ZEUS + H1 pdf fits including HERA-II high Q^2 data

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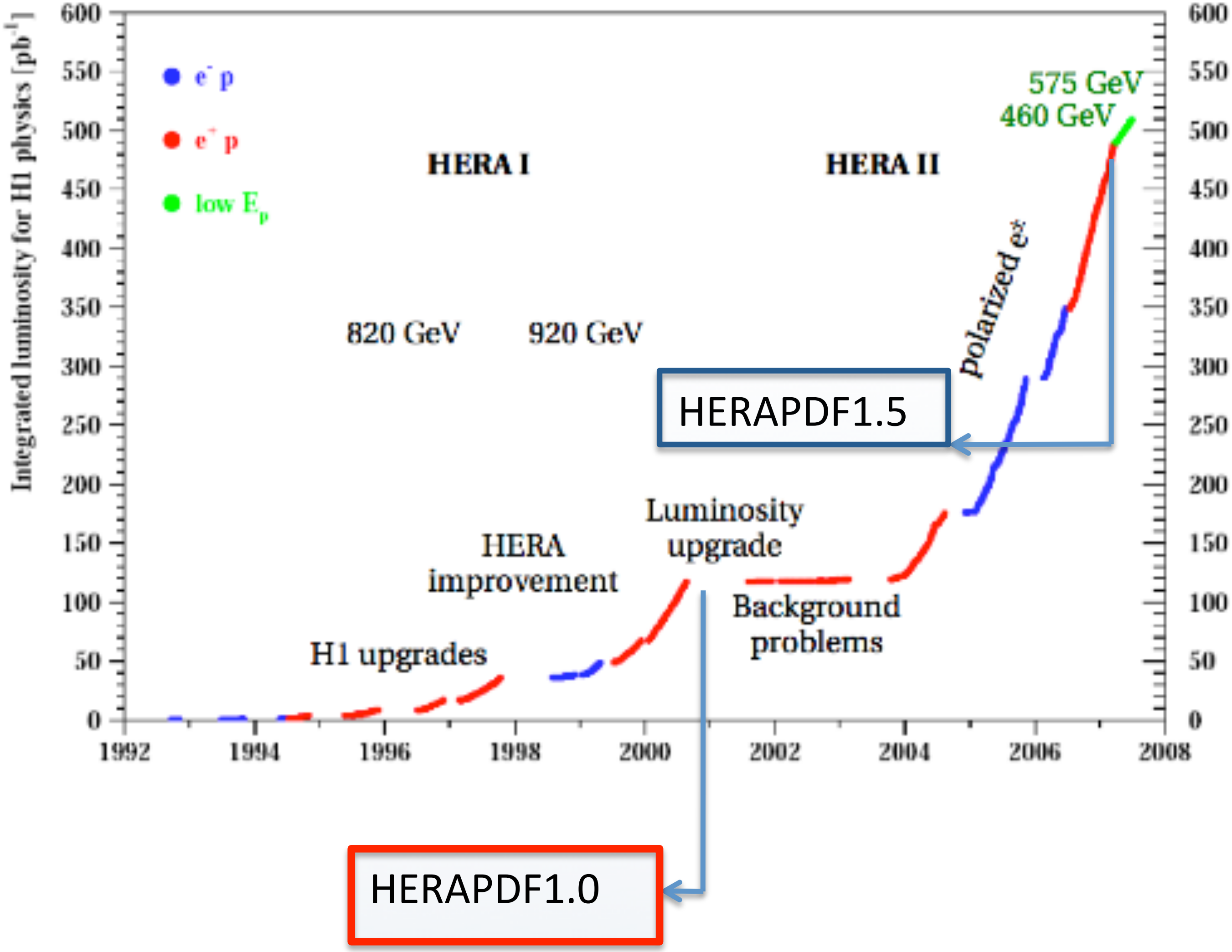
On behalf of the H1 and ZEUS Collaborations

Data sets



Combined HERA I+high Q2 HERA II Data [prelim]

Philosophy

Use only HERA data (combined H1+ZEUS) to have consistent data sets and better controlled systematic uncertainties. Allows for $\Delta\chi^2=1$ uncertainty criterion.

Comparison to pdf's using other data sets a test of universality.

Fix α_S, strange fraction, heavy quark masses, … in standard fit. Variations (except α_S considered as model uncertainty)

Use simple parametrizations with minimum number of parameters for central fits; uncertainty related to parametrization added in total pdf uncertainty

Data fitted; results

HERAPDF1.0

- ➔ HERA I NC+CC data after combination
- ➔ standard parametrization (10 free parameters)
- ➔ full errors for NLO
- ➔ only 2 central fits for 2 different values of alphas for NNLO

HERAPDF1.5

- ➔ HERA I+II NC+CC data after combination (only high-Q^2 HERA II data)
- ➔ standard parametrization (10 free parameters) for NLO
- ➔ extended parametrization (14 free parameters) for NNLO

HERAPDF1.5f

- ➔ HERA I+II NC+CC data after combination (only high-Q^2 HERA II data)
- ➔ extended parametrization (14 free parameters) for NLO

$Q^2 \geq 3.5$ GeV^2

$2\times10^{-4} \leq x \leq 0.65$

Parametrizations

For all pdf's: $xf(x,Q_0) = A \cdot x^B \cdot (1-x)^C \cdot (1+\epsilon\sqrt{x}+Dx+Ex^2)$

There is a pdf for glue, $u_{valence}$, $d_{valence}$, anti-U, anti-D (includes strange with fixed fraction)

Constraints for standard fit for HERAPDF:

- momentum sum rule, quark sum rules
- E=0 except for $u_{valence}$; D=0; ε=0
- one B for valence, one B for sea quarks
- require anti-u=anti-d as x->0 (fixes A for anti-d)
- for the sea, S=2×(anti-U+anti-D)

Only 10 free parameters:

B_{glue}, C_{glue},$B_{u\text{-}valence}$, $C_{u\text{-}valence}$, $C_{d\text{-}valence}$,$A_{anti\text{-}D}$, $B_{anti\text{-}D}$, $C_{anti\text{-}D}$, $C_{anti\text{-}U}$,$E_{\_u\text{-}valence}$

Extended (14 parameter) fit:

allow terms for low x gluon (a la MSTW) + let $u_{valence}$ and $d_{valence}$decouple at low x, by having separate B($u_{valence}$) and B($d_{valence}$)

Formalism and Assumptions

HERAPDF1.0:

NLO DGLAP MS-bar scheme, factorization scale is Q^2

Program used: QCDNUM, developed by M. Botje

Q^2_0=1.9 GeV^2. Light quark coefficient functions calculated in QCDNUM; heavy quark coefficient functions calculated in general-mass, variable-flavor-number scheme.

Modeling assumptions:

Parameter	Nominal	Lower	Upper
f_s	0.31	0.23	0.38
M_c [GeV]	1.4	1.35 (Q^2_0=1.8)	1.65
M_b [GeV]	4.75	4.3	5.0
Q^2_{min} [GeV^2]	3.5	2.5	5.0
Q^2_0 [GeV^2]	1.9	1.5 (M_c=1.6)	2.5 (M_c=1.6,f_c=0.34)
α_S	0.1176	0.1156 (not included in error band)	0.1196 (not included in error band)

Central values (HERAPDF1.0)

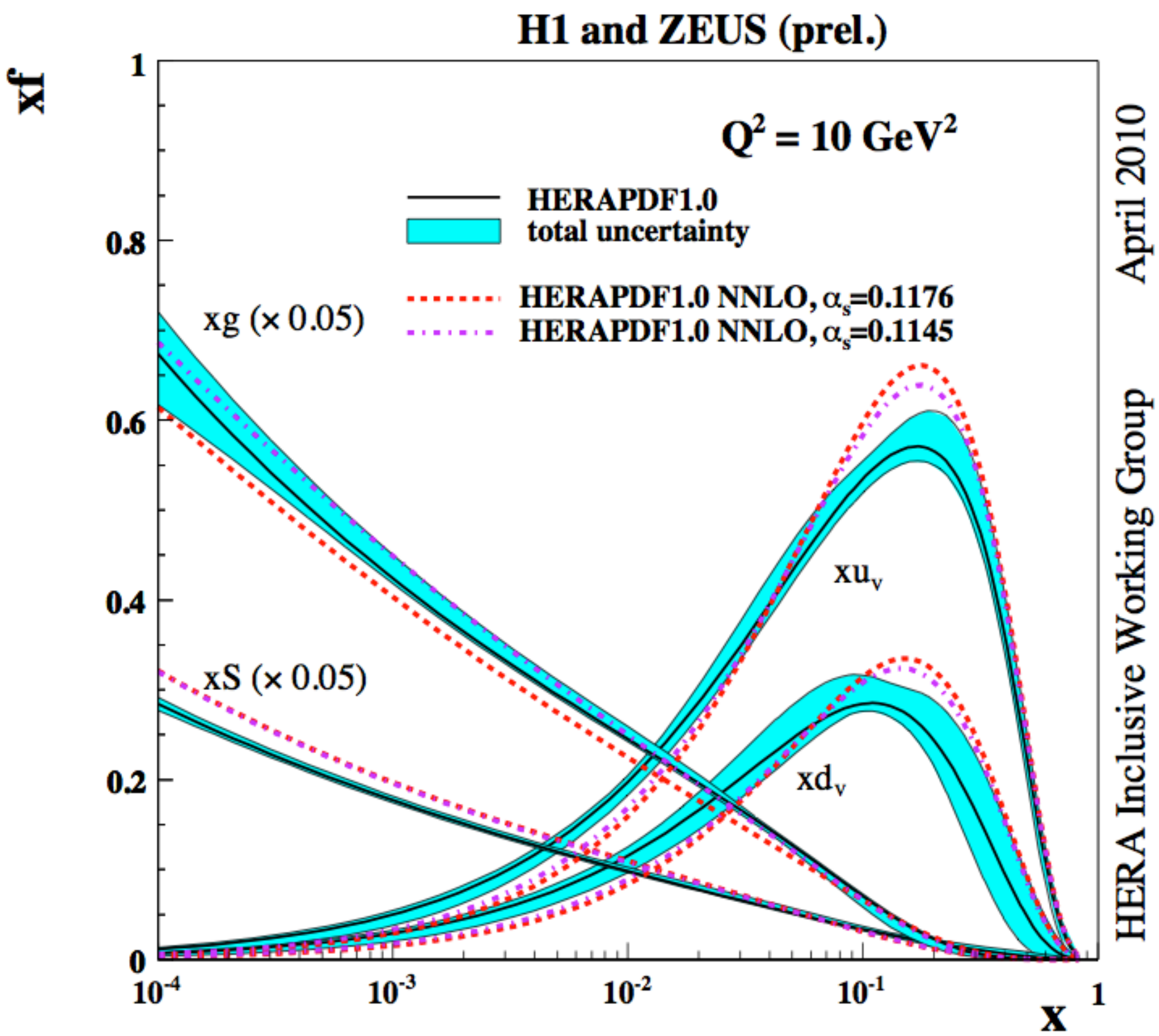
$$xf(x, Q_0) = A \cdot x^B \cdot (1-x)^C \cdot (1 + \epsilon\sqrt{x} + Dx + Ex^2)$$

	A	B	C	E
xg	6.8	0.22	9.0	
xu_v	3.7	0.67	4.7	9.7
xd_v	2.2	0.67	4.3	
xU-bar	0.113	-0.165	2.6	
xD-bar	0.163	-0.165	2.4	

Comments:

- gluons are valence-like at starting scale (not allowed to be negative in nominal fit)
- variations in the parametrization: allow negative gluon for reduced Q^2_0 fit, different $B(u_v)$ and $B(d_v)$, both of which tend to increase the uncertainty at small-x, and one of parameters in polynomial allowed to be non-zero for one of the pdfs – tends to increase pdf uncertainty at high-x
- envelope of results from different parametrizations taken as parametrization uncertainty
- charm uncertainty strongly correlated to gluon uncertainty

Comparison NNLO with NLO (HERA-I)



α_S(Mz) at NNLO = 0.1176

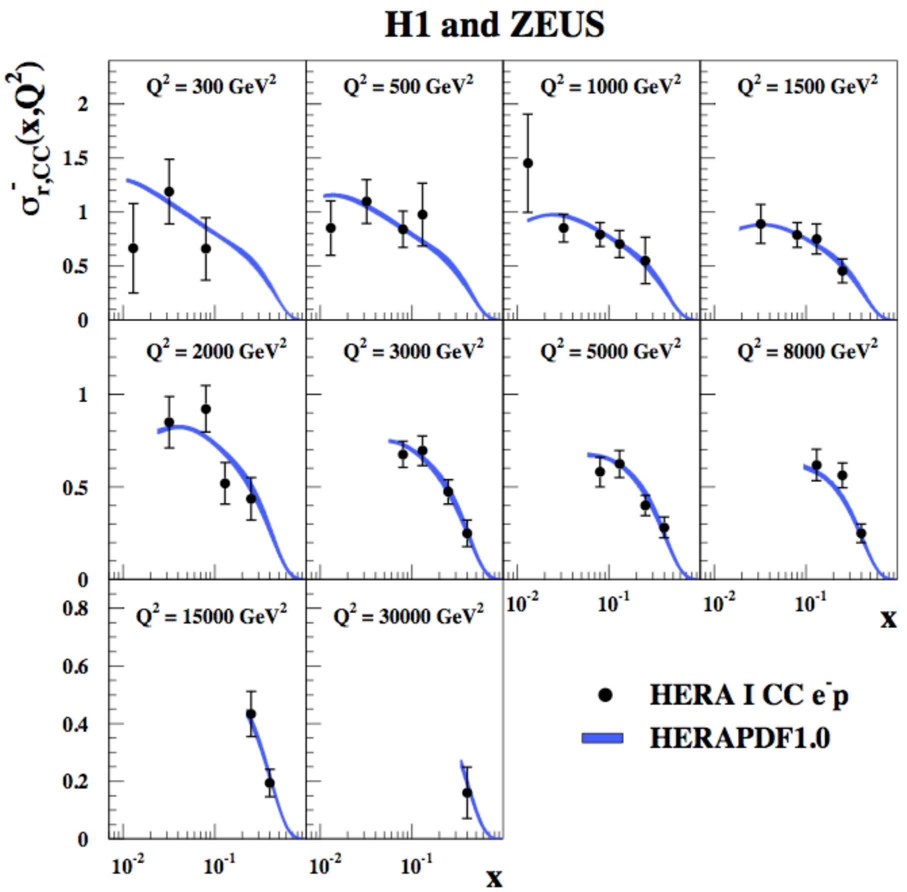
α_S(Mz) at NNLO = 0.1145

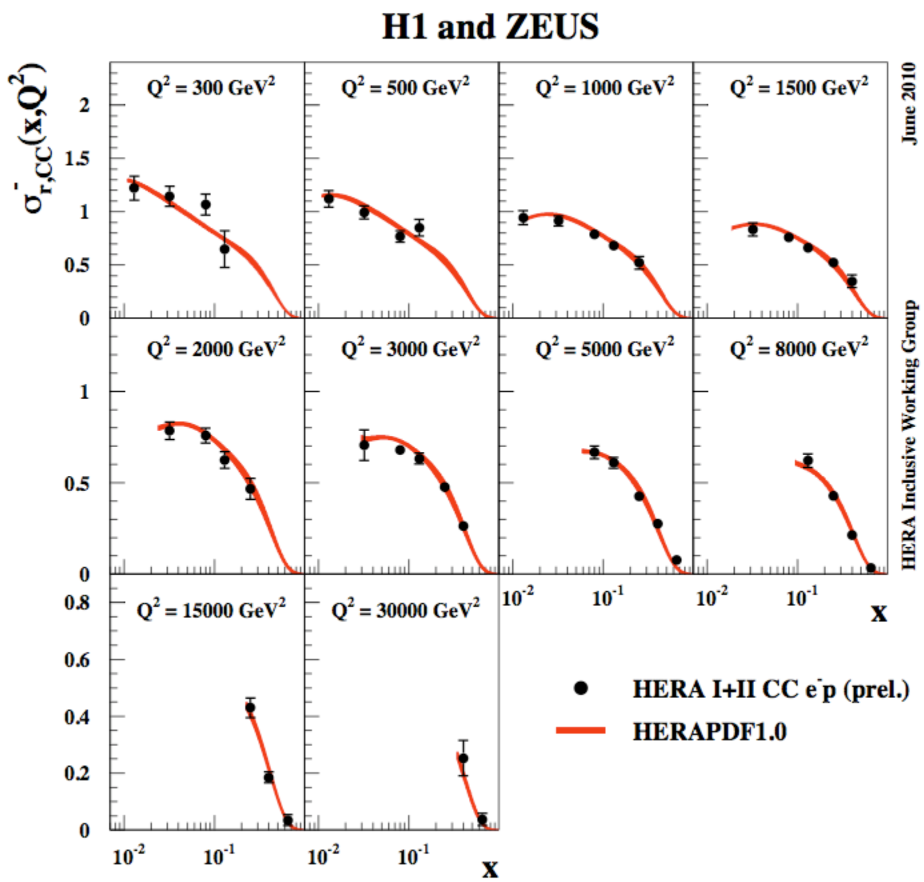
NNLO makes big difference in parton densities at high-x. Choice of α_S value important for small-x

Fits performed at NNLO using RT-VFNS; χ^2 60 units higher than for NLO; parametrizations no longer appropriate shape, causes large χ^2.

Adding the HERA II Data

HERA I and HERA II data are combined using averaging procedure (see previous talk): 674 unique cross sections points with 134 sources of systematic uncertainties

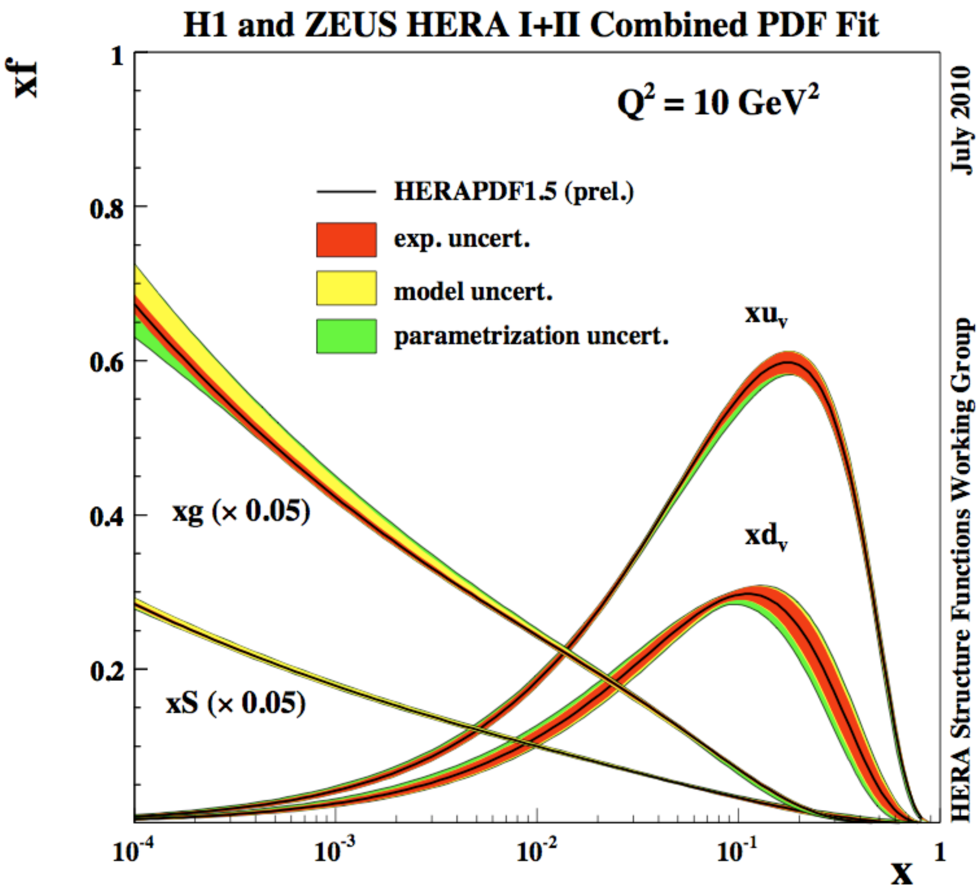


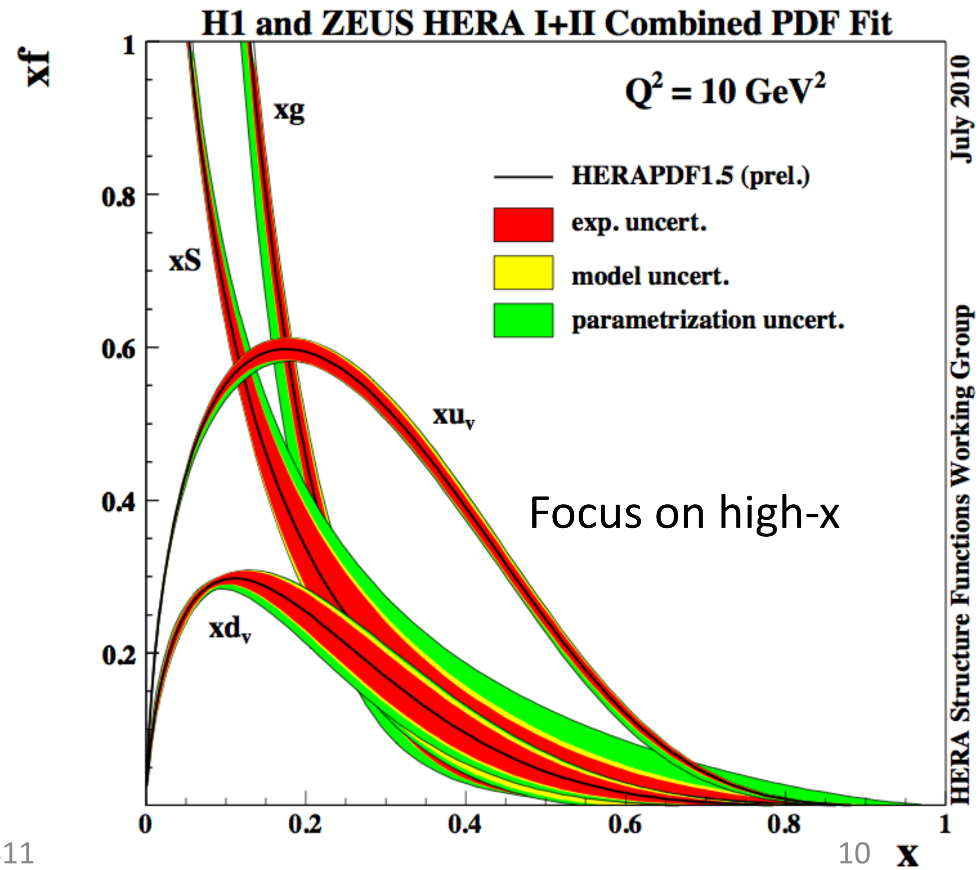


Great improvement in precision. – particularly Charged Current cross sections.

Standard NLO 10 parameter Results

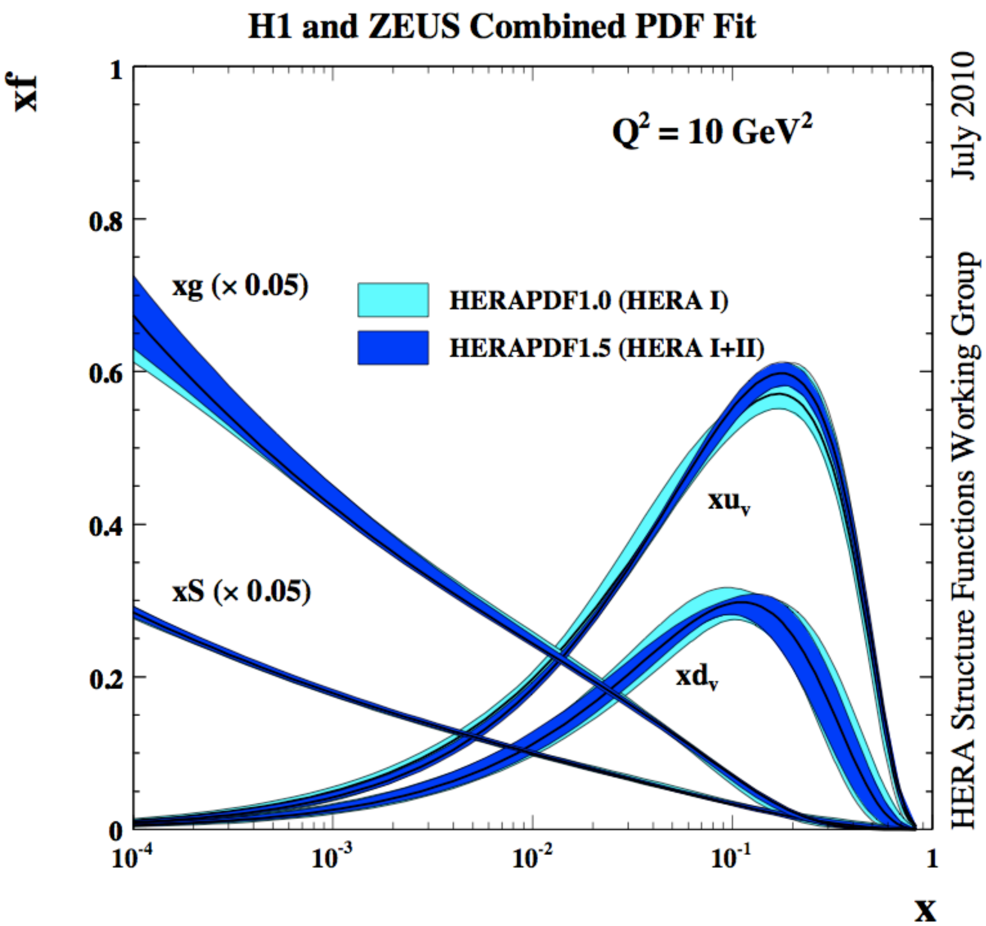
HERAPDF1.5



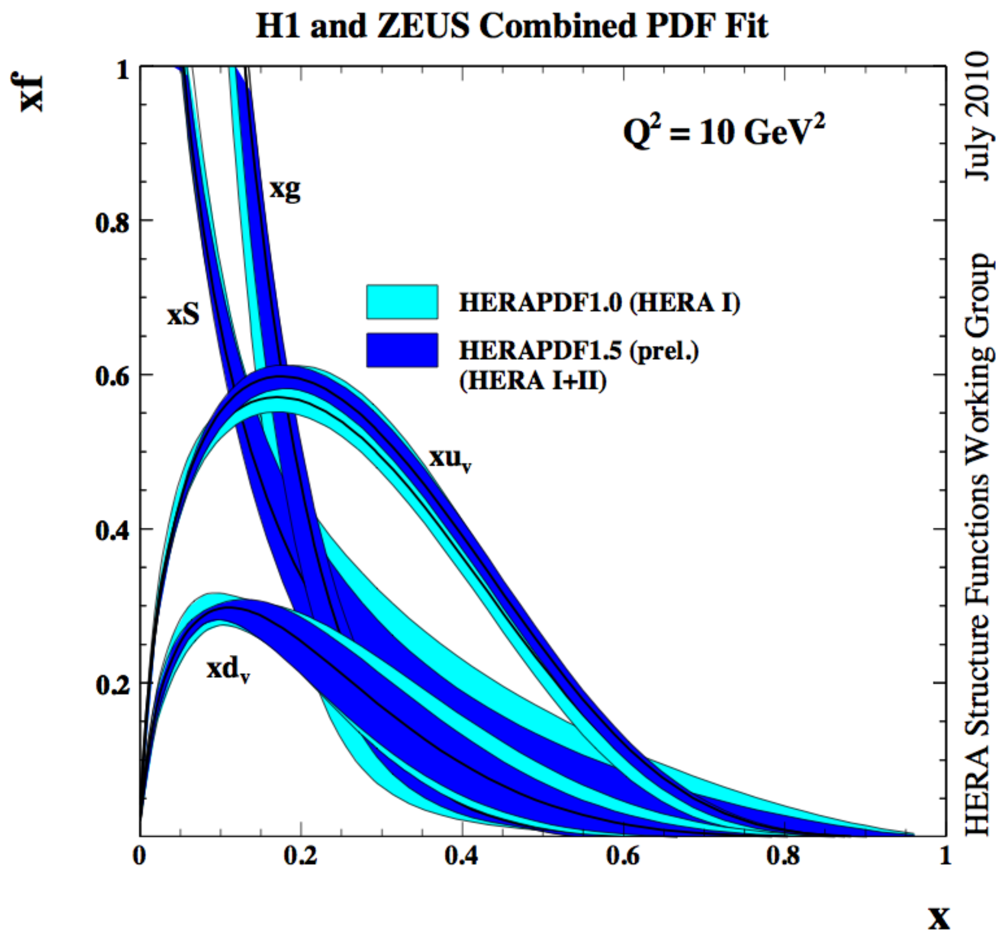


Focus on high-x

Comparison with HERA I only fit

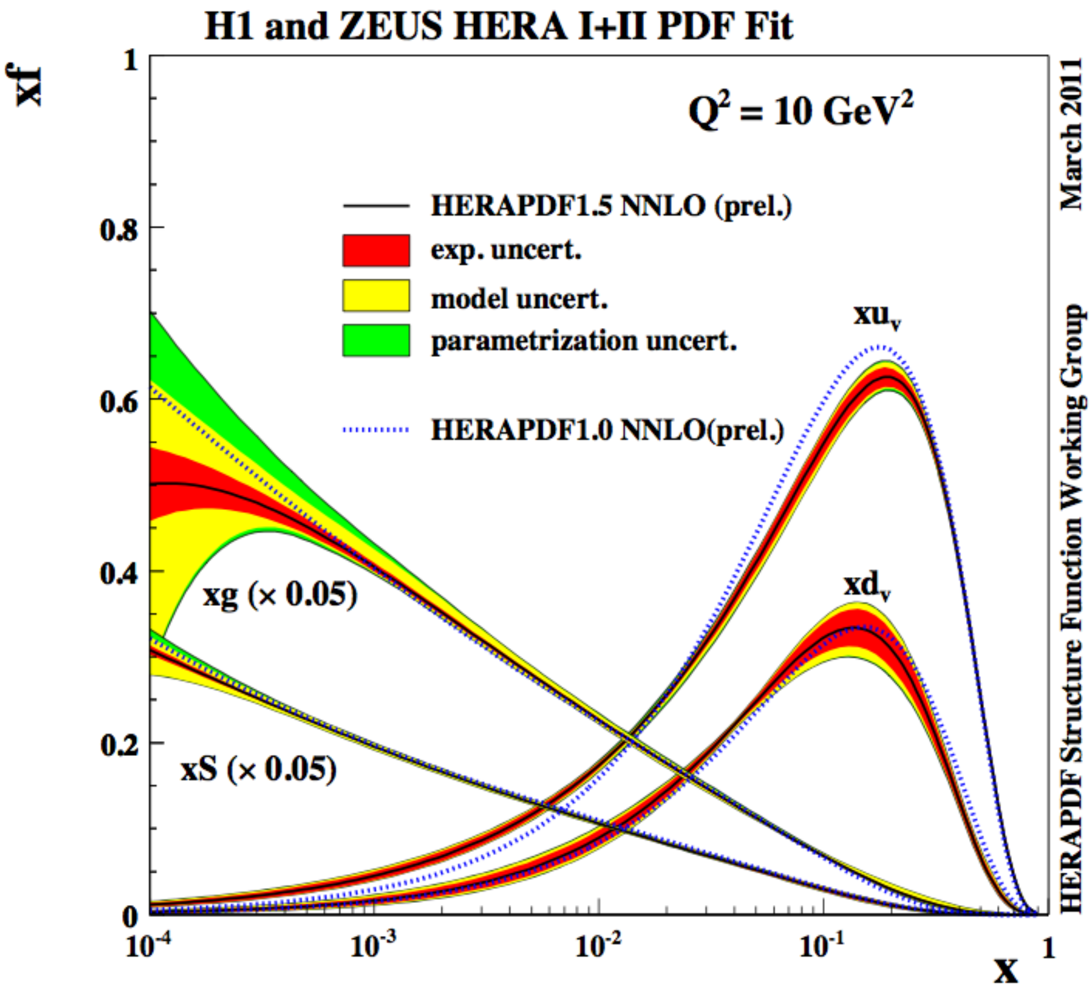


differences (smaller uncertainties) at high-x



NLO: consistent results, smaller uncertainties

NNLO: HERA I+II vs HERA I Results

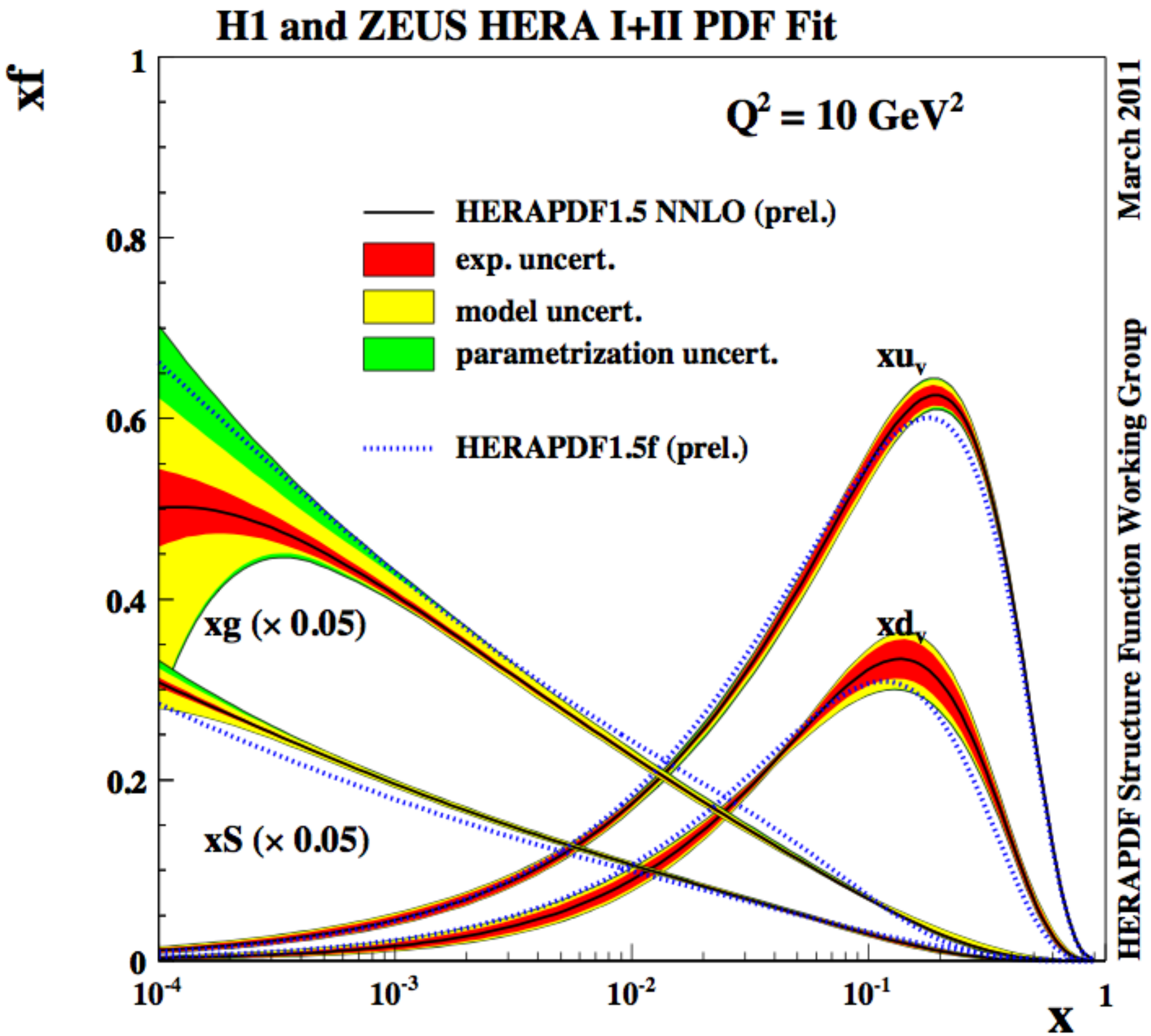


Differences at high-x due mainly to more flexible parametrization used when fitting HERA I+II data

Note: uncertainties at small-x significantly larger than for HERAPDF1.0 and HERAPDF1.5 NLO fits (mainly due to sensitivity to Q^2 cut variation in NNLO fit – sign of problems with DGLAP at small Q^2).

Fixed $\alpha_S(Mz)$ at NNLO = 0.1176

HERAPDF1.5 (NNLO vs NLO) Results



The more flexible 14 parameter fit is used here for the NLO fit as well. See some differences in the pdfs when going from NLO to NNLO with the same parametrization.

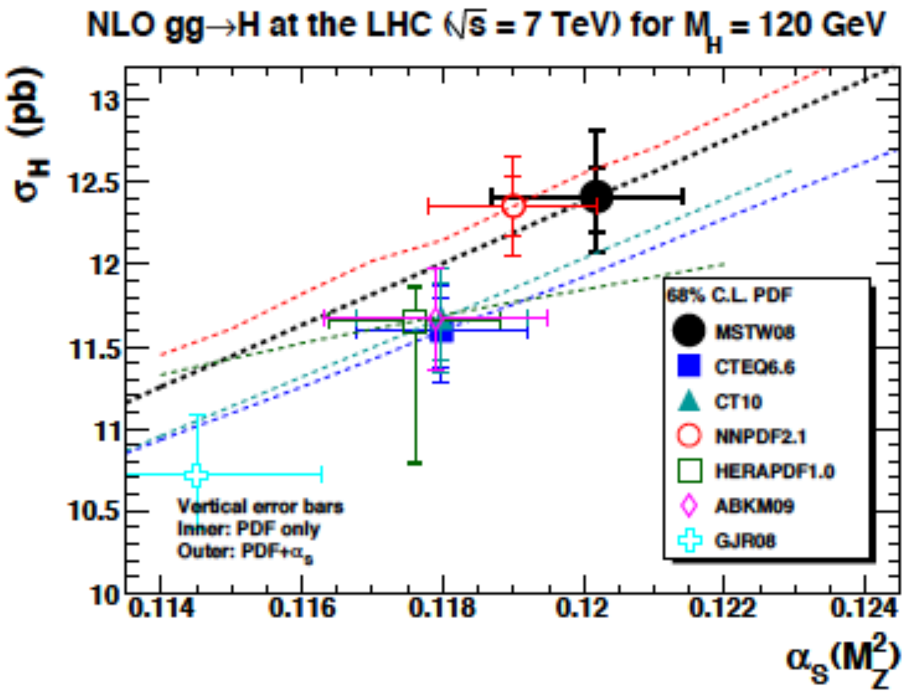
Fits performed at NNLO using RT-VFNS; χ^2 9 units higher than for NLO.

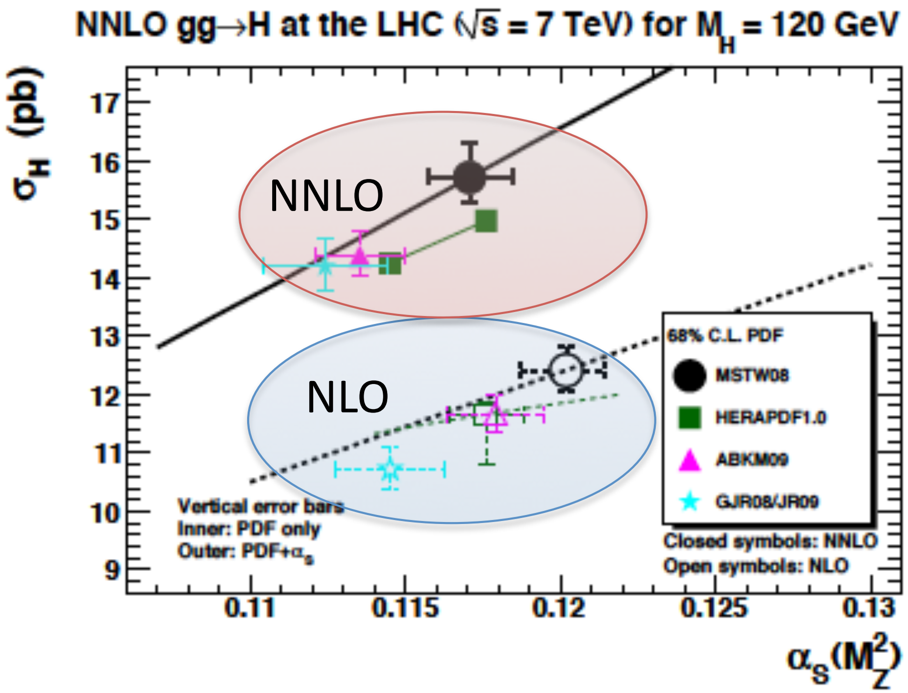
Fixed $\alpha_S(Mz)$ at NNLO = 0.1176

HERAPDF for LHC

Topic of great interest: Higgs production cross section

From G.Watt [PDF4LHC March 2011]



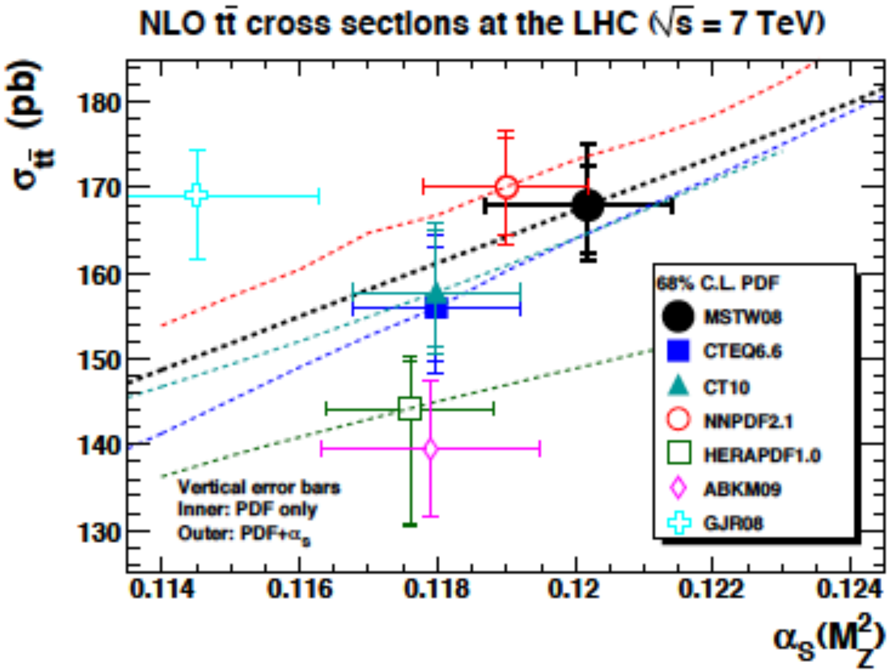


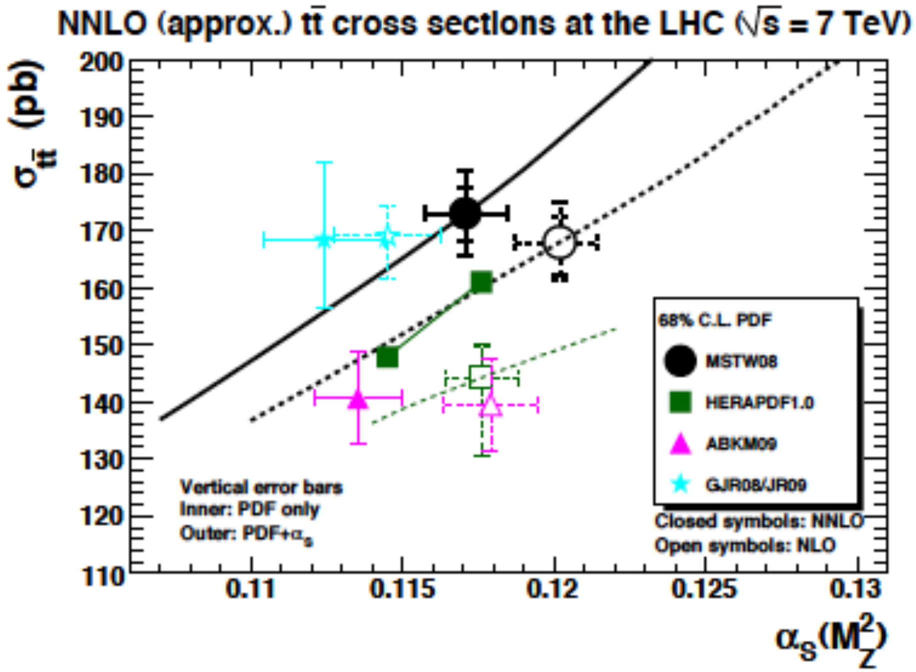
Full error not available for NNLO HERAPDF1.0
(here, two values of α_S)

HERAPDF for LHC

Top quark: M_t/E_P=0.05

From G.Watt [PDF4LHC March 2011]

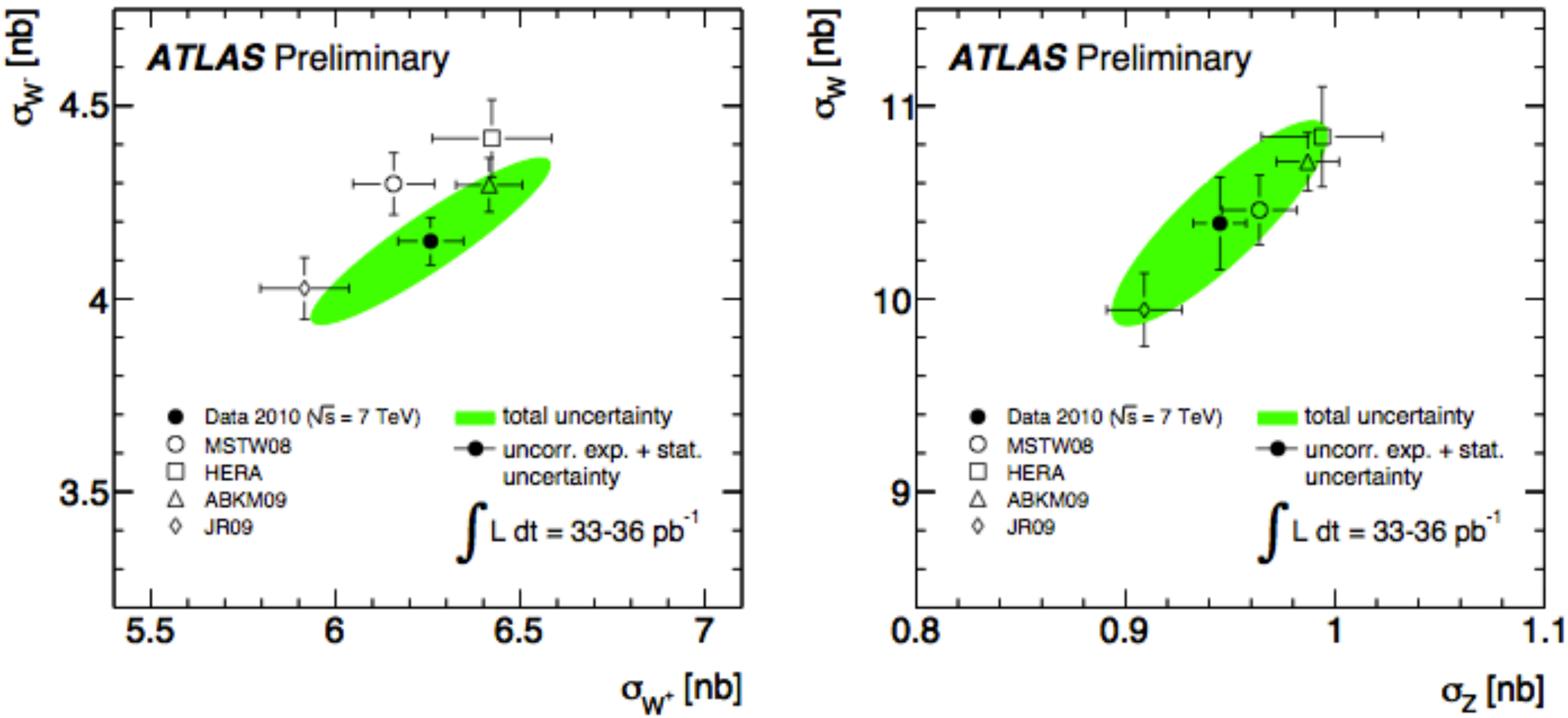




Comment: error bands from different predictions do not overlap: uncertainties do not contain 68% probability.

LHC predictions for W, Z cross sections

- Compare measured and predicted cross sections (NNLO):
  - HERAPDF1.0(alphas=0.1145), ABKM, JR09, MSTW08



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Summary of Fits

Inclusion of HERA II data gives much stronger constraints on pdfs at higher x

Difference between NLO and NNLO no longer so dramatic when HERA II data included and more flexible parametrization used.

Gluon at large-x difficult to constrain – see large differences between NLO and NNLO

Predictions available for Tevatron (not shown) and LHC

https://www.desy.de/h1zeus/combined_results/index.php?do=proton_structure