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INCLUSIVE NEUTRAL PARTICLE PRODUCTION IN $\bar{p}p$ - INTERACTIONS AT 22.4 GeV/c. Part I. Total and Topological Cross Sections of π°, $K^\circ/\bar{K}^\circ$, $\Lambda/\bar{\Lambda}$ Production. A Test of the KNO Scaling Hypothesis

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

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Боос Э.Г. и др.

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Исследование инклюзивного рождения γ, K^0_s, Λ, $\bar{\Lambda}$ -частиц в $\bar{p}p$ -взаимодействиях при импульсе 22,4 ГэВ/с. Часть 1. Полные и топологические сечения рождения нейтральных частиц. Изучение KNO -скейлинга

В работе представлены полные и топологические сечения рождения γ, $K^0/\bar{K}^0$, Λ, $\bar{\Lambda}$ -частиц в $\bar{p}p$ -взаимодействиях при 22,4 ГэВ/с. Сравниваются зависимости среднего числа нейтральных частиц от множественности в $\bar{p}p$ -взаимодействиях при различных энергиях. Показано, что для γ и K^0-рождения в $\bar{p}p$ -взаимодействиях при 22,4 ГэВ/с выполняется гипотеза KNO -скейлинга.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

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Inclusive Neutral Particle Production in $\bar{p}p$ Interactions at 22.4 GeV/c. Part I. Total and Topological Cross Sections of π^0, $K^0/\bar{K}^0$, , $\Lambda/\bar{\Lambda}$ production. A Test of the KNO Scaling Hypothesis

In this paper we present the results of an analysis of inclusive production of $\gamma(\pi^0)$, K^0_s, Λ, $\bar{\Lambda}$ particles in $\bar{p}p$ interactions at 22.4 GeV/c. The total and topological inclusive cross sections of neutral particles were obtained. The charged multiplicity dependences of the mean number of π^0, $K^0/\bar{K}^0$, , $\Lambda/\bar{\Lambda}$ productions were studied. The KNO scaling hypothesis for π^0, K^0_s, Λ particles was tested.

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 inclusive production of $\gamma(\pi^0)$, K^0_S, Λ, and $\bar{\Lambda}$ (including Λ, $\bar{\Lambda}$ from Σ^0 and $\bar{\Sigma}^0$ decays) in $\bar{p}p$ interactions. The data have been obtained in exposures of the hydrogen bubble chamber "Ludmila" to a RF separated beam of 22.4 GeV/c antiprotons at the Serpukhov accelerator. Some information on the antiproton beam is given in ref. /1/.

About 40 000 pictures of the total sample of 300 000 have been used in this analysis. The pictures were scanned twice for all types of primary interactions. The scanning efficiency for the interactions with associated V^0's (V^0 stands for all neutral particles $\gamma(\pi^0)$, K^0_S, Λ, $\bar{\Lambda}$) was about 98%. The events were measured on semiautomatic measuring machines. The measurements were carried out using the geometric programs MDTHRESH or HYDRA-geometry. The kinematic programs GRIND or HYDRA-kinematics were used for kinematic fitting of the decays and conversion by the following hypotheses:

$$K^0 \to \pi^+\pi^-,$$
$$\Lambda \to p\pi^-,$$
$$\bar{\Lambda} \to \bar{p}\pi^+,$$
$$\gamma \to e^+e^-.$$

About 95% of unique V°'s (out of all V°'s) were identified using the kinematic programs and ionization information. In order to classify ambiguous V°'s, use was made of the transverse momentum distributions of negative tracks from V° decays (in the laboratory system) relative to the neutral-particle direction [2]. After using such a method, statistical weights were assigned to the remaining ambiguous particles [2].

Table 1 shows the numbers of unique and ambiguous neutral particles.

Table 1

The number of unique and ambiguous V°'s

Type of V° particles	γ	K^o_S	Λ	$\bar{\Lambda}$
Number of unique V°'s	770	363	159	107
Type of ambiguities	$K^o_S-\Lambda$	$K^o_S-\bar{\Lambda}$		
Number of ambiguities	13	14		

To correct for minimum decay length cuts and for decays outside the fiducial volume, a standard weight was assigned to each particle [2]. In order to check further V° losses, the expected forward-backward symmetry for γ and K^o_S longitudinal momenta in the c.m.s. was used. Corrections for unseen decay modes were made for K^o_S, Λ and $\bar{\Lambda}$ particles [3]. All corrections are discussed in more detail in ref. [2].

Table 2

The cross sections of V° production for events of different topology, the total inclusive cross sections and the mean number of neutral particles per inelastic $\bar{p}p$ interaction.

	$\sigma_0(V^o)$	$\sigma_2(V^o)$	$\sigma_4(V^o)$	$\sigma_6(V^o)$	$\sigma_8(V^o)$	$\sigma_{10}(V^o)$	$\sigma_{tot}(V^o)$	$\langle n(V^o)\rangle$
π^o	1.23 ± 0.37	15.91 ± 1.29	25.67 ± 1.70	19.36 ± 1.60	8.50 ± 1.18	2.01 ± 0.66	72.7 ± 8.0	1.86 ± 0.09
K^o_S	0.078 ± 0.023	0.61 ± 0.06	0.70 ± 0.07	0.63 ± 0.07	0.21 ± 0.04	0.046 ± 0.025	2.27 ± 0.12	0.058 ± 0.003
Λ	0.042 ± 0.019	0.46 ± 0.06	0.42 ± 0.05	0.20 ± 0.04	0.025 ± 0.020		1.15 ± 0.10	0.029 ± 0.003
$\bar{\Lambda}$	0.018 ± 0.013	0.26 ± 0.05	0.41 ± 0.06	0.22 ± 0.05	0.035 ± 0.018		0.94 ± 0.10	0.024 ± 0.008

In Table 2 we present the total inclusive cross sections ($\sigma_t(V^\circ)$), topological cross sections ($\sigma_n(V^\circ)$) and mean numbers of neutral particles per inelastic $\bar{p}p$ interaction ($\langle n(V^\circ)\rangle = \sigma_t(V^\circ)/\sigma_{in}$), where σ_{in} is the inelastic cross section[1]. All γ's were assumed to come from π° decays and hence the π° cross sections were obtained from the relations:

$$\sigma_t(\pi^\circ) = \frac{1}{2}\sigma_t(\gamma),$$

$$\sigma_n(\pi^\circ) = \frac{1}{2}\sigma_n(\gamma).$$

We see that $\sigma_2(\bar{\Lambda})$ is significantly smaller than $\sigma_2(\Lambda)$ and the difference is larger than one standard deviation. As the topological cross sections $\sigma_n(\Lambda)$ and $\sigma_n(\bar{\Lambda})$ are assumed to be equal according to CP-symmetry in $\bar{p}p$ interactions, the difference between $\sigma_2(\Lambda)$ and $\sigma_2(\bar{\Lambda})$ can be explained by additional scanning and measuring losses of $\bar{\Lambda}$ particles. Table 3 shows that the mean momentum of $\bar{\Lambda}$ particles for two-prong events in the laboratory system is significantly larger than that for higher topologies, i.e., one can suppose that additional losses are due to the most rapid $\bar{\Lambda}$ particles. Therefore $\bar{\Lambda}$'s are not used in the further analysis.

Table 4 shows the unweighed and weighed numbers of $V^\circ V^\circ$ particle pairs and the inclusive cross sections of $V^\circ V^\circ$-pair production in our experiment.

Figures 1 (a,b,c) show the variation of the total inclusive cross sections as a function of incident beam momentum for production of π°, $K^n(K^\circ/\bar{K}^\circ)$ and $\Lambda/\bar{\Lambda}$ in $\bar{p}p$-in-

Table 3

The mean momenta of Λ and $\bar{\Lambda}$ particles in the laboratory system for events of different multiplicities.

n	$\langle P_{lab}\rangle_\Lambda$	$\langle P_{lab}\rangle_{\bar{\Lambda}}$
2	1.73±0.20	11.20±1.10
4	2.37±0.18	8.47±0.65
6	3.12±0.32	7.63±0.70

Table 4

$V^\circ V^\circ$ inclusive production cross sections

	Unweighed number of particle pairs	Weighed number of particle pairs	$\sigma_{tot}(V^\circ V^\circ)$(mb)
$K^\circ K^\circ$	20	87	0.26±0.06
$K_S^\circ\Lambda$	12	69	0.21±0.06
$K_S^\circ\bar{\Lambda}$	12	87	0.26±0.08
$\Lambda\bar{\Lambda}$	10	73	0.22±0.07

teractions[4]. The values from pp data[5] are given for comparison. Our data are in good agreement with the $\bar{p}p$ data for other energies.

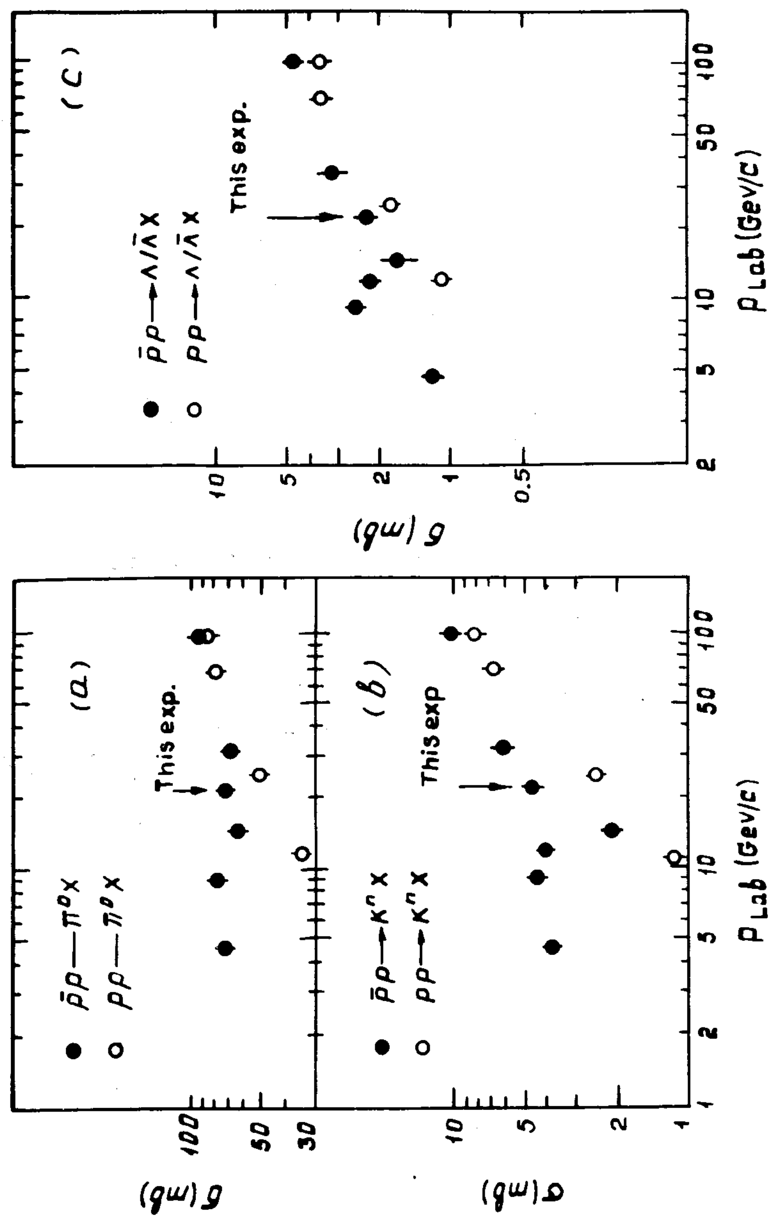

Fig. 1 (a,b,c). The variation of the total inclusive cross sections as a function of incident beam momentum for π°, K^n, $\Lambda/\bar{\Lambda}$ production in p̄p and pp interactions.

The mean number of neutral particles per inelastic p̄p collision as a function of topology ($\langle n(V^\circ)\rangle_n = \sigma_n(V^\circ)/\sigma_n$, σ_n is the topological cross section [1]) is presented in figs. 2(a,b,c). The figures also show corresponding results obtained in other experiments [4c,d,e]. There is no clear charged multiplicity dependence of $\langle n(\pi^\circ)\rangle_n$ and $\langle n(K^n)\rangle_n$ (figs. 2a,b) at 22.4 and 32 GeV/c. In contrast, one can see an approximately linear rise of $\langle n(\pi^\circ)\rangle_n$ at 14.75 GeV/c [4c] and 100 GeV/c [4e] and of $\langle n(K^n)\rangle_n$ at 100 GeV/c [4e] when the multiplicity varies from 2 to 8. Such correlations between neutral and charged particles were observed in pp interactions from 70 GeV/c and 100 GeV/c for π° and K° mesons, respectively [6].

The $\langle n(\Lambda/\bar{\Lambda})\rangle_n$ data (fig. 2c) strongly decrease with increasing charged multiplicity in our experiment and in p̄p collisions at 32 GeV/c but remain constant within errors in p̄p interactions at 100 GeV/c.

To test the KNO scaling hypothesis for π°, , K°_S, , Λ production [7], figures 3(a,b,c) show the $\langle n\rangle\cdot\sigma_n(V^\circ)/\langle n(V^\circ)\rangle\cdot\sigma_{in}$ data against $n/\langle n\rangle$ ($\langle n\rangle$ is the mean multiplicity of charged particles [1]). Data obtained in other p̄p experiments [8] and fits to high energy p̄p interactions [7] are given for comparison. There is no significant difference between all the data for π° and K°_S production but the scaling is not valid for Λ's as can be seen from fig. 3c. Only the 100 GeV/c data for Λ production are almost equal to the pp data while at lower energy the difference between the p̄p and pp data systematically decreases with increasing primary momentum.

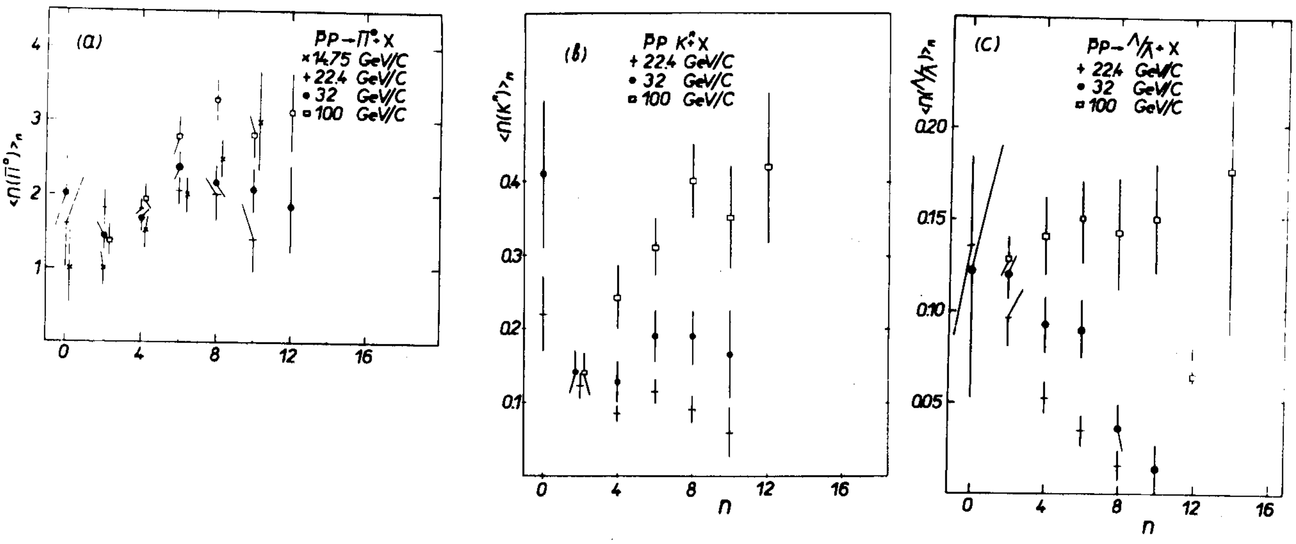

Fig. 2 (a,b,c). The mean multiplicities of π^o , $K^n, \Lambda/\bar{\Lambda}$ production as a function of charged multiplicity for $\bar{p}p$ interactions.

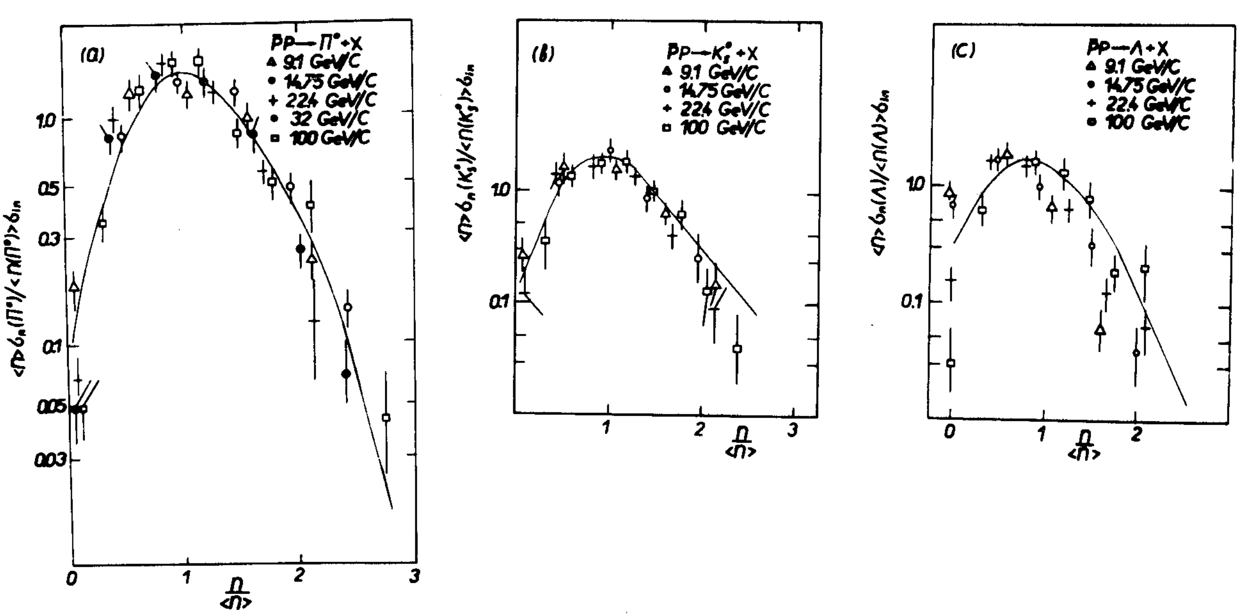

Fig. 3 (a,b,c). The KNO dependence for π^o , K^o_S , Λ production in $\bar{p}p$ and pp collisions. The solid curves are fits to high energy pp interactions.

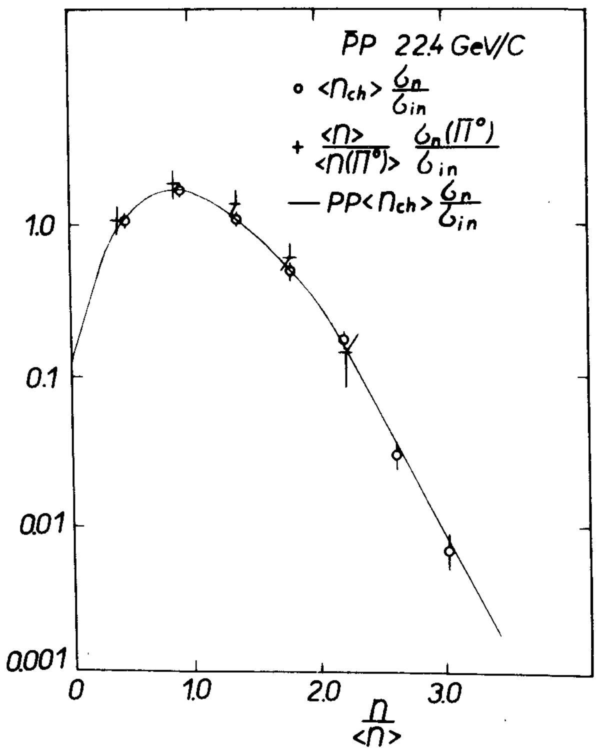

Fig. 4. The KNO dependences for charged particles and π^0 mesons in $\bar{p}p$ collisions at our energy. The solid curve is a fit of the KNO pp data for charged particles.

Figure 4 compares the KNO dependences for charged particles ($\langle n\rangle \cdot \sigma_n/\sigma_{in}$ per $n/\langle n\rangle$) (ref. /1/) and for π^0's in our $\bar{p}p$ interactions. The fit of the KNO pp data for charged particles /9/ is also shown. All the distributions are very similar.

Our main results are:

1. There is no clear correlation between the mean number of π^0-mesons and the number of charged particles in our experiment.

2. The mean number of $\Lambda/\bar{\Lambda}$ particles decreases with increasing charged multiplicity.

3. The KNO scaling hypothesis holds for π^0 and K^0_S production in $\bar{p}p$ and pp interactions in a broad energy interval.

4. The KNO dependences for charged particles and π^0-mesons in $\bar{p}p$ and pp interactions are very similar.

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