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APPROACH TO SCALING IN INCLUSIVE Λ PRODUCTION IN $K^\pm p$ INTERACTIONS

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ABSTRACT

An observation of large differences in inclusive Λ production in K^+p and K^-p interactions has led to a detailed study of the approach to scaling in these processes. A Regge and a quark model based analysis of the Λ production in $K^\pm p$ interactions is presented.

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1. INTRODUCTION

Recent experiments have improved our knowledge of Λ production in interactions of incident K^+ and K^- with protons. The analysis of the available data reveals some striking differences, which we present in sect. 2 of the present paper. These differences are analyzed in terms of the standard Regge model in sect. 3, showing that they can be traced to two distinct processes. In sect. 4, a link is made with the quark-parton model, showing the relative contributions of the exchange of u_v and s_v valence quarks. Our conclusions are summarized in sect. 5.

2. PRESENTATION OF THE DATA

Recent experiments in BEBC exposed to an RF separated beam [1] have provided results on the inclusive reactions

$$K^- p \rightarrow \Lambda + \text{anything at } 110 \text{ GeV/c and } 70 \text{ GeV/c} \quad (1)$$

$$K^+ p \rightarrow \Lambda + \text{anything at } 70 \text{ GeV/c} \quad (2)$$

When the invariant cross sections in the backward hemisphere

$$f_{K^\pm p \rightarrow \Lambda}^{K^\pm}(x, s) = \frac{1}{\pi p_{\text{max}}^{\text{cm}}} \int \frac{E^* d^2 \sigma_{K^\pm p \rightarrow \Lambda}}{dx dp_T^2} dp_T^2$$

are compared to data obtained at lower energies [2] (fig. 1) it is seen that the scaling limit is reached for $x < -0.5$ in K^+p reactions. The x and p_T are as usual the Feynman variable and the transverse momentum. In the true scaling limit it is expected that the K^-p data should yield the same $f(x)$ as in K^+p . From fig. 1 it is clear that there are large deviations from this limit; all the K^-p data from 32 to 110 GeV/c lie approximately a factor 2 above the K^+p data.

A comparison of the total cross sections (fig. 2) shows that the excess of Λ production by incident K^- over K^+ , large at low incident momentum, decreases with momentum.

In order to investigate the different behaviour in K^+p and K^-p reactions, we consider the main Λ production channels in the two cases to be as follows:

$$K^-p \rightarrow \Lambda + X_{ns} \quad (\text{hypercharge annihilation}) \quad (3)$$

$$K^-p \rightarrow \Lambda + \text{strange particles} + X_{ns} \quad (4)$$

$$K^+p \rightarrow \Lambda + \text{strange particles} + X_{ns} \quad (5)$$

where X_{ns} denotes an inclusive set of non-strange particles.

In order to check whether the observed differences can be attributed to hypercharge annihilation (3) which is present in K^-p reactions, but not in K^+p , we focus our attention on the channels (4) and (5).

Channel (4) cannot be readily isolated experimentally, but its behaviour can be inferred from its subchannel

$$K^-p \rightarrow \Lambda + K_n + \text{anything} \quad (6)$$

where the K_n denotes a neutral kaon identified by its visible decay in the bubble chamber. The total cross sections for channel (6) shown in fig. 2 substantially exceeds the total cross section for reaction (2), showing that hypercharge annihilation alone cannot account for the differences between reactions (1) and (2). We recall here that the cross section for the forward Λ production associated with a pair of kaons is small in the processes described above.

3. REGGE ANALYSIS

Following the authors of ref. [3], we analyze the channels (3), (4) and (5) in terms of Regge exchanges. In the single Regge limit (M^2 large, $t \ll M^2$) there are three Regge exchange processes to be considered (as indicated in fig. 3):

- (a) ϕ , f' exchange, responsible for hypercharge annihilation.
- (b) ρ , ω , f , A_2 exchanges, contributing to the associated production channel (4).

- (c) Pomeron exchange, also contributing to channel (4), and the only contribution to channel (5).

It is clear that, in this framework, the observed excess of associated production in K^-p reactions is to be traced to a substantial contribution of exchanges belonging to the ρ , ω , f , A_2 family.

The Regge exchanges can be parametrized as

$$\begin{aligned}
 & \begin{matrix} K^- \\ p \rightarrow \Lambda \\ f \end{matrix} \left(\frac{M_x^2}{s}, t, s \right) = A_P \left(\frac{M_x^2}{s}, t \right) s^{\alpha_P(0)-1} + A_\rho \left(\frac{M_x^2}{s}, t \right) s^{\alpha_\rho(0)-1} \\
 & \quad + A_\phi \left(\frac{M_x^2}{s}, t \right) s^{\alpha_\phi(0)-1} \\
 & \begin{matrix} K^+ \\ p \rightarrow \Lambda \\ f \end{matrix} \left(\frac{M_x^2}{s}, t, s \right) = A_P \left(\frac{M_x^2}{s}, t \right) s^{\alpha_P(0)-1}
 \end{aligned} \tag{7}$$

where M_x is the missing mass (the mass of the system denoted "anything" in reactions (1) and (2)), t is the squared four momentum transfer from p to Λ , A_ρ denotes the sum of the ρ , ω , f , A_2 exchange contributions and A_ϕ denotes the sum of the ϕ and f' exchange contributions.

At the energies considered here, $\frac{M_x^2}{s} \approx 1 - x$. Using the values $\alpha_P(0) = 1$, $\alpha_\rho(0) = 0.5$ and $\alpha_\phi(0) = 0$, and integrating over t , we obtain for the difference between the invariant cross sections

$$\begin{matrix} K^- \\ p \rightarrow \Lambda \\ f \end{matrix} (x, s) - \begin{matrix} K^+ \\ p \rightarrow \Lambda \\ f \end{matrix} (x, s) = A_\rho(x) s^{-1/2} + A_\phi(x) s^{-1} . \tag{8}$$

The available data are shown on fig. 4 and fitted to relation (8) in several x intervals. The results, given in table 1, indicate that good fits are obtained over the whole region $x < 0$. In the region $(-0.8 < x < 0)$ the A_ϕ term is dominant, but the presence of the A_ρ term is clear in the $(-1 < x < -0.8)$ region. As s increases, the influence of the A_ρ term disappears more slowly than that of the A_ϕ term, thus the scaling limit is expected to be reached in the $(-1 < x < -0.8)$ region at higher momenta $p_{LAB}^K \gtrsim 200$ GeV/c) than in the region $(-0.8 < x < 0.0)$.

These observations are compatible with some of the rules for early scaling linked to exoticity see e.g. [4]; the systems $K^- \bar{p} \Lambda$ and $p \bar{\Lambda}$ are non exotic, with no expectation of early scaling, whereas the system $K^+ p \bar{\Lambda}$ is exotic, with early scaling expected.

4. QUARK PARTON MODEL ANALYSIS

The Regge terms of relation (8) can be represented by the quark diagrams of fig. 5. Diagram 5(a), with u_v exchange is related to the ρ, ω, f, A_2 contribution. Diagram 5(b), drawn as the line-reversed reaction $K^- \bar{\Lambda} \rightarrow \bar{p} + \text{anything}$, with s_v exchange, is related to the ϕ, f' exchange or hypercharge annihilation. In the quark approach the s^{-1} dependence of the s_v exchange term and $s^{-1/2}$ dependence of the u_v exchange term may be linked to the behaviour of the valence quark distributions in the region of small x [5]. Indeed, the diagrams 5(a) and 5(b) are expected to contribute to inclusive Λ production in a particular configuration of the valence-quarks, namely, when the relative momenta of a u_v from the proton and a $\bar{u}_v$ from the kaon in the process (a), an s_v from the lambda and an s_v from the kaon in the process (b) are of the order of the typical meson mass or less. The probabilities of these configurations are related to the non-strange and strange valence quark distribution functions respectively, by the relations

$$P(a) \sim \left(\int_0^{\frac{2m}{\sqrt{s}}} u_v(x) dx \right)^2 \quad (9)$$

$$P(b) \sim \left(\int_0^{\frac{2m}{\sqrt{s}}} s_v(x) dx \right)^2 \quad (10)$$

where it is assumed that the distribution function of a valence quark of given type is independent of the quantum numbers of the parent hadron. It can be easily shown that, if the $u_v(x)$ is proportional to $x^{-1/2}$ in the small x region, eq. (9) yields the $s^{-1/2}$ term of eq. (8). This behaviour of $u_v(x)$ was assumed in [6] and applied to the description of the beam dependence of the ratio of positive to negative pion distributions in the proton hemisphere in meson induced interactions. It is worth noticing that this behaviour is also consistent with the results of measurements of the

proton structure functions in deep inelastic scattering processes [5] and in u^+u^- pair production processes [7]. Similarly, if the $s_v(x)$ is constant in the small x region, as was assumed in [8] in order to describe the particle spectra in K^+p interactions within the quark-fusion model framework, eq. (10) yields the s^{-1} term of eq. (8).

We note, that within the quark approach the observed importance of the ρ , ω , f , A_2 or u -quark exchange term for $x \rightarrow -1$ may be linked to the fact that, when the u_v quark is slow the $u_v d_v$ diquark is fast and, a Λ produced by the $u_v d_v$ diquark carries a large fraction of the proton momentum.

5. CONCLUSIONS

The observed difference in inclusive Λ production between K^-p and K^+p reactions, shows the following properties when analyzed in terms of Regge exchanges, or of valence quark exchanges:

- The process of an s -quark exchange (or ϕ , f' trajectory exchange), shows an s^{-1} behaviour, and is important for all $x < 0$ at the energies discussed here.
- The process of a u_v quark exchange (or ρ , ω , f , A_2 exchange), shows a $s^{-1/2}$ behaviour and is only significant at $x \rightarrow -1$. This behaviour may be understood in terms of the relative momenta of the u_v quark and the $(u_v d_v)$ diquark in the proton.
- The non-scaling behaviour of the $K^-p \rightarrow \Lambda + X$ reaction is expected to be negligible for incident momenta above 200 GeV/c.

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Results of the $A*s^{-1}$ fits
to the data

x interval	χ^2/ND	A
0-0.2	2.4/3	7.0 ± 0.17
0.2-0.4	7.9/3	7.6 ± 0.19
0.4-0.6	2.6/3	8.0 ± 0.20
0.6-0.8	2.2/3	8.4 ± 0.20
0.8-1.0	50/3	6.0 ± 0.16

Results of the $A_\phi*s^{-1} + A_\rho*s^{-1/2}$ fits
to the data

x interval	χ^2/ND	A_ϕ	A_ρ
0-0.2	.75/2	6.1 ± 0.7	0.21 ± 0.16
0.2-0.4	5.7/2	6.4 ± 0.8	0.25 ± 0.17
0.4-0.6	2.3/2	7.6 ± 0.8	0.10 ± 0.17
0.6-0.8	1.4/2	7.4 ± 0.8	0.22 ± 0.16
0.8-1.0	2/2	1.3 ± 0.7	1.1 ± 0.16

TABLE 1

FIGURE CAPTIONS

- Fig. 1 Invariant cross sections in the backward hemisphere for the processes $p \rightarrow K^{\pm} \Lambda$.
- Fig. 2 Total inclusive Λ cross section in $K^{\pm}p$ interactions and total inclusive $\Lambda K n$ cross section in $K^{\mp}p$ interactions as a function of $K^{\pm}$ momentum.
- Fig. 3 Single Regge limit for Λ production in $K^{\pm}p$ interactions showing the exchanged trajectories.
- Fig. 4 $A * s^{-1}$ and $A_{\phi} * s^{-1} + A_{\rho} * s^{-1/2}$ fits to the data.
- Fig. 5 Quark diagrams for Λ production in $K^{\mp}p$ interactions:
- (a) u_v quark exchange related to the ρ , ω , f , A_2 contribution.
 - (b) s_v quark exchange related to the ϕ , f' contribution.

Fig. 1

Fig. 2

Fig. 3

$$f_{p \rightarrow \Lambda}^{K^-}(x, S) - f_{p \rightarrow \Lambda}^{K^+}(x, S)$$

Fig. 4

(a)

(b)

Fig. 5