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On behalf of the H1 and ZEUS collaborations

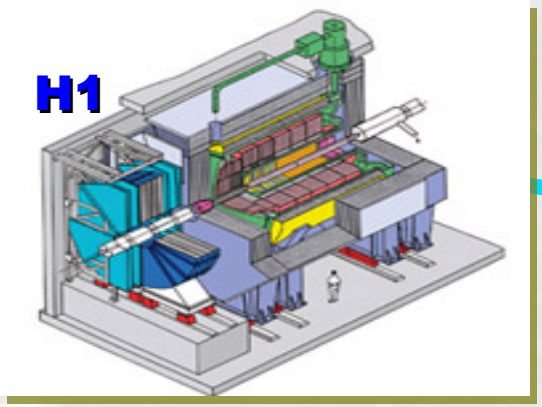
Precise proton structure determination from inclusive DIS and heavy flavor production at HERA

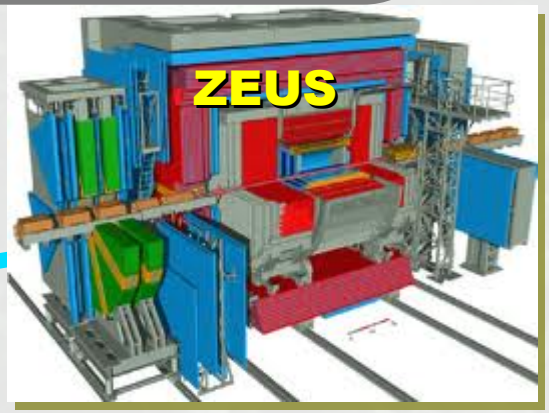
May 26-June 1

Particle Physics and Cosmology

24th Recontres de Blois, France, 2012

HERA collider





- E_{proton} = 920 GeV
- $E_{e+/e-}$ = 27.6 GeV

- 0.5 fb^{-1} per experiment
- In operation 1992-2007

HERA was constructed to study the proton structure function

- 2 Running periods HERAI and HERAII
- Polarization of the lepton beam of P_e ~40 %
- Two general purpose detectors ZEUS and H1
- Rich physics program

Deep Inelastic Scattering at HERA

- Q^2 – virtuality of the exchanged photon

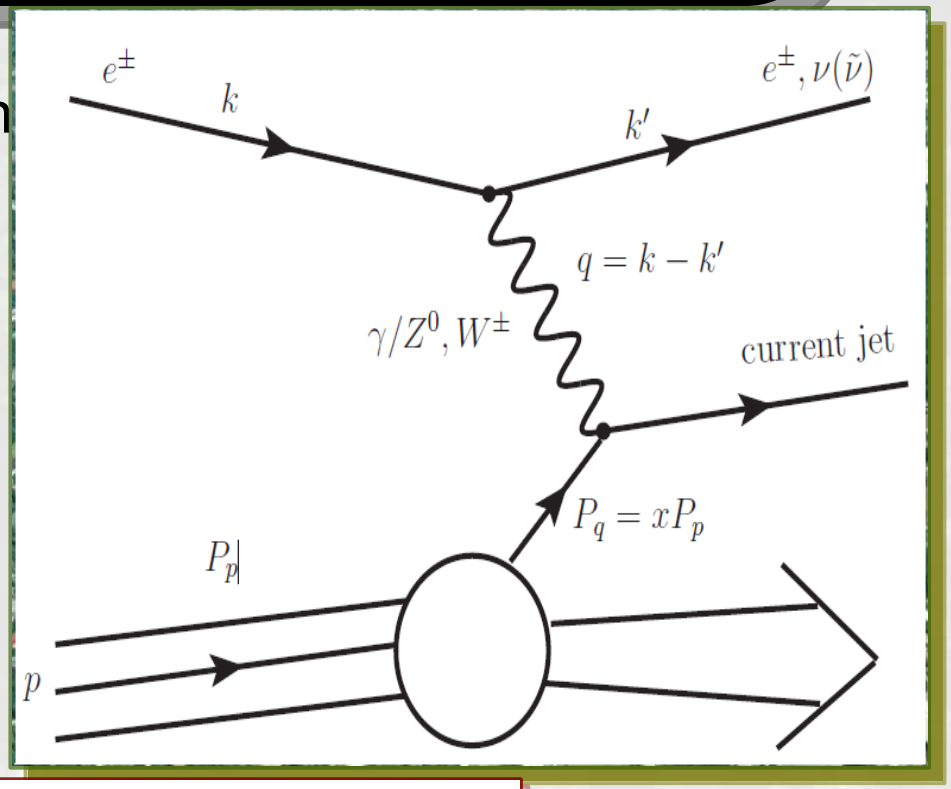
  $Q^2 = -q^2 = -(k - k')^2$

- x – Bjorken scaling variable $x = \frac{Q^2}{2P \cdot q}$

  fraction of momentum carried by the struck quark

- y – inelasticity $y = \frac{P \cdot q}{P \cdot k}$

  fraction of the lepton momentum transferred to the photon



Neutral Current processes (Z/γ exchange) cross section is

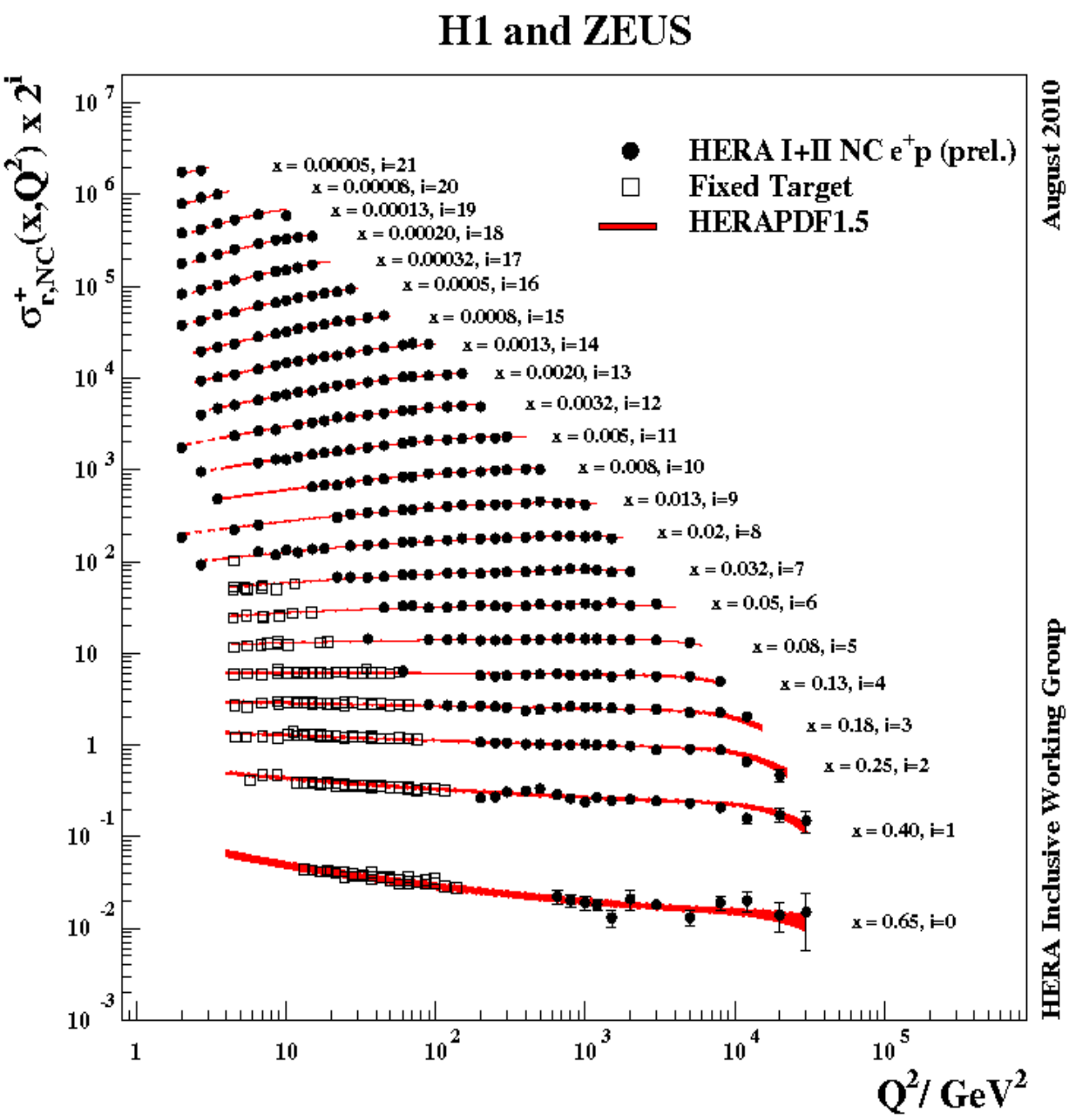
$$\frac{d^2\sigma^{e^{\pm}p}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\tilde{F}_2(x,Q^2) \mp Y_- x\tilde{F}_3(x,Q^2) - y^2 F_L(x,Q^2)\right]$$

$$Y_{\pm} = 1 \pm (1-y)^2$$

Structure functions

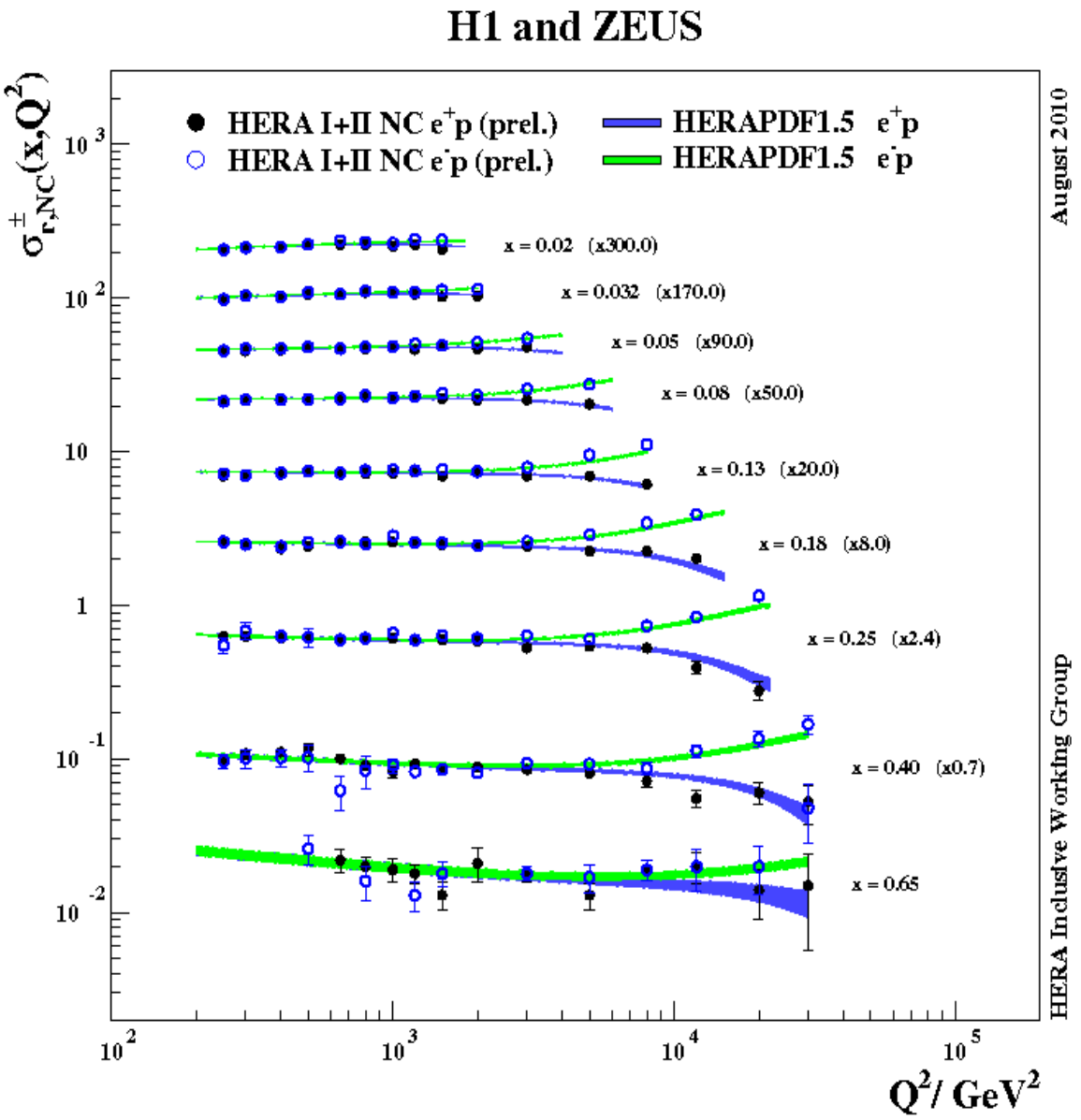
- F_2 – dominant, sensitive to sea quarks, gluon
- xF_3 – sensitive to valence quarks, relevant at high Q^2
- F_L – sensitive to gluon, relevant at high y

Precision at HERA



- HERA cover larger kinematic phase space than fix target experiments
- From the scaling violations (slope) we can constrain gluon PDFs
- HERA data only based predictions (HERAPDF) describe fix target data

Precision at HERA



- Difference seen in e-p and e+p cross sections at high Q^2 allows to measure non dominant effects

Measurement of xF_3

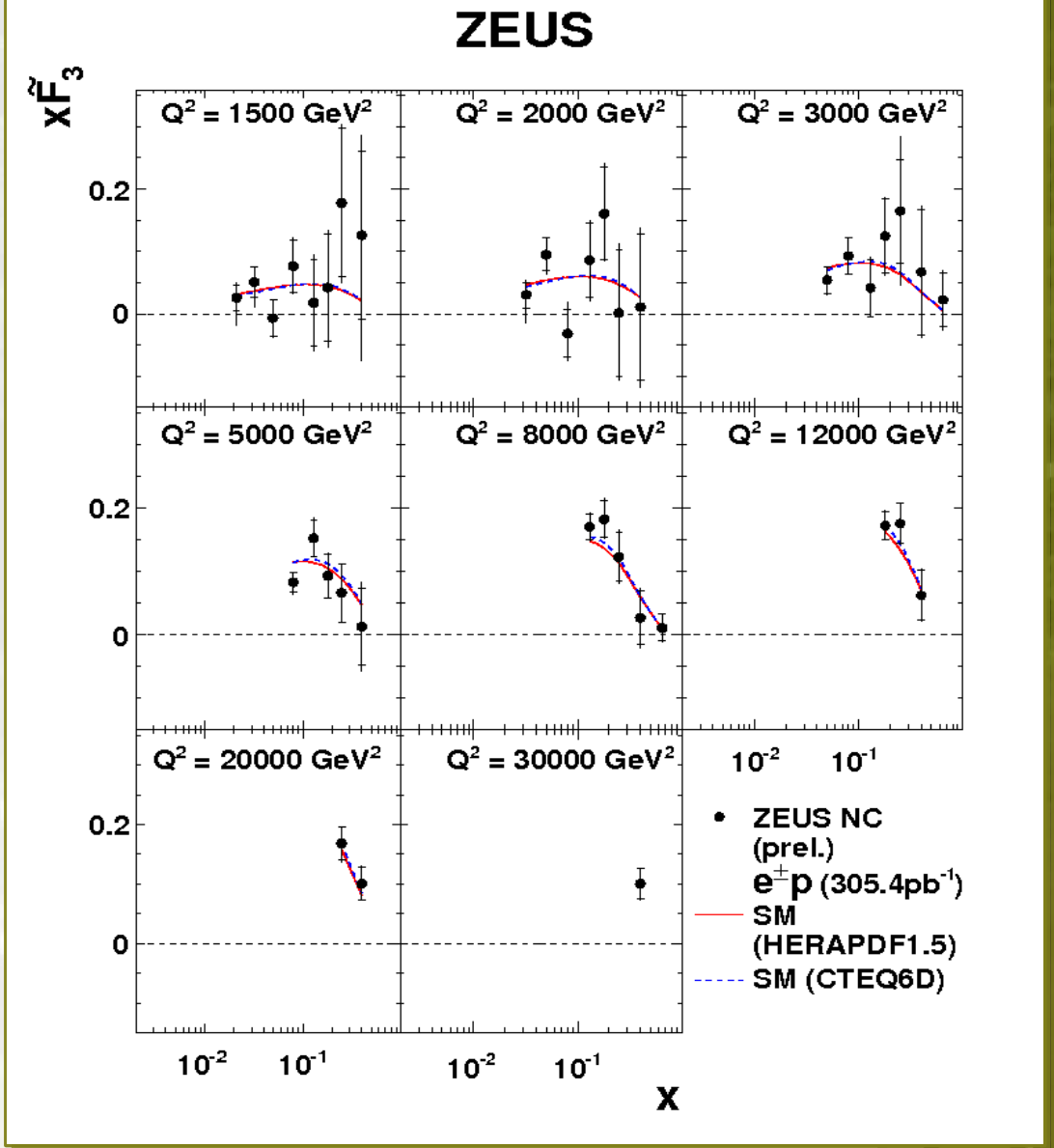
ZEUS-prel-11-003

$$x\tilde{F}_3 = \frac{Y_+}{2Y_-}(\tilde{\sigma}^{e^-p} - \tilde{\sigma}^{e^+p})$$

- xF_3 describes valence quarks distribution and has γZ and Z terms only.

$$x\tilde{F}_3 = -a_e\chi_Z xF_3^{\gamma Z} + 2v_e a_e \chi_Z^2 xF_3^Z$$

- 2 data sets are needed **e+ e-** to extract xF_3
- Results are described by Standard Model predictions



y<0.9, Q^2>200 GeV^2

Measurement of $F_2^{\gamma Z}$

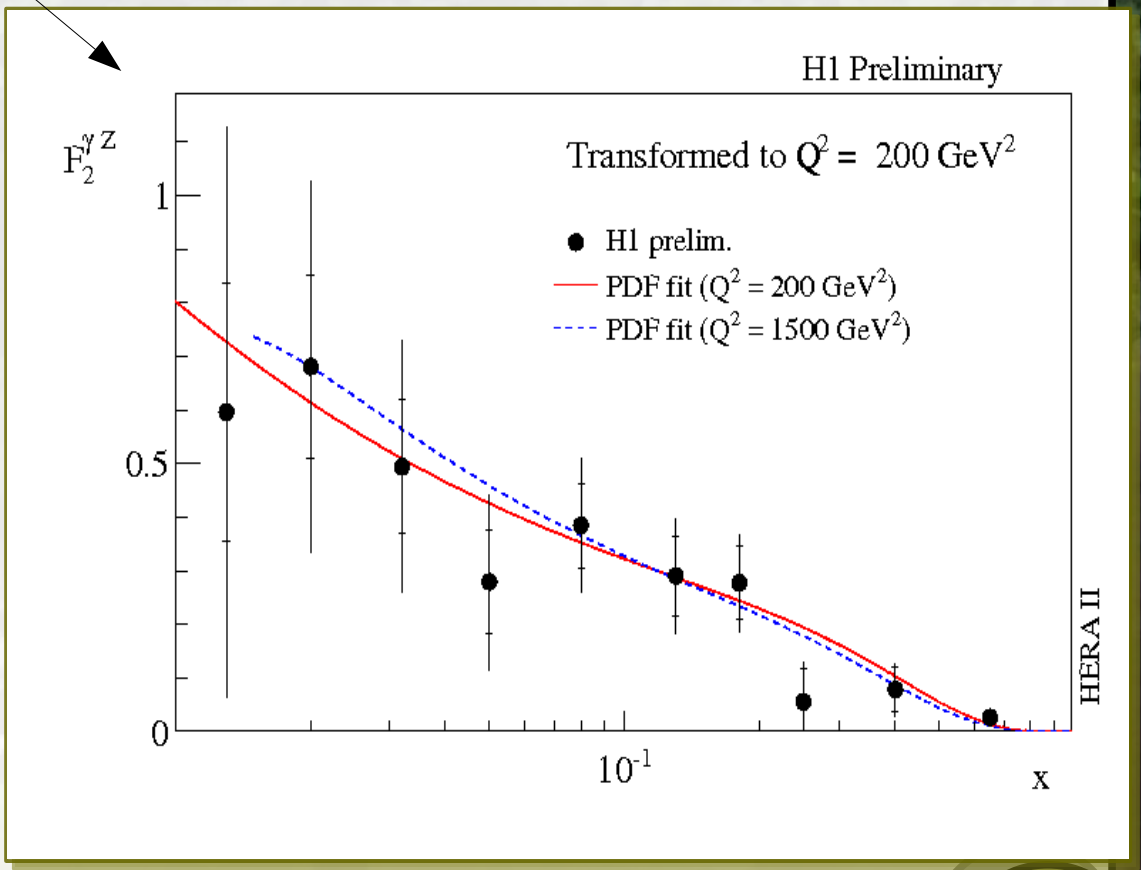
H1 -prelim-12-142

$$\frac{\sigma^{\pm}(P_L)-\sigma^{\pm}(P_R)}{P_L-P_R}=\frac{\kappa Q^2}{Q^2+M_Z^2}\left[\mp a_e F_2^{\gamma Z}+\frac{Y_-}{Y_+}\upsilon_e x F_3^{\gamma Z}-\frac{Y_-}{Y_+}\frac{\kappa Q^2}{Q^2+M_Z^2}(\upsilon_e^2+a_e^2)x F_3^Z\right]$$

- $F_2^{\gamma Z}$ is an interference term of photon and Z exchange contribution to F_2

$$\tilde{F}_2 = F_2^{\gamma} - (v_e - P_e a_e)\chi_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 - 2P_e v_e a_e)\chi_Z^2 F_2^Z$$

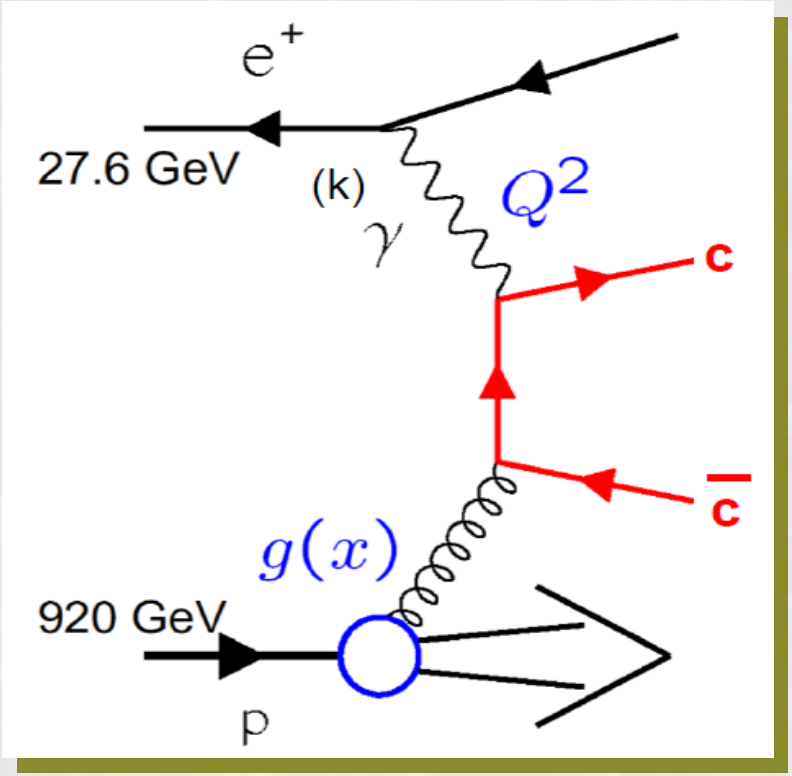
- Z exchange is strongly suppressed
- 4 data sets are needed: **e+** and **e-** data with **left**-(P_L) and **right** handed (P_R) polarization
- Contribution from $xF_3^{\gamma Z}$ taken out by averaging over e+ and e- $F_2^{\gamma Z}$



The first measurement

Heavy flavor production in DIS at HERA

- **Boson-gluon fusion** is a dominant process for the charm production in DIS
- **Charm** contribution to the inclusive DIS cross section is up to 30% (**sizeable part**), beauty ~3%
- Measurements in the heavy flavor sector give information about the **gluon PDF** also

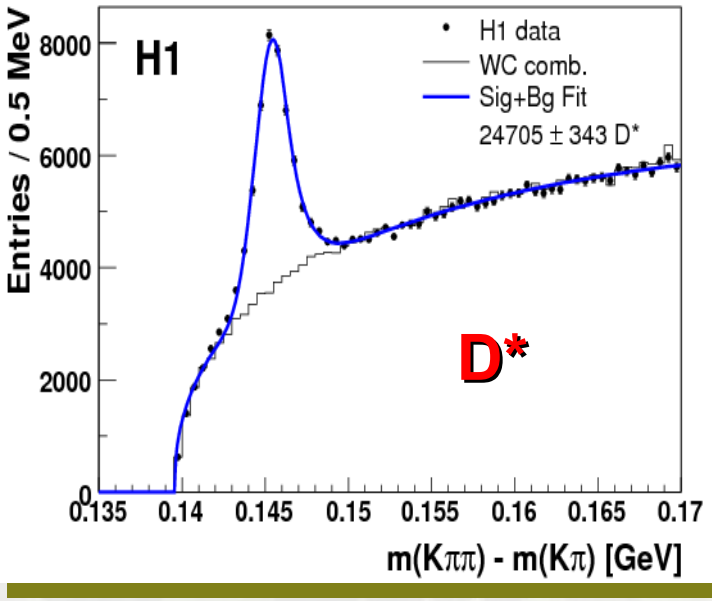


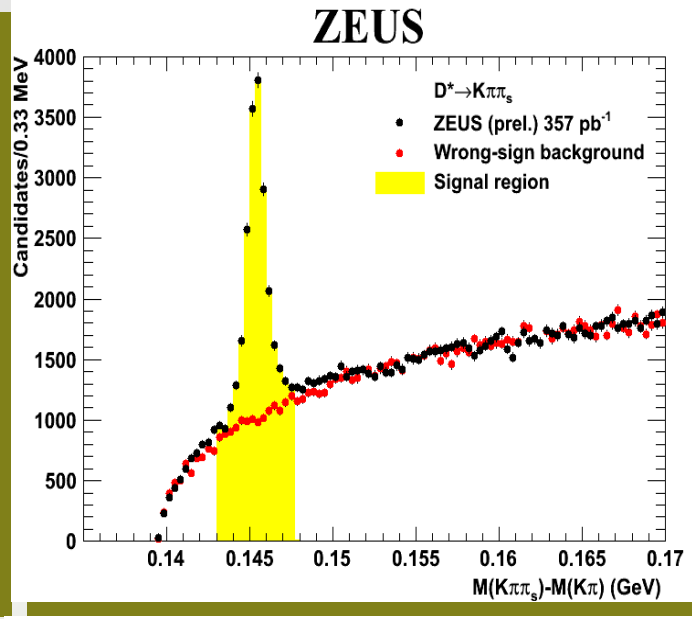
$$\frac{d\sigma^{c\bar{c}}(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[1+(1-y)^2\right]\left(F_2^{c\bar{c}}(Q^2,x) - \frac{y^2}{1+(1-y)^2}F_L^{c\bar{c}}(Q^2,x)\right)$$

Charm tagging

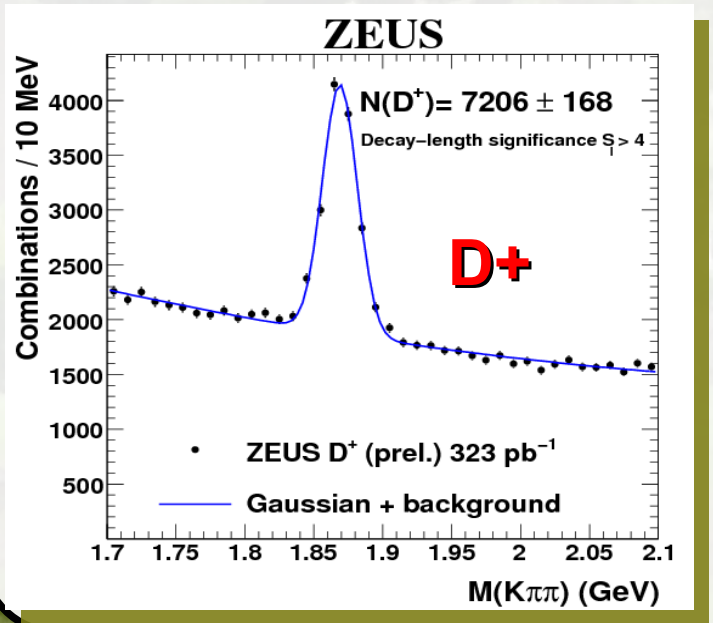
ZEUS-prel-10-005,-11-012
H1/DESY-11-066

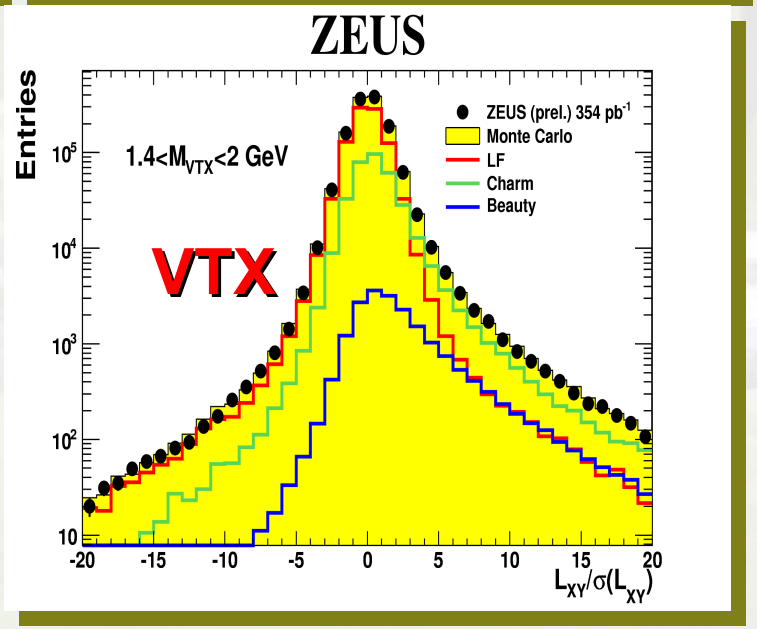
- **Signature decays** of $D^{+/-}$ or $D^{*+/-}$ or **secondary vertices**

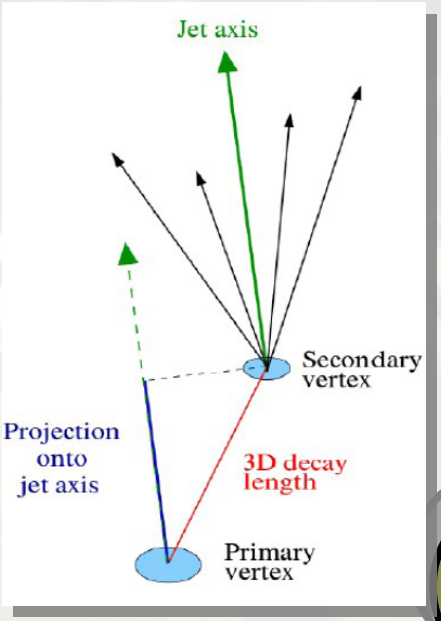




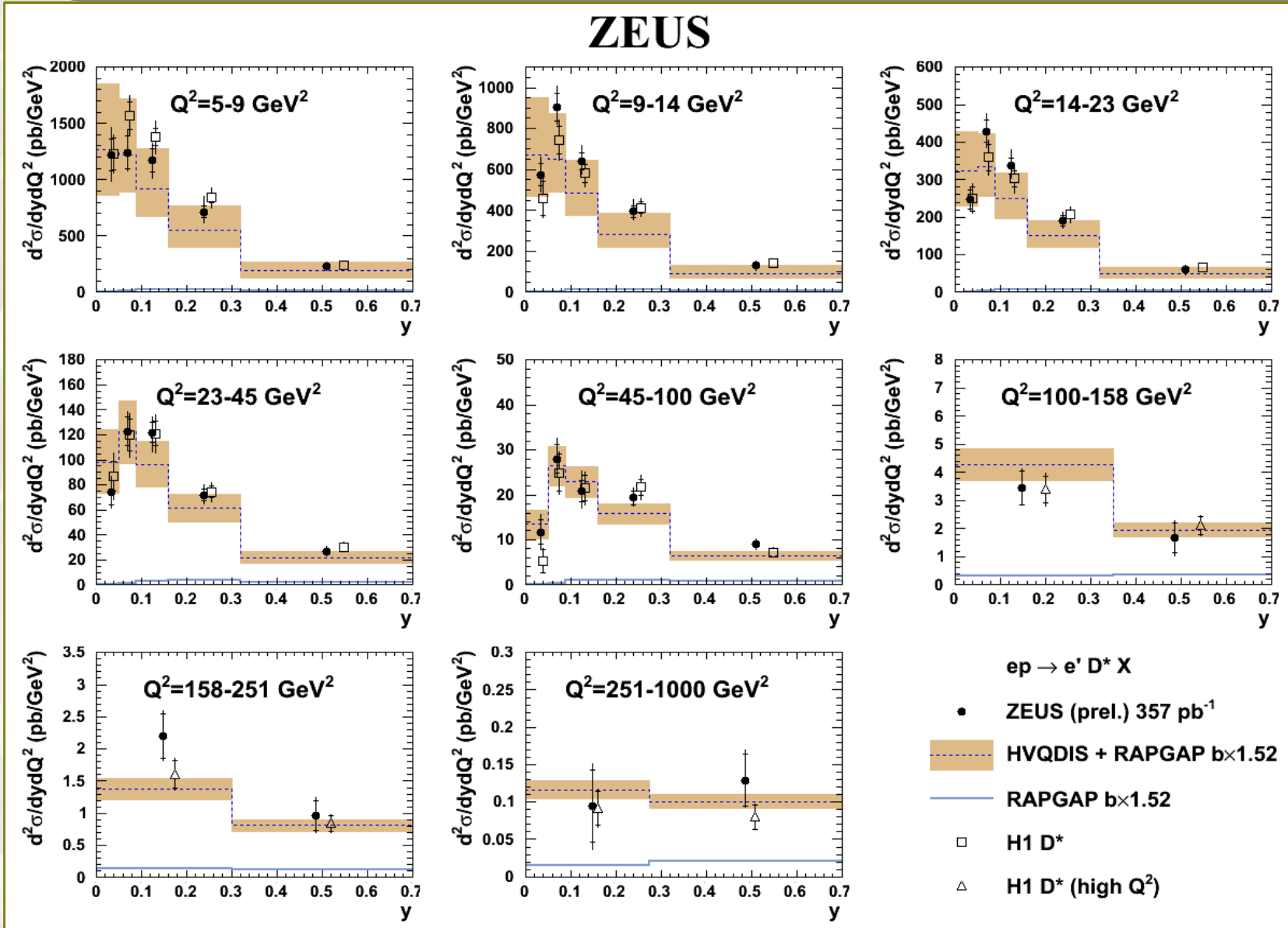
- $D^+ \rightarrow K^- \pi^+ \pi^+$
- $D^{*+} \rightarrow D^0 \pi^+_s$
  $\rightarrow K^- \pi^+$
- Both mas of the charm hadrons and life time information can be used to tag charm







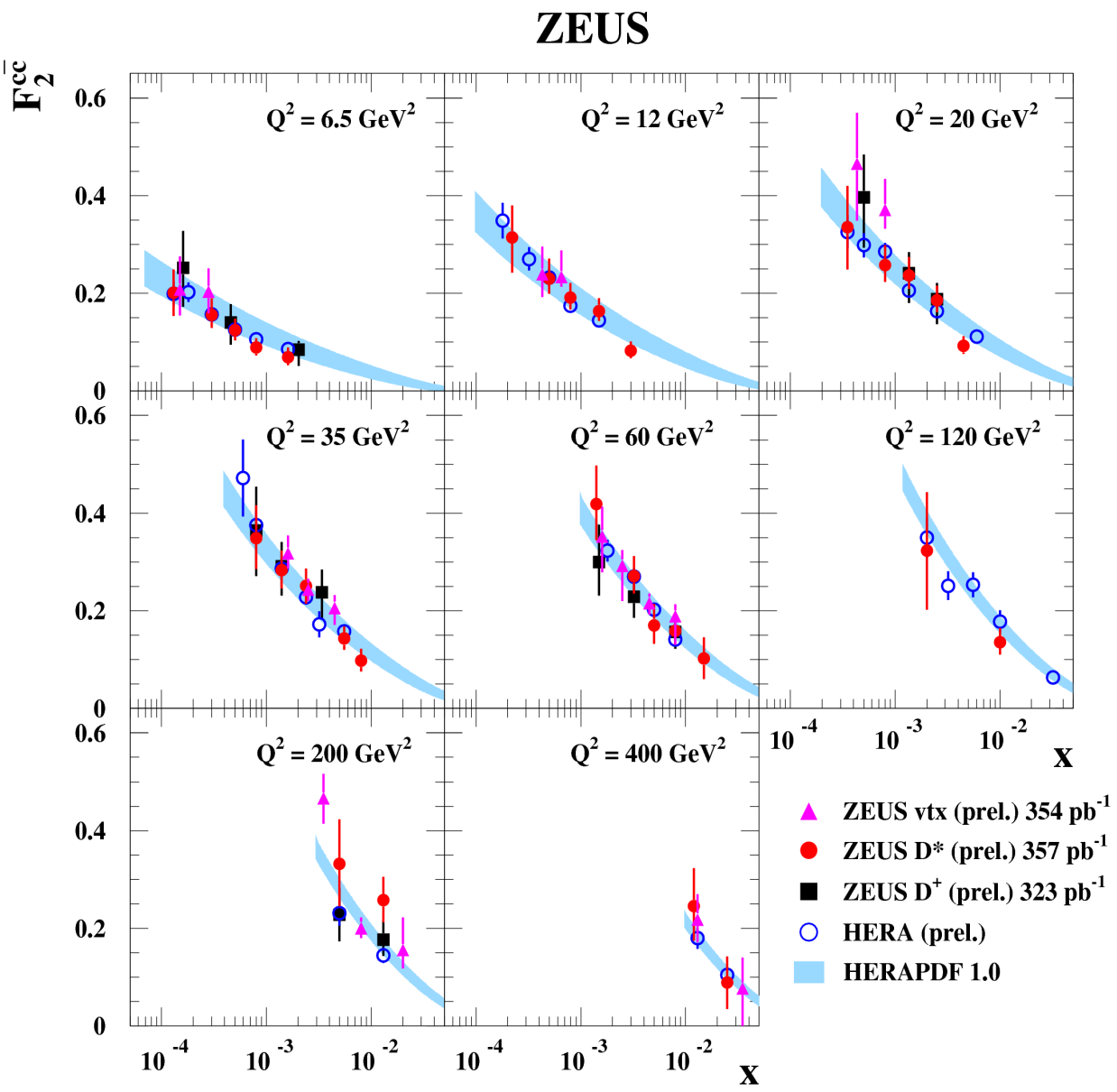
D* cross sections ZEUS-prel-11-012,H1/DESY-11-066



It is an input to extract F_2^{cc}

- **H1 and ZEUS agree** both with NLO QCD predictions

F_2^{cc} measurements



- Measurements are described by the HERAPDF (prediction doesn't contain these charm cross sections)
- New measurements agree with the combined previous HERA results
- New data will improve HERA combined result

From structure functions to PDFs

Factorization theorem for the structure function with exchange of vector bosons

$$F_2^{\gamma,Z,W^\pm}(x,Q^2) = \sum_{i=q\bar{q}g} \int_1^x dz \otimes C_2^{\gamma,Z,W^\pm}\left(\frac{x}{z}, \mu_R, \mu_F, \alpha_s, Q^2\right) \otimes f_i(z, \mu_F, \mu_R)$$

Measured cross sections **Matrix elements from pQCD** **PDFs**

- X dependence is not calculable with pQCD
- Parametrize PDFs for g, u_v, d_v with simple approach at the starting Q_0^2
- Evolve PDFs with DGLAP for other scale Q^2
- Construct cross sections from PDFs
- Perform χ^2 fit to experimental data

Simple approach

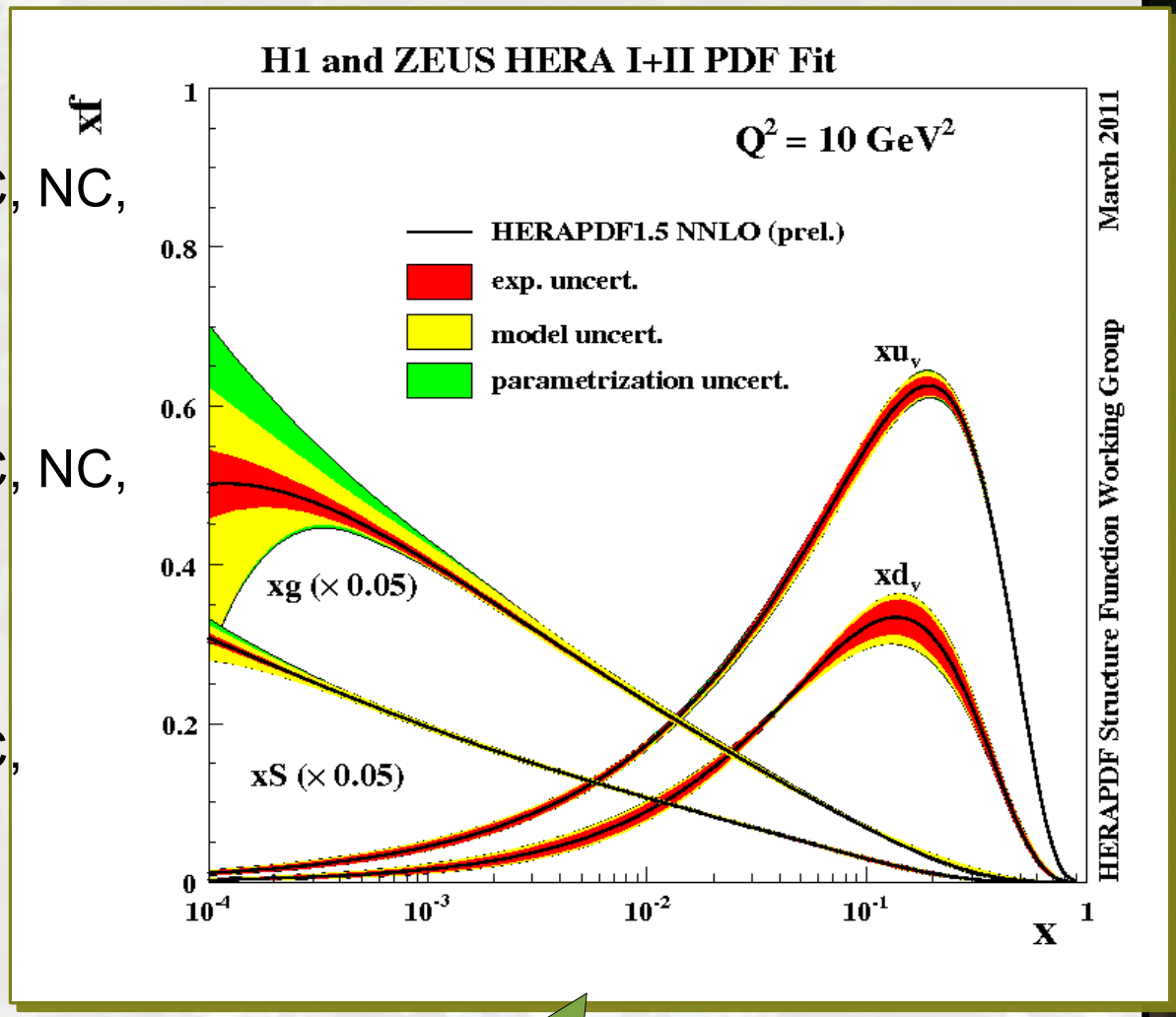
$$xq_i(x) = A_i \cdot x_i^{B_i}(1-x_i)^{C_i} \cdot P_i(x)$$

A-normalization, B-low x, C-high x

- 13 parameter fit with additional constrains

HERAPDF history

	. . .	
Jun '11	**HERAPDF 1.7**	HERAI+HERAII CC, NC, jets,charm
Mar '11	**HERAPDF 1.6**	HERAI+HERAII CC, NC, jets
Jul '10	**HERAPDF 1.5** recommended, released at LHAPDF	HERAI+HERAII CC, NC **NLO, NNLO**
Nov '09	**HERAPDF 1.0**	HERAI CC, NC

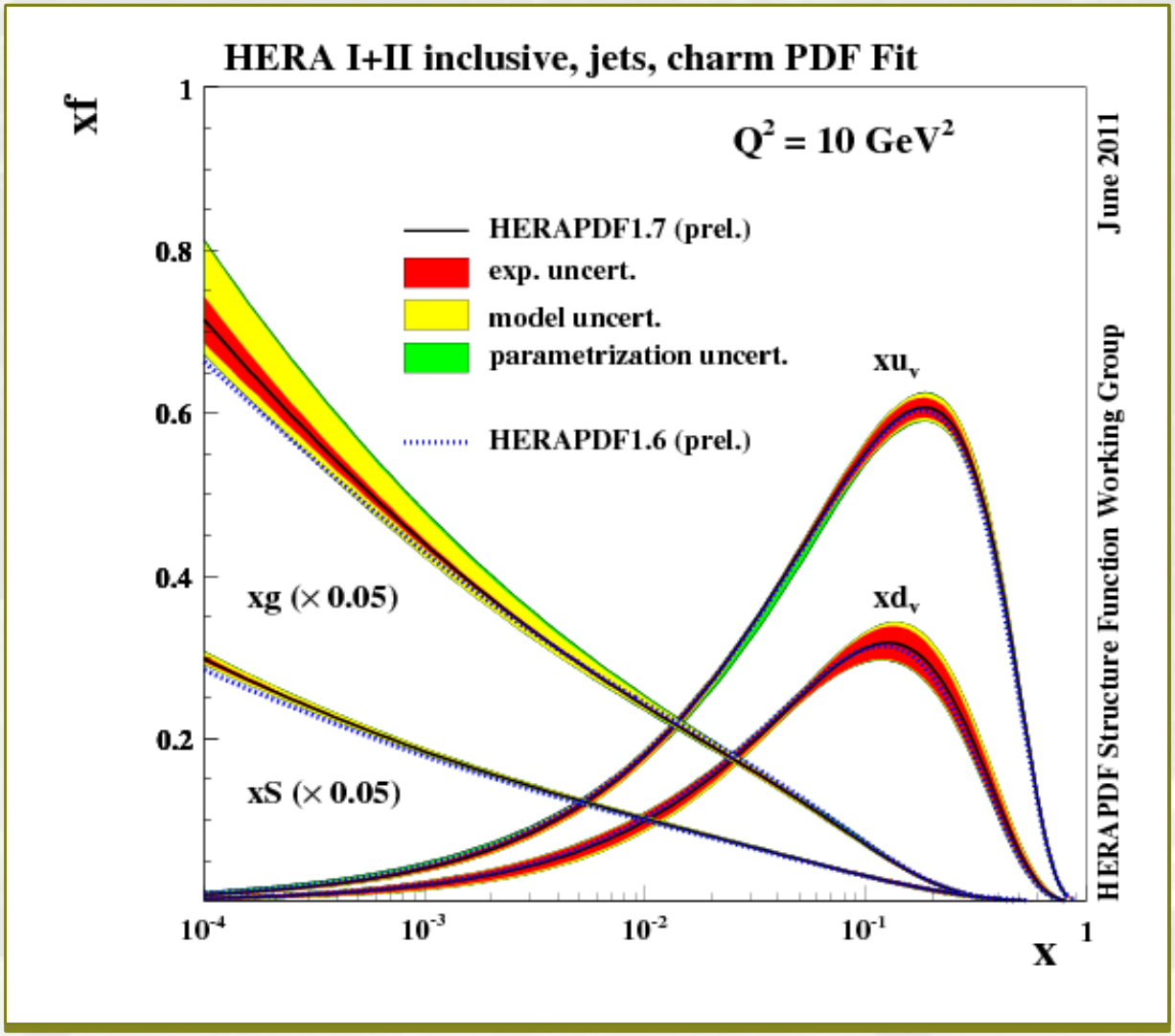


HERA data only

HERAPDF 1.7

H1-prelim-11-143,
ZEUS-prel-11-010

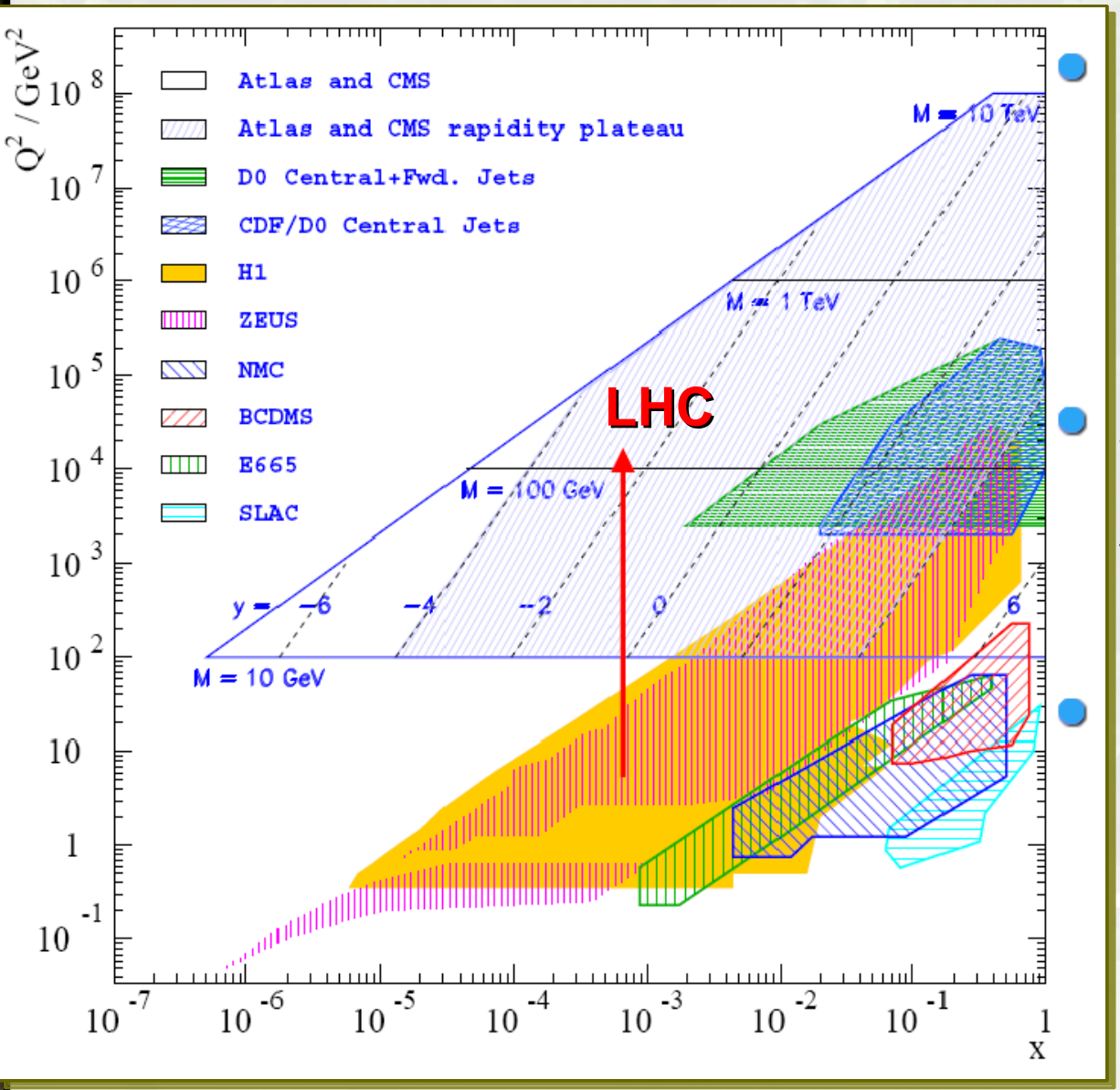
- HERAI CC, NC, jets, charm, HERAII CC, NC charm, jets, NLO version



1.7 NLO

Data from HERAII are only preliminary, improvements are expected

From HERA to LHC

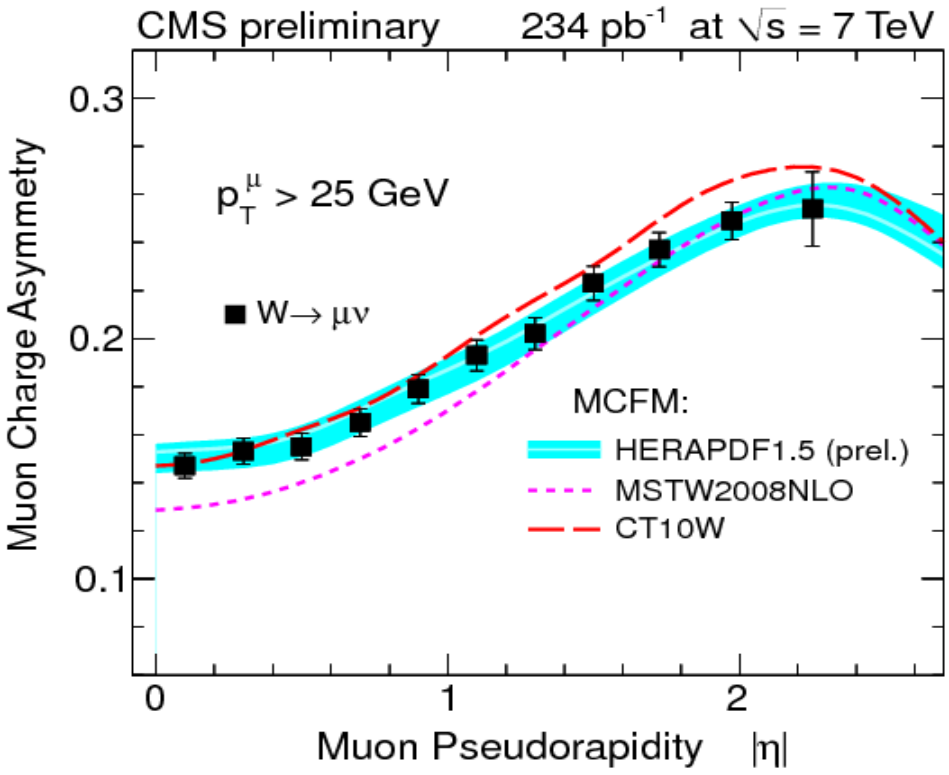


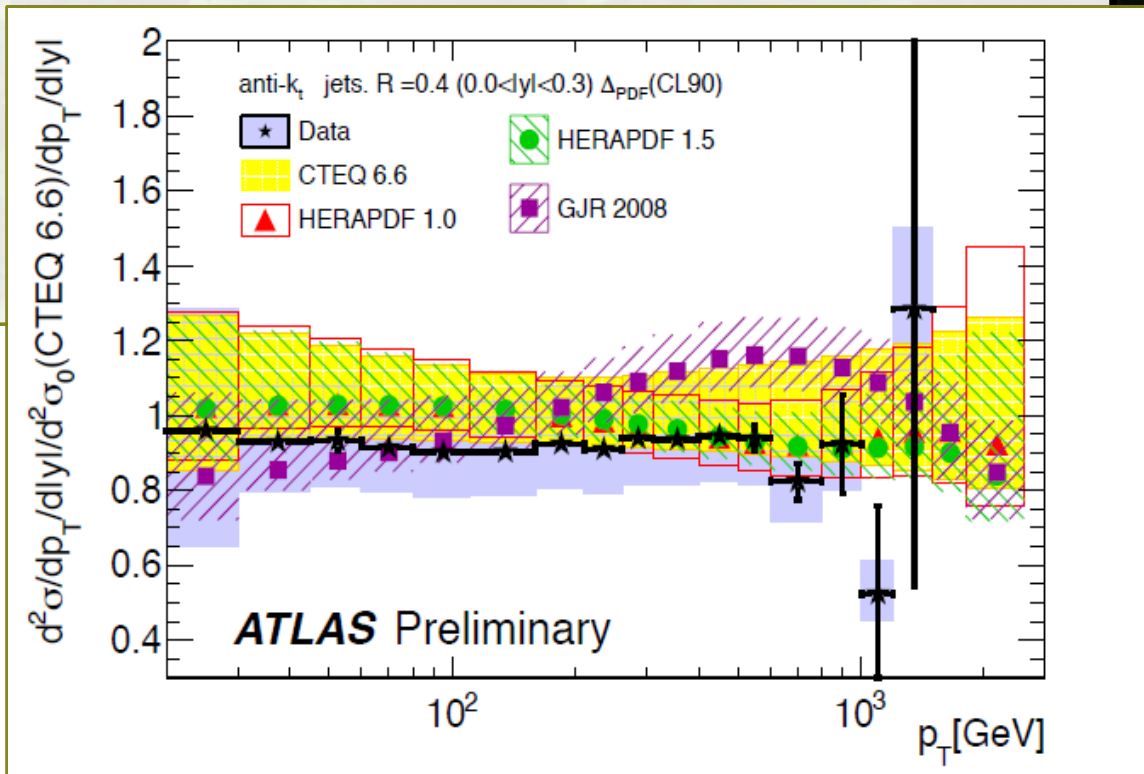
- Data from fixed target experiments (high x) can not be easily extrapolated to HERA data (low x)
- X behavior is taken from the data, while Q^2 can be evolved with DGLAP
- Measurements from HERA can be used for theoretical prediction for the LHC kinematic region with proper Q^2 evolution

HERAPDF and LHC results

- W lepton charge asymmetry is sensitive to the ratio of u and d quarks

$$A_\ell(\eta_\ell) = \frac{\mathrm{d}\sigma_{W+}/\mathrm{d}\eta_\ell - \mathrm{d}\sigma_{W-}/\mathrm{d}\eta_\ell}{\mathrm{d}\sigma_{W+}/\mathrm{d}\eta_\ell + \mathrm{d}\sigma_{W-}/\mathrm{d}\eta_\ell}$$





- Jet data are sensitive to strong coupling constant and gluon

Data from LHC will put further constrains to PDFs

More LHC results at M. Martinez and D. Froidevaux talks on Tuesday

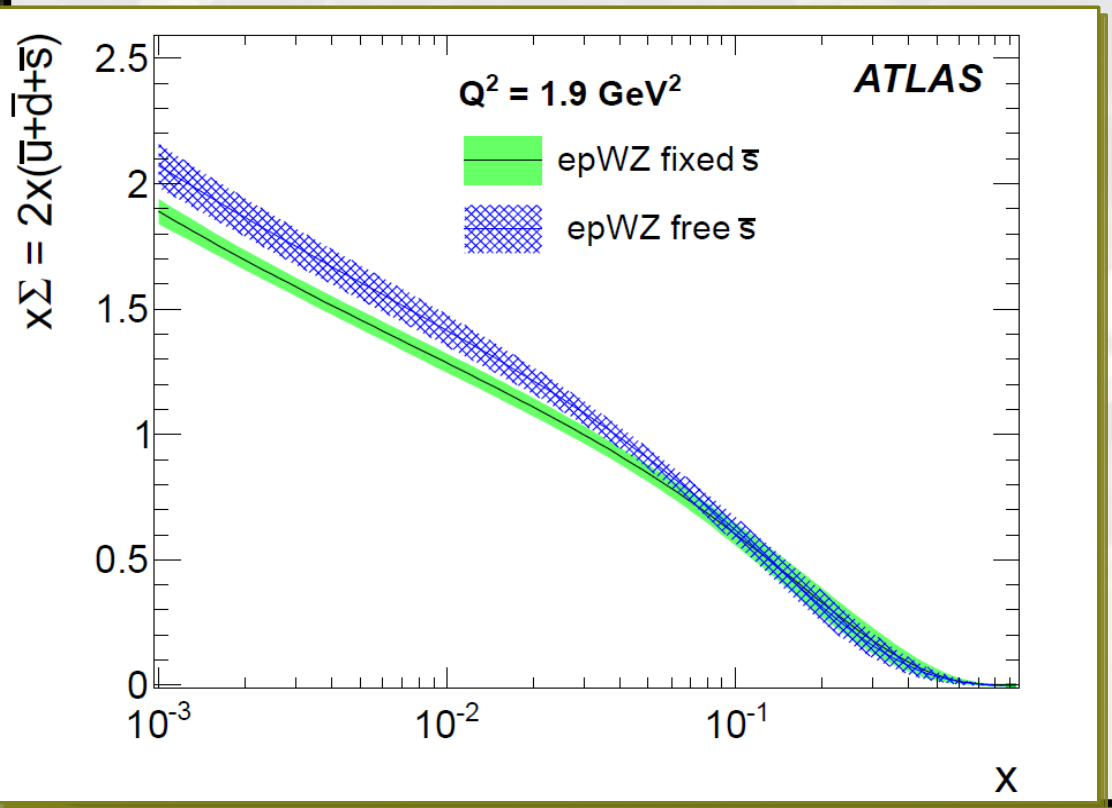
- **LHC data are described by HERAPDF**

HERAFitter

http://projects.hepforge.org/herafitter/

- Based NOT only on HERA data, but also on LHC, Tevatron, fixed target ...
- Different processes available: Drell-Yan, DIS, Diffraction,W/Z/top production ...
- Different model/schemes approaches: ABKM, MSTW, CTEQ, FastNLO, Applgrid, Hathor
- Output is: PDFs, theoretical cross sections, coupling constant ...

First publication is out *arXiv:1203.4051*

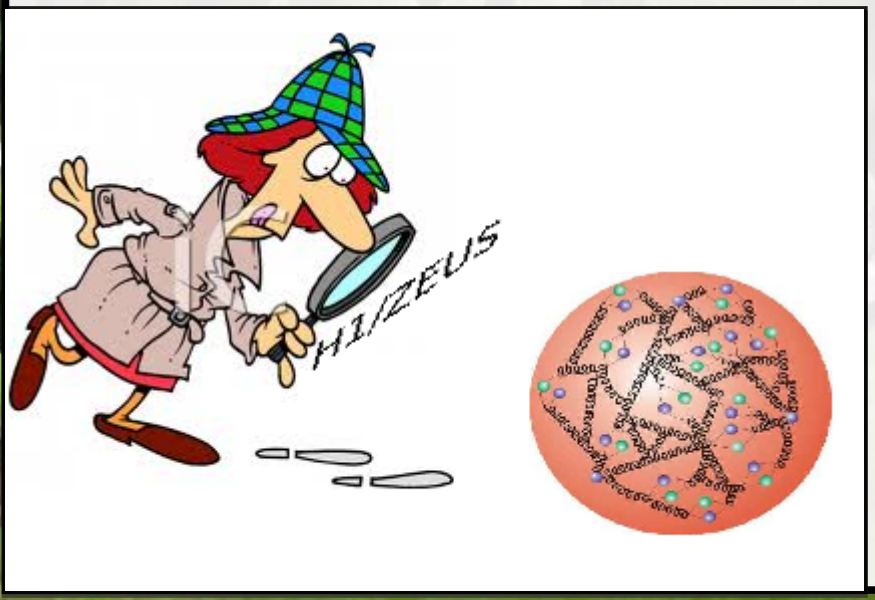


Open source project. First beta release at HepForge.

- Distribution of the light strange sea quarks
- ATLAS and HERA data

Summary

- HERA provided **unprecedented knowledge** about proton structure at low x
  - Presented **inclusive measurements** will improve electro-weak fit
  - Presented **charm measurements** will improve gluon PDF
  - Recommended PDF is HERAPDF is 1.5
  - Recent HERAPDF 1.7 was presented



- **PDFs from HERA are important** inputs for LHC predictions
- **HERAFitter** gives possibility to further improve PDFs by adding measurements from other experiments