Study of inclusive production of Λ-hyperons in the target fragmentation region in *pp* interactions at 360 GeV/*c* by a triple Regge analysis

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(Submitted 16 September 1986)
Pis'ma Zh. Eksp. Teor. Fiz. **44**, No. 9, 407–411 (10 November 1986)

The inclusive production of Λ-hyperons has been studied in the target fragmentation region in *pp* interactions at 360 GeV/*c*. A three-Reggeon analysis of the differential cross section for the production of Λ-hyperons is used to evaluate the intercept of the effective kaon trajectory: $\simeq(-0.6)$. In virtual "K^+"p interactions, the behavior of the average multiplicity and that of the correlation moments as functions of the center-of-mass energy of the virtual "K^+"p system agree well with the corresponding behavior in real K^+p interactions.

INTRODUCTION

This letter reports a study of the inclusive production of Λ-hyperons in *pp* interactions on the basis of a Regge-pole pattern.

The results were obtained in experiment NA23, carried out at CERN with the RCBC rapidly circulating bubble chamber and the EHS European hybrid spectrometer. The experimental apparatus has been described in detail in previous papers.[1]

The bubble chamber, filled with liquid hydrogen, is positioned in a magnet with a field of about 3 T and is bombarded by a proton beam with a momentum of 360 GeV/*c*. The secondary charged particles from the interaction of the beam protons with the liquid hydrogen in the chamber are detected in the chamber itself and in a charged-particle spectrometer behind the chamber.

The events on whose results the analysis of the present letter is based were found as a result of measurements of about 95% of the events detected on 160 000 photographs. The statistical significance of the sample is ~ 1.6 events/μb. Among all the measured events with V^0 particles, 1915 were selected on the basis that the V^0 particles in these events have the Λ-hyperon hypothesis. After a cutoff in terms of the probability of a kinematic fit at the 1% level and a rejection of the decays which can be fitted in

more than one way, the final sample, used for the physical analysis, contained 798 decays. These decays were classified as Λ-hyperons. Events falling in the fragmentation region of the target were selected on the basis of the amount of momentum transferred from the target proton to the Λ-hyperon: $|t_{p\Lambda}| = (P_p - P_\Lambda)^2 < 4.0$ GeV^2 (the region $x_F < -0.2$). Because of the limited statistical base, Λ-hyperons from the decays of Σ^0 and $\Sigma(1385)$ were not singled out.

1. Triple Regge analysis. In the Regge-Müller phenomenology, the cross section for the production of Λ-hyperons in the proton fragmentation region can be described by the expression

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

where the functions $G_{ijk}(t)$ contain Regge residues and signatures; the trajectories α_i and α_j correspond to the exchanges of K, K_A, K^*, and K^{**} (strange Reggeons; α_k corresponds to the exchange of a pomeron; and M^2 is the square of the missing mass with respect to the Λ-hyperon).

In the limit of exchange degeneracy we have

$$\frac{d^2\sigma}{dtd(M^2/s)} = G(t)(M^2/s)^{1-2\alpha_{eff}(t)}, \quad (2)$$

where α_{eff} is the effective "K"-meson trajectory at the $p\bar{\Lambda}$ vertex. Expression (2) is approximated by a distribution in M^2/s in the momentum-transfer intervals shown in Fig. 1:

$(-1.0 < t < 0.0;\ -2.0 < t < -1.0;\ -3.0 < t < -2.0;$

$-4.0 < t < -3.0$ GeV^2).

The residue $G(t)$ is parametrized as follows:

$$G(t) = A \exp(Bt). \quad (3)$$

The results of the fit show that the values of the intercept $\alpha_{\text{eff}}(0)$ and the slope α'_{eff} are correlated. Under the plausible assumption $\alpha'_{\text{eff}} \simeq -0.8$ regarding the magnitude of the slope, the intercept of the effective trajectory turns out to be $\alpha_{\text{eff}}(0) = -0.60 \pm 0.15$, and the approximating curves reproduce the data well for all M^2/s. The measured slope of the effective trajectory agrees well with the published data of other experiments and is evidence that the production of Λ-hyperons in the proton fragmentation region is dominated by the exchanges of a kaon trajectory with an unnatural parity.

2. Test of the factorization of pomeron exchange. The hypothesis of the factorization of pomeron exchange can be used to relate the two-particle inclusive particle distributions in the fragmentation regions of the beam and the target to the single-particle inclusive distributions and the total cross section.[3] In the target fragmentation region, the rapidity distribution of the detected particle can be written

$$\frac{d\sigma}{dY}(pp \to \pi^-) = \beta_p F_p^{p \to \pi^-}(|Y|), \quad (6)$$

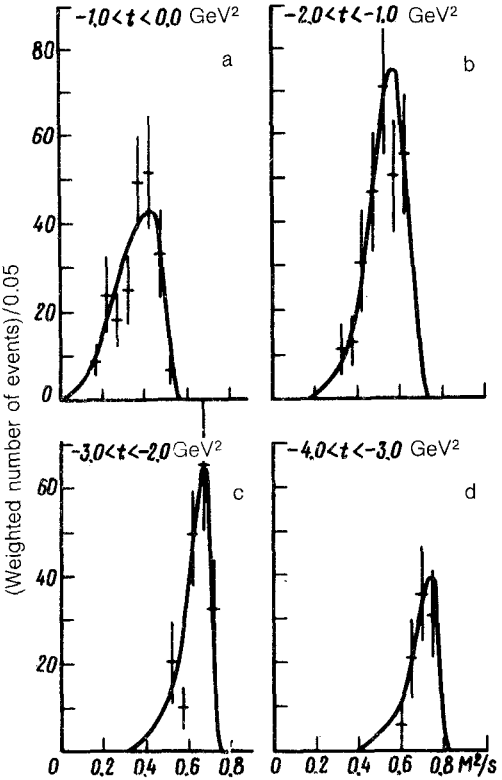

FIG. 1. Distribution in the variable M^2/s in the reaction $p \xrightarrow{p} \Lambda$ at 360 GeV/c in various intervals of the momentum transfer $t_{p\Lambda}$: a— $-1.0 < t < 0.0$ GeV^2; b— $-2.0 < t < -1.0$ GeV^2; c— $-3.0 < t < -2.0$ GeV^2; d— $-0.4 < t < -0.3$ GeV^2. The smooth curves are the result of a fit.

$$\frac{d^2\sigma(pp \to \pi^- \Lambda)}{dY_{\pi^-}\, dY_\Lambda} = F_p^{p \to \pi^-}(|Y_{\pi^-}|) F_p^{p \to \Lambda}(|Y|), \tag{7}$$

where the particles π^- and Λ are emitted into different hemispheres in the c.m. frame. Under the assumption of pomeron exchange factorization we can then write

$$\frac{d^2\sigma}{dY_{\pi^-}\, dY_\Lambda} = \frac{1}{\sigma_{tot}(pp)} \frac{d\sigma}{dY_{\pi^-}} \frac{d\sigma}{dY_\Lambda}. \tag{8}$$

Figure 2 shows data on the left and right sides of Eq. (8) separately as functions of Y_Λ for two different intervals of Y_{π^-}. Within the errors, these results agree well with each other (the standard deviation is 10.0% with $\chi^2 = 0.5$ per degree of freedom), confirming the validity of the hypothesis of pomeron exchange factorization. A similar conclusion was reached previously on the basis of a comparison of the single-particle[4] and two-particle[2] distributions of π mesons.

3. Virtual "K^+"p interactions. As was shown in the first section of this letter, in events with $|t_{p\Lambda}| \leqslant 4.0$ GeV^2 the $p\bar{\Lambda}$ vertex is dominated by the exchanges of a "K^+"-messon pole. Such events may be interpreted as cases of a virtual "K^+"p interaction at another proton vertex.

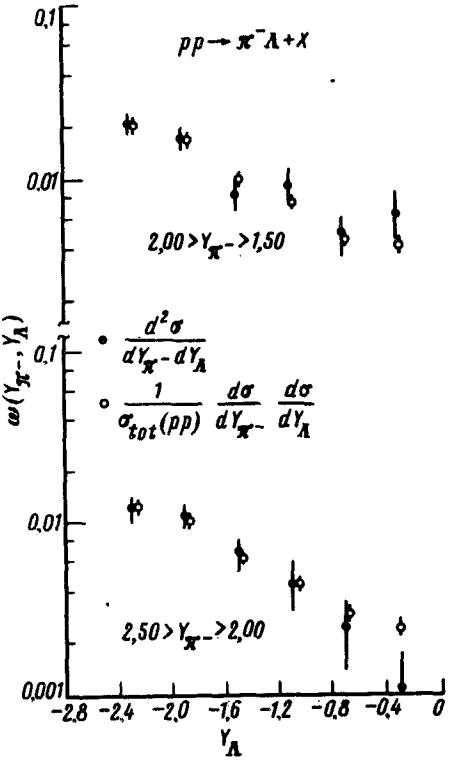

FIG. 2. Test of factorization of pomeron exchange in pp interactions at 360 GeV/c. Open circles—two-particle distribution; filled circles—product of single-particle distributions.

Figure 3a shows the average charged-particle multiplicity $\langle n_{ch} \rangle$ for the charged particles produced in these interactions versus the effective mass of the "K^+"p system, along with data from real "K^+"p experiments.[5] The two sets of points agree well with each other and conform to the common curve

$$\langle n_{ch} \rangle = (1{,}79 \pm 0.07) + (0{,}12 \pm 0.05) \ln M^2 + (0{,}16 \pm 0.07) \ln^2 M^2 . \quad (9)$$

Also shown in this figure (3b and 3c) are corresponding data for the second and third correlation moments of the multiplicity distribution in "K^+"p interactions:

$$C_q = \frac{\langle n^q \rangle}{\langle n \rangle^q} . \quad (10)$$

Within the errors, the quantities C_2 and C_3 are roughly constant over the energy interval considered here, indicating an approximate KNO scaling[6] of the average charged-particle multiplicity in both real and virtual "K^+"p interactions.

CONCLUSION

We have studied the inclusive production of Λ-hyperons in the target fragmentation region in pp interactions at 360 GeV/c. The results of this study can be summarized as follows.

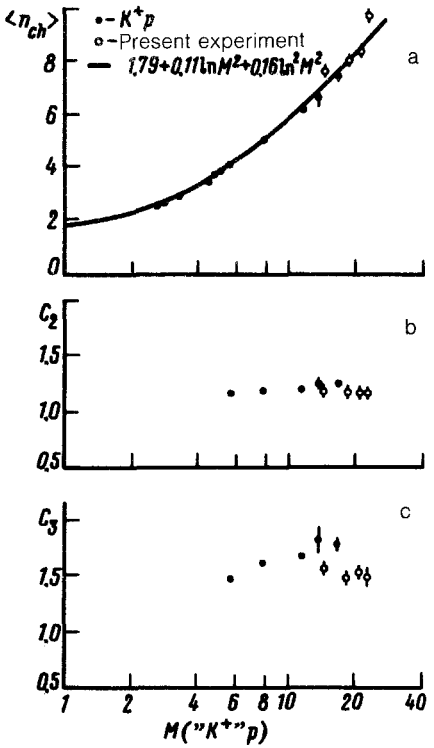

FIG. 3. a—Average multiplicity of secondary charged particles, $\langle n_{ch} \rangle$; b,c—moments of the multiplicity distribution; C_2 (b) and C_3 (c), in the virtual "K^+"p interaction as functions of the energy of the "K^+"p system in the c.m. frame (filled circles). The open circles show the observed energy dependence in "K^+"p interactions. The smooth curve is the result of a fit.

1) In the target fragmentation region, the behavior of the differential cross section for Λ-hyperon production agrees well with the hypothesis that Regge diagrams with the exchange of an effective "K^+" trajectory, with an intercept $\alpha_{\text{eff}}(0) \simeq -0.6$, are dominant.

2) Comparison of the single-particle and a two-particle distributions of π^- mesons and Λ-hyperons in the reaction $pp \to \Lambda\pi^- + X$ confirms the validity of the hypothesis of pomeron exchange factorization.

3) The behavior of the first moments of the distributions in the charged-particle multiplicity in the virtual "K^+"p interactions agrees well with corresponding data on real "K^+"p directions and is of a scaling nature.

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[1]J. L. Bailly *et al.*, Z. Phys. **C22**, 119 (1984); J. L. Bailly *et al.*, Z. Phys. **C23**, 205 (1984); M. Asai *et al.*, Z. Phys. **C27**, 11 (1985).
[2]J. G. Rushbrooke *et al.*, Phys. Rev. Lett. **39**, 117 (1977).
[3]R. C. Brower *et al.*, Phys. Rev. D **7**, 2080 (1978).
[4]J. Whitemore, Phys. Lett. **60B**, 241 (1976); J. Erwin *et al.*, Phys. Rev. Lett. **33**, 1352; E. M. Beier *et al.*, Phys. Rev. Lett. **37**, 1120 (1976).
[5]J. Whitemore, Phys. Rep. **10C**, 273 (1974); Phys. Rep. **27C**, 187 (1976); I. V. Ajinenko *et al.*, Nucl. Phys. **123B**, 493 (1977); I. V. Ajinenko *et al.*, Z. Phys. **C4**, 181 (1980); M. Barth *et al.*, Z. Phys. **C2**, 285 (1979); W. M. Morse *et al.*, Phys. Rev. D **15**, 55 (1977); D. Brick *et al.*, Paper submitted to Nineteenth International Conference on High Energy Physics, 1978.
[6]Z. Koba *et al.*, Nucl. Phys. **B40**, 317 (1972).

Translated by Dave Parsons