

# 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:

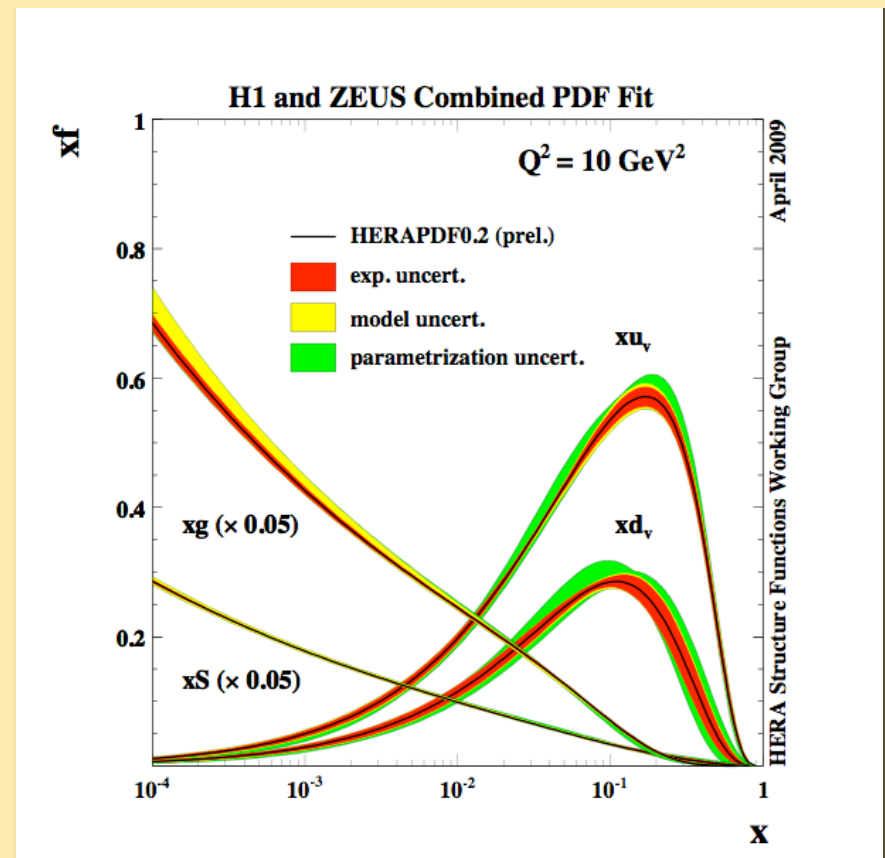
⇒ Experiments cross calibrate each other

❖ 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:

⇒  $E_p=820$  ( $\sqrt{s}=300$ ) and  $E_p=920$  ( $\sqrt{s}=320$ ) GeV,  $L=240$  pb<sup>-1</sup>

For DIS 2008 we used:

- CC e<sup>-</sup>p data: H1 98, ZEUS 98
- CC e<sup>+</sup>p data: H1 94-97, H1 99-00, ZEUS 94-97, ZEUS 99-00
- NC e<sup>-</sup>p data: H1 98, ZEUS 98
- NC e<sup>+</sup>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  $Q^2$ ”  $0.2 \leq Q^2 \leq 12$  GeV<sup>2</sup>
- H1 96-00 “bulk”  $12 \leq Q^2 \leq 150$  GeV<sup>2</sup>
- ZEUS BPC/BPT, SVX95 ( $0.045 \leq Q^2 \leq 17$  GeV<sup>2</sup>)

110 correlated systematic error sources

3 “procedural uncertainties” related to the averaging procedure

# Averaging procedure

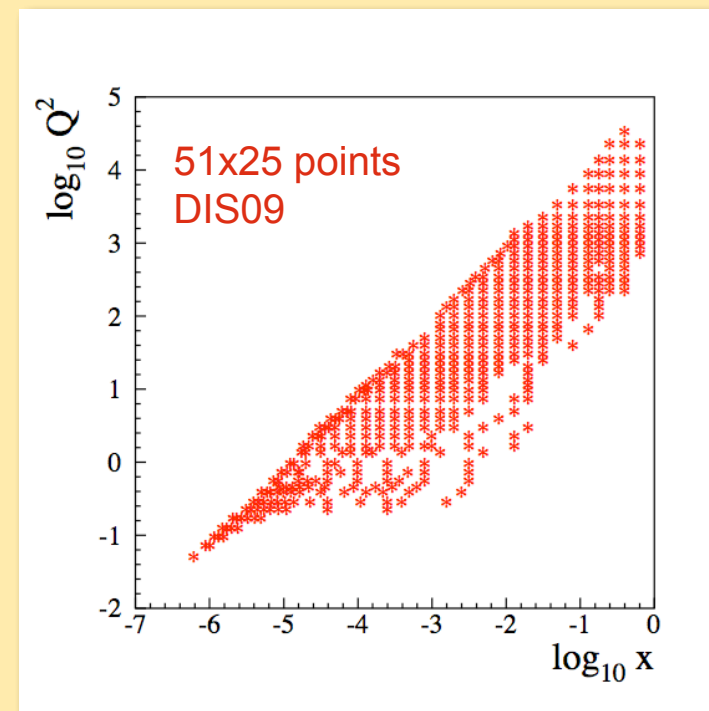
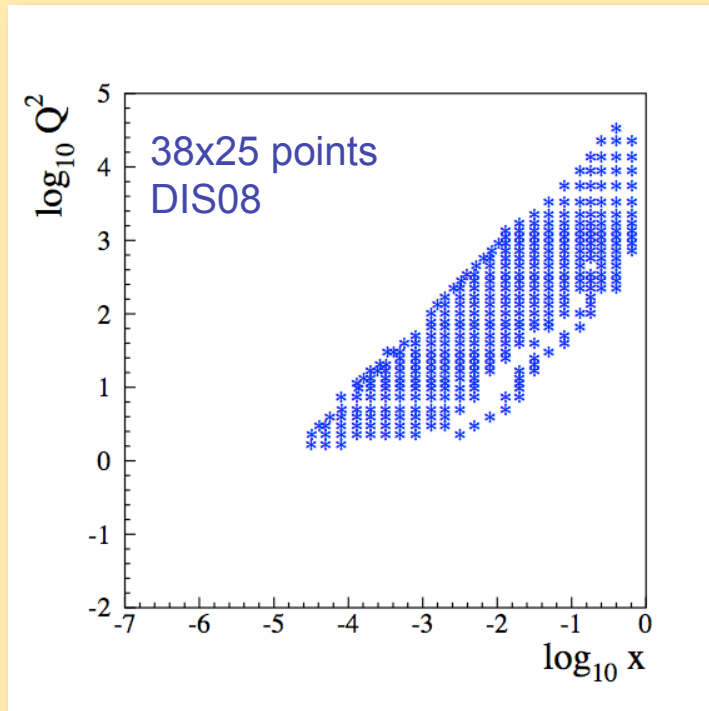
- Swim all points to a common  $x$ - $Q^2$  grid
- Moved<sup>(1)</sup> 820 GeV data to 920 GeV p-beam energy
- Calculate average values and uncertainties
- Evaluate “procedural uncertainties”

<sup>(1)</sup> Except for data points with  $y > 0.35$

# x-Q<sup>2</sup> common grid

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

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



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:

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

Neutral Current:

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

with

$$\Delta\sigma_{NC}^{e^\pm p}(x, Q^2, y_{920}, y_{820}) = F_L(x, Q^2) \left[ \frac{y_{820}^2}{Y_{820}^+} - \frac{y_{920}^2}{Y_{920}^+} \right] + xF_3(x, Q^2) \left[ \pm \frac{Y_{820}^-}{Y_{820}^+} \mp \frac{Y_{920}^-}{Y_{920}^+} \right]$$

# Averaging procedure

Described in detail in [arXiv:0904.0929](https://arxiv.org/abs/0904.0929)

Additive error sources:

$$\chi_{\text{exp}}^2(\mathbf{m}, \mathbf{b}) = \sum_i \frac{[m^i - \sum_j \Gamma_j^i b_j - \mu^i]^2}{\Delta_i^2} + \sum_j b_j^2.$$

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

$$\chi_{\text{exp}}^2(\mathbf{m}, \mathbf{b}) = \sum_i \frac{[m^i - \sum_j \gamma_j^i m^i b_j - \mu^i]^2}{\delta_{i,\text{stat}}^2 (m^i - \sum_j \gamma_j^i m^i b_j) + (\delta_{i,\text{uncor}} m^i)^2} + \sum_j b_j^2.$$

with

$$\gamma_j^i = \Gamma_j^i / \mu^i$$

$$\delta_{i,\text{stat}} = \Delta_{i,\text{stat}} / \mu^i$$

$$\delta_{i,\text{uncor}} = \Delta_{i,\text{uncor}} / \mu^i$$

# 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)

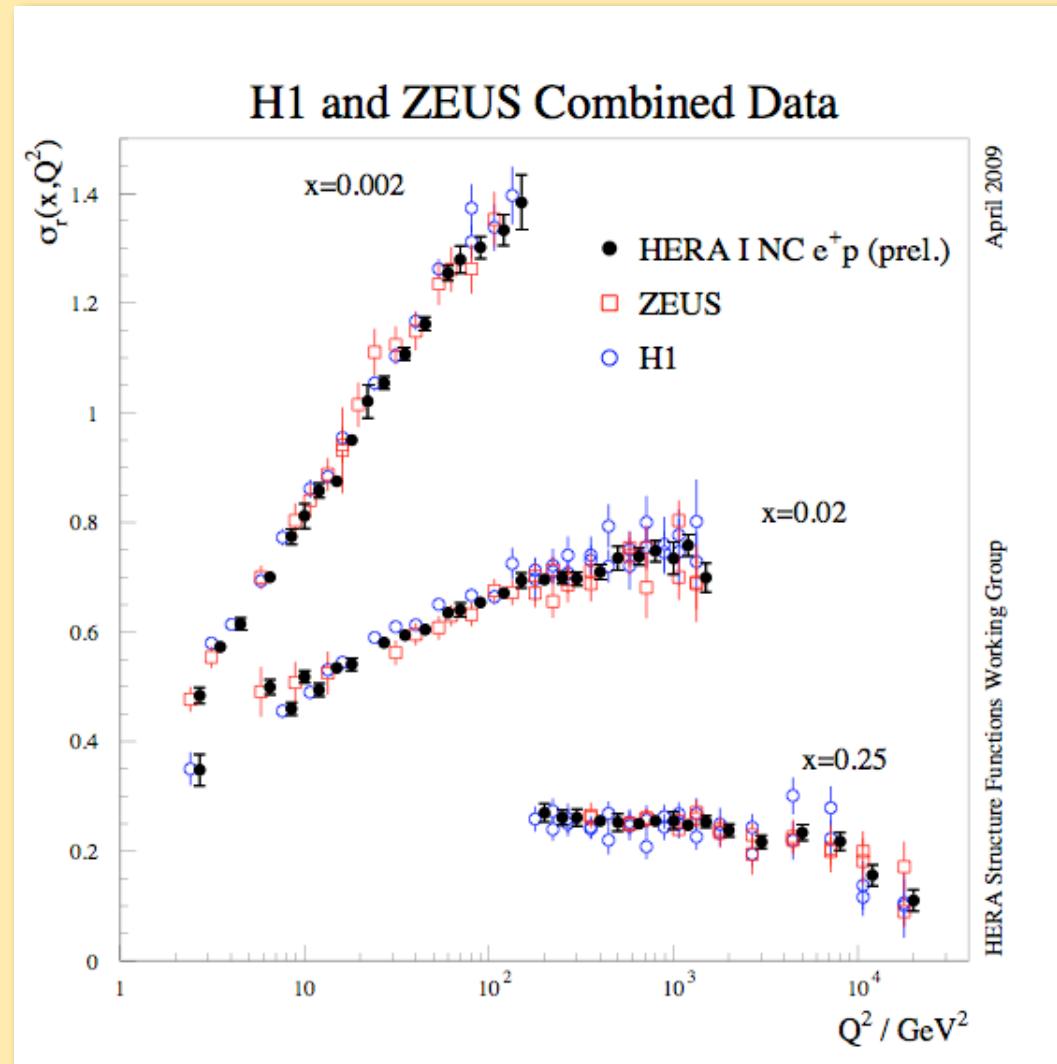
In fact a more general study of the possible correlated systematic uncertainties between H1 and ZEUS has been performed:

- Identified 12 possible uncertainties of common origin
- Compare  $2^{12}$  averages taking all pairs as corr./uncorr. in turn.

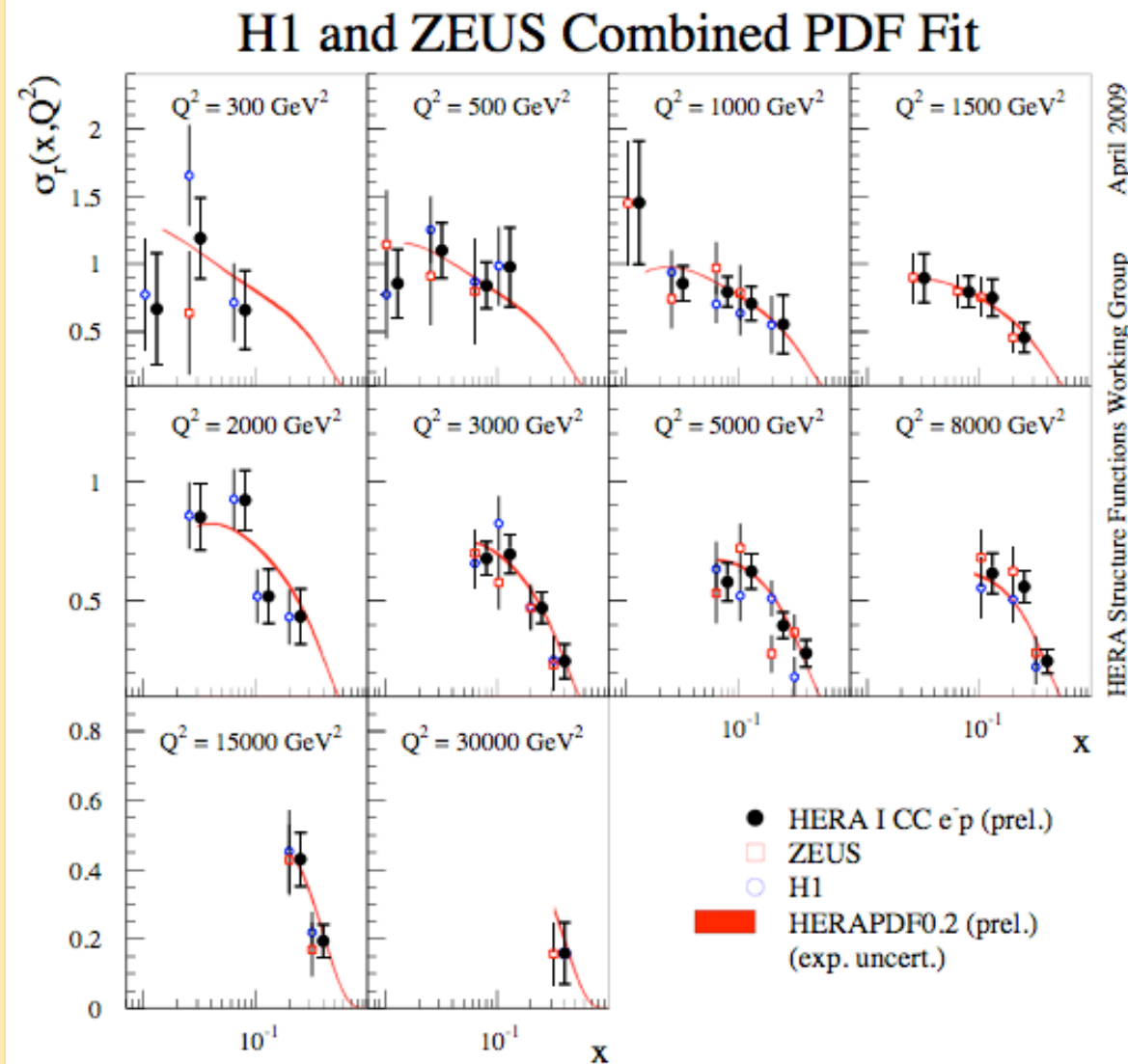
Mostly negligible except for **photoproduction** and **hadronic energy scale** 8

# Averaged cross sections

$$\chi^2/\text{ndf} = 699/716$$

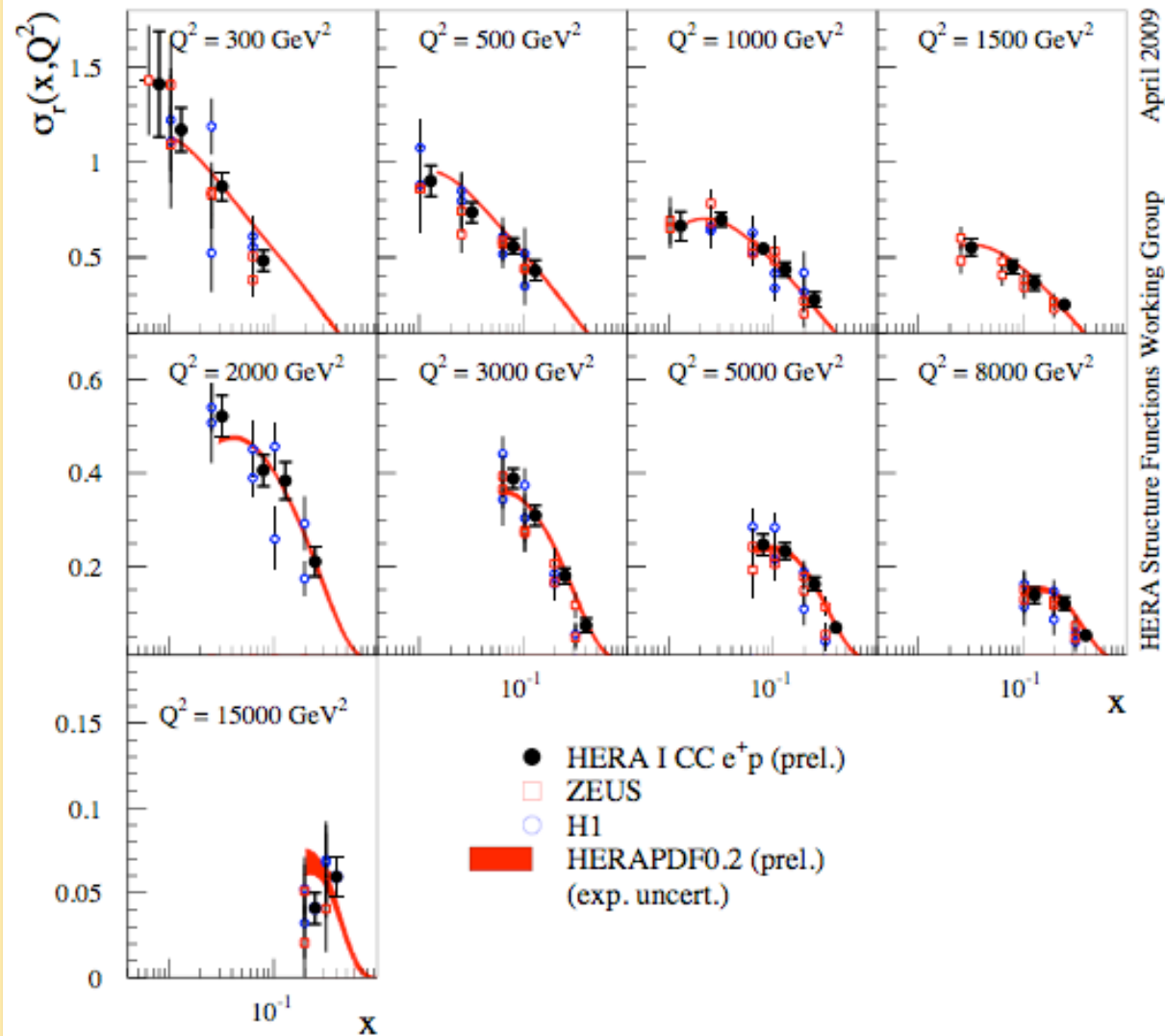


# CC e

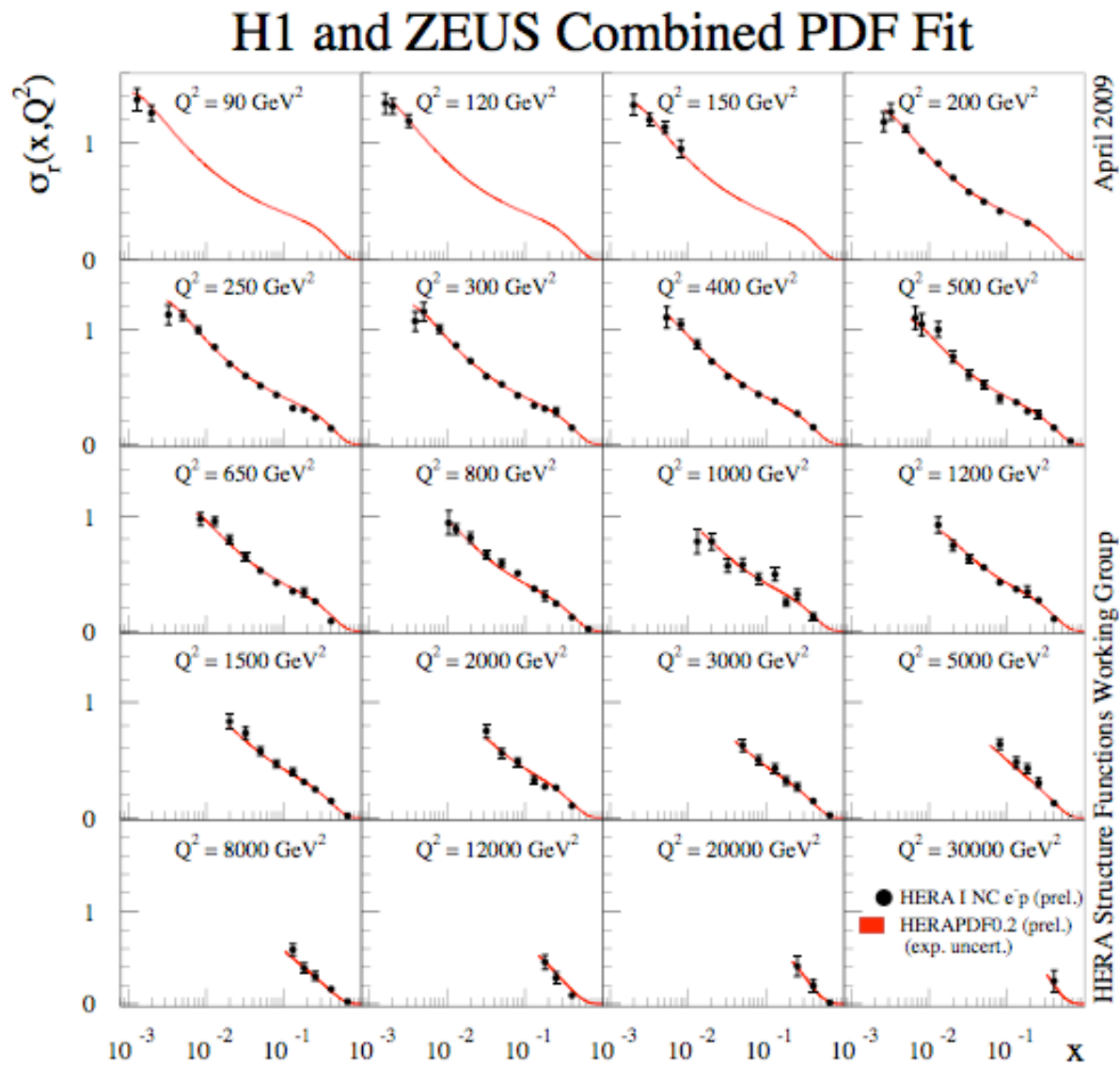


# CC $e^+p$

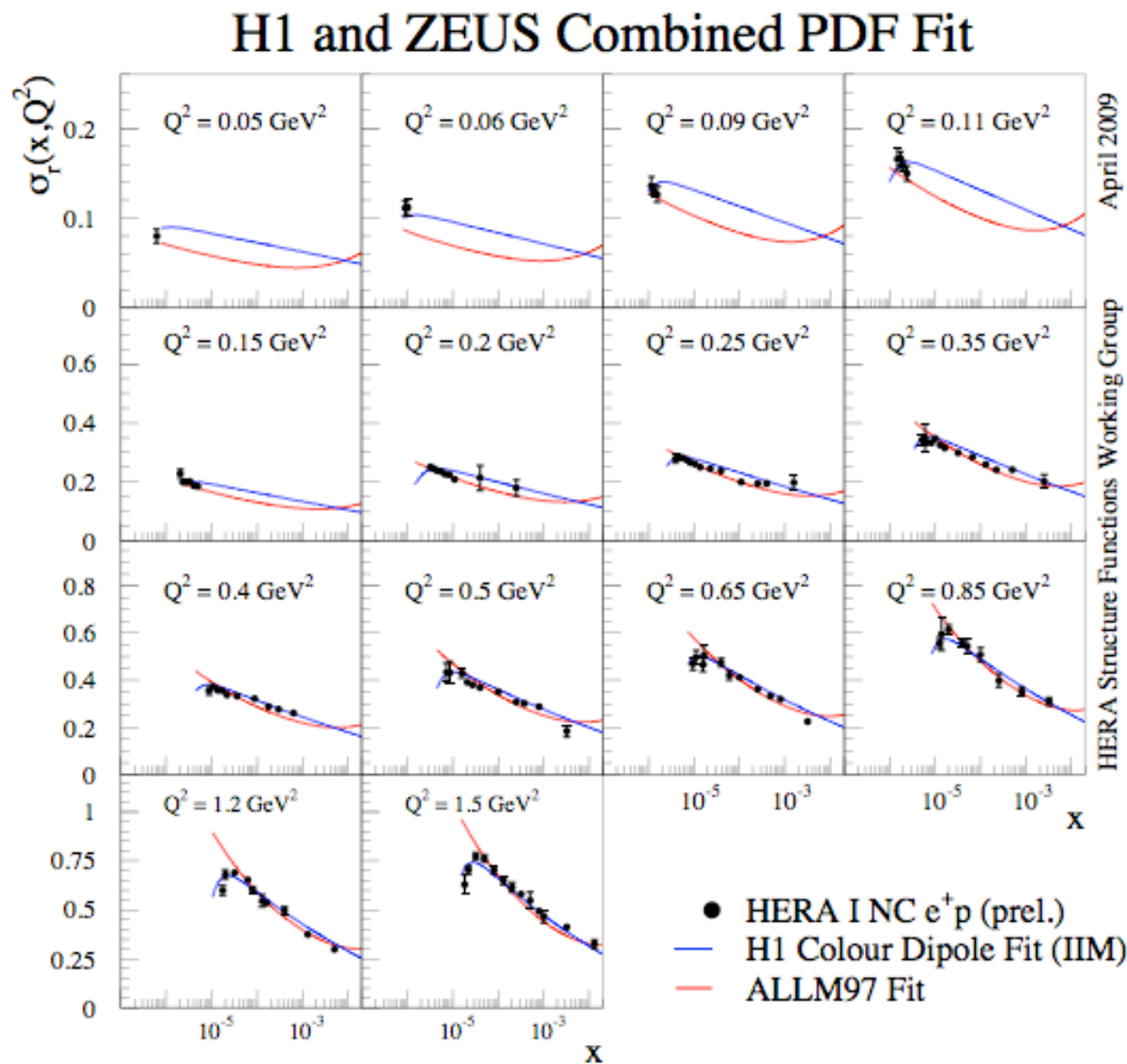
## H1 and ZEUS Combined PDF Fit



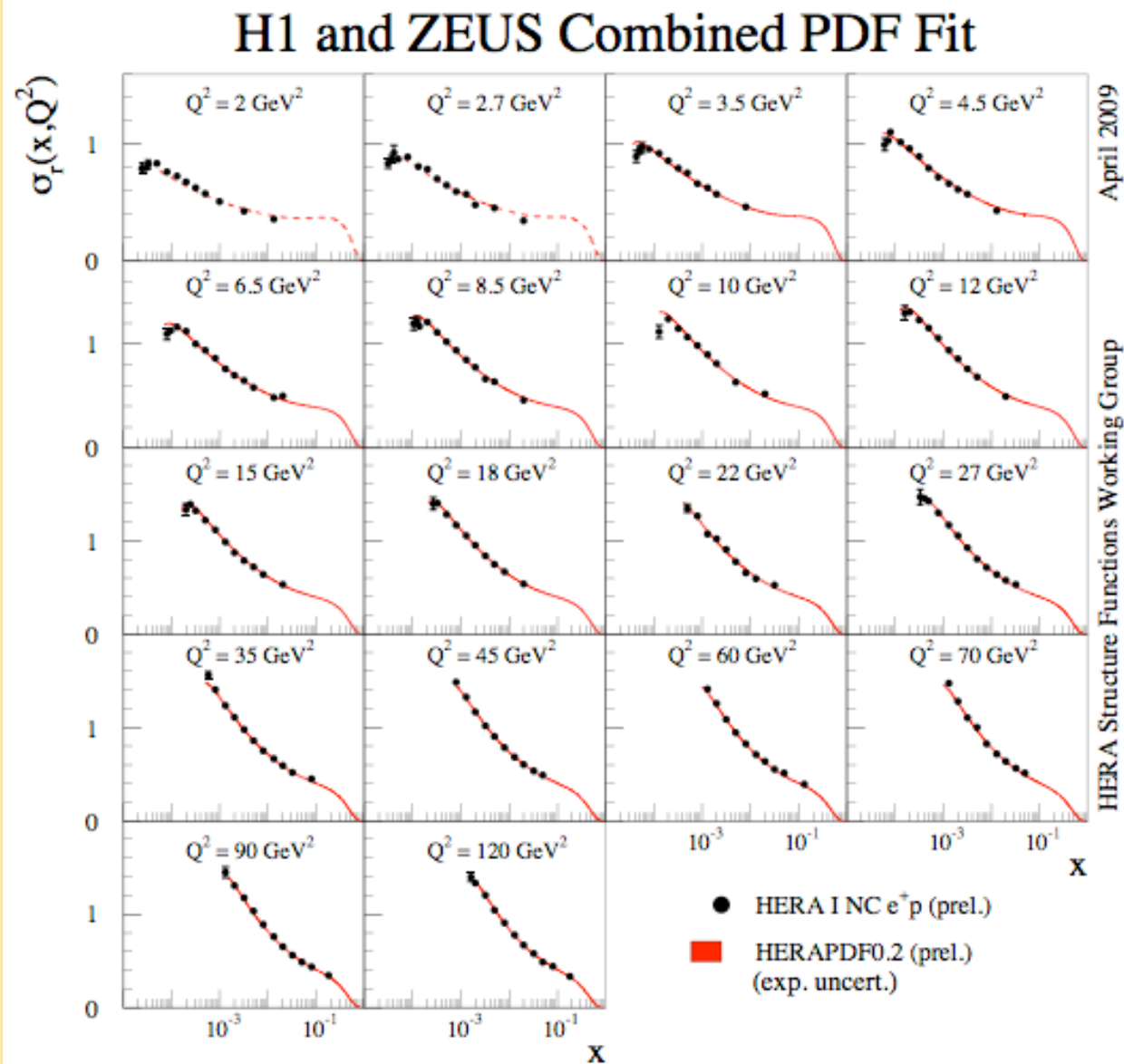
# NC e<sup>-</sup>p



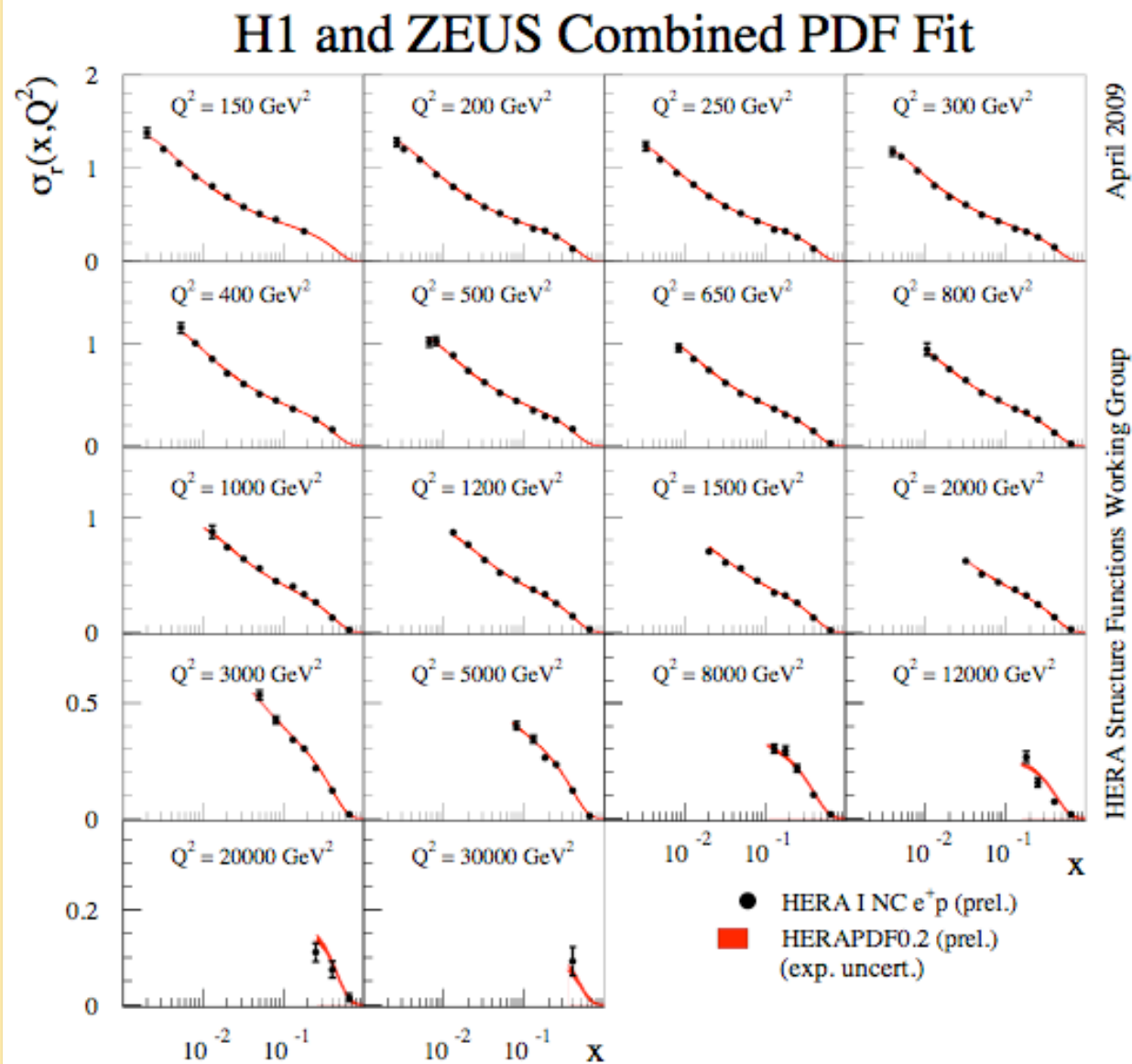
NC  $e^+p$   
Low- $Q^2$



# NC $e^+p$ Mid- $Q^2$



# 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])