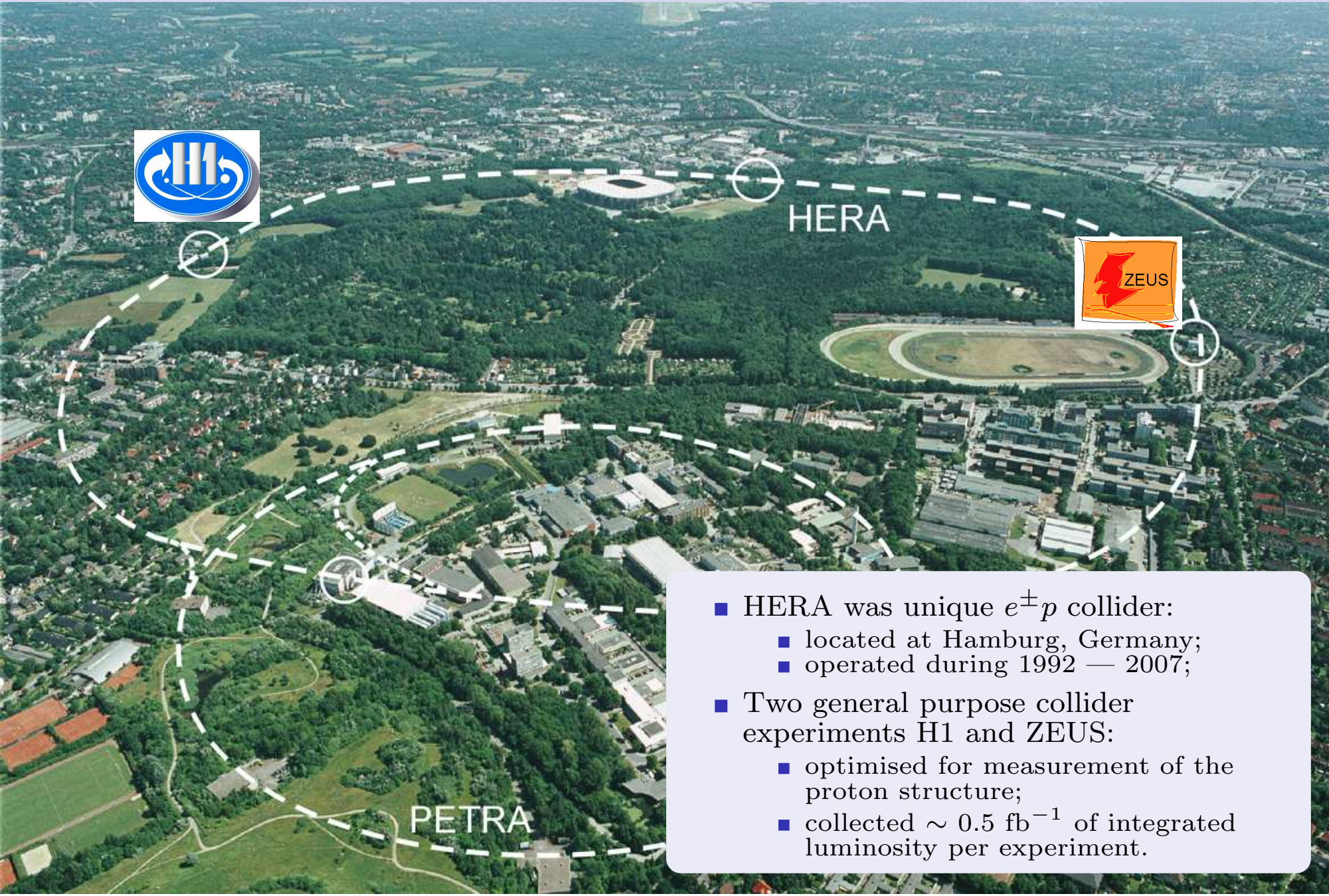
Determination of the proton PDFs at HERA

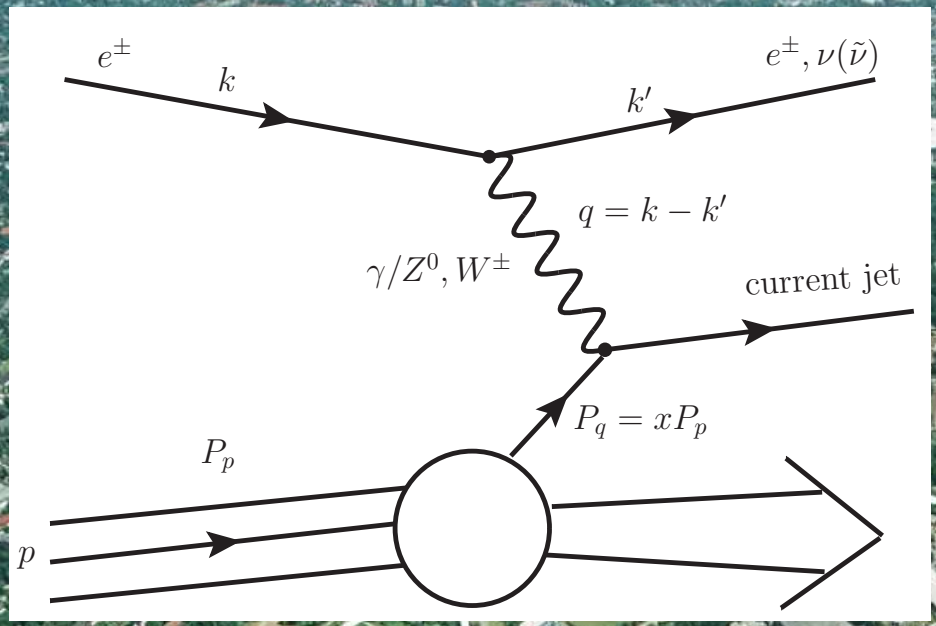
Denys Lontkovskyi
ZEUS, DESY
On behalf of the H1 and ZEUS Collaborations

HERA collider. H1 and ZEUS experiments.



- HERA was unique $e^{\pm}p$ collider:
  - located at Hamburg, Germany;
  - operated during 1992 — 2007;
- Two general purpose collider experiments H1 and ZEUS:
  - optimised for measurement of the proton structure;
  - collected ~ 0.5 fb^{-1} of integrated luminosity per experiment.

HERA collider. H1 and ZEUS experiments.



HERA

ZEUS

Kinematics:

- momentum transfer: $Q^2 = -q^2 = -(k - k')^2$
- Bjorken scaling variable: $x = \frac{Q^2}{2p \cdot q}$

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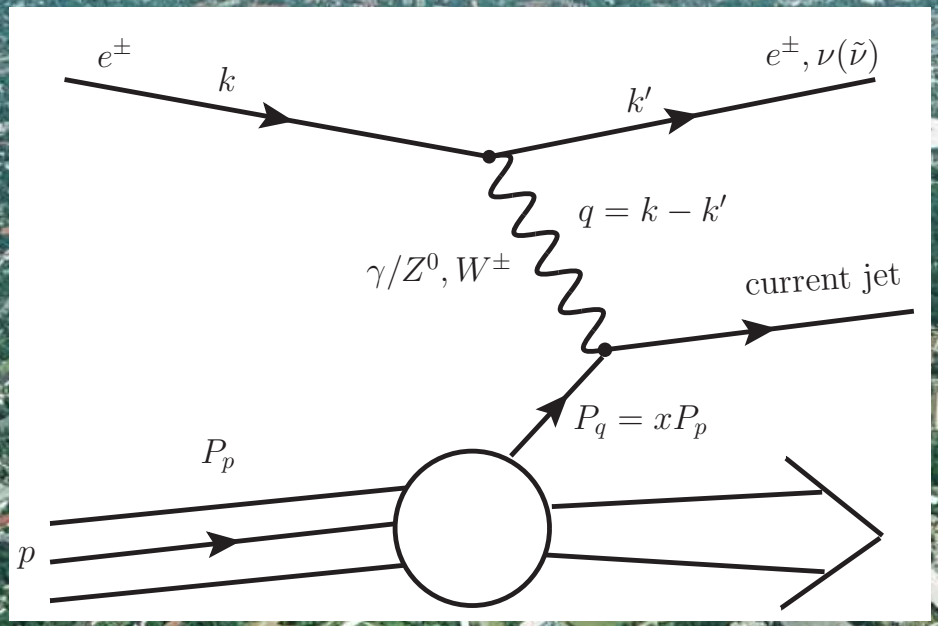

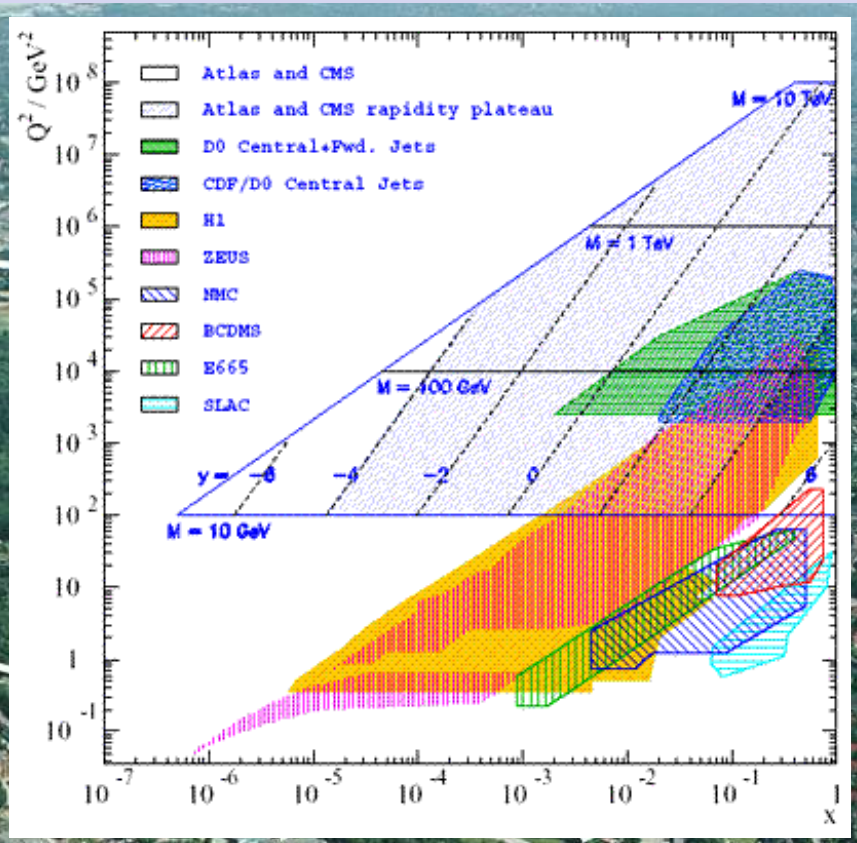

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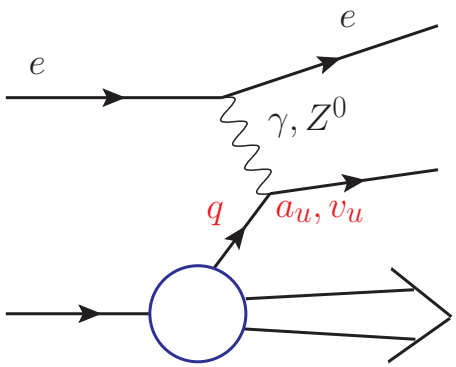
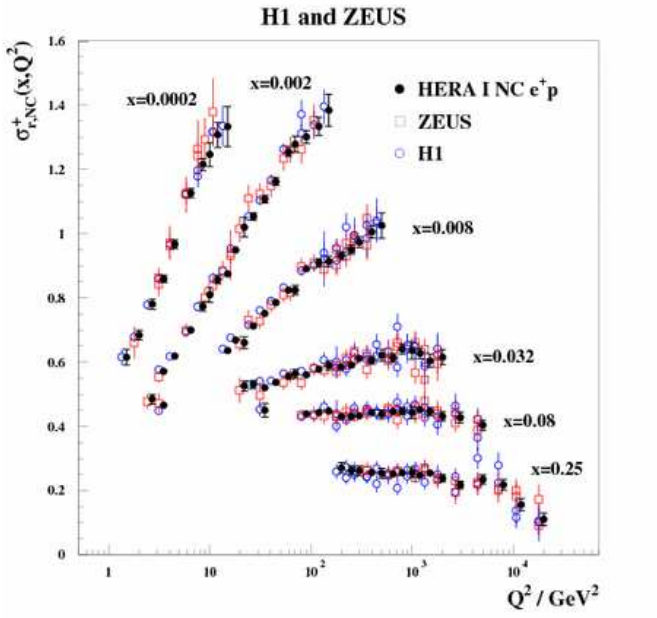
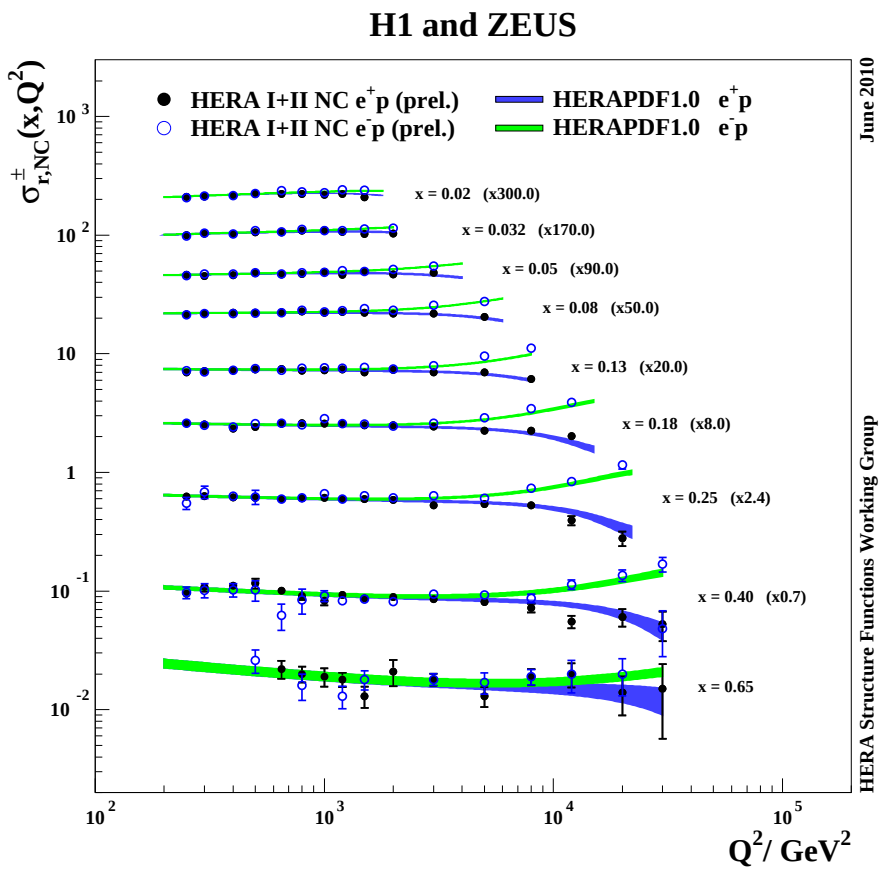
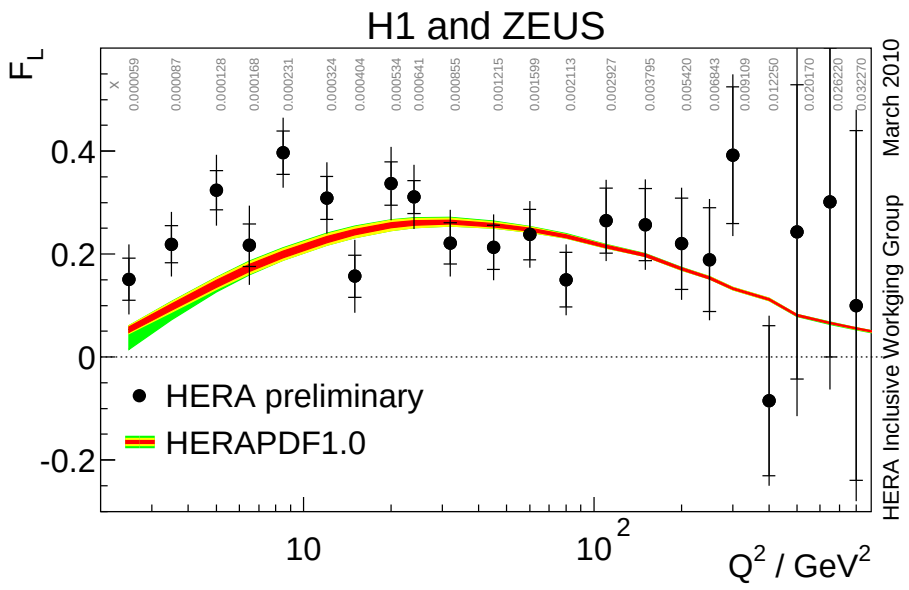
Sensitivity of inclusive data to the proton PDF









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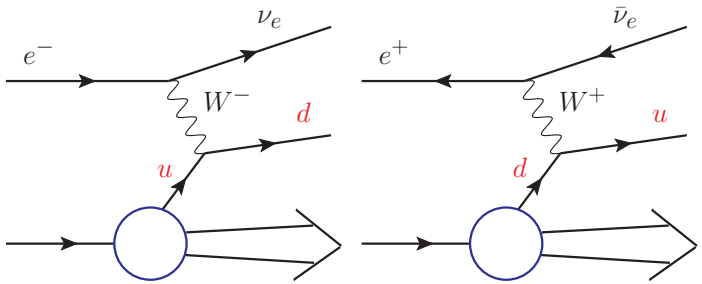
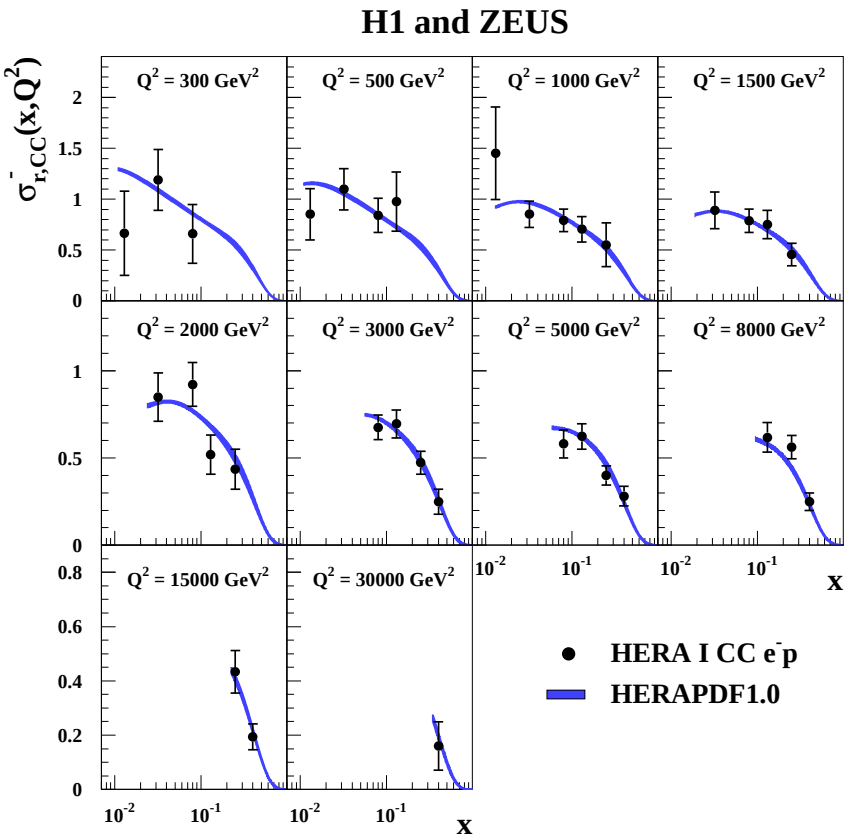
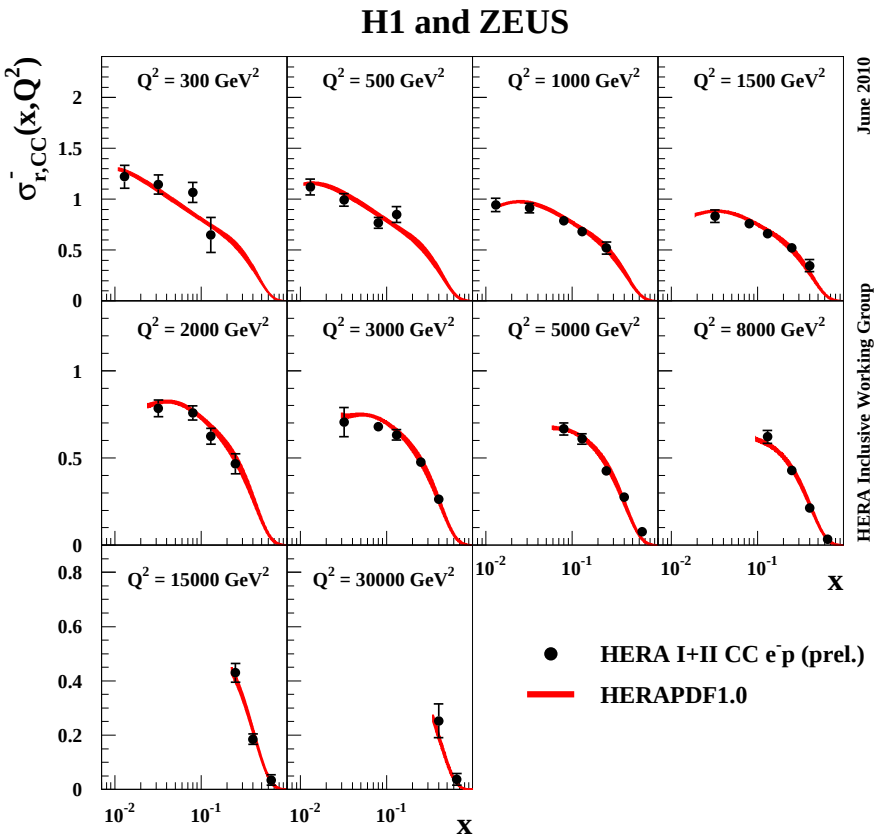






QCD analysis

Analysis strategy:

- Parametrise PDFs at the starting scale Q_0^2
  - $xg, xu_V, xd_V, x\bar{U} = x\left(\bar{u} + \{\bar{c}\}\right), x\bar{D} = x\left(\bar{d} + \bar{s} + \{\bar{b}\}\right)$
- Evolve PDFs using DGLAP equations to $Q^2 > Q_0^2$
  - NLO and NNLO DGLAP evolution QCDNUM [Comp. Ph. Comm. 182 (2011) 490]
  - Heavy flavours treated in GM-VFNS RT as for MSTW08
- Construct cross sections from PDFs and coefficient functions for every data point
- Perform χ^2 fit to the experimental data

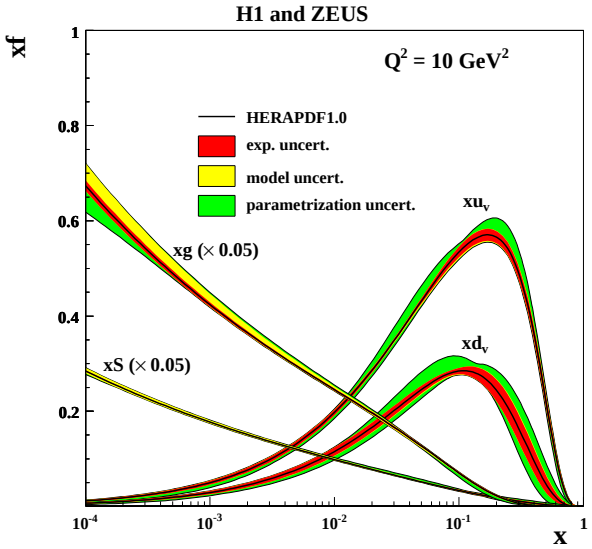
HERA unique data:

- Consistent set of measurements $\hookrightarrow \chi^2_{min} + 1$ criterion
- No need for:
  - nuclear corrections
  - neutrino heavy target corrections

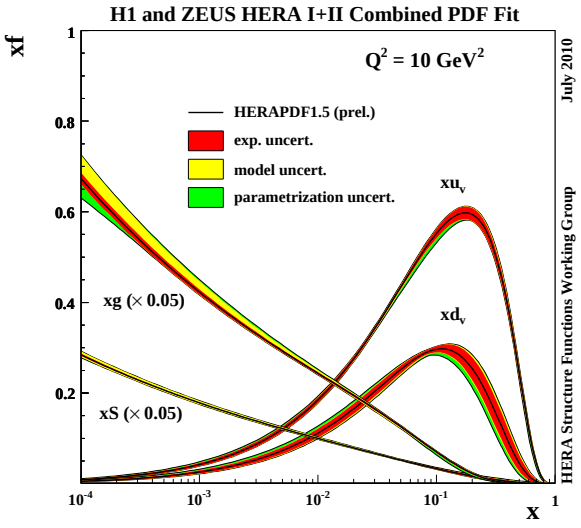
HERAPDF series

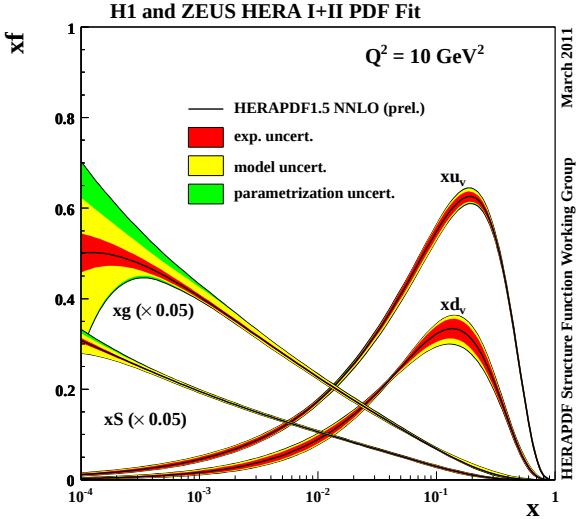
[JHEP 1001:109 (2010)] [H1-prelim-10-141,ZEUS-prel-10-017] [H1prelim-11-034, ZEUS-prel-11-001]

HERAPDF1.0 ⟶

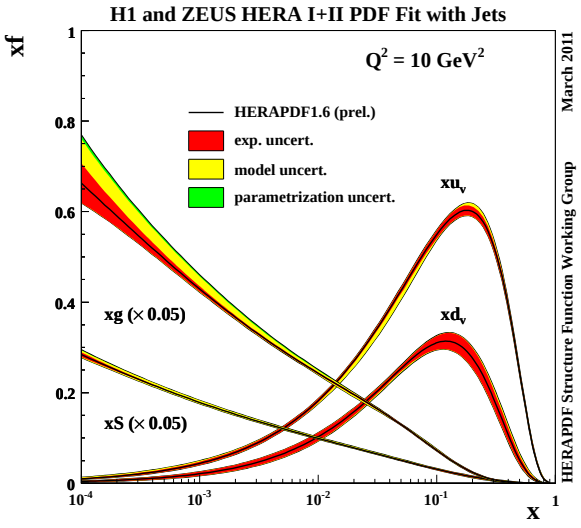


HERAPDF1.5 NLO ⟶





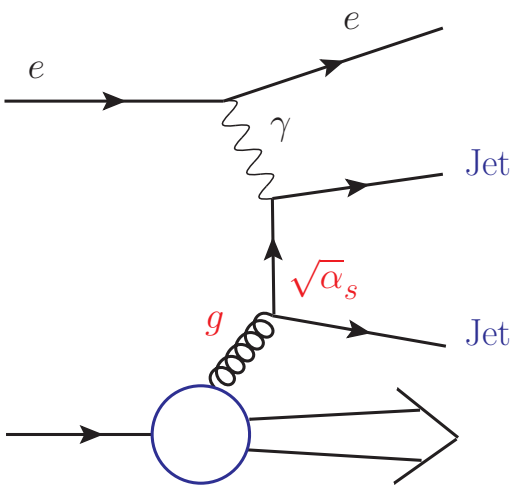
HERAPDF1.6

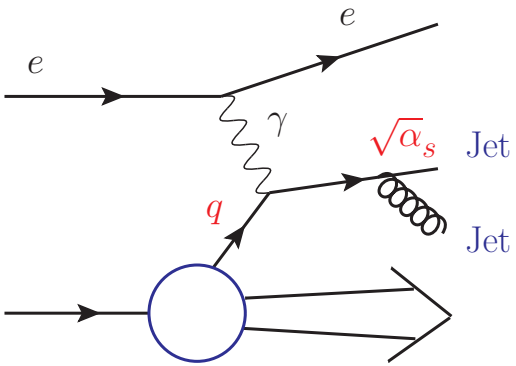


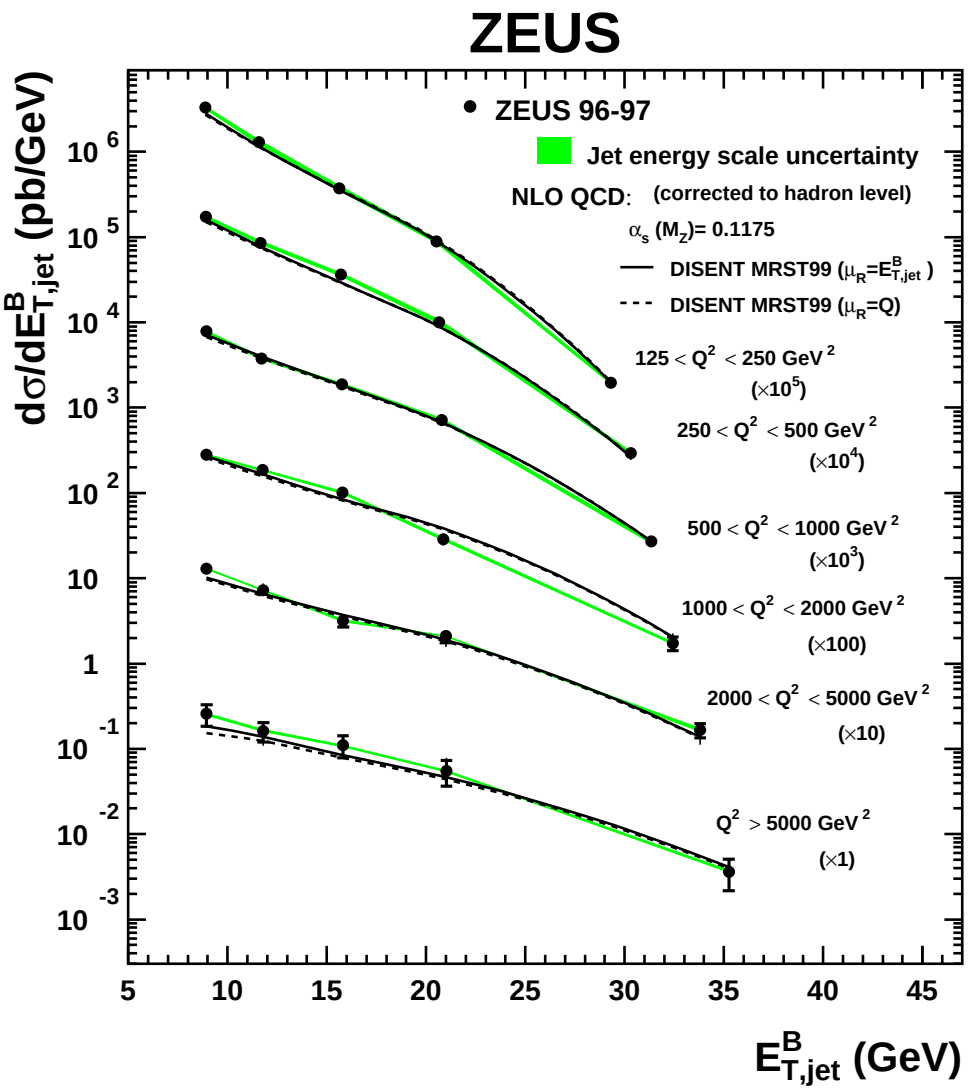
HERAPDF1.5 NNLO

[H1prelim-11-042, ZEUS-prel-11-002]

Sensitivity of jet data to the gluon PDF and α_s

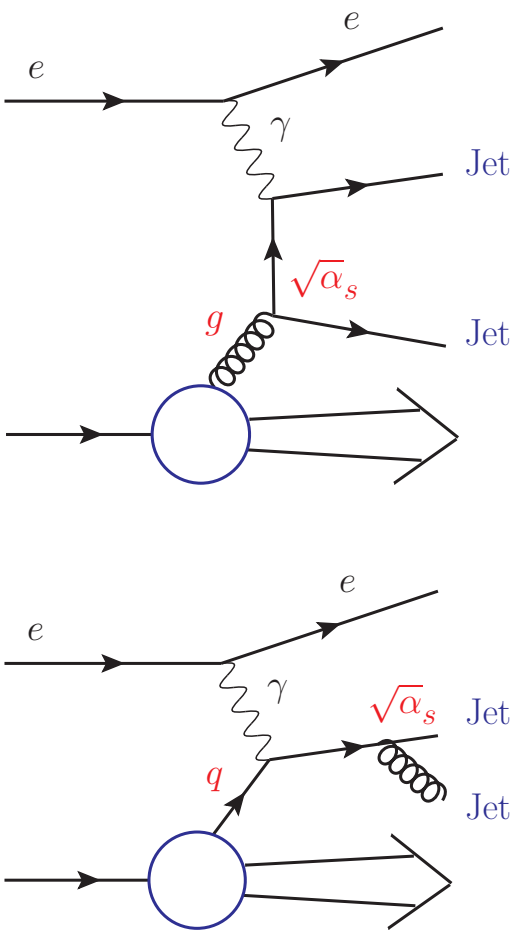


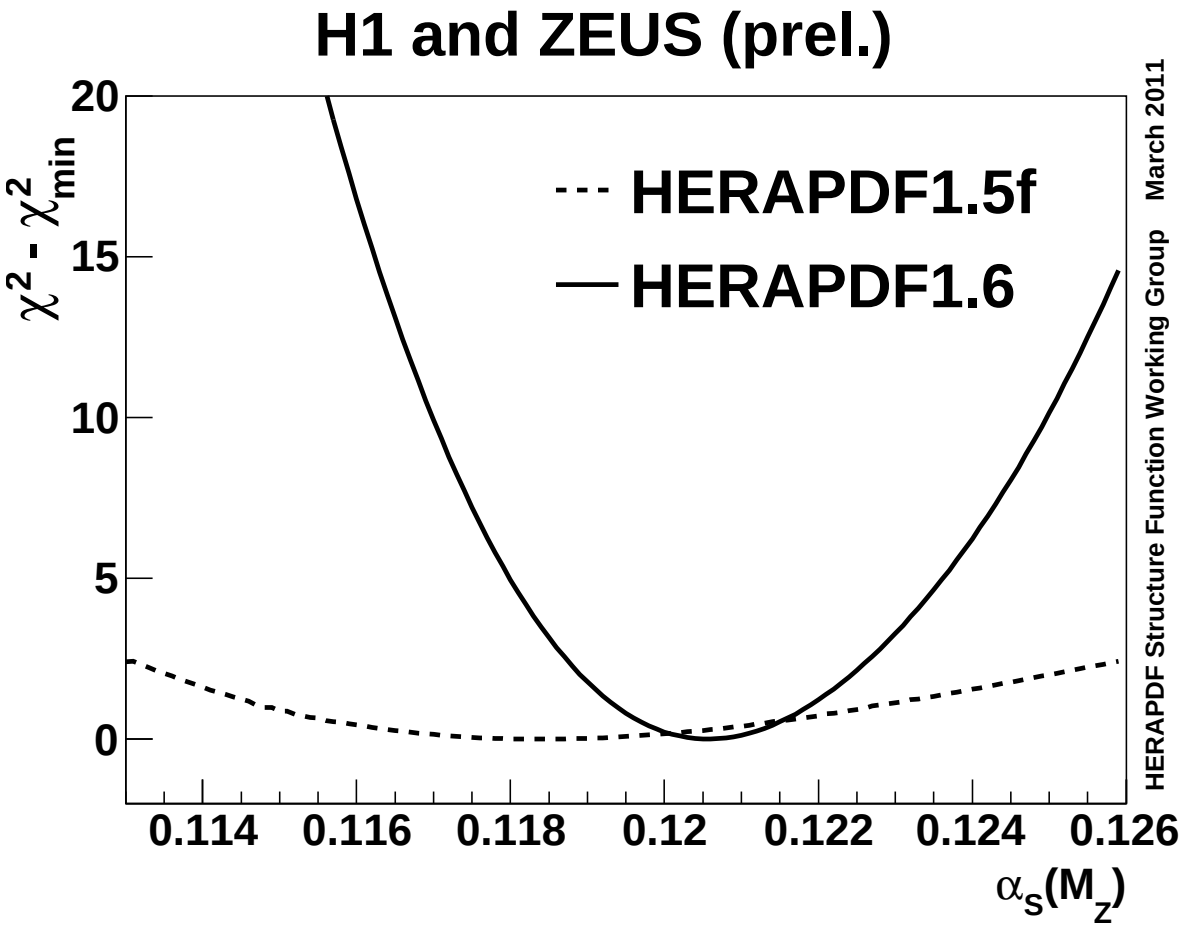




- Jet data is sensitive to the gluon PDF and to the value of $\alpha_s\,(M_Z)$.

Sensitivity of jet data to the gluon PDF and α_s





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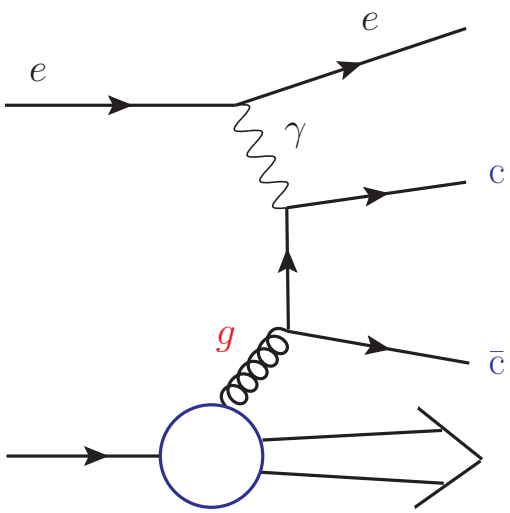
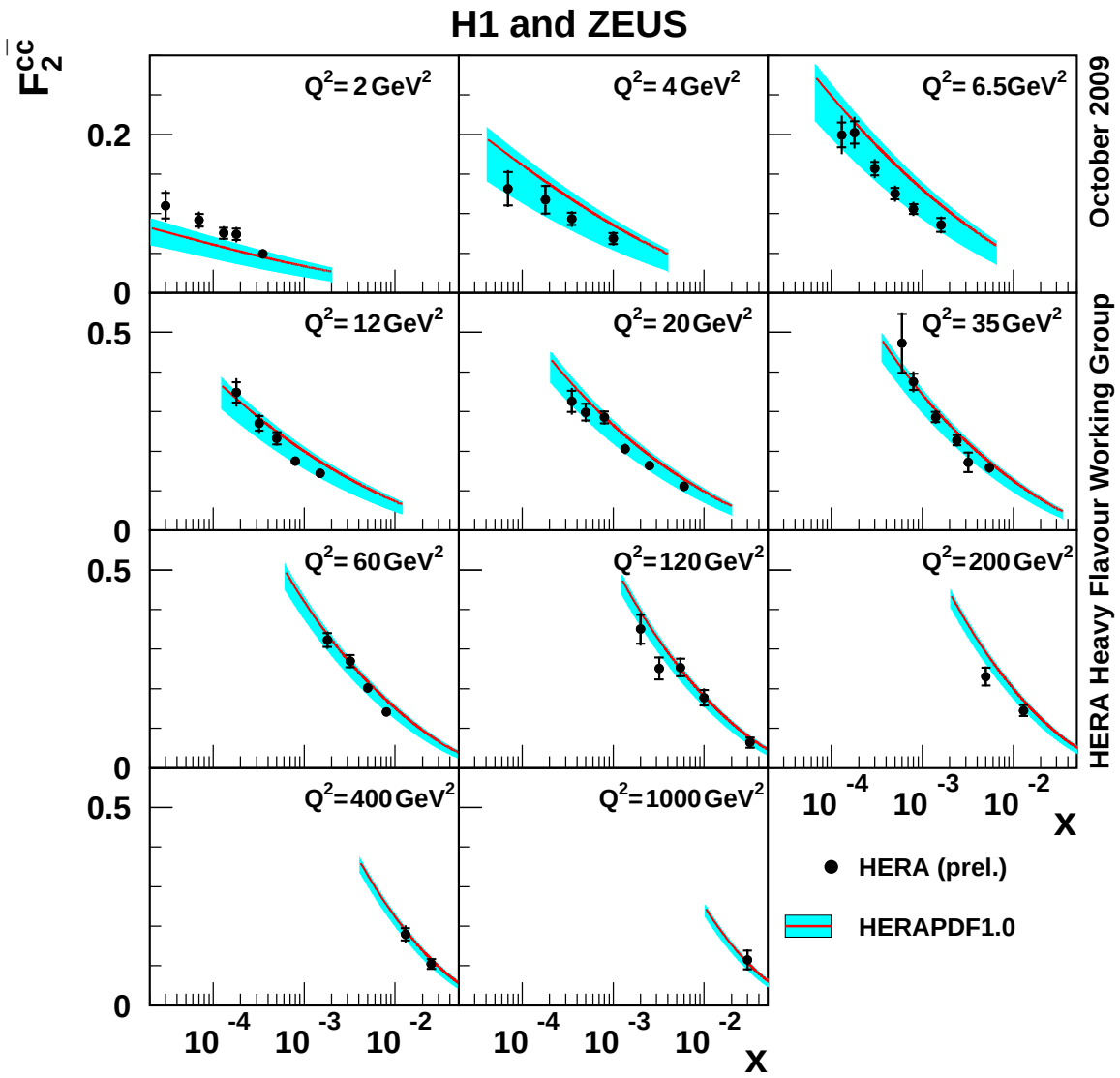
Sensitivity of $F_2^{c\bar{c}}$ to charm and gluon PDFs





- The $F_2^{c\bar{c}}$ allows to determine the optimal charm mass parameter (m_c^{model}) for the various schemes.

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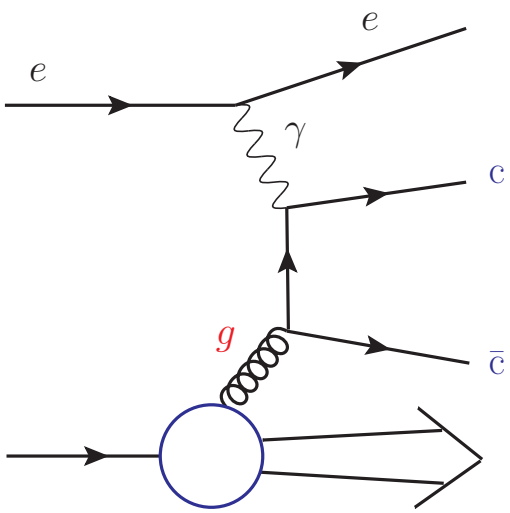

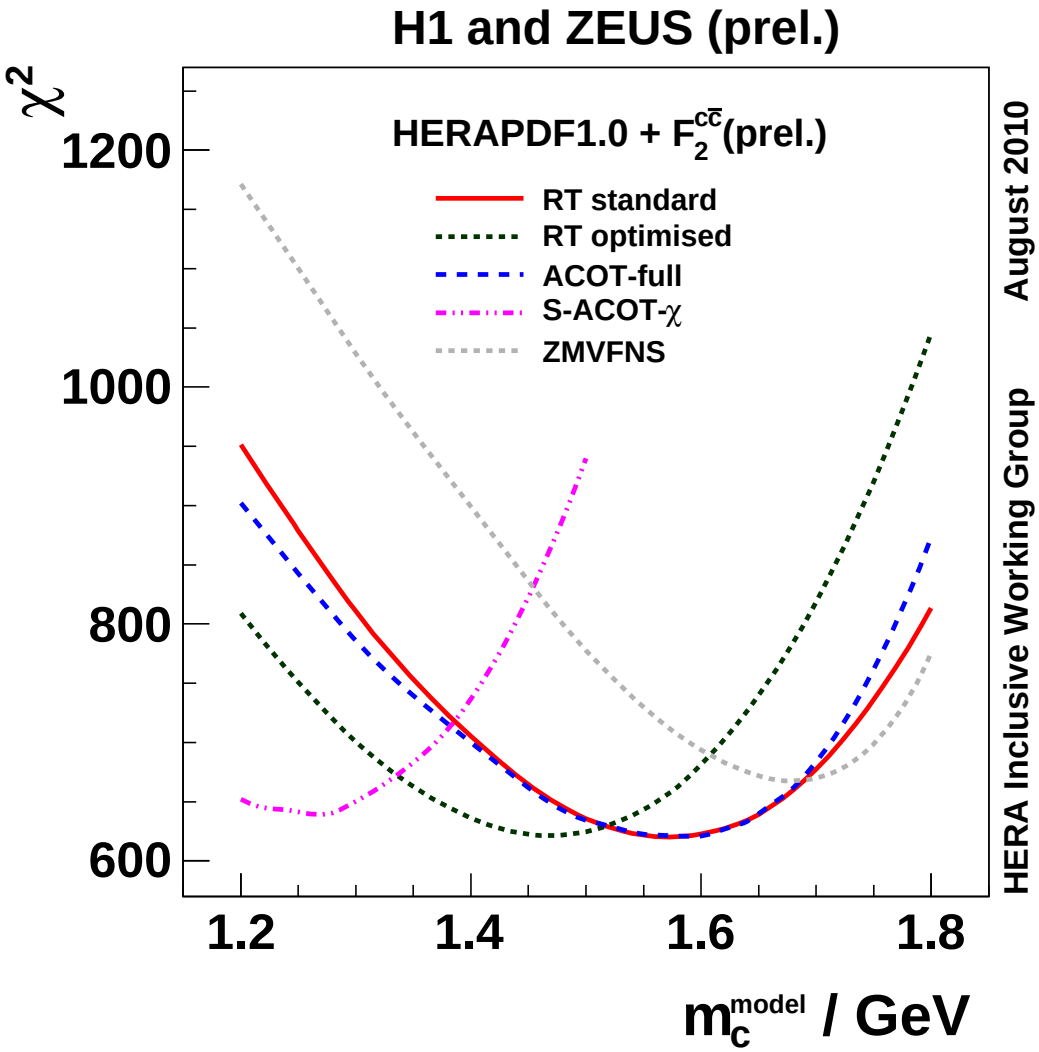

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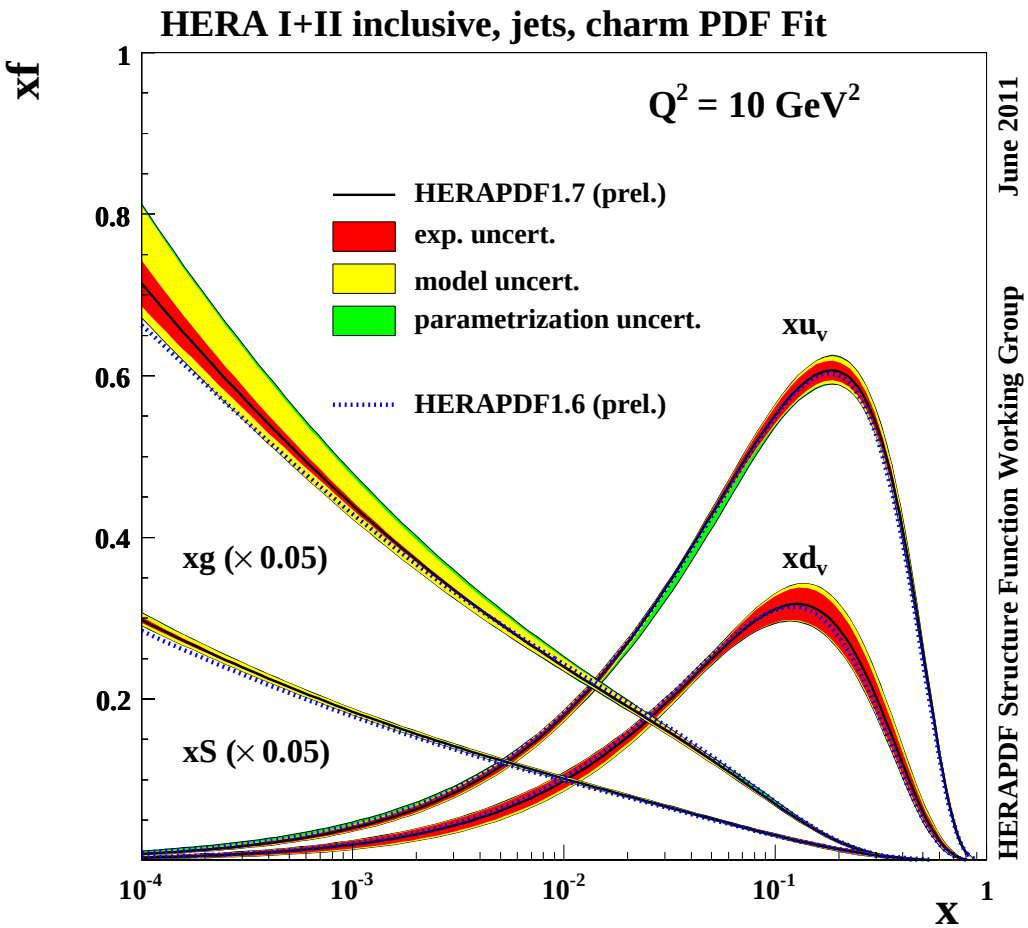
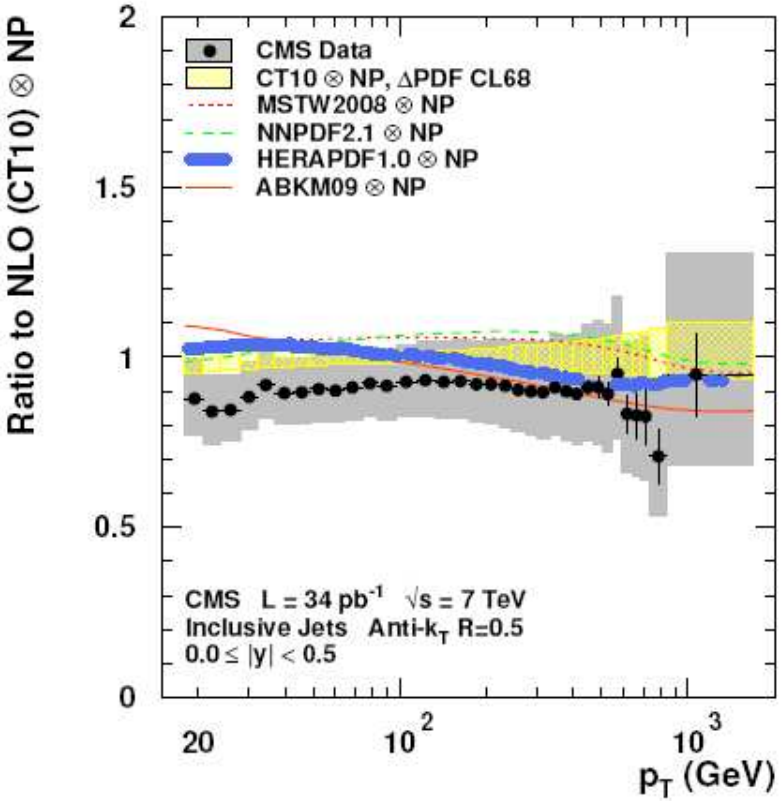
HERAPDF 1.7

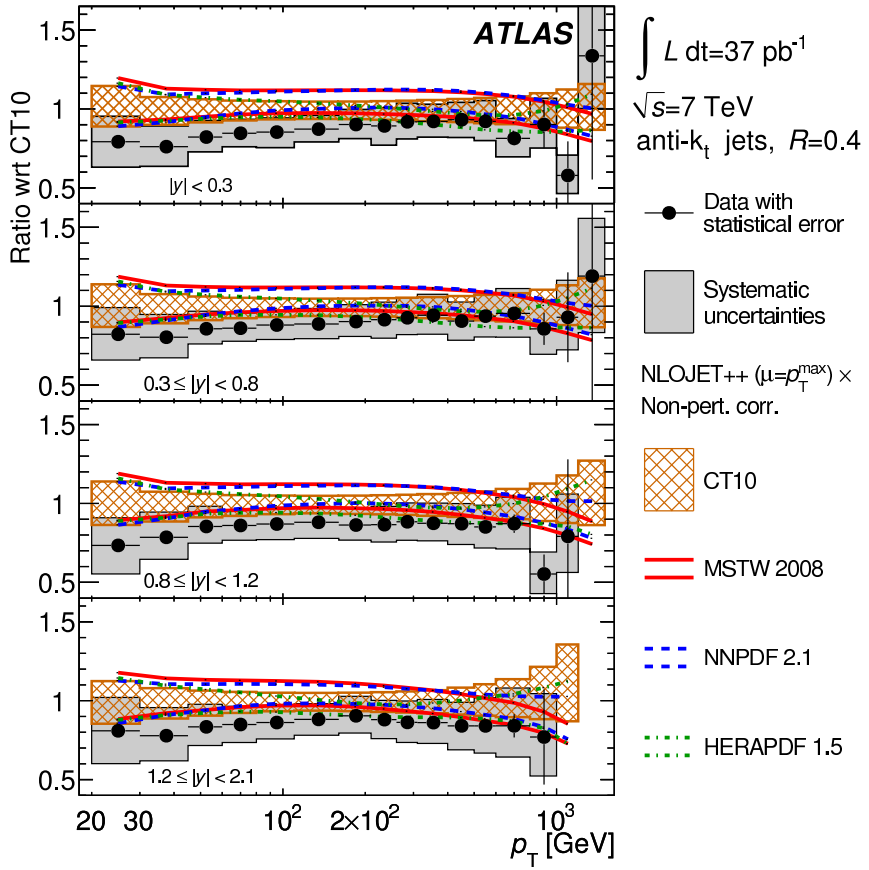


[H1prelim-11-143, ZEUS-prel-11-010]

HERAPDF predictions for LHC



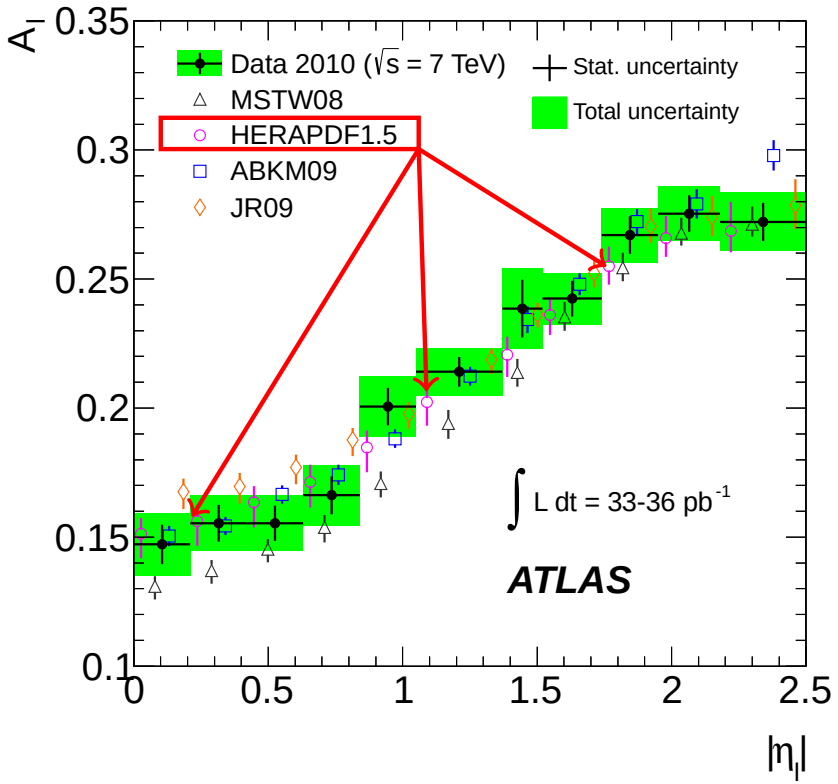
[CMS NOTE 2011/004]

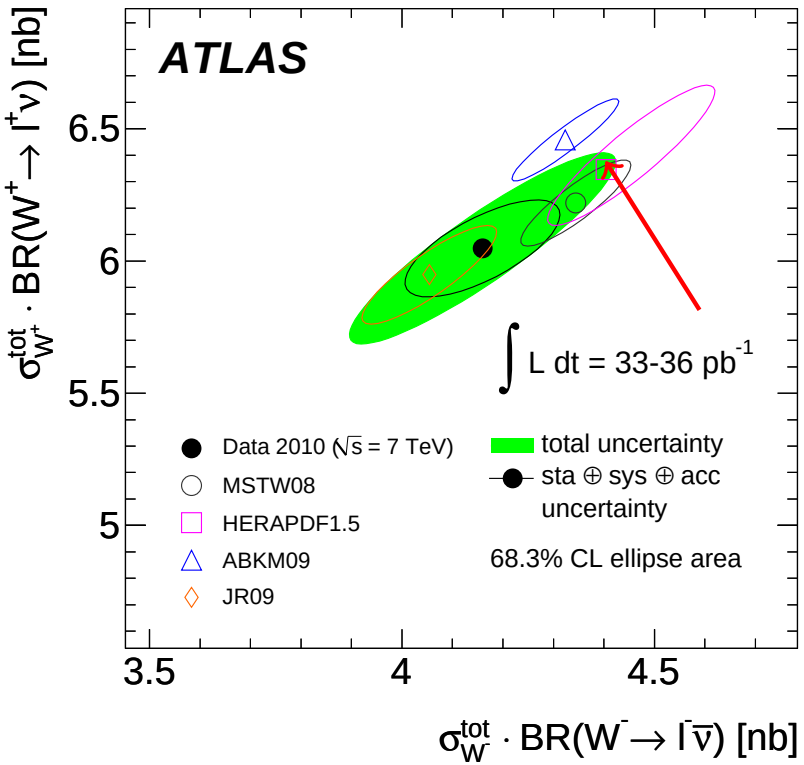


[arXiv:1112.6297]

- HERAPDFs provides competitive predictions for pp processes at high energy.

HERAPDF predictions for LHC





[CERN-PH-EP-2011-143]

- HERAPDF1.5 NNLO provides a prediction consistent with measurements at LHC.

HERAFitterβ

HERAFitter is an **open source** QCD fit package for pPDF determination.
`herafitter.hepforge.org`

- Data:
  - DIS ep
    - Inclusive
    - Jets
  - DY pp and $p\bar{p}$
    - W, Z cross sections
    - Z rapidity
    - W asymmetries
    - Jets
- Output:
  - PDFs predefined scales
  - LHAPDF grids
  - Theory predictions per data points
  - Pulls per data points
- Theory (DIS):
  - ZM-VFNS accessed from QCDNUM [Comp. Ph. Comm. 182 (2011) 490]
  - RT optimal as in MSTW
- Treatment for jets:
  - FastNLO: [hep-ph/0609285]
    - A wrapper around NLOjet++
  - Applgrid: [Eur Phys J C 66 (2010) 503]
    - A wrapper around MCFM, NLOjet++
- Error treatment:
  - Correlated, uncorrelated
  - Hessian method
  - MC method
- Parametrisation studies:
  - Standard functional form of PDFs
  - CTEQ
  - Chebyshev

Summary and conclusions

- New precise determination of pPDF HERAPDF 1.7 based on:
  - combined inclusive HERAI + HERAII NC and CC data;
  - reduced proton energy data;
  - HERA jet data;
  - combined $F_2^{c\bar{c}}$.

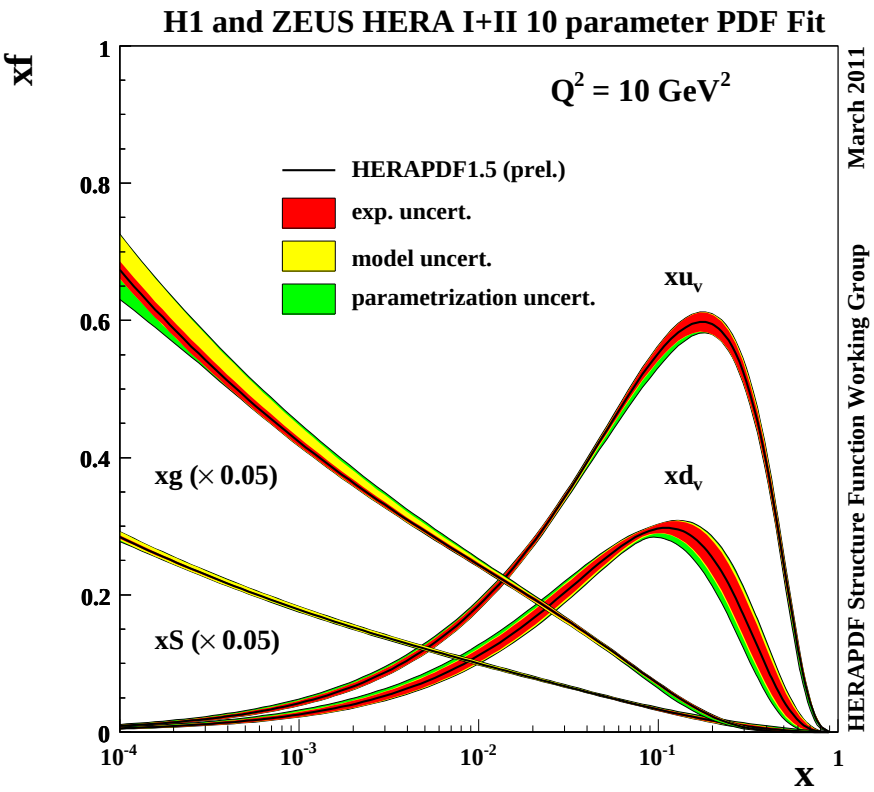
- Inclusion of jet data reduces strong correlation between α_s and gluon PDF.
- Combined $F_2^{c\bar{c}}$ is sensitive to the gluon and charm content of the proton and the charm mass parameter.
- Predictions based on the proton PDFs extracted from $e^{\pm}p$ data alone provide good description of the LHC data.

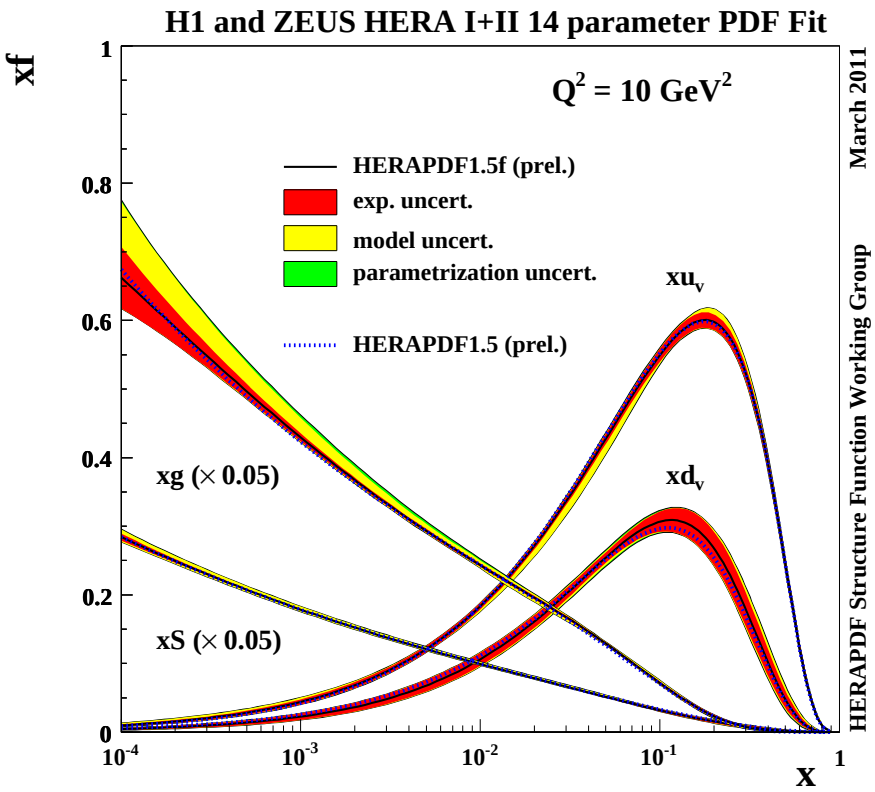
- Open source HERAFitterβ project.

BACK-UP

QCD analysis

- NLO and NNLO DGLAP evolution QCDNUM
- RT-VFNS (as for MSTW08)
- PDF parametrisation at Q_0^2: $xg, xu_V, xd_V, x\bar{U} = x\left(\bar{u} + \{\bar{c}\}\right), x\bar{D} = x\left(\bar{d} + \bar{s} + \{\bar{b}\}\right)$
  - 10 free parameters fit (HERAPDF1.0, HERAPDF1.5 NLO)
    $xf\left(x, Q_0^2\right) = Ax^B\left(1-x\right)^C\left(1 + Dx + Ex^2\right)$
  - 14 free parameters fit (HERAPDF1.5 NNLO, HERAPDF1.6, HERAPDF1.7)
    $xf\left(x, Q_0^2\right) = Ax^B\left(1-x\right)^C\left(1 + Dx + Ex^2\right) - A'x^{B'}\left(1-x\right)^{25}$


H1 and ZEUS HERA I+II 10 parameter PDF Fit
xf
Q^2 = 10 GeV^2
HERAPDF1.5 (prel.)
exp. uncert.
model uncert.
parametrization uncert.
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
March 2011
HERAPDF Structure Function Working Group
x


H1 and ZEUS HERA I+II 14 parameter PDF Fit
xf
Q^2 = 10 GeV^2
HERAPDF1.5f (prel.)
exp. uncert.
model uncert.
parametrization uncert.
HERAPDF1.5 (prel.)
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
March 2011
HERAPDF Structure Function Working Group
x