Future Prospects in Particle Physics

Birmingham, 30 June 99

Institute *of* **Physics**

Future *eP* Physics

The Outlook for HERA

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... opportunities for You !

Introduction

- The Electron-Proton Collider - HERA:

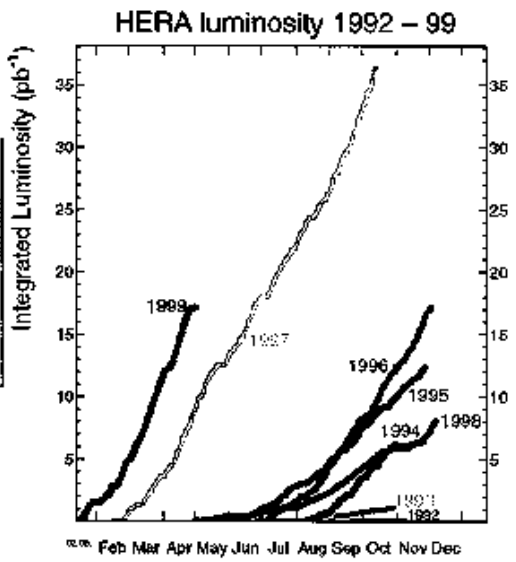
HERA

'93-'97 **Positron** **Proton**
27.5 GeV **820 GeV**

NOW **Electron** **Proton**
27.5 GeV **920 GeV**

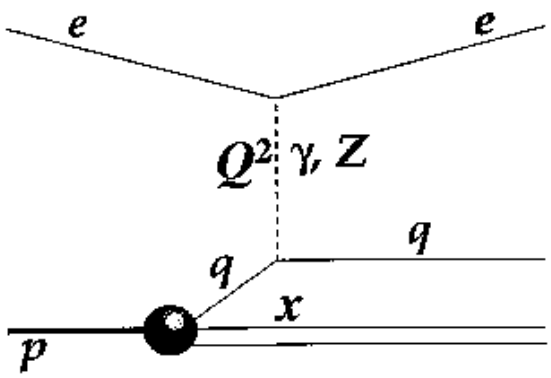
The* Proton Structure *machine

	Luminosity (pb^{-1})	
	H1	ZEUS
e^+p	37	48
e^-p	18	16

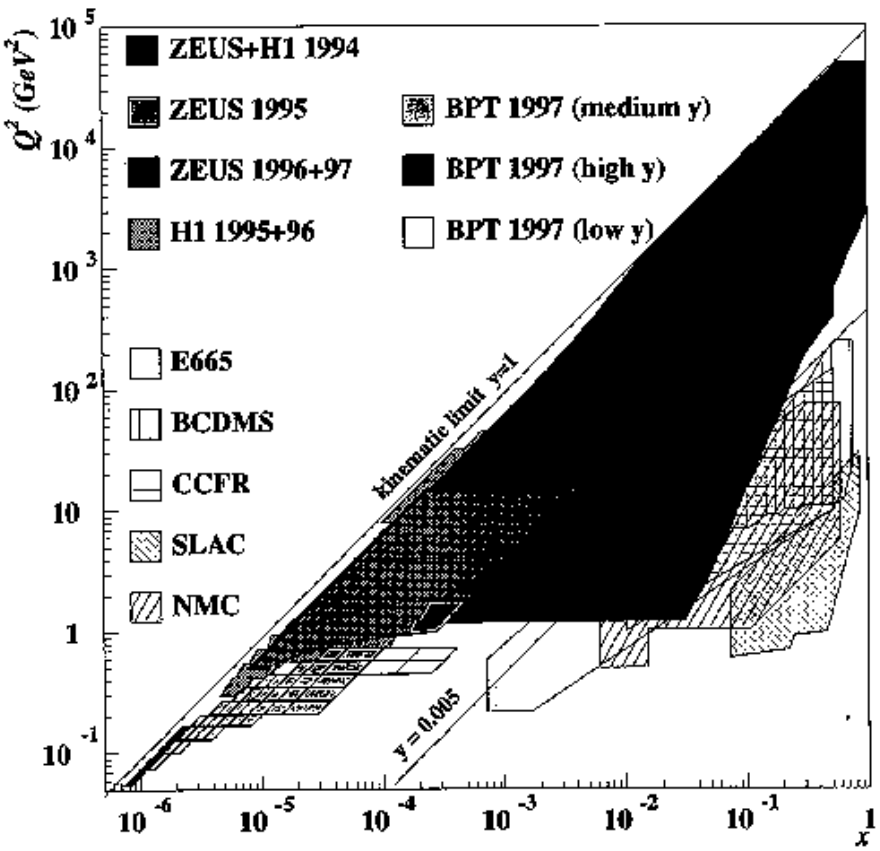


Physics at HERA:

Overview!



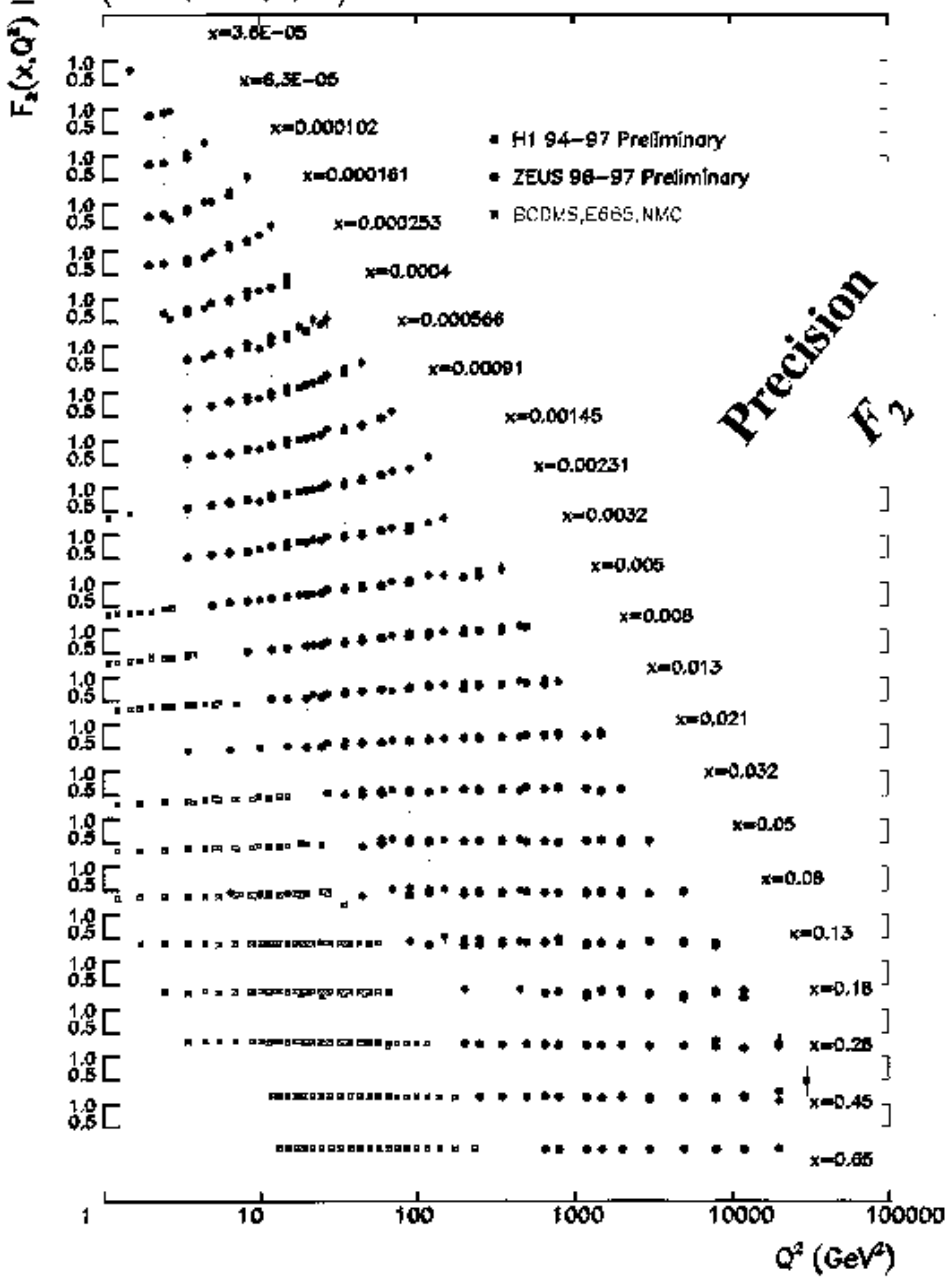
ZEUS 1997 Preliminary



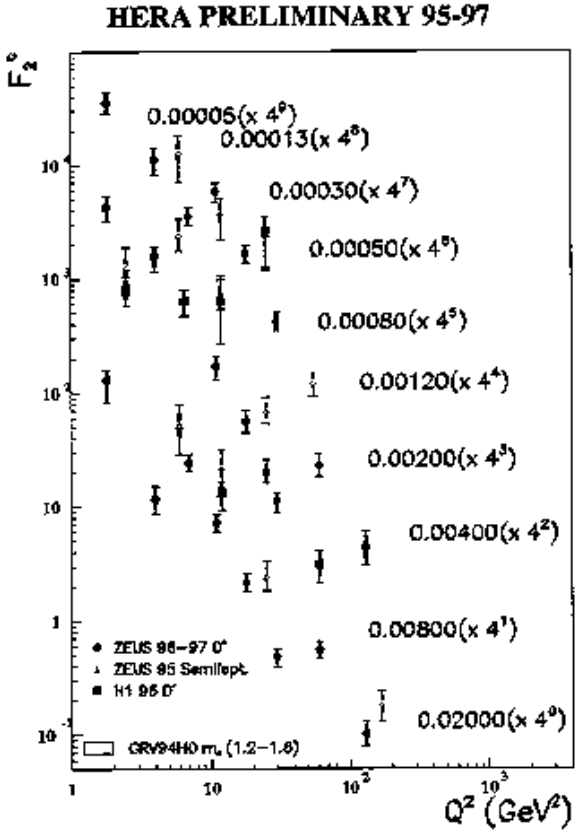
Physics at HERA: *Overview!*

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

$$Y_\pm = \left(1 \pm (1-y)^2\right)$$



Physics at HERA: *Overview!*



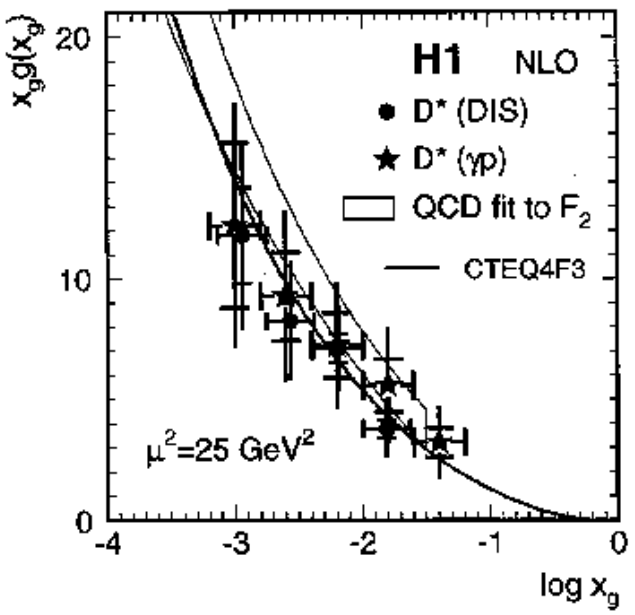
$$\frac{d^2\sigma_{c\bar{c}}^{e^+P}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4 x} Y_+ F_2^{c\bar{c}}$$

Charm contribution is large: 10-30%

Strong scale non-invariance

Data well described by NLO QCD

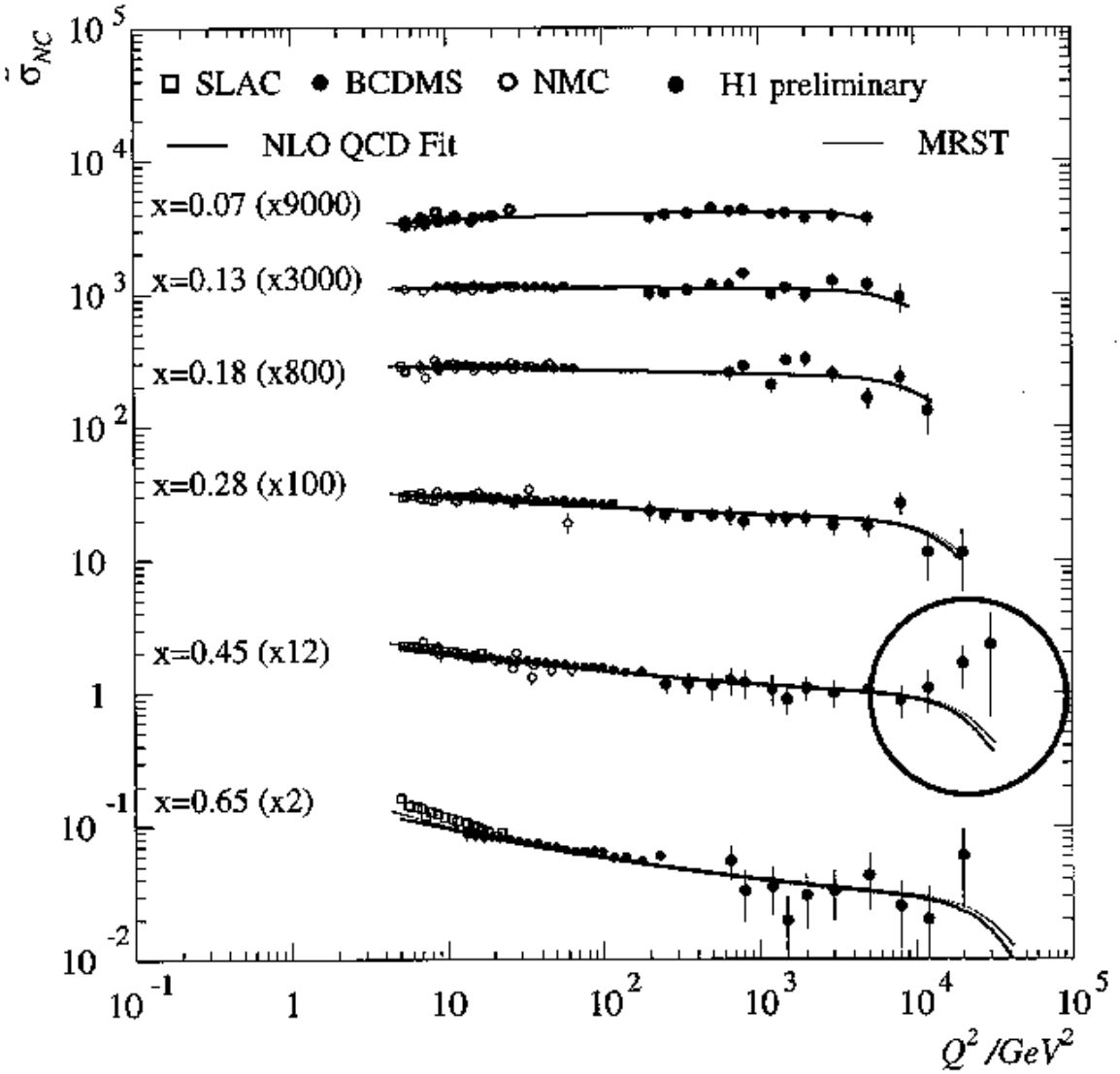
Gluon extracted from measured D^* cross sections using NLO QCD



'Universal' gluon distribution?

***HERA* and *H1/ZEUS* Upgrades required!**

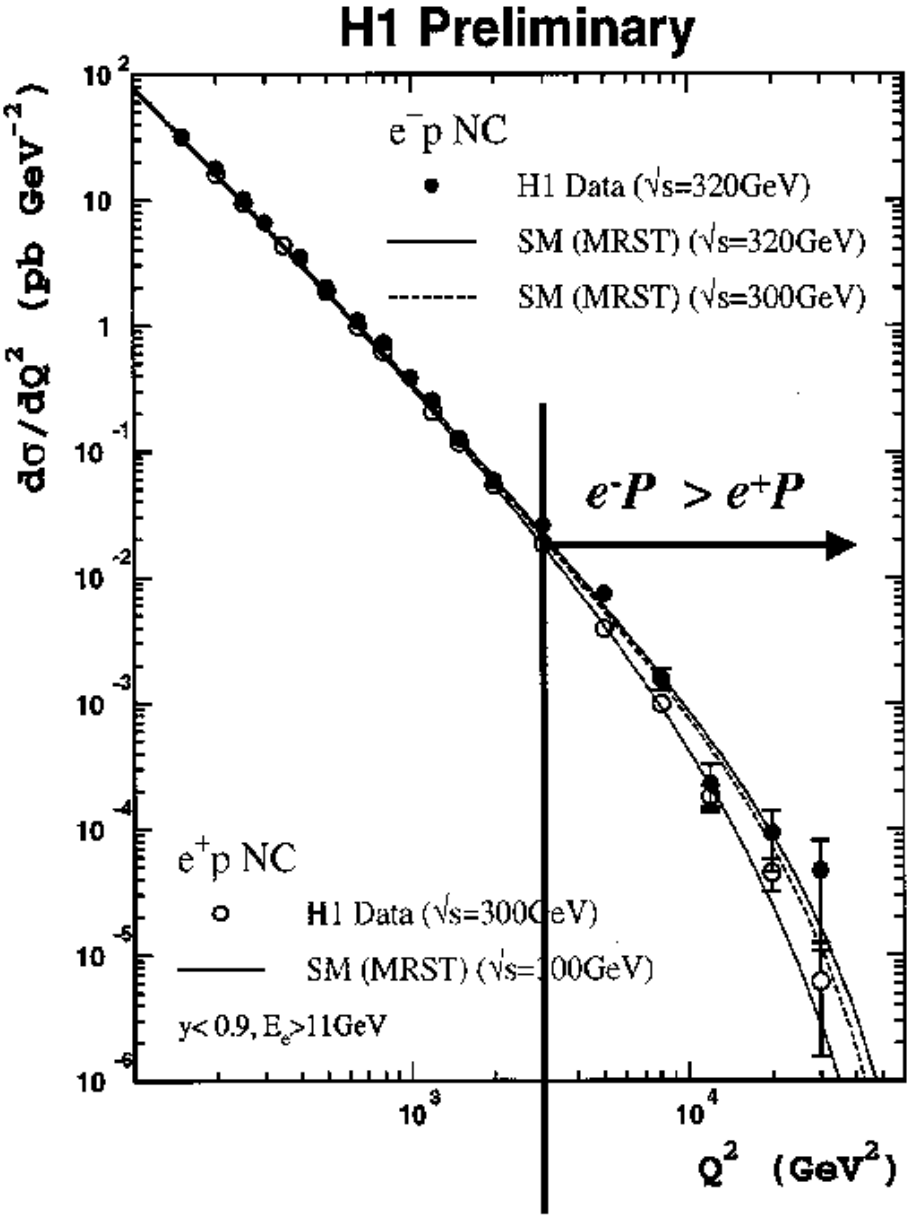
Focus on highest possible Q^2 to search for *NEW* physics



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

- Towards xF_3:

$$\frac{d^2\sigma_{\mathrm{NC}}^{e^{\pm}P}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left[Y_+ F_2^{\mathrm{NC}} \mp Y_- xF_3^{\mathrm{NC}} - y^2 F_{\mathrm{L}}^{\mathrm{NC}}\right]$$

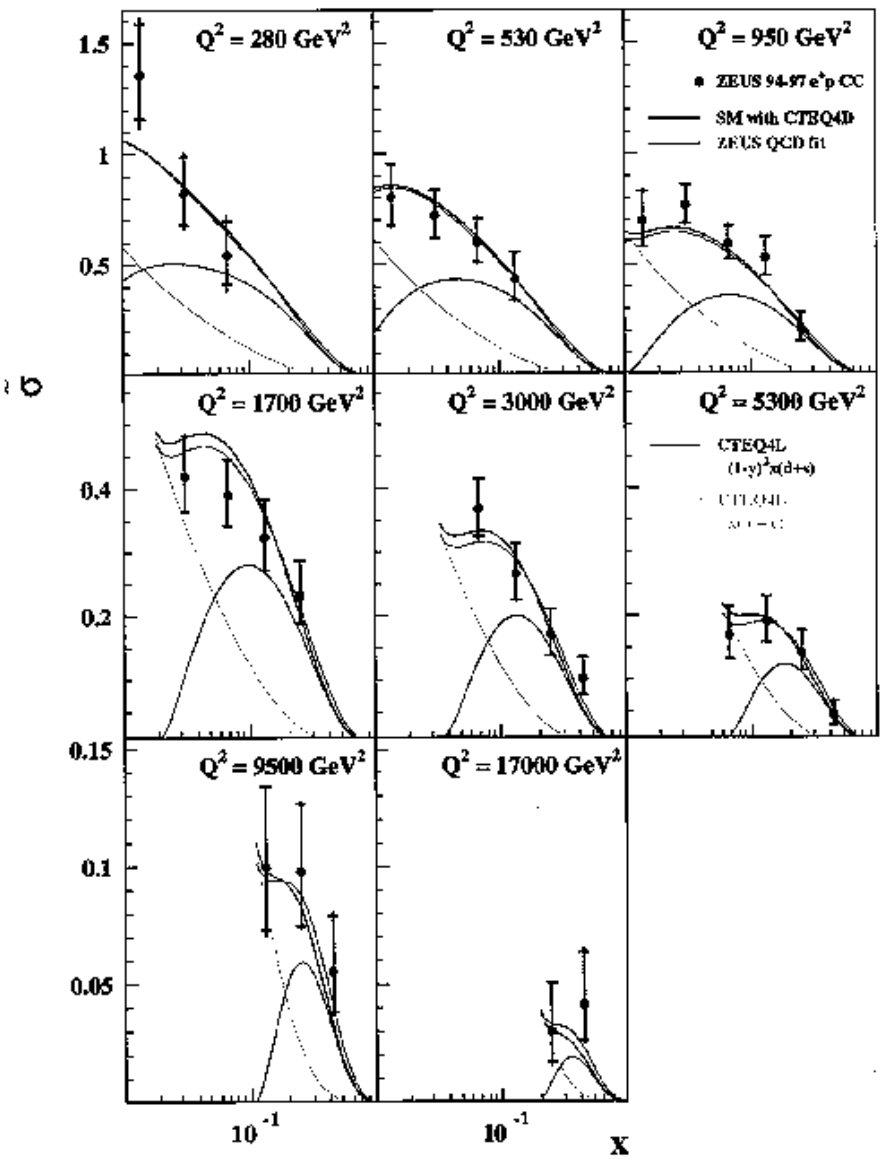


Physics at HERA: *Overview!*

- Charged Current:

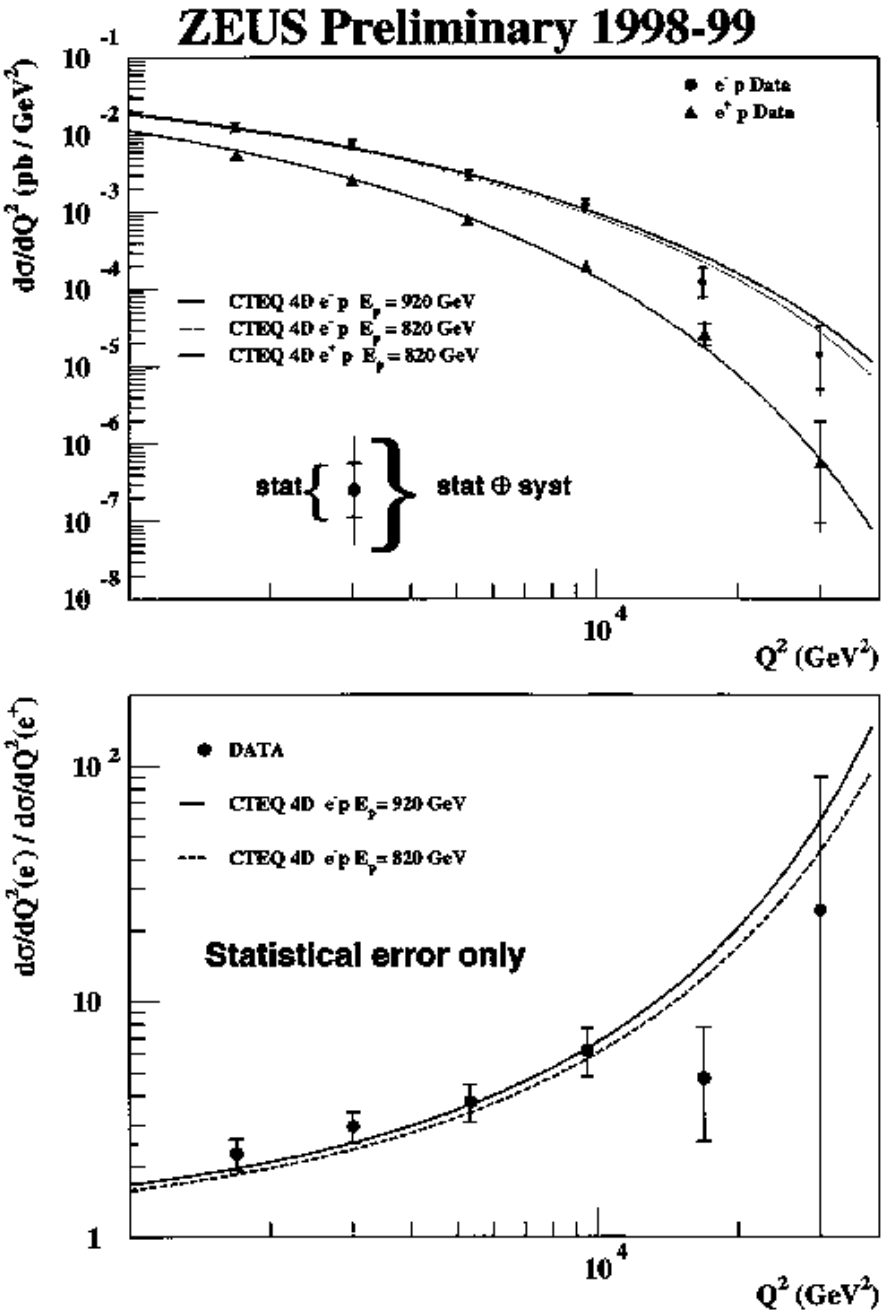
$$\tilde{\sigma}^{e^+P}_{CC} = \frac{\left(Q^2 + M_W^2\right)^2}{G_\mu^2 M_W^4} \frac{d^2\sigma^{e^+P}_{CC}}{dxdQ^2} = x\left(\bar{u} + \bar{c} + (1-y)^2(d+s)\right)$$

ZEUS CC 1994-97



- Towards *d/u* ratio:

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



The HERA Upgrade

Luminosity Upgrade:

- **Factor 5 larger than present luminosity**

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

Polarisation for Collider Experiments:

- **Polarised electron/positron beams**

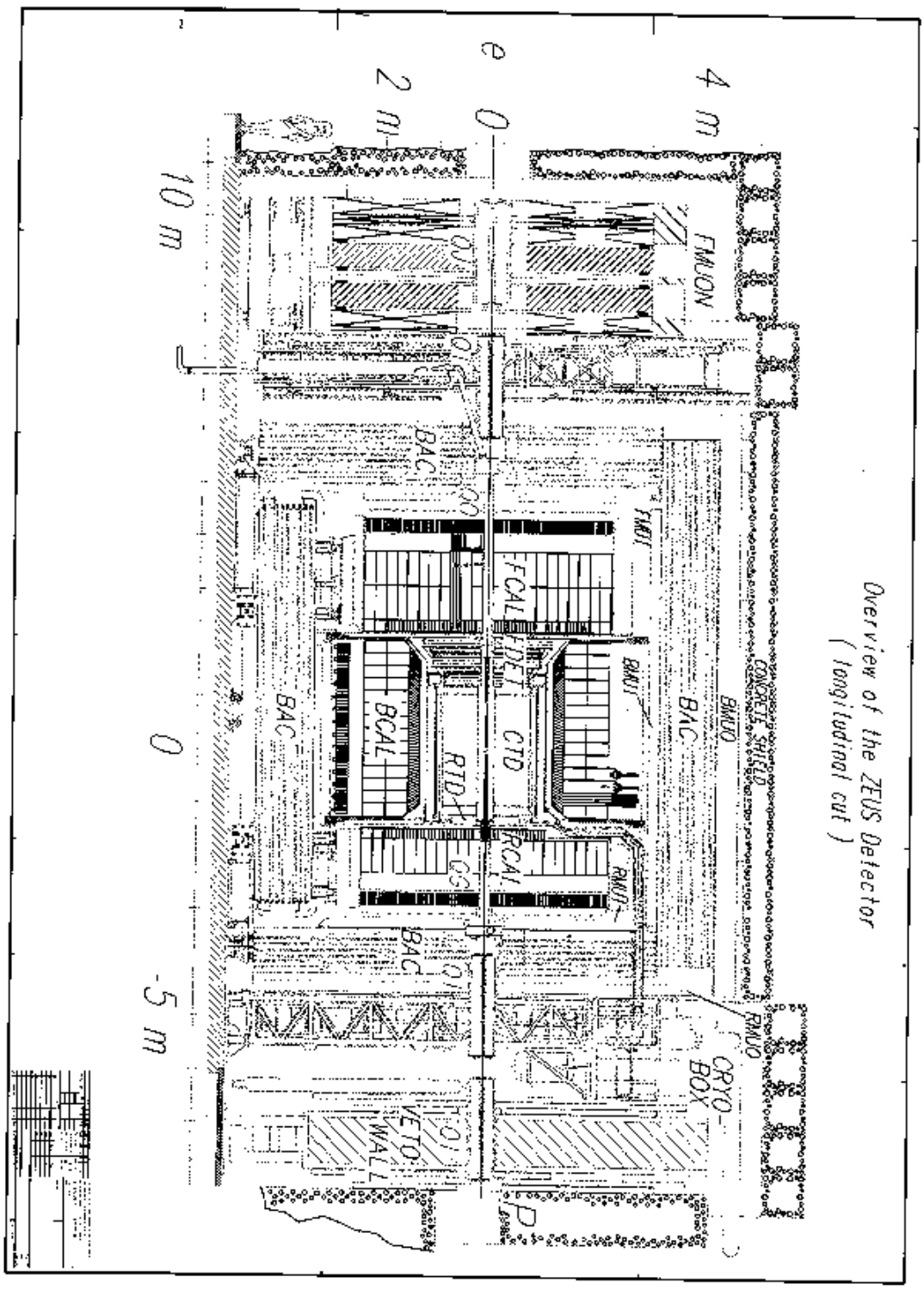
  $\Rightarrow$ 70%

Running Programme:

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

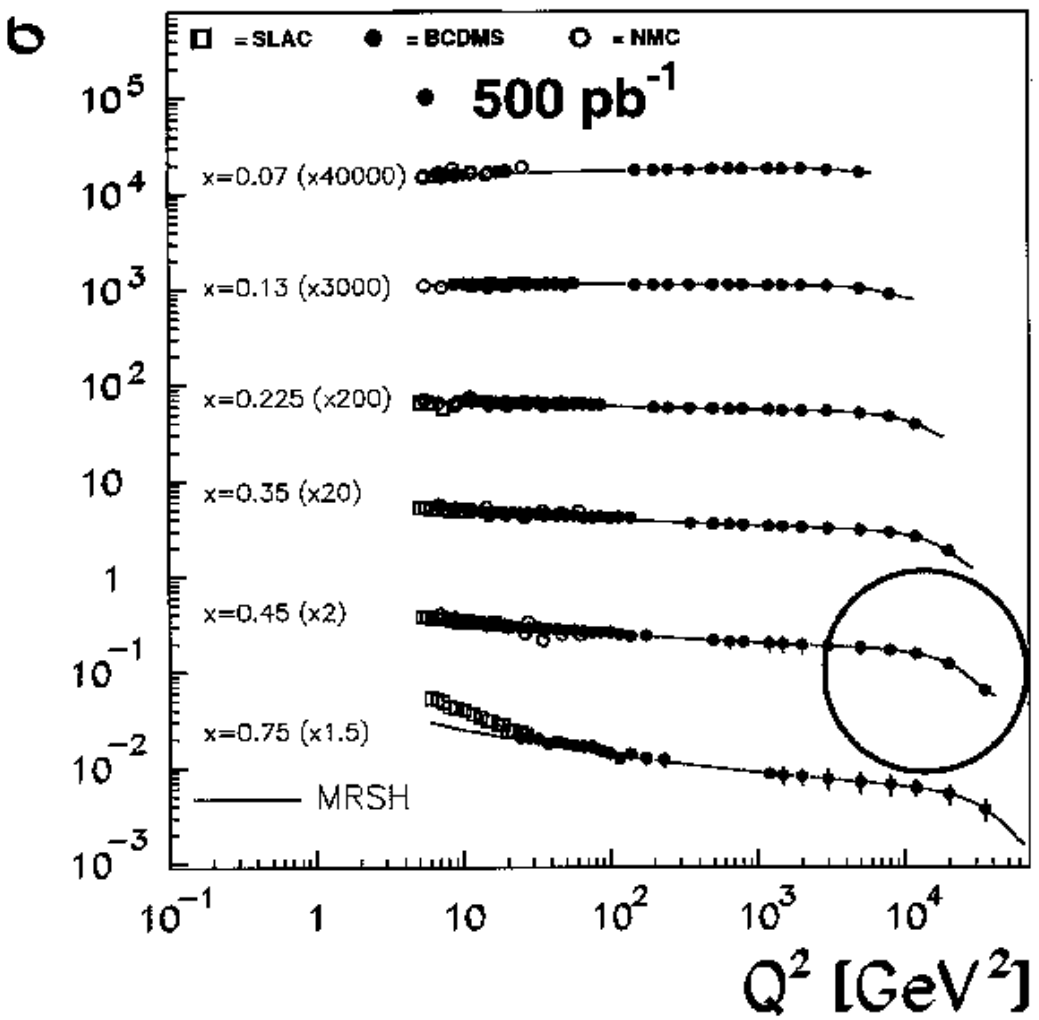
  $\Rightarrow$ ~ 1000 pb^{-1} for H1 and ZEUS

The HERA Upgrade

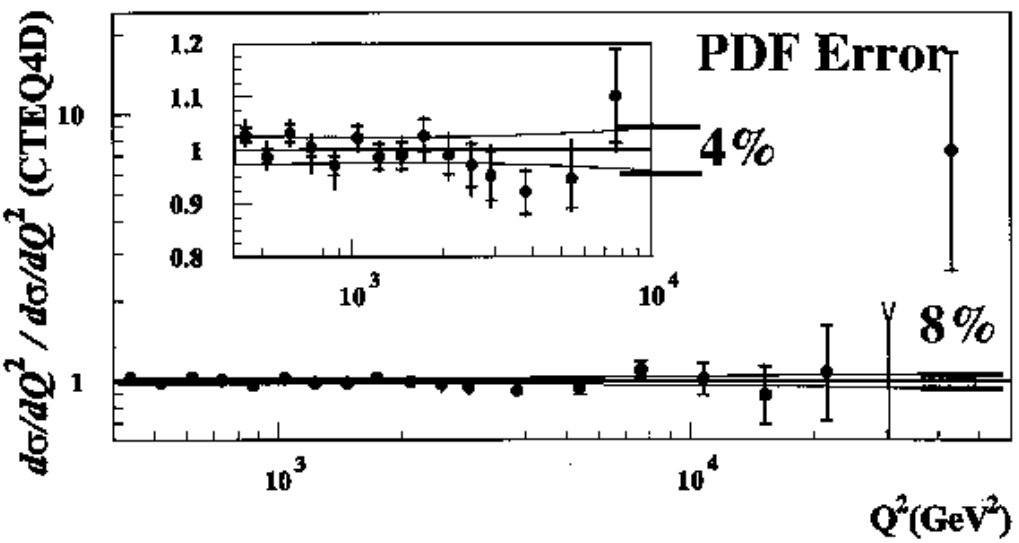


Future Physics at HERA

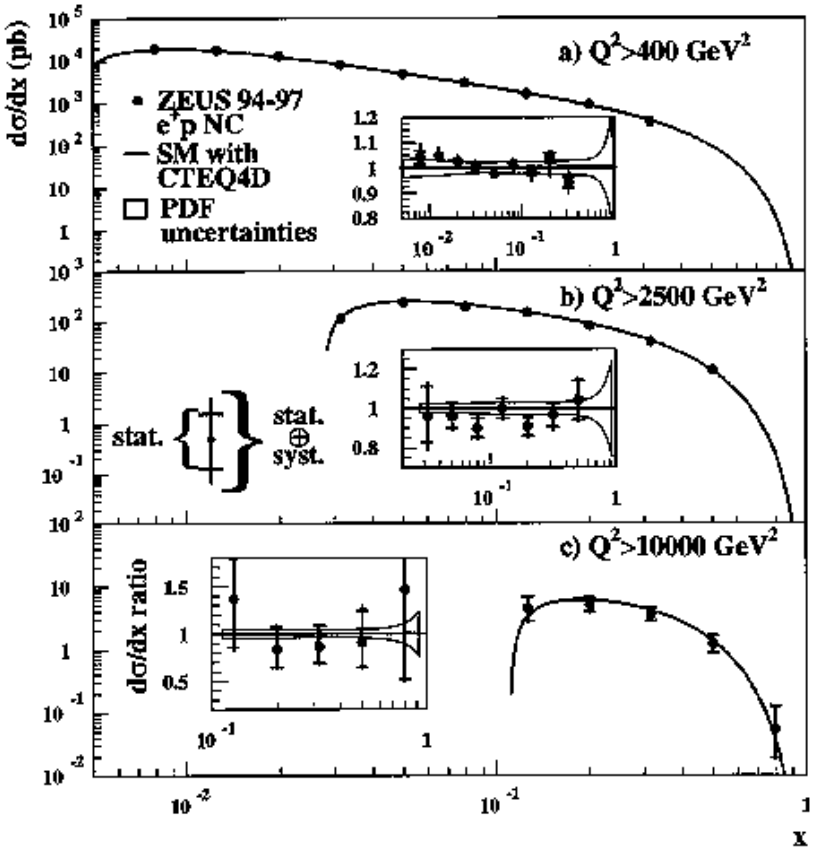
1000 pb^{-1}	$\sigma(e^-P)$ pb $Q^2 > 10{,}000$ GeV^2		$\sigma(e^+P)$ pb $Q^2 > 10{,}000$ GeV^2	
E_P GeV	NC	CC	NC	CC
820	[illegible]	4.8	2.0	0.5
920	[illegible]	3.7	2.5	[illegible]



- Prediction of cross sections at high Q^2:



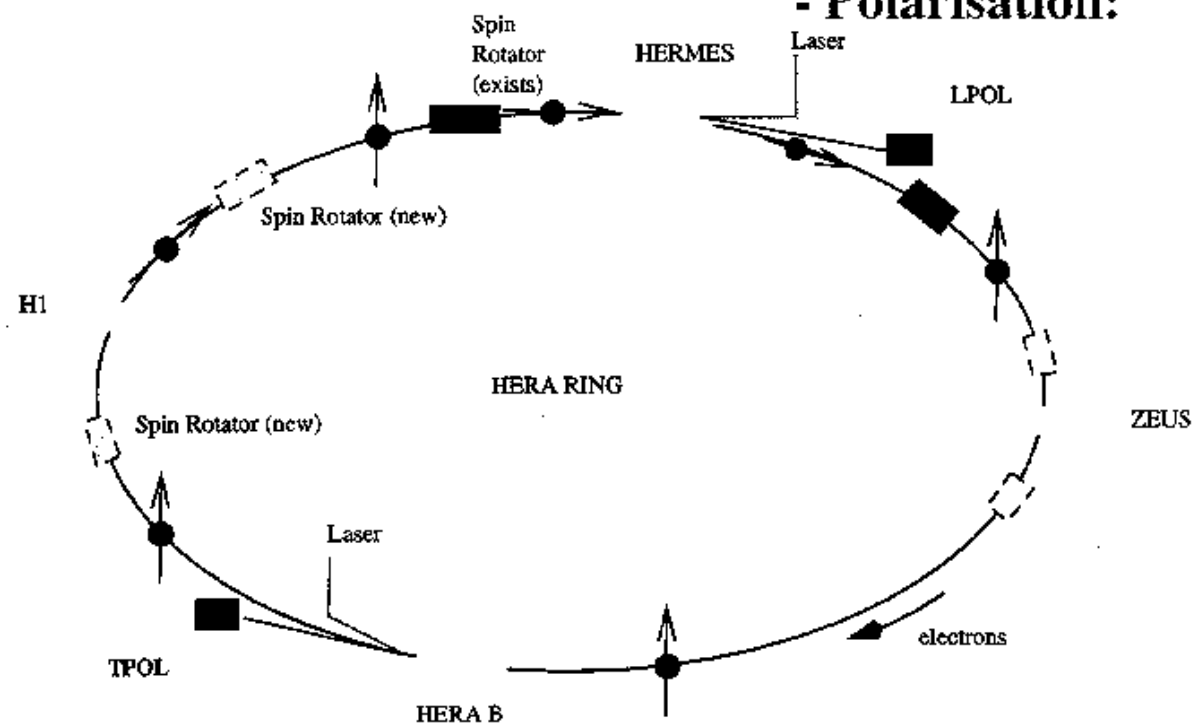
ZEUS NC 1994 – 97

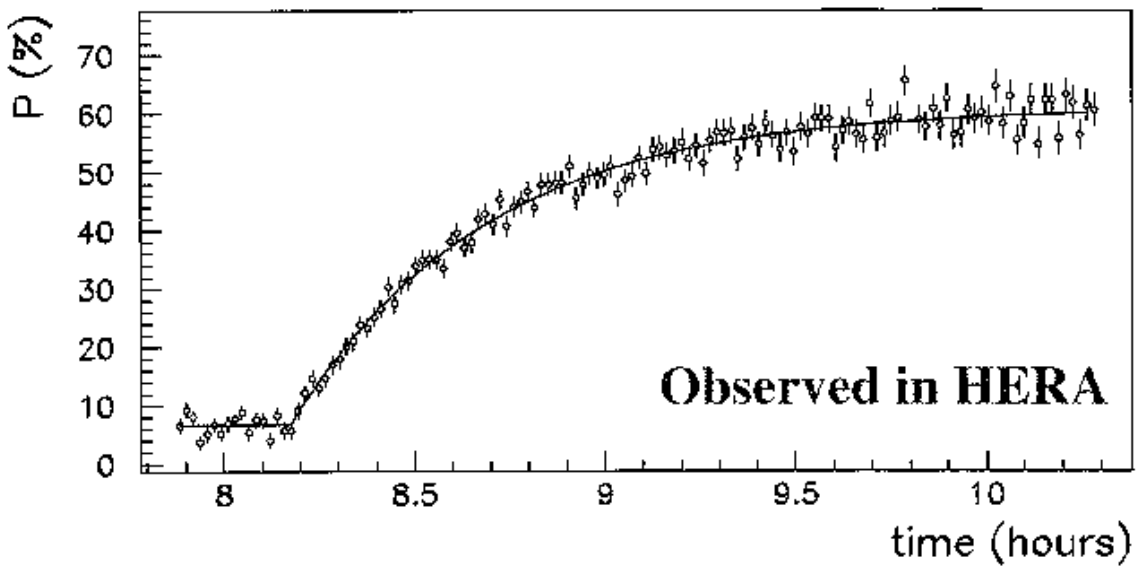


Cross section prediction to better than ~ 10% over most of kinematic range

The HERA Upgrade

- Polarisation:

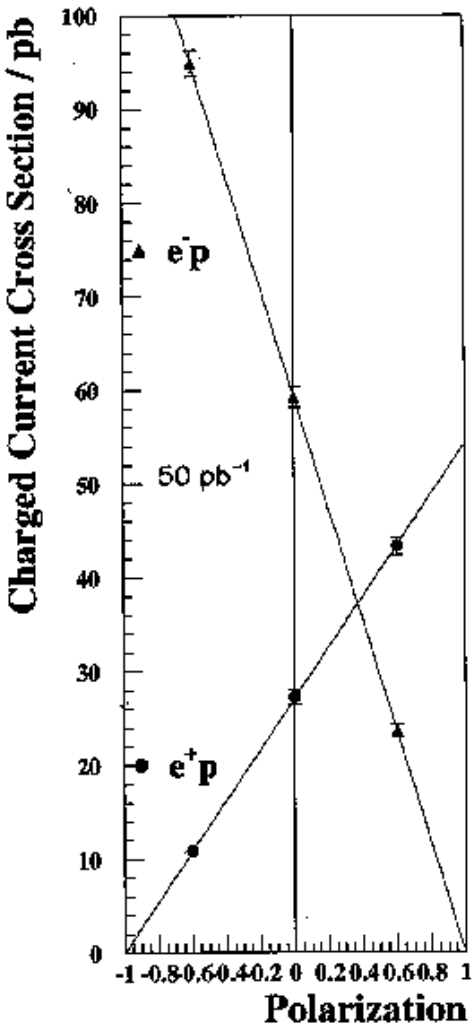




- **Design goal 70% looks achievable**

- **Charged Current:**

$e\,p \rightarrow \nu\,X$



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

P = polarisation

Resolution on M_W

80 MeV

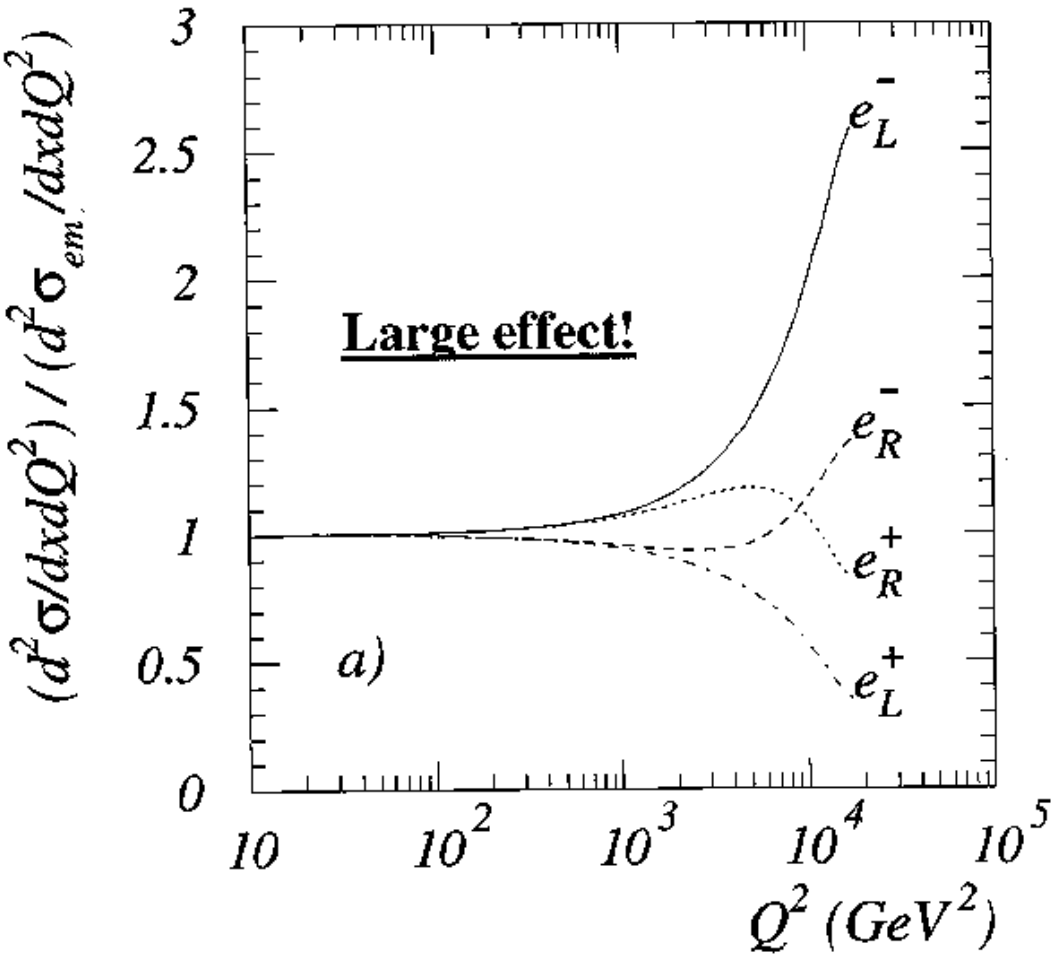
Exclusion limit

$M_W(R) > 400$ 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

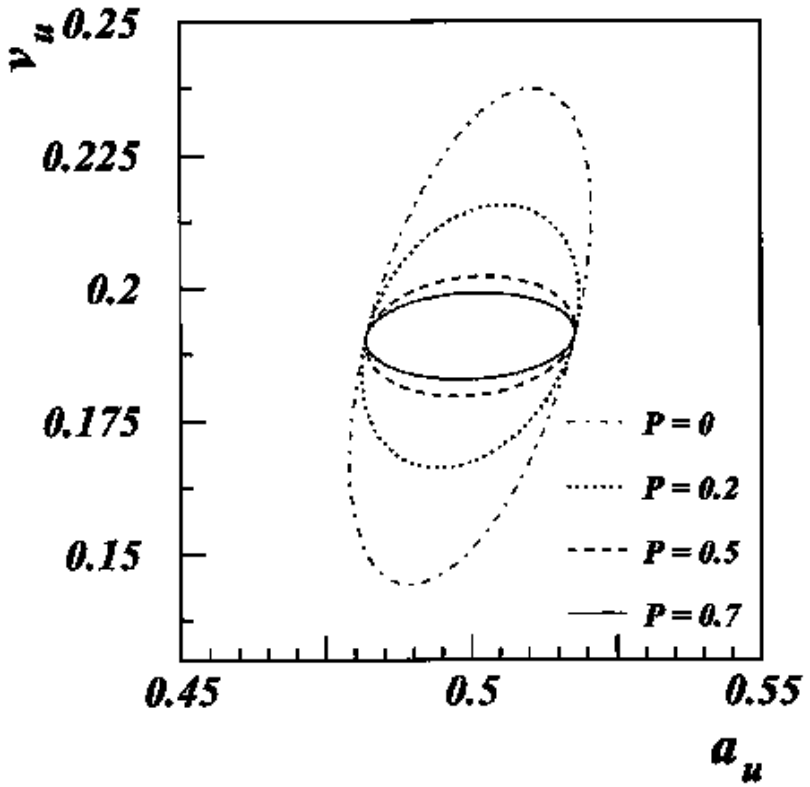
$x = 0.2$

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

- Determination of light quark couplings to Z:

Parity violation in SM $\Rightarrow g_{\mathrm{L}}^{\mathrm{NC}} \neq g_{\mathrm{R}}^{\mathrm{NC}}$

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

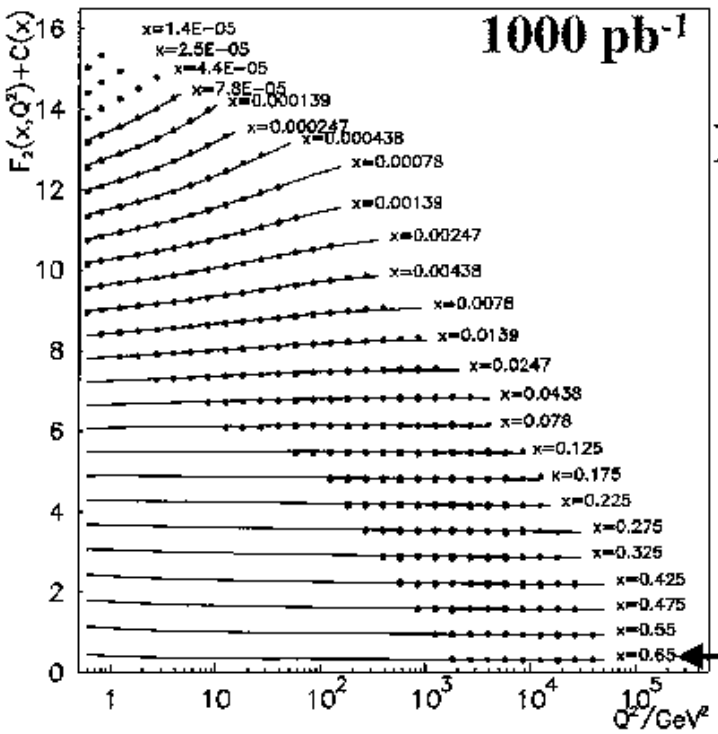
$e^{\pm}_{\mathrm{L,R}}$, $P = \pm 70\%$

$250\,\mathrm{pb}^{-1}$ per beam

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

Future Physics at HERA

- The Structure Function F_2



High Precision F_2

Large x, Q^2 range

$\rightarrow$

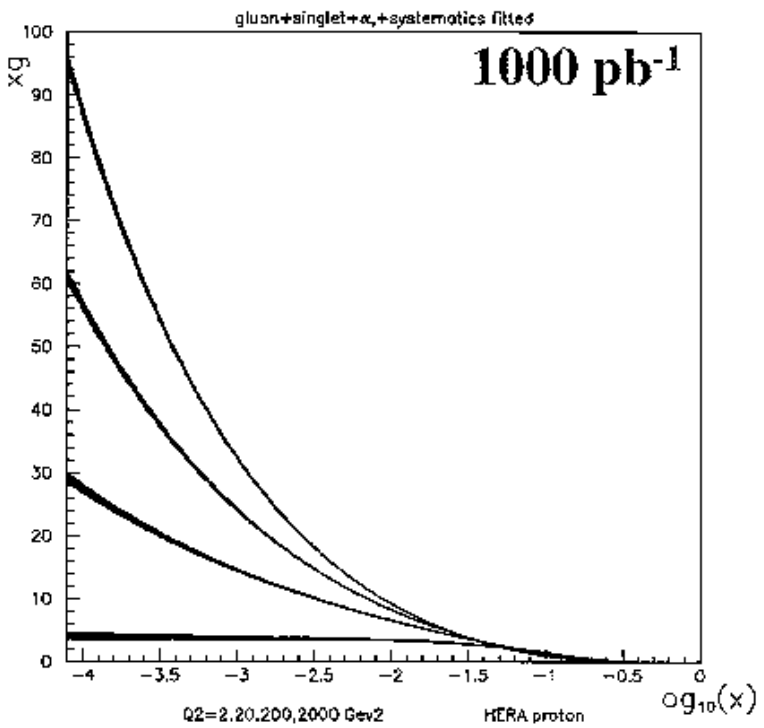
α_S and xg

$x = 0.65$

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

$\Delta\alpha_S \leq 0.003$

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

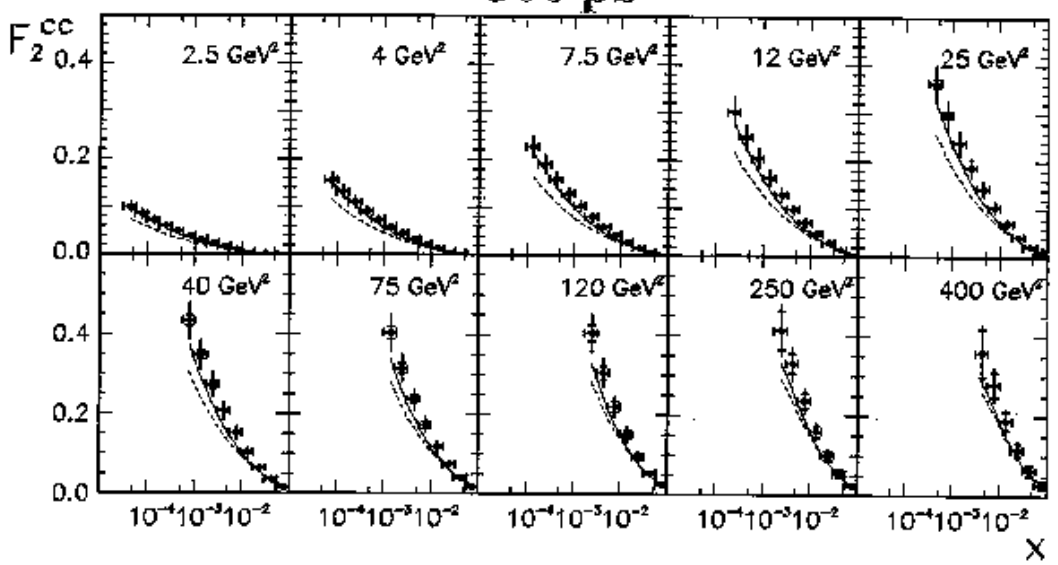


Future Physics at HERA

- Heavy flavours in the proton:

Charm:

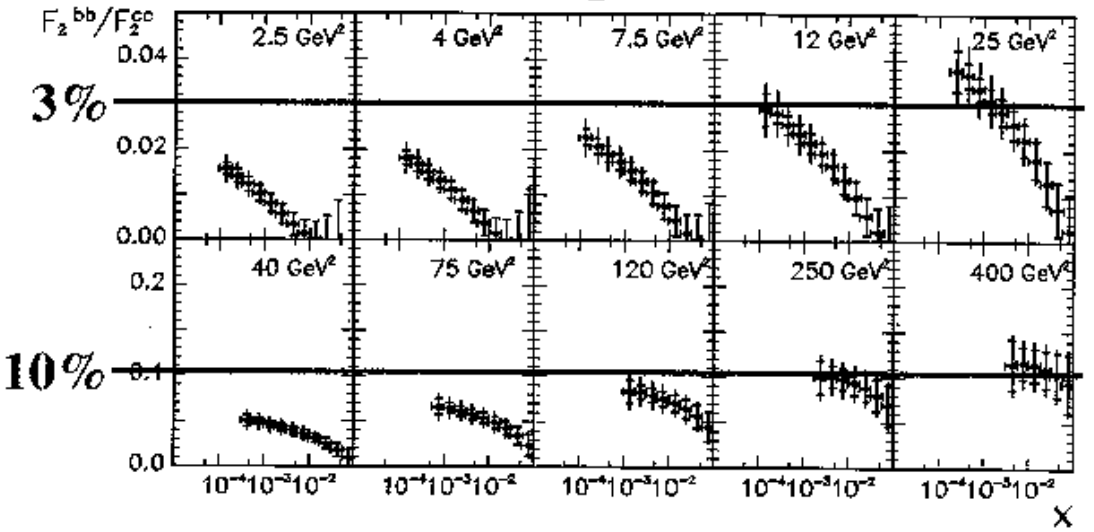
500 pb^{-1}



- High precision F_2^{Charm}

Bottom:

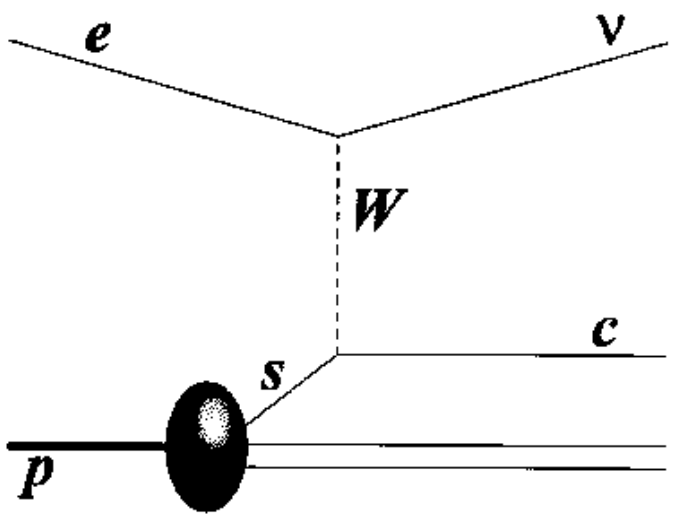
500 pb^{-1}



- Sensitivity to bottom contribution to F_2

Future Physics at HERA

- 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

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**

  → Opportunities for you...

- **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 ...**

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 /Forward Silicon Tracker

Scattered Electron Detection at High Q^2:

... also charm and beauty tagging especially at high x:

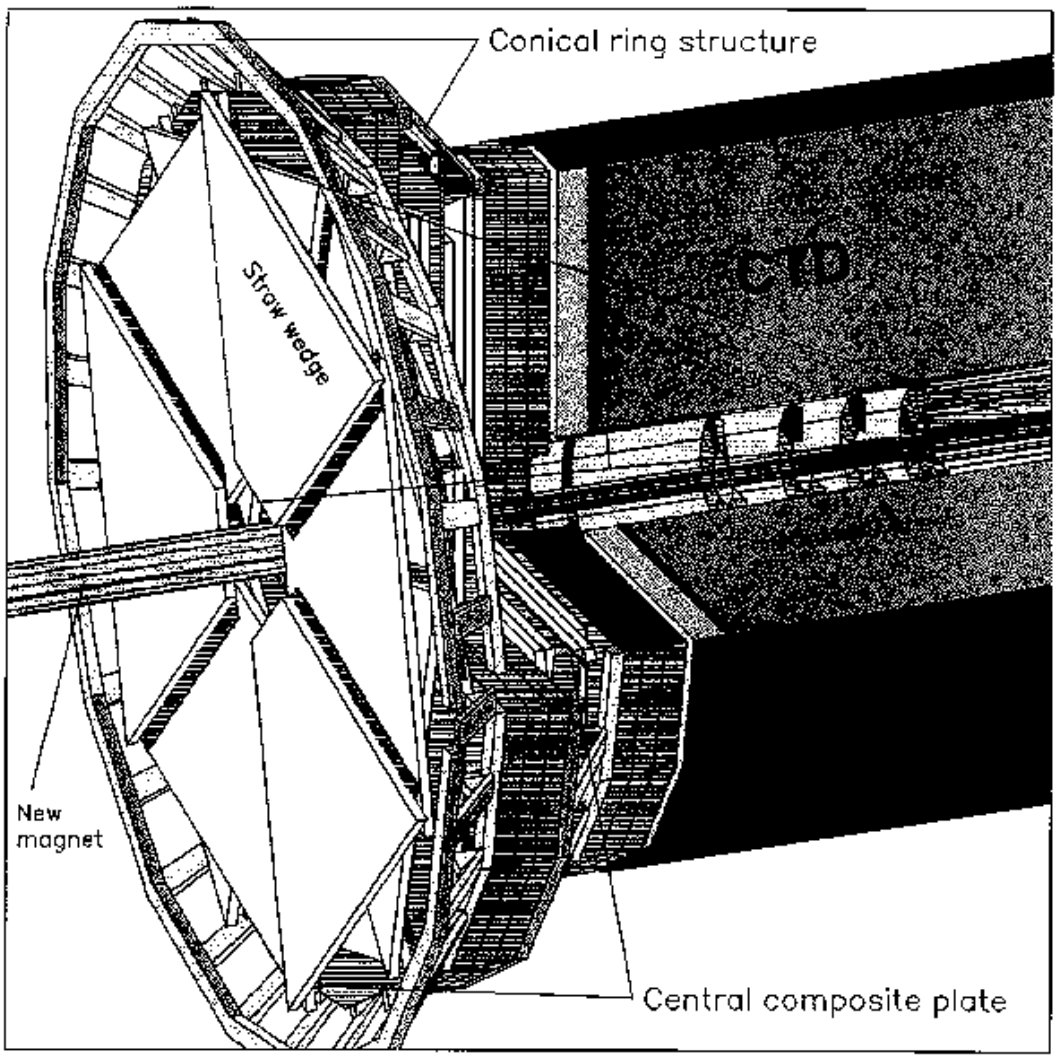
- Upgrade forward tracking detectors

  ZEUS: *NEW* Straw Tube Tracker

  H1: *NEW* Planar Drift Chambers

The Collider Detector Upgrades H1 - similar focus...

- The upgraded tracking system for ZEUS



Forward Tracker Upgrades:

- **Increase number of track space points**
- **Reduce ambiguities**
- **Increase track finding efficiency**

Opportunities we can take up...

- Important NEW measurements to be made starting 2001
- You / your group can enhance experimental program in key hardware / software areas
- UNMINED SEEM OF PHYSICS FOR You to exploit