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γ AND π° PRODUCTION IN $\bar{p}p$ INTERACTIONS AT 22.4 GeV/c

Dubna - Alma-Ata - Helsinki - Moscow -
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γ AND π° PRODUCTION IN $\bar{p}p$ INTERACTIONS AT 22.4 GeV/c

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

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Батюня Б.В. и др. **E1-80-262**

Образование γ-квантов и π^{0}-мезонов
в $\bar{p}p$-взаимодействиях при 22,4 ГэВ/с

Изучается образование γ-квантов и π^{0}-мезонов в $\bar{p}p$-взаимодействиях при 22,4 ГэВ/с. Получена оценка образования π^{0}-мезонов в аннигиляционных событиях. Измерен коэффициент линейной зависимости между средним числом π^{0}-мезонов и числом ассоциированных отрицательно заряженных частиц, который оказался равным 0.26 ± 0.06.

Показано, что в спектрах продольных импульсов γ-квантов, π^{0}-мезонов и поперечных импульсов γ-квантов наблюдаются закономерности, согласующиеся с гипотезой скейлинга в среднем.

Экспериментальные данные сравнивались с предсказаниями кварк-партонной модели.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1980

Batyunya B.V. et al. **E1-80-262**

γ and π^{0} Production in $\bar{p}p$ Interactions
at 22.4 GeV/c

In this paper we study $\gamma(\pi^{0})$-production in $\bar{p}p$-interactions at 22.4 GeV/c. An estimate of the π^{0}-multiplicity in annihilation events has been obtained. The dependence of the average number of π^{0}-s on the number of assotiated charged particles has been studied. The inclusive $\gamma(\pi^{0})$-spectra agree with the hypothesis of scaling in the mean.

The experimental data are compared with quark-parton model predictions.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1980

We present here results of the analysis of 2440 e^+e^- pairs out of 37000 $\bar{p}p$ interactions at 22.4 GeV/c obtained by exposing the HBC Ludmila to a RF separated antiproton beam at the Serpukhov accelerator. The experimental procedure and some results concerning $\gamma(\pi^0)$ production in 22.4 GeV/c $\bar{p}p$ interactions have been published elsewhere /1/.

Due to large losses of γ-s in the backward c.m.s. hemisphere, these γ-s were replaced by those from the forward hemisphere, reflected about $p^*_L = 0$, according to cp-symmetry.

In Table 1 we present some average characteristics of γ-s and π^0-mesons. The latter are obtained from the relations /2/:

$$<|p^*_L|>_{\pi^0} = 2<|p^*_L|>_\gamma , \qquad (1)$$

$$<p^{*2}_L>_{\pi^0} = 3<p^{*2}_L>_\gamma - \frac{m^2_{\pi^0}}{4} , \qquad (2)$$

$$<p^2_T>_{\pi^0} = 3<p^2_T>_\gamma - \frac{m^2_{\pi^0}}{2} , \qquad (3)$$

which are valid under the assumption that π^0-s are the only source of γ-s.

Table 1

Mean values for different momentum variables of γ and π^0.

	$<p^{lab}>$ GeV/c	$<\|p^*\|>$ GeV/c	$<\|p^*_L\|>$ GeV/c	$<p^{*2}_L>$ $(GeV/c)^2$	$<p_T>$ GeV/c	$<p^2_T>$ $(GeV/c)^2$
γ	1.004 $\pm$.038	0.285 $\pm$.007	0.197 $\pm$.007	0.114 $\pm$.010	0.169 $\pm$.004	0.052 $\pm$.003
π^0			0.394 $\pm$.014	0.337 $\pm$.029		0.147 $\pm$.009

Table 2

The topological cross sections of π^0-s production in $\bar{p}p$ and pp interactions and their differences

Topology	$\sigma_n(\pi^0)$ $\bar{p}p \to \pi^0(22.4)$ mb	$\sigma_n(\pi^0)$ $pp \to \pi^0(24)$ mb	$\sigma_n^{\bar{p}p} - \sigma_n^{pp}$ mb	$\beta = \frac{\Delta\sigma_n}{\sigma_n^{\bar{p}p}}$	$\langle n_{\pi^0} \rangle$ $\bar{p}p$ (22.4)
0	1.05 ±0.18				1.63 ±0.33
2	14.05 ±0.75	13.92 ±0.96	0.13 ±1.22	0.01	1.59 ±0.18
4	23.50 ±0.99	21.46 ±0.65	2.04 ±1.18	0.09	1.66 ±0.08
6	20.69 ±0.97	13.02 ±0.36	7.67 ±1.03	0.37	2.19 ±0.12
8	9.75 ±0.70	4.36 ±0.23	5.39 ±0.74	0.55	2.39 ±0.19
10	2.34 ±0.35	0.25 ±0.06	2.09 ±0.36	0.89	1.65 ±0.26
12	0.47 ±0.18		0.47 ±0.18	1.0	1.96 ±0.79
14	0.034 ±0.034		0.034 ±0.034	1.0	0.57 ±0.60
all	71.89 ±1.78	53.0 ±1.2	17.8 ±2.2		1.84 ±0.06
$\langle n \rangle$	4.92 ±0.34		7.00 ±0.41		

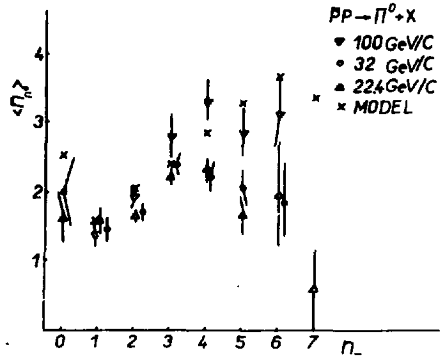

Fig.2. Average number of π^0-s vs number of negative particles, n_-.

This linear law is not valid at large n_- because of energy consideration. In fig.2 we display $\langle n_{\pi^0}\rangle$ vs n_- for $\bar{p}p$ interactions at 100 [7], 32 [8] and 22.4 GeV/c. As is seen, the linear increase of $\langle n_{\pi^0}\rangle$ with n_- takes place in the interval $1 \leqslant n_- \leqslant 4$. For $n_- > 4$, $\langle n_{\pi^0}\rangle$ at 22.4 and 32 GeV/c is smaller than $\langle n_{\pi^0}\rangle$ at 100 GeV/c in accordance with a weaker phase space limitation in the latter case. Besides, the data at 100 GeV/c indicate a possible increase of the $\langle n_{\pi^0}\rangle$ and n_- correlation with increasing energy. The value of the parameter b calculated in the interval $0 \leqslant n_- \leqslant 4$ is equal to 0.26 ± 0.06 in our experiment. This is in agreement with the critical liquid model [9], which predicts the slope to be independent of the type of colliding particles and to increase with increasing free energy E_a^* (see fig.3).

Previously we have compared our experimental data on charged particle production in $\bar{p}p$ interactions at 22.4 GeV/c [11] with the events generated according to the quark-parton model [12]. The dependence of $\langle n_{\pi^0}\rangle$ on n_- presented in fig.2 for generated events shows that the π^0 yeld is overestimated in the model: $\langle n_{\pi^0}\rangle_{mod} = 2.12$ as compared to $\langle n_{\pi^0}\rangle_{exp} = 1.84 \pm 0.06$. The data are described by the model only for $n_- = 1$ and 3. The linear dependence of $\langle n_{\pi^0}\rangle$ on n_- is specific to the models with abundant resonance production. For example, if π-mesons are produced only in the decays of ω-type resonances, then $\langle n_{\pi^0}\rangle = n_-$. The dependence becomes weaker in the case when ρ-mesons are the sources of π-mesons [13]. The overestimated value of $\langle n_{\pi^0}\rangle_{mod}$ for $n_- \geqslant 4$ is likely to be due to the overevaluated resonance yield in the model (the fraction of

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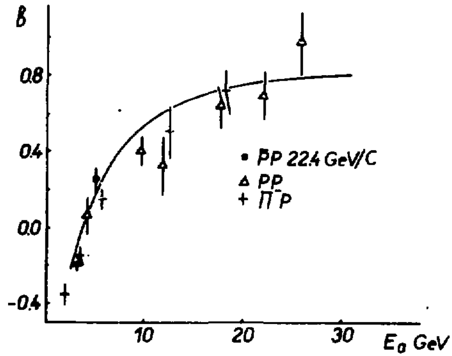
* The free energy E_a is equal to $\sqrt{S} - 2m_p$ and to $\sqrt{S}$ for non-annihilation and annihilation channels, respectively. According to a 23% contribution of annihilation to the total inelastic $\bar{p}p$ cross section at 22.4 GeV/c, we get $E_a = 5.17$ GeV.

Fig.3. Slope parameter b in eq.(5) vs free energy E_a for different reactions [10]. The full line is the prediction of the critical liquid model.



directly produced π-s in the model is only ~7% of all π-mesons).

According to the hypothesis of scaling in the mean [14], the one-particle inclusive distributions of the longitudinal and transverse momenta in multiparticle reaction scale as follows:

$$\frac{1}{\sigma_n}\frac{d\sigma_n}{d\xi_n} = \phi_L(\xi_n), \quad \xi_n = \frac{p_L^*}{\langle|p_L^*|\rangle_n}, \tag{6}$$

$$\frac{1}{\sigma_n}\frac{d\sigma_n}{d\eta_n} = \phi_T(\eta_n), \quad \eta_n = \frac{p_T}{\langle p_T\rangle_n}, \tag{7}$$

where σ_n is the topological cross section and the functions ϕ_L and ϕ_T are independent of primary energy, multiplicity and initial states.

We check the validity of scaling in the mean in the reactions

$$\bar{p}p \to \gamma + X, \tag{8}$$

$$\bar{p}p \to \pi^0 + X \tag{9}$$

at 22.4 GeV/c.

The values $\langle|p_L^*|\rangle$ and $\langle p_T\rangle$ for γ-s are given in Table 3 for $n = 2,4,6$ and for all topologies.

The distributions $\phi_L(\xi_n)$ calculated for different topologies as well as for all the events of the reaction (8) are displayed in fig.4. The concentration of the data points near each other indicates the independence of charged multiplicity. The solid curve in fig.4 is the result of approximation of the corresponding distributions in the reaction $\pi^- p \to \gamma + X$ at

Table 3

The average longitudinal and transverse momenta of γ-s. (The 5 GeV/c $\pi^- p$-data are from ref.15).

Topology	2	4	6	All	
				$\bar{p}p \to \gamma + X$ 22.4 GeV/c	$\pi^- p \to \gamma + X$ 5 GeV/c
$\langle\lvert p_L^*\rvert\rangle_n$ GeV/c	0.235 $\pm$0.017	0.211 $\pm$0.012	0.178 $\pm$0.010	0.197 $\pm$0.007	0.147 $\pm$0.004
$\langle p_T\rangle_n$ GeV/c	0.158 $\pm$0.007	0.178 $\pm$0.007	0.176 $\pm$0.007	0.168 $\pm$0.004	0.172 $\pm$0.002

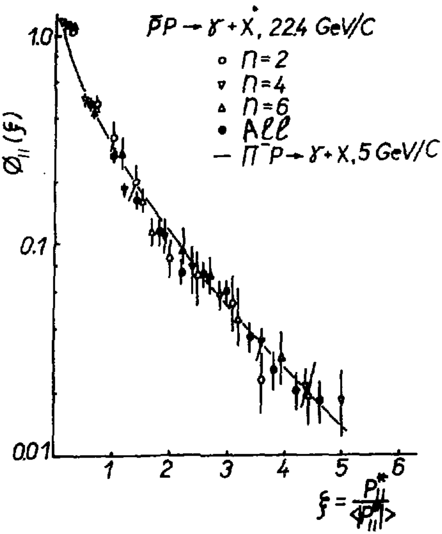


Fig.4. Normalized distribution $\frac{1}{\sigma}\frac{d\sigma}{d\xi}$ for different topologies n in the reactions $\bar{p}p \to \gamma + X$ at 22.4 GeV/c. The full line approximates the data in the reaction $\pi^- p \to \gamma + X$ at 5 GeV/c.

5 GeV/c [15]. It also well describes our data thus indicating the independence of $\phi_L(\lambda)$ on the type of colliding particles and their energy.

To obtain the scaling distribution $\phi_L(\xi)$ for π^0-s, we use the integral equation [15].

$$\frac{1}{\sigma}\frac{d\sigma}{d\xi_\gamma} = \langle|p_L^*|\rangle \int_A^\infty \frac{\phi_L(\xi_{\pi^0})}{\langle|q_L^*|\rangle\sqrt{\xi_{\pi^0}^2 + \frac{m^2}{\langle|q_L^*|\rangle^2}}}, \qquad (10)$$

Table 4

Parameters of function (12)

	A_1	A_2	$\chi^2/D.F.$
$\bar{p}p \to \pi^o + X$, 22.4 GeV/c	1.08 $\pm$0.07	1.10 $\pm$0.05	15/10
$\pi^- p \to \pi^o + X$, 5 GeV/c	1.04 $\pm$0.03	1.05 $\pm$0.02	54/71

where $\phi_L(\xi_{\pi^o}) = \frac{1}{\sigma}\frac{d\sigma}{d\xi_{\pi^o}}$,

$p_L^*(q_L^*)$ is the longitudinal momentum of $\gamma(\pi^o)$ and m is the π^o mass. The lower integration limit depends on ξ_γ in the following way

$$A = 2\xi_\gamma - \frac{m^2}{8\xi_\gamma <|p_L^*|>^2}. \qquad (11)$$

The normalized experimental ξ_γ distributions shown in fig.4 were fitted by formula (10) with the function

$$\phi_L(\xi_{\pi^o}) = A_1 \exp(-A_2|\xi_{\pi^o}|) \qquad (12)$$

with A_i (i = 1,2) as free parameters. In Table 4 these parameters are compared with the corresponding ones in the reaction $\pi^- p \to \pi^o + X$ at 5 GeV/c. As these parameters agree within errors, we can conclude that the distribuons $\frac{1}{\sigma}\frac{d\sigma}{d\xi}$ are independent of colliding particles and incident energy.

In fig.5 we compare the distribution $\phi_L(\xi)$ in the reaction (9) with the quark-parton model predictions /12/. Despite the overestimation of π^o-production, the normalized distribution is well described by the model.

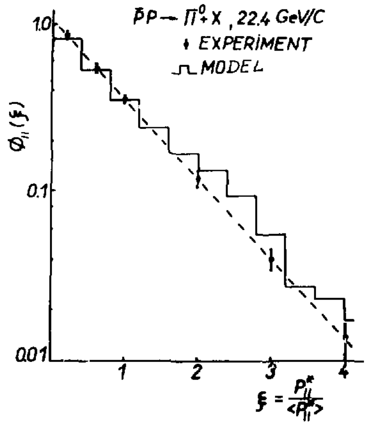


Fig.5. Experimental and quark-parton model distributions $\frac{1}{\sigma}\frac{d\sigma}{d\xi}$ in the reaction $\bar{p}p \to \pi^o + X$ at 22.4 GeV/c.

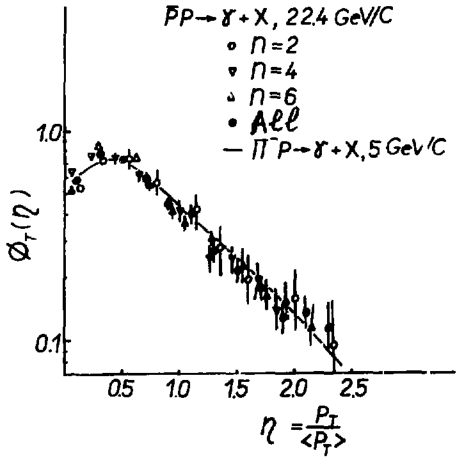


Fig.6. Normalized distribution $\frac{1}{\sigma}\frac{d\sigma}{d\eta}$ for different topologies in the reactions $\bar{p}p \to \gamma + X$ at 22.4 GeV/c. The full line approximates the data in the reaction $\pi^- p \to \gamma + X$ at 5 GeV/c.

The scaling distribution $\phi_T(\eta_n)$ for the reaction (8) in terms of the transverse scaling variable $\eta_n = \frac{p_T}{\langle p_T \rangle_n}$ is shown in fig.6 in comparison with the corresponding distributions in the reaction $\pi^- p \to \gamma + X$ at 5 GeV/c. Again, $\phi_T(\eta_n)$ seems to be independent of multiplicity, the type of colliding particles and primary energy.

Conclusions:

1. The average number of charged particles accompanying "annihilation" π^0-s (7.00 $\pm$ 0.41) is higher than the one for all events with π^0-s (4.92 $\pm$ 0.34).

2. The value of the slope parameter b in eq.(5) determined in an interval of $0 \leq n_- \leq 4$ is in agreement with the critical liquid model prediction.

3. The hypothesis of scaling in the mean is found to be valid for γ-s and π^0-s.

4. The quark-parton model slightly overestimates the average number of π^0-s, but describes well the normalized $\phi_L(\xi)$-distribution.

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ТЕМАТИЧЕСКИЕ КАТЕГОРИИ ПУБЛИКАЦИЙ ОБЪЕДИНЕННОГО ИНСТИТУТА ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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