Structure Functions and Events at High Q^2

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for the H1 and ZEUS Collaborations

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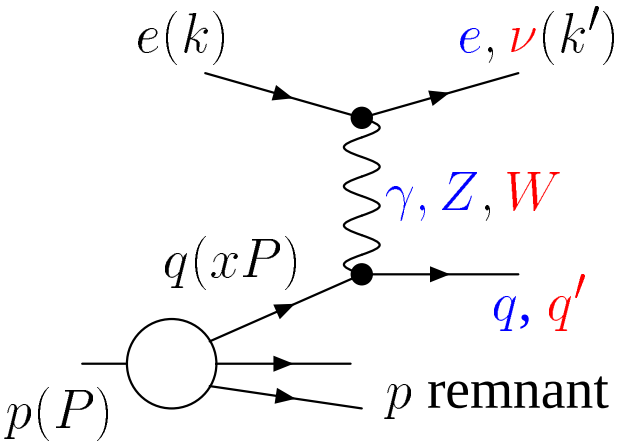
- Introduction to DIS
- Structure Functions at HERA
  - Kinematic range for HERA
  - Structure Function F_2 in HERA range
  - NLO QCD Fit for the Gluon Structure
  - F_2 at low Q^2
  - Charm Contribution to F_2
  - Longitudinal Structure Function F_L
- Events at Very High Q^2
  - Standard Model Predictions
  - Event Selection
  - CC Events
  - NC Events
  - Combined H1/ZEUS Cross Section

Deep Inelastic Scattering (DIS)



Q^2 = 4-momentum transfer

x = parton momentum fraction

y = fractional energy transfer

$M = \sqrt{s\,x} = E_{\rm cm}^{eq}$

$$Q^2 = -q^2 = -(k-k')^2 \qquad x = \frac{Q^2}{2\,P\cdot q} \qquad y = \frac{P\cdot q}{P\cdot k}$$

$$\frac{d^2\sigma(e^{\pm}p)}{dx\,dQ^2} = \frac{4\pi\alpha^2}{xQ^4}\left[xy^2F_1 + (1-y)F_2 \mp \left(y-\frac{y^2}{2}\right)xF_3\right]$$

$$= \frac{4\pi\alpha^2}{xQ^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2 - \frac{y^2}{2}F_L \mp \left(y-\frac{y^2}{2}\right)xF_3\right]$$

Longitudinal Structure Function : $F_L = F_2 - 2xF_1$

Longitudinally polarized photons : $\sigma_L \approx F_L$

Transversely polarized photons : $\sigma_T \approx 2xF_1 = F_2 - F_L$

$R = \dfrac{\sigma_L}{\sigma_T}$

F_3 unimportant for $Q^2 \ll M_Z^2$

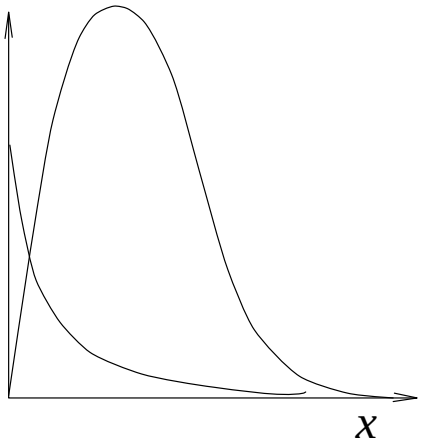
F_L $y \ll 1$ QPM: $F_L = 0$

F_2 , Partons and Quantum Chromodynamics (QCD)

$$F_1(x) = \sum_{i=u,d,s,c,\ldots} A_i(Q^2)\,\frac{1}{2}\left(q_i(x)+\bar{q}_i(x)\right)$$

$$F_2(x) = \sum_{i=u,d,s,c,\ldots} A_i(Q^2)\,x\left(q_i(x)+\bar{q}_i(x)\right)$$

$$xF_3(x) = \sum_{i=u,d,s,c,\ldots} B_i(Q^2)\,x\left(q_i(x)-\bar{q}_i(x)\right)$$



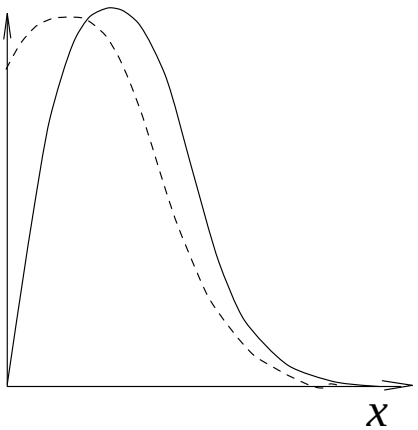
$$A_i(Q^2) = e_i^2 - 2e_i v_e v_i P_Z + (v_e^2+a_e^2)(v_i^2+a_i^2)P_Z^2$$

$$B_i(Q^2) = -2e_i a_e a_i P_Z + 4 v_e a_e v_i a_i P_Z^2$$

Weak propagator term : $P_Z = \dfrac{1}{4\sin^2\theta_W \cos^2\theta_W}\dfrac{Q^2}{Q^2+M_Z^2}$

QPM: $2xF_1 = F_2$ (Callan-Gross relation) $\Rightarrow$ $F_L = 0$

$$R = F_L / (2xF_1) = 0$$



Gluon emission $\Rightarrow$ Q^2 dependence of F_i

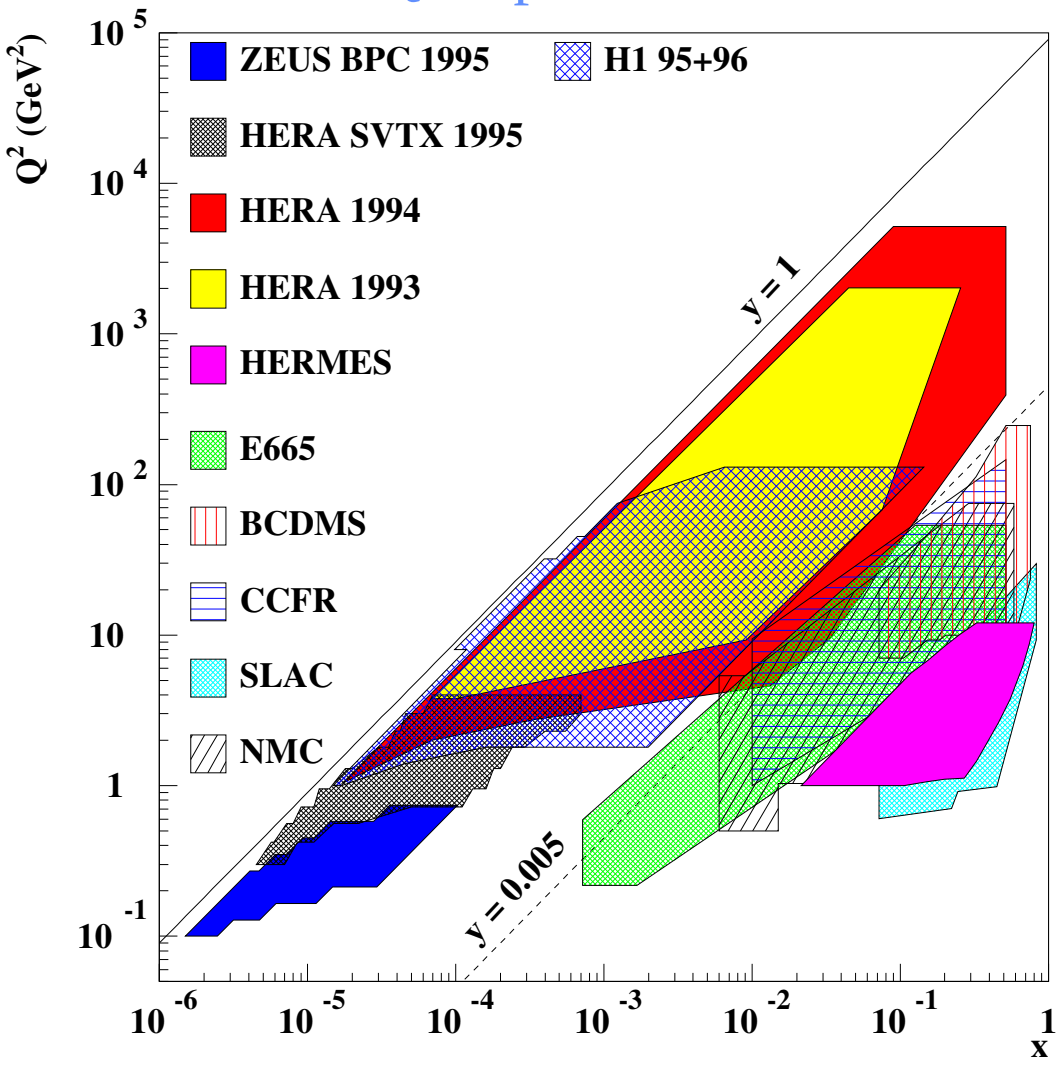
$\Rightarrow$ scaling violation

Evolution equations

- DGLAP (Dogshizer-Gribov-Lipatov-Altarelli-Parisi)
- BFKL (Balitzky-Fadin-Kuraev-Lipatov
- CCFM (Ciafaloni-Catani-Fiorani-Marchesini)

Kinematical Domains of Lepton-Nucleon Scattering Data

Q^2-x plane

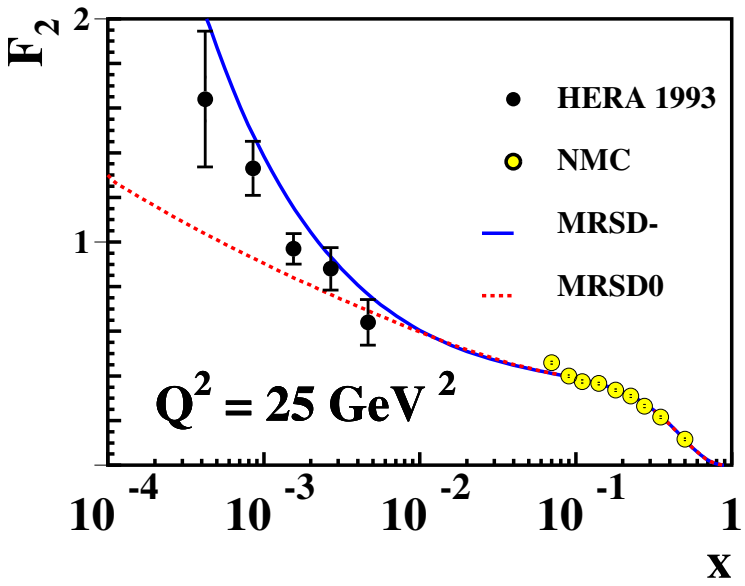


HERA *ep* collider: extension of kinematic range

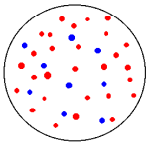
- $y \rightarrow .005$ overlap with fixed target experiments
- $y \rightarrow .82$ sensitive to F_L
- $Q^2 \rightarrow .1$ GeV^2 transition to photoproduction (γp reactions)
- $x \rightarrow 2 \times 10^{-6}$
- $Q^2 \rightarrow 45000$ GeV^2

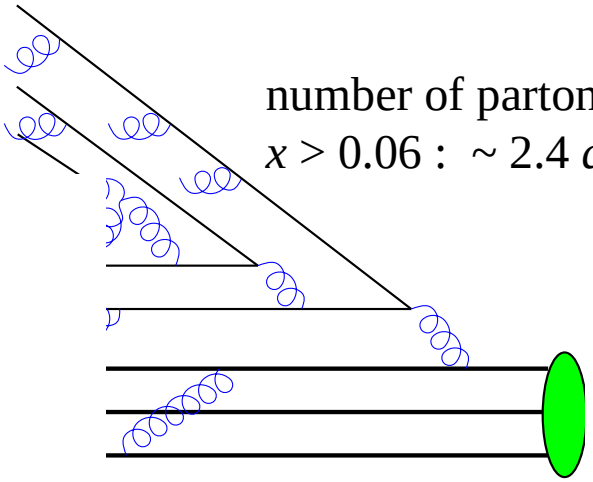
Exciting (New?) Physics

Parton Distributions inside the Nucleon

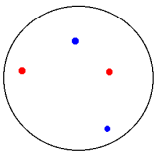


$x \sim 10^{-4}$:
~ 9 q , ~ 24 g





number of partons at $Q^2 = 25\ GeV^2$
$x > 0.06$: ~ 2.4 q , ~ 1.8 g



at low x gluon/sea distributions rise steeply $\rightarrow$ blow up?
dynamics driven by the gluon (e.g. DGLAP evolution)

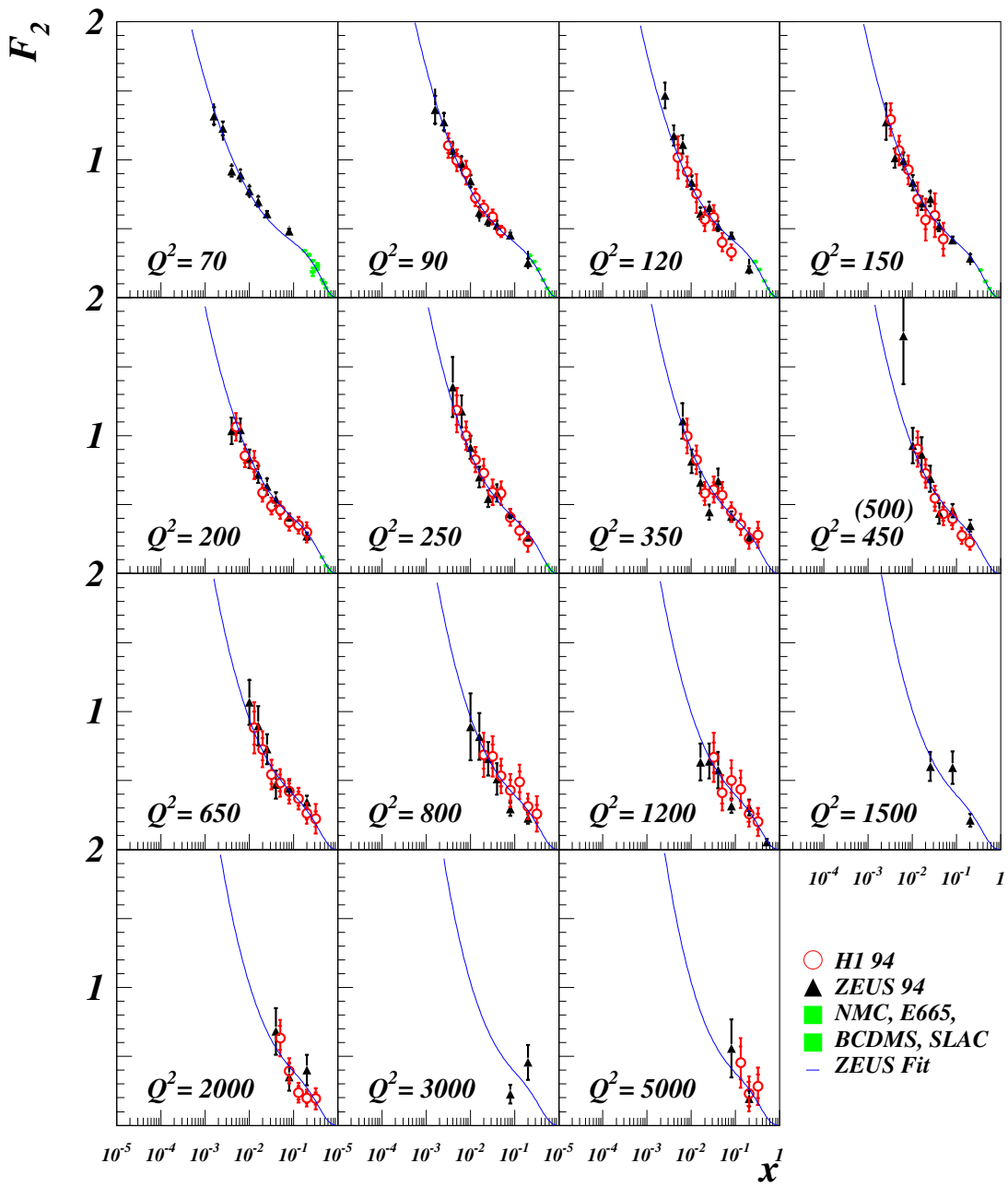
But: No theoretical prescription for parton density functions $q(x,Q^2)$
Need input functions at fixed (low) Q_0 scale -- evolve to higher Q^2

popular parametrizations: CTEQ, MRS, GRV, ...

e.g. $$q_i(x,Q_0^2) = A_i x^{B_i} (1-x)^{C_i} (1 + D_i + E_i \sqrt{x})$$

F_2 at HERA '94 high Q^2

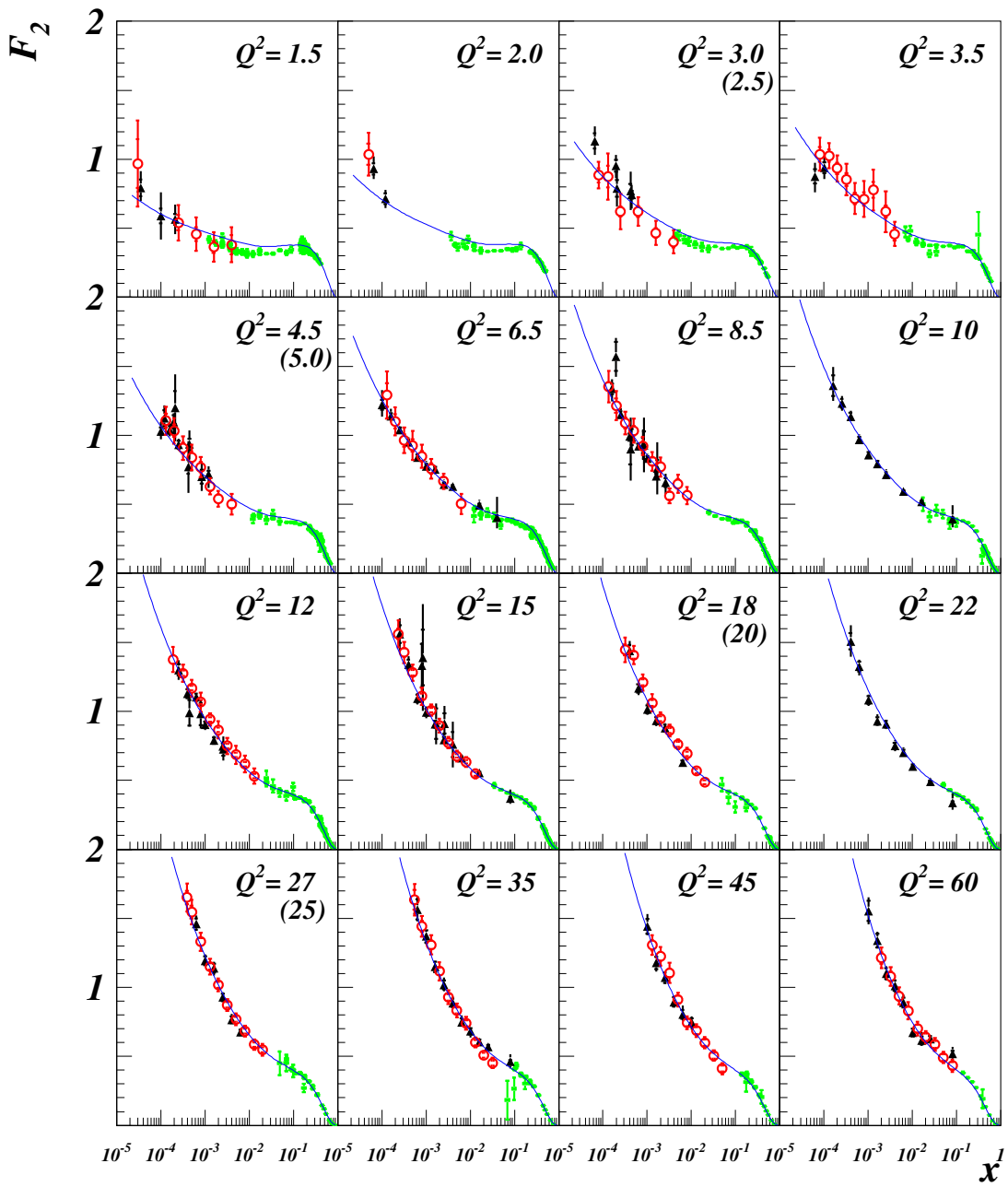
$L \sim 3\ p\mathrm{b}^{-1}$, statistical errors dominate



fixed target data stop at $Q^2 = 200\ \mathrm{GeV}^2$

F_2 at HERA '94 low Q^2

$L \sim 3\ p\mathrm{b}^{-1}$, systematic errors ~ 5 % (dominant, except at high Q^2)

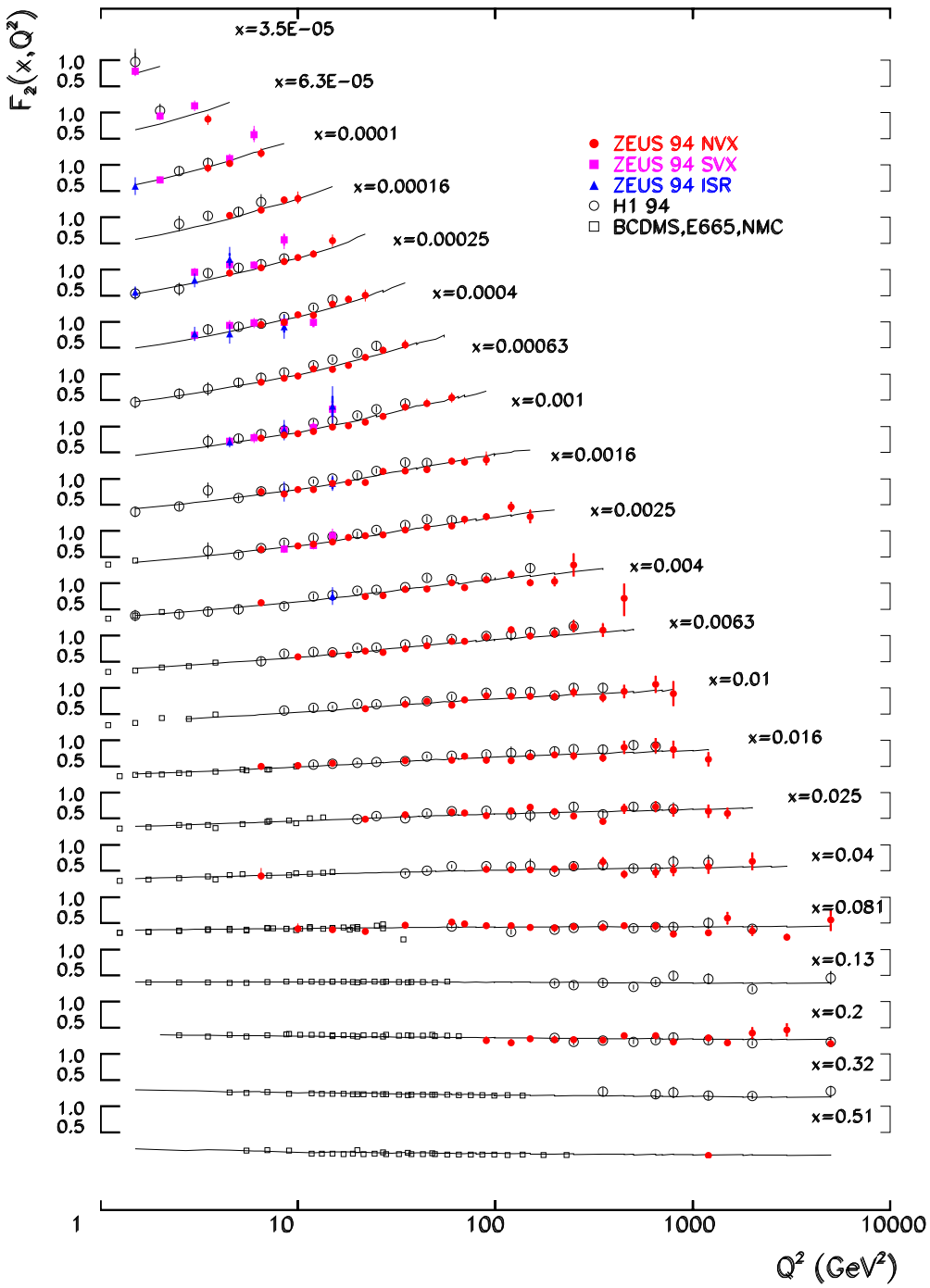


→ good agreement between HERA and fixed target experiments

→ F_2 rises with decreasing x , even down to lowest Q^2

Scaling Violation in F_2

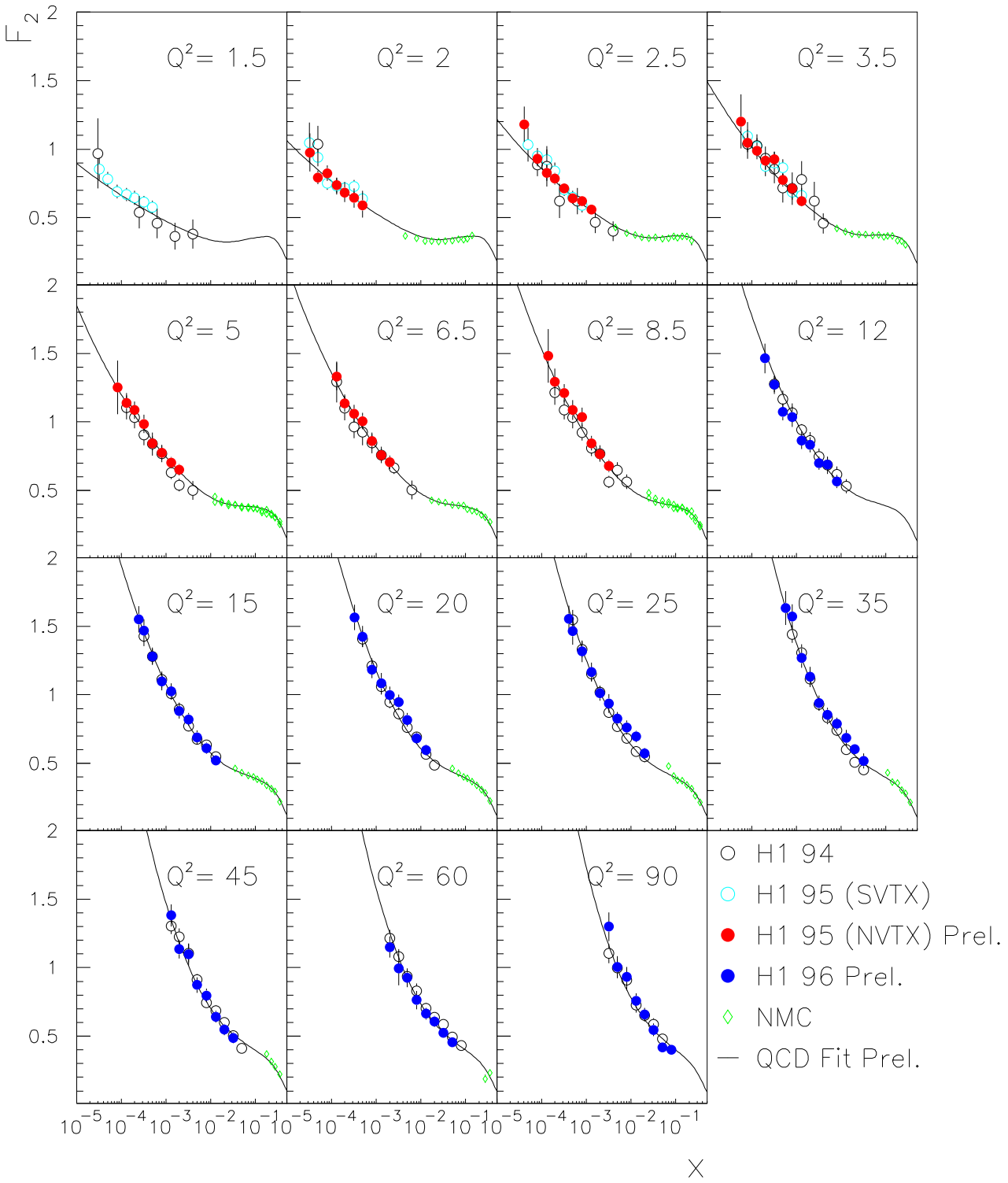
QCD (NLO fit) correctly predicts violation of scaling
(= Q^2 dependence of $F_2(x,Q^2)$)



DGLAP evolution works well at HERA !

New Data on F_2 from H1 ('95, '96)

preliminary data, correspond to $L \sim 24\ pb^{-1}$



Approaching Photoproduction ...

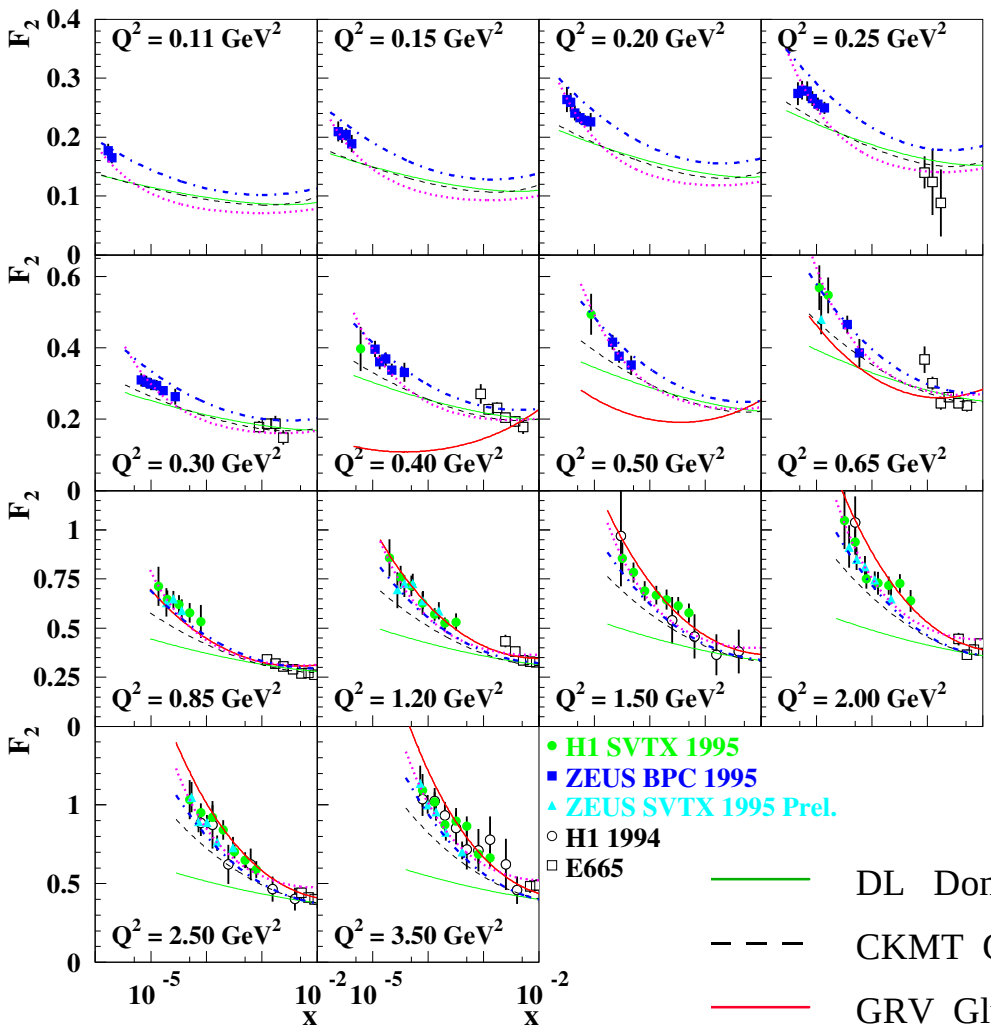
→ shift of the interaction point (SVTX) : $Q^2 > .35$ GeV^2

$$Q^2 = 2E'E(1+\cos\theta_e)$$

→ low angle detectors (ZEUS: BPC '95, H1: VLQ in '98) $Q^2 > .1$ GeV^2

→ events with initial state QED radiation (photon in tagger)

$$Q^2 = 2E'(E-E_\gamma)(1+\cos\theta_e)$$



DL Donnachie Landshoff

CKMT Capella, Kaidalov et al.

GRV Glück, Reya, Vogt

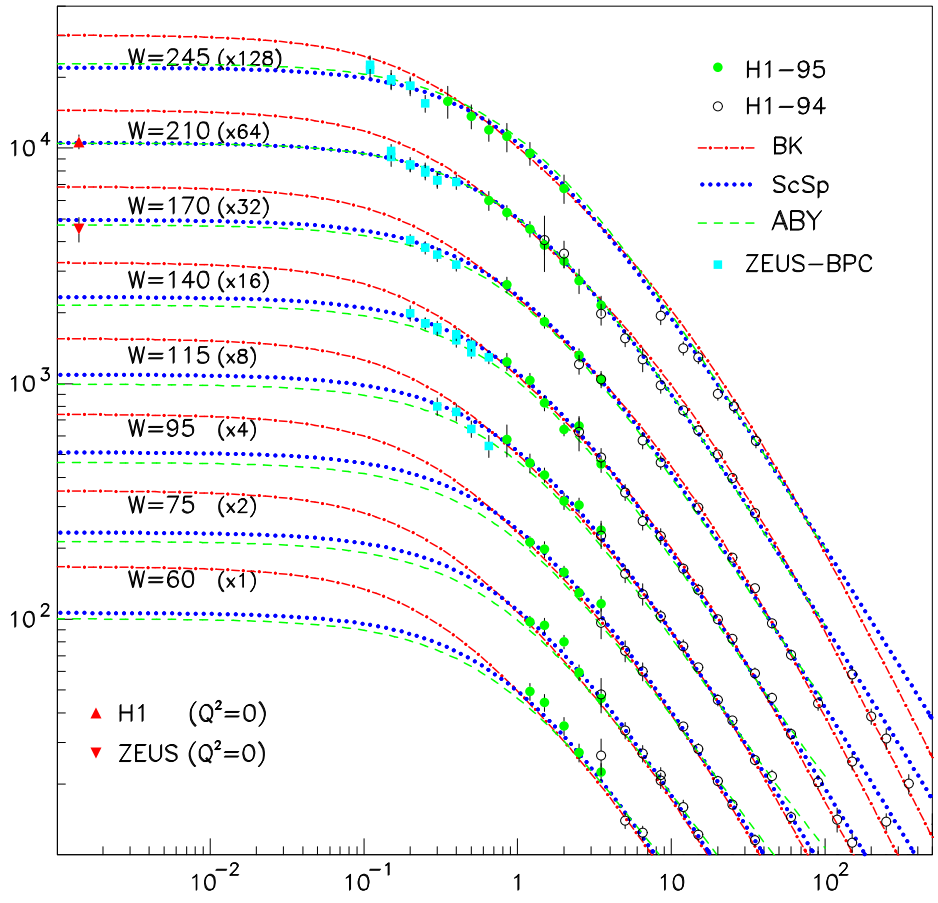
ABY Adel, Barreiro, Yndurain

BK Badelek, Kwiecinski

Check of Photoproduction Limit

$$\sigma^{eff}_{\gamma^* p} = \sigma_T + \frac{2(1-y)}{2-2y+y^2}\sigma_L \qquad \left(\approx \sigma^{tot}_{\gamma^* p} \cong \frac{4\pi^2\alpha}{Q^2} F_2(W^2, Q^2) \right)$$

$W^2 \approx Q^2 / x$ center of mass energy of γp system



Spiesberger, Schildknecht generalized VDM, tuned to HERA

→ consistency between H1 (SVTX), ZEUS (BPC) and their high energy γp (Q^2=0) cross sections

→ some models fail to describe γp (Q^2=0) if not included in fit

→ all models fail to describe low energy γp (Q^2=0) cross sections except ALLM (Abramowicz et al.) and DL, which do, however, not describe the very low Q^2 HERA data

Gluon Structure of the Proton

NLO QCD Fit to F_2 with Gluon and Quark Densities

→ input: parton densities at some (low) Q_0^2

→ fit F_2 for $Q^2 > Q_0^2$

$$\frac{d}{d\ln Q^2}\begin{pmatrix} g \\ q_S \end{pmatrix} = \frac{\alpha_S(Q^2)}{2\pi}\begin{bmatrix} P_{gg} & P_{gq} \\ P_{qg} & P_{qq} \end{bmatrix} \otimes \begin{pmatrix} g \\ q_S \end{pmatrix}$$

$$\frac{d}{d\ln Q^2} q_{NS} = \frac{\alpha_S(Q^2)}{2\pi} P_{qq}^{NS} \otimes q_{NS}$$

DGLAP evolution equations for the parton densities, for singlet and non-singlet parts

$$\frac{1}{x}F_2(x,Q^2) = \sum_{i=1}^{n_f} e_i^2 C_i(x,Q^2) \otimes (q+\bar{q})(x,Q^2) + C_g(x,Q^2) \otimes g(x,Q^2)$$

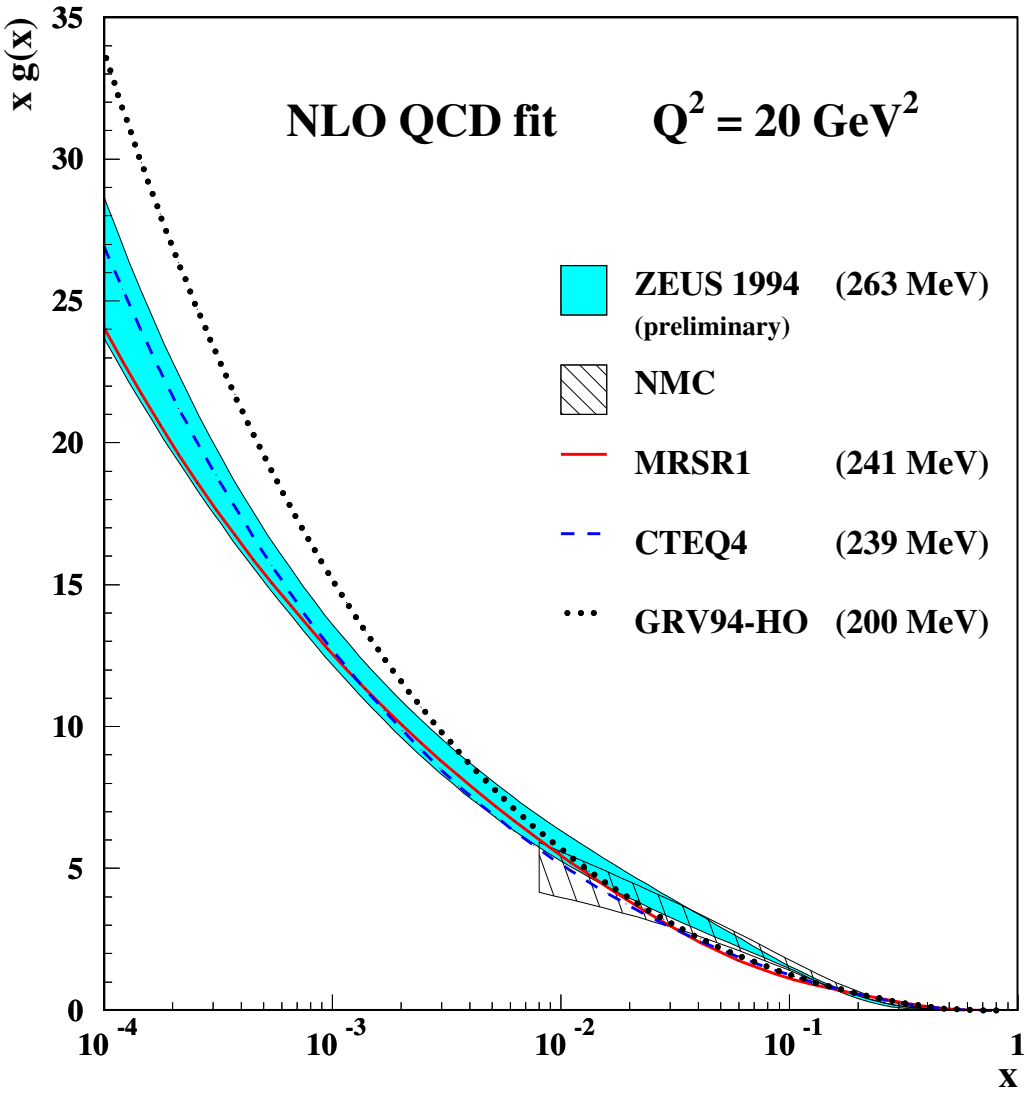
$C_i(x,Q^2)$ and $C_g(x,Q^2)$: calculable in QCD $\sim O(\alpha_S(Q^2)) + \ldots$

ZEUS: $Q_0^2 = 7$ GeV^2 "sea-type" gluon input
data '94 $Q^2 > 1.5$ GeV^2 fit includes fixed target data from NMC

H1: $Q_0^2 = 1$ GeV^2 "valence-type" gluon input
data '94-96 $Q^2 > 1.5$ GeV^2 fit includes fixed target data from NMC and BCDMS

Gluon from ZEUS NLO QCD Fit

ZEUS, NMC data, $Q^2 > 1.5$ GeV^2
$Q_0^2 = 7$ GeV^2 $xg(x,Q^2)$ with 4 parameters
3 flavours, charm calculated in NLO (Riemersma et al.)
from boson gluon fusion (BGF)
$\alpha_S(M_Z^2) = 0.113$ $m_C = 1.5$ GeV

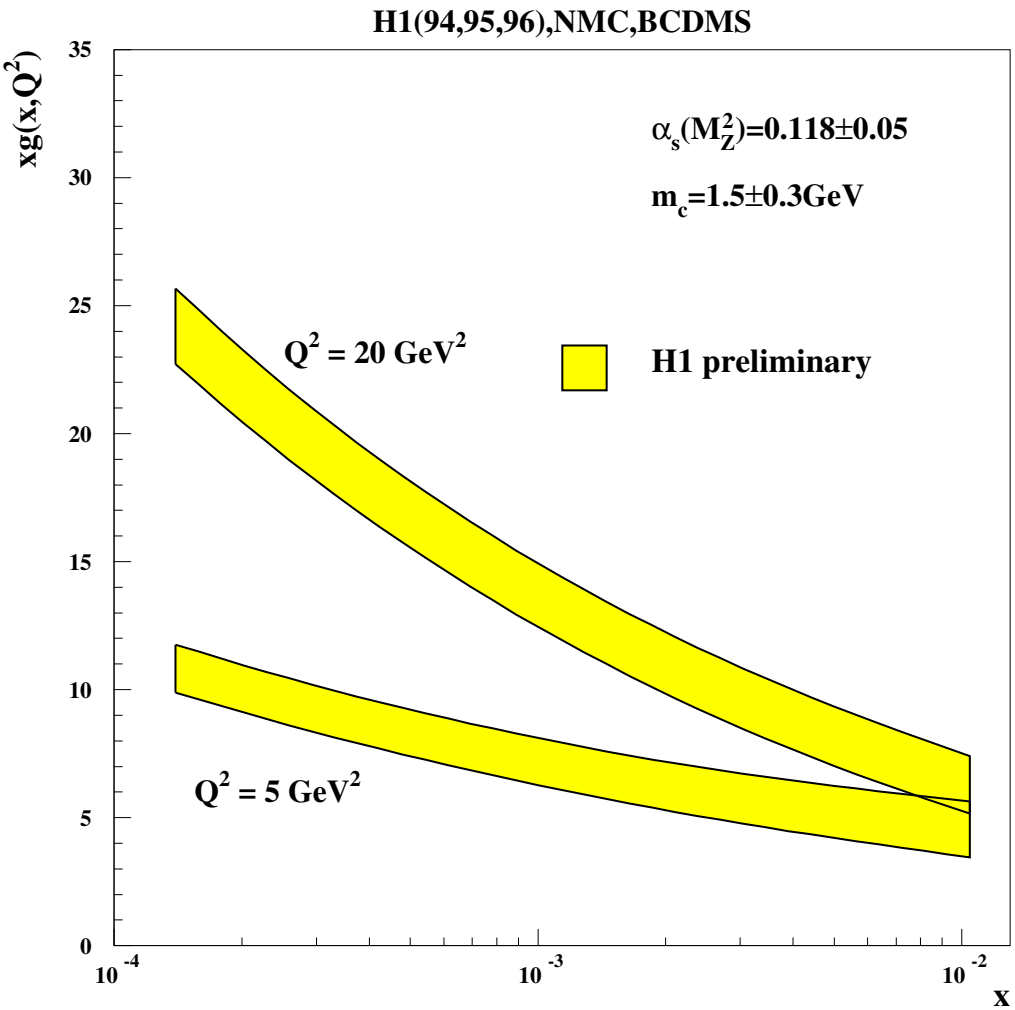


→ precision about 10 - 15 %

→ $xg(x)$ consistent with MRS (R1) and CTEQ4

Gluon from H1 NLO QCD Fit

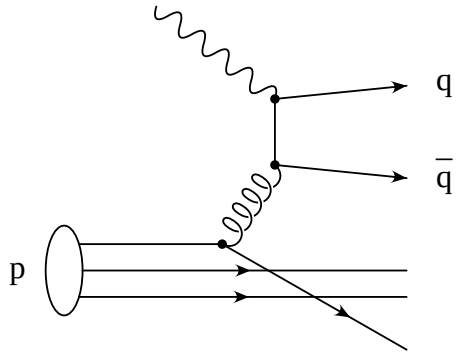
H1('94, '95, '96), NMC, BCDMS data
$Q^2 > 1.5\ \mathrm{GeV}^2$, $y < 0.6$
$Q_0^2 = 1\ \mathrm{GeV}^2$ $xg(x,Q_0^2)$ with 3 parameters
3 flavours, charm calculated in NLO (Riemersma et al.) from BGF
uncertainties of $\alpha_S(M_Z^2)$ and m_C included in the fit



→ due to systematic uncertainties (mainly from $\alpha_S(M_Z^2)$ and m_C) not sensitive to high x

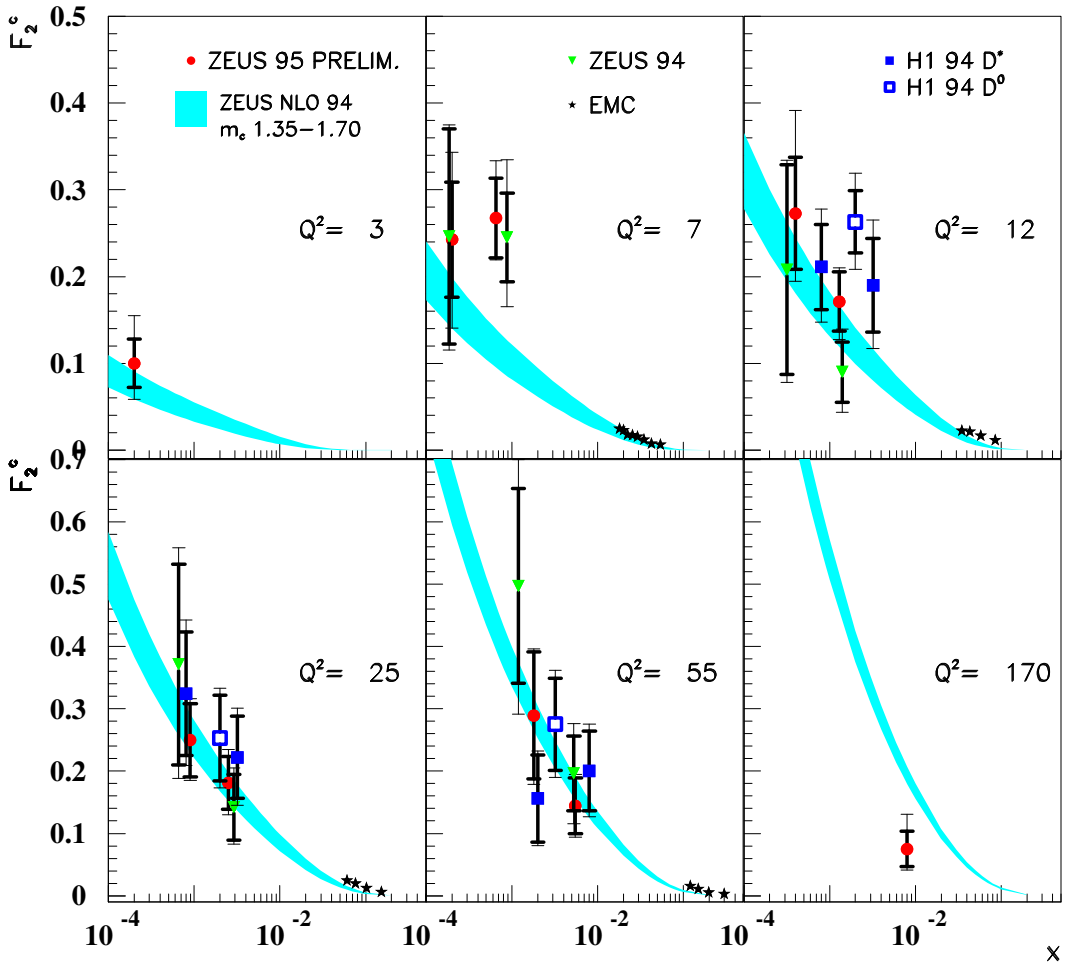
→ good agreement between H1 and ZEUS as x decreases ...

Charm Contribution to F_2



$c\bar{c}$ production via boson gluon fusion in NLO (Riemersma et al.)

data from D^0, D^* production



→ $F_2^C \sim 0.25\, F_2$ (~ 10 times larger than at large x)

→ consistent with predictions from NLO QCD fit + BGF

Longitudinal Structure Function F_L

NC cross section given by

'94: $y = .69$

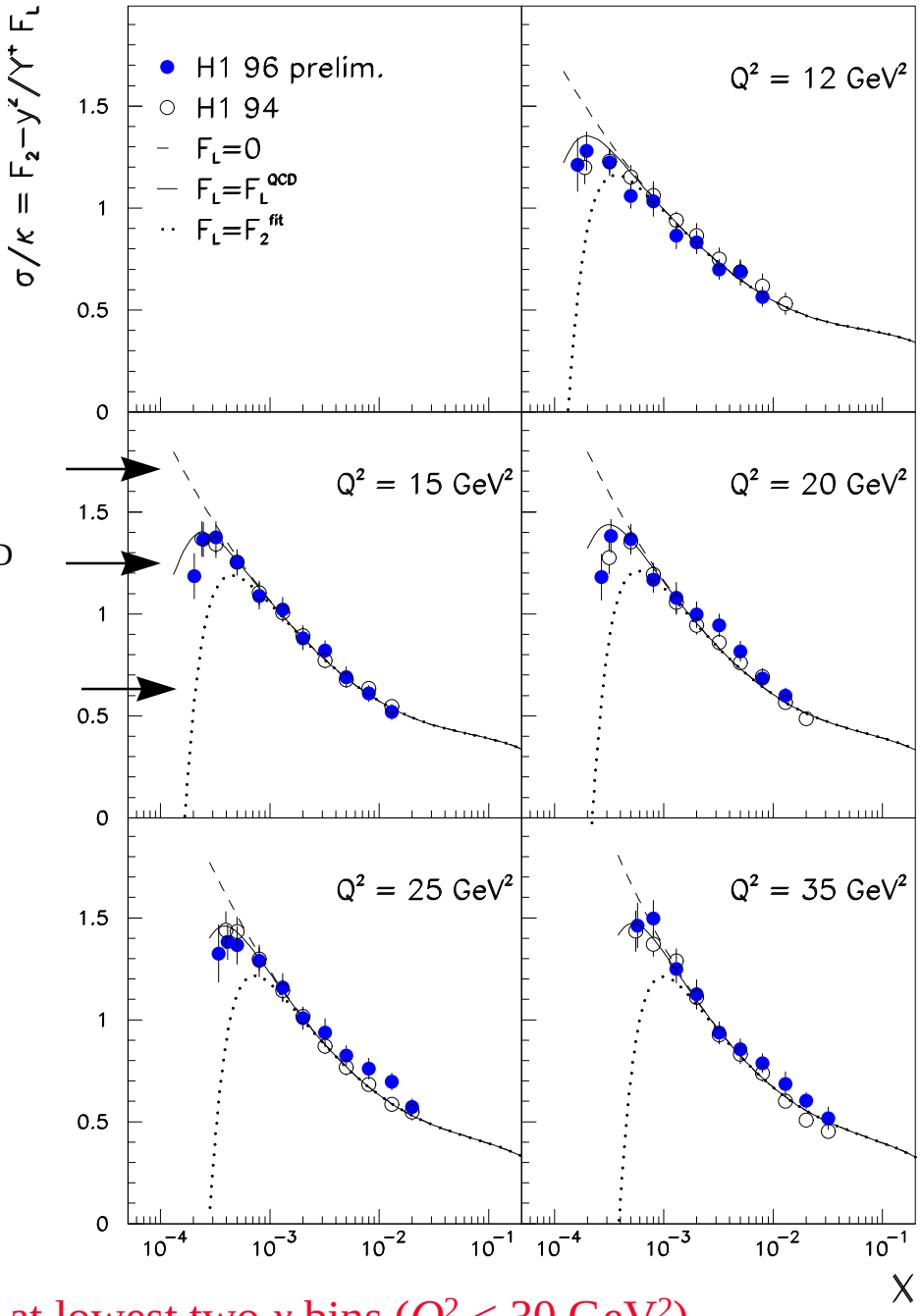
'96: $y = .68, .82$

→ sensitive to F_L !

$$\frac{\sigma}{k} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

(k is a kinematical factor)

Fit: NLO QCD to F_2 for $y < 0.35$



$F_L = 0$

$F_L = F_L^{QCD}$

$F_L = F_2$

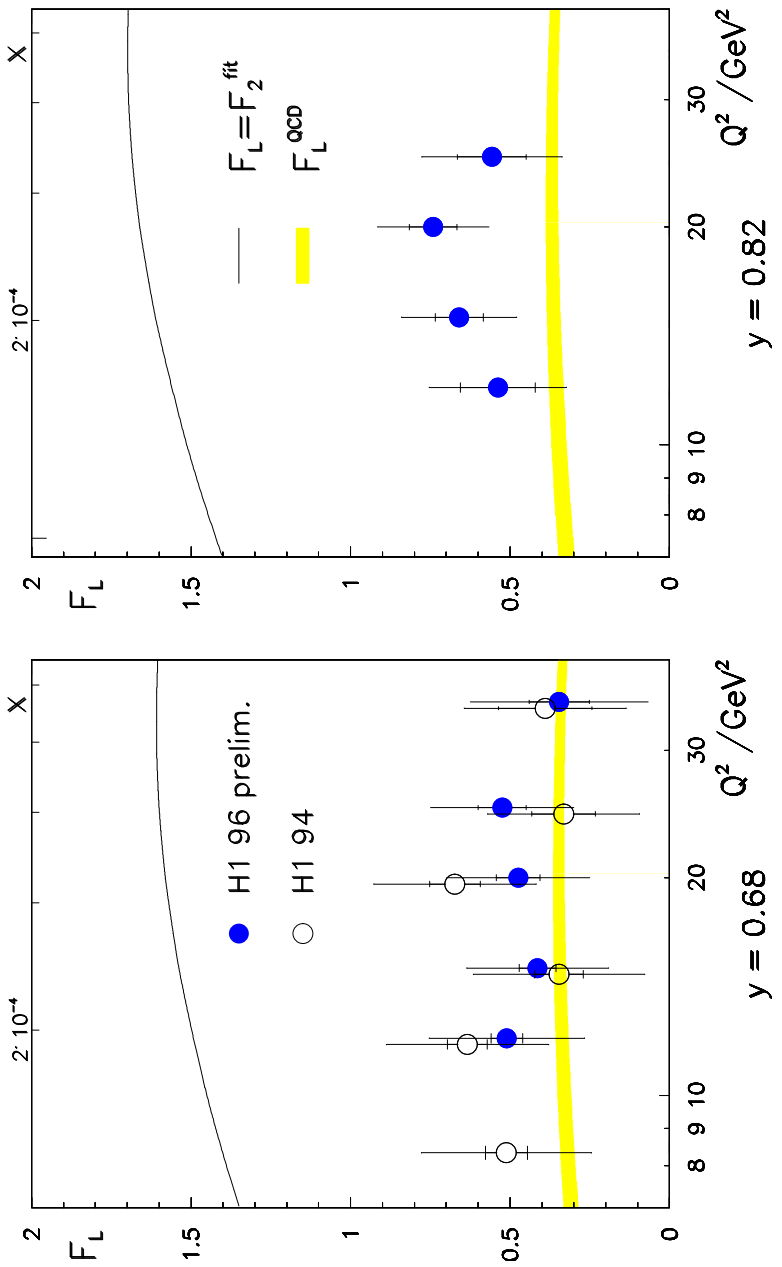
'96 points: at lowest two x bins ($Q^2 < 30$ GeV^2)

Structure Function F_L (continued)

$$F_L = \left(F_2^{Fit} - \frac{\sigma}{k} \right) \frac{1+(1-y)^2}{y^2}$$

measured cross section at y = .68, .82

F_2 from NLO DGLAP fit for y <.35



note: points at same y have correlated errors

F_L compatible with QCD predictions,
but systematically higher by 1-2 σ

Summary: Structure Functions from H1 and ZEUS

- Present HERA data on F_2 are consistent with NLO DGLAP down to $Q^2 = 1$ GeV^2 .
  Data well described in new kinematic range
  1 GeV$^2 \cdot < Q^2 <$ 5000 GeV^2 and 5 x $10^{-5} < x < 0.3$

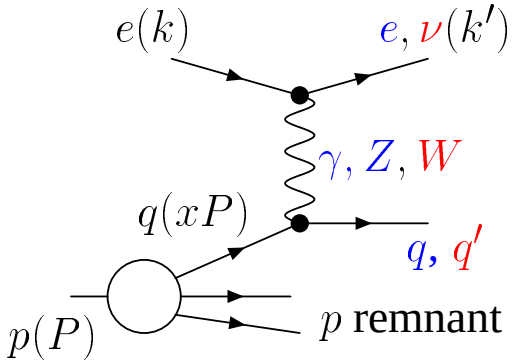
- Measurements in the transition region from DIS to photoproduction are challenging present models.
  No model is able to describe transition region AND photoproduction in a consistent way.

- New NLO QCD fits show a very steep rise of the gluon density with decreasing x.
  The gluon is dominating the dynamics at low x.

- The measured charm contribution to F_2 is about 25 % at low x and consistent with the NLO QCD analysis of F_2.

- The longitudinal structure function F_L is determined at low x relying on the DGLAP Q^2 evolution of F_2 .
  Results are compatible with QCD, but systematically 1-2 % higher.

Deep Inelastic Scattering at Very Large Q^2



Q^2 = 4-momentum transfer

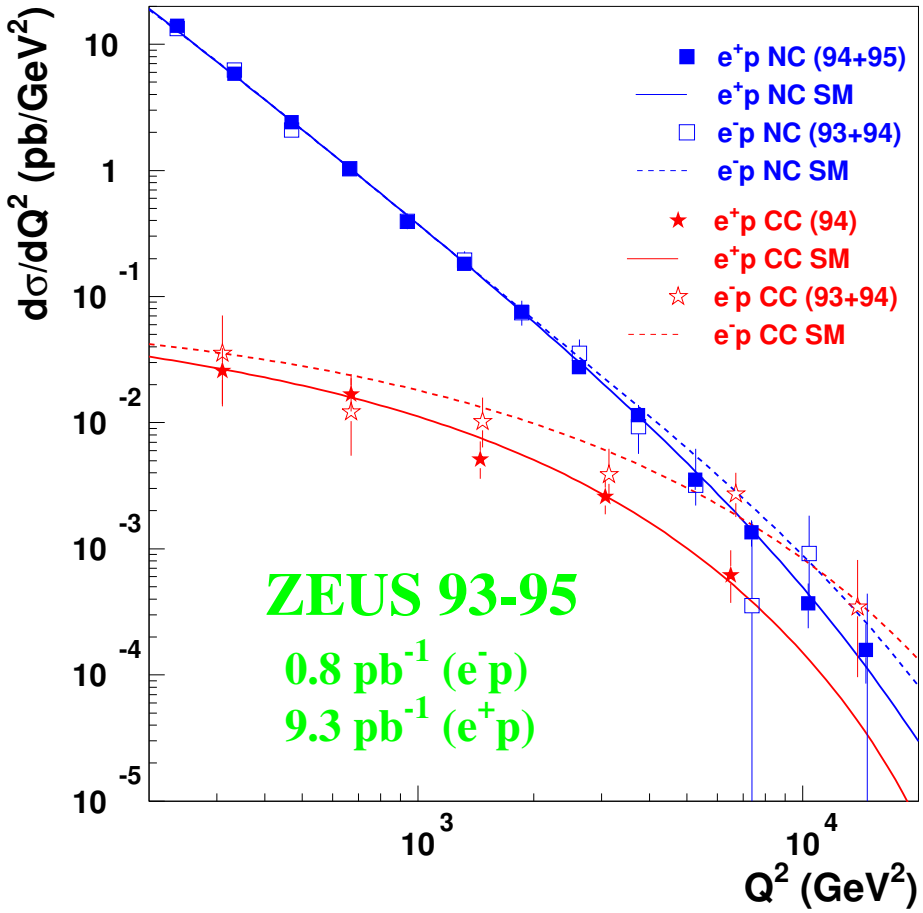
x = parton momentum fraction

y = fractional energy transfer

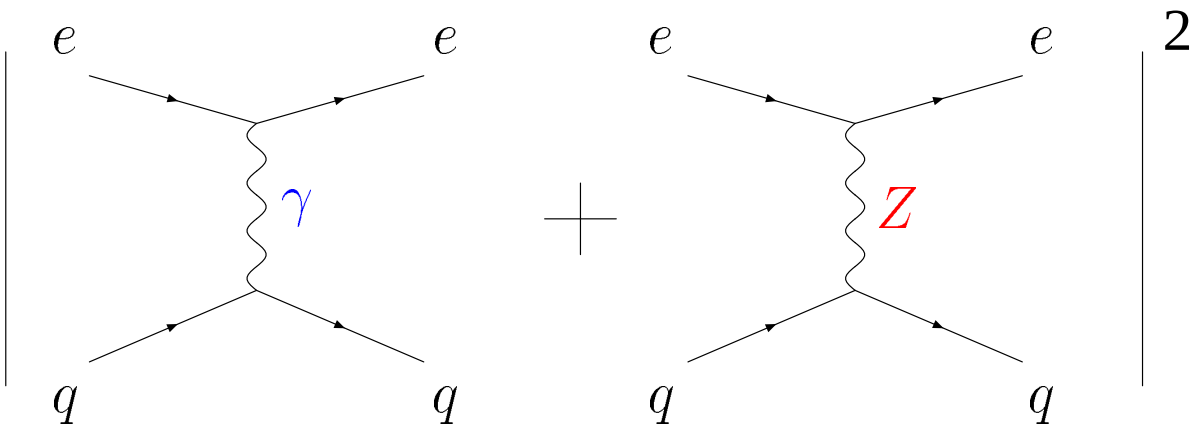
$M = \sqrt{s\,x} = E^{eq}_{\rm cm}$

At very large Q^2 ($Q^2 \sim 10000$ GeV^2) Z-exchange dominant in NC reactions

→ NC and CC reaction cross sections become roughly equal



NC and CC Cross Sections



Amplitudes for NC, for CC only 2nd diagram, with $Z \rightarrow W$, $e \rightarrow \nu$

At large Q^2 (and consequently large x) sea quarks and gluons may be safely neglected:

NC cross section:

$$\frac{d^2\sigma(e^+p)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\sum_v \left[Y_+ A_v - Y_- B_v\right] x q_v(x,Q^2)$$

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

CC cross section:

$$\frac{d^2\sigma(e^+p)}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_w^2}{Q^2+M_w^2}\right)^2 (1-y)^2\, d(x,Q^2)$$

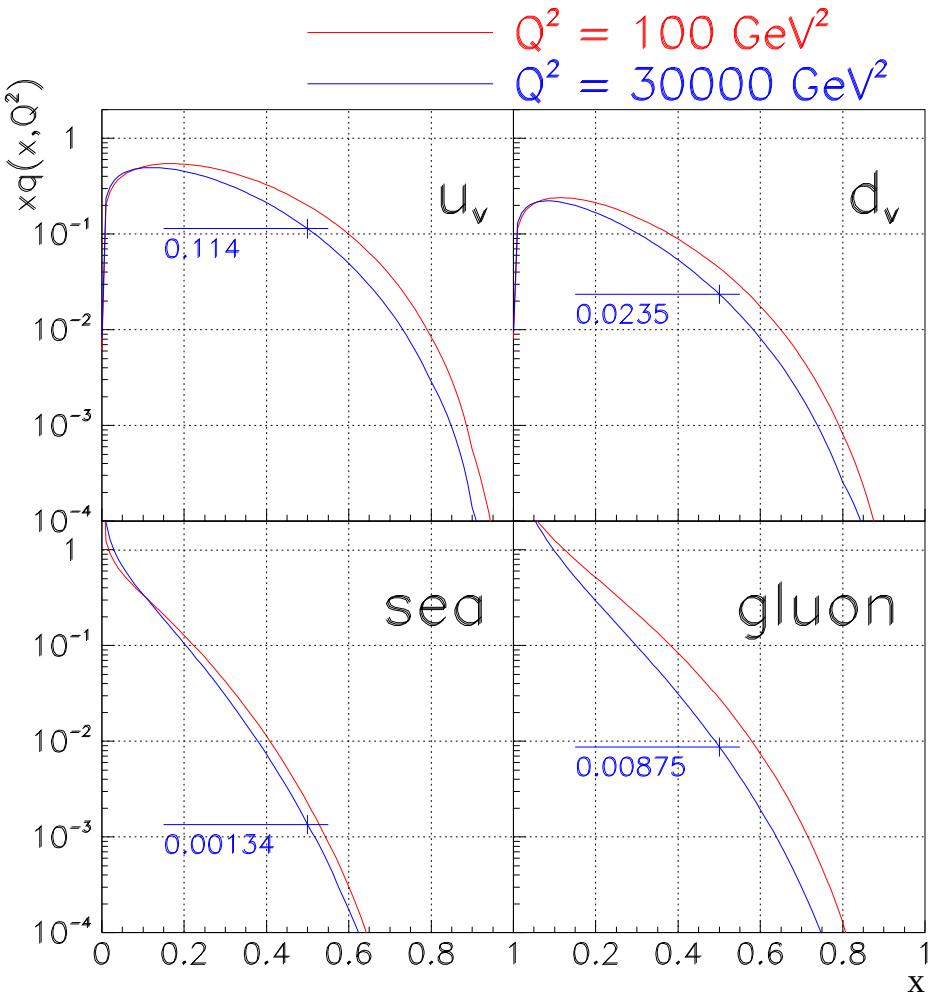
(electroweak coefficient functions A_v, B_v known to .25 %)

Input to Cross Section Prediction

DIS cross sections are given by the valence quark densities $q_v(x,Q^2)$ of the proton:

→ parton densities determined from NLO DGLAP fits at lower Q^2. High x well constrained by fixed target exp.

→ parton densities are evolved via DGLAP to high Q^2

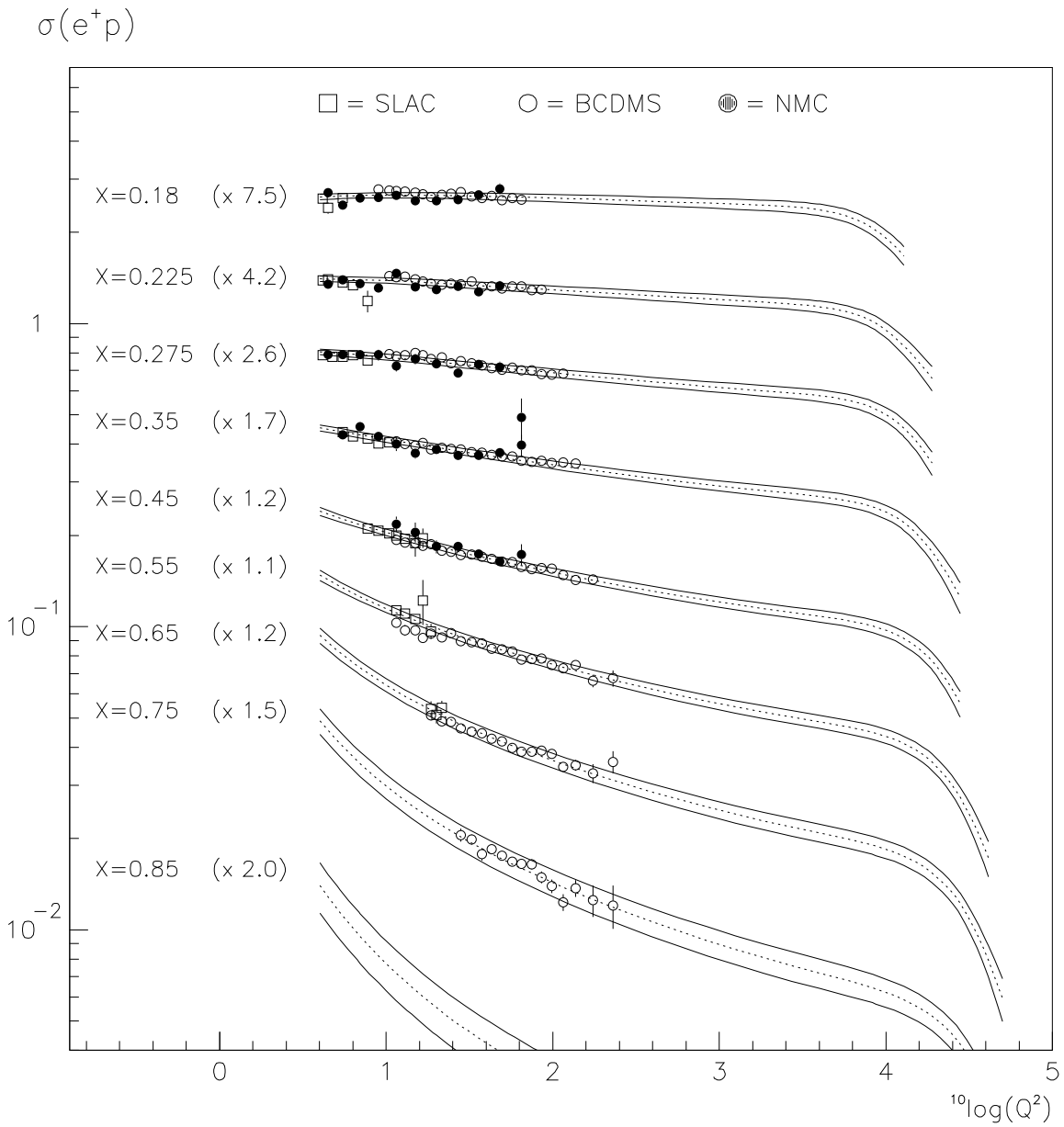


numbers given indicate typical parton densities at $x = 0.5$

→ u_v density dominates NC cross section: $u_v > d_v$
d_v density dominates CC cross section: $d_v >$ sea

Cross Section Prediction for NC

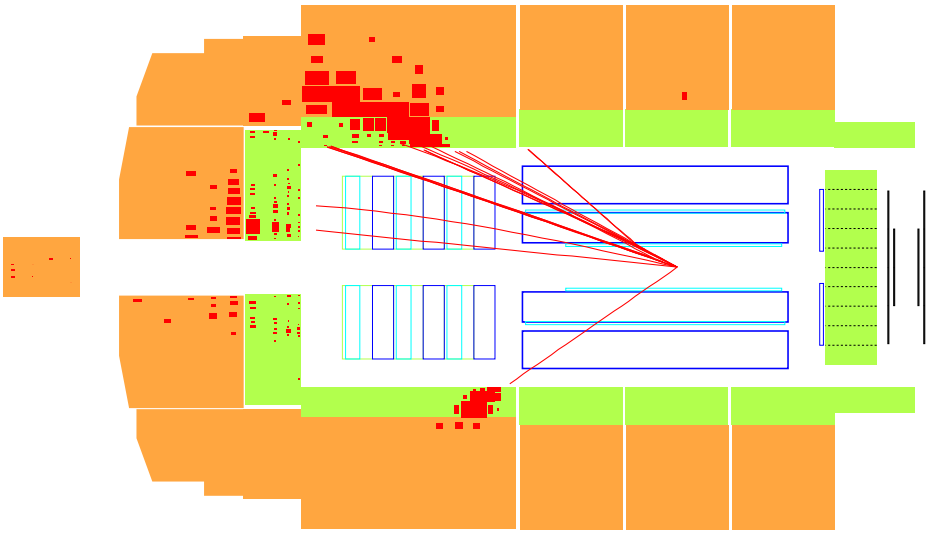
Note negative sign of weak interference term:
e^+p cross section is predicted to strongly drop above $Q^2 > M_Z^2$
(e^-p cross section will show a strong rise)



error bands correspond to uncertainties in the parton densities (~ 6 %)

High Q^2 Event in the H1 Detector

H1 Detector



kinematics: $Q^2 = 16950\ \text{GeV}^2$, $y = .44$, $M = 196\ \text{GeV}$

Characteristics of the H1 detector:

Liquid Argon Calorimeter

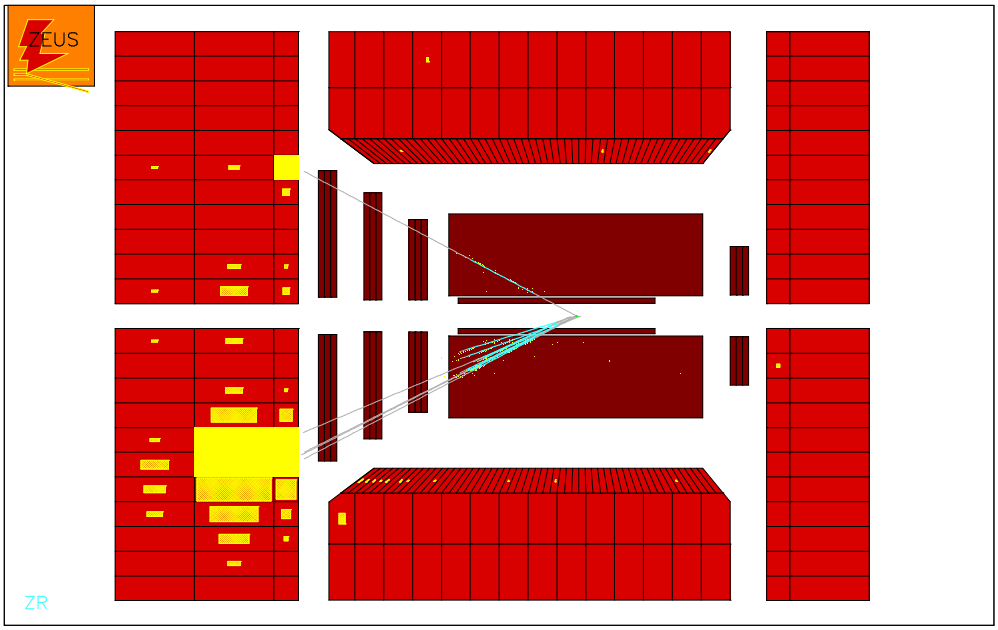
44000 cells

$\sigma(\theta_e) = 2$ mrad $\qquad \dfrac{\sigma}{\sqrt{E(e)}} = 12\,\%$

$\dfrac{\sigma}{\sqrt{E(h)}} = 50\,\% \qquad \Delta E / E(syst) = 3-4\,\%$

High Q^2 Event in the ZEUS Detector

ZEUS Detector



Characteristics of the ZEUS detector:

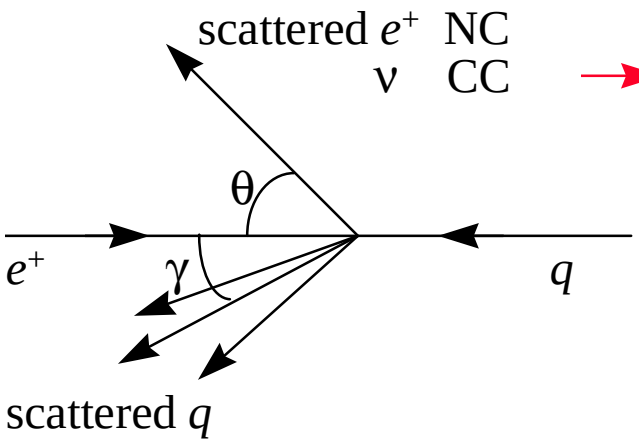
Uranium Scintillator Calorimeter

6000 cells

$\sigma(\theta_e) = 5$ mrad $\qquad \frac{\sigma}{\sqrt{E(e)}} = 18\,\%$

$\frac{\sigma}{\sqrt{E(h)}} = 35\,\% \qquad \Delta E / E(syst) = 3\,\%$

Reconstruction of Event Kinematics



→ For NC events, 4 variables are available:

θ_e polar angle of scattered e

E'_e energy of scattered e

γ polar angle of scattered q

E_q energy of scattered q (jet)

any two of them can be used to reconstruct x and Q^2

→ For CC events, only E_q and γ are usable (ν escapes).

→ All 4-momenta reconstructed using calorimeter cells
E_q and γ are estimated from hadronic final state (MC corrections).

Reconstruction techniques applied by the two experiments:

Technique	Variables	Features	used by
Electron	E'_e , θ_e	+ no MC needed – depends on E scale	H1
Double Angle	θ_e , γ	+ no E scale dependence – MC needed, sensitive to hard ISR	ZEUS
Hadron	E_q , γ	only choice for CC	H1, ZEUS

Both experiments use alternative method for cross check in NC

Event Kinematics (continued)

electron

$E'_e \quad \theta_e$

$E_T = E'_e \sin\theta_e$

hadronic system

$$(p_T)_{had} = \sqrt{\left(\sum_i p_x^i\right)^2 + \left(\sum_i p_y^i\right)^2}$$

$$(E - p_z)_{had} = \sum_i \left(E^i - p_z^i\right)$$

$$\cos\gamma = \frac{(p_T)_{had} - (E - p_z)_{had}}{(p_T)_{had} + (E - p_z)_{had}}$$

H1

$$y_e = 1 - \frac{E'_e(1-\cos\theta_e)}{2E_e}$$

$$Q_e^2 = \frac{E_T^2}{1-y_e}$$

$$M_e = \sqrt{s\,x_e} = \sqrt{\frac{Q_e^2}{y_e}}$$

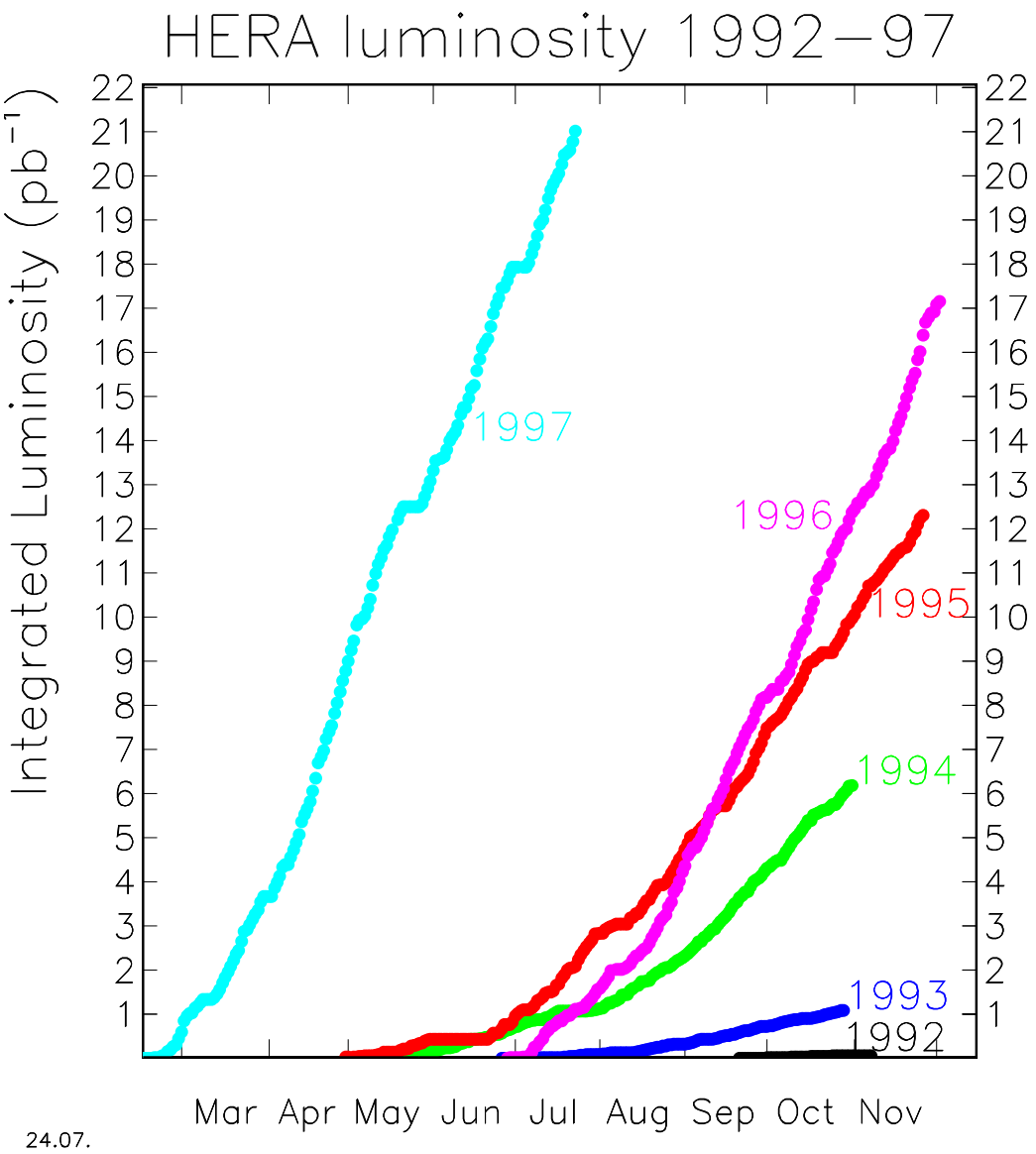
ZEUS

$$x_{DA} = \frac{E_e}{E_p}\frac{\sin\gamma}{(1-\cos\gamma)}\frac{\sin\theta_e}{(1-\cos\theta_e)}$$

$$y_{DA} = \frac{\sin\theta_e(1-\cos\gamma)}{\sin\gamma + \sin\theta_e - \sin(\gamma+\theta_e)}$$

$$Q_{DA}^2 = s\,x_{DA}\,y_{DA}$$

Data Volume by End of July 1997



Previous analyses (Jan. 97) based on

14.2 pb^{-1}	for H1	now	23.7 pb^{-1}
20.1 pb^{-1}	for ZEUS	now	33.5 pb^{-1}

Data Selections NC Events

- Identified isolated electron

  $p_T^e > 25$ GeV and track , $\theta_e > 10°$ (H1)

  ($E'_e > 20$ GeV and track) or ($p_T^e > 30$ GeV for $\theta_e < 17°$) (ZEUS)

- Vertex from Trackers

- Longitudinal Momentum Conservation

  from initial state: $E - P_z = 2\,E_e = 55$ GeV
  in final state $E - P_z$ reduced by particles escaping in e direction,
  (e.g. ISR, photoproduction events)
  H1: $E - P_z > 43$ GeV
  ZEUS: $E - P_z > 44$ GeV for $\theta_e < 17°$, else > 40 GeV

- Kinematic Cut

  H1: $Q^2 > 2500$ GeV^2 ZEUS: $Q^2 > 5000$ GeV^2

Data Selection CC Events

- Cut in total transverse missing momentum

  H1: $p_T^{miss} > 50$ GeV
  ZEUS: $p_T^{miss} > 30$ GeV

  + vertex requirement + ...

Backgrounds in Selected Data Samples

NC Events:

- Photoproduction of high E_T Jets
- Prompt photon production (QCD Compton)
- Two-photon processes
- W,Z production with decays to leptons

→ H1 ($Q^2 > 10000$ GeV^2) < .1 event
ZEUS ($x > .45$, $y > .25$) < .1 event

CC Events:

→ no backgrounds because of high missing p_T
no sign of contamination from cosmics (visual scan)

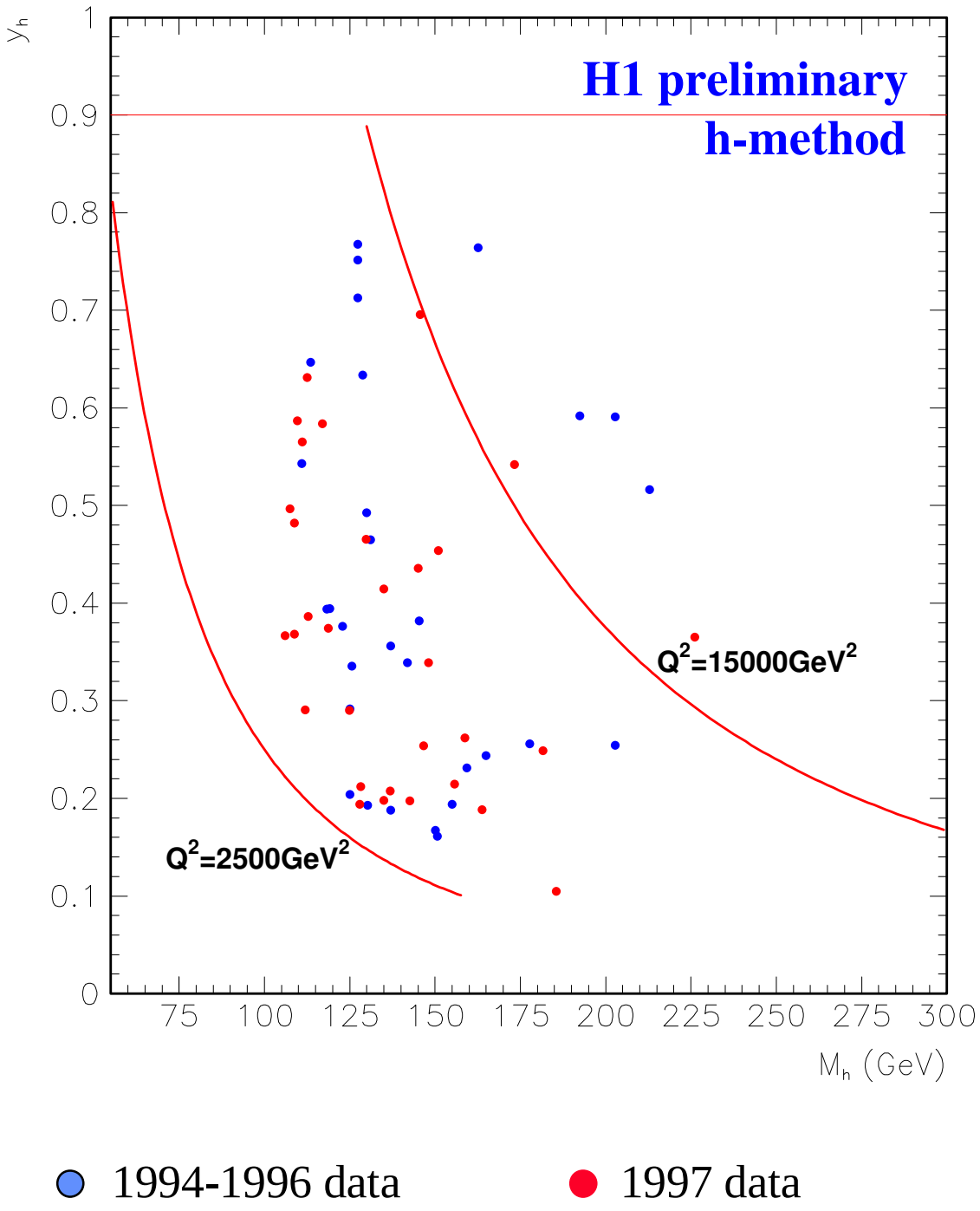
Uncertainties in SM Predictions for NC

Theoretical		Experimental	
Electroweak param.	.25 %	Energy scale,	
Radiative Corrections	2.0 %	smearing,	
Structure Functions	6.5 %	resolution	
(fixed target data,		H1:	8.5-30 %
uncertainty in α_S ,		(lowest to highest Q^2)	
PDF parametrization)		ZEUS:	6.5 %
		($x > .55$ and $y > .25$)	

Uncertainty in SM prediction is smaller than 35 %

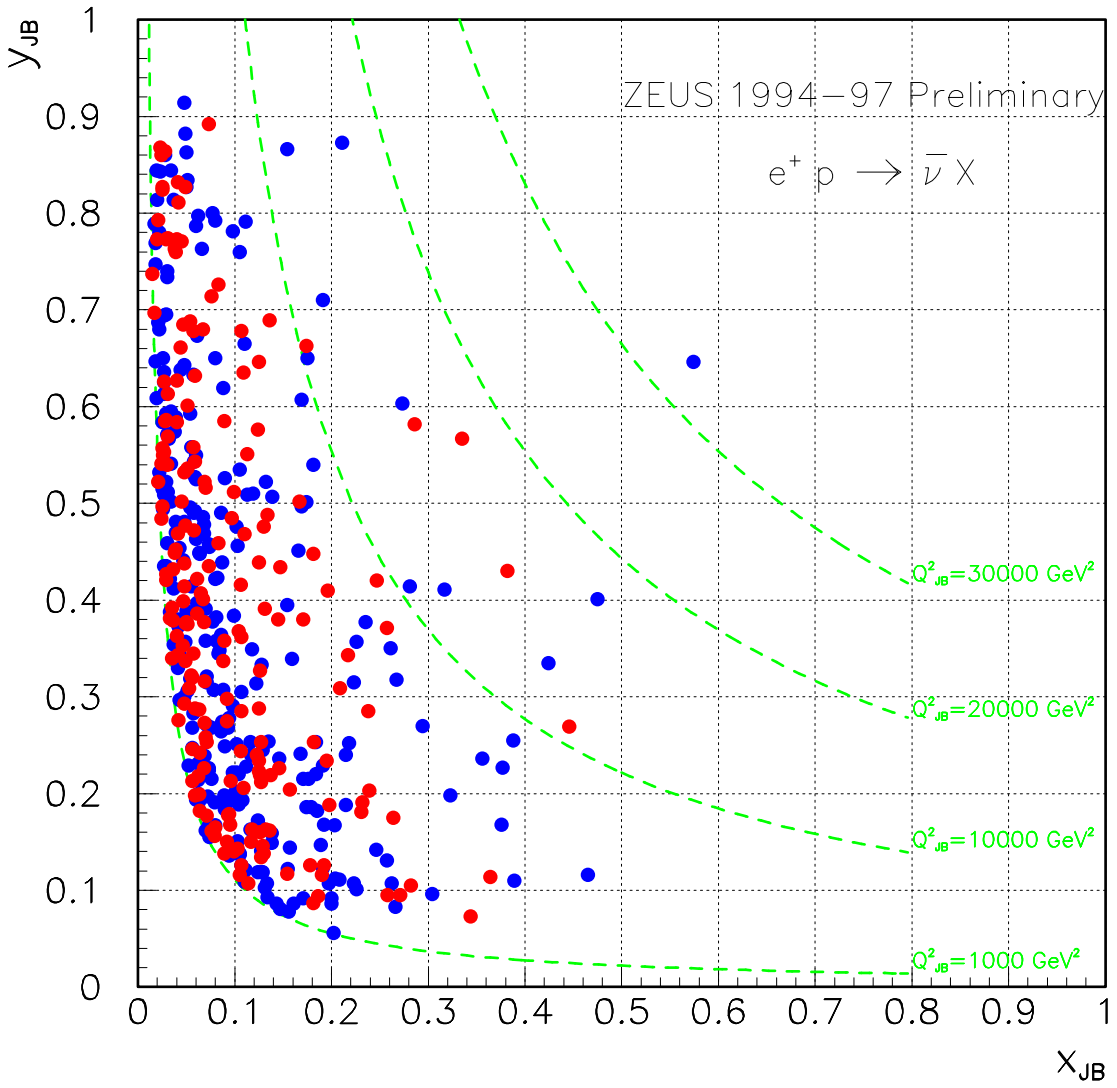
H1 CC 1994-1997 $L = 23.7\ \mathrm{pb}^{-1}$

Event distribution in M and y



ZEUS CC 1994-1997 $L = 33.5\ \text{pb}^{-1}$

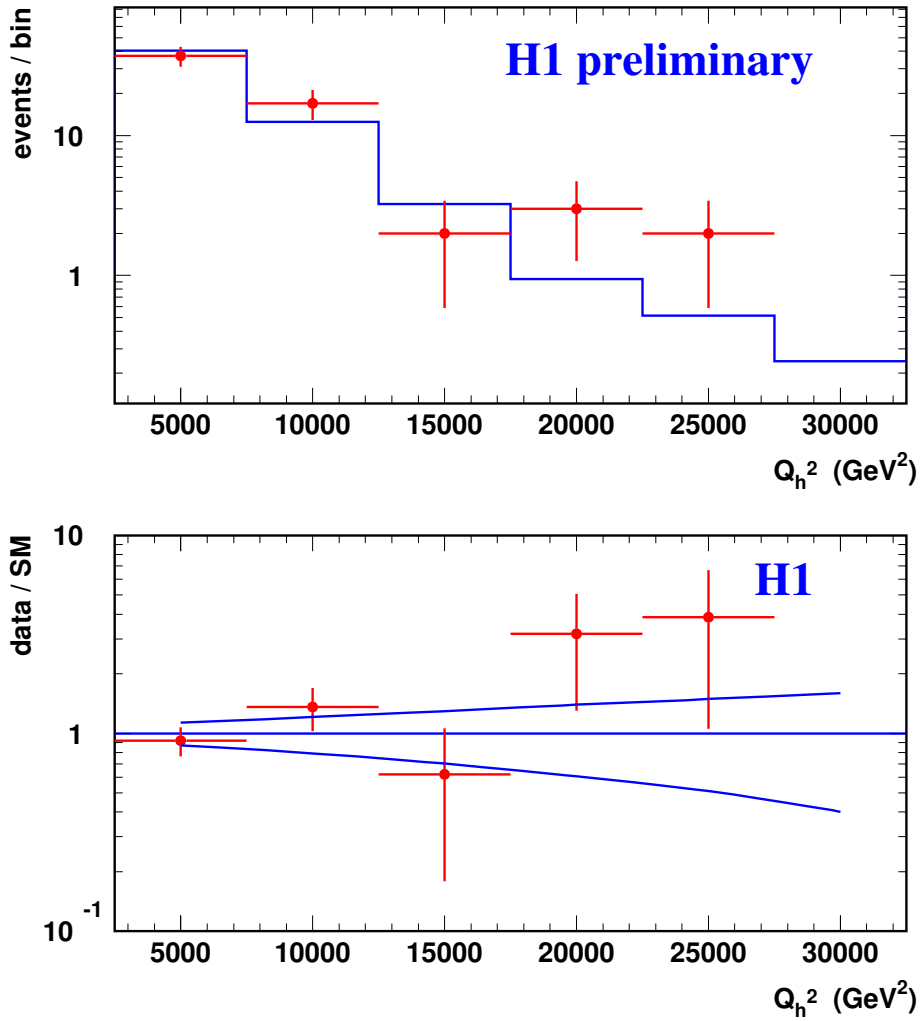
Event distribution in x and y



1994-1996 data 1997 data

H1 CC 1994-1997 $L = 23.7\ \mathrm{pb}^{-1}$

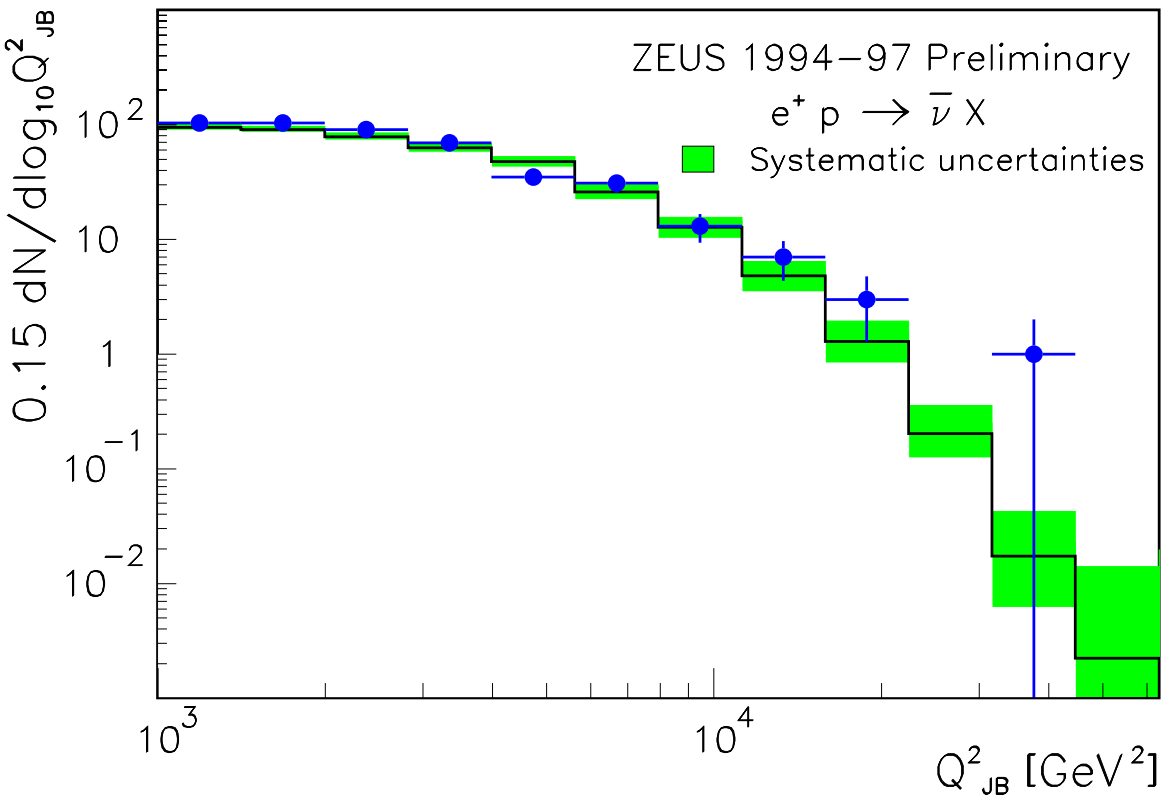
Event distribution in Q^2



Q^2 cut (GeV^2)	N(obs)	N(exp)
> 2500	61	56.3 ± 9.40
> 5000	43	34.7 ± 6.90
> 10000	13	8.33 ± 3.10
> 15000	6	2.92 ± 1.44
> 20000	4	1.21 ± .64

ZEUS CC 1994-1997 $L = 33.5\ \text{pb}^{-1}$

Event distribution in Q^2



Q^2 cut (GeV^2)	N(obs)	N(exp)
> 1000	455	419. ± 35.5
> 10000	15	9.4 ± 3.0
> 15000	5	2.0 ± .9
> 20000	1	.46 ± .30
> 30000	1	.03 ± .04

CC Events : Summary '94-'97

H1

Q^2 cut (GeV^2)	N(obs)	N(exp)
> 2500	61	56.3 ± 9.40
> 5000	43	34.7 ± 6.90
> 10000	13	8.33 ± 3.10
> 15000	6	2.92 ± 1.44
> 20000	4	1.21 ± .64

ZEUS

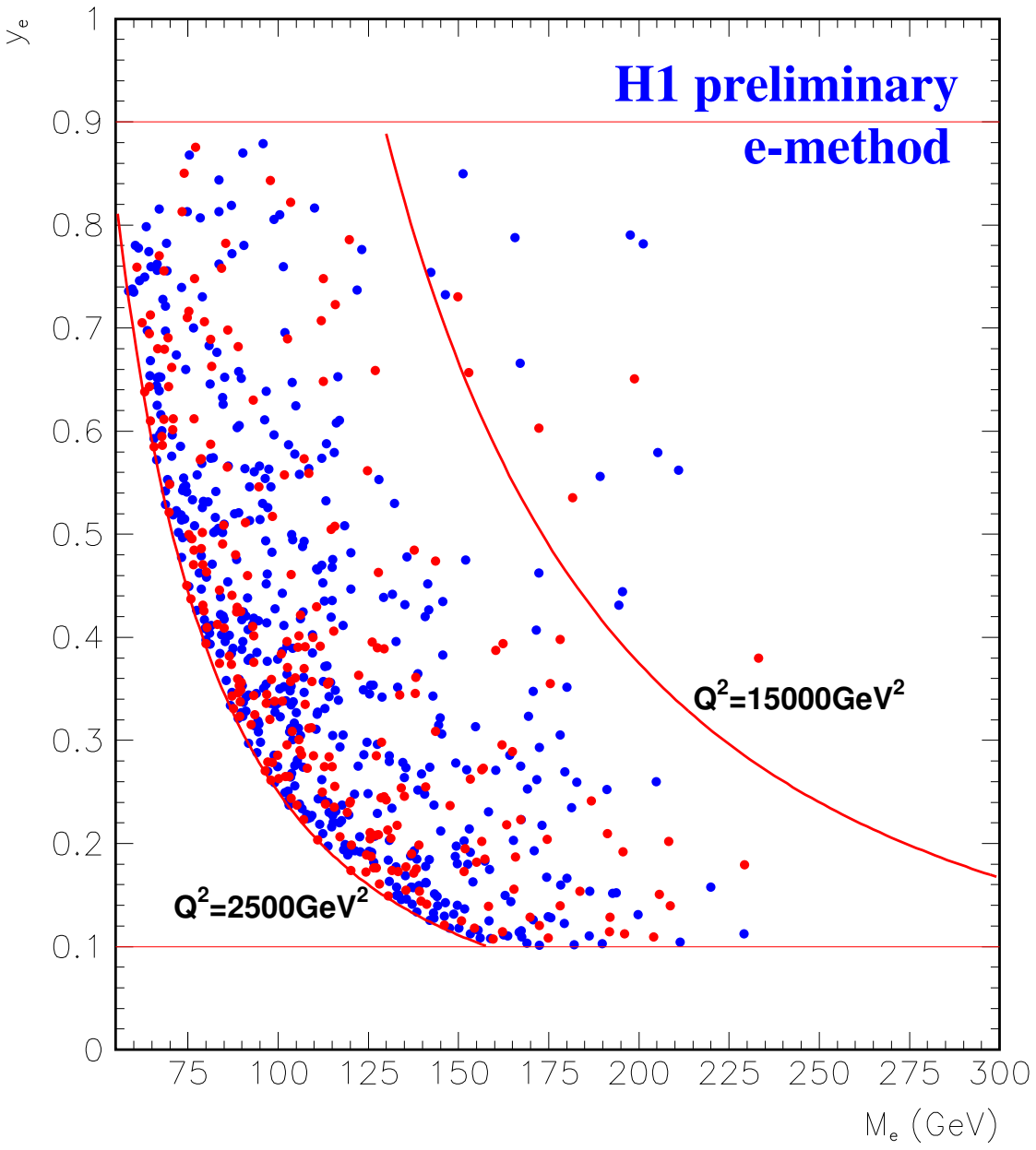
Q^2 cut (GeV^2)	N(obs)	N(exp)
> 1000	455	419. ± 35.5
> 10000	15	9.4 ± 3.0
> 15000	5	2.0 ± .9
> 20000	1	.46 ± .30
> 30000	1	.03 ± .04

H1 and ZEUS combined

Q^2 cut (GeV^2)	N(obs)	N(exp)	$P(N>\text{N(obs)})$
> 10000	28	17.7 ± 4.3	0.060
> 15000	11	4.92 ± 1.7	0.036
> 20000	5	1.67 ± .7	0.046

H1 NC 1994-1997 $L = 23.7\ \text{pb}^{-1}$

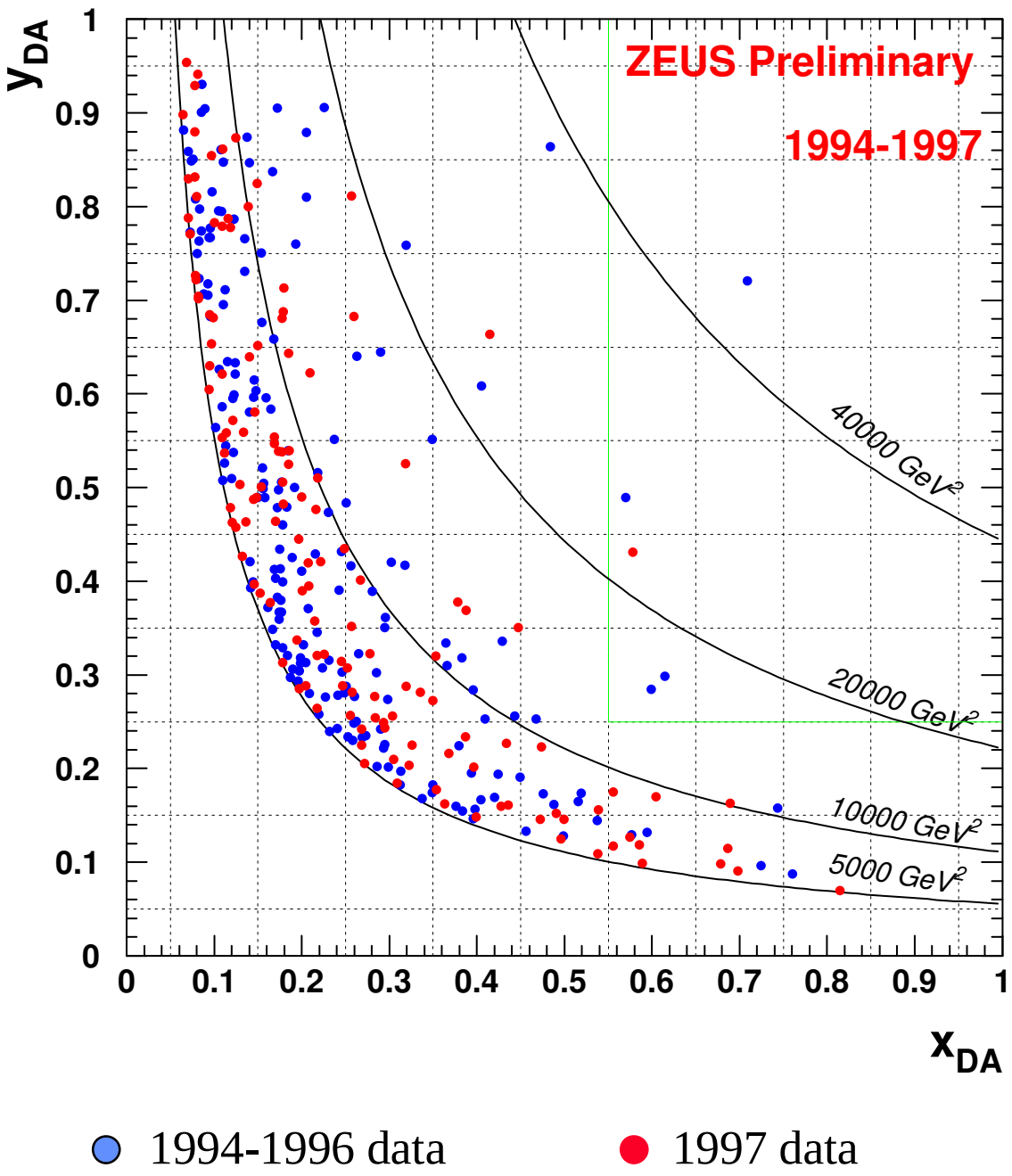
Event distribution in M and y



1994-1996 data 1997 data

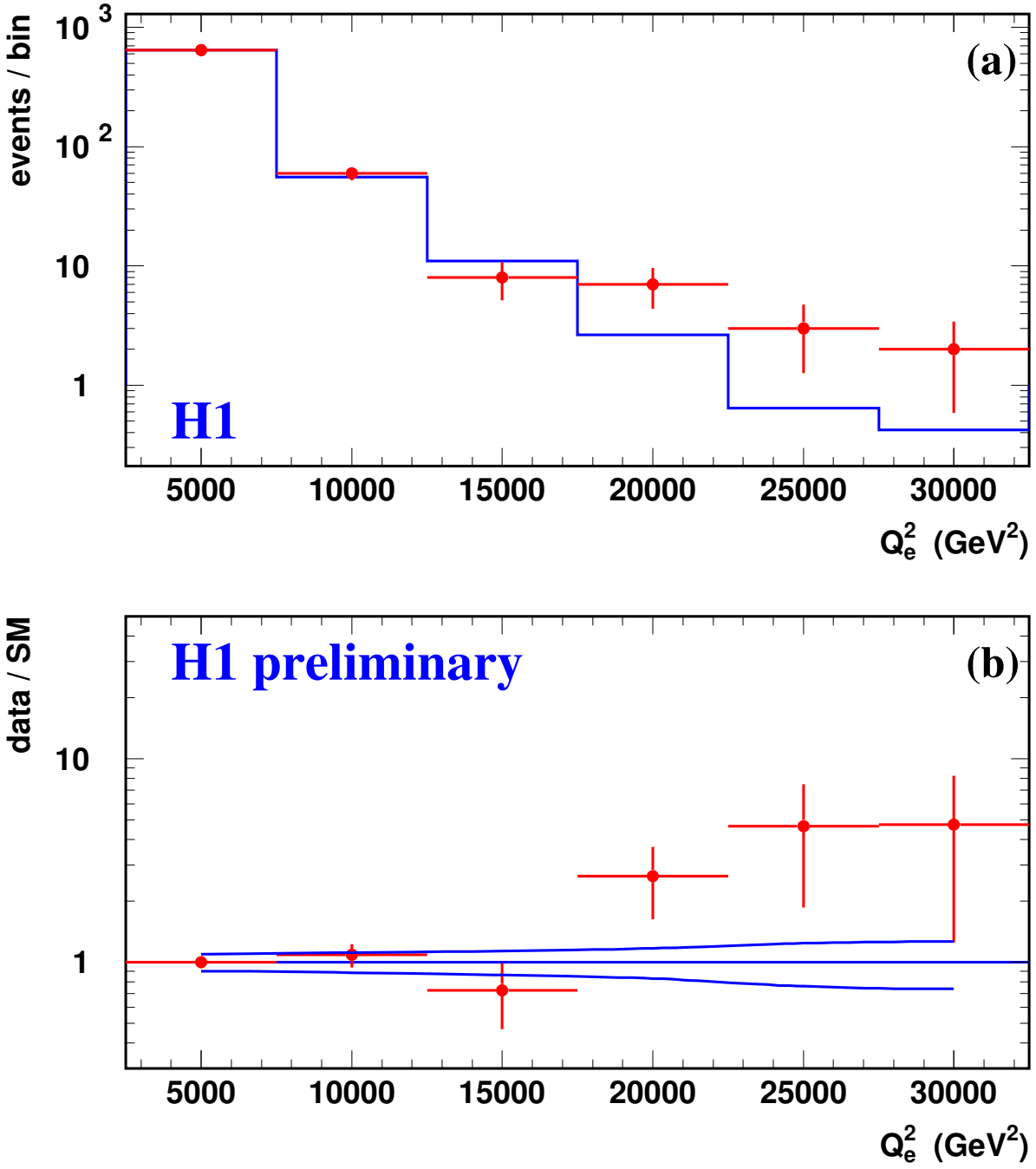
ZEUS NC 1994-1997 $L = 33.5\ \mathrm{pb}^{-1}$

Event distribution in x and y



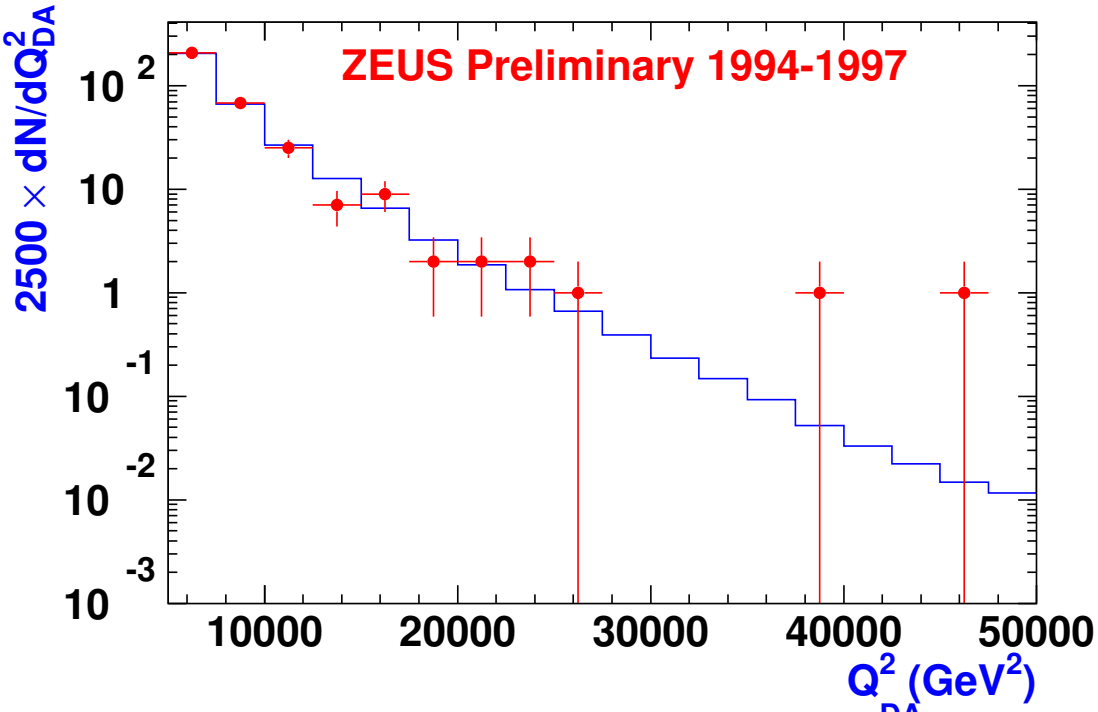
H1 NC 1994-1997 $L = 23.7\ \mathrm{pb}^{-1}$

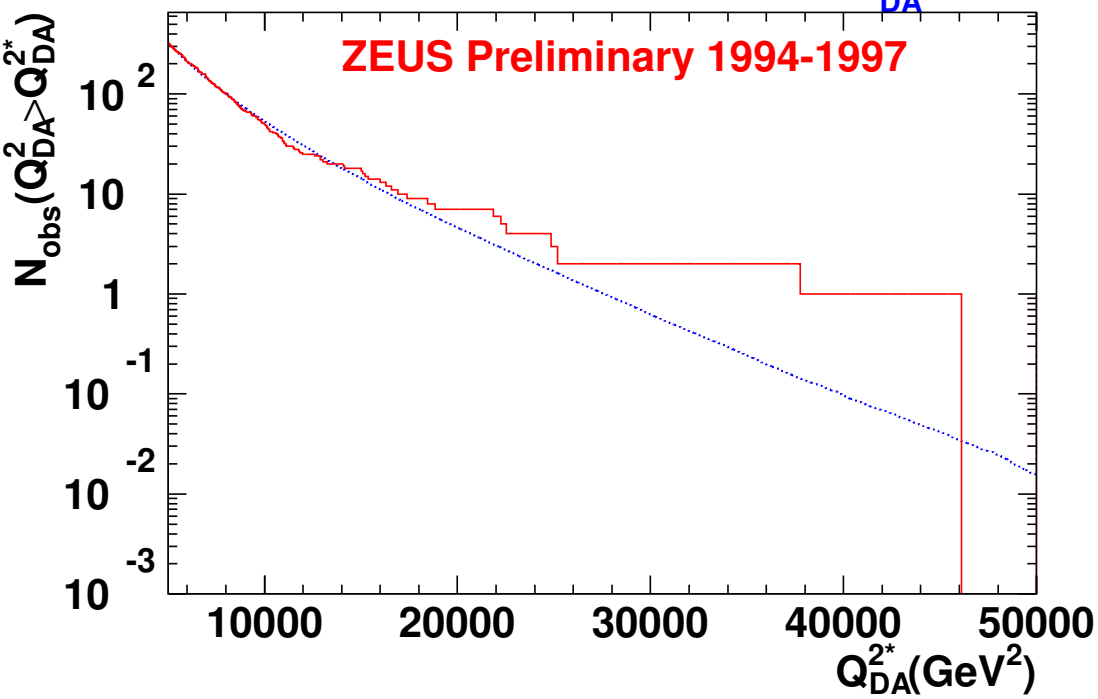
Event distribution in Q^2



ZEUS NC 1994-1997 $L = 33.5\ \mathrm{pb}^{-1}$

Event distribution in Q^2





NC Events : Summary '94-'97

H1

Q^2 cut (GeV^2)	N(obs)	N(exp)
> 2500	724	714.1 ± 69.0
> 5000	193	193.9 ± 20.7
> 10000	31	31.0 ± 3.9
> 15000	18	8.00 ± 1.16
> 20000	7	2.28 ± .38
> 30000	2	.40 ± .14

ZEUS

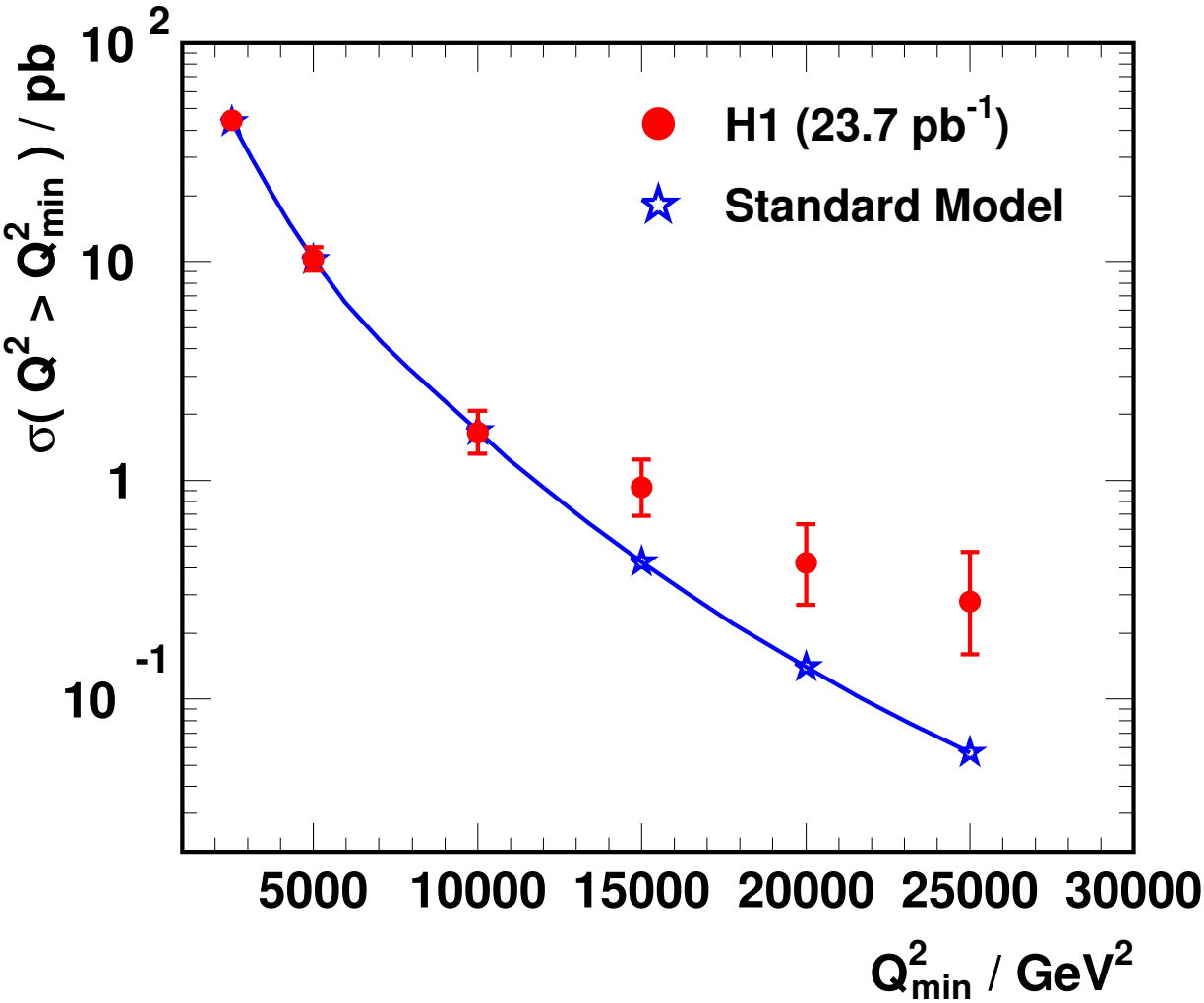
Q^2 cut (GeV^2)	N(obs)	N(exp)
> 5000	326	328 ± 15
> 20000	7	4.60 ± .38
> 35000	2	.242 ± .017

H1 and ZEUS combined

Q^2 cut (GeV^2)	N(obs)	N(exp)	$P(N>\text{N(obs)})$
> 20000	14	6.88 ± .53	0.013

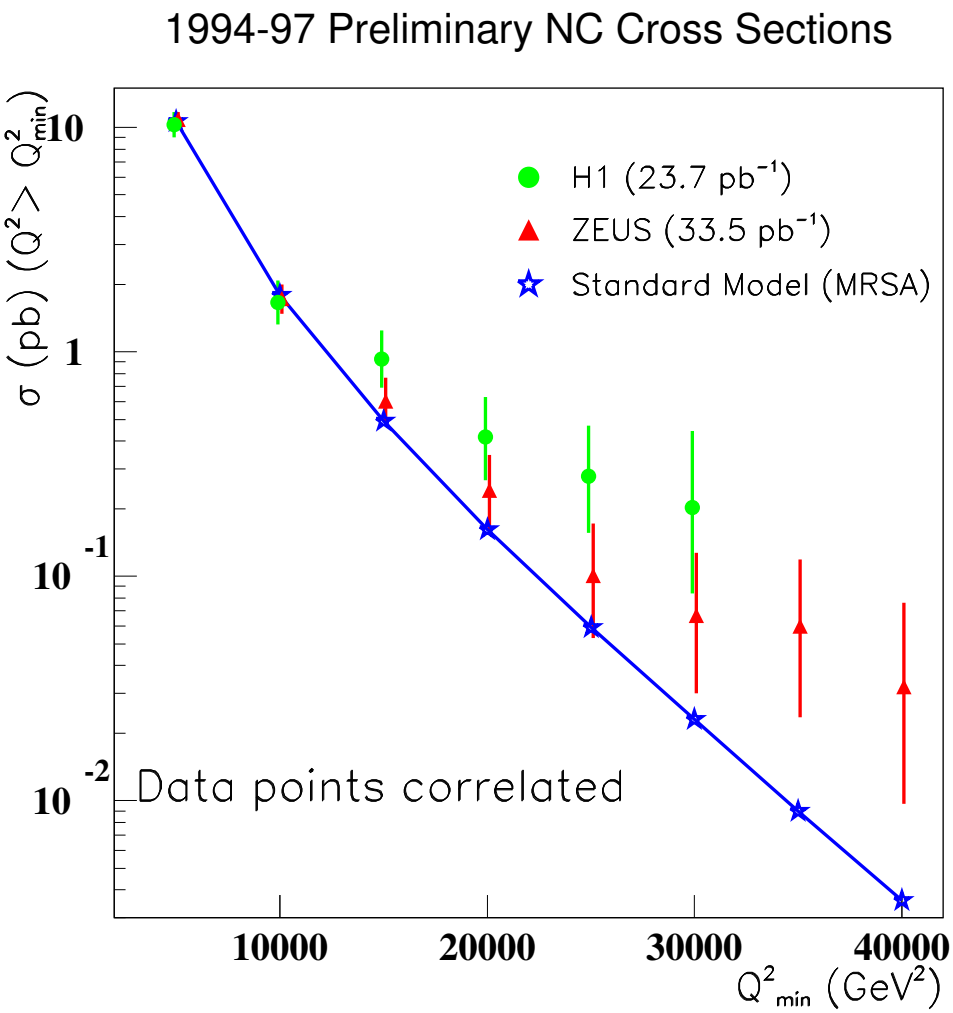
Comparison of H1 Cross Section to Standard Model

Cross sections for $Q^2 > Q^2_{min}$



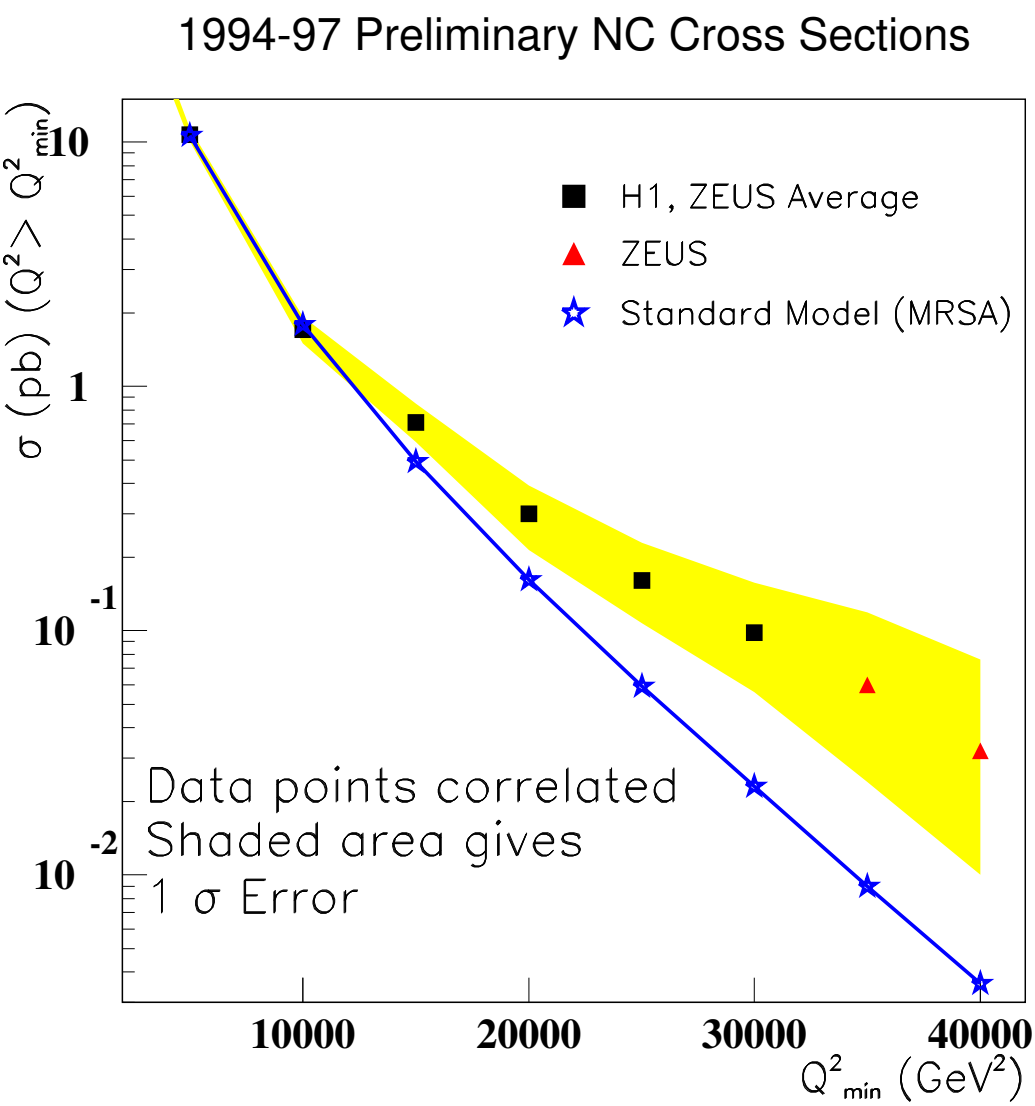
Comparison of ZEUS Cross Section to Standard Model

Cross sections for $Q^2 > Q^2_{min}$



Combined H1and ZEUS Cross Sections compared to Standard Model

Cross sections for $Q^2 > Q^2_{min}$



Preliminary NC Cross Sections

cross sections for $Q^2 > Q^2_{min}$

Q^2_{min} (GeV^2)	H1 Nobs	H1 σ(pb)	ZEUS Nobs	ZEUS σ(pb)
2500	724	$43.3^{+4.6}_{-3.9}$		
5000	193	$10.3^{+1.4}_{-1.2}$	326	$10.9^{+0.8}_{-0.8}$
10000	31	$1.66^{+0.42}_{-0.33}$	50	$1.73^{+0.28}_{-0.25}$
15000	18	$0.93^{+0.32}_{-0.24}$	18	$0.60^{+0.16}_{-0.14}$
20000	7	$0.42^{+0.21}_{-0.15}$	7	$0.24^{+0.11}_{-0.08}$
25000	4	$0.28^{+0.19}_{-0.12}$	3	$0.10^{+0.07}_{-0.05}$
30000	2	$0.21^{+0.24}_{-0.12}$	2	$0.067^{+0.060}_{-0.037}$

Combined H1/ZEUS NC Cross Sections

Q^2_{min} (GeV^2)	H1+ZEUS σ(pb)	SM σ(pb)
2500		43.7
5000	$10.7\ ^{+0.7}_{-0.7}$	10.6
10000	$1.70\ ^{+0.23}_{-0.20}$	1.79
15000	$0.71\ ^{+0.14}_{-0.12}$	0.49
20000	$0.30\ ^{+0.092}_{-0.076}$	0.161
25000	$0.16\ ^{+0.069}_{-0.053}$	0.059
30000	$0.098\ ^{+0.059}_{-0.042}$	0.023

Cross Sections for $Q^2 > Q^2_{min}$

Conclusions High Q^2 Events

- Preliminary results from H1 and ZEUS at HERA on Events with very large Q^2 for NC and CC.
  For $Q^2 < 10000$ GeV^2 Standard Model gives an excellent description of the data

- Charged Current (CC: $e^+ p \rightarrow \bar{\nu} X$)

  For $Q^2 > 10000$ GeV^2 tendency of the data to be somewhat above Standard Model expectations:
  H1 and ZEUS observe in this region
  → 28 events, where 17.7 $\pm$ 4.3 are expected
  $P(N>N_{obs}) = 6$ % from SM

- Neutral Current (NC: $e^+ p \rightarrow e^+ X$)

  also here tendency of the data to be above SM expectations for $Q^2 > 15000$ GeV^2 :
  Above $Q^2 > 20000$ GeV^2 , H1 and ZEUS observe
  → 14 events, where 6.88 $\pm$ 0.53 are expected
  $P(N>N_{obs}) = 1.3$ % from SM

  NC cross sections of both experiments in agreement

Significance of excess in Q^2 has not decreased with the 1997 data