ELECTROWEAK PHYSICS AT HERA

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At HERA, electroweak physics can be investigated in deep inelastic scattering. The H1 experiment determined QCD and electroweak parameters simultaneously for the first time in a global fit to the cross sections measured at HERA I. At HERA II, the longitudinal polarisation of the lepton beam gives access to the chiral properties of neutral and charged current interactions at high momentum transfers. Due to the higher luminosity, the number of candidate events for single W production has increased, but still more statistics is needed to draw final conclusions.

1. Combined QCD and EW Fit of HERA I data

During the HERA I phase, which ended in the year 2000, the H1 and ZEUS experiments collected each about 20 pb^{-1} of e^-p and 100 pb^{-1} of e^+p data at center-of-mass energies of 300 and 320 GeV. The resulting measurements of the inclusive neutral and charged current cross sections span a wide range in x and Q^2 and have been used by H1 to extract for the first time in a global fit the parton density functions (pdfs) as well as electroweak parameters¹, which is possible because they affect the cross sections in different phase space regions in different ways.

At low values of $Q^2 \ll M_Z^2$, the neutral current ep scattering reaction is dominated by photon exchange and thus allows the extraction of the pdfs of the proton. At $Q^2 \geq M_Z^2$, the Z exchange and its interference with the photon exchange become more significant and allow an extraction of the axial and vector couplings of the Z to the up and down quarks. These measurements are shown in figure 1 together with the CDF and LEP results for the charm and bottom quark, which are expected in the Standard Model to be equal to the up and down quark values, respectively. The charged current cross section depends on the propagator mass of the exchanged boson M_{prop} and its coupling G to the quarks. In the Standard Model they

Figure 1. Results of the combined QCD and EW fit for the axial and vector couplings of the light quarks to the Z^0 compared to the Standard Model expectation and the results for c and b quarks from LEP and CDF.

are identical to the mass of the $W^\pm$ boson and the Fermi constant G_F . Figure 2 shows the results of a fit in which both parameters are adjusted (shaded ellipse) as well as the propagator mass resulting from a fit where the coupling is fixed to G_F . Both fits agree with the world averages for M_W and G_F .

Figure 2. Result of the combined QCD and EW fit for the coupling constant G and the propagator mass M_{prop} compared to the world averages for G_F and M_W .

2. Polarised CC and NC cross sections from HERA II data

Besides the increased luminosity, the main feature of HERA II is the longitudinal polarisation of the lepton beam at the H1 and ZEUS experiments, which is ideal for many electroweak measurements. Currently, samples of about 150 pb^{-1} for e^-p and 50 pb^{-1} for e^+p have been obtained per experiment, with approximately equal amounts of integrated luminosity for left- and right-handed polarisation of typically 30% on average.

Figure 3 shows the total charged current cross section measured by H1 and ZEUS as a function of the lepton beam polarisation P_e for both e^-p and e^+p data ^{2,3}. Together with the HERA I data at $P_e = 0$, the new HERA II data show a clear linear dependence on the polarisation, which illustrates the chiral structure of the charged current interaction. A common fit to the e^+p data from H1 and ZEUS leads to an extrapolated cross section at $P_e = -1$ of $\sigma_{CC}^{\text{tot}} = -1.0 \pm 1.8_{\text{stat}} \pm 1.1_{\text{sys}} \text{ pb}$, which is consistent with the Standard Model expectation of 0.

Figure 4 shows the single differential charged and neutral current cross sections for the left-handed and right-handed e^+p data measured by the ZEUS experiment. For charged current data, the larger cross section for the right-handed sample can clearly be seen for $d\sigma/dQ^2$, $d\sigma/dx$ and $d\sigma/dy$. Effect of the polarisation on the neutral current is visible in the ratio of $d\sigma/dQ^2$ for both helicities and will become more pronounced with increased statistics, especially for high values of Q^2 .

Figure 3. H1 and ZEUS measurements of the charged current cross sections for e^-p and e^+p data as a function of the polarisation P_e of the lepton beam.

Figure 4. Differential charged (left) and neutral (right) current cross sections for the polarised HERA II datasets measured by the ZEUS experiment.

3. Single $W^\pm$ production in HERA I and HERA II data

Real $W^\pm$ bosons can be produced at HERA with a cross section of about 1 pb. The H1 experiment analysed all available data with a total integrated luminosity of 279 pb $^{-1}$ for W 's decaying into electron or muon plus a corresponding neutrino, whereas the ZEUS experiment has performed the analysis in the electron channel on 106 pb $^{-1}$ of e^+p data. The signature of such events is an isolated lepton and high missing transverse momentum. The hadronic system often has a low transverse momentum P_T^X and is thus lost in the beampipe, but also spectacular events with a central jet leading to high values of P_T^X are observed.

Figure 5 shows the P_T^X distribution for the e^-p (121 pb $^{-1}$) and e^+p (158 pb $^{-1}$) data as observed by the H1 experiment. The e^-p data agree well with the Standard Model expectation: in total 12 events are observed with 15.8 ± 2.2 expected, at $P_T^X > 25$ GeV 2 events are observed compared to an expectation of 4.4 ± 0.7 . However, in the e^+p data 28 events are observed with only 18.5 ± 2.6 expected, at $P_T^X > 25$ GeV 15 events are observed with 4.6 ± 0.8 expected. In 106 pb $^{-1}$ of e^+p data the ZEUS experiment observes 2 events in the electron channel with 3 ± 0.4 expected.

Figure 5. P_T^X distribution observed by the H1 experiment for a) e^-p data and b) e^+p data from HERA I and HERA II running phase combined.

4. Conclusions

Several measurements related to the properties of the electroweak interactions performed by the H1 and ZEUS experiments have been presented. Using the full HERA I data set, H1 has performed for the first time a combined fit of QCD and electroweak parameters. The results agree with the expectations from the Standard Model within errors. They will become more precise once HERA II data will be included in this analysis, not only due to the increased statistics at high values of Q^2 , but also due to the lepton beam polarisation, which improves the sensitivity to some parameters, for example to the vector couplings of the light quarks. The analysis of the polarised HERA II data has started. Among the first results are the polarisation dependence of the neutral and charged current cross sections and the analysis of events with isolated leptons and missing transverse energy, as they are expected in the Standard Model from the production of real $W^\pm$ bosons. In the e^+p data of HERA I and II combined, H1 observes an excess of these events at high values of $P_T^X > 25$ GeV with 15 events in the data compared to an expectation of 4.6 ± 0.8 . The ZEUS experiment does not confirm this excess. More e^+p data are needed to gain further understanding of these events.

References

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