QCD analysis with determination of $\alpha_S(M_Z)$ based on HERA inclusive and jet data: HERAPDF1.6

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Low-x meeting

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What inclusive data?

The HERA-I and preliminary HERA-II combined NC and CC e+ and e- cross sections that go into HERAPDF1.5, 1.5f and 1.5NNLO– see talk of V Radescu

What jet data?

High Q^2 Inclusive jet production from ZEUS (HERA-I)
Low Q^2 inclusive jet production from H1(HERA-I)
HighQ^2 normalised jet cross-sections from H1 (HERA-I and II)

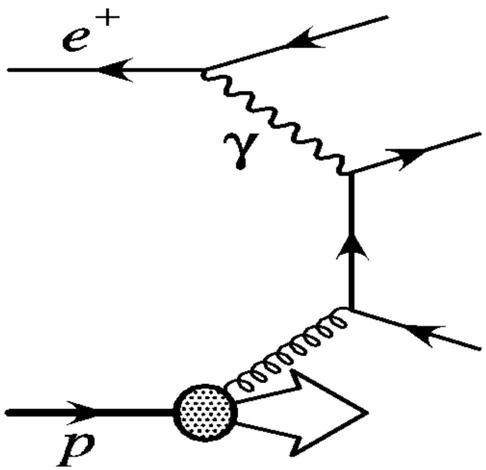
What QCD analysis?

The HERAPDF NLO fit formalism with free as well as fixed $\alpha_S(M_Z)$.
Thus QCDNUM17 is used for the DGLAP evolution of PDFs and to calculate inclusive cross sections (using Thorne variable flavour number scheme) and NLOjet++/FASTNLO is used for the fast evaluation of the jet cross sections.

Why include jet data?

The value of $\alpha_S(M_Z)$ is strongly correlated to the gluon PDF shape in fits to inclusive data alone because the gluon is determined from the scaling violations

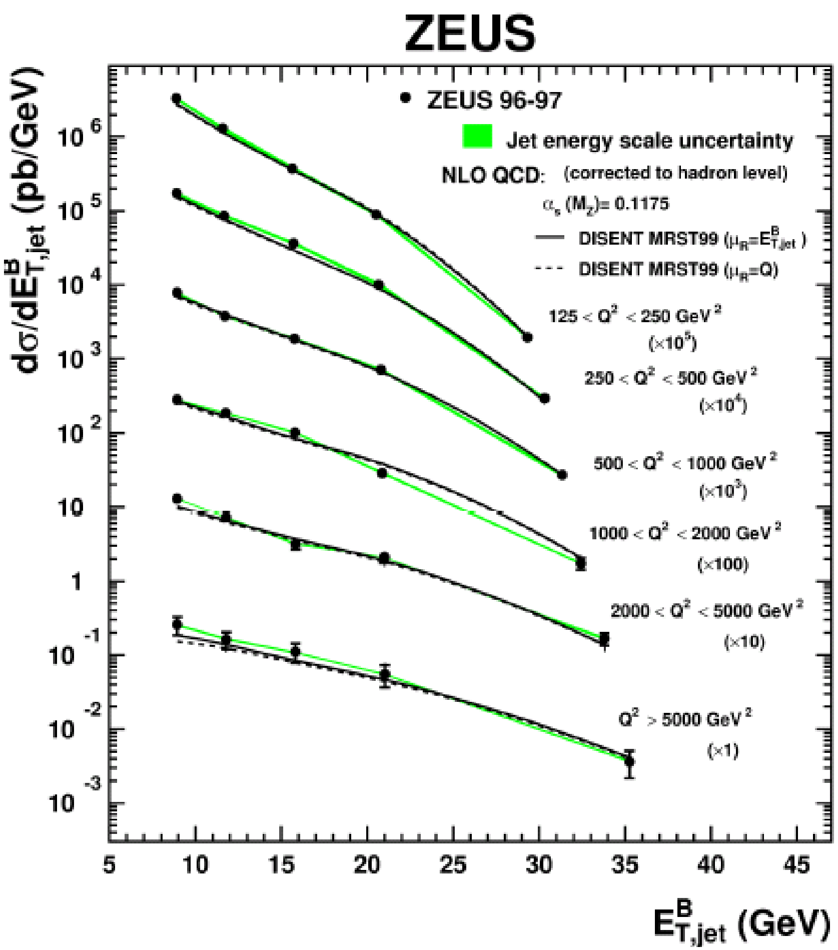
Jet data give us a cross-section which depends directly on the gluon PDF this extra information reduces the strong correlation

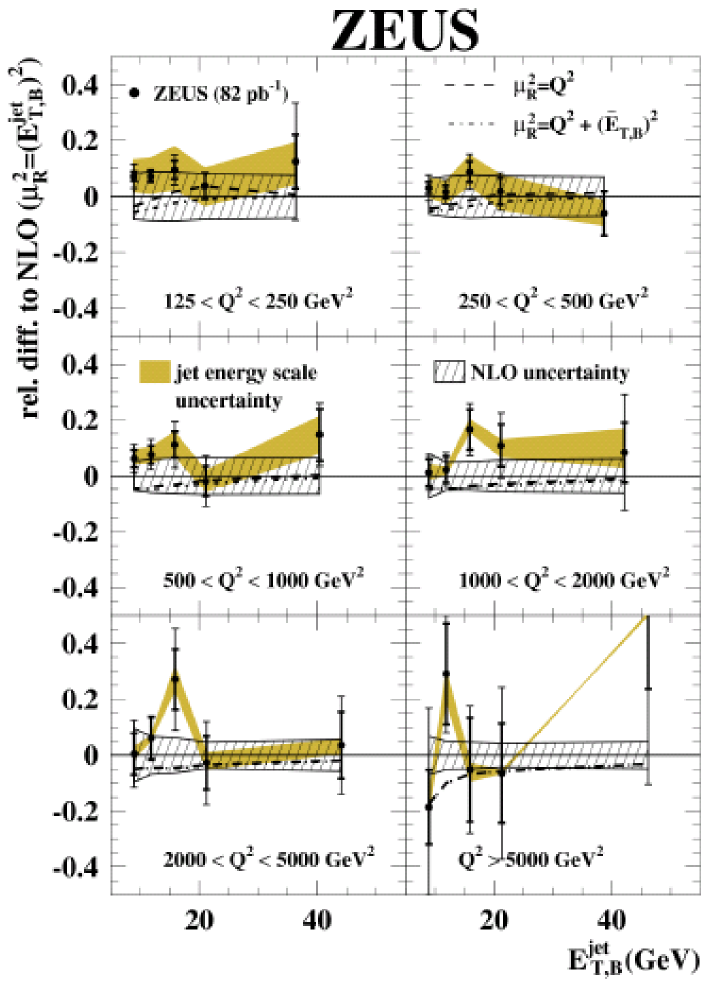


The jet cross-sections have non negligible correlated errors (~5%) even though the Jet Energy Scale is well determined (~1%).These systematic uncertainties are treated as fully correlated In addition to this the 3 procedural errors of the HERAI+II inclusive cross-section data are also treated as correlated. Correlations are treated as nuisance parameters by the Hessian method.

Predictions for jet cross-sections need hadronisation corrections which have some uncertainty. The uncertainties on the hadronisation corrections are evaluated by the Offset method

ZEUS data: 38.6pb^{-1} PLB547,164(2002) and 82pb^{-1} NPB765,1(2007)



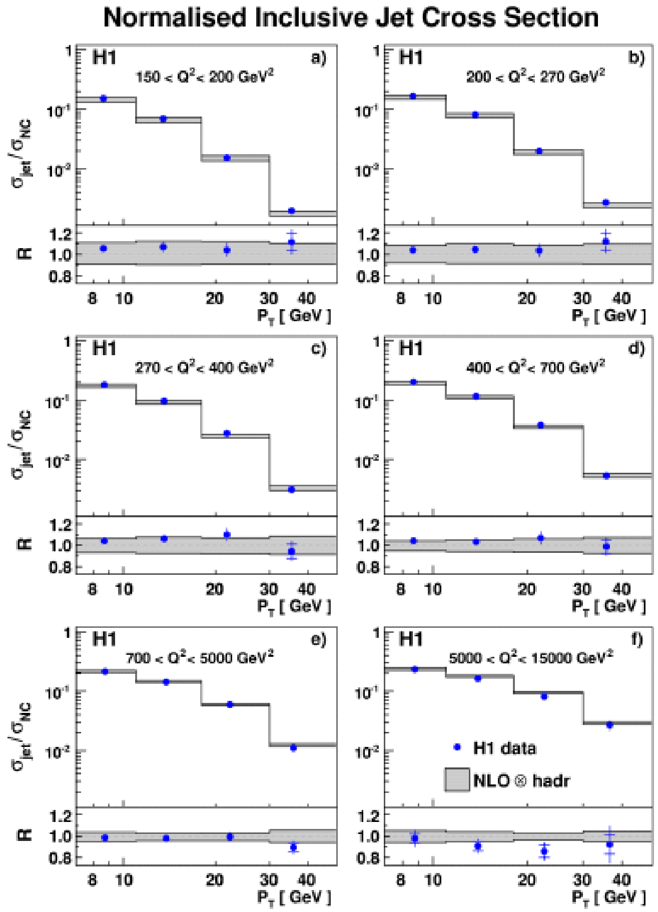


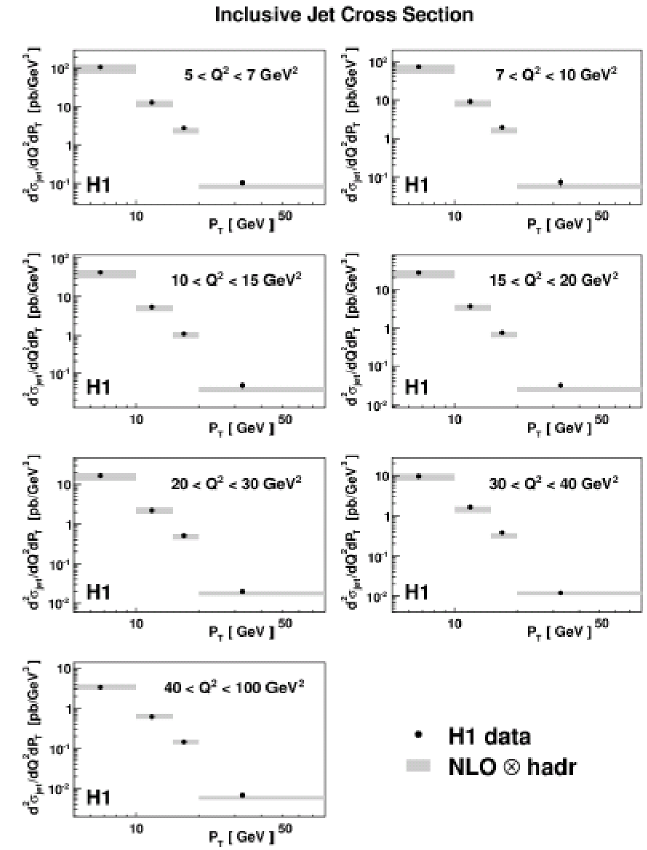
Experimental error ~15%uncorrelated and 4% correlated

Theoretical error ~ 5-10%, high Q^2 > 125 GeV^2

Scale of the jet measurement: ET of the leading jet

H1 data: 395pb^{-1}EPJC65,363(2010) and 43.5pb^{-1} EPJC67,1(2010)





Experimental error ~6% uncorrelated and 3% correlated

Theoretical error ~ 5-10%, high Q^2
150 <Q^2 <15000 GeV^2

Experimental error ~9% uncorrelated and 8% correlated

Theoretical error ~ 10-30%, low Q^2
5 < Q^2 <100 GeV^2 NLO/LO < 2

Scale of the jet measurement: $\sqrt{(ET^2 + Q^2)}$

A reminder of the PDF parametrisation: u_valence, d_valence, U and D type Sea and the gluon are parametrised by the form $xf(x,Q_0^2)=Ax^B(1-x)^C(1+Dx+Ex^2)$

	A	B	C	D	E
uv	Sum rule	free	free	free	free
dv	Sum rule	free	free	var	var
UBar	=(1-fs)ADbar	=BDbar	free	var	var
DBar	free	free	free	var	var
glue	Sum rule	free	free	var	var

HERAPDF1.5f and HERAPDF1.6 are both 14 parameter fits

A'g	B'g
free	free

extended gluon parametrisation $Ag\ x^{Bg}\ (1-x)^{Cg}\ (1+Dx+Ex^2) - A'g\ x^{B'g}\ (1-x)^{25}$

The table summarises our extended parametrisation choices and the parametrisation variations that we consider in our uncertainty estimates (and we also vary the starting scale Q^2_0).

Model uncertainties on m_c, m_b, f_s, Q^2min are also included

RESULTS

The HERAPDF1.5f PDFwith jet data added is called HERAPDF1.6

The $\chi 2$ of the fit is 811.5 for 766 degrees of freedom

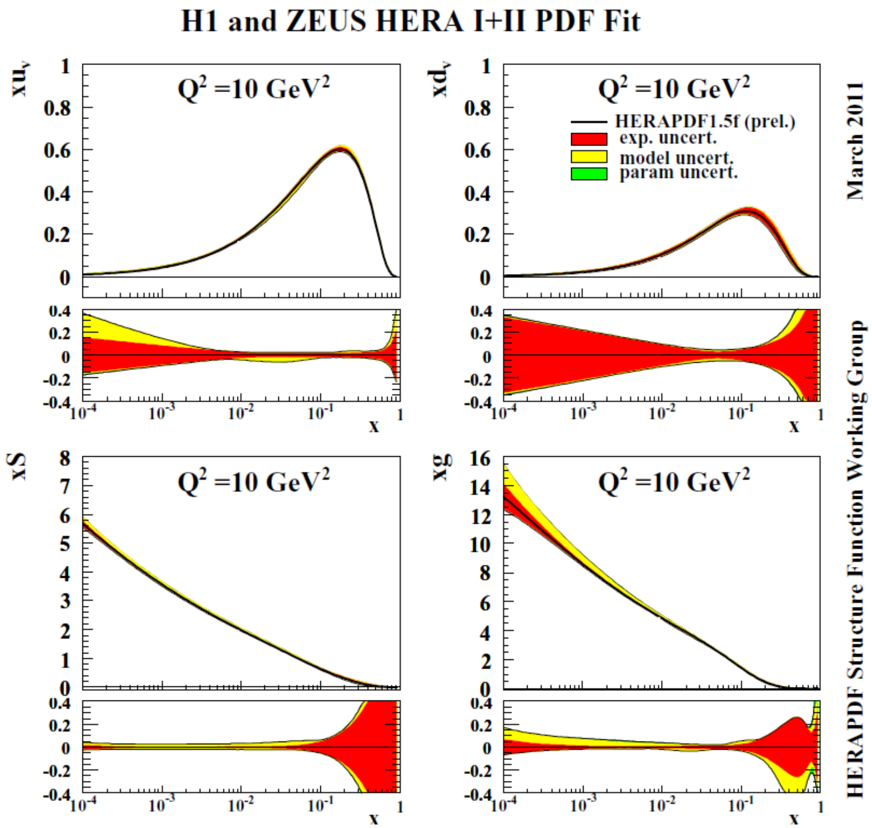
There is no tension between the jet data sets and the inclusive data set

HERAPDF1.6	$\chi 2$	ndp
All data	811.5	780
Inclusive cross sections	730.2	674
Jet cross sections	81.3	106

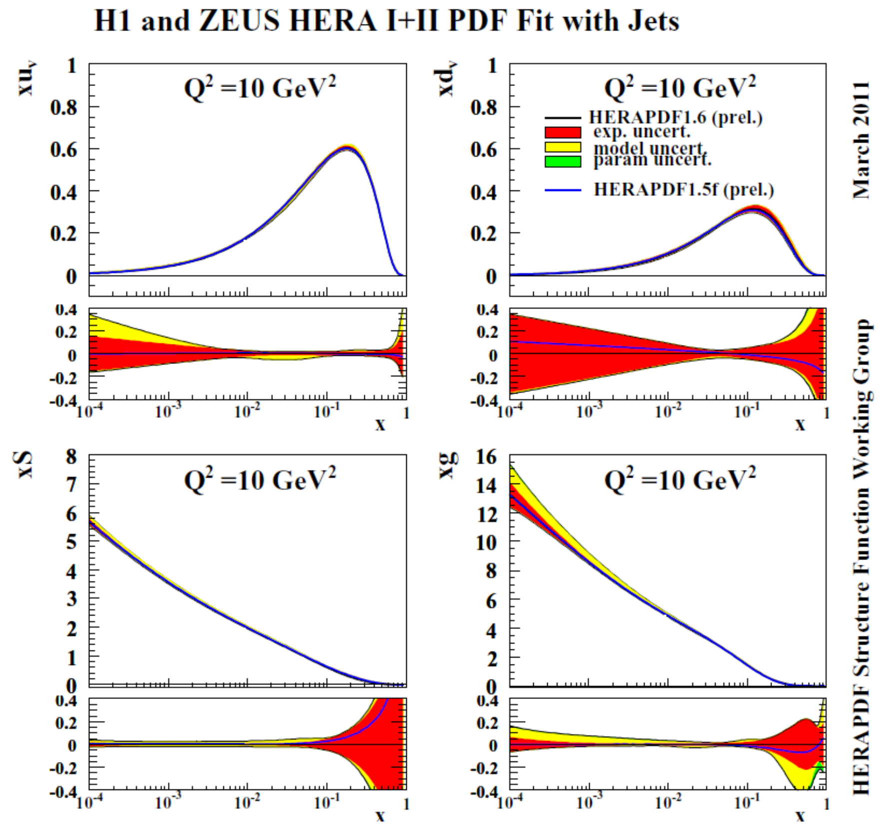
HERAPDF1.5f	$\chi 2$	ndp
Inclusive cross sections	729.9	674

Compare fits with and without jets with fixed $\alpha_S(M_Z) = 0.1176$.

HERAPDF1.5f **HERAPDF1.6**



Without jets



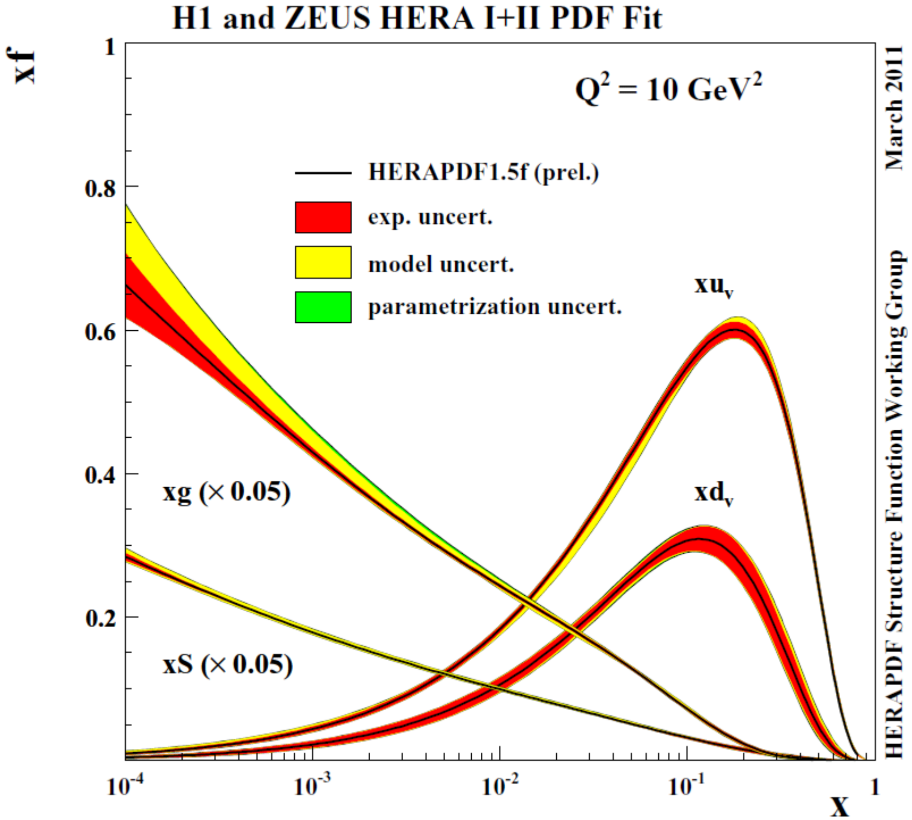
With jets

There is little difference in the size of the uncertainties after adding the jet data –but there is a marginal reduction in high-x gluon uncertainty.

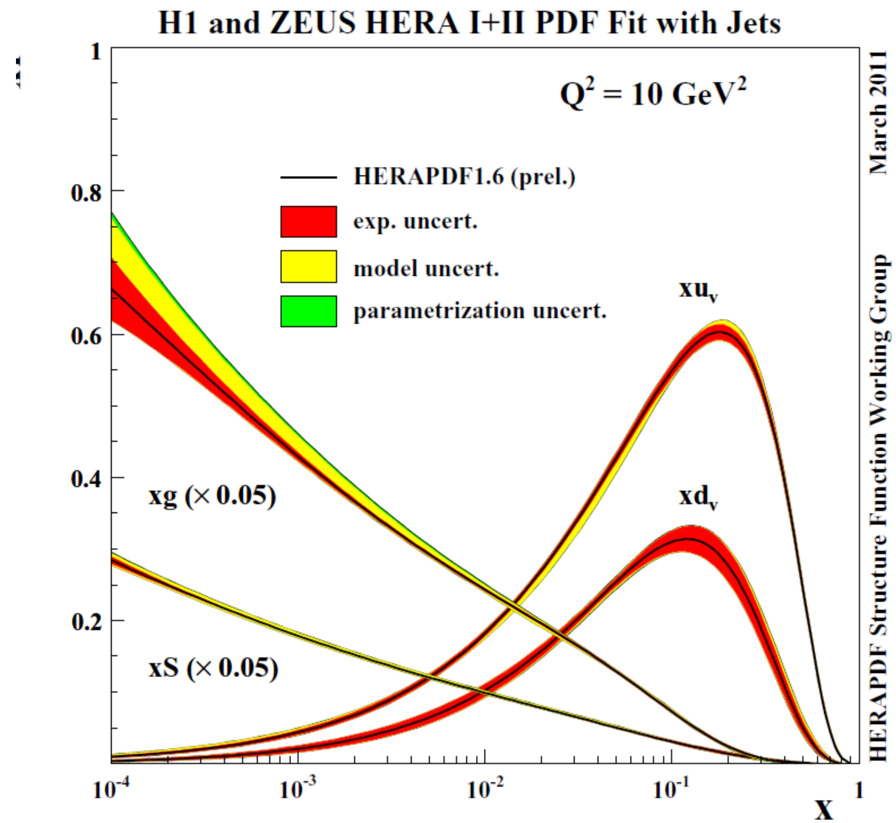
The fit with jets has a softer high-x Sea this is illustrated by the blue line on the right hand side plot– this shows the central value of the PDF without jets

Compare fits with and without jets with fixed $\alpha_S(M_Z) = 0.1176$.

HERAPDF1.5f **HERAPDF1.6**



Without jets



With jets

Now free $\alpha_S(M_Z)$

$\alpha_S(M_Z) = 0.1202 \pm 0.0013$ (exp) ± 0.0007(model/param) ± 0.0012(hadronisation)

$+0.0045/-0.0036$ (scale)

$\alpha_S(M_Z) = 0.1202 \pm 0.0019$(excluding scale) $+0.0045/-0.0036$ (scale)

Where the scale error is evaluated by changing the renormalisation and factorisation scales of both the inclusive and the jet data by a factor of 2.
The dominant contribution to scale error is from the jet renormalisation scale.
Note the $\chi 2$ of the fit prefers the central scales

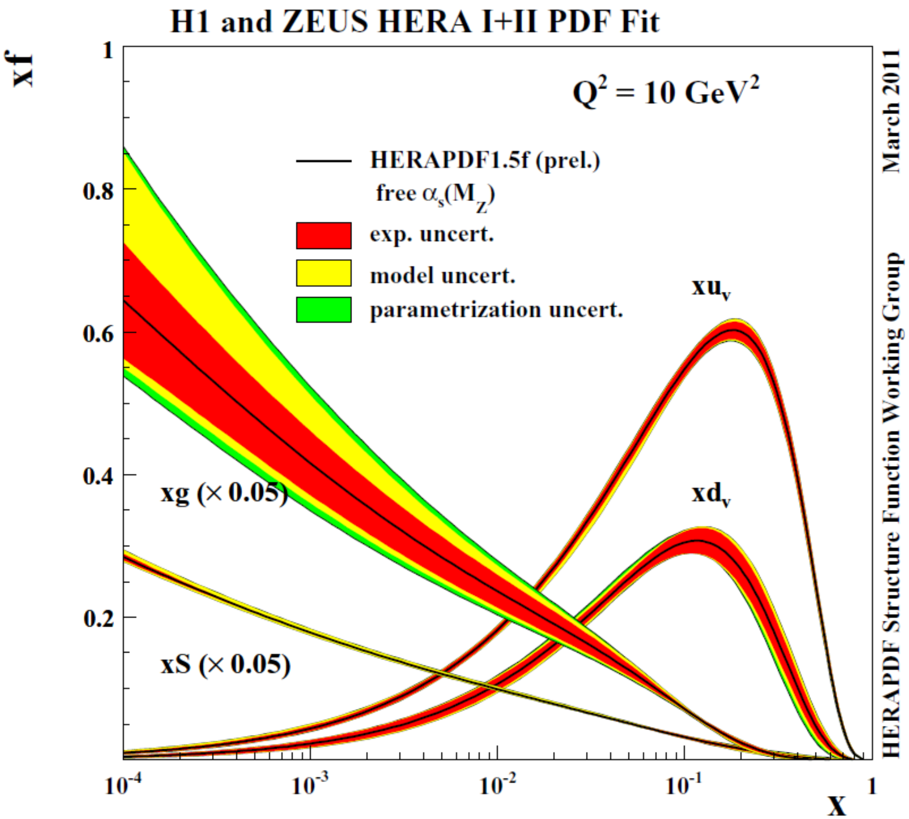
HERAPDF1.6 $\alpha_S(M_Z)$ =0.1176 fixed

	$\chi 2$	ndp
All data	811.5	780
Inclusive cross sections	730.2	674
Jet cross sections	81.3	106

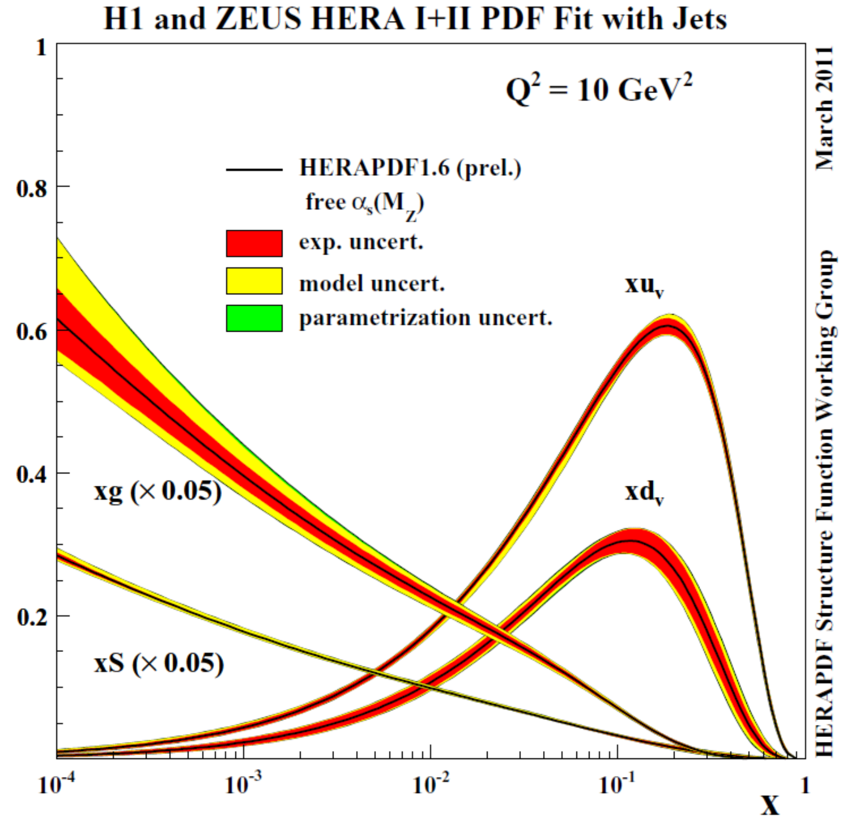
HERAPDF1.6 $\alpha_S(M_Z)$ free

	$\chi 2$	ndp
All data	807.6	780
Inclusive cross sections	730.0	674
Jet cross sections	77.6	106

Compare HERAPDF1.5f (no jets) and HERAPDF1.6 (with jets) both with free $\alpha_S(M_Z)$



Without jets

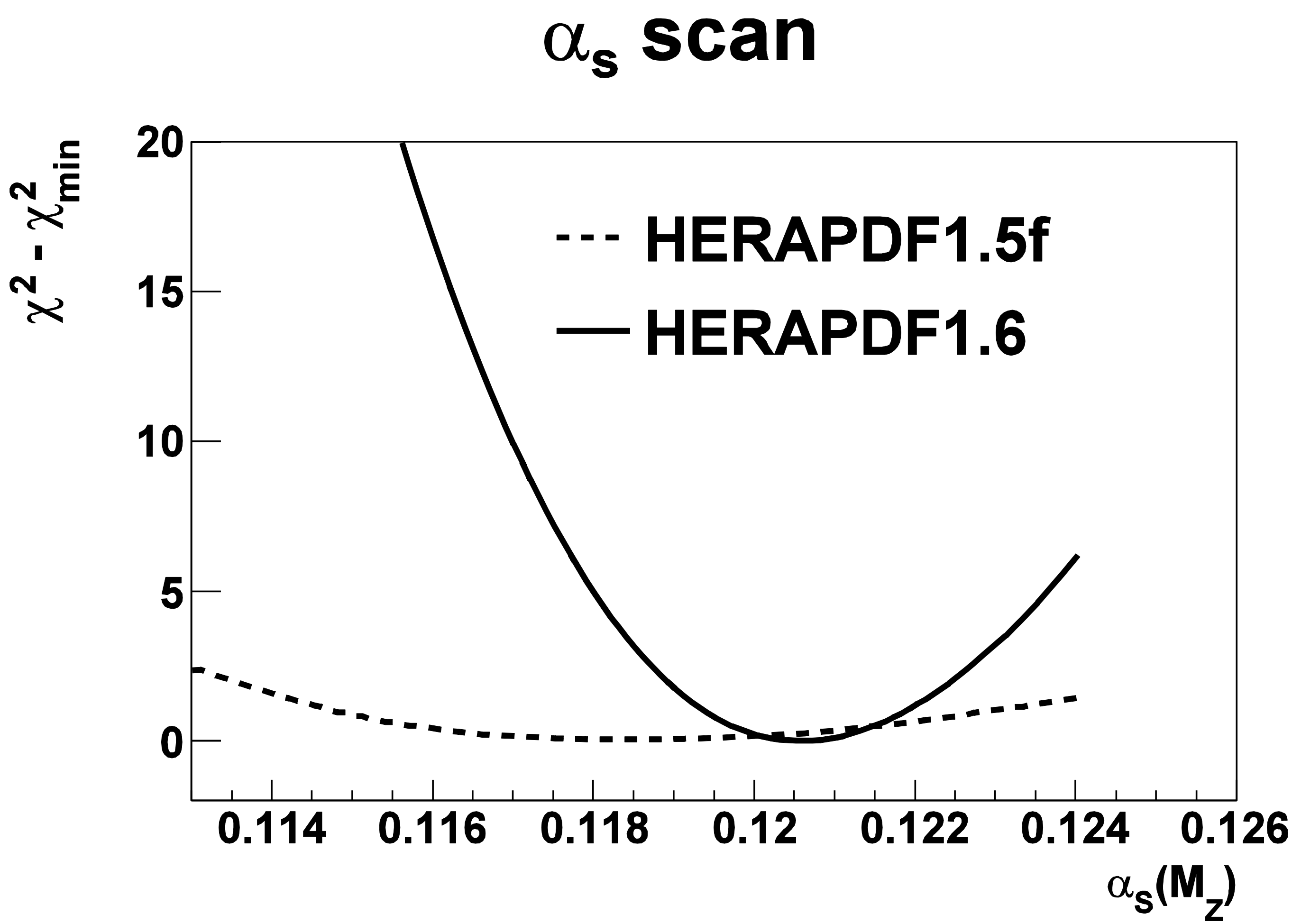


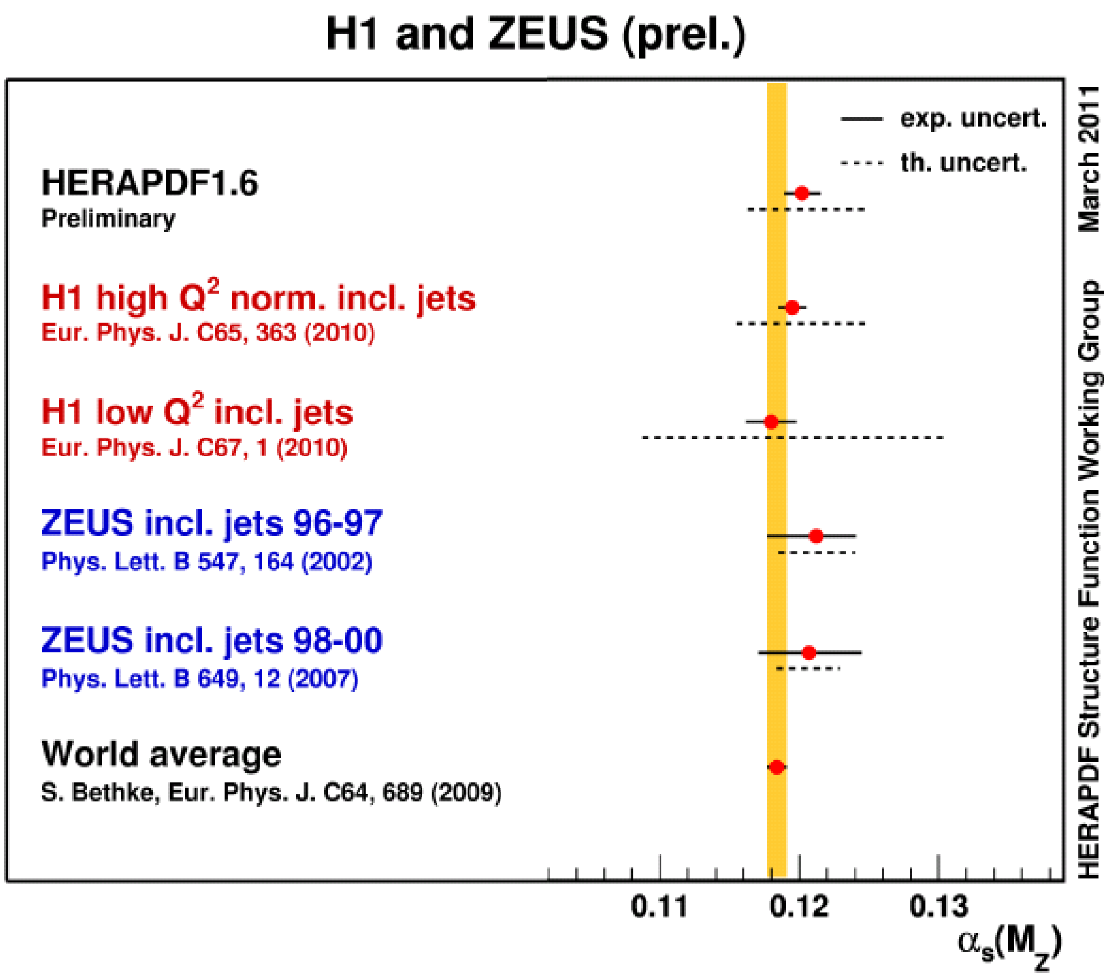
With jets

Jets decrease uncertainty on the low-x gluon dramatically- without jets the correlation of the gluon PDF and $\alpha_S(M_Z)$ is very strong and the $\chi2$ has only a shallow dependence on $\alpha_S(M_Z)$

The χ2 scan of HERAPDF1.5f (no jets) and HERAPDF1.6 (with jets) vs $\alpha_S(M_Z)$ illustrates how shallow the variation of χ2 is without the jets

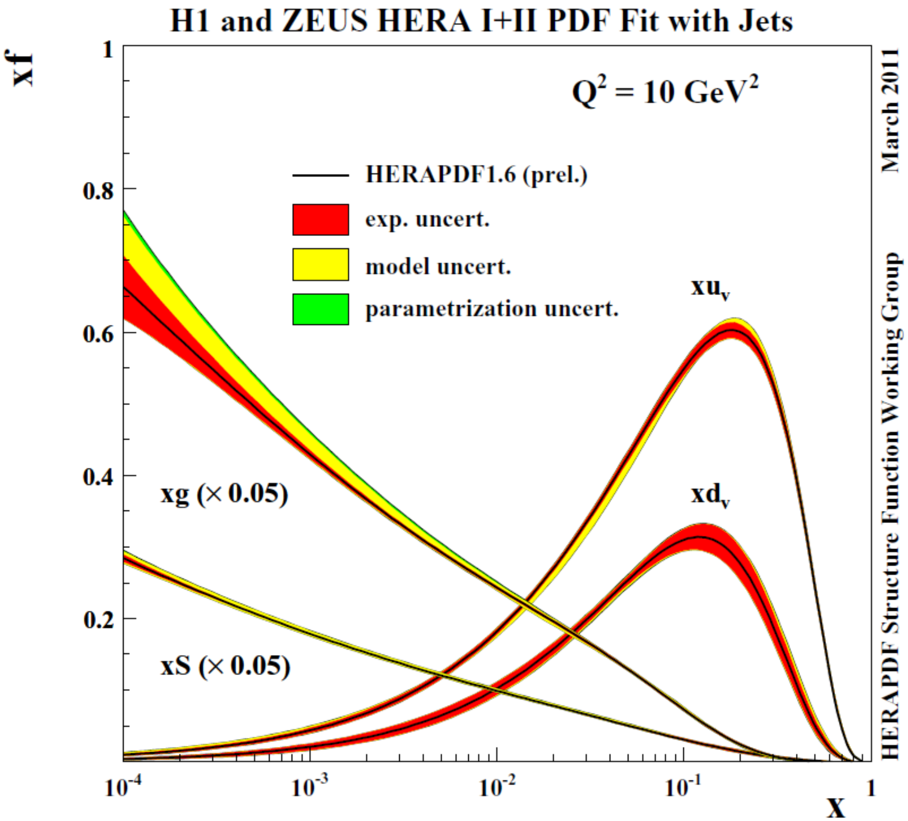
But this is not the only advantage of adding jets --- the model and parametrisation errors are also very large without jets -- but quite 11small with jets (more than compensating for the hadronisation uncertainty)



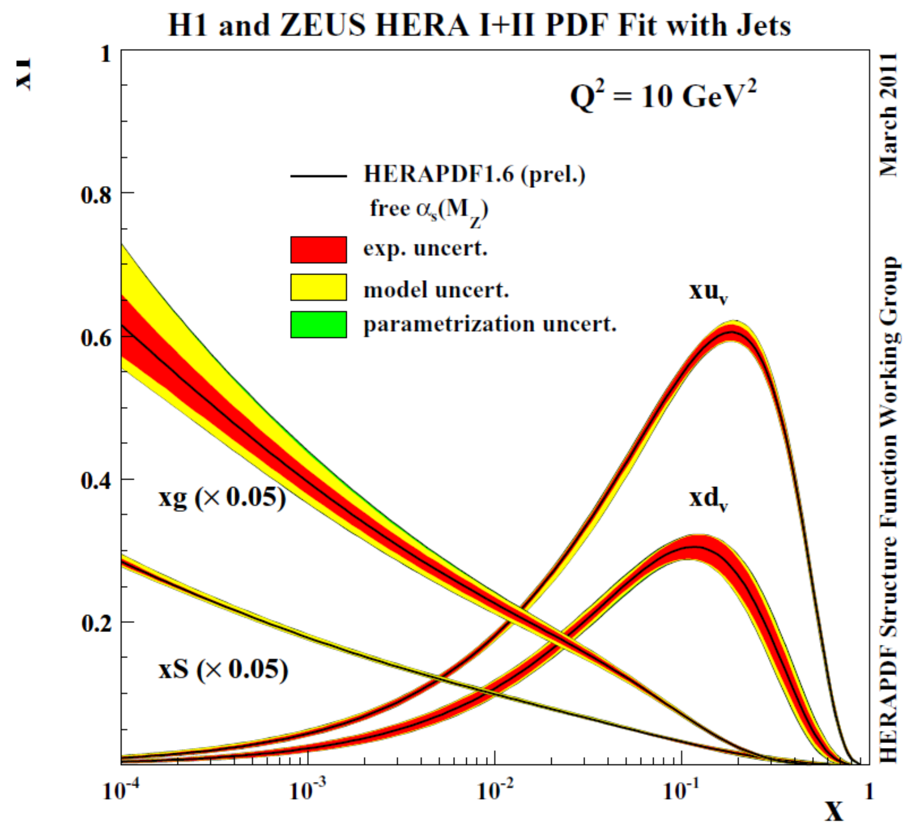


- NOTE for HERAPDF1.6 the PDF uncertainty is part of the experimental uncertainty
- For H1 it is part of the theory uncertainty
- For ZEUS it is part of the experimental uncertainty

Finally compare the HERAPDF1.6 fit with fixed $\alpha_S(M_Z)$ to that with free $\alpha_S(M_Z)$



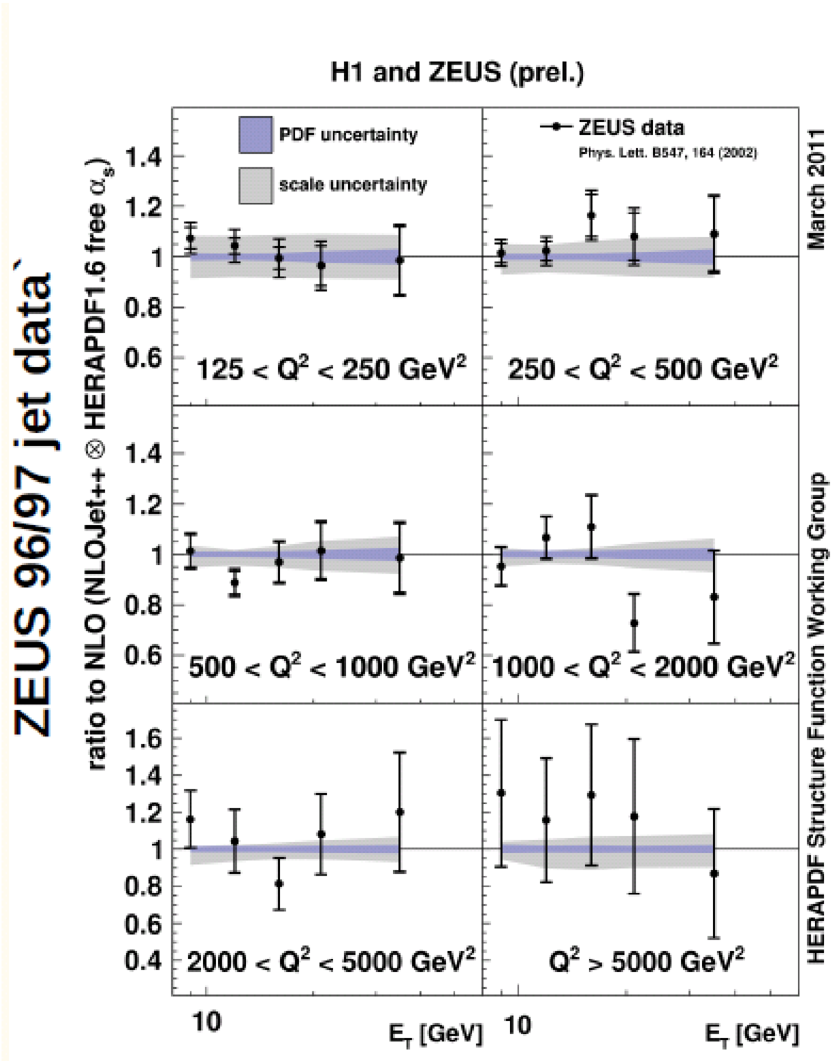
With jets and fixed $\alpha_S(M_Z) = 0.1176$

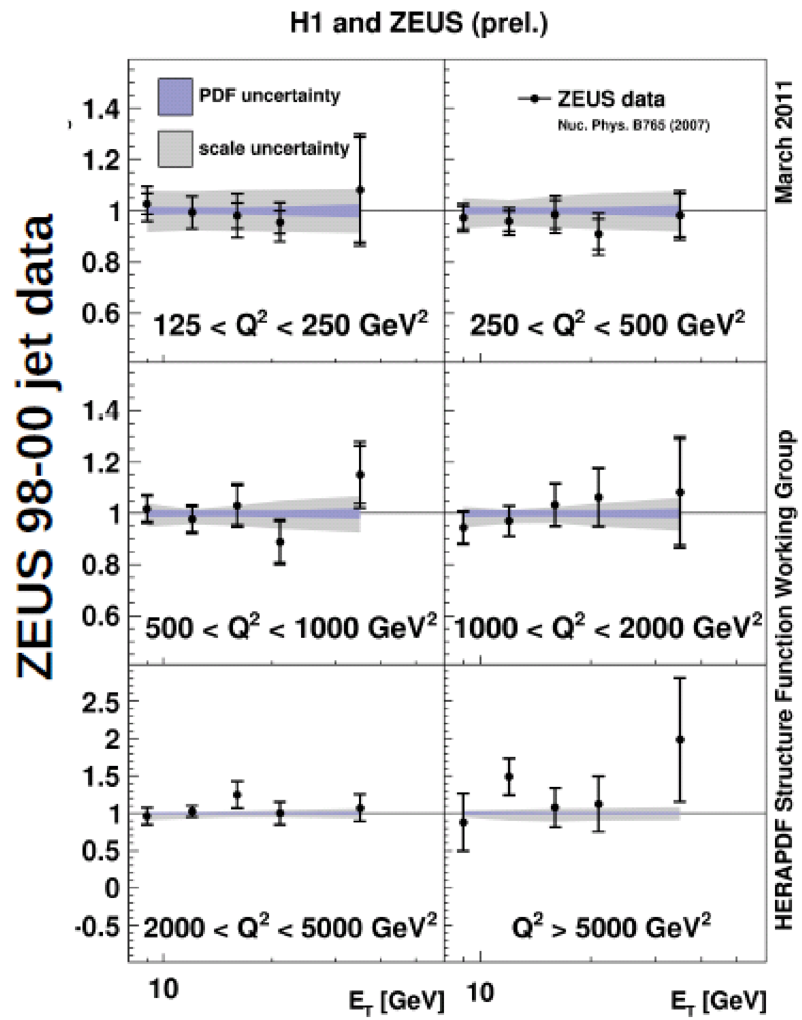


With jets and free $\alpha_S(M_Z) = 0.1202 \pm 0.0019$ (excluding scale error)

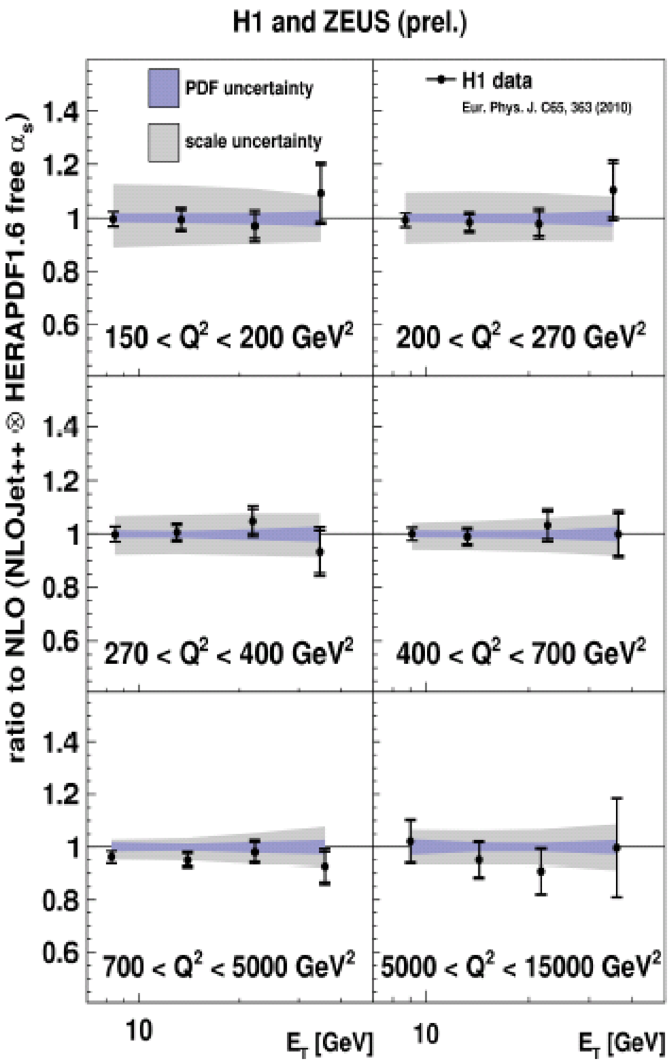
The freedom in $\alpha_S(M_Z)$ affects only the gluon

Data description

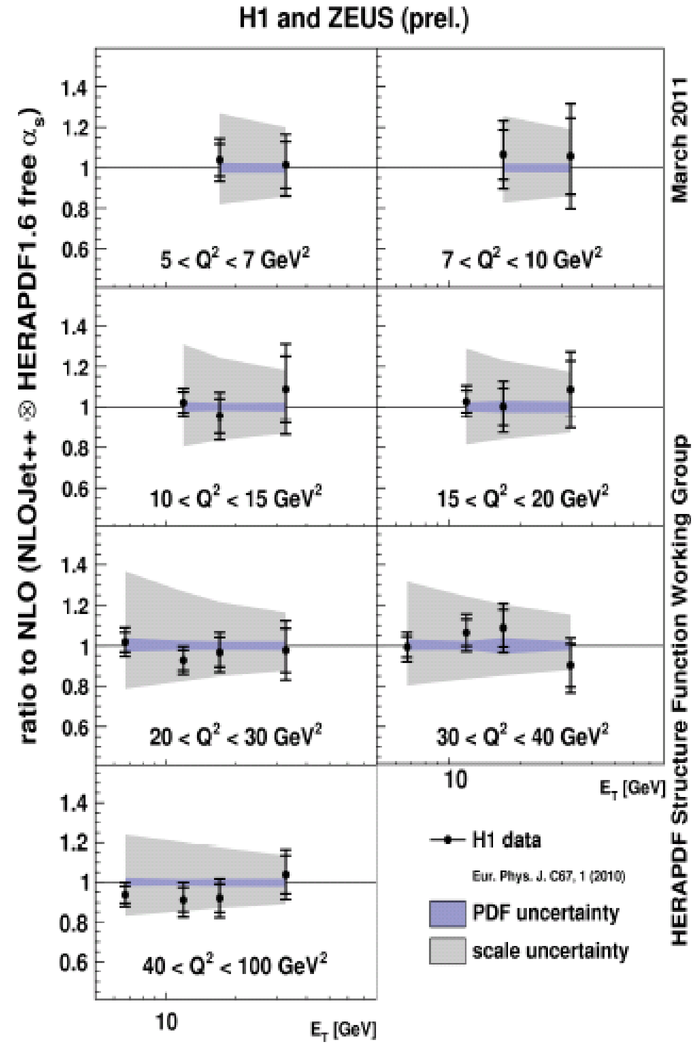


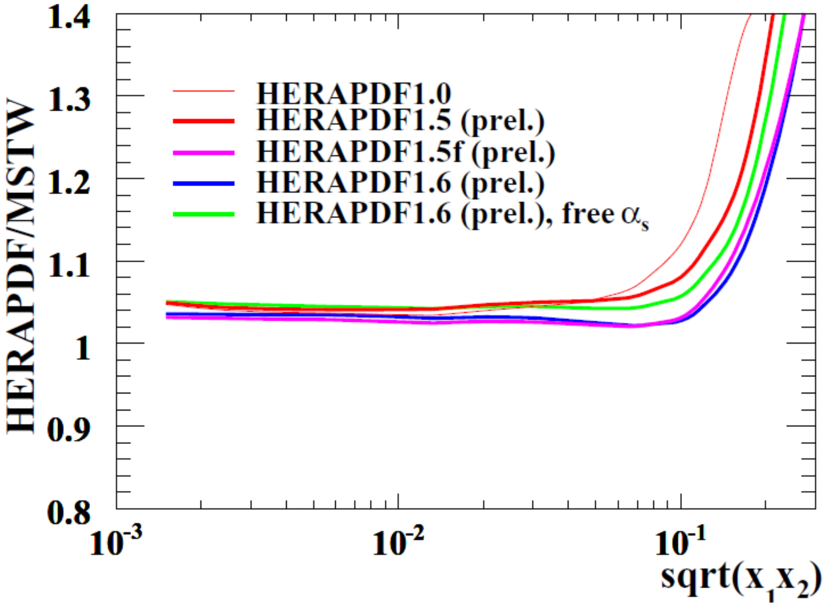


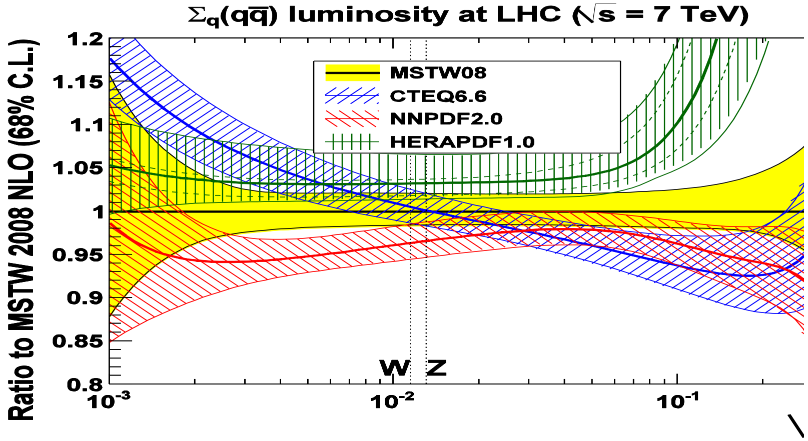
H1 high Q^2 jet data



H1 low Q^2 jet data





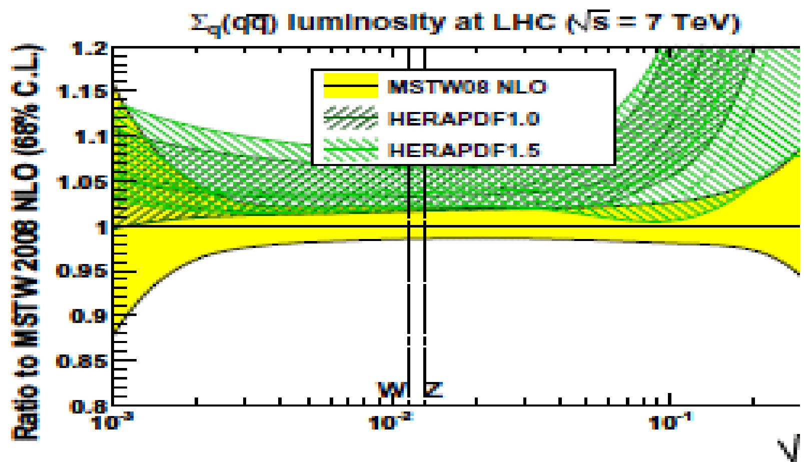


The q-qbar luminosity at NLO

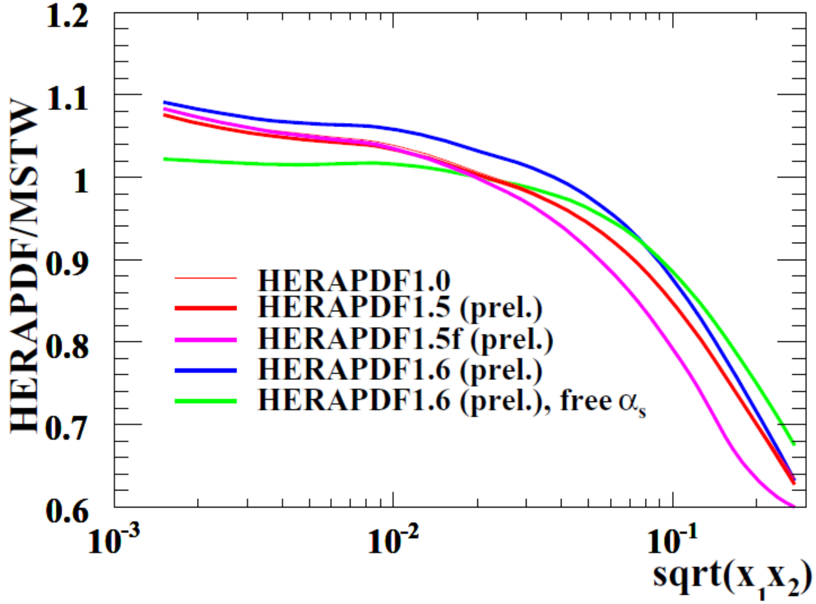
HERAPDF1.5 is softer than 1.0 at high-x and 1.5f is even softer

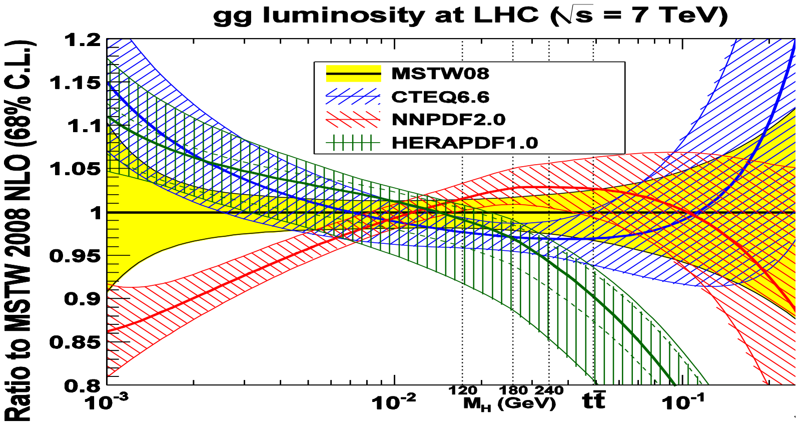
Adding the jets makes very little difference (HERAPDDF1.6)

Letting alphas be free so that $\alpha_S(M_Z)$=0.1202 rather than 0.1176 does harden the high-x quark distribution marginally



LHC luminosity plots for 7 TEV





The g-g luminosity at NLO

HERAPDF1.5 is on top of 1.0 and 1.5f is slightly softer

Adding the jets hardens the high-x gluon (HERAPDF1.6)

Letting alphas be free so that $\alpha_S(M_Z)$=0.1202 rather than 0.1176 reduces the low-x gluon

LHC luminosity plots for 7 TEV

Summary

The H1 and ZEUS collaborations have used combined HERA I +II inclusive cross-section data plus H1 and ZEUS inclusive jet production cross-sections in an NLO QCD PDF analysis.

If the resulting HERAPDF1.6 is compared to a fit without the jets (HERAPDF1.5f) with $\alpha_S(M_Z)$ fixed then:

•there is a marginal reduction in high-x gluon uncertainty.

•the high-x Sea becomes softer

If the resulting HERAPDF1.6 is compared to a fit without the jets (HERAPDF1.5f) with $\alpha_S(M_Z)$ free then:

•there is a dramatic reduction in low-x gluon uncertainty

•the value of $\alpha_S(M_Z)$ is well determined in the fit with jets as

$\alpha_S(M_Z) = 0.1202 \pm 0.0019$(excluding scale) $+0.0045/-0.0036$ (scale)

because the jets have reduced the strong correlation between the gluon PDF shape and $\alpha_S(M_Z)$