Combination of H1 and ZEUS Inclusive Cross Section Data

S. Glazov

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Outline

- Motivation for combination of the data
- H1-ZEUS averaging group
- First results → CC and NC cross section polarization dependence, xF_3.
- Averaging program
- Influence of assumptions on systematic uncertainties
- Next steps

Motivation for the combination of the data

Data from H1 and ZEUS experiments are used together in global QCD fits. It is better to use combined HERA data instead.

- Simplicity — single data set is much easier to work with.
- Systematic uncertainties — correlation of H1 and ZEUS data can be better handled.
- Cross check — combination procedure allows for model independent check of the data consistency.
- Cross calibration — systematic uncertainties are reduced as a result of averaging.

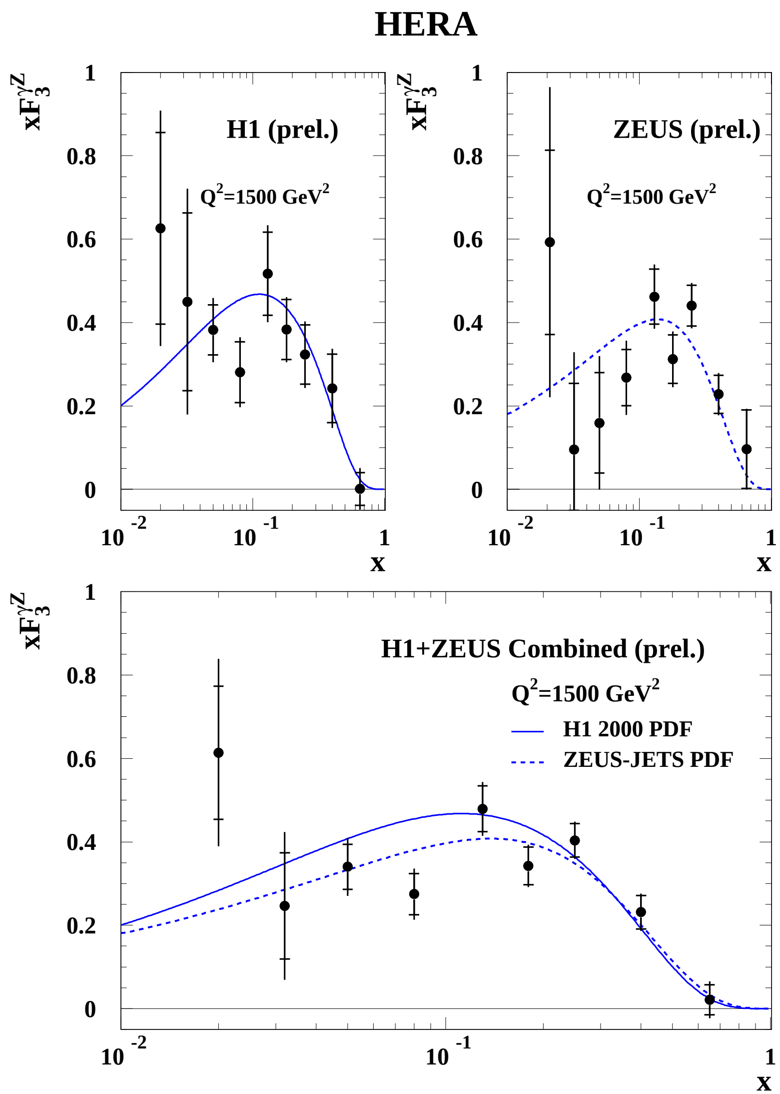
Averaging procedure was developed during HERA-LHC workshop. Last summer cross collaboration H1-ZEUS averaging group has been formed.

Combined H1+ZEUS SF and PDF working group

J. Feltesse, V. Chekelian, A. Cooper-Sarkar,
J. Ferrando, S. Glazov, M. Klein, K. Nagano,
U. Noor, Y. Ri, E. Rizvi, E. Tassi, Z. Zhang

- Combination of the data prior to common QCD fit
- Start with the published HERA I data
- Both collaborations to check their own correlated systematics and check for possible correlations of the two experiments.
- The combination method to be checked by both collaborations, to be checked by other techniques (BLUE).
- Select common grid, extrapolation functions.

H1 ZEUS Combination — First Results



Large increase compared to HERA-I of e^- sample allows to improve precision of the interference structure function $xF_3^{\gamma Z}$

- First combined H1-ZEUS SF result
- For now uses total errors to combine the data since the measurement uncertainties are dominated by stat. errors.

Similar combinations for CC/NC polarization dependence.

X-sections averaging procedure

Standard F_2 or other cross section measurement representation:

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

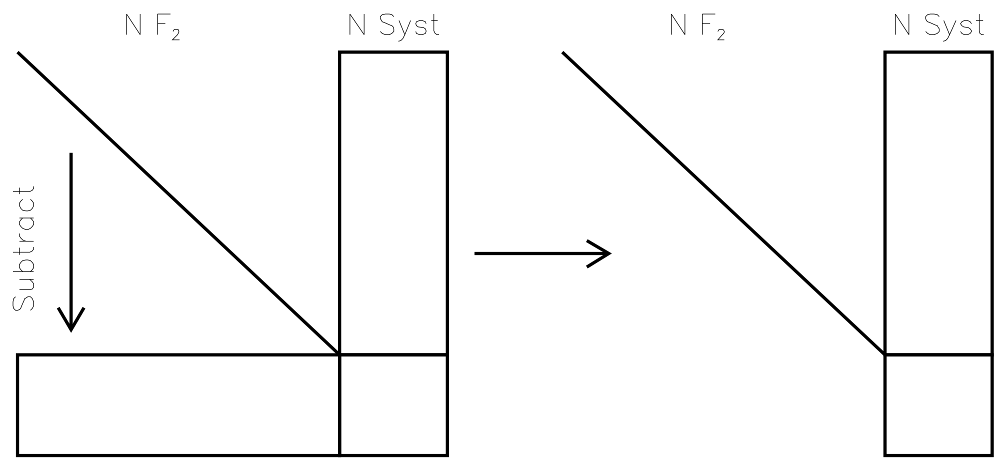
Here α_j — are correlated systematic uncertainty sources.

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 $\rightarrow$ *average* F_2

Some Technical Details

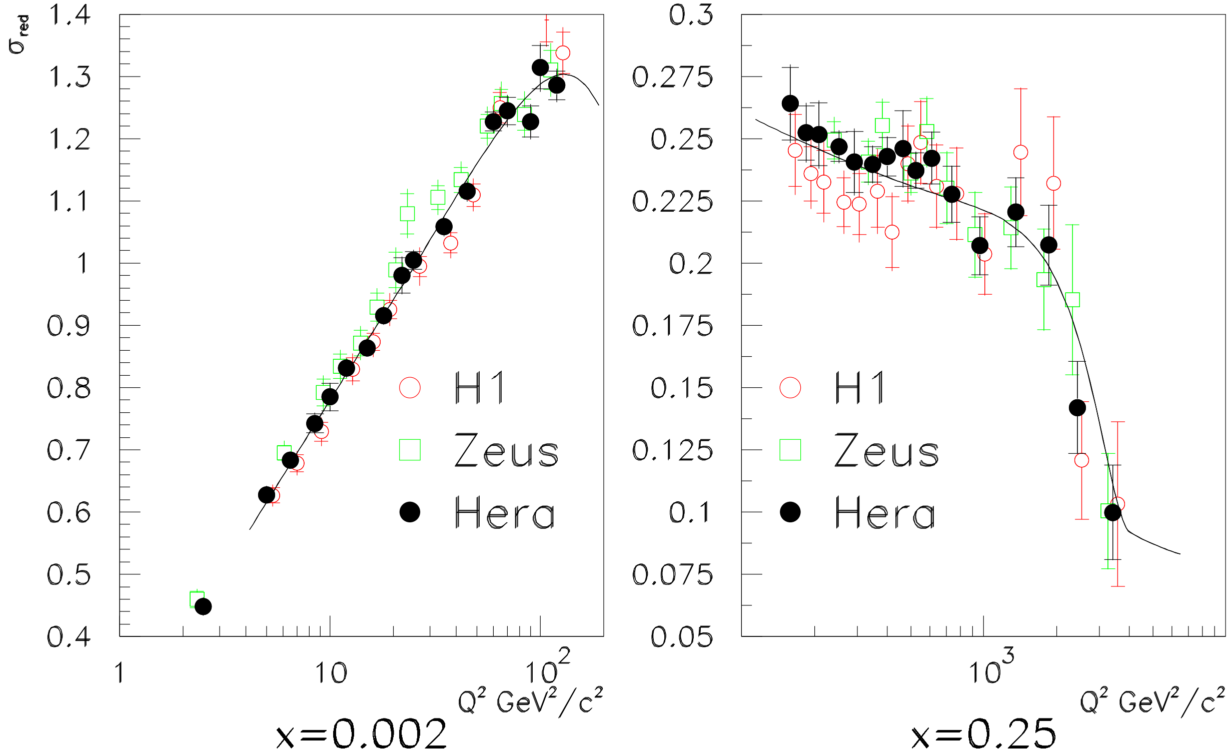
- Many more free parameters (all F_2 points !) vs QCD fit
- Data points from different experiments must be quoted at about the same Q^2, x.
- χ^2 has simple quadratic form $\rightarrow$ minimum is obtain by solving $N_{F_2} + N_{Syst}$ system of linear equations.



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

The averaging procedure is checked by E. Tassi (ZEUS), agreed to serve as the main code for combination. BLUE code will be used as another cross check.

Effect of the Averaging



Cross calibration of systematic uncertainties leads to better than $1/\sqrt{2}$ improvement for systematic errors dominated regions. Simple $1/\sqrt{2}$ improvement for stat. error dominated domain.

Effect of H1 — ZEUS correlations

Cross section measurements for different x, Q^2 are correlated because of systematic uncertainties α_j. Sources of systematic uncertainties may be the same for H1 and ZEUS — potential correlation of H1 and ZEUS measurements.

Obvious correlations are 0.5% theoretical uncertainty in $ep \to ep\gamma$ cross section used for luminosity calculation (1% for W, Z at LHC). Other correlations are not so clear:

- H1 and ZEUS follow a bit different prescription for data correlation for different data sets. H1 correlates "more" while ZEUS correlates "less".
- Even within each experiment similar sources lead to uncorrelated uncertainties. For example, calorimeter energy scale uncertainty in "backward" and "central" calorimeters.
- Some similar systematic effects are estimated by completely different means.

H1 and ZEUS systematic sources

data set	process	$\delta^{\mathcal{L}}$	δ^{E}	δ^{θ}	δ^{h}	δ^{N}	δ^{B}	δ^{V}	δ^{S}
H1 minimum bias 97	e^+p NC	$\mathcal{L}1$	$E1$	$\theta1$	$h1$	$N1$	$B1$	–	–
H1 low Q^2 96 – 97	e^+p NC	$\mathcal{L}2$	$E1$	$\theta1$	$h1$	$N1$	$B1$	–	–
H1 high Q^2 94 – 97	e^+p NC	$\mathcal{L}3$	$E2$	$\theta2$	$h2$	$N1$	$B2$	–	–
H1 high Q^2 94 – 97	e^+p CC	$\mathcal{L}3$	–	–	$h2$	$N1$	$B2$	$V1$	–
H1 high Q^2 98 – 99	e^-p NC	$\mathcal{L}4$	$E2$	$\theta3$	$h2$	$N1$	$B2$	–	$S1$
H1 high Q^2 98 – 99	e^-p CC	$\mathcal{L}4$	–	–	$h2$	$N1$	$B2$	$V2$	–
H1 high Q^2 99 – 00	e^+p NC	$\mathcal{L}5$	$E2$	$\theta3$	$h2$	$N1$	$B2$	–	$S1$
H1 high Q^2 99 – 00	e^+p CC	$\mathcal{L}5$	–	–	$h2$	$N1$	$B2$	$V2$	–

data set	process	x range		Q^2 range (GeV^2)	(GeV^2)	$\delta^{\mathcal{L}}$ (%)	ref.	comment
H1 minimum bias 97	e^+p NC	0.00008	0.02	1.5	12	1.7	[30]	$\sqrt{s} = 301$ GeV
H1 low Q^2 96 – 97	e^+p NC	0.000161	0.20	12	150	1.7	[30]	$\sqrt{s} = 301$ GeV
H1 high Q^2 94 – 97	e^+p NC	0.0032	0.65	150	30 000	1.5	[1]	$\sqrt{s} = 301$ GeV
H1 high Q^2 94 – 97	e^+p CC	0.013	0.40	300	15 000	1.5	[1]	$\sqrt{s} = 301$ GeV
H1 high Q^2 98 – 99	e^-p NC	0.0032	0.65	150	30 000	1.8	[3]	$\sqrt{s} = 319$ GeV
H1 high Q^2 98 – 99	e^-p CC	0.013	0.40	300	15 000	1.8	[3]	$\sqrt{s} = 319$ GeV
H1 high Q^2 98 – 99	e^-p NC	0.00131	0.0105	100	800	1.8	this rep.	$\sqrt{s} = 319$ GeV; high-y data
H1 high Q^2 99 – 00	e^+p NC	0.0032	0.65	150	30 000	1.5	this rep.	$\sqrt{s} = 319$ GeV; incl. high-y data
H1 high Q^2 99 – 00	e^+p CC	0.013	0.40	300	15 000	1.5	this rep.	$\sqrt{s} = 319$ GeV
BCDMS-p	μp NC	0.07	0.75	7.5	230	3.0	[4]	require $y_\mu > 0.3$
BCDMS-D	μD NC	0.07	0.75	7.5	230	3.0	[4]	require $y_\mu > 0.3$

Data Set	Ndata	Norm	Nsys	Kinematic range of the data
NC e^+p 96-97 [15]	242	2% (1%)	10 1,2,3,4,5,6,7,8,9,10	$2.7 < Q^2 < 30,000$ GeV^2 $6.3 \times 10^{-5} < x < 0.65$
CC e^+p 94-97 [16]	29	2%	3 5,6,11	$280 < Q^2 < 17,000$ GeV^2 $0.015 < x < 0.42$
NC e^-p 98-99 [17]	92	1.8%	6 12,13,14,15,16,11	$200 < Q^2 < 30,000$ GeV^2 $0.005 < x < 0.65$
CC e^-p 98-99 [18]	26	1.8%	3 17,18,11	$280 < Q^2 < 17,000$ GeV^2 $0.015 < x < 0.42$
NC e^+p 99-00 [19]	90	2%	8 12,13,14,15,19,11,20,21	$200 < Q^2 < 30,000$ GeV^2 $0.005 < x < 0.65$
CC e^+p 99-00 [20]	30	2%	3 17,-18,11	$280 < Q^2 < 17,000$ GeV^2 $0.008 < x < 0.42$
DIS jets e^+p 96-97 [13]	30	2%	1 22	$125 < Q^2 < 30,000$ GeV^2 $8 < E_T^B < 100$ GeV
γp dijets 96-97 [14] $x_\gamma^{obs} > 0.75$	38	2%	1 22	$14 < E_T^{jet1} < 75$ GeV

Published H1 and ZEUS data sets and assumed correlations. Systematic effects sometimes correlated CC and NC measurements.

Check of H1 — ZEUS correlations

```
28 -10  ! Photoproduction background (H1 - ZEUS)
2   -3  ! SpaCal - LAr  E-scale     (H1 only)
4    6  ! SpaCal theta -- LAr theta (H1 only)
5    6  ! LAr theta 2 periods       (H1 only)
7     8 ! H1 Hadronic scale SpaCal/LAr  (H1 only)
4   -21 ! H1-Zeus low Q2 scat. angle.
6   -22 ! H1-Zeus high Q2 scat. angle.
2    23 ! H1-Zeus e-scale SpaCal
3   -23 ! H1-Zeus e-scale LAr
24   25 ! Zeus FCAL-BCAL                (ZEUS only)
24   26 ! Zeus FCAL-RCAL                (ZEUS only)
24    8 ! Zeus FCAL-H1 LAr hadronic scale
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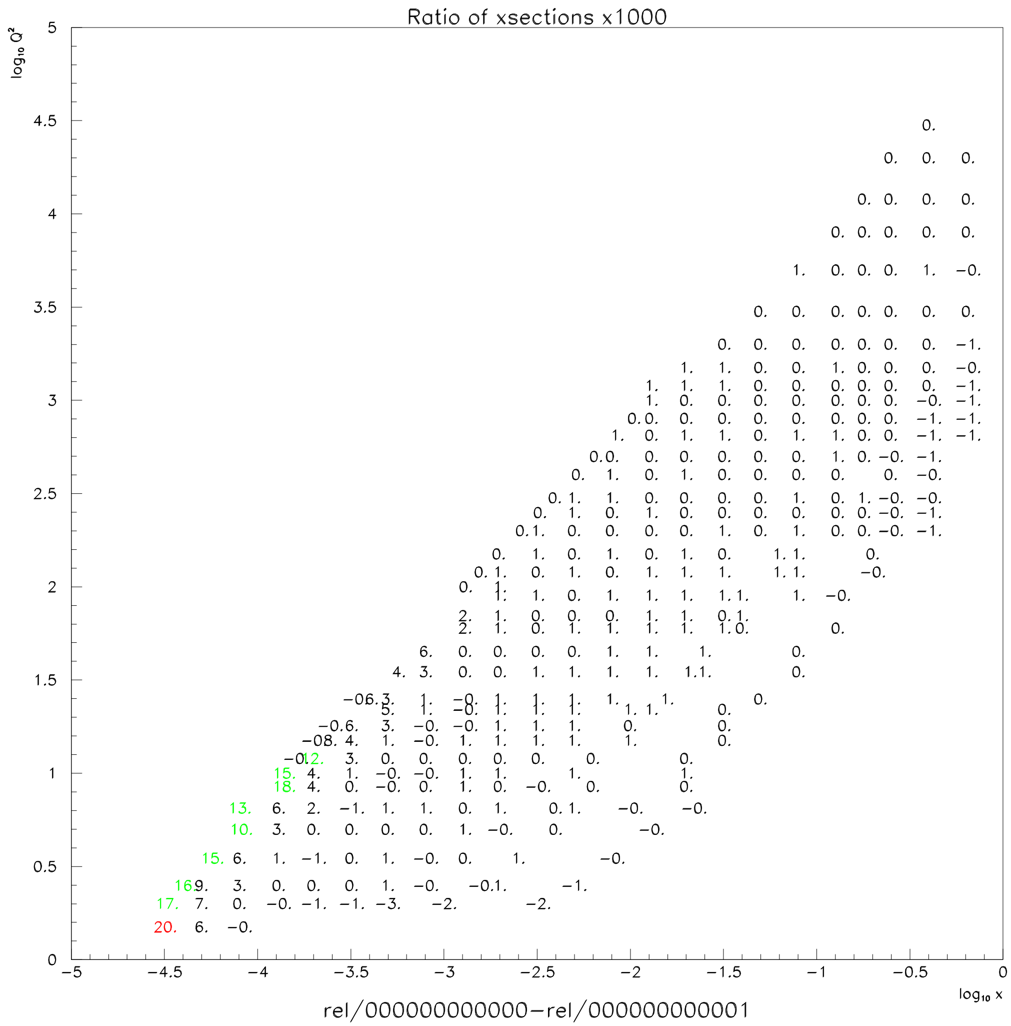
Assume 100% correlation for some sources and compare the average result to the fully uncorrelated case. Try $2^{12} - 1$ possible combinations to be used as an uncertainty estimate. Use fully uncorrelated case as the central value.

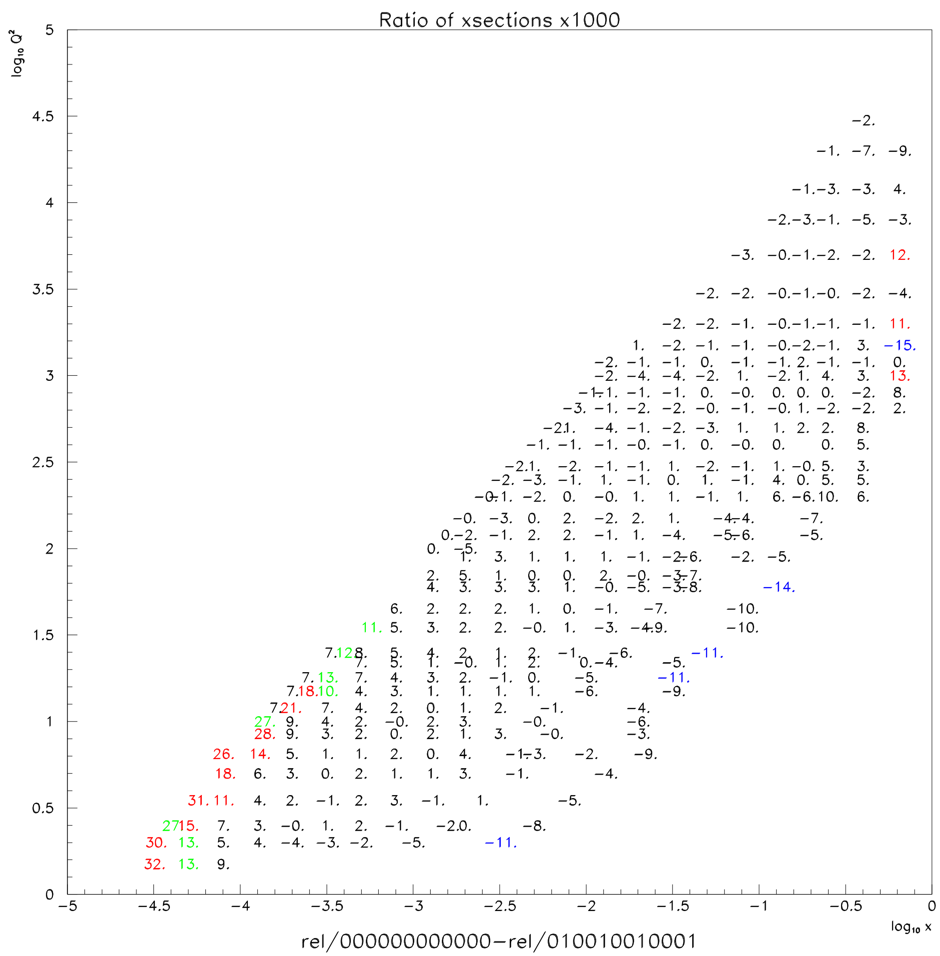
(Uncorrelated/ γp correlated -1) $\times$ 1000

Black: $< 1\%$ difference
Green: $> 1\%$ difference
Blue: $< -1\%$ difference
Red: $> 1/2\sigma_{tot}$



(Ratio -1)$\times$1000) of the average NC e^+p cross sections for different correlation assumptions.

(Uncorrelated/Largest change−1) × 1000



γp, H-scale LAr-SpaCal, E-scale ZEUS-H1 (SpaCal), ZEUS FCAL-RCAL

Conclusions and Outlook

- H1-ZEUS combination work in progress.
- Basic agreement on the combination program and cross checks.
- Agreement on the treatment of the systematic uncertainties

Next steps:

- Fix Q^2, x grid, select swimming procedure.
- Release the average data.
- QCD fits to the combined HERA data.