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Bose-Einstein Correlations of Charged and Neutral Kaons in Deep Inelastic Scattering at HERA

ZEUS Collaboration

Abstract

Bose-Einstein correlations of charged and neutral kaons have been measured in $e^{\pm}p$ deep inelastic scattering with an integrated luminosity of $121\,\text{pb}^{-1}$ using the ZEUS detector at HERA. The two-particle correlation function was studied as a function of the four-momentum difference of the kaon pairs, $Q_{12} = \sqrt{-(\text{p}_1 - \text{p}_2)^2}$, assuming a Gaussian shape for the particle source. The values of the radius of the production volume, r, and of the correlation strength, λ, were obtained for both neutral and charged kaons. The radii for charged and neutral kaons are similar and are consistent with those obtained at LEP.

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1 Introduction

The use of Bose-Einstein correlations (BEC) in particle physics as a method of determininig the size and the shape of the source from which particles originate was first considered by Goldhaber et al. [1, 2] in 1959 for $p\bar{p}$ annihilations. Bose-Einstein correlations originate from the symmetrization of the two-particle wave function of identical bosons and lead to an enhancement of boson pairs emitted with small relative momenta. The effect is sensitive to the size of the emitting source. The studies of BEC for pairs of identical particles have been carried out in a large variety of particle interactions. In particular, H1 and ZEUS have reported results on inclusive charged particle pairs in $e^{\pm}p$ collisions at HERA [3, 4]. Recent reviews [5–9] summarise the underlying theoretical concepts and experimental results. The measurements of the radius of the emission source have been mostly performed for neutral and charged pions. For other bosons, e.g. kaons, the information is scanty.

This paper reports first results on BEC for pairs of charged ($K^{\pm}K^{\pm}$) and neutral ($K^0_S K^0_S$) kaons in deep inelastic scattering (DIS) at HERA. The measurements are compared with results from e^+e^- interactions whose fragmentation properties are expected to be similar to the current region of DIS [10]. However, proton fragmentation may lead to a significant difference in the properties of the hadronic final state.

The correlation function for two identical kaons is defined as

$$R(Q_{12}) = \frac{P(Q_{12})}{P_0(Q_{12})}, \tag{1}$$

where Q_{12} is the four-momenta difference of the kaons with four momenta p_1 and p_2 given as

$$Q_{12} = \sqrt{-(\mathrm{p}_1 - \mathrm{p}_2)^2} = \sqrt{M^2_{KK} - 4m^2_K}, \tag{2}$$

where M_{KK} is the invariant mass of the pair of kaons and m_K is the kaon rest mass. The function $P(Q_{12})$ in Eq. (1) is the two-particle density: $P(Q_{12}) = (1/N)(dn_{KK}/dQ_{12})$, where n_{KK} is the number of kaon pairs and N is the number of events. The denominator of Eq. (1), $P_0(Q_{12})$, is the two-particle density in the absence of BEC.

For a static source with a Gaussian density distribution, the correlation function can be parametrised as follows [2]:

$$R(Q_{12}) = 1 + \lambda \exp(-r^2 Q^2_{12}). \tag{3}$$

The λ parameter gives information about the strength of the BEC. For a completely coherent source, λ is zero, while for a completely incoherent source, λ is one [11]. Contributions from decays of short-lived resonances can further modify this parameter. The parameter r is related to the size of the source and is called the radius in the following sections.

2 Experimental set-up

The analysis was performed with data taken by the ZEUS detector between 1996 and 2000 at HERA. The data from $e^{\pm}p$ collisions collected in this period with electron[1] energy $E_e = 27.5\,\text{GeV}$ and proton energy $E_p = 820\,\text{GeV}$ $(1996-1997)$ or $E_p = 920\,\text{GeV}$ $(1998-2000)$ correspond to an integrated luminosity of $121\,\text{pb}^{-1}$.

A detailed description of the ZEUS detector can be found elsewhere [12]. A brief outline of the components that are most relevant for this analysis is given below.

Charged particles are tracked in the central tracking detector (CTD) [13], which operates in a magnetic field of 1.43 T provided by a thin superconducting coil. The CTD consists of 72 cylindrical drift chamber layers, organized in 9 superlayers covering the polar-angle[2] region $15^\circ < \theta < 164^\circ$. The transverse-momentum resolution for full-length tracks is $\sigma(p_T)/p_T = 0.0058p_T \oplus 0.0065 \oplus 0.0014/p_T$, with p_T in GeV. To estimate the energy loss, dE/dx, of tracks, the truncated mean of the sense-wire pulse-heights was recorded for each track, discarding the 10% lowest and up to the 30% highest pulses [14–16]. The measured dE/dx values were normalised to the dE/dx peak position for tracks with momenta $0.3 < p < 0.4$ GeV, the region of minimum ionisation for pions. Henceforth, dE/dx is quoted in units of minimum ionising particles (mips). The resolution of the dE/dx measurement for full-length tracks is about 9%. The tracking system was used to establish the primary and secondary vertices.

The high-resolution uranium–scintillator calorimeter (CAL) [17] consists of three parts: the forward, the barrel and the rear (RCAL) calorimeters. Each part is subdivided transversely into towers and longitudinally into one electromagnetic section and either one or two hadronic sections. The smallest subdivision of the calorimeter is called a cell. The CAL energy resolutions, as measured under test-beam conditions, are $\sigma(E)/E = 0.18/\sqrt{E}$ for electrons and $\sigma(E)/E = 0.35/\sqrt{E}$ for hadrons, with E in GeV.

[1] Here and in the following, the term „electron" denotes generically both the electron and the positron.
[2] The ZEUS coordinate system is a right-handed Cartesian system, with the Z axis pointing in the proton beam direction, referred to as the "forward direction", and the X axis pointing left towards the center of HERA. The coordinate origin is at the nominal interaction point.

The energy of the scattered electron was corrected for energy loss in the material between the interaction point and the calorimeter using the small-angle rear tracking detector [18,19] and the presampler [18,20].

3 Event and track selection

The inclusive neutral current DIS process $e(k) + p(P) \to e(k') + X$ can be described in terms of the following kinematic variables: Q^2, the virtuality of the exchanged photon, x, the Bjorken scaling variable and y, the fraction of the lepton energy transferred to the proton in the proton rest frame. They are defined as follows: $Q^2 = -q^2 = -(k - k')^2$; $x = Q^2/(2P \cdot q)$; $y = (q \cdot P)/(k \cdot P)$, where k, k' and P are the four-momenta of initial and final scattered electrons and incoming proton, respectively. These variables were reconstructed using the electron method (denoted by the subscript e), which requires measurements of the energy and angle of the scattered electron.

A three-level trigger system [12] was used to select events online. At the third level, electrons with energy greater than 4 GeV and position outside a rectangle defined by $|\mathrm{X}| < 12\,\mathrm{cm}$, $|\mathrm{Y}| < 6\,\mathrm{cm}$ on the face of the RCAL were accepted. Data below $Q^2 \sim 20\,\mathrm{GeV}^2$ were prescaled to reduce the trigger rate.

The offline selection of DIS events was based on the following requirements:

- $|\mathrm{Z}_{\mathrm{vtx}}| < 50\,\mathrm{cm}$, where $\mathrm{Z}_{\mathrm{vtx}}$ is the Z component of the primary-vertex position determined from the tracks. This cut reduces the background from non-ep interactions;
- an identified scattered electron in the CAL with energy $E_e \geq 8.5\,\mathrm{GeV}$;
- $2 \leq Q_e^2 \leq 15000\,\mathrm{GeV}^2$;
- $35 < \delta < 60\,\mathrm{GeV}$, where $\delta = \sum E_i(1 - \cos\theta_i)$, E_i is the energy of the i^{th} calorimeter cell and θ_i is its polar angle as viewed from the primary vertex. The sum runs over all CAL cells. This cut reduces the background from photoproduction and events with large initial-state radiation;
- $y_e \leq 0.95$, to remove events with misidentified scattered electrons;
- $y_{\mathrm{JB}} \geq 0.04$, to remove events with low hadronic activity, where y_{JB} is the value of y reconstructed using the Jacquet-Blondel method [21].

Good quality tracks measured in the CTD with high acceptance and resolution were selected using the following requirements: transverse momentum $p_T > 0.15\,\mathrm{GeV}$ and pseudorapidity $|\eta| < 1.75$. In addition, the tracks were required to pass through more than three CTD superlayers.

After the above cuts, the data sample contained 25 million events with at least two good tracks and the average Q^2 of the sample was $\langle Q^2 \rangle = 35\,\text{GeV}^2$.

3.1 Selection of charged kaons

Charged kaons were selected using the energy-loss measurement, dE/dx. The analysis used all tracks fitted to the primary vertex with the exception of the scattered-electron track. Tracks were selected as described above. The dE/dx as a function of momentum for positively charged tracks is shown in Fig. 1a. The curves indicate the region used for identification of positively charged kaons. Kaons were selected by requiring $f < dE/dx < F$, where f and F are functions of the track momentum, p, motivated by the Bethe-Bloch equation. For positive kaons $f = 0.08/p^2 + 1.0$, $F = 0.17/p^2 + 1.03$ mips and for negative kaons $f = 0.08/p^2 + 1.0$ and $F = 0.18/p^2 + 1.03$ mips (with p in GeV). The slight difference arises from the different response of the CTD to positive and negative tracks. The kaons were identified for $p < 0.9\,\text{GeV}$ and $dE/dx > 1.25$ mips.

The kaon identification efficiency for $p_t > 0.15\,\text{GeV}$, $|\eta| < 1.5$ and $p < 0.9\,\text{GeV}$ was 61%, with a purity of 90%. The resulting data sample contained 55522 K^+K^+ or K^-K^- pairs.

3.2 Neutral kaon selection

The K^0_S mesons were identified using the charged-decay channel $K^0_S \to \pi^+\pi^-$ with a similar selection as in a previous publication [22]. The pion tracks were required to originate from secondary vertices. Assigning the pion mass to both tracks, the invariant mass $M(\pi^+\pi^-)$ was calculated and the candidate was accepted if the mass was within $\pm\, 20\,\text{MeV}$ of the nominal PDG [23] K^0_S mass. To eliminate tracks from photon conversions and $\Lambda/\bar{\Lambda}$ contamination, the electron, pion and proton masses were assigned to tracks and the following cuts were used: $M(e^+e^-) > 80\,\text{MeV}$ and $M(\pi p) > 1121\,\text{MeV}$.

The following additional requirements were applied to the selected K^0_S candidates:

- $2 < L_d < 30\,\text{cm}$, where L_d is the decay length of the K^0_S candidate;
- $\Delta Z < 0.8\,\text{cm}$, where ΔZ is the projection on the Z axis of the vector defined by the primary interaction point and the point of closest approach of the K^0_S candidate;
- $\alpha_{XY} < 8^\circ$, where α_{XY} is the (collinearity) angle between the candidate K^0_S momentum vector and the vector defined by the interaction point and the K^0_S decay vertex in the XY plane;
- $p_t^{\text{PA}} > 0.11\,\text{GeV}$, where the Podolanski-Armenteros variable p_t^{PA} is the projection of the candidate pion momentum onto a plane perpendicular to the K^0_S momentum direction [24].

The total number of K_S^0 candidates was 725505. After all cuts, the selected data sample contained 19494 $K_S^0 K_S^0$ pairs and 400 triples. Each combination of two particles was included in the analysis. Figure 1b shows the $\pi^+\pi^-$ invariant mass distribution after the K_S^0-pair selection and a fit to the signal plus linear background, which resulted in an estimated background of 1.4%.

4 Monte Carlo simulation

Inclusive DIS events with $Q^2 > 2\,\mathrm{GeV}^2$ were generated without BEC using the ARIADNE 4.10 Monte Carlo (MC) model [25] interfaced with HERACLES 4.6.1 [26] via the DJANGOH 1.1 program [27, 28] in order to incorporate first-order electroweak corrections. The Lund string model [29] was used for the description of hadronisation, as implemented in the JETSET 7.4 [30] program.

The generated events were passed through a full simulation of the detector using the GEANT 3.13 program [31] and reconstructed and analyzed in the same way as the data. The ARIADNE MC sample corresponds to a similar integrated luminosity as that of the data.

5 Extraction of BEC parameters

The main difficulty in measuring BEC is in the construction of a reference sample which should be as close as possible to the analyzed data in all aspects but free from the Bose-Einstein effect. The obvious reference sample provided by unlike-sign charged kaon pairs cannot be used due to the strong signal of the $\phi^0(1020) \to K^+K^-$ decay at low values of Q_{12}.

A reference sample can be derived from a Monte Carlo simulation without BEC. In this so-called single-ratio method, the correlation function $R(Q_{12})$ is defined as: $R^S(Q_{12}) = P(Q_{12})^{\mathrm{data}}/P(Q_{12})^{\mathrm{MC,noBEC}}$, where $P(Q_{12})^{\mathrm{data}}$ is the normalized two-particle density distribution for the data and $P(Q_{12})^{\mathrm{MC,noBEC}}$ is the corresponding distribution obtained for MC without BEC. However, this approach requires a correct simulation of the physics processes in the absence of BEC, as well as a good description of the detector effects.

In another approach, a reference sample can be obtained using an event-mixing procedure where two kaons from different events are combined. This method, which is used in this analysis, is less sensitive to imperfections in the MC simulation. To correct for other correlations lost in the event-mixing procedure, the two-particle correlation function $R(Q_{12})$ was calculated using the double-ratio method:

$$R(Q_{12}) = \frac{P(Q_{12})^{\text{data}}}{P_{\text{mix}}(Q_{12})^{\text{data}}} \Bigg/ \frac{P(Q_{12})^{\text{MC,noBEC}}}{P_{\text{mix}}(Q_{12})^{\text{MC,noBEC}}}, \tag{4}$$

where $P_{\text{mix}}(Q_{12})^{\text{data}}$ is the two-particle density constructed from pairs of kaons coming from different events and $P_{\text{mix}}(Q_{12})^{\text{MC,noBEC}}$ is obtained in a similar way for MC events. The double-ratio method was used for the main analysis and the single-ratio method only to estimate systematic uncertainties.

To fit the correlation function $R(Q_{12})$ defined by Eq. (4), the modified Goldhaber parametrisation (Eq. (3)) multiplied by an empirical term $1+\beta Q_{12}$, which accounts for the presence of possible long-range two-particle correlations for high Q_{12}, is often used:

$$R(Q_{12}) = \alpha(1 + \lambda e^{-Q_{12}^2 r^2})(1 + \beta Q_{12}). \tag{5}$$

Such correlations are imposed for example by energy and charge conservation, phase-space constraints or strangeness compensation. In this analysis, the β parameter was found to be zero within errors and its possible deviation from zero was included in the systematic uncertainties.

6 Systematic uncertainties

Systematic uncertainties on the fitted λ and r parameters arise from event and track selection, the modeling of dE/dx, the fitting procedure and the construction of the reference sample. They were calculated from the deviation of the fit parameters from their nominal values after changing the analysis cuts or procedures. For charged kaons, a bias originating from the contamination of the experimental kaon sample by pion, proton and antiproton is expected. For neutral kaons, a bias can be introduced by the contamination of the sample by $K_S^0 K_S^0$ pairs from the decay of $f_0(980)$ resonance. These effects are discussed in the next sections.

The following systematic studies were carried out for the charged kaon sample. The resulting changes for λ and r are given in parentheses as $[\Delta\lambda, \Delta r]$:

- the correlation function was calculated using the single-ratio method $[-0.01, -0.03]$;
- the fit was repeated for different lower and upper limits of Q_{12}. In addition the binning in Q_{12} was modified $[^{+0.04}_{-0.04}, ^{+0.09}_{-0.04}]$;
- the momentum range was reduced to $p < 0.7\,\text{GeV}$ for both the double $[+0.06, +0.06]$ and single $[+0.01, -0.01]$ ratio methods;

- the definition of the kaon band was varied for the double-ratio method $[-0.02, +0.05]$ and the single-ratio method $[-0.04, -0.02]$;
- the track quality cuts were changed within their resolutions $[-0.02, +0.04]$;
- the DIS selection cuts on E_e, y_e, $y_{\rm JB}$, δ were varied within the resolutions $[^{+0.02}_{-0.02}, ^{+0.02}_{-0.02}]$;
- the influence of pion, proton and antiproton contamination was checked by tightening and relaxing the kaon selection criteria. The purity was raised to 99% $[+0.05, +0.07]$ and was brought down to 80% $[-0.04, -0.05]$.

The following systematic uncertainties for neutral kaons were considered:

- the correlation function was calculated using the single-ratio method $[+0.10, +0.02]$;
- the fit was repeated for different lower and upper limits of Q_{12}. In addition, the binning in Q_{12} was modified $[^{+0.04}_{-0.04}, ^{+0.09}_{-0.04}]$;
- the cuts on the K^0_S momentum, $\alpha_{\rm XY}$, ΔZ, $M(\pi^+\pi^-)$ were varied $[-0.08, -0.08]$;
- the cut on $p_t^{\rm PA}$ was changed to 0.12 GeV $[+0.04, +0.02]$;
- the full Eq. (5) was used to check the sensitivity of the fit to possible long-range correlations $[+0.11, +0.03]$;
- the track quality cuts were changed within the resolution $[+0.15, +0.02]$;
- the cut to remove the e^+e^- background was changed to $M(e^+e^-) > 50$ MeV $[+0.08, +0.03]$;
- the DIS selection cuts on E_e, y_e, $y_{\rm JB}$, δ were varied within resolutions $[^{+0.02}_{-0.02}, ^{+0.02}_{-0.02}]$.

The contributions from the different groups of systematic uncertainties in the parameters λ and r were added in quadrature separately for positive and negative variations. The overall systematic uncertainties in λ and r for $K^\pm K^\pm$ and $K^0_S K^0_S$ are presented in Table 1.

7 Results

7.1 Correlations in $K^\pm K^\pm$ pairs

Figure 2 shows the measured two-particle correlation function for $K^\pm K^\pm$ pairs. The results obtained by the fit function given by Eq. (5) with $\beta = 0$ are $r = 0.57 \pm 0.09$ fm and $\lambda = 0.31 \pm 0.06$. The 90% purity of the kaon selection introduces in the kaon pair sample an 18% admixture of unlike particles pairs which are not correlated. The measured λ is therefore expected to be underestimated by 18%. The systematic checks involving purity confirm this expectation. After the correction for purity, the result is $\lambda = 0.37 \pm 0.07^{+0.09}_{-0.08}$. The value of the radius is not affected by this correction and the result is $r = 0.57 \pm 0.09^{+0.15}_{-0.08}$ fm. The corrected parameters of BEC correlations for $K^{\pm}K^{\pm}$ pairs are presented in Table 1. The radius value is consistent with that for charged particles: $r = 0.54 \pm 0.03^{+0.03}_{-0.02}$ fm for H1 [3] and $r = 0.666 \pm 0.009^{+0.022}_{-0.036}$ fm for ZEUS [4]. The obtained value of λ for kaons is in agreement with the H1 result for charged particles $\lambda = 0.32 \pm 0.02 \pm 0.06$, although somewhat smaller than the ZEUS result $\lambda = 0.475 \pm 0.007^{+0.011}_{-0.003}$.

7.2 Correlations in $K^0_S K^0_S$ pairs

The $K^0_S K^0_S$ pairs may originate not only from $K^0 K^0$, $\bar{K}^0 \bar{K}^0$ (strangeness $S = \pm 2$) states but also from the $K^0 \bar{K}^0$ (strangeness $S = 0$) system, which may come from the decay of resonances. It has been shown [32, 33] that a Bose-Einstein-like enhancement is nevertheless expected in the Q_{12} distribution of the $K^0_S K^0_S$ pairs, even when their origin is from the $K^0 \bar{K}^0$ system. According to the MC simulation of DIS events, about 75% of low-Q_{12} $K^0_S K^0_S$ pairs come from $K^0 \bar{K}^0$. Similar to the case of charged kaons, Eq. (5) with $\beta = 0$ was used to fit the correlation function calculated for $K^0_S K^0_S$ pairs. The so-called raw results are $\lambda = 1.16 \pm 0.29^{+0.28}_{-0.08}$ and $r = 0.61 \pm 0.08^{+0.07}_{-0.08}$ fm. The results are presented in Table 1 and Fig. 3. The measured radii for $K^{\pm}K^{\pm}$ and $K^0_S K^0_S$ are close to each other.

For $K^0_S K^0_S$ the fit does not take into account a possible contamination from the scalar $f_0(980)$ resonance decaying below the $K\bar{K}$ threshold. The decay channel $f_0(980) \to K^0 \bar{K}^0$ is not included in the standard MC, therefore the $f_0(980)$ contribution may distort the strength of the Bose-Einstein effect. In order to investivate this, a MC sample with BEC at maximum strength was generated. A comparison of this MC with the data showed an excess for $Q_{12} < 0.6$ GeV, which may indicate a possible f_0 contribution. The same excess is also visible in the M_{KK} distribution, as illustrated in Fig. 4a.

The expected contribution from f_0 can be approximated by a modified Breit-Wigner function as proposed by Flatté [34–36]:

$$\frac{d\sigma}{dM_{KK}} = N_F \cdot \frac{m_0^2 \cdot \Gamma_{KK}}{(m_0^2 - M_{KK}^2)^2 + (m_0 \cdot (\Gamma_{\pi\pi} + \Gamma_{KK}))^2}, \quad (6)$$

where $m_0 = 0.954$ GeV is the mass of $f_0(980)$ and the widths $\Gamma_{\pi\pi}$ and Γ_{KK} are related to the coupling constants $g_\pi = 0.11$ and $g_K = 0.423$ by $\Gamma_{\pi\pi} = g_\pi \sqrt{M_{KK}^2/4 - m_\pi^2}$ and $\Gamma_{KK} = g_K \sqrt{M_{KK}^2/4 - m_K^2}$. The normalization factor, N_F, was adjusted to give the total number of $f_0(980) \to K^0_S K^0_S$ decays for $M_{KK} < 1.8$ GeV. Fig. 4a shows the distribution of $d\sigma/dM_{KK}$ according to Eq. (6). Figure 4b shows the M_{KK} distribution in the data after subtraction of the standard MC without BEC together with different contributions of the f_0 resonance. An f_0 contribution of about 7% is sufficient to account for the data, therefore, the present analysis cannot distinguish the Bose-Einstein effect from the effect of an f_0 contribution. Assuming that both BEC and f_0 are present, the amount of f_0 was estimated from the shape of the $R(Q_{12})$ distribution (Eq. (4)). For this purpose, fits of the correlation function were carried out with different percentages, c_{f_0}, of f_0 subtracted from the data. A shallow minimum of the $\chi^2(c_{f_0})$ value for $c_{f_0} = 4\%$ was found, with one-sigma limits of $c_{f_0} = 1\%$ and $c_{f_0} = 7\%$. The values of λ and r at $c_{f_0} = 4\%$ were taken as the most probable result and their uncertainties were calculated from the one sigma limits of c_{f_0}.

The results corrected for the f_0 contamination are included in Table 1. After adding the uncertainties coming from the f_0 subtraction to systematics, the corrected results are $\lambda = 0.70 \pm 0.19^{+0.47}_{-0.53}$ and $r = 0.63 \pm 0.09^{+0.11}_{-0.08}$ fm. The uncertainty on a possible f_0 admixture leads to a large systematic uncertainty on λ. The radius r is less sensitive to the f_0 admixture. The radii for $K^0_S K^0_S$ and $K^{\pm}K^{\pm}$ are very similar.

7.3 Comparison with e^+e^- interactions

Figure 5 shows the comparison for r between DIS and e^+e^- annihilation results at LEP [36–39] for both charged and neutral kaons. The radius value obtained in DIS agrees with the measurements from LEP. The same figure also presents DIS results for unidentified charged particles. The kaon results agree with those for charged particles within systematic uncertainties. The λ value for charged kaons in DIS is somewhat smaller than that in e^+e^- collisions, which may be related to the fact that the DIS data mostly populate the proton fragmentation region in the Breit frame.

8 Conclusions

Bose-Einstein correlations have been measured for pairs of charged and neutral kaons in deep inelastic scattering at HERA using the ZEUS detector. The values of the radius for charged and neutral kaons agree within systematic uncertainties. They are also consistent with the measurements for charged particles in DIS and kaons in e^+e^- collisions at LEP. The $f_0(980) \to K^0_S K^0_S$ decay can significantly affect the λ parameter for $K^0_S K^0_S$ correlations.

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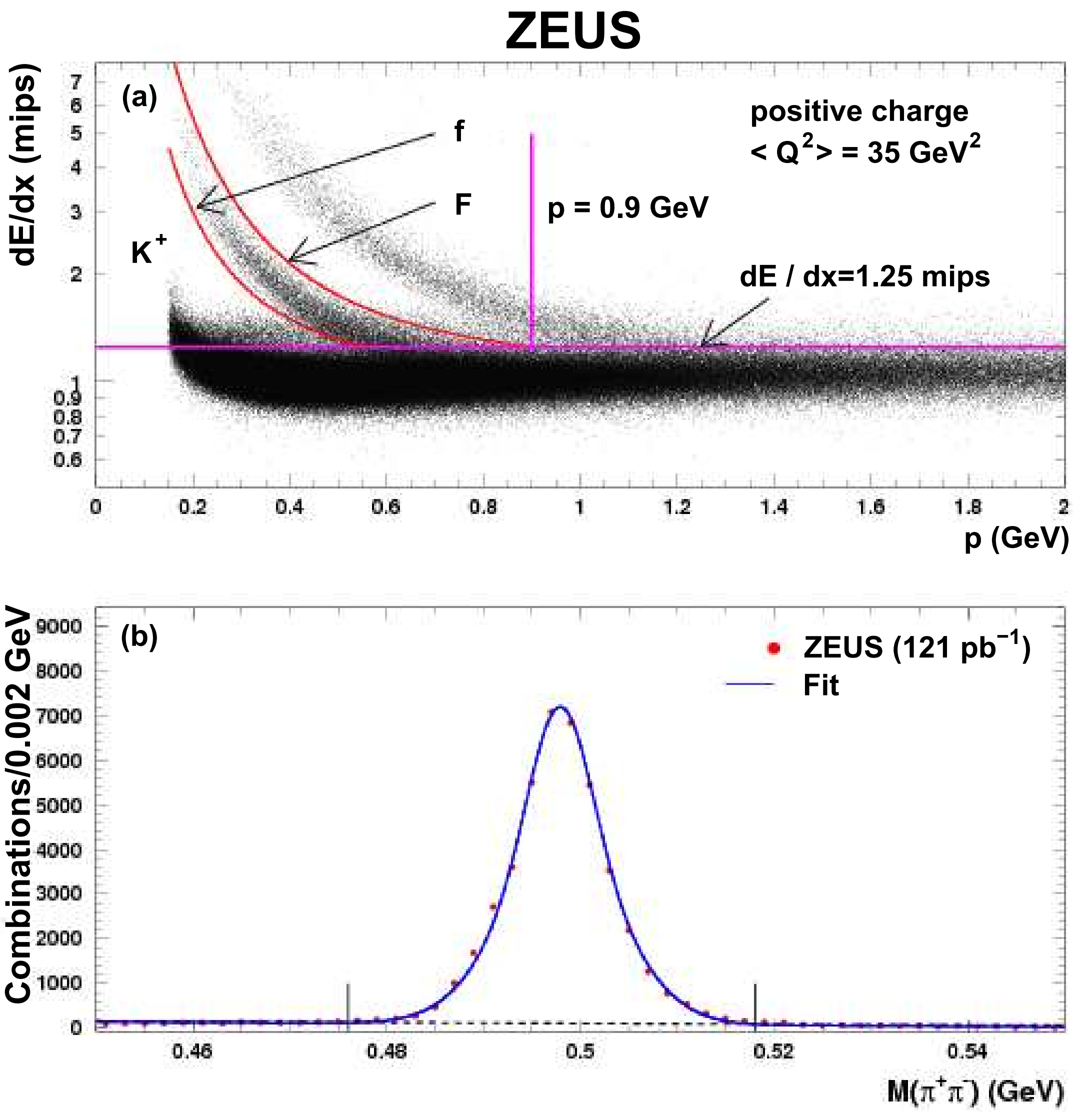

Figure 1: *(a) The energy-loss dE/dx as a function of the momentum p for tracks with positive charge. The tracks with $f < dE/dx < F$, $dE/dx > 1.25$ mips and $p < 0.9\,GeV$ were taken as K^+. (b) The $\pi^+\pi^-$ invariant-mass distribution of the K^0_S candidates. The solid line shows the result of a fit with the sum of two Gaussian functions and linear background. The two Gaussians were fixed to the same mean value. A mass in agreement with the Particle Data Group value [23] and a width of 3.2 MeV (6.3 MeV) were obtained from the fit for the central (second) Gaussian. The dashed line shows the linear background. The short vertical lines show the mass window used to define the signal.*

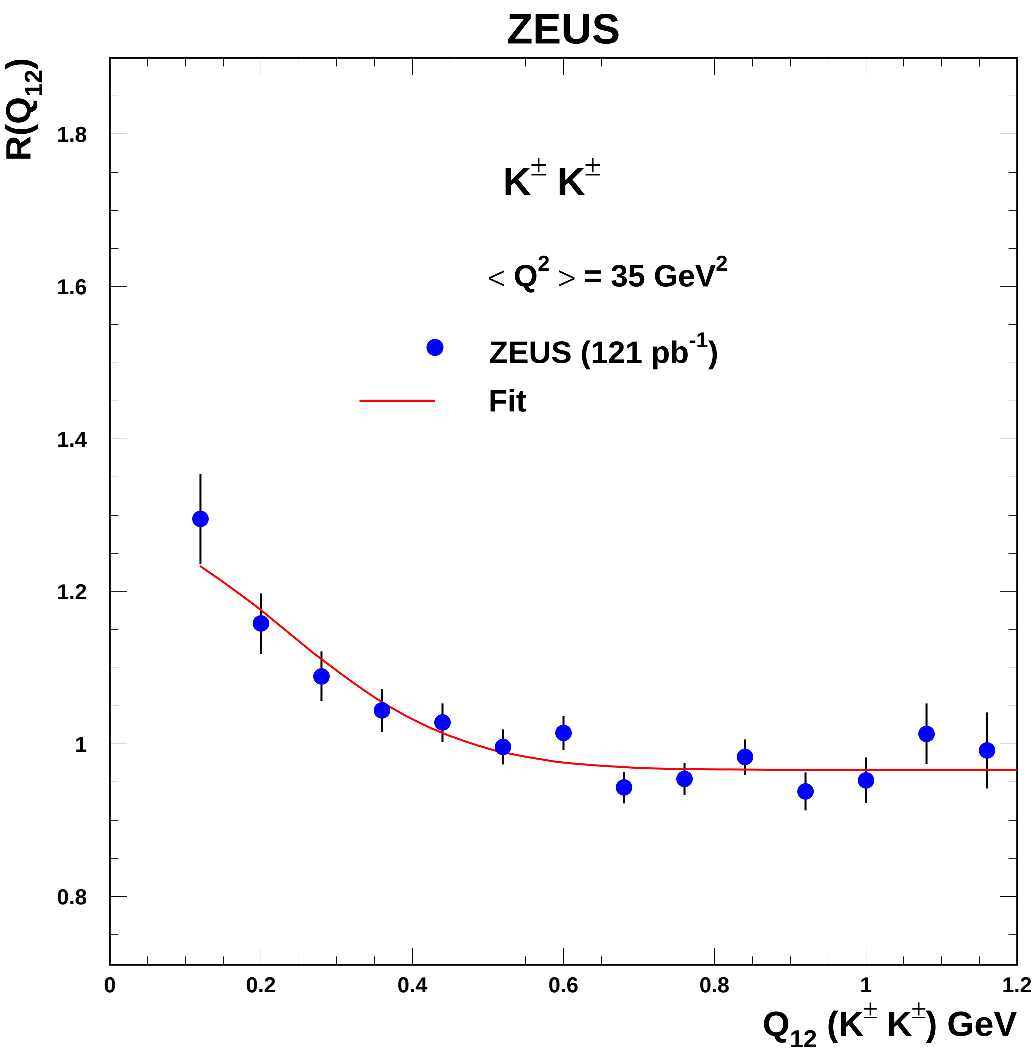

Figure 2: *The two-particle correlation function for charged kaons with a fit to Eq. (5), with* $\beta = 0$*. The error bars represent the statistical uncertainties.*

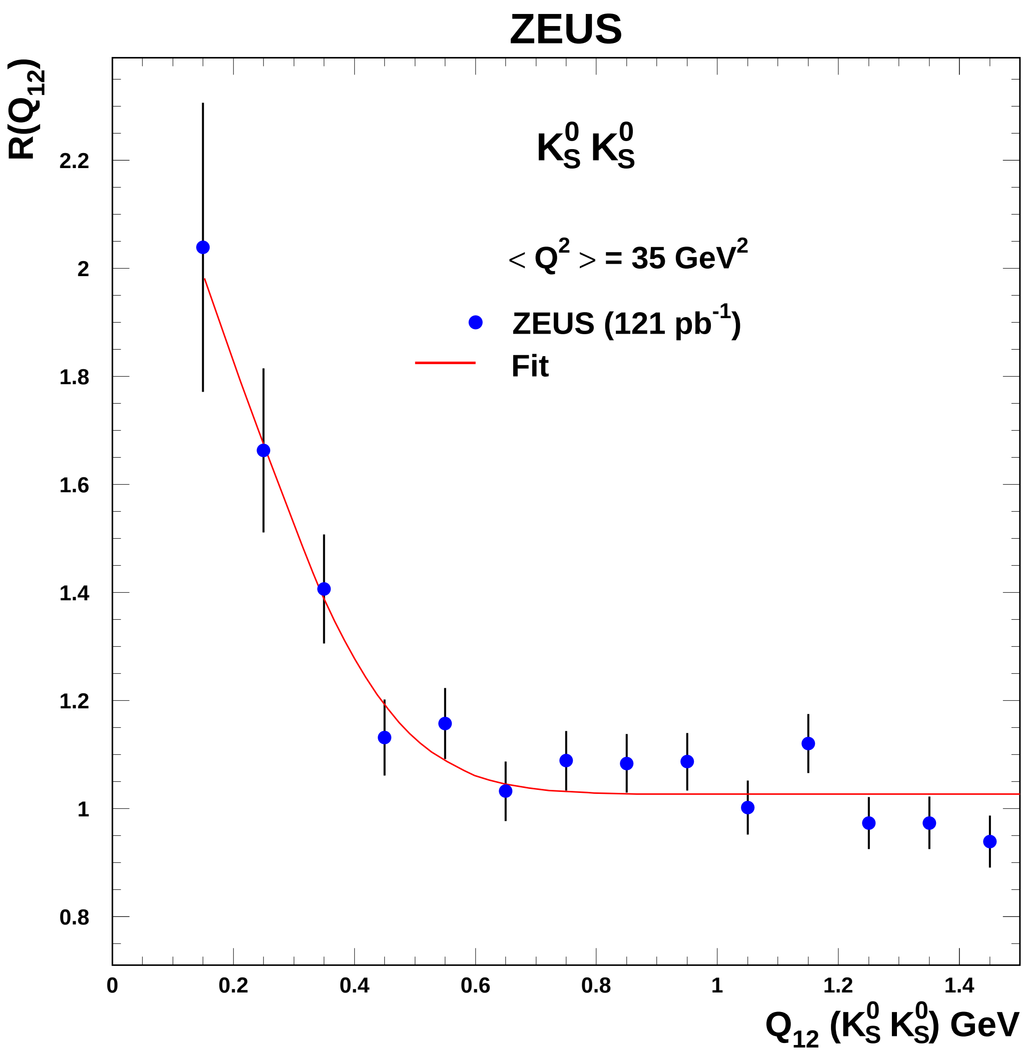

Figure 3: *The two-particle correlation function for neutral kaons with a fit to Eq. (5), with $\beta = 0$. The error bars represent the statistical uncertainties.*

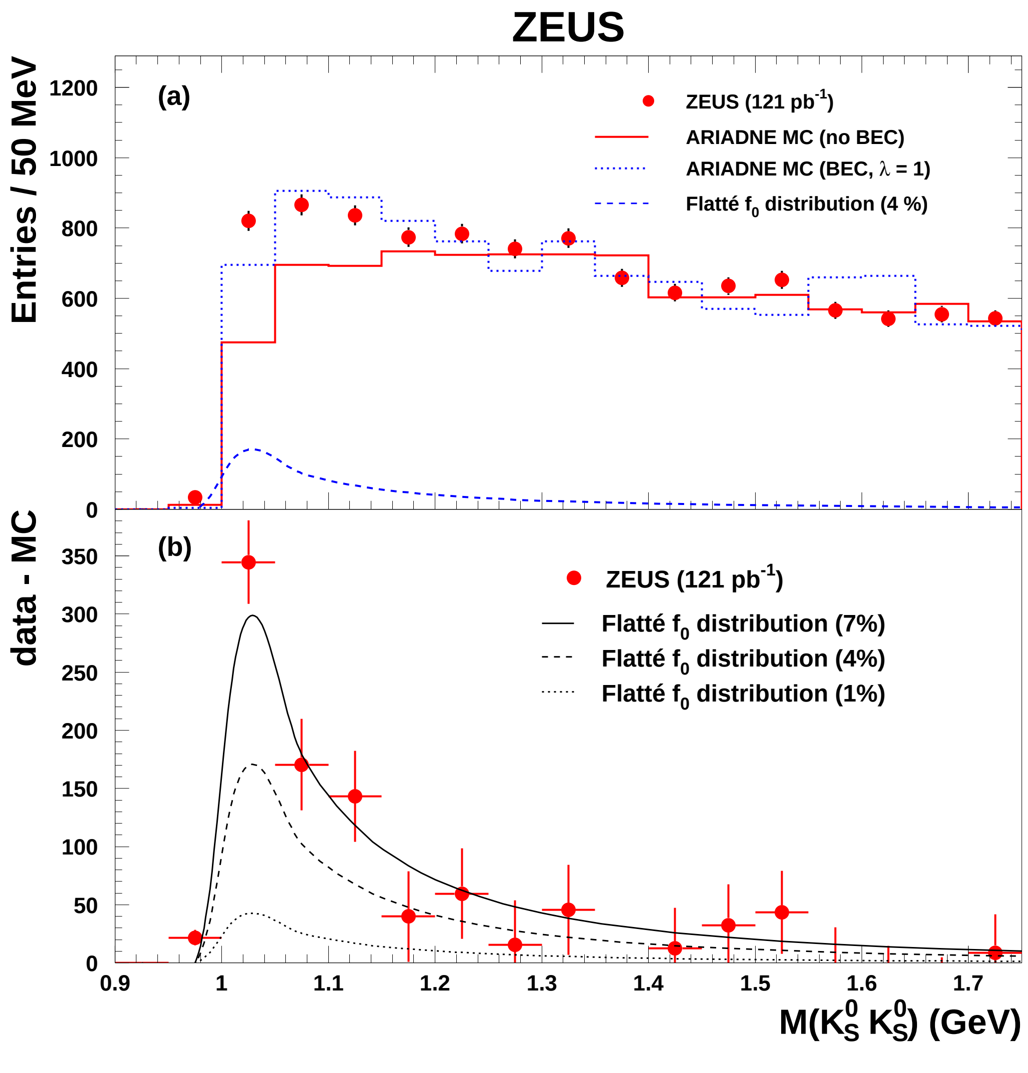

Figure 4: *(a) $K^0_S K^0_S$ invariant mass for data (points) and Monte Carlo with BEC (dotted histogram) and without BEC (full-line histogram). The dashed line shows the Flatté function used to describe the f_0 resonance. (b) The difference between data and MC without BEC compared to different f_0 contributions.*

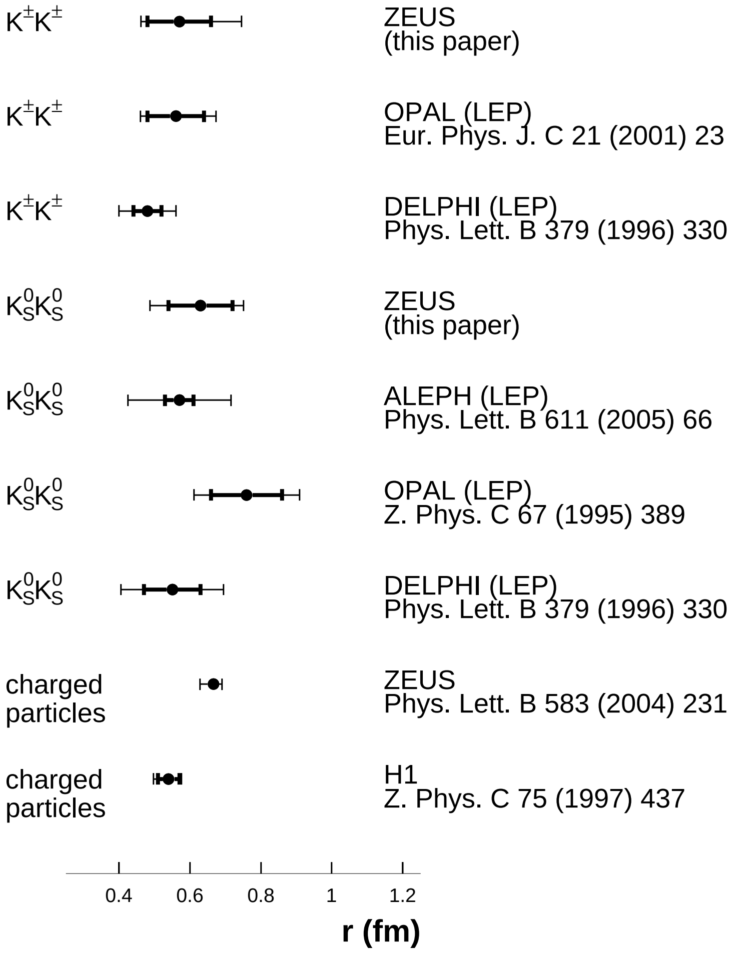

Figure 5: *Comparison of DIS and LEP results for r obtained from Bose-Einstein correlation studies of charged and neutral kaons and unidentified charged particles. The DIS result for neutral kaons is corrected for the* f_0 *contribution.*

	λ	r [fm]
$K^{\pm}K^{\pm}$ (corrected)	$0.37 \pm 0.07\ ^{+0.09}_{-0.08}$	$0.57 \pm 0.09\ ^{+0.15}_{-0.08}$
$K^0_S K^0_S$ (raw)	$1.16 \pm 0.29\ ^{+0.28}_{-0.08}$	$0.61 \pm 0.08\ ^{+0.07}_{-0.08}$
$K^0_S K^0_S$ (corrected)	$0.70 \pm 0.19\ ^{+0.28+0.38}_{-0.08-0.52}$	$0.63 \pm 0.09\ ^{+0.07+0.09}_{-0.08-0.02}$

Table 1: *The radius r and the correlation strength λ for charged and neutral kaons extracted from fitting the Goldhaber parametrization (Eq. (5) with $\beta = 0$) to the Bose-Einstein correlation function. The first uncertainties are statistical and the second systematic. The raw results for $K^0_S K^0_S$ pairs correspond to those shown in Fig. 3; the corrected results were obtained after subtraction of the f_0 contribution from the data. For the corrected values the third uncertanty comes from the f_0 subtraction.*