Diffractive DIS with a Leading Proton at HERA-2

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on behalf of the H1 Collaboration

- Selection of Diffraction at HERA
- H1 Forward Proton Spectrometer
- New H1 FPS HERA-2 results:

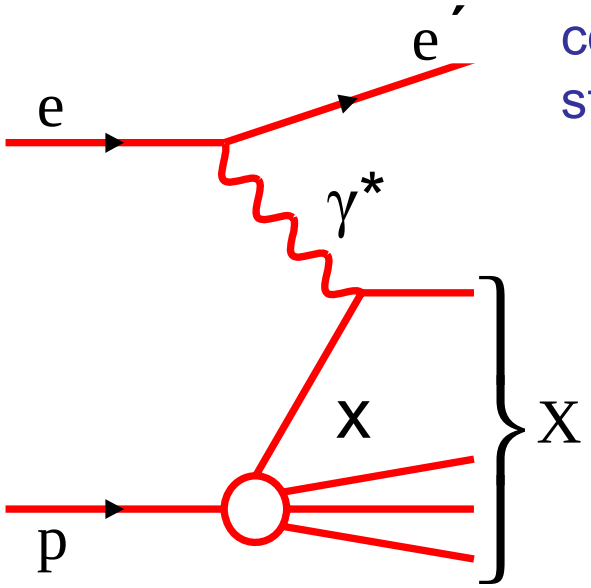
➔ Diffractive reduced cross section $\sigma_r^{D(3)}$

➔ LRG / FPS cross section ratio

Diffractive DIS at HERA

➔Probe structure of color singlet exchange with virtual photon at HERA → F_2^D

Standard DIS



F_2 → probe structure of proton

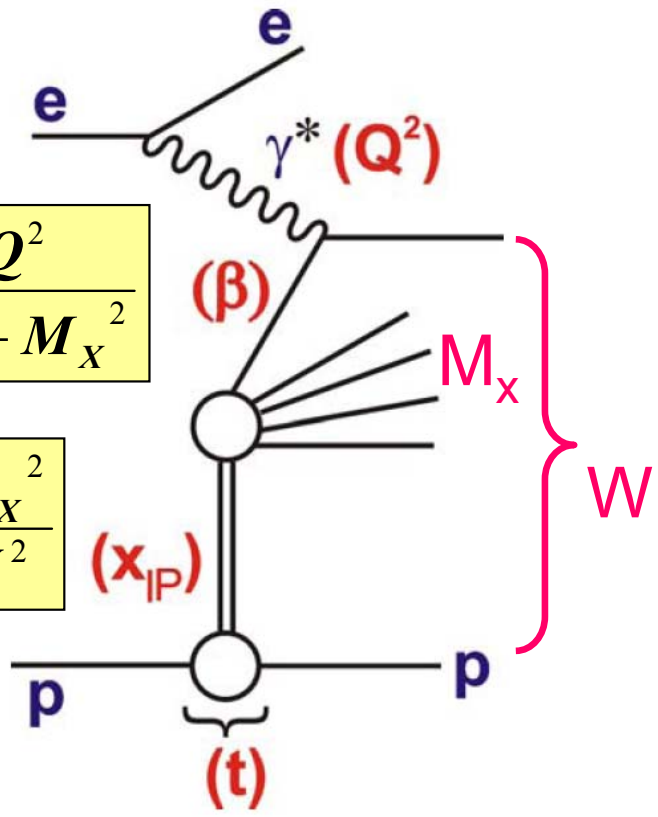
Momentum fraction of color singlet carried by struck quark

$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^2}$$

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

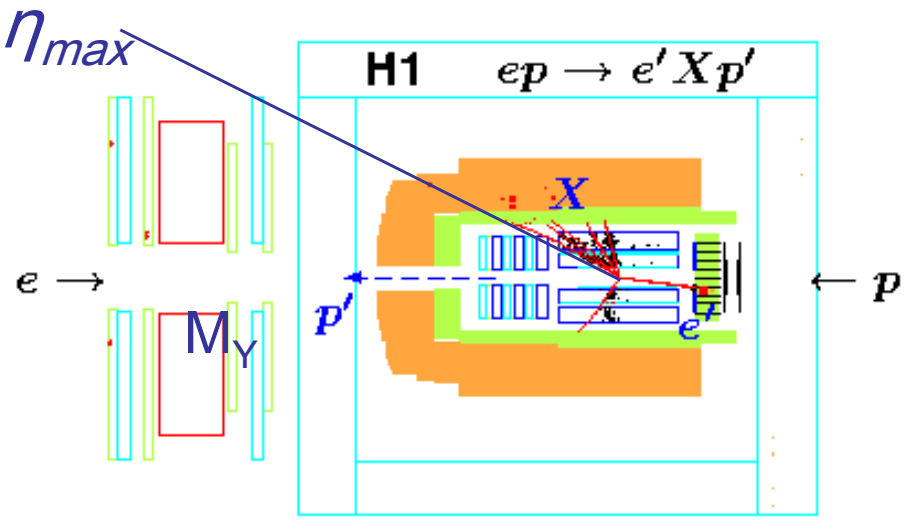
Momentum fraction of proton carried by colour singlet exchange

Diffractive DIS



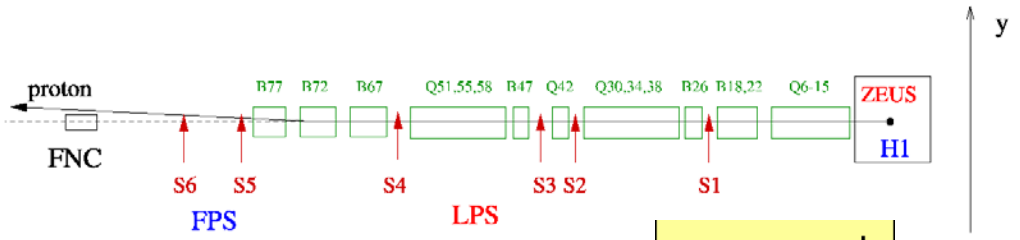
Selection of diffraction at HERA

Large rapidity gap (LRG) between leading proton p' and X



- high statistics, data integrated over $|t|<1\text{GeV}^2$
- p-dissociation contribution
- limited by systematic uncertainties related to missing proton

Forward Proton Spectrometer H1 FPS



+ ZEUS LPS

$$x_{IP} = 1 - \frac{E'_p}{E_p}$$

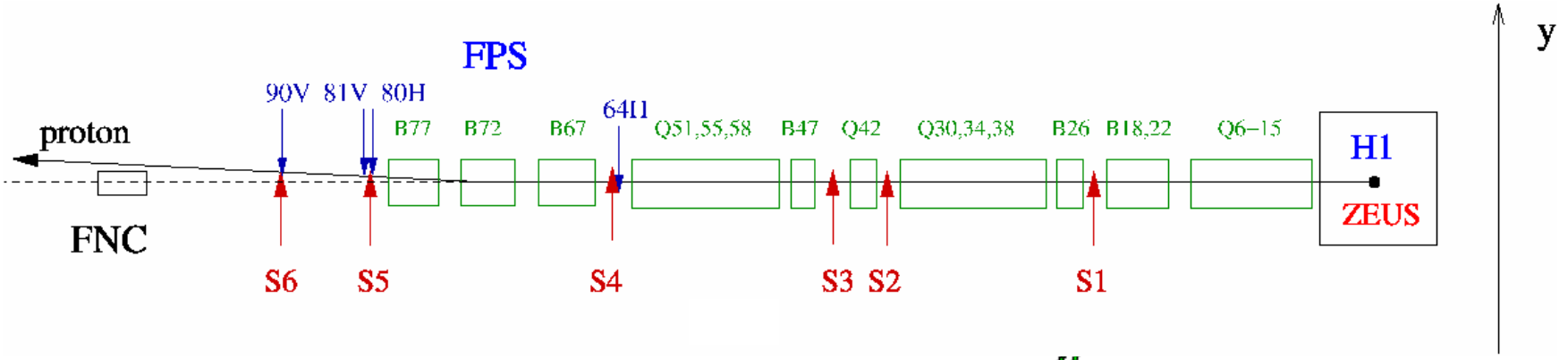
- free of p-dissociation background
- x_{IP} and t-measurements
- access to high x_{IP} range (IP+IR)
- low geometrical acceptance

➔ LRG and FPS methods have different systematic uncertainties

➢ Are LRG and FPS methods compatible?
LRG / FPS ratio ➔ p-dissociation to LRG data ($M_Y<1.6$ GeV)

Forward Proton Spectrometer

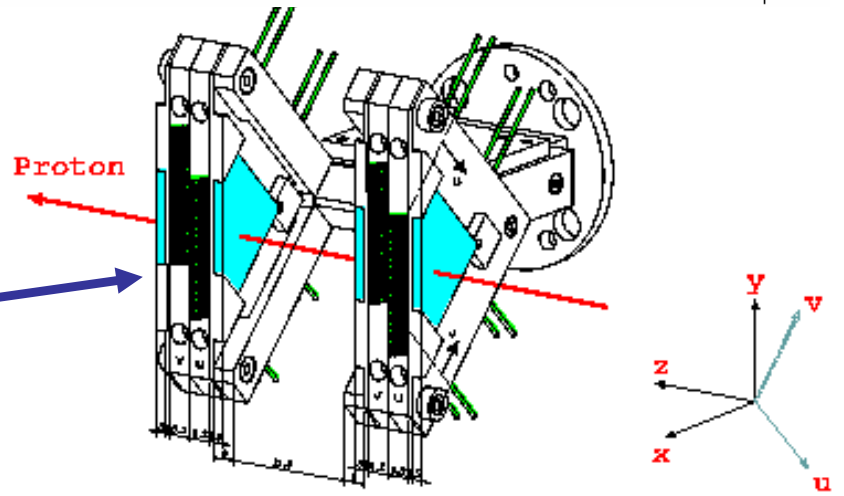
- Purpose: measurement of leading proton momentum using coordinate detectors and system of HERA magnets
- Roman Pot technology, scintillating fibre detectors readout by position sensitive photo-multipliers



Vertical detectors at 81m and 90m: $0.1<x_{IP}<0.4$

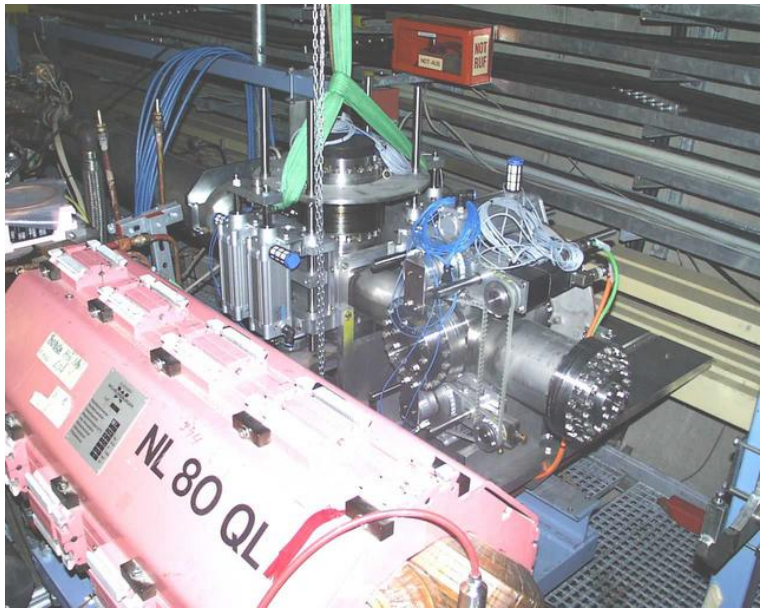
Horizontal detectors at 61m and 80m: $x_{IP}<0.1$

➔ this analysis



HERA II: FPS detector upgrade

- New fibre detector technology:
  - ➔ radiation resistant scintillating fibres
- New position sensitive 16/64 channel photo-multipliers
- New precision detector positioning and control system



- FPS HERA-2 data samples: 2005-07 e^-p and e^+p interactions
- Luminosity ~156 pb^{-1}

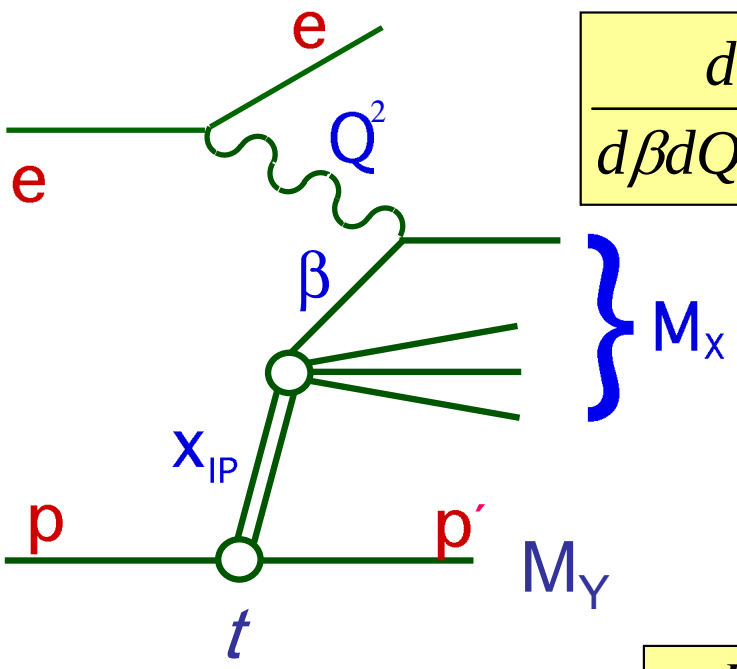
Statistics of DIS events with a leading proton in Horizontal Roman Pots:

Medium Q^2 ($4<Q^2<110$ GeV^2)
~68.200 events

High Q^2 ($120<Q^2<700$ GeV^2)
~400 events

➔ 20 times higher statistics than collected at HERA-1

Diffractive Reduced Cross Section



$$\frac{d^4\sigma}{d\beta dQ^2 dx_{IP} dt} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_r^{D(4)}(\beta, Q^2, x_{IP}, t)$$

Relation to F_2^D and F_L^D:

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{2(1 - y + y^2/2)} F_L^{D(4)}$$

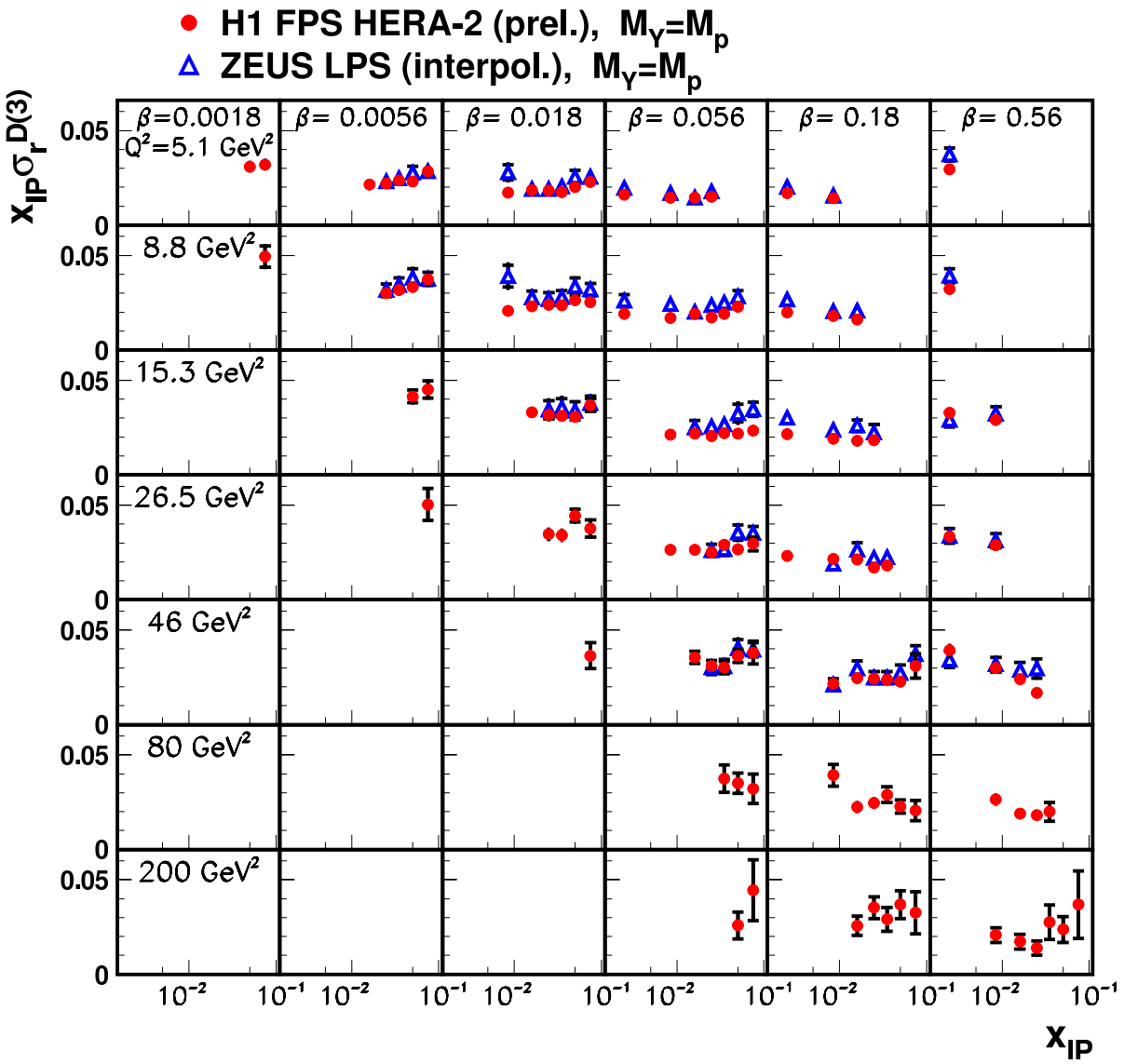
$$\sigma_r^D \approx F_2^D \text{ at low and medium y}$$

Integrate over $|t|<1$ GeV^2 → to compare with LRG and diffractive PDF predictions

$$\sigma_r^{D(3)} = \int \sigma_r^{D(4)} dt$$

$\sigma_r^{D(3)}$: H1 FPS vs ZEUS LPS

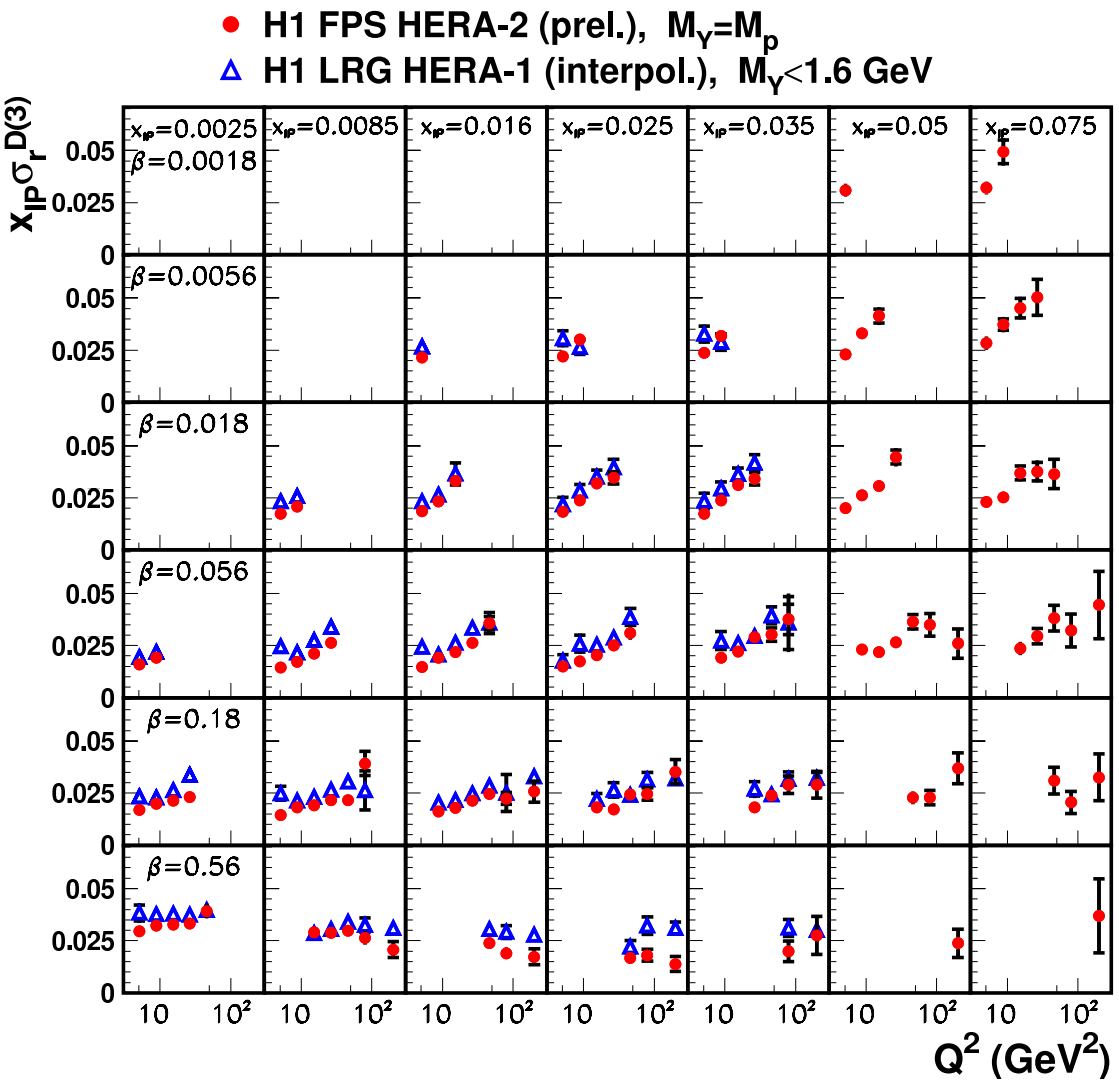
Forward Proton Spectrometer data



- New FPS HERA-2 data $M_Y=M_p$
- Δ ZEUS LPS data, $M_Y=M_p$
- x_{IP}-dependence in (β,Q^2) bins

- Reasonable agreement of new H1 FPS and ZEUS LPS data → within uncertainties
- H1 FPS norm. uncertainty ~6%, ZEUS LPS norm. uncertainty $\pm^{11\%}_{7\%}$
- new H1 FPS HERA-2 data extend phase space to higher Q^2

$\sigma_r^{D(3)}$: H1 FPS vs H1 LRG data



- New FPS HERA-2 data $M_Y=M_p$
- Δ H1 LRG HERA-1 data $M_Y<1.6$ GeV
- Q^2-dependence in (x_{IP},β) bins

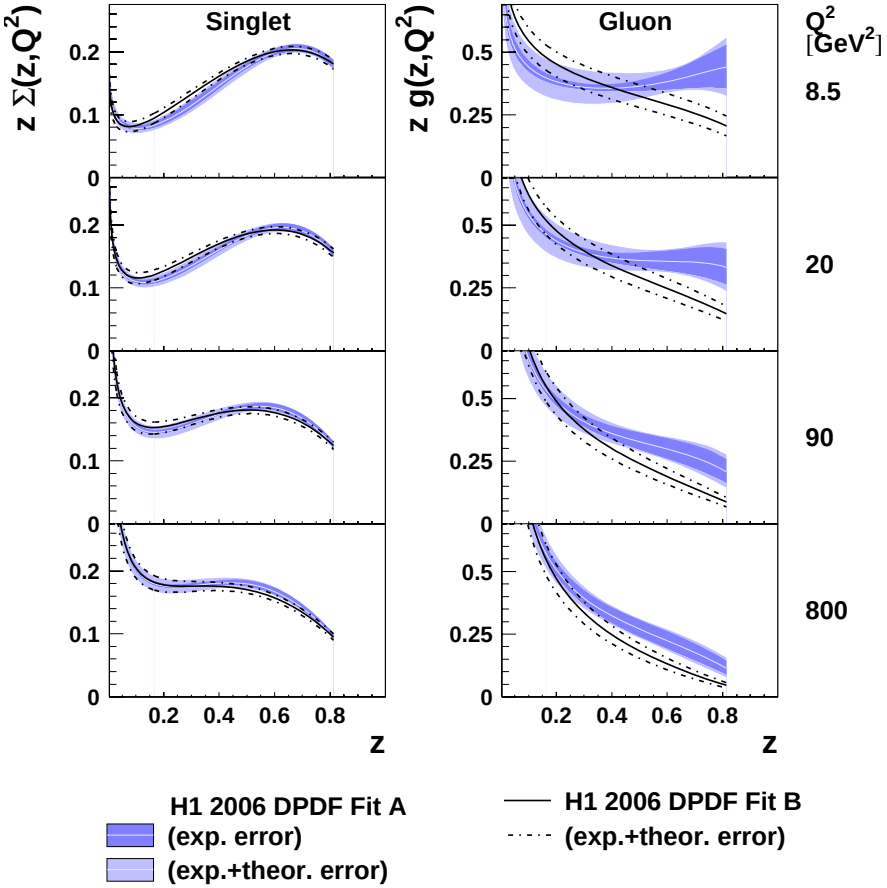
- Reasonable agreement in Q^2 dependence of H1 FPS and H1 LRG data
- new FPS HERA-2 data extend LRG measurements to higher x_{IP}

- p-dissociation contribution in LRG data ($M_Y<1.6$ GeV) is not subtracted
- LRG / FPS relative norm. uncertainty ~8.5%

DPDFs from Inclusive Diffractive DIS

NLO DGLAP fit to H1 LRG HERA-1 data:

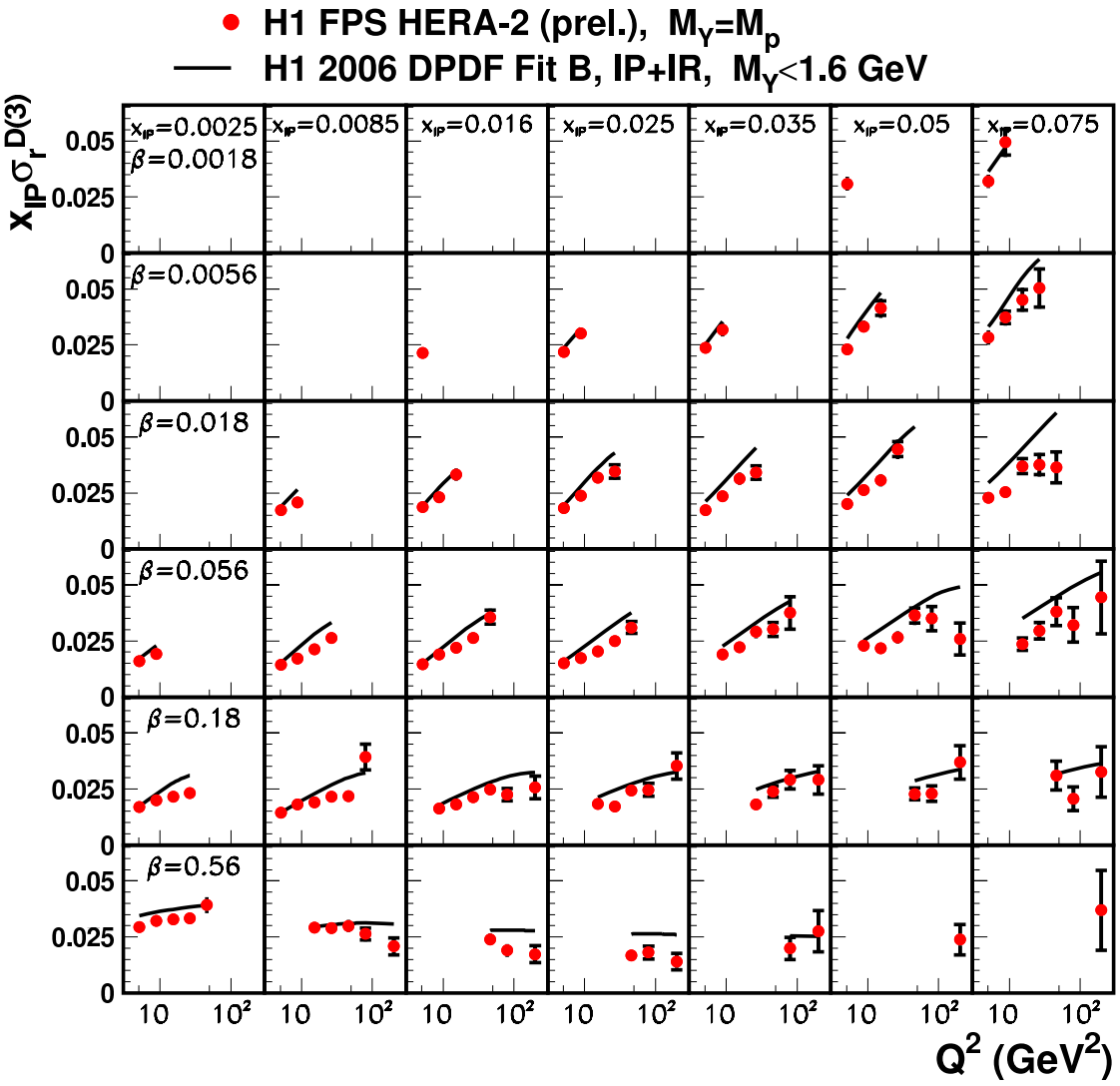
$$F_2^{D(4)}(\beta, Q^2, x_{IP}, t) = f_{IP}(x_{IP}, t) \cdot F_2^{IP}(\beta, Q^2) + f_{IR}(x_{IP}, t) \cdot F_2^{IR}(\beta, Q^2)$$



- assumption: proton vertex factorization for IP and IR
- constrains quark singlet DPDF and gluon DPDF at low z
- at high momentum fraction QCD evolution is driven by quark radiation ➔ no sensitivity to gluon DPDF

This analysis: compare new H1 FPS HERA-2 data with predictions based on H1 2006 DPDF Fit B

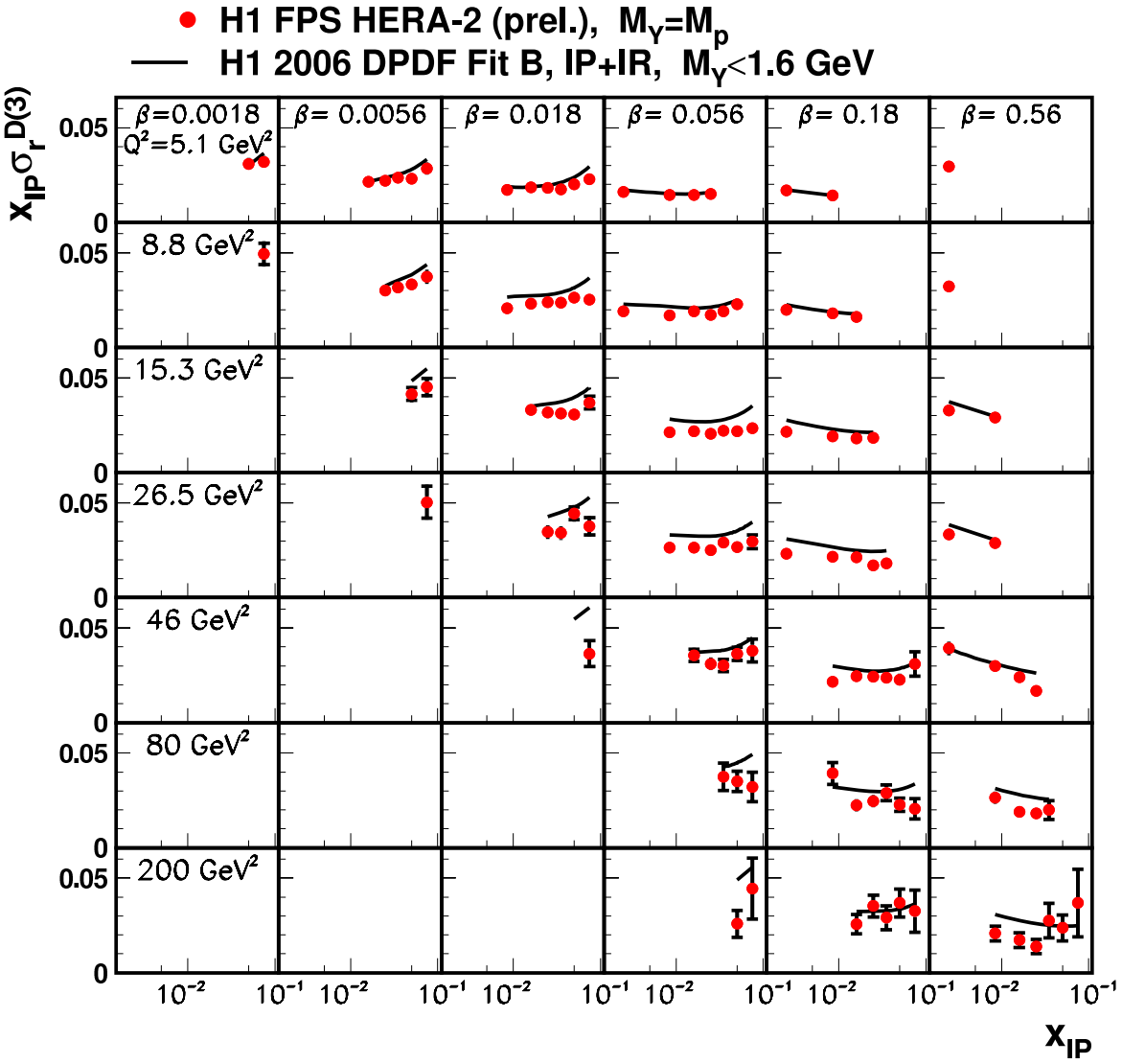
H1 FPS: Q^2 dependence of $\sigma_r^{D(3)}$



- New FPS HERA-2 data $M_Y=M_p$
- H1 2006 DPDF Fit B $M_Y<1.6$ GeV
- Q^2-dependence in (x_{IP},β) bins
- Positive scaling violations except for high $\beta \rightarrow$ large gluon contribution to diffractive exchange

- difference in normalization → p-dissociation contribution to DPDF
- FPS HERA-2 data: syst. uncertainty ~8%, norm. uncertainty ~6%

H1 FPS: x_{IP} dependence of $\sigma_r^{D(3)}$



- New FPS HERA-2 data $M_Y=M_p$

– H1 2006 DPDF Fit B $M_Y<1.6$ GeV

x_{IP}-dependence in (β,Q^2) bins

- $x_{IP}\sigma_r^{D(3)}$ decreases with x_{IP} at high β

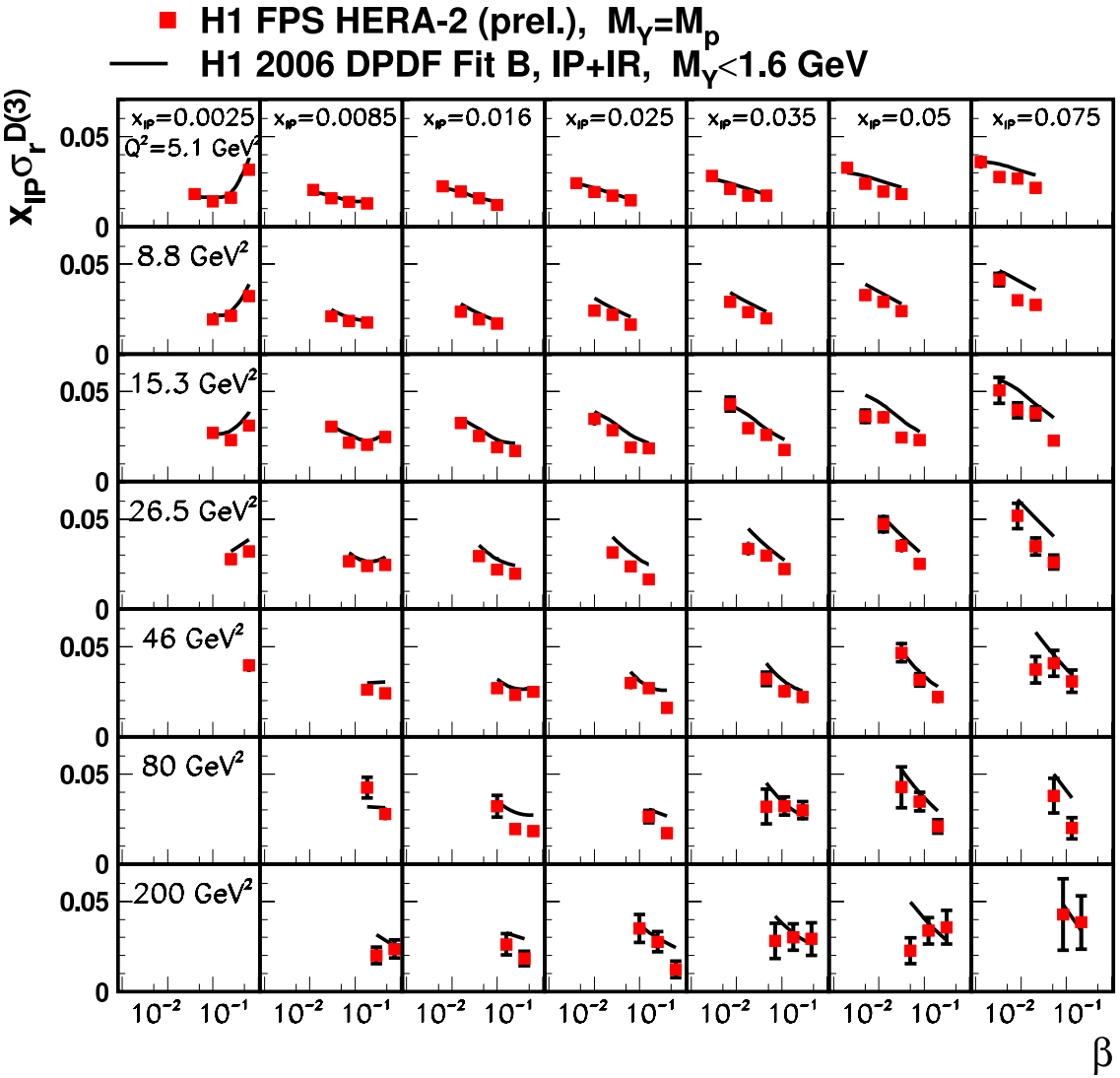
➔ IP exchange

- rises at low β and high x_{IP}

➔ IR contribution

- difference in normalization → p-dissociation contribution to DPDF

H1 FPS: β dependence of $\sigma_r^{D(3)}$



■ New FPS HERA-2 data $M_Y=M_p$

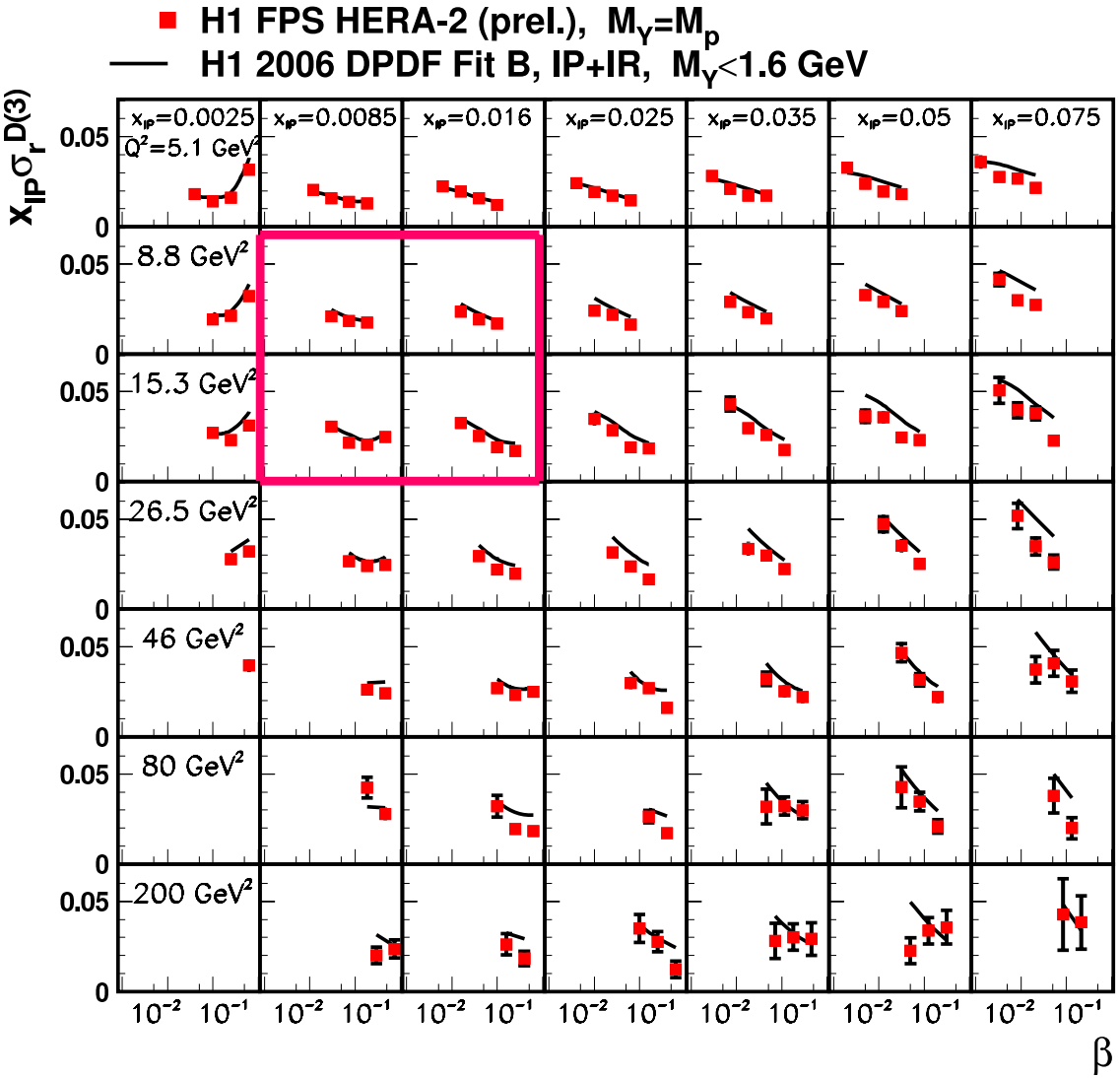
— H1 2006 DPDF Fit B $M_Y<1.6$ GeV

β-dependence in (x_{IP},Q^2) bins

• $\sigma_r^{D(3)}$ decreases with β except for high β and low x_{IP} and Q^2 (range of higher twist)

• difference in normalization → p-dissociation contribution to DPDF

H1 FPS: β dependence of $\sigma_r^{D(3)}$

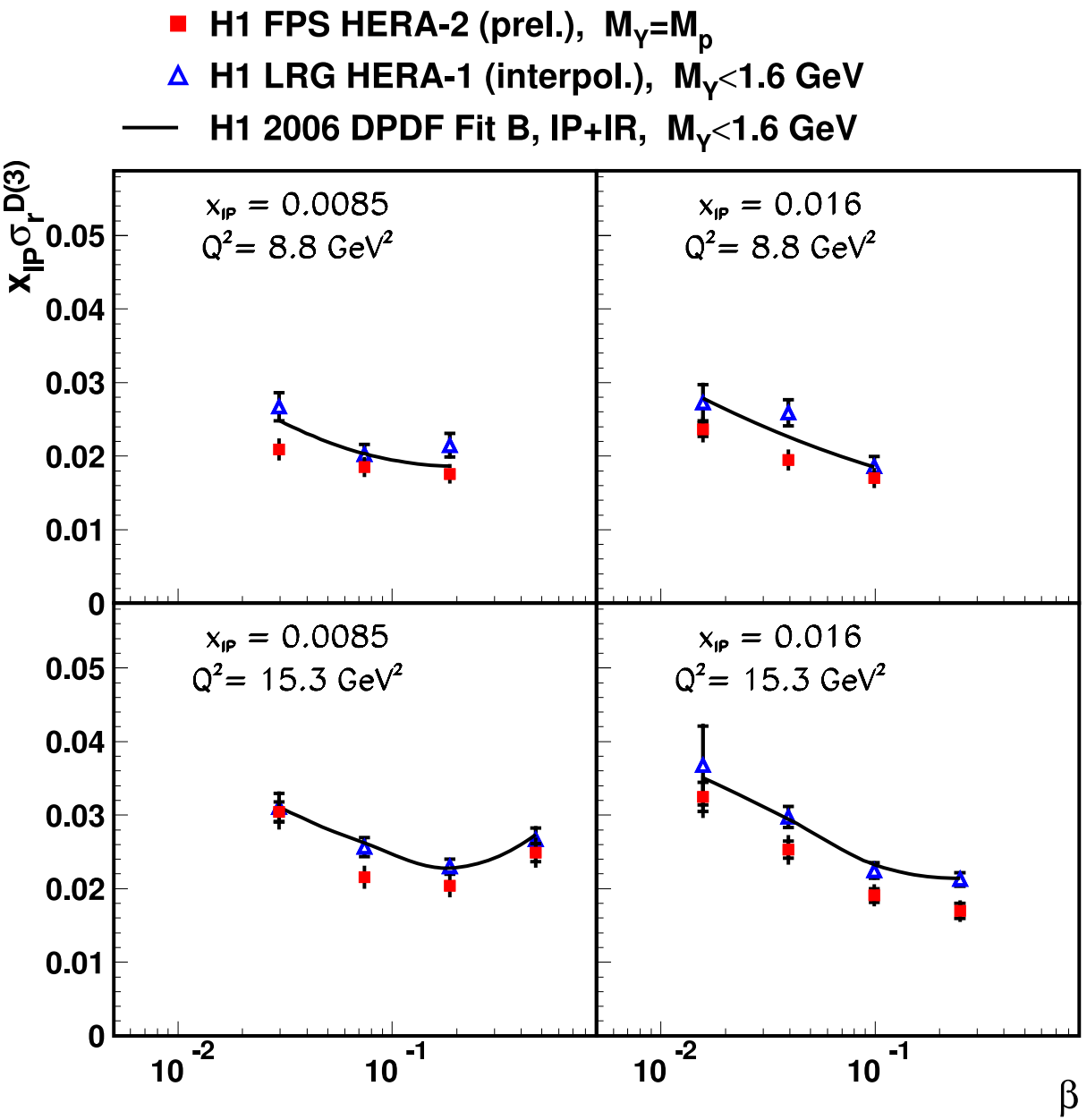


- New FPS HERA-2 data $M_Y=M_p$
- H1 2006 DPDF Fit B $M_Y<1.6$ GeV

➔ look to selected (x_{IP},Q^2) bins

- difference in normalization → p-dissociation contribution to DPDF

H1 FPS: β dependence of $\sigma_r^{D(3)}$



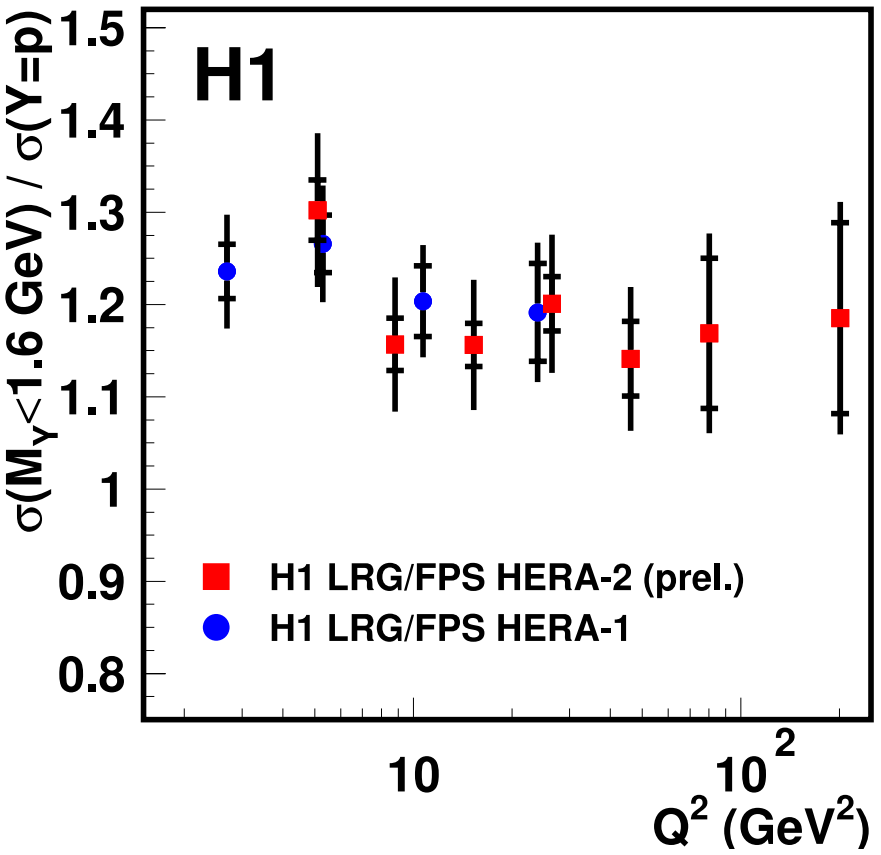
β-dependence in selected (x_{IP},Q^2) bins

- new FPS HERA-2 data reached precision comparable with H1 LRG

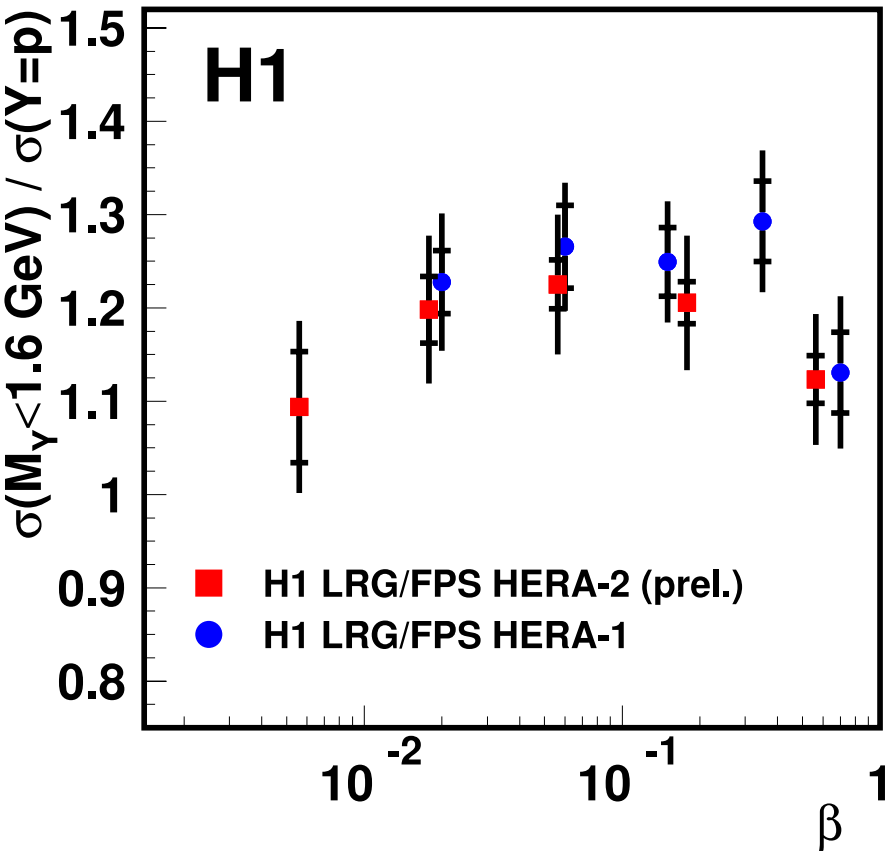
difference in normalization → p-dissociation contribution to DPDF and LRG data

LRG to FPS ratio

Q^2 dependence



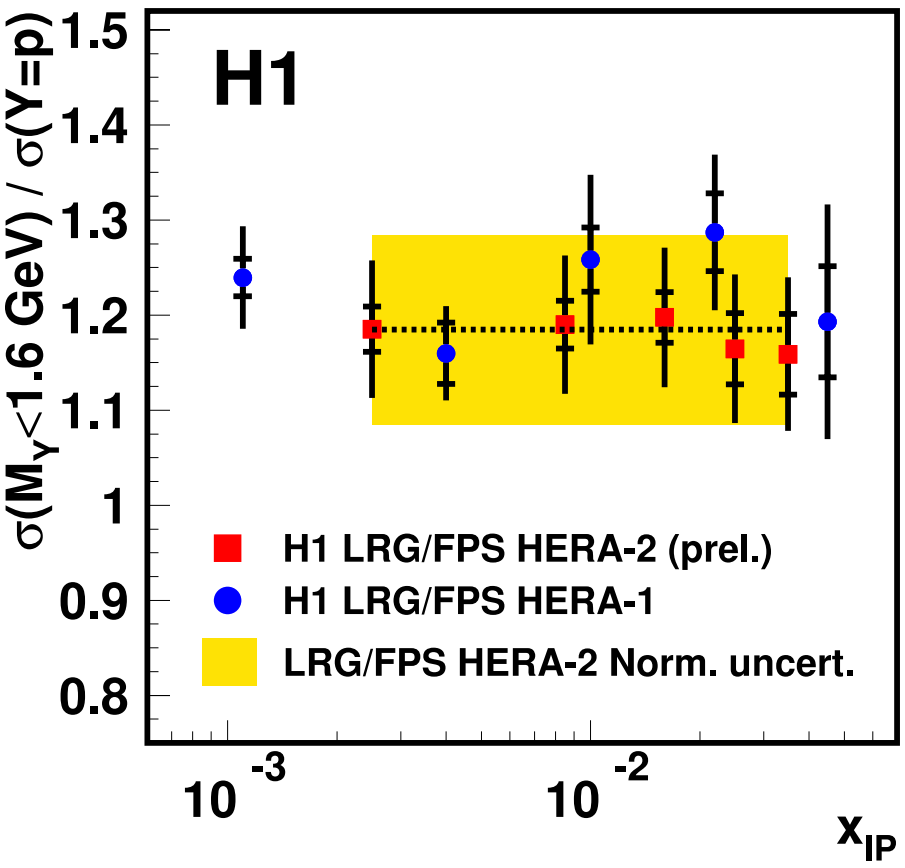
β dependence



- Ratio of LRG HERA-1 to new FPS HERA-2 data is consistent with H1 HERA-1 result
- FPS HERA-2 data extend to higher Q^2 and lower β
- LRG / FPS normalization uncertainty of 8.5% is not shown

LRG to FPS ratio

x_{IP} dependence



M_Y-dependence:
➔ LRG / FPS ratio has no strong dependence on Q^2,β, x_{IP} within uncertainties → consistent with proton vertex factorization

➔ estimate p-dissociation contribution to H1 LRG data

H1: $\sigma(M_Y<1.6\ \text{GeV})/\sigma(Y=p) = 1.18 \pm 0.01(\text{stat}) \pm 0.06(\text{syst}) \pm 0.10(\text{norm})$

Compared to H1 HERA-1 result: $1.23 \pm 0.03(\text{stat}) \pm 0.16(\text{syst})$

→ common norm. uncertainty of H1 LRG data ~6% included

Summary

- New high statistics diffractive DIS data are measured with H1 Forward Proton Spectrometer at HERA-2

➢ consistent results with H1 FPS and ZEUS LPS HERA-1

➢ extend FPS HERA-1 measurements to higher Q^2 range

➢ consistent results with Large Rapidity Gap method in shape of diffractive reduced cross section

➢ FPS extend LRG measurements to higher x_{IP} range

➢ Ratio of LRG to FPS cross section is consistent with proton vertex factorization