# MULTIPLICITY FLUCTUATIONS IN DIS

LESZEK ZAWIEJSKI
FOR THE ZEUS COLLABORATION
*HEP XII Department, Institute of Nuclear Physics, PL-30-055 Kraków, Poland*
*E-mail: leszek@chall.ifj.edu.pl*

The charged multiplicity fluctuations in deep-inelastic scattering (DIS) are investigated in order to test perturbative QCD and local parton hadron duality (LPHD). The fluctuations were measured with the ZEUS detector at HERA in restricted phase space domains in the current Breit frame region. The measurements are compared to analytic pQCD + LPHD predictions and QCD-based Monte Carlo models.

## 1 Introduction

The studies of multiplicity fluctuations in restricted domains of the phase space reveal the nature of particle correlations and are sensitive to the dynamics of the underlying process. The hadronic final state in DIS is a result of a hard partonic scattering at a large momentum transfers $Q \gg \Lambda$. A subsequent parton cascade development down to some QCD cut-off $Q_0$ and fragmentation occuring at small momentum transfers lead to the observed hadrons. The characteristic QCD scale $\Lambda$ is of the order of a few hundred MeV. At present there are two main approaches for the description of the hadronic final state: the QCD-based Monte Carlo programs and analytic perturbative QCD calculations [1] in conjunction with the Local Parton-Hadron Duality (LPHD) hypothesis [2]. In Monte Carlo programs, the partonic final state is generated according to the pQCD picture and below $Q_0 \simeq 1$ GeV the transition from partons to hadrons is performed by applying non-perturbative models. In analytic calculations, the parton cascade develops down to $Q_0$, close to $\Lambda$. In this case the direct comparison of the spectra of partons with those of hadrons becomes possible, without involving any hadronization model.

In the multiplicity fluctuations studies, the method of normalized factorial moments, $F_q$, was used [3]. Experimentally, the moments of order $q$ were calculated by counting $n$, the number of charged particles in a restricted region of phase space, $\Omega$:

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

where $< \ldots >$ denotes averaging over all events in the sample. The phase space region, of size $\Omega$, was defined either as a polar-angle ring around the jet axis or as an upper limit on the particle transverse momentum calculated with respect to the jet axis.

## 2 Angular multiplicity fluctuations

The factorial moments were measured as a function of the ring width $\theta$ in the corresponding cone with half opening angle $\Theta_0$ [4]. Substituting $\theta$ with a

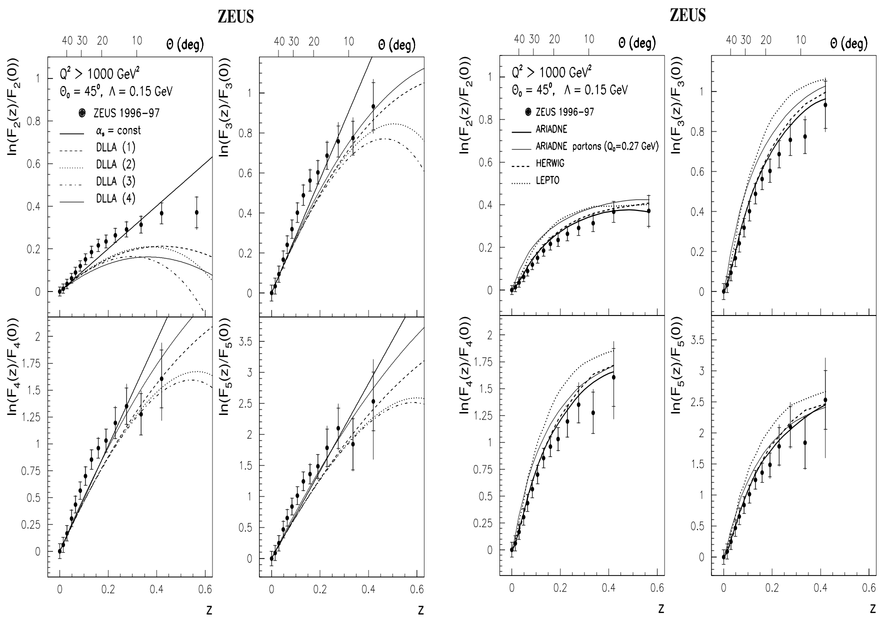


Figure 1. (Left): Comparison of the factorial moments with QCD+LPHD calculations. The curve DLLA (4) includes a correction from the MLLA in the calculation of $D_q$; (Right): Comparison of the factorial moments with different MC models at the hadron level. The parton-level from the ARIADNE MC generator, which is consistent with LPHD and represents the analytic calculation, is also shown.

scaling variable, $z = \ln(\Theta_0/\theta)/\ln(E\Theta_0/\Lambda)$, the experimental results can be compared with analytic calculations where $\Theta_0$ is the half opening angle of a cone around an outgoing quark, of energy E, 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 *Rényi* dimensions [5] and can be calculated either in a fixed-coupling regime or in a running-coupling regime (see [1] and refs. therein) of the Double Leading Log 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. For the higher order moments, an improvement is observed particularly for calculations in Modified Leading Log Approximation (MLLA) [6] (see Fig. 1(left)). The data are compared with Monte Carlo models [7,8,9] at the hadron level in Fig. 1(right). All models reproduce the trends seen in the data. The same figure also shows the parton level of ARIADNE. 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 predictions, soft gluons in a limited $p_t$ region are independently emitted due to a coherence effect [10]. For the measurements of the $p_t^{cut}$ moments, Eq. (1) was used with the requirement that all counted particles should have transverse momentum $p_t < p_t^{cut}$. The $p_t^{cut}$ multiplicity moments have been calculated using DLLA+LPHD [10]. For small values of $p_t^{cut}$, theory predicts:

$$F_q(p_t^{cut}) \simeq 1 + \frac{q(q-1)}{6} \frac{\ln(p_t^{cut}/Q_0)}{\ln(E/Q_0)}. \tag{3}$$

If $p_t^{cut} \to Q_0$, then all $F_q \to 1$ and the multiplicity distribution approaches a Poissonian distribution. Figure 2 shows $p_t^{cut}$ moments in DIS [4] together with Monte Carlo predictions at the hadron and parton levels. The partons of the ARIADNE MC generator are consistent with analytic calculations. For $p_t^{cut}$ $< 1$ GeV, all moments rise in contradiction to the analytic QCD predictions. The MC results for hadrons show similar trends to the data.

## 4 Conclusions

The multiplicity fluctuations have been measured in DIS in restricted phase space regions to test pertubative QCD. For angular factorial moments, the differences between data and analytic calculations are quantitative and become smaller for higher order moments and MLLA corrections. A qualitative disagreement between the QCD+LPHD and the data has been observed for $p_t^{cut}$ moments. This, for the first time, indicates a limit of the LPHD hypothesis applied to the multiplicity fluctuations. The MC programs show the large impact of the hadronisation stage on the multiplicity distributions.

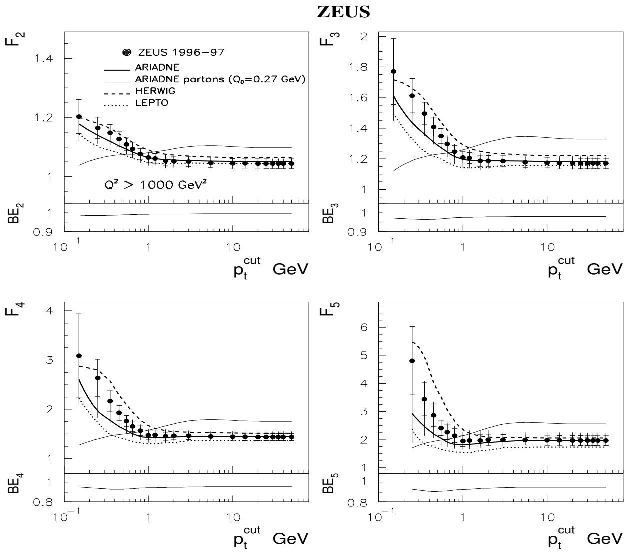


Figure 2. Comparison of the factorial moments calculated as a function of $p_t^{cut}$ with different MC models at hadron level and parton-level ARIADNE, which represents analytic calculations and is consistent with LPHD.

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