Neutral & Charged Current Cross Sections at High Q^2 From HERA

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- HERA: QCD & EW Sensitivity
- Neutral Current Cross Sections
- Charged Current Cross Sections

Eram Rizvi

Queen Mary
University of London

Deep Inelastic Scattering

$$\frac{d\sigma^{\pm}_{NC}}{dxdQ^2} \approx \frac{e^4}{8\pi x}\left[\frac{1}{Q^2}\right]^2 \left[Y_+\tilde{F}_2 \mp Y_- x\tilde{F}_3 - y^2\tilde{F}_L\right]$$

$$\frac{d\sigma^{\pm}_{CC}}{dxdQ^2} \approx \frac{1 \pm P_e}{2}\frac{g^4}{64\pi x}\left[\frac{1}{M_W^2 + Q^2}\right]^2 \left[Y_+\tilde{W}_2^{\pm} \mp Y_- x\tilde{W}_3^{\pm} - y^2\tilde{W}_L^{\pm}\right]$$

Modified at high Q^2 by Z propagator

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

$\tilde{F}_2 \propto \sum (xq_i + x\bar{q}_i)$ dominant contribution

$x\tilde{F}_3 \propto \sum (xq_i - x\bar{q}_i)$ only sensitive at high Q^2

$\tilde{F}_L \propto \alpha_s \cdot xg(x, Q^2)$ only sensitive at low Q^2 and high y

similarly for $W_2^{\pm}$, $xW_3^{\pm}$ and $W_L^{\pm}$

For purely weak CC interaction xW_3 contributes over full phase space

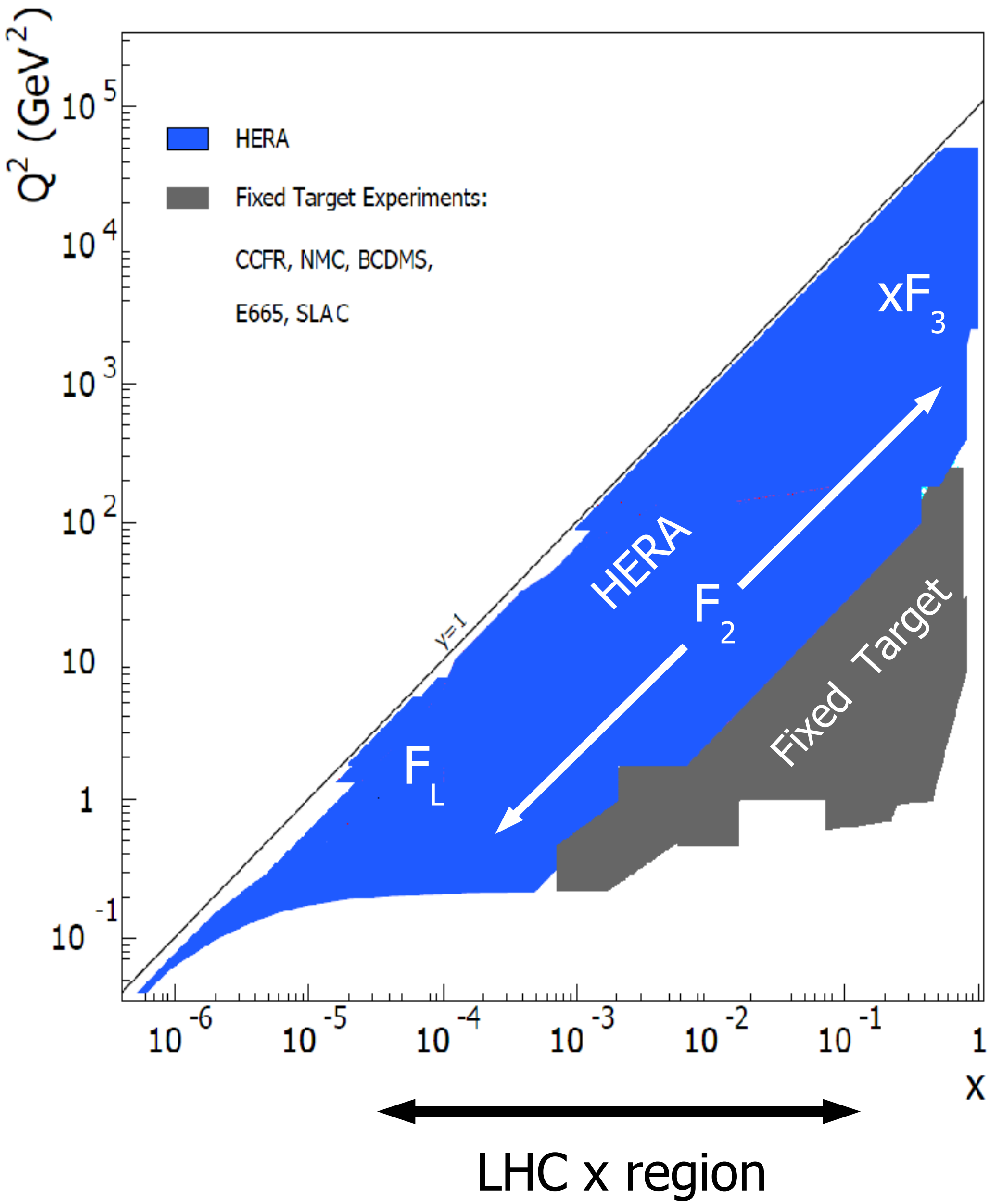
Structure functions parameterise proton structure: how far from point like

For pointlike proton: $\frac{d^2\sigma_{NC}}{dxdQ^2} = \frac{e^4}{8\pi x}\frac{1}{Q^4}Y_+$

SM predicts CC cross section $\frac{d^2\sigma^{\pm}_{CC}}{dxdQ^2} \propto \frac{1 \pm P_e}{2}$ linear scaling of cross section zero for LH e^+ or RH e^-

$P_e=-1$ $\quad$ $P_e=+1$

HERA Kinematics



HERA has large kinematic reach

QCD understanding needed across full x, Q^2 range

NC process: EW physics lies at high Q^2

CC process: purely weak - flavour info for PDFs

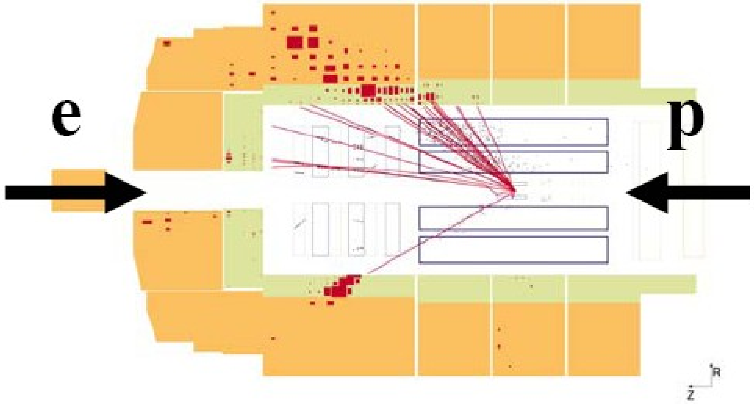
- Measure cross sections
- Fit data – extract PDFs & EW physics

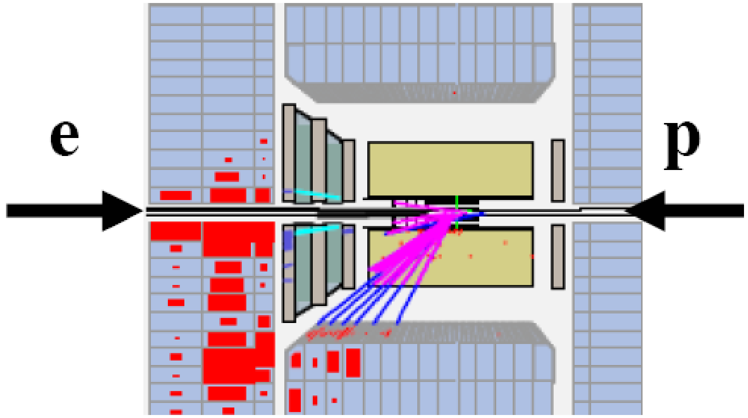
HERA PDFs extrapolate into LHC region

LHC probes proton structure where gluon dominates (gluon collider)

HERA data crucial in calculations of new physics & measurements at LHC

NC & CC Event Selection





Neutral current event selection:

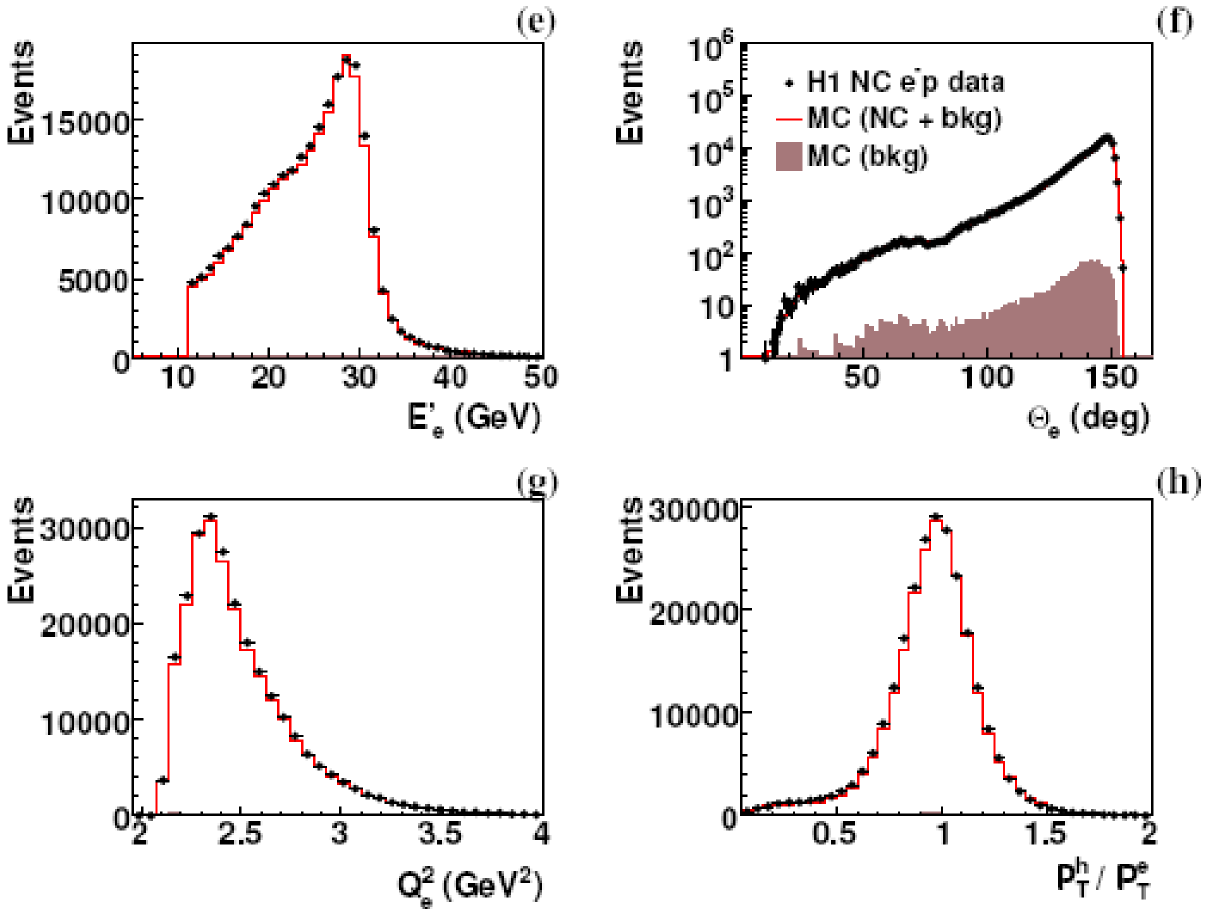
- High P_T isolated scattered electron/positron
- Suppress huge phototproduction background by imposing longitudinal energy-momentum conservation
- Kinematics may be reconstructed in many ways: energy/angle of hadrons & scattered lepton provides excellent tools for sys cross checks
- Removal of scattered lepton provides a high stats "pseudo-charged current sample" Excellent tool to cross check CC analysis
- Final selection: ~10^5 events per sample

Charged current event selection:

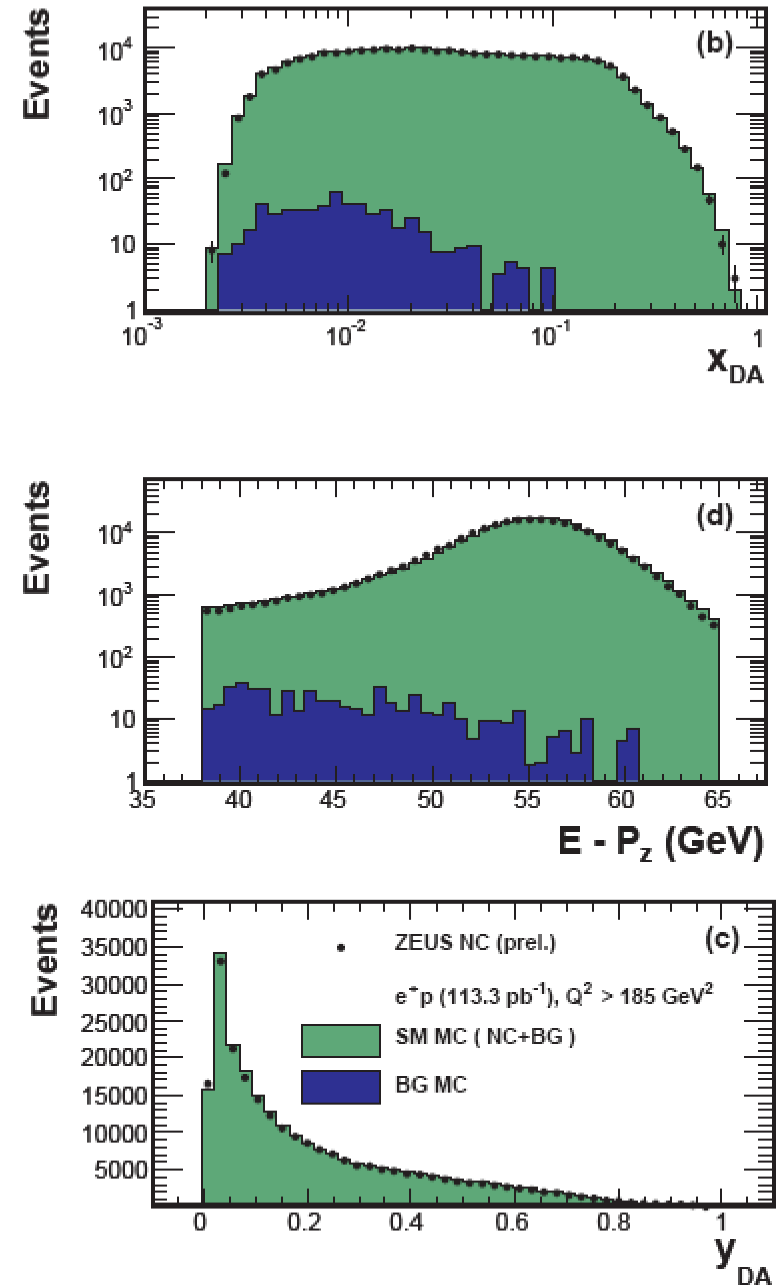
- Large missing transverse momentum (neutrino)
- Suppress huge phototproduction background
- Topological finders to remove cosmic muons
- Kinematics reconstructed from hadrons
- Final selection: ~10^3 events per sample

NC - Control Distributions

e^-p H1



e^+p ZEUS



NC control distributions for data & simulation
Good description

NC - Lepton Charge Asymmetry

$\tilde{\sigma} \approx F_2$ at low Q^2 $\quad xq + x\bar{q}$

~3% precision achieved

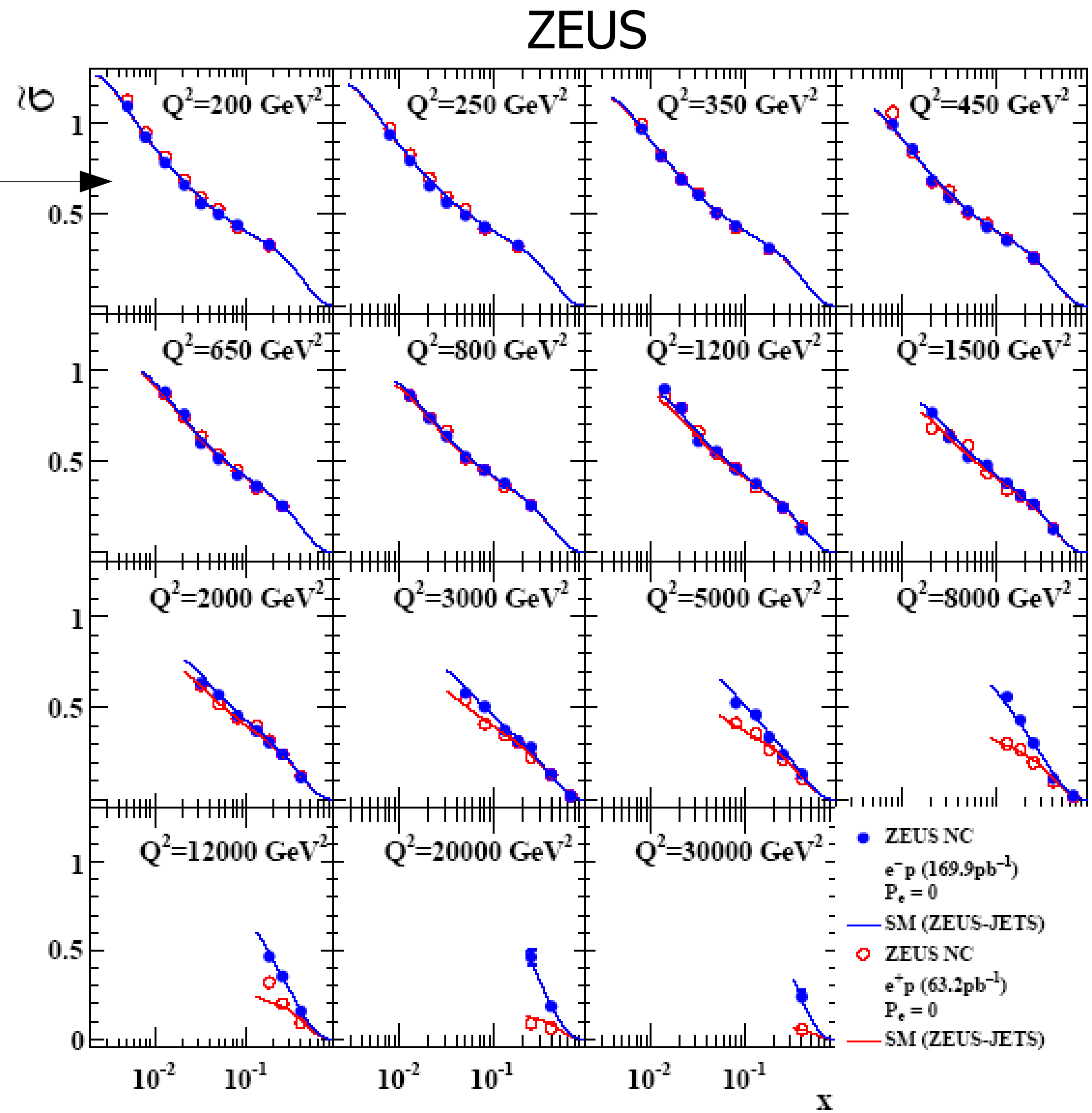
Lepton charge asymmetry in NC due to xF_3 structure function

Sensitive to combination

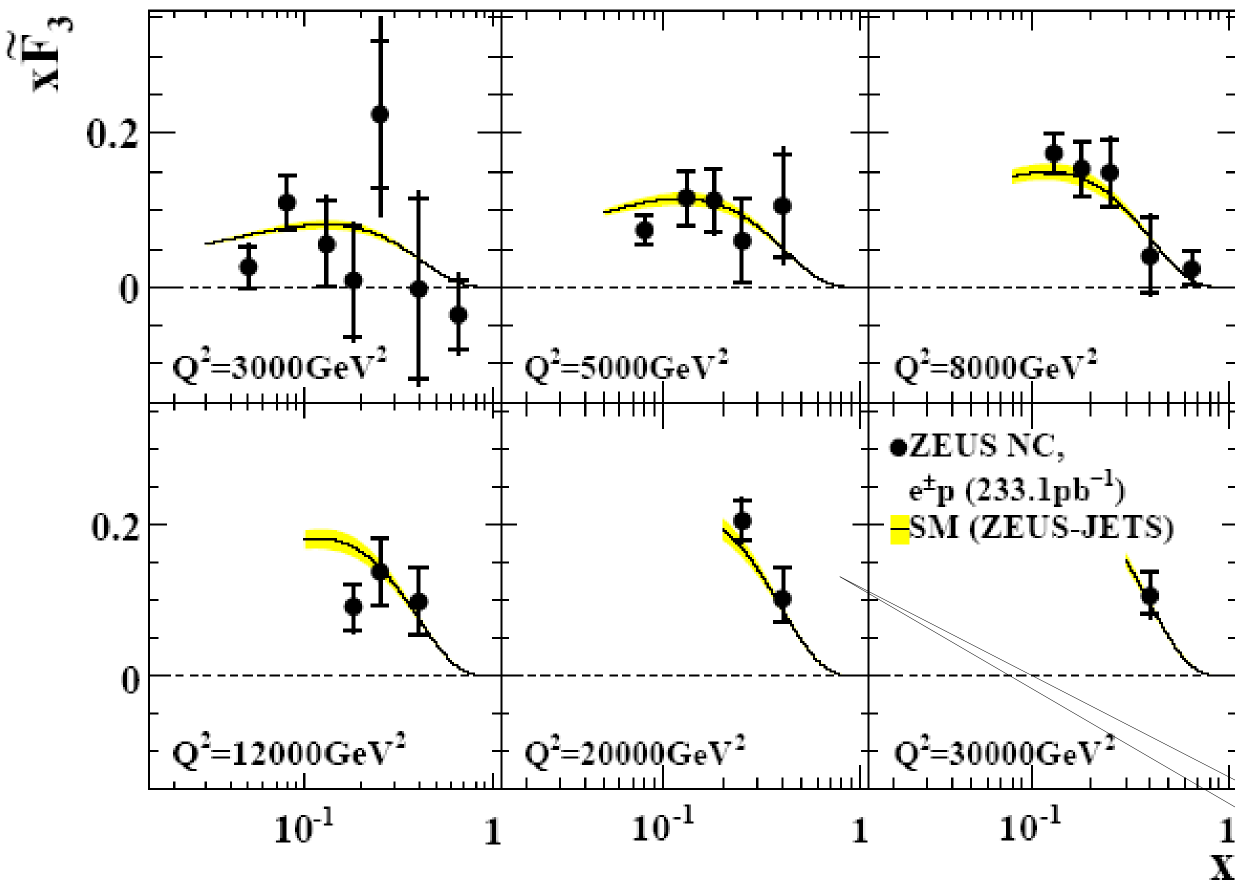
$xq - x\bar{q}$

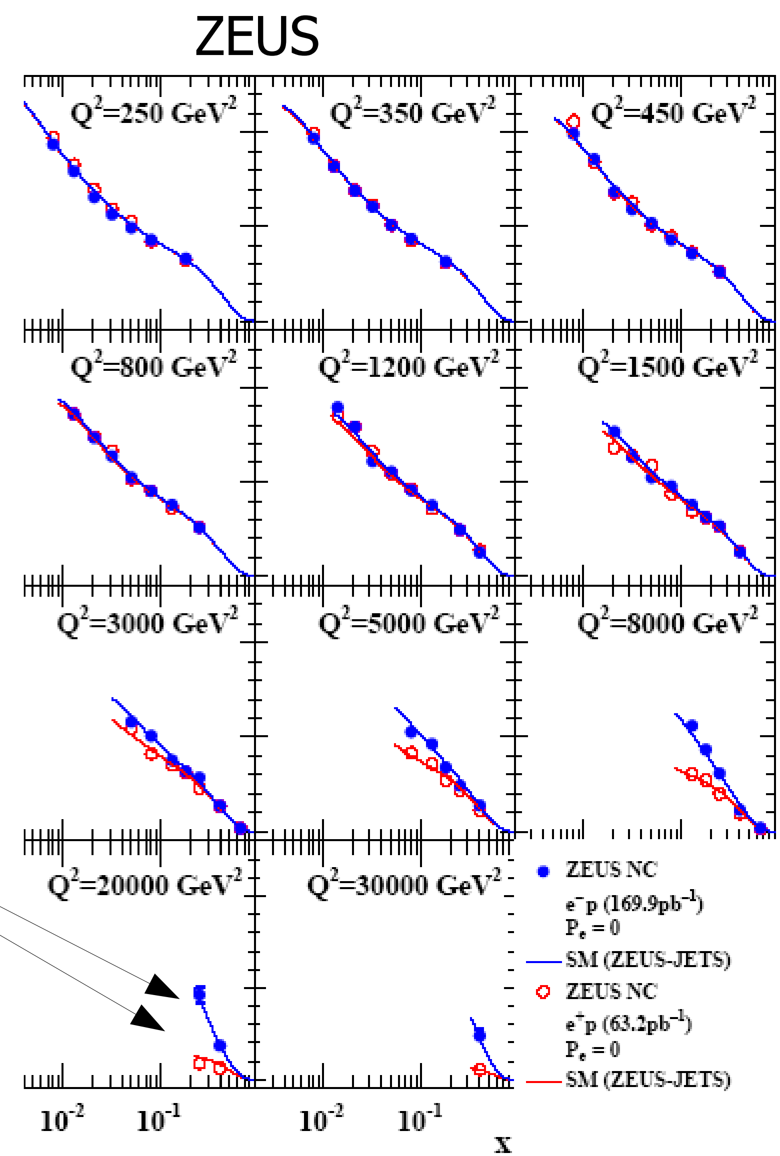
Measures valence quark distributior

Clearly seen as Q^2 approaches M_Z^2



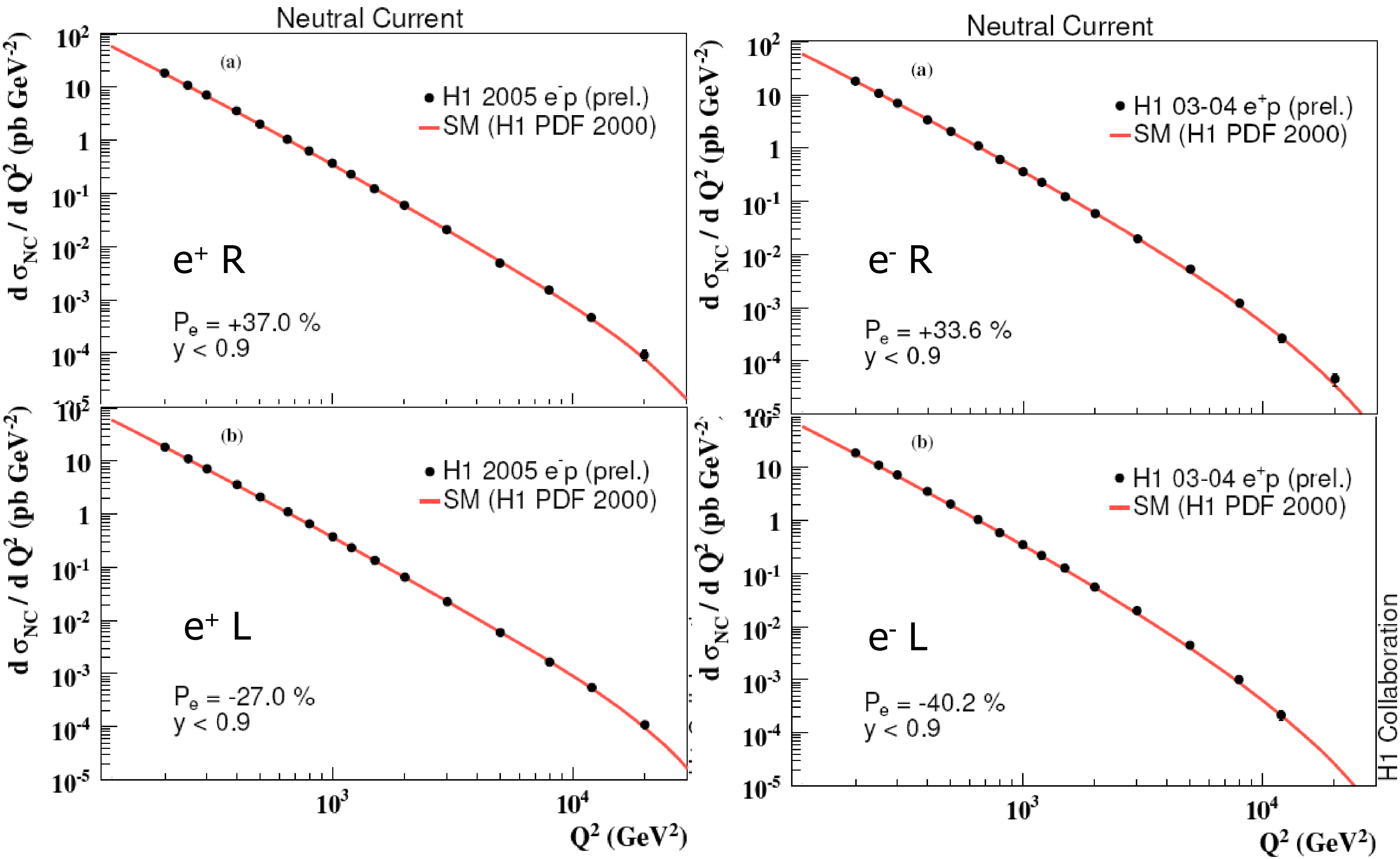
NC - Lepton Charge Asymmetry





e^-p = 170 pb^{-1}
factor 3 improvement e^+p sample to come

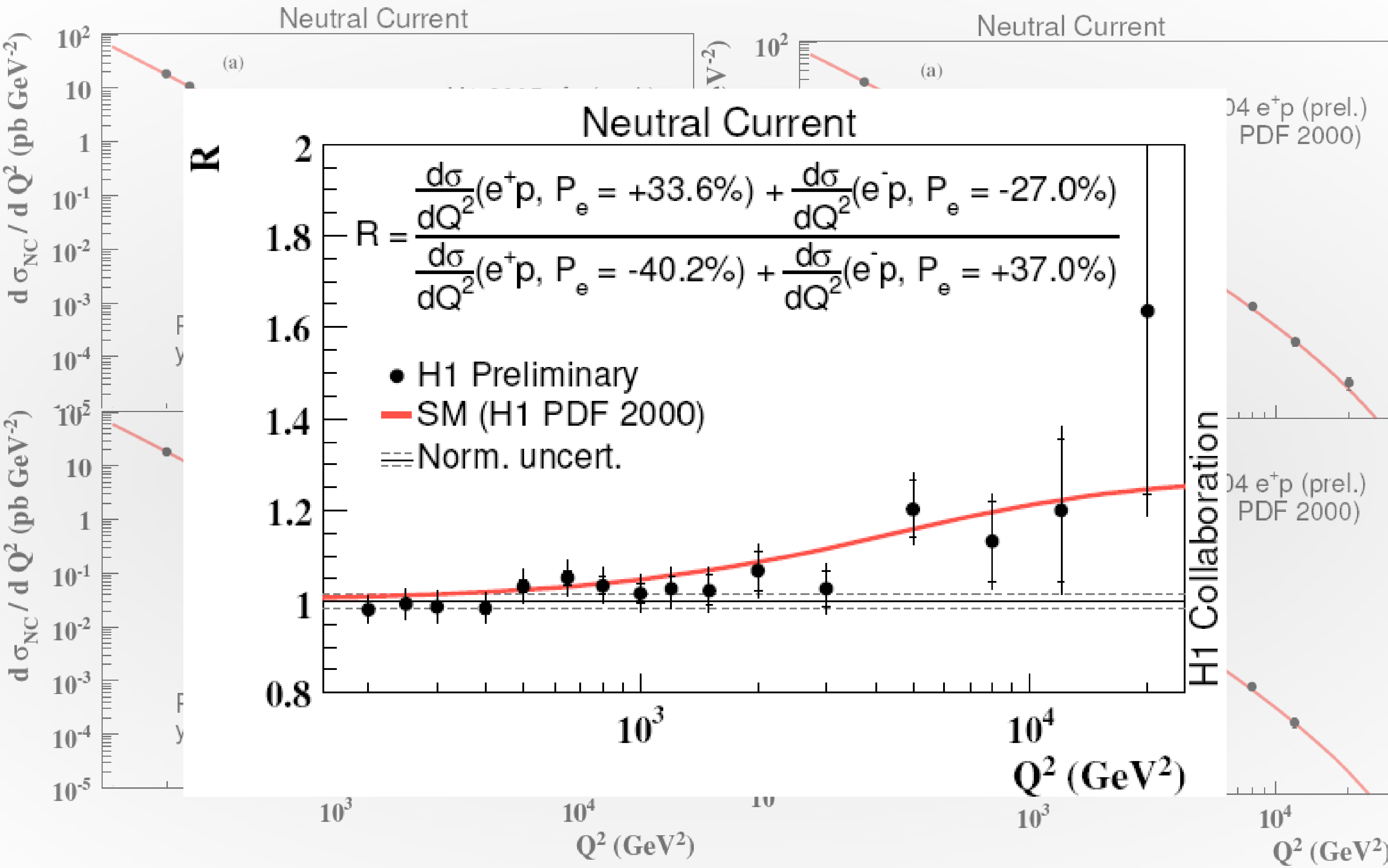
NC - Polarised Leptons



F_2 dominates below EW scale - photon exchange

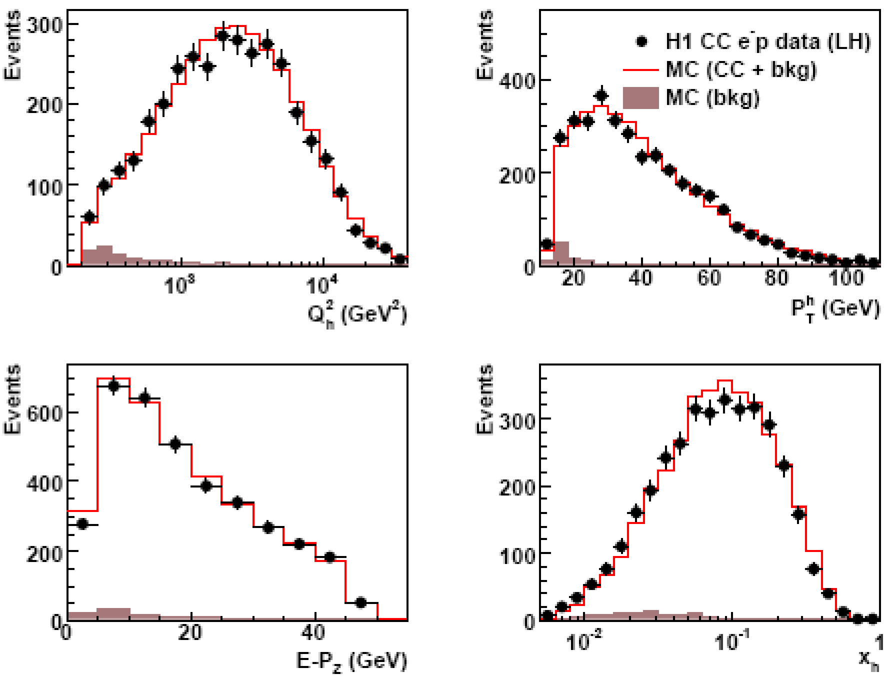
sensitvity to EW parts of xF_3 & F_2 from γ/Z^0 interference

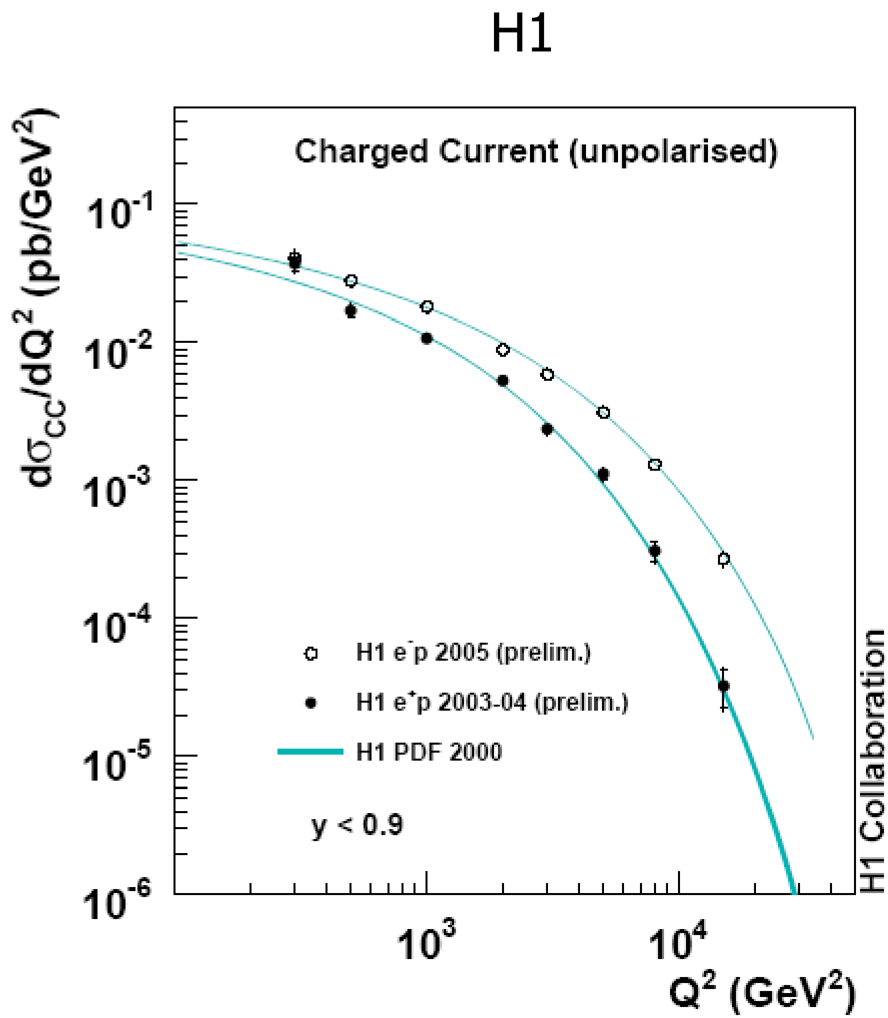
NC - Polarised Leptons



Data consistent with SM expectation - limited at high Q^2 by stat precision
H1 analysis of ~50% of total luminosity

CC - e±p scattering





CC cross section described by SM
difference between e^+ and e^- scattering due to different quarks

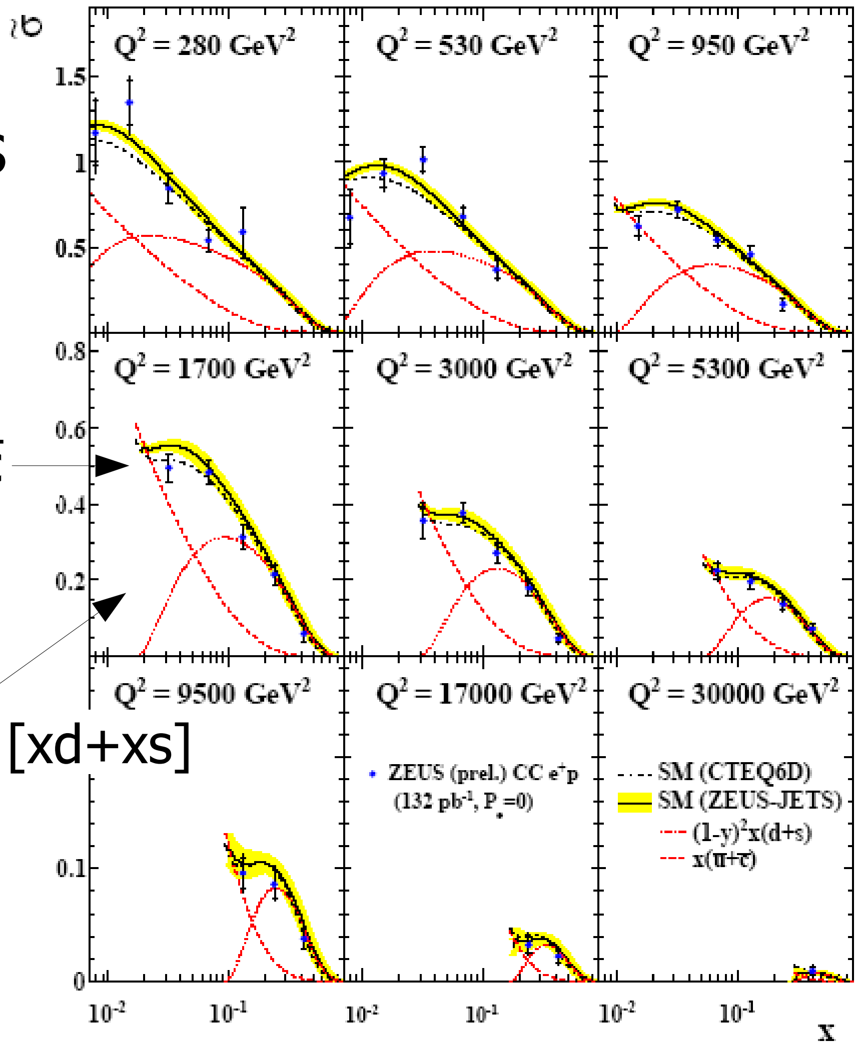
CC - $e^{\pm}p$ scattering

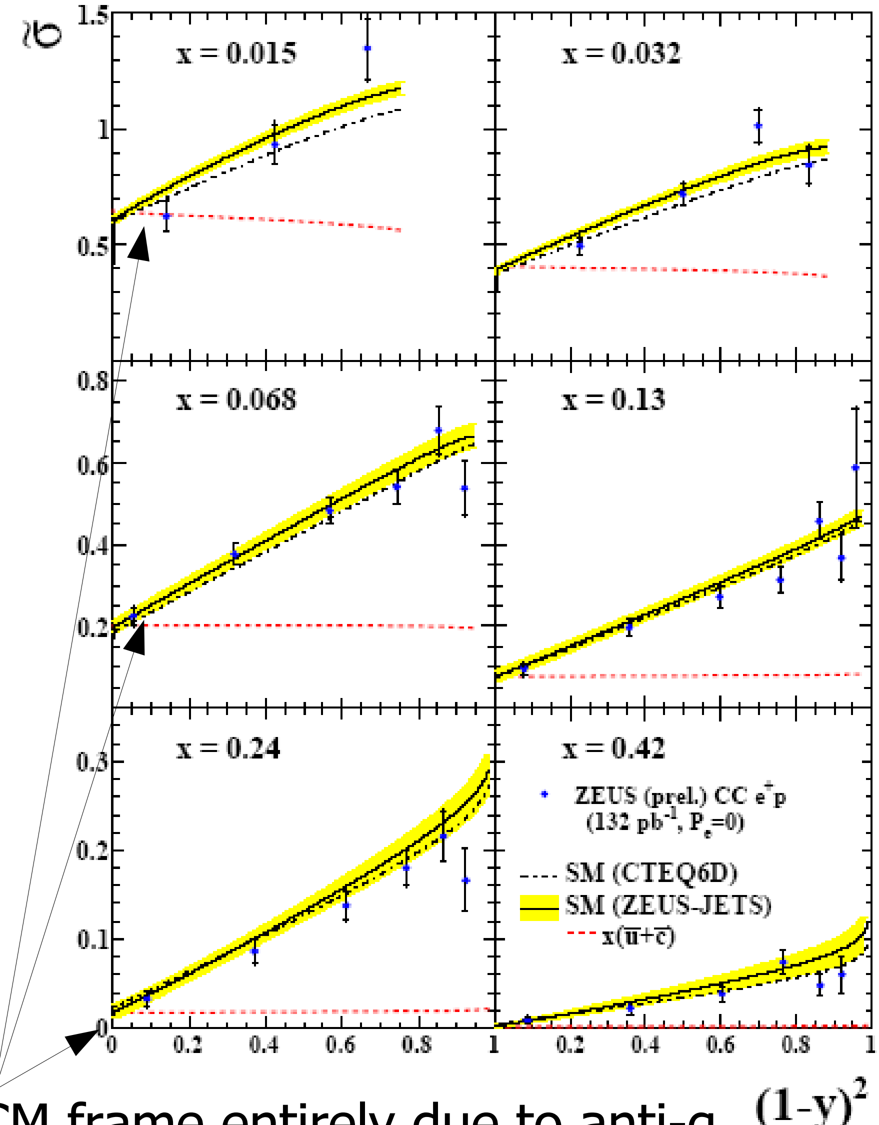
CC interaction allows clean flavour decomposition
CC e^{+} determines d quark density at high x (little sensitivity from NC)

ZEUS

$x\bar{u}+x\bar{c}$

$(1-y)^2\,[xd+xs]$



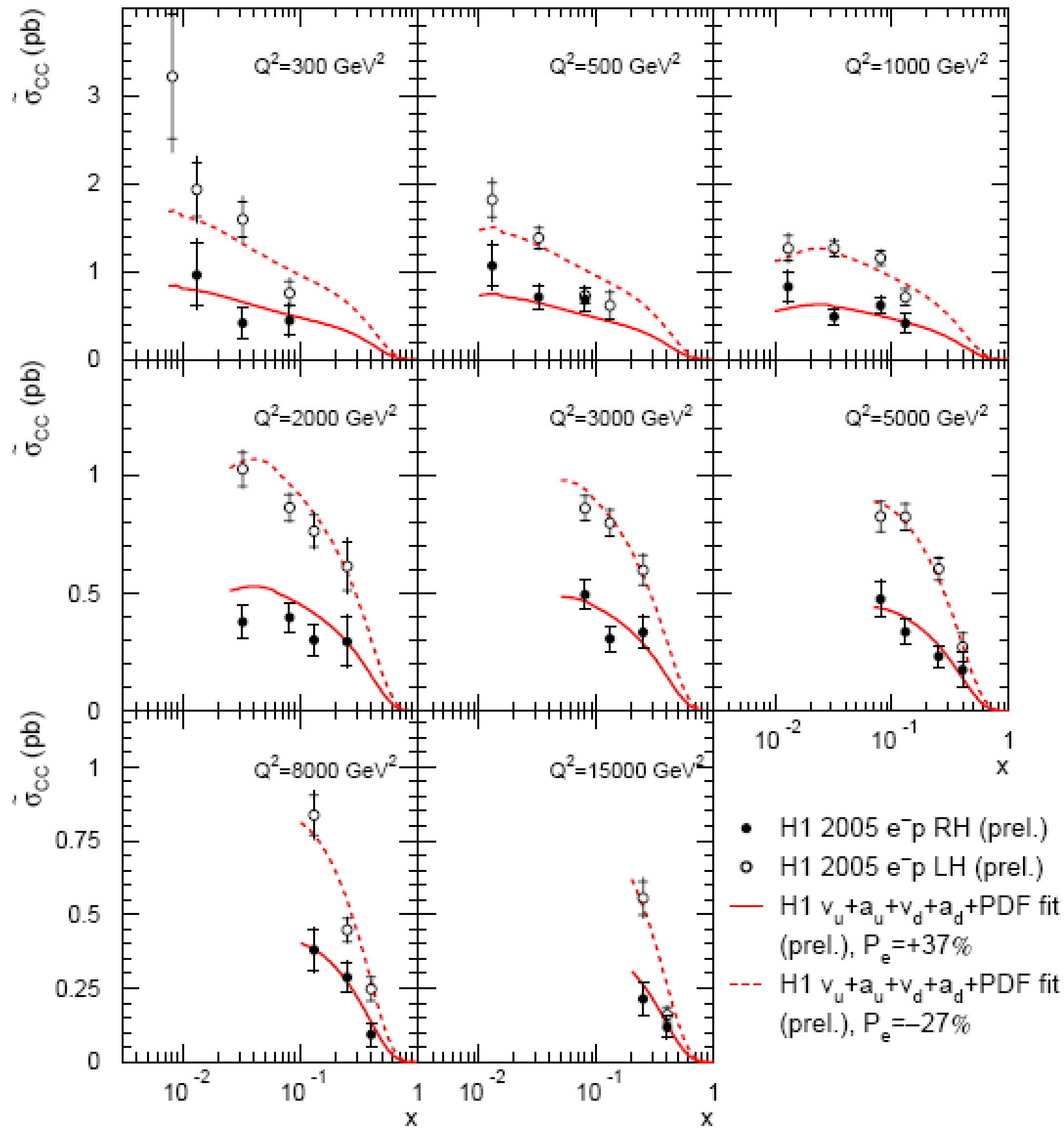


ZEUS

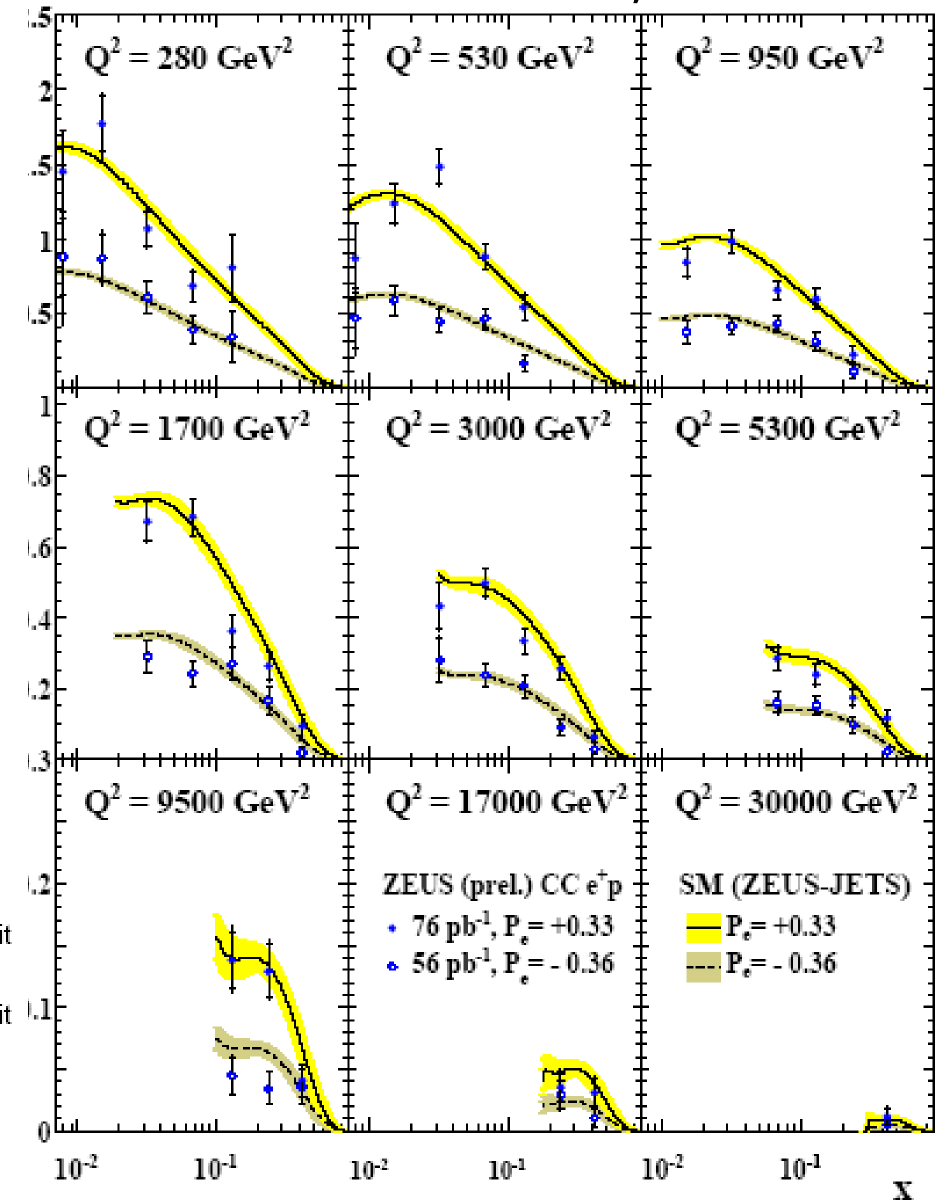
$(1-y)^2 \propto (1-\cos\theta^*)$ back scattering in eq CM frame entirely due to anti-q

CC - Polarisation Asymmetry

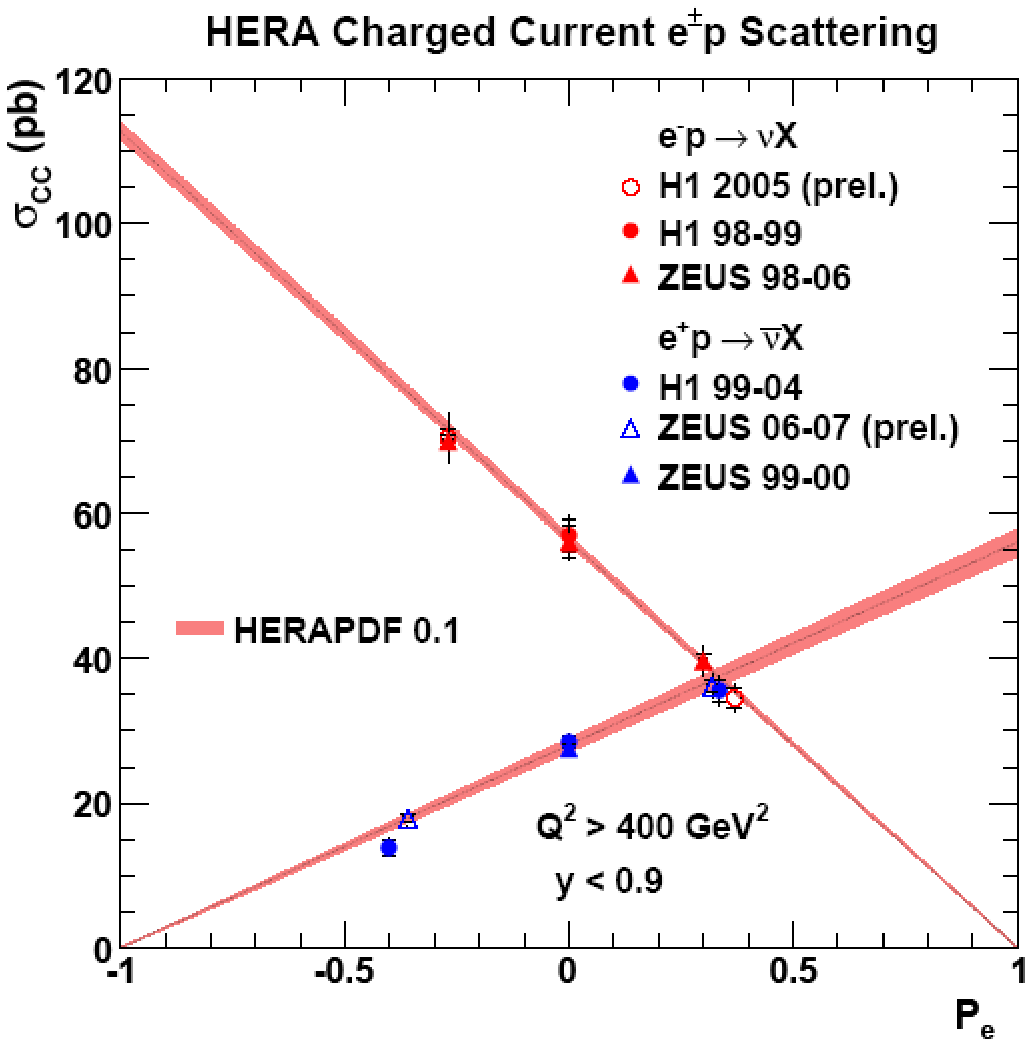
H1 e-p LH, RH



ZEUS e+ LH, RH



CC - Polarisation Asymmetry



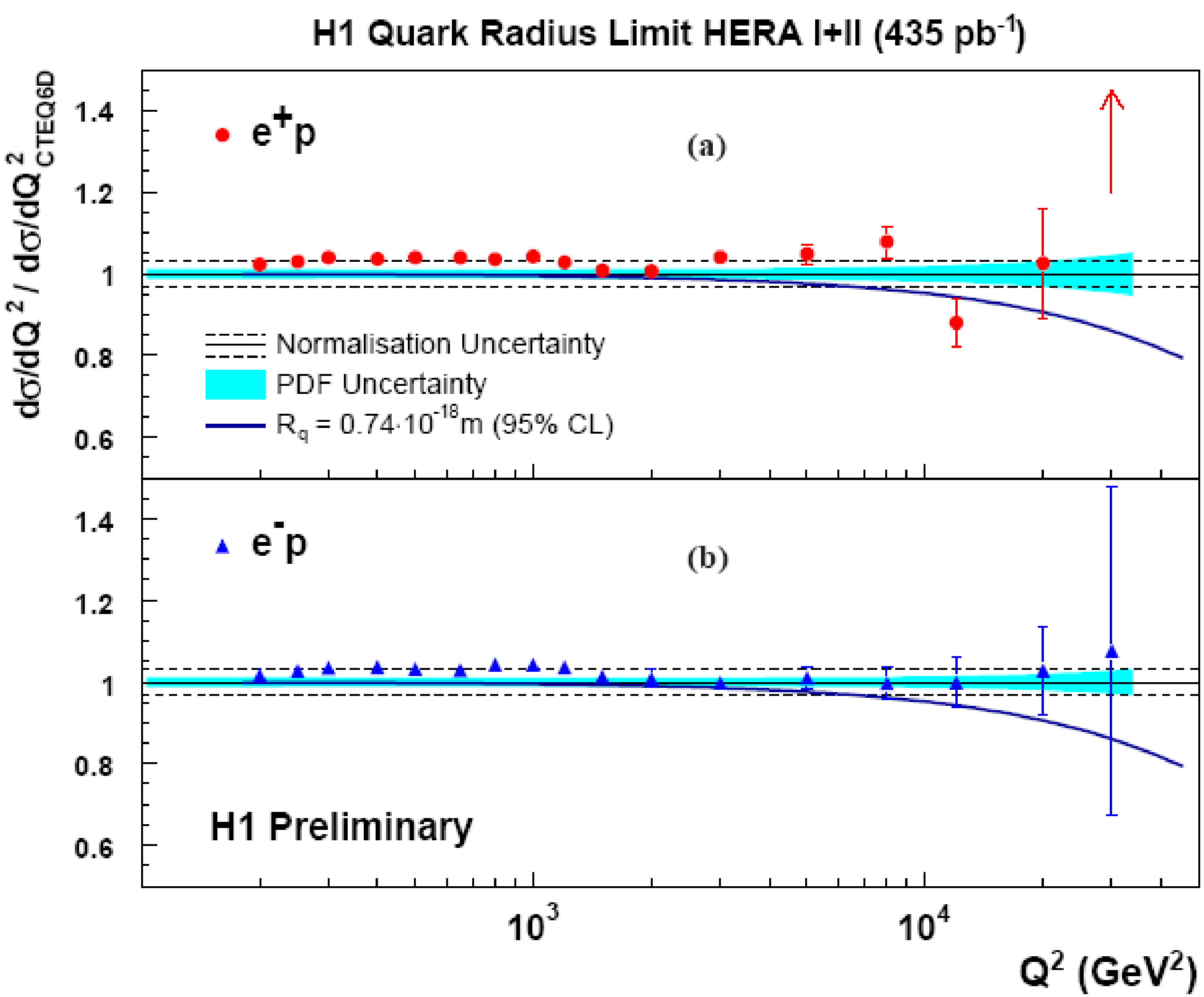
Do not constrain linear fit to
SM expectation of zero cross section
Derive mass limit on W_R assuming

$g_L = g_R$

massless ν_R

positron data: 208 GeV (H1)
electron data: 186 GeV (H1)
180 GeV (Zeus)

NC - Quark Charge Radius



H1 combined HERA-I + part of HERA-II data

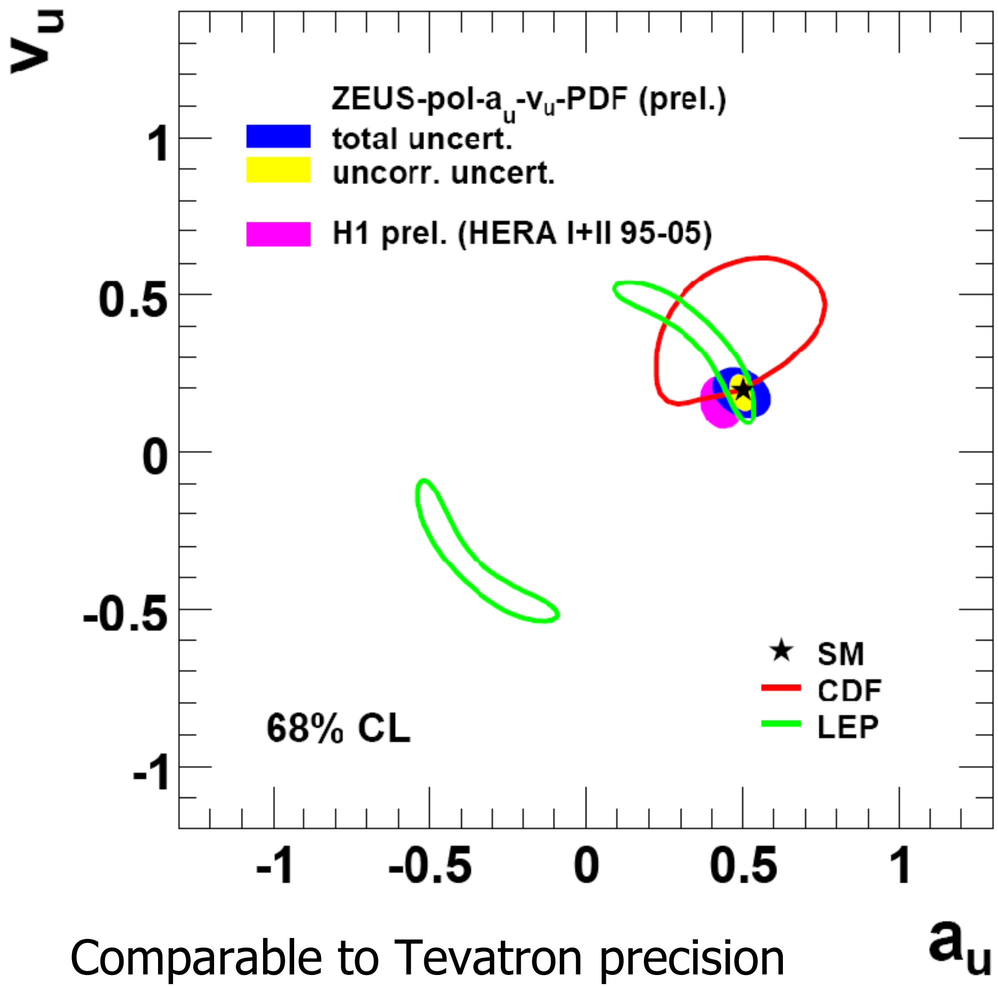
Perform EW form factor analysis for quark charge radius

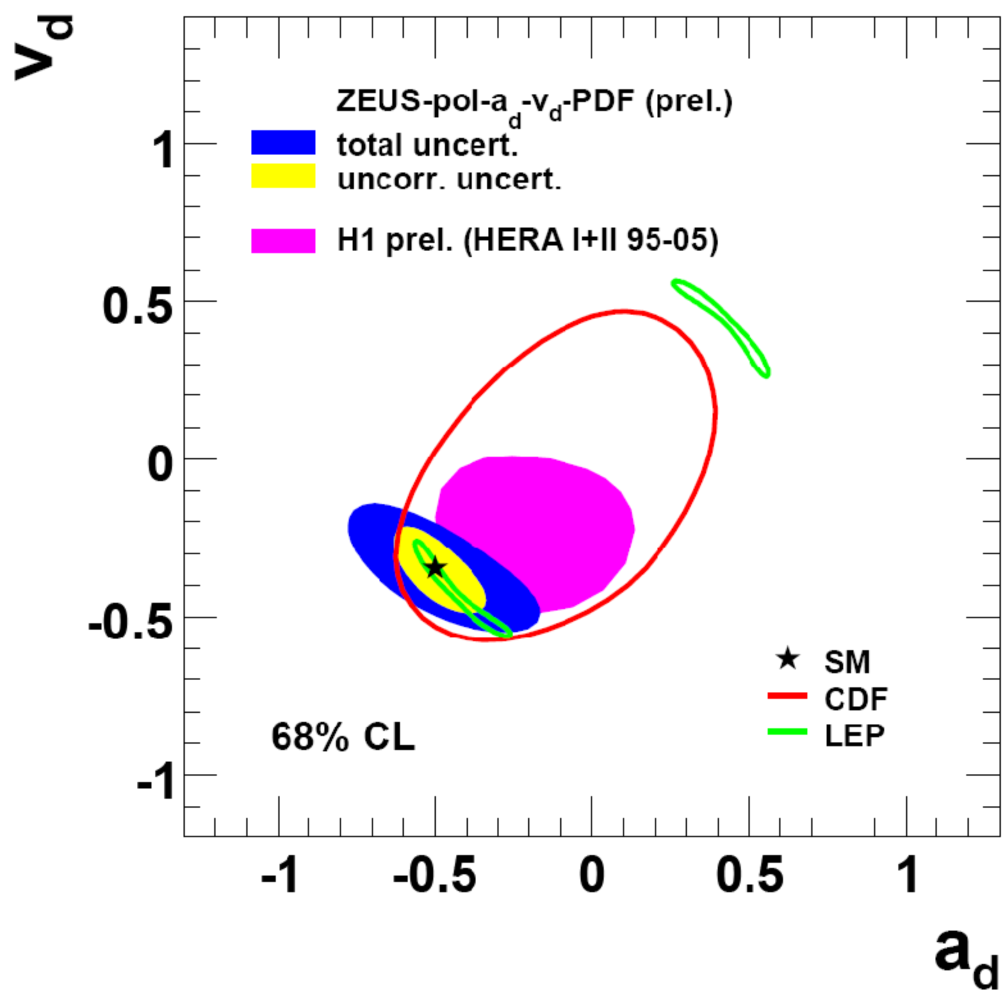
Leads to suppression of SM at large Q^2

Fit $d\sigma/dQ^2$ to extract limit

$R_q < 0.74 \cdot 10^{-18}$m

EW Couplings





Comparable to Tevatron precision

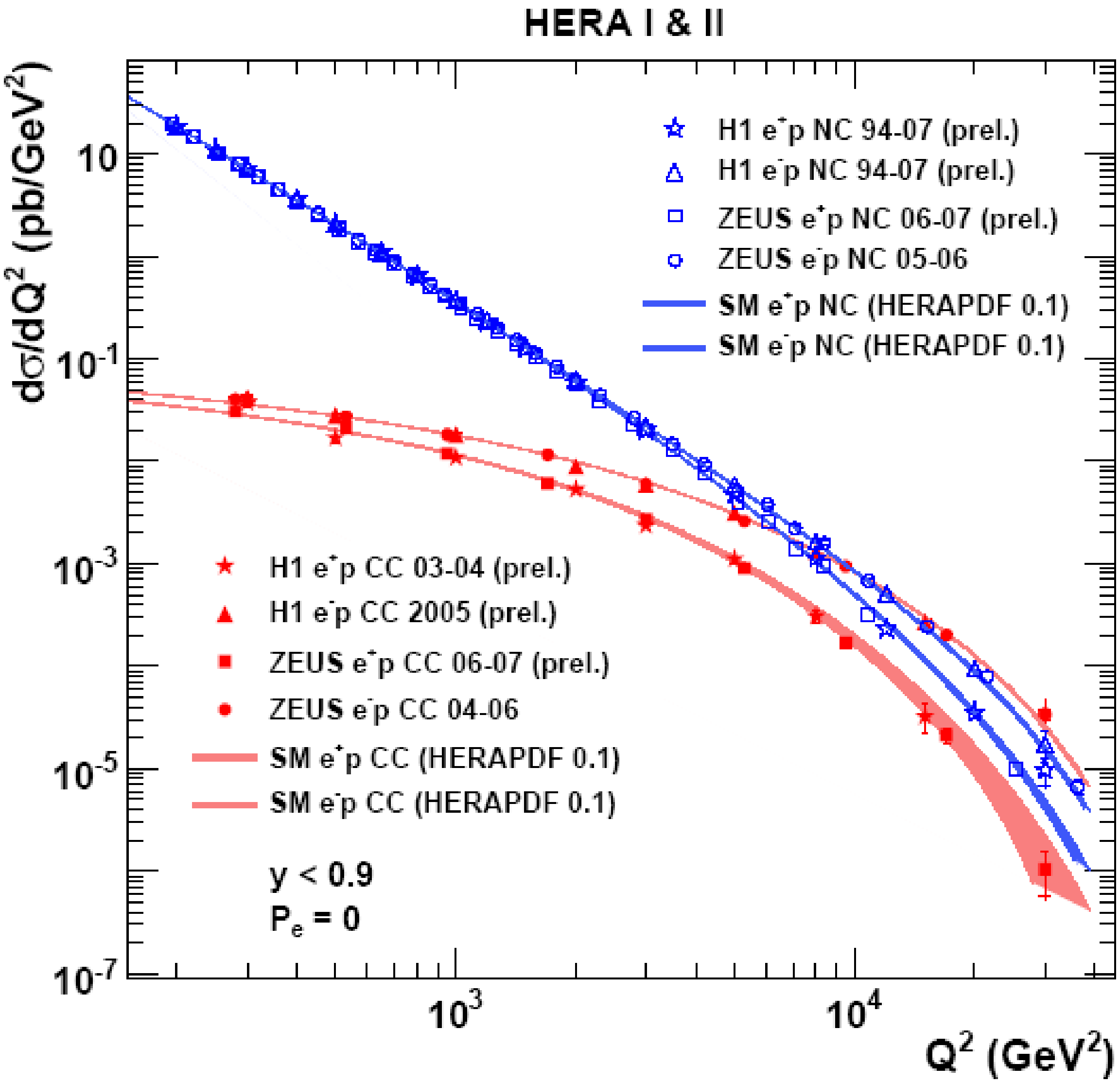
Resolve LEP ambiguity

Inclusion of HERA-II polarised data improves vector precision

Fit to a_u/v_u/PDFs or a_d/v_d/PDFs

improvements to come with ~ double data volume

Summary



- SM performs excellently (as usual)
- NC and CC data provide stringent PDF constraints
- Simultaneous QCD & EW fits performed on HERA data
- Polarised CC gives direct sensitivity $W_R \Rightarrow$ limit set
- Extraction of quark couplings to Z^0
- H1 & ZEUS combination will improve precision
- Final analyses of complete HERA dataset to come soon...