VIRTUAL PHOTON STRUCTURE AT HERA

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On behalf of the ZEUS Collaboration.

Measurements of the structure of the virtual photon in the transition region between quasi-real photons and those far from mass-shell have been made with the ZEUS detector at HERA, using an integrated luminosity of 38 pb^{-1}. Dijet final states are identified, and differential cross sections are presented in terms of $x_\gamma^{\rm OBS}$, an estimator of the fraction of the photon energy which takes part in the QCD subprocess. Comparison is made to theoretical predictions.

1 Introduction

HERA allows for studies of jet production in a wide range of photon virtualities, Q^2, and transverse energies of jets. In the deep inelastic scattering (DIS) regime, Q^2 typically above 10 GeV^2, the interaction between the incoming positron and proton is mediated by a structureless virtual photon. On the other hand, in the photoproduction regime, $Q^2 \simeq 0$ GeV^2, the photon may interact as an entity, i.e. the direct component, or as a source of partons, i.e. the resolved component, where one of these partons, carrying a fraction of the photon's momentum, x_γ, enters the hard subprocess. Resolved photoproduction is commonly described via parton distribution functions which receive contributions from both perturbative and non-perturbative terms.

This paper studies jet production in a large range of photon virtualities, including the transition region from photoproduction to DIS, with the aim of understanding the evolution of the photon structure with increasing photon virtuality.

The study of jet production introduces a second energy scale, e.g. $\overline{E}_T$, the average transverse energy of the two highest E_T jets in a given event, and allows the determination of x_γ through [1]:

$$x_\gamma^{\rm OBS} = \frac{\sum_{\rm jets} E_T^{\rm jet} {\rm e}^{-\eta^{\rm jet}}}{2yE_e} \ , \qquad (1)$$

where $E_T^{\rm jet}$ is the transverse energy of the jet and $\eta^{\rm jet}$ is the pseudorapidity, defined as a function of the polar angle $\theta^{\rm jet}$: $\eta^{\rm jet} = -\ln(\tan\frac{\theta^{\rm jet}}{2})$.

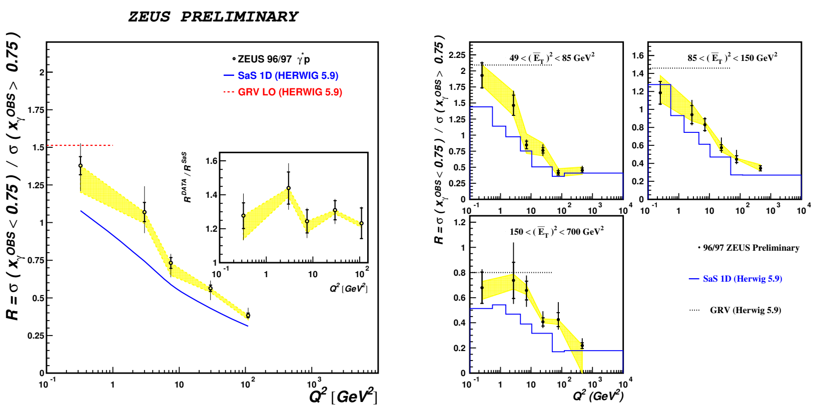

Figure 1. The ratio of cross sections $R = \sigma(x_\gamma^{\rm OBS} < 0.75)/\sigma(x_\gamma^{\rm OBS} > 0.75)$ as a function of Q^2 (left) and the same ratio in different ranges of $\overline{E}_T^2$ (right). The solid line is the HERWIG MC using the SaS1D parametrization for the photon PDFs and the dotted horizontal line is the HERWIG prediction using the GRV parametrization for the real photon PDFs.

At leading order (LO) perturbative QCD for $x_\gamma^{\rm OBS} > 0.75$, the direct component dominates, while the $x_\gamma^{\rm OBS} < 0.75$ region is sensitive mainly to the resolved component. However, events with low values of $x_\gamma^{\rm OBS}$ can also be produced when initial- and final-state parton showers give rise to hadronic activity outside the dijet system. In pQCD, $x_\gamma^{\rm OBS}$ is well defined at all orders. Hence, measurements based on it can be compared with theoretical predictions at any given order.

Triple differential cross sections with respect to Q^2, $\overline{E}_T$ and $x_\gamma^{\rm OBS}$ are compared to LO MC predictions based on different extrapolations of the real photon structure to higher virtualities.

2 Results and discussion

The dijet differential cross sections, $d^3\sigma/(dx_\gamma^{\rm OBS} dQ^2 d\overline{E}_T^2)$ corrected to the hadron level, have been measured using the $\mathrm{k_T}$ jet algorithm in the $\gamma^* p$ frame. The measured cross section is for dijet events in the pase-space region defined by: $0.2 < y < 0.55$, and $0.1 < Q^2 < 0.55$ GeV^2, $1.5 < Q^2 < 10^4$ GeV^2.

The ratio of cross sections $R = \sigma(x_\gamma^{\rm OBS} < 0.75)/\sigma(x_\gamma^{\rm OBS} > 0.75)$ as a function of Q^2 is shown in Fig. 1 (left). The ratio falls with increasing Q^2. In the inset the ratio of the data with the HERWIG [2] prediction using the

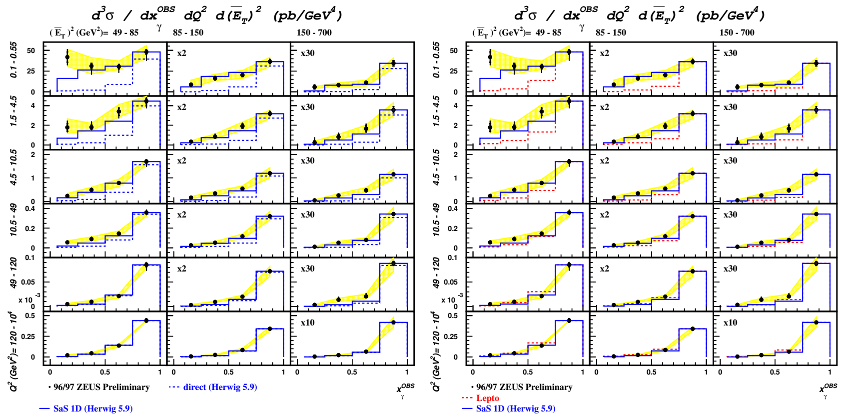

Figure 2. Triple differential cross section $d^3\sigma/(dx_\gamma^{\rm OBS}dQ^2d\overline{E}_T^2)$ as a function of $x_\gamma^{\rm OBS}$ for different regions in Q^2 and $\overline{E}_T^2$. The points represent the measured cross sections with statistical errors (inner error bars) and uncorrelated systematic errors added in quadrature to them (outer error bars). The shaded bands display the uncertainty in the plotted quantities due to that in the jet energy scale. In the left plot the solid line is the HERWIG MC using the SaS1D parametrization for the photon PDFs and the dashed line is the LO-direct part only from HERWIG. In the right plot the solid line is the same and the dashed line is the prediction using the LEPTO MC.

SaS1D parametrization [3] for the photon PDFs is presented. There is no dependence of this ratio with the photon virtuality. The ratio R in three ranges of $\overline{E}_T^2$ is also shown in Fig. 1 (right). The ratio of the data falls with increasing Q^2 for each range of $\overline{E}_T^2$. These results can be interpreted as showing the suppression of the virtual photon structure with increasing photon virtuality. The HERWIG prediction using SaS1D also falls with increasing Q^2 but underestimates the measured ratio.

The measured triple differential dijet cross sections $d^3\sigma/(dx_\gamma^{\rm OBS}dQ^2d\overline{E}_T^2)$ are shown as a function of $x_\gamma^{\rm OBS}$ in Fig. 2 in different regions of Q^2 and $\overline{E}_T^2$. In the left plot the LO HERWIG predictions using the SaS1D parametrization of the photon PDFs are shown as well as the LO-direct part only of the HERWIG predictions. The HERWIG predictions do not describe the absolute cross section of the data and are therefore normalized to the highest $x_\gamma^{\rm OBS}$ bin ($x_\gamma^{\rm OBS} > 0.75$) in order to compare the shape of the data with that of the MC predictions.

For each $\overline{E}_T^2$ bin, the cross section in the low $x_\gamma^{\rm OBS}$ region falls faster with increasing Q^2 than the cross section in the high $x_\gamma^{\rm OBS}$ region. For the bins with $Q^2 > \overline{E}_T^2$ the data are well described by the HERWIG predictions including only the LO-direct component. In the bins with $Q^2 < \overline{E}_T^2$ the LO-direct component is not enough to describe the data.

In the right plot of Fig. 2 a comparison of the cross sections with the LEPTO [4] MC is shown. For $Q^2 > \overline{E}_T^2$, LEPTO describes the data. LEPTO is a DIS MC generator and this region is the one where LEPTO is expected to be valid.

3 Conclusions

Dijet triple differential cross sections, $d^3\sigma/(dx_\gamma^{\rm OBS} dQ^2 d\overline{E}_T^2)$, have been measured using the longitudinally invariant $\mathrm{k_T}$ jet algorithm in the $\gamma^* p$ frame for $10^{-1} < Q^2 < 10^4$ GeV^2 and $0.2 < y < 0.55$. The cross sections are measured for jets with $-3 < \eta^{\rm jet} < 0$, $E_{T,1}^{\rm jet} > 7.5$ GeV, and $E_{T,2}^{\rm jet} > 6.5$ GeV in different bins of Q^2 and $\overline{E}_T^2$.

The $x_\gamma^{\rm OBS}$ dependence of the measured cross sections varies with increasing Q^2 and $\overline{E}_T^2$. In each region of $\overline{E}_T^2$, the low-$x_\gamma^{\rm OBS}$ cross section decreases rapidly as Q^2 increases.

The predictions of HERWIG using the SaS1D photon PDFs describe the cross sections well for $Q^2 > \overline{E}_T^2$. In this region, the LO direct component alone describes the data well. For $Q^2 < \overline{E}_T^2$, a resolved component is needed.

The ratio $R = \sigma(x_\gamma^{\rm OBS} < 0.75)/\sigma(x_\gamma^{\rm OBS} > 0.75)$ for dijet cross sections decreases as Q^2 increases in all the $\overline{E}_T^2$ regions. However, the measured ratio lies above the predictions of HERWIG using the SaS 1D photon PDFs. The data may be interpreted in terms of a resolved component that is suppressed as the photon virtuality increases.

References

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