Precision Measurement of F_2 with H1

Towards today
The Measurement
Results
QCD Analysis

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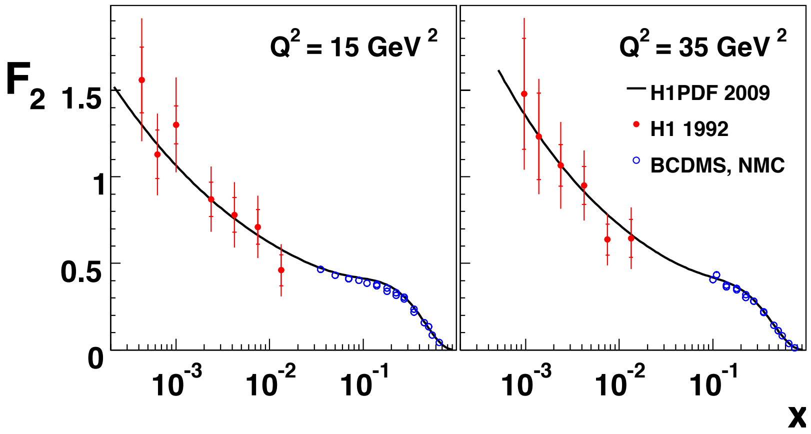
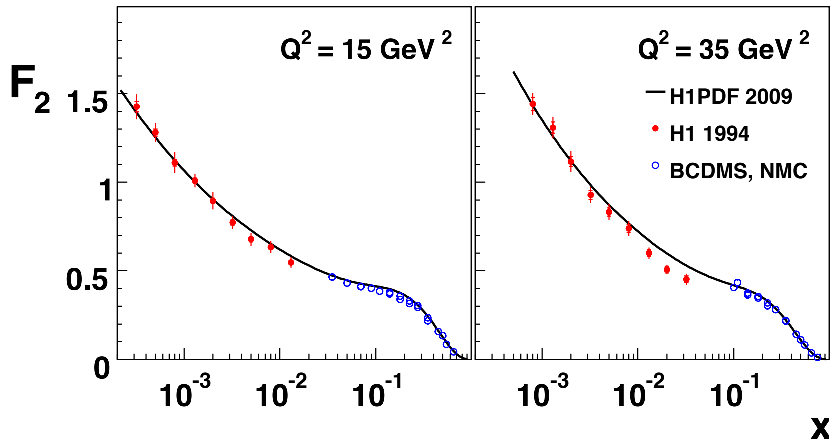
As F_2 developed..

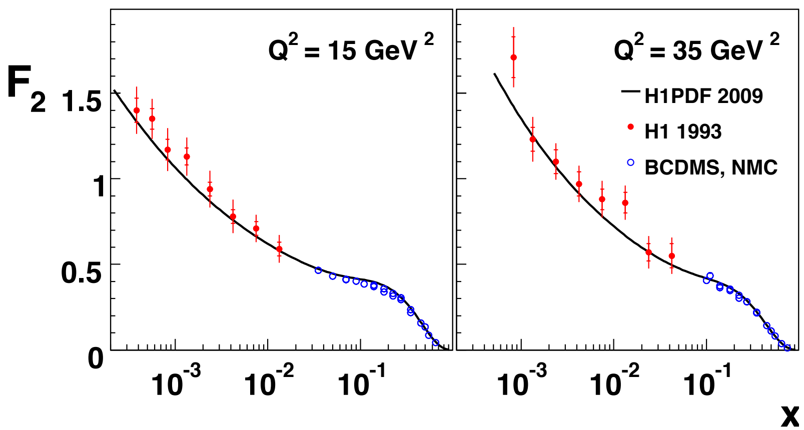
1992 [data] – discovery of the rise



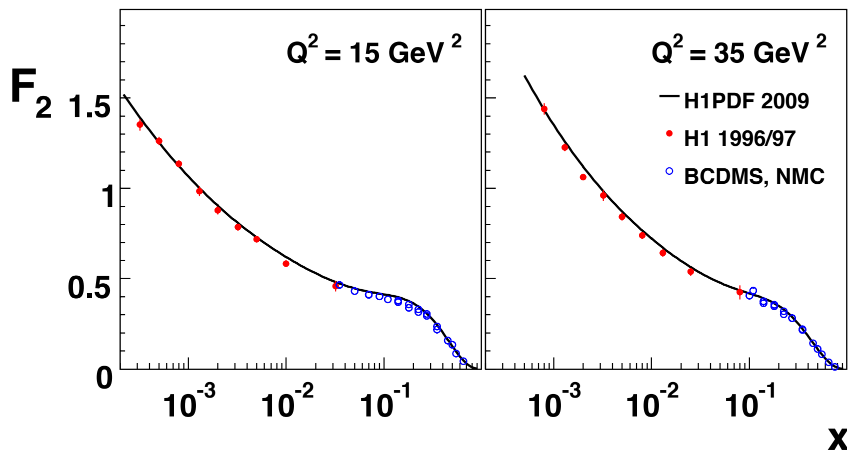
1994 – the last BEMC result 3%



1993 – a first measurement



1996/7 –first accurate SPACAL 2%



BCDMS: final publication 15 years after the experiment proposal 1974

Systematic errors

		e	m
E_e	2% and ±2% smearing	5-15%	3-6%
ϑ	5 mrad	4-12%	4-8%
y_{JB}	fragmentation [D⁻, PS vs HERWIG], 7% energy scale, $(y_{JB}-y_{Gen})/y_{Gen}$, thresholds	–	10-25%
Z_{vtx}	statistics, satellite bunch, comparison of methods I, II		7%
BPC, tracker cut, EBDi/ECRA, cluster-hit			6%
structure fct.	D^-/D^0 (lowest x).		5-10%
radiative corrections	(MC statistics for I) Z_{vtx}, $E-p_z$ in MC	8%	2%
bin centre correction	$(\sqrt{E_e}, \vartheta \to x, Q^2)$	5%	2%
		17-29%	18-29%

- statistics: 950 events
- Scale error: lumi 7% TOF, trigger → 9%

H1 July 1993

σ_r Errors in 2009

Spacal
Double angle calibration: 0.2%
up to 1% at 2 GeV

BST /CJC/ BDC 0.2mrad

Low y E_h: 2% at 0.01
LAr: 15% of its noise

z vertex 0.3%

eID: max 1%
BDC 0.5%

Iteration --

RC to alpha in MC 0.3%

Negligible

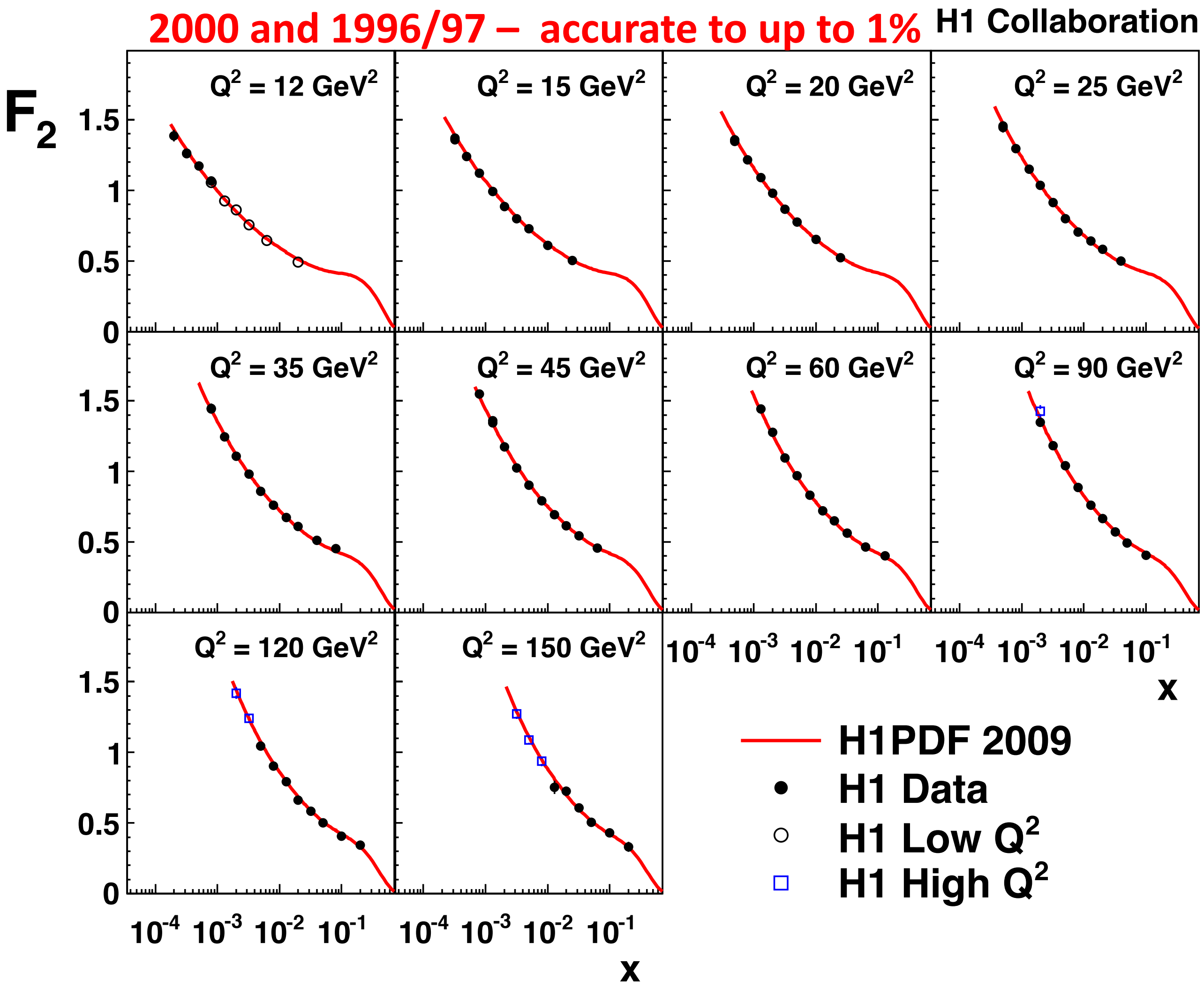
1.3-3%

~10^6

+ Lumi 1.2% trigger --

H1 April 2009

The present measurement



$$F_2 = \frac{\sigma_r}{1 - f(y)\frac{R}{1+R}}$$

R taken from own QCD fit. Very small effect as y < 0.6

Important input to the combined H1/ZEUS data. At $Q^2 \sim 30\ \mathrm{GeV}^2$ the accuracy further reduced (1.3 → 1.1%) and the amount of systematic uncertainties from 75 to 55%.

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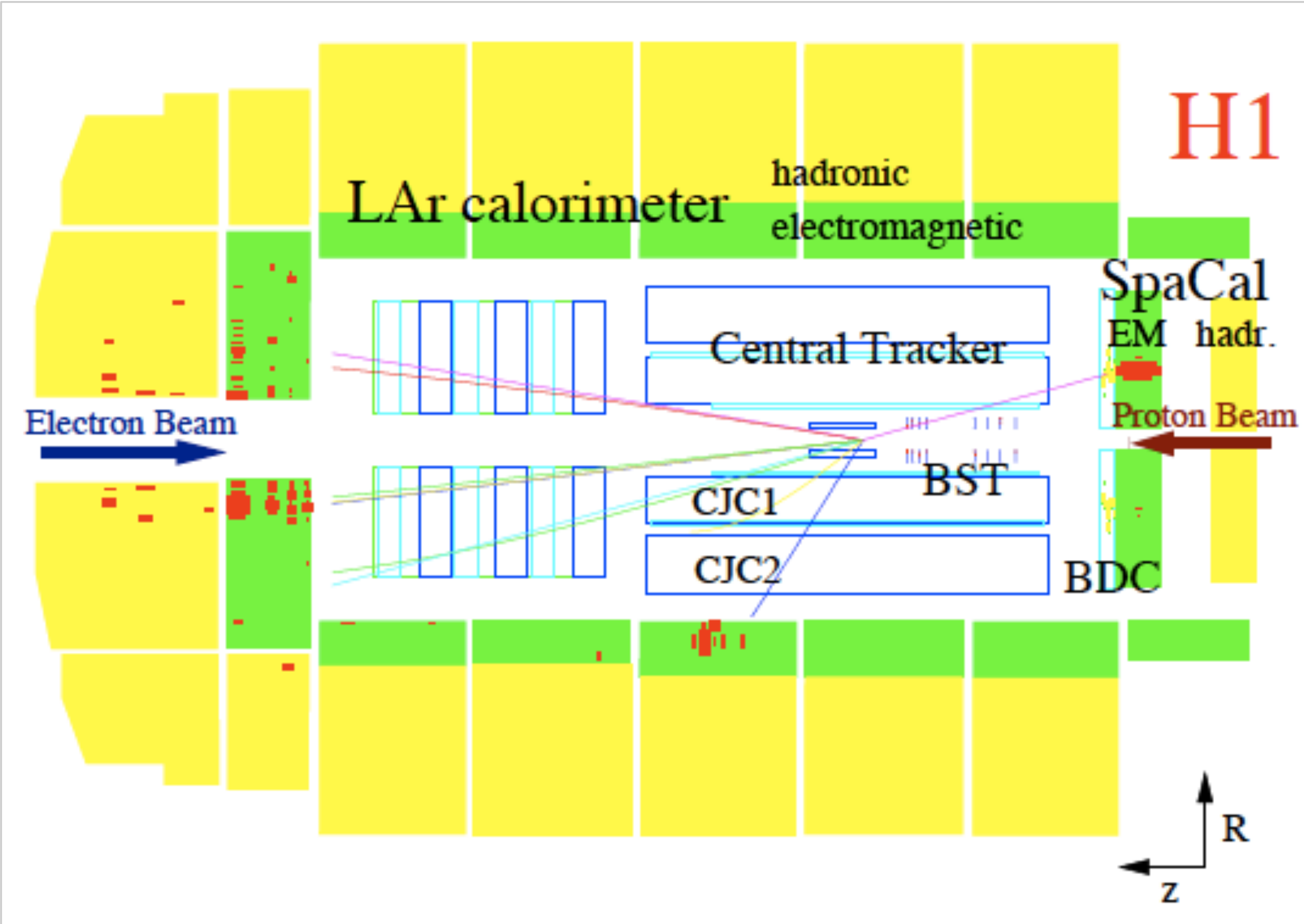
DIS Event in the H1 Detector



Event Selection

Description	Requirement
Kinematic Range	$Q_e^2 > 10\,\mathrm{GeV}^2$
Scattered positron energy	$E'_e > 11\,\mathrm{GeV}$
SpaCal cluster radius	$R_{\log} < 4\,\mathrm{cm}$
Energy in hadronic SpaCal section	$E_\mathrm{h}/E'_e < 0.15$
BDC validation	≥ 4 linked hits, BDC-SpaCal radial match $<2.5\,\mathrm{cm}$
Radial cluster position	$r_\mathrm{Spac} < 73\,\mathrm{cm}$
Vertex z position	$\lvert z_\mathrm{vtx} \rvert < 35\,\mathrm{cm}$
Transverse momentum balance	$P_\mathrm{T}^h / P_\mathrm{T}^e > 0.3$
Longitudinal momentum balance	$E - P_z > 35\,\mathrm{GeV}$
QED Compton Rejection	Topological veto

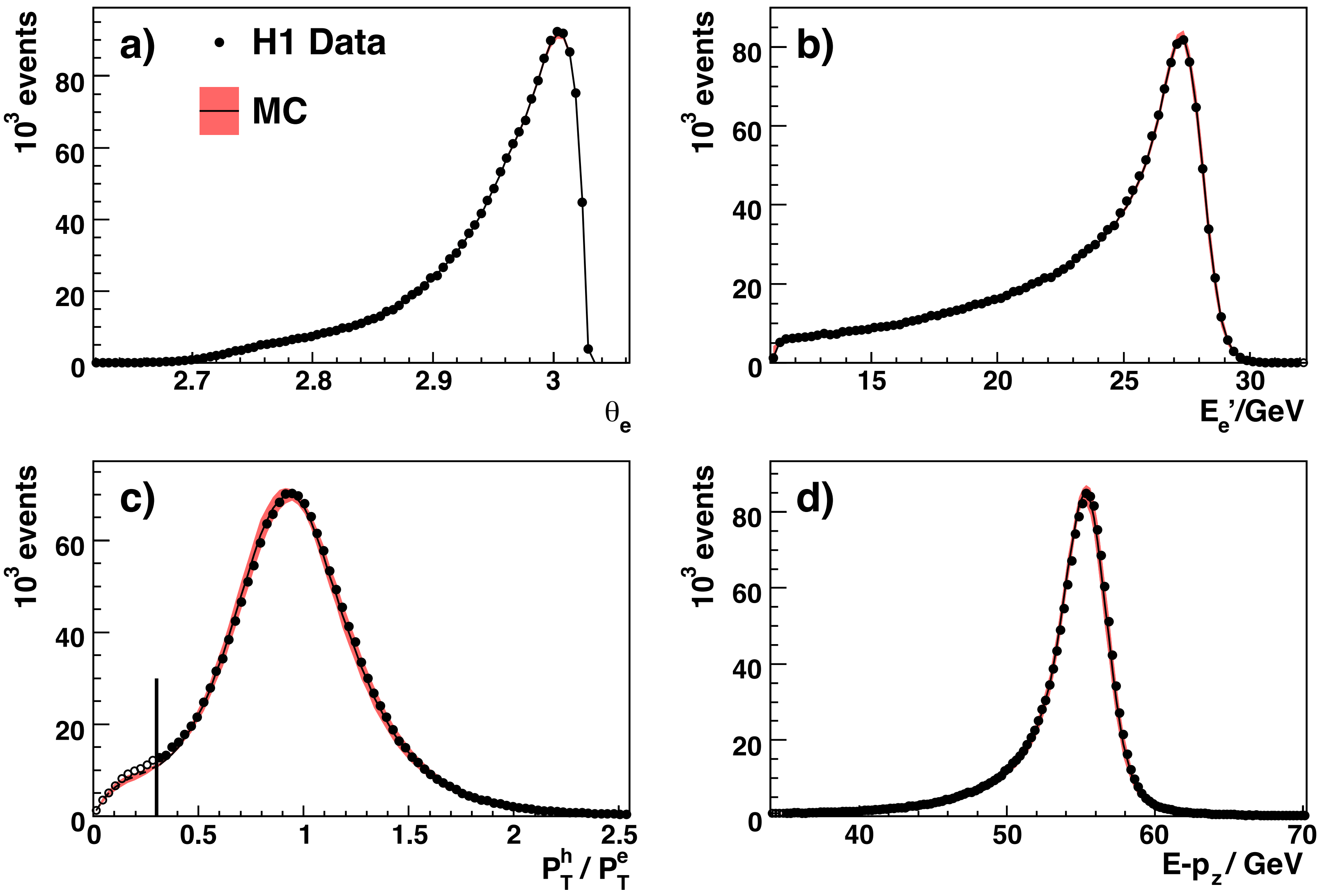
Low Q^2 – next talk
F_L a separate task

3 electron ID and validation cuts

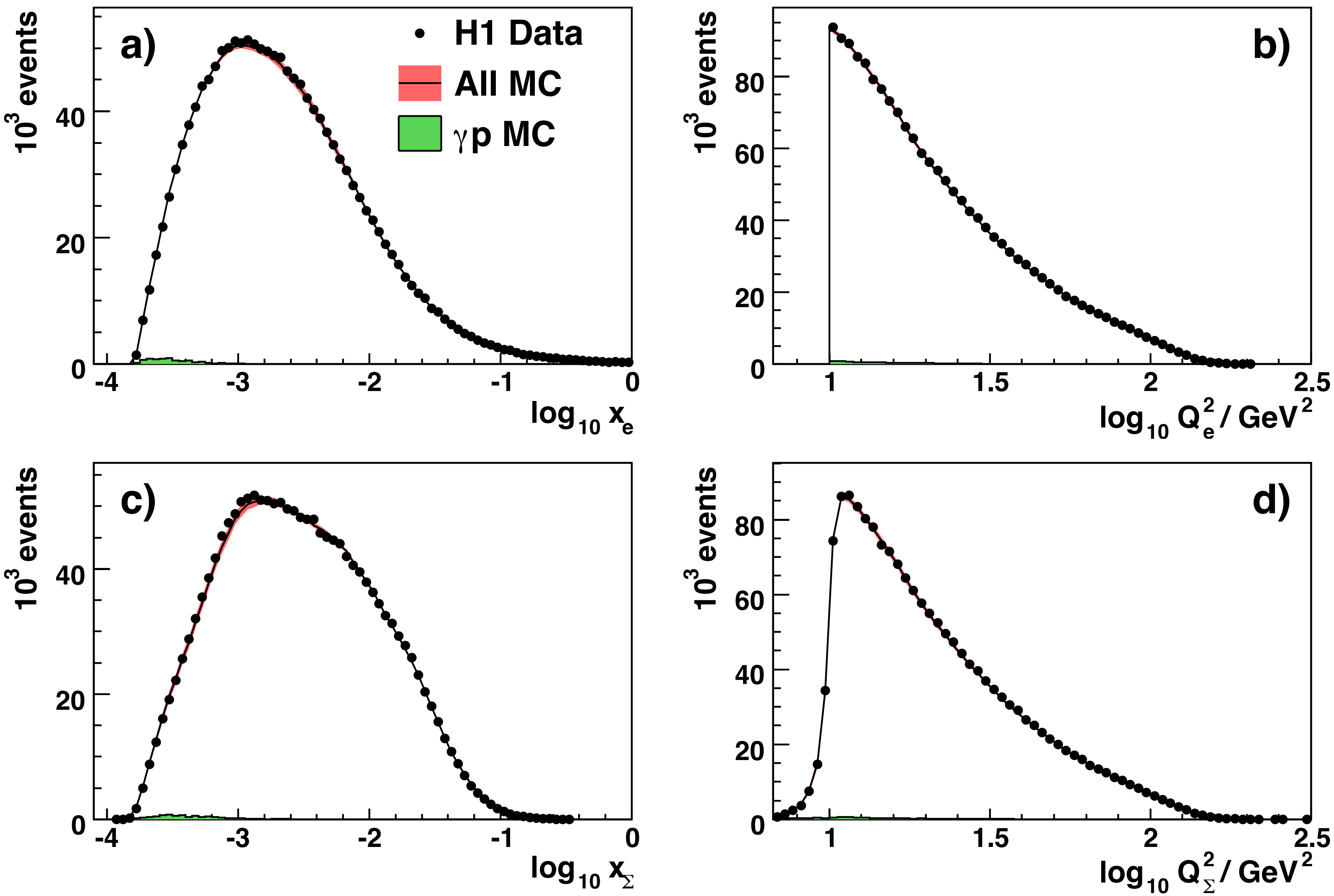
DIS: vertex and e/h pt balance

h.o. QED radiation anti-cuts

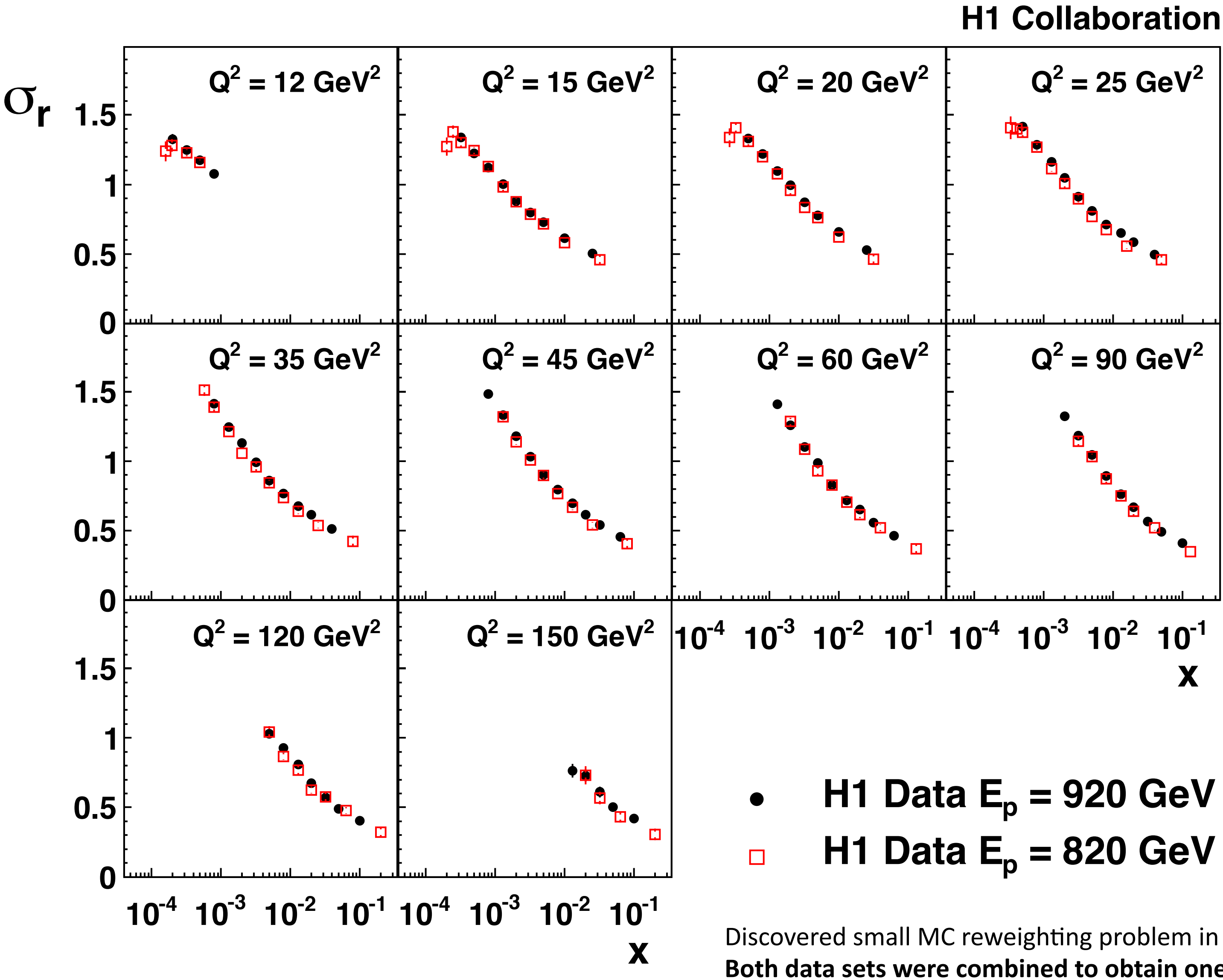
Control Plots



Control Plots (e and Σ)



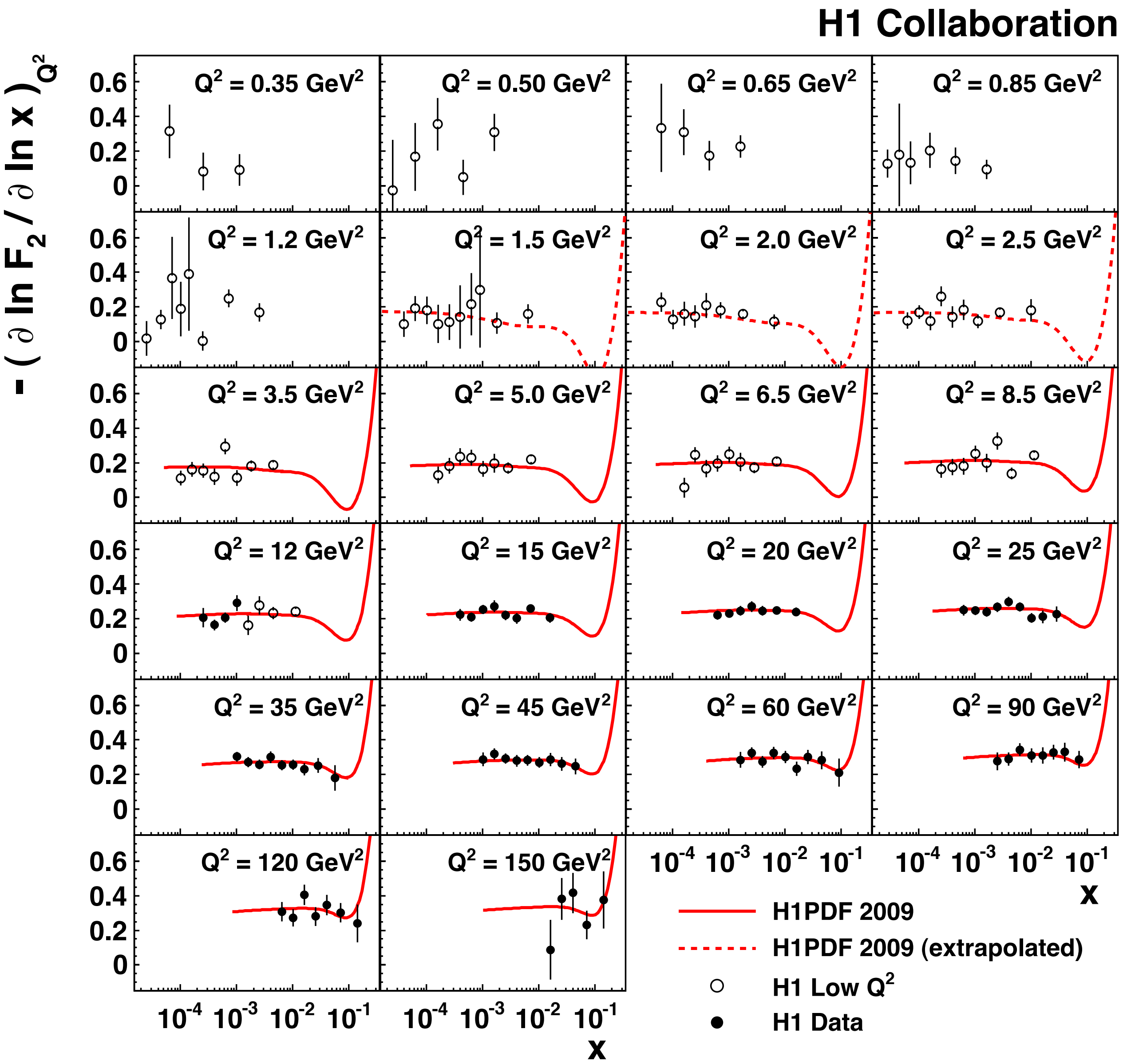
Comparison of 820 (96/97) and 920 (2000) Data



Discovered small MC reweighting problem in 820 GeV data

Both data sets were combined to obtain one set of H1 data

x Dependence



Not excluded that "the rise" is a "two-dimensional phenomenon", i.e. for $F_2 \sim x^{-\lambda}$, $\lambda=\lambda(x,Q^2)$

H1 previously:
Phys.Lett.B520:183,2001

$$F_2(x,Q^2) = c(Q^2)x^{-\lambda(Q^2)}$$

$$\lambda(Q^2) = a\cdot \ln(Q^2/\Lambda^2)$$

$$\Lambda = 292 \pm 20(st) \pm 51(sy)MeV$$

$$Q^2 \geq 3.5GeV^2, x \leq 0.01$$

H1pdf2009

Parameterisations

$$xg(x) = A_g x^{B_g} (1-x)^{C_g} [1 + D_g x],$$
$$xu_v(x) = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}},$$
$$xd_v(x) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}},$$
$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}},$$
$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}.$$

Fit results

xP	A_P	B_P	C_P	D_P
xg	5.66*	0.243	18.76	34.0
xu_v	5.15*	0.784	3.25	–
xd_v	3.29*	0.784*	4.77	–
$x\bar{U}$	0.105*	−0.177	2.42	–
$x\bar{D}$	0.152	−0.177*	3.42	–

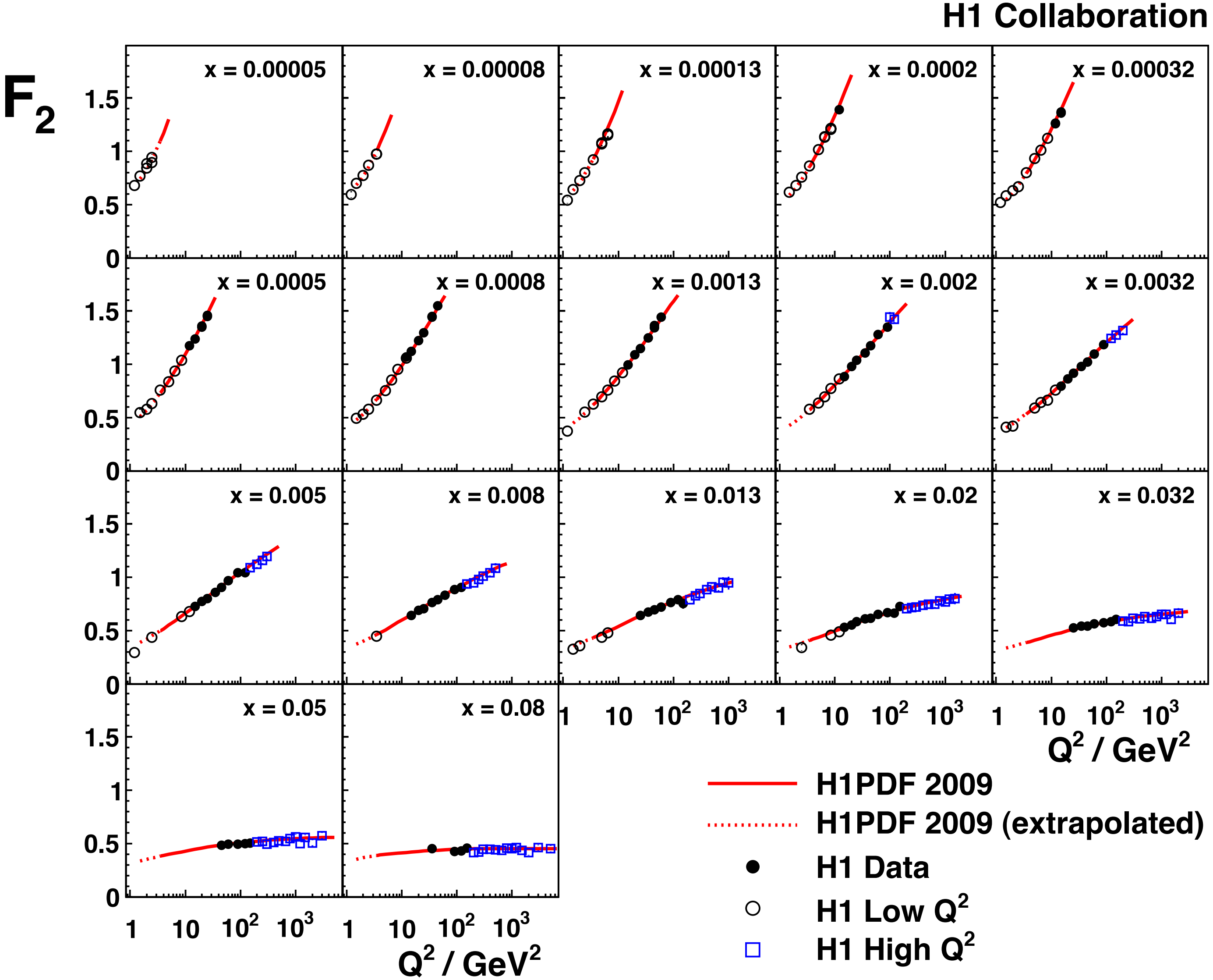
Parameter assumptions

$$B_{u_v} = B_{d_v}$$
$$B_{\bar{U}} = B_{\bar{D}}$$
$$A_{\bar{U}} = A_{\bar{D}} \cdot (1 - f_s)$$
A_{u_v}, A_{d_v}, A_g : **Quark counting and Momentum sum rules**

Q_0^2=1.9 GeV^2
NLO, QCDNUM, VFNS

Data set	Data points	χ^2_{unc}
Low Q^2	58	55.9
Medium Q^2	99	81.5
e^+p NC high Q^2, 94 – 97	130	92.6
e^+p CC high Q^2, 94 – 97	25	21.2
e^-p NC high Q^2, 98 – 99	139	112.1
e^-p CC high Q^2, 98 – 99	28	17.3
e^+p NC high Q^2, 99 – 00	147	137.4
e^+p CC high Q^2, 99 – 00	28	31.1

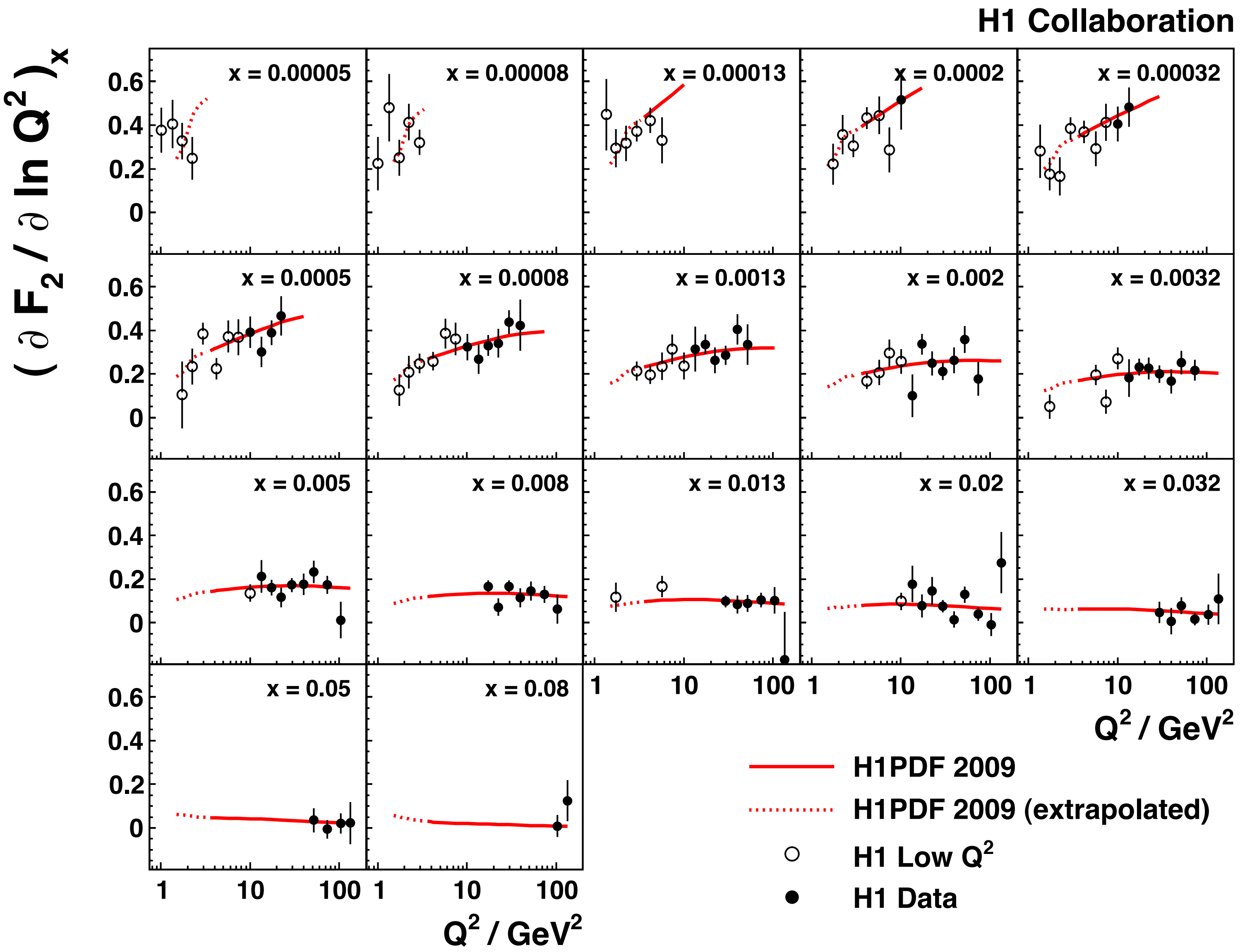
Q^2 Dependence – F_2



Data are consistent with other H1 data at lower and at larger Q^2

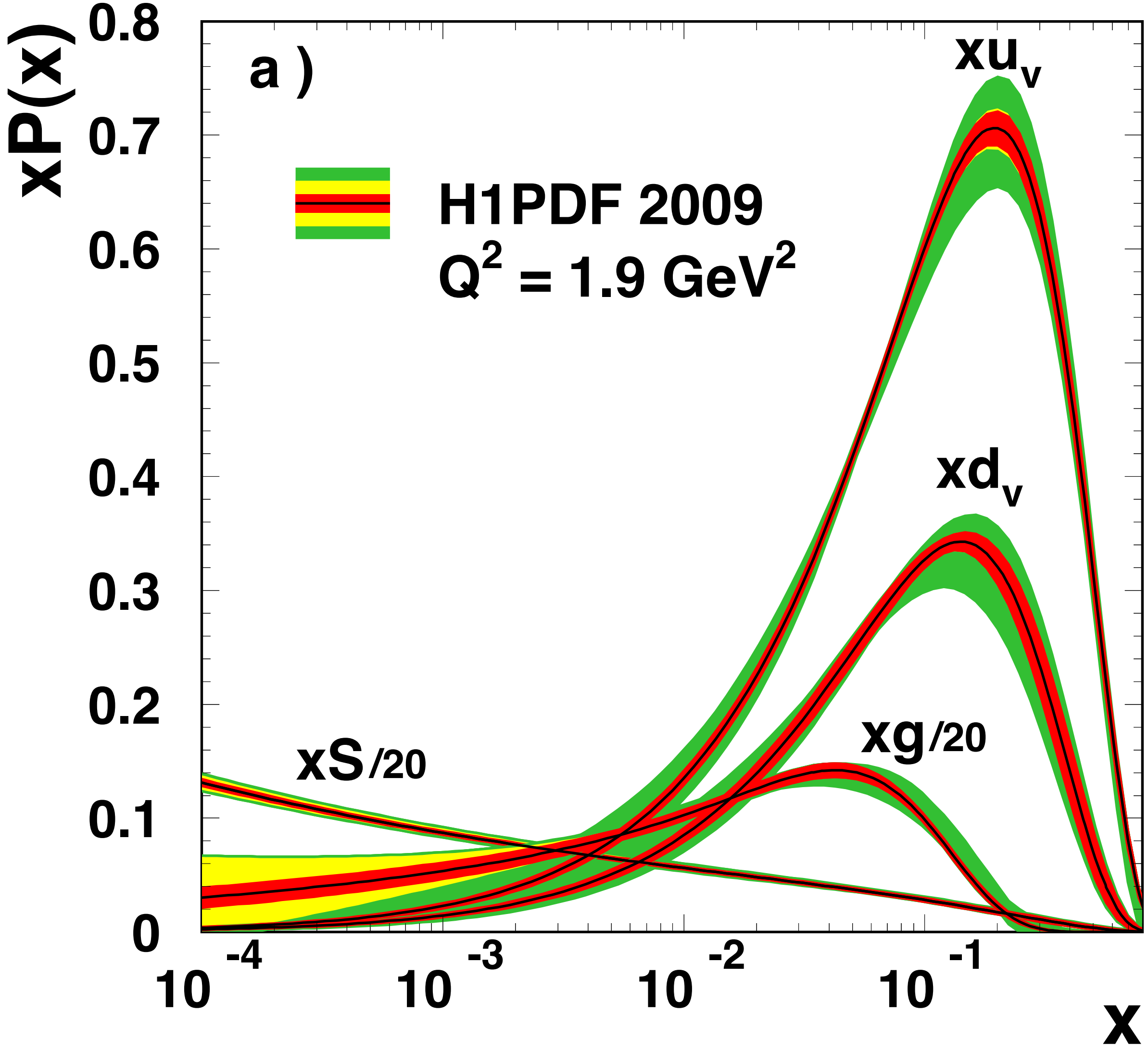
cf S.Glazov: Low Q^2 Talk

Q^2 Dependence – $dF_2/d\ln Q^2$



Q^2 dependence well described by NLO QCD fit to the H1 data and its extrapolation

Partons at the Initial Scale



Red: experimental

Yellow: exp+model:

-m_c, m_b, f_s
- Q^2_{min}=2.25 – 5 GeV^2
- Q^2_0 = 1.9 -1.5 GeV^2

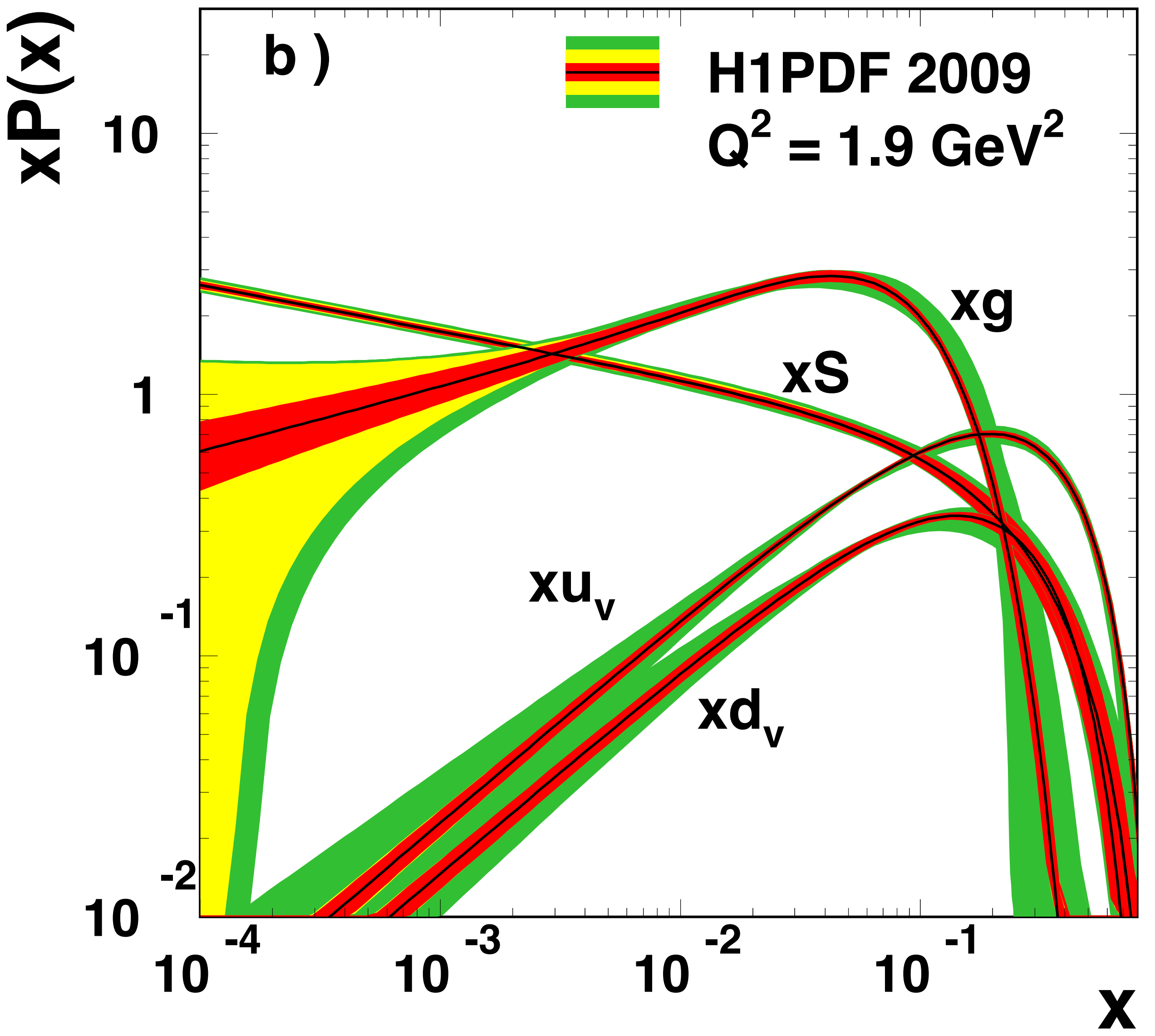
Green: +parameterisation

$P(x)=Ax^B(1-x)^C[1+Ex+Dx^2..]$

For error bands require:
- D, E if $\chi^2 < \chi^2_0 + 3$
- F_2 and $F_L > 0$
- allow for non-canonical (νN) valence/sea quark ratios at large x

.. A first attempt to quantify parameterisation uncertainty.

Partons at the Initial Scale



Large uncertainty of gluon at low x

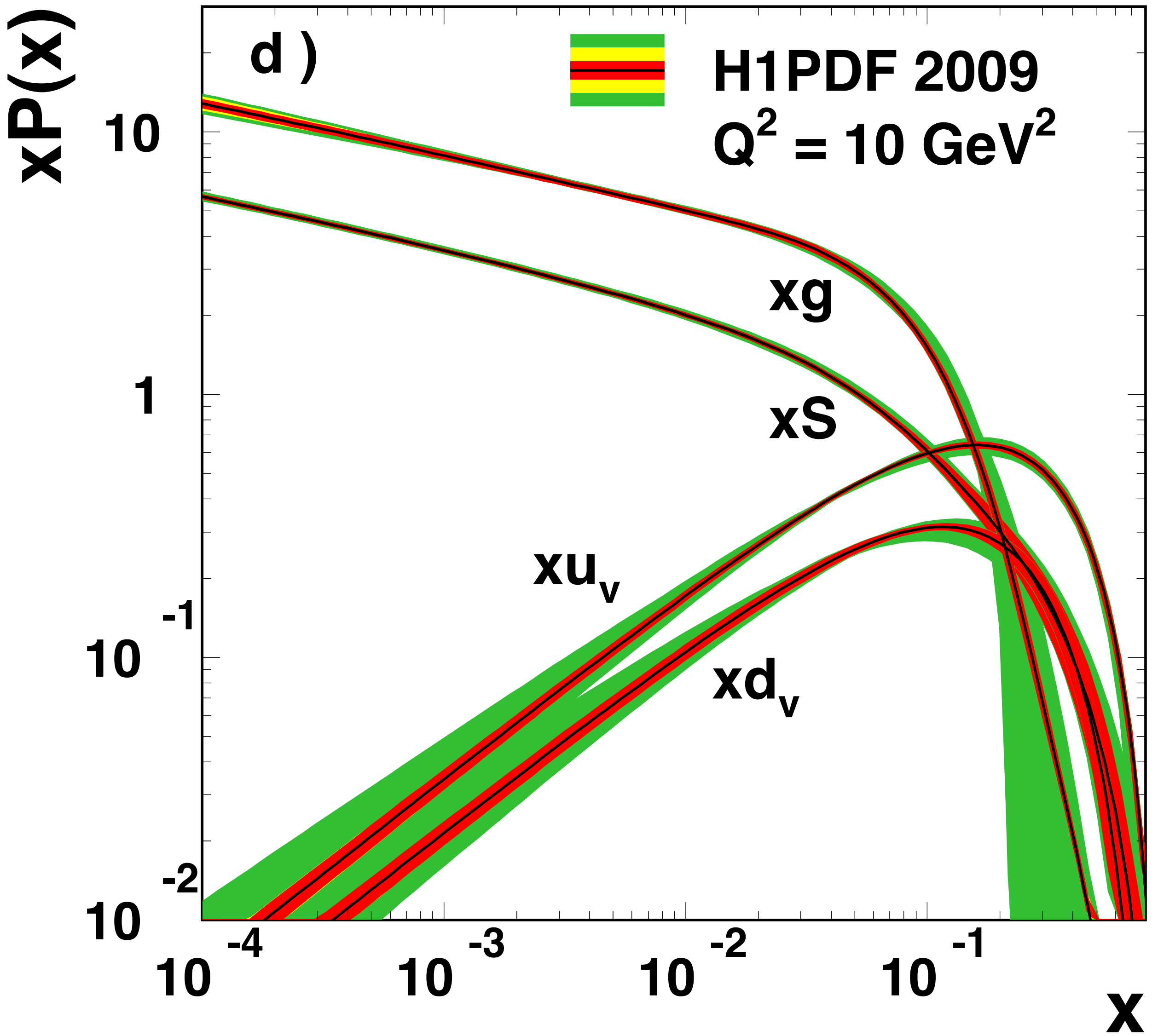
-further reduced with low energy and F_L data **(cf Talks of J.Grebenyuk and V.Radescu)**

-Q^2_0 variation mimics parameterisation uncertainty (yellow ~ green)

Large uncertainty of gluon also at large x

Note that this fit describes the Tevatron jet data well.

Evolution drives Gluon and Sea to large values at low x



Valence quarks remain rather unaffected as non-singlet quantities. Some constraints on valence quarks at low x may be expected from $W^{\pm}$ asymmetry data at the LHC. At high x d_v remains uncertain.

Summary

Recent data have been presented on the reduced cross section at $y<0.6$, $12 \leq Q^2 \leq 150$ GeV^2

These represent the most accurate data on the proton structure function F_2 obtained so far.

The evolution of the measurements of F_2 over the past almost 20 years has been consistent and lead to a reduction of the uncertainties from initially ~20% to nearly 1% now.

The data have been used in the combination with the ZEUS data and while dominating the combination in the here covered region of phase space they are still improved by the average.

The partial derivative of $F_2(x,Q^2)$ wrt. ln(x) is about constant at low x in the DIS region of Q^2.

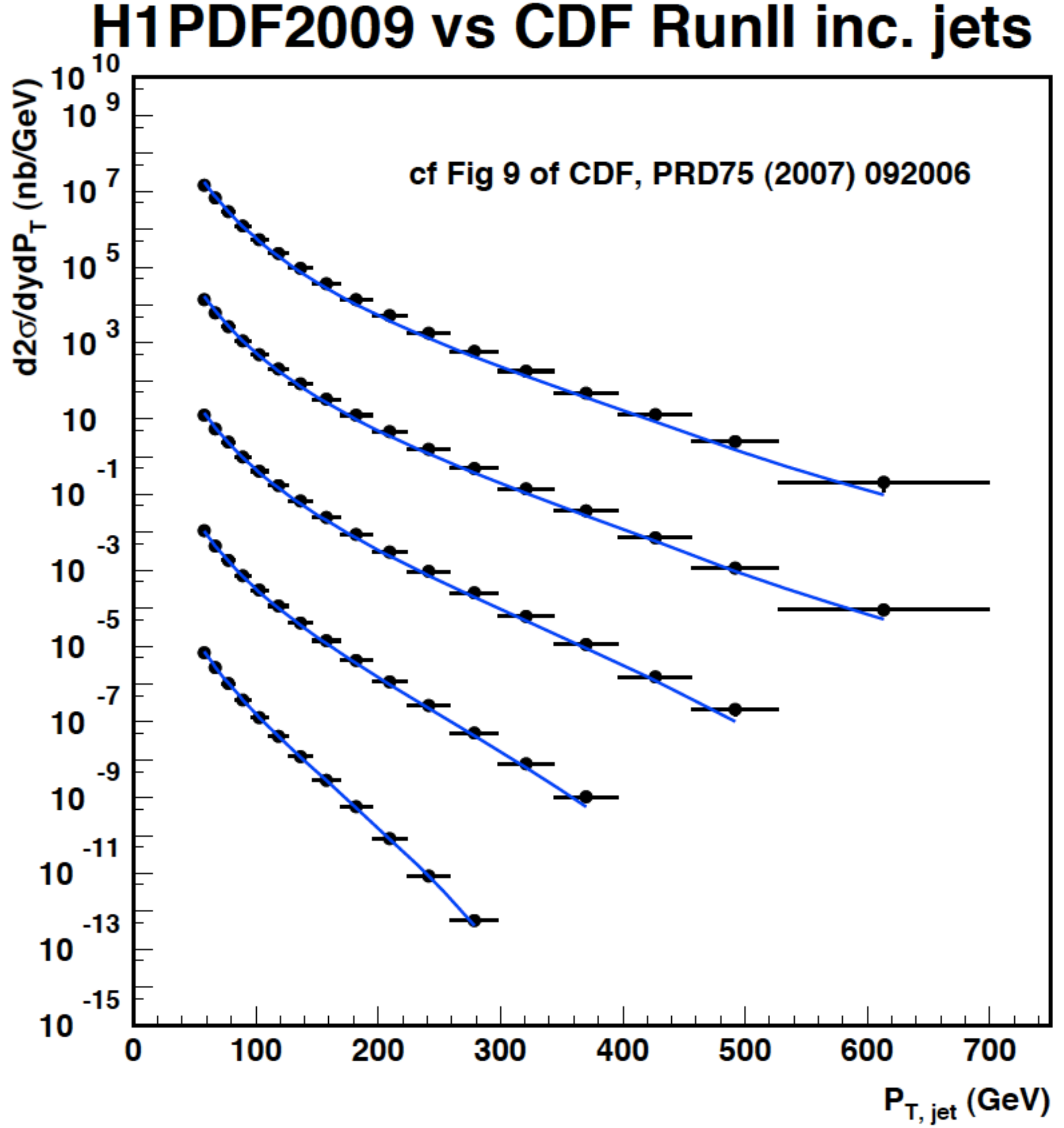
A refined NLO QCD fit was made with a minimum number of parameters on the chosen initial parton distributions, xg, xu_v, xd_v, and the total up and down anti-quark distributions.

The lnQ^2 derivative is described by NLO QCD and in accord with a rising gluon density at low x.

The fit method attempts to quantify the uncertainty due to the parameterisations of the pdf's in a way, which has been adopted in the HERAPDF1.0 subsequent fit.

Overall there is very good agreement with NLO QCD, yet much is still to be learned on the structure of the proton and its inherent parton dynamics [cf further talks and the future..].

Backup



|y| < 0.1

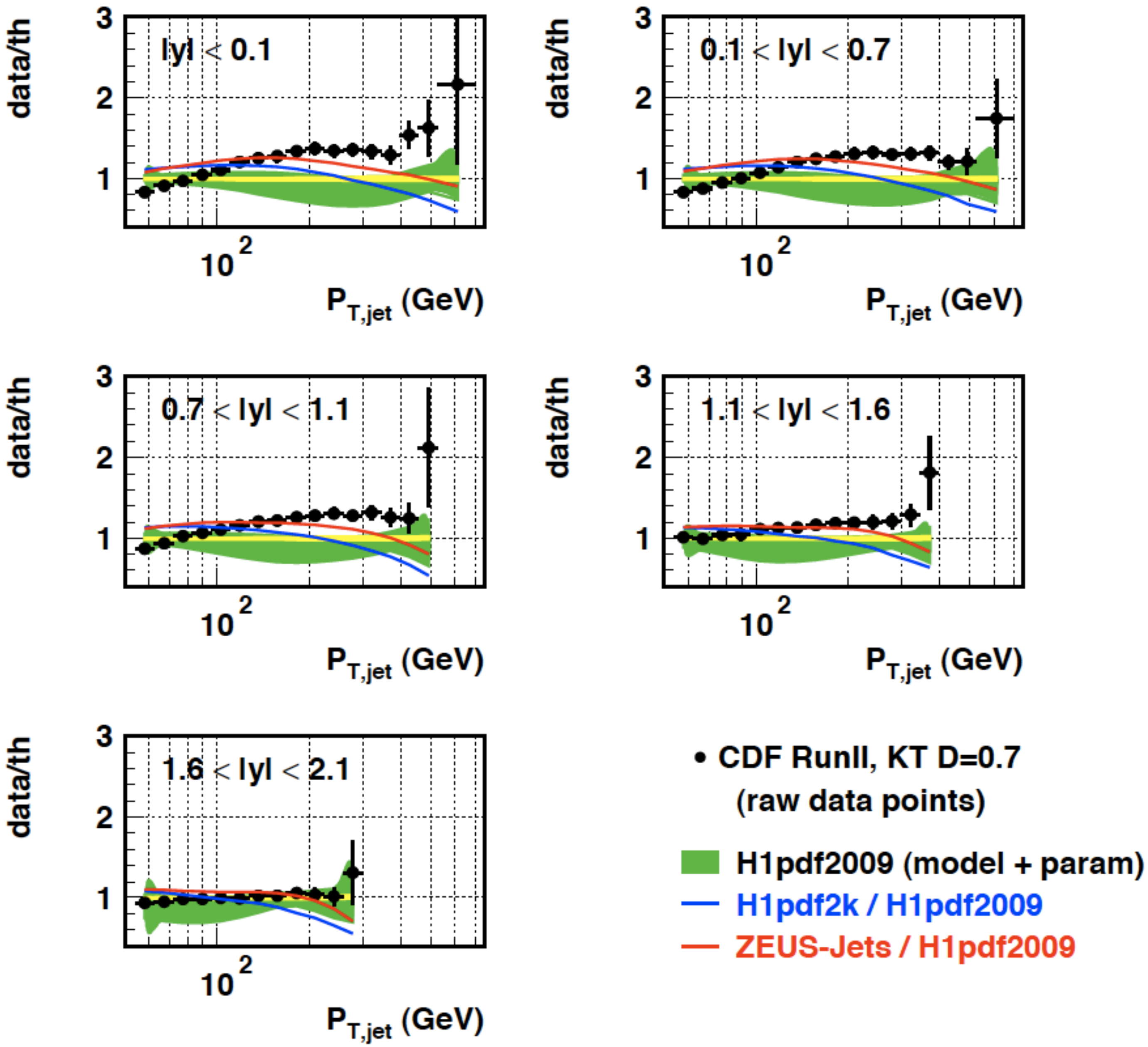
0.1 < |y| < 0.7

0.7 < |y| < 1.1

1.1 < |y| < 1.6

1.6 < |y| < 2.1

H1PDF2009 vs CDF RunII inc. jets



Consistency of 96/97 and 2000 data

Table 5 Shifts in the central values of the systematic uncertainties determined for the combination of the 1996/1997 data at $E_p = 820\,\text{GeV}$ and the 2000 data at $E_p = 920\,\text{GeV}$. The value for each shift is given in units of the original uncertainty. Note that for the two data sets some of the correlated systematic error sources were defined differently

Systematic source	Shift	
	1996/1997	2000
E'_e scale	0.72	0.50
E'_e linearity	–	−0.39
Polar angle θ_e	−0.46	0.09
LAr hadronic scale	−0.86	−0.13
LAr noise	−0.22	0.04
SpaCal hadronic scale	–	0.35
γp background	0.11	−0.11
Luminosity	0.64	−0.46