RECENT RESULTS FROM THE H1 EXPERIMENT

E. PEREZ*
CE-Saclay, DSM / DAPNIA / Spp
F-91191 Gif-sur-Yvette, France
E-mail: eperez@hep.saclay.cea.fr

A review is given of some of the recent results of the H1 experiment at the HERA *ep* collider, as of the DIS conference in April 2006. These are based on an integrated luminosity of up to $275\,\mathrm{pb}^{-1}$. Measurements of deep-inelastic scattering at high momentum transfer benefit from the increased statistics and exploit the polarisation of the lepton beam. New measurements of the properties of the hadronic final state improve our understanding of Quantum Chromodynamics. The structure of diffraction is studied in detail and the factorisation properties are tested extensively. Measurements of rare processes and searches for physics beyond the Standard Model are presented at the end of this review.

1. Deep-Inelastic Scattering at large momentum transfer

The cross section σ_{CC} of the charged current (CC) Deep-Inelastic Scattering (DIS) process, $e^-(e^+)p \to \nu_e(\bar{\nu}_e) + X$ in which a W boson is exhanged, has been measured for several values of the polarisation P_e of the incoming lepton. The measurements, shown in Fig. 1, exhibit the linear dependence of this cross section on the lepton polarisation, $\sigma_{CC}(e^\pm) \propto (1 \pm P_e)$, as predicted in the Standard Model (SM) in which right-handed charged currents do not exist. The preliminary e^-p measurements are based on the full statistics collected in 2005 and complement the polarised e^+p measurements recently published[1]. In addition to these total cross section measurements, differential cross sections as a function of Q^2 are seen to be well described by the SM expectation.

At high Q^2, effects of the lepton beam polarisation are also visible in Neutral Current (NC) DIS scattering. These enter mainly via $\gamma - Z$ interference, leading to an enhanced cross section for right-handed (left-handed) positrons (electrons) in e^+p (e^-p) scattering, and decreasing the cross sec-

*Work partially supported by DESY.

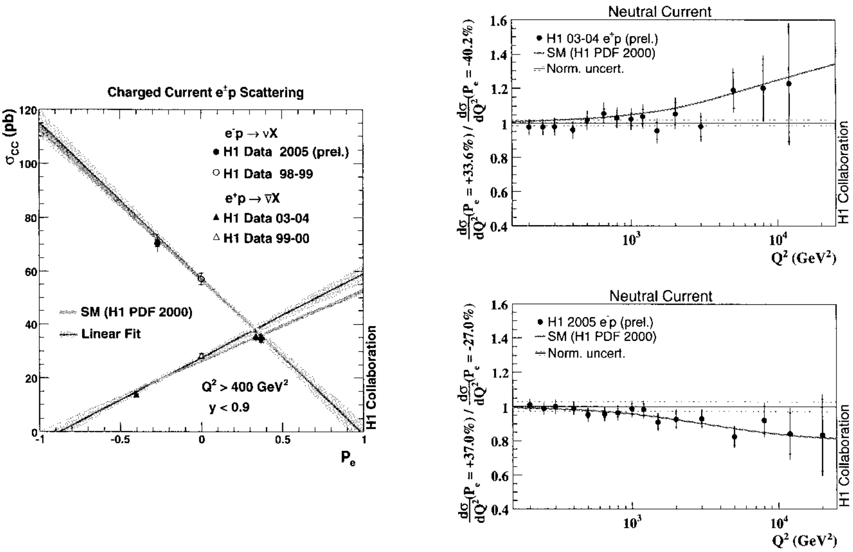

Figure 1. (left) Polarisation dependence of the CC DIS cross sections. (right) Ratios of the NC cross sections measured with leptons of positive and negative polarisations, for e^+p (upper plot) and e^-p (lower plot) scattering.

tion in the converse configurations. Figure 1 shows that the expected polarisation dependence is confirmed in both the e^+p and e^-p datasets, although with limited precision so far. The large statistics of the HERA II e^-p dataset, compared to that accumulated during the first phase of HERA, has also allowed the parity-violating structure function xF_3 to be extracted with an increased precision from differential measurements of $\sigma(e^-p) - \sigma(e^+p)$.

2. The hadronic final state in DIS

The analysis of the very well understood HERA I data continues to provide a rich harvest of results. A recent measurement of the high Q^2 NC DIS inclusive jet cross section in the Breit frame leads to a measurement of the strong coupling constant $\alpha_S(M_Z)$ with an experimental error of only 1.3%. Unfortunately the theoretical error is still about 5%, as obtained by the usual variation of the factorisation and renormalisation scales.

In high Q^2 NC DIS events, the normalised charged particle momentum distribution $1/N dn^{\pm}/dx_p$ has been measured, for tracks in the current region of the Breit frame carrying a fractional momentum $x_p = 2p_{track}/Q$. In

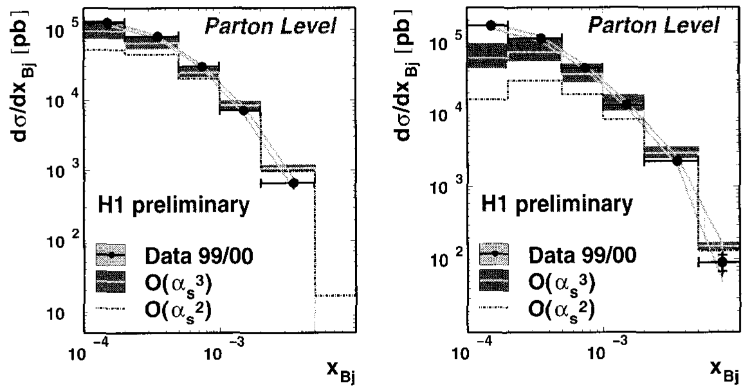

Figure 2. *Differential 3-jet cross sections in low Q^2 NC DIS as a function of Bjorken x for (left) two central jets and one forward jet and for (right) two forward jets and one central jet.*

contrast to earlier analyses, the increased statistics allow the full x_p range to be explored. The measured distributions exhibit clear scaling violations and show a good agreement with those measured in e^+e^- collisions, supporting the idea of quark fragmentation universality. Moreover, the comparison of these measurements with recent next-to-leading order (NLO) calculations shows a sensitivity of these data to the fragmentation functions.

In low Q^2 DIS, the production of isolated neutral mesons has been separated from that of prompt photons, allowing a new measurement of prompt photon production to be performed, which agrees well with a recent $O(\alpha_{em}^3)$ calculation. A search for the production of a strange pentaquark has been finalised and no signal has been observed[2].

Recent investigations of QCD dynamics at low Bjorken x have been performed using forward jets in low Q^2 DIS. As confirmed in[3] the observed rate of forward jets is larger than that predicted by Monte-Carlo models and NLO calculations at low x. Using increased statistics with respect to[3], differential measurements of the production of three jet events have been performed. Subsamples of events with one forward jet and two central jets, and with two forward jets and one central jet, have also been investigated separately. As shown in Fig. 2, the $O(\alpha_S^3)$ prediction from NLOJET++ describes rather well the measured cross section for the former subsample, but fails at low x when two jets are emitted in the forward region. In the latter case, the description is, however, drastically improved when going from LO to NLO. This represents a strong hint that, in this phase space region, the effects of k_T unordered gluon radiation are important.

3. Diffractive processes

3.1. *Diffractive production of Vector Mesons*

In the diffractive photoproduction of ρ mesons at low t, the squared four-momentum transferred at the proton vertex, no hard scale is present and this process is expected to be described by Regge phenomenology. The trigger conditions during the HERA I running period prevented this process from being studied in detail. This has been overcome at HERA II with the installation of the Fast Track Trigger, which is sensitive to low transverse momentum tracks. In data taken in 2005, a huge sample of ~ 250000 $\rho \to \pi^+\pi^-$ photoproduction events was recorded. This allowed the dependence of the cross section on t and on the γp centre-of-mass energy, W, to be determined precisely over a large W range. The W dependence of the cross section is well described by a power law, $d\sigma/dt \propto W^{4(\alpha(t)-1)}$. The extracted trajectory, $\alpha(t)$ as a function of t, is shown in Fig. 3 together with a linear fit $\alpha(t) = \alpha_0 + \alpha' t$. This is the first extraction of this trajectory using data from a single experiment[a]. Although the intercept α_0 agrees well with that obtained from fits to hadronic cross sections, the slope α' is significantly smaller, in unexpected contradiction with the idea of a universal "soft Pomeron" trajectory.

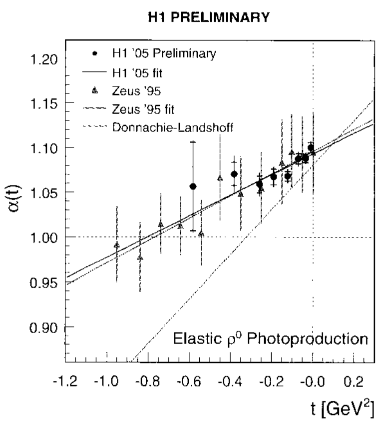

Figure 3. The trajectory of the diffractive exchange in elastic ρ production. A linear fit is also shown, together with the "soft Pomeron" trajectory extracted from fits to hadronic cross sections. The fit to the H1 measurements leads to an intercept $\alpha_0 = 1.093 \pm 0.003(stat.)^{+0.008}_{-0.007}(syst.)$ and to a slope parameter $\alpha' = 0.116 \pm 0.027(stat.)^{+0.036}_{-0.046}(syst.)$, considerably lower than that of the "soft Pomeron".

[a] A previous extraction of this trajectory was performed using HERA data together with low W data from the OMEGA experiment. The result was quite similar to that reported here, but concerns were raised[4] about the normalisation of the datasets, and the possible exchange of other trajectories which might affect the lowest W data.

3.2. *Diffractive DIS and QCD factorisation*

In a recently published measurement of diffractive DIS[5], using events in which the leading proton is tagged in Roman Pots comprising the Forward Proton Spectrometer (FPS), the t dependence of the diffractive DIS (DDIS) cross section was measured. It was found to be independent of the variables which describe the process at the photon vertex, within the experimental uncertainties. This method of selecting diffractive events is, however, statistically limited and, for precise measurements over a wide kinematic range, diffractive events are instead selected by requiring the presence of a "large rapidity gap" (LRG). An example of the latter measurements, published at the time of the conference[6], is shown in Fig. 4 (left). The positive scaling violations, observed up to large values of β (the fractional momentum of the interacting quark with respect to that of the colourless exhange), are suggestive of a large gluonic content of the diffractive exchange. Assuming that the dependences of the DDIS cross section on the variables at the photon vertex (β and Q^2) can be factorised from those on the proton vertex

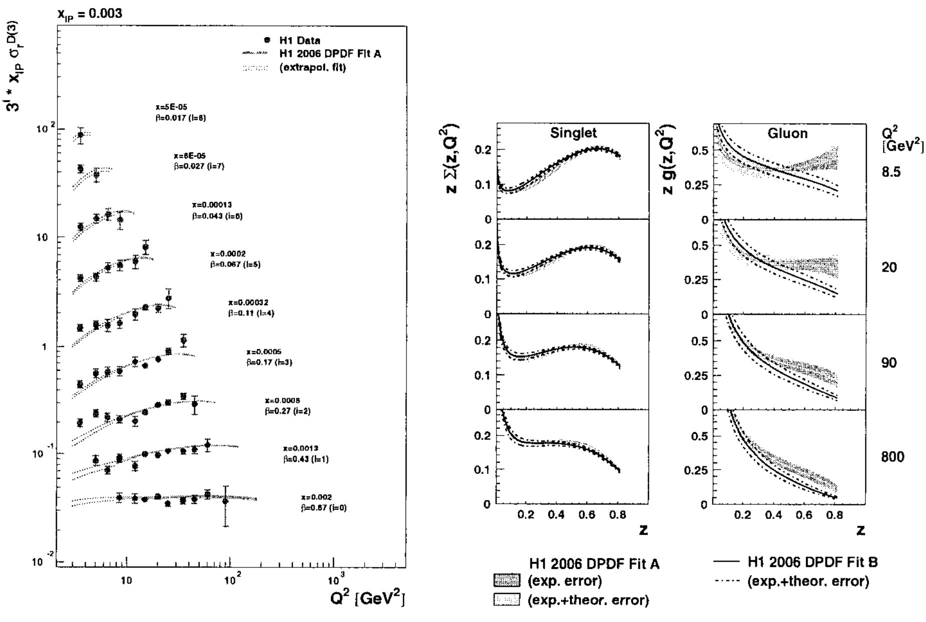

Figure 4. (left) Example measurements of the "reduced" DDIS cross section. (right) Diffractive parton densities extracted from a QCD analysis of these measurements. "Fit A" and "Fit B" correspond to different parametrisation choices at the starting scale, and yield a similarly good χ^2 to the measured cross sections.

variables[b], a next-to-leading order QCD analysis allows diffractive parton densities to be extracted, as shown in Fig. 4 (right). As expected, the singlet distribution is much better constrained than the diffractive gluon density. Moreover, the gluon density at large fractional momentum depends significantly on the parametrisation choice: the two fits depicted in Fig. 4 have a similarly good χ^2 for the fit to the inclusive data.

The DDIS cross sections measured with the LRG and the FPS methods are in very good agreement, when taking into account the $\sim 23\%$ contribution from proton dissociation which enters in the LRG measurements. Good agreement is also obtained with a new preliminary measurement based on LRG data taken between 1999 and 2004, performed in the medium Q^2 range. In the latter dataset, the so-called "M_X" method has also been tried, in which a two-component fit is performed with a diffractive component and an exponentially falling "background" in the $ln(M_X)$ spectrum. In H1, the reconstruction of the mass M_X of the diffractively produced system makes use of energy deposits up to $\eta = 3.4$ only in pseudorapidity. This results in a limited lever-arm for the subtraction: no measurement can be made at large M_X, where the subtraction would be large and where differences between the H1 LRG and the ZEUS M_X measurements have been seen.

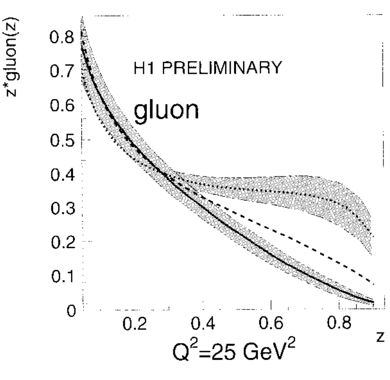

Figure 5. Diffractive gluon density for $Q^2 = 25$ GeV^2. The lower curve shows the result of a combined fit to inclusive and dijet measurements. The upper (middle) curve shows the result of "Fit A" ("Fit B") to the inclusive measurements alone.

Direct constraints on the diffractive gluon density can be obtained from diffractive charm or jet production, assuming that QCD factorisation holds. A recent analysis of diffractive dijet production in DIS was carried out in

[b]The present data show no indication that this "proton vertex factorisation" does not hold.

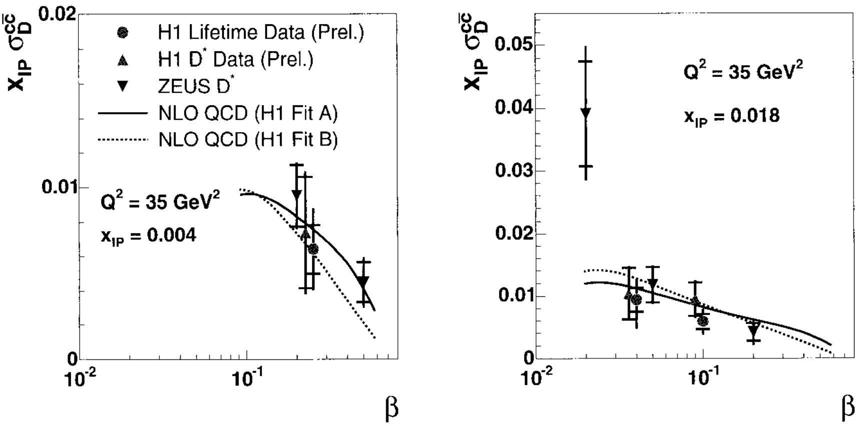

Figure 6. The reduced diffractive charm cross section compared with NLO predictions.

an extended kinematic domain and using larger statistics compared to the previous H1 preliminary result. The comparison of the measured cross sections with the NLO predictions based on the QCD fits presented above shows that QCD factorisation holds within the large theoretical uncertainties of the NLO prediction, with "Fit B" being somehow preferred by the dijet data. A combined fit to both the inclusive and dijet cross sections describes both datasets well, and yields a smaller uncertainty on the diffractive gluon density, as shown in Fig. 5.

QCD factorisation in diffractive DIS has been studied further by performing a new measurement of diffractive charm production, which exploits the long lifetime of charmed hadrons and separates charm from light quarks using the track impact parameters measured with the H1 silicon detector. An example of the measured cross sections is shown in Fig.6. A good agreement is observed both with the diffractive D^* measurements and with the NLO predictions based on the fits to the inclusive diffractive data.

4. Rare processes and searches for "exotic" physics

The HERA II e^-p data have been used to set new constraints on excited neutrinos, which would be much more copiously produced in e^-p than in e^+p collisions. No signal has been observed in any of the three analysed channels.

Events with two or three leptons in the final state have been investigated using 275 pb^{-1} of data taken up to 2005. A small excess of events is visible

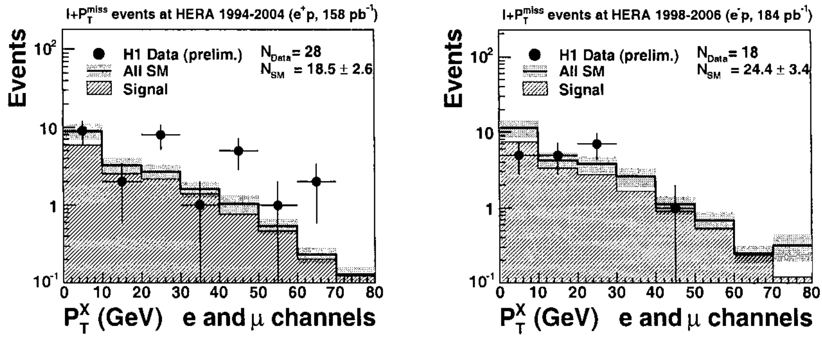

Figure 7. Distribution of the transverse momentum of the hadronic final state in events with a lepton (e or μ) and missing transverse momentum, measured in (left) e^+p and (right) e^-p collisions. The hatched histogram shows the contribution from W production.

for large transverse momenta of the leptons, although no new spectacular multi-electron event with an invariant mass above 100 GeV is observed in the HERA II data. A measurement of τ pair production using HERA I data has been completed and published recently[7], which agrees well with the SM prediction.

An abnormally large rate of events with a lepton (e or μ), missing transverse momentum and a hard hadronic system with transverse momentum P_T^X is observed in the e^+p H1 data. In $158\,\text{pb}^{-1}$ of e^+p data collected until 2004, 15 events are observed at $P_T^X > 25$ GeV for an expectation of 4.6 ± 0.8 events. The corresponding probability for a statistical fluctuation amounts to a 3.4σ deviation. This excess is, however, not observed in the e^-p data collected until 2006, as shown[c] in Fig. 7. It will hopefully be clarified with the e^+p data which are now being collected since summer 2006.

References

1. H1 Collab., A. Aktas et al., *Phys. Lett.* **B634**, 173 (2006).
2. H1 Collab., A. Aktas et al., *Phys. Lett.* **B639**, 202 (2006).
3. H1 Collab., A. Aktas et al., *Eur. Phys. J.* **C46**, 27 (2006).
4. A. Donnachie and P.V. Landshoff, *Phys. Lett.* **B478**, 146 (2000).
5. H1 Collab., A. Aktas et al., hep-ex/0606003, submitted to *Eur. Phys. J.* **C**.
6. H1 Collab., A. Aktas et al., hep-ex/0606004, submitted to *Eur. Phys. J.* **C**.
7. H1 Collab., A. Aktas et al., hep-ex/0604022 , submitted to *Eur. Phys. J.* **C**.

[c] The results shown here have been updated with respect to those shown at DIS'06, to include the full e^-p data.