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High Q^2 Neutral Currents using the Complete HERA Data

H1 Collaboration

Abstract

Neutral Current $e^{\pm}p \rightarrow e^{\pm}X$ single differential cross sections $\mathrm{d}\sigma/\mathrm{d}Q^2$ are presented using the full HERA dataset recorded with the H1 detector. The cross sections are measured in the region of large negative four-momentum transfer squared $Q^2 \geq 200\,\mathrm{GeV}^2$ and inelasticity $y < 0.9$. The total integrated luminosity amounts to $270\,\mathrm{pb}^{-1}$ of e^+p and $165\,\mathrm{pb}^{-1}$ of e^-p data. The measurements are compared to predictions of the Standard Model. A form factor analysis is performed and an upper limit is obtained on the quark radius of $0.74 \cdot 10^{-18}\,\mathrm{m}$ at 95% CL.

Neutral current interactions at high four momentum transfer Q^2 at HERA provide an important test of the Standard Model (SM) at the high energy frontier. This paper presents a new measurement using the full HERA dataset recorded with the H1 detector. The single differential cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ is analysed over a wide Q^2 range from $200\,\mathrm{GeV}^2$ to $30000\,\mathrm{GeV}^2$. The measurement combines the previously published [1, 2, 3] HERA I data and preliminary HERA II data with longitudinally polarised lepton beams. Part of the HERA II data has been already analysed [4] and the remaining data from the years 2006 and 2007 is now included. Table 1 summaries the different data sets used in the cross section measurements. The longitudinal polarisation of the electron[1] beam P_e is defined as $P_e = (N_R - N_L)/(N_R + N_L)$, where $N_R(N_L)$ is the number of right (left) handed leptons in the beam.

Beam	$\sqrt{s}$ (GeV)	Dataset	$\mathcal{L}(\mathrm{pb}^{-1})$	$P_e(\%)$	Reference
e^+	301	$94-97$	35.6	0	[1]
e^+	319	$99-00$	65.2	0	[3]
e^+	319	$03-04$ R	26.9	33.6	[4]
		$03-04$ L	20.7	-40.2	
e^+	319	$06-07$	121.3	2.5	this analysis
e^-	319	$98-99$	16.4	0	[2]
e^-	319	$04-05$ R	29.6	37.0	[4]
		$04-05$ L	68.6	-27.0	
e^-	319	06	50.2	-5.3	this analysis
All	319	$94-07$	434.5	0	

Table 1: The integrated luminosity ($\mathcal{L}$) and the luminosity weighted average polarisation (P_e) of all data sets used in the combination. All data are corrected to $P_e = 0$ and $\sqrt{s} = 319$ GeV.

The data analysis and the cross section measurement of the new periods follow the same procedure as used in previous publications [1, 2, 3]. The cross sections are determined separately for e^-p and e^+p data. The data from different running periods are averaged by taking a simple weighted mean using the total errors of the measurements. Correlated errors are treated as being correlated across the data sets as well as point-to-point within a data set. Prior to the combination with the unpolarised HERA I data, the combined HERA II datasets are corrected for their small residual polarisations to $P_e = 0$. The $94-97$ data are corrected to a centre-of-mass energy of $319\,\mathrm{GeV}$ before combining with the other data sets. A normalisation uncertainty due to the luminosity measurement is determined to be $\pm 4.0\%$ for all HERA II data, which results in an average uncertainty of 3.3% for all data periods. In the figures this uncertainty is not included in the error bars but shown separately as dashed lines.

The combined cross sections for the e^-p, e^+p and $e^{\pm}p$ data are shown in figures 1-3, compared to the corresponding SM expectations determined from the H1 2000 PDF fit [3]. By combining the individual cross section measurements the precision of data for $Q^2 \geq 1000$ GeV^2 is improved dramatically and a total uncertainty of below 10% is achieved up to $Q^2 = 20\,000$ GeV^2.

[1]Unless stated explicitly, 'electron' refers to both electron and positron in the following.

The entire NC sample, corresponding to an integrated luminosity of $435\,\mathrm{pb}^{-1}$, is used to perform a form factor analysis to search for quark substructure. The strategy of the analysis closely follows the previous HERA I publication [5]. Cross section calculations in the SM are performed in the DIS scheme in next-to-leading order QCD using the CTEQ6D parton density functions [6]. The PDF uncertainty of the SM prediction is taken into account. An upper limit of $0.74 \cdot 10^{-18}\,\mathrm{m}$ at 95% CL is derived on the quark radius. The effect of such a quark radius is illustrated in figure 4.

References

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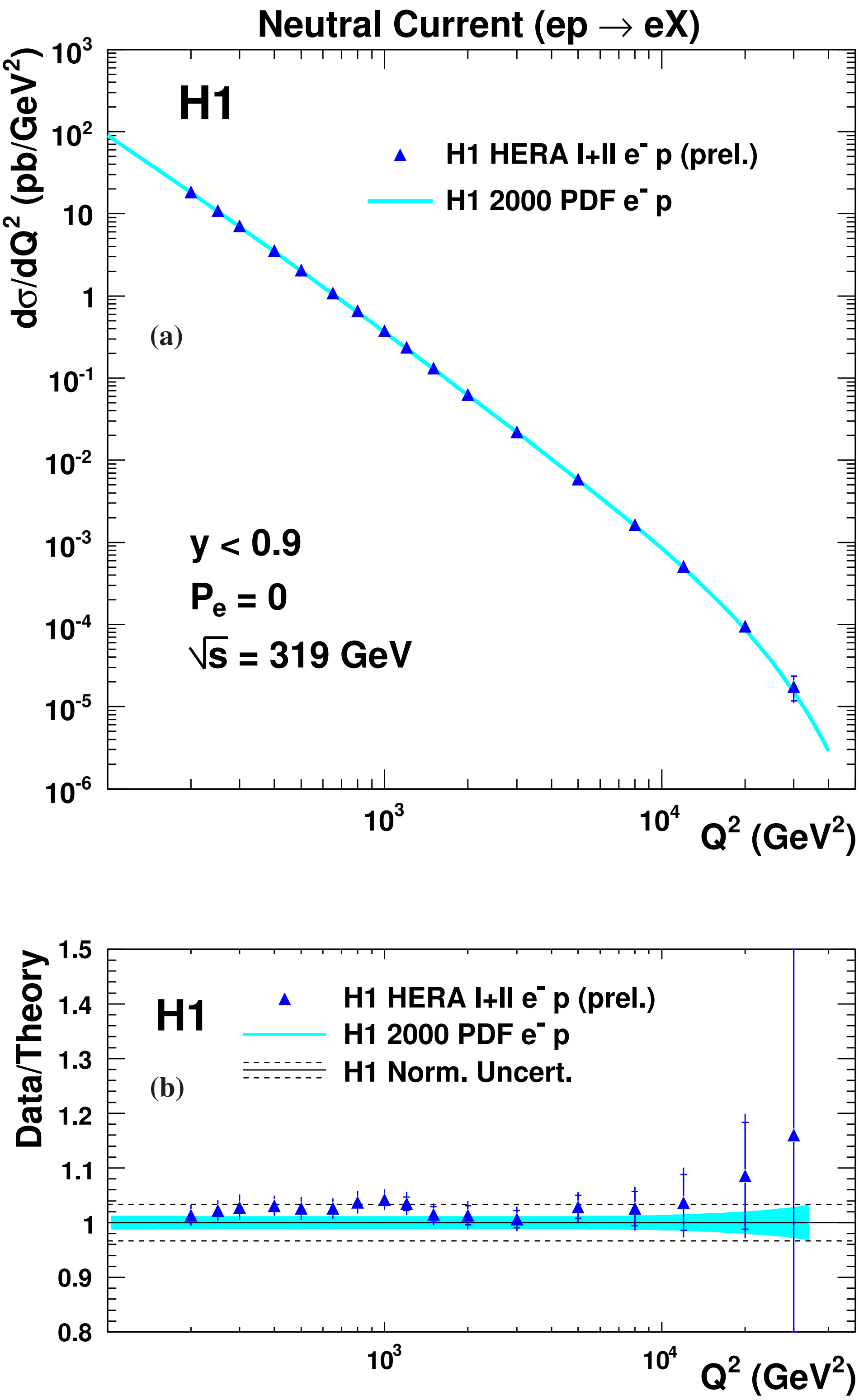

Figure 1: (a) The Q^2 dependence of the NC cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ for e^-p scattering. The total integrated luminosity amounts to $165\,\mathrm{pb}^{-1}$. The full curve represents the Standard Model expectation determined from the H1 2000 PDF fit [3]. (b) The ratio of the cross section to the Standard Model expectation. In (a) and (b) the inner and outer error bars represent the statistical and total measurement errors, respectively. An additional normalisation uncertainty of the data is not included in the error bars but indicated in (b) separately by the dashed lines. The shaded error band in (b) shows the PDF uncertainty of the Standard Model prediction.

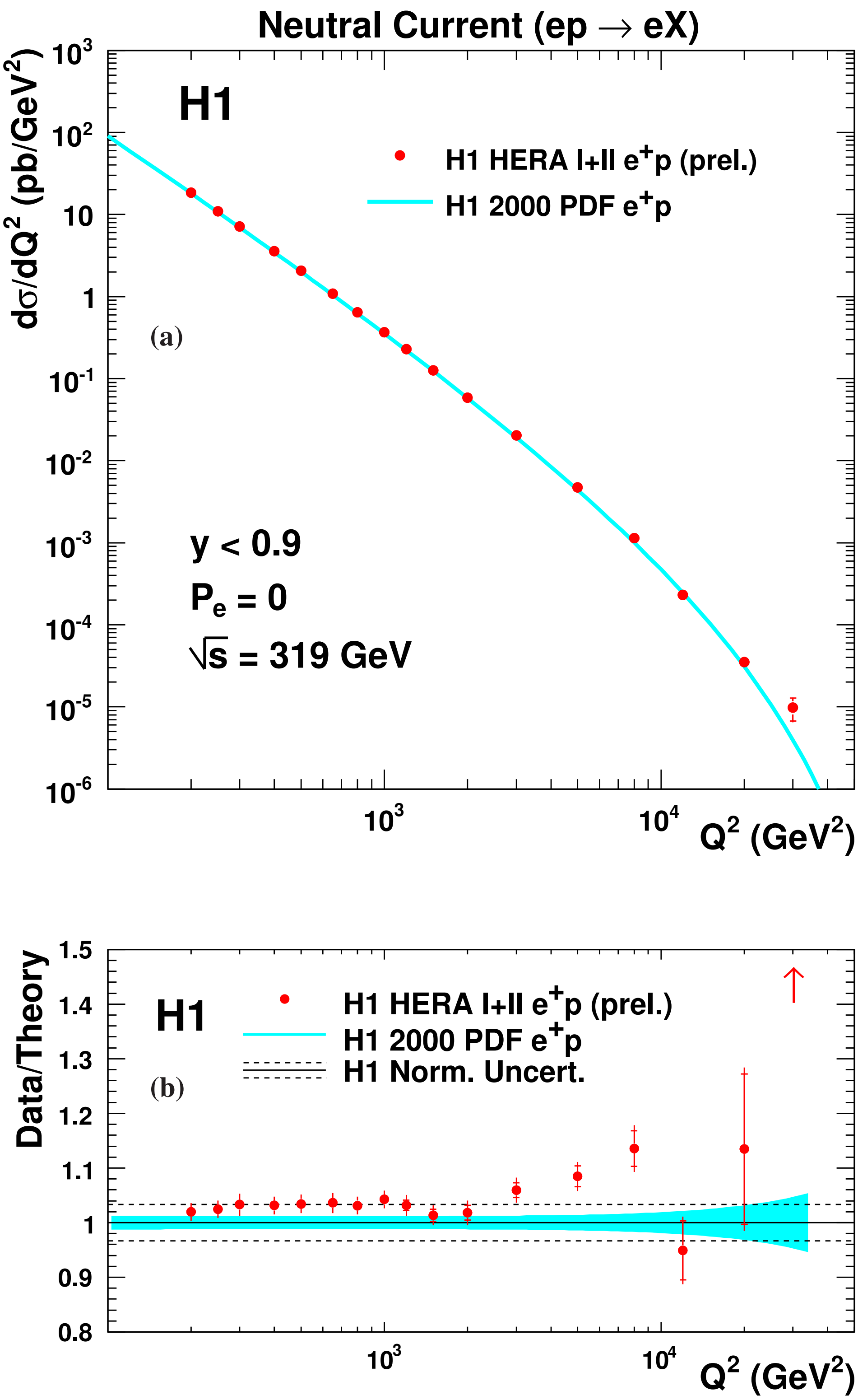

Figure 2: (a) The Q^2 dependence of the NC cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ for e^+p scattering. The total integrated luminosity amounts to $270\,\mathrm{pb}^{-1}$. The full curve represents the Standard Model expectation determined from the H1 2000 PDF fit [3]. (b) The ratio of the cross section to the Standard Model expectation. The error bars and bands are defined as for figure 1.

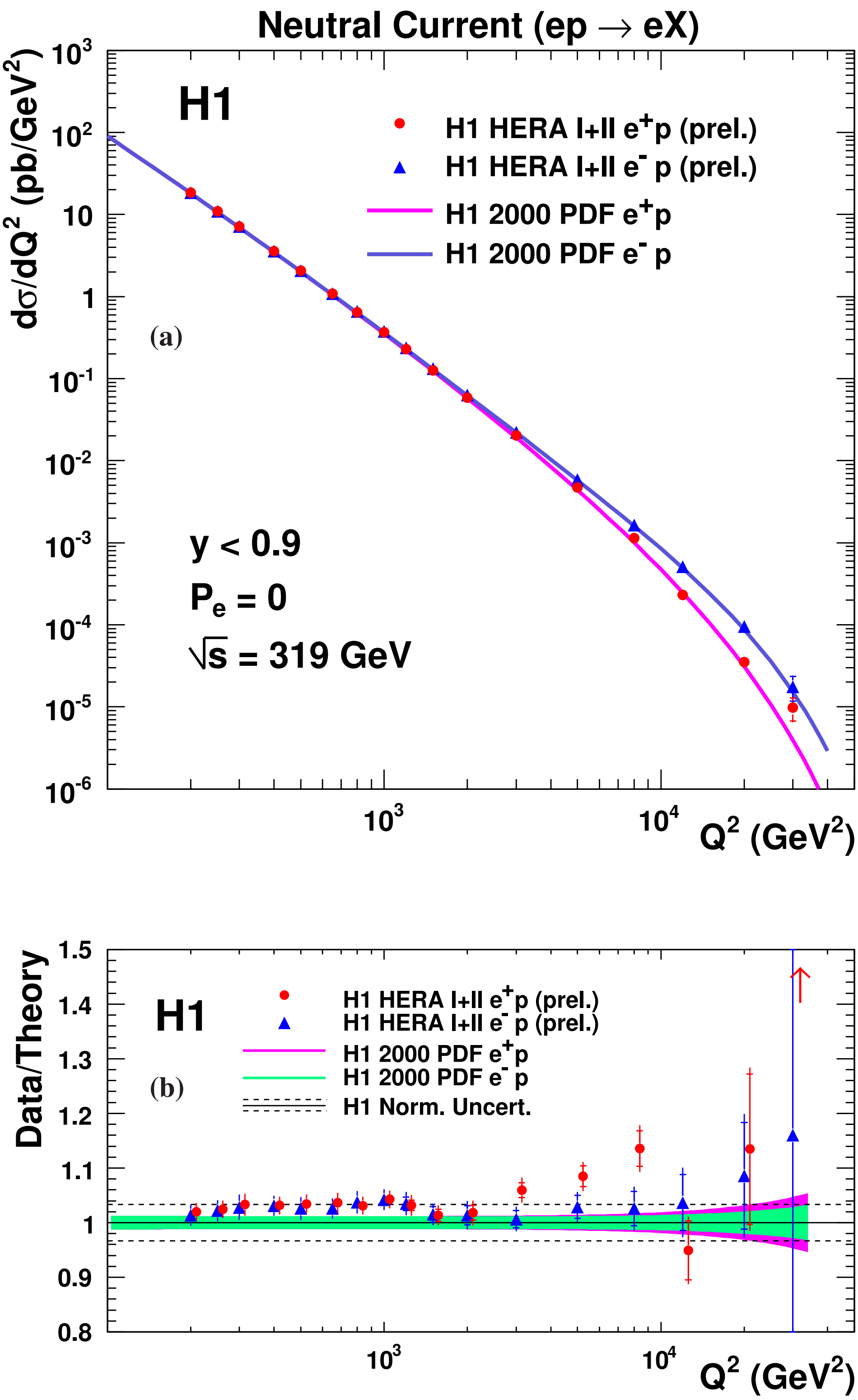

Figure 3: (a) The Q^2 dependence of the NC cross sections $\mathrm{d}\sigma/\mathrm{d}Q^2$ for $e^{\pm}p$ scattering. The full curved represents the Standard Model expectations determined from the H1 2000 PDF fit [3]. (b) The ratio of the cross sections to the Standard Model expectation. The error bars and bands are defined as for figure 1.

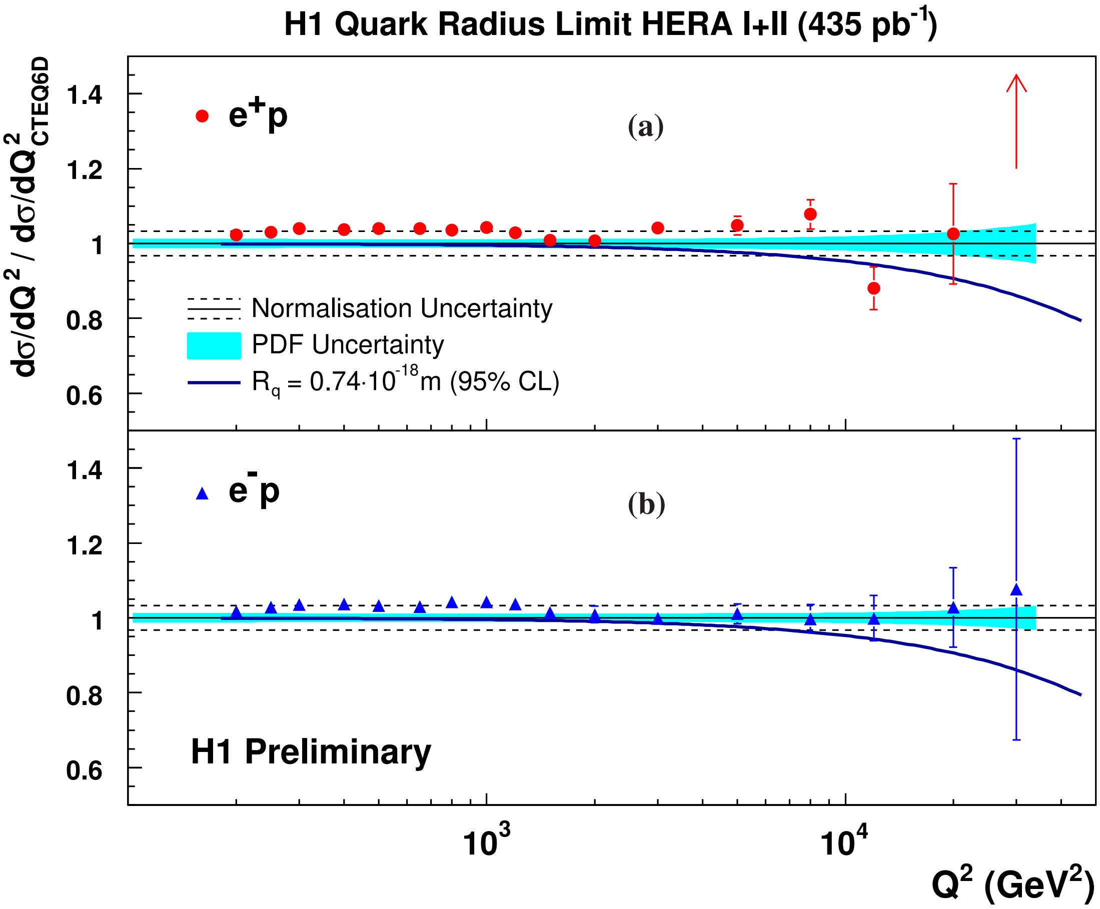

Figure 4: The NC cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ normalised to the Standard Model expectation determined from CTEQ6D [6] for e^+p (a) and e^-p (b) scattering. The curves represent the corrections to the SM prediction due to a hypothetical finite quark radius of $0.74 \cdot 10^{-18}\,\mathrm{m}$, the 95% CL exclusion limit obtained from a combined form factor analysis of the data shown in (a) and (b). The error bands are defined as for figure 1 and the error bars represent the statistical and uncorrelated errors of the measurements added in quadrature. An additional normalisation uncertainty of the data is not included in the error bars but indicated separately by the dashed lines.