Electroweak Results from HERA

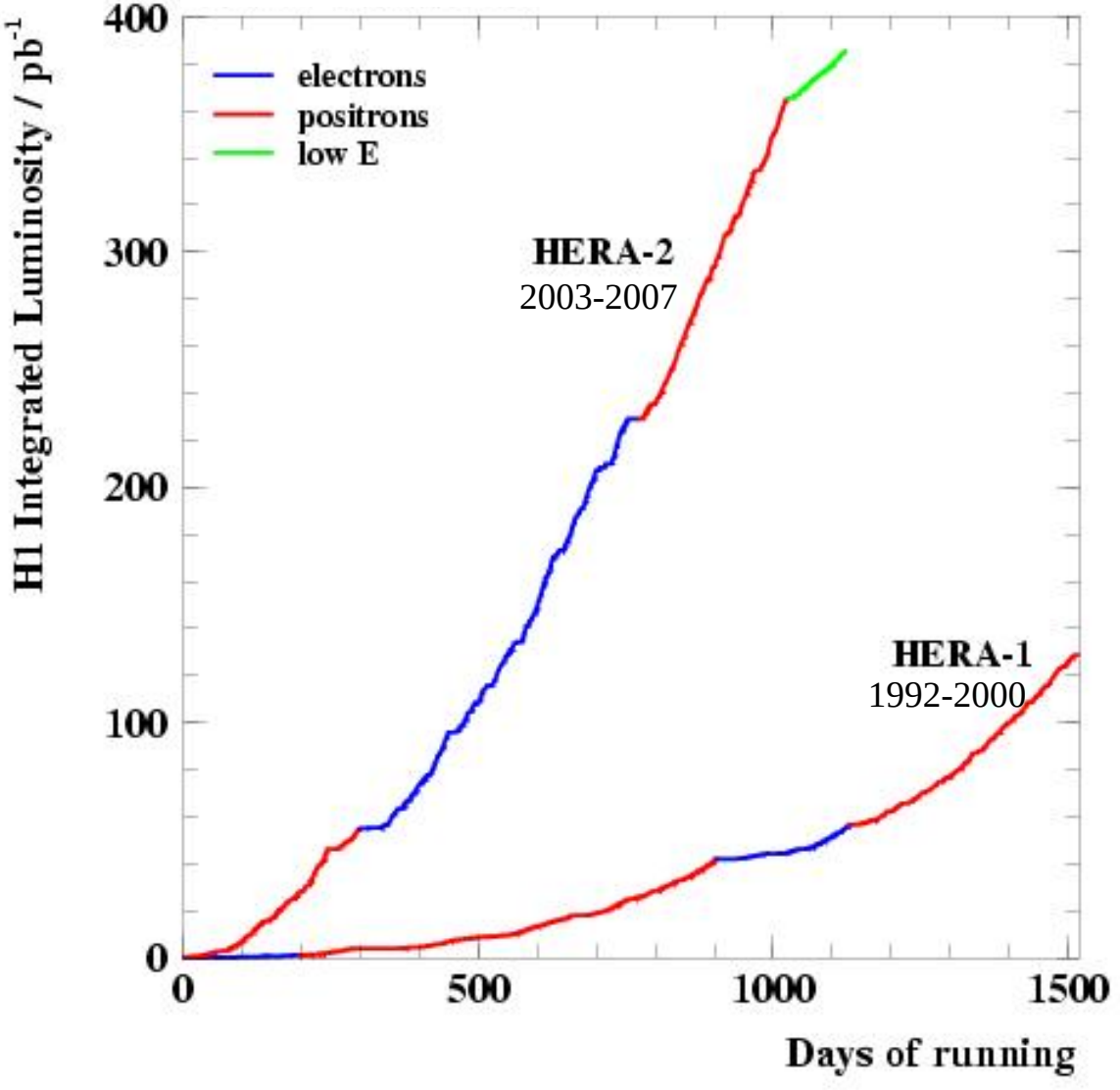
Z. Zhang
LAL, Orsay

On behalf of

OUTLINE

Introduction
Unified EW forces & W propagator mass
NC & parity violation
CC & right-handed currents
Light quark couplings to Z
W production

HERA-1+2 Data Sample (Integrated Luminosity)



	HERA-1	HERA-2
e-	~20pb^{-1}	~200pb^{-1}
e+	~100pb^{-1}	~200pb^{-1}

➔ H1+ZEUS: ~1fb^{-1}

➔ HERA-2:
polarized e$^{\pm}$ beams in both left-hand (LH) and right-hand (RH) modes

➔ Low E proton data unique for g density

Results reported here were based on published HERA-1 data and part of analysed HERA-2 data

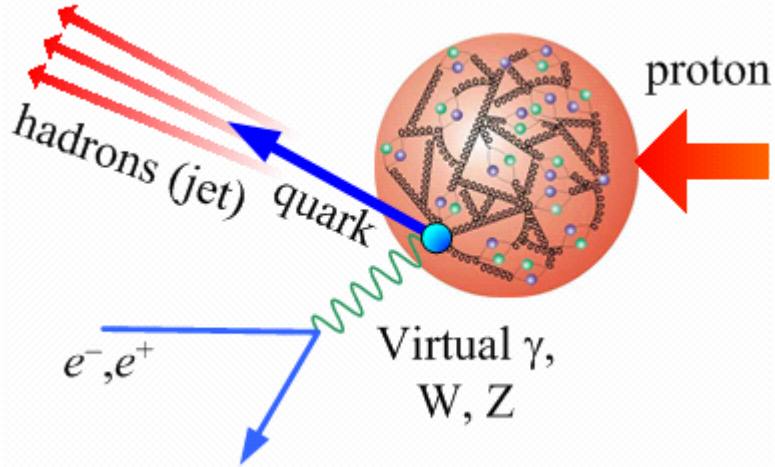
Inclusive Neutral Current (NC) & Charged Current (CC) Cross Sections

Structure Functions (SFs)

Parton Distribution Functions (PDFs)

Electroweak Parameters

Polarization P_e (HERA-2 only)



NC & CC Cross Sections and Structure Functions

NC Cross Section:

$Q^2 = -q^2 = -(k-k')^2$
x: momentum fraction of the struck parton
$y = Q^2/xs$

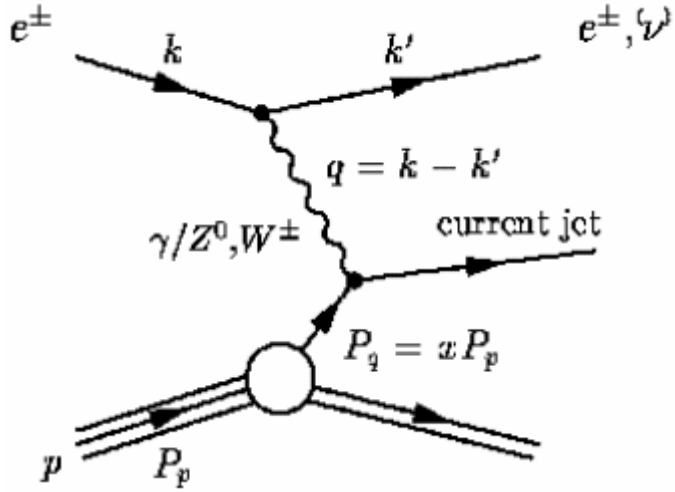
NC Reduced cross section: $\tilde{\sigma}_{NC}(x,Q^2)$

$$\frac{d^2\sigma_{NC}(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} Y_+ \left[\tilde{F}_2 - \frac{y^2}{Y_+}\tilde{F}_L \mp \frac{Y_-}{Y_+} x\tilde{F}_3\right]$$

Dominant contribution

Sizeable only at high y (y>~0.6)

Contribution only important at high Q^2



CC Cross Section:

W propagator mass term

$$\frac{d^2\sigma_{CC}(e^{\pm}p)}{dxdQ^2} = \frac{G_F^2}{2\pi x}\left(\frac{M_W^4}{Q^2+M_W^2}\right)^2 \frac{1}{2}\left[Y_+ W_2 - y^2 W_L \mp Y_- x W_3\right]$$

CC Reduced cross section: $\tilde{\sigma}_{CC}(x,Q^2)$

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

PDFs, Light Quark Couplings to Z and Polarization

NC structure functions (SFs) have 3 or 2 well defined contributions from

γ exchange γZ interference Z exchange

$$\tilde{F}_2 = F_2 - (v_e - P_e a_e) K_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 - 2P_e v_e a_e) K_Z^2 F_2^Z$$

$$x\tilde{F}_3 = -(a_e - P_e v_e) K_Z x F_3^{\gamma Z} + [2 v_e a_e - P_e (v_e^2 + a_e^2)] K_Z^2 x F_3^Z$$

$$K_Z = \frac{Q^2}{(Q^2 + M_Z^2)^2} \frac{1}{4 \sin^2\theta_W \cos^2\theta_W}$$

$$[F_2, F_2^{\gamma Z}, F_2^Z] = x \sum [e_q^2, 2 e_q v_q, v_q^2 + a_q^2](q + \bar{q})$$

$$[x F_3^{\gamma Z}, x F_3^Z] = 2x \sum [e_q a_q, v_q a_q](q - \bar{q})$$

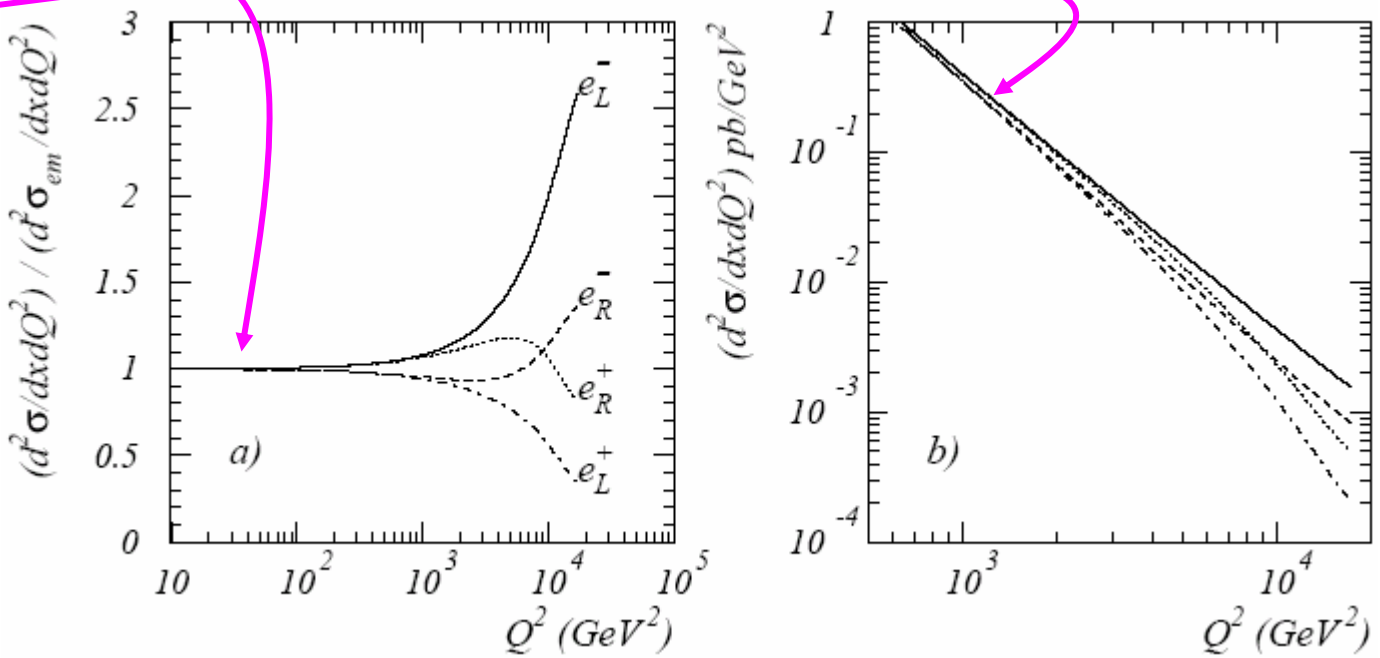
Valence quarks u_v, d_v

PDFs: Parton Distribution Functions
q=u,d,c,s,b & gluon g

➔ SFs are primary source of constraint on **PDFs** q, g(via scaling violation)
➔ SFs are also sensitive to **(light) quark couplings** to the Z boson v_q, a_q
➔ **Polarized $e^\pm$ beam** helps to constrain v_q

NC & CC Cross Sections Dependence on P_e

For NC: em contribution dominating at low Q^2 is independent of P_e.
weak NC only significant at high Q^2



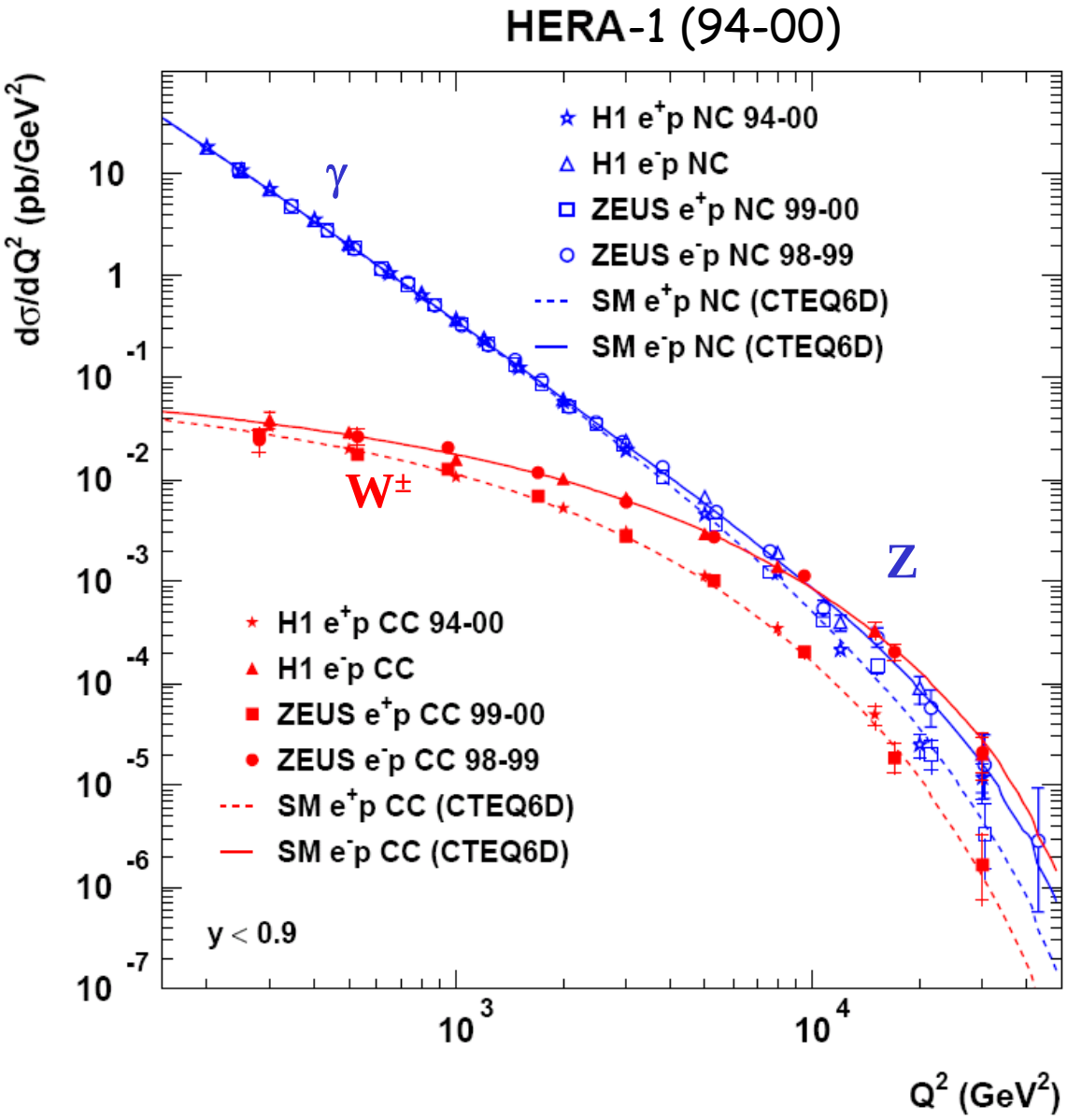
For CC, linear dependence on P_e:

$$\sigma^{\pm}(P_e) = (1 \pm P_e)\underbrace{\sigma^{\pm}(0)}_{\text{HERA-I}}$$

P_e<0: Left handed
P_e>0: Right handed

HERA-2: SM expectations:
Fully left-handed e+ beam or
fully right-handed e- beam,
the CC cross section vanishes.
➔ Sensitive to right-handed current

Unified EW Forces & W Propagator Mass



Published HERA-1 data:

→ comparable NC & CC cross sections at high Q2

→ residual differences due to u/d flavour asymmetry and ≠ helicity factors

→ flatter CC cross section due to W propagator mass (space-like)

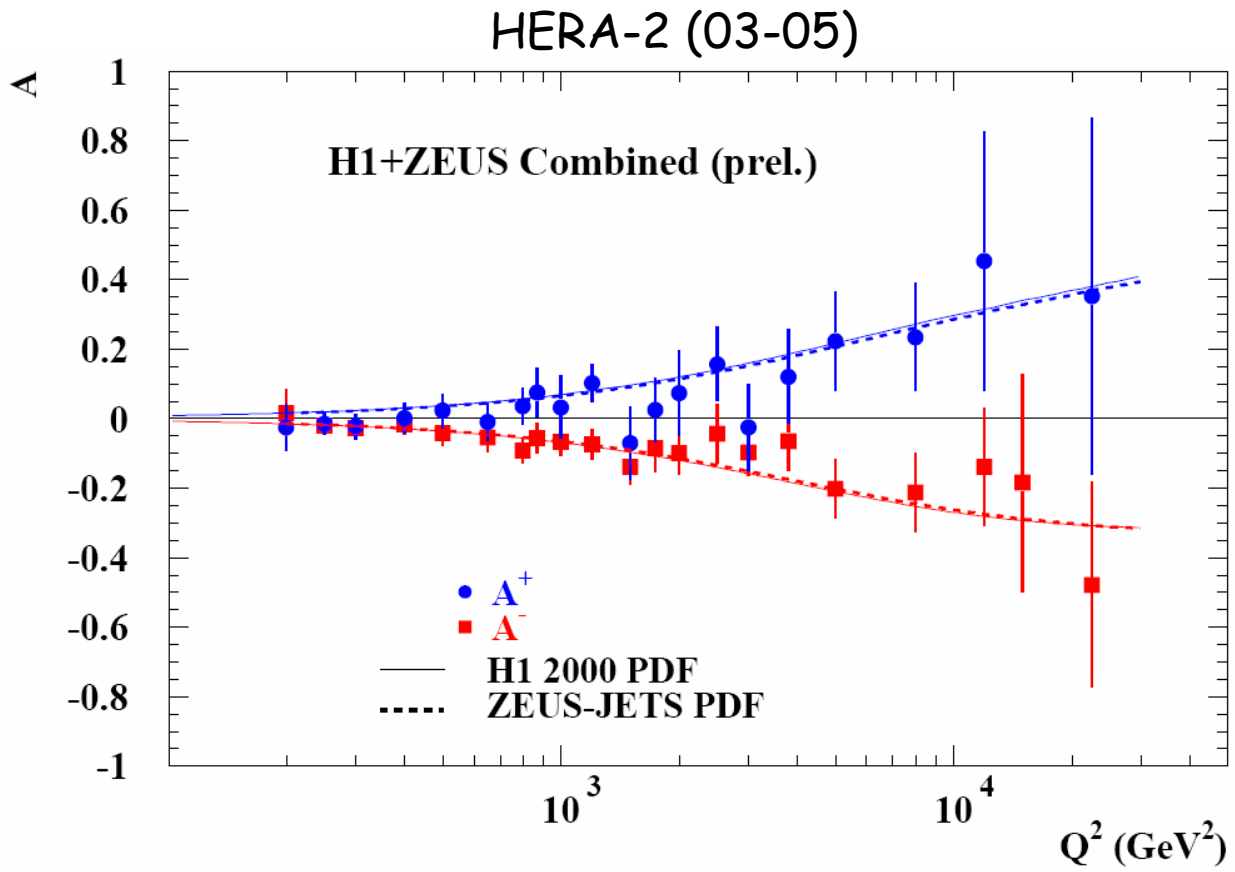
A combined EW+PDF fit to HERA-1 data (mainly CC e- ~20pb^{-1}) gives:

$\delta M_W \sim 1.8$GeV

HERA-2 has 10x more e-

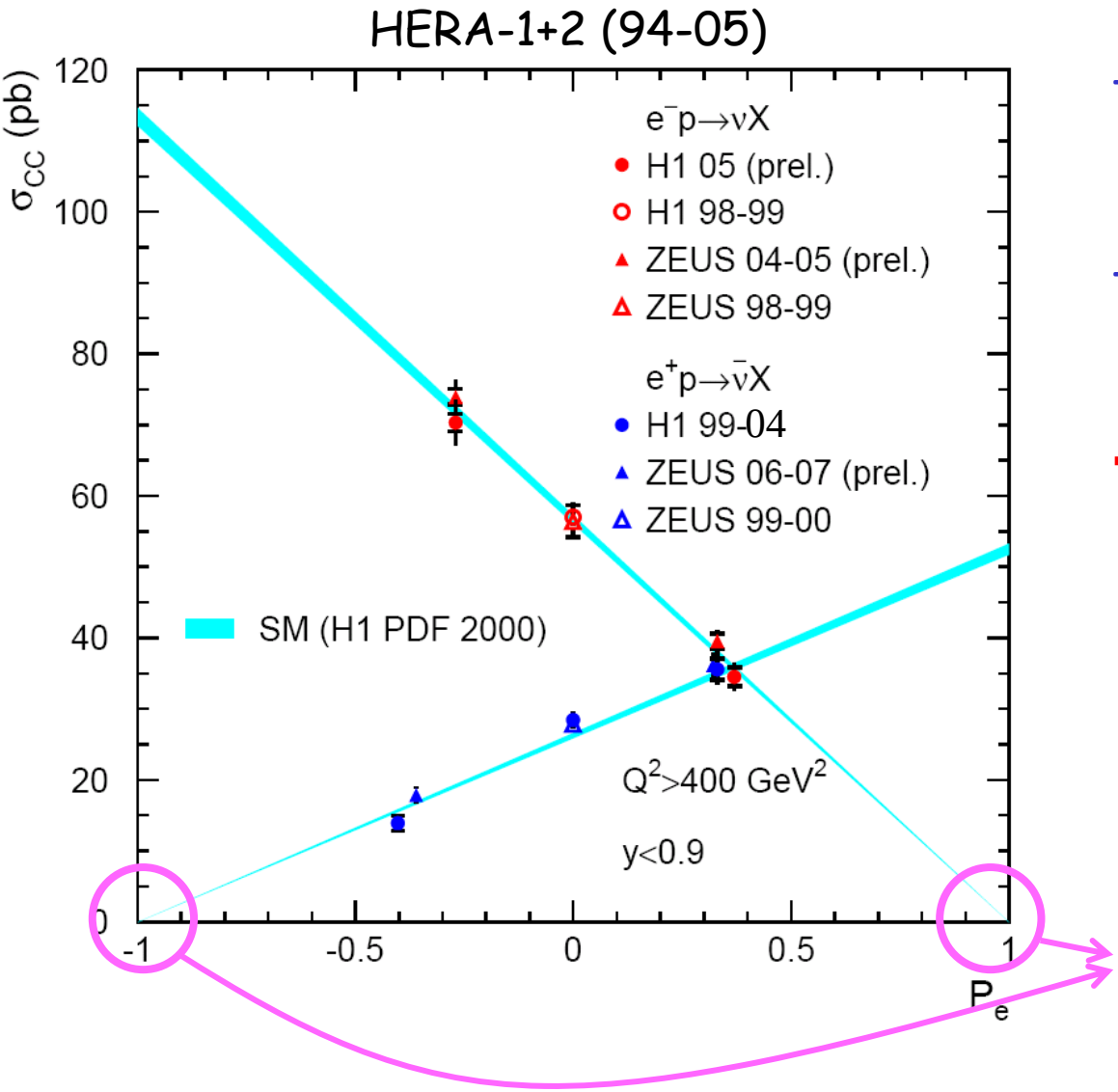
NC High Q^2 Cross Sections & Parity Violation

Polarisation asymmetry: $$A^{\pm} = \frac{2}{P_R - P_L} \cdot \frac{\sigma^{\pm}(P_R) - \sigma^{\pm}(P_L)}{\sigma^{\pm}(P_R) + \sigma^{\pm}(P_L)}$$



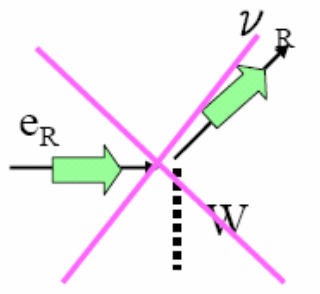
➔ First observation of parity violation in weak NC at high Q^2

Total CC Cross Section and Right-Handed Currents



- Measurements in agreement with linear P_e dependence of SM expectation
- Straight line fits constrain right-handed current contributions:

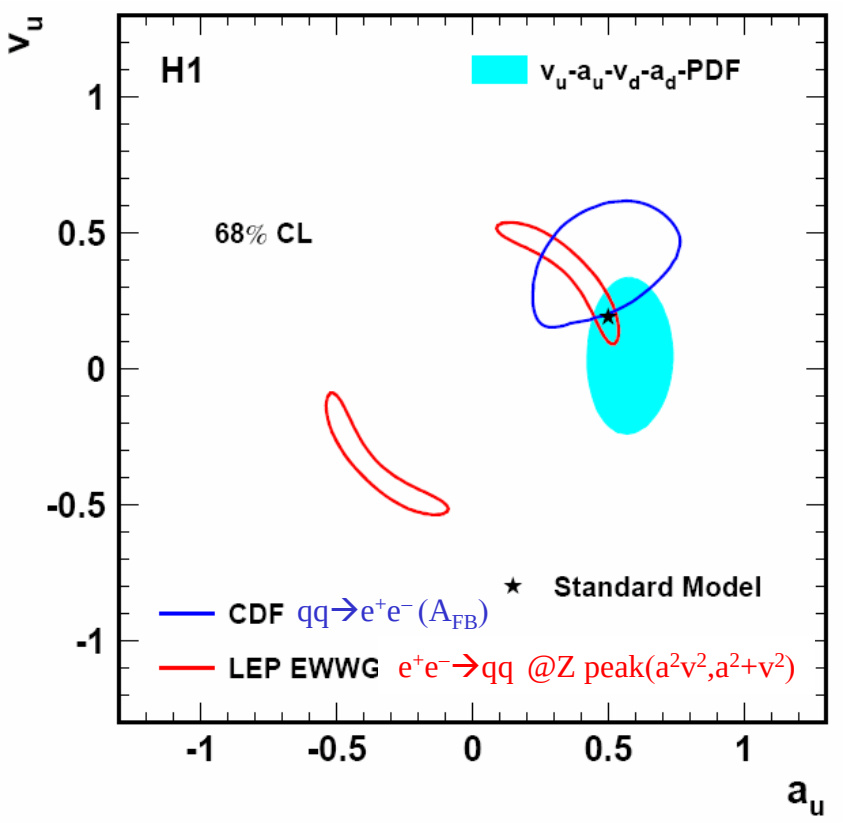
➔ Mass limit W_R at 95%CL assuming $g_R=g_L$, light ν_R
- >208 GeV (H1, e-)
- >186 GeV (H1, e+)
- >180 GeV (ZEUS e-)

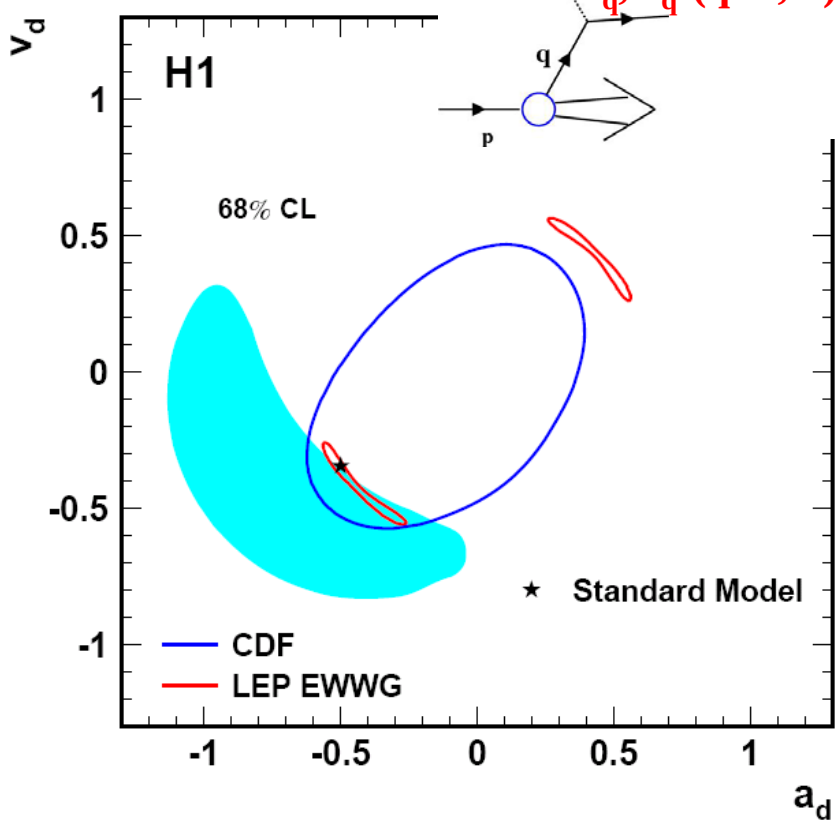


Absence of right-handed currents

Combined EW+PDF Fit & Light Quark-Z Couplings

HERA-1 (94-00)



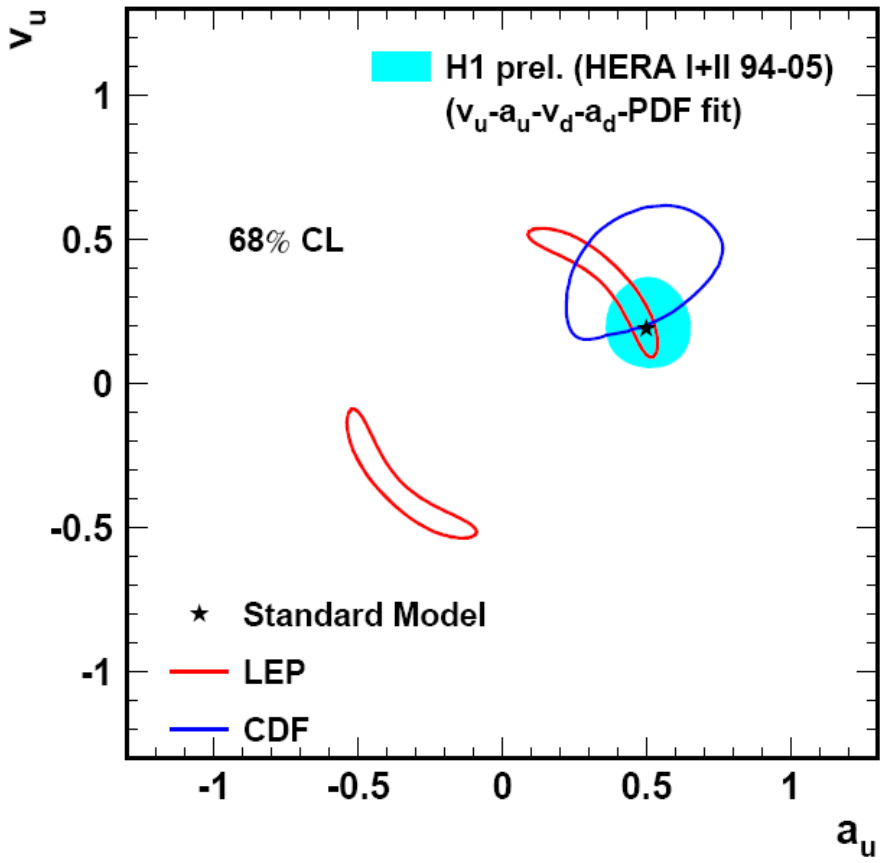


➔ Precision from HERA-1 data already comparable with other determinations

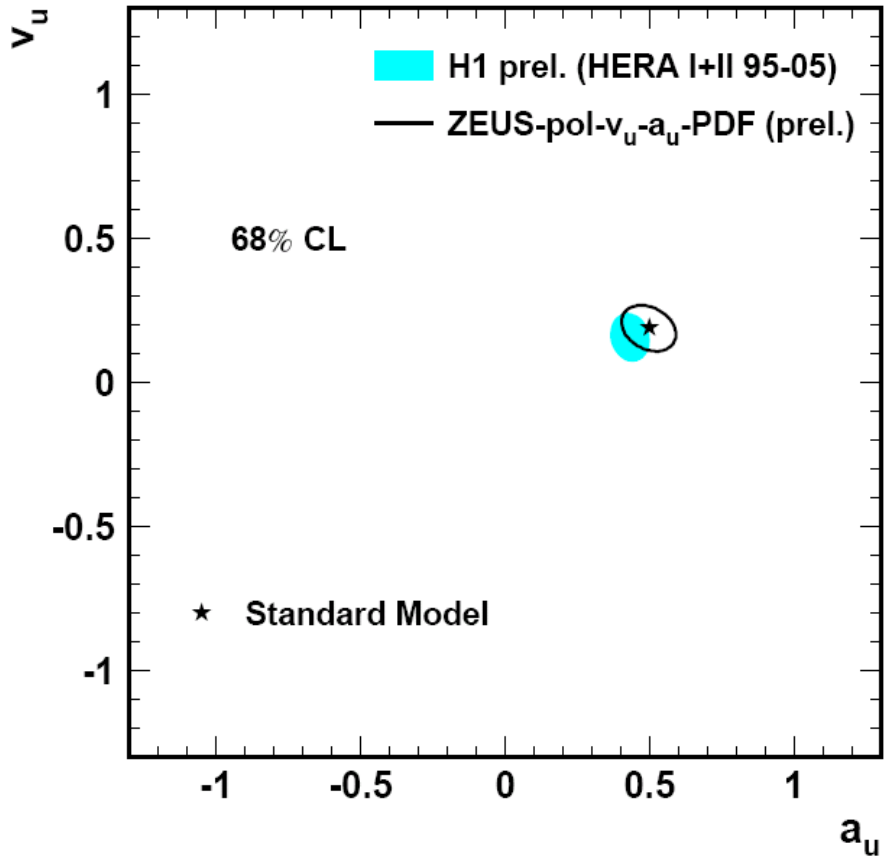
➔ Determinations at HERA & Tevatron resolve sign ambiguity from LEP

Improved Precision with Polarisation at HERA-2

HERA-1+2 (94-05)



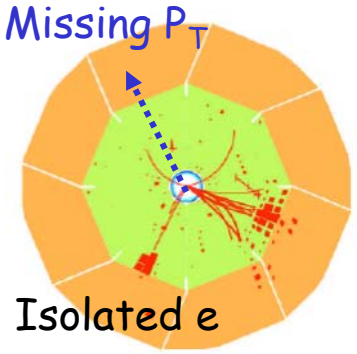
v_u-a_u-PDF fit ➔ More constrained fit



➔ HERA has the best precision on u quark coupling to Z

➔ Still have a factor 2 more data (HERA-2) to add

Isolated Leptons & W Production at HERA



Subsample with P_T^X>25GeV:

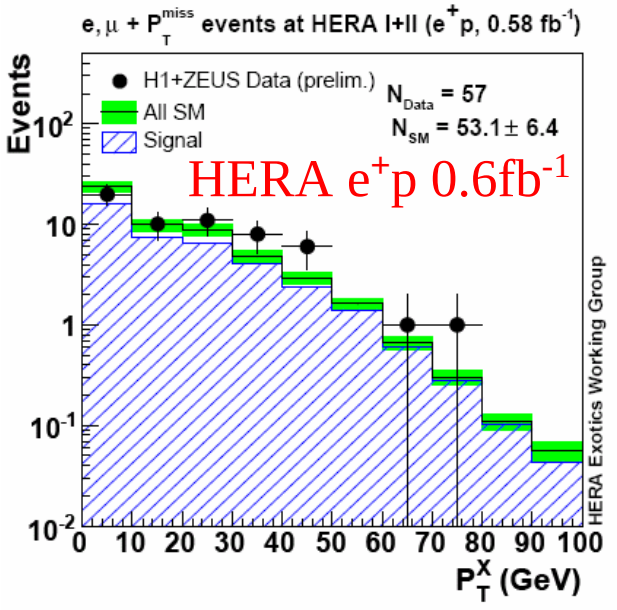
Obs. / exp.

H1+ZEUS e-: 6 / 10.6±1.4

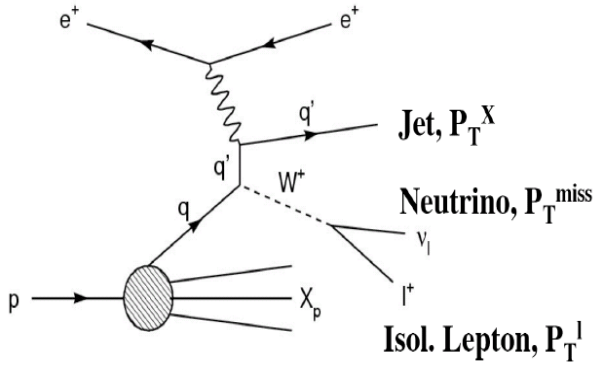
H1+ZEUS e+: 23 / 14.6±1.9

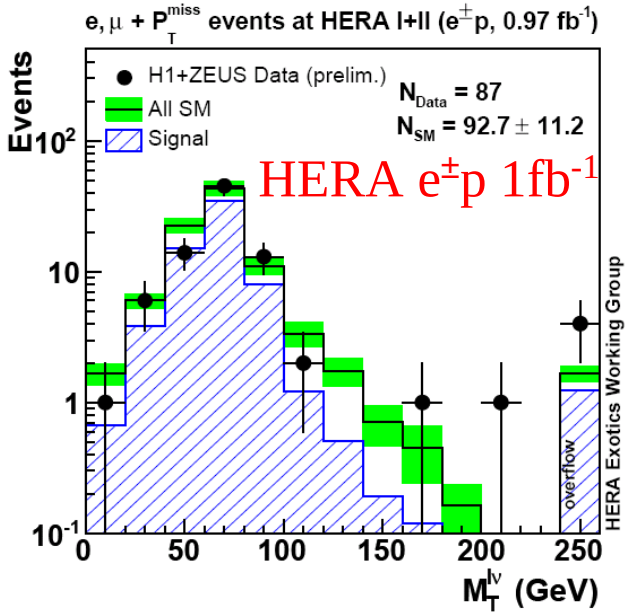
H1 e+: 3σ

(see D. South's talk for detail)



W production: dominant SM contribution





H1: 1.23 ± 0.25 (stat) ± 0.22 (syst) pb

SM: 1.31 ± 0.20 pb

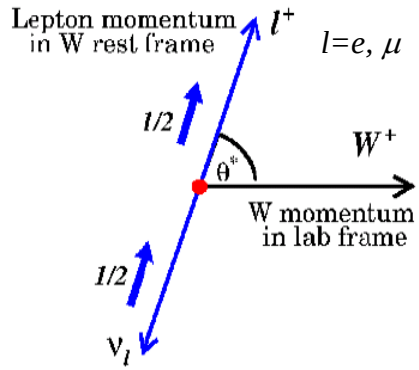
1st Measurement of W Polarisation Fractions @ HERA

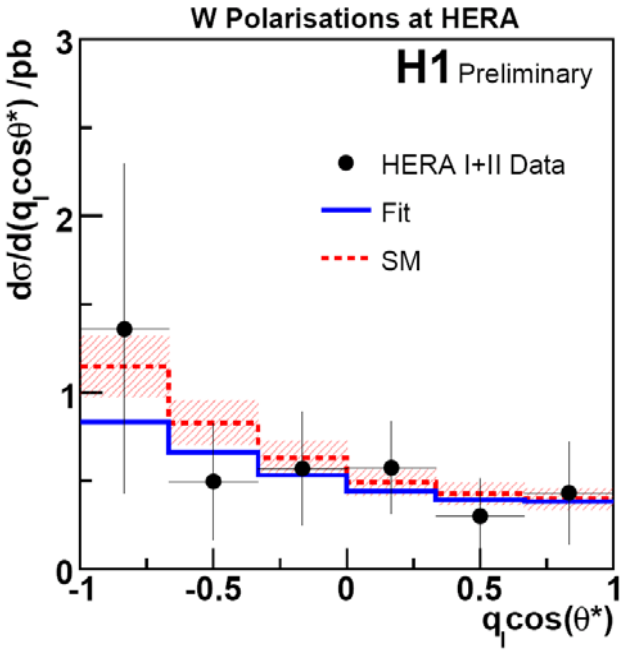
Restricted to the isolated lepton sample in which a W is reconstructed

Angular distribution and polarisation fractions:

$$\frac{dN}{d\cos\theta^*} = F_- \frac{3}{8}\left(1-\cos\theta^*\right)^2 + F_0 \frac{3}{4}\sin^2\theta^* + F_+ \left(1+\cos\theta^*\right)^2$$

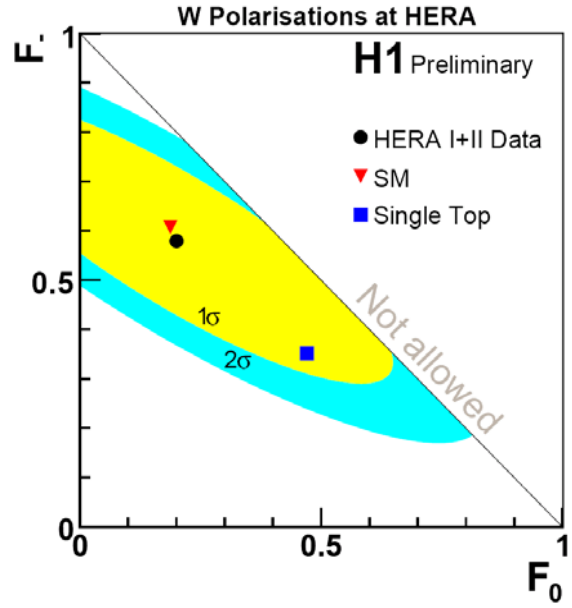
left longitudinal right $F_+ = 1 - F_- - F_0$





H1 1-parameter fit:
$F_0 = 0.15 \pm 0.21_{stat} \pm 0.09_{sys}$
$F_- = 0.58 \pm 0.15_{stat} \pm 0.12_{sys}$

SM expectations:
$F_0 = 0.19 \pm 0.01_{stat}$
$F_- = 0.61 \pm 0.01_{stat}$



Summary and Prospects

- The unique HERA ep collider & its data
  - Precision measurements of QCD
  - Primary source of Parton Distribution Functions (PDF)
  - Valuable for EW tests/measurements via NC/CC at high Q^2
    - → Light quark couplings to Z
    - → W production and properties

- HERA data taking is over but many results with improved precision are expected in next years