THE ZEUS EXPERIMENT AT HERA.

Proposal 760

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in collaboration with
Argonne, Bologna, Bonn, Brookhaven, Calabria, Columbia, DESY, DESY-Zeuthen, Florence, Frascati, Freiburg, Hamburg, Iowa, Jülich, Krakow, Louisiana, Madison (Wisconsin), Madrid, Manitoba, McGill, Moscow, NIKHEF, Ohio, Padova, Pennsylvania, Rome, Santa Cruz, Seoul, Siegen, Tel Aviv, Tokyo, Tokyo Metropolitan Univ., Torino, Toronto, Virginia, Warsaw, Weizmann Inst., Yokohama, York (Ontario).

Introduction

In 1996 HERA again ran with 820 GeV protons and 27.5 GeV positrons. A total of 17 pb^{-1} of luminosity was delivered of which almost 11 pb^{-1} was collected by the ZEUS experiment for physics analysis. These numbers represent an increase of roughly fifty percent compared with 1995 and the data was collected over a significantly shorter running period. Towards the end of the run HERA was regularly delivering more than 1 pb^{-1} per week of which ZEUS used typically 80%.

The ZEUS detector as a whole continued to function well. The increase in luminosity made it necessary to employ more stringent triggers than in previous years – in particular, making much tighter use of the tracking information – and the collaboration is beginning to have to be more selective on the physics data that it is able to record on tape. Analysis of the 1994 data is now nearing completion and that of the 1995 data is well advanced.

Hardware developments.

The ZEUS apparatus was improved in a number of ways for the 1996 running.

1. The scintillator in the beampipe calorimeter (BPC) suffered some radiation damage in 1995, and was replaced for 1996. To reject photons, scintillator fingers have been added in front of the BPC. The BPC extends the ZEUS coverage of Q^2 down to 0.1 GeV^2.
2. In order to extend the energy range of 'tagged' photoproduction, taggers were added at 8m and 44m from the interaction point.
3. The Rear Calorimeter has already been equipped with a plane of high granularity Si diodes, inserted into the calorimeter at around the electromagnetic shower maximum, to improve the hadron/electron identification. A similar device has been planned for the Forward Calorimeter and approximately 50% was installed for the 1996 run.
4. Finally, 1996 was the first year in which all 6 stations of the Leading Proton Spectrometer were operational. This detector is a key component in the study of diffractive processes.

CTD performance.

The Central Tracking Detector (CTD), together with its associated readout and trigger electronics, has been the major contribution made by the UK groups to the ZEUS detector, and it remains our joint task to operate it effectively and obtain the optimum results from it. The CTD is an essential component of almost all ZEUS triggers and of all ZEUS physics analyses.

In data taking the CTD has performed very reliably, with less than 2% of dead channels and little contribution to the experimental running downtime. No signs of aging are apparent. Work has been done to upgrade the software infrastructure, in particular by removing various obsolescent or 'legacy' packages, so that the CTD can run as smoothly as possible for the lifetime of HERA. In similar vein, we continue to improve the data quality monitoring, a task in which our graduate students at DESY play a key role. At the offline level, the CTD software is now reasonably mature. Improvements in the dE/dx algorithm were introduced this year, and we have continued to refine the Monte Carlo description of the detector to match the demands of the latest physics analyses.

Trigger and running.

ZEUS operates a three-level trigger, of which the first level is a hardware-based system whose principal aim is to reduce backgrounds from processes that do not come from the interaction point. Information from the CTD makes an important contribution to this, by means of dedicated pipelined processor cards which enable (r, z) information from track segments in the superlayers 1,3, and 5 to be incorporated into the trigger. This system gives fast recognition of the point of origin of tracks, and is currently used by the great majority of first level triggers.

Until 1996 only information from superlayer 1 was used in this trigger. Superlayers 3 and 5 were used in 1996 following installation and commissioning in 1995. The inclusion of superlayers 3 and 5 has reduced the trigger rate from slots requiring calorimeter and CTD information by around 10%. It will also allow us the flexibility to implement more types of trigger in the CTD in future years. The performance of the hardware has been very reliable. Comparison of the output with a software simulation of the algorithms shows better than 99% agreement.

The global second level trigger applies software cuts to clean the event sample further and identify certain classes of physics event. The CTD component to this, which makes use of data from all five axial superlayers, enables detailed information on the tracking and vertexing to be used in the event selection. It is used by most physics filters at this level. For 1996 running the CTD transputer network was successfully reconfigured in order to reduce the trigger latency. Further studies were made to consider what steps might be required if and when the HERA luminosity and first level trigger rate increase.

At the third trigger level all the event information is available and essentially a full track reconstruction is performed which reduces the trigger rates to an acceptable level. Different types of physics selection can be made using software algorithms similar to those used offline. All the ZEUS physics analysis groups contribute here.

ZEUS data-taking has continued smoothly through 1996. As mentioned above, we have had extended periods in which the ZEUS detector uses more than 80% of the available luminosity. The UK groups have continued to play a full part in the data-taking, and have provided several of the designated shift leaders and their deputies.

Physics analysis.

During 1996 a large number of analyses were completed and published by the ZEUS collaboration. This has been made possible to a large extent by the ZARAH computing system and environment, which was designed and implemented by the collaboration. It is based on the rapid accessibility of events on disk storage, which together with an Ampex tape system and high CPU power provides an outstandingly versatile and fast data handling capability. The ZEUS Monte Carlo production facility, FUNNEL, which allows full event simulation and reconstruction to be run on a cluster of UNIX machines, has also been of vital importance. The computing resources of the ZEUS member institutions, including the UK groups, are now being exploited in conjunction with those at DESY to run FUNNEL. This system has been very effective in ensuring that individual institutions of the collaboration contribute fully to the Monte Carlo effort. By the end of October 1996 about 35 million events had been fully simulated and reconstructed of which the UK share was a little under one million events. In this way the use of resources is maximised in performing the massive amounts of computation which the physics analyses demand.

In the following summary, we concentrate especially on those physics areas where the UK members of ZEUS have been particularly active. Many of the results described have been presented at the International Conference on High Energy Physics (ICHEP96) which took place in Warsaw earlier this year; some contributions to the Workshop on Future Physics at HERA which was held at DESY earlier this year are also mentioned.

During 1995-96 ZEUS-UK provided one of the coordinators of the Hard Photoproduction analysis group, the ZEUS Tracking coordinator, and the overall Physics Coordinator. In addition we provide "common task" people in the areas of ZEUS Monte Carlo and the ZEUS Event Display.

1. *Jet Physics.* A number of studies have been made at HERA of the properties of quasi-real photoproduction. The resolved and direct subprocesses (see Fig.. 1) most commonly produce two outgoing quarks or gluons which at high E_T manifest themselves as two jets. The study of jet physics continues to be an area of significant UK effort. In a recent paper, the angular distribution was measured for photoproduced dijets. The measurement builds on the previous measurement of the cross sections for direct and resolved photoproduction, in which a separation between the two event classes was developed based upon the variable x_γ^{OBS}, the fraction of the momentum of the photon which is manifest in the two highest transverse energy jets in the final state.

   In direct photoproduction the dominant processes involve the exchange of a quark propagator, whereas the dominant resolved processes involve gluon exchange. A measurement of the angular distribution of dijets for each type of process is expected to show behaviour characteristic of fermion and boson exchange for direct and resolved processes respectively, i.e. distributions proportional to $(1-|\cos\theta^*|)^{-1}$ and $(1-|\cos\theta^*|)^{-2}$. The variable $\cos\theta^*$ is the cosine of the dijet scattering angle in the jet-jet centre of mass system. Fig. 2 shows that this is indeed the case: the data is compared to next-to-leading order QCD calculations and is seen to agree well.

   In addition to these measurements, updates of the 1993 dijet cross sections using 1994 data have been presented, and studies of the issues raised by comparisons with theory led to a written contribution to the HERA workshop. Developing areas of interest in which UK physicists are currently involved include the study of charm inside photoproduced jets in the current data, as well as the future potential of this after the installation of a microvertex detector. Some of this work was also included in a HERA workshop contribution.

2. *Prompt Photons.* In addition to dijet processes mentioned above, final states with a single high E_T jet accompanied by a high E_T photon are also possible: a jet plus "prompt" photon final state. It was demonstrated for the first time that high energy photons can scatter elastically off quarks, by observing isolated high transverse energy photons emerging from hard photoproduction processes, accompanied by a balancing high E_T jet, and showing the prominent presence of the "direct" process, in which the incoming photon is itself totally absorbed by a quark in the proton. This can be seen in Fig. 3 where the x_γ distribution of prompt photon events is shown. Preliminary results were presented at the DIS'96 conference in Rome and as a submitted paper to ICHEP96.

3. *Rapidity Gaps between Jets in Photoproduction.* In 1994 ZEUS published an indication of an excess in the fraction of events with a large rapidity gap between jets, over what would be expected from non-diffractive processes. This can be interpreted as a signal for for diffraction taking place within the regime of perturbative QCD and studying this process could help to unravel the overlap between QCD and Regge phenomenology. For the HERA

workshop a perturbative QCD calculation of colour singlet exchange was implemented into HERWIG. Including this process HERWIG is able to describe the fraction of events with a gap between jets over the number without a gap. HERWIG also predicts that this gap-fraction would rise at large rapidity intervals but a detector upgrade in the forward region of the ZEUS detector would be necessary to see this rise. In Fig.4 the published ZEUS gap-fraction is shown together with the predictions of HERWIG (with and without colour singlet exchange) and of PYTHIA which does not include colour singlet exchange. Fig.4(a) is for the present ZEUS acceptance; Fig.4(b) shows how much the signal for hard diffractive processes could be improved if the forward acceptance were increased by one unit of pseudorapidity.

4. *Inclusive K^0 Production in Jets.* A first inclusive study of K^0 mesons in hard photo-produced jets has been carried out. Preliminary results were presented at ICHEP96. It is apparent that the standard parameters of the PYTHIA Monte Carlo overestimate the numbers of K^0 mesons in jets (see Fig.5). This reinforces earlier investigations of K^0's in jets produced in other circumstances, and indicates that further work is needed in this area.

5. *Colour Coherence in Photon Induced Reactions.* In order to study colour coherence effects Monte Carlo studies of 3-jet events were performed where two of the jets were required to have $E_T > 30$ GeV and a third jet with $E_T > 3$ GeV is present. In the Fig.6 the pseudorapidity of the third jet in the partonic centre-of-mass frame (η_3) is shown for HERWIG (solid line), for PYTHIA (dashed line) and for PYTHIA with all of the coherence in the parton shower switched off (dotted line). Thus the solid line represents the highest degree of coherence and the dotted line the lowest. In Fig.6(a) only direct photoproduction processes are shown and in Fig.6(b) only resolved photoproduction processes are shown. The distributions can be understood if one considers the third jet to arise primarily from initial state radiation. Then the effect of coherence is to suppress large angle radiation and the degree of our sensitivity to coherence is given by the amount of difference between the three histograms. This study has been published in the Proceedings of the HERA Workshop. A study similar to this has already been performed with $p\bar{p}$ data at the Tevatron but the ability to distinguish between direct and resolved photoproduction processes is a clear advantage at HERA.

6. *Elastic J/Ψ Photoproduction.* The reaction $e^+p \to e^+pJ/\psi$ has been studied and the cross section for elastic J/ψ photoproduction has been measured as a function W in the range $40 < W < 140$ GeV. The photoproduction cross section, $\sigma_{\gamma p \to J/\psi p}$, is observed to rise with W (see Fig.7). A fit to the ZEUS data to determine the parameter δ in the form $\sigma_{\gamma p \to J/\psi p} \propto W^\delta$ yields the value $\delta = 0.91 \pm 0.21 \pm 0.12$. This value of δ disfavours both a flat W dependence, $\sigma_{\gamma p \to J/\psi p} \propto W^0$, and that expected in the soft pomeron model of reference in which δ is expected to take the value $\delta = 0.22$ in this W range. Perturbative QCD calculations have been shown to give a good description of the data. The differential cross section $d\sigma/d|t|$ has been measured over the range $|t| < 1.0$ GeV^2. It falls exponentially with a slope parameter of $4.6 \pm 0.4^{+0.4}_{-0.6}$ GeV^{-2}. In addition, the decay angular distributions are shown to be consistent with s-channel helicity conservation.

7. *Study of Elastic ρ^0 Photoproduction at HERA.* The physics of diffractive scattering processes has emerged as one of the most interesting topics of study in the early running of HERA. Up to now, the cross section for events in which the virtual photon diffractively dissociates into a vector meson has been determined by the H1 and ZEUS experiments without measuring the scattered proton. A new measurement has been performed using the ZEUS Leading Proton Spectrometer (LPS) which detects protons scattered at very small angles. In this spectrometer, silicon micro-strip detectors are used in conjunction

with the proton beam line elements to precisely measure the momentum of the scattered proton with accuracies of 0.4% in the longitudinal momentum and 5 MeV in the transverse momentum. The use of the LPS also eliminates the contamination from events with diffractive dissociation of the proton into low mass states. The process has been investigated in the range of $0.073 < |t| < 0.4$ GeV^2 for photon virtualities $Q^2 < 1$ GeV^2 and photon-proton centre of mass energies W between 50 and 100 GeV. For the first time at HERA t has been determined directly by measuring the momentum of the scattered proton using the LPS. In the measured range the differential cross section $d\sigma/dt$ (see Fig.8) exhibits an exponential shape with a slope $b = 9.8 \pm 0.8(\text{stat.}) \pm 1.1(\text{syst.})$ GeV^{-2}.

8. *Measurement of Light Vector Meson Production in DIS and Photoproduction.* Studies have continued into vector meson production in both DIS and photoproduction. In DIS the exclusive production of ρ^0, ϕ and J/ψ mesons has been studied and cross sections measured as a function of Q^2, p_T^2, t and W, where p_T is the transverse momentum with respect to the proton beam direction, t is the square of the four-momentum transfer at the photon vertex and W is the photon-proton centre of mass energy. The strong rise of the cross sections $\sigma(\gamma^* p \to V^0 p)$ with W compared to those measured by other DIS experiments at lower energies cannot be explained by production through soft Pomeron exchange alone. However, the rise is consistent with recent perturbative QCD calculations where the rise of the cross section with W is associated with the increase in the gluon momentum density of the proton at low x. The photoproduction cross sections of light vector mesons, which at HERA energies are characterised by a slow rise with W, are in agreement with theoretical models based on Regge theory and the exchange of a soft Pomeron. The different behaviours in the low and high Q^2 regions suggest that there is a transition region between low and high photon virtualities. Measurements of the vector meson cross sections at lower Q^2 values may provide information about where the transition occurs and its origin. As more data are taken and newer elements of the ZEUS detector are exploited such measurements will be made become possible.

9. *Charm Production in Deep Inelastic Scattering (DIS) at HERA.* Charm production in DIS proceeds mainly via the photon gluon fusion mechanism. Thus measurement of the charm production cross section is of great importance for understanding the gluon dynamics of the proton; it can also provide insight into the charm production mechanism and test ideas about the origin of charm in the proton. Charm is identified by the $D^{*\pm} \to D^0 \pi_s^\pm$, $D^0 \to K^\mp \pi^\pm$ or $D^0 \to K^\mp \pi^\pm \pi^\pm \pi^\mp$ decay channels. In both cases (but especially the latter, where the combinatorial background is significantly larger) the signal to noise ratio is greatly improved when particle identification is used. For the latter case we exploit the measured rate of energy loss in the CTD. Figure 9 shows the distribution of the mass difference between D^* and D^0 for the decay $D^0 \to K^\mp \pi^\pm$. The present analysis on 1995 data aims to provide a measurement of F_2^{charm} at HERA with improved statistics and in a wider range than that measured from 1994 data by both ZEUS and H1. The use of the $D^0 \to K^\mp \pi^\pm \pi^\pm \pi^\mp$ channel offers a new way to tag charm at HERA, and consequently increases strongly the statistics available.

10. *Hadronic Final States in DIS at HERA.* The fragmentation functions, $D(x_p, Q^2)$, are comparable to structure functions in as much as neither can be calculated in perturbative QCD but given a measured starting distribution one knows how to evolve in Q^2 for a given x_p, where x_p is the scaled momentum $2p/Q$ in the current region of the Breit frame. The scaling violations of the fragmentation function with increasing Q are due to increased phase space for gluon radiation leading to softer particle spectra; the scaling violations at large x_p allow a measurement of α_s. Such studies have been performed at LEP by incorporating lower energy PETRA data; at HERA a range of Q^2 is available to make this measurement

in a single experiment. In principle the whole range of x_p could be used to extract α_s but theoretical understanding limits us to this large x_p region.

The preliminary inclusive cross sections, $1/\sigma_{\rm tot} d\sigma/dx_p$, for charged particle production in the current fragmentation region of the Breit frame are shown in Fig. 10 where the errors are statistical only. The turn over at low x_p and low Q^2 is an artefact of mass effects depopulating the current region. At $Q^2 > 100$ GeV^2, the Q^2 dependence of the inclusive scaled momentum cross section in the different x_p bins becomes greater as x_p increases indicating scaling violations. Larger statistics are needed to gain the necessary precision at large x_p and high Q^2 before the measurement becomes competitive with other determinations of α_s.

11. *Transverse Energy Flow Distributions in Deep Inelastic Scattering at HERA.* The observed rise of F_2 at small x and fixed Q^2 can be described by both types of parton density evolution equations currently discussed, i.e. the BFKL and the DGLAP equations. One of the main differences in these evolution schemes is that the DGLAP evolution predicts a strong ordering in the transverse momentum of the gluons emitted whereas the BFKL scheme does not. As a consequences one expects that the average number of emitted gluons and the average transverse momentum of the gluons is larger, if the parton dynamics is determined by the BFKL rather than by the DGLAP evolution. Therefore it was hoped that, by looking at the hadronic transverse momentum (E_T^*) flow distributions in the γp cms, one could obtain information about the parton dynamics. Results from a recent analysis of ZEUS data have been compared with new model calculations which include the simulation of the hadronisation. For fixed values of Q^2 and W the E_T^* flow distributions are almost flat in η^* at a level of 2 GeV per unit of η^*, except for $Q^2 \gtrsim 40\,{\rm GeV}^2$ where the distribution rises towards the photon fragmentation region ($\eta^* \sim 2 - 2.5$). Here η^* denotes the pseudorapidity in the $\gamma^* p$ cms. These features are described satisfactorily by the latest versions of the model calculations although they are based on different parton dynamics. This is due to a considerable flexibility in the treatment of the hadronization. This analysis is thus unable to draw any firm conclusion regarding the underlying parton evolution dynamics.

12. *Search for Right-handed W-bosons and Heavy Neutrinos.* The Standard Model of fundamental interactions breaks parity, but it is still a mystery how and why this happens. One explanation is that there is also a right-handed $SU(2)$ gauge group which is associated to very heavy vector bosons that have not yet been observed. An alternative would be that the right-handed W boson (W_R) has a mass as low as that of the known left-handed W, and that the symmetry is solely broken by the very high mass of right-handed neutrinos (N_R). Low energy measurements, especially the $K_L^0 - K_S^0$ mass difference, impose severe limits on the possible masses of a light W_R which depend critically on assumptions about the right-handed Cabibbo-Kobayashi-Maskawa matrix describing the mixing between different quark flavours due to the new interaction. On the other hand, direct searches at hadron colliders have not been able to probe this region of parameter space because the W_R would in this case decay only into jets where the background is prohibitively large. The ZEUS experiment at HERA would be able to directly detect a heavy right-handed neutrino in combination with a light right-handed W boson, if nature chose to make use of this loophole in our existing knowledge. As no excess of such events were found, the result of the measurement was presented in terms of limits on the possible values of the coupling g_R between the right-handed W boson and the fermions, as a function of the mass of the W and the heavy neutrino N_R. ZEUS is sensitive to the interesting possibility that the right-handed W_R mass, m_{W_R}, is less than that of the heavy neutrino (m_{N_R}). The mass range covered includes the case that m_{W_R} is near to that of the known left-handed W, as

well as cases where the heavy neutrino has a mass close to that of the recently found top quark. The result was presented at ICHEP '96 in Warsaw.

13. *Monte Carlo Studies for the Investigation of Axial and Vector Coupling of the Z^0 at HERA.* Methods for determining the Neutral Current (NC) axial and vector couplings of the Z^0 to the quarks at HERA have been studied. Without beam polarisation, limits on deviations from the Standard Model (SM) value of the axial coupling of the up-type quark to the Z^0 may be obtained using ratios of NC cross sections to Charged Current (CC) cross sections. Assuming an electron (positron) beam polarisation of 70%, ratios of polarised NC and CC cross sections may be used to set limits on deviations of the up-type quark vector coupling from the SM value. In a study for the recent HERA Workshop it was shown that with an integrated luminosity of $1000\,\mathrm{pb}^{-1}$, divided equally between the left- and right-handed electron and positron beams, fractional errors on v_u, a_u, v_d and a_d of 13%, 6%, 17% and 17% may be obtained from a full fit, while if the d (u) quark couplings are held fixed while the u (d) quark couplings are allowed to vary then the errors on v_u (v_d) and a_u (a_d) are 4% (6%) and 4% (10%) respectively. These results are summarised in Fig.11.

Further prospects for structure function physics were studied in a HERA physics workshop during this year. The workshop was based on the experience gained in the first four years of running at HERA, and on recent important theoretical developments, in particular the extension of next-to-leading order (NLO) calculations to more observables, and on small x resummations. The major goals on the experimental side were to estimate the systematic precision which may be achieved for the proton structure function, extend the scope of the studies to the charm contribution to the proton structure functions at low x, and to investigate measurements of the pion structure function. The knowledge of existing HERA data allowed for much more reliable simulations than in previous workshops. Recommendations on future HERA running were made which are included in the proceedings of the workshop. A challenging scenario of running HERA for many years has been developed. It requires the accumulation of high luminosity for both lepton beam charges and also the acceleration of deuterons. This will permit very high precision to be reached, i.e. an error level of only a few % for the proton structure function F_2, and also accurate results for F_L, F_2^c and F_π. On the basis of this data, high precision studies of QCD in the regions of very small x and of very large Q^2 can be performed. HERA still remains a unique instrument for the study of lepton-hadron interactions at the highest energies, and its potential is only gradually becoming realised. We expect significantly higher luminosities in the future and eventually polarised electron and positron beams.

Publications.

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2. *Study of Elastic ρ^0 Photoproduction at HERA using the ZEUS Leading Proton Spectrometer* M. Derrick et al., DESY 96-183 (1996) accepted by Zeitschrift f. Physik - MS 418
3. *Search for Lepton Flavour Violation in ep Collisions at 300 GeV Centre of Mass Energy* M. Derrick et al., DESY 96-161 (1996) submitted to Zeitschrift f. Physik
4. *Measurement of Elastic Omega Photoproduction at HERA* M. Derrick et al., DESY 96-159 (1996) accepted by Zeitschrift f. Physik - MS 482
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6. *Dijet Angular Distributions in Resolved and Direct Photoproduction at HERA* M. Derrick et al., Physics Letters B 384 (1996) 401-413

7. *Observation of Events with an Energetic Forward Neutron in Deep Inelastic Scattering at HERA* M. Derrick et al., Physics Letters B 384 (1996) 388-400
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9. *Measurement of the Reaction $\gamma^* p \to \phi p$ in Deep Inelastic Scattering at HERA* M. Derrick et al., Physics Letters B 380 (1996) 220-234
10. *Measurement of the Diffractive Cross Section in Deep Inelastic Scattering* M. Derrick et al., Zeitschrift f. Physik C 70 (1996) 391-412
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13. *Rapidity Gaps between Jets in Photoproduction at HERA* M. Derrick et al., Physics Letters B 369 (1996) 55-68
14. *Measurement of the Proton Structure Function F_2 at low x and low Q^2 at HERA* M. Derrick et al., Zeitschrift f. Physik C 69 (1996) 607-620
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17. *Exclusive $\rho(0)$ Production in Deep Inelastic Electron-Proton Scattering at HERA* M. Derrick et al., Physics Letters B 356 (1995) 601-616
18. *Diffractive Hard Photoproduction at HERA and Evidence for the Gluon Content of the Pomeron* M. Derrick et al., Physics Letters B 356 (1995) 129-146
19. *Measurement of the Diffractive Structure Function in Deep Inelastic Scattering at HERA* M. Derrick et al., Zeitschrift f. Physik C 68 (1995) 569-584

Ph.D Theses.

1. D. Bailey (Oxford) *The performance of the ZEUS CTD z-by-timing system and a study of charm production at HERA.*
2. V.L. Harris (IC) *Studies in the Breit frame at HERA.*
3. B.H.Y. Hung (IC) *J/ψ meson production in positron proton collisions at HERA.*
4. M.L. Utley (Glasgow) *A first study of the structure of the virtual photon at HERA.*
5. A.F. Whitfield (IC) *A measurement of vector meson production in ep collisions with the ZEUS detector at HERA.*
6. T. Yip (Oxford) *Inelastic J/ψ photoproduction in electron-proton collisions at HERA.*

Talks on ZEUS and ZEUS-related physics given at International Conferences.

1. N. Brook, *The Measurement of Fragmentation Functions in the Breit Frame.* DIS 96 Workshop, Rome, April 1996.
2. N. Brook, *The Measurement of Fragmentation Functions in the Breit Frame.* Workshop on HERA Physics, Durham, UK, June 1996.

3. P. Bussey, *Observation of isolated high E_T photons in hard photoproduction at HERA.* DIS 96 Workshop, Rome, April 1996.
4. J. M. Butterworth, *HERA Physics* Madison Phenomenology Symposium, Madison, USA April 1996.
5. R.J. Cashmore, *Status Report - ZEUS.* Report to DESY PRC, January 1996.
6. R.J. Cashmore, *Electro Weak Summary talk.* HERA Workshop, DESY, May 1996.
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9. R. Devenish, *Present data source for gluon distribution function.* DIS and Related Phenomena, Rome, 1996.
10. L. Lindemann, *Prospects for measuring F_L.* Low x and QCD Workshop Durham, UK, June 1996
11. N.A. Pavel, *Transverse Energy Flow Measurements in DIS.* Low x and QCD Workshop Durham, UK, June 1996
12. A. Quadt, *Structure Functions.* $\bar{p}p$ Collider Workshop, Padova, Italy, June 1996.
13. T.P. Shah, *Hadronic Final States in DIS Events at HERA.* International Symposium on Multiparticle Dynamics, Faro, Portugal, September 1996.
14. L.E. Sinclair, *Rapidity Gaps in Hard Photoproduction.* Topical Conference on Hard Diffractive Processes, Eilat, Israel, February 1996.
15. D. Waters, *Charged Current DIS and W Production at HERA.* International Conf. on High Energy Physics, Warsaw, Poland, July 1996

Contributions to the Workshop on Future Physics at HERA.

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3. J. Blumlein, A.T. Doyle, F. Hautmann, M. Klein, A. Vogt
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5. N. Brook, T. Carli, R. Mohr, M. R. Sutton, R. Waugh *Tuning Monte Carlo Event Generators to HERA Data*
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6. P. Bussey, B. Levtchenko and A. Shumilin
   Prompt photon, Drell-Yan and Bethe-Heitler processes in hard photoproduction
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7. J.M. Butterworth, L. Feld, M. Klasen and G. Kramer

Matching Experimental and Theoretical Jet Definitions for Photoproduction at HERA
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8. J.M. Butterworth, M. Hayes, M.H. Seymour and L. E. Sinclair
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9. R. Cashmore, E. Elsen, B.A. Kniehl, H.Spiesberger
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10. R.J. Cashmore, S. Dagan, O. Deppe, J. Edmonds, J.C. Hart, H. Hessling, K.R. Long, J.K. Sedgbeer, H. Spiesberger, R. Walczak, A.F. Whitfield and F. Zetsche
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11. A.Lebedev, L.Sinclair, E.Strickland, J.Vazdik
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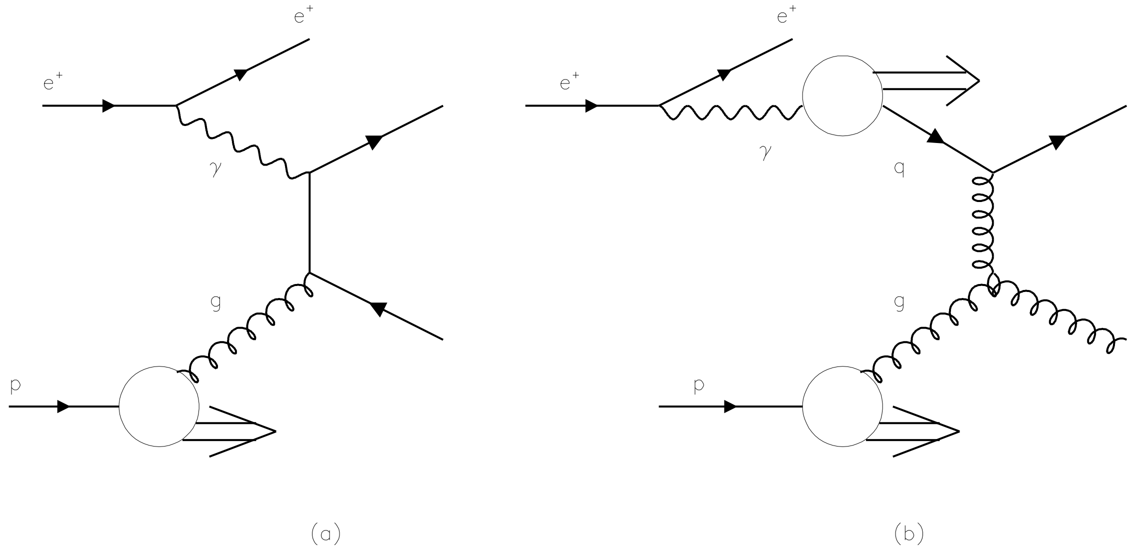

Figure 1: Examples of LO QCD (a) 'direct' and (b) 'resolved' dijet production diagrams.

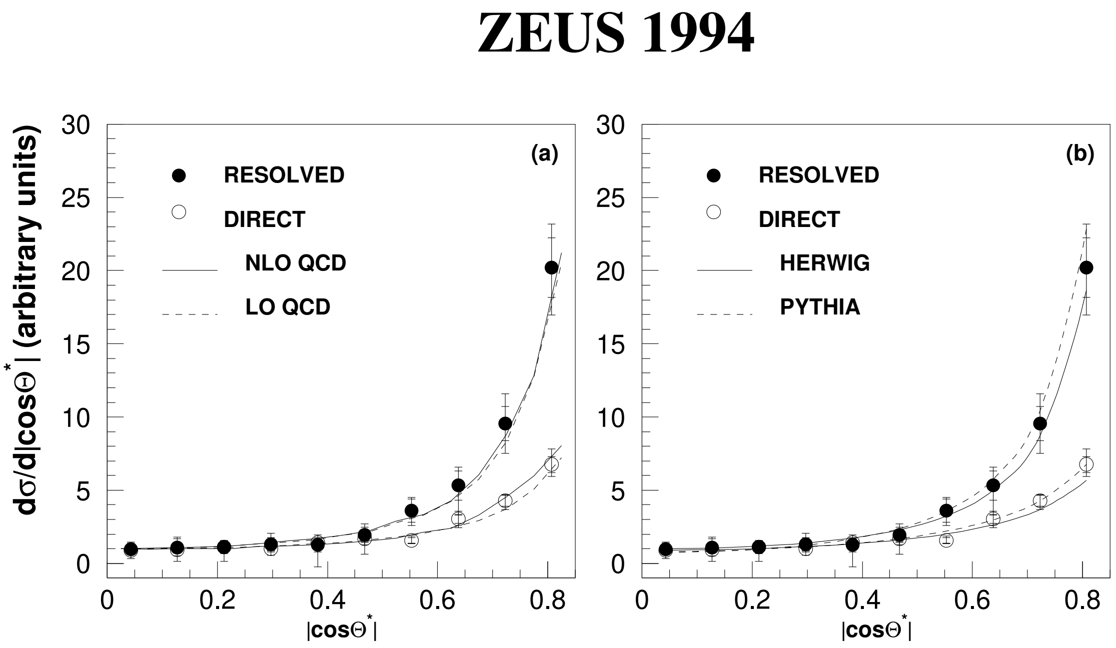

Figure 2: $d\sigma/d|\cos\theta^*|$ normalized to one at $\cos\theta^* = 0$ for resolved (black dots) and direct (open circles) photoproduction. In (a) the ZEUS data are compared to the NLO prediction and the LO prediction. The parton distribution sets used in the calculation are CTEQ3M for the proton and GRV (LO) for the photon. The PYTHIA and HERWIG distributions are shown in (b) The inner error bars are the statistical errors and the outer are the sum in quadrature of the statistical and systematic errors, excluding the energy scale and luminosity uncertainties.

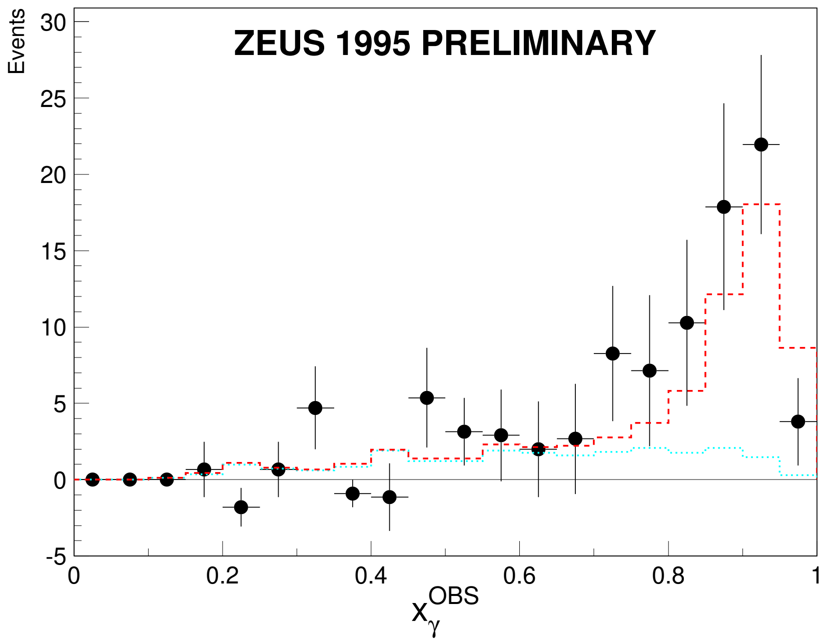

Figure 3: x_γ distribution of prompt photon events. The data is shown as points with error bars; Monte Carlo predictions of direct and resolved subprocesses are shown as dashed and dotted histograms respectively.

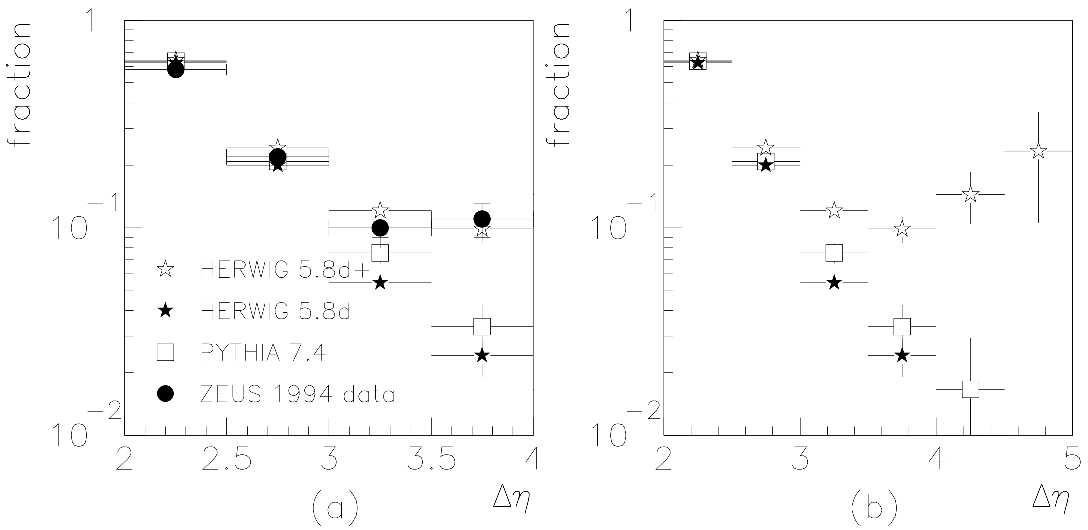

Figure 4: Rapidity Gaps between Jets in Photoproduction: (a) for the present ZEUS acceptance and (b) for the case where the forward acceptance is increased by one unit in η.

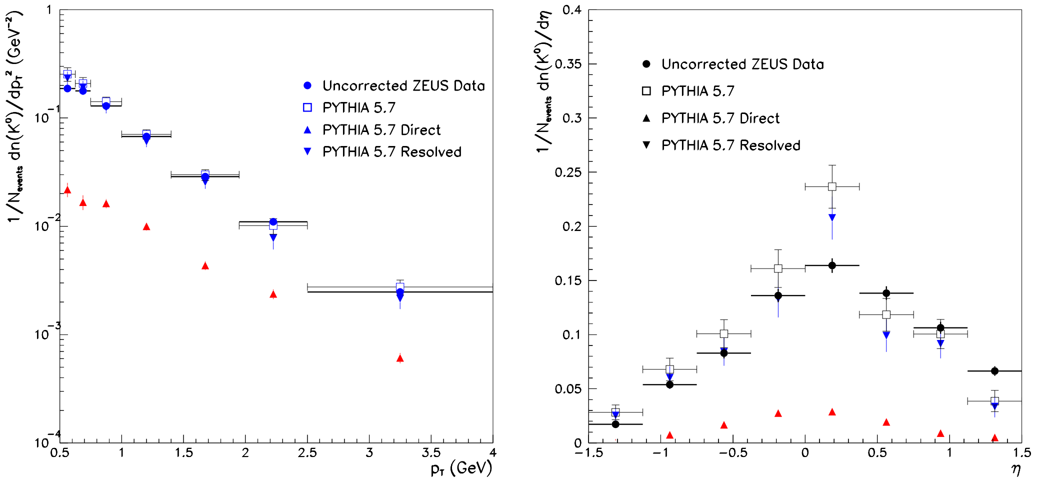

Figure 5: Uncorrected distributions in p_T and pseudorapidity η for K^0 mesons in events containing a jet with $E_T \geq 7$ GeV and $|\eta| \leq 0.5$ compared with predictions of PYTHIA.

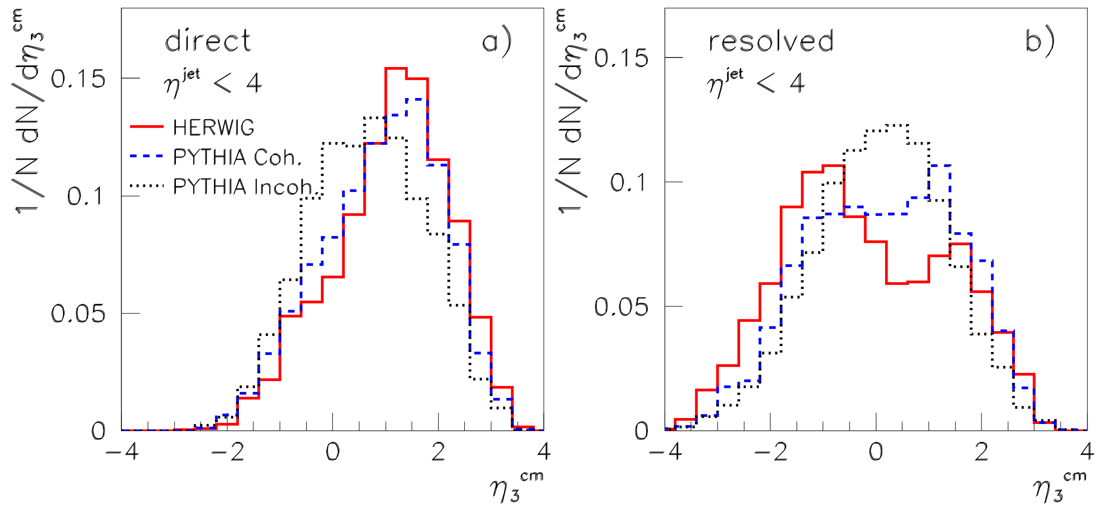

Figure 6: Pseudorapidity (η_3) distribution for the third jet in 3-jet events where the other two jets have $E_T > 30GeV$. The figures (a) and (b) show the distributions for direct and resolved photoproduction processes respectively.

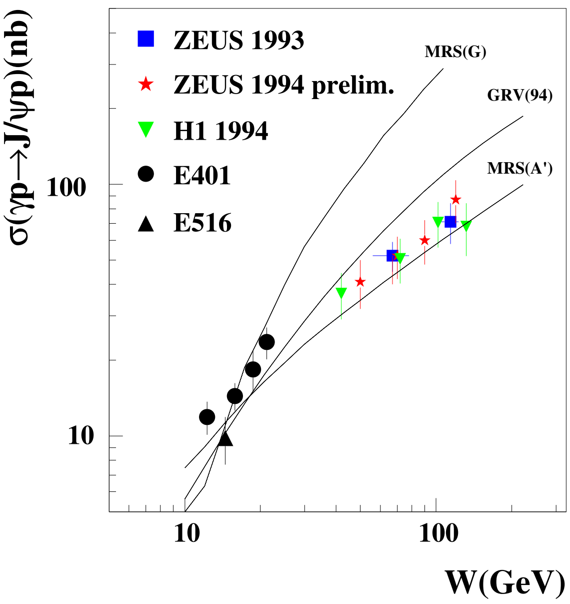

Figure 7: Elastic J/ψ photoproduction cross section as a function of W for ZEUS, H1 and lower energy experiments. The curves show QCD calculations for various choices of parton distributions.

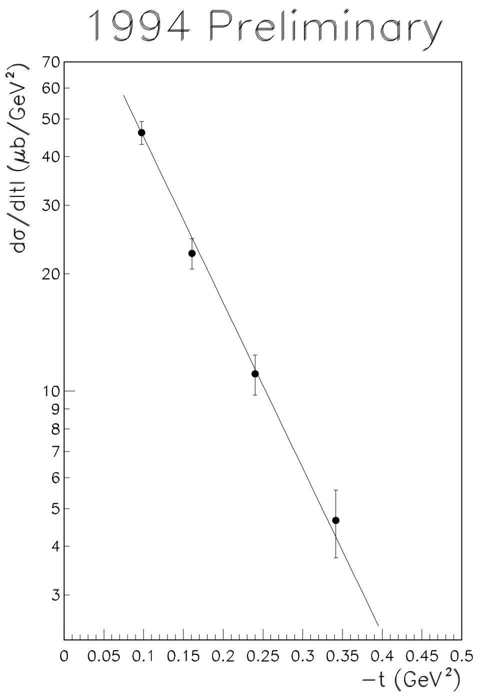

Figure 8: Differential cross section for elastic ρ^0 photoproduction as measured with the LPS

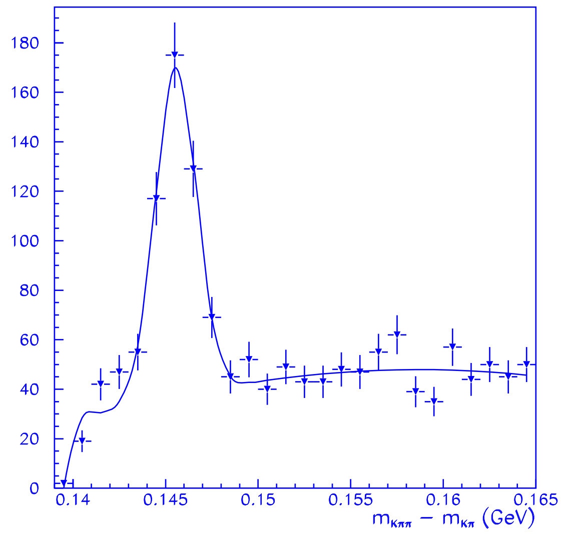

Figure 9: Mass difference between D* and D^0 for the decay D$^0 \rightarrow K^-\pi^+$ (and charge conjugated) observed in 1995 data for $Q^2 > 4$ GeV^2. The full line is the result of a fit to a gaussian and a polynomial background.

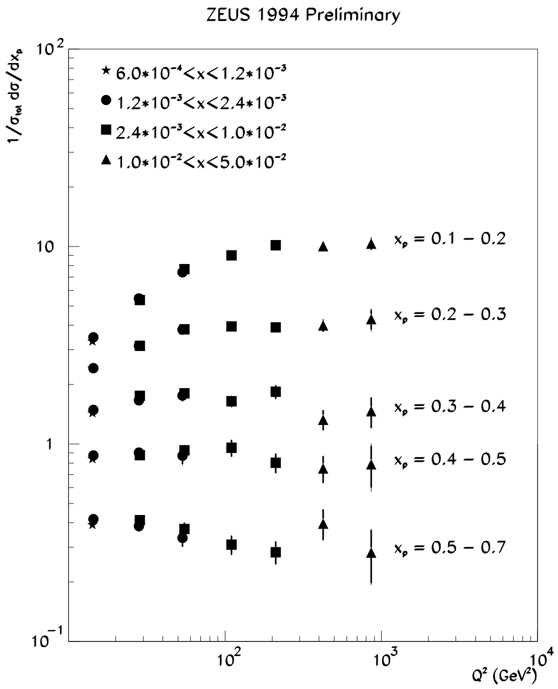

Figure 10: Preliminary inclusive scaled momentum cross section in the Breit frame for different x bins as a function of Q^2.

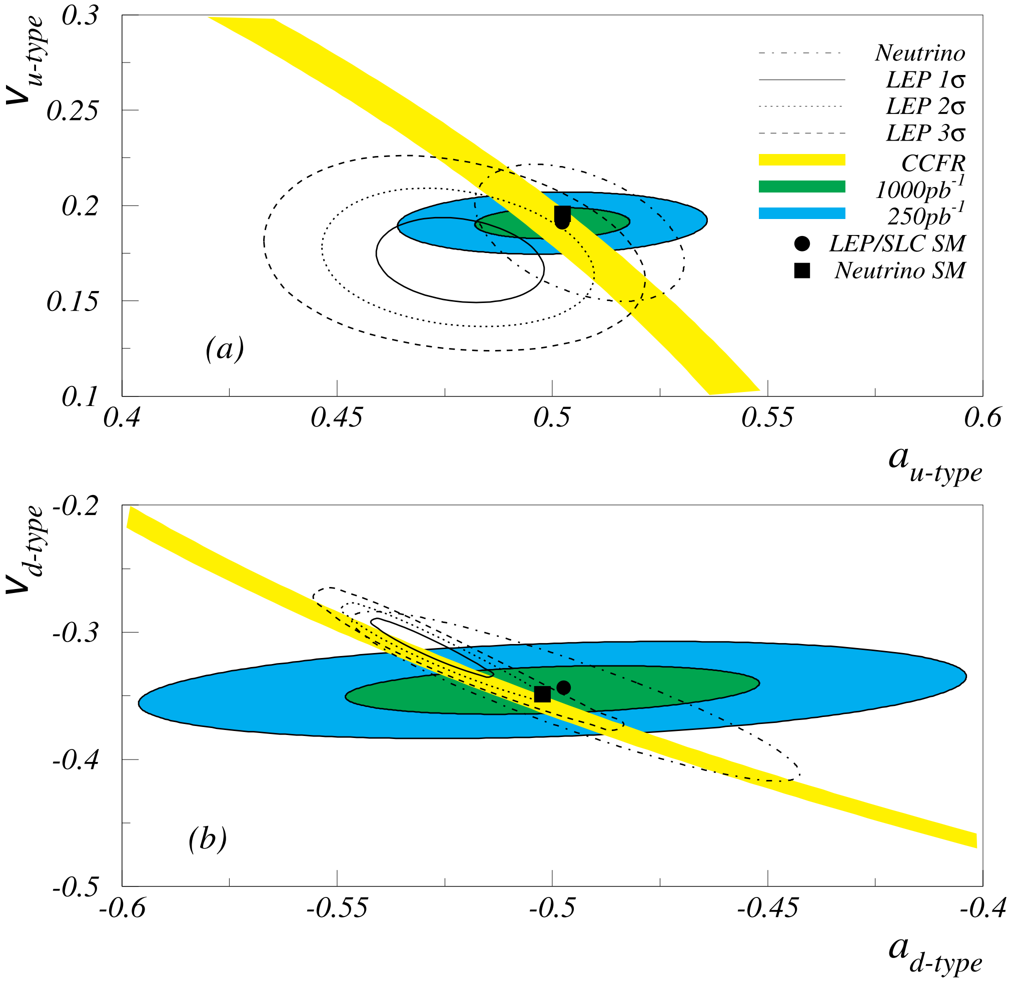

Figure 11: Summary of measurements of u-type (a) and d-type (b) quark couplings to the Z^0. The obtainable results of a measurement at HERA are shown as the shaded ellipses for 250 pb^{-1} and 1000 pb^{-1} of data. Fits for the couplings of the u (d) quarks were performed with the d (u) quark couplings fixed at their SM values. The open ellipse drawn with a dash-dotted line shows the one standard deviation (1σ) contour obtained in a fit of the four chiral couplings of the u and d quarks to a compilation of neutrino DIS data. The solid, dotted and dashed ellipses show the 1, 2 and 3 σ limits of the combined LEP/SLD results for the c and b quark couplings. In the case of the CCFR the couplings of the u (d) quarks are obtained with the d (u) quark couplings fixed at their SM values. SM coupling values including radiative corrections appropriate for comparison with e^+e^- (circle) and neutrino (square) measurements are also shown.