Deep-Inelastic e^+p Scattering at Very High Q^2 from ZEUS at HERA

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- Introduction to e^+p DIS at ZEUS
- Cross Section Measurements
- Electroweak Propagator Masses M_Z, M_W
- Conclusion and Outlook

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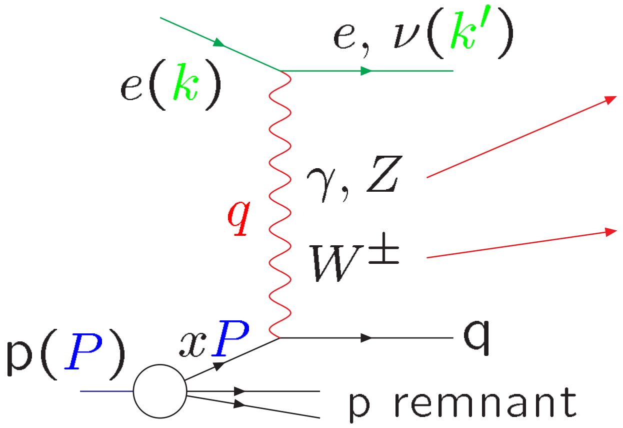
Define DIS Kinematic Variables



Neutral Current (NC)

Scattered e in main detector

e balances hadronic P_T

Charged Current (CC)

Scattered ν invisible

P_T imbalance

hadronic system only

Kinematic Variables:

four–momentum transfer squared:

$$Q^2 = -q^2 = -(k - k')^2$$

parton momentum fraction (Bjorken scaling variable):

$$x = Q^2/(2\, q \cdot P)$$

inelasticity (fractional energy transfer in p rest frame):

$$y = (q \cdot P)/(k \cdot P)$$

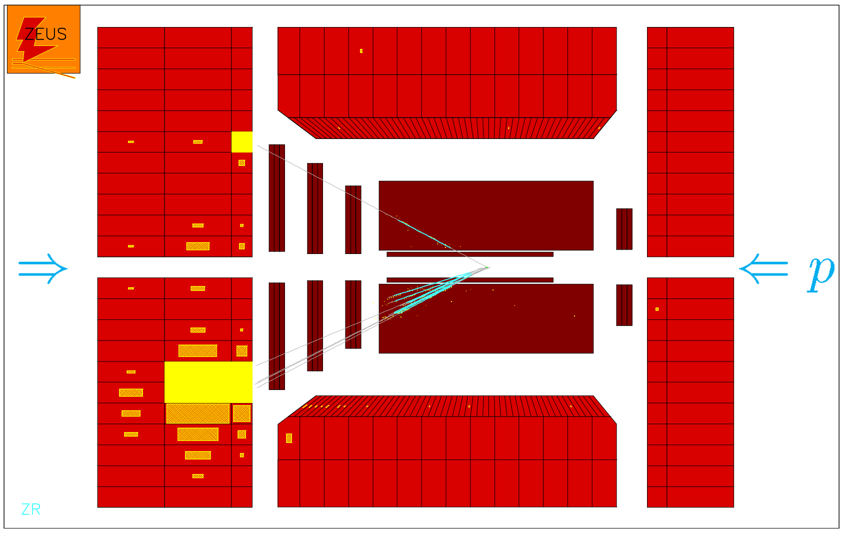
$$Y_{\pm} = \left(1 \pm (1-y)^2\right)$$

where:

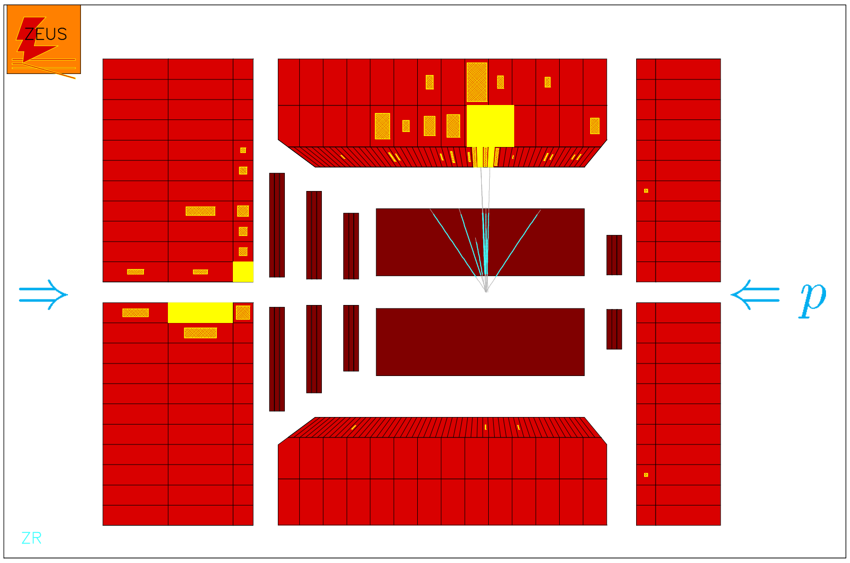
$$Q^2 = sxy \text{ and } \sqrt{s} = 300 \text{ GeV}$$

ZEUS Data Sample

Neutral Current

$e^+ \Rightarrow$  $\Leftarrow p$

Charged Current

$e^+ \Rightarrow$  $\Leftarrow p$

- 1994-1997 e^+p runs
- $E_e = 27.5$ GeV, $E_p = 820$ GeV
- $\sqrt{s} = 300$ GeV
- $\mathcal{L} = 46.6\ \mathrm{pb}^{-1}$

NC/CC DIS Cross Section Formulae

Neutral Current

$$\frac{d^2\sigma^{e^+p\to e^+X}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\,\mathcal{F}_2^{\mathrm{NC}} - Y_-\,\mathcal{F}_3^{\mathrm{NC}}\right]$$

- $\mathcal{F}_2^{\mathrm{NC}}$ and $\mathcal{F}_3^{\mathrm{NC}}$ contain PDF's and EW parameters $M_Z, \sin^2\theta_W$, etc.
- Propagator terms (not shown):
  - $\rightarrow$ Photon–exchange dominates at low Q^2
  - $\rightarrow$ For $Q^2 \gtrsim M_Z^2$, γ and Z contributions similar
  - $\rightarrow$ At high Q^2, gain sensitivity to Z mass

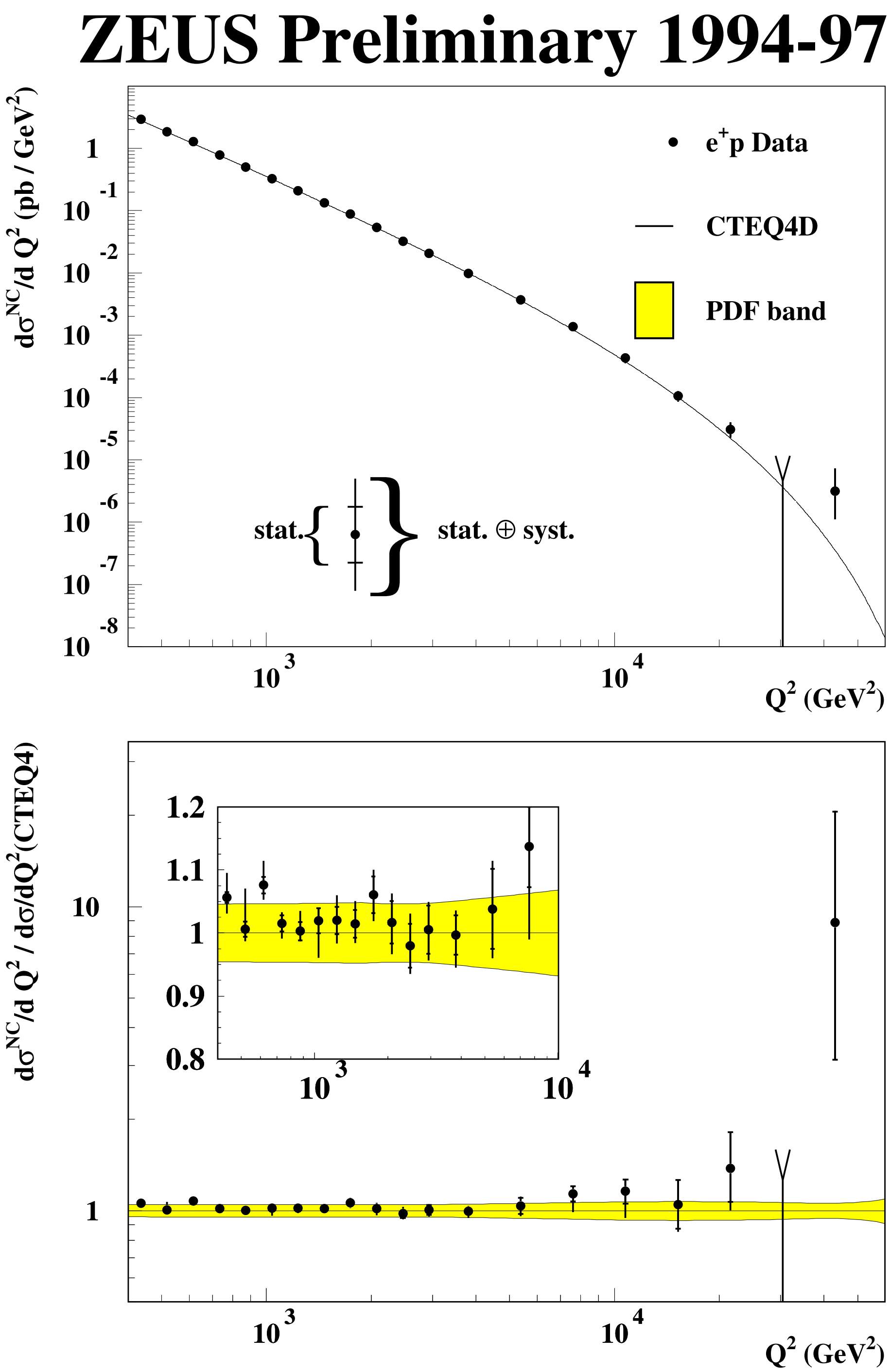
Charged Current

$$\frac{d^2\sigma^{e^+p\to \nu X}}{dx\,dQ^2} = \frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2\left[Y_+\,\mathcal{F}_2^{\mathrm{CC}} - Y_-\,\mathcal{F}_3^{\mathrm{CC}}\right]$$

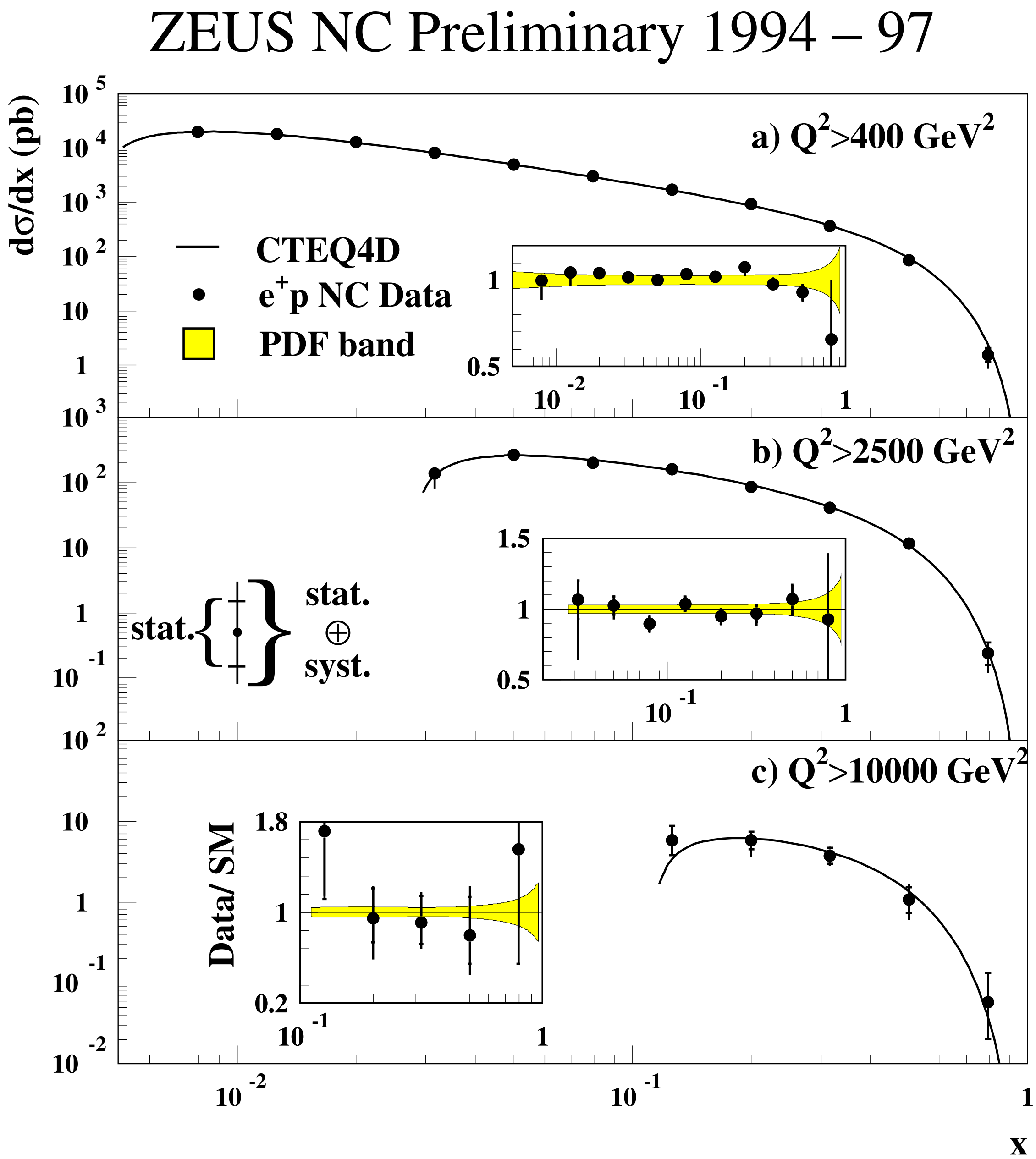
- Propagator term:
  - $\rightarrow$ At low Q^2, weak Q^2 dependence
  - $\rightarrow$ At high Q^2, gain sensitivity to W mass

Radiative corrections are substantial

NC Cross Section $d\sigma/dQ^2$

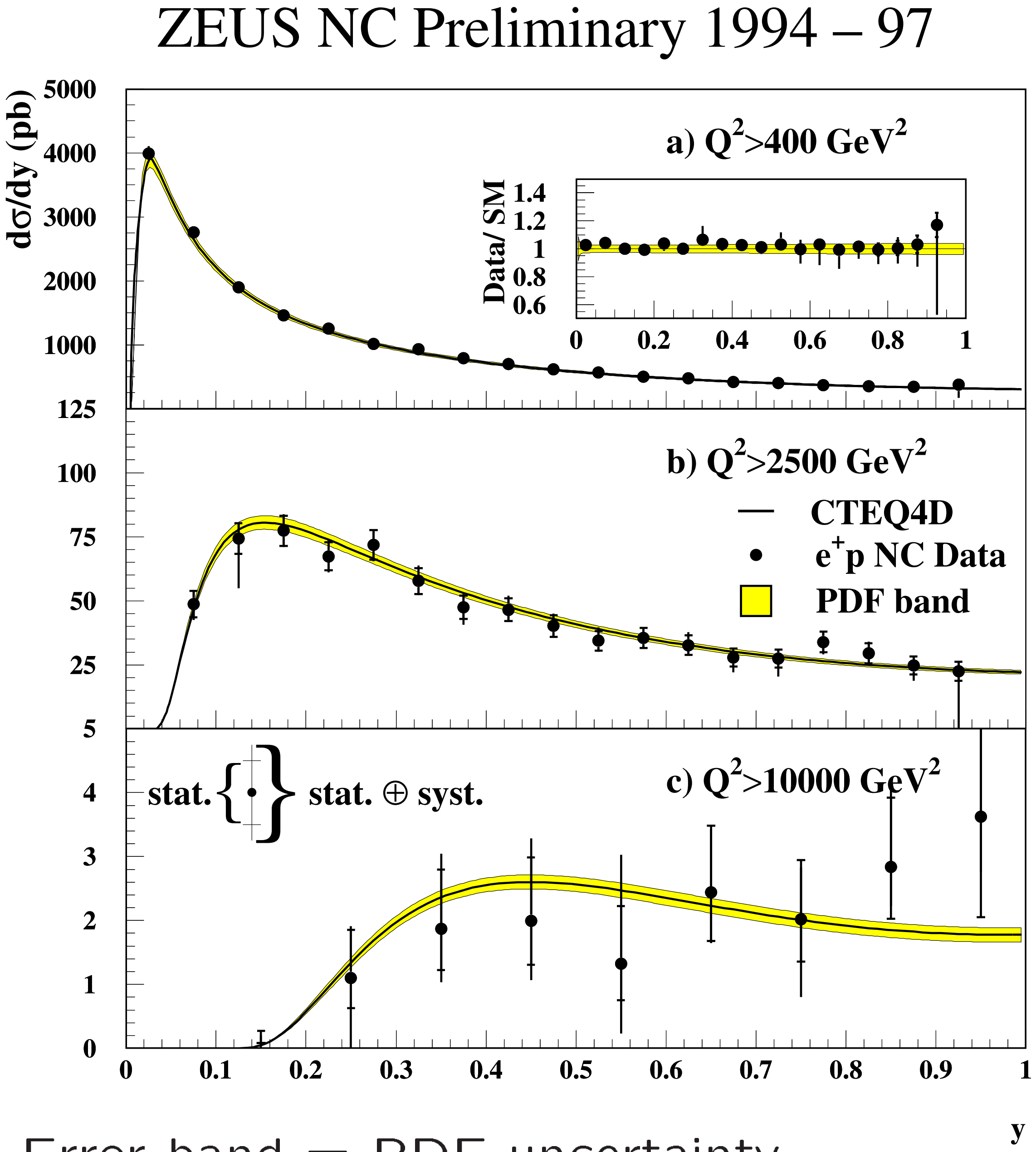


- Error band = PDF uncertainty
- Very good agreement with SM prediction
- Slight excess at highest Q^2



- Error band = PDF uncertainty
- Very good agreement with SM prediction
- No significant deviations at high x
  - $\rightarrow$ eq resonance might appear here $M_{eq} = 300\sqrt{x}$
  - $\rightarrow$ effect might level out due to binning

NC Cross Section $d\sigma/dy$

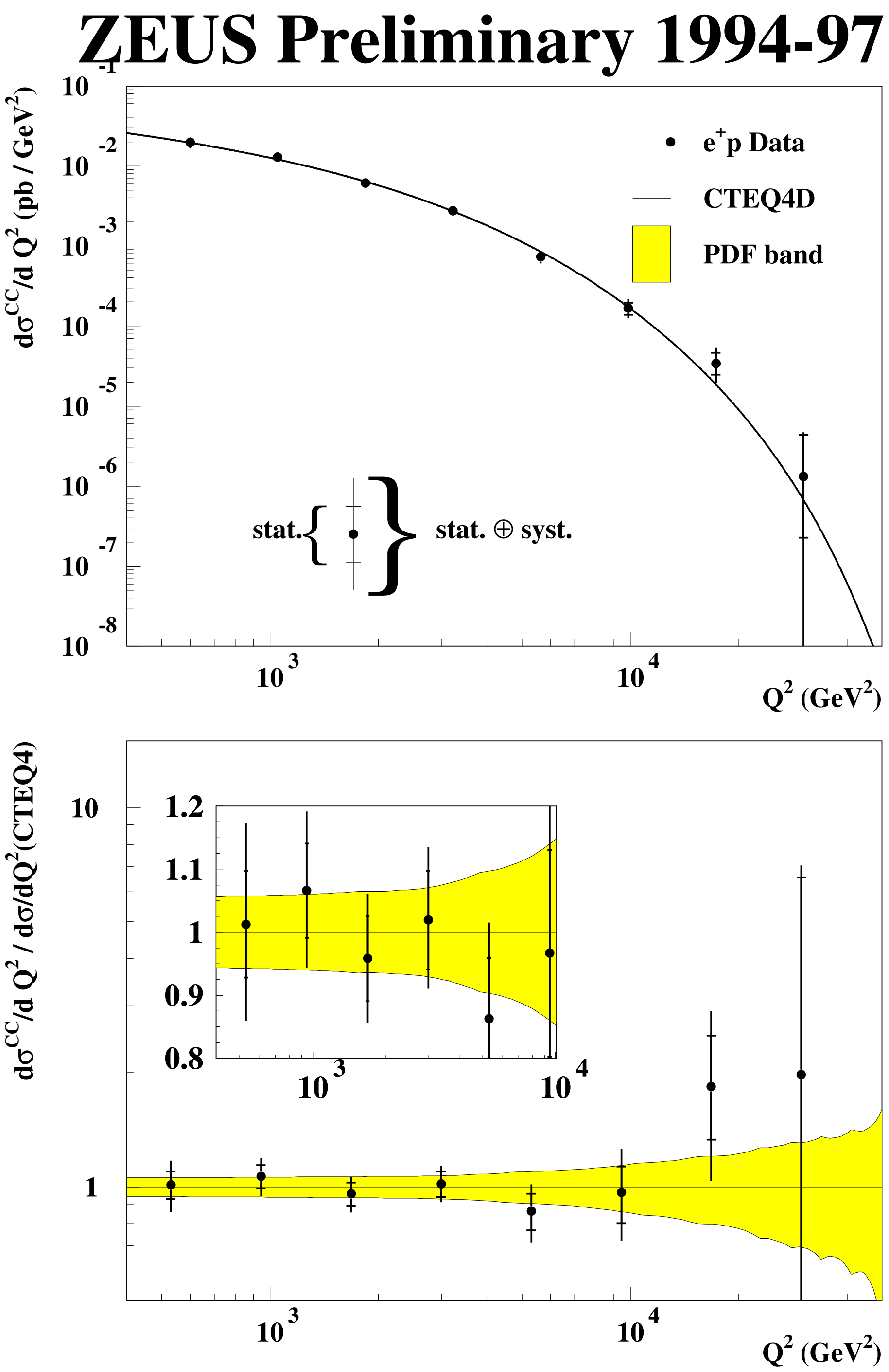


- Error band = PDF uncertainty
- Very good agreement with SM prediction
- No significant deviations from SM shape

  → eq resonance could cause deviation,

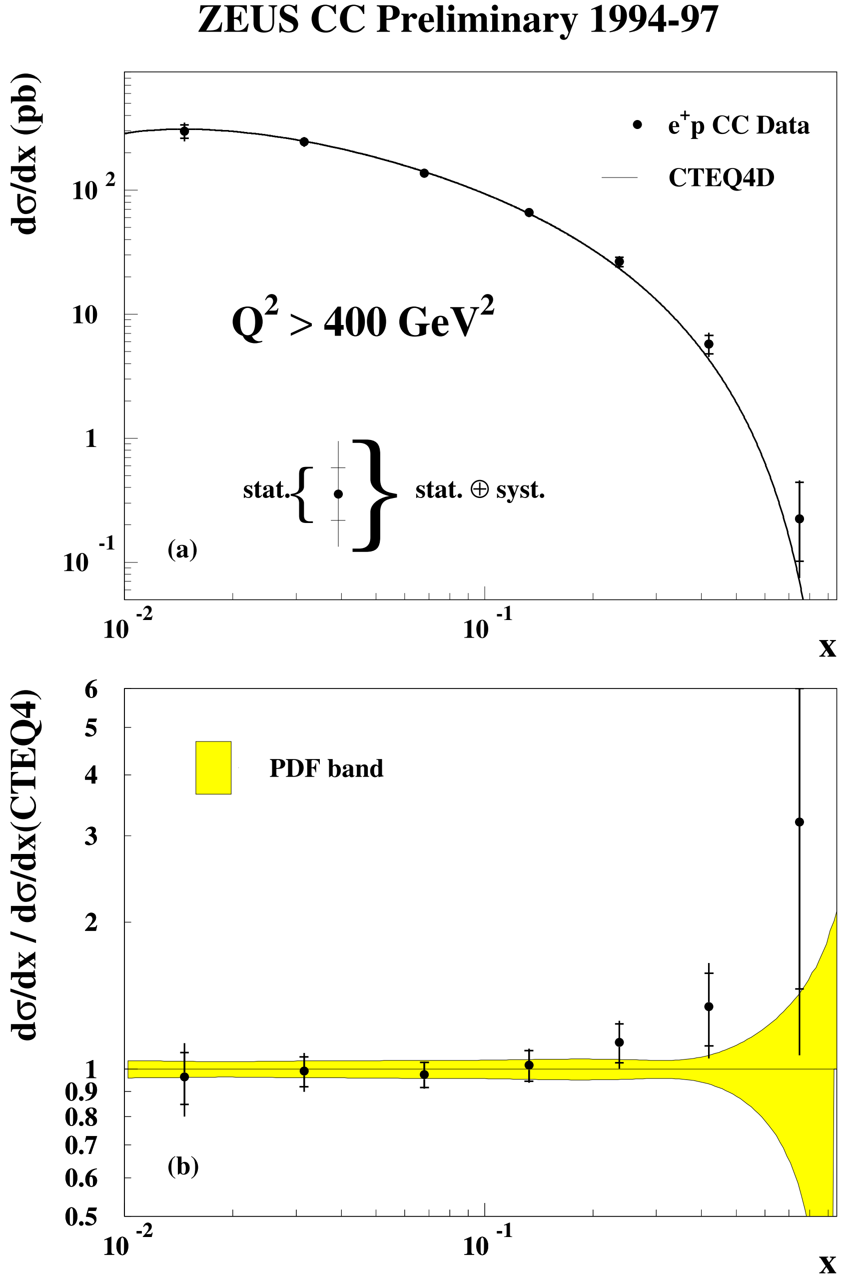
  e.g., scalar LQ $d\sigma/dy$ independent of y

CC Cross Section $d\sigma/dQ^2$



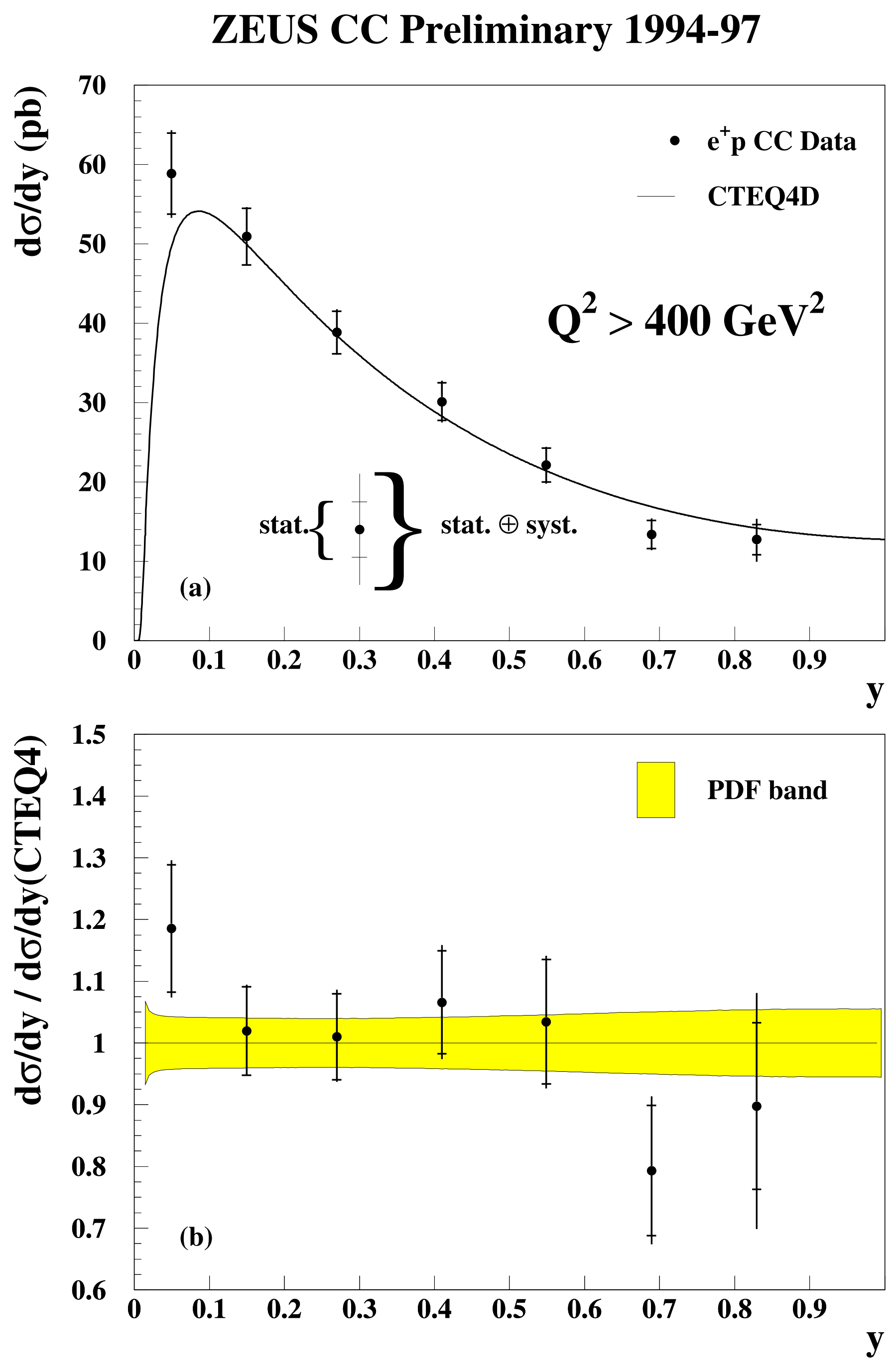
- Error band = PDF uncertainty
- Good agreement with SM prediction
- Slight excess at highest Q^2

CC Cross Section $d\sigma/dx$



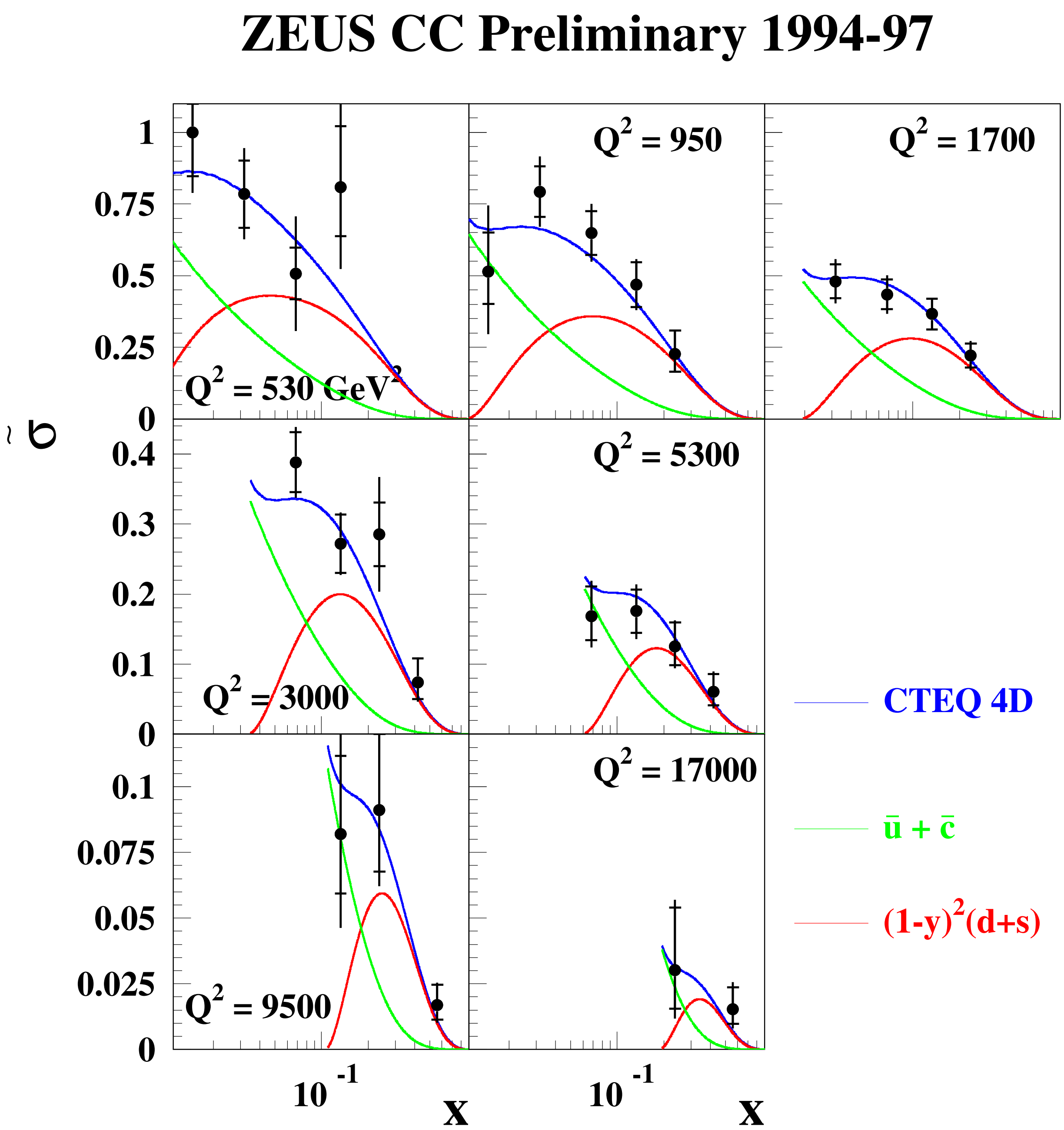
- Error band = PDF uncertainty
- Good agreement with SM prediction
- Slight excess at highest x
  - $\rightarrow$ eq resonance might appear here $M_{eq} = 300\sqrt{x}$
  - $\rightarrow$ effect might level out due to binning

CC Cross Section $d\sigma/dy$ (ZEUS)



- Error band = PDF uncertainty
- Data slightly "softer" than expected

CC Reduced Cross Section $\tilde{\sigma}$

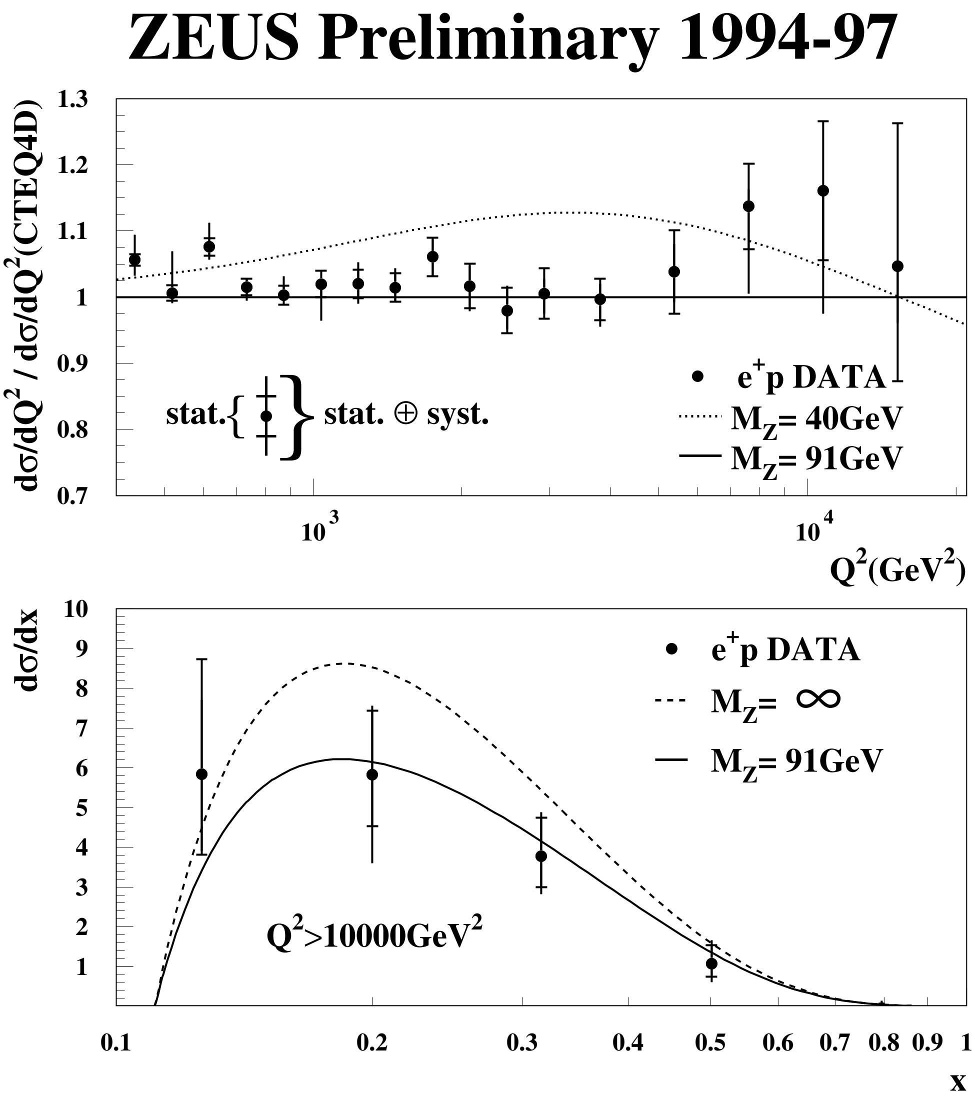


- Sensitivity to PDF's:

$$\tilde{\sigma} = \frac{d^2\sigma}{dx dQ^2} \cdot \frac{2\pi x}{G_F^2} \cdot \left(\frac{M_W^2}{Q^2+M_W^2}\right)^{-2}$$

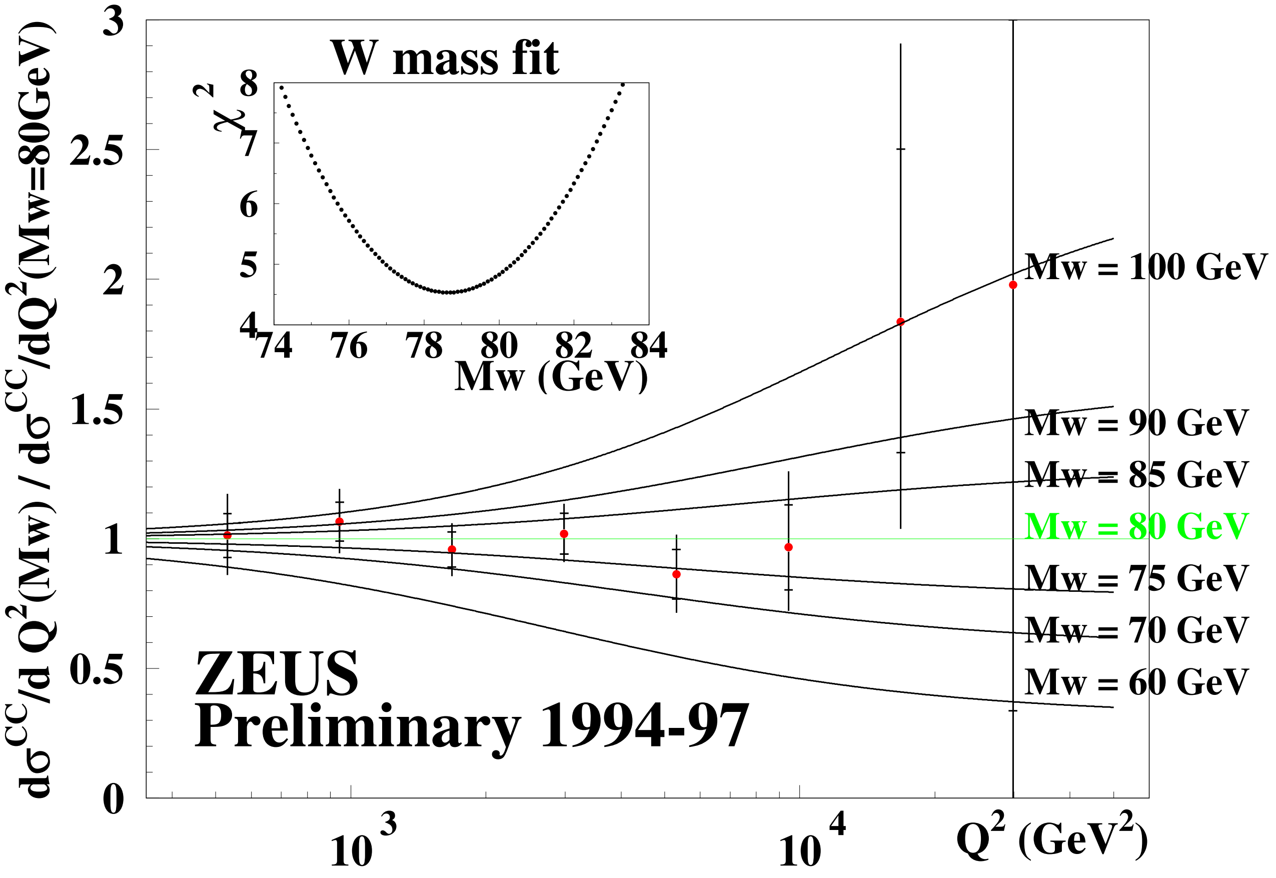
$$= (\bar{u} + \bar{c}) + (1-y)^2(d+s)$$

Z Mass Sensitivity



- $M_Z = 91.188 \pm 0.007$ (PDB 98)
- Small sensitivity to M_Z from propagator terms in NC cross section
- Confirm EW prediction in spacelike regime

W Mass Determination



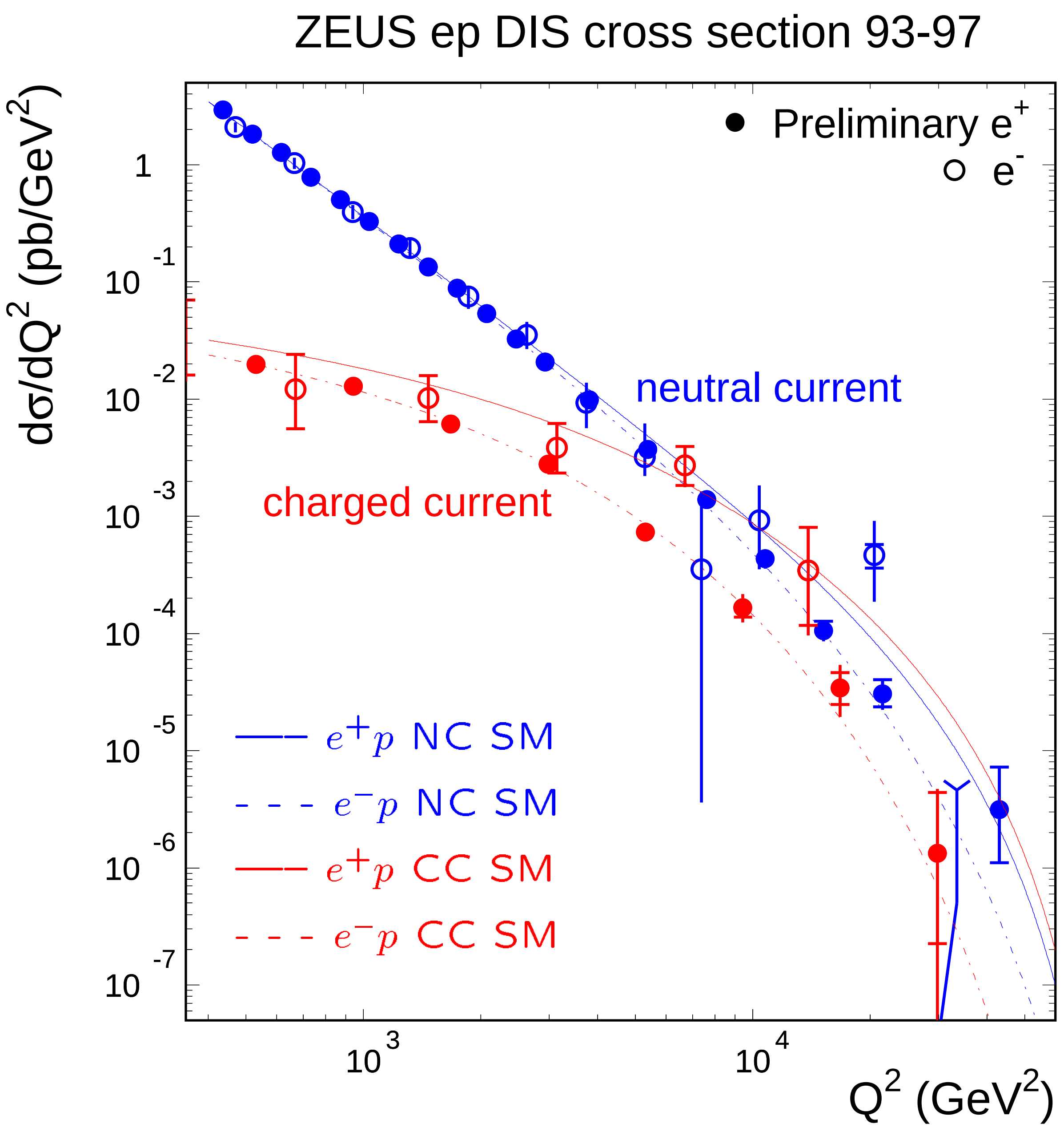
- $M_W = 80.41 \pm 0.10$ (PDB 98)
- Sensitivity to M_W from CC propagator terms
- χ^2–fit SM to data (other EW params fixed):

$$\boxed{M_W = 78.6^{+2.5}_{-2.4}\,(\text{stat.})\ {}^{+3.3}_{-3.0}\,(\text{syst.})\ \text{GeV}}$$

- Confirm EW prediction in spacelike regime

  $\rightarrow$ Agreement $\Rightarrow$ good knowledge of E_{had} scale

NC/CC $d\sigma/dQ^2$ Comparison



- $\sigma(\mathrm{NC}) \approx \sigma(\mathrm{CC})$ for $Q^2 \gtrsim M^2_{W,Z} \approx 10^4$
- Region $Q^2 \gtrsim 10^4\,\mathrm{GeV}^2$ still statistics–limited
- $\mathcal{L}(e^+) = 46.6\,\mathrm{pb}^{-1}$; $\mathcal{L}(e^-) = 0.54\,\mathrm{pb}^{-1}$
- e^-p statistics–limited:
  more e^- running underway 1998–2000

Conclusions and Outlook

Conclusions

- ZEUS NC and CC cross sections for
  Q^2 up to several $10^4\,\mathrm{GeV}^2$
  in excellent agreement with Standard Model
  - → Excess at $Q^2 \gtrsim 20000\,\mathrm{GeV}^2$ not confirmed in 1997 data but still present
  - → HERA has discovery window for eq resonances
- ZEUS gaining sensitivity to EW propagator masses: M_W and M_Z

Outlook

- 1998–2000: e^-p data at $E_p = 920$ GeV
  - → so far ×10 statistics: $\sim 4.5\,\mathrm{pb}^{-1}$
  - → expect $\sim 35\,\mathrm{pb}^{-1}$ 1999–2000
- After 2000: HERA upgrade: $\sim 170\,\mathrm{pb}^{-1}$ / year

$$\boxed{\text{We anticipate an exciting future for high–}Q^2\text{ physics at HERA}}$$