New Results on Neutral and Charged Current Scattering at high Q^2 from H1 and ZEUS

Frank Lehner
DESY
22603 Hamburg, Germany
E-mail: lehnerf@mail.desy.de

Abstract

The recent observation by the H1 and ZEUS experiments at HERA of an excess of deep-inelastic ep scattering events at high Q^2 is discussed. For $Q^2 > 15000$ GeV^2 H1 detects in the neutral channel 18 events, while about 8 were expected and ZEUS observes for $Q^2 > 35000$ GeV^2 2 events, but expects 0.2. I will give a short introduction to DIS and explain the selection criteria used in both analyses. The Poisson Probabilities of the excess are given and discussed. Finally I report about a search for isolated high energetic leptons with an imbalance in transverse momentum. While the majority of events show topologies typical for charged current processes, five events have been observed by H1 with an isolated e^- or $\mu^\pm$ of large p_t. The corresponding standard expectation from W production with subsequent decay into leptons is 1.75 events.

1 Introduction

High energy physics at HERA offers the unique possibility to investigate the structure of protons by colliding a 27.5 GeV electron beam with a 820 GeV proton beam. This collision has a center of mass energy (cms) of $\sqrt{s} \approx 300$ GeV, which corresponds to a 50 TeV fixed target beam. If the virtuality of the exchanged boson at high squared 4-momentum transfers Q^2 is around 10^4, HERA allows to probe distances in the proton down to $2 \cdot 10^{-16}$ cm. In the years 1994-1996 and until July 1997 the two detectors at HERA, H1 and ZEUS, collected an integrated luminosity $\mathcal{L}$ of 23.7 pb^{-1} and 33.5 pb^{-1} respectively. Therefore both experiments are sensitive to cross sections in the order of 50 fb.

In this paper the published HERA results [1], [2] and their recent update [3], [4] for the summer conferences are presented. This includes a search for isolated highly energetic leptons (e, μ) with large missing energy. Before discussing the results I will give a small overview of deep inelastic scattering.

2 Deep Inelastic Scattering

Deep inelastic scattering (DIS) is usually described by introducing the following kinematic variables

$$Q^2 = -(k-k')^2 \quad \text{4-momentum transfer} \tag{1}$$

$$x = \frac{Q^2}{2P \cdot (k-k')} \quad \text{parton momentum fraction} \tag{2}$$

$$y = \frac{P \cdot (k-k')}{P \cdot k} \quad \text{fractional energy transfer} \tag{3}$$

$$M = \sqrt{sx} = E_{cm}^{eq} \quad \text{mass of } eq\text{-System} \tag{4}$$

where k and k' denote the 4-momentum of the incoming and outgoing lepton and P the 4-momentum of the Proton. Only 2 out of the 3 kinematic variables Q^2, x, y are independent for a fixed cms energy s due to relation $Q^2 = sxy$.

The double differential cross section for neutral current (NC) DIS, where a neutral boson is exchanged, can be written in the following form [5].

$$\frac{d^2\sigma^{NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left\{Y_+(y)F_2(x,Q^2) + Y_-(y)xF_3(x,Q^2) - y^2F_L(x,Q^2)\right\} \tag{5}$$

$$Y_\pm = 1 \pm (1-y)^2 \tag{6}$$

The generalized structure functions F_i can be expressed in terms of quark densities[1]

$$\begin{pmatrix} F_2(x,Q^2) \\ xF_3(x,Q^2) \end{pmatrix} = x \sum_{q=quarks} \begin{pmatrix} C_2^q(Q^2)\left[q(x,Q^2)+\overline{q}(x,Q^2)\right] \\ C_3^q(x,Q^2)\left[q(x,Q^2)-\overline{q}(x,Q^2)\right] \end{pmatrix}$$

The electroweak coefficients C_i^q contain the photonic, the Z° and the interference couplings as well as their propagator terms of the standard electroweak theory to the quarks and are predicted to be known to 0.25 % in the HERA range [8].

The NC DIS cross section depends at high Q^2 and high x on the valence structure in the proton. Since the charge of the u-Quark is twice the charge of the d and the quark density of the u-Quark for protons is greater than the density of the d-Quark, $u(x) > d(x)$, the cross section is dominated by the u-Quark contribution. In the case of CC events where the interaction is mediated by a $W^\pm$ exchange, the dominating quark density depends on the charge of the beam lepton. During the years 1994-1997 HERA was running with positrons allowing a better life time of the lepton beam. Therefore the d-Quark contribution dominates the CC cross section. Both cross sections for NC and CC have been measured by H1 [9] and ZEUS [10] in previous years up to $Q^2 = 15000$ GeV^2 and were found to be in agreement with the standard DIS expectations.

The uncertainties in the predictions of ep cross sections at high Q^2 due to structure functions have been carefully investigated by a NLO QCD analysis of data at high x and lower Q^2 from various fixed target experiments [11]. Since the QCD evolution is believed to be safe, the main uncertainty is due to systematic errors in the fixed target experiments. At high $x \sim 0.5$ and $Q^2 \sim 3 \cdot 10^4$ GeV^2 the uncertainty in the NC cross section was estimated to be about 6 % containing a contribution due to the variation of α_s by 5 % and due to an uncertainty of 50 % on the strange quark content in the proton. Similar results were found by comparing the shapes of existing parton densities in the high Q^2 regime. The uncertainty in the structure function F_2 have been recently cross checked and basically verified by members of the CTEQ Collaboration [12]. However it turned out, that assumptions like a big intrinsic charm component in the proton at very high x [13], where $\overline{c} \neq c$, or a peaking u-distribution at $x \approx 1$ [12], could eventually be a contribution to HERA when Q^2 is sufficiently large. Such a new component is only conceivable at very large x beyond the measured region of fixed target experiments. Also the Tevatron provides an important constraint, because ep scattering is linear in the quark densities, while $p\overline{p}$ is quadratic, so that an excess at HERA implies a large effect at the Tevatron.

A further uncertainty of 2 % on the expectations of the cross section is due to radiative corrections. It has been estimated by comparing the radiative cross sections as calculated in existing MC generators and semi-analytical programs.

The 4π-detectors at HERA measure both the scattered electron and the hadronic final state, providing various methods to determine the kinematical variables defined above. This novel feature of the experiments, compared to the fixed target ones, offers important cross check of systematic effects, radiative corrections and calibrations. Table 1 shows the techniques used for reconstruction. The main method employed by

Technique	Variables	Features	Used by
Double Angle	θ_e, θ_h	Independent of E-scales	ZEUS
Electron	E_e, θ_e	Depends only on electron	H1
Hadron	E_h, θ_h	Only choice for CC	H1+ZEUS
Sigma Σ	E_e, θ_e, E_h	Insensitive to ISR	H1

Table 1: Various reconstruction methods of the kinematic variables used by H1 and ZEUS in deep inelastic scattering.

H1 is the Electron method, which is based on electron information only. It provides the most precise reconstruction at high y which is most relevant for the analysis described below. The influence of initial state photon radiation (ISR) can be checked by comparing to the Σ technique, which gives precise

[1]The longitudinal structure function F_L can safely be neglected at high Q^2.

information over the whole kinematic range and is essentially independent of ISR. The Double Angle method, preferentially used by ZEUS, has a high accuracy at high Q^2 and does not suffer from potential miscalibration effects in the energy scales. There is only one technique available for Charged Current (CC) processes. The Hadron or Jacquet-Blondel method makes use of the hadronic information and provides a fair reconstruction of the kinematics. A detailed comparison of the various reconstruction techniques for events at high Q^2 and kinematical shifts in the presence of ISR can be found in [6] and [7].

3 The H1 and ZEUS Detectors

Detailed descriptions of the H1 and ZEUS detectors can be found in [14] and [15]. For the high Q^2 analysis both experiments rely essentially on their calorimeters to measure the final state positron or hadronic flow with high transverse energy.

The H1 liquid argon (LAr) sampling calorimeter [16] covers the polar angular range [2] $4° \leq \theta \leq 153°$. It consists of a lead/argon electromagnetic section of fine granularity followed by a stainless steel/argon hadronic section which provide in total ~ 44000 read-out cells. Electromagnetic showers are measured with a resolution of $\sigma(E)/E = 12\%/\sqrt{E/[GeV]} \oplus 1\%$. After software energy weighting the resolution for hadronic showers is $\sigma(E)/E = 50\%/\sqrt{E/[GeV]} \oplus 2\%$. These resolutions were measured in test beams at CERN with electron energies up to 166 GeV and pion energies up to 200 GeV [16]. The absolute energy scales are known to the level of 3 % and 4 % for electromagnetic and hadronic energies respectively. The high granularity offers an angular resolution of the positron measured from the electromagnetic shower of ~ 2 mrad below 30° and ≤ 5 mrad at larger angles.

The ZEUS uranium/scintillator calorimeter [17] covers the polar angular range $2.6° \leq \theta \leq 176.1°$ and is segmented longitudinally in ~ 6000 read-out cells. It provides a resolution of $\sigma(E)/E = 18\%/\sqrt{E/[GeV]}$ for electromagnetic showers and $\sigma(E)/E = 35\%/\sqrt{E[GeV]}$ for pion induced hadronic showers as measured in test beams for energies up to 120 GeV. The electromagnetic and hadronic absolute energy scales are known to 3 %. The angular resolution of the positron is ~ 5 mrad.

Both experiments use their central tracking to determine the primary interaction vertex, and determine the luminosity from the rate of the Bethe-Heitler $ep \rightarrow ep\gamma$ bremsstrahlung measured in a luminosity monitor.

4 Event Selection

The main selection criteria designed by H1 and ZEUS to find NC DIS events at high Q^2 are listed in Table 4 and rely essentially on calorimetric information. Both H1 and ZEUS require for identification an isolated positron candidate. Beside the energy cut a cluster-track link matching is imposed down to $\theta > 10°$ by H1 and $\theta > 17°$ by ZEUS to suppress background from photoproduction of prompt photons. Below 17° ZEUS employs a slightly more severe $P_{t,e}$ cut (30 GeV compared to 25 GeV for H1) in the transverse momentum of the scattered electron. Both positron selection efficiencies exceed 90 % everywhere within the acceptance cuts. The requirement for longitudinal momentum conservation, expressed by $\sum E - P_z$, eliminates the background from photoproduction of high E_t jets. Since conservation of $\sum E - P_z$ in DIS events holds, a peaking distribution at $2 \cdot E_e^0$ is expected. Hence this cut also rejects DIS events where a (undetected) very hard collinear γ is emitted by the initial state positron. To remove QED-Compton scattering, events are rejected which have a second isolated electromagnetic cluster typically found back to back in azimuthal direction. Additionally Table 4 presents selection cuts for CC DIS events in the high Q^2 domain, relying also on calorimetric information.

Following the above selection complemented by further cuts dedicated to specific background sources and described in detail in [1] and [2], the non-DIS background is estimated to be negligible in the high Q^2 data sample considered.

Figure 1 shows an example of a very high Q^2 event in the H1 detector. These high Q^2 and high x events have characteristic features, which are experimentally very clean. The scattered positron has been

[2] The z-axis is taken to be in the direction of the incident proton and the origin of the coordinate system is the nominal ep interaction point.

Selection NC-Events	
H1	ZEUS
Electron Identification	
shower shape analysis	shower shape analysis
isolation in $\eta - \phi$ cone ($R < 0.25$)	isolation in $\eta - \phi$ cone ($R < 0.8$)
$P_{t,e} > 25$ GeV	$E_e > 30$
cluster-track matching for $\theta > 10°$	cluster-track matching for $\theta > 17°$
	$(P_{t,e} > 30, \theta < 17°)$
Tracking vertex	
$\|z_{vertex}\| < 35$ cm	$\|z_{vertex}\| < 50$ cm
Longitudinal momentum conservation	
$43 < \sum E - P_z < 63$ GeV	$40 < \sum E - P_z < 70$ GeV
$(P_{t,miss}/\sqrt{E_t} < 3\sqrt{GeV})$	$(44 < \sum E - P_z, \theta < 17°)$
Kinematic cuts	
$Q_e^2 > 2500$ GeV^2	$Q_{DA}^2 > 5000$ GeV^2
$0.1 < y_e < 0.9$	$0.05 < y_{DA}$
Selection CC-Events	
$P_{t,miss} > 50$ GeV	$P_{t,miss} > 15\ GeV$
$P_{t,miss}/E_t > 0.6$	$P_{t,miss}/E_t > 0.4$

Table 2: Selection criteria applied by H1 and ZEUS for NC and CC events.

strongly recoiled and travels opposite to the beam positron. Its energy can reach up to 350 GeV. The large transverse momentum is nicely balanced by a hadronic jet, as visible in the $r - \phi$-view of figure 1.

5 Results of the DIS samples

5.1 General properties of NC events

In Figure 2 (left) the two-dimensional distribution of y_e against $M_e = \sqrt{xs}$, the invariant mass of the electron-quark system, is shown. The data are recorded in the years 1994-1996 and partially 1997 by H1 and correspond to an accumulated Luminosity of $\mathcal{L} = 23.7$ pb^{-1}. A similar distribution of y_{DA} versus x_{DA} is presented on the right side. The total Luminosity for ZEUS amounts to $\mathcal{L} = 33.5$ pb^{-1}. In both plots isolines of fixed Q^2 are plotted. H1 observes for $Q_e^2 > 2500$ GeV^2 724 NC DIS events, which is in good agreement with their expectation of 714 ± 69. ZEUS observes 326 NC DIS candidates satisfying their selection criteria and a cut of $Q_{DA}^2 > 5000$ GeV^2. Again there is an excellent agreement with the standard DIS expectations of 328 ± 15 events.

5.2 Q^2-distribution of NC events

In Figure 3 the measured Q_e^2-spectrum of the H1 NC data is shown in comparison with the expectations from standard NC DIS processes. The lower plot shows the ratio of the Q_e^2 distribution and the expectation . The shown errors, resulting from the convolution of the statistical error of the Monte Carlo and the systematic errors of the data, are correlated for different Q_e^2 bins and are indicated in the lower figure as lines above and below unity. These lines correspond to $\pm 1\sigma$ contours and are dominated by the uncertainty in the electromagnetic energy scale of the calorimeter and vary between 8.5 % in the lowest Q^2 bin to 30 % at the highest values of Q_e^2. Whereas for Q_e^2 below 15000 GeV^2 the data agree well, at larger Q^2 a significant deviation is visible and the data exceeds the NC DIS expectation.

Figure 4 shows for the ZEUS NC selection the measured Q_{DA}^2 distribution in comparison with the expectation from standard DIS processes. The lower plot gives the number of events observed above a threshold in Q_{DA}^2 and compares to the DIS expectation. At $Q_{DA}^2 > 20000$ GeV^2 the data is seen to be above the predictions.

Candidate from NC sample

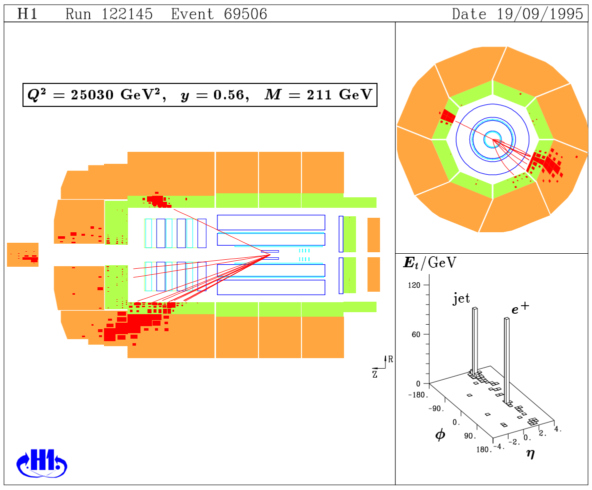

Figure 1: Example of a high Q^2 events recorded by the H1 experiment. The incoming positron is entering from the left, the proton from the right. The recoiled hadronic system balances the transverse momentum of the scattered positron.

To quantify the differences measured by H1 and ZEUS, the Poisson probabilities $\mathcal{P}(N \geq N_{obs})$ are calculated that in a random set of experiments the number of NC DIS events N would fluctuate to values equal to or larger than the observed number of events N_{obs}. The systematic error δb on the mean number of expected events b is taken into account by using the convolution:

$$\mathcal{P}(N \geq N_{obs}) = \int_0^\infty dz G(z; b, \delta b) \sum_{k=N_{obs}}^{\infty} p(k; z) \tag{7}$$

where $p(k; z)$ is the Poisson probability to observe k events when the number of expected events is z, i.e. $p(k; z) = e^{-z} z^k / k!$. $G(z; b, \delta b)$ is the Gaussian probability density function for the NC DIS expectation z of mean value b and width δb.

For $Q_e^2 > 15000$ GeV^2 the number of events observed by H1 is $N_{obs} = 18$ for an expectation of 8.0 ± 1.16. This corresponds to a probability of $\mathcal{P}(N_{exp} \geq N_{obs}) = 3.4 \cdot 10^{-3}$. At high Q^2 the H1 data exceed clearly the NC DIS expectation significantly, especially at invariant masses of the lepton-quark system of $M_e \approx 200$ GeV. To investigate this prominent excess, H1 considered mass windows of various total widths ΔM_e. The central values M_e of the mass windows were varied in steps of 1 GeV between 80 GeV and 250 GeV and the number of observed and expected events are determined for different minimal y_e-values. The most significant excess is observed by H1 for a central mass value $M_e \approx 200$ GeV and for a cut of $y_e > 0.4$. Considering a width of $\Delta M_e = 25$ GeV H1 observed 8 events, where only 1.53 are expected, corresponding to a Poisson probability of $\mathcal{P}(N_{exp} > N_{obs}) = 3.3 \cdot 10^{-4}$. The probability to see such an excess in a random set of experiments anywhere in any M_e window was calculated to be of the order of 1 %.

For $Q_{DA}^2 > 35000$ GeV^2 the number of measured events in ZEUS is $N_{obs} = 2$, whereas $N_{exp} = 0.24 \pm 0.02$ are expected. The resulting probability is here $\mathcal{P}(N_{exp} \geq N_{obs}) = 2.5 \cdot 10^{-2}$. In the case of ZEUS the excess is also at the largest Q_{DA}^2. For $x_{DA} > 0.55$ corresponding to masses $M_{DA} > 220$ GeV and $y_{DA} > 0.25$ ZEUS found 5 events compared to a standard expectation of 1.51 ± 0.13. The Poisson probability is here $\mathcal{P}(N_{exp} > N_{obs}) = 1.9 \cdot 10^{-2}$.

The situation comparing the two experiments in terms of masses is somewhat unclear. H1 observed 8 events at $y_e > 0.4$ and masses $M_e \approx 200$ GeV, while ZEUS measured 4 events at masses of $M_{DA} \approx 230$ GeV. The difference between H1 and ZEUS can not be due to the different methods of mass

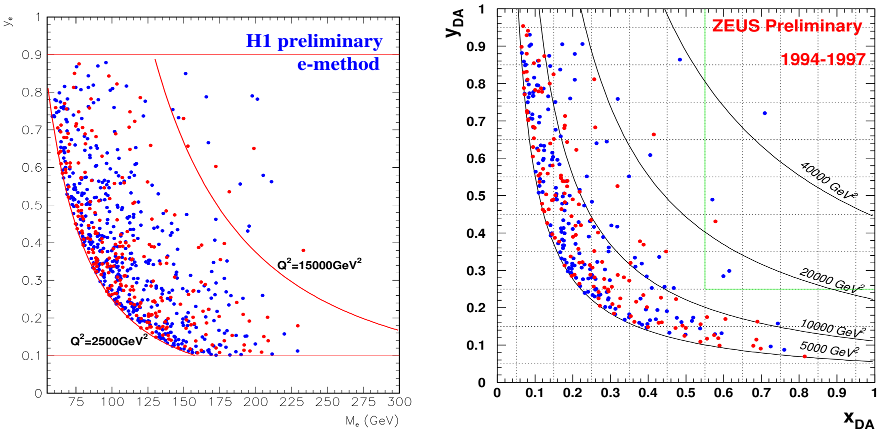

Figure 2: (left) H1 selected NC DIS candidates in $y_e - M_e$ plane; (right) ZEUS selected NC DIS candidate events in $y_{DA} - x_{DA}$ plane.

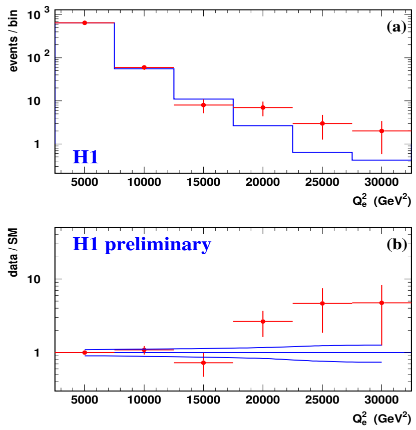

Figure 3: (a) The measured Q_e^2 distribution of the selected NC DIS candidate events for the H1 data (points) and for standard NC DIS expectation (histogram); (b) ratio of the observed and expected number of events as a function of Q_e^2; the lines above and below unity specify the $\pm 1\sigma$ levels of the combined statistical and systematic errors of the NC DIS expectation.

reconstruction used by the two experiments. ZEUS found for the DA-method a small 2 % probability for mass shifts greater than 10 % in the presence of ISR. Increasing the H1 electromagnetic energy scale by the quoted 3 % uncertainty leads to an increase in M_e of about 6 GeV. The maximal uncertainty in the hadronic angle reconstruction claimed by ZEUS reduces M_{DA} from 230 GeV to 223 GeV. Therefore it is very unlikely that both excesses are caused by a common single narrow resonance.

Figure 5 shows the integrated cross section $\sigma(Q^2 > Q^2_{min})$ in picobarn for the entire kinematic range $y \leq 1$. Both measurements agree within their errors. Note that the data points are fully correlated. In figure 5(right) the combination from both experiments is shown. The shaded area gives the 1σ error of the measurement. Of course, at this stage, due to the limited statistics, one cannot exclude the possibility that the whole effect is a statistical fluctuation.

5.3 Results on the CC sample

Figure 6 shows the Q^2-distribution of the CC sample found by H1. For $Q_h^2 > 2500$ GeV^2 H1 observed 61 events and expected 56.3 ± 9.4. However at high Q^2 the data seem to overshoot the standard CC expectations. At $Q_h^2 > 20000$ H1 measured 3 events where only 1.21 ± 0.64 are expected.

ZEUS found for $Q_h^2 > 15000$ GeV^2 5 events, but expects only 2 ± 0.9. Combining H1 and ZEUS together results in 29 events for $Q_h^2 > 10000$ GeV^2, where 17.7 ± 4.3 are expected. This is not a significant excess but a tendency for the data to be above the standard DIS expectations.

6 Search for isolated high energy leptons with missing transverse momentum

H1 and ZEUS performed a search for events with an imbalance in transverse momentum. Such events are CC-processes where a t-channel exchange of a W takes place. The expected cross section for standard cuts is of the order of 20 pb. However the production of a real or virtual W with subsequent decay in leptons is possible only with a much smaller cross section of around 70 fb per channel and charge.

H1 found in 1994 an event [18] of unusual characteristics ($e^+p \to \mu^+X$), which exhibits an isolated high momentum muon recoiling against a system of hadrons. The imbalance in the transverse momentum suggests the presence of an undetected final state particle. With the collected Luminosity of the years 1994-1996 and partly 1997 a new search is now presented [19].

For H1, the event selection is based on the usual CC Selection [20]. After requiring a missing transverse momentum $p_{t,miss}$ in the Calorimeter of more than 25 GeV and removing residual non ep background, 336 events remain in the data sample. Beyond this inclusive selection the search for final states is based on the presence of tracks with a polar angle $\theta > 10°$ and with transverse momentum $p_t > 10\ GeV$. Isolation criteria for those high momentum tracks are given by their distance D_{jet} to the closest hadronic jet and D_{track} to the closest drift chamber track both evaluated in the pseudorapidity-azimuth plane $\eta - \Phi$. Both distances to the neighbored object track and jet are defined as $D_{obj} = \sqrt{(\Delta\eta_{track-obj})^2 + (\Delta\Phi_{track-obj})^2}$. The jets are identified with a cone algorithm using $R_{cone} < 1$ and $E_T < 5$ GeV. Figure 7(a) shows the correlation between D_{track} and D_{jet} for all high p_t tracks in the CC sample. Five events are found to have well isolated tracks. After applying a lepton identification requirement to the tracks, 5 candidates show up with a lepton well isolated from other charged tracks and hadronic jets. The five events are 2 μ^+, 2 μ^- and 1 e^-. No e^+ candidate was observed in the selected sample.

Figure 8 shows all five high $p_{t,miss}$ events which have been recorded by H1 in the years between 1994 and July 1997. The μ's leaving the detector have transverse momenta between 23-80 GeV. In all events a global missing $p_{t,miss}$ of more than 18 GeV is observed.

The main contribution to the cross section of W production is due to photoproduction interactions with radiation of a real W from the quark line, followed by its leptonic decay. It is peaked at low values of the transverse momentum p_T^X of the recoil hadron system X, and shows a Jacobian peak at the W mass value in the lepton-neutrino transverse mass $M_T^{l\nu}$ spectrum. About 10 % of the cross section for production of an isolated lepton and missing transverse momentum is due to virtual W exchange in the t channel. This process generates events with a lepton-neutrino transverse mass $M_T^{l\nu}$ which can be low. Figure 9 shows as dots for a luminosity by a factor 500 higher than the data, the expected distribution of W events in the ($p_T^X, M_T^{l,\nu}$) variables. The standard expectations are calculated using the Monte-Carlo program EPVEC [21] and have been independently cross checked by [22]. The corresponding values measured for the five events are indicated by the error contours. As discussed above, the W events accumulate at large $M_T^{l\nu}$ values and low values of p_T^X.

The overall acceptance of the event selection combined with the isolation criteria is 40 % in the electron channel and 12 % for the muon channel. This numbers include trigger efficiencies. At high transverse momentum of the hadronic system p_T^X of 40 GeV the muon channel reaches a plateau in acceptance of 60 %.

In the electron channel H1 observes 1 e^- events, where 1.34 ± 0.2 are expected from W production. For the μ channel however 4 μ candidates are seen where only 0.41 ± 0.07 are expected. Only one out of the four μ events is found in a phase space region likely to be populated by W production, namely at high transverse masses $M_T^{l\nu}$ and low values of p_T^X.

The ZEUS search is based on 1994-1996 and partly 1997 data with a total luminosity of $\mathcal{L} = 33.5\ \mathrm{pb}^{-1}$. The selection cutes were similar to H1 requiring a $p_{t,miss}$ in the calorimeter of greater than 25 GeV and a well isolated high energy track with transverse momentum of $p_t > 10$ GeV separated in $\eta - \Phi$ space.

In the muon channel, after imposing a muon identification criterion, ZEUS found no event, but expects 0.48 from W processes. In the electron channel ZEUS observed 2 e^+ events, where 4 have been expected.

7 Conclusions

Increasing luminosity at HERA now offers the possibility to study e^+p scattering close to the kinematic limit, and to investigate rare event topologies with sufficient statistics. In this context observations made by H1 and ZEUS were presented. A preliminary update on the 1994-1996 high Q^2 analyses showed that the excess of NC events at large Q^2 is present also in the early 1997 data. Given the fact, that the NC and CC predictions agree well with the existing experimental data for Q^2 below 15000 GeV^2 and QCD evolution to the kinematic region beyond $Q^2 > 15000$ GeV^2 is believed to be safe, it is unlikely that the excess of events at high Q^2 can be understood within the SM. Furthermore, H1 found five events with missing transverse momentum and an isolated highly energetic lepton compared to a prediction from W production of 1.75. Whether one or both observations can be interpreted as statistical fluctuations or in terms of new physics requires, however, additional data to be taken.

8 Outlook

HERA has continued to take data until October 1997. The expectation to double the 1994-1996 statistics in the year 1997 has been fulfilled. HERA produced in 1997 34 pb^{-1} compared to the 1996 value of 15 pb^{-1}. For the years 1998-1999 HERA prepares for an e^-p running with an expected integrated luminosity similar to 1997 or even more. In the year 2000 an upgrade of the machine is planned with a seven fold gain in the luminosity. There will also be the possibility to run with polarized e^+/e^-.

9 Acknowledgments

I wish to thank the organizers of the QFTHEP 1997 workshop for their hospitality and efforts. I thank my colleagues from H1 and ZEUS for their support.

References

[1] H1 Coll., C. Adloff et al., Z. Phys. C74 (1997) 191

[2] ZEUS Coll., J. Breitweg et al., Z. Phys. C74 (1997) 207

[3] B. Straub, Talk at the International Lepton Photon Symposium LP97, Hamburg, 1997

[4] E. Elsen, Talk at the International Conference on High Energy Physics EPS, Jerusalem, 1997

[5] G. Ingelman and R. Rückl, Phys. Lett. B201 (1988) 369

[6] G. Bernardi and U. Bassler, Z. Phys. C76 (1997) 223

[7] G. Wolf, DESY preprint 97-047

[8] W. Hollik et al., in W. Buchmüller, G. Ingelman, editors, *Proceedings of the Workshop Physics at HERA*, page 923. Hamburg, 1992.

[9] H1 Coll., S. Aid et al., Phys. Lett. B379 (1996) 319

[10] ZEUS Coll., M. Derrick et al., Phys. Rev. Lett. 75 (1995) 1006

[11] M. Botje, Talk at the 5th International Workshop on Deep Inelastic Scattering and QCD (DIS97), Chicago, 1997.

[12] S. Kuhlmann, H. Lai and W.K. Tung, hep-ph/9704338

[13] S.J. Brodsky et al. Phys. Lett. B93 (1980) 451;
J.F. Gunion and R. Vogt, hep-ph/9706252;
W. Melnitchouk and W.A. Thomas, hep-ph/9707387

[14] H1 Coll., I. Abt et al., Nucl. Instr. and Meth. A386 (1997) 310; *idem* Nucl. Instr. Meth. A386 (1997) 348.

[15] ZEUS Coll., "The ZEUS Detector", DESY Status Report 1993.

[16] H1 Calorimeter Group, B. Andrieu et al., Nucl. Instr. and Meth. A336 (1993) 460;
ibid, A344 (1994) 492;
ibid, A350 (1994) 57;
ibid, A336 (1993) 499.

[17] M. Derrick et al., Nucl. Instr. and Meth. A309 (1991) 77;
A. Andersen et al., Nucl. Instr. and Meth. A309 (1991) 101;
A. Bernstein et al., Nucl. Instr. Meth. A336 (1993) 23.

[18] H1 Coll., DESY preprint DESY 94-248; *idem* S. Aid et al., Z Phys. C71 (1996) 211.

[19] H1 Coll., *Observation of Events with a High Energy Isolated Lepton and Missing Transverse Momentum at HERA*, paper submitted to the International Conference on High Energy Physics EPS, Jerusalem, 1997.

[20] H1 Coll., S. Aid et al., Z. Phys. C67 (1995) 565.

[21] U. Baur, J.A.M. Vermaseren, D. Zeppenfeld, Nucl. Phys. B375 (1992) 3.

[22] E. Boos, private communication

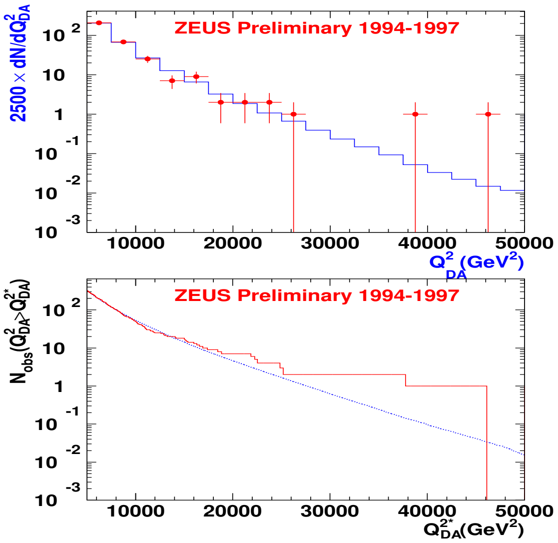

Figure 4: Upper plot: ZEUS Q^2_{DA} distribution in comparison to Monte Carlo DIS prediction (histogram). The lower plot shows the number of events above a given Q^2 cut. The data curve exceeds for $Q^2_{DA} >$ 20000 GeV^2 the standard DIS expectation.

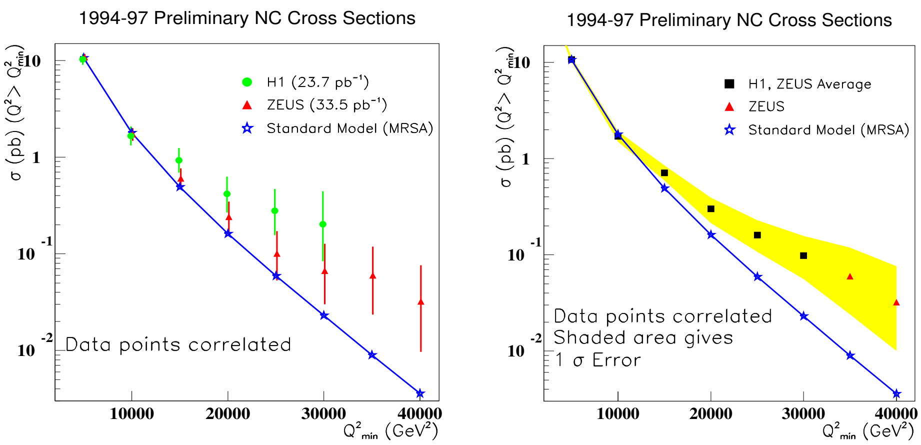

Figure 5: (left) integrated cross sections $\sigma(Q^2 > Q^2_{min})$ in [pb] for $y \leq 1$ from H1 and ZEUS data compared to standard DIS expectation (MRSA); (right) combined cross sections $\sigma(Q^2 > Q^2_{min})$ in [pb] for $y \leq 1$.

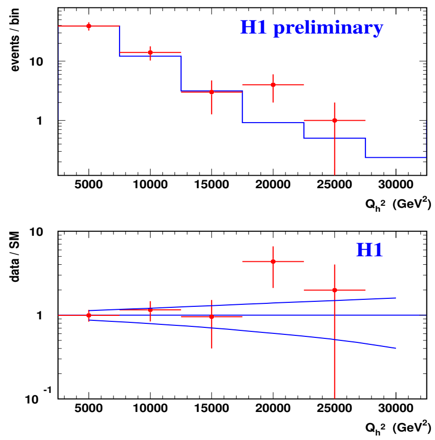

Figure 6: Q_h^2 distribution of the CC sample as measured by H1. The lower plot shows the ratio between measured and expected number of events. Indicated are the $\pm 1\sigma$ contour lines.

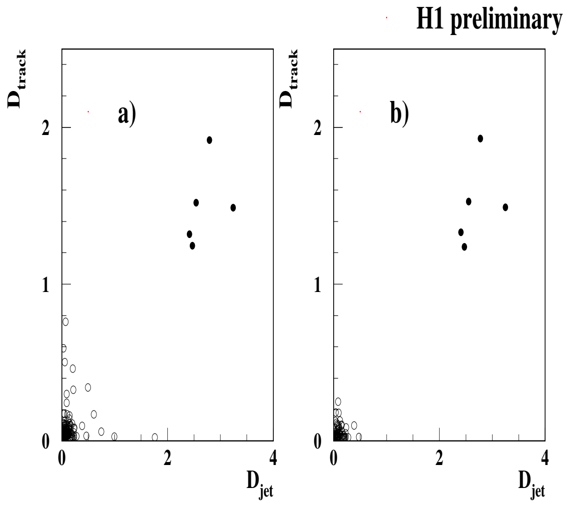

Figure 7: Correlation between the distances D_{jet} and D_{track} of high p_t tracks with $p_t > 10$ GeV to its closest hadronic jet and closest track as found with the H1 detector. In (a) all tracks of the CC sample are shown with momenta $p_t > 10$ GeV; in (b) an additional electron or muon matching criterion is required for the high energy track. The 5 isolated tracks remain.

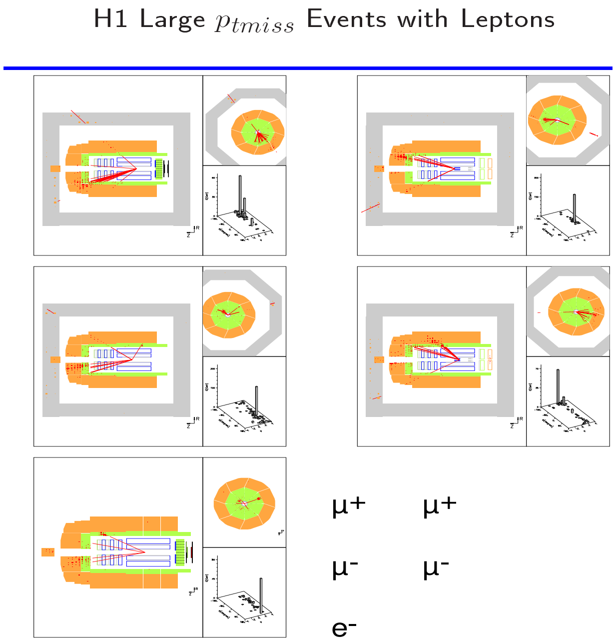

Figure 8: All high $p_{t,miss}$ lepton events recorded in 1994-1997 by the H1 experiment.

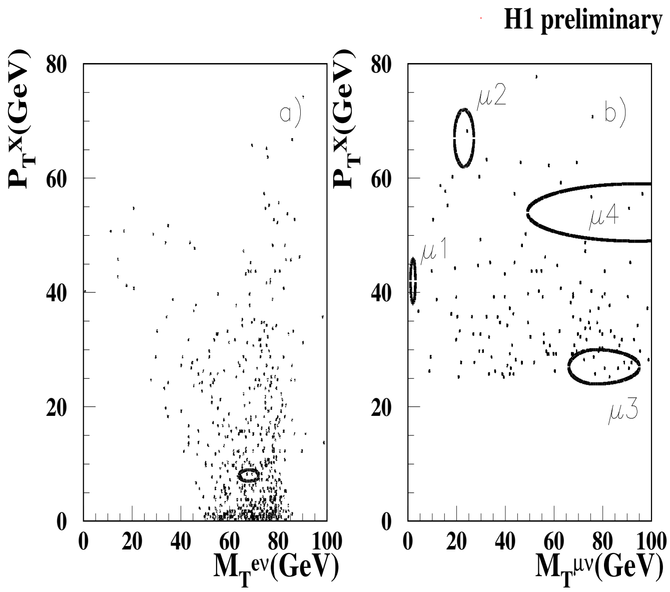

Figure 9: Distribution of the five measured events in H1. The measurement errors of the single events are indicated as error ellipses and correspond to the 1 σ uncertainty on the measured parameters of each event. The dots show the standard model expectation for W production for an accumulated luminosity of 500 times higher than the data. In (a) the electron candidate is shown; (b) shows the muon channel.