HERAPDF1.5 at LO
MPI2013, Antwerp

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On behalf of the H1 and ZEUS collaborations

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Motivation for an LO version of the HERAPDF

PDFs at LO are used for the simulation of parton showers, underlying event, minimum bias and pile-up
A set of LO PDFs together with a 'matching' set of NLO PDFs is useful for NLO+PS calculations such as MC@NLO OR POWHEG

The LHC at 13 or 14TeV will extend kinematic coverage to lower values of Bjorken x

The HERAPDF has a special emphasis on low x because it fits only HERA data

Reminder of the HERAPDF

HERAPDF uses the combined H1 and ZEUS data on:

- Inclusive Neutral and Charged Current processes for e^+p and e^-p scattering at 820,920 GeV proton beam energy from HERA-I (HERAPDF1.0) published and HERA I+II (HERAPDF1.5) still preliminary

This means that HERAPDF uses purely proton data

•No need for deuterium corrections, or heavy target corrections

•No assumption on strong isospin needed to get the d-quark

•A very well understood consistent data set JHEP 1001 (2010) 109 + updates

The HERA data combination gives us a well understood, consistent and accurate data set with systematic errors which are smaller than the statistical errors across most of the kinematic plane. The total errors are ~1% for Q^2 ~20-100 GeV^2 and less than 2% for most of the rest of kinematic plane.

This allows us to use the $\chi 2$ tolerance $\Delta\chi 2 = 1$ to set 68% limits on the PDFs from experimental sources

Where does the information on parton distributions come from?

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

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

- The charged currents give us flavour information for high-x valence PDFs

NC e+ and e-

$$\frac{d^2\sigma(e\pm N)}{dxdy} = \frac{2\pi\alpha^2 s}{Q^4}\, Y_+ \left[F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2) \pm \frac{Y_-}{Y_+} xF_3(x,Q^2)\right], \quad Y_\pm = 1 \pm (1-y)^2$$

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

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

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

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

$[xF_3^{\gamma Z}, xF_3^Z] = \Sigma_i\, 2[e_ia_i, v_ia_i]\quad [xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$

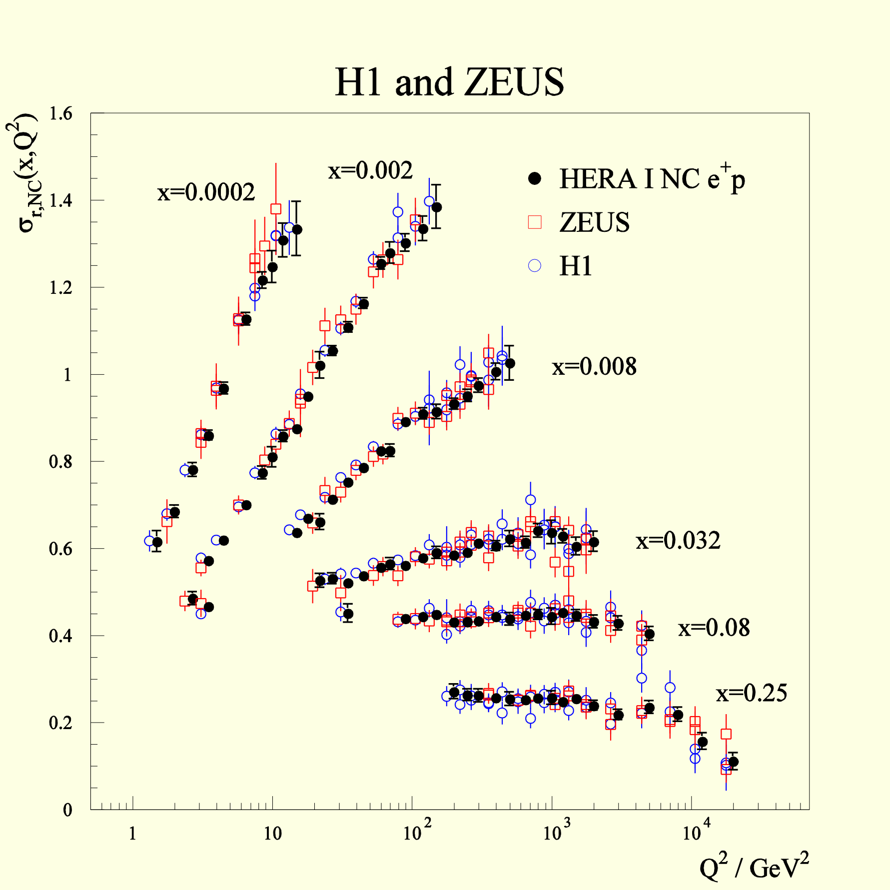
So that $xF_3^{\gamma Z} = 2x[e_ua_uu_v + e_da_dd_v] = x/3\,(2u_v+d_v)$

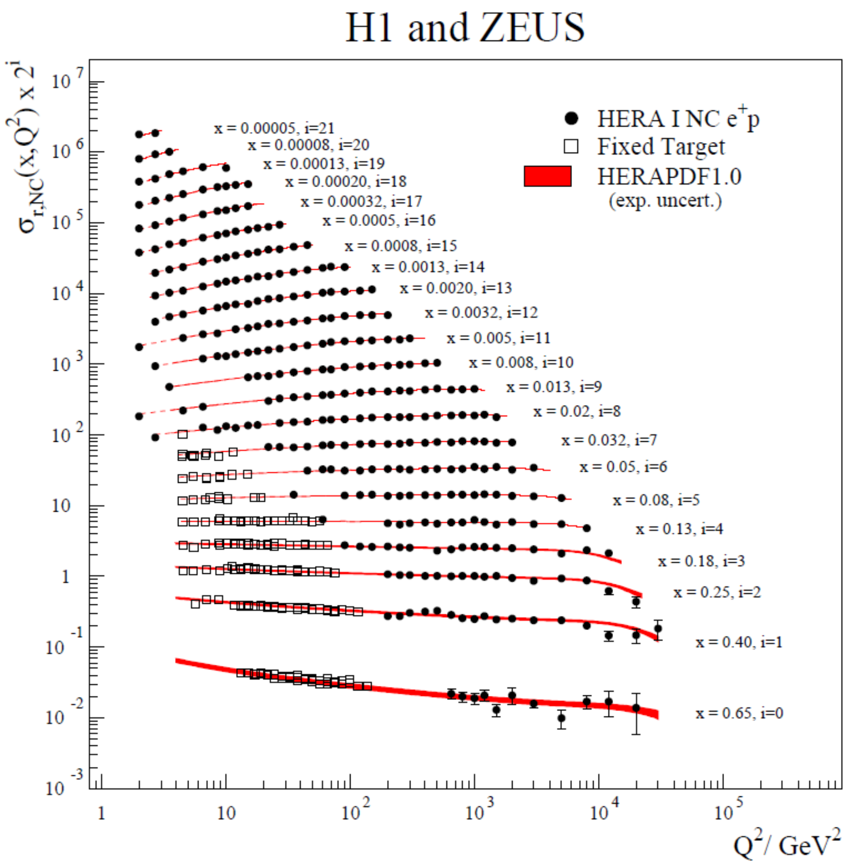
Where $xF_3^{\gamma Z}$ is the dominant term in xF_3

The neutral current F2 gives the low-x Sea

The difference between e- and e+ also gives a valence PDF for x>0.01- not just at high-x

And of course the scaling violations give the gluon PDF





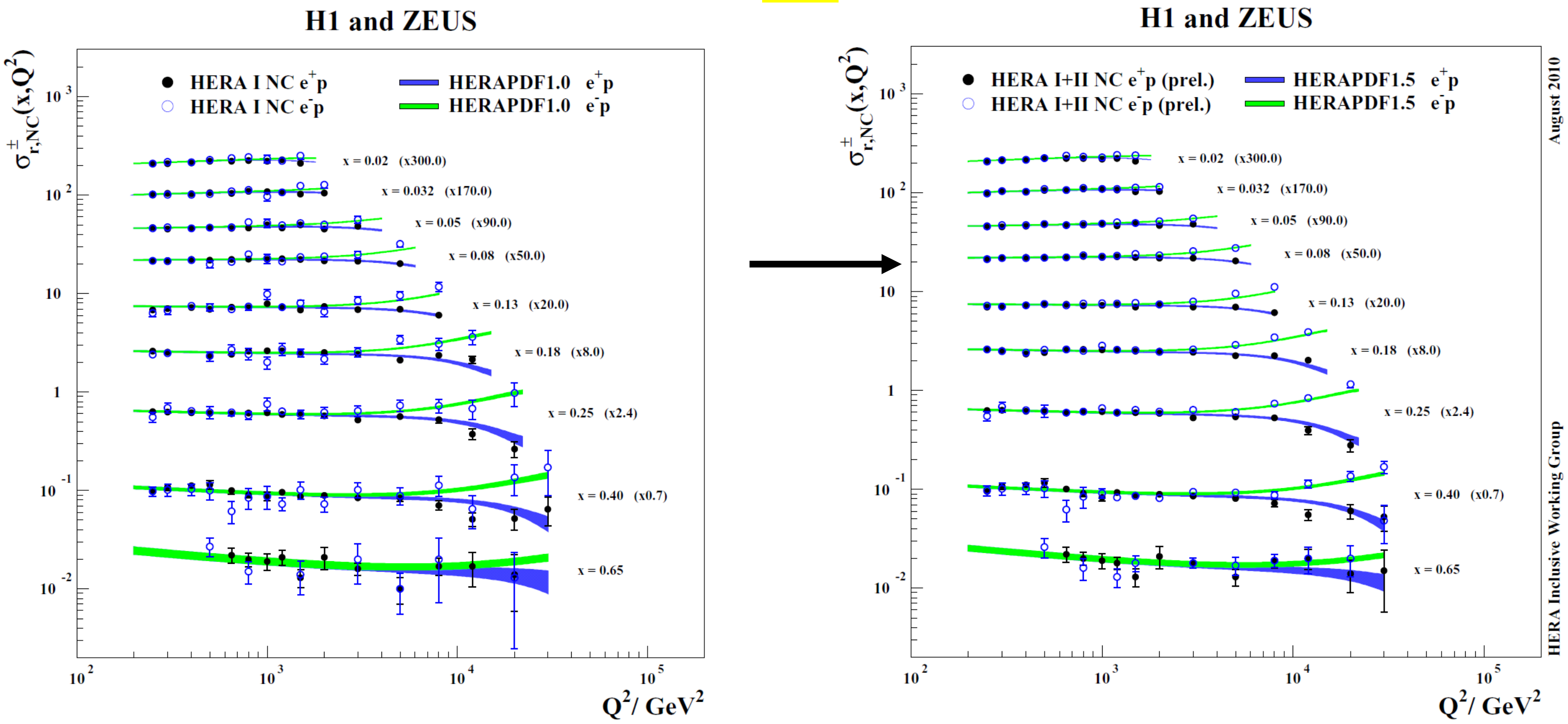
This page shows NC e+ combined data

Above : Results of the combination compared to the separate data sets

Right: the full NC e+ data

Note the kinematic coverage to very low x

HERAPDF1.0 at NLO is published (JHEP 1001 -109). It has been updated to HERAPDF1.5 NLO and NNLO : this is an update of data AND fit

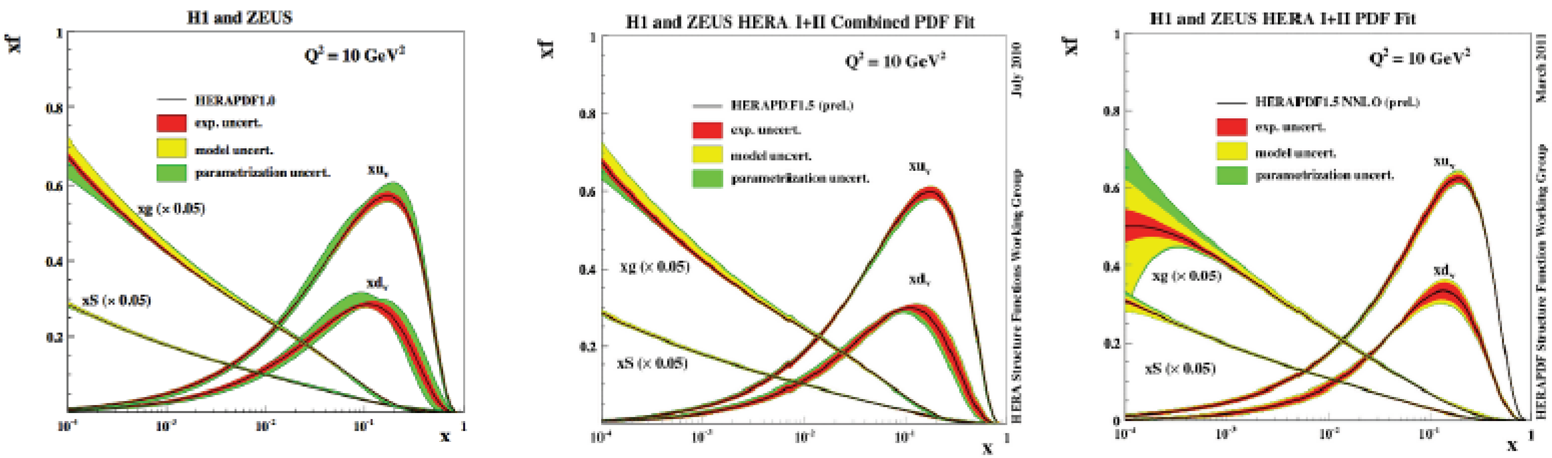


Uses preliminary HERA I+II data combination

The HERAPDF1.5 LO is based on these data

Reminder of released PDF sets from HERA

- In LHAPDF:
  - HERAPDF1.0 NLO: based on published HERA I data (with Uncertainties)
  - HERAPDF1.5 NLO: based on preliminary HERA I+II data (with Uncertainties)
  - HERAPDF1.5 NNLO: based on preliminary HERA I+II data (with Uncertainties)



- Studies
  - HERAPDF1.0 NNLO: based on published HERA I data (2 central lines with different alphas)
  - HERAPDF1.6 NLO: based on preliminary HERA I+II and inclusive jets
  - HERAPDF1.7 NLO: : based on preliminary HERA I+II, inclusive jets, charm, low energy runs

QCD Fit Settings

The QCD fit was performed using the HERAFitter
As far as possible the same settings are used as for HERAPDF1.5 NLO

- **Data:**
  - Use HERA 1+2 preliminary data as used for HERAPDF1.5 series
  - 130 sources uncorrelated, 3 procedural (arising from the procedure of data combination) correl.
  - HERAPDF chisquare style, with $\Delta\chi^2 = 1$ criterion.

$$\chi^2 = \sum_i \frac{\left[\mu_i - m_i\left(1 - \sum_j \gamma_j^i b_j\right)\right]^2}{\delta^2_{i,\mathrm{unc}} m_i^2 + \delta^2_{i,\mathrm{stat}} \mu_i m_i \left(1 - \sum_j \gamma_j^i b_j\right)} + \sum_j b_j^2$$

- **Theory:**
  - Use 10p fit as done for HERAPDF1.5NLO (parametrisation with positive defined PDFs)

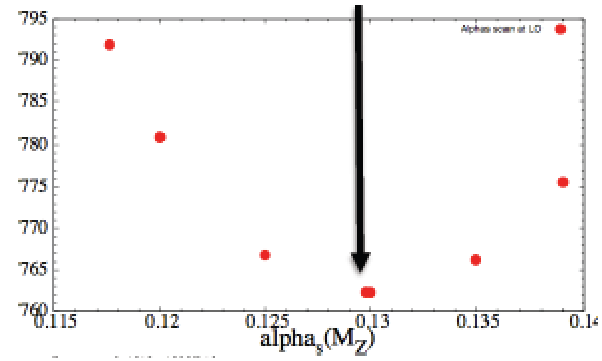
$$\begin{aligned}
xu_v(x) &= A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + E_{u_v} x^2) \\
xd_v(x) &= A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}} \\
x\bar{U}(x) &= A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}} \\
x\bar{D}(x) &= A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}} \\
xg(x) &= A_g x^{B_g} (1-x)^{C_g} .
\end{aligned}$$

At Q^2_0=1.9 GeV^2
A_{uv},A_{dv},A_g from the number and momentum sum-rules
B_{uv}= B_{dv}, B_{ubar}=B_{dbar}
A_{dbar}, A_{ubar} such that ubar = dbar as $x \rightarrow 0$

Strangeness fraction suppressed such that sbar ~dbar/2
$Q^2 > 3.5$ GeV^2, m_c=1.4 GeV, m_b=4.75 GeV,
Heavy quarks from the Thorne-Roberts variable Flavour Number Scheme at LO.
Note FL at LO is considered to be $O(\alpha_s)$ not zero

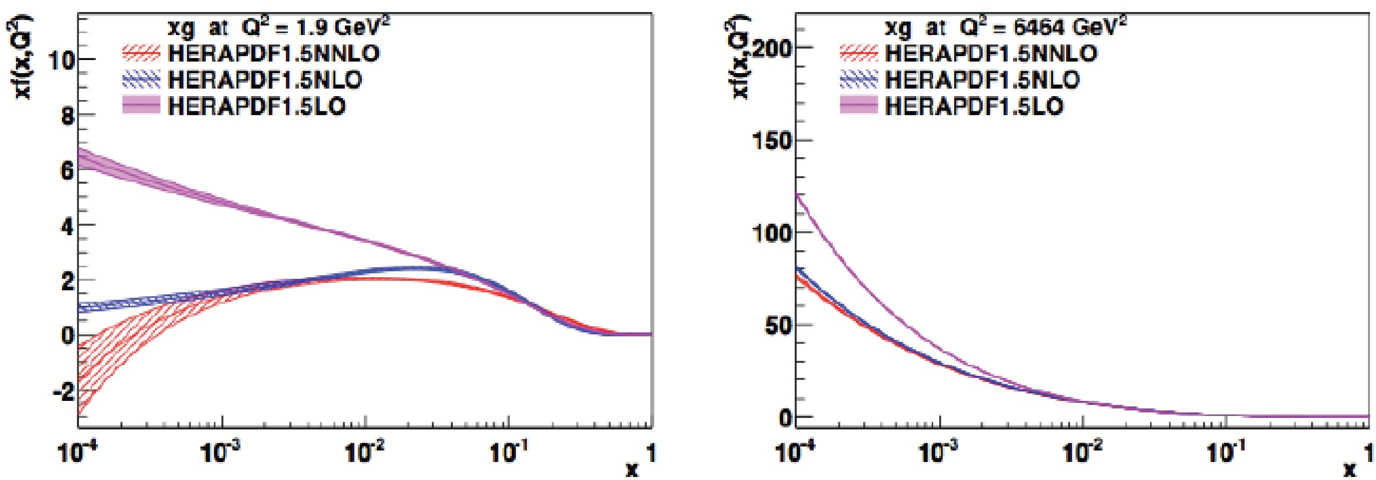
The value of $\alpha_S(M_Z)$ at LO is not held the same as the NLO value
A $\chi 2$ scan is performed to determine the best value $\alpha_S(M_Z)$ =0.13

This is similar to the LO value used by CTEQ6



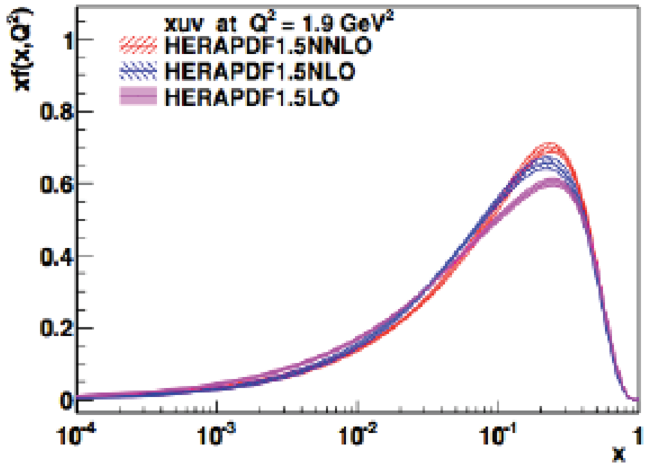
The $\chi 2$ of the fit is 762 for 664 degrees of freedom.
This is only somewhat worse than the NLO fit which has $\chi 2$ = 736

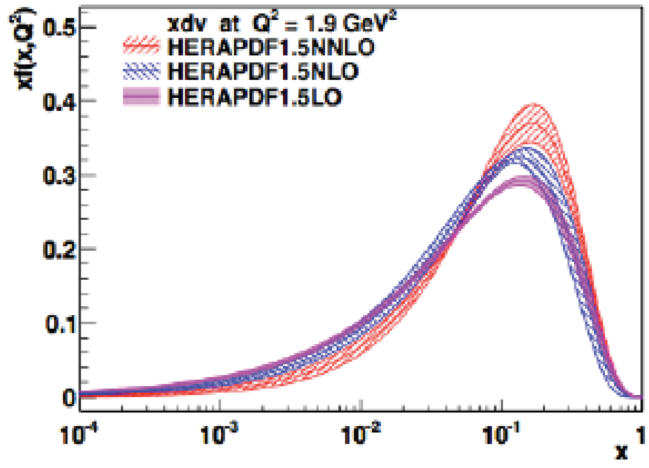
THE LO PDFS are provided with experimental uncertainties in the eigenvector format

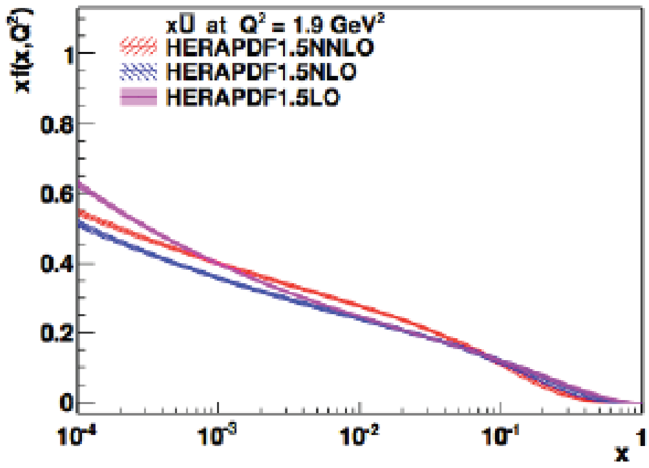


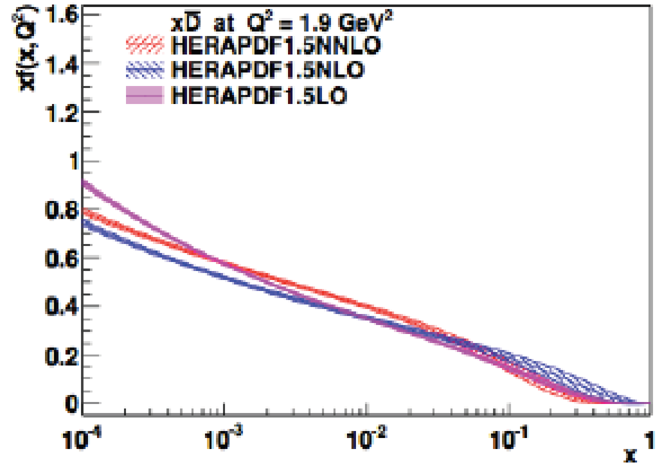
Compare the LO, NLO and NNLO gluons at the starting scale and at the mass^2 of the W

Differences are less in the valence and sea sectors

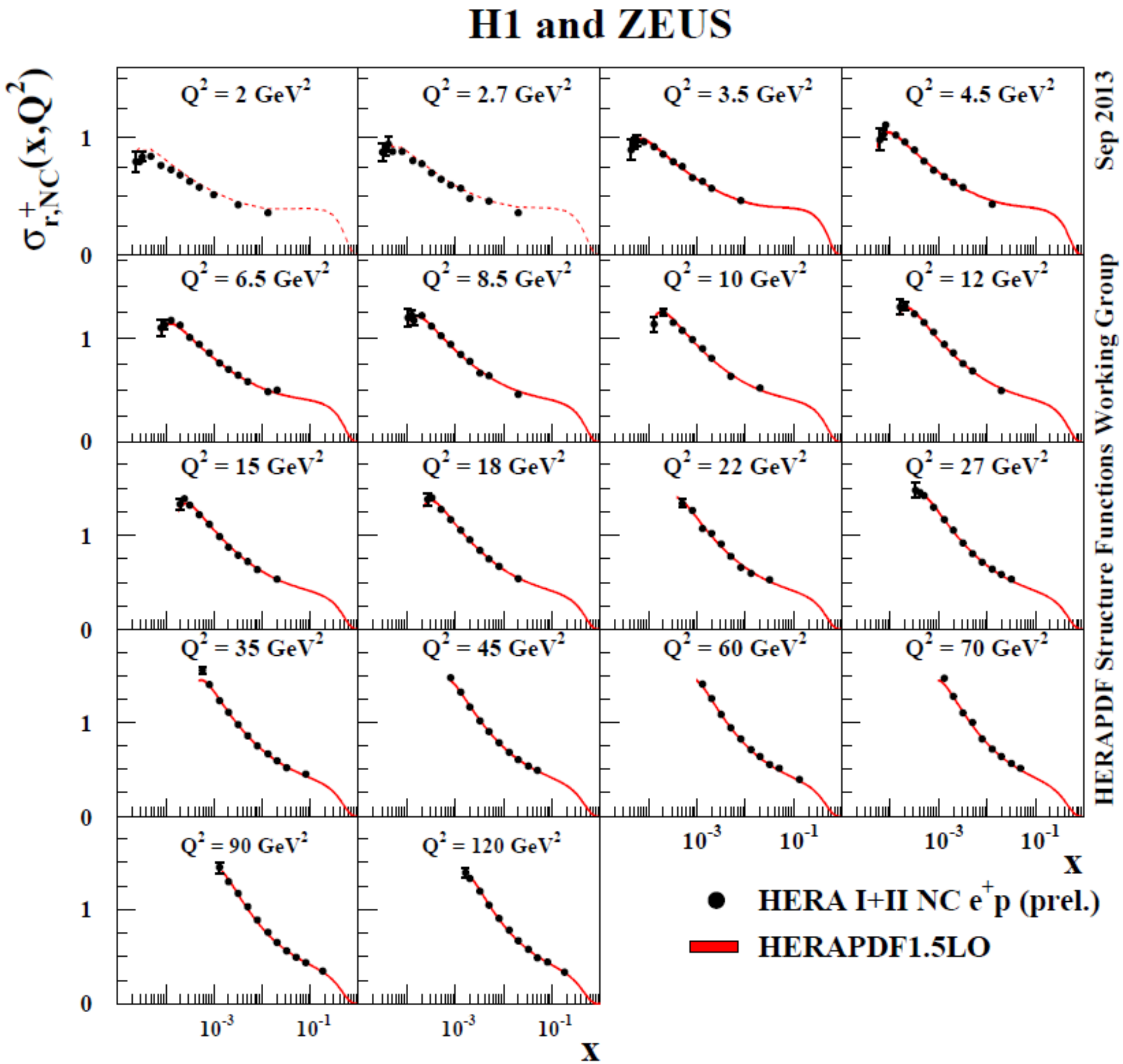






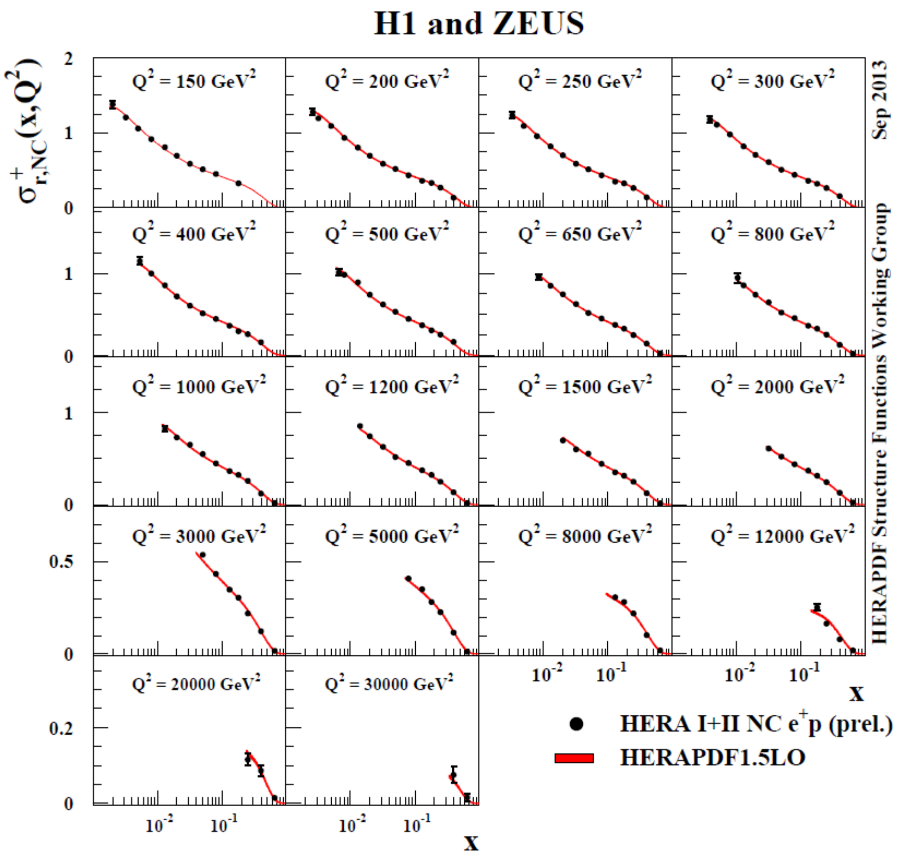


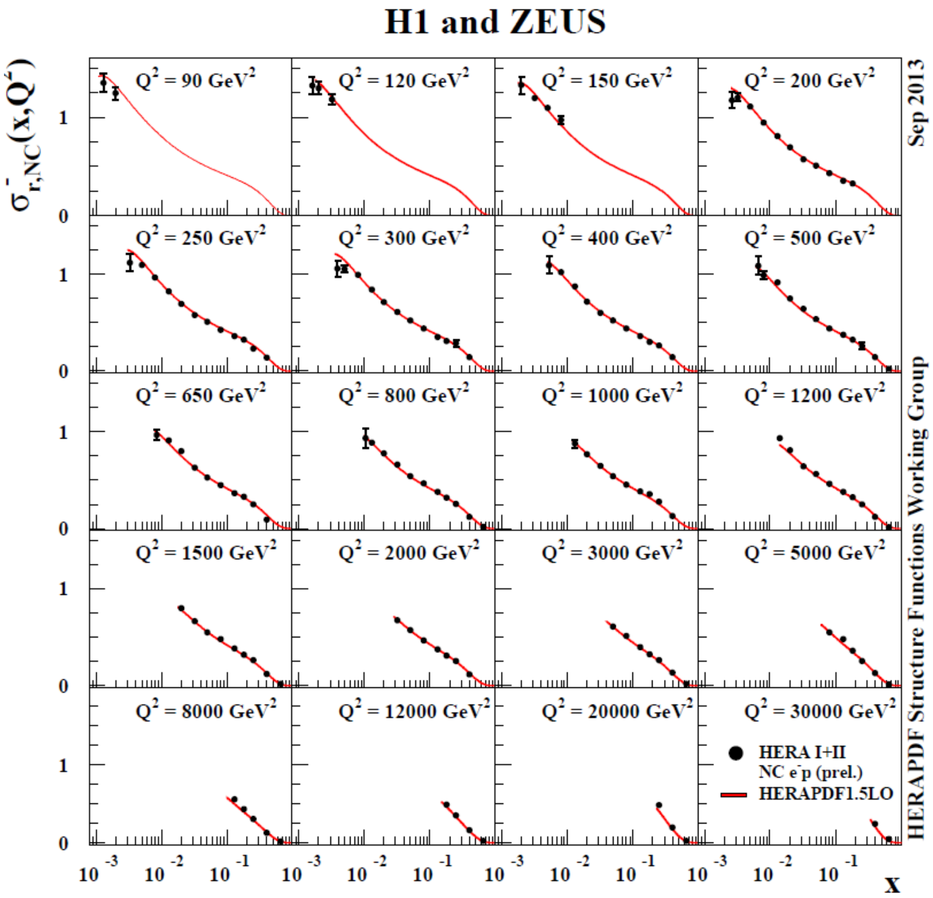
Data/ Fit comparison for low Q^2 NC e+



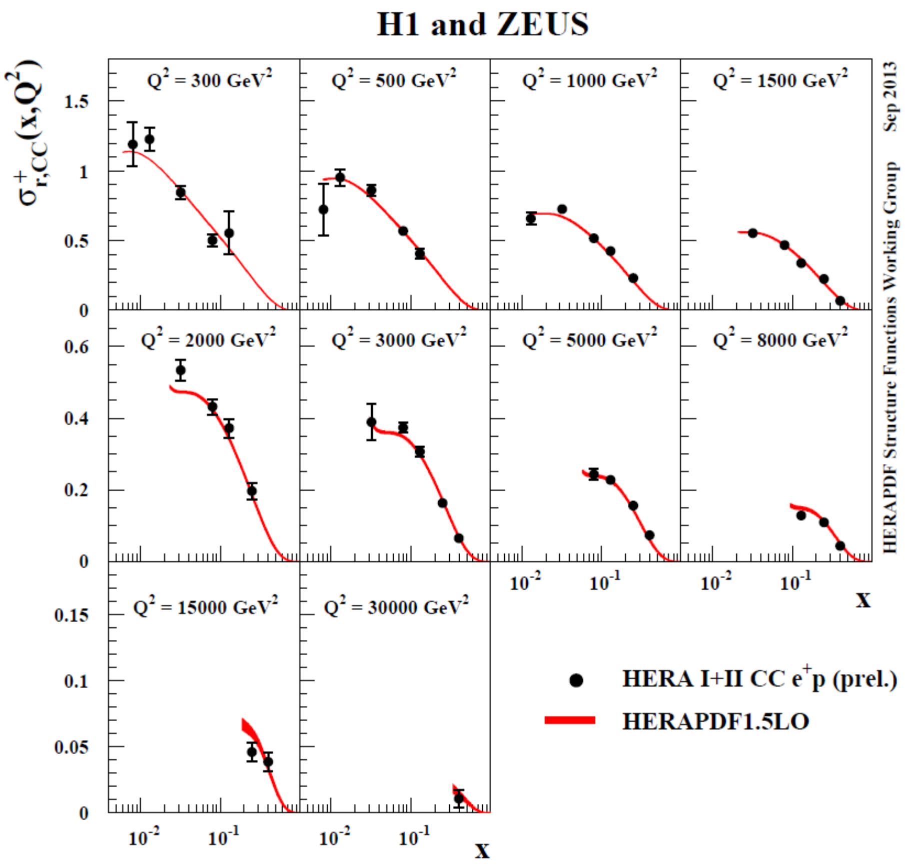
Note the good description of low x data – even below the Q^2 cut of the fit

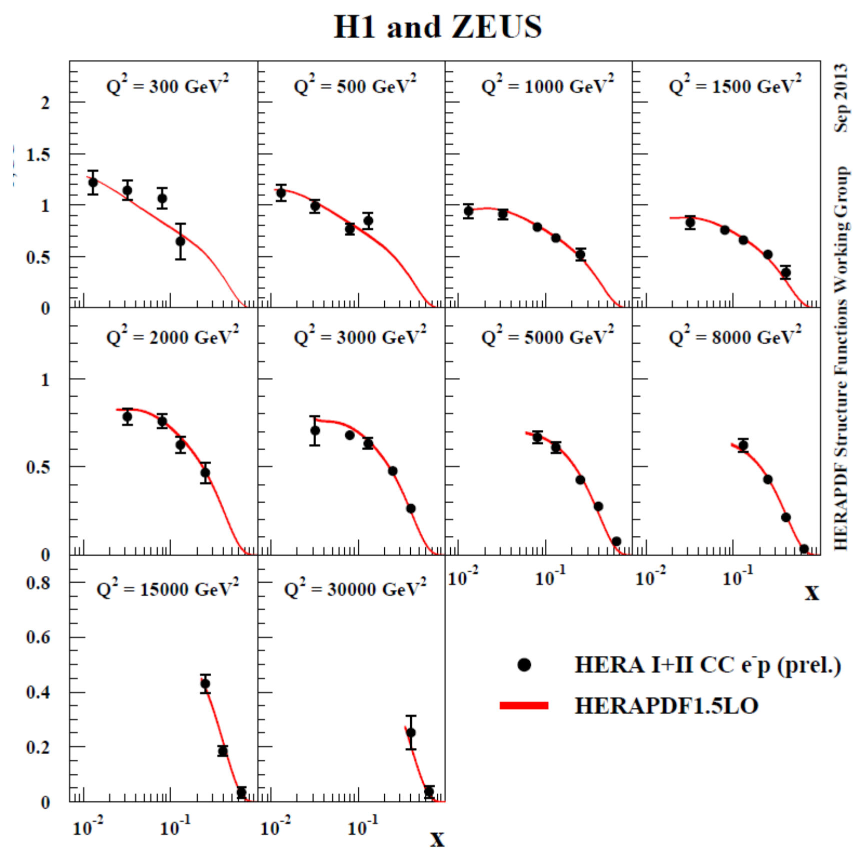
Data/ Fit comparison for high Q^2 NC e+ and e-

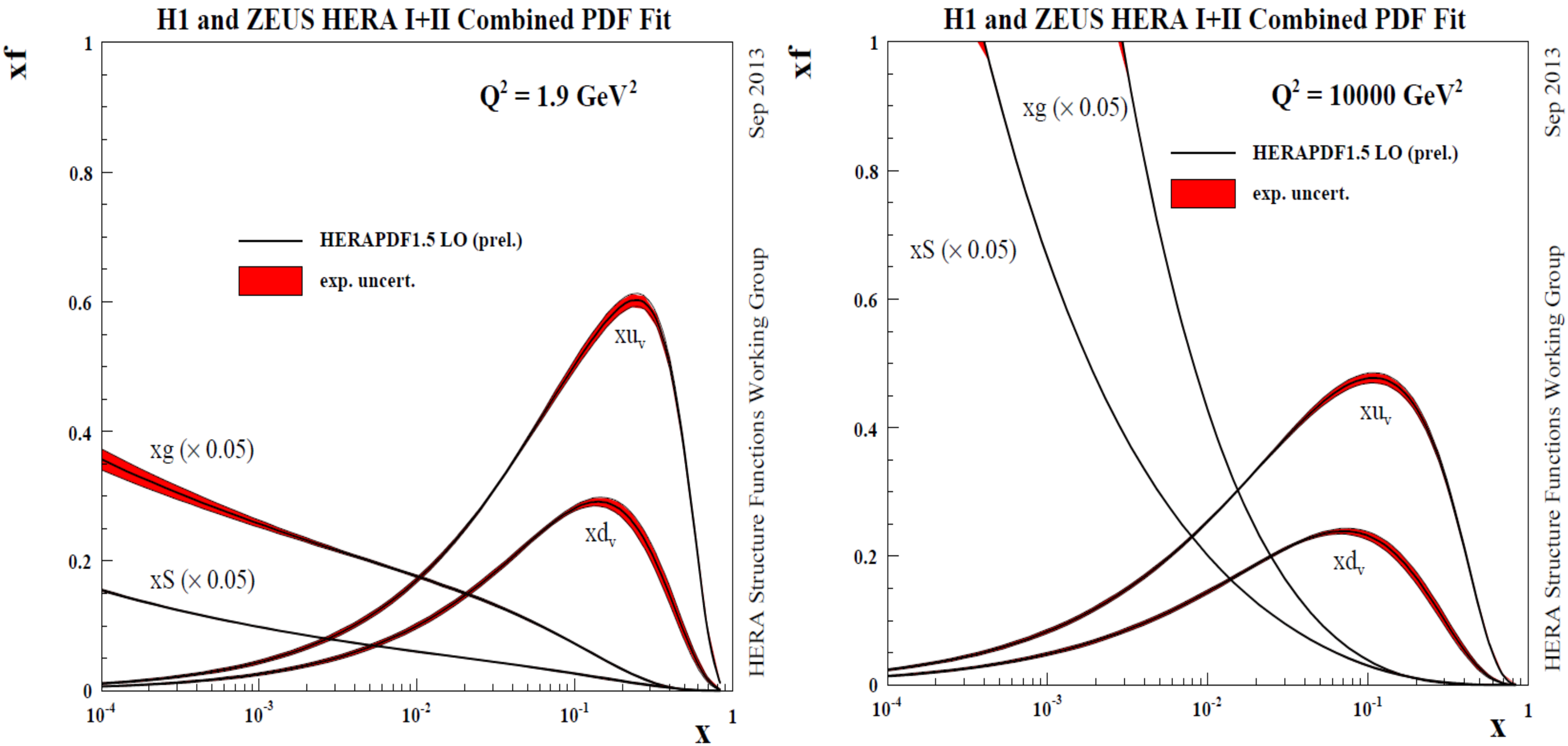




Data/ Fit comparison for high Q^2 CC e+ and e-






H1 and ZEUS HERA I+II Combined PDF Fit
xf
Q^2 = 1.9 GeV^2
HERAPDF1.5 LO (prel.)
exp. uncert.
xg (× 0.05)
xS (× 0.05)
xu_v
xd_v
x
Sep 2013
HERA Structure Functions Working Group
H1 and ZEUS HERA I+II Combined PDF Fit
xf
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xu_v
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Sep 2013
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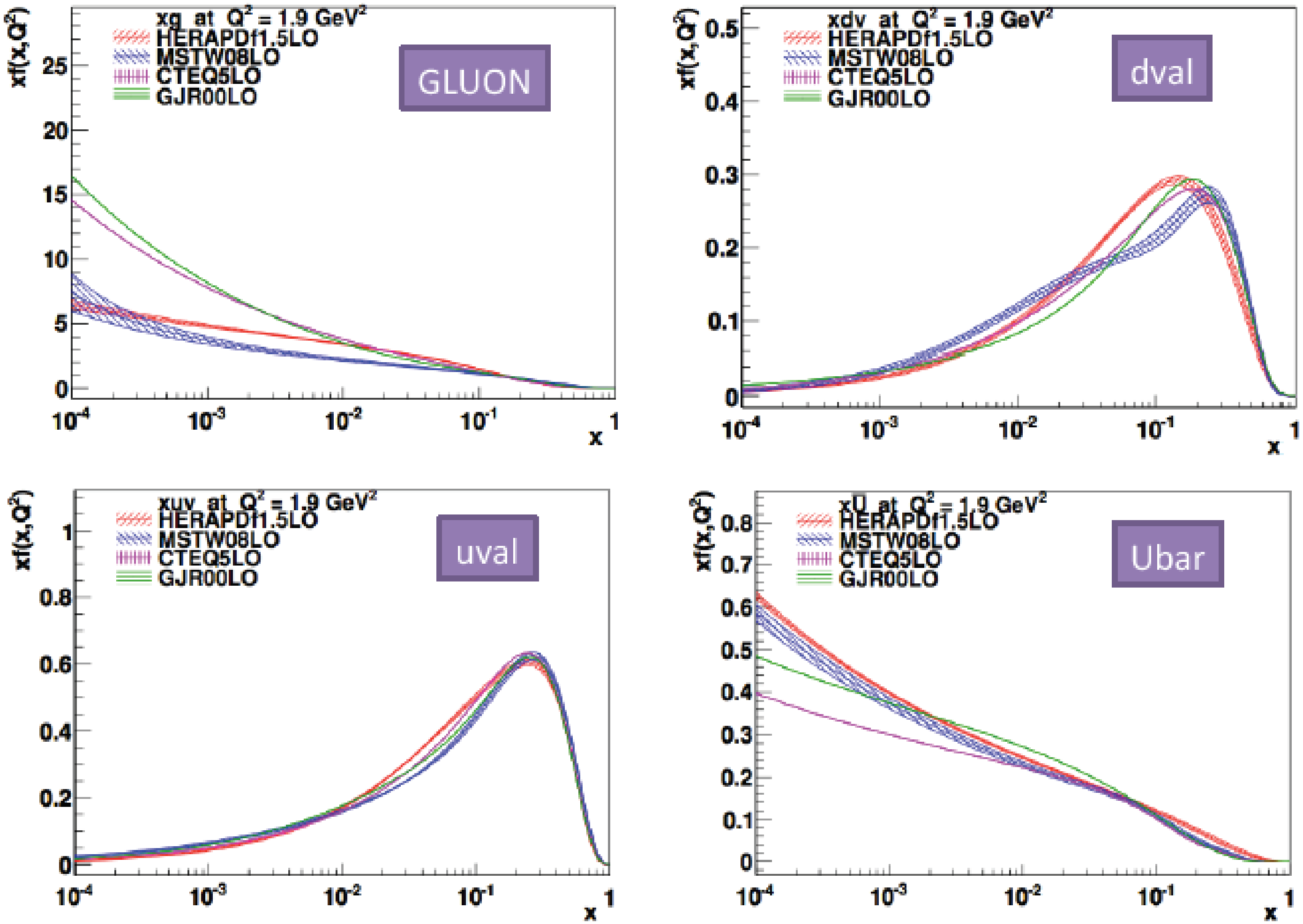
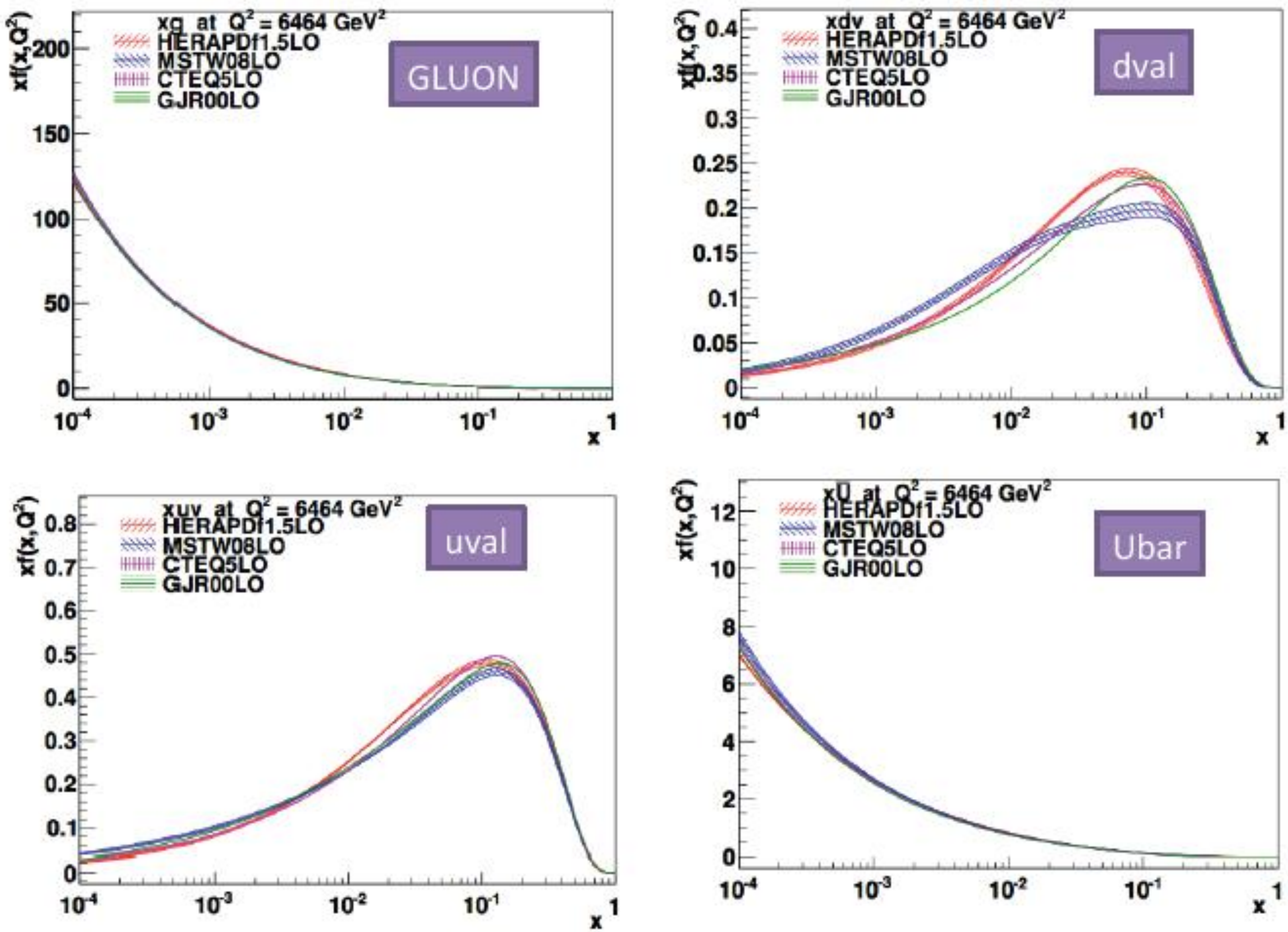
Comparisons with other LO PDFs (at Q2=1.9 GeV2)



Comparisons with other LO PDFs (at Q2=Mw GeV2)



USE of HERAPDF1.5 LO

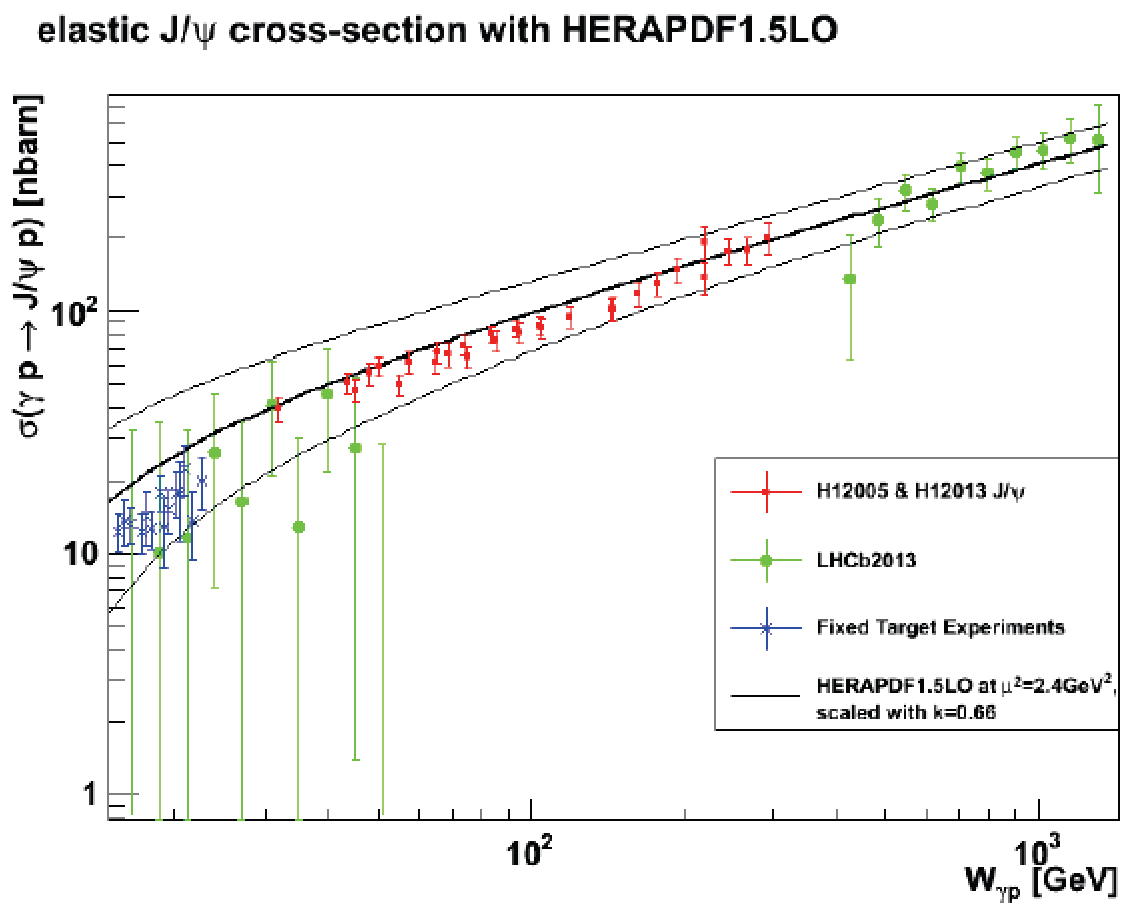
Comparison on J/ψ data

Using photoproduction J/ψ to probe small x gluons

Andreas Weiden

H1 Summer Student

August 28th 2013



USE of HERAPDF1.5 LO

with thanks to Hannes Jung

CTEQ6L used for comparison

checks done with and w/o simulation of multiparton interactions

1. Inclusive jets (in central and forward region)

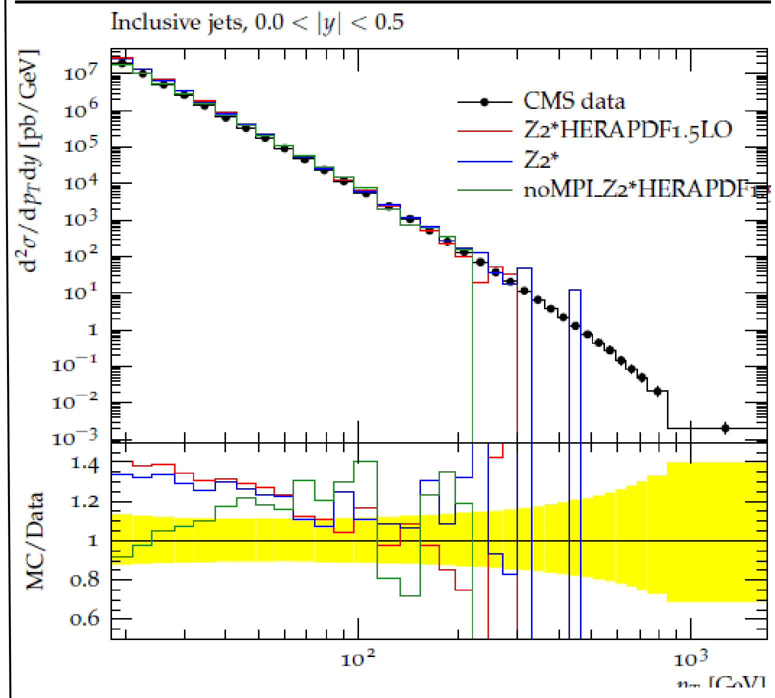
(important cross check, since these measurements are used also for PDF determination and NP&PS corrections determined from shower MCs are applied to NLO predictions used in the PDF fits)

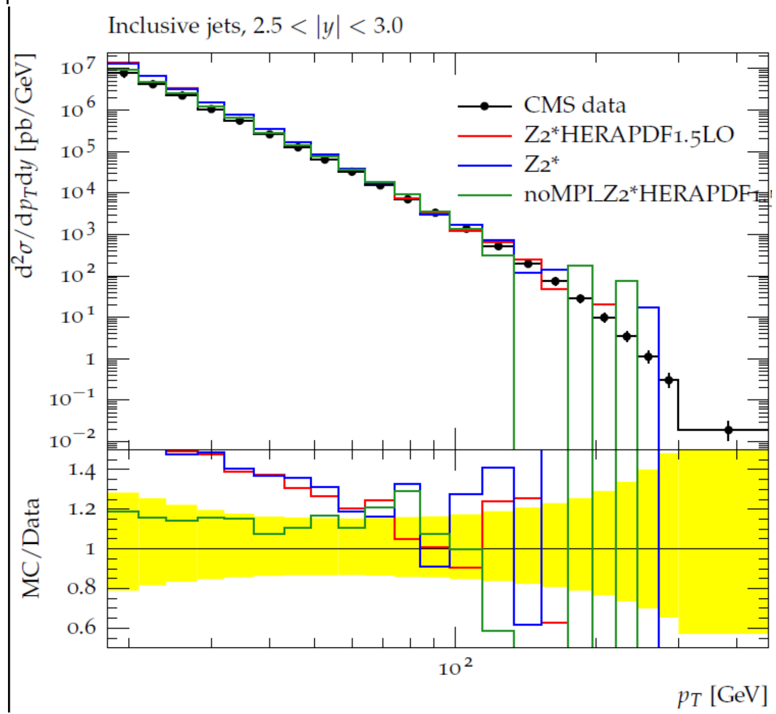
2. Energy flow in forward region

3. Underlying Event (charged particle multiplicity in transverse region as function of leading jet or leading track pt)

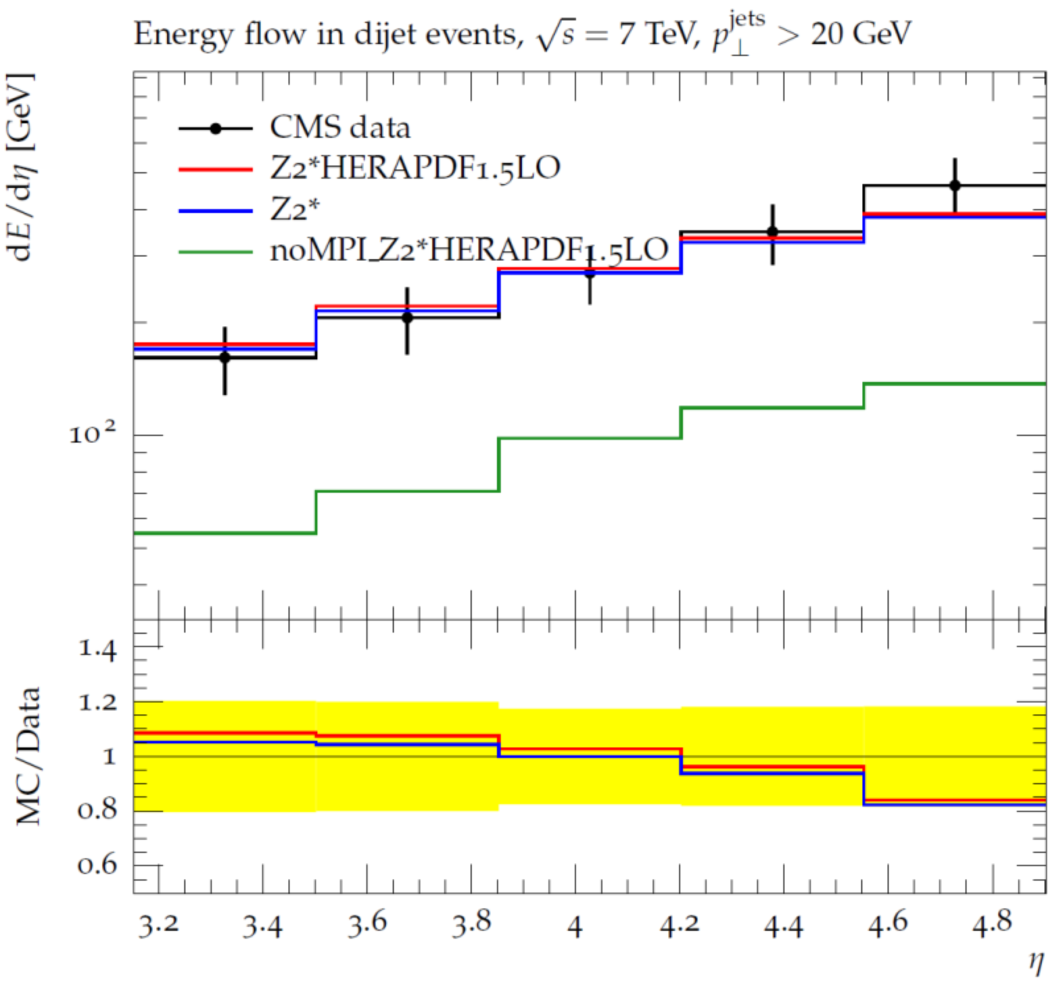
Inclusive jets

- MC describes measurements without MPI:
  - HERAPDF1.5LO agrees with CTEQ6L
  - Z2* is a PYTHIA tune tuned to CTEQ6L
- significant effect from MPI
  - gluon at small x very important
  - POWHEG is better with MPI included



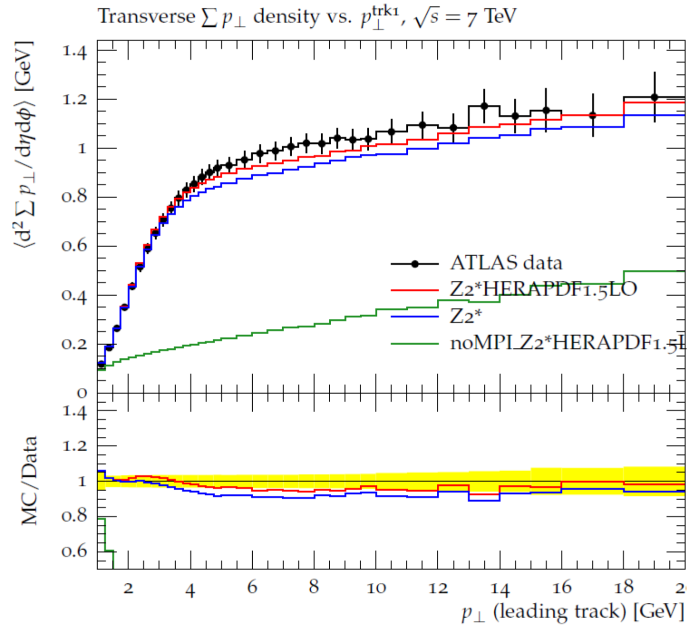


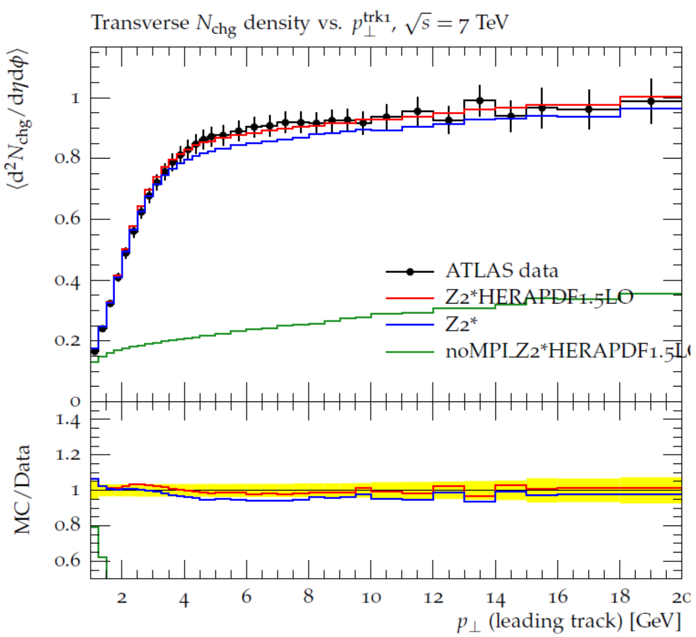
Energy flow



- without MPI, predictions agree but are too low compared to data
- with MPI, CTEQ6L and HERAPDF1.5LO both agree with measurement

Underlying event





- with MPI predictions agree with each other
- without MPI data are not described

- With MPI, HERAPDF1.5LO gives better description of UE measurements (even without further tuning) compared to CTEQ6L

- HERAPDF1.5LO describes measurements similarly to CTEQ6L
- HERAPDF1.5LO gives better agreement with UE measurements than CTEQ6L, although parameters were tuned to CTEQ6L
  - description can be further improved with tuning MPI parameters
- HERAPDF1.5LO can be used for MC simulation:
  - for non-perturbative (hadronization +MPI) correction
  - for parton shower corrections, which are essential for jets, vector-boson, Higgs etc if measurements to be compared to NLO parton level calcs

  (see: S. Dooling, P. Gunnellini, F. Hautmann, and H. Jung. Longitudinal momentum shifts, showering and nonperturbative corrections in matched NLO-shower event generators. arXiv 1212.6164 and 10.1103/PhysRevD.87.094009)
  - simulation of min-bias events (50 – 100 pileup events expected)

Summary

- A LO PDF is particularly useful for Monte Carlo event generators and the simulation of higher order corrections via parton showers.

- Presented a LO HERAPDF1.5 PDF set based on preliminary HERA I+II combined data inclusing experimental uncertainties.
  - Based on identical settings as HERAPDf1.5 NLO (different alphas)
  - Initial tests show that HERAPDF LO set describes measurements similarly to CTEQ 6LO (even if parameters were tuned for CTEQ!)

- The set is presented with **20 error sets (10 eigenvectors) for the experimental uncertainties**
- The set is readily formatted for the LHAPDFv5 style.

EXTRAS