Combined Electroweak and QCD Fit to NC and CC Data

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On behalf of the H1 Collaboration

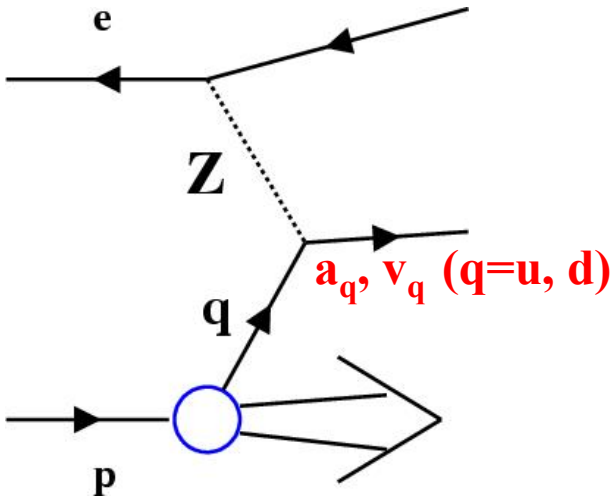
Outline

- 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

$$\frac{d^2\sigma^{\pm}_{\rm NC}}{dxdQ^2} \sim Y_+\tilde{F}_2 \mp Y_- x\tilde{F}_3 \qquad \text{with} \quad Y_\pm = 1 \pm (1-y)^2$$

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

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

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

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

$$xF_3^{\gamma Z} = 2x\sum_q e_q a_q \{q - \bar{q}\}$$

➔ a_q mainly constrained by $xF_3^{\gamma Z}$

➔ v_q constrained by F_2^Z

Additional Sensitivity @ HEAR-2

Polarized e beam (P_e) ➔ Additional terms

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

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

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

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

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

➔additional constraint on 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^2_0=4GeV^2):

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

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

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 Q2 99-00	e^+p NC	150-30000
High Q^2 99-00	e^+p CC	300-15000

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

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:

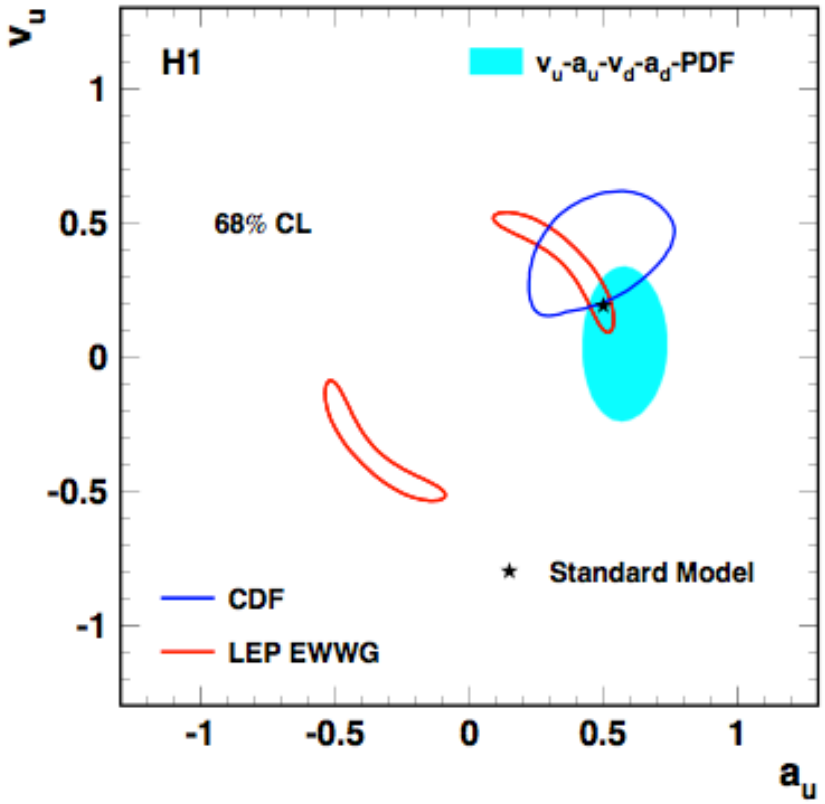
$$\chi^2(\sigma^{\text{data}}, \alpha) = \sum_{\text{exp. data}} \frac{\left[\sigma^{\text{data}}\left(1 - \sum_l \alpha_l \delta_l\right) - \sigma^{\text{th}}\right]^2}{\delta^2_{\text{stat}} + \delta^2_{\text{uncor}}} + \sum_l \alpha_l^2$$

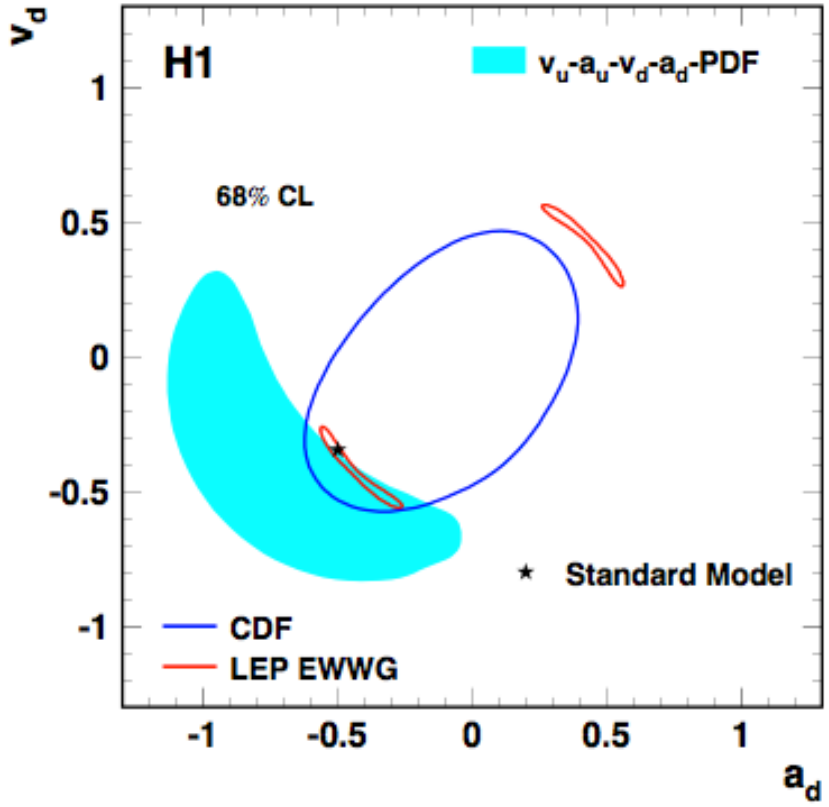
where δ_l are different correlated syst error sources
σ^{th} is based on NLO DGLAP evolution equations

Published Results based on HERA-1 Data

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

χ^2/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: $ee \rightarrow qq(\gamma)$, $a^2_q+v^2_q$

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

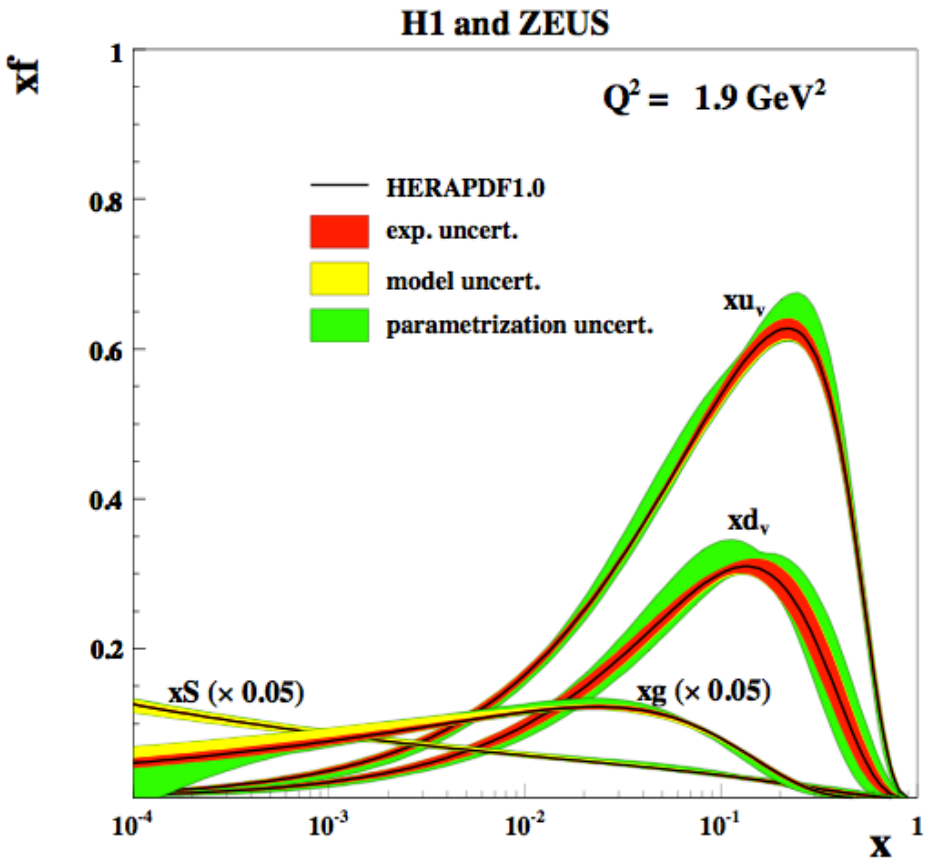
➔ In total, up to 19 datasets are used in the combined fit

Use Alternative PDF Forms

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

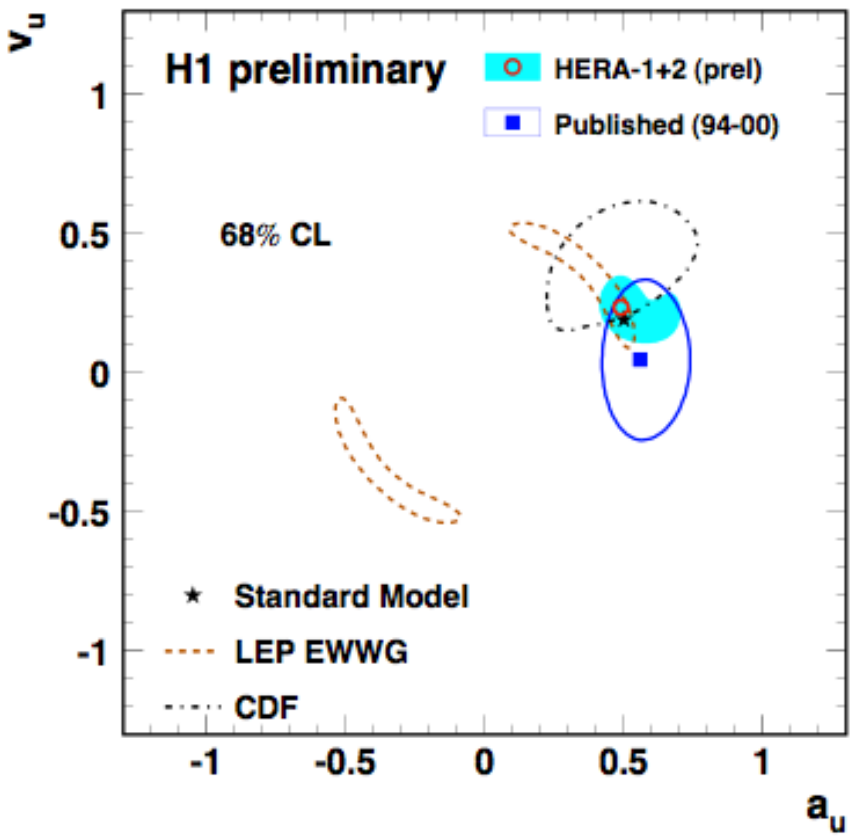
PDF forms a la HERAPDF1.0 (Q^2_0=1.9GeV^2):

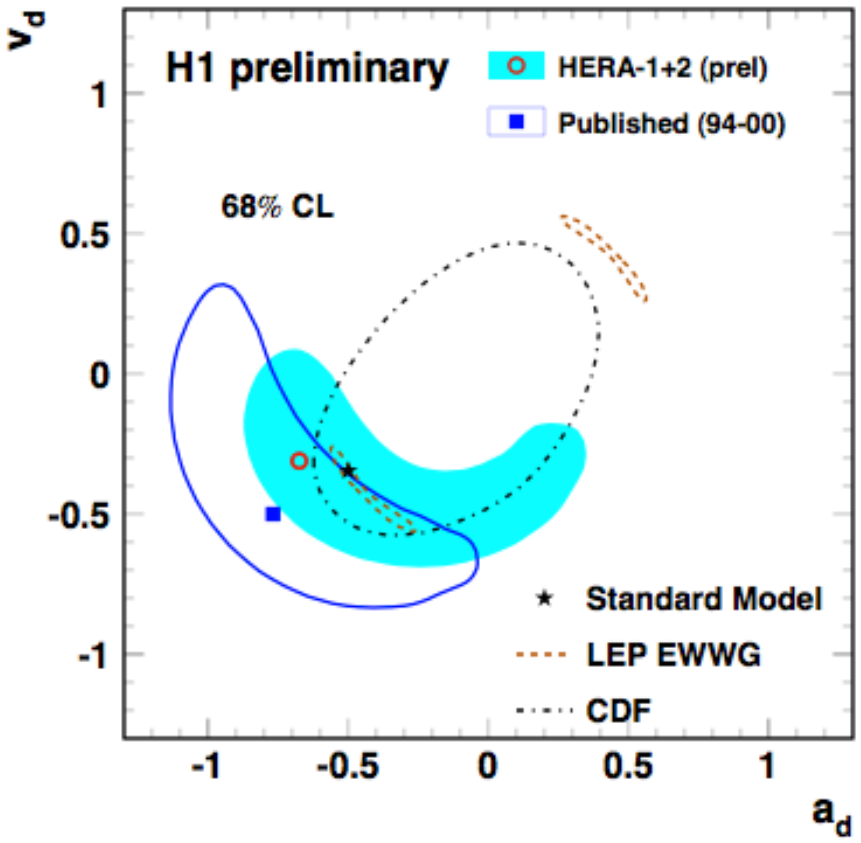
$$
\begin{aligned}
xg(x) &= A_g x^{B_g}(1-x)^{C_g} \\
xu_v(x) &= A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}\left(1+E_{u_v}x^2\right) \\
xd_v(x) &= A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}} \\
x\overline{U}(x) &= A_{\overline{U}} x^{B_{\overline{U}}}(1-x)^{C_{\overline{U}}} \\
x\overline{D}(x) &= A_{\overline{D}} x^{B_{\overline{D}}}(1-x)^{C_{\overline{D}}}
\end{aligned}
$$



Fit Results (1)

χ^2/dof=1183.8/(1244-14)=0.96



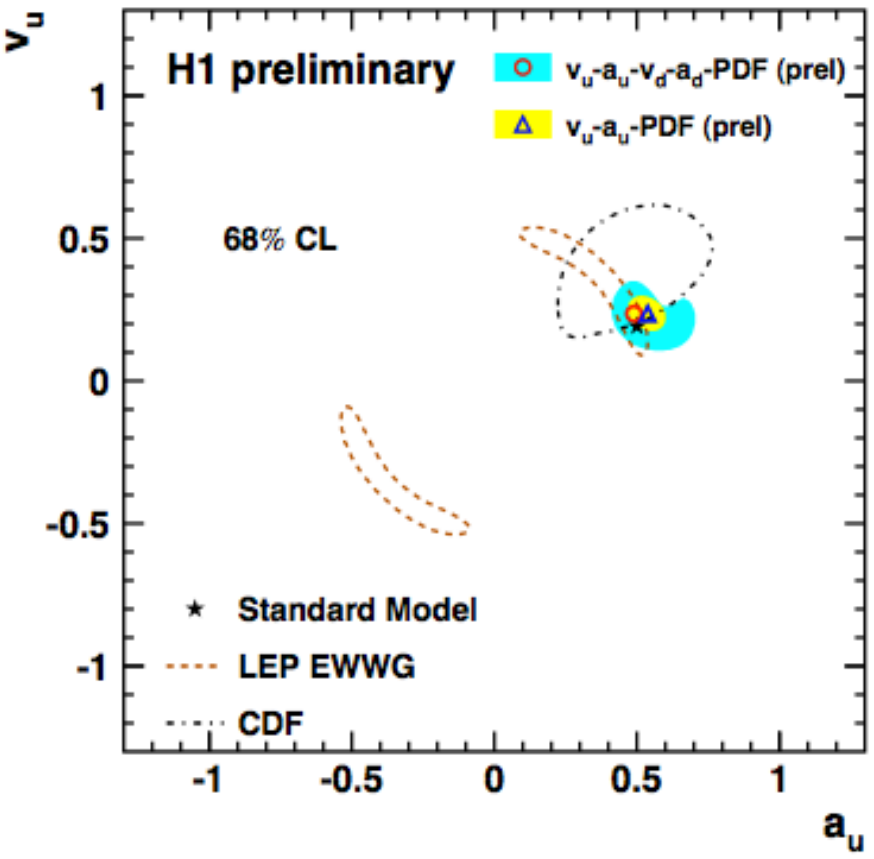


➔ Weak couplings v_q: much improved as expected

Fit Results (2)

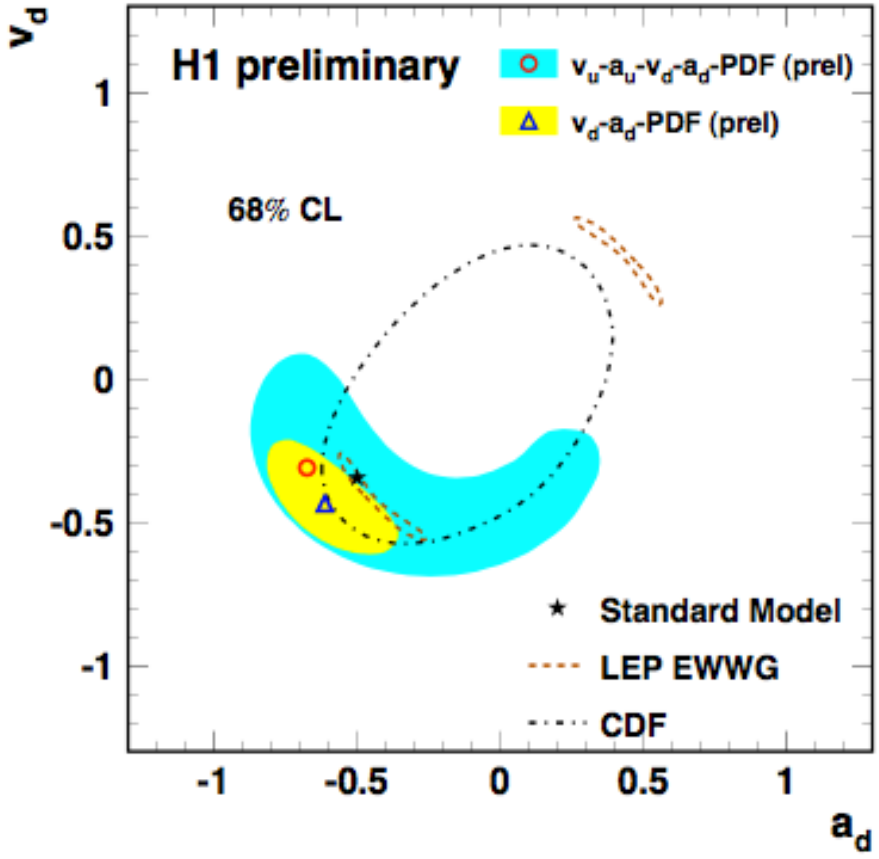
Fix d quark couplings & fit v_u-a_u-PDF

χ^2/dof=1184.5/(1244-12)=0.96



Fix u quark couplings & fit v_d-a_d-PDF

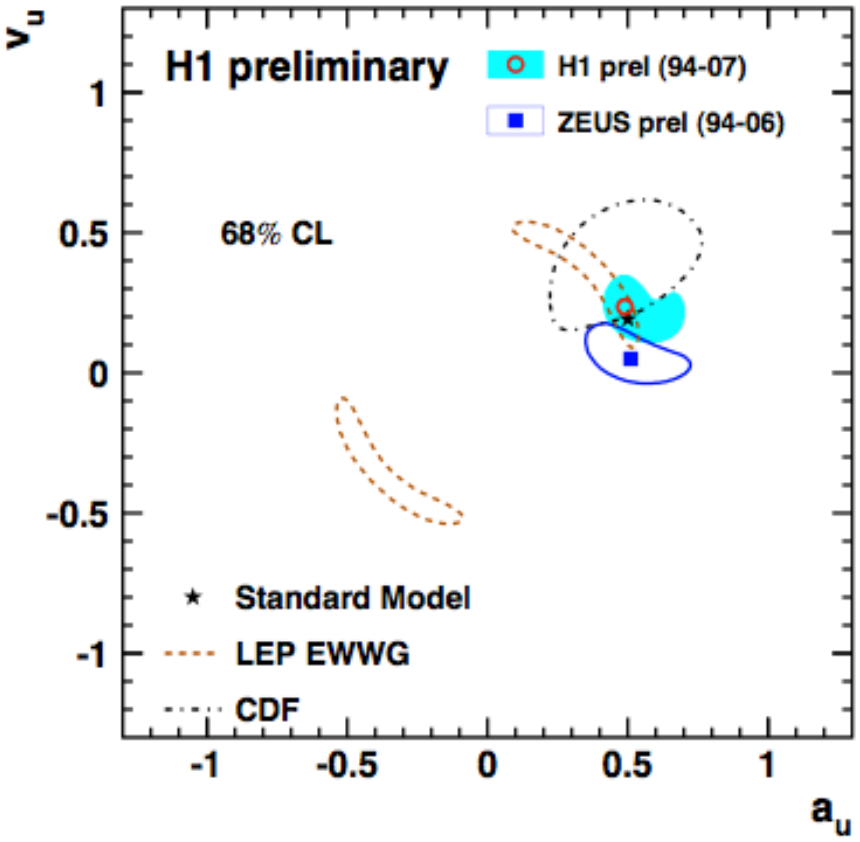
χ^2/dof=1184.2/(1244-12)=0.96

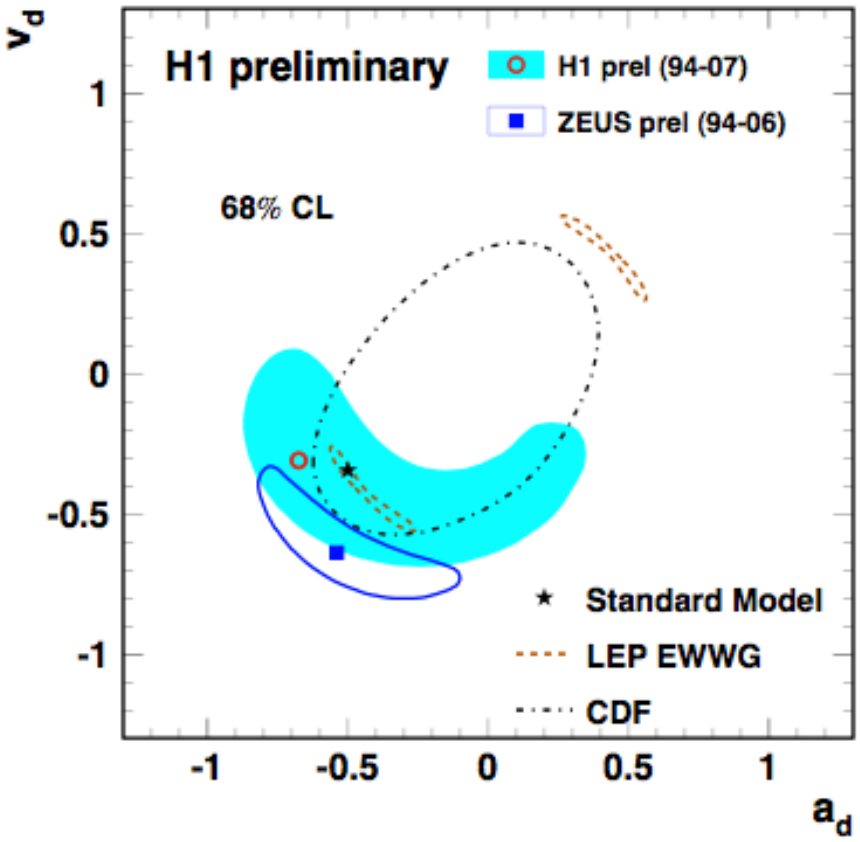


➔ Reduced correlation and thus much improved precision

Comparison With ZEUS

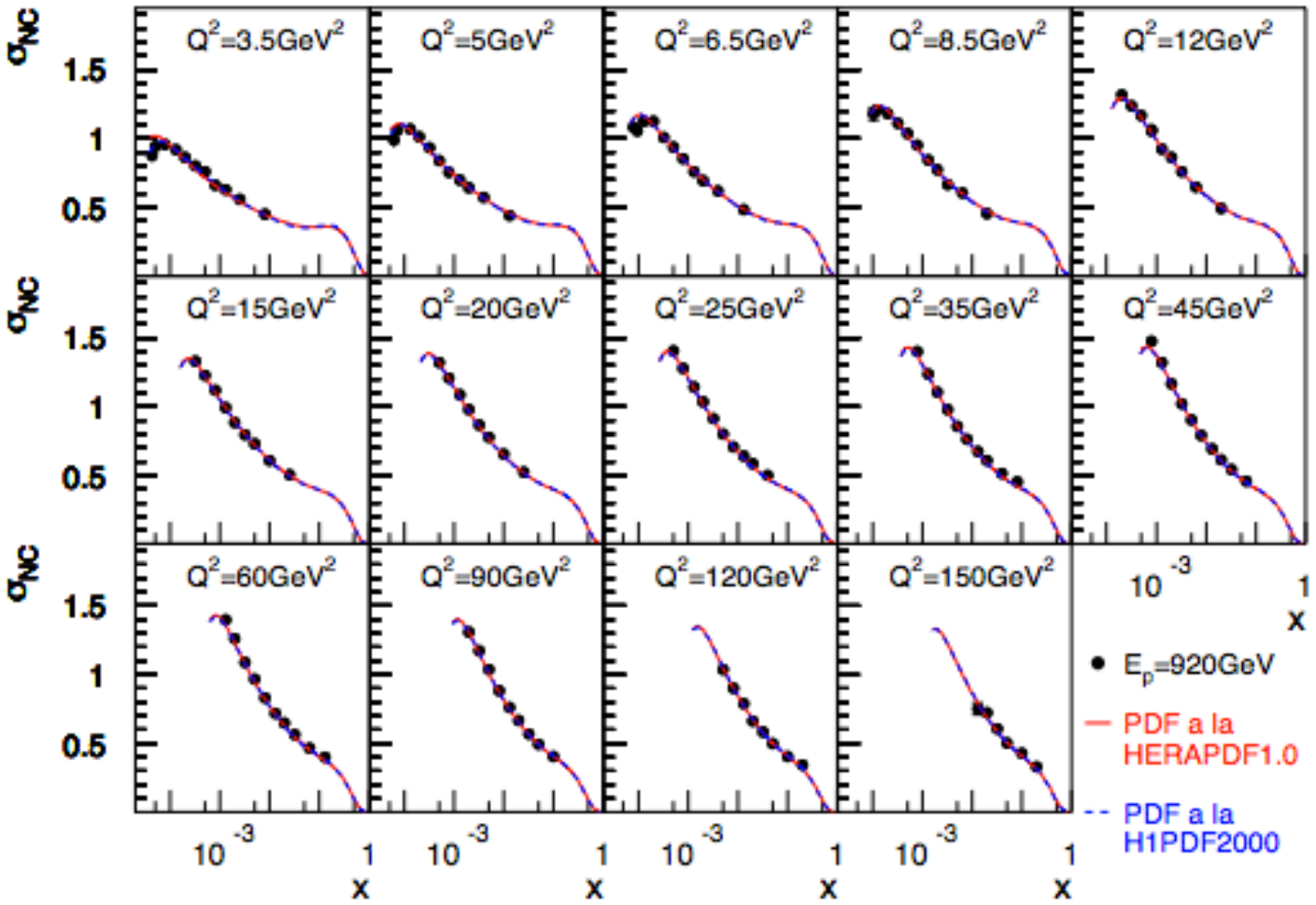
ZEUS-prel-07-027:
- including only HERA-2 e- 04-06
- PDF a la ZEUS-JETS fit: **Eur. Phys. J. C42 (2005) 1, hep-ph/0503274**





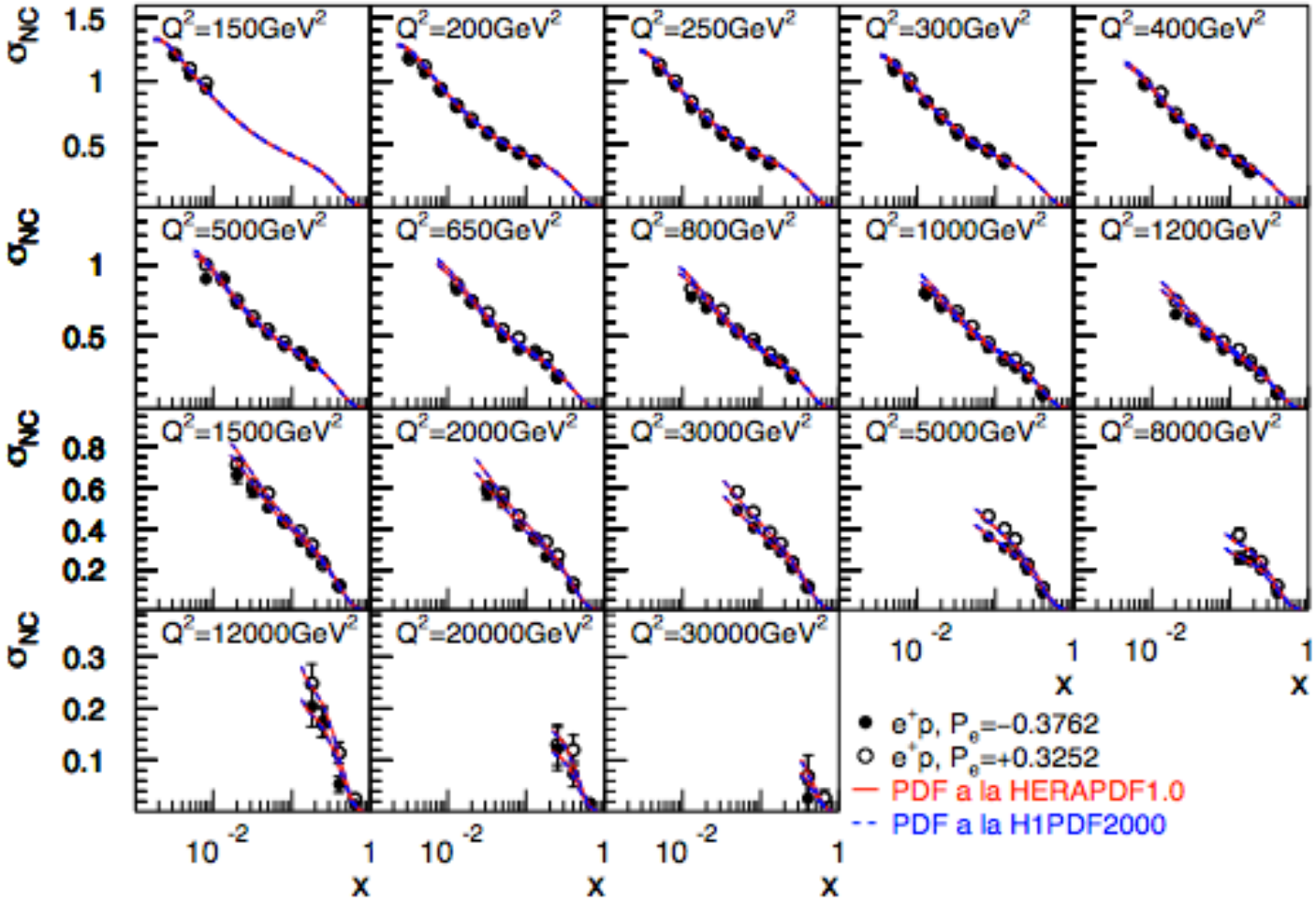
➔ Improved precision expected with combined H1+ZEUS data

Measurements vs. Fit (example 1)



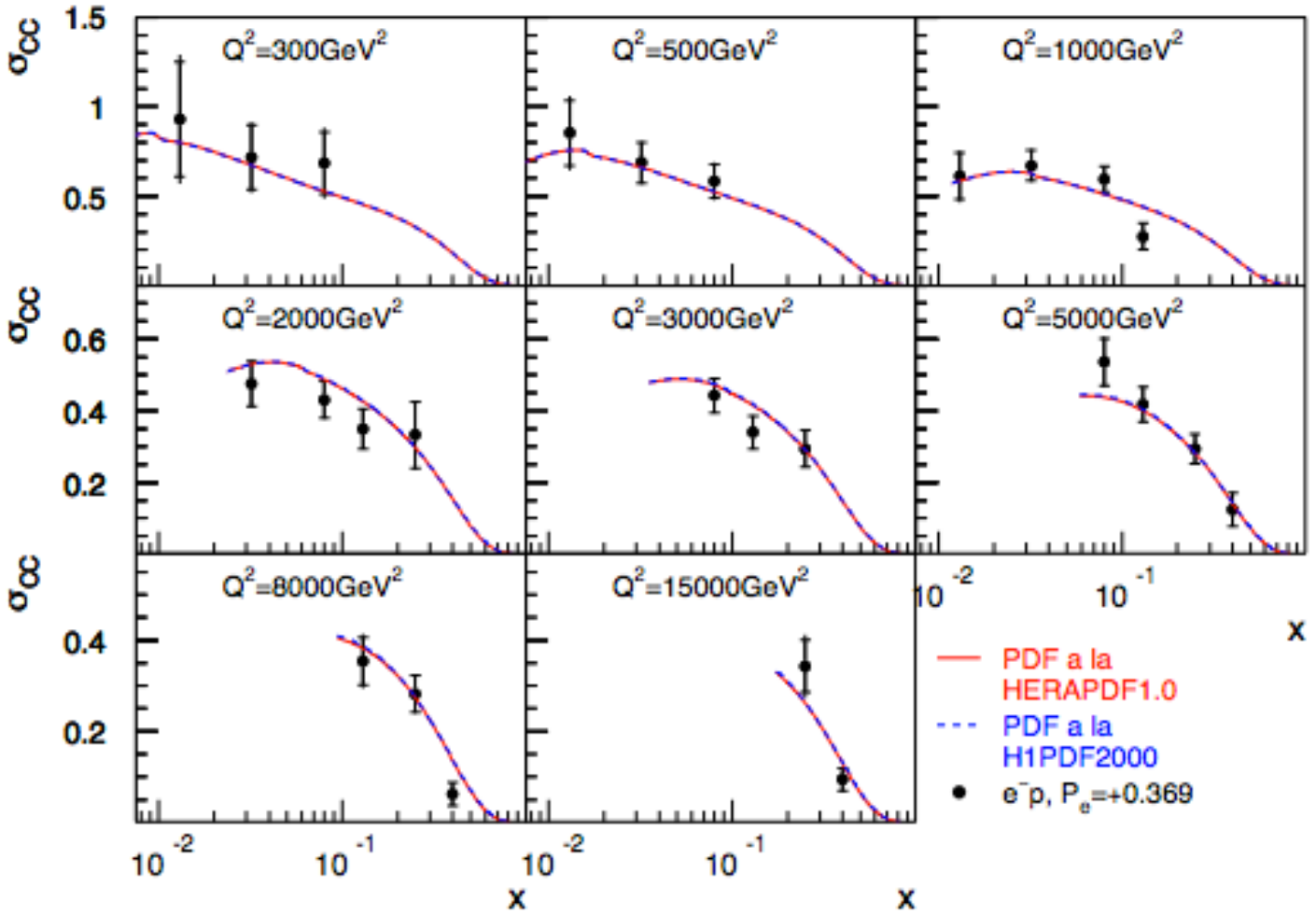
PDF	χ^2 (stat+uncor)	χ^2 (cor)
A la HERAPDF1.0	81.8	5.1
A la H1PDF2000	86.8	7.5

Measurements vs. Fit (example 2)



PDF	χ^2 (stat+uncor) LH / RH	χ^2 (cor) 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^2_{min})
- Other SM model uncertainties (m_t, M_W, M_Z, α_s)
- Parameterization (Different PDF forms, Q^2_0)

	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 HERAPDF 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 H1PDF2000

	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