Recent HERA results on inclusive deep inelastic scattering

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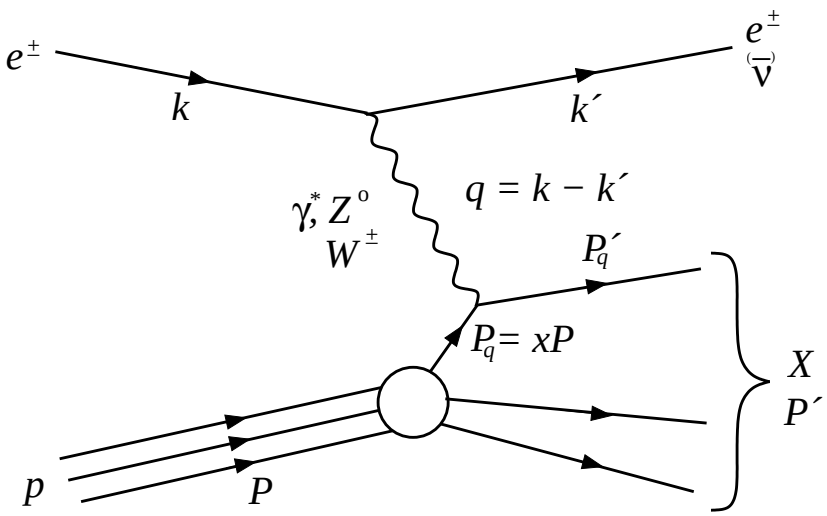
Moriond QCD, 31.3.2004

- Structure functions and parton densities
- α_S determination
- Polarized charged current cross section

Deep inelastic scattering



Kinematic variables:

- $Q^2 = -q^2 =$ momentum transfer
- $y = \frac{P\cdot q}{P\cdot k} = (1+\cos\Theta^*_{eq})/2 =$ inelasticity
- $s = (P+k)^2 = (320\,\mathrm{GeV})^2 = ep$ cms energy
- $x = \frac{Q^2}{ys} =$ momentum fraction

reconstructed from e and/or hadronic final state.

Neutral current:

$$\frac{d^2\sigma^{NC}}{dx\,dQ^2}(e^+_{L,R}) = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\,F_2^{L,R} - Y_-\,xF_3^{L,R} - y^2F_L\right]$$

$$Y_+ = 1+(1-y)^2, \quad Y_- = 1-(1-y)^2$$

$$F_2^{L,R} = \sum_q x \left[q(x,Q^2) + \bar{q}(x,Q^2)\right] A_q^{L,R}$$

$$xF_3^{L,R} = \sum_q x \left[q(x,Q^2) - \bar{q}(x,Q^2)\right] B_q^{L,R}$$

$$A_q^{L,R} = e_q^2 + 2e_e(v_e \pm a_e)e_q v_q \chi_Z + (v_e \pm a_e)^2(v_q^2 + a_q^2)\chi_Z^2$$

$$B_q^{L,R} = \pm 2e_e(v_e \pm a_e)e_q a_q \chi_Z \pm (2v_e a_e)v_q a_q \chi_Z^2$$

with $L = +$, $R = -$

$$\chi_Z = \frac{1}{4\sin^2\Theta_W \cos^2\Theta_W} \frac{Q^2}{Q^2 + M_Z^2}$$

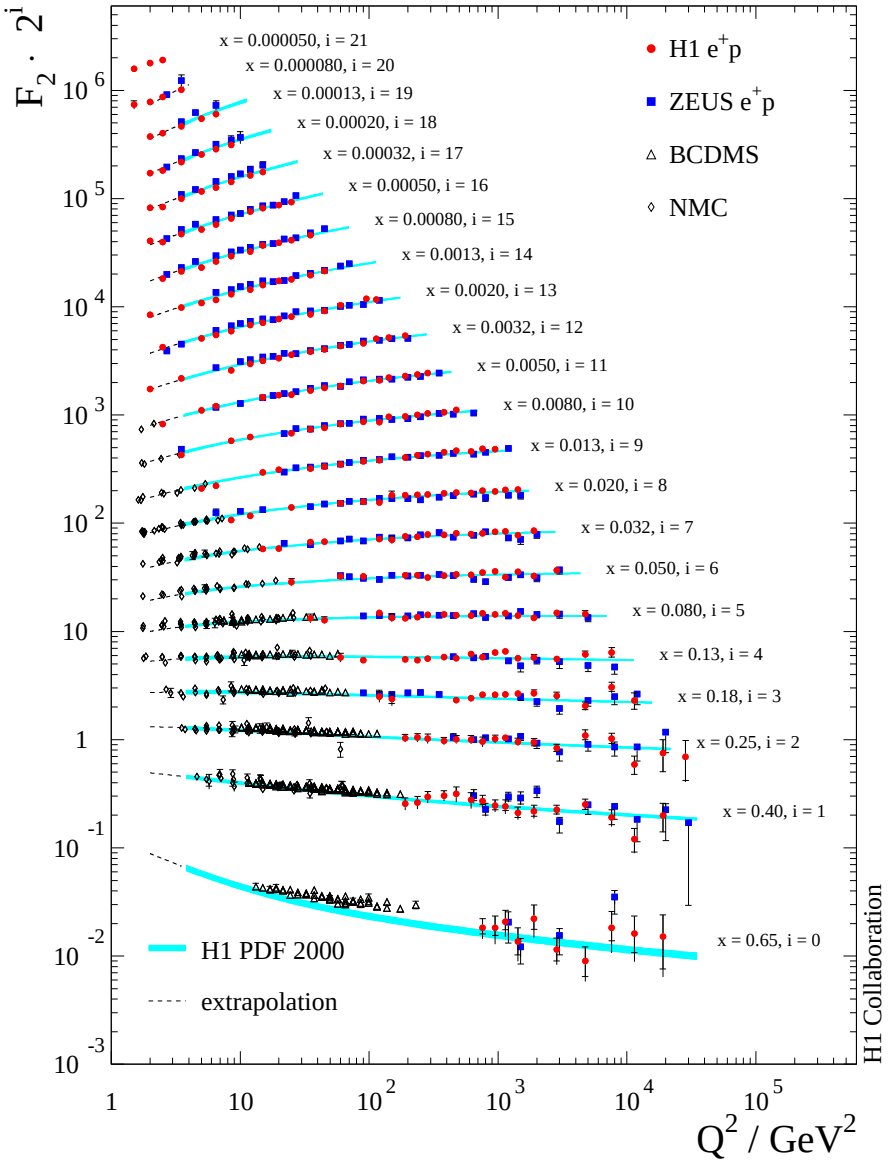
Charged current:

$$\frac{d^2\sigma^{CC}}{dx\,dQ^2}(e^+) = (1+P)\frac{G_F^2}{2\pi}\left[\frac{M_W^2}{Q^2+M_W^2}\right]^2 x\left[\bar{u} + \bar{c} + (1-y)^2(d+s+b)\right]$$

Longitudinal polarization:

$$P = \frac{N_R - N_L}{N_R + N_L}$$

F_2

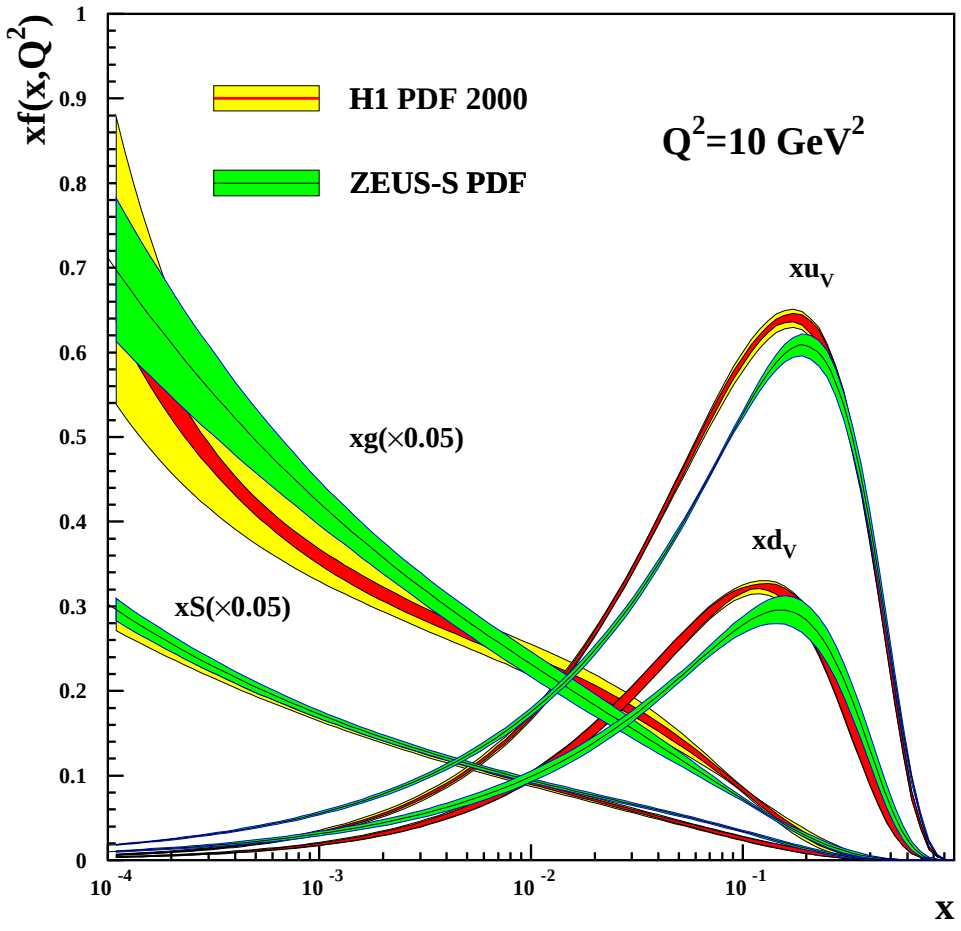


- HERA data cover 4 decades in x and Q^2. Good agreement between H1 and ZEUS.
- Experimental precision reaches 2–3% in the central region.
- Smooth transition to fixed target data, except at the highest x.
- Strong scaling violations: $\partial F_2/\partial Q^2$ varies with x.

$\Rightarrow$ Gluon density and α_S determination.

- Parton densities are parametrised in x at a starting scale $Q_o^2 = 4\,\mathrm{GeV}^2$.
- Good NLO QCD fit of Q^2 evolution using DGLAP equation.

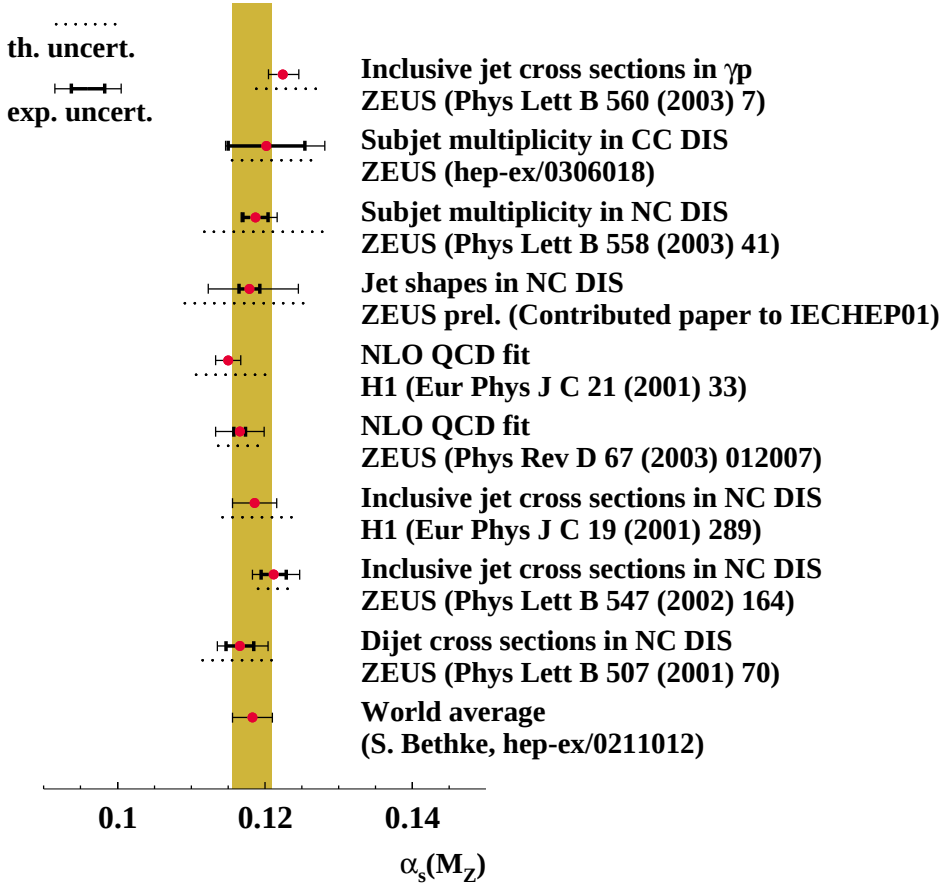
Parton Density Functions



- PDFs and uncertainties extracted from NLO DGLAP QCD fits to F_2.
- Strong rise of the Sea towards low x, driven by gluon splitting.
- Satisfactory agreement between ZEUS and H1.
- Remaining differences due to:
  - Kinematic range, starting scale.
  - Inclusion of fixed target data.
  - PDF parametrisation.
  - Heavy quark treatment.
- Differences are smaller at larger Q^2.

α_S

- α_S extracted from NLO DGLAP QCD fits to F_2.
- Needs HERA + fixed target data.
- H1: 0.1150 $\pm$ 0.0017 (exp.) + 0.0009 - 0.0007 (model) $\pm$ 0.005 (scale)
- ZEUS: 0.1166 $\pm$ 0.0008 (unc.) $\pm$ 0.0032 (corr.) $\pm$ 0.0036 (norm.) $\pm$ 0.0018 (model) $\pm$ 0.004 (scale)
- HERA experimental error competitive with the world average.
- Largest uncertainty due to renormalisation and factorisation scale variation by factor 4 (H1) or 2 (ZEUS).



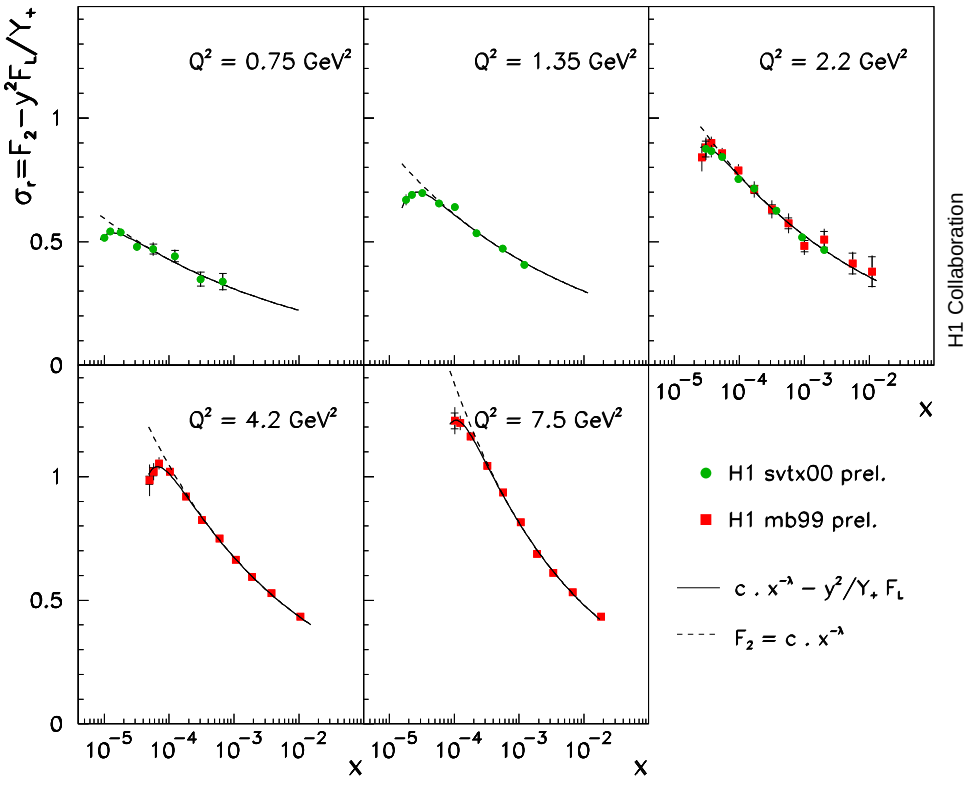
- NNLO analysis should reduce the scale uncertainty by factor 2–3.

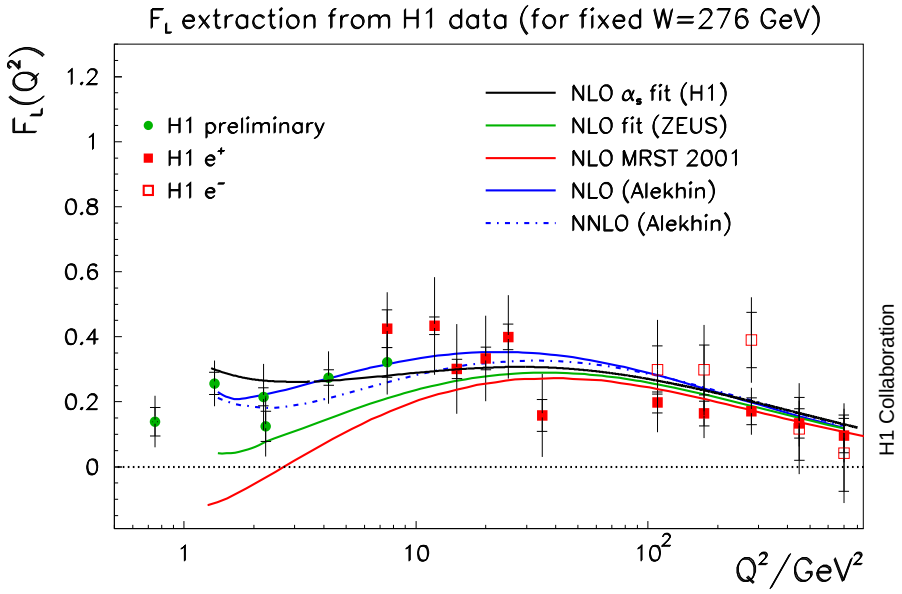
F_L extraction

$$\frac{xQ^4}{2\pi\alpha^2 Y_+}\frac{d^2\sigma^{NC}}{dx\,dQ^2} = F_2 - \frac{y^2}{Y_+}F_L$$

Exploit kinematic factor y^2/Y_+ at high y = low x.

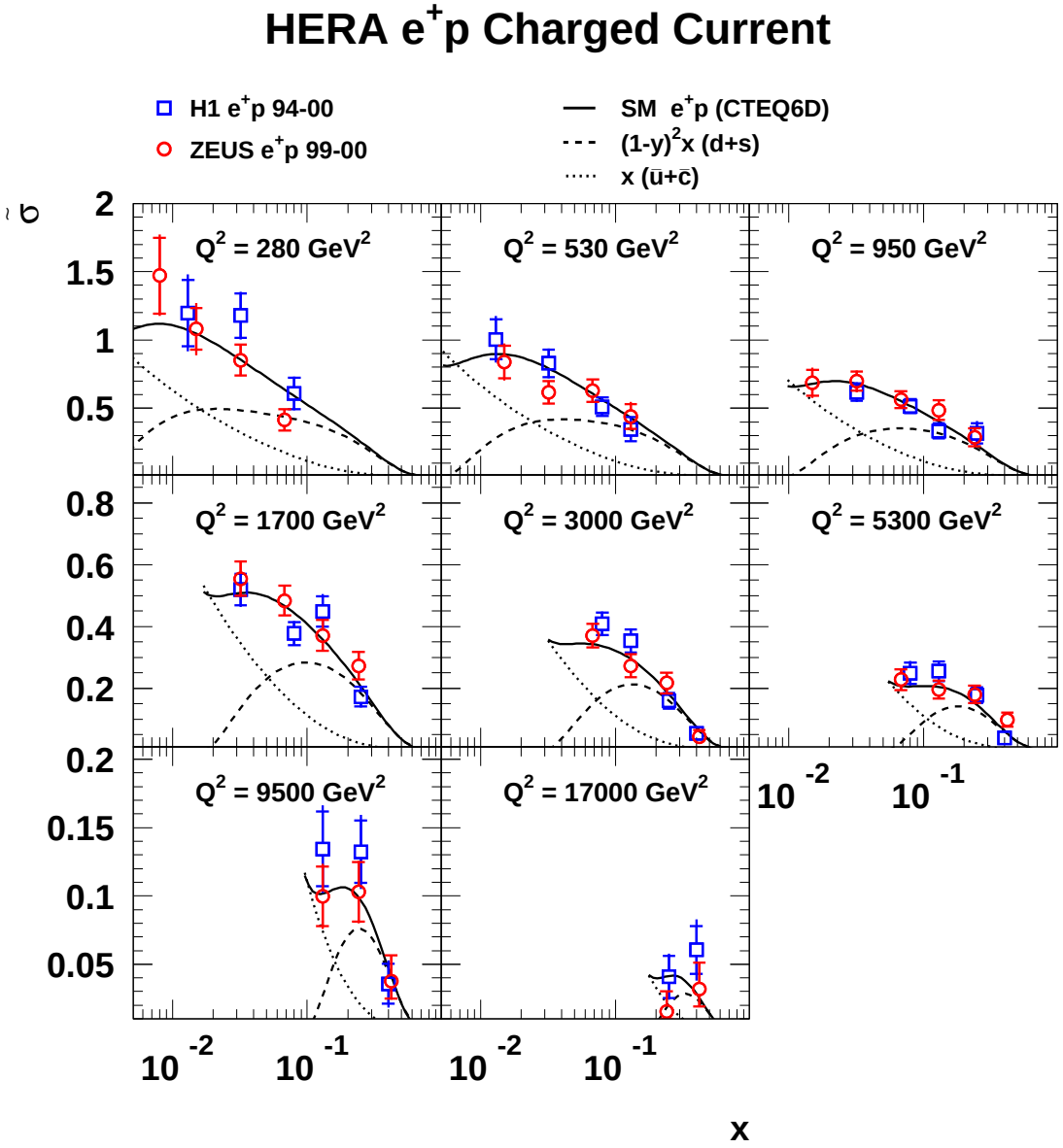
Fit $F_2 \sim x^{-\lambda}$ and extract F_L.





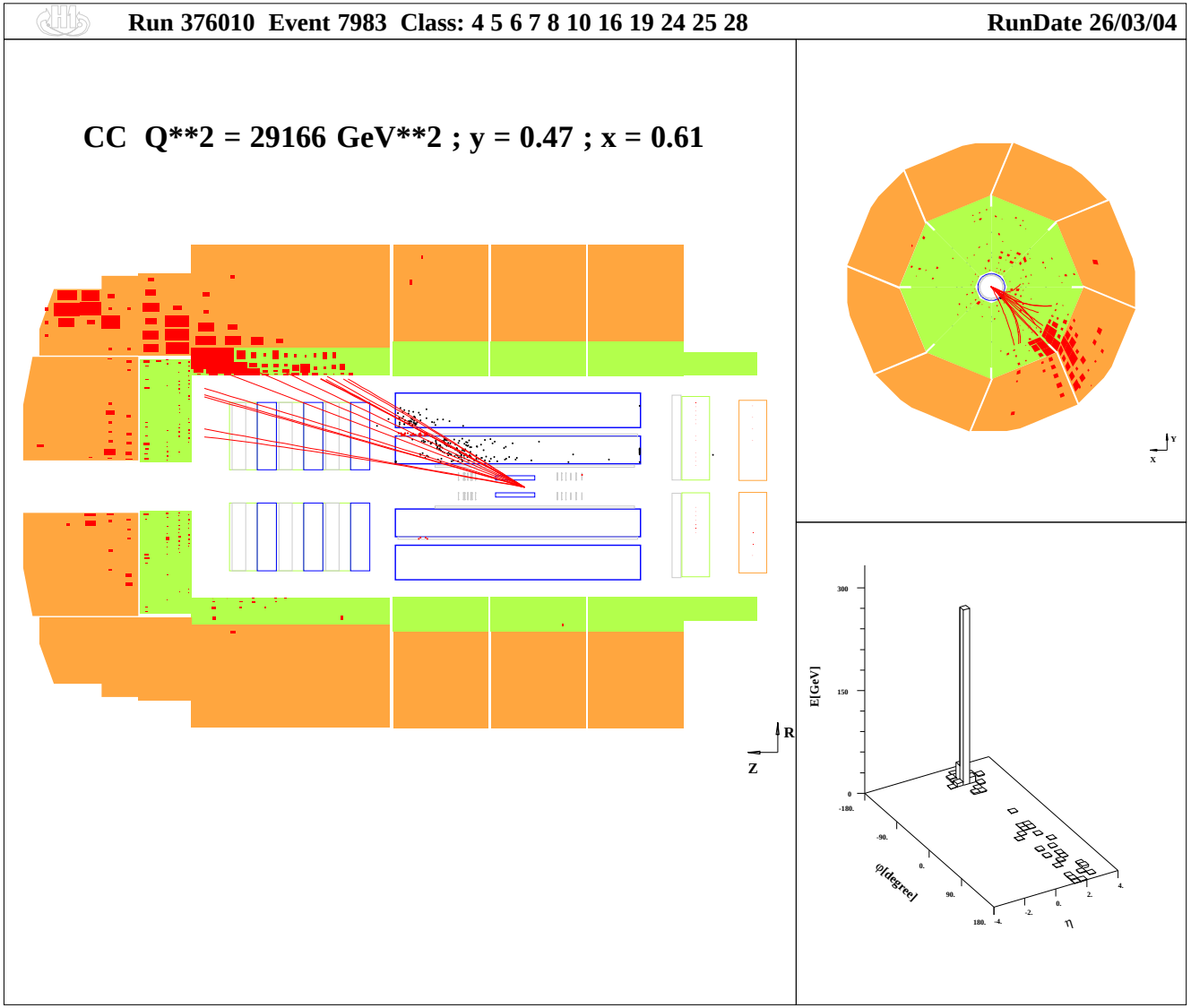
- $F_L = 0$ in the naive parton model.
- Off-mass-shell quarks after gluon radiation or splitting couple to longitudinal photons.
- QCD calculations differ at low Q^2.
- Need run at reduce proton beam energy for direct F_L measurement!

$$\frac{d^2\sigma^{CC}}{dx\,dQ^2}(e^+) \sim x\left[\bar{u} + \bar{c} + (1-y)^2(d+s)\right]$$

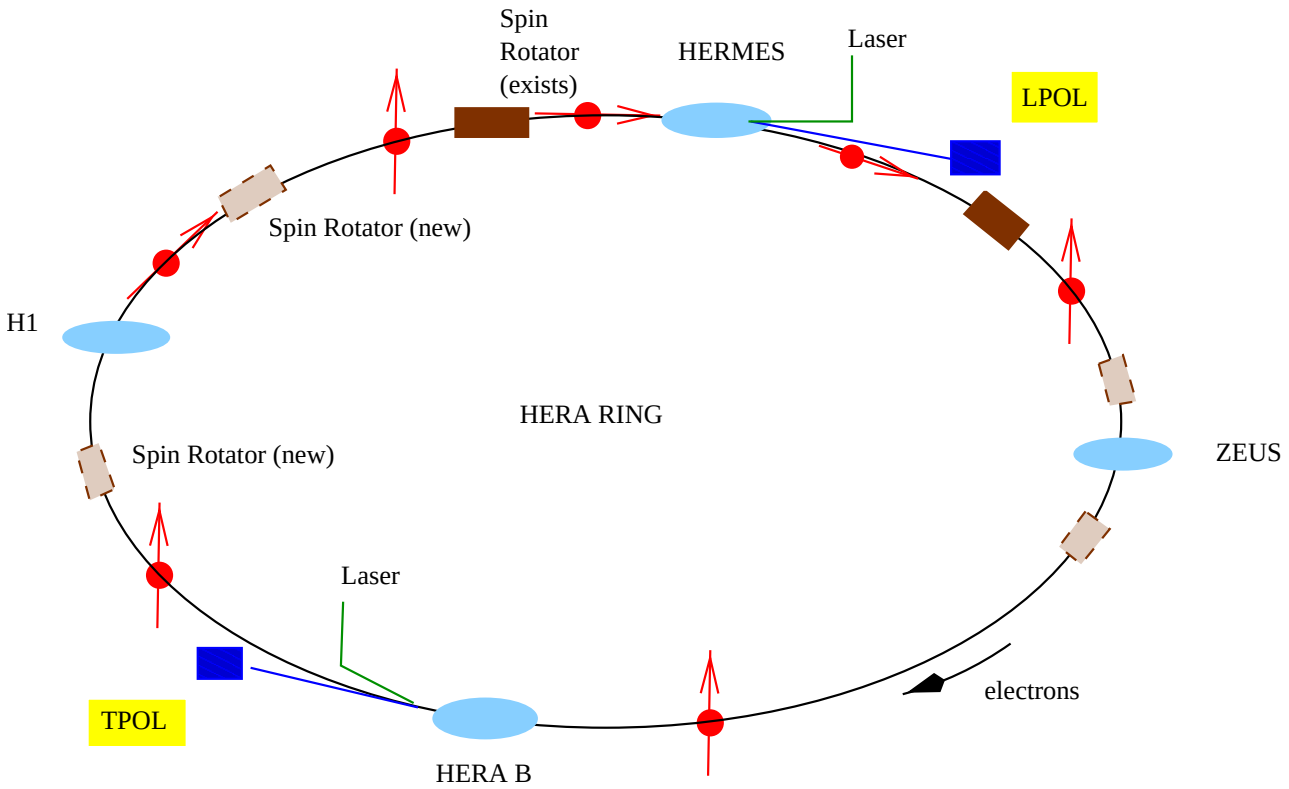


- The double-differential charged current cross section has been measured at medium and high Q^2.
- It agrees with Standard Model expectation.
- It allows a flavour decomposition, giving access to $d + s$.
- More data are being collected at HERA II.

A charged current event from last Friday

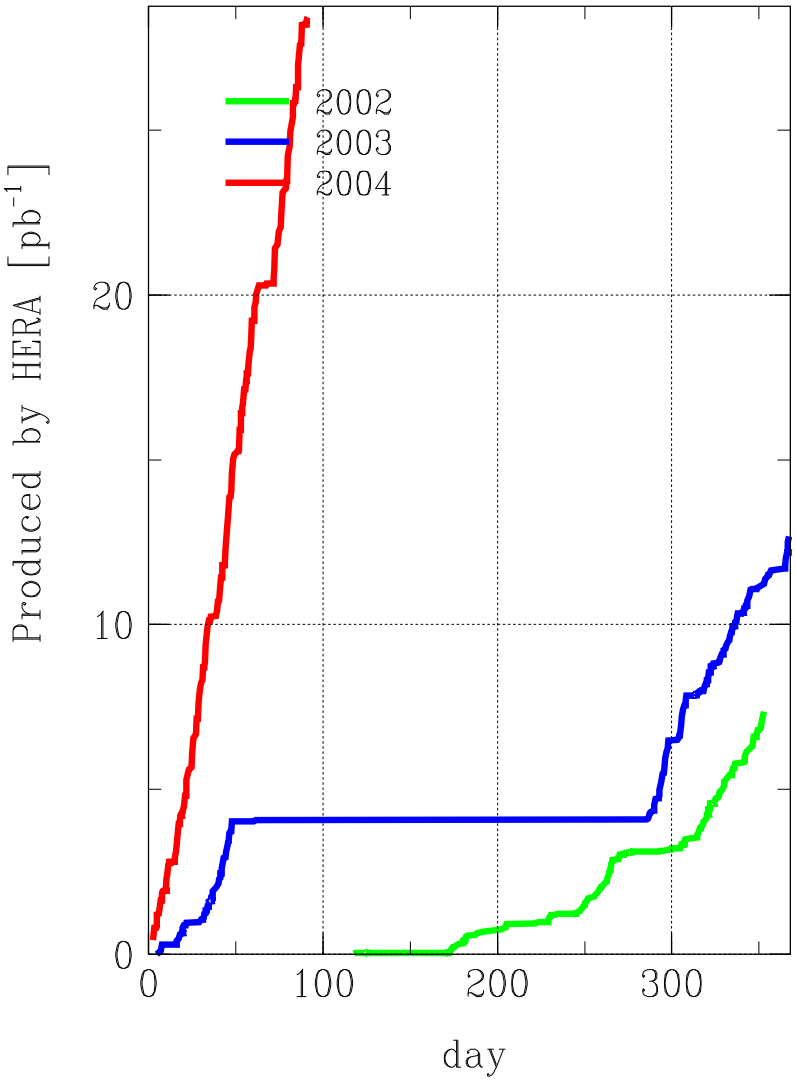


Positron beam polarization



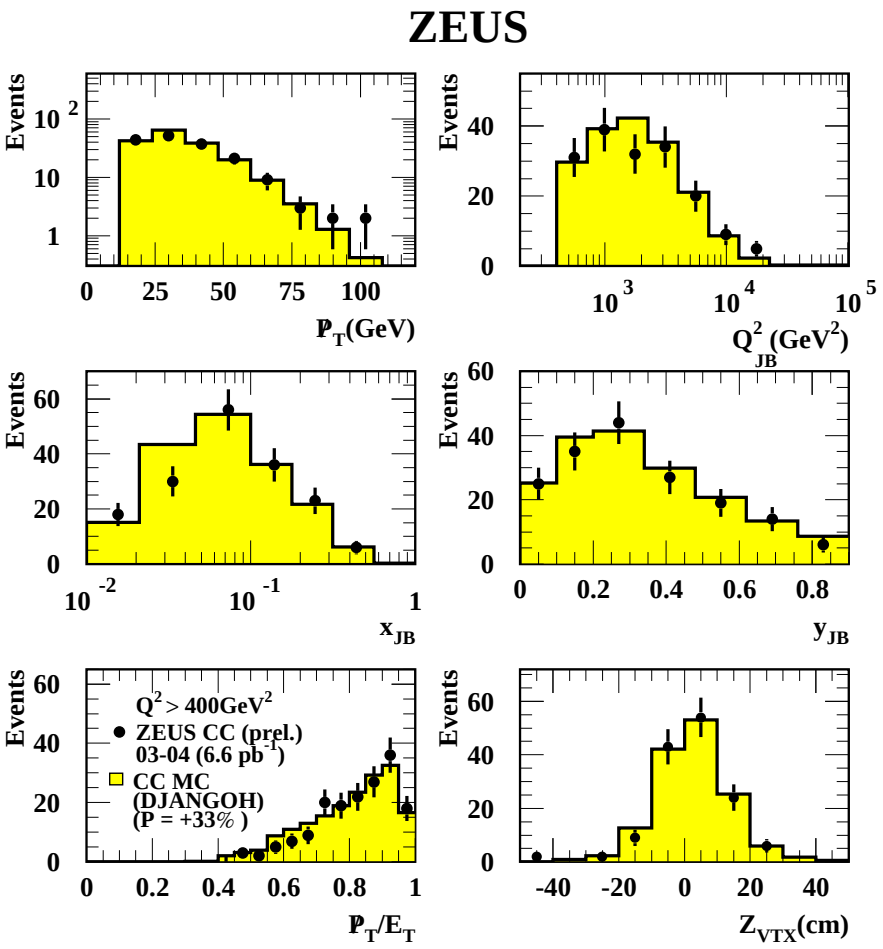
- e^+ magnetic moment couples to storage ring dipole field. Sokolov-Ternov build-up of transverse polarization by synchrotron radiation: $\tau \approx 25\,\text{min}$. $P = 40\%$ reached.
- Spin Rotators use $g - 2$ precession to get longitudinal polarization at the IPs.
- Polarimeters use asymmetries in Compton backscattered polarized laser light.

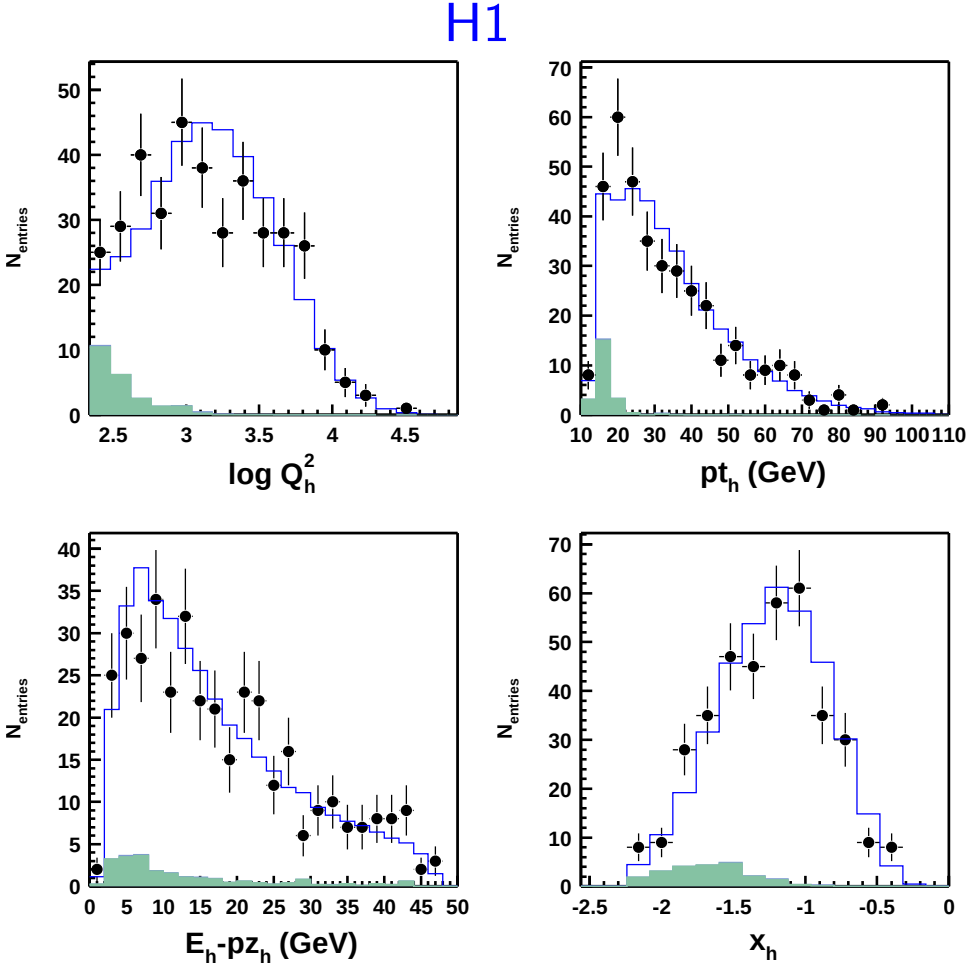
HERA II luminosity



- HERA experiments suffered from large proton-gas background in 2002.
- The pumping power was increased and the synchrotron radiation shielding was improved in the 2003 shutdown.
- HERA is now operating close to design beam currents.
- We expect improvements in duty cycle and specific luminosity (strong beam-beam effect under study).

Charged current analyses: data vs MC

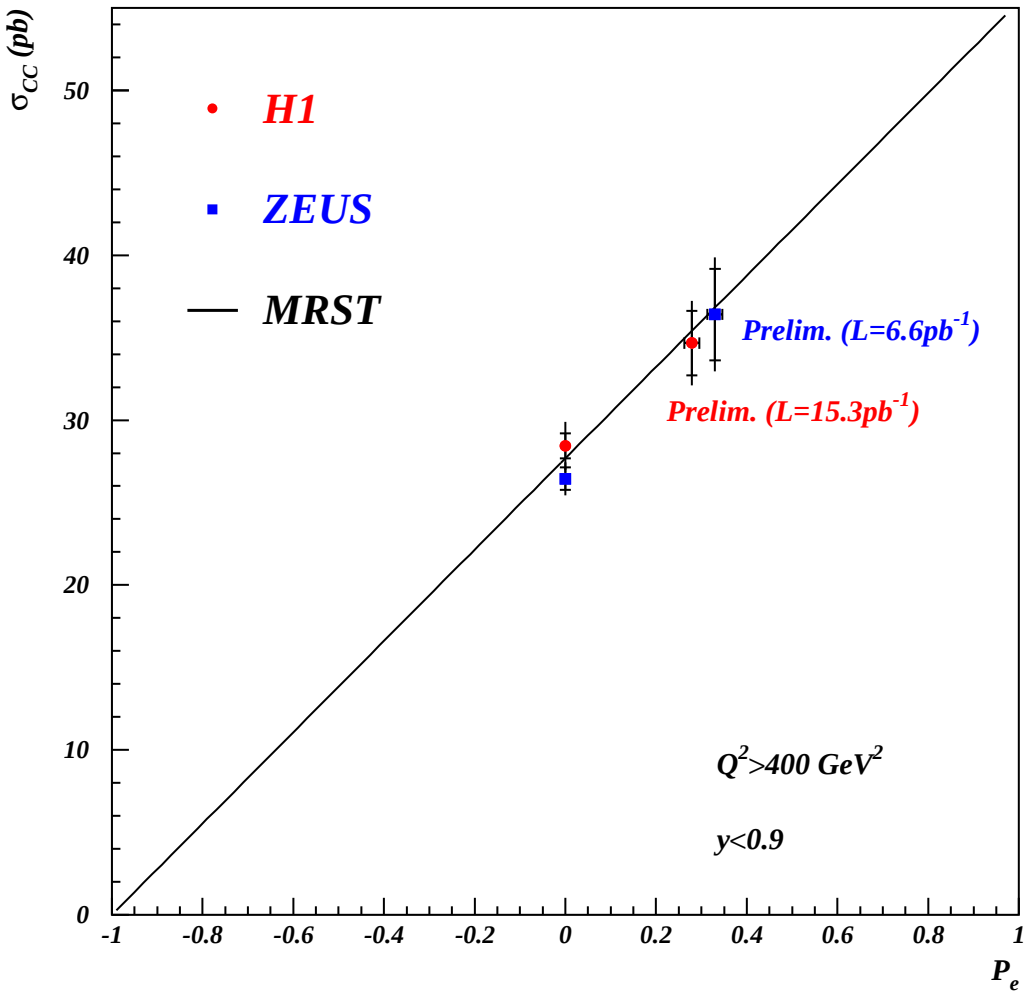




$\mathcal{L} = 6.6\,\mathrm{pb}^{-1}$, $< P >= 33\%$

$\mathcal{L} = 15.3 \pm 0.4\,\mathrm{pb}^{-1}$, $< P >= 28 \pm 1.7\%$

Polarised $e^{\pm}p$ charged current cross section



- The charged current e^+p cross section is measured at $\sim 30\%$ right-handed polarization.
- For $P = 0$ it has been measured at HERA I.
- It is consistent with the Standard Model expectation.
- It is the first measurement of the helicity structure of charged current interactions with a space-like gauge boson.

Helicity flip

- HERA spin rotators will be moved up to negative helicity on 1.4.2004.
- Expect measurement of the full charged current polarization dependence by summer.
- Expect measurement of parity violation in neutral current interactions by summer.

Summary

- Precision data from inclusive deep inelastic scattering continue to be a stringent testing ground for QCD.
- Parton densities and α_S have been extracted in NLO approximation.
- No deviations from DGLAP evolution equation have been observed.
- F_L has been extracted and agrees with QCD expectation. A run at reduced proton energy is required for a direct measurement.
- HERA II with higher luminosity and longitudinally polarized e^+ and e^- beams offers a rich potential for scrutinizing QCD tests in the coming years.
- The polarization dependence of the charged current cross section has been measured for the first time at HERA II and agrees with the Standard Model expectation.