Inclusive Neutral Current Scattering at HERA and α_s

Remarks to Status and Future

Max Klein (H1, DESY Zeuthen)

-recent measurements of the proton structure function F2 at HERA

-the strong coupling constant and the role of fixed target experiments

-the gluon momentum density (xg) and the longitudinal structure function (FL)

-determination and assumptions on parton distribution functions (pdf)

-summary

DESY Forum on QCD, pdfs ..., part I, 25.3.2003

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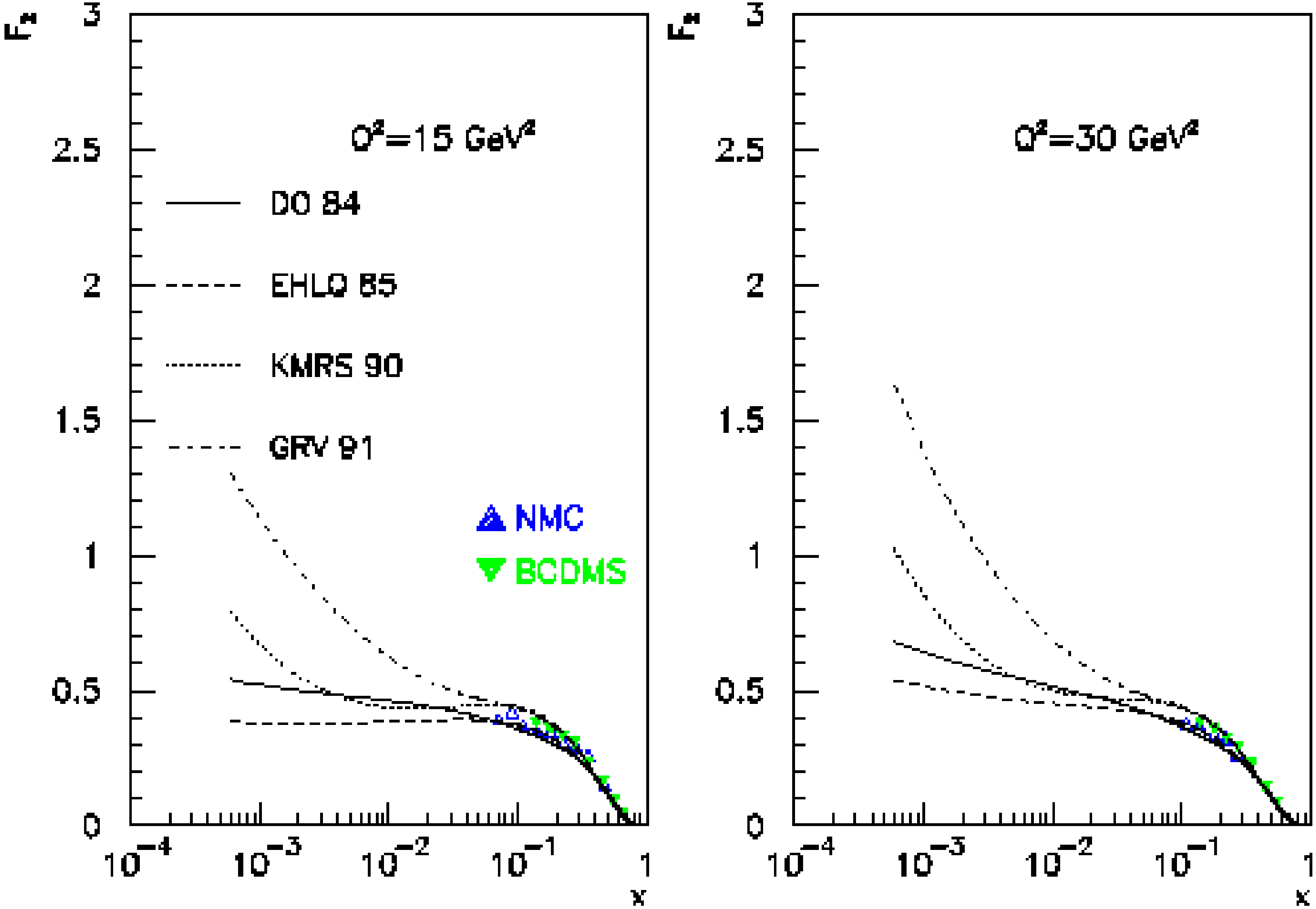
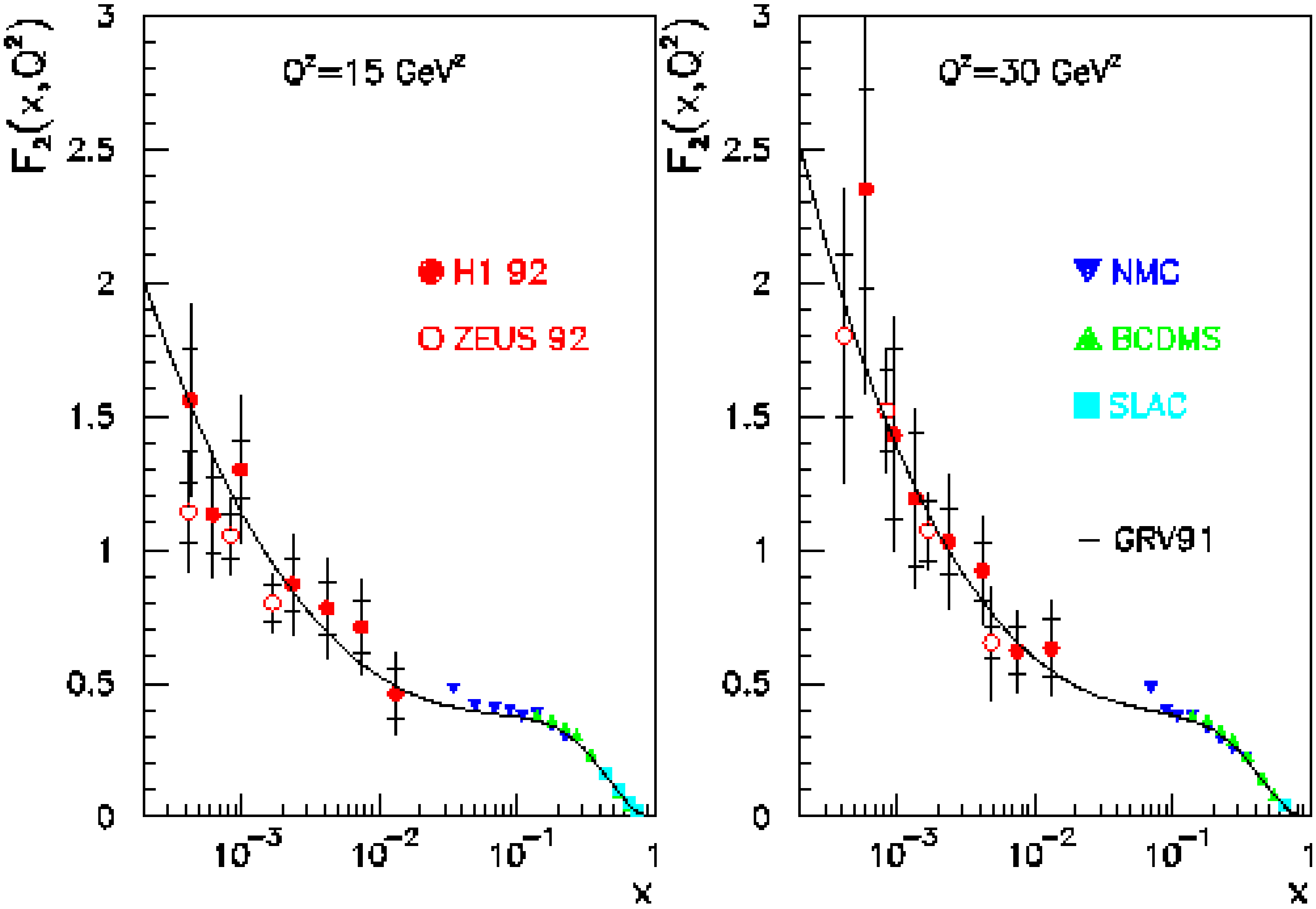
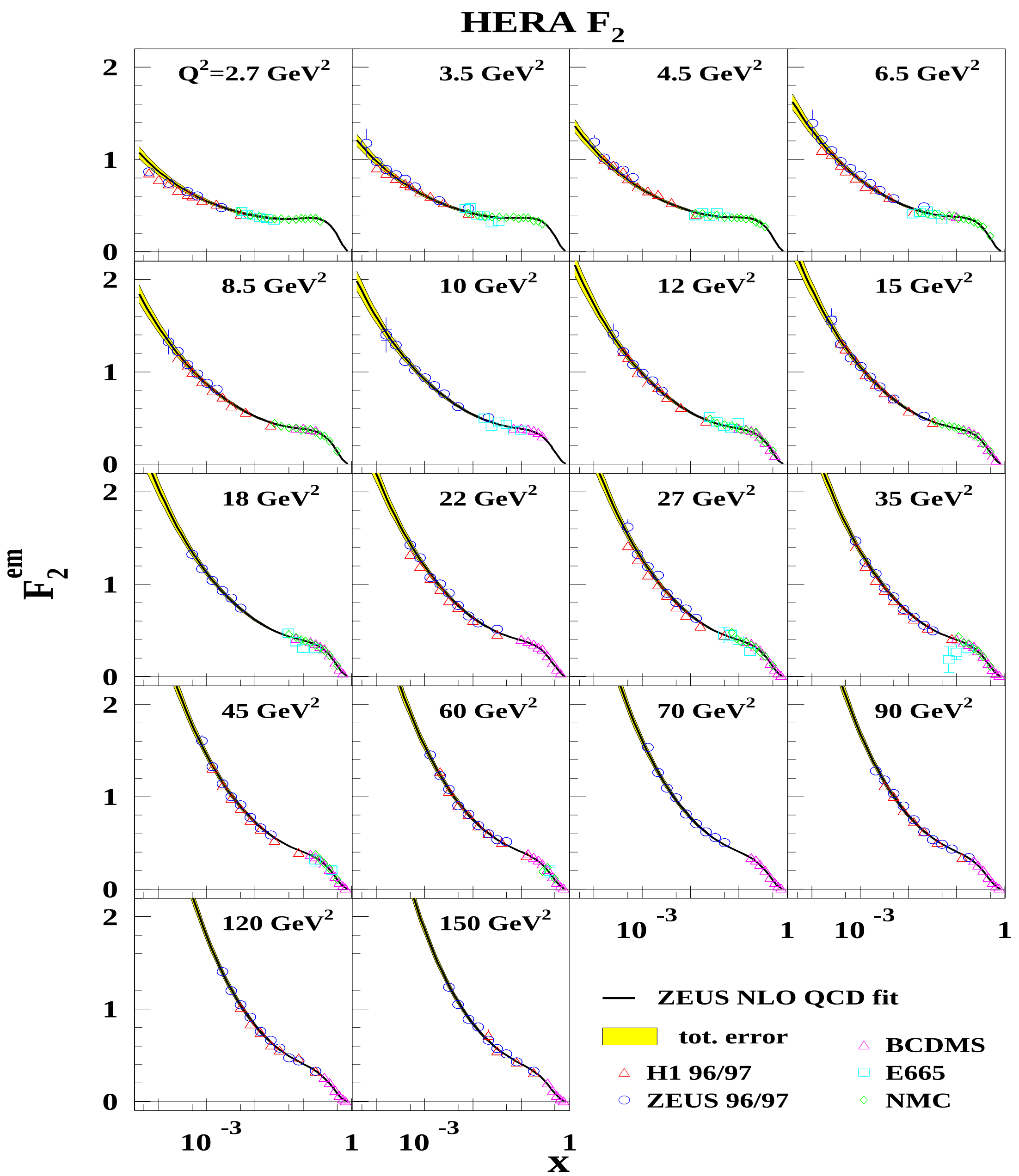


F₂
3
2.5
2
1.5
1
0.5
0
Q^2=15 GeV^2
DO 84
EHLQ 85
KMRS 90
GRV 91
NMC
BCDMS
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
Q^2=30 GeV^2

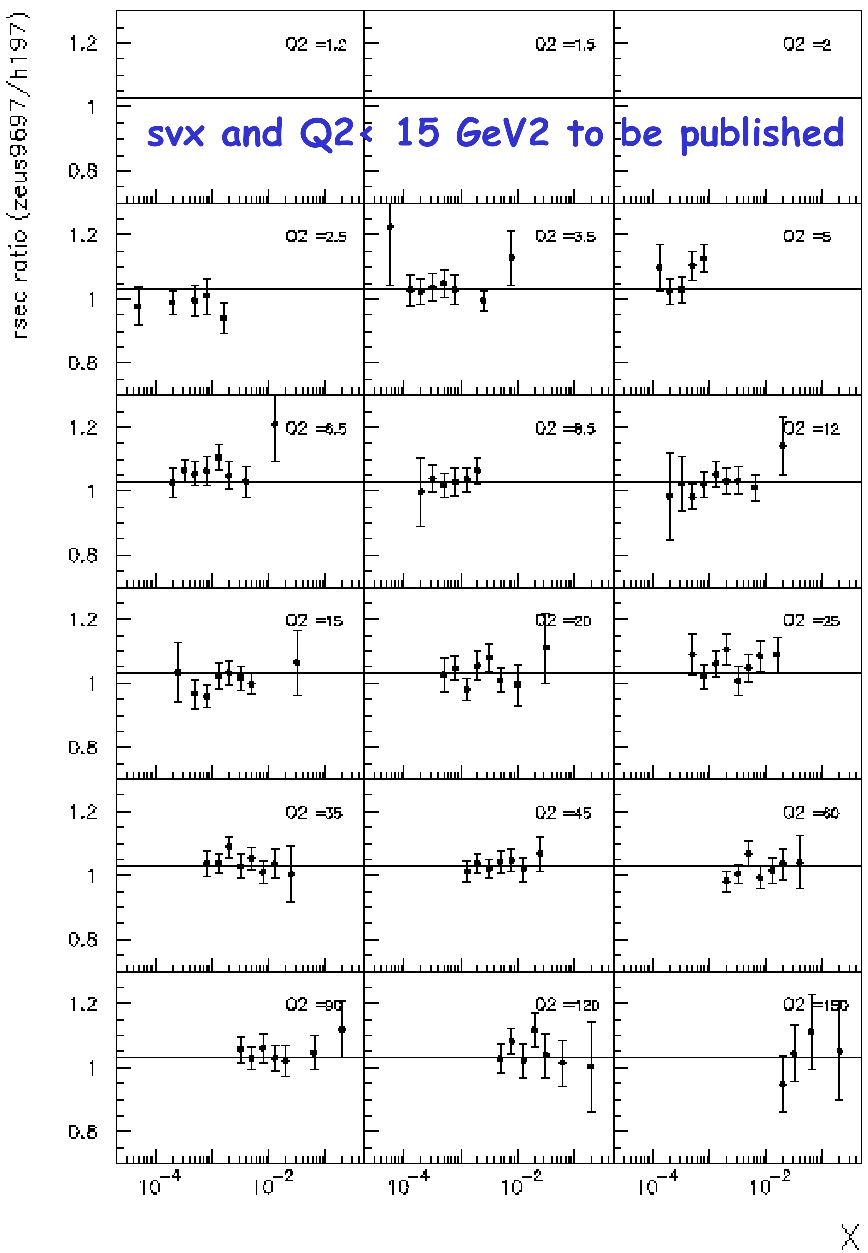


HERA: F2 is rising towards low Bjorken x – observed with 20nb-1

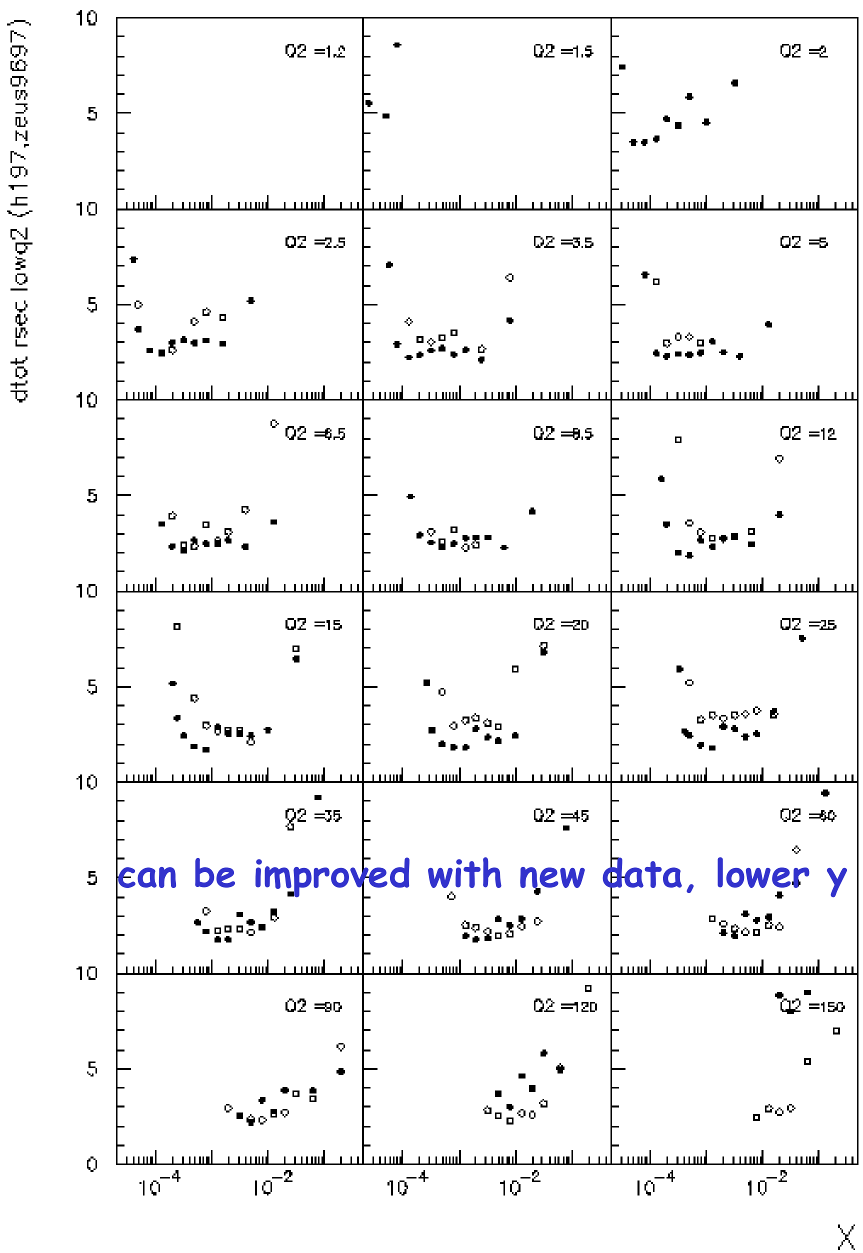


- Most accurate data on F2(x,Q2) from HERA published so far in DIS region

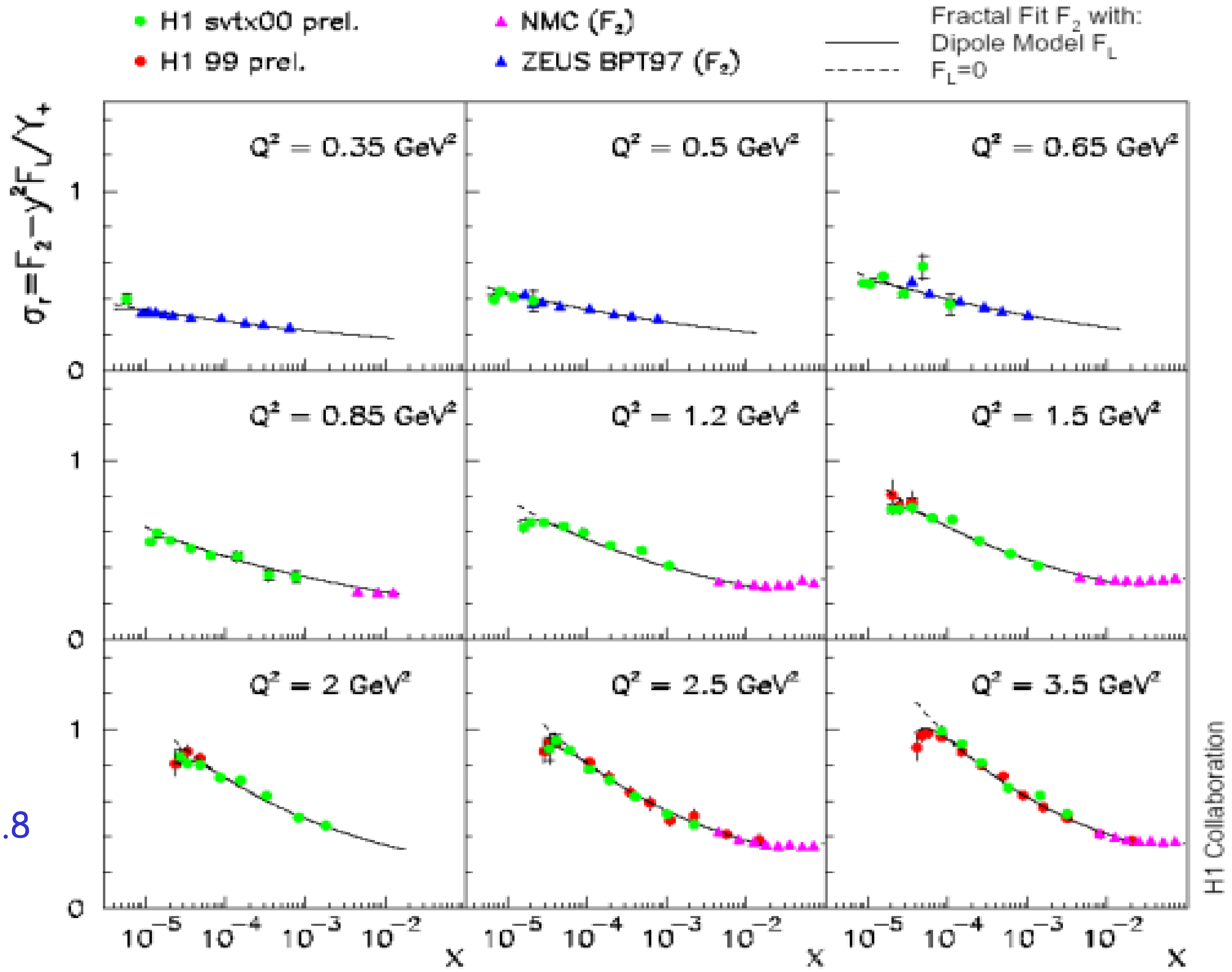
F2(ZEUS/H1)



total uncertainties

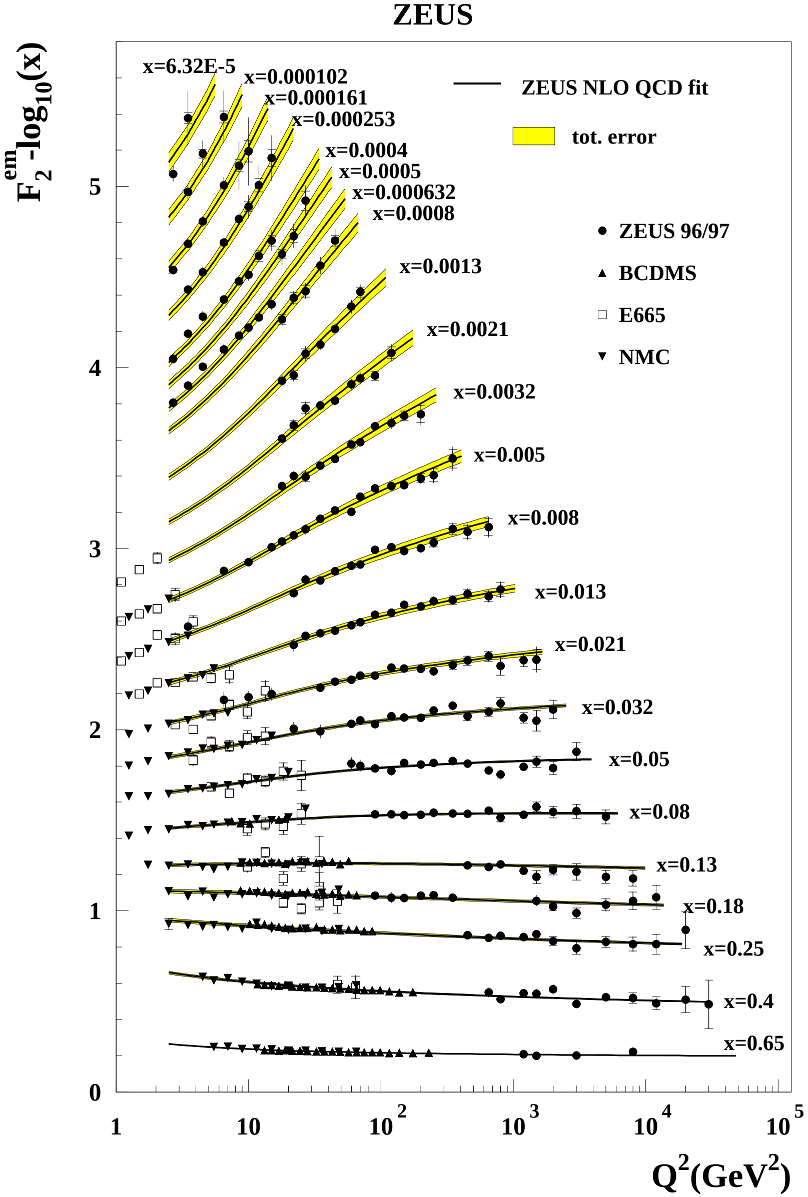


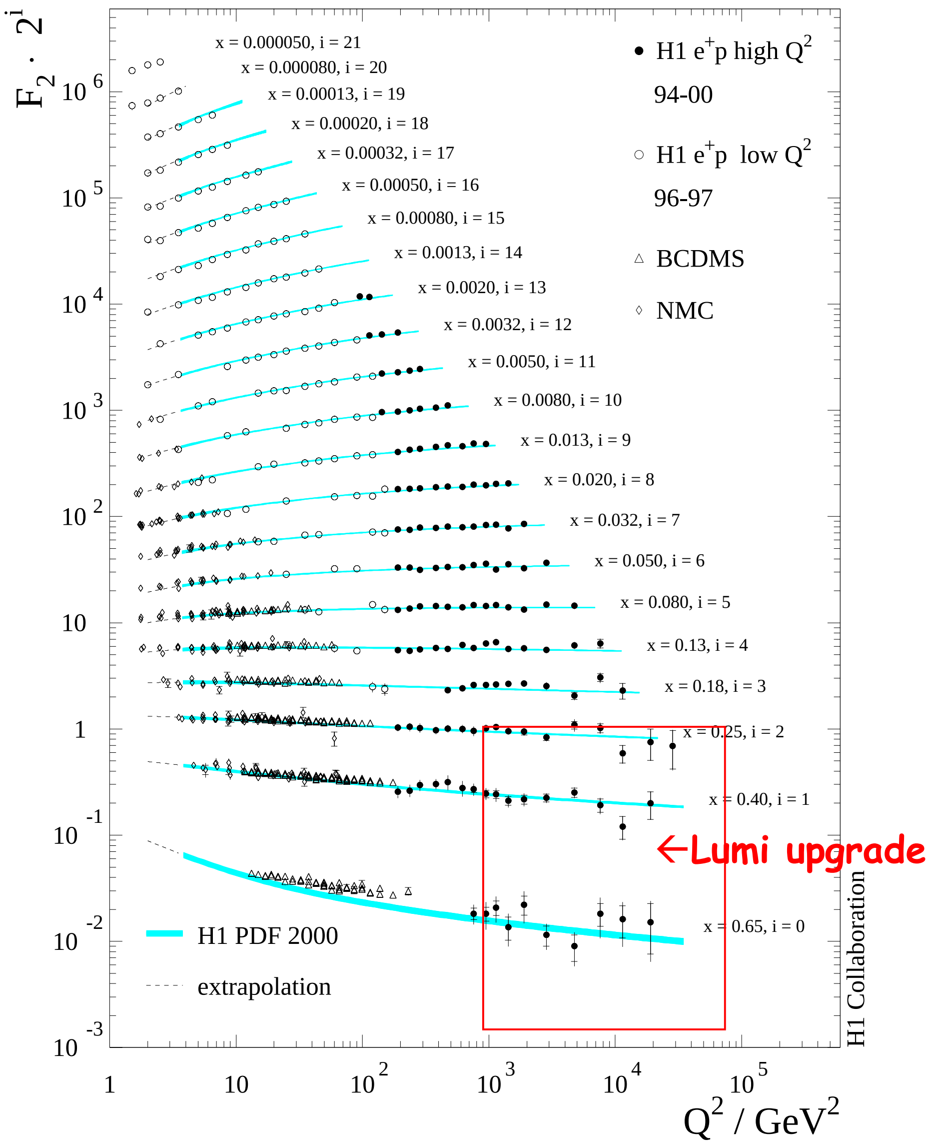
low Q2 reduced cross section



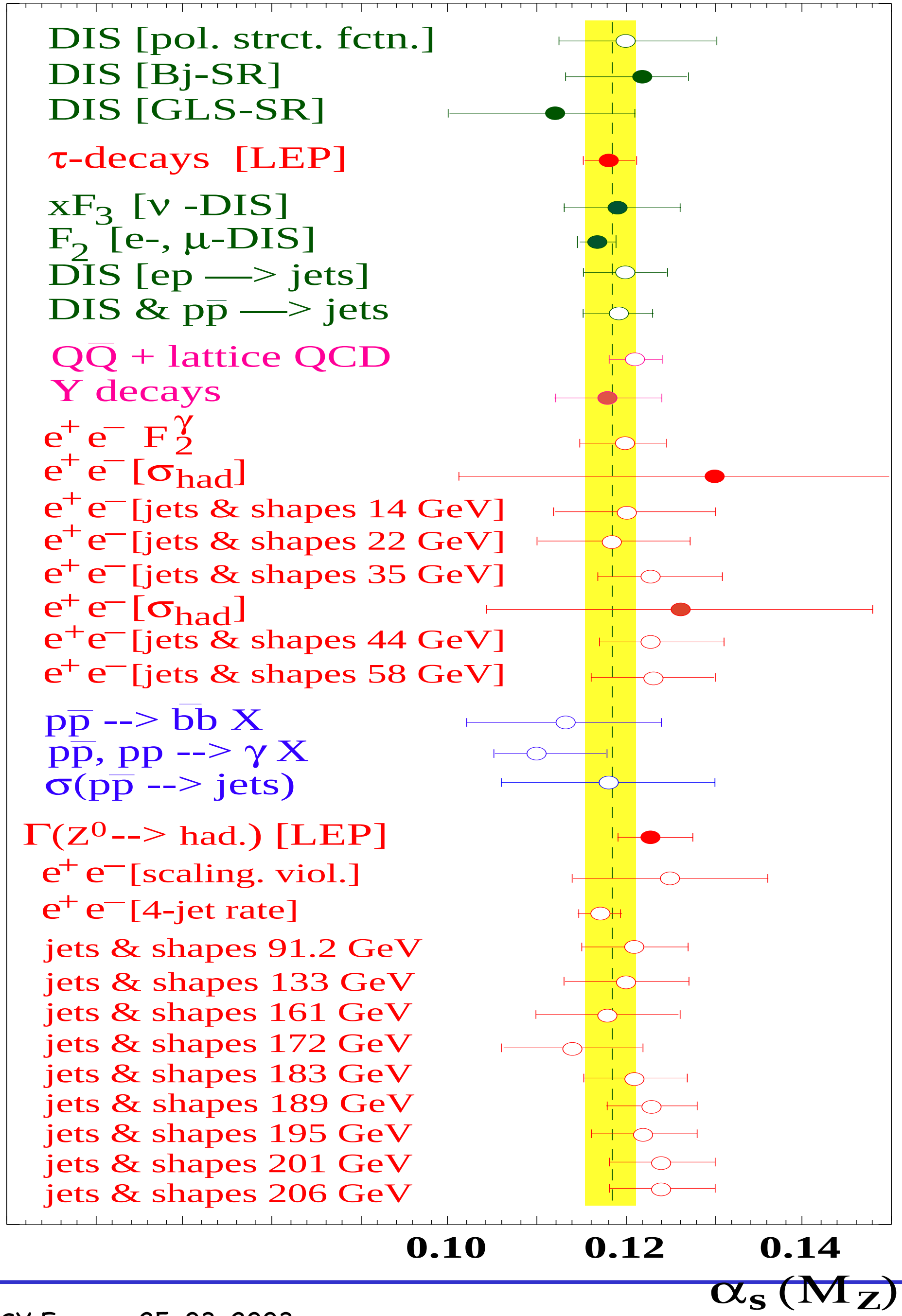
y < 0.8

not shown due to lack of time





ZEUS 96-97, DESY 02-105, Phys.Rev. D67(2003)012007 H1 94-00, DESY 03-038, to appear



0.1183+-0.0027 NNLO

S.Bethke hep-ex/0211012

not shown due to lack of time

HERA results on the strong coupling constant from F2

- **H1** 0.1150 +- 0.0017(exp) + 0.0009 - 0.0007(model)

proton data and only H1+BCDMS
Q2(H1)>3, Q2(BCDMS)>7GeV2,W2>10GeV2

EPJ C21(01)33
R.Wallny Thesis 01-058

if: systematic errors are not fitted: +0.0005
NMC replaces BCDMS 0.116+-0.003 (exp)
4 light flavours: +0.0003
BCDMS deuteron data added: 0.1158 +- 0.0016 (exp)

- **ZEUS**

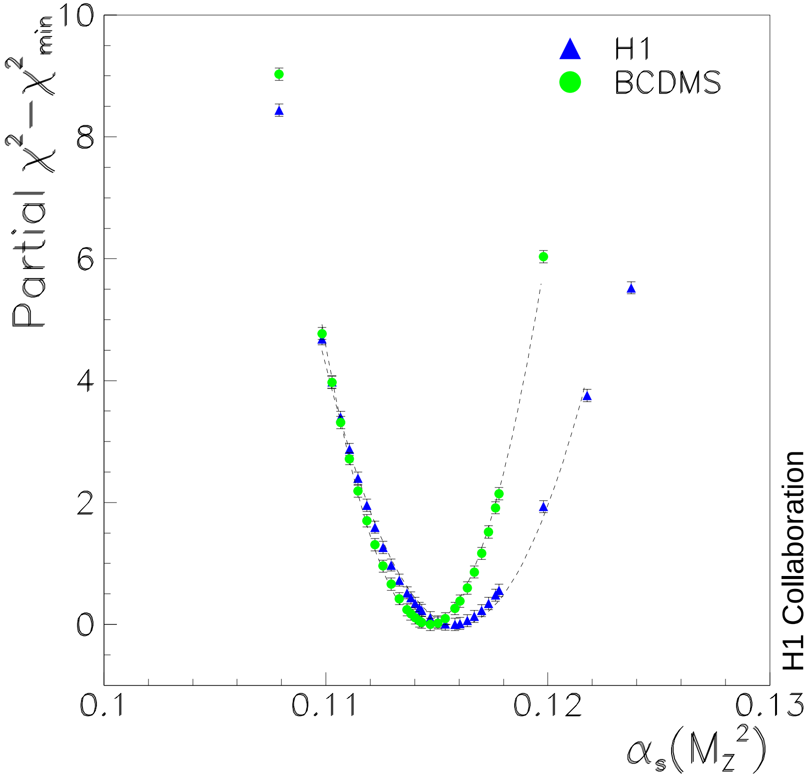
0.1166 +- 0.0008(unc) +- 0.0032(corr) +- 0.0036(norm) +- 0.0018(model)

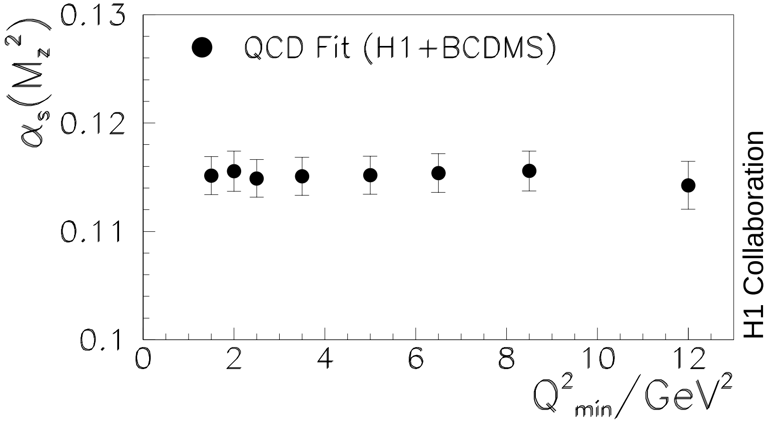
p:BCDMS,NMC,E665 d:NMC,E665 d/p: NMC xF3: CCFR

systematic errors are not allowed to vary in chi2 minimisation
Q2>2.5 GeV2, W2>20GeV2, RT-VFNS
fit alphas, xg, uv, dv, sea, dbar-ubar (MRST)
if fixed flavour scheme is used: +0.0010
M.Botje programme

hep-ex/0208023
PR D67(03)012007

H1-DIS measurement of alphas with H1 and BCDMS data





joint determination of alphas, xg, V,A
no interest in quarks → two pdfs only

9 F2 = 3 xV +11xA = 4xU+xD

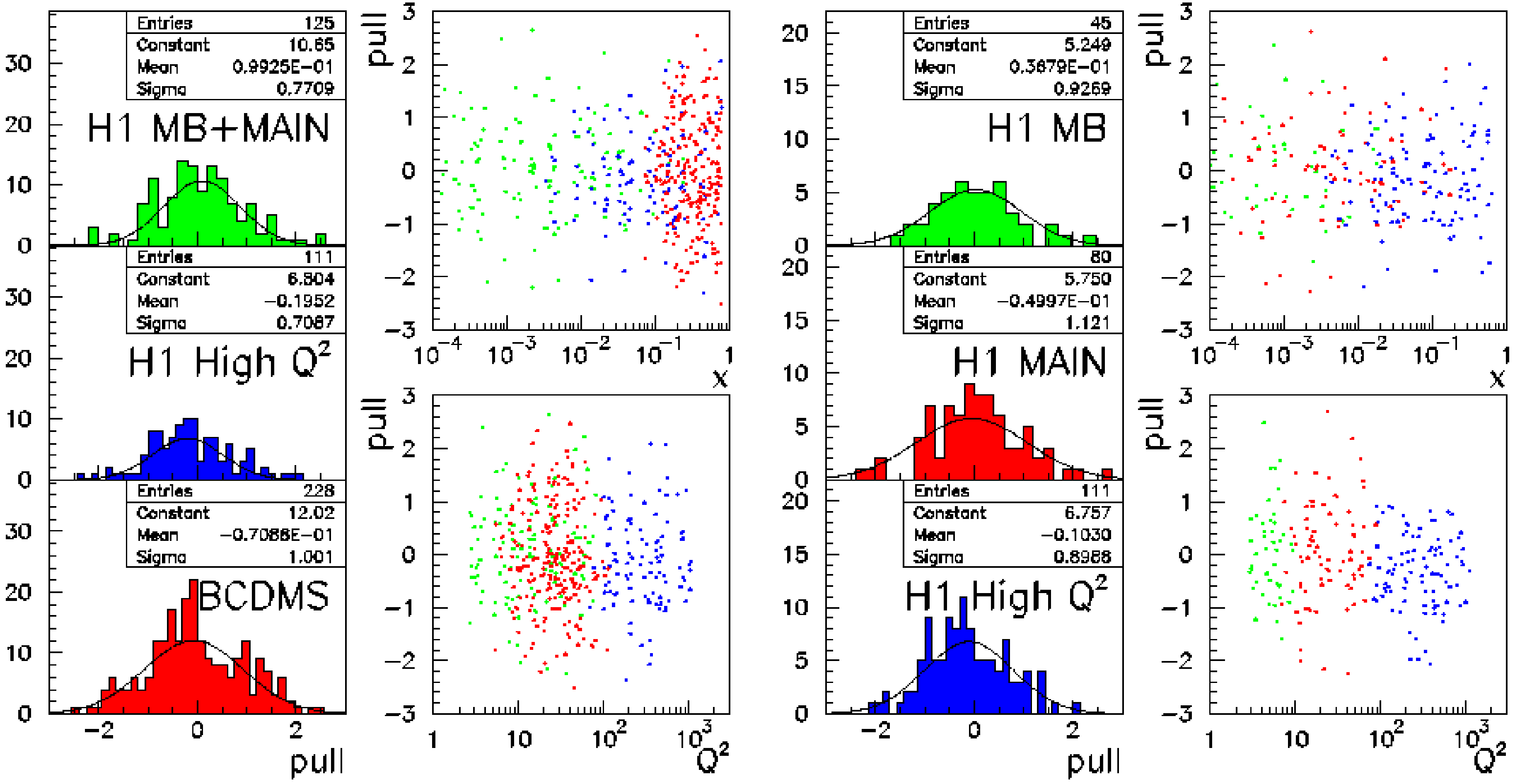
$$V \xrightarrow[\bar{u}=\bar{d}]{} \frac{3}{4}(3u_v - 2d_v)$$

$$A \xrightarrow[\bar{u}=\bar{d}]{} \bar{u} - \frac{1}{4}(u_v - 2d_v)$$

→chi2+1 well defined
two consistent exp data sets

x space: C.Pascaud, F.Zomer, DESY 96-266

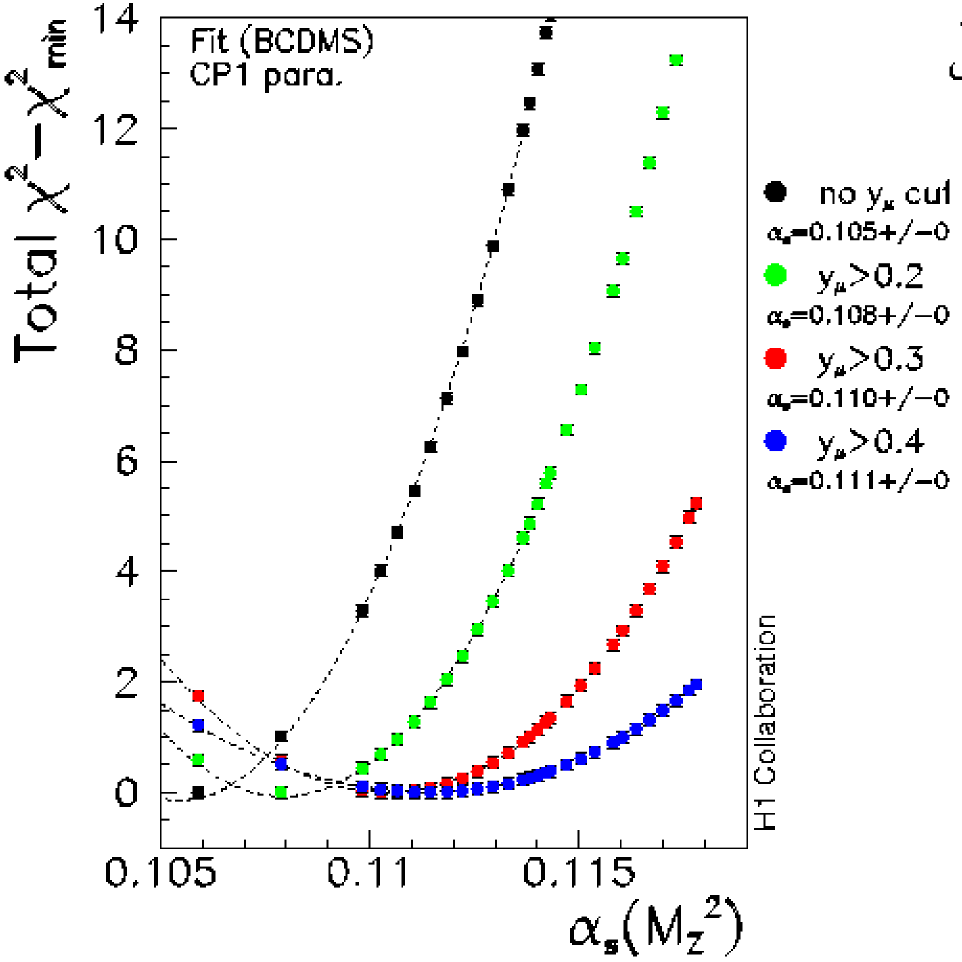
pull distributions: DIS data consistent with NLO pQCD

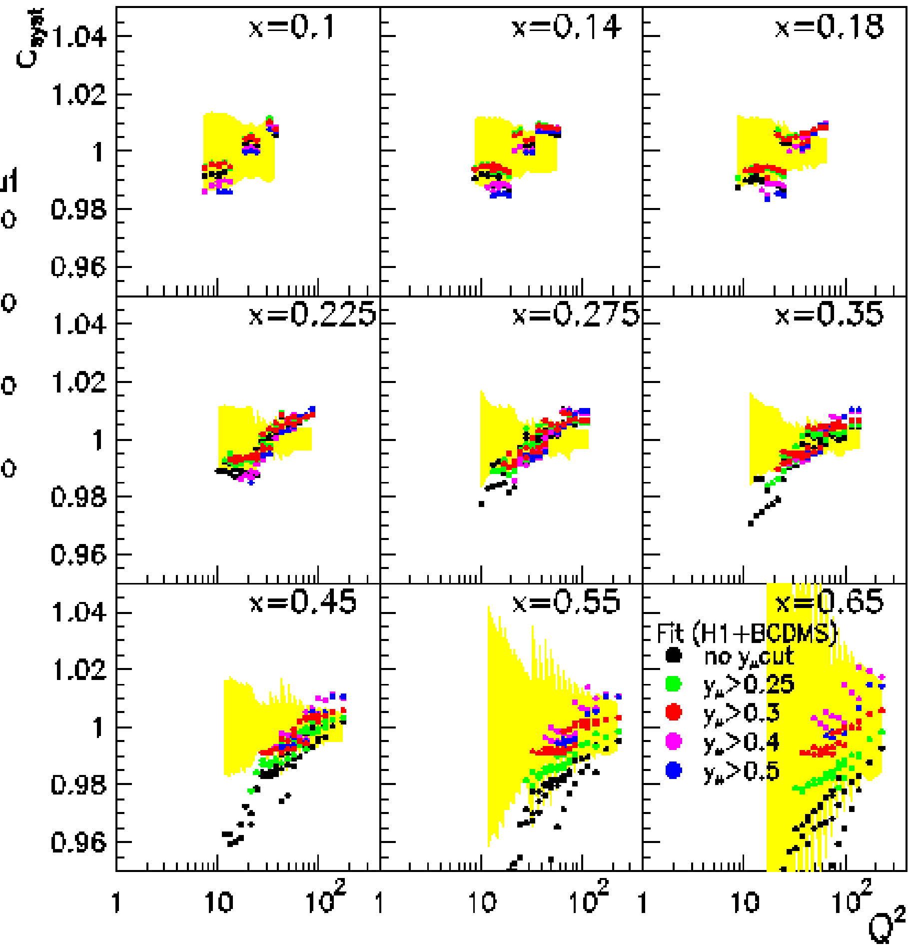


H1 + BCDMS fit
y(BCDMS) > 0.3

fit to H1 data alone
if x>0.0005 → +0.00051

the problem of the BCDMS data





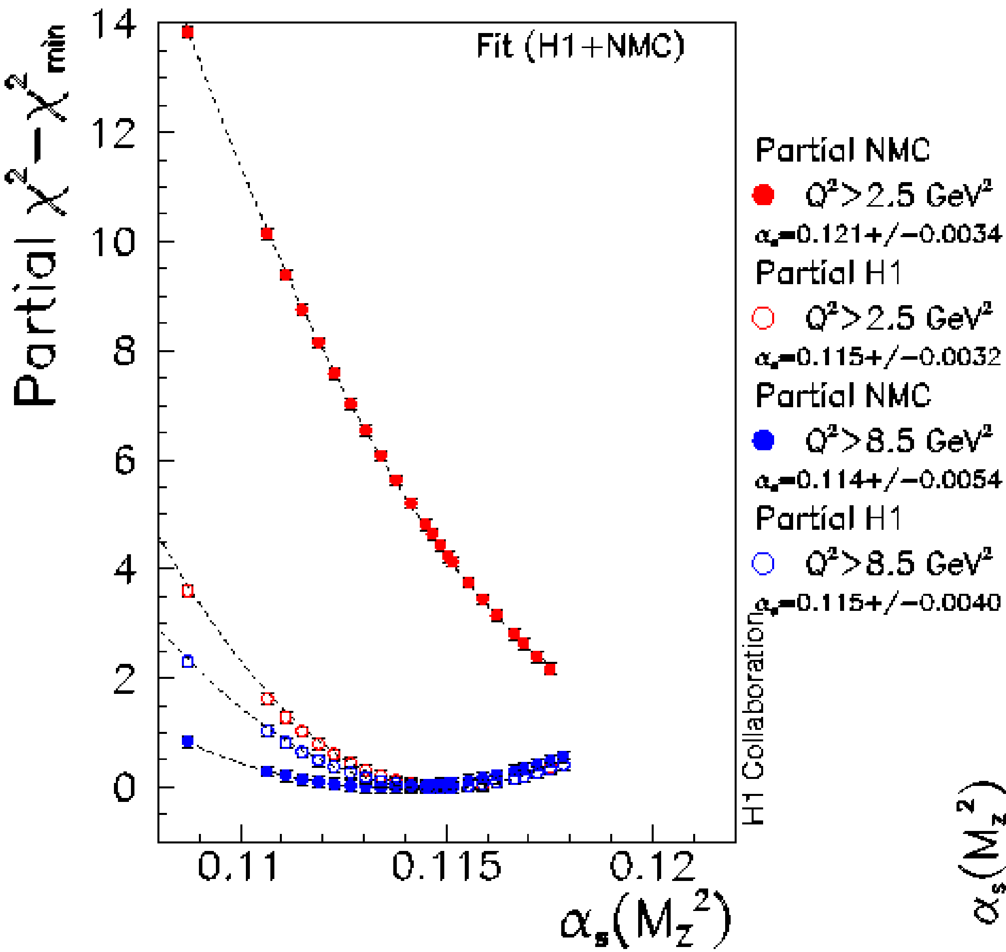
systematic errors of BCDMS data

alphas (BCDMS) very low and strongly y dependent („electron method")

low y – large x region in conflict with SLAC F2

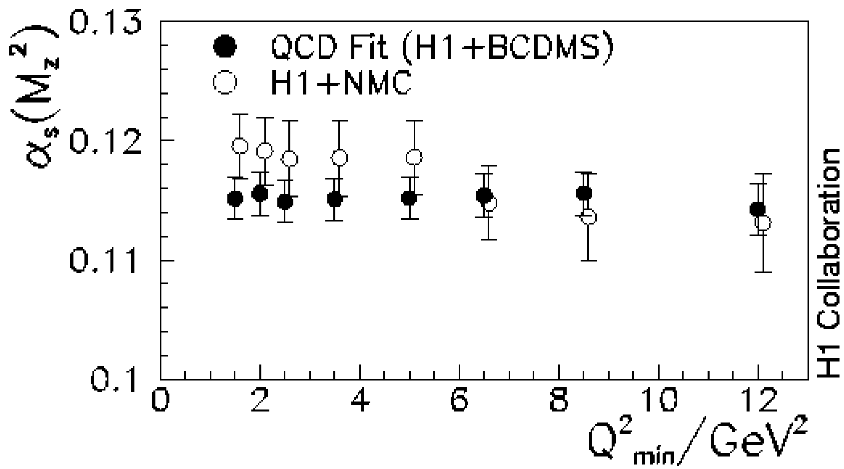
shifts imposed by QCD fit to BCDMS data

the problems of the NMC data



- NMC drives fit to high alphas
- unbound fit requires 1/Q2 terms
  W cut not enough
- for Q2>5GeV2: small impact left
  but then smaller alphas preferred

→remeasure at HERA with Ep/2 the medium Q2 - larger x region with large luminosity. Systematics superior over fixed target exps.



cf also A.Vogt DIS96 Roma

Three-loop : fermionic contributions to nonsinglet splitting function

S.M., Vermaseren, Vogt hep-ph/0209100

$$P_{ns}^{(2)}(x) = 16 C_A C_F n_f \Big(p_{qq}(x) \Big[\frac{5}{9}\zeta_2 - \frac{209}{216} - \frac{3}{2}\zeta_3 + \frac{1}{3}\mathrm{Li}_3(x) - \frac{167}{108}\ln(x) + \frac{1}{3}\ln(x)\zeta_2 - \frac{1}{4}\ln^2(x)\ln(1-x)$$

NNLO corrections to pQCD

NLO folklore: vary renorm. scale ($\frac{1}{4}$ .. 4) Q2 → determines thy error

observation: H1/ZEUS: too large chi2 variations

H1: quote uncertainty of +-0.005

ZEUS: use (1/2.. 2) : mention uncertainty of +- 0.004

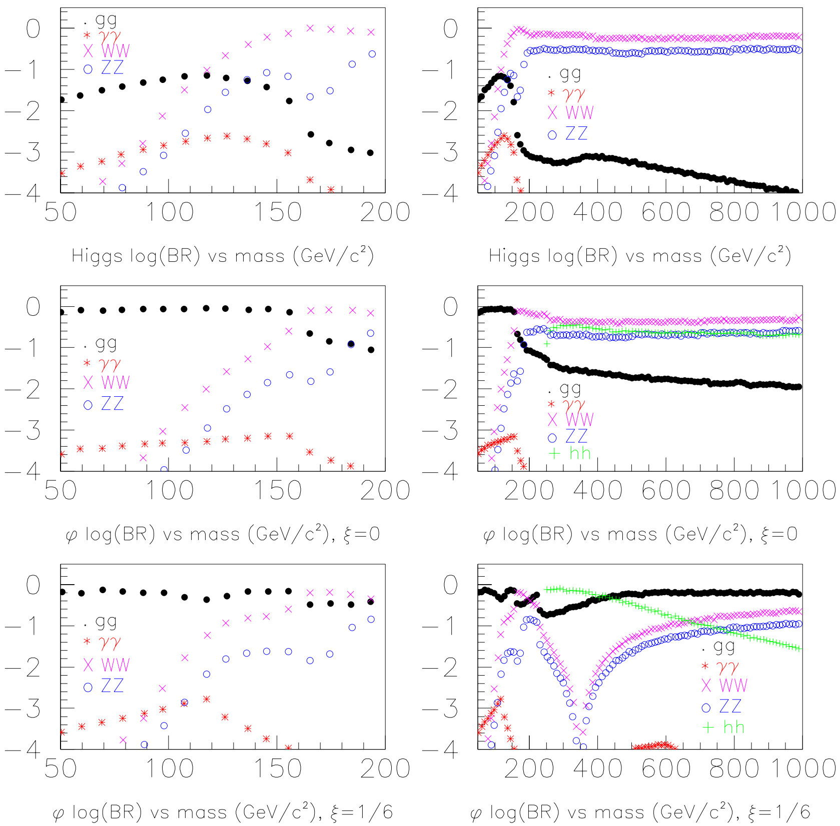
moment analyses: compare NLO with NNLO: -0.001 (Santiago & Yndurain)
NP, hep-ph/0102247

full calculations to 3 loop anomalous dimension progressing

NNLO has to include charm treatment in NNLO (mc +-100MeV is +-.0005)

higher experimental precision of HERA F2: challenge is less than 1 per cent
with efficient tracking + high resolution calorimetry + accurate/lots of lumi

extra dimensions



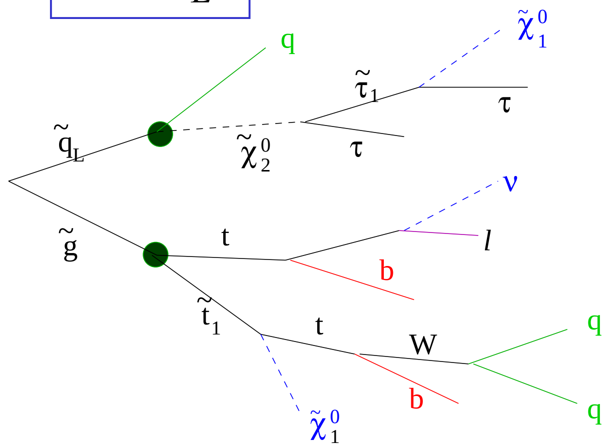
·G.Azuelos et al

Randall Sundrum Radion
two 4d surfaces (branes) bounding a 5d spacetime

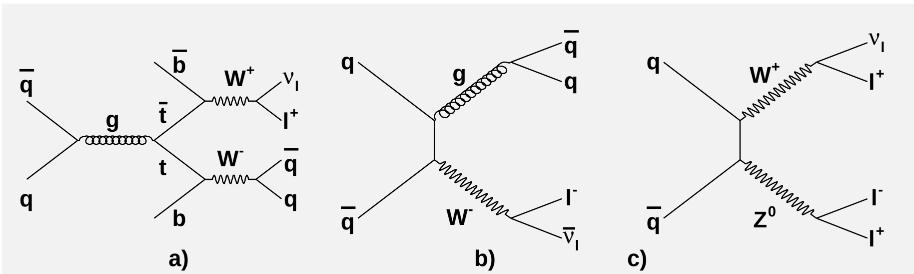
SM in theTeV brane + Planck brane +bulk.
Radion: massive bulk scalar interfering with Higgs

MSSM cascade from

$$qg \to \tilde{q}_L \tilde{g}$$

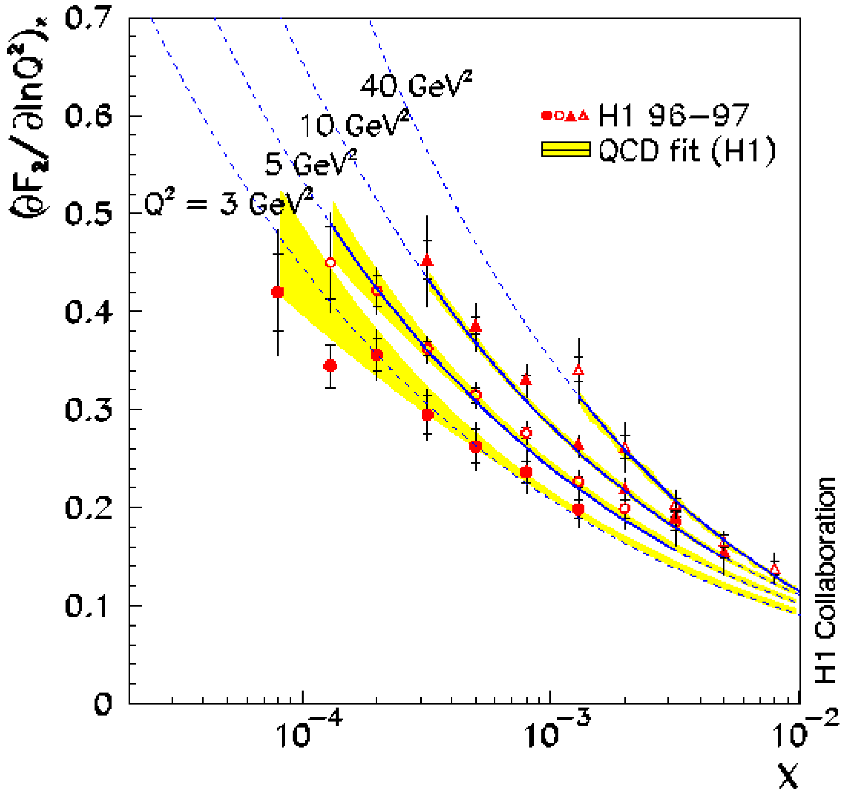


background processes (piling up)



Les Houches 2001, BSM, SLAC-PUB 9183

HERA is unique in determining pdf's and alphas

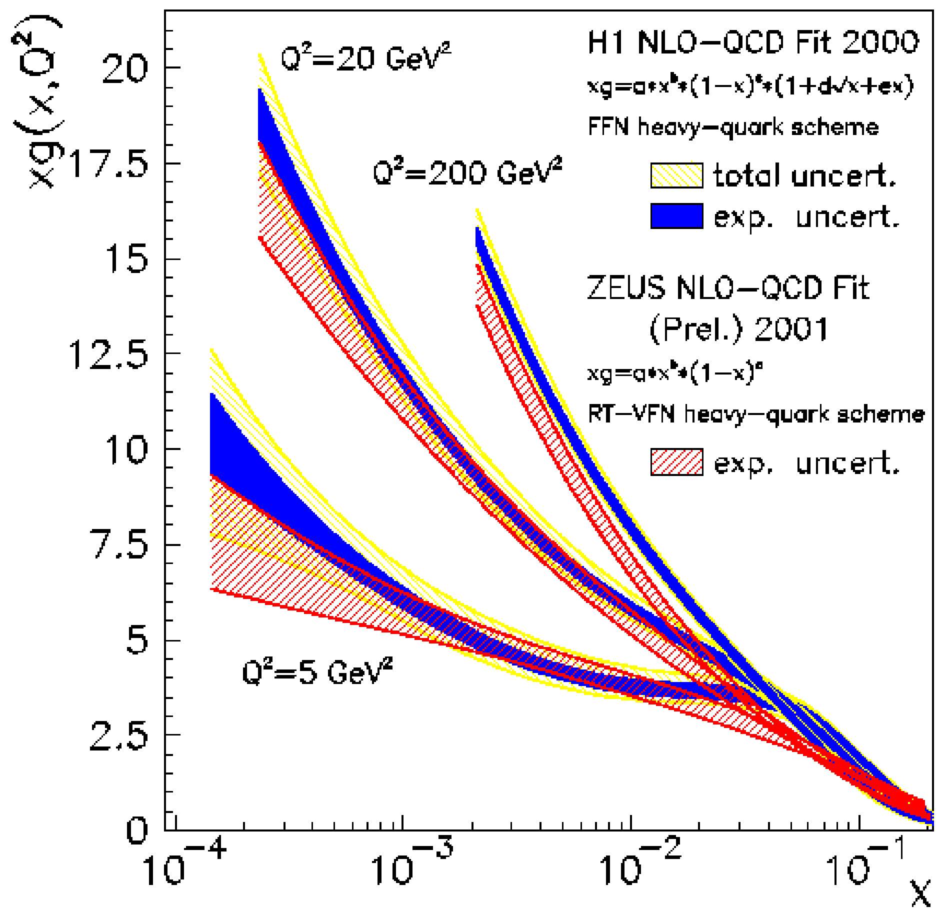


$$\frac{\partial F_2}{\partial \ln Q^2} \propto \alpha_s \cdot xg$$

xg depends on c treatment!

xg is not an observable

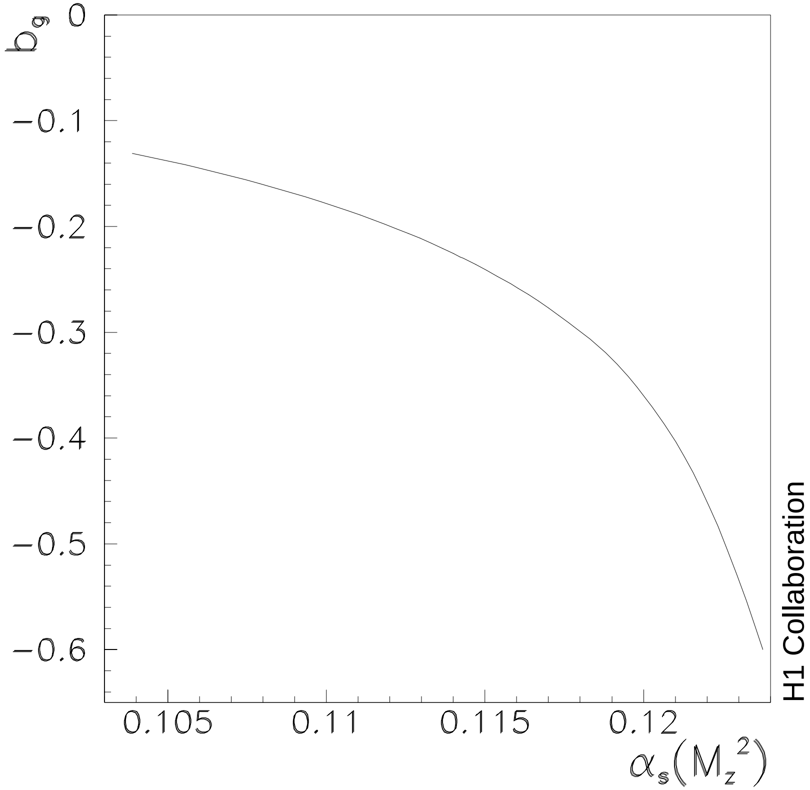
gluon momentum density

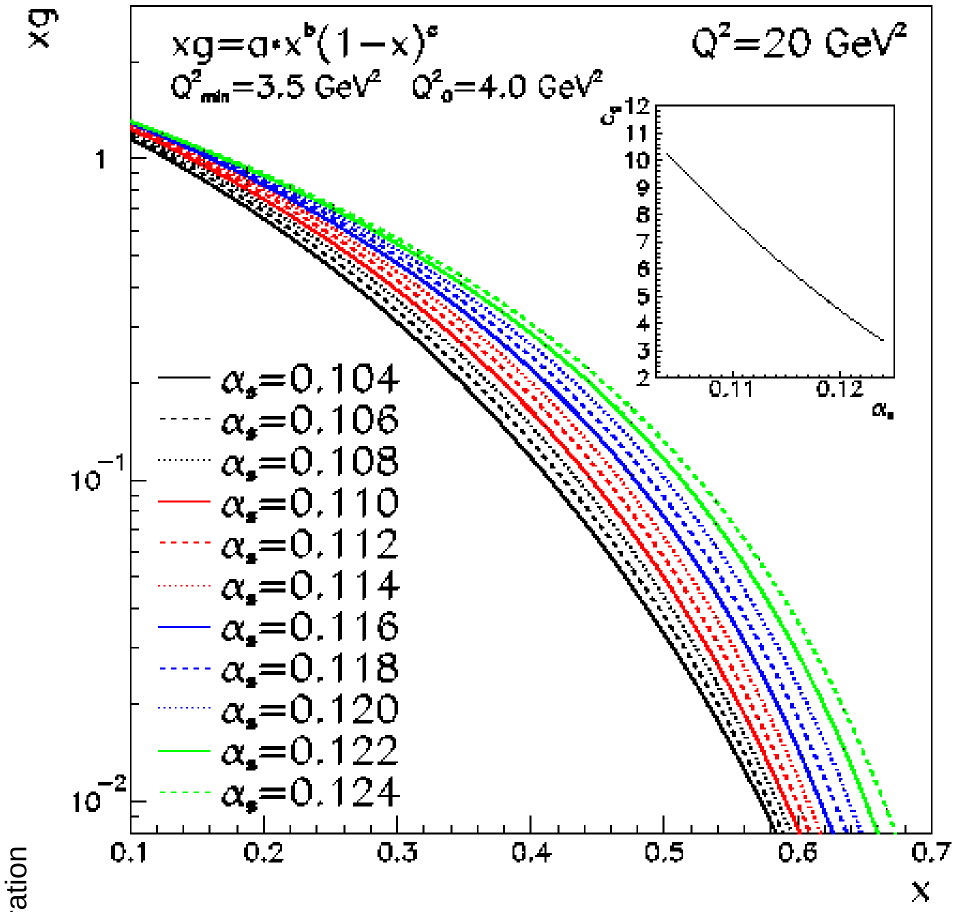


confirmed in recent studies by MCooper Sarkar

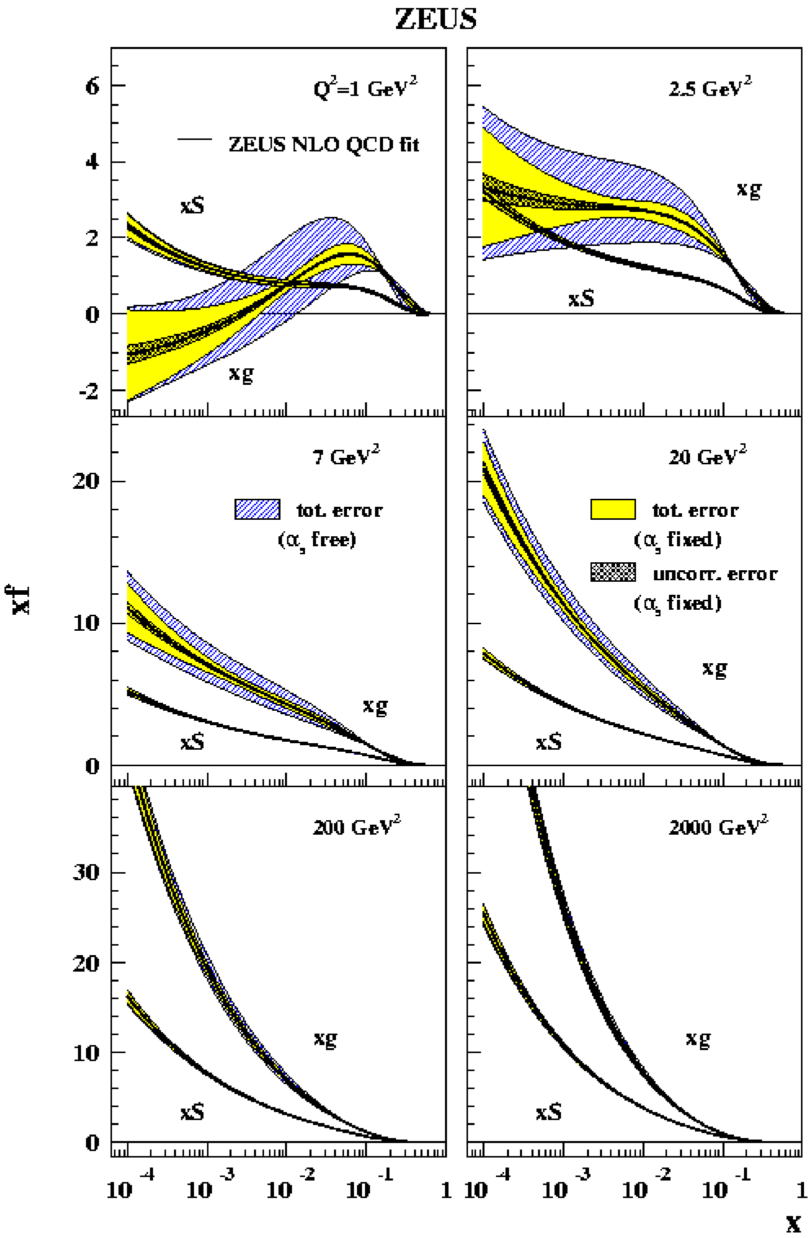
Correlation of alphas and xg
is resolvable in DIS fits

→ determination of alphas
and of the gluon distribution

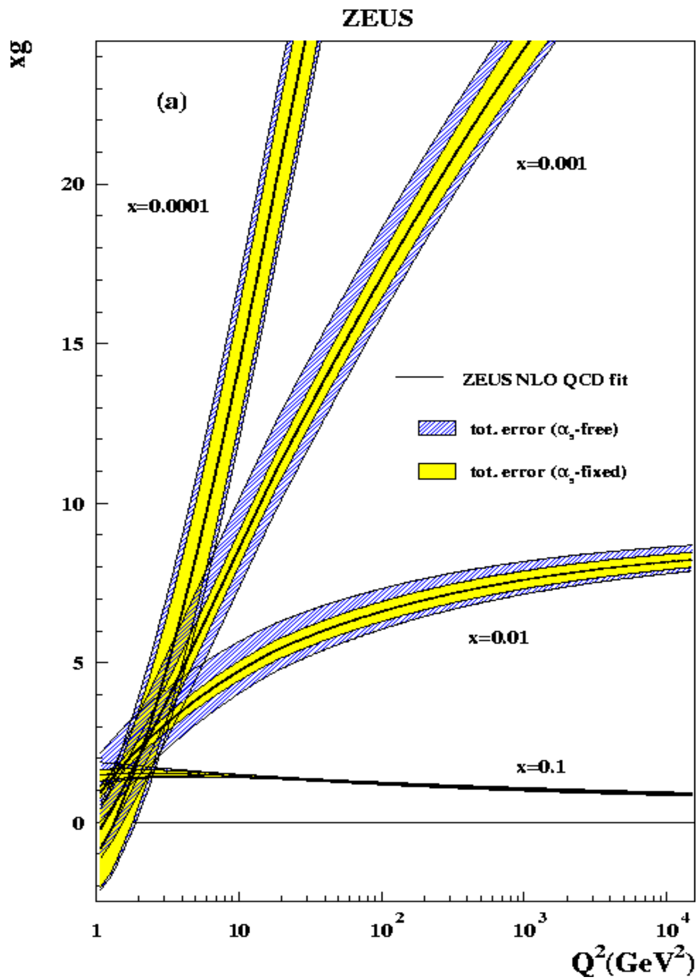




inclusive DIS fits yield small
gluon at large x – jets?

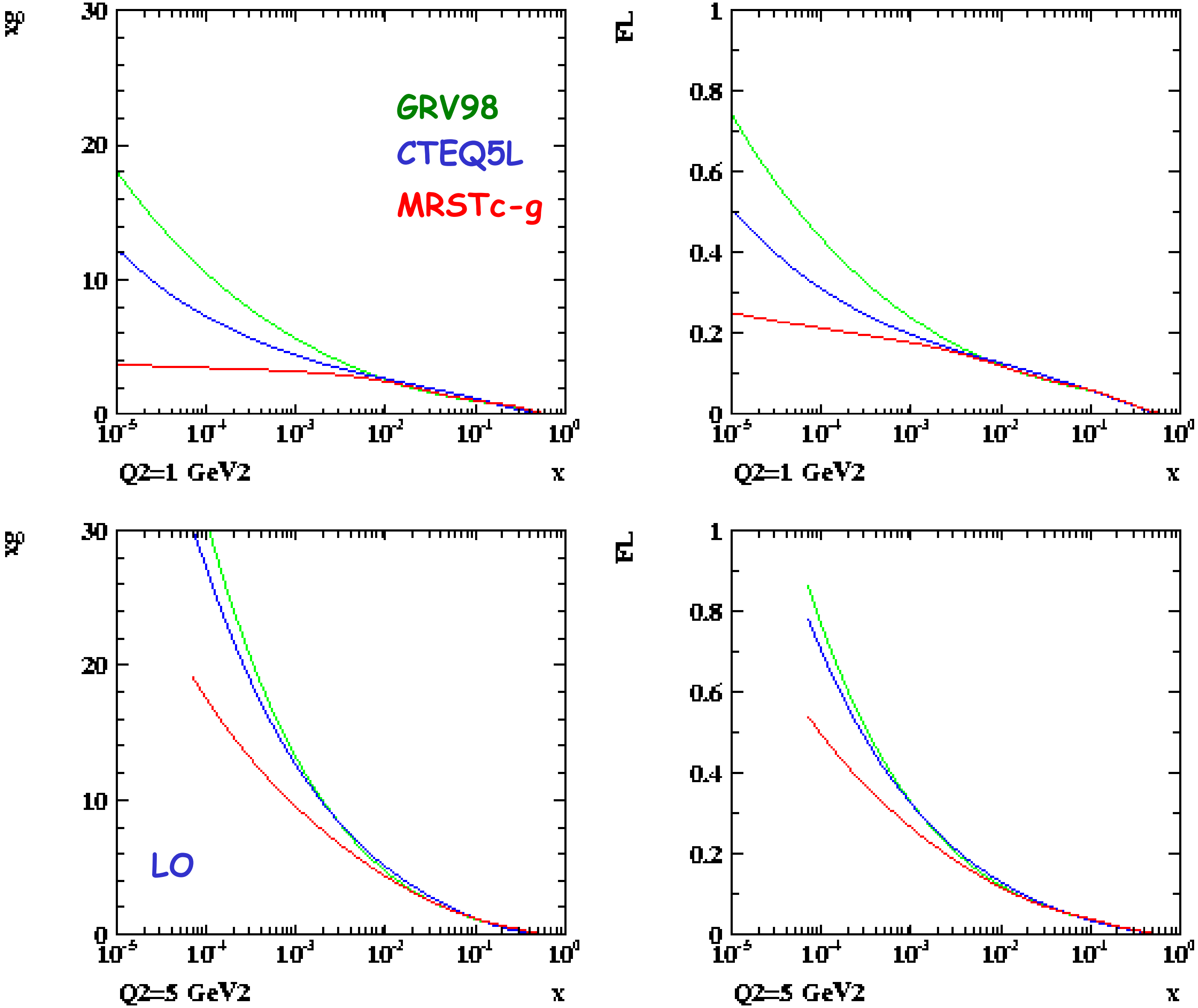


•is xg negative at small x,Q2?



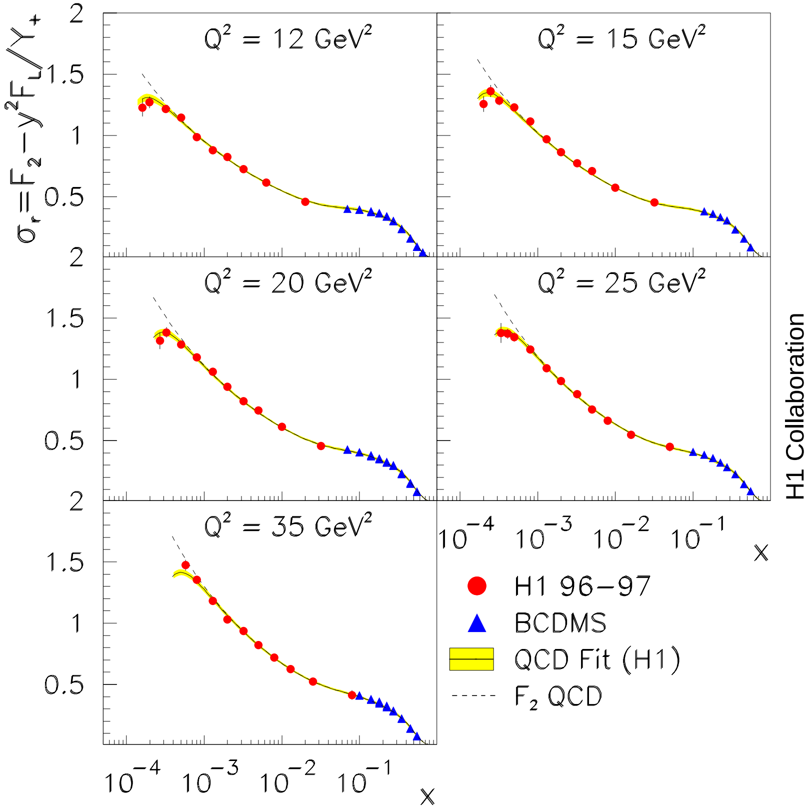
Q0 defines fwd or bwd extrapolation

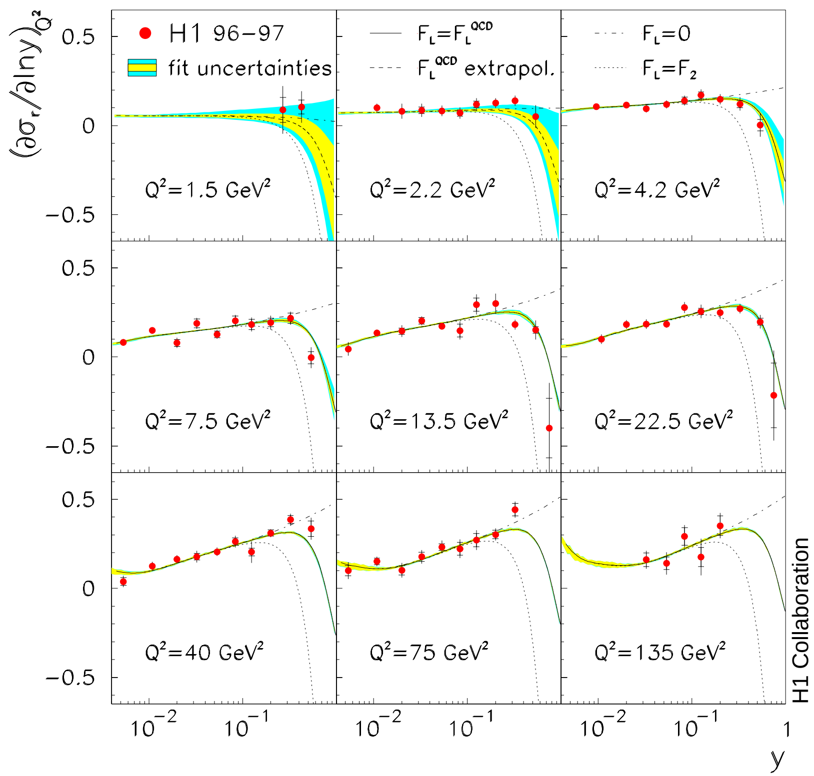
FL provides independent measure of xg



•Leading order calculation of AM equation

access to the longitudinal structure function at low Q2

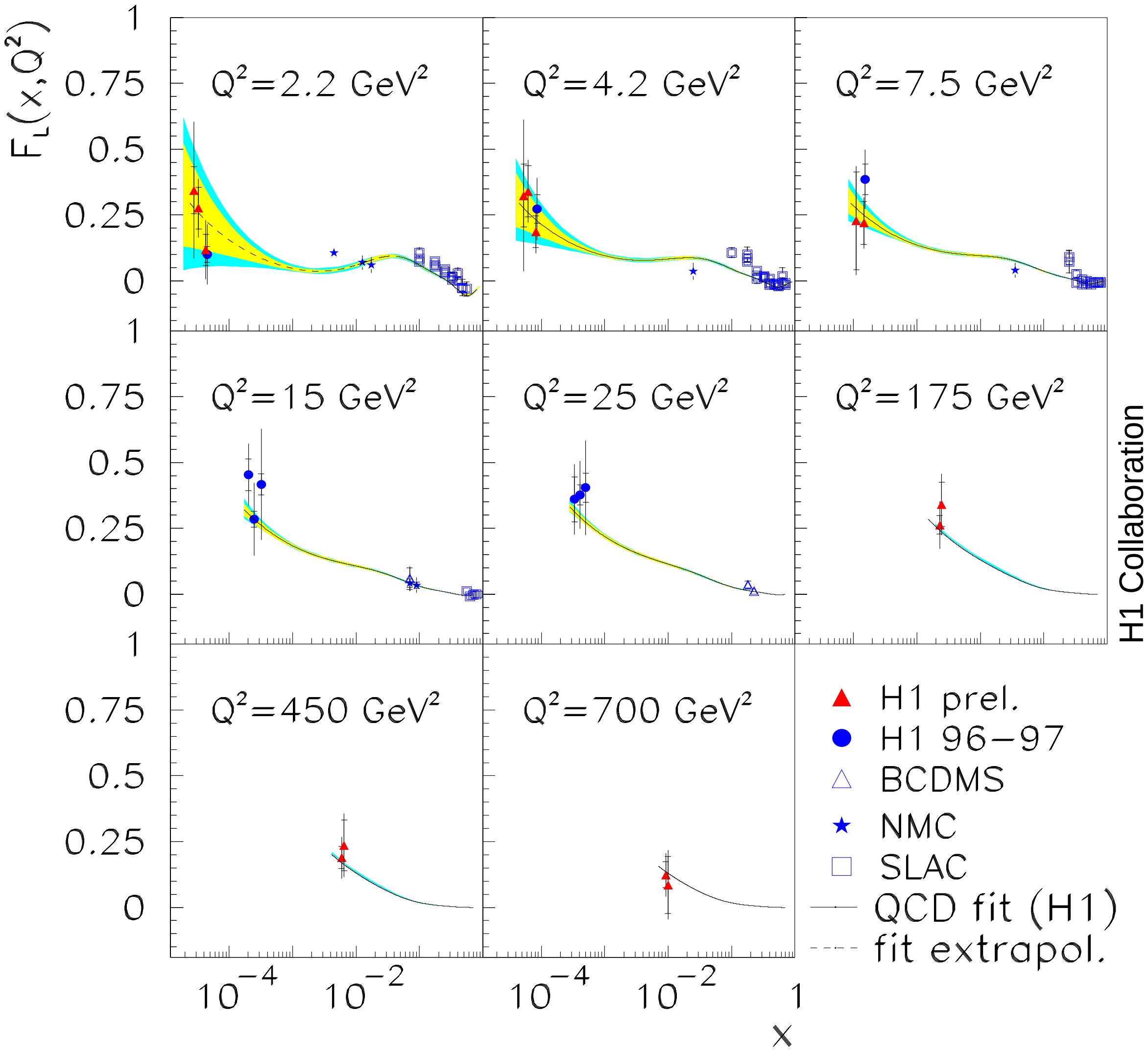




H1 EPJ C21(01)33

not shown due to lack of time

determination of the longitudinal structure function



y<0.9
(this is E'~2..3 GeV!)

needs assumption on F2

more accurate data
at all Q2 to come

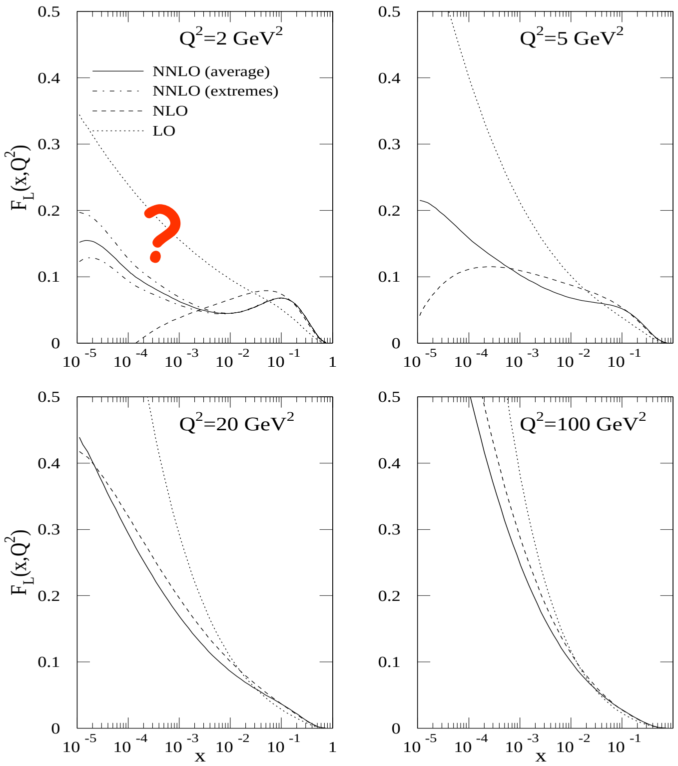
consistent with NLO QCD
i.e. scaling violations of F2

limited to smallest x

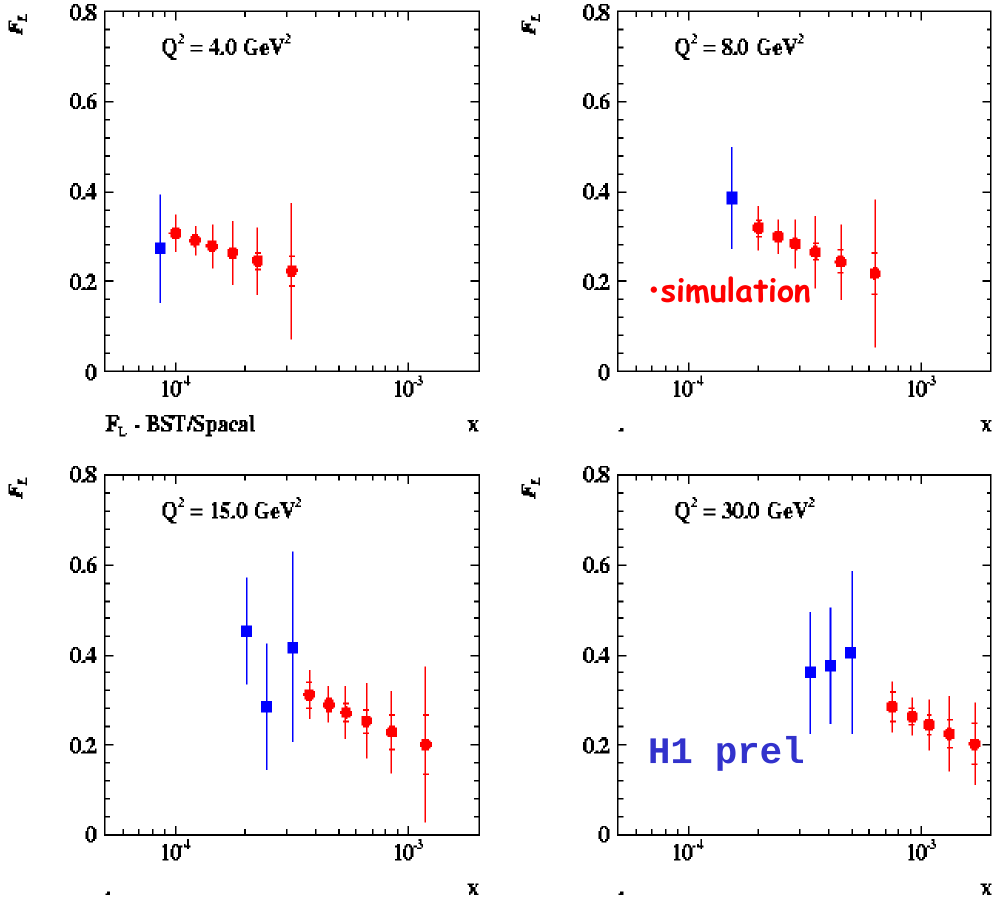
H1: EPJ C21(01)33, DIS01 and ICHEP02

Longitudinal structure function

Ho test of QCD and theory in transition region (dipole model)



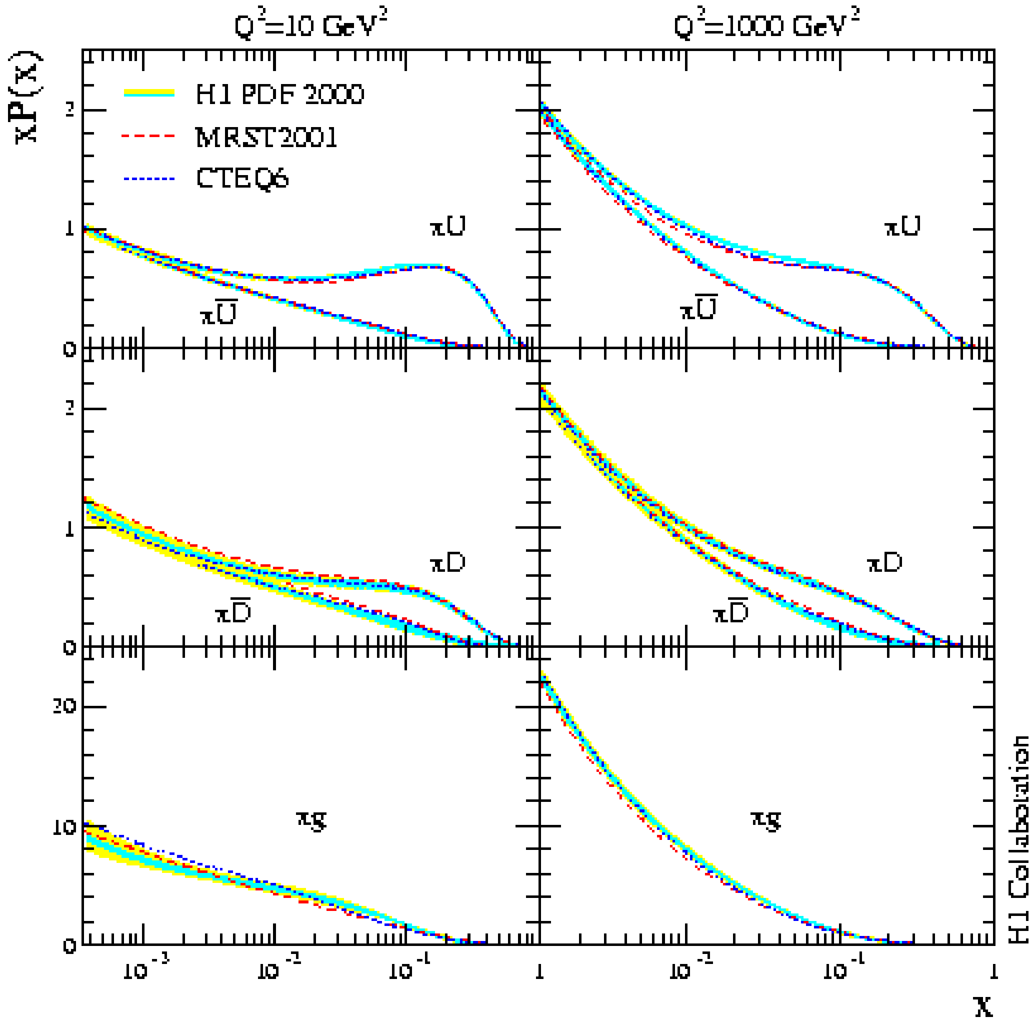
R.Thorne



require(s) variation of Ep, e.g. here:
920, 400, 500 GeV with about 200, 50, 10pb-1

cannot access Q2~1GeV2 in current IR configuration → „HERA3"

parton distribution functions from NLO QCD fits (H1)



$$xP = A_P x^{B_P} (1-x)^{C_P} f_p(x)$$

CC and NC cross sections are sensitive only to

$$U, \bar{U}, D, \bar{D}$$

→new/different QCD fit in which uv,dv,sea are replaced by these observables

light flavours (xg consistent)

possible with H1 data alone with assumption on sea symmetry

$$f_g = (1 + D_g x)$$

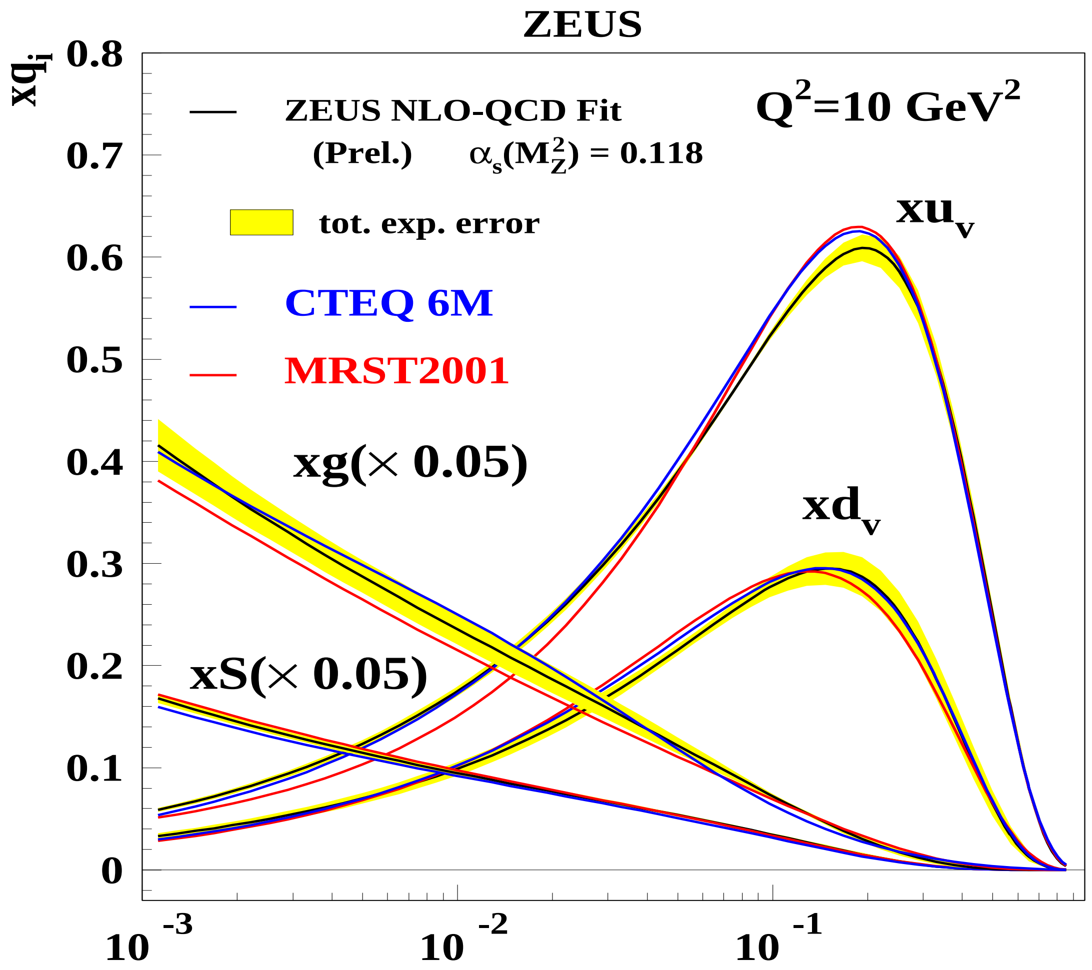
$$f_U = (1 + D_U x + F_U x^3)$$

$$f_D = (1 + D_D x)$$

$$f_{\bar{U}} = 1$$

$$f_{\bar{D}} = 1$$

parton distribution functions from NLO QCD fits (ZEUS)



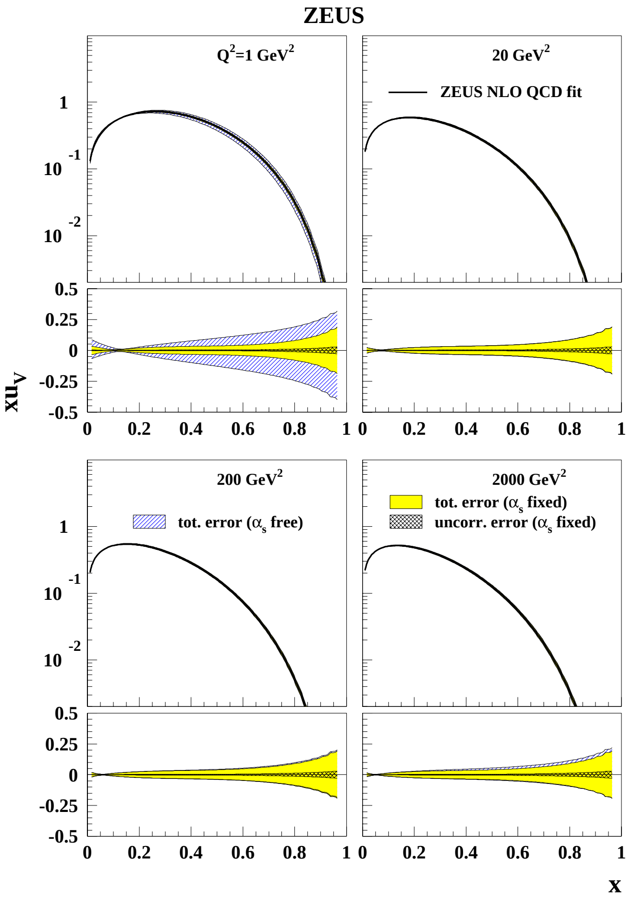
$$xu_v, xd_v, xS, xg, x\Delta$$

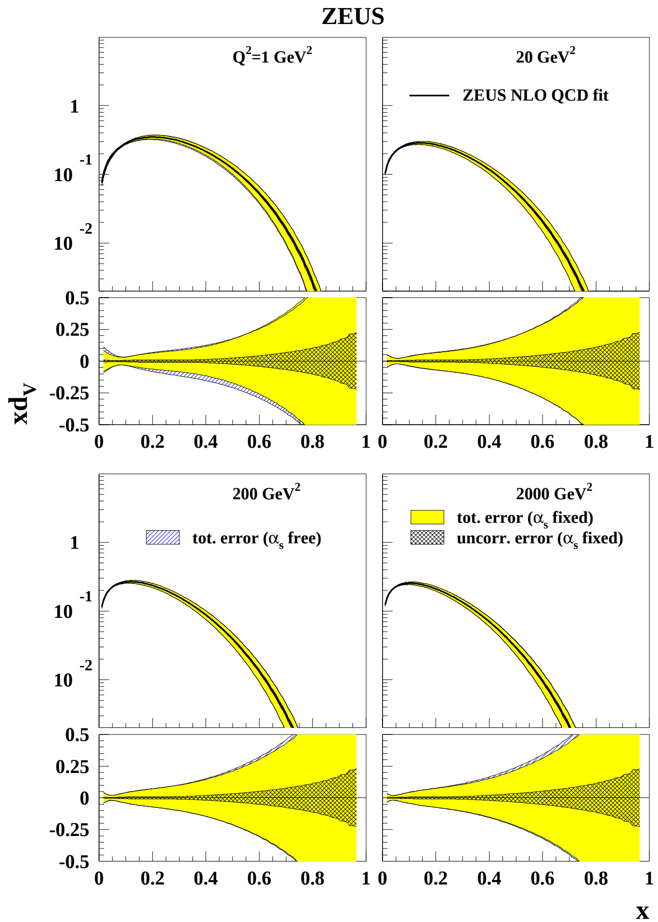
- 11 parameters besides alphas
- RT VFNS

- ZEUS
- BCDMS, NMC, E665, CCFR

ZEUS hep-ex/0208023   Phys Rev D67(2003)012007

valence quark distributions from QCD fits



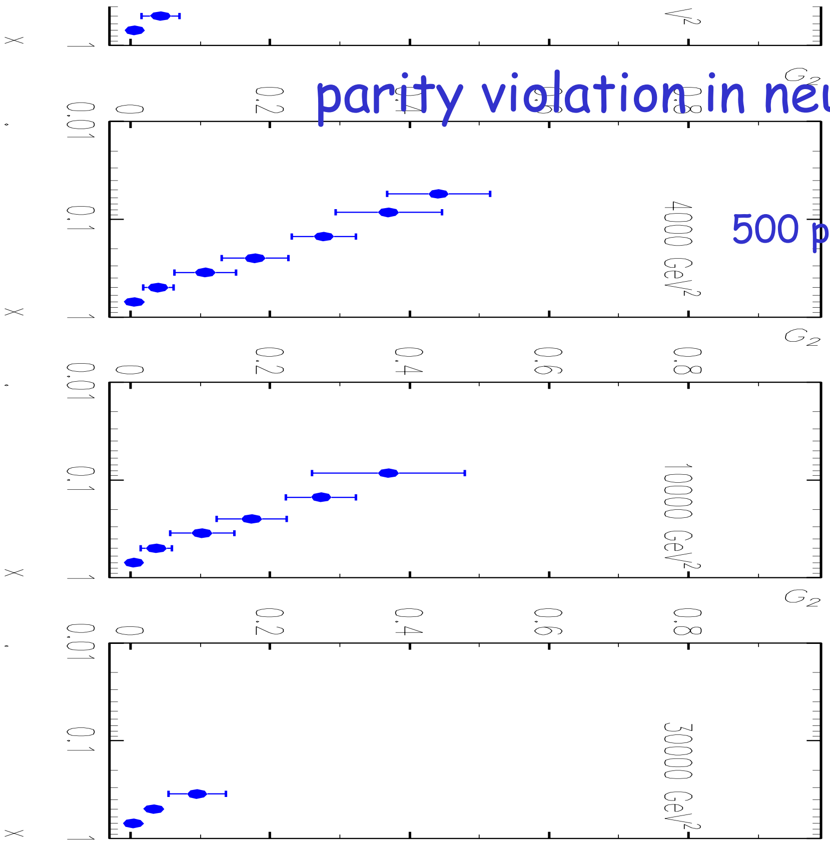


$$xP = A_p x^{B_P} (1-x)^{C_P} (1 + D_p x)$$

B=0.5 for up and down valence

measure dv/uv: *CC*, *G2* - but most accurate is ep/en with tagged proton spectator in electron-deuteron scattering at HERA

parity violation in neutral current scattering



500 pb-1 polarised e+ or e-p, 50% polarisation

$$A^{\pm} \cong \mp \lambda \kappa_Z a_e G_2 / F_2 \xrightarrow{x->1} \pm \lambda \kappa_Z (d_v + u_v)/(d_v + 4u_v)$$

$$G_2 = 2x \sum e_q v_q (q + \bar{q}) \approx 2/9x \sum (q + \bar{q})$$

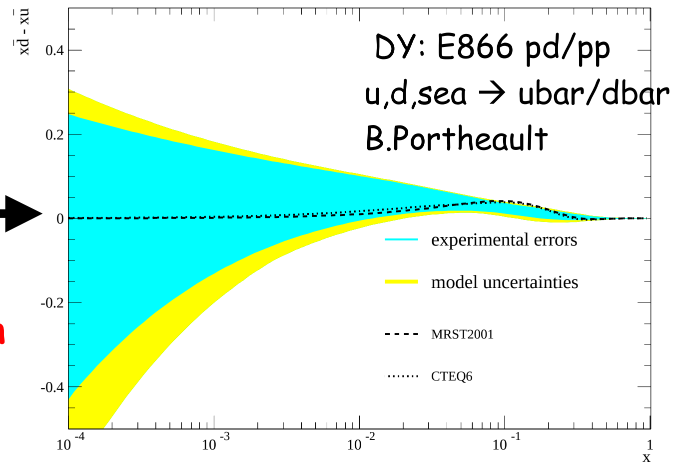
singlet

MK DIS01 Bologna

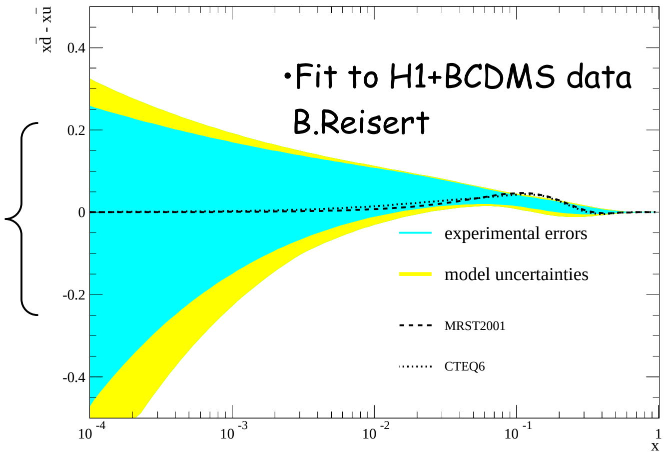
not shown due to lack of time

uncertainty of sea quarks - partonic description of the rise of F2?

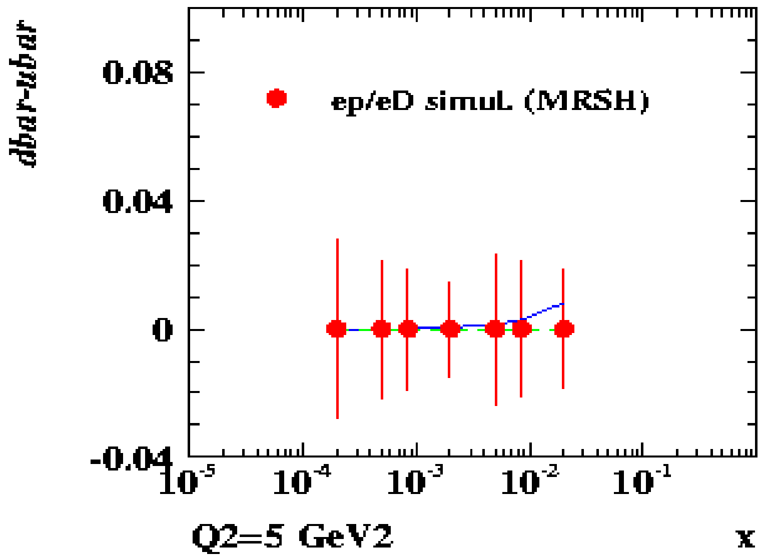
Standard assumption



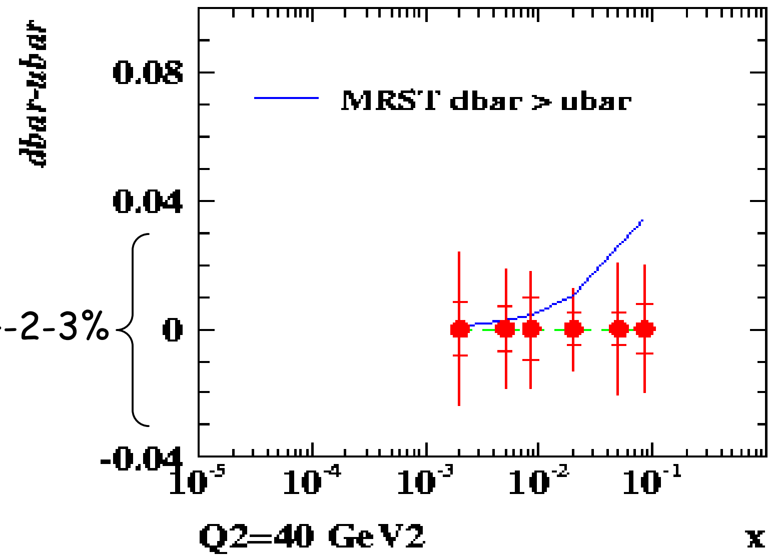
+-20%



shadowing is linked to diffraction → new field



+-2-3%



•Simulation of ed scattering in H1 (20pb-1)

+ Low x physics discovered as a new field of theoretical development and experimental fun – high density QCD

+ pQCD evolution tested with structure function data from HERA over 4 orders of magnitude in Q2

+ the ultimate precision of data and thy (N3LO) is still to be / is being approached (F2 1%, FL 5%, hiQ2 2% NC, 3% CC, about!)

+ the uncertainty of alphas from DIS/HERA may be halved to +-0.001 (Bethke hep-ex/0211012: 0.1183+-0.0027 NNLO)

+ the gluon determination cannot be completed without FL

+ parton distributions are determined with increasing accuracy from HERA data and are consistent with global fits.

+ the up and down quarks cannot be disentangled at low x and neither at high x without deuterons colliding with e+-

there are 4 experimental challenges to
the standard DIS programme at HERA

- high luminosity, i.e. 1000 pb-1
- high precision to better than a %
- lower Ep with substantial luminosity
- Deuterons in HERA

Considering further fundamental opportunities for

- Precision physics in the transition region
- eA
- Polarised eN scattering

there is no scientific reason to disrespect HERA