Fragmentation in DIS

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The fragmentation properties in deep-inelastic scattering (DIS) at HERA are investigated in order to test perturbative QCD and quark fragmentation universality. Selected results for the inclusive single particle distributions and the angular two-particle correlations in the current region of the Breit frame are presented and compared to results from e^+e^- collisions. The extension of the DIS fragmentation studies to the target region of the Breit frame are also reported.

1. INTRODUCTION

Many aspects of fragmentation phenomenon in DIS have been extensively studied through the last years by ZEUS in terms of the single particle scaled momentum distributions and the energy evolution of their higher order moments, fragmentation functions [1,2], the mean charged multiplicity energy dependence [3] or transverse momentum spectra [4]. These results were obtained in the current hemisphere of the Breit frame [5]. Recently the measurements were extended also to particle correlations [6] and in some limited range to the target fragmentation region. Such DIS studies allowed to test universality of perturbative QCD together with LPHD, universality of the quark fragmentation by comparison with e^+e^- data and to learn about the dynamics related with proton fragmentation hemisphere. In addition, obtained results uncover the current and target region relationship which can be quantitatively estimated.

2. SINGLE PARTICLE SPECTRA

The scaled momentum distributions in terms of the variable $\xi = \ln(1/x_p)$ ($x_p = 2p^{Breit}/Q$) in different (x, Q^2) bins are approximatelly Gaussian distributions of ξ with rising maximum and shifted peak position to higher ξ with rising Q^2 [2]. Such behaviour is generally consistent with MLLA calculacions in which color coherence phenomenon [7] was included. The available recently statistics for DIS events makes it possible to perform more detailed comparison of data with pQCD predicted energy evolution of higher moments of ξ distributions. These moments can be obtained from fits to distorted Gaussian as supplied by MLLA calculations:

$$D(\xi) \propto \exp\Big(\frac{1}{8}k - \frac{1}{2}s\delta - \frac{1}{4}(2+k)\delta^2 + \frac{1}{6}s\delta^3 + \frac{1}{4}k\delta^4\Big) \quad (1)$$

$\delta = (\ln(1/x_p) - l)/\sigma$ and l, σ, s and κ are the mean value, the dispersion, the skewness and the kurtosis of the ξ distribution. Fig. 1 shows Q^2 evolutions of these moments for the DIS, e^+e^- data and the MLLA predictions [8,9]. The MLLA predictions together with LPHD do not describe the data. The reasonable agreementbetween DIS and e^+e^- results is consistent with the universality of quark fragmentation.

3. ANGULAR CORRELATIONS

The correlations between all pairs of charged particles in the current region of the Breit frame in a cone of half-opening angle Θ were calculated according to the following formulae [10]:

$$Y(\epsilon) = \frac{\ln(\rho(\epsilon)/\rho_{mix}(\epsilon))}{\sqrt{\ln(Psin\Theta/\Lambda)}} \quad (2)$$

Such correlations were calculated and extensively studies in [10] where the scaling variable ϵ was

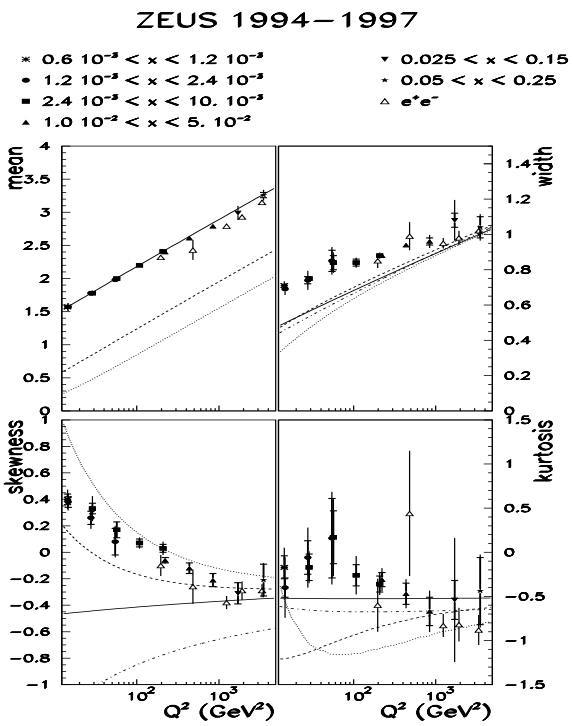

Figure 1. The moments of ξ distribution for DIS and e^+e^- data compared to MLLA predictions [8] (the full line is $Q_0 = \Lambda$, the dashed $Q_0 = 2\Lambda$, the dotted $Q_0 = 3\Lambda$). The dash-dotted line is prediction coming from ref [9].

introduced:

$$\epsilon = \frac{\ln(\Theta/\theta_{12})}{\ln(P\sin\Theta/\Lambda)} \tag{3}$$

where $P = Q/2$, Λ is the QCD energy scale and θ_{12} is the relative angle between two particles in each found pair. The $\rho(\epsilon)$ is the inclusive two-particle density:

$$\rho(\epsilon) = \frac{1}{N_{ev}}\frac{dn_{pair}}{d\epsilon} \tag{4}$$

and $\rho_{mix}(\epsilon)$ is calculated for particles from different events to remove any dynamical correlations for particles in events. Fig. 2 shows these results together with DLA predictions [10]. The DLA description fails at low Q^2 but improves with increasing Q^2.

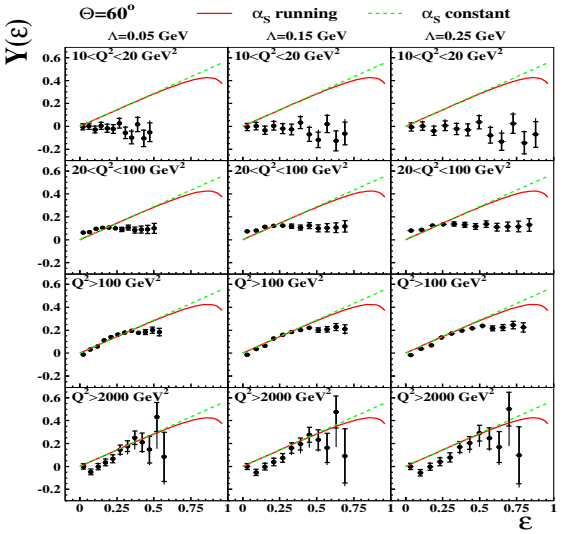

Figure 2. The angular correlations and DLA predictions [10].

4. CURRENT-TARGET REGION

In [2], the comparison of the scaled momentum, the transverse momentum and multiplicity spectra between the current and target region of the Breit frame were presented. The significant differencies were found suggest different dynamical mechanism in their origin. According to the recent results [11] the current and the target hemispheres cannot be treated separately when first order QCD processes such as boson-gluon fusion (BGF) and QCD Compton (QCDC) appear. In this case the calculations lead to the current-target anticorrelations. The experimental results confirm such predictions. The strenght of this effect can be supplied by the calculation of the correlation coefficient defined as follows:

$$\kappa = \frac{\langle n_c n_t\rangle - \langle n_c\rangle\langle n_t\rangle}{\sigma_c\sigma_t}. \tag{5}$$

n_c (n_t) is the number of particles in the current (target) region and σ_c (σ_t) is the standard deviation of the multiplicity distributions in current (target) region. The value of κ is limited, $-1 \le \kappa \le 1$, and in absence of the correlations $\kappa = 0$. Fig. 3 shows the dependence of the correlation coefficient κ as a function of x and Q^2. Anti-

correlations are getting stronger with descreasing x and become weaker with increasing Q^2.

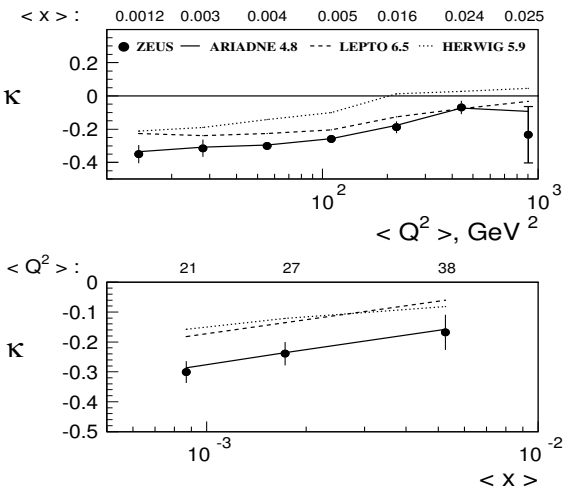

Figure 3. The evolution of the correlation coefficient κ with Q^2 and x.

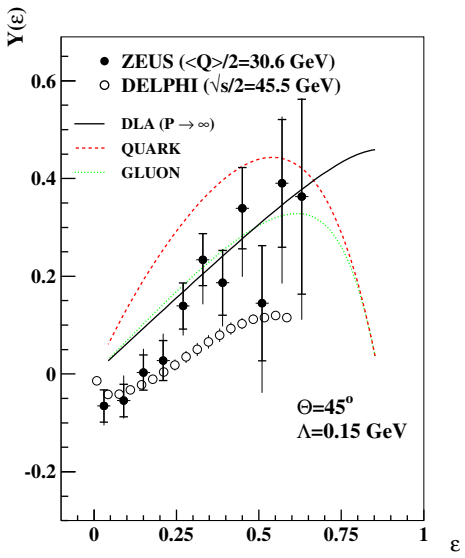

Figure 4. The angular correlations measured in DIS and e^+e^- data [12]. In addition the asymptotic DLA predictions [10] and those for final energy of the initial quark or gluon.

5. QUARK FRAGMENTATION UNIVERSALITY

The quark fragmentation universality was checked previously for single particle spectra [2] (fragmentation function and mean multiplicity) by comparison of DIS and e^+e^- data. The results support the universality of the quark fragmentation. In Fig. 4 such comparison is presented for the angular correlations $Y(\epsilon)$.

The disagreement for correlations between the DIS and e^+e^- data is observed. A large part of these differencies can be explained by influence of the first order QCD processes (BGF and QCDC) as the different jet configurations in the current and target region would change the number of migrated particles into each hemispheres.

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