Measurement of the Longitudinal Structure Function in Diffraction F_L^D

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(on behalf of the H1 Collaboration)

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Diffraction Conference

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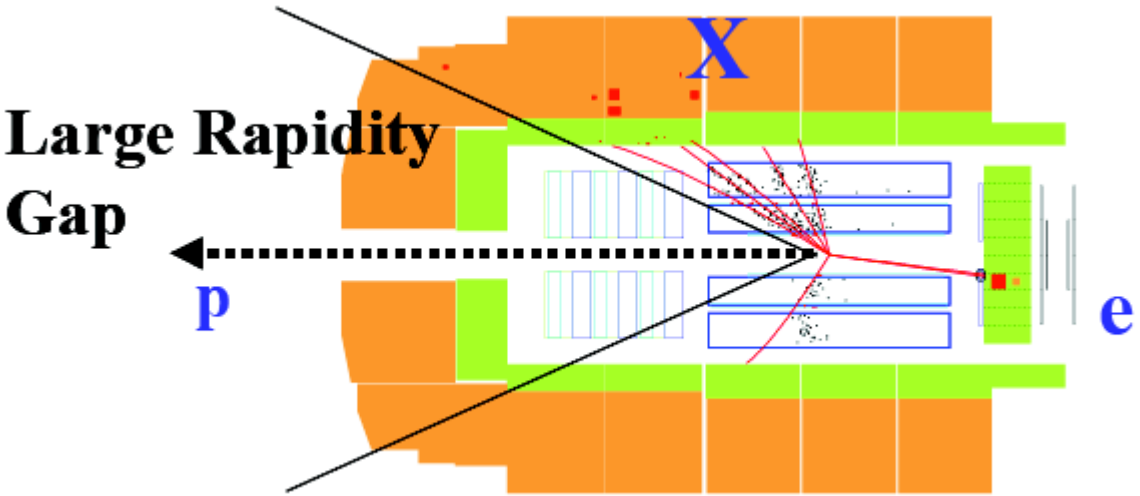
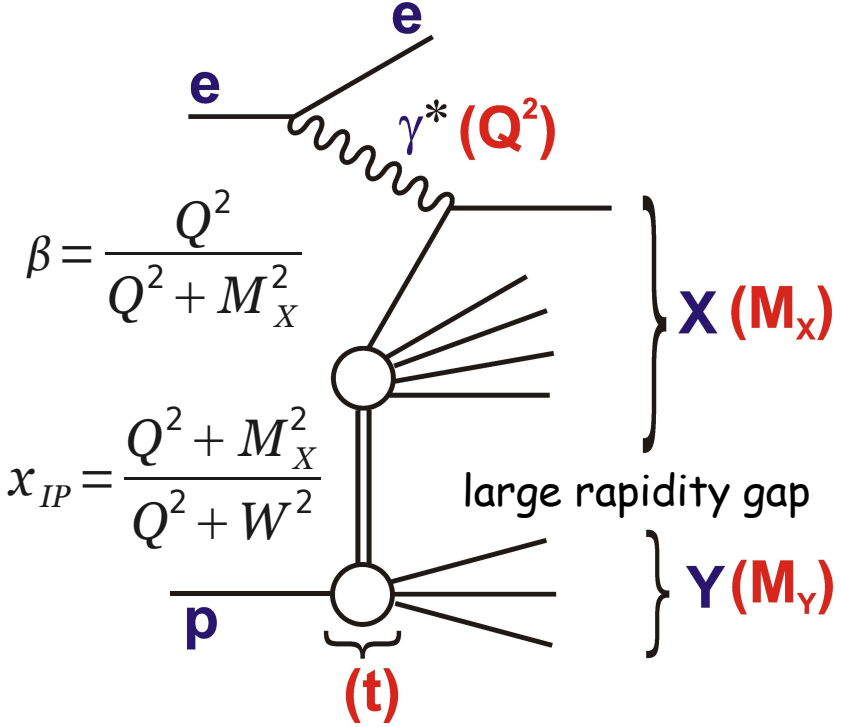
Diffractive DIS



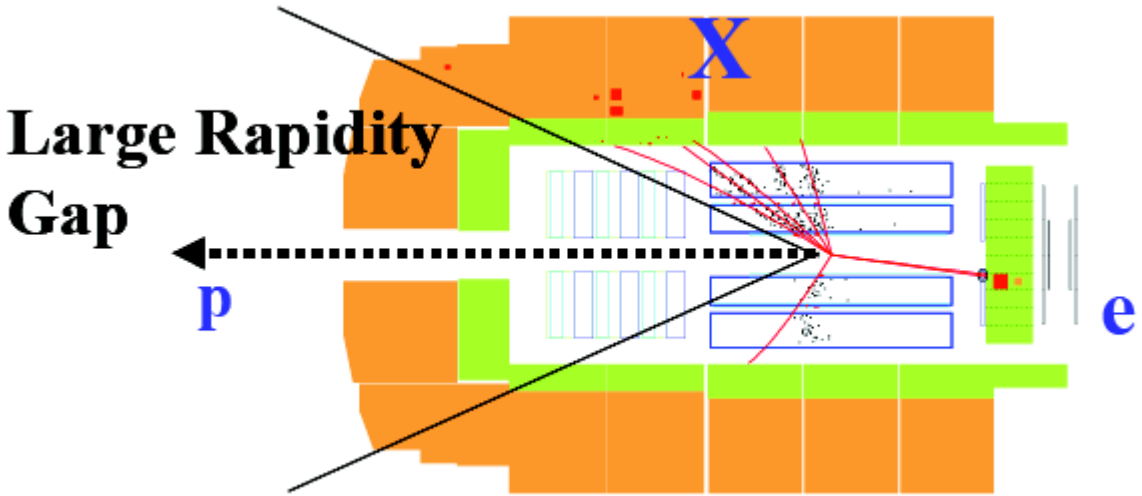


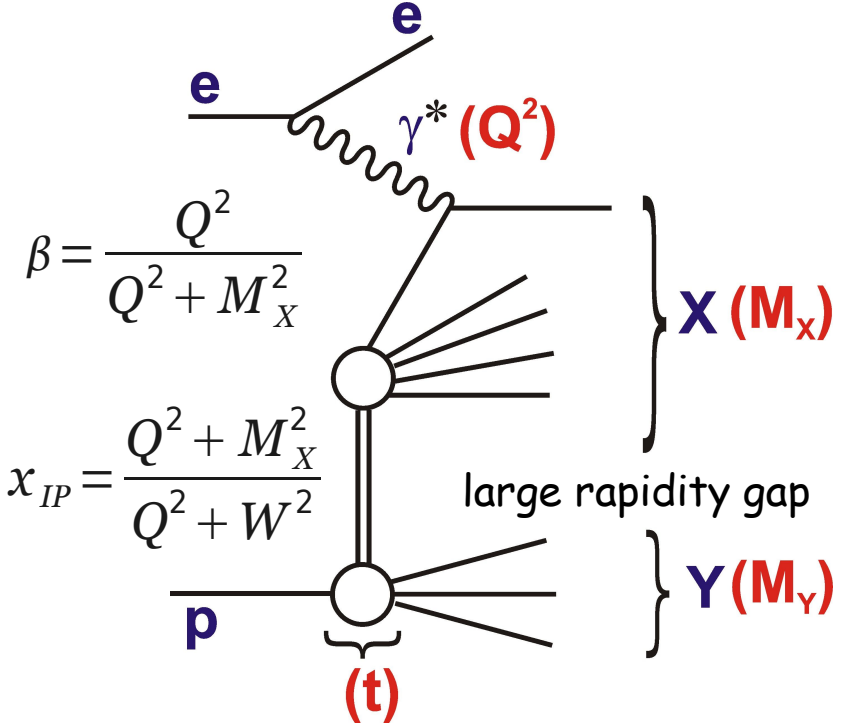
- diffractive reduced cross section

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D \qquad Y_+ = 1 + (1-y)^2$$

$$\frac{d^3\sigma^{ep\to eXY}}{dx_{IP}\, d\beta\, dQ^2} = \frac{2\pi\alpha^2}{\beta Q^4} Y_+ \sigma_r^D(x_{IP}, \beta, Q^2)$$

Diffractive DIS





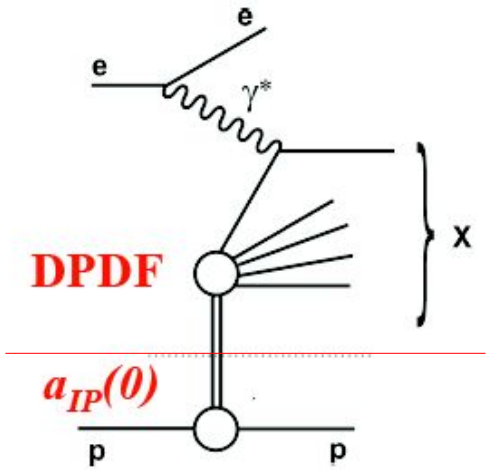
- diffractive reduced cross section

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D \qquad Y_+ = 1 + (1-y)^2$$

- this analysis focuses on the diffractive longitudinal proton structure function

QCD Factorisation in Diffraction

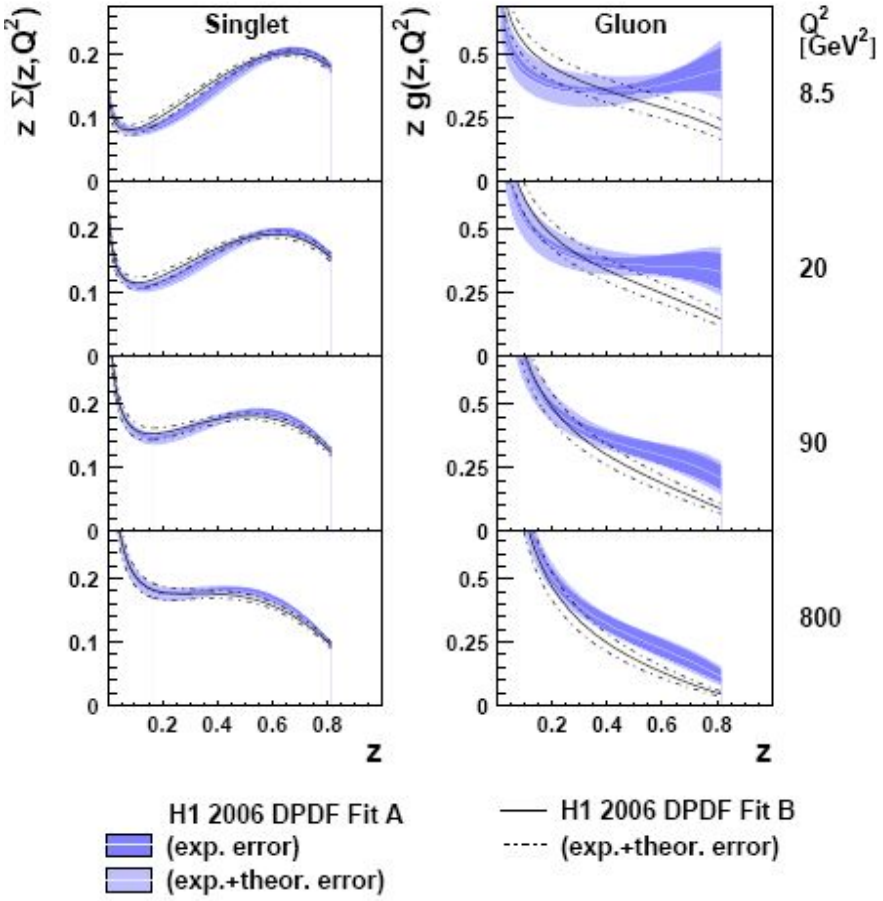
- diffractive parton densities
  - extracted from the inclusive measurements → H1 2006 DPDF Fits
  - x_{IP} dependence factorised



  - NLO QCD fit (β and Q^2 dependence)
  - singlet parametrisation:

$$z\Sigma(z,Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$$

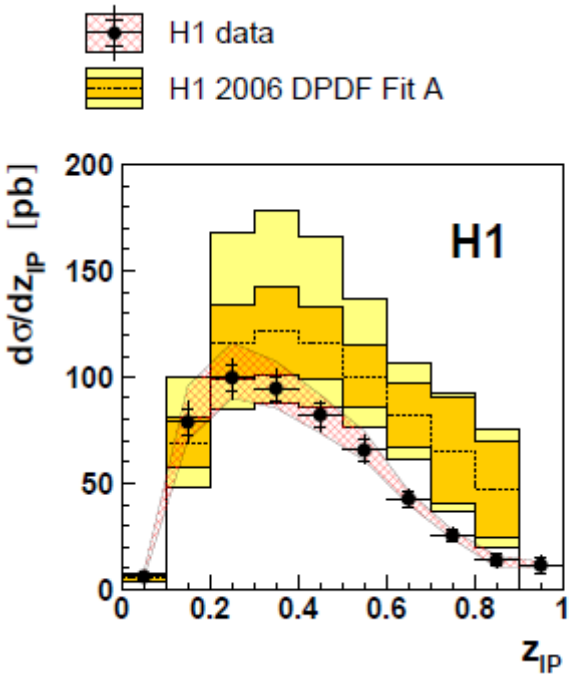
  - 2 gluon parametrisations:
    - Fit A $\quad z_g(z,Q_0^2) = A_g(1-z)^{C_g}$
    - Fit B $\quad z_g(z,Q_0^2) = A_g$

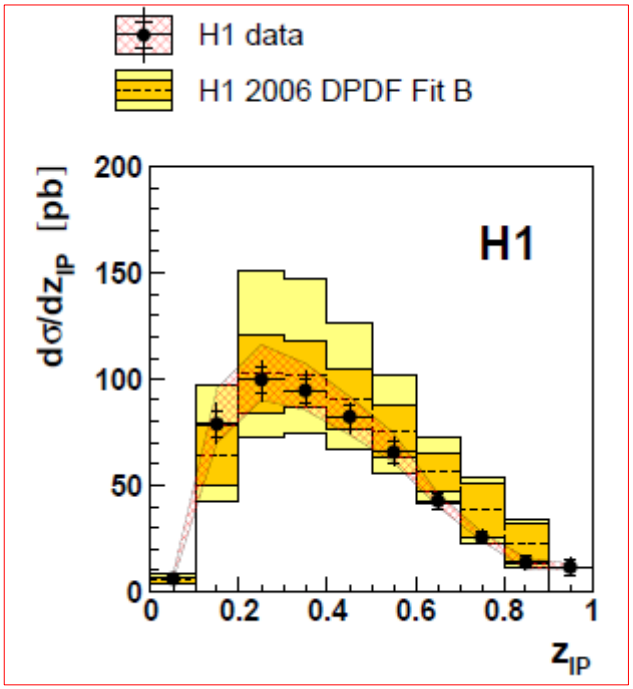


QCD Factorisation in Diffraction

- inclusive measurements constrain quarks
- gluons are constrained weakly from the scaling violations $\frac{d\,\sigma_r^D}{d\,\ln Q^2}$

- diffractive dijets in DIS
  - compatible with the parton densities from H1 2006 DPDF Fits
  - QCD factorisation holds
  - Fit B preferred





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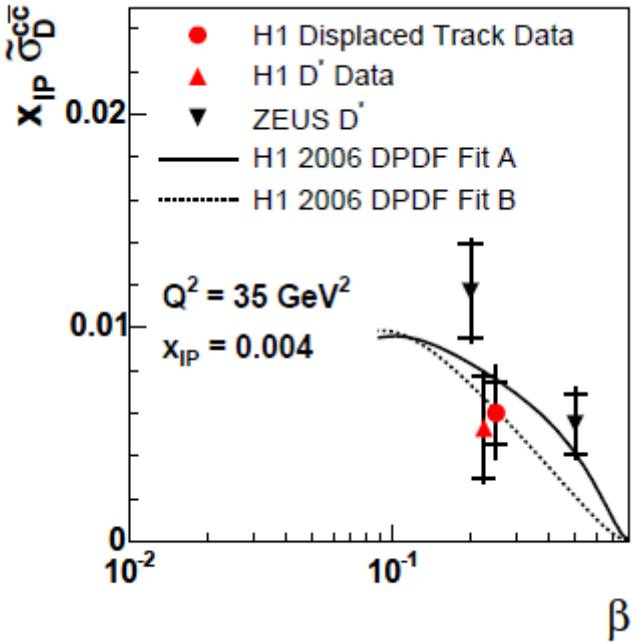
- diffractive charm production
  - low statistics



QCD Factorisation in Diffraction

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- diffractive charm production
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- FLD measurement
  - probes low x_{IP} and β region inaccessible by dijets and D^*

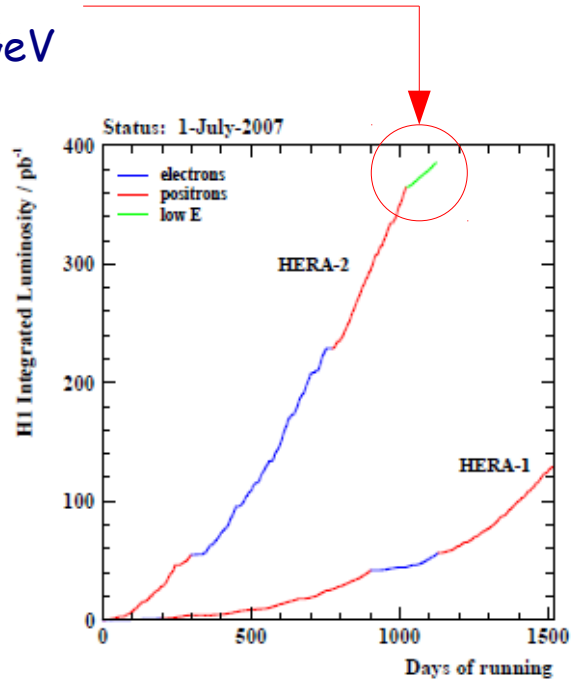
$$F_L^D \sim x\,g(x)$$

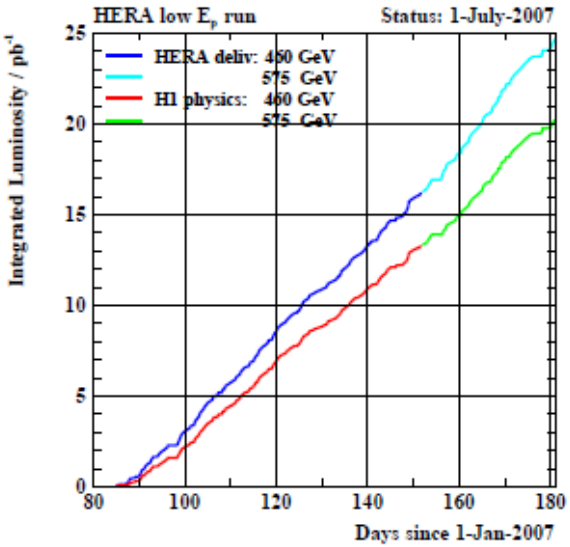
HERA Low Energy Runs

- last months of HERA running were dedicated to the measurements of F_L and F_L^D

  → low energy runs

  - E_p = 460 GeV
  - E_p = 575 GeV





- nominal proton beam energy
  - E_p = 820 GeV
  - E_p = 920 GeV

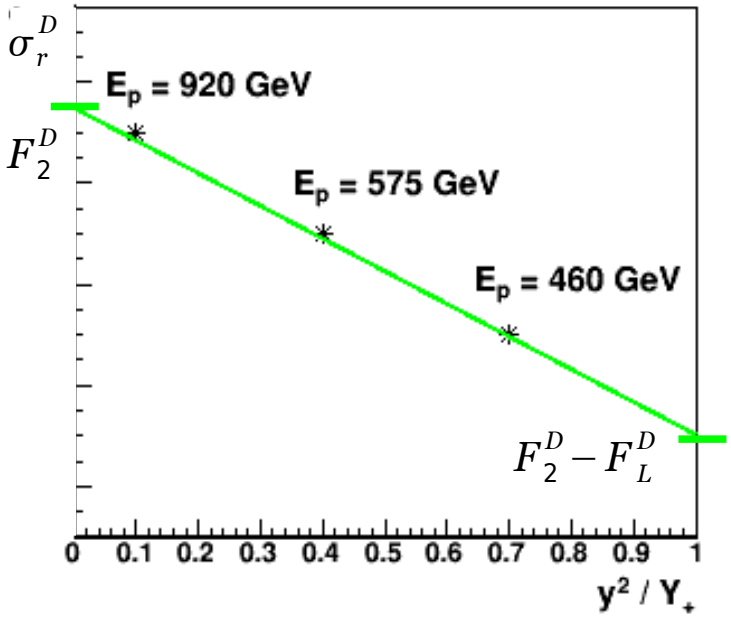
Measurement Strategy

- analysis closely follows the measurement of the inclusive F_L by H1 (published as DESY-08-053)

- Rosenbluth plots
  - separate the structure functions F_L^D and F_2^D by combining measurements at different y (for the fixed x_{IP}, β, Q^2)

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D \qquad Y_+ = 1 + (1-y)^2$$

$$Q^2 = x_{IP}\, \beta\, y\, s$$



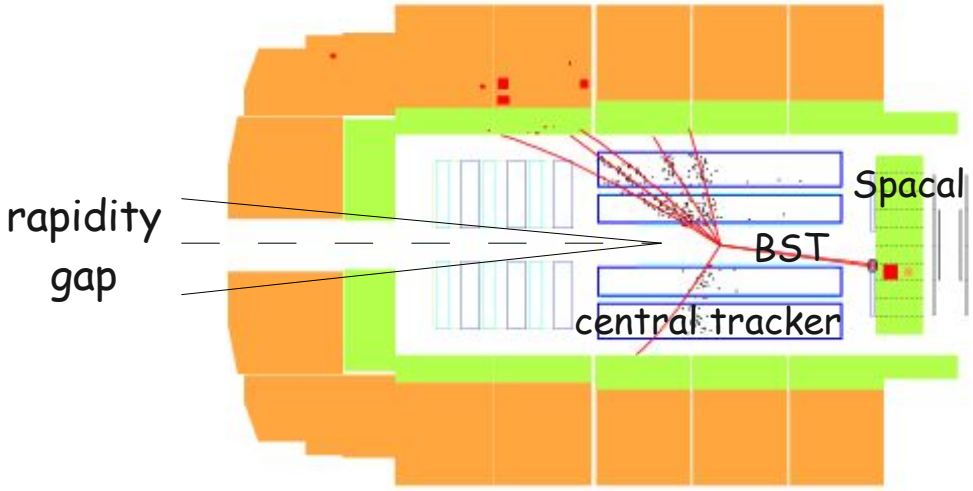
  - data at different centre-of-mass energy needed
    - 2 pb^{-1} E_p = 820 GeV
    - 21 pb^{-1} E_p = 920 GeV
    - 6 pb^{-1} E_p = 460 GeV
    - 4 pb^{-1} E_p = 575 GeV

Data Selection and H1 Detector

- diffractive selection:
  - large rapidity gap → $\eta_{max} < 3.3$
- F_L^D selection:
  - $Q^2 > 2.5\ \mathrm{GeV}^2$
  - high y region sensitive to F_L^D → $y < 0.9$
  - kinematic variables reconstructed from the scattered positron

$$Q^2 = 4\,E_e\,E_e'\cos^2\frac{\theta_e}{2} \qquad y = 1-\frac{E_e'}{E_e}\sin^2\frac{\theta_e}{2} \approx 1-\frac{E_e'}{E_e}$$

  - low scattered positron energy → $E_e' > 3.4\ \mathrm{GeV}$
  - high level of photoproduction background
  - challenging measurement requiring precise positron identification
    - cluster (Spacal calorimeter)
    - track (central tracker and/or Backward Silicon Tracker)



Background at High y

- data at high y contain photoproduction background
  - scattered positron escapes the central detector through the beam-pipe
  - one of the hadronic final state particles is mis-identified as the scattered positron
  - background from hadronic particles is almost charge symmetric $\frac{N^{+}_{bg}}{N^{-}_{bg}} \sim 1$

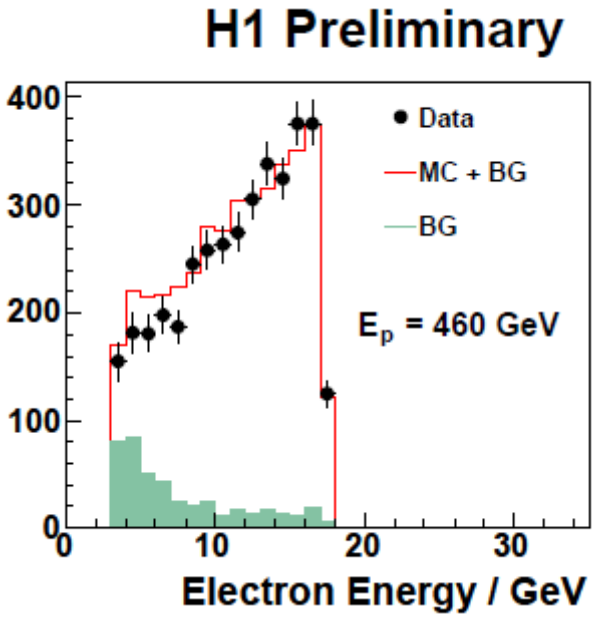
- background subtraction using the charge of the scattered positron candidate

N^{+} = signal events + background from π^{+}

N^{-} = background from π^{-}

$$N_{signal} = N^{+} - N^{-}$$

Monte Carlo Simulation



data with positive charge

background determined from the data with negative charge

signal Monte Carlo (based on H1 2006 DPDF Fit B) + background from data

- Monte Carlo does not simulate F_L^D → it overshoots data at high y

$$\sigma_r^D(F_L^D = 0) = F_2^D$$

Normalisation of Data Sets

- data cross section is corrected for proton dissociation
  - rapidity gap selection accepts events with dissociated protons up to M_Y = 1.6 GeV (acceptance of the forward detectors near the beam pipe)
  - 7% uncertainty → can it be reduced?

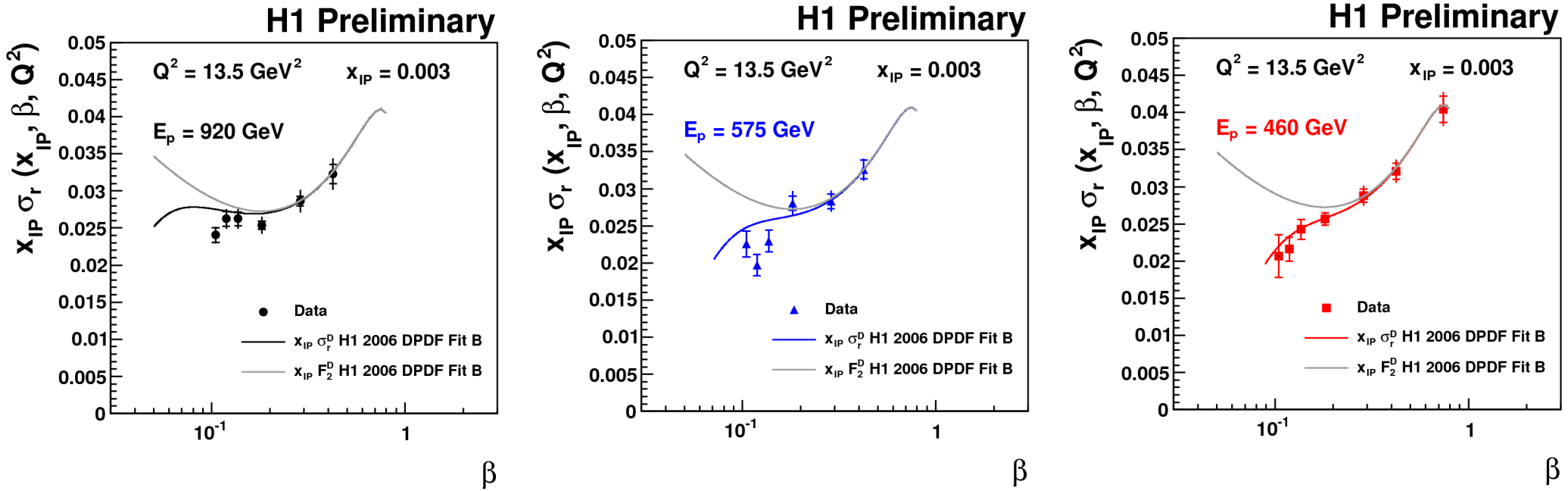
- use as constraint that F_2^D is independent of the beam energy
  - no significant contribution from F_L^D at low y (high β)
  - data cross sections normalised to H1 2006 DPDF Fit B at Q^2 = 13.5 GeV^2, 0.28 < β < 0.42 in order to give the same F_2^D
  - normalisation changed by < 4%
  - uncertainty reduced to 2.5%

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$

$$Q^2 = x_{IP}\, \beta\, y\, s$$

Diffractive Reduced Cross Sections

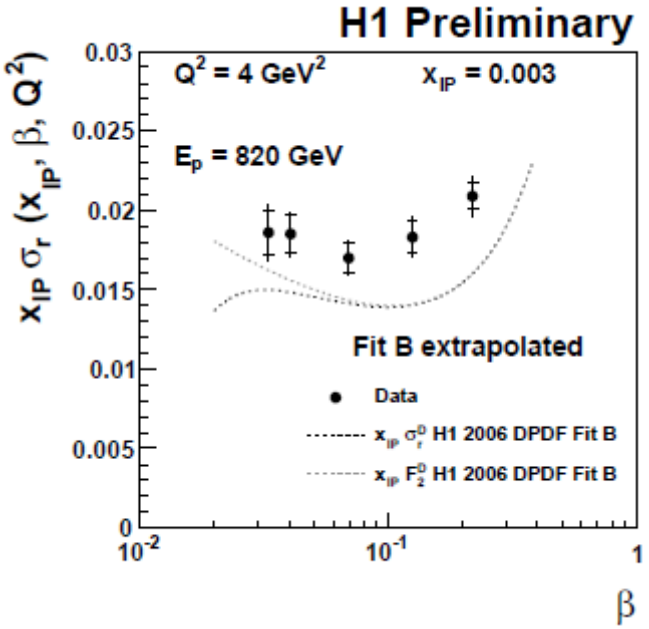
- $7 < Q^2 < 32\ \mathrm{GeV}^2$
- E_p = 920, 575, 460 GeV

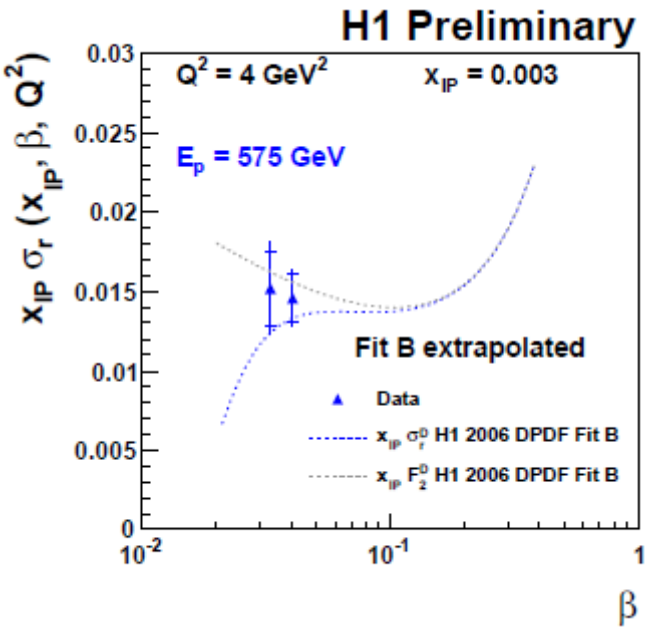


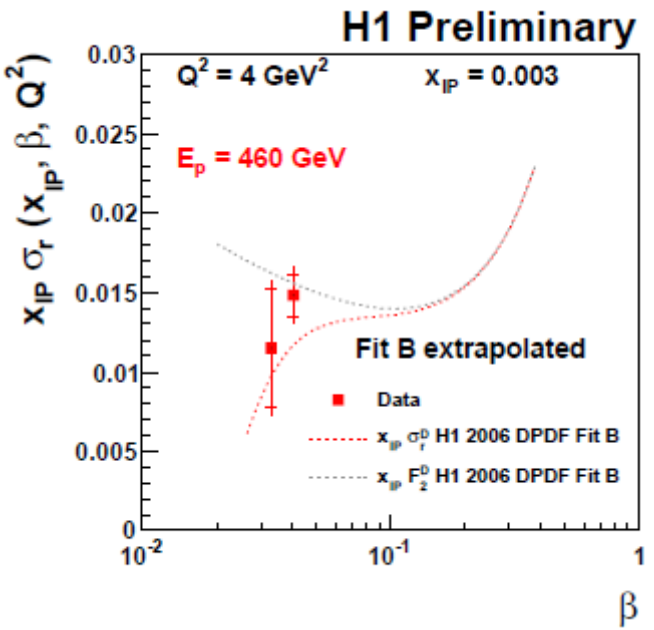
- cross sections agree with H1 2006 DPDF Fit B
- contribution of non-zero F_L^D observed → fall at low β
- prediction for $\sigma_r^D(F_L^D = 0) = F_2^D$ overestimates data

Diffractive Reduced Cross Sections

- $2.5 < Q^2 < 7\ \mathrm{GeV}^2$
- E_p = 820, 575, 460 GeV

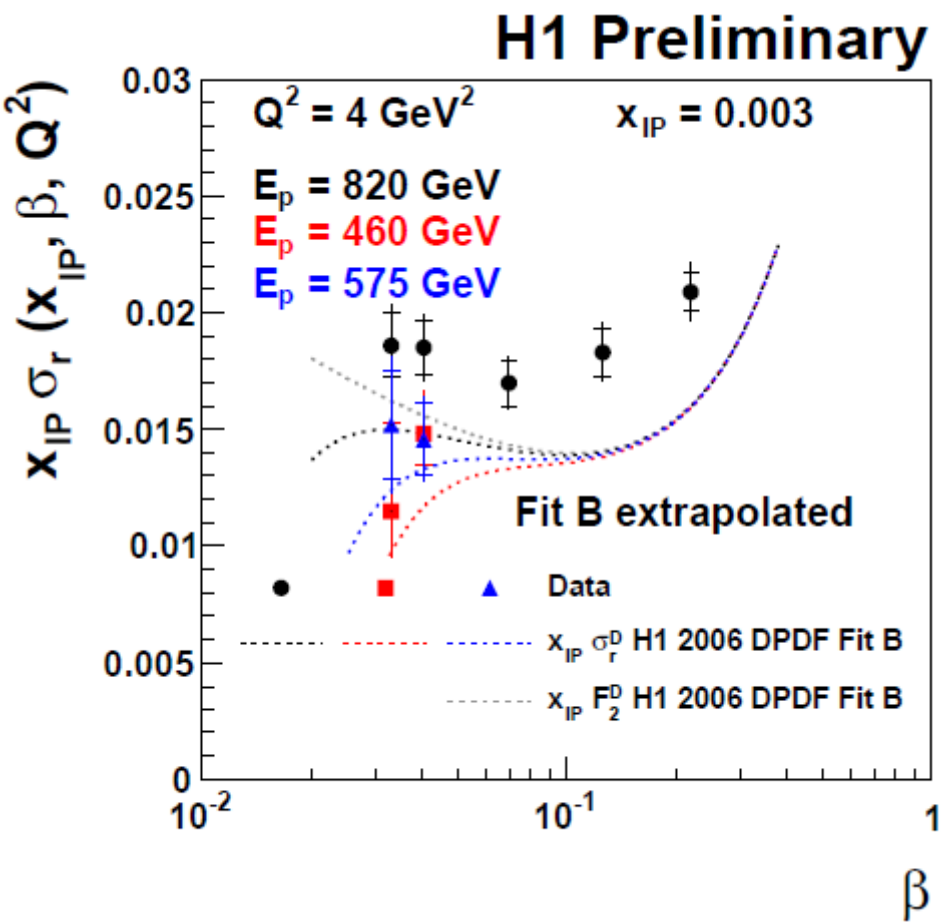


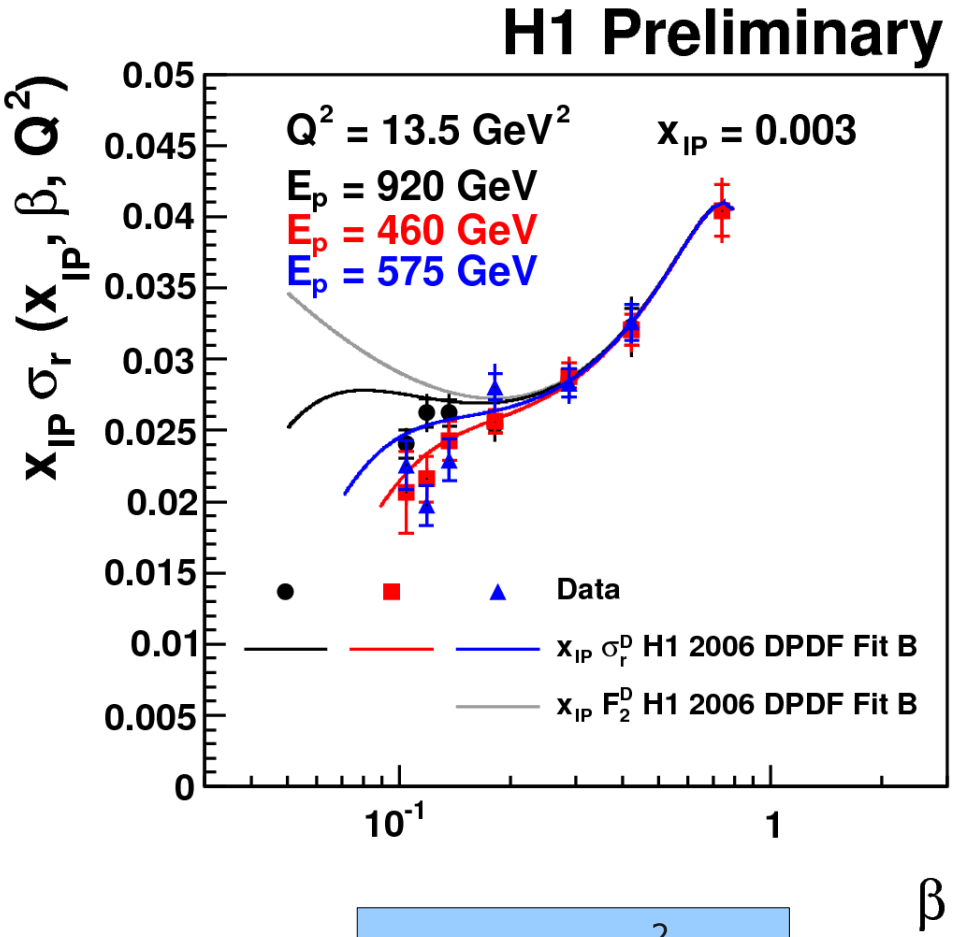




- data at E_p = 820 GeV from the publication DESY-06-049
  - cover larger β range
  - used to determine H1 2006 DPDF Fit A and Fit B
  - the Fits are known to underestimate data at $Q^2 < 8.5\ \mathrm{GeV}^2$

Sensitivity to F_L^D





- data cross sections are sensitive to F_L^D

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$

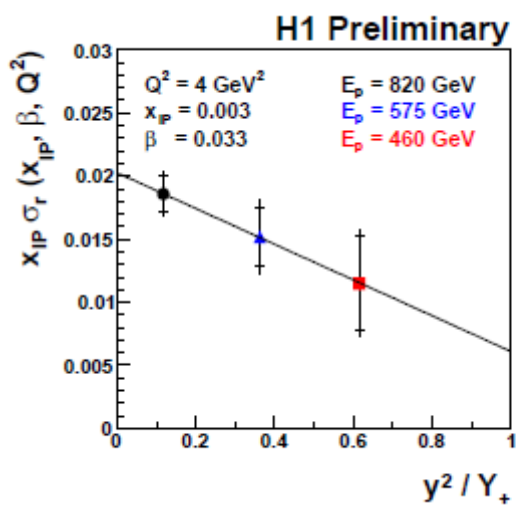
$$Q^2 = x_{IP}\,\beta\,y\,s$$

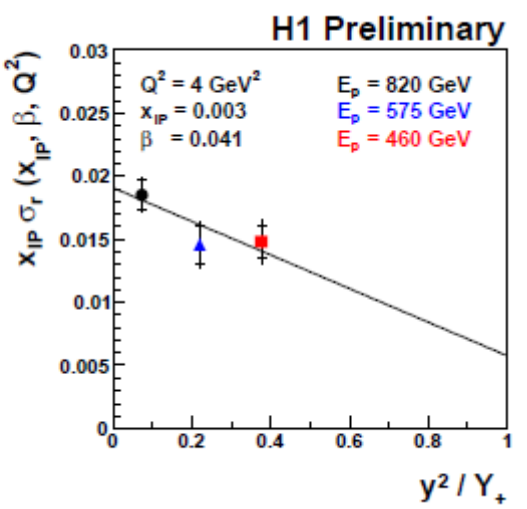
F_L^D Fits

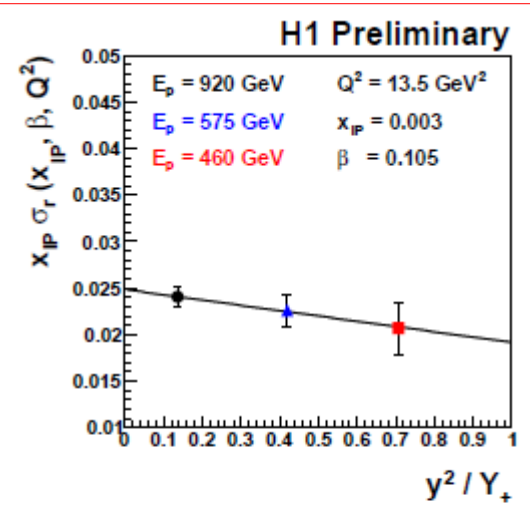
- linear fit in the Rosenbluth plots to obtain F_2^D and F_L^D

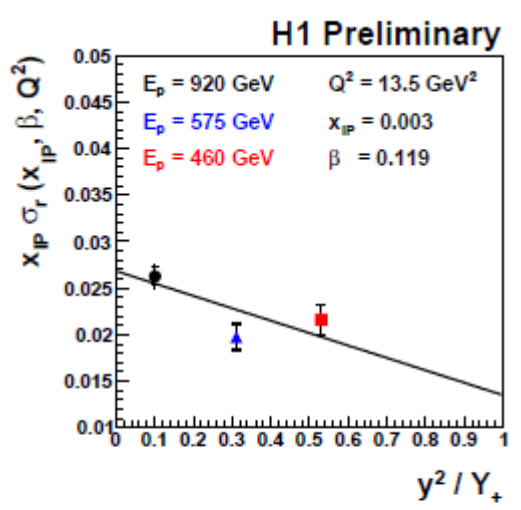
$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$

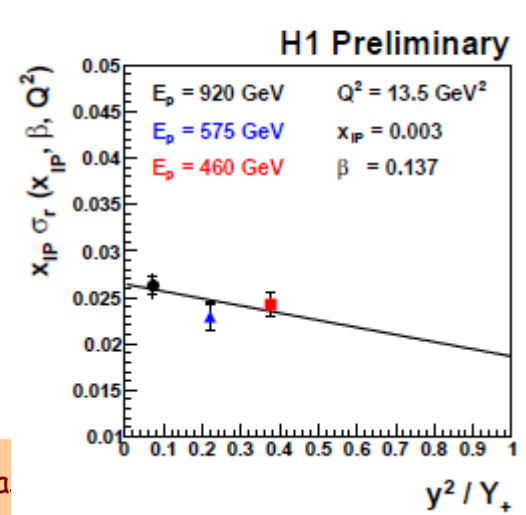
- highest sensitivity to F_L^D at high y (low β)

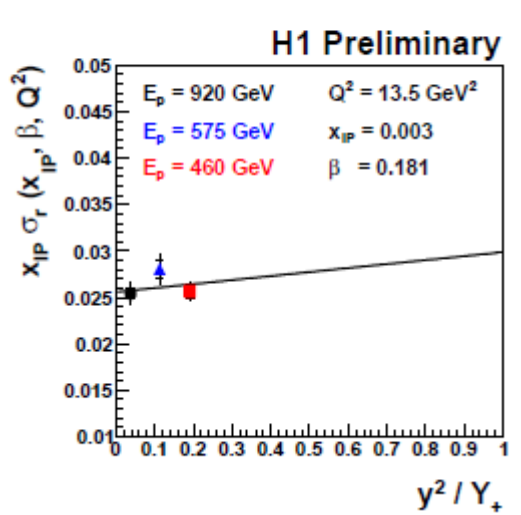




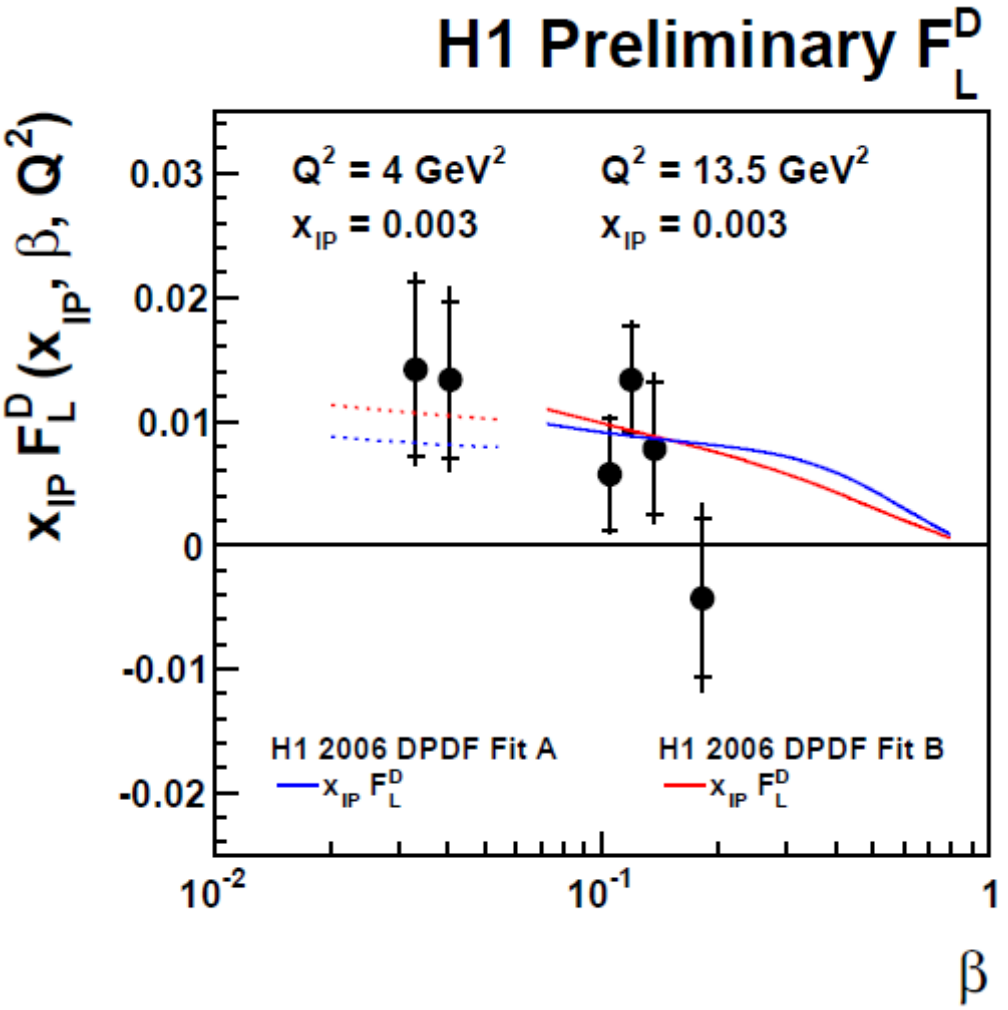








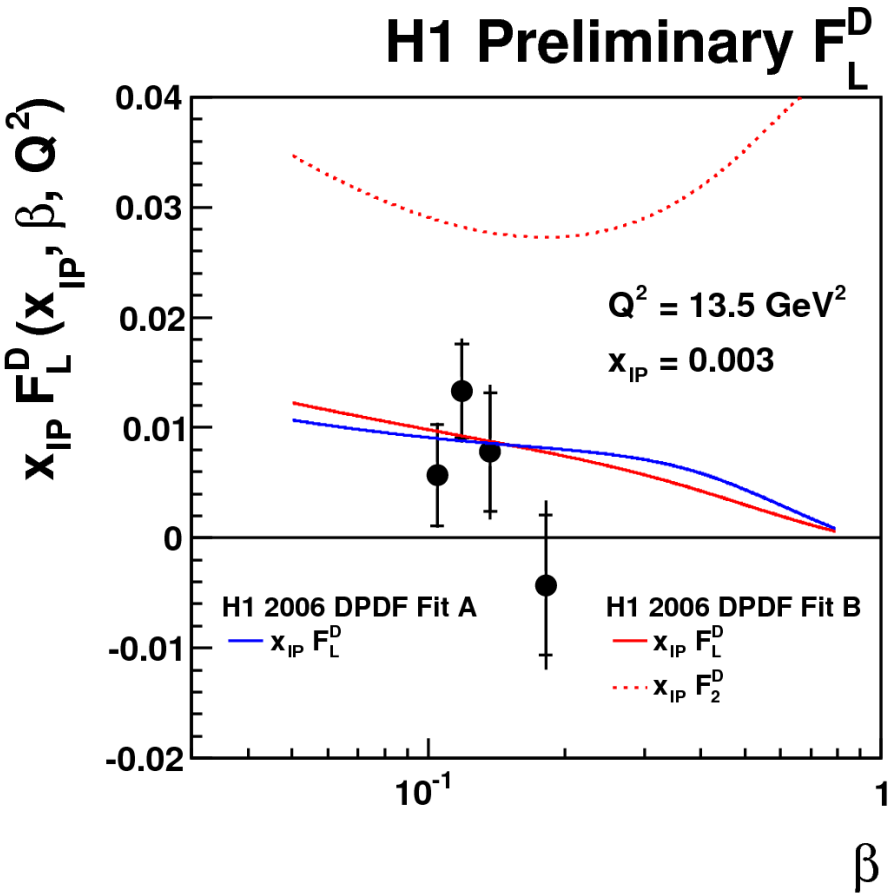
F_L^D Results



- F_L^D is measured
  in the kinematic region:
  $2.5 < Q^2 < 32$ GeV^2
  $0.001 < x_{IP} < 0.01$
- measurements are corrected to:
  Q^2 = 4 and 13.5 GeV^2
  x_{IP} = 0.003

- **significantly non-zero results (more than 5σ)**
- **consistent with the H1 2006 DPDF Fits**
  - based on DPDF's and factorisation
  - extrapolation of the Fits shown for Q^2 = 4 GeV^2

F_L^D Results



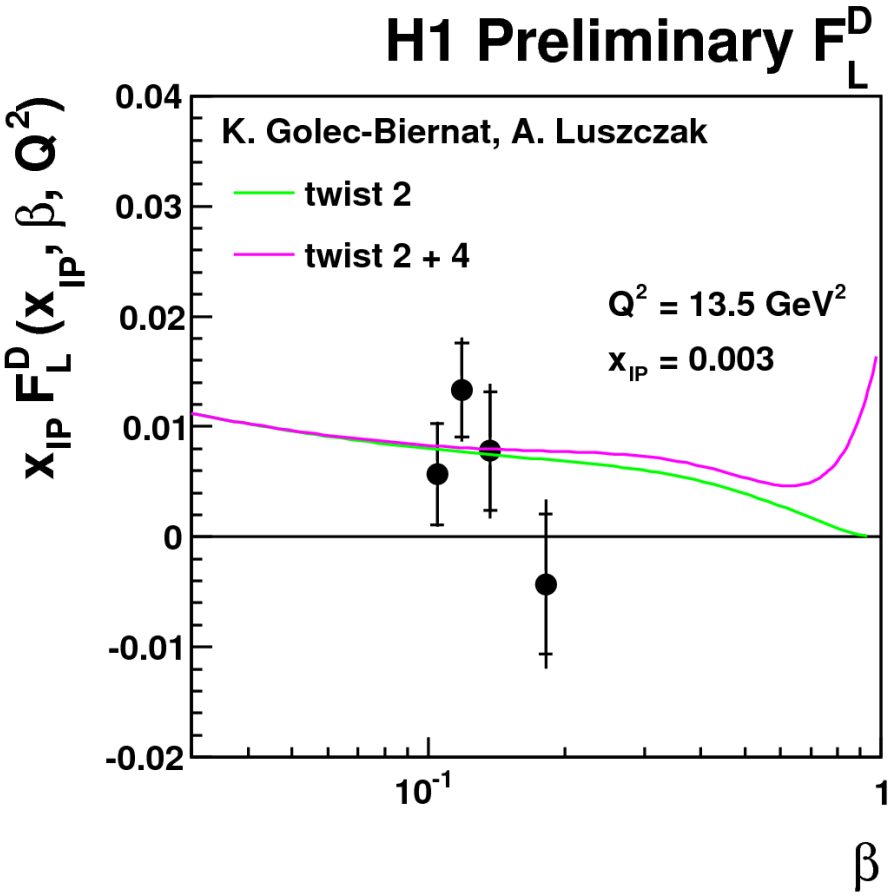
- F_2^D prediction gives the upper bound for F_L^D in the range of validity of the Fits

QCD Fits and Higher Twist Effects

- higher twist longitudinal contribution to diffraction at high β implies large F_L^D (e.g. BEKW)
- F_2^D dominated by F_L^D at high β and low Q^2

$$F_2 = F_T + F_L$$

- QCD fits from H1 only consider the leading twist and do not predict large F_L^D



- **measurement is also consistent with K. Golec-Biernat et al.**
- **no sensitivity to the twist 4 contribution in the current β range**

Summary

- **the first F_L^D measurement**
- significant non-zero value (more than 5σ)

- a new, independent test of the diffractive gluon density
- verification of the QCD factorisation in diffractive DIS
  - dijets
  - D^*
  - F_L^D

- F_L^D measured at $Q^2 = 13.5\ \text{GeV}^2$, $x_{IP} = 0.003$ and $\beta \sim 0.1$
  $Q^2 = 4\ \text{GeV}^2$, $x_{IP} = 0.003$ and $\beta \sim 0.03$