\alpha_k(0)-\alpha_i(t)-\alpha_j(t)} \quad (3)$$

with the triple Regge diagram for the case of proton fragmentation into Λ as shown in Fig. 1. In (3) $G_{ijk}(t)$ contains the Regge residues and signature factors, $\alpha_i(t)$ and $\alpha_j(t)$ represent the strange meson trajectories K , K_A , K^* and K^{**} for the $p\bar{\Lambda}$ vertex and the intercept $\alpha_k(0)$ controls the reggeon-particle total cross section. For reactions (1) and (2), with an exotic quantum number for the combination $ab\bar{c}(K^+ p\bar{\Lambda}, \pi^+ p\bar{\Lambda})$, the pomeron term

dominates for the trajectory α_k , hence $\alpha_k(0)=\alpha_p(0)=1$ and the energy dependence disappears in (3). Introducing further the effective exchange-degenerate trajectory $\alpha(t)=\alpha_i(t)=\alpha_j(t)$ and remembering that $M^2/s \simeq 1-x$, where x is the Feynman variable, one can rewrite (3) as

$$d^2\sigma/dt dx = G(t) (1-|x|)^{1-2\alpha(t)}. \quad (4)$$

The absence of energy dependence in (4) agrees with the behaviour exhibited by the experimental data. It has been shown in [12] that in reactions (1) and (2) the Λ inclusive cross section increases significantly with increasing energy. However, this increase is mainly concentrated in the central region ($x \simeq 0$), while in the proton fragmentation region ($x \leq -0.4$) the Λ cross section is practically constant over the beam momentum interval 32-250 GeV/c.

The $d^2\sigma/dt dx$ distributions at 250 GeV/c are shown in Fig. 2 as functions of x , for four different t -intervals for reaction (1) and six t -intervals for reaction (2). The

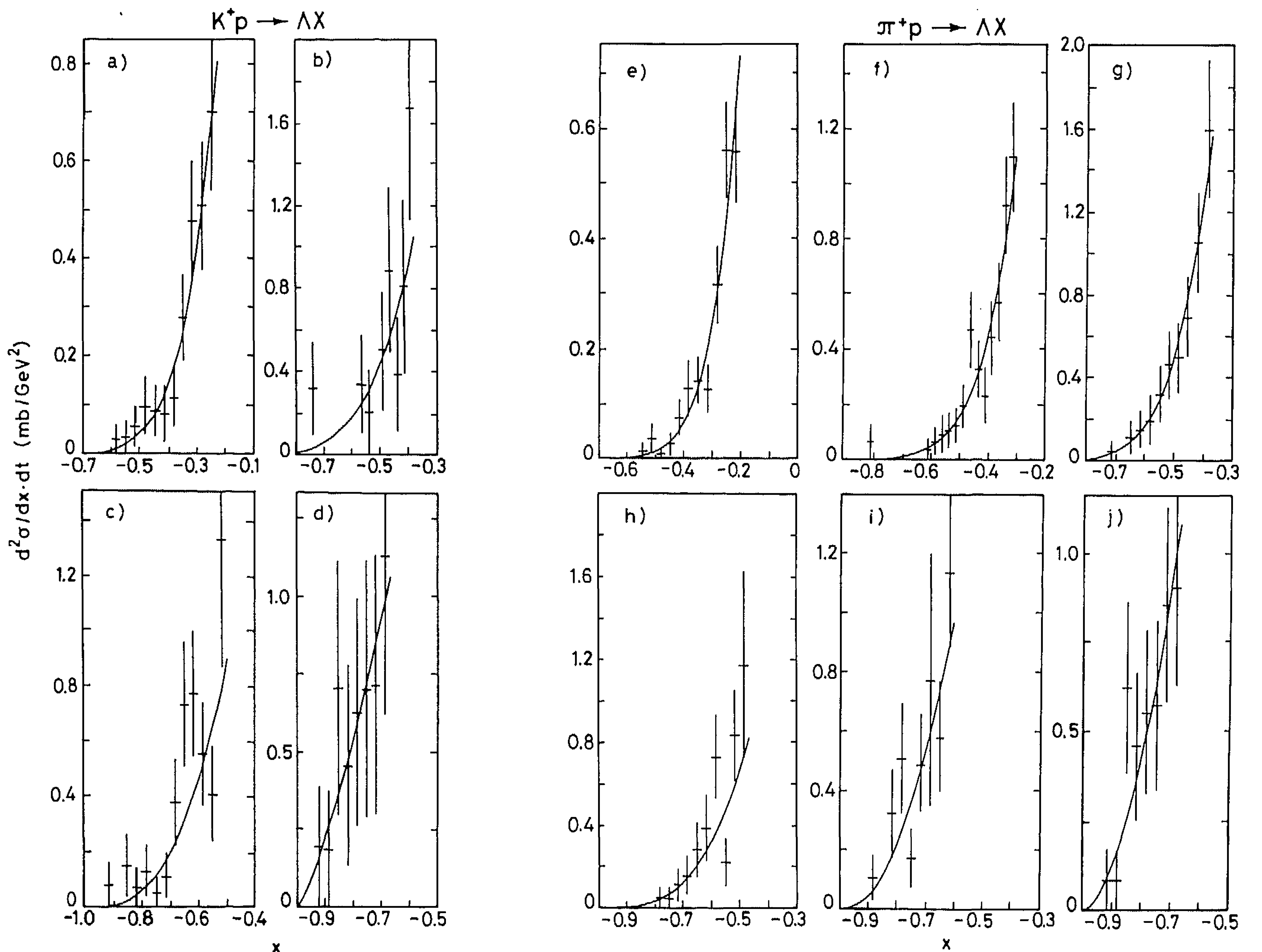


Fig. 2a-j. The $d^2\sigma/dx dt$ distribution as a function of x for the t -intervals a $-4 < t < -2$, b $-2 < t < -1.5$, c $-1.5 < t < -0.5$, d $-0.5 < t < -0.2$ GeV² for reaction (1) and for the t -intervals e

$-5 < t < -3$, f $-3 < t < -2$, g $-2 < t < -1.5$, h $-1.5 < t < -1$, i $-1 < t < -0.5$, j $-0.5 < t < -0.2$ GeV² for reaction (2) at 250 GeV/c. Smooth curves represent the best fits by the form (4)

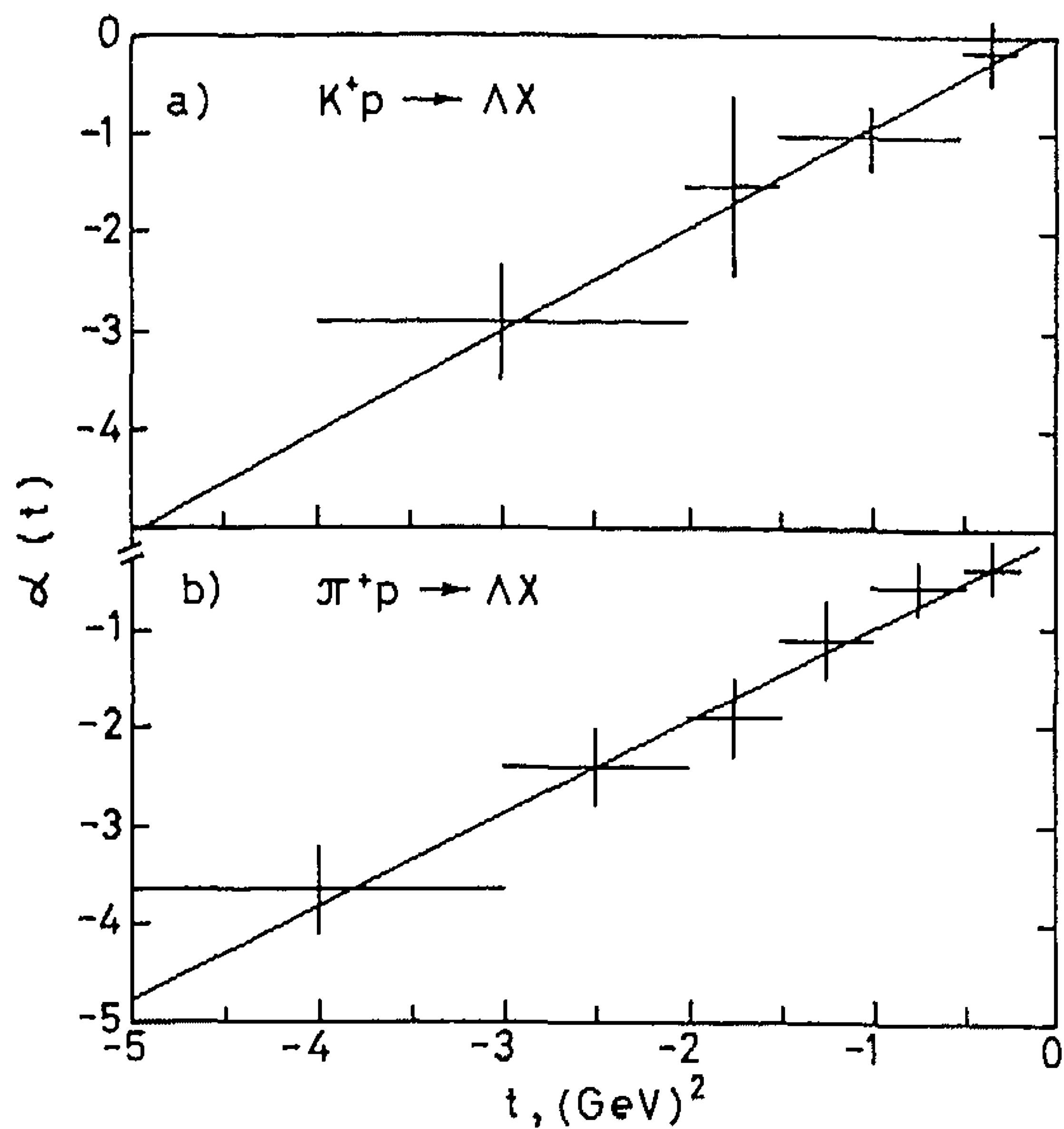


Fig. 3a, b. Effective Regge trajectory $\alpha(t)$ for reactions (1) a and (2) b obtained in the triple-Regge fit. The straight lines are the best fits by the form $\alpha(t) = \alpha(0) + \alpha' t$

x -intervals used in the fit of (4) are chosen so that the phase space effect near the Chew-Low boundary cannot affect the cross sections. The results of the fit are shown by smooth curves.

The trajectories $\alpha(t)$ obtained for reactions (1) and (2) are plotted versus t in Fig. 3. They are well described by the linear form $\alpha(t) = \alpha(0) + \alpha' t$ (straight lines in Fig. 3) with the fitted values of parameters

$$\alpha(0) = 0.08 \pm 0.27,$$

$$\alpha' = 1.03 \pm 0.48 \text{ GeV}^{-2} \text{ for reaction (1),}$$

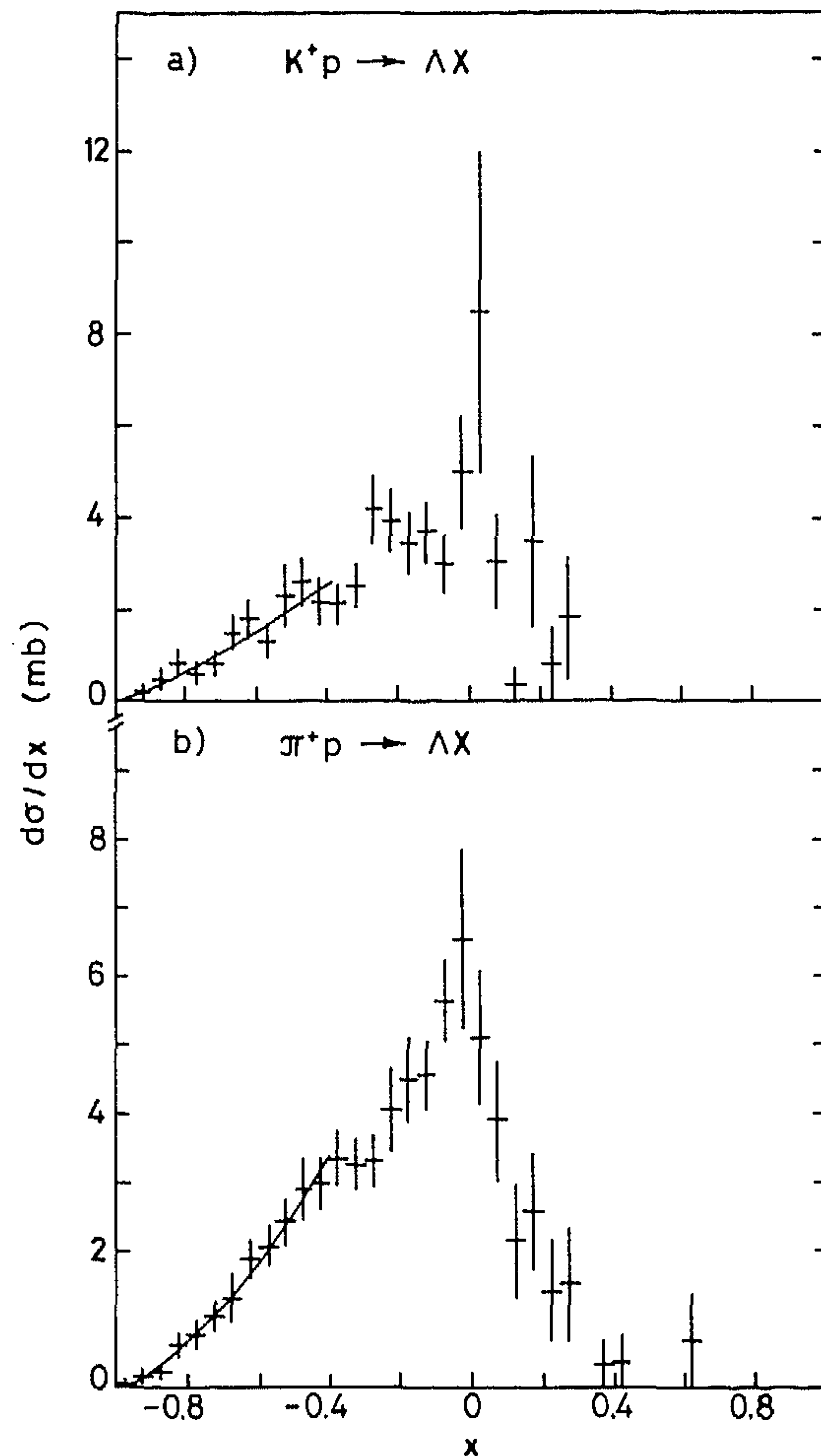


Fig. 4a, b. The $d\sigma/dx$ distributions of Λ in reactions (1) a and (2) b at 250 GeV/c. The smooth curves are the best fits by the form $d\sigma/dx = \text{const} \cdot (1 - |x|)^{1 - 2\alpha(0)}$

Table 1. Strange meson trajectory obtained from the triple Regge analysis

Reaction	p_{beam} (GeV/c)	$\alpha(0)$	α' (GeV $^{-2}$)	Upper limit of $ t $ used (GeV 2)	Ref.
$pp \rightarrow \Lambda X$	12	-0.54 ± 0.07	0.89 ± 0.08	3.6	[1]
	19	-0.38 ± 0.11	1.15 ± 0.07	4.0	[2]
	24	-0.09 ± 0.04	1.04 ± 0.05	3.6	[1]
	69	-0.20 ± 0.22	0.93 ± 0.08	11.0	[3]
	360	-0.60 ± 0.15	0.8	4.0	[4]
$(p/\bar{p})p \rightarrow \Lambda X$	> 10	-0.20 ± 0.10	0.80 ± 0.10		[13]
$\pi^- p \rightarrow \Lambda X$	15	-0.4 ± 0.1	0.90 ± 0.15	1.0	[5]
$\pi^+ p \rightarrow \Lambda X$	250	-0.07 ± 0.22	0.94 ± 0.30	5.0	this work
$K^+ p \rightarrow \Lambda X$	8.2	-0.12 ± 0.15	0.77 ± 0.11	2.5	[9]
	16	-0.20 ± 0.16	0.69 ± 0.13	6.0	[9]
	32	-0.22 ± 0.16	0.78 ± 0.18	2.0	[10]
	250	0.08 ± 0.27	1.03 ± 0.48	4.0	this work
$K^- p \rightarrow \Lambda X$	4.2	-0.06 ± 0.04	1.02 ± 0.02	1.0	[6]
	8.25	-0.15 ± 0.04	0.84 ± 0.04	1.6	[7]
	10, 16				
	and 110	-0.15 ± 0.15	0.8	1.6	[8]

$$\alpha(0) = -0.07 \pm 0.22,$$

$$\alpha' = 0.94 \pm 0.30 \text{ GeV}^{-2} \text{ for reaction (2).}$$

These values are compared with the results from other experiments in Table 1. There is reasonable agreement between the different analyses. As done in [4, 8] we have also tried to fit our data with the fixed value of $\alpha' = 0.8 \text{ GeV}^{-2}$. This yields the intercept value of $\alpha(0) = -0.26 \pm 0.34$ for reaction (1) and $\alpha(0) = -0.28 \pm 0.15$ for reaction (2).

The vertex function $G(t)$ determined from the fit of (4) shows, within large errors, a weak dependence on t . For fixed $\alpha' = 0.8 \text{ GeV}^{-2}$ the average values of the vertex function equal $(7.3 \pm 4.3) \text{ mb} \cdot \text{GeV}^{-2}$ and $(8.4 \pm 3.0) \text{ mb} \cdot \text{GeV}^{-2}$ for reactions (1) and (2), respectively. Assuming constant value of $G(t)$ and integrating (4) over t one obtains $d\sigma/dx \sim (1-|x|)^{1-2\alpha(0)}$. The fit of this form to the experimental $d\sigma/dx$ spectra in the $x \leq -0.4$ region gives $\alpha(0) = -0.11 \pm 0.10$ and -0.23 ± 0.07 for reactions (1) and (2), respectively (the result of the fit is shown in Fig. 4 by smooth curves).

In conclusion, we have shown that the triple Regge model gives a good description of the data on inclusive Λ production in the proton fragmentation region of reac-

tions (1) and (2) at 250 GeV/c. The parameters of the effective strange meson trajectory agree with those obtained in the majority of other experiments. From the value of the intercept $\alpha(0)$ for this trajectory obtained in different experiments it appears that the unnatural kaon trajectory with the intercept $\alpha(0) = -0.2$ is favoured over the natural kaon trajectory with $\alpha(0) = -0.4$.

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