New Measurement and QCD Analysis of DIS Data from HERA

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On behalf of
the H1 Collaboraton

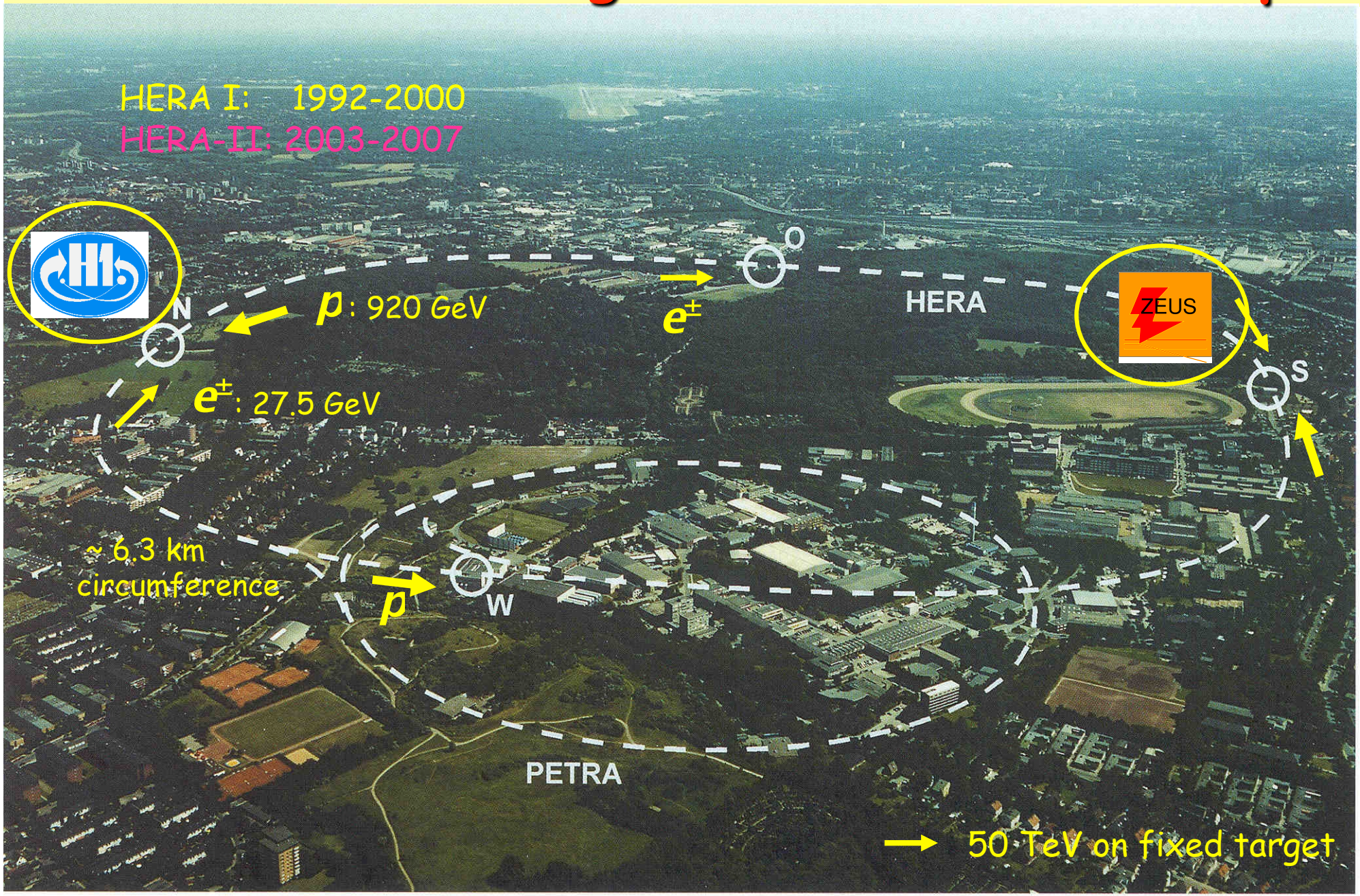
The talk covers 3 H1 publications

1) Inclusive deep inelastic scattering at high Q^2 with longitudinal polarised lepton beams at HERA
(arXiv:1206.7007, submitted to JHEP; brand new → focus of the talk)

2) Determination of the integrated luminosity at HERA using elastic QED Compton events
arXiv:1205.2448, submitted to EPJC

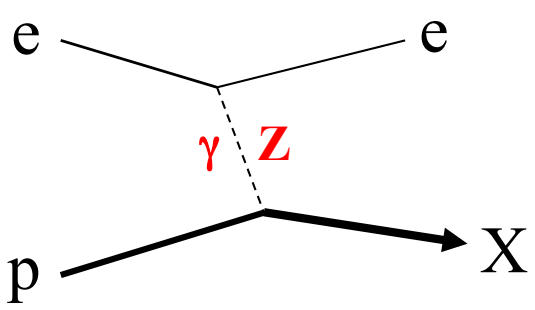
3) Measurement of the inclusive $e^{\pm}p$ scattering cross section at high inelasticity y and the structure function F_L
arXiv:1012.4355, Eur.Phys.J.C71 (2011) 1579

HERA used to be Largest Electron Microscope



Neutral and Charged Current DIS

NC $e^{\pm}p$ event



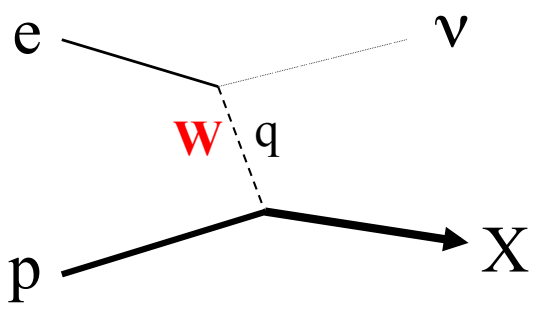
Event kinamatics:

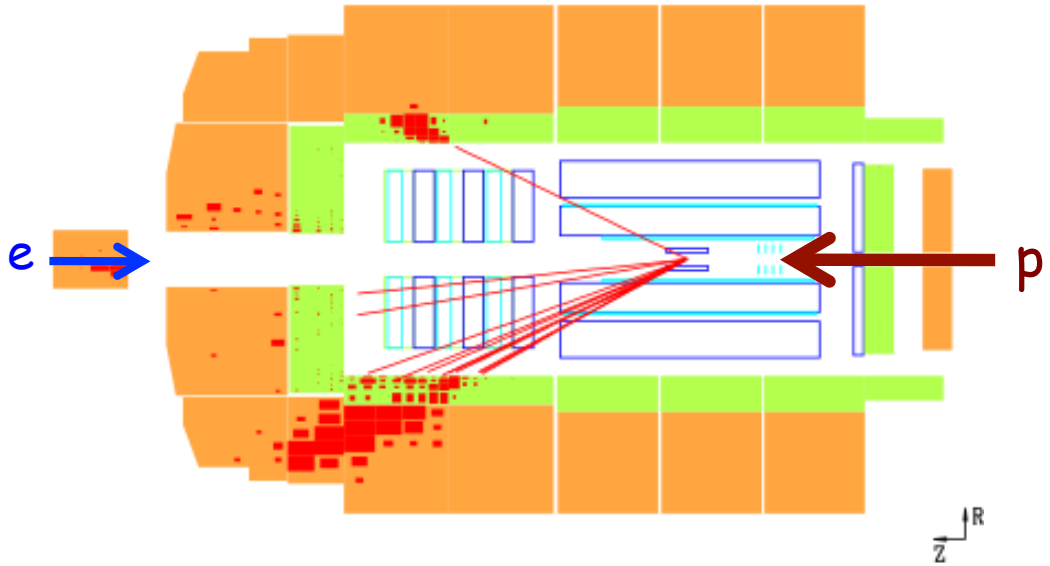
$Q^2=-q^2$

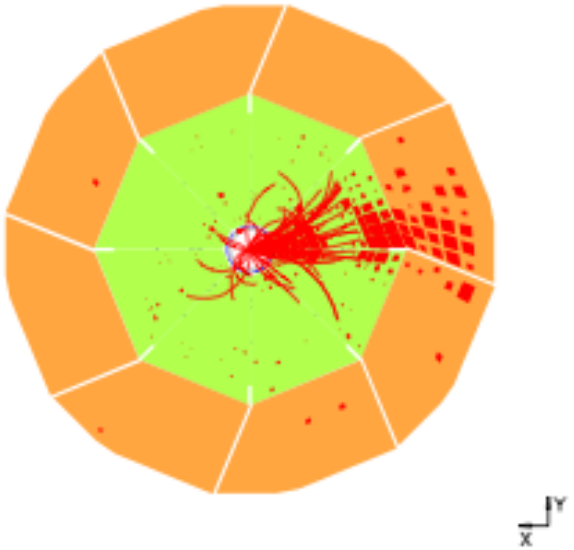
x: momentum fraction of struck parton

$Y=Q^2/sx$: inelasticity

CC $e^{\pm}p$ event







Final states e & X balanced in transverse plane

Unbalanced due to missing ν

HERA II vs. HERA I

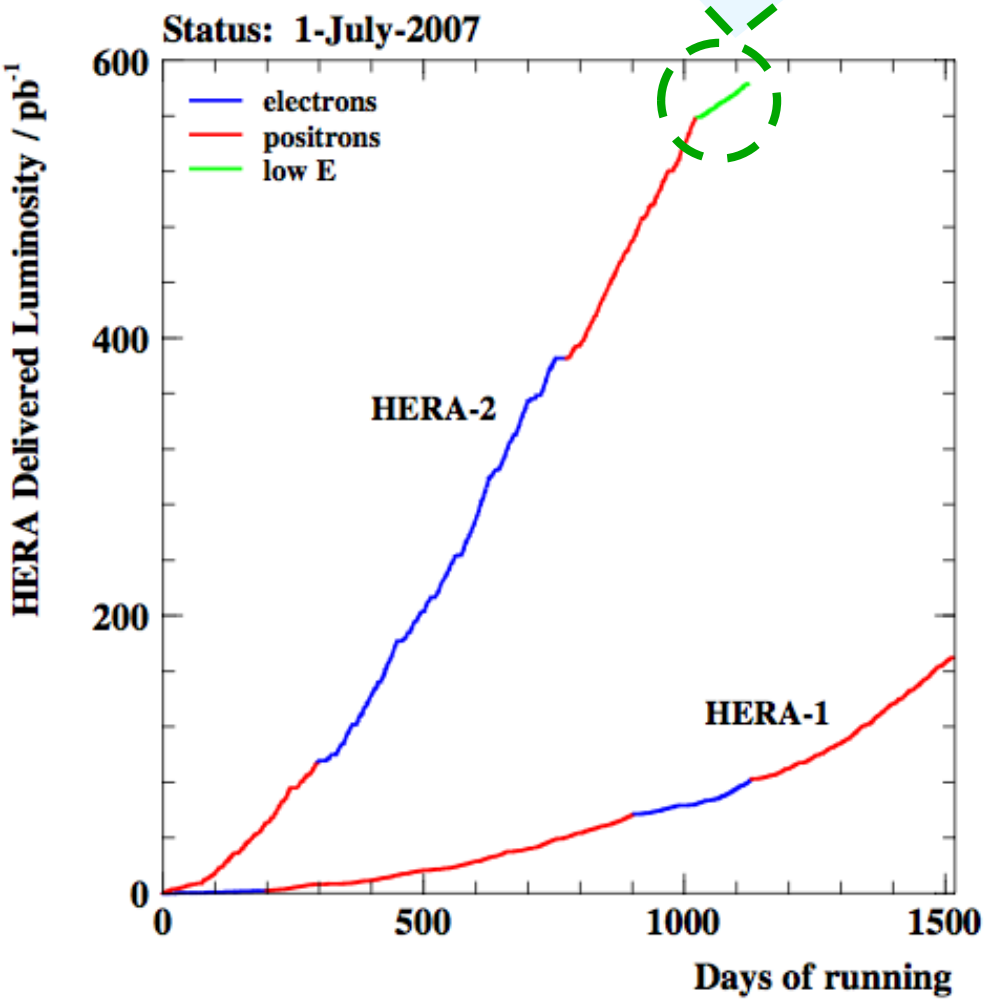
Nominal proton beam energy:
E_p=920GeV

e^-p & e^+p
Polarized $e^\pm$ beams
➔ 4 distinct data sets

	R	L
e^-p	$\mathcal{L} = 47.3\,\mathrm{pb}^{-1}$ $P_e = (+36.0 \pm 1.0)\%$	$\mathcal{L} = 104.4\,\mathrm{pb}^{-1}$ $P_e = (-25.8 \pm 0.7)\%$
e^+p	$\mathcal{L} = 101.3\,\mathrm{pb}^{-1}$ $P_e = (+32.5 \pm 0.7)\%$	$\mathcal{L} = 80.7\,\mathrm{pb}^{-1}$ $P_e = (-37.0 \pm 0.7)\%$

Integrated luminosity determined with elastic QED Compton events
(→ slide 6)

Lower energies:
E_p=460, 575 GeV
➔ F_L measurement

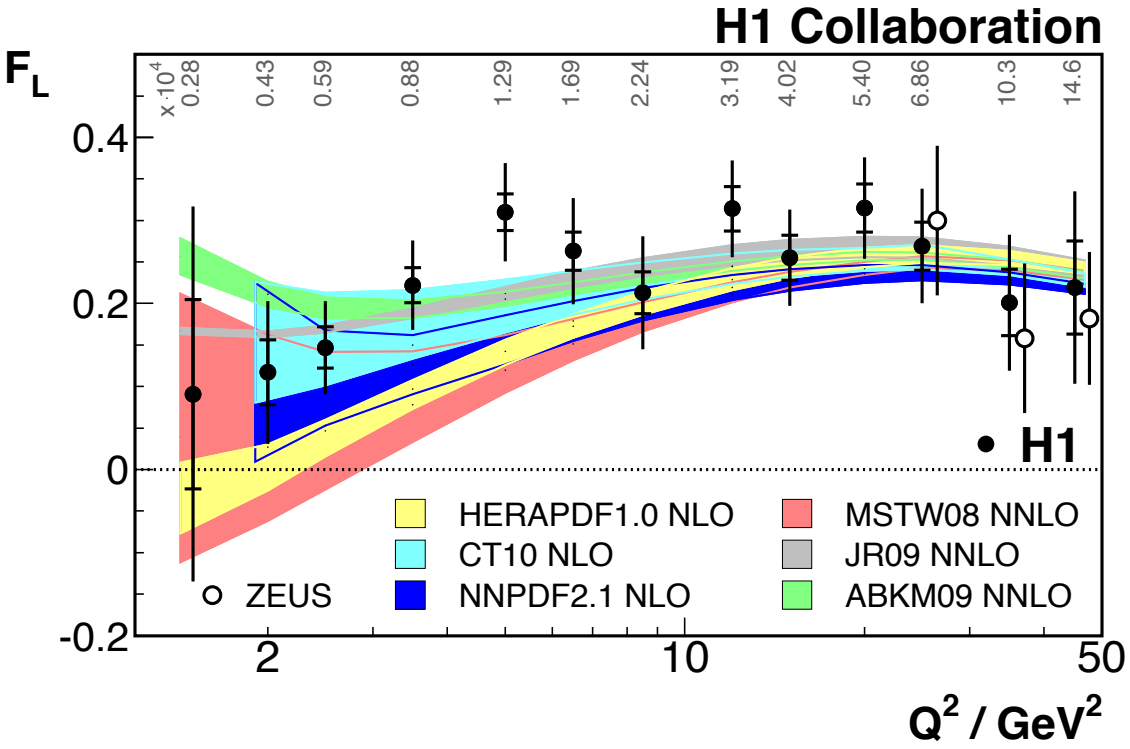


Direct Measurement of F_L

Based on HERA II data with E_p=460, 575 & 920* GeV
Kinematic range: $1.5<Q^2<120\text{GeV}$, $1.9\times10^{-5}<x<0.01$, $y<0.85$

$$\sigma_r(x,Q^2) \equiv \frac{Q^4 x}{2\pi\alpha^2\left[1+(1-y)^2\right]}\cdot\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\,\mathrm{d}Q^2} = F_2(x,Q^2) - \frac{y^2}{1+(1-y)^2}F_L(x,Q^2)$$

Different proton beam energies → different inelasticity y



Direct F_L measurement in agreement with pert. QCD expectation

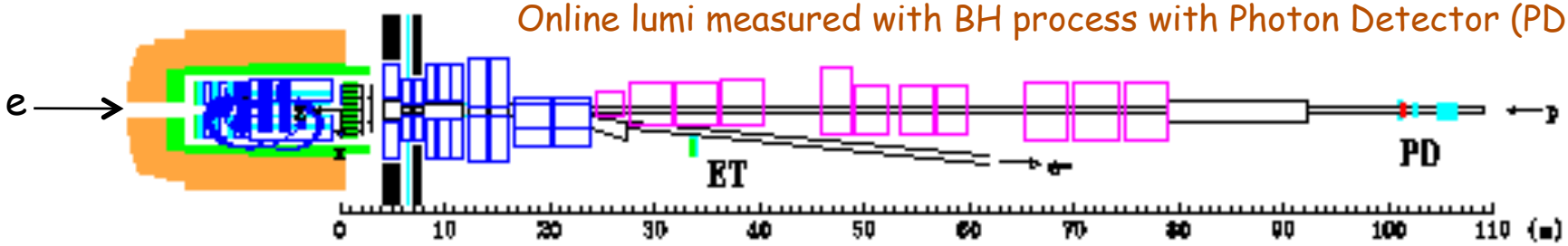
Since $F_L \sim xg$

➔ HERA data @ low Q^2, x provide a direct constraint of gluon density of the proton

*At 920GeV, it's combined with HERA I
➔ Combined low Q^2 data set (slide 14)
The low E_p data
➔ Combined low E_p data set (slide 14)

Luminosity Measurement from QED Compton

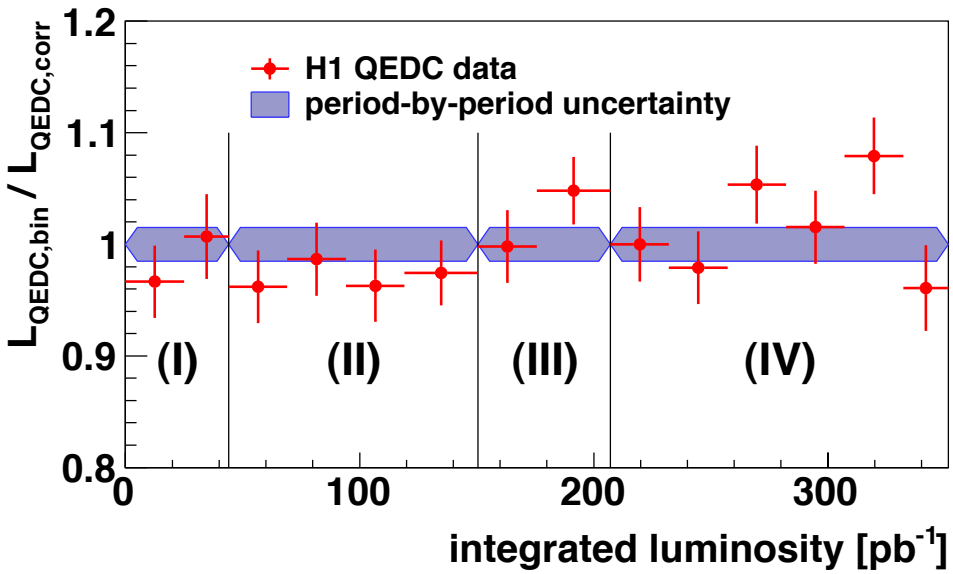
Online lumi measured with BH process with Photon Detector (PD)



$$\mathcal{L} = \frac{N_{\text{events}}}{\sigma_{ep\to e\gamma p}}$$

Bethe-Heitler (BH) process: e, γ collinear to the beam, high rate (~1MHz) but large syst uncertainty (3.4% for HERA II)

Elastic QED Compton process: e, γ at large angles (in main detector) small rate (10^{-3} Hz) but syst similar to cross section measurement



Integrated QED Compton lumi:

351.6 pb^{-1} ± 0.8%(stat) ± 2.1%(syst)

of which theory uncertainty: 1.1%

New High Q^2 Cross Section Measurements

Based on full HERA II data at E_p=920GeV

CC total cross sections

$Q^2>400$ GeV^2, $y<0.9$

NC & CC single different cross section $d\sigma/dQ^2$

NC: $200<Q^2<50000$ GeV^2, $y<0.9$

CC: $300<Q^2<30000$ GeV^2, $y<0.9$

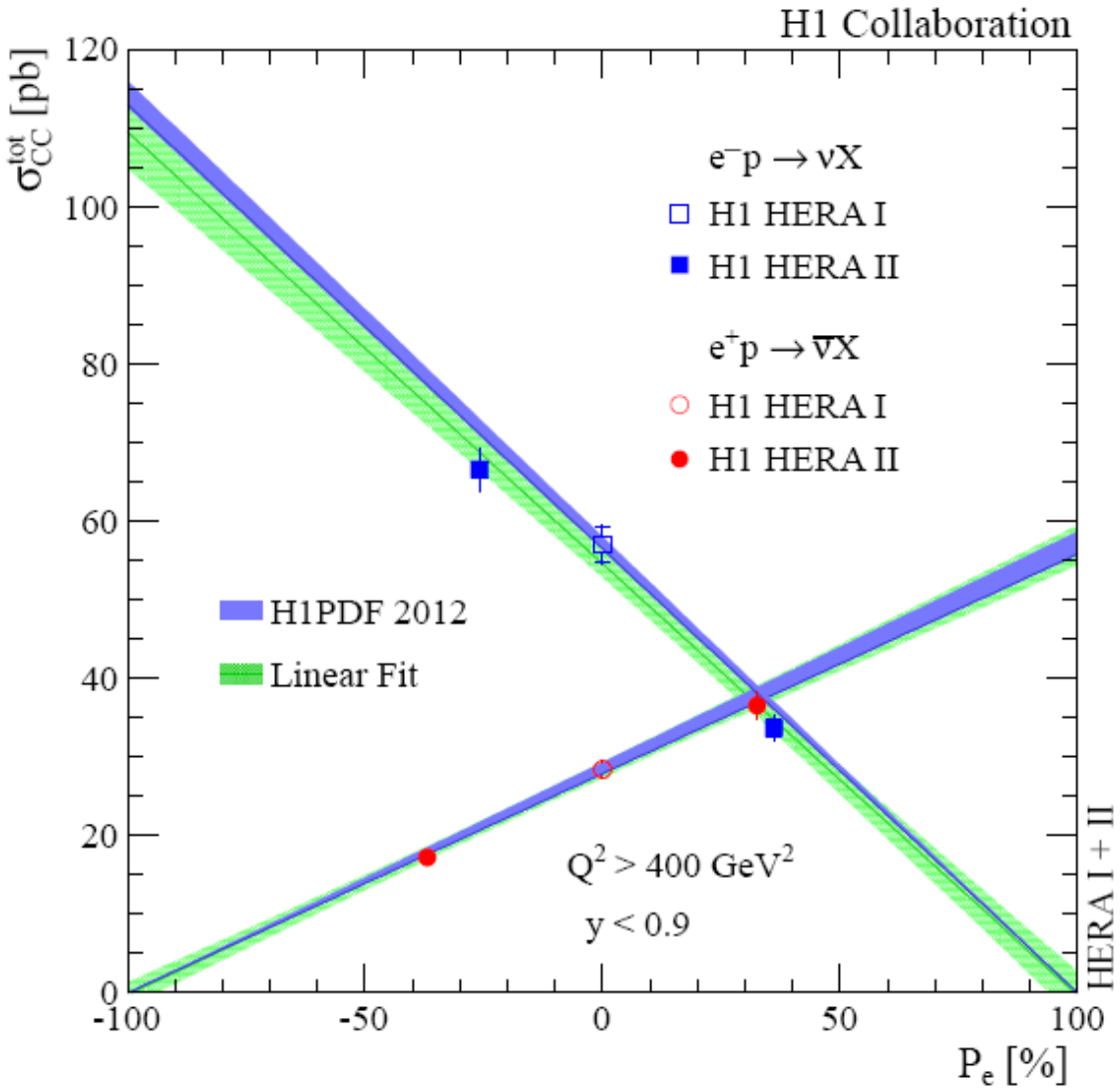
NC & CC double differential cross sections

NC: $60<Q^2<50000$ GeV^2, $0.0008<x<0.65$

CC: $300<Q^2<30000$ GeV^2, $0.008<x<0.4$

Total CC Cross Sections

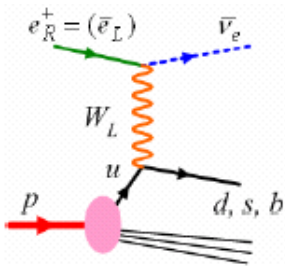
SM CC: $\sigma^{\pm}_{CC}(P_e) = (1 \pm P_e)\sigma^{\pm}_{CC}(0)$



Right Handed CC: $\sigma^{\pm}_{RHCC}(P_e) = (1 \mp P_e)\sigma^{\pm}_{RHCC}(0)$

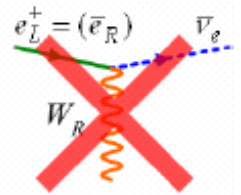
Extrapolated cross sections~0
- at P_e=+1 for e^-
- at P_e=−1 for e^+

➔ Only left-hand W in SM

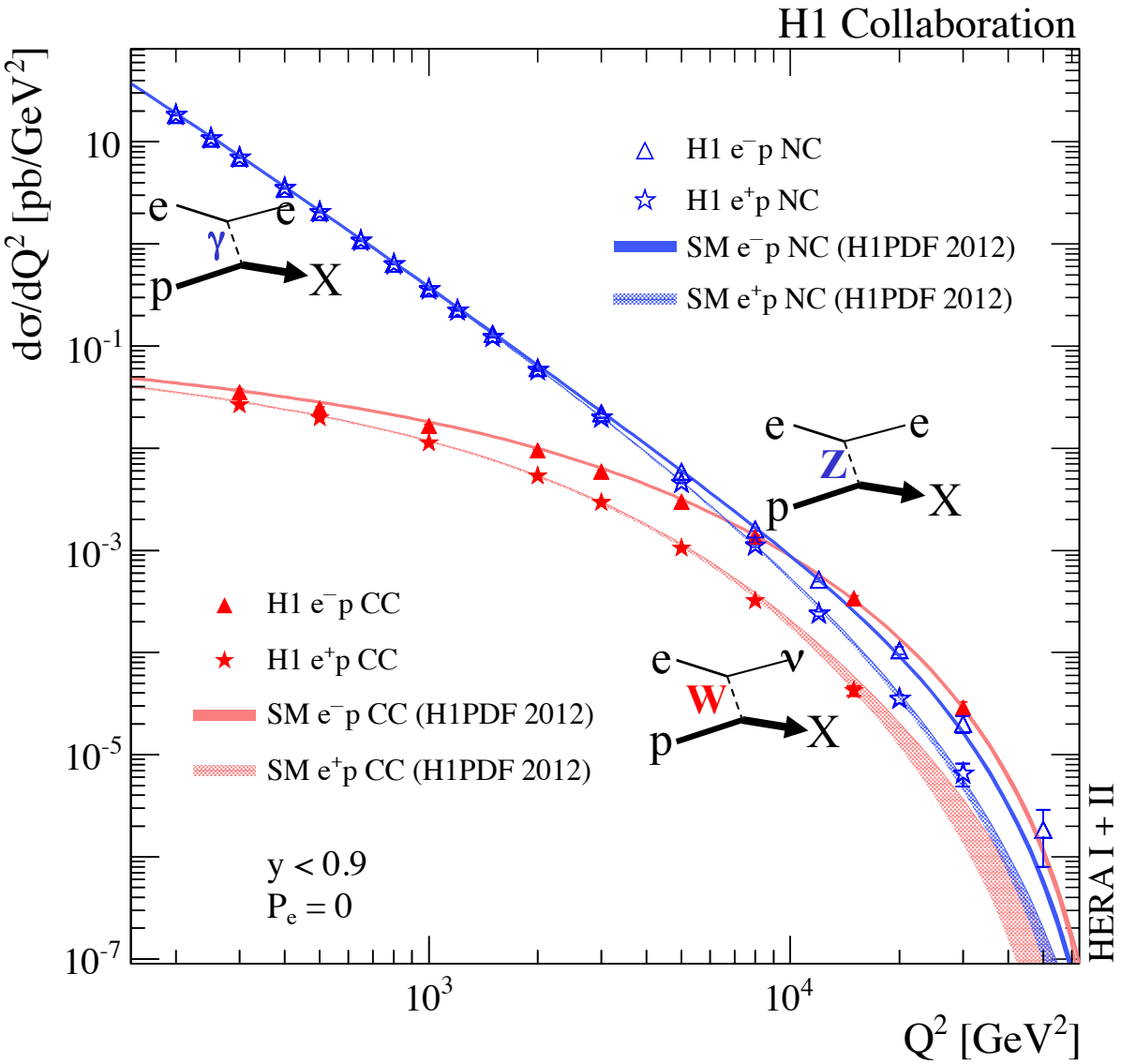


If $g_L = g_R$ & ν_R light

➔ e^-: $M_{WR} > 214$ GeV (95%CL)
➔ e^+: $M_{WR} > 194$ GeV (95%CL)



HERA I+II Combined NC & CC $d\sigma/dQ^2$



Combined HERA I+II data

→**Typical total precision:**

NC e^+: ~1.5%

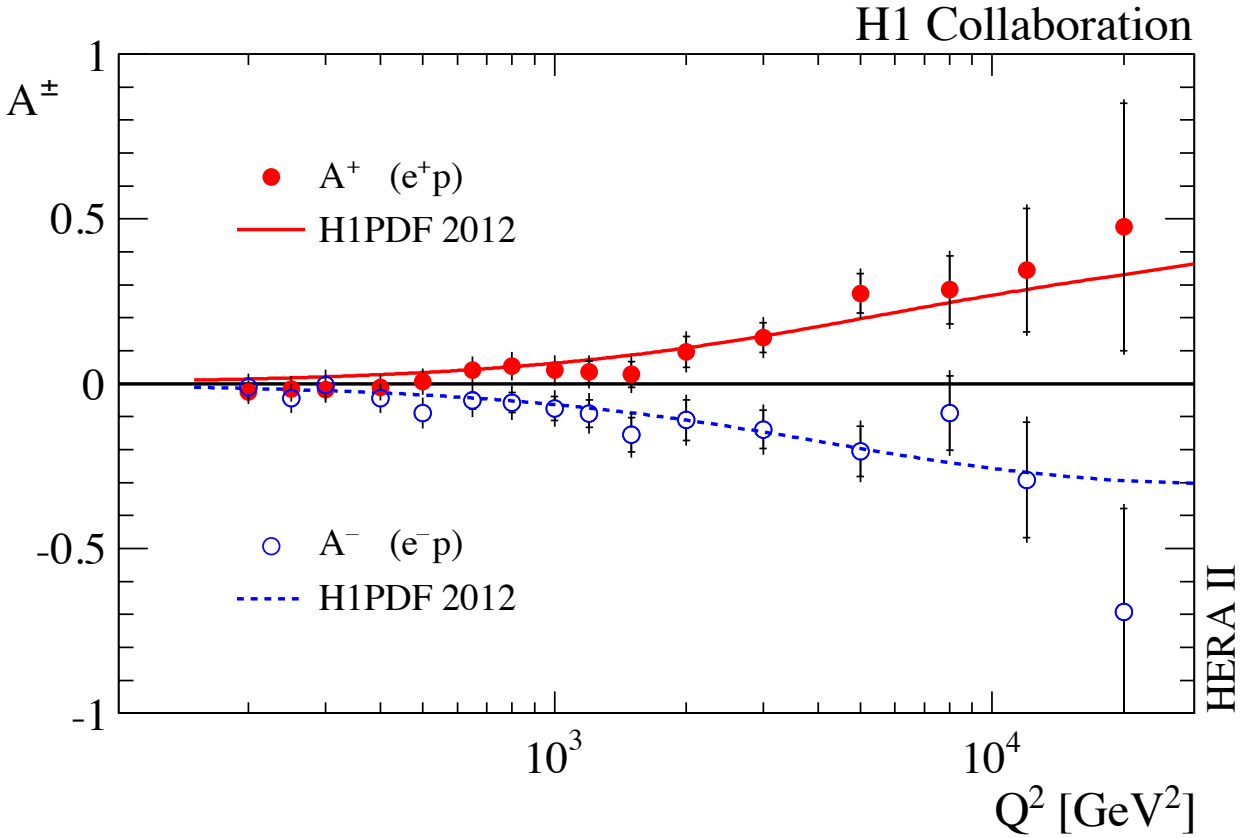
NC e^-: ~2.0%

***CC* $e^\pm$: ~4%**

→ Beautiful illustration of unification of electromagnetic and weak interaction strength

NC Polarization Asymmetry

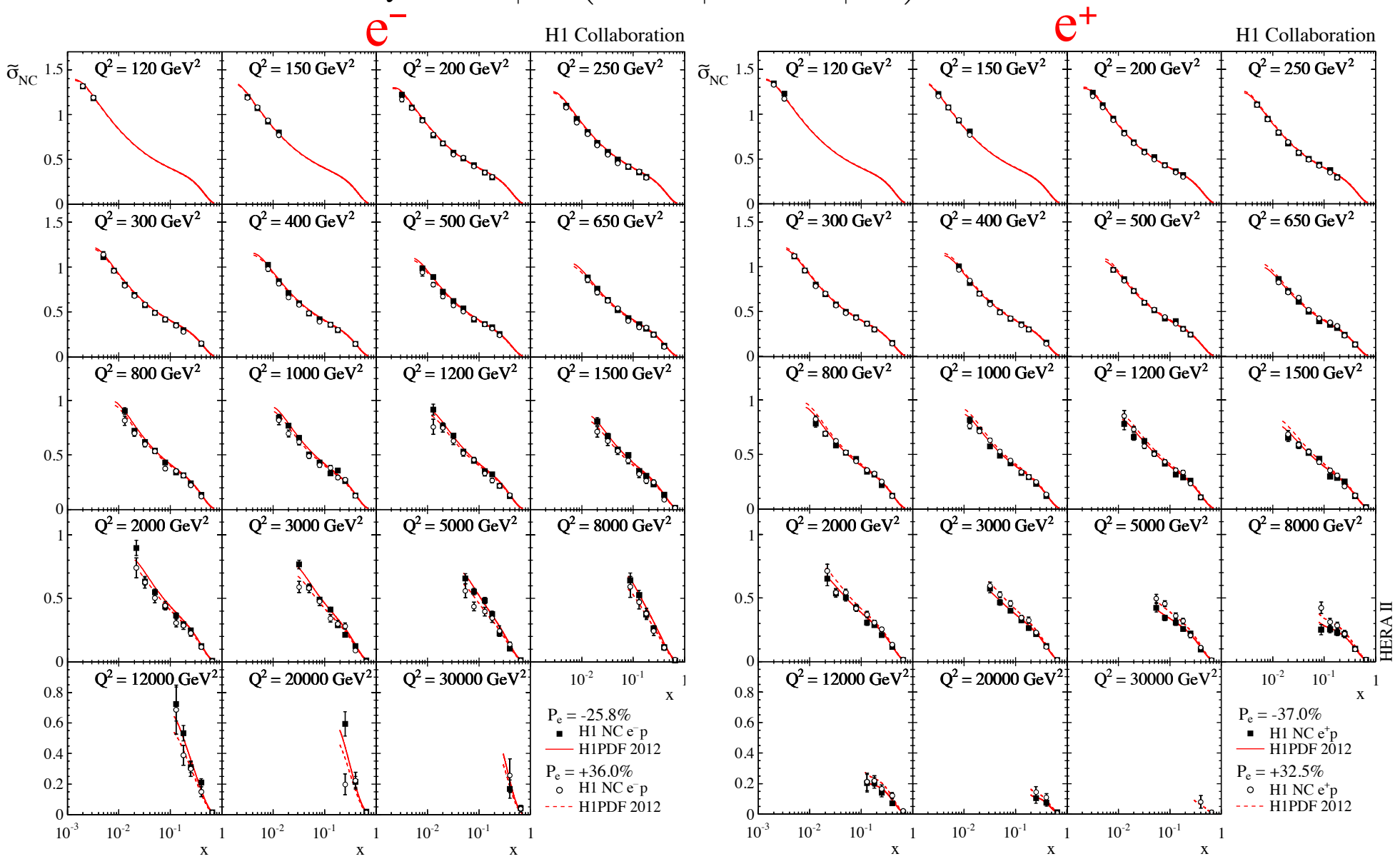
$$A^{\pm} = \frac{2}{P_L^{\pm} - P_R^{\pm}} \cdot \frac{\sigma^{\pm}(P_L^{\pm}) - \sigma^{\pm}(P_R^{\pm})}{\sigma^{\pm}(P_L^{\pm}) + \sigma^{\pm}(P_R^{\pm})}$$



A direct measure of parity violation effect in NC DIS

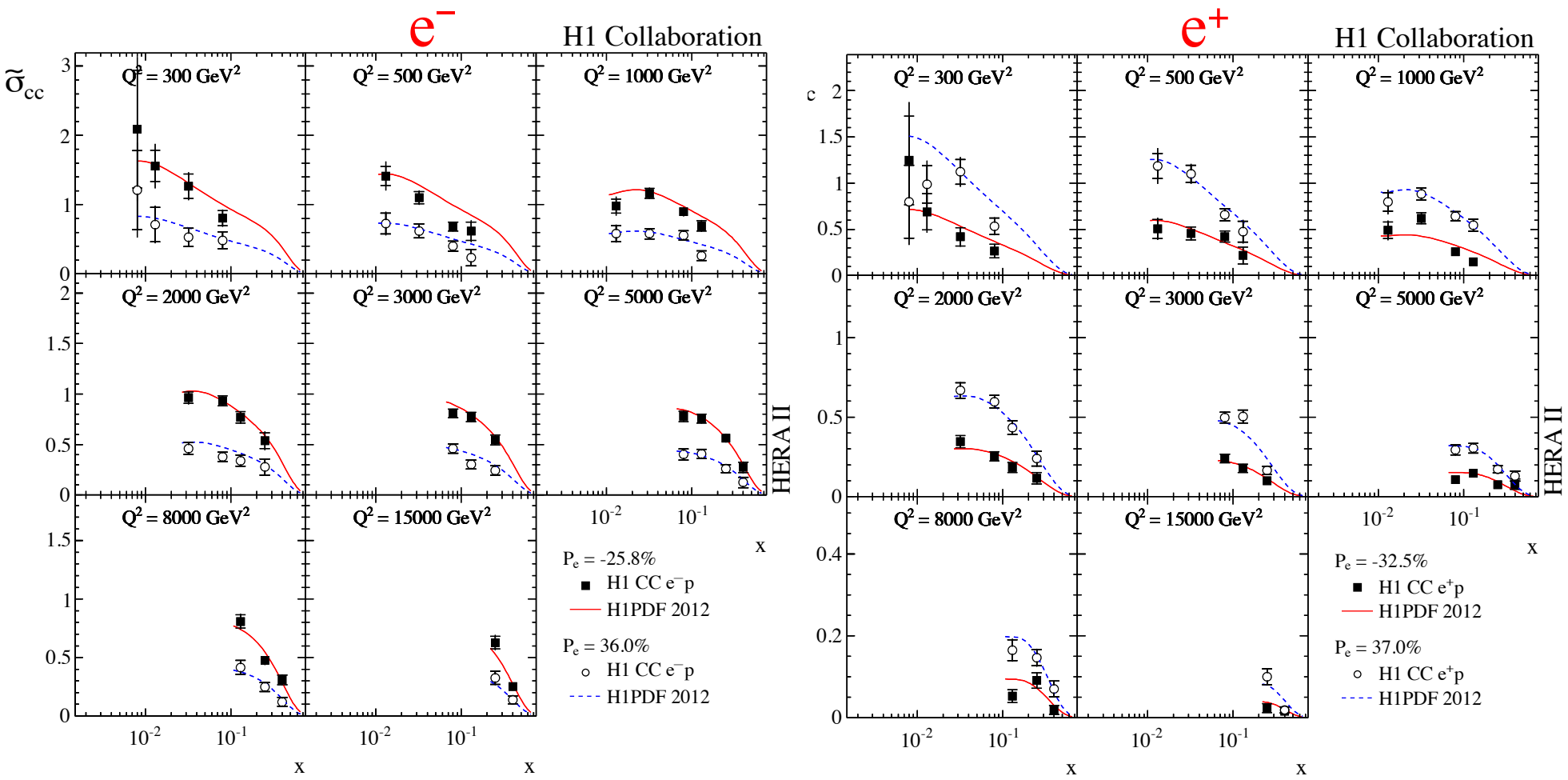
NC Double Differential Cross Sections

$$\tilde{\sigma}^{\pm}_{\mathrm{NC}}(x,Q^2) \equiv \frac{\mathrm{d}^2\sigma^{\pm}_{\mathrm{NC}}}{\mathrm{d}x\mathrm{d}Q^2}\frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+} = \left(\tilde{F}_2^{\pm} \mp \frac{Y_-}{Y_+}x\tilde{F}_3^{\pm} - \frac{y^2}{Y_+}\tilde{F}_L^{\pm}\right)(1+\Delta^{\mathrm{weak}}_{\mathrm{NC}}) \qquad Y_{\pm} = 1 \pm (1-y)^2$$



CC Double Differential Cross Sections

$$\tilde{\sigma}^{\pm}_{\mathrm{CC}} \equiv \frac{4\pi x}{G_F^2}\left[\frac{M_W^2+Q^2}{M_W^2}\right]^2 \frac{\mathrm{d}^2\sigma^{\pm}_{\mathrm{CC}}}{\mathrm{d}x\mathrm{d}Q^2} = (1 \pm P_e)\left(Y_+ W_2^{\pm} \mp Y_- x W_3^{\pm} - y^2 W_L^{\pm}\right)(1+\Delta^{\mathrm{weak}}_{\mathrm{CC}})$$

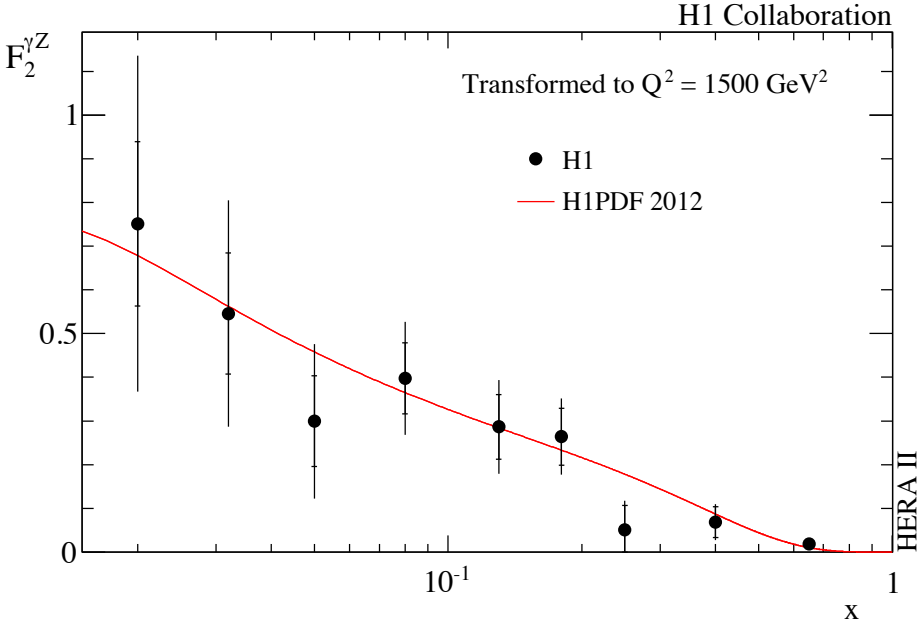


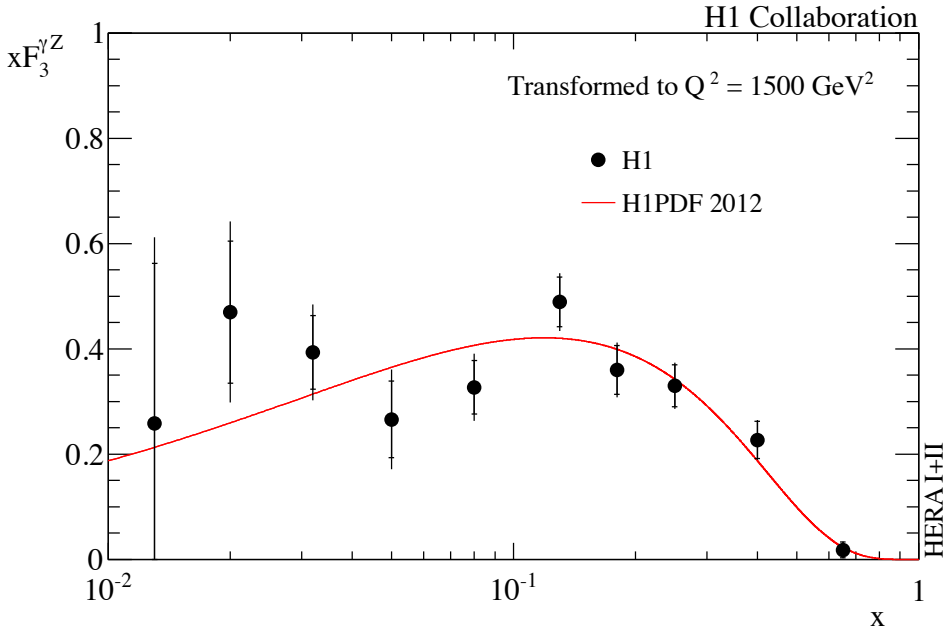
Different CC cross sections for left and right handed polarised CC cross sections provide unique flavor decomposition of proton

Structure Functions $F_2^{\gamma Z}$, $xF_3^{\gamma Z}$

First measurement $F_2^{\gamma Z}$ extracted from polarized NC cross sections

Improved $xF_3^{\gamma Z}$ using combined HERA I+II data





x dependence of $F_2^{\gamma Z}$ and $xF_3^{\gamma Z}$ reflects their parton compositions

$F_2^{\gamma Z} \sim q + \bar{q}$ $\qquad$ $xF_3^{\gamma Z} \sim xq_v$

New QCD Analysis: H1PDF 2012

In order to see the impact of the new HERA II NC+CC high Q^2 data on PDFs, a NLO QCD fit performed including all published H1 data

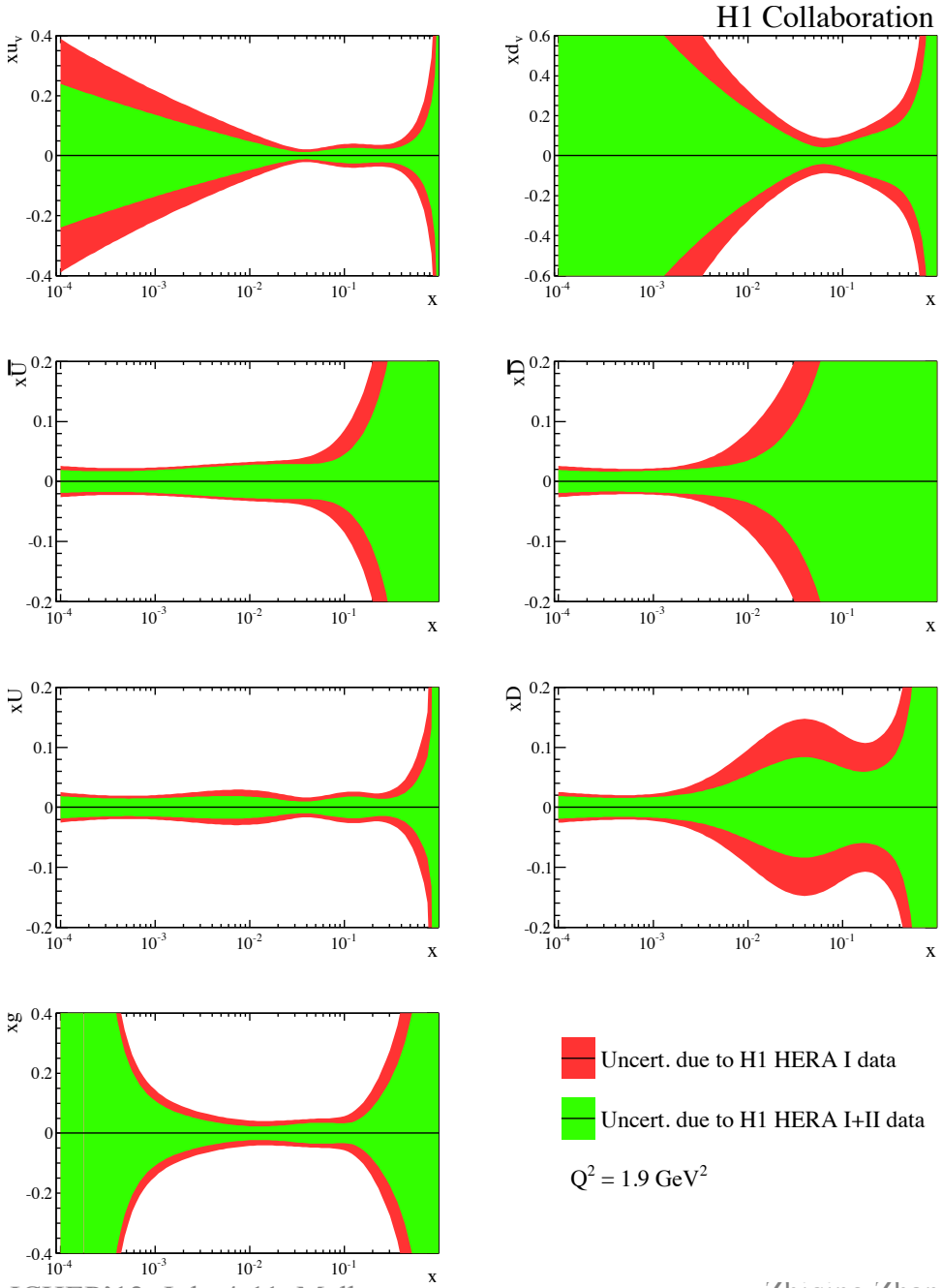
Published earlier HERA data have been the main inputs to all global PDFs fits

New

Data set	$x_{\min}$	$x_{\max}$	$Q^2_{\min}$ (GeV^2)	$Q^2_{\max}$ (GeV^2)	$\delta\mathcal{L}$ (%)	Ref.	Comment
e^+ Combined low Q^2	0.00004	0.20	0.5	150	0.5	[72]	$\sqrt{s} = 301, 319$ GeV
e^+ Combined low E_p	0.00003	0.003	1.5	90	0.5	[72]	$\sqrt{s} = 225, 252$ GeV
e^+ NC 94-97	0.0032	0.65	150	30 000	$0.5 \oplus 1.4$	[1]	$\sqrt{s} = 301$ GeV
e^+ CC 94-97	0.013	0.40	300	15 000			
e^- NC 98-99	0.0032	0.65	150	30 000	$0.5 \oplus 1.7$	[2]	$\sqrt{s} = 319$ GeV
e^- CC 98-99	0.013	0.40	300	15 000			
e^- NC 98-99 *high y*	0.00131	0.0105	100	800			$\sqrt{s} = 319$ GeV
e^- NC 99-00	0.0032	0.65	150	30 000	$0.5 \oplus 1.4$	[3]	$\sqrt{s} = 319$ GeV; incl. *high y*
e^+ CC 99-00	0.013	0.40	300	15 000			$\sqrt{s} = 319$ GeV
e^+ NC *high y*	0.0008	0.0105	60	800	$2.3 \oplus 1.0 \oplus 1.1$		$\sqrt{s} = 319$ GeV
e^- NC *high y*	0.0008	0.0105	60	800	$2.3 \oplus 1.2 \oplus 0.8$		$\sqrt{s} = 319$ GeV
e^+ NC L	0.002	0.65	120	30 000	$2.3 \oplus 1.5$		$\sqrt{s} = 319$ GeV
e^+ CC L	0.008	0.40	300	15 000			
e^+ NC R	0.002	0.65	120	30 000	$2.3 \oplus 1.5$		
e^+ CC R	0.008	0.40	300	15 000			
e^- NC L	0.002	0.65	120	50 000	$2.3 \oplus 1.5$		
e^- CC L	0.008	0.40	300	30 000			$\sqrt{s} = 319$ GeV
e^- NC R	0.002	0.65	120	30 000	$2.3 \oplus 1.5$		
e^- CC R	0.008	0.40	300	15 000			

The data cover ~5 orders of magnitude in Q^2 and x

Impact of the New HERA II Data



HERAFitter based on QCDNUM (v17.04)
NLO, MSbar scheme
RT heavy flavor mass scheme

5 sets of PDFs with 13 free parameters with quark number and momentum sum rules:

$$
\begin{aligned}
xg(x) &= A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{25}, \\
xu_v(x) &= A_{u_v} x^{B_{uv}}(1-x)^{C_{uv}}\left(1+E_{u_v}x^2\right), \\
xd_v(x) &= A_{d_v} x^{B_{dv}}(1-x)^{C_{dv}}, \\
x\overline{U}(x) &= A_{\overline{U}} x^{B_{\overline{U}}}(1-x)^{C_{\overline{U}}}, \\
x\overline{D}(x) &= A_{\overline{D}} x^{B_{\overline{D}}}(1-x)^{C_{\overline{D}}}.
\end{aligned}
$$

➔ Improvement in precision for all PDFs in full x range in particular for down-type quarks xD

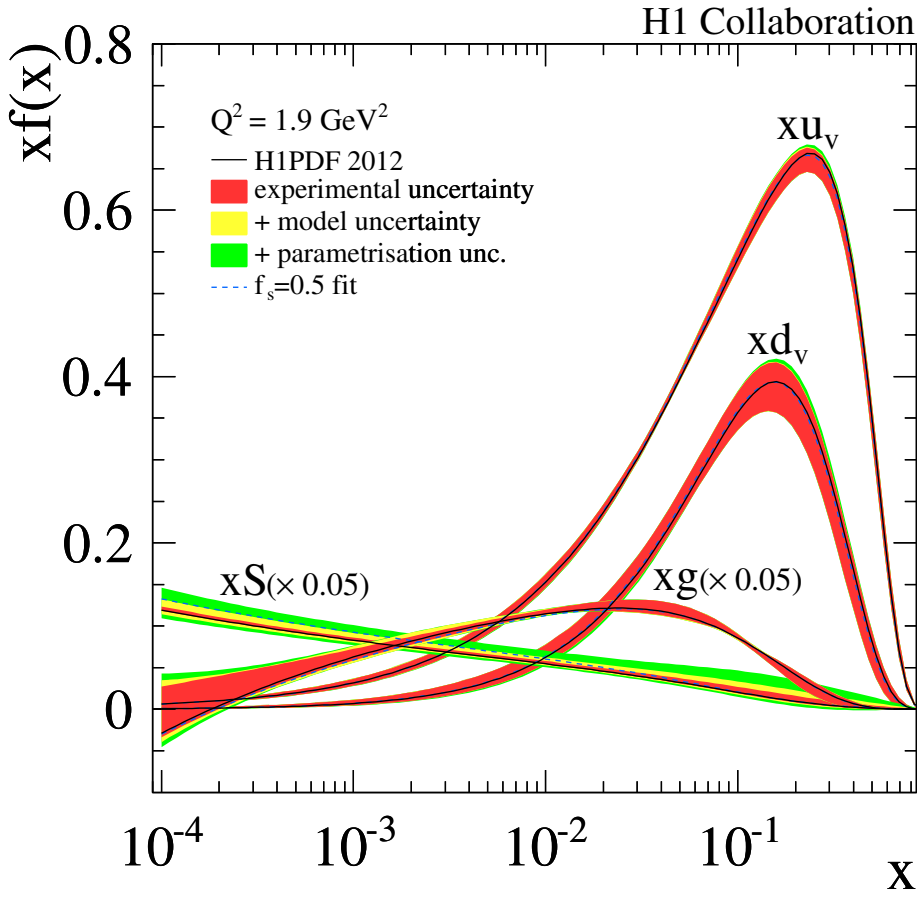
Summary

- New and Final NC + CC high Q^2 cross section for HERA II ready
- Integrated luminosity measurement at 2.3% with QED Compton
- With the polarized lepton beams at HERA II, parity violation effects observed/confirmed with improved precision
- Absence of right-handed CC W boson
- First $F_2^{\gamma Z}$ and improved $xF_3^{\gamma Z}$ determinations
- Direct F_L measurement in extended kinematic region
- These data valuable for further constraining PDFs
- H1+ZEUS HERA II combination will come soon

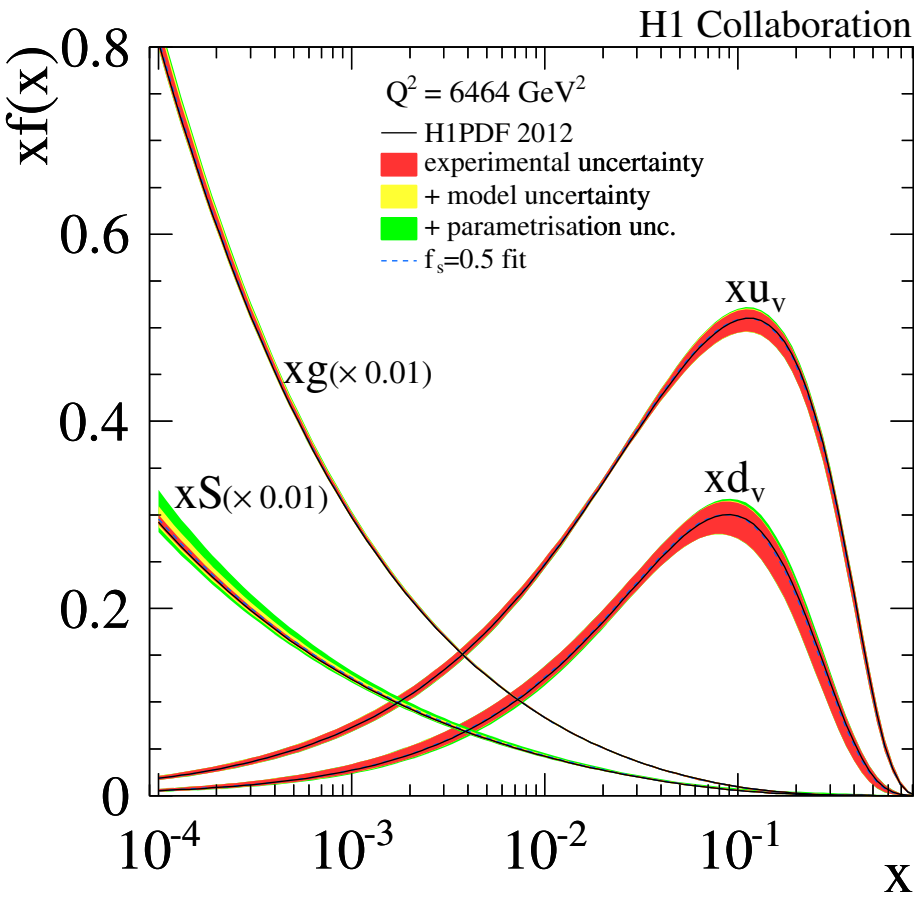
Extra Slides

H1PDF 2012

$Q^2=1.9GeV^2$



$Q^2=M^2_W$



At weak boson mass scale (LHC kinematic region), gluon density is by far the dominant contribution