Combined HERA-I inclusive DIS measurements

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DIS 2009 Workshop - Madrid

Outline:

- Motivation
- Data sets and averaging procedure
- Results

Motivation

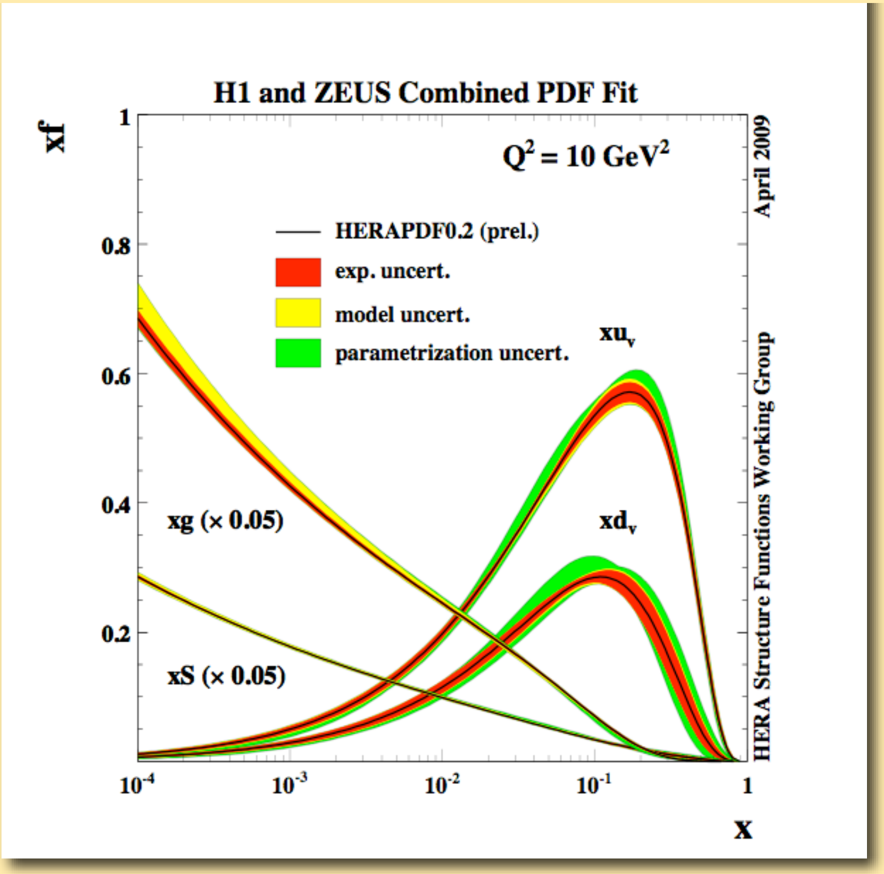
❖ Averaging H1 and ZEUS HERA-I data provides a model independent tool to study consistency of the data and to reduce systematic uncertainties:

⇒ Experiments cross calibrate each other

❖ The combination method include full error correlations and an uncertainty related to the averaging procedure

❖ The combined HERA-I cross sections are used as single input in a QCD analysis to extract new proton's PDFs: HERAPDF0.2

⇒ see V. Radescu[86]



Data Sets

New average based on the complete HERA-I inclusive NC and CC DIS data:

⇒ Ep=820 ($\sqrt{s}$=300) and Ep=920 ($\sqrt{s}$=320) GeV, L=240 pb^{-1}

For DIS 2008 we used:

- CC e^-p data: H1 98, ZEUS 98
- CC e^+p data: H1 94-97, H1 99-00, ZEUS 94-97, ZEUS 99-00
- NC e^-p data: H1 98, ZEUS 98
- NC e^+p data: ZEUS 96-97, ZEUS 99-00, H1 99-00 "high Q^2"

New data sets:

see A. Petrukhin[54], J. Kretzschmar[56]

- H1 95-00 "low Q^2" $0.2 \le Q^2 \le 12$ GeV^2
- H1 96-00 "bulk" $12 \le Q^2 \le 150$ GeV^2
- ZEUS BPC/BPT, SVX95 ($0.045 \le Q^2 \le 17$ GeV^2)

110 correlated systematic error sources

3 "procedural uncertainties" related to the averaging procedure

Averaging procedure

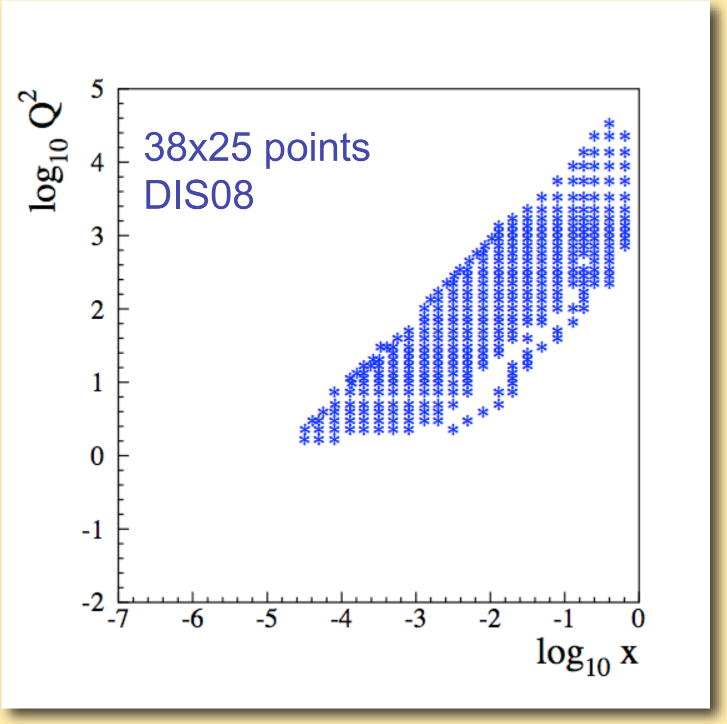
- Swim all points to a common x-Q^2 grid
- Moved[1] 820 GeV data to 920 GeV p-beam energy
- Calculate average values and uncertainties
- Evaluate “procedural uncertainties”

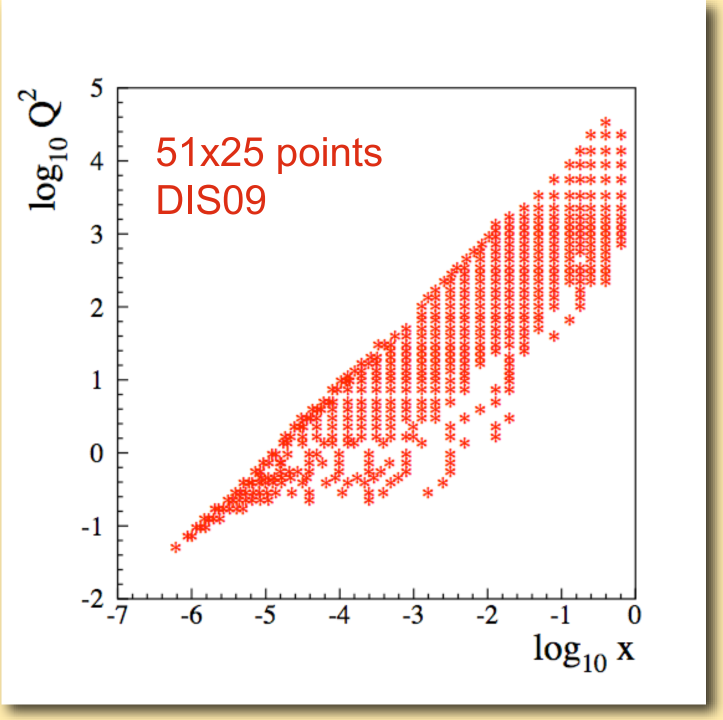
[1] Except for data points with $y > 0.35$

x-Q^2 common grid

Prior to combination the H1 and ZEUS measurements are transformed to a common grid of x-Q^2 points:

$$\sigma^{e^\pm p}_{NC,CC}(x_{grid}, Q^2_{grid}) = \frac{\sigma^{th,e^\pm p}_{NC,CC}(x_{grid}, Q^2_{grid})}{\sigma^{th,e^\pm p}_{NC,CC}(x, Q^2)} \sigma^{e^\pm p}_{NC,CC}(x, Q^2)$$





Negligeable uncertainty due to this correction procedure

820/920 GeV data sets

The averaged cross sections have been obtained after having corrected all E_p=820 GeV (with y < 0.35) data points to E_p=920 GeV

Charged current:

$$\sigma^{e^\pm p}_{CC\ 920}(x, Q^2) = \sigma^{e^\pm p}_{CC\ 820}(x, Q^2)\frac{\sigma^{th,e^\pm p}_{CC\ 920}(x, Q^2)}{\sigma^{th,e^\pm p}_{CC\ 820}(x, Q^2)}$$

Neutral Current:

$$\sigma^{e^\pm p}_{NC\ 920}(x, Q^2) = \sigma^{e^\pm p}_{NC\ 820}(x, Q^2) + \Delta\sigma^{e^\pm p}_{NC}(x, Q^2, y_{920}, y_{820}).$$

with

$$\Delta\sigma e^\pm p_{NC}(x, Q^2, y_{920}, y_{820}) = F_L(x, Q^2)\left[\frac{y^2_{820}}{Y^+_{820}} - \frac{y^2_{920}}{Y^+_{920}}\right] + xF_3(x, Q^2)\left[\pm\frac{Y^-_{820}}{Y^+_{820}} \mp \frac{Y^-_{920}}{Y^+_{920}}\right]$$

Averaging procedure

Described in detail in arXiv:0904.0929

Additive error sources:

$$\chi^2_{\exp}(\boldsymbol{m}, \boldsymbol{b}) = \sum_i \frac{\left[m^i - \sum_j \Gamma^i_j b_j - \mu^i\right]^2}{\Delta_i^2} + \sum_j b_j^2.$$

For multiplicative error sources small biases to lower cross sections values may occur. This can be avoided modifying the χ^2 definition as follows:

$$\chi^2_{\exp}(\boldsymbol{m}, \boldsymbol{b}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\text{stat}}\left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\text{uncor}}\, m^i\right)^2} + \sum_j b_j^2.$$

with $\gamma^i_j = \Gamma^i_j/\mu^i$ $\delta_{i,\text{stat}} = \Delta_{i,\text{stat}}/\mu^i$ $\delta_{i,\text{uncor}} = \Delta_{i,\text{uncor}}/\mu^i$

Procedural Uncertainties

Three procedural uncertainties are introduced:

1. Additive vs Multiplicative nature of the error sources
   (Typically below 0.5%)

2. Correlated systematic unc. for the photoproduction background
   (Few % only at high-y)

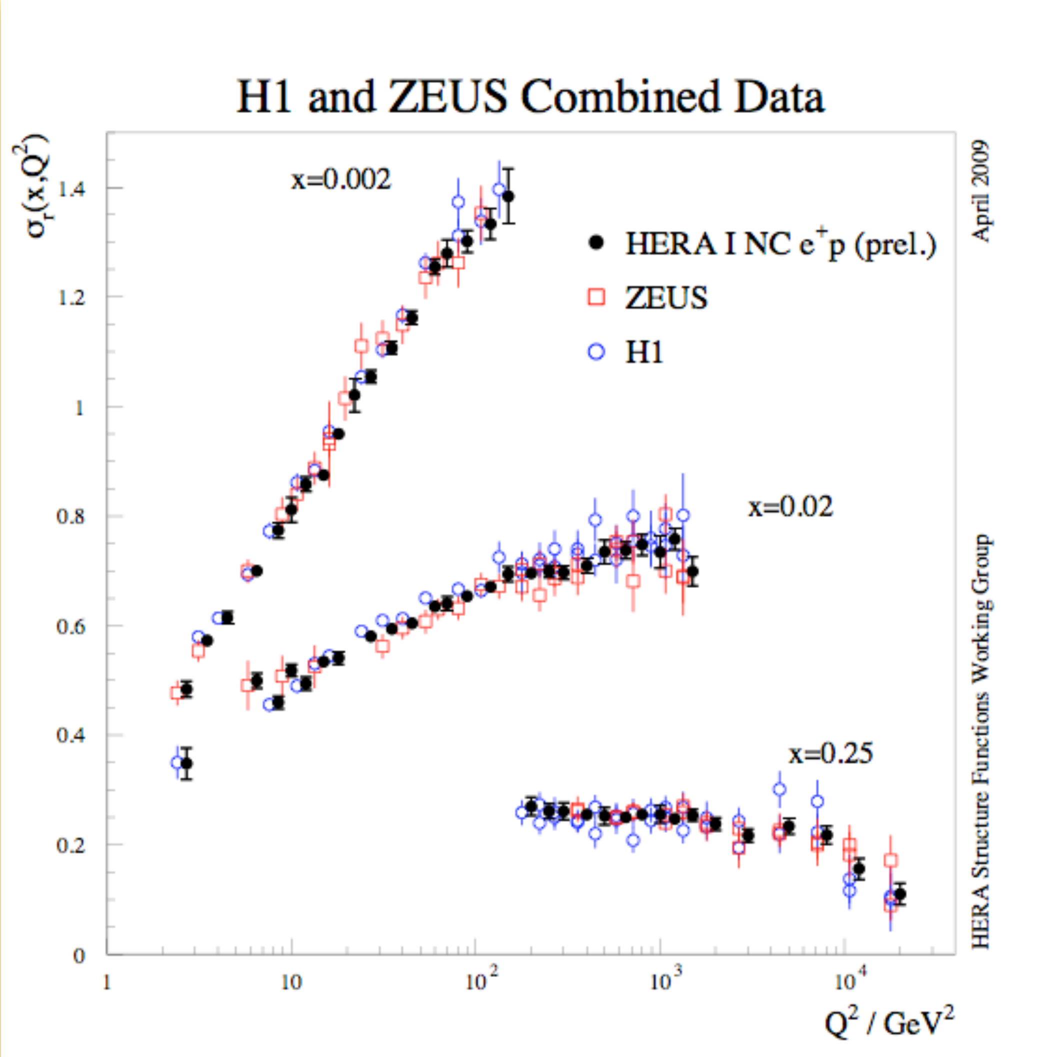
3. Correlated systematic unc. for the hadronic energy scale
   (At the ‰ level)

In fact a more general study of the possible correlated systematic uncertainties between H1 and ZEUS has been performed:
- Identified 12 possible uncertainties of common origin
- Compare 2^{12} averages taking all pairs as corr./uncorr. in turn.

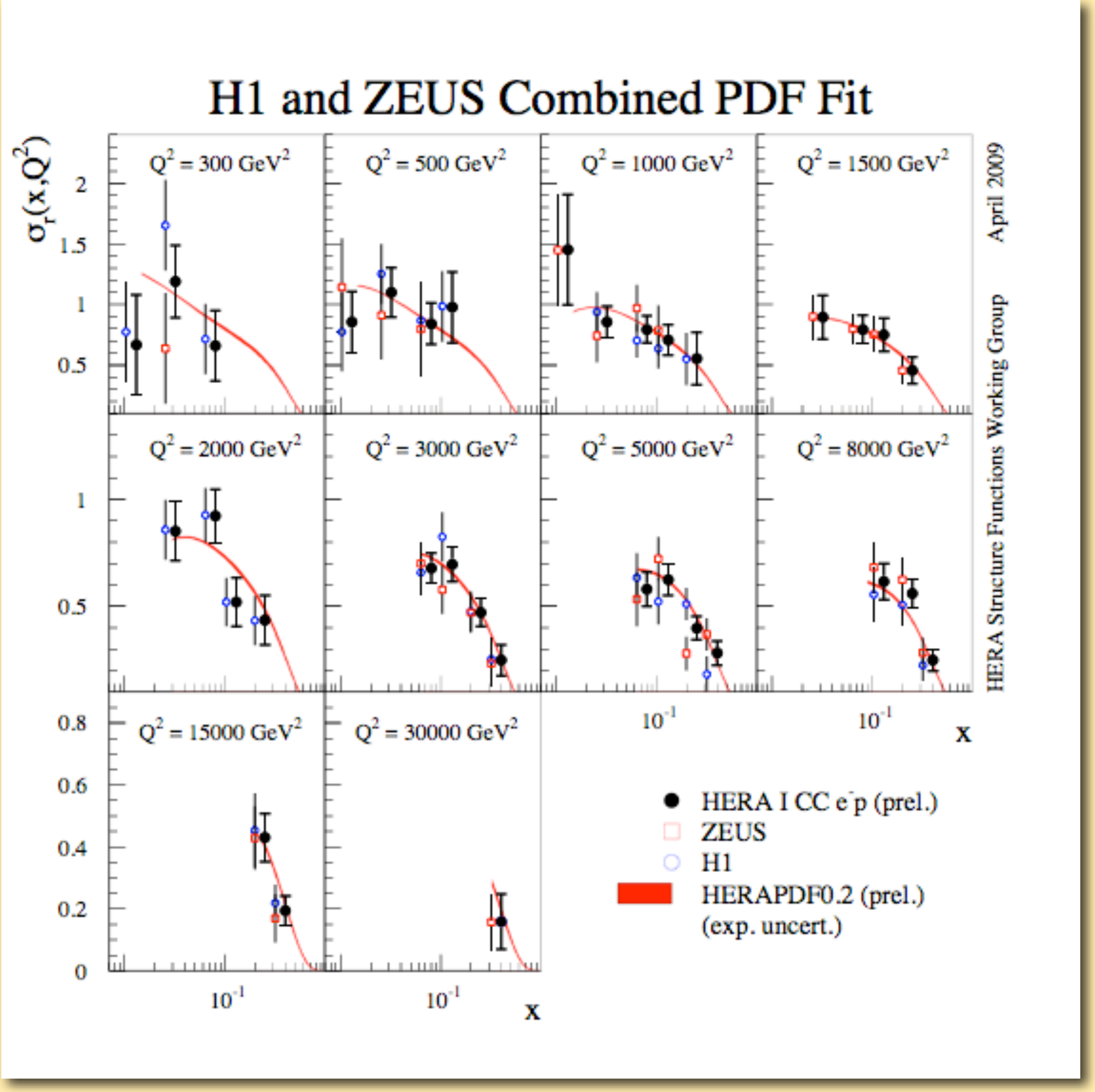
Mostly negligible except for photoproduction and hadronic energy scale

Averaged cross sections

χ^2/ndf =699/716



CC e⁻p


H1 and ZEUS Combined PDF Fit
$\sigma_r(x,Q^2)$
Q^2 = 300 GeV^2
Q^2 = 500 GeV^2
Q^2 = 1000 GeV^2
Q^2 = 1500 GeV^2
Q^2 = 2000 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5000 GeV^2
Q^2 = 8000 GeV^2
Q^2 = 15000 GeV^2
Q^2 = 30000 GeV^2
10^{-1}
x
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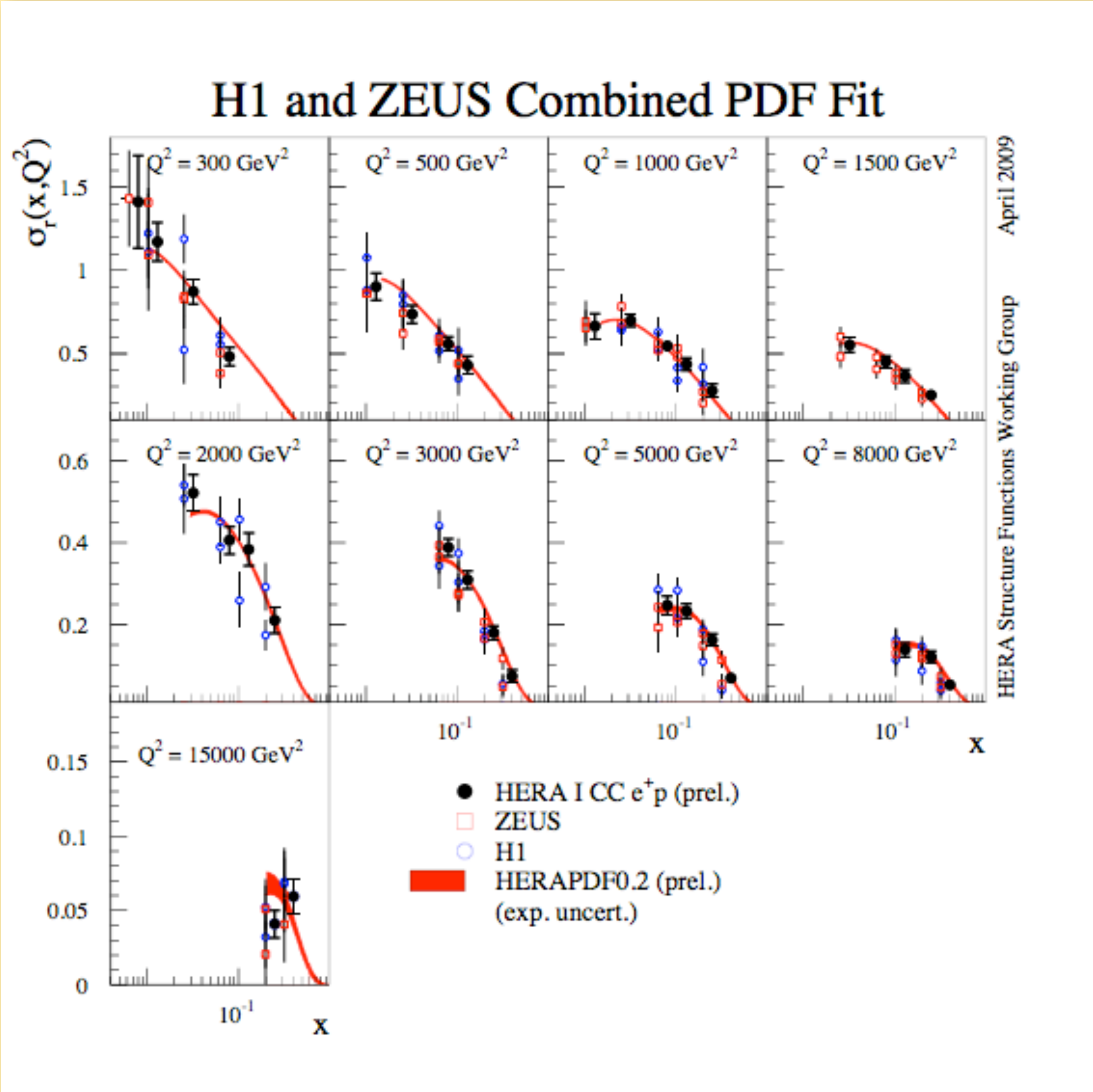
HERA I CC e⁻p (prel.)
ZEUS
H1
HERAPDF0.2 (prel.)
(exp. uncert.)

CC e^+p


H1 and ZEUS Combined PDF Fit
σ_r(x,Q²)
Q² = 300 GeV²
Q² = 500 GeV²
Q² = 1000 GeV²
Q² = 1500 GeV²
Q² = 2000 GeV²
Q² = 3000 GeV²
Q² = 5000 GeV²
Q² = 8000 GeV²
Q² = 15000 GeV²
1.5
1
0.5
0.6
0.4
0.2
0.15
0.1
0.05
0
10⁻¹
x
HERA I CC e⁺p (prel.)
ZEUS
H1
HERAPDF0.2 (prel.)
(exp. uncert.)
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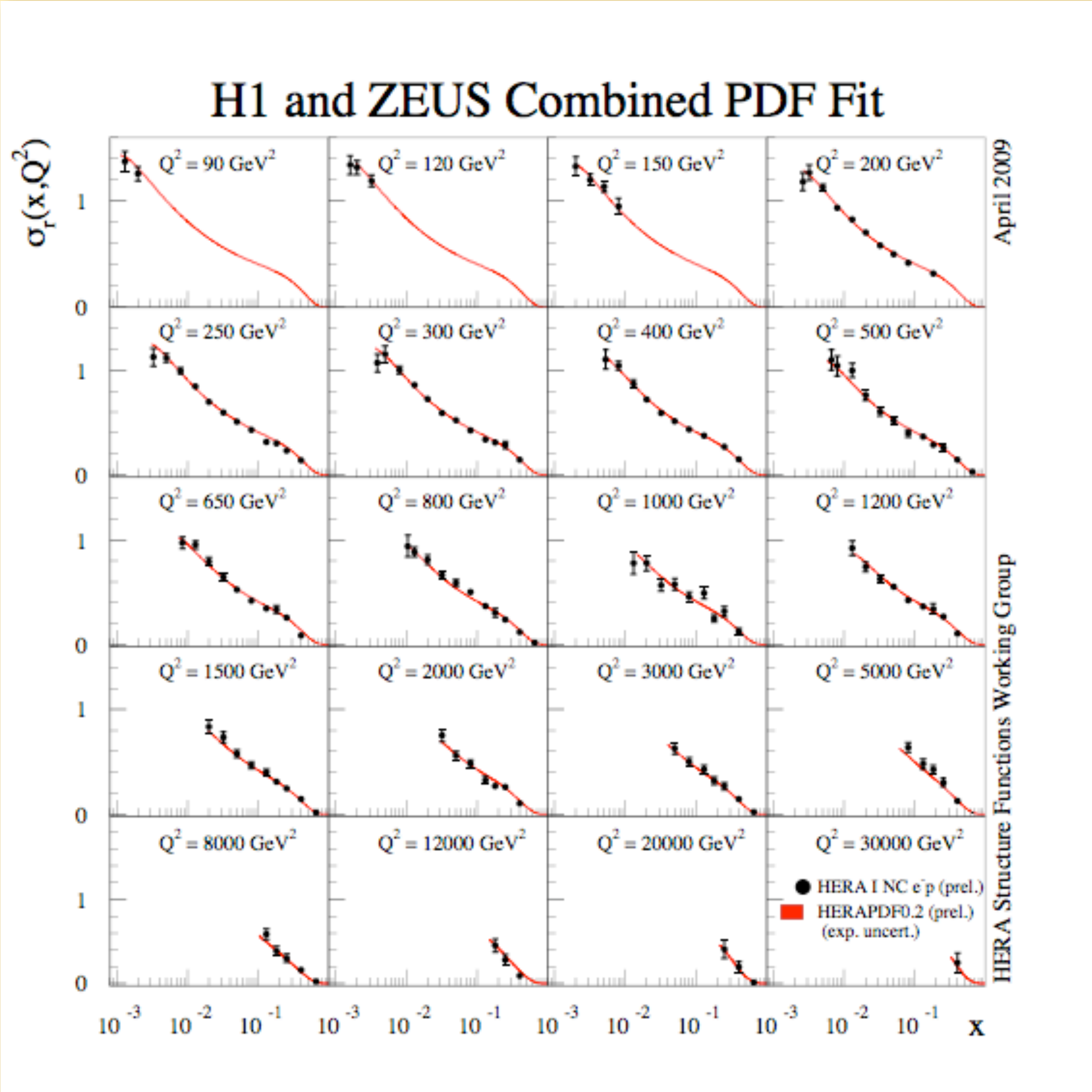
NC e^-p



H1 and ZEUS Combined PDF Fit
σr(x,Q²)
Q² = 90 GeV²
Q² = 120 GeV²
Q² = 150 GeV²
Q² = 200 GeV²
Q² = 250 GeV²
Q² = 300 GeV²
Q² = 400 GeV²
Q² = 500 GeV²
Q² = 650 GeV²
Q² = 800 GeV²
Q² = 1000 GeV²
Q² = 1200 GeV²
Q² = 1500 GeV²
Q² = 2000 GeV²
Q² = 3000 GeV²
Q² = 5000 GeV²
Q² = 8000 GeV²
Q² = 12000 GeV²
Q² = 20000 GeV²
Q² = 30000 GeV²
HERA I NC e⁻p (prel.)
HERAPDF0.2 (prel.)
(exp. uncert.)
x
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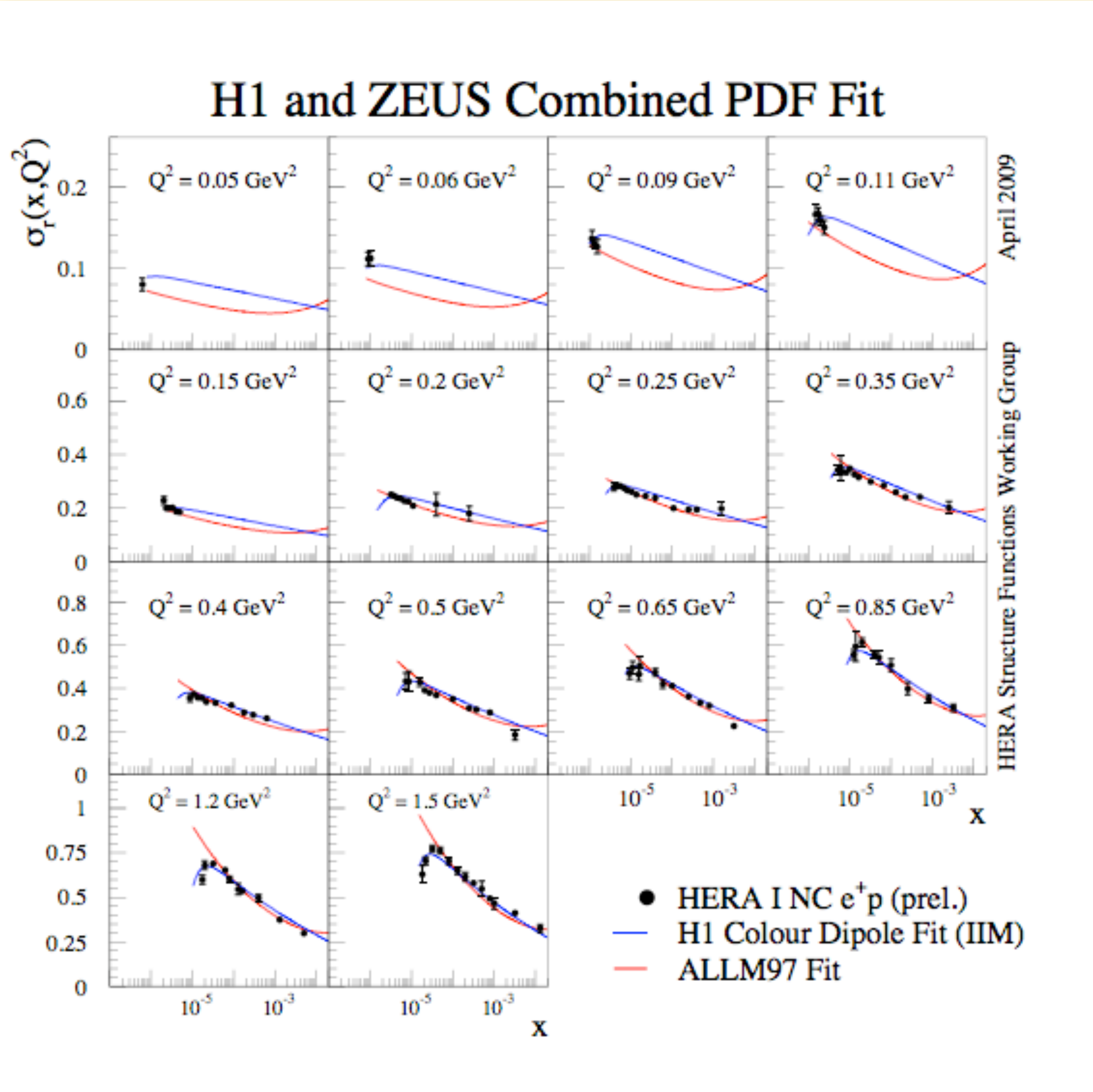
H1 and ZEUS Combined PDF Fit
σr(x,Q²)
Q² = 0.05 GeV²
Q² = 0.06 GeV²
Q² = 0.09 GeV²
Q² = 0.11 GeV²
Q² = 0.15 GeV²
Q² = 0.2 GeV²
Q² = 0.25 GeV²
Q² = 0.35 GeV²
Q² = 0.4 GeV²
Q² = 0.5 GeV²
Q² = 0.65 GeV²
Q² = 0.85 GeV²
Q² = 1.2 GeV²
Q² = 1.5 GeV²
x
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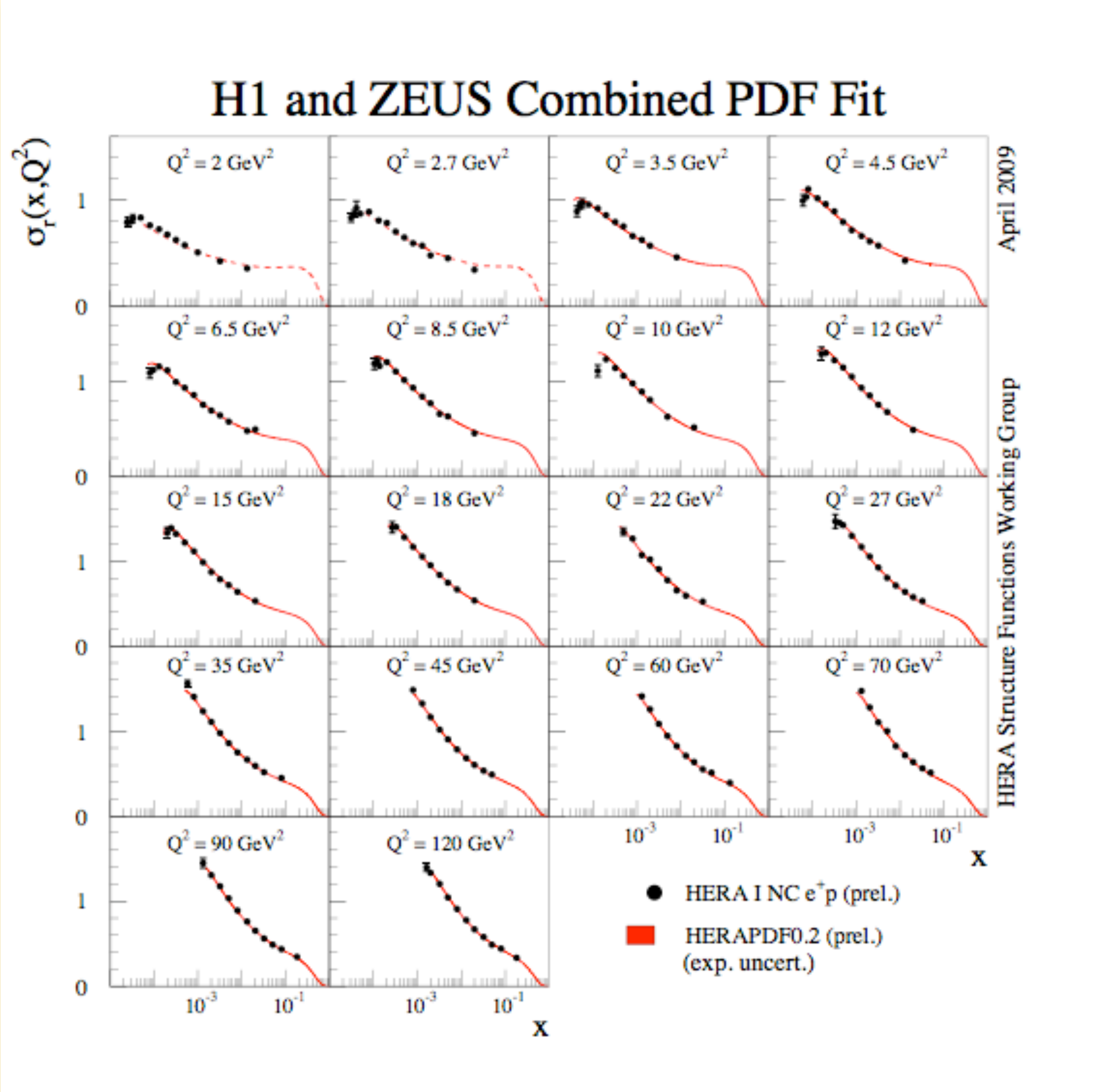
HERA I NC e⁺p (prel.)
H1 Colour Dipole Fit (IIM)
ALLM97 Fit

NC e^+p Low-Q^2


H1 and ZEUS Combined PDF Fit
σr(x,Q²)
Q² = 2 GeV²
Q² = 2.7 GeV²
Q² = 3.5 GeV²
Q² = 4.5 GeV²
Q² = 6.5 GeV²
Q² = 8.5 GeV²
Q² = 10 GeV²
Q² = 12 GeV²
Q² = 15 GeV²
Q² = 18 GeV²
Q² = 22 GeV²
Q² = 27 GeV²
Q² = 35 GeV²
Q² = 45 GeV²
Q² = 60 GeV²
Q² = 70 GeV²
Q² = 90 GeV²
Q² = 120 GeV²
x
HERA I NC e⁺p (prel.)
HERAPDF0.2 (prel.)
(exp. uncert.)
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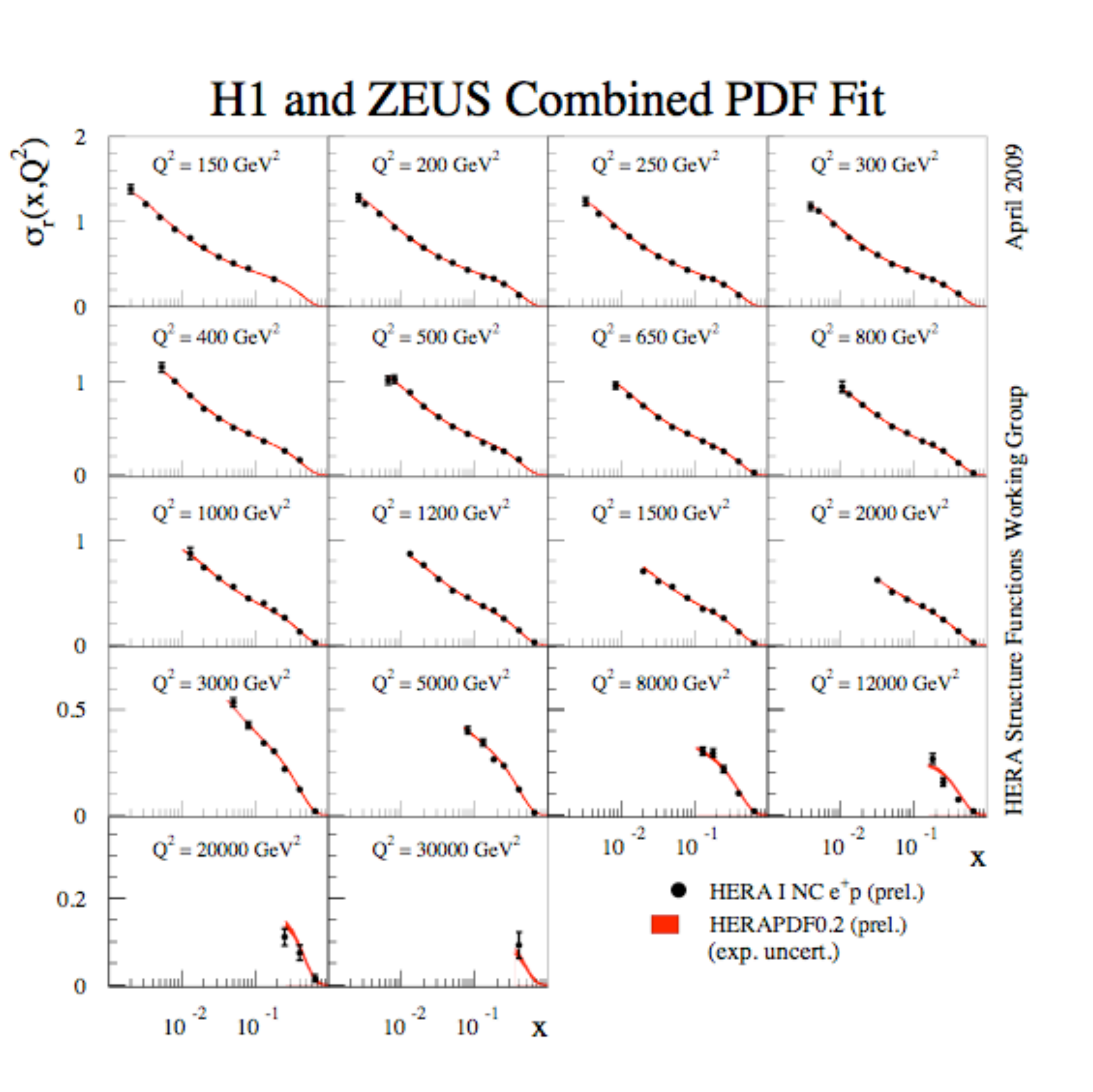
NC e^+p Mid-Q^2


H1 and ZEUS Combined PDF Fit
$\sigma_r(x,Q^2)$
Q^2 = 150 GeV^2
Q^2 = 200 GeV^2
Q^2 = 250 GeV^2
Q^2 = 300 GeV^2
Q^2 = 400 GeV^2
Q^2 = 500 GeV^2
Q^2 = 650 GeV^2
Q^2 = 800 GeV^2
Q^2 = 1000 GeV^2
Q^2 = 1200 GeV^2
Q^2 = 1500 GeV^2
Q^2 = 2000 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5000 GeV^2
Q^2 = 8000 GeV^2
Q^2 = 12000 GeV^2
Q^2 = 20000 GeV^2
Q^2 = 30000 GeV^2
x
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HERA I NC e^+p (prel.)
HERAPDF0.2 (prel.)
(exp. uncert.)

NC e^+p High-Q^2

Summary

- Averaged cross sections now based on the complete HERA-I final data set
- Averaging procedure provides a model independent tool to study consistency of the data and to reduce systematic uncertainties
- These combined HERA-I cross sections used as input in a new QCD analysis to extract new and very precise proton's PDFs (HERAPDF0.2) (see V. Radescu[86])