SEARCH FOR ODDERON INDUCED CONTRIBUTIONS TO EXCLUSIVE π^0 PHOTOPRODUCTION AT HERA

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A search for contributions from odderon - photon fusion to exclusive single π^0 production via $ep \rightarrow e\pi^0 N^*$ in the photoproduction regime at HERA, at an average photon - proton centre-of-mass energy $\langle W \rangle = 210$ GeV, and for photon virtualities of $Q^2 < 0.01$ GeV^2 is reported. The measurement proceeded via detection of the π^0 decay photons, the leading neutron from the N^* decay, and the scattered electron. No indication for an odderon contribution was found. An upper limit is presented for the cross section integrated in the "visible" range 0.02 GeV$^2 < -t < 0.3$ GeV^2. It was derived as $\sigma(\gamma p \rightarrow \pi^0 N^*) < 39$ nb at 95 % CL. This excludes an odderon - photon fusion cross section of 400 nb as predicted by theory.

1 Introduction

The soft (non-perturbative) odderon $\mathbb{O}$ is introduced in elastic hadron-hadron scattering as the $(C = P = -1)$ - partner of the pomeron $I\!P$[1]. A conjecture by Pomeranchuk, known as the Pomeranchuk theorem[2], states that in the limit of asymptotic energies the difference between particle - particle and particle - antiparticle total cross sections vanishes. However, the odderon trajectory which is assumed to have an intercept $\alpha_{\mathbb{O}}(0)$ close to 1 contributes with different signs to the particle - particle and particle - antiparticle total cross sections, and thus leads to a finite difference at high energies. This effect could not be observed by experiment so far.

Since high energy hadron - hadron and hadron - antihadron scattering is completely dominated by the pomeron, it is worthwhile to look for a reaction where pomeron exchange cannot contribute. A good choice is the exclusive photoproduction of pseudoscalars at HERA via $\gamma\mathbb{O}$ fusion. The measurement presented here concentrates on the exclusive π^0 production since a calculation by Berger et al.[3] predicts a sizeable cross section for this process (see Fig.1):

$$ep \rightarrow e\pi^0 N^*, \tag{1}$$

where the proton is excited to either a continuum state or to an (I = 1/2) - isobar with negative parity. The results depend only marginally on the details of the excitation process which is here modelled in such a way that only negative parity isobars N^* contribute.

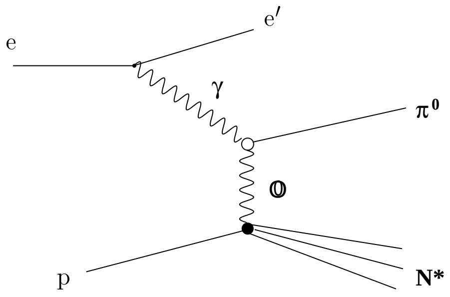

Figure 1. Diagram for the process under investigation: The proton is excited into an (I=1/2) - isobar while a high energy single π^0 is produced by odderon-photon fusion.

For quantitative predictions a model in the framework of non-perturbative QCD, the Model of the Stochastic Vacuum[4] (MSV), is used and applied to high energy scattering by functional methods[5], where the proton is treated as a quark-diquark system in transverse space.

2 Event Selection

The analysis presented here is based on data taken in 1999 and 2000 where electrons (respectively positrons) of 27.56 GeV were collided with protons of 920 GeV. The integrated luminosity is $L = 30.6\ \mathrm{pb}^{-1}$. Events with $Q^2 < 0.01\ \mathrm{GeV}^2$ and $0.3 < y < 0.7$ were selected by measuring the almost undeflected electron in a low-angle electron detector 33 m downstream from the interaction point. The presence of an intermediate excited nucleonic state is proven by detecting a high energy decay neutron in the forward neutron calorimeter of H1. The exclusively produced π^0, finally, is expected to take over the photon's and odderon's energies and momenta where the odderon merely affects the pion's transverse momentum. Consequently, the two decay photons of the π^0 show up in the so-called backward region, i.e. downstream the electron beam. Part of this region is covered by two electromagnetic calorimeters SpaCal[6] ("Spaghetti Calorimeter" at $z \approx -155$ cm) and VLQ[7] ("Very Low Q^2" at $z \approx -302$ cm) (see Fig.2). It is required that either one photon be reconstructed in the SpaCal and one in the VLQ, or that two photons be reconstructed in the same VLQ module, where a photon in the SpaCal or in the VLQ is defined as a cluster with an energy larger than 90 MeV or 2 GeV, respectively. A sketch of SpaCal and VLQ, projected onto a plane perpendicular to the beam line, is given in Fig.2. Since the events to

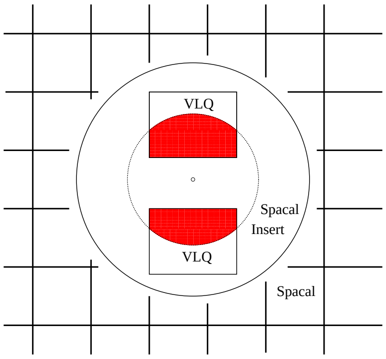

Figure 2. Sketch of the VLQ and the SpaCal, projected onto a plane perpendicular to the beam line. The two rectangles represent the upper and lower modules of the VLQ calorimeter and the ring gives the region shaded by dead material (SpaCal insert). The rest of the SpaCal is represented by the region outside the solid circle, covered by the square grid.

be selected must not contain tracks of charged particles, no interaction vertex must be reconstructed.

The variable $\sum_i (E - P_z)_i$ where i runs over all particles either in the initial or final state is constructed such that it equals twice the electron beam energy if no particles go undetected. A cut of 49 GeV $< \sum_{i=e',\gamma,\gamma} (E - P_z)_i <$ 60 GeV serves to reject non-exclusive events.

A two-photon invariant mass window is defined by fitting a Gaussian to the measured invariant mass spectrum (see Fig.3). Two-photon candidates with their mass inside a four standard deviations region around the mean π^0 mass are accepted as pions. The selection yields 13 exclusive pion candidates according to the definition given above.

3 Monte Carlo Models

The simulation programs used are PYTHIA[8] and DIFFVM[9]. Originally, the DIFFVM event generator produces exclusive vector mesons by pomeron exchange based on the Vector Meson Dominance model. This generator has been extended to include odderon exchange with an exclusive π^0 in the final state, with a t-distribution of the signal process as calculated in Berger et al.[3]. The extended event generator is called OPIUM[10] [a].

[a] for "Odderon and Pomeron Induced Unified Meson maker"

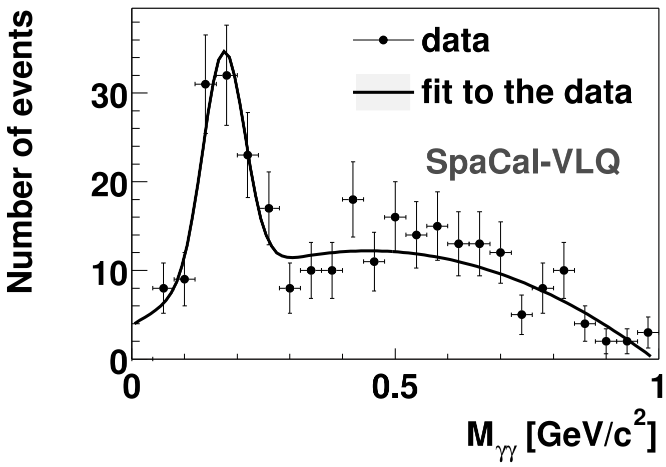

Figure 3. Invariant mass spectrum of the two-photon candidates for events where one photon is detected in the VLQ and one in the SpaCal. In addition, a neutron and the scattered electron are detected.

PYTHIA, as a universal tool to describe γp interactions, is used to simulate all backgrounds which do not originate from the $\gamma\mathbb{O}$ fusion but have the same signature. These are mainly inclusive events with low multiplicity and a pion in the final state, and events from exclusive ω or ρ^0 photoproduction where the vector meson decays into $\pi^0\gamma$. Contributions from Regge exchange (ω-trajectory) or the $\gamma\gamma$ fusion ("Primakoff effect"), leading to elastic single π^0 production, are negligible.

Following an advice by the author of PYTHIA[11], also a modified version of PYTHIA is used for the background description, referred to as "PYTHIA-mod". Here certain processes are excluded where isospin conservation is not explicitly taken care of. It is expected that measured kinematical distributions fit in between the predictions of these two versions of the model.

4 Results

Fig.4 shows the final two photon mass distribution, with all selection criteria applied. The expectations from PYTHIA and PYTHIA-mod lie between 13 and 4 events. The theoretical model predicts 230 events, whereas 13 events

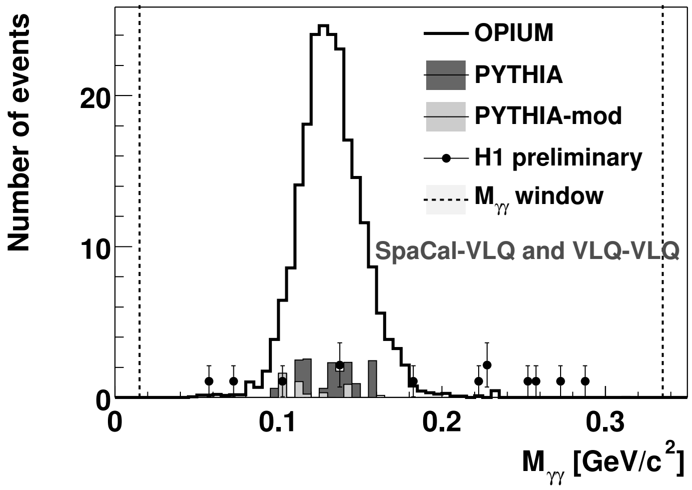

Figure 4. Invariant mass spectrum of the two-photon candidates after the event selection.

are observed in the data.

The measured cross section is converted into an upper limit[12] with the background prediction by PYTHIA-mod, taking into account systematic uncertainties[13] which are dominated by the properties of the forward neutron calorimeter. The result is

$$\sigma_{\gamma p \to \pi^0 N^*}(\gamma\mathbb{O}\text{ -fusion}) < 39 \text{ nb} \qquad (95\ \%\ \text{CL}) \tag{2}$$

at an average γp centre-of-mass energy $\langle W \rangle = 210$ GeV, and t restricted to the visible range $0.02\ \text{GeV}^2 < -t < 0.3\ \text{GeV}^2$. This has to be compared with the predicted value of 400 nb at HERA energies which apparently is incompatible with observation.

5 Conclusion and Outlook

This analysis has demonstrated that an odderon induced process for exclusive π^0 photoproduction as predicted by Berger et al. is not compatible with the data. Nevertheless, two possible interpretations of the non-observation can be conceived:

1. The energy dependence of the cross section is different from that assumed. This would imply that the odderon intercept $\alpha_{\mathbb{O}}(0)$ is consider-

ably smaller than one. A value of $\alpha_{\mathbb{O}}(0) < 0.65$ would be compatible with the measurement, but this would mean that the object exchanged does not possess the property of a "genuine" odderon, namely $\alpha_{\mathbb{O}}(0) \approx 1$.

2. The coupling at the $\gamma\mathbb{O}\pi$-vertex is smaller due to the Goldstone Boson[14] nature of the π^0.

There is no evidence of the existence of the odderon in the form suggested in Berger et al.[3] - and so the pomeron's enigmatic counterpart continues to keep its secrets.

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