Measurement of the Longitudinal Structure Function in Diffraction F_L^D

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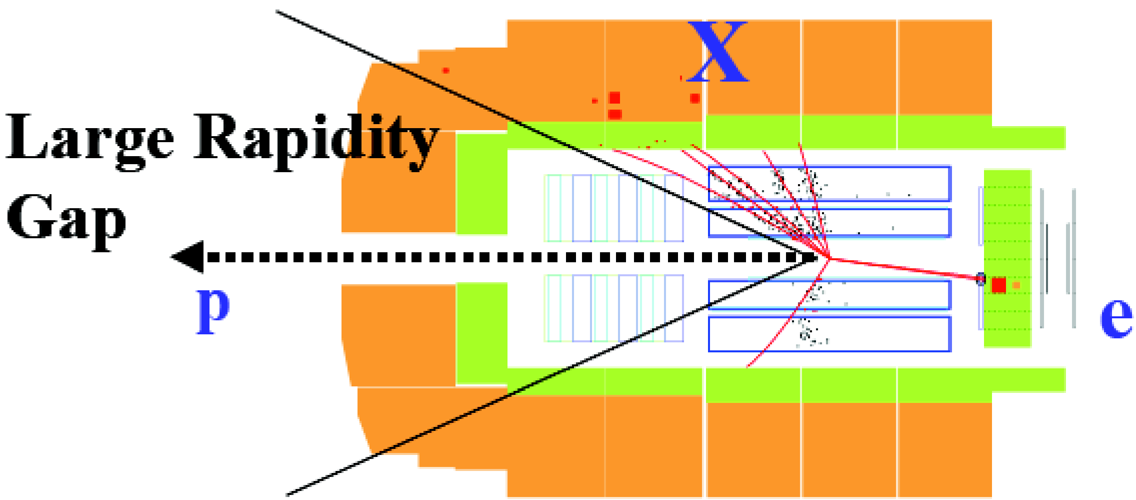
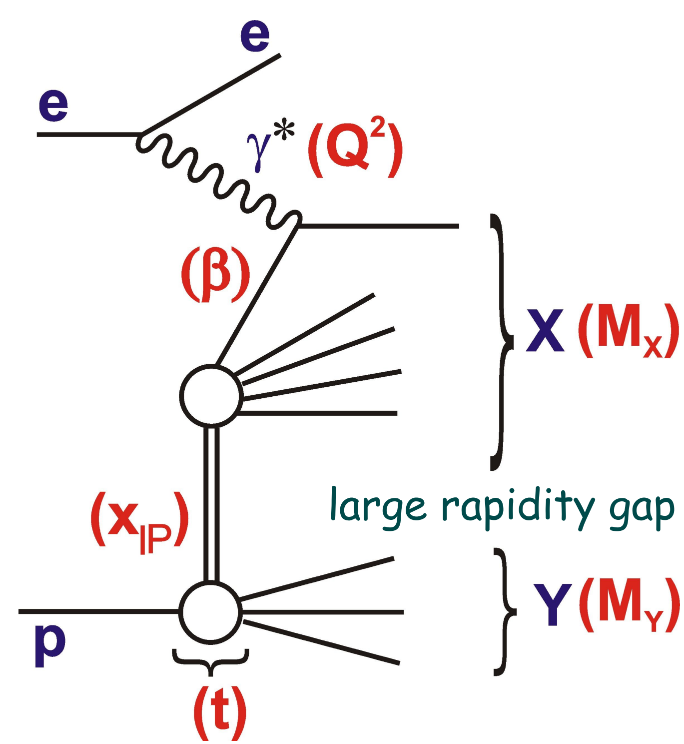
Diffractive Kinematics and Rapidity Gap





$$x = x_{IP}\,\beta$$

$$\beta = \frac{Q^2}{Q^2 + M_X^2}$$

$$x_{IP} = \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

Proton Structure Functions in Diffraction

- structure functions F_2^D and F_L^D (similar to inclusive F_2 and F_L)

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

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

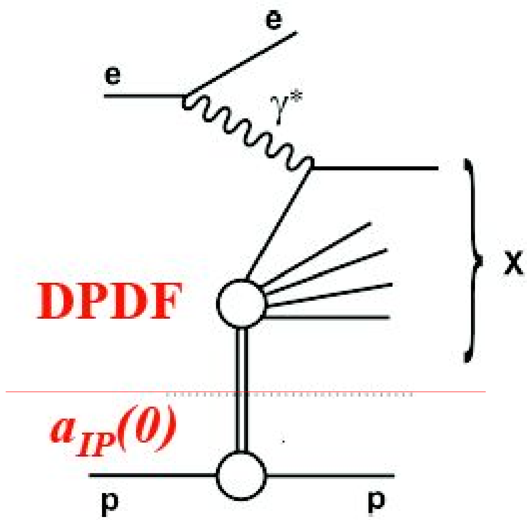
$$Y_+=1+(1-y)^2$$

- F_L^D contributes to the reduced cross section mainly at high y (low β)

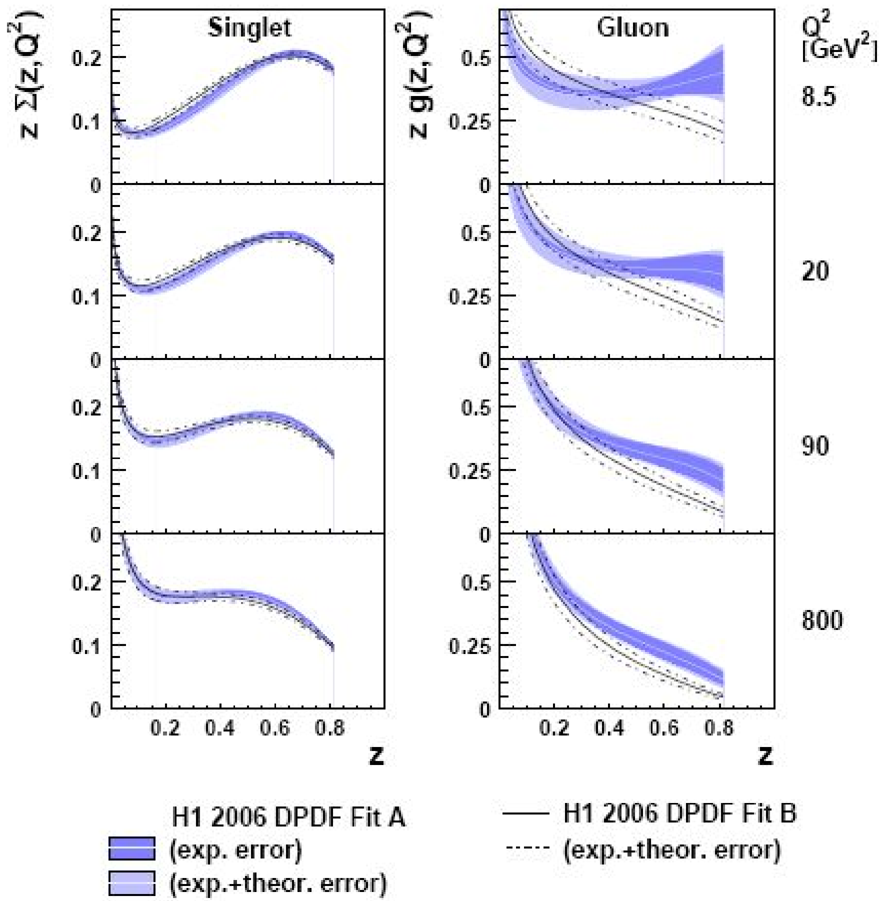
$$Q^2=x_{IP}\,\beta\,y\,s$$

QCD Factorisation in Diffraction

- diffractive parton densities are extracted from the inclusive measurements from the NLO QCD fit (β and Q^2 dependence)
  - singlet: $z\Sigma(z,Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$
  - gluon: 2 parametrisations (Fit A and Fit B)



x_{IP} dependence is factorised in the pomeron flux $\alpha_{IP}(0)$



$z_g(z,Q_0^2) = A_g(1-z)^{C_g}$ $\quad$ $z_g(z,Q_0^2) = A_g$

H1 NLO QCD DPDF fit to F_2^D

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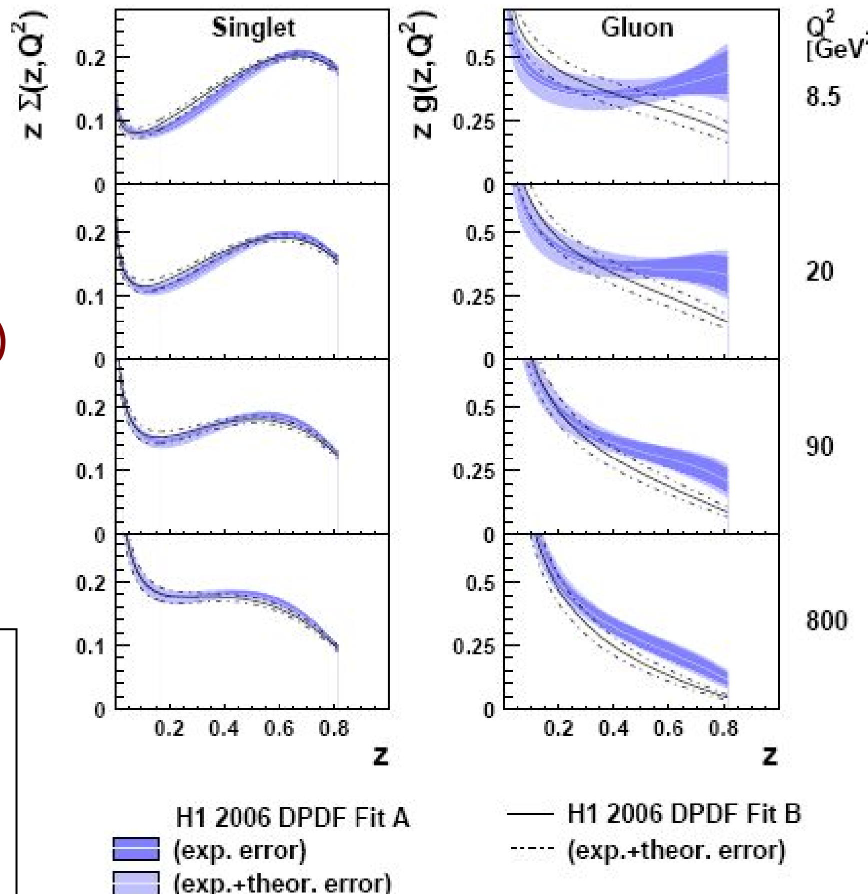
- diffractive dijet measurement is compatible with the gluon densities extracted from the inclusive analyses are correct (Fit B preferred) and shows that the QCD factorisation holds



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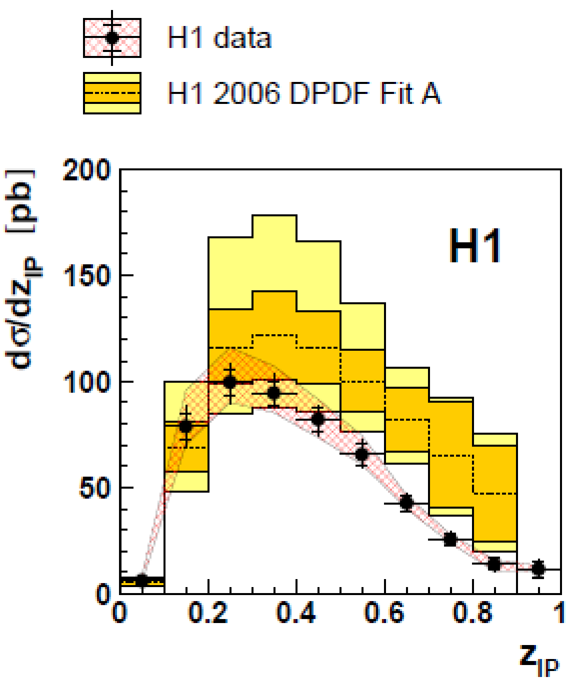

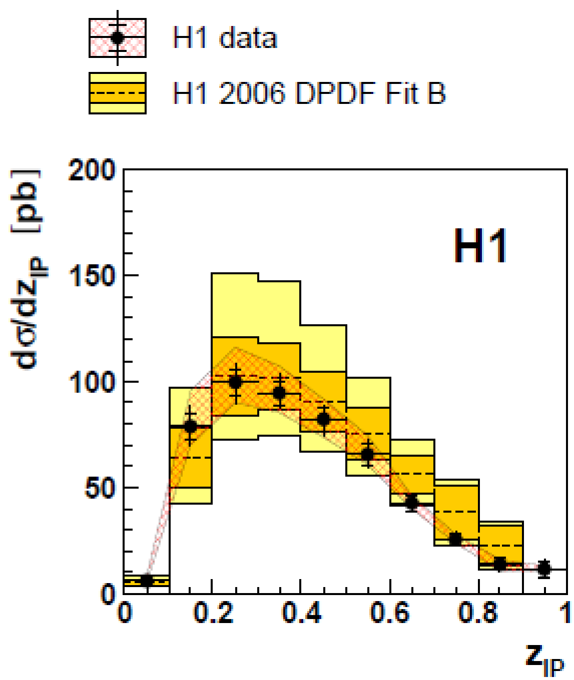

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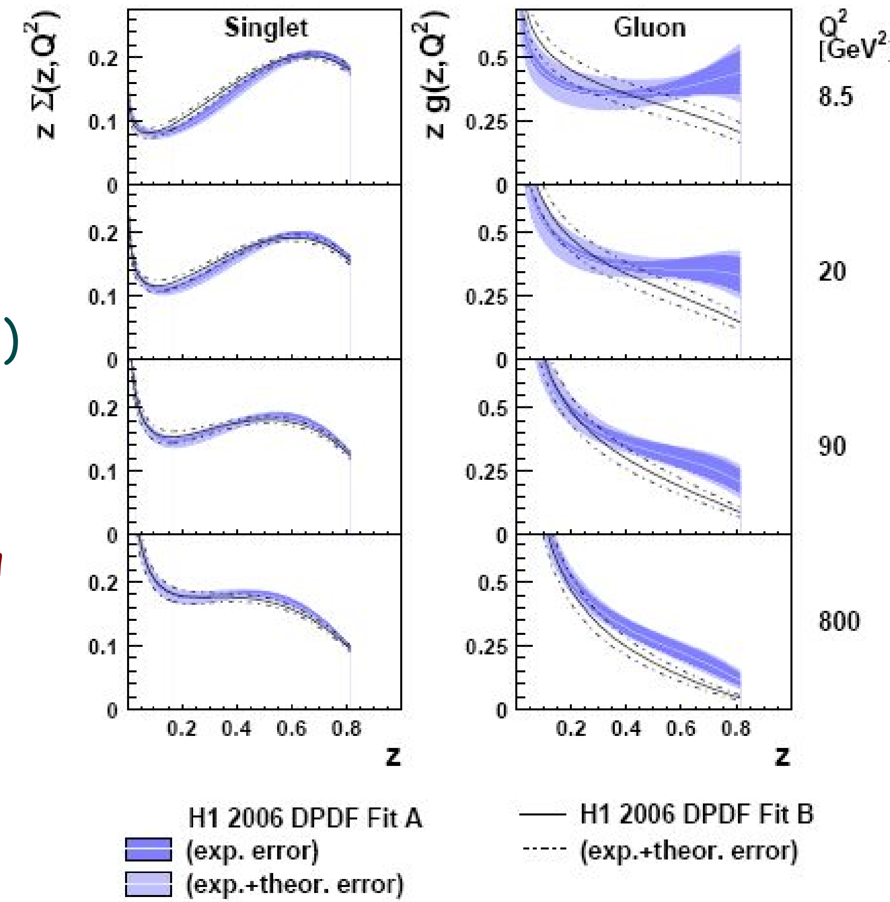
- inclusive measurements constrain quarks, gluons are constrained weakly from the scaling violations



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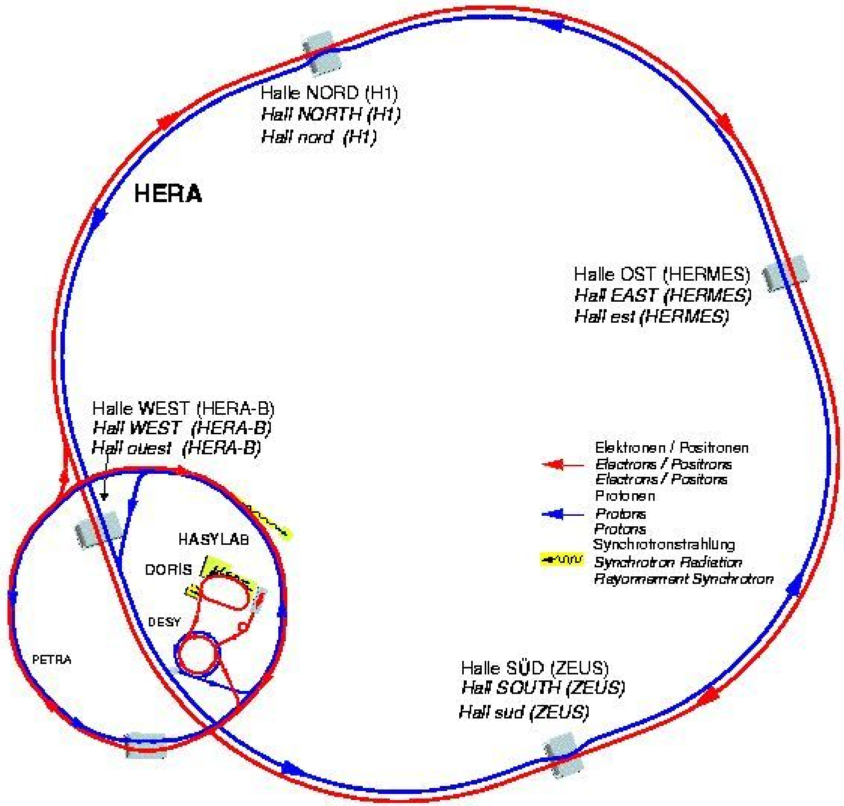
- diffractive dijet measurement is compatible with the gluon densities extracted from the inclusive analyses are correct (Fit B preferred), and shows that the QCD factorisation holds
- inclusive measurements constrain quarks, gluons are constrained weakly from the scaling violations
- observables sensitive to the gluons provide crucial tests of the theory and important extra constraints on the gluon

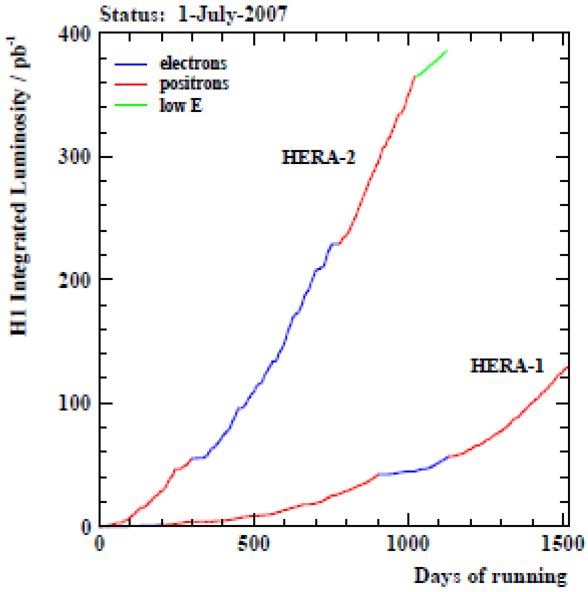
$$F_L^D \sim x\, g(x)$$

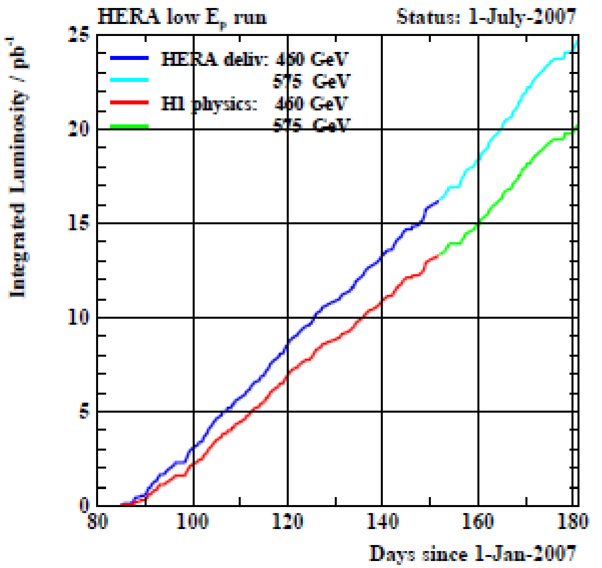
→ F_L^D is sensitive to gluons

HERA Low Energy Runs

- HERA *ep* collider stopped operating in 2007
- nominal E_p = 920 GeV
- E_e = 27.5 GeV







- last months of HERA running were dedicated to the data for F_L and F_L^D measurements
- runs with the reduced proton beam energies of 460 and 575 GeV

Measurement Strategy

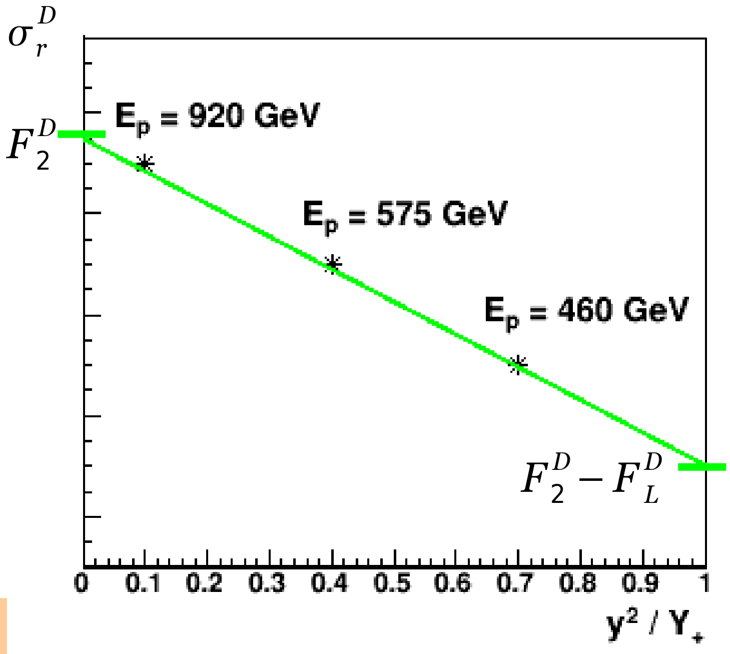
- analysis closely follows the measurement of the inclusive F_L (recently done by H1)
- diffractive reduced cross sections are determined in fixed x_{IP}, β, Q^2 bins
- in order to distinguish between F_L^D and F_2^D we need to measure at different y (for the fixed x_{IP}, β, Q^2)

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

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

- combine the cross section measurements from runs with different centre-of-mass energy
  - H1 2007 e^+ data
    - 21 pb^{-1} E_p = 920 GeV
    - 11 pb^{-1} E_p = 460 GeV
    - 6 pb^{-1} E_p = 575 GeV

$$Y_+ = 1 + (1-y)^2$$

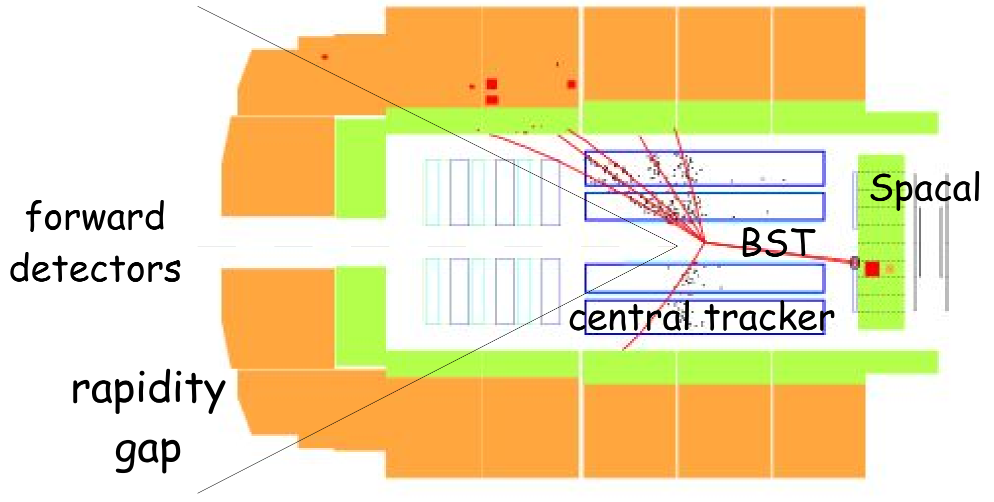


Data Selection and H1 Detector

- rapidity gap selection
- $Q^2 > 7$ GeV^2
- $y < 0.9$
  - high y region sensitive to F_L^D
  - $E_e' > 3.4$ GeV $\quad y \approx 1 - \frac{E_e'}{E_e}$
  - more photoproduction background at lower electron energies (challenging measurement)
- $E - p_z > 35$ GeV
- kinematic variables reconstructed from the scattered electron

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

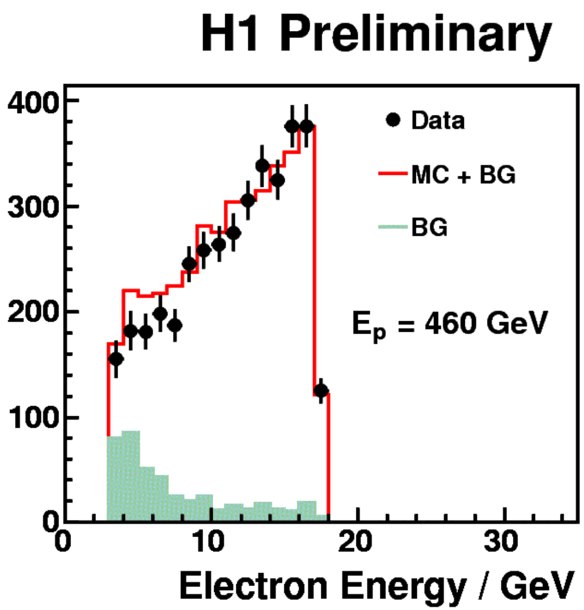
- forward detectors
  - forward muon detector
  - forward plug calorimeter
  - forward scintillators
- electron identification
  - Spacal calorimeter
  - central tracker
  - Backward Silicon Tracker



Background at High y

- data at high y contain photoproduction background
  - scattered electron escapes the central detector through the beam-pipe
  - one of the hadronic final state particles is mis-identified as the scattered electron
  - background from hadronic particles is almost charge symmetric

$$\frac{N^{+}_{bg}}{N^{-}_{bg}} = asym \sim 1$$

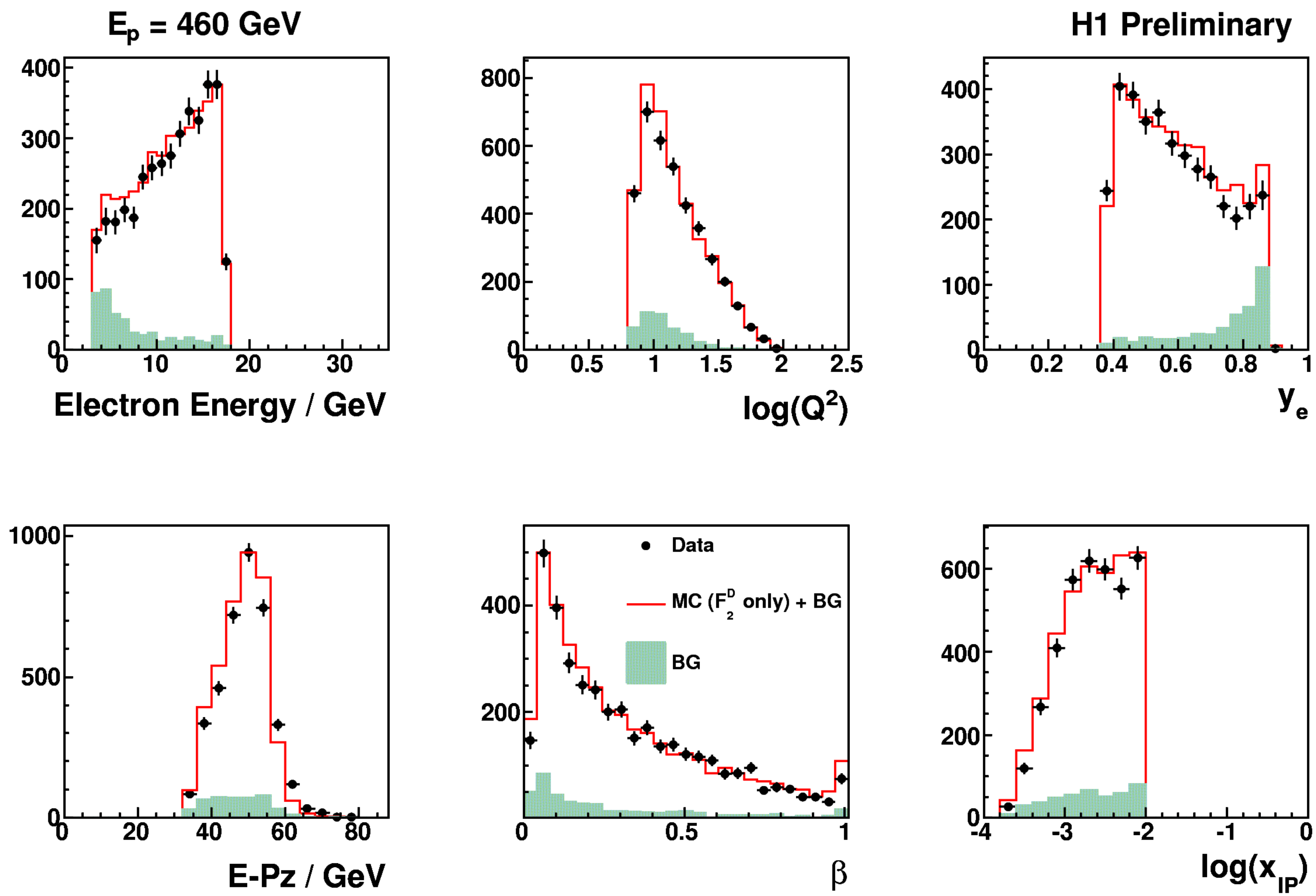


- background subtraction
  - require positive charge of the scattered lepton candidate in the signal data
  - estimate the background using the negative sample and the measured asymmetry factor

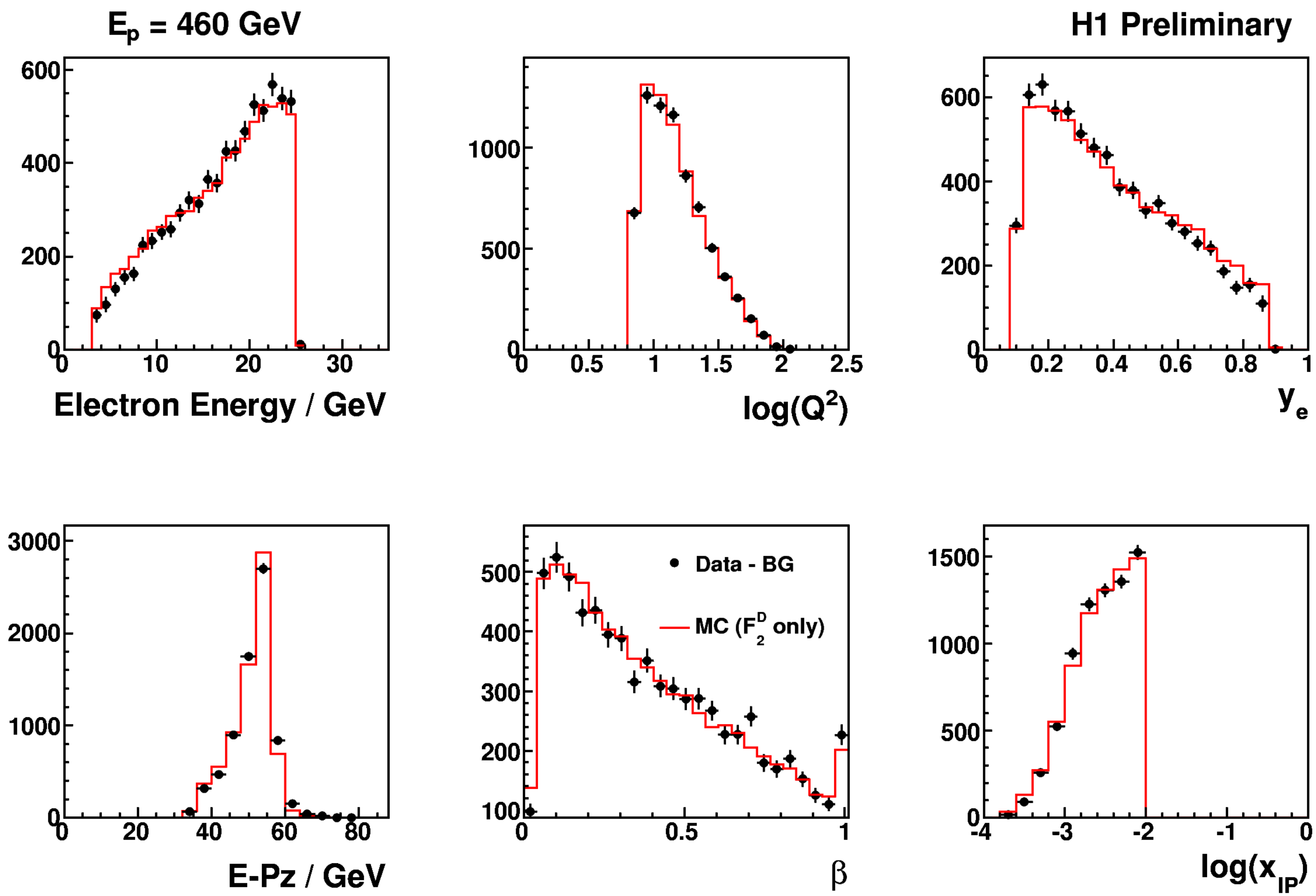
$$N_{signal} = N^{+} - asym\ N^{-}$$

background in the plot determined from the data
MC includes F_2^D only

Control Plots for Ep = 460 GeV (y > 0.38)

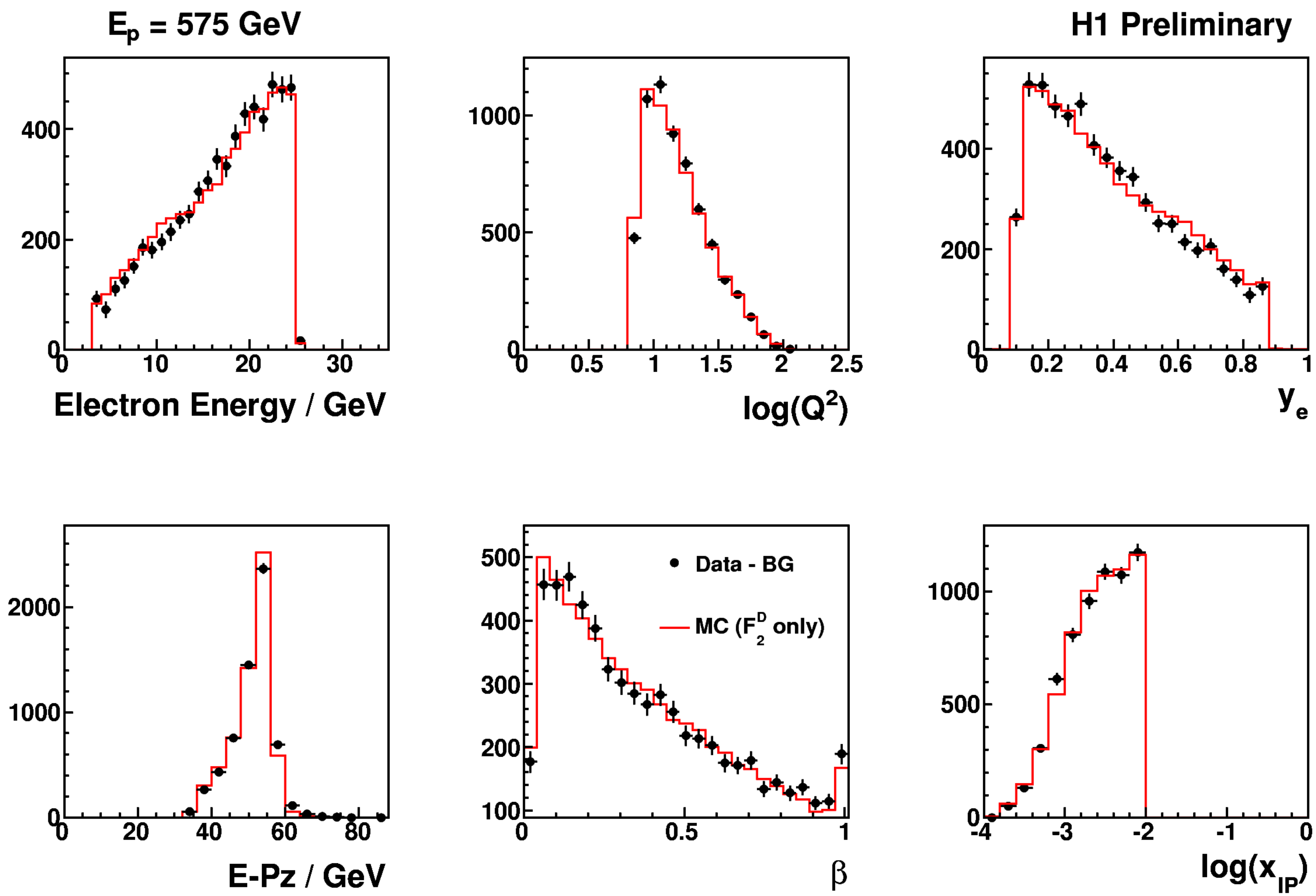


460 GeV Data after Background Subtraction (all *y*)



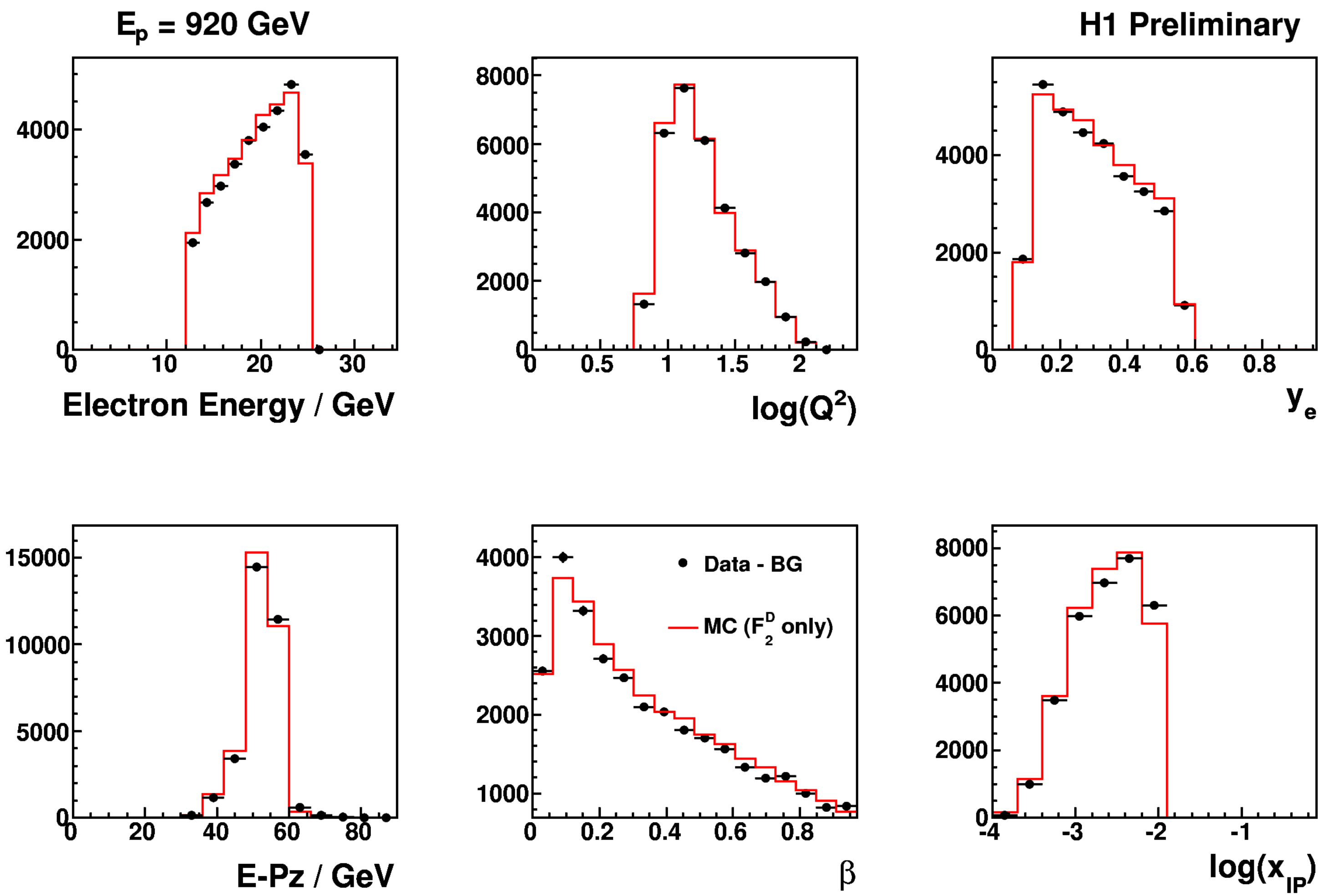
- data well described by the simulation

575 GeV Data after Background Subtraction (all *y*)



- data well described by the simulation

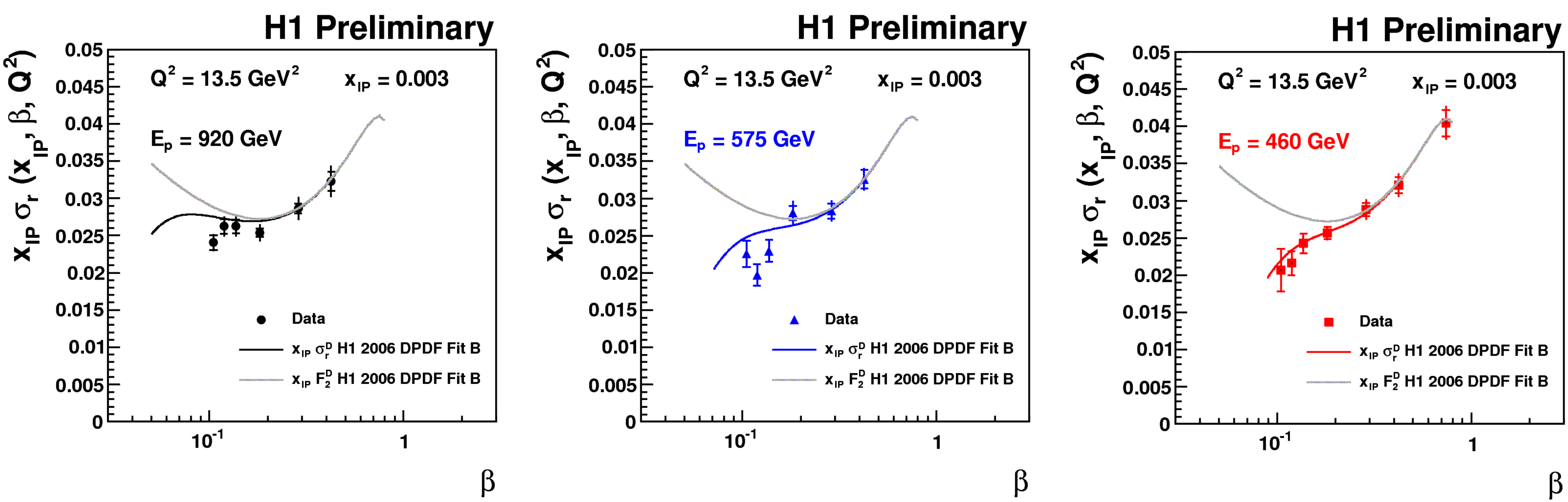
920 GeV Data after Background Subtraction (all *y*)



- data well described by the simulation

Diffractive Reduced Cross Sections

- data cross section corrected for proton dissociation
  - rapidity gap selection accepts events with dissociated protons up to about M_Y = 1.6 GeV (acceptance of the forward detectors near the beam pipe)
- use as constraint that F_2^D is independent of the beam energy
  - no significant contribution from F_L^D at high β (low y)
  - data cross sections re-normalised at 0.28 < β < 0.42 in order to give the same F_2^D

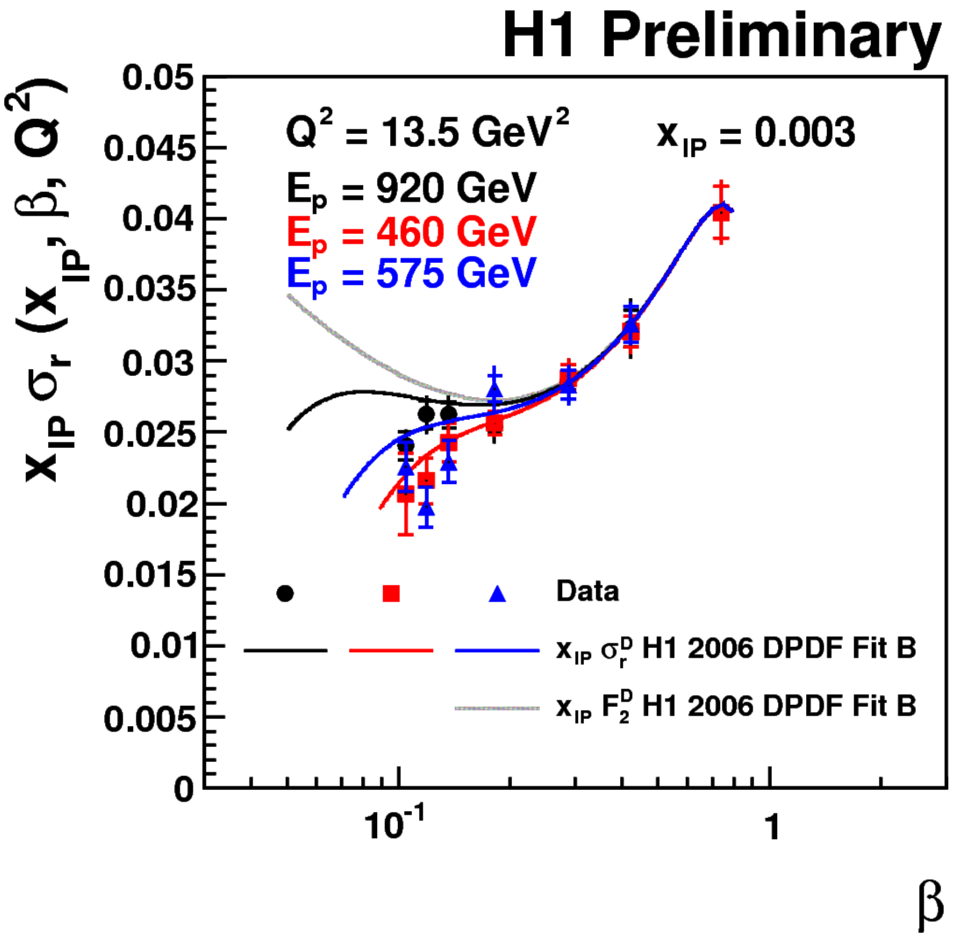


Diffractive Reduced Cross Sections

- data cross sections sensitive to F_L^D

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

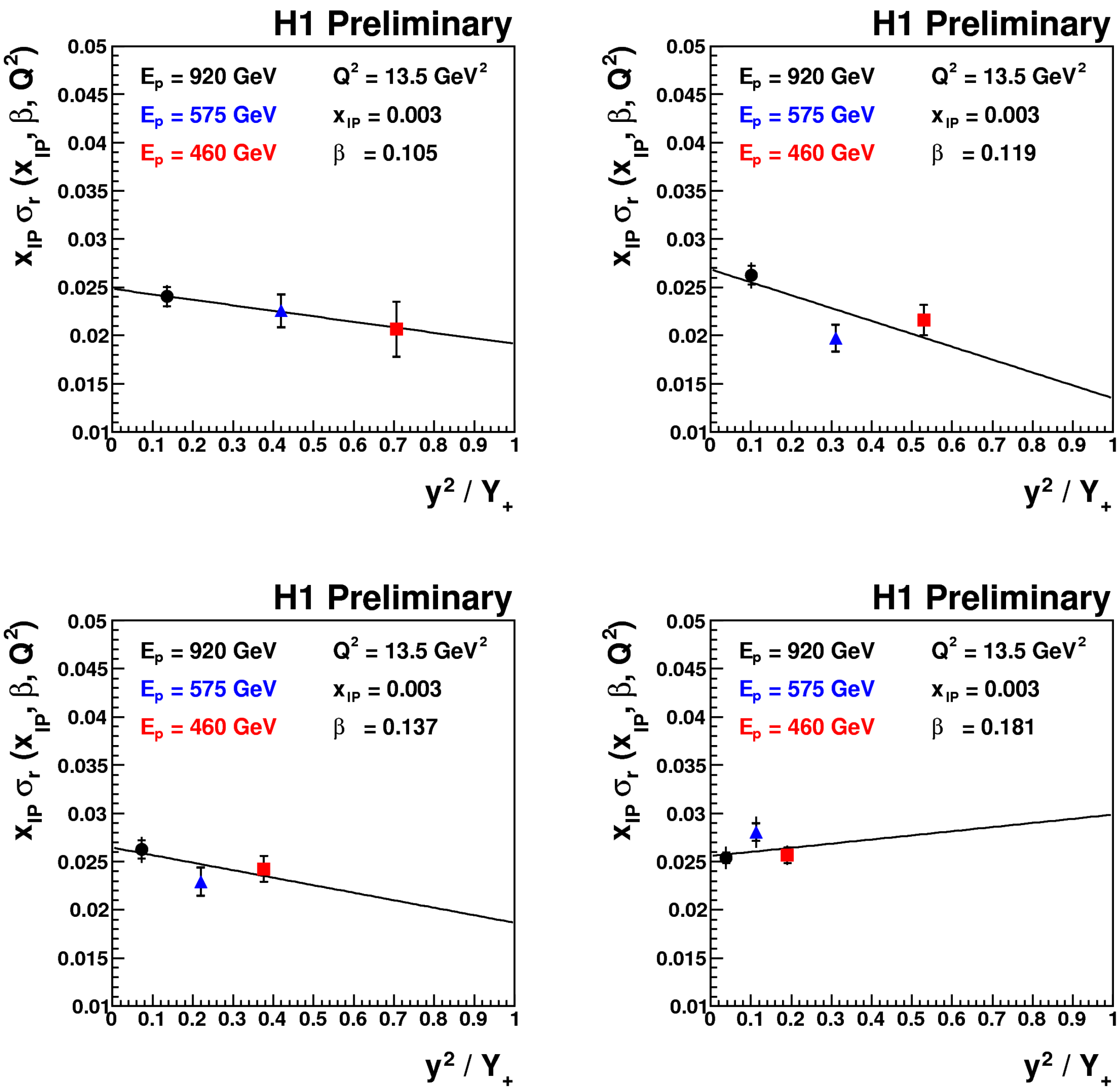
$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$



F_L^D Fits

- highest sensitivity to F_L^D at low β (high y)
- linear fit to obtain F_2^D and F_L^D

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



F_L^D Results

- F_L^D measured in the kinematic region:

  $7 < Q^2 < 32$ GeV^2

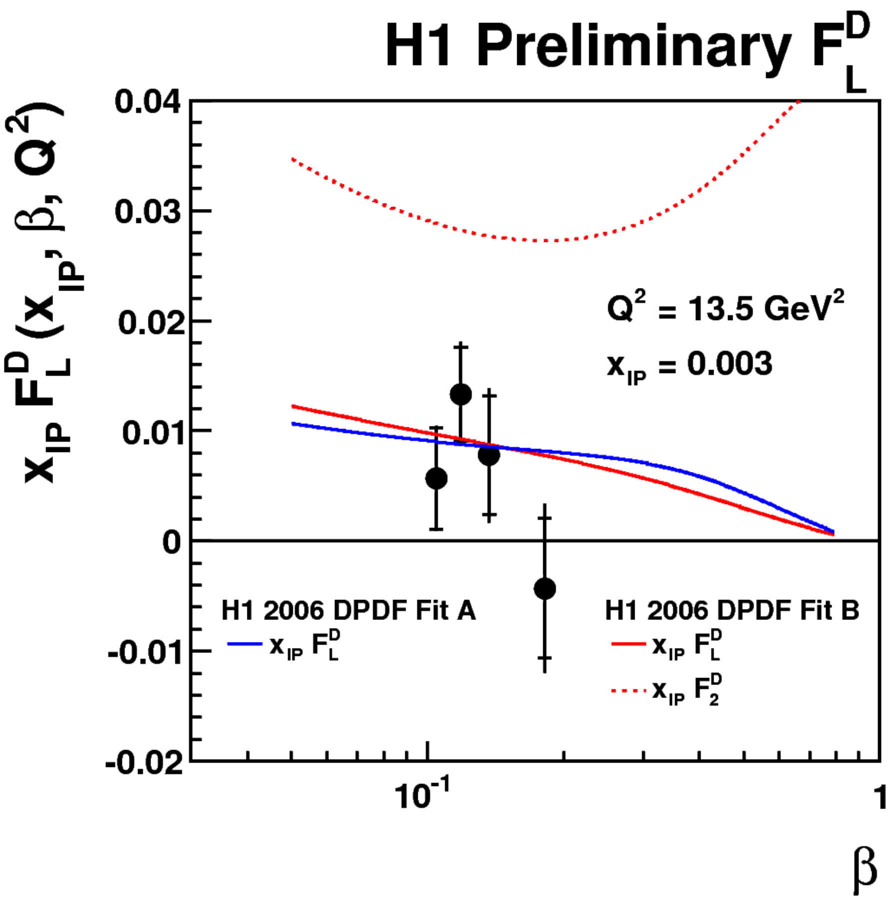
  $0.001 < x_{IP} < 0.01$

- measurement corrected to:

  $Q^2 = 13.5$ GeV^2

  $x_{IP} = 0.003$

- the measurement represents non-zero value with more than 3σ significance
- results consistent with the H1 2006 DPDF Fits (based on DPDF's and factorisation)

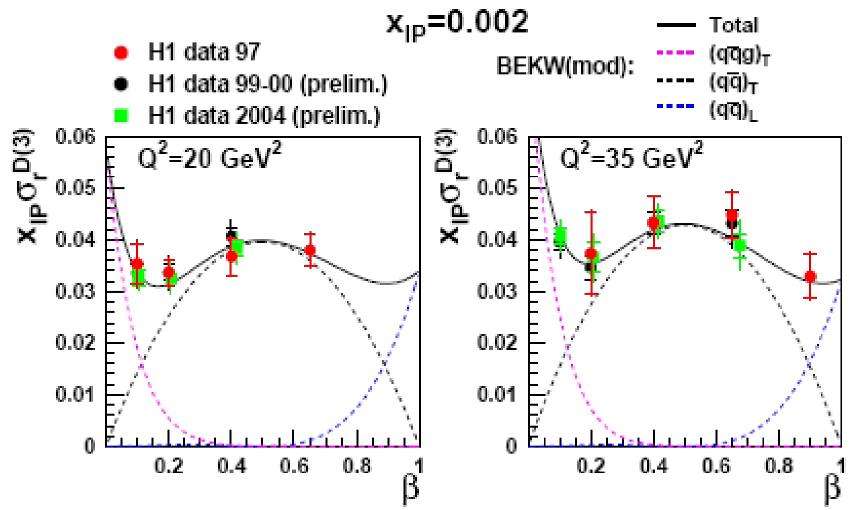


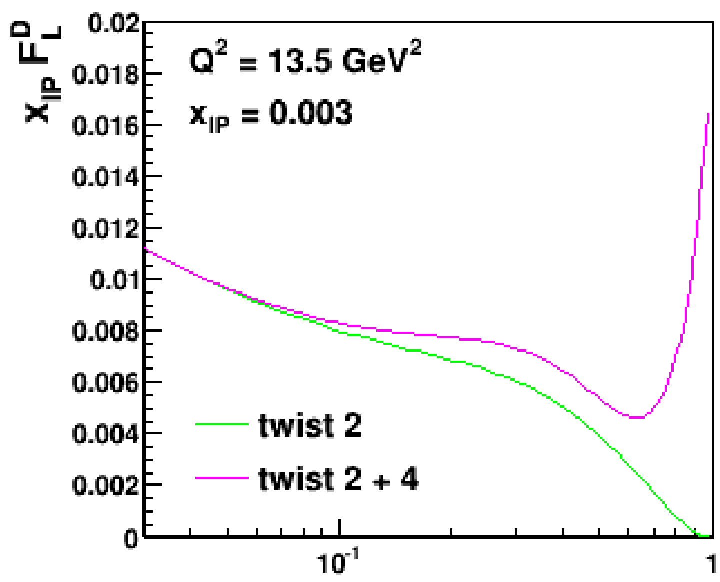
QCD Fits and Higher Twist Effects

- higher twist longitudinal contribution to diffraction at high β (e.g. BEKW) implies large F_L^D
  (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 include the leading twist and do not predict large F_L^D
- e.g. Golec-Biernat fits data with both F_L^D twist 2 and twist 4
- a measurement of F_L^D can give insight into an as yet unexplored area of diffraction

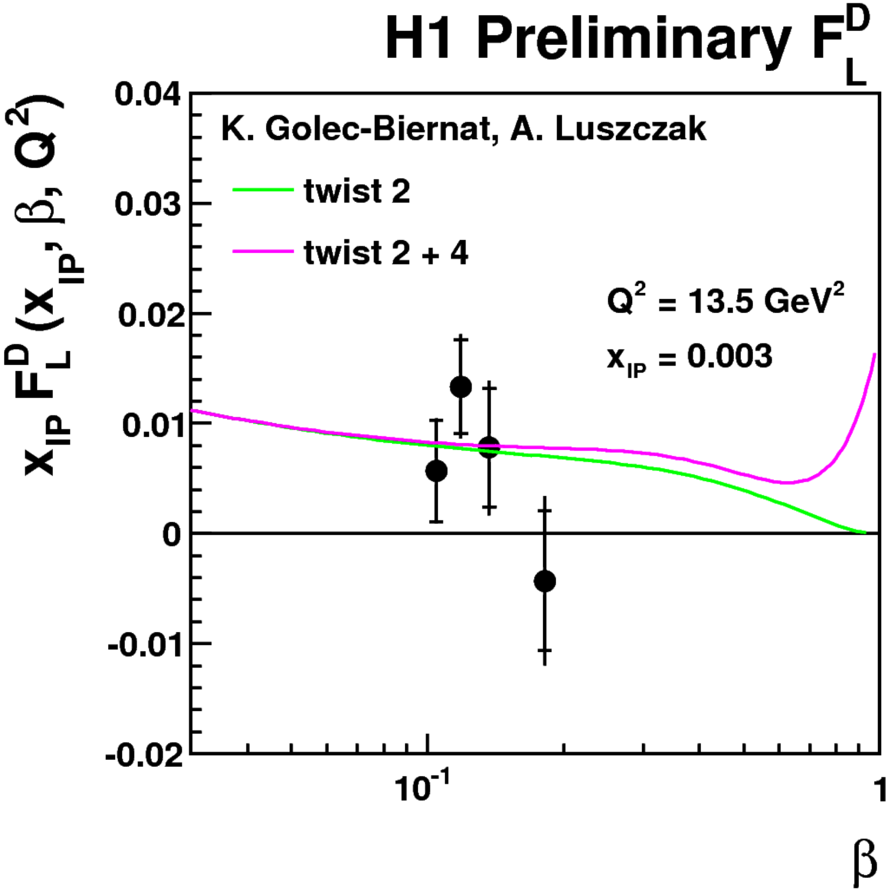




predictions by K. Golec-Biernat

F_L^D Results

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



Summary

- **the first F_L^D measurement**

- F_L^D measured at Q^2 = 13.5 GeV^2, x_{IP} = 0.003 and $\beta \sim 0.1$
- the measurement represents a significant non-zero value (3σ)
- the measurement explores new territory in diffraction
- a new, independent test of the diffractive gluon density and verification of the QCD framework as applied to diffraction