Determination of electroweak parameters at HERA with the H1 experiment

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On behalf of the H1 Collaboration

DIS 2005, Madison, USA

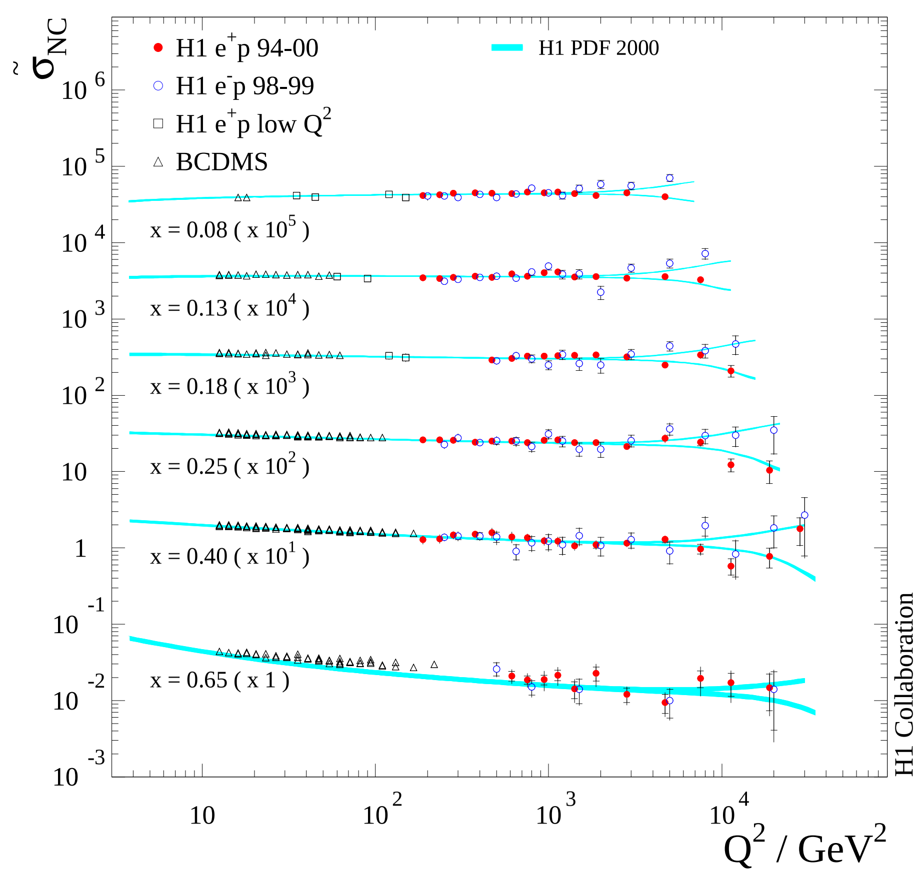
Outline

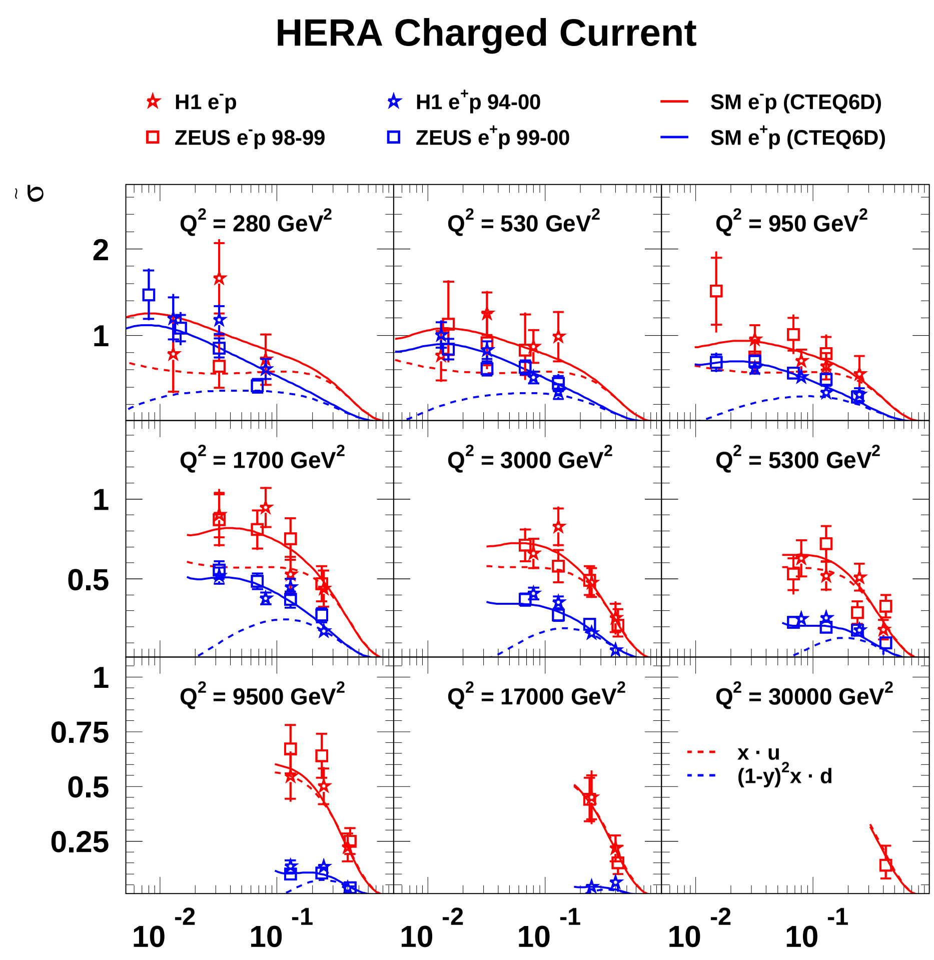
Aim is to determine electroweak parameters with a combined QCD-electroweak analysis using H1 data from HERA I

- Fitting schemes
- Propagator Mass analysis
- On Mass Shell (OMS) fit analysis
- Quarks couplings to the Z
- Conclusions and outlook

HERA I data

Exploit the potential for electroweak physics with the HERA I NC and CC data





CC cross section and M_W

$$\frac{d^2\sigma^{\pm}_{CC}}{dx\, dQ^2} = \frac{G^2}{2\pi} \cdot \left(\frac{M_W^2}{Q^2 + M_W^2} \right)^2 \cdot \Phi^{\pm}(pdfs)$$

Mw is propagator mass (enters in Q2 dependency)
Fermi constant G includes most of the radiative corrections

$$\frac{d^2\sigma^{\pm}_{CC}}{dx\, dQ^2} = \frac{\pi\alpha^2}{4M_W^4 \left(1 - \frac{M_W^2}{M_Z^2}\right)^2} \cdot \frac{1}{|1-\Delta r|^2} \cdot \left(\frac{M_W^2}{Q^2 + M_W^2} \right)^2 \cdot \Phi^{\pm}(pdfs)$$

OMS scheme : Mw also enters in normalization
Radiative correction Δr computed in SM framework

Interpretations of Mw in both schemes

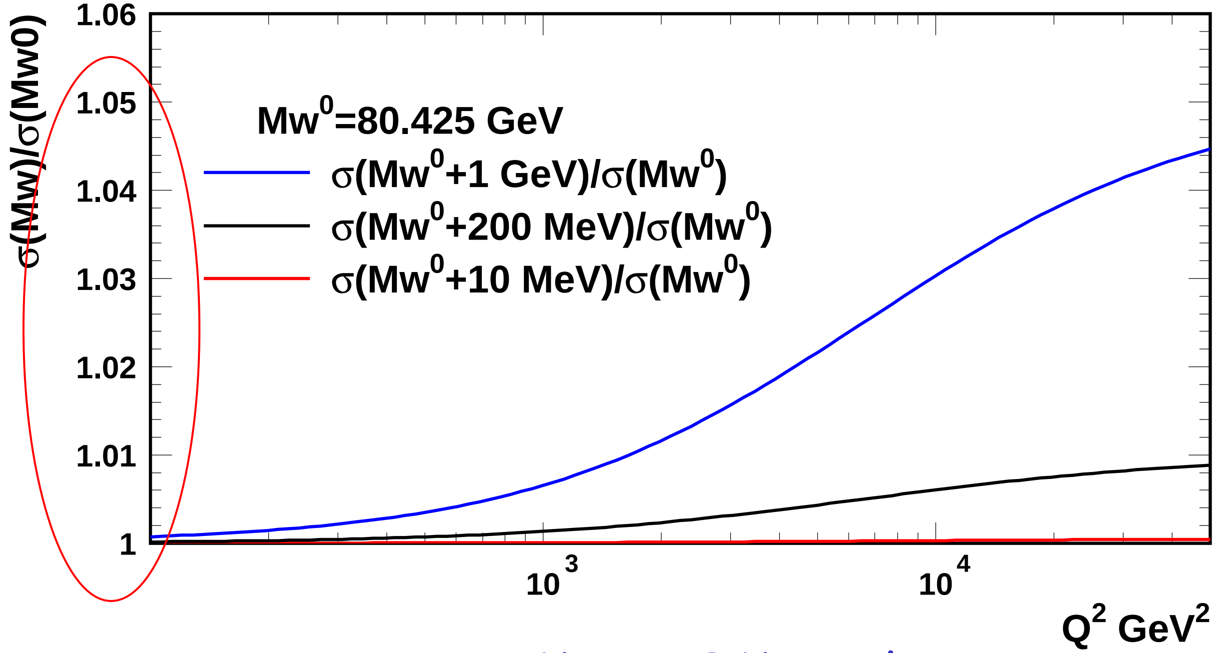
- The propagator mass measurement is a model independent measurement of Mw
  Unique using HERA t-channel exchange

- The determination of Mw in OMS scheme is a Standard Model-dependent determination of the Mw parameter
  dependency upon Mtop and Mhiggs

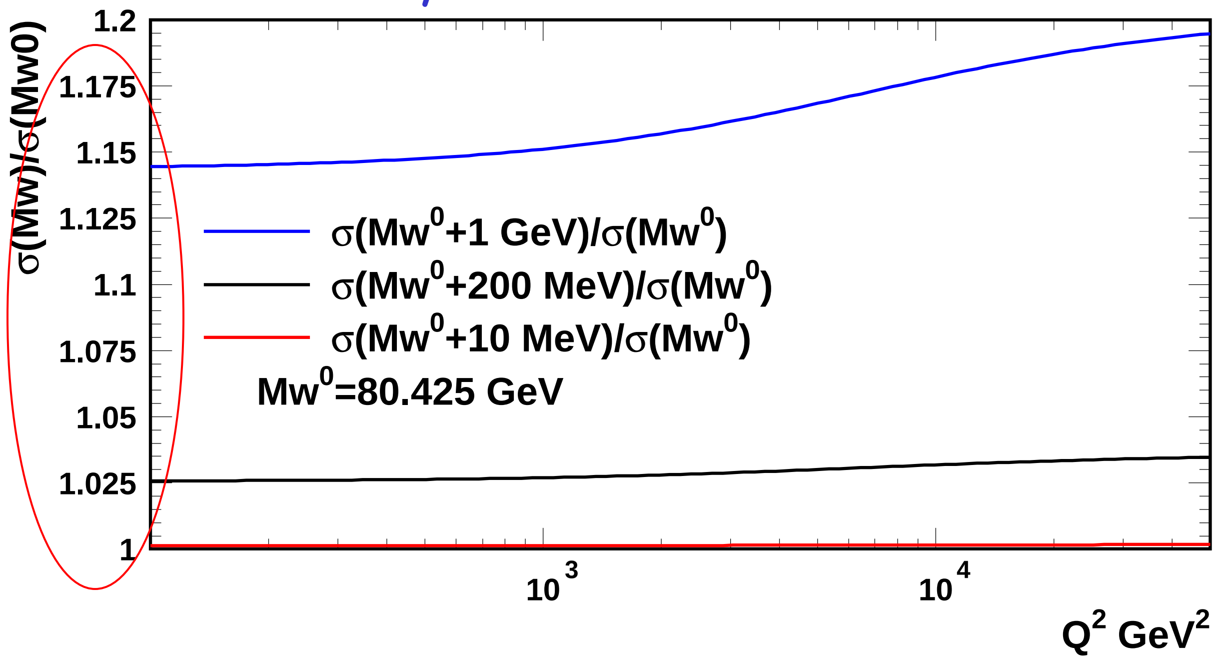
- Use both strategies

Major progress is to perform a EW-QCD combined fit to consistently include uncertainty from proton structure : use the H1PDF2000 QCD analysis

Sensitivity to the propagator mass



Sensitivity to Mw in OMS scheme



The H1 QCD pdfs analysis (Eur Phys J C30, 2003))

Idea is to take the H1PDF2000 fit as a **basis**

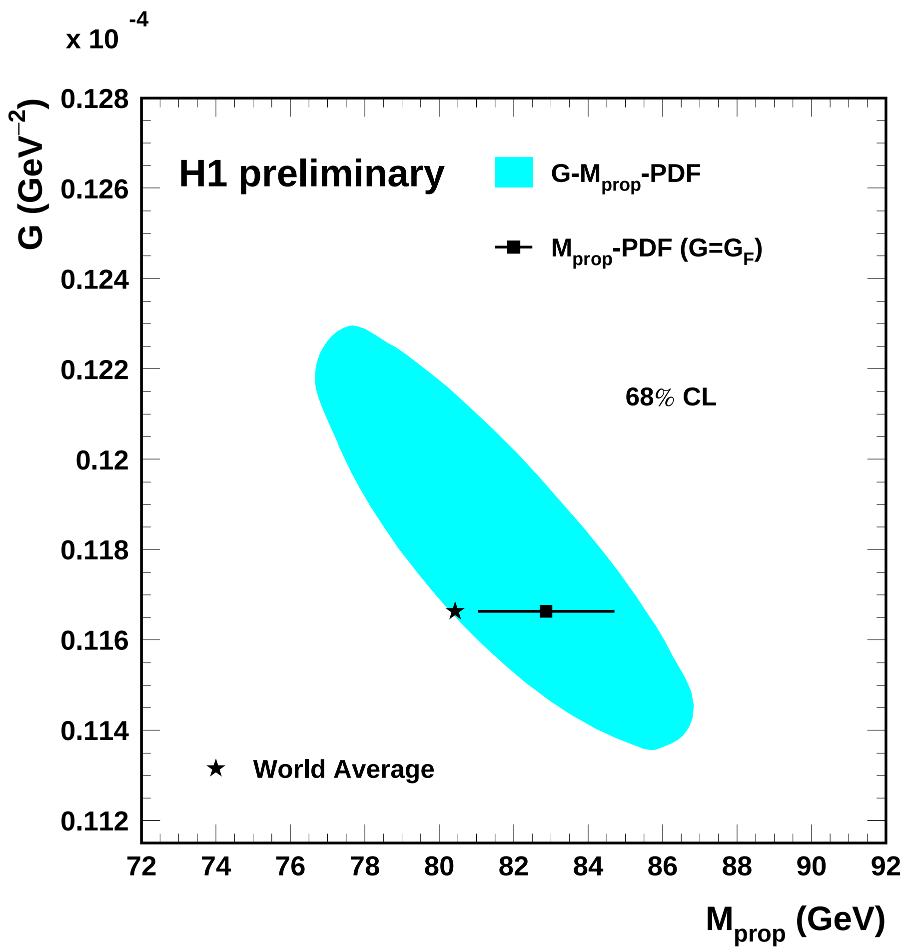
NLO QCD massless scheme
Pascaud Zomer χ^2 definition

H1 Data Sets:
Minimum Bias 97
low Q2 96-97
high Q2 94-97 e^+p NC and CC
high Q2 98-99 e^-p NC and CC
high Q2 99-00 e^+p NC and CC

Result is a 10-parameter fit of parton densities

Propagator mass analysis

G-propagator mass fits



G-Mprop-QCD fit

⇒ fix GF to the SM value and fit propagator mass with pdfs

Propagator mass fit

➡ Parton densities are determined using some Mw
It is not coherent to use fixed pdfs to fit Mw

Pdfs fixed to H1PDF2000 fit
Mw= 82.370 ± 1.572 GeV

Fit of pdfs + Mw (as the propagator mass)

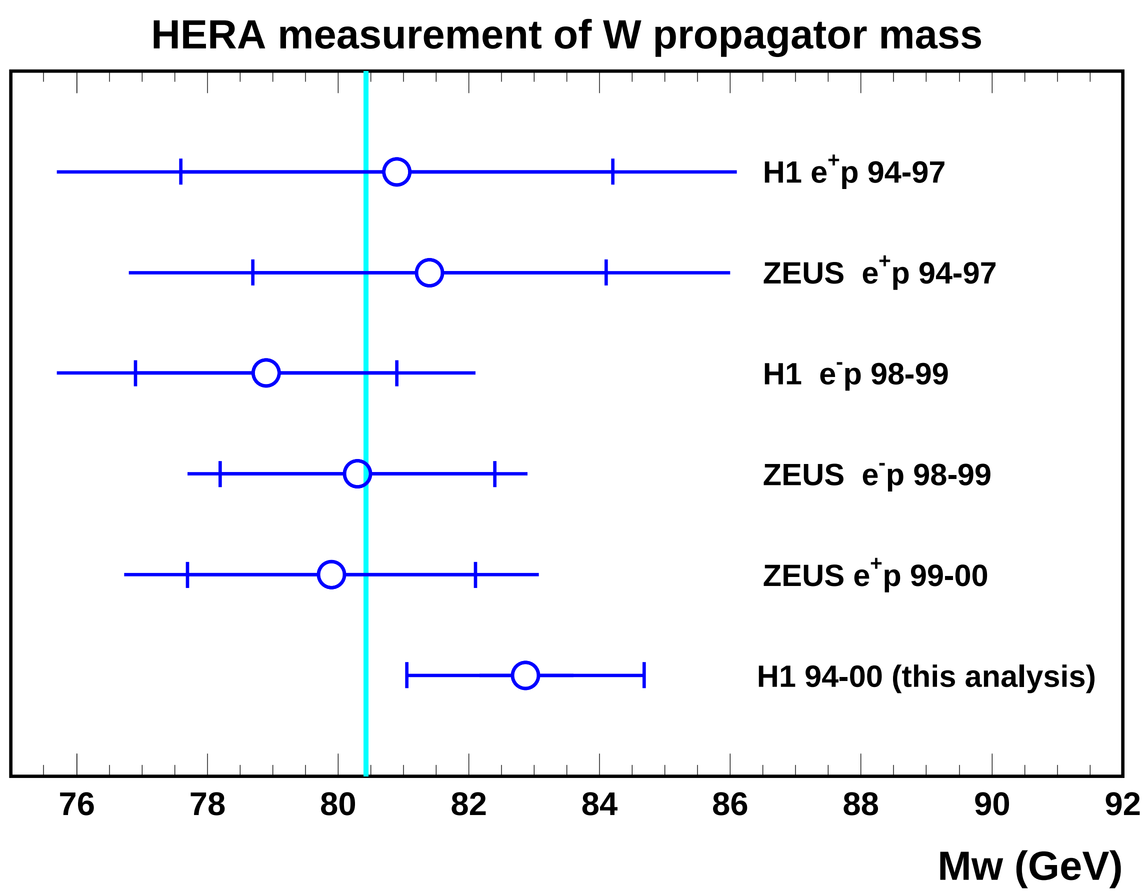
$$M_W = 82.87 \pm 1.83\,(\mathrm{exp})\,^{+0.30}_{-0.16}\,(\mathrm{mod})\ \mathrm{GeV}$$

Model uncertainties (α_s, Q_0^2,....)

Mw is correlated with all the other fit parameters

- First coherent determination of propagator mass in ep collisions

Summary of Propagator Mass results



H1 94-00 result : $M_W = 82.87 \pm 1.83\,(\mathrm{exp})\,^{+0.30}_{-0.16}\,(\mathrm{mod})$ GeV

“On Mass Shell” analysis

OMS scheme Mw fit

- Need to compute the radiative correction Δr
  Function of α,Mz,Mw,Mtop,Mhiggs,
  (and other fermion masses)
  computed with H. Spiesberger EPRC program

- EPRC compute Δr including
  $O(\alpha)$ +$O(\alpha\alpha_s)$+leading $O(\alpha^2)$ terms
  (introduce theoretical uncertainty)

- This method is not a measurement of Mw but
  a parameter determination in SM framework

W propagator self energy

$$\Delta r = \Delta\alpha - \frac{c_W^2}{s_W^2}\Delta\rho + \Delta r_{rem}$$

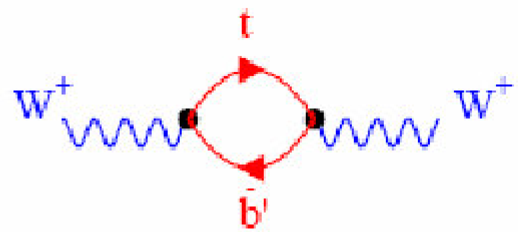
$\Delta\alpha_{lept}$

Computable

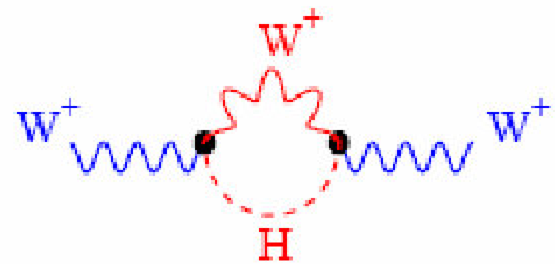
$\Delta\alpha_{quarks}$

Hadronic photon
Vacuum polarization
Not computable
Parameterized with
e+e- data

$\Delta\rho^{top} \propto M_{top}^2$



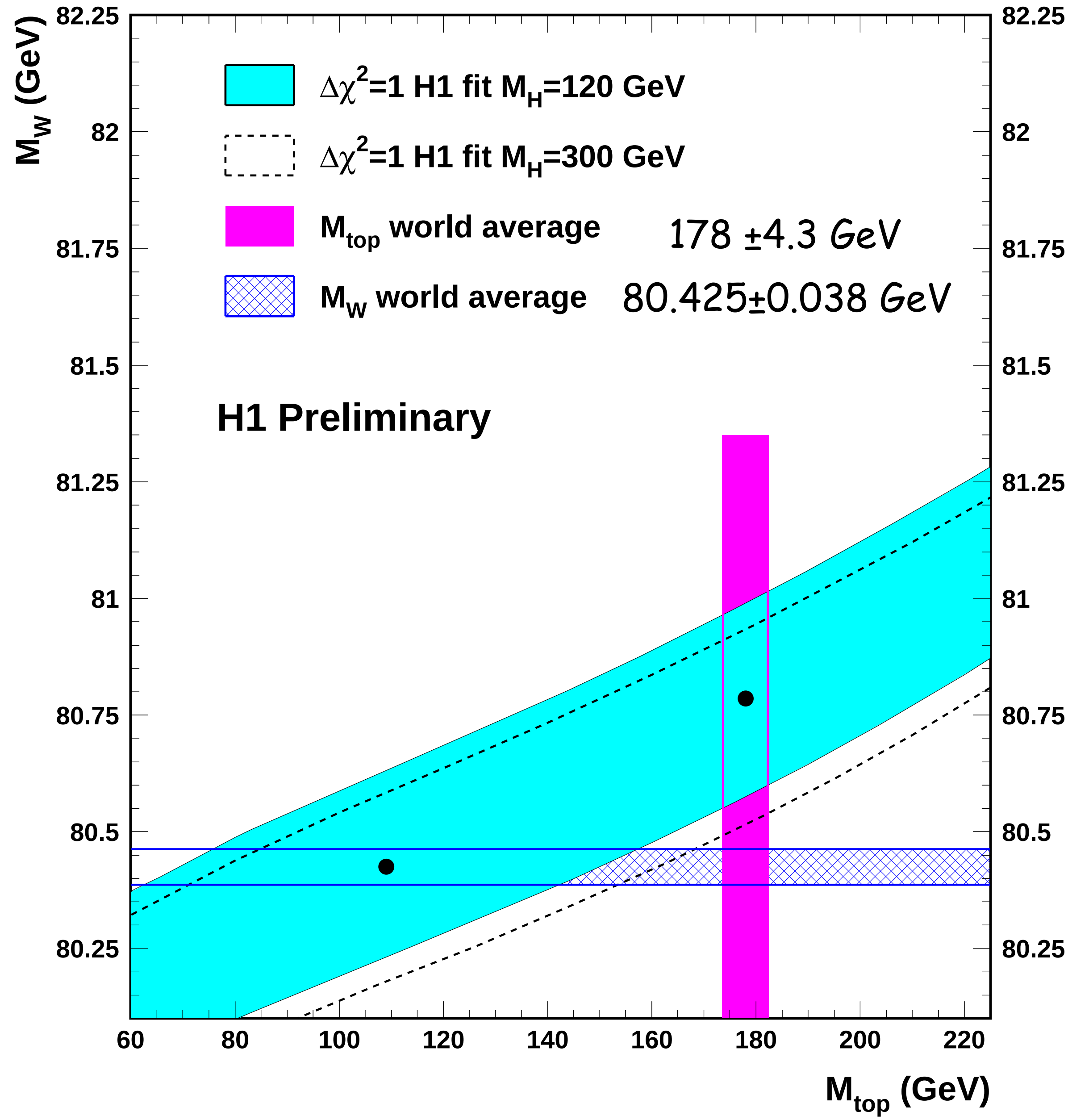
$\Delta r_{rem}^{Higgs} \propto \ln M_{Higgs}$



Mw-Mtop-QCD fit

TeVatron direct Mtop measurement ➡ allows to constrain Mw with H1 data

Higher Higgs mass shift the allowed region



QCD+Mw fit results

Using Mtop=178 GeV, Mhiggs=120 GeV

⇒ Mw=80.786 ± 0.207(exp) GeV
(1.7 σ from world average 80.425 GeV)

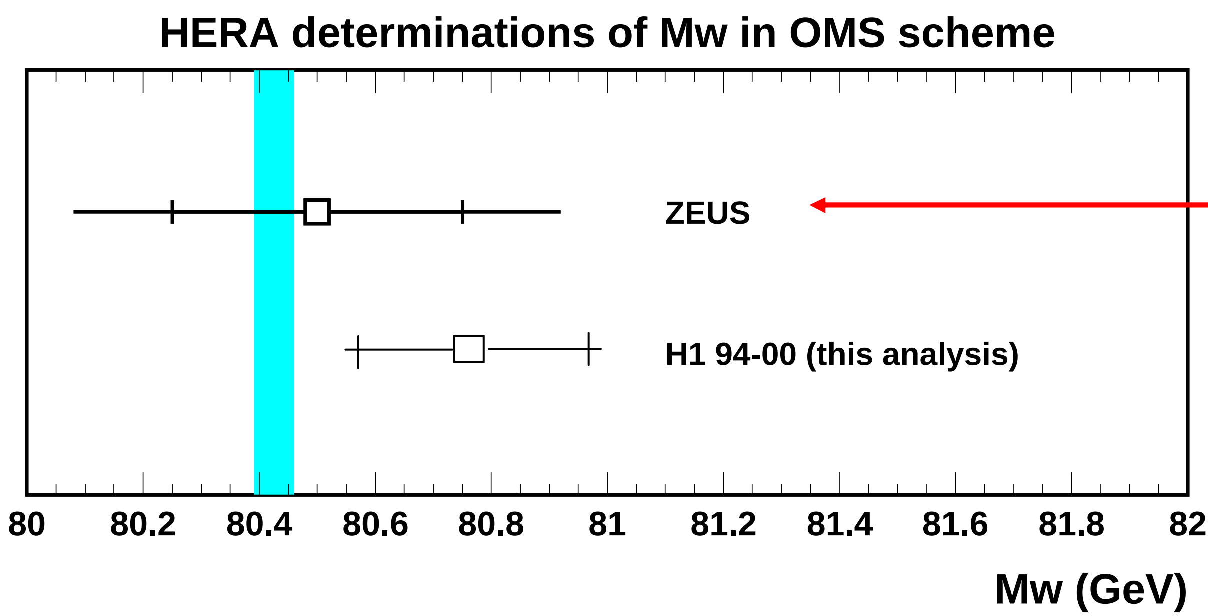
Uncertainties :

- QCD model uncertainty
- Mtop and Mhiggs uncertainties
- Theoretical uncertainties from Δr

$$M_W = 80.786 \pm 0.207(\mathrm{exp})\,^{+0.048}_{-0.029}(\mathrm{mod}) \pm 0.025(\mathrm{top})$$
$$\pm 0.033(\mathrm{th}) - 0.084(\mathrm{Higgs})\ \mathrm{GeV}$$

(120->300 GeV)

HERA determinations of Mw in OMS scheme



Pdfs uncertainty
□(0.3 GeV)

In the OMS scheme $\sin^2\Theta_W=1-M_W^2/M_Z^2$
can be derived using the M_Z value from world average

$$\Rightarrow \sin^2\theta_W = 0.2151 \pm 0.0040\,(\mathrm{exp})\,^{+0.0019}_{-0.0011}\,(\mathrm{th})$$

Consistency of HERA data with the Standard Model

Mtop+QCD and Mhiggs+QCD fits

Fix Mw to the world average and fit other parameters via the radiative correction Δr

Fit Mtop + QCD parameters
Mtop=108 ± 44 GeV

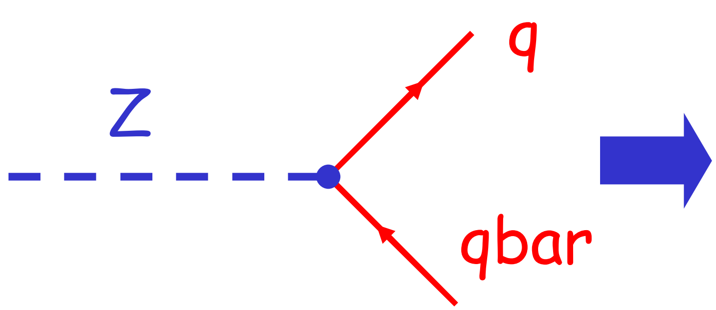
Fit $\log_{10}$(Mhiggs) + QCD parameters
$\log_{10}$(Mhiggs)=3.9 ± 2.2

➡ Top mass consistent with direct measurement

➡ Higgs Mass larger than 50 GeV

Quarks couplings to the Z

Quarks couplings to the Z



$$\frac{ig}{\cos\theta_W}\gamma^\mu \frac{v_q - a_q\gamma^5}{2}$$

$a_q = I_3^L$ Axial coupling, I^3=+1/2 for u, -1/2 for d

$v_q = I_3^L - 2e_q \sin^2\theta_W$ Vector coupling

Z couplings in DIS

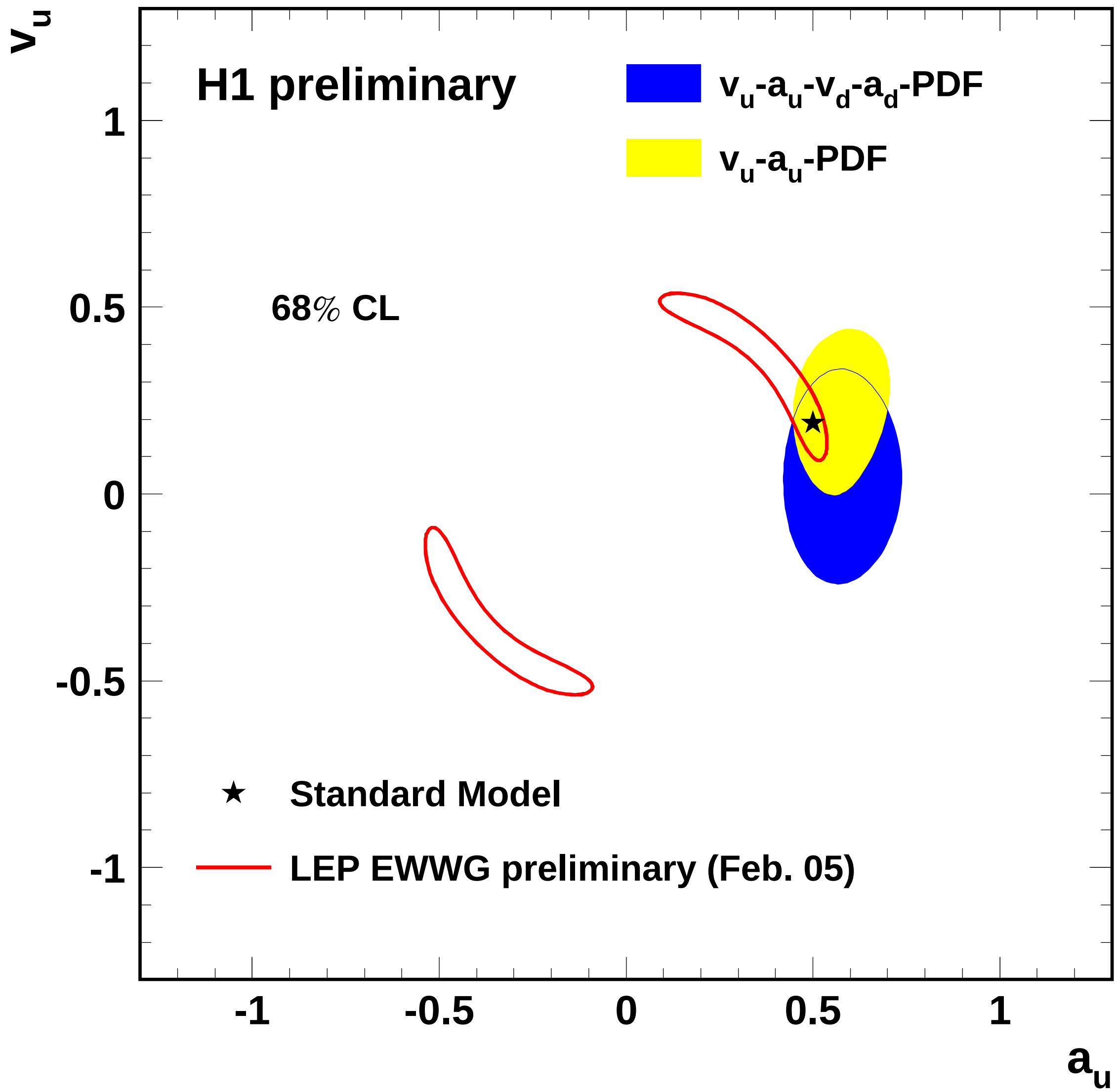
$$F_2 = \sum_q \left[e_q^2 - 2e_q v_q v_e \chi_Z + \left(v_q^2 + a_q^2 \right)\left(v_e^2 + a_e^2 \right) \chi_Z^2 \right] x(q + \bar{q})$$

$$xF_3 = \sum_q \left[-2e_q a_q a_e \chi_Z + 4 v_q a_q v_e a_e \chi_Z^2 \right] x(q - \bar{q})$$

➡ Determination of the four a_U, v_U, a_D, v_D

➡ More sensitivity to the U coupling than to the D couplings (pdfs sensitivity)

U quark results

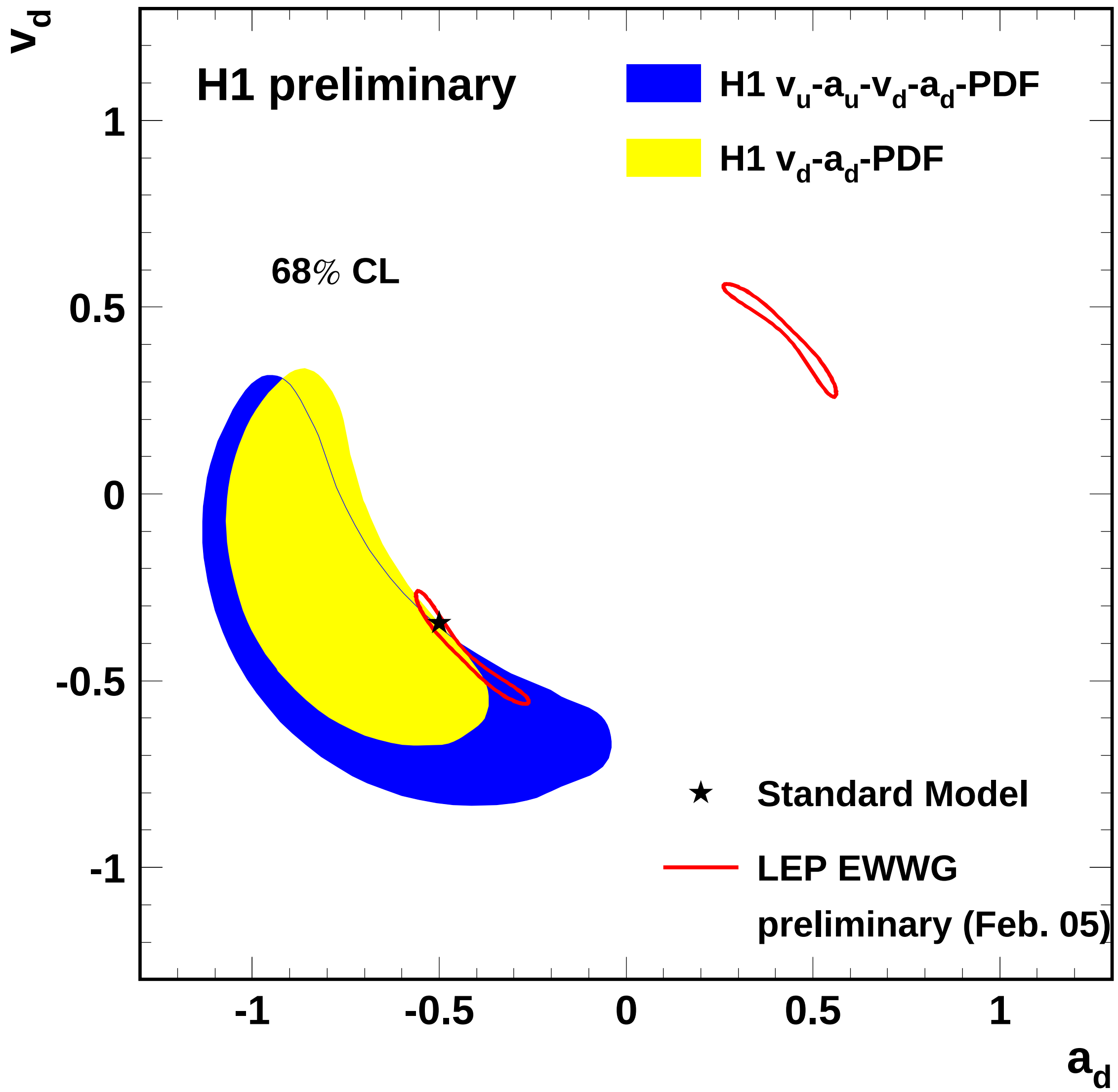


Fit of pdfs
+couplings

H1 result removes
LEP ambiguities

First HERA result
on this topic

D quark results



H1 precision limited for D

Not final word : HERA II polarized measurements will help

Deviation from the Standard Model : Right Handed Isospin

In SM the quarks comes in isospin doublets ($I_3^L=\pm\frac{1}{2}$) for Left components and isospin singlets ($I_3^R=0$) for the Right components

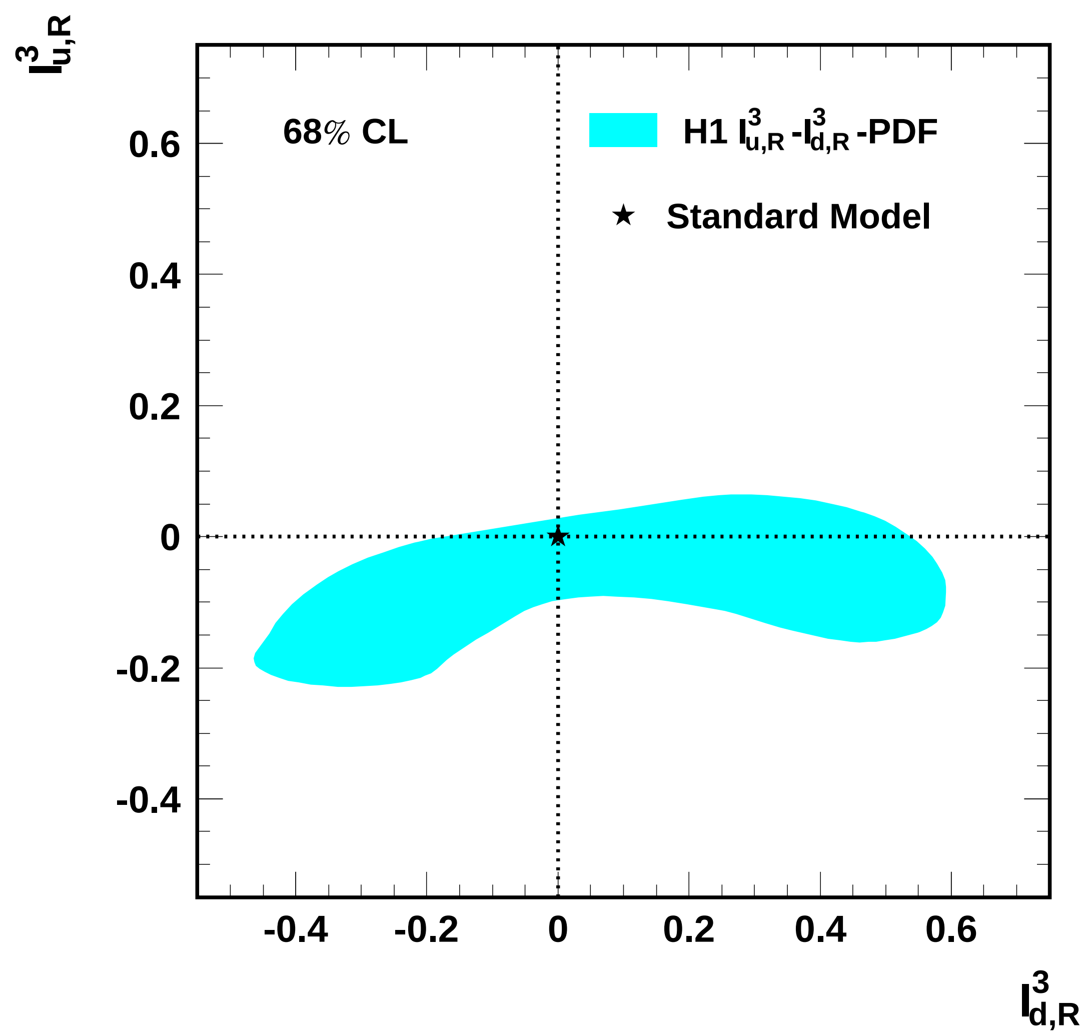
Allow an Isospin for right-handed U and D quarks $I_3^R \neq 0$

$$a_q = I_3^L - I_3^R$$

$$v_q = I_3^L - 2e_q \sin^2\theta_W + I_3^R$$

➡ Perform a fit of $I_3^R(U)$ and $I_3^R(D)$ (2+10 parameters)

Result of the I3R(U)-I3R(D)-QCD fit



I3R(U) and I3R(D) compatible with zero

Constraint is stronger for U

Conclusions and outlook

Use ofa new combined EW-QCD analysis allows to extract electroweak parameters with the H1 HERA I data

➡ W mass measurement with the propagator mass

➡ Mw fit in the OMS scheme

- First measurement of quarks couplings to the Z in ep collisions

Complementary to LEP heavy quarks measurements

➡ HERAII polarized data will help