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A TEST OF THE FACTORIZATION HYPOTHESIS OF LEADING REGGE TRAJECTORIES FOR INCLUSIVE REACTIONS $\bar{p} + p \to \pi^- + x$, $\bar{p} + p \to \Lambda + x$ IN THE PROTON FRAGMENTATION REGION AT 22.4 GEV/C

Alma-Ata - Dubna - Helsinki - Prague - Tbilisi Collaboration

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Боос Э.Г. и др. E1 - 11878

Проверка гипотезы факторизации лидирующих траекторий Редже в инклюзивных реакциях $\bar{p}+p\to\pi^-+X$, $\bar{p}+p\to\Lambda+X$ в области фрагментации протона при первичном импульсе 22,4 ГэВ/с

Проверялось выполнение гипотезы факторизации лидирующих траекторий Редже (P, ρ, ω, f, A_2) в реакциях $\bar{p}+p\to\pi^-+X$, $\bar{p}+p\to\Lambda+X$ в области фрагментации протона-мишени при первичном импульсе 22,4 ГэВ/с. Установлено, что гипотеза факторизации выполняется для реакции рождения π-мезонов и Λ-гиперонов на уровне статистической точности экспериментальных данных.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Boos E.G. et al. E1 - 11878

A Test of the Factorization Hypothesis of Leading Regge Trajectories for Inclusive Reactions $\bar{p}+p\to\pi^-+X$, $\bar{p}+p\to\Lambda+X$ in the Proton Fragmentation Region at 22.4 GeV/c

The factorization hypothesis of leading Regge trajectories (P, ρ, ω, f, A_2) has been tested for inclusive reactions $\bar{p}+p\to\pi^-+X$, $\bar{p}+p\to\Lambda+X$ in the proton fragmentation region at 22.4 GeV/c. The factorization hypothesis holds for both reactions within statistical errors of the experimental data.

The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

In order to test the factorization hypothesis of leading Regge-trajectories, we use a method suggested by Miettinen[1] who considered Mueller-Regge phenomenological analysis of inclusive processes[2].

In Mueller-Regge analysis the single particle inclusive cross section of the reaction

$$a + b \to c + X \qquad (1)$$

is connected by the optical theorem to the forward elastic scattering amplitude for the three-body process

$$a + b + \bar{c} \to a + b + \bar{c} . \qquad (1a)$$

The elastic process (1a) in the target fragmentation region (single Regge limit) is shown by the diagram in *Fig. 1*, where α_i is one of the leading Regge-trajectories (P, ρ, ω, f, A_2) known from two-body reactions. For scattering (1a) the total 3-body energy is the missing mass squared $M^2=(P_a+P_b-P_c)^2$ of reaction (1) and the momentum transfer $U=(P_b-P_c)^2$ is the mass squared of the $b\bar{c}$ system (it must be small for the single Regge limit).

The Regge expression for the invariant cross section of reaction (1) is[3]:

$$f(S,\bar{p}) = \beta_P(\bar{p}) + \sum_M \beta_M(\bar{p})\cdot S^{-1/2}. \qquad (2)$$

The pomeron $\beta_P(\bar{p})$ and meson $\beta_M(\bar{p})$ residue functions can be factorized according to the factorization hypothesis:

$$\beta_i(\bar{p}) = \gamma_a^i \cdot \Gamma^i_{(b\bar{c})}(\bar{p}), \tag{3}$$

where γ_a^i are the couplings of trajectories α_i to particle a obtained from the total cross sections and $\Gamma^i_{(b\bar{c})}(\bar{p})$ are the unknown couplings of the α_i trajectories to the $(b\bar{c})$ system (*Fig. 1*).

Using the expressions (2) and (3) and taking into account exchange degeneracy in duality models [3,4], Miettinen has obtained relationships connecting the amplitudes $f(b \xrightarrow{a} c)$ of the production of particle c in the target fragmentation region for different beam particles. In these relationships the unknown coupling $\Gamma^i_{(p\bar{c})}(\bar{p})$ was eliminated. A test of factorization predictions can be done by comparing experimental single-particle inclusive spectra with those calculated from Miettinen's relationship. This method has been used to test factorization hypothesis in different inclusive reactions [5].

In this paper we compare the calculated results with experimental invariant cross sections

$$f(x, p_T^2) = \frac{2E^*}{\pi\sqrt{S}} \frac{d^2\sigma}{dx\,dp_T^2} \tag{4}$$

of π^--production in the reaction

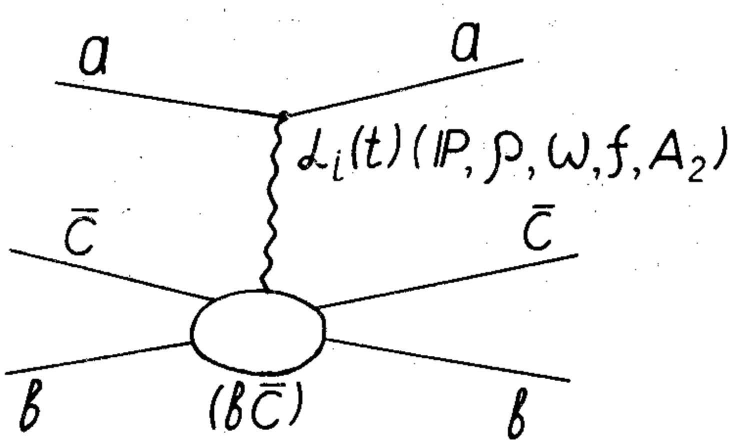

Fig. 1. One-reggeon diagram for the three-body elastic process $a+b+c \to a+b+c$.

$$\bar{p} + p \to \pi^- + X \tag{5}$$

and with integrated invariant cross sections

$$F(x) = \frac{2}{\pi\sqrt{S}} \int E^* \frac{d^2\sigma}{dx\,dp_T^2}\, dp_T^2 \tag{6}$$

of Λ-production in the reaction

$$\bar{p} + p \to \Lambda + X. \tag{7}$$

In the expressions (4), (6) E^* is the energy of the studied particle in the c.m.s., $\sqrt{S}$ is the energy of the reaction in the c.m.s., $x = 2 \cdot p^*_\parallel/\sqrt{S}$ is the Feynman variable, p_T^2 is the transversal momentum squared of the studied particle.

The experimental data were obtained from a bubble chamber experiment at 22.4 *GeV/c* for which experimental details have been published earlier [6]. The cross sections of π^- and Λ production are based on 18 000 and 15 000 interactions, respectively. For calculation we used cross sections of the reactions

$$\begin{aligned} &p + \bar{p} \to \pi^- + X \quad \text{at 24 } GeV/c\,[7], \\ &\pi^- + p \to \pi^- + X \quad \text{at 18 } GeV/c\,[8], \end{aligned} \tag{8}$$

and

$$\begin{aligned} &p + p \to \Lambda + X \quad \text{at 19 } GeV/c\,[9], \\ &\pi^- + p \to \Lambda + X \quad \text{at 18 } GeV/c\,[10], \end{aligned} \tag{9}$$

Using the expressions (2) and (3) and the connections between the couplings [1,4],

$$\begin{aligned} &\gamma_\pi^\rho = \gamma_\pi^f = \gamma_\pi^M, \quad \gamma_N^f = \gamma_N^\omega, \quad \gamma_N^\rho = \gamma_N^{A_2}, \\ &\Gamma^\rho_{(p\bar{c})} = \Gamma^\omega_{(p\bar{c})} = \Gamma^f_{(p\bar{c})} = \Gamma^{A_2}_{(p\bar{c})} = \Gamma^M_{(p\bar{c})} \end{aligned} \tag{10}$$

(here $c = \pi^-, \Lambda$) we can write the structural functions for processes (5), (7), (8), (9). The structural functions are

$$f(p \xrightarrow{\bar{p}} c) = \gamma_N^P \cdot \Gamma^P_{(p\bar{c})} + 2\,[\gamma_N^f + \gamma_N^\rho] \cdot \Gamma^M_{(p\bar{c})} \cdot S_{\bar{p}}^{-1/2}$$

$$f(p \xrightarrow{\pi^-} c) = \gamma_\pi^P \cdot \Gamma^P_{(p\bar{c})} + 2 \cdot \gamma_\pi^M \cdot \Gamma^M_{(p\bar{c})} \cdot S_{\pi^-}^{-1/2}$$

$$f(p \xrightarrow{p} c) = \gamma_N^P \cdot \Gamma^P_{(p\bar{c})} \;, \qquad (11)$$

where $S_{\bar{p}}$ and S_{π^-} are the reaction energies squared in the c.m.s. for $\bar{p}p$ and $\pi^- p$ interactions. The values of the couplings γ_a^i are[11]

$$\gamma_N = 6.1\ \text{mb}^{1/2}, \quad \gamma_\pi = 3.6\ \text{mb}^{1/2},$$

$$\gamma_N^f = \gamma_N^\omega = 6.3\ \text{mb}^{1/2}, \quad \gamma_N^\rho = \gamma_N^{A_2} = 1.4\ \text{mb}^{1/2}$$

$$\gamma_\pi^\rho = \gamma_\pi^f = 2.9\ \text{mb}^{1/2} \qquad (12)$$

Combining eqs. (11) and (12), we get a relationship between the structural functions

$$f(p \xrightarrow{\bar{p}} c) = 2.393 \cdot f(p \xrightarrow{\pi^-} c) - 0.412\, f(p \xrightarrow{p} c). \qquad (13)$$

In *Fig. 2* we show the dependence of the experimental and predicted cross sections $f(p \xrightarrow{\bar{p}} \pi^-)$ on the x and p_T^2 variables in the backward hemisphere of x region. It is seen from *Fig. 2* that experimental data and calculated values agree within statistical errors over the range $x < -0.1$ and for all values of p_T^2 (except $x = -0.3$ and $0 < p_T^2 < 0.04$). The difference between experimental data and calculated values at $x = 0$ systematically decreases with increasing p_T^2, which is difficult to understand in the frame of the one-reggeon model.

It is interesting to compare our results with those obtained for the reaction $\bar{p} + p \to \pi^- + x$ at 4.6 *GeV/c* and 9.1 *GeV/c*[5c]. A significant discrepancy between experimental data and calculated values for π^--production was found for all negative values of x and for

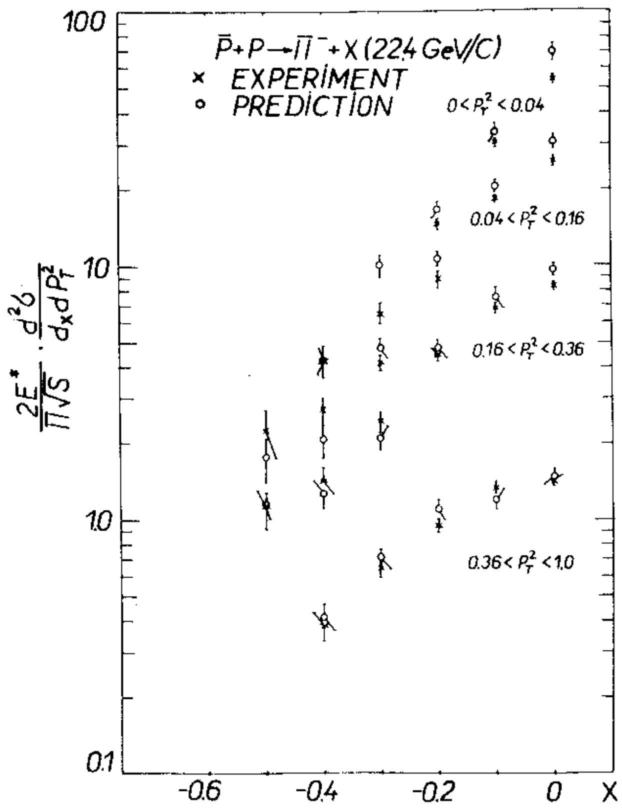

Fig. 2. The dependence of experimental and from eq.(13) calculated invariant cross section $f(x,p_T^2) = \frac{2E^*}{\pi\sqrt{S}} \frac{d^2\sigma}{dx\, dp_T^2}$ *on the* x *and* p_T^2 *variables for the reaction* $\bar{p} + p \to \pi^- + X$.

p_T^2 intervals of $0 < p_T^2 < 1$ at 4.6 *GeV/c* and $0.2 < p_T^2 < 1.0$ at 9.1 *GeV/c*. For a p_T^2 interval of $0 < p_T^2 < 0.2$ the experimental data and calculated values agree at 9.1 *GeV/c*. The discrepancy was explained to be due to annihilation violating factorization because the annihilation component is supposed to affect mostly at high p_T and to decrease with increasing energy. From this explanation one can understand in part a better agreement between experimental and calculated data at our

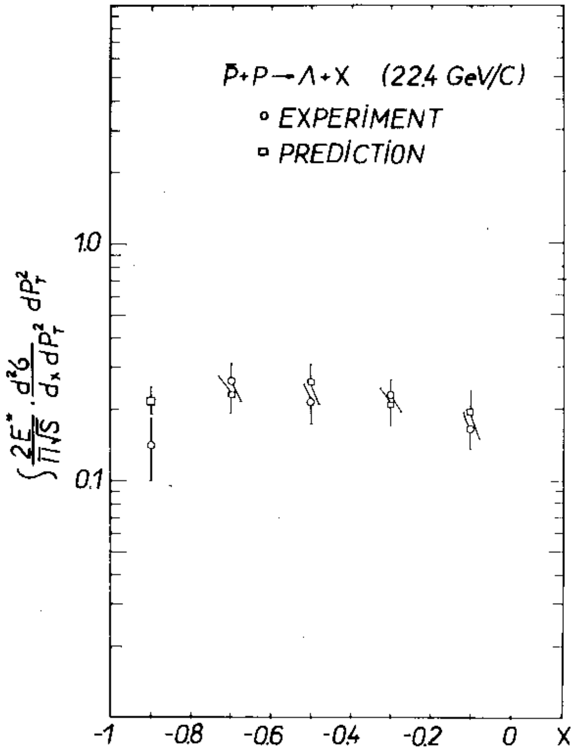

Fig. 3. The dependence of experimental and from eq. (13) calculated integrated cross section $F(x) = \int \frac{2E^*}{\pi\sqrt{S}} \frac{d^2\sigma}{dx\, dp_T^2} \cdot dp_T^2$ *on* x *for the reaction* $\bar{p} + p \to \Lambda + X$.

energy as the fraction of annihilation is about 20% of the total cross section (by the difference $\sigma_t(\bar{p}p) - \sigma_t(pp)$) while at 4.6 *GeV/c* and 9.1 *GeV/c* this fraction is ~50% and ~30%, respectively. But we see that for our data there is an agreement at all values of p_T^2, i.e., the influence of annihilation is not seen for high p_T.

In *Fig. 3* we show experimental and from eq. (13) calculated integrated cross section F(x) for the reaction $\bar{p} + p \to \Lambda + X$. We notice that the experimental and calculated distributions agree within errors. Since the

annihilation component is absent in this reaction, it would be interesting to test factorization also at lower energies.

CONCLUSION

In the frame of the considered model the factorization hypothesis holds, within statistical errors of the experimental data, for inclusive π^- and Λ production in the region $-1.0 < x < 0.1$ and $0 < p_T^2 < 1$ in $\bar{p}p$ interactions at 22.4 *GeV/c*.

REFERENCES

1. *Miettinen H.I. Phys.Lett., 1972, 38B, p.431.*
2. *Mueller A.H. Phys. Rev., 1970, D2, p.2963.*
3. *Chan H.M. et al. Phys. Rev. Lett., 1971, 26, p.672.*
4. *Kugler M. Developments in High Energy Physics, ed. P.Urban , Springer-Verlag, 1970.*
5. *a) Fry J.R. et al. Nucl.Phys., 1973, B58, p.420.*
   b) Paler K. et al. Phys. Lett., 1974, 48B, p.151.
   c) Gregory P. et al. Nucl.Phys., 1974, B78, p.222.
6. *Boos E.G. et al. Nucl.Phys., 1977, B121, p.381. Batyunya B.V. et al. JINR, 1-11194, Dubna, 1977.*
7. *Blobel V. et al. Nucl.Phys., 1974, B69, p.454.*
8. *Powers J.T. et al. Phys.Rev., 1973, D8, p.1947.*
9. *Boggilo H. Nucl.Phys., 1973, B57, p.77.*
10. *Stuntebeck P.H. et al. Phys. Rev., 1974, D9, p.608.*
11. *Brower R.C. et al. Phys. Rev., 1973, D7, p.2080.*

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