INVESTIGATION OF POMERON- AND ODDERON INDUCED PHOTOPRODUCTION OF MESONS DECAYING TO PURE MULTIPHOTON FINAL STATES AT HERA

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Cross section measurements made at HERA for the reactions $\gamma p \to \omega p$ and $\gamma p \to \omega\pi^0 X$, and on searches for the reactions $\gamma p \to \pi^0 N^*$, $\gamma p \to f_2(1270)X$, and $\gamma p \to a_2^0(1320)X$, where N^* denotes an excited nucleon state, are presented. The mean γp centre-of-mass energies were $\langle W \rangle = 200$ GeV and 215 GeV, respectively. Cross sections for the Pomeron-mediated reactions were determined in agreement with previous measurements and phenomenological expectations. In contrast, Odderon induced processes have not been observed; upper limits on cross sections are below predictions from a non-perturbative QCD model.

1 Introduction

The Pomeron[1] ($I\!P$) — the Regge-trajectory[2] that is thought to dominate the hadronic cross section at high energies — exchanges only vacuum quantum numbers and in particular it is *even* under crossing *i.e.* has C-parity of +1. Its hypothetical partner that is *odd* under crossing *i.e.* $C = -1$, called the Odderon[3] ($I\!O$), has not been observed yet.

This note reports on cross section measurements of the Pomeron mediated processes $\gamma p \to \omega p$ and $\gamma p \to \omega\pi^0 X$ as well as on searches for the Odderon induced reactions $\gamma p \to \pi^0 N^*$, $\gamma p \to f_2(1270)X$ and $\gamma p \to a_2^0(1320)X$ in photoproduction ($Q^2 \approx 0$) at HERA, where N^* denotes an $I = 1/2$ nucleonic state. The respective processes leading to the above final states are sketched schematically in figure 1. Only purely photonic final states of the mesons are analysed, since together with the C-parity of the incoming photon the number of final state photons uniquely determines the C-parity of the exchanged trajectory, viz. an even number of final states photons can only be produced if odd C-parity ($I\!O$) is exchanged from the proton side, and vice versa an odd number of final state photons can only produced by a C even

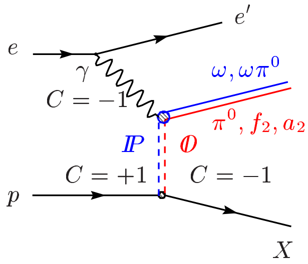

Figure 1. Generic graph illustrating γp interactions via Pomeron and Odderon exchange, respectively.

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($I\!P$) exchange.

Vector meson photoproduction can be well described in the framework of the vector meson dominance (VMD) model combined with Regge phenomenology[4]. In order to describe the Odderon induced pseudoscalar and tensor meson production of the π^0, the f_2 and the a_2^0 a genuine non-perturbative QCD model is applied, namely the *Stochastic Vacuum Model*[5,6] (SVM), in which the proton is treated as quark-diquark system and the photon as a quark-antiquark colour dipole. Both are convoluted with appropriate wavefunctions of the initial and final states, respectively.

2 Event Selection

The analyses are based on data samples taken in the years 1996 (ω, $\omega\pi^0$, f_2 and a_2^0), 1999 and 2000 (both for the exclusive π^0). The integrated luminosities are 4.5 pb^{-1} for 1996 and 30.6 pb^{-1} for the years 1999 and 2000 combined, respectively.

Electrons of 27.6 GeV were brought to collision with protons of 820 GeV[a]. Photoproduction events were selected by demanding the scattered electron to be detected under very low angles in a small angle electron detector (ET) 33 m downstream the electron beam, resulting in a limited phase-space of $Q^2 < 0.01$ GeV^2 and $0.3 < y < 0.7$.

Depending on the meson analysed the number of photons in the final state varies from two to five: $\pi^0 \to \gamma\gamma$, $\omega \to \pi^0\gamma \to 3\gamma$, $f_2 \to \pi^0\pi^0 \to 4\gamma$, $a_2^0 \to \pi^0\eta \to 4\gamma$, and $\omega\pi^0 \to (\pi^0\gamma)\pi^0 \to 5\gamma$, respectively. These photons are detected in the backward calorimeter(s) of the H1-detector[7], since the mesons are produced with only little transverse momentum but large and negative longitudinal momentum as the initial quasi-real photon is emitted nearly parallel to the incident electron with energies of $\sim 8 - 20$ GeV. For 1996 the analyses were restricted to the SpaCal[8] only and for the exclusive π^0-measurement of 1999+2000 the VLQ-calorimeter[9] was included additionally.

To ensure that the events selected were indeed exclusive a variant of energy-momentum conservation was utilised, viz. $\Sigma := \sum_i E^{(i)} - p_z^{(i)} \in [50(49), 60]$ GeV, where the sum runs over all photons the SpaCal, the VLQ and the electron in the ET. The number in brackets refers to the exclusive pion analysis. If Σ is found to be equal (within resolutions) twice the beam energy of 55 GeV the whole final state is detected.

For the mesons decaying via π^0's and η's appropriate mass windows for the respective $\gamma\gamma$-masses were chosen.

[a] For the years 1999 and 2000 the proton energy was 920 GeV.

For the ω it was further required that the interaction occurred elastically by imposing cuts limiting the mass of possible proton-excitations to less than 1.6 GeV, in contrast to the exclusive π^0 were it was explicitely demanded that the proton was excited into a state (N^*) decaying into a leading neutron, which was detected in the forward neutron calorimeter. For the remaining analyses no constraints on the outgoing baryonic final state were imposed.

3 Monte Carlo Models

In order to describe the processes under study DiffVM[11] and a derivative of this generator called OPIUM[12b] were used. In addition to the processes based on Pomeron exchange combined with VMD as implemented in DiffVM, OPIUM is capable to generate pseudoscalar and tensorial mesons as described in[6]. The background consisting of inclusive γp-interactions and mesons decaying via charged pions, was studied using Pythia[10].

4 Results

The left part of figure 2 shows the invariant $\pi^0\gamma$-mass spectrum from which a cross section for elastic ω-photoproduction of

$$\sigma(\gamma p \rightarrow \omega p) = (1.25 \pm 0.17(\mathrm{stat}) \pm 0.22(\mathrm{syst})\,\mu\mathrm{b})$$

was derived. The right part of the figure shows the invariant mass of exclusive

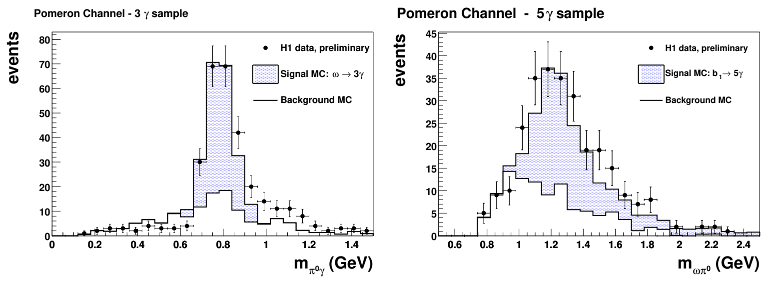

Figure 2. Three (left) and five (right) photon invariant mass spectra, made up of $\pi^0\gamma$- for the ω and $\omega\pi^0$ final states.

$\omega\pi^0$-pairs for which a cross section of

$$\sigma(\gamma p \rightarrow \omega\pi^0 X) = (980 \pm 200(\mathrm{stat}) \pm 200(\mathrm{syst})\,\mathrm{nb})$$

[b] OPIUM is an acronym for *Odderon, Pomeron Induced Unified Meson maker*

was found. Figure 3 shows the invariant mass spectra of the π^0-, f_2- and a_2^0-

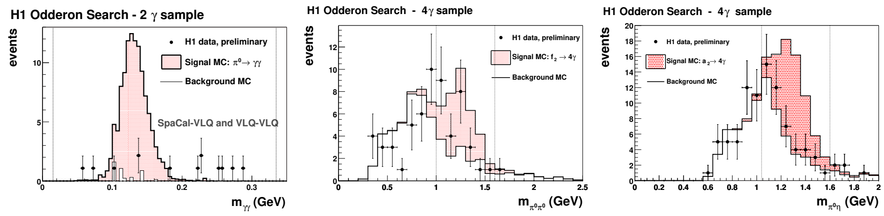

Figure 3. The left part shows the invariant mass of exclusive $\gamma\gamma$-pairs, the middle part shows the invariant $\pi^0\pi^0$-mass and in the left the mass of $\pi^0\eta$-pairs is shown.

searches, respectively. Since the distributions observed are compatible with background alone, 95% confidence level limits were derived (with the SVM predictions in brackets):

$$\begin{array}{rll} \sigma_{\rm acc}(\gamma p \to \pi^0 N^*) & < 39\,{\rm nb} & \quad (200\,{\rm nb}) \\ \sigma(\gamma p \to f_2 X) & < 16\,{\rm nb} & \quad (21\,{\rm nb}) \\ \sigma(\gamma p \to a_2^0 X) & < 96\,{\rm nb} & \quad (190\,{\rm nb}) \end{array}$$

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