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Deeply virtual compton scattering and light cone wave function

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Abstract. This paper reports the measurement of the cross section for the exclusive production of a real photon in diffractive interactions ($ep \to e\gamma p$) and the measurement of the electromagnetic component of the photon light-cone wave function (LCWF).

1 Deeply virtual compton scattering

1.1 Introduction

Deeply Virtual Compton Scattering (DVCS) can be regarded as elastic scattering of a virtual photon off the proton with the exchange of a colourless object. In the presence of a hard scale, $Q^2 >> \Lambda^2_{\mathrm{QCD}}$, perturbative QCD (pQCD) can be applied. At the lowest order of pQCD calculations, this exchange involves two gluons in a colourless configuration with different longitudinal and transverse momenta. These unequal momenta arise as a consequence of the mass difference between the incoming virtual photon and the outgoing real photon. The DVCS amplitude factorises into a hard-scattering part, calculable in pQCD and a soft part which can be absorbed into the GPDs [1]. The kernels of the evolution equations for the GPDs are known to next-to-leading order (NLO) [2,**?**] and thus the GPDs can be evaluated at all values of Q^2 given an input at some starting scale. The cross section at sufficiently large Q^2 is expected to rise steeply with increasing the centre-of-mass energy of the virtual photon-proton system, W, due to the rise of the parton densities in the proton towards small values of the Bjorken scaling variable x.

The data were collected with the ZEUS detector at HERA in collisions of 27.5 GeV positrons with 820 GeV protons (96-97) and in collisions of 920 GeV proton with both positrons and electrons (98-00). The integrated luminosity of the e^+p and e^-p sample correspond to 95 pb^{-1} and 17 pb^{-1} respectively. The kinematic range is $Q^2 > 5$ GeV^2 and $40 < W < 140$ GeV.

1.2 Results for the DVCS

The Q^2 dependence of σ_{DVCS} interactions measured at the reference value $< W >=$ 89 GeV is shown in Fig. 1.

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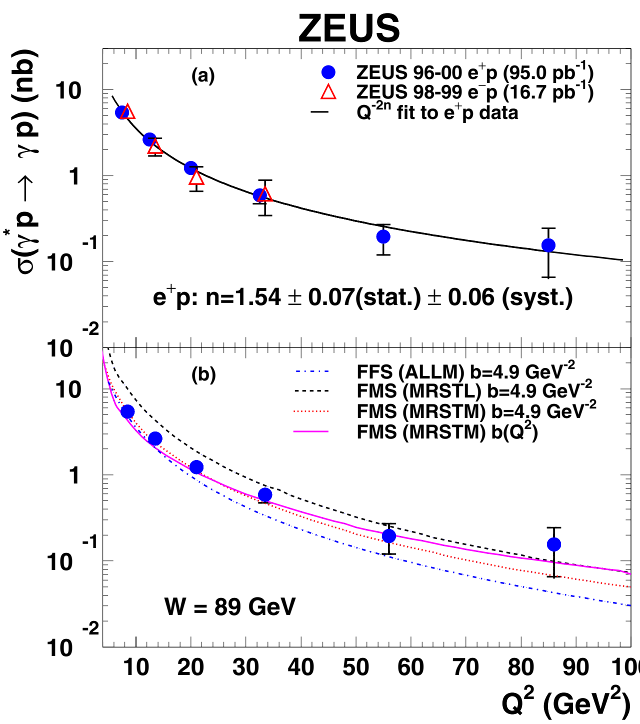

Fig. 1. a The DVCS cross section $\sigma(\gamma^* p \to \gamma p)$ as a function of Q^2 for $< W >=$ 89 GeV, for e^+p data (*dots*) and e^-p data (*triangles*); the *solid line* shows the result of the fit (*see text*)

The e^+p and e^-p measurements are consistent within the uncertainties. Fits of the form Q^{-2n} to the e^+p and e^-p data give n $= 1.54 \pm 0.07$ (stat.) $\pm$ 0.06(syst.) and $n = 1.69 \pm 0.21$(stat.) $^{+0.09}_{-0.06}$(syst.), respectively. These values are lower than in the case of exclusive vector meson production [4,5] at the same W, where $n \approx 2$. A comparison of the cross section as a function of Q^2, for fixed W, with the pQCD predictions of Freund, McDermott and Strikman based on the MRST parameterisation of the parton distribution functions (PDFs) [6,7] is presented in Fig. 1b. The two curves represent the predictions made

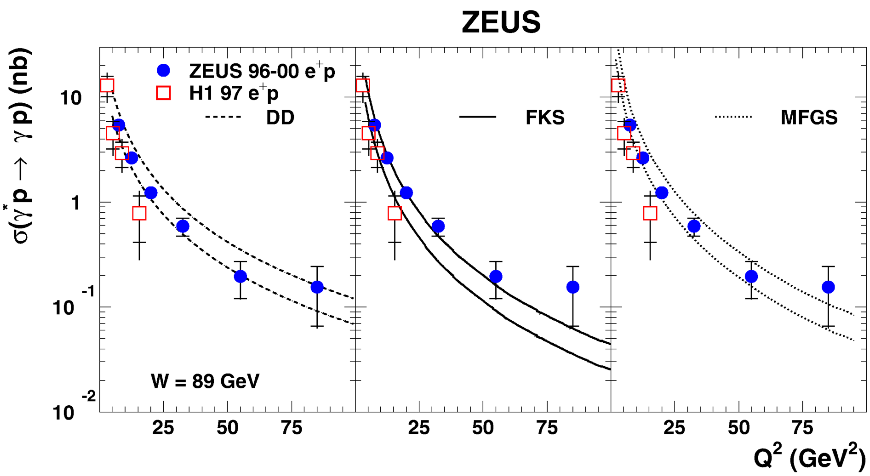

Fig. 2. The DVCS cross section, $\sigma(\gamma^* p \to \gamma p)$ as a function of Q^2 for ZEUS (*dots*) and H1 (*squares*) data compared to predictions based on colour-dipole models

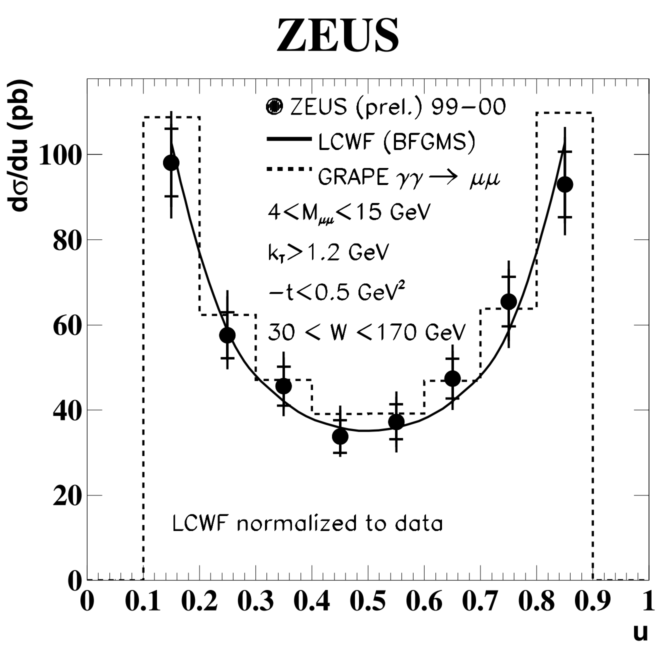

Fig. 3. Differential cross section $d\sigma/du$ measured for $30 < W < 170\,\mathrm{GeV}$, $4 < M_{\mu\mu} < 15\,\mathrm{GeV}$, $k_T > 1.2\,\mathrm{GeV}$ and $-t < 0.5\,\mathrm{GeV}^2$. The *dashed histogram* represents the GRAPE Monte Carlo. The *solid curve* represents the BFGMS prediction [3] for the photon LCWF [15]

using the LO(MRSTL) and NLO (MRSTM) versions of the PDFs, the latter of which is closer to the data. The t slope b was assumed 4.9 GeV^{-2} in both cases. The third curve corresponds to predictions based on MRSTM, which assumes a Q^2-dependent b value. The best agreement between the data and the prediction is achieved using $b = 8[1 - 0.15\ln(Q^2/2)]$ GeV^{-2}, a parameterisation that describes the production of vector mesons at HERA. The data are also compared to the expectations of FFS [8], assuming $b = 4.9\,\mathrm{GeV}^{-2}$; for $Q^2 > 20\,\mathrm{GeV}^2$ the predictions underestimate the data.

The DVCS cross section has also been calculated using colour-dipole models, which have been successful in describing both the inclusive and the diffractive DIS cross sections at high energies [9,10,11,12]. The various dipole models differ in their formulation of the dipole cross section. The Q^2 dependence of σ_{DVCS} has been compared to the expectations of three colour-dipole models, by Donnachie and Dosch (DD) [12], Forshaw, Kerley and Shaw (FKS) [9,13] and McDermott, Frankfurt, Guzey and Strikman (MFGS) [14,11]. The comparisons are shown in Fig. 2, for two different values of b, $b = 4\,\mathrm{GeV}^{-2}$ (upper curve) and $b = 7$ GeV^{-2} (lower curve) assumed for the models. All three models give an acceptable description of the data. Also shown are the H1 measurements [15], extrapolated to $W = 89\,\mathrm{GeV}$ using the W^δ dependence of the measured e^+p cross section.

2 Light cone wave function of the photon

2.1 Introduction

The internal structure of hadrons and photons is described by light cone wave functions (LCWF) that are essential quantities for understanding the interactions of hadrons. While the electromagnetic component of the photon LCWF can be calculated within QED, the hadronic component is model dependent and must therefore be confronted with data.

The present measurement of the electromagnetic component of the photon LCWF was performed using a sample of $ep \to ep\mu^+\mu^-$ events, collected with the ZEUS detector during 99-00 years, corresponding to an integrated luminosity of $55.4\,\mathrm{pb}^{-1}$.

2.2 Results for LCWF

The cross section, measured as a function of the variable u, the longitudinal momentum-fraction carried by the muon of a given sign, is presented in Fig. 3 and compared to theoretical predictions (BFGMS) [16] normalized to the data. For this purpose, the predictions were adapted to the muon's analysis: $\Phi^2_{\mu\mu/\gamma} = (u^2 + (1-u)^2)/(M^2_{\mu\mu}u(1-u) - m^2_{\mu\mu})$. The data were also compared to the predictions of the Monte Carlo generator GRAPE [17]. This program is an event generator for dilepton production in ep collisions and it is based on exact matrix elements. The predictions are in agreement with the data.

The present measurement provides the first evidence that diffractive dissociation of particles can be reliably used to measure the LCWFs. Furthermore, it gives support to the method used in previous measurements of the pion LCWF [18,19] and to possible future applications [20].

References

1. J.C. Collins and A. Freund: Phys. Rev. D **59**, 74009 (1999)
2. A. Freund and M. McDermott: Eur. Phys. J. C **23**, 651 (2002)
3. A. Freund and M. McDermott: Phys. Rev. D **65**, 091901 (2002)
4. ZEUS Coll., J. Breitweg et al.: Eur. Phys. J. C **6**, 603 (1999)
5. H1 Coll., C. Adloff et al.: Phys. Lett. B **483**, 360 (2000)
6. R.S. Thorne et al.: Preprint hep-ph/0106075, (2001)
7. A.D. Martin et al.: Nucl. Phys. Proc. Suppl. **79**, 105 (1999)
8. L.L. Frankfurt, A. Freund, and M. Strikman: Phys. Rev. D **58**, 114001 (1998) Erratum-ibid D **59**, 119901 (1999)
9. J.R. Forshaw, G. Kerley, and G. Shaw: Phys. Rev. D **60**, 074012 (1999)
10. E. Gotsman, E. Levin, and U. Maor: Phys. Lett. B **425**, 369 (1998)
11. M. McDermott et al.: Eur. Phys. J. C **16**, 641 (2000)
12. A. Donnachie and H.G. Dosch: Phys. Lett. B **502**, 74 (2001)
13. J.R. Forshaw, G. Kerley, and G. Shaw: Nucl. Phys. A **675**, 80c (2000)
14. M. McDermott, R. Sandapen, and G. Shaw: Eur. Phys. J. C **22**, 655 (2002)
15. H1 Coll., C. Adloff et al.: Phys. Lett. B **517**, 47 (2001)
16. S.J. Brodsky, L. Frankfurt, J.F. Gunion, A.H. Mueller, and M. Strikman: Phys. Rev. D **50**, 3134 (1994)
17. T. Abe: Comp. Phys. Comm. **136**, 126 (2001)
18. E791 Collaboration E.M. Aitala et al.: Phys. Rev. Lett. **86**, 4768 (2001)
19. E791 Collaboration E.M. Aitala et al.: Phys. Rev. Lett. **86**, 4773 (2001)
20. D. Ashery: Comments on Modern Physics **2A**, 235 (2002)