Averaging of the structure functions – update II

- The method – reminder
- Features (old and new) of the averaging program
- Average of all published H1/Zeus data
- Some first results using the average data
- Next steps

Reminder: the averaging procedure

Standard F_2 representation:

$$\chi^2(\{F_2^{true}\},\{\alpha\}) = \sum_i \frac{\left[F_2^{i,true} - \left(F_2^i + \sum_j \frac{\partial F_2^i}{\partial \alpha_j}\alpha_j\right)\right]^2}{\sigma^2_{F_2}} + \sum_j \frac{\alpha_j^2}{\sigma^2_{\alpha_j}}. \quad (1)$$

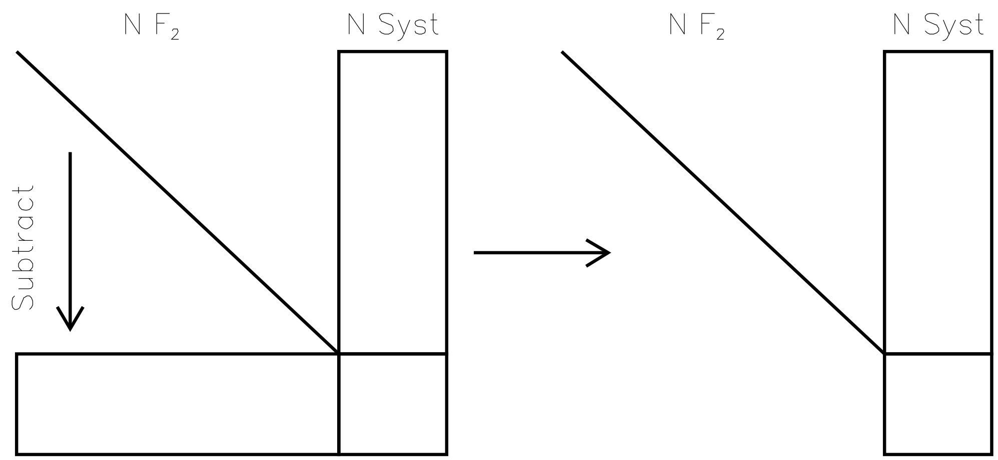
Here α_j — are correlated systematic uncertainty sources.

For several experiments, $\chi^2_{tot} = \sum_{exp}\chi^2_{exp}$. This χ^2 is normally used in QCD fits where $F_2^{true} = F_2^{theory}(glue, quarks)$.

Fit vs F_2, α values → *average* F_2

Some Technical Details

- Many more free parameters (all F_2 points !) vs QCD fit
- Data points from different experiments must be quoted at about the same Q^2, x.
- χ^2 has simple quadratic form $\rightarrow$ minimum is obtain by solving $N_{F_2} + N_{Syst}$ system of linear equations.
- The solution can be obtain using technique similar to simultaneous Z-vertex fit in H1 reconstruction:



(requires $\sim N_{F_2} \times N_{syst}^2$ operations).

Status of cross section averaging program

- Written in FORTRAN, under CVS, uses cernlib.
- Can calculate simultaneous average for different data types with correlated systematic sources (e.g. NC and CC cross sections which depend on hadronic energy scale)
- All data points are interpolated to the grid points defined by H1/Zeus grid, this interpolation uses NC/CC cross section parametrization obtained in H1 QCD fit (normally small correction factor).
- The cross section data points can be adjusted to the same center of mass energy using H1 cross section parametrizations.
- Output format directly suitable for H1 QCD fitting program.

Output data format

Three options for the output data format:

1. Complete *covariance matrix* of all $X-$section measurements.
2. Dependence of the average X-section on each systematic source + correlation matrix for the systematic sources.
3. Same as 2) but systematic error matrix is diagonalized

The (dis?)advantage of the first approach that the systematic uncertainties are frozen, they can not be modified by an external user (similar to Zeus offset method). The second-third approaches are very similar to the standard representations of the individual experiments, both "offset" and "lagrange multiplier" methods can be used.

Cross checks of the program

- Reasonable behaviour for toy dataset
- Passes trivial checks – no change of systematic uncertainties if same dataset is averaged to itself.
- Average of H1/Zeus data separately:

$$\chi^2/ndf_{\mathrm{H1\ only}} = 113.4/154$$
$$\chi^2/ndf_{\mathrm{Zeus\ only}} = 101.7/119$$

- For a set of random σ, α points χ^2 is calculated using the original data vs the average data:

Check Chi2 for several points

Che	Std Chi2	Ave1 Chi2	Ave2 Chi2	Ave1/Std-1	Ave2/Std-1
0	0.195525E+04	0.195525E+04	0.195525E+04	0.677409E-07	0.677409E-07
1	0.138108E+11	0.138108E+11	0.138108E+11	-0.156344E-08	-0.156344E-08
2	0.137381E+11	0.137381E+11	0.137381E+11	-0.113673E-08	-0.113673E-08
3	0.127106E+11	0.127106E+11	0.127106E+11	0.363016E-09	0.363015E-09
4	0.129243E+11	0.129243E+11	0.129243E+11	-0.593676E-09	-0.593678E-09
5	0.136068E+11	0.136068E+11	0.136068E+11	-0.998215E-10	-0.998215E-10
6	0.132560E+11	0.132560E+11	0.132560E+11	-0.113940E-09	-0.113939E-09
7	0.134828E+11	0.134828E+11	0.134828E+11	-0.458048E-09	-0.458048E-09
8	0.142298E+11	0.142298E+11	0.142298E+11	-0.151956E-08	-0.151956E-08
9	0.129747E+11	0.129747E+11	0.129747E+11	-0.131950E-08	-0.131950E-08
10	0.135709E+11	0.135709E+11	0.135709E+11	-0.151286E-08	-0.151287E-08

→ OK

Average of all HERA data

Changes in systematic uncertainties:

Fitted systematics:

		shift	uncertainty
1	zlumi1_zncepl	-1.2841	0.5836
2	h2_Ee_Spacal	0.6440	0.3281
3	h3_Ee_Lar_00	-0.8265	0.4435
4	h4_ThetaE_spacal	-0.2569	0.6566
5	h5_ThetaE_94-97	-0.1756	0.7802
6	h6_ThetaE_00	-0.3027	0.5288
7	h7_H_Scale_Spacal	0.3750	0.4813
8	h8_H_Scale_Lar	-0.8554	0.5353
9	h9_Noise_Hcal	-0.6404	0.3591
10	h10_GP_BG_Spacal	-0.1805	0.8260
11	h11_GP_BG_LAr	1.0769	0.8560
12	h12_BG_CC_94-97	0.2680	0.7883
13	h13_BG_CC_98-00	-1.0295	0.8589
14	h14_ChargeAsym	0.0246	0.9993
15	hllumi1_SPACAL_bulk	-0.0696	0.5612
16	hllumi2_SPACAL_MB	1.0815	0.6271
17	h1lumi3_LAr_94-97_e+p	-2.7111	0.6103
18	h1lumi4_LAr_e-p	-0.6585	0.7737
19	h1lumi5_LAr_2000	-2.5156	0.5885

- Good global $\chi^2/ndf = 533.9/601$
- Most of the changes are within 1σ
- Several systematic sources are reduced by factor 2 and more

Uncertainties of the averaged data

More than $\sqrt{2}$ reduction of systematic errors leads to similar correlated and uncorrelated uncertainties even for low Q^2 data:

```
Reaction =   615
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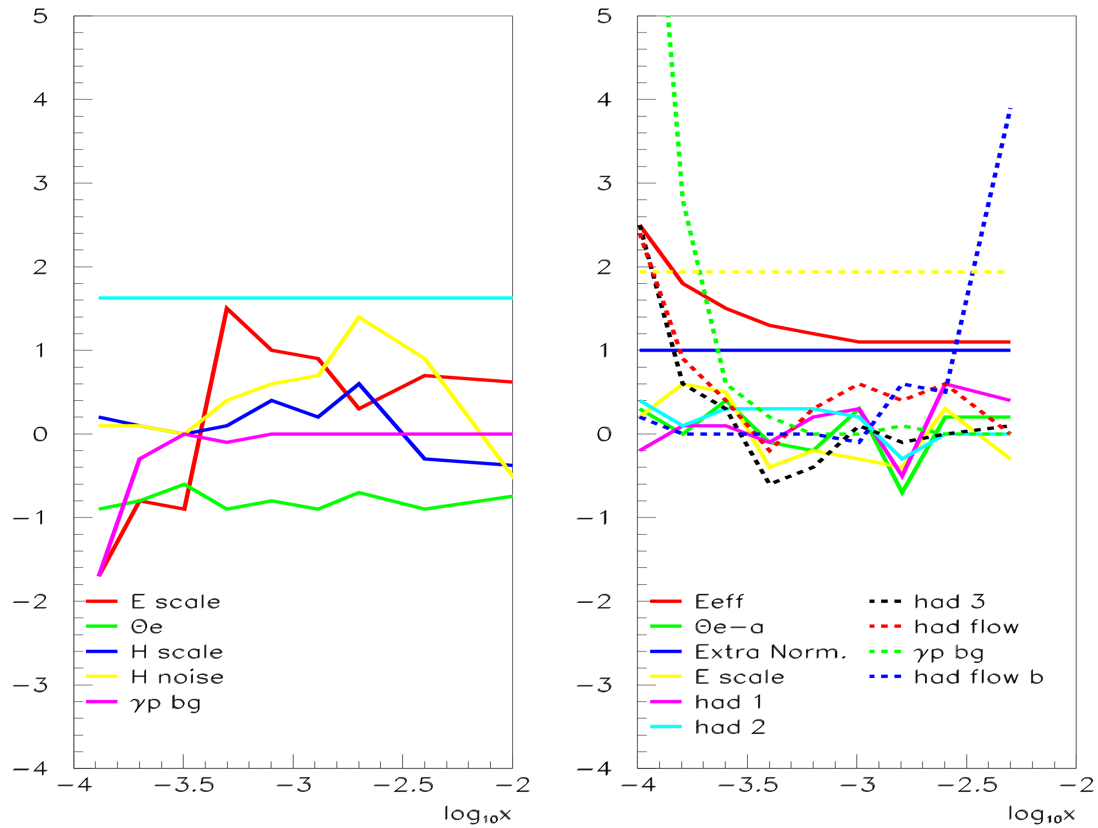
Q2	X	X-sect	E-Uncor	E-Corr	E-Total
15.0000	0.0002	1.3118	0.0602	0.0151	0.0620
15.0000	0.0002	1.3841	0.0258	0.0243	0.0355
15.0000	0.0003	1.2891	0.0210	0.0157	0.0262
15.0000	0.0005	1.2055	0.0164	0.0116	0.0201
15.0000	0.0008	1.1041	0.0138	0.0102	0.0172
15.0000	0.0013	0.9665	0.0126	0.0094	0.0157
15.0000	0.0020	0.8639	0.0114	0.0080	0.0140
15.0000	0.0032	0.7743	0.0125	0.0077	0.0147
15.0000	0.0050	0.6975	0.0085	0.0062	0.0105
15.0000	0.0100	0.5820	0.0064	0.0068	0.0094

How this is possible ?

Reduction of the systematic errors

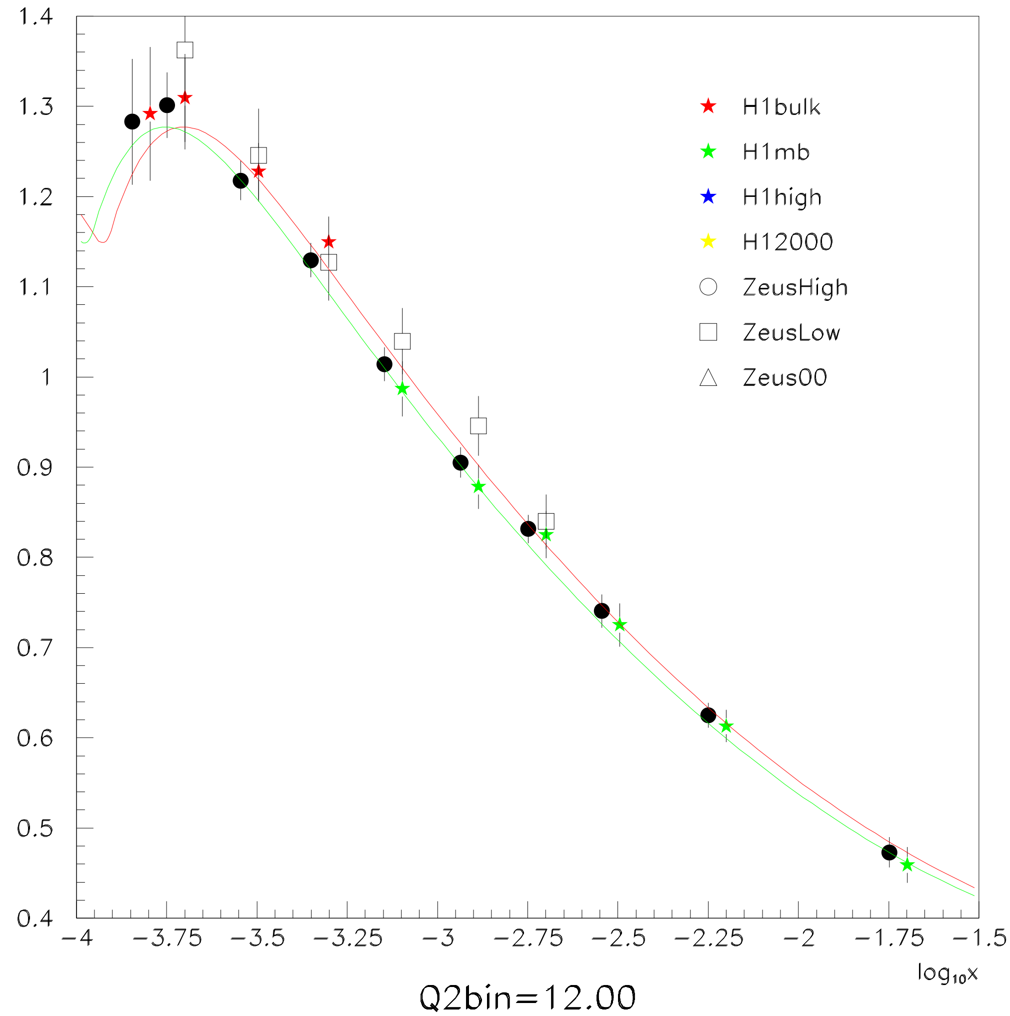
H1 and Zeus use different kinematic reconstruction methods – different shape vs x, Q^2.



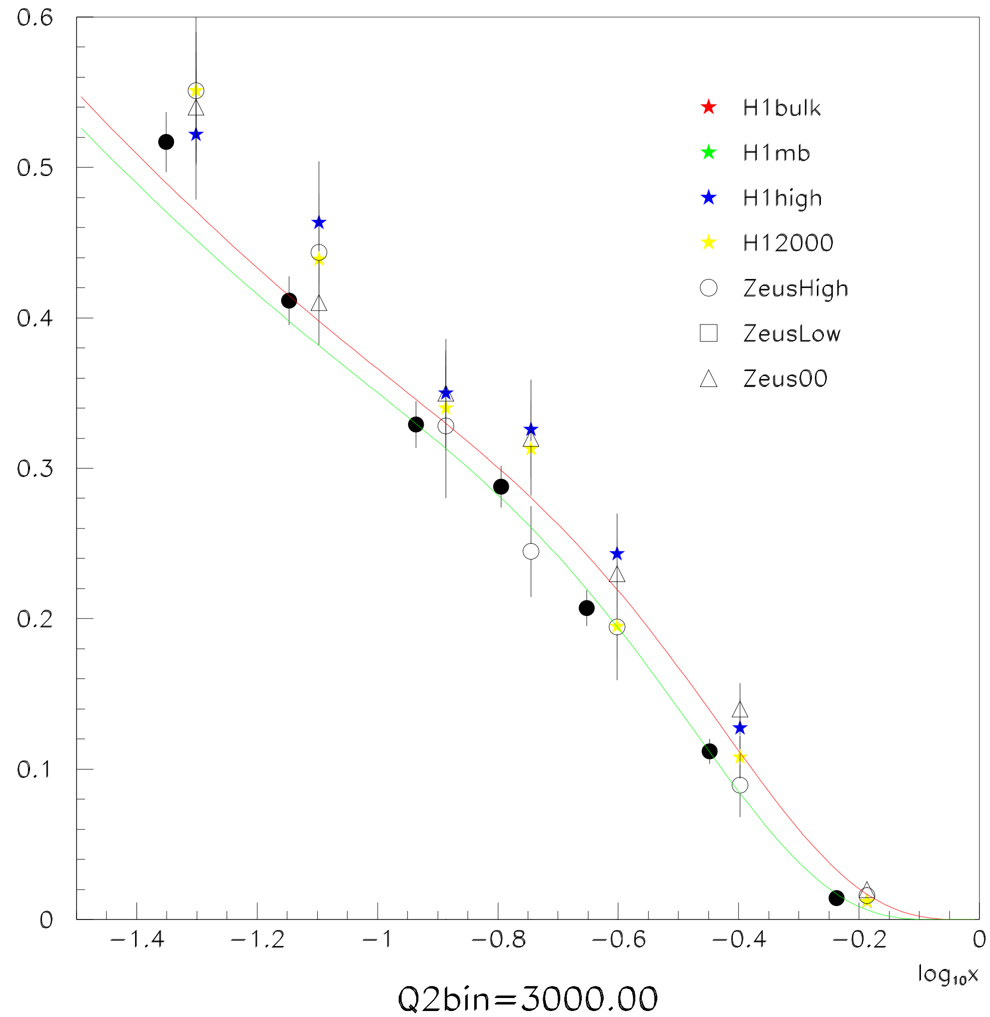
Sensitivity to syst. errors for $Q^2 = 6.5$ GeV^2

Average of all published HERA NC/CC data

- H1: low Q^2 96-97, NC/CC 94-97, NC/CC 98 NC/CC 00
- Zeus: NC 96-97, CC/NC e^-p 98, e^+p 99-00

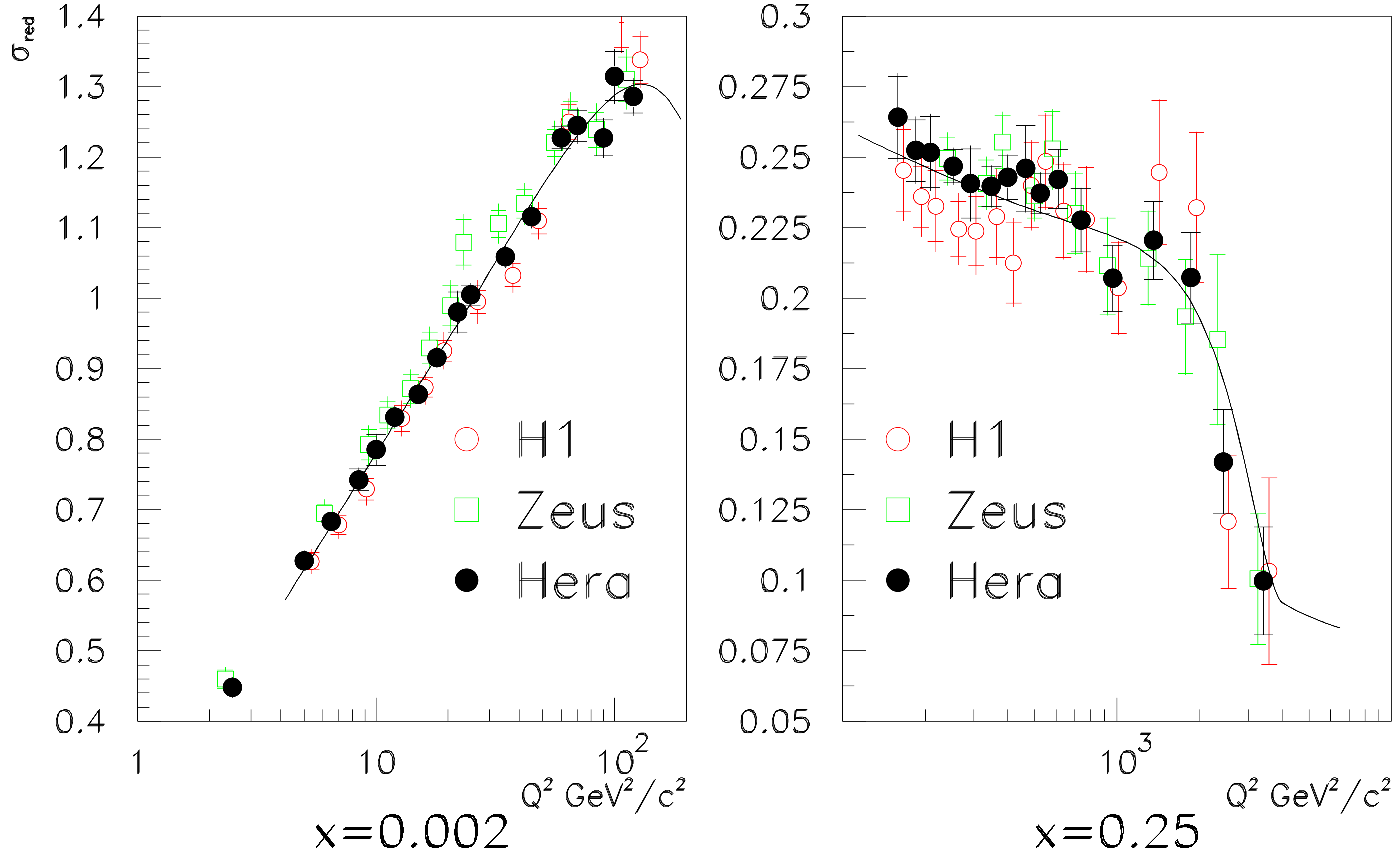


Average of all published HERA NC/CC data



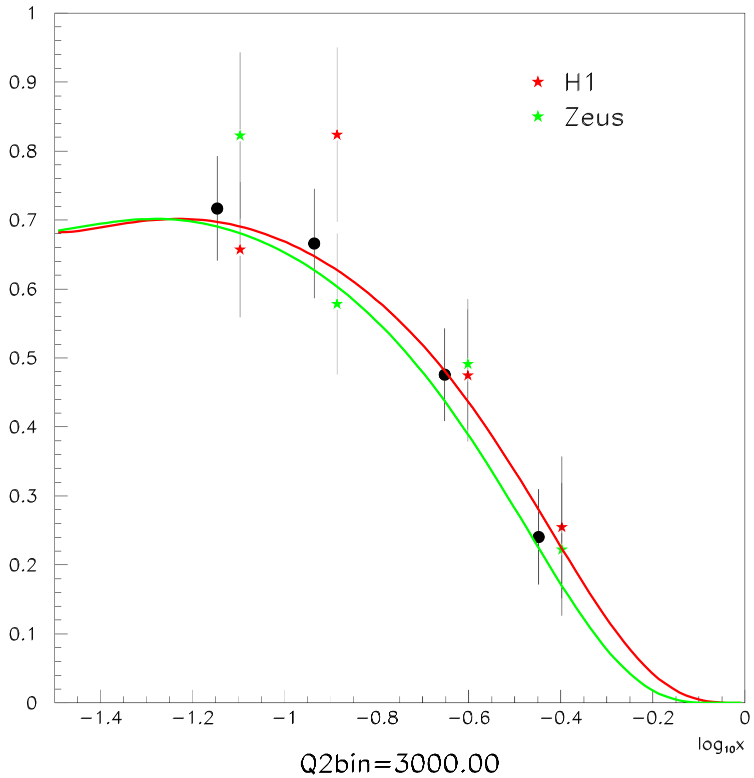
Factor of ~ 2 improvement in errors. For low $Q^2 \sim 10$ GeV^2/c^2 data reaches $< 2.0\%$ precision. Bins at $Q^2 = 3000.$ GeV^2/c^2 have 4% precision (plus 0.5% overall luminosity uncertainty).

Q^2 dependence of NC e^+p X-section

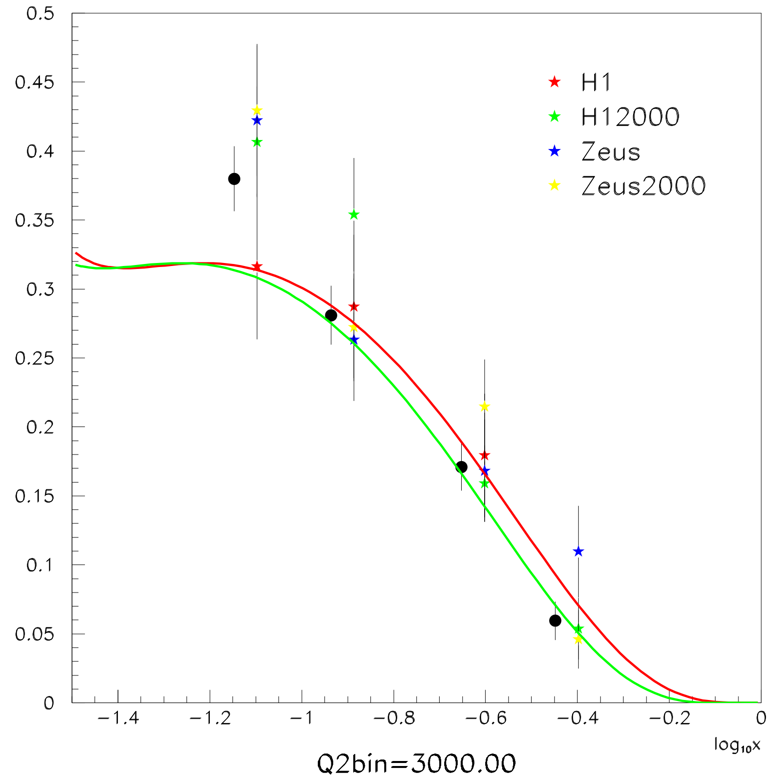


Here H1/Zeus data sets are *average* of all H1/Zeus published data.

CC e^-p and e^+p



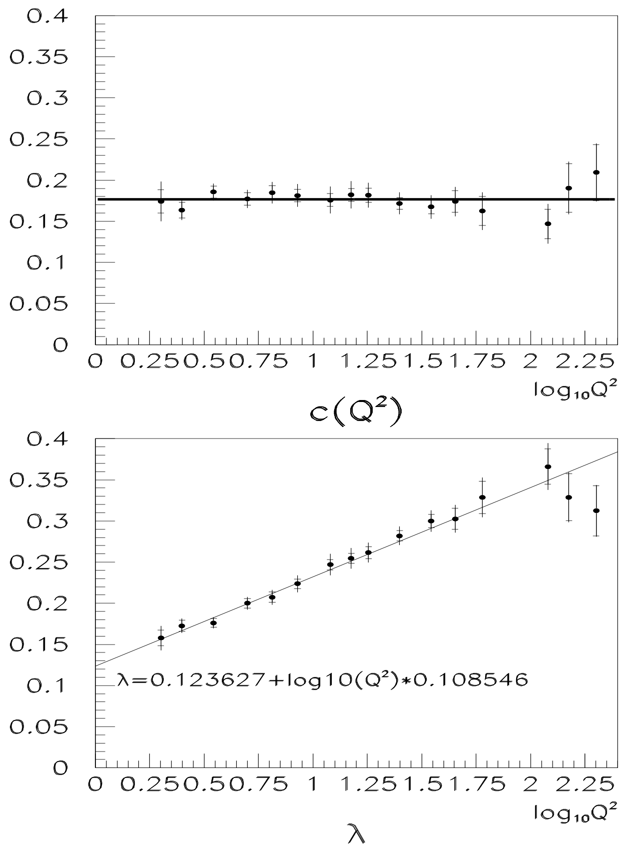
e^-p



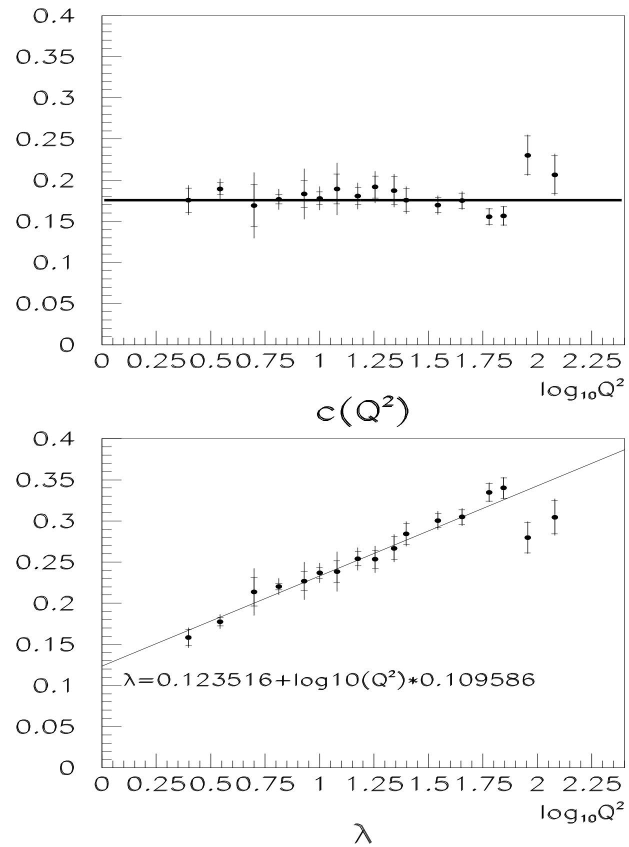
e^+p

For e^+p, errors are reduced by about factor of 2 vs each dataset.

$c \cdot x^{-\lambda}$ fits to low Q^2 F_2



H1



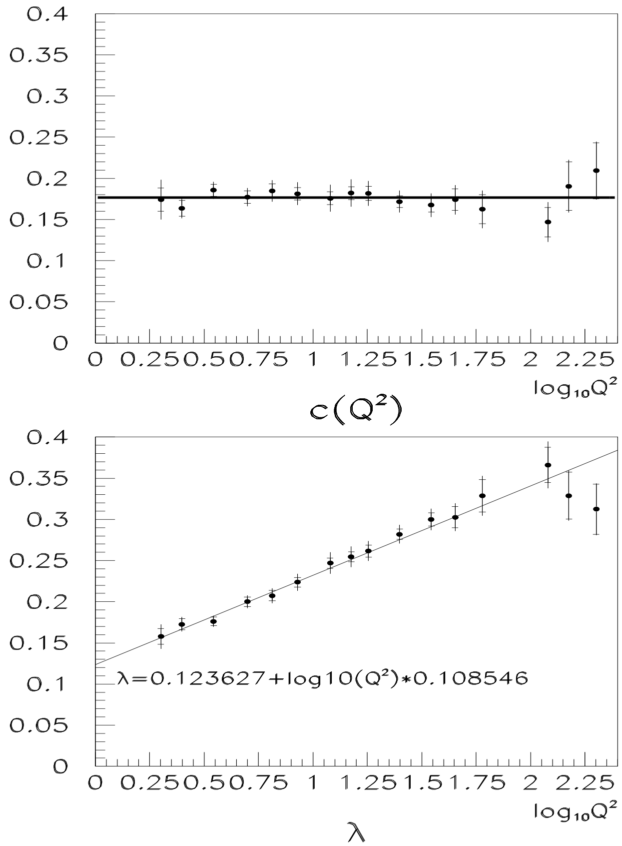
Zeus

For $x < 0.01$, fit using

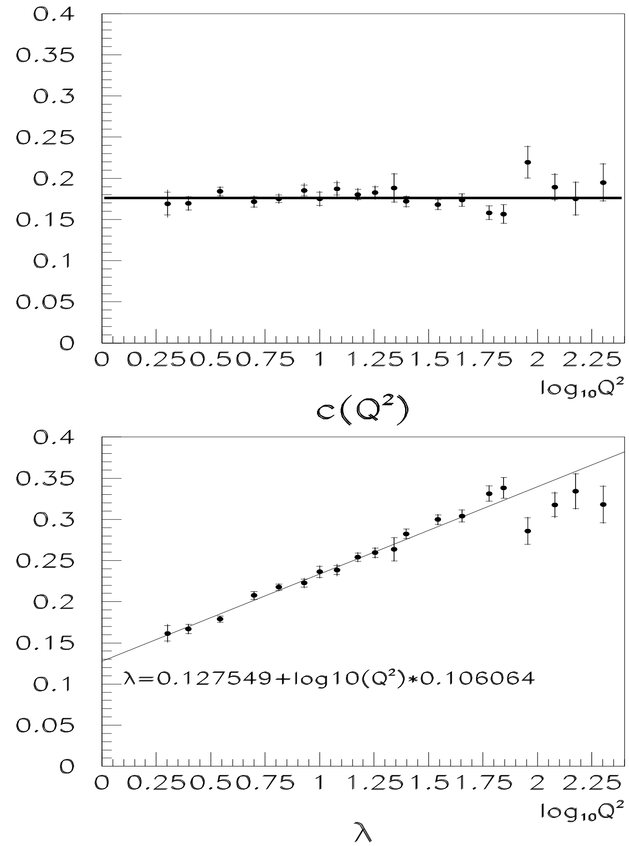
$$F_2 = C(Q^2) \cdot x^{-\lambda}$$

$c \cdot x^{-\lambda}$ fit to low Q^2 data

Fit to combined dataset:



H1



Hera

The errors for λ are reduced twice vs H1.

Conclusions/next steps

- Good agreement btw H1 and Zeus data.
- Remarkable reduction of the total errors which needs further investigations → H1/Zeus joint averaging group → official HERA average.
- Model independent analysis of the average data
- QCD analysis of the average data.
  Joint H1/Zeus QCD fit ?
- Additional options for the averaging, for example xF_3 can be further improved if F_2 measured with e^-, e^+ data is averaged. F_L exrtraction can be also optimized.
- Stat. errors are significant across the kinematic plane → more X-section data is wellcome.