Multiplicity structure in inclusive and diffractive deep inelastic e^+p collisions at HERA

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Abstract. The multiplicity structure of the hadronic final state system X produced in diffractive deep-inelastic e^+p collisions of the type $e^+p \to e^+XY$, in which the photon dissociation system X is separated from a leading low mass baryonic state Y by a large rapidity gap, has been measured. Results are presented on charged particle multiplicity distributions and rapidity spectra. We investigate the kinematical dependences of the mean multiplicity and the particle density in rapidity space on the diffractive variables. The comparison with non-diffractive deep-inelastic e^+p collisions has been performed.

Keywords: Charged particle multiplicity, diffractive deep-inelastic e^+p collision.
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INTRODUCTION

The observation of "Large Rapidity Gap" (LRG) events in deep-inelastic (DIS) ep scattering at HERA renewed the interest in diffraction. To develop an understanding of the diffractive process, it is tempting and traditional to start from the popular pomeron picture. The pomeron is regarded as a color-singlet hadronic component in the target proton and the virtual photon in diffractive DIS (DDIS) probes the quark content of the pomeron. Just as in the case of the proton, the pomeron could then be characterized by diffractive structure functions. The pomeron structure functions should be universal if the pomeron were indeed an intrinsic part of the target proton wave function. However, striking similarities between inclusive and diffractive data in DIS have led to the insight that "the pomeron in the proton" is a dynamical effect of the interaction and thus not universal. The data provide strong hints that the underlying short-time, hard scattering sub-processes are identical in inclusive and diffractive DIS. The formation of a rapidity gap would then be a soft process happening on a longer time scale.

MULTIPLICITY DISTRIBUTION AND MOMENTS

Q^2 dependence of $\langle n \rangle$ in DIS and DDIS at fixed W

In the simple quark-parton model the properties of the hadronic system produced in DIS depend on the kinematical variables x_{Bj} and Q^2 only through the invariant mass W of the hadronic system. In QCD, weak scaling violations of the quark fragmentation

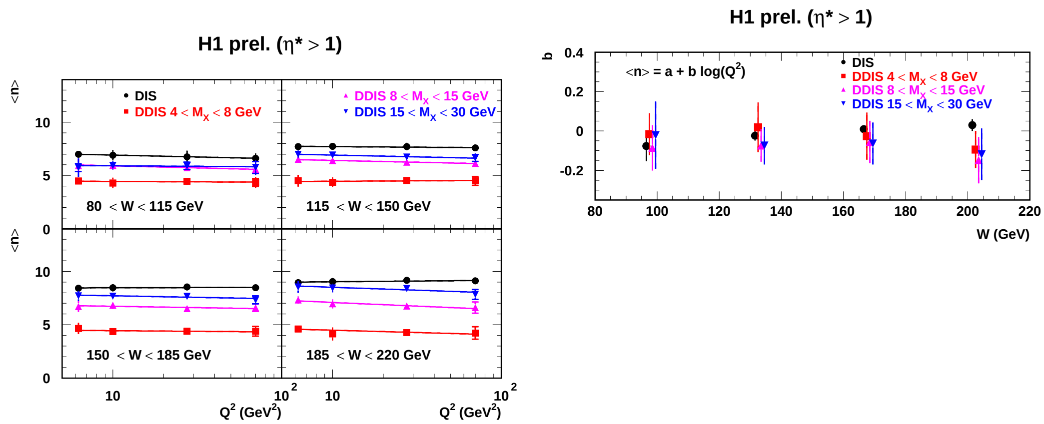

FIGURE 1. The Q^2 dependence of $\langle n \rangle$ for bins in W for either DIS and DDIS data (at fixed M_X).

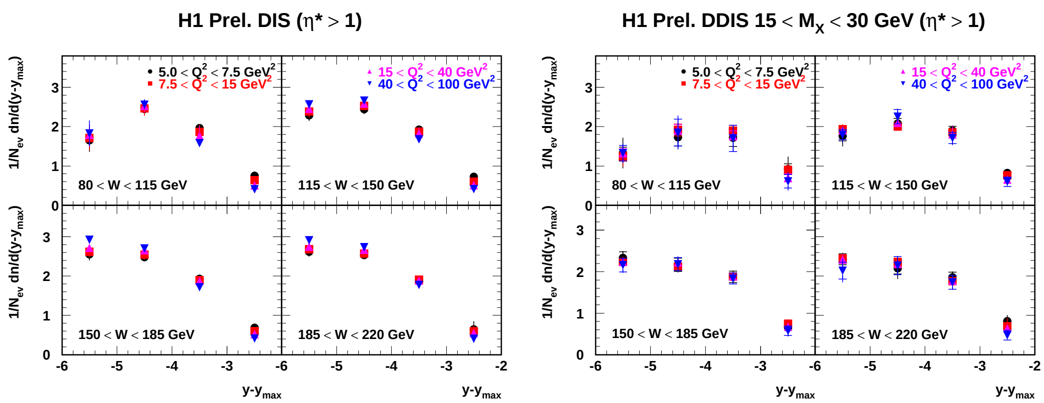

FIGURE 2. Rapidity densities in DIS and DDIS as a function of $y - y_{max}$.

functions and of the parton distributions introduce a Q^2 dependence even at fixed W. Figure 1 (left) shows the Q^2 dependence of $\langle n \rangle$ for bins in W for either DIS and DDIS data (at fixed M_X). The data were fitted to a form $\langle n \rangle = a + b\log(Q^2)$. The slopes b are given in Figure 1 (right). The data show no dependence on Q^2.

The Q^2 dependence is examined in more detail in Figure 2, where the rapidity densities in DIS and DDIS, respectively, are plotted as a function of $y - y_{max}$; $y_{max} = \ln(W/m_\pi)$ is the maximum rapidity at a given W and is calculated event-by-event. With W fixed, the spectra for DIS show little, if any Q^2 dependence. The same holds within errors for DDIS spectra at fixed M_X. We further note that the particle density is essentially independent of W. The mean multiplicity in DIS is predominantly a function of W and not of Q^2 and x separately.

β dependence of $\langle n \rangle$ at fixed M_X in DDIS

Various models view DDIS as elastic scattering of the virtual photon Fock states ($q\bar{q}$, $q\bar{q}g$, ...) off the target, with subsequent hadronisation, leading to the diffractive system X.

In such models, the relative fraction of quark and gluon fragmentation depends strongly on β.

The results for $\langle n \rangle$ are shown in Figure 3. Within errors, no dependence on β is observed when M_X is kept fixed. Combining the observation of the previous section with the results of this section, we conclude that the mean multiplicity of the diffractive system X is essentially a function of M_X only.

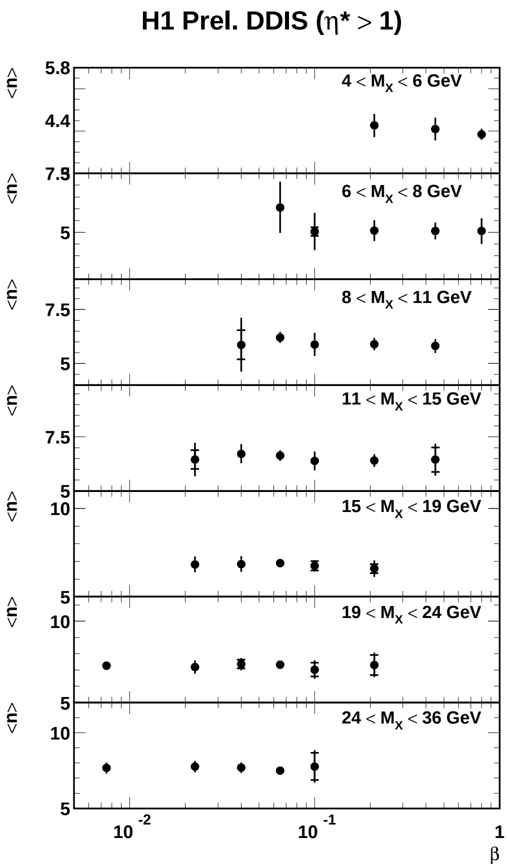

FIGURE 3. Dependence of $\langle n \rangle$ on β.

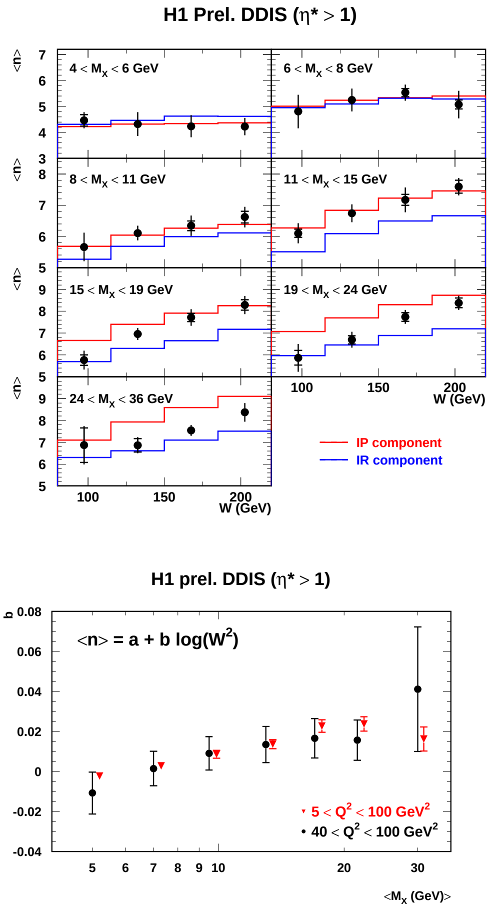

FIGURE 4. Mean multiplicity as a function of W ($x_{\mathbb{P}}$) for fixed bins in M_X.

W dependence at fixed M_X in DDIS

Based on experimental evidence, one often assumes Regge factorisation, whereby F_2^D is decomposed into a pomeron flux factor and the structure function of the pomeron. Regge factorisation states that the diffractive parton densities are independent of $x_{\mathbb{P}}$ and/or t.

Figure 4 (top) shows the mean multiplicity as a function of W ($x_{\mathbb{P}}$) for fixed bins in M_X and $5 < Q^2 < 100$ GeV^2. The curves are the predictions from the pomeron and reggeon component in the resolved pomeron picture.

Figure 4 (bottom, dots) shows the parameter b from a fit $\langle n \rangle = a + b \log(W^2)$. We observe the strongest W dependence for diffractive masses $M_X > 10$ GeV.

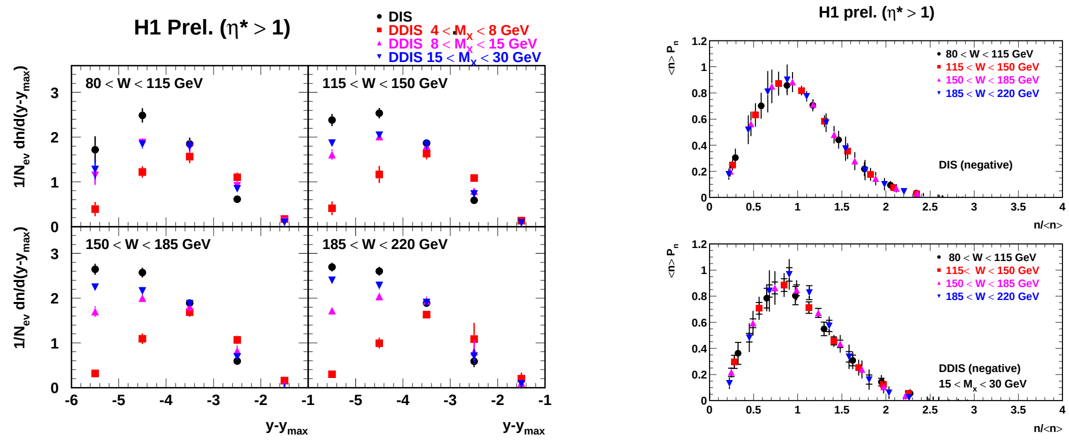

FIGURE 5. Particle density in rapidity space (left) and KNO scaling (right).

In models which assume Regge factorisation no W dependence at fixed values of M_X is expected. On the contrary, in models in which the rapidity gap formation is due to multiple soft rearrangements of colour configurations and where diffraction is a dynamical effect of the DIS interaction itself, such a W dependence occurs naturally as the energy evolution of the particle density in perturbative QCD is controlled by the anomalous multiplicity dimension $\gamma = \mathrm{d}\ln\langle n\rangle/\mathrm{d}\ln W^2$.

Regge factorisation breaking is also expected in multiple scattering (absorption) models. For DIS these effects are predicted to diminish with increasing Q^2. Figure 4 (bottom, triangles) shows the mean multiplicity only in the highest Q^2 bin ($40 < Q^2 < 100$ GeV^2). Factorisation breaking is, within the errors, not dependent on Q^2.

COMPARISON OF DIS AND DDIS

Figure 5 (left) shows the particle density in rapidity space as a function of $y - y_{max}$ for DIS and DDIS data (at fixed M_X).

In rapidity regions sufficiently far away from the gap (right side), we observe that the particle density is remarkably similar for DIS and DDIS at the highest M_X.

To demonstrate the energy scaling of the multiplicity distribution in DIS and DDIS, Figure 5 (right) shows the KNO distributions $\langle n\rangle P(n)$ versus $n/\langle n\rangle$ for different values of W, for negative particles in the domain $\eta^* > 1$. We observe, within the errors, KNO scaling for DIS and DDIS. The shape of the KNO distribution is similar for DIS and DDIS.

CONCLUSIONS

The charged particle multiplicity structure has been studied for DIS and DDIS events. The main kinematical variable for DIS is W and for DDIS it is M_X. The similarities for DIS and DDIS are in favor of models which incorporate the scattering of the virtual photon on the proton itself. The formation of a rapidity gap would then be a soft process happening on a longer time scale.