New H1 Results at High Q^2

Ursula Bassler

LPNHE-Paris,
CNRS-IN2P3

On behalf of the

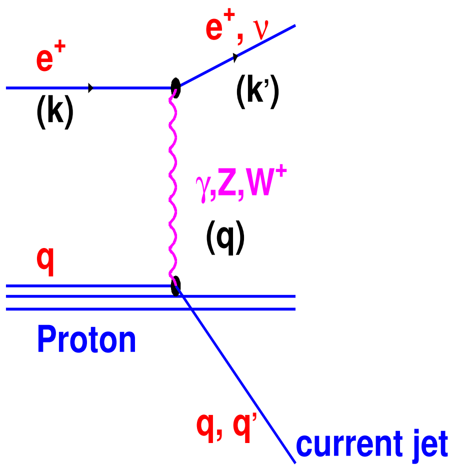
H1 Collaboration

- Introduction to H1 and HERA and High Q^2 Results from 94-96
- New H1 Results at High Q^2 (incl. 97)

EPS-HEP 97, Jerusalem, August 20th, 1997

Introduction

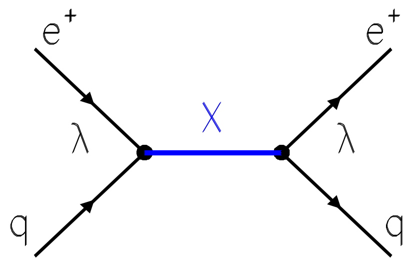
- Probe the proton at very small distances ($\geq 10^{-16}$m) via t-channel exchange of virtual gauge bosons



$$Q^2 = -(k-k')^2 = sxy$$
$$x = \frac{Q^2}{2(P.q)}$$
$$y = \frac{(P.q)}{(P.k)}$$
$$M = \sqrt{sx}$$

$\Rightarrow$ proton SF's, pQCD tests, jets, EW propagators

- Search for s-channel production of new particles with Yukawa couplings to e-q system



$M_X \leq 300$GeV

e.g. leptoquarks

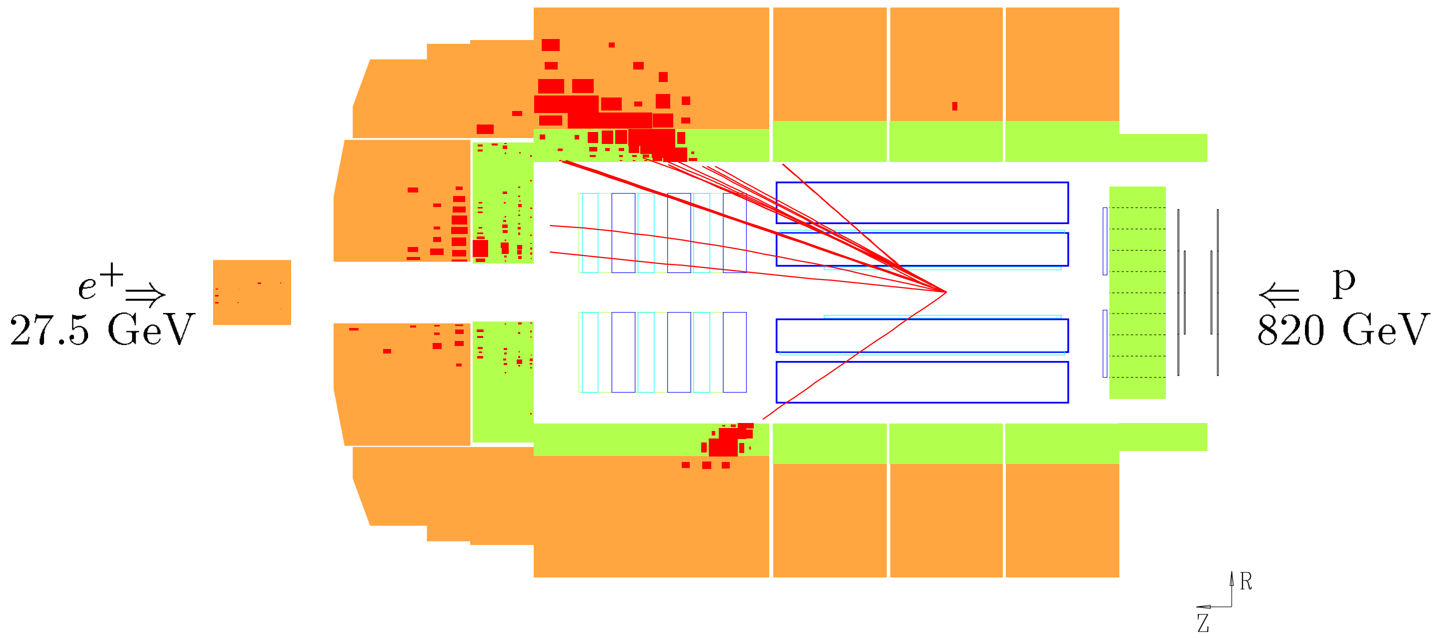
leptogluons

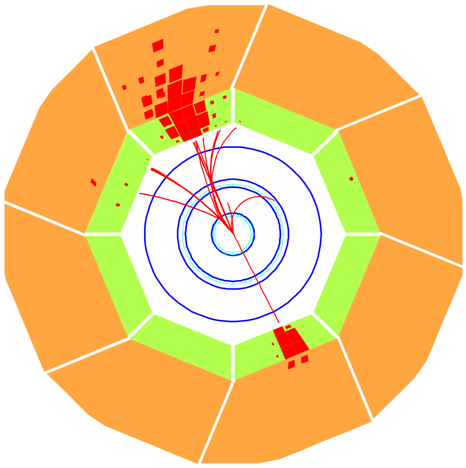
$\not{R}_p$ squarks

- Search for new t- or u-channel boson exchange or contact interactions for $M \gg \sqrt{s}$

NC DIS Event

$\boldsymbol{Q^2 = 16950\ \mathrm{GeV}^2, \quad y = 0.44, \quad M = 196\ \mathrm{GeV}}$





Liquid Argon Calorimeter:

44000 Cells

$\sigma(E)/E(em) \simeq 12\%/\sqrt{E/\mathrm{GeV}} \oplus 1\%$

$\sigma(E)/E(had) \simeq 50\%/\sqrt{E/\mathrm{GeV}} \oplus 2\%$

$\Delta E/E_{em} = 3\%$

$\Delta E/E_{had} = 4\%$

$\Delta\theta_e = 2 - 5$ mrad

measured quantities:

e^+: energy E

polar angle θ

hadrons: $\Sigma = \sum_{hadrons}(E_h - p_{z,h})$

$\tan\gamma/2 = \Sigma/p_{t,h}$

Kinematic Reconstruction

- measured quantities:
  - e^+: energy E'_e polar angle θ_e
  - hadrons: $\Sigma = \sum_{hadrons}(E_h - p_{z,h})$ $\tan\gamma/2 = \Sigma/p_{t,h}$
- Electron Method: $y_e = 1 - \frac{E'_e}{E_e}\sin^2\frac{\theta_e}{2}$ $Q^2_e = 4E'_e E_e \cos^2\frac{\theta_e}{2}$
  - most precise at high y / low x
  - degrades severly at low y
- Hadron Method: $y_h = \frac{\Sigma}{2E_e}$ $Q^2_h = \frac{p^2_{t,h}}{1-y_h}$
  - least precise
  - only method for charged current
- Σ Method: $y_\Sigma = \frac{\Sigma}{\underbrace{\Sigma + E'_e(1-\cos\theta_e)}_{2\cdot \mathrm{E_{Incident\ Electron}}}}$ $Q^2_\Sigma = \frac{E'^2_e \sin^2\theta_e}{1-y_\Sigma}$
  - precise over the whole kinematic range
  - independent of QED initial state radiation
- Double Angle Method:

$$y_{DA} = \frac{\tan\gamma/2}{\tan\gamma/2 + \tan\theta/2} \qquad Q^2_{DA} = 4E^2_e \frac{\tan\theta}{2} \frac{\cot\theta/2}{\tan\gamma/2 + \tan\theta/2}$$

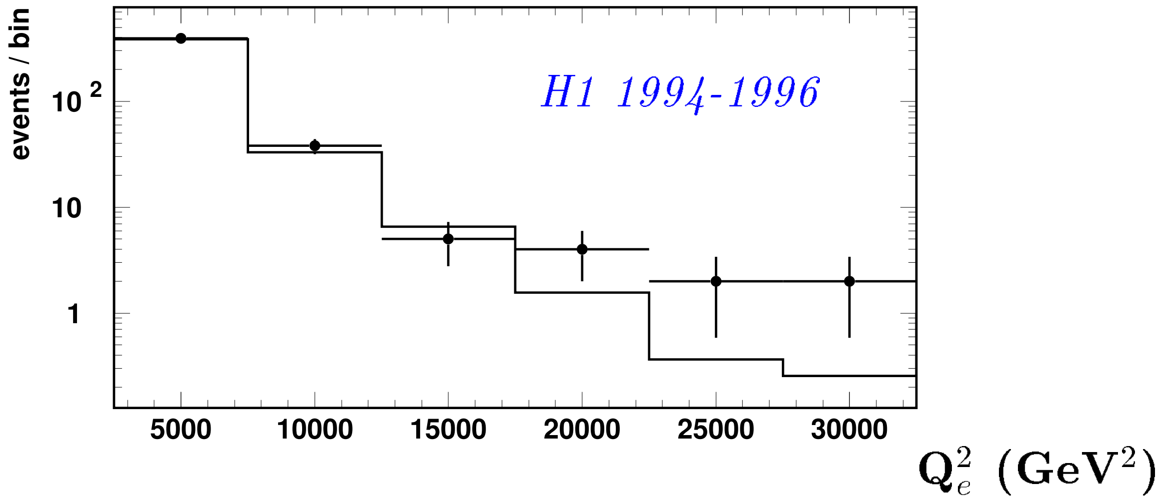
  - high precision at high Q^2, independent of absolut energy scale
  - sensitive to QED radiation

Excess of High Q^2 Events at HERA

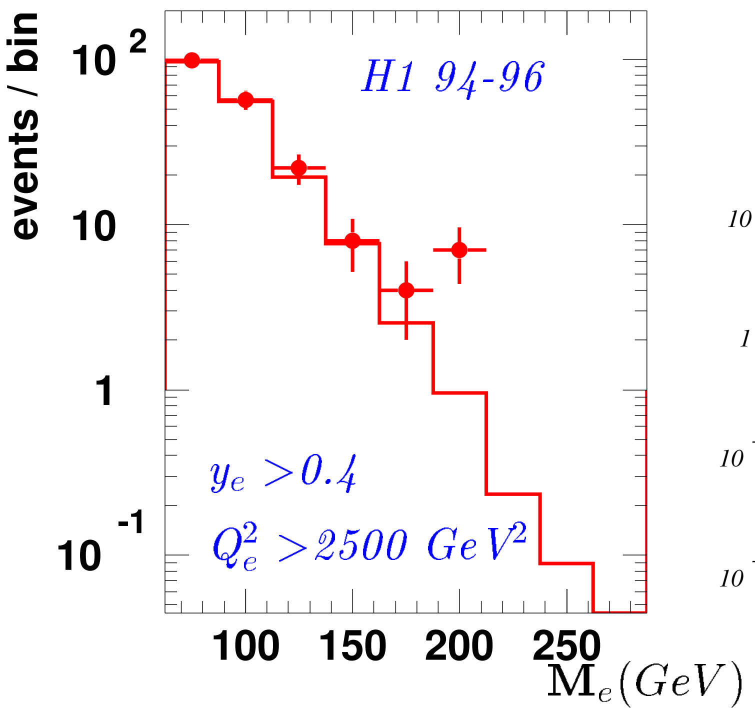
first publications:

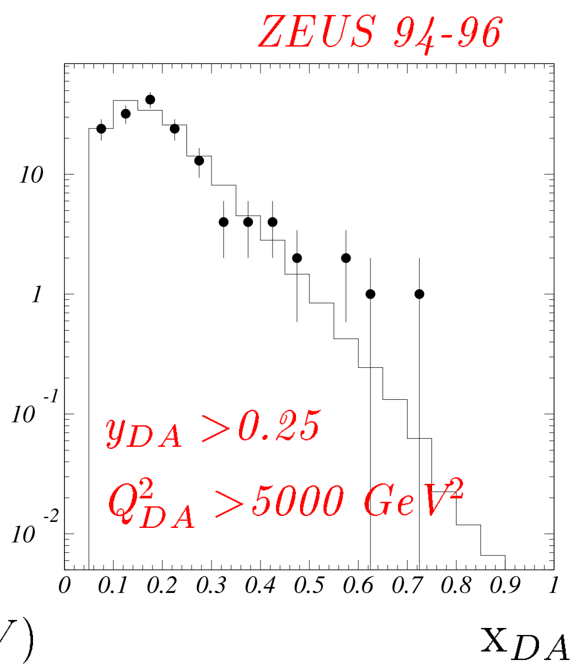
H1: $14.2\ pb^{-1}$ Z.Phys **C74** (1997) 191

ZEUS: $20.1\ pb^{-1}$ Z.Phys **C74** (1997) 207



$Q_e^2 > 15000\ \mathrm{GeV}^2$: N_{obs}=12 $\Leftrightarrow$ N_{exp}=4.71, $\mathcal{P} = 6 \times 10^{-3}$





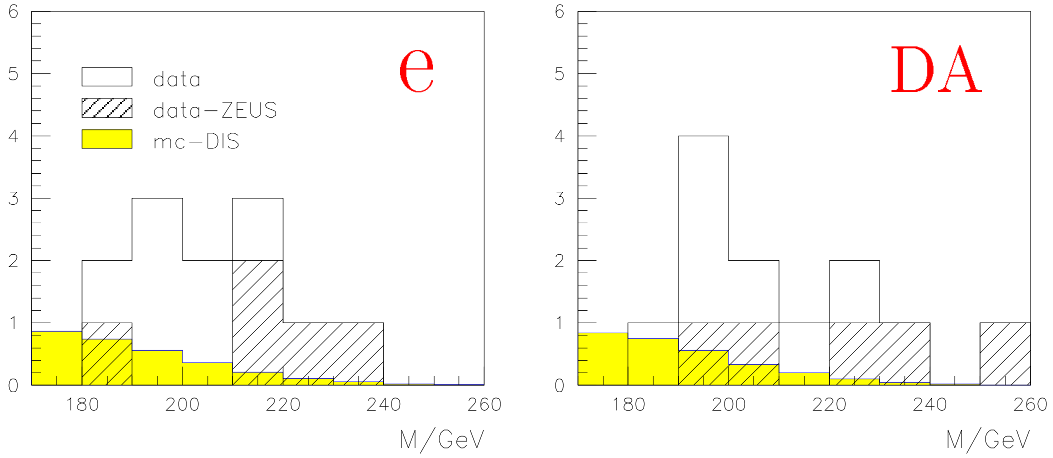
M_e=200$\pm$12.5 GeV $y_e > 0.4$: N_{obs}=7 $\Leftrightarrow$ N_{exp}=0.95

$x_{DA} > 0.55$ $y_{DA} > 0.25$: N_{obs}=4 $\Leftrightarrow$ N_{exp}=0.91

Are ZEUS and H1 compatible in mass?

Comparison of Mass Distributions H1 - ZEUS

selection: $Q^2_\omega > 15000$ GeV^2; $M_\omega > 180$ GeV



different reconstruction methods:

- different biases from systematic effects
- different behaviour for initial state QED radiation

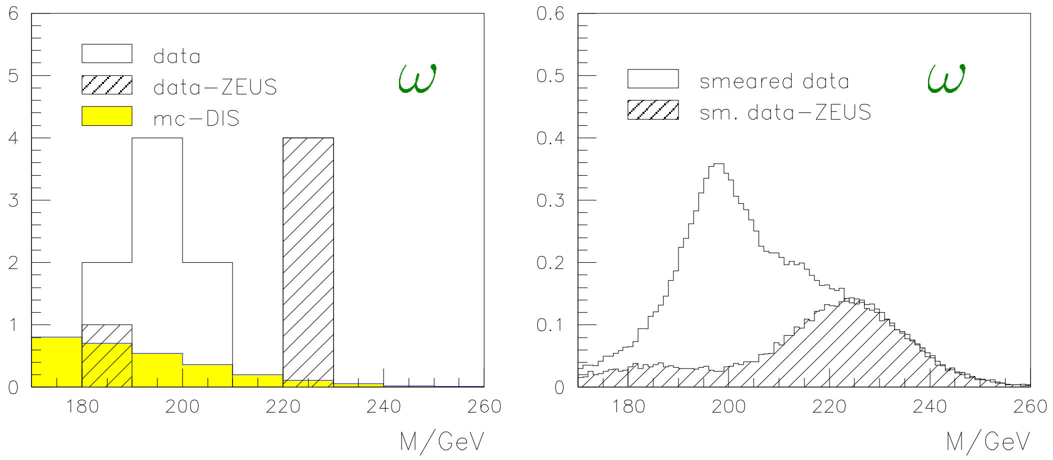
$\Rightarrow$ Comparison with the ω-method

U.Bassler, G.Bernardi DESY-97-136 / Z.Phys.C

- determination of kinematics and errors on event by event basis:

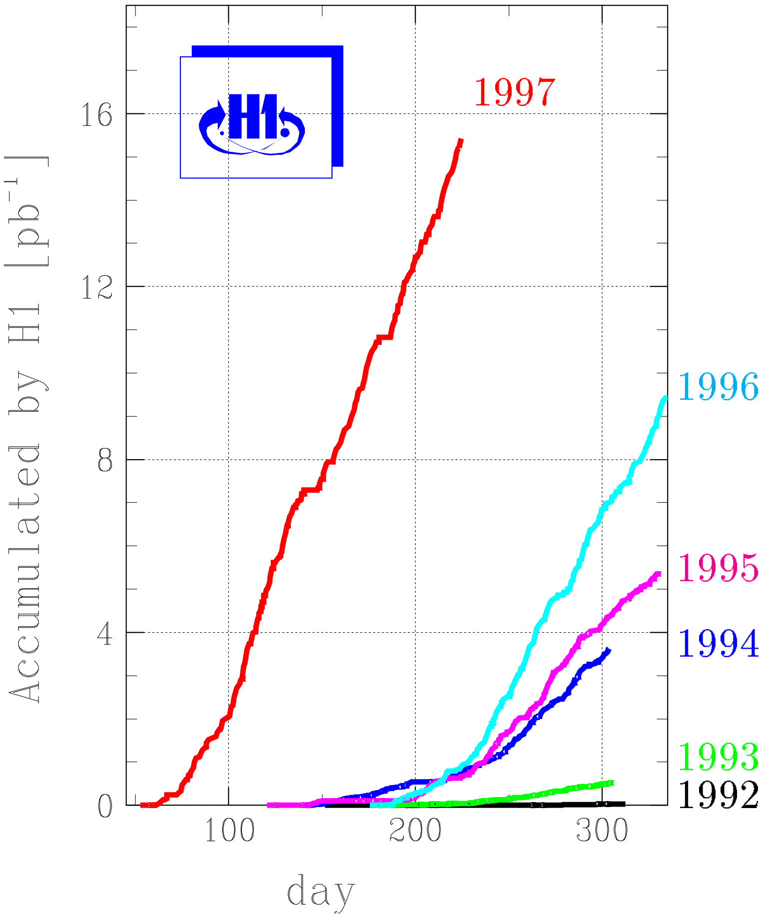
$$(1 - y_e)\frac{\delta E}{E} + y_h \frac{\delta \Sigma}{\Sigma} = y_e - y_h$$
$$-p_{T,e}\frac{\delta E}{E} + p_{T,h}\frac{\delta \Sigma}{\Sigma} = p_{T,e} - p_{T,h}$$

- identification/correction of radiative events



Datasets do not suggest single narrow resonance !

New Results of H1 at High Q^2



- Structure Functions at High Q^2
- Events at Very High Q^2 in CC and NC
- Events with isolated leptons

Structure Functions at High Q^2

kinematic domain: $150\ \mathrm{GeV}^2 \leq \mathrm{Q}^2 \leq 5000\ \mathrm{GeV}^2$
$0.003 \leq x \leq 0.32$

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+F_2(x,Q^2) - y^2F_L(x,Q^2) - Y_-xF_3(x,Q^2)\right]$$

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

F_2, F_3: generalized structure functions

F_L: longitudinal structure function

$$F_2 = F_2^{em} + \frac{Q^2}{Q^2+M_Z^2}F_2^{int} + \frac{Q^4}{(Q^2+M_Z^2)^2}F_2^{wk} = F_2^{em}(1+\delta_Z)$$

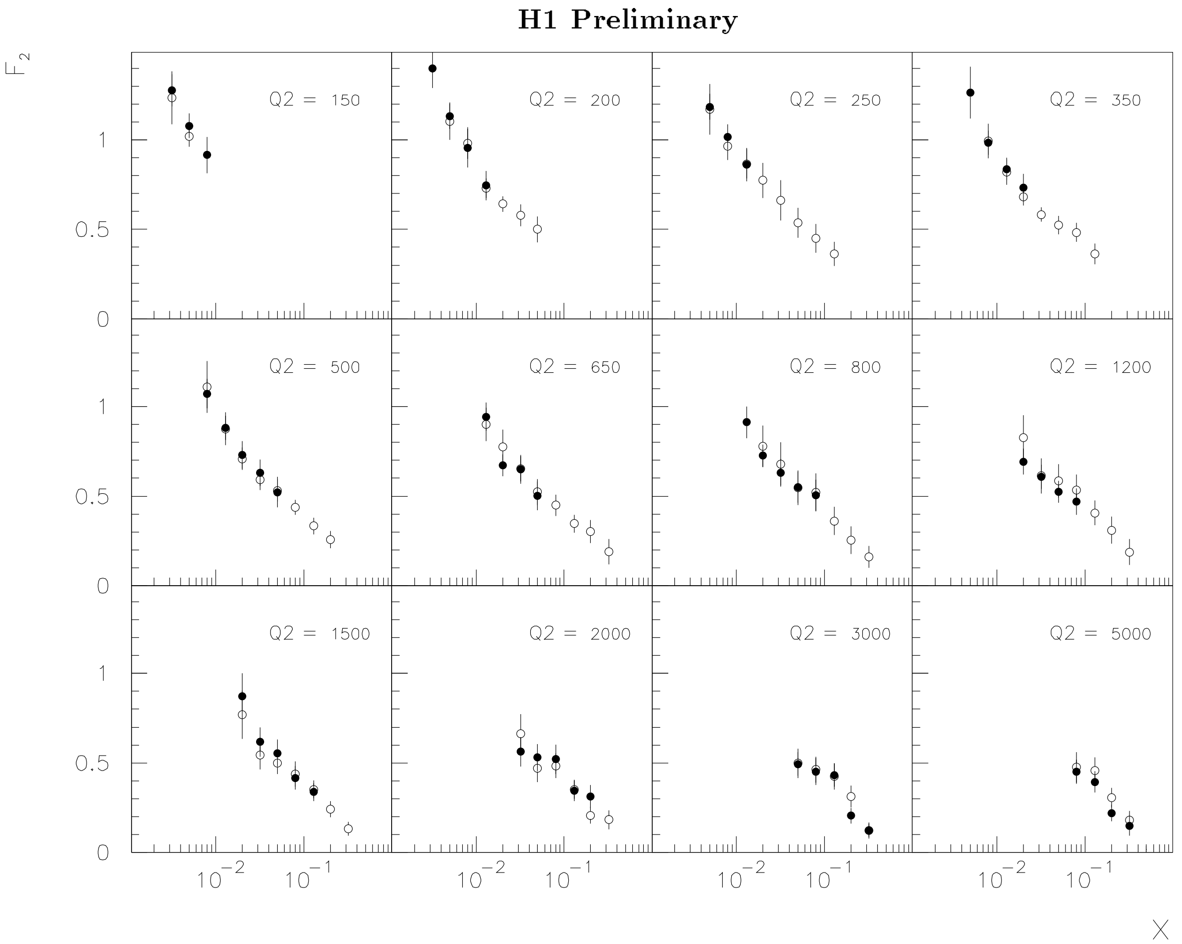
F_2^{em}: photon exchange
F_2^{wk}: Z° exchange
F_2^{int}: γZ° interference

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2Y_+}{xQ^4}F_2^{em}(1+\delta_Z-\delta_3-\delta_L)$$

$\delta_Z - \delta_3$: $< 1\%$ at $\mathrm{Q}^2 < 1500\ \mathrm{GeV}^2$
$\approx 10\%$ at $\mathrm{Q}^2 = 5000\ \mathrm{GeV}^2$ and x=0.08
δ_L: negligible at $y < 0.5$
$\approx 5\%$ at $y = 0.9$

F_2 at High Q^2

F_2 measurement on 95-96-97 datasets with $\mathcal{L} = 22pb^{-1}$



Comparison between e-method ($\bullet$) and Σ method ($\circ$):

- difference in systematic effects, e.g. calibration
- difference in rad. corrections

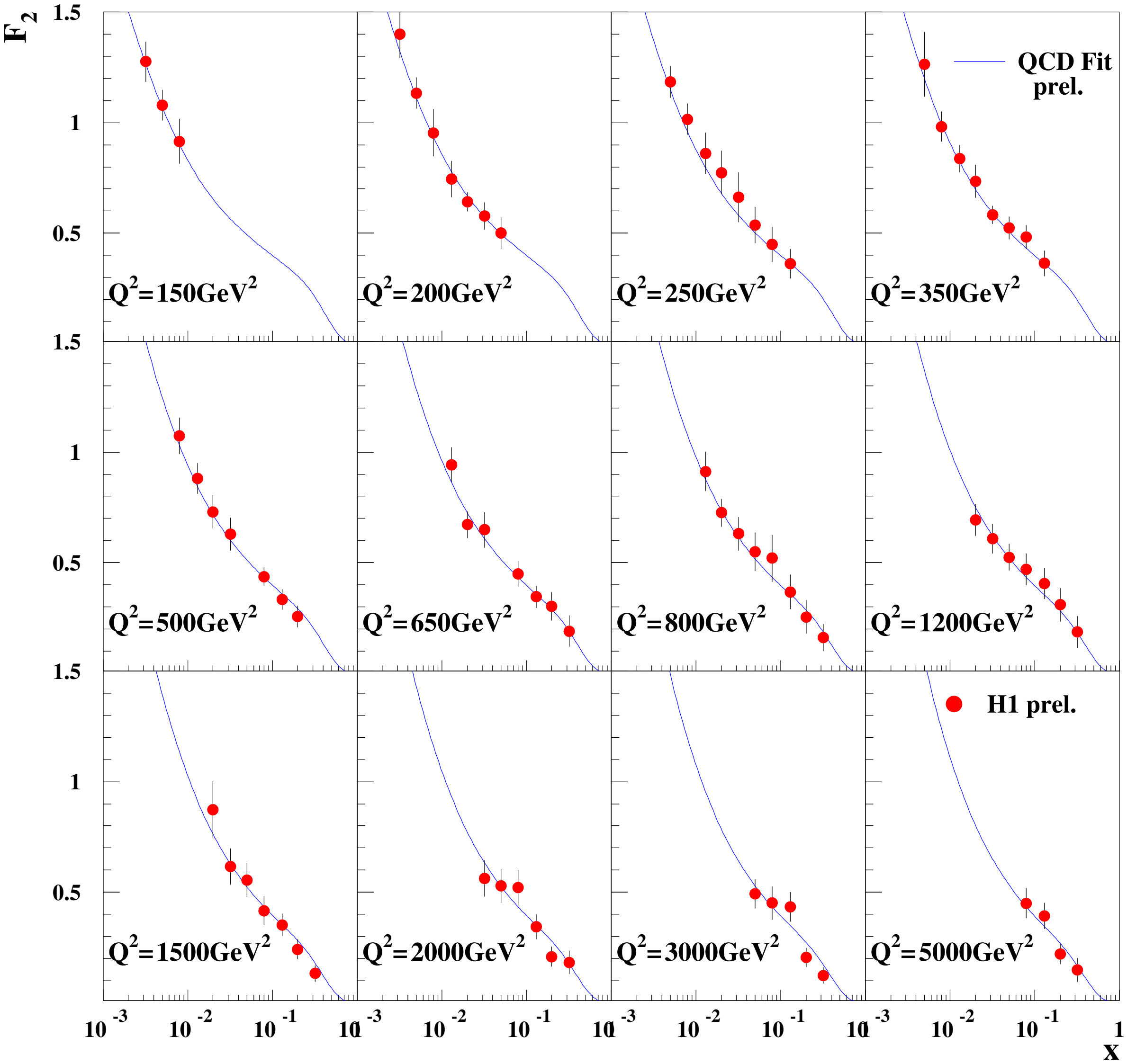
$\Rightarrow$ Powerful check of Result

$\Rightarrow$ Conservative estimate of syst. errors

$\Rightarrow$ Good agreement with 94 measurement

F_2 at High Q^2 - NLO QCD-fit

Final Result: e-method at $y > 0.15$
Σ method at $y < 0.15$



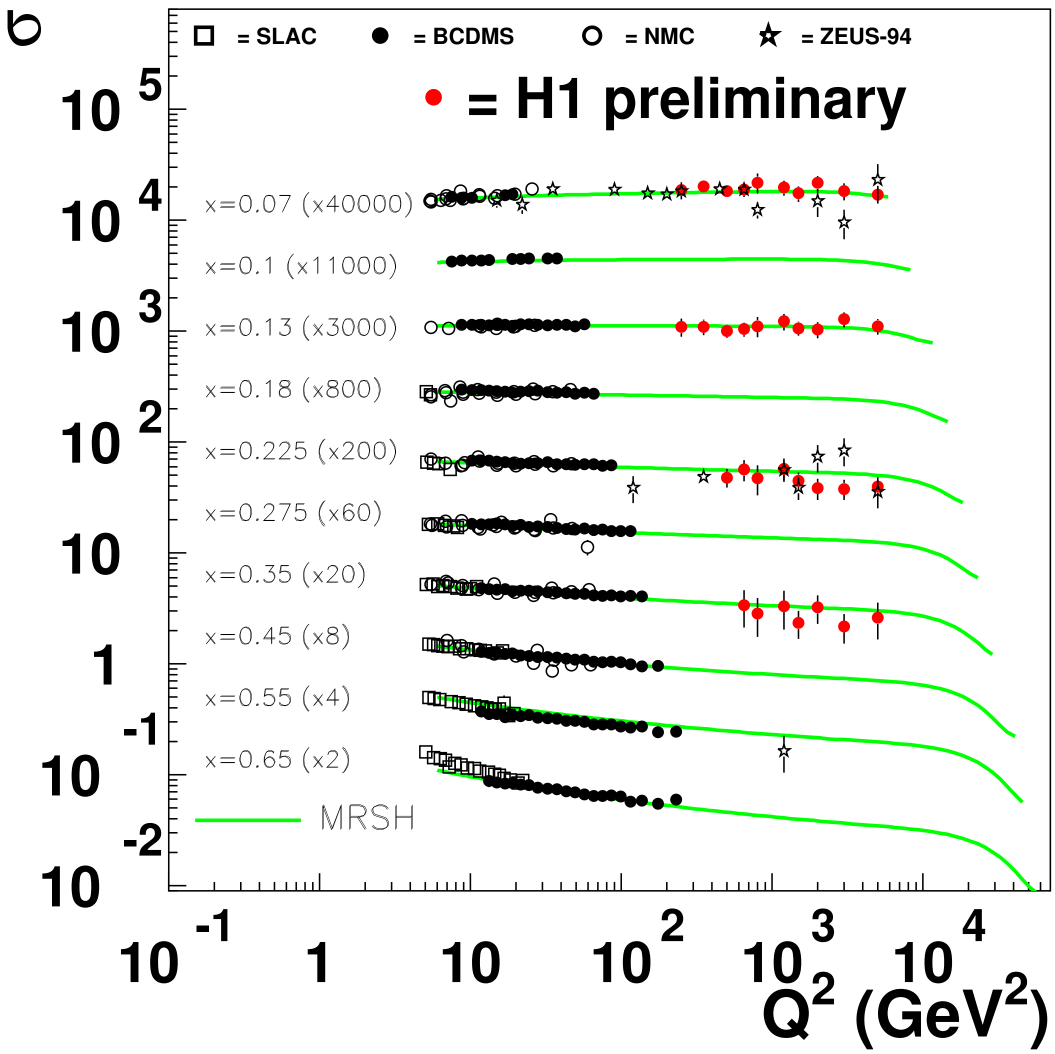
NLO QCD-fit on 94-96 H1 low Q^2 data ($Q^2 \leq 120$ GeV^2), NMC and BCDMS data, as described in EPS-HEP 260

but without HERA high Q^2 94 data

$\Rightarrow$ good agreement with the DGLAP evolution of the QCD fit at high Q^2

$\mathrm{d}\boldsymbol{\sigma}/\mathrm{d}\boldsymbol{x}\mathrm{d}\boldsymbol{Q}^2$ at High $\boldsymbol{Q}^2$

reduced cross section: $\sigma(e^+p) = \frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\mathrm{d}Q^2}$



QCD evolution well constrained by

- low Q^2 fixed target data
- high Q^2 HERA data

Very High Q^2: Event Selection

same selection as for 94-96 sample

Neutral Current Selection

- electron identification:
  - shower shape test in calorimeter
  - isolation in $\eta - \phi$ cone $(R < 0.25)$
  - track matching the calorimeter cluster
- $\boxed{E_{T,e} > 25\mathrm{GeV}}$ $\boxed{\Theta_e > 10^o}$
- $\boxed{0.1 < y_e < 0.9}$ $\boxed{Q_e^2 > 2500\mathrm{GeV}^2}$
- momentum balance
  - transverse: $P_{T,miss}/\sqrt{E_T} < 3\sqrt{GeV}$
  - longitudinal: $43 < \sum E - P_z < 63\mathrm{GeV}$
    $2E_e^o = 55\mathrm{GeV}$ expected
    cuts events with initial state radiation

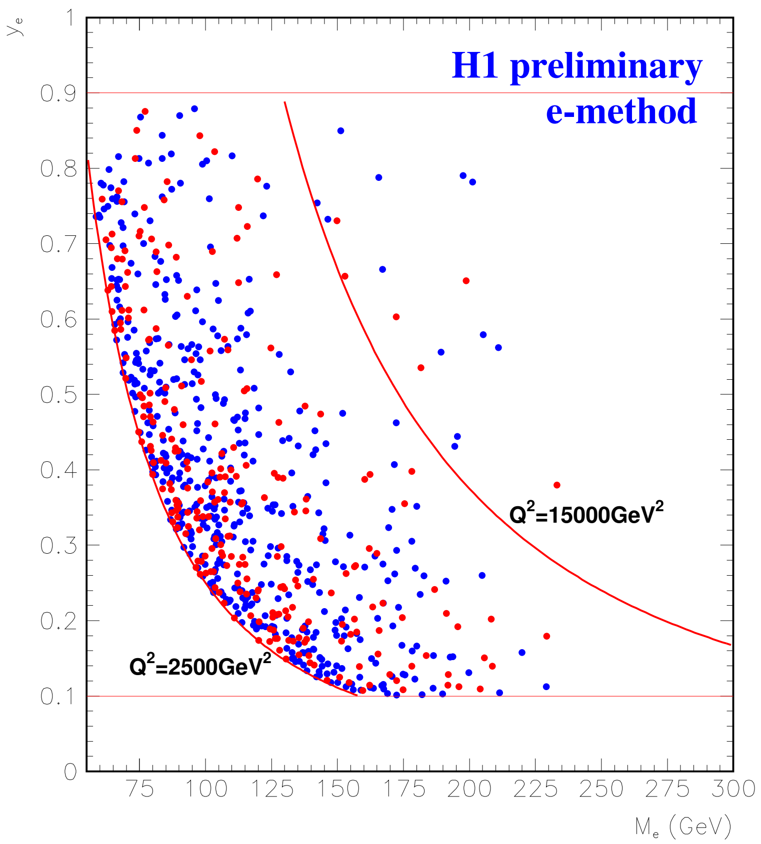
Charged Current Selection

- $\boxed{P_{T,miss} > 50\mathrm{GeV}}$
- $\frac{E_T - P_{T,h}}{E_T} < 0.5$

Remaining Background

- $< 0.1\%$ on full NC sample
- dominating source: photoproduction of jet-jet events

NC Data Sample in the $\boldsymbol{M}$-$\boldsymbol{y}$ Plane



● 1994-96 Data ● 1997 Data

$$0.1 < y_e < 0.9 \qquad \mathcal{L} = 23.69 \pm 0.35 \text{ pb}^{-1}$$

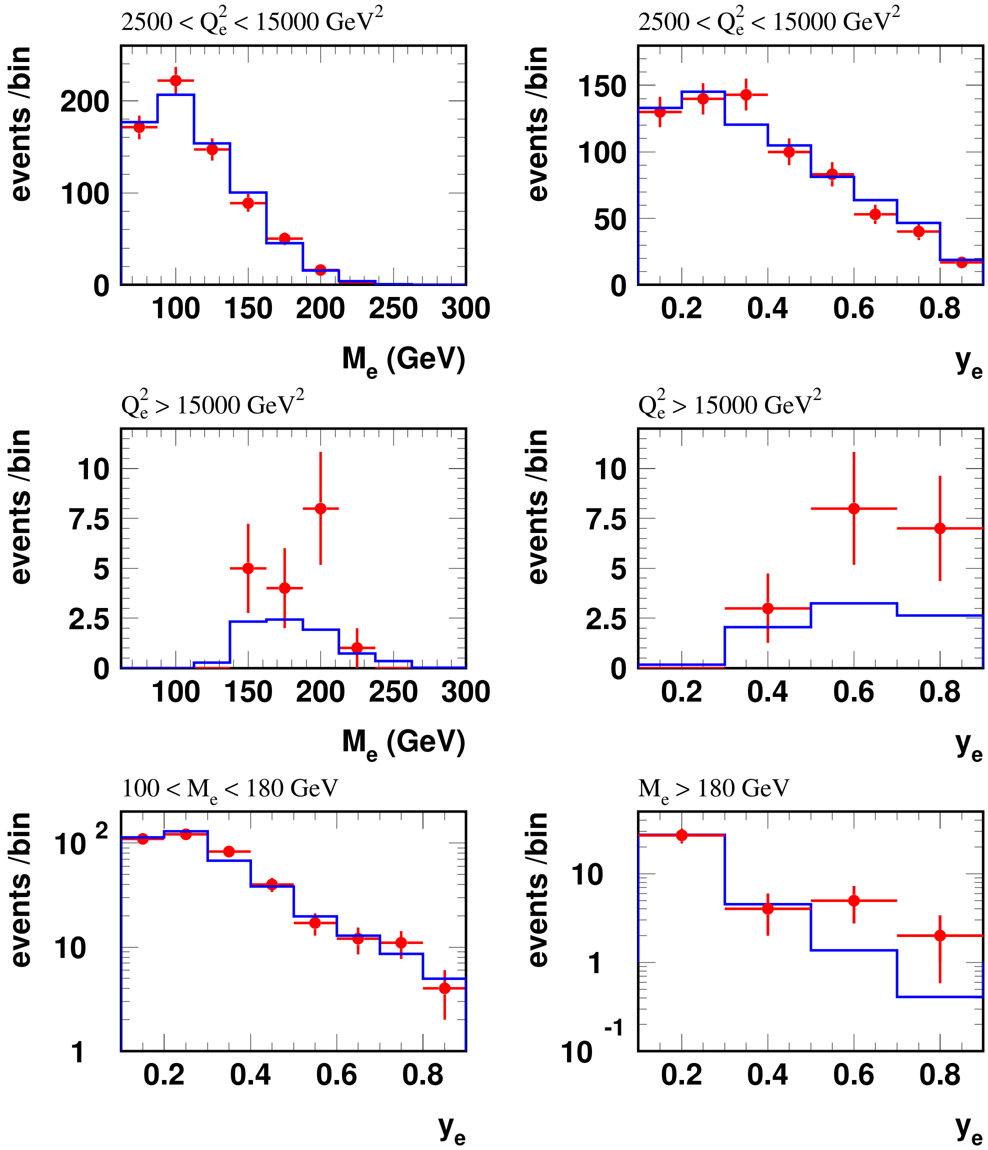
$$Q_e^2 > 2500\text{GeV}^2\text{: Obs. } = 724 \;\Leftrightarrow\; \text{Exp. } = 714 \pm 69$$

$$Q_e^2 > 15000\text{GeV}^2\text{: Obs. } = 18 \;\Leftrightarrow\; \text{Exp. } = 8.0 \pm 1.2$$

Notes : NC DIS yield given after simulation and event selection;
Kinematics directly from reconstructed electron;
Efficiency from geometrical acceptance and event selection $\sim 80\%$ for events generated within measured kinematic range.

Basic Kinematic Distributions

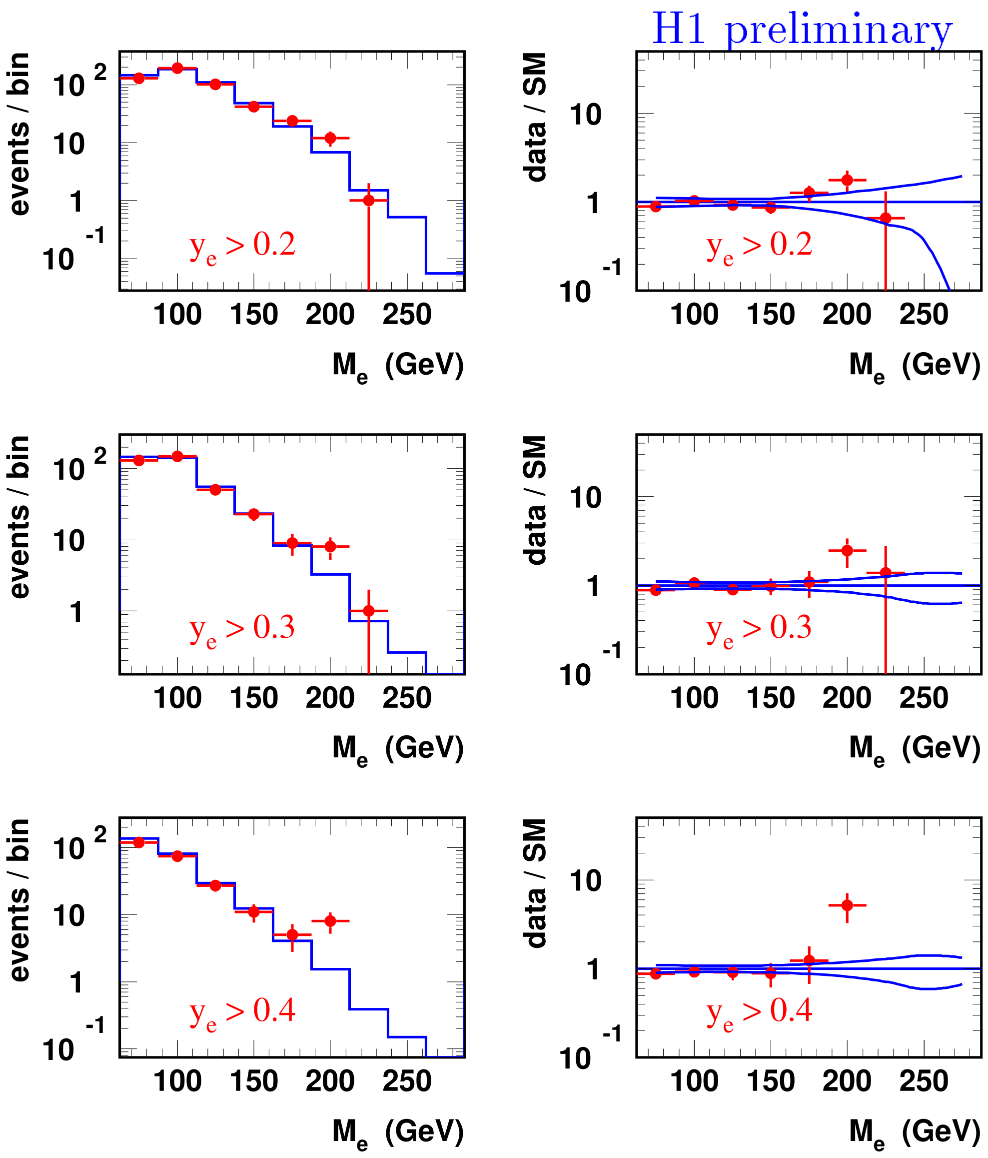
H1 preliminary



The basic observations remain
with the 97 data sample included:

- data exceeds NC DIS expectation at high Q^2 (especially at $M_e \sim 200$GeV);
- at high $M_e \Rightarrow$ difference visible at large y_e.

Mass Dependence



The basic observations remain with 97 data included:

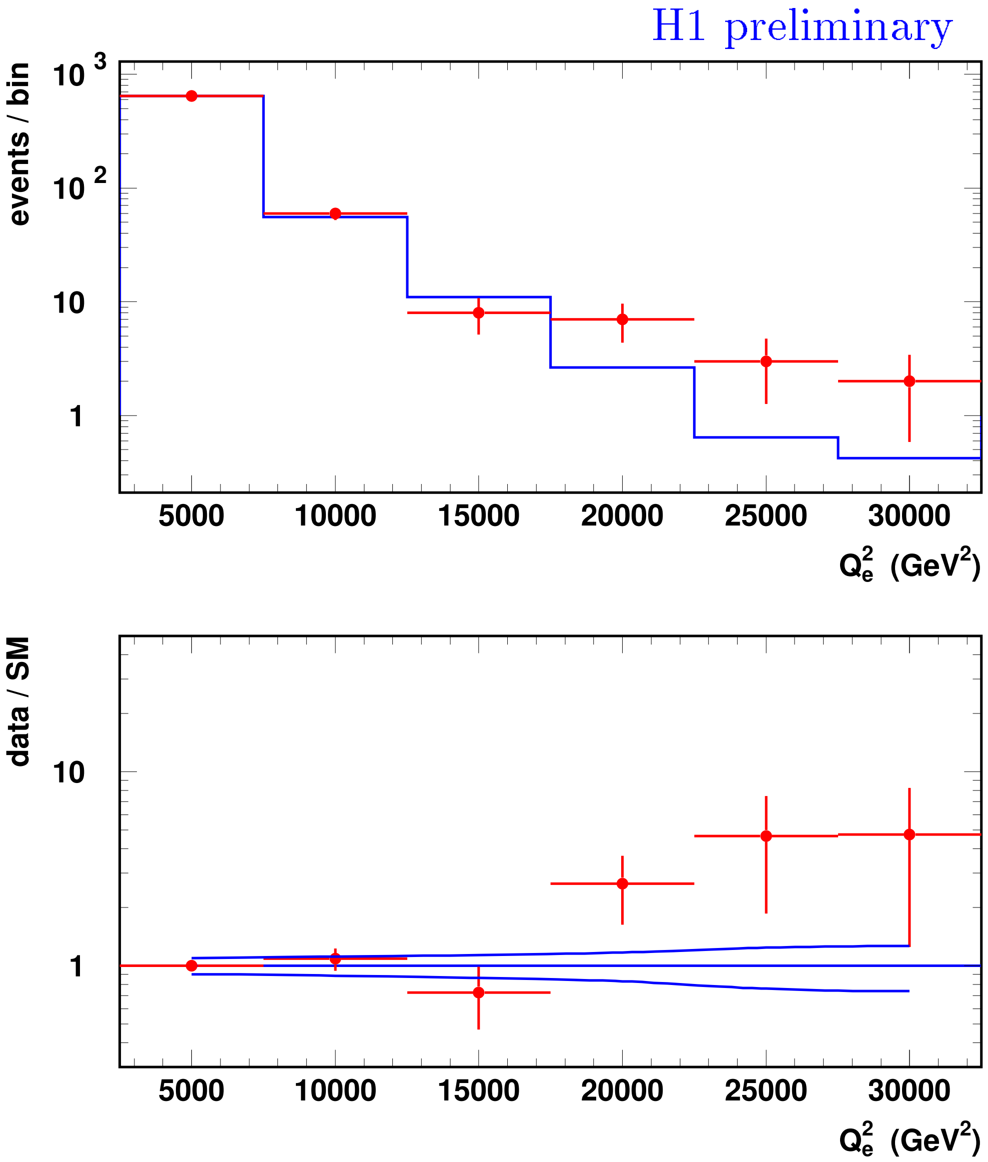
- Excess seen at high mass
- More visible at large y_e

At M_e = 200 GeV ±12.5 GeV and $y_e > 0.4$:

$$\mathrm{N}_{obs} = 8 \Leftrightarrow \mathrm{N}_{exp} = 1.53 \pm 0.29$$

$$\mathcal{P}(N \geq N_{obs}) = 3.3 \times 10^{-4}$$

Q^2 Dependence



Significant excess for Q_e^2 above $\sim 15000\text{GeV}^2$

Note: Errors dominated by uncertainty on e.m. energy scale
$\sim 8.5\%$ at low Q_e^2 $\qquad \sim 30\%$ at highest Q_e^2

Integrated Q^2 Dependence: $Q^2 > Q^2_{min}$

1994 - 1996 Data						
Q^2_{min}/ GeV^2	2500	5000	10000	15000	20000	30000
N_{obs}	443	122	20	12	5	2
N_{DIS}	426.7 $\pm$38.4	116.2 $\pm$11.6	18.3 $\pm$2.4	4.71 $\pm$0.76	1.32 $\pm$0.05	0.23
$\mathcal{P}$	0.35	0.35	0.39	6×10^{-3}	1.4×10^{-2}	2.3×10^{-2}
1994 - 1997 Data H1 preliminary						
Q^2_{min}/ GeV^2	2500	5000	10000	15000	20000	30000
N_{obs}	724	193	31	18	7	2
N_{DIS}	714.1 $\pm$69.0	193.9 $\pm$20.7	31.0 $\pm$3.90	8.00 $\pm$1.16	2.28 $\pm$0.38	0.40 $\pm$0.14
$\mathcal{P}$	0.44	0.51	0.49	3.4×10^{-3}	1.1×10^{-2}	6.6×10^{-2}

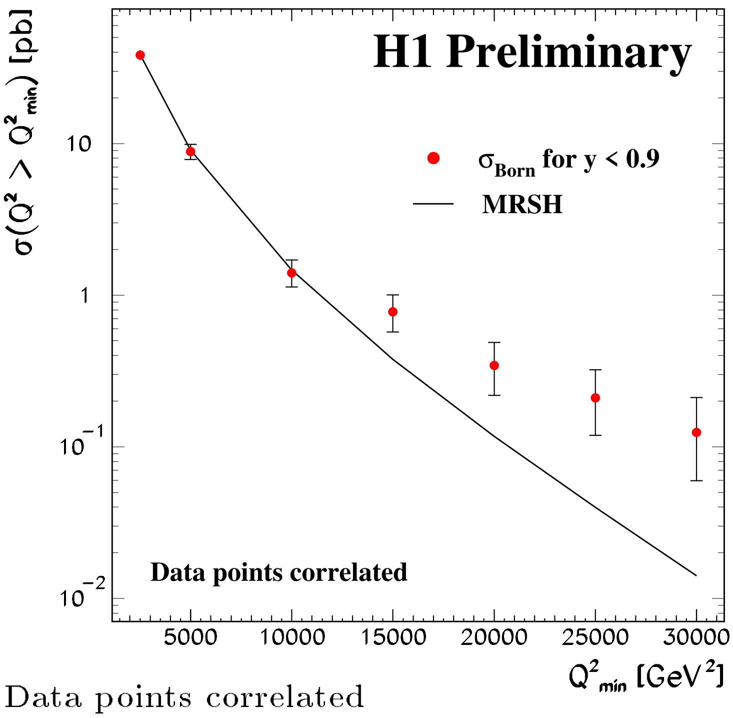
$\mathcal{P} \equiv \mathcal{P}(N \geq N_{obs.})$

- Good agreement up to $Q^2_{min} = 10000 GeV^2$ with NC DIS Standard Model
- The significance of the excess at $Q^2_{min} = 15000$ GeV^2 slightly increases when including the 1997 data.

Integrated Born Cross-Sections for $Q^2 > Q^2_{min}$ and $y < 0.9$

H1 Preliminary

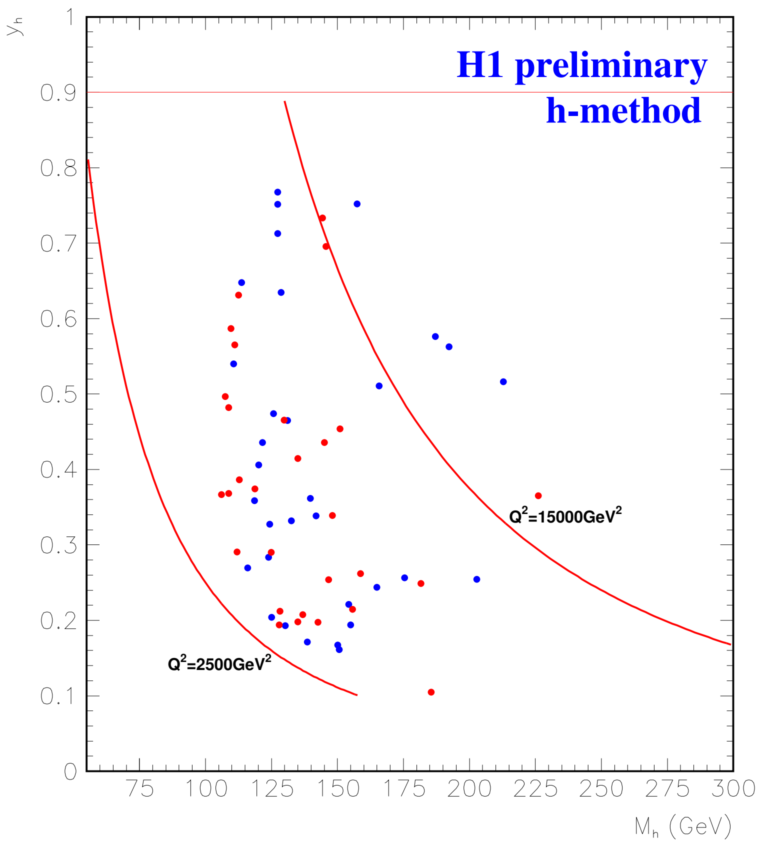
Q^2_{min}	$N_{\rm obs}$	σ_{Born}/pb	σ_{SM}/pb
2500	724	$38.35^{+2.84}_{-2.84}$	38.62
5000	193	$8.86^{+1.02}_{-1.02}$	9.03
10000	31	$1.40^{+0.30}_{-0.27}$	1.49
15000	18	$0.78^{+0.22}_{-0.20}$	0.38
20000	7	$0.343^{+0.146}_{-0.125}$	0.117
25000	4	$0.210^{+0.112}_{-0.091}$	0.040
30000	2	$0.124^{+0.087}_{-0.064}$	0.014



Data points correlated

- Error combination assumes Gaussian systematics and Poisson distributed N_{obs}.
- Corrected (assuming NC DIS Standard Model) for migrations due to real QED emission, acceptance and resolution $\rightarrow$ the Q^2 scale $=$ true hard scale from exchanged EW bosons.

CC Data Sample in the $\boldsymbol{M}$-$\boldsymbol{y}$ Plane



• 1994-96 Data • 1997 Data

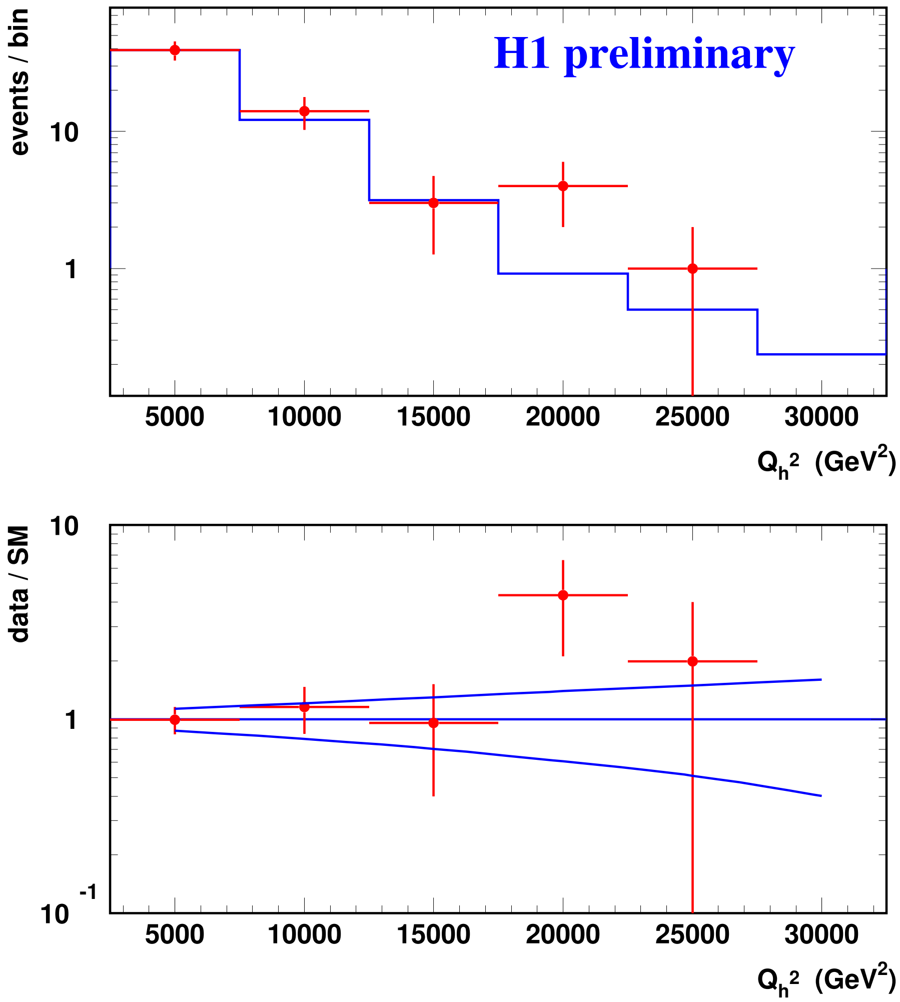
$y_h < 0.9 \quad \mathcal{L} = 23.69 \pm 0.35\ \mathrm{pb}^{-1}$

$Q_h^2 > 2500\mathrm{GeV}^2$: Obs. $= 61 \;\Leftrightarrow\;$ Exp. $= 56.3 \pm 9.4$

$Q_h^2 > 15000\mathrm{GeV}^2$: Obs. $= 6 \;\Leftrightarrow\;$ Exp. $= 2.9 \pm 1.4$

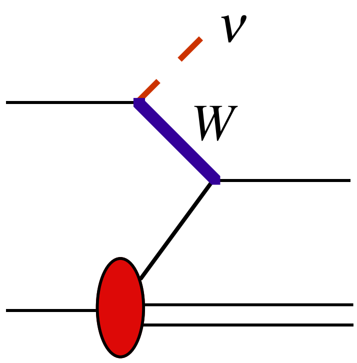
Notes : CC DIS yield given after simulation and event selection;
Kinematics directly from reconstructed hadrons;
Efficiency from geometrical acceptance and event selection $\sim 80\%$ for events generated within measured kinematic range.

Q^2 Dependence

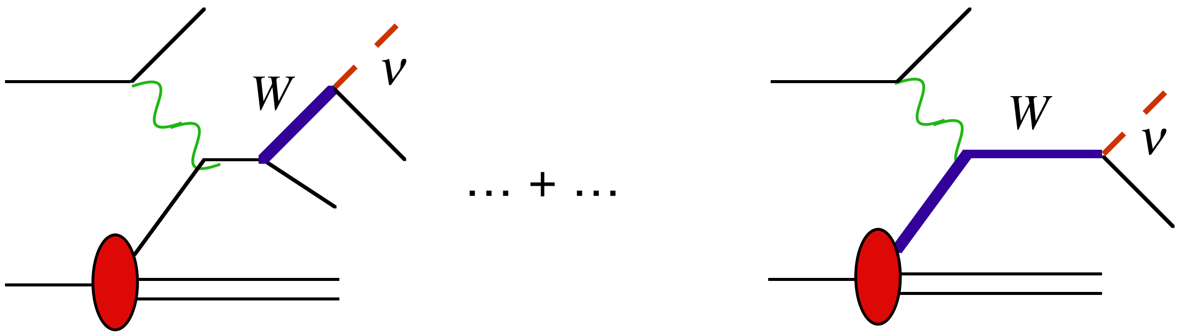


- Good agreement up to $Q^2_{min} = 10000 GeV^2$ with CC DIS Standard Model
  - A slight excess of events is observed at high Q^2_h
  - For $Q^2 > 15000$ GeV^2: $N_{obs} = 6 \Leftrightarrow N_{exp} = 2.9$
    $\Rightarrow \mathcal{P}(N > N_{obs})$ =0.13

Isolated Leptons from W-processes

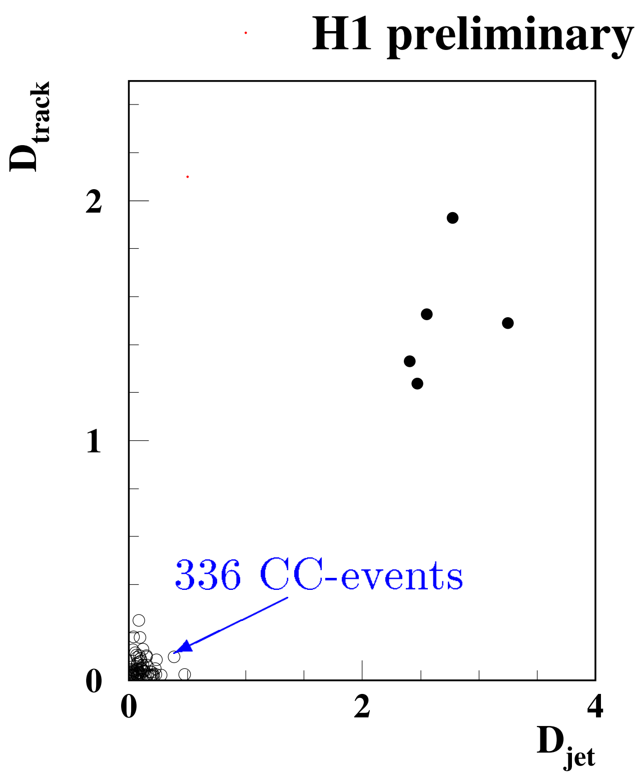


t-channel exchange in CC-Processes:
$\sigma \approx 20$ pb



production of real and virtual W with subsequent leptonic decay
$\sigma \approx 70$ fb

$\Rightarrow$ processes characterized by large missing momentum



selection:

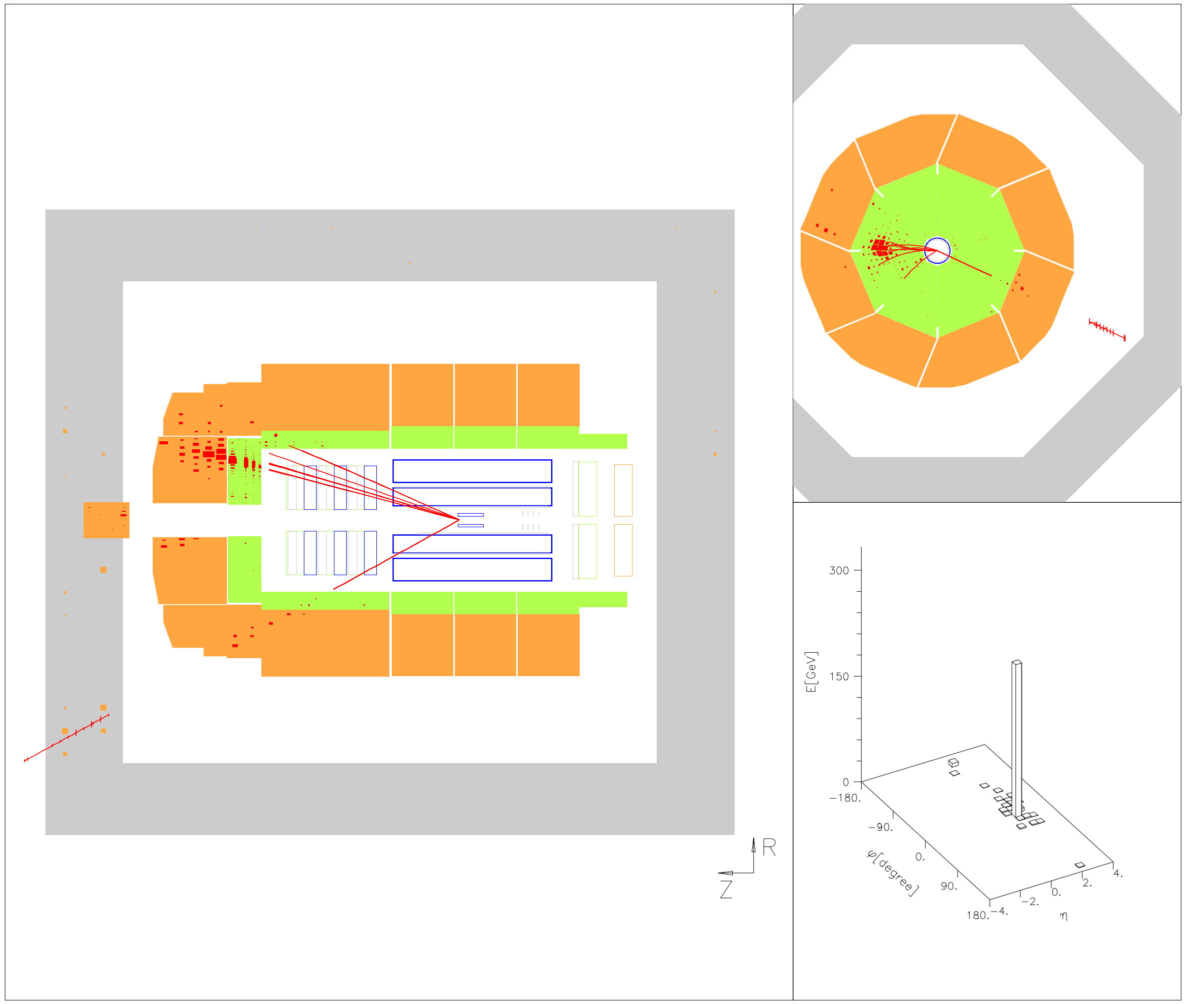
- based on CC selection: $p_{t,miss} > 25$ GeV

+ search for isolated tracks with $p_t > 10 GeV$

$\Rightarrow$ 5 leptons found:

$2\ \mu^+,\ 2\ \mu^-,\ 1\ e^-$

μ^+ candidate

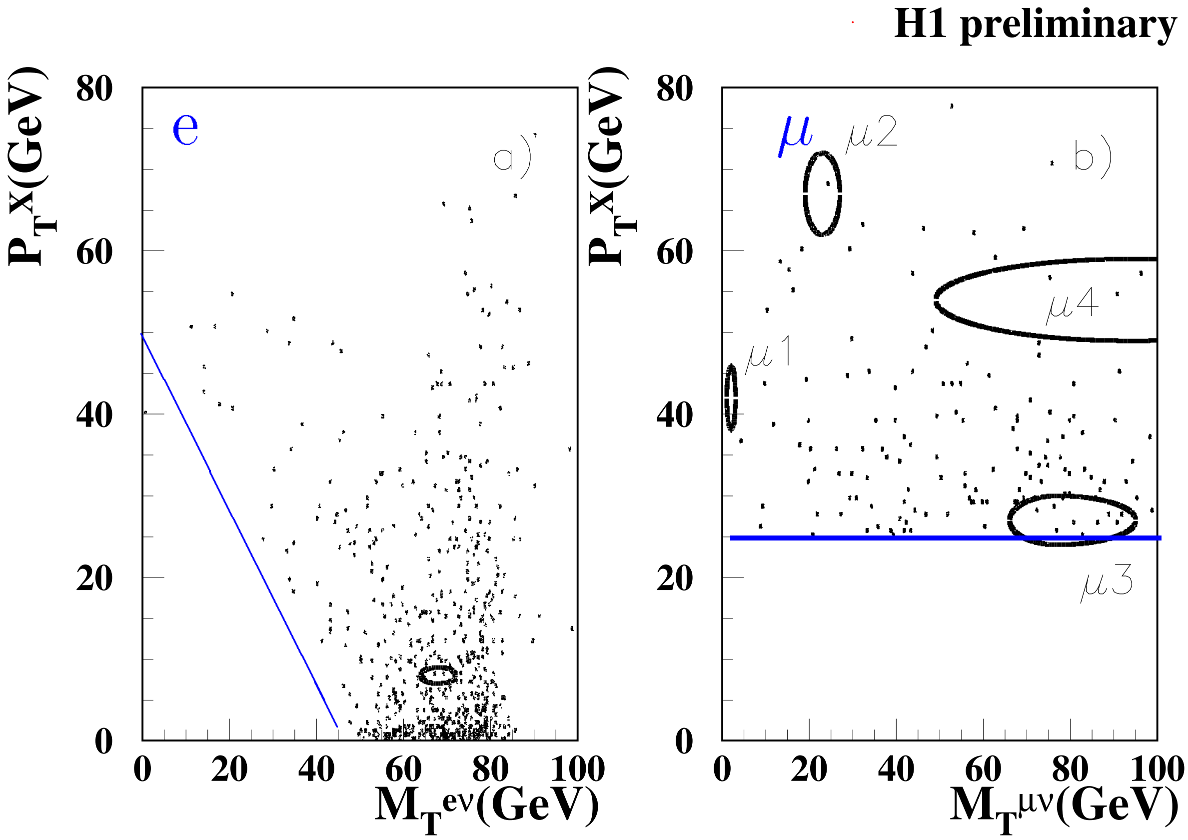


	MUON-2
isolated lepton : p_t (GeV)	28^{+6}_{-4}
hadronic system : p_t (GeV)	67 ± 5
event properties : P_t^{miss} (GeV)	43^{+5}_{-6}
M_t lepton-ν (GeV)	23^{+5}_{-4}

Kinematics of Isolated Leptons

Expected kinematic signature fro W production:

- small p_t hadronic
- Jacobian peak in $\mathrm{M}_{T(l\nu)} \approx \mathrm{M}_W$



$\mathcal{L}(\mathrm{MC}) = 500\mathcal{L}(\mathrm{data})$

e-events: $N_{obs} = 1$ N_{exp}=1.34

μ-events: $N_{obs} = 4$ N_{exp}=0.41

background: < 0.05

from $\gamma p \to Q\bar{Q}$, $\gamma\gamma \to \tau^+\tau^-$

Summary & Outlook

- A new measurement of the proton structure function F_2 for $150 \leq Q^2 \leq 5000$ GeV^2 was presented with an accuracy of 10 - 15% and in good agreement with expectations from pQCD.

- An excess of NC events at $Q^2 \geq 15000$ GeV^2 is visible with the statistics accumulated up to the middle of 1997 ($\mathcal{L} \approx 24$ pb^{-1}):
18 events observed for 8 events expected with $\mathcal{P}(N > N_{obs}) = 3.4 \times 10^{-3}$.

- 4 events with an isolated μ and high missing p_t were observed.

- An additional $\mathcal{L} \approx 15$ pb^{-1} are expected for the end of the 1997 running.