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CERN -PRE 93-008

84 8315

HEN-345 (1993)

**TWO-PARTICLE AZIMUTHAL AND RAPIDITY CORRELATIONS
IN INTERVALS OF TRANSVERSE MOMENTUM
IN π^+p -INTERACTIONS AT 250 GeV/c**

EHS/NA22 Collaboration

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Abstract

A multi-dimensional analysis of two-particle correlations in π^+p -interactions at 250 GeV/c shows interesting structure. Particularly strong positive short-range rapidity and azimuthal correlations are observed for low- p_T like-sign pairs. This observation is not reproduced by models used for comparison (FRITIOF, DPM, quark gluon (multi) string model). A possible explanation is Bose-Einstein interference not included in these models.

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1 Introduction

Two-particle correlation functions have large positive values in the central region of hadron-hadron, lepton-hadron and e^+e^- -collisions. Recent results are presented in [1-8], reference to earlier ones can be obtained from there. Presently existing low- p_T Monte Carlo models for hadron interactions are not able to describe the short-range correlations observed [2,7]. Furthermore, also for e^+e^- -models two particle-correlations are found to be more stringent tests than single-particle distributions [8,9]. To find the origin of disagreement between models and data, more detailed analysis of correlation phenomena is required, including that of correlation functions in more dimensions.

The recent revival of interest in a detailed investigation of two-particle correlations is connected with the observation of an intermittency effect in hadron production, for which the importance of a multidimensional analysis has recently been established [10]. Interesting effects, in particular on the p_T dependence of intermittency, are observed in the NA22 experiment [11]. A detailed investigation of two-particle correlations and intermittency can be performed in the same experiment.

The results on two- and three-particle rapidity correlations in π^+p , K^+p and pp -interactions at 250 GeV/c are published in [7]. In this paper, azimuthal correlations and rapidity correlations are presented for π^+p -interactions at 250 GeV/c, both for all particles and for particles in different transverse momentum intervals. The results are compared with model predictions.

Section 2 contains the description of the experimental method and the data sample. In Section 3 we give some information on the models used for comparison. The experimental results are presented and compared to the model predictions in Sect. 4. The main conclusions are summarized in Sect. 5.

2 Experimental method

The data are obtained with the European Hybrid Spectrometer (EHS) using the Rapid Cycling Bubble Chamber (RCBC) as a vertex detector. EHS is exposed to a 250 GeV/c tagged positive, meson enriched beam and a minimum bias interaction trigger is used. The details of the spectrometer and the trigger can be found in [12]. The average momentum resolution $\Delta p/p$ varies from a maximum of 2.5% at 30 GeV/c to around 1.5% above 100 GeV/c.

Events are accepted for the present analysis when measured and reconstructed charge multiplicity are consistent, charge balance is satisfied, no electron (of $p_{lab} < 200$ MeV/c) is detected and the number of badly reconstructed (and therefore rejected) tracks is at most 0, 1, 1, 2 and 3 for events with charge multiplicity 2, 4, 6, 8 and >8 , respectively. After these cuts, our inelastic sample consists of about 97 000 π^+p events.

Single-diffractive events are defined as events of charge multiplicity $n \leq 6$ with at least one positive particle having Feynman $|x| > 0.88$ and are removed from

the sample. This corresponds to a reduction by 12 500 events. As shown in [7], exclusion of single-diffractive events facilitates comparison to model predictions and to correlations in other types of collisions (e^+e^- , lh), but does not significantly affect the two-particle correlations in the central region of hadron-hadron collisions.

For momenta $p_{lab} < 0.7$ GeV/c, the range in the bubble chamber and/or the change of track curvature is used for proton identification. In addition, a visual ionization scan has been used for $p_{lab} < 1.2$ GeV/c on 62% of the π^+p sample. Particles identified as protons are removed from the sample for rapidity correlation analysis and are used with the proton mass in the analysis of azimuthal correlations. Particles with momenta $p_{lab} > 1.2$ GeV/c are not identified in the present analysis and are treated as pions.

The loss of events during measurement and reconstruction is corrected for by means of the topological cross section data [12].

Corrections for rejected tracks amount to 6-7% of the tracks. They are approximately independent of the multiplicity n and are assumed to be independent of rapidity y . It has been verified that the results do not change if the analysis is restricted to the sub-sample of events with all tracks accepted.

3 Quark models

In the present paper a comparison is performed with three models: FRITIOF [13], a two string version of the dual parton model (2-string DPM) [14] and the quark-gluon string model (QGSM) [15].

In FRITIOF each of the colliding particles is excited to form a dipole. The meson dipole fragments like a quark-antiquark chain in e^+e^- -annihilation and the nucleon dipole like a quark-diquark chain in lepton-nucleon collisions. The model includes gluon radiation, hard parton scattering and diffractive-like excitation.

In the DPM version used [16], two strings are formed in the interaction. One string is stretched between the meson quark and the proton diquark, the other between the meson antiquark and the residual single proton quark.

Quark fragmentation is performed according to the symmetric LUND model [17]. The primordial transverse momentum of valence quarks corresponds to a Gaussian distribution with average $\langle k_t \rangle = 0.42$ GeV/c. Parameter values are default, except for the width of the Gaussian p_x and p_y transverse momentum distribution for primary hadrons ($\sigma = 0.44$ GeV/c). The model, furthermore, includes the production of tensor mesons in the ratio PS:V:T=50:35:15. Monte Carlo events satisfying the "diffractive" criteria (see Sect.2 above) are excluded.

The quark-gluon string model [15], just as DPM, is based on dual topological unitarization. In addition to the two strings used in our DPM version, in QGSM strings are formed between sea quarks and antiquarks of the colliding hadrons. The transverse momentum distributions of valence and sea quarks in the hadron are of the form $P(k_t^2) = A \exp(-bk_t^2)$ with $b = 6.25$ (GeV/c) $^{-2}$ for the cylindrical diagram. The string breaking algorithm of QGSM is described in [15]. The last break-up of the

string is an isotropic two-particle cluster decay. A ratio PS:V=1:1 is used, without addition of tensor mesons.

All peculiarities of particle identification and experimental cuts were taken into account in the Monte Carlo simulation before comparing to the data. It has been verified by a Monte Carlo run at generator level that this does not change the results by more than the statistical errors.

Comparison of our charge multiplicity distributions and single-particle inclusive spectra have been performed with 2-string DPM and FRITIOF in [12] and with QGSM in [15]. In general, both models reproduce the single-particle inclusive distributions. The multiplicity distributions are reproduced best in QGSM. In particular, this is true at large multiplicity n , where multi-string formation is important.

4 Results

4.1 Rapidity correlations

The rapidity correlation function can be written in the form

$$C_2(y_1, y_2) = \rho_2(y_1, y_2) - \rho_1(y_1)\rho_1(y_2) \quad (1)$$

where

$$\rho_1(y) = (1/\sigma_{in})d\sigma/dy, \quad \rho_2(y_1, y_2) = (1/\sigma_{in})d^2\sigma/dy_1dy_2$$

are densities normalized to the particle multiplicity and particle pair multiplicity, respectively. Commonly used are also the normalized correlation functions or factorial cumulants:

$$K_2(y_1, y_2) = \frac{\rho_2(y_1, y_2)}{\rho_1(y_1)\rho_1(y_2)} - 1. \quad (2)$$

The correlation functions $C_2(y_1, y_2)$ and $K_2(y_1, y_2)$ are connected to the factorial moments used in the analysis of fractal properties (intermittency) of multiparticle production. For rapidity bin size δy near rapidity y_i , the factorial moment $\tilde{F}_2$ and the normalized factorial moment F_2 averaged over all events, can be written in the form [18]:

$$\langle \tilde{F}_2 \rangle_i = \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_1 \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_2 \rho_2(y_1, y_2) = \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_1 \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_2 C_2(y_1, y_2) + \left(\int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy \rho_1(y) \right)^2 \quad (3a)$$

$$\langle F_2 \rangle_i = \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_1 \int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy_2 \rho_2(y_1, y_2) / \left(\int_{y_i - \frac{\delta y}{2}}^{y_i + \frac{\delta y}{2}} dy \rho_1(y) \right)^2. \quad (3b)$$

To calculate factorial moments analytically, it is necessary to know the analytical expression for the correlation function. The fact that normalized factorial moments increase with decreasing bin size δy [11] leads to the expectation that the correlation function C_2 (or K_2) has a residual structure inside the interval $\delta y=0.5$, commonly used as the smallest bin size in correlation studies.

To appreciate this structure we fit $C_2(y_1, y_2)$ and $K_2(y_1, y_2)$, measured with resolution $\delta y = 0.5$ near $y_1 = 0$, by the functions

$$f_1 = c \exp[-(y_2 - y_0)^2 / 2\sigma^2] \quad (4)$$

$$f_2 = a \exp(-by_2) \quad \text{for } y_2 \geq 0 \quad (5)$$

To be consistent with the data, the function value averaged over the corresponding y_2 interval is used in the fitting procedure. The results are shown in Fig.1 and 2a for C_2 and K_2 , respectively, for y_1 restricted to a central bin ($-0.25 \leq y_1 < 0.25$). In these and the following figures four charge combinations are given for the particle pairs: both negative ($--$), both positive ($++$), of opposite charge ($+-$) and of arbitrary non-zero charge (cc). The corresponding parameters are presented in Tables 1 and 2 for C_2 and Tables 3 and 4 for K_2 . The Gaussian function (4) (full lines) gives a much better description of the rapidity correlation for the central rapidity bin than the exponential (5) (dashed lines). The results are similar for bin size $\delta y = 0.1$ (not shown).

The $K_2(0, y_2)$ are further used for the analysis of the p_T -dependence of correlation phenomena. In Fig.2b,c the $K_2(0, y_2)$ functions are shown for particles with $p_T < 0.30$ GeV/c and $p_T > 0.30$ GeV/c, together with results of their fit by functions (4) and (5). The parameters of these functions are given in Tables 5-8. For low- p_T particles, $K_2(0, y_2)$ is larger near $y_2 = 0$ than for higher p_T , in particular for the ($--$) combination.

In our intermittency analysis [11], the values of factorial moments are averaged in rapidity between -2 and $+2$. This procedure is equivalent to averaging the correlation functions and cumulants along the diagonal in the (y_1, y_2) -plane. For this reason, the correlation functions can be rewritten in variables corresponding to diagonals in the (y_1, y_2) -plane, which we take as $x_1 = \frac{y_1 + y_2}{2}$; $x_2 = \frac{y_2 - y_1}{2}$.

The correlation function $C_2(x_1, x_2)$ and the normalized factorial cumulant $K_2(x_1, x_2)$, averaged over the x_1 -region $(-1.25, 1.25)$, with $\delta x_2=0.5$ and 0.1 , are shown in Figs. 3 and 4a, respectively. For ($--$) and (cc)-pairs, K_2 increases for δx_2 between 0.5 and 0.1 by the amounts:

$$\Delta K_2^{cc} = 0.014 \pm 0.004$$

$$\Delta K_2^{--} = 0.034 \pm 0.008 .$$

Assuming a power-law behavior $F_2 \sim (\delta x_2)^{-f_2}$, we find $f_2^{cc} = 0.008 \pm 0.003$ and $f_2^{--} = 0.021 \pm 0.005$, in rough agreement with the slopes found in the last ref. [11]. Less significant increase is visible for ($+-$) than for ($--$)-pairs in K_2 (Fig.4a), thus indicating that the rise of the factorial moments with decreasing resolution is mostly due to like-sign pairs.

In Fig.4b,c the cumulants $K_2(x_1, x_2)$ are shown for $x_1 \in [-1.25, 1.25]$ with the

results of fits by the functions

$$f_3 = c \exp(-x_2^2/2\sigma^2) \quad (6)$$

$$f_4 = a \exp(-bx_2) \quad \text{for } x_2 \geq 0 \quad (7)$$

in x_2 -binning of $\delta x_2 = 0.5$ and 0.1 , respectively. The fitting procedure is the same as for (4) and (5). (Note that resolution $\delta x = 0.1$ is equivalent to resolution $\delta y = 0.14$ since the y -scale is multiplied by $\sqrt{2}$, compared to the x -scale.) The fit results are given in Tables 9-12. Now both functions fail to fit the data. Acceptable χ^2 values are only obtained if the fit is restricted to the region $|x_2| \leq 0.4$ (Table 10a).

4.2 Azimuthal correlations

In hh -interactions, no distinguished direction exists in the plane transverse to the beam and the distribution in the azimuthal angle φ is uniform. A two-particle correlation, however, exists also in φ and can be expressed as the distribution in $\Delta\varphi = |\varphi_1 - \varphi_2|$, the azimuthal angle between two particles, defined between 0 and π . The azimuthal correlation may depend on the charge of the particles in the pair, on the rapidity distance $\Delta y = |y_1 - y_2|$ between these particles and on transverse momentum.

Already the first experiments extensively studying two-particle correlations as a function of both rapidity and azimuthal angular separation [19,20] could show that the correlation at small rapidity distance is strongest when the two particles are produced in the same ($\Delta\varphi = 0$) or opposite ($\Delta\varphi = \pi$) directions in transverse momentum. The range of the rapidity correlation is larger towards $\Delta\varphi = \pi$ than towards $\Delta\varphi = 0$. Furthermore, significant differences in the shape of the joint rapidity and azimuthal correlation functions have been observed for pairs of like and unlike pions [20].

In Fig.5a, the probability distribution $W(\Delta\varphi, \Delta y)$, defined as the number of pairs at $(\Delta\varphi, \Delta y)$ normalized to unity, is shown as a function of $\Delta\varphi$, for all charge combinations, in the Δy intervals for $\Delta y < 1$, $1 < \Delta y < 2$ and $2 < \Delta y < 3$. The absence of correlation in φ would correspond to flat distribution in $\Delta\varphi$ at the value $W(\Delta\varphi, \Delta y) = 1/\pi$ (dotted lines). The distribution is influenced by conservation of transverse momentum, by decay of resonances (for unlike-sign particles) and by Bose-Einstein correlations (for identical particles). In all cases, W is larger than $1/\pi$ for $\Delta\varphi > \pi/2$ and has a maximum at $\Delta\varphi = \pi$. Except for $(--)$ pairs at $\Delta y < 1$, the W function is smaller than $1/\pi$ for $\Delta\varphi < \pi/2$. The source of such a global anti-correlation is transverse momentum conservation.

Model predictions are shown in Fig.5a for FRITIOF2.0 (dot-dashed), two string DPM (full line) and multi-string QGSJ (dashed). The comparison with the data shows that it is easier to predict azimuthal correlations at large than at small Δy , where models differ from each other and from the experimental data. Differences between experiment and all models exist at small $\Delta\varphi$ and $\Delta y < 1$, in particular

for $(--)$ and $(++)$ pairs. The QGSM shows somewhat better agreement with the experimental distributions than the other models. This is a consequence of the multi-string structure of QGSM, where strong azimuthal correlations existing within one string are destroyed and the $\Delta\varphi$ -dependence is weaker than in the two-string models.

In Fig.5b,c, the azimuthal distributions are shown for particles with different transverse momentum ($p_T < 0.30$ GeV/c and $p_T > 0.30$ GeV/c), in comparison with the model calculations. A comparison of these figures shows that the azimuthal distributions have a strong p_T -dependence. Large positive azimuthal correlations exist at low $\Delta\varphi$ and $\Delta y < 1$ for like-sign pairs of particles with small p_T (Fig.5b).

Bose-Einstein correlations (for recent reviews see [21]) are not included in the models and may well be the most important source of this disagreement. The influence of Bose-Einstein correlation is reduced in the $(++)$ combination due to the influence from the (positive) beam particles.

To estimate the influence of Bose-Einstein interference quantitatively, results from pion-interferometry analysis of our data [22] have been used to impose weights on $(--)$ pairs at small Q^2 in QGSM. These weights are defined to reproduce the experimental Q^2 dependence of the ratio R between the $(--)$ pairs and pairs from a mixed-event sample. The effect on the QGSM $(--)$ azimuthal distribution in the upper left in Fig.5a, at small Δy is very small (within errors) when no p_T cut is applied. For $(--)$ pairs of $p_T < 0.3$ GeV/c particles (upper left in Fig.5b) inclusion of Bose-Einstein correlation in the above approximation does lead to a positive correlation at small $\Delta\varphi$, but the value of it is about half of that of the data. For a more accurate treatment, Bose-Einstein correlations have to be incorporated as an integral part into future hadronization models and φ correlations should be an additional challenge for their constructors.

For $(+-)$ pairs the first bin is contaminated by Dalitz-decay and γ -conversion and not considered. From the remaining points at $\Delta y < 1$, one can see that the anti-correlation in the data is underestimated by the models for low p_T and overestimated for higher p_T .

As the transverse momentum of particles increases (Figs.5c) the peak at $\Delta\varphi = \pi$ becomes more pronounced. This is reproduced by the models and reflects momentum compensation.

4.3 Asymmetry of azimuthal distributions

The correlation in azimuthal angles $W(\Delta\varphi)$ can be characterized by the asymmetry A defined as

$$A = \frac{N(\Delta\varphi > \pi/2) - N(\Delta\varphi < \pi/2)}{N(\Delta\varphi > \pi/2) + N(\Delta\varphi < \pi/2)} . \quad (10)$$

The asymmetry parameter is an integral parameter of the $W(\Delta\varphi)$ distribution and can be used in an analysis of the azimuthal distributions in their dependence on rapidity gap Δy of particle pairs and p_T of particles.

In Fig.6a we plot A versus the rapidity gap Δy for the different charge combinations. At small Δy , the Δy dependence of A is similar for $(++)$ and $(--)$ pairs, both starting from a small value and showing a steep increase of A with increasing Δy . At larger Δy , the asymmetry A decreases for $(--)$ pairs and remains approximately unchanged for $(++)$ pairs. This latter effect is due to the anticorrelation of beam- and target-like particles at large Δy . For $(+-)$ pairs, A is large at $\Delta y = 0$, but decreases with increasing rapidity gap. For cc -pairs this structure practically cancels and A is practically constant.

The experimental dependence is not reproduced in the models. For DPM this observation agrees with the conclusion from an analysis of pp -interactions at 360 GeV/c in NA23 [2]. For QGSM the difference with experiment in asymmetry is smaller than for DPM and FRITIOF.

In Fig.6b and 6c the asymmetry parameter $A(\Delta y)$ is shown for particles with different p_T -cuts. For particles with $p_T < 0.30$ GeV/c, the A -values are negative at small Δy for $(++)$ and $(--)$ pairs, but positive for $(+-)$ pairs. For high- p_T particles, A is always positive, but remains higher for $(+-)$ pairs at small Δy than for $(--)$ pairs. For all charge combinations and all values of Δy , the A -values increase with increasing p_T of the particles.

No good model description is available for $(--)$ and $(++)$ pairs at small Δy , both for all p_T and in limited p_T regions. When adding Bose-Einstein effects by the weighting procedure, again practically no difference is observed in the QGSM predictions for the $(--)$ pairs at $\Delta y < 1$ without p_T cut (upper left of Fig.6a). For $(--)$ pairs at small p_T (upper left of Fig.6b) the value for A changes from 0.00 to 0.03 (not shown). Again, this is about 50% of the discrepancy between model and experiment.

For $(+-)$ pairs at small Δy , models give too large an asymmetry parameter A for large p_T and too small A for low p_T . For QGSM this failure is canceled in the distribution for all p_T .

5 Conclusions

In this paper we report on results of a study of two-particle rapidity- and azimuthal angle correlations in π^+p interactions at an incident beam momentum of 250 GeV/c.

- In particular for $(--)$ particle pairs, the correlation functions depend more strongly on transverse momentum than for $(+-)$ pairs and are largest for small- p_T particles.
- In particular for like-sign particle pairs, the correlation functions $C_2(\frac{y_1+y_2}{2}; \frac{y_2-y_1}{2})$ and $K_2(\frac{y_1+y_2}{2}; \frac{y_2-y_1}{2})$ increase in their maximum when the resolution $\delta(\frac{y_2-y_1}{2})$ changes from 0.5 to 0.1. This is in agreement with the intermittency effect observed in factorial moment analysis.
- Significant deviations from FRITIOF, DPM and QGSM model predictions are observed for correlations at small values of $\Delta\varphi$ and Δy and in the asymmetry at

small Δy for like-charge particle pairs. These effects are enhanced for particles with small transverse momentum. Rough treatment of Bose-Einstein correlations can account for about half of the effect at low p_T . A more accurate treatment should be a challenge for future hadronization models.

- In addition, there is no good model description of the $\Delta\varphi$ distribution and asymmetry for $(+-)$ pairs at small Δy , in particular in separated p_T regions.

Acknowledgements

It is a pleasure to thank the EHS coordinator L. Montanet and the operating crews and staffs of EHS, SPS en H2 beam, as well as the scanning and processing teams of our laboratories for their invaluable help with this experiment. We are grateful to III. Physikalisches Institut B, RWTH Aachen, Germany, Department of High Energy Physics, Helsinki University, Finland, University of Warsaw and Institute of Nuclear Problems, Warsaw, Poland for early contributions to this experiment. We thank the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) for support of this project within the program for subsistence to the former Sovjet Union (07-13-038).

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Table 1: Fits of $C_2(y_1, y_2)$ -functions for resolution $\delta y=0.5$ by formula (4)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
C_2^{--}	0.241 ± 0.007	-0.033 ± 0.021	0.804 ± 0.022	5.3/4
C_2^{++}	0.342 ± 0.008	-0.030 ± 0.021	0.921 ± 0.021	1.2/4
C_2^{+-}	0.561 ± 0.007	-0.030 ± 0.013	1.020 ± 0.015	1.2/4
C_2^{cc}	1.725 ± 0.015	-0.021 ± 0.008	0.981 ± 0.010	5.0/4

Table 2: Fits of $C_2(y_1, y_2)$ -functions for resolution $\delta y=0.5$ by formula (5)

Function	a	b	χ^2/NDF
C_2^{--}	0.266 ± 0.009	1.001 ± 0.061	28.2/2
C_2^{++}	0.370 ± 0.010	0.778 ± 0.047	28.5/2
C_2^{+-}	0.593 ± 0.010	0.650 ± 0.024	66.9/2
C_2^{cc}	1.845 ± 0.021	0.693 ± 0.017	176.2/2

Table 3: Fits of $K_2(y_1, y_2)$ -functions for resolution $\delta y=0.5$ for all particles by formula (4)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.370 ± 0.010	-0.132 ± 0.027	0.911 ± 0.032	6.4/4
K_2^{++}	0.357 ± 0.008	-0.058 ± 0.023	0.963 ± 0.028	1.3/4
K_2^{+-}	0.719 ± 0.009	-0.223 ± 0.022	1.266 ± 0.029	2.4/4
K_2^{cc}	0.545 ± 0.005	-0.099 ± 0.011	1.090 ± 0.014	5.2/4

Table 4: Fits of $K_2(y_1, y_2)$ -functions for resolution $\delta y=0.5$ for all particles by formula (5)

Function	a	b	χ^2/NDF
K_2^{--}	0.400 ± 0.014	0.905 ± 0.062	19.1/2
K_2^{++}	0.385 ± 0.012	0.744 ± 0.048	21.2/2
K_2^{+-}	0.739 ± 0.013	0.550 ± 0.024	33.3/2
K_2^{cc}	0.576 ± 0.007	0.629 ± 0.016	110.5/2

Table 5: Fits of $K_2(y_1, y_2)$ -functions for particles with $p_T < 0.3$ GeV/c by formula (4)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.516 ± 0.022	-0.117 ± 0.032	0.761 ± 0.034	2.8/4
K_2^{++}	0.410 ± 0.017	-0.022 ± 0.032	0.780 ± 0.035	1.9/4
K_2^{+-}	0.747 ± 0.016	-0.275 ± 0.040	1.316 ± 0.055	5.6/4
K_2^{cc}	0.604 ± 0.009	-0.091 ± 0.016	1.023 ± 0.020	13.1/4

Fig.6: Fits of $K_2(y_1, y_2)$ -functions for particles with $p_T < 0.3$ GeV/c by formula (4)

Function	a	b	χ^2/NDF
K_2^{--}	0.560 ± 0.030	1.182 ± 0.103	9.6/2
K_2^{++}	0.454 ± 0.023	0.997 ± 0.091	12.4/2
K_2^{+-}	0.784 ± 0.022	0.572 ± 0.042	6.1/2
K_2^{cc}	0.659 ± 0.012	0.726 ± 0.030	32.9/2

Fig.7: Fits of $K_2(y_1, y_2)$ -functions for particles with $p_T > 0.3$ GeV/c by formula (4)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.204 ± 0.018	-0.131 ± 0.066	0.724 ± 0.072	1.7/4
K_2^{++}	0.236 ± 0.013	-0.075 ± 0.050	0.873 ± 0.055	4.0/4
K_2^{+-}	0.641 ± 0.015	-0.178 ± 0.029	1.016 ± 0.034	2.0/4
K_2^{cc}	0.436 ± 0.077	-0.091 ± 0.018	0.944 ± 0.021	3.1/4

Fig.8: Fits of $K_2(y_1, y_2)$ -functions for particles with $p_T > 0.3$ GeV/c by formula (5)

Function	a	b	χ^2/NDF
K_2^{--}	0.196 ± 0.022	1.110 ± 0.230	6.7/2
K_2^{++}	0.257 ± 0.019	0.895 ± 0.125	2.7/2
K_2^{+-}	0.663 ± 0.019	0.766 ± 0.030	16.2/2
K_2^{cc}	0.461 ± 0.010	0.784 ± 0.037	35.7/2

Fig.9: Fits of $K_2(x_1, x_2)$ -functions for resolution $\delta x_2=0.5$ by formula (6)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.294 ± 0.006	$0. \pm 0.010$	0.466 ± 0.011	18.7/4
K_2^{++}	0.242 ± 0.005	$0. \pm 0.009$	0.481 ± 0.010	27.1/4
K_2^{+-}	0.611 ± 0.005	0.043 ± 0.006	0.640 ± 0.006	33.9/4
K_2^{cc}	0.438 ± 0.003	$0. \pm 0.004$	0.596 ± 0.005	58.6/4

Fig.10: Fits of $K_2(x_1, x_2)$ -functions for resolution $\delta x_2=0.1$ by formula (6)

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.296 ± 0.004	$0. \pm 0.007$	0.471 ± 0.007	73.4/26
K_2^{++}	0.237 ± 0.003	$0. \pm 0.007$	0.481 ± 0.006	93.6/26
K_2^{+-}	0.620 ± 0.003	0.034 ± 0.003	0.624 ± 0.004	47.9/26
K_2^{cc}	0.433 ± 0.002	$0. \pm 0.003$	0.580 ± 0.003	183.4/26

Fig.10a: Fits of $K_2(x_1, x_2)$ -functions for resolution $\delta x=0.1$ by formula (6) in the interval $(-0.4, 0.4)$

Function	c	$\langle y \rangle$	σ	χ^2/NDF
K_2^{--}	0.322 ± 0.005	$0. \pm 0.007$	0.359 ± 0.011	5.7/6
K_2^{++}	0.255 ± 0.004	$0. \pm 0.007$	0.376 ± 0.012	12.2/6
K_2^{+-}	0.632 ± 0.005	0.030 ± 0.003	0.591 ± 0.020	3.2/6
K_2^{cc}	0.453 ± 0.003	$0. \pm 0.004$	0.492 ± 0.009	6.5/6

Fig.11: Fits of $K_2(x_1, x_2)$ -functions for resolution $\delta x_2=0.5$ by formula (7)

Function	a	b	χ^2/NDF
K_2^{--}	0.289 ± 0.005	1.612 ± 0.059	51.3/2
K_2^{++}	0.241 ± 0.004	1.611 ± 0.054	63.9/2
K_2^{+-}	0.633 ± 0.005	1.056 ± 0.019	254.3/2
K_2^{cc}	0.454 ± 0.003	1.277 ± 0.017	390.6/2

Fig.12: Fits of $K_2(x_1, x_2)$ -functions for resolution $\delta x_2=0.1$ by formula (7)

Function	a	b	χ^2/NDF
K_2^{--}	0.363 ± 0.007	1.849 ± 0.056	45.6/13
K_2^{++}	0.293 ± 0.005	1.839 ± 0.050	56.2/13
K_2^{+-}	0.727 ± 0.007	1.189 ± 0.018	415.0/13
K_2^{cc}	0.520 ± 0.003	1.438 ± 0.015	593.3/13

FIGURE CAPTIONS

- Fig.1 Correlation functions $C_2(0, y_2)$ in π^+p interactions at 250 GeV/c for non-single-diffractive events as compared with functions (4) and (5) for rapidity resolution $\delta y = 0.5$, solid and dot-dashed lines, respectively.
- Fig.2 Normalized cumulant functions $K_2(0, y_2)$ for particles with a) all p_T , b) $p_T < 0.30$ GeV/c and c) $p_T > 0.30$ GeV/c, as compared to functions (4) and (5), solid and dot-dashed lines, respectively.
- Fig.3 Correlation functions $C_2(x_1, x_2)$ for $x_1 \in [-1.25; 1.25]$ with resolutions 0.5 (triangles) and 0.1 (full circles).
- Fig.4 Normalized cumulant functions $K_2(x_1, x_2)$ for particles with all p_T with resolutions $\delta x = 0.5$ and 0.1 (a), the same cumulant functions as compared to functions (6) and (7), solid and dot-dashed lines, respectively, with resolutions $\delta x = 0.5$ (b) and 0.1 (c).
- Fig.5 $W(\Delta\varphi, \Delta y, p_T)$ for inclusive non-single-diffractive π^+p interactions at 250 GeV/c as compared DPM (full line), FRITIOF (dot-dashed) and QGSM (dashed): a) all p_T , b) $p_T < 0.30$ GeV/c, c) $p_T > 0.30$ GeV.
- Fig.6 Asymmetry $A(\Delta y)$, as compared with calculations in DPM (full line), FRITIOF (dot-dashed) and QGSM (dashed): a) all p_T , b) $p_T < 0.30$ GeV/c, c) $p_T > 0.30$ GeV/c.

Fig.1

Fig.2a

Fig.2b

$p_T > 0.30 \text{ GeV}/c$

Fig.2c

Fig.3

Fig.4a

Fig.4b

Fig.4c

Fig.5a

Fig.5b

Fig.5c

Fig.6a

$p_T < 0.30 \text{ GeV}/c$

Fig.6b

$p_T > 0.30 \text{ GeV}/c$

Fig.6c