Odderon and Pomeron Physics in Multi-Photon Final States at HERA

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In this contribution the first search at HERA for Odderon induced reactions is presented and contrasted with cross section measurements for Pomeron induced processes. The searches are performed in the channels $\gamma p \to \pi^0 N^*$, $\gamma p \to f_2(1270)X$ and $\gamma p \to a_2^0(1320)X$, where N^* denotes an excited nucleon state. The rates found are compatible with the background alone, and upper limits were derived which are below the expectations of a specific non-perturbative QCD model. In contrast to these findings the cross sections for the Pomeron mediated processes — $\gamma p \to \omega p$ and $\gamma p \to \omega\pi^0 X$ — were found to be in perfect agreement with earlier measurements and expectations from Regge theory with soft Pomeron exchange. The mean γp centre-of-mass energies were $\langle W \rangle =$ 200 GeV and 215 GeV, respectively.

1. Introduction

With the advent of HERA diffractive physics experienced a remarkable renaissance as it turned out that roughly ten per cent of the physics observed was diffractive in nature. In particular diffractive photoproduction of vector mesons could be analysed at hitherto unexplored energies.

Diffractive vector meson photo-(and electro)production is thought to proceed via Pomeron exchange, where according to Vector Meson Dominance (VMD) the photon fluctuates into a (virtual) $q\bar{q}$ pair that subsequently undergoes a hadronic scattering with the proton, where the $q\bar{q}$ pair is turned into a real vector meson by the interaction with the Pomeron[1].

According to [2] there should — aside the vacuum exchange of the Pomeron — also be a hadronic exchange with *odd* C-parity, which should manifest itself in a finite difference in the total cross sections for pp and $p\bar{p}$ scattering, or respectively in a non-vaninishing $\Delta\rho_{pp}^{p\bar{p}}$ at asymptotic energies. Due to its odd C-parity this exchange became known as the so-called Odderon.

In a series of papers [3] predictions for Odderon-induced meson production for π^0-mesons and f_2 and a_2^0 mesons are given. The calculations are performed in the Stochastic Vaccum Model (SVM)[8]. In these calculations the proton is required to be excited into an N^* nucleonic state. The π^0 analysis presented in the following takes this explicitely into account, in contrast to the f_2 and a_2^0 analyses which are inclusive in the sense that the baryonic final state is ignored completely.

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2. Event Selection

The analyses presented here 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 (920 GeV for the years 1999 and 2000). Photoproduction events were selected by demanding the scattered electron to be detected under very low angles in a small angle electron detector 33 m downstream the electron beam, limiting the values for the virtuality Q^2 and inelasticity y to $Q^2 < 0.01$ GeV^2 and $0.3 < y < 0.7$, respectively.

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. By counting the number of photons in the final state, one uniquely determines the C-parity of the produced system and thus of the hadronic exchange. These photons are detected in the backward calorimeter(s) of the H1-detector[4], since the mesons are produced with only little transverse but large longitudinal momentum. For 1996 the analyses were restricted to the backward electromagnetic calorimeter (SpaCal)[5] only, and for the exclusive π^0-measurement of the years 1999 and 2000 the very low angle calorimeter (VLQ)[6] and the Forward Neutron Calorimeter (FNC)[7] were included additionally.

To ensure that the events selected were indeed exclusive a variant of energy-momentum conservation was utilised, viz. 50(49) GeV$< \Sigma <$ 60 GeV, where $\Sigma := \sum_i E^{(i)} - p_z^{(i)}$, and the sum runs over all photons the SpaCal, the VLQ and the scattered electron. The number in brackets refers to the exclusive pion analysis. If Σ is found to be equal (within resolution) 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 around the their nominal values of 135 MeV and 547 MeV were chosen.

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[10] and a derivative thereof called OPIUM[11] [2] 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 tensor mesons as described in[3]. The background consisting of inclusive γp-interactions and mesons decaying via charged pions, was studied using Pythia[9].

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

4. Results

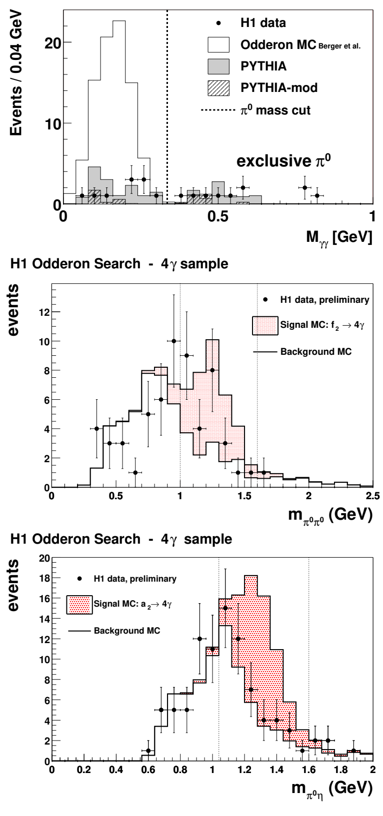

Figure 1. The top part shows the invariant mass of exclusive $\gamma\gamma$-pairs, the middle part shows the invariant $\pi^0\pi^0$-mass and in the lowest the mass of $\pi^0\eta$-pairs is shown.

Figure 1 shows the π^0-[12], f_2- and a_2^0-searches, respectively. Since the distributions observed are compatible with the background alone, 95% confidence level limits on the cross sections are given. The predictions of the SVM are give in brackets for comparison.

$$\begin{array}{rcll} \sigma_{\rm acc}(\gamma p \to \pi^0 N^*) & < & 49\,{\rm nb} & (> 200\,{\rm nb}) \\ \sigma(\gamma p \to f_2 X) & < & 16\,{\rm nb} & (21\,{\rm nb}) \\ \sigma(\gamma p \to a_2^0 X) & < & 96\,{\rm nb} & (190\,{\rm nb}) \end{array}$$

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

$$\sigma(\gamma p \to \omega p) = (1.3 \pm 0.2({\rm stat}) \pm 0.2({\rm syst}))\,\mu{\rm b}$$

was derived. This result agrees well with expectations from the VDM combined with Regge extrapolations. In addition the diffractive slope b, characterising the differential cross section $d\sigma/d|t| \propto \exp(-b|t|)$ was extracted: $b = (10.2 \pm 1.1({\rm stat}) \pm 2.0({\rm syst})\,{\rm GeV}^{-2}$ which is in accordance with other measurements.

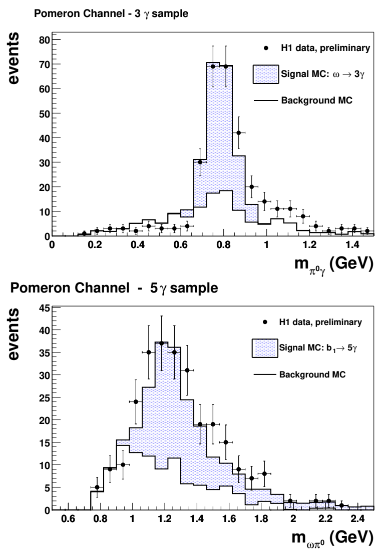

Figure 2. Three (top) and five (bottom) photon invariant mass spectra, made up of $\pi^0\gamma$- for the ω and $\omega\pi^0$ final states.

The lower part of the figure shows the invariant mass of exclusive $\omega\pi^0$-pairs for which a cross section of

$$\sigma(\gamma p \to \omega\pi^0 X) = (1.0 \pm 0.2({\rm stat}) \pm 0.2({\rm syst}))\,\mu{\rm b}$$

was found. This result matches the expectation of resonant b_1 photoproduction, as shown by the filled histogram, although due to the lack of a spin parity analysis it cannot be firmly stated that the observed signal indeed stems from the decay $b_1 \to \omega\pi^0$. Subtracting a non-resonant contribution of $\sim 0.2\ \mu$b as taken from PYTHIA, one arrives at a cross section for resonant $\omega\pi^0$ photoproduction of $\sim 0.8\ \mu$b, which can be compared to a Regge extrapolation of low energy measurements of b_1-mesons that yields an expectation of 0.7 μb.

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