

Physics at LHC-2008 Split, October 1st 2008

Claude Vallée

CPPM/DESY, on behalf of ZEUS and H1



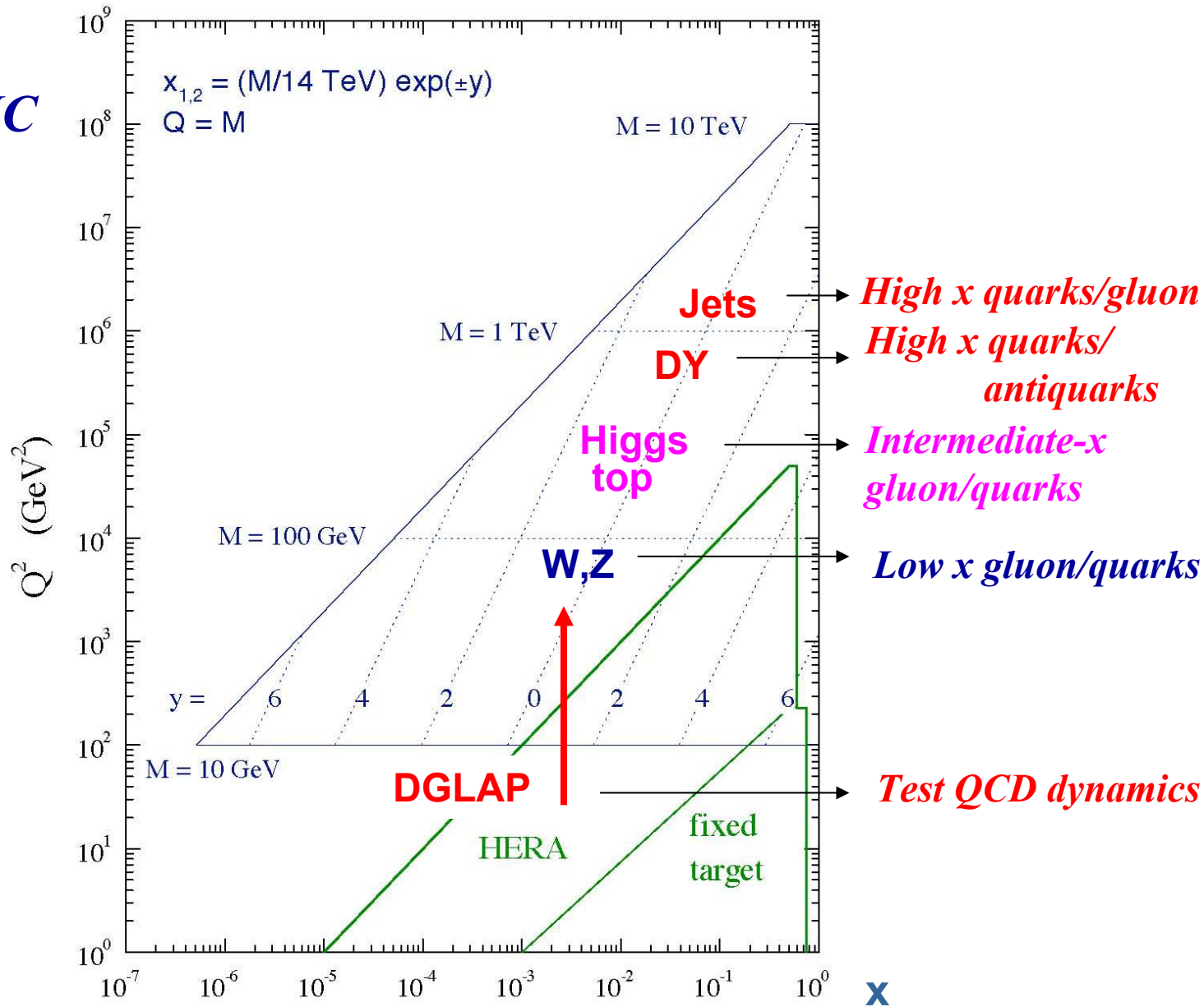
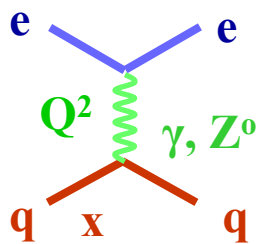
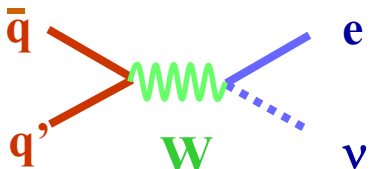
FUNCTIONS

STRUCTURE

HERA



Kinematics: HERA ↔ LHC



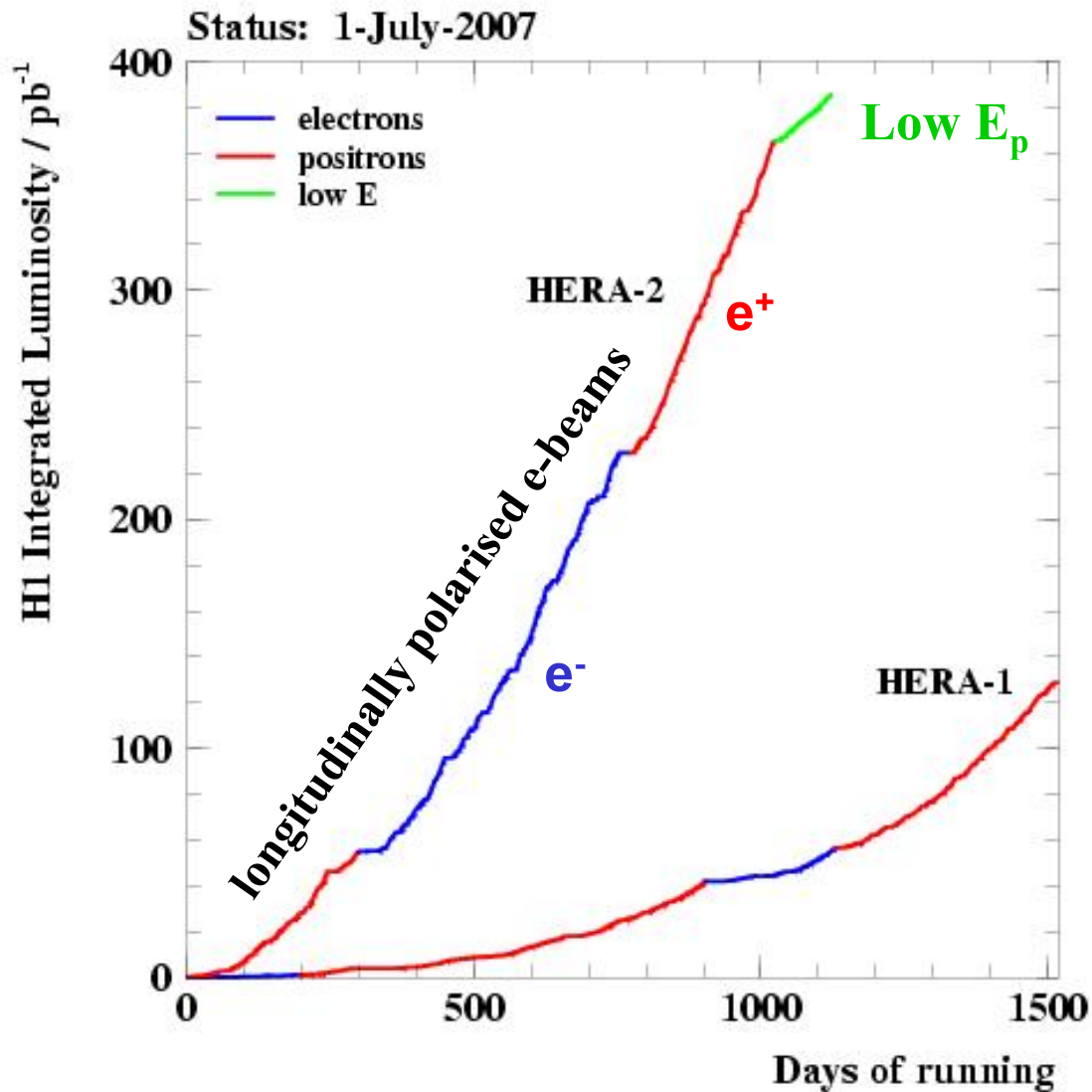
The questions to be answered at HERA

Does the electron probe behave as expected ?

Is the quark point-like ?

What are the quarks and gluon distributions in the proton ?

Is QCD dynamics well understood to evolve them to the LHC scale ?



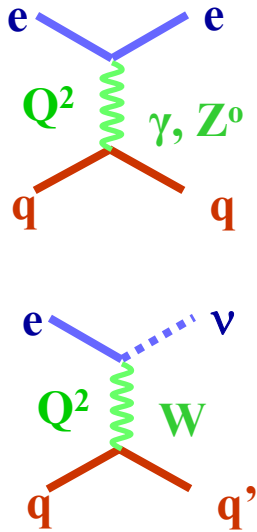
The final HERA data samples

$\sim 0.5 \text{ fb}^{-1}$ / experiment

balanced e^+p and e^-p samples

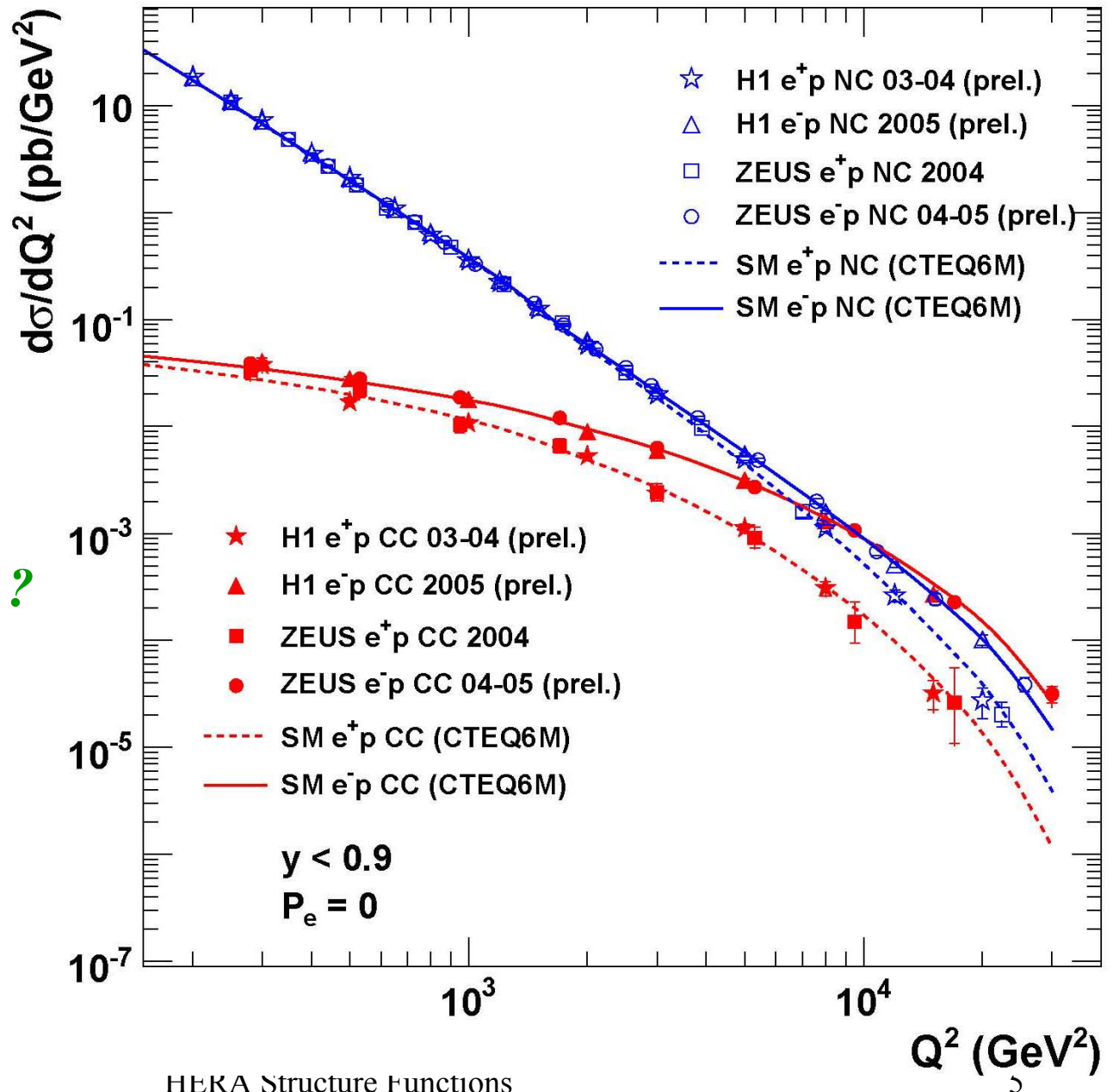
$\sim 35\%$ polarised e at HERA II

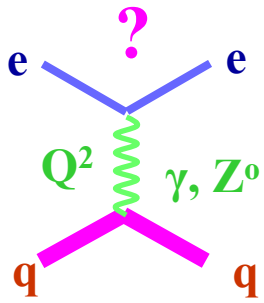
Low- E_p runs for F_L



*Does the e-probe
behave as expected?*

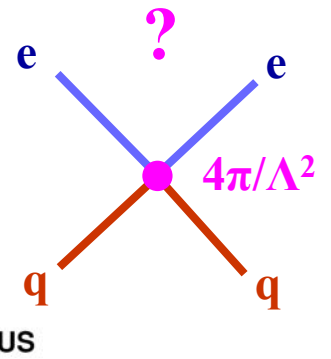
YES!
EW unification
in the t-channel
at the $M_{W,Z}$ scale



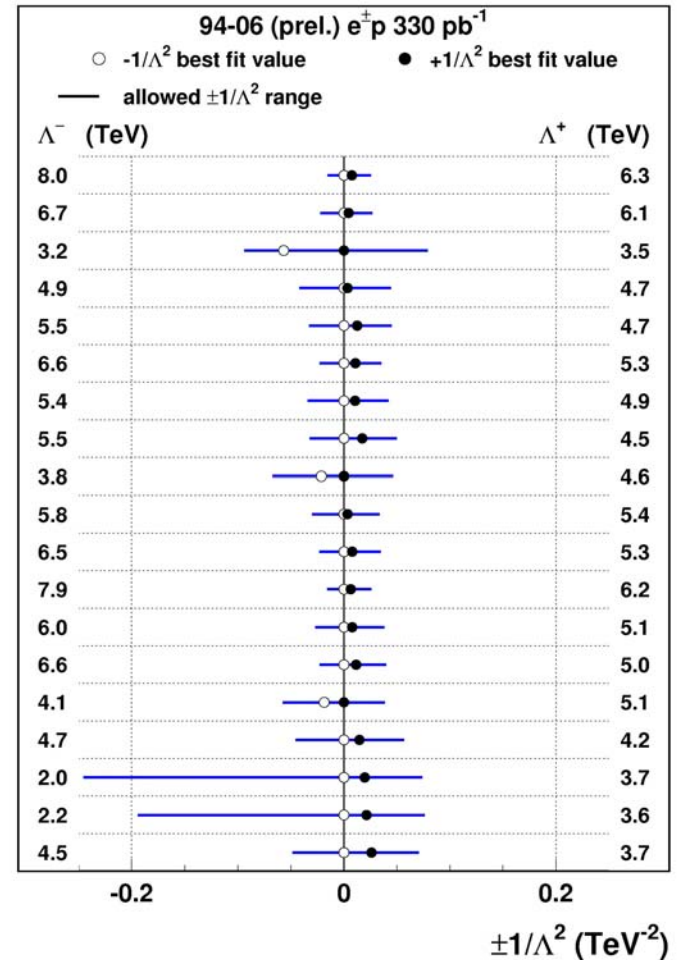
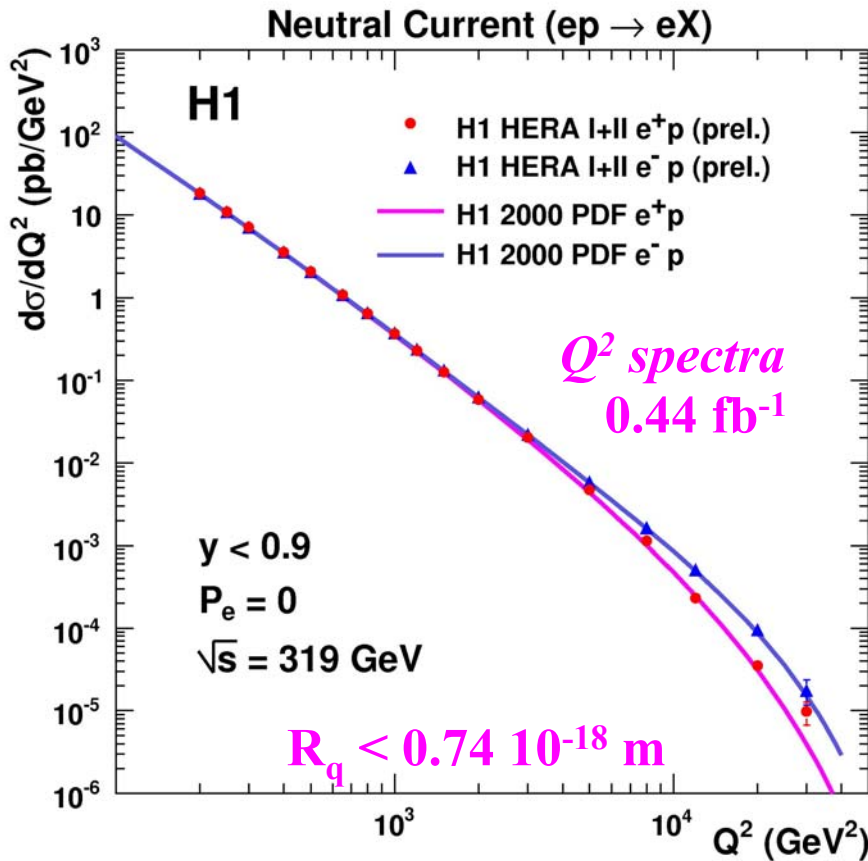


Is the quark point-like ?
YES! ...at the HERA scale

quark radius R_q
 factor: $(1 - R_q^2 Q^2 / 6)$

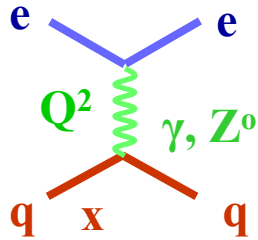


ZEUS

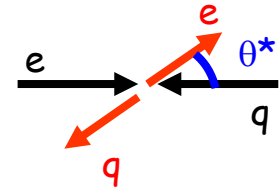


ZEUS 0.33 fb^{-1} : $R_q < 0.62 \cdot 10^{-18} \text{ m}$

MEASURING THE PROTON STRUCTURE



$$\tilde{\sigma}_{NC}^{\pm} = \frac{d^2 \sigma_{NC}^{e^{\pm} p}}{dx dQ^2} \frac{x Q^4}{2\pi \alpha^2 Y_{\pm}}$$



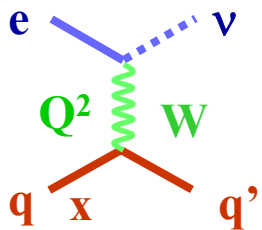
$$y = Q^2/sx = (1 - \cos\theta^*)/2$$

$$= \tilde{F}_2 - \frac{y^2}{Y_+} \tilde{F}_L \mp \frac{Y_-}{Y_+} x \tilde{F}_3 \quad Y_{\pm} = 1 \pm (1 - y)^2$$

valence + sea quarks

gluon

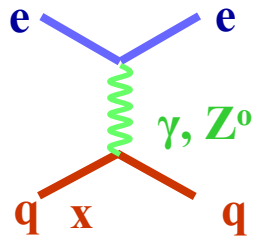
valence quarks



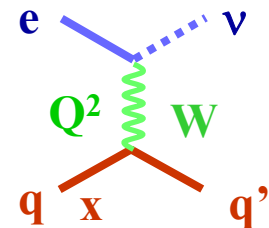
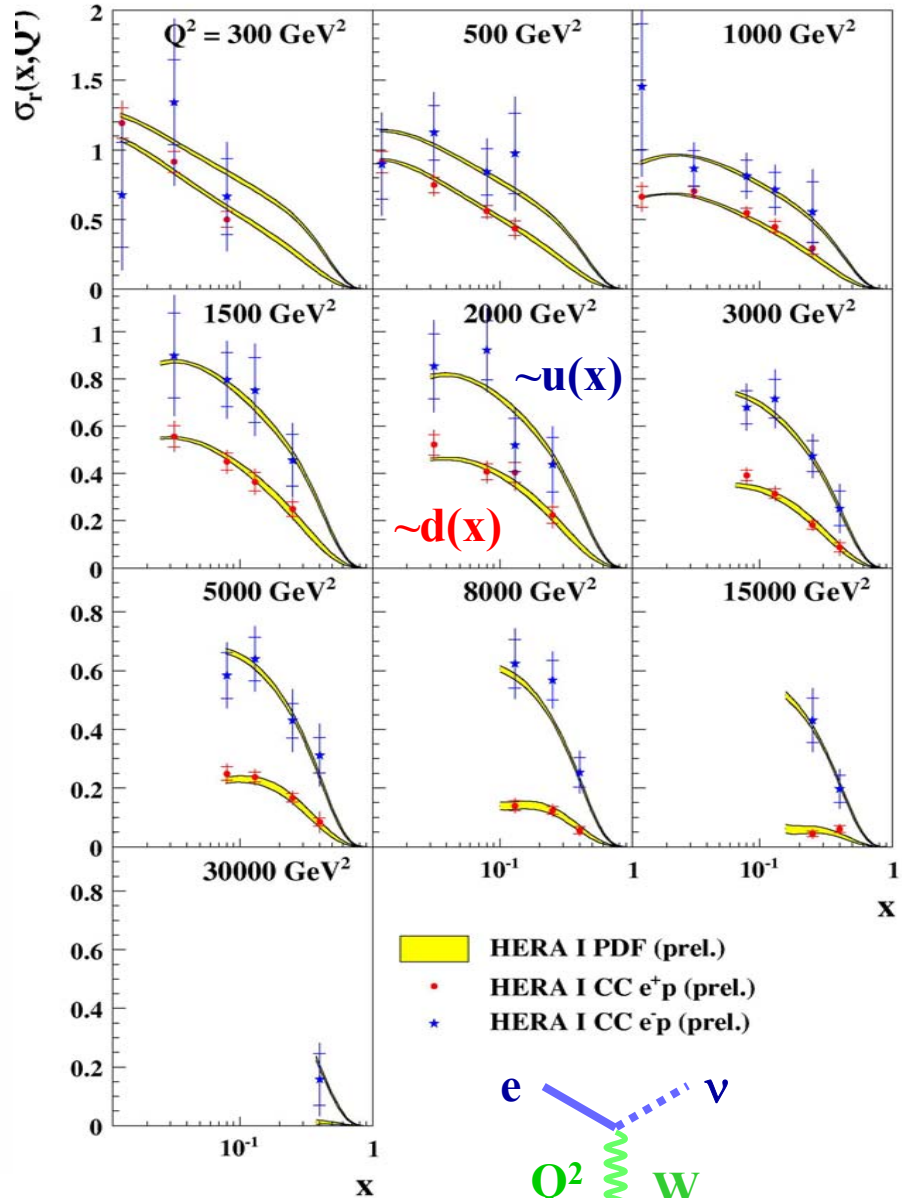
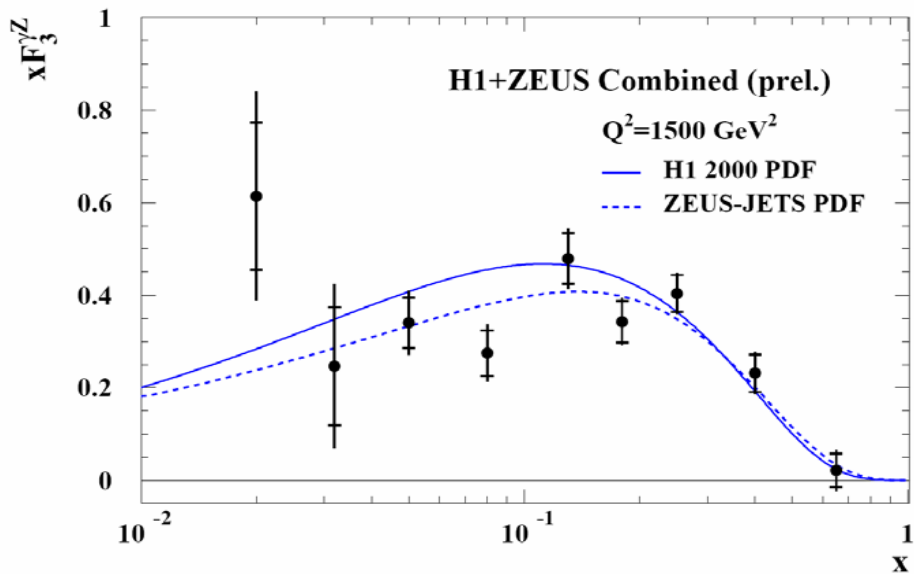
$$\sigma_{CC}(e^+ p) \propto x[(1 - y^2)(d + s) + (\bar{u} + \bar{c})] \quad \times (1 + P_e)$$

$$\sigma_{CC}(e^- p) \propto x[(u + c) + (1 - y^2)(\bar{d} + \bar{s})] \quad \times (1 - P_e)$$

PROTON STRUCTURE: valence quarks



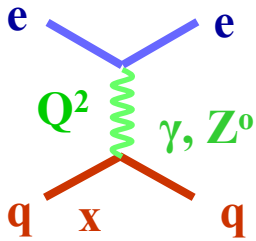
$$xF_3 \sim \sigma(e^-) - \sigma(e^+) \\ \sim (2u_v + d_v)$$



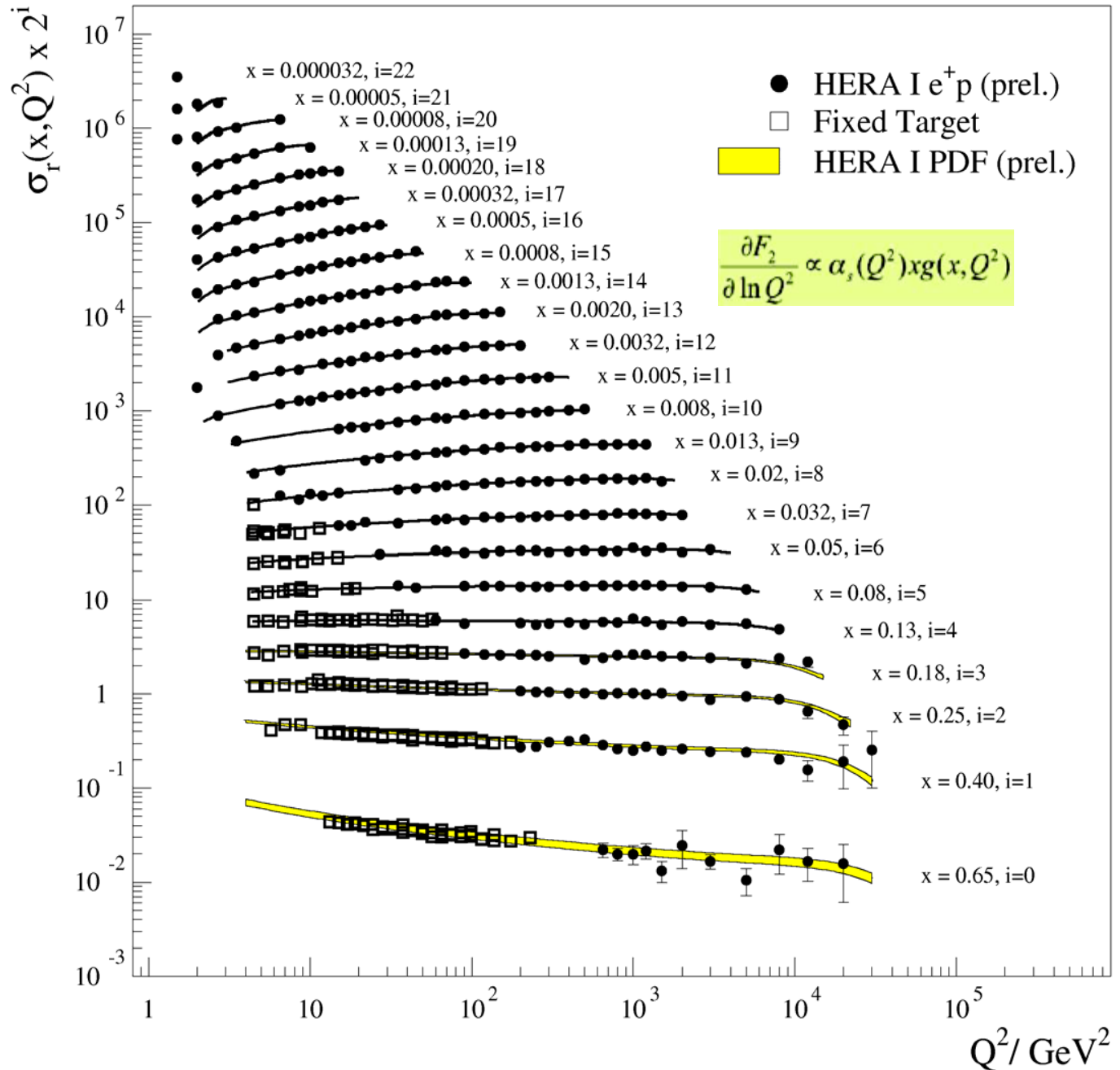
PROTON STRUCTURE:

valence + sea
quarks

$$F_2(x, Q^2)$$



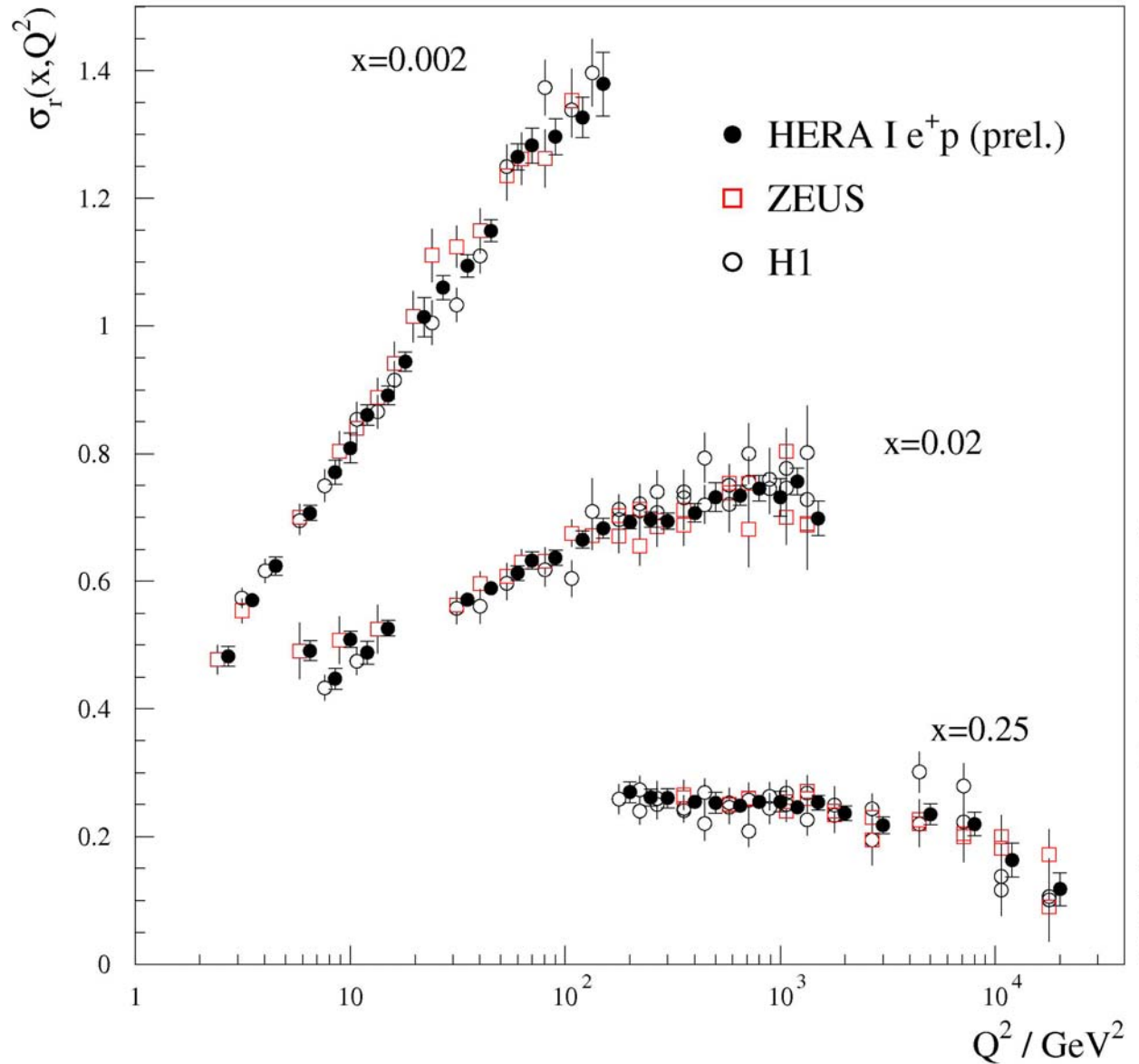
DGLAP works
on a very large
phase space !



***PROTON
STRUCTURE:***

*the power of
combining*

**Systematic
uncertainties
reduced together
with statistical errors**

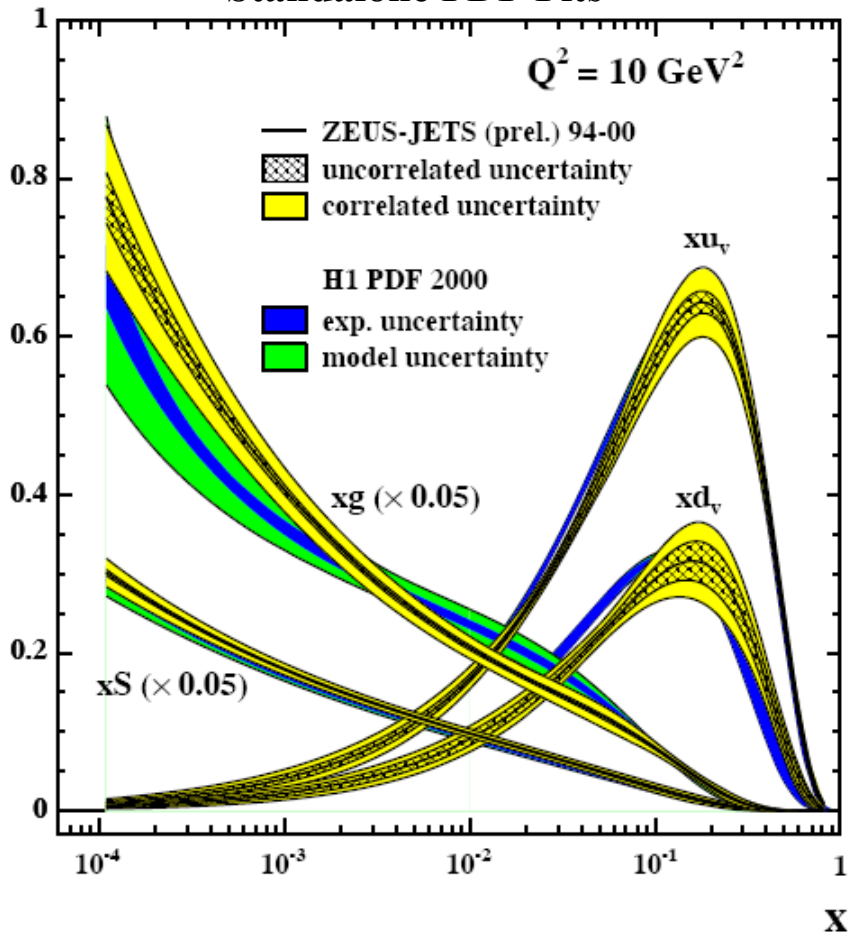


HERA Structure Functions Working Group

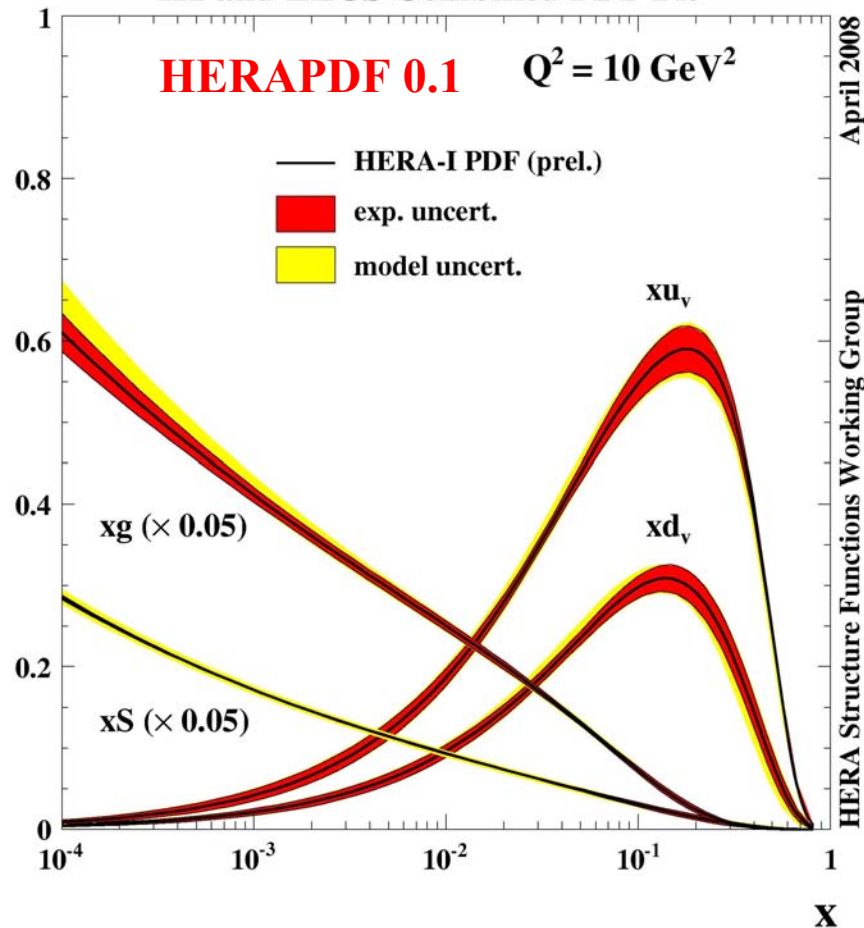
Extracting the essence of Structure Functions

Common PDF Fit on HERA I combined data

Standalone PDF Fits



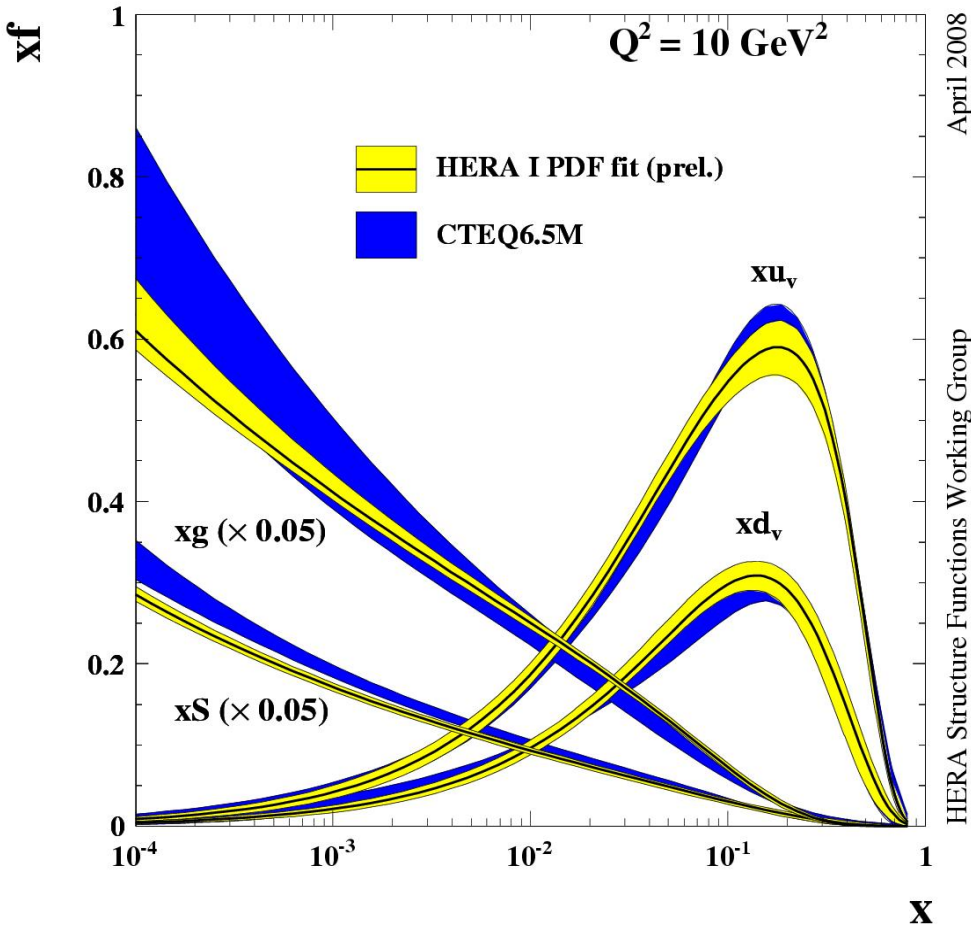
H1 and ZEUS Combined PDF Fit



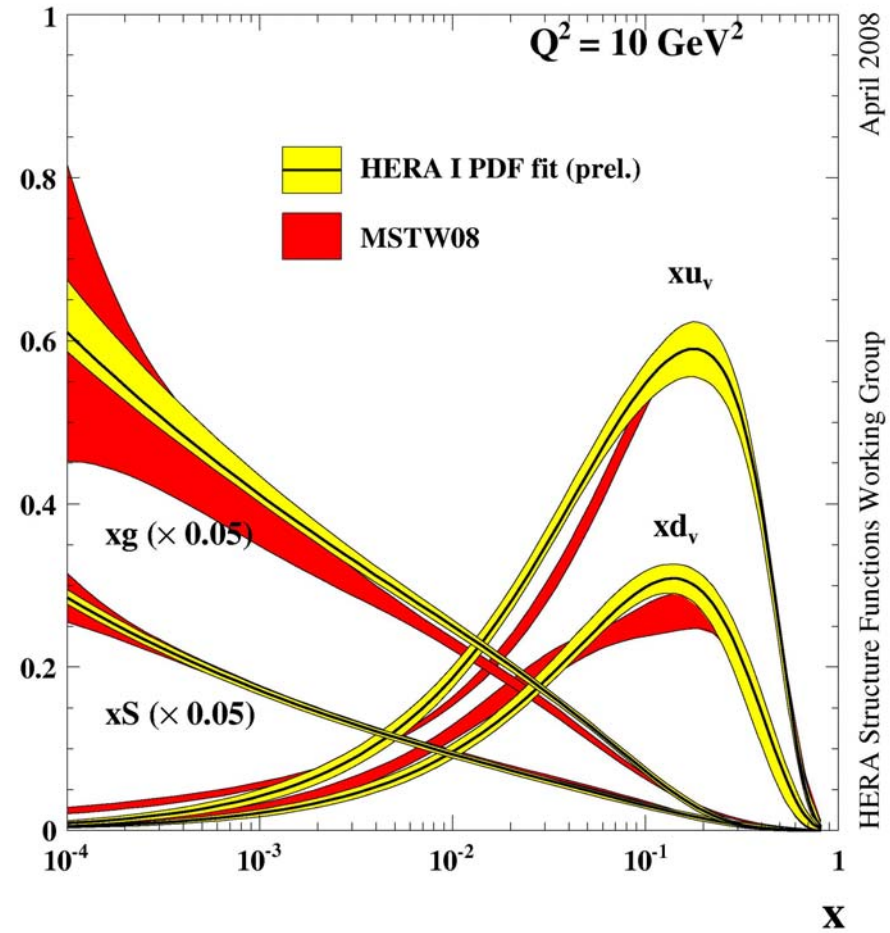
HERAPDF0.1 *versus* CTEQ and MSTW

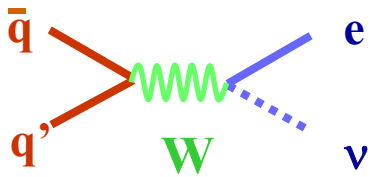
Uncertainty on low-x gluon and sea strongly reduced

H1 and ZEUS Combined PDF Fit



H1 and ZEUS Combined PDF Fit

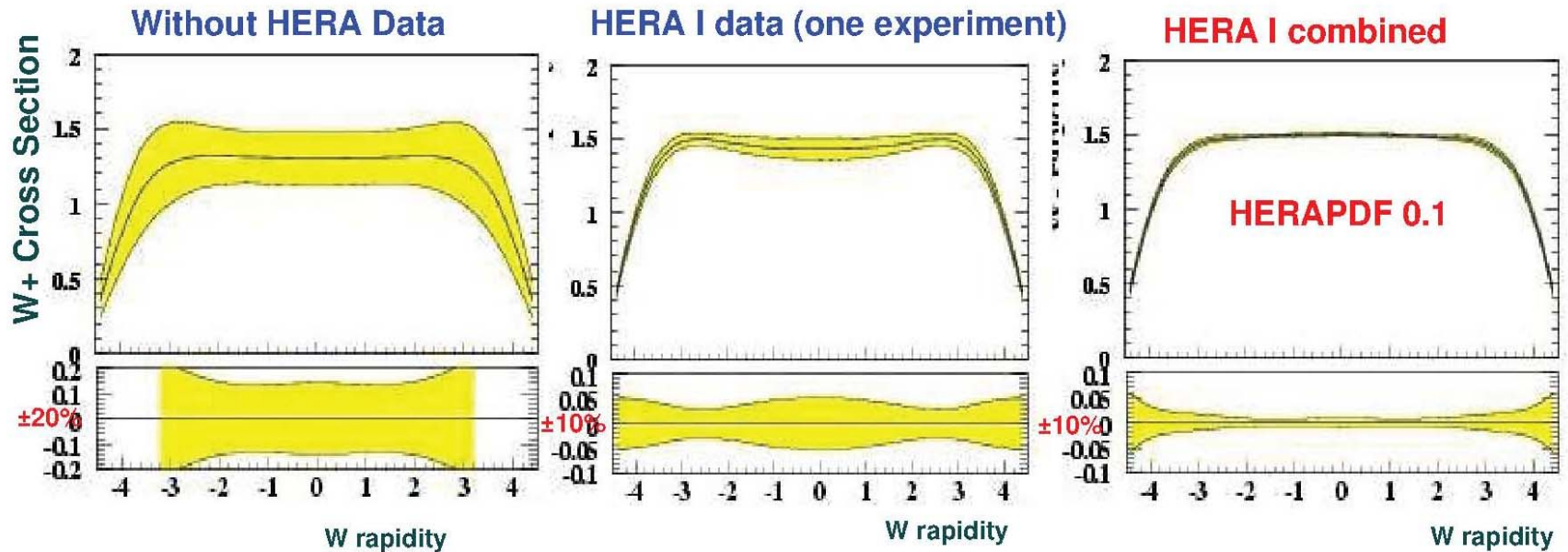




HERAPDF0.1 *impact on LHC*

The example of W production

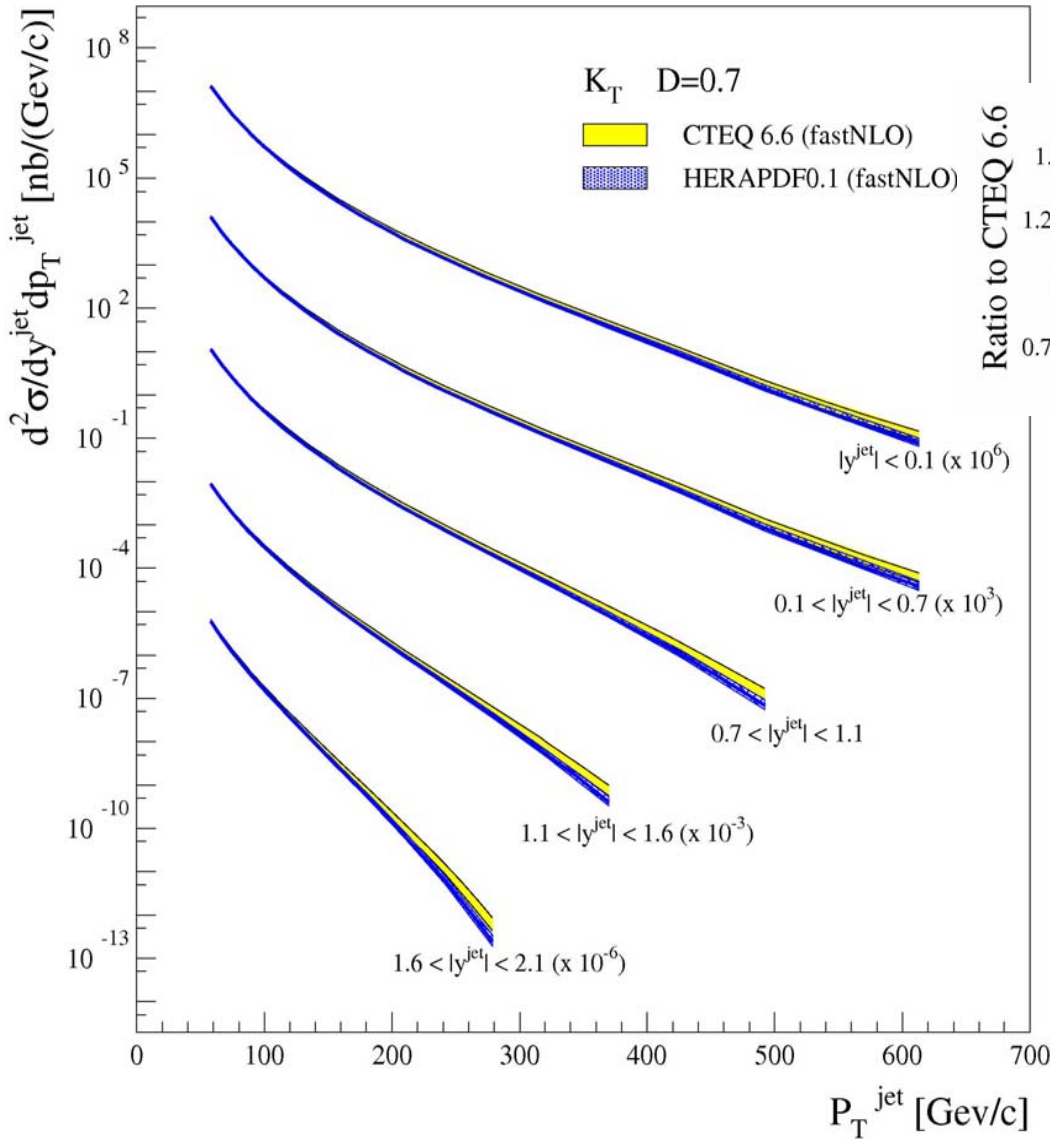
M. Cooper / E. Perez



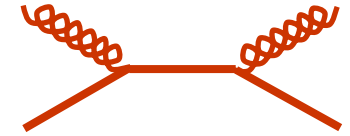
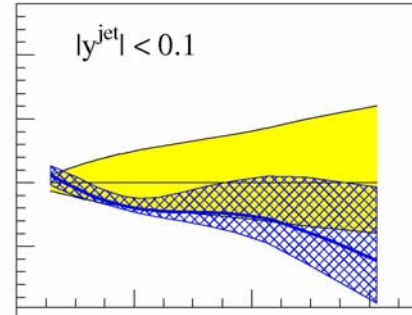
HERAPDF0.1 being publicly released in LHAPDF (version 5.5.x)

...to be exercised by the LHC experiments !

Tevatron Jet Cross Sections



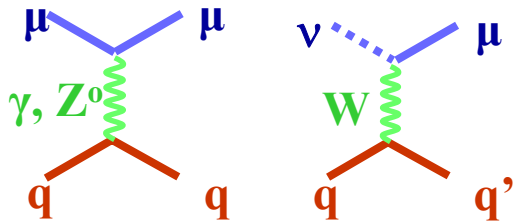
HERAPDF0.1 *impact on LHC* the gluon at high x



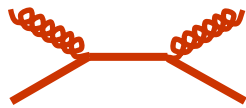
Brand new preliminary results from E. Tassi based on a pre-release in LHAPDF

Reasonable behaviour at high x though no input from Tevatron High- P_T jets in the fit

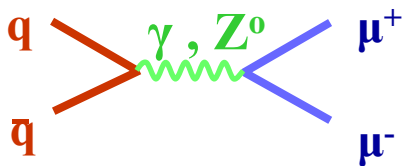
COMPLEMENTARY INPUTS to the PROTON PDF's



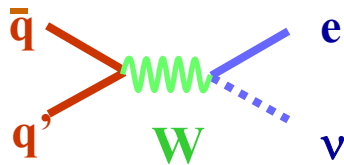
Fixed Target NC/CC
→ high-x quarks



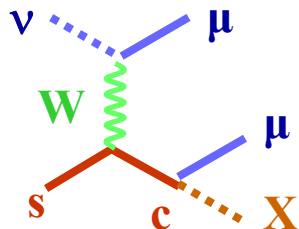
Tevatron High- P_T jets
→ high-x gluon



Fixed Target Drell-Yan
→ high-x antiquarks and \bar{u}/\bar{d} asymmetry

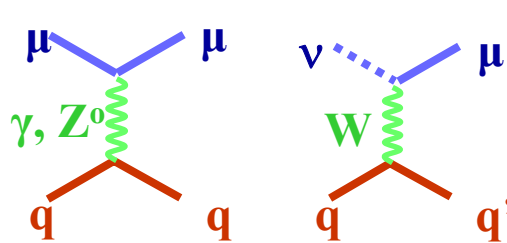


Tevatron W^+/W^-
→ u/d asymmetry at high x



Dimuons in Fixed Target CC
→ strange sea

COMPLEMENTARY INPUTS to the PROTON PDF's (personal comments)



Fixed Target NC/CC

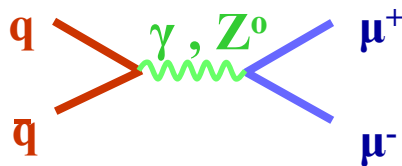
Nuclear corrections (CC) and possible Higher Twists (low Q^2)

Still needed with final HERA II high Q^2 NC/CC ?



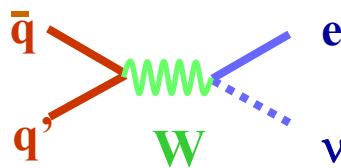
Tevatron High- P_T jets

Still needed with high precision HERA F_2 + jets ?



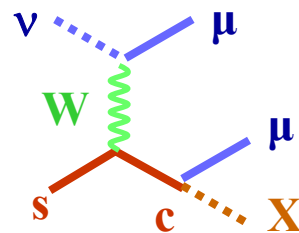
Fixed Target Drell-Yan

Nuclear corrections same as in DIS ?



Tevatron W^+/W^-

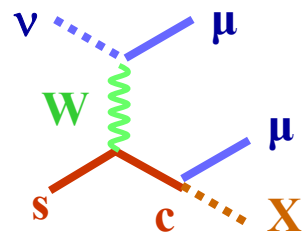
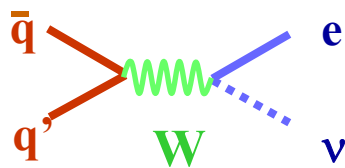
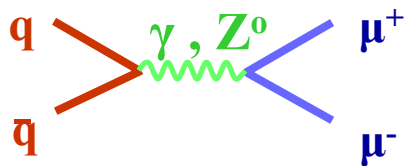
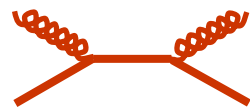
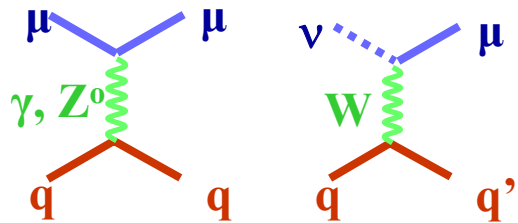
Special data will stay necessary for subtle asymmetry effects



Dimuons in Fixed Target CC

Increased tolerance needed in global fits

→ minimize number of experiments



TOWARDS OPTIMAL PROTON PDF's FOR LHC

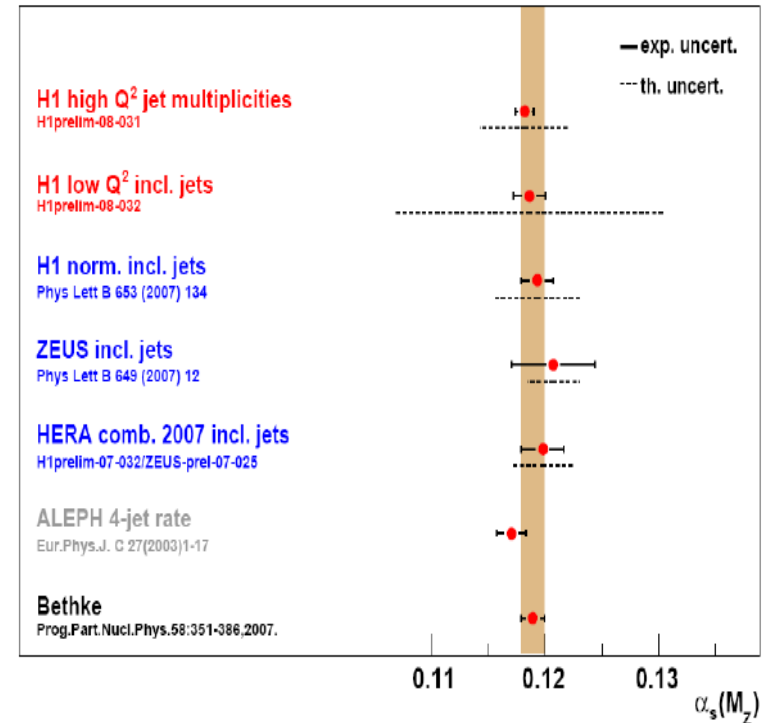
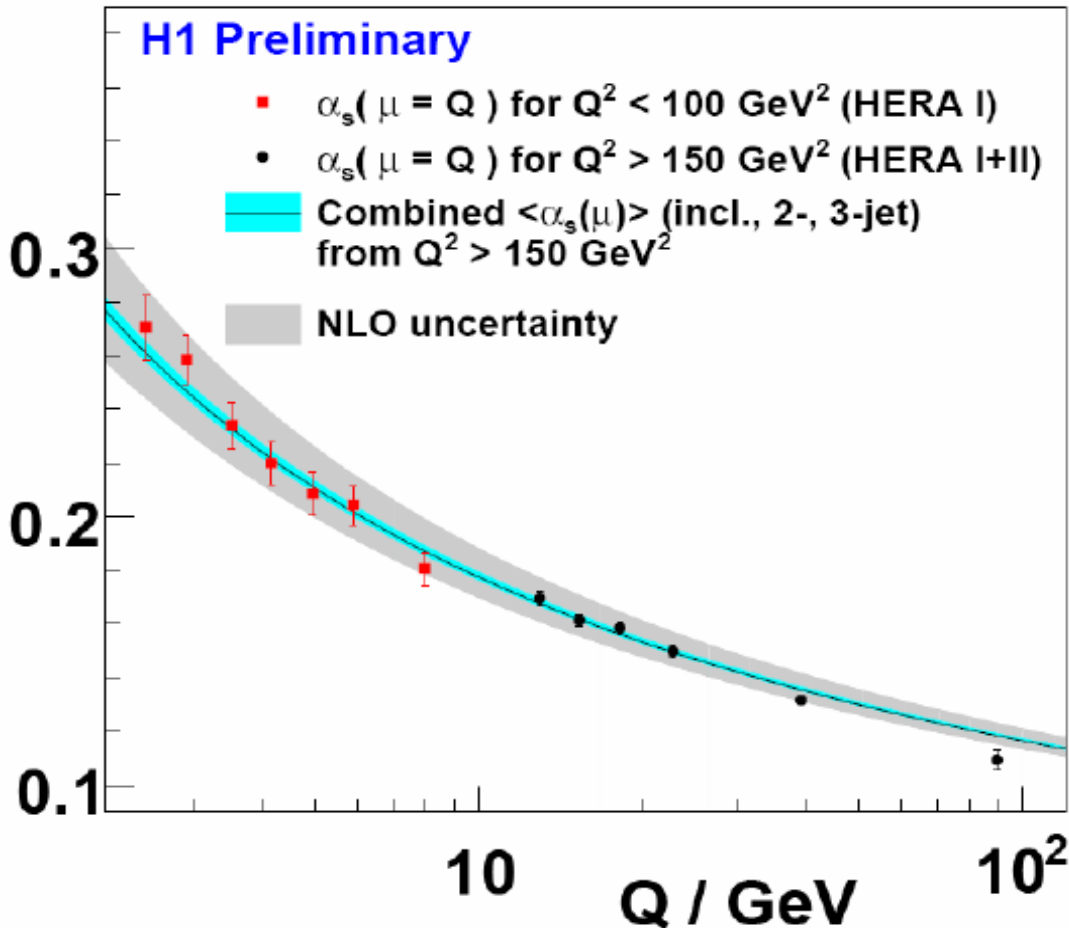
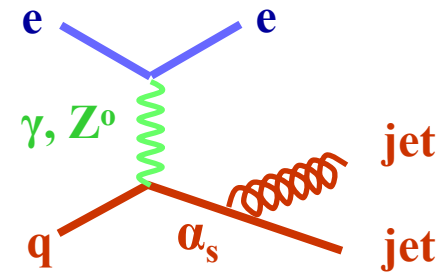
**In the era of
high precision HERA results**

*optimal inputs for LHC PDF's
and
PDF model uncertainties*

**are essential questions
to be addressed by the
PDF4LHC workshop**

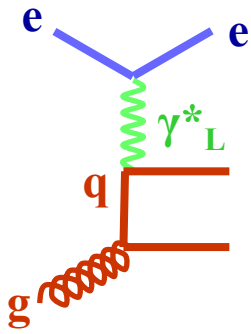
QCD Dynamics:

the strong coupling α_s from multi-jet rates



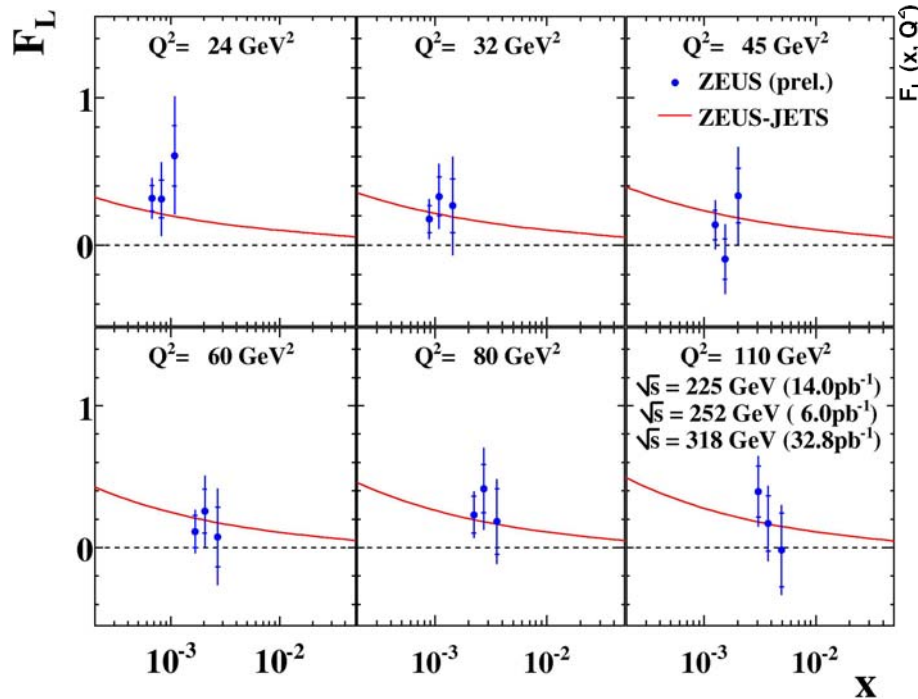
**HERA exp. error $\sim 0.7\%$
a challenge for theory !**

QCD Dynamics: directly probing the gluon with F_L



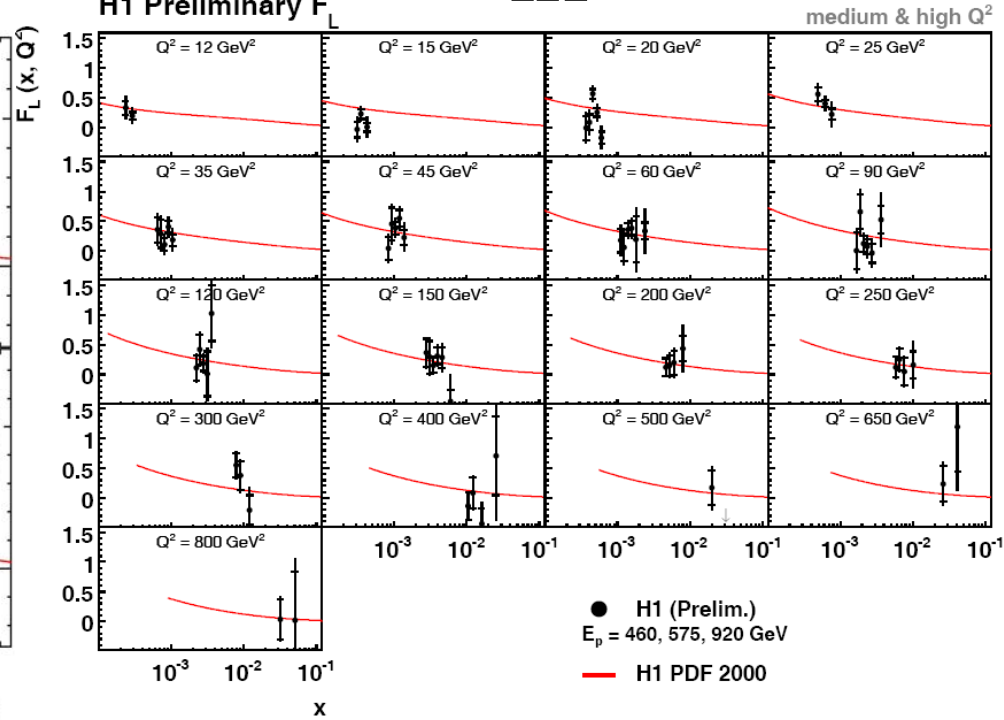
$$\tilde{\sigma}_{NC} = \frac{d^2\sigma_{NC}^{ep}}{dx dQ^2} / \left(\frac{2\pi\alpha^2}{xQ^4} Y_+ \right) = F_2 - \frac{y^2}{1+(1-y)^2} F_L \quad \mathbf{y = Q^2/sx}$$

ZEUS

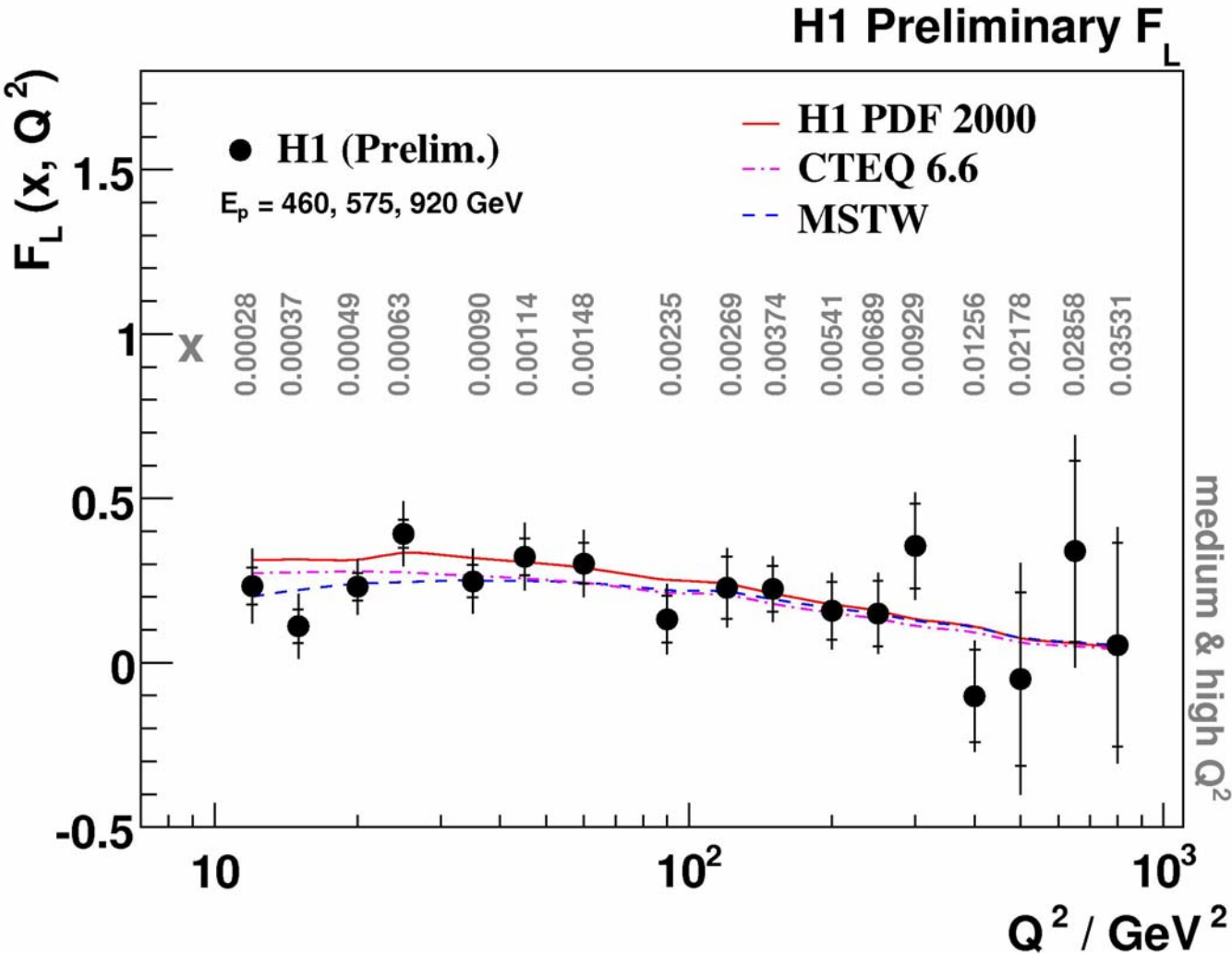


H1

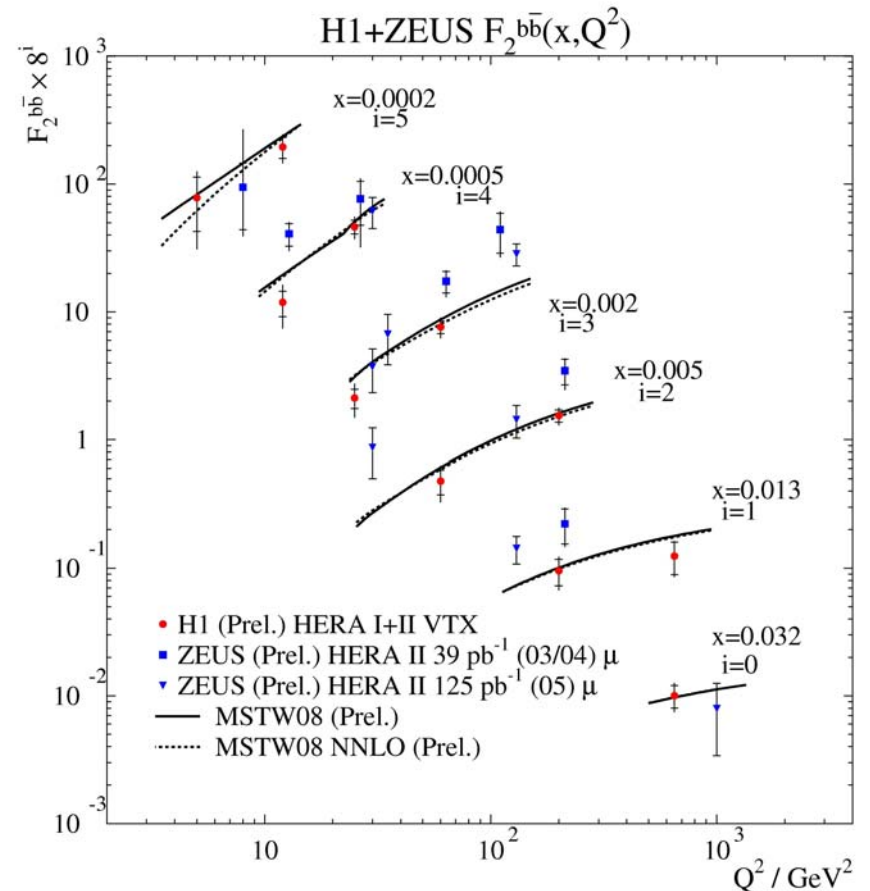
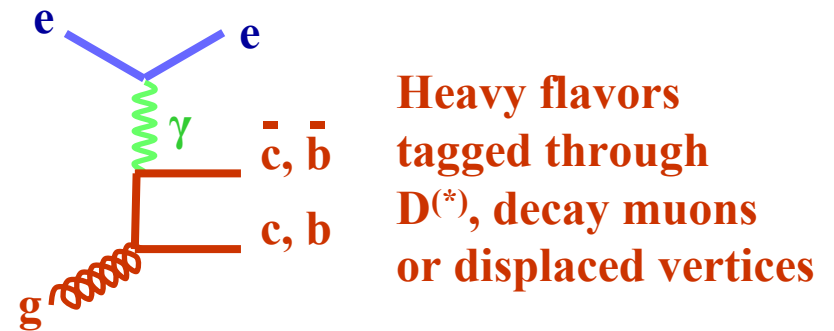
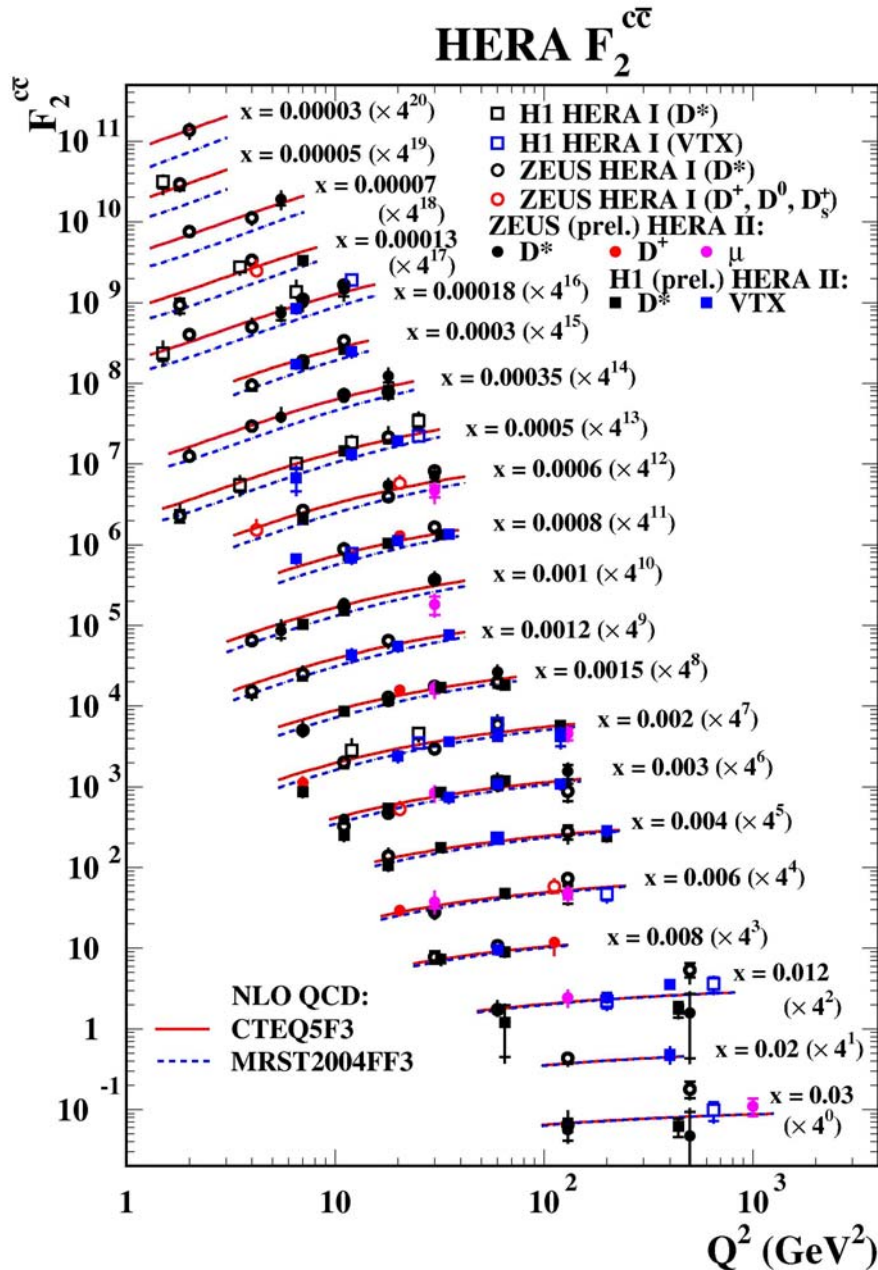
H1 Preliminary F_L



QCD Dynamics: F_L compatible with NLO DGLAP predictions



QCD Dynamics: Heavy Quark generation well described by DGLAP



Paving the way to optimal LHC PDF's



**DGLAP OK so far, more
to come from Inc+HF+Jets fits**

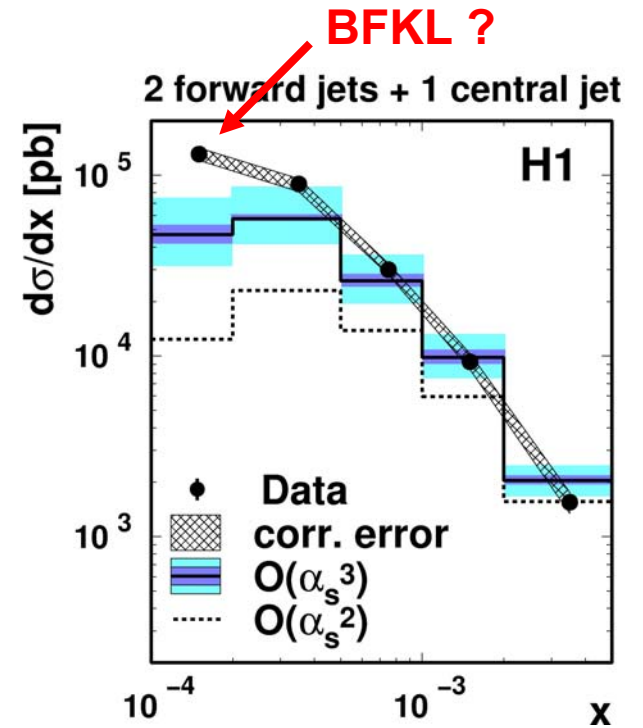
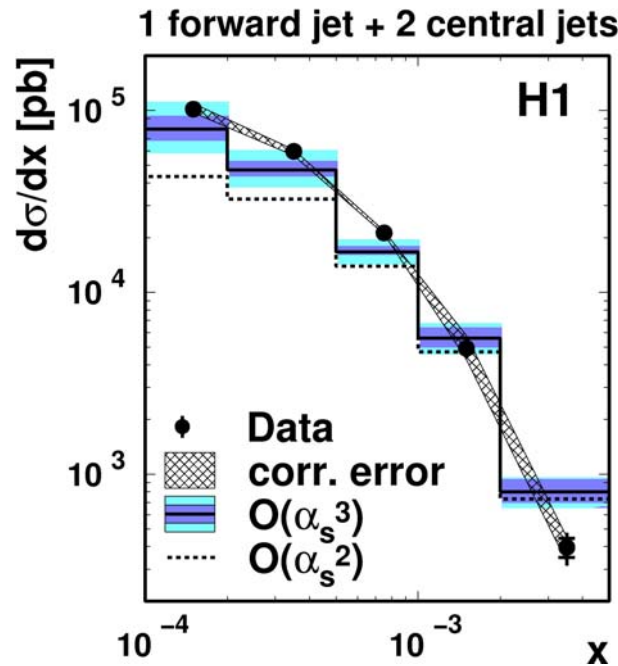
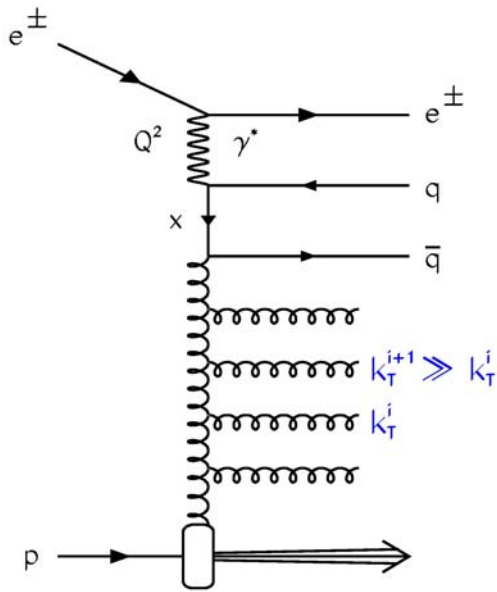
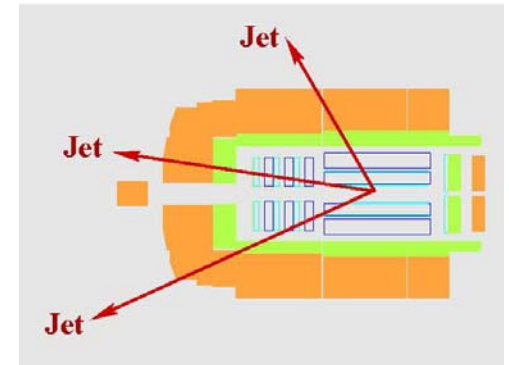
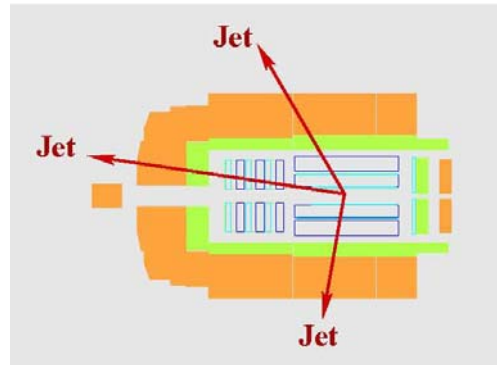
**Next breakthrough expected
at high x from final HERA II High Q^2 data**

**Recent breakthrough in precision at low x
from H1-ZEUS combinations**

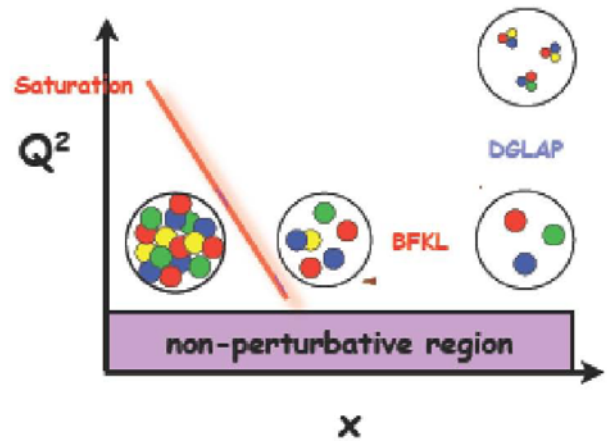


Some more on QCD dynamics

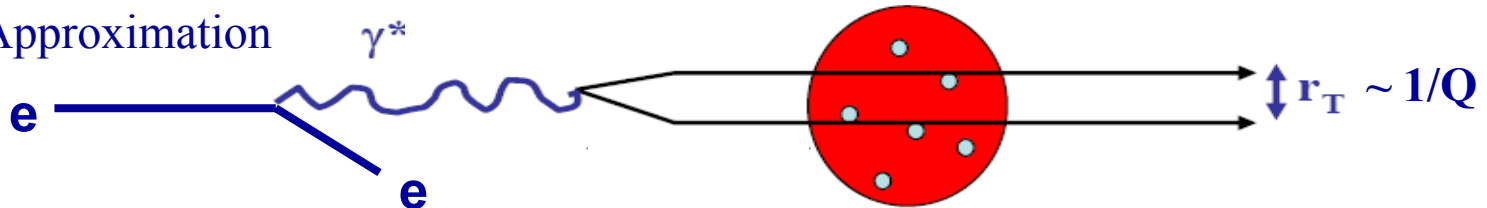
QCD Dynamics: probing DGLAP with multijets at low x



***QCD Dynamics:
the very low x / low Q² limit***



Williams-Weizsäcker
Approximation



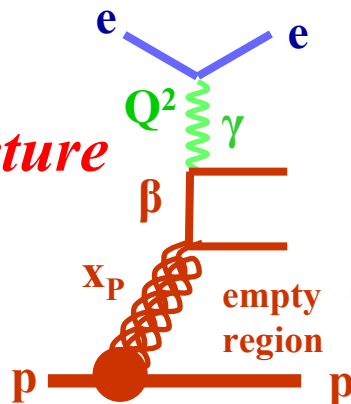
$$d\sigma_{ep}/dydQ^2 \sim \Phi_{\gamma^*}(y, Q^2) \times \sigma_{\gamma^*p}(W^2, Q^2) \quad W^2 \sim Q^2/x$$

$$\alpha/Q^2 [1+(1-y)^2]/y \quad \alpha/Q^2 \times q(x)$$

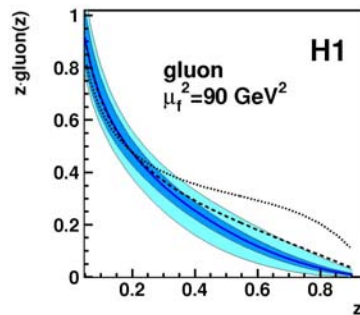
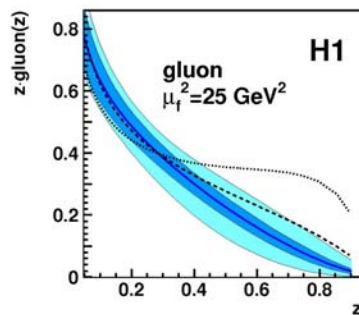
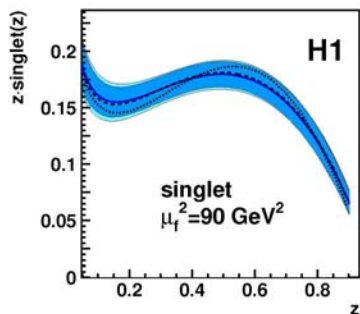
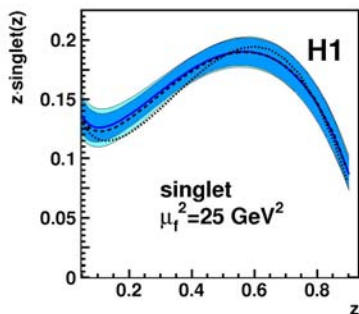
Allows to relate low-x dynamics, deep-inelastic scattering, photoproduction, diffraction and saturation

A wealth of HERA results with vector mesons, DVCS, exclusive and inclusive diffraction

QCD Dynamics: the perturbative structure of Diffraction



- H1 2007 Jets DPDF
- exp. uncertainty
- exp. + theo. uncertainty
- H1 2006 DPDF fit A
- H1 2006 DPDF fit B



HERA inclusive diffraction

