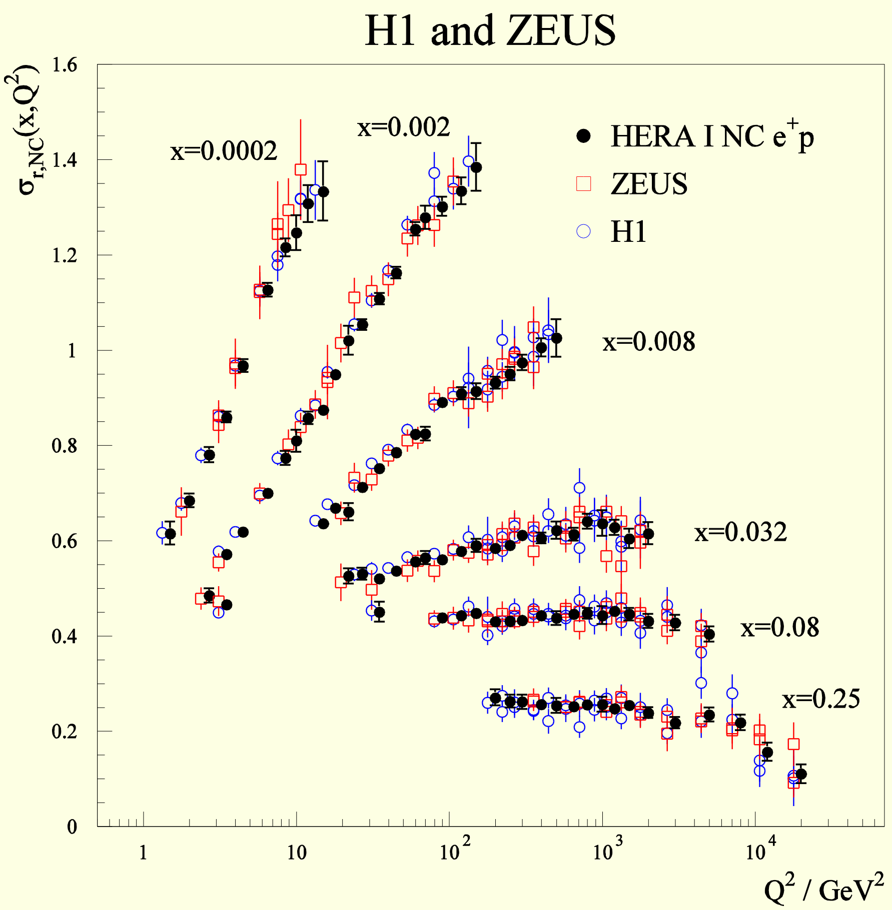
QCD at the LHC: PDF Summary

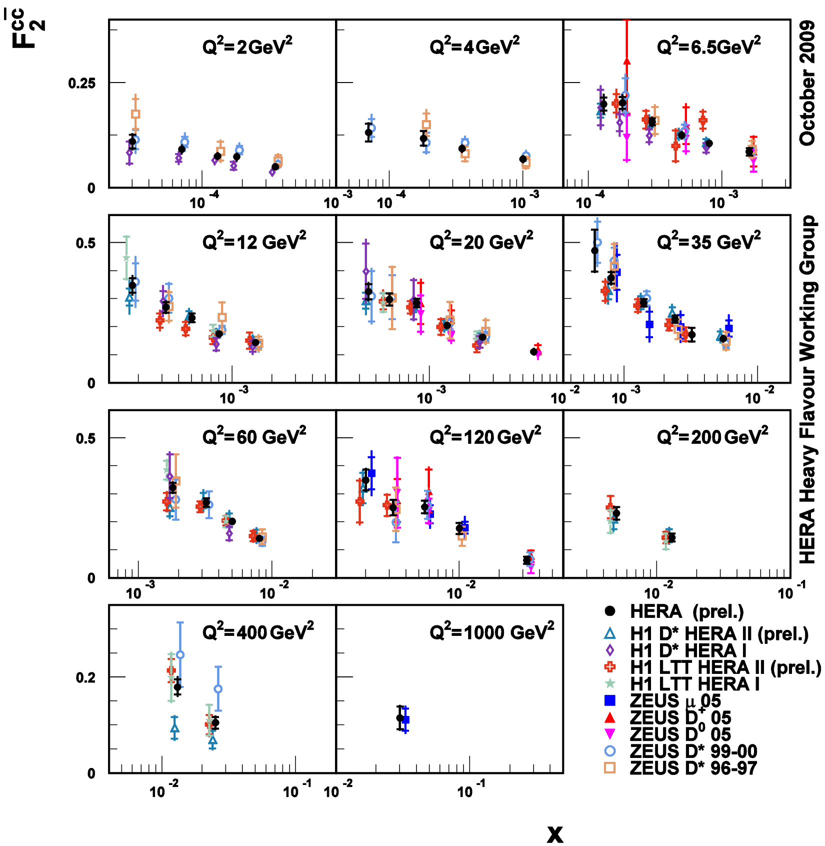
A M Cooper-Sarkar
Oxford University

With thanks to Graeme Watt of MSTW for many relevant plots

Let's start with updates on relevant DATA inputs

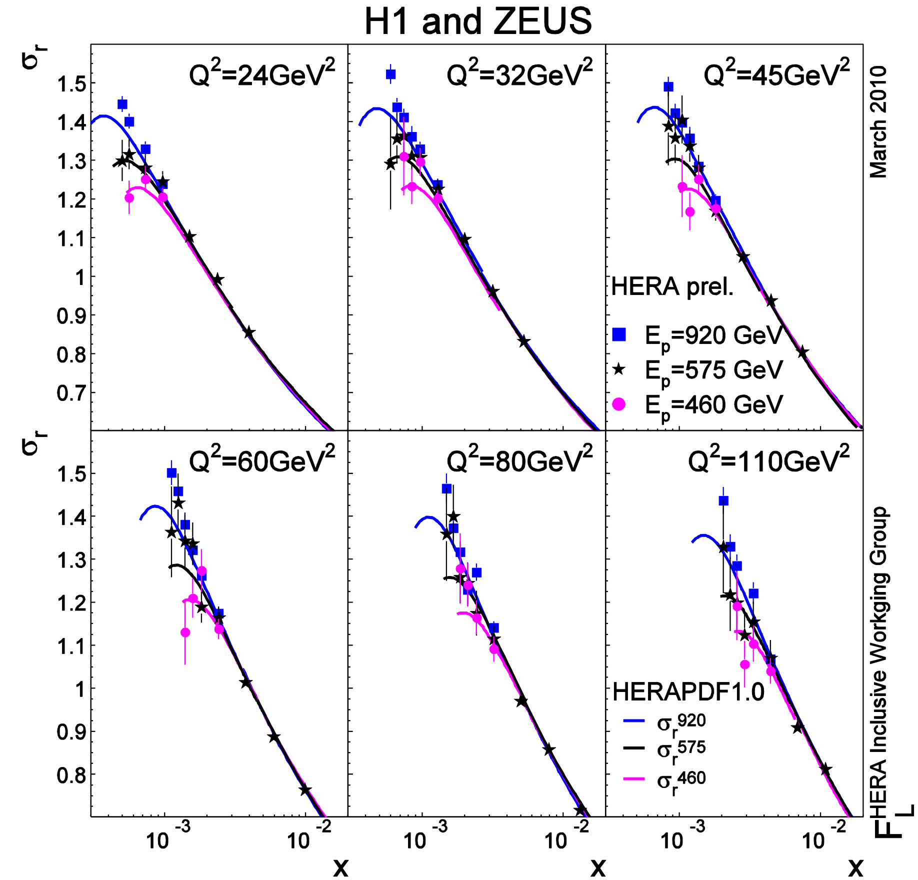


The HERA-I inclusive cross-section combination for NC and CC e+ and e-
JHEP 1001.109 arxiv:0911.0884
This is the basis for HERAPDF1.0



The HERA-I (and some II) F2(charm) combination
Preliminary
New constraints on charm treatment

Talks by S Glazov, R Placakyte

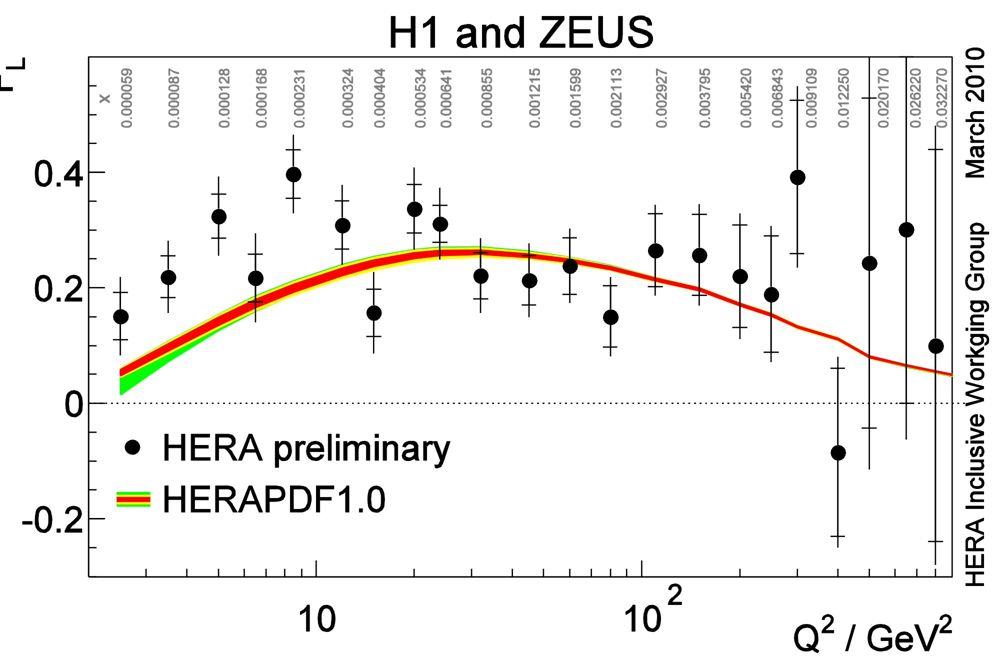


Talk by V Radescu

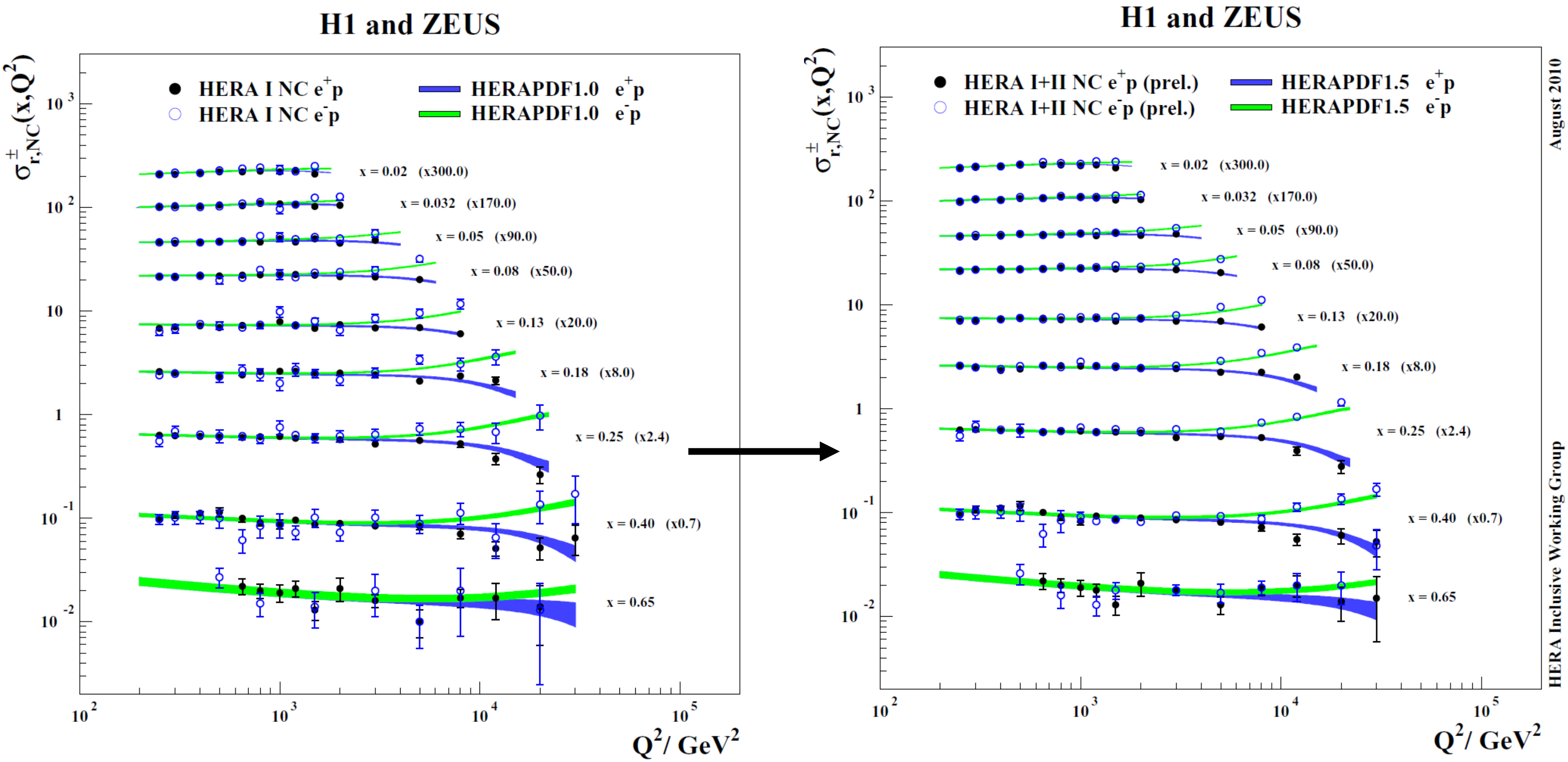
And the FL combination that is derived from it

NLO DGLAP does not do quite such a good job describing these data

The HERA-II low energy runs inclusive cross-section combination Preliminary



The high Q^2 HERA-II inclusive cross-section combination (preliminary). These data have been combined wth the HERA-I data and HERAPDF1.0 has recently been updated to HERAPDF1.5 by including these data



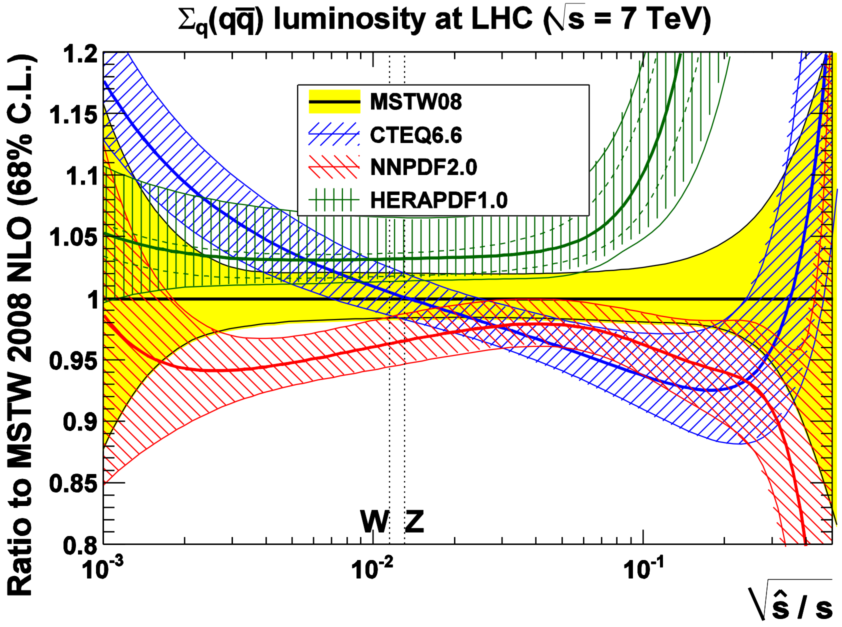
The data on the left has been updated to the data on the right

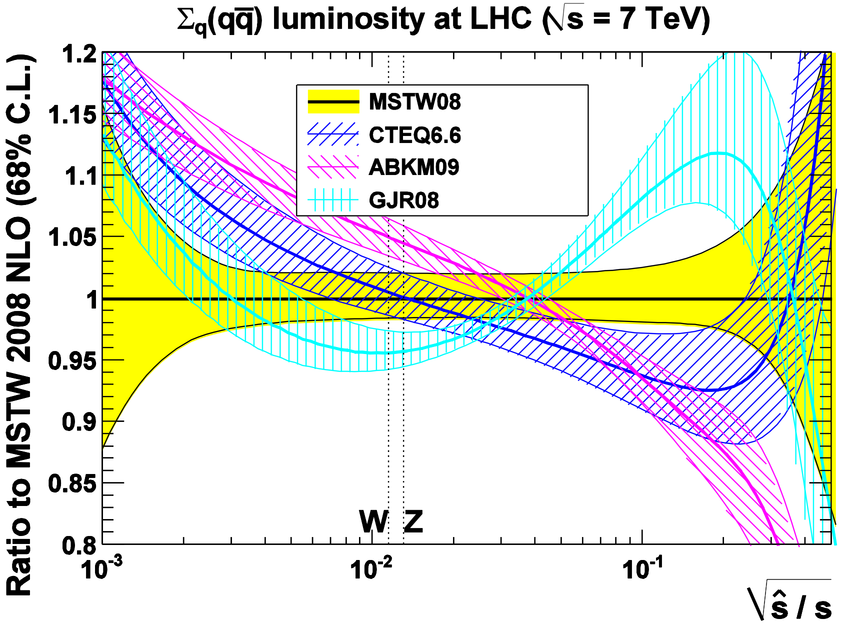
The HERAPDF1.0 fit on the left has been updated to the HERAPDF1.5 fit on the right.

New high-x constraints from these data.

Talk by V Radescu

The PDF4LHC group has been comparing PDFs at the level of parton-parton lumiosities





q-qbar luminosity plots

We can understand some of these differences:

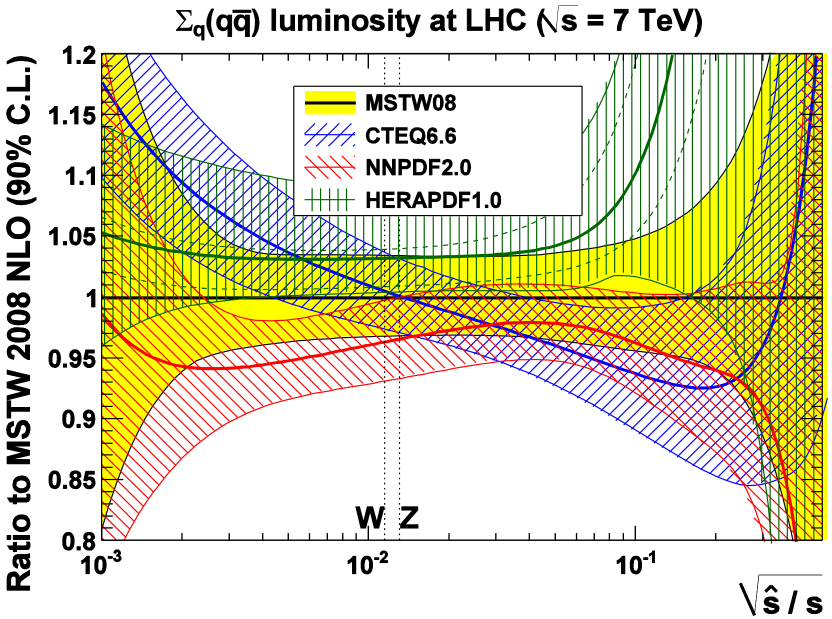
Low SCALE

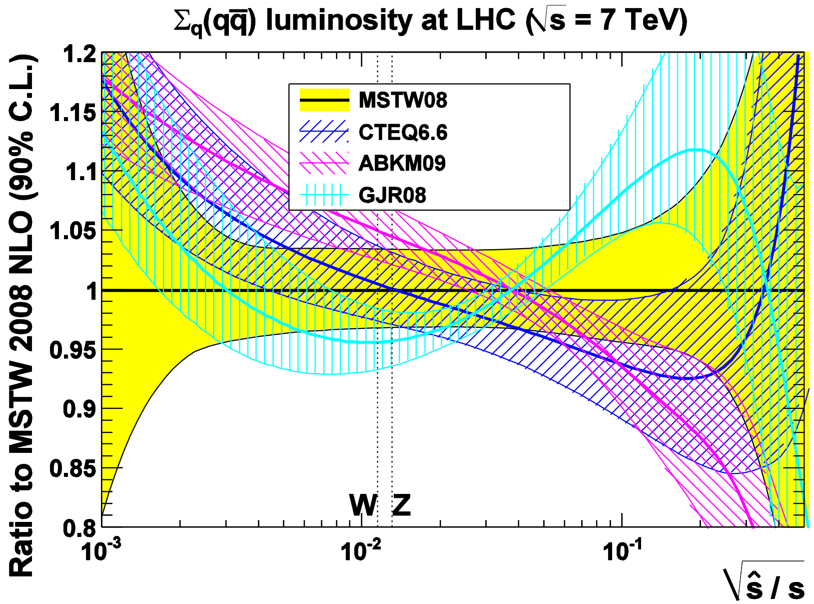
1. HERAPDF is a few percent higher at low x because the combined HERA data normalisation has increased by ~2.5% compared to the separate data sets
2. NNPDF is low because of the use of Zero-Mass VFN
3. Perhaps ABKM/GJR are high because of the use of FFN

High SCALE

1. HERAPDF has more Sea quarks at high-x
2. This also seems true for GJR

But let’s not get too excited about 68%CL plots

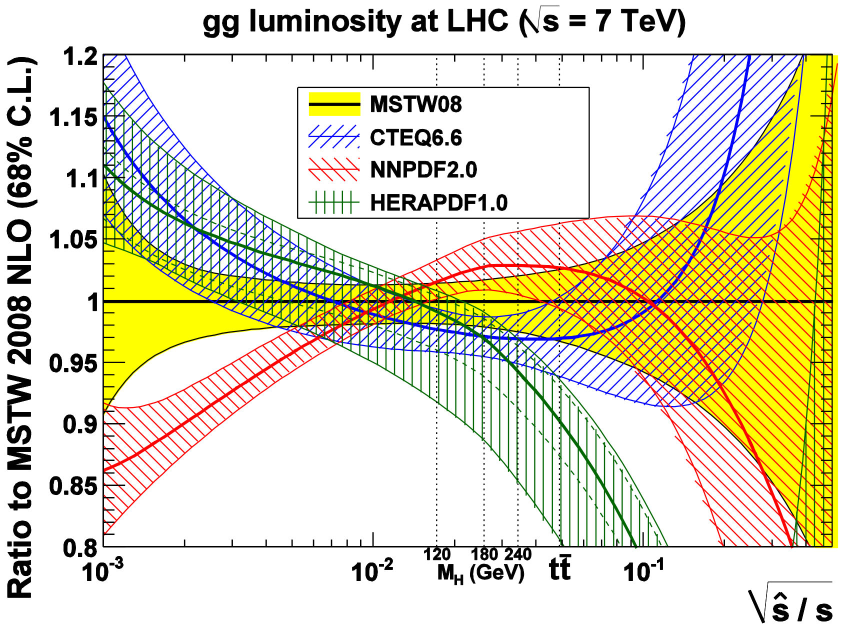


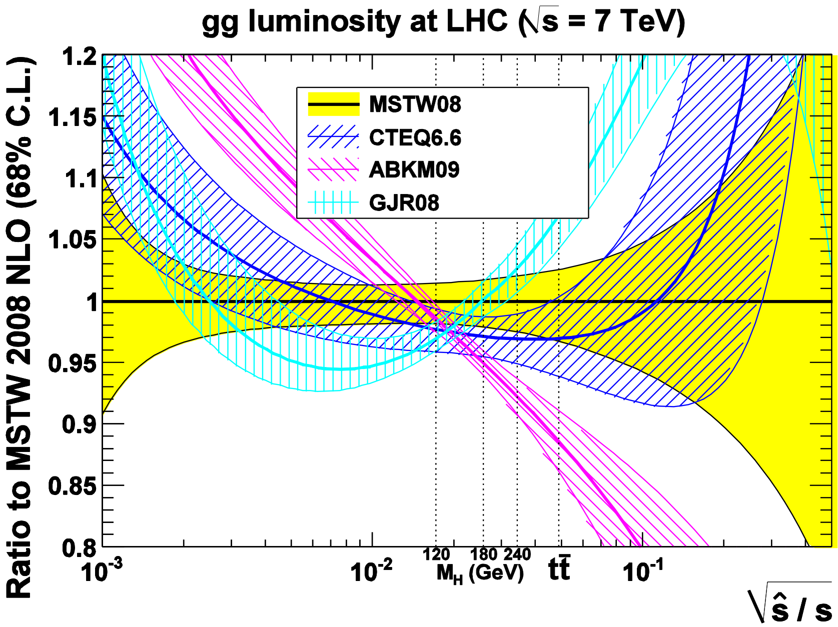


Look at the 90% CL plots where no PDF looks ‘outlandish’

These plots cover the whole range of scales for LHC

Over much of the range there is agreement within 10%





Also consider the g-g luminosity plots

At low-scale some of the same comments on the differences apply

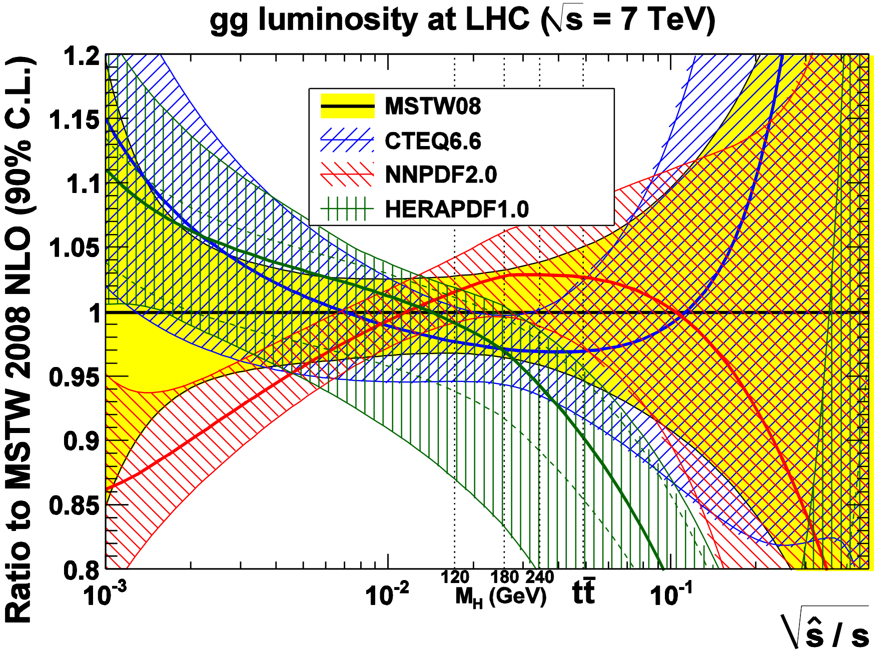
At high-scale we were told that HERAPDF has no Tevatron jet data in it (also ABKM)

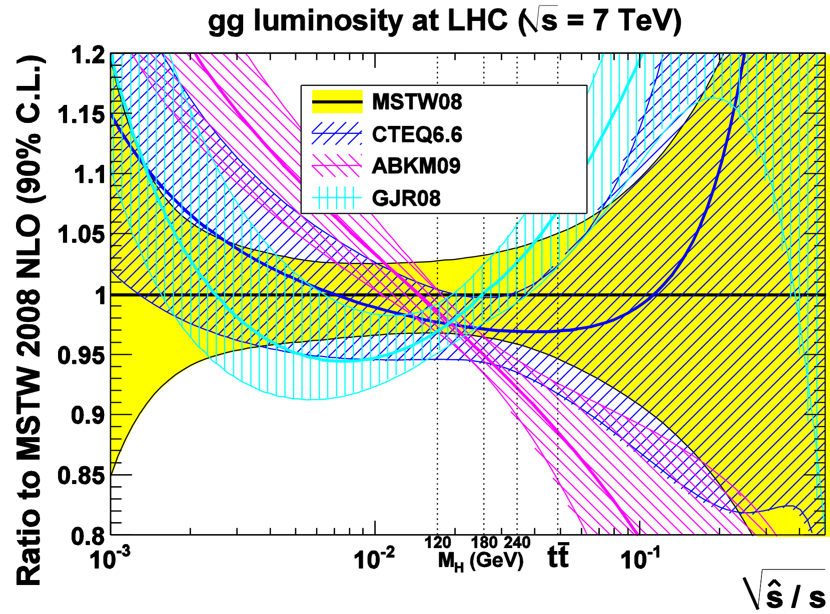
Whereas CTEQ has ‘too much’

BUT

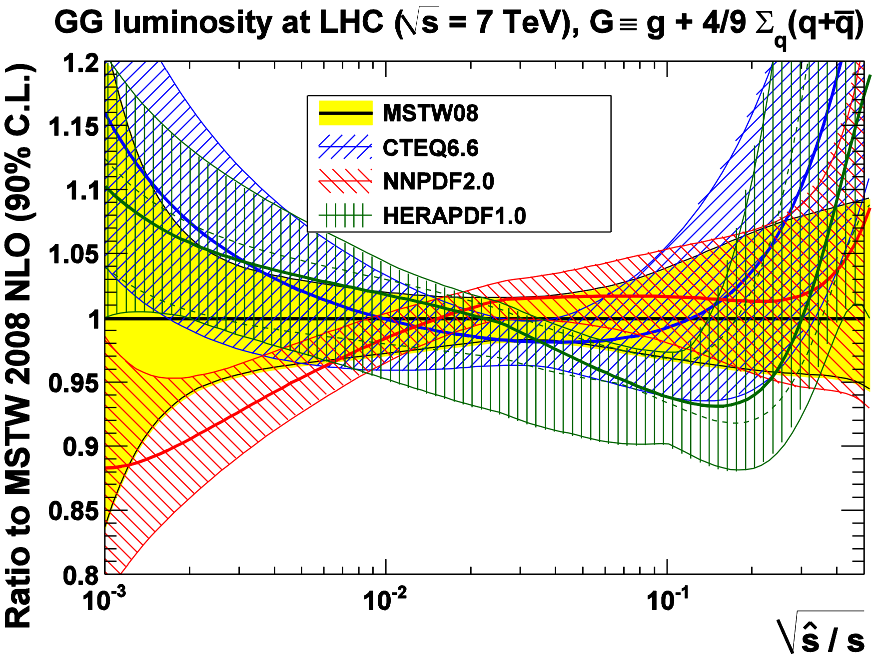
1. HERAPDF can describe Tevatron jet data
2. GJR also has no Tevatron jet data

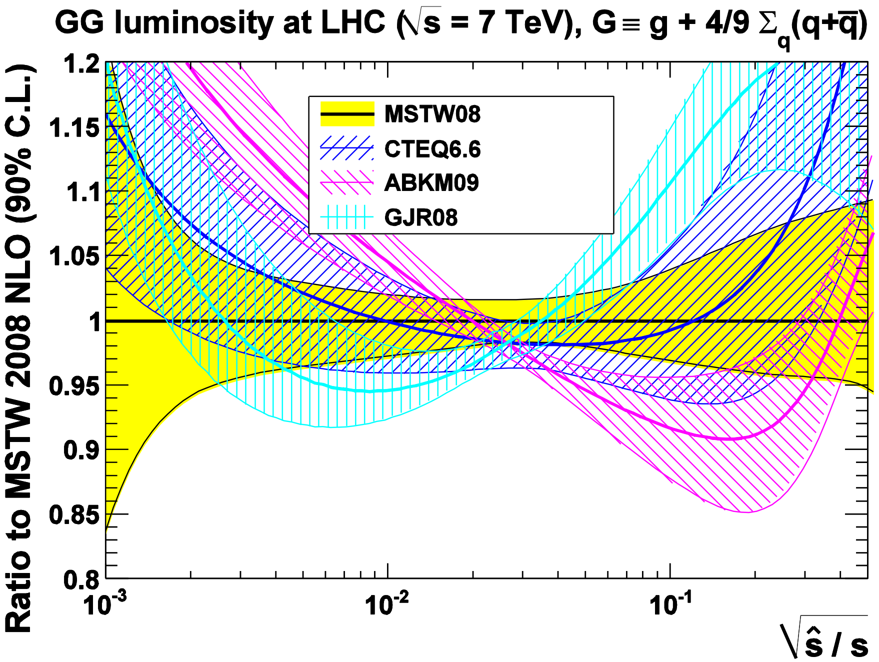
Note for Higgs ~150 GeV there is agreement to ~5%



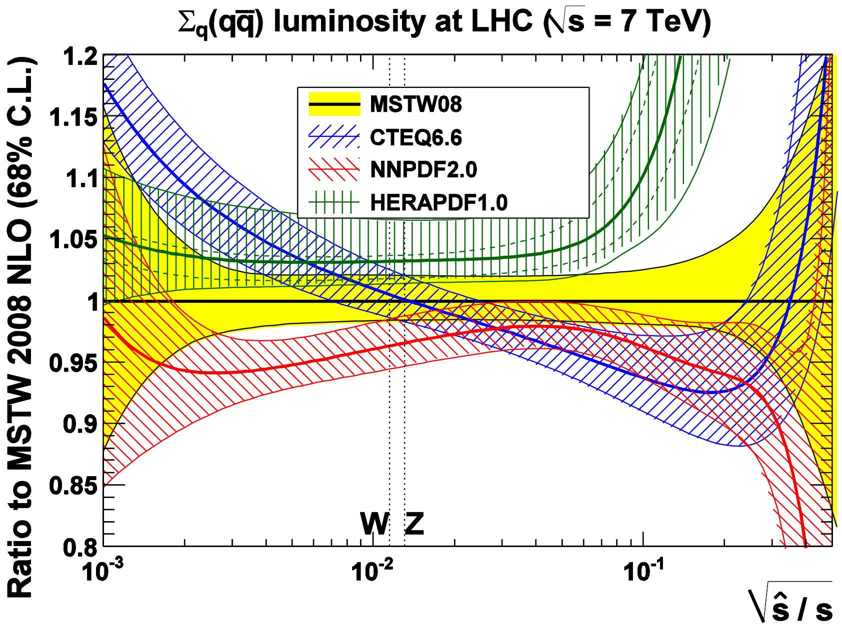


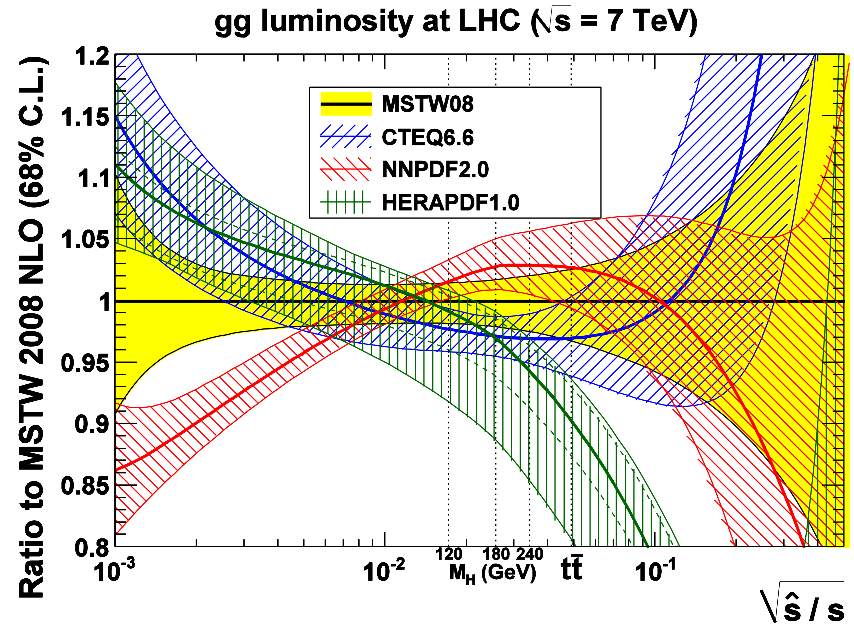
But at 90%CL there is considerable overlap between having too much or too little Tevatron jet data!



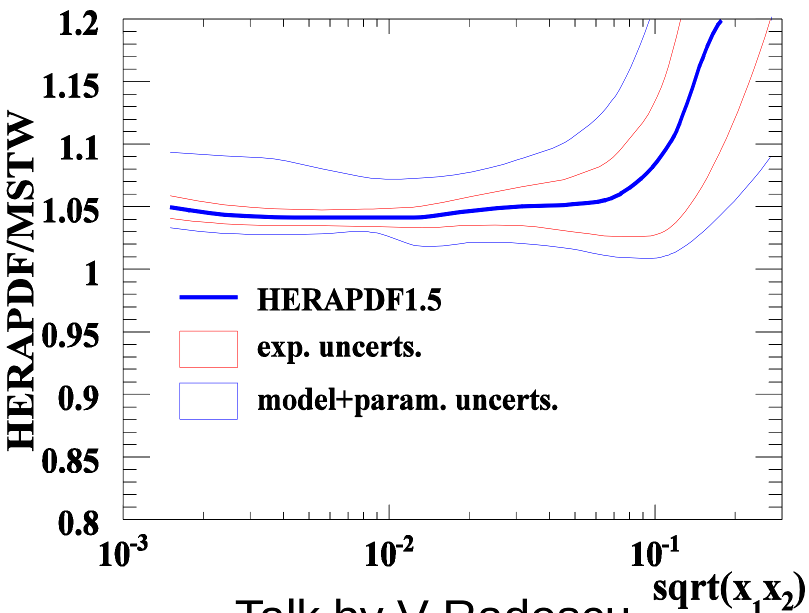


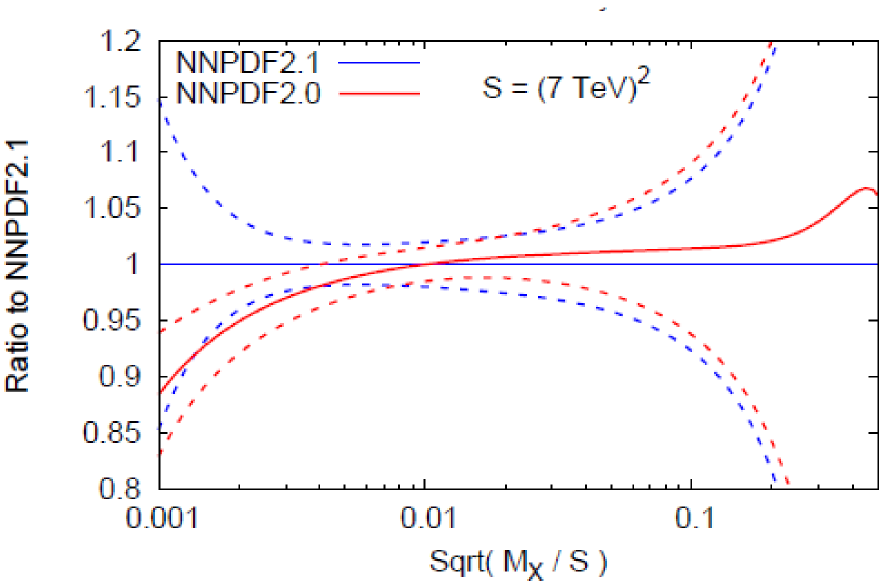
Perhaps G-G luminosity is a better thing to compare for high-Et jets?
G=g+4/9(q+qbar)





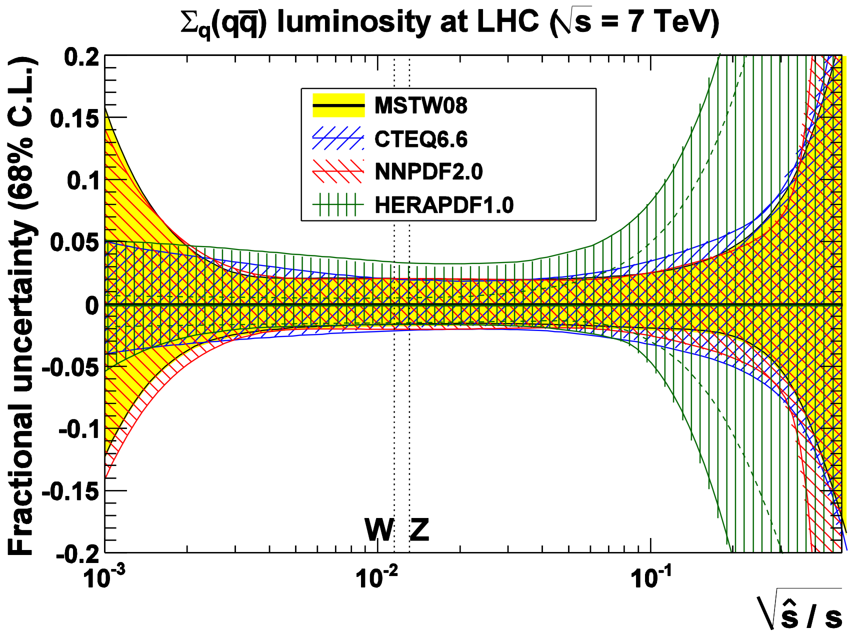
There have been updates at this meeting which bring HERAPDF and NNPDF somewhat closer to MSTW

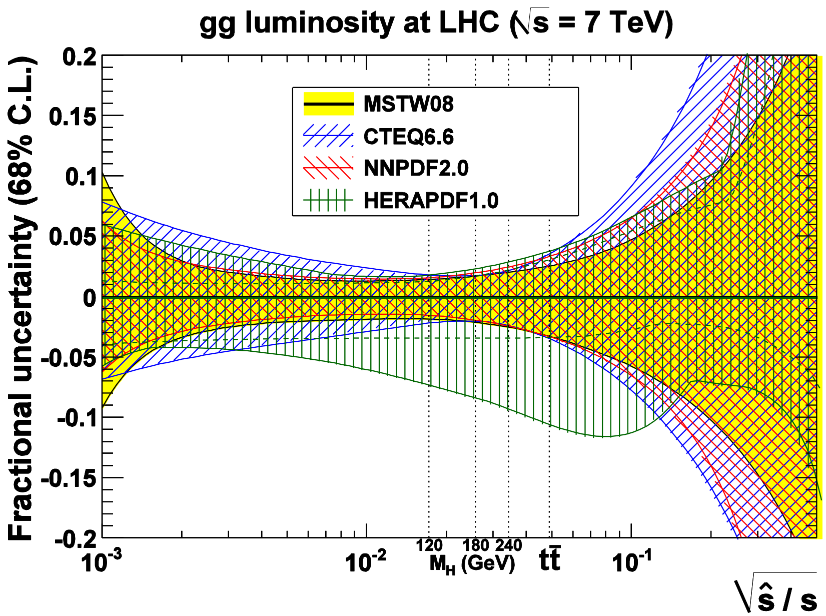




Talk by V Radescu

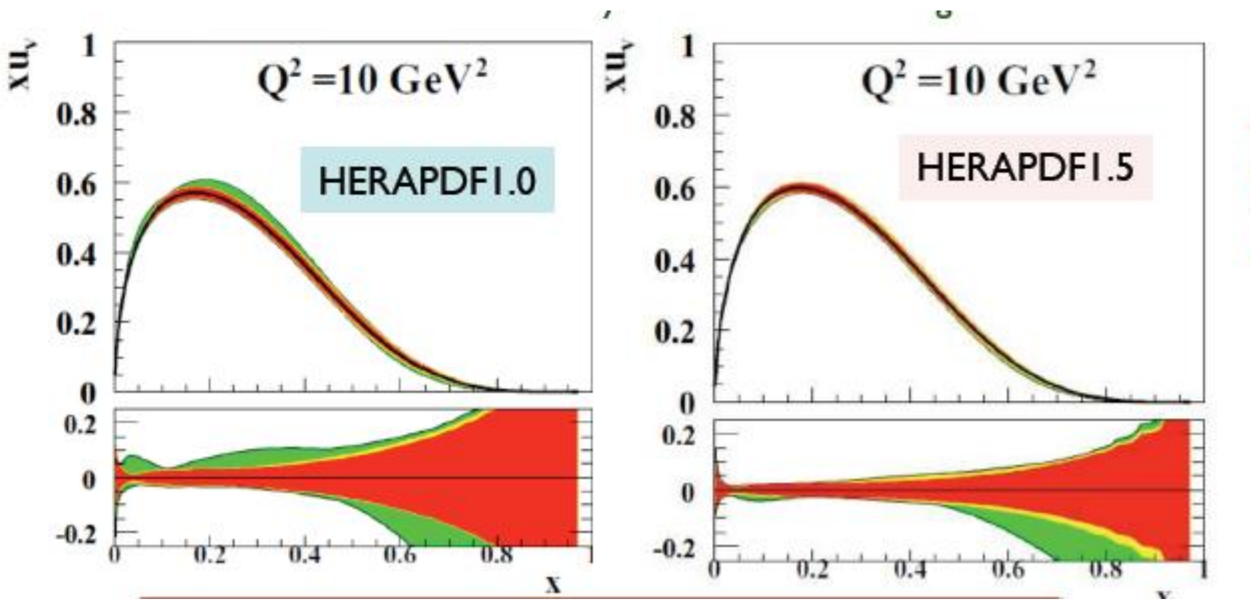
Talk by M Ubiali

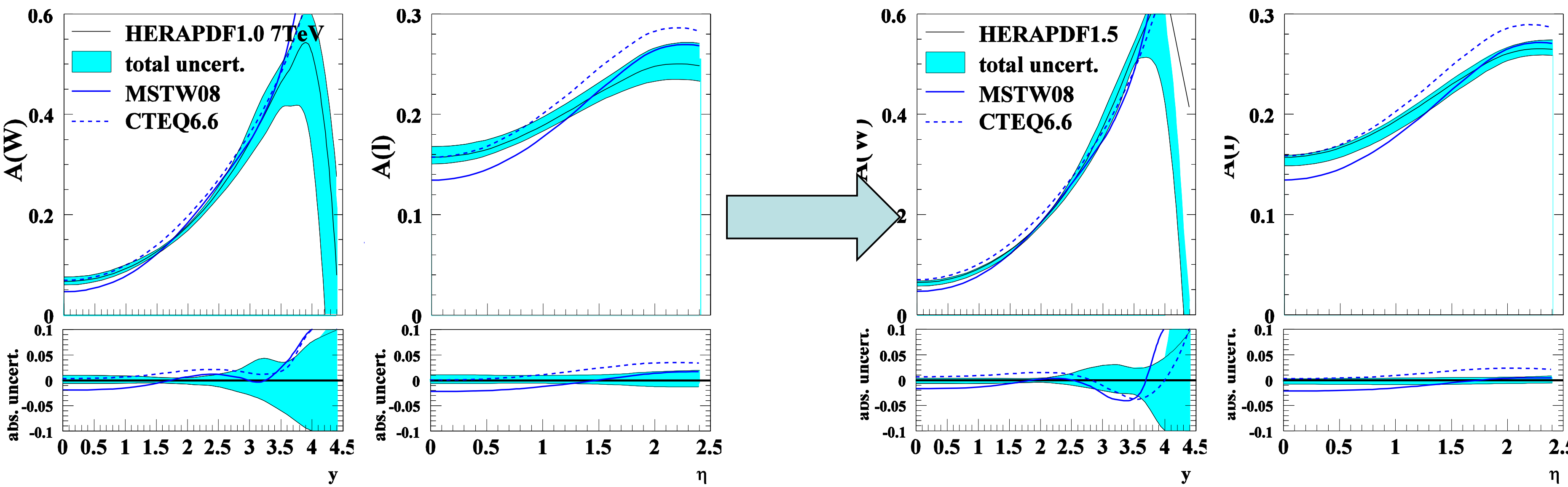




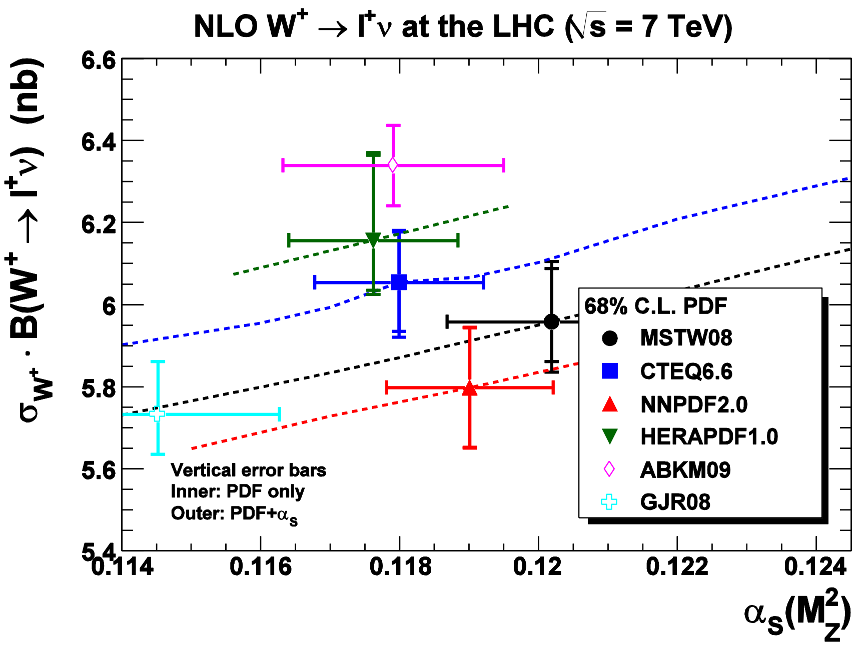
It is also interesting to compare the sizes of the PDF uncertainties
These are surprisingly similar despite being estimated in very different ways.

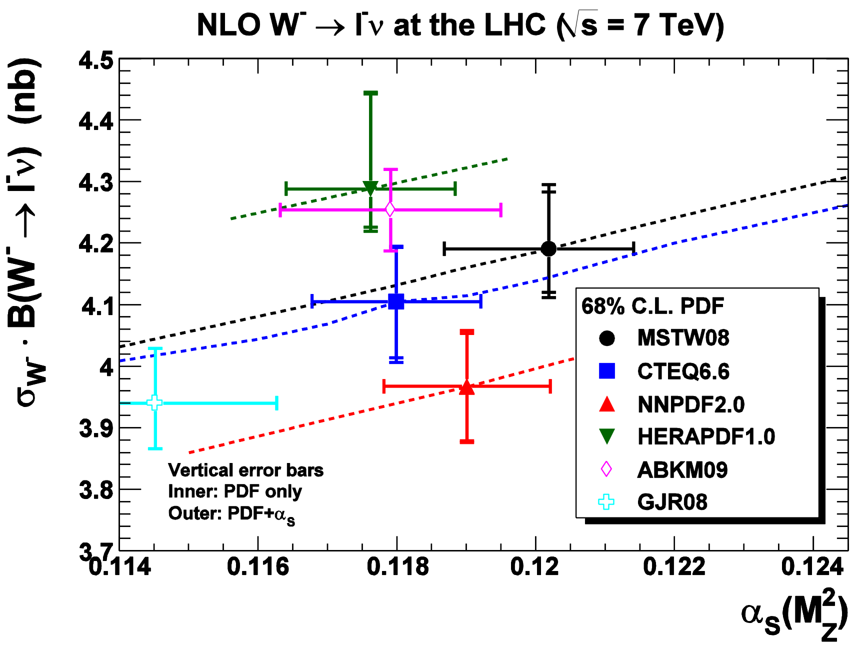
CTEQ, MSTW use increased χ2 tolerances Δχ2=(10-100) which cover input data set ‘inconsistencies’ and possibly limitations of parametrisation choice
NNPDF have a much more flexible parametrisation and a more statistically robust way off estimating uncertainties from many input data sets
HERAPDF have a very consistent input data set, use Δχ2=1, but also consider model and parametrisation uncertainties– the high-x uncertainties have recently been reduced in HERAPDF1.5





Talk by V Radescu



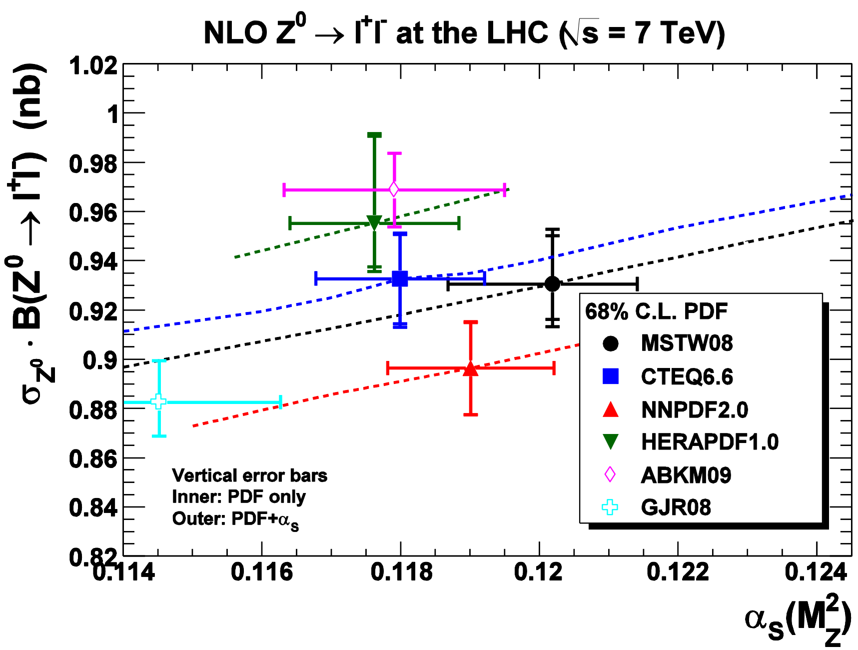


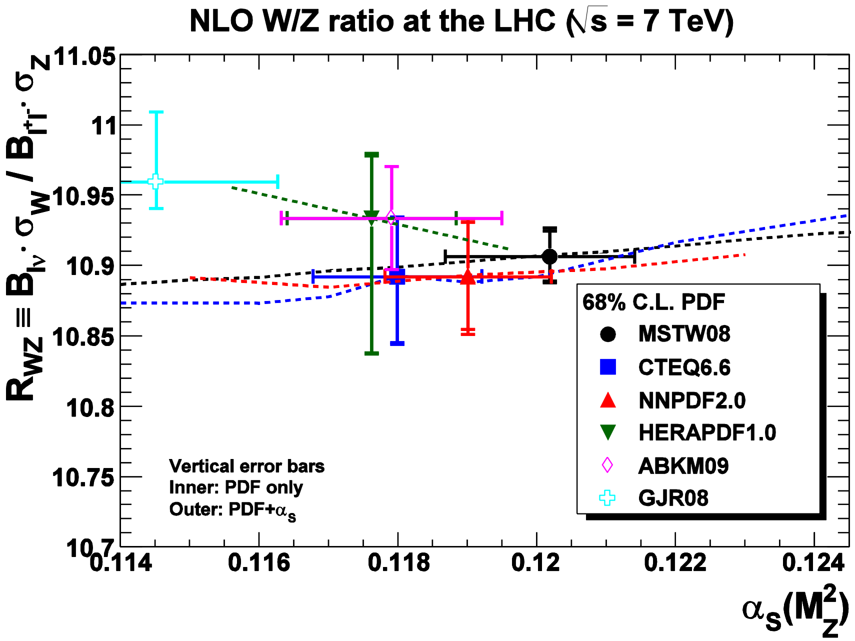
Now let's look at predictions for LHC cross-sections: first W/Z

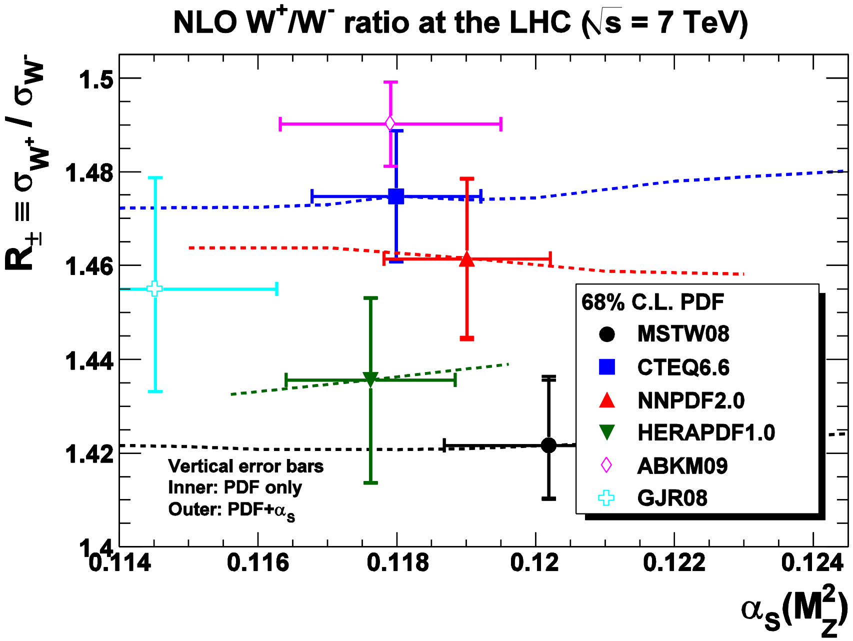
Overall disagreement ~8% in W, Z cross-sections

The PDF4LHC recommendation is to take the envelope of the NNPDF, MSTW, CTEQ predictions --even this may not be enough!

One suggestion is to use a common value of αs(MZ) – but this doesn't solve everything– another important consideration is the heavy quark mass scheme and value of charm mass





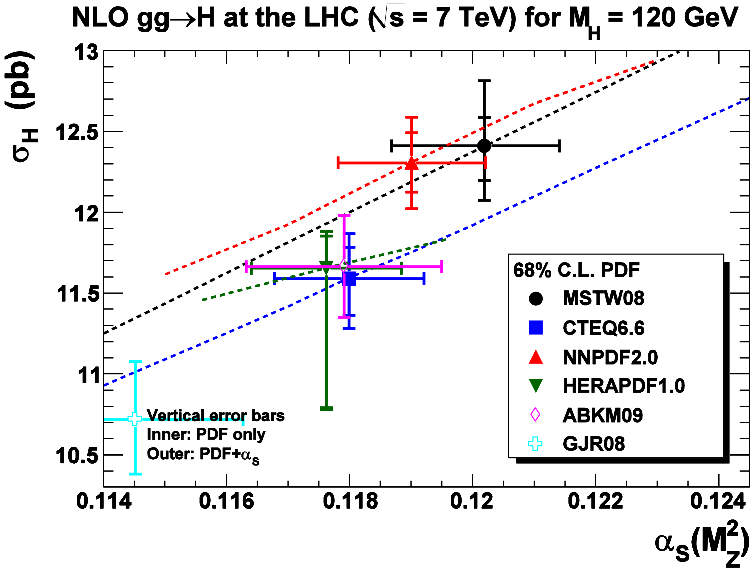


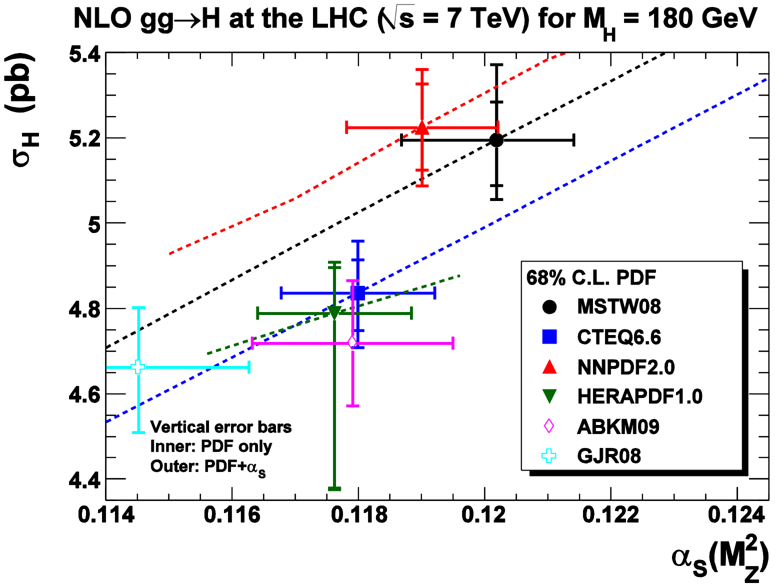
W/Z ratio is much better- within ~1% - golden SM measurement

But W+/W- ratio is not so good— ~ 5%

Disagreement in u/d quark shapes– early LHC measurement can resolve this

- Maybe even with data collected by the end of this year!





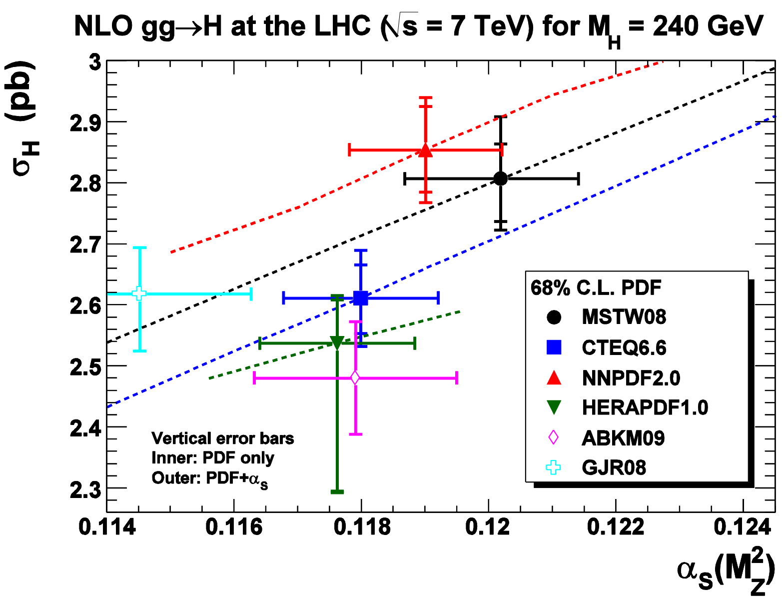
And then there are the gluon-gluon induced cross-sections

Spread in Higgs production cross-sections is now > 15%

Dependence on $\alpha_S(M_Z)$ is also increased- use of a common value would certainly decrease discrepancy..

But there are disagreements as to the correct value (talk by S Alekhin): NNPDF, CTEQ, HERAPDF, MSTW all provide PDFs at a series of $\alpha_S(M_Z)$ values ~0.114-0.122

PDF4LHC recommends adding $\Delta\alpha_S(M_Z)$~0.0012 uncertainty (at 68%CL) in quadrature with PDF uncertainty

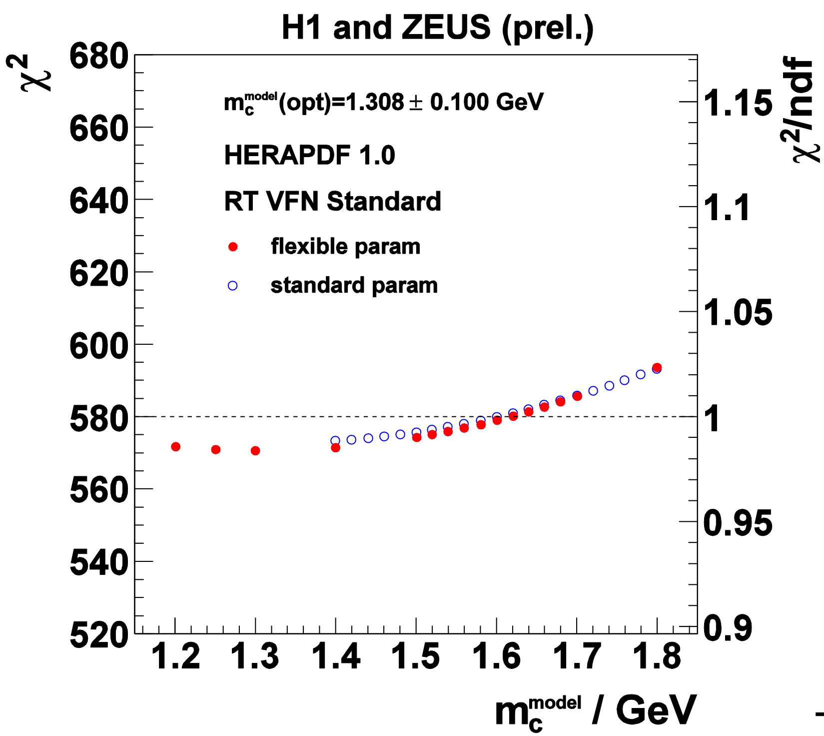


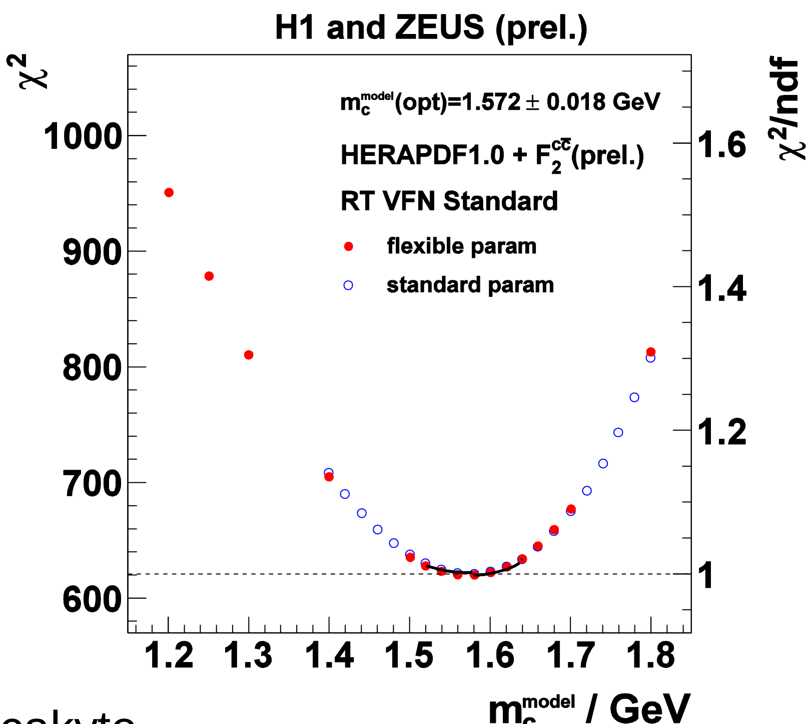
Talks by P. Jimenez-Delgado, J. Blumlein

Let's look into the treatment of charm – there are ideological battles- some say Fixed Flavour Number schemes are the only way to go, others favour Variable Flavour Number. These days these are usually General Mass VFNs rather than Zero-Mass.

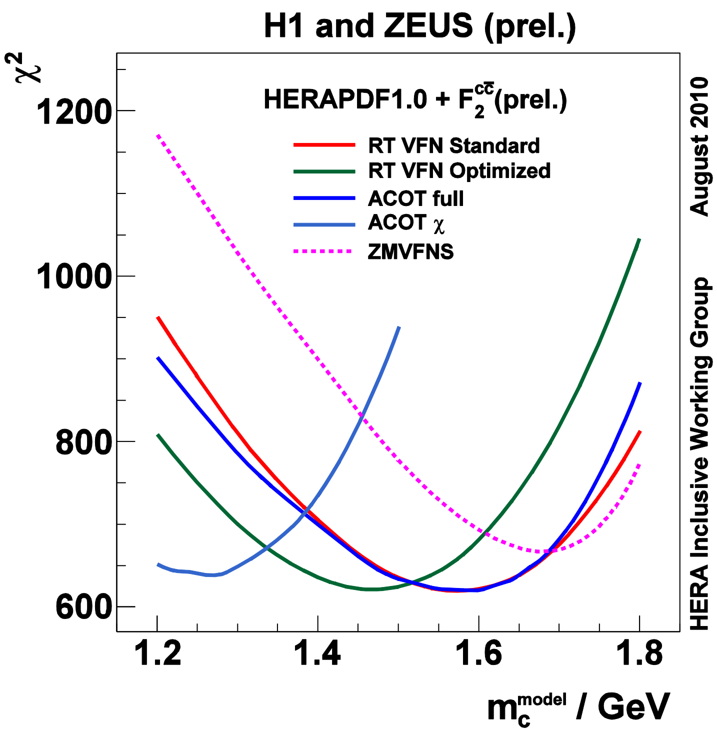
The value of the charm mass used has a significant influence on the W/Z cross-sections Δmc=+0.25 GeV gives +2.5% increase in cross-section . Thus PDFs are now also providing charm (and bottom) mass series (MSTW, HERAPDF, NNPDF)

BUT the new HERA F2(charm) data have some discriminating power





Talk by R Placakyte



But the HERAPDF uses the Thorne General Mass Variable Flavour Number Scheme for heavy quarks as used by MSTW08

This is not the only GMVFN

CTEQ use ACOT- χ

NNPDF2.0 use ZMVFN

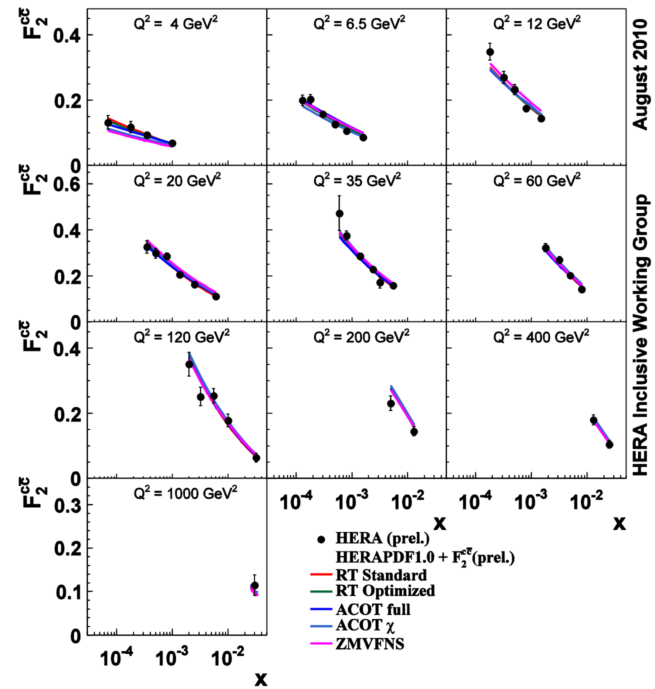
For each of these schemes the data prefer a different value of the charm mass. All schemes fit well (though ZMVFN is not so good)

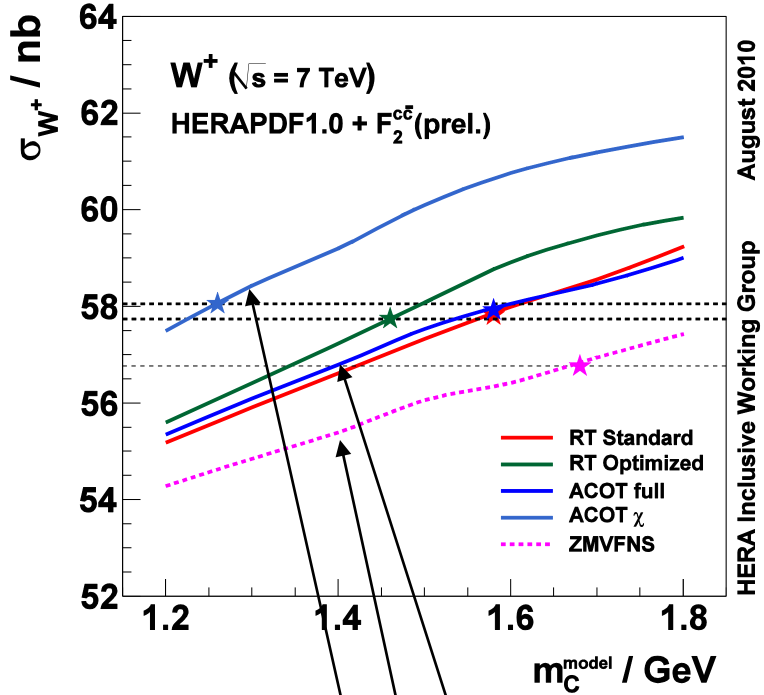
We have re-analysed the HERAPDF+F2c data using several different GMVFN heavy quark schemes

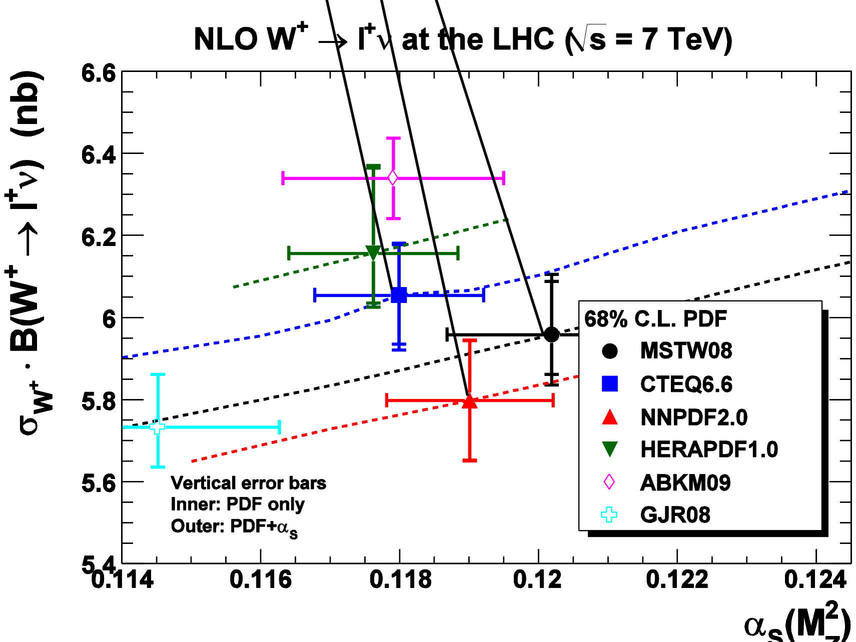
	m_c^{thr} (opt) / GeV	stat	syst	
RT stand	1.57	±0.02	+0.01	-0.03
RT optim	1.47	±0.02	+0.01	-0.03
ACOT full	1.58	±0.02	+0.02	-0.04
ACOT χ	1.25	±0.02	+0.02	-0.04
ZMVFNS	1.67	±0.02	+0.06	-0.06

Talk by R Placakyte

Model and param. Errors included







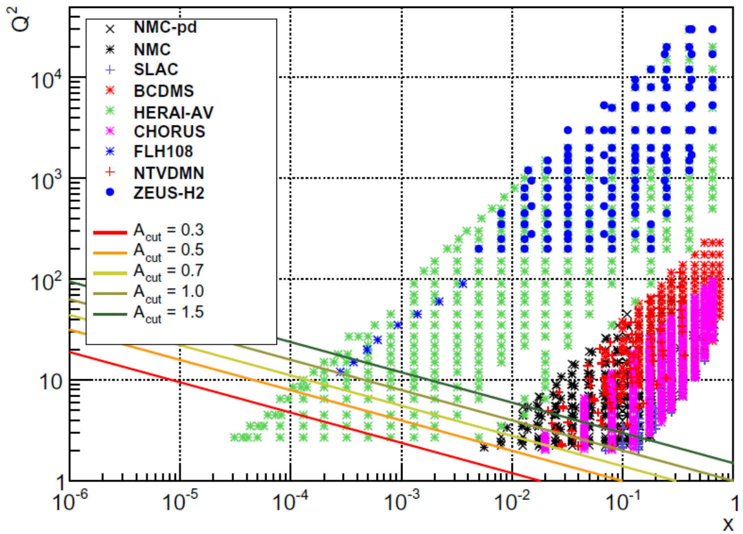
We then use each of these schemes to predict W and Z cross-sections at the LHC (at 7 TeV) as a function of charm mass parameter

If a fixed value of mc is used then the spread is considerable (~7%)- but if each prediction is taken at its own optimal mass value the spread is dramatically reduced (~2%) even when a Zero-Mass (ZMVFN) approximation has been used

scheme	m_c^{model}(opt)	χ^2/dof	χ^2/ndp	σ_Z(nb)	σ_{W^+}(nb)	σ_{W^-}(nb)
RT Standard	$1.58^{+0.02}_{-0.03}$	620.3/621	42.0/41	$29.27^{+0.07}_{-0.11}$	$57.82^{+0.14}_{-0.22}$	$40.22^{+0.10}_{-0.15}$
RT Optimized	$1.46^{+0.02}_{-0.04}$	621.6/621	46.5/41	$29.17^{+0.07}_{-0.13}$	$57.75^{+0.14}_{-0.26}$	$40.15^{+0.10}_{-0.18}$
ACOT full	$1.58^{+0.03}_{-0.04}$	621.2/621	59.9/41	$29.28^{+0.10}_{-0.13}$	$57.93^{+0.18}_{-0.24}$	$40.16^{+0.12}_{-0.16}$
S-ACOT-χ	$1.26^{+0.02}_{-0.04}$	639.7/621	68.5/41	$29.37^{+0.08}_{-0.15}$	$58.06^{+0.16}_{-0.30}$	$40.23^{+0.11}_{-0.21}$
ZMVFNS	$1.68^{+0.06}_{-0.07}$	667.4/621	88.1/41	$28.71^{+0.19}_{-0.20}$	$56.77^{+0.33}_{-0.34}$	$39.46^{+0.24}_{-0.25}$
			differences	0.7% 2.3%	0.5% 2.3%	0.2% 2.0%

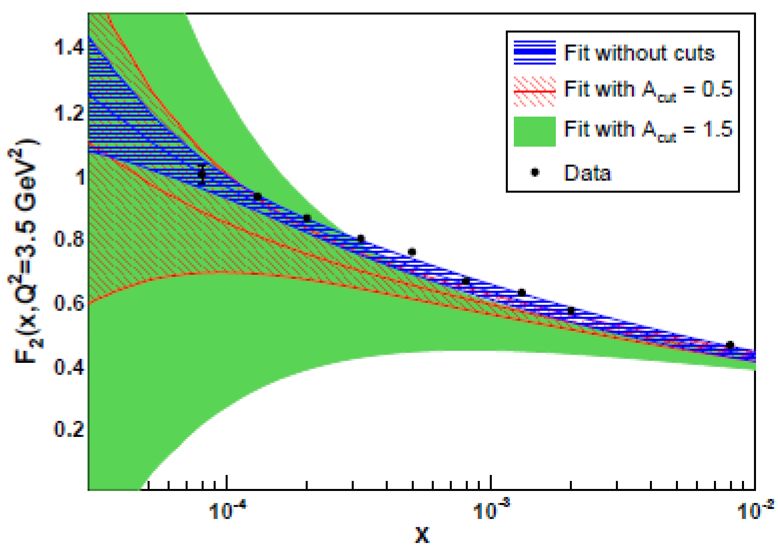
The PDFs MSTW08, CTEQ6.6, NNPDF2.0 do NOT use charm mass parameters at the optimal values- and this may explain their differing predictions.

We have also worried about the applicability of NLO DGLAP for the low-x,Q2 part of the kinematic plane

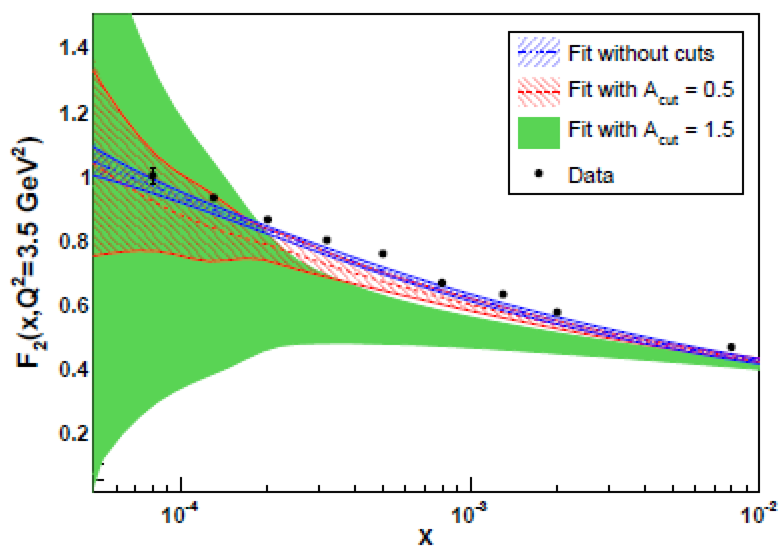


Caola, Forte, Rojo noticed tension between the low-x,Q2 data and higher x, Q2 data using the combined HERA-I data

Talk by F Caola

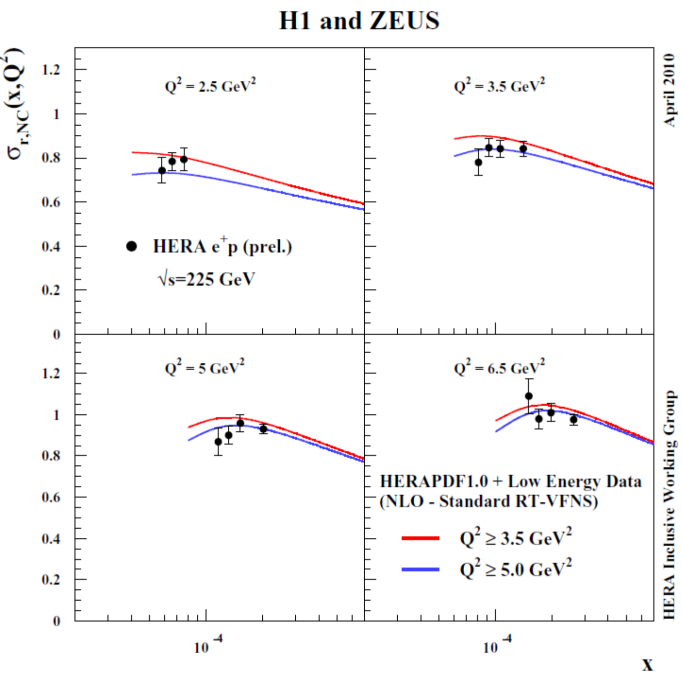


Before combined HERA-I

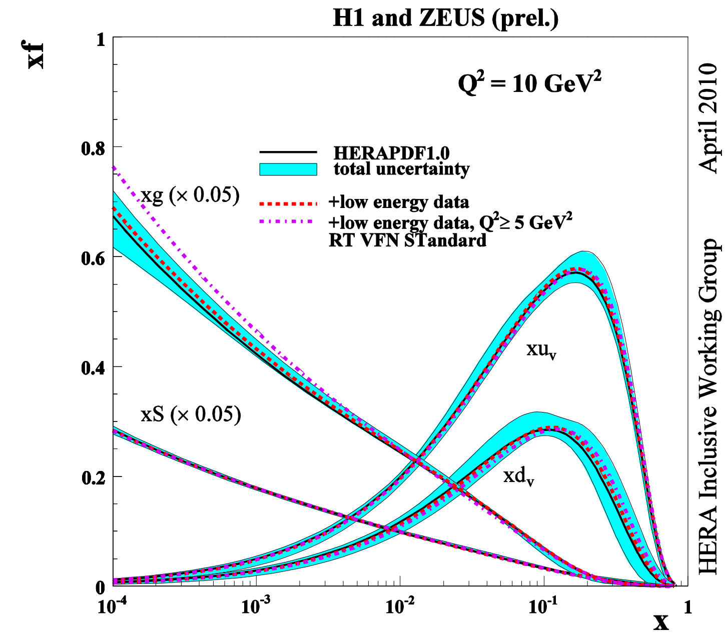


With combined HERA-I

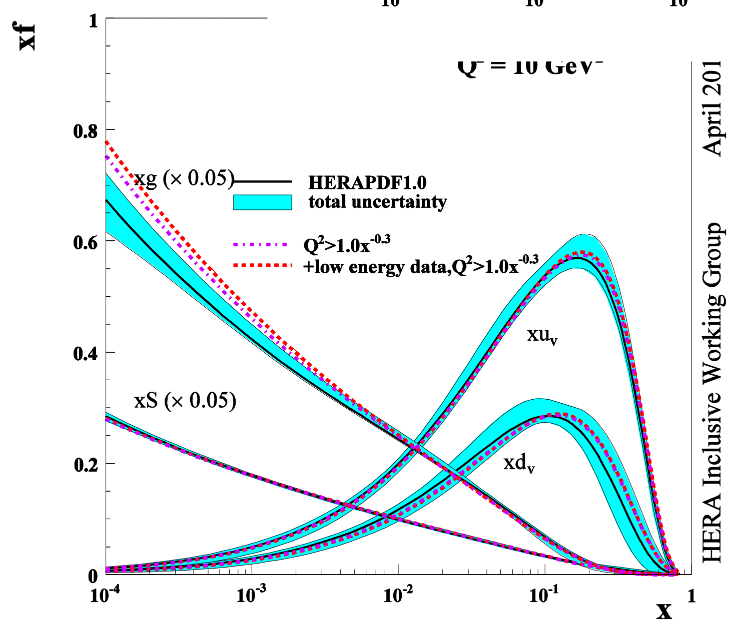
The HERA low energy data runs have now been combined and when these data are used in the HERAPDF fit we find increased tension with low-x, Q^2 data



Imposing a Q^2 cut improves $\chi 2$ and changes the gluon shape outside error bands



The high energy and low energy data sets are both well fit and brought into agreement with each other again if a cut $Q^2 > 1.0\ x^{-0.3}$ is imposed



NOTE 1: NNLO fits do NOT help to resolve low x-Q2 tension

NOTE 2: fortunately this does not matter much for W/Z Higgs at the LHC- but it may matter for LHC-B

We also worried about the discrepancy between Tevatron lepton asymmetry data and PDFs

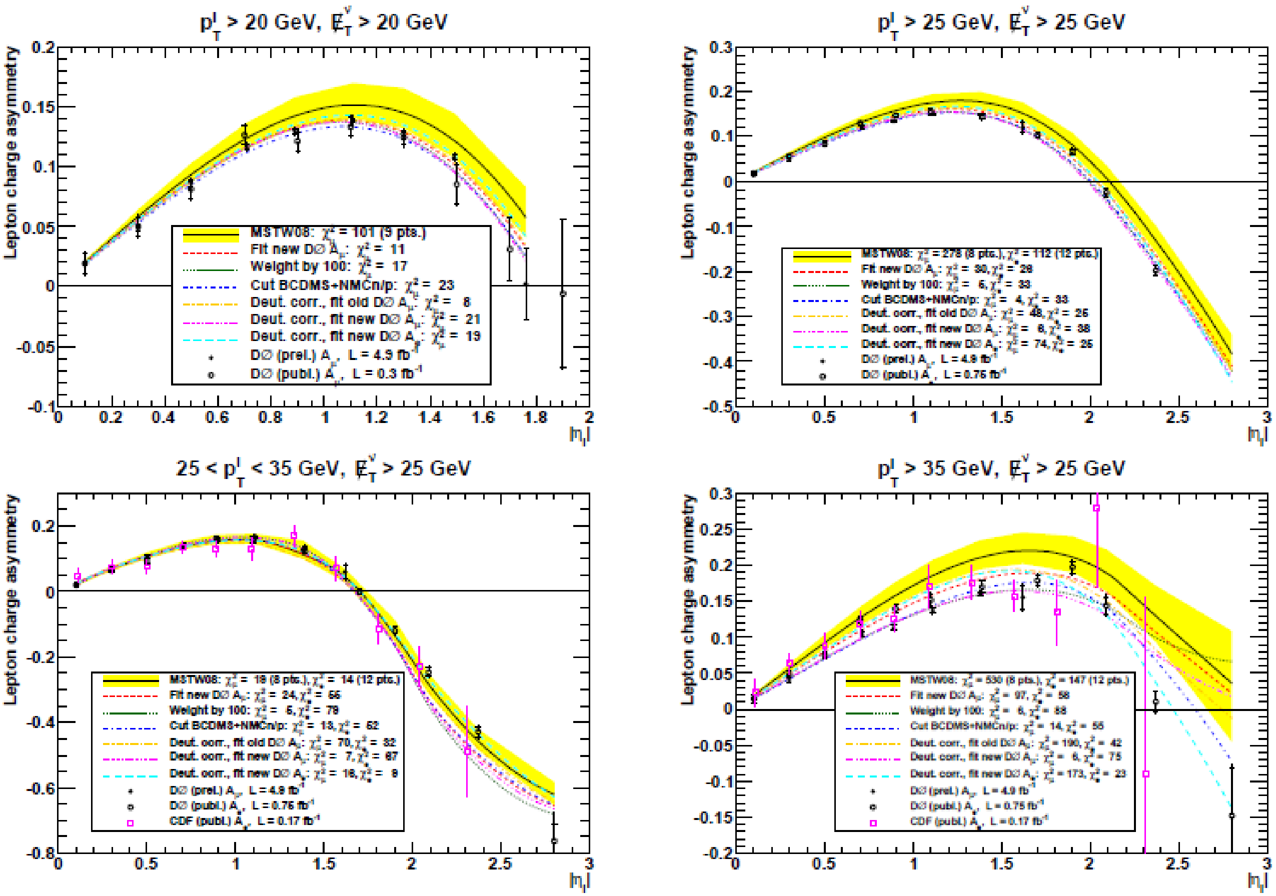
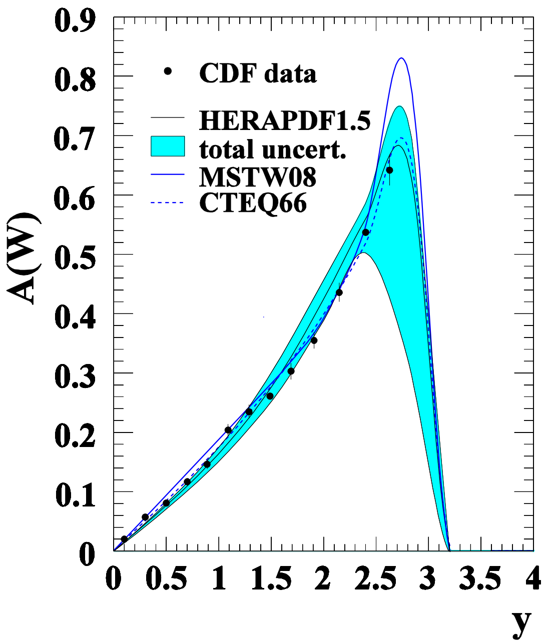
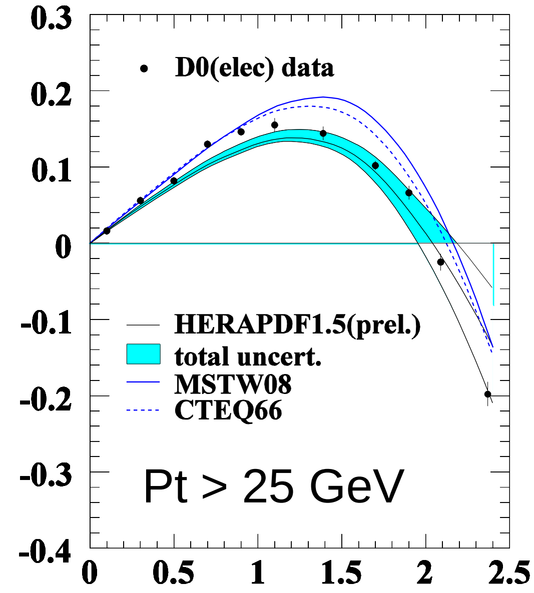


Illustration from MSTW08 – standard Yellow bands do not fit well. There is tension with NMC and BCDMS deuteron data. Alternative fits changing deuterium corrections have been tried- seems a bit arbitrary? (talk by S Alekhin)

The problem could be in the modelling of the pt spectra?





At this meeting we have seen more recent fits to the W and lepton asymmetry data

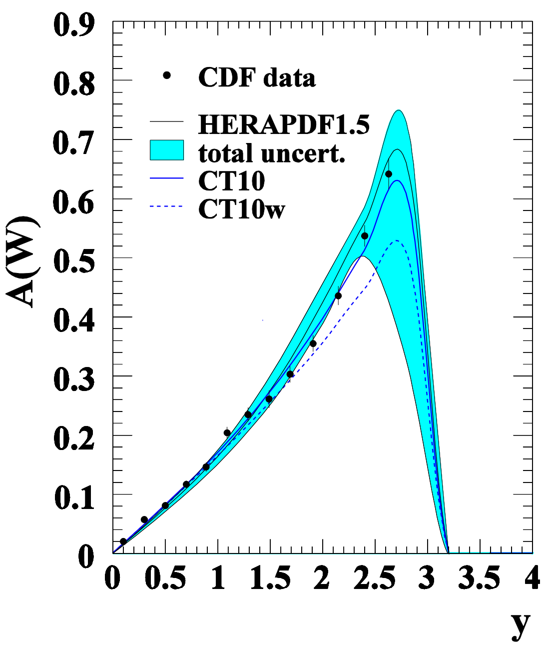
MSTW08, CTEQ66 and HERAPDF1.5 describe the W-asymmetry data..

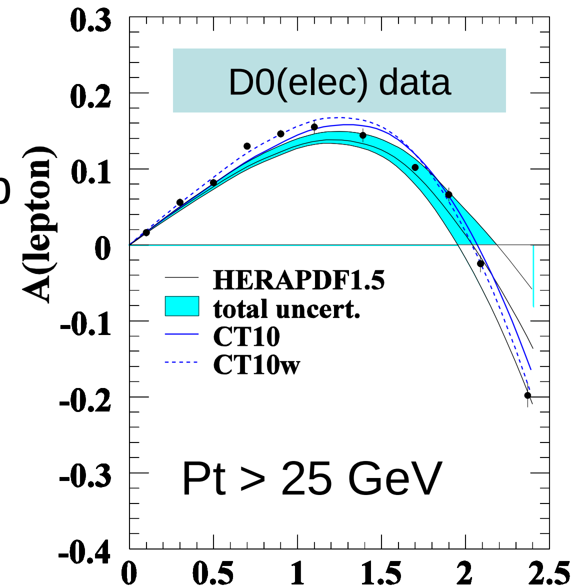
But MSTW08 and CTEQ66 do Not describe the D0 electron asymmetry (pt> 25 GeV) data well

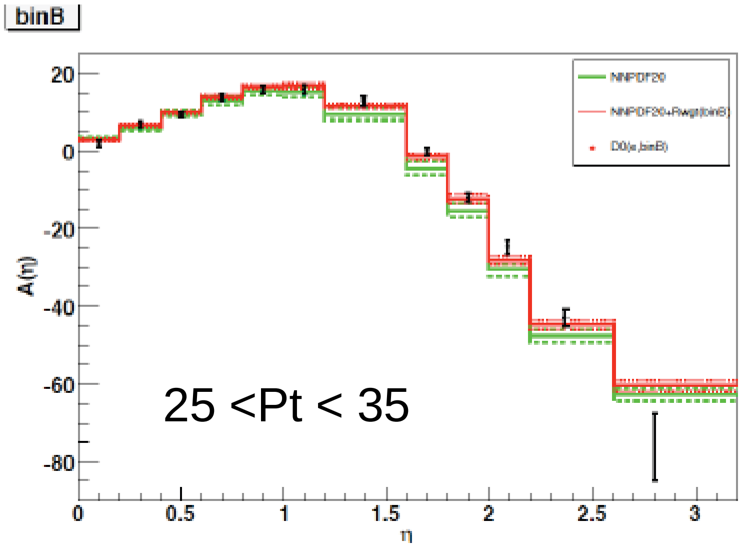
HERAPDF1.5 does a better job– NOTE it uses only proton data so is not subject to deuterium correction uncertainties

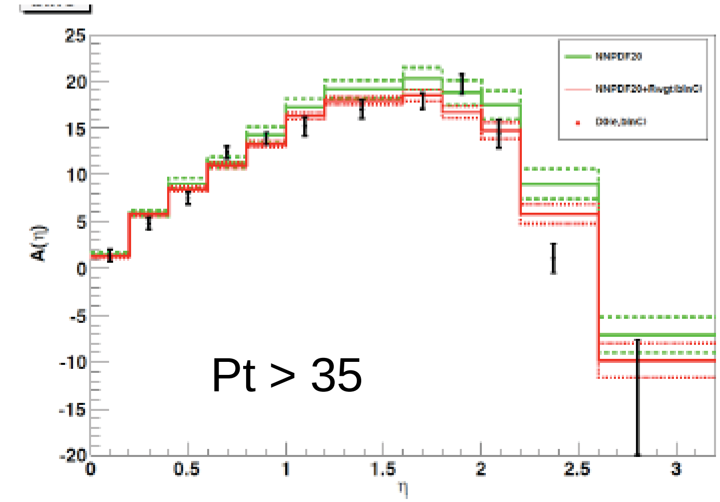
CT10/CT10w both do a better job of describing the electron asymmetry than CTEQ6.6 with CT10w doing the best job by definition

However it has sacrificed a good description of the W-asymmetry









Talk by M Ubiali

NNPDF have looked at D0 electron data in two pt bins using a technique of re-weighting which assesses the compatibility of new data sets with the bulk of data. They find significant discrepancies for the high pt > 35 GeV data

So perhaps the description of the pt spectra is more likely to be the problem than the deuterium corrections

FINALLY

We also discussed the PDF4LHC recommendations for PDF+alphas uncertainties.

A.Vicini applied these to Higgs production for NLO and NNLO and suggested a useful pragmatic simplification for the alphas part

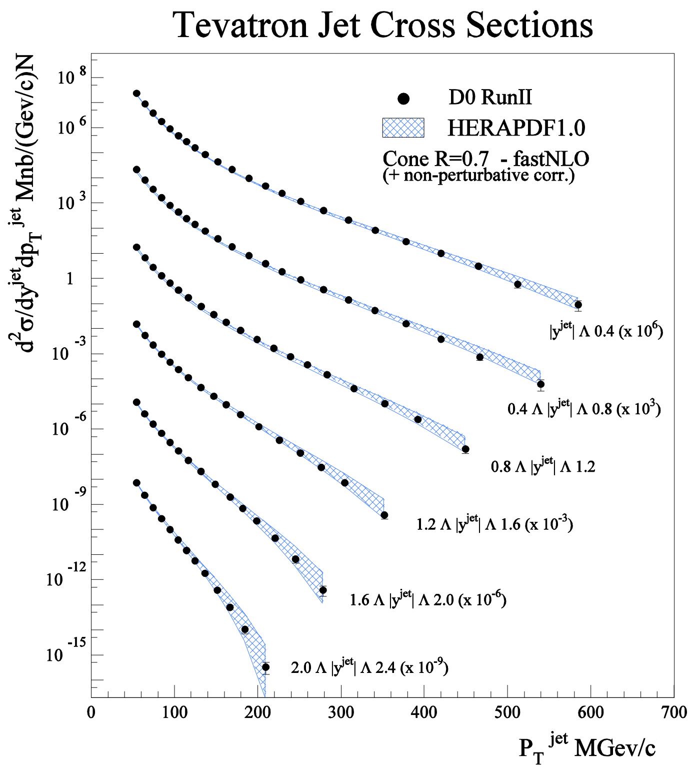
It's clear that the audience disputed the recommendations

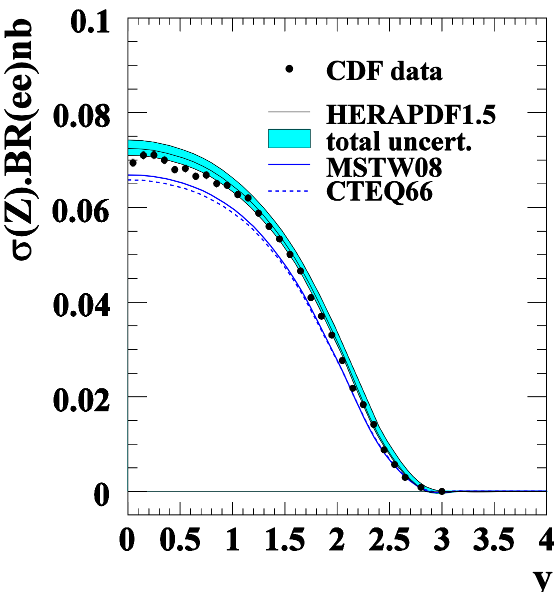
But the work of the PDF4LHC is to document the differences and similarities between PDF sets and their predictions, try to understand them and resolve them where possible, but also to respect these differences where they reflect genuine physics uncertainties.

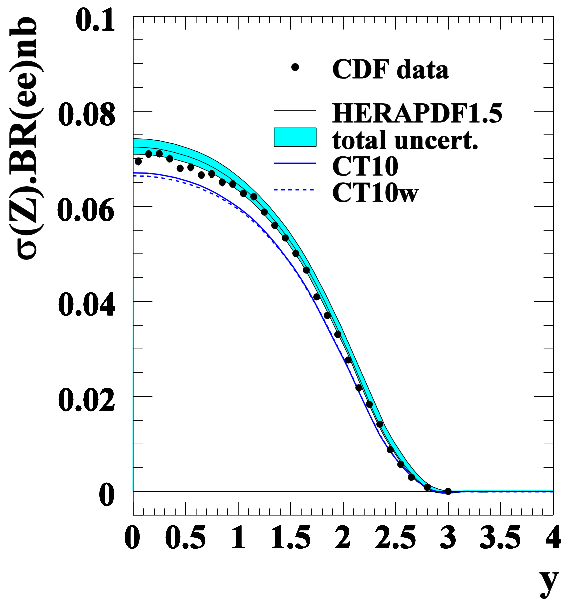
CONCLUSIONS:

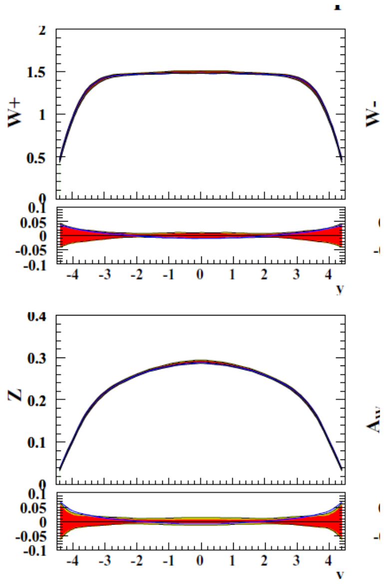
Lets keep on working – next PDF4LHC at DESY, Nov 29th

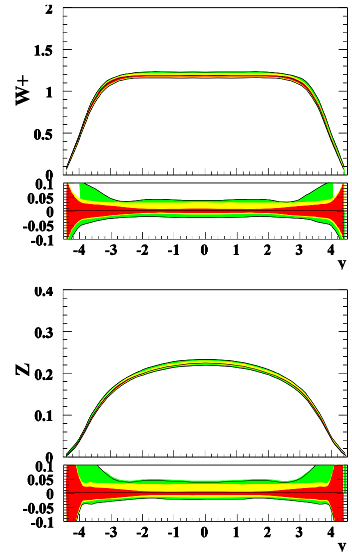
extras


Tevatron Jet Cross Sections
D0 RunII
HERAPDF1.0
Cone R=0.7 - fastNLO
(+ non-perturbative corr.)
|y^jet| Λ 0.4 (x 10^6)
0.4 Λ |y^jet| Λ 0.8 (x 10^3)
0.8 Λ |y^jet| Λ 1.2
1.2 Λ |y^jet| Λ 1.6 (x 10^-3)
1.6 Λ |y^jet| Λ 2.0 (x 10^-6)
2.0 Λ |y^jet| Λ 2.4 (x 10^-9)
d^2σ/dy^jet dp_T^jet Mnb/(Gev/c)N
P_T^jet MGev/c


CDF data
HERAPDF1.5
total uncert.
MSTW08
CTEQ66
σ(Z).BR(ee)nb
y


CDF data
HERAPDF1.5
total uncert.
CT10
CT10w
σ(Z).BR(ee)nb
y





Model errors are the most signficant in the central region: m_c, m_b, fs, Q^2_{min}

m_c =1.35 – 1.65 GeV is the dominant contribution… but this can be improved if F2(charm) data are used…..

However PDF fitting should also include consideration of model errors and parametrisation errors

HERAPDF1.0
experimental plus
model errors plus
parametrisation