Recent combined results of H1 & ZEUS

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on behalf of the H1 and ZEUS Collaborations

Outline:

- HERA combination groups
- Recent results
- Plans

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

PRC meeting , DESY, April 28, 2011

Universität Hamburg

HERA Combination Working Groups

Goal: Exploit the full potential of the HERA data

Proton Structure: NC and CC cross sections, QCD analyses including NC, CC, jets, charm data → precise PDFs

Jets: combine measurements of jet cross sections and extract α_s

Heavy Flavors: combine measurements of charm and beauty production as an input for PDFs

Diffraction: extraction of the proton diffractive structure function, better understanding of color neutral exchanges

ElectroWeak: test EW unification in the t-channel, W-production

Exotics: reach the best sensitivity to BSM physics (CI and LQ)

https://www.desy.de/h1zeus/combined_results

HERAPDFs

HERA analyses of NC and CC, jet inclusive cross sections almost completed →
Many of the H1 and ZEUS measurements are combined:
⇒ Strong consistency check of the measurements
⇒ Experiments "cross-calibrate" each other: reduction of the syst. uncert.
⇒ Combined data set ideal input for a DGLAP QCD analysis to extract proton's PDFs
→ consistent data sets and theory

HERAPDF1.0

- → HERA I NC+CC data after combination } published
- → full errors for NLO } published
- → 2 central fits for 2 different values of α_s for NNLO
- → HERAPDF1.0 plus low energy and charm data

HERAPDF1.5 – smaller uncertainty at high-x

- → HERA I+ high-Q^2 HERAII NC+CC data after combination
- → full errors for NLO
- → more flexible parameterization for NLO (*)
- → PDF fit at NNLO with full error (*)

HERAPDF1.6 – included jet data

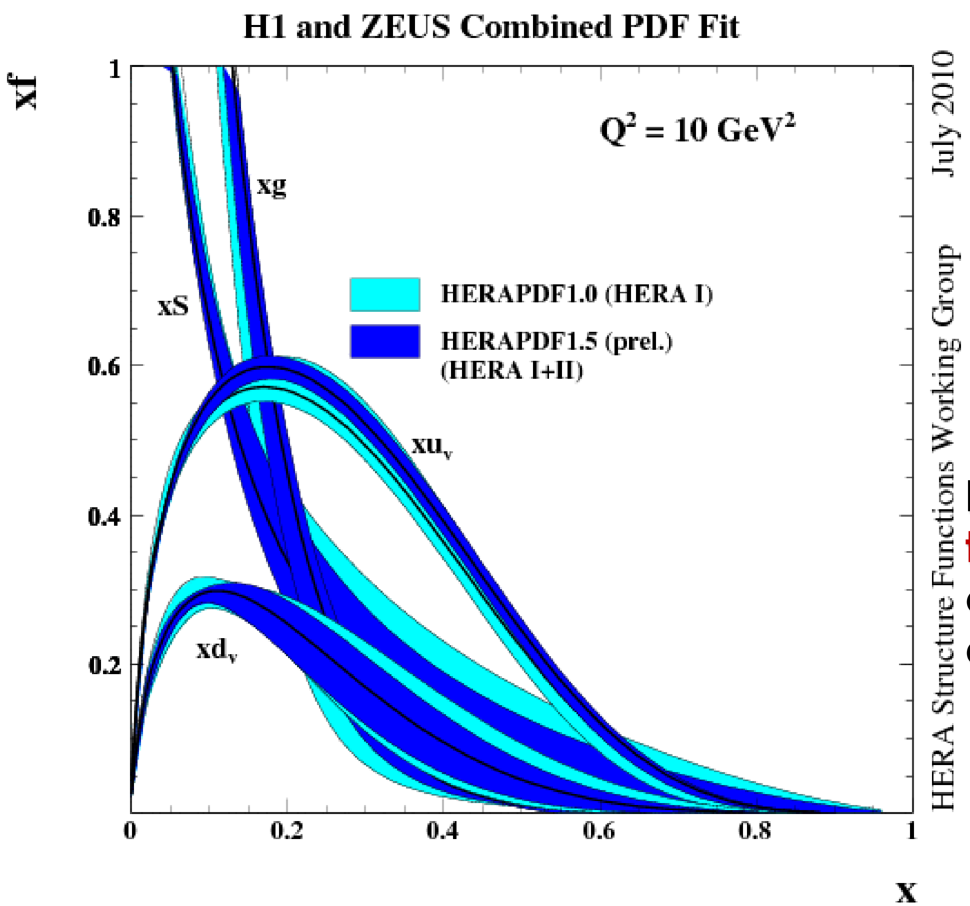
- → HERA I+ high-Q^2 HERAII NC+CC data + jet data
- → PDF fit + free α_s for NLO (*)
- → α_s determination from simultaneous fit (*)

(*) New results since last PRC

Reminder: HERAPDF1.5 (NLO)

QCD fit based on HERAI+II high-Q^2

$xg, xu_v, xd_v, xS = x\overline{U} + x\overline{D}$ at the scale Q^2=10 GeV²



HERAPDF1.0

vs

HERAPDF1.5

Inclusion of the HERA II data reduces the uncertainties on PDFs at high x, especially visible on the valence distributions!

HERAPDF1.5 NNLO

Analysis based on HERAI+II NC and CC DIS combined data

H1-prel-11-042/ZEUS-prel-11-002

HERAPDF1.5 vs. HERAPDF1.5f (NLO)

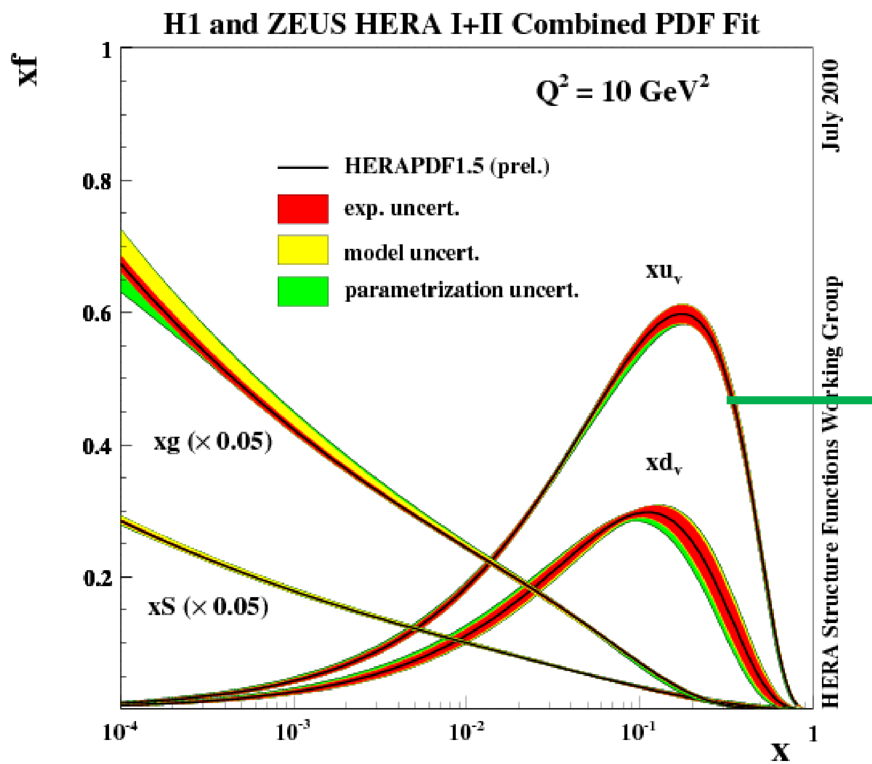
HERAPDF1.5 was updated from the standard parameterization to a more flexible parameterization HERAPDF1.5f → needed for NNLO & jets fits

Flexible parameterization allows terms for low x gluon and lets u_{val} and d_{val} decouple at low x

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

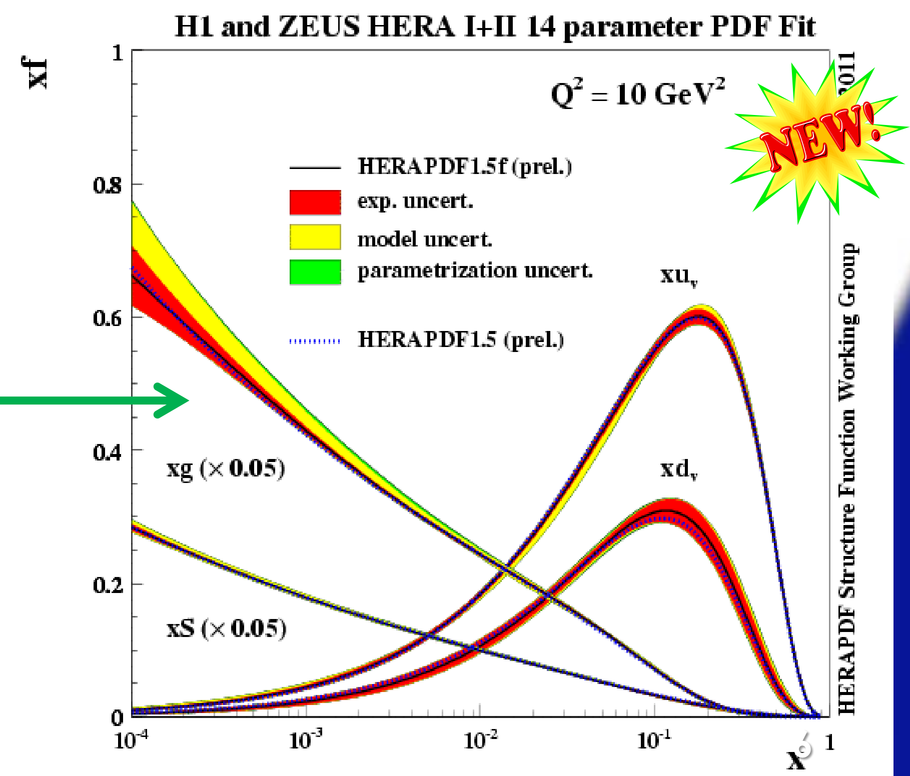
10 Parameter fit

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



More flexible 14 Parameter fit

$$xf(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^2) - A'x^{B'}(1-x)^{25}$$

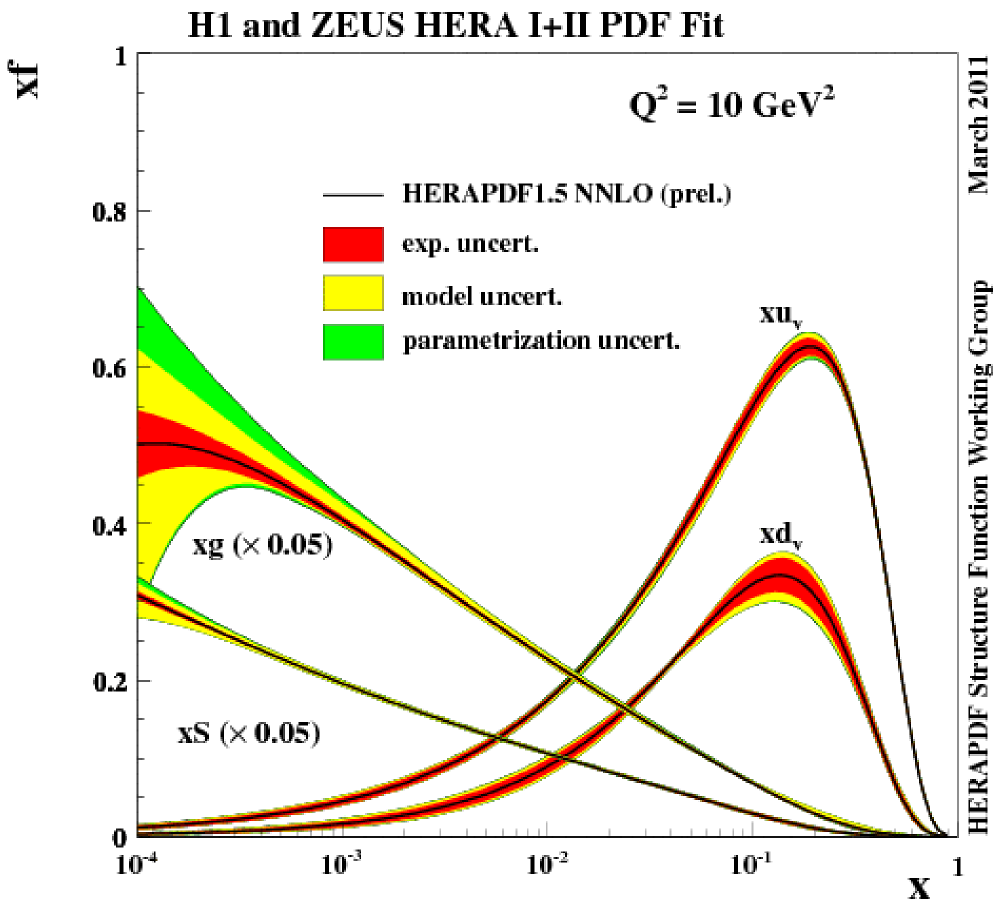


HERAPDF1.5 (NNLO)

NEW!

HERAPDF1.5 NNLO and their full uncertianties (exp., model, param.) at the scale Q^2=10 GeV^2

$$xg\,,\, xu_v\,,\, xd_v\,,\, xS = x\overline{U} + x\overline{D}$$



More flexible 14 Parameter fit

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

Gluon uncertainties at low-x significantly larger than for HERAPDF1.5 NLO fits (mainly due to sensitivity to Q^2 cut variation in NNLO fit)

- **HERA NNLO PDFs available for cross section calculations at NNLO**

HERAPDF1.6

&

determination of α_s

QCD analysis based on HERAI+II + DIS jet data

H1-prel-11-034/ZEUS-prel-11-001

HERAPDF1.6 – data sets

- The same DIS data as HERAPDF1.5:
  HERA I+II, NC+CC, H1+ZEUS combined data

+

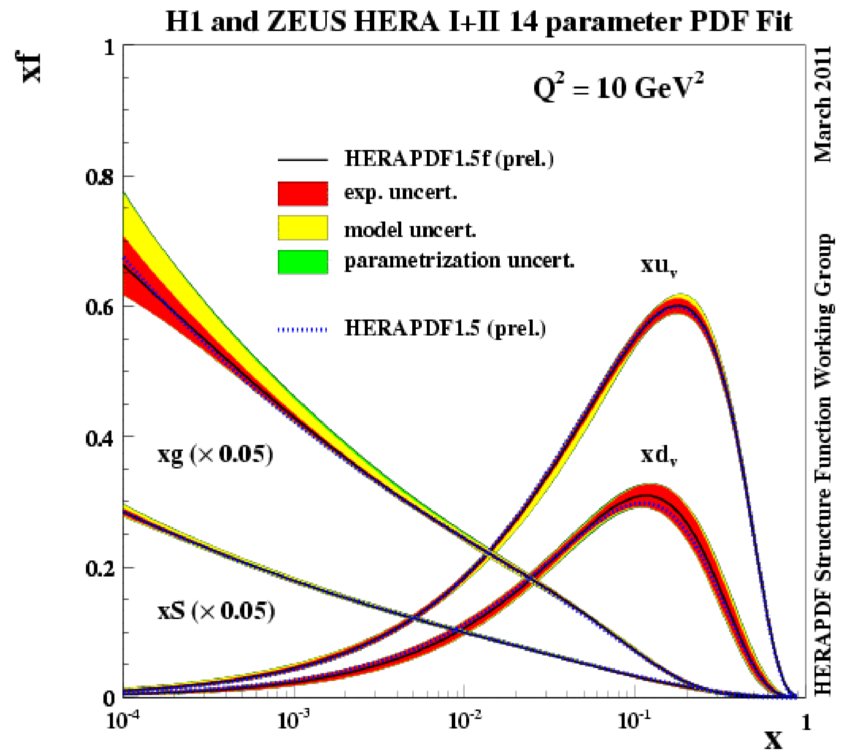
- four inclusive DIS jet measurements:

  HERA I + II high Q^2 normalized jets (H1)
  HERA I low Q^2 jets (H1)
  96-97 high Q^2 jets (ZEUS)
  98-00 high Q^2 jets (ZEUS)

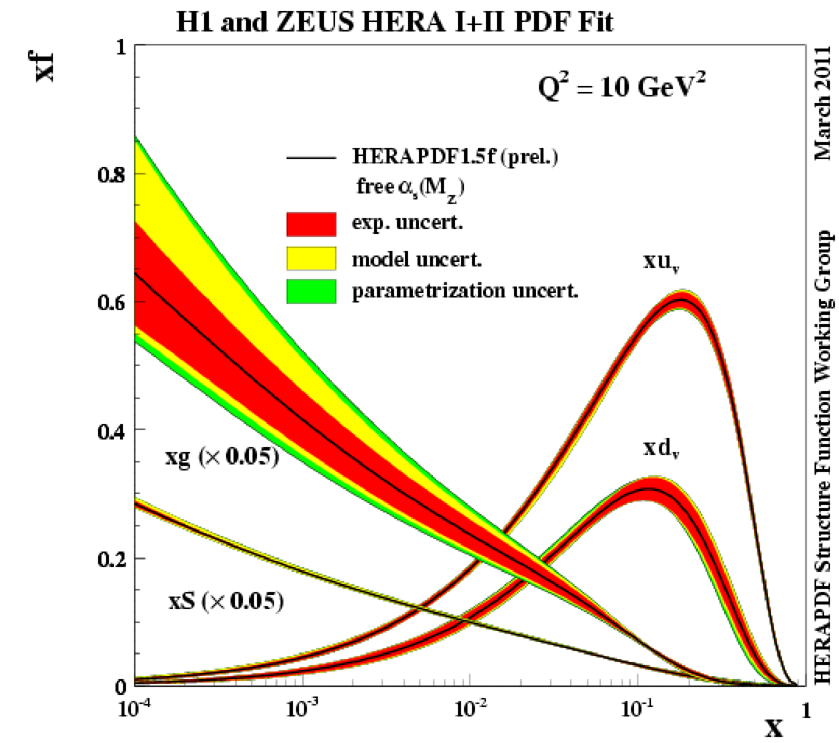
✓ Correlated errors between jet measurements taken into account
✓ PDF fit with free α_s

Transition to free α_s

No jets, fixed α_s



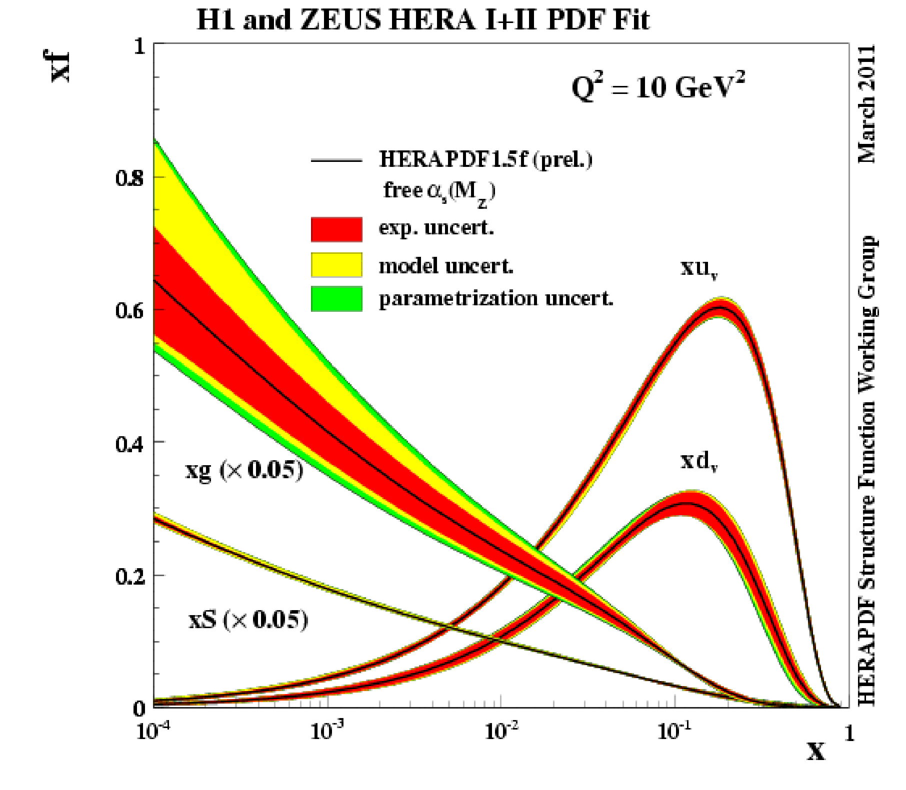
No jets, free α_s



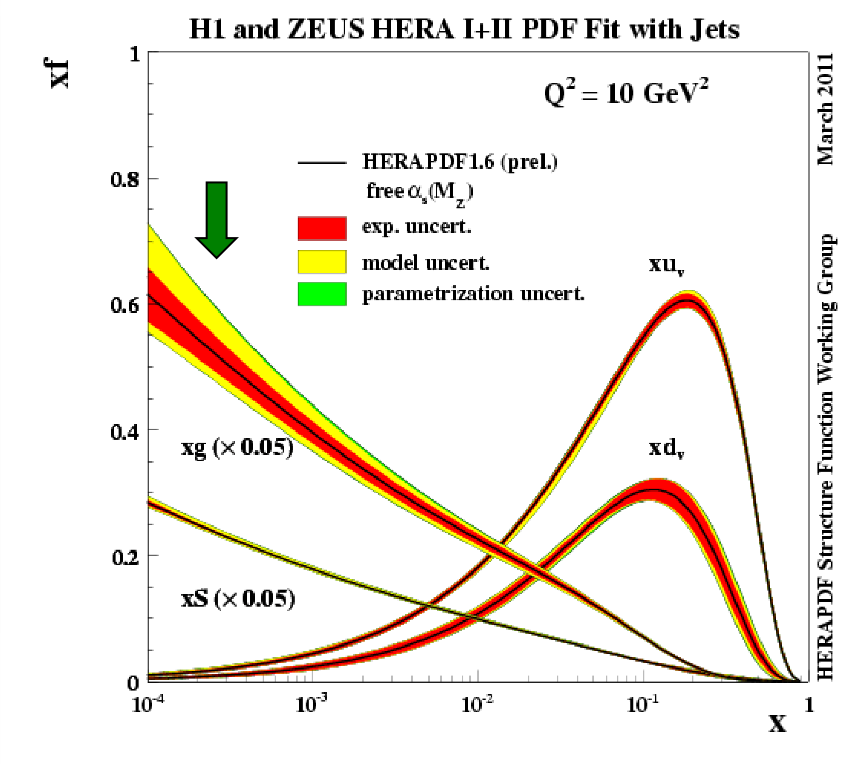
- Large gluon (xg(x)) – α_s correlation → freeing α_s in fits increases gluon uncertainty at low x

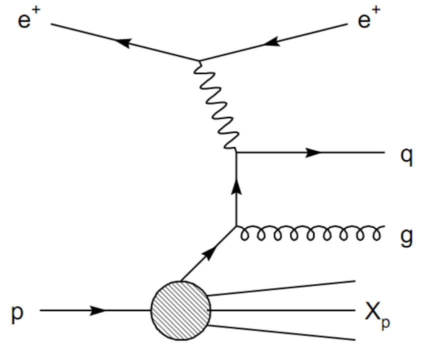
Transition to free α_s

No jets, free α_s



With jets, free α_s





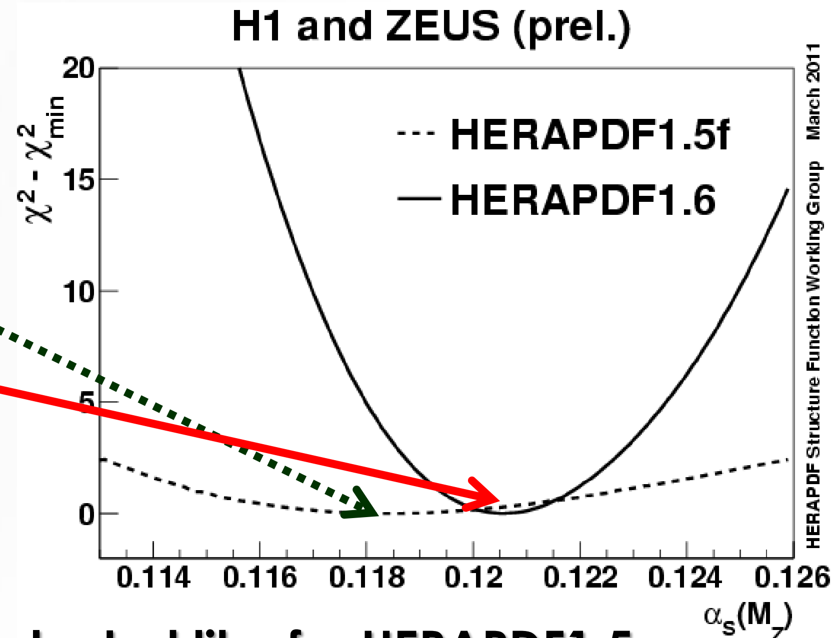
- **Including jets:**
  - **reduced xg(x) – α_s correlation and improve uncertainty.**

Determination of α_s simultaneously with PDFs

HERAPDF1.6 fit was performed using α_s as a free parameter

Fit without jet data (HERAPDF1.5f)
little sensitivity to α_s

Including jets (HERAPDF1.6)
precise α_s determination



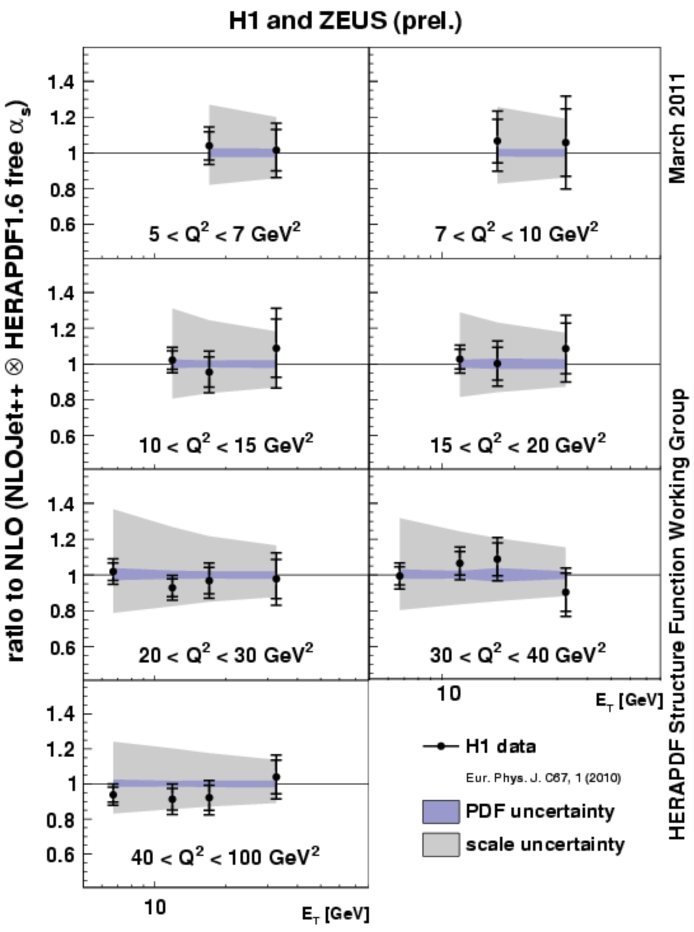
Model and parameterization uncertainty evaluated like for HERAPDF1.5

$$\alpha_s = 0.1202 \pm 0.0013(\text{exp}) \pm 0.0007(\text{mod/par}) \pm 0.0012(\text{hadr})^{-0.0036}_{+0.0045}(\text{scale})$$

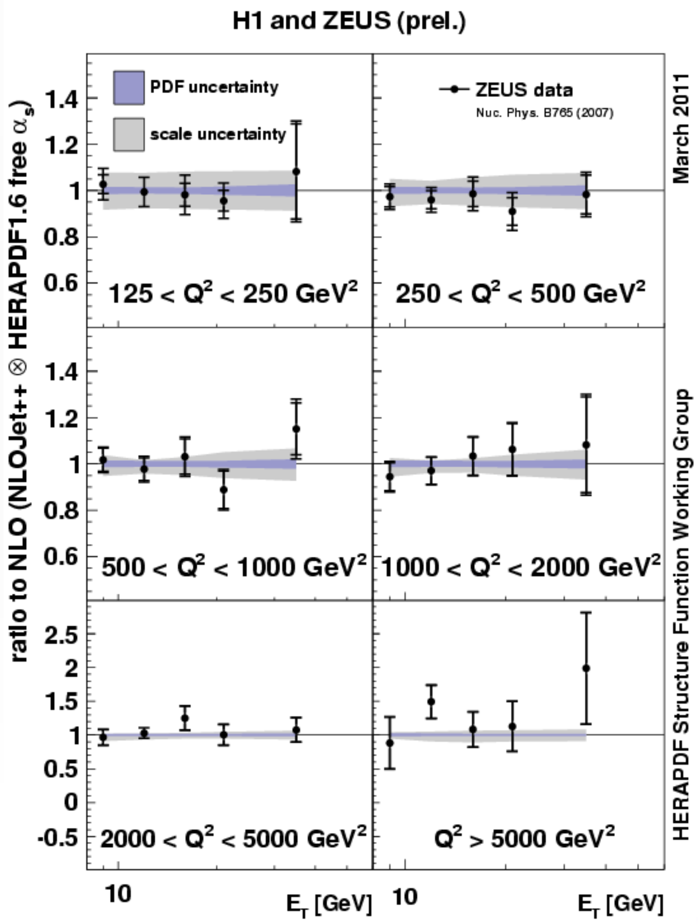
- **Jet data provide strong constraints for the determination of α_s simultaneously with PDFs**
- **Fitted α_s consistent with world average & other HERA measurements**

HERA jet data vs. HERAPDF1.6

5< Q² < 100 GeV²



Q² > 125 GeV²

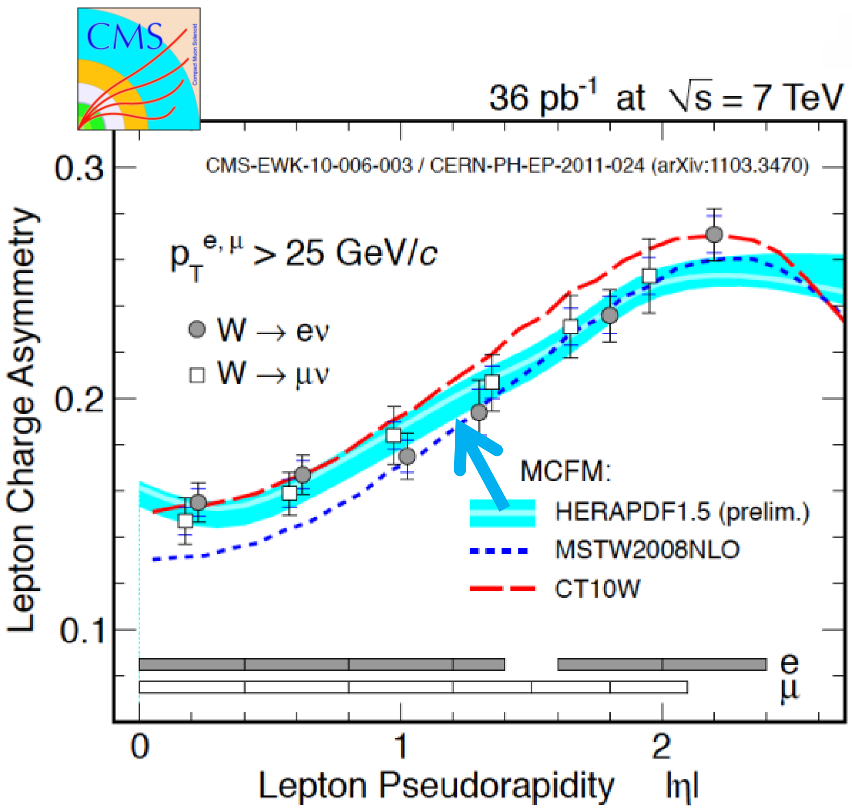


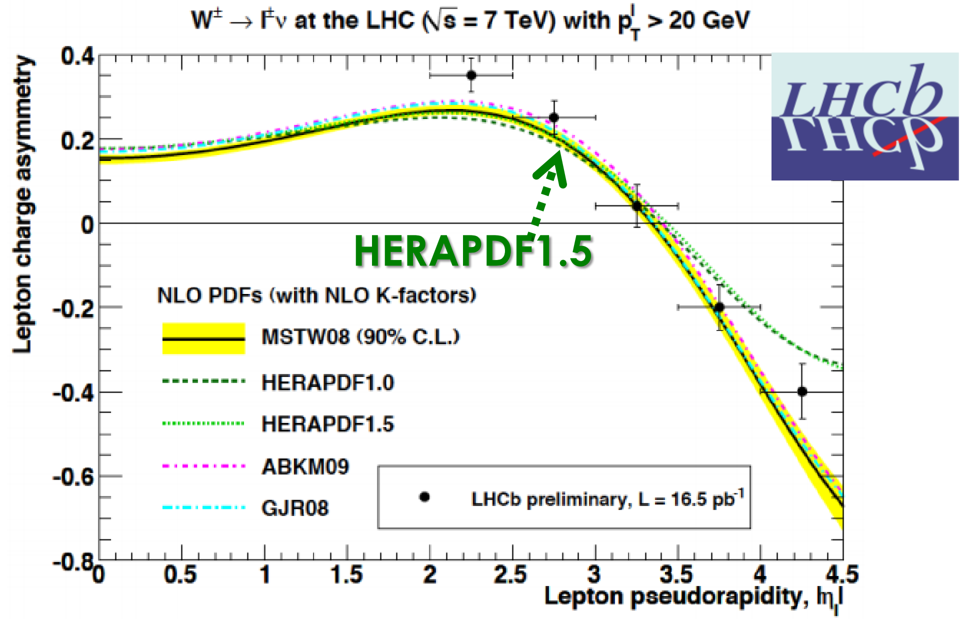
Consistent description of the jet cross sections

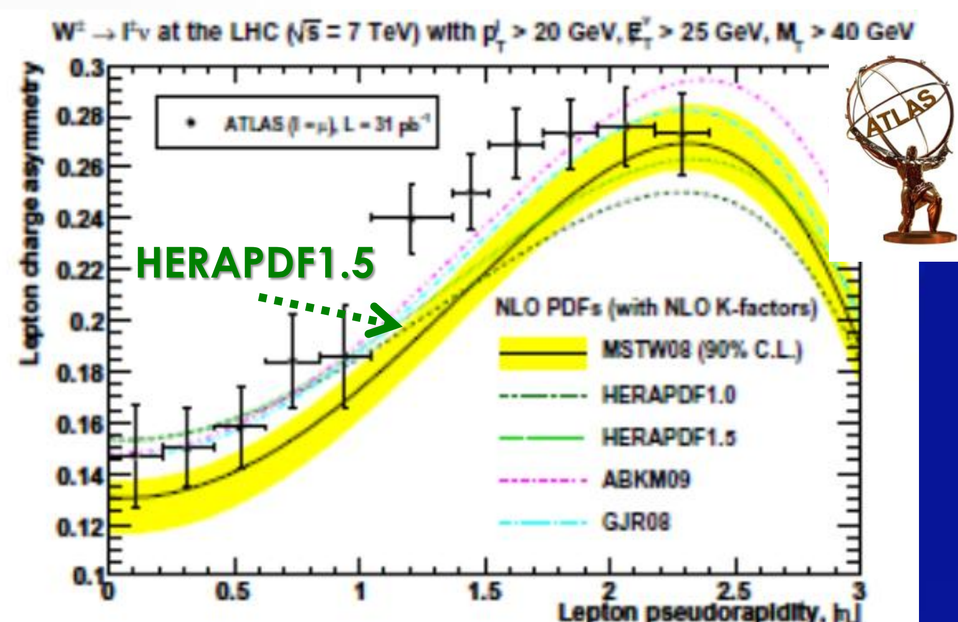
LHC data
vs
HERAPDFs

W and lepton asymmetries at LHC

W asymmetry is sensitive to differences between u and d





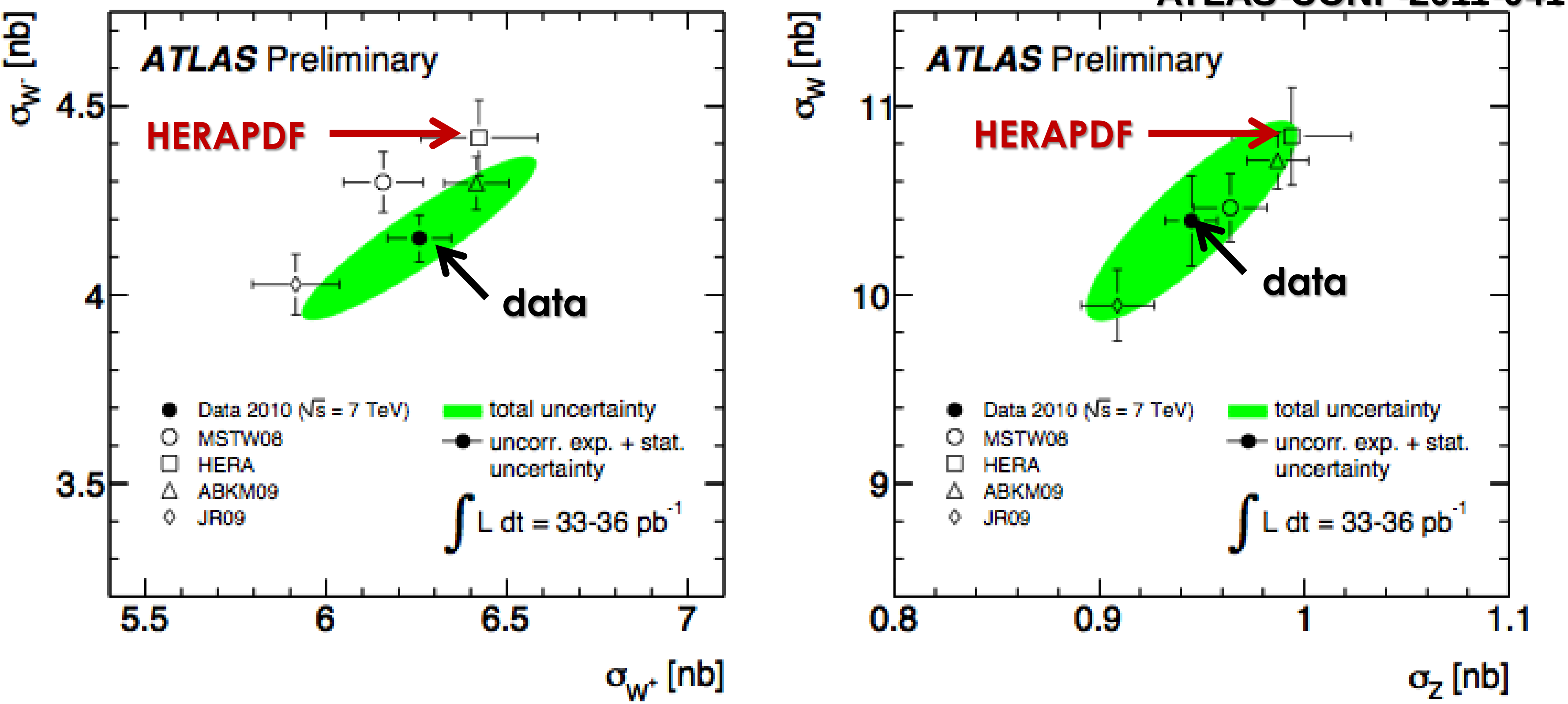


HERAPDF provides good description of pp processes

W, Z production

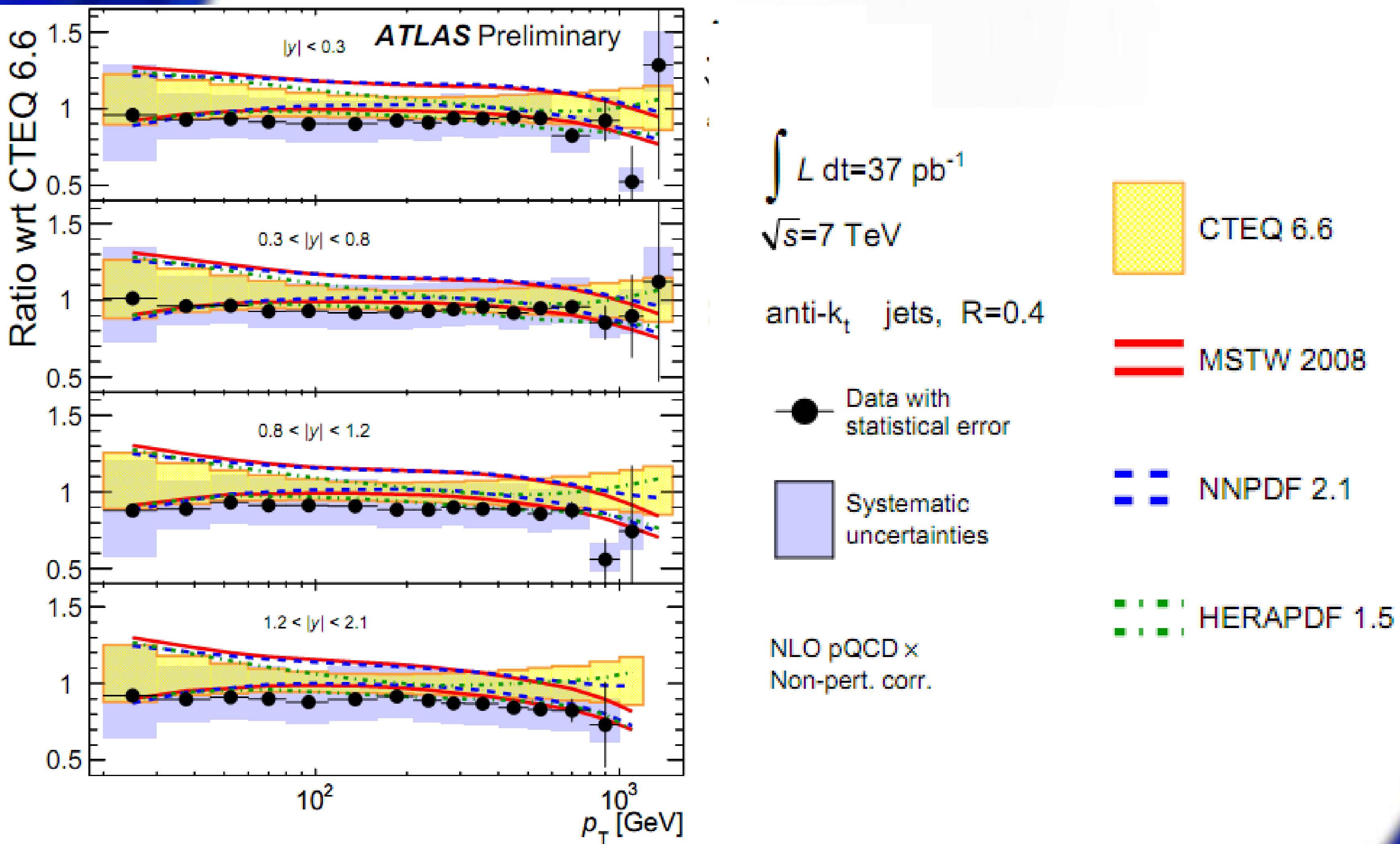
- Compare measured and predicted cross sections (NNLO):
  - HERAPDF1.0(α_s=0.1145), ABKM, JR09, MSTW08

ATLAS-CONF-2011-041



HERAPDF based solely on ep data provides a competitive prediction to the LHC data!

Jets at LHC



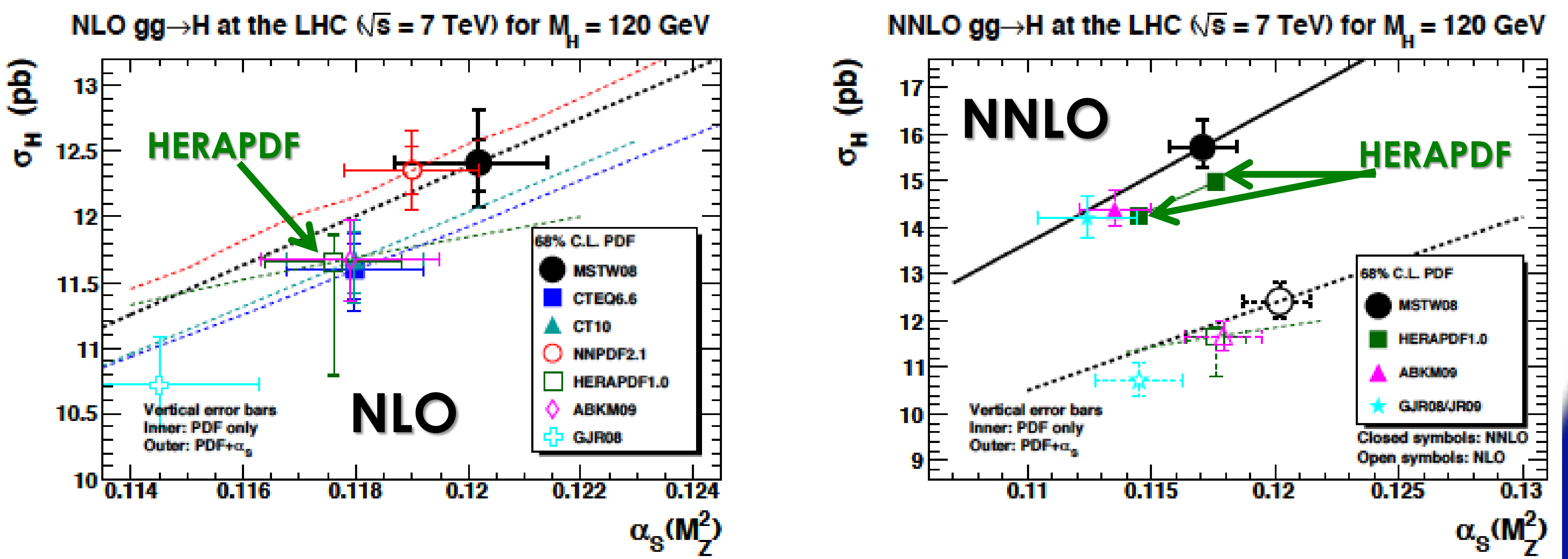
HERAPDF1.5 set without jet data
- provides very good description of the jet data

Predictions for Higgs production at LHC

Topic of great interest→ Higgs production cross section

gg→H E_{cms} = 7 TeV M_H = 120 GeV

From G.Watt [PDF4LHC March 2011]



HERAPDF based solely on ep data provides a competitive prediction compared to global PDF sets

Plans & Further Strategy

Plans & Further Strategy

Proton Structure Functions:

- PDF fit based on full H1 & ZEUS published data including ZEUS NC HERAII e+p high-Q^2, charm, low energy and jet data sets

Heavy Flavours :

- Finalize combination of measurements of charm production - F_2^{cc}

Diffraction :

- Combine ZEUS and H1 inclusive diffractive cross- sections

$\Rightarrow$ QCD analysis →DPDF

Jets:

- Combine H1 and ZEUS DIS jet cross-sections

$\Rightarrow$ Extract α_s

Summary and Outlook

- Combined analyses improve the precision and enhance HERA data visibility

- New precise PDF determination from HERA:
  - PDF analysis is performed at NLO and NNLO.
  - Fit to DIS inclusive + jet data provides determination of α_s with consistent treatment of PDF uncertainties

- HERA continues to provide precise data & HERAPDF and is used for the first LHC measurements

- Work is in progress in the other combination areas

A number of important results are expected in the next two years

Extra-slides

PDF determination at HERA

QCD Fit settings:

- NLO (and NNLO) DGLAP evolution equations QCDNUM package (M. Botje)
- RT-VFNS (as for MSTW08)
  Other schemes were investigated as well: RT (optimal), ACOT (full and χ), FFNS
- PDF parameterized at the starting scale Q_0^2 :

$$xg, xu_{val}, xd_{val}, x\overline{U} = x\overline{u}(+x\overline{c}), x\overline{D} = x\overline{d} + x\overline{s}(+x\overline{b})$$

✓ central fit with *10 free parameters* (standard) - HERAPDF1.0, HERAPDF1.5(NLO)

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

B_{gl}, C_g, $B_{u\text{-}val}$, $C_{u\text{-}val}$, $C_{d\text{-}val}$, $A_{anti\text{-}D}$, $B_{anti\text{-}D}$, $C_{anti\text{-}D}$, $C_{anti\text{-}U}$, $E_{\_u\text{-}val}$

✓ central fit with 14 free parameters (flexible) - HERAPDF1.5 NNLO and jet fits

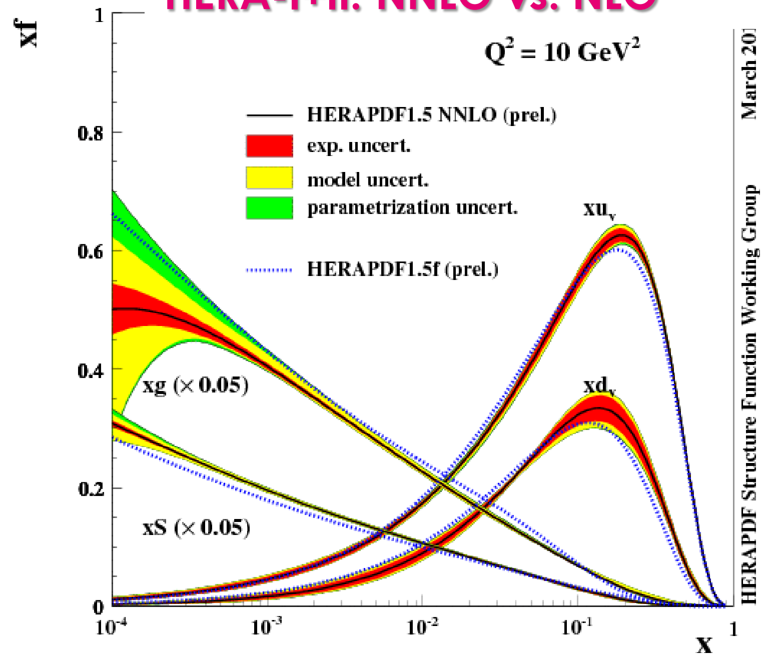
$$xf(x, Q_0^2) = Ax^B(1-x)^C(1 + Dx + Ex^2) - A'x^{B'}(1-x)^{25}$$

→ allow terms for low x gluon + let u_{val} and d_{val} decouple at low x, by having separate $B(u_{val})$ and $B(d_{val})$

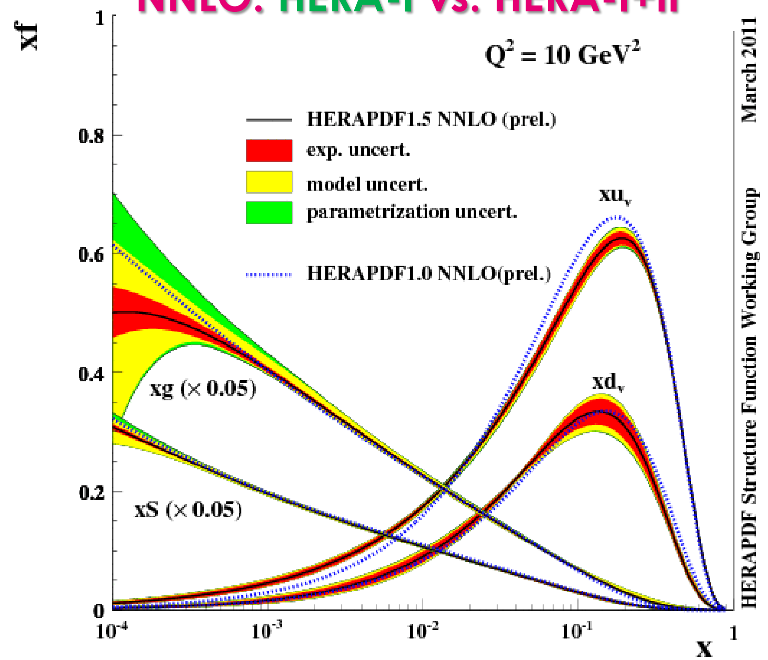
QCD fits based on HERAI+II data HERAPDF1.5 (NNLO)

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

HERA-I+II: NNLO vs. NLO



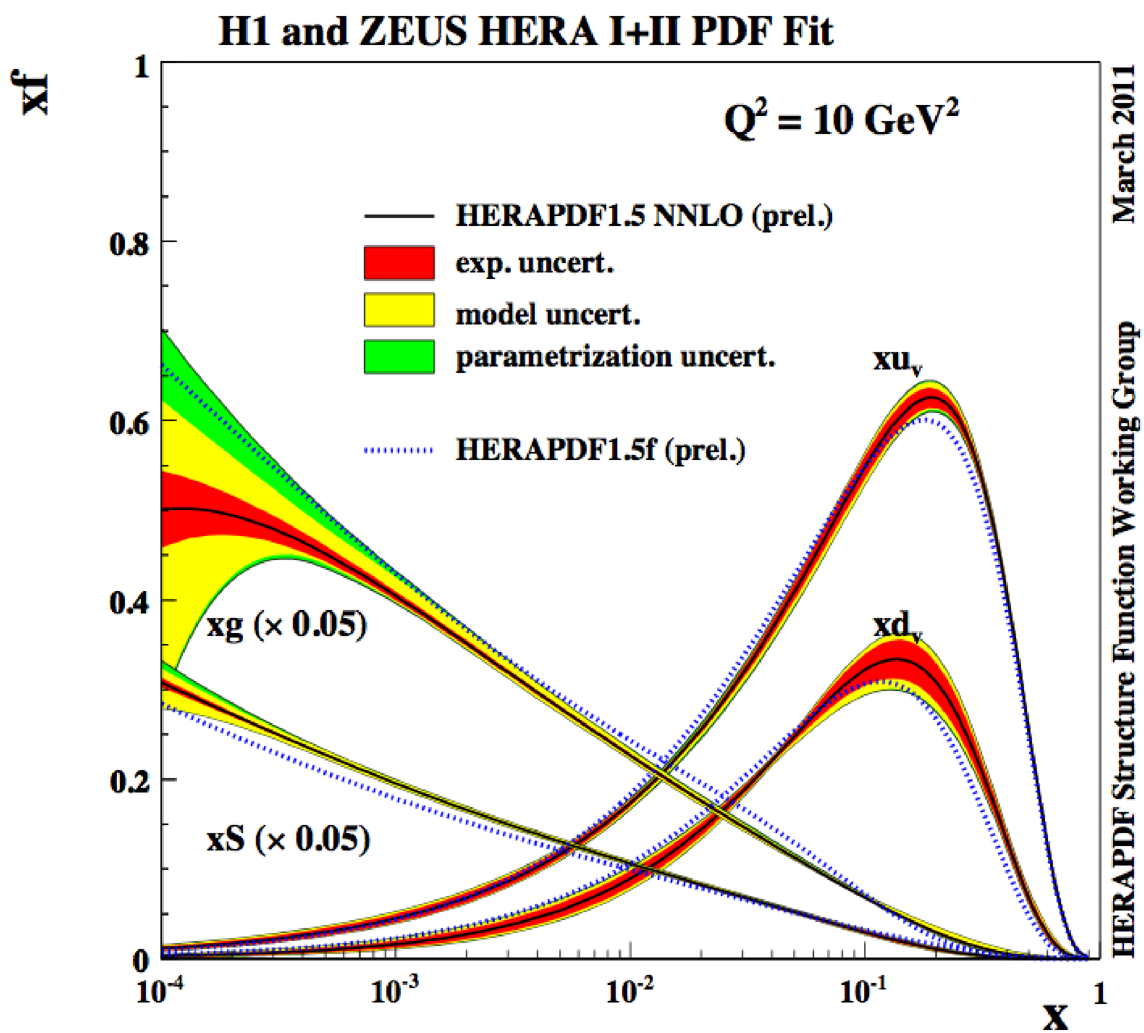
NNLO: HERA-I vs. HERA-I+II



scheme	NNLO $\alpha_S(Mz)$=0.1176	NLO $\alpha_S(Mz)$=0.1176
All χ^2/dof	744.3/660	735.1/660

- **HERAPDF1.5 NLO vs NNLO** is in much better agreement than for **HERAPDF1.0** → use of a more flexible parametrisation for the central fit (10 vs 14 parameters fit)
- **HERAPDF1.5 NNLO** has **harder gluon** and **softer valence at high x** compared to **HERAPDF1.0** NNLO fit.

HERAPDF1.5 (NNLO vs NLO)



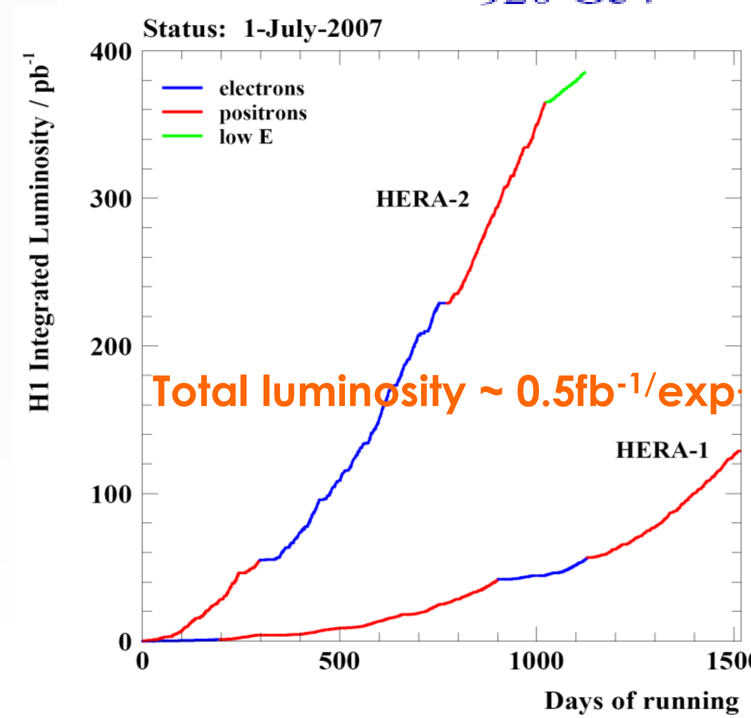
The more flexible 14 parameter fit is used here for the NLO fit as well. See some differences in the pdfs when going from NLO to NNLO with the same parametrization.

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

Fixed $a_S(Mz)$ at NNLO = 0.1176

HERA: World's Only ep Collider

HERA: world's largest "electron-microscope"!
(with "resolving power": $Q^2 \sim 1/\lambda^2$ (10^{-18}m))



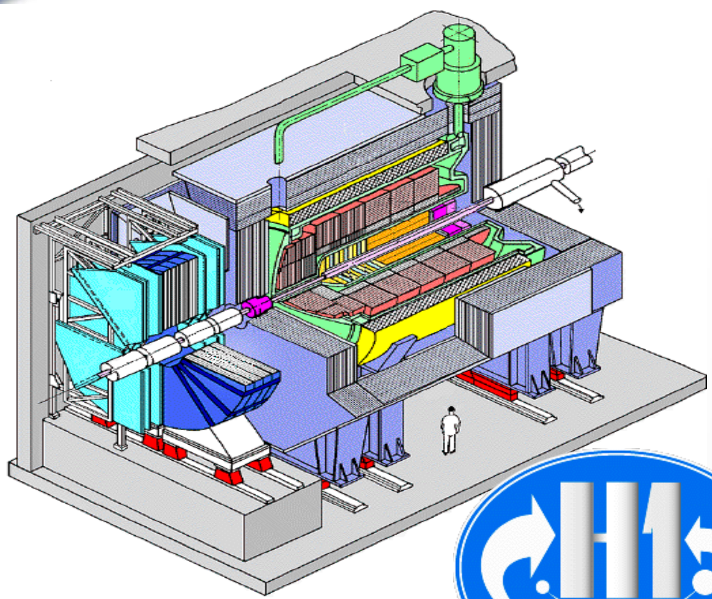
Presented results:

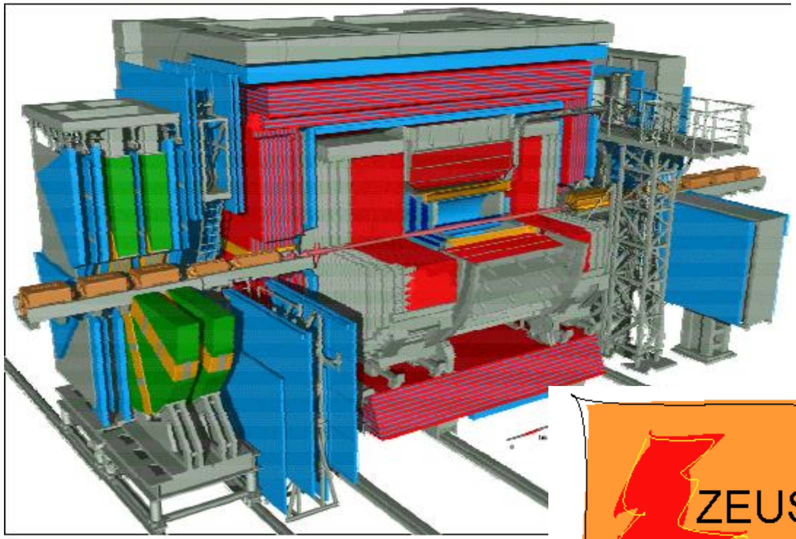
HERA-I: 1992-2000 L~120 pb^{-1}/exp.
- precision measurements at low/medium-Q^2

…and a glimpse of high-Q^2 potential

HERA-II 2002-2007 L~350 pb^{-1}/exp.
- luminosity upgrade → larger statistics for high-Q^2
- Polarized e+/e- beam → direct EW sensitivity
- Low energy data (Ep=450, 575 GeV) → FL

H1 & ZEUS: Hermetic multi-purpose detectors





Liquid Argon Calorimeter

optimized for precision measurement of the scattered lepton

$\sigma_E/E = 11\%/\sqrt{E}$ (electrons)

$\sigma_E/E = 50\%/\sqrt{E}$ (hadrons)

Uranium-scintillator Calorimeter

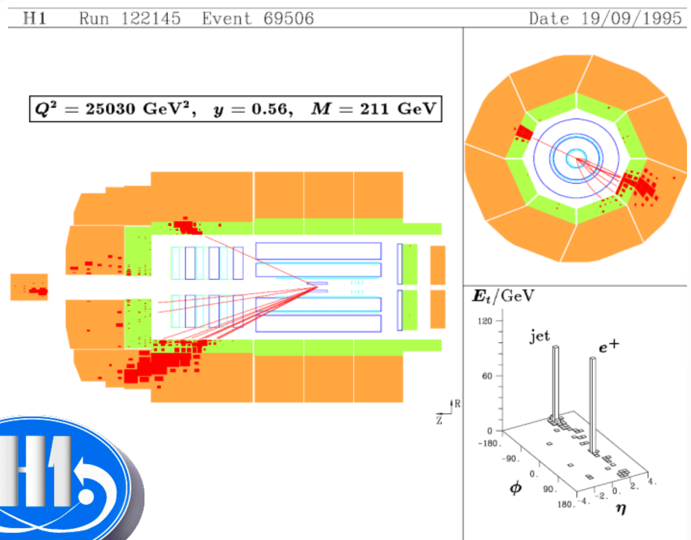
optimized for precision measurement of the hadronic final state

$\sigma_E/E = 18\%/\sqrt{E}$ (electrons)

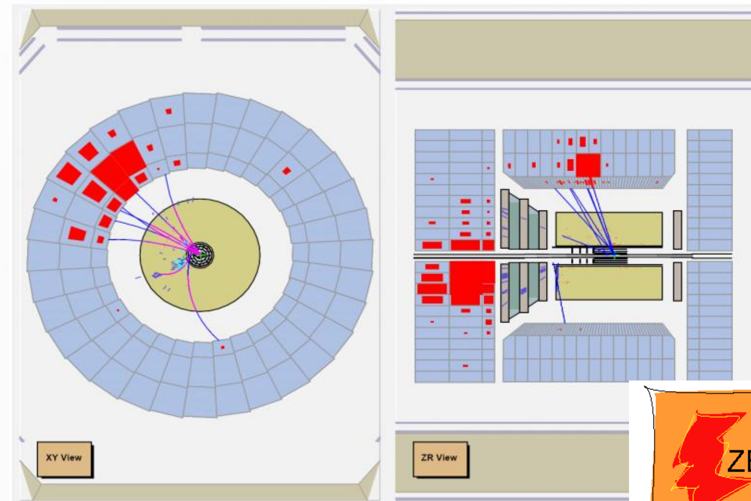
$\sigma_E/E = 35\%/\sqrt{E}$ (hadrons)

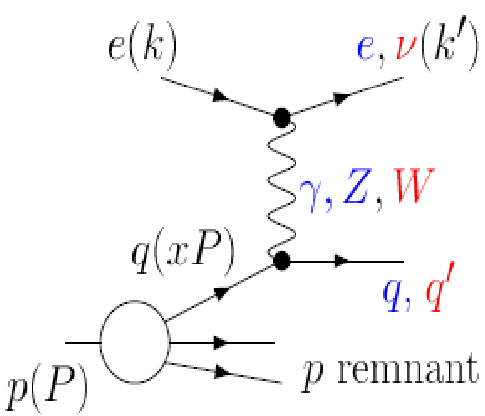
Deep Inelastic Scattering Processes

Neutral Current



Charged Current





$$Q^2 = -(k - k')^2$$

$$x = \frac{Q^2}{2P \cdot (k - k')}$$

$$y = \frac{P \cdot (k - k')}{P \cdot k}$$

Q^2 = -(4-momentum of propagator)^2 – the virtuality of the exchanged boson.

x – fractional momentum of proton carried by struck quark q

y – fractional energy of the incoming lepton transferred to the proton in the proton's rest frame (inelasticity)

Deep Inelastic ep Scattering

NC: Sensitive to gluons, valence quarks and see quarks

$$\frac{d^2\sigma^{\pm}_{NC}}{dxdQ^2} \approx \frac{2\alpha\pi^2}{xQ^4}\left[Y_+ F_2 \mp Y_- xF_3 - y^2 F_L\right] \qquad Y_\pm = \tfrac{1}{2}(1 \pm (1-y^2))$$

$$F_2 \propto \sum_i e_i^2 (xq_i + x\bar{q}_i)$$

Directly sensitive to quark distribution
Gluon from scaling violations.

$$xF_3 \propto \sum_i xq_i - x\bar{q}_i$$

Valence quarks

$$F_L \propto \alpha_s xg$$

Gluon at NLO

Use 'reduced cross section'
to remove kinematic dependence:

$$\sigma_r = \frac{xQ^2}{2\alpha\pi^2 Y_+}\frac{d^2\sigma^{\pm}_{NC}}{dxdQ^2} \approx F_2$$

CC: Flavour decomposition

e-p: $$\frac{d^2\sigma^{-}_{CC}}{dxdQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)\left[u + c + (1-y)^2(\bar{d}+\bar{s})\right]$$

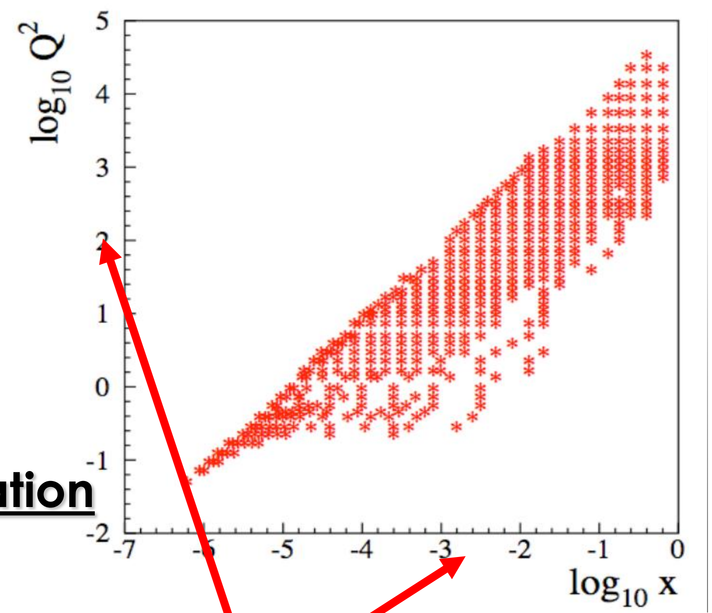
e+p: $$\frac{d^2\sigma^{+}_{CC}}{dxdQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)\left[\bar{u} + \bar{c} + (1-y)^2(d+s)\right]$$

Inclusive cross section combination HERA-I

- H1 & ZEUS have combined inclusive DIS cross sections from HERA I data => New average with L=240 pb^{-1}

- <u>Combination procedure:</u>

1) Swim all point to a common Q^2-x grid
2) Move 820 GeV data to 920 GeV p-beam energy (not for NC at y>0.35)
3) Calculate average values and uncertainties
4) Evaluate "procedural uncertainties"



- <u>$\chi 2$ minimalisation method for data combination</u>

1402 data points combined to 741 cross section measurements:

- 110 correlated syst. error sources (H1 & ZEUS)

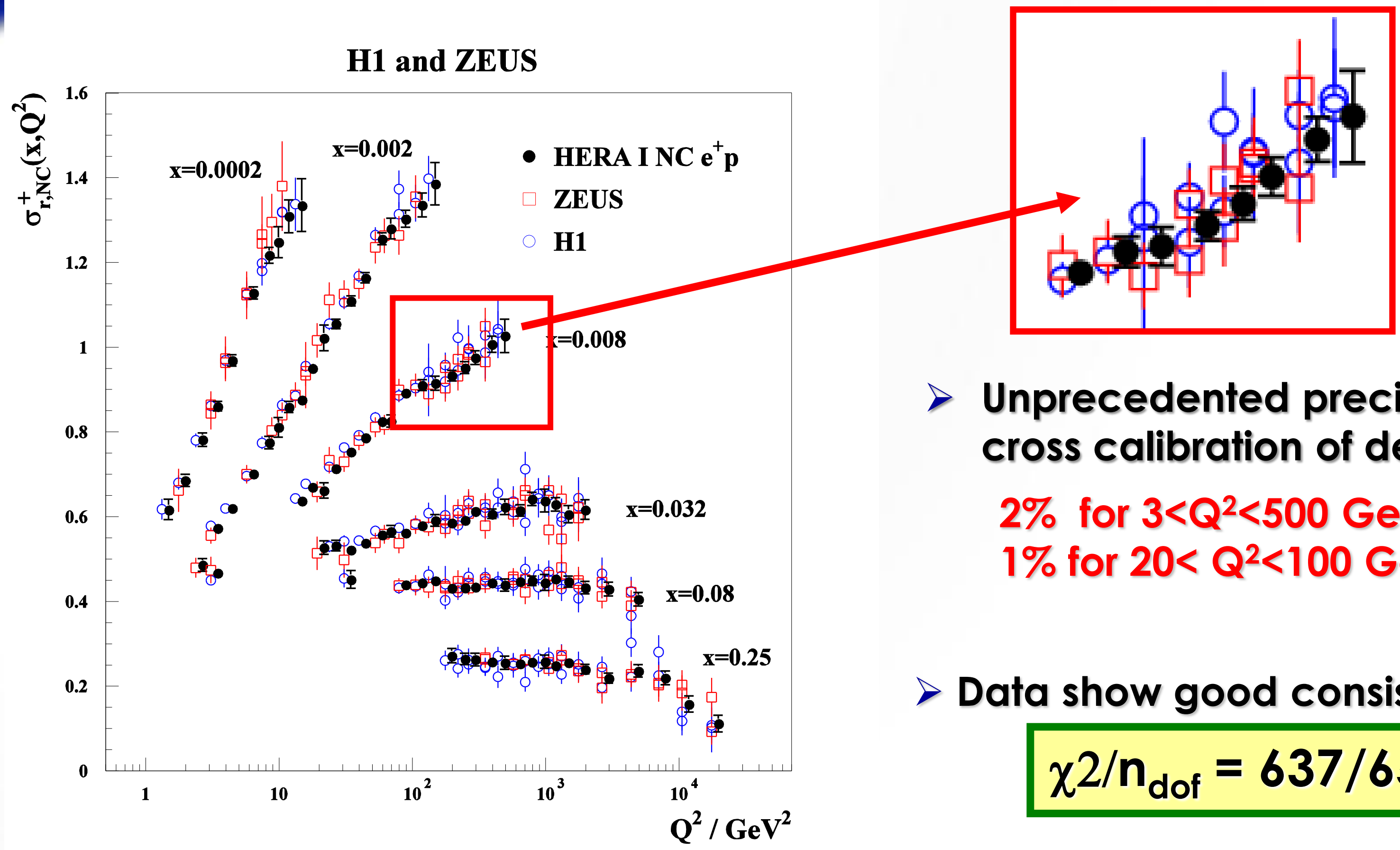
- 3 procedural uncertainties

-H1 & ZEUS syst. assumed independent (except 0.5% lumi normalisation)

Span 6 orders of magnitude in x and Q^2

The Power of Combination (JHEP01 (2010) 109)

- Combined are full published HERA-I NC, CC $e^{\pm}p$ cross sections



- Unprecedented precision due to cross calibration of detectors

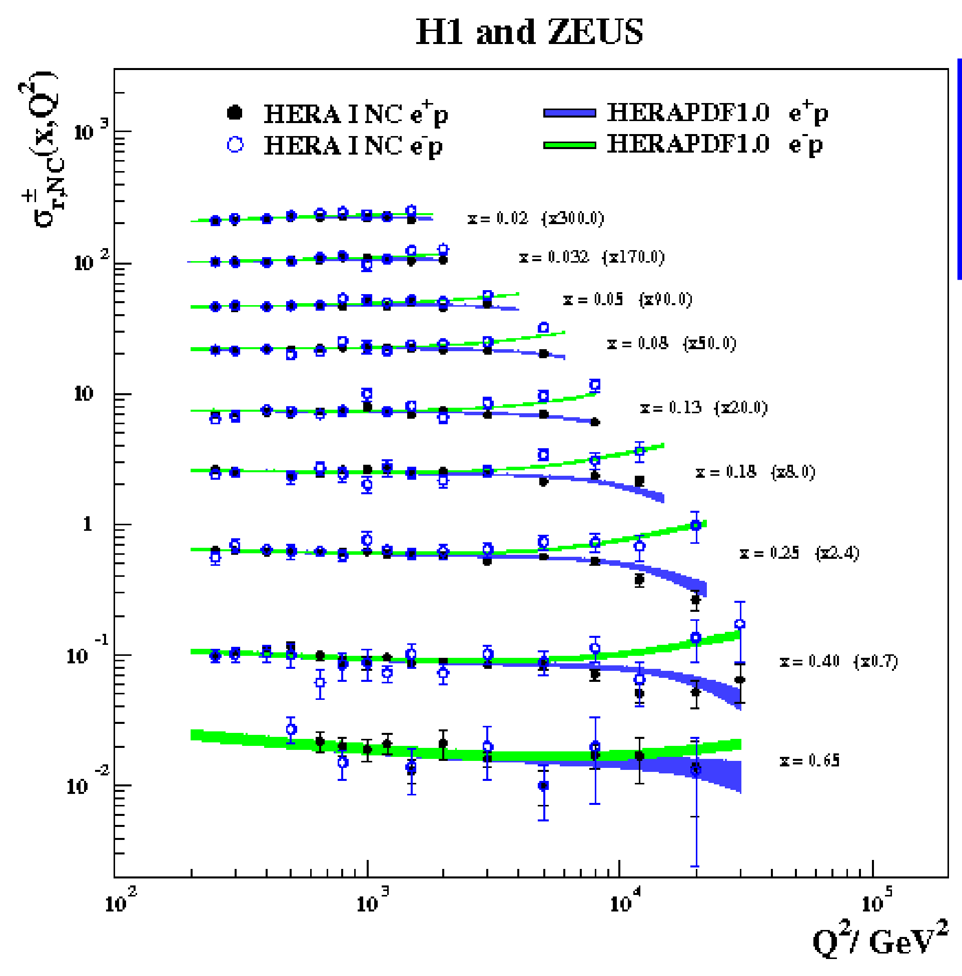
  2% for $3<Q^2<500$ GeV^2
  1% for $20< Q^2<100$ GeV^2

- Data show good consistency

  $\chi2/n_{dof}$ = 637/656

QCD analysis based on HERA-I data → HERAPDF1.0

HERA-I combined NC at high-Q^2 data



NC data at high-Q^2 → Zγ interference **destructive (e+p)** and **constructive (e-p)**

- Good agreement between data and **NLO QCD fit (HERAPDF1.0)**

Including **HERA-II high-Q^2 data** → improvement **at high-Q^2 and high-x** is expected

Combination of the high-Q^2 data

Extension of the published combination of the HERA I data:

Used data:

✓ HERA-I as in JHEP01(2010)109

✓ HERAII:

H1, HERA II (high Q^2, P=0)	ZEUS, HERA II (high Q^2, P=0)
CC e-p	NC e-p
CC e+p	CC e-p
NC e-p	CC e+p
NC e+p	

Method of combination:

- HERA-I : same as in JHEP01(2010)109
- HERA-II : three additional procedural errors

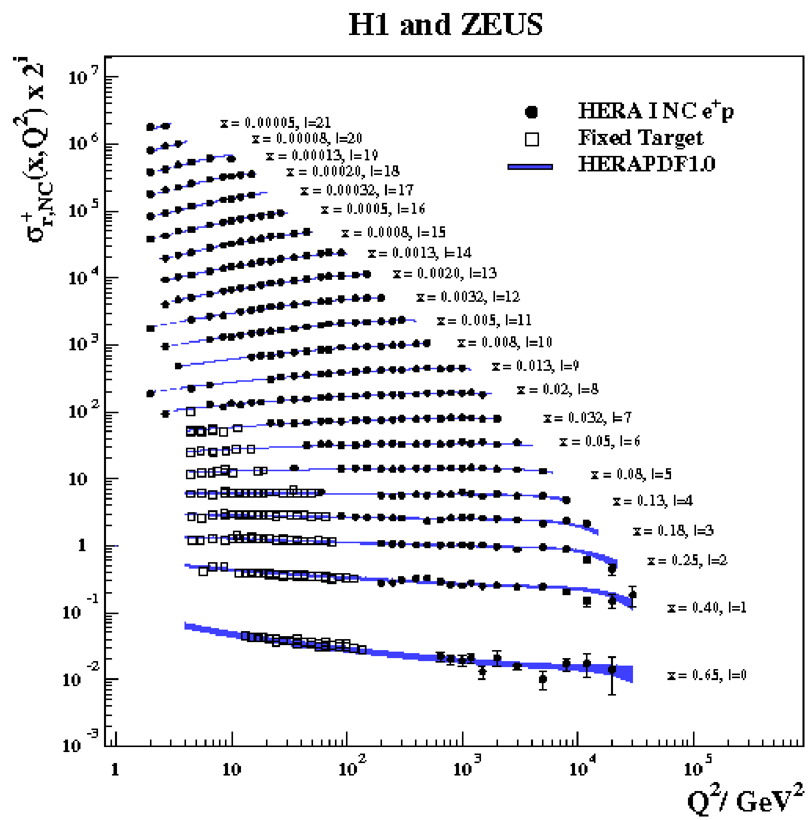
$\chi 2/n_{dof} = 967/1032$

QCD analysis based on HERA-I + HERA-II high-Q^2 data

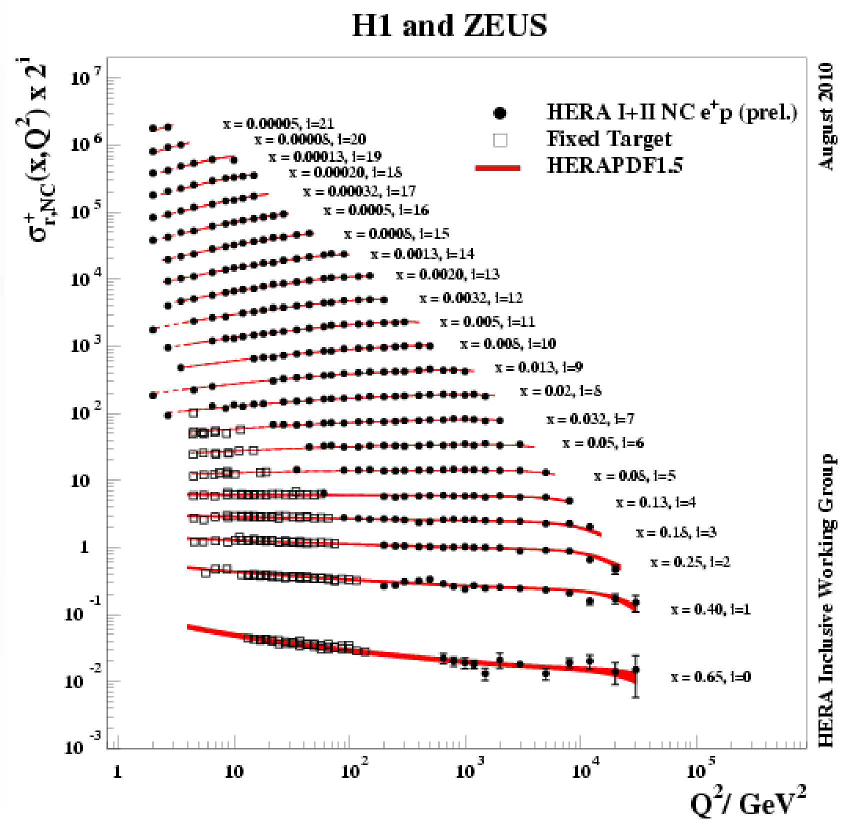
HERAPDF1.5

Combination of NC data

HERA-I combined results:



HERA-I+II combined results:



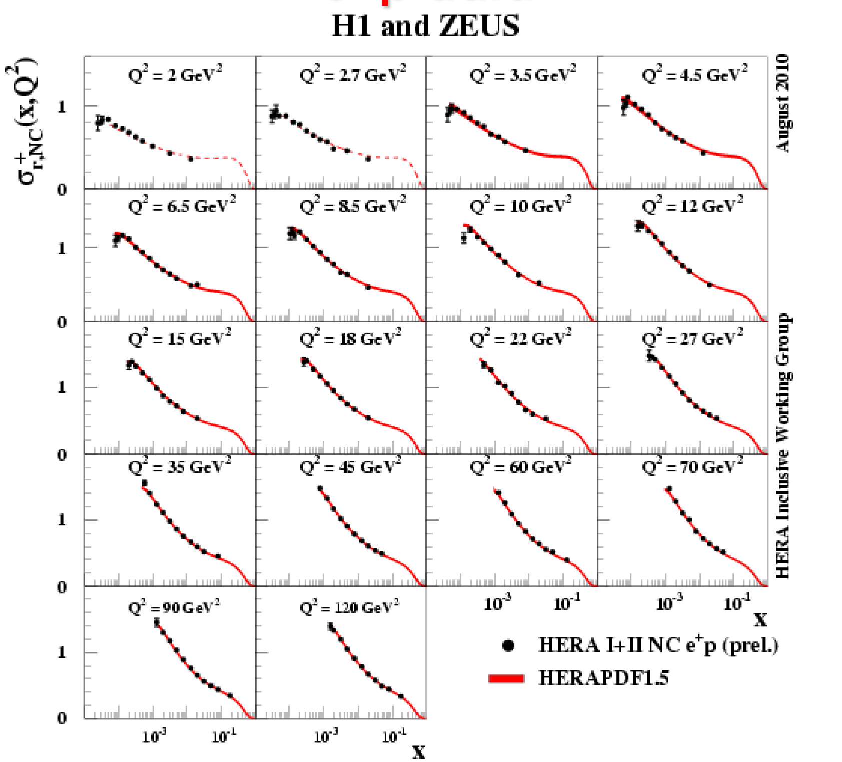
- Data show strong **scaling violations at low x** → large gluon density

New HERA-II measurements → increased precision at high-Q^2

F_2 with combined HERA-I+II NC

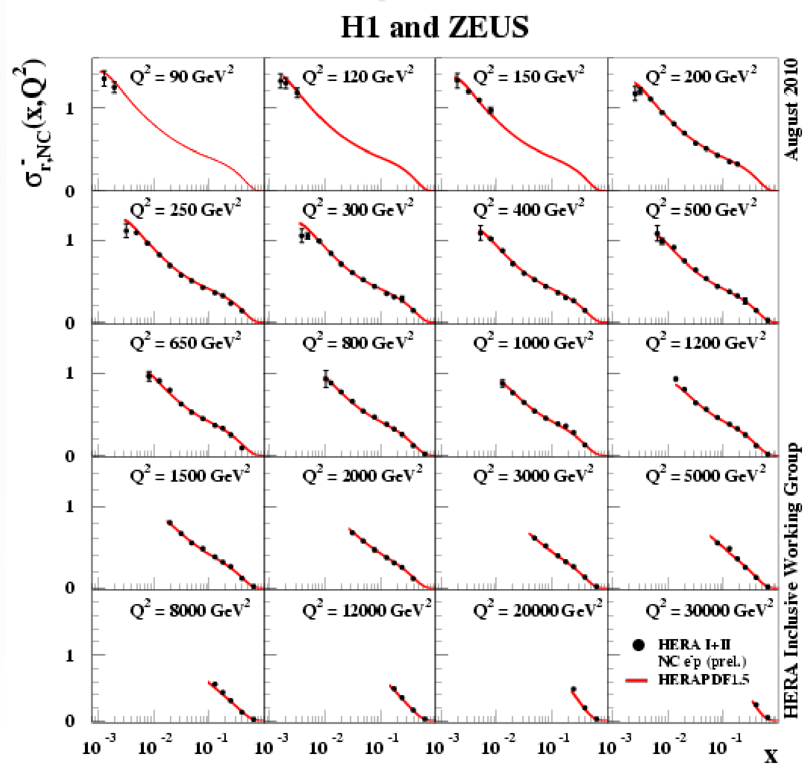
Low/medium Q^2 bins (2-120 GeV^2)

e+p data



High Q^2 bins (90-30000 GeV^2)

e-p data

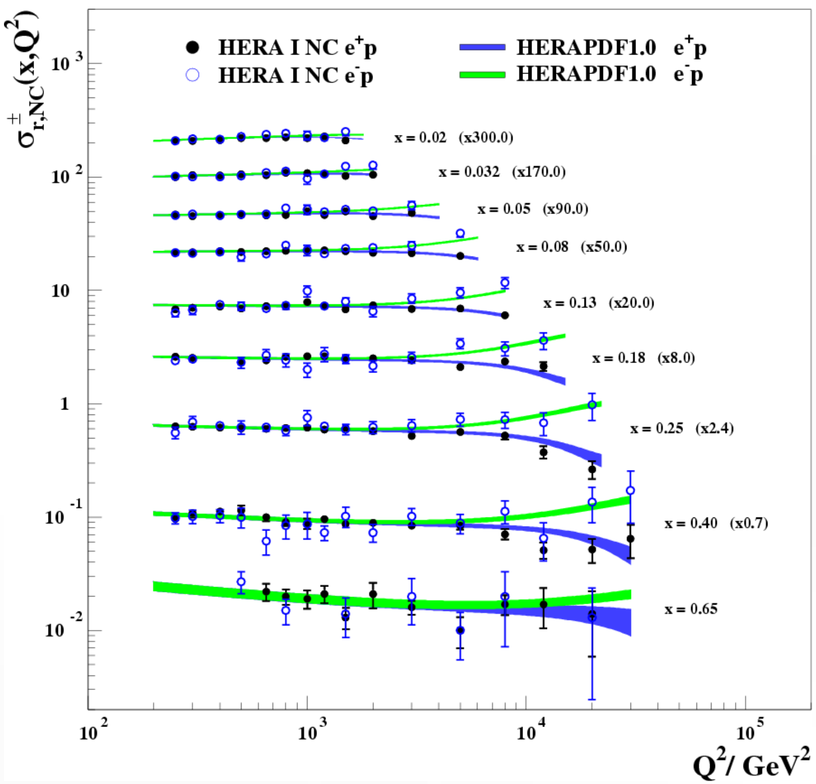


- $F_2(x,Q^2)$ shows strong rise as x->0, the rise increases with increasing Q^2
- Data well described by QCD fit from Q^2=2 to 30000 GeV^2

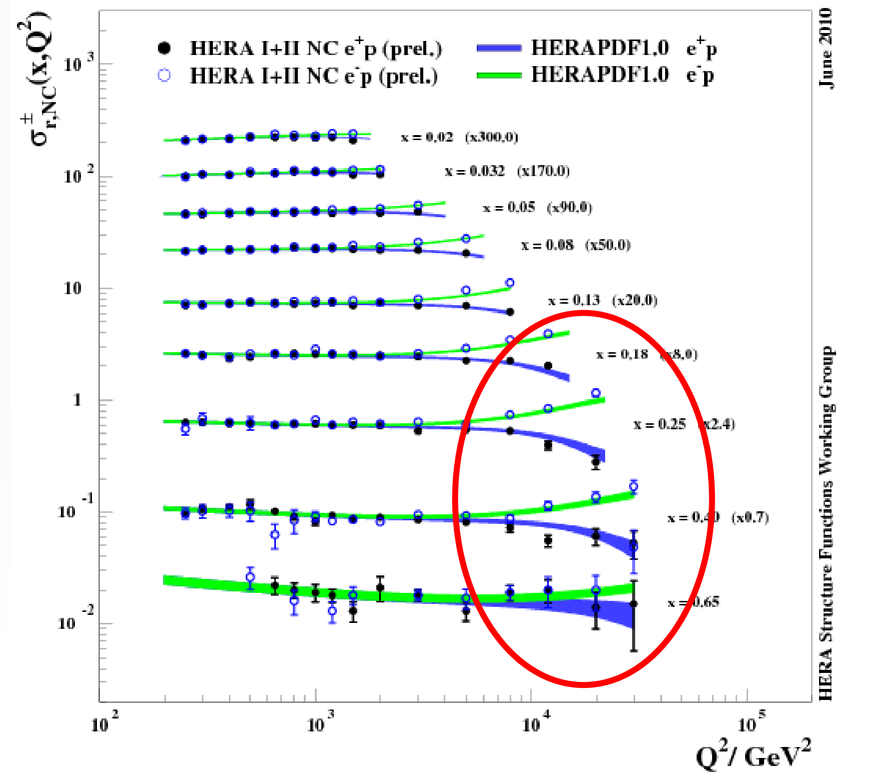
Combination of NC high-Q^2 data

NC data at high-Q^2 → $Z\gamma$ interference destructive (e+p) & constructive (e-p)

HERA-I combined results vs. HERAPDF1.0



HERA-I+II combined results vs HERAPDF1.0

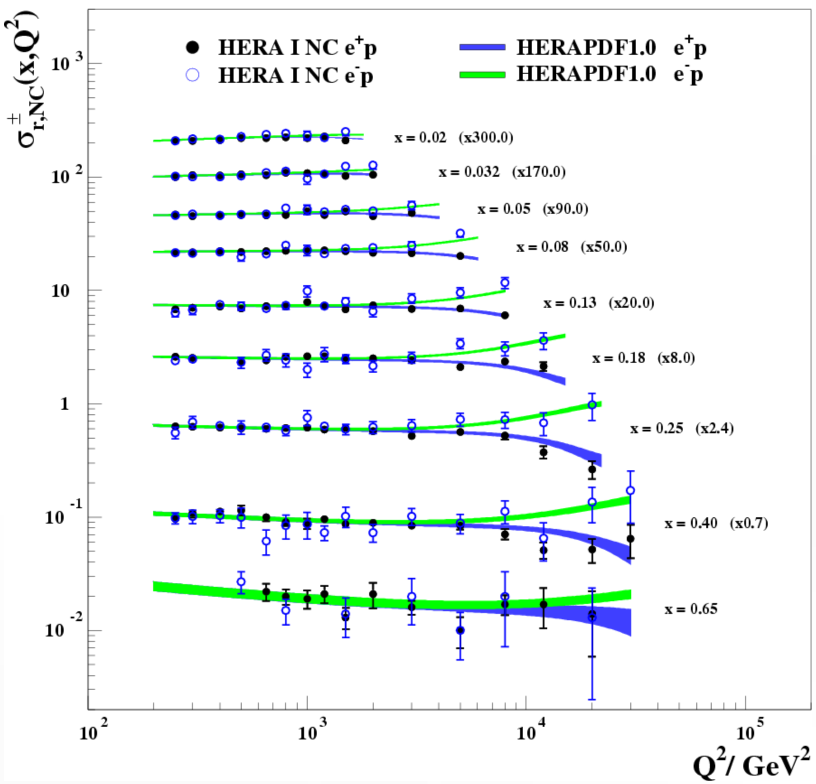


Including HERA-II high-Q^2 data → improved data precision at high-Q^2 and high-x

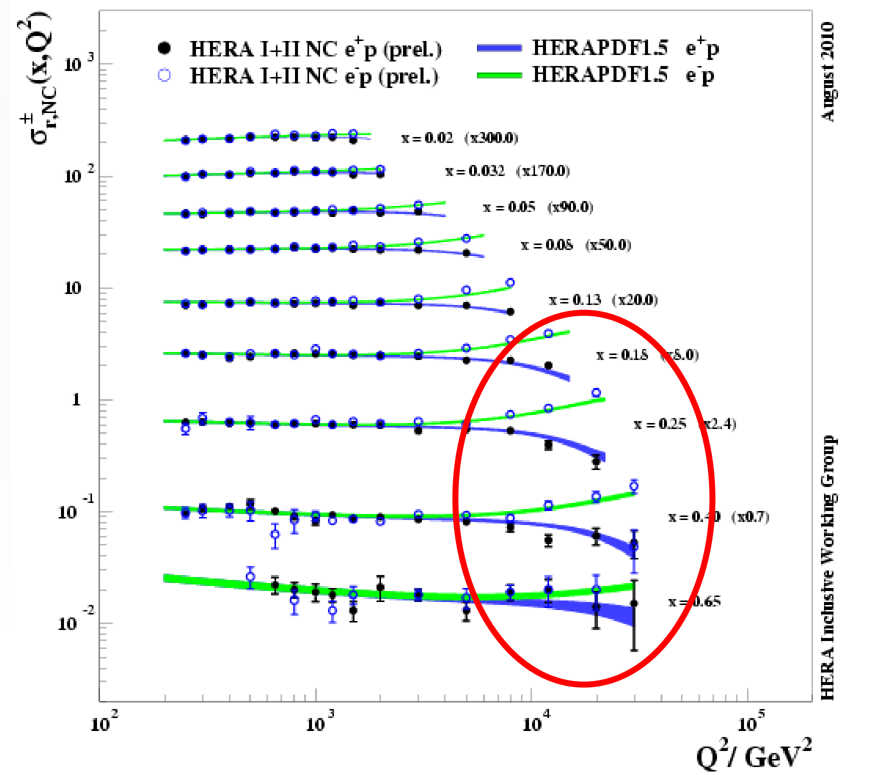
Combination of NC high-Q^2 data

NC data at high-Q^2 → $Z\gamma$ interference destructive (e^+p) & constructive (e^-p)

HERA-I combined results vs. HERAPDF1.0



HERA-I+II combined results vs. HERAPDF1.5



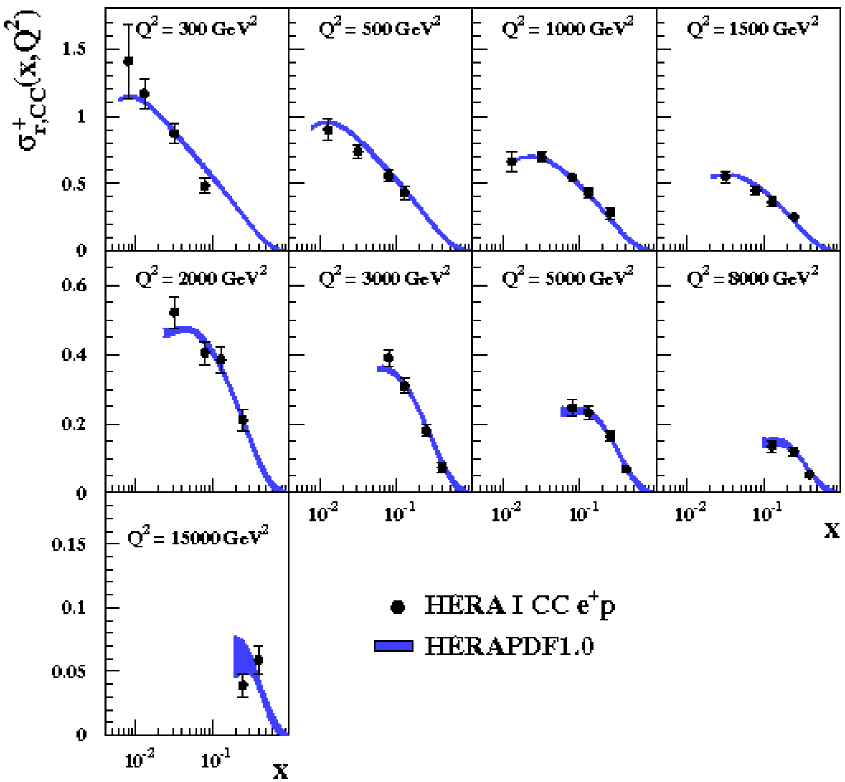
Including HERA-II high-Q^2 data → improved PDF precision at high-Q^2 and high-x

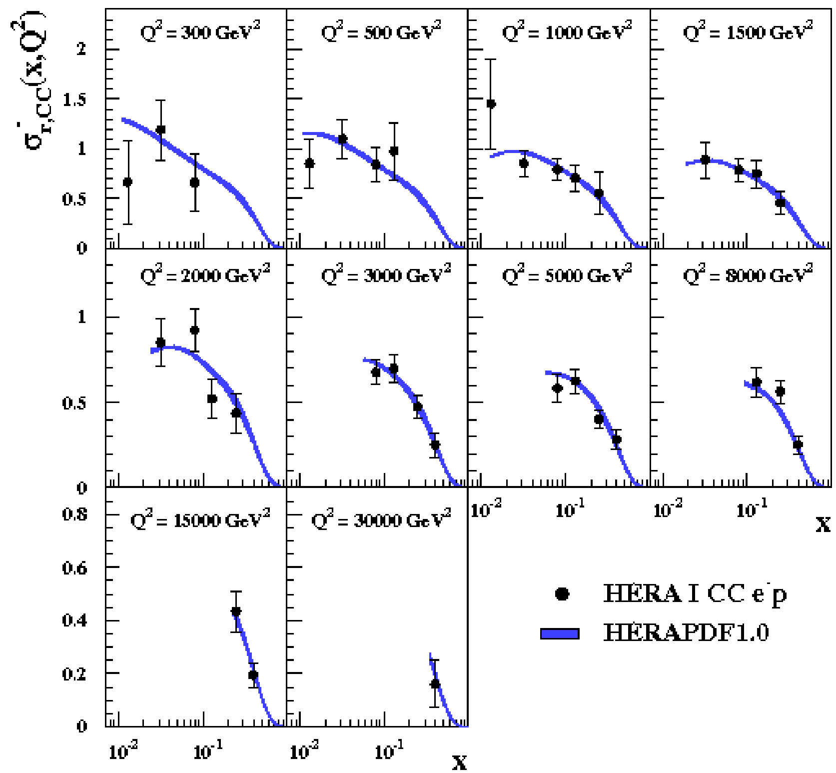
Combined HERA-I CC data vs. HERAPDF1.0

- CC e^+p/e^-p allows to disentangle contributions of **d** and **u** quarks
- Probes flavor structure of the proton

$$\tilde{\sigma}_{cc}^{e+p} \sim \bar{u}+\bar{c}+(1-y)^2(d+s)$$

$$\tilde{\sigma}_{cc}^{e-p} \sim u+c+(1-y)^2(\bar{d}+\bar{s})$$





e^+p most sensitive to $d(x,Q^2)$
e^+p valence quarks suppressed by factor $(1-y)^2$

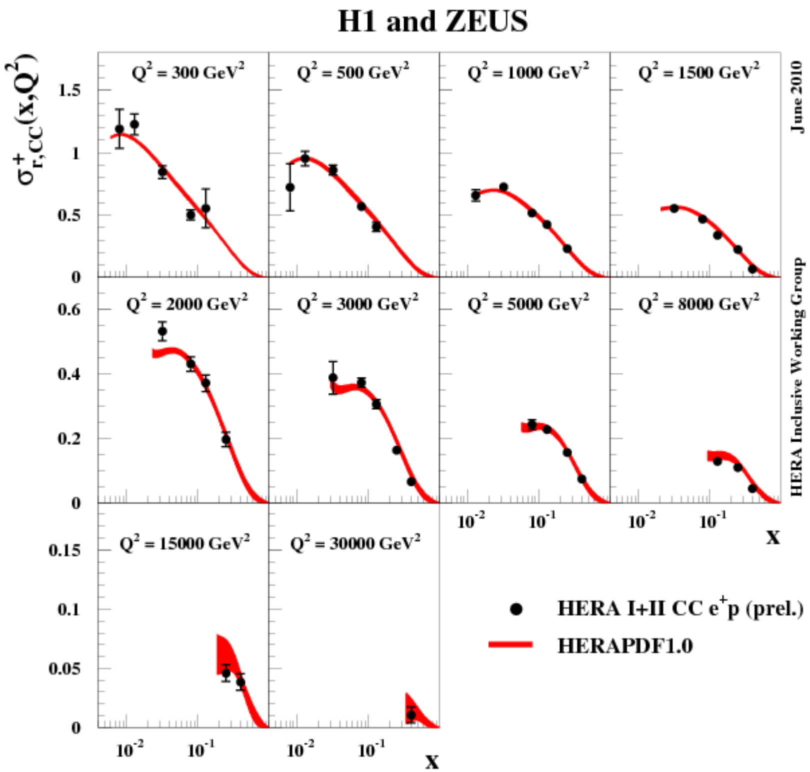
e^-p most sensitive to $u(x,Q^2)$

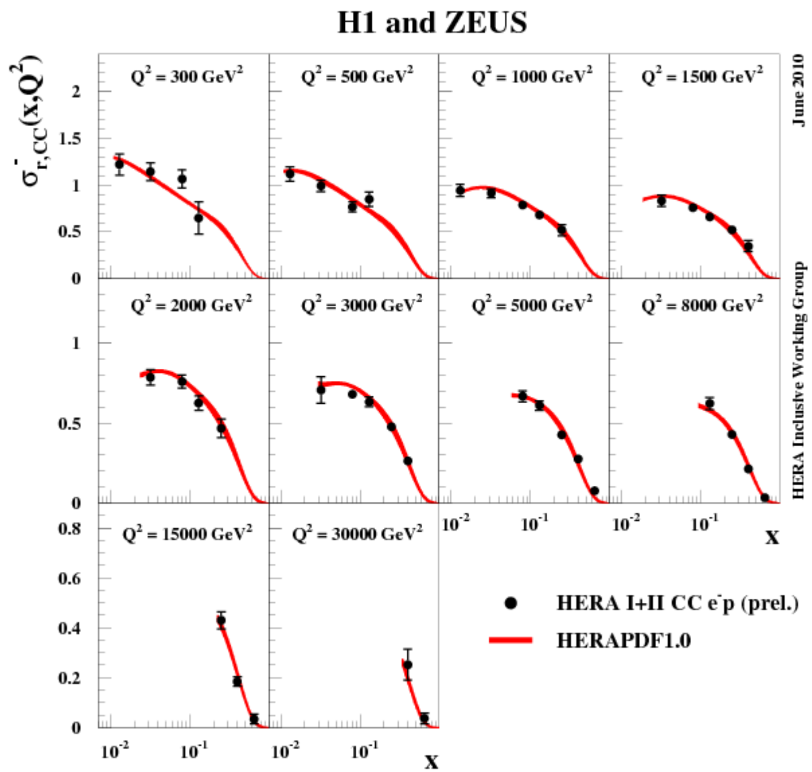
Combined HERAI+II CC data vs. HERAPDF1.0

- CC e^+p/e^-p allows to disentangle contributions of **d** and **u** quarks
- Probes flavor structure of the proton

$$\tilde{\sigma}_{cc}^{e+p} \sim \bar{u} + \bar{c} + (1-y)^2 (d+s)$$

$$\tilde{\sigma}_{cc}^{e-p} \sim u + c + (1-y)^2 (\bar{d} + \bar{s})$$





e^+p most sensitive to $d(x,Q^2)$
e^+p valence quarks suppressed by factor $(1-y)^2$

e^-p most sensitive to $u(x,Q^2)$
10 x higher statistic than in JHEP01(2010)109

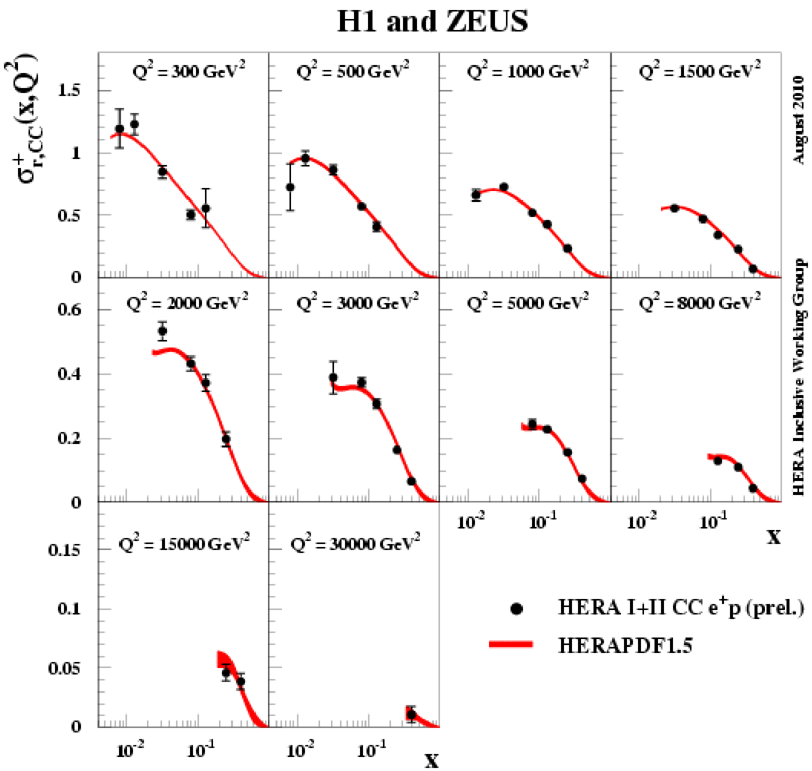
Including HERA-II high-Q^2 data → increased data precision

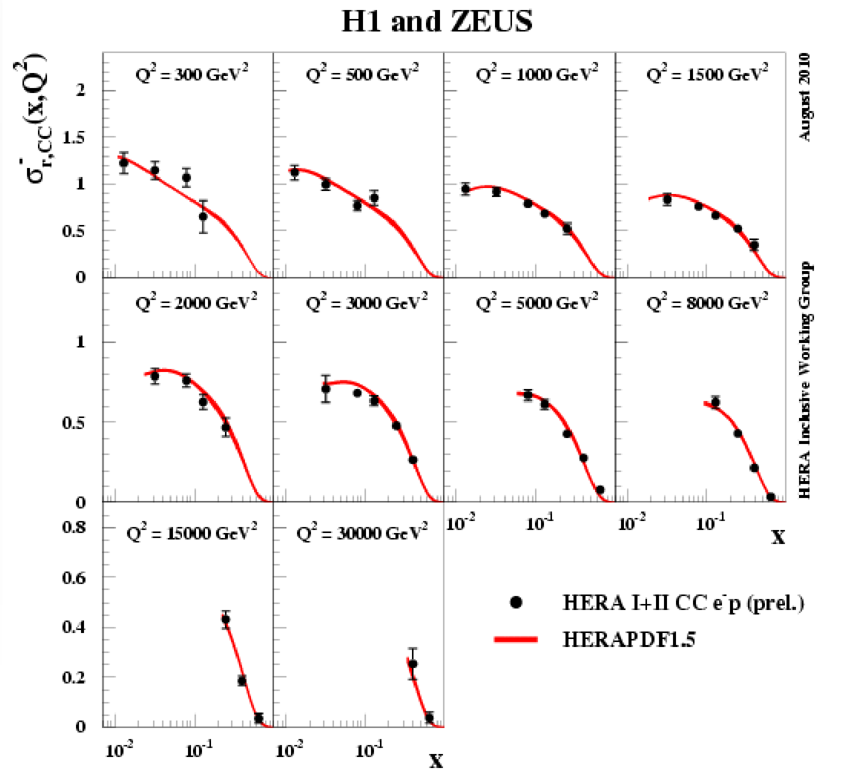
Combined HERAI+II CC data vs. HERAPDF1.5

- CC e^+p/e^-p allows to disentangle contributions of d and u quarks
- Probes flavor structure of the proton

$$\tilde{\sigma}_{cc}^{e+p} \sim \bar{u} + \bar{c} + (1-y)^2 (d+s)$$

$$\tilde{\sigma}_{cc}^{e-p} \sim u + c + (1-y)^2 (\bar{d} + \bar{s})$$



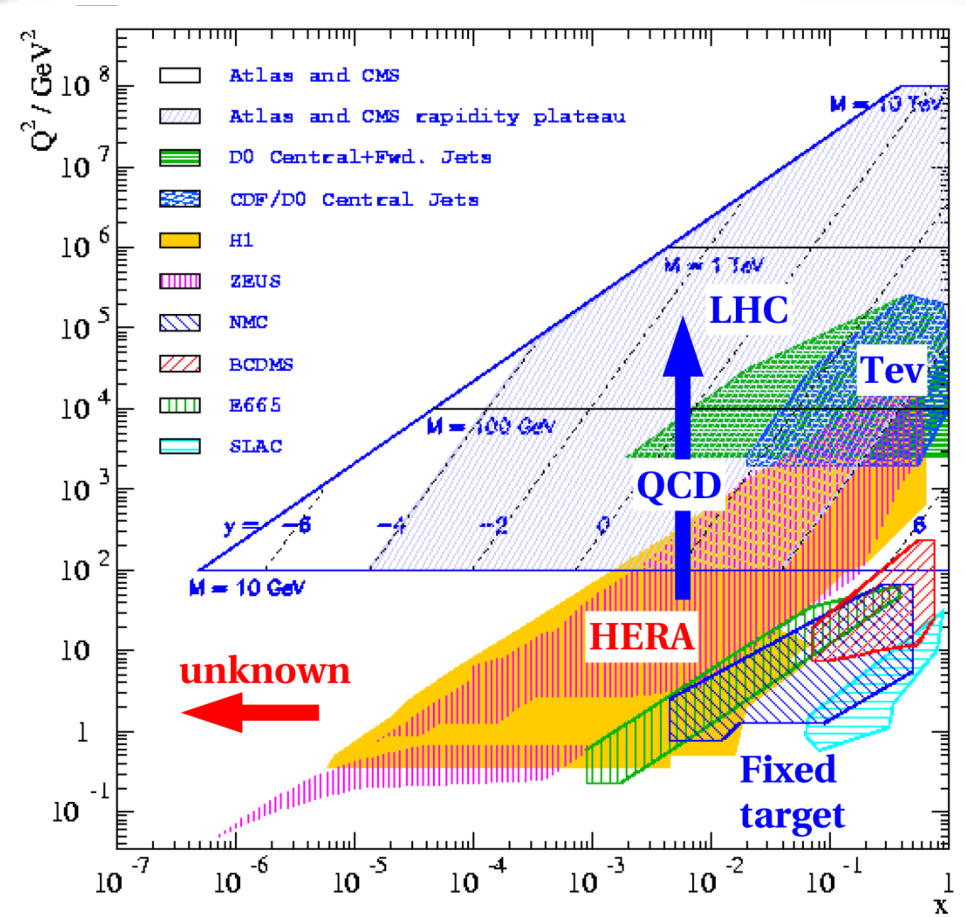


e^+p most sensitive to $d(x,Q^2)$
e^+p valence quarks suppressed by factor $(1-y)^2$

e^-p most sensitive to $u(x,Q^2)$
10 x higher statistic than in JHEP01(2010)109

Including HERA-II high-Q^2 data → increased PDF precision

Kinematic plane



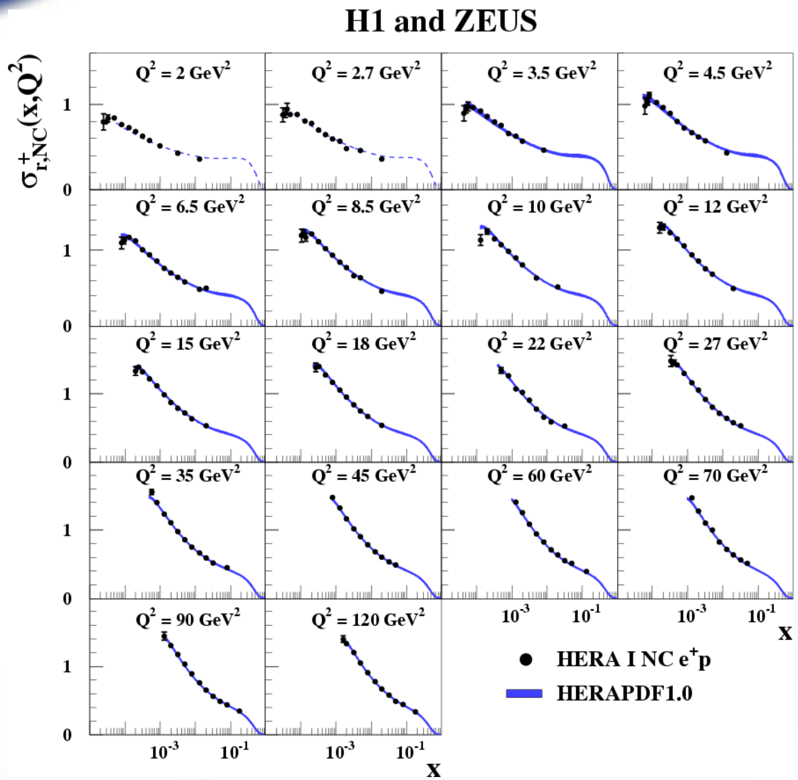
QCD evolution extrapolates HERA measured PDFs to LHC

PDF's obtained in low x regime at HERA are applicable to LHC

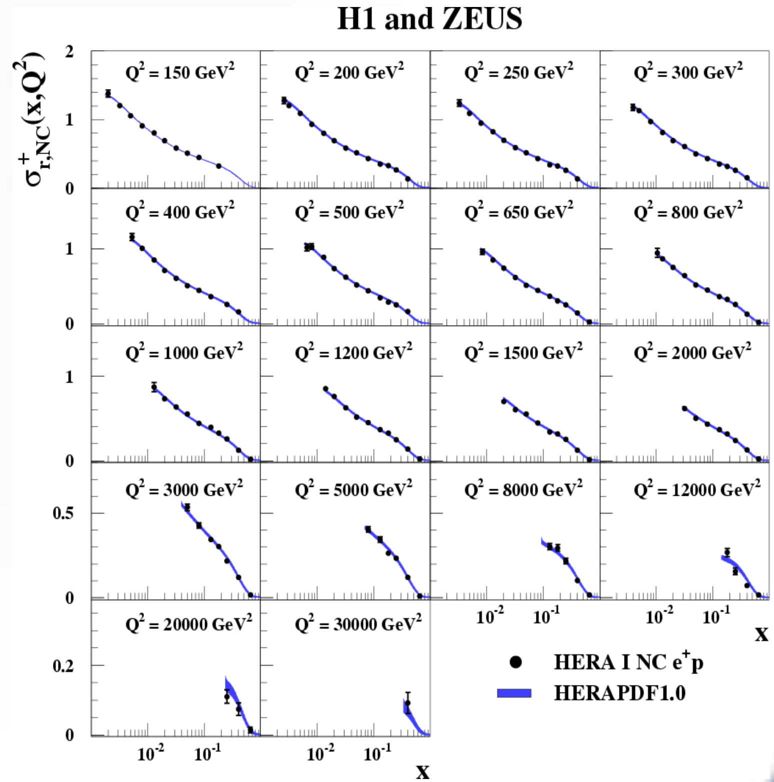
HERA data cover LHC central rapidity range for M > 100 GeV

F_2 with combined e+p HERA-I NC

Low/medium Q^2 bins (2-150 GeV^2)



High Q^2 bins(150-30000 GeV^2)

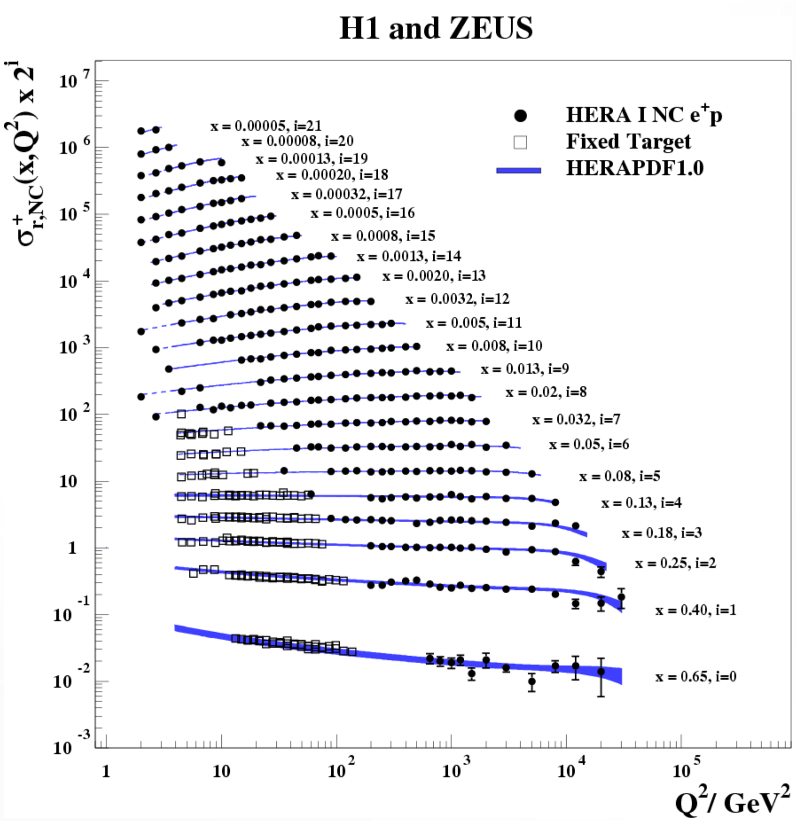


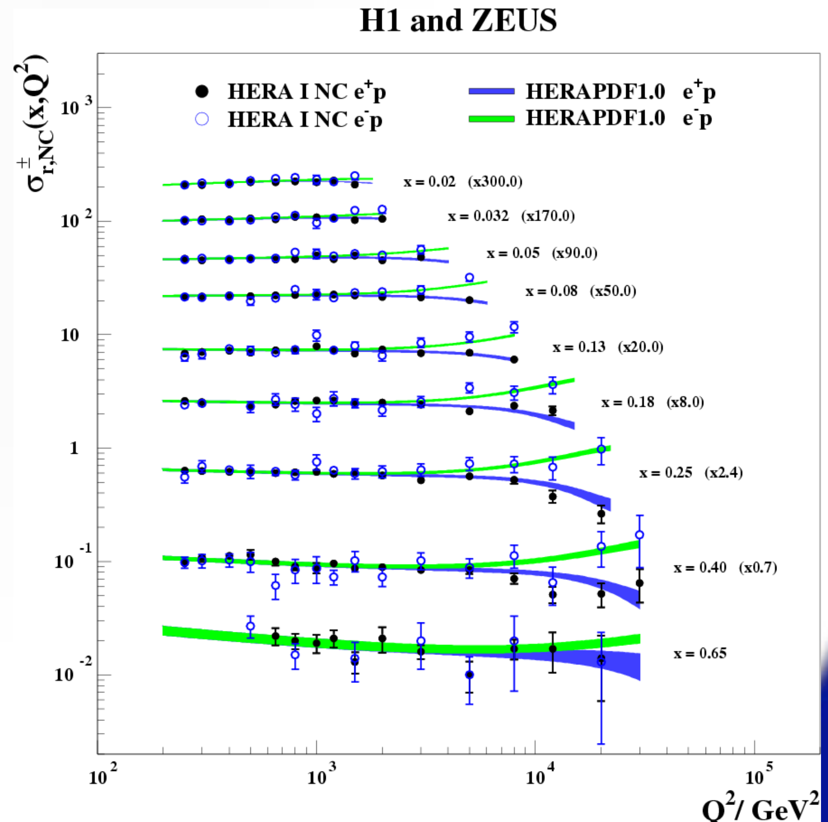
- $F_2(x,Q^2)$ shows strong rise as $x \rightarrow 0$, the rise increases with increasing Q^2
- Data well described by QCD fit from Q^2=2 to 30000 GeV^2

HERA-I combined NC

- Data show strong **scaling violations at low x** → large gluon density

- NC data at high-Q2: Zγ interference **destructive (e+p)** and **constructive (e-p)**





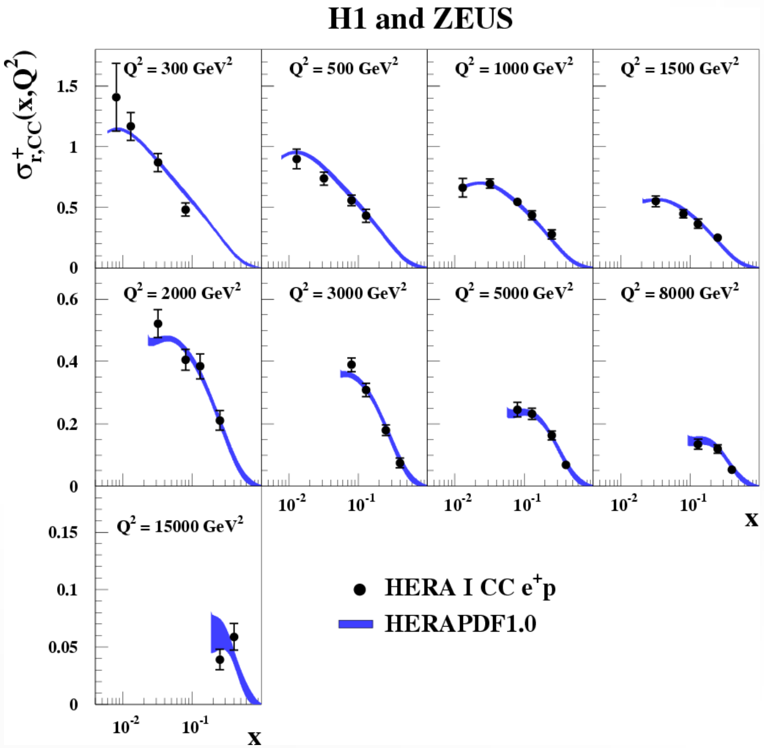
Good agreement between data and NLO QCD fit!

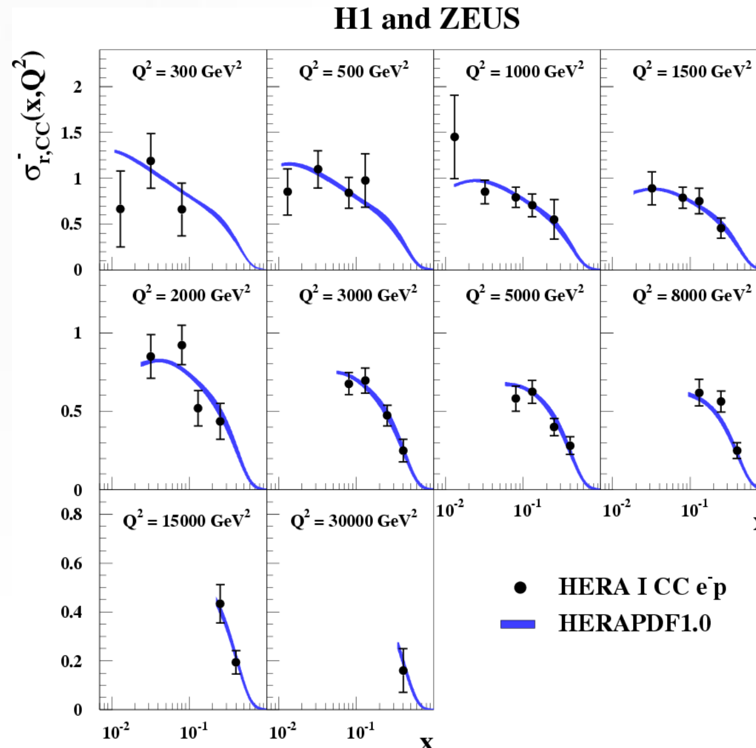
HERA-I combined CC data

- CC e^+p/e^-p allows to disentangle contributions of d and u quarks
- Probes flavor structure of the proton

$$\tilde{\sigma}_{cc}^{e+p} \sim \bar{u} + \bar{c} + (1-y)^2 (d+s)$$

$$\tilde{\sigma}_{cc}^{e-p} \sim u + c + (1-y)^2 (\bar{d}+\bar{s})$$





- e^+p most sensitive to $d(x,Q^2)$
- e+p valence quarks suppressed by factor $(1-y)^2$

- e^-p most sensitive to $u(x,Q^2)$
- Low luminosity (16pb-1/exp.) → Big statistical errors

HERA-I QCD fit - HERAPDF1.0

- Fit uses **combined H1&ZEUS NC, CC data only**
- DGLAP equations at **NLO in MSbar scheme**
- Parameterize parton distribution functions at starting scale and evolve with Q^2.
- **Thorne-Roberts Variable Flavour Number Scheme** (as for MSTW08):
  →takes the quark masses into account

Scheme	TRVFNS
Evolution	QCDNUM17.02
Order	NLO
Q_0^2	1.9 GeV^2
$f_s = s/D$	0.31
Renorm. scale	Q^2
Factor. scale	Q^2
Q^2_{min}	3.5 GeV^2
$\alpha_S(M_Z)$	0.1176
M_c	1.4 GeV
M_b	4.75 GeV

PDFs at the starting scale parameterised as:
$xf(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^2)$
where xf = xu_{val}, xd_{val}, xg, xUbar, xDbar

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	-	-

Results:
10 parameters for central fit
$\chi2/n_{dof}$ = 574/582

HERA-I QCD fit - uncertainties

➢ **Experimental uncertainty:**

Take into account experimental errors including, correlations bin to bin and between experiments/datasets => $\Delta\chi^2=1$

➢ **Model uncertainty includes theoretical errors:**

Variation	Standard Value	Lower Limit	Upper Limit
f_s	0.31	0.23	0.38
m_c [GeV]	1.4	$1.35^{(a)}$	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	$1.5^{(b)}$	$2.5^{(c,d)}$

➢ **Parameterisation uncertainty:**

Vary parameterisation of PDFs at starting scale by adding in extra parameters in the fit

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)

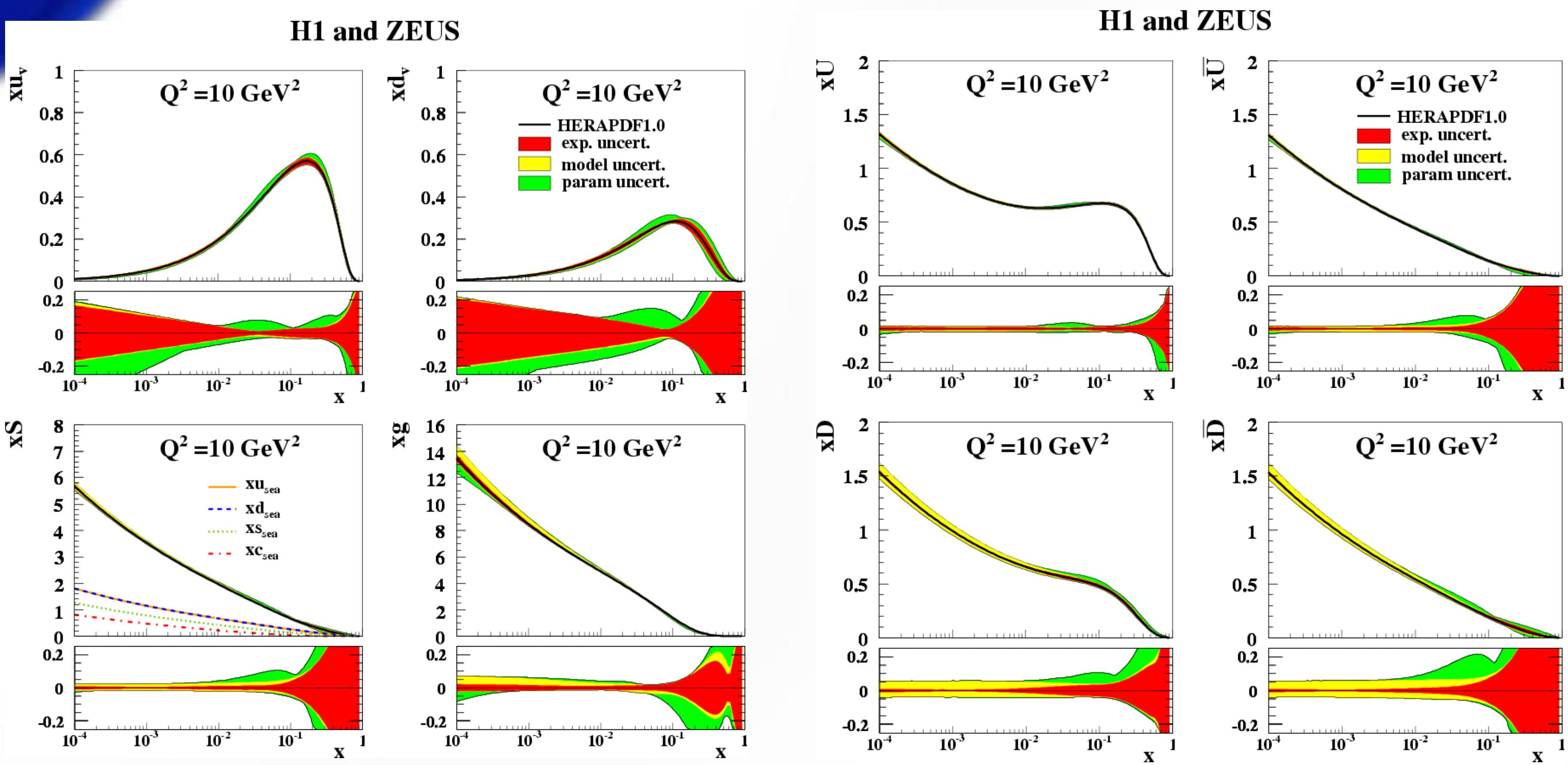
Only 10 free parameters:

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 $B(d_{valence})$

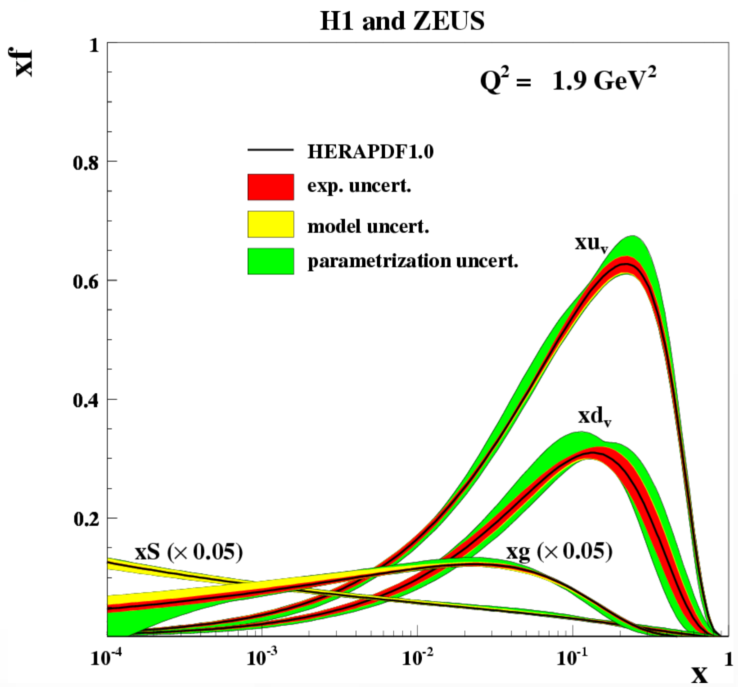
HERAPDF1.0 at Q^2=10GeV^2

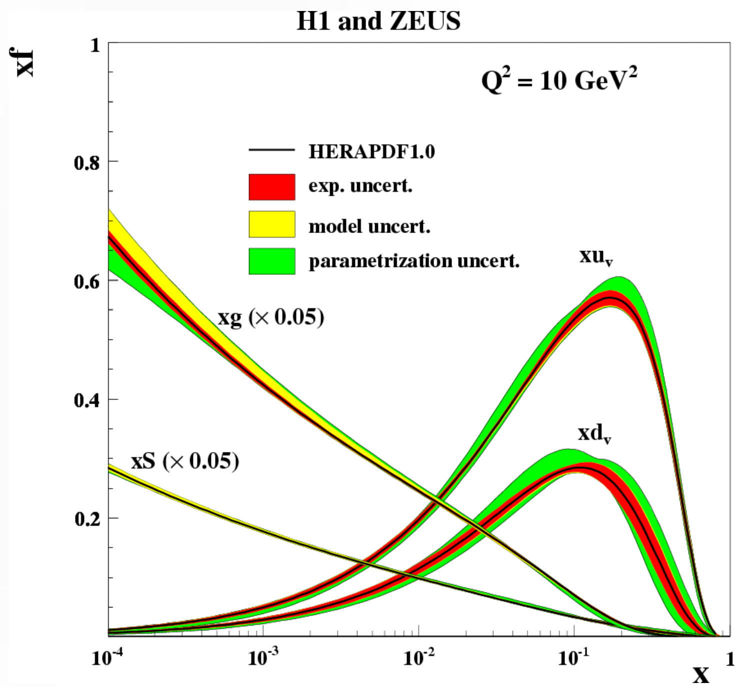


- High precision for sea and gluon at low x
- Reasonable precision for valence at high x
- Gluon error relatively large at high x

HERAPDF1.0

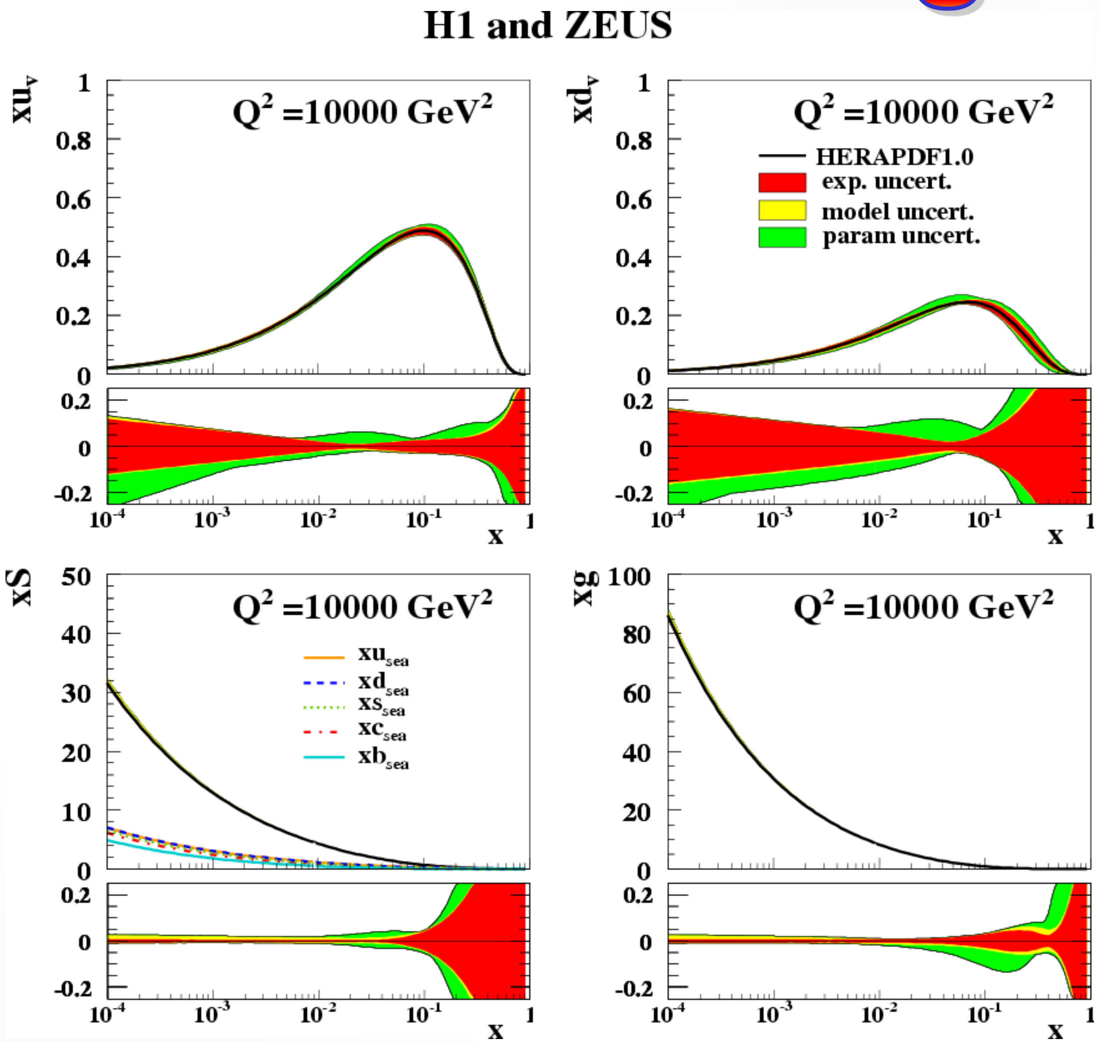
Distributions for valence quarks, see and gluons





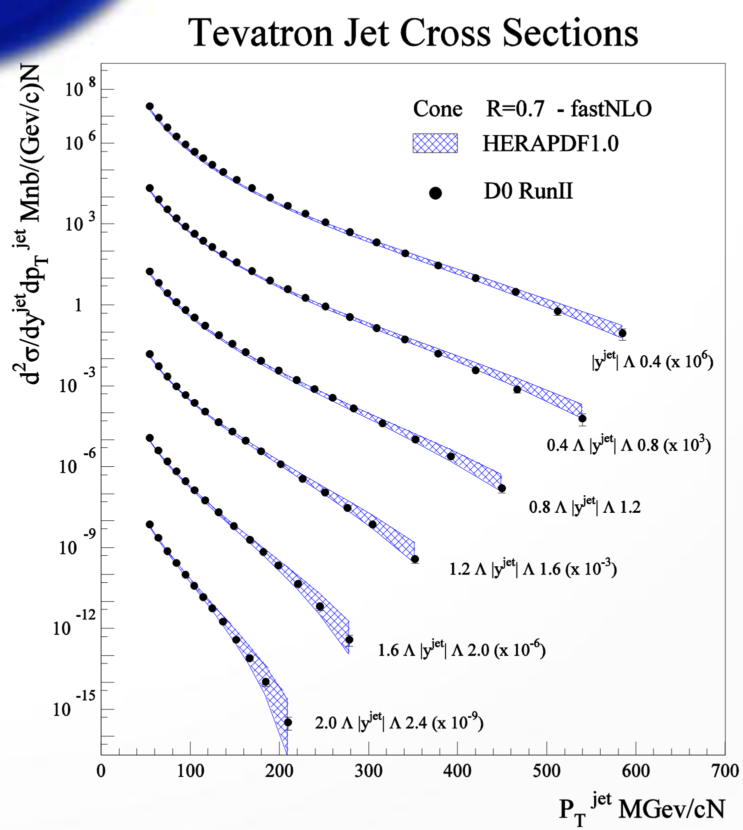
Gluon and see distributions are scaled by factor 20

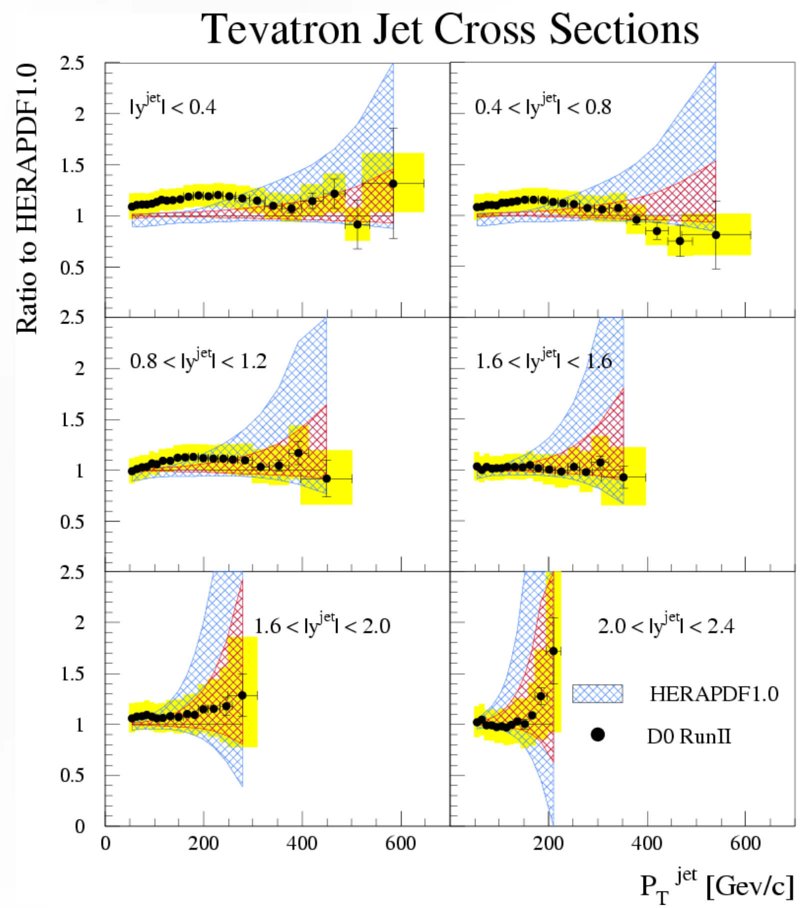
HERAPDF1.0 at high Q^2



Small errors on gluon & see distributions at LHC energies
→ enables precise predictions for LHC cross sections

HERAPDF1.0: Crosscheck with TeVatron data





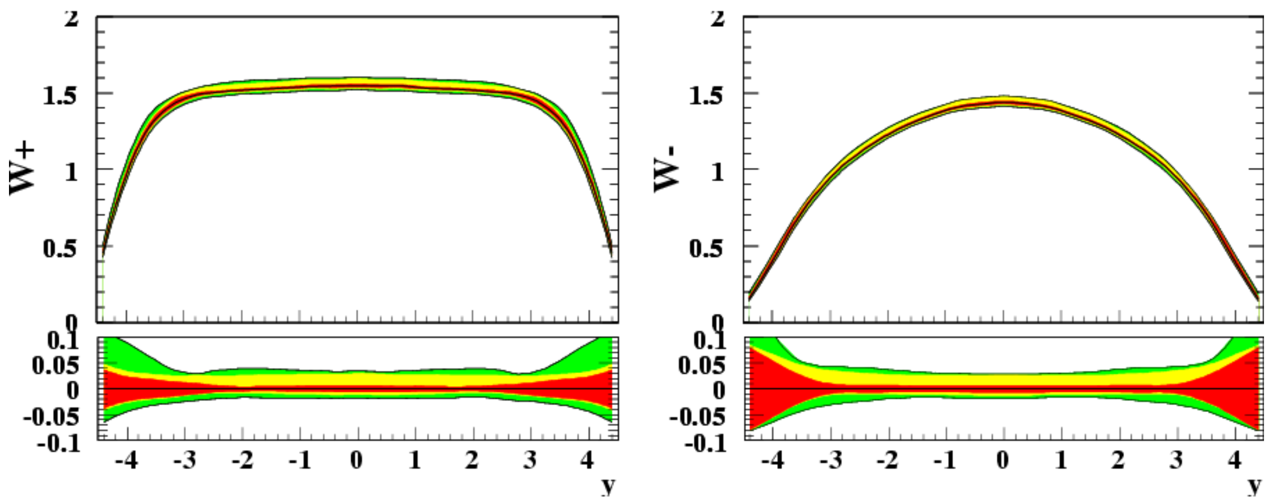
HERAPDF1.0 describes TeVatron data up to the high-Et jet production!

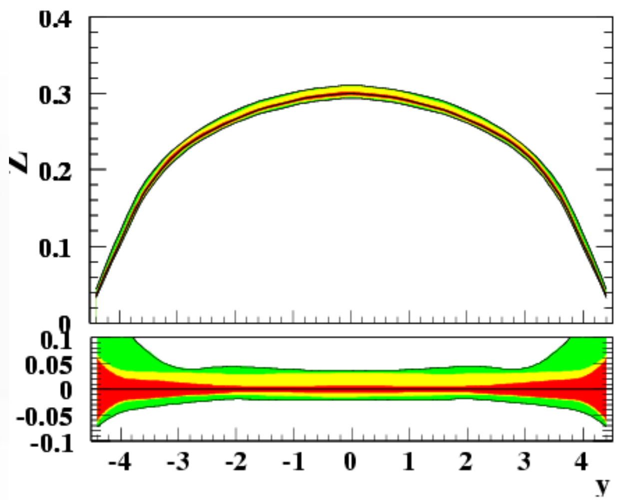
Ratio of D0 high Et jet cross-section to HERAPDF1.0 prediction:
- **Total PDF uncertainty blue**
- **PDF experimental red**
- **Systematic experimental error yellow**

HERAPDF1.0: Impact on LHC

Predictions for the W/Z production cross sections using HERAPDF1.0 (including experimental, model and parameterisation uncertainties)

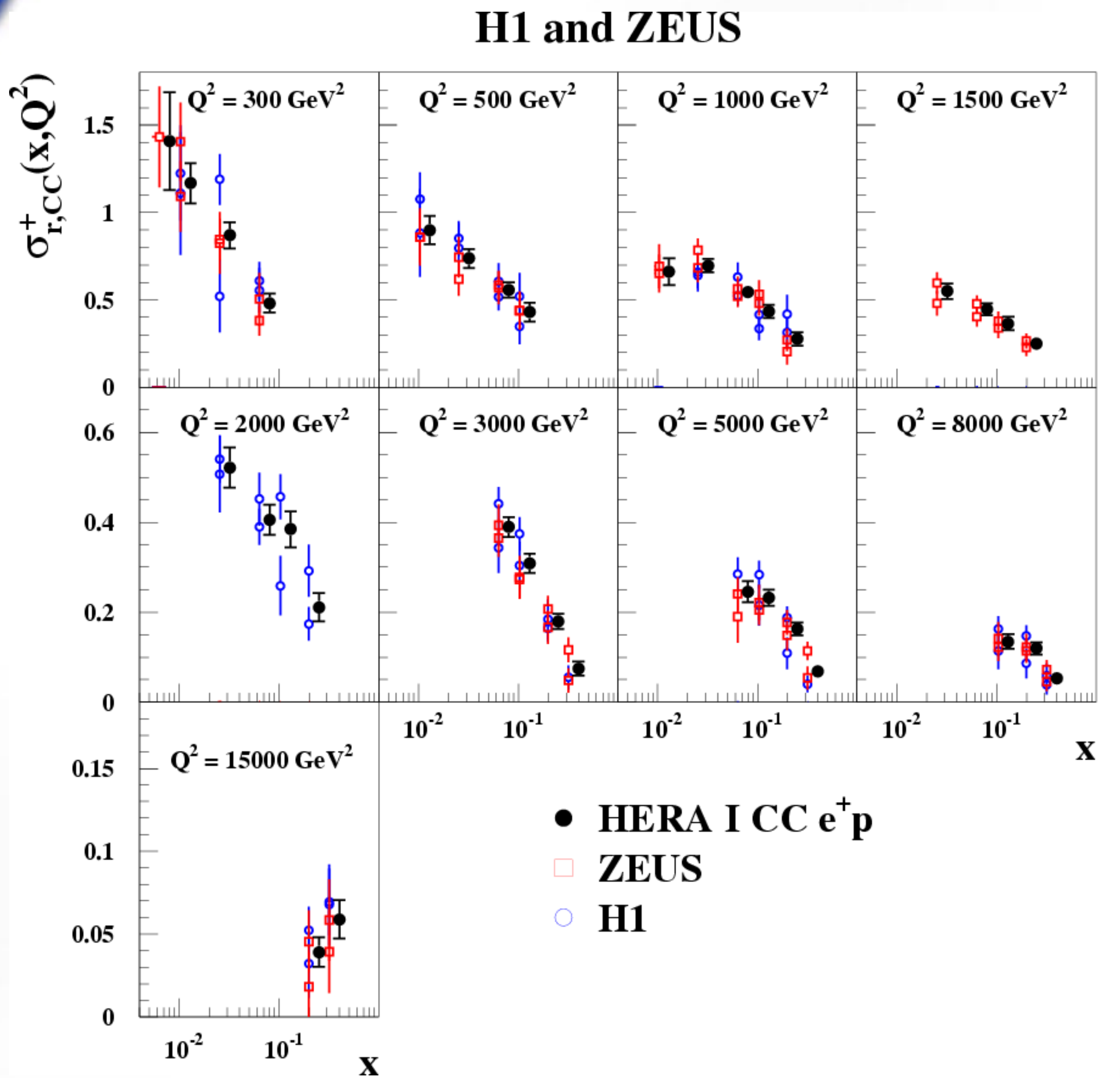
W and Z rapidity distributions



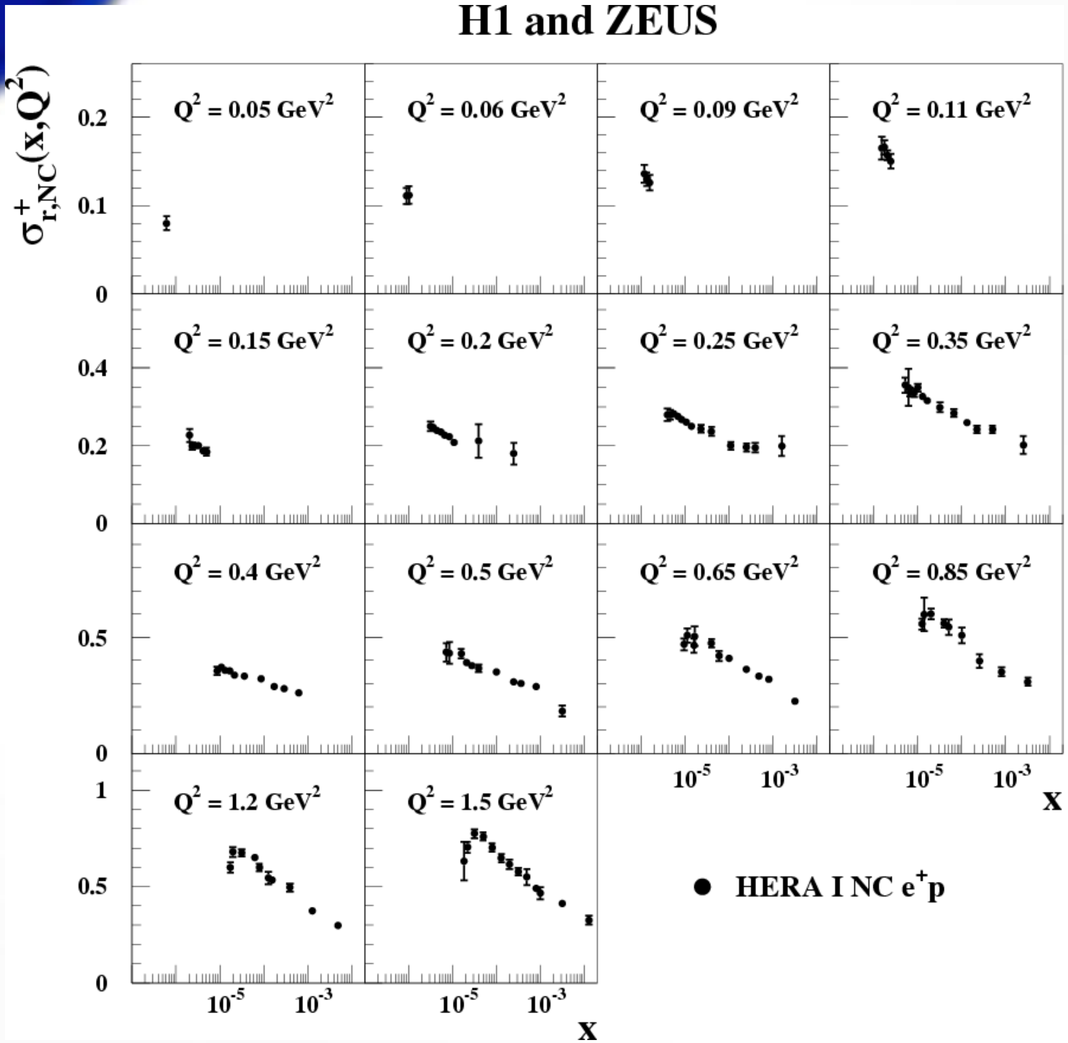


- **Precision:**
  4% uncertainties in the central rapidity range
- **Improvement is expected with HERAII data at large y (high-x)**

HERA combined CC e+p

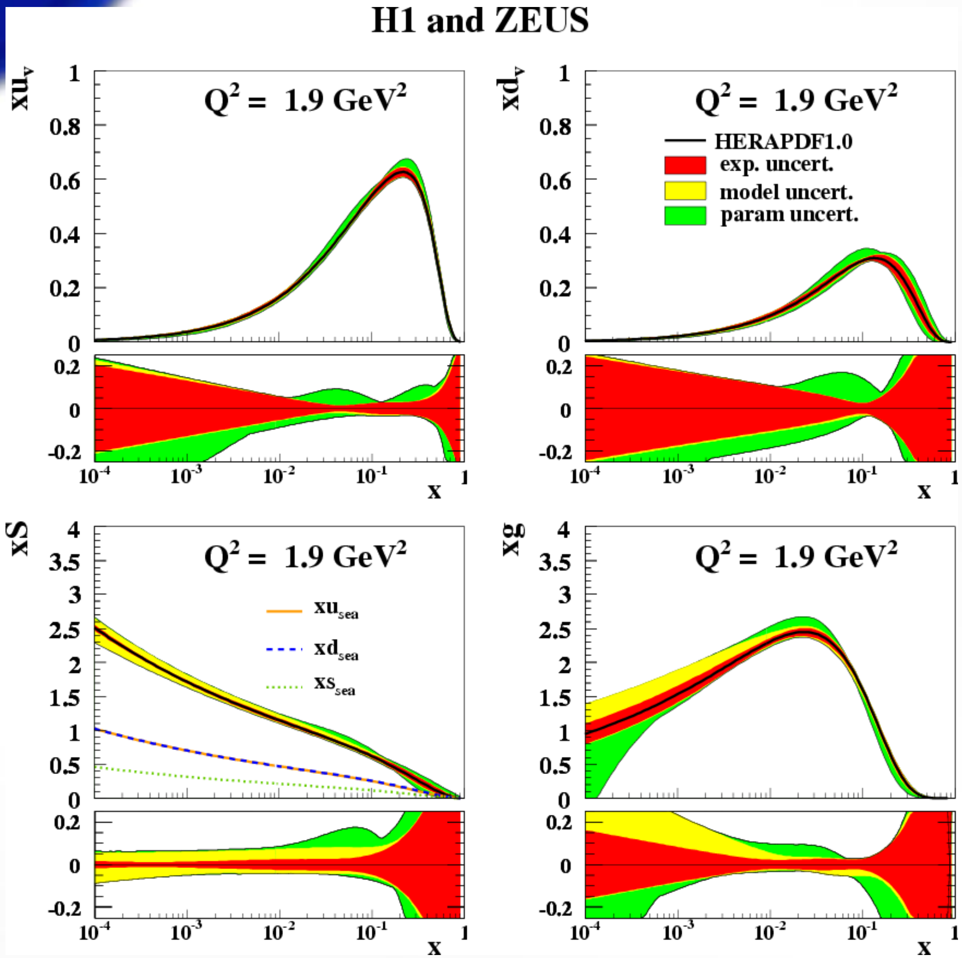


HERA combined NC e+p at very low Q2

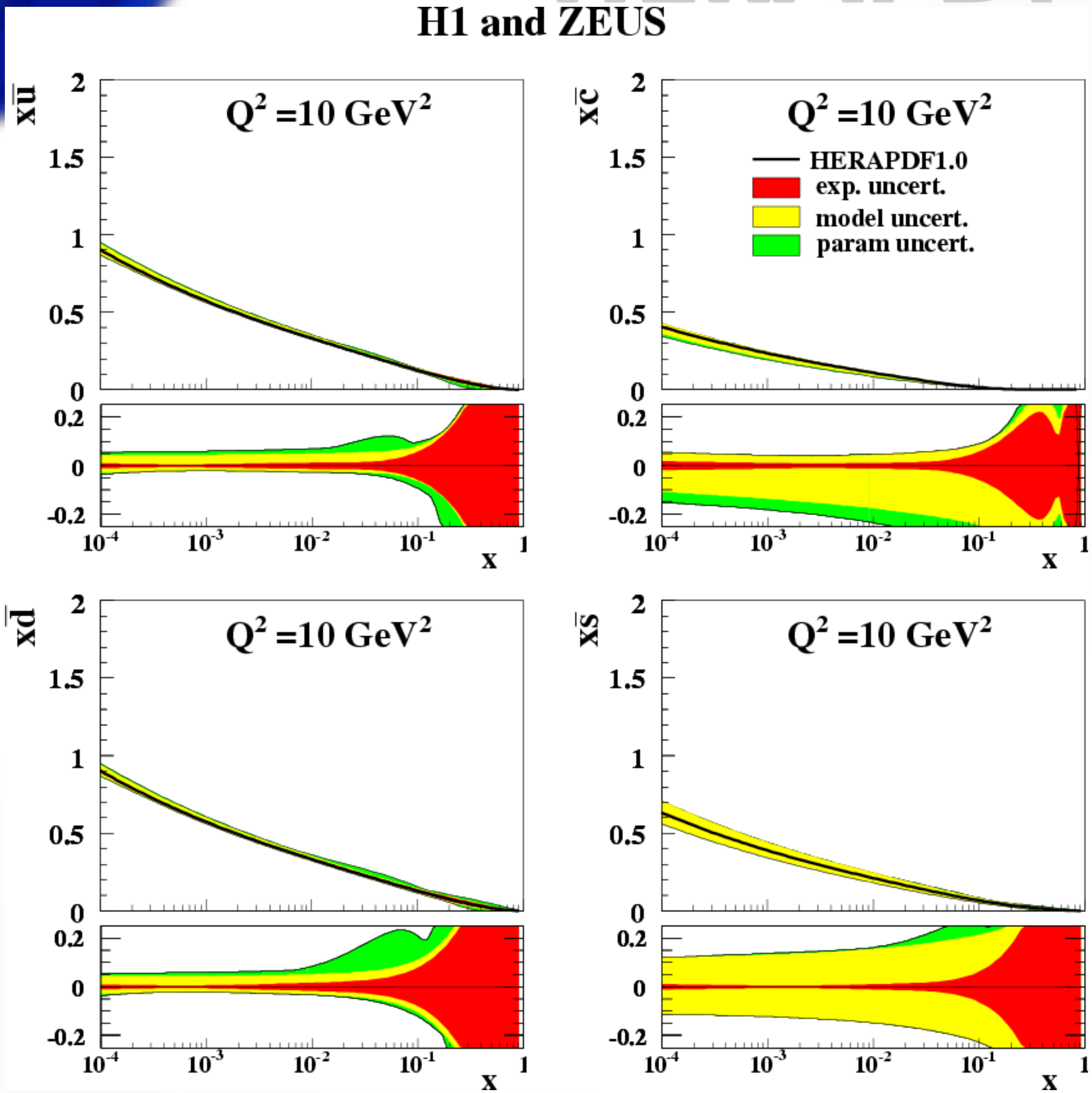


- Data shown in very low Q^2 region (0.05-1.5 GeV2)
- pQCD not expected to work in the very low Q^2 region.

PDF from HERAPDF1.0 at low Q2

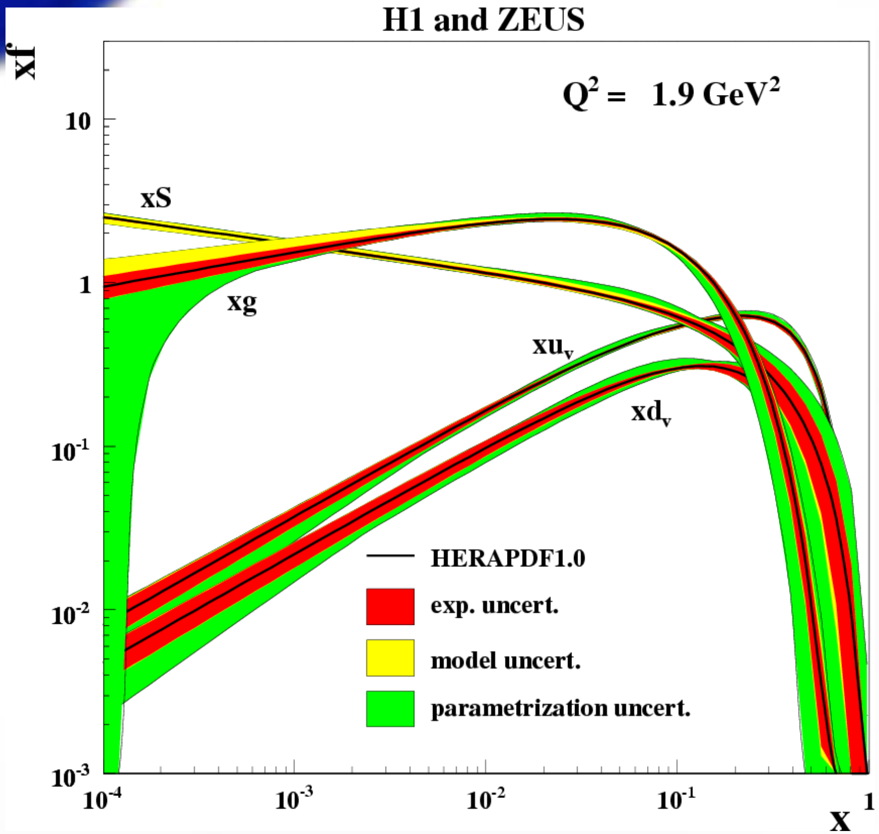


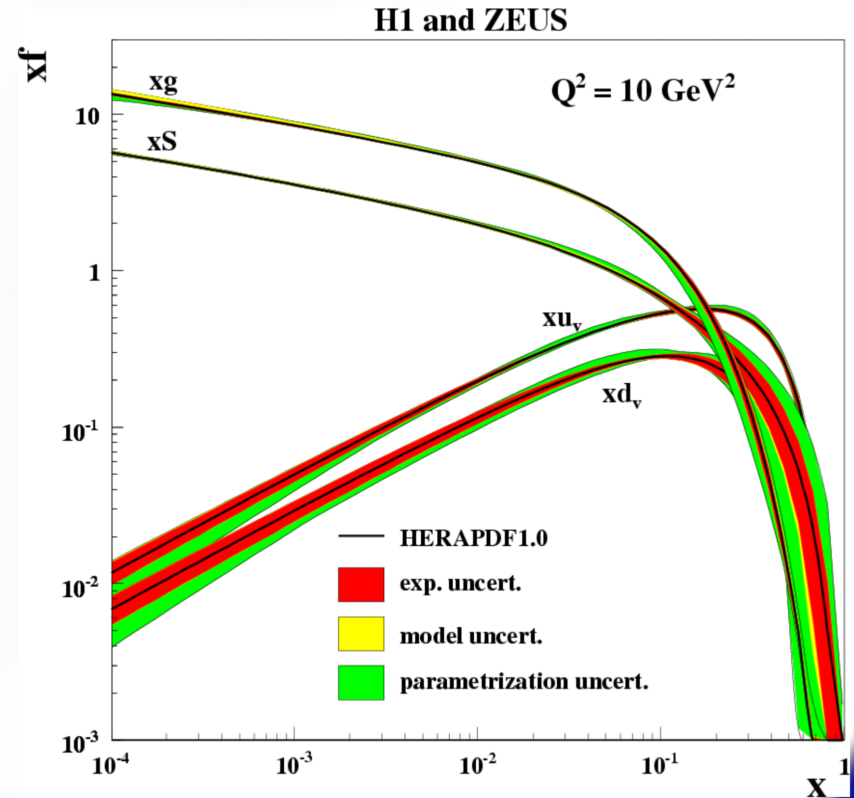
HERAPDF1.0



Parton Distribution Function xu, xd, xs and xc at Q^2 = 10 GeV^2

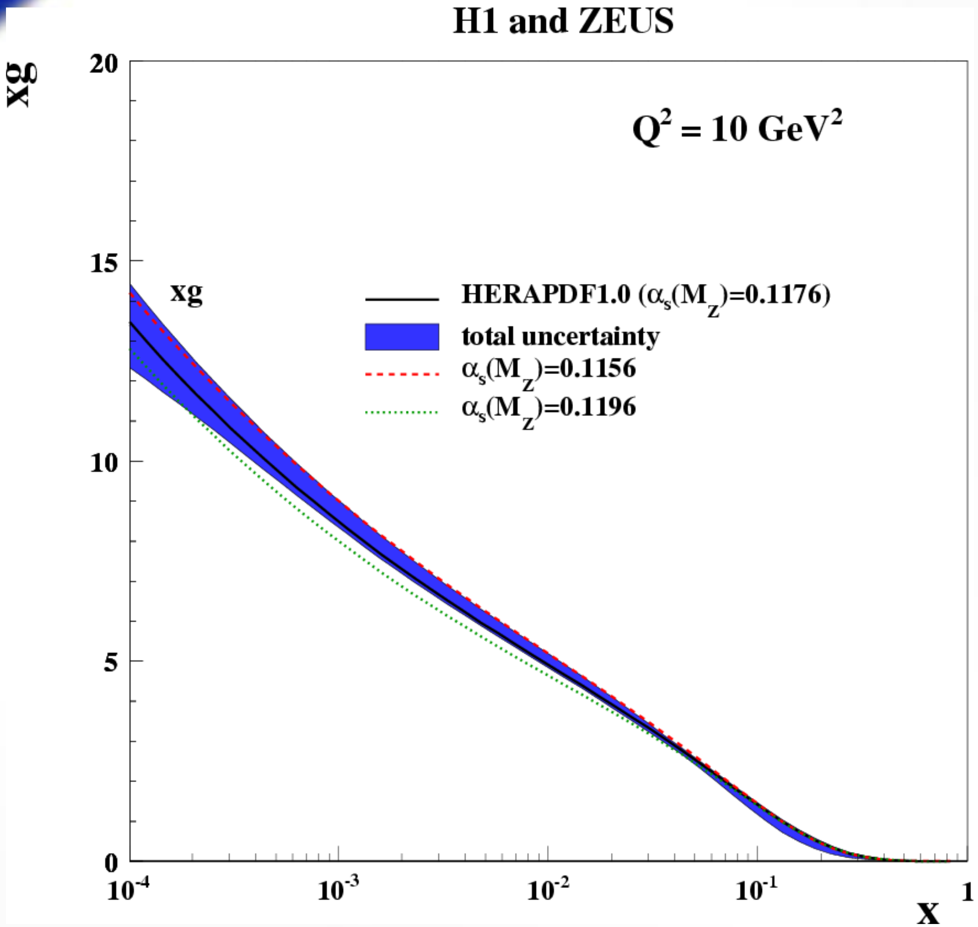
PDF from HERAPDF1.0



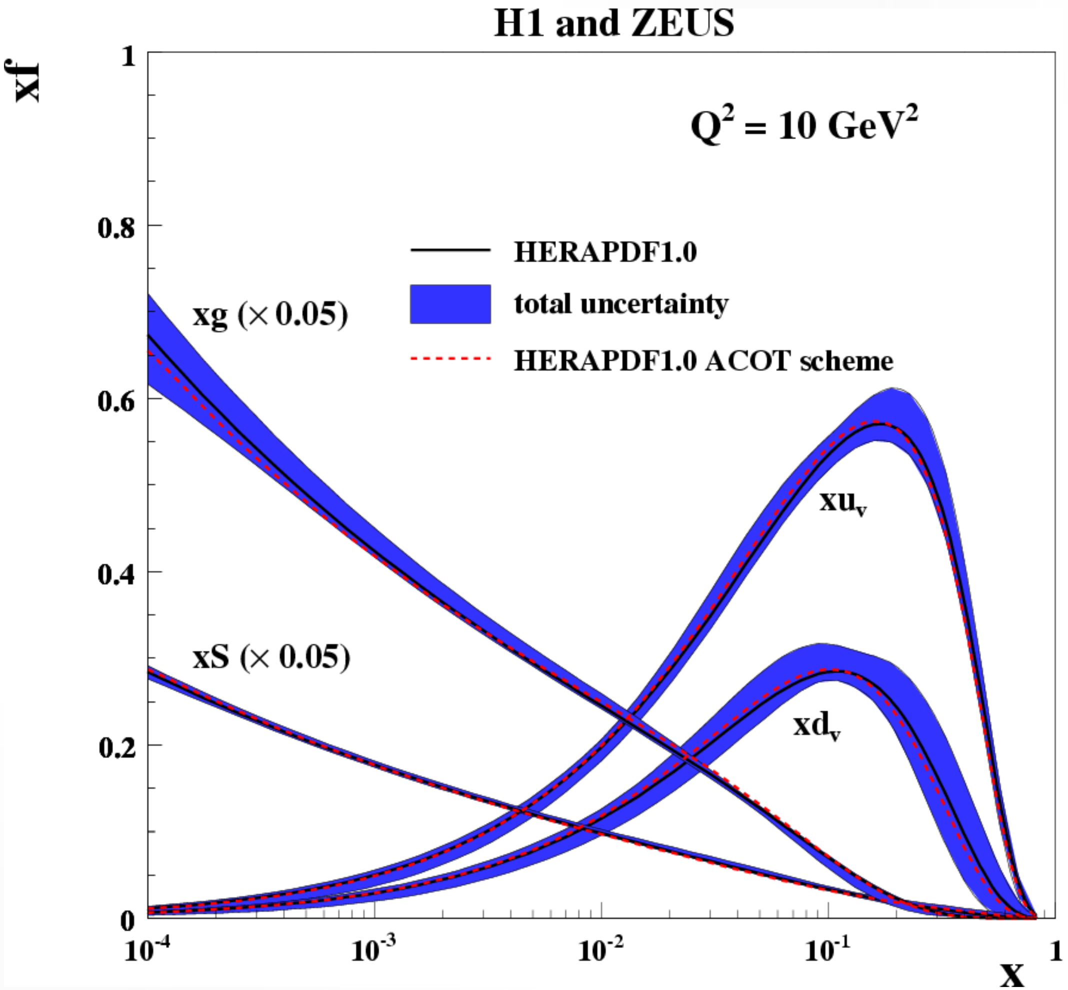


Distributions for valence quarks, see and gluons (logarithmic scale)

Gluon density vs different α_s values

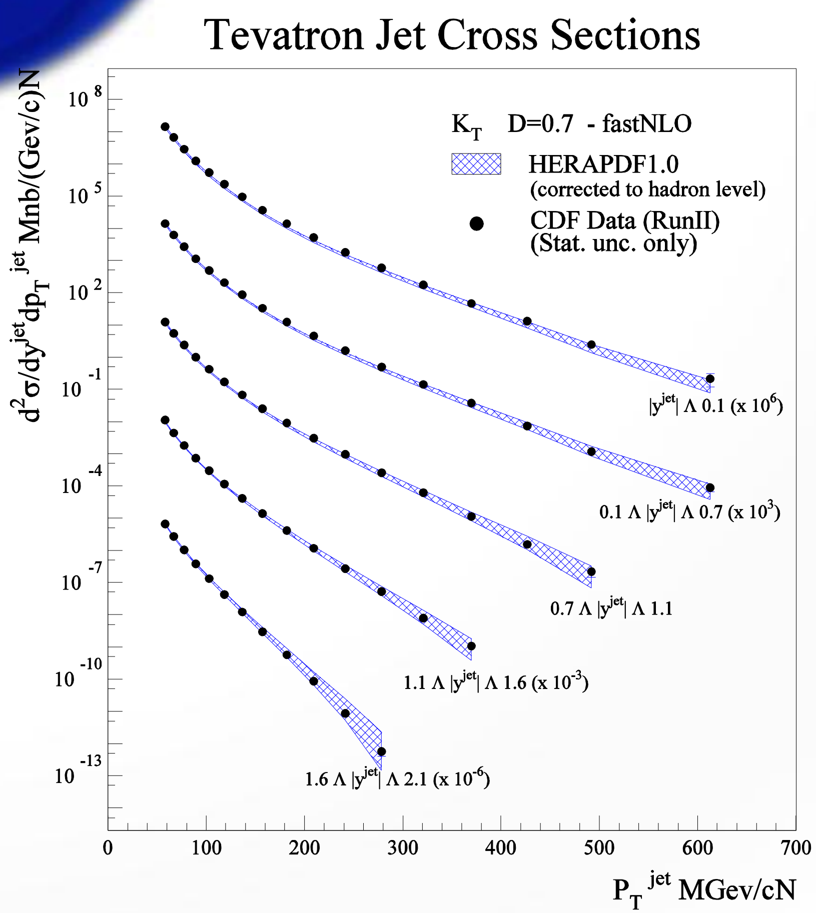


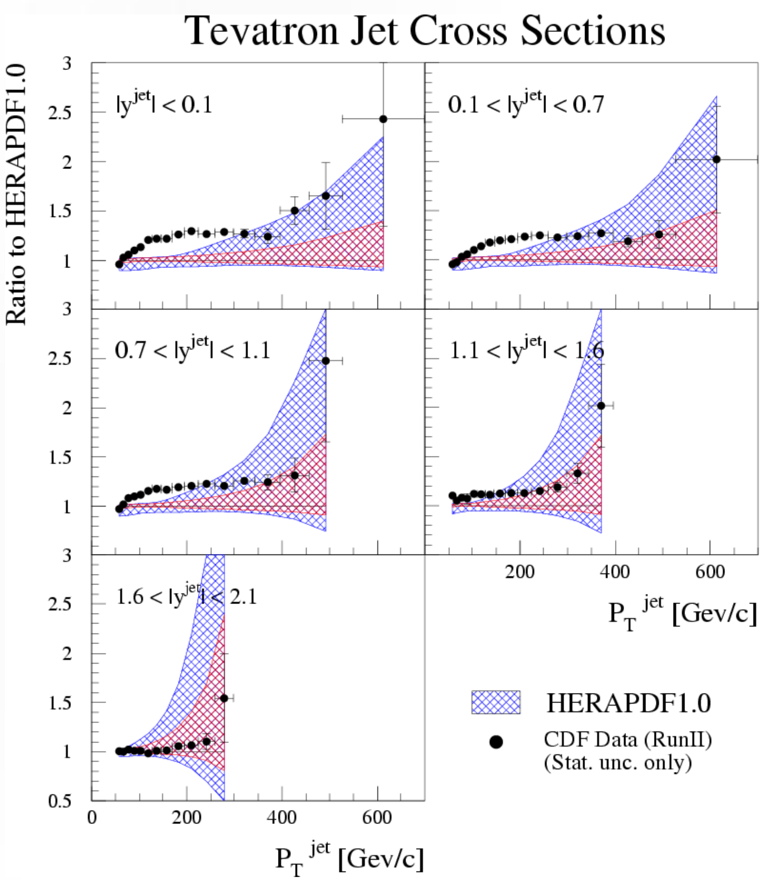
HERAPDF1.0 vs. HERAPDF1.0 ACOT scheme

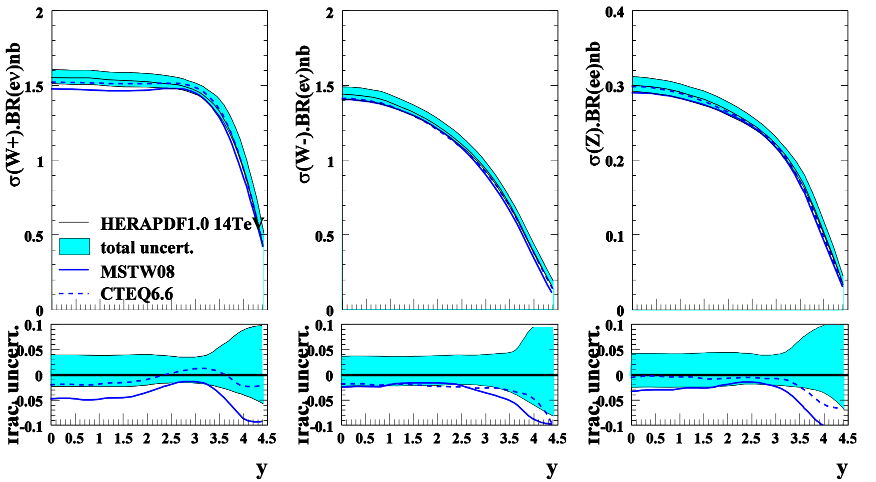


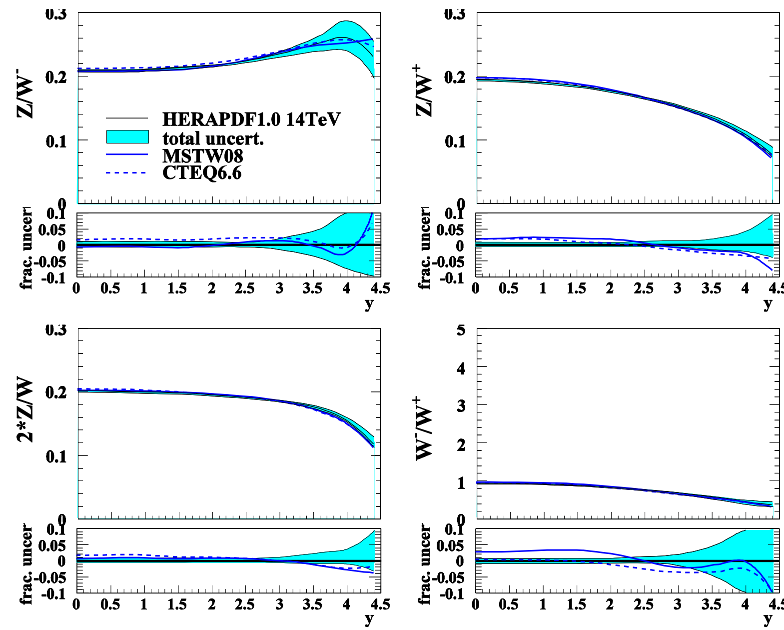
Distributions for valence quarks, see and gluons

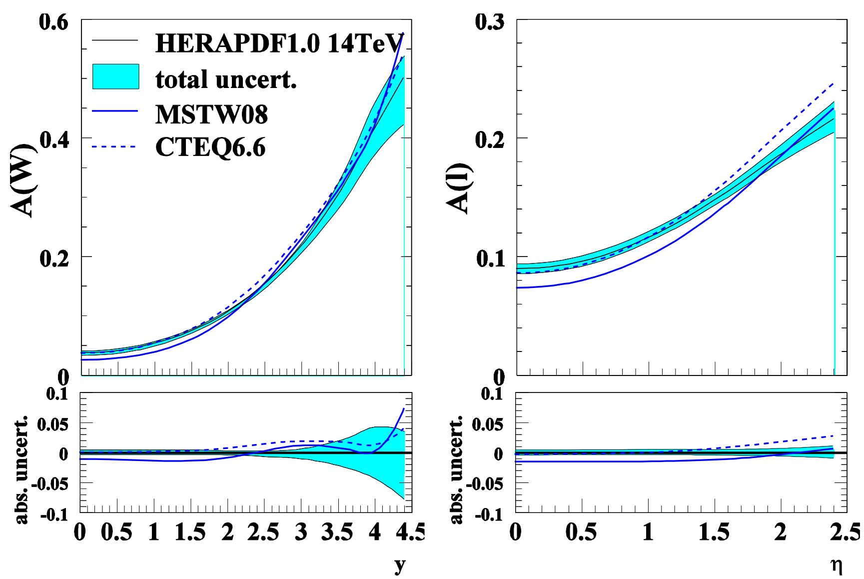
CDF jet data with HERAPDF1.0











HERAPDF1.0 predictions for W/Z production at LHC

These are at 14TeV but 10TeV and 7TeV exist

These show the full uncertainty bands of HERAPDf1.0 and compare to CTEQ66 and MSTW08 central values

Procedural Uncertainties

1. Additive vs Multiplicative nature of the error sources

Only normalizations uncertainties are taken as multiplicative
(=> Typically below 0.5%, a few % at high-Q2)
A general study of the possible correlated systematic uncertainties between H1 and ZEUS has been performed:
- Identified 12 possible uncertainties of common origin
- compared 212 averages taking all pairs as corr/uncor in turn

Mostly negligible except for:

2. Correlated syst. uncert. for the photoproduction background

(Typically below 0.5%, but larger at high-y)

3. Correlated syst. uncert. for the hadronic energy scale

(Typically below 0.5%, significant only at low-y)

Procedural Uncertainties for HERA-II high-Q^2

Three additional procedural errors

- **Correlate across all data files**
  $\delta_{ave,had}$ hadronic energy scale
  $\delta_{ave,gp}$ background due to photoproduction
- **$\delta_{ave,rel}$ change <u>relative to absolute errors</u>**
  (Only lumistays relative)