Neutral- and charged-kaon Bose-Einstein correlations in DIS

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Abstract. The results of the measurements of Bose-Einstein correlations (BEC) between identified kaons are presented for deep inelastic scattering (DIS) at HERA. An integrated luminosity of 121 pb^{-1} of $e^{\pm}p$ collisions data have been analysed. The two-particle correlation function was studied as a function of the $Q_{12} = \sqrt{-(p_1 - p_2)^2}$ - four momenta difference of the kaon-pair, assuming a Gaussian shape of BEC source. The values of radius, r, of the production volume and as a coherence strength factor, λ, were obtained for both, neutral and charged kaon-pairs. The results of r and λ are disccused and compared with the LEP measurements.

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Two identical bosons emitted from the same source show the tendency to have similar energy-momentum characteristic. This enhancement in the production of identical bosons with almost equal momenta is called Bose-Einstein effect and was first observed by Goldhaber *et al.*[1] in $p\bar{p}$ collisions.An important information on non-perturbative QCD and hadronisation processes can be obtained from analysys of Bose-Einstein effect of hadronic final states produced in particle reactions. Moreover, space-time characteristic of the particle emission region provides some knowledge about emission source size in different reactions.

The study of the size of BEC of identical bosons pairs in DIS has beed extended to pairs of $K_s^0 K_s^0$ and $K^{\pm}K^{\pm}$. From LEP results for BEC and FDC (Fermi-Dirac correlations) a hierarchy of the size of the emission volumes is observed. This hierarchy seems to decrease as the hadron mass increases [2]. New DIS results may bring new information about this behaviour.

The DIS data sample was taken during the 1996-2000 period from $e^{\pm}p$ collisions for the Q^2 range from 2 to 15000 GeV^2 for 121 pb^{-1} of integrated luminosity. The ZEUS detector is described in detail in [3]. The analysed data comes from the central tracking detector (CTD) and CALorimeter (CAL).

The two-particle correlation function $R(Q_{12})$ was calculated using double ratio method and divided by correction coefficient to remove correlations other than BEC:

$$R(Q_{12}) = \frac{P(Q_{12})^{\text{data}}}{P_{\text{mix}}(Q_{12})^{\text{data}}} \Big/ \frac{P(Q_{12})^{\text{MC,noBEC}}}{P_{\text{mix}}(Q_{12})^{\text{MC,noBEC}}} \quad , \tag{1}$$

where the so-called mixed-event sample P_{mix} contains pairs of bosons coming from different events. Q_{12} is given by $Q_{12} = \sqrt{-(p_1 - p_2)^2} = \sqrt{M^2 - 4m_{boson}}$, where M is the invariant mass of the two particles with four-momenta p_1 and p_2 and mass m_{boson}.

Assuming a Gausian shape of emission source, $R(Q_{12})$ can be described by the standard Goldhaber-like function:

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

where the most important parameters are r - a geometrical radius of the boson emitting source and λ - a coherence strength factor. The remaining parameters, α and δ, describe the overall normalization and non-linearity in the behavior of background. This parametrisation is introduced for a spherically symmetric boson emitting source and was used to fit data and extract the values of r and λ.

Figure 1a shows the measured two-particle correlation function of $K^{\pm}K^{\pm}$ pairs with fit. The extracted values of the BEC parameters for charged kaon-pairs are in Table 1.

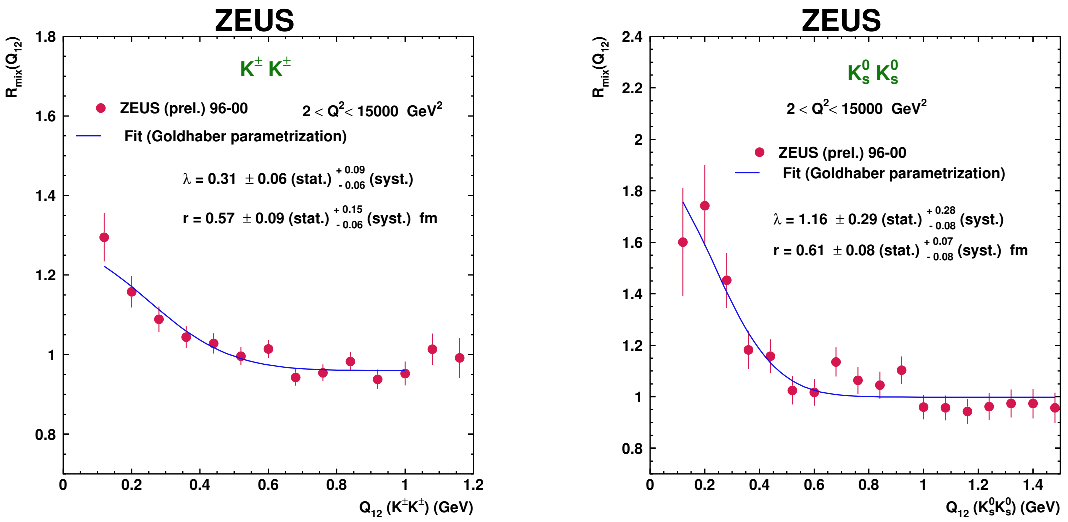

FIGURE 1. Bose-Einstein correlation function of (a) $K^{\pm}K^{\pm}$ and (b) $K^0_s K^0_s$ pairs.

The radius value for charged kaons is consistent with that for charged pions [4]. However, the λ value for kaons is smaller than for pions. Figure 2a shows the comparison of DIS and LEP results [5,6] for r and λ. The good agreement with LEP for radius is observed. The λ value for DIS is smaller than for LEP. This is due to the fact that the DIS data populate mostly proton fragmentation region, the number of non prompt kaons in the final state may significantly increase.

Like for charged kaons, the extracted values of BEC parameters for neutral kaons are presented in Table 1. Figure 1b shows the correlation function of $K^0_s K^0_s$ pairs with the Gaussian fit. The radius for $K^0_s K^0_s$ is in good agreement with that for $K^{\pm}K^{\pm}$ but the λ value is larged than for charged kaons. This may be explained by $f_0(980)$ resonance impact on the low Q_{12} region which is not well described in the ZEUS Monte Carlo. It was veryfied that small contribution of such resonance can significantly decrease λ value. The corresponding change in the value of r is small.

TABLE 1. The two-particle emitter size and the strength factor obtained from BEC. The first and the second errors are the statistical and systematic respectivly.

	r **[fm]**	λ
$K^{\pm}K^{\pm}$	$0.57 \pm 0.09 \, ^{+0.15}_{-0.06}$	$0.31 \pm 0.06 \, ^{+0.09}_{-0.06}$
$K^0_s K^0_s$	$0.61 \pm 0.08 \, ^{+0.07}_{-0.08}$	$0.57 \pm 0.09 \, ^{+0.28}_{-0.08}$
pions*	$0.666 \pm 0.009 \, ^{+0.022}_{-0.036}$	$0.475 \pm 0.007 \, ^{+0.011}_{-0.003}$

* charged pions published by ZEUS [4]

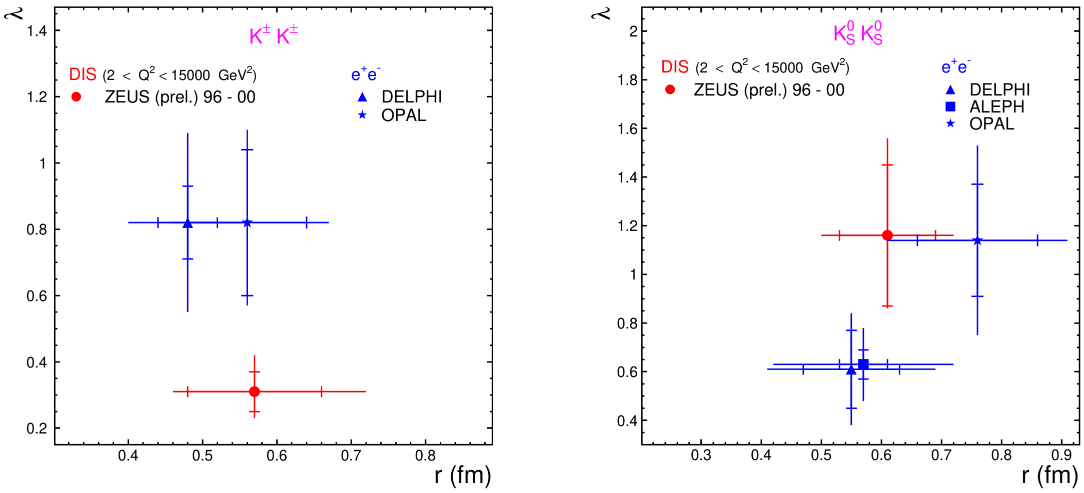

FIGURE 2. Comparison of DIS and e^+e^- LEP results for r and λ obtained from BEC of (a) $K^{\pm}K^{\pm}$ and (b) $K^0_s K^0_s$ pairs.

Figure 2b shows the comparison between DIS and LEP results [5,7,8] for neutral kaons. The radius value obtained in DIS agrees with the measurements from LEP. Although the λ value is larger for DIS than for ALEPH and DELPHI is similar to the OPAL measurements within the uncertainties. An influence of $f_0(980)$ resonance was not removed from our analysys and from OPAL measurements but was excluded from ALEPH and DELPHI studies.

The LEP results on BEC and FDC suggest that radius depends on the hadron mass. This results as well as the recent DIS results for pions and kaons are plotted in Figure 3. The $r(m)$ behaviour is compared with Heisenberg uncertainty relation and QCD approach based on the the virial theorem [2]. Both theoretical expectations well describe the data. However, string (LUND) model does not predict such dependece. This requires more studies on heavier particles in DIS.

Bose-Einstein correlations of charged and neutral kaons have been studied in DIS

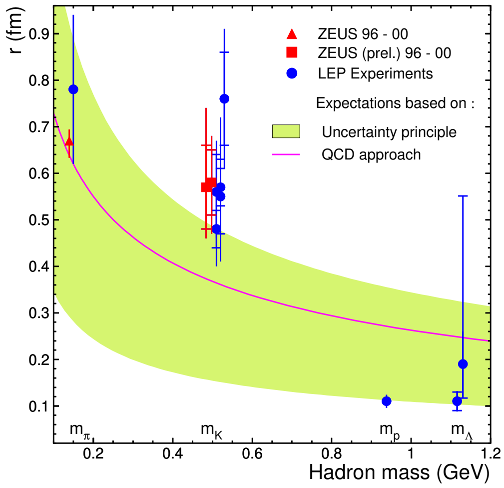

FIGURE 3. The dependence of the radius on the hadron mass. The results obtained in DIS and LEP are compared with the thoretical predictions.

at HERA. The values of radius for charged and neutral kaons and also for charged pions agree within errors. They are also compatible with LEP measurements. The difference between λ values for charged and neutral kaons can be due to possible influence of the proton fragmentations mechanism and production of $f_0(980)$ resonance.

In order to confirm the $r(m)$ dependence observed at LEP, more studies on Bose-Einstein and Fermi-Dirac correlations for identified baryons are needed.

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REFERENCES

1. Goldhaber *at al.*, *Phys. Rev. Lett* **3**, 181 (1959),
   Goldhaber *at al.*, *Phys. Rev.* **D 120**, 300 (1960).
2. G. Alexander *Rep. Prog. Phys.* **66**, 481-522 (2003);
   G. Alexander, I. Cohen, E. Levin, *Phys. Lett.* **B 452**, 159 (1999).
3. ZEUS Collab., U. Holm (ed.), *The ZEUS Detector. Status Report* (unpublished), DESY (1993), available on `http://www-zeus.desy.de/bluebook/bluebook.html`
4. ZEUS Collab., S. Chekanov *at al.*, *Phys. Lett.* **B 583**, 231 (2004).
5. DELPHI Collab., P. Abreu *at al.*, *Phys. Lett.* **B 379**, 330 (1996).
6. OPAL Collab., G. Abbiendi *at al.*, *Eur. Phys. J.* **C 21**, 23 (2001).
7. OPAL Collab., R. Akers *at al.*, *Z. Phys.* **C 67**, 389 (1995).
8. ALEPH Collab., S. Schael *at al.*, *Phys. Lett.* **B 611**, 66 (2005).