BOSE-EINSTEIN CORRELATIONS IN $\bar{p}p$ ANNIHILATIONS AT REST

The CPLEAR Collaboration

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Abstract

Two-charged-pion correlations were studied in $\bar{p}p$ ($\rightarrow 2\pi^+2\pi^-n\pi^0, n \geq 0$) annihilations at rest with the CPLEAR detector at the Low-Energy Antiproton Ring (LEAR). A strong enhancement was found in the production of pairs of like-sign pions with a small value of the relative four-momentum Q , with respect to pairs of unlike-sign pions. The observed enhancement was interpreted as a consequence of the Bose-Einstein symmetrization of the two-pion wave function. The data are well represented by a correlation function parametrized as a double-Gaussian; an exponential parametrization is also statistically acceptable. The value of the correlation strength is found to be > 1 . The high-quality large data samples together with the ability for $K^\pm$ identification and final-state separation allowed the study of systematic effects impacting on the Q dependence of the correlation function and on the extracted space parameters of the pion sources.

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1 Introduction

The first indication of Bose-Einstein (BE) correlations in particle physics came from the observation of a strong positive correlation between like-sign pions produced close in phase space in low-energy $\bar{p}p$ annihilations and its interpretation in terms of symmetrization of the wave function (the GGLP effect [1]). Since then, this type of correlation has been well established in a variety of high-energy processes, and allows, in principle, the determination of the space parameters describing the region from which bosons are emitted [2]. However, the range and the strength of the effect are less well established. Results from $\bar{p}p$ experiments are given in [3-15]. The phenomenon of BE correlations is seen as an enhanced probability for identical bosons to be emitted with small relative momenta, in comparison with non identical ones. The phenomenon is usually described in terms of a correlation function. The two-particle correlation function C_2 is related to the Fourier transform, $\tilde{\rho}$, of the particle source distribution in space ρ :

$$C_2(p_1, p_2) = \frac{P(p_1, p_2)}{P_0(p_1, p_2)} = 1 + \lambda |\tilde{\rho}(p_1, p_2)|^2 \quad (1)$$

where p_1, p_2 are the four-momenta of the two identical bosons, $P(p_1, p_2)$ is the measured two-boson probability density, and $P_0(p_1, p_2)$ is the expected distribution in the absence of BE symmetrization. The parameter λ , referred to as the "incoherence" or "chaoticity" parameter, was first introduced by Deutschmann et al. [5]. Empirically, λ measures the strength of the correlation. Most experiments found $\lambda < 1$ which may signal coherent components in the particle source, although much simpler explanations (poor detector resolution, particle misidentification, normalization procedure, resonance production and decay, final state interactions, and lack of knowledge about the shape of the source distribution) have been proposed [2]. Two experiments on $\bar{p}p$ annihilation at rest [5,10] however, reported a value of the parameter $\lambda > 1$.

The CPLEAR experiment has been designed to study at LEAR the breaking of discrete symmetries (CP/T/CPT) within the neutral kaon system [16]. Essential for the experiment are the fast and efficient separation of pions and kaons, as well as the good momentum and vertex resolution and high-statistics data samples. These features are also essential for BE correlation studies.

Here we shall report in some detail on the two-charged-pion correlation function (hereafter called two-pion correlation function) in $\bar{p}p$ annihilation at rest as measured with the CPLEAR detector. In Section 2 we give the characteristics of the CPLEAR detector relevant for this analysis, the event selection criteria with particular emphasis on possible systematic effects, and the normalization procedure. In Section 3 we present the data and in Section 4 we discuss specific final states and the effect of the resonances. In Section 5 we discuss the systematic effects due to particle misidentification. We have given a preliminary report of this analysis in [17].

2 Event selection and normalization

The CPLEAR detector is cylindrically symmetric and built inside a solenoidal magnet of 3.6 m length and 2 m diameter, with a field of 0.44 T. Antiprotons of 200 MeV/c momentum, provided by LEAR and monitored by a scintillator, stop and annihilate at the centre of the detector, in a spherical target of 7 cm radius, filled with gaseous hydrogen

at 16 bar. Tracking is provided by two layers of proportional chambers, six layers of drift chambers, and two layers of streamer tubes. Outside the tracking devices there are 32 sectors of Scintillator (S_1) - Cherenkov (C) - Scintillator (S_2) sandwiches providing particle identification and a fast trigger. The efficiency for detecting a charged kaon at the first trigger level is 75%, while a pion rejection efficiency of 99.7% is found in the relevant momentum region [18]. The outermost detector is an 18-layer gas-sampling electromagnetic calorimeter.

The data analysed here are part of the data collected in 1991 and 1992, and correspond to two different trigger conditions. One sample of ≈ 3.4 M events taken with a minimum bias trigger (requiring at least one hit in the scintillator S_1 in coincidence with the incoming antiproton) was used for the study of the BE correlations. A second data sample of ≈ 0.5 M events for which a kaon was required in the trigger, served for the investigation of the influence of $K^\pm \pi^\mp K_S$ and $K^+ K^- \pi^+ \pi^-$ channels on the two-pion correlation function in case of particle misidentification.

From the total of 3.4M minimum bias events, well balanced between opposite magnetic field polarity settings, 409k four-prong events, called hereafter "pion sample", were selected according to the criteria :

- (i) four tracks balanced in charge,
- (ii) no kaon at the first trigger level (no $S_1 \bar{C} S_2$ for a momentum > 0.30 GeV/c),
- (iii) good quality of event reconstruction and no secondary vertex,
- (iv) opening angle larger than 100 mrad between any two charged tracks to avoid pion pairs with insufficient two-track resolution and lepton pairs from gamma conversion.

The cut (iii) deserves some comments. A vertex resolution better than 0.3 cm is achieved for a single vertex reconstruction. For each event and for both possible combinations, two vertices were determined from tracks with opposite sign. The event was then rejected when the distance between the vertices was larger than 1 cm. This cut combined with (ii) rejects most of the pion pairs from K_S decay. The contamination of charged and/or neutral kaons in the remaining pion sample is estimated to be less than 0.6%.

In order to extract the two-pion correlation function (1) from the data, the distribution $P_{like}(p_1, p_2)$ of the like-sign pion pairs ($\pi^\pm \pi^\pm$) has to be compared with a reference distribution free of any correlation but otherwise subject to the same experimental selection criteria and arising from the same production mechanism. For $\bar{p}p$ annihilations at rest, where phase space is limited and no particle emission direction is preferred, an appropriate choice is the corresponding distribution $P_{unlike}(p_1, p_2)$ of the unlike-sign pion pairs $\pi^+ \pi^-$ in the same events [10,14]. Hence we take for the two-pion correlation function: $C_2 = P_{like}(p_1, p_2)/P_{unlike}(p_1, p_2)$. In this way, correlations due to phase space are taken into account, but additional correlations from resonances and final state interactions may be introduced. The latter, Coulomb and strong, are unlikely to have any significant impact on the two-pion correlation function [19].

3 Inclusive data analysis

The data were analysed as a function of the pion relative four-momentum Q , where $Q^2 \equiv -(p_1 - p_2)^2$. All tracks were treated as pions and the like-sign and the unlike-sign

Q distributions were normalized to the same total number of combinations, so that in the absence of any correlation (BE, kinematical or dynamical), the correlation function should be flat, $C_2(Q) = 1$ (which for the convenience of the reader is presented in all figures by a dotted line).

In Fig. 1 we present (solid circles) the two-pion correlation function $C_2(Q)$. In this figure, $\pi^+\pi^+$ and $\pi^-\pi^-$ pairs are combined since they show the same Q distributions within errors. The bin width (0.02 GeV/c) is chosen according to the Q resolution of the detector. A clear enhancement can be seen in the low- Q region and is attributed to BE correlations. The dip around $Q = 0.72$ GeV/c is caused by $\pi^+\pi^-$ pairs resulting from the decay of $\rho^0 \rightarrow \pi^+\pi^-$. No dip is seen from $K_S \rightarrow \pi^+\pi^-$ decay, expected to be around $Q = 0.41$ GeV/c, confirming that the pion sample is almost free from $K^\pm\pi^\mp$ K_S contamination. For comparison we show (open circles) the correlation function $C_2(Q)$ obtained from 200k four-prong annihilation events generated by Monte Carlo (MC), undergoing full detector simulation and analysed with the same chain of reconstruction and fitting programs as real data. The BE effect as well as Coulomb and strong final-state interactions are not simulated.

No significant signal at low Q is seen for the simulated events. A slight discrepancy appears between the real data and the simulated events at $Q > 0.5$ GeV/c. A careful analysis of this region reveals that the corresponding $P_{unlike}(Q)$ distribution of non-resonant pion pairs is steeper for real data than for MC events. No attempt was made to correct the pion data by MC results since it is not evident that the BE effect factorizes with other correlations and also that the resonances are correctly described in the simulation.

The data for $Q \leq 0.5$ GeV/c were first fitted by a single-Gaussian parametrization [1]:

$$C_2(Q) = N[1 + \lambda \exp(-r^2 Q^2)] \quad (2)$$

where the parameter r is the radius of the source, λ measures the strength of the correlation and N is an overall normalization factor. The results of the fit are: $\lambda = 1.96 \pm 0.03$, $r = (1.04 \pm 0.01)$ fm and $N = 0.90 \pm 0.03$, where the quoted errors are only statistical. This value of $\lambda > 1$ confirms previous experiments dealing with $\bar{p}p$ annihilation at rest [5,10]. The statistical correlation coefficient between λ and r is: $c(\lambda, r) = 0.75$ suggesting that the radius cannot be interpreted independently from λ [20].

However, the quality of the fit is very poor; the single-Gaussian parametrization (dashed line in Fig.1) is inadequate to describe the data, especially at low values of Q . The strengthening of $C_2(Q)$ at $Q < 0.1$ GeV/c, reported also in [13,21], suggests the use of a parametrization with two sources:

$$C_2(Q) = N[1 + \lambda_1 \exp(-r_1^2 Q^2) + \lambda_2 \exp(-r_2^2 Q^2)]. \quad (3)$$

The result of the double-Gaussian fit describes the data very well also at low Q and is shown in Fig. 1 as a solid line. The fitted parameters are given in the first row of Table 1. A positive statistical correlation remains between λ_1 and r_1 , $c(\lambda_1, r_1) = 0.89$. Other relevant statistical correlation coefficients are: $c(\lambda_1, \lambda_2) = -0.51$, $c(r_1, r_2) = 0.49$ and $c(\lambda_2, r_2) = 0.14$.

An alternative parametrization of the data is:

$$C_2(Q) = N[1 + \lambda_e \exp(-r_e Q)] \quad (4)$$

the result of which is quoted in the first row of Table 2, and shown in Fig. 1 as a dot-dashed line. The exponential parametrization (4) describes the data equally well as (3).

The present statistics do not allow discrimination between them, as the available phase space changes with Q^2 and the number of pion pairs decreases rapidly with Q .

In order to estimate the systematic errors, the data were analysed separately for $\pi^+\pi^+$ and $\pi^-\pi^-$ combinations, for normal and reverse magnetic field settings, for different running periods, different bin widths and different fit intervals. The variations of the parameters from the various fits with respect to the final fit were added in quadrature to define the overall systematic errors. Note that the values of the parameters are not affected by the upper limit of the Q -range used to perform the fit, provided the upper limit for Q is kept between 0.35 and 0.55 GeV/c. The errors given in Tables 1 and 2 represent the combined statistical and systematic errors.

The quality of the data is crucial in this kind of studies. For example, if we relax the cut (iii) mentioned in Section 2 and accept distances between vertices up to 3 cm, the correlation function shown in Fig. 2 (open circles) appears strongly reduced at small Q . This suppression follows from the inclusion of events with no genuine single vertex (vertex distance between 1 and 3 cm, 20% of the total). Fitting only these events (solid circles in Fig. 2) to a single-Gaussian parametrization we find: $\lambda = 1.35 \pm 0.09$ and $r = (0.70 \pm 0.05)$ fm (solid line). However, reducing the vertex distance to less than 1 cm does not seem to alter the correlation function any further.

For completeness, the pion sample was also analysed through the Kopylov-Podgoretskii [22] variables q_T and q_0 , where $q_0 = |E_1 - E_2|$ is the modulus of the energy difference while q_T denotes the component of the three-momentum vector $\vec{q} = \vec{p}_1 - \vec{p}_2$ transverse to $\vec{p}_1 + \vec{p}_2$. The correlation function $C_2(q_T, q_0)$ was fitted according to the double-Gaussian parametrization as a function of q_T for various q_0 ranges. It was found that the parameter λ_1 depends on the selected q_0 range (for lower values of q_0 , larger values of λ_1 are found). For $0 < q_0 \leq 0.1$ GeV, the result of the fit is: $\lambda_1 = 1.36 \pm 0.05$, $r_1 = (1.01 \pm 0.02)$ fm, $\lambda_2 = (2.09 \pm 0.18)$, $r_2 = (2.95 \pm 0.17)$ fm and $N = 0.84 \pm 0.02$, in fair agreement with the result listed in Table 1.

4 Separation of final states

Resonances are believed to considerably affect the observed two-pion correlations [14,23,24]. A sizeable fraction of the pion pairs contains at least one resonance decay pion. Interference between direct pions and pions from resonance decays should lead to a sharp rise of the correlation function as $Q \rightarrow 0$ with a width determined by the resonance decay length. Pions from η and ω decays are expected to show interference for $Q < 0.01$ GeV/c which is a Q region excluded by the present experiment (because of the finite momentum resolution, few of these pairs may show up in the observable range). For a short-lived resonance, such as the ρ ($c\tau = 1.3$ fm), the interference extends up to values of $Q \sim 0.15$ GeV/c and can easily be observed in the data. In order to investigate the influence of the resonance decays and/or the π^0 multiplicity on the two-pion correlation function a total of 291k four-prong events were fitted subsequently to the $2\pi^+2\pi^-$ (four constraints) and the $2\pi^+2\pi^-\pi^0$ (one constraint) hypothesis. The fit probabilities were used to split this data sample into three event classes :

- $2\pi^+2\pi^-$ (36k events),
- $2\pi^+2\pi^-\pi^0$ (136k events),

- the remaining ones (119k events), mainly $2\pi^+2\pi^-n\pi^0$, $n \geq 2$, since the contamination of six-prong events was estimated by MC simulation to be less than 0.7%.

The $2\pi^+2\pi^-$ sample, which is free from η and ω decays, allows the study of the effects from ρ decay. The correlation function $C_2(Q)$ of these events is shown in Fig. 3. We observe a dip around 0.72 GeV/c characteristic of the $\rho^0 \rightarrow \pi^+\pi^-$ decay and a strong signal for $Q < 0.15$ GeV/c. This is the region where the interference between pions from $\rho^0 \rightarrow \pi^+\pi^-$ decay and direct pions is expected. The double-Gaussian parametrization (3) shown as a solid line in Fig. 3 describes the data very well ($\chi^2/NDF = 14/18$), while the single-Gaussian parametrization (2), shown as a dashed line in Fig. 3, fails in the momentum region $Q < 0.15$ GeV/c. The results of the double-Gaussian fit are given in the second row of Table 1. The two Gaussians corresponding to the two sources are drawn separately in Fig. 3. The source with the larger radius r_2 (narrower distribution) may be associated with the $\rho^0 \rightarrow \pi^+\pi^-$ resonance. The source with the smaller radius r_1 (wider distribution) is in good agreement with that of the single-Gaussian parametrization, suggesting that the production region of "direct" particles is mainly determined by the slope of $C_2(Q)$ for $Q > 0.1$ GeV/c [24]. For completeness, the results of the fit to the exponential parametrization (4) are given in the second row of Table 2.

The $2\pi^+2\pi^-\pi^0$ sample contains effects from both ω and ρ decay. The correlation function $C_2(Q)$ for this sample, shown in Fig. 4, exhibits lower values around 0.4 GeV/c than the $2\pi^+2\pi^-$ data of Fig. 3. This suppression can be explained [14] by the contribution of the $\rho\omega$ and $\omega\pi^+\pi^-$ channels (the $\pi^+\pi^-$ pair takes on the average two thirds of the ω energy). Figure 4 shows the results of parametrizations (2) and (3). The results of parametrizations (3) and (4) are given in the third row of Tables 1 and 2 respectively.

Figure 5 shows $C_2(Q)$ for the third class of events. The suppression around 0.4 GeV/c is even more pronounced than in the cases of Figs. 3 and 4. It should be noticed that these events are dominated by $\pi^0\pi^0$ pairs for which BE correlations are expected to be even stronger than the corresponding ones for $\pi^\pm\pi^\pm$ pairs [25]. Hence the data of Fig. 5 may be influenced by such $\pi^0\pi^0$ correlations and/or limitations of phase space. The result of the fit to the double-Gaussian parametrization (3) is displayed in Fig. 5 as a dashed line and listed in the fourth row of Table 1. In order to take the slow variation of $C_2(Q)$ at large Q into account, the double-Gaussian function of Eq. (3) was multiplied with the additional term $(1 + \delta Q)$. The data in the range $0 < Q < 1$ GeV/c were fitted with this parametrization. The results of this fit, presented as a solid line in Fig. 5 are: $\lambda_1 = 2.29 \pm 0.15$, $r_1 = (0.88 \pm 0.02)$ fm, $\lambda_2 = 2.84 \pm 0.45$, $r_2 = (2.10 \pm 0.17)$ fm, $N = 0.51 \pm 0.03$ and $\delta = (1.28 \pm 0.18)$ (GeV/c) $^{-1}$. Note that with this fit the radii r_1 and r_2 are preserved but the strengths λ_1 and λ_2 are enhanced (see Table 1).

5 Kaonic channels

Particle misidentification is believed to affect the observed two-pion correlations [2]. The results presented in Sections 3 and 4 are based on pion samples almost free from charged and/or neutral kaon contaminations. Since we have the possibility of $K^\pm$ identification, which was not the case in many previous experiments, we investigated the effect of K^+K^- and $K^\pm K_S$ pairs on the two-pion correlations (no like-sign kaon pairs are produced in $\bar{p}p$ annihilation at rest because of phase space limitations). For this purpose, the sample of ≈ 0.5 M four-prong events obtained with the kaon trigger was analysed. Except for criterium

(ii) all data were passed through the same chain of cuts as in the case of pions (Section 2) and charged kaons were treated as pions.

Kaon contamination affects the pion correlation function mainly in two ways:

1. charged kaons misidentified as pions do not qualify for BE correlations, and the mass-mismatch leads to a wrong calculation of Q ;
2. pions from K_S decay are not coherent with the pions from annihilation.

Both the presence of incoherent pions and non identical particle pairs ($K\pi$) tend to dilute the BE effect. In the following we briefly discuss two cases of kaon contamination and their impact on the two-pion correlation functions. With our limited phase space and the low multiplicity of emitted particles, the situation is obviously much different than in many high energy experiments.

Particle misidentification:

To isolate the case where the K^+K^- pair is misidentified as a $\pi^+\pi^-$ pair, the final state $K^+K^-\pi^+\pi^-$ was selected (43k events), and the correlation function $C_2(Q)$ was studied treating all particles as pions. These data (solid circles in Fig. 6) give rise to only a small enhancement at small Q . The dip around 0.6 GeV/c is due to $K^* \rightarrow K^\pm\pi^\mp$ where the charged kaon is treated as a pion.

Events with the final state $K^+K^-\pi^+\pi^-$ were generated in a MC simulation and analysed in the same way as real data. The $C_2(Q)$ distribution for the MC events (not shown in Fig. 6) is in good agreement with the data, suggesting that the Coulomb and strong final state interactions as well as the quantum statistical correlations between a particle and an antiparticle predicted in [25], may have only a negligible net effect.

Events from the $K^+K^-\pi^+\pi^-$ sample were also added incoherently and in various amounts to the pion sample, separately for the $P_{like}(Q)$ and the $P_{unlike}(Q)$ distributions. As an example, the correlation function $C_2(Q)$ is displayed in Fig. 6 (open circles) for a sample artificially contaminated with 20% of $K^+K^-\pi^+\pi^-$ events. The comparison with the fit of the data without kaon contamination (solid line) shows that a contamination as high as 20% reduces $C_2(Q)$ at $Q < 0.3$ GeV/c by only a minor amount. This is so because the $C_2(Q)$ distribution of the contaminating sample exhibits also a small enhancement at low Q .

K_S decay:

The two-pion correlation function is also affected by pion pairs from K_S decays, provided that the corresponding secondary vertex is indistinguishable from the primary vertex. We selected a sample of 113k $K^\pm\pi^\mp K_S(\rightarrow \pi^+\pi^-)$ events and treated the charged kaon as a pion. From these data we computed the correlation function $C_2(Q)$ shown in Fig. 7 (solid circles). The dip around 0.41 GeV/c, which turns out to be a pronounced signature for neutral kaon contamination, and $C_2(Q) > 1$ outside the dip are both related to the K_S decay. Corresponding MC calculations (not shown in Fig. 7) are in agreement with the data. The large enhancement observed at low Q which cannot originate from BE correlations is related to the event selection as well as to the analysis criteria. Because of this enhancement, we do again not expect a significant influence from K_S decay events contaminating our pion sample, similar to our above findings for particle misidentification. The open circles in Fig. 7 display the correlation function $C_2(Q)$ of the pion sample after admixture of as much as 20% of $K^\pm\pi^\mp K_S$ events. The characteristic dip at 0.41 GeV/c persists at a reduced level (note: this dip is totally absent in the pion sample distribution of

Fig. 1). Fitting the distribution of the mixed data sample for $Q < 0.34$ GeV/c reproduces within errors the values of the parameters quoted in Table 1 for the pion sample. Clearly, this result applies strictly only to our event selection and analysis criteria and is not of general validity.

6 Conclusions

We have studied the two-charged-pion correlations in $\bar{p}p \rightarrow 2\pi^+2\pi^-n\pi^0, n \geq 0$ annihilations at rest. We observed an enhancement at low values of the relative four-momentum Q which we analysed with various parametrizations and interpreted in terms of BE correlations. Values > 1 for the correlation strength were extracted, as in previous experiments dealing with $\bar{p}p$ annihilation at rest. The pion sample was found to be consistent with two pion sources of different radius; one of ~ 1 fm is associated with direct pions, and another of ~ 2 fm with pions from resonance decays interfering with direct pions. The exponential parametrization is statistically equivalent to a parametrization using two Gaussians.

High statistics, good momentum and vertex resolution, as well as the possibility of $K^\pm$ identification and final state separation allowed the study of systematic effects that may affect the two-pion correlation function. It is found that short-lived resonances enhance the correlation function at low Q , whereas events with two vertices suppress it. The influence of kaons on the pion sample is found to be not important for contaminations as large as 20%.

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Tables

Table 1. Results of the fits obtained with the double-Gaussian parametrization (3) of the two-pion correlation function $C_2(Q)$.

	λ_1	r_1 (fm)	λ_2	r_2 (fm)	N	χ^2/NDF
pion sample	1.48 ± 0.07	0.92 ± 0.03	1.78 ± 0.19	2.20 ± 0.14	0.88 ± 0.01	31/18
$2\pi^+2\pi^-$	1.33 ± 0.16	0.65 ± 0.10	1.70 ± 0.74	2.09 ± 0.52	1.00 ± 0.01	14/18
$2\pi^+2\pi^-\pi^0$	1.68 ± 0.14	0.91 ± 0.05	1.60 ± 0.33	1.98 ± 0.22	0.92 ± 0.02	22/18
$2\pi^+2\pi^-n\pi^0$	1.41 ± 0.24	0.90 ± 0.07	1.64 ± 0.38	2.03 ± 0.37	0.80 ± 0.02	16/18

Table 2. Results of the fits obtained with the exponential parametrization (4) of the two-pion correlation function $C_2(Q)$.

	λ_e	r_e (fm)	N	χ^2/NDF
pion sample	4.79 ± 0.10	1.89 ± 0.04	0.84 ± 0.01	46/20
$2\pi^+2\pi^-$	3.44 ± 0.26	1.04 ± 0.16	0.87 ± 0.01	16/20
$2\pi^+2\pi^-\pi^0$	5.37 ± 0.19	1.83 ± 0.05	0.87 ± 0.02	36/20
$2\pi^+2\pi^-n\pi^0$	4.71 ± 0.21	1.85 ± 0.08	0.76 ± 0.02	17/20

Figure Captions

- Fig. 1. Two-pion correlation functions $C_2(Q)$ of the pion sample, for real (solid circles) and simulated (open circles) data. The curves correspond to the best fits obtained with the single-Gaussian (dashed line), double-Gaussian (solid line) and exponential (dot-dashed line) parametrizations.
- Fig. 2. Two-pion correlation function $C_2(Q)$ for events with no genuine single vertex (solid circles), and the correlation function resultant from the addition of these events to the pion sample (open circles). The solid line corresponds to the single-Gaussian parametrization. The dashed line is the result of the double-Gaussian fit shown in Fig. 1.
- Fig. 3. The two-pion correlation function $C_2(Q)$ for the $2\pi^+2\pi^-$ final state. The dashed and the solid lines are the fits to the single-Gaussian and double-Gaussian parametrizations respectively. The curves labeled (1) and (2) are the individual contributions from the two sources in the double-Gaussian parametrization (see also Table 1).
- Fig. 4. The two-pion correlation function $C_2(Q)$ for the $2\pi^+2\pi^-\pi^0$ final state. The dashed and the solid lines correspond to the single-Gaussian and double-Gaussian parametrizations respectively. The individual contributions from the two sources in the double-Gaussian parametrization are drawn separately (see also Table 1).
- Fig. 5. The two-pion correlation function $C_2(Q)$ for the $2\pi^+2\pi^-\pi^0$, $n \geq 2$ final state. The dashed and the solid lines correspond to the double-Gaussian and the "modified" double-Gaussian parametrizations (see text) respectively. The individual contributions from the two sources in the double-Gaussian parametrization are drawn separately (see also Table 1).
- Fig. 6. The two-pion correlation function $C_2(Q)$ for $K^+K^-\pi^+\pi^-$ events where the kaons are treated as pions (solid circles). The correlation function $C_2(Q)$ (open circles) is constructed from 20% $K^+K^-\pi^+\pi^-$ events added to the pion sample of Fig. 1 and has to be compared with the solid line which is the double-Gaussian fit of Fig. 1.
- Fig. 7. The two-pion correlation function $C_2(Q)$ for $K^\pm\pi^\mp K_S(\rightarrow \pi^+\pi^-)$ events where the charged kaon is treated as a pion (solid circles). The correlation function $C_2(Q)$ (open circles) is constructed from 20% $K^\pm\pi^\mp K_S(\rightarrow \pi^+\pi^-)$ events added to the pion sample of Fig. 1 and has to be compared with the solid line which is the double-Gaussian fit of Fig. 1.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7