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INCLUSIVE NEUTRAL PARTICLE PRODUCTION IN $\bar{p}p$ INTERACTIONS AT 22.4 GeV/c.

Part II. Differential Distributions. Study of the Λ Polarization

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

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Боос Э.Г. и др. E1 - 11666

Исследование инклюзивного рождения γ, K^o_S, Λ, $\bar{\Lambda}$ -частиц в $\bar{p}p$ -взаимодействиях при импульсе 22,4 ГэВ/с. Часть II. Дифференциальные распределения. Изучение поляризации Λ-гиперонов

В работе представлены дифференциальные распределения по P^2_T и переменной Фейнмана X для γ, K^o_S, Λ рождения в $\bar{p}p$-взаимодействиях при импульсе 22,4 ГэВ/с. Проводятся сравнения с данными по рождению γ, K^o_S, Λ -частиц в pp -взаимодействиях при близких энергиях и в $\bar{p}p$-взаимодействиях при других энергиях. Делается описание распределений по быстроте в с.ц.м. для $K^o/\bar{K}^o$ -мезонов и γ-квантов в $\bar{p}p$ -взаимодействиях при 22,4 ГэВ/с моделью слияния кварков. Получено отличное от нуля значение средней по всему фазовому объему поляризации Λ-гиперонов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Boos E.G. et al. E1 - 11666

Inclusive Neutral Particle Production in $\bar{p}p$ Interactions at 22.4 GeV/c. Part II. Differential Distributions. Study of the Λ Polarization

The differential distributions over longitudinal and transverse variables for inclusive γ, K^o_S, Λ production in $\bar{p}p$ interactions at 22.4 GeV/c are presented. The rapidity distributions in the c.m.s. for γ and $K^o/\bar{K}^o$ particles were compared with the quark-antiquark fusion model.
A non-zero Λ polarization of -0.414 ± 0.206 was measured.
The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

In this paper we present the results of an investigation of the differential distributions over longitudinal and transverse kinematical variables from inclusive γ, K^o_S, Λ production in $\bar{p}p$ interactions at 22.4 GeV/c.

Mean values of the Λ polarization were also measured.

This paper is the second part of the publication devoted to inclusive neutral particle production in $\bar{p}p$ interactions at 22.4 GeV/c. In the first part [1] we present the total and topological inclusive cross sections and test the KNO scaling hypothesis for $\gamma(\pi^o)$, K^o_S, Λ, $\bar{\Lambda}$-particles.

The methodical questions concerning scanning and measurement of the events with neutral particles in our experiment are discussed in ref. [2].

Figure 1 (a,b,c) presents the invariant cross sections $F(x) = \frac{2}{\pi\sqrt{S}} \int E^* \frac{d^2\sigma}{dx\, dp_T^2} dp_T^2$ against x for γ, K^o and Λ particles in our $\bar{p}p$ interactions and in other experiments [3]. In the above equality $x = p_L^* 2/\sqrt{S}$ (Feynman's variable), where $\sqrt{S}$ is the reaction energy in the c.m.s., p_L is the V^o longitudinal momentum in the c.m.s. and E^* is the V^o energy in the c.m.s.

Figure 1a shows that for γ production in the central region $F(x)$ decreases with increasing energy from 4 up to 20 GeV. The behaviour of $F(x)$ shows an approximate agreement with the scaling in an energy interval of 20-100 GeV. The $F(x)$ function for K^n particles (fig. 1b) in the central region is almost constant from 4 to 20 GeV and then rises with increasing energy up to 100 GeV. Figure 2 presents $F(x)$ at $x = 0$ as a function of $S^{-1/4}$ for K^o_S production in $\bar{p}p$ and pp interactions/4/. One can see that the $\bar{p}p$ data do not show a linear behaviour. Such nonlinear energy dependences for $\pi^{\pm}$ and K^o_S production in the central region in several types of interactions are well described by the two-Regge model taking into account the Regge-Regge term contribution/5/. In this model the F(O) function approaches the scaling limit according to the law:

$$F(O) = A(m_T) + B(m_T)\cdot S^{-1/4} + C(m_T)\cdot S^{-1/2},$$

where $m_T = \sqrt{m^2 + p_T^2}$ is the transverse mass of the inclusive particle.

There is uncertainty in the behaviour of $F(x)$ in view of the current statistical accuracy for γ and K^n particles in the fragmentation region and for Λ particles over the whole interval of x. From figs. 1a and 1b one can see that there is some evidence for decrease of $F(x)$ with increasing energy for γ's and for scaling behaviour of $F(x)$ for K^n's in the fragmentation region.

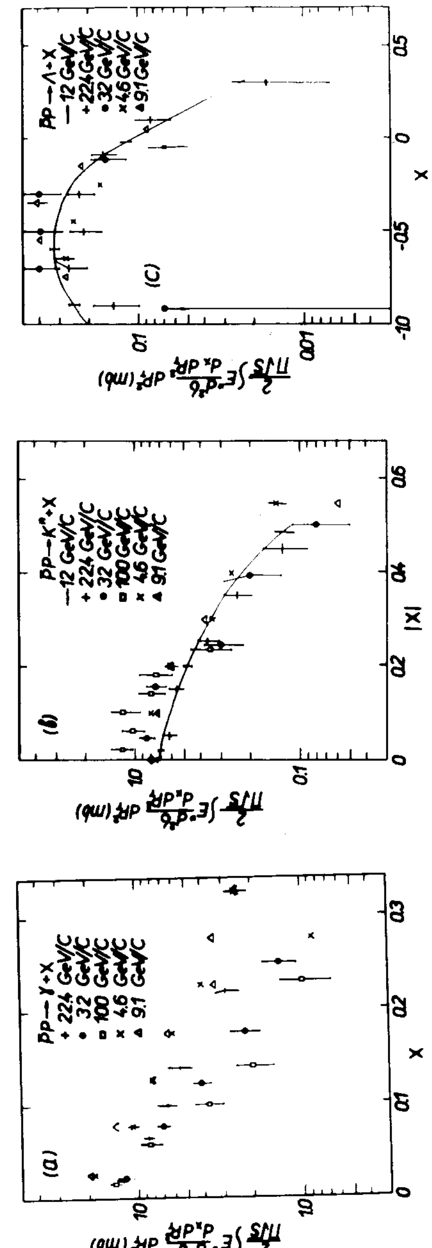

Fig. 1(a,b,c). The distributions of the invariant differential cross sections $F(x) = \int \frac{2E^*}{\pi\sqrt{S}} \frac{d^2\sigma}{dx\,dp_T^2} dp_T^2$ for γ, K^n, Λ particles.

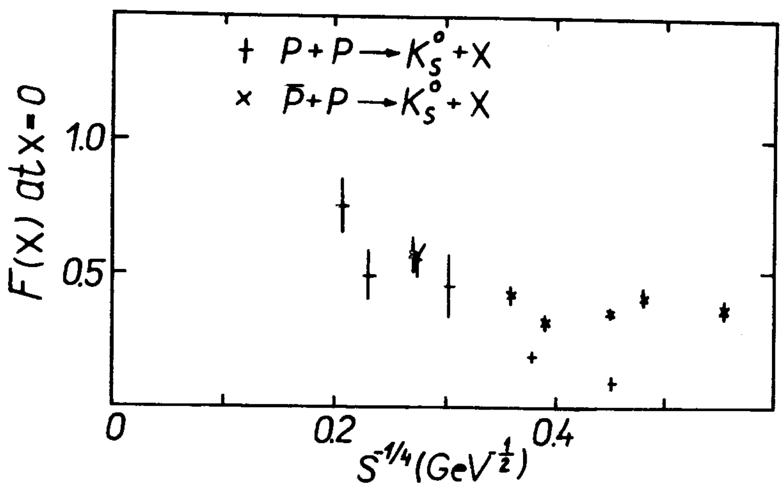

Fig. 2. The dependence of F(x) (at x = 0) on $S^{-1/4}$ for K_S^o production in $\bar{p}p$ and pp interactions.

The rapidity distributions in the center-of-mass system ($d\sigma/dy^*$) for γ and K^n production in $\bar{p}p$ interactions at our energy were described by the quark-antiquark fusion model taking into account both direct meson production and meson production from resonance decay. The differential cross sections were calculated by the formula [6]:

$$\frac{d\sigma}{dy^*} = \frac{\pi g^2}{M_c M_c'} \{ f_a^q(x_1) f_b^{\bar{q}}(x_2) + (q \leftrightarrow \bar{q}) \} (\frac{2J+1}{3}),$$

$$x_{1,2} = [\frac{M_c}{\sqrt{S}} ch\, y^* \pm \frac{M_c'}{\sqrt{S}} sh\, y^*], \quad M_c' = \sqrt{M_c^2 + \langle p_T^2 \rangle},$$

where M_c is the mass of the particles studied; $g^2/4\pi = 0.5$ is the parameter found in ref. [6] from a simultaneous description of ρ^o production in πp and pp interactions; $f_i^{q(\bar{q})}$ are the structural functions of quarks q (antiquarks $\bar{q}$) in hadrons i ($\bar{p}$ or p); J is the spin of the particle studied.

The factor $M_c' = \sqrt{M_c^2 + \langle p_T^2 \rangle}$ is due to the transverse motion of quarks inside hadrons. This motion determines the average transverse momentum of direct mesons (or resonances). The parameter $\langle p_T^2 \rangle = 0.25$ is the same as in ref. [6].

For $K^o/\bar{K}^o$ meson production the corresponding decay channels of resonances $K^{\pm *}$, K^{o*}, , $\bar{K}^{o*}$ were considered.

The γ-quantum spectra was determined for direct π^o production and for π^o mesons produced from the decay of resonances $K^{\pm *}$, K^{o*}, $\bar{K}^{o*}$ and $\rho^{\pm}$, ω , $\eta \to 3\pi$. Furthermore the channel of decaying η's directly into γ's ($\eta \to \gamma\gamma$) was taken into account.

The experimental distributions and the distributions calculated by the quark-antiquark fusion model are presented in figs. 3(a,b). From these figures it is seen that the theory is in goog agreement with experiment both for γ and K^n spectra.

The total inclusive cross sections obtained by this model are equal to 140 mb and 4.4 mb for γ's and K^n's, respectively. This also agrees with the experimental data [1].

The p_T^2 distributions for V^o's are given in figs. 4 (a,b,c). Data from other experiments are shown for comparison [3b,c,d; 7]. We

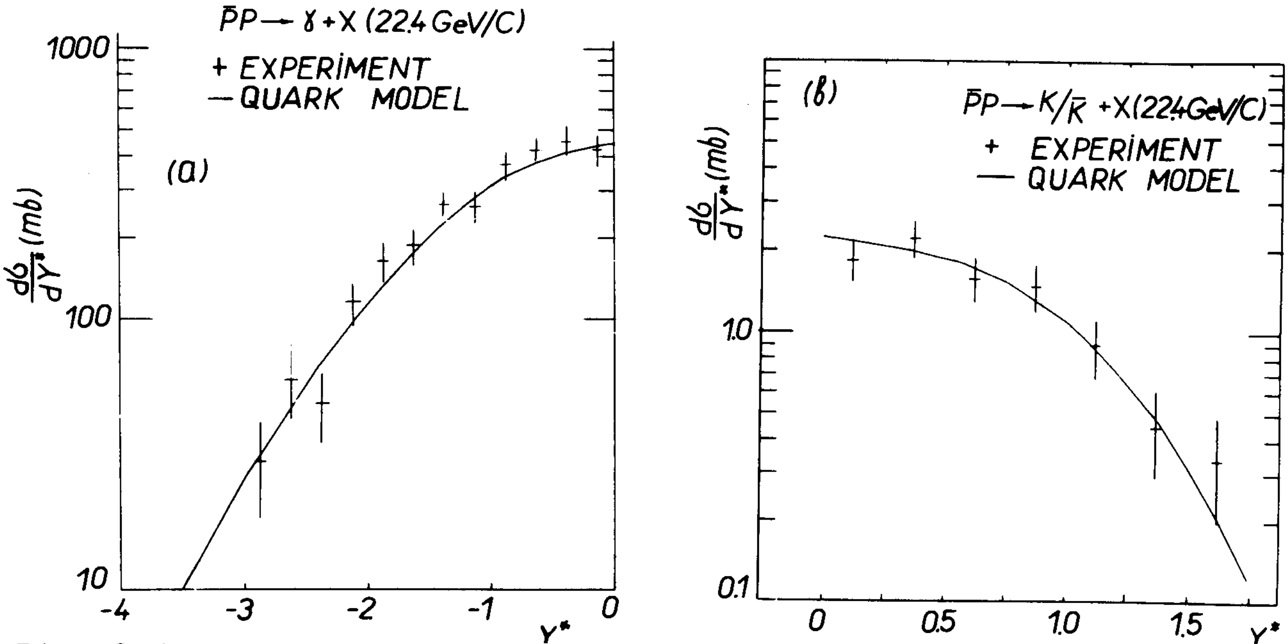

Fig. 3 (a,b). The rapidity distributions in the c.m.s. ($d\sigma/dy^*$) for γ and K^n production in $\bar{p}p$ interactions at our energy. The solid curves are the result of calculation by the quark model (see text).

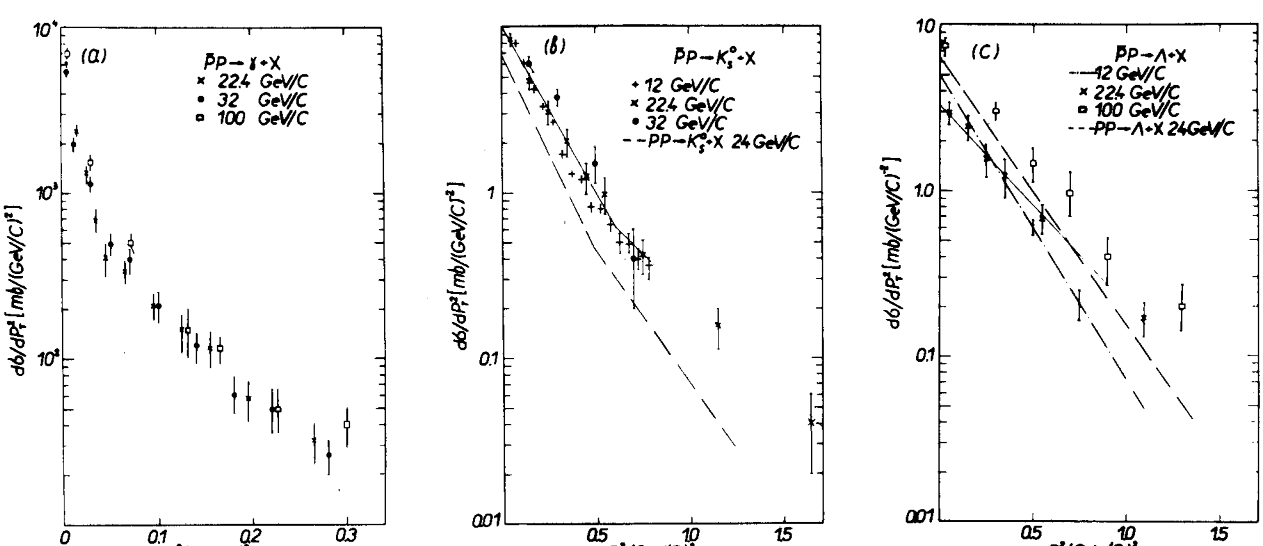

Fig. 4 (a,b,c). The p_T^2 distributions for γ, K_S°, Λ particles. The solid lines in fig. 4b (at $0 < p_T^2 < 0.55$) and in fig. 4c are the results of fitting by the exponential function. The solid line in fig. 4b at $p_T^2 > 0.55$ is hand-drawn to guide the eye.

see that the distributions for γ's and K^o_S's are characterized by a break in the slope. This break is usually observed for meson production in all types of interactions.

Figure 4a shows that the difference of $\sigma_{tot}(\gamma)$ (about 40 mb) between $\bar{p}p$ collisions at 22.4 GeV/c and 100 GeV/c [3d] is due to γ-quanta in the region $p_T^2 < 0.1\,(GeV/c)^2$. In the region $p_T^2 > 0.1$ both distributions are similar. The p_T^2 distributions in $\bar{p}p$ interactions at 22.4 GeV/c and 32 GeV/c [3c] coincide within errors inside the whole interval of p_T^2.

The solid curve in fig. 4b represents the result of a fit by an exponential function in the region $0 < p_T^2 < 0.55$ to our K^o_S data. The slope parameter equals 4.6±0.4. At $p_T^2 > 0.55$ the curve is hand-drawn to guide the eye. In this region there is some evidence that the slope of the p_T^2 distribution for K^o_S's in pp collisions at 24 GeV/c [7] (dashed line) is steeper than in our experiment. As in the case of charged pion [8] production, this difference can be explained by the annihilation final states in $\bar{p}p$ interactions.

Figure 4c shows the p_T^2 distributions for Λ production. The solid line is the result of an exponential fit to our data. The slope parameter equals 2.8±0.26. The slope parameter of the distribution for Λ's in interactions at 12 GeV/c [3b] is 4.12±0.07 (chain-dotted line) while from fig. 4c it is seen that the $\bar{p}p$ data at 100 GeV/c and our data are almost parallel.

The dashed line in fig. 4c represents the pp data for Λ's at 24 GeV/c [7] (the energy is almost the same as ours). These

data seem to fall off more sharply than our $\bar{p}p$ data. This fact is in contrast with the result of comparison of the $\bar{p}p$ and pp data for Λ's at 100 GeV/c [3d].

The table summarizes the mean values of $p_T (\langle p_T \rangle_{V^o})$ and $p_T^2 (\langle p_T^2 \rangle_{V^o})$ for V^o production in $\bar{p}p$ interactions [3] (V^o is one of the neutral particles). The mean values of p_T^2 for π^o's were calculated by the formula [9]:

$$\langle p_T^2 \rangle_{\pi^o} = 3\langle p_T^2 \rangle_{\gamma} - \frac{1}{2} m^2_{\pi^o} .$$

We have tested the mean value (for all events) of the polarization using the expression for $\cos\theta$ probability:

$$W(\cos\theta) = 1 - \alpha P \cos\theta,$$

where $\alpha = 0.647$ and P is the polarization factor.

$$\cos\theta = \frac{(\vec{P}_{\bar{p}} \times \vec{P}_{\Lambda}) \cdot \vec{P}_p}{|\vec{P}_{\bar{p}} \times \vec{P}_{\Lambda}| \cdot |\vec{P}_p|} .$$

Here $\vec{P}_{\bar{p}}$ is the laboratory momentum of primary antiprotons, $\vec{P}_{\Lambda}$ is the laboratory momentum of Λ particles and $\vec{P}_p$ is the proton momentum from the Λ decay in the Λ rest frame. The polarization factor P was defined by fitting the $\cos\theta$ distribution by a linear expression. We have obtained P=-0.414± ±0.206. In other $\bar{p}p$ experiments the P factors were equal to

P = -0.013±0.049 at 12 GeV/c [3b],
P = -0.45±0.21 at 100 GeV/c [3d].

In pp interactions in an energy interval of 12-300 GeV [10], as in $\bar{p}p$ collisions at

Table

The average transverse momenta for V° particles

P(GeV/c)	$<p_T>_\gamma$	$<p_T^2>_\gamma$	$<p_T^2>_{\pi^0}$	$<p_T>_{K^0_s}$	$<p_T^2>_{K^0_s}$	$<p_T^2>_\lambda$	$<p_T^2>_\lambda$
I2				0.449 ±0.004		0.437 ±0.004	
22.4	0.I62 ±0.006	0.048 ±0.004	0.I34 ±0.0I2	0.434 ± 0.0I4	0.256 ± 0.0I6	0.502 ±0.020	0.3I4 ±0.023
32.0	0.I70 ±0.0I0			0.430 ±0.05		0.450 ±0.050	
I000	0.I59 ±0.006	0.043 ±0.003	0.II9 ±0.009	0.470 ±0.0I8	0.295 ±0.022	0.490 ±0.020	0.302 ±0.022

12 GeV/c, the mean value of the P factor was equal to zero, although this factor was not equal to zero in several intervals of x and p_T in pp interactions at 6, 19, 24 GeV/c /11/ and in $\bar{p}p$ interactions at 12 GeV/c /3b/.

We see that the P factors in $\bar{p}p$ collisions at our energy and at 100 GeV/c are similar within the statistical errors. As they in both experiments are very large, we have only some hint of non-zero values for the Λ polarization.

In conclusion we would like to note the following main results:

1. In the central region there is some evidence for scaling behaviour of the invariant differential cross section F(x) for $\bar{p}p \to \gamma$ + all from 22.4 GeV/c to 100 GeV/c while for $K^0/\bar{K}^0$ production F(x) rises in this energy interval.

2. The increase of the total inclusive cross section of production with energy in $\bar{p}p$ collisions is due to γ's with $p_T^2 < 0.1$ (GeV/c)^2.

3. The experimental distributions dσ/dy* for γ and K^n production in $\bar{p}p$ interactions at 22.4 GeV/c are well described by the quark-antiquark fusion model.

4. The slope parameter of the p_T^2 distribution for Λ particles in our experiment is significantly lower than that obtained in $\bar{p}p$-interactions at 12 GeV/c.

5. There is an indication of a non-zero value of the polarization (as in $\bar{p}p$ interactions at 100 GeV/c).

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REFERENCES

1. Boos E.G. et al. JINR, E1-11665, Dubna, 1978.
2. Batyunya B.V. et al. JINR, 1-11194, Dubna, 1977.
3. a) $\bar{p}p$ at 4.6, 9.1 GeV/c; Kegan M.T. et al. Contr. to the Tbilisi Conf. 682/A2-92, 1976; b) at 12 GeV/c; Bertrand D. et al. CERN/EP/PHYS-77-20 1977. c) at 32 GeV/c; Jabiol M.L. et al. Nucl.Phys., 1977, B127, p.365. d) at 100 GeV/c; Raja R. et al. Phys.Rev., 1977, D15, p.627.
4. The value of $F(0)$ for $\bar{p}p$ at 100 GeV/c is taken from ref./3d/. In that paper there are references to the data from other experiments.
5. Shlyapnikov P.V. et al. Preprint IHEP, 76-97, Serpukhov, 1976.
6. Knyazev V.V. et al. Preprint IHEP, 77-106, Serpukhov, 1977.
7. Blobel V. et al. Nucl.Phys., 1976, B69, p.269.
8. Boos E.G. et al. Nucl.Phys., 1977, B121, p.381.
9. Kopylov G.I. Phys.Lett., 1972, 41B, p.371.

10. a) pp at 12 GeV/c; Jaeger K. et al. Phys.Rev., 1975, D11, p.1756; at 205 GeV/c; Jaeger K. et al. Phys.Rev., 1975, D11, p.2405; at 300 GeV/c; Sheng A. et al. Phys.Rev., 1975, D11, p.1733; b) at 24 GeV/c; Blobel V. et al. Nucl.Phys., 1977, B122, p.429.
11. Lesnik A. et al. Phys.Rev.Lett., 1975, 35, p.770; Aahlin P. et al. Lett. Nuovo Cim., 1978, 21, p.236:, Ref./10b/.

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