MULTIPLICITY FLUCTUATIONS AND BOSE-EINSTEIN CORRELATIONS IN DIS AT HERA

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Results of the recent studies of the multiplicity fluctuations and Bose-Einstein correlations (BEC) in deep-inelastic scattering (DIS) at large Q^2 are reviewed. The measurements were done with the ZEUS detetor at HERA.

1 Introduction

Various aspects of multihadron production can be revealed through multiplicity fluctuations and particle correlations studies. The fluctuations are sensitive to soft particle dynamics and their measurements allow to test perturbative QCD [1] and local parton hadron duality (LPHD) hypothesis [2]. In BEC studies [3], the correlation function gives information about the shape, size and lifetime of the boson emitter source.

In the fluctuations studies, the method of normalized factorial moments, F_q, was used [4]. The moments of order q were calculated by counting n, the number of charged particles in a restricted region of phase space, Ω:

$$F_q(\Omega) \ = < n >^{-q} < n(n-1)\ldots(n-q+1) >, \qquad (1)$$

where $< \ldots >$ denotes averaging over the sample and Ω is defined either as a polar-angle ring around the jet axis or as an upper limit on the particle transverse or absolute momentum calculated w.r.t. the jet axis.

2 Angular multiplicity fluctuations

The factorial moments were measured as a function of the ring width θ in the corresponding cone with half opening angle Θ_0 [5]. Substituting θ with a scaling variable, $z = \ln(\Theta_0/\theta)/\ln(E\Theta_0/\Lambda)$, the experimental results can be compared with analytic calculations where E is energy of an outgoing quark radiating the gluons. The QCD + LPHD prediction for F_q is:

$$\ln\frac{F_q(z)}{F_q(0)} = z\ (1-D_q)(q-1)\ \ln(E\Theta_0/\Lambda), \qquad (2)$$

where D_q are the Rényi dimensions [6] which can be calculated either in a fixed or in a running-coupling regime (see [1]) of the Double Leading Log

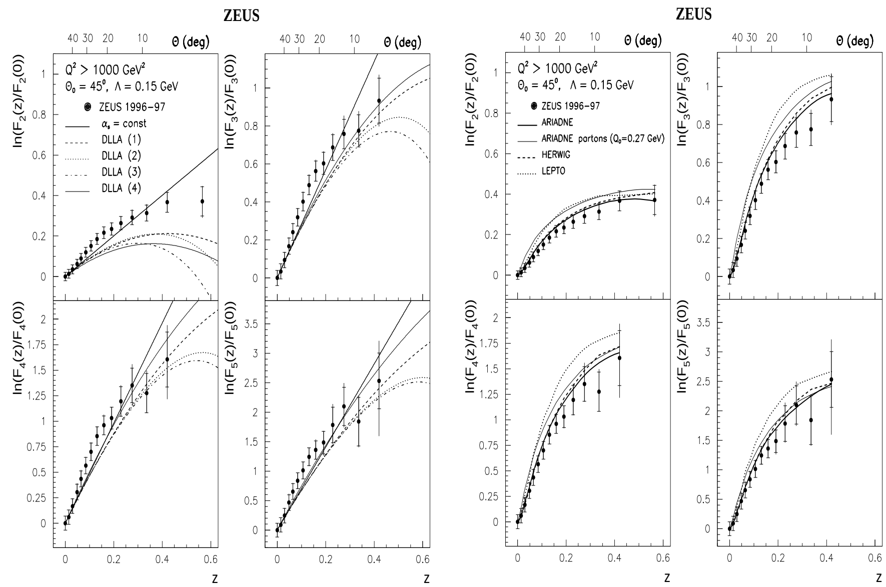

Figure 1. (Left): Comparison of the factorial moments with QCD+LPHD calculations. The curve DLLA (4) includes a correction from the MLLA in the calculation of D_q; (Right): Comparison of the factorial moments with different MC models at hadron and parton level.

Approximation (DLLA). For independent particle production: $D_q = 1$ and $F_q(z) = F_q(0)$. Figure 1(left) compares the factorial moments for the DIS data with the QCD predictions. A significant disagreement with the data was found. Figure 1(right) shows comparison with Monte Carlo predictions at hadron and parton levels. All MC models reproduce the trends seen in the data. For consistency with the LPHD picture, the parton cascade was cut-off at $Q_0 = 0.27$ GeV, which is close to $\Lambda = 0.22$ GeV. For higher order moments, the parton level is closer to the data than the analytic calculations.

3 Multiplicity fluctuations in limited momentum space

According to QCD+LPHD predictions [7], the normalized factorial moments are expected to behave as

$$F_q(p_t^{cut}) \simeq 1 + \frac{q(q-1)}{6} \frac{\ln(p_t^{cut}/Q_0)}{\ln(E/Q_0)}, \qquad F_q(p^{cut}) \simeq const(q) > 1, \tag{3}$$

when particles are restricted in either the transverse momentum $p_t < p_t^{cut}$ or in spherical momentum $p < p^{cut}$. If $p_t^{cut} \to Q_0$, then all $F_q \to 1$ and

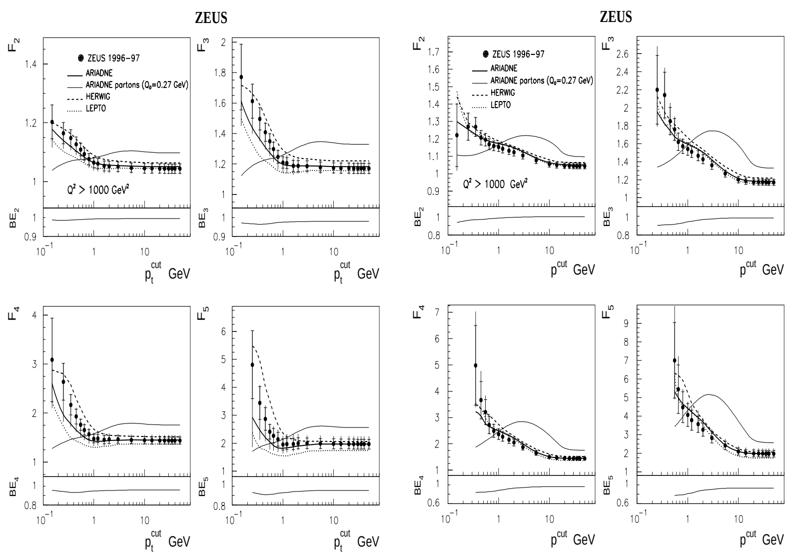

Figure 2. (Left): Comparison of the factorial moments calculated as a function of p_t^{cut} with different MC models at hadron level and parton-level ARIADNE, which represents analytic calculations and is consistent with LPHD; (Right): The same for p^{cut} factorial moments.

the multiplicity distribution approaches Poissonian distribution due to the coherence effect of soft gluons in a parton cascade. This is not the case for soft gluons with spherical momentum cut. Figure 2 shows p_t^{cut} and p^{cut} moments [5] together with Monte Carlo predictions at the hadron and parton levels. The parton level is consistent with analytic calculations. For $p_t < 1$ GeV, Fig. 2(left), all moments rise in contradiction to the analytic QCD predictions. The MC results for hadrons show similar trends to the data. The similar behaviour is found for p^{cut} factorial moments for small momentum cut off, Fig. 2(right). The observed disagreement between QCD+LPHD and the measurements is on qualitative level.

4 Bose-Einstein correlations at large $\mathbf{Q}^2$

Bose-Einstein correlations between pairs of identical bosons can be expressed by the two-particle correlation function of the Lorentz-invariant four-momentum transfer $Q_{12} = \sqrt{-(p_1 - p_2)^2}$ (p_1, p_2 are the four-momenta of the particles) : $R(Q_{12}) = \rho(Q_{12})/\rho_0(Q_{12})$, where $\rho_0(Q_{12})$ represents the two-particle density without the Bose-Einstein effect. After the corrections for

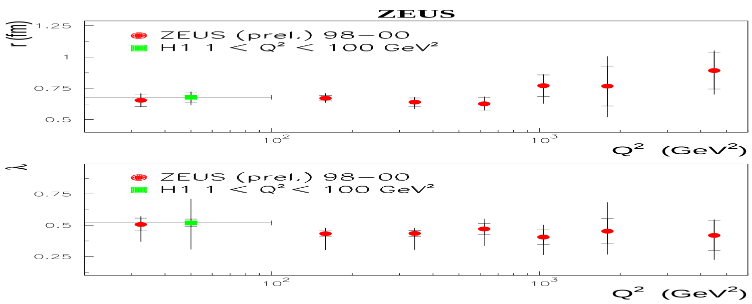

Figure 3. The radius r and strength λ of BEC as a function of Q^2.

dynamical correlations and detector effects (Monte Carlo without BEC), the correlation function R was fitted to the following expression:

$$R(Q_{12}) = \kappa(1 + \epsilon Q_{12})(1 + \lambda e^{-r^2 Q_{12}^2}), \tag{4}$$

where r estimates the size of the two-boson emitter which is taken to be of Gaussian shape, λ measures the BEC strength, factor $1 + \epsilon Q_{12}$ takes into acount possible long-range momentum correlations and κ is the normalization constant.
The BEC were studied to test of the energy dependence of r and λ. Figure 3 shows r and λ as a function of four-momentum transfer squared Q^2. No Q^2 dependence was found for r and λ. The H1 DIS results [8] at lower Q^2 are consistent with ZEUS data.

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