

Combined Electroweak and QCD Fit to NC and CC Data



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On behalf of the H1 Collaboration



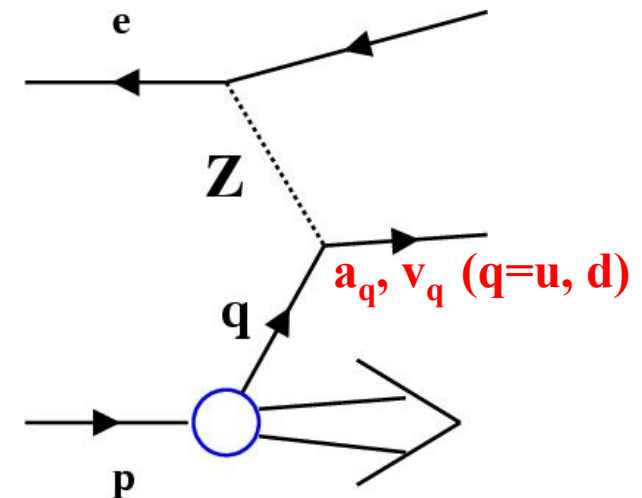
Outline

- Introduction
- New constraints from HERA-2 Data with P_e
- Results
- Summary

Introduction

- Inclusive NC and CC cross section data
→ Primary constraint of Parton Distribution Functions (PDFs)

- NC cross section at high Q^2
→ also sensitive to light quark couplings to the Z boson



Coupling Sensitivity @ HERA-1

$$\frac{d^2\sigma_{\text{NC}}^{\pm}}{dx dQ^2} \sim Y_+ \tilde{F}_2 \mp Y_- x \tilde{F}_3 \quad \text{with} \quad Y_{\pm} = 1 \pm (1-y)^2$$

$v_e \sim 0$, \rightarrow some of the terms are negligible

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

$$x \tilde{F}_3 = -a_e \kappa_Z x F_3^{\gamma Z} + \cancel{2 v_e a_e \kappa_Z^2 x F_3^Z}$$

$$F_2^Z = x \sum_q (v_q^2 + a_q^2) \{q + \bar{q}\} \quad \kappa_Z^{-1} = \frac{2\sqrt{2}\pi\alpha}{G_F M_Z^2} \frac{Q^2 + M_Z^2}{Q^2}$$

$$x F_3^{\gamma Z} = 2x \sum_q e_q a_q \{q - \bar{q}\}$$

$\rightarrow a_q$ mainly constrained by $x F_3^{\gamma Z}$

$\rightarrow v_q$ constrained by F_2^Z

Additional Sensitivity @ HEAR-2

Polarized e beam (P_e) \rightarrow Additional terms

Structure function formulae
given for e^-p scattering,
for e^+p , $P_e \rightarrow -P_e$

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

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

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

$$[xF_3^{\gamma Z}, xF_3^Z] = 2x \sum_q [e_q \cancel{a_q}, \cancel{v_q} a_q] \{q - \bar{q}\}$$

\rightarrow additional constraint on $\cancel{v_q}$ by $F_2^{\gamma Z}$

Fit Strategy (1)

Phys. Lett. B632 (2006) 35, hep-ex/0507080

- Using not only NC high Q^2 data but also precision low Q^2 data & CC high Q^2 data

- ➔ 5 sets of PDFs are constrained a la H1PDF2000 ($Q_0^2=4\text{GeV}^2$):

Eur. Phys. J. C30(2003)1, hep-ex/0304003

$$\begin{aligned}
 xg(x) &= A_g x^{B_g} (1-x)^{C_g} (1 + D_g x) \\
 xU(x) &= A_U x^{B_U} (1-x)^{C_U} (1 + D_U x + F_U x^3) \\
 xD(x) &= A_D x^{B_D} (1-x)^{C_D} (1 + D_D x) \\
 x\bar{U}(x) &= A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}} \\
 x\bar{D}(x) &= A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}
 \end{aligned}$$

10 free parameters for PDFs with constraints (momentum sum rule, quark counting rules, etc)

Dataset	Process	Q^2 (GeV ²) range
Mini bias 97	e ⁺ p NC	1.5-12
Low Q^2 96-97	e ⁺ p NC	12-150
High Q^2 94-97	e ⁺ p NC	150-30000
High Q^2 94-97	e ⁺ p CC	300-15000
High Q^2 98-99	e ⁻ p NC	100-30000
High Q^2 98-99	e ⁻ p CC	300-15000
High Q^2 99-00	e ⁺ p NC	150-30000
High Q^2 99-00	e ⁺ p CC	300-15000

Fit Strategy (2)

Phys. Lett. B632 (2006) 35, hep-ex/0507080

- Combined couplings & PDFs fit
- ➔ Correlation between couplings & PDFs is properly taken into account
- Minimize χ^2 function in QCDFIT by taking into account of correlations among one dataset and between datasets:

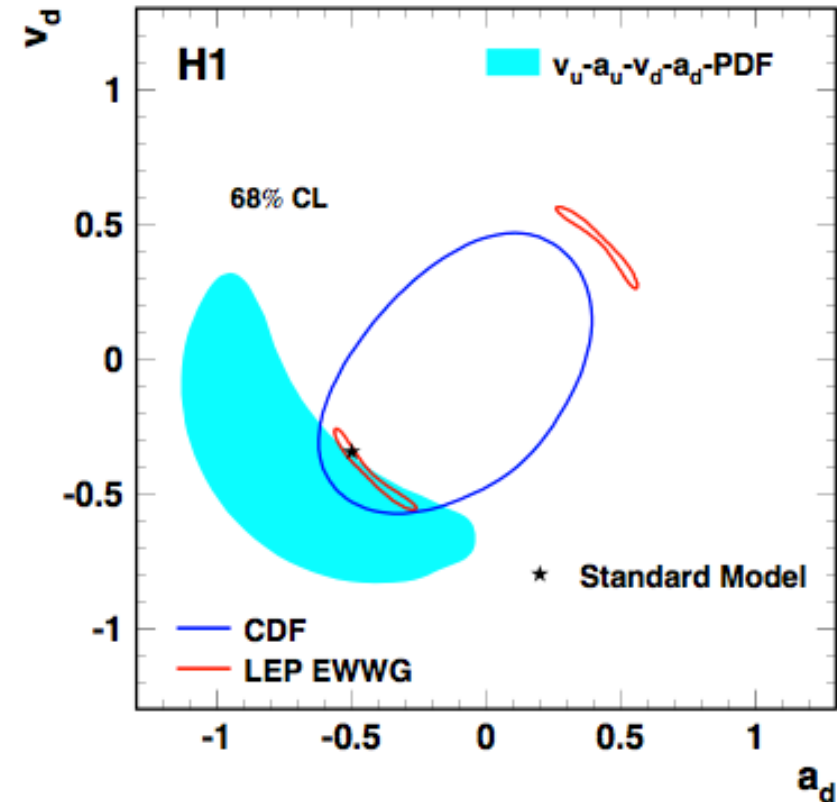
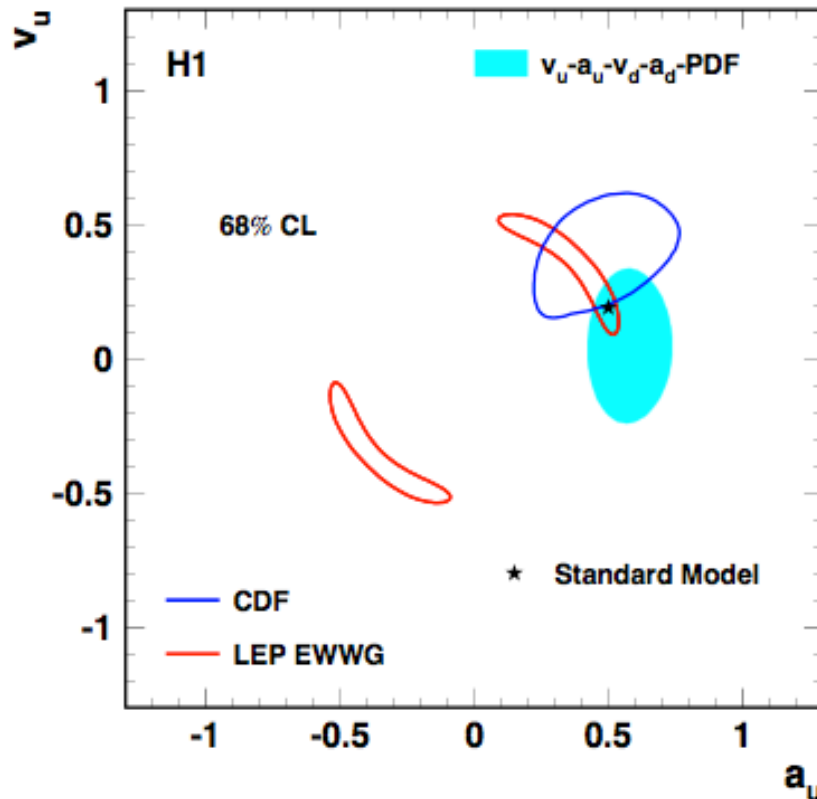
$$\chi^2(\sigma^{\text{data}}, \alpha) = \sum_{\text{exp. data}} \frac{[\sigma^{\text{data}} (1 - \sum_l \alpha_l \delta_l) - \sigma^{\text{th}}]^2}{\delta_{\text{stat}}^2 + \delta_{\text{uncor}}^2} + \sum_l \alpha_l^2$$

where δ_l are different correlated syst error sources
 σ^{th} is based on NLO DGLAP evolution equations

Published Results based on HERA-1 Data

Phys. Lett. B632 (2006) 35, hep-ex/0507080

$$\chi^2/\text{dof}=531.7/(622-14)=0.87$$



CDF: $qq' \rightarrow e+e^-$ (Drell-Yan), A_{FB}

Phys.Rev. D71 (2005) 052002, hep-ex/0411059

LEP/SLC: $ee \rightarrow qq(\gamma)$, $a_q^2 + v_q^2$

Phys.Rept.427:257,2006, hep-ex/0509008

→ HERA determination:
complementary & competitive

Including New Data

- Newly published low Q^2 data & previously published one
→ combined into 4 datasets (typical precision: 1.3-2%)

Eur. Phys. J. C63 (2009) 625, arXiv:0904.0929 [hep-ex]

Eur. Phys. J. C64 (2009) 561, arXiv:0904.3513 [hep-ex]

- New preliminary HERA-2 NC & CC data (8 datasets)
→ included

CC data: refer to the talk by S. Shushkevich

NC data: refer to the talk by V. Chekelian

- ➔ In total, up to 19 datasets are used in the combined fit

Use Alternative PDF Forms

JHEP 1001:109,2010, arXiv:0911.0884 [hep-ex]

PDF forms a la HERAPDF1.0 ($Q^2_0=1.9\text{GeV}^2$):

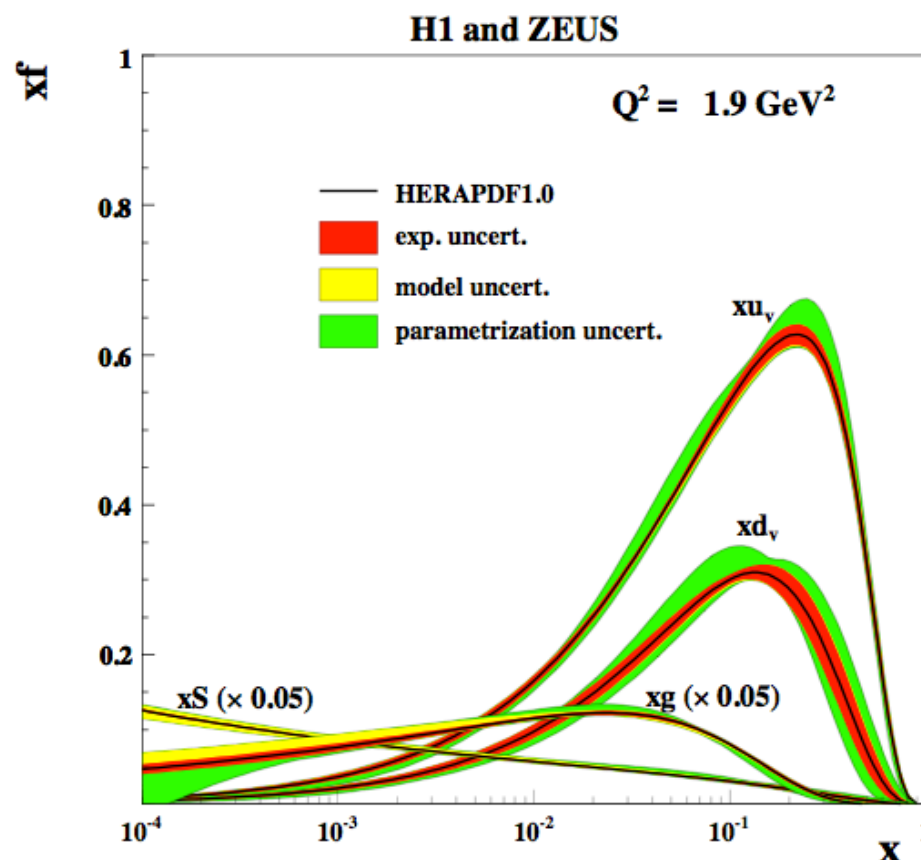
$$xg(x) = A_g x^{B_g} (1-x)^{C_g}$$

$$xu_v(x) = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + E_{u_v} x^2)$$

$$xd_v(x) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}}$$

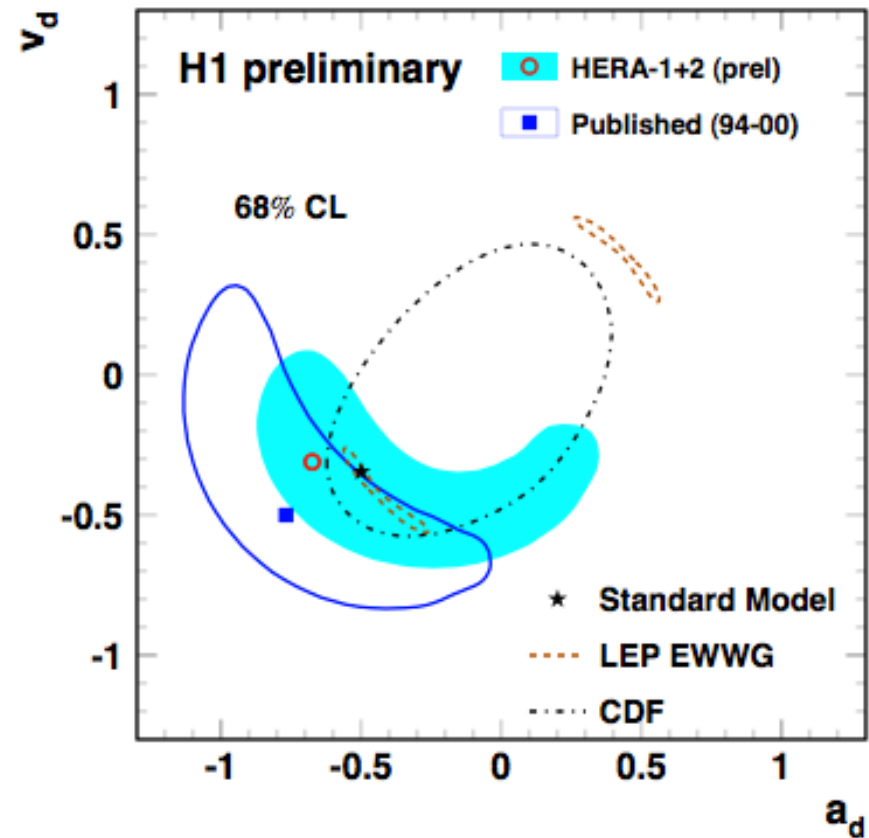
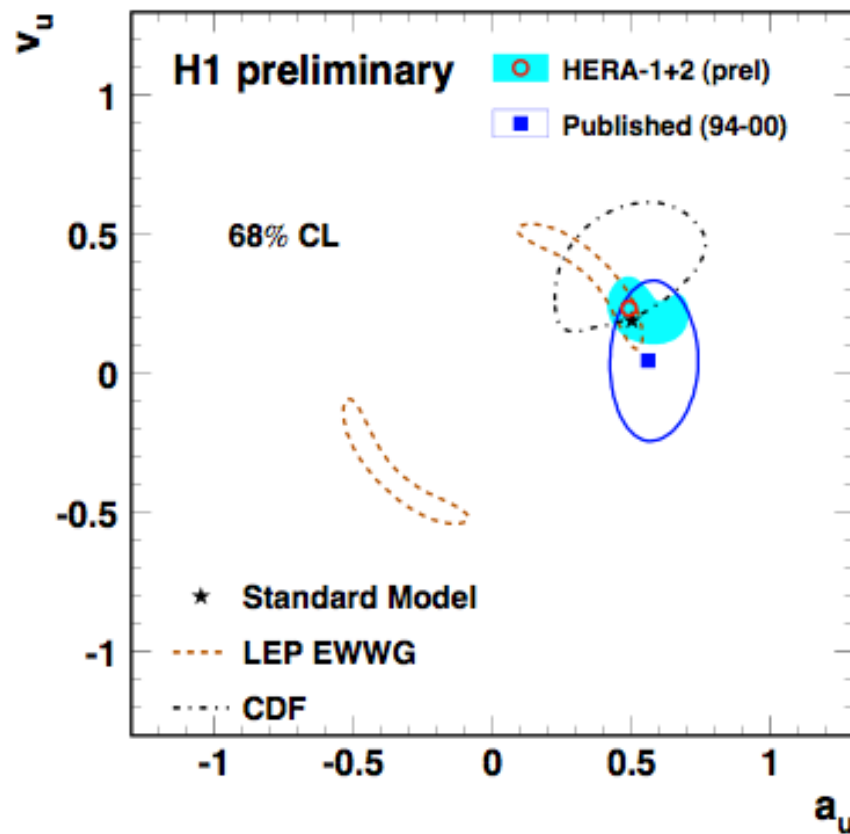
$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}}$$

$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}$$



Fit Results (1)

$$\chi^2/\text{dof}=1183.8/(1244-14)=0.96$$

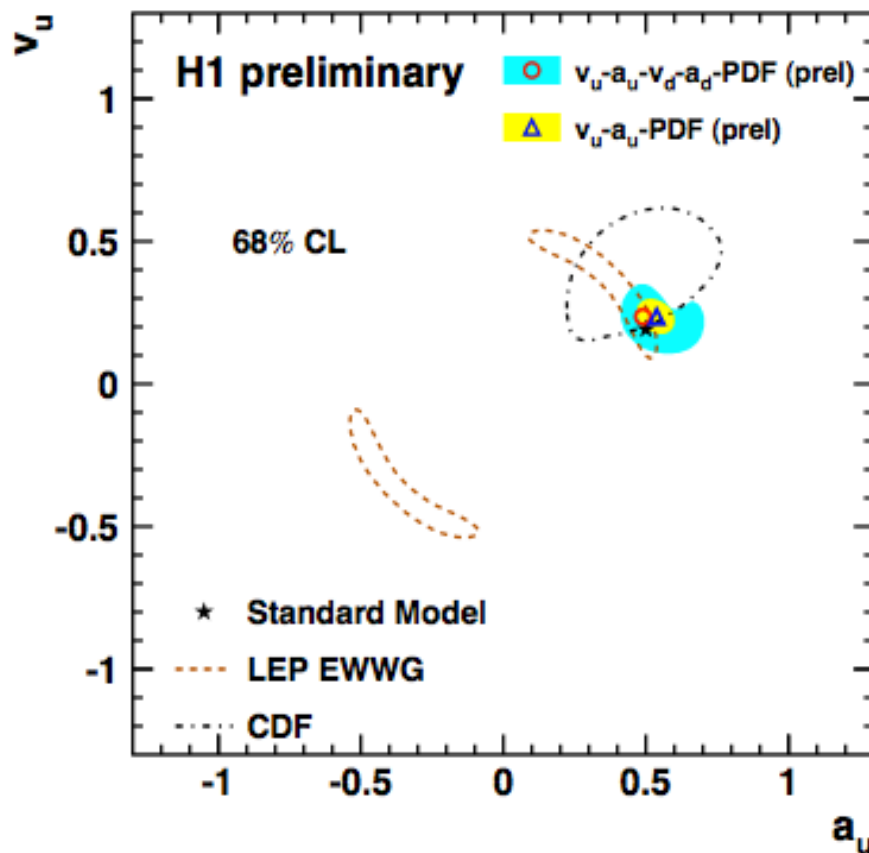


→ Weak couplings v_q : much improved as expected

Fit Results (2)

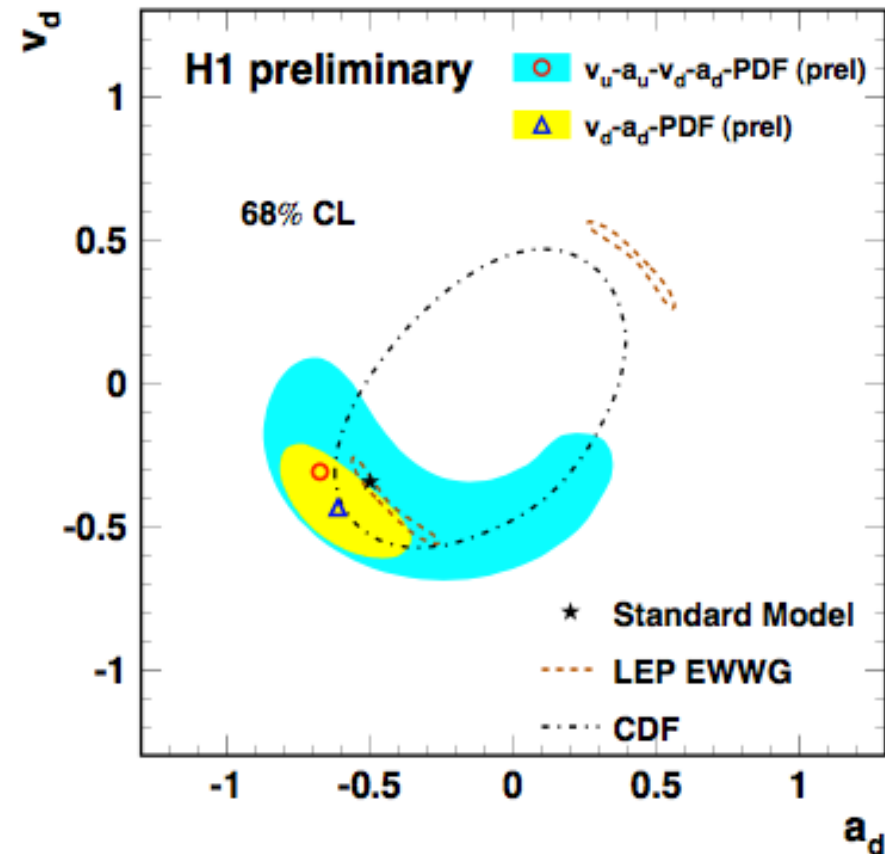
Fix d quark couplings & fit v_u - a_u -PDF

$$\chi^2/\text{dof}=1184.5/(1244-12)=0.96$$



Fix u quark couplings & fit v_d - a_d -PDF

$$\chi^2/\text{dof}=1184.2/(1244-12)=0.96$$



→ Reduced correlation and thus much improved precision

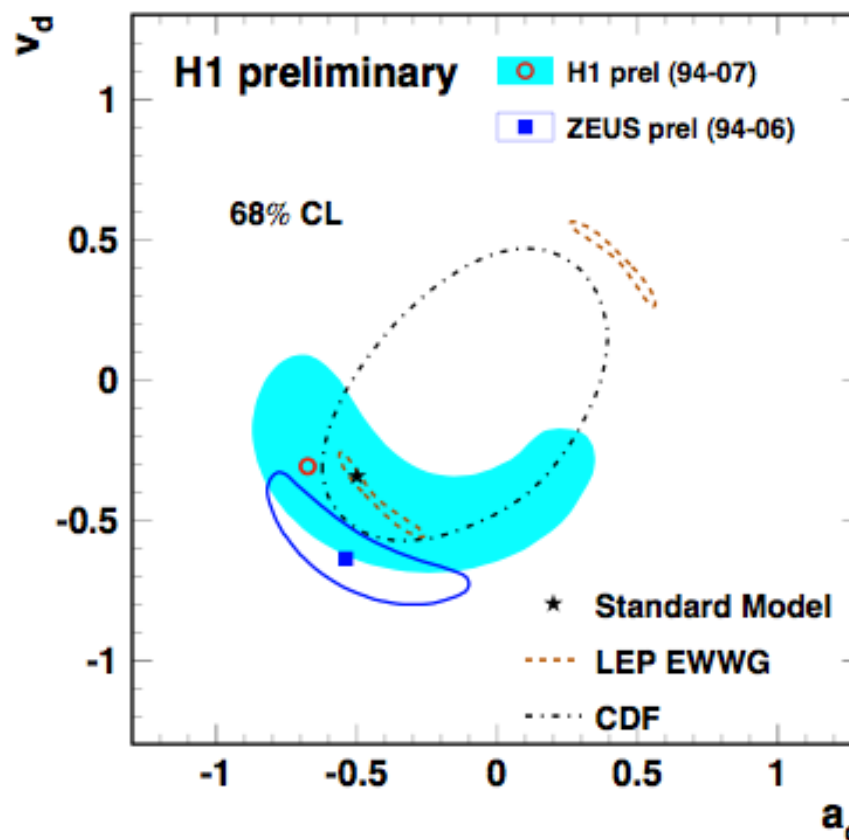
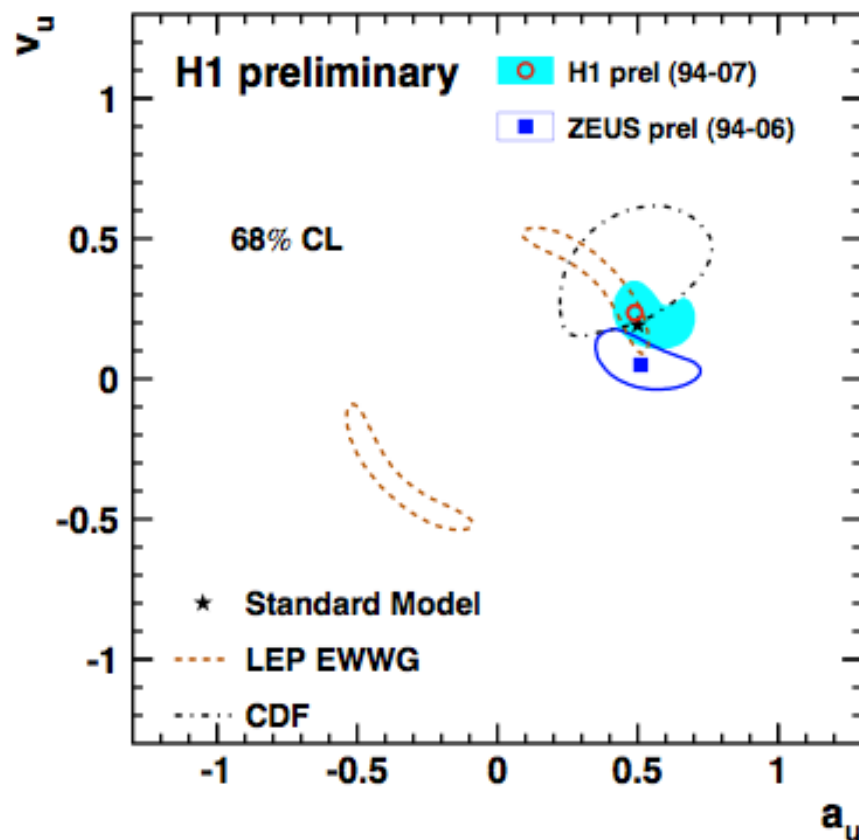
Comparison With ZEUS

ZEUS-prel-07-027:

- including only HERA-2 e- 04-06

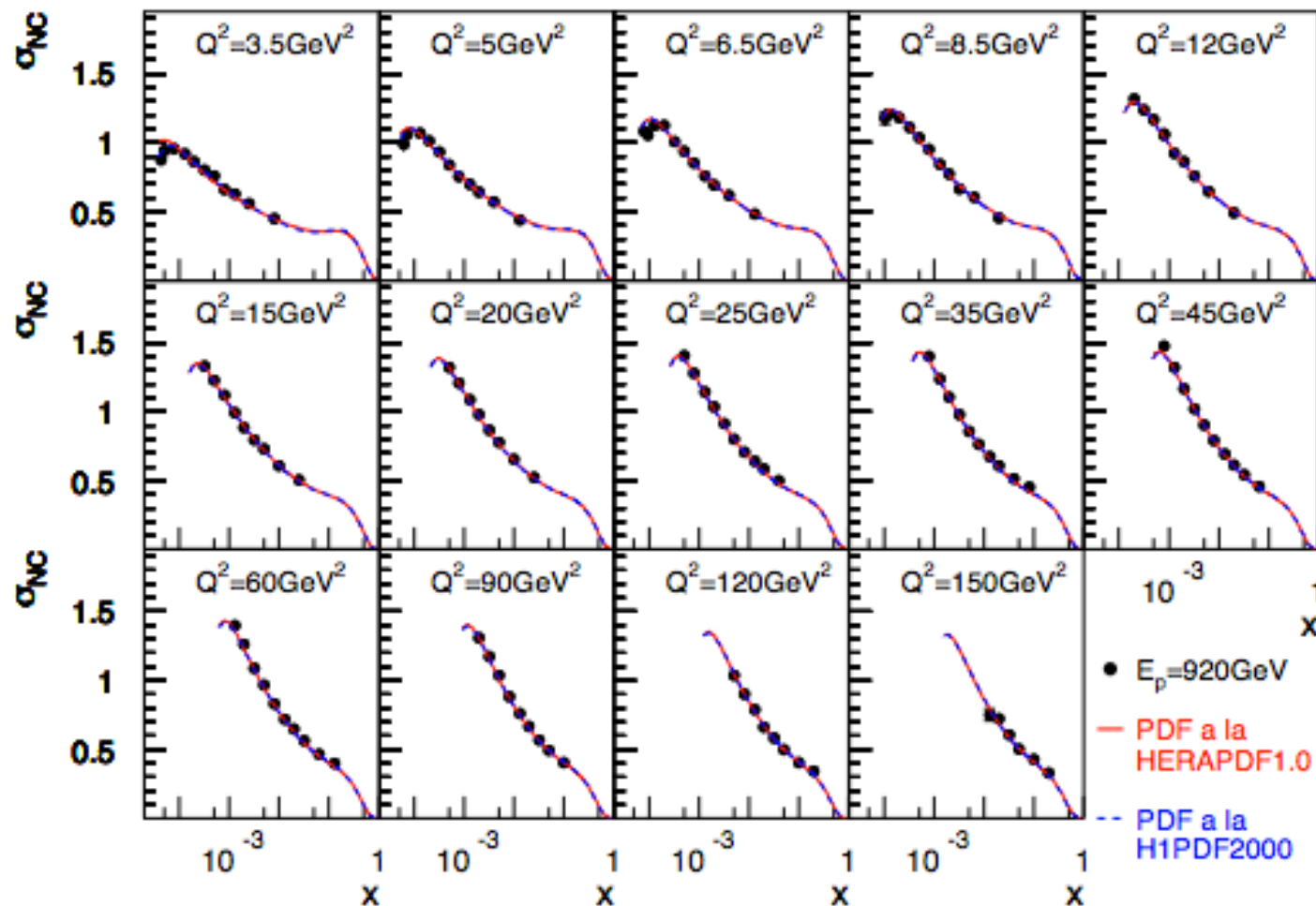
- PDF a la ZEUS-JETS fit:

Eur. Phys. J. C42 (2005) 1, hep-ph/0503274



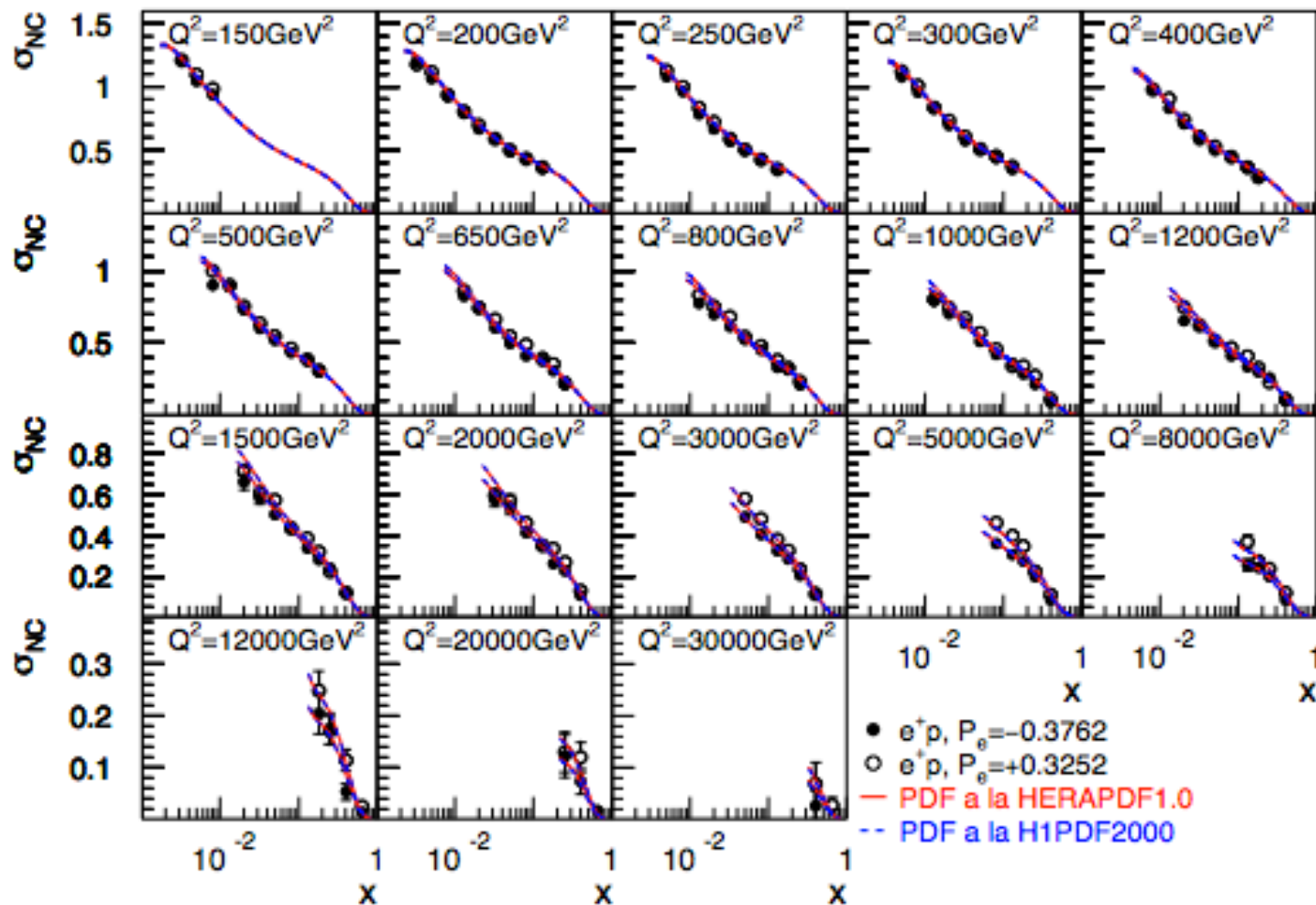
→ Improved precision expected with combined H1+ZEUS data

Measurements vs. Fit (example 1)



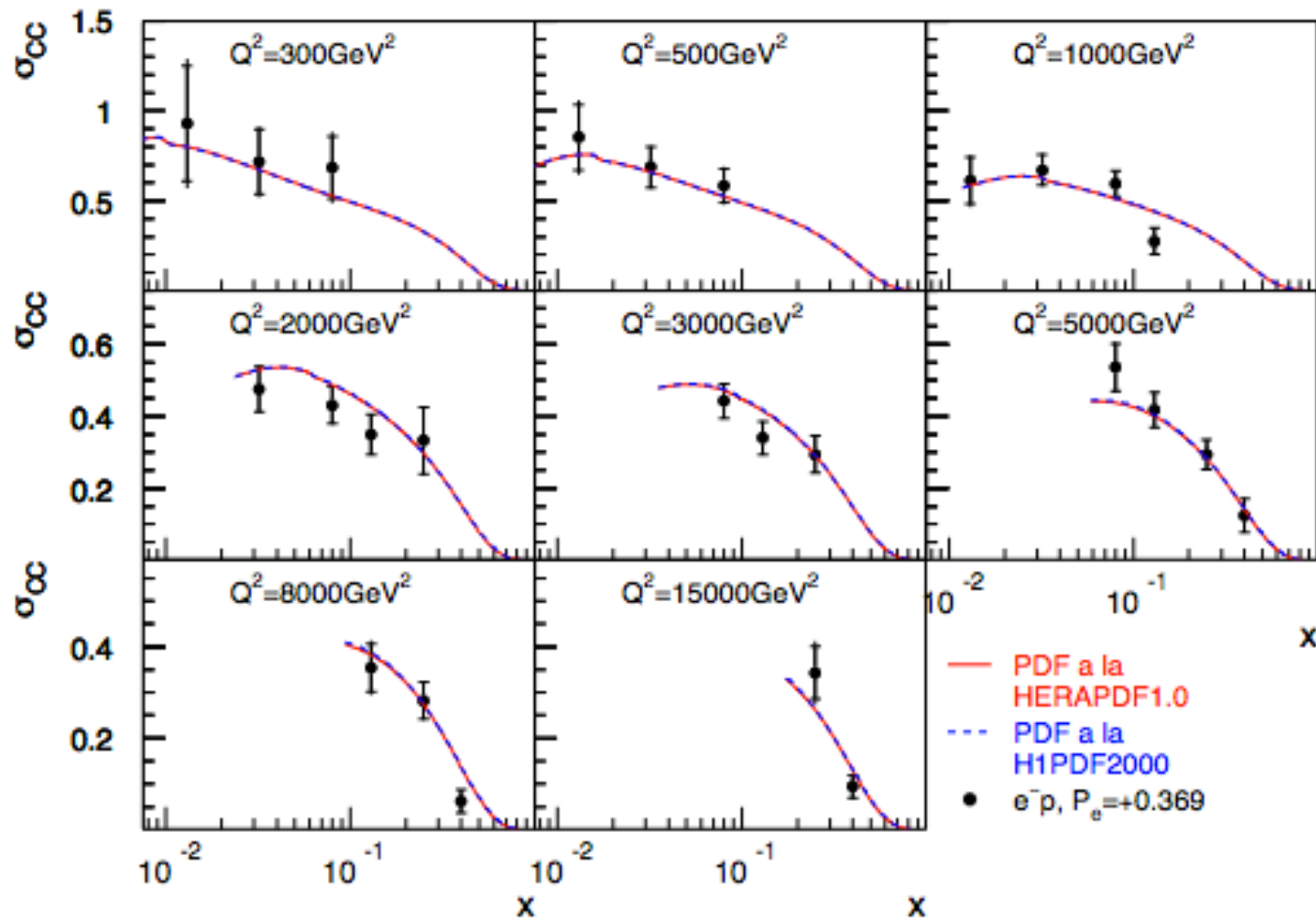
PDF	χ^2 (stat+uncor)	χ^2 (cor)
A la HERAPDF1.0	81.8	5.1
A la H1PDF2000	86.8	7.5

Measurements vs. Fit (example 2)



PDF	χ^2 (stat+uncor)	χ^2 (cor)
	LH / RH	LH / RH
A la HERAPDF1.0	77.7 / 121.8	0.7 / 0.7
A la H1PDF2000	76.9 / 120.6	0.3 / 0.3

Measurements vs. Fit (example 3)



PDF	χ^2 (stat+uncor)	χ^2 (cor)
A la HERAPDF1.0	26.0	0.1
A la H1PDF2000	26.7	0.1

Summary and Outlook

- HERA is primarily a QCD machine
but has also sensitivities to EW parameters
 - light quark couplings to the Z boson
 - W (propagator) mass
 - top quark mass through radiative loop effects in DIS
- HERA-II data [with polarized e^\pm beam and higher L] have brought new sensitivity to coupling determination
- Final words need combined H1+ZEUS data

Systematic Studies

- Model uncertainties ($f_s, m_c, m_b, Q_{\min}^2$)
- Other SM model uncertainties (m_t, M_W, M_Z, α_s)
- Parameterization (Different PDF forms, Q_0^2)

	a_u	V_u	a_d	V_d
Model	± 0.02	± 0.01	± 0.03	± 0.01
SM	± 0.02	± 0.01	± 0.03	± 0.02
Param.	± 0.03	± 0.02	± 0.06	± 0.06
Total syst	± 0.04	± 0.02	± 0.07	± 0.06
Exp.	± 0.06	± 0.08	± 0.19	± 0.27

Correlation

PDF a la HERA PDF 1.0

	a_u	v_u	a_d	v_d
a_u	1.000	-0.309	0.699	-0.395
v_u		1.000	-0.424	0.835
a_d			1.000	-0.671
v_d				1.000

PDF a la H1 PDF 2000

	a_u	v_u	a_d	v_d
a_u	1.000	-0.114	0.572	-0.245
v_u		1.000	-0.266	0.847
a_d			1.000	-0.548
v_d				1.000

- Two PDF choices have similar correlation
- The strongest correlations are v_u vs. v_d & a_u vs. a_d
- The correlation between PDFs and couplings (unshown) is weaker