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STUDY OF VIRTUAL PHOTON STRUCTURE IN CHARM PRODUCTION AT HERA*

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The dependence of the virtual-photon structure on its virtuality, Q^2, has been studied in events containing dijets and a charm quark with the ZEUS detector at HERA using an integrated luminosity of $103.7\,\mathrm{pb}^{-1}$. The measurement was performed in the kinematic range $Q^2 < 5 \times 10^3\ \mathrm{GeV}^2$ using events containing a $D^{*\pm}(2010)$ meson. Events having two jets with large transverse energies were selected using the k_T clustering algorithm. The ratio of dijet cross sections at low x_γ^{obs} ("resolved photon") relative to high x_γ^{obs} ("direct photon") was measured as a function of Q^2, where x_γ^{obs} is the fractional momentum of the photon participating in the dijet production, and is compared to the predictions of leading order pQCD. The ratio does not change significantly with Q^2, in marked contrast to previous dijet measurements which did not require the presence of charm.

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1. Introduction

The need for a partonic structure to the quasi-real photon ($Q^2 < 1\mathrm{GeV}^2$) is well established, both from studies of $\gamma\gamma$ processes at LEP [1], and jet photoproduction at HERA. Such processes can be separated into two components: direct photon processes, with the photon acting as a point-like probe of the proton and the majority of the momentum of the photon taking part in the hard subprocess, and resolved photon processes, with the photon acting as a source of partons, which carry a small fraction of the photon's momentum and take part in the hard subprocess. This behaviour

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can be described in terms of a photon parton density function (PDF). The photon PDF can then be evolved in Q^2 perturbatively to extend to virtual photons [2]. It is expected, however, that as Q^2 becomes non zero, the resolved component will be suppressed logarithmically with Q^2, with only direct processes remaining above the cut off, $Q^2 \sim (E_{\rm T}^{\rm jet})^2$, where $E_{\rm T}^{\rm jet}$ is the jet transverse energy. Studies of inclusive dijet production in DIS at HERA indeed support these predictions [3, 4].

Studies of dijet photoproduction, where the presence of charm is demanded in the final state, also strongly suggest a suppression of the photon structure dependent upon the mass of the parton in the photon [5]. The question of how this suppression evolves with Q^2 and whether the suppression due to the presence of charm and that due to non-zero photon virtuality share a common physical mechanism are addressed here.

2. Event selection

Events were selected from the data collected with the ZEUS detector at HERA during 1996–2000, corresponding to an integrated luminosity of 103.7 pb^{-1}. The ratio of dijet cross sections for low to high $x_\gamma^{\rm obs}$ have been measured as a function of Q^2 in the restricted kinematic region:

- $0.2 < y < 0.65$;
- $E_{\rm T}^{jet1,2} > 7.5, 6.5{\rm GeV}$, $|\eta^{\rm jet}| < 2.4$;
- $p_{\rm T}(D^*) > 3.0{\rm GeV}$, $|\eta(D^*)| < 1.5$;
- $Q^2 < 1.0$, $1.0 < Q^2 < 4.5$, $4.5 < Q^2 < 10.5$, $10.5 < Q^2 < 49.0$, $49.0 < Q^2 < 5000.0{\rm GeV}^2$;

Jets were reconstructed using the longitudinally invariant $K_{\rm T}$ clustering algorithm in the laboratory frame [6]. $D^*(2010)$ mesons were reconstructed and the number of D^*s extracted using a three parameter unbinned fit to the distribution of $\Delta M = m(K\pi\pi_s) - m(K\pi)$. Events where direct or resolved processes dominate were separated experimentally using the quantity $x_\gamma^{\rm obs}$ [7];

$$x_\gamma^{\rm obs} = \frac{\Sigma_{\rm dijets} E_{\rm T}^{\rm jet} {\rm e}^{-\eta^{\rm jet}}}{2yE_e}\,.$$

3. Comparison to LO QCD predictions

The ratio of cross sections $\sigma(x_\gamma^{\rm obs} < 0.75)/\sigma(x_\gamma^{\rm obs} > 0.75)$ as a function of Q^2 has been measured and is compared to various LO pQCD models in figures 1 and 2. Within uncertainties, the measured ratio is consistent with being flat with Q^2.

Figure 1 shows two predictions from the HERWIG [8] Monte Carlo generator, using the SaS1D photon PDF [2], both with and without a suppression of photon structure with increasing virtuality, Q^2. Whilst the data slightly favour the model with suppression enabled, the uncertainty on the measurement does not allow discrimination between the models. The comparison of the two HERWIG predictions confirms that the expected suppression has a physical origin, and is not a consequence of some kinematic bias.

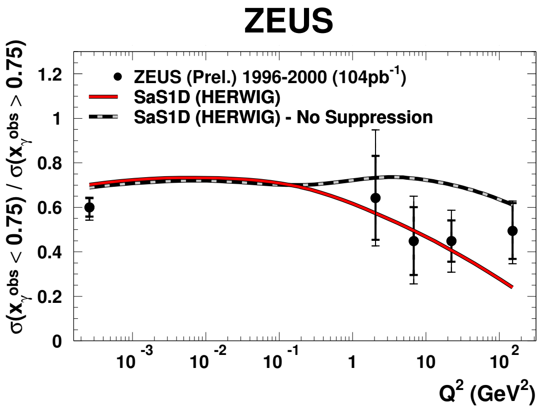

Fig. 1. Ratio of low to high $x_\gamma^{\rm obs}$ for dijet events containing a D^*, compared to the LO predictions of SaS1D virtual photon structure function.

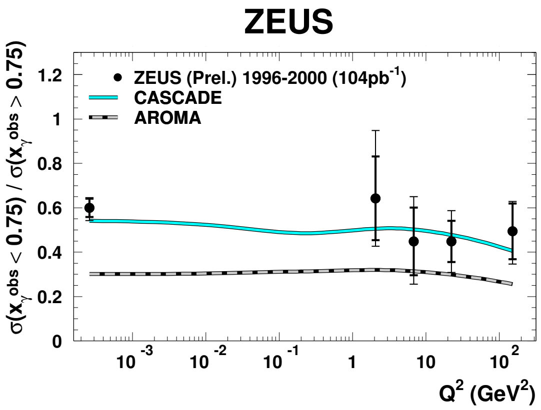

Fig. 2. Comparison of the measured data, to the LO predictions of AROMA implementing the DGLAP evolution scheme and CASCADE implementing CCFM evolution.

Figure 2 shows a comparison to two models where no photon structure has been explicitly assumed, with the low-$x_\gamma^{\rm obs}$ contribution coming from the parton-shower evolution. The AROMA [9] model, implementing the DGLAP [10] evolution scheme, is observed to lie consistently below the data across the whole range. The CASCADE [11] model, implementing a version of the CCFM [12] evolution scheme, is seen to describe the data well.

4. Comparison to inclusive case

That the measured ratio does not change significantly with Q^2 is in marked contrast to studies where no charm tag is required. In order to meaningfully compare this result to that of the inclusive case, it is important to understand both the precise origin of the data's shape, and any bias introduced due to the restricted D^* kinematics. MC studies have shown that D^*'s from resolved events are indeed more heavily suppressed by the $p_{\rm T}(D^*)$ and $|\eta(D^*)|$ cuts than the direct [13], leading to some artificial suppression of the ratio. The effect of extrapolating to the entire D^* kinematic region has been estimated using Herwig MC and is shown in figure 3.

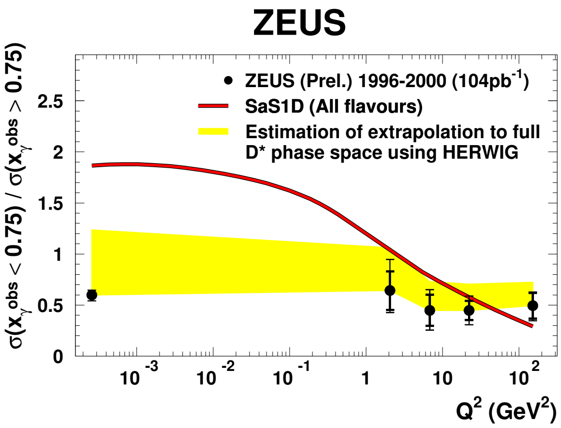

Fig. 3. Comparison of the measured data, with a D^* tag, to the prediction of SaS1D virtual photon structure function for the inclusive ratio, with no D^* tag. The shaded band represents an estimate of the maximum suppression due to D^* kinematics.

It is not possible to compare directly to previous measurements of virtual-photon structure since this analysis is carried out in a different kinematic region. However, in figure 3, the result is compared to a prediction of Herwig with SaS1D [8] virtual-photon PDF for all flavours in the same kinematic region. It is clear that the resolved photon component falls off much less rapidly in the presence of charm than it does when charm is not required.

This apparent contrast strongly suggests that the two suppressions, that due to the presence of charm and that due to increasing photon virtuality, are not independent.

5. Summary

The ratio of cross sections for low to high $x_\gamma^{\rm obs}$ regions as a function of Q^2 has been measured for dijet events containing a D^* meson, and is found to be approximately flat. The result has been compared to several LO QCD models, and in order to describe the data it appears necessary to either introduce a virtual photon PDF to DGLAP evolution or to implement CCFM evolution where no explicit photon PDF is assumed.

After corrections for the D^* kinematics, the ratio was found to fall off much less rapidly in the presence of charm than in the inclusive case, implying that the suppressions of the resolved photon component due to charm and that due to increasing photon virtuality are not independent.

REFERENCES

[1] ALEPH Coll., R. Barate *et al.*, *Phys. Lett.* **B458**, 152 (1999).

[2] G.A. Schuler, T. Sjostrand, `hep-ph/9601282`.

[3] ZEUS Coll. The Q^2 and $E_{\rm T}^2$ dependence of dijet cross sections in $\gamma^* p$ interactions at HERA, Contributed paper 636 to EPS 2001, Budapest, Hungary.

[4] K. Sedlak *et al*, Structure of virtual photons at HERA, Photon 2001, Ascona, Switzerland.

[5] ZEUS Coll. (J. Breitweg *et al.*) *Eur. Phys. J.* **C6**, 67 (1999).

[6] S. Catani *et al*, *Nucl. Phys. Proc. Suppl.* **29A**, 136 (1992).

[7] ZEUS Coll., Three-jet distributions in photoproduction at HERA, Contributed paper 544 to ICHEPP 1999, Tampere, Finland.

[8] G. Marschesini *et al*, *Comput. Phys. Commun.* **67**, 465 (1992).

[9] G. Ingleman *et al*, *Comput. Phys. Commun.* **101**, 135 (1997).

[10] V.N. Gribov, L.N. Lipov, *Sov. J. Nucl. Phys.* **15**, 438 (1972). L.N. Lipatov, *Sov. J. Nucl. Phys.* **20**, 94 (1975). G. Altarelli, G. Parisi, *Nucl. Phys.* **B126**, 298 (1977). Yu.L. Dokshitzer, *Sov. Phys. JETP* **46**, 641 (1977).

[11] H. Jung, G.P. Salam, *Eur. Phys. J.* **C19**, 351 (2001).

[12] M. Ciafaloni, *Nucl. Phys.* **B296**, 49 (1988).

[13] B. J. West, Charm and the Virtual Photon at HERA and a Global Tracking Trigger for ZEUS., DESY-Thesis-2001.