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Triple Regge analysis of inclusive Λ production in K^+p and π^+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

$$K^+ p \rightarrow \Lambda + X \tag{1}$$
$$\pi^+ p \rightarrow \Lambda + X \tag{2}$$

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

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

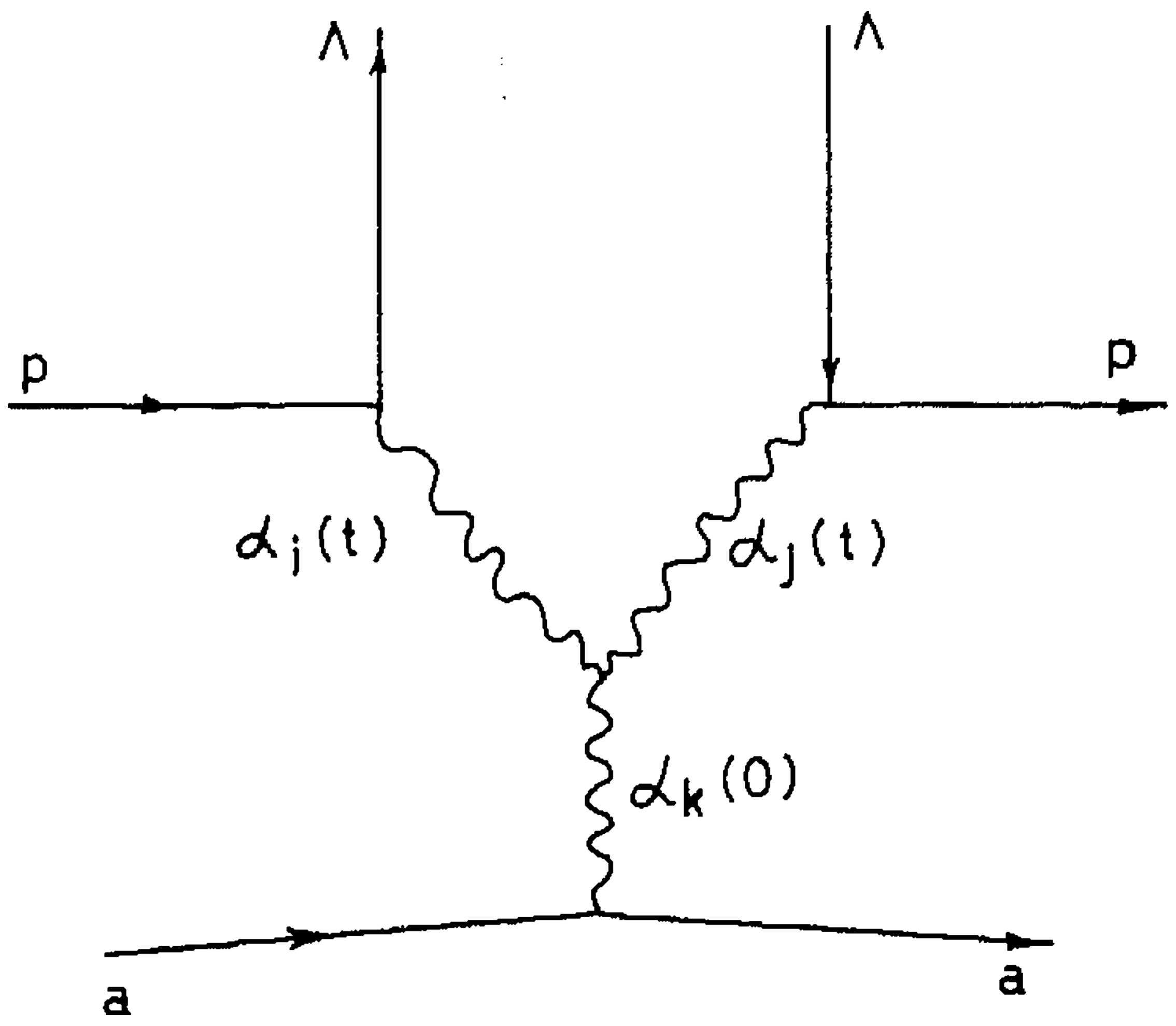

Fig. 1. The triple-Regge diagram for the inclusive reaction $a + p \rightarrow \Lambda + X$

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lower energies. Here, we selected a sample of unambiguously identified 3C-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

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

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

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

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 ($x \leqq -0.4$) 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

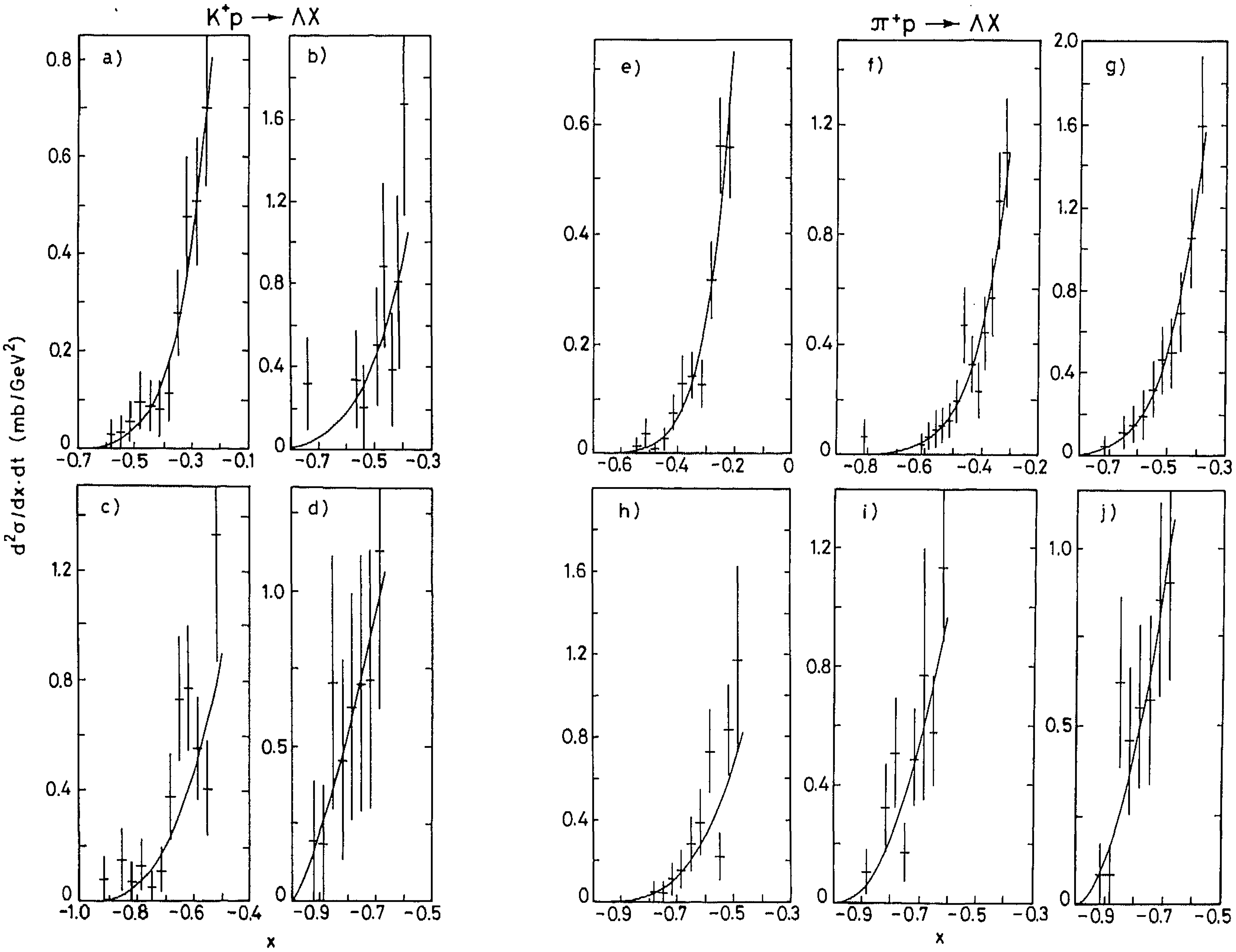

Fig. 2a–j. The $d^2\sigma/dx\,dt$ distribution as a function of x for the t-intervals **a** $-4<t<-2$, **b** $-2<t<-1.5$, **c** $-1.5<t<-0.5$, **d** $-0.5<t<-0.2$ GeV^2 for reaction (1) and for the t-intervals **e** $-5<t<-3$, **f** $-3<t<-2$, **g** $-2<t<-1.5$, **h** $-1.5<t<-1$, **i** $-1<t<-0.5$, **j** $-0.5<t<-0.2$ GeV^2 for reaction (2) at 250 GeV/c. Smooth curves represent the best fits by the form (4)

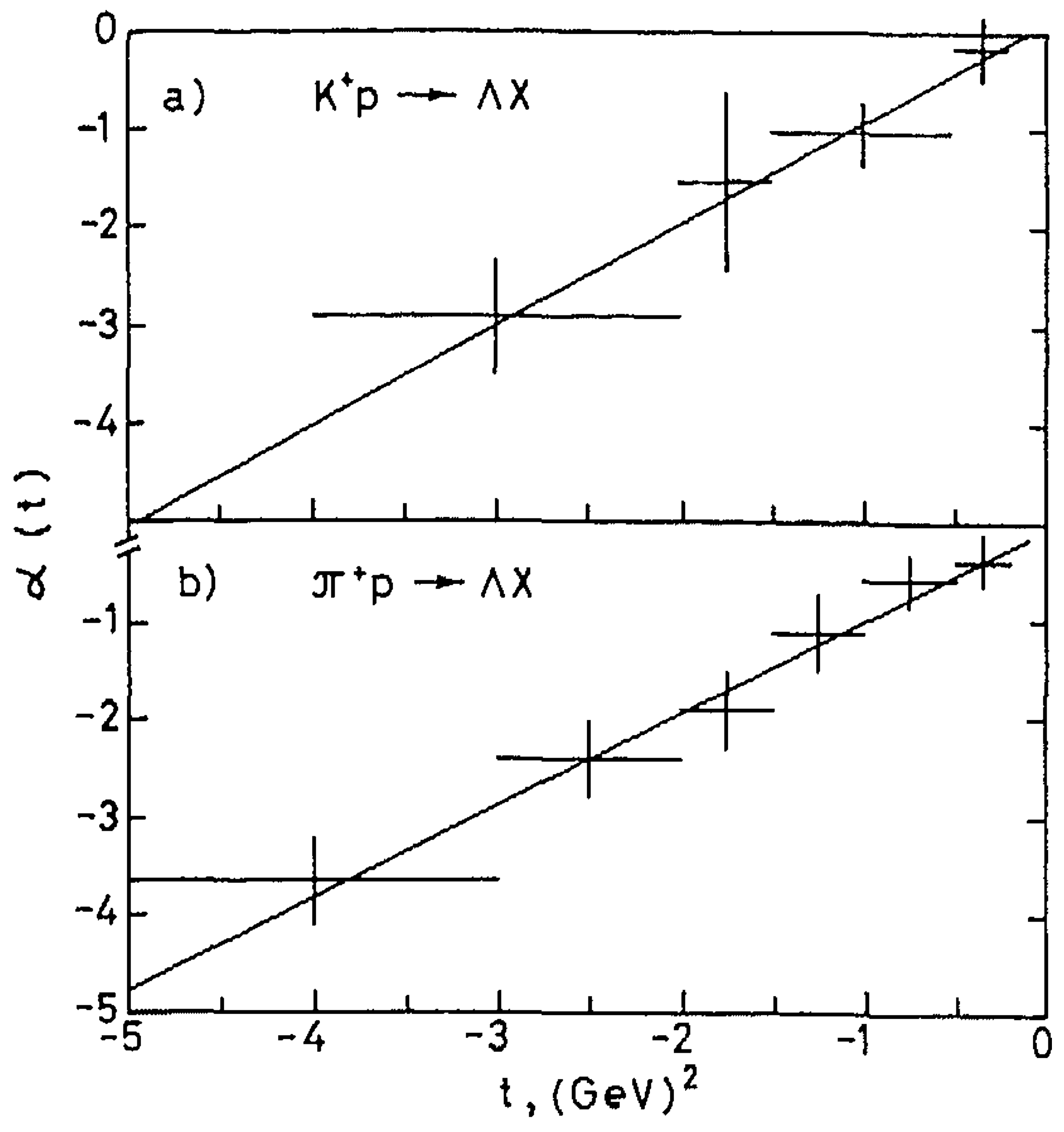

Fig. 3a, b. Effective Regge trajectory $\alpha(t)$ for reactions (1) **a** and (2) **b** obtained in the triple-Regge fit. The straight lines are the best fits by the form $\alpha(t) = \alpha(0) + \alpha' t$

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

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

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

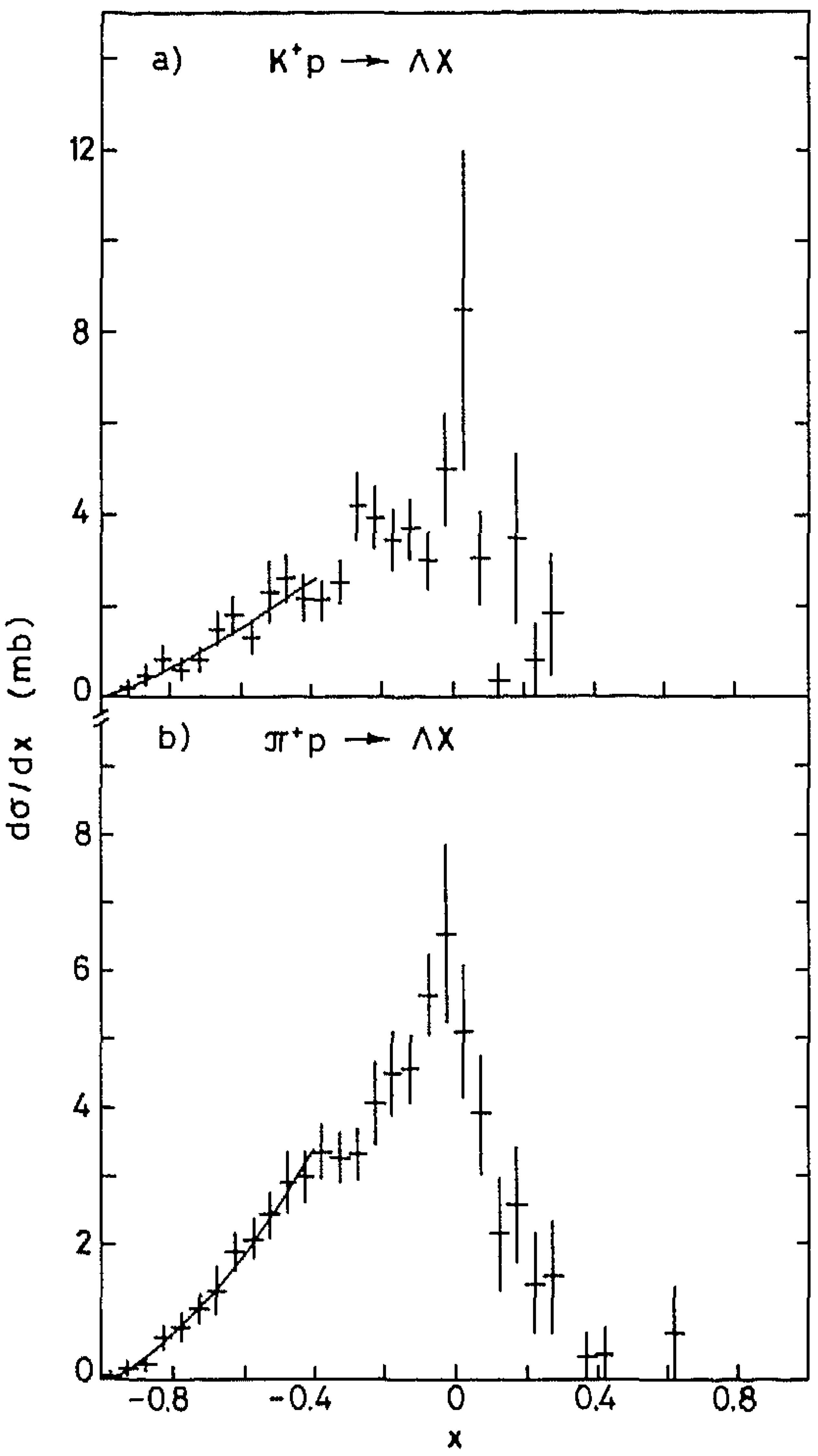

Fig. 4a, b. The $d\sigma/dx$ distributions of Λ in reactions (1) **a** and (2) **b** at 250 GeV/c. The smooth curves are the best fits by the form $d\sigma/dx = \text{const} \cdot (1 - |x|)^{1 - 2\alpha(0)}$

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]

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

$\alpha' = 0.94 \pm 0.30\ \mathrm{GeV}^{-2}$ 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 $\alpha' = 0.8\ \mathrm{GeV}^{-2}$. 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 $\alpha' = 0.8\ \mathrm{GeV}^{-2}$ the average values of the vertex function equal $(7.3 \pm 4.3)\ \mathrm{mb \cdot GeV}^{-2}$ and $(8.4 \pm 3.0)\ \mathrm{mb \cdot GeV}^{-2}$ 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 $x \leqq -0.4$ 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 reactions (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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