



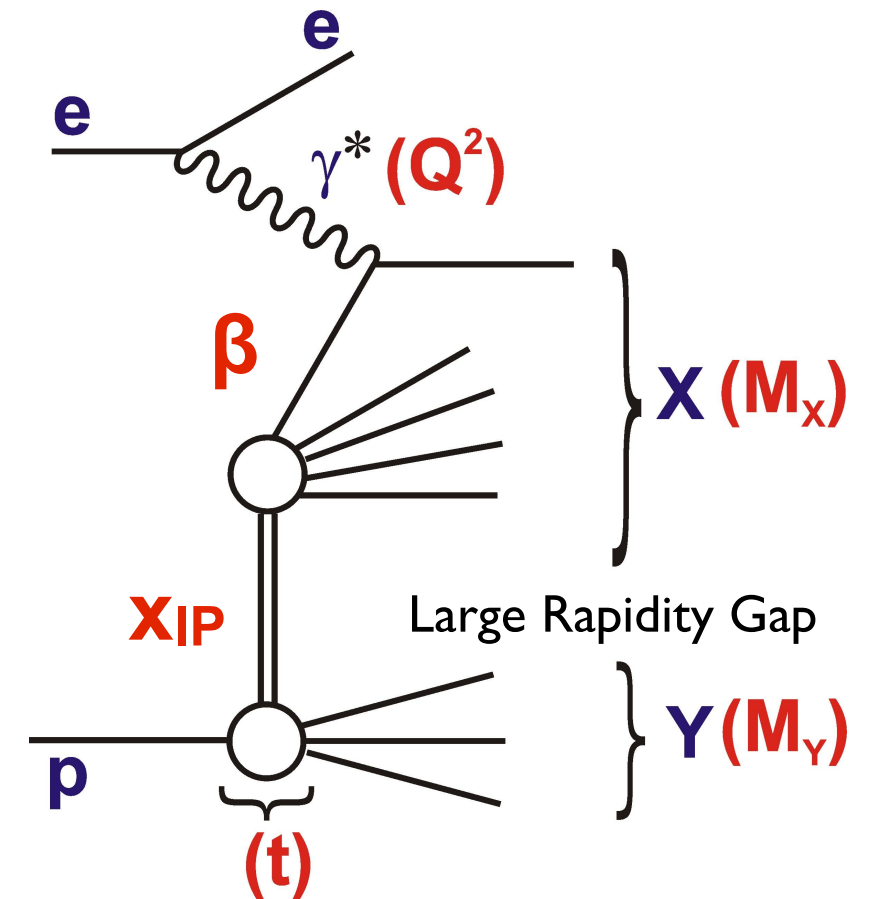
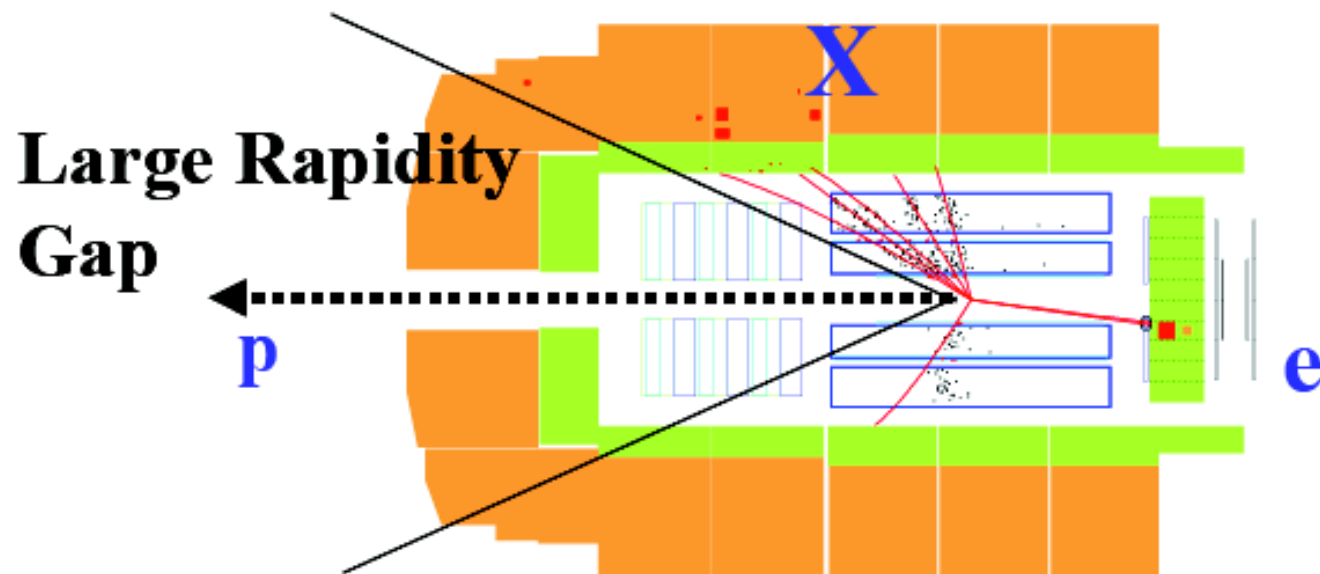
Measurement of the Diffractive Longitudinal Structure Function FLD at HERA

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(CERN, Charles University in Prague)
on behalf of the H1 Collaboration

DIS Conference, Bonn
23/03/2012

Diffractive DIS

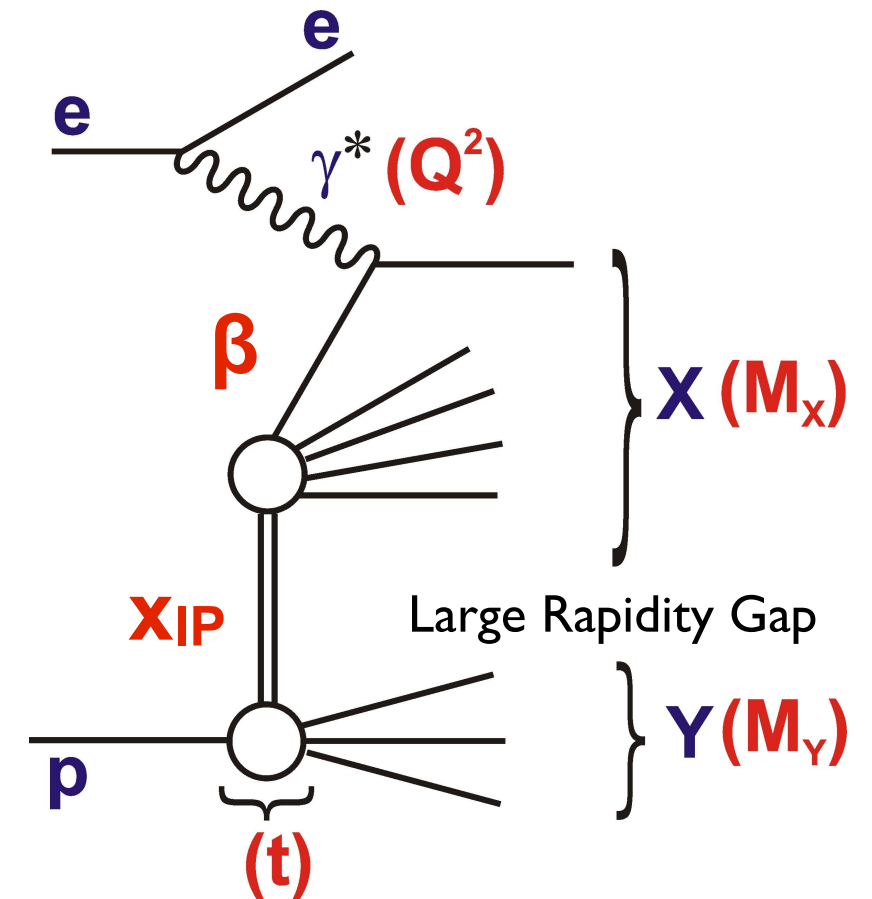
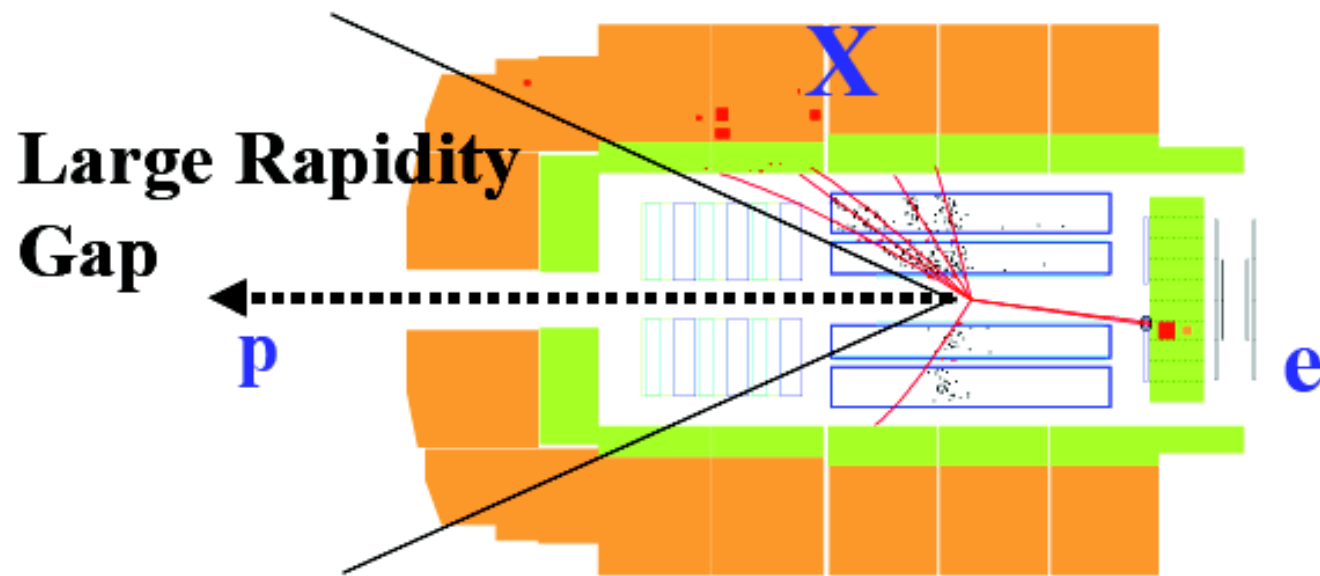


- Diffractive reduced cross-section:

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

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

Diffractive DIS



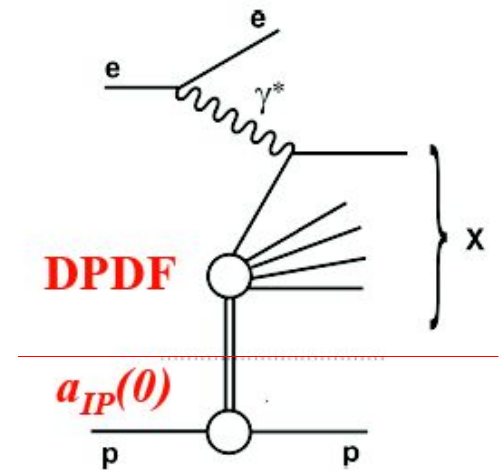
- Diffractive reduced cross-section:

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

- This analysis measures the diffractive longitudinal proton structure function.
- FLD only contributes at high values of y .

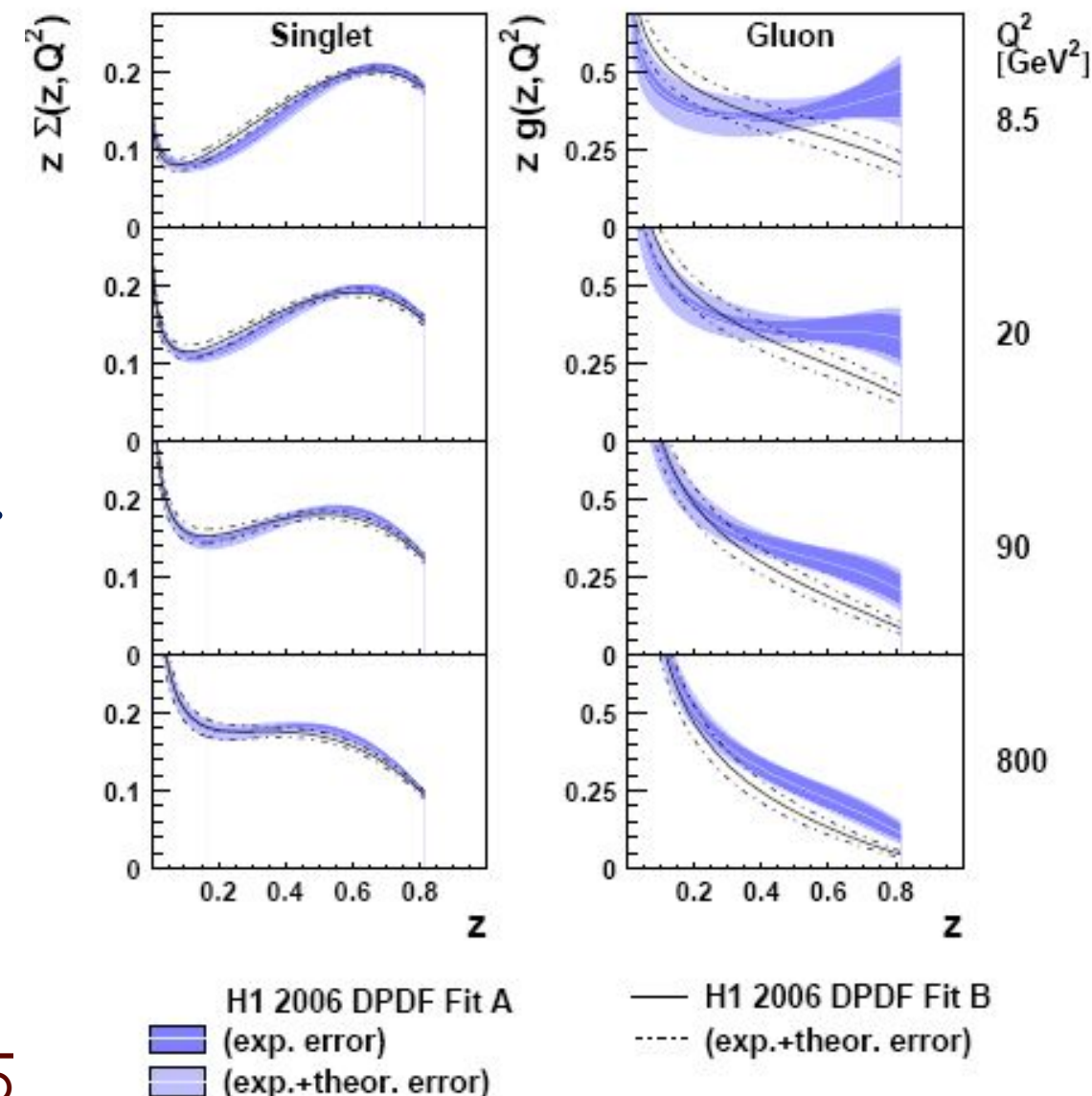
QCD Factorization in Diffraction

- QCD factorization
 - x_{IP} dependence can be factorized in the pomeron flux.



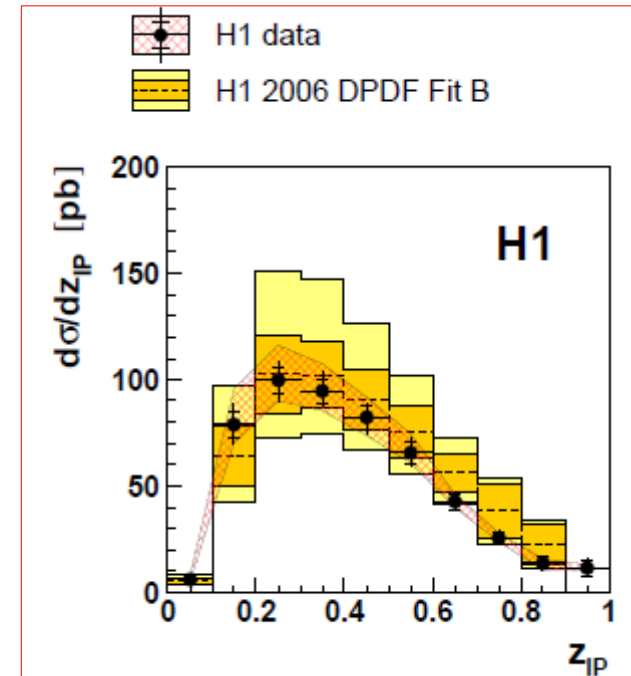
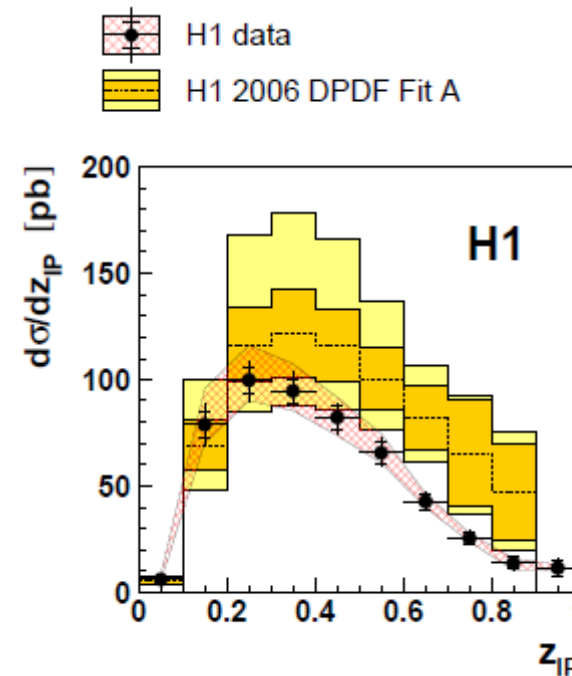
- Diffractive parton densities
 - β and Q^2 dependence
 - H1 2006 DPDF Fit A and Fit B are extracted from the NLO QCD fits to the inclusive measurements.
 - Inclusive measurements constrain quarks.
 - Gluons are constrained weakly from the scaling violations.

$$\frac{d\sigma_r^D}{d\ln Q^2}$$



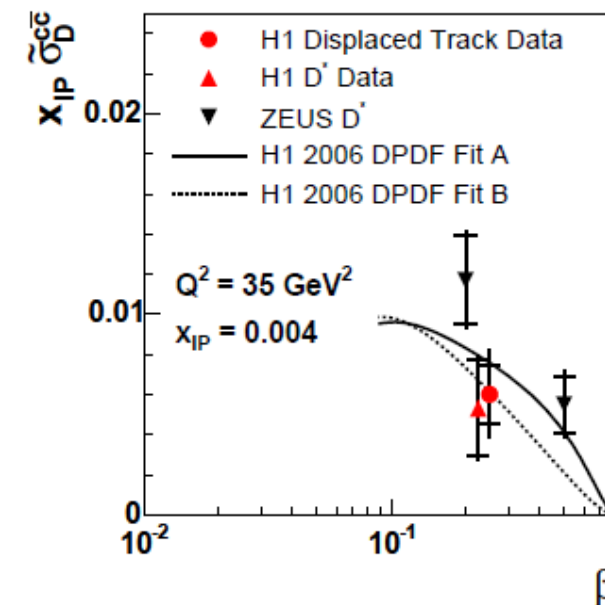
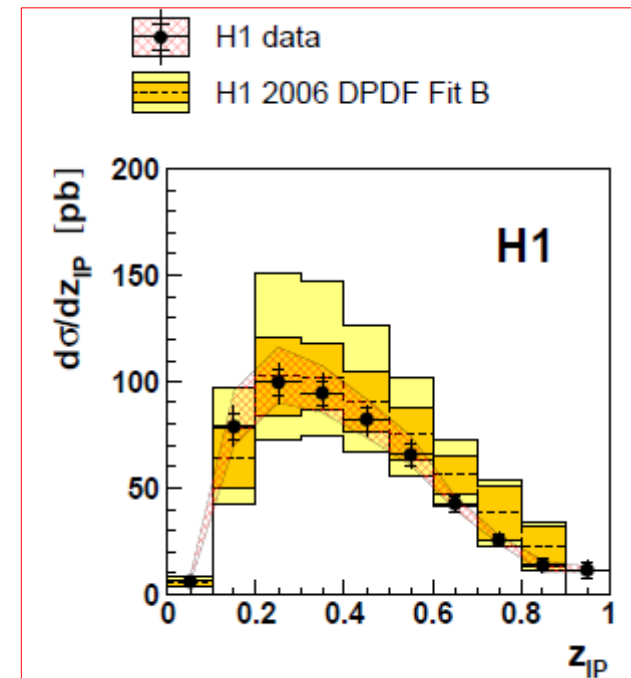
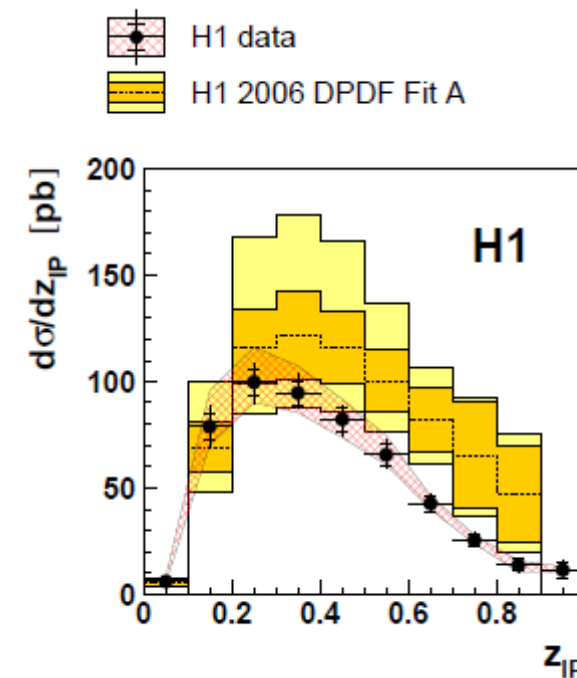
Tests of QCD Factorization

- Diffractive dijets in DIS
 - compatible with the parton densities from H1 2006 DPDF Fits
 - QCD factorisation holds.



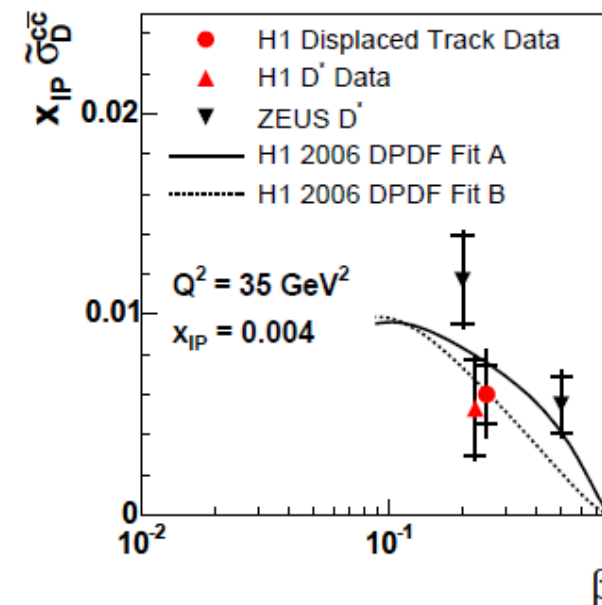
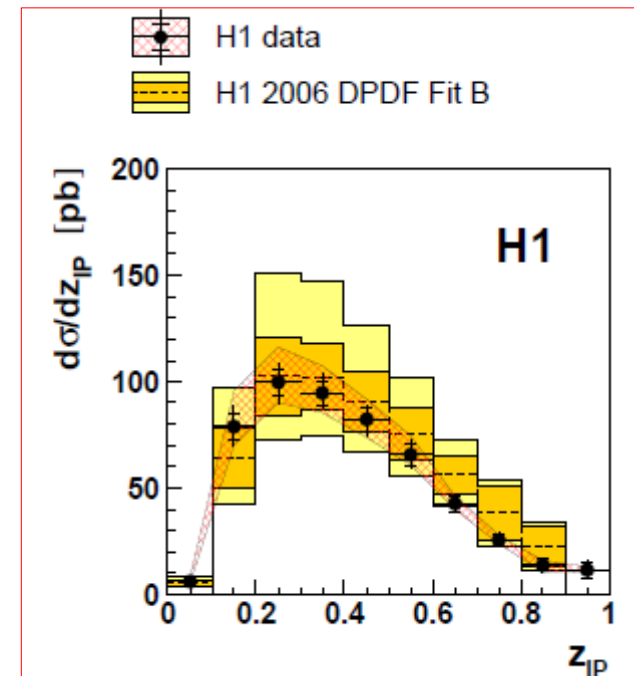
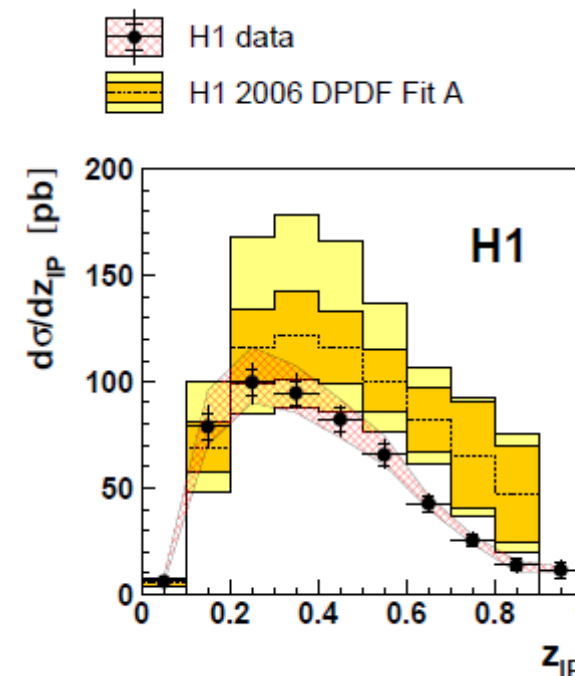
Tests of QCD Factorization

- Diffractive dijets in DIS
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- Diffractive charm production
 - low statistics



Tests of QCD Factorization

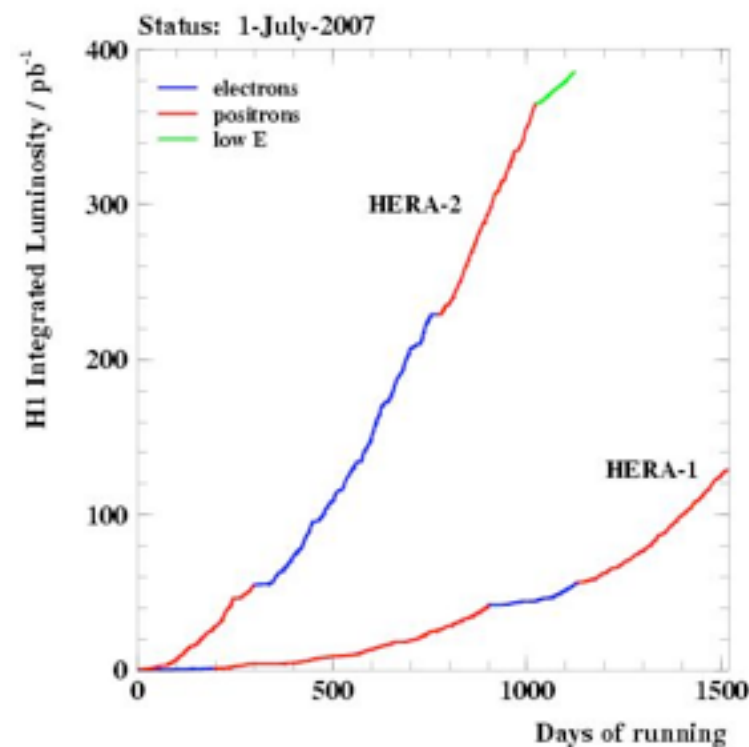
- Diffractive dijets in DIS
 - compatible with the parton densities from H1 2006 DPDF Fits
 - QCD factorisation holds.
- Diffractive charm production
 - low statistics
- FLD measurement
 - probes low x_{IP} and β region inaccessible by dijets and D^*



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

HERA Low Energy Runs

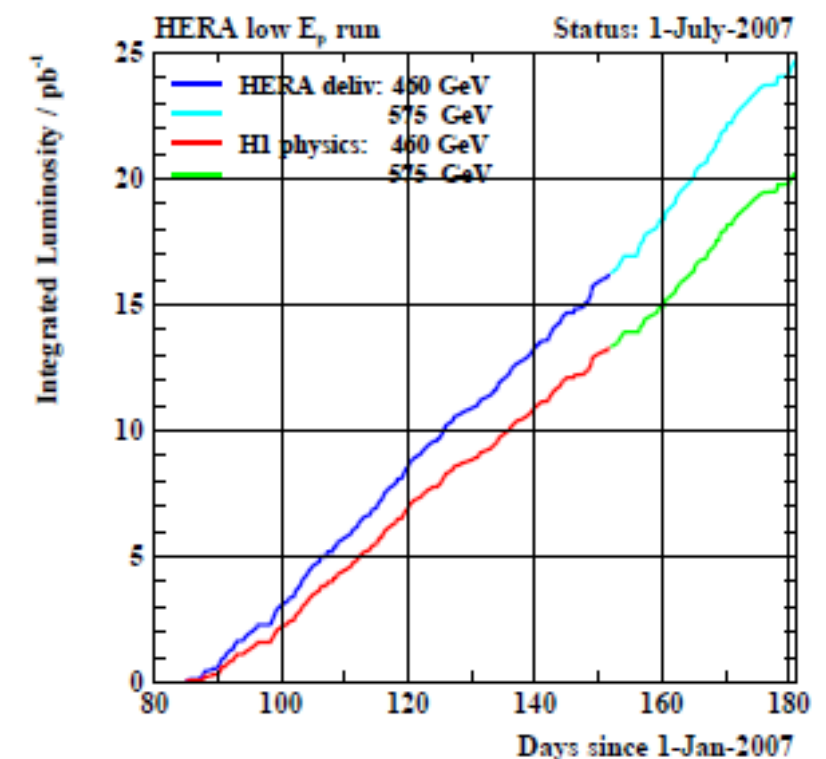
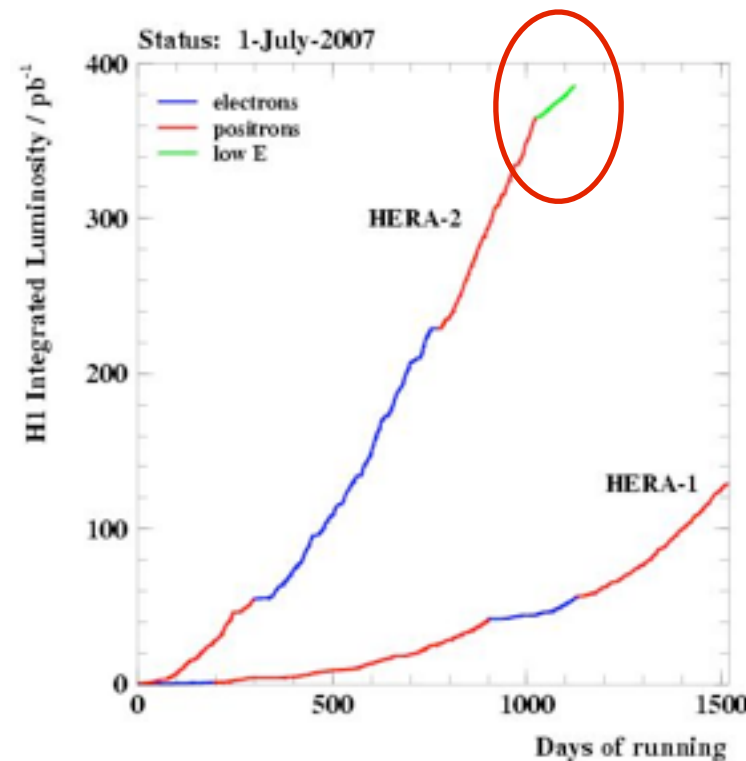
- HERA nominal proton beam energy:
 - $E_p = 820$ GeV (HERA-I phase)
 - $E_p = 920$ GeV (HERA-II phase)



HERA Low Energy Runs

- HERA nominal proton beam energy:
 - $E_p = 820$ GeV (HERA-I phase)
 - $E_p = 920$ GeV (HERA-II phase)
- HERA was operating at reduced proton beam energies in the last months of data taking.

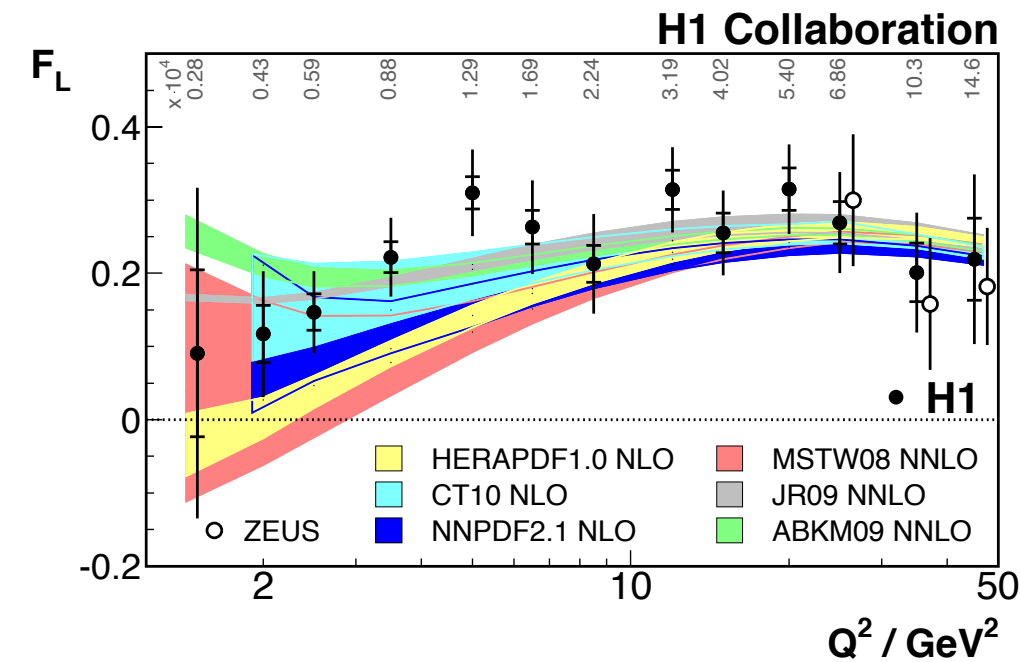
- $E_p = 460$ GeV
- $E_p = 575$ GeV



- The low energy data serve for the purposes of the FL and FLD measurements.

Measurement Strategy

- The analysis closely follows the measurement of the inclusive FL by H1 (DESY-10-228).



- Rosenbluth plots
- Separate the structure functions FLD and F2D by combining measurements at different y (for fixed x_{IP} , β , Q^2).

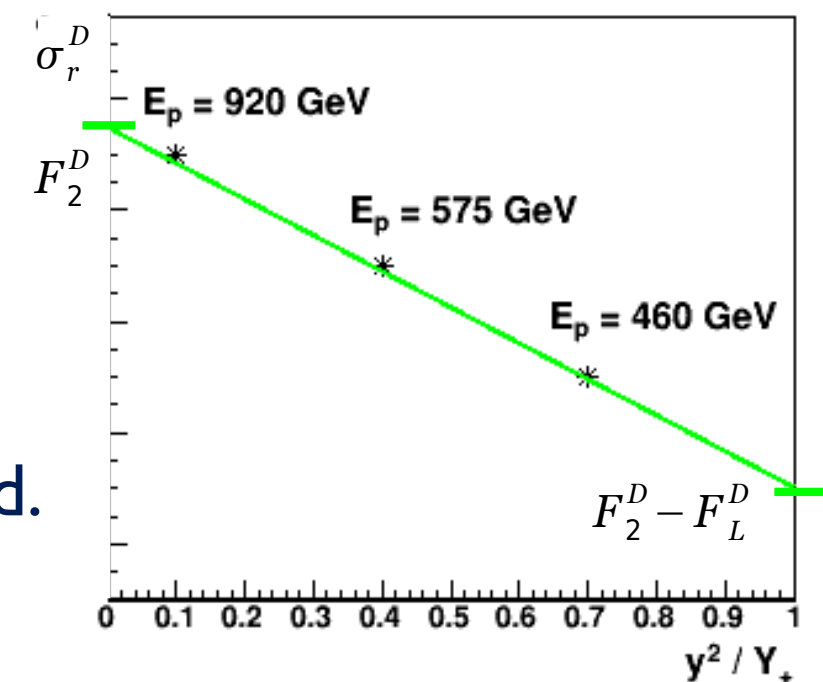
$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D \quad Y_+ = 1 + (1 - y)^2$$

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

- Data at different centre-of-mass energy are needed.

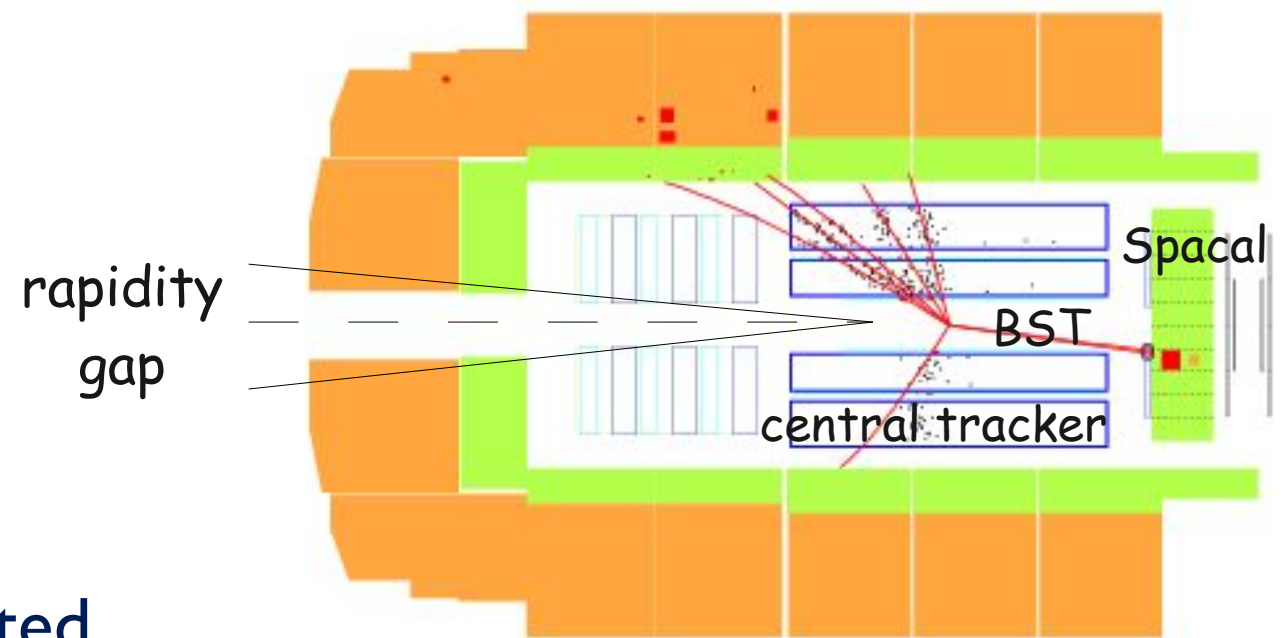
- The following data sets are used:

• $E_p = 820$ GeV	(DESY-06-049)	} e^+p collisions
• $E_p = 920$ GeV	127 pb ⁻¹	
• $E_p = 460$ GeV	9 pb ⁻¹	
• $E_p = 575$ GeV	5 pb ⁻¹	



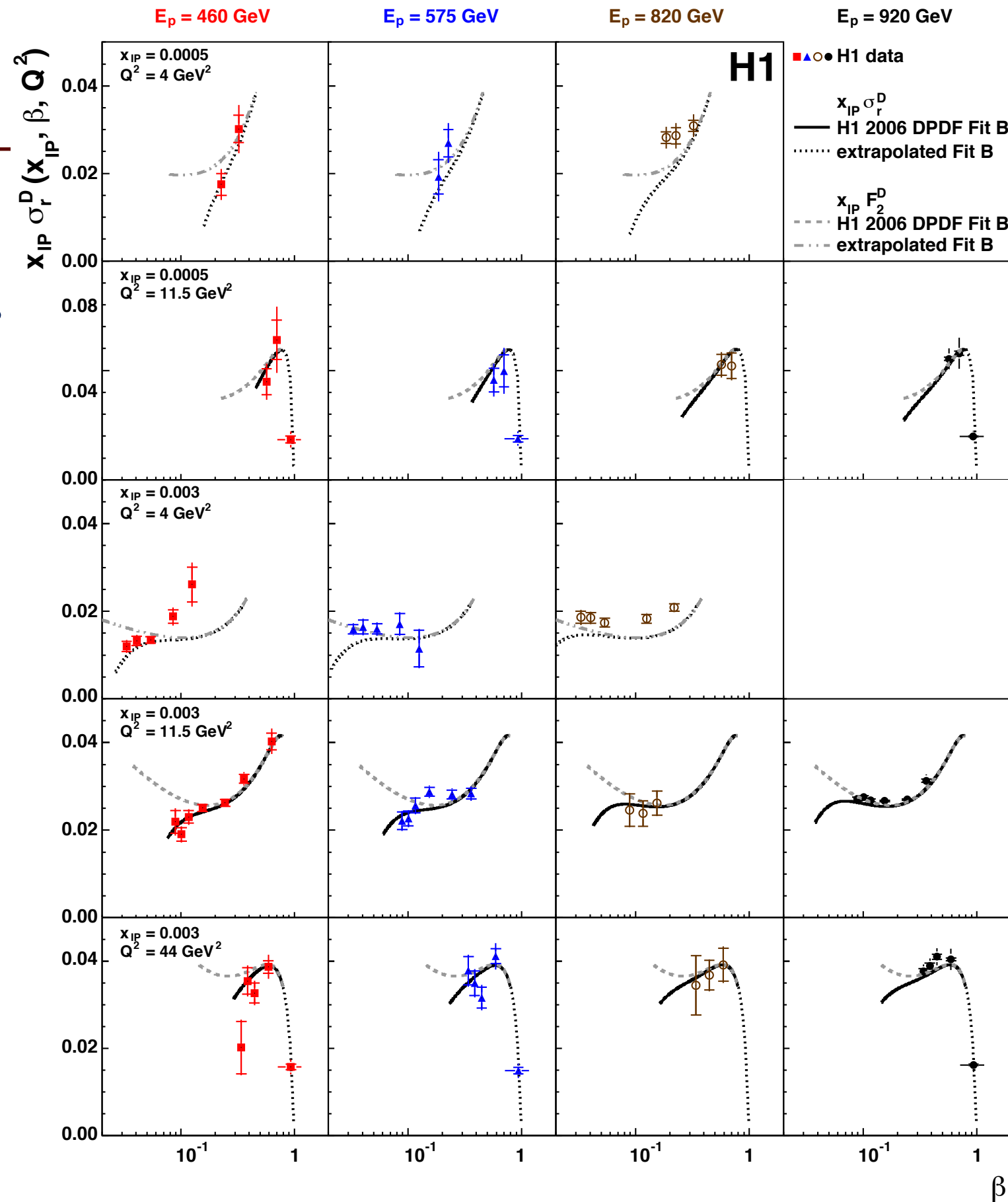
Data Selection and H1 Detector

- Diffractive selection:
 - Large Rapidity Gap ($\eta_{\max} < 3.3$)
- FLD selection:
 - Kinematic variables are reconstructed from the scattered positron.
 - $Q^2 > 2.5 \text{ GeV}^2$
 - FLD can be measured only when accessing high y ($y < 0.9$) which requires to measure low scattered positron energies ($E'_e > 3.4 \text{ GeV}$).
 - This region suffers from photoproduction background.
 - It is a challenging measurement requiring precise positron identification.
 - Cluster from the SpaCal calorimeter is linked to a track from the central tracker and/or the Background Silicon Tracker.



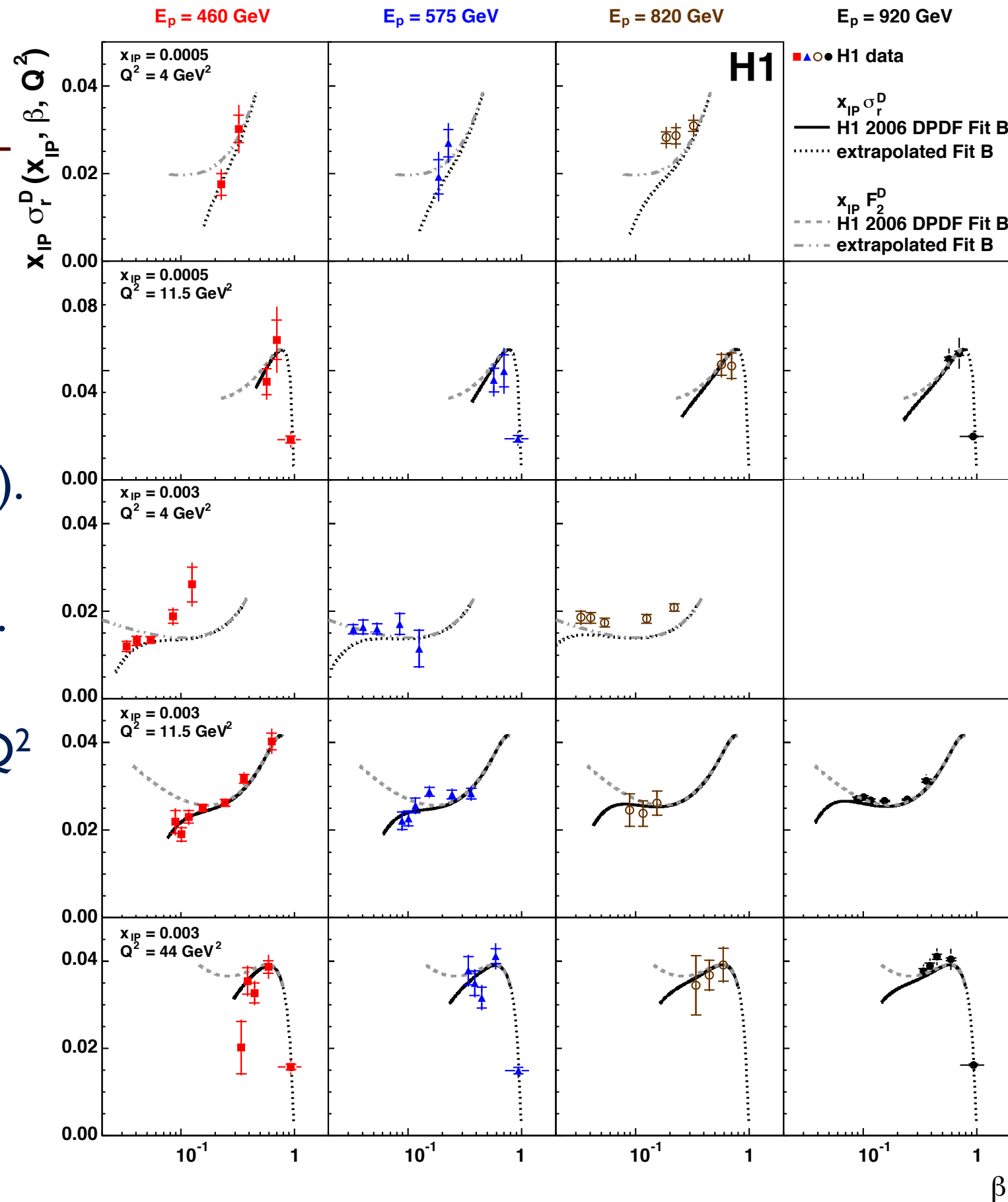
Diffractive Reduced Cross-Sections

- Diffractive reduced cross-sections are measured in bins of x_{IP} , β , Q^2 at:
 - $x_{\text{IP}} = 0.0005, 0.003$
 - $Q^2 = 4, 11.5, 44 \text{ GeV}^2$
- Trigger does not allow to analyze data at $Q^2 = 4 \text{ GeV}^2$ in the $E_p = 920 \text{ GeV}$ data set.
- Data cross-sections are sensitive to FLD at high y (low β).



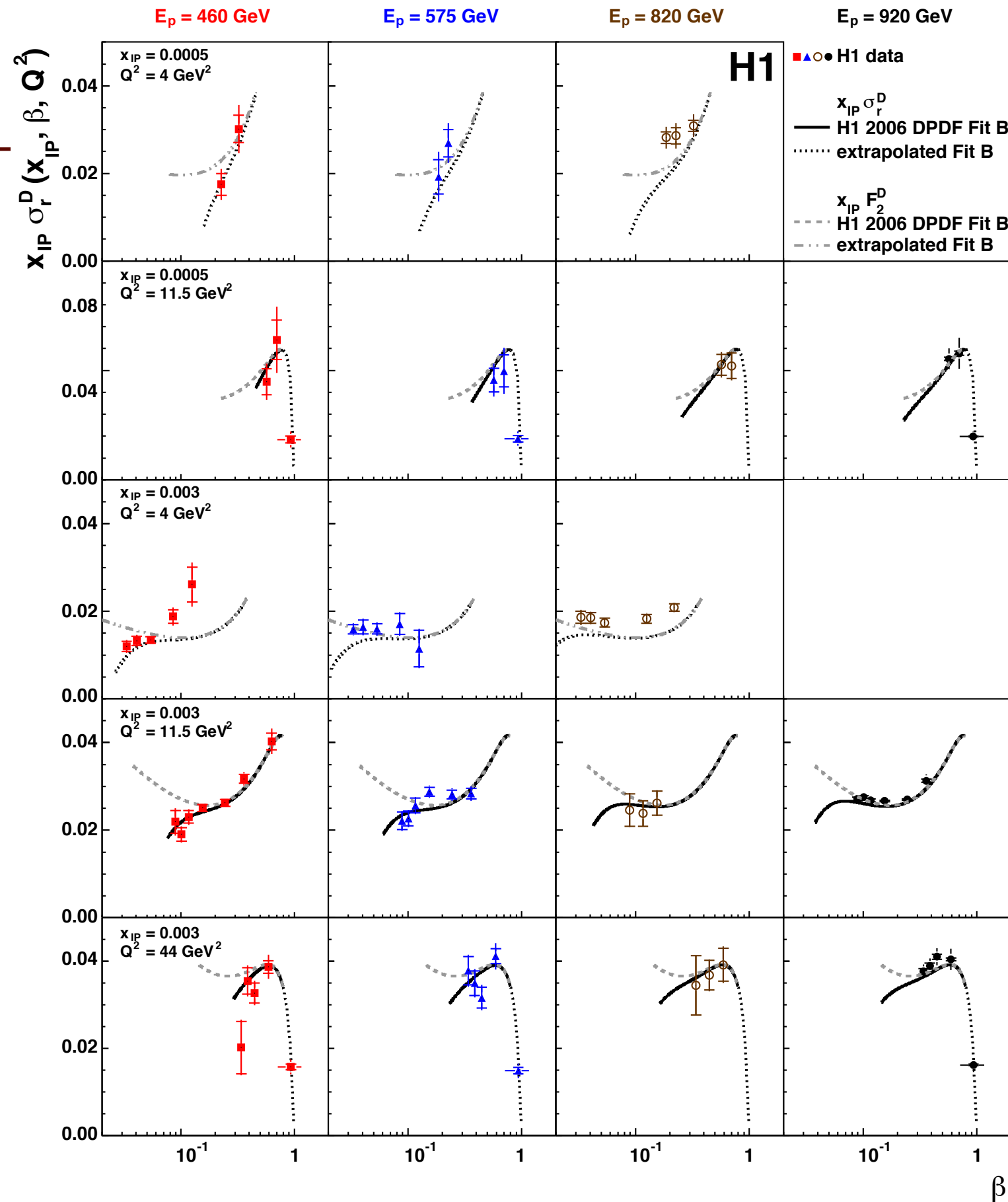
Diffractive Reduced Cross-Sections

- Previously published data at $E_p = 820$ GeV are also used for the FLD extraction (DESY-06-049).
- This data set was used to determine H1 2006 DPDF Fits.
- The published cross-sections are interpolated to the x_{IP}, β, Q^2 values used in the FLD analysis using H1 2006 DPDF Fit B.
- H1 2006 DPDF Fits are known to underestimate data at $Q^2 < 8.5$ GeV².



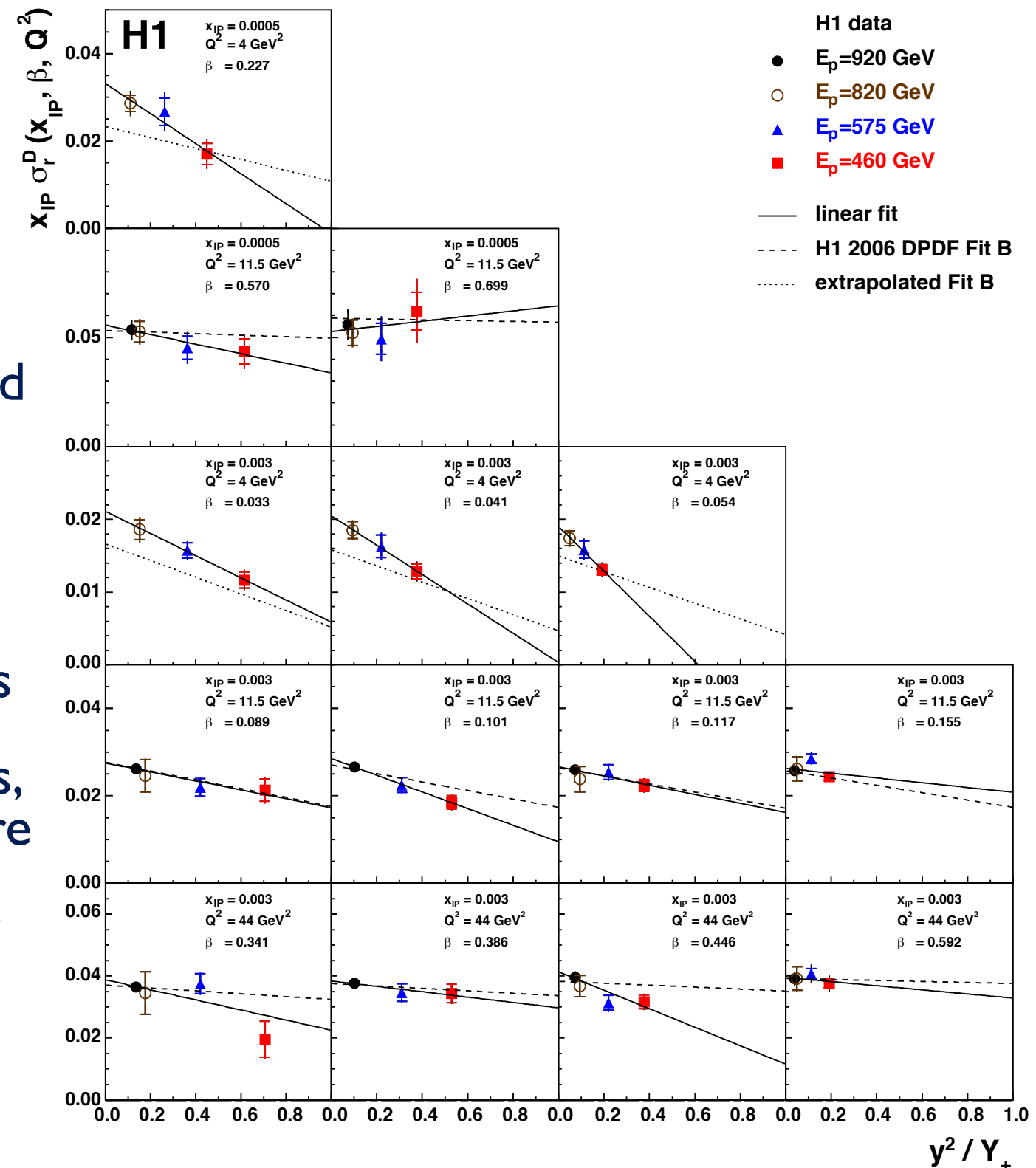
Diffractive Reduced Cross-Sections

- H1 2006 DPDF Fit B is used to correct the data to the $x_{\text{IP}}, \beta, Q^2$ bin center values.
- The shape of the cross-section is largely unconstrained at $\beta \rightarrow 1$.
- Therefore, only the average cross-section is given in the highest β bin.
- Data support the hypothesis that $\sigma_r^D \rightarrow 0$ as $\beta \rightarrow 1$.
- There is no evidence for a large higher twist FLD contributions in this region.



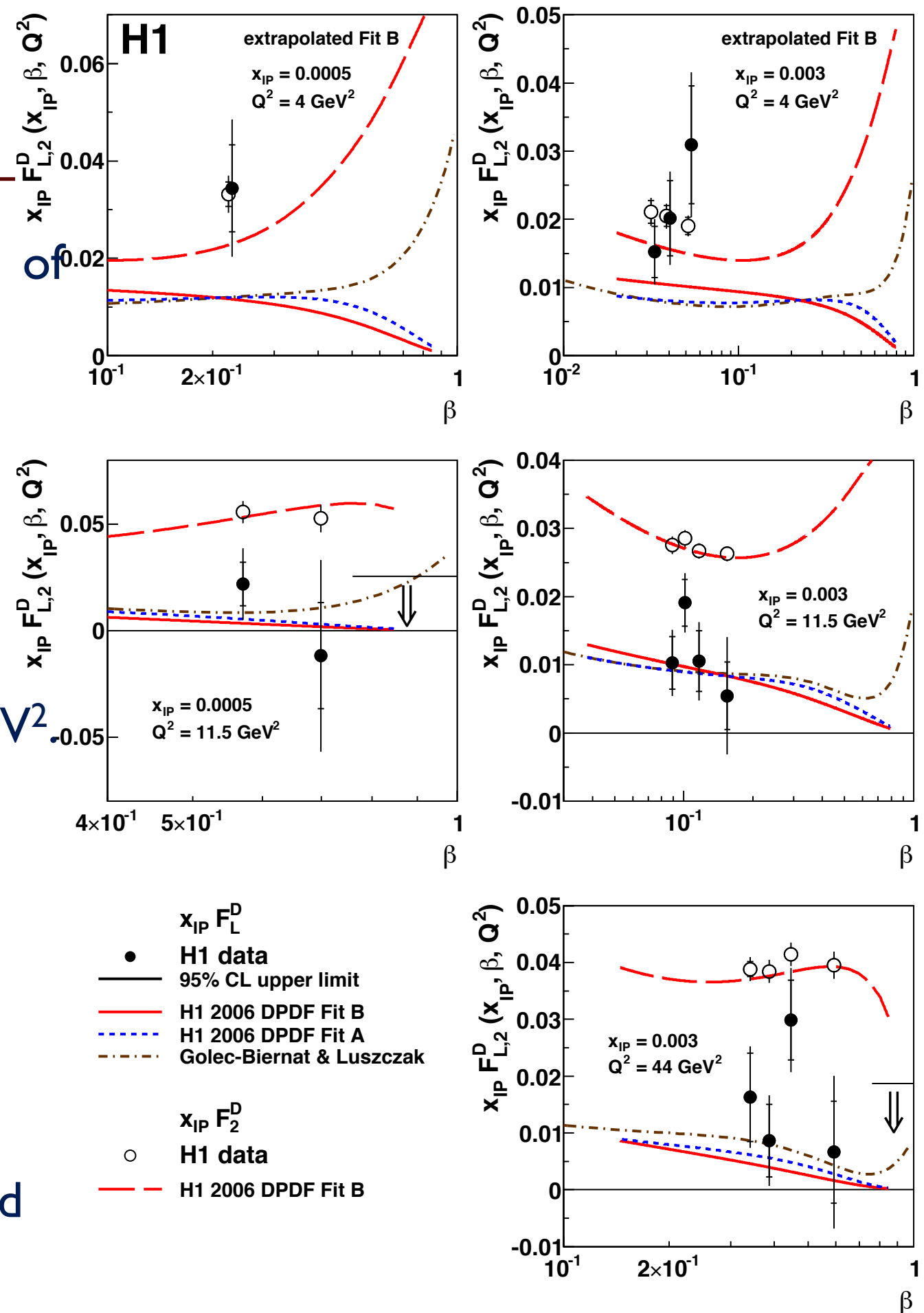
Extraction of FLD and F2D

- FLD and F2D are extracted as parameters of a linear fit in the Rosenbluth plots.
- Errors on FLD and F2D are evaluated in the fits to the cross-section measurements with:
 - statistical errors only
 - statistical and uncorrelated errors
 - statistical and uncorrelated errors, where the cross-section points are shifted up and down for each correlated systematic uncertainty (offset method)



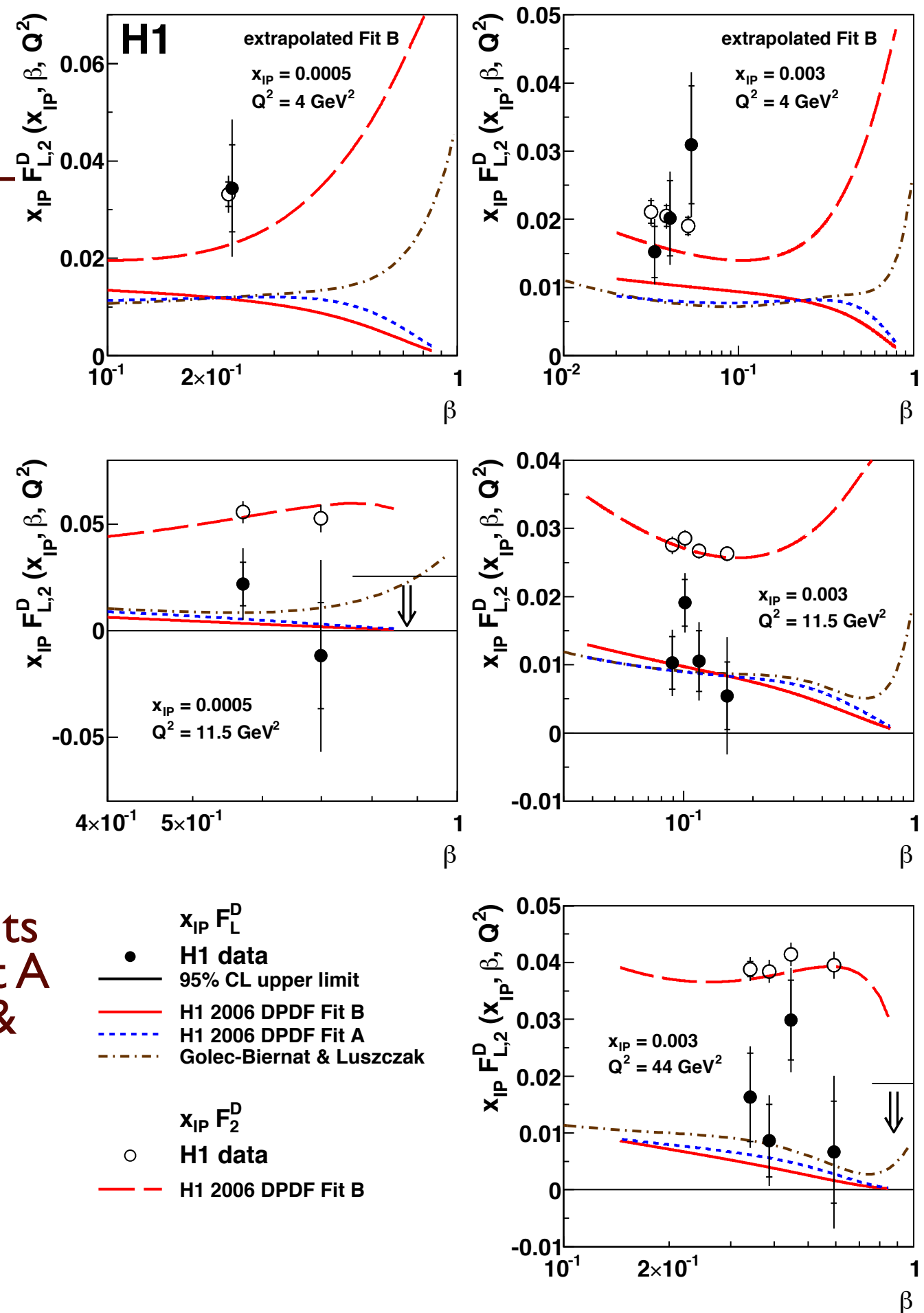
FLD and F2D

- FLD and F2D is measured in bins x_{IP}, β, Q^2 at:
 - $x_{IP} = 0.0005, 0.003$
 - $Q^2 = 4, 11.5, 44 \text{ GeV}^2$
 - $0.033 < \beta < 0.7$
- F2D measurements agree well with H1 2006 DPDF Fit B at $Q^2 \geq 11.5 \text{ GeV}^2$.
- There are significant non-zero FLD measurements in each x_{IP}, Q^2 bin.
- Five FLD points are greater than 0 by more than 3σ .
- Upper limits on FLD and F2D at the 95% confidence level are derived at the highest β bins (at $\beta = 0.76$).



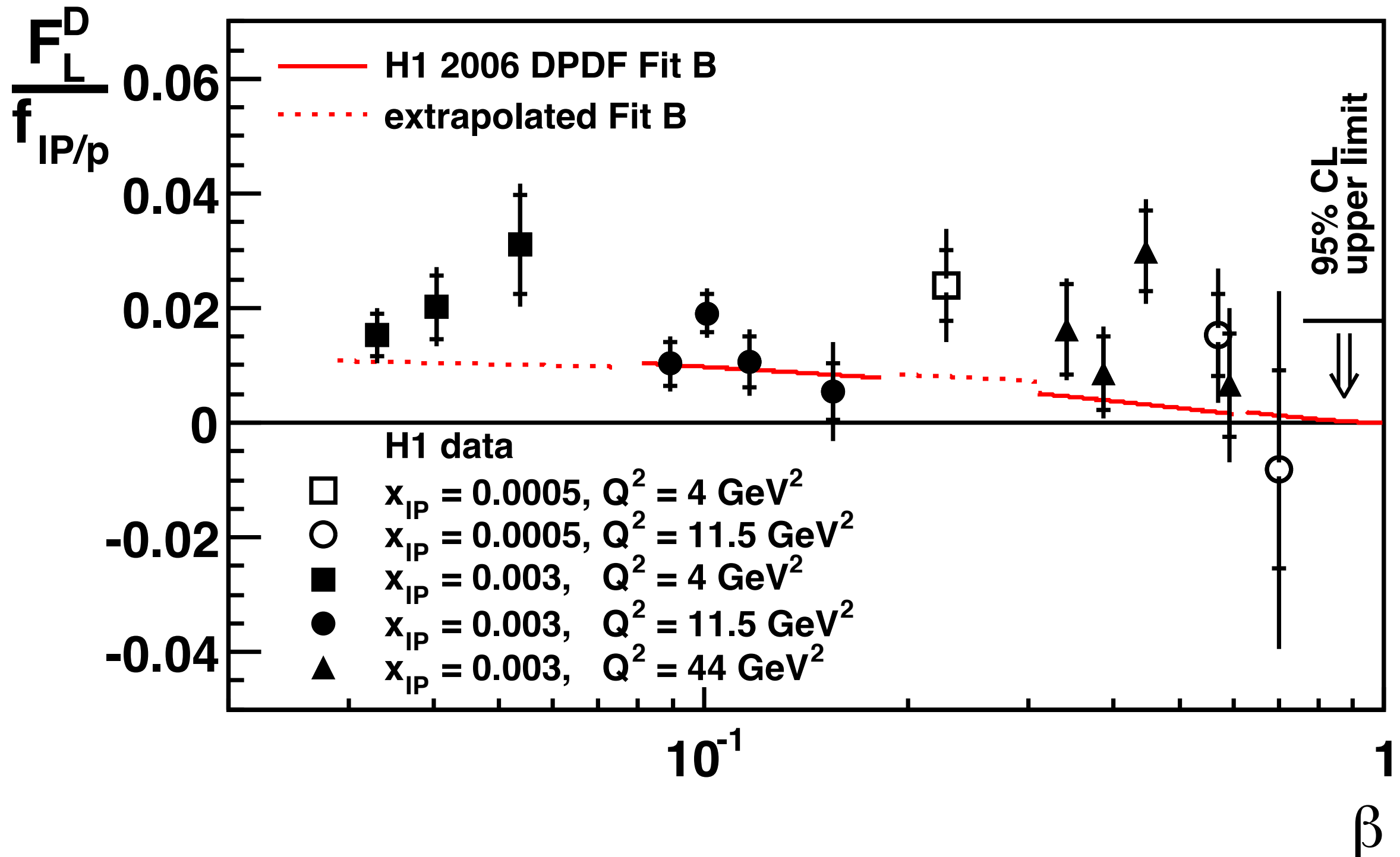
FLD and F2D

- Higher twist longitudinal contribution to diffraction at high β implies large FLD (e.g. BEKW [hep-ph/9803497]).
- QCD fits from H1 only consider the leading twist and do not predict large FLD.
- For $Q^2 \geq 11.5 \text{ GeV}^2$, the measurements are consistent with H1 2006 DPDF Fit A and Fit B and with the Golec-Biernat & Łuszczak model [arXiv:0704.1608].



FLD Results

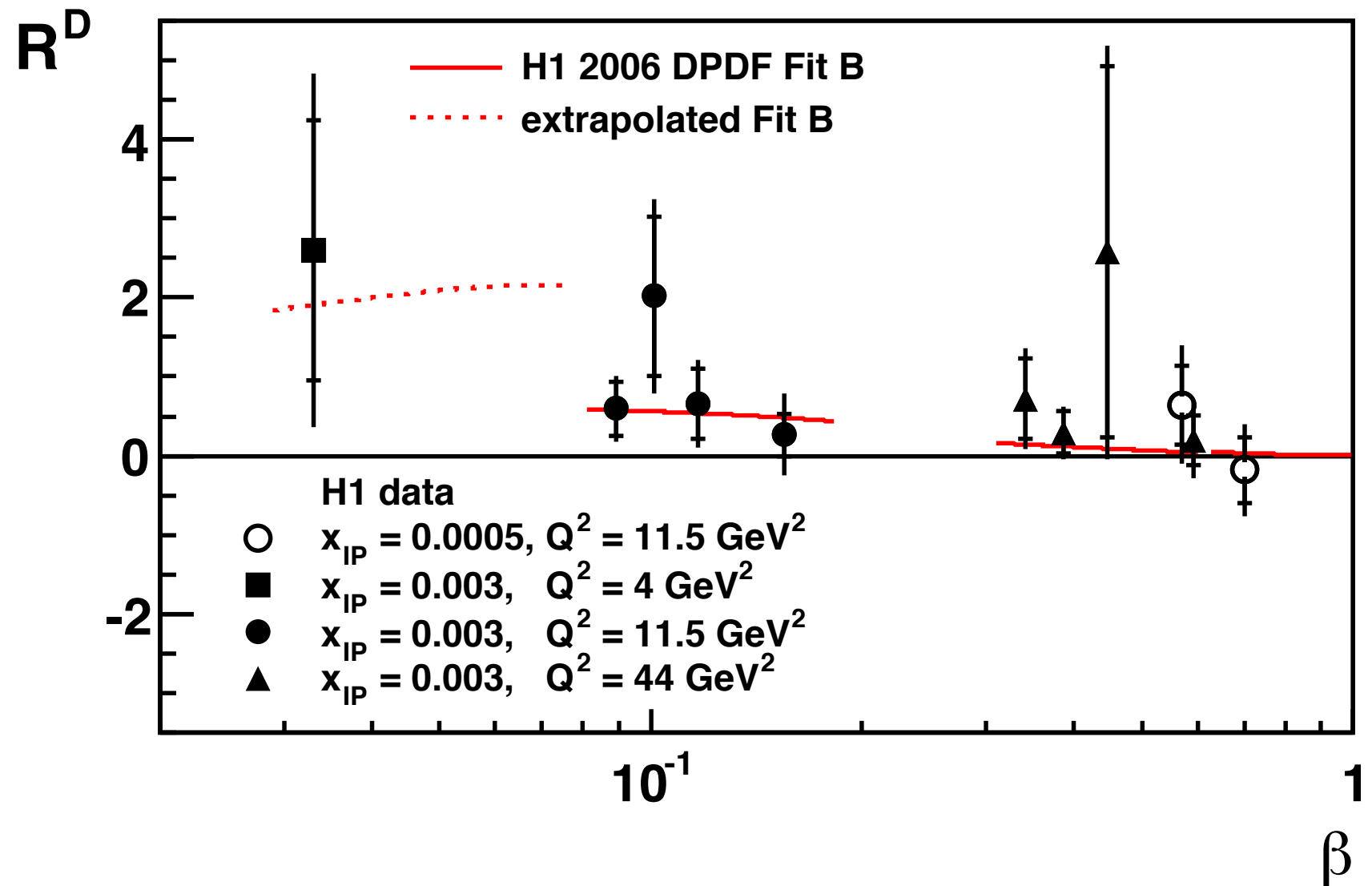
H1 Collaboration



Photoabsorption Ratio for Diffraction

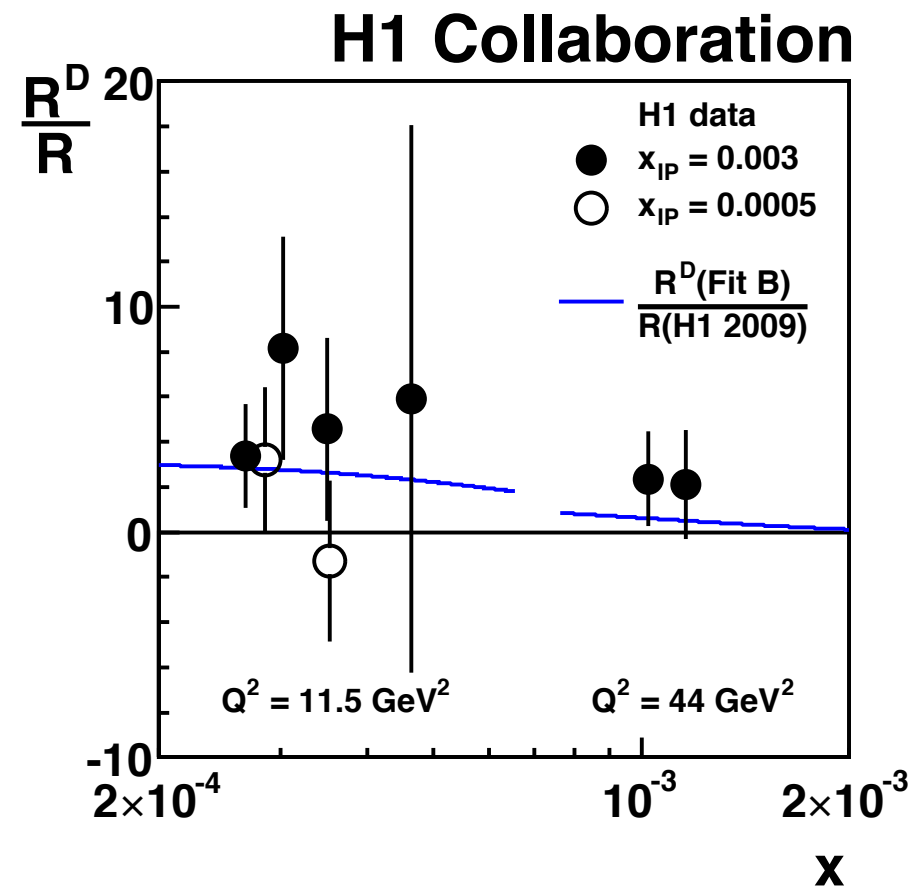
H1 Collaboration

$$R^D = F_L^D / (F_2^D - F_L^D)$$



- Data are compatible with H1 2006 DPDF Fit B.
- Data at $Q^2 = 11.5 \text{ GeV}^2$ indicate that the longitudinally and transversely polarized photon cross-sections are of the same order of magnitude ($R^D \sim 1$ and $F_2^D \sim 2 \cdot F_L^D$).

Ratio R^D/R



- Ratio R^D/R quantifies relative importance of longitudinally and transversely polarized photons in inclusive and diffractive scattering.
- Data are reproduced by H1 2006 DPDF Fit B and H1 PDF 2009.
- $R^D/R = 2.8 \pm 1.1$
- Longitudinally polarized photon contribution plays larger role in diffraction than in the inclusive case.

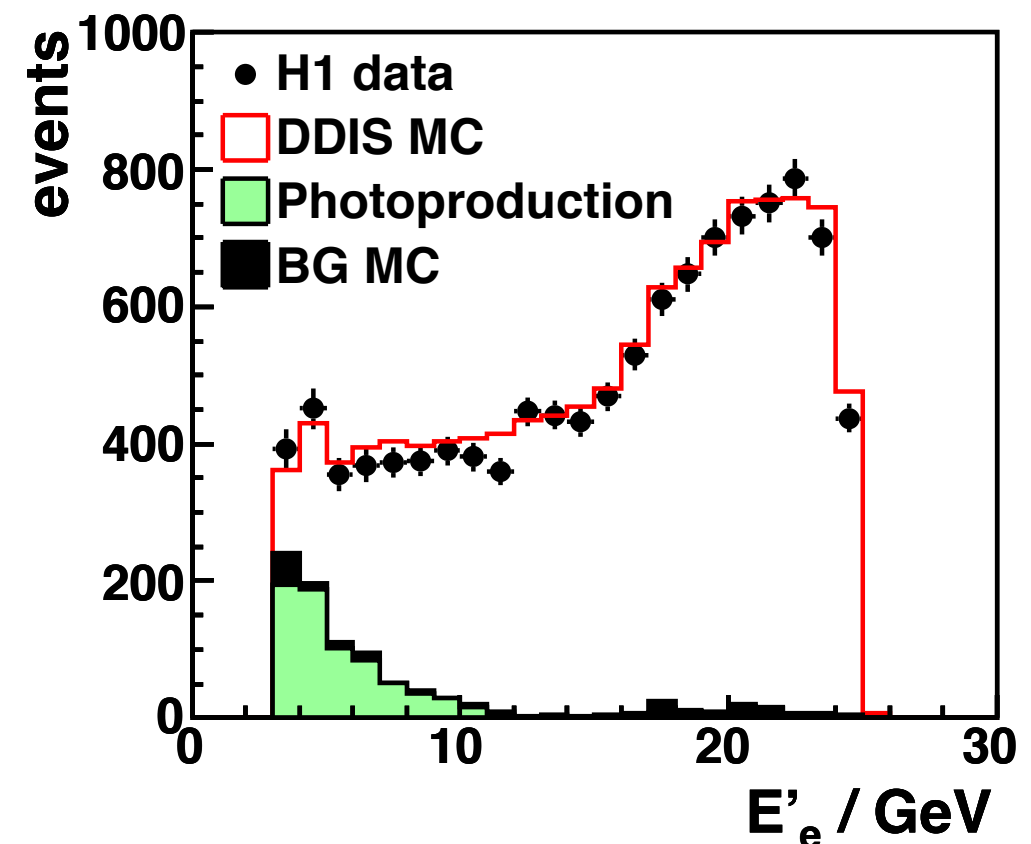
Summary

- The first measurement of FLD
- FLD is measured at:
 - $x_{\text{IP}} = 0.0005, 0.003$
 - $Q^2 = 4, 11.5, 44 \text{ GeV}^2$
 - $0.033 < \beta < 0.7$
- For $Q^2 \geq 11.5 \text{ GeV}^2$, the measurement is consistent with H1 2006 DPDF Fit A and Fit B and with the Golec-Biernat & Łuszczak model.
- Diffractive cross-sections for longitudinally and transversely polarized photons are of comparable size.
- Ratio R_D/R is measured at $Q^2 \geq 11.5 \text{ GeV}^2$.
- R_D/R is well reproduced by H1 2006 DPDF Fit B and H1 PDF 2009.
- Longitudinally polarized cross-section plays larger role in diffraction than in the inclusive case.

backup

Background at High y

- Data at high y contain **photoproduction background**.
 - In photoproduction processes, the scattered positron escapes from the central detector undetected through the beam pipe.
 - Hadronic final state particles can be mis-identified as the scattered positron.
 - Background from hadronic particles is almost charge symmetric.
- $E_p = 460 \text{ GeV}$
- Photoproduction background is subtracted in a data-driven way using the reconstructed charge of the scattered positron candidate.
 - $N^+ = \text{signal events} + \text{background from } \pi^+$
 - $N^- = \text{background from } \pi^-$
 - $N_{\text{signal}} = N^+ - N^-$



Normalization of Data Sets

- Luminosity is measured with 3% (4%) precision for $E_p = 920$ (460, 575) GeV data.
- Due to the acceptance of the forward detectors near the beam-pipe, the Large Rapidity Gap selection accepts events with dissociated protons up to $M_Y \sim 1.6$ GeV.
- The data cross-section measurements are corrected to $M_Y < 1.6$ GeV, $|t| < 1$ GeV² using simulation.
- Systematic uncertainty on this correction is 7% and it is strongly correlated between the data sets.
- For optimal extraction of FLD, the cross-section measurements at low y (where the sensitivity to FLD is minimal) are normalized to HI 2006 Fit B.
- Normalization factors of 0.97, 0.99, 0.97 are needed for $E_p = 460, 575, 920$ GeV.
- The $E_p = 820$ GeV data set is already consistently normalized as it was used to determine HI 2006 DPDF Fit B.

