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THE "H.B.T. EFECT", MAIN REASON FOR INTERMITTENCY IN 3-D PHASE SPACE IN hh REACTIONS[1]

UA1-MINIMUM BIAS-Collaboration

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The contribution of like sign particle correlations to the rise of factorial moments depends on the phase space variable used. It is small in the 1-dimensional phase space given by the pseudorapidity η, where the 2-body correlation function is dominated by unlike sign particle correlations, but it is dominant in the higher dimensional phase space. The differential 2-body correlation function of like sign particles shows a steep rise for the four momentum transfer $Q^2 \to 0$, comparable with a power law.

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1. Introduction

The aim of this paper is to study the contribution of the like sign particle correlations to the phenomenum of intermittency [1]. We cannot distinguish between the quantum statistical symmetrization effect, called HBT (Hanbury-Brown-Twiss) effect, or BE (Bose-Einstein) effect, and other short range correlations of like-sign particles (e.g. from the decay of higher resonances). Nevertheless, for simplicity we will call all short range correlations of like sign particles HBT or BE effect throughout this paper.

After giving the definitions and the specification of the data sample in sections 2 and 3, we present the analysis in section 4. We used three methods: a) comparison of φ_i^{ls} with φ_i^{all}, b) the method of "pair subtraction" and c) a detailed study of the two particle correlation function. For our analysis we used two different variables: the pseudorapidity η and the four-momentum difference Q^2 between pairs. The conclusions of our results are given in section 5.

2. Definitions

We use the usual "vertical" FM of order i:

$$\langle F_i \rangle = \frac{1}{M}\sum_{m=1}^{M}\frac{\langle n_m(n_m-1)\cdots(n_m-i+1)\rangle}{\langle n_m\rangle^i} = \frac{1}{M}\sum_{m=1}^{M}\frac{\int_{\Omega_m}\prod_k d\eta_k\rho_i(\eta_1,\cdots,\eta_i)}{\int_{\Omega_m}\prod_k d\eta_k\rho_1(\eta_1)\cdots\rho_1(\eta_i)} \tag{1}$$

where ρ_i is the inclusive i-particle density function. For the computation of the integrals a binning of the original region $\Delta\eta$ into M subintervals of the size $\delta\eta$ is introduced. The number of particles in the m-th bin n_m is counted. The integration domain $\Omega_B = \sum_{m=1}^{M}\Omega_m$ thus consists of M i-dimensional boxes Ω_m of edge length $\delta\eta$. The brackets $\langle\ \rangle$ denote the averages over the event sample.

Selfsimilar density fluctuations at all scales $\delta\eta$ would lead to a power law dependence of $\langle F_i\rangle$ on $\delta\eta$:

$$\langle F_i\rangle \propto \left(\frac{1}{\delta\eta}\right)^{\varphi_i} \tag{2}$$

$$\log\langle F_i\rangle = a_i + \varphi_i\cdot\log\left(\frac{1}{\delta\eta}\right)$$

This behavior is called intermittency [2] and the parameters φ_i (slopes of the $\langle F_i\rangle$ in a log-log scale) are called intermittency exponents.

Recently a considerable improvement of the factorial moment method to study correlations has been proposed in [3] with the measurement of the correlation integrals $\langle C_i\rangle$. These quantities are closely related to the $\langle F_i\rangle$. The main difference is that the integration domain $\Omega_B = \sum_{m=1}^{M}\Omega_m$ is extended to a strip domain Ω_S which depends only on $\delta\eta$:

$$\langle C_i(\delta\eta)\rangle = \frac{\int_{\Omega_S}\prod_k d\eta_k\rho_i(\eta_1,\cdots,\eta_i)}{\int_{\Omega_S}\prod_k d\eta_k\rho_1(\eta_1)\cdots\rho_1(\eta_i)} \tag{3}$$

The counting procedure for the correlation integral requires, that all i- tuples in $[0,\Delta\eta]$ which are separated by a distance less than $\delta\eta$ are counted. In [3] a detailed discussion of the implementation of the $\langle C_i\rangle$ has been given. The method of counting i-tuples which is used in this paper is given by the "GHP" integral [4]:

$$\langle C_i(\delta\eta)\rangle = \frac{1}{Norm}\left\langle i!\sum_{j_1<\cdots<j_i}\prod_{k_1,k_2}\Theta(\delta\eta - |\eta_{j_{k_1}}-\eta_{j_{k_2}}|)\right\rangle \tag{4}$$

where Θ is the usual Heaviside step function and $Norm$ is obtained by "event mixing" [3].

We have verified, that the values of $\langle F_i\rangle$ and $\langle C_i\rangle$ are almost identical in the case of the analysis in $\delta\eta$ [5, 6] (differences are of the order of the statistical errors in our data sample of 160.000 events, see fig. 1a). One advantage of $\langle C_i\rangle$ is the better statistical accuracy. We use here another advantage: since (4) depends only on differences of phase space variables, we can replace $|\eta_{j_{k_1}}-\eta_{j_{k_2}}|$ by $-(p_{j_{k_1}}-p_{j_{k_2}})^2$, and $\delta\eta$ by Q^2, where p is the four-momentum of a particle. Thus we are able to measure the $\langle C_i\rangle$ as a function of Q^2, which is the theoretically preferred variable in jet evolution. In (4) the product extends over all possible pairs of an i-tuple. It contributes to $\langle C_i\rangle$ only if <u>all</u> pairs satisfy the condition $|\eta_{j_{k_1}}-\eta_{j_{k_2}}| < \delta\eta$. In the case of the Q^2-analysis we have modified this condition: only i-tuples with $q_{12}^2+q_{13}^2+\cdots+q_{(i-1)i}^2 < Q^2$, where $q_{ab}^2 = -(p_{j_{k_a}}-p_{j_{k_b}})^2$, contribute to $\langle C_i\rangle$ and we obtain:

$$\langle C_i(Q^2)\rangle = \frac{1}{Norm}\left\langle i!\sum_{j_1<\cdots<j_i}\Theta(Q^2 - \sum_{k_1,k_2} q_{j_{k_1},j_{k_2}}^2)\right\rangle \tag{5}$$

In analogy to the usual analysis with FM, we will search for a power law of the $\langle C_i\rangle$ as a function of Q^2:

$$\langle C_i\rangle \propto \left(\frac{1}{Q^2}\right)^{\varphi_i} \tag{6}$$

Eqn. (5) is conceptually different from eqn. (4) for $i\geq 3$. However, the search for a power law is motivated by the desire to search for selfsimilar dynamics in the production of particles, not knowing a priori in which variable it might show up. The variable Q^2 defined above has been proposed in [7] and used in the analysis of higher order Bose-Einstein correlations [8]. In choosing this variables, we are able to demonstrate the close connection between intermittency analysis and the analysis of Bose-Einstein correlations. Moreover, we want to remind the reader that there exists the simple relation between Q^2 and the invariant mass M_i of the i-tuple: $Q^2 = M_i^2-(im_\pi)^2$ in the case all particles are pions. The Bose-Einstein correlations are given in the differential form. Let's denote $N^{(i)}(Q^2)\,dQ^2$ as the number of i-tuples found in $[Q^2, Q^2+dQ^2]$ where $N^{(i)}(Q^2)$ is the i-body density function $\rho_i(k_1,k_2,\ldots,k_i)$, integrated over all phase space variables k_i except Q^2, and let's define $N_{mix}^{(i)}(Q^2)\,dQ^2$ as the expected number of i-tuples in the same interval in absence of correlations. $N_{mix}^{(i)}(Q^2)$ is the product of single particle densities $\rho_1(k_1)\ldots\rho_1(k_i)$ integrated in the same manner as $\rho_i(k_1,k_2,\ldots,k_i)$. It can be obtained by Monte Carlo integration, or simply by event mixing[2]. The proper normalization of the event mixing term is achieved by demanding the total number of mixed i-tuples in the overall phase space region (in our case: $|\eta| \leq 3, \phi \leq 2\pi, p_T > 0.15 GeV$) to be $N_{evt} \cdot \langle n \rangle^i$ where $\langle n \rangle$ is the measured mean number of particles per event in this overall region, and N_{evt} the total number of events. This can be obtained e.g. by generating a Poissonic multiplicity distribution of the mixed events with the mean value $\langle n \rangle$. The Bose Einstein correlations are usually presented in the form $f_{BE}^{(i)} = N^{(i)} / \left(const \cdot N_{mix}^{(i)} \right)$, where $const$ is choosen such that this ratio is equal to 1 in a suitably choosen Q^2 region (usually $Q^2 > 1$). The connection with $\langle C_i \rangle$ is given by eqn. (7):

$$\langle C_i(Q^2) \rangle = \frac{\int_0^{Q^2} N^{(i)} (Q_1^2)\, dQ_1^2}{\int_0^{Q^2} N_{mix}^{(i)} (Q_1^2)\, dQ_1^2} \qquad (7)$$

We will measure in the following also the properly normalized differential 2-body density correlation function

$$f(l) = \frac{N^{(2)}(l)}{N_{mix}^{(2)}(l)} \quad , \quad l = Q^2 \quad or \quad \delta\eta \qquad (8)$$

3. Data Sample

The data sample consists of approximately 160.000 non-single-diffractive events at $\sqrt{s}$= 630 GeV. All data were taken using a "minimum bias" trigger [10], requiring at least one charged particle in the pseudorapidity range of $1.5 < |\eta| < 5.6$ in each of the downstream arms of the detector. All information used for this analysis was obtained from reconstructed trajectories measured by the UA1 central detector [11]. Only vertex associated charged tracks with transverse momentum $p_T \geq 0.15$ GeV/c, $|\eta| \leq 3$, good measurement quality and fitted length $\geq$ 30cm have been used. To calculate Q^2, we assumed that all charged particles are pions.

Extended studies [12] have been done in a previous paper concerning systematic erros which may arise from track measuremnts in the UA1 central detector. When necessary, corrections have been applied to the data for acceptance loss, double countings of tracks, loss of nearby track pairs and γ-concersions in the beam pipe.

The error of the pseudorapidity measurement varies between $\bar{\sigma}_\eta = 0.007$ ($|\eta| < 1.5$) and $\bar{\sigma}_\eta = 0.034$ ($1.5 \leq |\eta| \leq 3.5$). The error of Q^2 has been estimated from the errors of track-fits and has been also determined directly at $Q^2 = 0.17$ from the width of K_s^0-decays. It is given by $\Delta Q^2 = 2Q \cdot \Delta Q + (\Delta Q)^2$ with $\Delta Q \simeq 8$ MeV, where ΔQ is approximately constant over the whole region of investigation.

[2]The event mixing technique has been recently discussed and justified in refs. [3, 9].

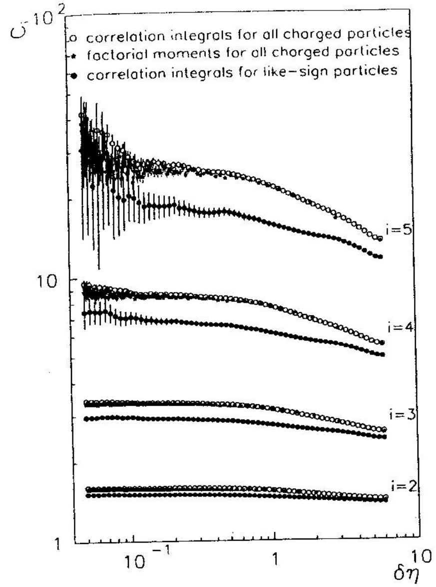

Fig. 1a

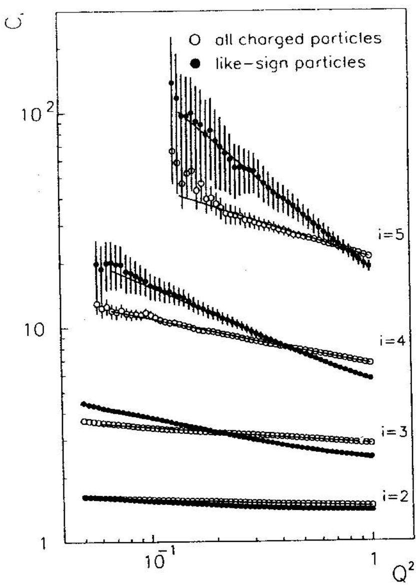

Fig. 1b

Fig. 1 The rise of the factorial moments and correlation integrals **a)** with decreasing $\delta\eta$, **b)** with decreasing Q^2. The indicated errors are statistical only. Additional systematic errors arise from uncertainties of acceptance corrections. Their magnitudes are: $\pm 1.5\% (i = 2)$, $\pm 3\% (i = 3)$, $\pm 7\% (i = 4)$, $\pm 14\% (i = 5)$. Since these numbers are independent from $\delta\eta$ or Q^2, they concern only the absolute values of the FM or C_i but not the slopes.

4. Analysis

4.1 Charge dependence of slope parameters

Fig. 1 shows the rise of $\langle F^i \rangle$ or $\langle C^i \rangle$ for two different data samples with decreasing bin size[3] in $\delta\eta$ (fig. 1a) and Q^2 (fig. 1b) in a log-log plot. The first data sample contains only like-sign particles and the second one all charged particles. The comparison in fig. 1 shows, that $\varphi_i^{all} = \frac{1}{2}\varphi_i^{ls}$ is fulfilled approximately in the Q^2 representation (table 1) whereas at the same time only small differences are visible in the $\delta\eta$ analysis[4]. This demonstrates that the influence of thé BE correlations is strongly dependent on the variable used and turns out to be more important in the higher dimensional phase space. It has been conjectured [14, 15, 16] that intermittency occurs in the higher dimensional phase space and the bending of the $\langle F_i \rangle$ or $\langle C_i \rangle$ in fig. 1a is due to the projection to the 1-dimensional pseudorapidity space. However, figs.1a,b demonstrate, that with projections we may also select different mechanisms: in fig. 1a

[3]In all figures of this paper bin sizes increase from left to right. This differs from the usual convention of drawing $\langle F_i \rangle$ or $\langle C_i \rangle$ values where the bin sizes increase from right to left.

[4]This is in agreement with an earlier UA1 analysis [13] , where in a very central ($|\eta| < 1.5$) region even no difference between φ_i^{all} and φ_i^{ls} has been found.

Table 1 The results of fitting the $\langle C_i \rangle$ ($i = 2, \ldots, 5$) as a function of Q^2 to a power law (6). In fig. 1b the fitted functions superimposed to the data are shown. The fitted slope parameters are given for two different data samples. The errors indicated are only statistical.

slope parameters	φ_2	φ_3	φ_4	φ_5
all charged particles	0.0348 ± 0.0006	0.078 ± 0.001	0.213 ± 0.004	0.338 ± 0.019
like-sign particles	0.0522 ± 0.0009	0.147 ± 0.001	0.443 ± 0.010	0.855 ± 0.051

the like sign particle correlations are significantly smaller than the correlations of all charged particles, but they dominate (for small Q^2) in fig. 1b. It should be stressed that in fig. 1b a good linearity shows up in agreement with eqn. (6) and the conjecture of intermittency. Slight deviations from this law (a bending upwards of $\langle C_2 \rangle$ and $\langle C_3 \rangle$ for the like-sign sample) vanish, if all charged particles are considered (open circles). This indicates, that the linearity is due to an interplay of all correlations, irrespectively of the distinct dynamical origin.

In this context, we want to refer also to another measurement of the correlations in the 3-d ($\eta - \phi - \log p_\perp$) phase space. There the integrated kumulant k_2 shows a power law over four magnitudes of phase-space volume elements [17].

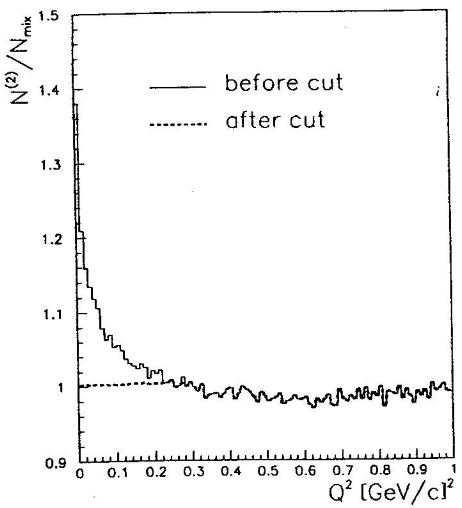

Fig. 2 The Bose-Einstein ratio before and after the subtraction of pairs with small Q^2.

4.2 The method of "pair subtraction"

With this method we attempt to measure the rise of the $\langle C_i \rangle$ in absence of the Bose-Einstein effect. To this end, like-sign pairs with small Q^2 were cut away until a

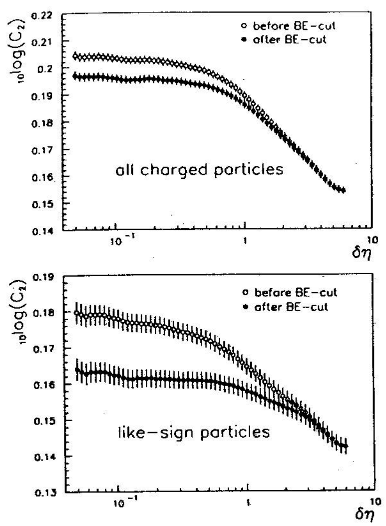

Fig. 3a

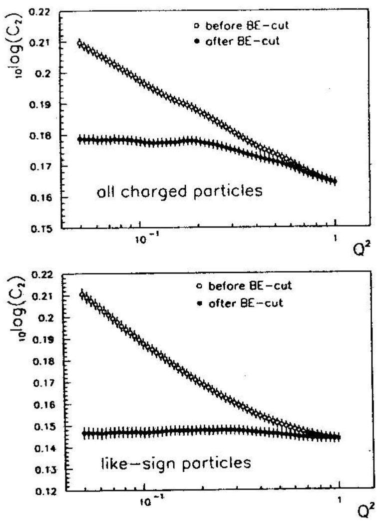

Fig. 3b

Fig. 3 The effect of the pair-subtraction (BE-cut) on the second order correlation integrals.

data sample is (artificially) achieved which exhibits no Bose-Einstein effect as shown in fig. 2.

The behavior of the $\langle C_2 \rangle$ before (open circles) and after (full circles) the subtraction of the BE pairs is shown in figs. 3a-b. In the case of the analysis in Q^2 (fig. 3b) and the sample of like-sign pairs no residual rise is left after the subtraction as expected, since $\langle C_2 \rangle$ is (apart from a normalization constant) the integral over the BE ratio shown in fig. 2 (see eqn. (7)). There is some residual rise in the sample of all particles in fig. 3b but it vanishes for $Q^2 \leq 0.2$ which indicates that in the region of small Q^2 only the BE correlations contribute to the overall 2-body correlation function.

The situation is different in the case of the analysis in $\delta\eta$ (fig. 3a): there is after the subtraction of BE pairs still some rise also in the case of the like-sign particles for $\delta\eta \gtrsim 1$ indicating the presence of some correlations which do not originate from the very short range BE correlations in Q^2. Only a small rise is left for $\delta\eta \lesssim 1$. We conclude therefore, that the rise in that region in the like-sign sample is mainly due to BE correlations.

In the case of all particles (fig. 3a) the subtraction of BE pairs has only a small influence and we conclude that the rise is mainly due to strong correlations of unlike-sign pairs.

The region in $\delta\eta$ which can be populated by BE pairs is given by the following relation [5]:

$$Q^2 = -\left(m_{T_1}^2 + m_{T_2}^2 - 2m_{T_1}m_{T_2}\cosh(\delta y)\right) + \left(p_{T_1}^2 + p_{T_2}^2 - 2p_{T_1}p_{T_2}\cos(\delta\phi)\right) \quad (9)$$

with $\delta\eta \approx \delta y$ and $m_T^2 = m^2 + p_T^2$.

Eqn. (9) shows that pairs with the same Q^2 can contribute at different $\delta\eta$ values, dependent on the transverse momenta p_T and the difference of azimuthal angles $\delta\phi$.

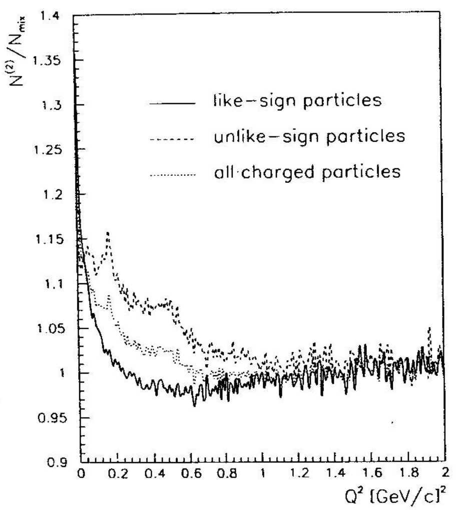

Fig. 4 Bose-Einstein ratios f_{BE} for different samples, as indicated.

4.3 A detailed study of the two-particle correlation functions

If one assumes that intermittency is indeed present and - as fig. 1b suggests - is dominated (in Q^2) by the BE correlations, one would expect that the shape of the BE ratio itself should be represented by a power law rather than by an exponential (or Gaussian). Therefore we present a measurement of differential 2-body density correlation functions $f(l)$, ($l = \delta\eta$ or Q^2) for like-sign pairs and unlike-sign pairs seperately and search for a singularity[5] for $l \rightarrow 0$, as an indication for intermittency. Fig. 4 shows the ratio $f_{BE}^{(2)} = (1/const) \cdot f(Q^2)$. This is the usual form in which BE correlations are presented. Fig. 4 shows a comparison of the samples of like-sign pairs with unlike sign pairs and all charged particles. Each sample is normalized to 1 separately for $Q^2 > 1$ by choosing "*const*". One observes a strong dominance of unlike-sign pair correlations for $0.03 \leq Q^2 \leq 1$ which is at least partly due to resonance and particle decays (e.g. there is a broad peak at $Q^2 \approx 0.5$ GeV/c^2 which is due to ρ decays ($m_\rho = \sqrt{Q^2 + 4m_\pi^2}$) and a peak at $Q^2 \approx 0.17$ GeV/c^2 which is due to remaining K_S^0 decays, where the decay point could not be resolved from the vertex). However, at very small $Q^2 (\leq 0.03$ GeV/c$^2)$ this function is nearly constant. Contrarily, the like-sign particle correlation function rises above one only for small $Q^2 (\lesssim 0.24$ GeV/c$^2)$. For very small $Q^2 (\lesssim 0.03$ GeV/c$^2)$ there is a cross-over and the function is rising very rapidly for $Q^2 \rightarrow 0$. Fig. 4 suggests that a possible singularity in the correlation function would be due to the like-sign particle contributions only. To resolve the small Q^2 region we choose again the log-log scale in fig. 5. Fig. 5b shows $f(Q^2)$, the same functions as fig. 4, the only difference – besides the different binning – is the proper normalization to the uncorrelated sample as described in section 2. Fig. 5b confirms the observations in fig. 4. The unlike sign correlation function stays approximately constant for $Q^2 \lesssim 0.17$. The rise near $Q^2 = 0.001$ can be attributed partly to the onset of γ-conversions (which contribute mainly to the region $Q^2 < 0.001$) but may be also at least partly due to the Coulomb attraction of the unlike sign pairs (+ 10% increase at $Q^2 = 0.001$ expected). The like sign correlation function continues to rise at least until $Q^2 = 0.001$ GeV^2. Once more we show the same analysis in $\delta\eta$ (fig. 5a). A comparison between figs. 5a and 5b confirms the results of the previous investigations: the 2-body correlation function of all charged particles is dominated by unlike-sign particle correlations when analysed in $\delta\eta$ but dominated by the like-sign correlation function when analysed at small Q^2.

5 - not in the mathematical sense: either due to the limited detector resolution or because of physical reasons there will be a cut-off at finite l.

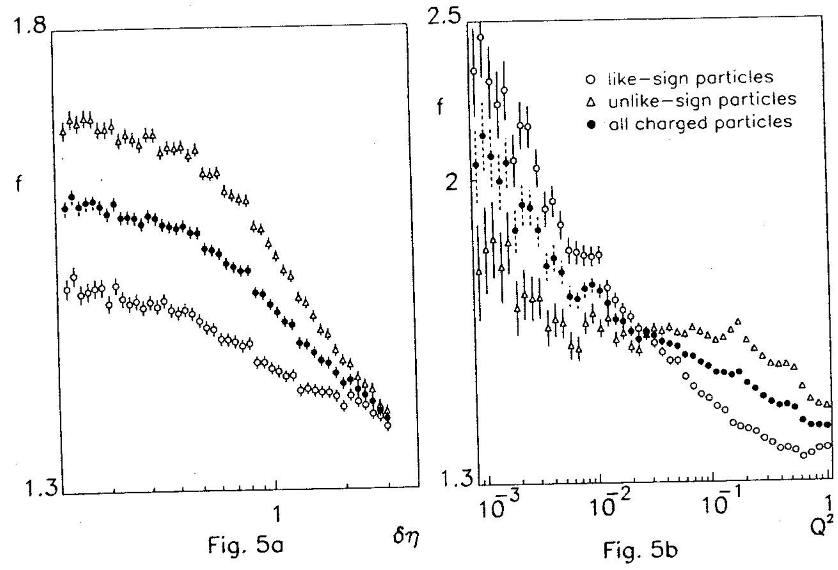

Fig. 5 The normalized two-body density correlation function f, eqn. (8) a) as a function of $\delta\eta$, b) as a function of Q^2.

The good resolution of the functions presented in fig. 5b permits to study the functional form of $f(Q^2)$ of the like-sign sample, and especially to search for a power law dependence. In fig. 6 we show a comparison with the following functions[6]:

$$f(Q^2) = a + b \cdot (Q^2)^{-\varphi} \quad (10)$$

6 The functional form of (10) has been proposed in [18] for a 3-dimensional analysis, a possible contribution from long range correlations can be absorbed in the parameter a.

Table 2: Parameters of the fits, shown in fig. 6. The errors include statistical and systematic uncertainties. The values in the brackets are obtained with sample 2, see text. Q^2 is in units $[(GeV/c)^2]$, r in [fm]. The data are not corrected for Coulomb repulsion.

fit to Eq.10	fit to Eq.11	fit to Eq.12
$a = 1.25 \pm 0.02$ (1.27)	$a' = 1.357 \pm 0.003$ (1.359)	$a'' = 1.355 \pm 0.003$ (1.357)
$b = 0.08 \pm 0.02$ (0.07)	$b' = 0.84 \pm 0.10$ (0.96)	$\lambda = 0.43 \pm 0.13$ (0.56)
$\varphi = 0.39 \pm 0.06$ (0.43)	$r = 1.39 \pm 0.11$ (1.50)	$r = 1.26 \pm 0.06$ (1.31)
$\chi^2/NF = 2.14$ (2.05)	$\chi^2/NF = 2.61$ (3.65)	$\chi^2/NF = 2.23$ (2.90)

$$f(Q^2) = a' + b' \exp(-rQ) \quad (11)$$
$$f(Q^2) = a''(1 + 2\lambda(1-\lambda)\exp(-rQ) + \lambda^2 \exp(-2rQ)) \quad (12)$$

Each of them has 3 free parameters: a, b, φ (eqn. (10)), a' , b', r (eqn. (12)) and a'', λ, r (eqn. (12)). The best agreement with the data (at small Q^2) is obtained by the power law of eqn. (10). Subsamples, with positive pairs or negative pairs only, agree within their statistical errors, each showing the excess of pairs at small Q^2 over an exponential ansatz separately. We have also studied the systematic uncertainties which arise from the inclusion of residual fake pairs on one side, and from the loss of real pairs on the other side by varying the selection criteria for accepted pairs. The result of this study gives a systematic uncertainty of +9.0%, +3.2% and -8.0%, -2.2% at $Q^2 = 0.001, 0.005\ (GeV/c)^2$, respectively. It should be stressed that with each selection and in particular with a sample (called sample 2) where all fake pairs have been removed by rigorous cuts, and which has been corrected for the severe loss of real pairs by Monte Carlo afterwards, we come to the same conclusion as above: the best agreement is obtained by a power law.

Table 2 contains the fit parameters of eqns. (10), (11) and (12) for the data as defined in section 3 and shown in fig. 6, and for sample 2 (in brackets).

In conclusion, the data of fig. 6 indicate, that one scale might be not enough to describe them satisfactorily, but they are in agreement with the conjecture of scale invariance.

5.Summary and Conclusions

- We studied the contribution of the (very short range) like sign particle correlations which we call the HBT or BE effect to the rise of factorial moments (or correlation integrals) with decreasing phase space bins.
- We used two variables for this study:

  (i) the 1-dimensional variable $\delta\eta$,

  (ii) the squared 4-momentum difference Q^2 between two particles.

  A study with a similar formalism in both variables was possible with the help of the correlation integrals [3], quantities which are closely related to the factorial moments, but which depend only on differences of phase space variables.

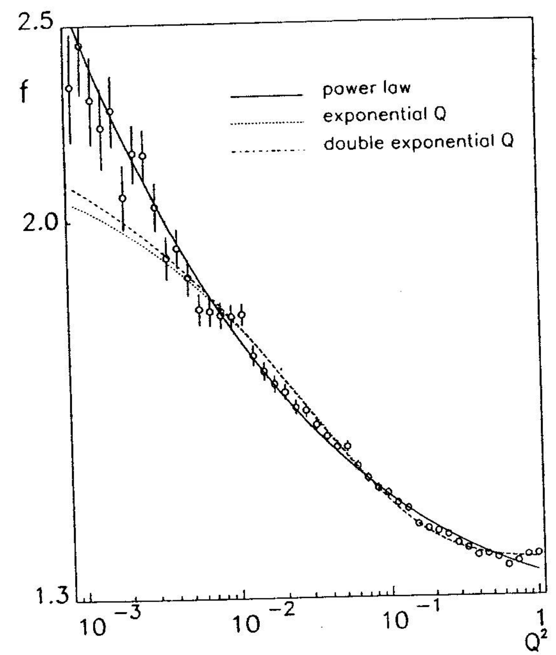

Fig. 6 The two-body density correlation function for like-sign particles fitted to (10), (11), (12), see text. The indicated errors are statistical only.

- Three methods have been applied:

  a comparison of slope parameters φ_i^{all} and φ_i^{ls} of the rise of the $\langle C_i \rangle$,

  the method of "pair subtraction",

  a search for a singularity in the two-particle density correlation function for like-sign pairs and unlike-sign pairs separately.

Our conclusions:

- The contribution of the HBT effect depends on the variable used. Whereas it is weak in the case of $\delta\eta$, it is the dominant contribution to the rise of $\langle C_i \rangle$ with decreasing Q^2 ($Q^2 \to 0$).
- Different dynamical mechanisms are dominant in the $\delta\eta$ and Q^2 analysis, this is confirmed directly by method 3: when analysed in $\delta\eta$, the two particle correlation function is dominated by the contribution of unlike-sign pairs whereas when analysed in Q^2 the dominance of the like-sign pairs shows up very clearly for small Q^2 ($< 0.03\ GeV/c^2$).

- The correlation integrals in fig. 1b show an almost perfect power law dependence of $\langle C_i \rangle$ on Q^2 over the whole region of analysis. It is due to the interplay of different mechanisms, however, for small Q^2 the $\langle C_i \rangle$s are dominated by the like sign particle correlations[7] for all orders $i = 2 - 5$.
- Restricting to the differential two-particle density correlation function, we observe a steep rise compatible with a power law down to $Q^2 = 0.001\ (\mathrm{GeV/c})^2$ for like sign pairs. Recently an attempt has been made to understand intermittency [21] in terms of this behaviour. Let's assume that all like sign particle correlations at small Q^2 are due to the H.B.T. effect. Then arguments have been given in [21], that a power law in the correlation function would imply strong fluctuations of the size of the interaction region. One possibility could be, that the interaction region is itself a fractal extending over a large volume.

It would be desirable to clarify in a future study the question if the interference effects from the decay products of known resonances [22, 23] are strong enough to explain the behaviour observed in fig. 6.

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