

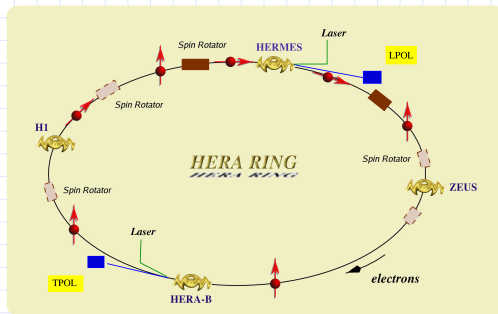
High Q^2 Neutral Current in Polarised $e^\pm p$ Collisions at HERA II

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Longitudinally Polarised Lepton Beam at HERA II



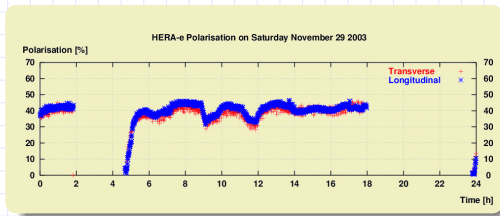
- Sokolov-Ternov effect
→ lepton beam has transverse polarisation
- Spin rotator before/after the H1/ZEUS/HERMES detectors

Polarisation:

$$P_e = \frac{N_{RH} - N_{LH}}{N_{RH} + N_{LH}},$$

N_{RH} (N_{LH}): number of RH(LH) leptons in the beam

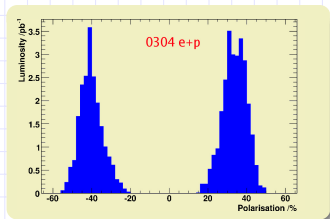
- Polarisation built-up time ~ 30 minutes
- Monitoring by two independent compton polarimeters



“Right handed” (RH) for $P_e > 0$
“Left handed” (LH) for $P_e < 0$

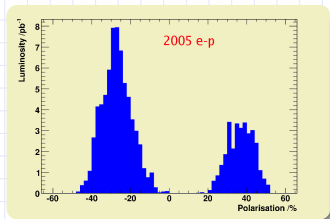
2003-04 e^+p

	Lumi, pb^{-1}	Polarisation
RH	26.9	$(+33.6 \pm 0.6)\%$
LH	20.7	$(-40.2 \pm 1.1)\%$



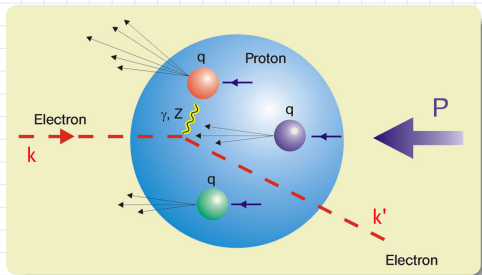
2005 e^-p

	Lumi, pb^{-1}	Polarisation
RH	29.6	$(+37.0 \pm 1.3)\%$
LH	68.6	$(-27.0 \pm 1.8)\%$



- HERA II lumi $\sim 150 \text{ pb}^{-1}$ (HERA I $\sim 120 \text{ pb}^{-1}$)
- HERA II e^-p lumi six times larger than HERA I e^-p

Neutral Current (NC) DIS: $e^\pm p \rightarrow e^\pm X$



Kinematics:

- $Q^2 = -(k - k')^2 = -q^2$
virtuality of γ^* , Z^0
- $x = Q^2 / 2(Pq)$ momentum fraction of proton carried by struck quark
- $y = (Pq) / (Pk)$ inelasticity
- $Q^2 = sxy$

DIS is sensitive probe of the proton structure

- High Q^2 : Probe with small spatial resolution $\lambda \sim 1/\sqrt{(Q^2)}$, resolve 1/1000th size of proton
- QCD, PDFs
- Probe EW dynamics

- NC DIS cross section:

$$\frac{d^2\sigma_{NC}(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} [Y_+ \tilde{F}_2 \mp Y_- x \tilde{F}_3 - y^2 \tilde{F}_L], \quad Y_\pm = 1 \pm (1-y)^2$$

Dominant contribution

Contribution only important at high Q^2

Sign changes in e^+/e^-

Sizeable only at high y

- NC reduced cross section:

$$\tilde{\sigma}_{NC}(e^\pm p) = \frac{xQ^4}{2\pi\alpha^2} \frac{1}{Y_+} \frac{d^2\sigma_{NC}(e^\pm p)}{dx dQ^2} = \tilde{F}_2 \mp \frac{Y_-}{Y_+} x \tilde{F}_3 - \frac{y^2}{Y_+} \tilde{F}_L$$

- in QPM:

$$F_2(x, Q^2) = x \sum A_i(q_i + \bar{q}_i)$$

$$xF_3(x, Q^2) = x \sum B_i(q_i - \bar{q}_i)$$

$$F_L = F_2 - 2xF_1 = 0 \text{ (Callan-Gross relation)}$$

Polarised Neutral Current Cross Section

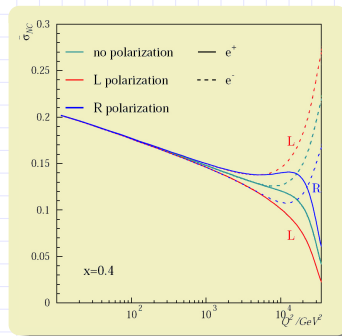
NC structure functions, \tilde{F}_2 and $x\tilde{F}_3$, can be decomposed as:

$$\begin{aligned} \tilde{F}_2 &= F_2 - \underset{\gamma \text{ exchange}}{(v_e \pm P_e a_e) \chi_Z F_2^{\gamma Z}} + \underset{\gamma Z \text{ interference}}{(v_e^2 + a_e^2 \pm 2P_e v_e a_e) \chi_Z^2 F_2^Z} \\ x\tilde{F}_3 &= - \underset{\gamma \text{ exchange}}{(a_e \pm P_e v_e) \chi_Z x F_3^{\gamma Z}} + \underset{Z \text{ exchange}}{(2v_e a_e \pm P_e (v_e^2 + a_e^2)) \chi_Z^2 x F_3^Z}, \end{aligned}$$

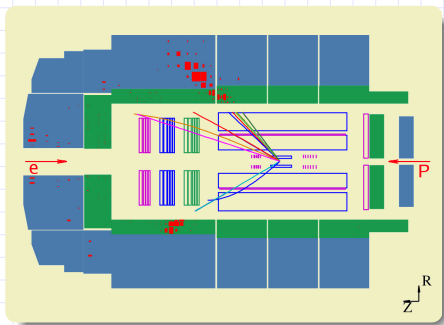
where: "+" for e^+p , "-" for e^-p

Polarisation dependence:

- Dominating e/m contribution is independent of P_e
- Polarised contribution appears at high Q^2 , mainly due to γZ interference



Neutral Current Event in the H1 Detector



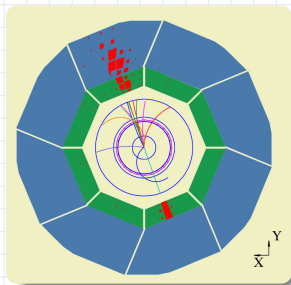
LAr calorimeter:

High granularity 45000 cells

$$\frac{\sigma(E)}{E} : \frac{12\%}{\sqrt{E/\text{GeV}}} \text{ e/m energy}$$

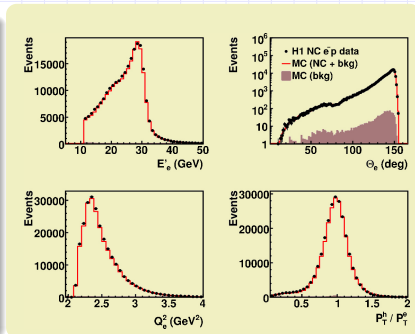
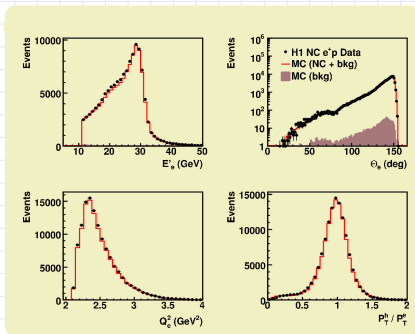
$$\frac{\sigma(E)}{E} : \frac{50\%}{\sqrt{E/\text{GeV}}} \text{ had energy}$$

- *Electron produces isolated and compact energy deposition*
- *Identified using shape and size of e/m shower profile*
- *Balanced by hadronic final state in φ*



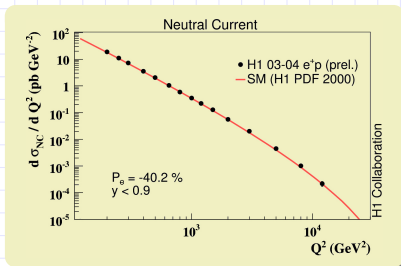
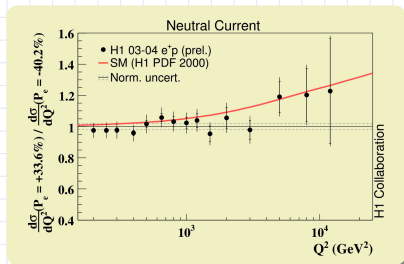
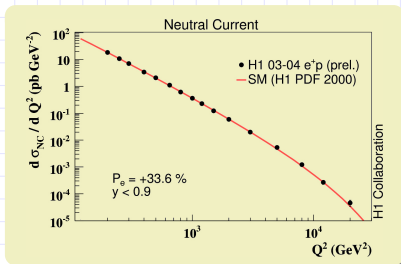
2003-04 e^+p

2005 e^-p



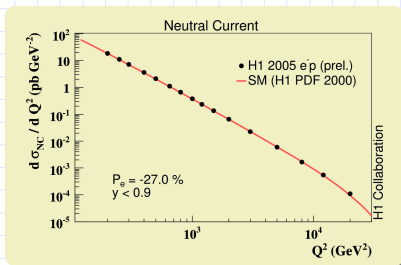
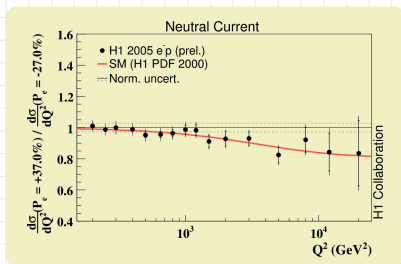
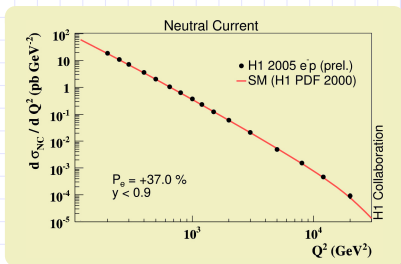
- *Electron energy (E_e'), scattering angle (θ_e), etc are described by MC*
- *Low background level. Main contributions: photoproduction(γp), QED compton, lepton-pair production*

2003-04 e^+p $d\sigma/dQ^2$ and RH/LH



- $\frac{d\sigma^{e^+p}}{dQ^2}$ (RH, LH) and RH/LH
- Rise of the ratio RH/LH as function of Q^2
- Polarisation asymmetry is not yet significant

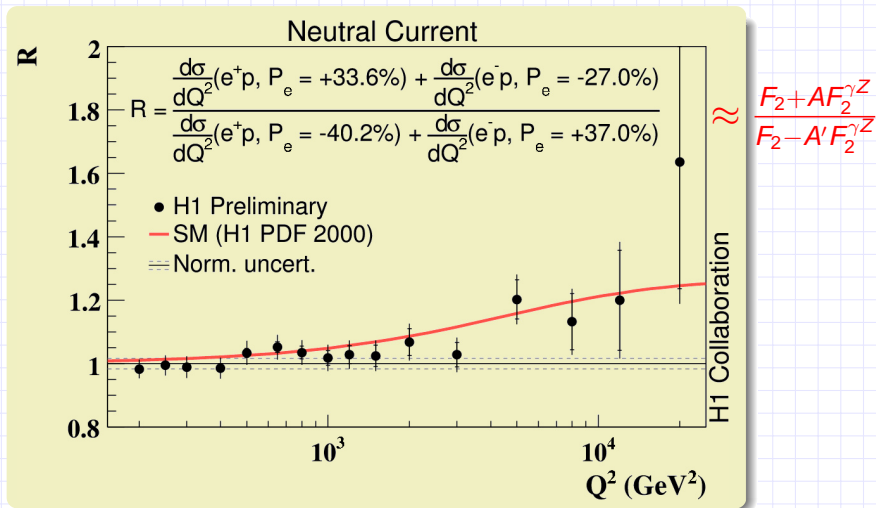
2005 e^-p $d\sigma/dQ^2$ and RH/LH



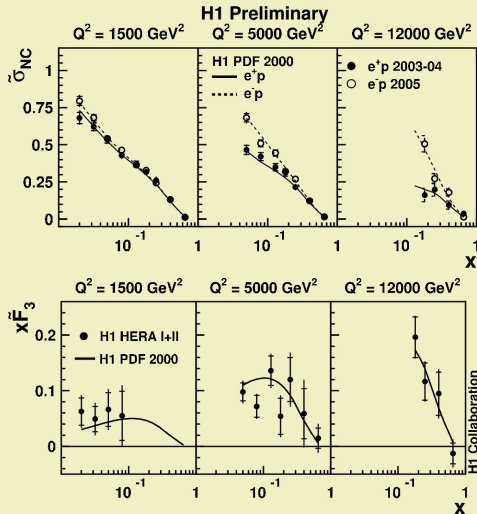
- $\frac{d\sigma^{e^-p}}{dQ^2}$ (RH, LH) and RH/LH
- Drop of the ratio RH/LH as function of Q^2
- Indication of the polarisation effect on NC cross sections, although significance is moderate

Polarisation Asymmetry in NC: Combination of Results

$$\sigma_{NC}^{e^{\pm}p} \sim \dots F_2 + \dots (-v_e \mp P_e a_e) F_2^{\gamma Z} \mp \dots a_e x F_3^{\gamma Z}$$



Neutral Current at High x and $x\tilde{F}_3$



- HERA II unpolarised cross-sections

$$\tilde{\sigma}_{NC}^{e^\pm p} = \tilde{F}_2 - \frac{y^2}{Y_+} \tilde{F}_L \mp \frac{Y_-}{Y_+} x\tilde{F}_3$$

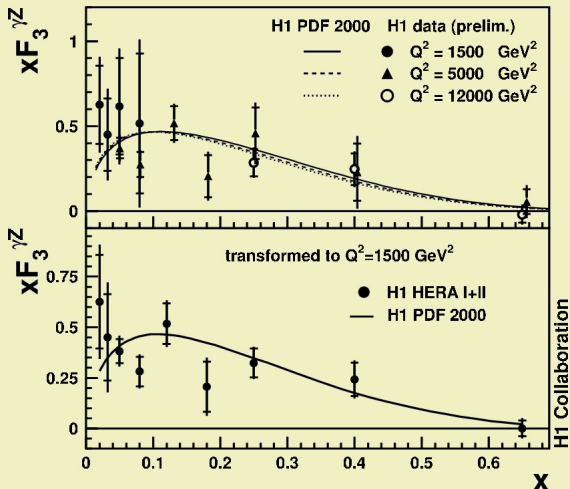
- $x\tilde{F}_3$ for HERA I+II:

$$x\tilde{F}_3 = \frac{Y_+}{2Y_-} (\tilde{\sigma}^{e^-p} - \tilde{\sigma}^{e^+p})$$

$$x\tilde{F}_3 = -a_e \frac{\kappa_W Q^2}{Q^2 + M_Z^2} xF_3^{\gamma Z} + (2v_e a_e) \left(\frac{\kappa_W Q^2}{Q^2 + M_Z^2} \right)^2 xF_3^Z$$

$$xF_3^{\gamma Z} = x\tilde{F}_3 / \left(\frac{-a_e \kappa_W}{Q^2 + M_Z^2} \right)$$

H1 Preliminary



- *HERA II NC cross sections for 2003-04 e^+p and 2005 e^-p interactions with longitudinally polarised lepton beams are measured*
- *Polarisation effects on NC cross sections are visible but significance is moderate*
- *The structure functions $x\tilde{F}_3$ and $xF_3^{\gamma Z}$ are determined using HERA I and HERA II with improved statistical precision*
- *Data is well described by Standard Model*