8th International Workshop

on

Deep Inelastic Scattering

Liverpool, 25th - 30th April 2000

Future High Q^2 Deep Inelastic Scattering at HERA

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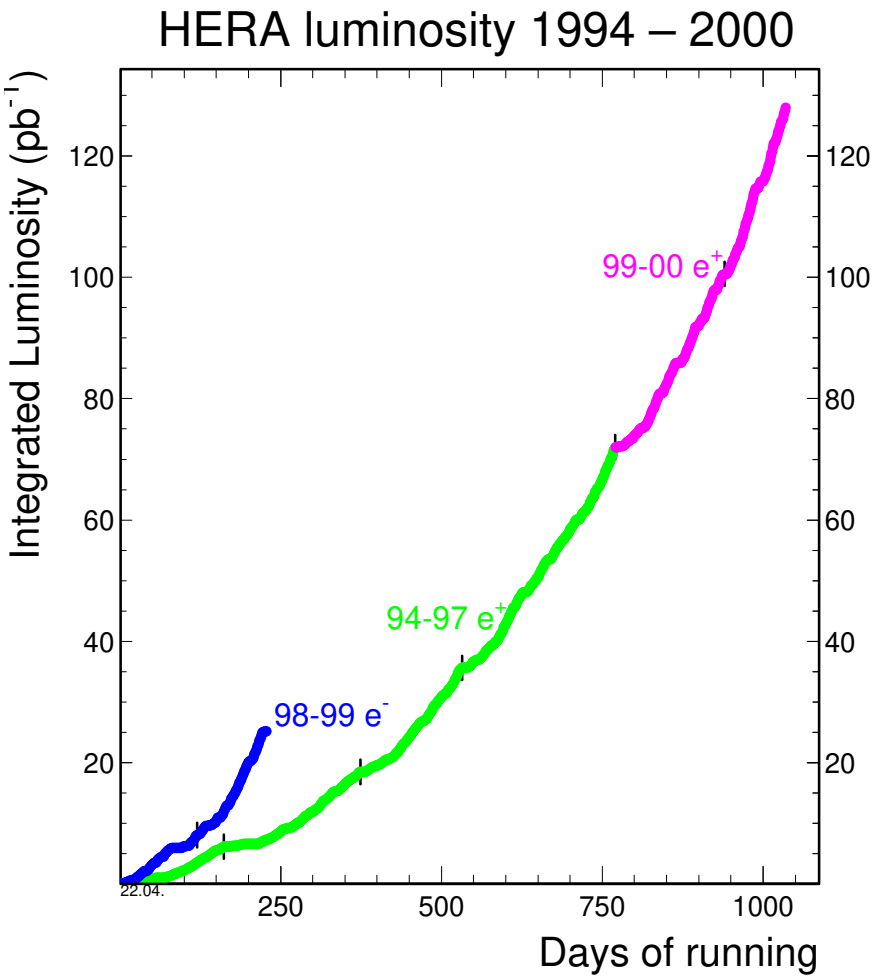
Introduction



	Luminosity (pb^{-1})	
	H1	ZEUS
e^+P (820)	37	48
e^-P (920)	18	16
e^+P (920)	> 40	> 40

To run with e^+P (920) until September 2000

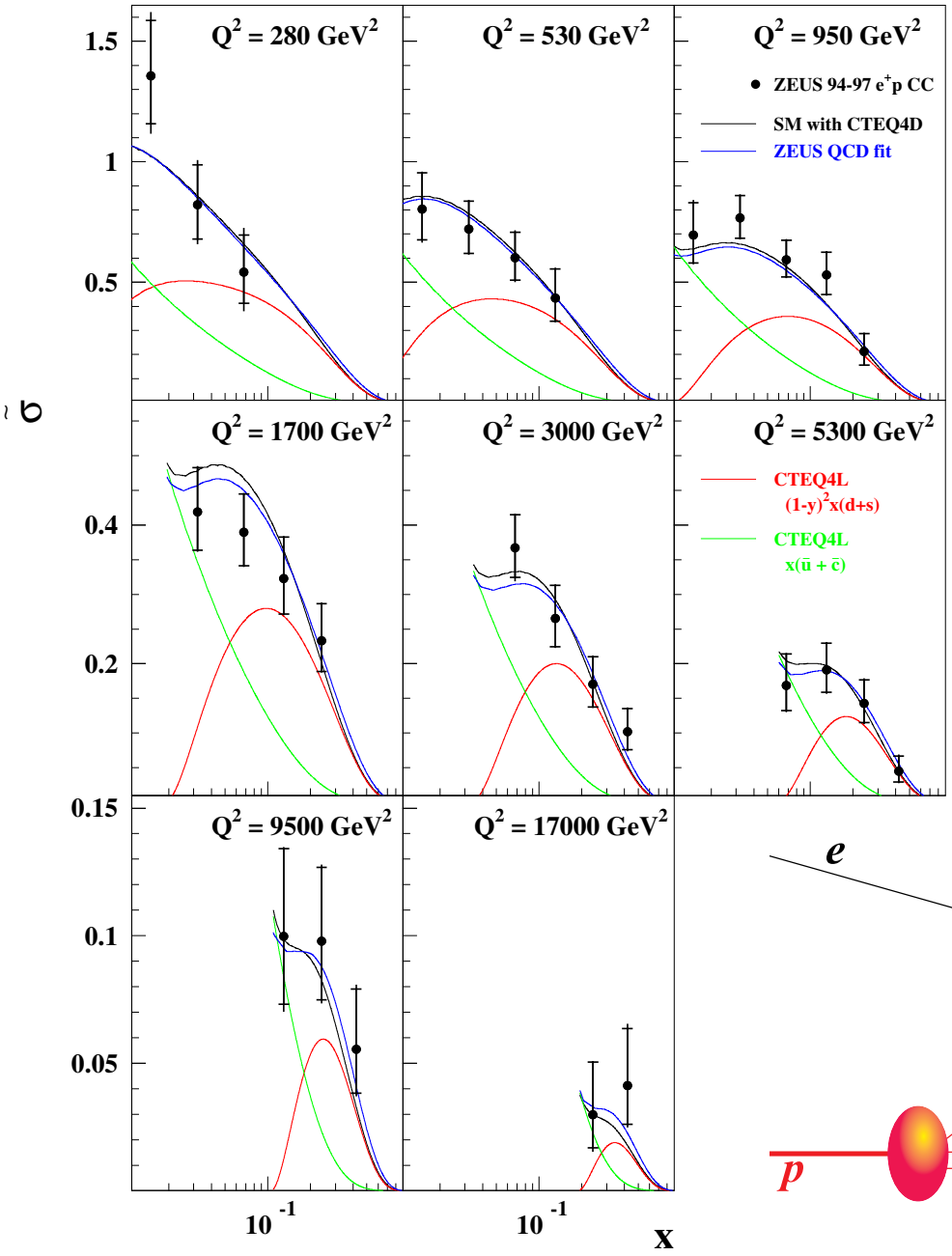
$\Rightarrow$ can expect combined e^+P data set approaching 150 pb^{-1}

Charged Current DIS

$$\tilde{\sigma}^{e^+P}_{CC} = \left\{ \frac{G_\mu^2}{2\pi x}\left[\frac{M_W^2}{Q^2+M_W^2}\right]^2 \right\}^{-1} \frac{d^2\sigma^{e^+P}_{CC}}{dxdQ^2}$$

$$\approx x\left(\bar{u}+\bar{c}+(1-y)^2(d+s)\right)$$

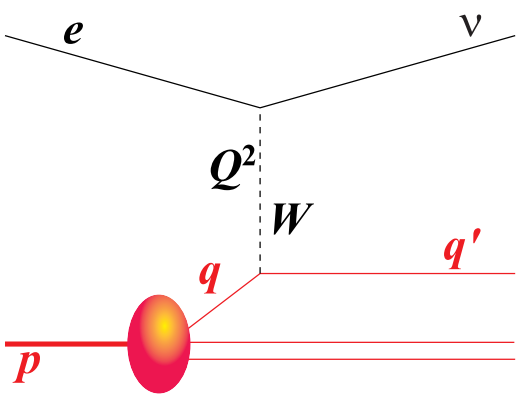
ZEUS CC 1994-97



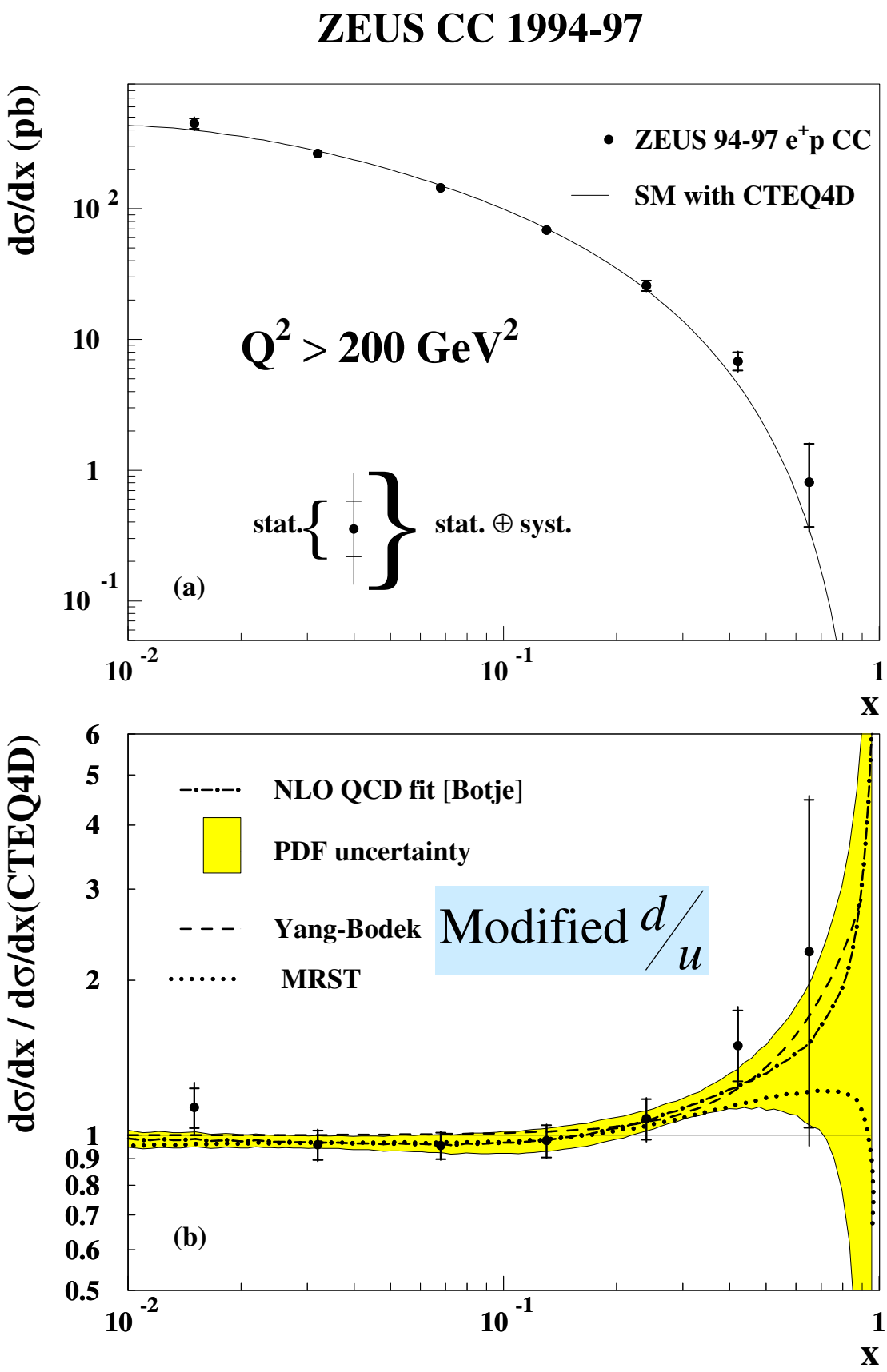
Sensitive to specific PDFs:

High x: d

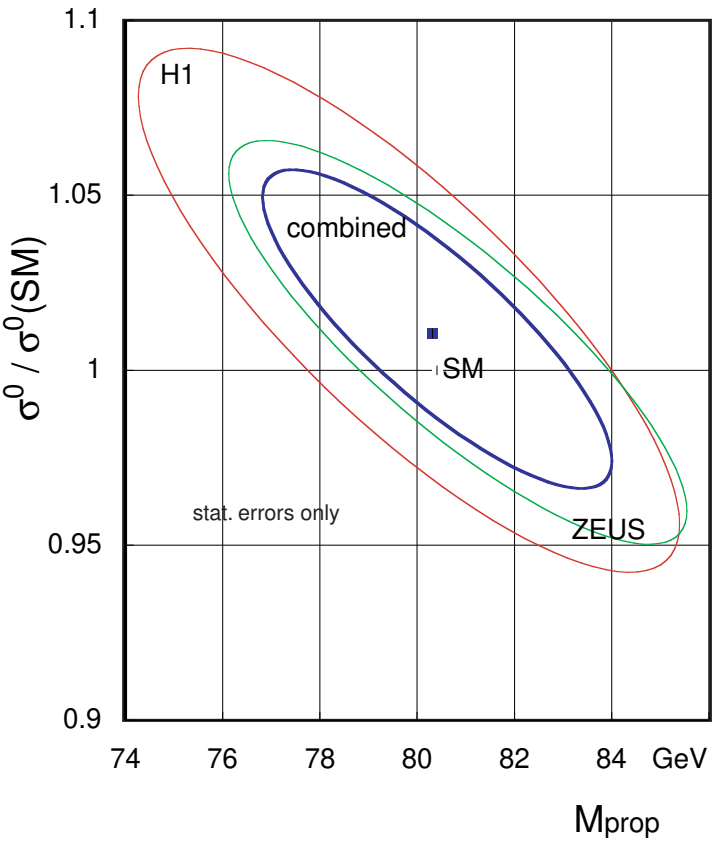
Low x: $\bar{u}$



Charged Current DIS



Charged Current DIS



$$\sigma^0 = \sigma^{CC}\left(Q^2 = 0\right)$$

Fit shape of $\frac{d\sigma}{dQ^2}$ for M_W

H1 : $M_W = 80.9 \pm 3.3 \pm 1.7 \pm 3.7$ GeV

Z : $M_W = 81.4 \pm 2.7 \pm 2.0 \pm 3.3$ GeV

Errors : Stat.; Sys.; PDF

Standard Model constraint :

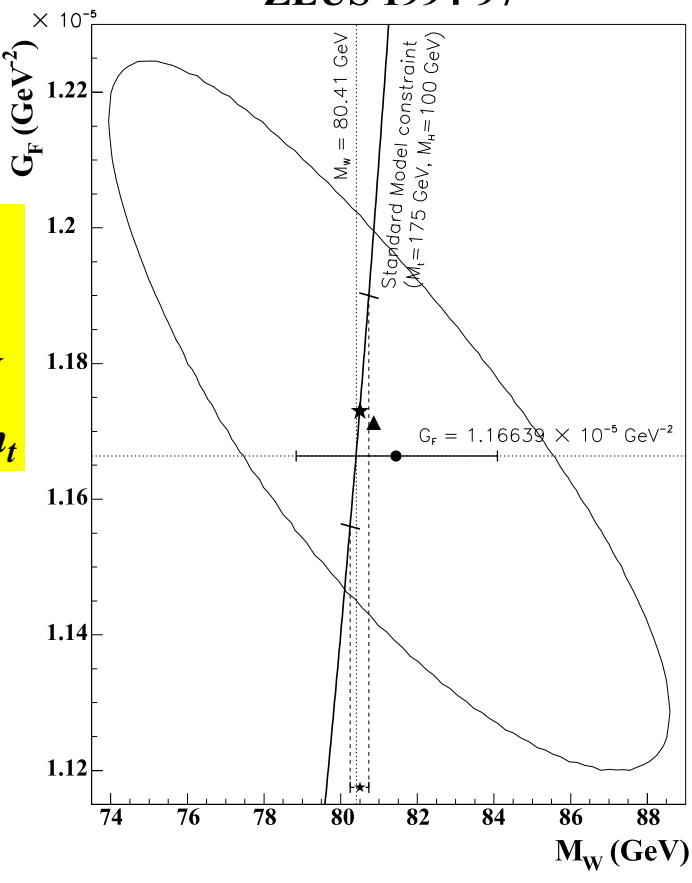
$$G_\mu = f\left(M_W; M_H, M_Z, m_t\right)$$

Z : $M_W = 80.50^{+0.24\ +0.13\ +0.30\ +0.03}_{-0.25\ -0.16\ -0.31\ -0.06}$ GeV

Errors : Stat.; Sys.; PDF; $\Delta M_H, \Delta M_Z, \Delta m_t$

Consistency check rather than a measurement of M_W

ZEUS 1994-97

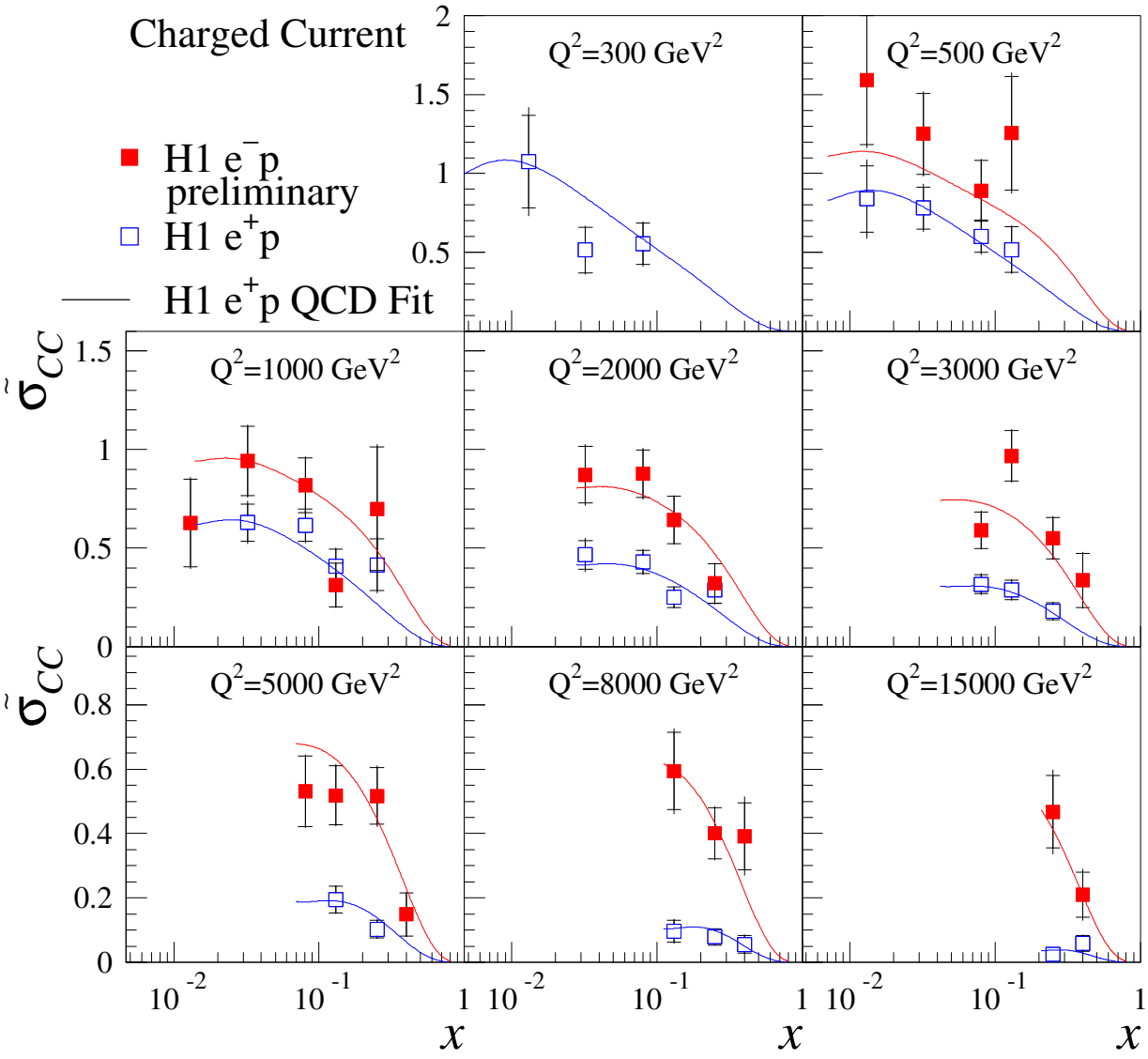


Charged Current DIS

- Towards *d/u* ratio:

$$\tilde{\sigma}^{e^-P}_{CC} = x\left(u + c + (1-y)^2\left(\bar{d} + \bar{s}\right)\right)$$

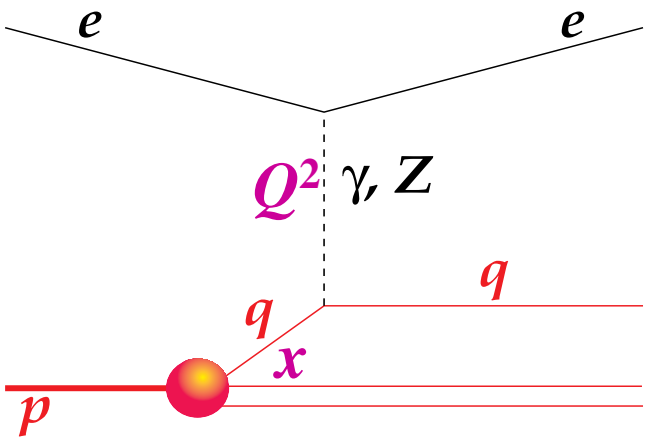
$$\tilde{\sigma}^{e^+P}_{CC} = x\left(\bar{u} + \bar{c} + (1-y)^2\left(d + s\right)\right)$$



$$\sigma^{e^-P}_{CC} > \sigma^{e^+P}_{CC} : xu \text{ versus } (1-y)^2\, xd$$

- **Towards a measurement of *d/u* using proton as target**

Neutral Current DIS

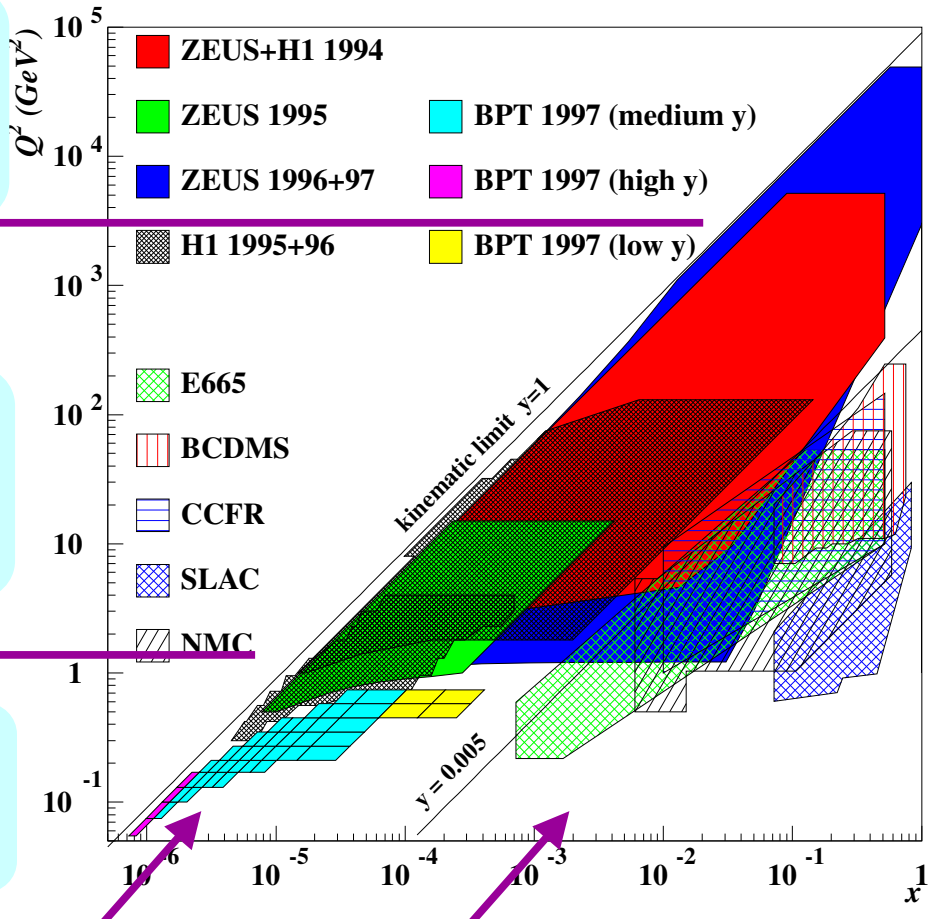


ZEUS 1997 Preliminary

Electroweak & Searches

Precision tests of QCD

Transition to photoprod



Sensitivity to F_L

Overlap with fixed target

Neutral Current DIS

$$\frac{d^2\sigma_{\mathrm{NC}}^{\mathrm{e}^{\pm}P}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left[Y_+ F_2^{\mathrm{NC}} \mp Y_- x F_3^{\mathrm{NC}} - y^2 F_{\mathrm{L}}^{\mathrm{NC}}\right]$$

$$Y_\pm = \left(1 \pm (1-y)^2\right) \quad y = \frac{Q^2}{xs} = \sin^2\frac{\theta^*}{2}$$

$$F_2^{\mathrm{NC}} = x\sum_q A_q\left(q + \bar{q}\right) \quad F_3^{\mathrm{NC}} = x\sum_q B_q\left(q - \bar{q}\right)$$

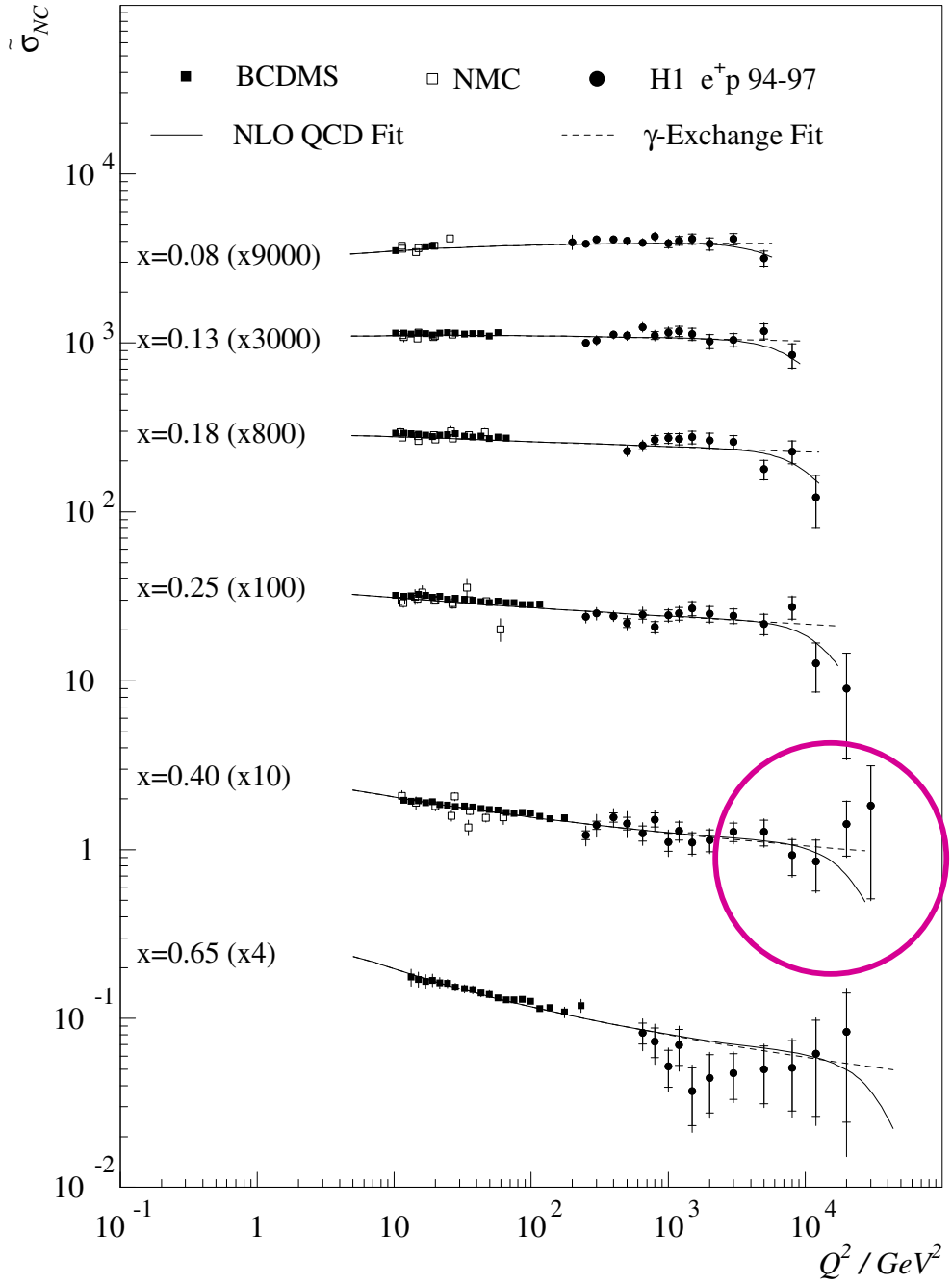
$$F_{\mathrm{L}}^{\mathrm{NC}} = \frac{\alpha_{\mathrm{S}}}{\pi}\left\{\left[\beta_1 \otimes F_2^{\mathrm{NC}}\right] + \left[\beta_2 \otimes xG\right]\right\}$$

$$\frac{dF_2^{\mathrm{NC}}}{d\ln Q^2} = \frac{\alpha_{\mathrm{S}}}{2\pi}\left\{\left[P_{\mathrm{qq}} \otimes F_2^{\mathrm{NC}}\right] + \left[P_{\mathrm{qG}} \otimes xG\right]\right\}$$

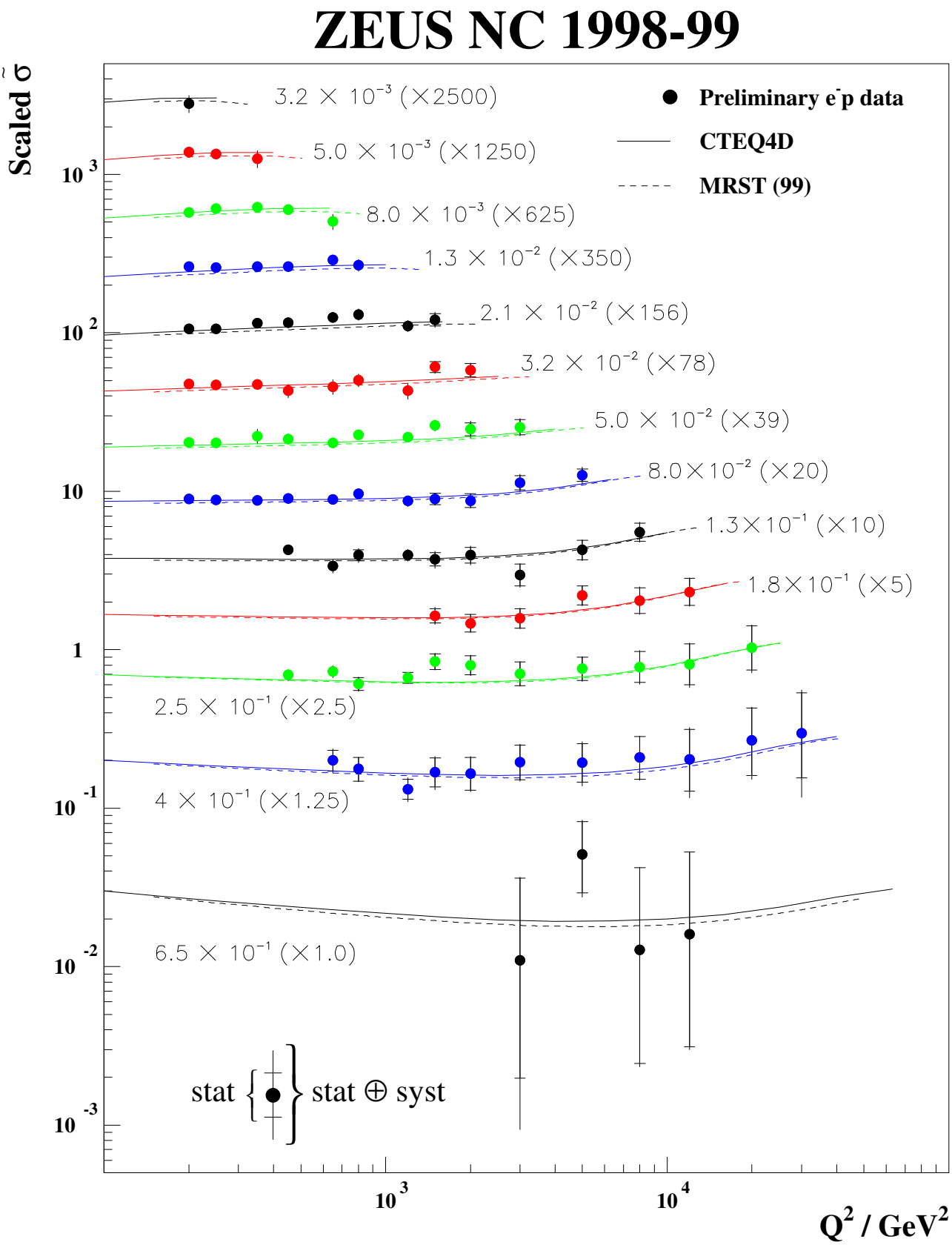
- ***F_2:***
  - → **QCD fits yield partons**
  - → **Scaling violations: NLO QCD, Gluon**
- ***F_{L}:***
  - → **NLO QCD, gluon**
- ***xF_3:***
  - → **Valence partons**

Neutral Current DIS

Focus on highest possible Q^2 to look for Z exchange and to search for *NEW* physics

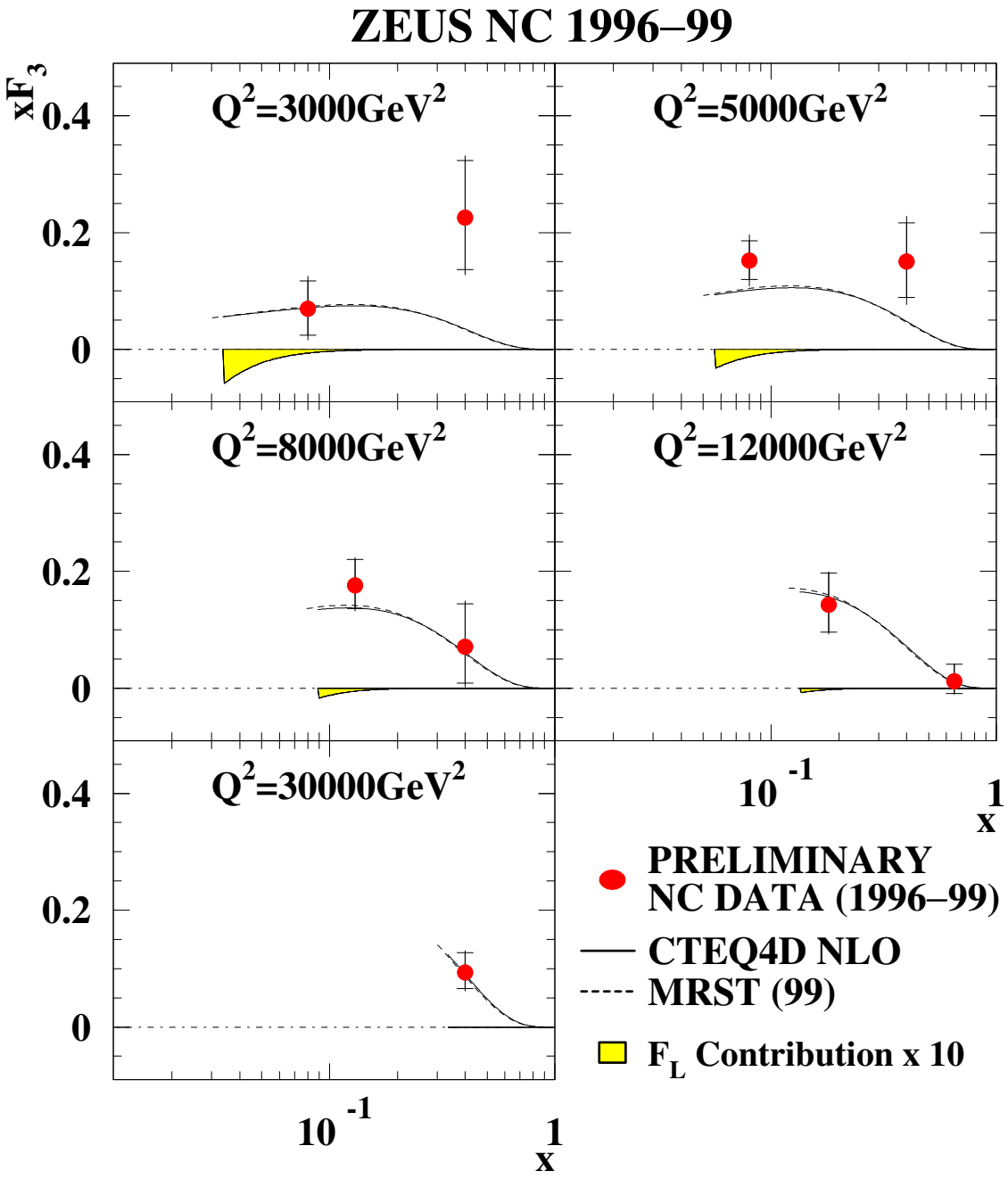


- **High Precision at low to medium Q^2, x**
- **First measurements at high Q^2, x**



- **First measurements of charge dependence of NC DIS at high Q^2, x**

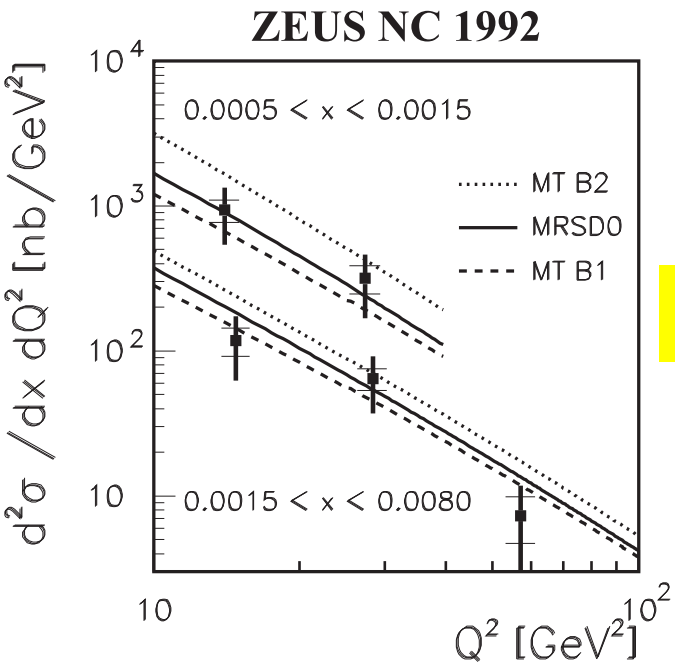
Observation of parity violation in NC DIS
γ-Z interference

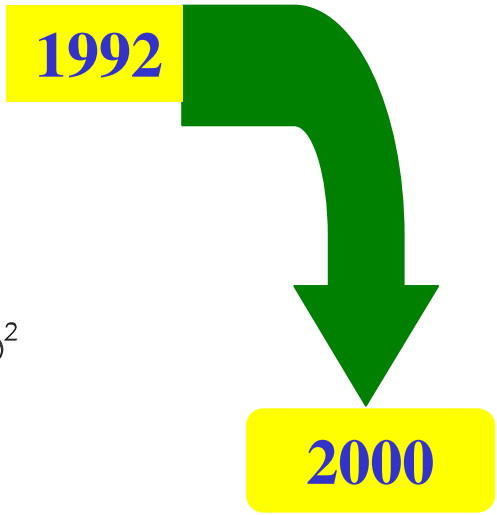


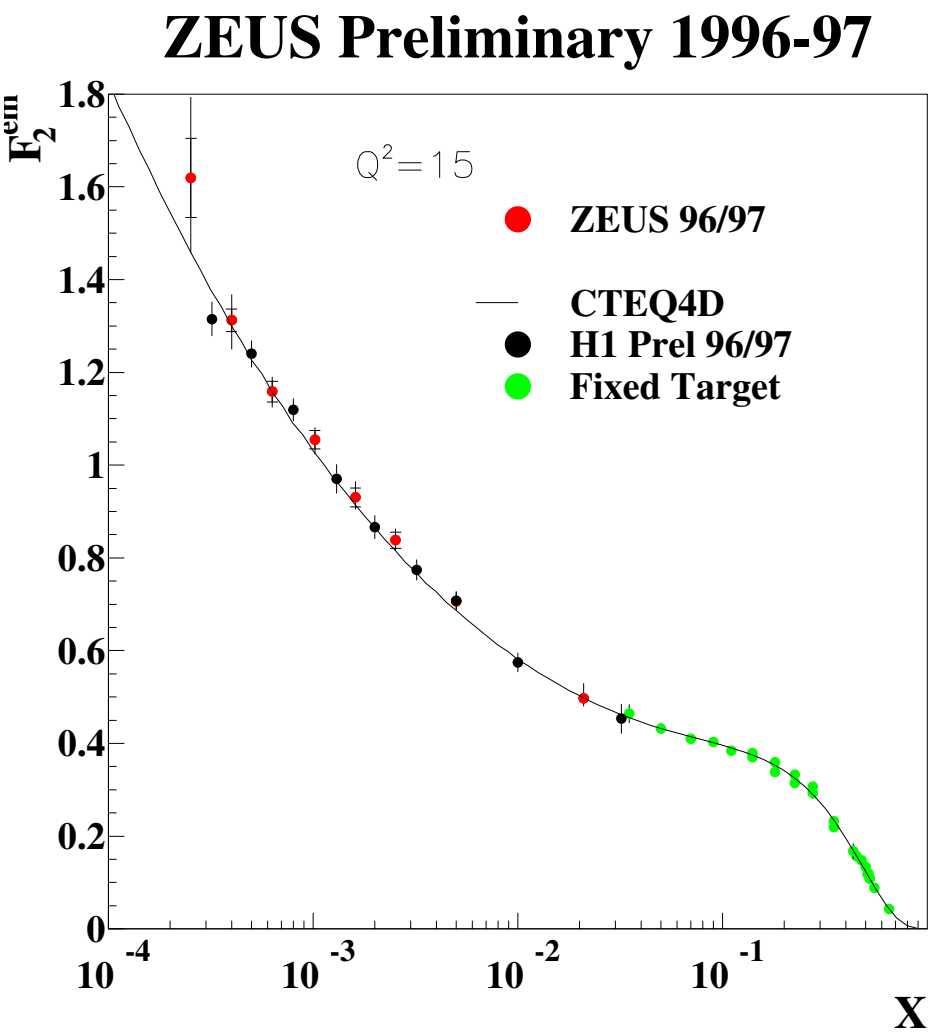
First direct look at the valence quarks!

- First measurement of xF_3 on *PROTON* at high Q^2, x

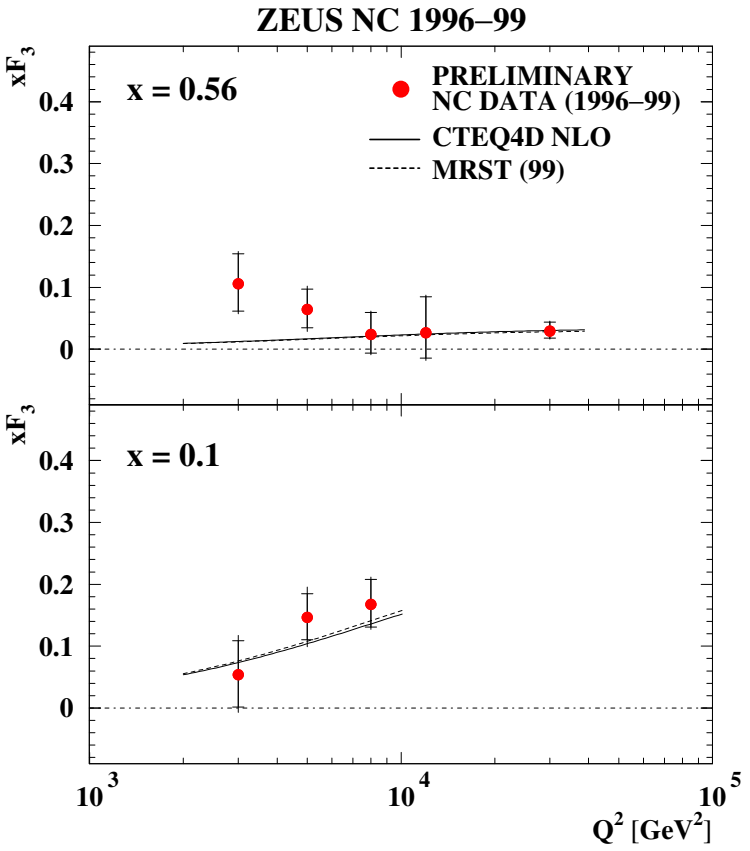
Neutral Current DIS







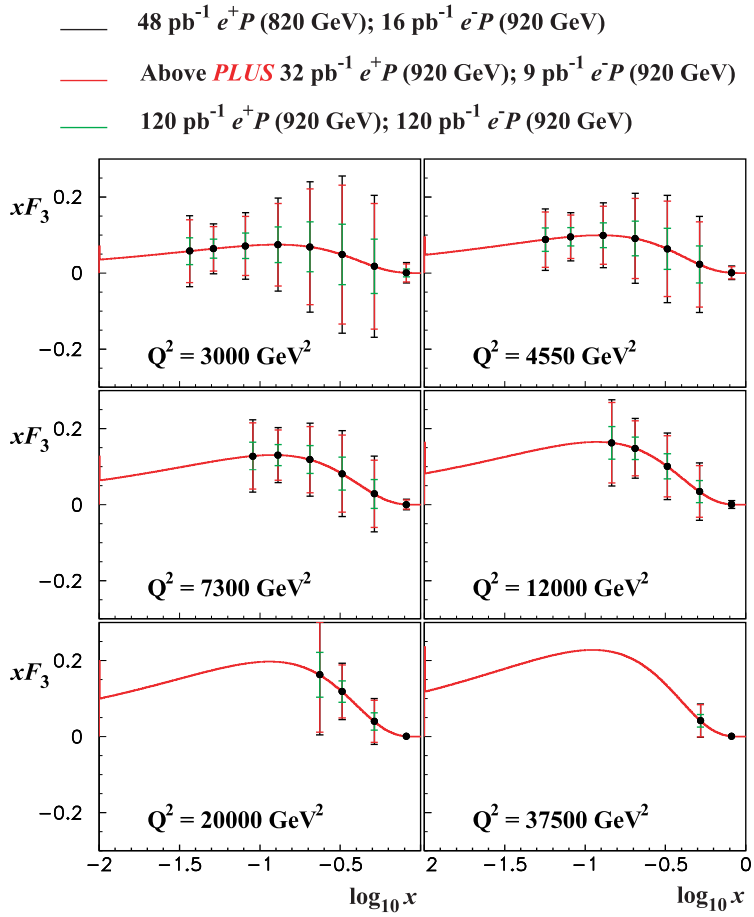
Neutral Current DIS



FIRST measurement

Statistically limited

Needs more data!



⇒ the HERA upgrade

Going into the upgrade with ...

- **Precision F_2; significantly constraining quark and gluon PDFs**
- **High Q^2 NC cross sections well described by the Standard Model**

  $\rightarrow$ PDFs; QCD evolution
- **High Q^2 CC cross sections well described by the Standard Model**

  $\rightarrow$ PDFs; d/u ratio
- **H1/ZEUS have performed detailed studies of unpolarised D.I.S.**
- **H1/ZEUS now ready for high luminosity and polarisation ...**

The HERA Upgrade

Luminosity Upgrade:

- **Factor 5 larger than present luminosity**

  $\Rightarrow$ > 150 pb^{-1} / year

Polarisation for Collider Experiments:

- **Polarised electron/positron beams**

  $\Rightarrow$ 70% (design goal)

Running Programme:

- **Six years of running at 150 pb^{-1}/year starting after 2000/2001 shutdown**

  $\Rightarrow$ ~ 1000 pb^{-1} for both H1 and ZEUS

The Collider Detector Upgrades

Main Detector Upgrades

Charm/Beauty Tagging:

- **ZEUS:** ***NEW*** **Silicon micro-vertex detector**

  H1: ***HAS*** **silicon micro-vertex detector**

  Improve by adding Backward Silicon Tracker and upgrading for Forward Silicon Tracker

Scattered Electron Detection at High Q^2:

… also charm and beauty tagging especially at high *x*:

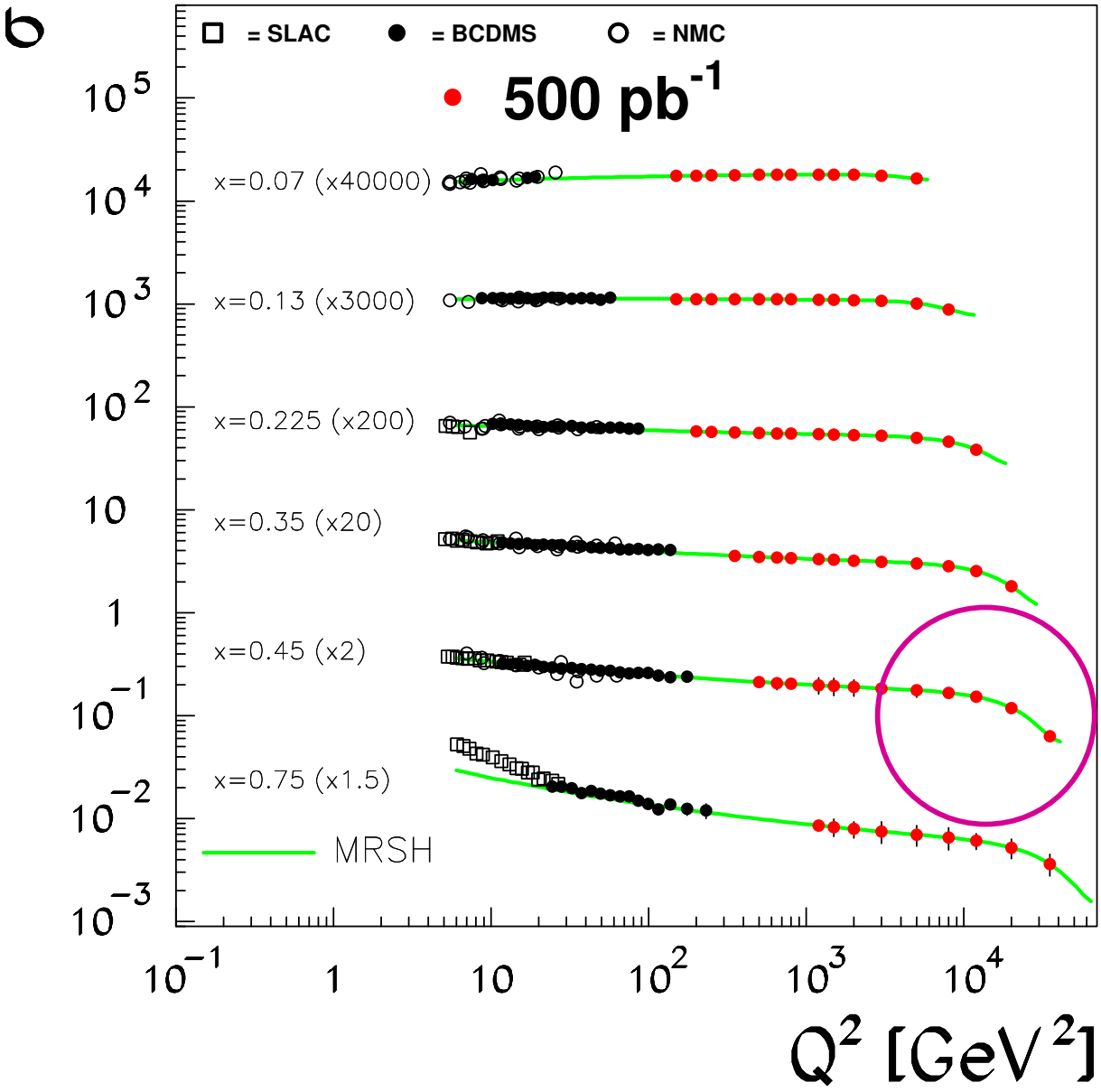
- **Upgrade forward tracking detectors**

  ZEUS: ***NEW*** **Straw Tube Tracker**

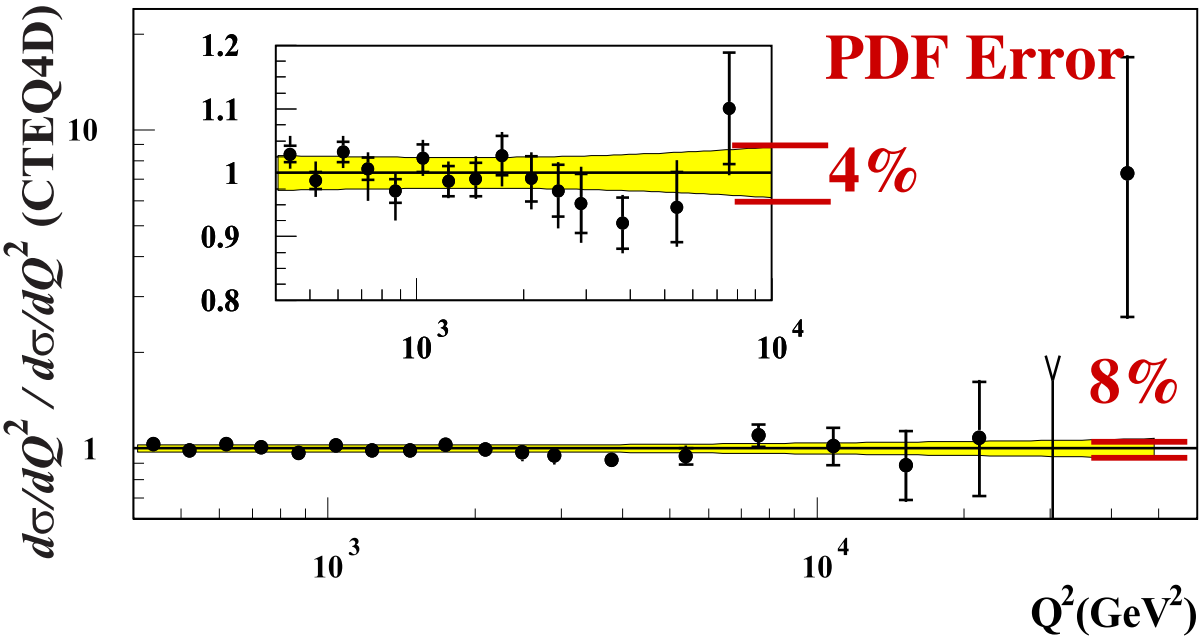
  H1: ***NEW*** **Planar Drift Chambers**

Future Physics at HERA

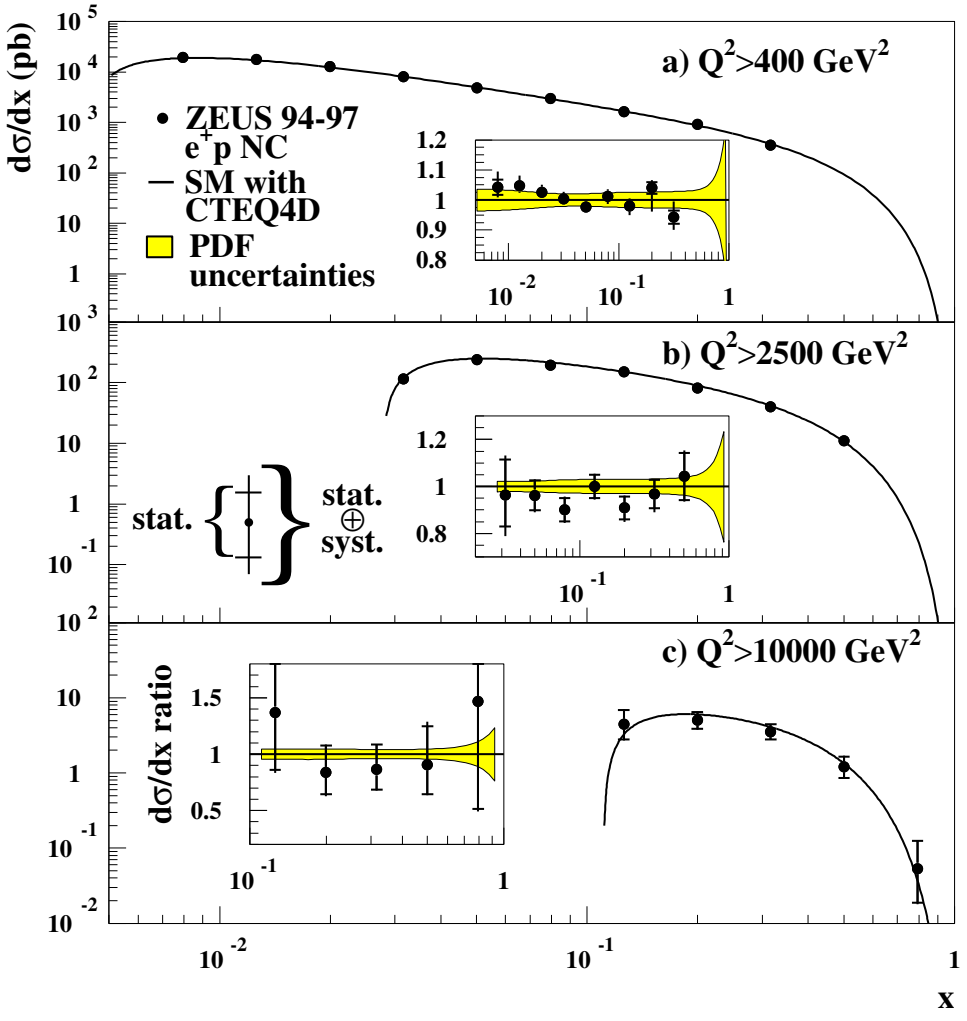
1000 pb^{-1}	$\sigma(e^-P)$ pb $Q^2 > 10{,}000$ GeV^2		$\sigma(e^+P)$ pb $Q^2 > 10{,}000$ GeV^2	
E_P GeV	NC	CC	NC	CC
820	4.1	4.8	2.0	0.5
920	4.9	5.7	2.5	0.7



- Prediction of cross sections at high Q^2:

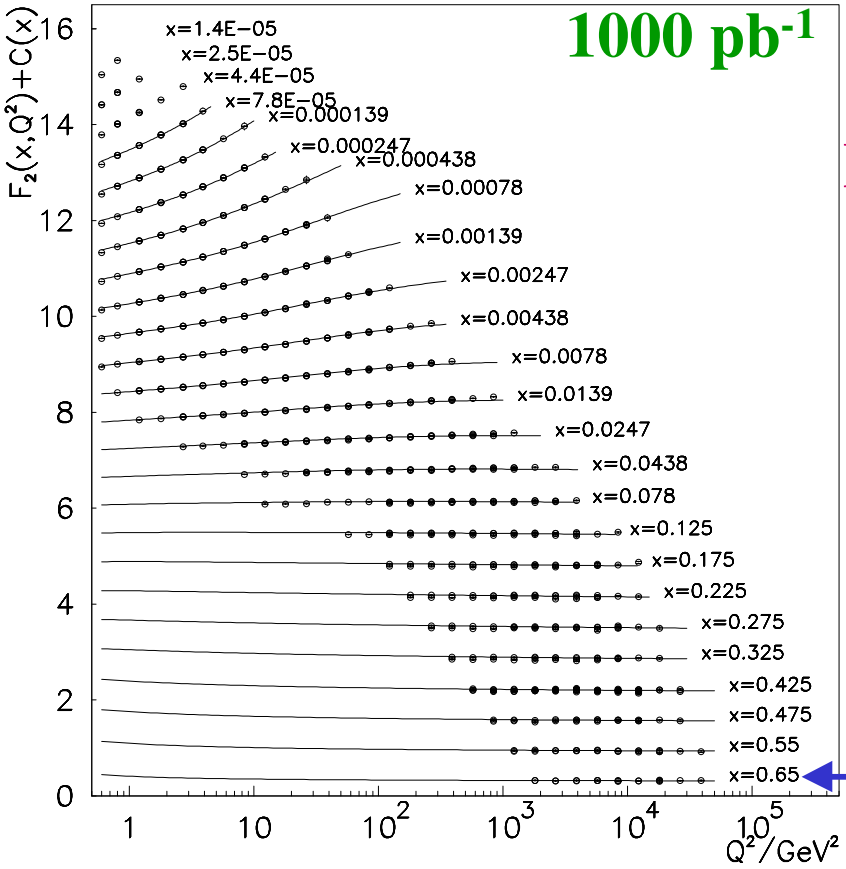


ZEUS NC 1994 – 97



Cross section prediction to better than ~ 10% over most of kinematic range

- The Structure Function F_2



High Precision F_2

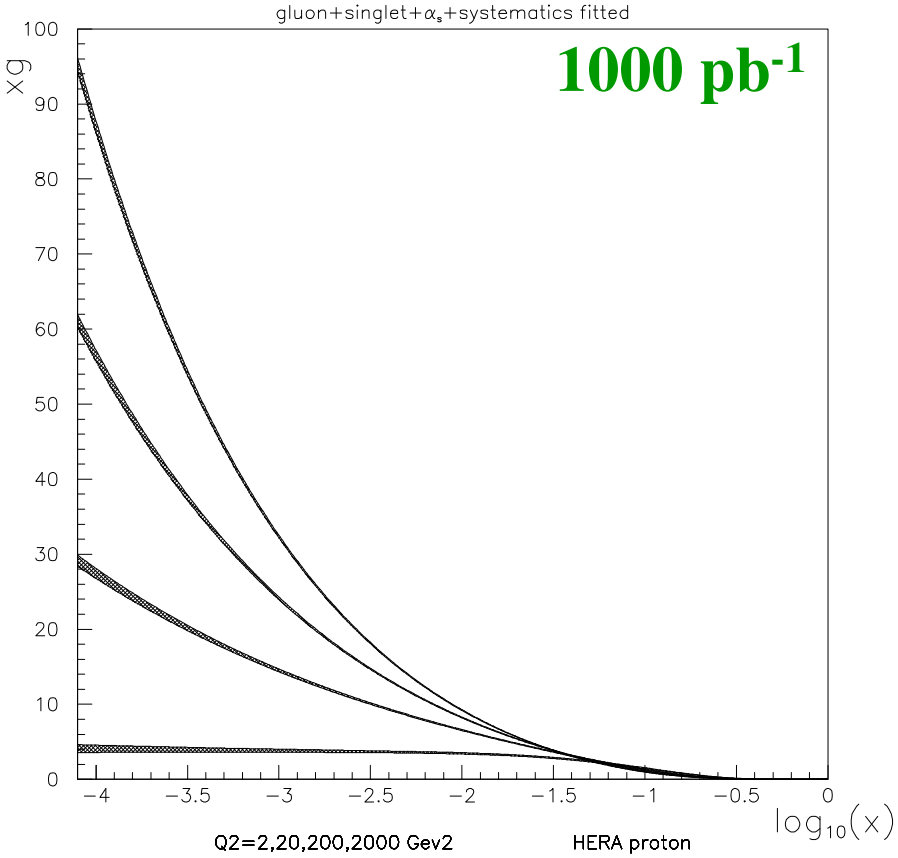
Large x, Q^2 range

→

α_S and xg

$x = 0.65$

$Q^2 = 4 \times 10^4$



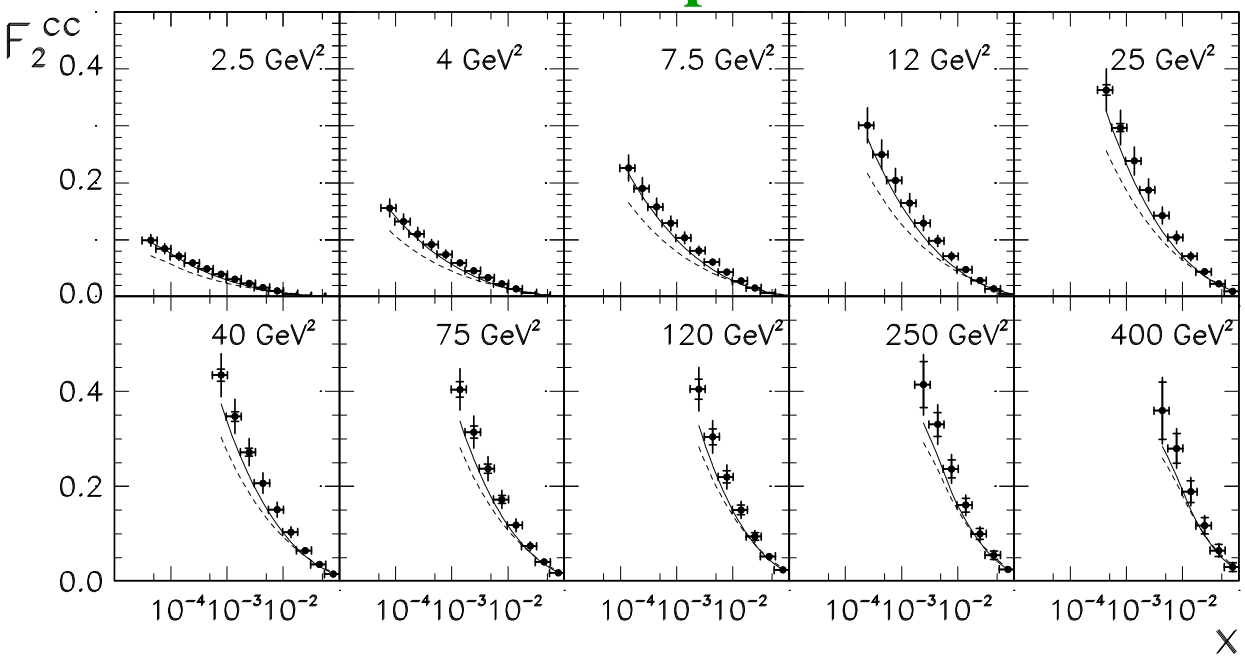
$$\Delta\alpha_S \leq 0.003$$

$$\frac{\Delta[xg]}{xg} \approx 3\%$$

- Heavy flavours in the proton:

Charm:

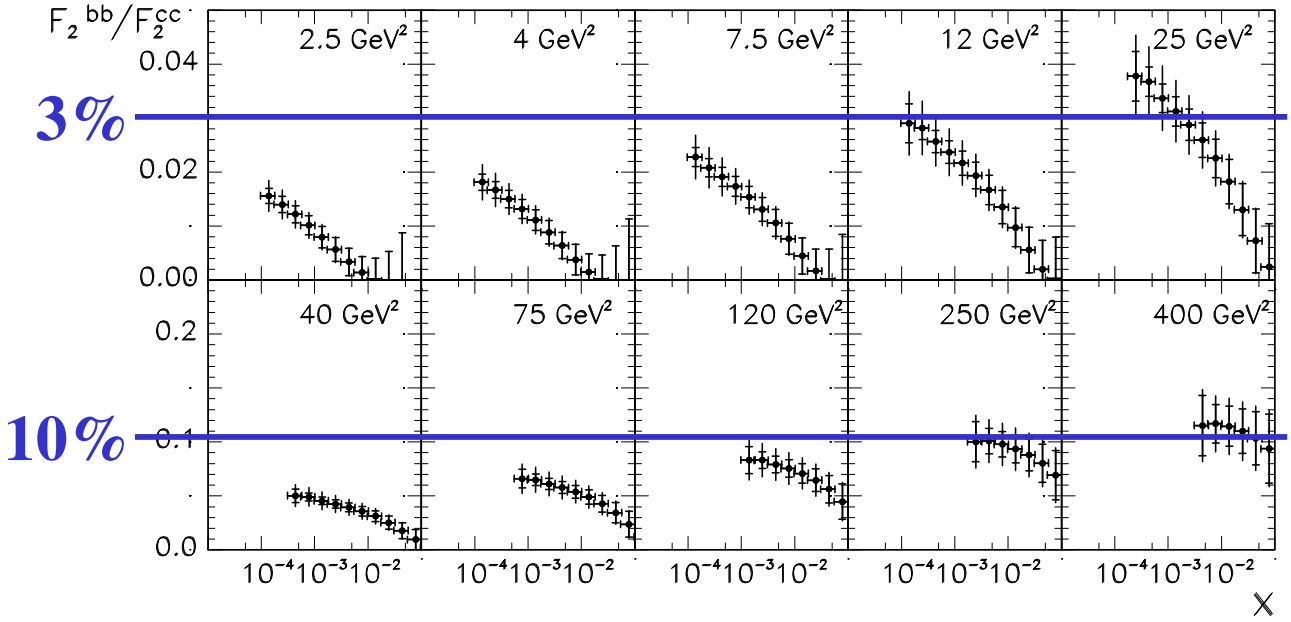
500 pb^{-1}



- High precision F_2^{Charm}

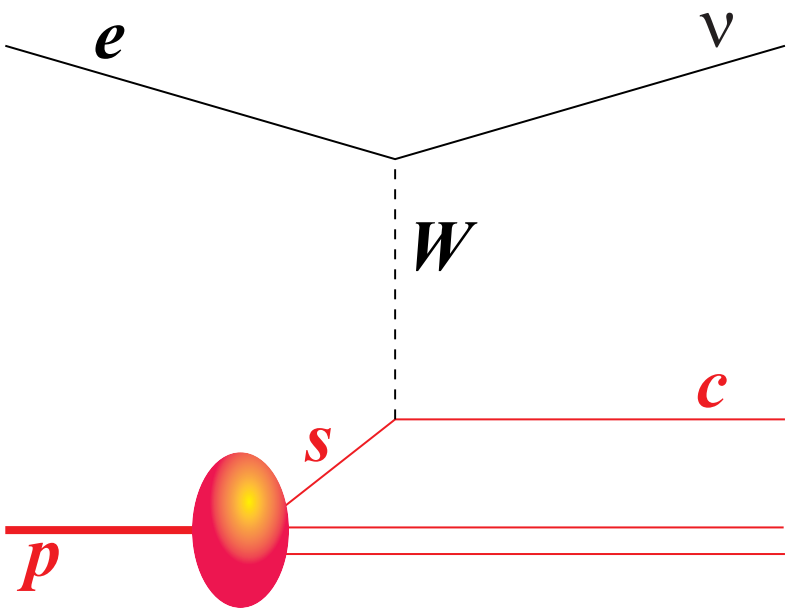
Bottom:

500 pb^{-1}



- Sensitivity to bottom contribution to F_2

- Charm in Charged Current:



Tag charm in CC events using MVD:

Strange contribution to F_2: Precision ~ 15 - 30%

Proton Structure:

Measurements of NC and CC DIS using high luminosity and upgraded detectors will constrain

Singlet, non-singlet quark densities

***u, d, s* (CC DIS)**

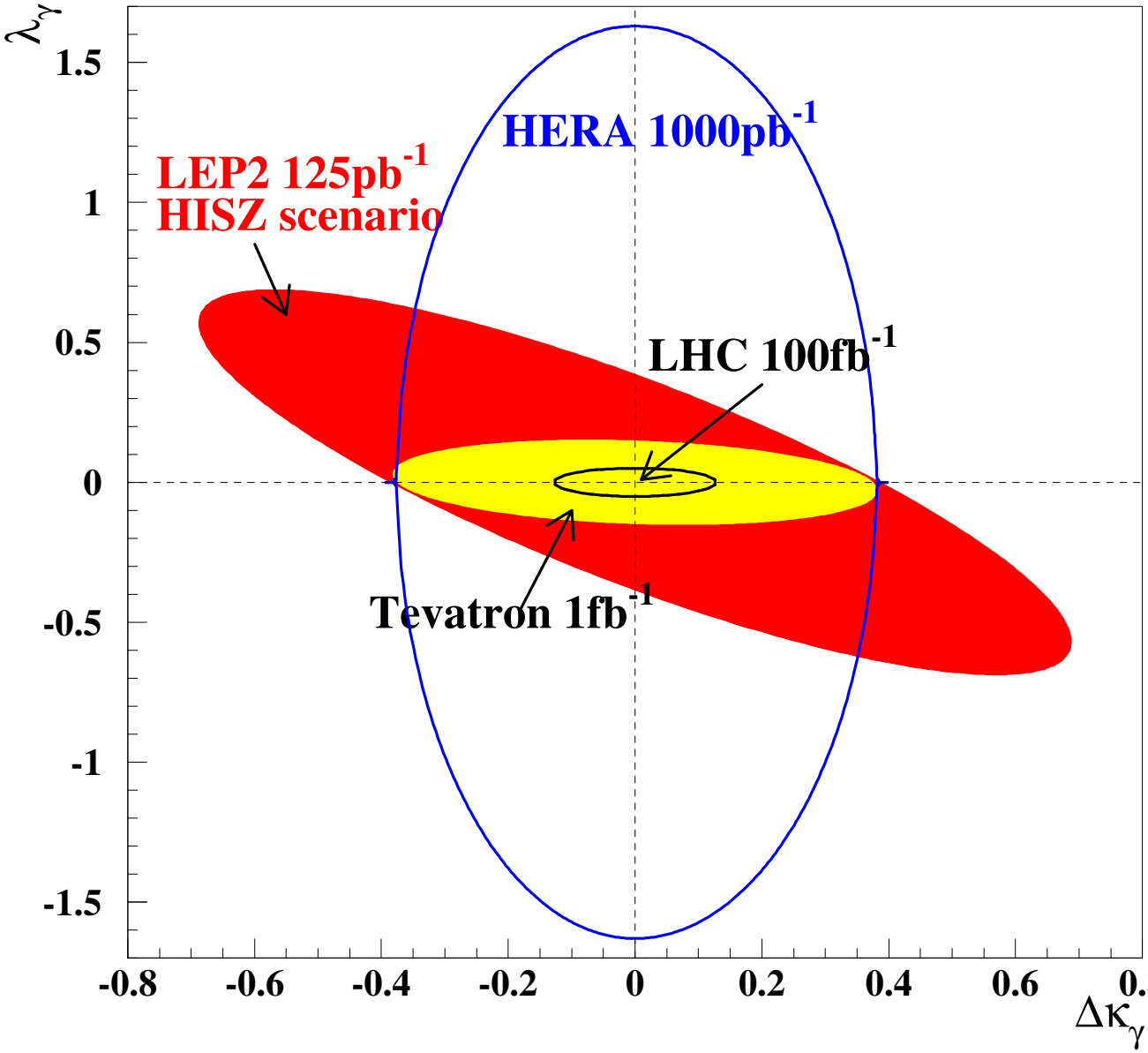
***c, b, g* (NC DIS)**

i.e. *COMPLETE* study of proton structure

- Sensitivity to *WWγ* vertex:

***W* production ⇒ *WW* γ vertex**

Anomalous couplings: $\Delta\kappa_\gamma$, λ_γ parameterise deviation from Standard Model

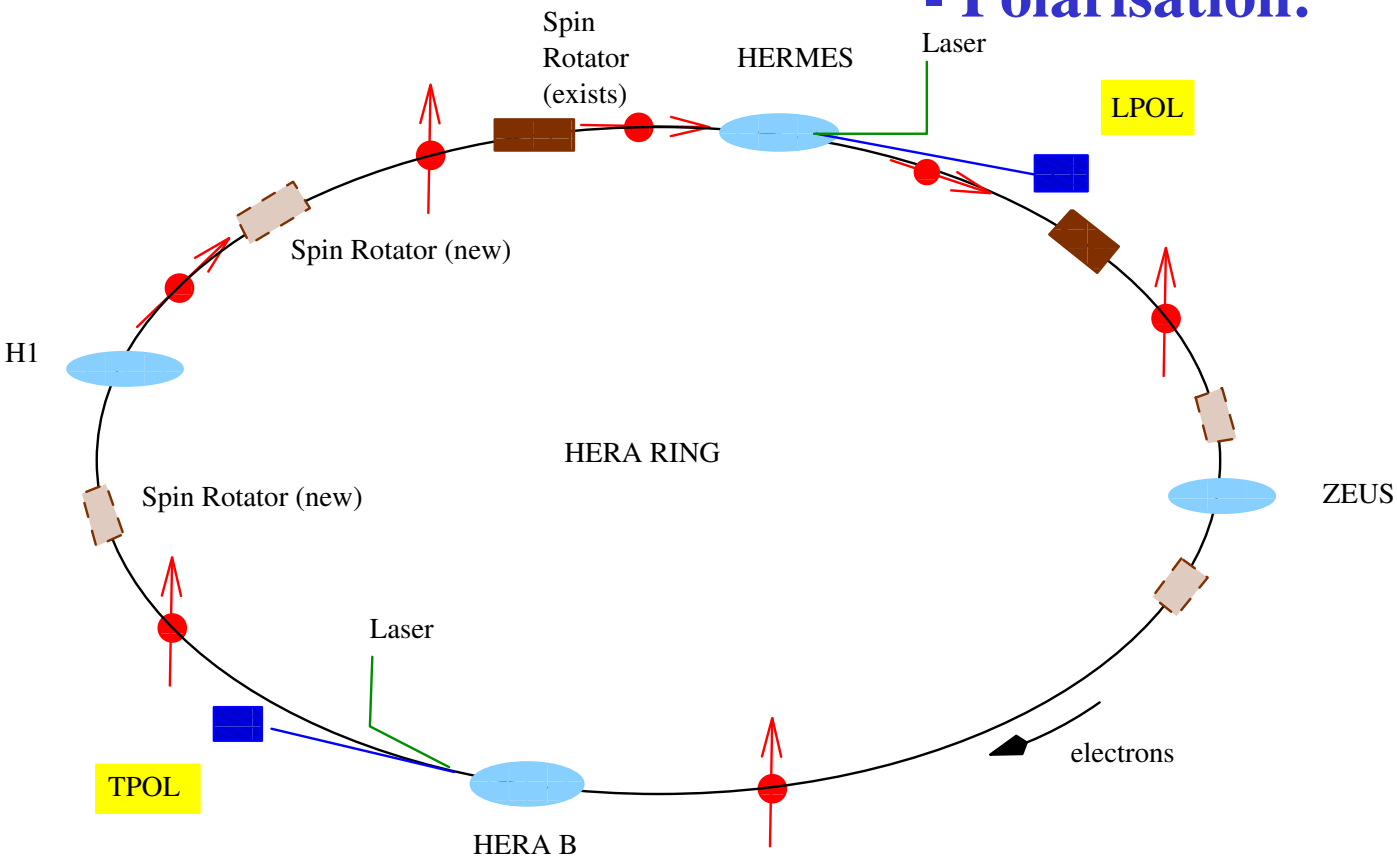


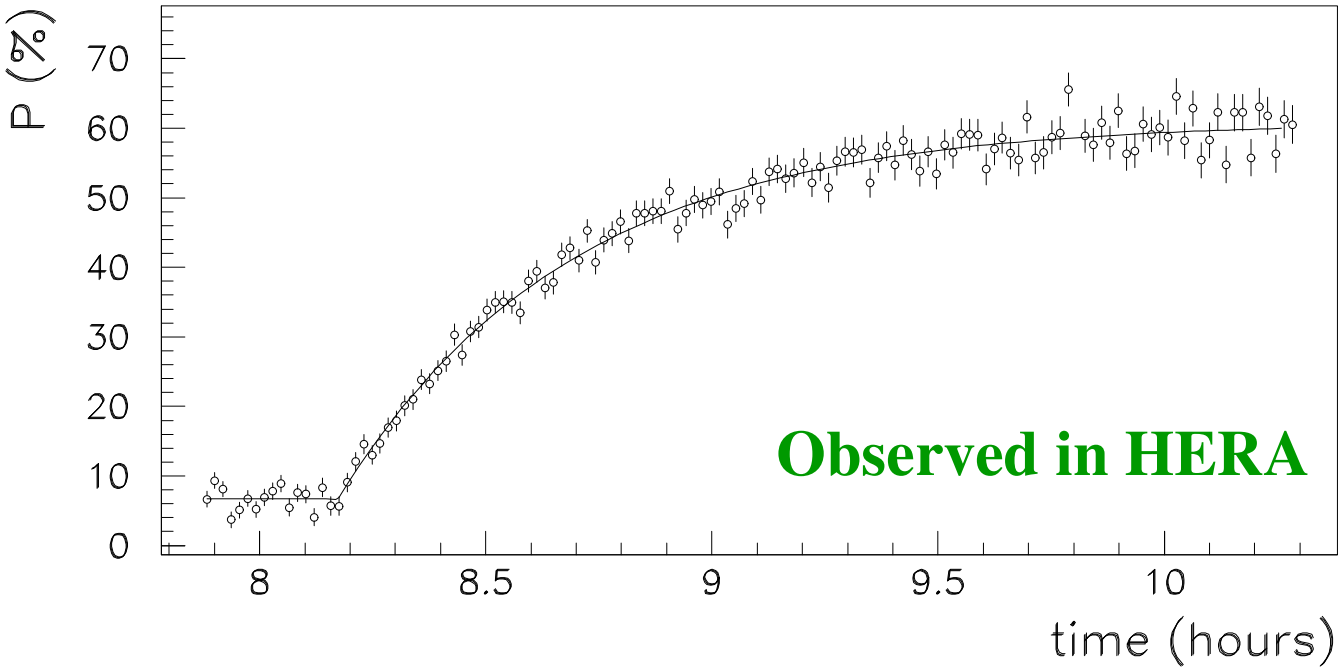
Insensitive to *WWZ*

Comparable to LEP2/Tevatron

The HERA Upgrade

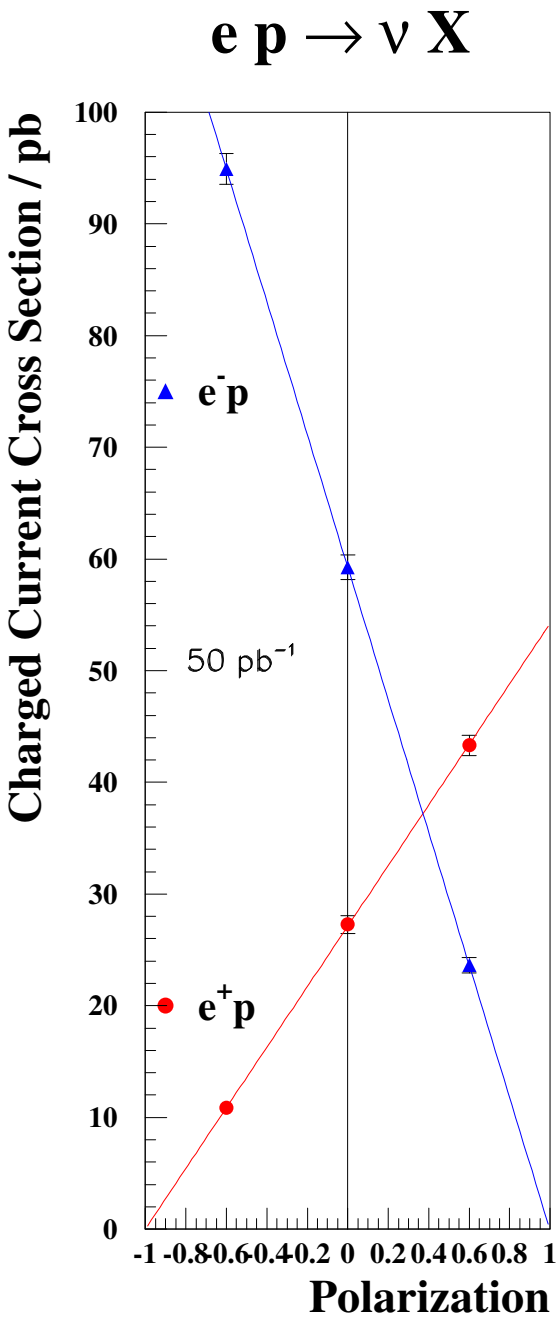
- Polarisation:





- **Design goal 70%: Polarisation ~ 60% looks achievable**

- Charged Current:



$$\sigma^{CC}_{e^{\pm}p} \propto (1 \pm P)$$

P = polarisation

Resolution on M_W

80 MeV

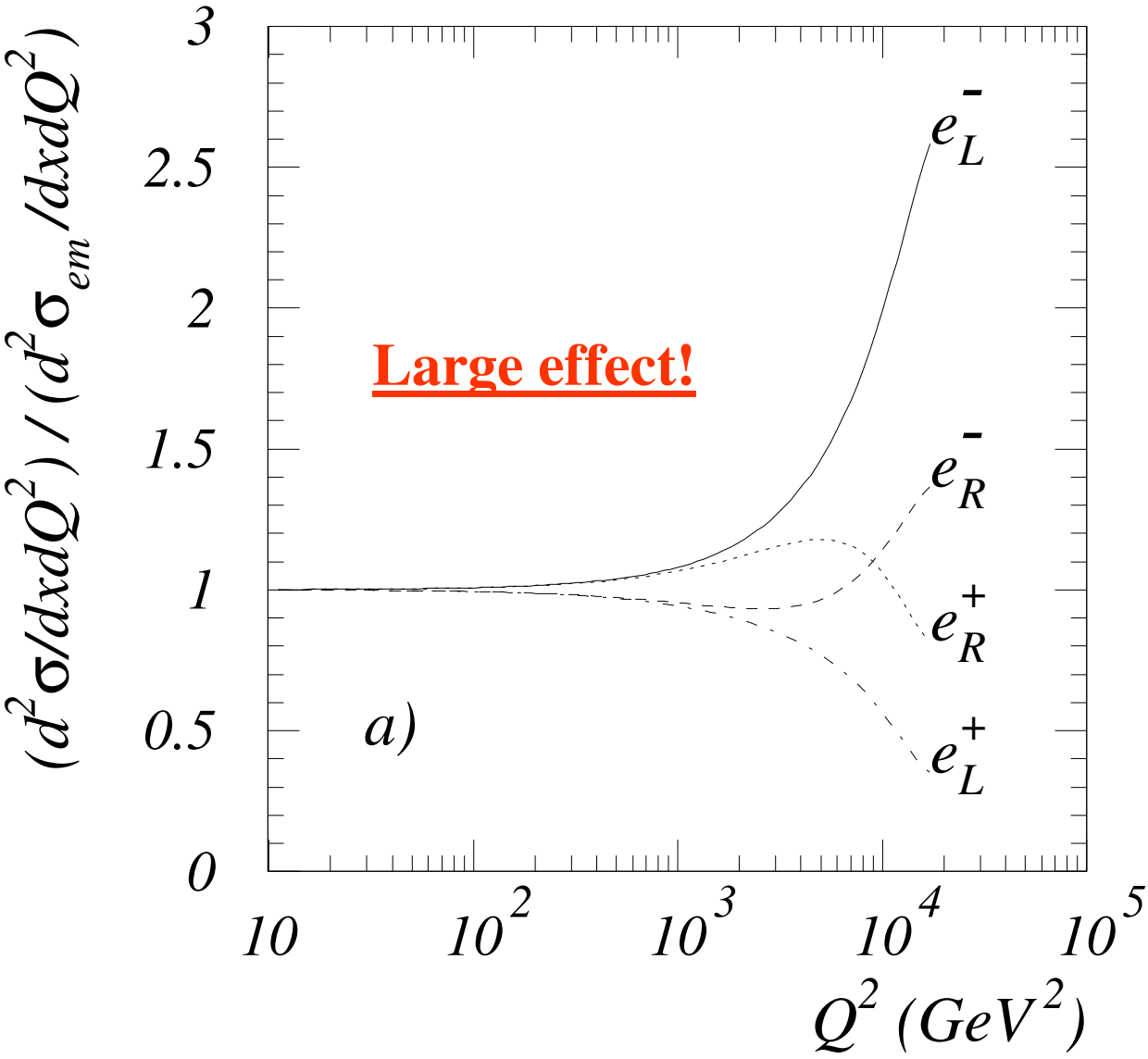
Exclusion limit

$M_W(R) > 400$ GeV

First measurement:

Possible with *ONE* years data

- Neutral Current:



Polarisation dependence of cross section large compared to statistical and PDF error:

Take bin centred at Q^2 = 10,000 GeV^2

x = 0.2

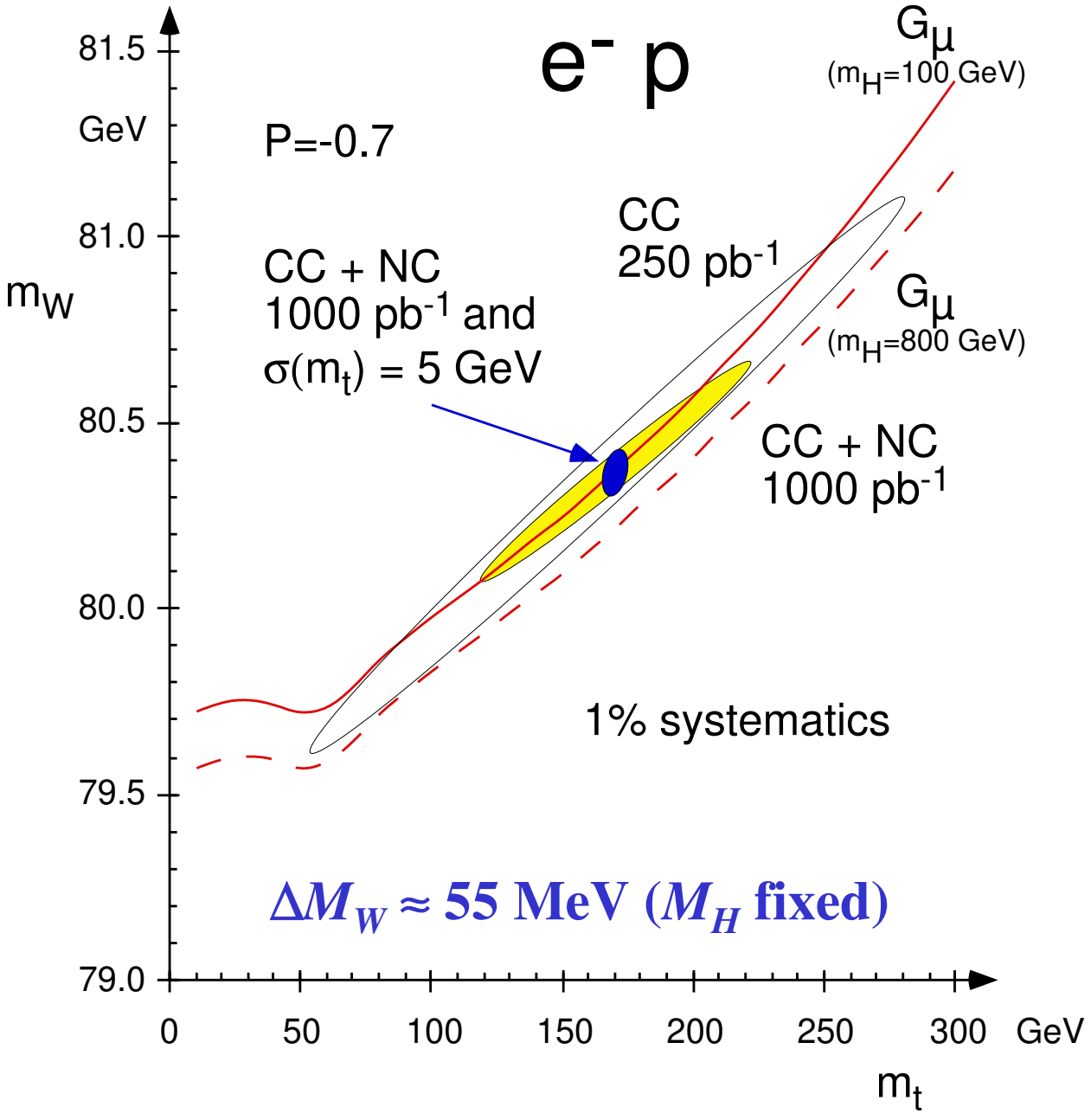
$$\frac{\Delta\sigma\left(e_L^-\right)}{\Delta\sigma\left(e_R^-\right)} \approx [170 \pm 6(\text{Stat.}) \pm 10(\text{PDF})]\%$$

- Electroweak Physics:

Standard Model:

Fully specified by α, M_Z, M_W, m_t and M_H

$\Rightarrow$ G_μ *constraint* - can be used to test SM

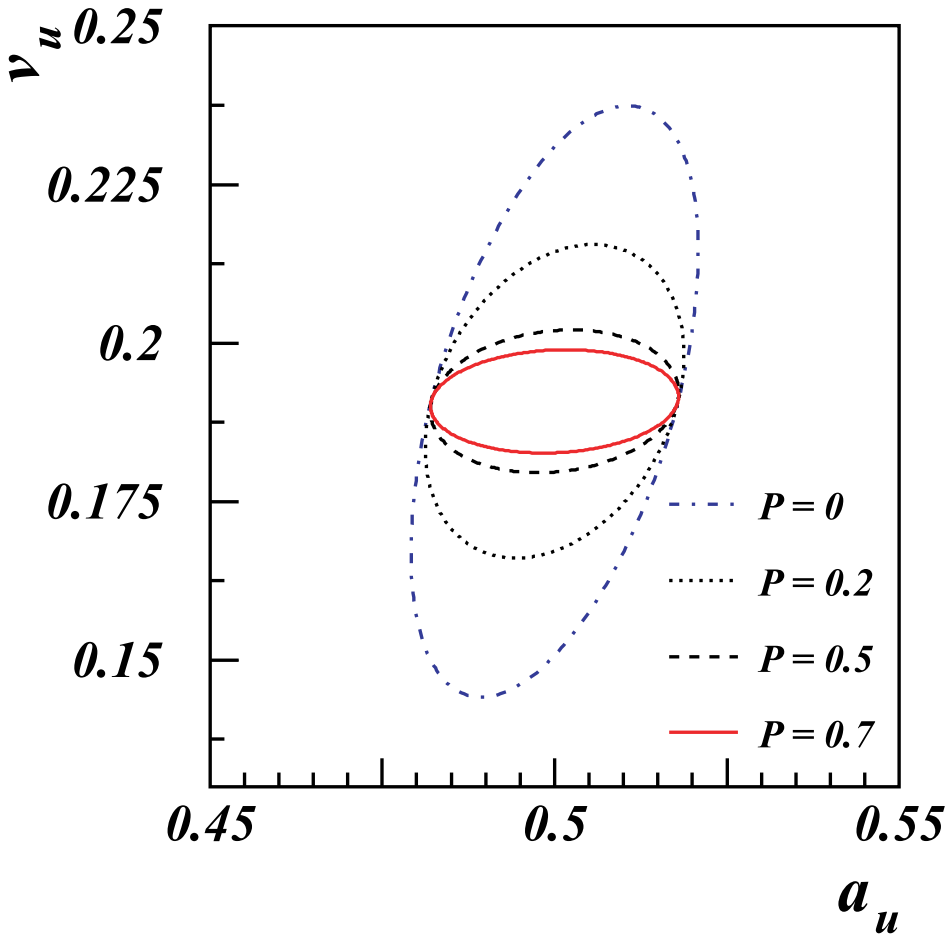


70% polarisation; 250 pb^{-1}: $\Delta M_W \approx 80$ MeV

- Determination of light quark couplings to *Z*:

Parity violation in SM $\Rightarrow g_L^{NC} \neq g_R^{NC}$

Hence, exploit polarisation dependence of NC DIS cross section to measure *u*- and *d*-quark vector and axial-vector couplings



Polarisation yields much improved sensitivity

$e^{\pm}_{L,R}$, $P = \pm 70\%$

250 pb^{-1} per beam

	v	*a*
u	13%	6%
d	17%	17%

- Searches for *NEW* Physics:

One Example:

- **On-shell scalar Leptoquark Production using polarised lepton beams**

  ➢ **In electron proton scattering the Standard Model Neutral Current cross section decreases as the polarisation increases**

  ➢ **The scalar leptoquark production cross section, however, is independent of electron polarisation**

→ **Enhance signal to background by 'turning off' SM using polarisation of $e^{\pm}$**

Summary

HERA Upgrade: High Luminosity

Polarisation

- **Measure F_2, xF_3, F_2^{ss}, F_2^{cc}, and F_2^{bb}: $10 < Q^2 < 40{,}000$ GeV^2**
- **Determine α_S, xg**
- **Measure the polarisation dependence of DIS at high Q^2**
  - **Precision test of Standard Model**
  - **u-, d-quark NC couplings**
- **Search for *NEW* Physics ...**