Results from H1 collaboration

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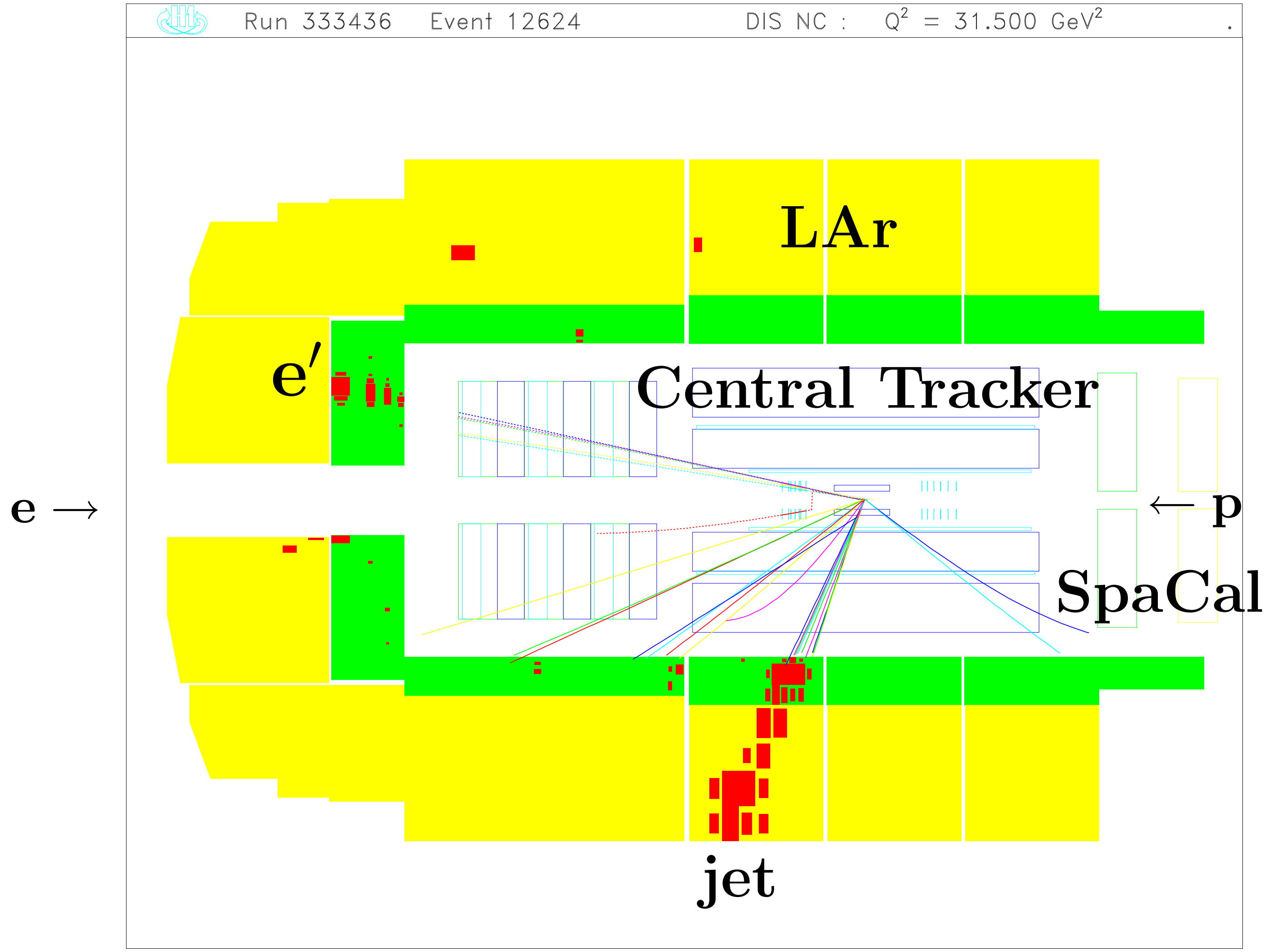
Outline

- HERA and H1
- Deep Inelastic Scattering and PDFs
- Where do we stand: from HERA to LHC
- Summary of HERA-I results
- New Results from HERA-II
- Next Steps at HERA
- Conclusions

Not complete overview of the results. Focus on inclusive measurements. For results on Diffraction, Jet physics see talks of X. Janssen and V. Efremenko.

HERA and H1

DIS Event Reconstruction



Virtuality:

$$Q^2 = 2E_eE'_e(1+\cos\theta_e)$$

Inelasticity:

$$y = 1 - \frac{E'_e(1-\cos\theta_e)}{2E_e}$$

Bjorken x:

$$x = Q^2/(Sy)$$

Kinematics can be reconstructed using e' or hadronic final state.

PDF determination

$$\frac{d^2\sigma^{NC}_{e^\mp p}}{dxdQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left(F_2 - \frac{y^2}{Y_+}F_L \pm \frac{Y_-}{Y_+}xF_3\right) \quad Y_\pm = 1 \pm (1-y)^2$$

Leading order relations:

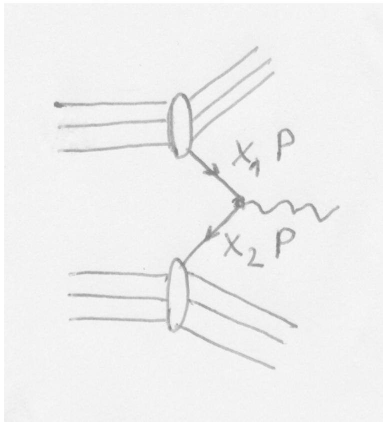
$$\boxed{\begin{array}{cc} F_2 & = x\sum e_q^2(q(x)+\bar{q}(x)) \\ xF_3 & = x\sum 2e_q a_q(q(x)-\bar{q}(x)) \\ \sigma^{CC}_{e^+p} & \sim x(\bar{u}+\bar{c}) + x(1-y)^2(d+s) \\ \sigma^{CC}_{e^-p} & \sim x(u+c) + x(1-y)^2(\bar{d}+\bar{s}) \\ pp \to (\ell\bar{\ell})X & \sim \sum x_1 x_2 q(x_1)\bar{q}(x_2) \end{array}}$$

DIS *ep* and *ed* data allows to unfold individual quark flavors.

Gluon is determined from F_2 scaling violation and from *pp* jet cross section.

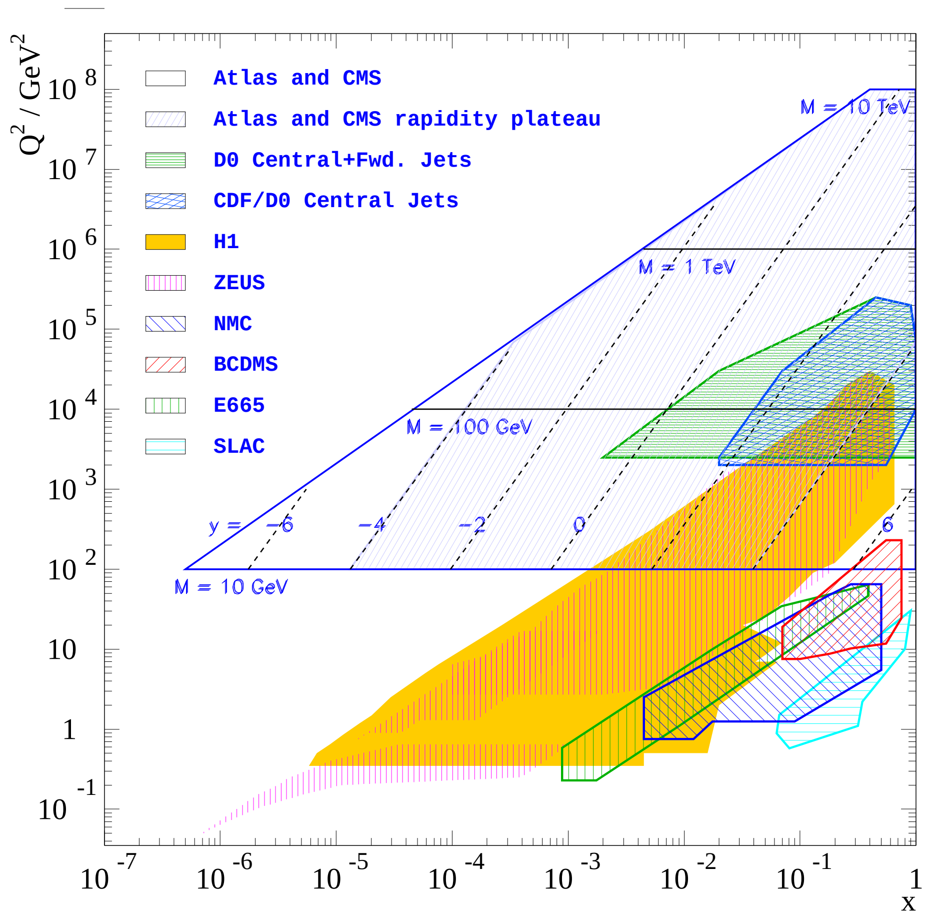
$F_L = 0$ at leading order; proportional to Gluon at higher orders.

HERA and LHC kinematics



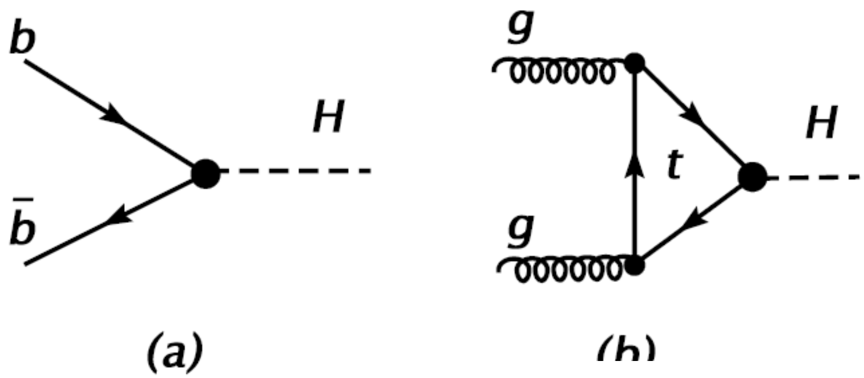
x_1, x_2 are momentum fractions. Factorization theorem states that cross section can be calculated using universal partons × short distance calculable partonic reaction.

$$x_{1,2} = \frac{M}{\sqrt{S}} \exp(\pm y)$$



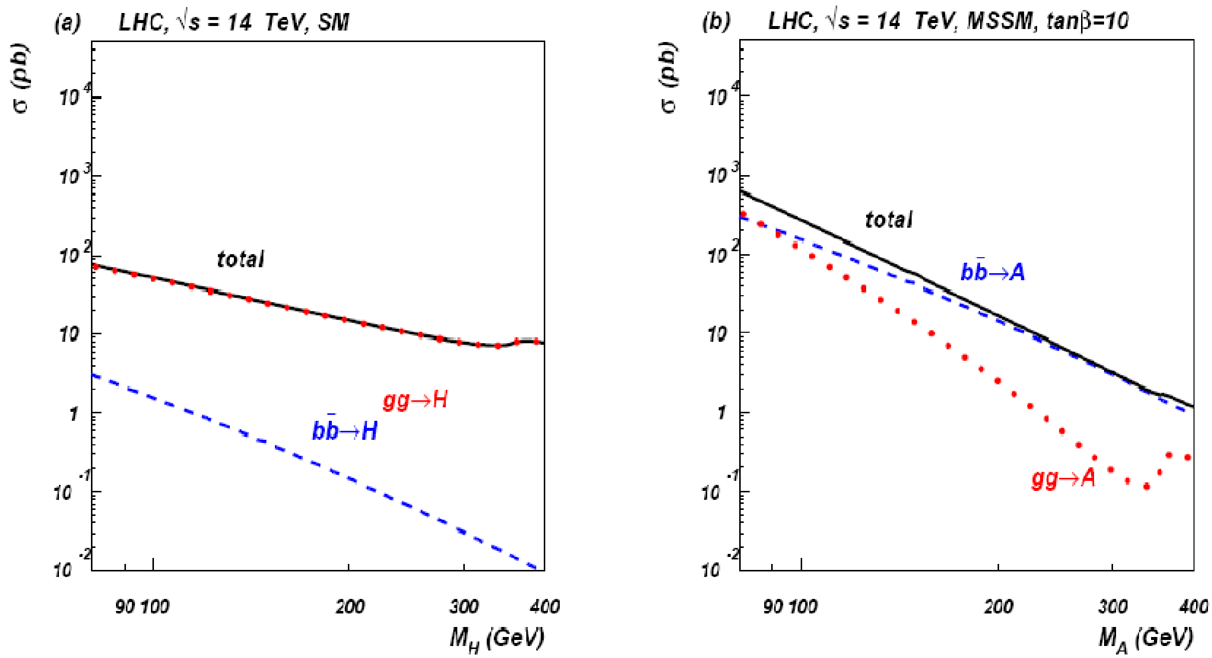
Notation clash: y – rapidity (LHC) vs y – inelasticity (HERA, $Q^2 = Sxy$).

Case study: Higgs production at LHC, SM vs MSSM



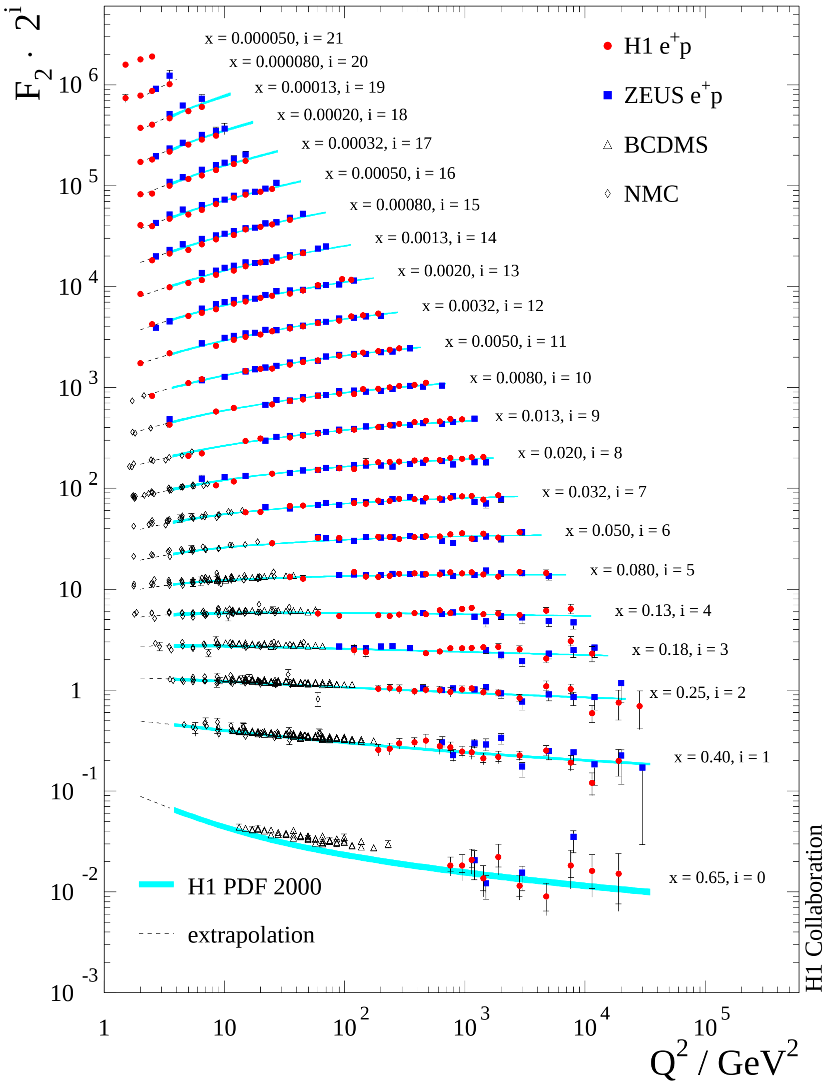
In SM, $b\bar{b} \to H$ is small vs $gg \to H$.
In MSSM, $b\bar{b} \to H$ can be enhanced by $\times \tan^2\beta$

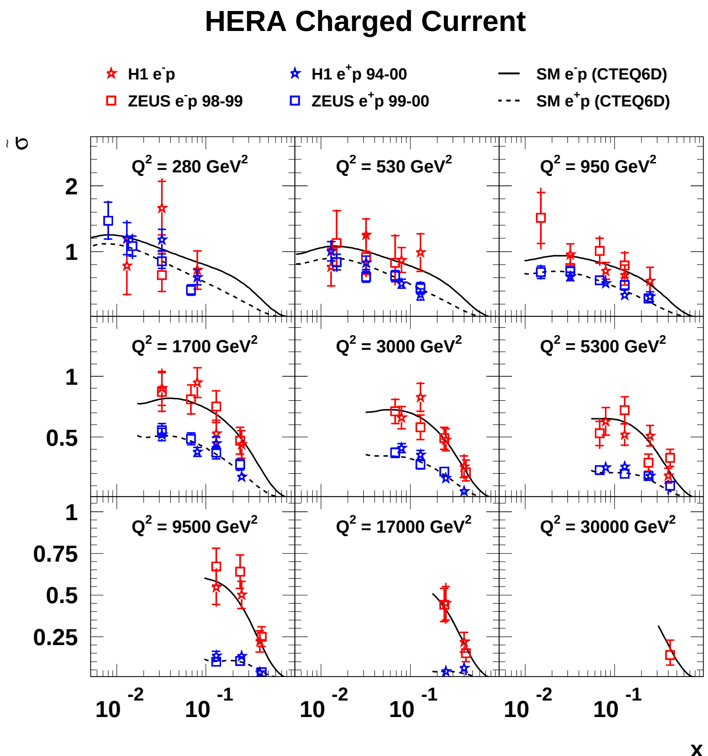
Even for MSSM with $\tan\beta = 10$, $b\bar{b} \to H$ dominates over gg production.



→ production cross section measurement of Higgs is a key ingredient to disentangle new physics scenarios.

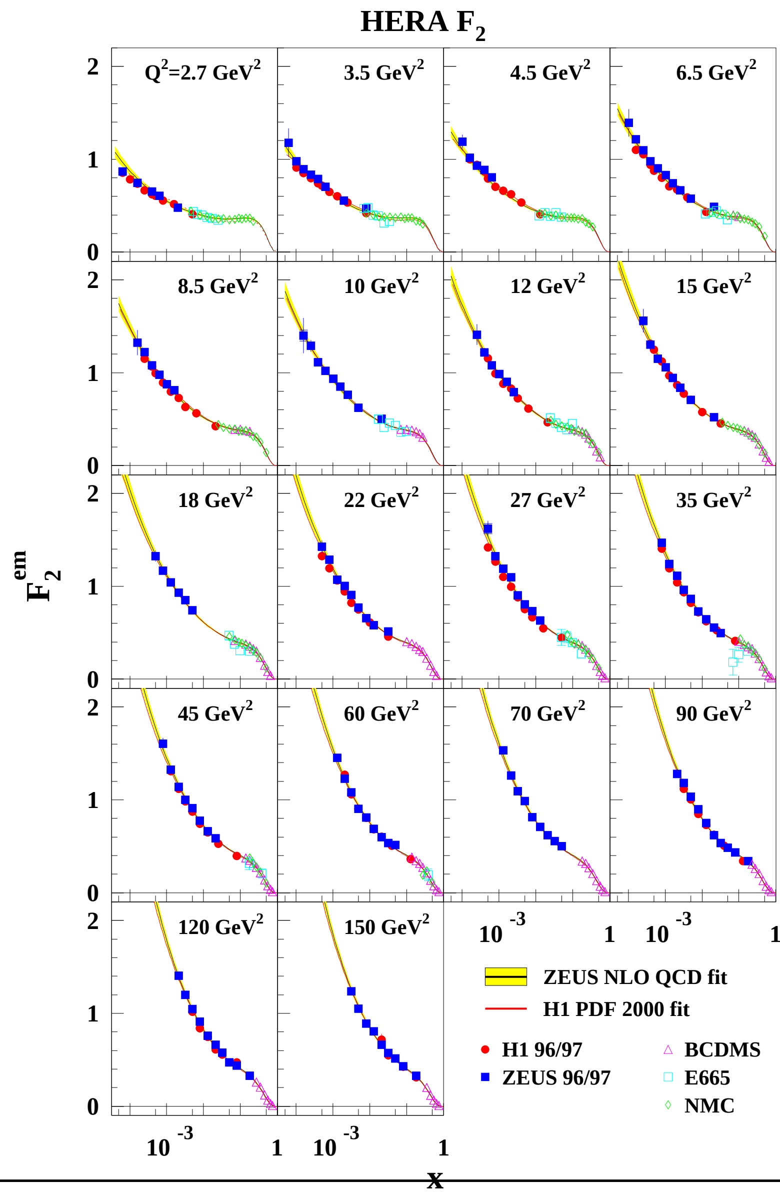
The Measured Cross Sections

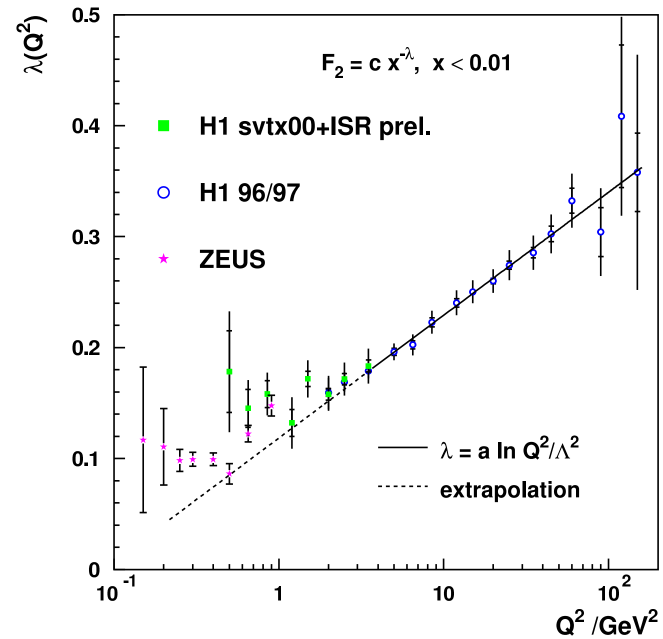




HERA data allows to measure $xU = x(u+c)$, $xD = x(d+s)$, $x\bar{U} = x(\bar{u}+\bar{c})$, $x\bar{D} = x(\bar{d}+\bar{s})$, and xg in a single experiment.

Measurement at low x

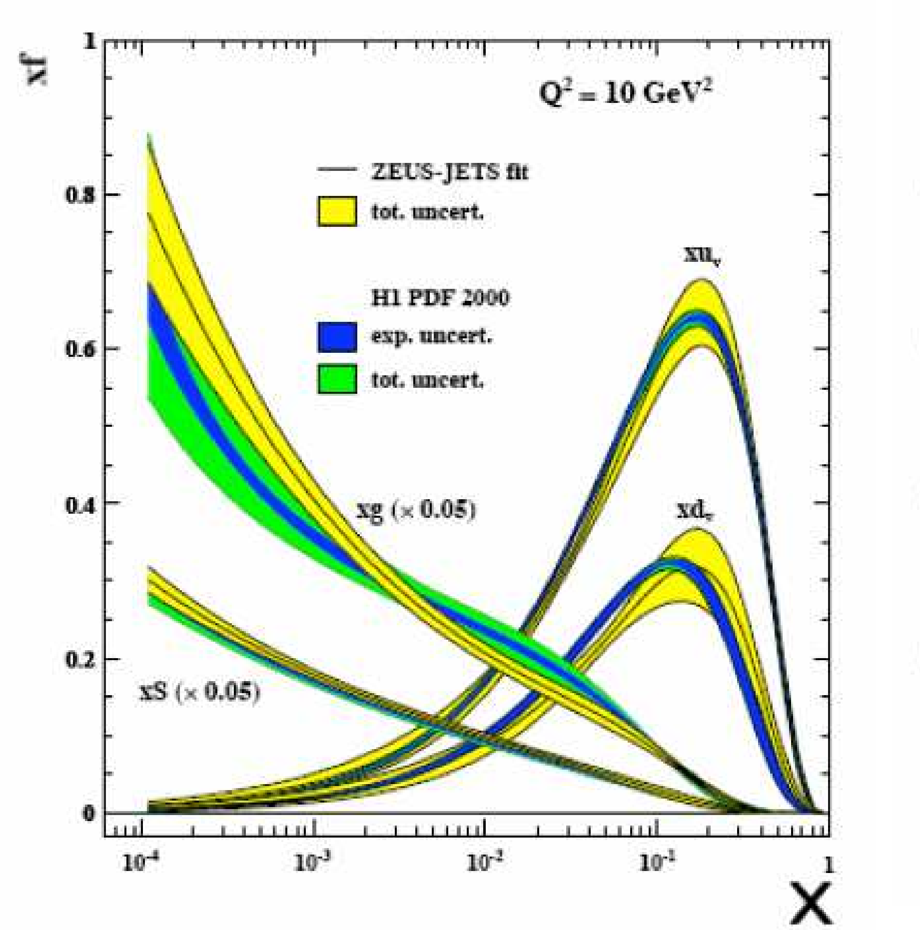




$F_2(x, Q^2)$ shows strong rise as $x \to 0$, the rise increases with increasing Q^2. To quantify the rise, $F = cx^{-\lambda}$ fit is performed for each Q^2 bin.

Currently $2 - 3\%$ precision ($\to 5\%$ for LHC X-sections), goal to reach 1%

PDFs extraction



ZEUS and H1 PDFs are extracted using their own data. Agree within the uncertainties, but shapes seems to be different.

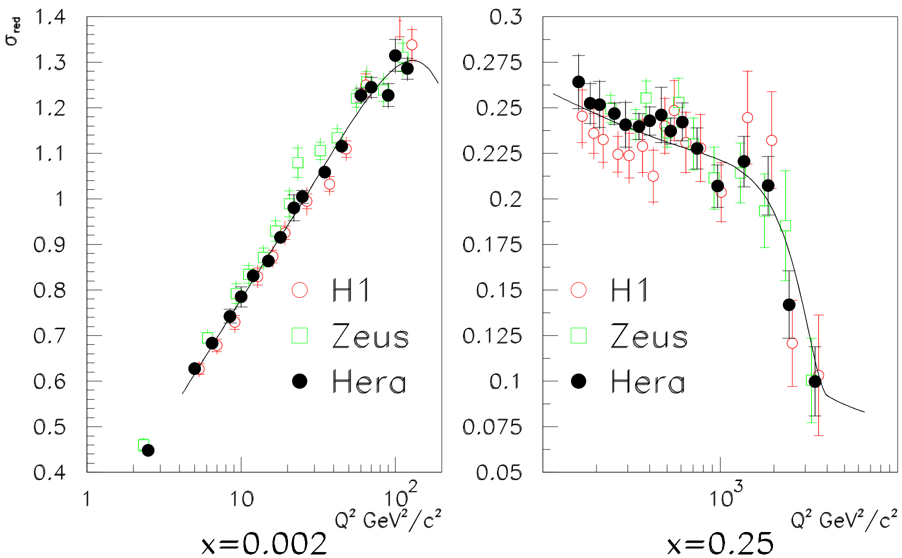
Combination of Experimental Data

Before fitting to theory one can combine data in a generalized averaging procedure. Achieved by fitting χ^2 vs F_2.

– Number of the fit parameters is equal to number of x, Q^2 points — large matrix inversion.

+ Simple quadratic dependence χ^2 — unique and simple solution.

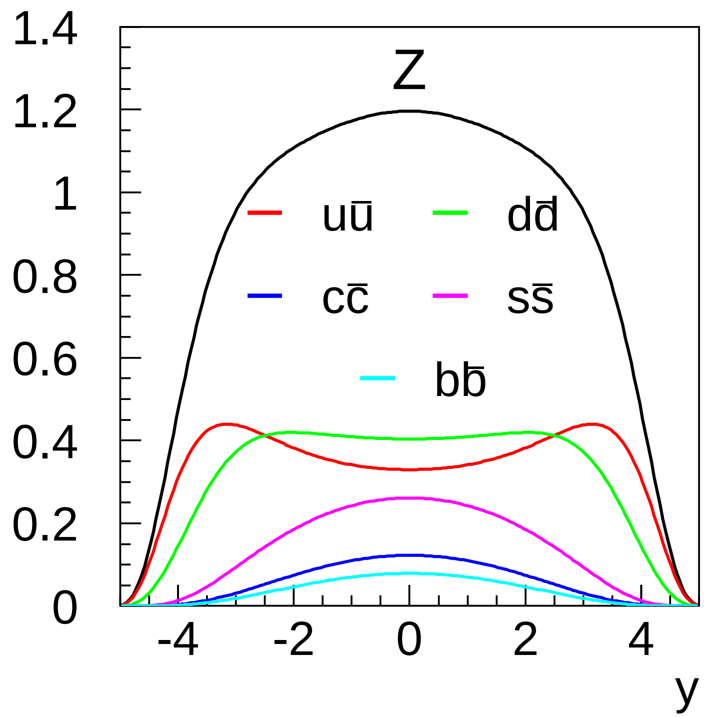
$$\sigma_{red}(e^+p) = F_2 - \frac{y^2}{Y_+}F_L - \frac{Y_-}{Y_+}xF_3$$

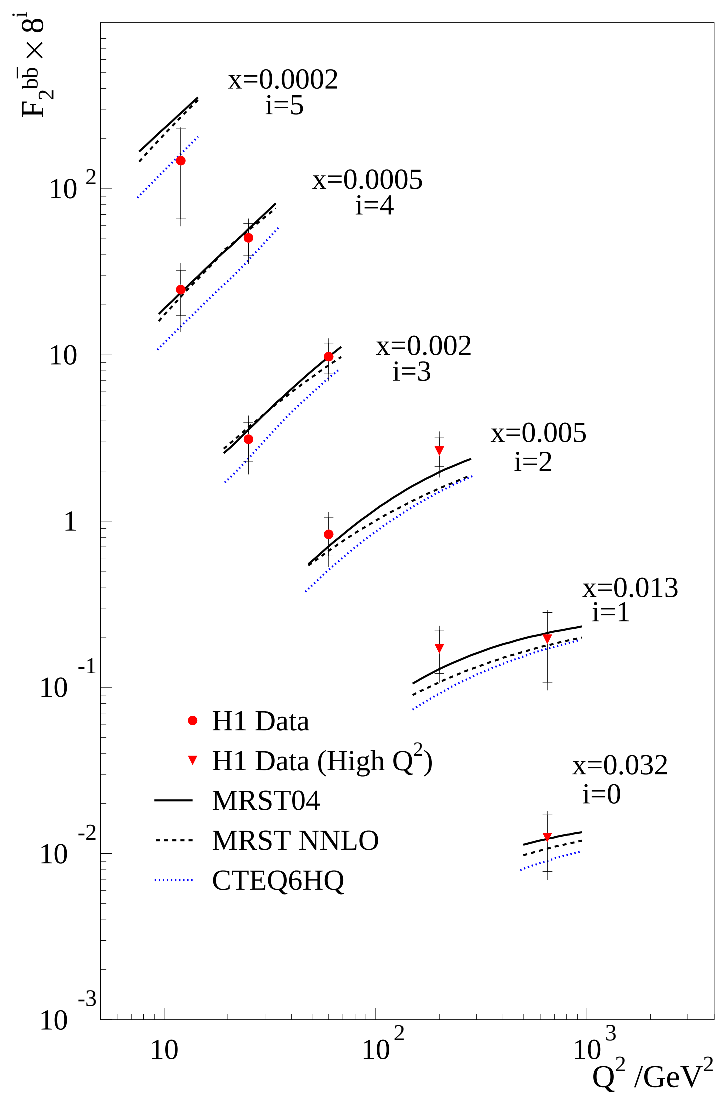


Average of H1 and Zeus data: model independent check of the consistency, $\chi^2/ndf = 534/601$. Experiments cross calibrate each other → systematic errors reduced.

H1 and ZEUS initiated work on HERA average DIS cross section

Z production flavor decomposition

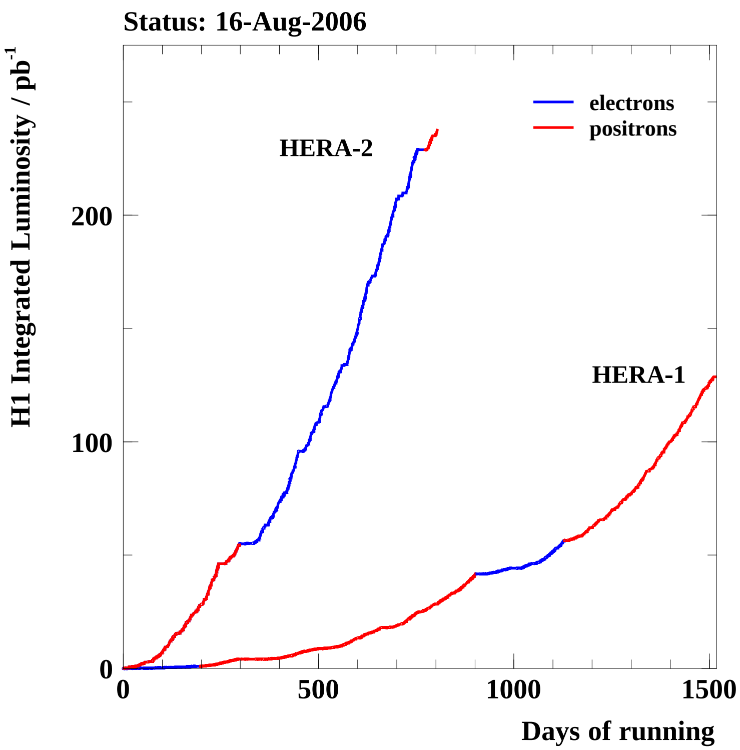


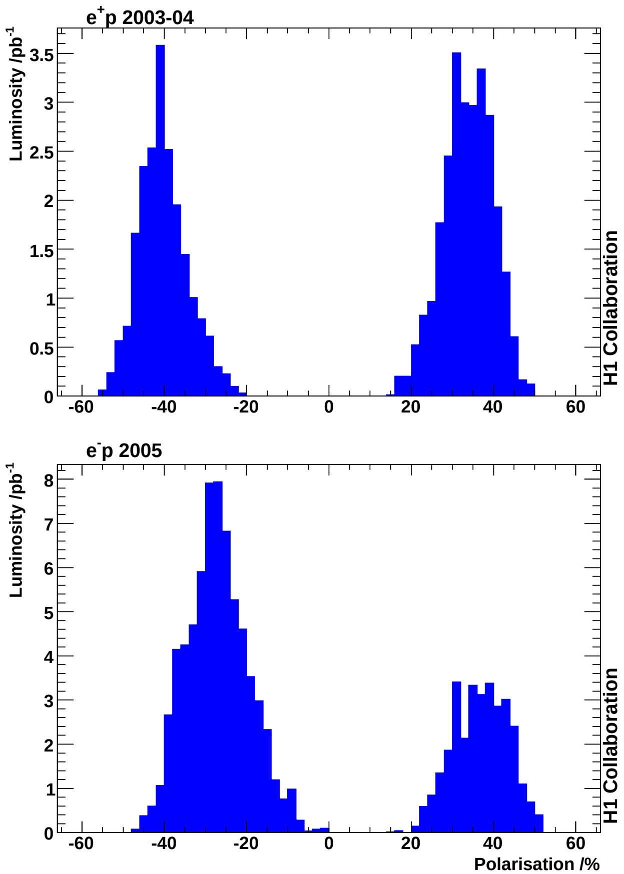


Larger coupling to Z vs γ makes $b\bar{b}$ contribution more important for Z production vs inclusive F_2.

F_2^{bb} is measured by H1, in relevant for LHC x range.

HERA-II Results

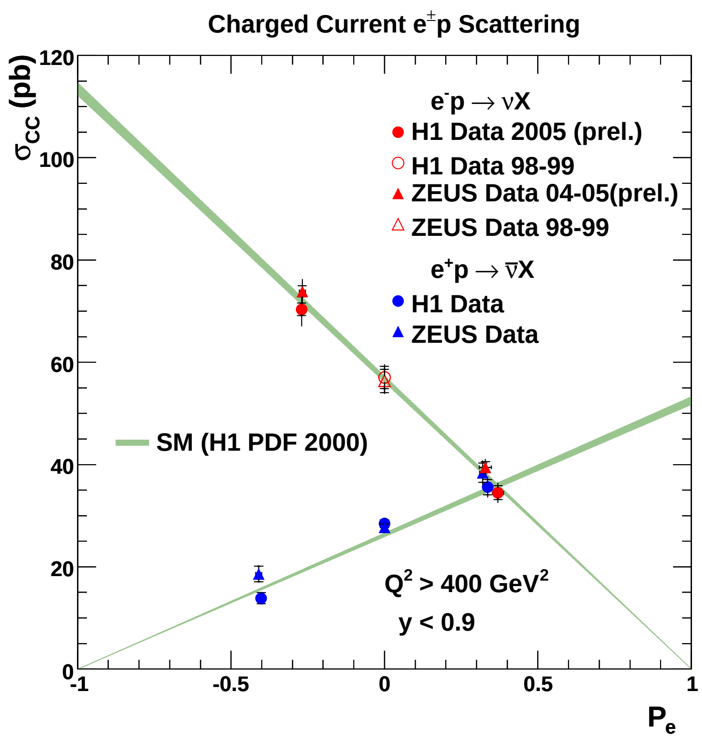




HERA-II upgrade provides better instantaneous luminosity and longitudinal beam polarization (about 30 – 40%).

About one year of operation left, shutdown summer 2007.

Charged Current Cross Section

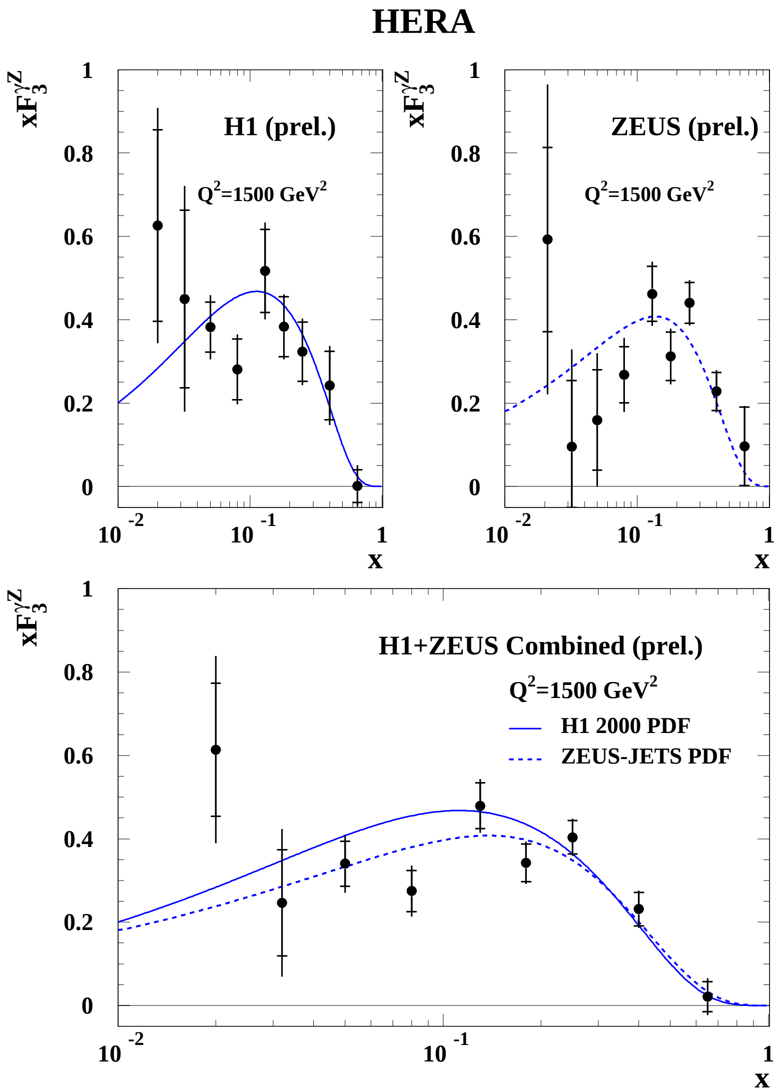


CC cross section is linearly proportional to the degree of the longitudinal beam polarization:

$$\frac{d^2\sigma_{CC}^{e^\pm p}}{dx dQ^2} = [1 \pm P_e] \, \frac{G_F^2}{2\pi x} \left[\frac{M_W^2}{Q^2 + M_W^2} \right]^2 \phi_{CC}^{\pm}$$

Consistent with no right-handed weak currents

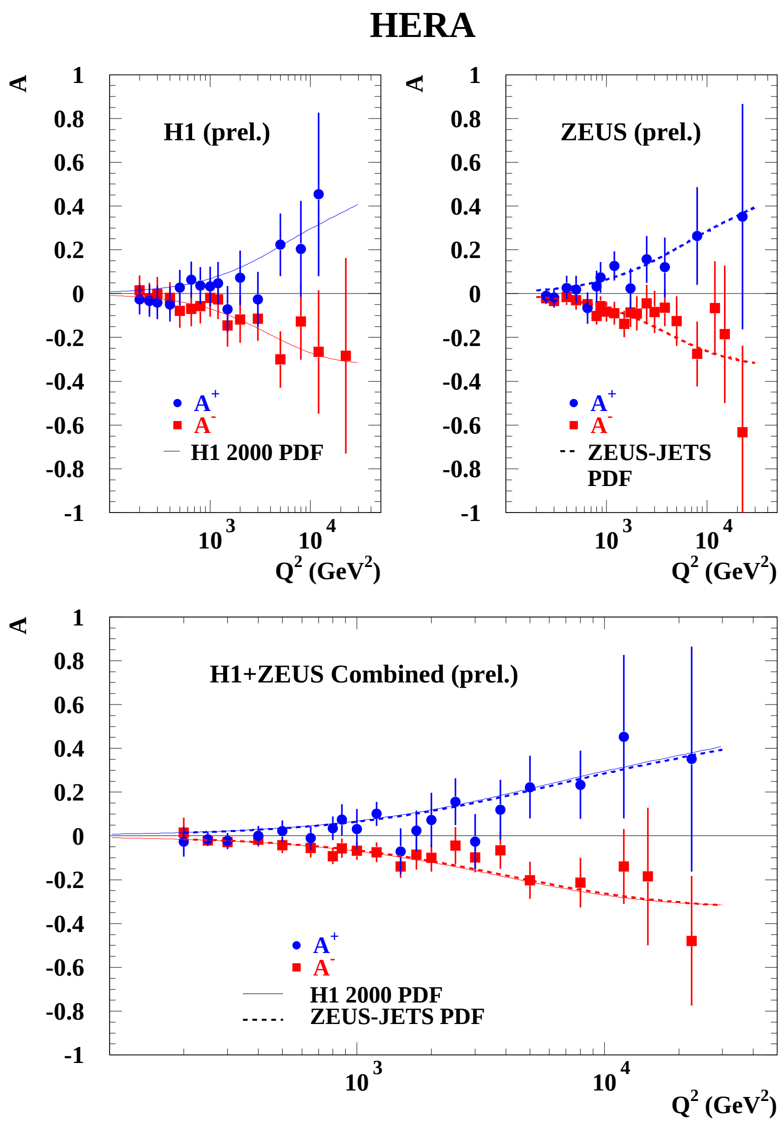
Neutral Current Cross Section and xF_3



Large increase compared to HERA-I of e^- sample allows to improve precision of the interference structure function $xF_3^{\gamma Z}$

- First combined H1-ZEUS SF result
- $xF_3^{\gamma Z}$ is consistent with no-enhancement for low x, supports q-$\bar{q}$ symmetric low x sea.

NC Cross Section Polarization Dependence



Neglecting pure Z exchange term, generalized F_2:

$$\overline{F_2^{\pm}} \approx F_2 + k(-v_e \mp P a_e) F_2^{\gamma Z}$$

where $k = \frac{1}{4 \sin^2 \theta_W \cos^2 \theta_W} \frac{Q^2}{Q^2 + M_Z^2}$

At leading order

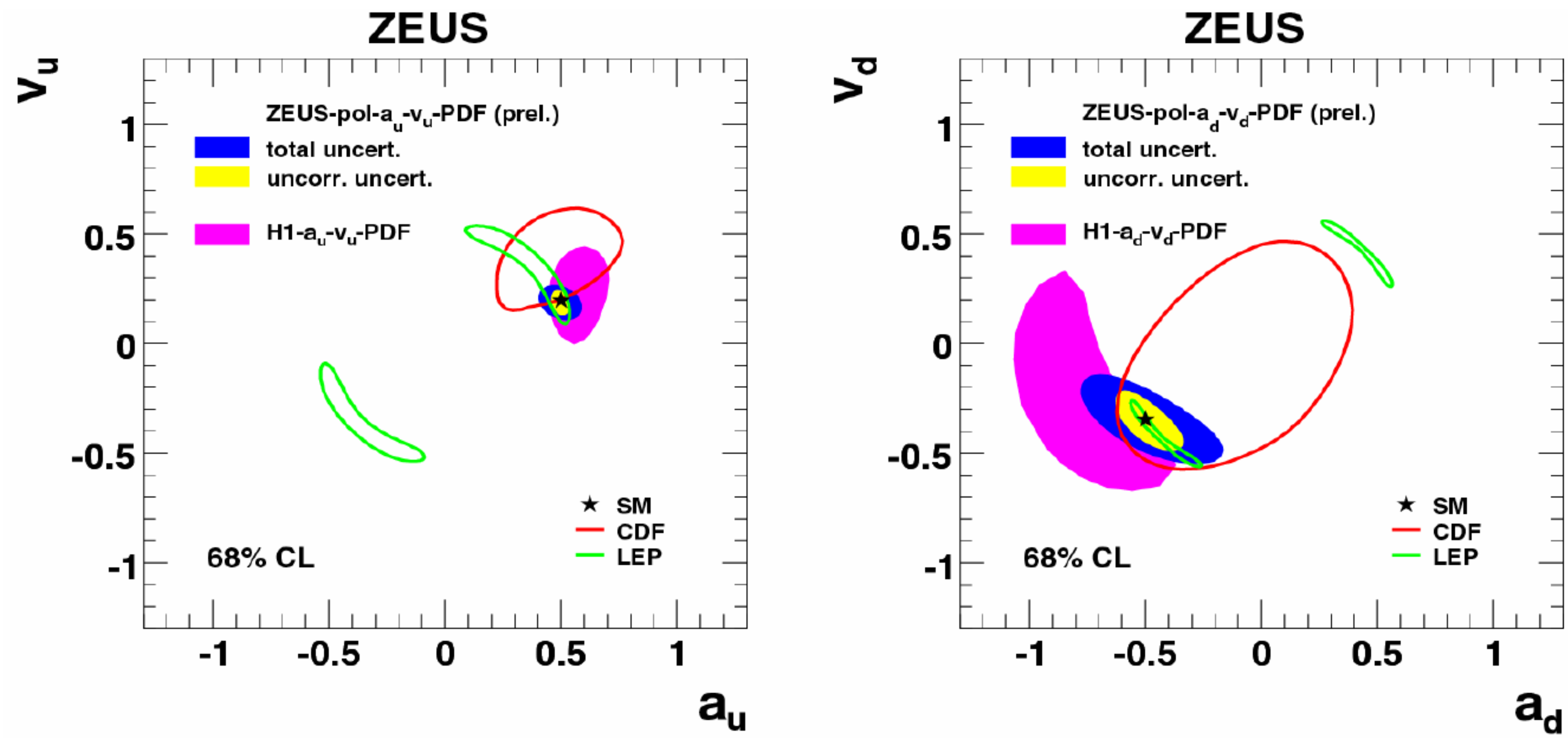
$$F_2^{\gamma Z} = x \sum 2 e_q v_q (q + \bar{q})$$

Defined as

$$A^{\pm} = \frac{2}{P_R - P_L} \frac{\sigma^{\pm}(P_R) - \sigma^{\pm}(P_L)}{\sigma^{\pm}(P_R) + \sigma^{\pm}(P_L)} \approx \mp k a_e \frac{F_2^{\gamma Z}}{F_2}$$

directly measures NC parity violation.

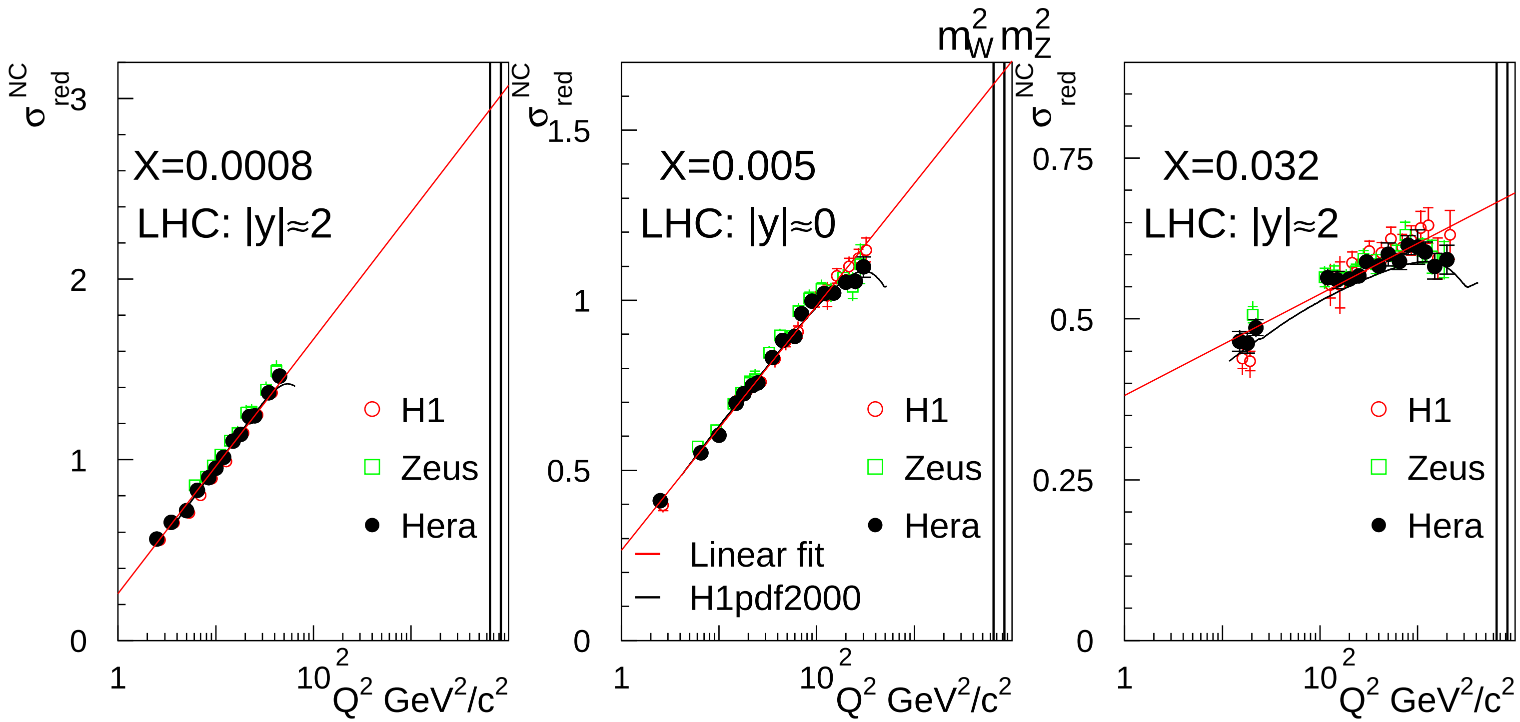
Combined EW-QCD fit



Sensitivity to a, v couplings of the light quarks to Z allows combined QCD-EW fit. H1 performs fit using unpolarized HERA-I data. ZEUS provides preliminary result including HERA-II data.

Polarization brings better sensitivity to v_q

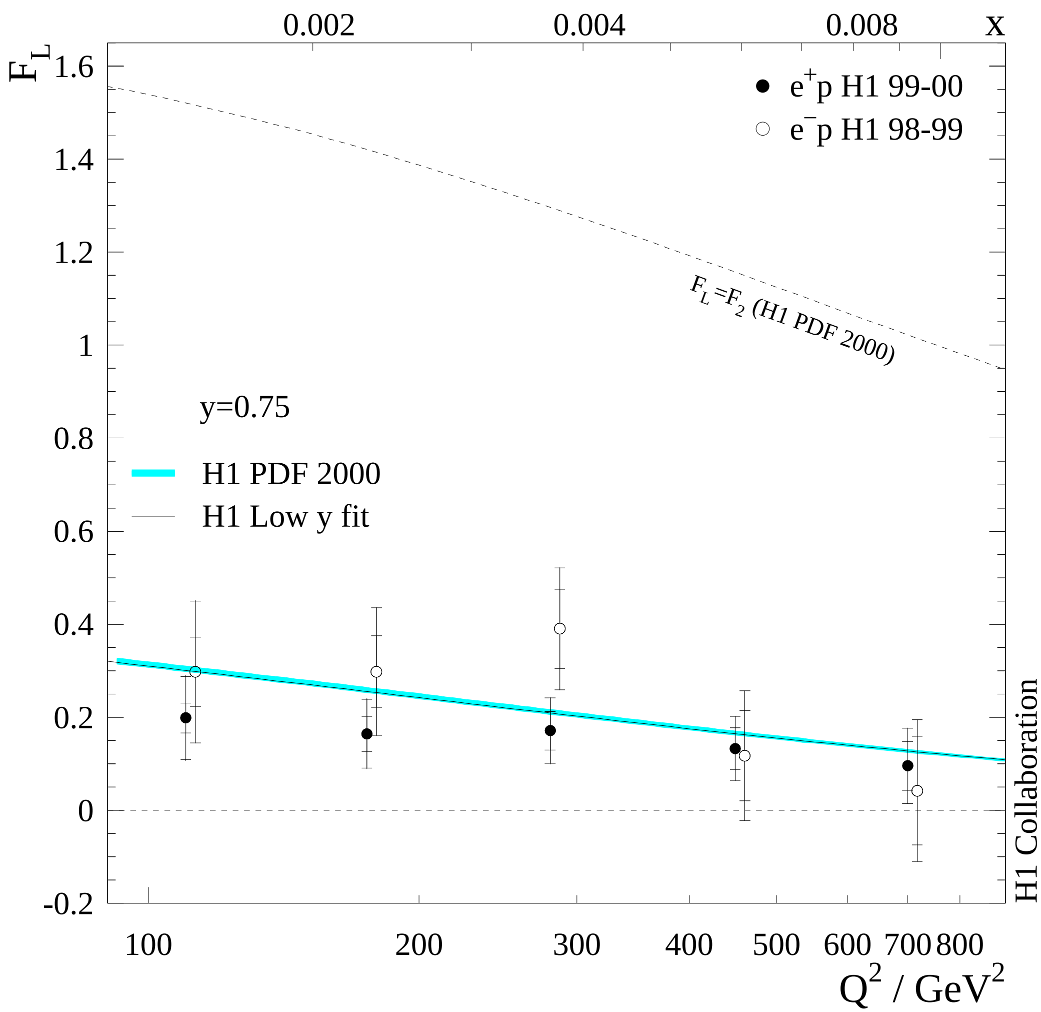
Extrapolation to LHC energies



HERA data covers complete central rapidity range of LHC for W, Z production. "Leading order" predictions can be read directly from HERA data + linear extrapolation.

Experimental part of PDF uncertainties comes from absolute F_2 normalization and the slope, $dF_2/d\log Q^2$ (gluon). Turn down of σ_{red}^{NC} for highest Q^2 ($\rightarrow$ highest y) is due to F_L.

Consistency check: H1 F_L determination at high Q^2



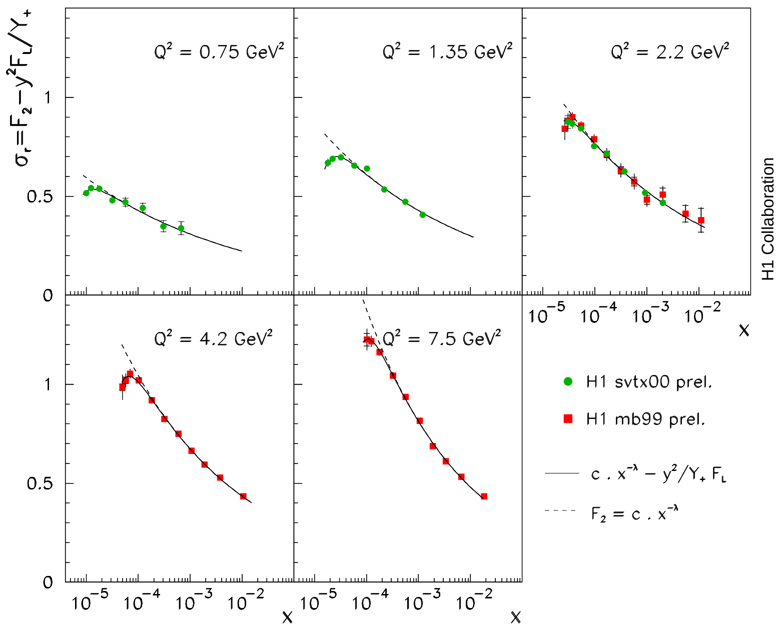
Determination of F_L as

$$F_L = \frac{Y_+}{y^2}\left(F_2^{fit} - \sigma_r\right)$$

Important consistency check of gluon determined from F_2 scaling violation vs X-section decrease at high y.

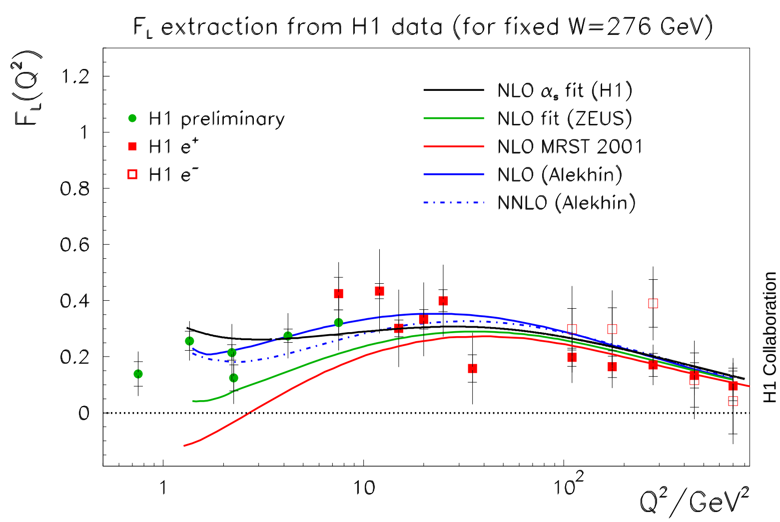
Still large statistical uncertainties, to be improved with HERA-II

Indirect F_L Determination at low Q^2

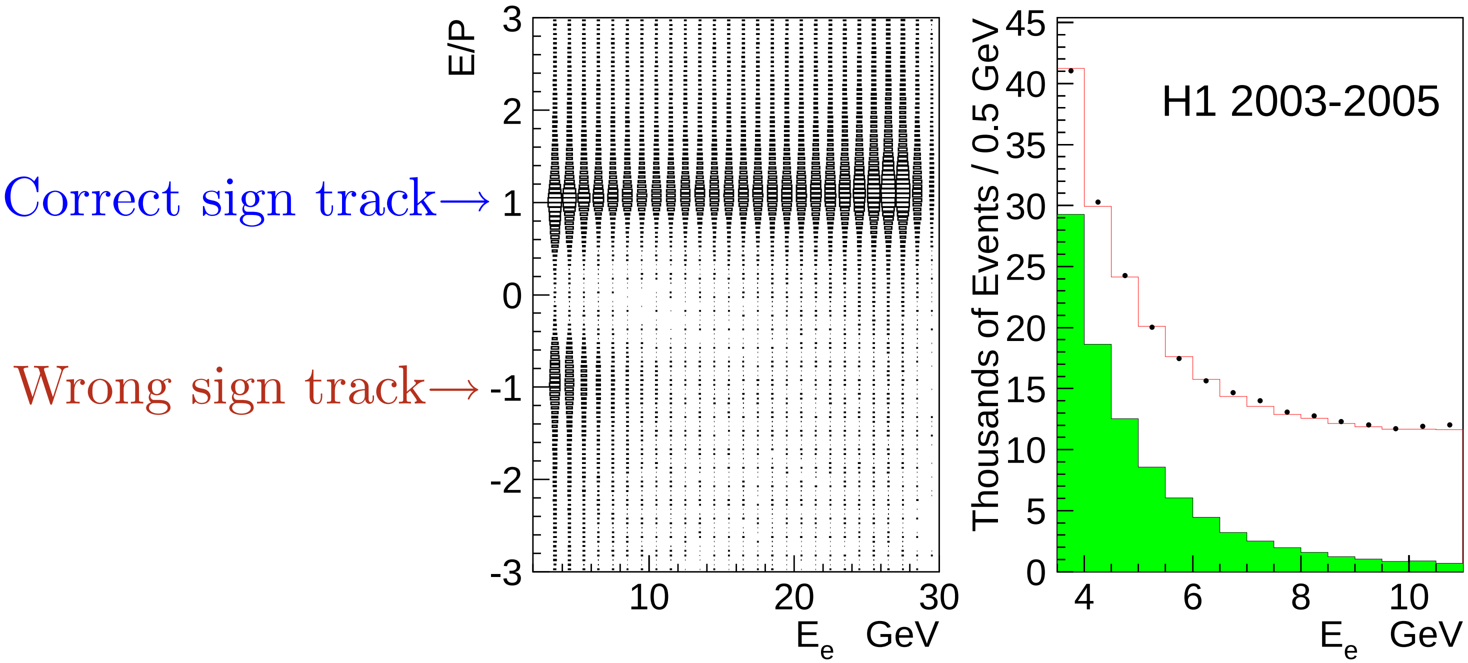


Reduced NC cross section shower "turn over" for high y – most likely influence of F_L. Use $F_2 \sim x^{-\lambda}$ approximation for F_2, determine F_L

Compilation of H1 F_L determinations. At low Q^2, predictions with larger F_L are preferred.



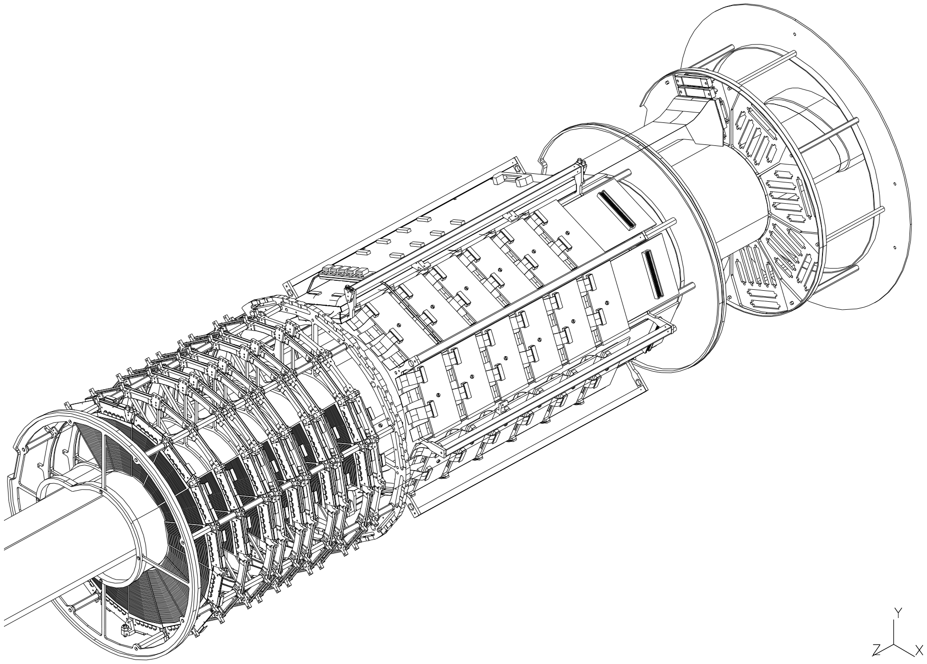
Experimental Challenges for F_L determination

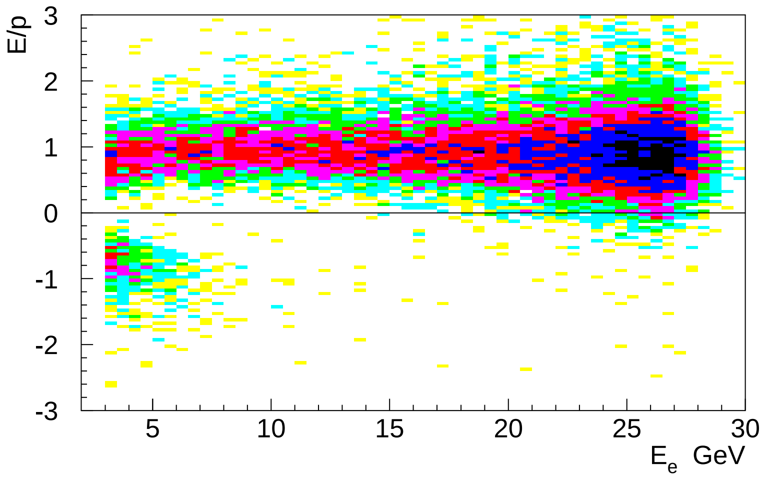


Measurement at high y (low scattered electron energy E_e) is challenging. The signature of the scattered electron can be faked by hadronic final state in a γp event.
Solution: estimate photoproduction background using electron candidates associated with wrong charge tracks. Charge symmetric lepton beam sample eliminates calorimeter response induced background charge asymmetry (p vs $\bar{p}$)

Backward Silicon Tracker 2006

2006 data – re-install Backward Silicon Tracker back in H1 detector. Covers $3 < Q^2 < 10\ \mathrm{GeV}^2$ range for $y > 0.6$.



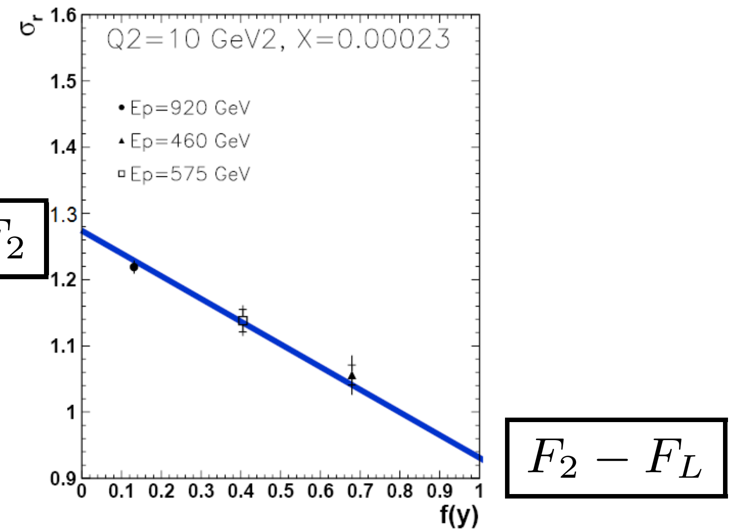


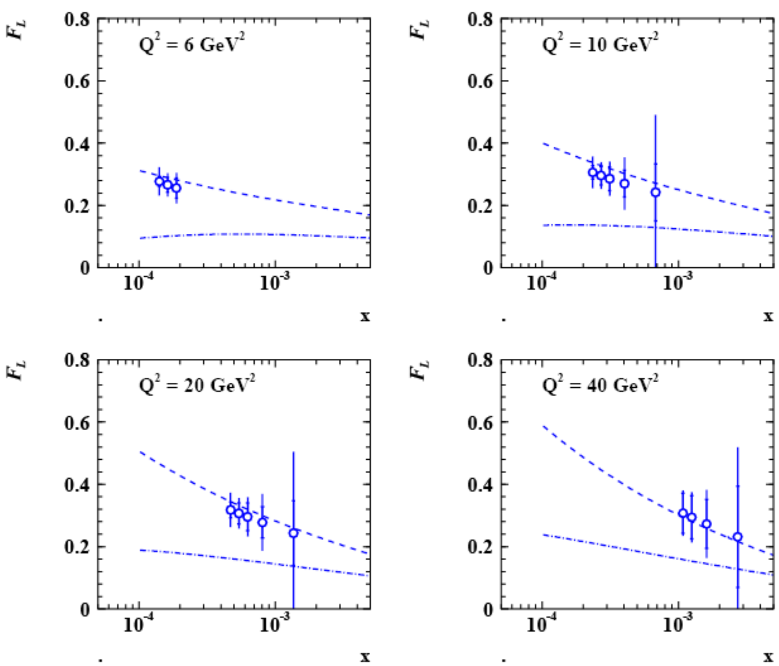
Allows scattered angle reconstruction/charge determination for the electron candidate.

F_L measurement

$$\sigma_r(x, Q^2) = F_2(x, Q^2) - f(y) F_L(x, Q^2)$$

Measure σ_r at the same Q^2, x for different beam energies





Measurement based on 10 pb^{-1} run at $E_p = 460$ GeV allows to distinguish between different PDF fits (MRST vs CTEQ).

PRC recommended to undertake low E_p run before HERA shutdown

Conclusions and Outlook

- HERA experiments provide unique information on proton structure at low x which is not only exciting by itself but also provides an important input for physics at LHC.
- Precision of HERA measurements has already reached $2-3\%$ level, next step is 1% which will be of importance for W, Z, H cross section predictions at LHC.
- Direct measurement of the longitudinal structure function F_L will provide an important check of the theory and a new handle on the gluon density.