Physics at LHC-2008 Split, October 1st 2008

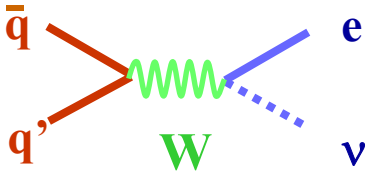
Claude Vallée
CPPM/DESY, on behalf of ZEUS and H1

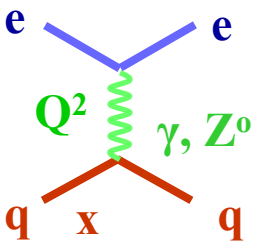
FUNCTIONS

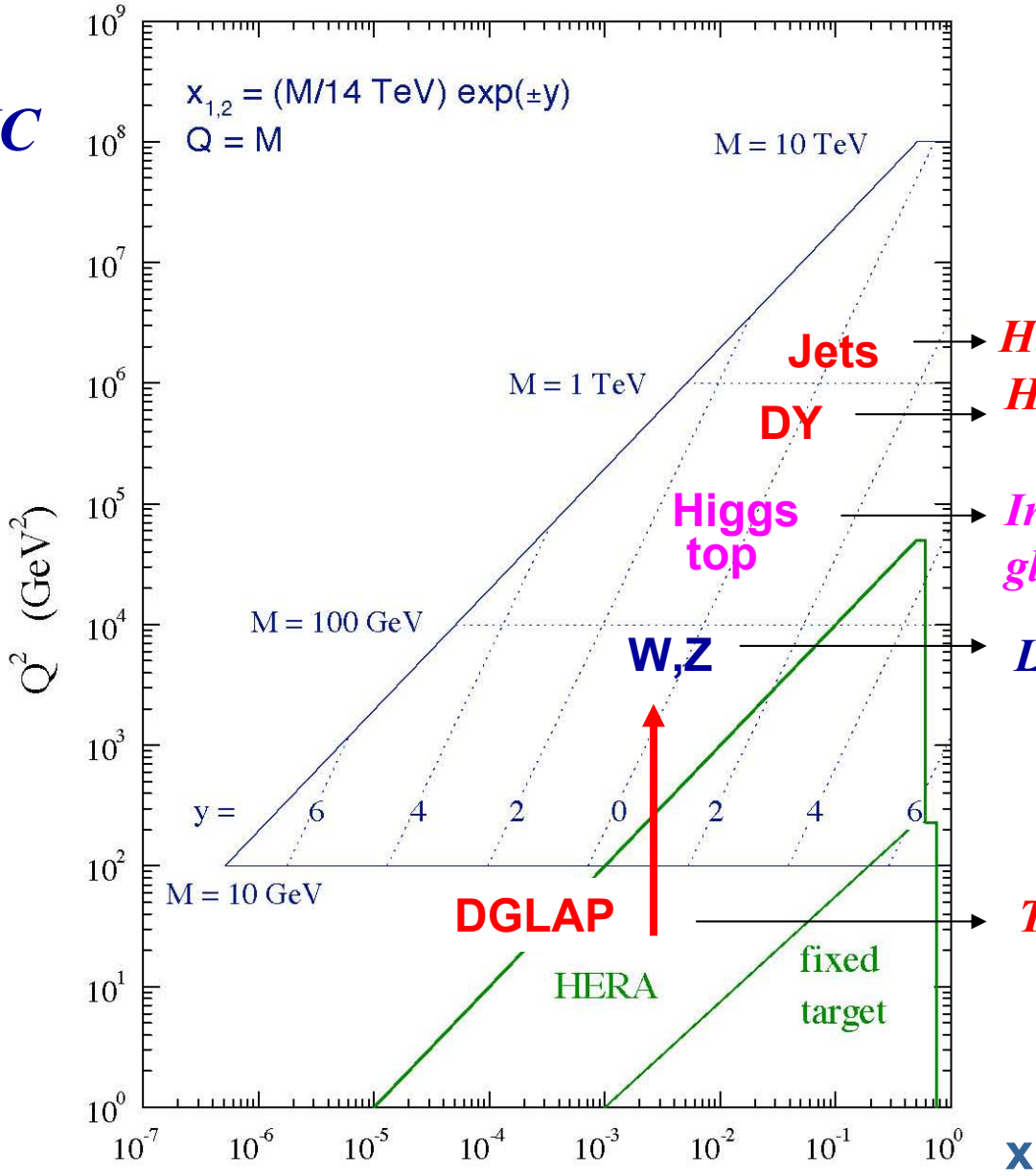
STRUCTURE

H E R A

Kinematics: HERA ↔ LHC







High x quarks/gluon

High x quarks/ antiquarks

Intermediate-x gluon/quarks

Low x gluon/quarks

Test QCD dynamics

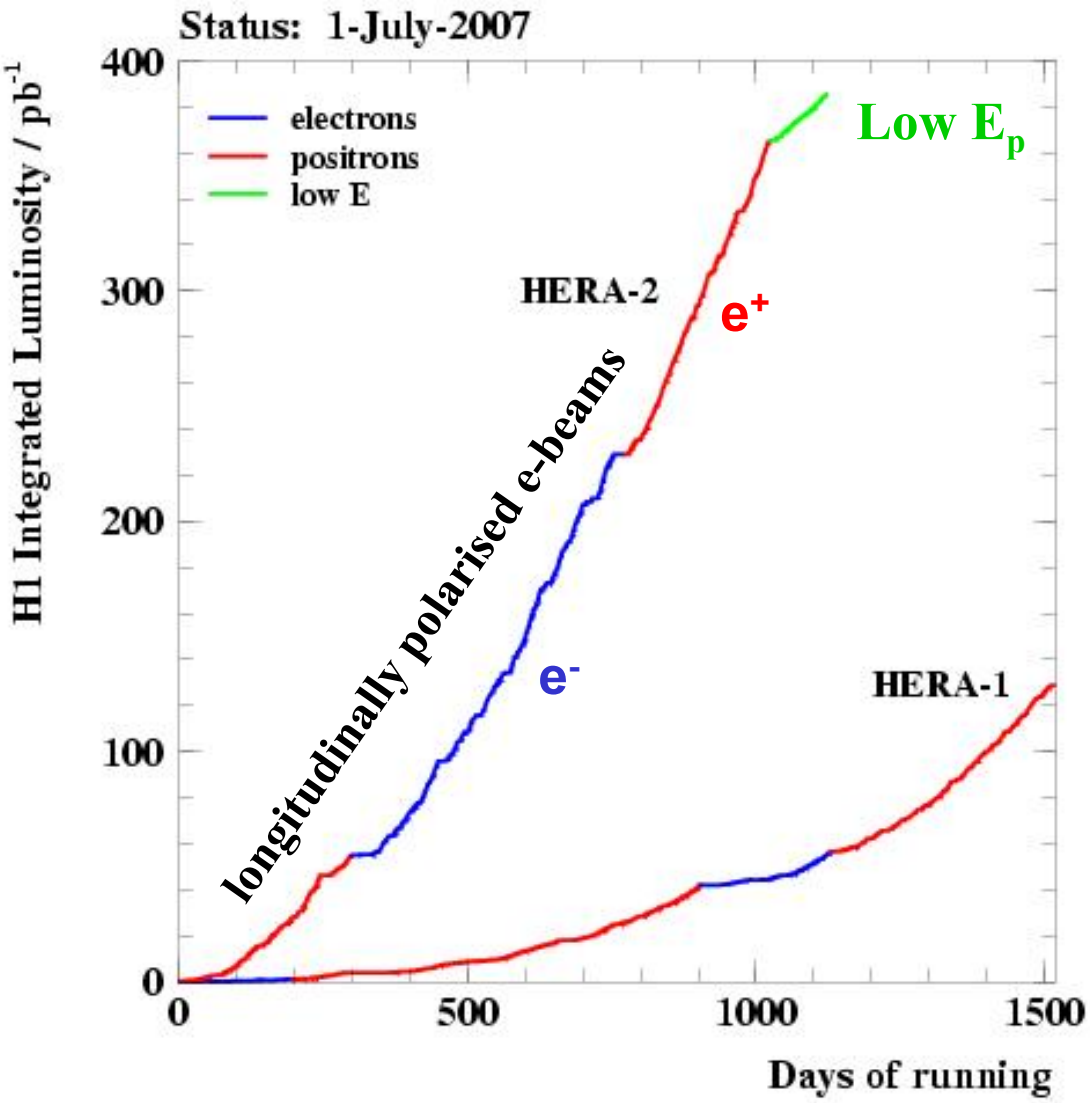
The questions to be answered at HERA

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 ?



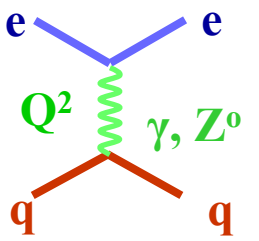
The final HERA data samples

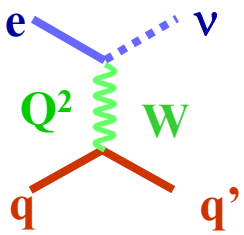
~0.5 fb^{-1} / experiment

balanced e^+p and e^-p samples

~35% polarised e at HERA II

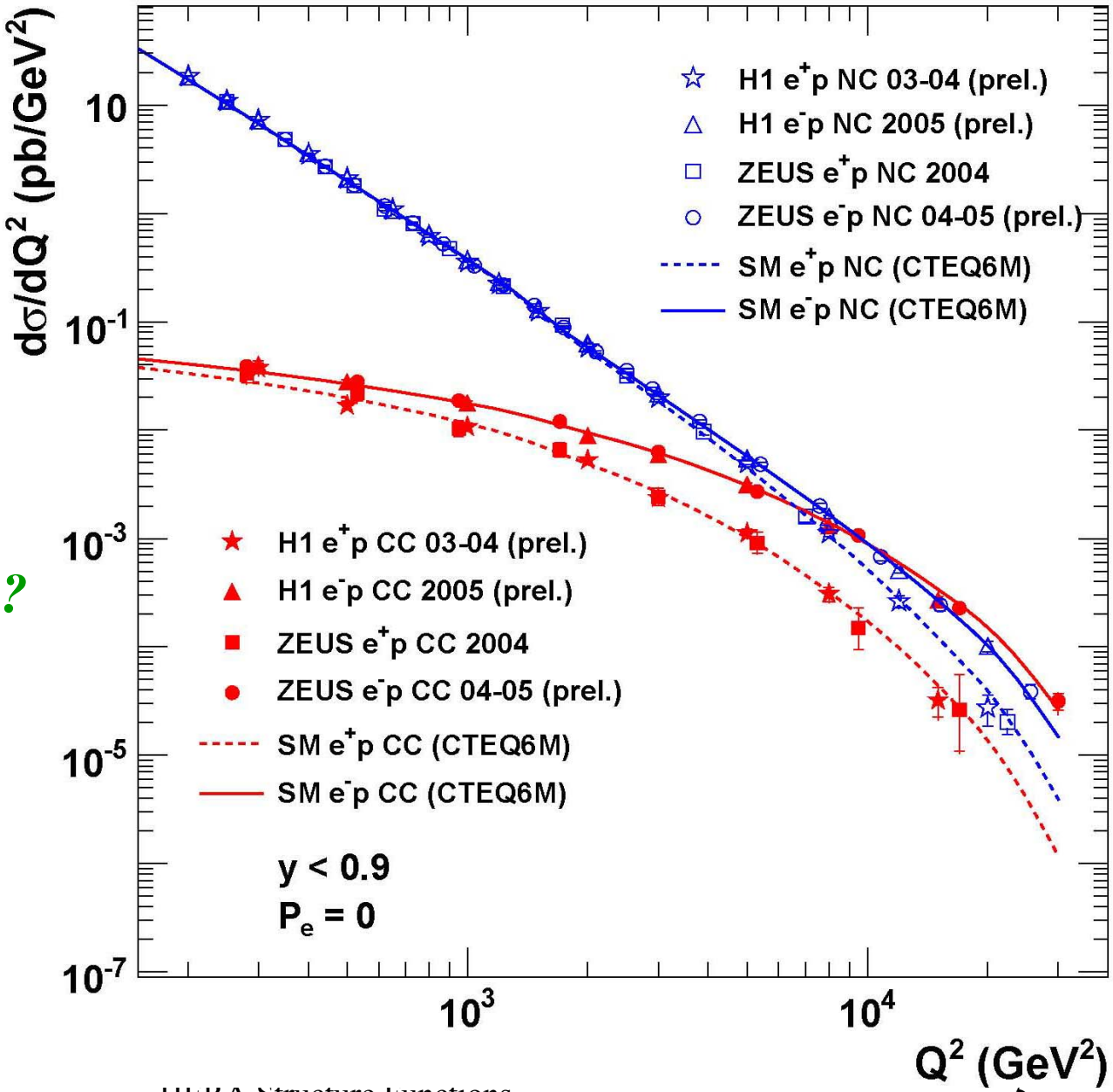
Low-E_p runs for F_L

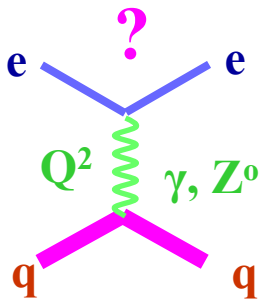




Does the e-probe behave as expected ?

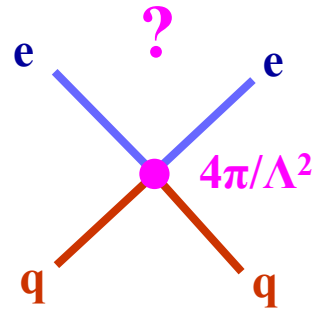
YES!
EW unification in the t-channel at the $M_{W,Z}$ scale



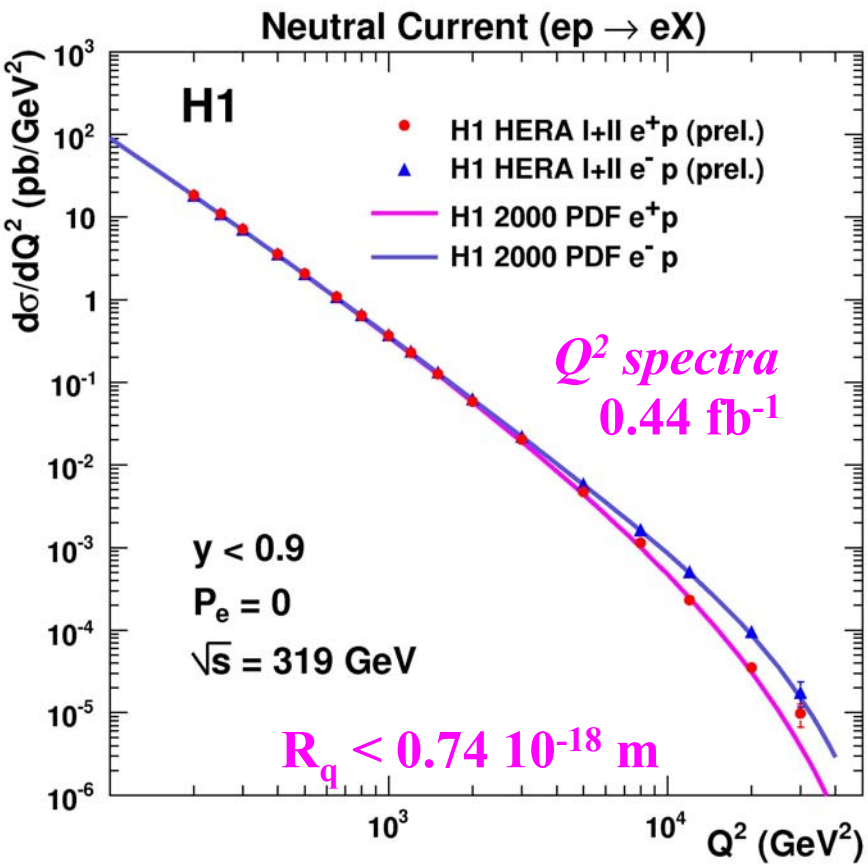


Is the quark point-like ?

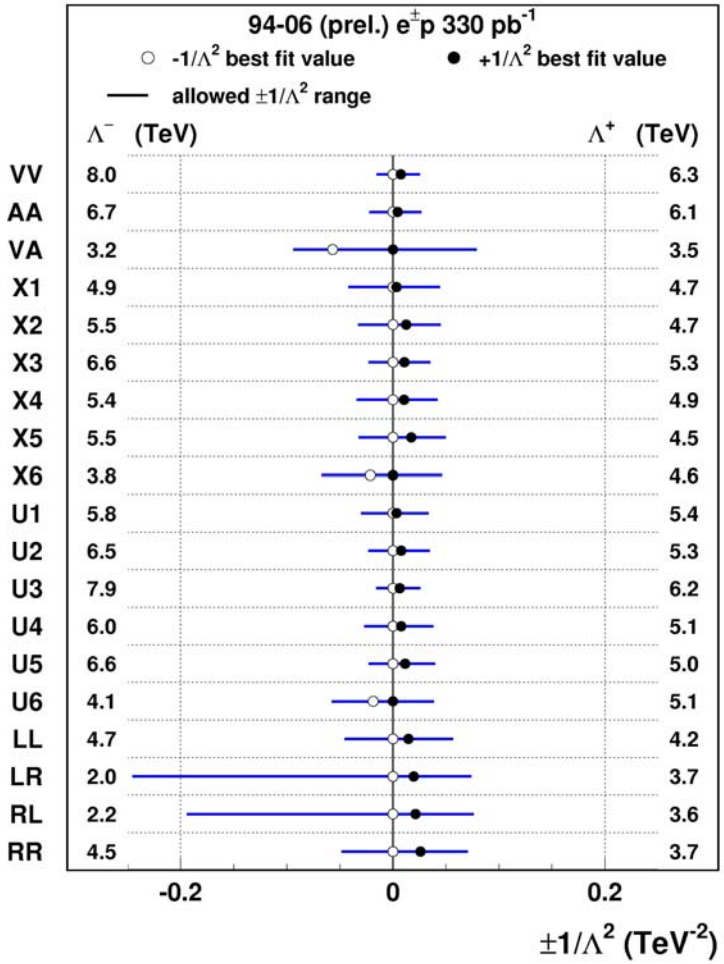
YES! …at the HERA scale



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

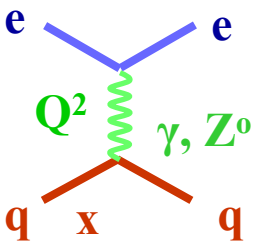


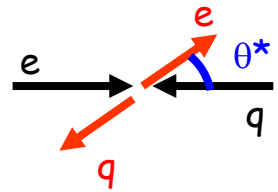
Q^2 spectra
0.44 fb^{-1}



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

MEASURING THE PROTON STRUCTURE





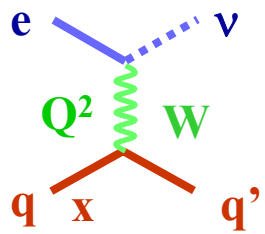
$$\tilde{\sigma}^{\pm}_{NC} = \frac{\mathrm{d}^2\sigma^{e^{\pm}p}_{NC}}{\mathrm{d}x\mathrm{d}Q^2}\frac{xQ^4}{2\pi\alpha^2 Y_+}$$

$$= \tilde{F}_2 - \frac{y^2}{Y_+}\tilde{F}_L \mp \frac{Y_-}{Y_+}x\tilde{F}_3$$

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

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

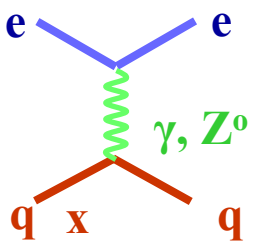
valence + sea quarks | **gluon** | **valence quarks**



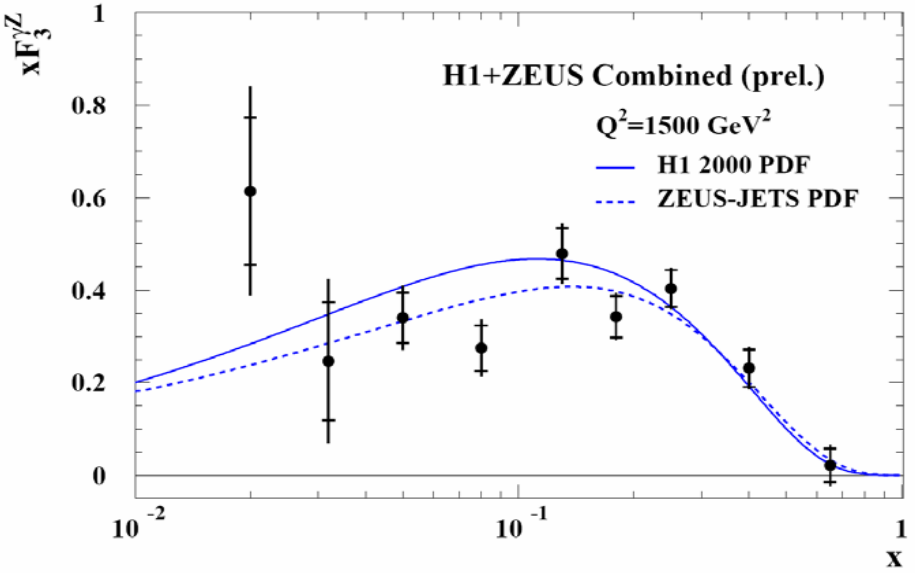
$$\sigma_{CC}(e^+p) \propto x[(1-y^2)(d+s)+(\bar{u}+\bar{c})] \quad \text{x } (1 + P_e)$$

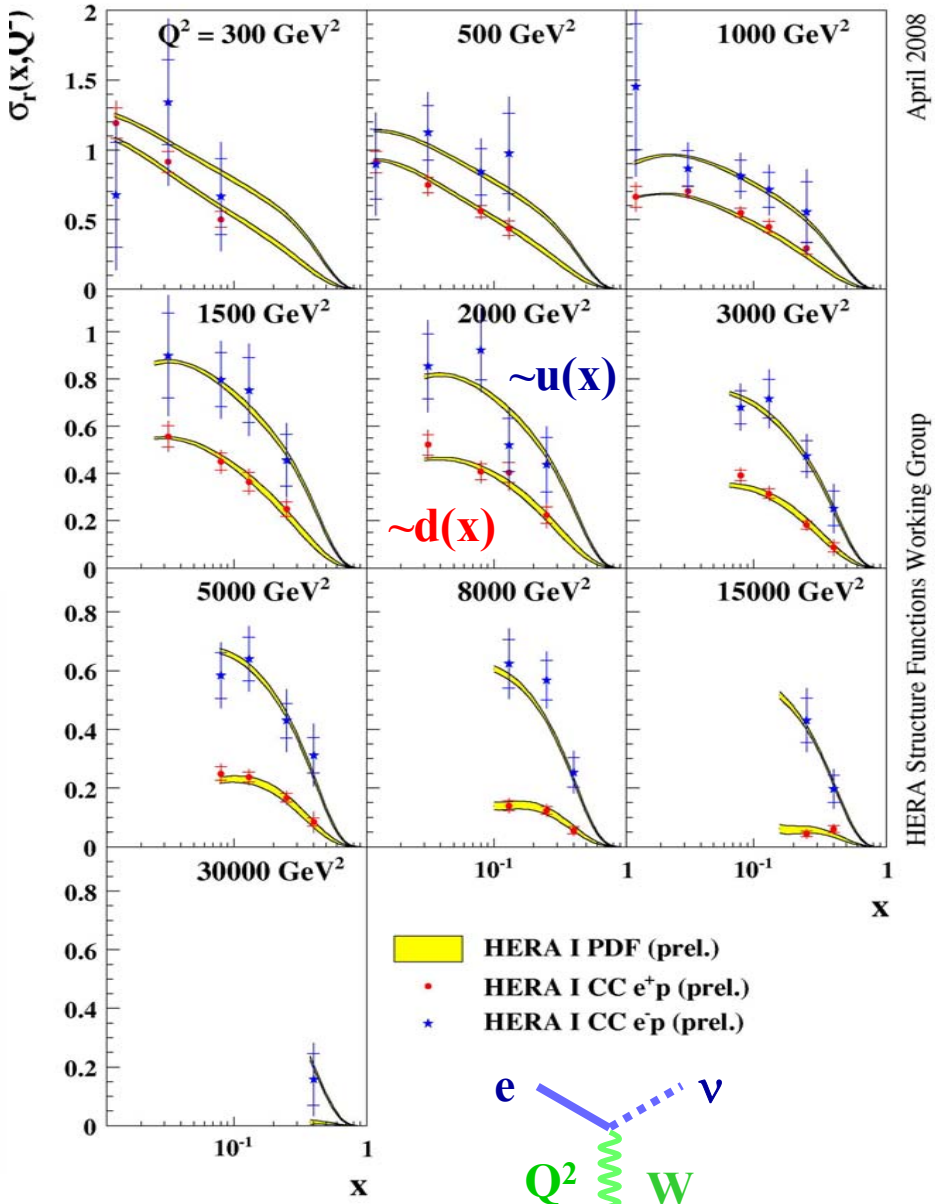
$$\sigma_{CC}(e^-p) \propto x[(u+c)+(1-y^2)(\bar{d}+\bar{s})] \quad \text{x } (1 - P_e)$$

PROTON STRUCTURE:
valence quarks



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

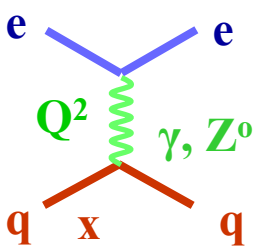




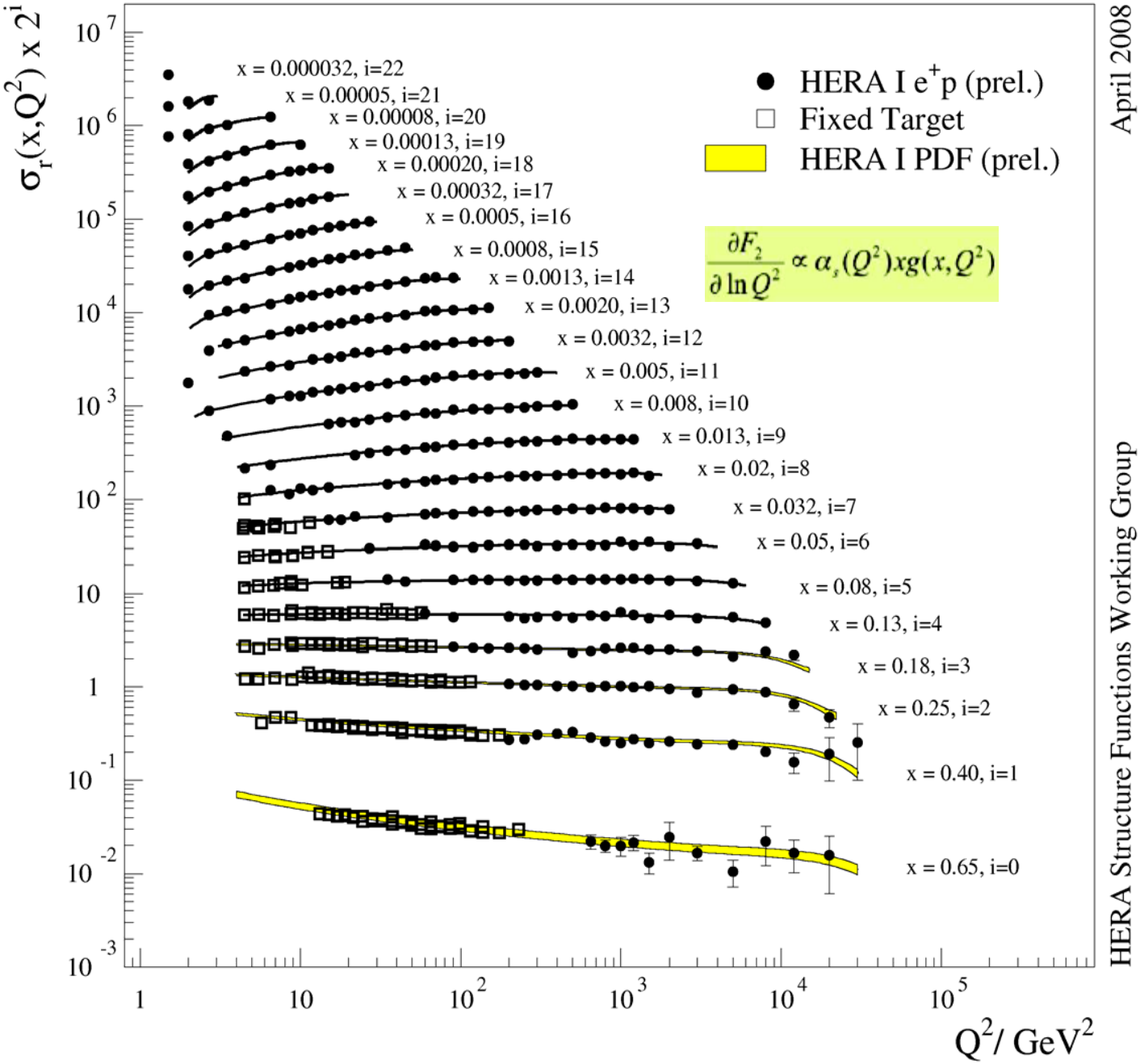
PROTON STRUCTURE:

valence + sea quarks

$F_2(x,Q^2)$



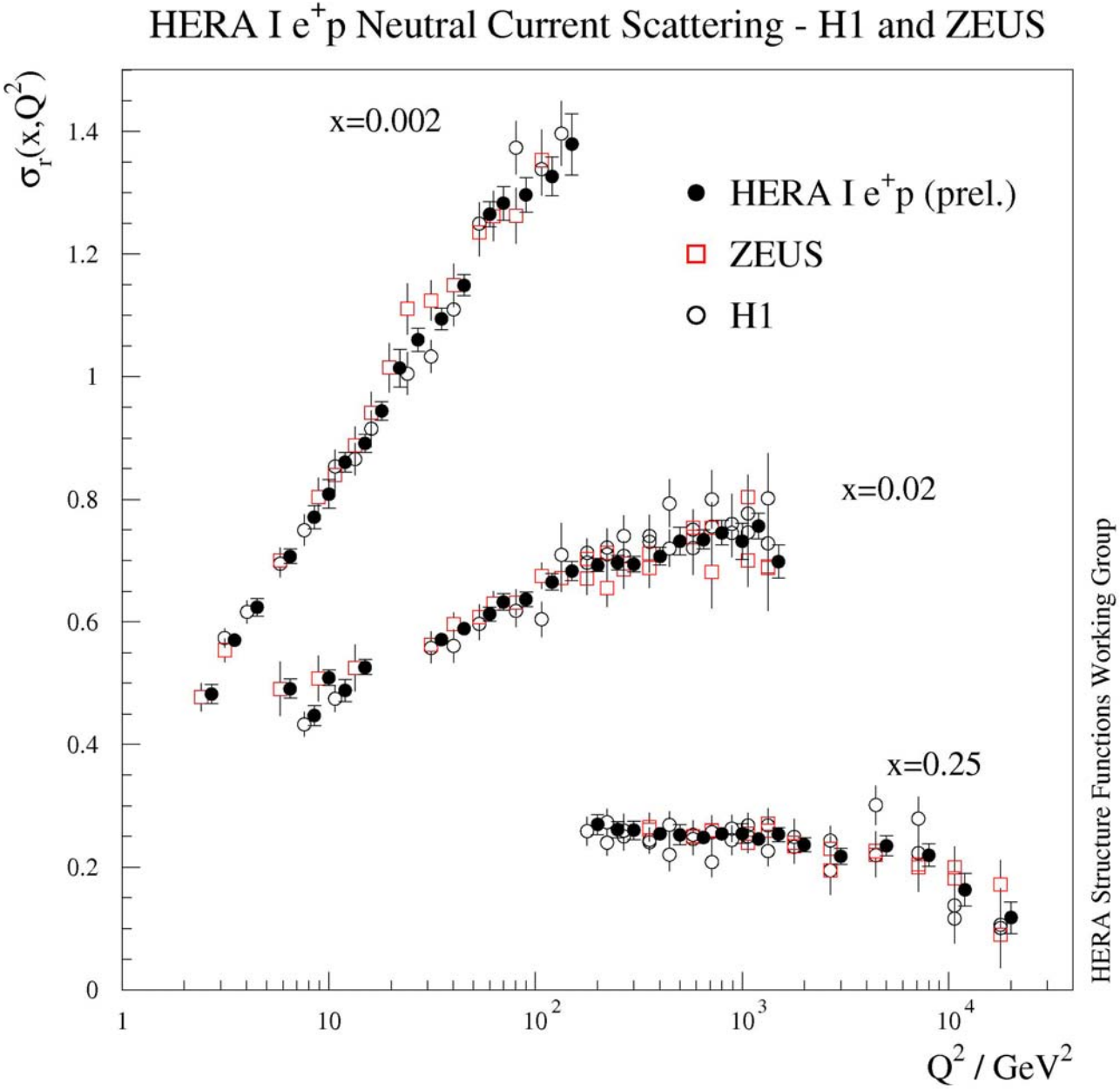
DGLAP works on a very large phase space !



PROTON STRUCTURE:

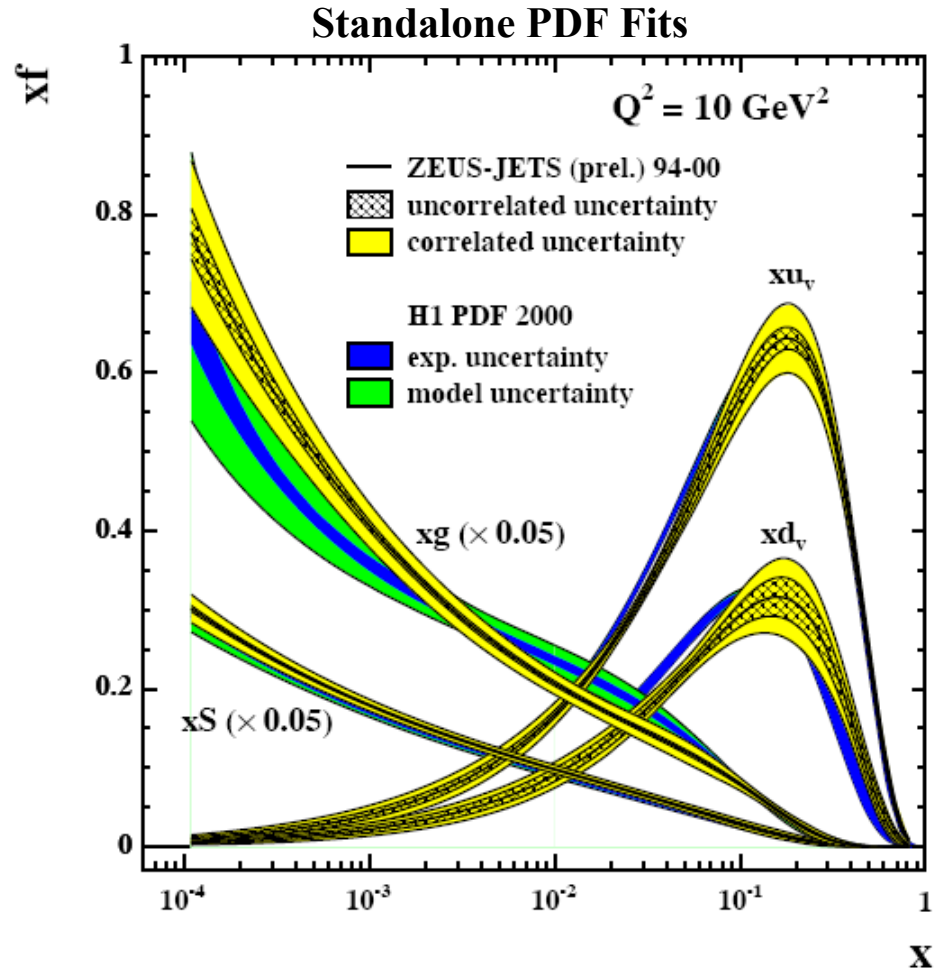
the power of combining

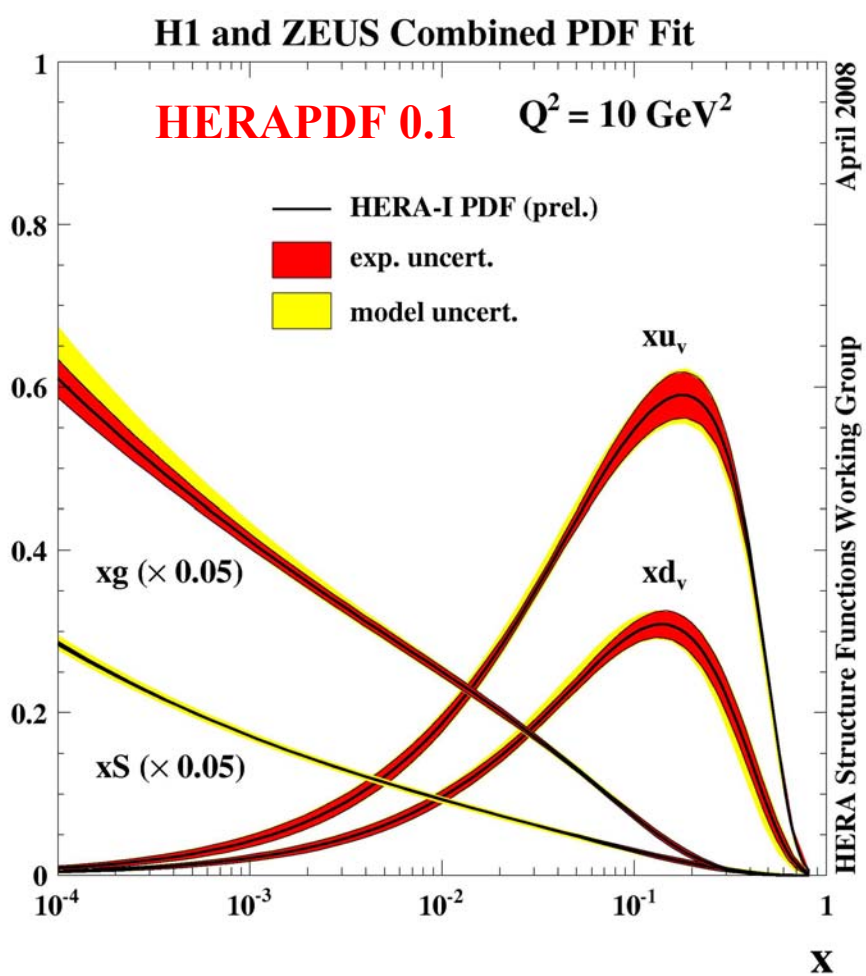
Systematic uncertainties reduced together with statistical errors



Extracting the essence of Structure Functions

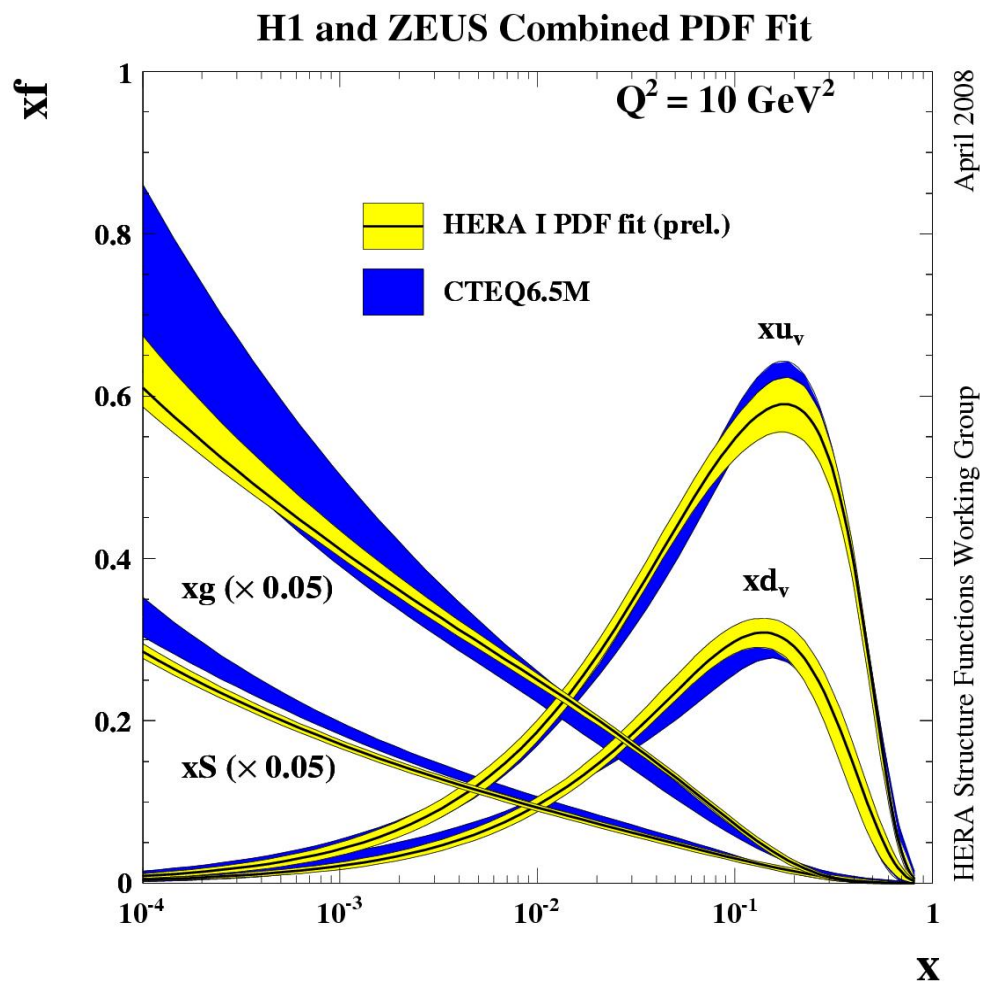
Common PDF Fit on HERA I combined data

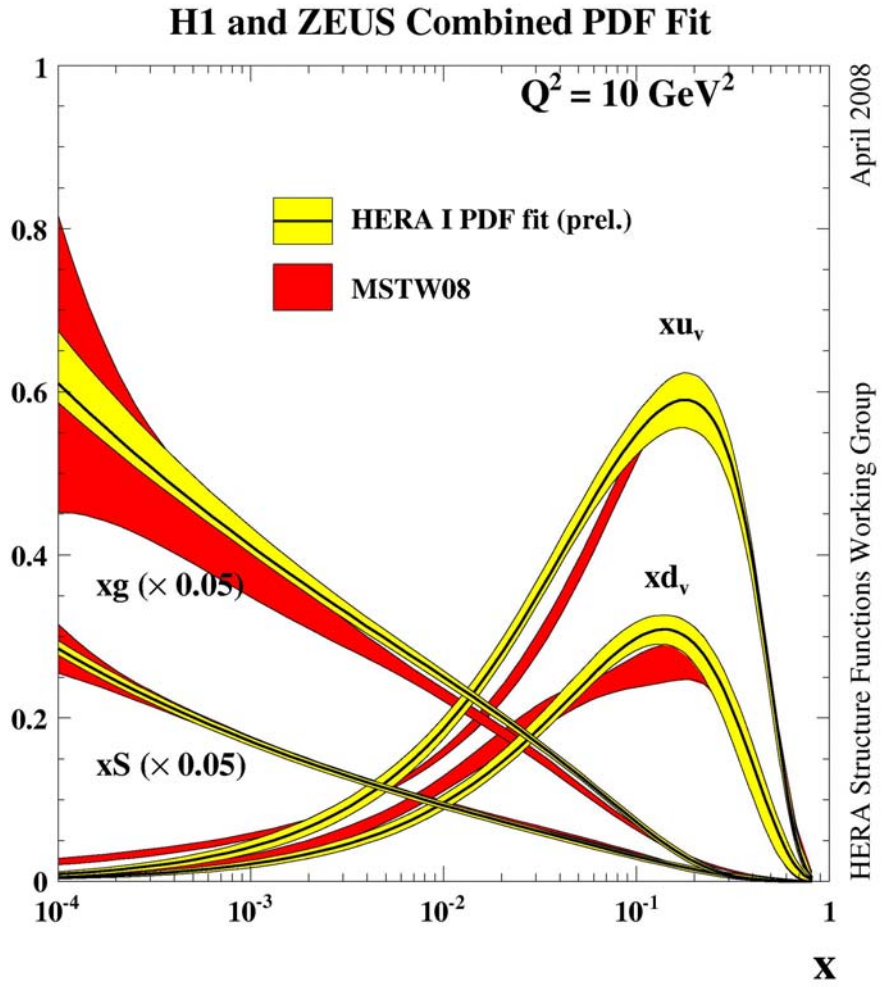


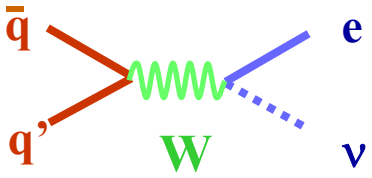


HERAPDF0.1 *versus* CTEQ *and* MSTW

Uncertainty on low-x gluon and sea strongly reduced



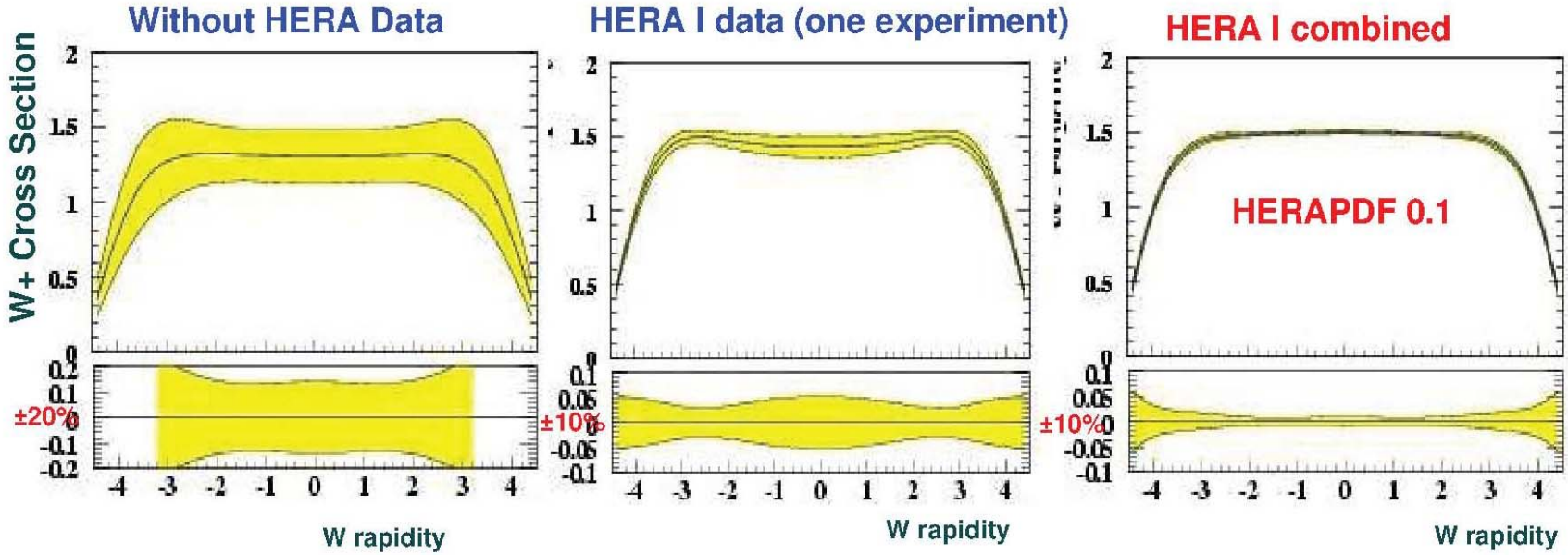




HERAPDF0.1 *impact on* LHC

The example of W production

M. Cooper / E. Perez

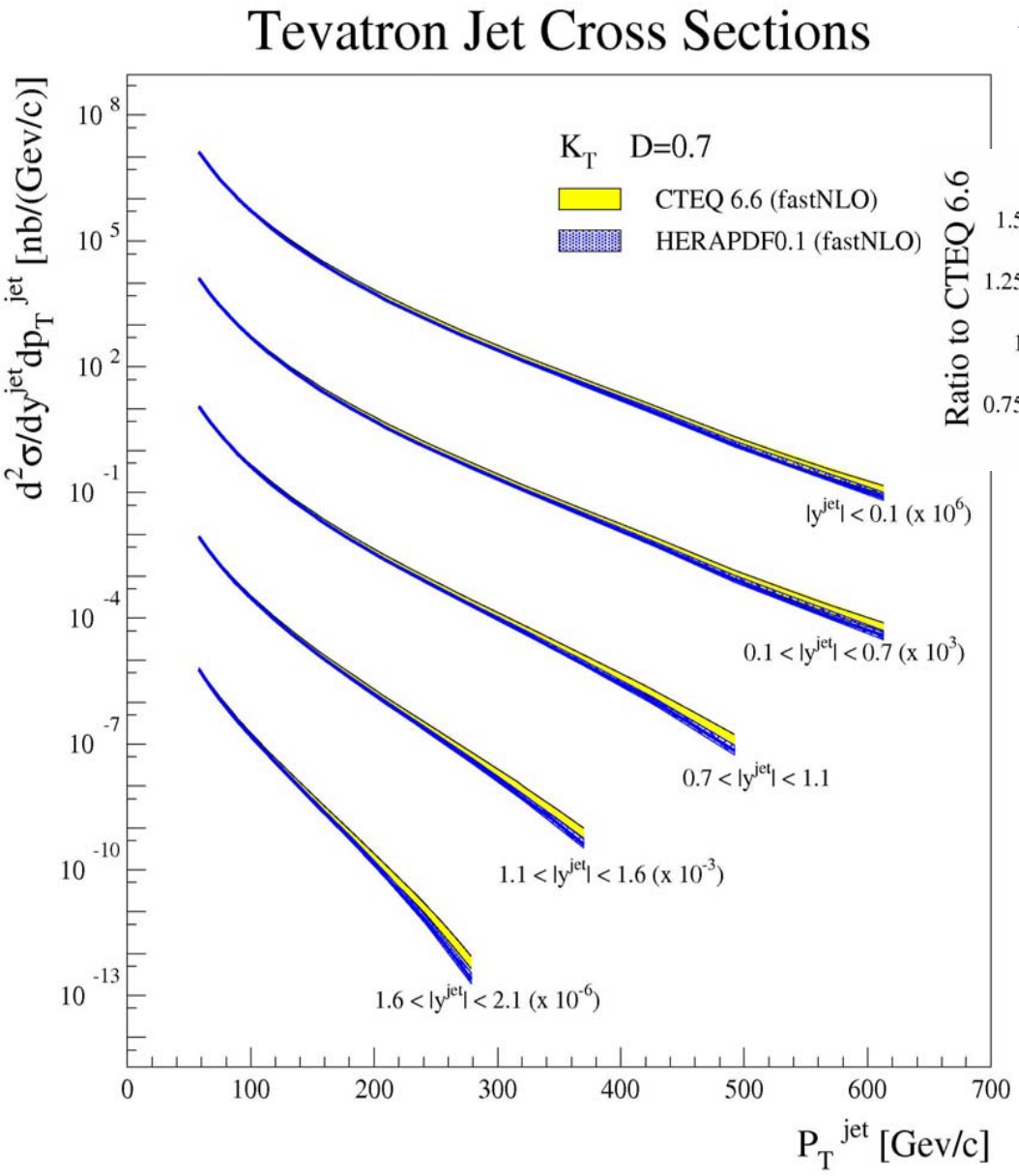


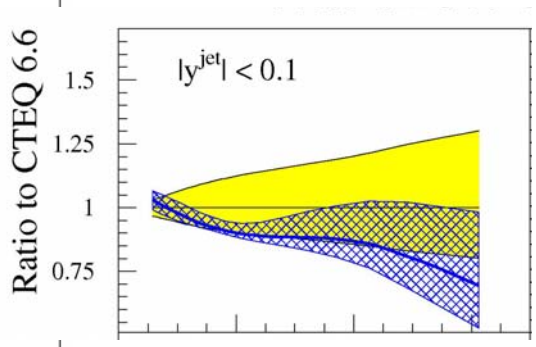
HERAPDF0.1 being publicly released in LHAPDF (version 5.5.x)

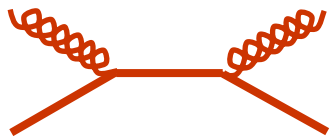
…to be exercised by the LHC experiments !

HERAPDF0.1 *impact on* LHC

the gluon at high x



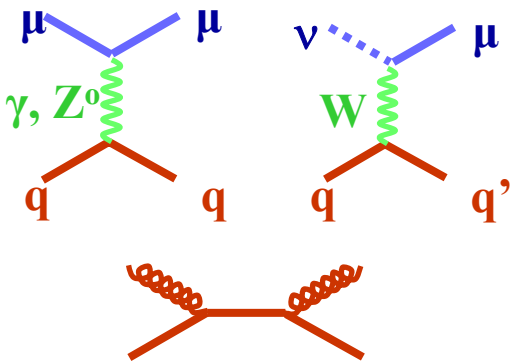




Brand new preliminary results from E. Tassi based on a pre-release in LHAPDF

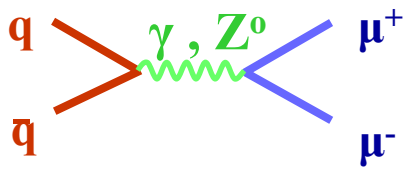
Reasonable behaviour at high x though no input from Tevatron High-P_T jets in the fit

COMPLEMENTARY INPUTS to the PROTON PDF's

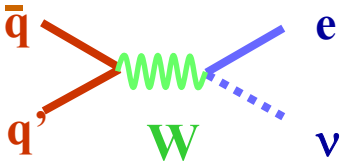


Fixed Target NC/CC
→ high-x quarks

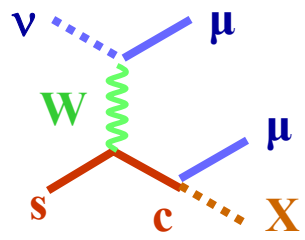
Tevatron High-P_T jets
→ high-x gluon



Fixed Target Drell-Yan
→ high-x antiquarks and ū/đ asymmetry

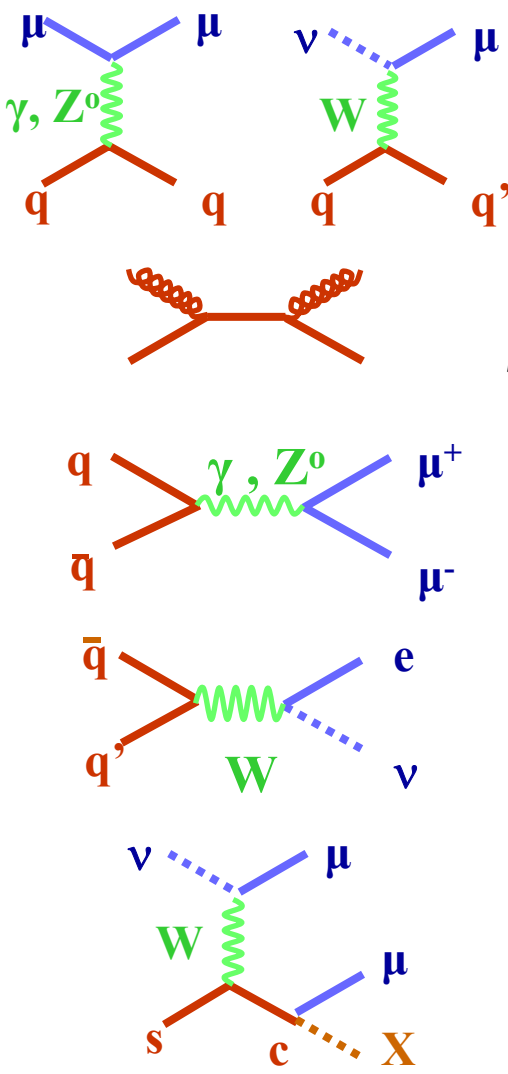


Tevatron W^+/W^-
→ u/d asymmetry at high x



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

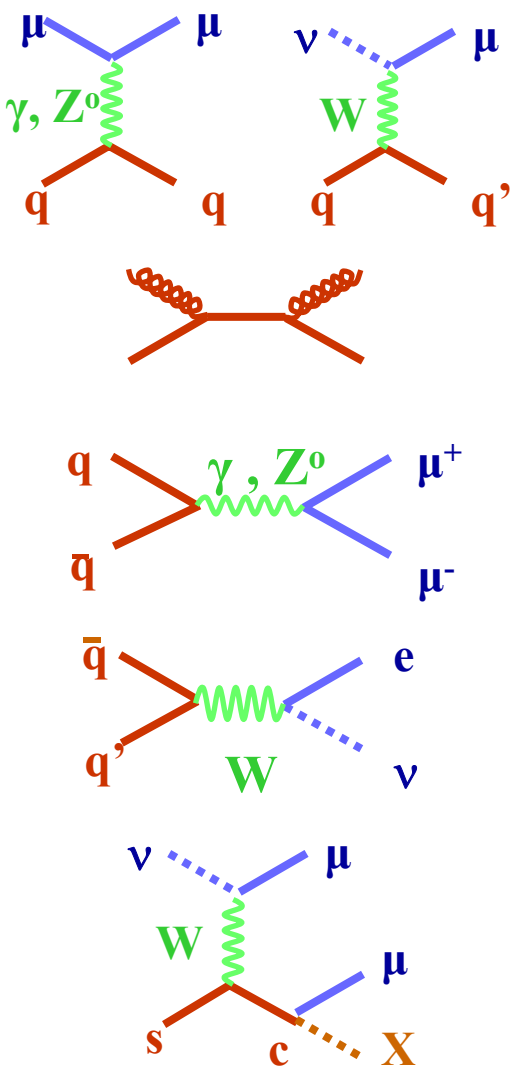
Nuclear corrections same as in DIS ?

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

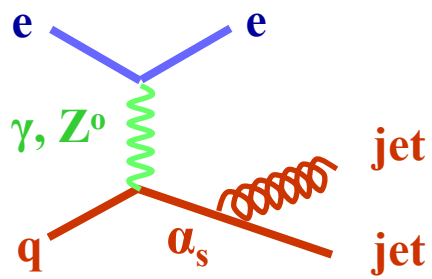
In the era of high precision HERA results

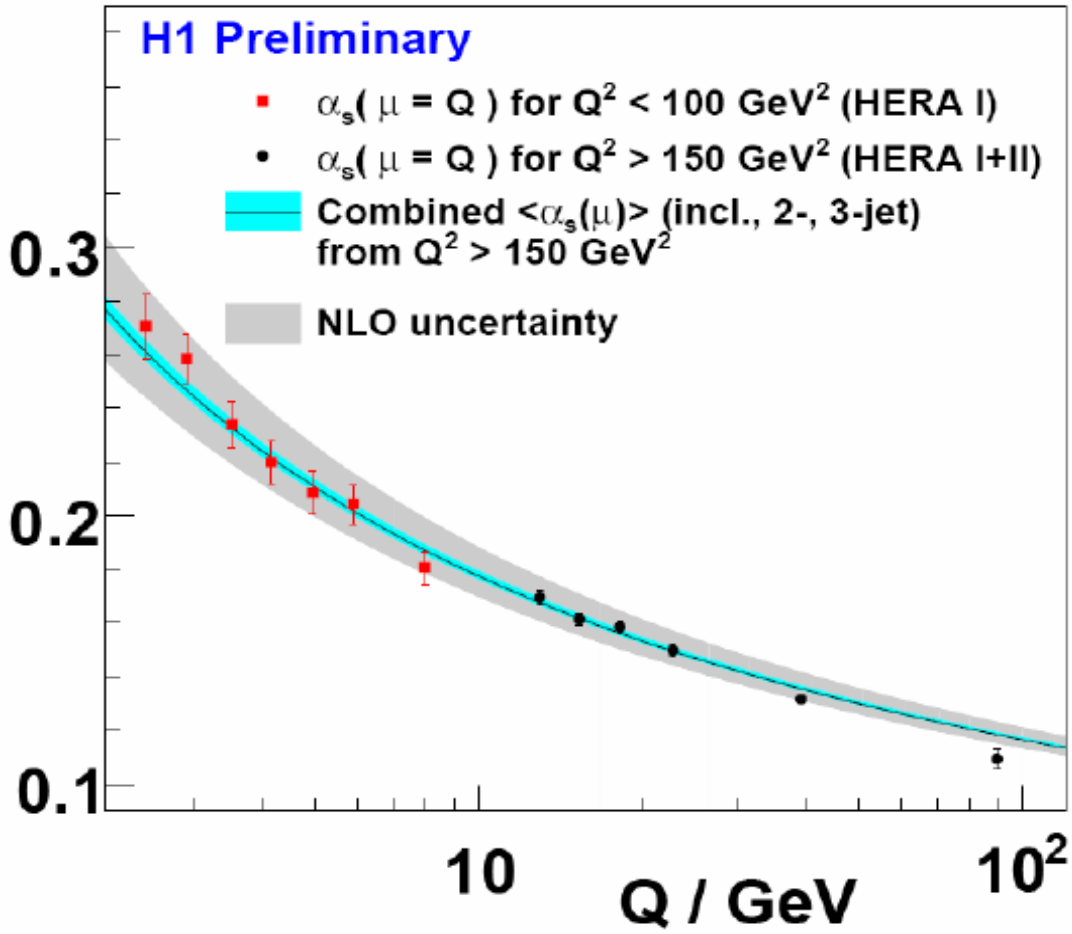
optimal inputs for LHC PDF's and PDF model uncertainties

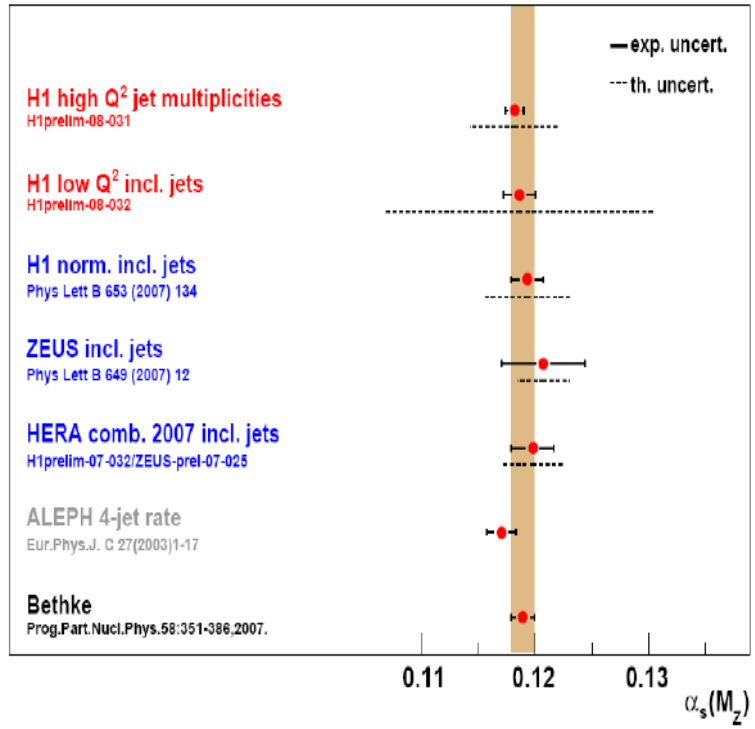
are essential questions to be addressed by the PDF4LHC workshop

QCD Dynamics:

the strong coupling α_s from multi-jet rates

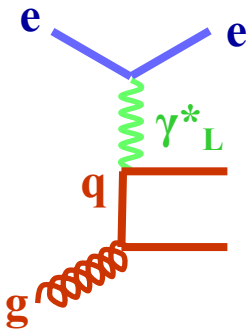






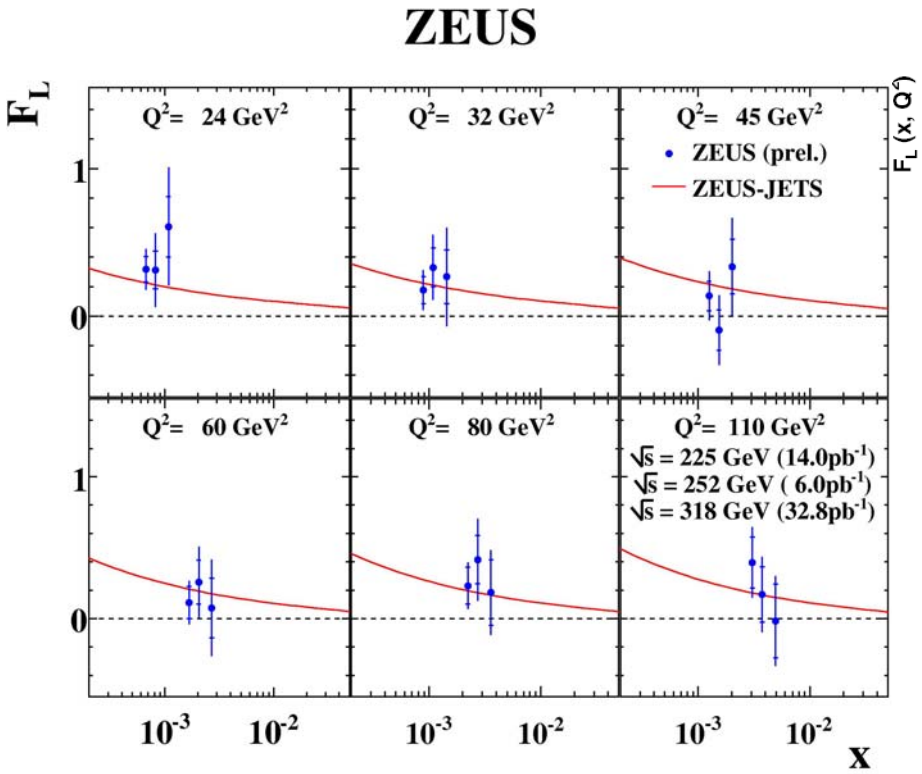
HERA exp. error ~ 0.7 %
a challenge for theory !

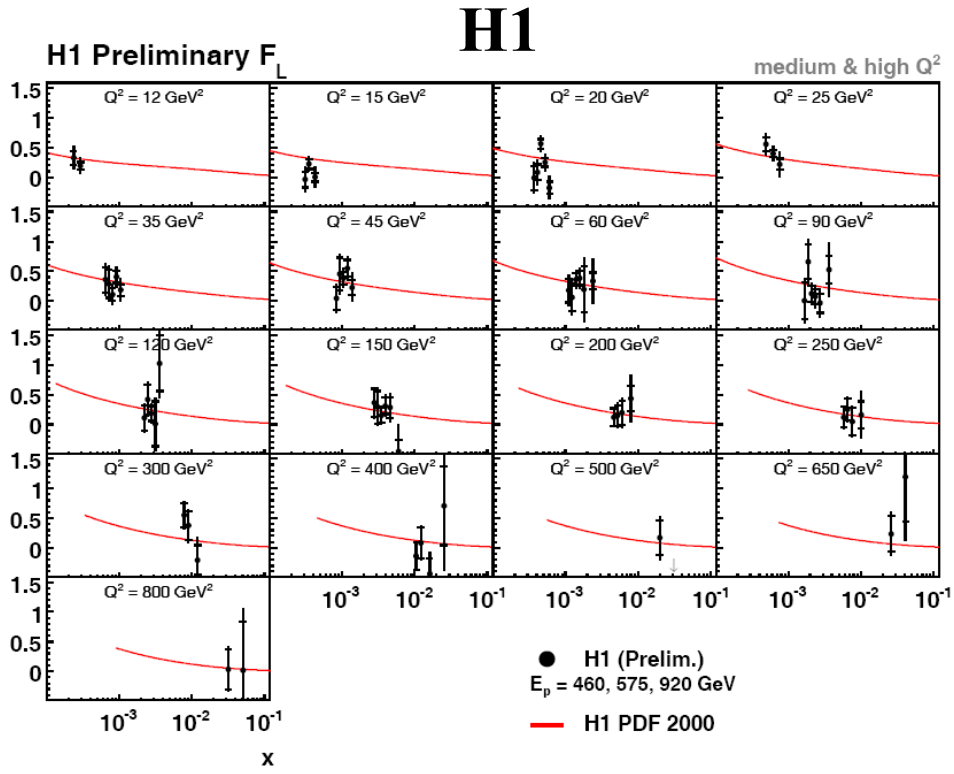
QCD Dynamics: directly probing the gluon with F_L



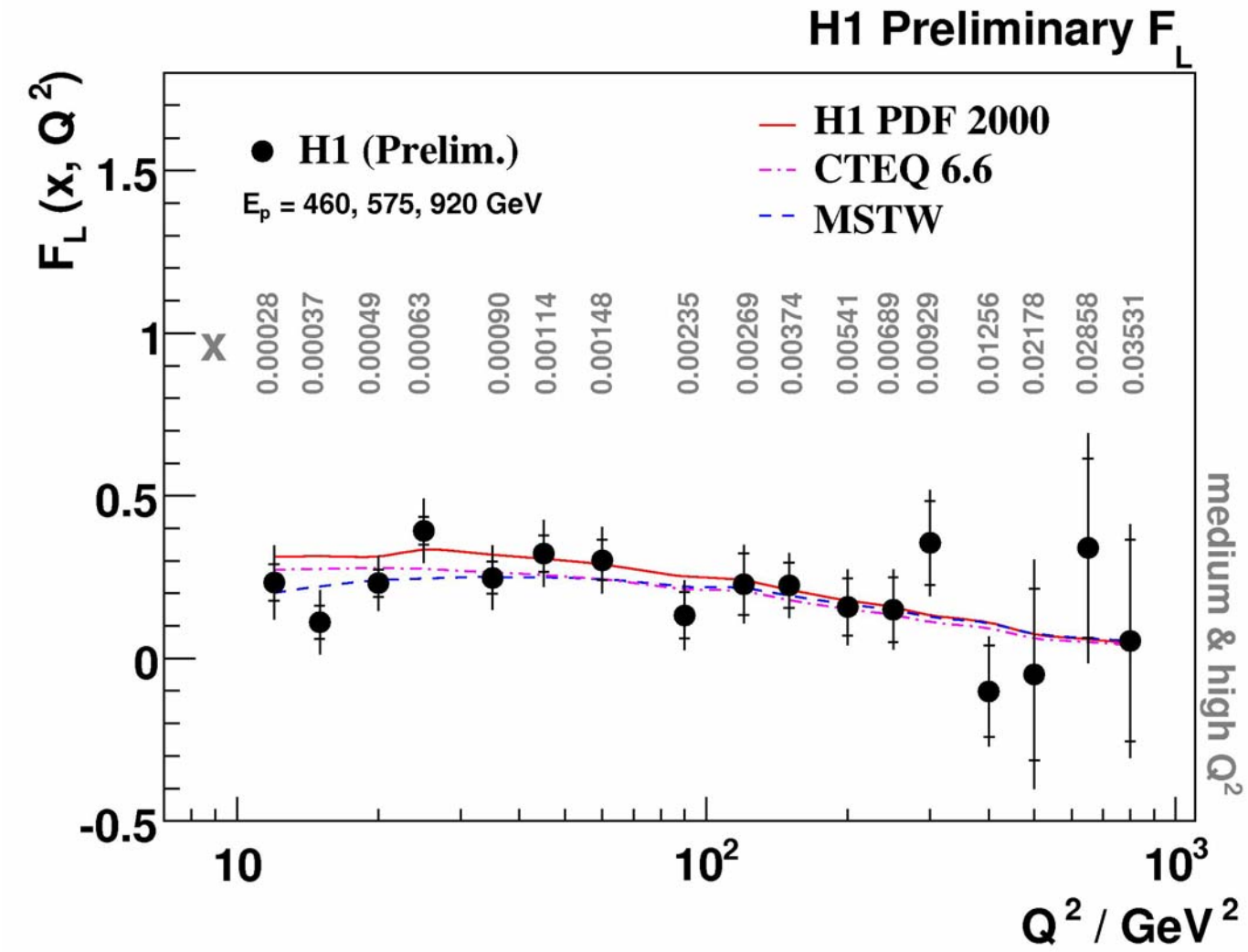
$$\tilde{\sigma}_{NC} = \frac{d^2\sigma^{ep}_{NC}}{dxdQ^2} \Big/ \left(\frac{2\pi\alpha^2}{xQ^4} Y_+ \right) = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

y = Q^2/sx

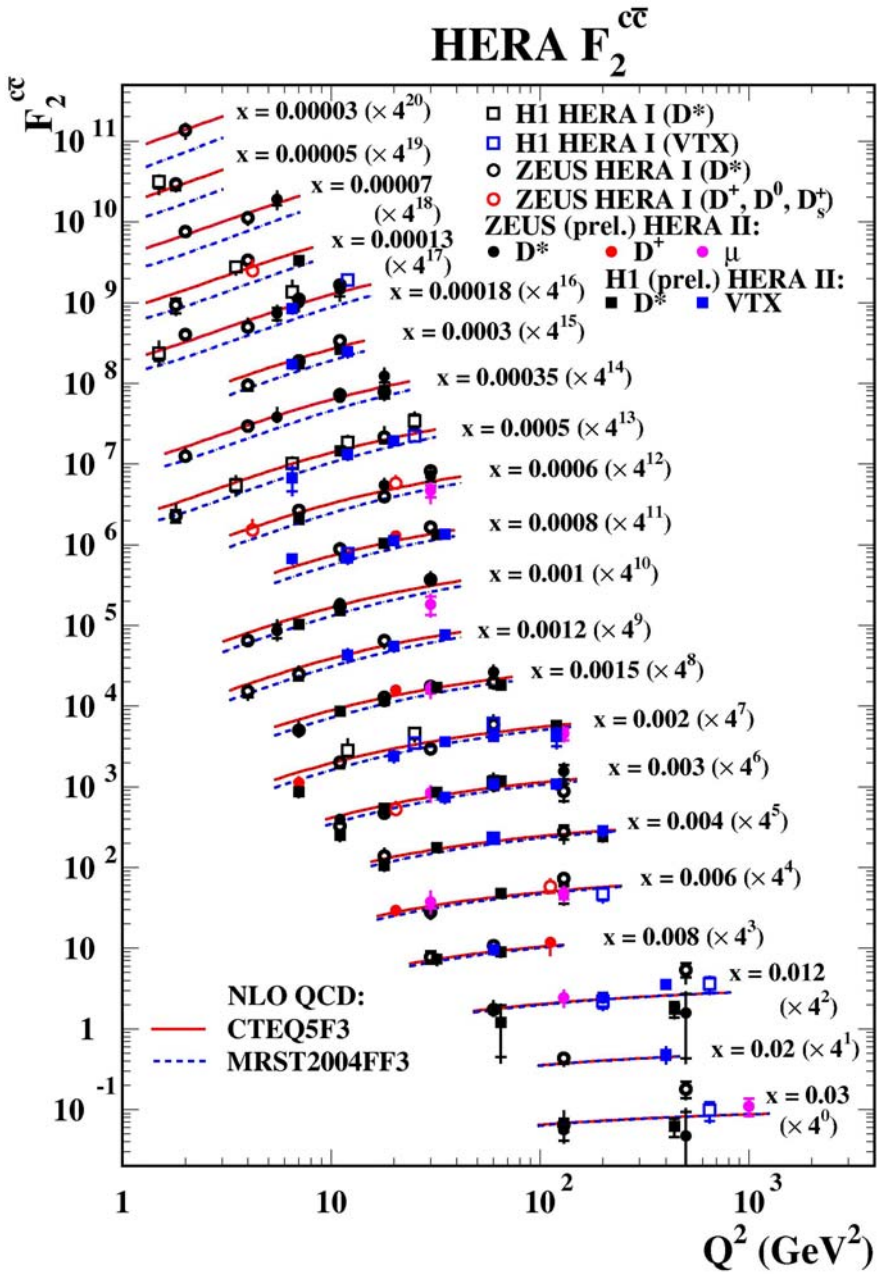


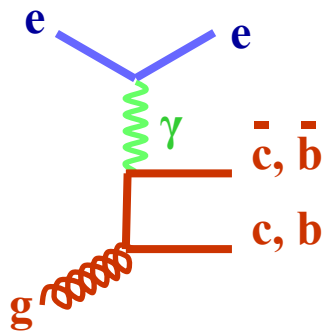


QCD Dynamics: F_L compatible with NLO DGLAP predictions

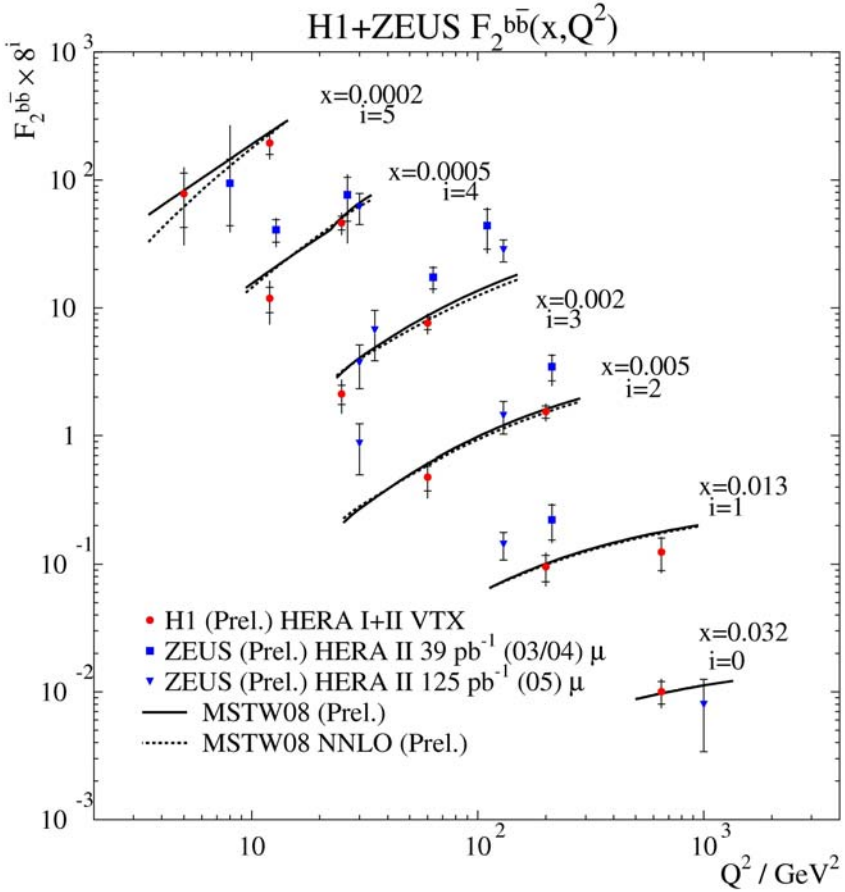


QCD Dynamics: Heavy Quark generation well described by DGLAP





Heavy flavors tagged through $D^{(*)}$, decay muons or displaced vertices



Paving the way to optimal LHC PDF's

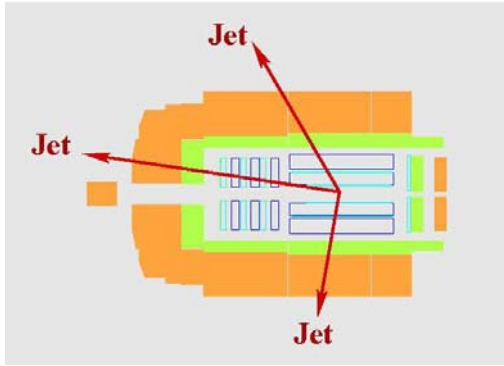
DGLAP OK so far, more to come from Inc+HF+Jets fits

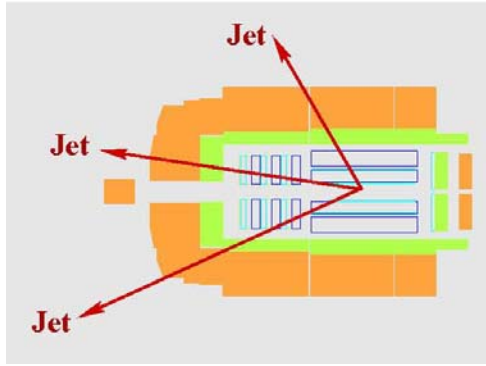
Next breakthrough expected at high x from final HERA II High Q^2 data

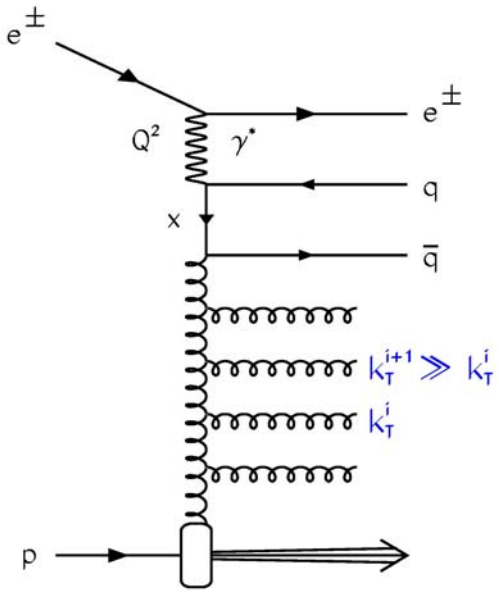
Recent breakthrough in precision at low x from H1-ZEUS combinations

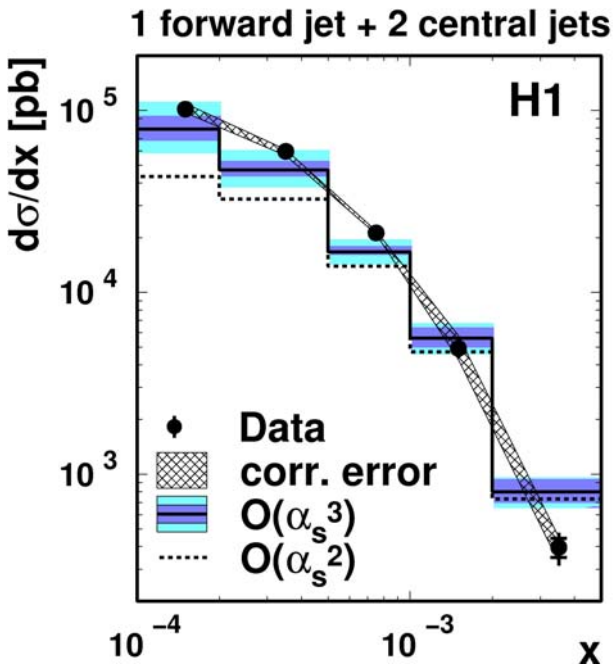
Some more on QCD dynamics

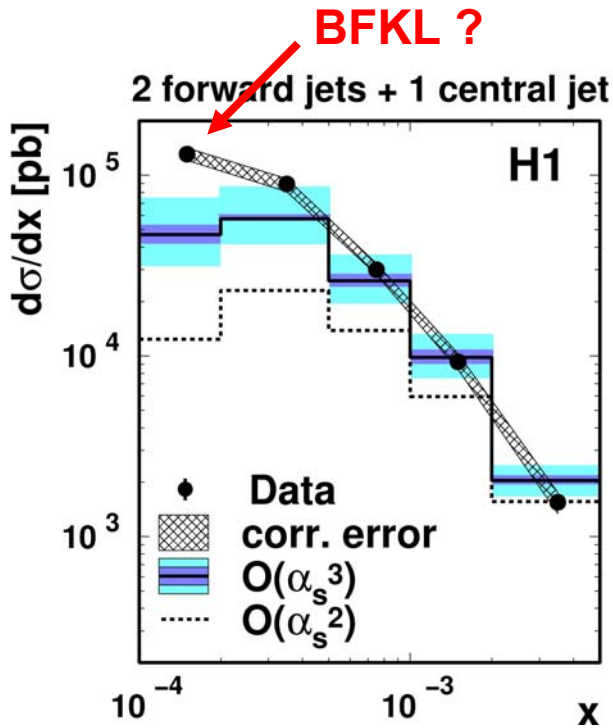
QCD Dynamics:
probing DGLAP with multijets at low x



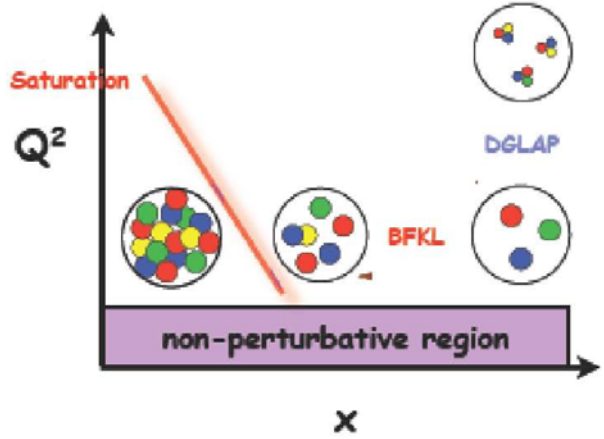




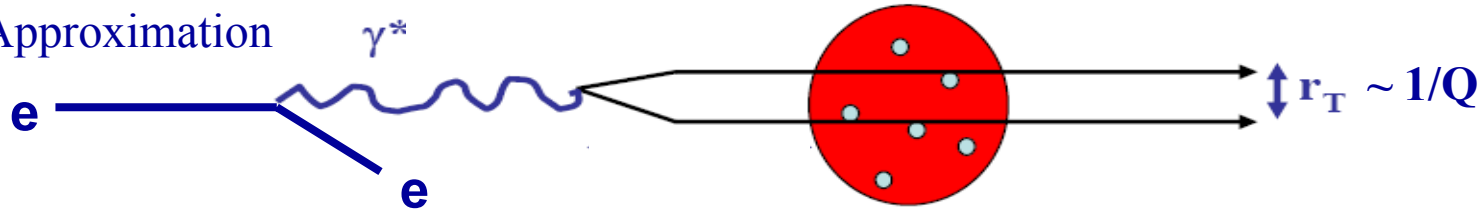




QCD Dynamics: the very low x / low Q^2 limit



Williams-Weizsäcker Approximation



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

$$\alpha/Q^2\,[1+(1-y)^2]/y \qquad \alpha/Q^2\, xq(x)$$

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