Neutral and Charged Current Cross Sections at HERA

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on behalf of the
H1 Collaboration

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Outline

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2. Kinematics and Detector
3. Experimental Procedure
4. Cross Sections
   Charged Currents (CC)
   Neutral Currents (NC)
5. Summary

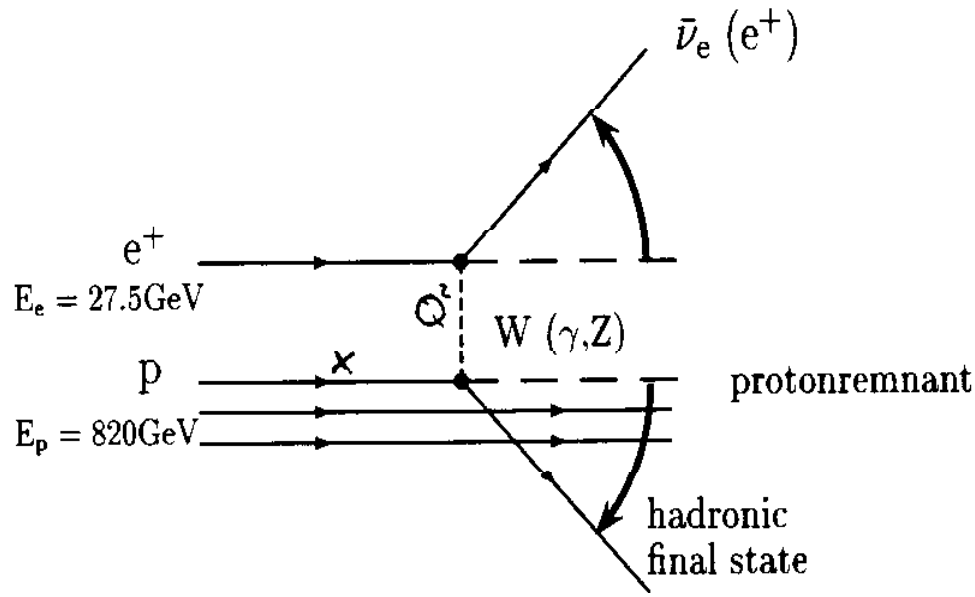
HERA

- HERA collides Protons $E_p = 820GeV$ with electrons (92-94) or positrons (94-97) of $E_e = 27.5GeV$; $\sqrt{s} = 300$ GeV;
  scattering of pointlike particles on a system with substructure

- use Deep Inelastic Scattering to study the proton in a new kinematic domain.
  Resolve structures of $10^{-18}m$ at large four momenta Q^2
  $\Delta r \Delta Q \approx \hbar$

- use 2 different probes, NC and CC reactions, to look at the proton
  address QCD and electroweak physics

Kinematics



Observables:

- fraction of proton momentum of incoming quark $x_{Bjorken}$ (0..1)
- four momentum transfer Q^2 (0..s)
- inelasticity y (0..1)
- constraint $Q^2 = sxy$

Cross Sections in DIS

NC: $e^{\pm}p \to e^{\pm} + X$

$$\frac{d^2\sigma^{NC}(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left(Y_+\mathcal{F}_2(x,Q^2) \mp Y_- x\mathcal{F}_3(x,Q^2)\right)$$

$Y_{\pm} = 1 \pm (1-y)^2$ kinematic factor

- $\mathcal{F}_2$, $\mathcal{F}_3$ Structure functions of the proton include Z^o-propagator and ew-couplings
- $\mathcal{F}_2$ contains the pure γ and Z^o exchange. $\sum(q+\bar{q})$
- $\mathcal{F}_3$ $\gamma - Z^o$ Interference term ← parity violation $\sum(q-\bar{q})$

CC: $e^+p \to \bar{\nu} + X; e^-p \to \nu + X$

$$\frac{d^2\sigma^{e^+p}}{dxdQ^2} = \frac{G_\mu^2}{\pi}\frac{1}{(1+Q^2/M_W^2)^2}((\bar{u}+\bar{c}) + (1-y)^2(d+s))$$

$$\frac{d^2\sigma^{e^-p}}{dxdQ^2} = \frac{G_\mu^2}{\pi}\frac{1}{(1+Q^2/M_W^2)^2}((u+c) + (1-y)^2(\bar{d}+\bar{s}))$$

$u = u(x,Q^2)$ momentum density of u quarks.
e^+ and e^- beam probe different flavor compositions

study cross sections in x, y, Q^2

Experimental Procedure

Kinematics reconstruction

- Jacquet–Blondel method (uses hadrons):
  $p_\perp^h = \sqrt{p_x^2 + p_y^2}$; e.g.$p_x = \sum_i p_{x_i}$
  $y_h = (E - p_z)/2E_e, Q_h^2 = (p_t^h)^2/(1 - y_h)$
- Resolution $\Delta p_t^h / p_t^h \approx 16\%$
- 4% uncertainty on the hadronic energy scale

Event Selection e^+p 94+95

- NC identification through scattered positron
- CC id by means of missing $p_\perp^h$
- Common selection cut $p_\perp^h > 12.5GeV$
- Luminosity analysed $\mathcal{L} = 6.57pb^{-1}$
- Filters against cosmic and halo μ

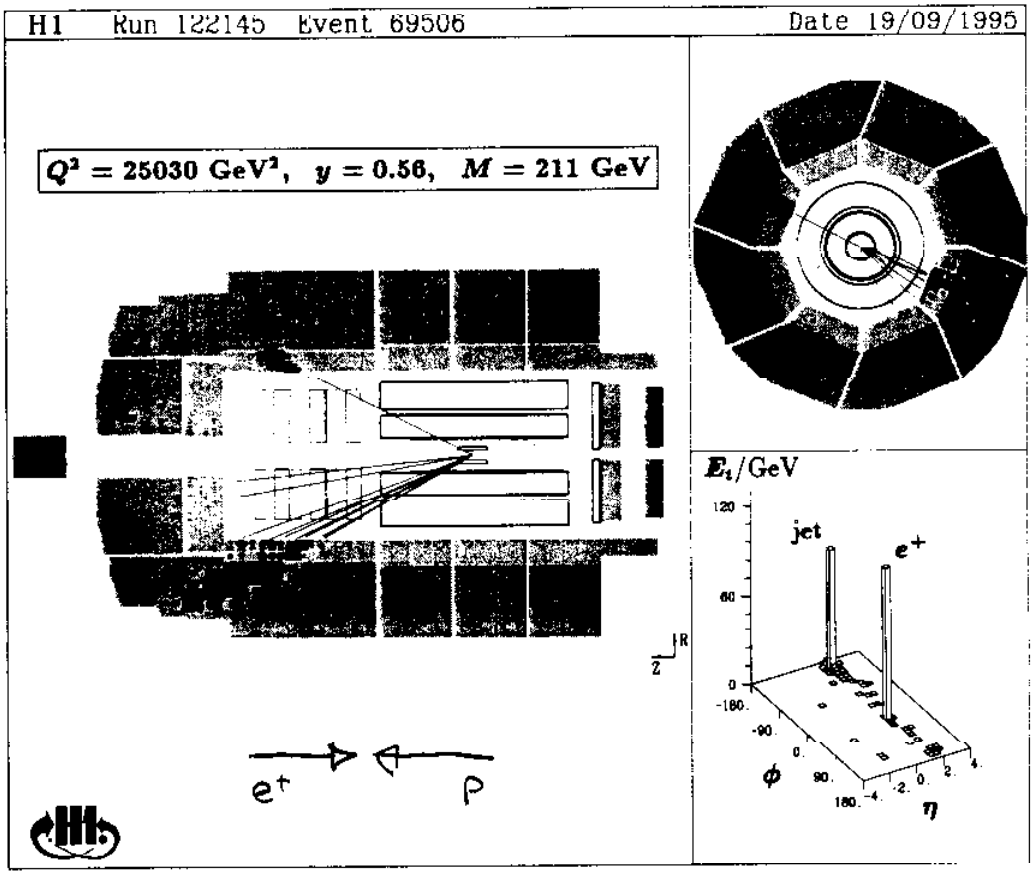
Efficiencies

- All determined from data

Correction for detector effects

- deconvolution

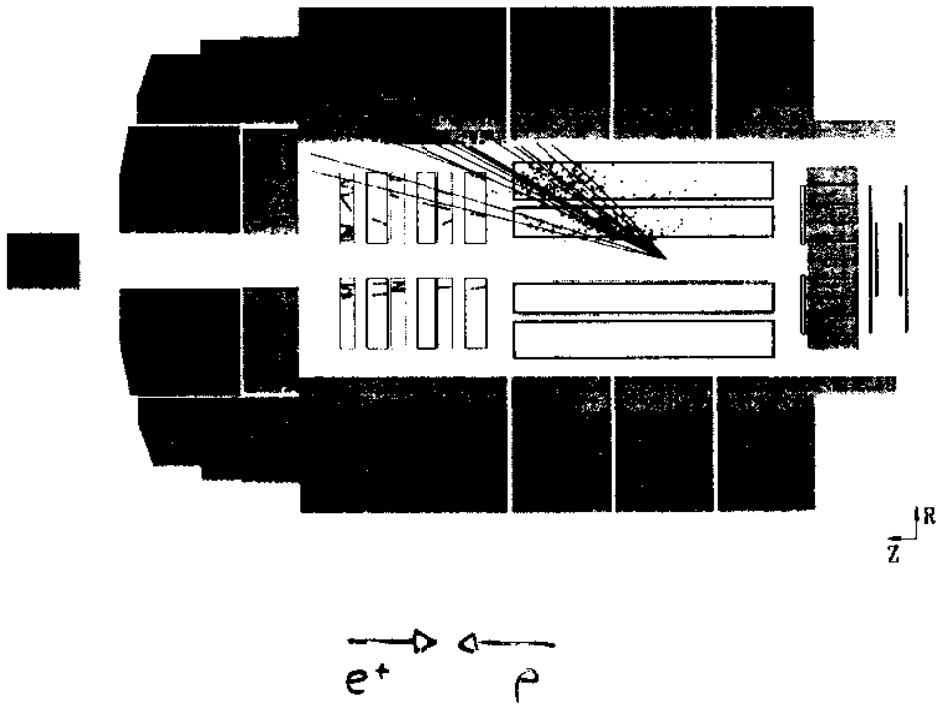
Candidate from NC sample

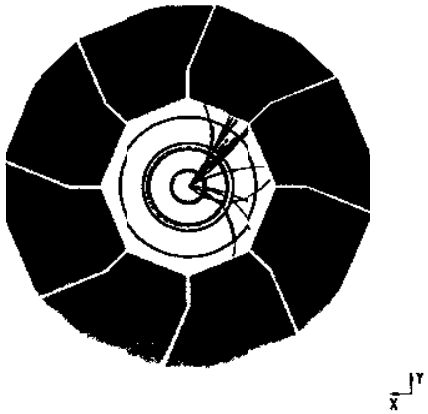


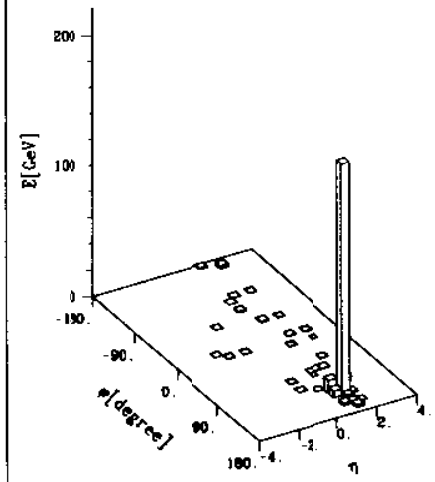
Liquid Argon Calorimeter

Run 85987 Event 99058 Class: 2 4 8 20 22 Run date 01/09/94

CC event Q**2 = 20000 GeV**2 y=0.49 x=0.44



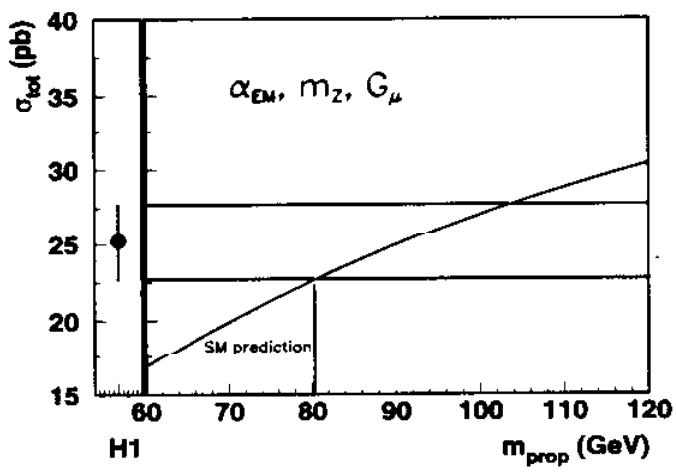




Total Cross Section CC e^+p

Cuts: $p_t > 12.5GeV$ and $0.1 < y < 0.9$

$\sigma_{\rm tot}^{\rm CC} = (25.2 \pm 2.5 \pm 0.8)$ pb (H1 preliminary)



$$\frac{d^2\sigma^{e^+p}}{dxdQ^2} = \frac{G_\mu^2}{\pi}\frac{1}{(1+Q^2/M_{prop}^2)^2}((\bar{u}+\bar{c}) + (1-y)^2(d+s))$$

Expect $\sigma_{tot}^{CC}(m_{prop} = \infty) = 45$ pb (MRSH)

$\rightarrow$ Propagator effect established

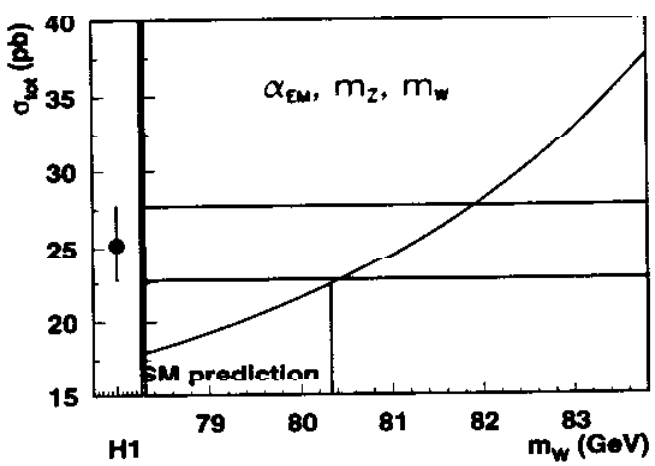
Propagator mass consistent with world average and $\Delta m_{prop} \approx 10$ GeV

Standard Model consistency check

Idea:

- CC cross section is dependent on $m_W, m_Z, m_t, m_H, \alpha_{EM}$ and all fermion masses
- include all 1-loop radiative corrections
- Replace Fermi–Coupling constant:
  $G_\mu = \frac{\pi\alpha}{\sqrt{2}m_W^2(1-m_W^2/m_Z^2)}\frac{1}{1-\Delta r(m_i)}$
  m_W enters cross section normalisation
- measure the CC cross section

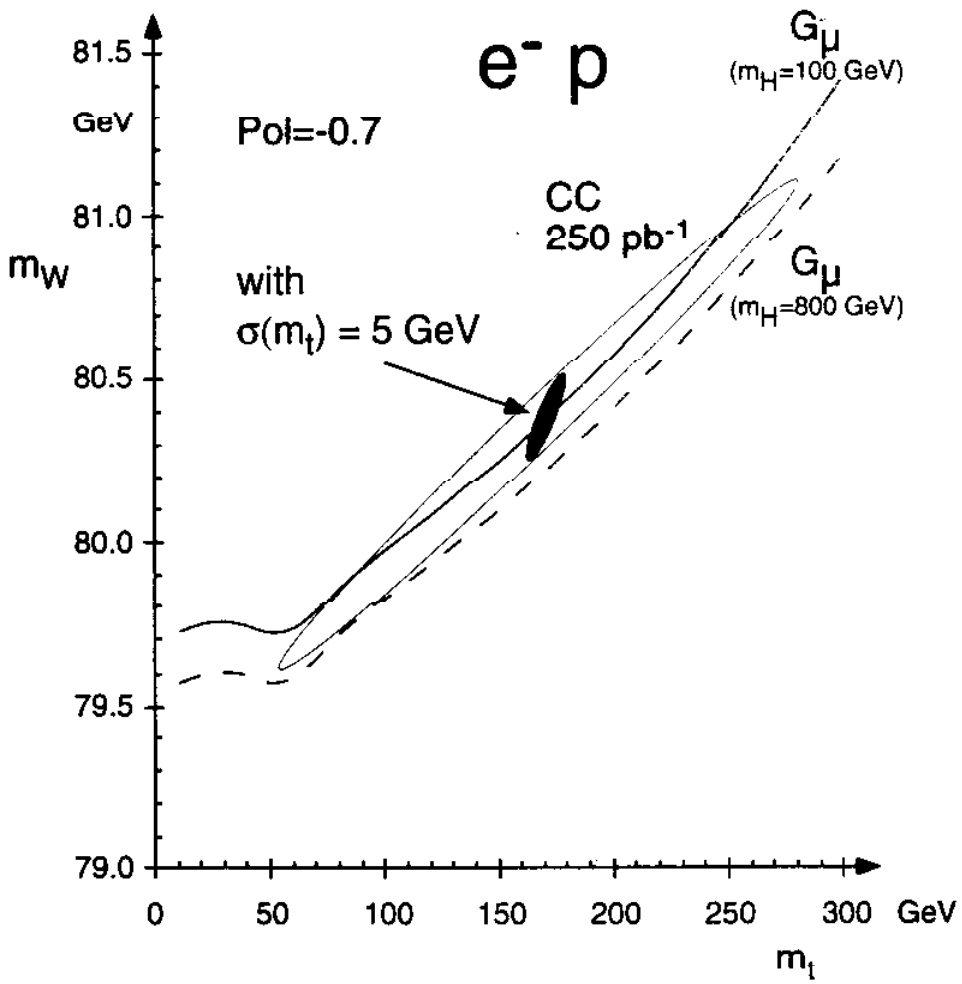
Check: Is the Standard Model complete or are there contributions to the interactions missing? (see Hera Workshop 96, R.Beyer et al.)



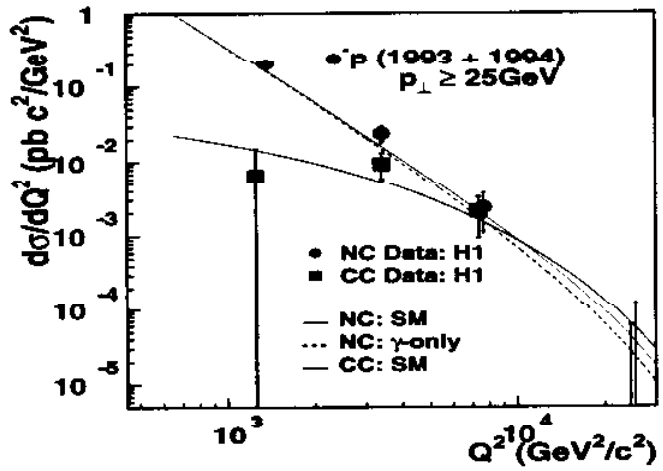
$\Delta m_W \approx 1$ GeV present level to which consistency is tested

Final expected precision ($\mathcal{L} = 1fb^{-1}$) on $\Delta m_W =$ 50 MeV for $m_t = 175 \pm 5$ GeV

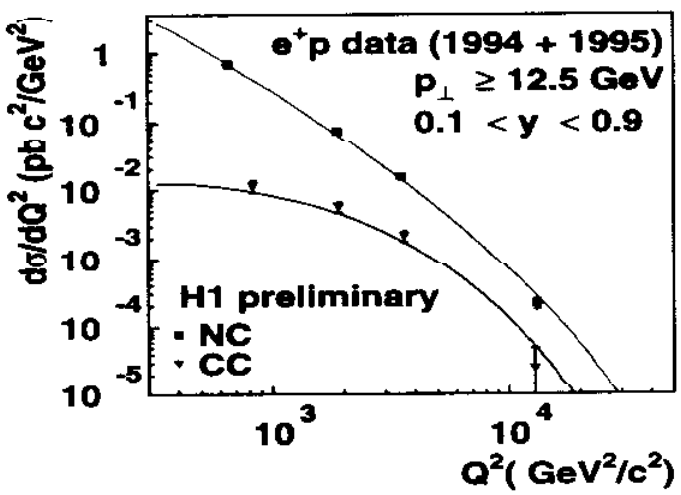
- Hera alone gives equivalent to G_μ
- measure parameters at high Q^2; need external input
- interpret
  - $m_W^{spacelike} \overset{?}{=} m_W^{timelike}$
  - m_H ?
  - extentions (new interactions)


e⁻ p
Pol=-0.7
CC
250 pb⁻¹
with
σ(m_t) = 5 GeV
G_μ
(m_H=100 GeV)
G_μ
(m_H=800 GeV)
m_W
GeV
81.5
81.0
80.5
80.0
79.5
79.0
0
50
100
150
200
250
300
GeV
m_t

$d\sigma/dQ^2$ for NC and CC Reactions

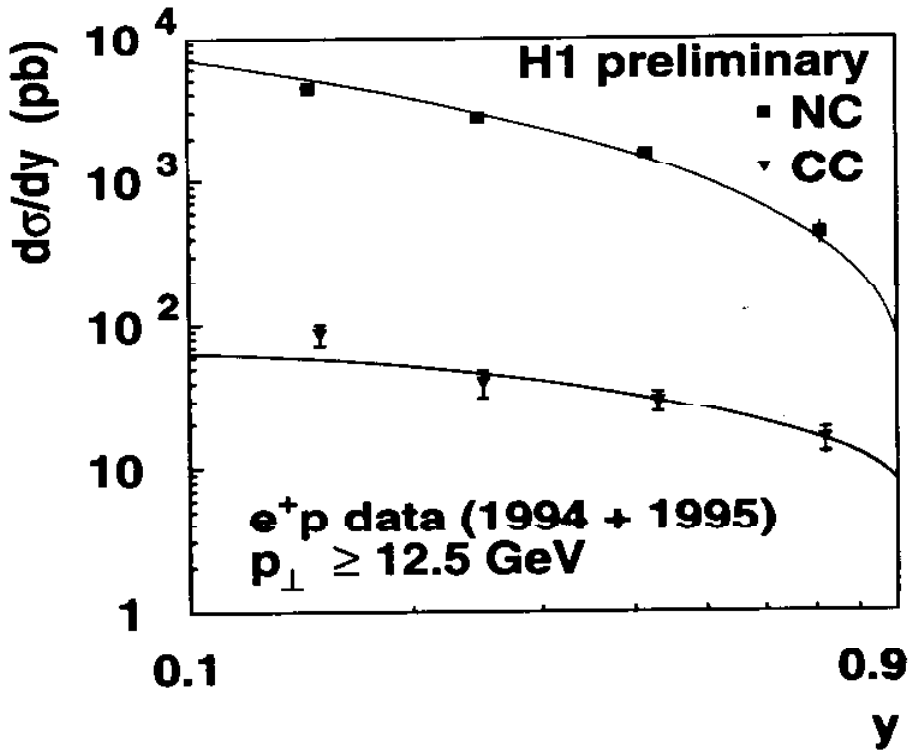


PLB 379(96)319



- NC and CC cross section have comparable size for $Q^2 \approx m_Z^2$ GeV^2.
- different NC/CC cross sections for $e^{\pm}p$
- in this data Z^o contribution statistically not significant

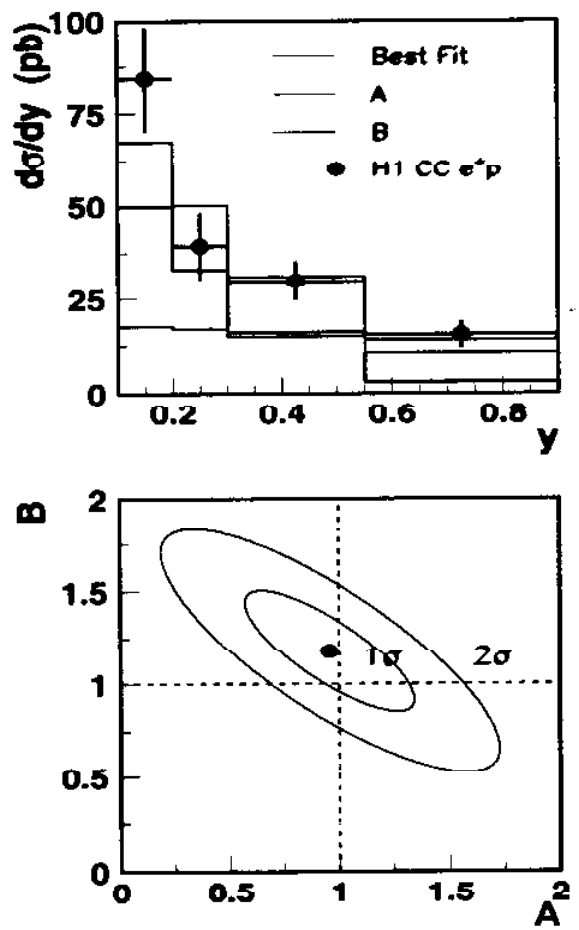
$d\sigma/dy$ for NC and CC Reactions e^+p



- NC data at low $p_\perp$ in agreement with expectations for DIS (MRSH parton densities)
- CC cross section tells anti quarks from quarks
  $\frac{d^2\sigma^{CC}}{dxdy} = \frac{G_\mu^2}{\pi s x}\frac{1}{(1+syx/M_W^2)^2}((\bar{u}+\bar{c}) + (1-y)^2(d+s))$

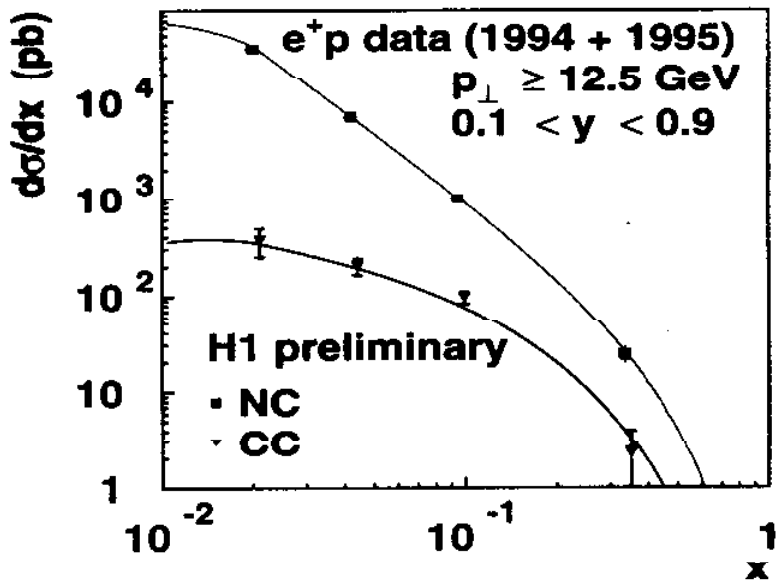
V-A Structure of the CC e^+p

$$\frac{d^2\sigma^{CC}}{dxdy} = \frac{G_\mu^2}{\pi x s}\frac{1}{(1+sxy/M_W^2)^2}(\mathrm{A}(\bar{u}+\bar{c}) + B(1-y)^2(d+s))$$



- y is the key to disentangle valence and sea quark contributions
- $A \neq 0$ means scattering on anti quarks contributes

$d\sigma/dx$ for NC and CC Reactions e^+p



- QCD evolution works: Parton densities fitted from low Q^2 data describe HERA data.
- Valence quark densities at large $x_{Bj} > 0.3$ $d\sigma^{CC}/dx \to d$; $d\sigma^{NC}/dx \to {}^4/_9 u + {}^1/_9 d$
- CC cross sections are sensitive to $\bar{u}/\bar{d}$ ratio (Tevatron W-production)

Summary

- HERA Physics at large virtualities starts to explore an untested kinematic domain
- Electroweak physics (space like)
  - ▷ W–Mass consistent with other measurements
  - ▷ NC and CC cross section have similar strength at $Q^2 \approx m_Z^2$
  - ▷ CC Helicity structure distinguishes quarks from anti quarks
  - ▷ QCD-evolution in Q^2 works; flavor deconvolution feasible
- Overall good description of NC, CC data by DIS Standard Model and QCD for $p_\perp > 12.5 GeV$ and $0.1 < y < 0.9$
- Outlook:
  Eagerly await much more $\mathcal{L}$,
  e^-p and Polarization.
  Precision data on electroweak and QCD parameters to come.