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LOW AND MEDIUM $p_\perp$ PHOTOPRODUCTION AT HERA

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ABSTRACT

Quasi-real photoproduction has been studied in the H1 detector, based on the low Q^2 ep-scattering at HERA. Results are presented on measurements of the total photoproduction cross section, elastic ρ^0 production $\gamma p \to \rho^0 p$ and inclusive charged particle spectra in the central region from inelastic γp interactions. Although difficult to interpret theoretically, low and medium $p_\perp$ photoproduction processes nevertheless provide essential information for the understanding and complete description of γp interactions at high energies.

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INTRODUCTION. It is well-known, that the photon is a pointlike gauge particle. Sometimes however, it can manifest itself as a complex object having an internal structure. This dual nature of the photon excites special interest in photoproduction physics. The recently commissioned electron-proton collider HERA in addition to its main task – measurement of deep inelastic scattering (DIS) – offers the possibility of studying photoproduction processes in a new energy domain compared with existed fixed target experiments. The bulk of the cross section is expected to be produced by soft photoproduction. Although they cannot be explained presently from first principles, these processes give important information on the complete description of γp interactions. So far the vector meson dominance model (VDM)[1] has been used to describe low $p_\perp$ photoproduction, while perturbative QCD pretends to explain high $p_\perp$ γp events. Matching between the two approaches is an important problem. Recently, a new and interesting attempt has been made to develop a combined description of soft and hard photoproduction at high energies[2]. The different scenarios presented there, including the whole concept used, can only be tested by confrontation with experimental data.

Thus, γp physics at HERA is potentially very fruitful. Below, first results on low and medium $p_\perp$ photoproduction are discussed, based on H1 data collected in 1992 at 26.7×820 GeV ep collision energy and corresponding to an integrated luminosity $\mathcal{L} \simeq 25$ nb^{-1}. Other interesting aspects of these data, related to the photoproduction of jets, have also been presented at this conference[3].

EVENT SELECTION. An important feature of the H1 detector and trigger design[4] is the possibility of keeping soft physics without affecting DIS and high $p_\perp$ photoproduction. This is by no means a trivial task, given the difficult background conditions at HERA. Most dangerous are proton-gas events in the ep interaction region which have a topology very similar to that of soft photoproduction events. The trigger for the minimum bias γp sample required a coincidence between signals from the H1 tracking system and the small angle electron tagger. The electron tagger is a part of the H1 luminosity monitor[4] and has an average acceptance of 35% for scattered electrons e' within the kinematical range $10^{-8} < Q^2 < 10^{-2}$ GeV^2 and $0.2 < y = 1 - E_{e'}/E < 0.8$. The events detected by such a trigger give a clean γp sample: the small amount of p-gas events appearing in random coincidence with the e' in the electron tagger, could be removed by further offline selections. Finally, the remaining background has been estimated to be less than 4% (2.2% from the p-gas and 1.6% from the e-gas events). The use of the electron tagger gives additional advantages: precise y (and thus $W_{\gamma p} = \sqrt{ys}$ at $Q^2 \to 0$) determination with an accuracy of (3-4)% and partial cancellation of the systematic error in the luminosity, related to the tagger acceptance ($\sigma_{\gamma p}^{tagged} \sim N_{\gamma p}/\mathcal{L} \sim A(\text{luminosity})/A(\gamma p)$). Most of the results presented are based on the e-tagged sample, except for quasi-elastic ρ^0 production where the acceptance of the H1 tracking system for the decay pions does not overlap with that of the tagger for the scattered electron.

TOTAL γp CROSS SECTION. A comprehensive summary of the total photoproduction cross section status in pre-HERA days can be found in[5]. A large variety of models, predicting $\sigma_{tot}(\gamma p)$ values between 145 μb and 760 μb at 250 GeV centre of mass energy, allowed HERA to make an immediate and valuable contribution to γp physics at high energies.

First measurements of the γp total cross section at HERA by ZEUS[6] and H1[7] were based on small statistics of 0.2 nb^{-1} and 1.5 nb^{-1} respectively. Here a new H1 result is presented which is in agreement with the published one, but has somewhat smaller error. A detailed description of the method used can be found elsewhere[7].

Data sample	$E_{e'}$ [GeV]	$W_{\gamma p}$[GeV]	$\mathcal{L}$ [nb^{-1}]	$N_{\gamma p}$	$\sigma_{\gamma p}$ [μb]
July 1992	$10 - 19$	195	1.5 ± 0.1	917 ± 38	$159 \pm 7(stat) \pm 20(syst)$
Fall 1992	$5 - 22$	197	21.9 ± 1.5	16393 ± 174	$156 \pm 2(stat) \pm 18(syst)$

Compared to the summer period, better background conditions due to improved beam quality and trigger tuning allowed the use of the full acceptance of the electron tagger, and thus reduced systematics related to the tagger calibration precision. The dominant contributions to the systematic error are a 6% uncertainty in the luminosity measurement and 10% error in the detector acceptance determination. The energy dependence of the γp total cross section is shown in fig. 1. Regge motivated parametrizations are in good agreement with the data, while the extreme models predicting strong rise of $\sigma_{tot}(\gamma p)$[8] can be ruled out. More elaborated 'eikonalized' models[9] can describe $\sigma_{\gamma p}(s)$ better than those using a simple ansatz: $\sigma_{\gamma p}(s) = \sigma^{soft} + \sigma^{jet}(s)$.

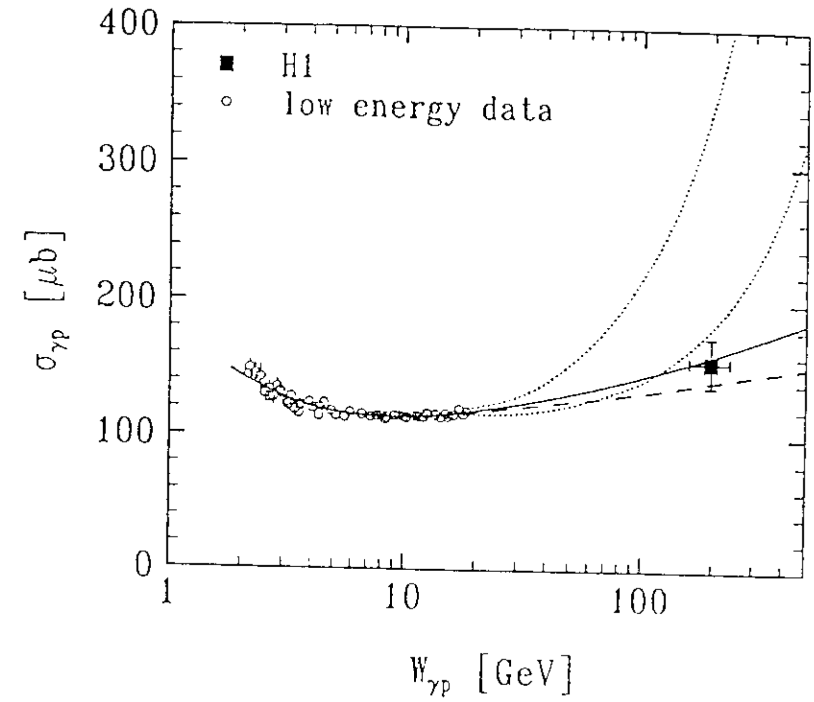

Figure 1: The energy dependence of the total γp cross section. The solid curve represents a Regge motivated fit of low energy data[10]. The dashed curve is the prediction of ALLM parametrization[11]. The dotted lines are obtained in the PYTHIA Monte Carlo[12] using the anzatz $\sigma_{\gamma p}(s) = \sigma^{soft} + \sigma^{jet}(s)$ with the Drees-Grassie parametrization of the photon structure function for $\hat{p}_t^{min} = 1.4$ GeV/c (upper line) and for $\hat{p}_t^{min} = 2.0$ GeV/c (lower line).

ELASTIC ρ^0 PRODUCTION. The study of elastic photoproduction of vector mesons, $\gamma p \rightarrow Vp$, in H1 relies mainly on the tracking system. Well measured 2-prong events with vertex position $|z_0| < 50$ cm have been selected, where the two charged particles in the final state were identified as pions or kaons by their dE/dx in the central jet chamber. The inelastic (and partially diffractive) components were suppressed by requiring no activity in the calorimeters, except for areas of possible small energy deposit from the vector meson decay products. The acceptance of the tracking chambers limited the available energy range of the elastic ρ^0 production to the $20 < W_{\gamma p} < 80$ GeV. This interval has been subdivided into two W-bins with approximately equal statistics: $W_{\gamma p} < 40$ GeV and $W_{\gamma p} > 40$ GeV. As an illustration, fig. 2 shows a nice ρ^0 signal in the $\pi^+\pi^-$ mass distribution for the high energy bin. $M_\rho = 769 \pm 7$ has been obtained from the fit by the relativistic Breit-Wigner cross section modified by the phenomenological Ross-Stodolsky factor[13], accounting for the skewing of the ρ^0-signal shape. Some indication of elastic φ production (10±3 events) is also seen in the K^+K^- mass spectrum. Comparison with the Monte Carlo has shown, that the remaining contamination from the diffractive component in our elastic ρ^0 sample is less that 10% in the range of four-momentum transfer squared $|t| < 0.4$ GeV^2.

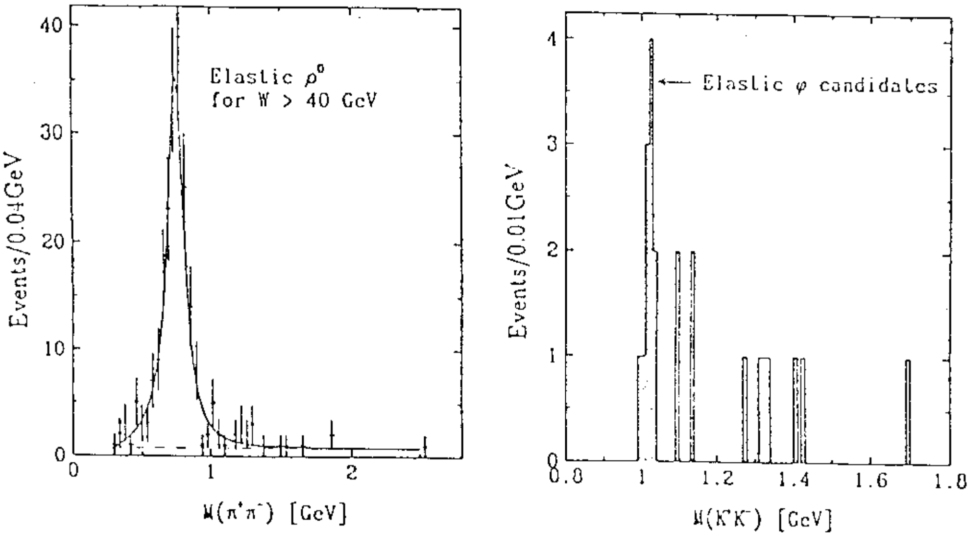

Figure 2: Signals of the elastic $\gamma p \rightarrow Vp$ scattering observed in the H1 detector

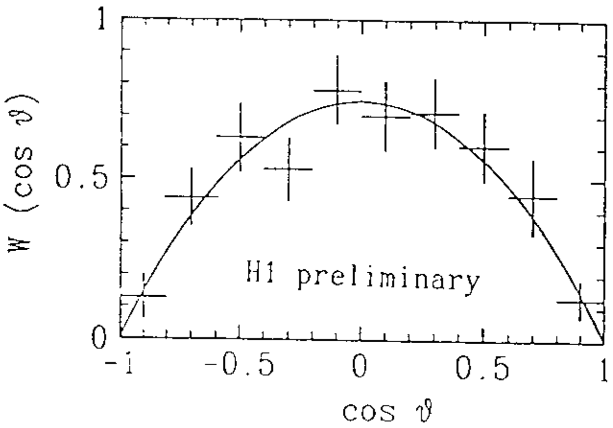

Figure 3: The angular distribution of the decay pions in the helicity frame.

The angular distribution of the decay pions (fig. 3) is in agreement with the $\sin^2\theta$ shape expected for transversly polarized photons at $Q^2 \rightarrow 0$ (in our sample the average value of $<Q^2>= 0.08$ GeV^2).

The slope of the t-distribution in the reaction $\gamma p \rightarrow \rho^0 p$ has been defined by fitting an exponent function e^{bt} to our data in the interval $|t| < 0.32$ GeV^2 (fig.4 a,b). The results for two energy intervals: $b = 9.4 \pm 1.1$ GeV^{-2} at $W_{\gamma p} = 20 - 40$ GeV and $b = 11.1 \pm 1.3$ GeV^{-2} at $W_{\gamma p} = 40 - 75$ GeV, are compared to the low energy data[13] in fig. 4c.

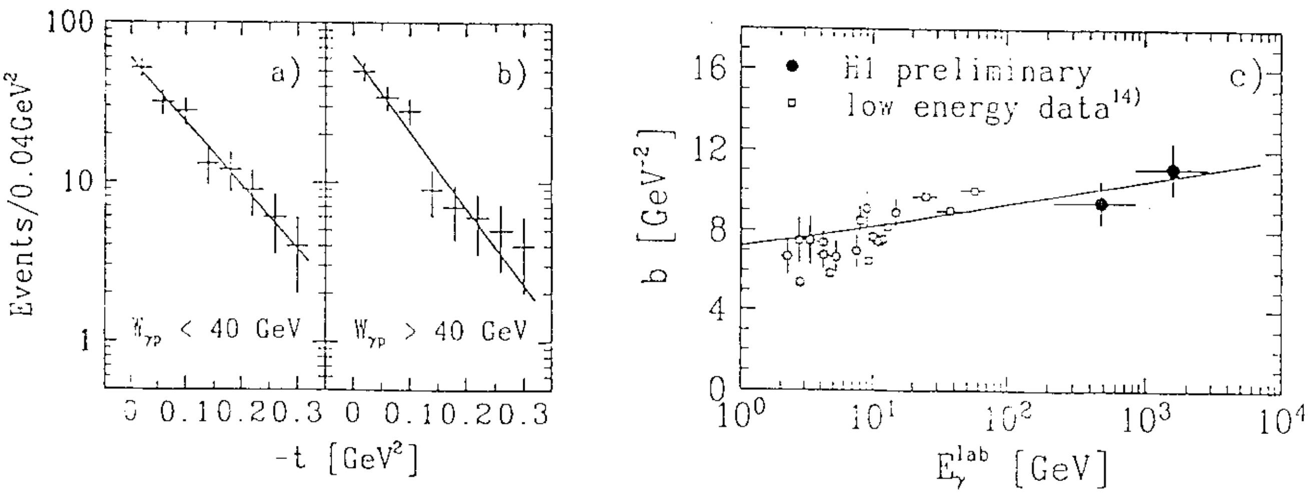

Figure 4: Slope of the elastic ρ^0 production. For the H1 data only statistical errors are shown. The line in fig. c) shows the phenomenological parametrization used in[2]

TRANSITION FROM SOFT TO HARD γp SCATTERING. For the inclusive particle distributions only charged tracks in the central region of $30° < \theta_{lab} < 150°$ and having $p_t > 0.3$ GeV/c were used. The total transverse energy in the event, E_T, was used as a measure of the 'hardness' of the γp interaction. Two parts have been selected from the whole e-tagged γp sample: 'soft' ($E_T < 5$ GeV) and 'hard' ($E_T > 10$ GeV). This selection was motivated by the Monte Carlo simulated events, using PYTHIA[12] with a $\hat{p}_t^{min}$ cutoff of 2.5 GeV/c for the hard γp scattering and low $p_\perp$ phase space Monte Carlo RAYPHOTON[15] for the soft γp scattering. The emphasis was put on getting 'hard' sample as clean as possible in order to be able to compare it with the QCD calculations, while the 'soft' one still may be contaminated by the medium $p_\perp$ events.

Fig. 5 shows, that the $p_\perp$ -distribution in the high E_T sample is described well by the PYTHIA Monte Carlo which included both direct and resolved photon contributions. The $p_\perp$ -distribution in the low E_T sample is a bit harder than the simple Monte Carlo, used in this case, predicts. Pseudorapidity distributions (fig. 5c) are very different for the two samples. Here only qualitative agreement with Monte Carli was observed. Note, that this distribution for the high E_T sample is sensitive not only to the photon structure function, but also to the scale of the hard process used (in our case it was $\hat{p}_t^2$). Finally, fig. 5d illustrates how the

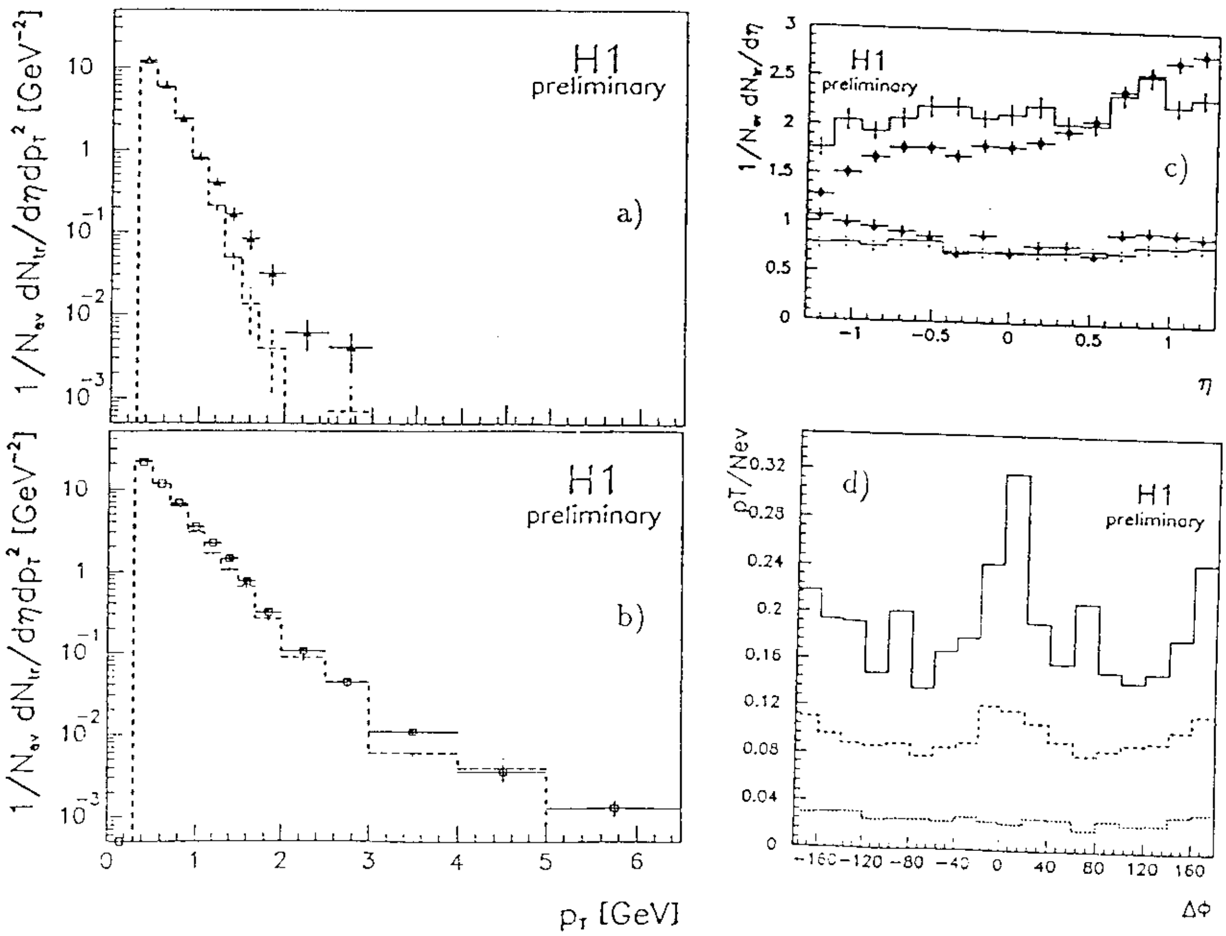

Figure 5: Inclusive $p_\perp$ spectra for the 'soft' (a) and 'hard' (b) γp events (points - data, histograms - MC); (c) pseudorapidity distributions for the 'soft' (triangles) and 'hard' (squares) samples compared to the Monte Carlo; (d) ϕ-distance to the highest $p_\perp$ particle in the event (dotted line - $E_T < 5$ GeV, dashed line - $E_T > 10$ GeV, solid line - $E_T > 20$ GeV)

event topology evolves with increasing E_T of the event: soft sample has no structure in the $\Delta\phi$-distribution, while for the $E_T > 20$ GeV particles clearly prefer two back-to-back cluster configuration ($|\Delta\phi| \simeq 0$ and $|\Delta\phi| \simeq \pi$), which is natural in case of jet production.

CONCLUSIONS. Already after the first months of operation at the level of few permille of the design luminosity, HERA has proven its great physics potential. New unexplored domains are opened both in deep inelastic scattering and photoproduction, and first interesting results have been obtained by H1 and ZEUS collaborations.

The γp total cross section has been measured at $\sqrt{s} \simeq 200$ GeV. No strong rise was observed, excluding some *extreme* minijet scenarios. The measurement is in good agreement with the Regge motivated parametrizations.

A clear ρ^0 signal is observed in the H1 detector. Both the angular distribution of the decay pions and the slope of the t-distribution show typical behaviour for the elastic scattering of transversly polarized photons: $\gamma p \to \rho^0 p$. The energy dependence of the elastic slope shows that the diffraction in γp interactions keeps shrinking at least up to $\sqrt{s} \simeq 80$ GeV.

Inclusive charged particle spectra demonstrate a transition from soft to hard γp scattering and the evidence of the jet formation in high-$E_\perp$ γp events.

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