INVESTIGATION OF POMERON- AND ODDERON INDUCED PHOTOPRODUCTION OF MESONS DECAYING TO PURELY PHOTONIC FINAL STATES AT HERA

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Cross section measurements made with the H1 detector at HERA are reported 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. The average photon - proton centre-of-mass energies at HERA were $\langle W \rangle = 200$ GeV and 215 GeV. Cross sections for the Pomeron - mediated reactions were determined in agreement with previous measurements and theoretical expectations. Processes mediated by Odderon - photon fusion could not be observed; upper limits on cross sections are below predictions from a non-perturbative QCD model.

1 Introduction

The Pomeranchuk trajectory ("Pomeron", $I\!P$) was introduced, in the framework of Regge theory, in order to explain the high energy behaviour of hadron-hadron scattering. The Pomeranchuk theorem states that, in the limit of very large energies, the difference between hadron-hadron and hadron-antihadron total cross sections vanishes.

Quantum Field Theory allows, however, for a finite difference e.g. due to the presence of an additional "odd under crossing" trajectory which contributes with different signs to particle-particle and particle-antiparticle scattering amplitudes and thus leads to different total cross sections [1]. No effects of this trajectory named "Odderon" ($I\!O$) have been experimentally observed so far.

We report here on cross section measurements 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 $\gamma p \to a_2^0(1320)X$ in the photoproduction regime. To describe $I\!O$ induced reaction, in the graph for elastic photoproduction of vector mesons, the Pomeron has to be replaced with the Odderon, and the vector meson with a pseudoscalar or tensor meson.

N^* denotes an $(I = 1/2)$ - nucleonic state. The former two processes are

*ON BEHALF OF THE H1 COLLABORATION

mediated by $I\!P$ exchange and have been observed before [2], the latter three are believed to proceed via $\gamma - I\!\!O$ fusion and have not been observed so far. Only meson decays to net multiphoton final states are considered. Vector and axial vector mesons, with an odd number of final state photons, carry odd C - parity ($I\!P$ exchange), while pseudoscalar and tensor mesons, with an even number of final state photons, carry even C - parity ($I\!\!O$ exchange).

Vector meson production can be well described by phenomenological models [3]. For quantitative predictions of Odderon induced processes a model in the framework of non-perturbative QCD, the Stochastic Vacuum Model (SVM) [4], is used. At HERA, a sizeable Odderon contribution to single pseudoscalar or tensor meson photoproduction is expected if simultaneously the proton is excited into an $(I = 1/2)$ – nucleonic state with negative parity [5].

2 Event Selection

The analysis with a single π^0 in the final state is based on data taken in 1999 and 2000 where electrons of 27.56 GeV were collided with protons of 920 GeV. The data sample for the remaining analyses was collected during the 1996 run period with a proton beam energy of 820 GeV. The data correspond to integrated luminosities of 30.6 pb^{-1} and 4.5 pb^{-1}, respectively.

Photons from meson decays are detected in the backward calorimeters SpaCal and VLQ [8] of H1 [7]. A photon in the SpaCal (VLQ) is defined as a cluster with an energy larger than 90 MeV (2 GeV). The study of the exclusive π^0 requires either that one photon be reconstructed in the SpaCal and the other one in the VLQ, or that two photons be reconstructed in the same VLQ module. The remaining analyses make only use of photons in the SpaCal with energies larger than 100 MeV. For final states with π^0's and η's, appropriate mass restrictions have to be obeyed.

In the π^0 data sample the presence of an intermediate excited nucleonic state N^* is verified by detecting a high energy decay neutron in the forward neutron calorimeter. In the case of the tensor mesons, no experimental distinction between elastic and proton - dissociative production is made. The same holds for $(\omega\pi^0)$ production. In the case of ω production a condition designed to suppress inelastic reactions is imposed.

To ensure exclusive meson production, no further cluster in the above calorimeters, or any charged particle in the track detectors is allowed. The variable $\sum_i (E - P_z)_i$, where i runs over all particles in the final state takes a value equal to twice the electron beam energy if no particle escapes undetected. A cut of 49 GeV $< \sum_{i=e',\gamma,\gamma} (E - P_z)_i <$ 60 GeV serves to reject non-exclusive or radiative events. For the 1996 data, the lower limit is 50 GeV.

3 Monte Carlo Models

The simulation programs used are PYTHIA [9] and DIFFVM [10]. The latter generator has been extended to the exclusive production of the $b_1(1235)$ meson and to include Odderon exchange according to the SVM with a single π^0, $f_2(1270)$, or $a_2^0(1320)$ in the final state, with t-distributions for the signal processes as calculated in [5] and assuming an Odderon intercept $\alpha_{\mathbb{O}}(0) = 1$. PYTHIA is used to simulate all backgrounds contributing to exclusive meson

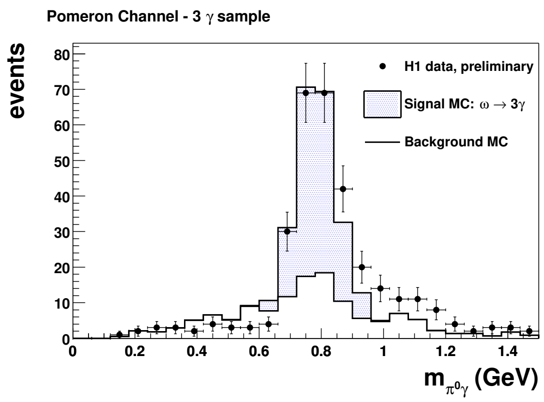

Figure 1. Three photon sample: π^0 - γ invariant mass.

production. These are mainly inclusive events with low multiplicity.

4 Results

Figure 1 shows the $\pi^0\gamma$ invariant mass distribution in the 3-photon sample from which a cross section was determined as

$$\sigma(\gamma p \to \omega p) = (1.25 \pm 0.17 \text{ (stat)} \pm 0.22 \text{ (syst)})\ \mu\text{b}.$$

In Fig. 2 the $\omega\pi^0$ invariant mass distribution in the 5-photon sample is shown. The absolute normalization of the resonant b_1 contribution to the $\omega\pi^0$ final state has been taken from the extended DIFFVM generator which was adjusted to fit the observed data. The non-resonant contribution is taken from the PYTHIA prediction. There is obviously substantial $\omega\pi^0$ diffractive photoproduction which might well proceed via dominant resonant $b_1(1235)$ production. The corresponding cross section is

$$\sigma(\gamma p \to (\omega\pi^0)X) = (980 \pm 200 \text{ (stat)} \pm 200 \text{ (syst)}) \text{ nb}.$$

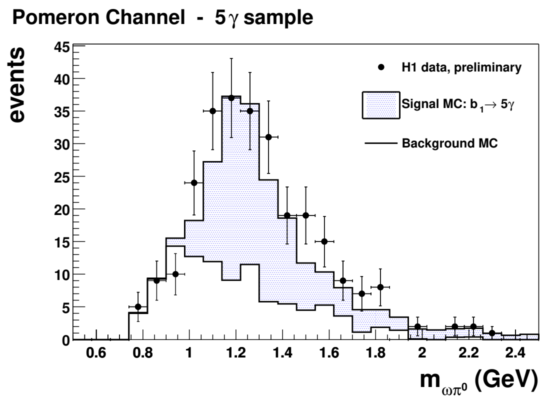

Figure 2. Five photon sample: ω - π^0 invariant mass.

This has to be compared with the sum of the non-resonant prediction by PYTHIA: $\sigma_{Pythia}(\gamma\ p\ \rightarrow\ (\omega\ \pi^0)\ X)\ =\ 190$ nb, and a cross section value

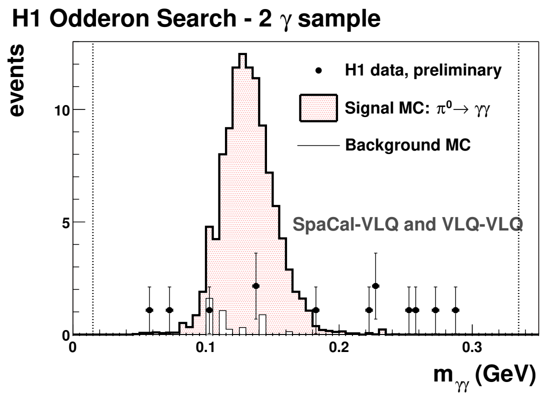

Figure 3. Two photon sample: γ - γ invariant mass.

measured for b_1 photoproduction at lower energies [2] (8 GeV, extrapolated to HERA energies): $\sigma_{extrap}(\gamma p \rightarrow b_1 p) = (660 \pm 250)$ nb. The data distributions in the exclusive 2-photon and 4-photon samples are compatible with the background expectation which is shown in the figures 3 and 4, 5. Converting the findings into numbers, one arrives, applying the prescriptions of [11], at upper limits of

$$\sigma(\gamma p \xrightarrow{\phi} \pi^0 N^*) < 39\,\text{nb} \qquad (95\ \%\ \text{CL})$$
$$\sigma(\gamma p \xrightarrow{\phi} a_2 X) < 96\,\text{nb} \qquad (95\ \%\ \text{CL})$$
$$\sigma(\gamma p \xrightarrow{\phi} f_2 X) < 16\,\text{nb} \qquad (95\ \%\ \text{CL})$$

to be compared with the SVM predictions of 200 nb, 190 nb, and 21 nb, respectively. The π^0 cross section refers to the "visible" range 0.02 GeV^2 $<$ $|t| <$ 0.3 GeV^2.

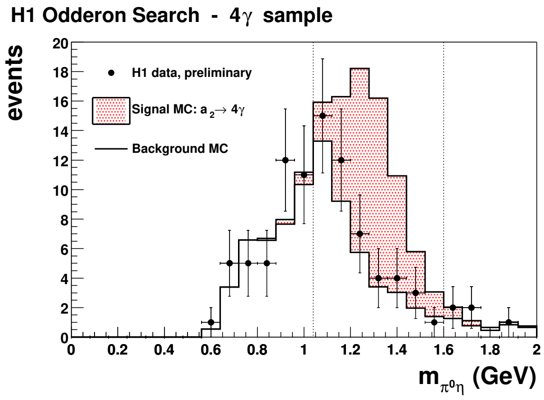

Figure 4. Four photon sample: π^0 - η invariant mass.

5 Conclusion

Our findings provide a rather clear picture: Pomeron induced reactions, investigated in purely photonic final states, have been measured in agreement with previous experiments. There is, however, no trace of Odderon induced reactions as predicted by the Stochastic Vacuum Model. The apparent absence of the Odderon is at present not understood.

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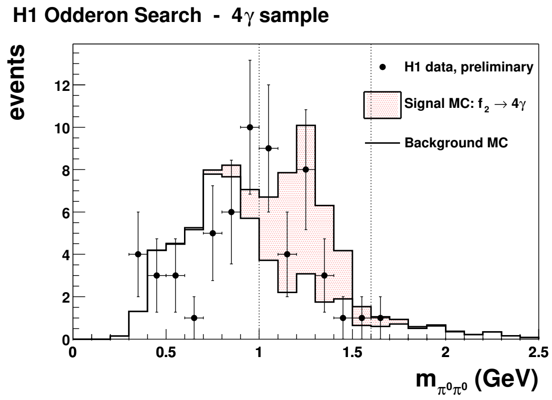

Figure 5. Four photon sample: π^0 - π^0 invariant mass.

References

1. L. Lukaszuk and B. Nicolescu, Lett. Nuov. Cim. **8** (1973) 405.
2. The Omega Photon Collaboration, M. Atkinson et al., Nucl. Phys. **B243** (1984) 1; ZEUS Collaboration, M. Derrick et al., Z. Phys. **C73** (1996) 73.
3. A. Donnachie and P. V. Landshoff, Phys. Lett. **B296** (1992) 227; J. Cudell et al., Phys. Rev. **D61** (2000) 34019; G. A. Schuler and T. Sjöstrand, Nucl. Phys. **B407** (1993) 539.
4. H. G. Dosch and Yu. A. Simonov, Phys. Lett. **B205** (1988) 339.
5. E. R. Berger et al., Eur. Phys. J. **C9** (1999) 491; E. R. Berger et al., Eur. Phys. J. **C14** (2000) 673; H. G. Dosch, private communication.
6. O. Nachtmann, Ann. Phys. **209** (1991) 436.
7. H1 Coll., I. Abt et al., Nucl. Instr. Meth. **A386** (1997) 310 and 348.
8. H1 SpaCal Group, T. Nicholls et al., Nucl. Instr. Meth. **A374** (1996) 149; M. Keller et al., Nucl. Instr. Meth. **A409** (1998) 604.
9. T. Sjöstrand, Comp. Phys. Comm. **82** (1994) 74; and private communication (2001).
10. B. List and A. Mastroberardino, "DIFFVM - A Monte Carlo Generator for Diffractive Processes in ep Scattering", available as: `http://www.desy.de/~heramc/mclist.html`.
11. R. D. Cousins and G. J. Feldman, Phys. Rev. **D57** (1998) 3873; R. D. Cousins and V. L. Highland, Nucl. Instr. Meth. **A320** (1992) 331.