Combination of the HERA data: HERAPDF1.0 and predictions for W/Z production at LHC

PDF4LHC

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- Data combination
- HERAPDF1.0
- Predictions for W/Z

Why combine ZEUS and H1 data?

We think we know how to extrapolate in Q^2

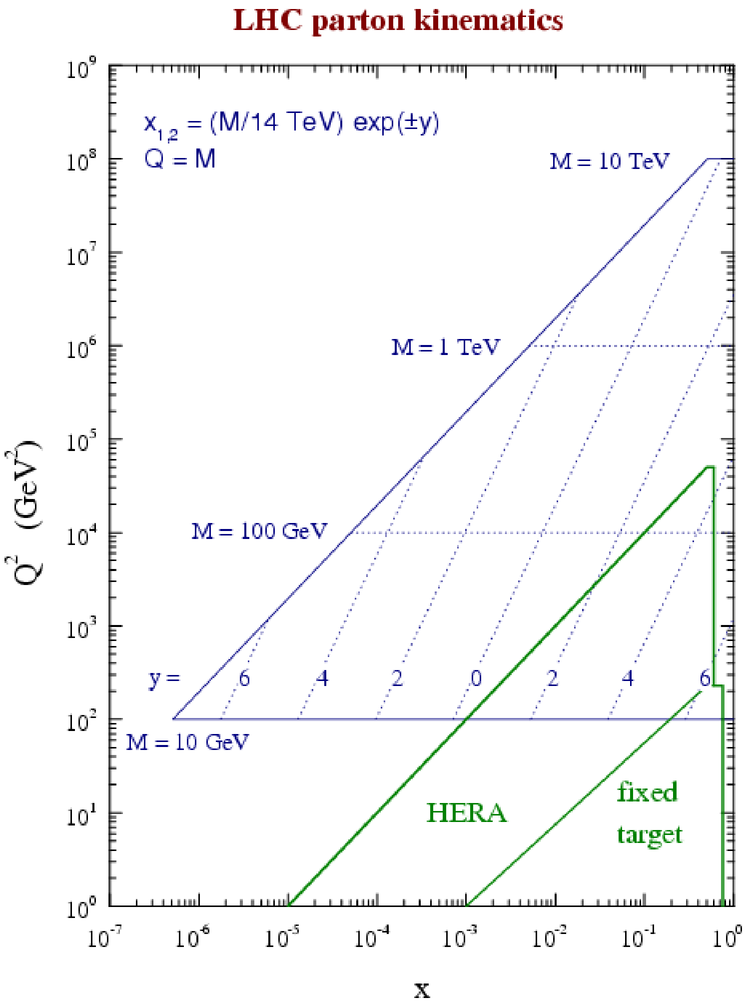
using (N)NLO QCD

We don't know how to extrapolate in x

The HERA data is our best guide

- 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 includes accounting for full systematic error correlations.
- The resulting combination is much better than expected from the increased statistics of combining two experiments.
- The post-averaging systematic errors are smaller than the statistical across a large part of the kinematic plane

Data Sets

2009 average based on the complete HERA-I inclusive NC and CC DIS data:

⇒ Ep=820 (√s=300) and Ep=920 (√s=320) GeV

200 pb^{-1} of e+p , 30 pb^{-1} of e-p

In 2008 we used:

- CC e^-p data: H1 98, ZEUS 98
- CC e^+p data: H1 94-97, H1 99-00, ZEUS 94-97, ZEUS 99-00
- NC e^-p data: H1 98, ZEUS 98
- NC e^+p data: ZEUS 96-97, ZEUS 99-00, H1 99-00 "high Q^2"

New data sets added in 2009:

- ➢ H1 95-00 "low Q^2" $0.2 \leq Q^2 \leq 12$ GeV^2
- ➢ H1 96-00 "bulk" $12 \leq Q^2 \leq 150$ GeV^2
- ➢ ZEUS BPC/BPT, SVX95 ($0.045 \leq Q^2 \leq 17$ GeV^2)

Very recently published H1 data sets

110 correlated systematic error sources from all these data sets

3 "procedural uncertainties" related to the averaging procedure

Averaging procedure

For more detail
see extras

- Swim all points to a common x-Q^2 grid
- Moved$^{(1)}$ 820 GeV data to 920 GeV p-beam energy
- Calculate average values and uncertainties

This is done by making a χ2 fit to the data points of both experiments which simply assumes that for each process (NC or CC, e+ or e-) and each x, Q^2 point (i) there is only one 'true' value of the cross-section- these are the predictions m_i _ whereas there can be several measurements of this value, from ZEUS and H1 and from different years of running- these are the measurements μ_i

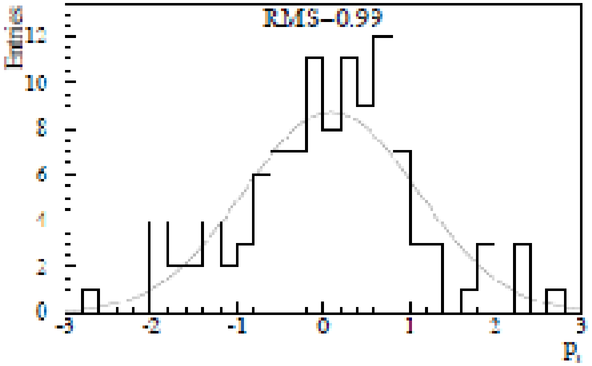
$$\chi^2_{\exp}(\boldsymbol{m}, \boldsymbol{b}) = \sum_i \frac{\left[m^i - \sum_j \Gamma^i_j b_j - \mu^i\right]^2}{\Delta^2_i} + \sum_j b^2_j .$$

For complete form of the χ2 see extras

- The chisq accounts for the correlated systematics of the data points- each data point can have several such uncertainties Γ, hence sum over j for each data point i, but these uncertainties are common to all data points for large sub-sets of data. The fit determines the value of the cross-sections m_i and the systematic shift parameters b_j
- Evaluate further uncertainties due to choices in combination procedure,e.g. Correlations between ZEUS and H1

1402 data points are averaged to 741 combined data points

χ2/ndf =637/656

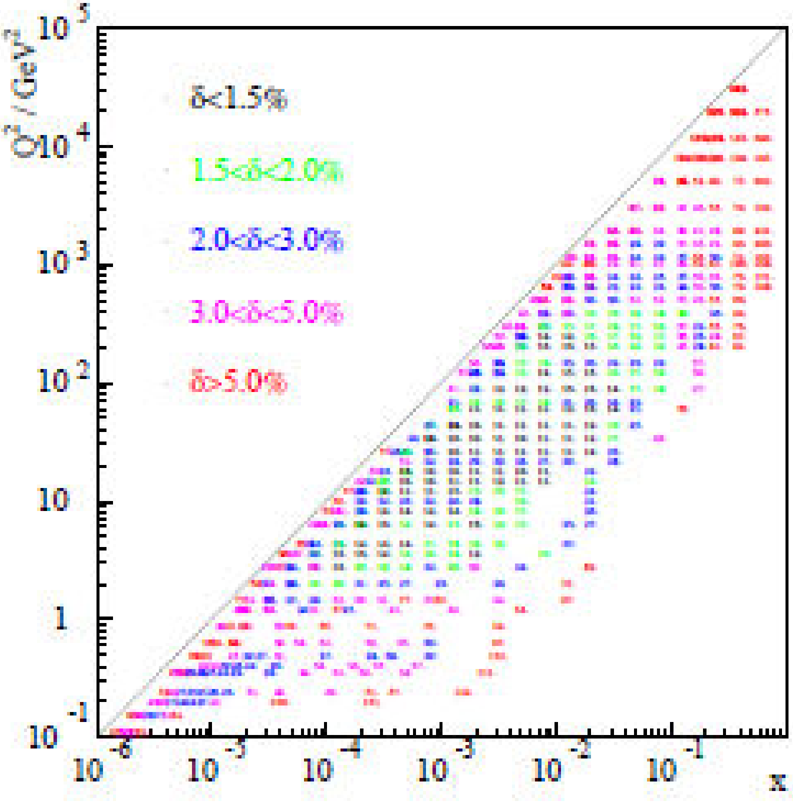


Systematic shift parameters b, shift most systematics < 1 std deviation

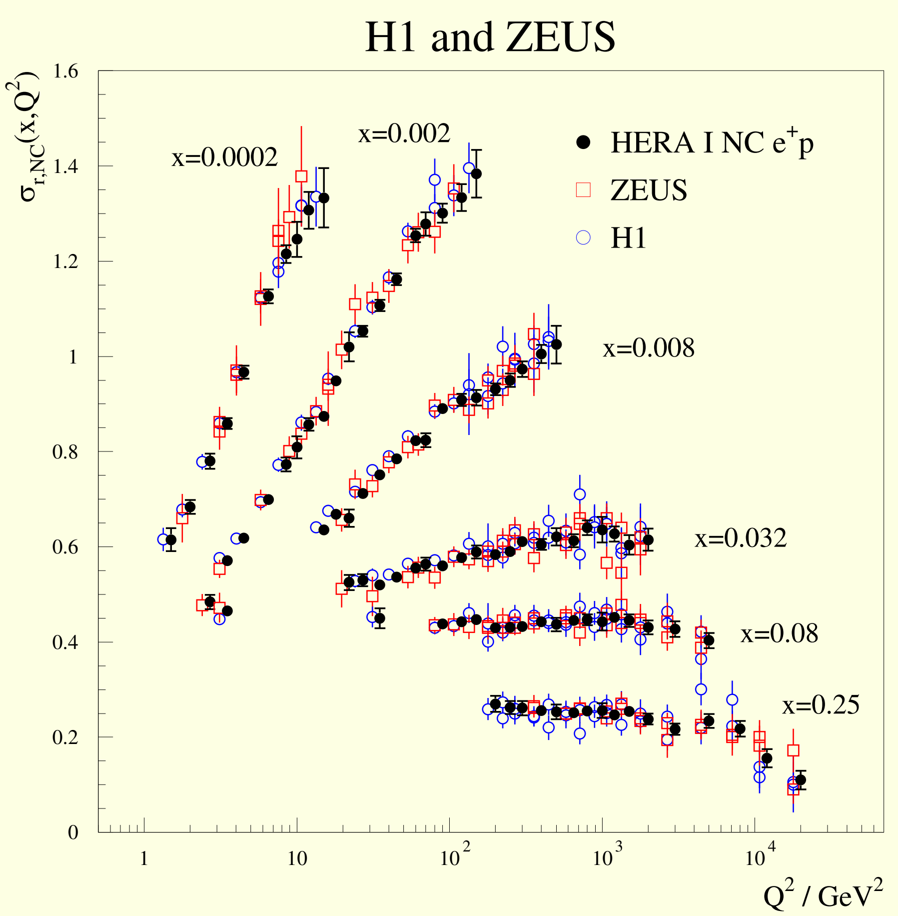
But the fit also determines uncertainties on the shift parameters Δb, some of these are much reduced e.g

ZEUS γp background uncertainty is reduced by 65%

H1 LAr hadron calorimeter energy scale uncertainty is reduced by 55%



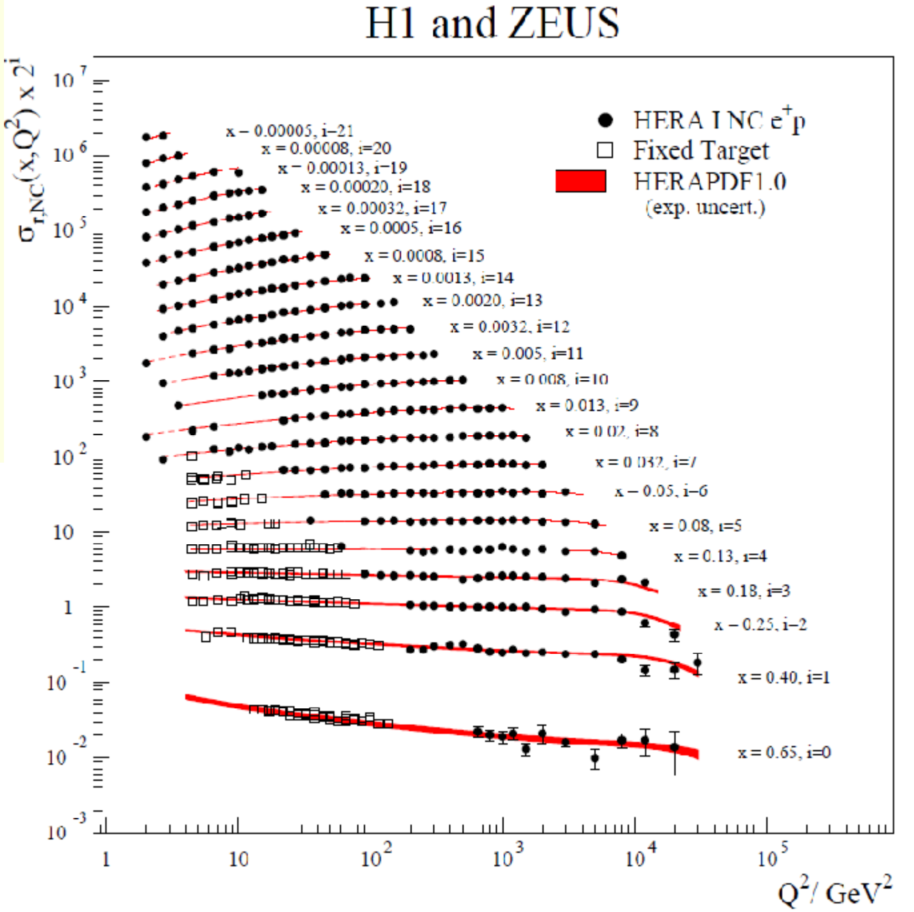
Resulting total uncertainties are <2% over a large part of the kinematic plane AND the contribution of correlated systematics to this errors is now < statistical error



Results of the combination compared to the separate data sets

This page shows NC e+ combined data

Further data plots on NCe-, CCe+, CCe- in extras



HERAPDF1.0
motivation

Some of the debates about the best way of estimating PDF uncertainties concern the use of many different data sets with varying levels of consistency.

The combination of the HERA data yields a very accurate and consistent data set for 4 different processes: e+p and e-p Neutral and Charged Current reactions.

Whereas the data set does not give information on every possible PDF flavour it does

- Give information on the low-x Sea (NCe+ data)
- Give information on the low-x Gluon via scaling violations (NCe+ data)
- Give information on high-x u (NCe+/e- and CCe-) and d (CCe+ data) valence PDFs
- Give information on u and d-valence shapes down to x~3 10^{-2} (from the difference between NCe+ and NCe-)

See extras

Furthermore, the kinematic coverage at low-x ensures that these are the most crucial data when extrapolating predictions from W, Z and Higgs cross-sections to the LHC

Correlated systematic uncertainties, χ2 and Δχ2

The data combination results in a data set which not only has improved statistical uncertainty, but also improved systematic uncertainty.

Even though there are 113 sources of correlated systematic uncertainty on the data points these uncertainties are small. The total systematic uncertainty is significantly smaller than the statistical uncertainty across the the kinematic region used in the QCD fits

This means that the method of treatment of correlated systematic uncertainties in our PDF fits is not crucial. We obtain similar results treating all systematic errors as correlated or as uncorrelated. (see my 'uncertainties' talk).

For our PDF fits we combine 110 sources of systematic uncertainty from the separate experiments in quadrature and OFFSET the 3 procedural systematics which derive from the method of data combination.

We set the experimental uncertainties on our PDFs at 68% CL by the conventional χ2 tolerance

$$\Delta\chi 2 = 1$$

Theoretical framework

Fits are made at NLO in the DGLAP formalism -using QCDNUM 17.04

The Thorne-Roberts massive variable flavour number scheme is used (2008 version) and compared with ACOT

The staring scale Q^2_0 (= 1.9 GeV^2) is below the charm mass^2 (mc=1.4 GeV) and charm and beauty (mb=4.75) are generated dynamically

A minimum Q^2 cut $Q^2 > 3.5\ GeV^2$ is applied to stay within the supposed region of validity of leading twist pQCD (no data are at low W^2)

Parametrisation and model assumptions (all values in green are varied)

We chose to fit the PDFs for:

gluon, u-valence, d-valence and the Sea u and d-type flavours:

Ubar = ubar, Dbar = dbar+sbar (below the charm threshold)

To the functional form $xf(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^2)$

The normalisations of the gluon and valence PDFs are fixed by the momentum and number sum-rules resp.

B(d-valence) = B(u-valence), B(Dbar) = B(Ubar),

A(Ubar) = A(Dbar) (1-fs), where sbar = fs Dbar, so that ubar → dbar as x→ 0 (fs=0.31)

Uncertainties due to model assumptions are evaluated by varying the following inputs

- Variation of the heavy quark thresholds:
  - Mc = 1.4 GeV → 1.35 - 1.50 GeV

    When Mc=1.35, Q^2_0 =1.8 GeV^2
  - Mb = 4.75 GeV → 4.30 - 5.00 GeV

- Variation of the sea fractions:
  - f_s = s/D = 0.31 → 0.23 - 0.38

s ≈ (0.3-0.6)d at Q^2~2

Since there is no HERA information on the strange PDF the strange sea fraction is varied by an amount which covers the recent findings of MSTW

- Variation of the starting scale of evolution of PDFs:
  - Q^2_0= 1.9 GeV^2 → 1.5 - 2.5 GeV^2:
    - for Q^2_0= 2.5 GeV^2 vary f_s=0.32 and Mc=1.6 GeV because $Q^2_0<Mc^2$
    - for Q^2_0= 1.5 GeV^2 vary f_s=0.29

Let us come back to this lowering of the starting scale

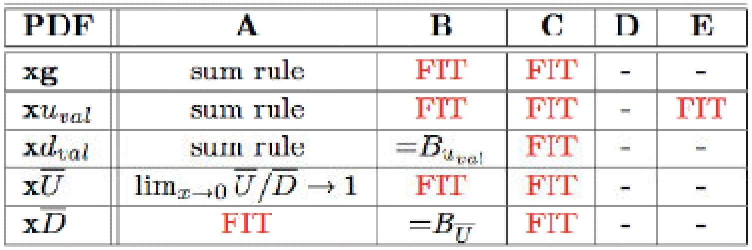
- Variation of the minimum Q^2 cut on data:
  - Q^2_{min}= 3.5 GeV^2 → 2.5 - 5.0 GeV^2

Parametrisation uncertainties- indicative, not exhaustive

The central fit is chosen as follows: start with a 9 parameter fit with all D and E parameters = 0 and then add D and E parameters one at a time noting the χ2 improvement. Chose the fit with the lowest χ2. This has E(u-valence) ≠ 0 and χ2/ndf = 574/582.

$xf(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^2)$

This happens to be the central fit



PDF	A	B	C	D	E
xg	sum rule	FIT	FIT	-	-
xu_{val}	sum rule	FIT	FIT	-	FIT
xd_{val}	sum rule	$=B_{u_{val}}$	FIT	-	-
$x\bar{U}$	$\lim_{x\to 0}\bar{U}/\bar{D}\to 1$	FIT	FIT	-	-
$x\bar{D}$	FIT	$=B_{\bar{U}}$	FIT	-	-

However the procedure is continued. We then start with this 10 parameter fit and add all the other D and E parameters one at a time noting the χ2 improvement. It turns out that there is no significant further improvement in χ2 for 11 parameter fits.

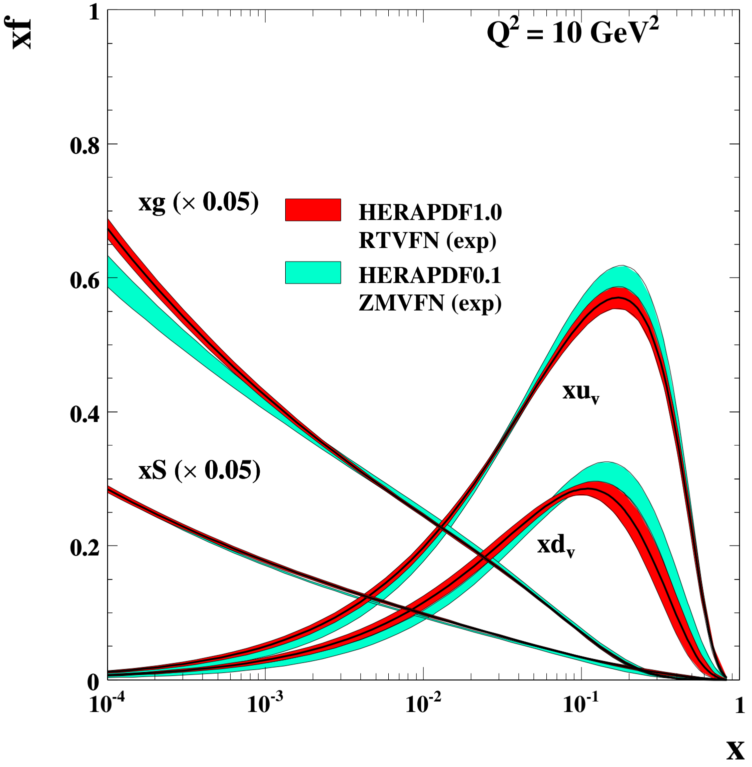
An envelope of the shapes of these 11 parameter fits is formed and used as a parametrization error. So far this addresses parametrization uncertainty at high-x.

Low-x is also addressed by considering the following variations:

1. Bdv free –this results in Bdv ≈ Buv
2. A negative gluon term: - A $x^B(1-x)^C$ is added to the usual gluon term, when the starting scale of the fit is lowered to Q^2_0=1.5 GeV^2 – this results in a small –ve gluon term

Neither variation results in a large χ2 change. These variations are also included in the envelope

RESULTS for HERAPDF1.0 --now close to final ---a paper is with the collaborations



Compared to last year's preliminary HERAPDF0.1:

1. Experimental errors are smaller (new H1 data sets)

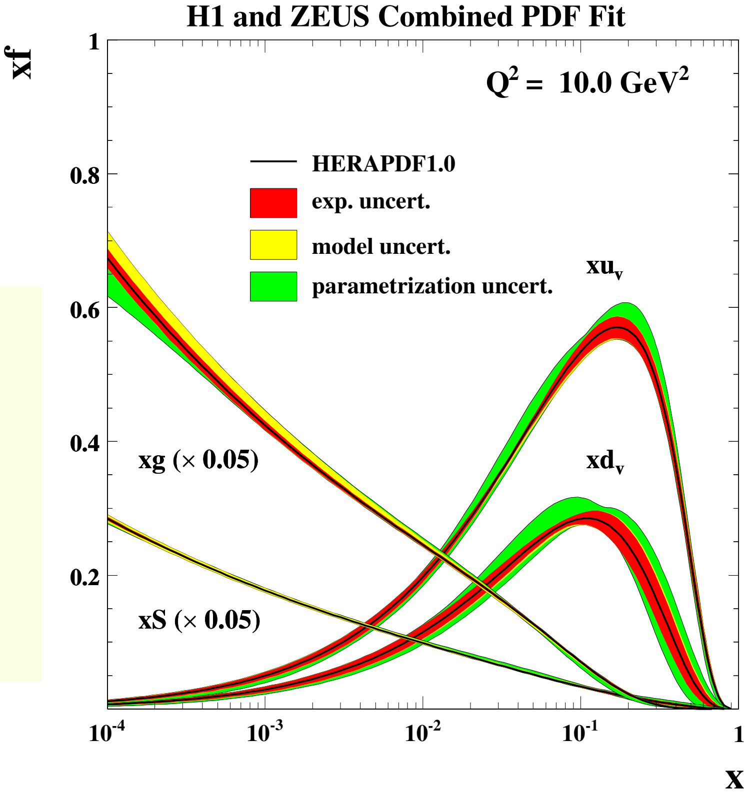
2. Massive heavy quark scheme is used

Now add model and parametrization uncertainty:

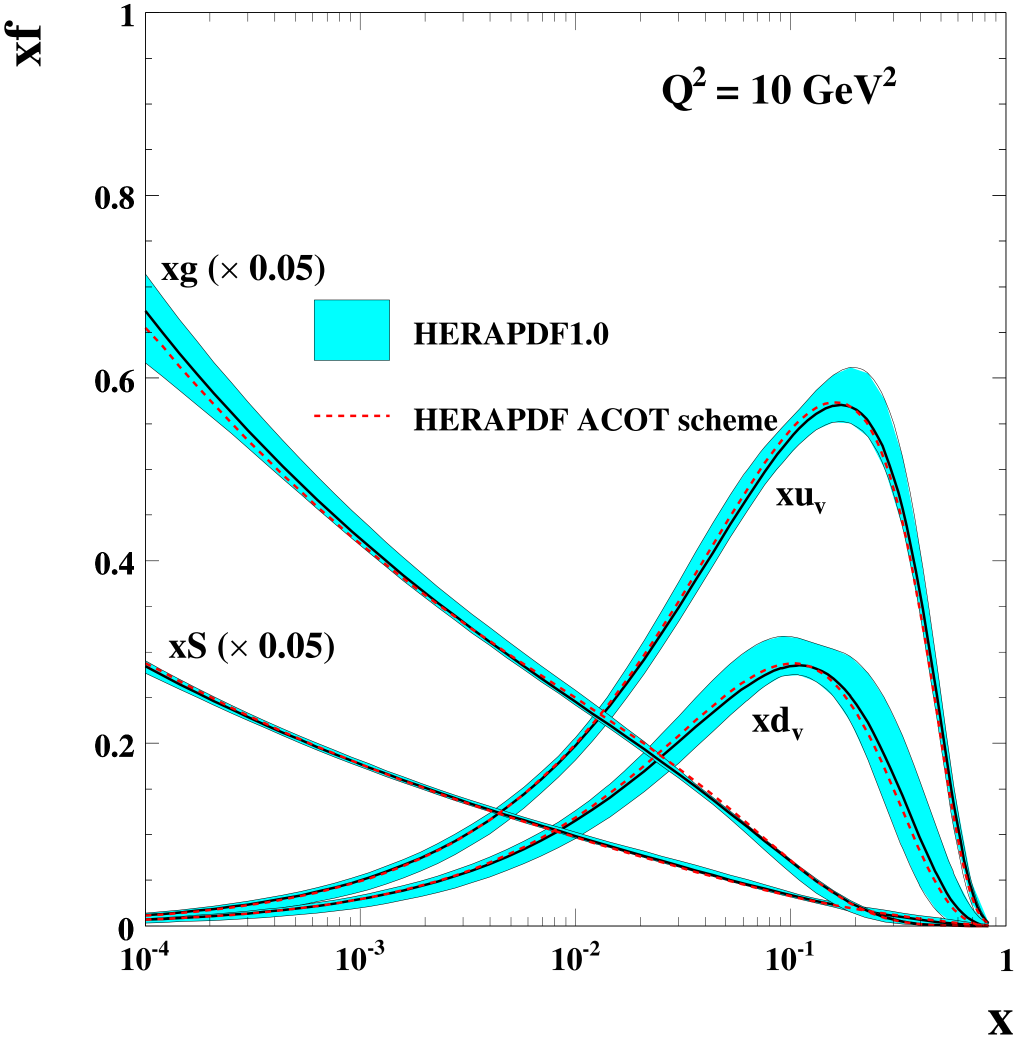
1. Variation of D and E parameters affects high-x

2. Negative gluon term affects low-x

3. Variation of Q^2_0 and Q^2_{min} dominate the model uncertainty of gluon at low-x



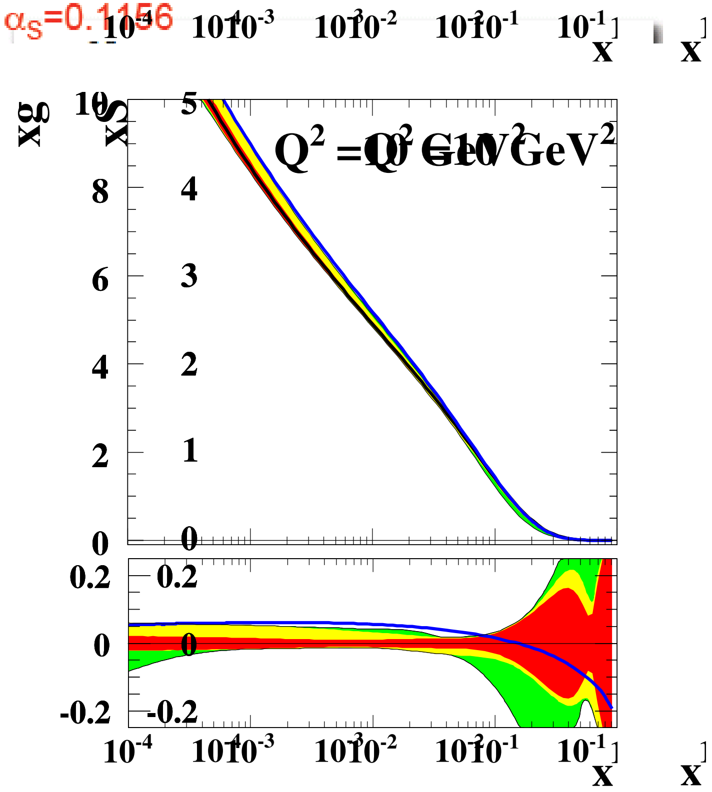
We also varied the heavy quark scheme to use ACOT-χ with advice from Fred Olness

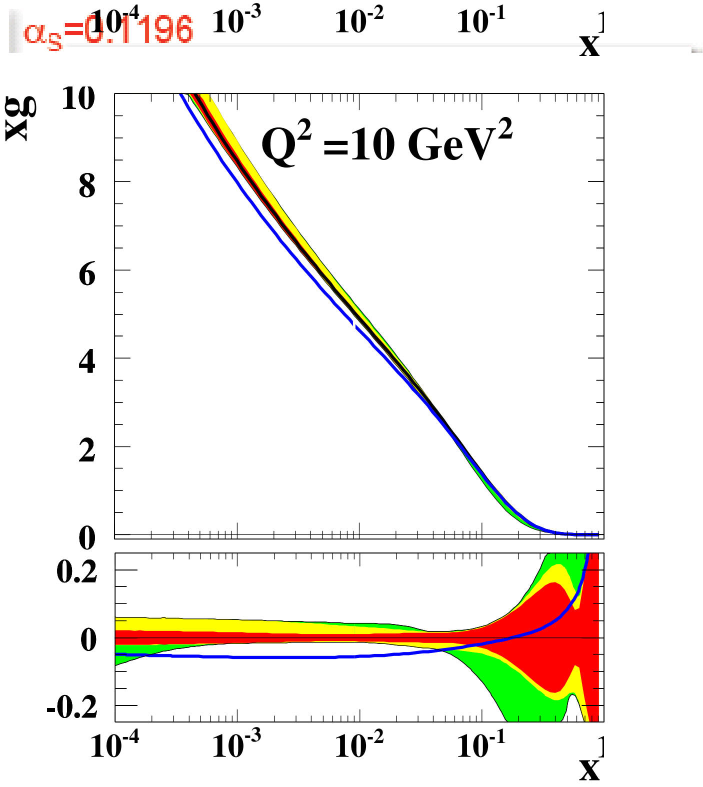


Variation of Strong Coupling

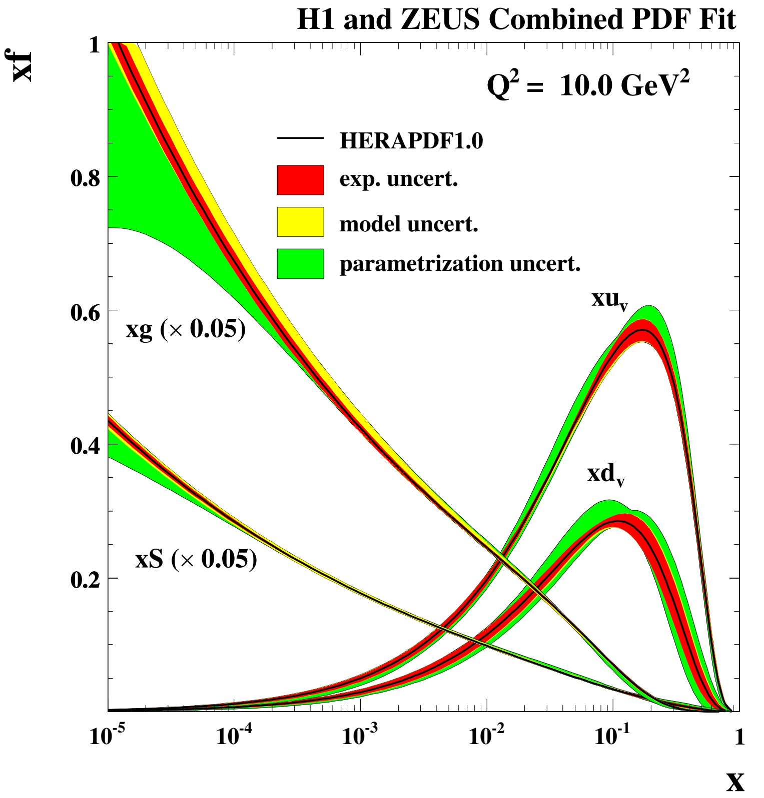
Most pronounced in the gluon distribution (as expected)

- Shown by the blue line

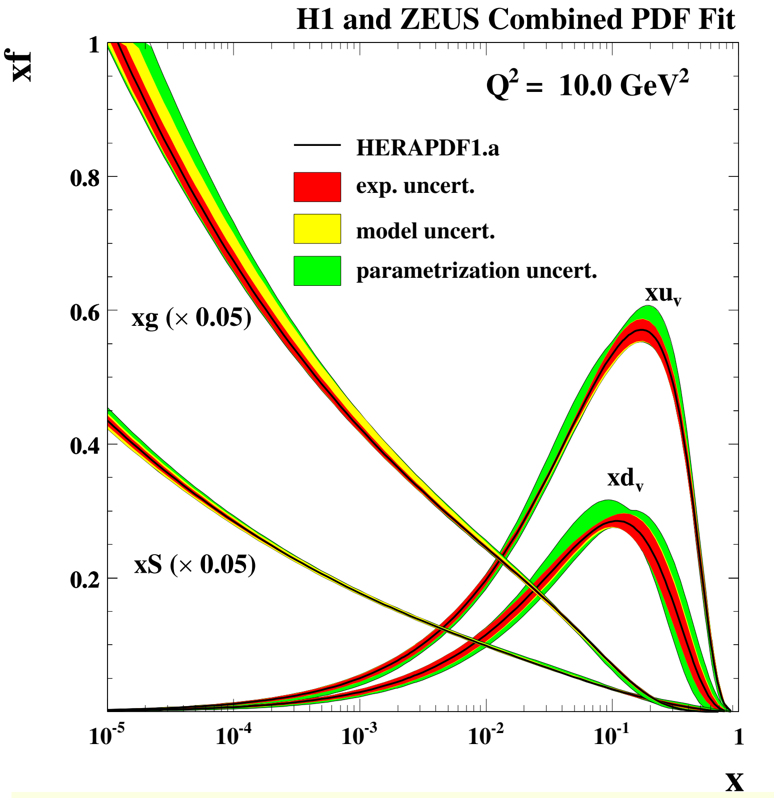




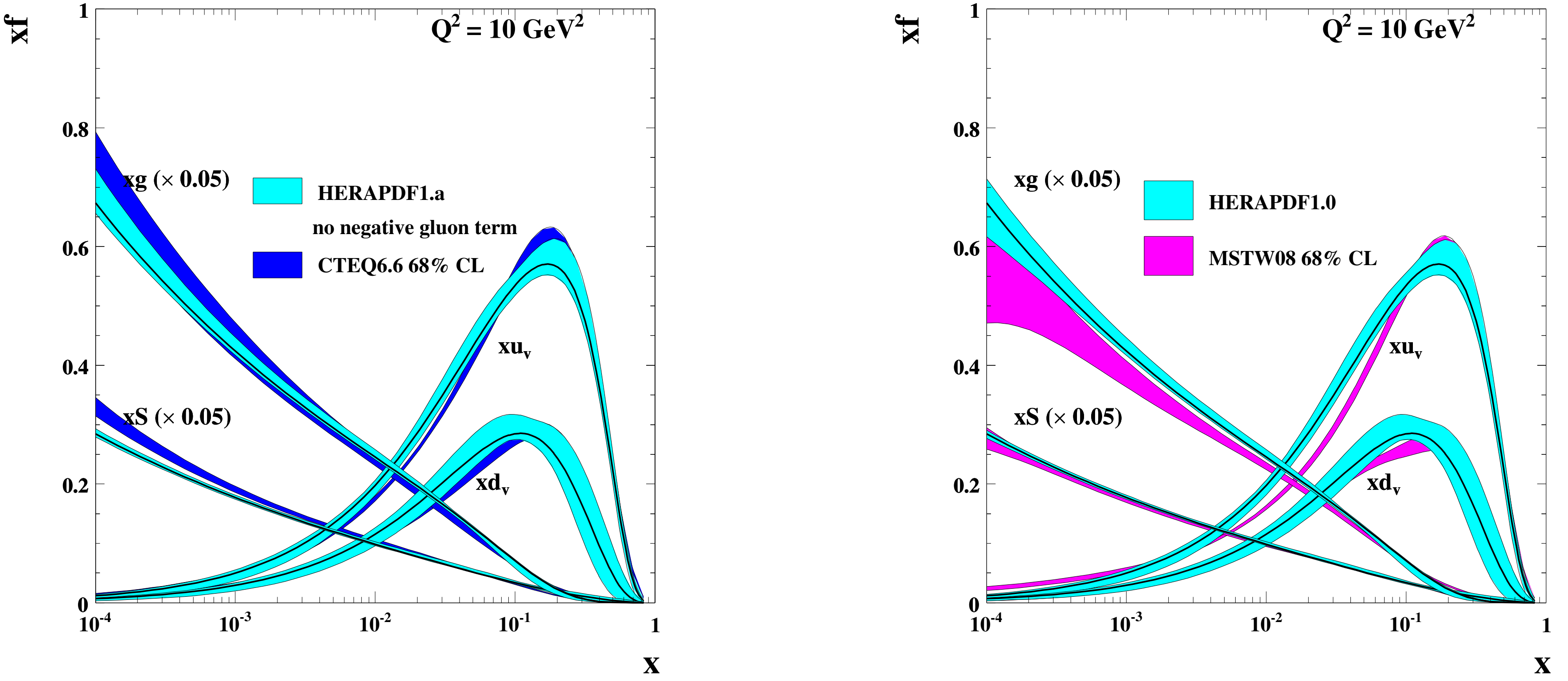
A closer look at the negative gluon term



Extend the scale down to $x = 10^{-5}$



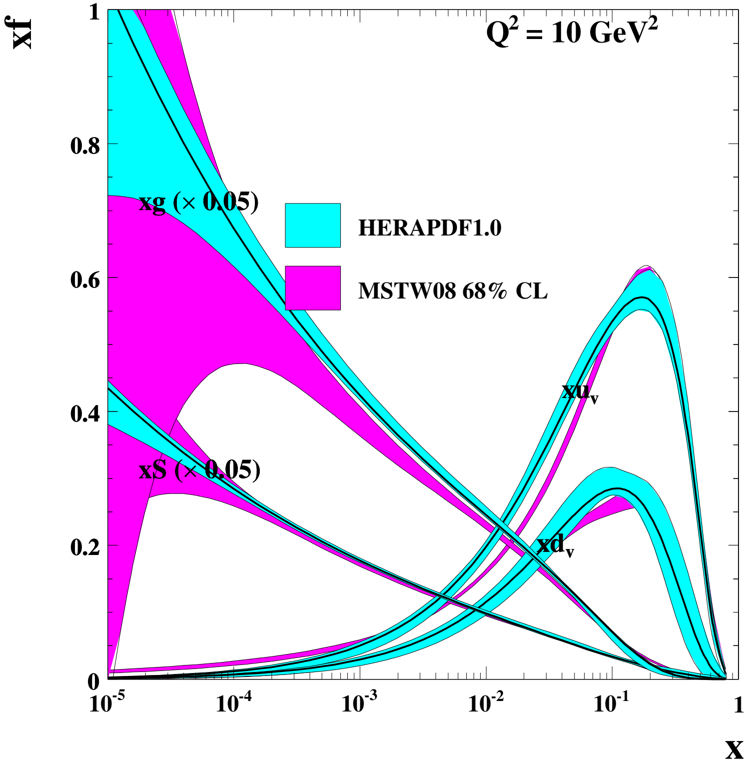
Compare to a HERAPDF1.a which does Not have this negative gluon term

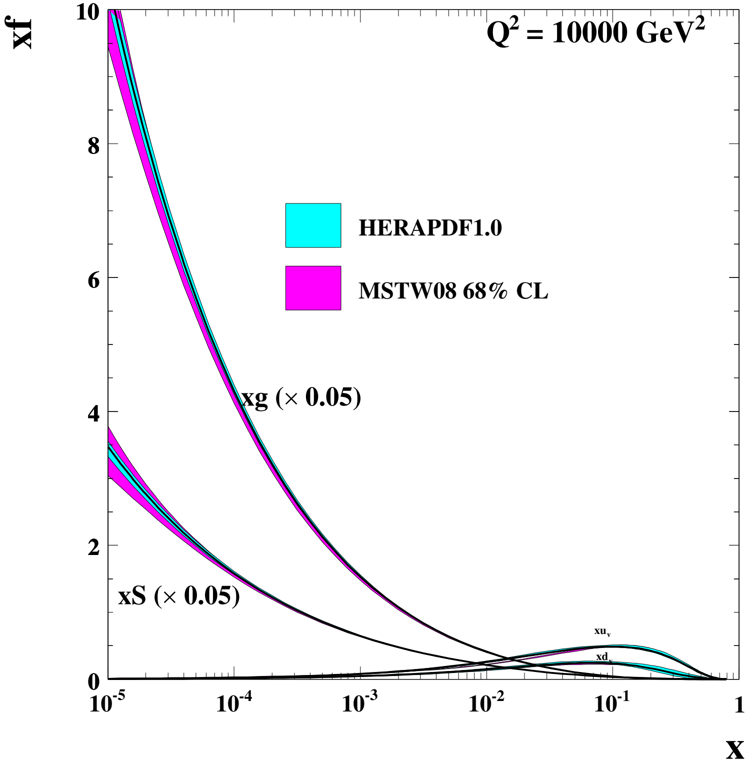


Compare HERAPDF1.0 to the global fits at 68%CL since $\Delta\chi 2=1$ was used for experimental uncertainties for HERAPDF.
However, HERAPDF1.0 includes all model and parametrization variants, so it is not completely clear that this is the relevant comparison.

Include the negative gluon variant when comparing to MSTW08
But not when comparing to CTEQ66 since they do not include such a parametrization.
For CTEQ66 compare to HERAPDF1.a which does not have the negative gluon term

It maybe fun to follow up this negative gluon term a bit more

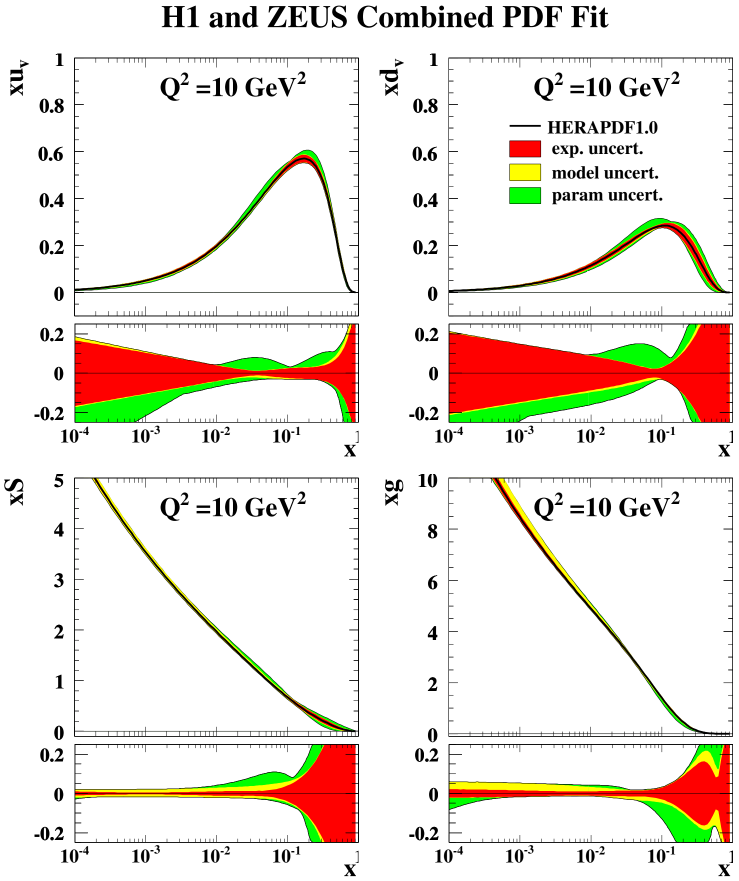


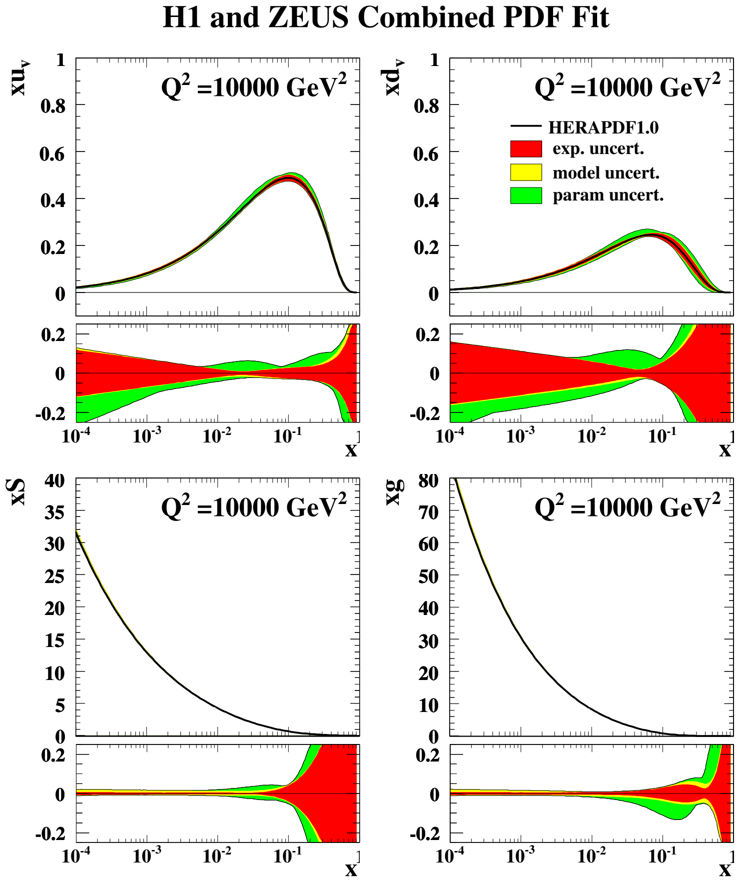


Here's what the comparison to MSTW08 would look like if we extended it down to 10^{-5}

Lowest x of data in HERAPDF x=0.4 10^{-5}

On the other hand at higher scale the negative gluon term is much less significant– ie for LHC W/Z production -even at high rapidity





To illustrate the uncertainties on HERAPDF1.0 more clearly look at fractional uncertainties on each PDF

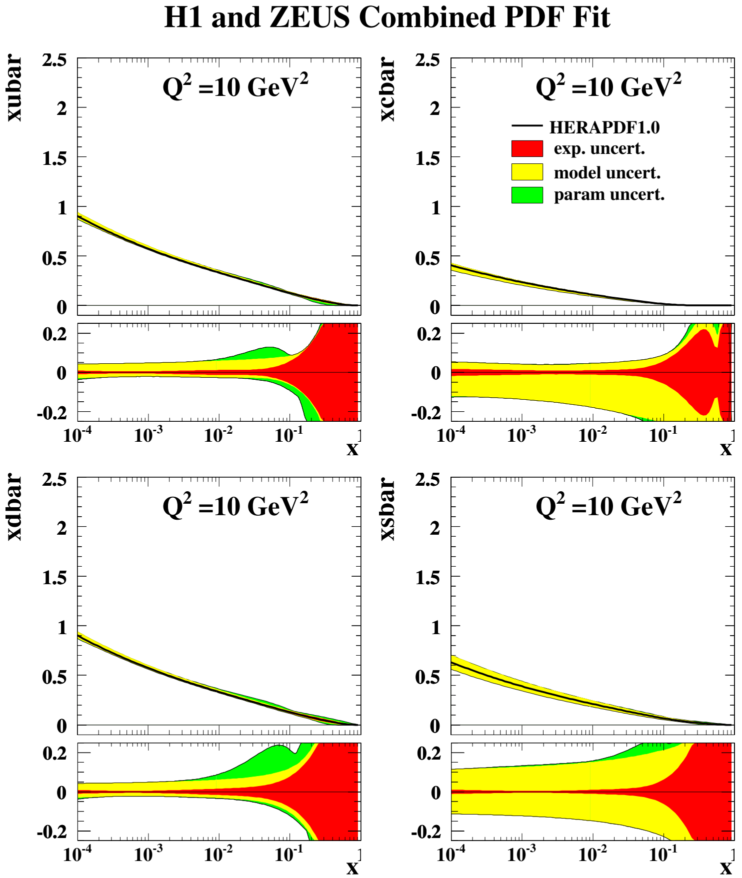
Note how these decrease as Q^2 increases

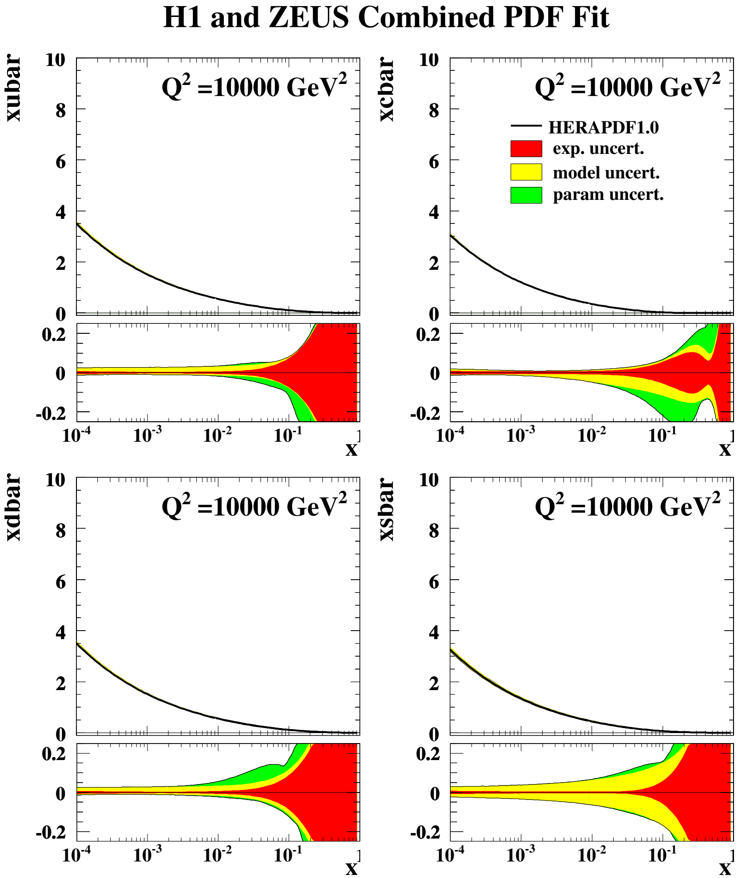
Impressive precision at the scale relevant for W/Z production at the LHC

Sea and gluon uncertainties are much reduced at higher scale: for $x < 5\ 10^{-2}$

they are < 2%

Not true that a gluon determined from HERA data alone cannot fit Tevatron jet data… see extras





Even when looking at sea flavour break-up uncertainties are not large at low-x for the dominant u and d flavours.

Uncertainties on the strange quark reflect uncertainty in fs

Uncertainties on the charm quark reflect those on the gluon which generates it.

Uncertainties on the flavour break-up of the sea are also much reduced at high scale

NOTE the HERA-II data are yet to be combined. This will reduce the uncertainties at high x

Summary on the HERAPDF fit

1. Consistent data set.
2. Small correlated systematic errors.
3. Δχ2=1 for experimental errors
4. 4 processes NC/CC e^+p/e^-p can determine Sea, gluon and valence PDFs
5. Model uncertainties
6. Parametrisation uncertainties

   - not as exhaustive as NNPDF but indicates in which kinematic regions these are important

Now some consequences for W/Z production at the LHC

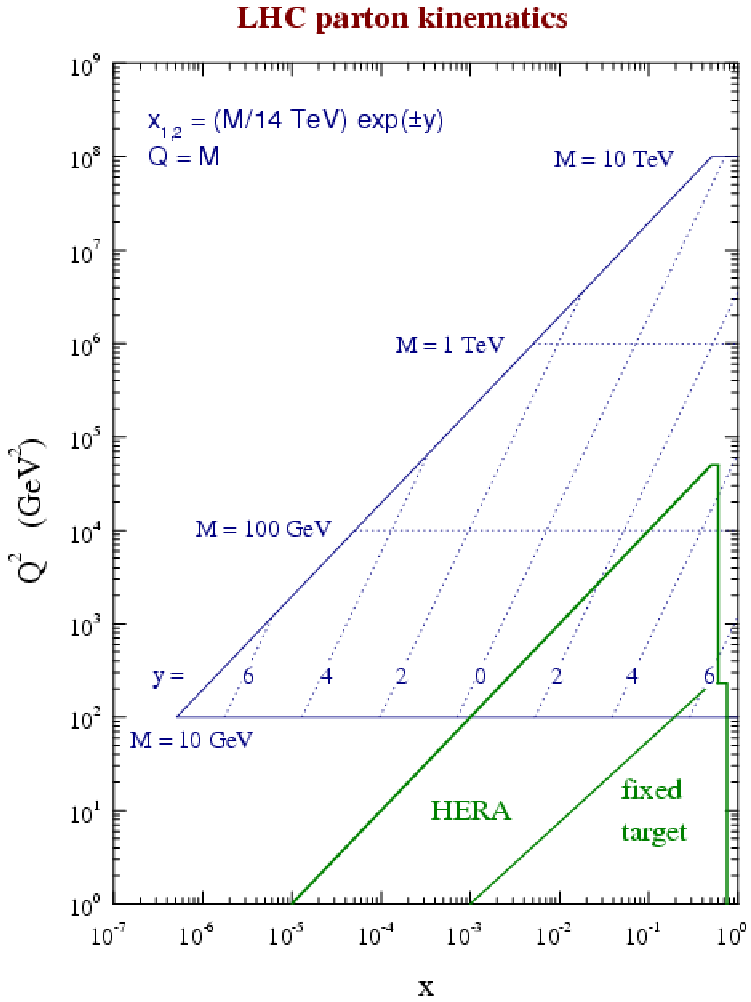
What changes about W/Z production for LHC running 10 TeV rather than 14 TeV

The central rapidity range for W/Z production AT LHC is still at low-x

(6×10^{-4} to 6×10^{-2}) at 14 TeV

(8.5×10^{-4} to 8.5×10^{-2}) at 10 TeV

Just slightly higher than before



The W and Z cross-sections decrease to ~70% of their values at 14TeV.

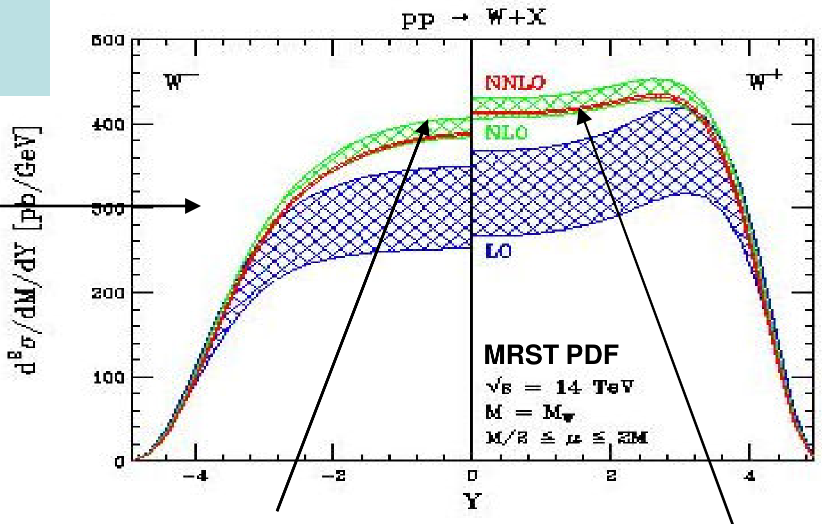
This means there will still be millions of events.

Who knows if we will even get 10TeV it looks more likely to be 8 TeV or even lower

WHAT DO WE KNOW WELL?

W/Z production have been considered as good standard candle processes with small theoretical uncertainty.

PDF uncertainty is THE dominant contribution and most PDF groups quote uncertainties <~3% (at 68%CL)



NNLO corrections small ~ few%
NNLO residual scale dependence < 1%

W Z cross-sections at 10 TeV

PDF set	$\sigma_{W+} B_{W\to l\nu}$ (nb)	$\sigma_{W-} B_{W\to l\nu}$ (nb)	$\sigma_Z B_{Z\to ll}$ (nb)
MSTW08	8.55±0.15	6.25±0.12	1.38±0.025
CTEQ66	8.77±0.18	6.22±0.14	1.40±0.027
HERAPDF10	**8.92±0.07** **±0.15±0.15**	**6.47±0.04** **±0.11±0.12**	**1.43±0.01** **±0.03 ±0.03**
HERAPDF01	**8.64±0.10±0.07**	**6.27±0.11±0.08**	**1.38±0.02±0.02**
CTEQ61	8.29±0.22	5.90±0.17	1.32±0.030

Agreement between PDFs which include massive heavy quark treatment is also to ~4%

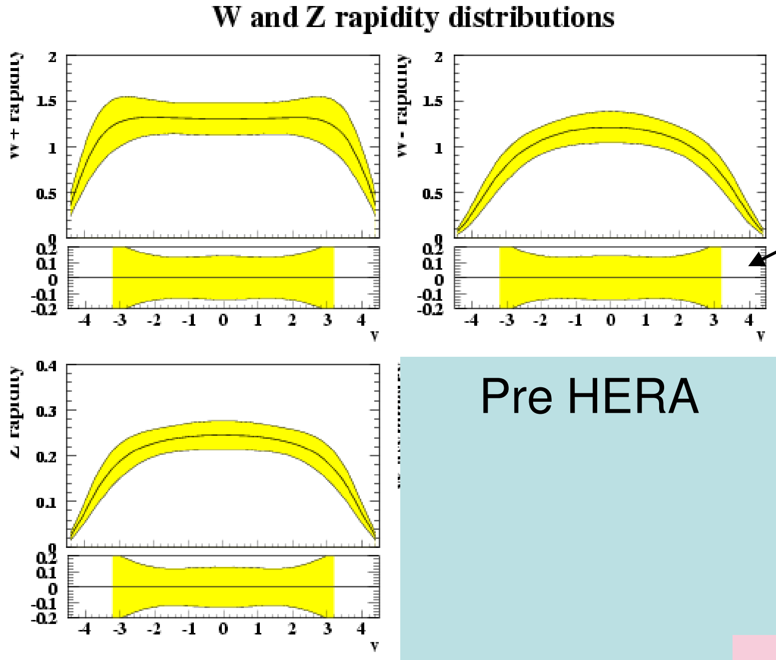
Can be used as a luminosity monitor?

HERAPDF1.0 experimental uncertainties are VERY small

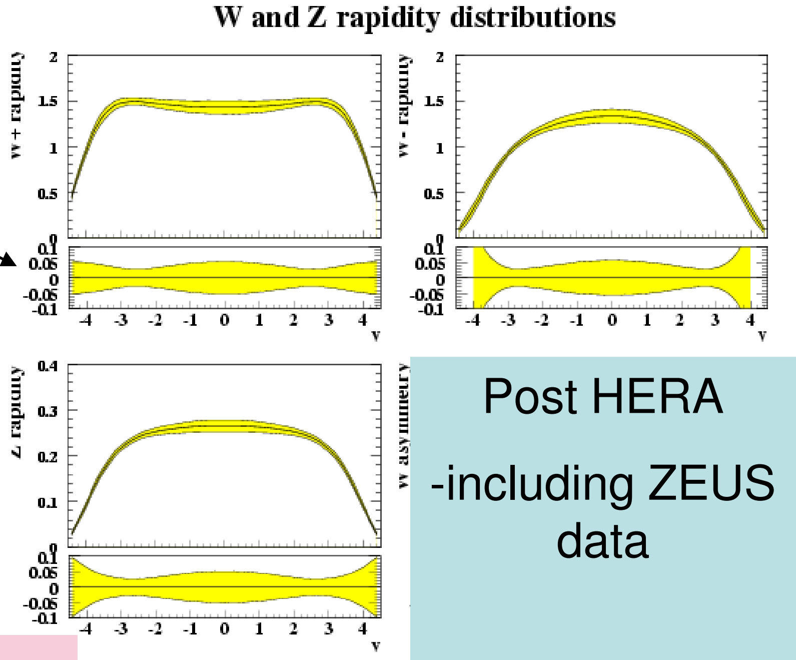
Model/parametrization uncertainties increase this…

WHY DO WE KNOW IT SO WELL? BECAUSE OF HERA.

Look in detail at predictions for W/Z rapidity distributions: Pre- and Post-HERA



Note difference in scale for fractional errors

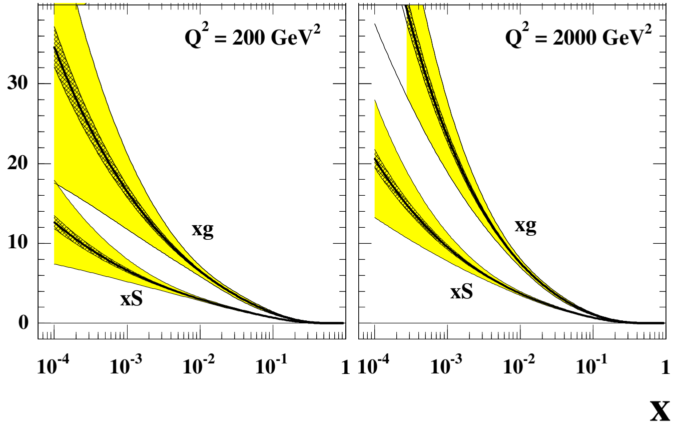


Pre HERA

Why such an improvement ?

Post HERA

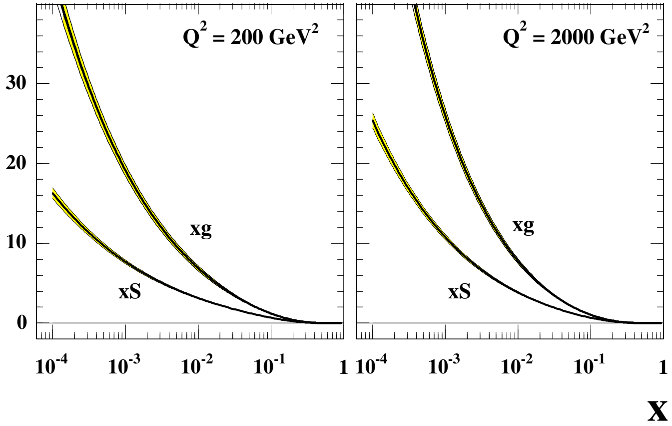
-including ZEUS data



It's due to the improvement in the low-x sea and gluon

At the LHC the q-qbar which make the boson are mostly sea-sea partons

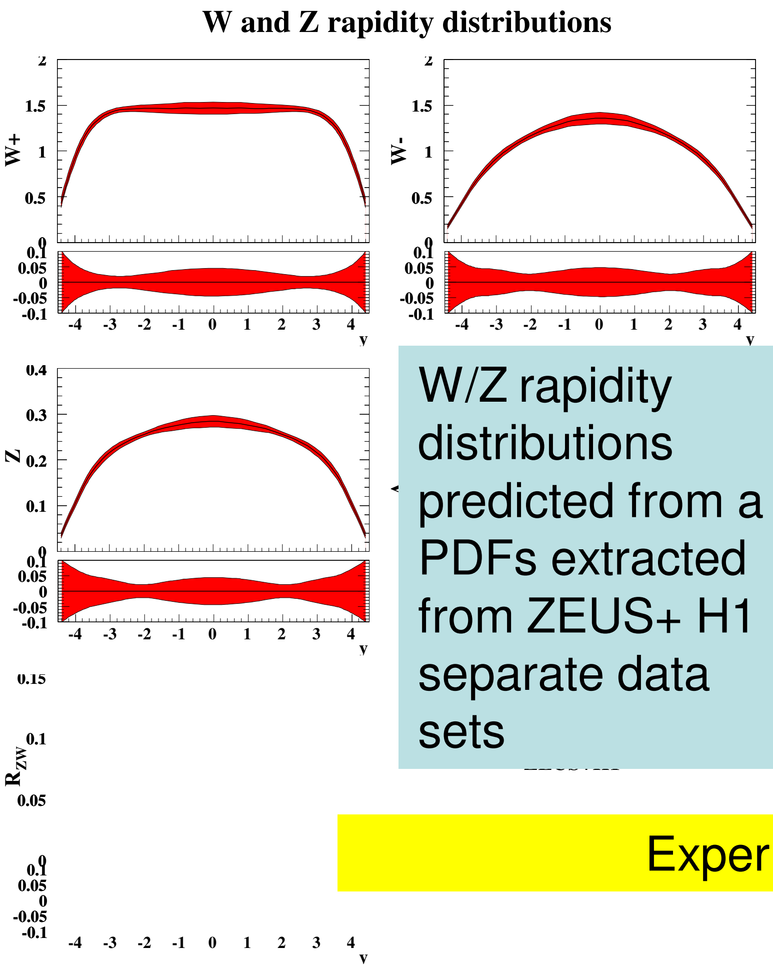
And at $Q^2 \sim M_Z^2$ **the sea is driven by the gluon**



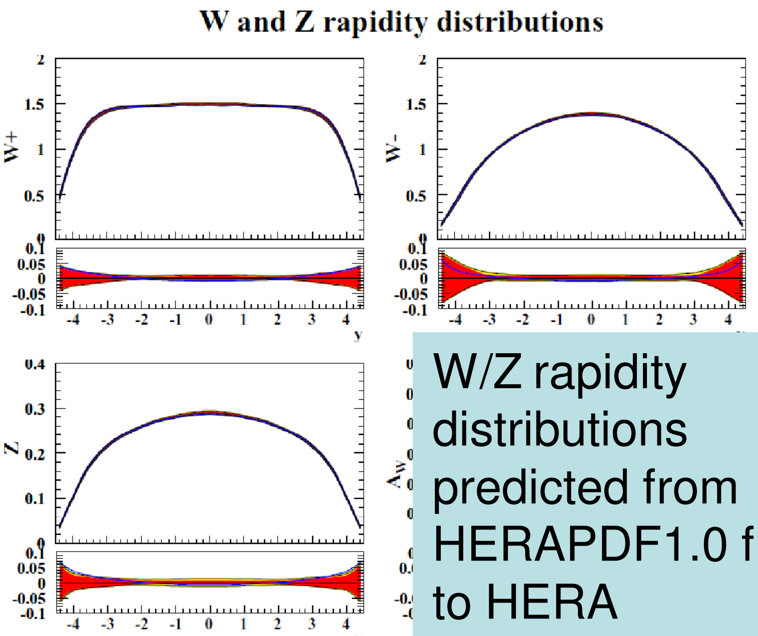
These illustrations at 14 TeV

And now we have much better HERA data from the H1/ZEUS combination

Use the HERAPDF to predict W and Z rapidity distributions at the LHC



W/Z rapidity distributions predicted from a PDFs extracted from ZEUS+ H1 separate data sets

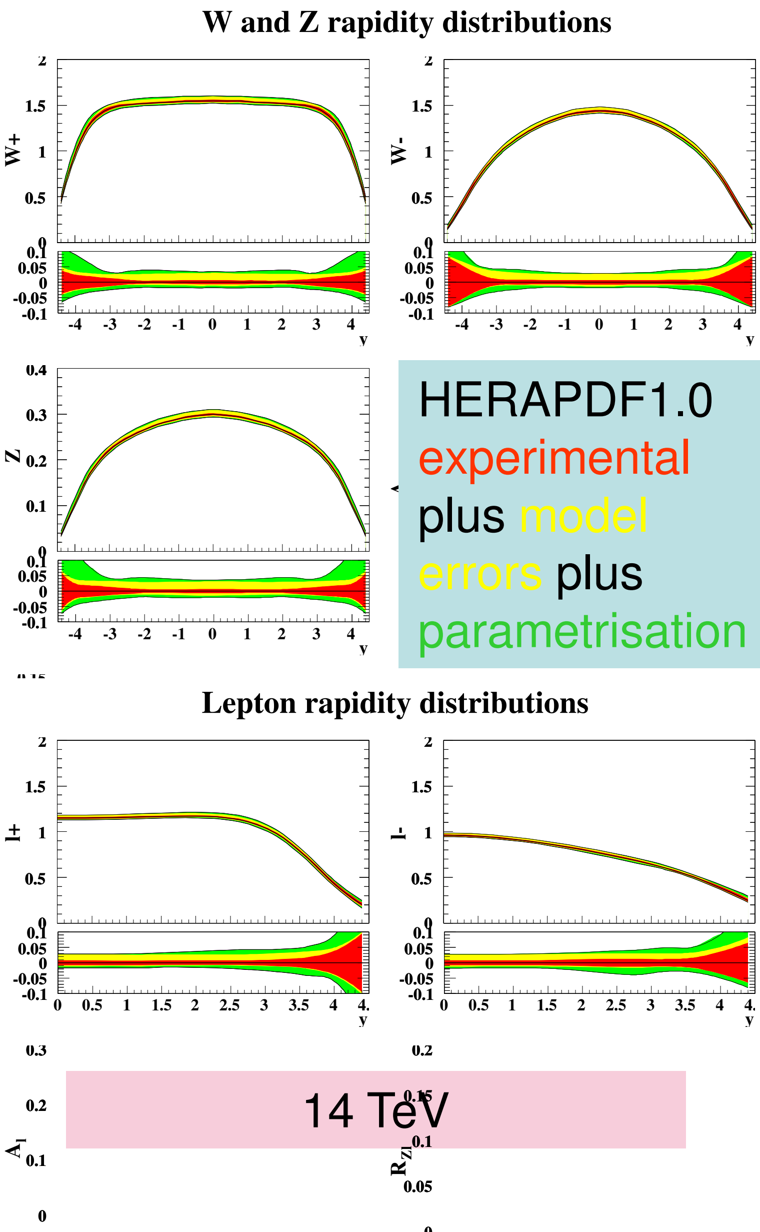


W/Z rapidity distributions predicted from HERAPDF1.0 fit to HERA combined data

Experimental errors only

Use the HERAPDF to predict W and Z rapidity distributions at the LHC

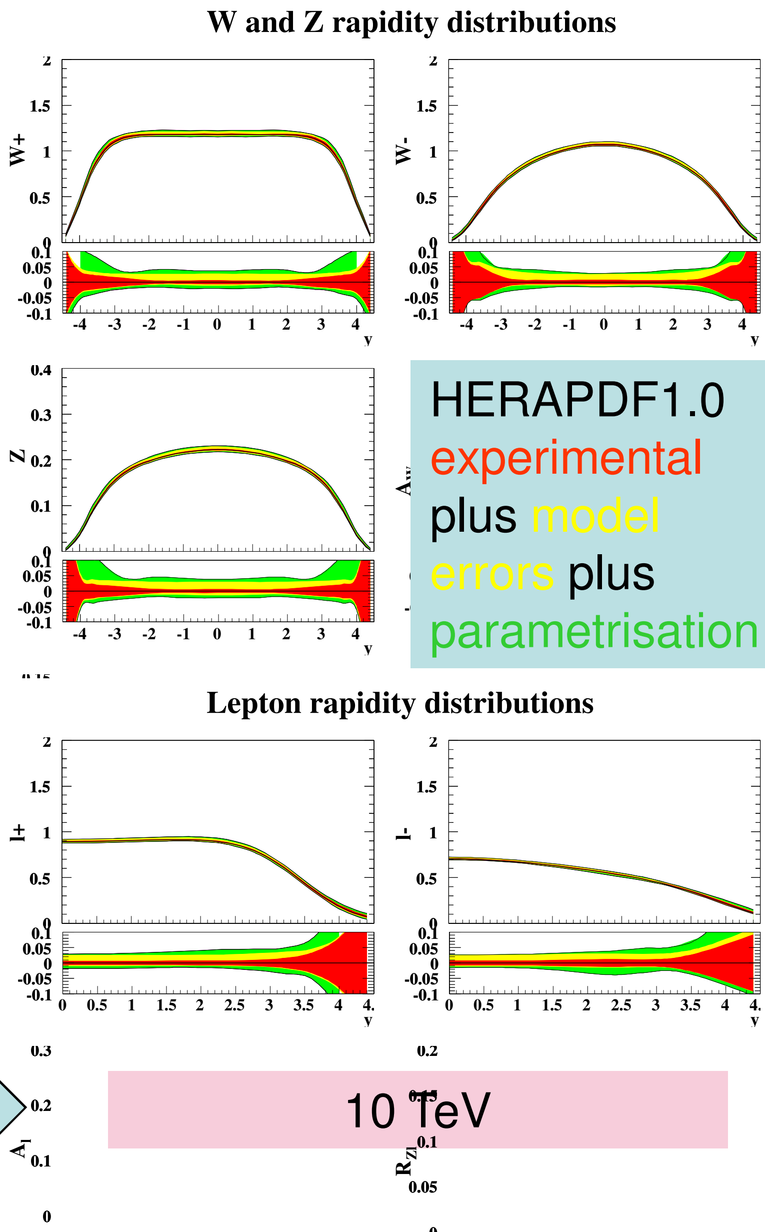
Now add model and parametrisation uncertainties


W and Z rapidity distributions

Lepton rapidity distributions

HERAPDF1.0
experimental
plus model
errors plus
parametrisation

14 TeV


W and Z rapidity distributions

Lepton rapidity distributions

HERAPDF1.0
experimental
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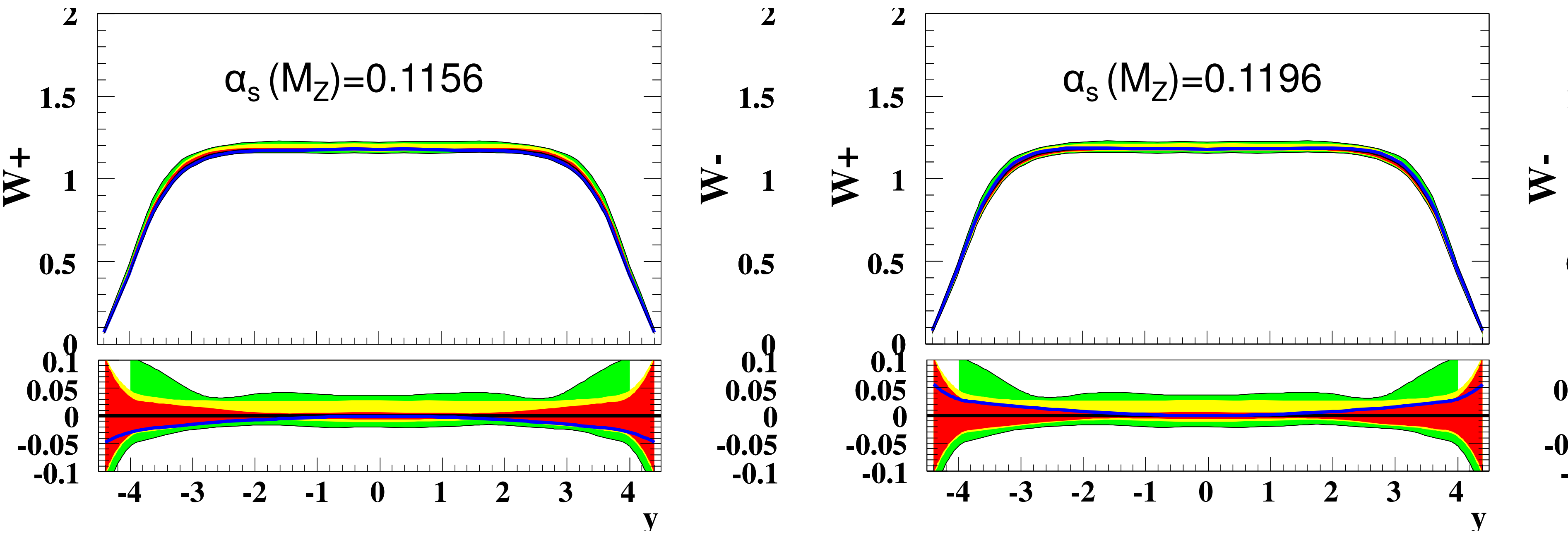


Looking at the uncertainties at central rapidity

Very small experimental uncertainty < 1%.

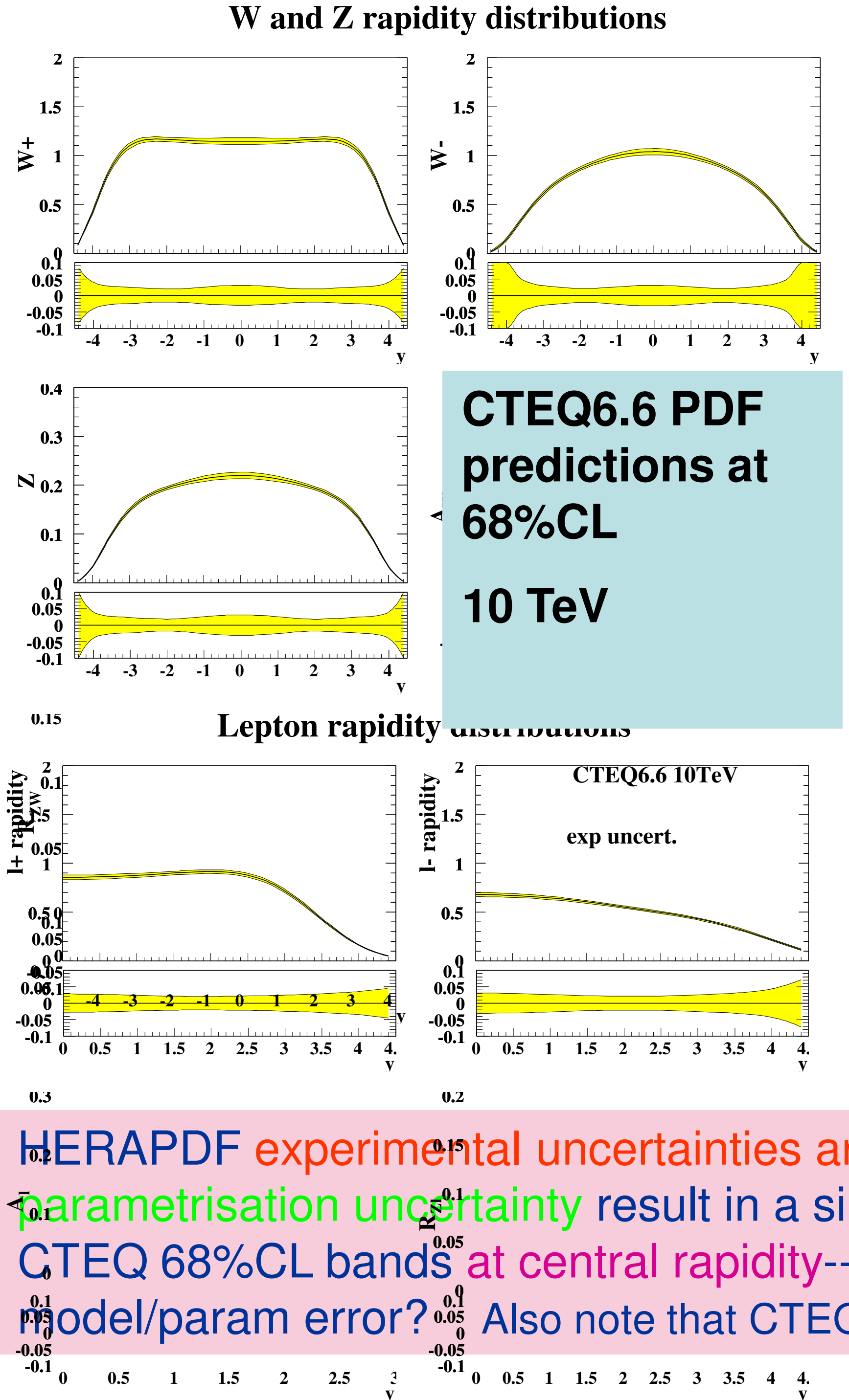
Model uncertainty ~2.5% from value of m_c and choice of Q20

Parametrisation uncertainty <~2% (But larger at high rapidity)

And one further point- the blue line on these plots illustrates the effect of variation of $\alpha_S(M_Z)$ from 0.1176 to 0.1196.. at 10 TeV

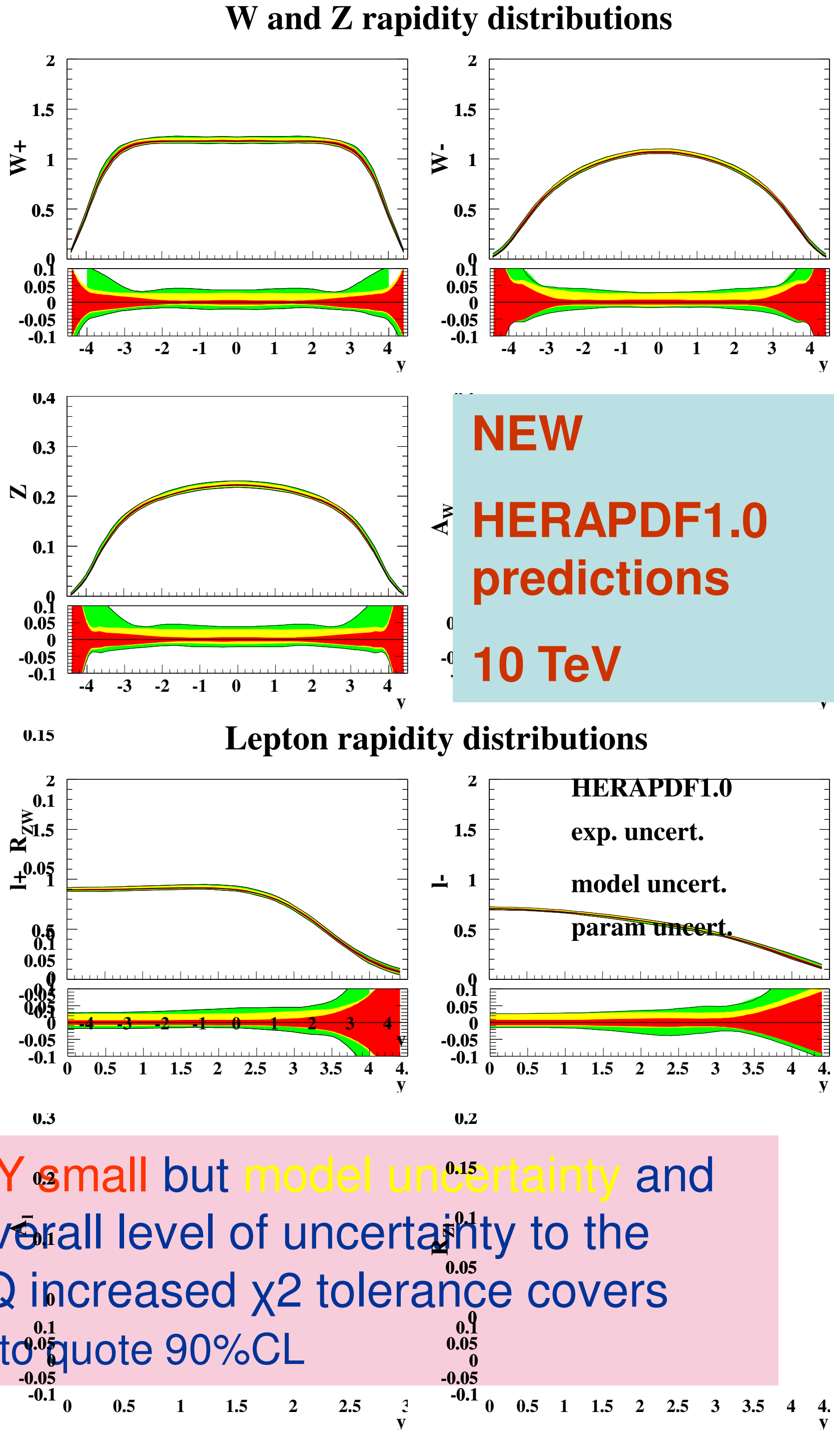
The effect is similar for W+, W-,Z and the decay leptons from the W's.

There is very little effect of $\alpha_S(M_Z)$ on the Asymmetry or Z/W ratio.



CTEQ6.6 PDF predictions at 68%CL

10 TeV

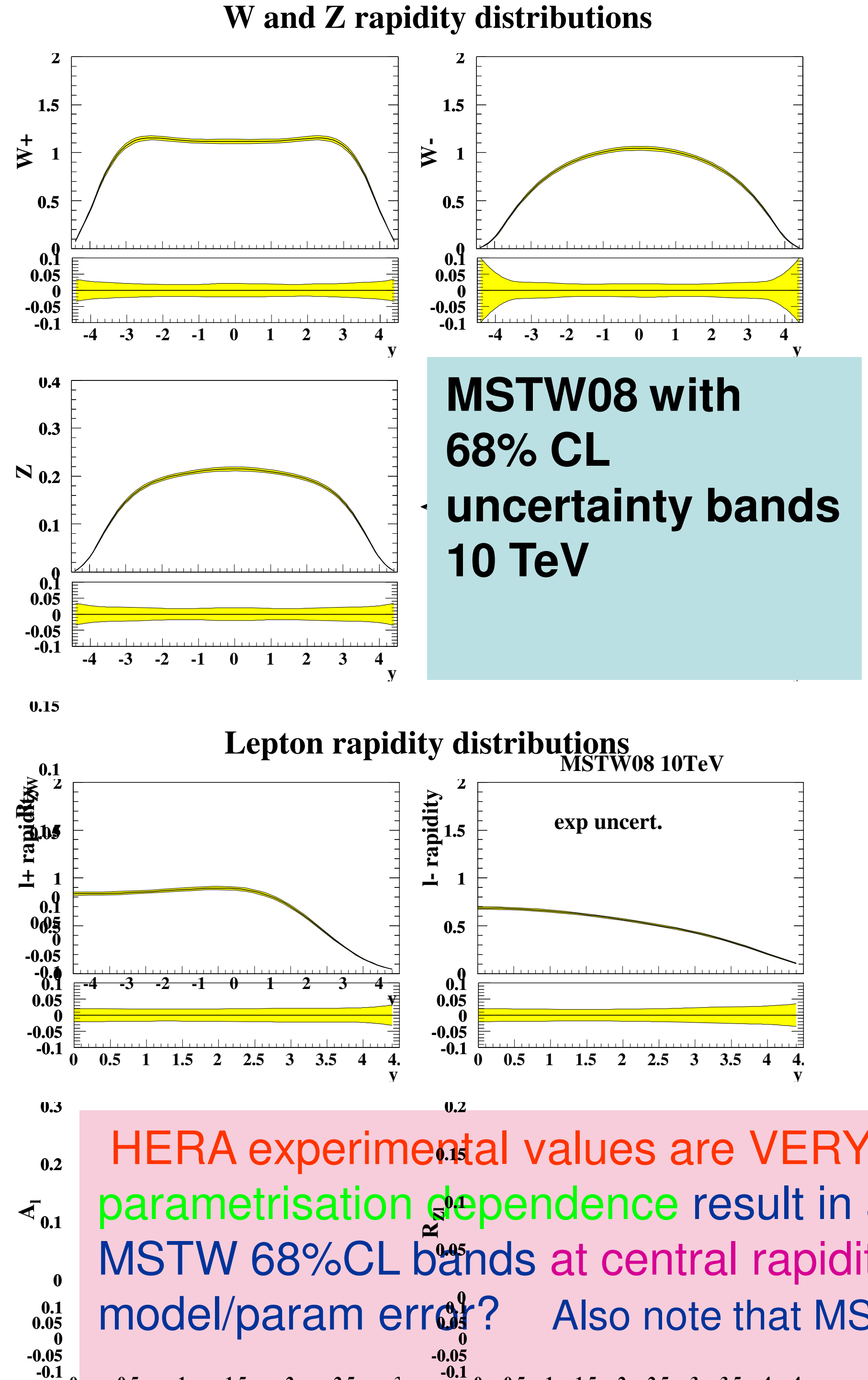


NEW

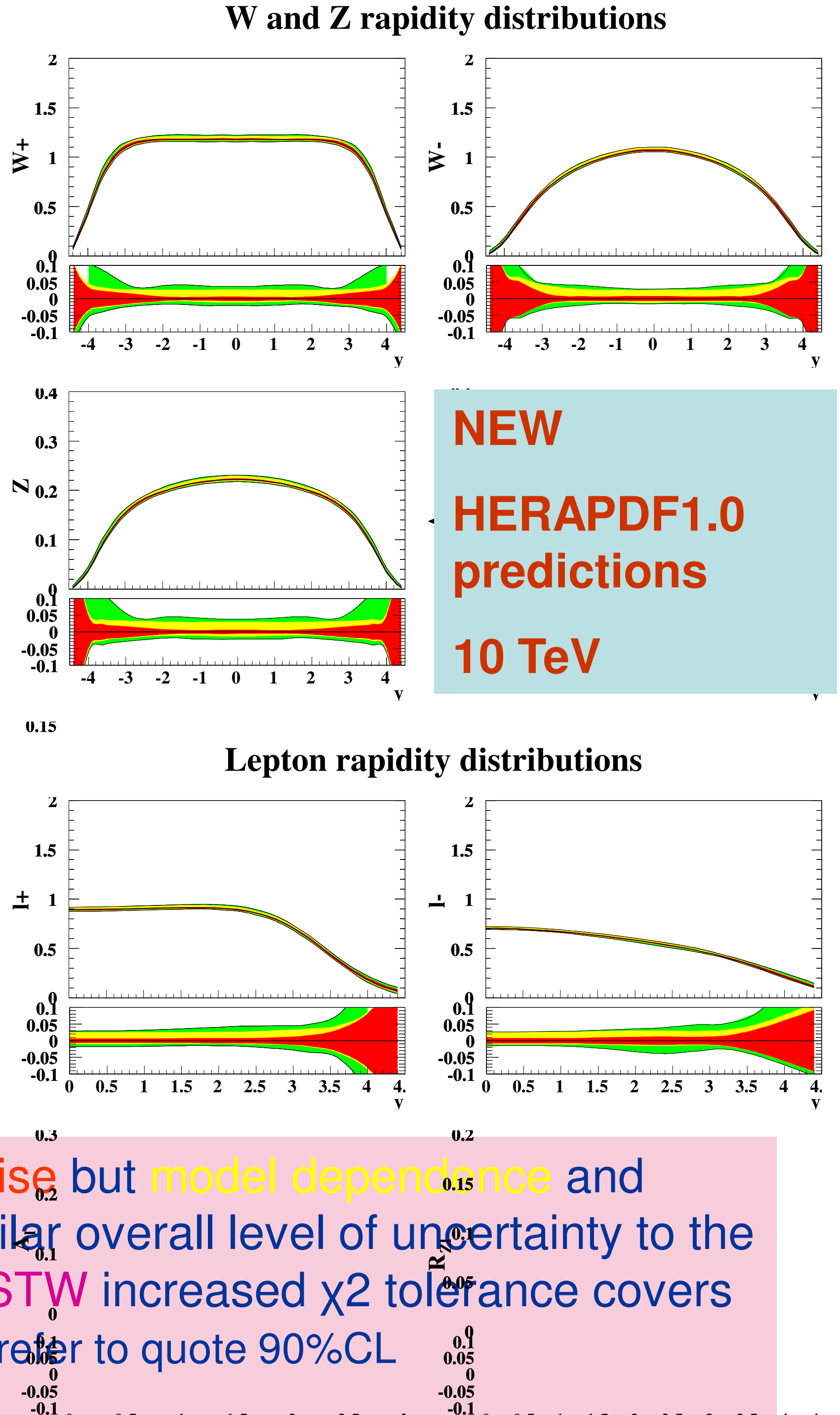
HERAPDF1.0 predictions

10 TeV

HERAPDF experimental uncertainties are VERY small but model uncertainty and parametrisation uncertainty result in a similar overall level of uncertainty to the CTEQ 68%CL bands at central rapidity--- CTEQ increased χ2 tolerance covers model/param error? Also note that CTEQ prefer to quote 90%CL



MSTW08 with 68% CL uncertainty bands 10 TeV



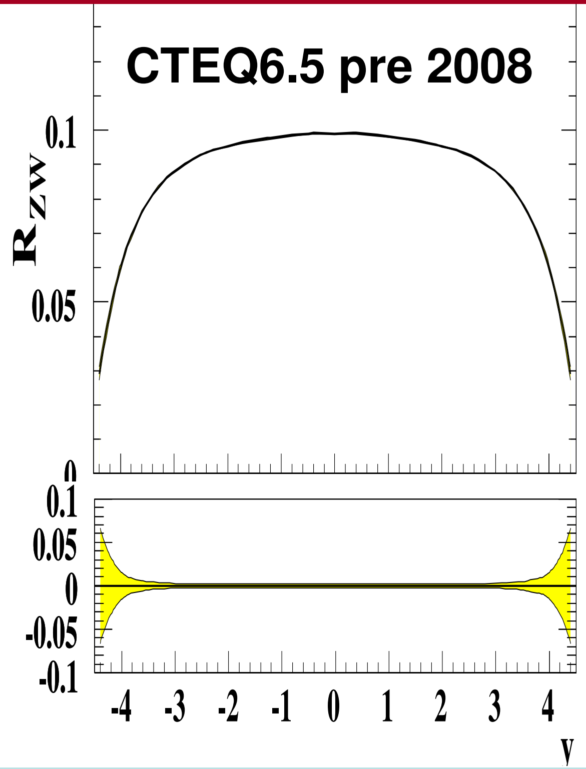
NEW

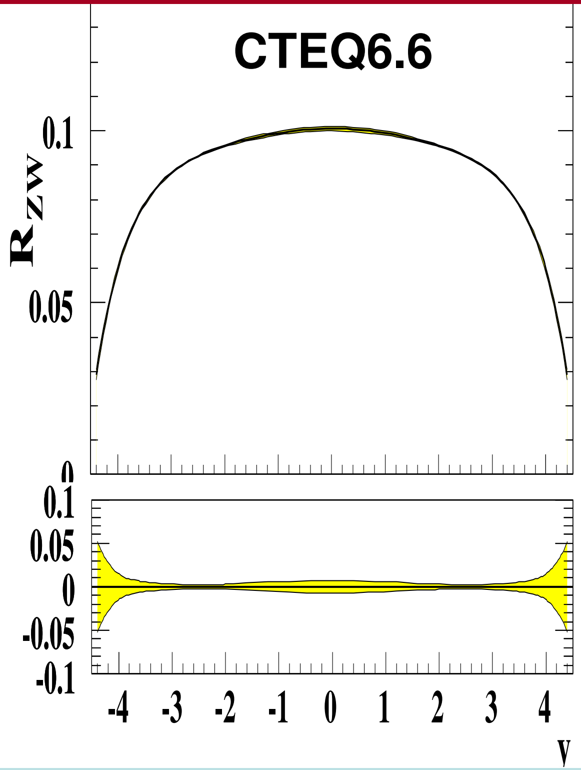
HERAPDF1.0 predictions

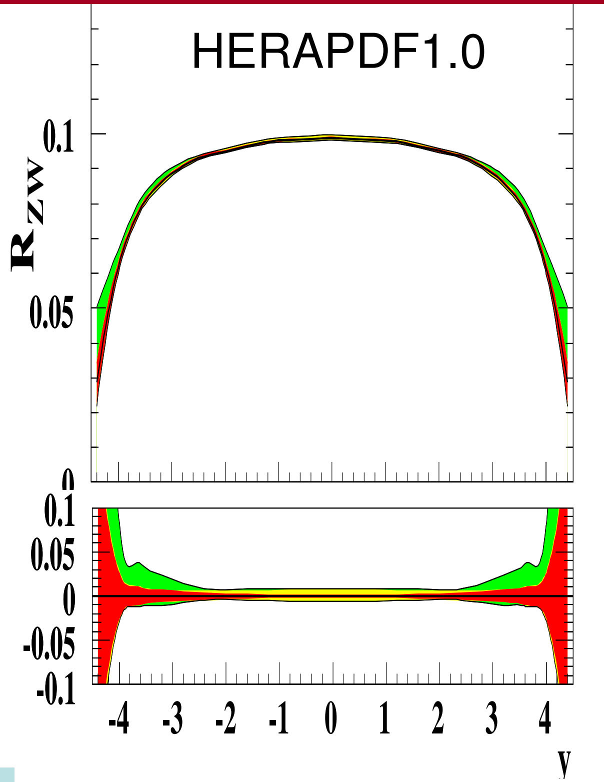
10 TeV

HERA experimental values are VERY precise but model dependence and parametrisation dependence result in a similar overall level of uncertainty to the MSTW 68%CL bands at central rapidity. MSTW increased χ2 tolerance covers model/param error? Also note that MSTW prefer to quote 90%CL

Now let's look at ratios: Z/W ratio is a golden benchmark measurement - 10TeV







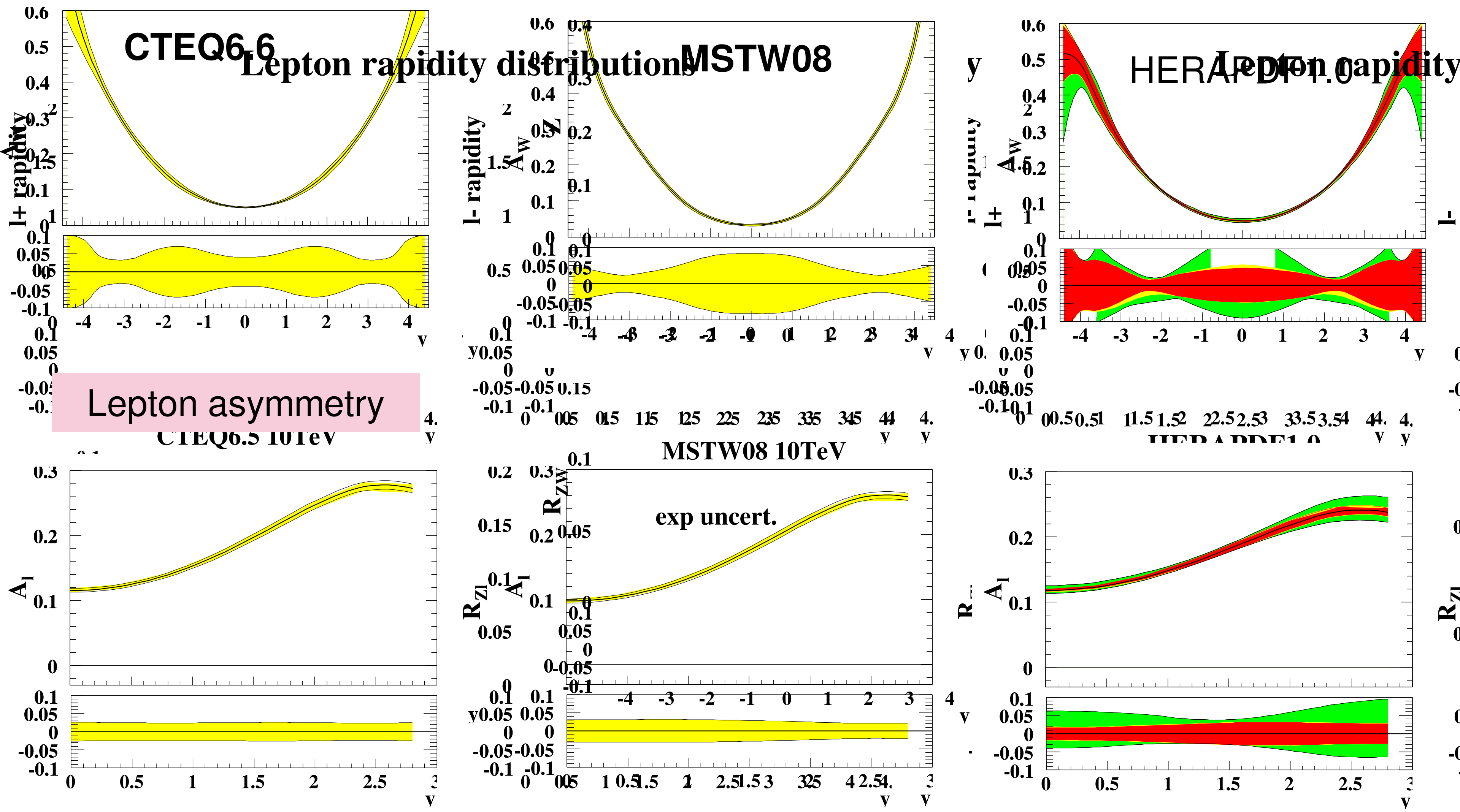
ZOOM in on Z/W ratio – there is fantastic agreement between PDF providers PDF uncertainty from the low-x gluon and flavour symmetric sea cancels out- and so do luminosity errors BUT there is somewhat more PDF uncertainty than we thought before 2008 (~1.5% rather than <1% in the central region)

This is due to the strangeness sector -it does not cancel out between Z and (W^+ + W^-)… it was always there we just didn't account for it

$$\frac{Z}{W^+ + W^-} = \frac{\text{u-ubar + d-dbar + s-sbar +c-cbar +b-bbar}}{\sim \text{(u-dbar + c-sbar) + (d-ubar+s-cbar)}}$$

YES this does translate to the Z/lepton ratio

But in the W asymmetry – there is NOT fanatastic agreement -10 TeV



Lepton asymmetry

Further sources of PDF uncertainty from the valence sector are revealed. . See extras

Summary on WZ

Prediction of W/Z at LHC from HERAPDF1.0 based on optimal HERA data combination –sorts out experimental uncertainty from model uncertainty from parametrisation uncertainty

For W, Z and decay lepton rapidity spectra in the central region

1. Very small experimental uncertainty < 1%.
2. Model uncertainty ~2.5% from value of m_c and choice of Q^2_0
3. Parametrisation uncertainty <~2% (But larger at high rapidity)

HERA combination improves our ability to make precision SM predictions for the LHC

For Z/W ratio

1. Very small experimental uncertainty~1% and Very small model/param uncertainty in both Z/W ratio and Z/lepton ratio~1-2

Golden SM benchmark measurement

For W asymmetry

- Experimental uncertainty~5%. Remaining model/parametrisation uncertainty in W and lepton asymmetry can be even larger
- LHC measurements will increase our knowledge of PDFS

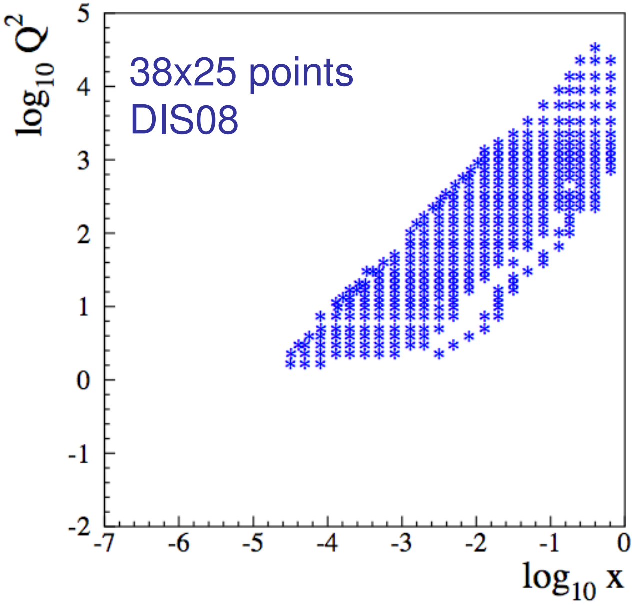
extras

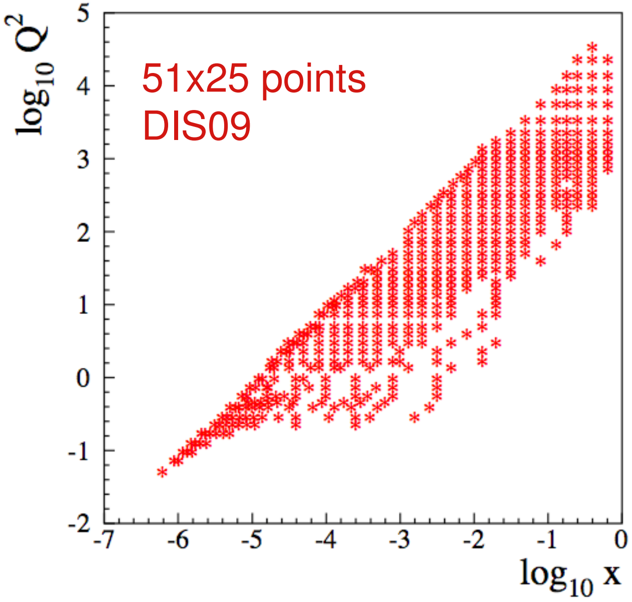
- Comination procedure
- HERAPDf1.0
- W/Z predictions 10/14TeV

x-Q^2 common grid

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

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





Negligable 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:

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

Neutral Current:

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

with

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

Form of the chisq

Described in detail in arXiv:0904.0929

Additive error sources:

$$\chi^2_{\mathrm{exp}}\left(\boldsymbol{m},\boldsymbol{b}\right) = \sum_i \frac{\left[m^i - \sum_j \Gamma^i_j b_j - \mu^i\right]^2}{\Delta_i^2} + \sum_j b_j^2.$$

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

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

with $$\gamma^i_j = \Gamma^i_j/\mu^i \quad \delta_{i,\mathrm{stat}} = \Delta_{i,\mathrm{stat}}/\mu^i \quad \delta_{i,\mathrm{uncor}} = \Delta_{i,\mathrm{uncor}}/\mu^i$$

Procedural Uncertainties

Three procedural uncertainties are introduced:

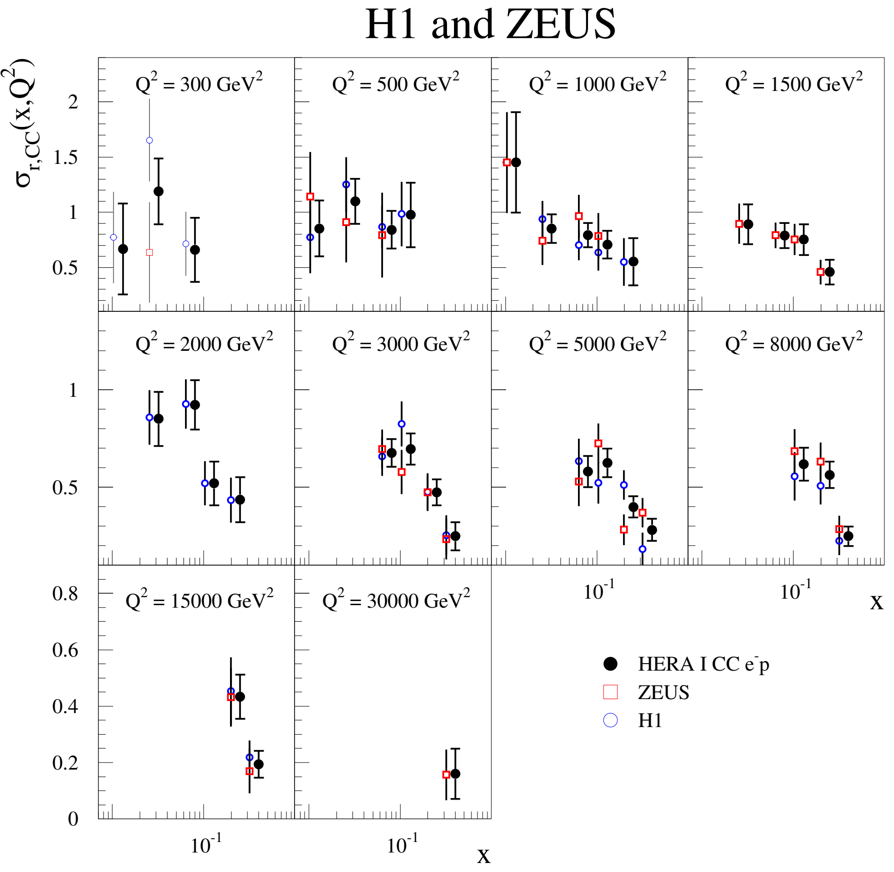
1. Additive vs Multiplicative nature of the error sources
   (Typically below 0.5%)

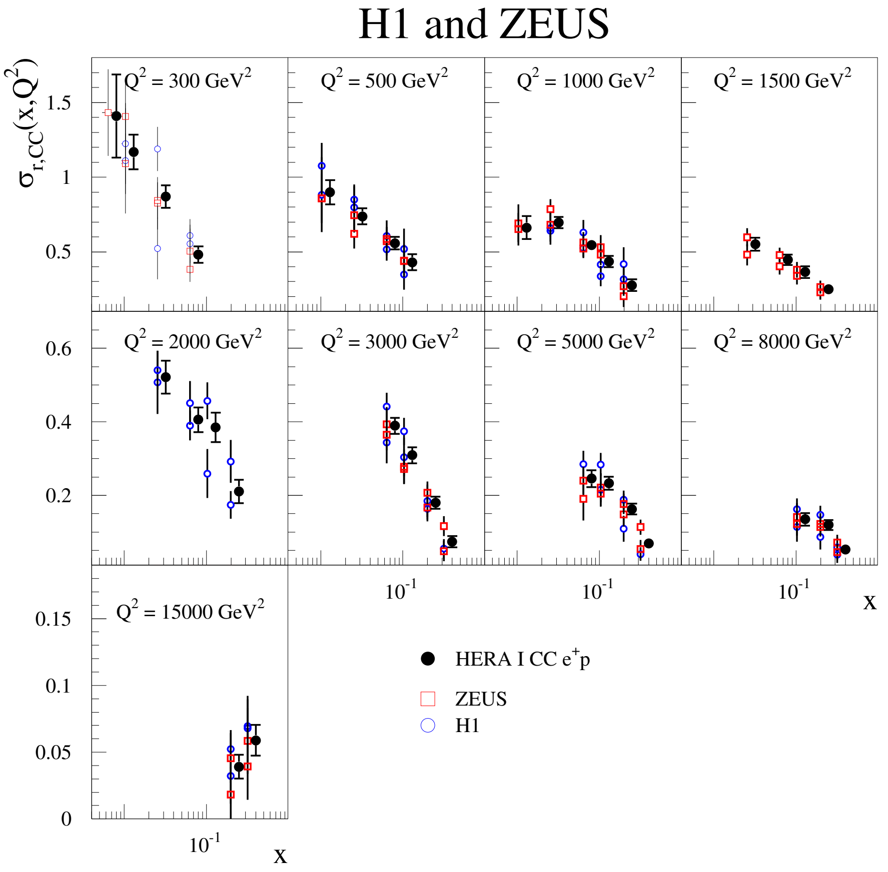
2. Correlated systematic unc. for the photoproduction background
   (Few % only at high-y)

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


H1 and ZEUS
$\sigma_{r,CC}(x,Q^2)$
Q^2 = 300 GeV^2
Q^2 = 500 GeV^2
Q^2 = 1000 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 = 15000 GeV^2
Q^2 = 30000 GeV^2
2
1.5
1
0.5
0.8
0.6
0.4
0.2
0
10^{-1}
x
HERA I CC e^-p
ZEUS
H1


H1 and ZEUS
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Q^2 = 300 GeV^2
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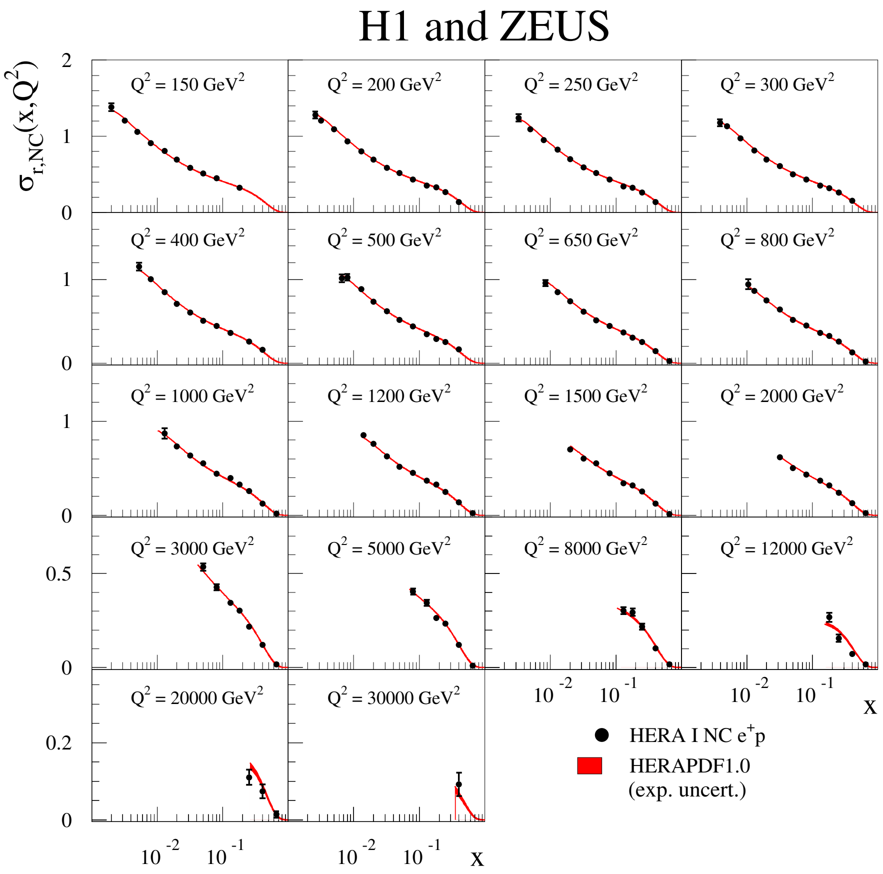
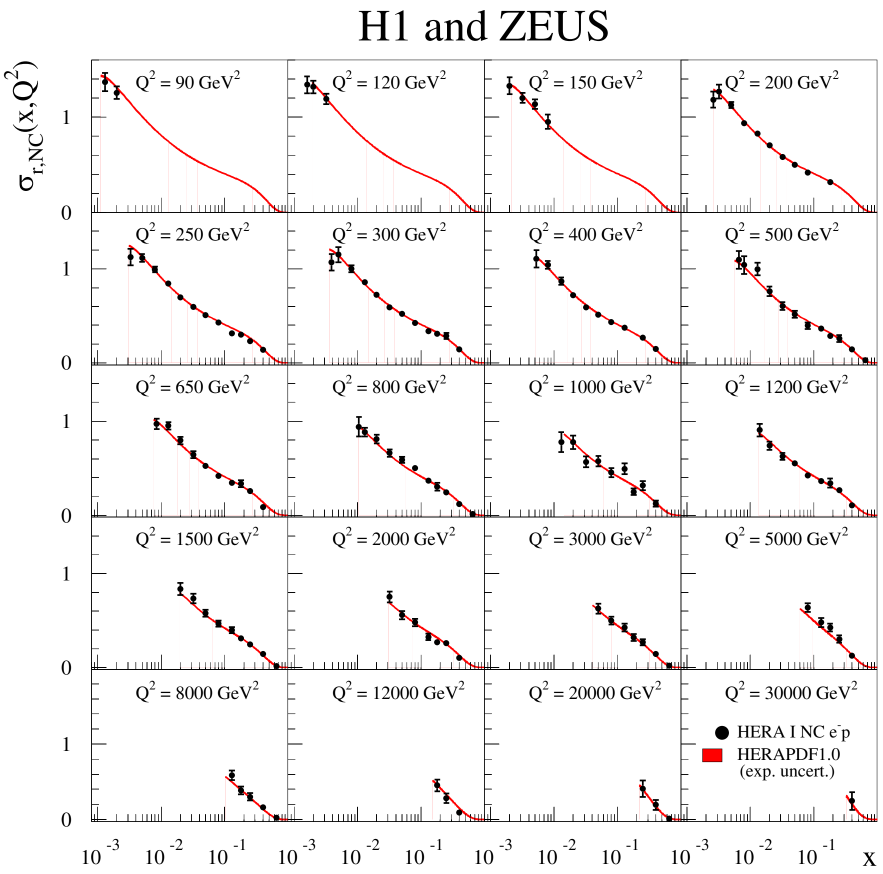
Q^2 = 1500 GeV^2
Q^2 = 2000 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5000 GeV^2
Q^2 = 8000 GeV^2
Q^2 = 15000 GeV^2
1.5
1
0.5
0.6
0.4
0.2
0.15
0.1
0.05
0
10^{-1}
x
HERA I CC e^+p
ZEUS
H1

CC e-p

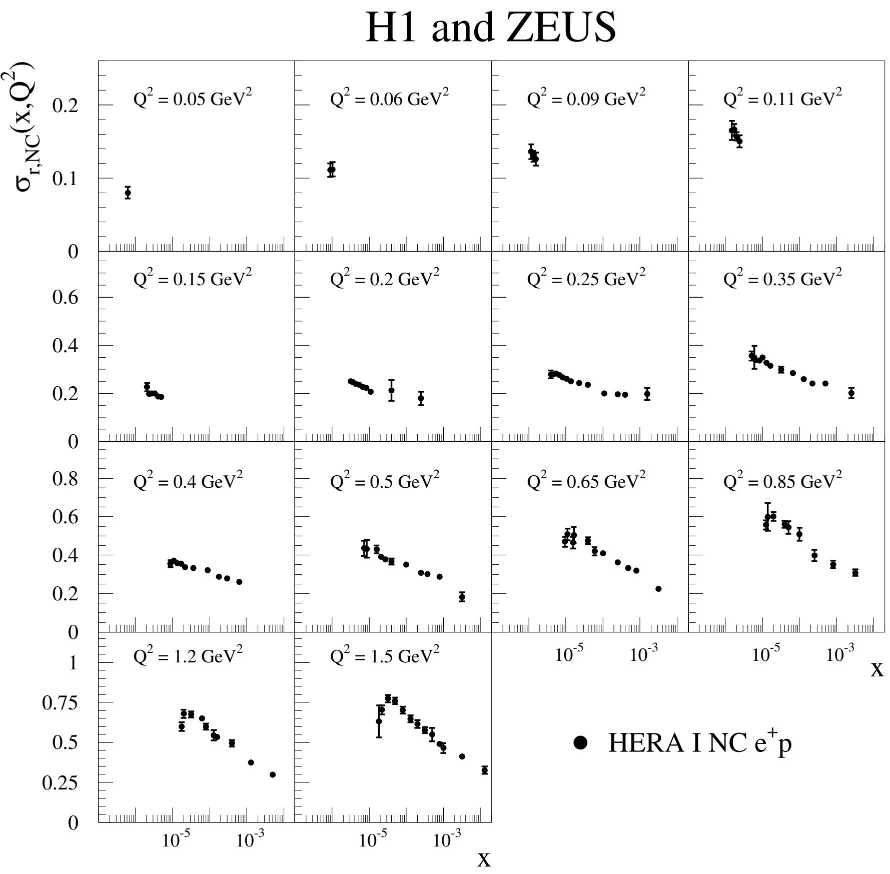
CC e-p



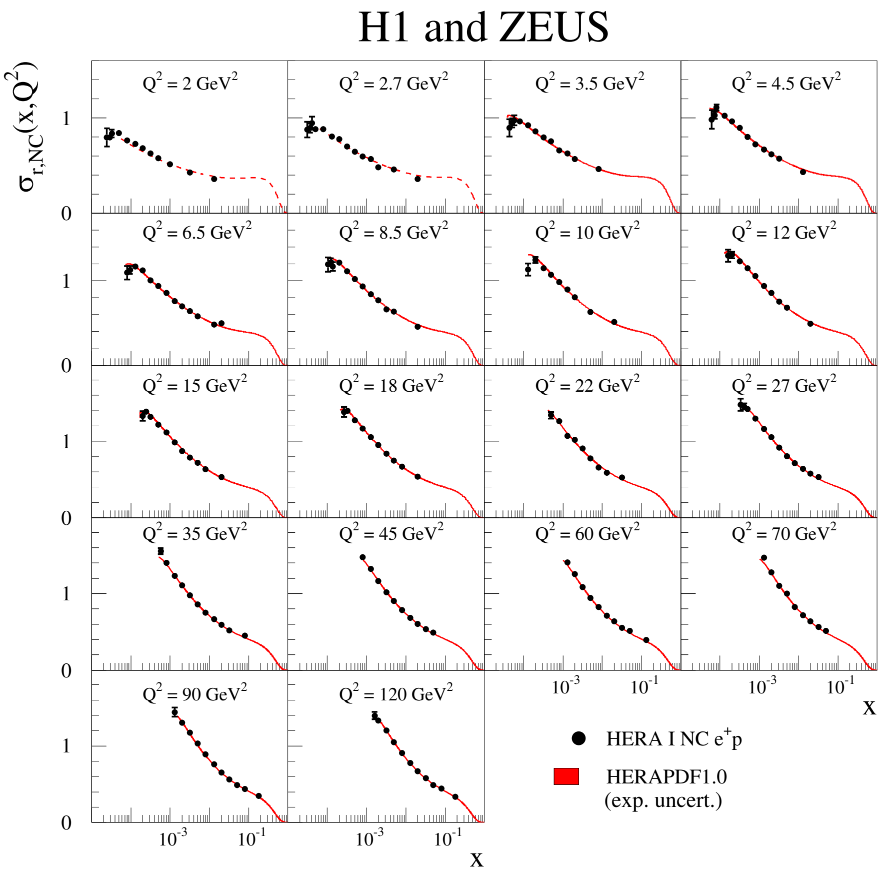


NC e+p high Q2

NC e-p



NC e+p low Q2



NC e+p med. Q2

Where does the information on PDFs come from in a HERA only fit?

CC e-p

$$\frac{d^2\sigma(e^-p)}{dxdy} = \frac{G_F^2\, M^4_W}{2\pi x(Q^2+M^2_W)^2}\,[x\,(u+c) + (1-y)^2 x\,(\bar{d}+\bar{s})]$$

CC e+p

$$\frac{d^2\sigma(e^+p)}{dxdy} = \frac{G_F^2\, M^4_W}{2\pi x(Q^2+M^2_W)^2}\,[x\,(\bar{u}+\bar{c}) + (1-y)^2 x\,(d+s)]$$

- We can use the reduced cross-sections to learn about high-x valence PDFs

For NC e+ and e-

$$\frac{d^2\sigma(e\pm N)}{dxdy} = \frac{2\pi\alpha^2 s}{Q^4}\, Y+\ \left[\ \mathbf{F_2}(x,Q^2) - \frac{y^2\, \mathbf{F_L}}{Y+}(x,Q^2) \pm \frac{Y\_x\mathbf{F_3}}{Y+}(x,Q^2)\right], \quad Y\pm = 1 \pm (1-y)^2$$

$F_2 = F_2^{\gamma} - v_e P_Z F_2^{\gamma Z} + (v_e^2+a_e^2)P_Z^2 F_2^Z$

$xF_3 = \quad - a_e P_Z\, xF_3^{\gamma Z} + 2v_e a_e P_Z^2\, xF_3^Z$

Where $P_Z^2 = Q^2/(Q^2 + M^2_Z)\ 1/\sin^2\theta_W$, and at LO

$[F_2\ _{,,} F_2^{\gamma Z}, F_2^Z] = \Sigma_i\ [e_i^2, 2e_i v_i, v_i^2+a_i^2][xq_i(x,Q^2) + xq_i(x,Q^2)]$

$[xF_3^{\gamma Z}, xF_3^Z] = \Sigma_i\ [e_i a_i, v_i a_i] \qquad [xq_i(x,Q^2) - xq_i(x,Q^2)]$

So that $xF_3^{\gamma Z} = 2x[e_u a_u u_v + e_d a_d d_v] = x/3\ (2u_v+d_v)$

Where $xF_3^{\gamma Z}$ is the dominant term in xF_3

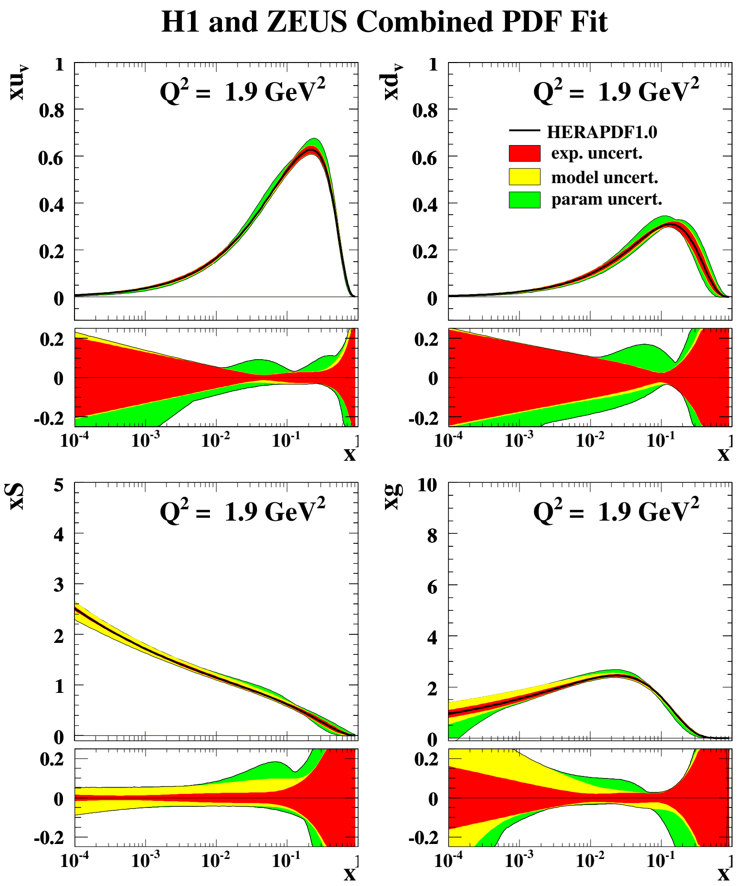
The difference between NC e+ and e- cross-sections gives the valence structure function xF3 due to γ/Z interference and Z exchange

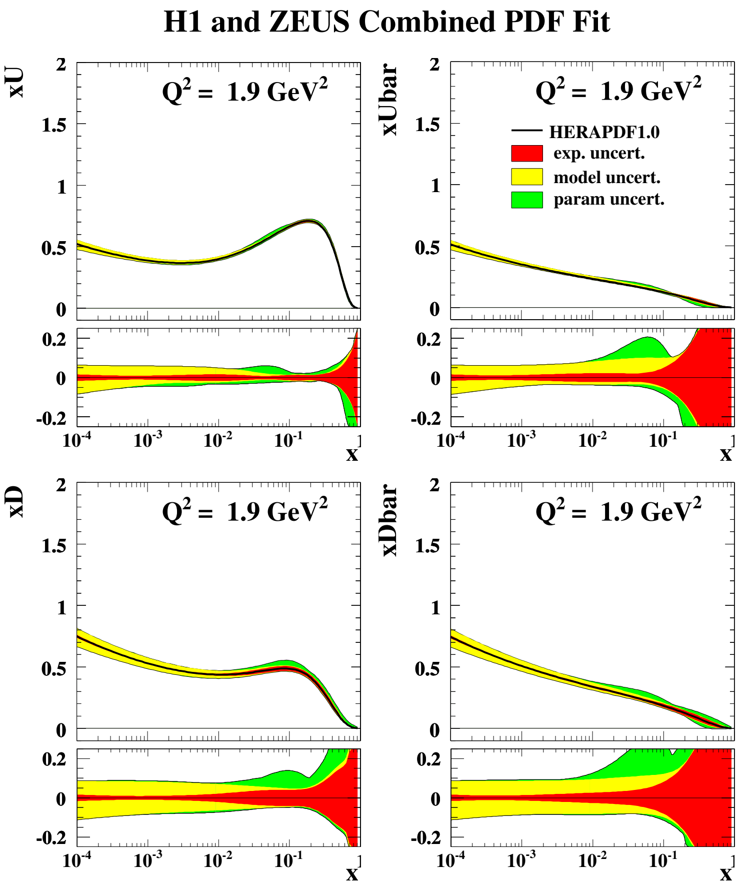
Note this is obtained on a pure proton target so

- No heavy target corrections
- No assumptions on strong isospin

(Unlike xF3 determined from neutrino scattering on heavy isocalar targets)

HERAPDF1.0 at the starting scale





At the staring scale the gluon is valence-like

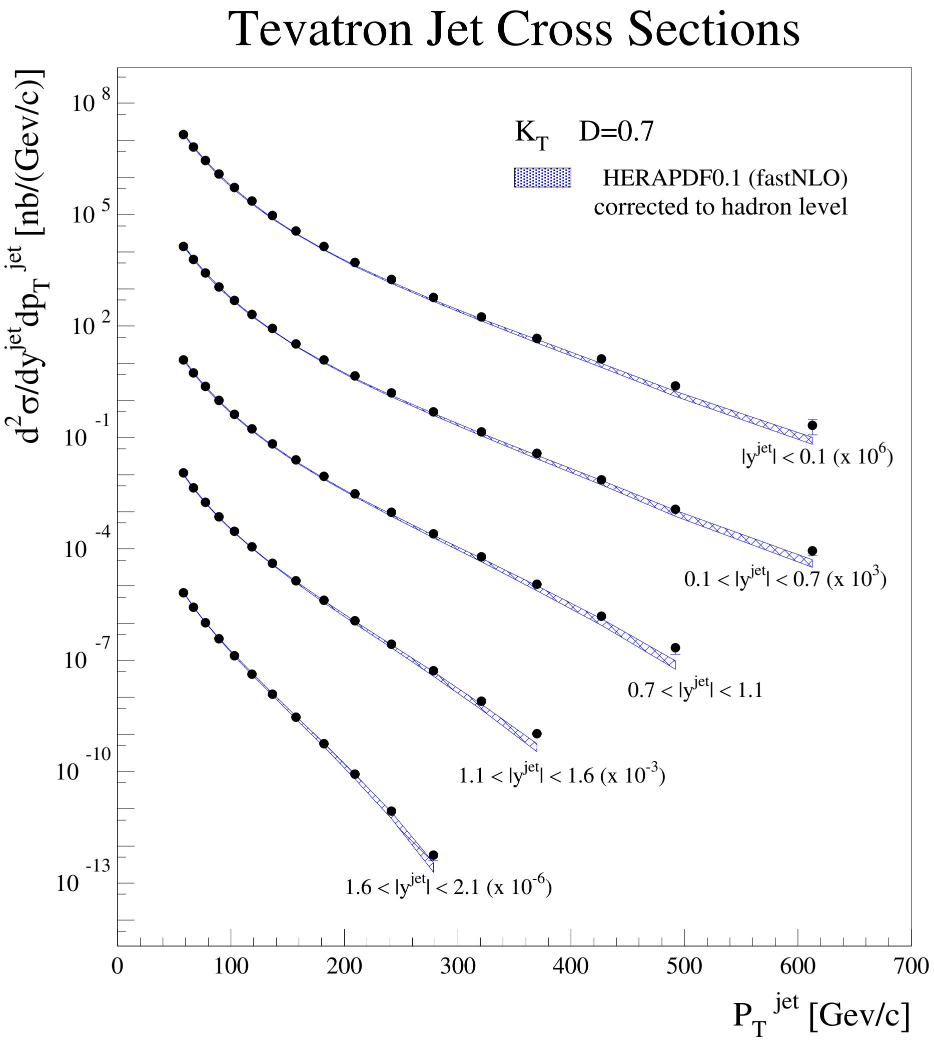
Variation of Q^2_0 and Q^2_{min} dominate the model uncertainty of sea and gluon at low-x

PDF parametrization uncertainty dominates valence PDFs and at high-x

Negative gluon term is visible at lowest-x

CDF Run-II jet data compared to HERAPDF0.1

Run-II jet data seem to be less hard than Run-I.. see Thorne's seminar



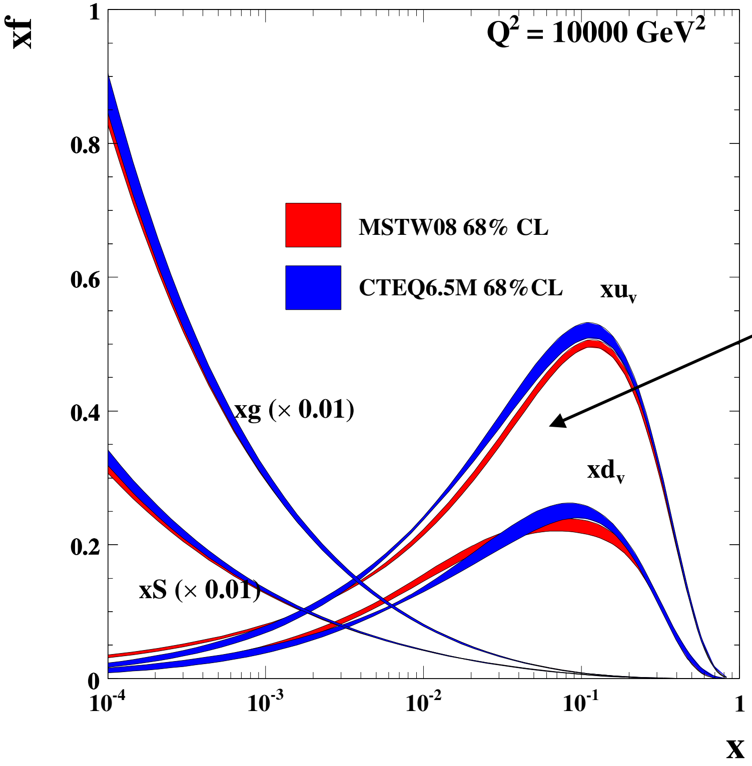
Dominantly, at LO $$A_W = \frac{(u(x_1)\,\mathrm{dbar}(x_2) - d(x_1)\,\mathrm{ubar}(x_2))}{(u(x_1)\,\mathrm{dbar}(x_2) + d(x_1)\,\mathrm{ubar}(x_2))}$$

Predictions for AW are different in the central region- because predictions for valence distributions at small-x are different

And at central rapidity $x_1 = x_2$

and ubar ~ dbar ~ qbar at small x

So $$A_W \sim \frac{(u - d)}{(u + d)} = \frac{(u_v - d_v)}{(u_v + d_v + 2\,\mathrm{qbar}\,)}$$



Actually this LO approx. is pretty good even quantitatively
The difference in valence PDFs you see here does explain the difference in A_W between MRST and CTEQ

As we move away from central rapidity: as x_1 increases (decreases) the larger (smaller) difference is weighted by larger (smaller) sea distributions at smaller (larger) x_2

x- range affecting W asymmetry in the measurable rapidity range at ATLAS (10TeV)

14 TeV W,Z xsecn table

PDF set	$\sigma_{W+} B_{W\to l\nu}$ (nb)	$\sigma_{W-} B_{W\to l\nu}$ (nb)	$\sigma_{Z} B_{Z\to ll}$ (nb)
ZEUS-2005	11.87±0.45	8.74±0.31	1.97±0.06
MSTW08	11.97±0.22	9.04±0.16	1.98±0.035
CTEQ66	12.34±0.34	9.06±0.22	2.02±0.04
HERAPDF01	**12.13±0.13**	**9.13±0.15**	**2.01±0.025**
HERAPDF10	**12.47±0.08**	**9.33±0.04**	**2.05±0.012**
CTEQ61	11.61±0.34	8.54±0.26	1.89±0.055
NNPDF1.0	11.83±0.26	8.41±0.20	1.95±0.04

PDF set	$\sigma_{W+} B_{W\to l\nu}$ (nb)	$\sigma_{W-} B_{W\to l\nu}$ (nb)	$\sigma_Z B_{Z\to ll}$ (nb)
HERAPDF10	**12.47±0.08** **±0.21 ±0.22**	**9.33±0.04** **±0.15 ±0.21**	**2.05±0.012** **0.04 ± 0.04**
fs=0.23-0.38	±0.01	±0.02	±0.005
Mb=1.43-1.5	±0.03	±0.02	0.005
Q^2_{min}=2.5-5.0	±0.03	±0.04	0.005
mc=1.35 mc=1.5	-0.06 +0.15	-0.05 +0.12	-0.02 +0.03
Q^2_0=2.5/mc=1.6	+0.25	+0.22	+0.04
Q^2_0=1.5	-0.11	-0.05	-0.02
α_s=0.1156-0.1196	±0.12	±0.07	±0.02
Euv and Duv	+0.22	+0.12	+0.04
Q^2_0=1.5 neg glue	-0.22	-0.16	-0.03
Euv and DUbar	+0.11	+0.04	+0.02
Euv and DDbar	+0.15	+0.21	+0.04

Model dependences

At 14TeV

Changes of the charm mass matter quite a bit

Here is where we see the 'CTEQ effect'– lowering (raising) it is closer to massless (massive) so smaller W/Z cross-sections fall (rise)

Changes of parametrisation also matter

PDF set	$\sigma_{W+} B_{W\to l\nu}$ (nb)	$\sigma_{W-} B_{W\to l\nu}$ (nb)	$\sigma_{Z} B_{Z\to ll}$ (nb)
HERAPDF0.2	**8.92±0.07** **±0.15 ±0.15**	**6.47±0.03** **±0.11 ±0.12**	**1.43±0.01** **±0.03 ±0.03**
fs=0.23-0.38	±0.01	±0.01	±0.005
Mb=1.43-1.5	±0.01	±0.01	0.001
Q^2_{min}=2.5-5.0	±0.01	±0.01	0.003
Mc=1.35 Mc=1.5	-0.05 +0.10	-0.04 +0.08	-0.01 +0.02
Q^2_0=2.5/mc=1.6	+0.18	+0.15	+0.03
Q^2_0=1.5	-0.08	-0.06	-0.02
α_s=0.1156-0.1196	±0.08	±0.05	±0.015
Euv and Duv	+0.17	+0.08	+0.03
Q^2_0=1.5 neg glu	-0.14	-0.10	-0.02
Euv and DUbar	+0.08	+0.03	+0.01
Euv and DDbar	+0.11	+0.15	+0.03

Model dependences

10TeV

Changes of the charm mass matter quite a bit

Here is where we see the 'CTEQ effect'– lowering (raising) it is closer to massless (massive) so smaller W/Z cross-sections fall (rise)

Changes of parametrisation also matter

Other updated plots inc. H1 new 2009 data are in PDF4LHC_may_09.ppt
so are other HERAPDF1.0 W/Z and lepton plots at 10 and 14TeV