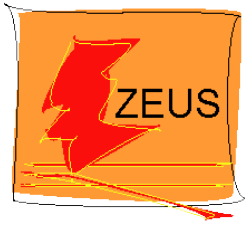
Combination of Inclusive $e^{\pm}p$ Cross-Section Measurements at HERA

Oleksii Turkot
DESY



On behalf of H1 and ZEUS Collaborations

Motivation

- HERA II data collected during 2002 — 2007 and provides aproximately 0.4 fb^{-1} of luminosity for each H1 and ZEUS experiments. Great statistical improvement compare to 0.1 fb^{-1} of HERA I.

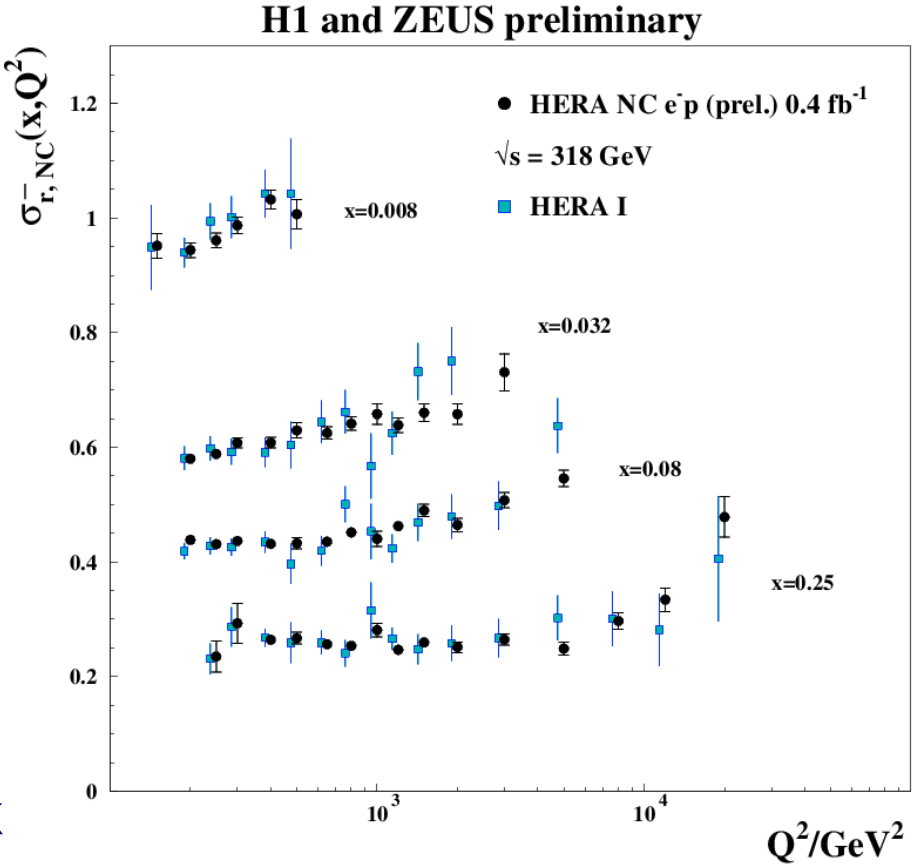
- 162 sources of correlated systematic uncertainties are taken into account.

- The combined HERA I+II cross sections are used as an input in a QCD analysis to extract new proton's PDFs.

  ➜ see V. Radescu talk.

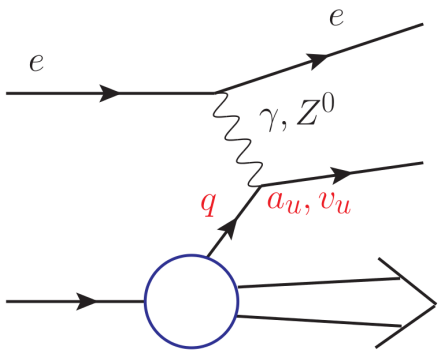
- HERAPDF 1.5 prel will be replaced by HERAPDF 2.0.

  ➜ see A. Cooper-Sarkar talk



Inclusive DIS

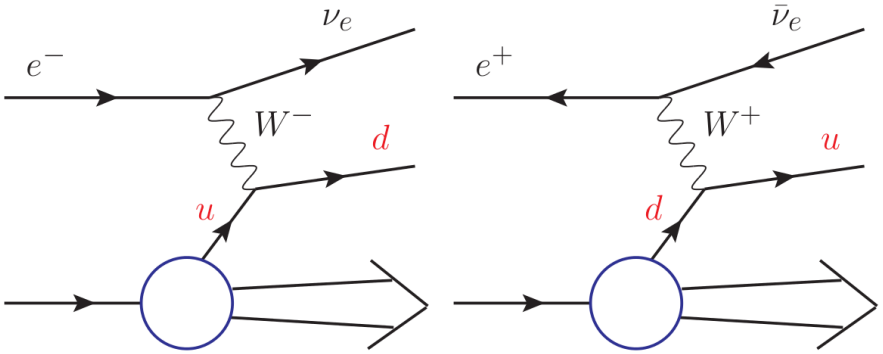
Neutral Current :



$$\frac{d^2\sigma_{NC}^{e\mp p}}{dxdQ^2}=\frac{2\pi\alpha^2\cdot Y_+}{xQ^4}\cdot\left(F_2(x,Q^2)\pm\frac{Y_-}{Y_+}\cdot x\cdot F_3(x,Q^2)-\frac{y^2}{Y_+}\cdot F_L(x,Q^2)\right)$$

$$Y_\pm=1\pm(1-y)^2$$

Charged Current :



$$\frac{d^2\sigma_{CC}^{e\mp p}}{dxdQ^2}=\frac{G_F^2}{4\pi x}\cdot\kappa^2\cdot\left(Y_+\cdot W_2^{\mp}\pm Y_-\cdot x\cdot W_3^{\mp}-y^2\cdot W_L^{\mp}\right)$$

$$\kappa=\frac{M_W^2}{M_W^2+Q^2}$$

ZEUS and H1 experiments

HERA is worlds only $e^{\pm}p$ collider :

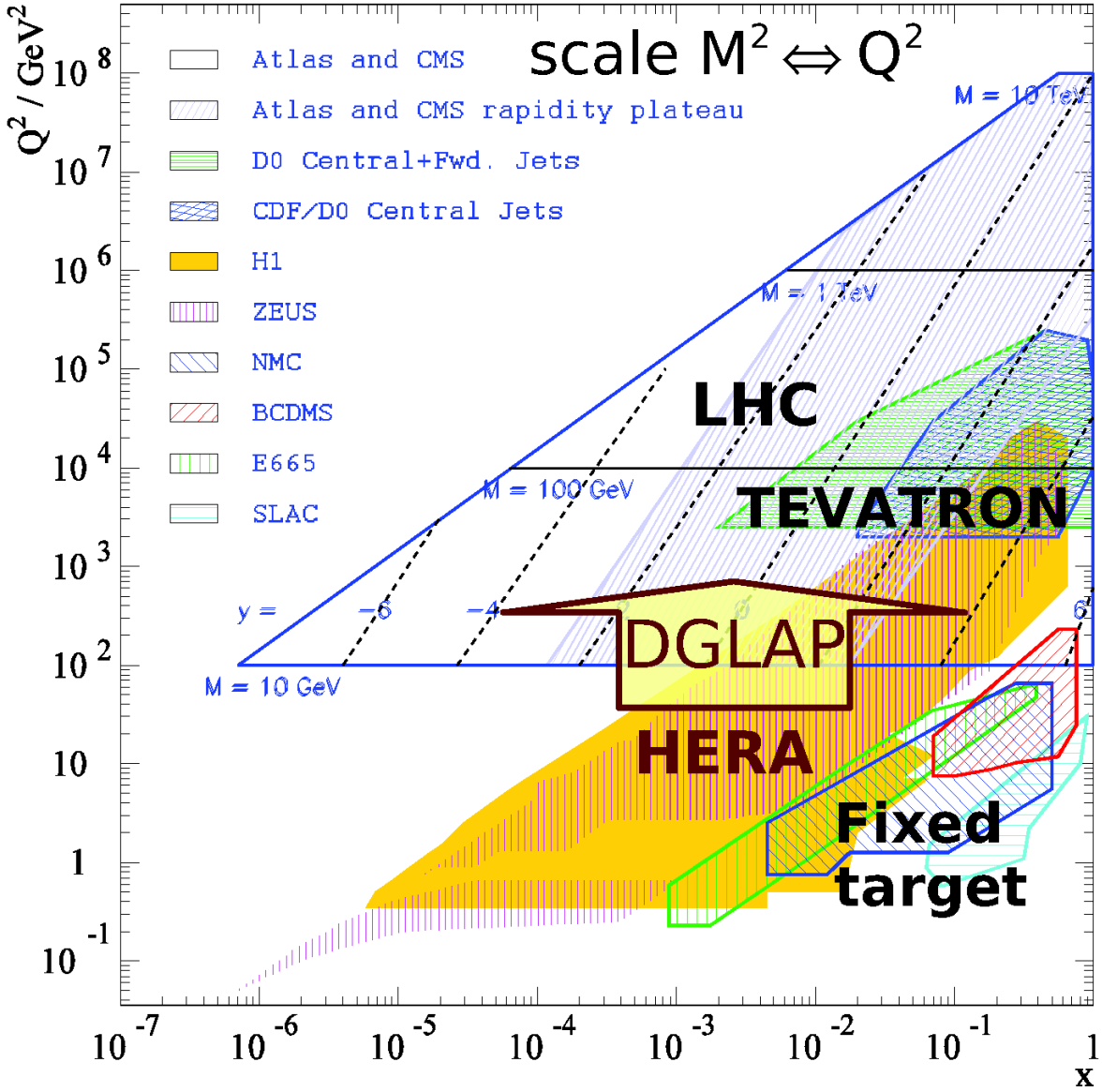
operated during 1992 — 2007;
$e^{\pm}$ energy 27.5 GeV;
p energies 920, 820, 575 and 460 GeV.

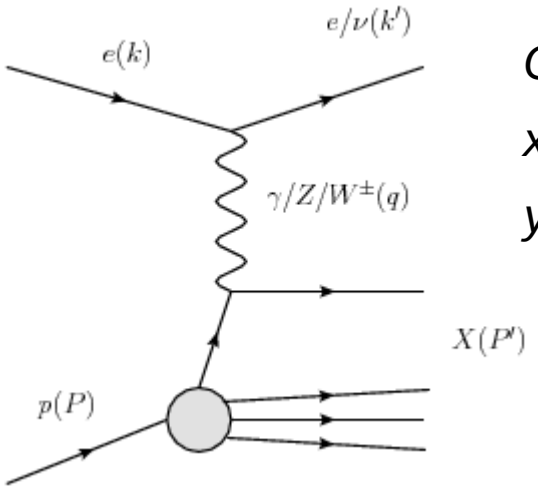
H1 and ZEUS — two colliding experiments at HERA :

~ 0.5 fb^{-1} of luminosity recorded by each experiment.

HERA data provides unique opportunity to study the structure of the proton.

HERA data and the LHC





$Q^2 = -(k - k')$

$x = Q^2 / 2P \cdot q$

$y = P \cdot q / P \cdot k$

HERA data covers nearly the whole x range of the LHC.

Evolution in Q^2 via DGLAP allows to extrapolate HERA PDFs into LHC region.

Inclusive DIS Data Samples

Input data — 41 final data sets with HERA inclusive measurements:

- 21 HERA I data samples
- 20 HERA II data samples, including:
  - 8 inclusive HERA II E_p = 920 GeV
  - 4 high y data E_p = 920 GeV
  - 4 high y data E_p = 575 GeV
  - 4 high y data E_p = 460 GeV

➜ see J.Grebenyuk and S.Shushkevich talks.

Total of **2927** data points combined to **1307**.

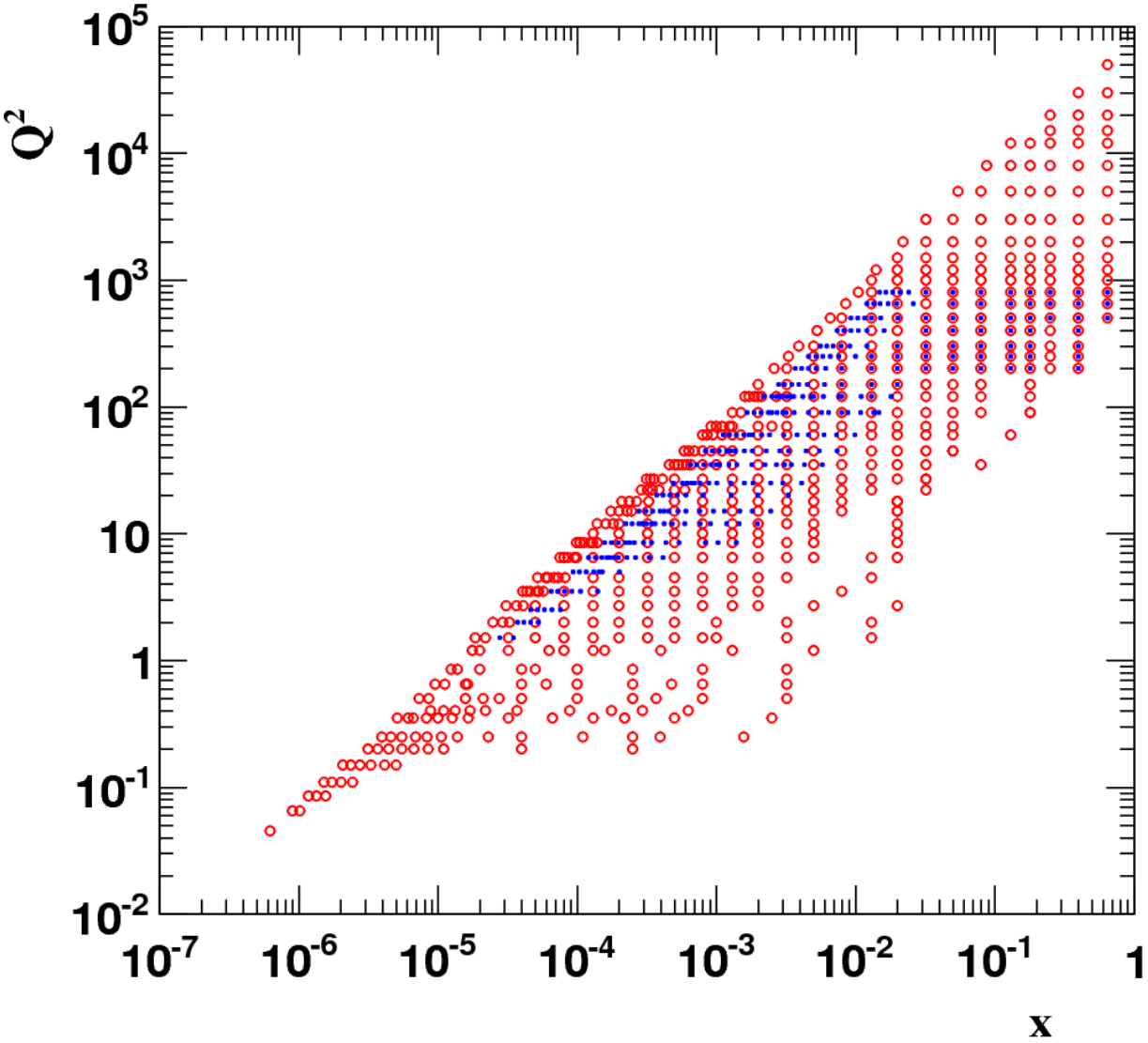
Combination procedure

- Swim all points to common x - Q^2 grids and to one of common proton beam energies.

- Average cross - section values.

- Evaluate procedural uncertainties.

x-Q^2 common grids



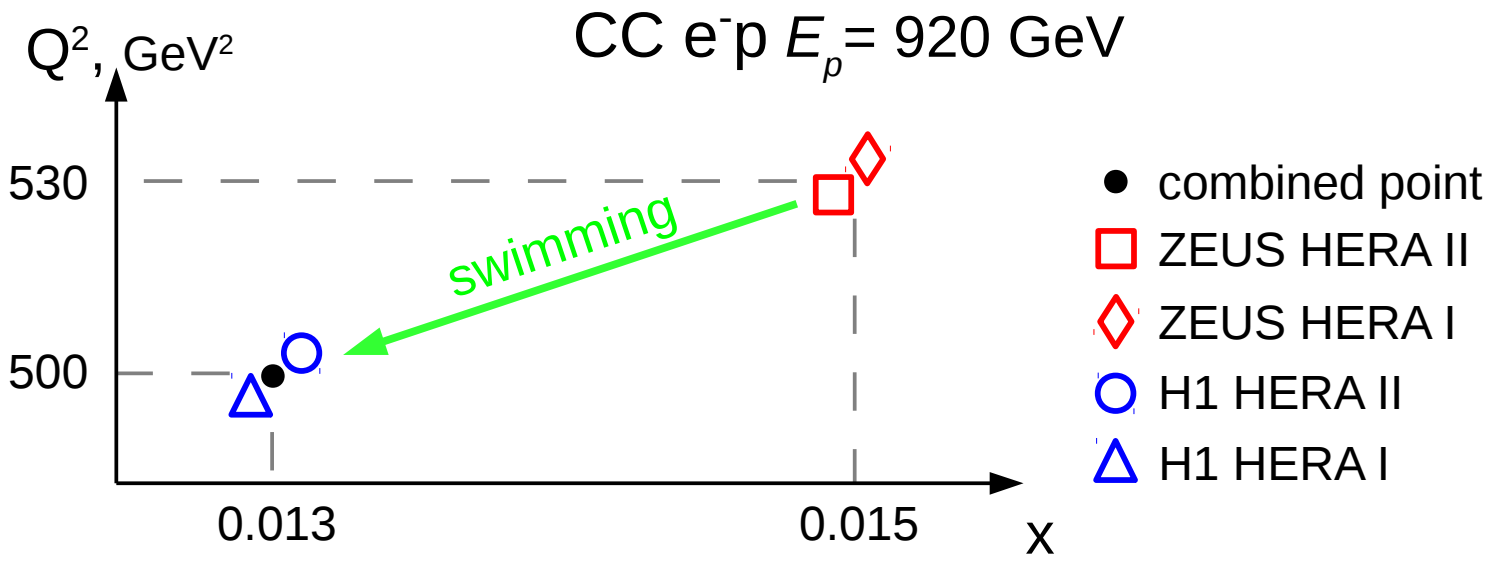
Two separate grids :

- inclusive grid, for E_p= 920 GeV and E_p= 820 GeV data sets;
- fine x grid, for E_p= 575 GeV and E_p= 460 GeV data sets.

Swimming procedure

$$\sigma^{e\mp p}_{meas}\left(x_{grid}, Q^2_{grid}\right) = \frac{\sigma^{e\mp p}_{model}\left(x_{grid}, Q^2_{grid}\right)}{\sigma^{e\mp p}_{model}\left(x_{meas}, Q^2_{meas}\right)} \cdot \sigma^{e\mp p}_{meas}\left(x_{meas}, Q^2_{meas}\right)$$

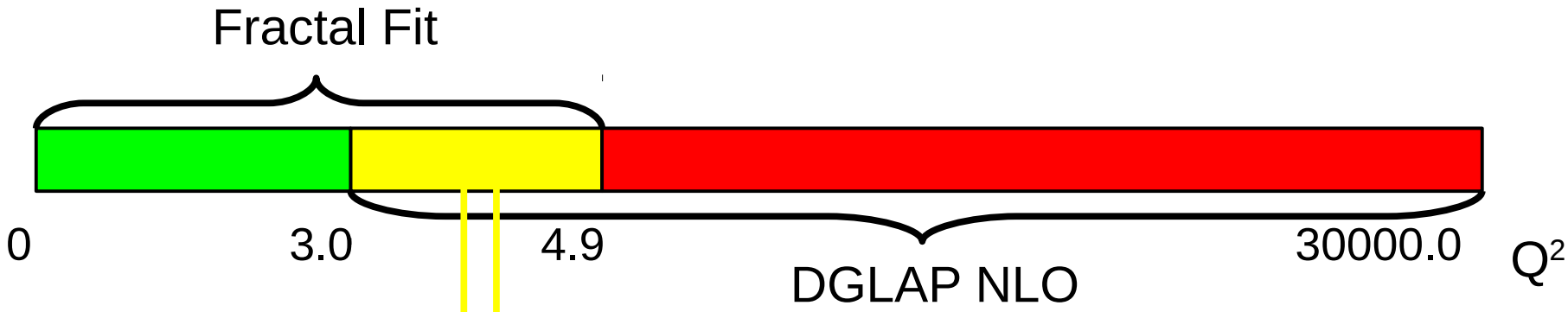
We need a model for the swimming.

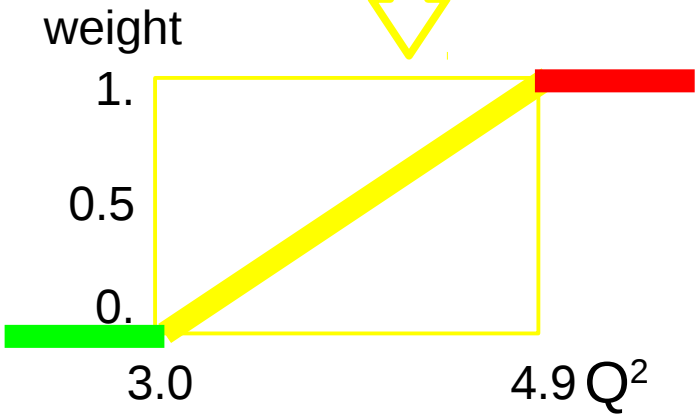


Swimming factors are usually at level of few percent.

Swimming procedure

The swimming done iterativaly with our own data.





Fractal and DGLAP QCD fits were performed with :

HERAFitter — open source QCD fit framework, available at www.herafitter.org .

Averaging of scale factors is performed in dependence on Q^2.

Cross Sections Averaging

The combination of the data done with HERAverager.

(available at wiki-zeuthen.desy.de/HERAverager).

All **162** correlated systematic sources are treated as multiplicative and the χ^2 definition:

$$\chi^2(\mathbf{m},\mathbf{b}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\mathrm{stat}}\,\mu^i\left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\mathrm{uncorr}}\, m^i\right)^2} + \sum_j b_j^2$$

Procedural errors are calculated:

- multiplicative vs additive;
- possible correlations between data sets :
  - photoproduction background;
  - hadronic energy scale.

Cross Sections Averaging

The combination of the data done with HERAverager.

(available at wiki-zeuthen.desy.de/HERAverager).

All **162** correlated systematic sources are treated as multiplicative and the χ^2 definition:

$$\chi^2(\mathbf{m},\mathbf{b}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\mathrm{stat}}\,\mu^i\left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\mathrm{uncorr}}\, m^i\right)^2} + \sum_j b_j^2$$

Procedural errors are calculated:

- multiplicative vs additive;
- possible correlations between data sets :
  - photoproduction background;
  - hadronic energy scale.

Cross Sections Averaging

The combination of the data done with HERAverager.

(available at wiki-zeuthen.desy.de/HERAverager).

All **162** correlated systematic sources are treated as multiplicative and the χ^2 definition:

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

Procedural errors are calculated:

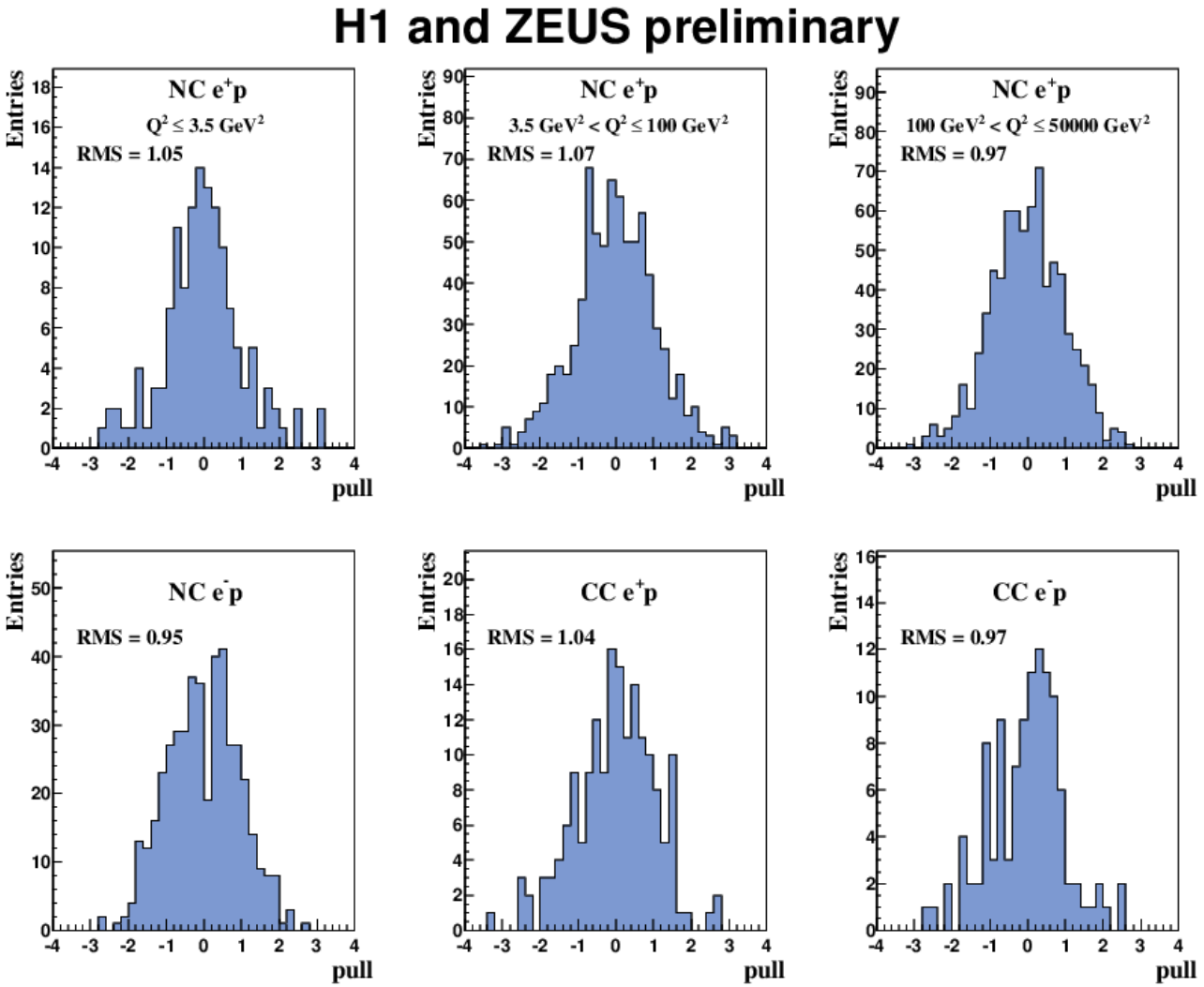
- multiplicative vs additive;
- possible correlations between data sets :
  - photoproduction background;
  - hadronic energy scale.

Fit results

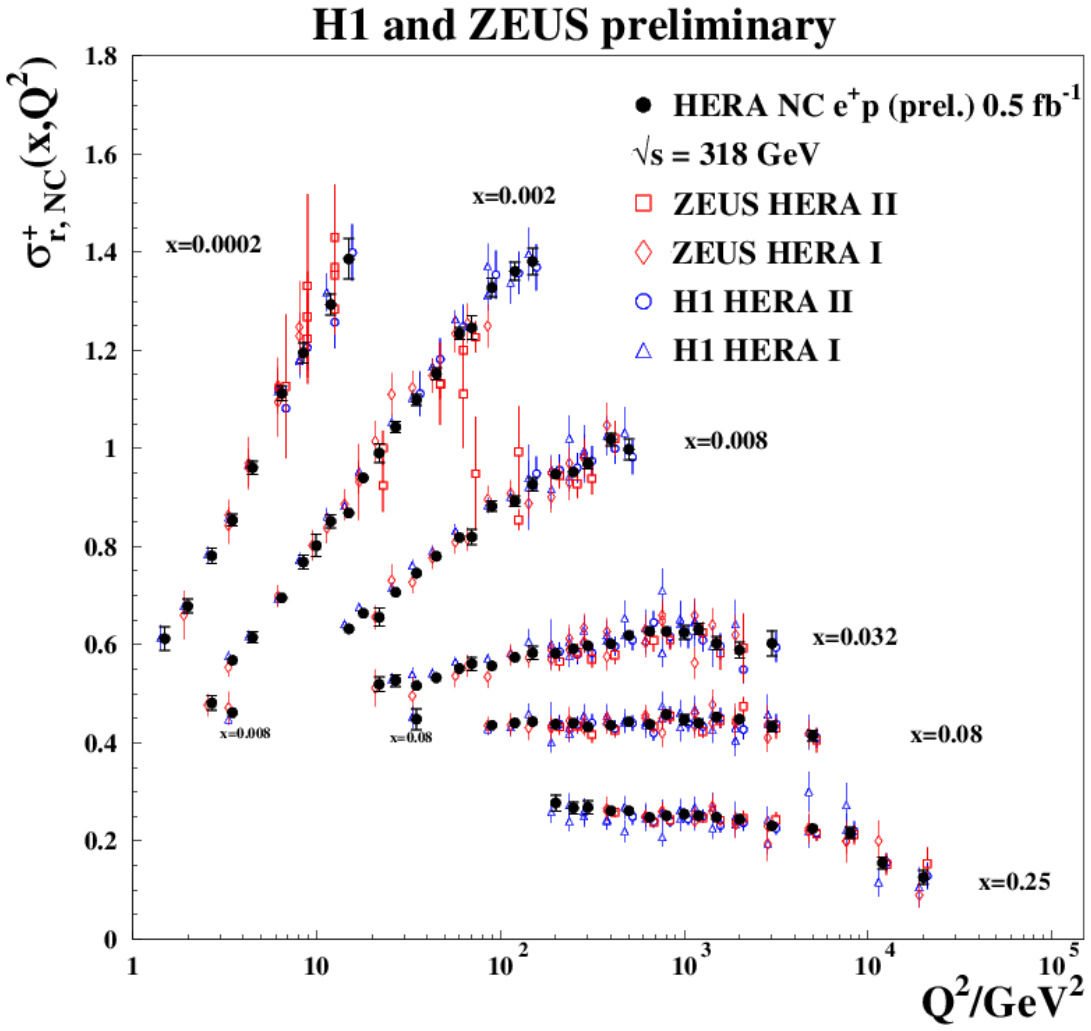
Good consistensy of data sets: χ^2 / ndf = 1685 / 1620

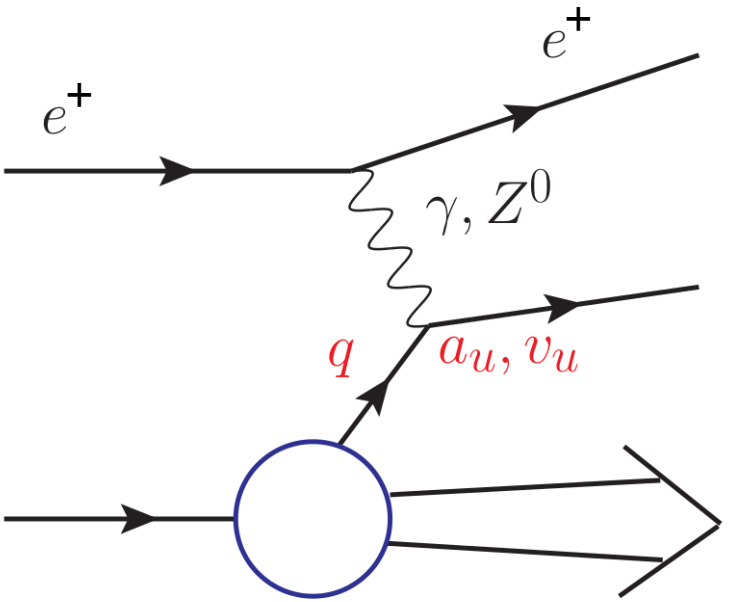
The pulls are defined as:

$$\text{pull}^{i,k} = \frac{\mu^{i,k} - m^{i}}{\sqrt{\Delta^2_{i,k} - \Delta^2_{i,\text{ave}}}}$$



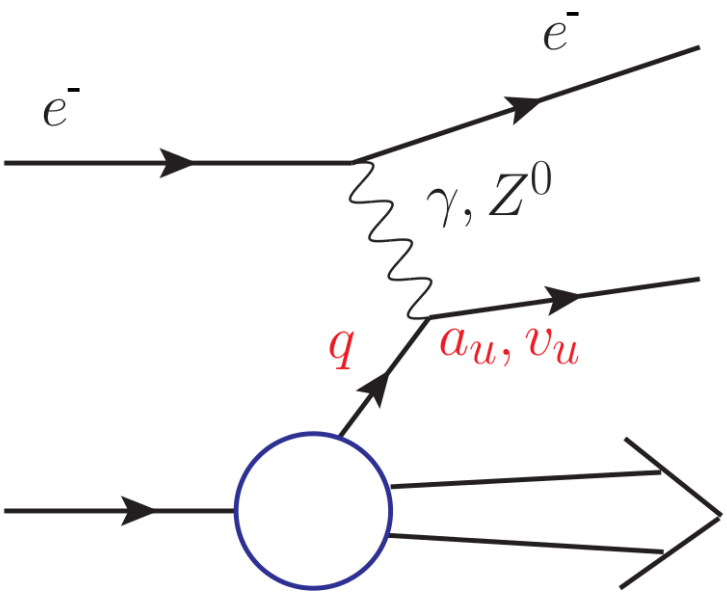
Averaged Cross Sections : NC e^+p

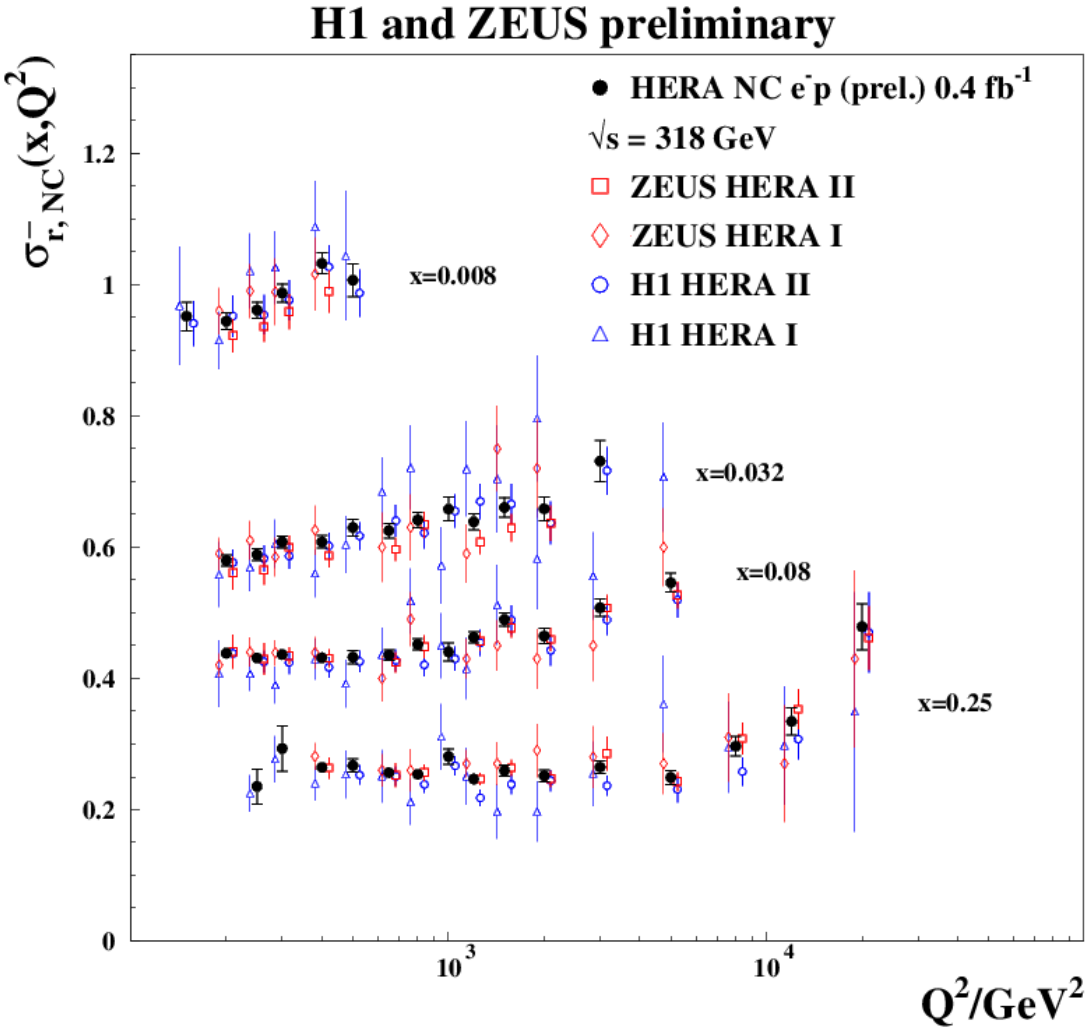




Many points are combined into one data point

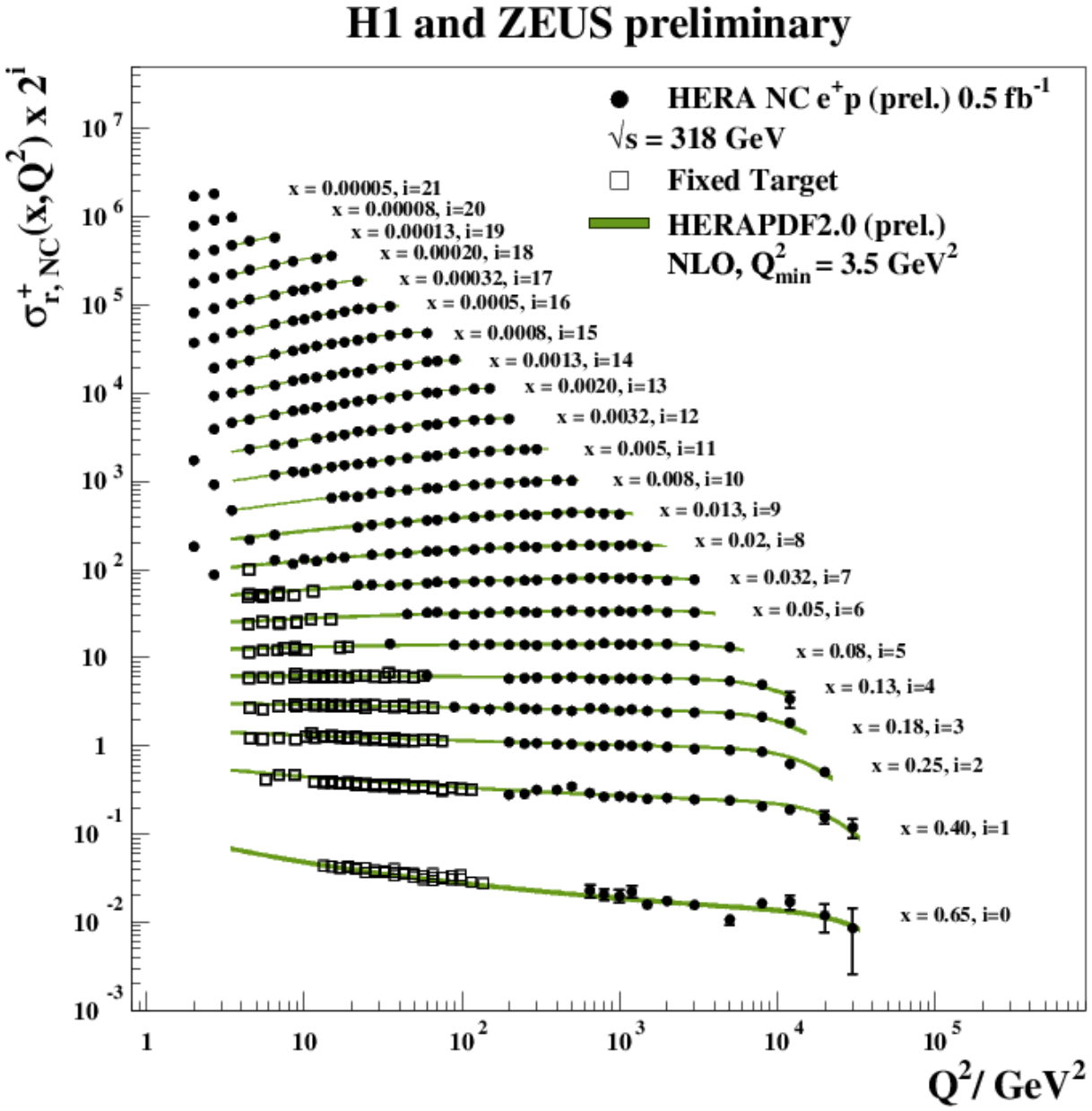
Averaged Cross Sections : NC e^-p





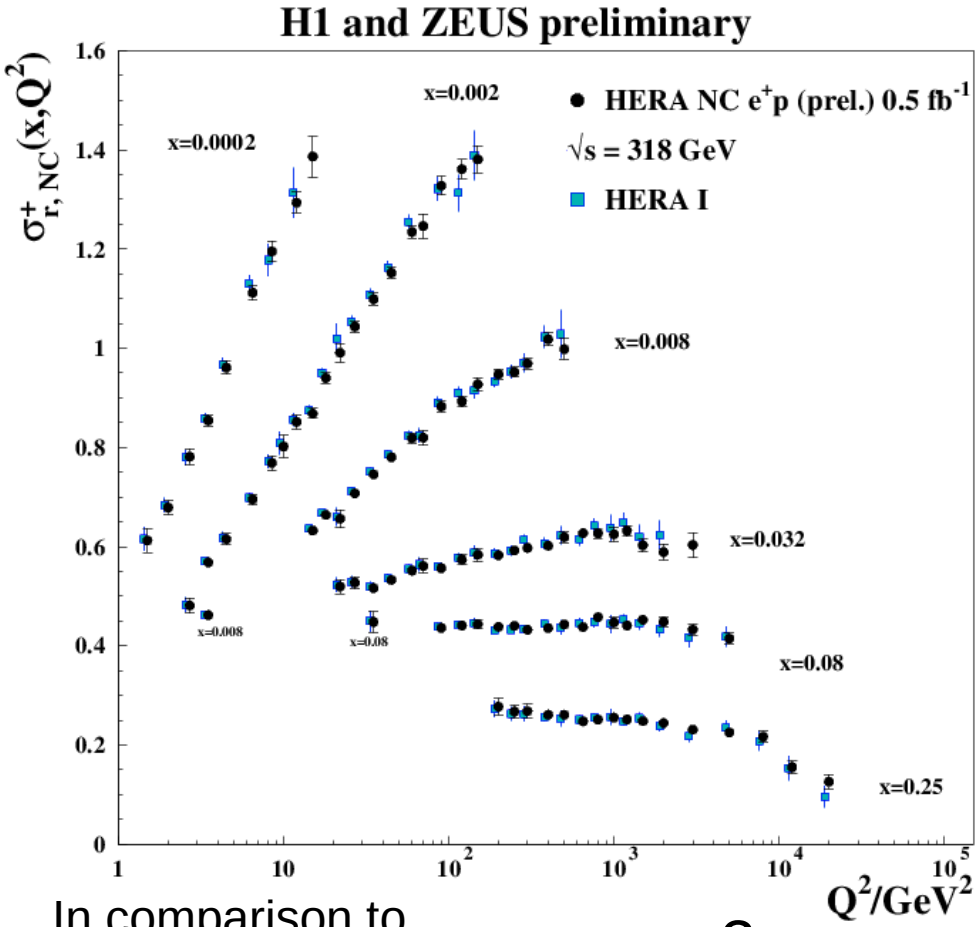
Many points are combined into one data point

Averaged Cross Sections : NC e^+p

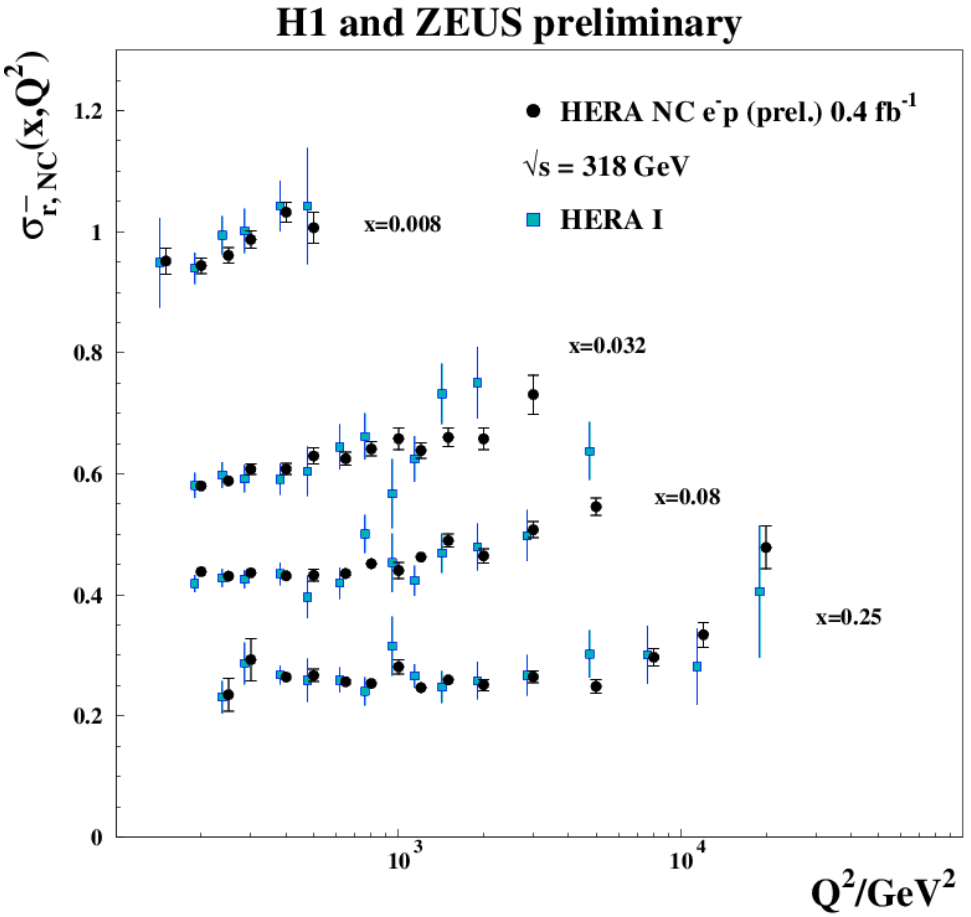


Averaged Cross Sections : NC ep

NC e^+p



NC e^-p

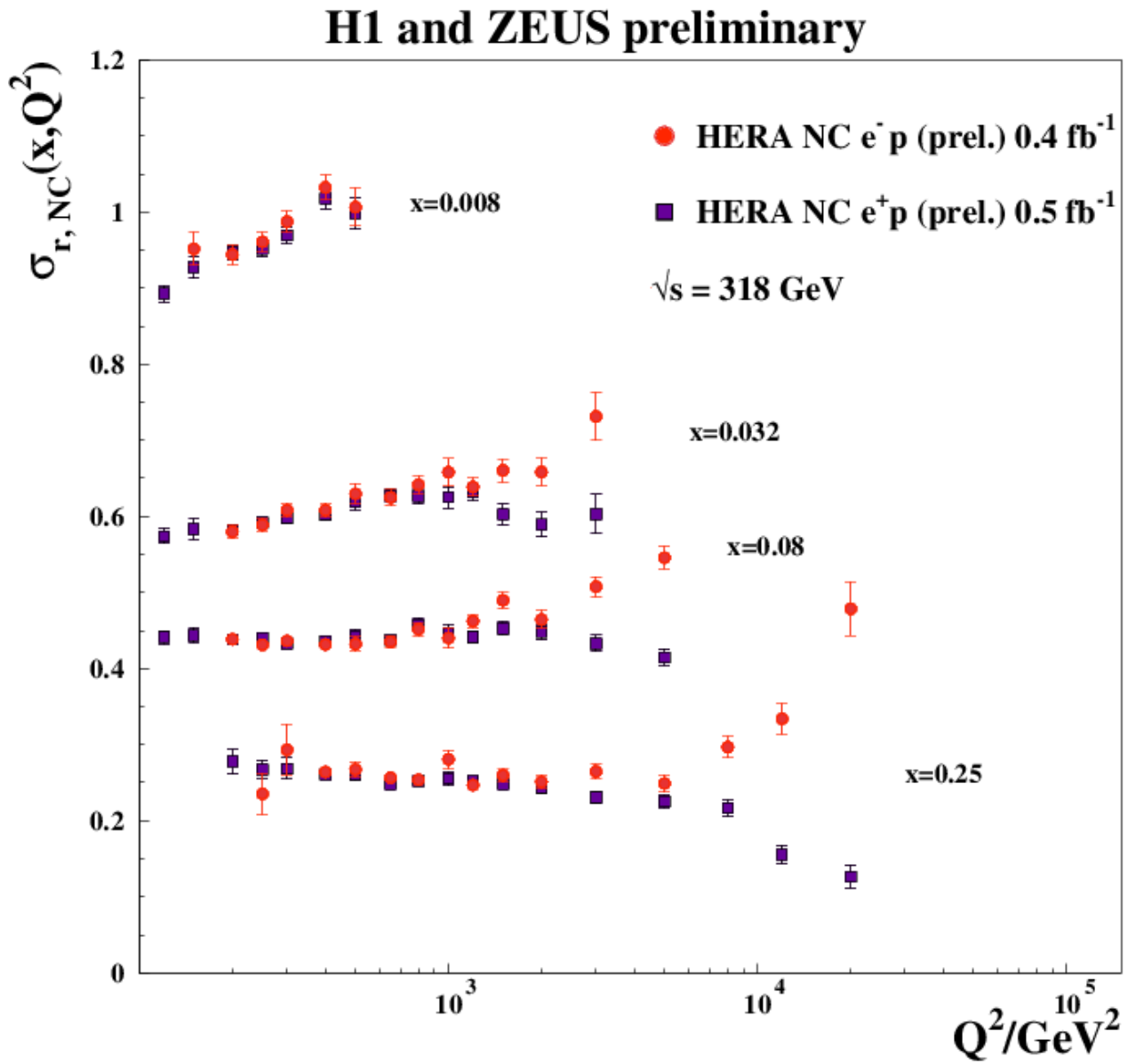


In comparison to HERA I luminosity :

x 3

x 10

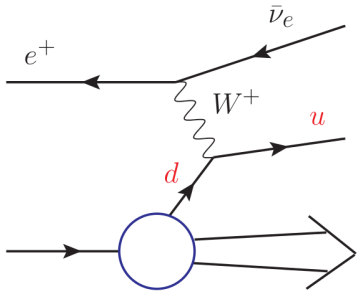
Big improvement in precision in comparison to HERA I, especially at high Q^2



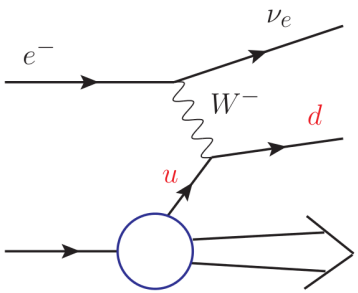
Difference in NC e^+p and e^-p at high Q^2 :

- $Q^2 \sim M_Z^2$! γZ^0 interference clearly seen :
  - In NC e^+p negative γZ^0 interference
  - In NC e^-p positive γZ^0 interference

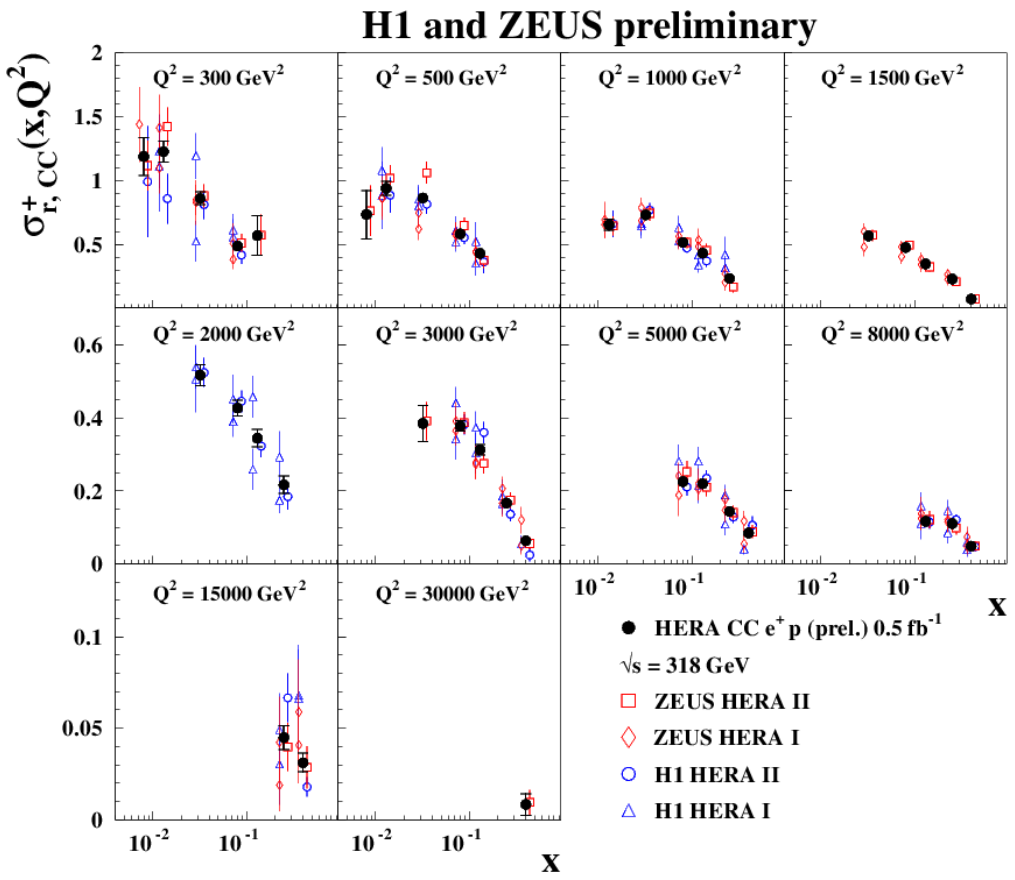
Electroweak effects clearly seen



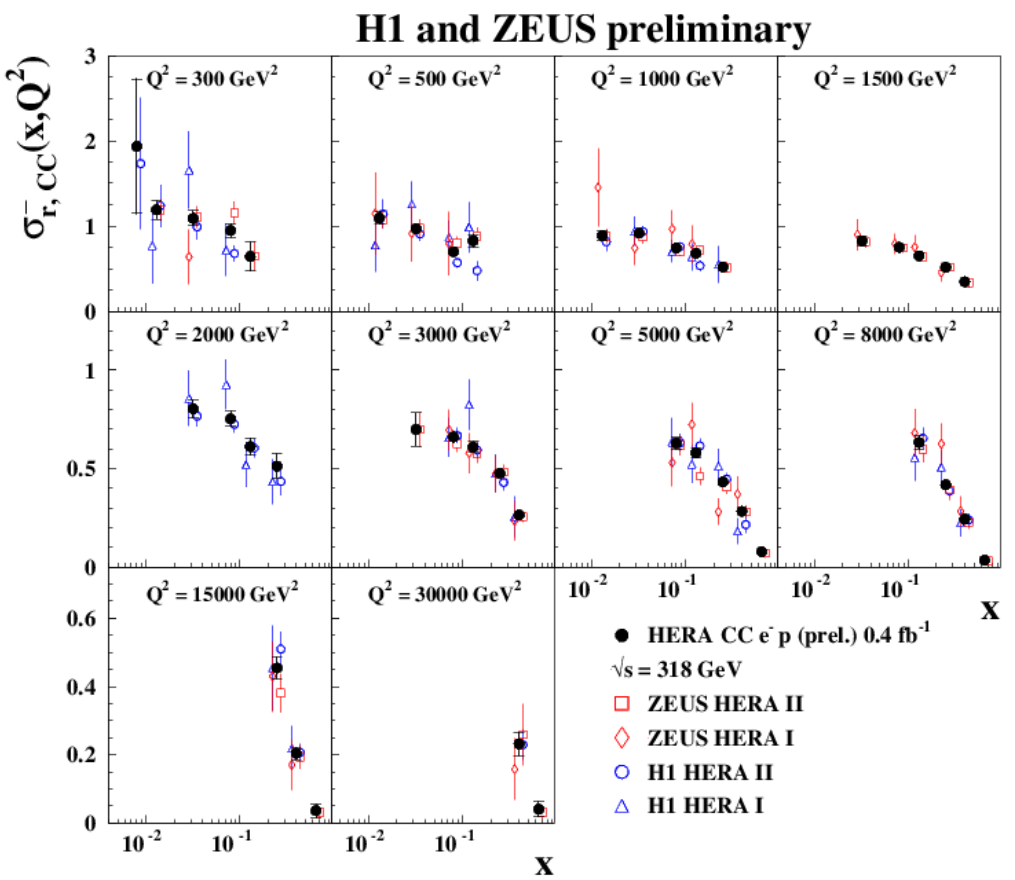
Averaged Cross Sections : CC ep



CC e^+p



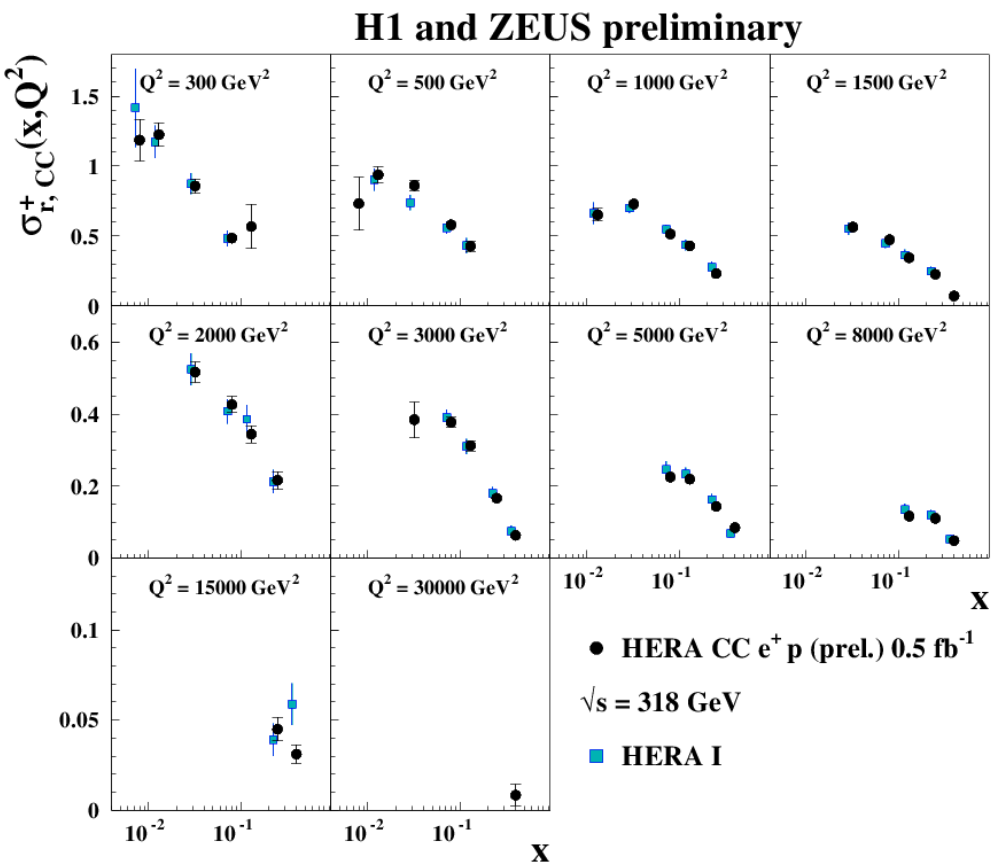
CC e^-p



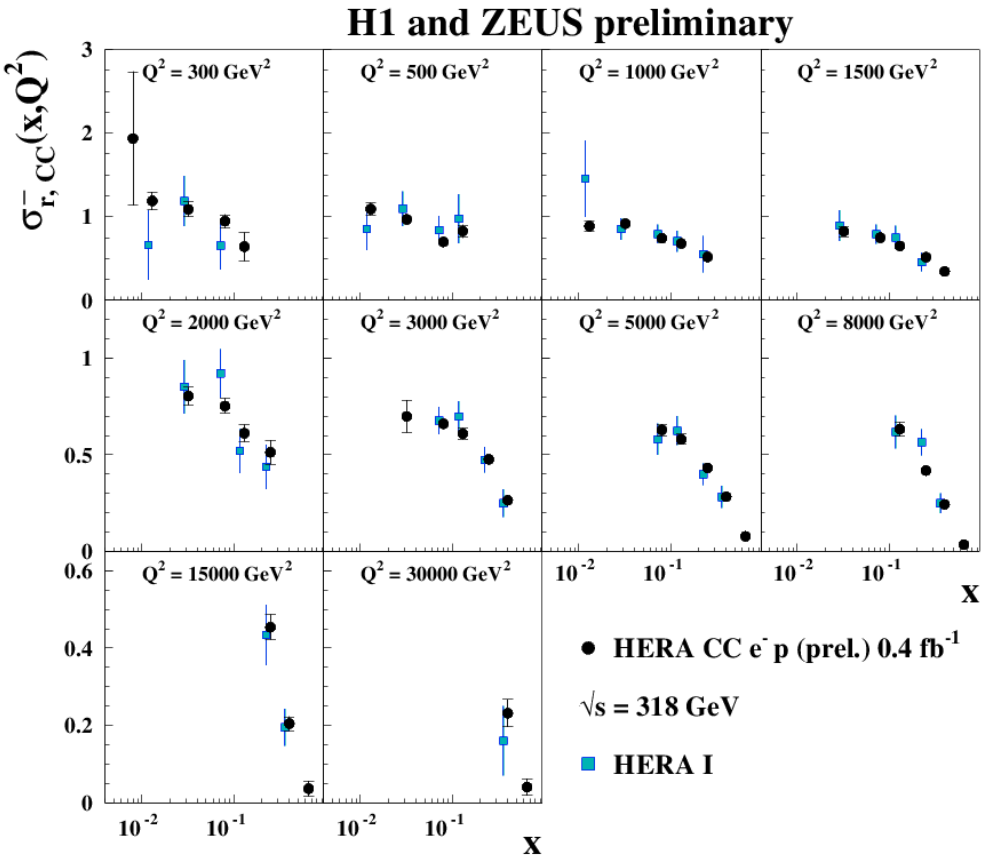
Many points are combined into one data point

Averaged Cross Sections : CC ep

CC e^+p



CC e^-p

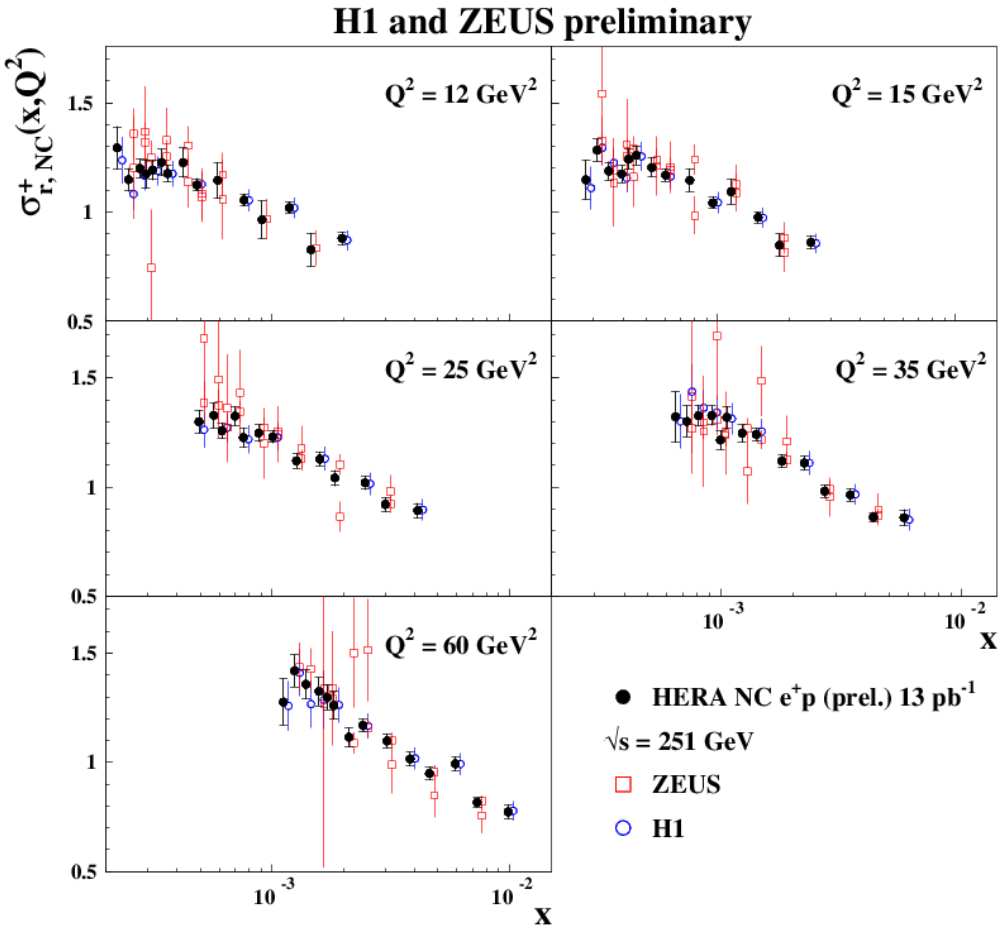


In comparison to HERA I luminosity : x 3 x 10

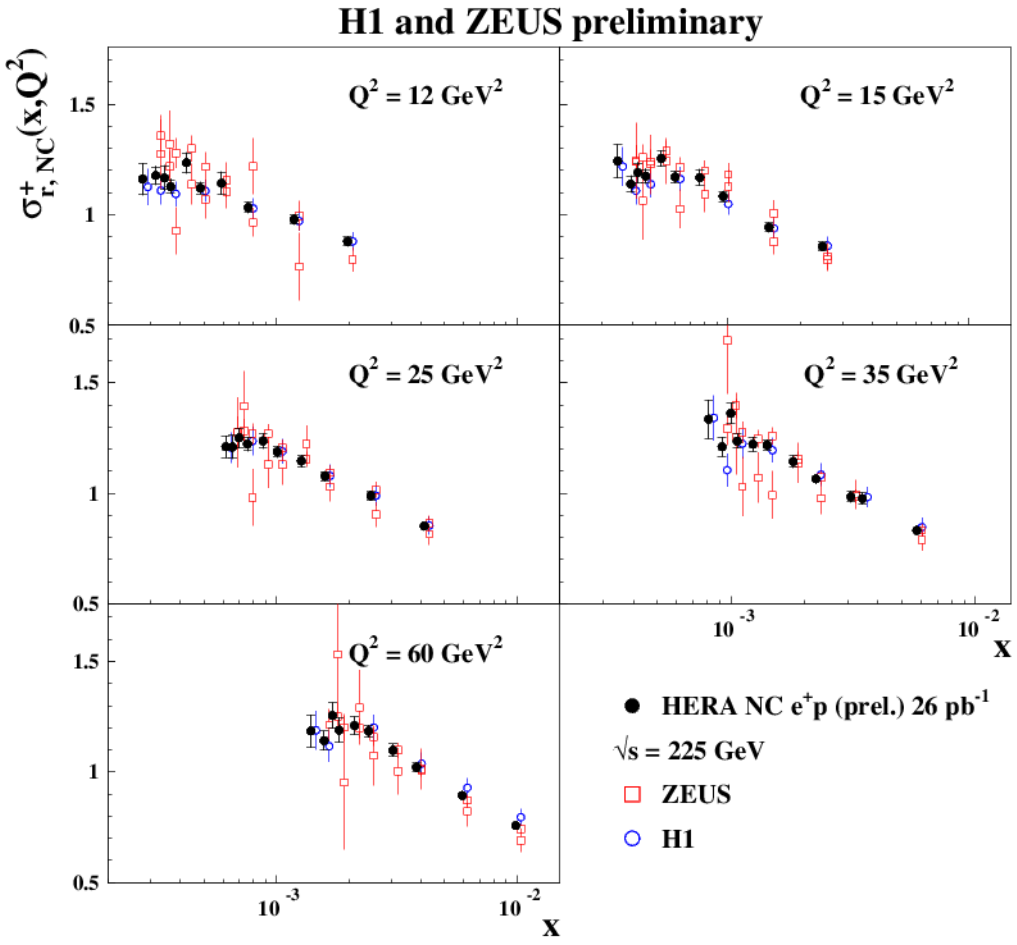
New data points, especially at high x

Averaged Cross Sections : NC e^+p

E_p = 575 GeV



E_p = 460 GeV

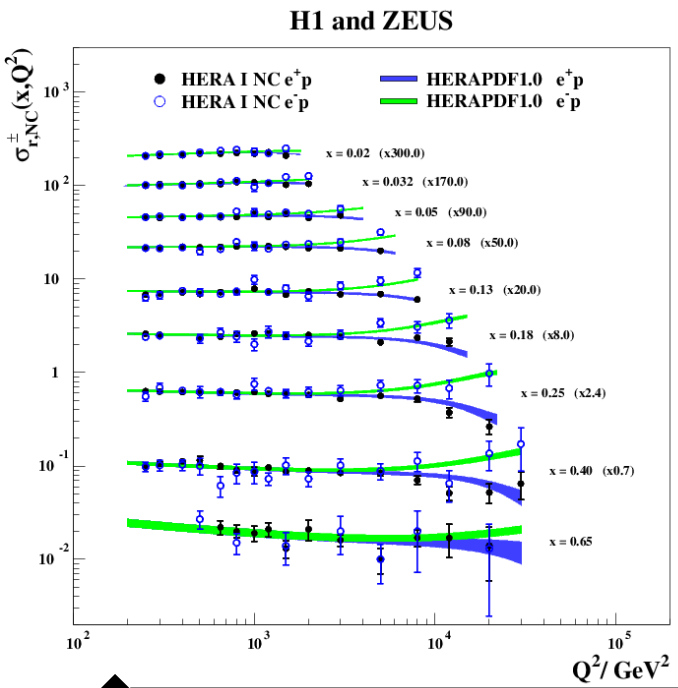


New proton beam energies data samples included

Summary

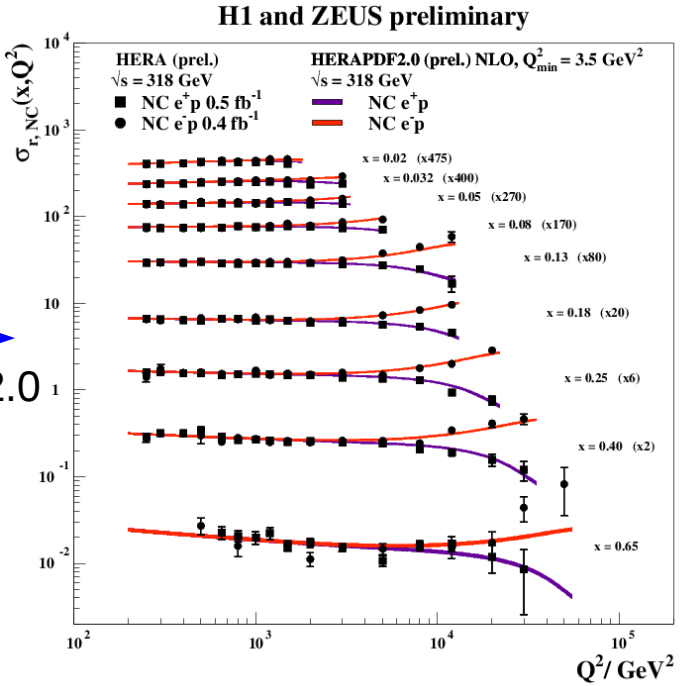
- Combination of all final inclusive deep inelastic cross sections measured by the H1 and ZEUS collaborations have been calculated.
- The total luminosity of about 1 fb^{-1} collected by two separate experiments provides us with cross sections of very high precision.
- Combined HERA I+II data used as an input in QCD analysis

➜ see V. Radescu talk.



HERAPDF 1.0

HERAPDF 2.0



Data Samples

H1					ZEUS				
Data set		$\mathcal{L}$ [pb^{-1}]	e^+ / e^-	$\sqrt{s}$ [GeV]	Data set		$\mathcal{L}$ [pb^{-1}]	e^+ / e^-	$\sqrt{s}$ [GeV]
HERA I E_p = 820 GeV and E_p = 920 GeV data sets									
H1 svx-mb	95-00	2.1	e^+ p	301, 319	ZEUS BPC	95	1.65	e^+ p	300
H1 low Q^2	96-00	22	e^+ p	301,319	ZEUS BPT	97	3.9	e^+ p	300
H1 NC	94-97	35.6	e^+ p	301	ZEUS SVX	95	0.2	e^+ p	300
H1 CC	94-97	35.6	e^+ p	301	ZEUS NC	96-97	30.0	e^+ p	300
H1 NC	98-99	16.4	e^- p	319	ZEUS CC	94-97	47.7	e^+ p	300
H1 CC	98-99	16.4	e^- p	319	ZEUS NC	98-99	15.9	e^- p	318
H1 NC HY	98-99	16.4	e^- p	319	ZEUS CC	98-99	16.4	e^- p	318
H1 NC	99-00	65.2	e^+ p	319	ZEUS NC	99-00	63.2	e^+ p	318
H1 CC	99-00	65.2	e^+ p	319	ZEUS CC	99-00	60.9	e^+ p	318
HERA II E_p = 920 GeV data sets									
H1 NC	03-07	182.0	e^+ p	319	ZEUS NC	06-07	135.5	e^+ p	318
H1 CC	03-07	182.0	e^+ p	319	ZEUS CC	06-07	132.0	e^+ p	318
H1 NC	03-07	151.7	e^- p	319	ZEUS NC	05-06	169.9	e^- p	318
H1 CC	03-07	151.7	e^- p	319	ZEUS CC	04-06	175.0	e^- p	318
H1 NC med Q^2	03-07	97.6	e^+ p	319	ZEUS NC nominal	06-07	44.5	e^+ p	318
H1 NC low Q^2	03-07	5.9	e^+ p	319	ZEUS NC satellite	06-07	44.5	e^+ p	318
HERA II E_p = 575 GeV data sets									
H1 NC high Q^2	07	5.4	e^+ p	252	ZEUS NC nominal	07	7.1	e^+ p	251
H1 NC low Q^2	07	5.9	e^+ p	252	ZEUS NC satellite	07	7.1	e^+ p	251
HERA II E_p = 460 GeV data sets									
H1 NC high Q^2	07	11.8	e^+ p	225	ZEUS NC nominal	07	13.9	e^+ p	225
H1 NC low Q^2	07	12.2	e^+ p	225	ZEUS NC satellite	07	13.9	e^+ p	225