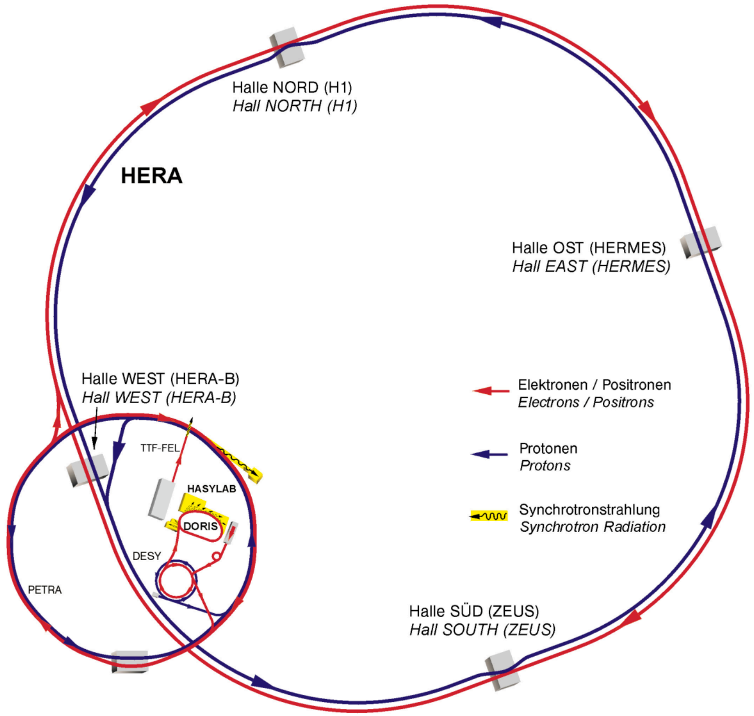
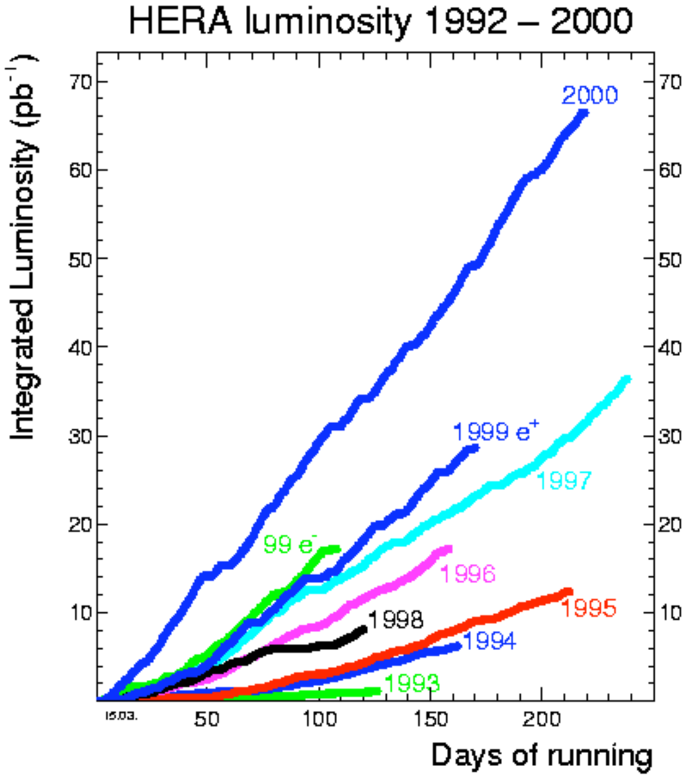
The ZEUS experiment

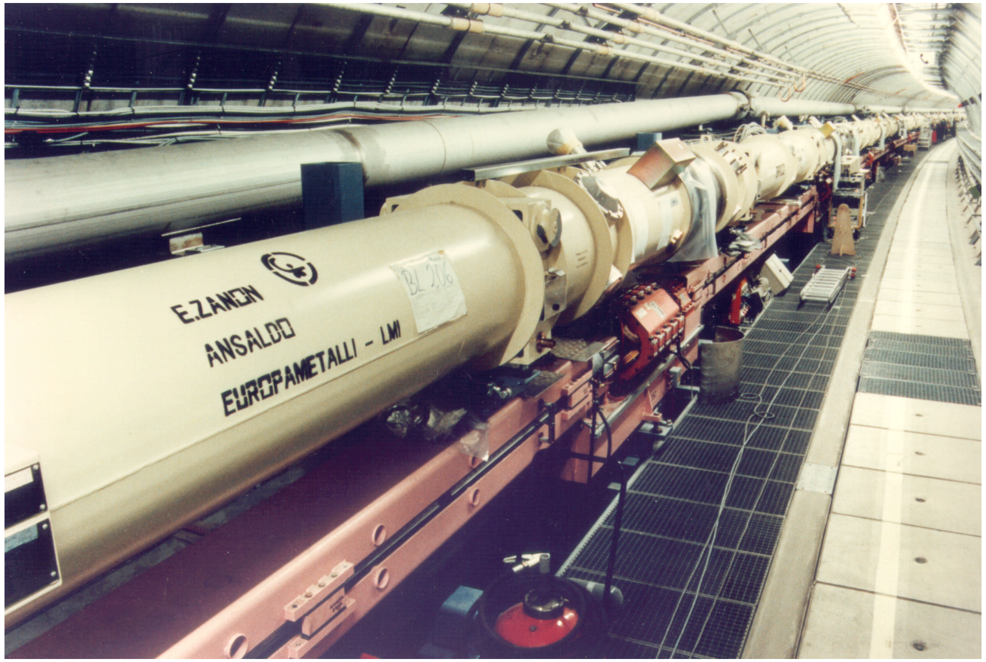
Alex Tapper

- The HERA accelerator
- The ZEUS detector
- Central Tracking Detector
- Transverse Polarimeter
- Physics at HERA I
- Plans for HERA II

The HERA accelerator

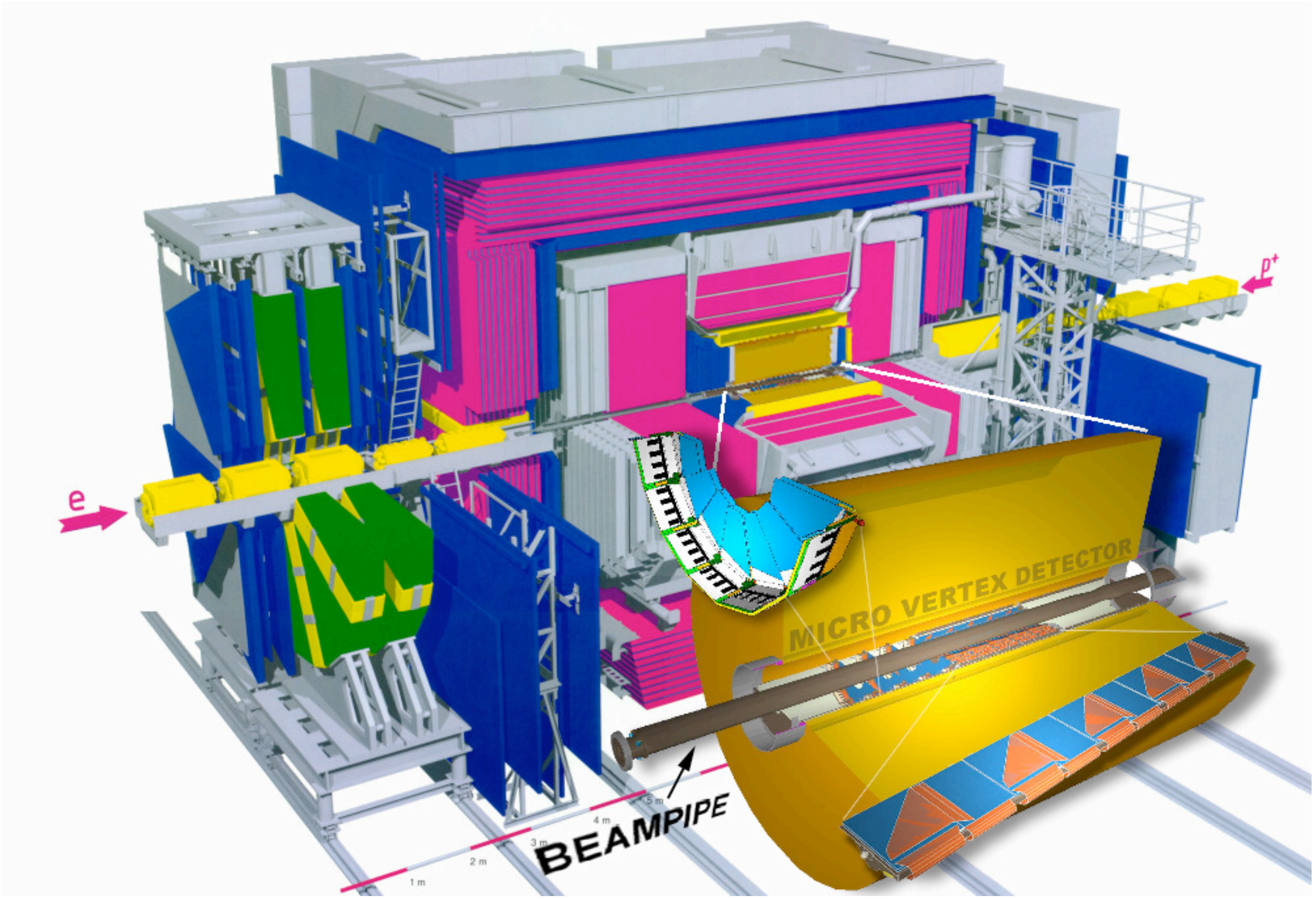


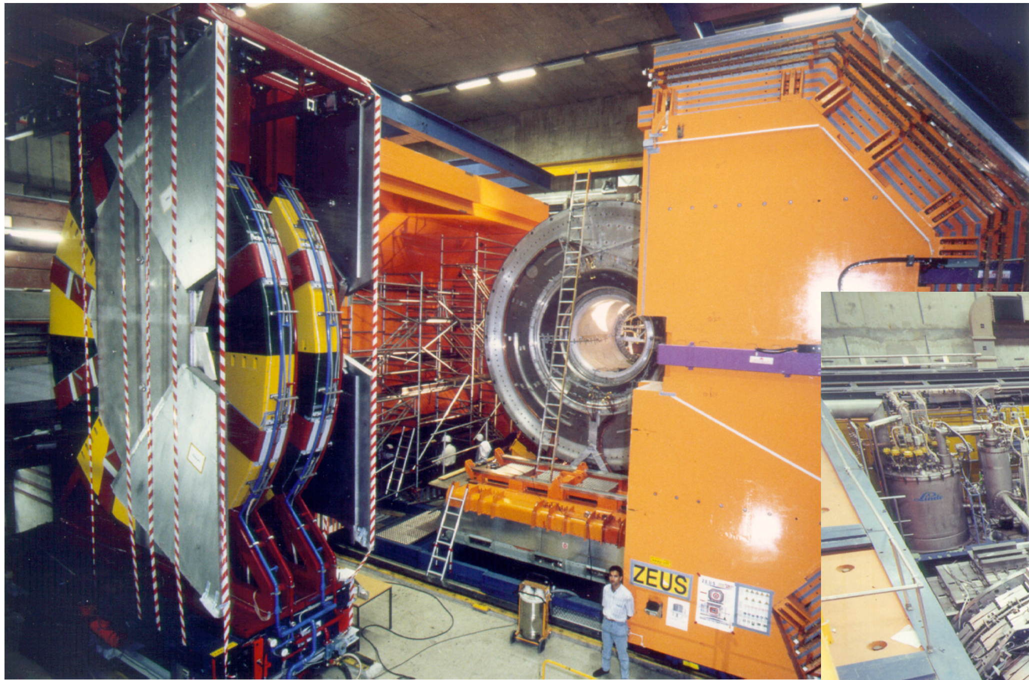


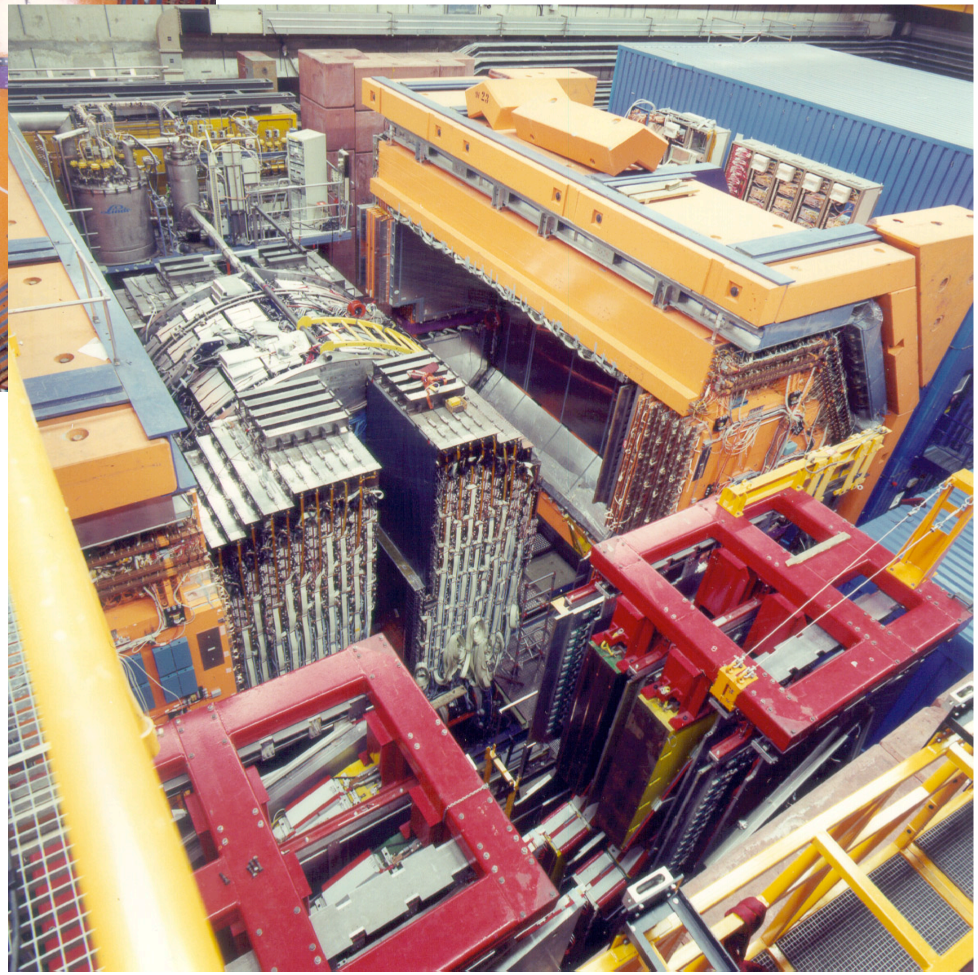


- Collides electrons/positrons with protons
- E_e=27.5 GeV
- E_p=920 GeV
- Centre-of-mass energy ~320 GeV

The ZEUS detector

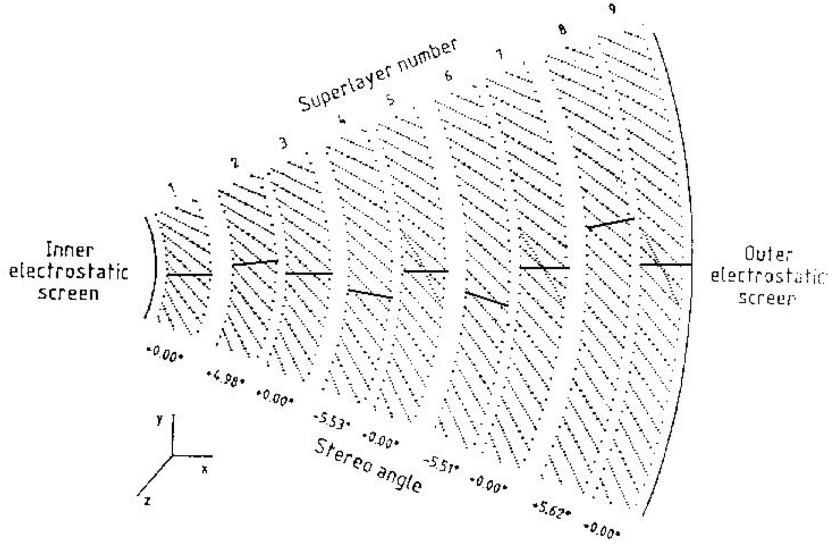


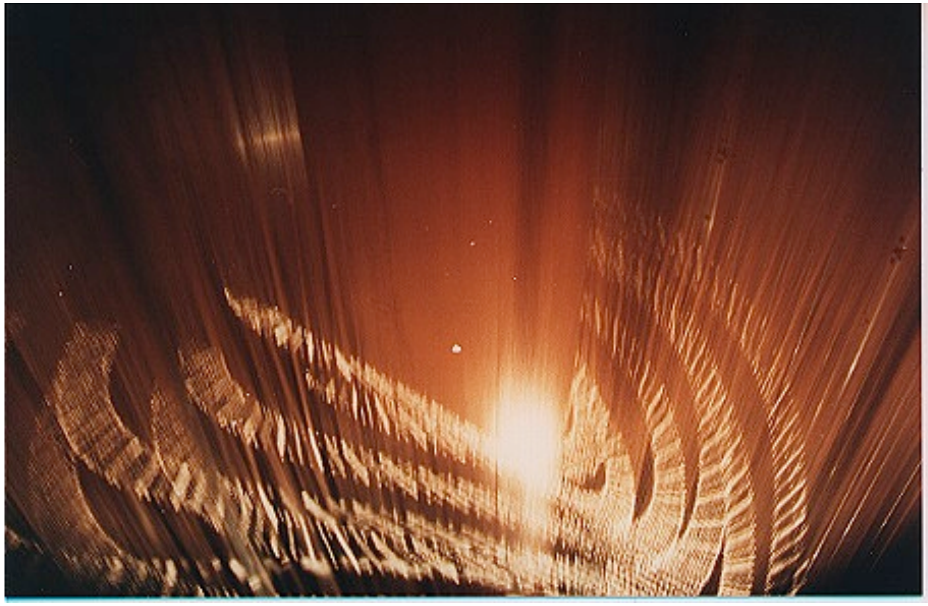
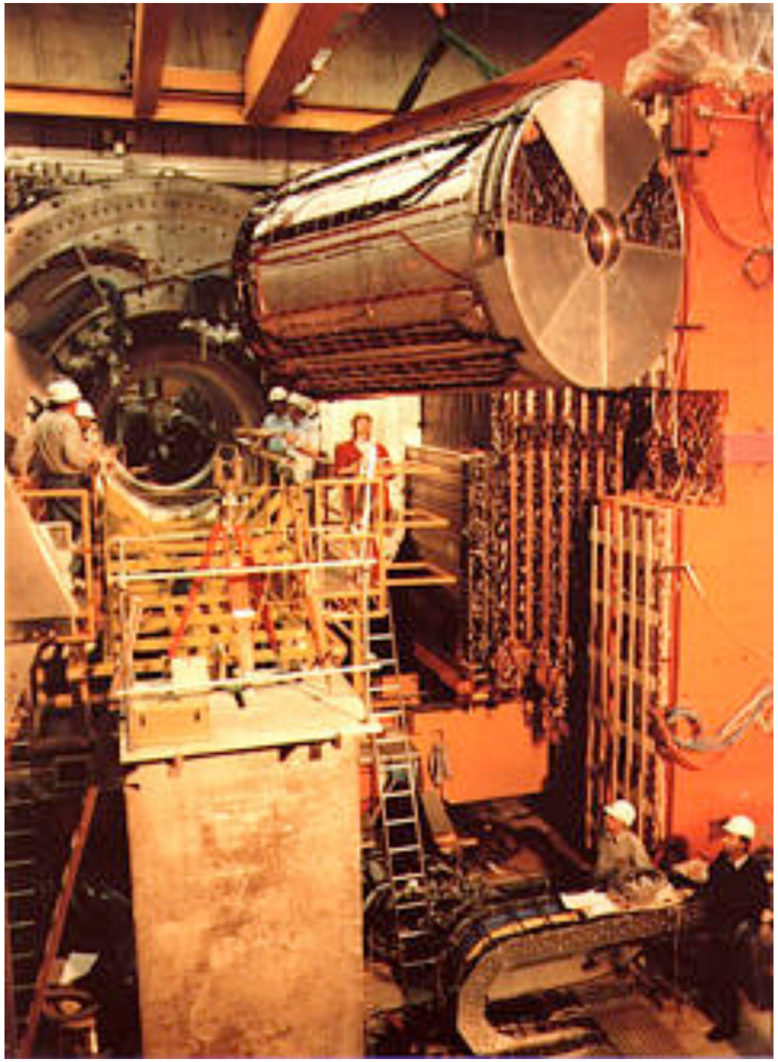

ZEUS



The Central Tracking Detector

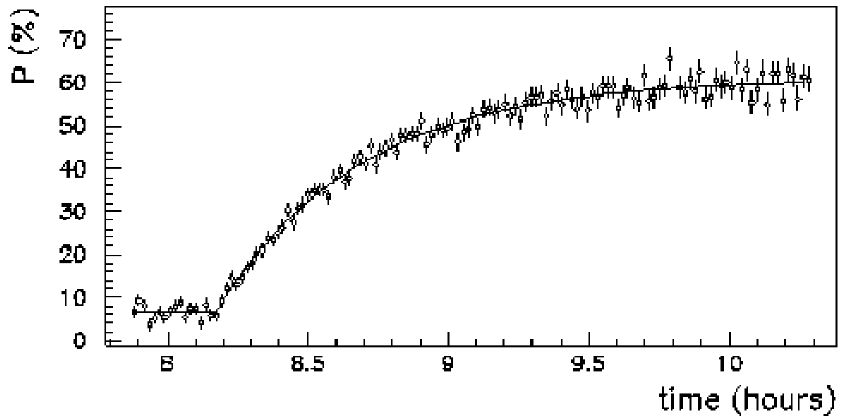
- Built by UK universities
- Cylindrical drift chamber
- ~25000 wires
- 1.43T field
- ~2m long
- ~1m radius

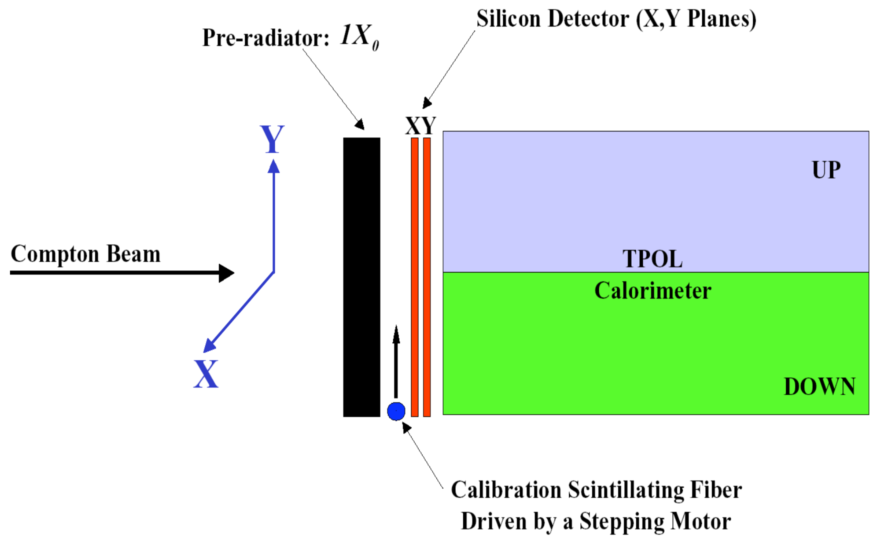


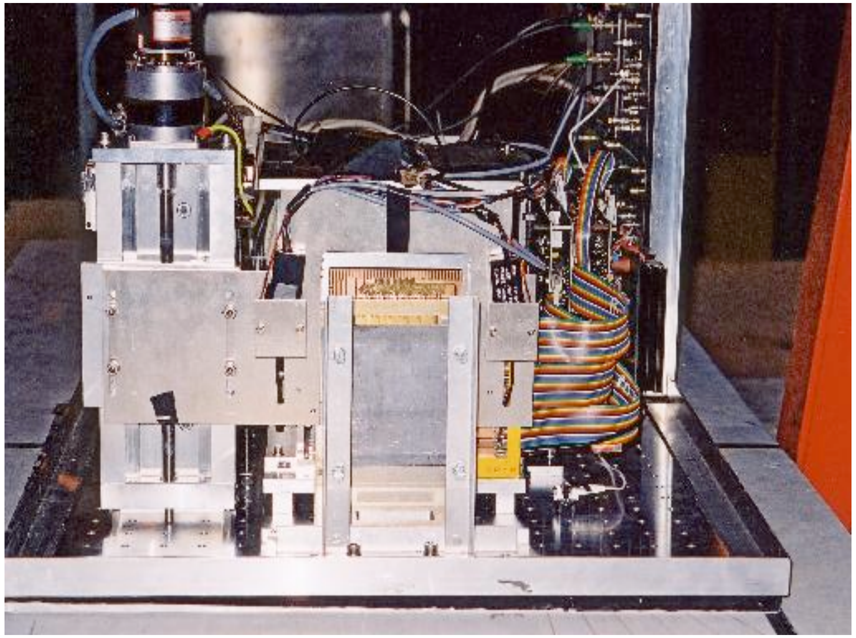



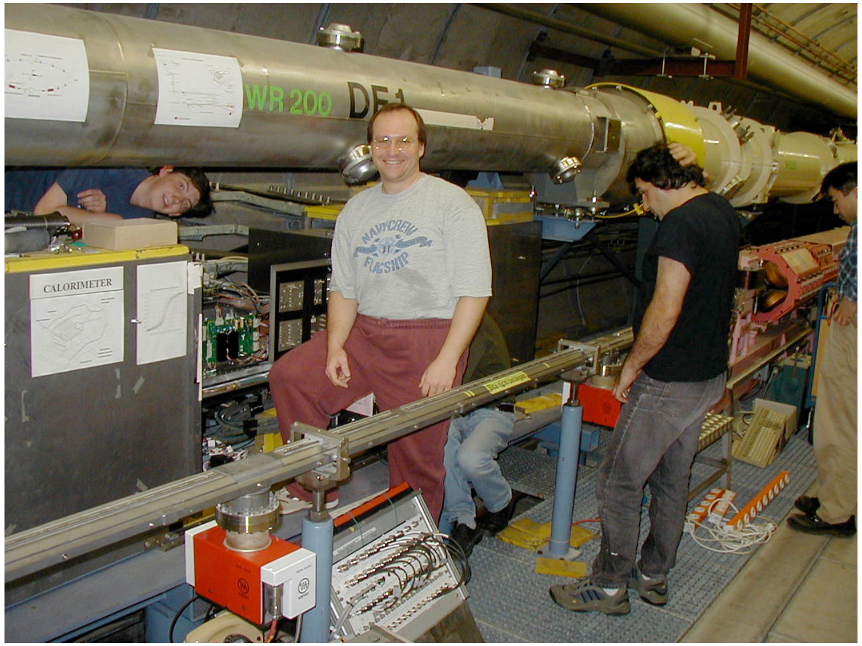
The Transverse Polarimeter

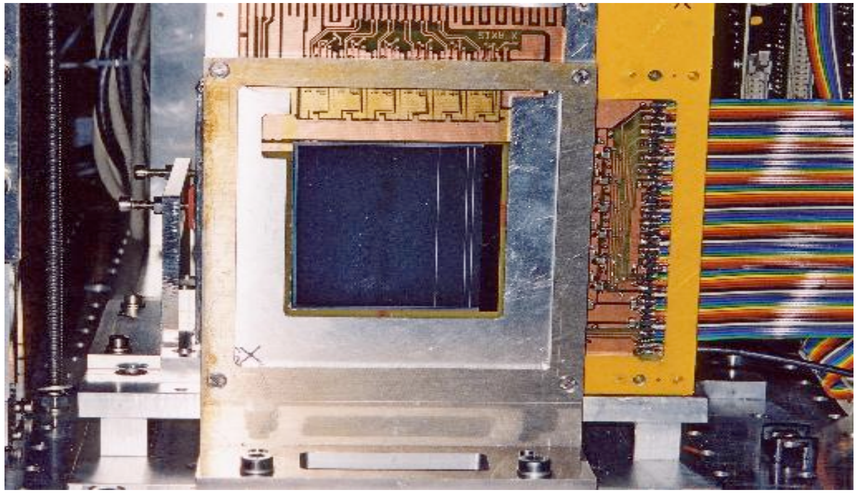
- Sokolov-Ternov effect leads to natural build up of transverse polarisation
- Spin rotators convert this to longitudinal polarisation
- TPOL measures spatial asymmetry in Compton scattered light from laser
- Si and scintillating fibre improve asymmetry measurement from CAL

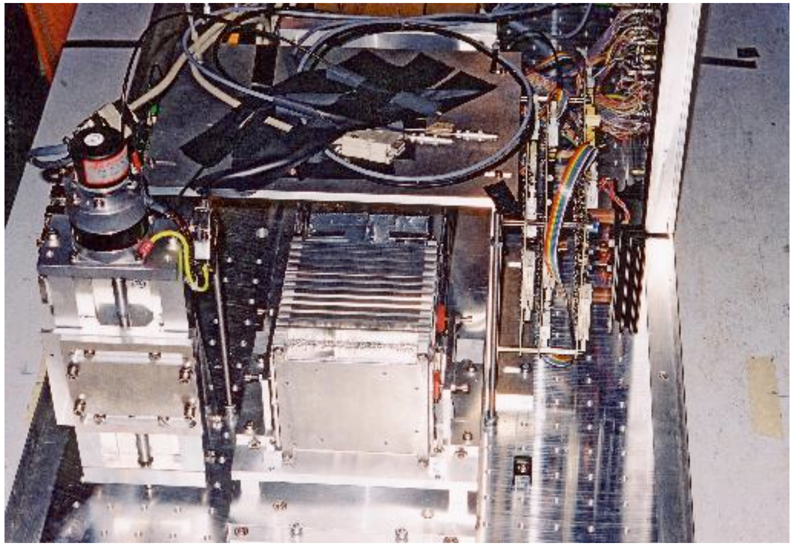






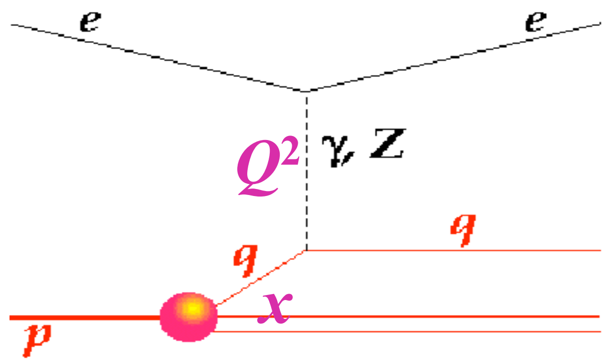

WR 200
CALORIMETER

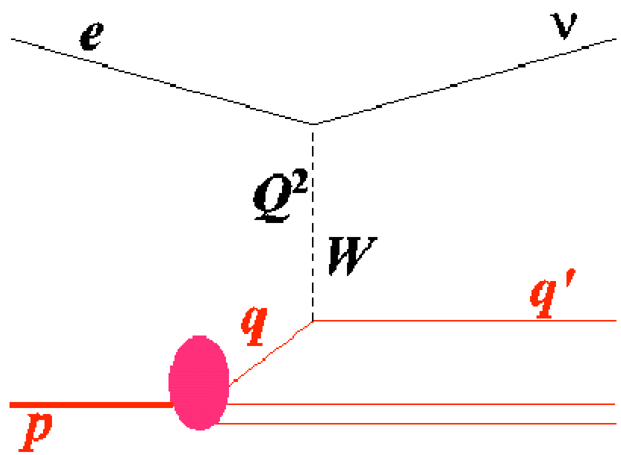


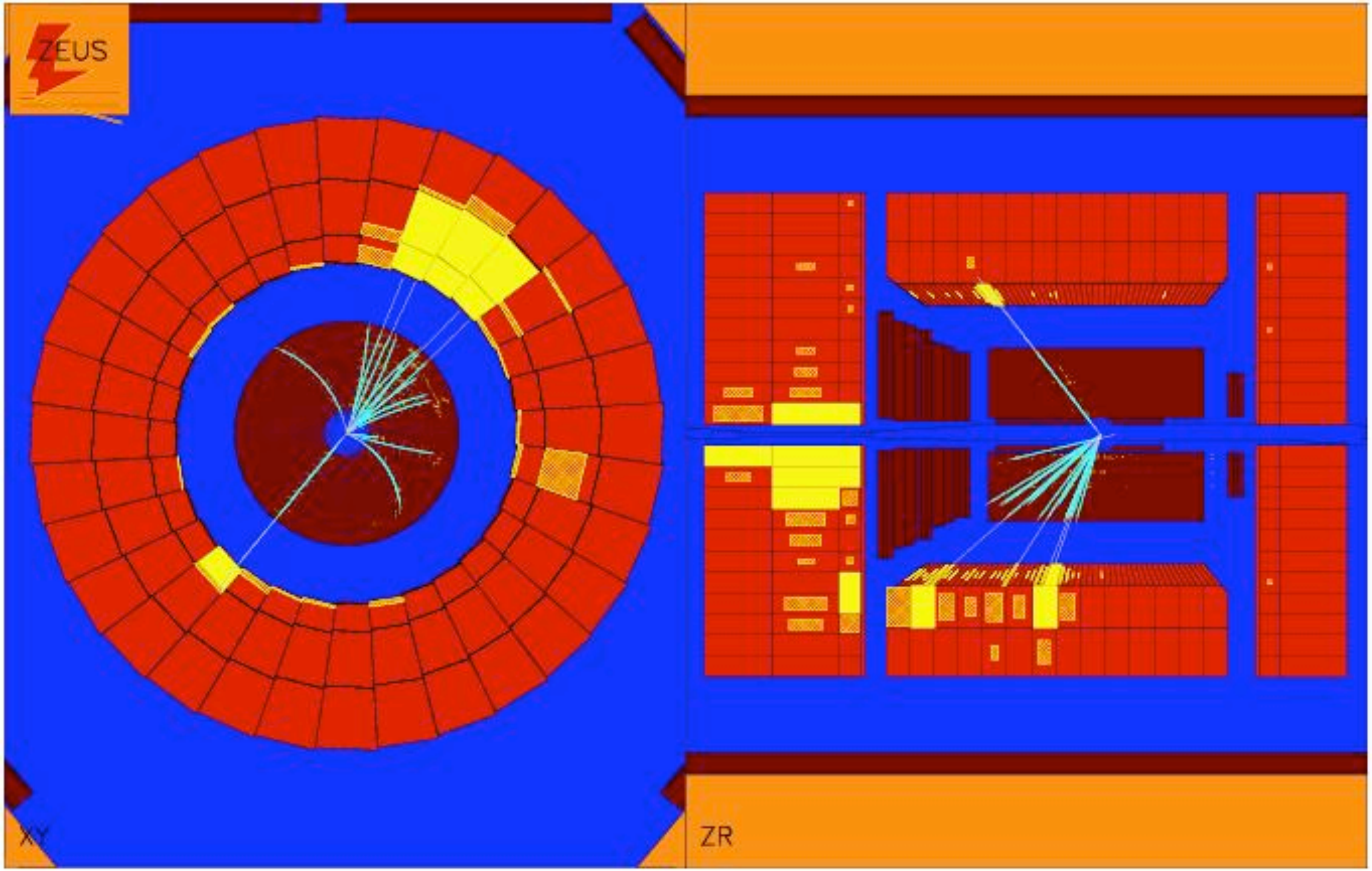


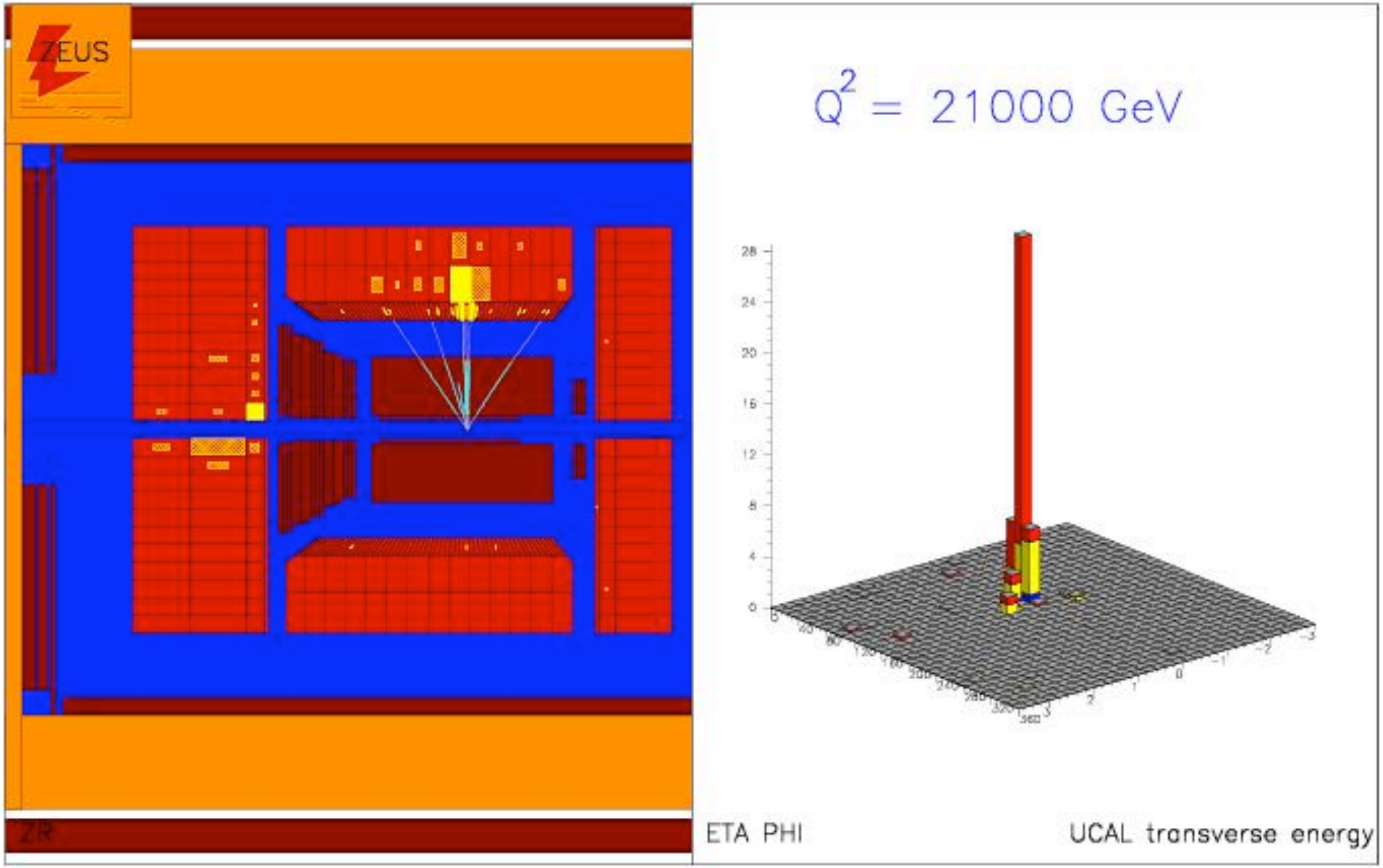
HERA I Physics

- Use electron to probe proton structure and investigate forces
- Q^2 resolving power
- x fraction of p momentum
- y inelasticity



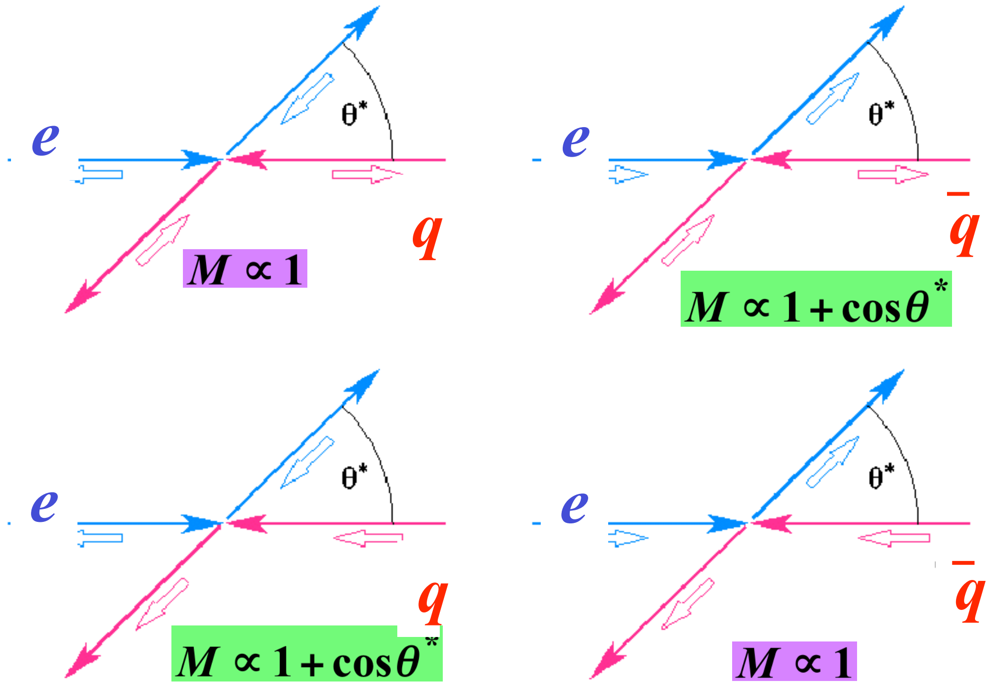



ZEUS
XY
ZR


ZEUS
ZR
$Q^2 = 21000\ GeV$
ETA PHI
UCAL transverse energy

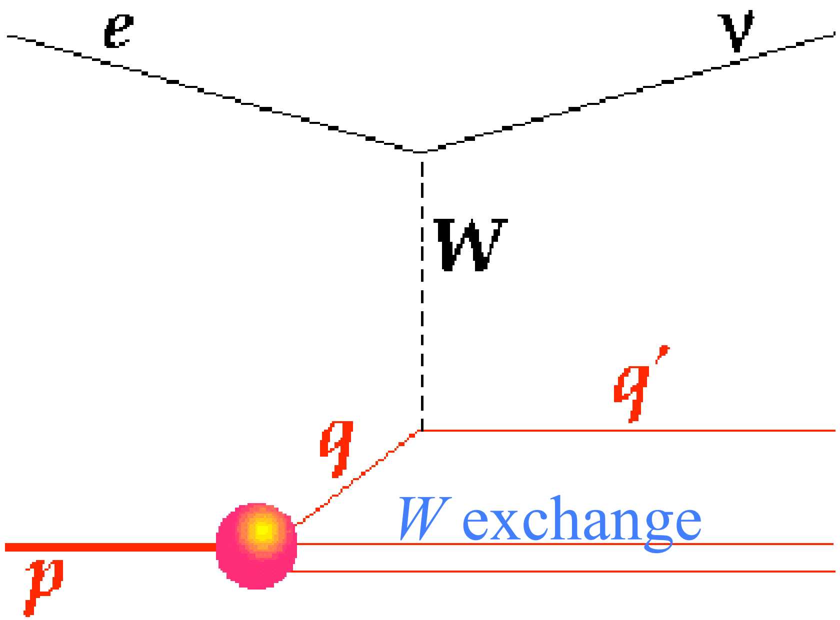
Lepton-quark scattering

- g , Z and W all VECTOR bosons
  - Þ helicity conserved (since mq, me << E)
- (angular momentum conserved)



$$|M(e_L + q_L)|^2 = |M(e_R + q_R)|^2 \propto 1$$

$$|M(e_L + q_R)|^2 = |M(e_R + q_L)|^2 \propto (1 + \cos\theta^*)^2 \propto \left(1 - \sin^2\frac{\theta^*}{2}\right)^2$$



- first example: charged current

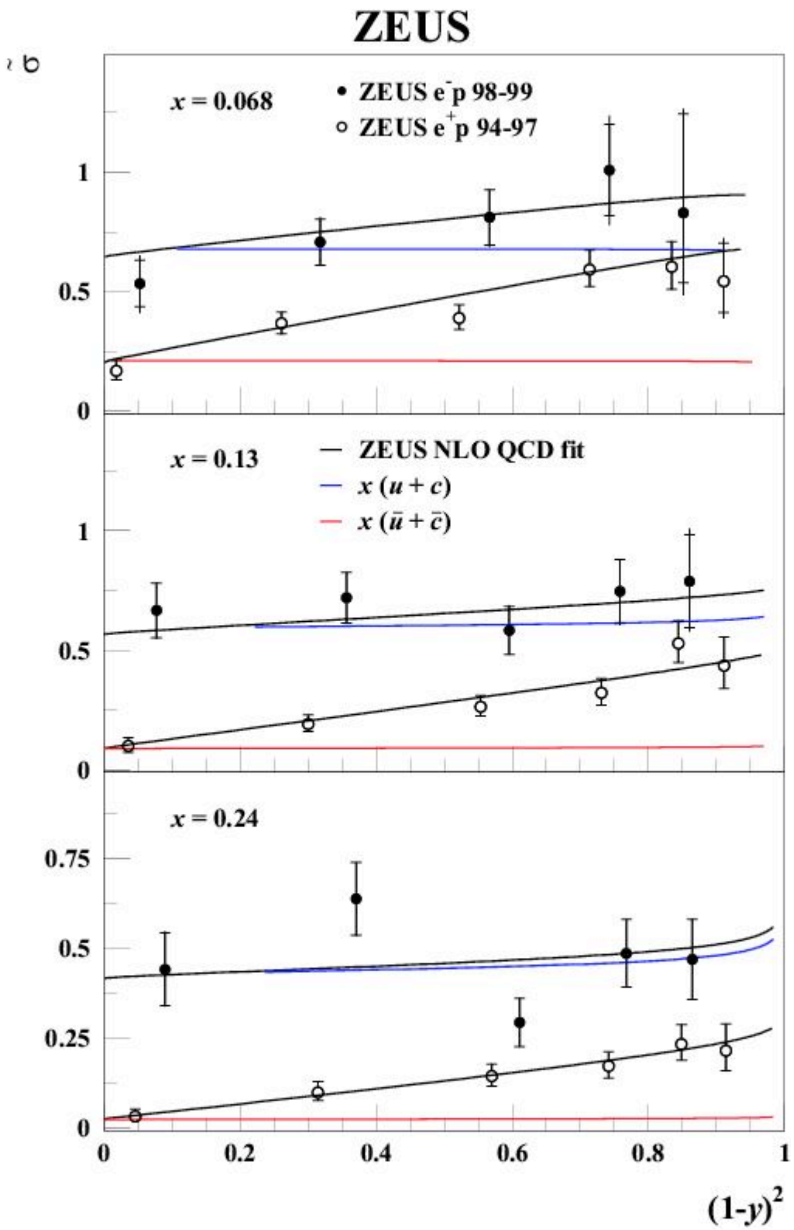
Define: $y = \sin^2 \frac{\theta^*}{2}$

e^+p: d, s* and *u-bar, c-bar

e^-p: u, c* and *d-bar, s-bar

$$\frac{d^2\sigma^{CC}}{dxdy} = \{\text{Coupling}\}\{\text{Propagator}\}\{\text{Angular factor} \otimes \text{PDF}\}$$

$$= \{\text{Coupling}\}\{\text{Propagator}\}\{\tilde{\sigma}^{CC}(x)\}$$



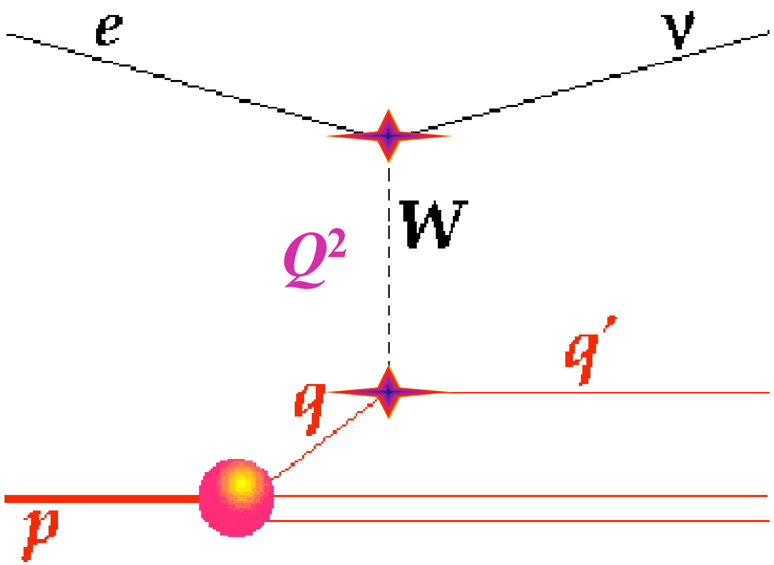
$$\tilde{\sigma}^{CC}_{e^+p} = (\bar{u}(x) + \bar{c}(x)) + (1-y)^2 (d(x) + s(x))$$

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

- e^+p read off d at $(1\text{-}y)^2 = 1$
- e^+p read off u at $(1\text{-}y)^2 = 0$

CC can be used to determine *u*, *d* PDFs

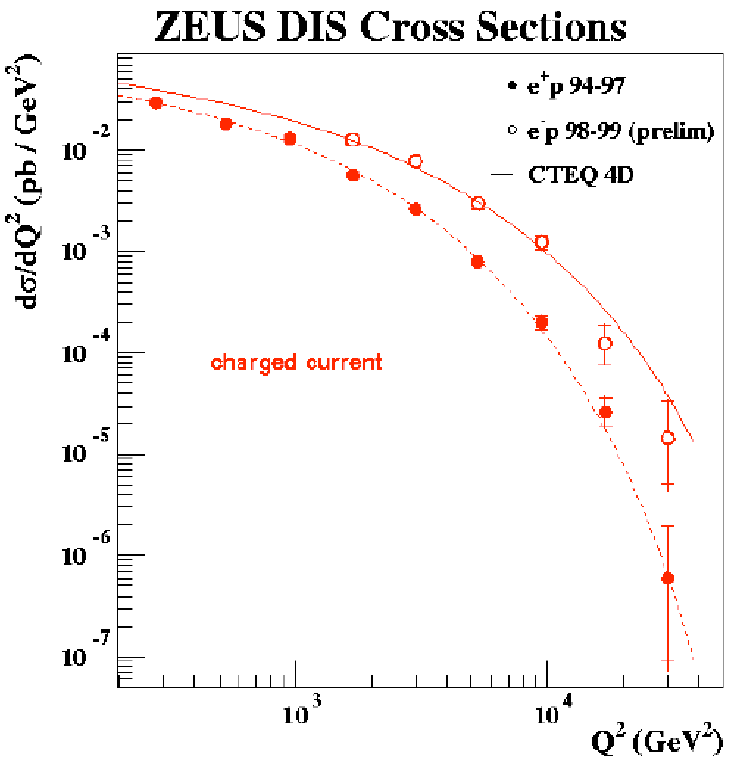
Charged Current



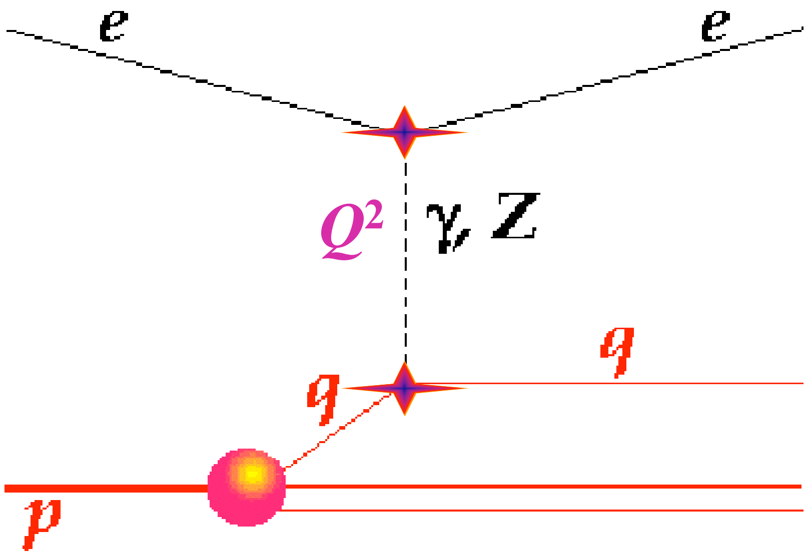
$$g^2 = \frac{8G_F M_W^2}{\sqrt{2}}$$

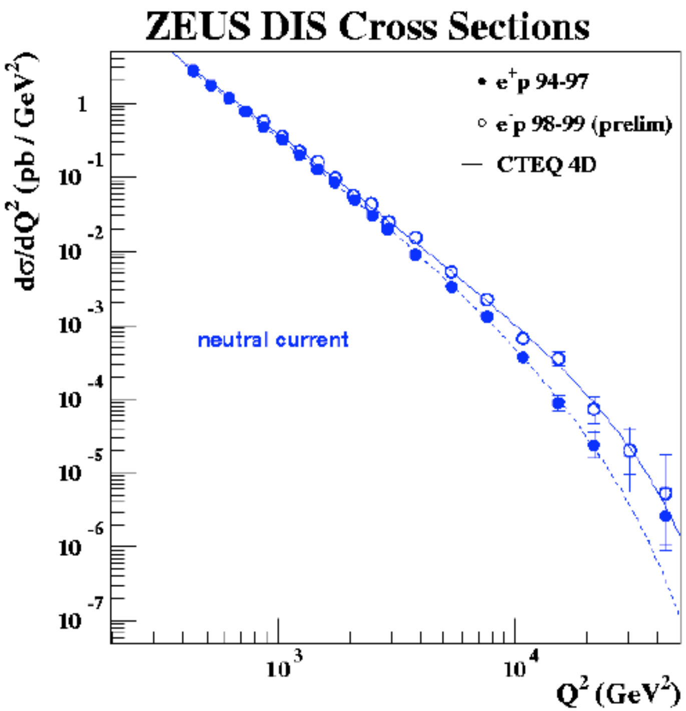
$$\left(\frac{1}{Q^2 + M_W^2}\right)^2$$

$$\frac{d\sigma_{e^\pm p}^{CC}}{dQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{Q^2 + M_W^2}\right)^2 \int \tilde{\sigma}_{e^\pm p}^{CC}\, dx$$



Neutral Current





$e^{\pm}$ p: **All flavours contribute**

$$\frac{d\sigma^{\pm}_{NC}}{dQ^2} \propto \left[\eta^{\pm}_{\gamma}\frac{1}{Q^2}+\eta^{\pm}_{Z}\frac{1}{Q^2+M_Z^2}\right]^2 \int \tilde{\sigma}^{\pm}_{NC}\,dx$$

- **Photon exchange - parity conserving**
- ***Z* exchange: Two pieces; one is parity conserving, the other violates parity**

Parameterise cross section collecting parity conserving pieces in one structure function, F_2, and pieces which violate parity in a second structure function xF_3:

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

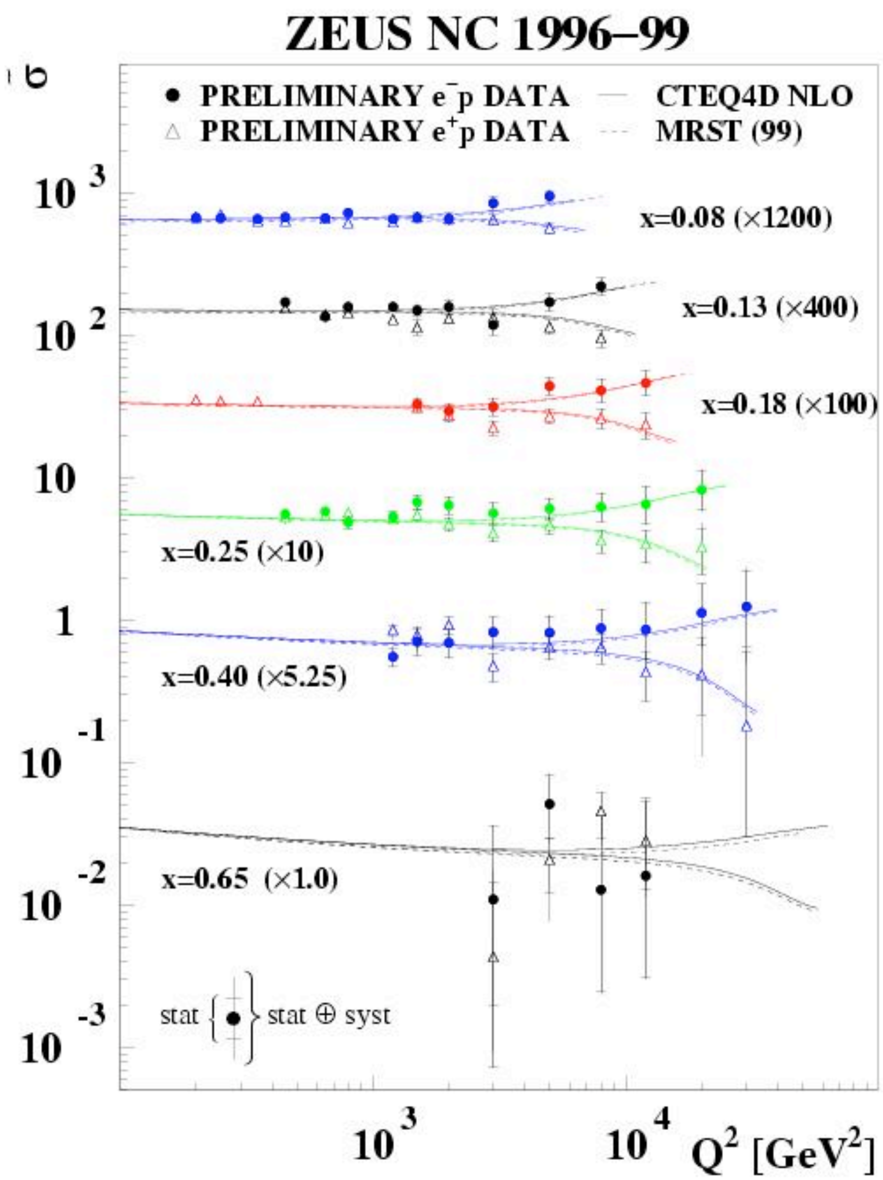
$$Y_\pm = 1 \pm (1-y)^2$$

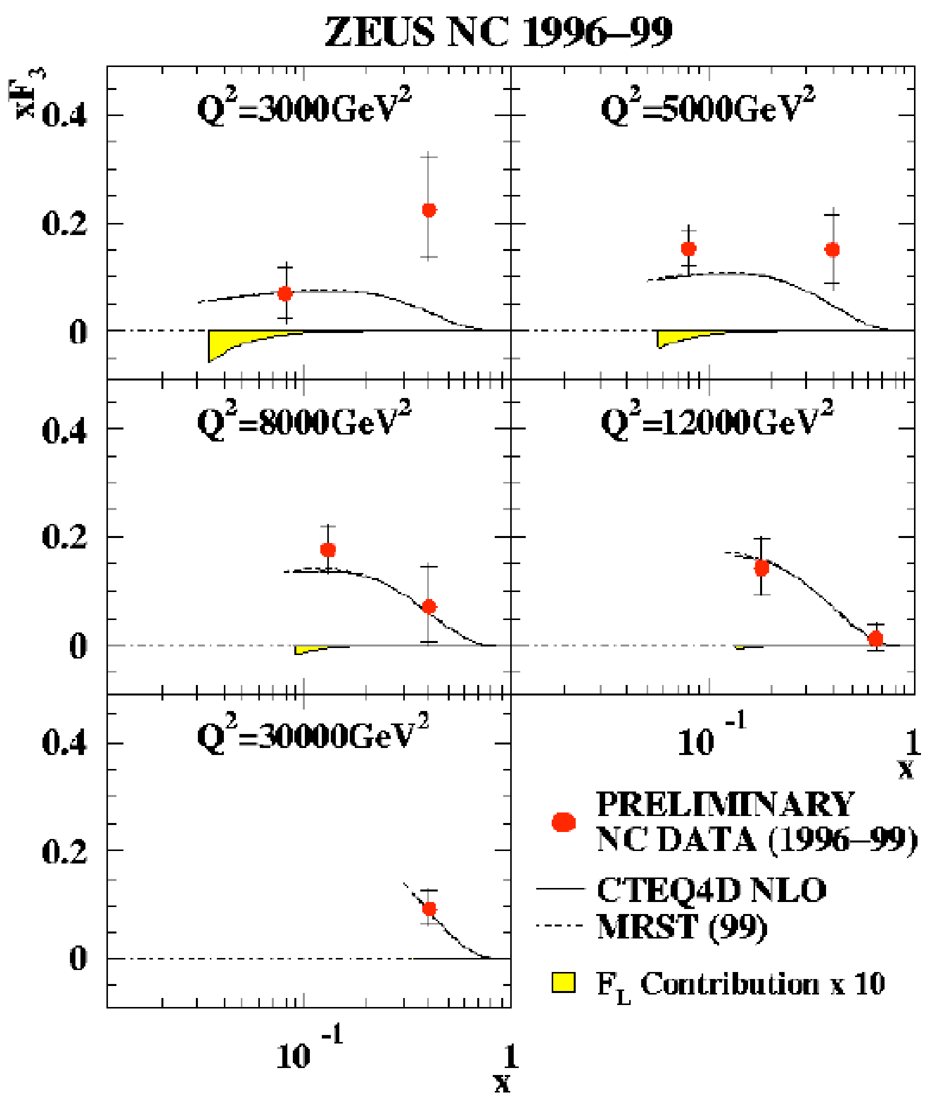
$$\tilde{\sigma}_{e^\pm p}^{NC} = \left[\frac{2\pi\alpha^2}{Q^4 x}\right]^{-1} \frac{1}{Y_+}\frac{d^2\sigma_{NC}^{e^\pm P}}{dxdQ^2}$$

$$F_2^{NC} = x\sum A_q\left(q(x) + \bar{q}(x)\right)$$

$$xF_3^{NC} = x\sum B_q\left(q(x) - \bar{q}(x)\right)$$

Focus on highest possible Q^2 to look for Z exchange

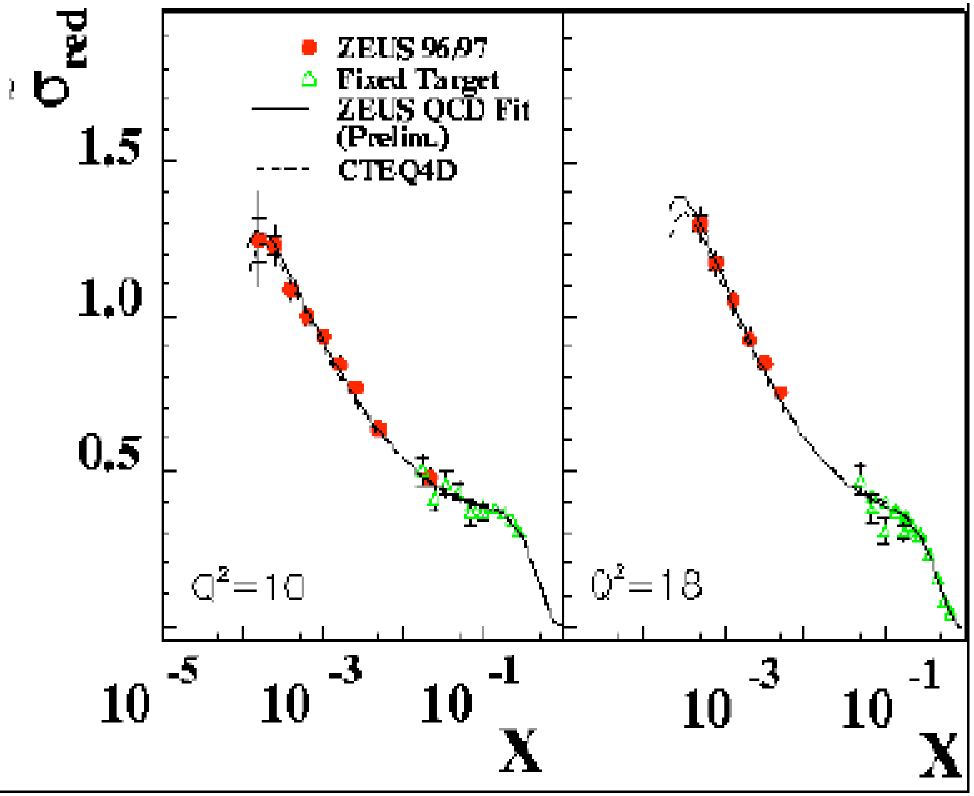




First direct look at the valence quarks in *ep*!

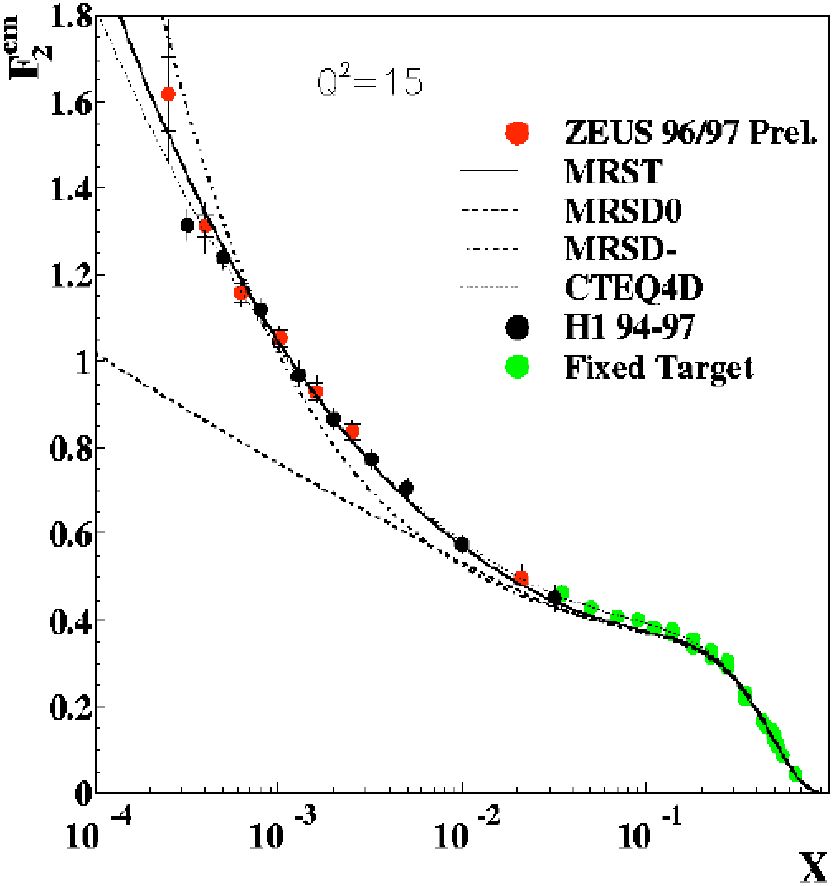
$$xF_3^{NC} = x\sum B_q\left(q(x) - \bar{q}(x)\right)$$

Proton Structure



Determine cross section, σ_r, make small corrections for xF_3, F_L, e/w contribution to F_2 (and radiative corrections)

$$F_2^{\text{em}} = \sigma_r\left(x, Q^2\right)\left(1 + \delta_{F_2}^{\text{ew}} + \delta_{xF_3} + \delta_{F_L}\right)\left(1 + \delta_{\text{rad}}\right)$$



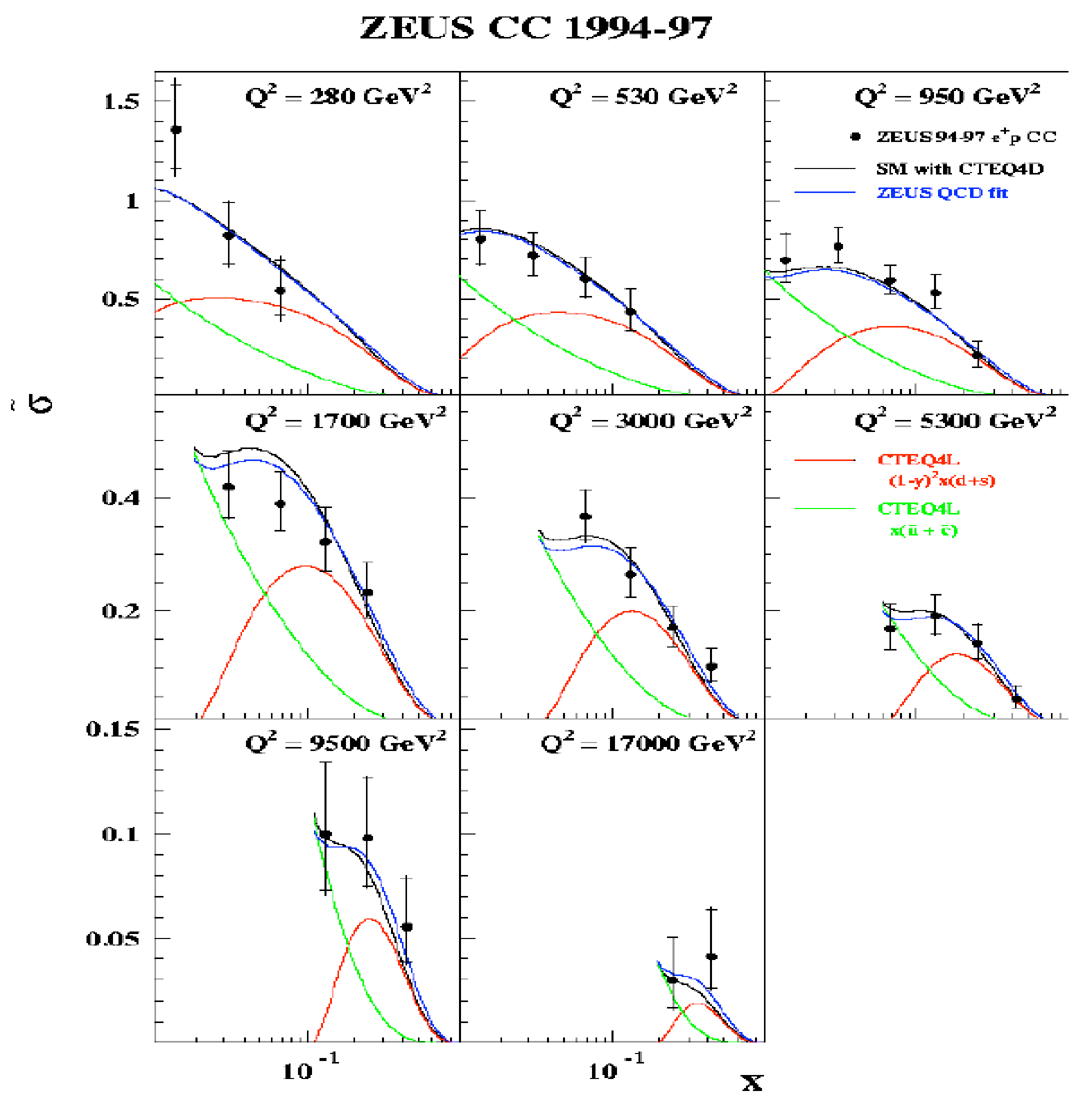
The proton structure function F_2:

$$F_2^{NC} = x\sum A_q\left(q(x)+\bar{q}(x)\right)$$

$$F_2^{em} = x\sum e_q^2\left(q(x)+\bar{q}(x)\right)$$

- HERA: Low x: Rapid rise of F_2 - $F_2 \sim x^{-}$

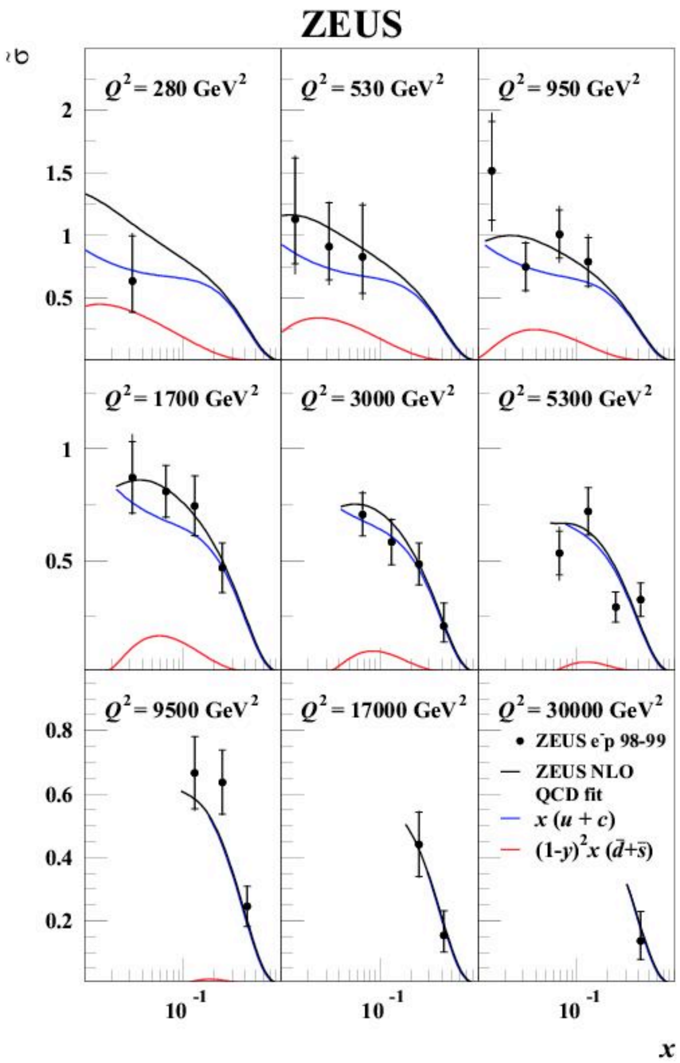
Quark Flavours



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

- Sensitive to specific flavours
- High x: d
- Low x: u-bar

Quark Flavours



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

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

- Sensitive to specific flavours
- High x: u
- Low x: d-bar

HERA II - Upgrade and Physics

Luminosity Upgrade:

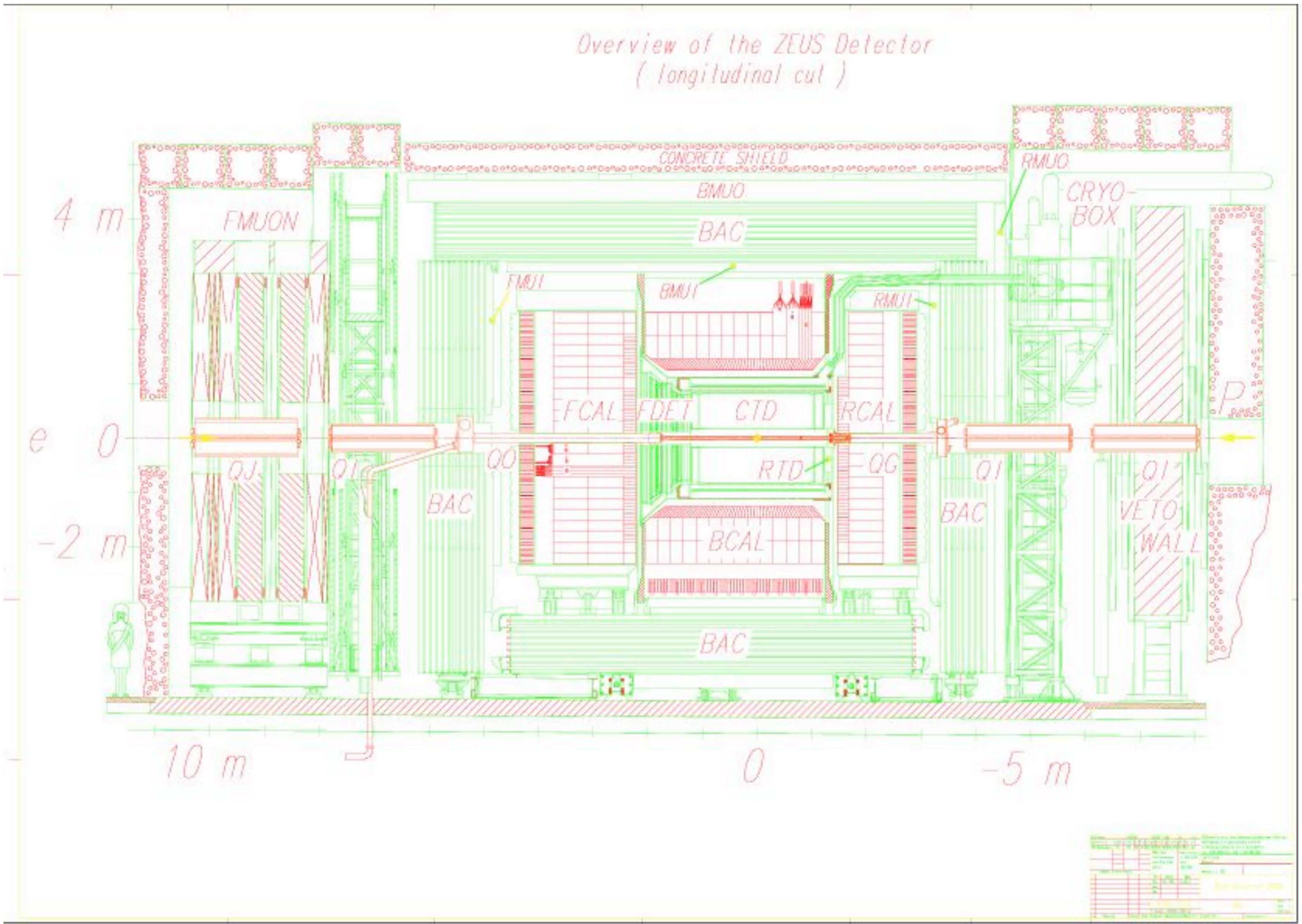
- Factor 5 larger than previous luminosity running
  - 200 pb^{-1} / year

Polarisation for Collider Experiments:

- Polarised electron/positron beams
  - > 50% (70% design goal)

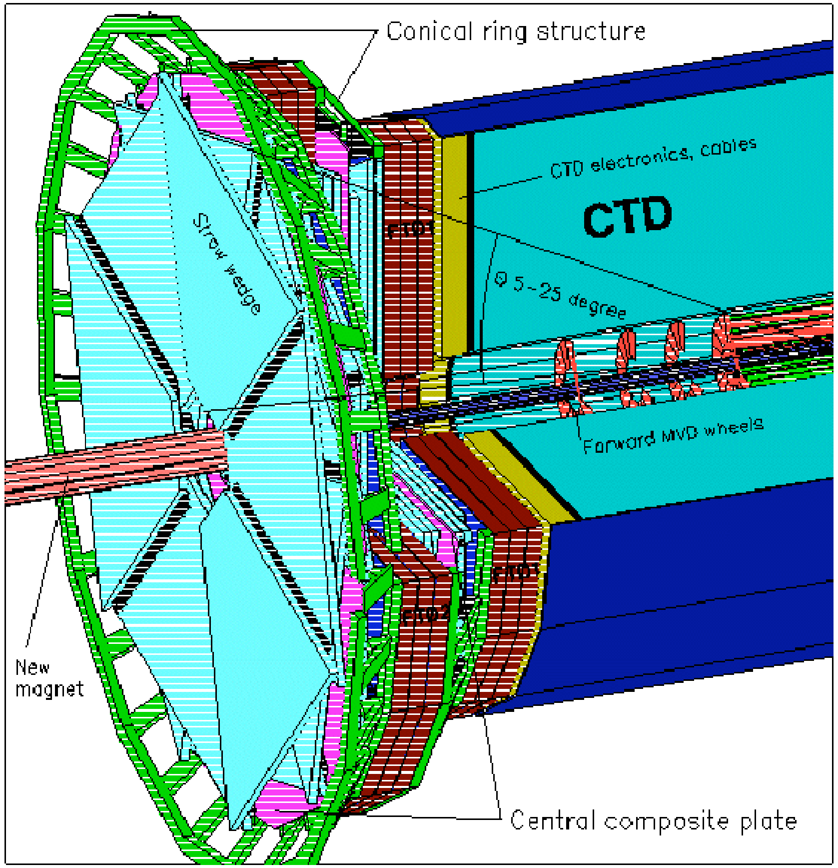
Running Programme:

- Goal to take 1000 pb^{-1} by end of running


Overview of the ZEUS Detector
(longitudinal cut)
CONCRETE SHIELD
BMUO
RMUO
CRYO-
BOX
FMUON
BAC
FMUI
BMUI
RMUI
4 m
FCAL
FDET
CTD
RCAL
e
0
P
QJ
QI
QO
RTD
QC
BAC
VETO
WALL
BCAL
-2 m
BAC
10 m
0
-5 m

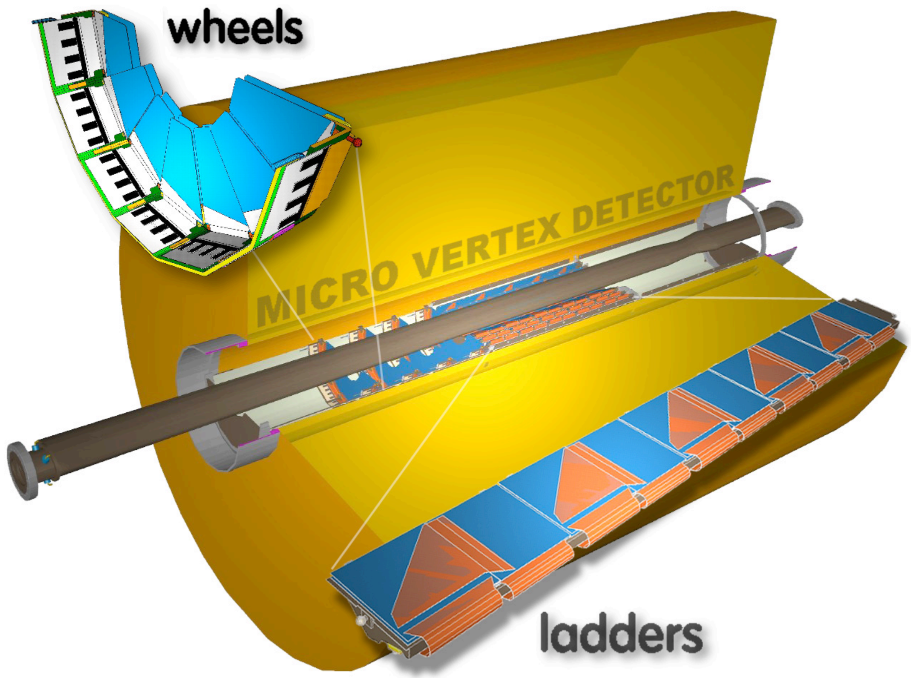
Forward tracker upgrade

- Straw tube tracker
- Increase number of track space points
- Reduce ambiguities
- Increase track finding efficiency



Micro Vertex Detector

- Good impact parameter resolution < 100 m m
- Improved track parameters at IP
- Increase in efficiency for charm 20
  - Þ Big impact on charm and beauty physics



Polarised Charged Current

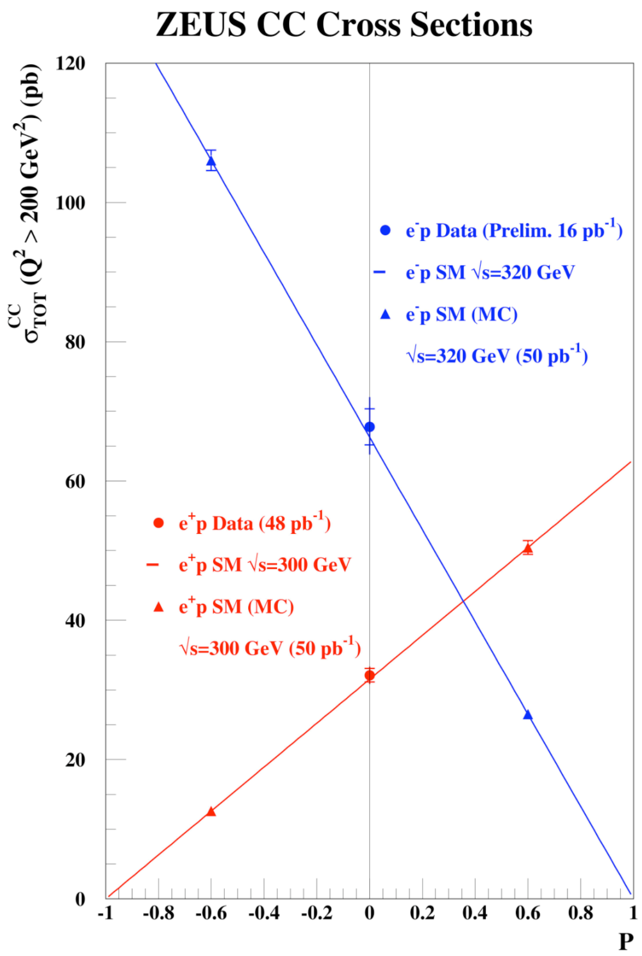
$$\sigma^{CC}_{e^{\pm}p} \propto (1 \pm P)$$

Exclusion limit

$M_W(\mathrm{R}) > 400$ GeV

First measurement:

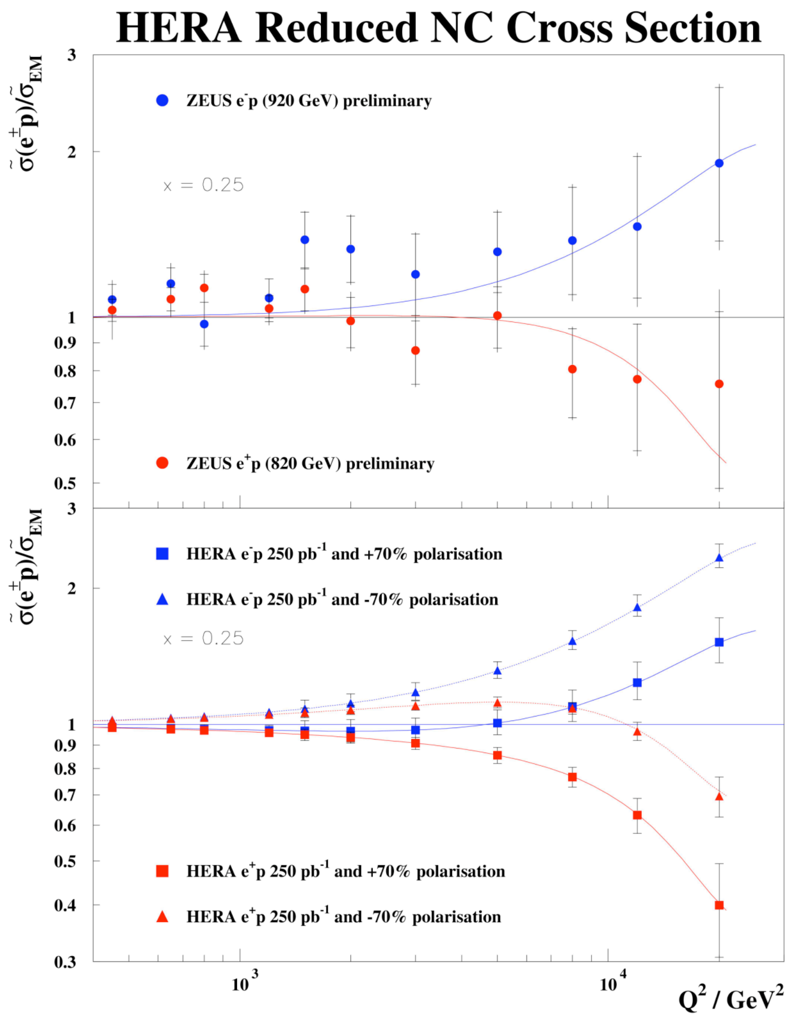
Possible with *ONE* years data



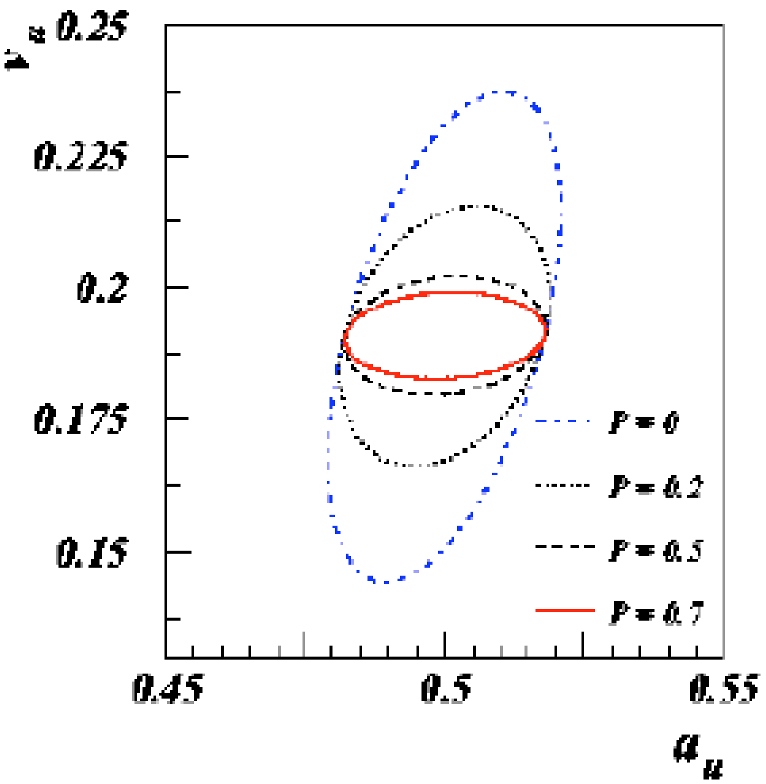
Polarised Neutral Current

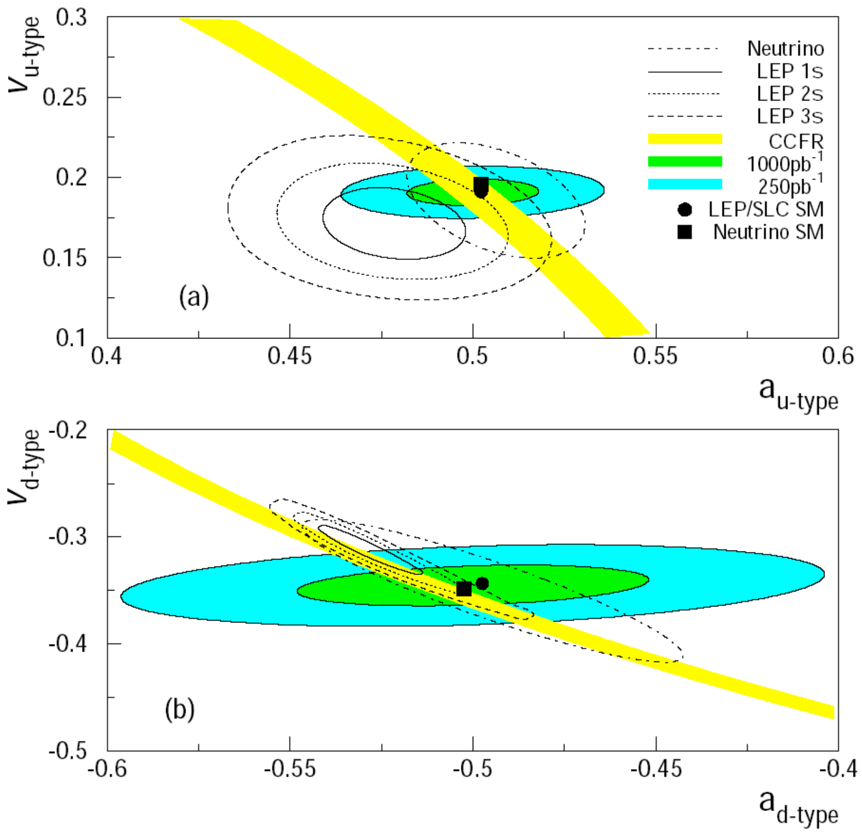
- g_L =/= g_R in SM
- exploit polarisation dependence of NC DIS
- measure u- and d-quark vector and axial-vector couplings

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



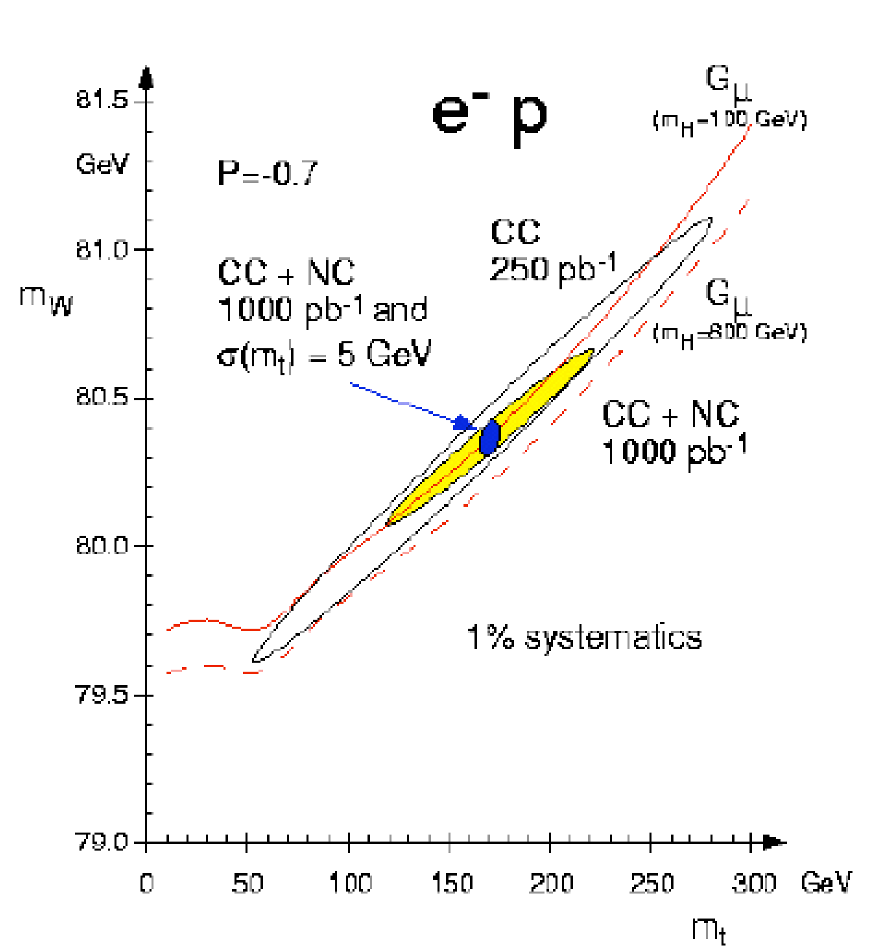
Light quark couplings to Z^0





Electroweak Physics

- Standard Model:
  - Fully specified by a , M_Z , M_W , m_t and M_H
- Measure CC and NC DIS cross sections to constrain M_W
- 70% polarisation
- 250 pb^{-1}
- D M_W » 55 MeV (M_H fixed)



Who and where?

- In London
  - Ken Long
  - Costas Foudas
  - Ash Jamdagni
  - Alex Tapper
  - Ricardo Goncalo

- At DESY
  - Fabio Metlica
  - Chris Collins-Tooth

HERA II schedule

- Luminosity running from yesterday until 1st March 2003
- Shutdown from 1st March scheduled to be 16 weeks
- Collide e^+p until Christmas 2003
- Switch to e^-p start 2004

- In 2nd year of Ph.D. take a lot of data!

Opportunities

- Test, install and commission Si detectors
- Analyse Si data
- Make 1st measurements
- C/C++/Java
- CTD HV system

- Use polarised data to make electroweak and structure function measurements?
- Use MVD to tag charm and beauty?
- Basically whatever you want!