Combination of H1 and ZEUS DIS $e^{\pm}p$ inclusive cross sections

On behalf of H1 and ZEUS Collaborations

HERA Structure Functions Working Group

Outlook

- Objectives
- Data sets
- Method of Combination
- Results

Objectives

- Combined reduced cross sections and SFs including full error correlations (this talk)

- Joint QCD analysis to get precise HERA PDFs

  (AM Cooper-Sarkar, next talk)

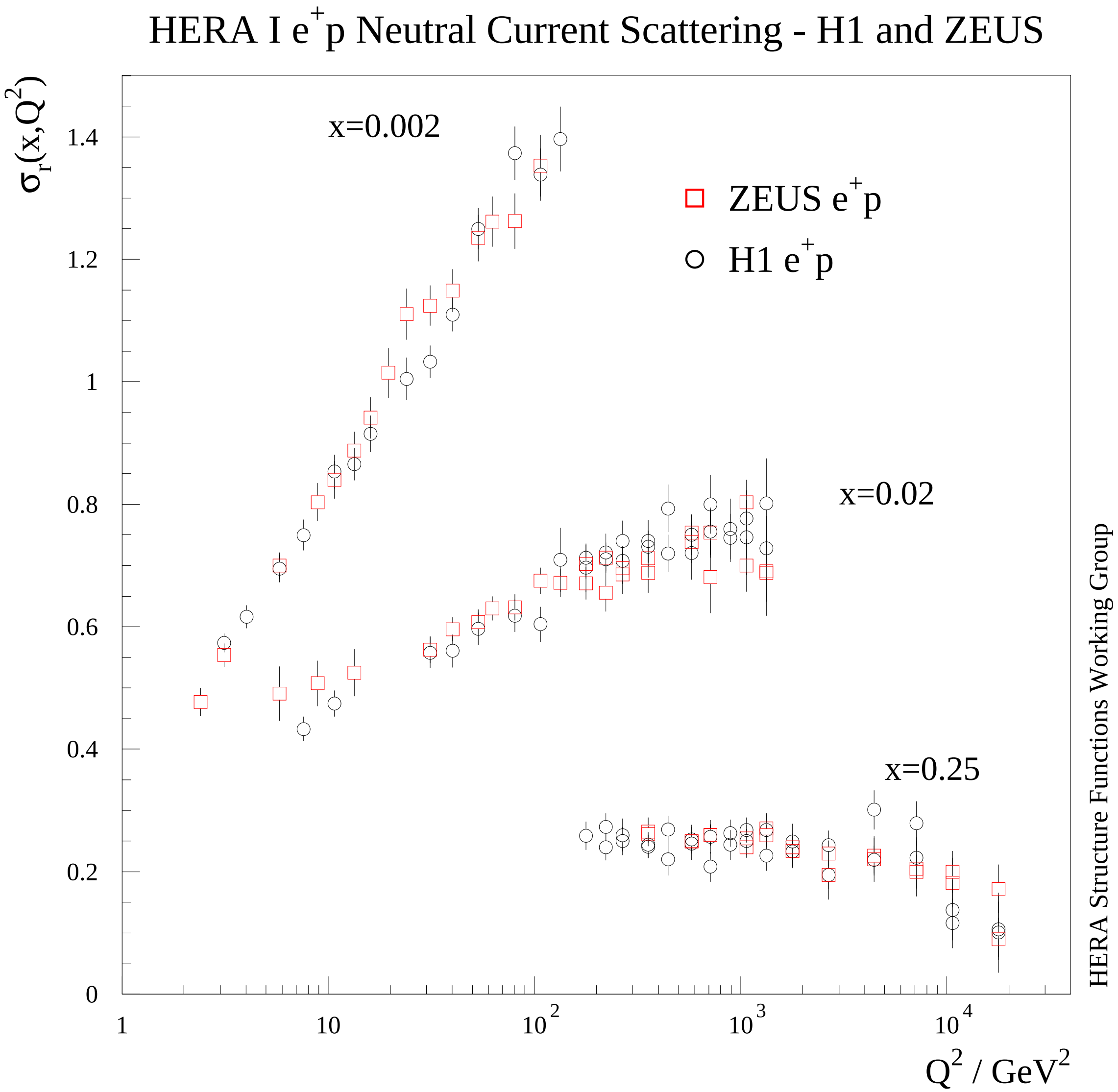
Based on published data sets (as in summer 2007)

Input data sets : Published HERA I cross sections

data set		x range		Q^2 range (GeV^2)		$\mathcal{L}$ pb^{-1}	comment
H1 NC min. bias	97	0.00008	0.02	1.5	12	1.8	e^+p $\sqrt{s} = 301$ GeV
H1 NC low Q^2	96 – 97	0.000161	0.20	12	150	17.9	e^+p $\sqrt{s} = 301$ GeV
H1 NC	94 – 97	0.0032	0.65	150	30 000	35.6	e^+p $\sqrt{s} = 301$ GeV
H1 CC	94 – 97	0.013	0.40	300	15 000	35.6	e^+p $\sqrt{s} = 301$ GeV
H1 NC	98 – 99	0.0032	0.65	150	30 000	16.4	e^-p $\sqrt{s} = 319$ GeV
H1 CC	98 – 99	0.013	0.40	300	15 000	16.4	e^-p $\sqrt{s} = 319$ GeV
H1 NC	99 – 00	0.00131	0.65	100	30 000	65.2	e^+p $\sqrt{s} = 319$ GeV
H1 CC	99 – 00	0.013	0.40	300	15 000	65.2	e^+p $\sqrt{s} = 319$ GeV
ZEUS NC	96 – 97	0.00006	0.65	2.7	30 000	30.0	e^+p $\sqrt{s} = 301$ GeV
ZEUS CC	94 – 97	0.015	0.42	280	17 000	47.7	e^+p $\sqrt{s} = 301$ GeV
ZEUS NC	98 – 99	0.005	0.65	200	30 000	15.9	e^-p $\sqrt{s} = 319$ GeV
ZEUS CC	98 – 99	0.015	0.42	280	30 000	16.4	e^-p $\sqrt{s} = 319$ GeV
ZEUS NC	99 – 00	0.005	0.65	200	30 000	63.2	e^+p $\sqrt{s} = 319$ GeV
ZEUS CC	99 – 00	0.008	0.42	280	17 000	60.9	e^+p $\sqrt{s} = 319$ GeV

With H1 NC min. bias ($Q^2 < 12$ GeV^2) moved up by 3.4 % after reanalysis of luminosity

Example of data set to be averaged



Method of combination

- **Move all data points to a common x-Q^2 grid**
- **Move 820 GeV data to 920 GeV beam energy**
- **Calculate the average values and the errors**
- **Evaluate the uncertainties related to the combination method**

Move all data points to x-Q^2 common grid

- Grid : H1 x binning and ZEUS Q^2 binning basically
- Straightforward interpolation :

$$\sigma_{ep}^{meas}(x_{grid}, Q^2_{grid}) = \frac{\sigma_{ep}^{th}(x_{grid}, Q^2_{grid})}{\sigma_{ep}^{th}(x, Q^2)} \sigma_{ep}^{meas}(x, Q^2)$$

- H1PDF2k and ZEUS-Jets fits have been used. Correction factors agree within a few permille and to better than to 2% for CC.

Move data to 920 GeV beam energy

Beam energy correction for CC data

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

Beam energy correction performed additively for NC data

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

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

Systematic error estimated by comparing $F_L = 0$ and $F_L = F_L$(H1PDF2k) :
at present up to 5 % at high y.

Averaging method

- A model independent combination, prior to performing QCD analysis, and which includes full error correlations.

  (A. Glazov – DIS 05 & HERA-LHC WS, code available for other WG)

- The key assumption is that H1 and ZEUS experiments are measuring the same cross sections at the same kinematical points.

- It minimises the following probability distribution →

χ^2 definition

$$\chi^2_{\text{exp}}\left(M^{i,\text{true}}, \Delta\alpha_j\right) = \sum_i \frac{\left[M^{i,\text{true}} - \left(M^i + \sum_j \frac{\partial M^i}{\partial \alpha_j}\Delta\alpha_j\right)\right]^2}{\sigma_i^2} + \sum_j \frac{\Delta\alpha_j}{\sigma^2_{\alpha_j}}$$

M^i measured central values

σ_i statistical and uncorrelated systematic uncertainties

σ_{α_j} correlated uncertainty

$\frac{\partial M^i}{\partial \alpha_j}$ sensitivity of the data to to the systematic source j

$M^{i,\text{true}}$ fitted H1-ZEUS combined H1-value

$\frac{\partial M^i}{\partial \alpha_j}\Delta\alpha_j$ fitted shift of the **i** data due to the **j** sys error source

It's a cross calibration of the correlated systematics between different data sets. If $\Delta\alpha_j$ = 0. it coincides with a standard average

χ^2 definition (cont'd)

$$\chi^2_{\mathrm{exp}}\left(M^{i,\mathrm{true}}, \Delta\alpha_j\right) = \sum_i \frac{\left[M^{i,\mathrm{true}} - \left(M^i + \sum_j \frac{\partial M^i}{\partial \alpha_j}\Delta\alpha_j\right)\right]^2}{\sigma_i^2} + \sum_j \frac{\Delta\alpha_j}{\sigma^2_{\alpha_j}}$$

Caution : Most errors are provided as a relative error but a smaller value of the cross section has a a smaller absolute error $\boldsymbol{\sigma_i}$.

Bias toward smaller averages ! (checked with a toy model)

Can be avoided by modifying chi^2 definition $\longrightarrow$

New χ^2 definition

$$\chi^2_{\rm exp}\left(M^{i,\rm true},\Delta\alpha_j\right)=\sum_i\frac{\left[M^{i,\rm true}-\left(M^i+\sum_j\frac{\partial M^i}{\partial\alpha_j}\frac{M^{i,\rm true}}{M^i}\Delta\alpha_j\right)\right]^2}{\left(\sigma_i\frac{M^{i,\rm true}}{M^i}\right)^2}+\sum_j\frac{\Delta\alpha_j^2}{\sigma^2_{\alpha_j}}$$

Normalisation is clearly relative (multiplicative).

Are the other systematics errors additive or multiplicative ? Debatable !

Impact is mostly negligible, except at very large Q^2 and x where statistical errors and fluctuations are the largest.

At that stage : an additional uncertainty has been added.

Correlation of systematics between H1 & ZEUS and between data sets of the same experiment ?

Similar methods for detector calbration, MC simulations of HFS DIS and photoproduction background. Some correlations should exist.
Have identified 12 possible uncertainties of common origin.

Compare 2^{12} averages taking all pairs as corr & uncorr in turn.
Determine average deviations from central values.

→ Mostly negligible except for photoproduction and hadronic energy scale

The sources of procedural errors related to the averaging procedure :

- Center of Mass Energy correction (at the per mille level but up to 5 % at large y, Q2 ~ 10 GeV^2)

- Multiplicative vs additive systematic errors (< 1 % except at large x, large Q^2)

- Correlations between experiments :

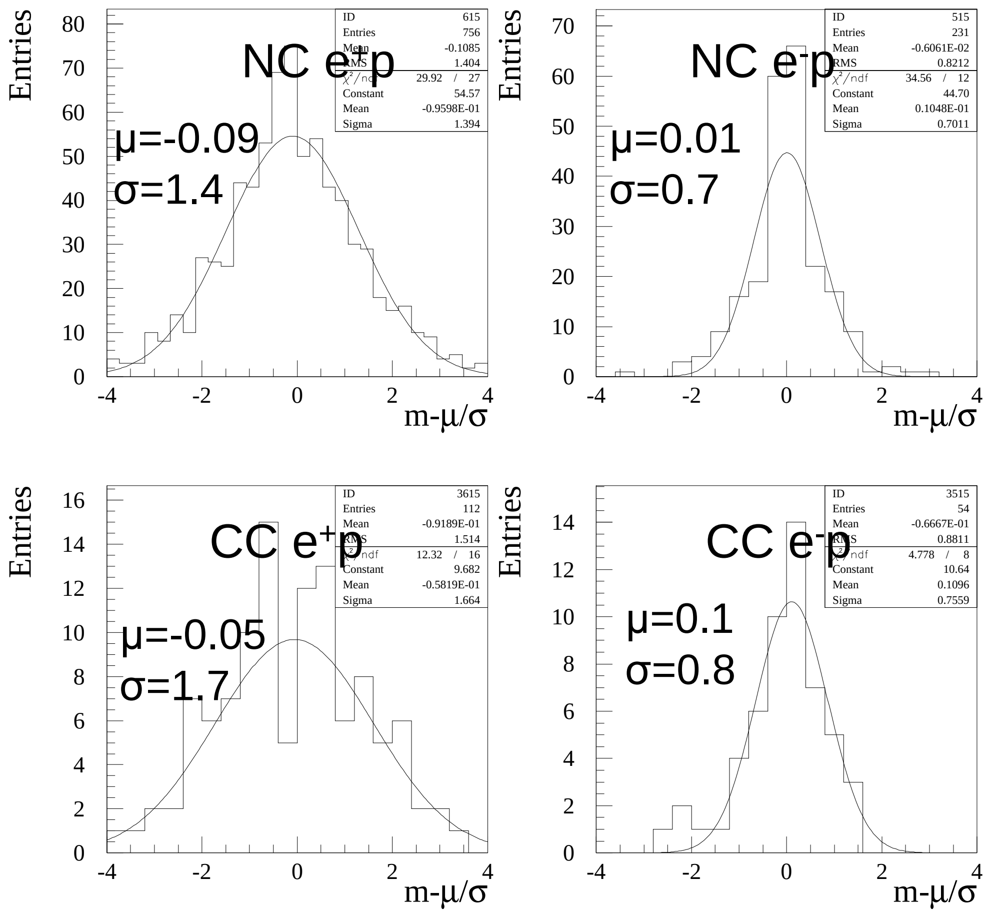
  Subtraction of photoproduction background assumed to be correlated in H1-ZEUS (1 - 2% at large y)

  Hadronic energy scale (1% at low y)

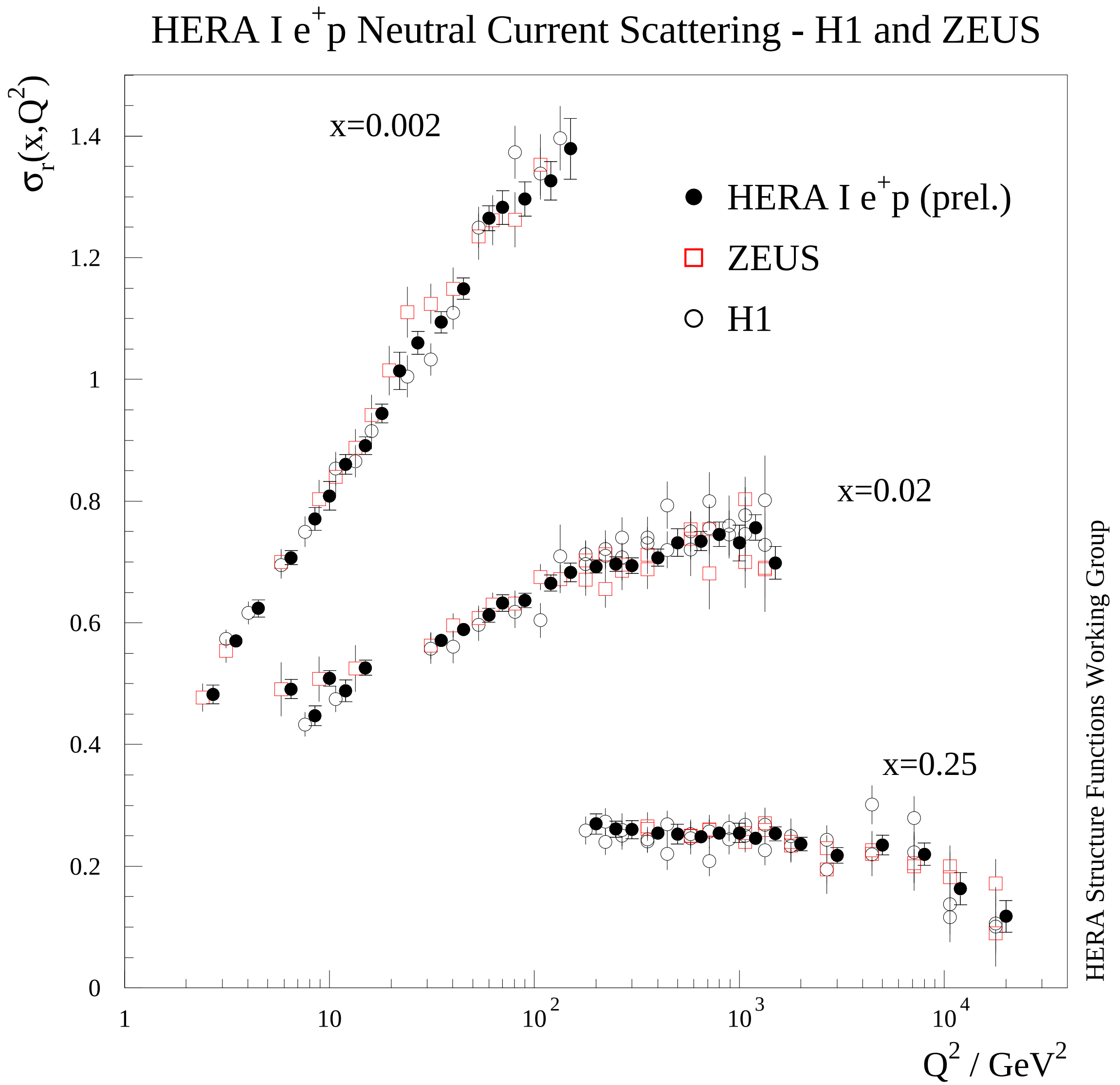
are added to the averaged data points. They are at the few permille level across most of kinematic plane with few exceptions.

Fit results: χ^2 and pulls

$$\chi^2 / ndf = 510/599$$



NC e^+p



HERA I e+p Neutral Current Scattering - H1 and ZEUS
σr(x,Q2)
x=0.002
x=0.02
x=0.25
HERA I e+p (prel.)
ZEUS
H1
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10 2
10 3
10 4
Q2 / GeV2
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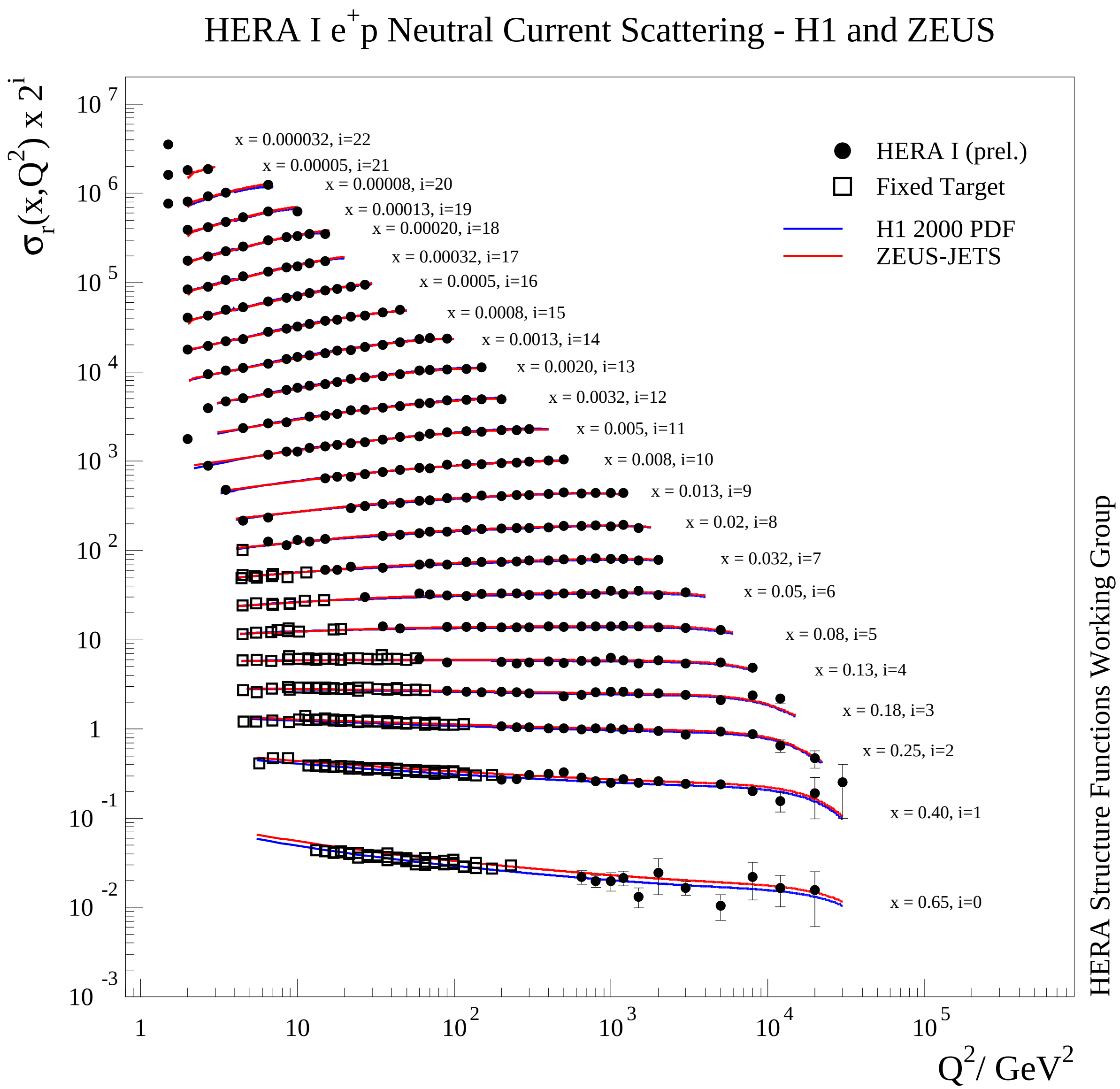
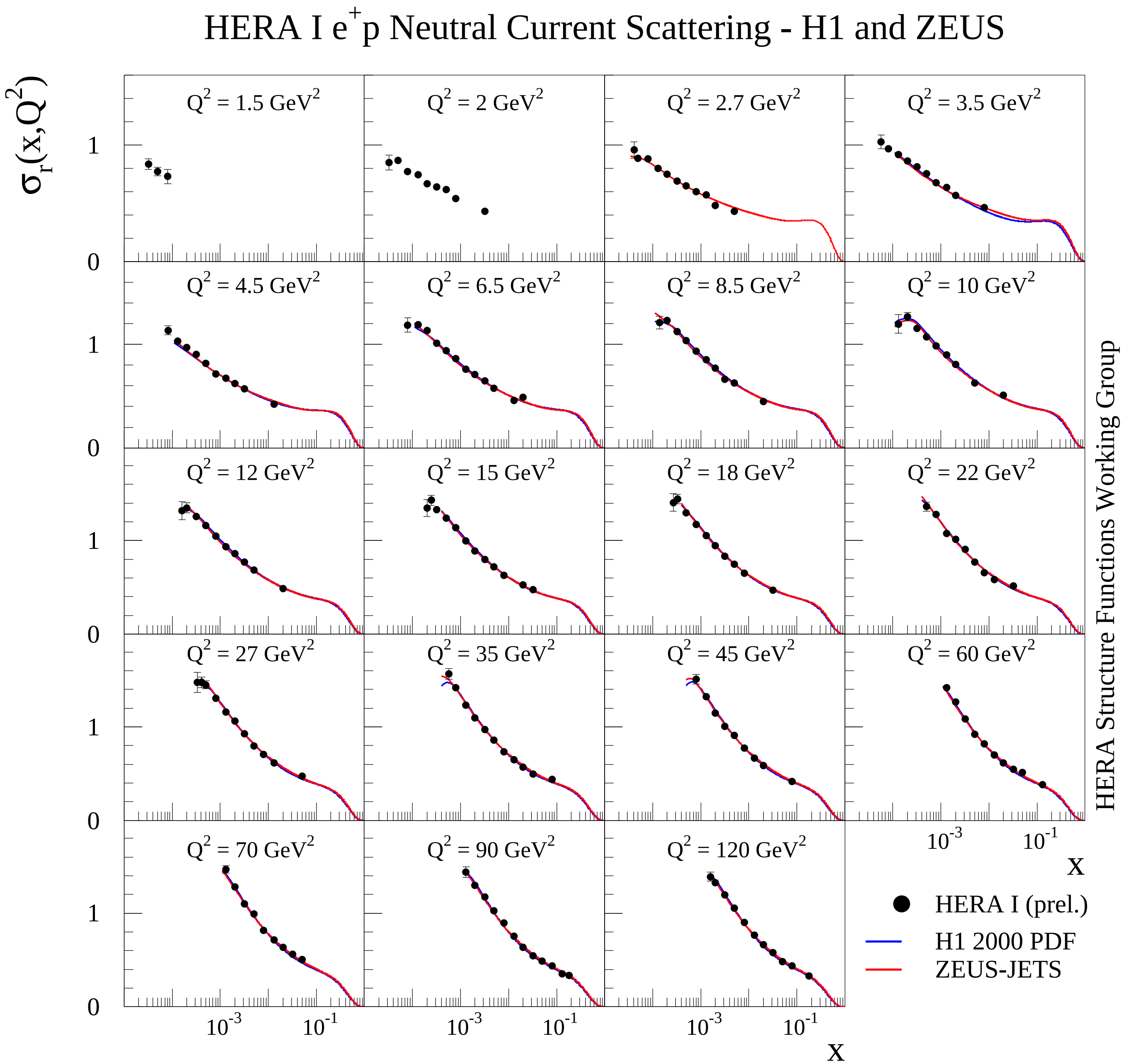
NC e^+p

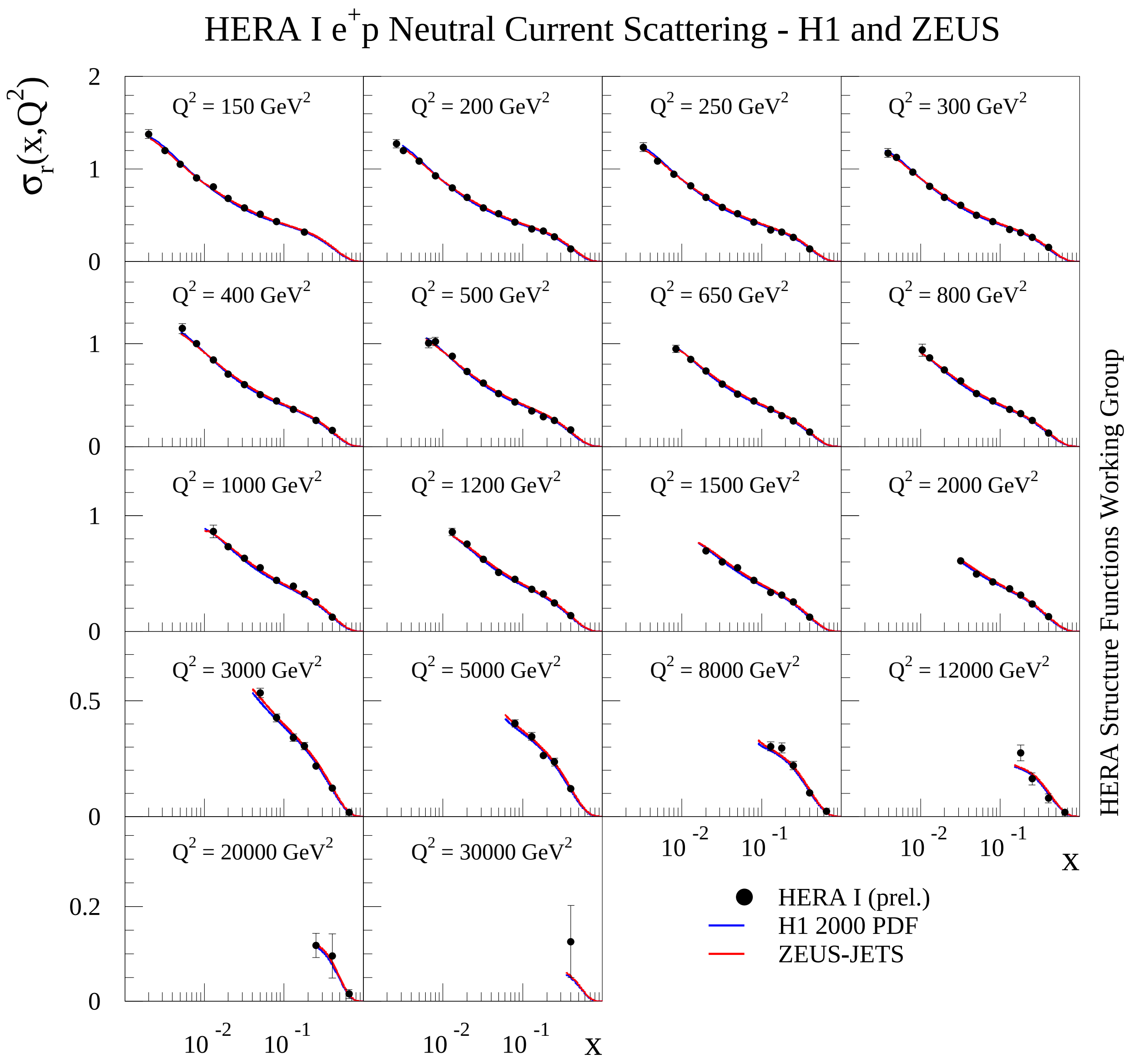

HERA I e+p Neutral Current Scattering - H1 and ZEUS
σr(x,Q2) x 2i
x = 0.000032, i=22
x = 0.00005, i=21
x = 0.00008, i=20
x = 0.00013, i=19
x = 0.00020, i=18
x = 0.00032, i=17
x = 0.0005, i=16
x = 0.0008, i=15
x = 0.0013, i=14
x = 0.0020, i=13
x = 0.0032, i=12
x = 0.005, i=11
x = 0.008, i=10
x = 0.013, i=9
x = 0.02, i=8
x = 0.032, i=7
x = 0.05, i=6
x = 0.08, i=5
x = 0.13, i=4
x = 0.18, i=3
x = 0.25, i=2
x = 0.40, i=1
x = 0.65, i=0
HERA I (prel.)
Fixed Target
H1 2000 PDF
ZEUS-JETS
Q2/ GeV2
HERA Structure Functions Working Group

NC e^+p



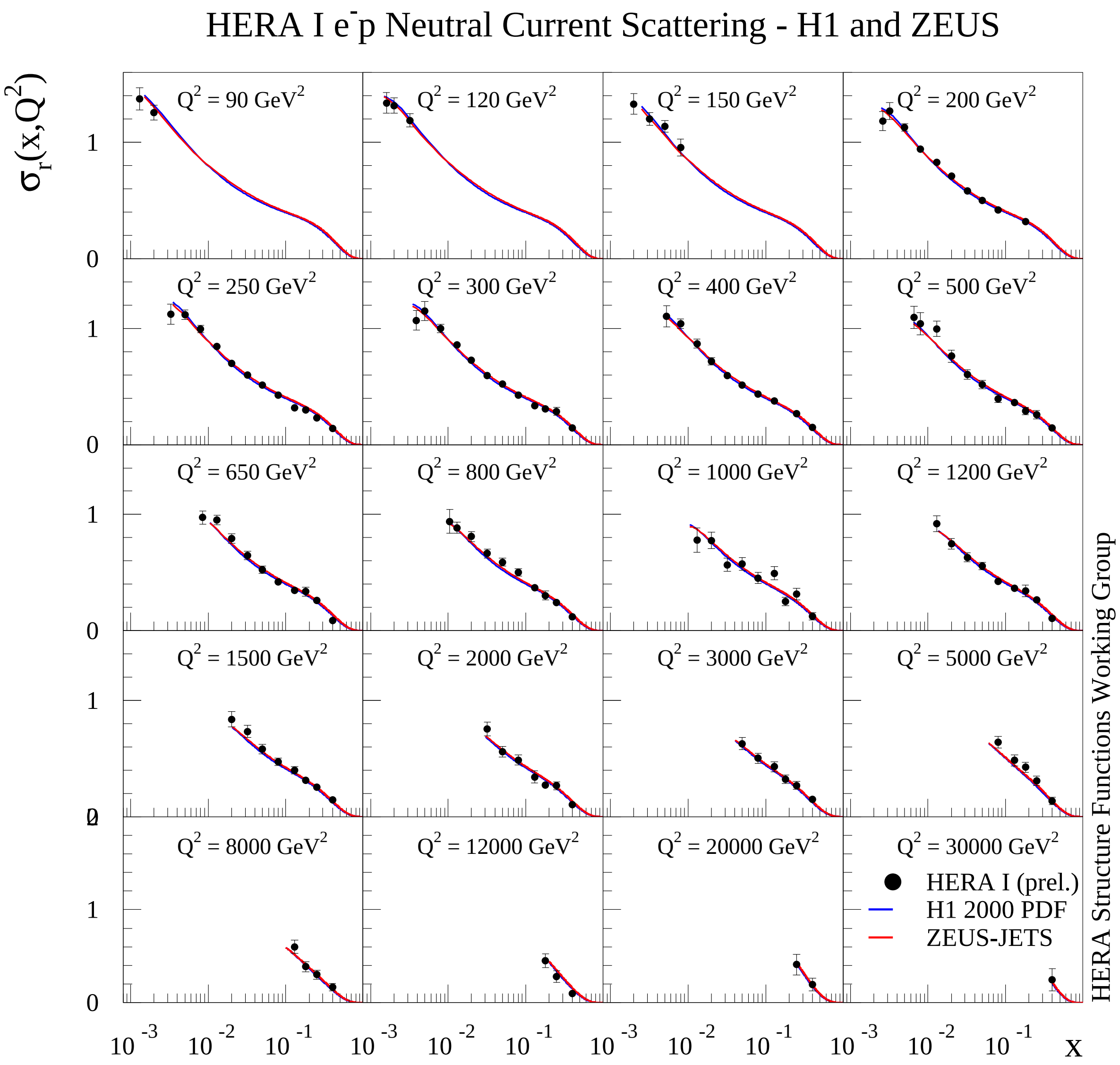
HERA I e+p Neutral Current Scattering - H1 and ZEUS
σr(x,Q2)
Q2 = 1.5 GeV2
Q2 = 2 GeV2
Q2 = 2.7 GeV2
Q2 = 3.5 GeV2
Q2 = 4.5 GeV2
Q2 = 6.5 GeV2
Q2 = 8.5 GeV2
Q2 = 10 GeV2
Q2 = 12 GeV2
Q2 = 15 GeV2
Q2 = 18 GeV2
Q2 = 22 GeV2
Q2 = 27 GeV2
Q2 = 35 GeV2
Q2 = 45 GeV2
Q2 = 60 GeV2
Q2 = 70 GeV2
Q2 = 90 GeV2
Q2 = 120 GeV2
0
1
10-3
10-1
x
HERA Structure Functions Working Group
HERA I (prel.)
H1 2000 PDF
ZEUS-JETS

NC e+p



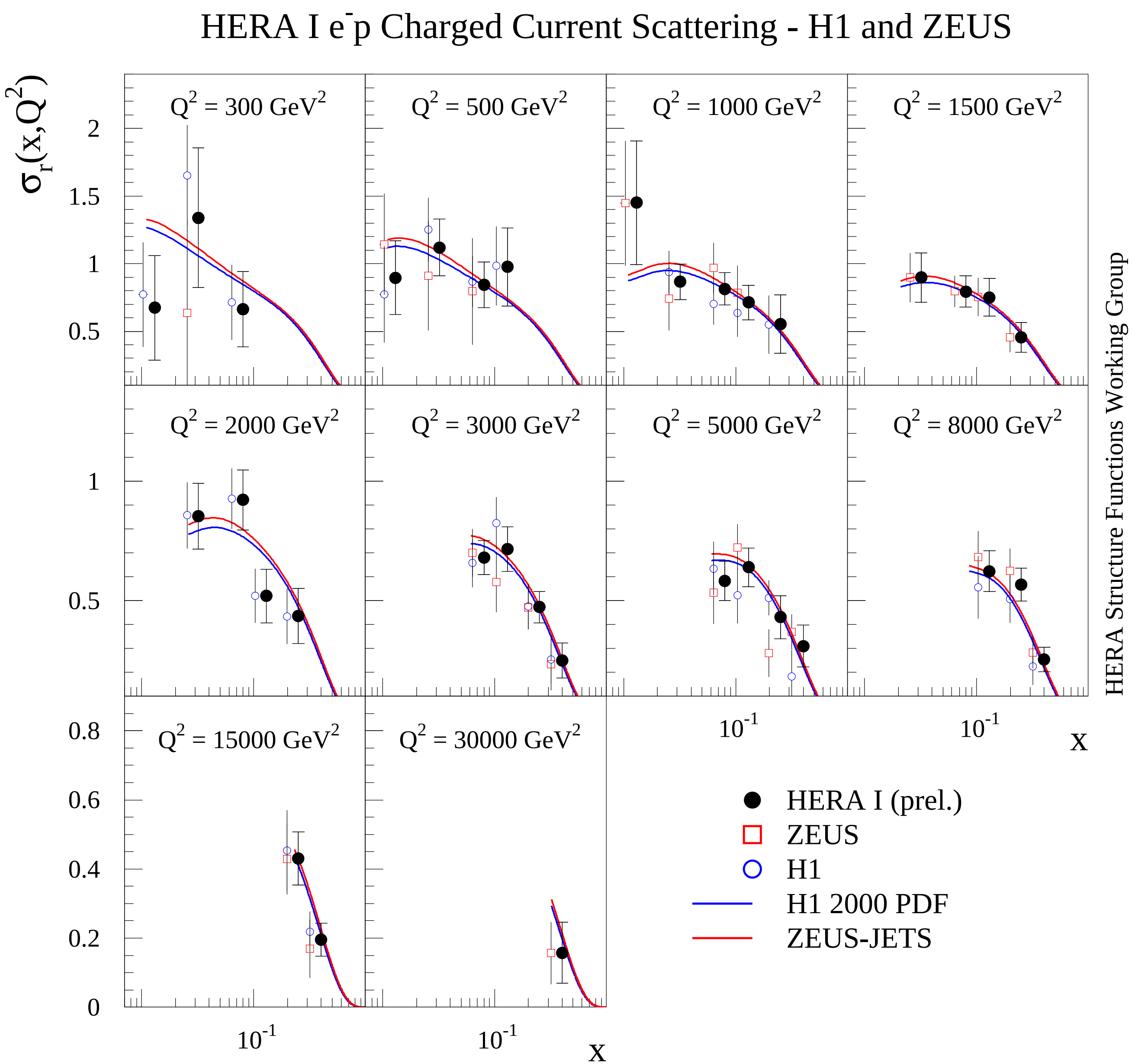
HERA I e+p Neutral Current Scattering - H1 and ZEUS
σr(x,Q2)
Q2 = 150 GeV2
Q2 = 200 GeV2
Q2 = 250 GeV2
Q2 = 300 GeV2
Q2 = 400 GeV2
Q2 = 500 GeV2
Q2 = 650 GeV2
Q2 = 800 GeV2
Q2 = 1000 GeV2
Q2 = 1200 GeV2
Q2 = 1500 GeV2
Q2 = 2000 GeV2
Q2 = 3000 GeV2
Q2 = 5000 GeV2
Q2 = 8000 GeV2
Q2 = 12000 GeV2
Q2 = 20000 GeV2
Q2 = 30000 GeV2
x
HERA I (prel.)
H1 2000 PDF
ZEUS-JETS
HERA Structure Functions Working Group

NC e^-p



HERA I e⁻p Neutral Current Scattering - H1 and ZEUS
$\sigma_r(x,Q^2)$
Q^2 = 90 GeV^2
Q^2 = 120 GeV^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
HERA I (prel.)
H1 2000 PDF
ZEUS-JETS
HERA Structure Functions Working Group
x

CC e^-p


HERA I e-p Charged Current Scattering - H1 and ZEUS
σr(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
Q2 = 30000 GeV2
10-1
x
HERA I (prel.)
ZEUS
H1
H1 2000 PDF
ZEUS-JETS
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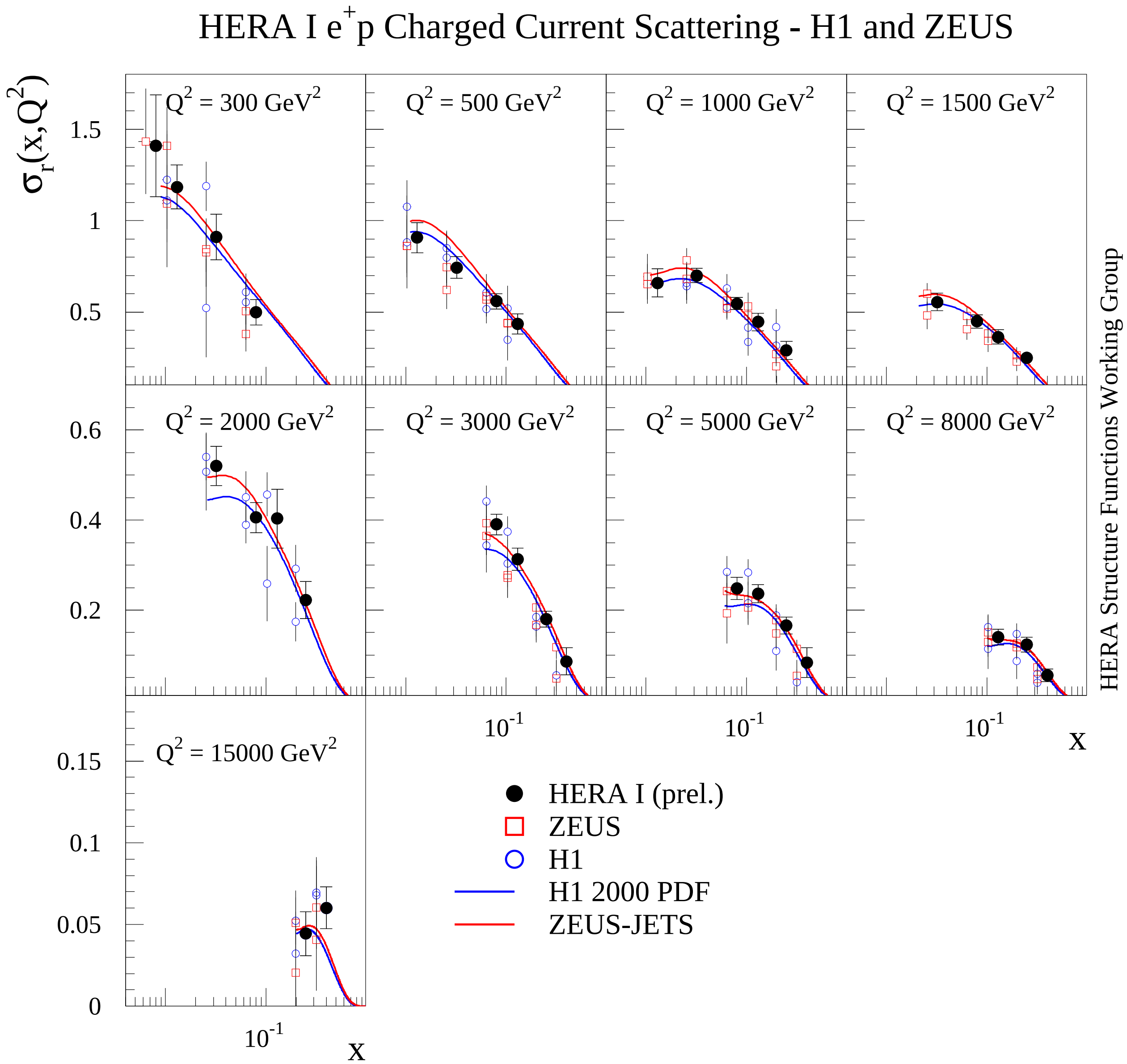
CC e^+p


HERA I e+p Charged Current Scattering - H1 and ZEUS
σr(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 Structure Functions Working Group
HERA I (prel.)
ZEUS
H1
H1 2000 PDF
ZEUS-JETS

Summary

- Averaging H1 and ZEUS data provides a model independent tool to study consistency of the data and to reduce systematics.
- Experiments cross calibrate each other.
- Combined data set should be published this year
- Combined HERA data allow better estimation of PDF → next talk.