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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 $K^+ \to \Lambda + X$ and $\pi^+ \to \Lambda + X$ 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

$$K^+ p \to \Lambda + X \quad (1)$$
$$\pi^+ p \to \Lambda + X \quad (2)$$

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

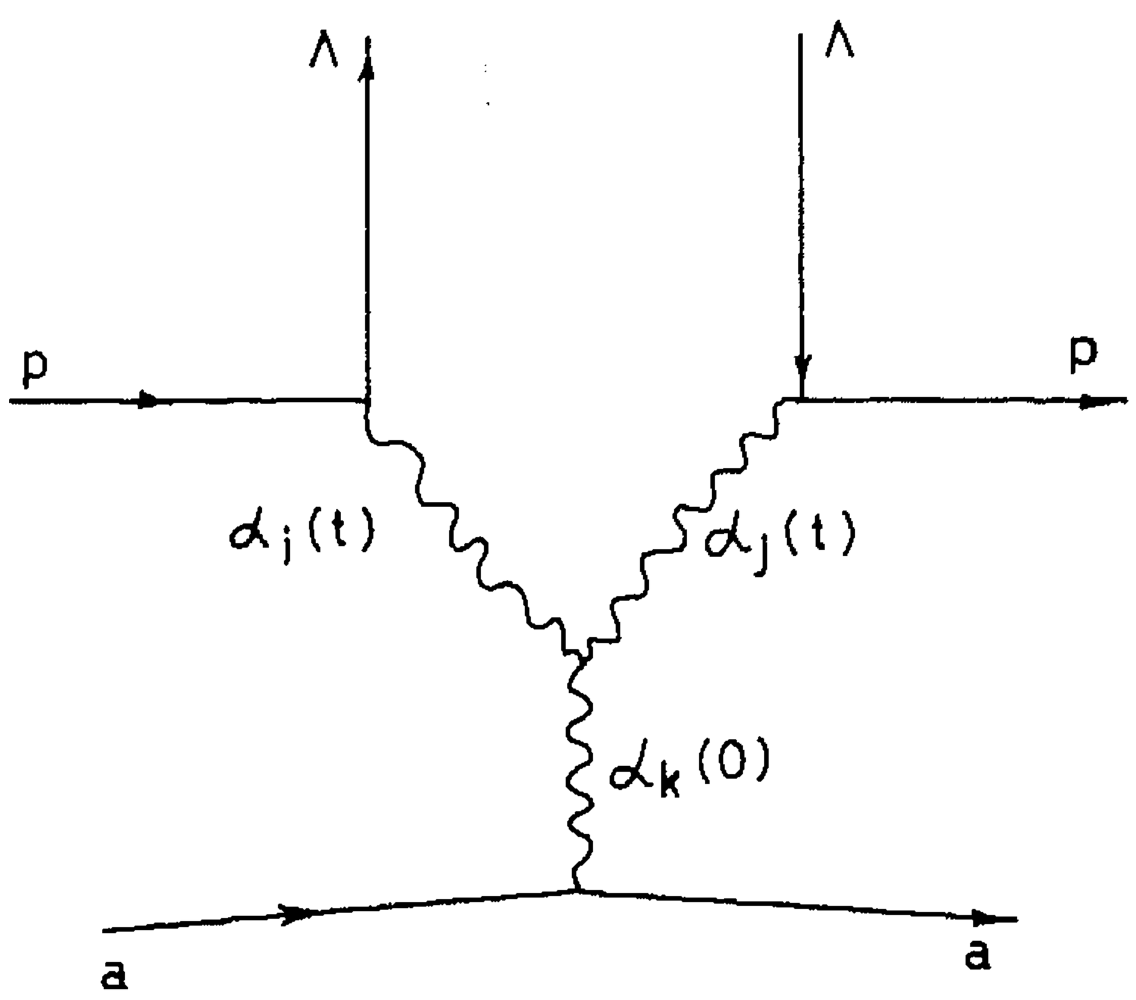

Fig. 1. The triple-Regge diagram for the inclusive reaction $a + p \to \Lambda + X$

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

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

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 ($x \leqq -0.4$) 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

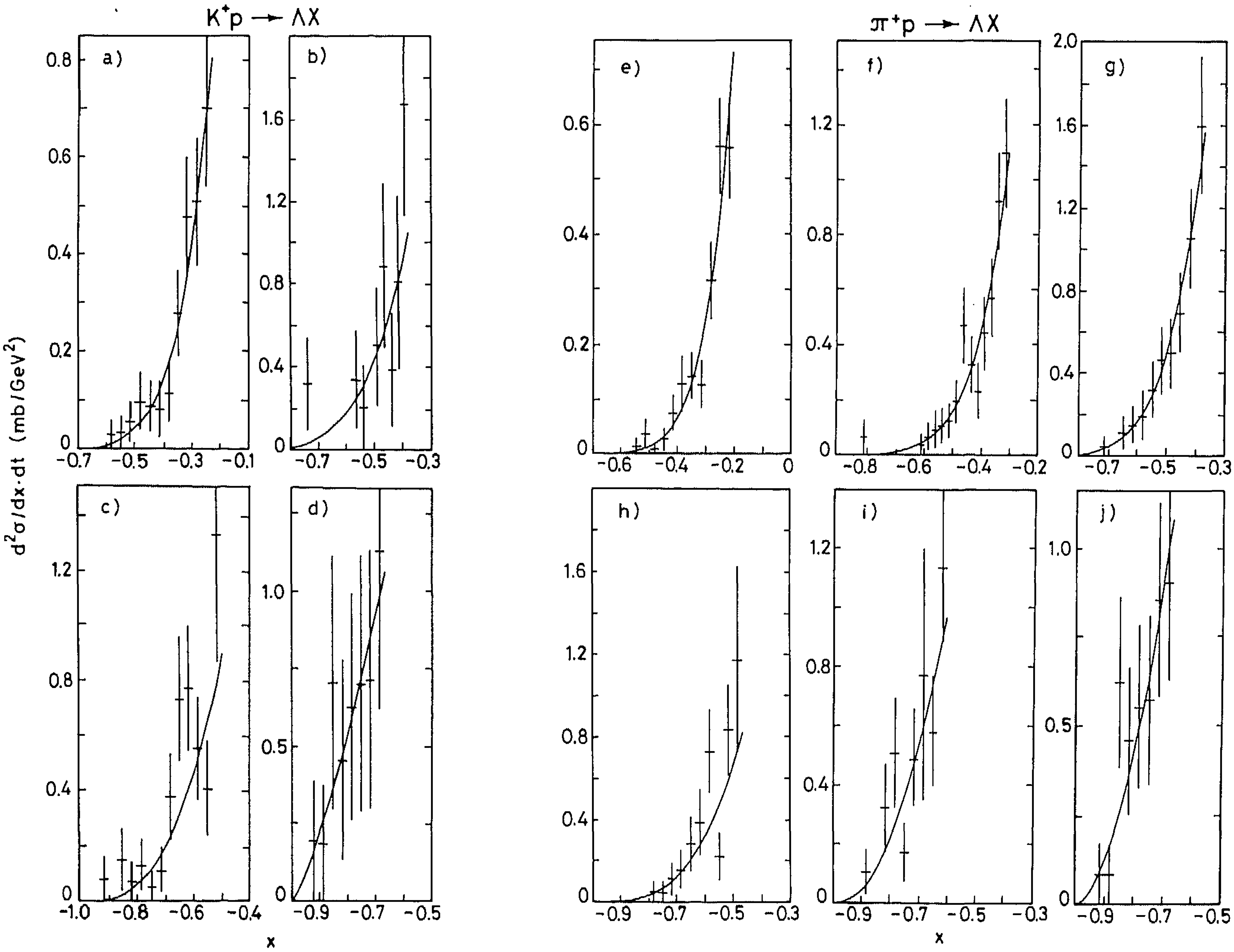

Fig. 2a–j. The $d^2\sigma/dx\,dt$ distribution as a function of x for the t-intervals **a** $-4<t<-2$, **b** $-2<t<-1.5$, **c** $-1.5<t<-0.5$, **d** $-0.5<t<-0.2$ GeV^2 for reaction (1) and for the t-intervals **e** $-5<t<-3$, **f** $-3<t<-2$, **g** $-2<t<-1.5$, **h** $-1.5<t<-1$, **i** $-1<t<-0.5$,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

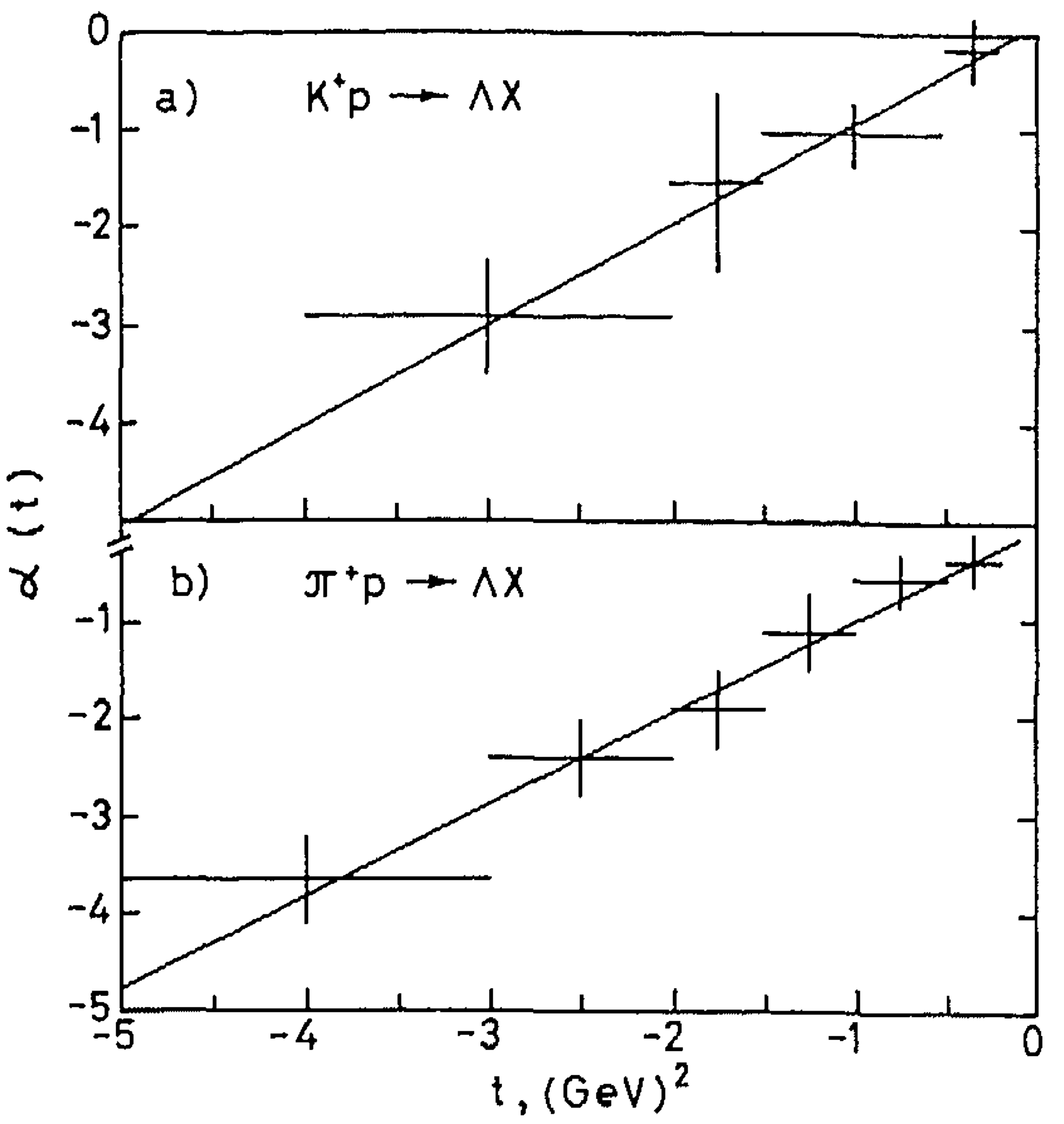

Fig. 3a, b. Effective Regge trajectory $\alpha(t)$ for reactions (1) **a** and (2) **b** obtained in the triple-Regge fit. The straight lines are the best fits by the form $\alpha(t)=\alpha(0)+\alpha' t$

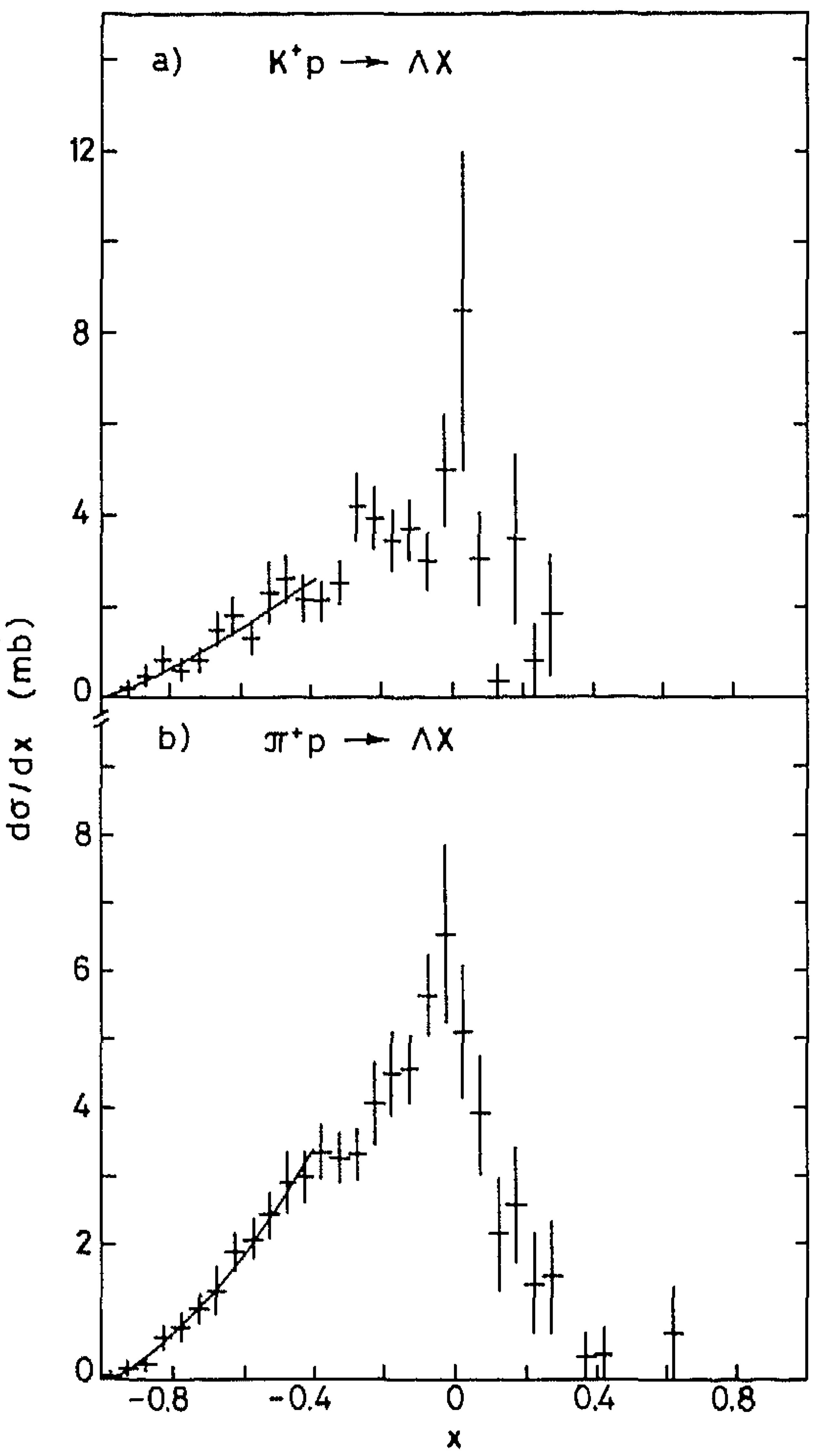

Fig. 4a, b. The $d\sigma/dx$ distributions of Λ in reactions (1) **a** and (2) **b** at 250 GeV/c. The smooth curves are the best fits by the form $d\sigma/dx=\text{const}\cdot(1-|x|)^{1-2\alpha(0)}$

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

$$\alpha(0)=\ 0.08\pm0.27,$$
$$\alpha'=1.03\pm0.48\ \text{GeV}^{-2}\quad \text{for reaction (1)},$$

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.
$pp\to\Lambda X$	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]
$(p/\bar{p})\,p\to\Lambda X$	>10	-0.20 ± 0.10	0.80 ± 0.10		[13]
$\pi^- p\to\Lambda X$	15	-0.4 ± 0.1	0.90 ± 0.15	1.0	[5]
$\pi^+ p\to\Lambda X$	250	-0.07 ± 0.22	0.94 ± 0.30	5.0	this work
$K^+ p\to\Lambda X$	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
$K^- p\to\Lambda X$	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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