Polarized Cross-Sections at HERA

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On behalf of
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- CC and NC cross-sections
- Summary

Deep Inelastic Scattering at HERA

DIS is a straightforward tool to probe p structure

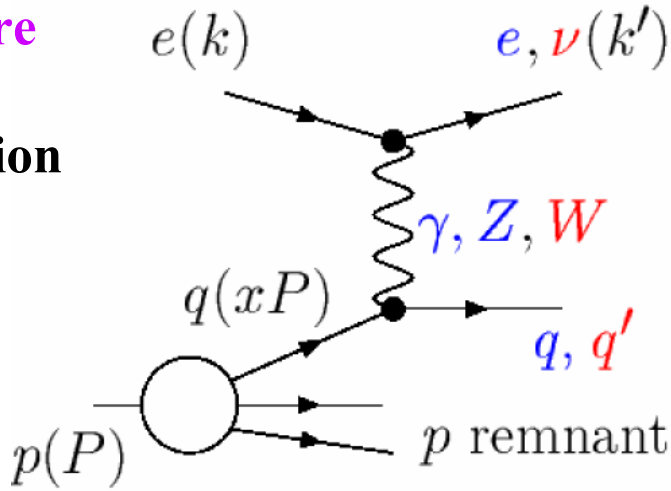
I. High-Q^2 DIS

→ Probe proton with small spatial resolution

$$Q^2 = -(k-k')^2 \qquad \lambda \sim 1/\sqrt{Q^2}$$

$Q^2_{MAX} = s$ HERA, the first ep collider

Ee=27.6 GeV, Ep=920 GeV



→ $\sqrt{s} \sim 319\ GeV, \quad Q^2_{MAX} \sim 10^5\ GeV^2, \lambda_{MAX} \sim 1/1000\, r_{proton}$

In the Standard Model (SM): ep DIS = incoherent sum of eq scatterings

II. High-Q^2 DIS

→Probe EW dynamics between eq (both via NC and CC!)

$$\sigma(ep) \propto \sum_{EW \otimes QCD} \sigma(eq) \otimes (pdf)$$

DIS Cross-Sections (unpolarized)

Experiment measures : Cross-sections ←→ Structure Functions (SFs)

- NC : $\frac{d^2\sigma^{NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} \times \{Y_+ F_2^{NC} \mp Y_- xF_3^{NC} - y^2 F_L^{NC}\}$

  ※ For γ^* probe, two SFs are needed (← two status of γ^*)

  ※ xF_3 : Sign changes in e^+/e^-

Measured in terms of:
- **Mom.frac. of q**
- **Spatial resultion**

$x = Q^2 / 2pq$: Mom. Fraction of the struck quark

$y = pq / pk$: Inelasticity

- CC : $\frac{d^2\sigma^{CC}}{dxdQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2 + Q^2}\right)^2 \times \{Y_+ F_2^{CC} \mp Y_- xF_3^{CC} - y^2 F_L^{CC}\}$

Theory interprets : SFs ← → Couplings, Parton Distribution Functions (PDFs)

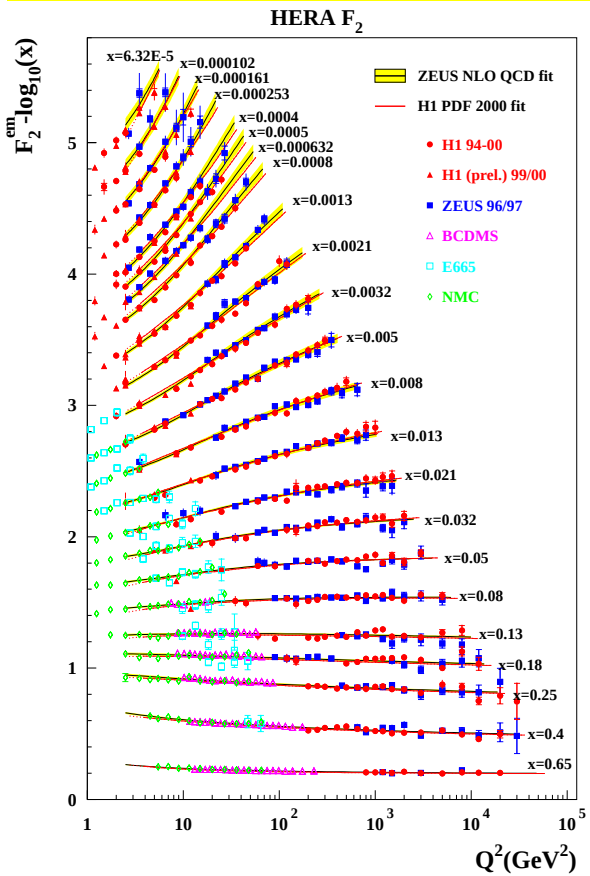
- PDFs include long-range effects. In spite, pQCD can predict how they "evolve" with Q^2 → DGLAP evolution equation

※ Q^2 dependence of F_2 → "Scaling Violation"

HERA-I : SFs

HERA-I : 94-00 both H1/ZEUS collected ~100 pb^{-1} of e^{+}p, ~15 pb^{-1} of e^{-}p

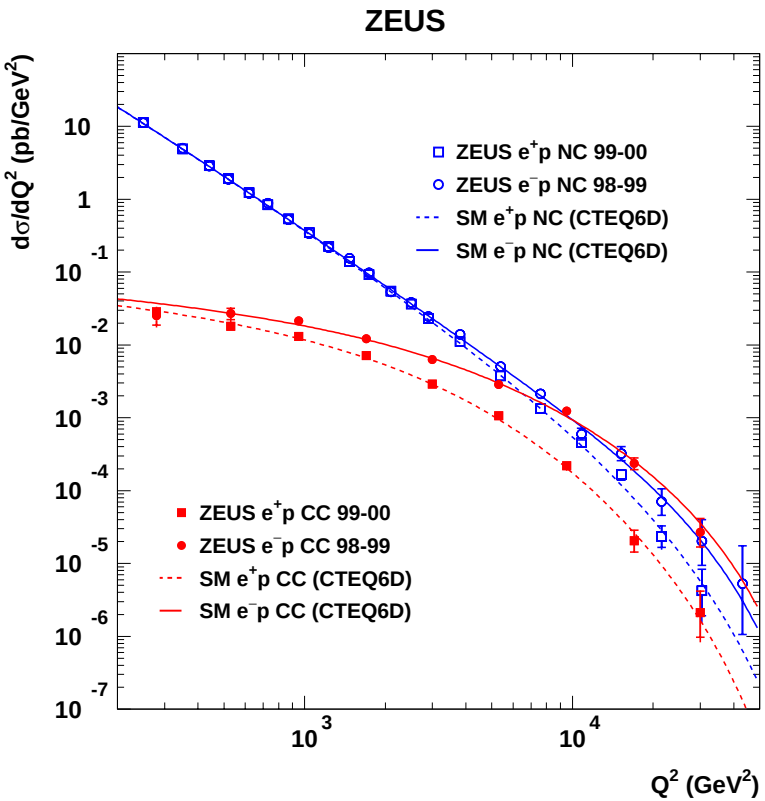
Inclusive SF measurements at mid Q^2



pQCD does excellent jobs !!

pQCD is fine
→ Began to join the game of EW

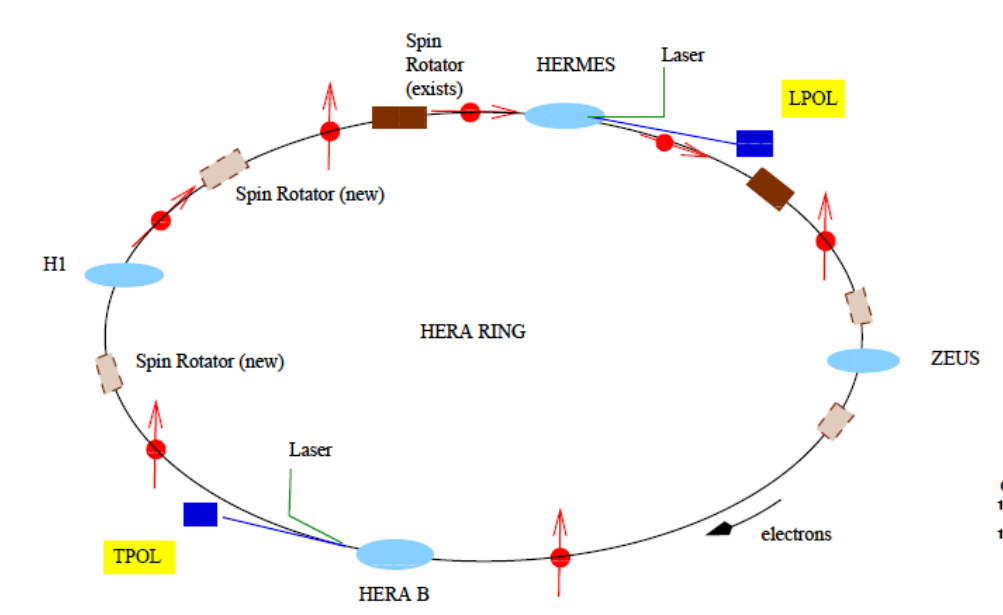
EW unification at high Q^2



(→ See talk by S.Schmitt, QCD-hard session)

HERA I → II

Longitudinal polarization of lepton beam : → Direct EW sensitivity



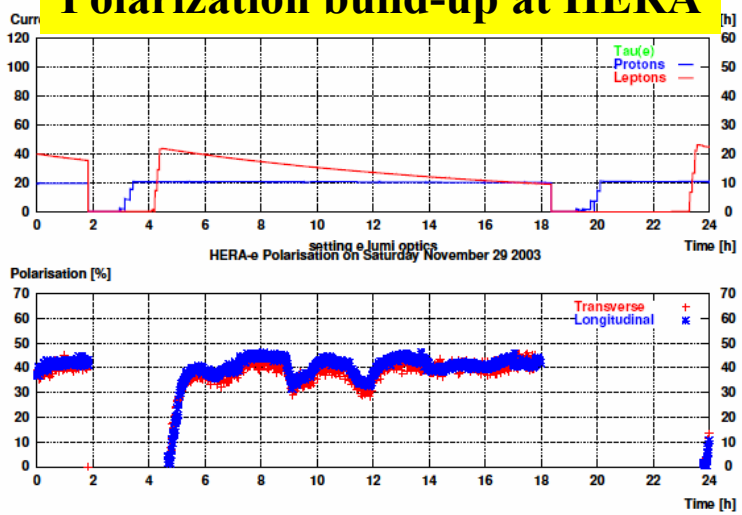
- Sokolov-Ternov effect

→ Lepton beam has transverse polarization

+

- Spin rotator before/after the H1/ZEUS/HERMES detectors.

Polarization build-up at HERA



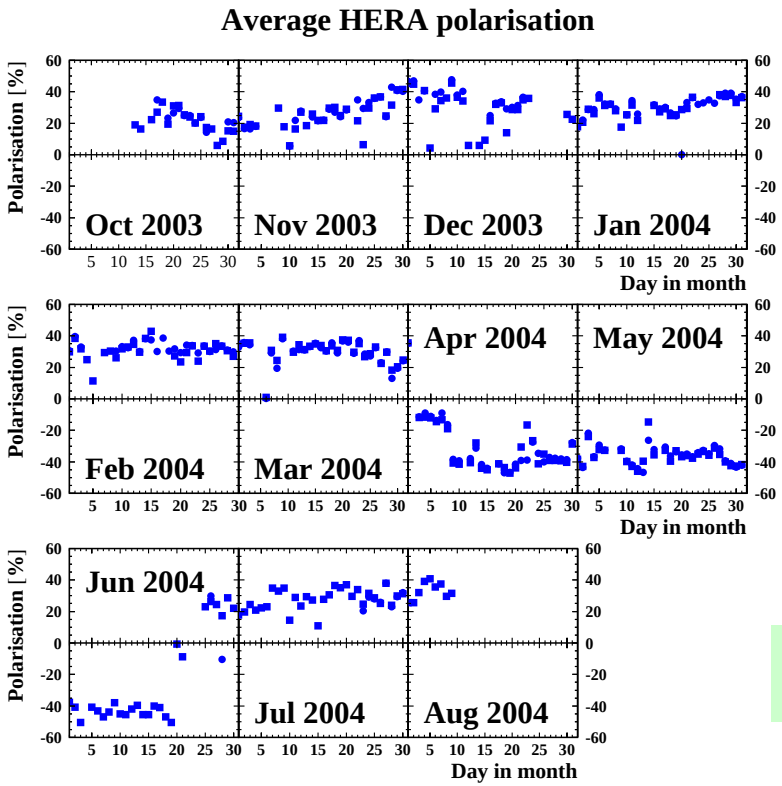
Luminosity Upgrade :

← High-Q^2 requires large luminosity

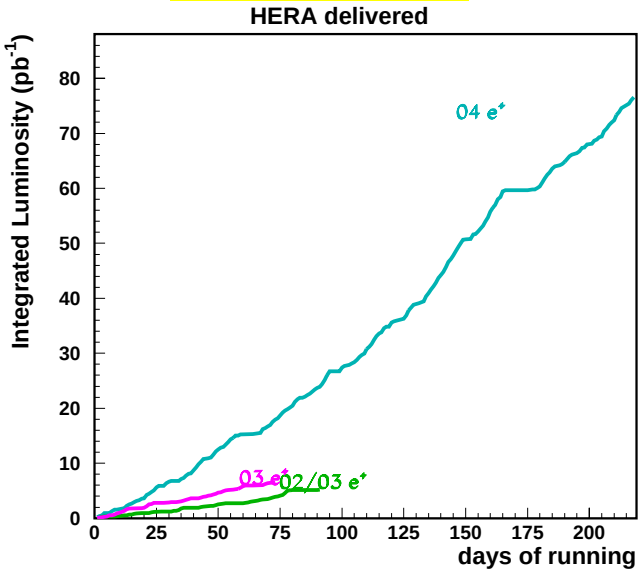
- Final focusing magnets in the detector

HERA-II Running

Longitudinal Polarization



Luminosity



→ HERA-II has begun!

Operation 2003-04 : e^+ p

- **H1 : 15.3 pb^{-1} at P=+33.0 %**
  21.7 pb^{-1} at P=-40.2 %
- **ZEUS : 14.1 pb^{-1} at P=+31.8 %**
  16.4 pb^{-1} at P=-40.2%

What presented in this talk are:
→ The first results of polarized DIS with both helicities at HERA scale !

Polarized Physics at HERA

CC = Pure Weak

→ Cross-section linearly depends on Polarization

→ Direct sensitivity to right-handed charged-current interaction

$$\sigma^{\pm}{}_{CC} = (1 \pm P)\,\sigma_{CC}(P = 0)$$

NC = Interference γ*/Z (+ Z*Z term)

→ Polarization dependence of cross-section is not so dramatic as in CC

→ Sensitivity to the quark coupling constants to Z through the polarization effects (With e^+/e^-, pol/unpol. vector/axial-vector couplings can be disentangled.)

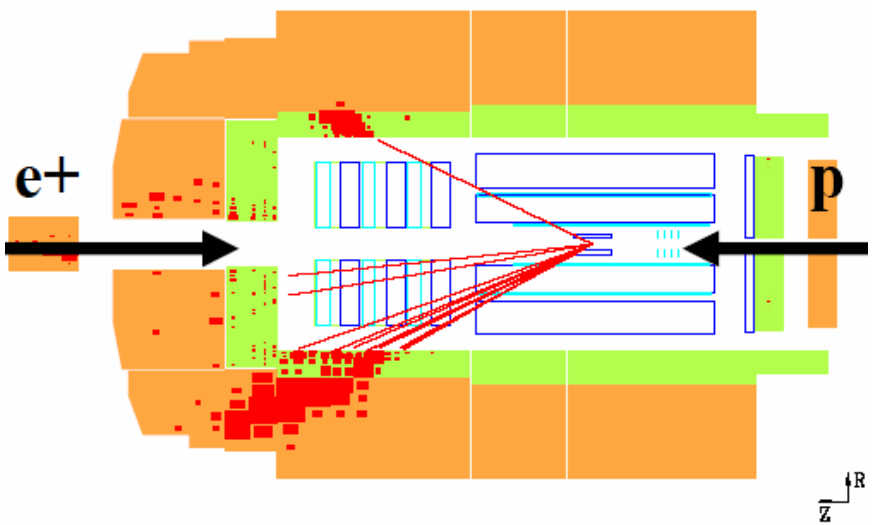
$$\sigma^{\pm}{}_{NC} = Y_+[F_2{}^{0,\pm} + P\,F_2{}^{P,\pm}] + Y_-[xF_3{}^{0,\pm} + P\,xF_3{}^{P,\pm}]$$

$$F_2{}^{P,\pm} = \sum x(q + \bar{q})[\mp 2aQ_q v_q \kappa_Z \pm 2va(v_q{}^2 + a_q{}^2)\kappa_Z{}^2]$$

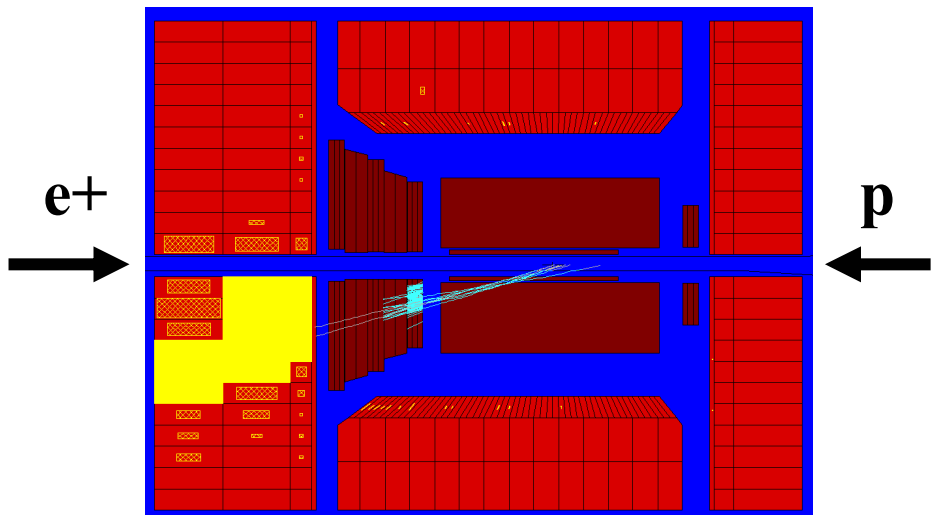
$$xF_3{}^{P,\pm} = \sum x(q - \bar{q})[2vQ_q a_q \kappa_Z - 2(v^2 + a^2)v_q a_q \kappa_Z{}^2]$$

DIS Events

NC Event



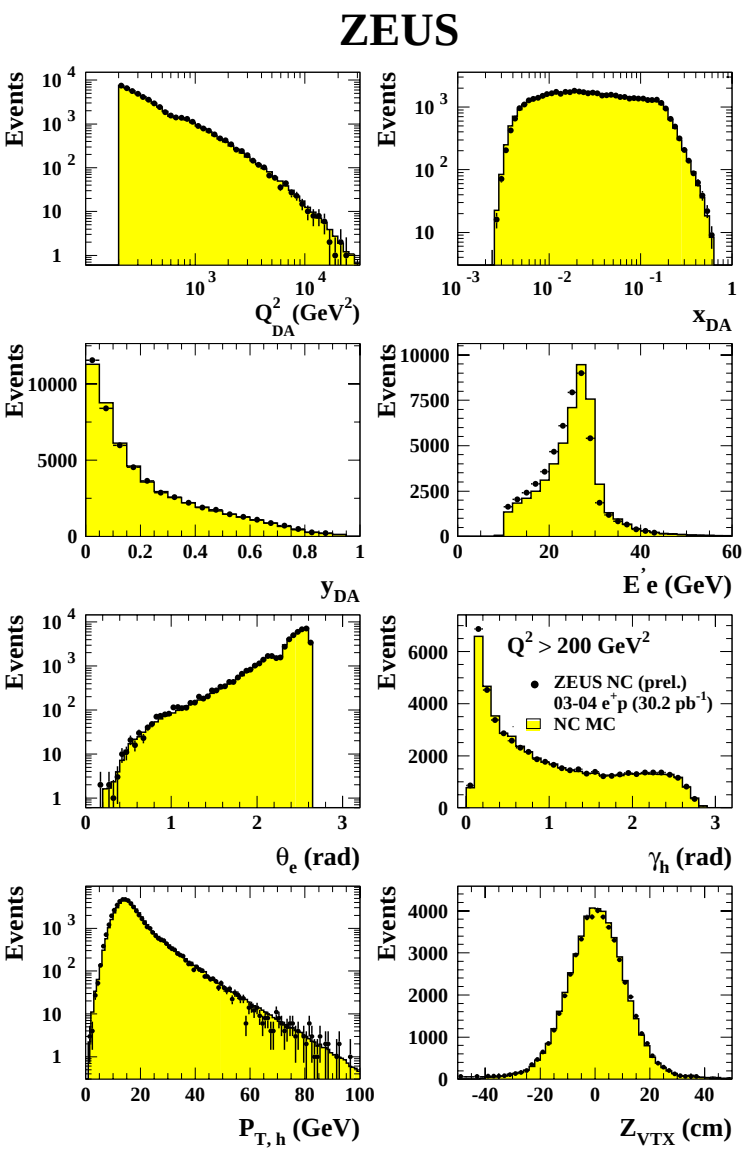
CC Event

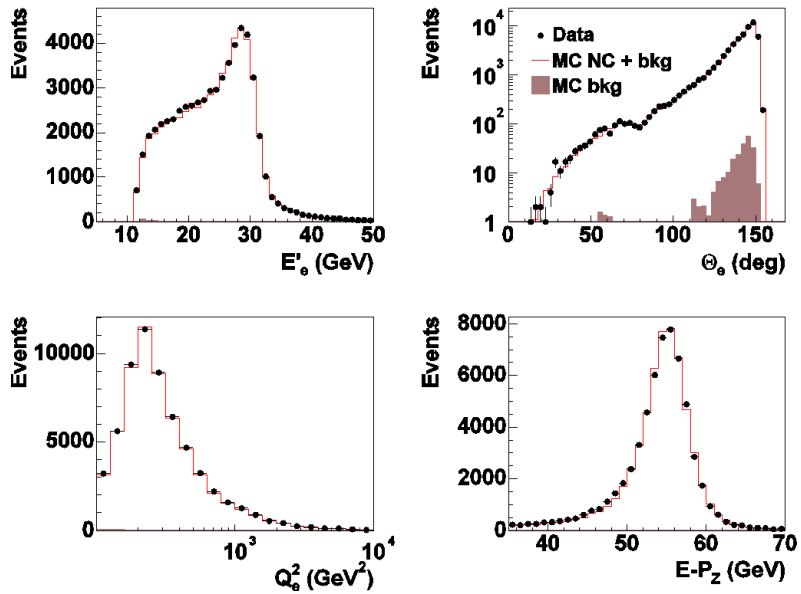


- Selection: presence of high p_T scattered electron
- Kinematics well reconstructed using either electrons or hadrons (or both)

- Selection: presence of large missing transverse energy: Pt,miss
- Kinematics reconstructed using hadrons (only possible)

NC Events : Detector Controls



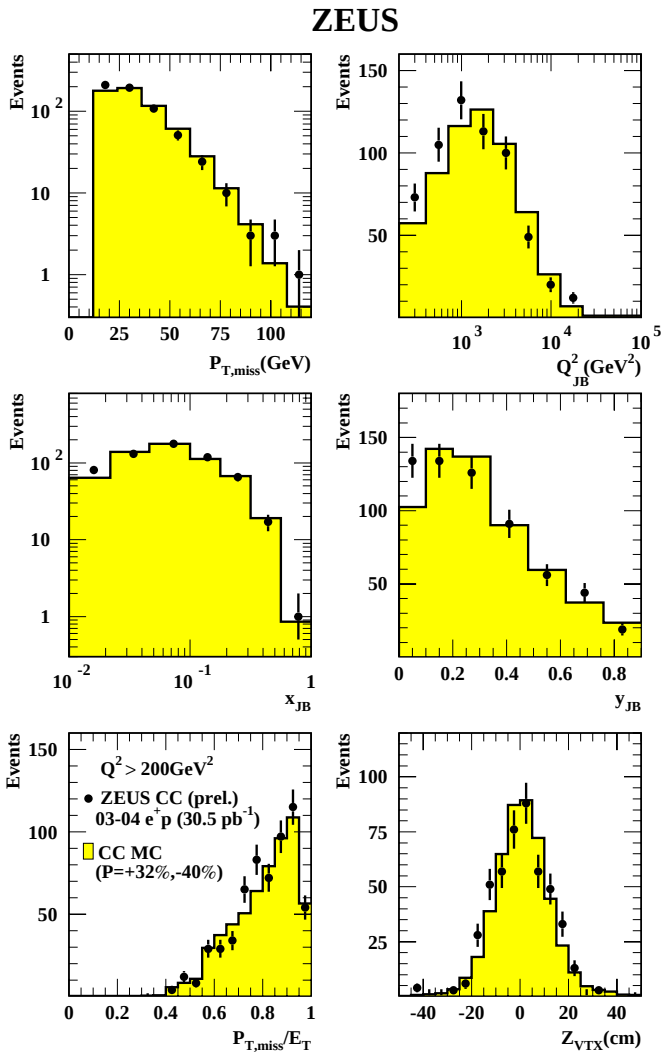


● Electron energy (Ee), scattering angle (θ_e) , angle of hadron system (γ_h), vertex position (Zvtx) etc. are well-reproduced.

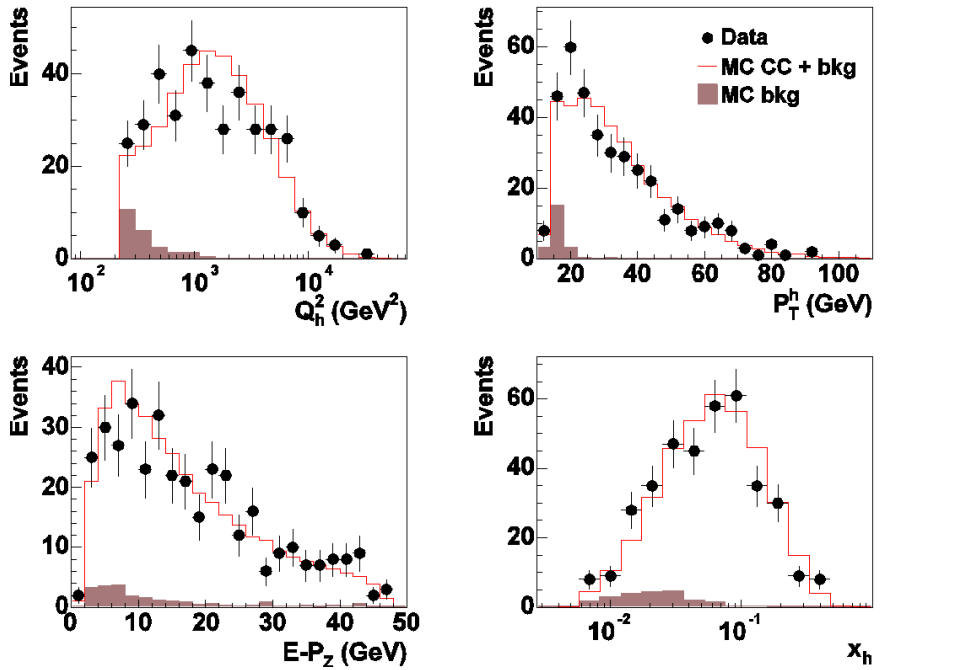
→ H1/ZEUS detectors are well performing and well understood.

● CC : Hadronic energy measurement is crucial. Well understood and checked with NC real data!

CC Events



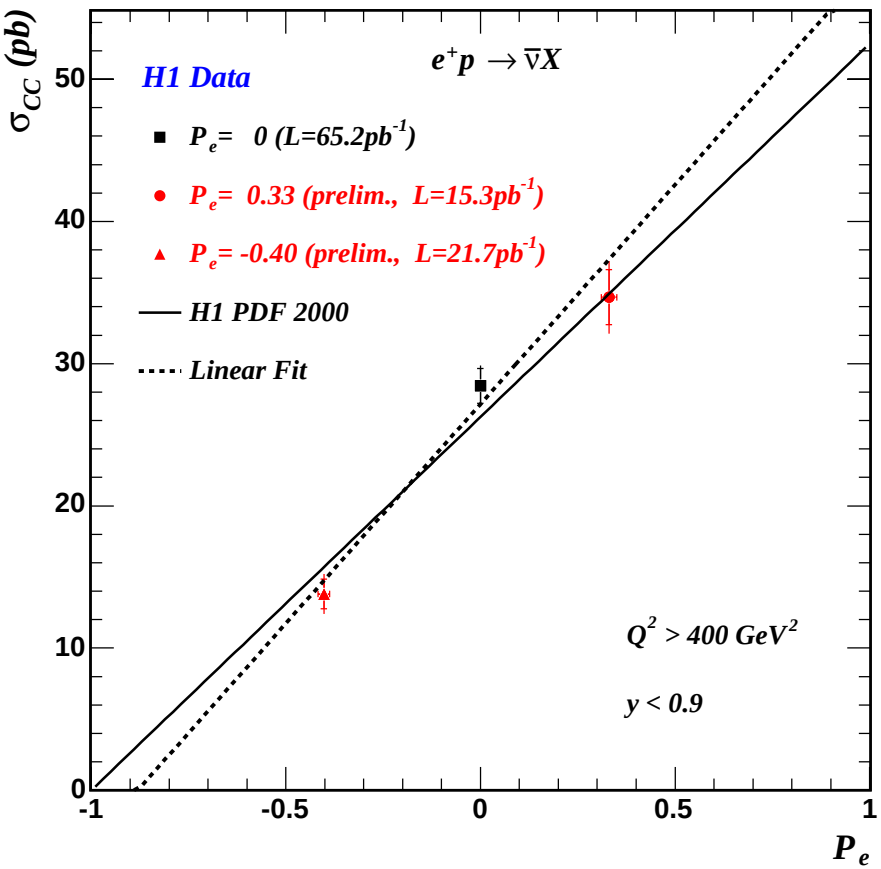
H1 Preliminary



- Missing transverse energy (P_T, miss) and longitudinal hadronic energy (E-P_Z) etc. are well described.

→ Ready to unfold data to get cross-sections!

CC Total Cross-Section [H1]



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

$$P = +33 \pm 2\%$$
$$\sigma = 34.67 \pm 1.9(stat.) \pm 1.7(syst.)\ pb$$
$$P = -40.2 \pm 1.5\%$$
$$\sigma = 13.80 \pm 1.0(stat.) \pm 1.0(syst.)\ pb$$

Lumi error included

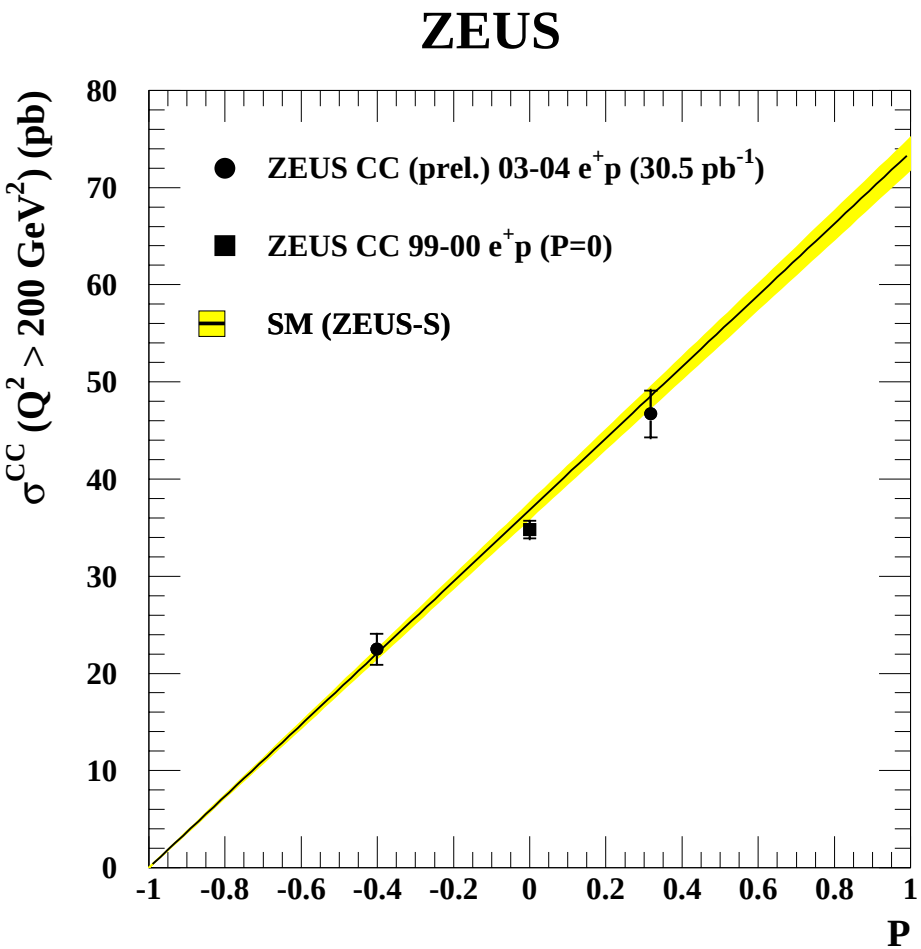
Remind: CC is pure weak
→ $\sigma_{CC}(P) = (1+P)\ \sigma_{CC}(P=0)$

A linear fit (w.r.t. P) gave:

$$\sigma_{CC}(P=-1) = -3.7 \pm 2.4(stat.) \pm 2.7(syst.)\ pb$$

- Consistent with the SM prediction of: σ_{CC} (RH)=0

CC Total Cross-Section [ZEUS]



$Q^2 > 200\ GeV^2$

$$P = +31.8 \pm 0.9\%\ (L = 14.1\ pb^{-1})$$
$$\sigma = 46.7 \pm 2.4(stat.) \pm 1.0(syst.)$$
$$\pm 2.3(lumi)\ pb$$

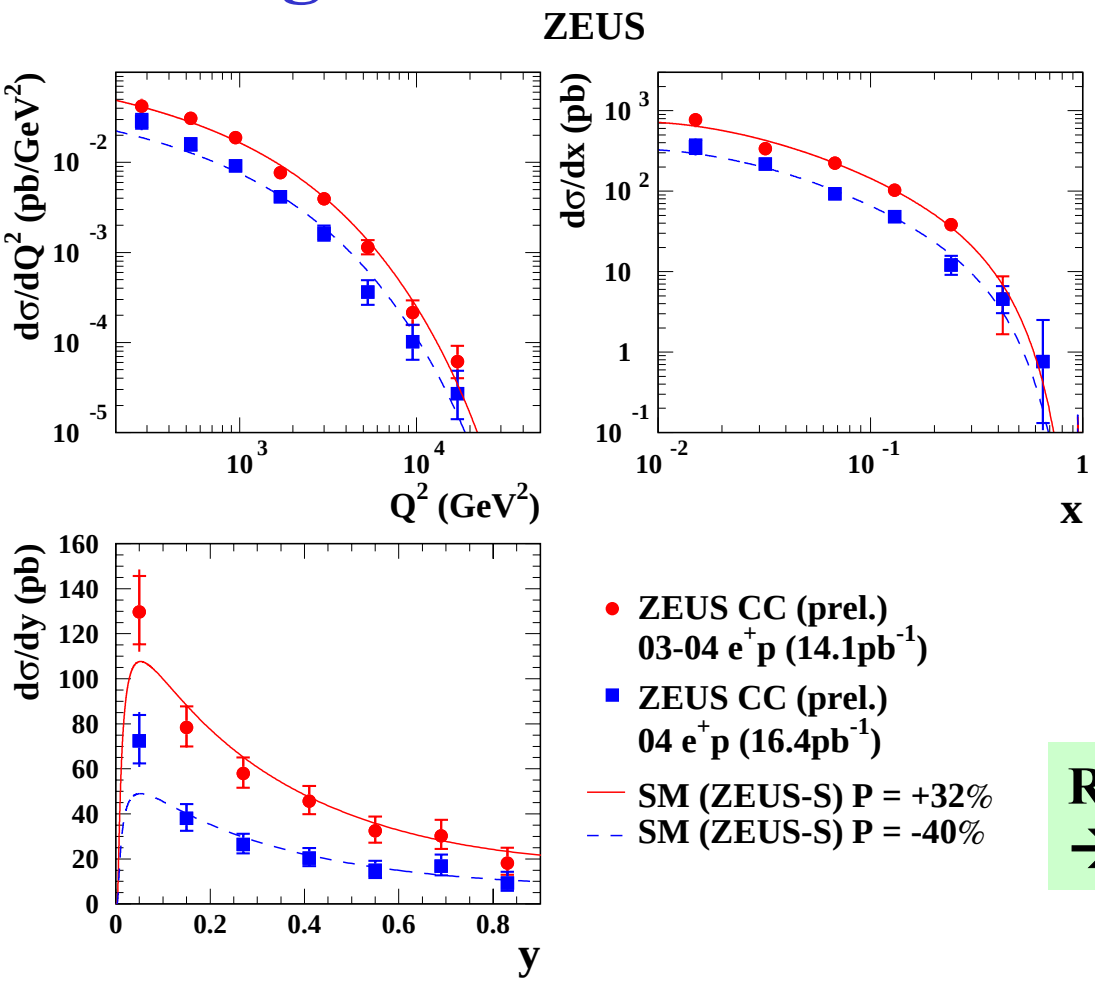
3.4 σ above the unpol. prediction

$$P = -40.2 \pm 1.1\%\ (L = 16.4\ pb^{-1})$$
$$\sigma = 22.5 \pm 1.6(stat.) \pm 0.5(syst.)$$
$$\pm 1.1(lumi)\ pb$$

6.1 σ below the unpol. prediction

- Consistent with the SM prediction (pdf=ZEUS-S)
- No apparent observation of σ_{CC} (RH).

CC Single Differential Cross-Sections [ZEUS]



- $d\sigma / dQ^2$
- $d\sigma / dx$
- $d\sigma / dy$

Remind: CC is pure weak
→ $\sigma_{CC}(P) = (1+P)\ \sigma_{CC}(P=0)$

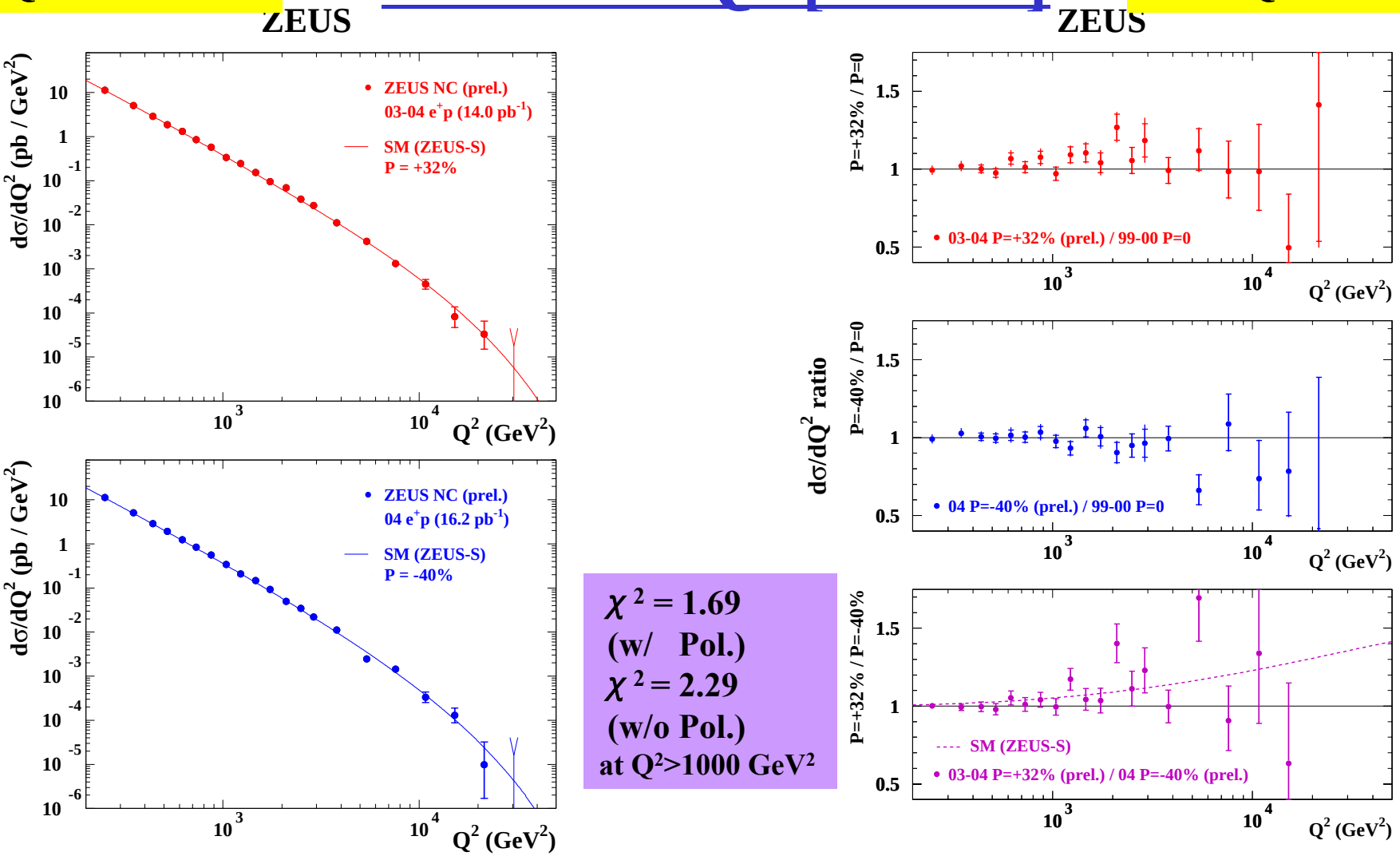
- Polarization effects observed in overall, i.e. no phase space bias.

→ Agrees with the SM prediction of : overall normalization change by (1+P) factor.

NC $d\sigma/dQ^2$ [ZEUS]

$Q^2 > 200$ GeV^2

$d\sigma/dQ^2$ ratio



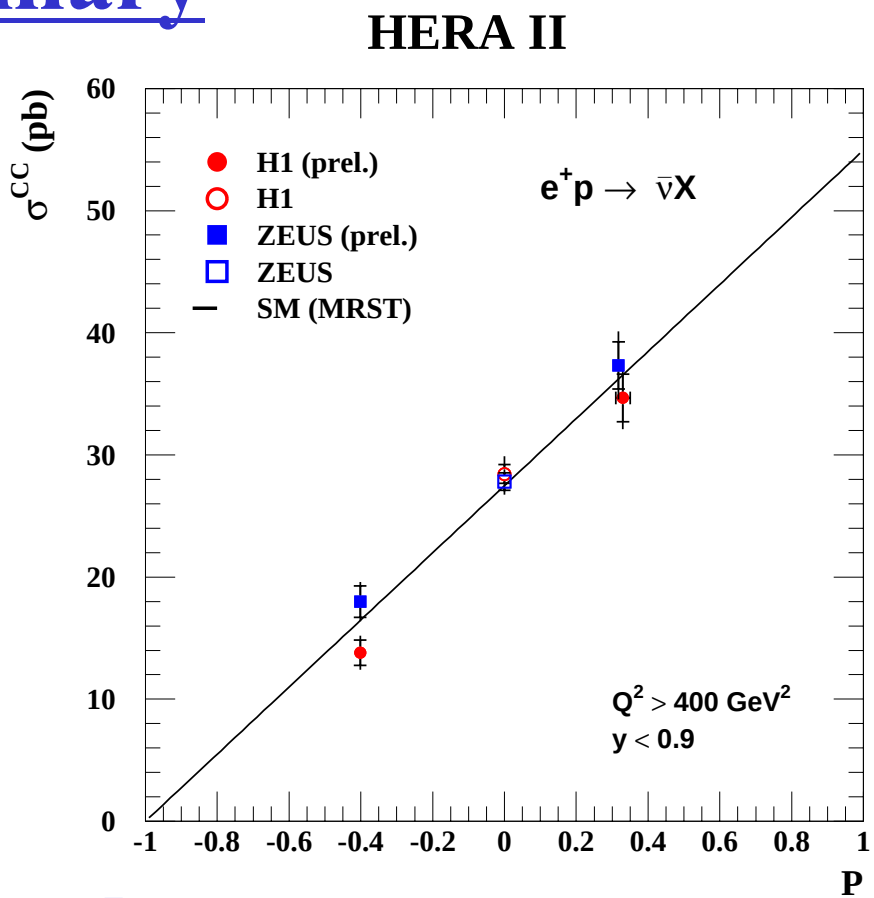
$\chi^2 = 1.69$ (w/ Pol.)
$\chi^2 = 2.29$ (w/o Pol.)
at $Q^2 > 1000$ GeV^2

- Consistent with the SM prediction including the Polarization effect.

(And data slightly favor it than the prediction for unpol. beam.)

Summary

- HERA-II has begun and achieved now a stable and regular operation!
- The first physics results using longitudinally polarized e^+ beam were presented.
- CC, pure Weak, cross-sections were consistent with the SM prediction, i.e.
  → Consistent with the $\sigma_{CC}(RH)=0$
- NC, interference between EM and Weak, cross-sections were consistent with the SM prediction with polarization effect included.



Outlook

- HERA will provide e^- from October (shutdown mid.August – September)

→ Much more on EW from HERA will come !