TOTAL PHOTOPRODUCTION CROSS SECTION AT $W_{\gamma p}$ OF 200 GEV AND ITS DECOMPOSITION

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H1 COLLABORATION

A new measurement of the total photoproduction cross section performed with the H1 detector at HERA is presented. For an average center of mass energy of 200 GeV for the photon proton subsytem a value of $\sigma_{tot} = 165 \pm 2 \pm 11\ \mu$b has been obtained. A detailed analysis of the data in adequate kinematical regions allowed for a decomposition of the total cross section in its elastic and single diffractive parts, based on safe estimates of the double diffractive contribution.

1 Introduction

The interaction of electrons and protons at the HERA collider ($E_e = 275$GeV, $E_p = 820$GeV) is dominated by photoproduction processes, in which the electron scatters through small angles emitting a quasi real photon, which then interacts with the proton.

A small angle electron detector[1] (electron tagger) located 33 m away from the nominal H1 interaction point is used to trigger on photoproduction events. It accepts electrons with scattering angles $\Theta' \leq 5\,$mrad. This corresponds to a virtuality of the photon of $Q^2 < 0.01\text{GeV}^2$.

The center of mass energy of the γp-subsystem $W_{\gamma p}$is directly related to the energy of the scattered electron E'_e. The acceptance of the tagger limits $W_{\gamma p}$ to the range $163 < W_{\gamma p} < 249$ GeV, with an average value of 200 GeV.

2 Photoproduction

The total photoproduction cross section, $\sigma_{tot}^{\gamma p}$ may be related to the differential ep cross section by the Weizsäcker-Williams formula for the photon flux $F(y, Q^2)$:

$$\frac{d^2\sigma^{ep}(s)}{dydQ^2} = \sigma_{tot}^{\gamma p}(ys)(1+\delta_{RC})F(y,Q^2) \qquad (1)$$

$$F(y,Q^2) = \frac{\alpha}{2\pi Q^2}\left(\frac{1+(1-y)^2}{y} - \frac{2(1-y)}{y}\cdot\frac{Q^2_{min}}{Q^2}\right) \qquad (2)$$

where $y = 1 - E'_e/E_e \cdot \sin^2(\theta/2)$, $s = (300\text{GeV})^2$ and $Q^2_{min} = (m_e y)^2/(1-y)$. θ is the polar angle with respect to the proton beam direction (z-axis). The factor $(1+\delta_{RC})$ takes QED radiative corrections to the Born cross section $\sigma_{tot}^{\gamma p}$ into account. A dependence of $\sigma_{tot}^{\gamma p}$ on Q^2 and a contribution from longitudinally polarized photons are neglected. These are good approximations in the present kinematic conditions[2].

Hadronic final states produced in real photon proton collisions resemble those observed in hadron hadron collisions. This similarity led to the phenomenological approach to describe photoproduction by the so called Vector Meson Dominance (VMD) model[3], where the photon first converts into a vector meson (predominantly a ρ^0) which then interacts with the proton. As in hadron hadron collisions, the total γp cross section has a substantial contribution from diffractive γp reactions, which have a final state topology radically different from the bulk of non-diffractive events. Since diffractive reactions involve no colour exchange between the incident particles, the final state is characterized by the appearance of large rapidity intervals, or gaps, with no hadrons. This feature of diffractive events is exploited below to determine their contributions to the γp cross section. We distinguish the following diffractive processes in photoproduction:

- Elastic vector meson production (EL) $\gamma + p \to V + p$, where V stands for one of the vector mesons ρ^0, ω, ϕ. The elastic reaction $\gamma + p \to \gamma + p$ has a very low cross section and is neglected[3].

- Single photon diffractive dissociation (GD) $\gamma + p \to X + p$, where the photon diffractively dissociates into a heavy hadronic state X and the proton stays intact.

- Single proton diffractive dissociation (PD) $\gamma + p \to V + Y$, where the proton fragments into a hadronic state Y and a vector meson is produced in photon direction.

- Double diffractive dissociation (DD) $\gamma + p \to X + Y$, where both photon and proton dissociate.

All processes $\gamma + p \to X$ not belonging to the contributions defined above are called non-diffractive (ND). These processes dominantly involve gluonic exchange between photon and proton.

3 Cross Section Measurement

To measure the diffractive γp cross sections we choose those variables in which a separation of diffractive and non-diffractive contributions is least model dependent. These variables, η_{max} and η_{min}, are related to the central rapidity gap in the hadronic final state.

For each event η_{max} (η_{min}) is defined as the maximum (minimum) pseudo-rapidity of all reconstructed charged tracks and all calorimeter clusters with energy larger than 400 MeV.

To obtain the diffractive γp cross sections we make a combined fit of the η_{max} and η_{min} distributions, as shown in Fig. 1.

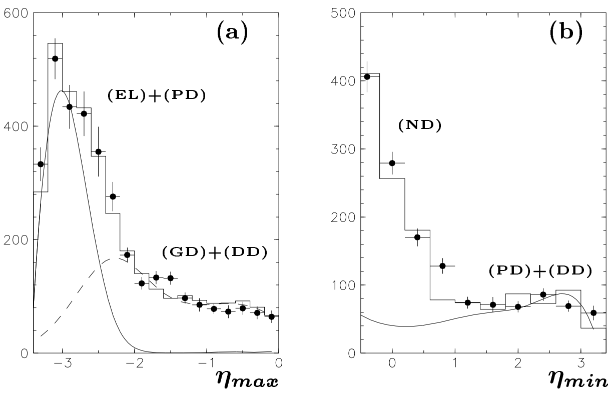

Figure 1: The η_{max} (a) and η_{min} (b) distributions. The solid circles represent the data. The histogram represents the result of a combined fit based on Monte-Carlo simulations summing over all five contributions and using $\sigma_{DD} = 20$ μb.

In this fit procedure the shapes of the spectra for each partial contribution are fixed from Monte Carlo calculations, while the cross sections σ_i for single diffractive and elastic reactions are left as free fit parameters. Since only three of the four diffractive cross sections can be reliably extracted from the fit we make an additional assumption about the value of the double diffractive cross section varying it from 0 to 40 μb.

4 Results

The cross sections σ_{EL}, σ_{GD} and σ_{PD} are displayed in Fig. 2a as functions of σ_{DD}. Fig. 2b shows $\sigma_{tot}^{\gamma p}$ and σ_{ND} as functions of σ_{DD}. The total cross section is remarkably insensitive on the assumption about σ_{DD} and changes only by 2.6 μb as σ_{DD} varies between 0 and 40 μb.

The results, averaged over σ_{DD} =0–40 μb are given in Table 1 along with the diffractive cross sections. For the total cross section, we finally obtain

$$\sigma_{tot}^{\gamma p} = 165.3 \pm 2.3(\text{stat.}) \pm 11.0(\text{syst.})\ \mu\text{b}.$$

The systematical error is dominated by the uncertainty of the electron tagger acceptance and the difference between the different Monte Carlo models used.

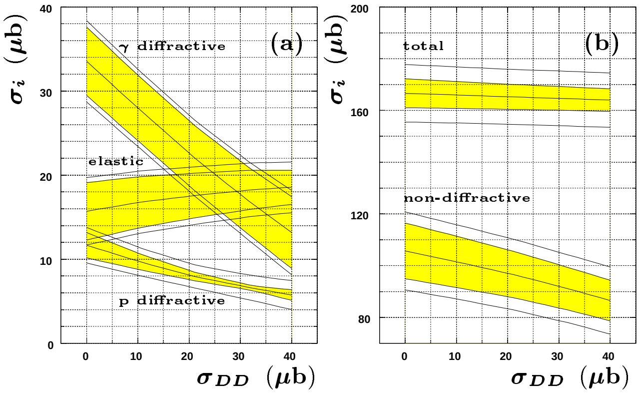

Figure 2: The measured partial diffractive (a) and non-diffractive and total (b) γp cross sections as function of the assumed double-diffractive cross section. The wide bands correspond to full statistical and systematic errors; the narrow grey bands show the systematic errors only.

A more detailed account of the procedures used to determine the systematic error is given elsewhere[4]. Our value for the cross section agrees well with previous determinations at HERA[5,6].

Table 1: Results for partial and total γp cross sections. The first error is statistical, the second one is systematic, and the third error reflects the systematic uncertainty due to the assumption on σ_{DD}. Their sum in quadrature is given as the full error.

process	*cross section* (μb)	*full error* (μb)
DD	20 ± 20 (assumed)	—
GD	23.4±2.6± 4.3±10.2	11.3
PD	8.7±1.5± 1.5± 3.0	3.6
EL	17.1±1.6± 3.7± 1.4	4.3
ND	96.1±3.5±14.7± 9.6	17.9
Total	165.3±2.3±10.9± 1.3	11.2

Acknowledgments

We are grateful to the HERA machine group whose outstanding efforts made this experiment possible. We appreciate the immense effort of the engineers and technicians who constructed and maintain the detector. We thank the funding agencies for their financial support of the experiment. We wish to thank the DESY directorate for the hospitality extended to the non-DESY members of the collaboration.

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