

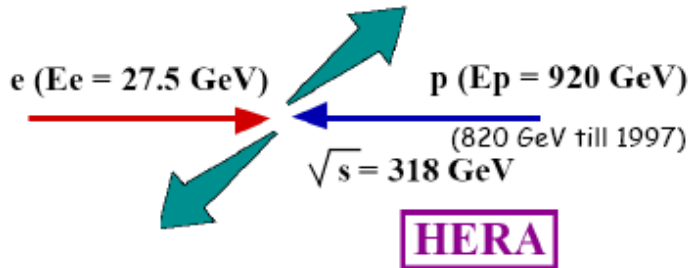
XLVth Rencontres de Moriond, 06.03-13.03.2010, La Thuile

EW Measurements at High Q^2 at HERA

S.Shushkevich, MPIM

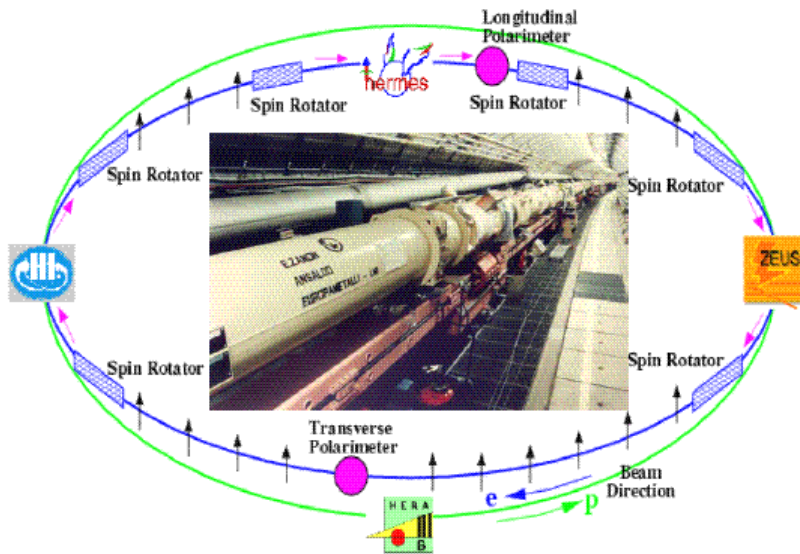


HERA ep collider (1992-2007)



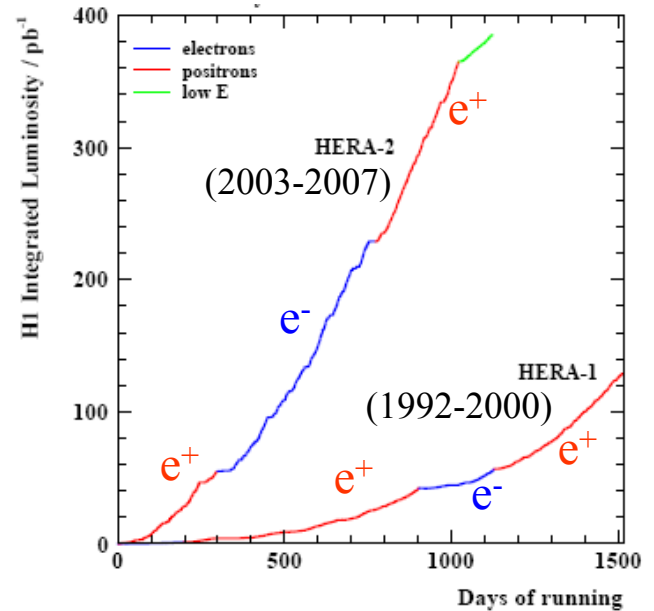
per exp.	HERA I	HERA II
e^+p	100 pb^{-1}	200 pb^{-1}
e^-p	20 pb^{-1}	180 pb^{-1}

in total $\sim 1 \text{ fb}^{-1}$ for H1 and ZEUS



$$Q^2_{\text{max}} \sim 10^5 \text{ GeV}^2$$

$$\lambda_{\text{min}} \sim 1/1000 R_{\text{proton}}$$

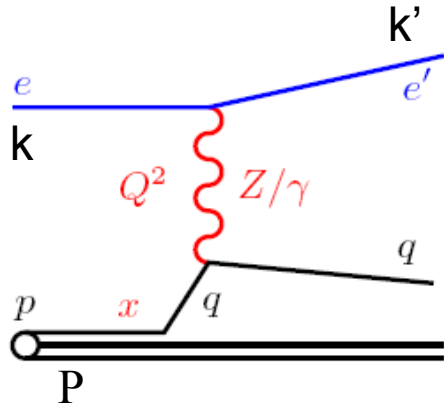


Longitudinal polarization of electron beam (2003-2007)

$$P_e = (N_R - N_L)/(N_R + N_L) \approx 40\%$$

Deep Inelastic Scattering (DIS)

Neutral current (NC)



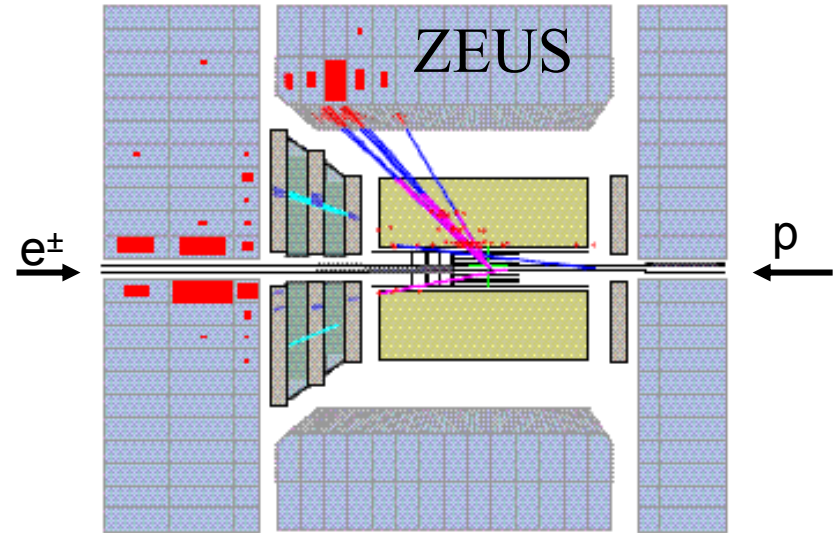
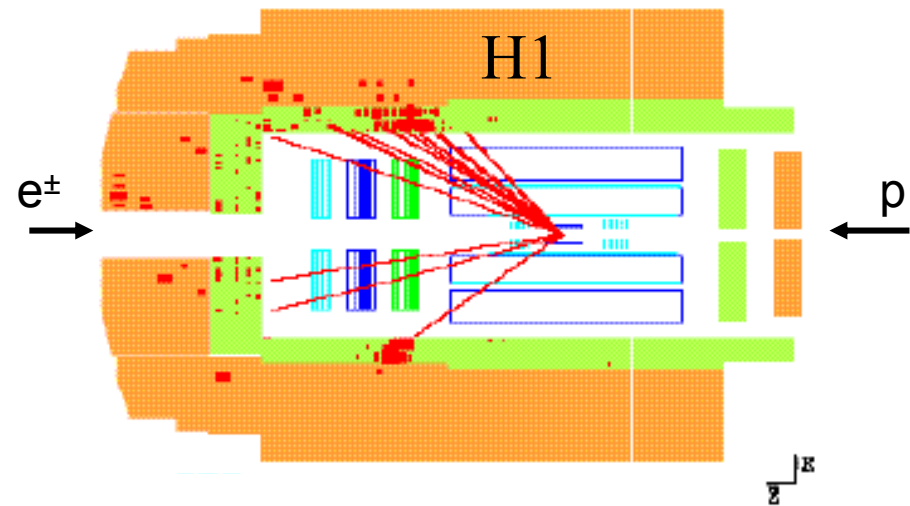
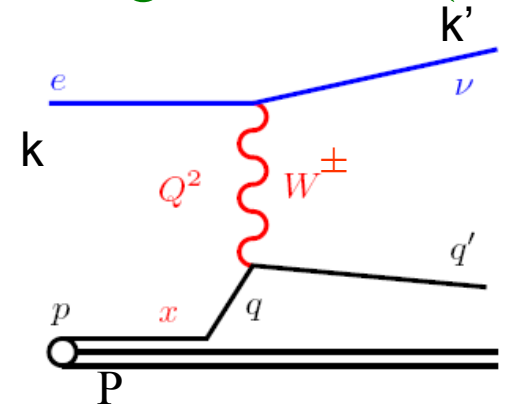
$$Q^2 = -q^2 = (k - k')^2 \quad \text{boson virtuality}$$

$$x = \frac{Q^2}{2(Pq)} \quad \text{Bjorken } x$$

$$y = \frac{(Pq)}{(Pk)} \quad \text{inelasticity}$$

$$Q^2 = sxy \quad s = (k + P)^2$$

Charged current (CC)

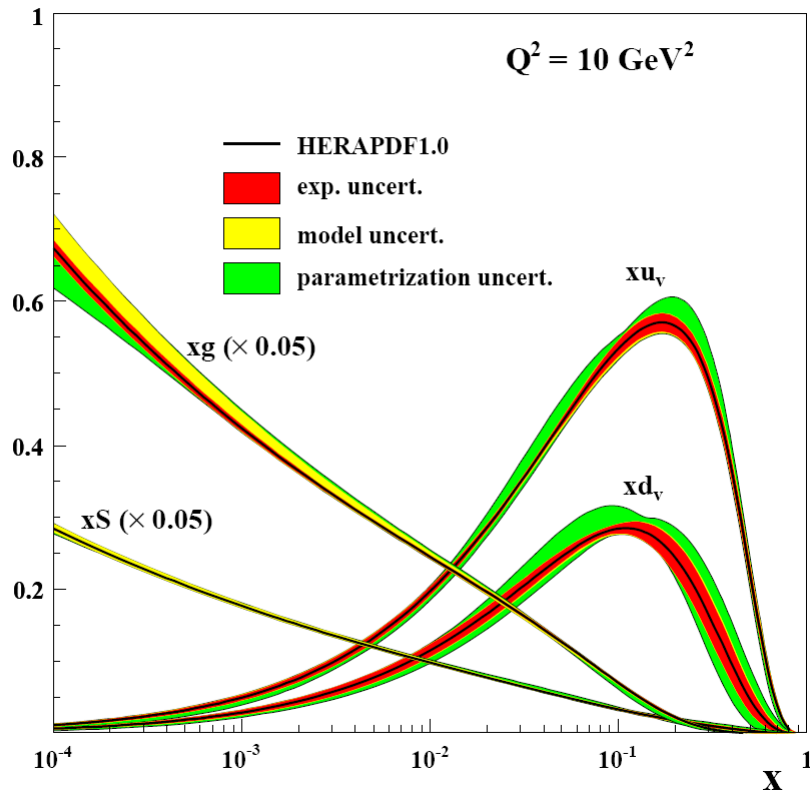


HERAPDF 1.0

→ H1+ZEUS combined data from HERA I

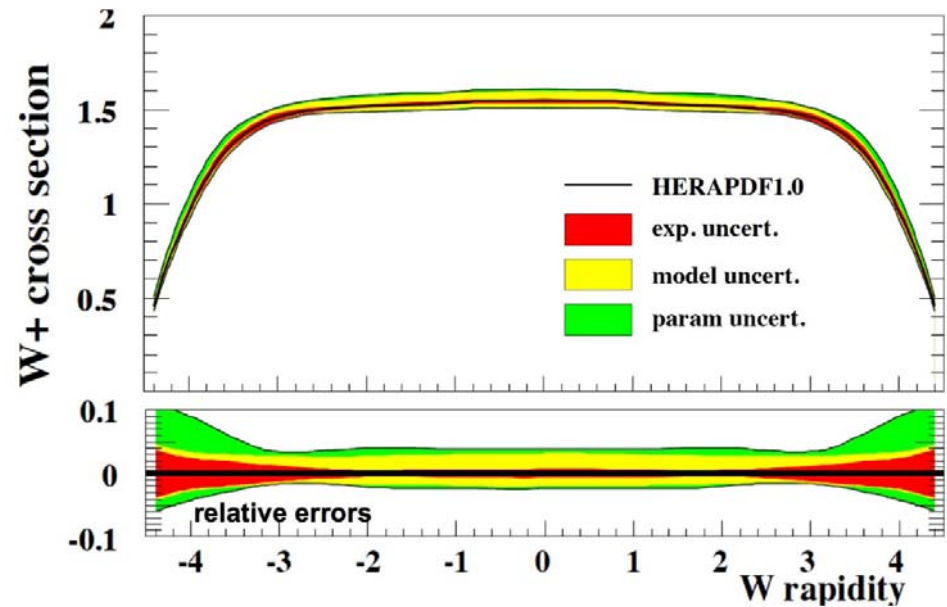
→ Parton distributions unfolded in NLO QCD fit using the HERA $e^\pm p$ data only

H1 and ZEUS



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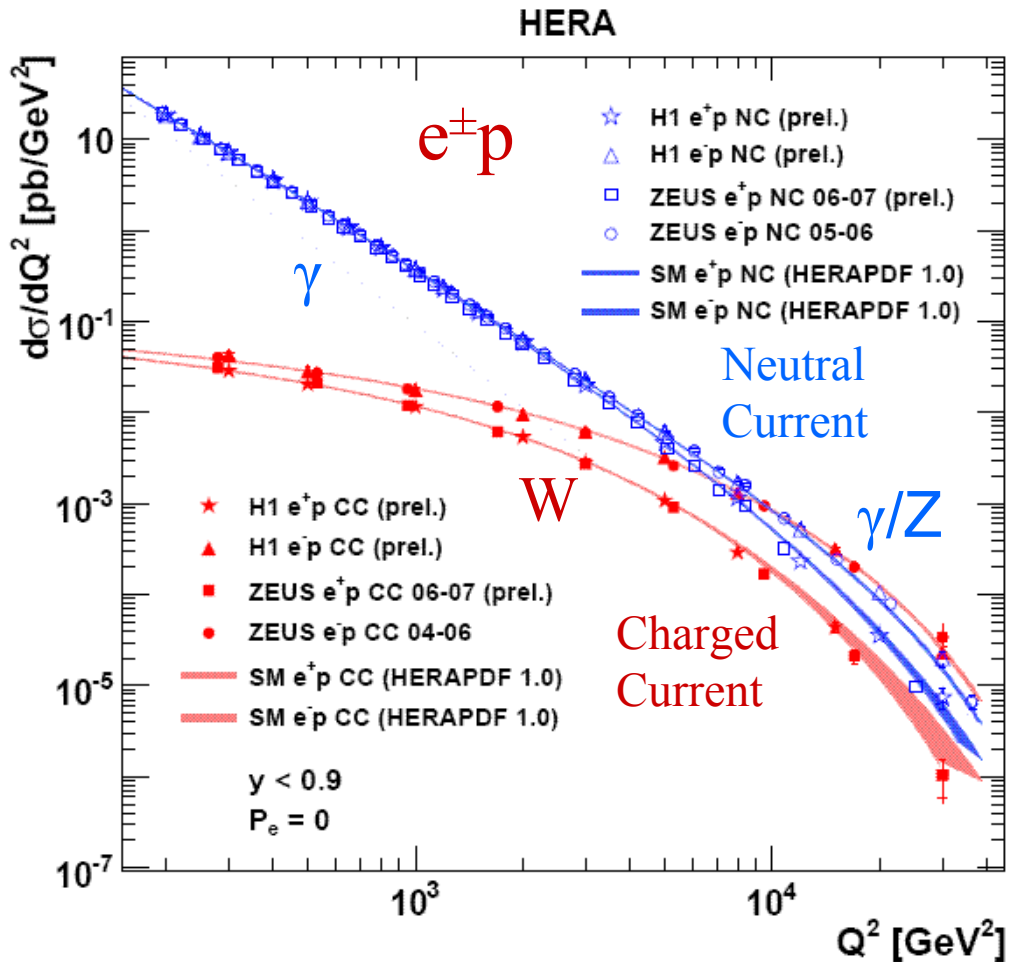
W+ production at LHC



The new measurements for Moriond EW 2010

- Full HERA II data for CC and NC from H1 and ZEUS (preliminary and publications)
 - Cross sections at high Q^2
 - CC polarization dependence
 - xF_3
 - NC polarization asymmetry
 - Electroweak fits
- A significant step in precision, towards full power of HERA

Electroweak unification



EW component of SM:
NC and **CC** cross sections become similar at

$$Q^2 \approx M_Z^2, M_W^2$$

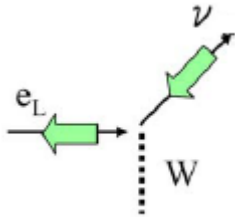
At the highest Q^2

→ Search for deviations from SM

quark radius $r_q < 10^{-18}$ m

Total Charged Current Cross Section

SM: weak CC is purely left-handed (V-A)

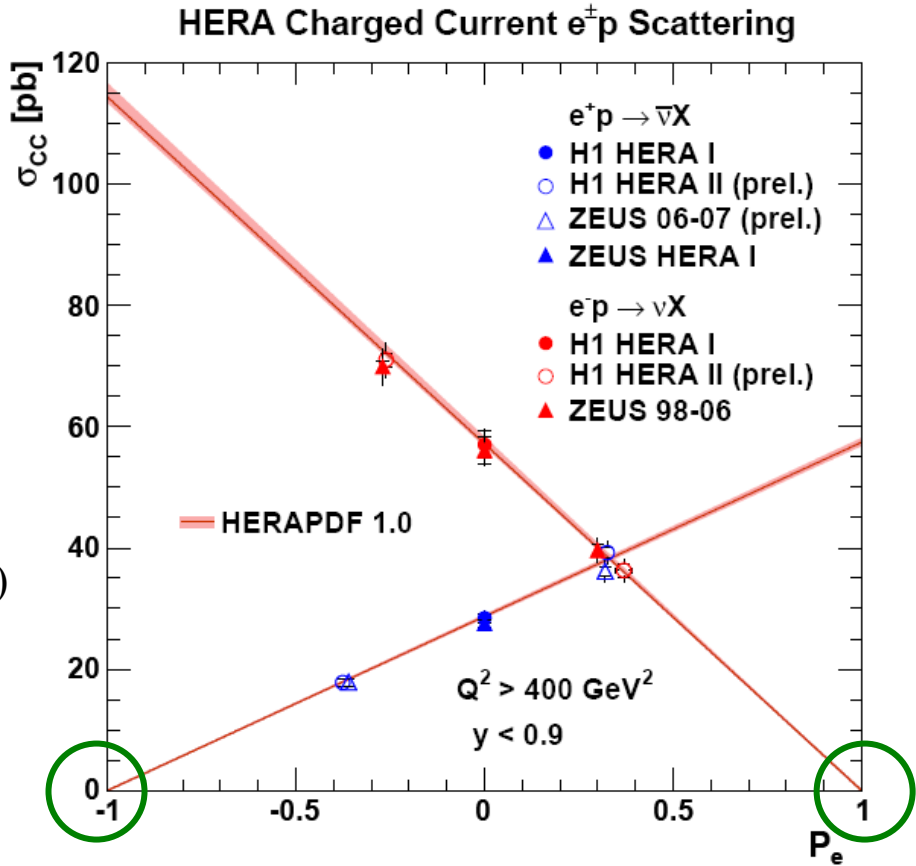


$$\sigma^{CC}(e^\pm p) = (1 \pm P_e) \sigma_{P_e=0}^{CC}(e^\pm p)$$

longitudinal polarization $P_e = (N_R - N_L)/(N_R + N_L)$

- Linear dependence σ^{CC} on P_e confirmed
- No right-handed CC observed
- Limit on the W_R boson mass

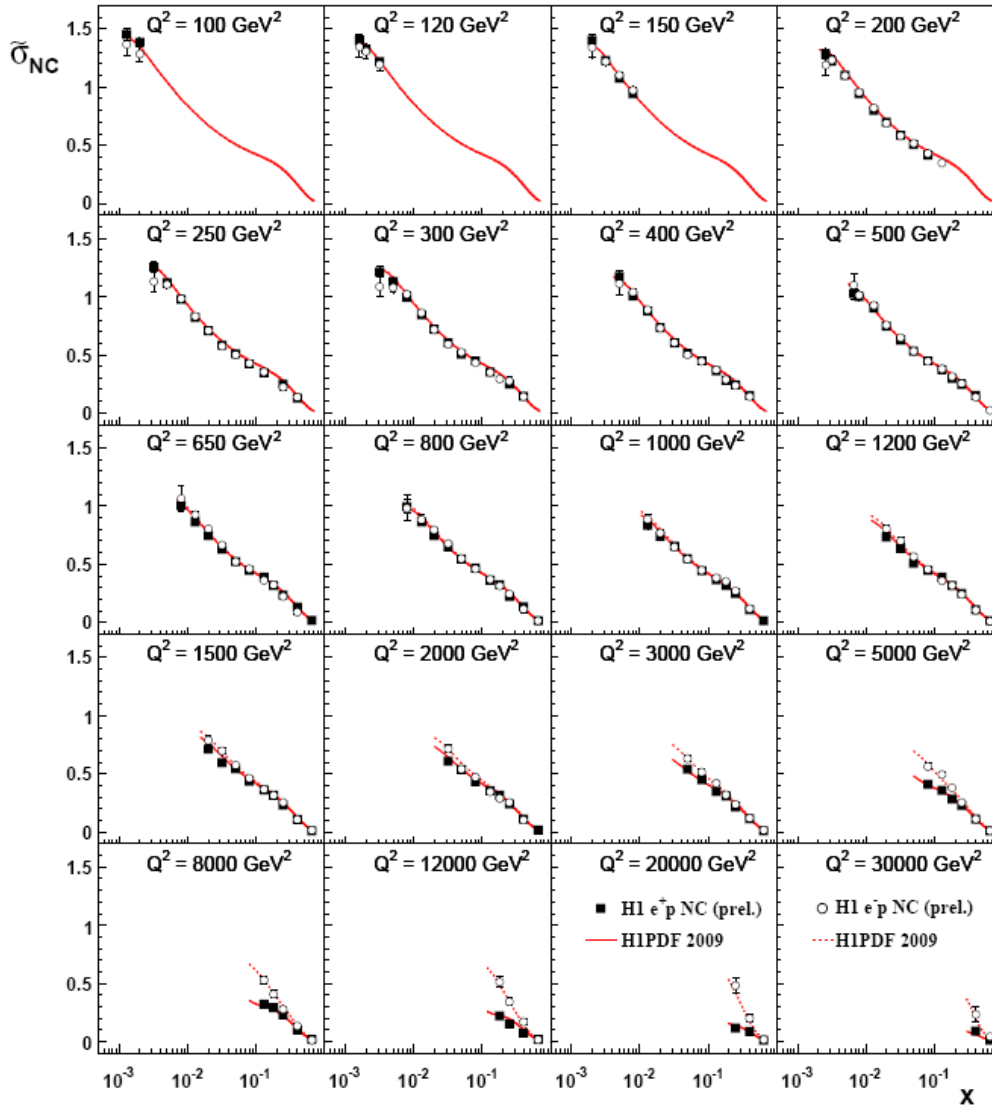
$$M_{W_R} \gtrsim 200 \text{ GeV}$$



Absence of right-handed weak current

Neutral Current Measurements at high Q^2

H1 Preliminary



$$\frac{d^2\sigma_{NC}(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha Y_\pm}{xQ^4} \cdot \tilde{\sigma}_{NC}^\pm$$

$$\tilde{\sigma}_{NC}^\pm = \tilde{F}_2(x, Q^2) \mp \frac{Y_-}{Y_+} x\tilde{F}_3(x, Q^2)$$

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

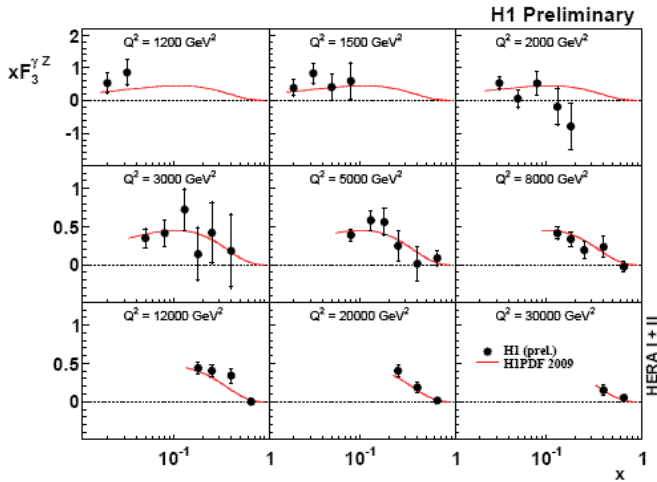
Main contribution

$$F_2 = \sum_q e_q^2 (xq + x\bar{q})$$

Difference in cross-sections at high Q^2 between e^+ and e^- is due to $x\tilde{F}_3$

HERA I + II

xF_3 structure function



reduced cross section at high Q^2

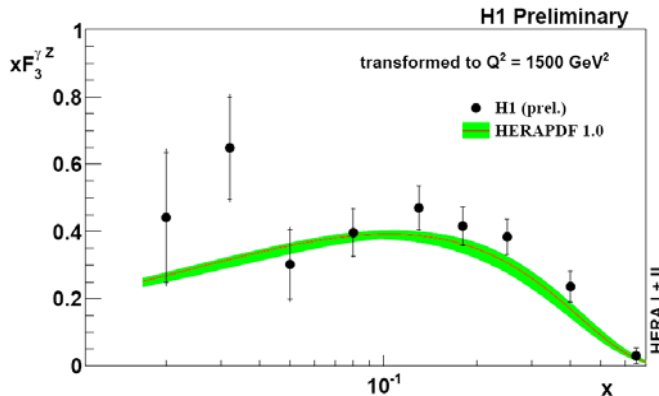
$$\tilde{\sigma}_{NC}(e^\pm p) = \tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3$$

mostly due to γZ interference

$$xF_3^{\gamma Z} = -\frac{Y_+}{2Y_-} [\tilde{\sigma}(e^- p) - \tilde{\sigma}(e^+ p)] / a_e \kappa_Z$$

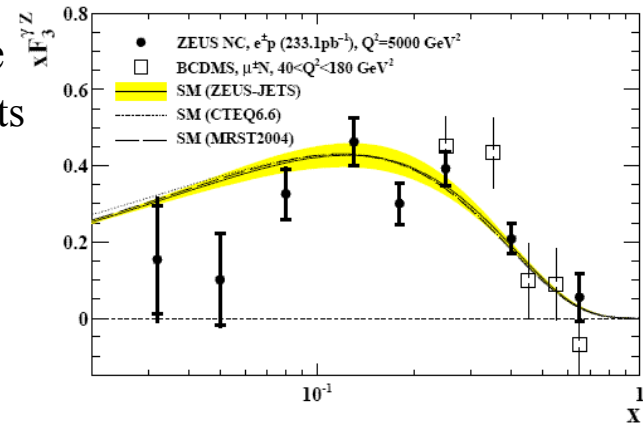
$$\kappa_Z = \frac{Q^2}{Q^2 + M_Z^2} \frac{1}{4 \cos^2 \Theta_W \sin^2 \Theta_W}$$

$$xF_3^{\gamma Z} \propto 2xu_v + xd_v$$



$xF_3^{\gamma Z}$: little Q^2 dependence
 \rightarrow transform all measurements
to one Q^2 value

constrain valence
quarks u_v, d_v at high x



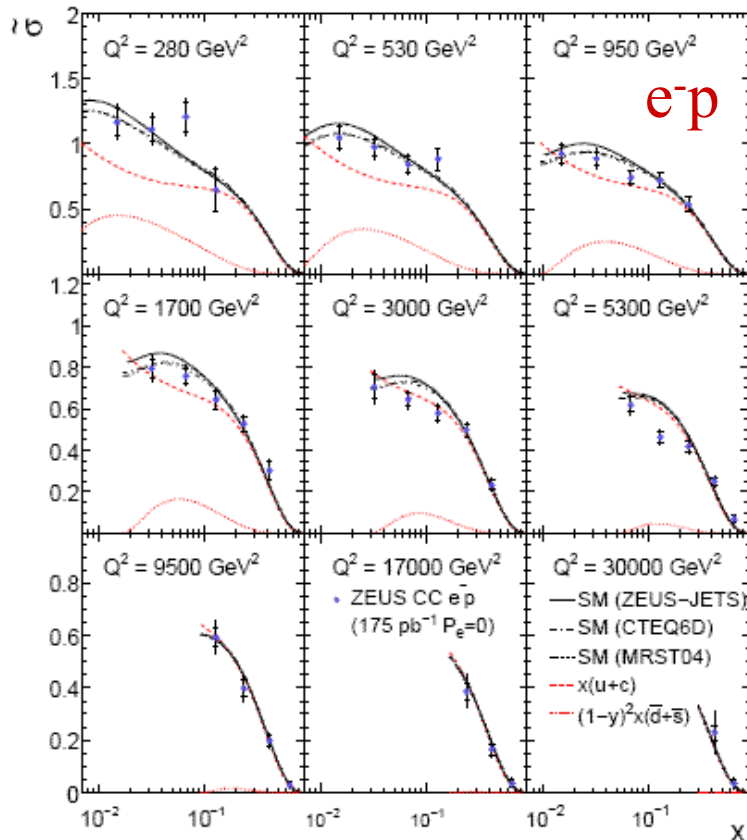
Charged Current Measurements

at high x

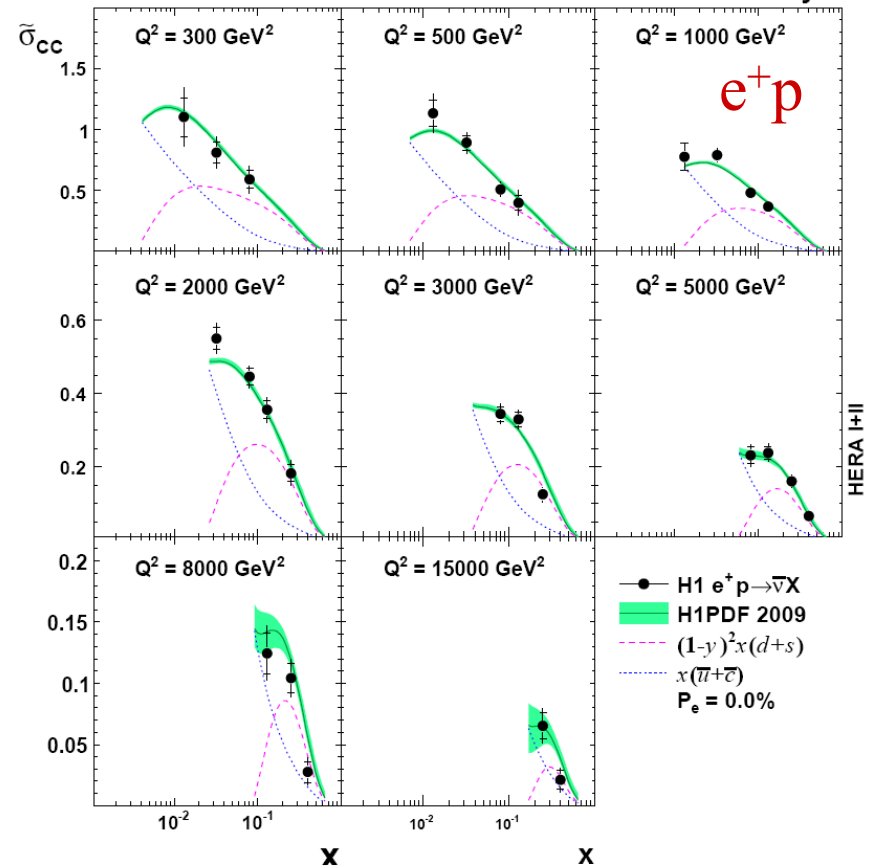
$$\tilde{\sigma}_{CC}(e^- p) \propto (xu + xc) + (1-y)^2(x\bar{d} + x\bar{s})$$

$$\tilde{\sigma}_{CC}(e^+ p) \propto (x\bar{u} + x\bar{c}) + (1-y)^2(xd + xs)$$

ZEUS



H1 Preliminary



→ constrain d and u quark densities; free of nuclear corrections and isospin assumptions

NC with longitudinally polarized leptons

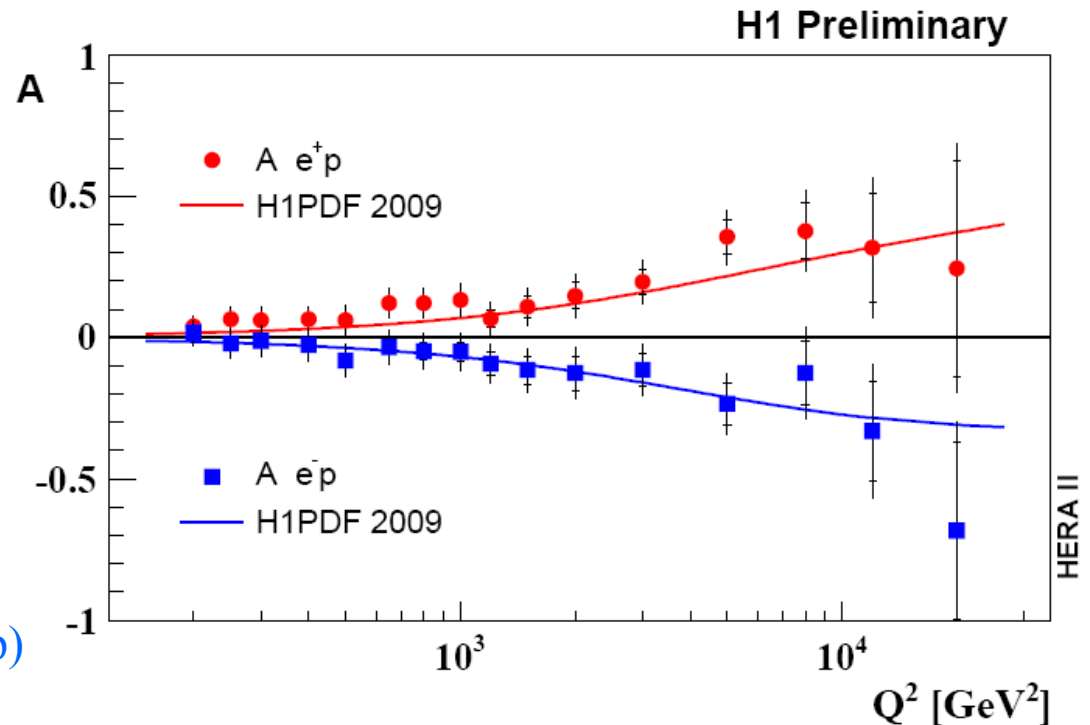
$$\begin{aligned} \tilde{F}_2^\pm &= F_2 - (v_e \pm P_e a_e) \kappa_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 \pm 2P_e v_e a_e) \kappa_Z^2 F_2^Z \\ x\tilde{F}_3^\pm &= - (a_e \pm P_e v_e) \kappa_Z xF_3^{\gamma Z} + (2v_e a_e \pm P_e (v_e^2 + a_e^2)) \kappa_Z^2 xF_3^Z \end{aligned}$$

$$P_e = \frac{N_R - N_L}{N_R + N_L} \quad \kappa_Z = \frac{Q^2}{Q^2 + M_Z^2} \frac{1}{4 \cos^2 \Theta_W \sin^2 \Theta_W}$$

Polarization Asymmetry

$$\begin{aligned} A^\pm &= \frac{2}{P_R - P_L} \frac{\sigma^\pm(P_R) - \sigma^\pm(P_L)}{\sigma^\pm(P_R) + \sigma^\pm(P_L)} \\ &\approx a_e \kappa_Z \frac{F_2^{\gamma Z}}{F_2} \propto \frac{1 + d_v / u_v}{4 + d_v / u_v} \end{aligned}$$

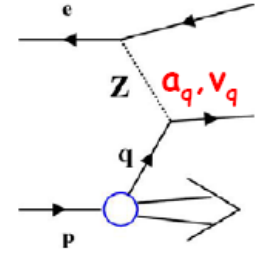
at low Q^2 $A(e^+p), A(e^-p) \approx 0$
 at high Q^2 non zero, $A(e^+p) \approx -A(e^-p)$



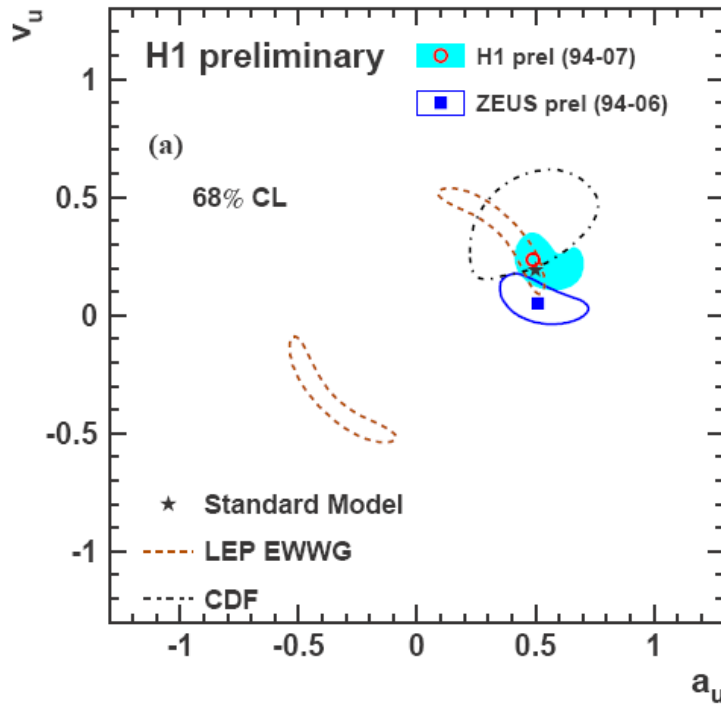
Light Quark Coupling to Z

simultaneous EW+PDF analysis of NC and CC data

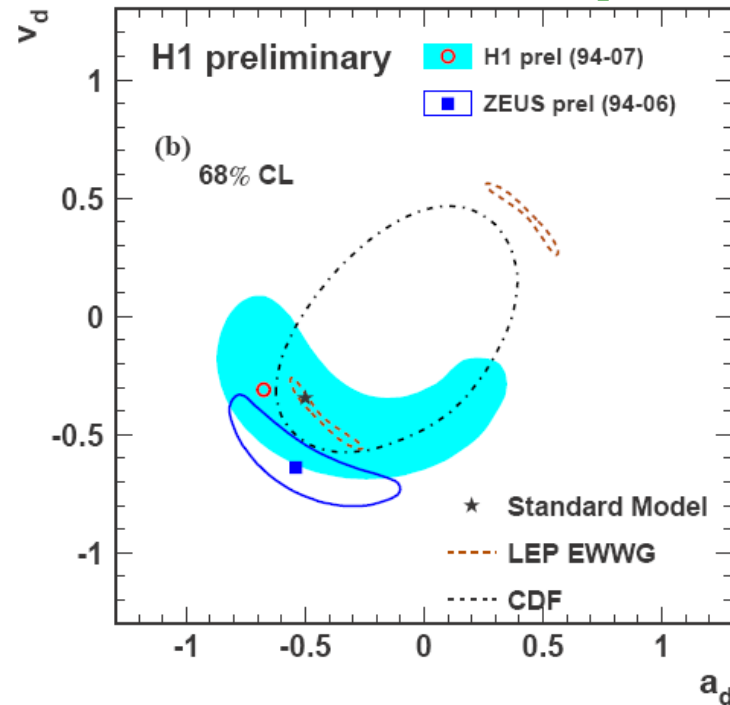
$$v_q = I_q^3 - 2e_q \sin^2 \Theta_W \quad a_q = I_q^3$$



u-quark



d-quark



Tevatron: $qq \rightarrow e^+e^-$ (A_{FB})

LEP EWWG: $ee \rightarrow qq$ at Z (a^2v^2, a^2+v^2)

→ resolves LEP ambiguity

→ the best precision on u quark coupling to Z

Conclusions

Over 15 years of HERA operation (1992-2007) H1 and ZEUS collected in total 1fb-1 (electrons/positrons positive/negative longitudinal polarization of the lepton beam)
→ Now the full power of this data at high Q^2 is revealed

- precise measurements of the proton structure functions / PDF's
- study of EW effects in NC and CC

Next step is to combine final H1 and ZEUS data from HERA I and HERA II and improve precision of PDFs.