Electroweak Physics at HERA

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DESY

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Introduction: How to do electroweak measurements in DIS

HERA I results: H1 combined QCD & EW fit

HERA II results: polarised CC cross sections

HERA I + II: Single W Production

Summary & Outlook

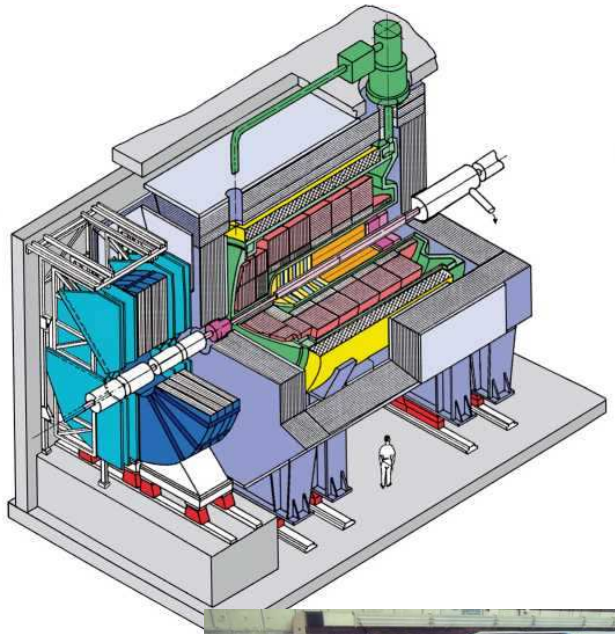
The HERA Experiments

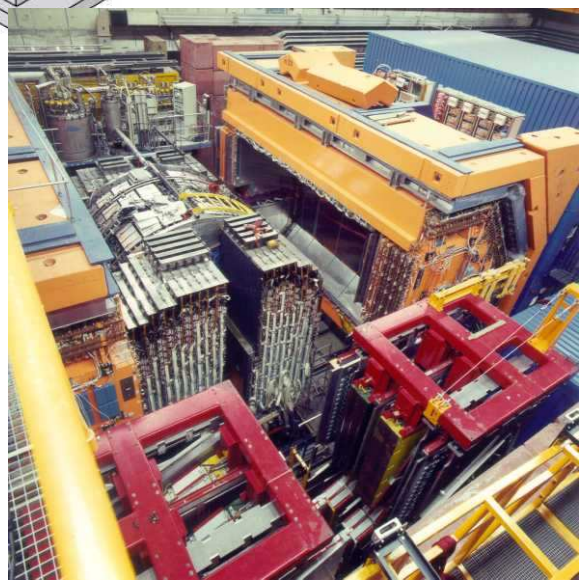
Electron Proton Collisions:

- $E_p = 920$ GeV, $E_e = 27.5$ GeV
- Experiments H1 & ZEUS

Luminosity per experiment

- HERA I:
  - $\simeq 20 pb^{-1}$ $e^- p$ data
  - $\simeq 100 pb^{-1}$ $e^+ p$ data
- after upgrade HERA II: longitudinal polarisation!
  - $\simeq 150 pb^{-1}$ $e^- p$ data
  - $\simeq 50 pb^{-1}$ $e^+ p$ data

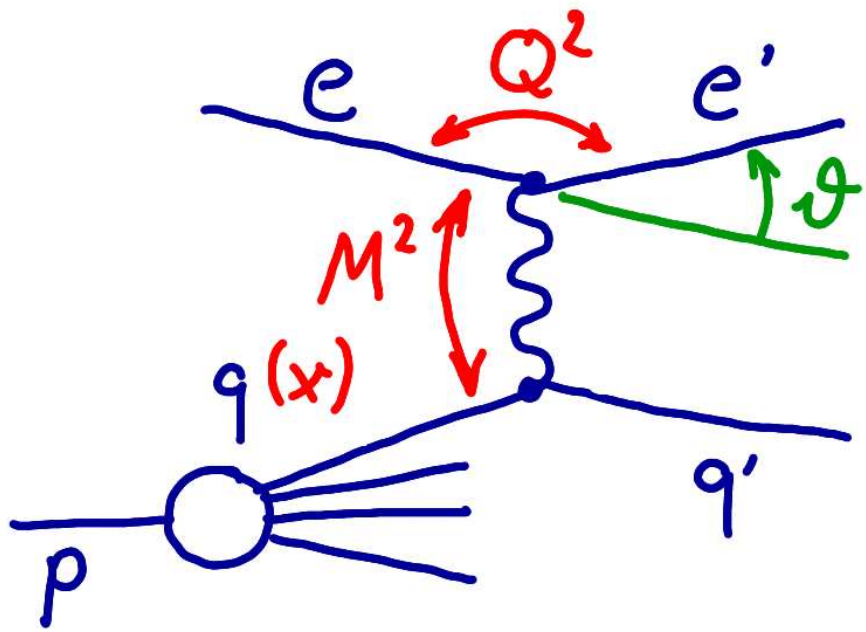




Deep Inelastic Scattering

Neutral Current

- scattered electron
- low Q^2: photon exchange
- high Q^2: also Z^0 exchange and Z^0–γ interference



Charged Current

- neutrino $\Rightarrow$ missing E_T
- $W^{\pm}$ exchange
- high Q^2: Electroweak Unification

Disentangling Proton Structure and Electroweak Effects

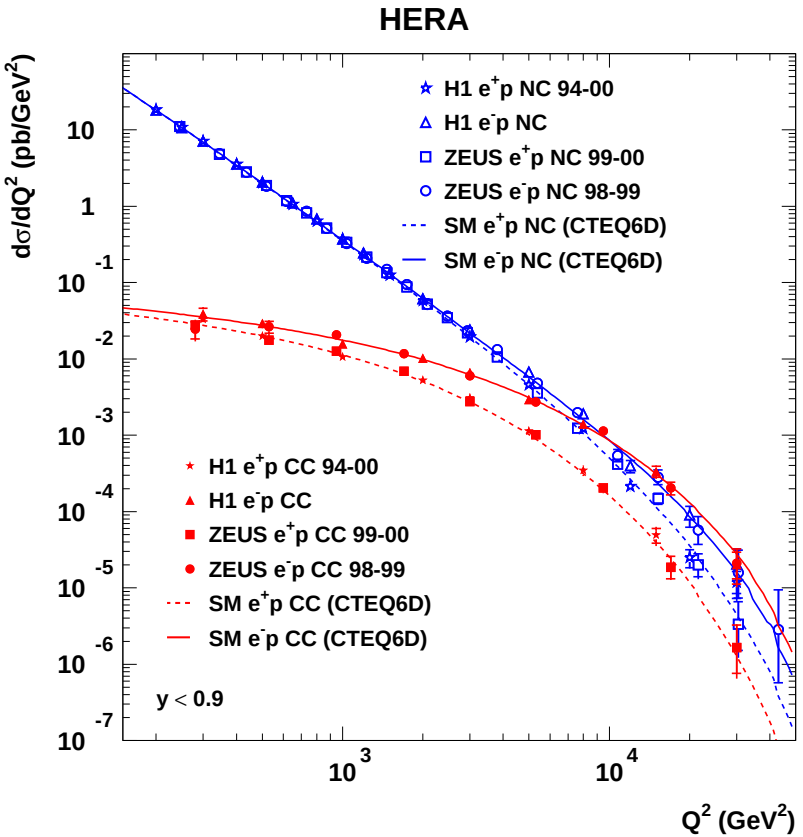
$$\frac{d^2\sigma^{NC}}{dxdQ^2} \sim |\frac{A}{Q^2} + \frac{B}{Q^2+M_Z^2}|^2 \times \text{pdf's} \qquad \frac{d^2\sigma^{CC}}{dxdQ^2} \sim G_F^2(\frac{M_W^2}{M_W^2+Q^2})^2 \times \text{pdf's}$$

bulk of data: $Q^2 << M^2_{Z/W}$:

- hard scattering = QED
- $\Rightarrow$ determine pdf's

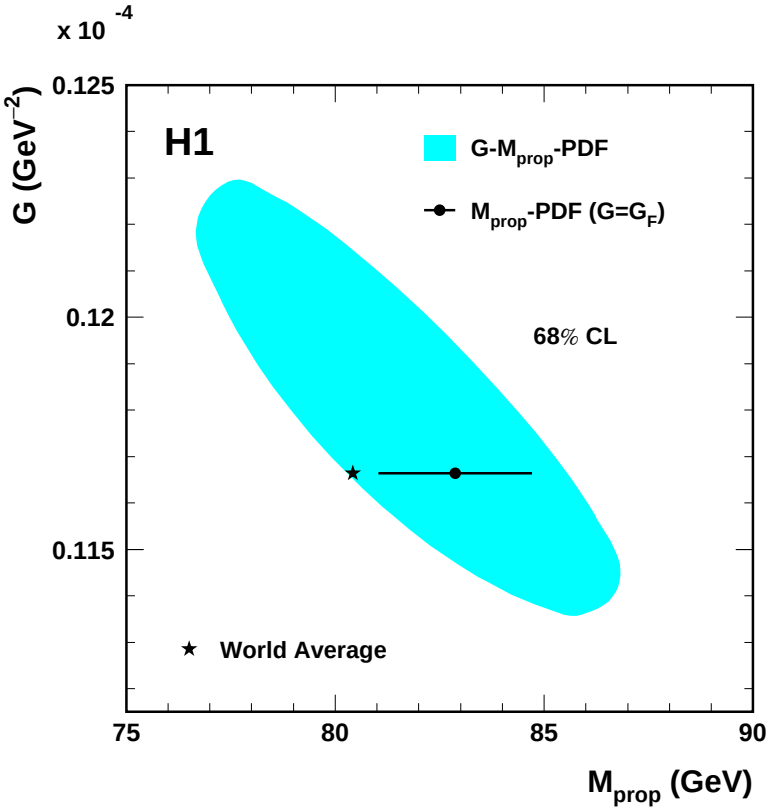
at high Q^2:

- QED $\longrightarrow$ electroweak
- $\Rightarrow$ sensitivity to electroweak parameters



HERA I results: H1 combined QCD & EW fit

- first combined fit of QCD & EW parameters at HERA
- $\Rightarrow$ understand correlations
- uses all HERA I data



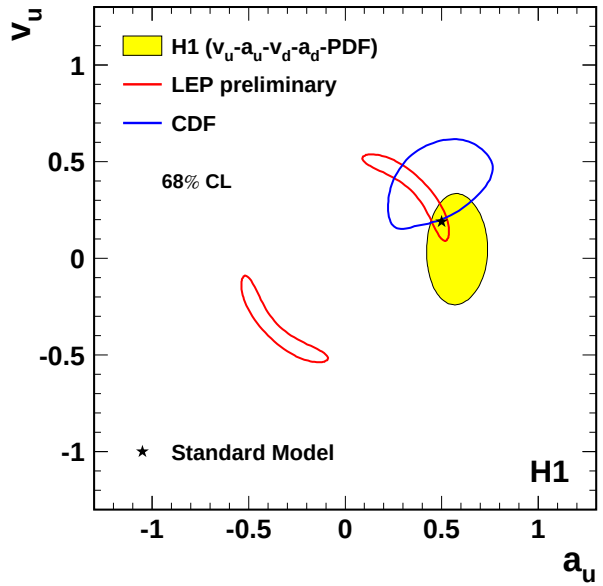
Charged Current Propagator Mass

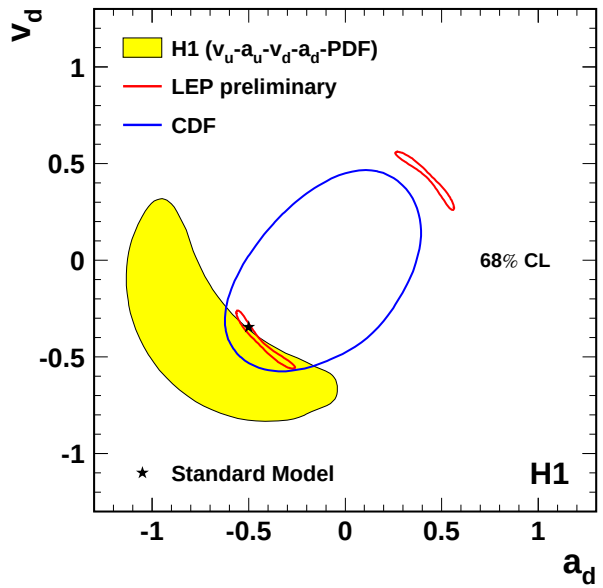
- Is it **really** $W^{\pm}$–exchange?
- fit M_{prop}, CC coupling G and pdf's
- $G = G_F$ fixed to PDG value
  $\Rightarrow M_{\mathrm{prop}} = 82.87 \pm 1.82_{\mathrm{exp}}\,^{+0.30}_{-0.16}|_{\mathrm{model}}$ GeV

H1 combined QCD & EW fit cont'd

Z^0 axial and vector couplings to up and down quark

- Standard Model:
  - $a_{u/d} = I^3_{u/d}$
  - $v_{u/d} = I^3_{u/d} - 2e_{u/d} \sin^2 \theta_w$
- Fit a_u, v_u, a_d, v_d and pdf's
  - superior sensitivity to a_u, v_u due to Z^0–γ interference
  - correlations illustrated by fixing either up- or down-quark couplings
- HERA II: expect improvement due to polarisation!

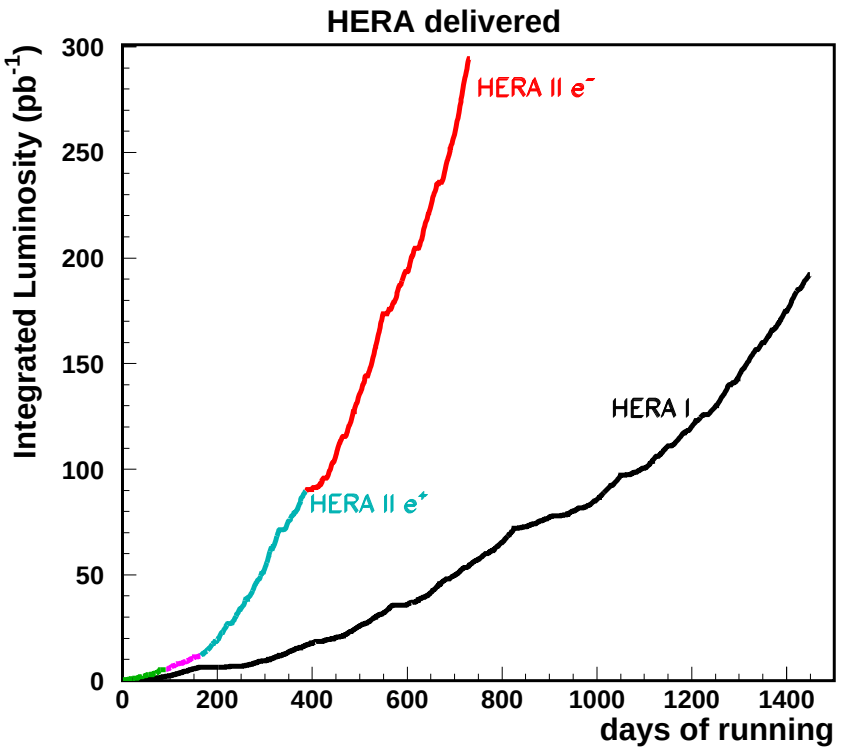




HERA II data sets

per experiment roughly

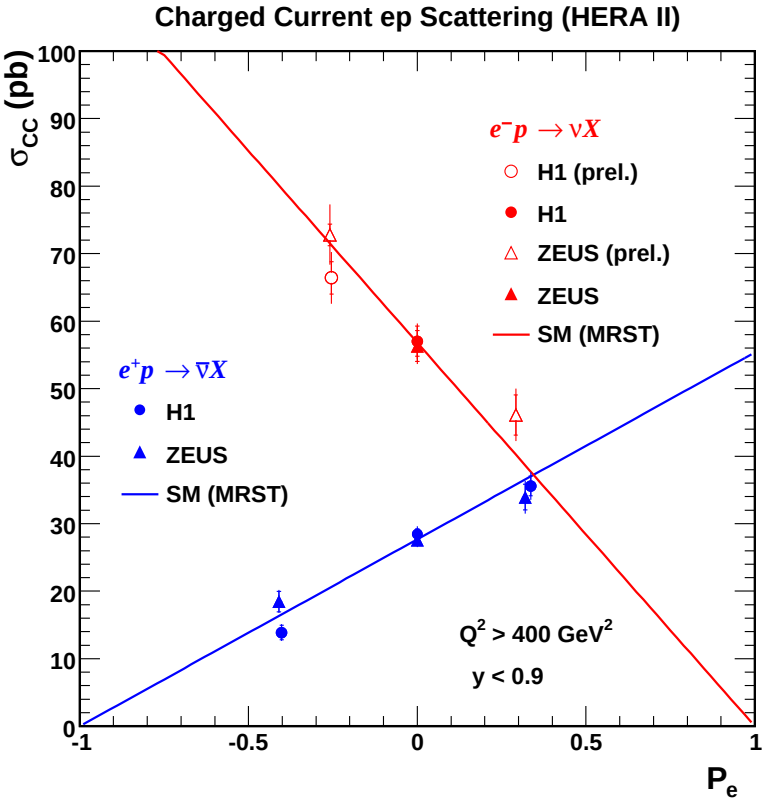
- e_L^+: 20 pb^{-1}, P = - 40%
- e_R^+: 15 pb^{-1}, P = + 32%
- e_L^-: 70 pb^{-1}, P = - 27%
- e_R^-: 40 pb^{-1}, P = + 33%



Testing the chiral structure of the weak interaction

Charged Current:

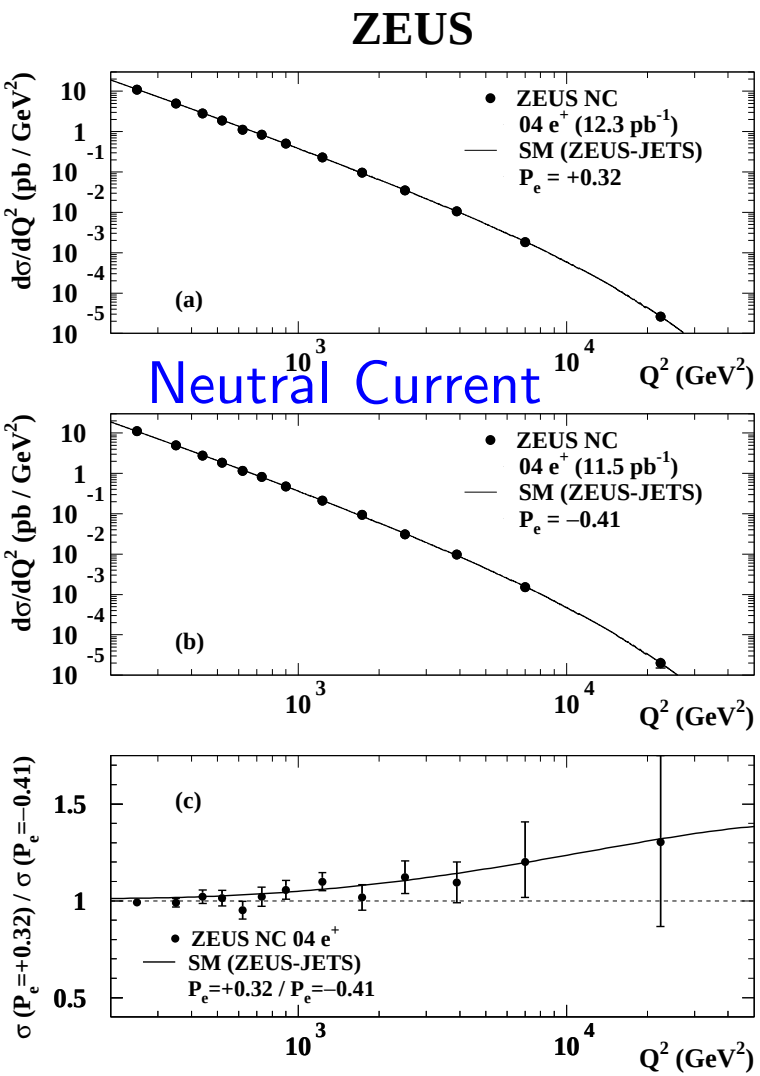
- weak interaction: only e_L^- (e_R^+)
- $\sigma_{CC}^{e^\pm p}(P) = (1 \pm P) \cdot \sigma_{CC}(P = 0)$
- good agreement with SM

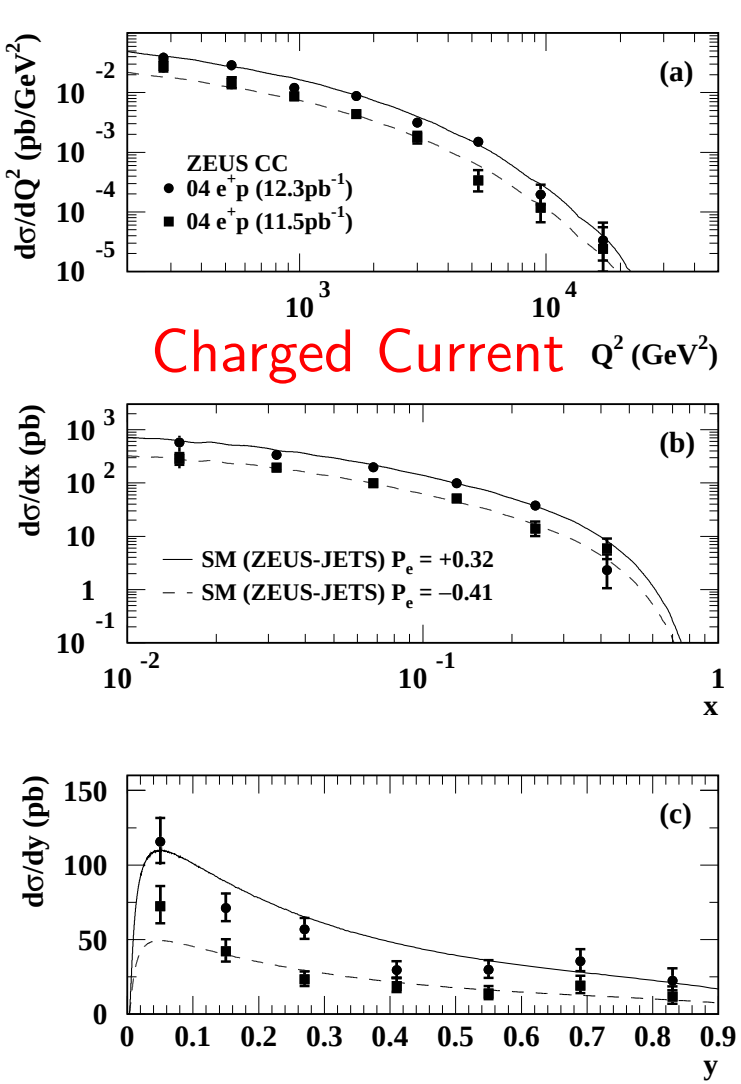


extrapolation to $P_{e^+} = -1$:

- $\sigma_{CC}^{\text{tot}} = -1.0 \pm 1.8_{\text{stat}} \pm 1.1_{\text{sys}}$ pb

Polarised differential cross–sections





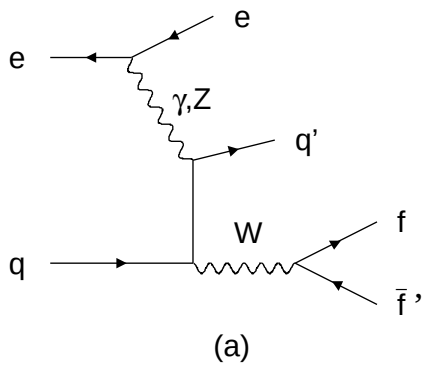
Single $W^{\pm}$ Production

Signature:

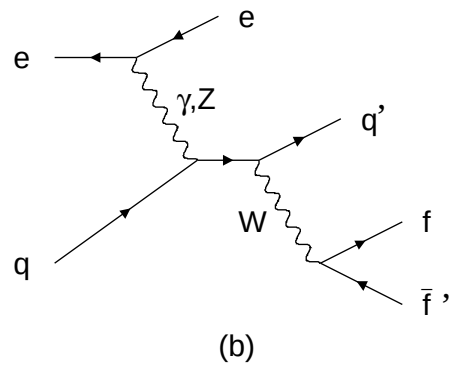
- isolated electron or muon
- missing transverse momentum

Backgrounds:

- NC with fake missing E_T
- CC with jet misidentified as lepton
- lepton pairs with one lepton lost in beam pipe



(a)



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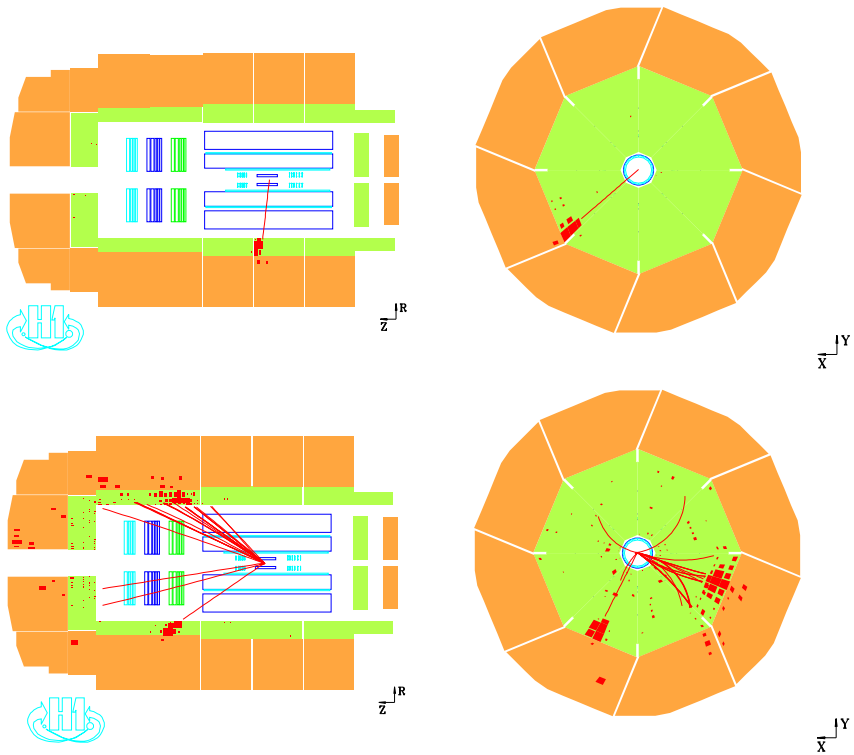

Single $W^{\pm}$ Production cont'd

ZEUS

- e^+p 99/00 + 03/04: 106 pb^{-1}
- isol. electrons, all P_T^X: 2 / 3 $\pm$ 0.39
- no excess at high P_T^X

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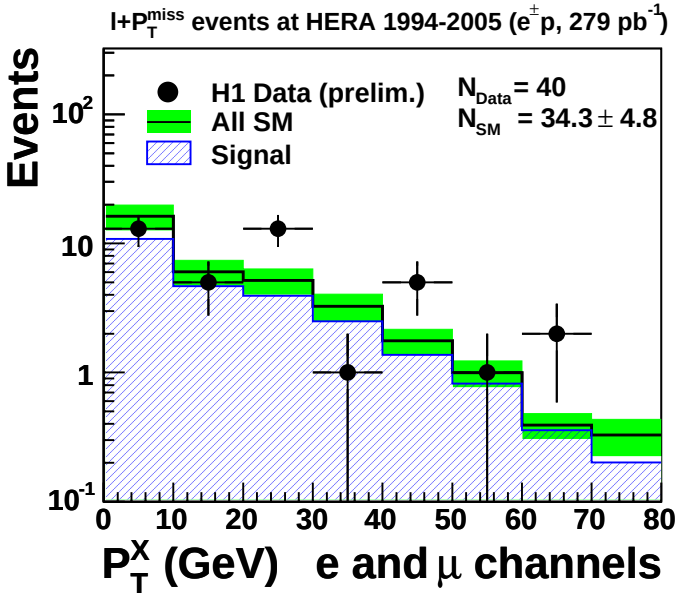
H1

- $e^{\pm}p$ 1994 – 2005: 279 pb^{-1}
- isol. e / μ, all P_T^X: 40 / 34.3 ± 4.8
- $P_T^X > 25$ GeV:
  - all data: 17 / 9.0 ± 1.5



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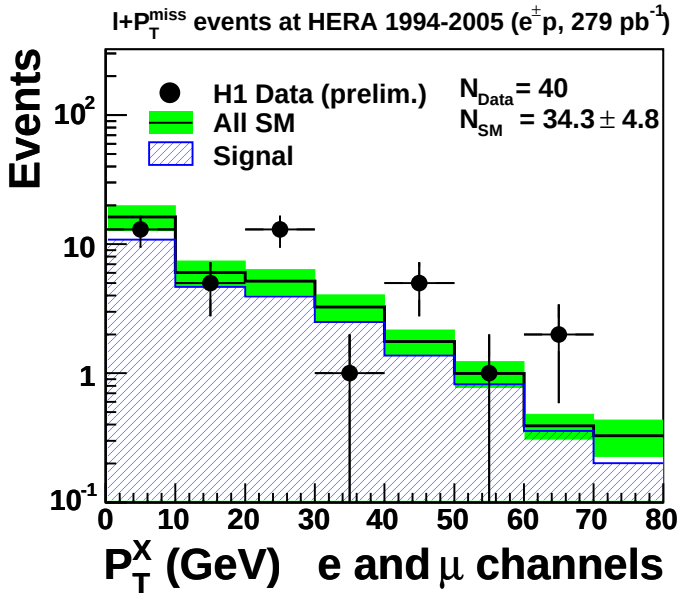
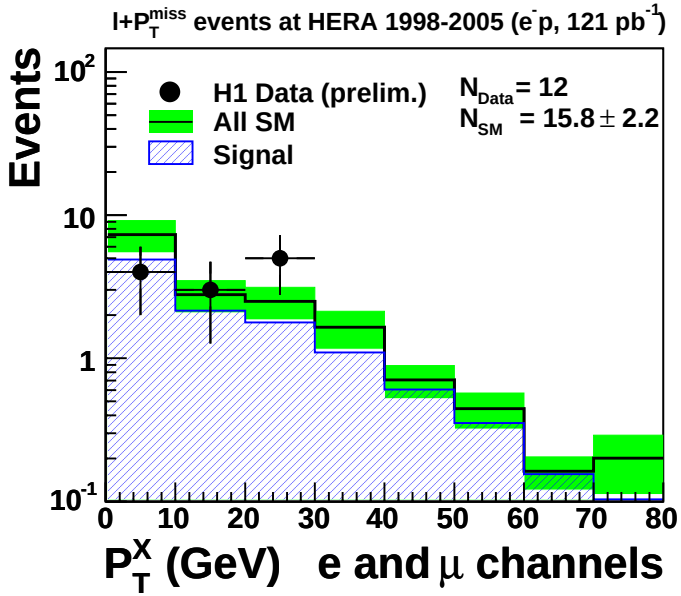
  - **agreement for e^-p: 2 / 4.4 ± 0.7**





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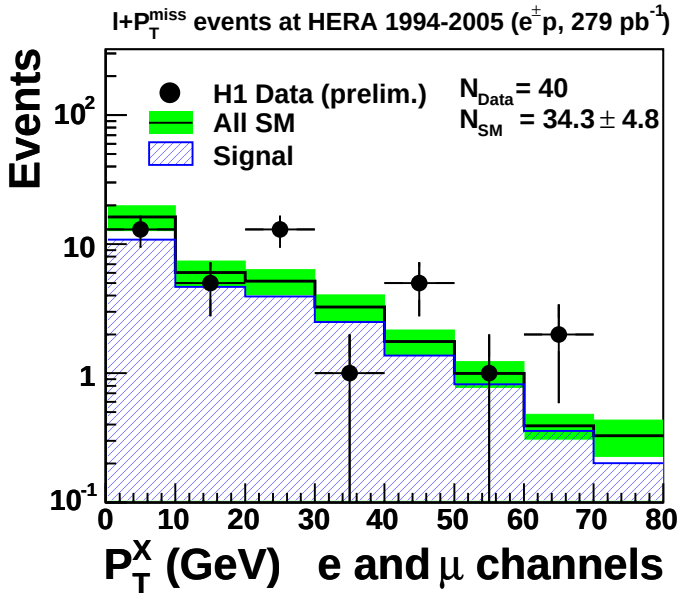
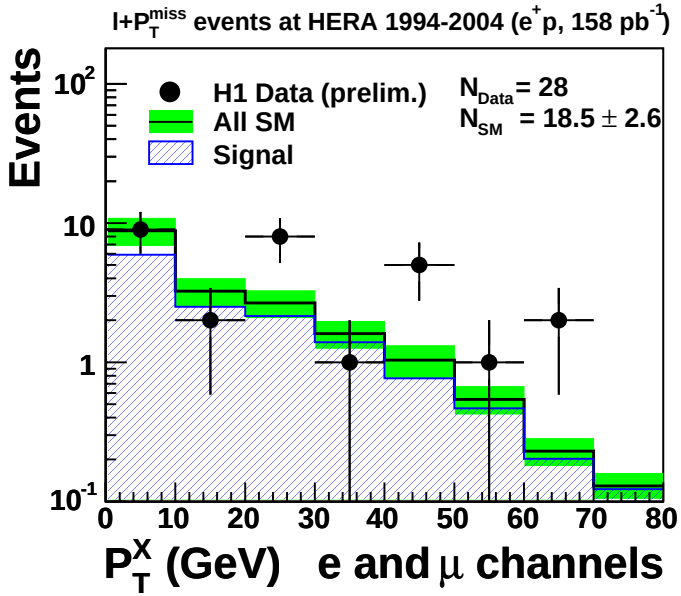
- $P_T^X > 25$ GeV:
  - all data: 17 / 9.0 ± 1.5
  - **agreement for e^-p: 2** / 4.4 ± 0.7
  - **excess in e^+p: 15** / 4.6 ± 0.8





Summary & Outlook

Summary

- first combined QCD & EW fit to HERA I data
- polarised cross–sections from HERA II
- single $W^{\pm}$ production still high at H1

Outlook

- all electroweak measurements will profit from
  - higher luminosity, esp. much more $e^{-}p$ data
  - electron / positron polarisation
- $\Rightarrow$ new results to come in the next years — stay tuned!