H1 QCD analysis of inclusive cross section data

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On behalf of the H1 Collaboration

I. The H1 inclusive DIS cross section data
What can we learn from them ?

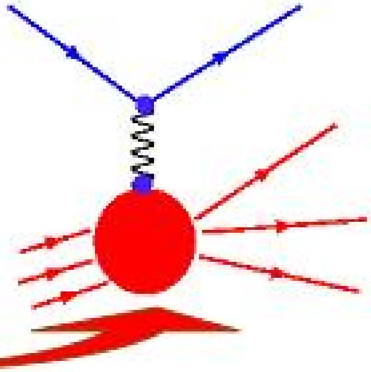
II. QCD analysis and extraction of parton distributions

II. Gluon and α_s determination

IV. Conclusion and outlook

Deep Inelastic Scattering

Inclusive lepton-proton cross section :



$$\frac{d^2\sigma^{\pm}_{NC}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\,\underbrace{\tilde{F}_2 - y^2\,\tilde{F}_L \mp Y_-\,x\tilde{F}_3}\right]$$

dominant

high y

high Q²

$$\frac{d^2\sigma^{\pm}_{CC}}{dx\,dQ^2} = \frac{G_F^2}{4\pi x}\left[\frac{M_W^2}{Q^2+M_W^2}\right]^2\left[Y_+\,F_2^{CC\pm} - y^2\,F_L^{CC\pm} \mp Y_-\,xF_3^{CC\pm}\right]$$

The QCD factorization theorem allows to express the structure functions as convolutions of universal parton density functions (p.d.fs) and perturbatively computable kernels

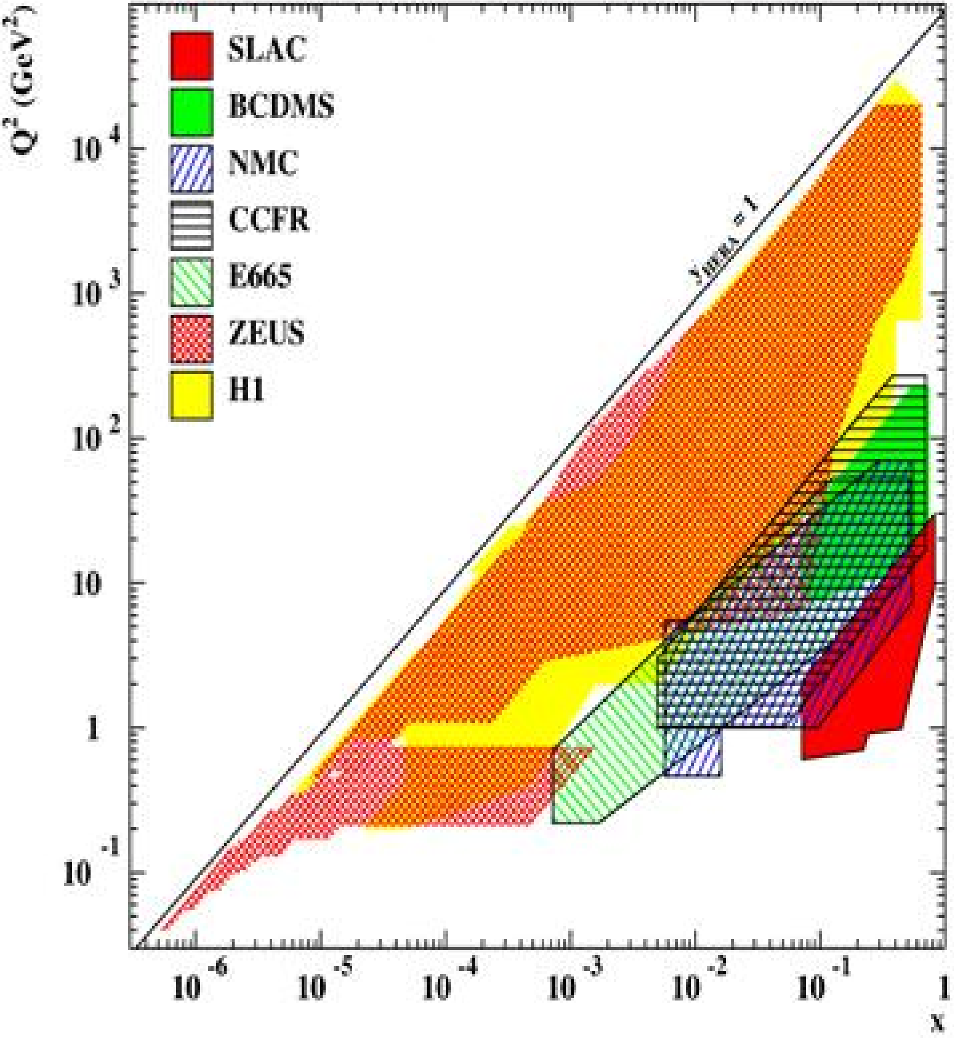
- Inclusive cross section allows tests of the structure of the EW interaction (and look for new physics)

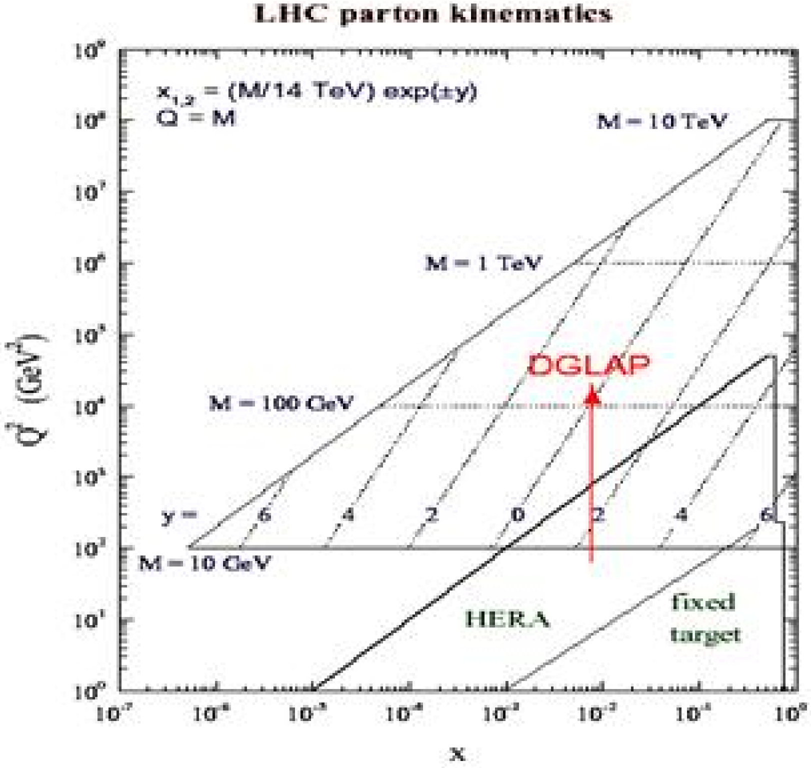
- Provided this is understood, one can use pQCD to obtain parton densities through QCD evolution (or any parameter entering in the cross section)

Now after the HERAI phase of data taking :
Full set of e^+ and e^- Neutral Current (NC) and Charged Current (CC) measurements.

HERAII results are already here ...

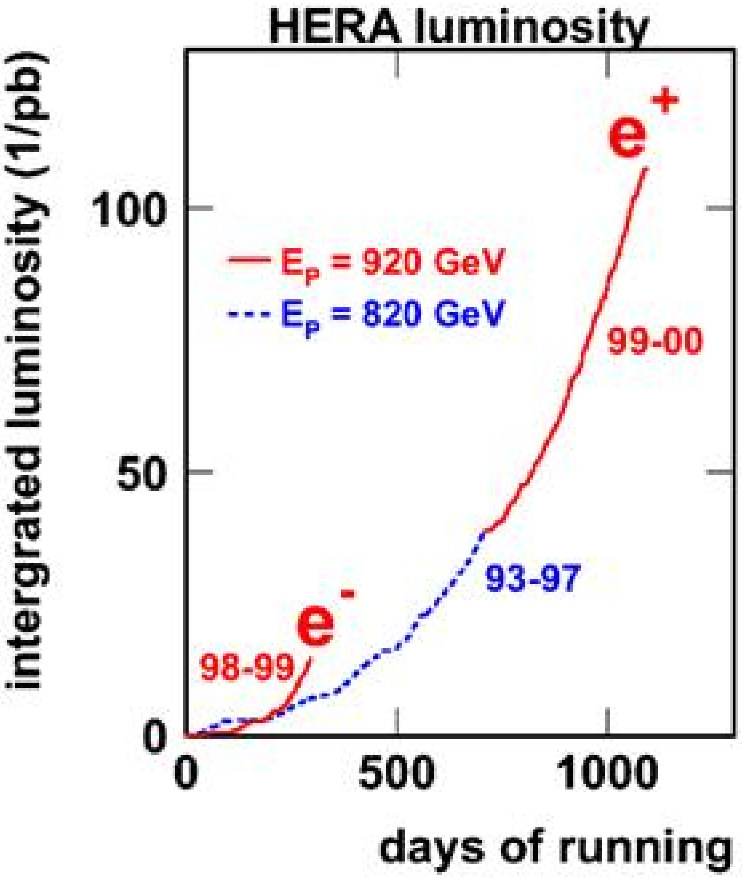
HERA data and DIS kinematics





HERA data in the relevant x region for LHC physics

H1 data sets



Low Q2 NC

e^+p (96-97) L=20 pb^{-1}

$1.5 < Q^2 < 150$ GeV^2

High Q^2

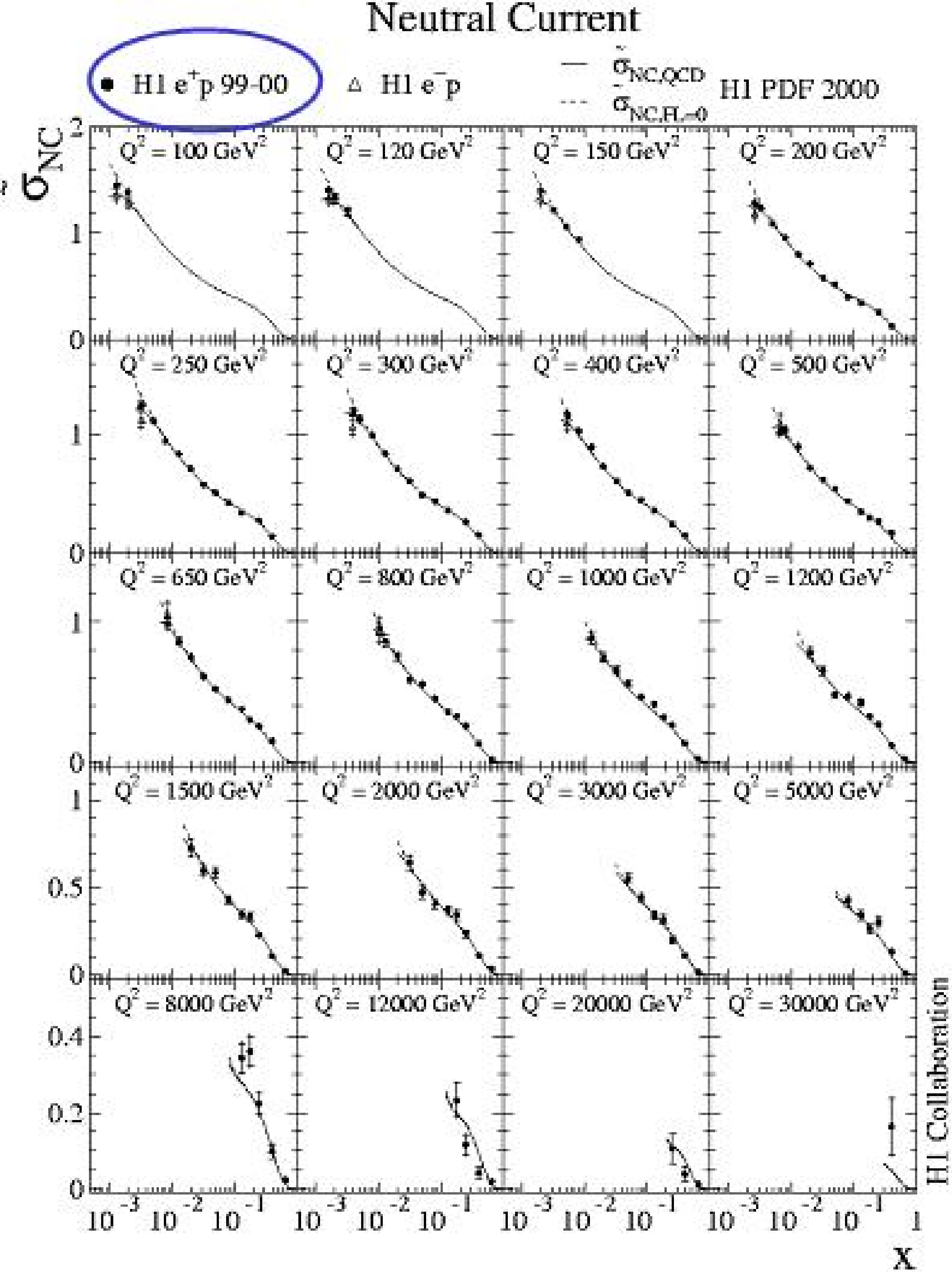
e^+p (94-97) L=35.6 pb^{-1}

e^-p (98-99) L=16.4 pb^{-1}

e^+p (99-00) L=65.2 pb^{-1}

NC: $150 < Q^2 < 30000$ GeV^2

CC: $300 < Q^2 < 15000$ GeV^2



$$\tilde{\sigma}^{\pm}_{NC} = \frac{1}{Y_+}\frac{xQ^4}{2\pi\alpha}\frac{d^2\sigma^{\pm}_{NC}}{dxdQ^2}$$

High Quality NC data

Precision ~2-3% for syst. and ~1-2% stat. error in most of the phase space

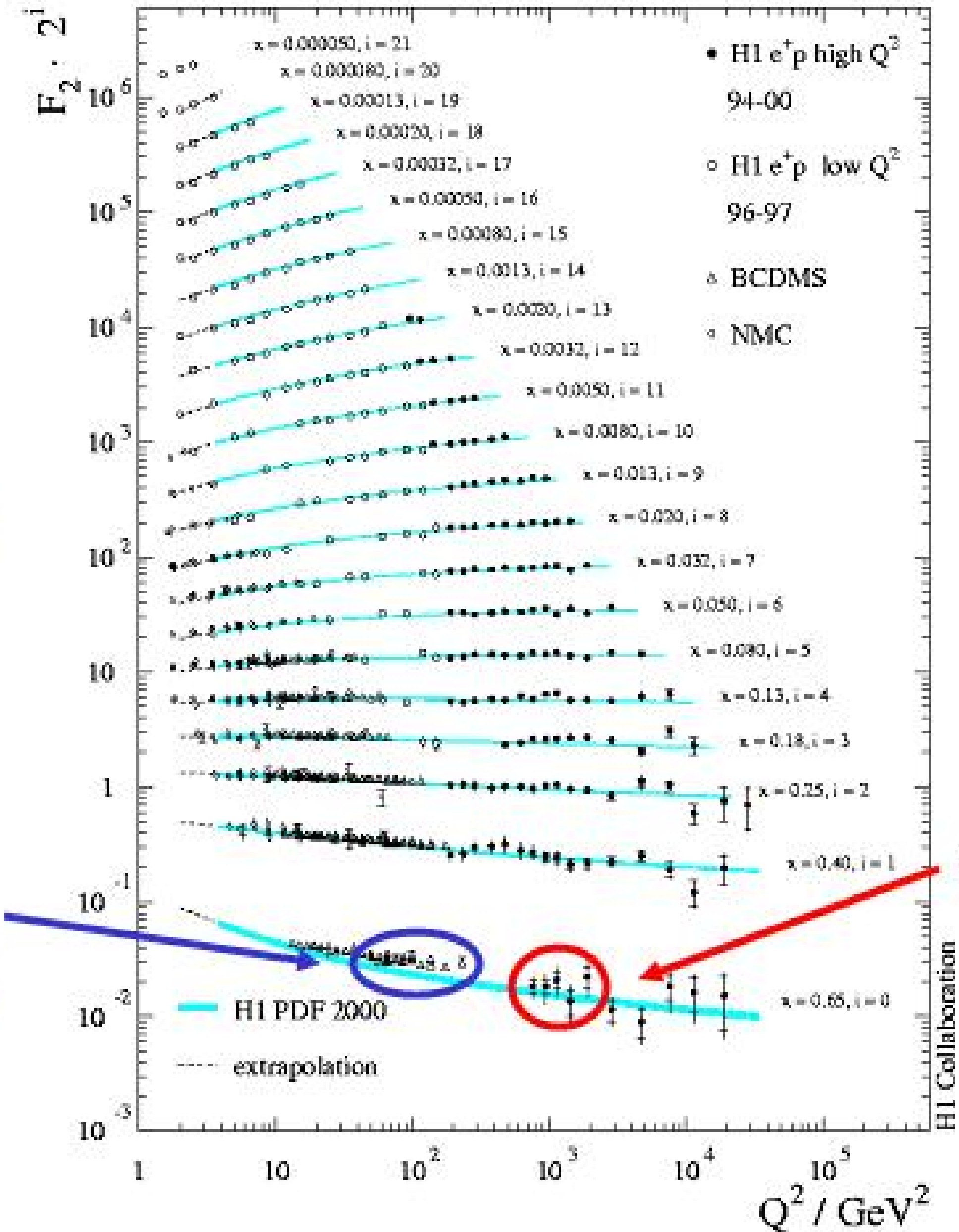
Full knowledge of correlation between systematic errors relevant for QCD analysis

Constaint on u and ubar

F2 extraction from H1 data

Scaling violations

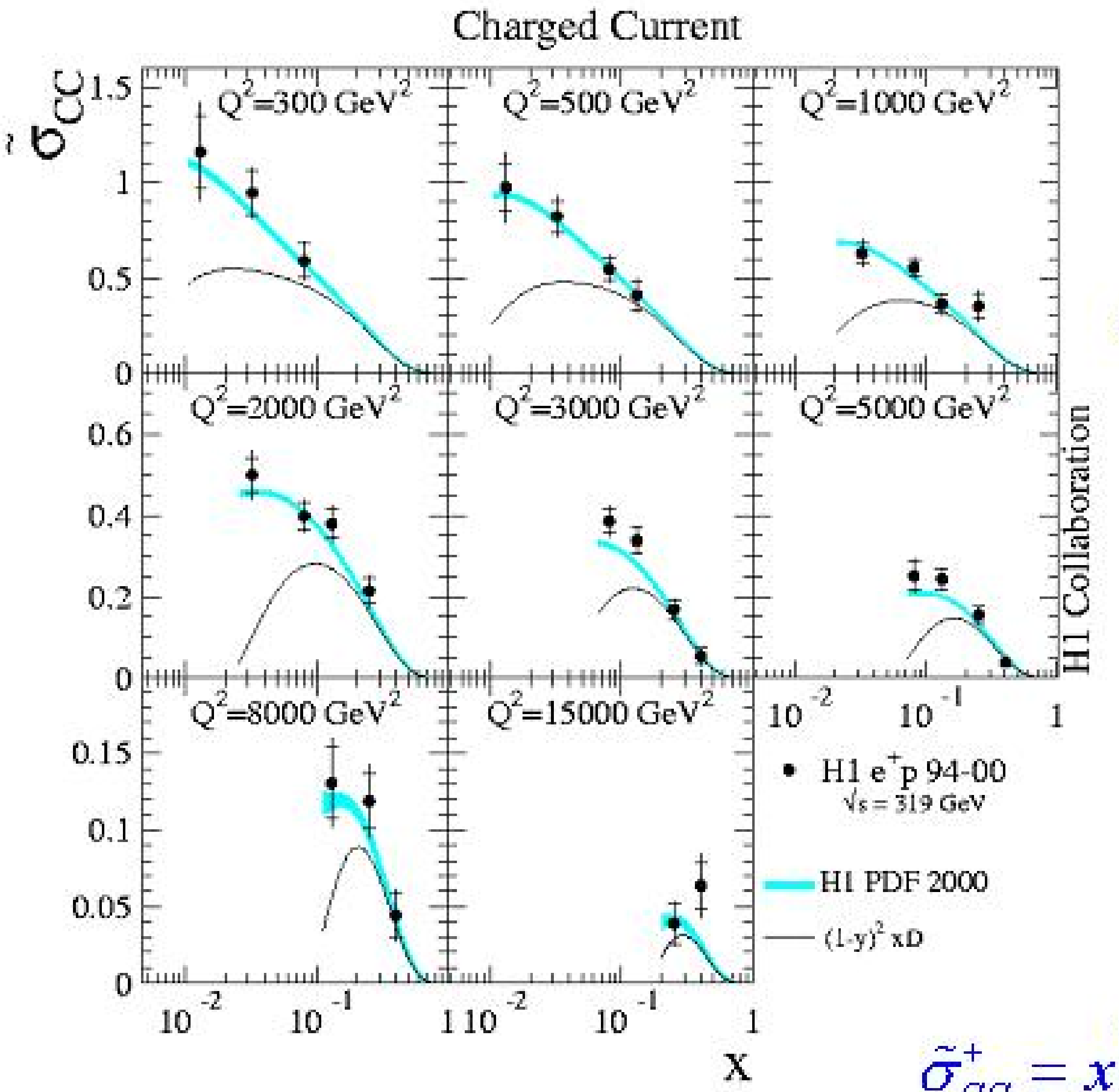
H1 data far from fixed target precision at high x (stat. lim.) Important for QCD evolution



BCDMS $\delta F2/F2 \sim 7\%$

Constraint on the gluon density

$\delta F2/F2 \sim 30\%$



$$\tilde{\sigma}^{\pm}_{CC} = \frac{2\pi x}{G_F^2}\frac{\left(Q^2+M_W^2\right)^2}{M_W^4}\frac{d^2\sigma^{\pm}_{CC}}{dxdQ^2}$$

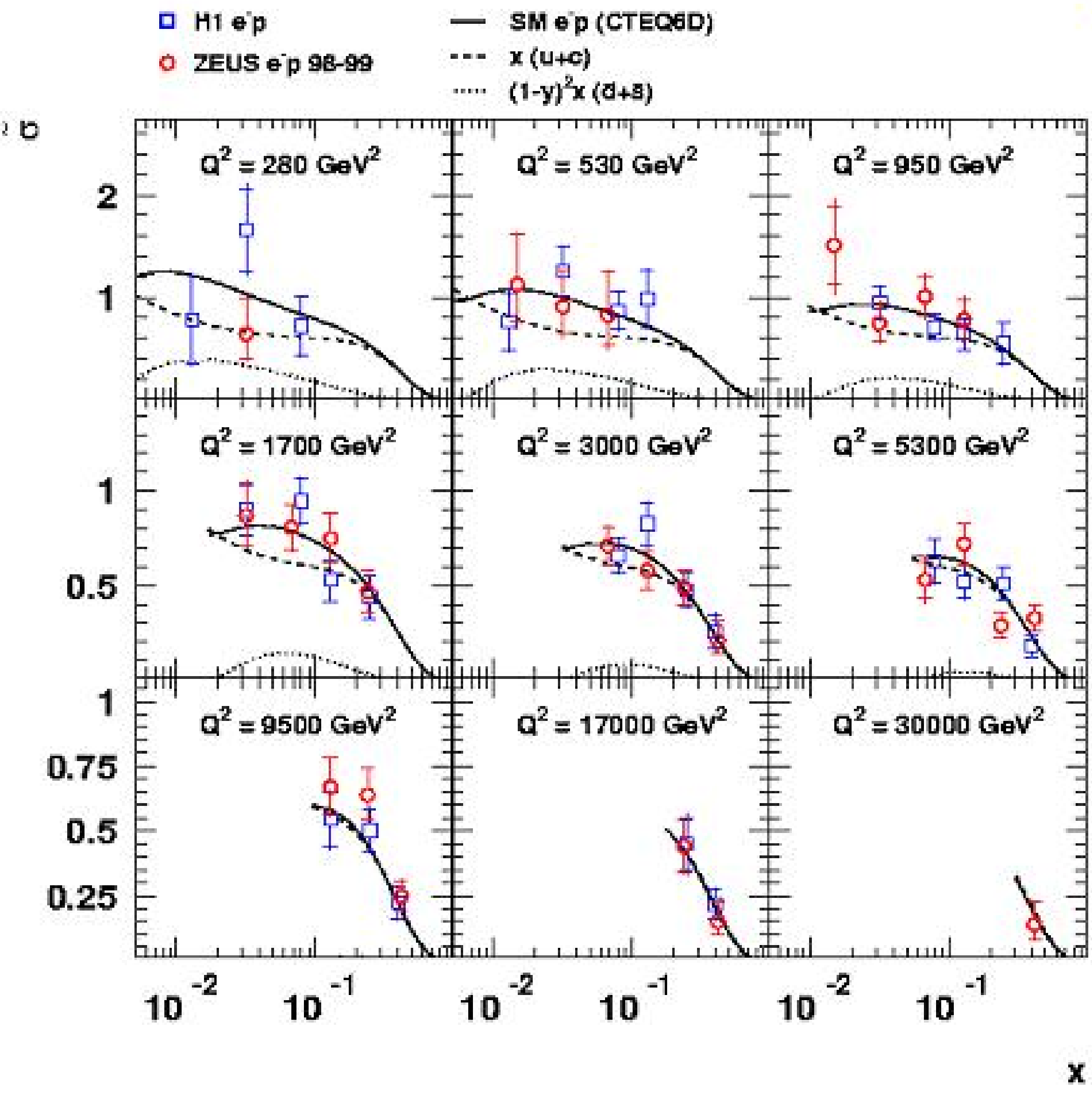
Typical
systematic errors
are ~6%

$$\tilde{\sigma}^{+}_{CC} = x\left[\bar{u}+\bar{c}+(1-y)^2(d+s)\right]$$

➡ Direct constraint on d at high x

HERA e^-p Charged Current

$$\tilde{\sigma}^-_{CC} = x\left[u+c+(1-y)^2\left(\bar{d}+\bar{s}\right)\right]$$



➡ Direct constraint on u at high x

Both e^+ and e^- Cross sections Are necessary For flavor separation in QCD fits

H1PDF2000 QCD Analysis

- NLO pQCD analysis in a Massless Scheme
- Pascaud-Zomer chi2 method for parameter determination and error estimate

$$\chi^2 = \sum_{data} \frac{\left(\sigma data - \sigma th \times (1 - \sum_{sources} s \times corsyst) \right)^2}{stat^2 + uncsyst^2} + \sum_{sources} s^2$$

Use of only H1 NC and CC high Q2 data

+ two sets of data at lower Q^2 (total 621 measurements)

Sensitivity and fitting scheme

Neutral Current

$$F_2 \propto \frac{4}{9}(u + c + \bar{u} + \bar{c}) + \frac{1}{9}(d + s + \bar{d} + \bar{s})$$

$$xF_3 \propto B_U(u + c - \bar{u} - \bar{c}) + B_D(d + s - \bar{d} - \bar{s})$$

Charged Current

e^+p $$\tilde{\sigma}_{CC}^- = x\left[u + c + (1-y)^2\left(\bar{d} + \bar{s}\right)\right]$$

e^-p $$\tilde{\sigma}_{CC}^+ = x\left[\bar{u} + \bar{c} + (1-y)^2(d + s)\right]$$

It is not possible to fully separate the different flavours with inclusive data : parametrization of

$$g, U = u + c, D = d + s, \bar{U}, \bar{D}$$

The Art of parameterization

- At the (low) scale Q_0^2 parton distributions are Parameterized with $x f(x,Q_0^2) = A x^{\underset{\uparrow}{B}} (1-x)^{\underset{\uparrow}{C}} \times P(x)$

  low x high x

- It is not trivial to have P(x) such that the fit is flexible enough and stable
- Errors (and distributions) depend on the parametric form chosen
- One also has to be kind enough with MINUIT as the fit is non-linear (dependency upon the starting parameters ...)

Any choice is to some extend arbitrary
(nature do not choose a parametric form)

Parametrization and constraints

Parameterize $g, U = u + c, D = d + s, \bar{U}, \bar{D}$

Assume that at Q_0^2 $\bar{c} = cfrac \times \bar{U}$ $\bar{s} = sfrac \times \bar{D}$ $\bar{s} = s, \bar{c} = c$

Parametric form $xf(x, Q_0^2) = Ax^B(1-x)^C \times P(x)$

Constraints from the momentum sum rule and counting rules

Same low x behaviour $B_U = B_{\bar{U}} = B_D = B_{\bar{D}}$

Also $U - \bar{U}, D - \bar{D}, \bar{u} - \bar{d} \xrightarrow[x \to 0]{} 0$

requires $A_U = A_{\bar{U}}, A_D = A_{\bar{D}}, A_{\bar{U}} = A_{\bar{D}} \dfrac{1 - sfrac}{1 - cfrac}$

No parameter is fixed to an arbitrary value

Parametric form obtained by adding parameters and looking for χ^2 saturation

General form :

$$xf(x,Q_0^2) = Ax^B(1-x)^C\left(1+\sum_{n=1}^{6} a_n x^{n(\delta+1)}\right)$$

δ fixed

$$\delta = -1/2 \Rightarrow x^{1/2}, x, x^{3/2}, x^2, x^{5/2}, x^3$$

$$\delta = 0 \Rightarrow x^1, x^2, x^3, x^4, x^5, x^6$$

Parametrization obtained has 10 free parameters

$$xg(x,Q_0^2) = Ax^B(1-x)^C(1+Dx)$$

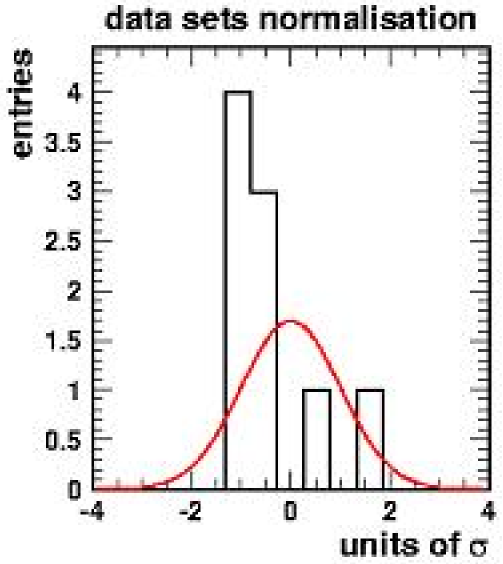
$$xU(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^3)$$

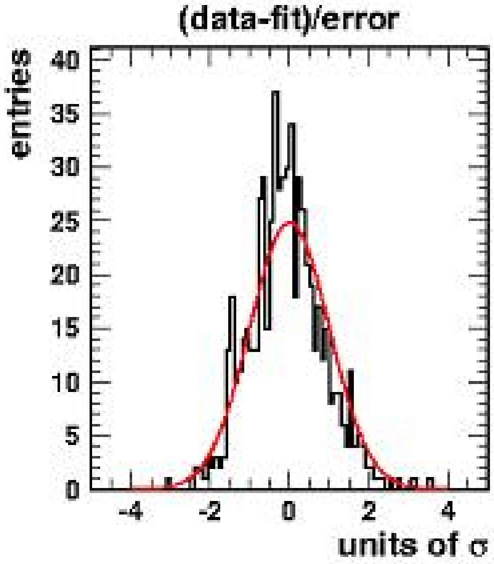
$$xD(x,Q_0^2) = Ax^B(1-x)^C(1+Dx)$$

$$x\bar{U}(x,Q_0^2) = Ax^B(1-x)^C$$

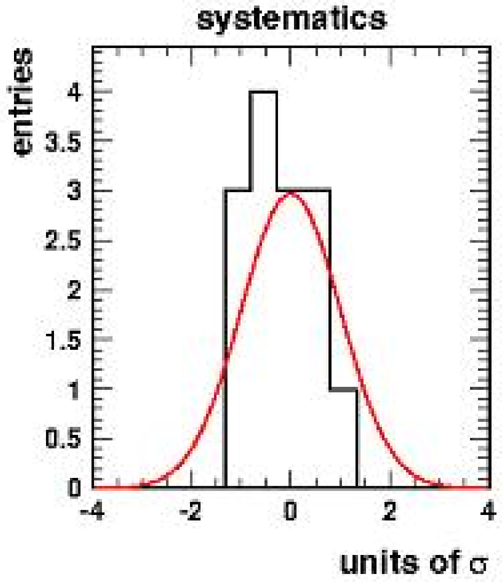
$$x\bar{D}(x,Q_0^2) = Ax^B(1-x)^C$$

Control of the fit quality


data sets normalisation

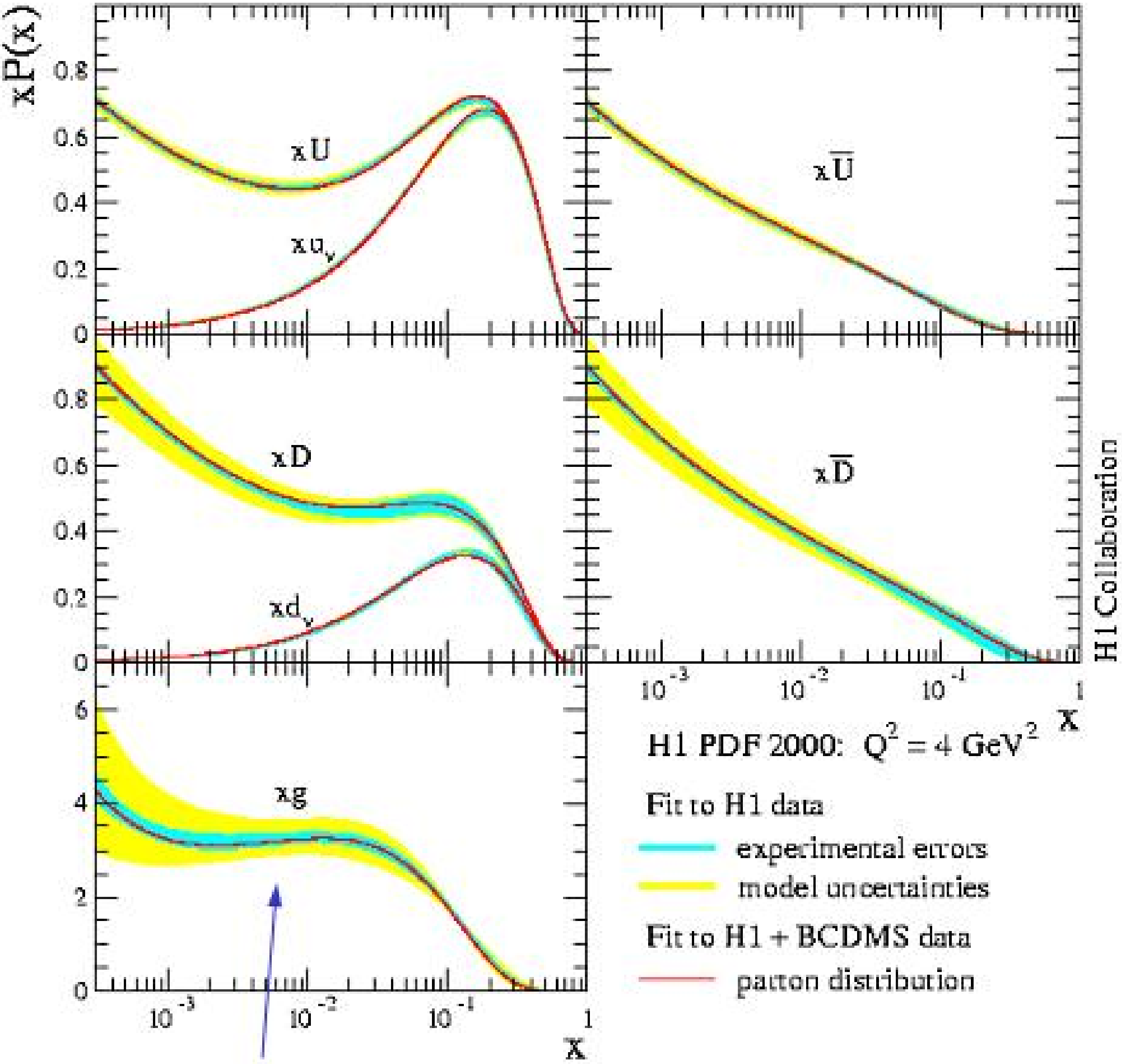

(data-fit)/error

Red curve is a gaussian expectation (no free parameter, sigma=1 and mean=0)


systematics

➡ Result is not driven by a ill-behaved systematic

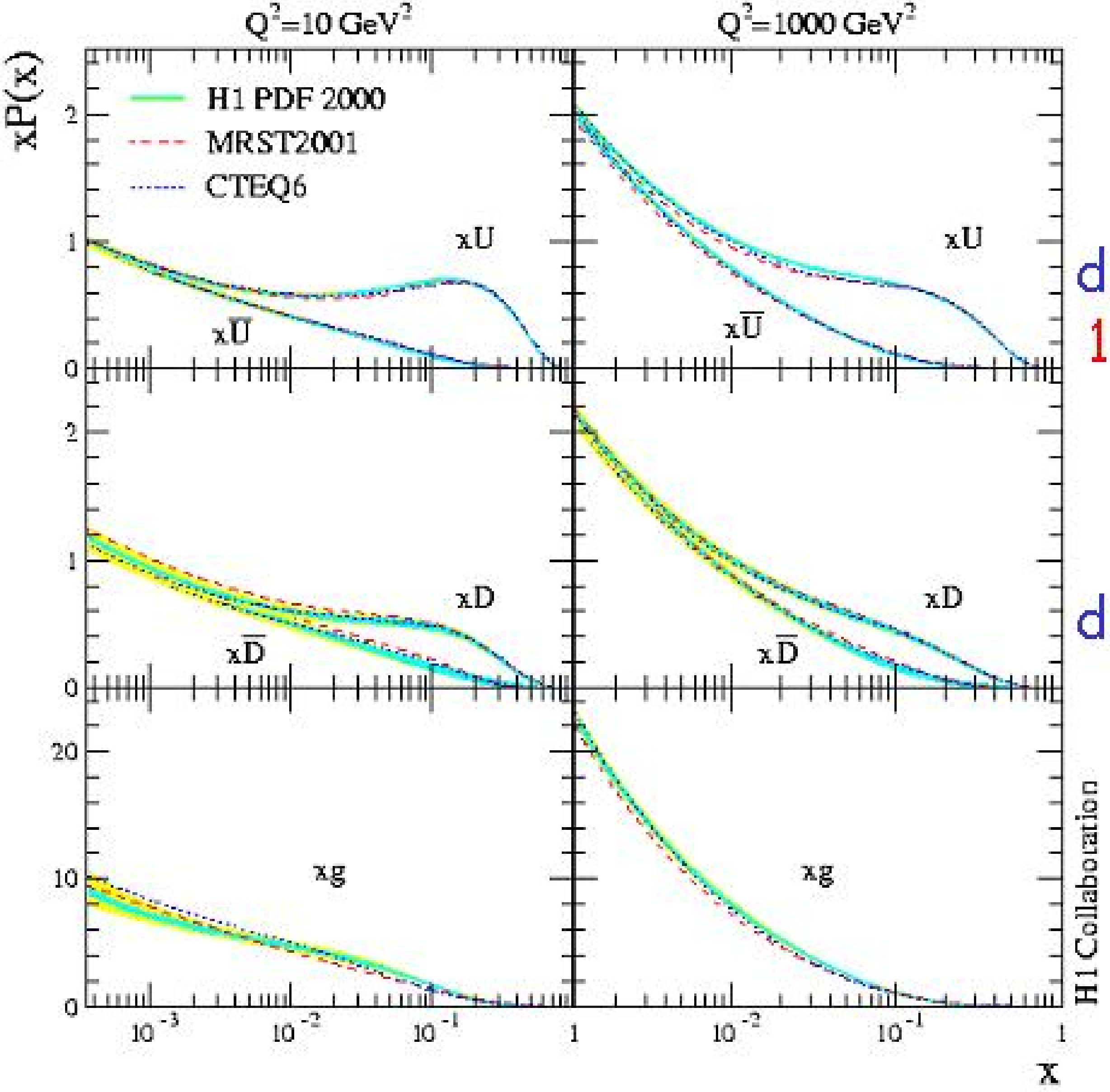
$$\chi^2_{tot} / ndf = 540/(621-10) = 0.88$$



Yellow band is variation
Of the fit parameters :
Input scale, minimum Q2
Charm an strange fraction
Quark masses
and α_s :

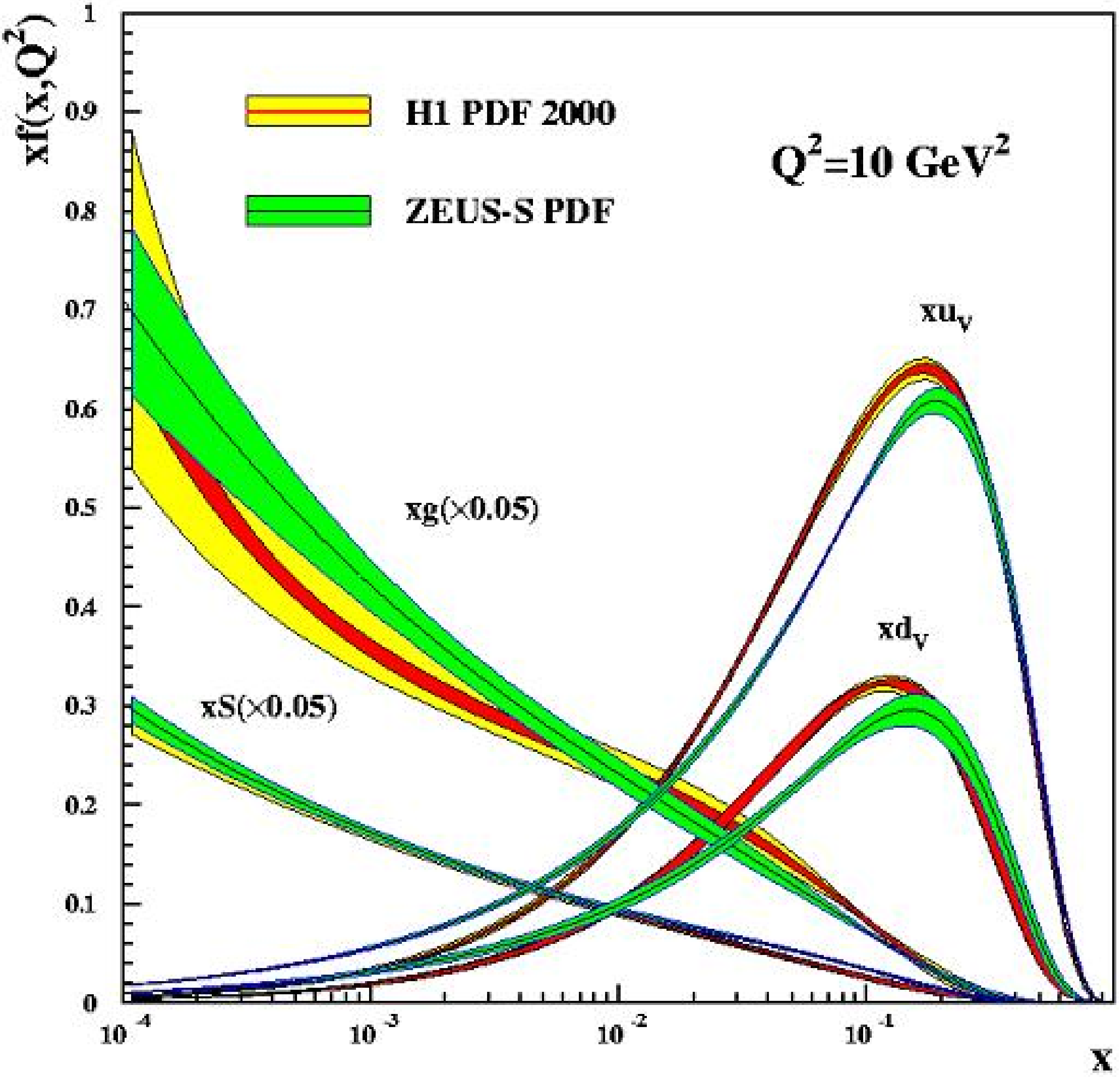
<<model uncertainties>>

variation of α_s is the main model uncertainty on the gluon

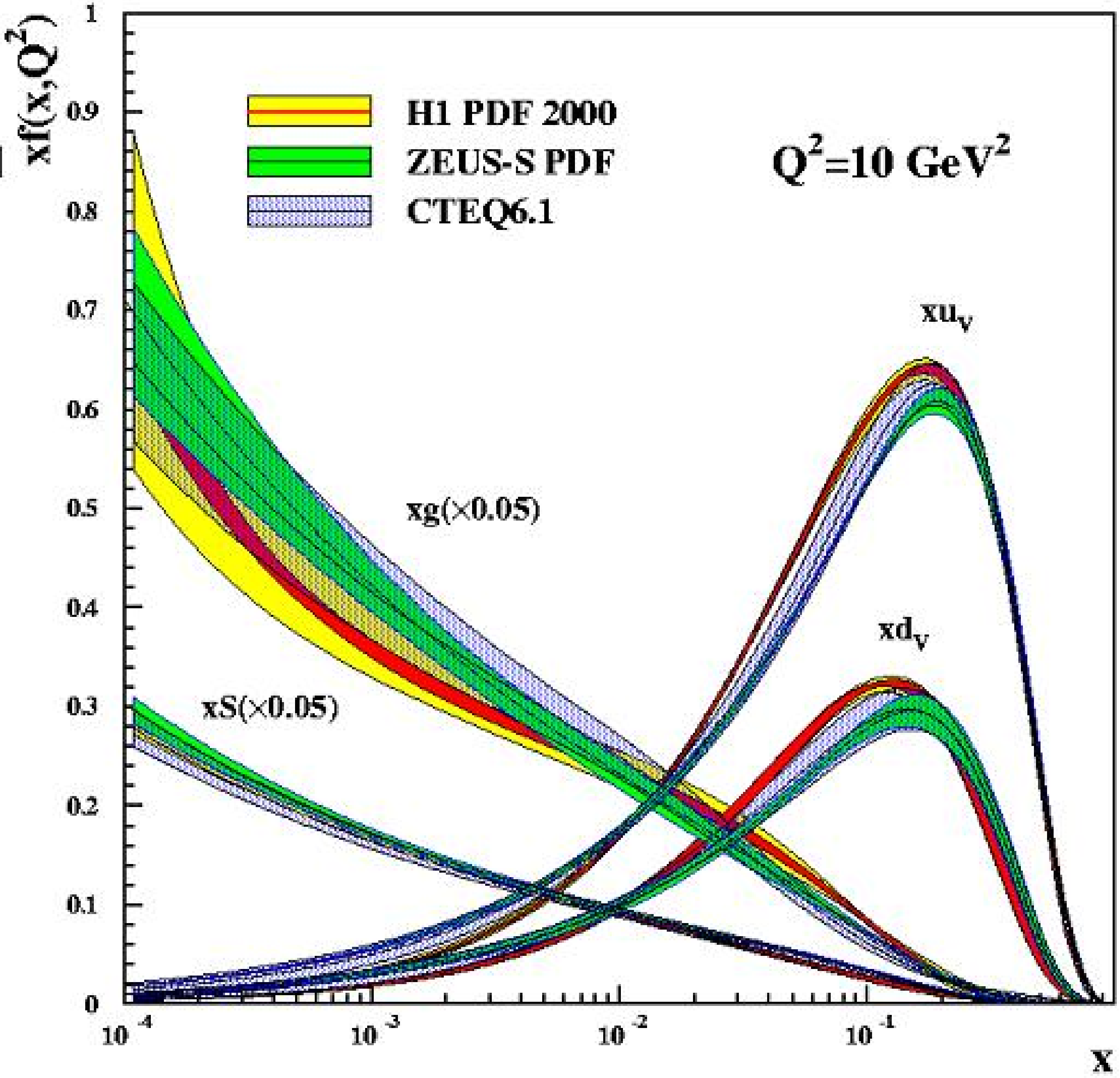


u type quark distribution precision is 1% for x=0.001 and 7% for x=0.65

d type quark distribution precision is 2% for x=0.001 and 30% for x=0.65



Reasonable
agreement
between the fits
given the different
Data and
fitting schemes

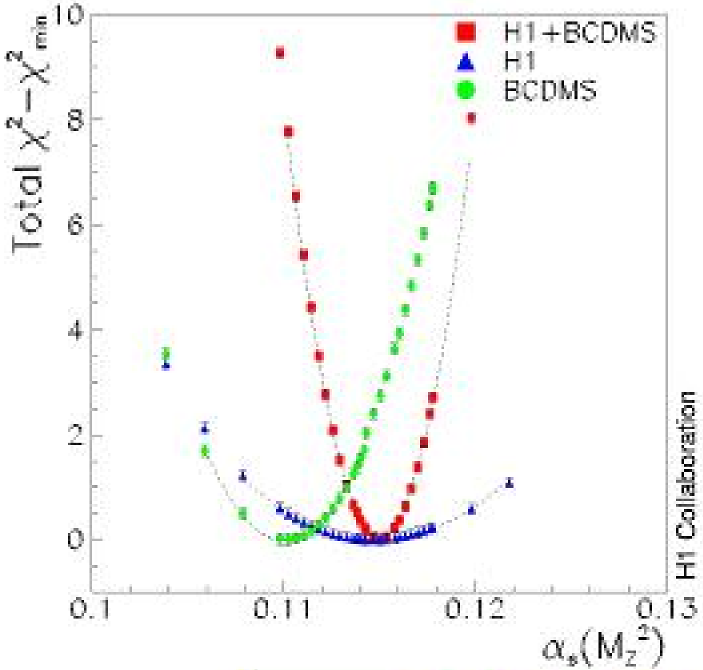


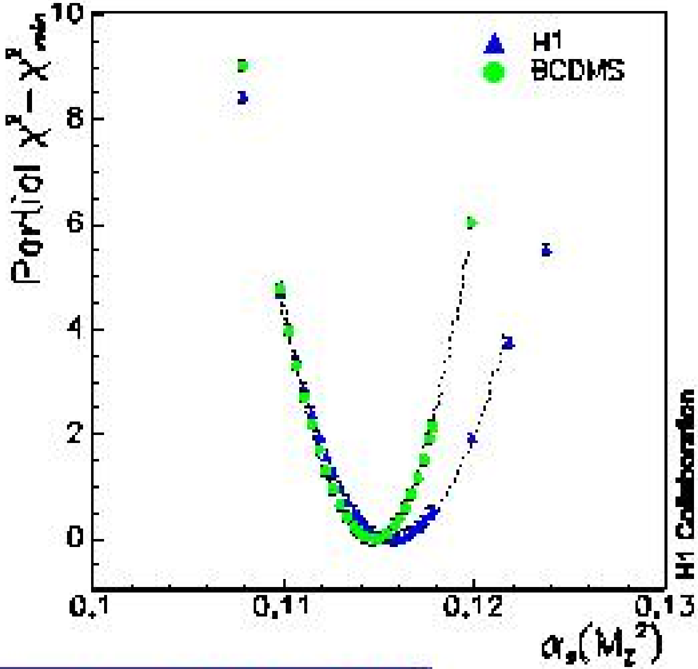
Reasonable agreement between the fits given the different Data and fitting schemes

Gluon and α_s determination

e^+p 96-97 data : $1.5 < Q^2 < 150$ GeV^2 and $3\ 10^{-5} < x < 0.2$
e^+p 94-97 high Q^2 with BCDMS μp data
NLO massive scheme

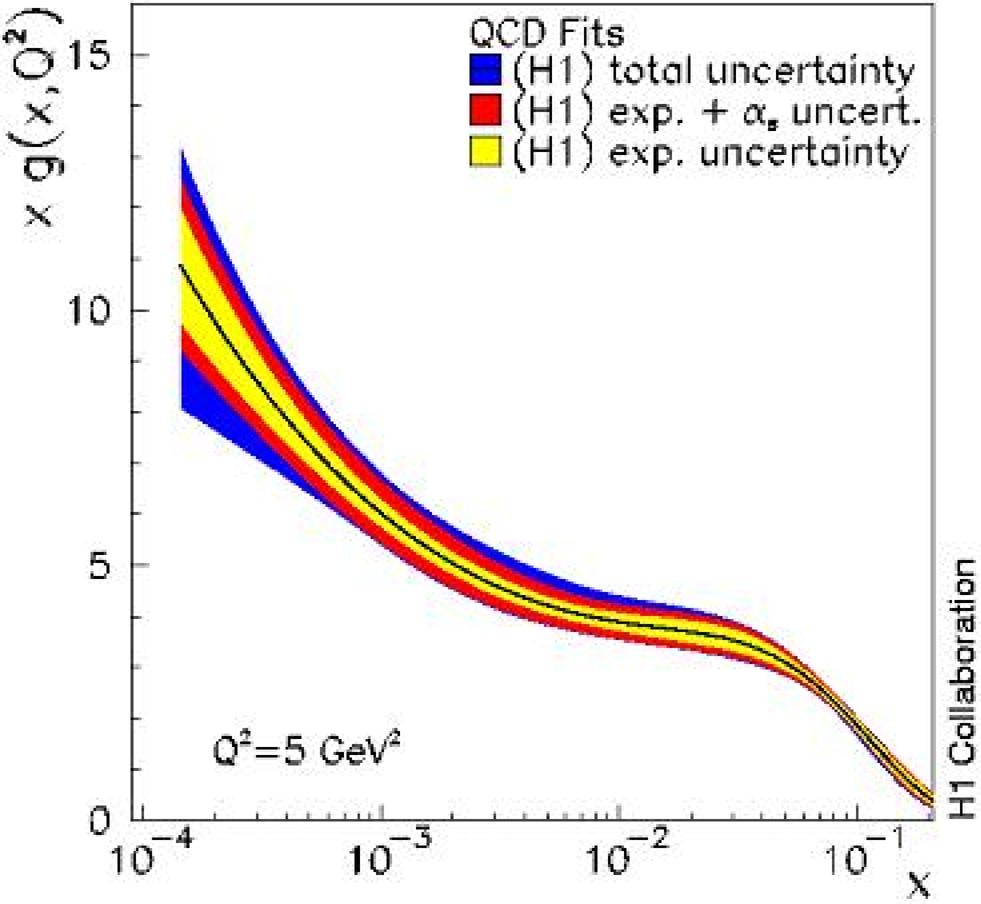
➡ focus on the determination of the gluon density and α_s

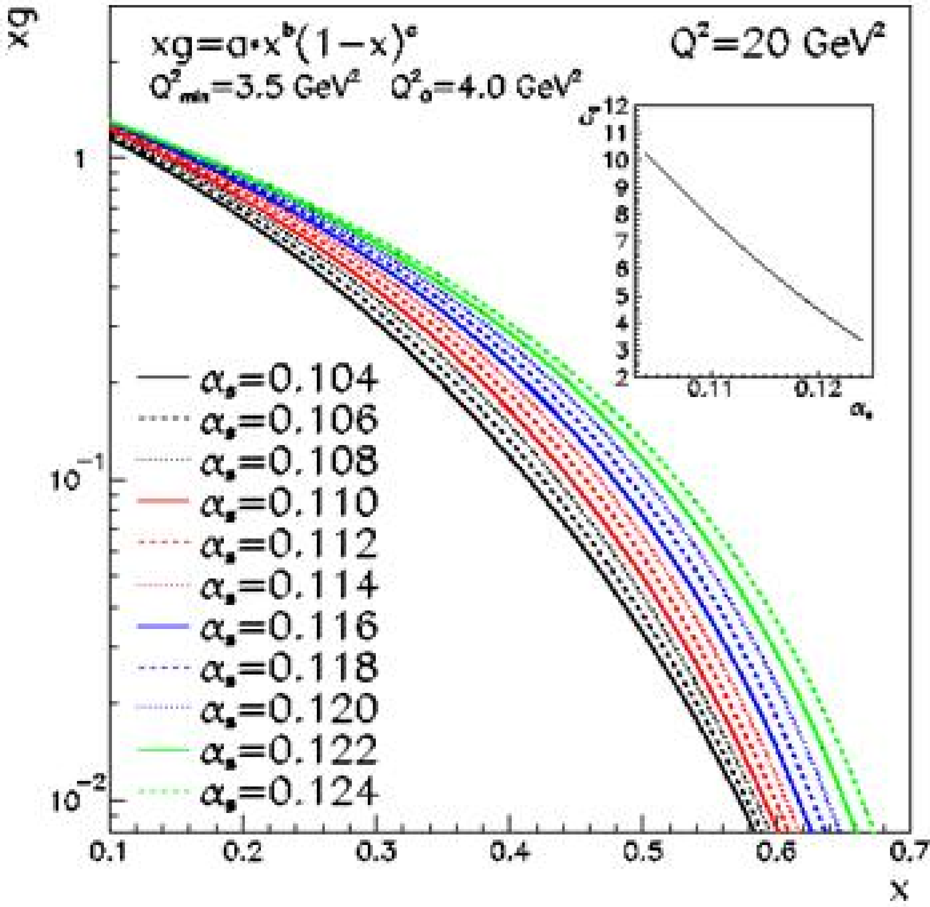




$\alpha_s = 0.1150 \pm 0.0019$ (exp) ± 0.005 (th)

Gluon and α_s determination





How to use the H1PDF2000 ?

- Functions for pdfs, stucture functions, cross sections are available in MSbar, DIS schemes and at LO : web page coming soon

- For easy error propagation : set of functions allowing the use of the Hessian method :

$$\Delta F^2 = \frac{1}{2}\sum_{i=0}^{9}(F(S_i^+) - F(S_i^-))^2$$

Conclusion and outlook

➡ Determination of flavour separated parton densities from H1 inclusive data only is a major achievment

- Add other processes measured with H1 in a global-like analysis (jets, high Q2 F2 charm and beauty)
- Combine with other data
- Perform combined QCD-EW fits