Imperial College London

Charged current DIS with polarised $e^{\pm}$ beams at HERA

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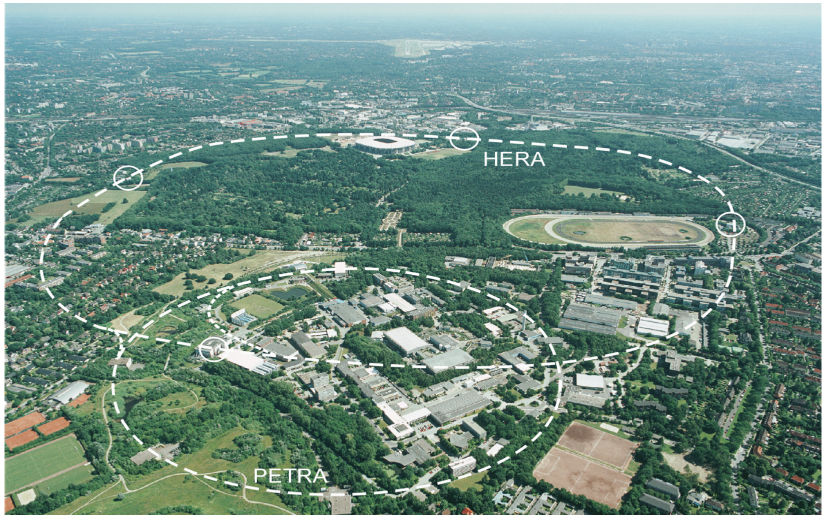
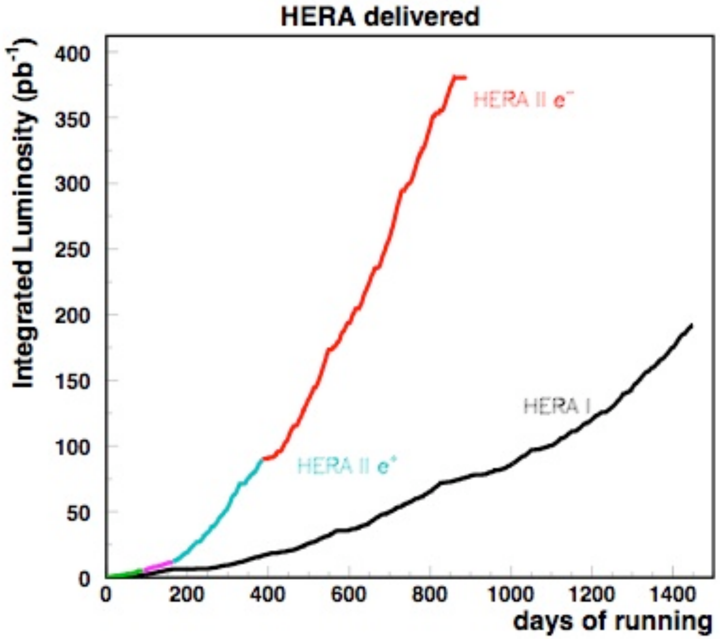
XXXIII INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

The HERA accelerator

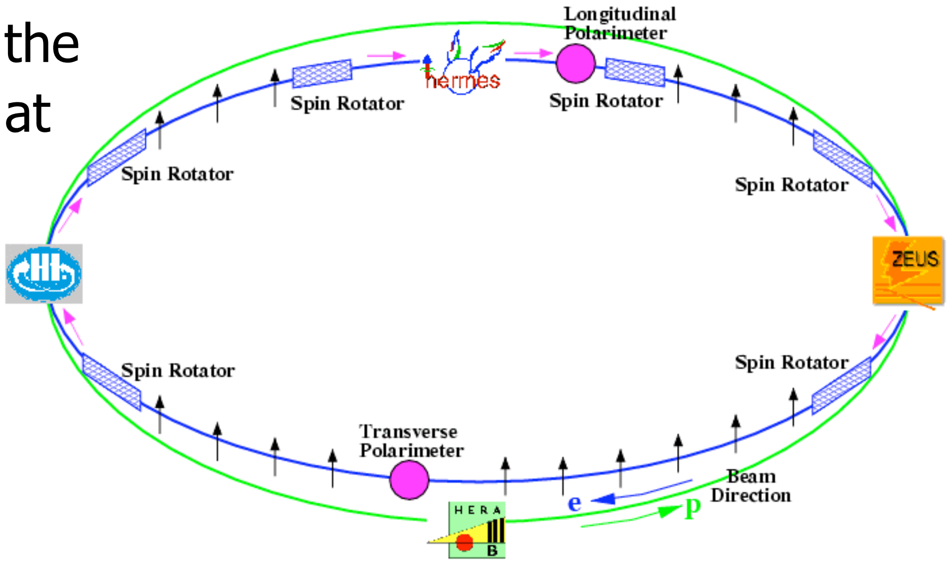




$\sqrt{s}$=320 GeV

Longitudinal polarisation at HERA

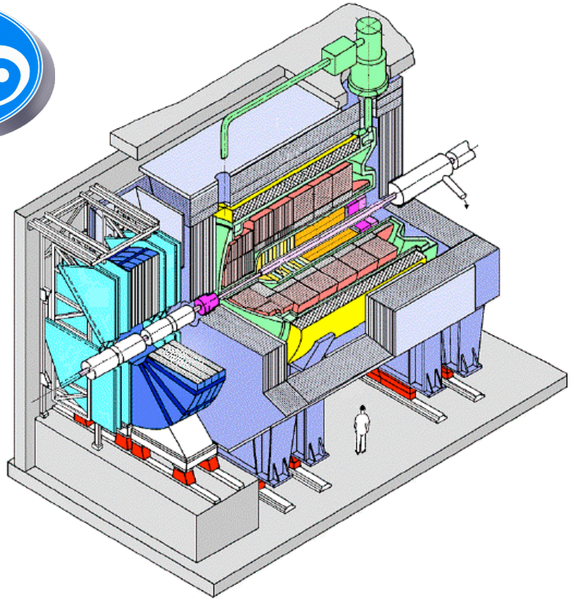
Longitudinal polarisation of the lepton beam at HERA: new at HERA II

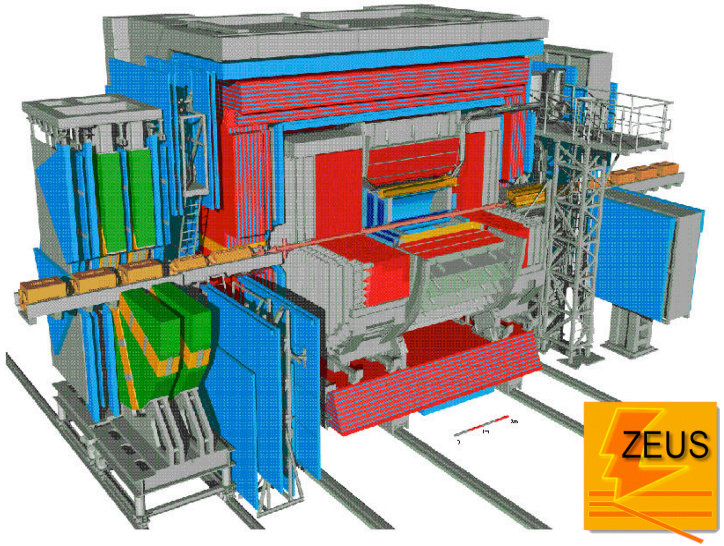


$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

- Transverse polarisation builds up naturally through synchrotron radiation (Sokolov-Ternov effect)
- Build-up time around 40 minutes at HERA
- Spin rotators flip transverse polarisation to longitudinal before interaction regions and back afterwards
- Polarisation measured by two independent Compton polarimeters (+ new one being commissioned currently)

The H1 and ZEUS detectors

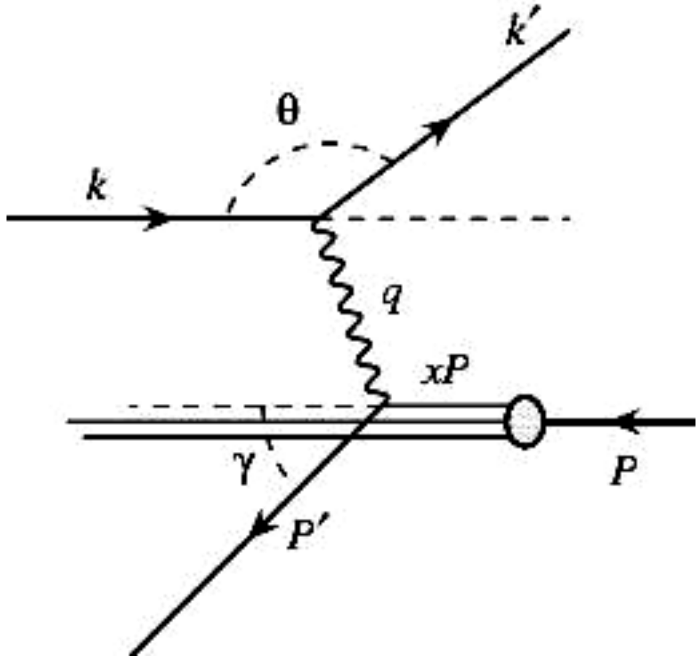




- LAr calorimeter (45000 cells)
- EM $$\frac{\sigma(E)}{E} = \frac{12\%}{\sqrt{E}} \oplus 1\%$$
- HAD $$\frac{\sigma(E)}{E} = \frac{50\%}{\sqrt{E}} \oplus 1\%$$

- DU calorimeter (6000 cells)
- EM $$\frac{\sigma(E)}{E} = \frac{18\%}{\sqrt{E}}$$
- HAD $$\frac{\sigma(E)}{E} = \frac{35\%}{\sqrt{E}}$$

Deep inelastic scattering at HERA



Two deep inelastic scattering processes:

— Neutral current: exchange of γ or Z^0
See talk by V. Chekelian

— Charged current: exchange of $W^{\pm}$
The topic of this talk

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

$$x = \frac{Q^2}{2p \cdot q} \qquad y = \frac{p \cdot q}{p \cdot k}$$

$$s = (p + k)^2 \qquad Q^2 = x \cdot y \cdot s$$

Q^2 is the probing power
x is the Bjorken scaling variable
y is the inelasticity

Charged current DIS at HERA

CC e^+p cross section:

Sensitive to density of d quark

$$\frac{d^2\sigma^{CC}(e^+p)}{dxdQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \underbrace{\left[\bar{u}+\bar{c}+(1-y)^2(d+s)\right]}_{\tilde{\sigma}(x,Q^2)/x}$$

CC e^-p cross section:

$$\frac{d^2\sigma^{CC}(e^-p)}{dxdQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \overbrace{\left[u+c+(1-y)^2(\bar{d}+\bar{s})\right]}^{\tilde{\sigma}(x,Q^2)/x}$$

Sensitive to density of u quark

Electron/positron-proton collisions probe different quark content of proton

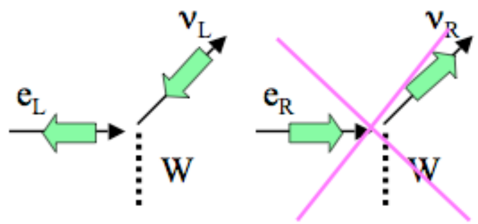
Big difference in cross section magnitude
— u-quark density larger than d-quark
— d-quark contribution suppressed by helicity factor $(1-y)^2$

Polarised charged current DIS

- Polarisation is asymmetry of helicity states

$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

- Helicity = chirality (neglecting masses)
- Can use polarised beams to directly test chiral structure of the Standard Model
- Standard Model weak interaction left-handed
  - only LH particles (RH anti-particles) interact



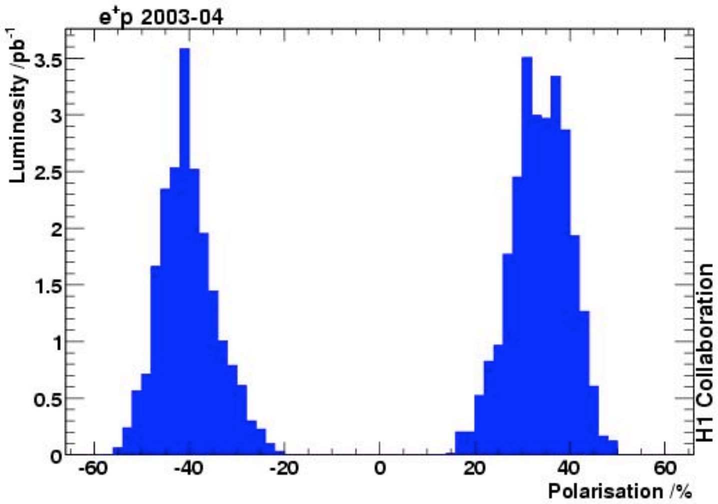
CC cross section modified by P_e:

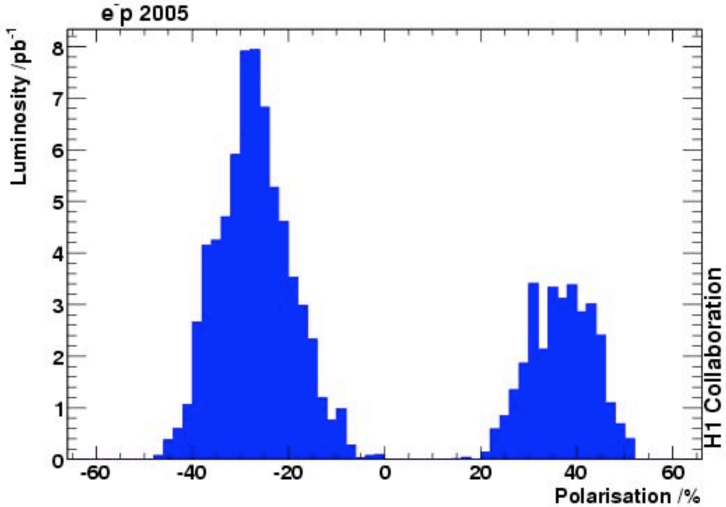
$$\sigma_{CC}^{e^\pm p}(P_e) = (1 \pm P_e) \cdot \sigma_{CC}^{e^\pm p}(P_e = 0)$$

Polarisation scales P_e=0 cross section linearly - clear and large effect at HERA

Standard Model predicts zero cross section for P_e=+1(-1) in $e^{-(+)}$p scattering

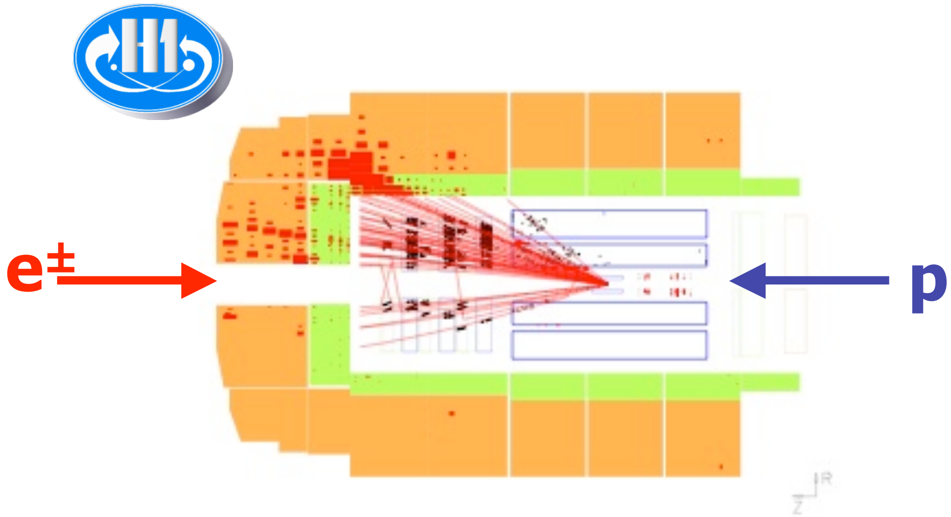
Data samples: luminosities and polarisations

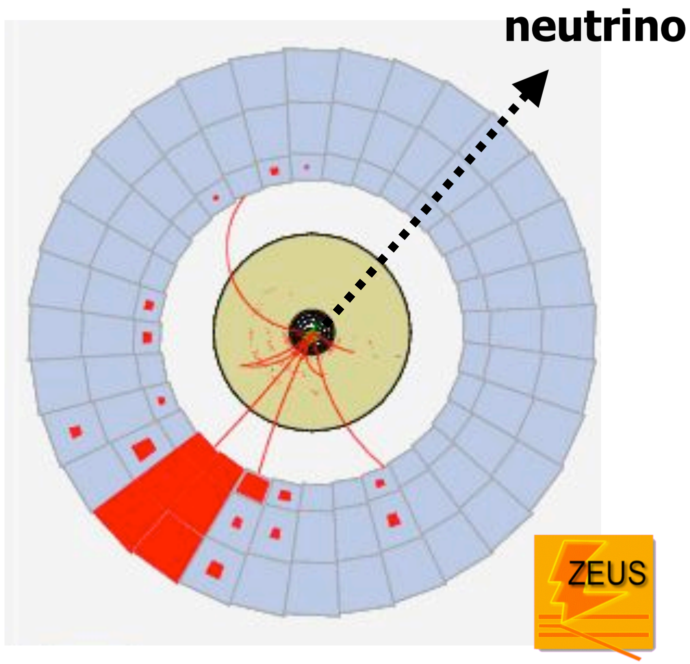




Data sample	H1		ZEUS	
	$P_e<0$	$P_e>0$	$P_e<0$	$P_e>0$
e^+p	$P_e=-0.40\pm0.01$ $L = 20.7$ pb^{-1}	$P_e=+0.34\pm0.01$ $L = 26.9$ pb^{-1}	$P_e=-0.41\pm0.01$ $L = 11.5$ pb^{-1}	$P_e=+0.32\pm0.01$ $L = 12.3$ pb^{-1}
e^-p	$P_e=-0.27\pm0.01$ $L = 68.6$ pb^{-1}	$P_e=+0.37\pm0.02$ $L = 29.6$ pb^{-1}	$P_e=-0.27\pm0.01$ $L = 78.8$ pb^{-1}	$P_e=+0.33\pm0.02$ $L = 42.7$ pb^{-1}

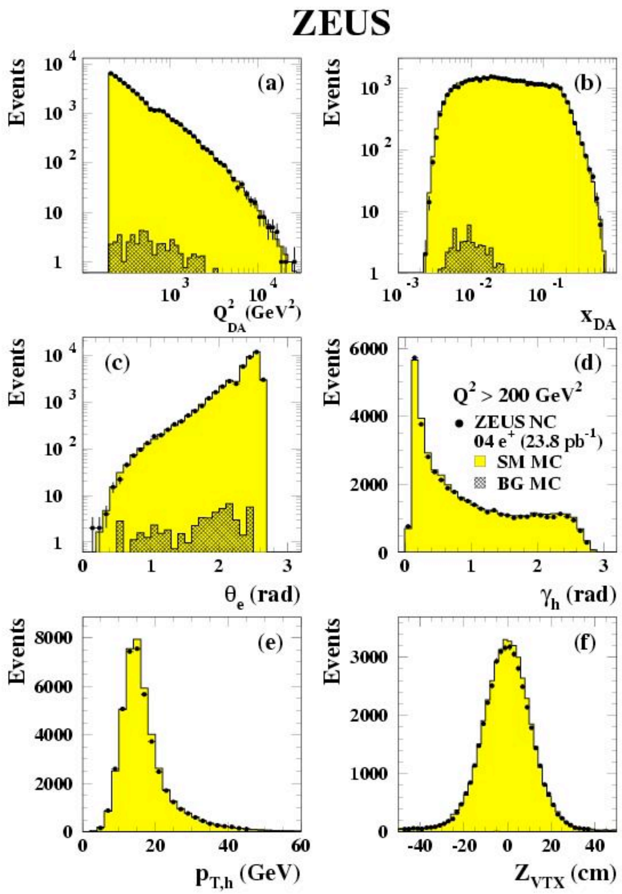
Charged current events

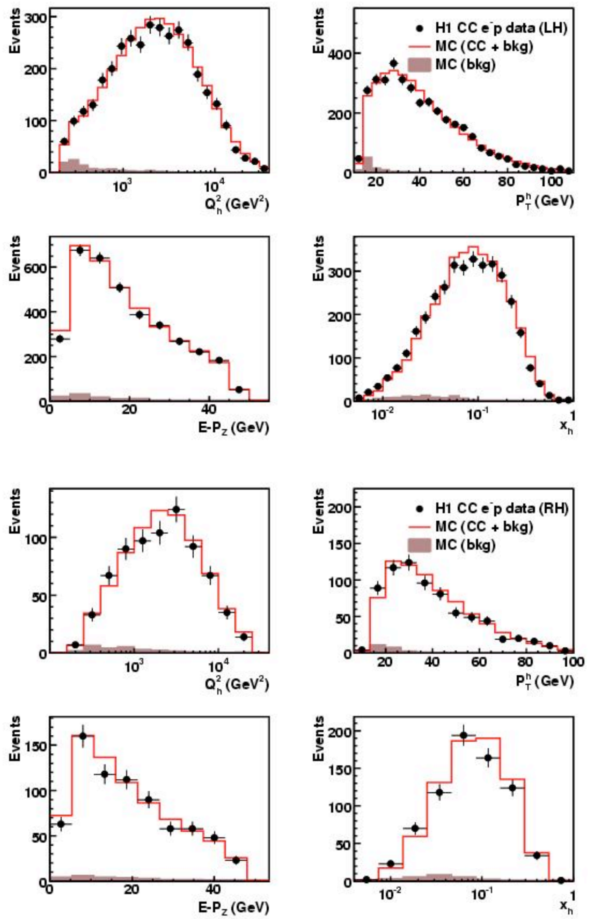




- Neutrino escapes undetected
- CC candidate events selected using missing E_T
- Topological cuts to remove non-ep backgrounds
- ep backgrounds estimated by MC and subtracted
  - Typically around 1%

Detector calibration

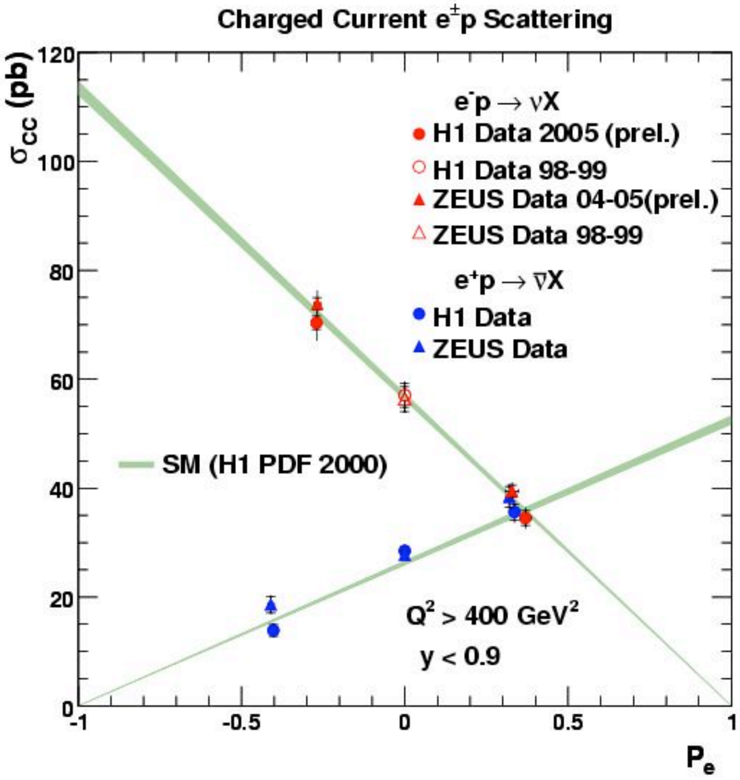


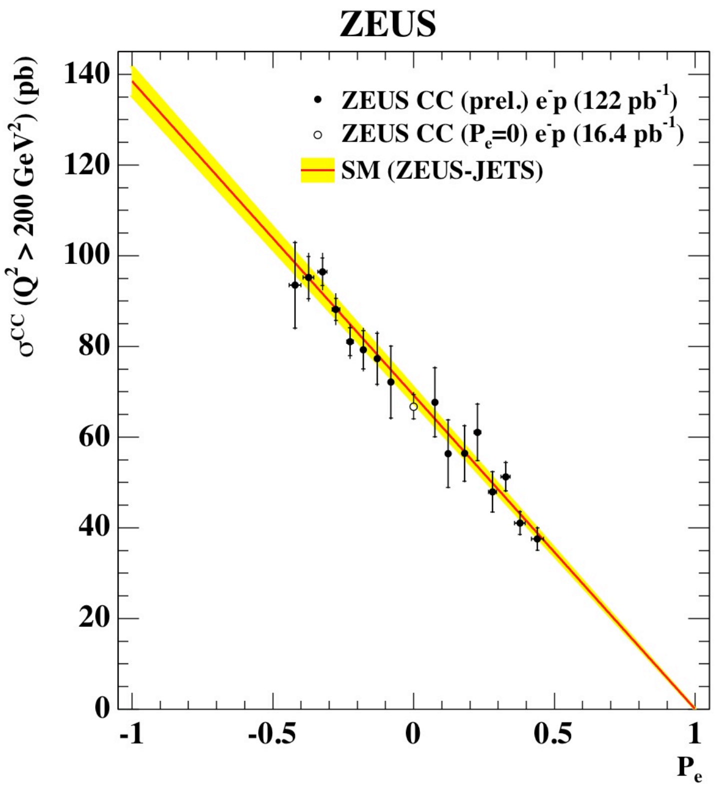


Only the hadronic final state available to reconstruct the event

- Excellent understanding of detector effects necessary
- Use high statistics NC DIS samples to calibrate detectors

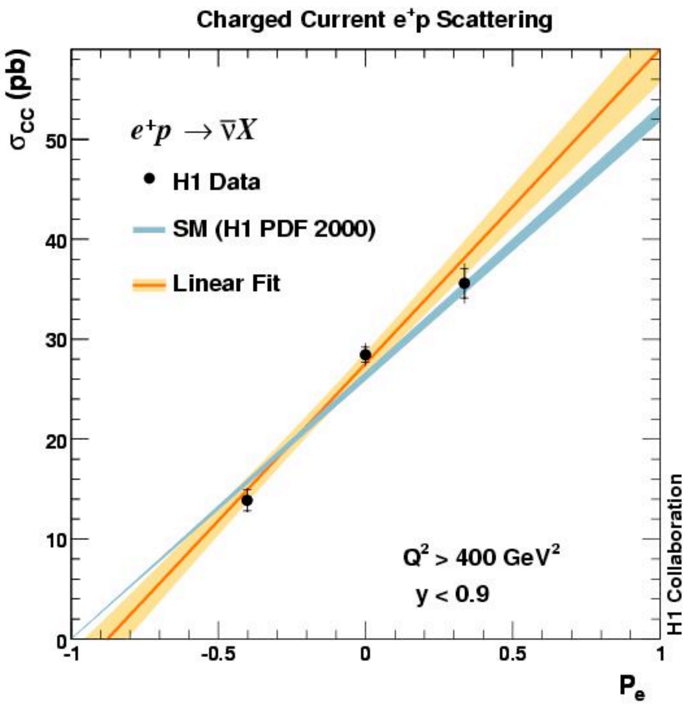
Dependence on P_e

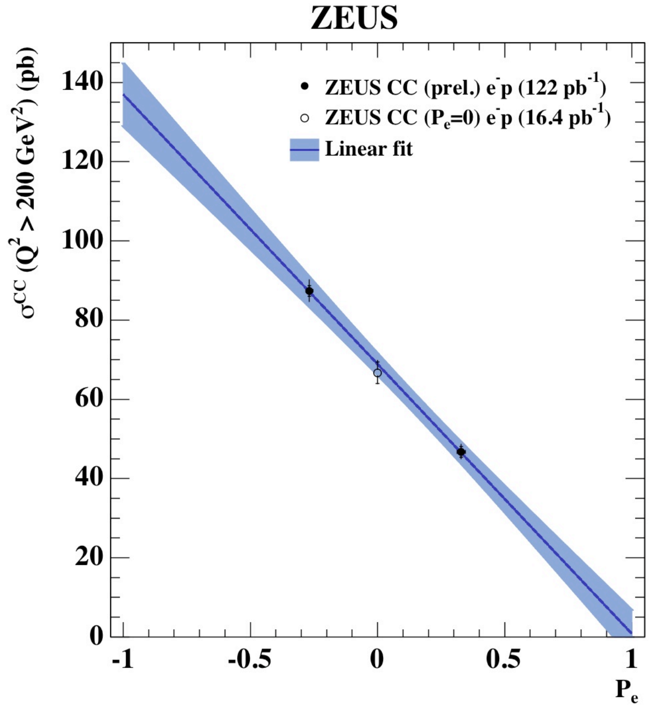




- Clearly demonstrate linear dependence on P_e
- Consistent with SM predictions
- Direct sensitivity to W_R ➔ next slide

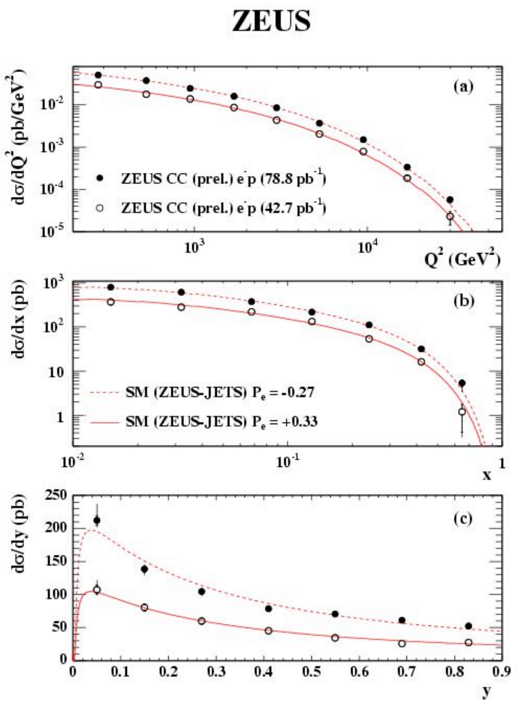
W_R mass limit

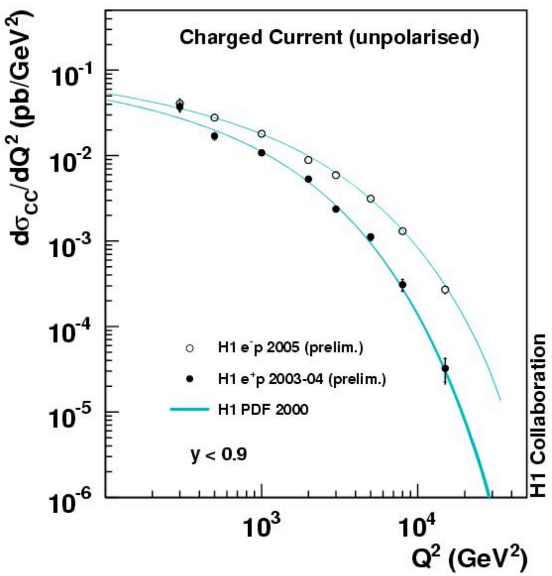




- Linear fit to P_e dependence gives cross section limit at P=-1(+1) for $e^{+(-)}p$
- Assume g_R=g_L and ν_R is light
- Cross section limit at P=-1(+1) for $e^{+(-)}p$ gives lower limit on mass of W_R
  - M_{WR}> 186 GeV @ 95% CL (from H1 e^-p)
  - M_{WR}> 180 GeV @ 95% CL (from ZEUS e^-p)
  - M_{WR}> 208 GeV @ 95% CL (from H1 e^+p)

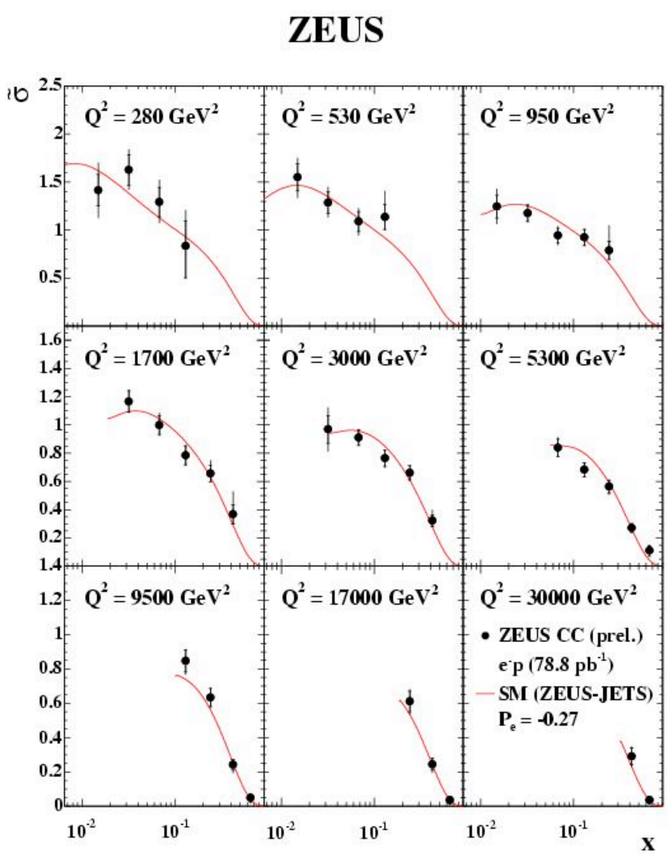
Single differential cross sections

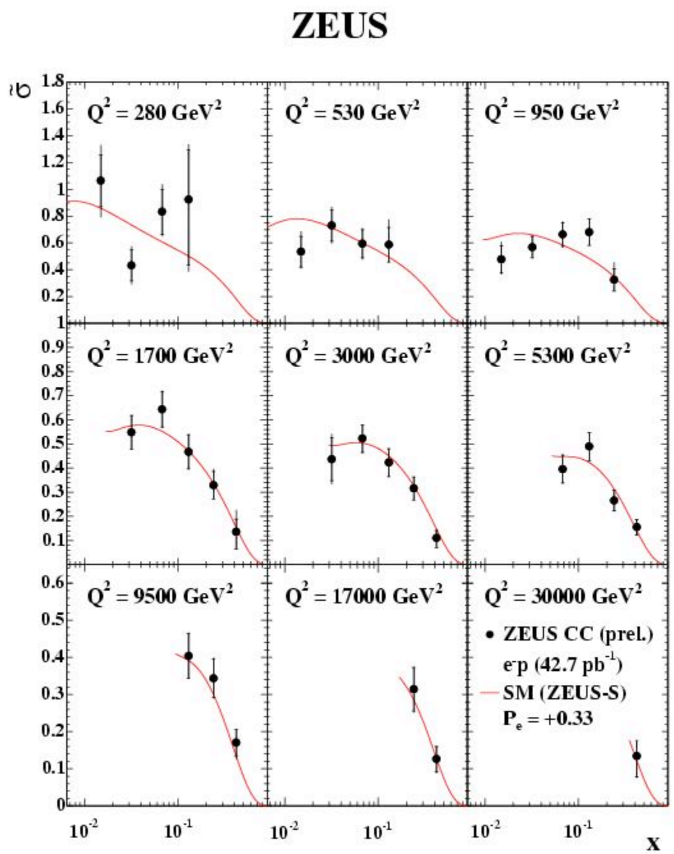




- Cross sections as a function of Q^2, x and y
  - Clear difference between different polarisations
  - Independent of kinematic variables as predicted by the SM
- Combine polarised samples to give unpolarised cross sections
  - Clear difference between e^-p and e^+p as predicted by SM

Double differential cross sections





- Reduced cross section = PDF content
- Measured with much higher precision than ever before in charged current DIS
- Input to QCD and EW fits ➔ see talk by Y. Ri

Summary and future prospects

- Charged current DIS with longitudinally polarised lepton beams measured
  - first e^+p results published (H1: PLB 634 (2006) 173 ZEUS: PLB 637 (2006) 210)
  - e^-p results preliminary
- Measurements in good agreement with Standard Model
- Set limit of M_{WR}>208 GeV
- Still more data to analyse in e^-p scattering
- More data to come in e^+p scattering
- Higher precision measurements to come