Angular Correlations and Distributions in $\bar{p}p$ Annihilation into Eight and Nine Pions at 5.7 GeV/c

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(Received 26 June 1968)

Appreciable angular correlations between pions have been observed for both $\bar{p}+p\rightarrow 4\pi^++4\pi^-$ and $\bar{p}+p\rightarrow 4\pi^++4\pi^-+\pi^0$ reactions. Deviation between the angular correlation predicted by the phase-space calculations and our experimental values seems to occur for definite-momentum configurations of the produced pions. The secondaries are not emitted in a jet structure, i.e., the transverse and c.m. longitudinal momentum of the pions are in satisfactory agreement with phase predictions. By comparing the results of this experiment with other $\bar{p}p$ data, some systematics seem to emerge for the angular distribution of secondary pions.

I. INTRODUCTION

In this article we report results of $\bar{p}p$ annihilations at 5.7 GeV/c into eight and nine pions. The experiment was done at CERN by exposing the 80-cm hydrogen bubble chamber to a separated $\bar{p}$ beam. A sample of 1347 eight-pronged events was obtained by scanning about 87 000 photographs twice. The purpose of this paper is to study the correlations and the angular distributions of the final pions.

II. EXPERIMENTAL PROCEDURE AND CROSS SECTIONS

The events were measured with conventional measuring machines and processed through the standard CERN chain of programs. The events were classified in the following three channels:

$$(1)\quad \bar{p}+p\rightarrow 4^++4\pi^-,$$

$$(2)\quad \bar{p}+p\rightarrow 4\pi^++4\pi^-+\pi^0,$$

$$(3)\quad \bar{p}+p\rightarrow \text{no fit}.$$

Because of the high number of particles produced, no attempt was made to identify reactions with baryon and antibaryon in the final state. These events were then included in the "no-fit" channel.

From the study of the χ^2 distribution and the missing-mass (M_m^2) plots we have obtained 117 and 243 events for reactions (1) and (2), respectively. These are the samples which are then utilized for the study of the correlations and angular distributions.

From the cutoffs on the χ^2 and M_m^2 chosen it is possible to estimate that the contamination of events of the type $\bar{p}+p\rightarrow 4\pi^++4\pi^-+n\pi^0$ ($n\geq 2$) in reaction (2) is less than $(1\pm1)\%$, while events with baryon and antibaryon in the final state are all included in the no-fit channel.

The cross sections measured in this experiment were found to be

$$\sigma(\bar{p}+p\rightarrow 4\pi^++4\pi^-)=0.12\pm0.01\text{ mb},$$

$$\sigma(\bar{p}+p\rightarrow 4\pi^++4\pi^-+\pi^0)=0.25\pm0.02\text{ mb},$$

$$\sigma(\bar{p}+p\rightarrow \text{no fit})=0.58\pm0.03\text{ mb},$$

$$\sigma(\bar{p}+p\rightarrow 8\text{ prongs})=0.96\pm0.03\text{ mb}.$$

III. PRODUCTION ANGULAR DISTRIBUTIONS

Because of CR invariance[1] (C and R are, respectively, the charge conjugation and rotation operators) the $\cos\theta\ \pi^+$ angular distribution in the c. m. system must be equal to the reflection of the π^- distribution, while the

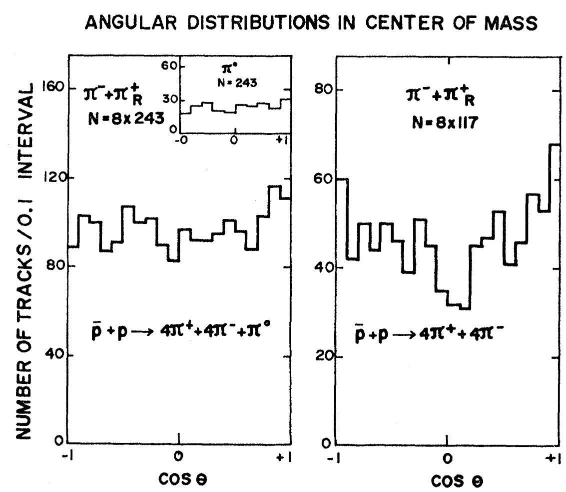

FIG. 1. Angular distributions of the π^- and reflected π^+ (π_R^+) with respect to $\bar{p}$ direction for $\bar{p}p$ annihilation into eight and nine pions. For the $\bar{p}p\rightarrow 4\pi^+4\pi^-\pi^0$ reaction the histogram in the upper insert shows the c.m. π^0 angular distribution.

[1] A. Pais, Phys. Rev. Letters 3, 242 (1959).

TABLE I. The A and C parameters for $\bar{p}p$ annihilation at different energies and multiplicities.

Final state	Incident momentum (GeV/c)	Reference	$\pi^{\pm}$ $A=F/B$	$\pi^{\pm}$ $C=P/E$	π^0 $A=F/B$	π^0 $C=P/E$
$2\pi^+2\pi^-$	1.61	a	1.06±0.09	1.15±0.15		
	~3.28	b	1.26±0.08	1.79±0.12		
	5.7	c	1.33±0.10	2.33±0.18		
$2\pi^+2\pi^-\pi^0$	1.61	a	1.17±0.04	1.08±0.07	···	1.41±0.09
	~3.28	b	1.27±0.04	1.36±0.09	···	···
	5.7	d	1.27±0.10	1.85±0.09	···	···
$3\pi^+3\pi^-$	1.61	e	0.61±0.18	1.41±0.41		
	3	f	1.03±0.07	1.16±0.05		
	3.28	b	1.11±0.09	1.08±0.09		
	5.7	g	1.31±0.09	2.19±0.10		
$3\pi^+3\pi^-\pi^0$	1.61	e	1.08±0.44	1.06±0.21		···
	3	f	1.07±0.03	1.11±0.03	1.12±0.07	0.86±0.07
	3.28	b	1.15±0.06	1.25±0.06		0.89±0.11
	5.7	g	1.15±0.04	1.53±0.08	1.26±0.15	1.69±0.22
	7	h	1.31±0.10	1.46±0.12		···
$4\pi^+4\pi^-$	3	f	1.1 ±0.1	1.17±0.10		
	3.28	b	1.01±0.09	0.89±0.08		
	3.6	f	0.9 ±0.1	1.24±0.09		
	5.7	i	1.02±0.11	1.20±0.11		
$4\pi^+4\pi^-\pi^0$	3	f	1.1 ±0.1	0.9 ±0.1	···	···
	3.28	b	1.13±0.07	0.89±0.06	···	···
	3.6	f	0.9 ±0.1	1.2 ±0.1	···	···
	5.7	i	1.04±0.07	1.03±0.07	1.19±0.21	1.09±0.20

[a] B. C. Maglić, G. R. Kalbfleisch, and M. L. Stevenson, Phys. Rev. Letters **7**, 137 (1961).
[b] T. Ferbel *et al.*, Phys. Rev. **143**, 1096 (1966).
[c] A. Accensi *et al.*, Phys. Letters **20**, 557 (1966).
[d] K. Böckmann *et al.*, Nuovo Cimento **42**, 954 (1966).
[e] See compilation done in Ref. d.
[f] See Ref. 2.
[g] A. Fridman, G. Maurer, A. Michalon, J. Oudet, B. Schiby, R. Strub, C. Voltolini, and P. Cüer, Phys. Rev. **167**, 1268 (1968).
[h] T. Ferbel, A. Firestone, J. Johnson, J. Sandweiss, and H. D. Taft, Nuovo Cimento **38**, 19 (1965).
[i] This experiment.

π^0 distribution should show symmetry around $\cos\theta=0$ for the $\bar{p}p\rightarrow 4\pi^+4\pi^-\pi^0$ reaction. For the entire sample of fitted events, this is verified within the statistical errors ($\chi^2=23.9$ for 30 degrees of freedom).

Figure 1 shows the pion c. m. angular distributions for the two reactions under study. Here the c.m. angular distributions for the outgoing pions are defined with respect to the nucleon direction for π^+ and to the antinucleon direction for π^- and π^0. For each distribution the asymmetry $A=F/B$ and the collimation $C=P/E$ parameters have been calculated. F and B are the number of pions emitted in the forward and backward hemispheres, while P and E are the number of pions in the polar ($|\cos\theta|\geq 0.5$) and the equatorial ($|\cos\theta|<0.5$) cones. Table I gives the A and C parameters obtained in the experiment and, for comparison, data for other multiplicities and energies.

From Table I we note that (a) for a given channel, C seems to increase with increasing c. m. energy, (b) for the same energy, C appears to decrease when a neutral pion is added to a given final-pion configuration, and (c) for a given energy, C seems to decrease with increasing number of charged pions.

In order to observe a possible correlation between the production angular distribution and p^*, the c.m. momentum of the produced pions, the A and C parameters were calculated for different p^* intervals (see Table II). Although the errors are rather large, A appears to be not very sensitive to the pion momenta, while C increases with increasing p^*. A similar effect was found in $\bar{p}p$ annihilations into six and seven pions at 3 GeV/c.[2] This could indicate that there are energetic pions which contribute mainly to the anisotropy of the angular distribution.

TABLE II. Asymmetry and collimation parameters for various momentum intervals Δp^* in GeV/c.

$\bar{p}+p\rightarrow 4\pi^++4\pi^-$	π^+	Δp^*	0 – 0.2	0.2 – 0.4	0.4 – 0.6	0.6 –
		F/B	0.95±0.24	1.12±0.16	0.87±0.15	1.11±0.24
		P/E	1.12±0.28	0.91±0.13	1.33±0.23	2.07±0.46
$\bar{p}+p\rightarrow 4\pi^++4\pi^-+\pi^0$	$\pi^{\pm}$	Δp^*	0 – 0.2	0.2 – 0.4	0.4 – 0.6	0.6 –
		F/B	1.03±0.15	1.00±0.10	0.99±0.13	1.45±0.29
		P/E	0.79±0.11	1.00±0.10	1.11±0.14	1.51±0.30
	π^0	Δp^*	0 – 0.36	0.36–		
		F/B	1.2 ±0.3	1.2 ±0.3		
		P/E	1.0 ±0.3	1.2 ±0.3		

[2] J. A. Danysz, B. R. French, and V. Simak, Nuovo Cimento **51**, 801 (1967).

IV. ANGULAR CORRELATIONS

Figures 2 and 3 show the c.m. opening-angle distribution between like and unlike pions for the reaction

$$\bar{p}+p\to 4^{+}+4\pi^{-}$$

and

$$\bar{p}+p\to 4\pi^{+}+4\pi^{-}+\pi^{0}.$$

The curves in these figures represent the phase-space calculations obtained by the Monte Carlo method.

As first observed in $\bar{p}p$ annihilation at 1.05 GeV/c,[3] some difference between the like and unlike distributions appears in each channel. This effect was interpreted by Goldhaber *et al.*[4] in terms of the Fermi statistical model modified by symmetrizing the wave function for like pions in the final state.

For each channel we have calculated the correlation parameters γ for like (γ^{l}) and unlike (γ^{u}) pions. The γ parameter is defined as the ratio of the number of pion

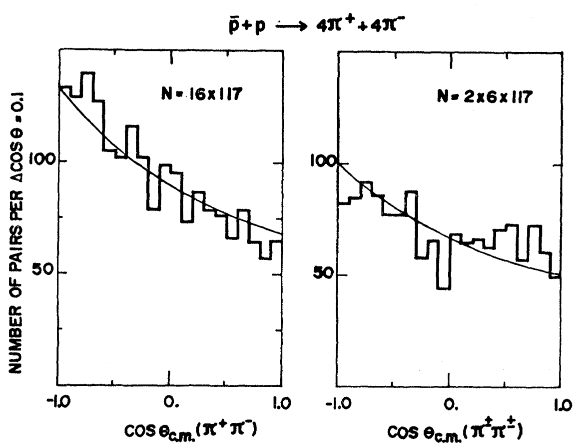

FIG. 2. Distributions of the c.m. opening angle between unlike and like pions produced in the $\bar{p}+p\to 4\pi^{+}+4\pi^{-}$ reaction. The curves represent the predictions of the statistical model.

pairs (n_B) having opening angles greater than 90° to the number of pairs (n_F) with this angle less than 90°. Table III gives the γ values found in this experiment and those obtained from various $\bar{p}p$ annihilation experiments at different energies. For each case we have also calculated by the Monte Carlo method the γ^{c} and $\gamma^{\pm 0}$ values predicted by the usual statistical model.[5] $\gamma^{\pm 0}$ is obtained from pion pairs having the masses of a charged and a neutral pion, while γ^{c} is calculated from a pair having the $\pi^{\pm}$ masses.

From Table III one sees that (a) for a given channel, γ^{l} and γ^{u} approach the statistical-model values with increasing c.m. energy, and (b) for eight and nine pions

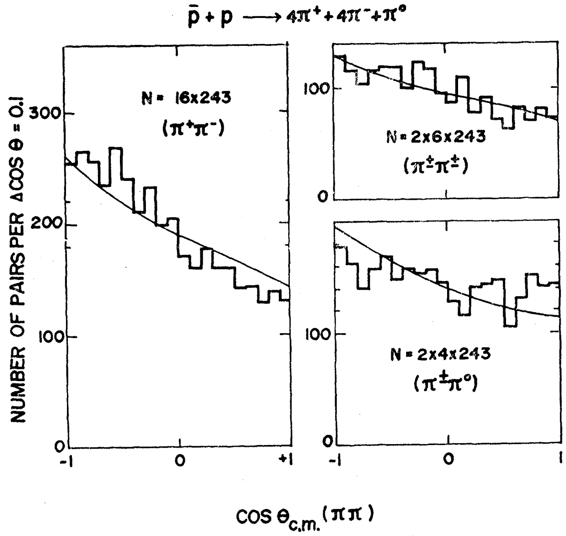

FIG. 3. Distributions of the c.m. opening angle between unlike and like pions produced in the $\bar{p}+p\to 4\pi^{+}+4\pi^{-}+\pi^{0}$ reaction. The curves represent the predictions of the statistical model.

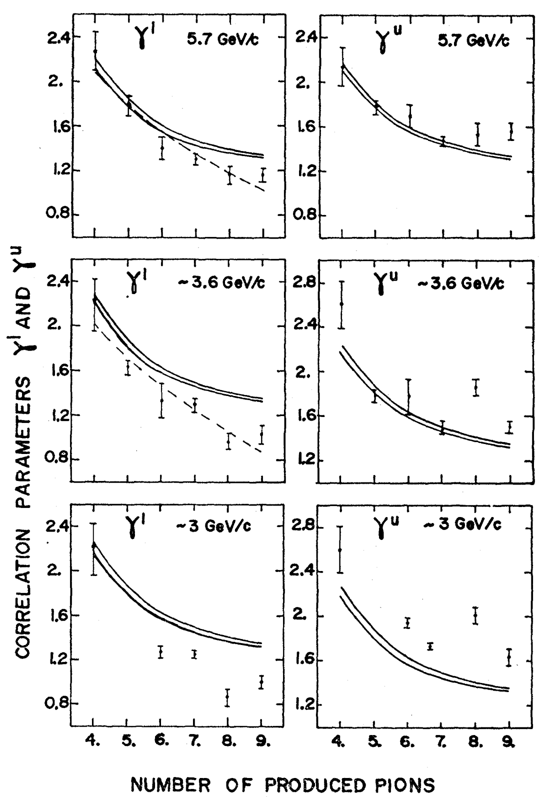

FIG. 4. Correlation parameters versus the number of produced pions n for energies where the available data are the most complete. The dashed lines were obtained by fitting the data with an Ae^{-na} law. The upper and lower continuous curves connect the superior and inferior limits, respectively, of the errors bars on each point obtained by a Monte Carlo statistical-model calculation. The point with $n=4$ at ~3.6 and ~3 GeV/c was taken from an experiment realized at 3.28–3.66 GeV/c (for references, see Table III).

[3] G. Goldhaber, W. B. Fowler, S. Goldhaber, T. F. Hoang, T. E. Kalogeropoulos, and W. M. Powell, Phys. Rev. Letters **3**, 181 (1959).

[4] G. Goldhaber, S. Goldhaber, W. Lee, and A. Pais, Phys. Rev. **120**, 300 (1960).

[5] P. P. Strivastava and E. G. G. Sudarshan, Phys. Rev. **110**, 765 (1958); see also Ref. 4.

TABLE III. The γ correlation parameters for $\bar{p}p$ annihilation at different energies and multiplicities.

Final state	Incident momentum (GeV/c)	Ref.	Experimental values γ^l	γ^{+-}	γ^u	$\gamma^{\pm 0}$	Statistical model γ^{st} γ^c	$\gamma^{\pm 0}$	$\gamma^l-\gamma^c$	$\gamma^u-\gamma^c$
$2\pi^+2\pi^-$	1.6	a	1.2 ±0.1	2.2 ±0.1			2.25±0.04		−1.05±0.14	−0.05±0.14
	3.25	b	2.6 ±0.5	2.3 ±0.3			2.22±0.04		0.38±0.54	0.08±0.34
	3.28–3.66	c	2.19±0.23	2.60±0.21			2.22±0.04		−0.03±0.27	0.38±0.25
	5.7	d	2.27±0.17	2.14±0.17			2.14±0.04		0.13±0.21	0.00±0.21
	7	e	2.2 ±0.3	1.51±0.17			2.19±0.04		0.01±0.34	−0.6 ±0.21
$2\pi^+2\pi^-\pi^0$	3.25	b	1.68±0.017		1.90±0.14		1.82±0.03	1.74±0.04	−0.14±0.04	0.08±0.17
	3.28–3.66	c	1.63±0.06		1.78±0.06		1.82±0.03	1.74±0.04	−0.19±0.09	−0.04±0.09
	5.7	f	1.78±0.09		1.77±0.06		1.79±0.03	1.71±0.04	−0.01±0.12	−0.02±0.09
$3\pi^+3\pi^-$	1.2	g	0.92±0.01	2.48±0.04			1.60±0.02		−0.68±0.03	0.88±0.06
	1.6	a	0.92±0.07	2.45±0.1			1.59±0.02		−0.67±0.09	0.86±0.12
	3	h	1.27±0.05	1.94±0.04			1.60±0.02		−0.33±0.07	0.34±0.06
	3.25	b	1.17±0.10	2.02±0.15			1.60±0.02		−0.43±0.12	0.42±0.17
	3.28–3.66	c	1.33±0.15	1.78±0.15			1.60±0.02		−0.27±0.17	0.18±0.17
	4	i	1.4 ±0.3	1.5 ±0.2			1.60±0.02		−0.20±0.32	0.10±0.22
	5.7	j	1.4 ±0.1	1.7 ±0.1			1.57±0.02		−0.17±0.12	0.13±0.12
$3\pi^+3\pi^-\pi^0$	1.6	a	1.23±0.06		1.88±0.05		1.48±0.02	1.47±0.02	−0.25±0.08	0.40 0.07
	3	h	1.25±0.03		1.73±0.03		1.47±0.02	1.47±0.02	−0.22±0.05	0.26±0.05
	3.25	b	1.35±0.08		1.58±0.08		1.47±0.02	1.48±0.02	−0.12±0.10	0.11±0.10
	3.28–3.66	c	1.29±0.06		1.50±0.06		1.48±0.02	1.46±0.02	−0.19±0.08	0.02±0.08
	4	i	1.3 ±0.1		1.5 ±0.1		1.47±0.02	1.46±0.02	−0.17±0.12	0.03±0.12
	5.7	j	1.30±0.05	1.47±0.04		1.66±0.6	1.46±0.02	1.44±0.02	−0.16±0.07	0.01±0.06
$4\pi^+4\pi^-$	3	h	0.86±0.08	2.01±0.07			1.39±0.01		−0.53±0.09	0.62±0.08
	3.6	h	0.97±0.07	1.86±0.07			1.40±0.01		−0.43±0.08	0.46±0.08
	5.7	k	1.16±0.08	1.53±0.10			1.38±0.01		−0.22±0.09	0.15±0.11
$4\pi^+4\pi^-\pi^0$	3	h	1.00±0.06		1.63±0.07		1.34±0.01	1.34±0.02	−0.34±0.07	0.29±0.08
	3.6	h	1.03±0.08		1.51±0.05		1.34±0.01	1.34±0.02	−0.31±0.09	0.17±0.06
	5.7	k	1.16±0.06	1.56±0.07		1.41±0.09	1.33±0.01	1.33±0.03	−0.17±0.07	0.23±0.08

[a] N. H. Xuong and G. R. Lynch, Phys. Rev. **128**, 1849 (1962).
[b] T. Ferbel, Ph.D. thesis, Yale University, 1963 (unpublished).
[c] T. Ferbel, A. Firestone, J. Sandweiss, H. D. Taft, M. Gailloud, T. W. Morris, W. J. Willis, A. H. Bachman, P. Baumel, and R. M. Lea, Phys. Rev. **143**, 1096 (1966).
[d] A. Accensi *et al.*, Phys. Letters **20**, 557 (1966).
[e] J. A. Johnson, Ph.D. thesis, Yale University, 1965 (unpublished).
[f] V. Alles-Borelli *et al.*, Nuovo Cimento **50**, 776 (1967).
[g] See Ref. 6.
[h] See Ref. 2.
[i] J. P. Porte, Ph.D. thesis, University of Paris, 1964 (unpublished).
[j] A. Fridman, G. Maurer, A. Michalon, J. Oudet, B. Schiby, R. Strub, C. Voltolini, and P. Cüer, Phys. Rev. **167**, 1268 (1968); K. Böckmann *et al.*, Nuovo Cimento **42**, 954 (1956).
[k] This experiment.

in the final state, the differences $|\gamma^u-\gamma^c|$ and $|\gamma^l-\gamma^c|$ appear to have comparable values (see also Fig. 4).

This last point can indicate that the symmetrization of the wave function as proposed in Ref. 4 for low multiplicities is perhaps a too rough approximation for channels with eight and nine outgoing pions. Indeed, for low multiplicities the γ^u parameters were found to be nearly equal to γ^c. The small observed difference was supposed to be due, via momentum conservation, to the deformation of the opening-angle distribution for like pions.

For higher multiplicities a more refined model can be useful. This has been confirmed by a recent work on the energy dependence of the angular correlation in $\bar{p}p$ annihilations.[6]

Figure 4 shows the γ^l and γ^u parameters considered as functions of the number of outgoing pions n at 5.7, $\sim$3.6, and $\sim$3 GeV/c, where the data are the most abundant. Within the present statistics, the γ^l behavior can be parametrized by an Ae^{-na} law. It appears that no such simple parametrization can be employed for the γ^u curve.

For the two fitted curves in Fig. 4, the following constants were obtained:

$$A=3.8\pm0.9,\quad a=-0.14\pm0.03 \quad \text{at} \quad 5.7\ \text{GeV}/c,$$

and

$$A=3.9\pm1.0,\quad a=-0.16\pm0.03 \quad \text{at} \sim 3.6\ \text{GeV}/c.$$

In Fig. 5 we have presented the data in the same way as in Ref. 7. The $\gamma^{l,u}$ parameters were plotted versus the quantity $\Delta=(|\mathbf{P}_i|-|\mathbf{P}_j|)$, where $\mathbf{P}_i$ and $\mathbf{P}_j$ are the c.m. momenta of the pions in the pairs. Although the errors are rather large, the conclusions are qualitatively similar to those obtained in π^+p interactions at 8 GeV/c.[7] The deviations between the experimental data and the phase-space predictions appear to be important when Δ is small (see Fig. 5). Figure 6 shows another set of correlation parameters $\delta^{l,u}$ as a function of $\Delta' = |\mathbf{P}_i-\mathbf{P}_j|$, where $\delta^{l,u}$ is defined as

$$\delta^{l,u}=(n_B{}^{l,u}-n_F{}^{l,u})/(n_B{}^{l,u}+n_F{}^{l,u}).$$

[6] O. Czyzewsky and M. Szeptycka, Phys. Letters **25B**, 482 (1967).

[7] J. Bartke *et al.*, Phys. Letters **24B**, 163 (1967).

The quantity Δ' was used because this is the variable which enters into the two-pion correlation function proposed in Ref. 4. The $\gamma^{\pm 0}$ and $\delta^{\pm 0}$ parameters are not represented on Figs. 5 and 6 for the $\bar{p}+p\rightarrow 4\pi^{+}+4\pi^{-}+\pi^{0}$ reaction, because these values, within the present statistics, are compatible with the phase-space model over the entire Δ and Δ' range. From Fig. 6 one sees that for both channels $\delta^{\pm\pm}$ is significantly different from δ^{+-} when $|\mathbf{P}_i-\mathbf{P}_j|\sim 0.45$ GeV/c. Within the present statistics these last two figures seem to indicate that the deviation between our experimental data and the statistical model occurs mainly for the pion-pair configurations in momentum space having $|\mathbf{P}_i|\sim|\mathbf{P}_j|$ and $|\mathbf{P}_i-\mathbf{P}_j|\sim 0.45$ GeV/c.

The production of resonances may have an influence on the correlation parameters. However, the observation of resonances in the final state is rather difficult here because of the high combinational background. In the study of the two-, three-, and four-π mass distributions, resonances have not been observed. Therefore no attempt has been made to explain the deviation (or part of it) between the experimental γ and δ values and the phase-space predictions as being due to resonances produced in the final state.

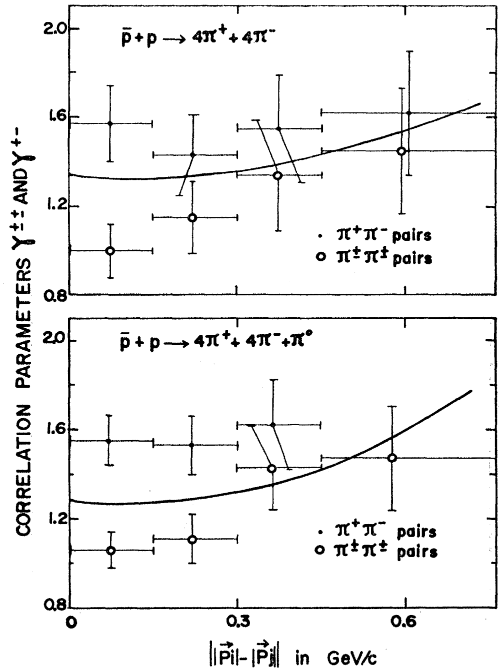

FIG. 5. Correlation parameters $\gamma^{\pm\pm}$ and γ^{+-} versus ($|\mathbf{p}_i|-|\mathbf{p}_j|$) (see text). The curves show the phase-space behavior obtained by a Monte Carlo calculation.

V. PRODUCTION MECHANISM

Figures 7–9 show the c.m. longitudinal (P_l^*) and transverse ($P_\perp$) momentum distributions for the reactions with eight and nine produced pions. In Figs. 10 and 11 are presented $P_\perp$ distributions for different $|P_l^*|$ intervals of charged pions. The curves in these figures represent phase-space predictions and are in satisfactory agreement with the experimental data. This shows that the secondaries are not emitted in a jet structure (i.e., with small transverse momentum) and that the usual statistical model gives a relatively good description of our data despite the weak two-pion correlation found in this experiment.

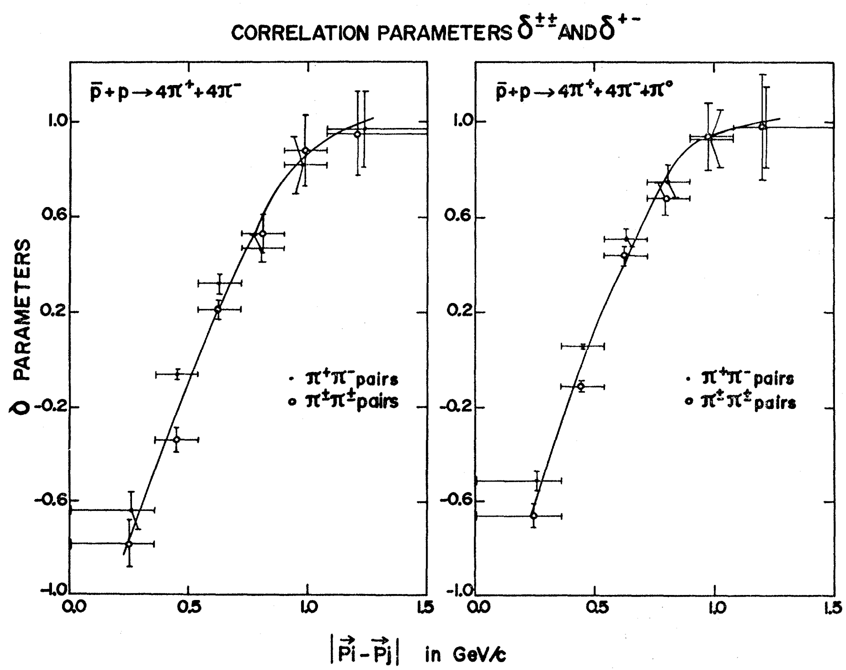

FIG. 6. Correlation parameters $\delta^{\pm\pm}$ and δ^{+-} versus $|\mathbf{p}_i-\mathbf{p}_j|$ (see text). The curves show the phase-space behavior obtained by a Monte Carlo calculation.

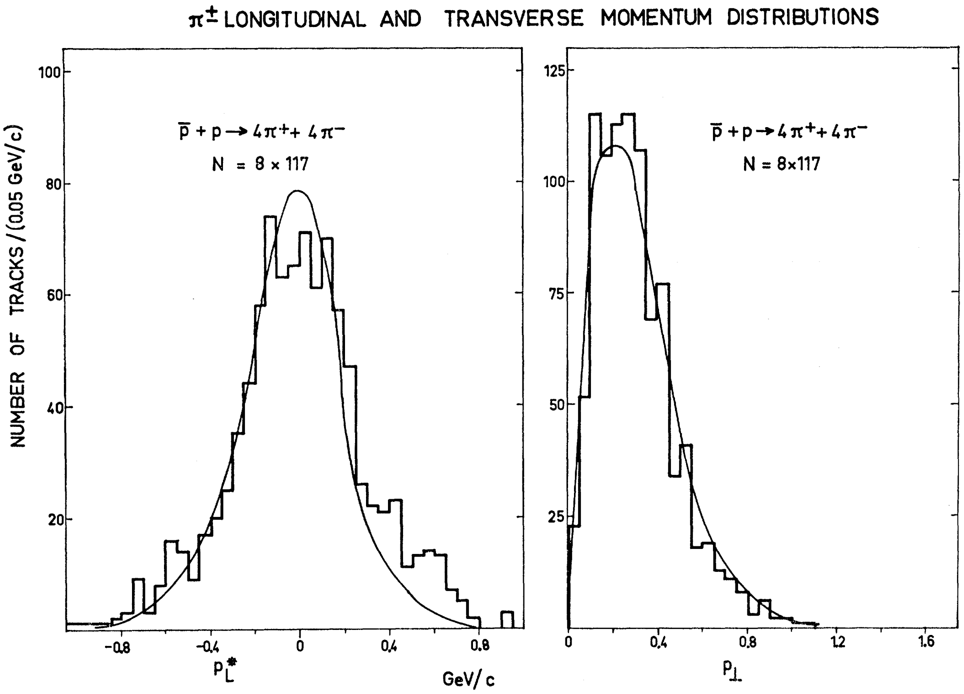

FIG. 7. The $\pi^{\pm}$ longitudinal and transverse momentum distributions for the $\bar{p}+p \rightarrow 4\pi^{+}+4\pi^{-}$ reaction. The curves were calculated from the statistical model.

A general feature of the $\bar{p}p$ annihilation into pions, at least for low multiplicities, is the relatively important forward (backward) peaking of π^{-} (π^{+}) in the c.m. system. Although this effect can be important, the contribution of the peaked pions to the partial cross section is small.[8] At 5.7 GeV/c the peaking is not important for the $\bar{p}p \rightarrow 8\pi$ and $\bar{p}p \rightarrow 9\pi$ reactions. This can be qualitatively explained by assuming a cloud-core model for the nucleon and antinucleon in $\bar{p}p$ annihilation.[9,10] In this approach one assumes that the clouds are responsible for the forward (backward) peaking of the π^{-} (π^{+}), while the symmetric part of the angular

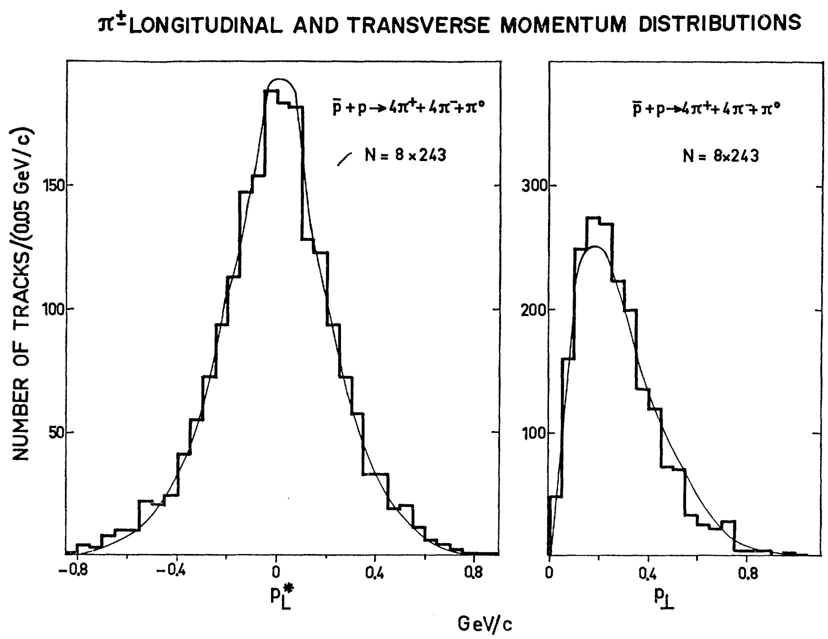

FIG. 8. The $\pi^{\pm}$ longitudinal and transverse momentum distributions for the $\bar{p}+p \rightarrow 4\pi^{+}+4\pi^{-}+\pi^{0}$ reaction. The curves were obtained from the statistical model.

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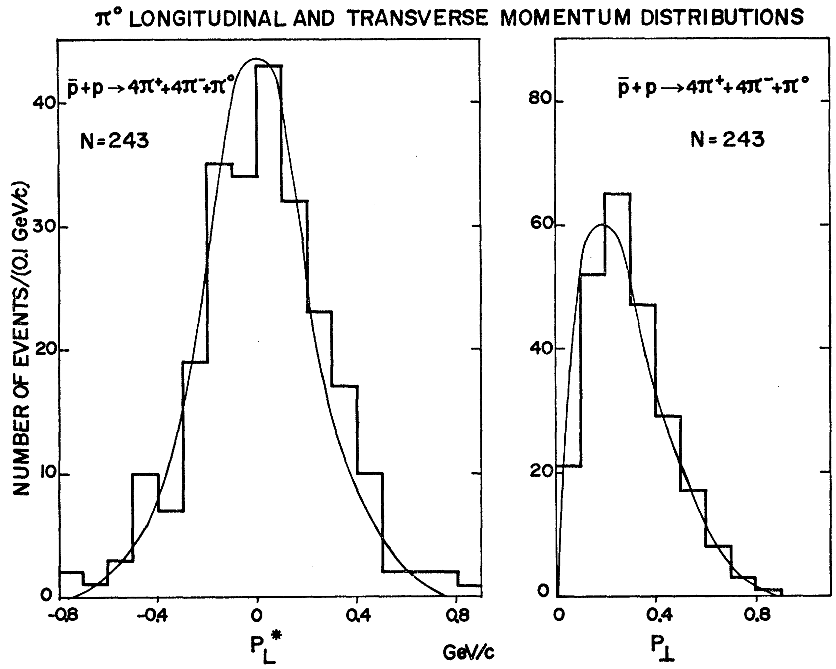

FIG. 9. The π^0 longitudinal and transverse momentum distributions for the $\bar{p}+p\rightarrow 4\pi^+ + 4\pi^- + \pi^0$ reaction. The curves were calculated from the statistical model.

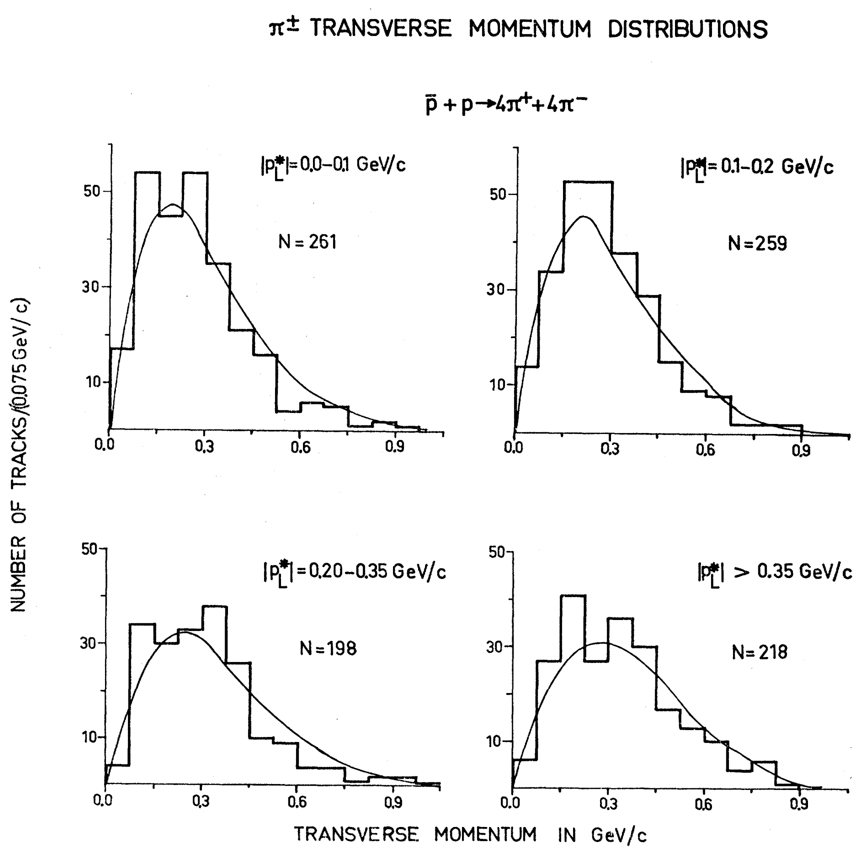

FIG. 10. The $\pi^{\pm}$ transverse momentum distributions for different longitudinal momentum intervals for the $\bar{p}+p\rightarrow 4\pi^+ + 4\pi^-$ reaction. The curves are the statistical-model predictions.

distribution comes mainly from core-core interactions. With increasing multiplicities, the contribution of the core-core part of the interaction increases and the peaking becomes then less important. This seems to be verified for the existing $\bar{p}p$ annihilation data.[11]

[11] See Ref. 8.

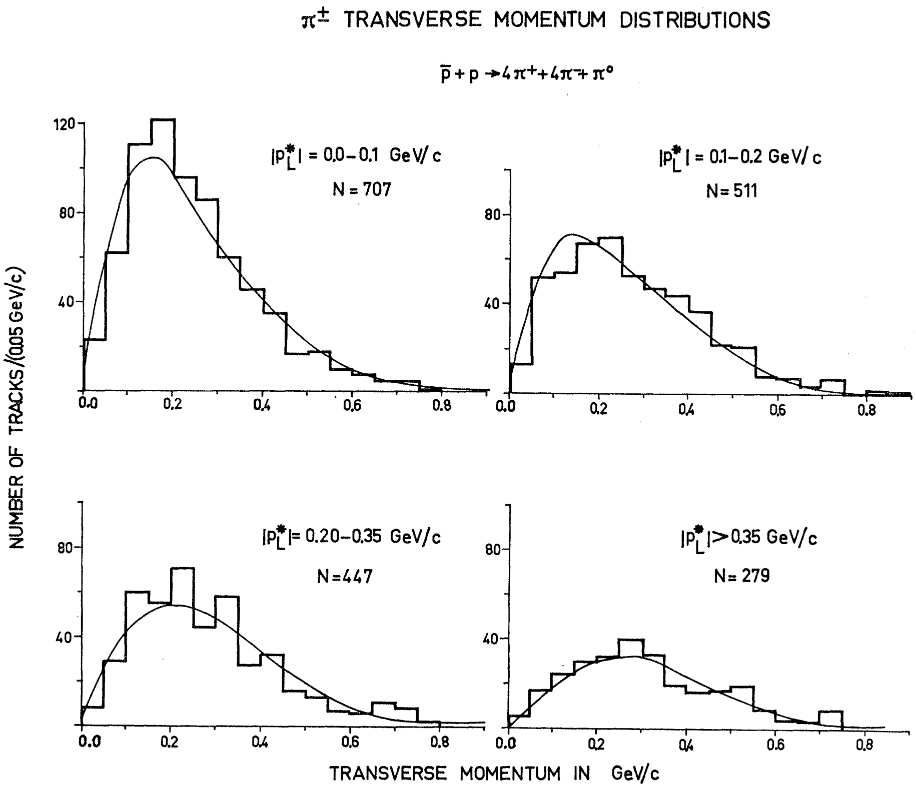

FIG. 11. The $\pi^{\pm}$ transverse momentum distributions for different longitudinal momentum intervals for the $\bar{p}+p\rightarrow 4\pi^{+}+4\pi^{-}+\pi^{0}$ reaction. The curves are the statistical-model predictions.

VI. CONCLUSIONS

The present data show that the forward (backward) peaking of the c.m. angular distributions for the π^{-} (π^{+}) pions is not very pronounced. For the $\bar{p}+p\rightarrow 4\pi^{+}+4\pi^{-}+\pi^{0}$ reaction, the π^{0} angular distribution is compatible with isotropy. For each reaction, the asymmetry and collimation parameters were calculated and compared with data at other energies and multiplicities. For a given energy the collimation parameter C tends to decrease with increasing number of outgoing pions, while for a given channel it increases with c.m. energy. The C parameter is also sensitive to the c.m. momenta of the outgoing pions. One observes an increase of C with momenta of the produced pions. This indicates that the anisotropy of the angular distribution seems to come mainly from energetic pions.

For $\bar{p}+p\rightarrow 4\pi^{+}+4\pi^{-}$ and $\bar{p}+p\rightarrow 4\pi^{+}+4\pi^{-}+\pi^{0}$ reactions, some difference can be seen in the c.m. opening-angle distribution for like and unlike pion pairs. The correlation parameters found in this experiment show significant differences from the statistical-model predictions. These parameters depend appreciably on the momenta of the pions entering into the pairs. For both reactions studied, it seems that the deviation between the experimental correlation parameters and those predicted by the usual statistical model occurs mainly for a definite configuration in momentum space of the pions in the pair ($|\mathbf{P}_i|\sim|\mathbf{P}_j|$ and $|\mathbf{P}_i-\mathbf{P}_j|\sim 0.45$ GeV/c).

The longitudinal and transverse momentum distributions of the secondaries are in satisfactory agreement with phase-space predictions. Transverse momentum distributions for different c.m. longitudinal momentum bands are compatible, within the present statistics, with phase-space calculations.

ACKNOWLEDGMENTS

We are grateful to Professor H. Filthuth for encouraging and supporting this work. It is a pleasure to thank Dr. B. R. French for a fruitful discussion. We also want to thank Professor Monsonego, Dr. A. Pape, Dr. R. Sosnowski, and Dr. F. C. Chen for interesting and useful discussions and Mrs. E. Jegham for her help during the analysis.