



Diffraction DIS with a Leading Proton at HERA-2

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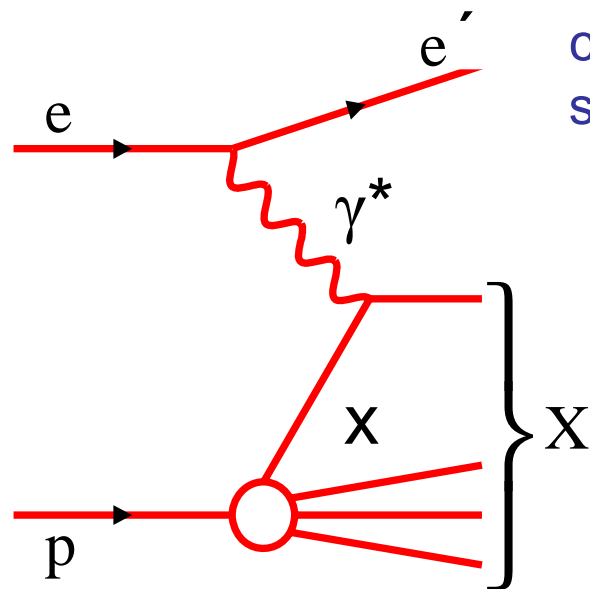
on behalf of the H1 Collaboration

- 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



$F_2 \rightarrow$ probe structure of proton

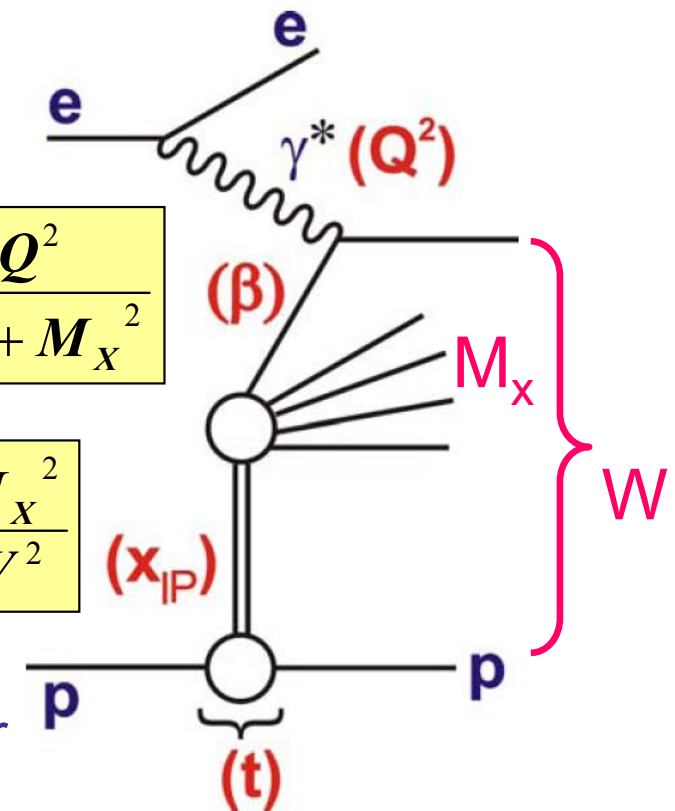
Momentum fraction of color singlet carried by struck quark

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

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

Momentum fraction of proton carried by colour singlet exchange

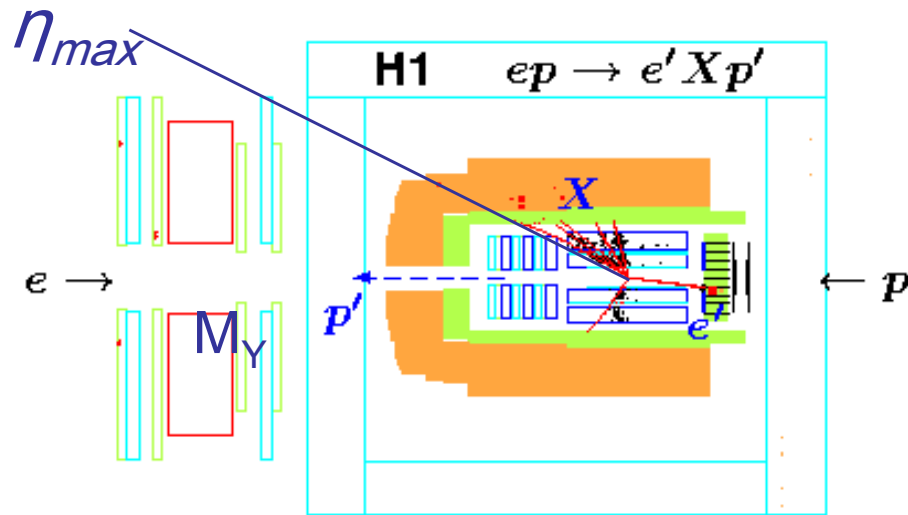
Diffractive DIS





Selection of diffraction at HERA

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

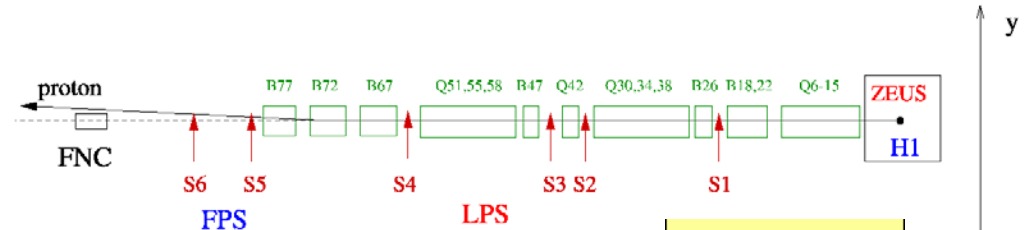


- high statistics, data integrated over $|t| < 1 \text{ GeV}^2$
- p-dissociation contribution
- limited by systematic uncertainties related to missing proton

➤ Are LRG and FPS methods compatible?

LRG / FPS ratio → p-dissociation to LRG data ($M_Y < 1.6 \text{ GeV}$)

Forward Proton Spectrometer H1 FPS



+ ZEUS LPS

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

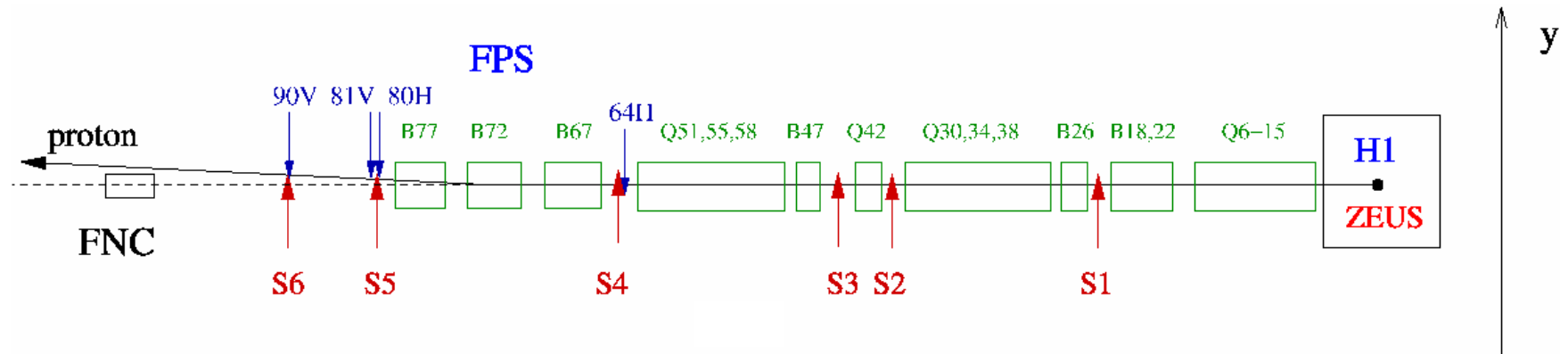
- free of p-dissociation background
- x_{IP} and t-measurements
- access to high x_{IP} range (IP+IR)
- low geometrical acceptance

➔ LRG and FPS methods have different systematic uncertainties



Forward Proton Spectrometer

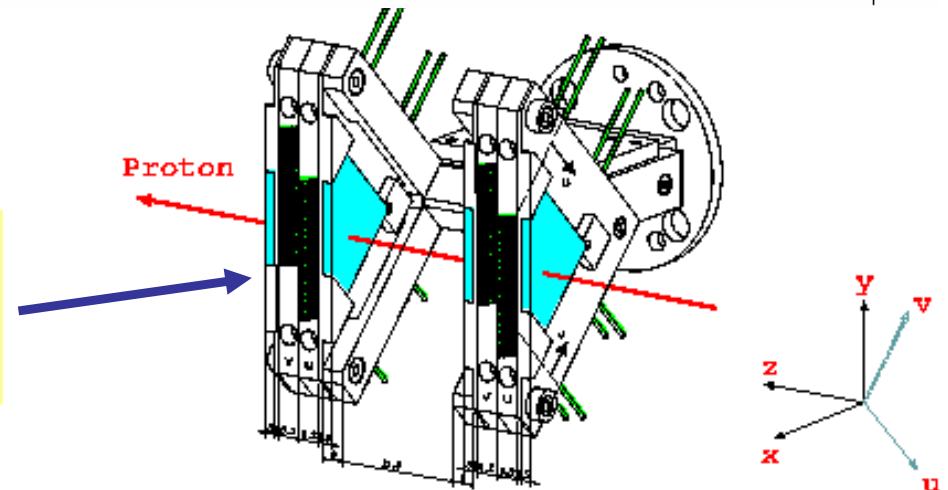
- **Purpose:** measurement of leading proton momentum using coordinate detectors and system of HERA magnets
- **Roman Pot** technology, scintillating **fibre detectors** readout by position sensitive photo-multipliers



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

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

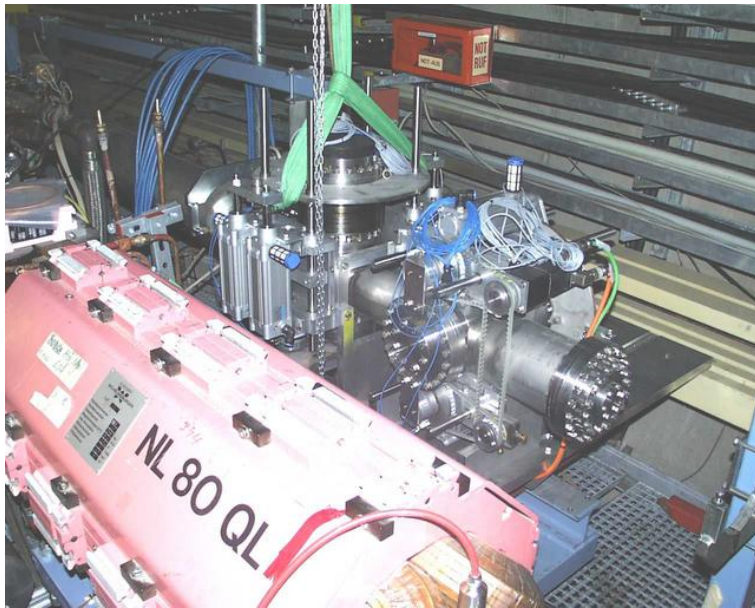
→ this analysis





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 $\sim 156 \text{ pb}^{-1}$

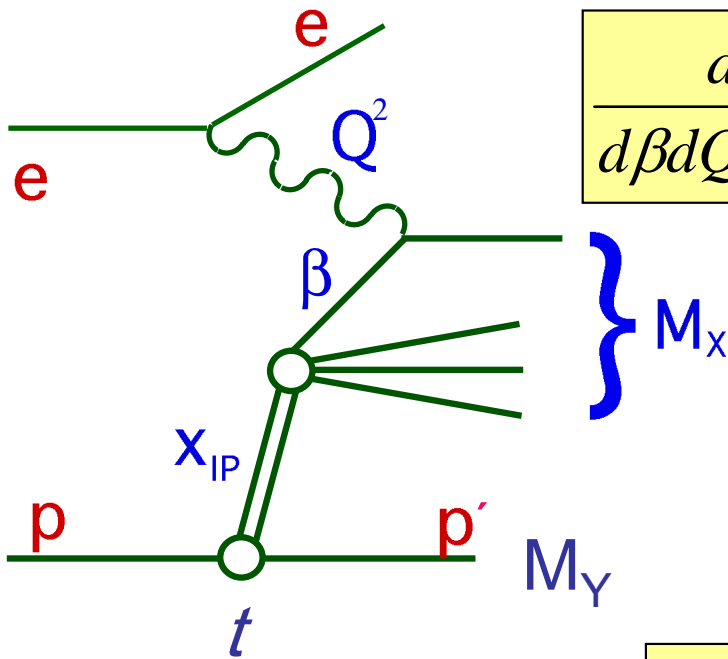
Statistics of DIS events with a leading proton in Horizontal Roman Pots:

Medium Q^2 ($4 < Q^2 < 110 \text{ GeV}^2$)
 ~ 68.200 events

High Q^2 ($120 < Q^2 < 700 \text{ GeV}^2$)
 ~ 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 :

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

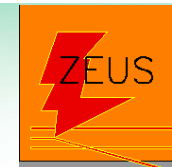
$$\sigma_r^D \approx F_2^D \text{ at low and medium } y$$

Integrate over $|t| < 1 \text{ GeV}^2 \rightarrow$
to compare with LRG and
diffractive PDF predictions

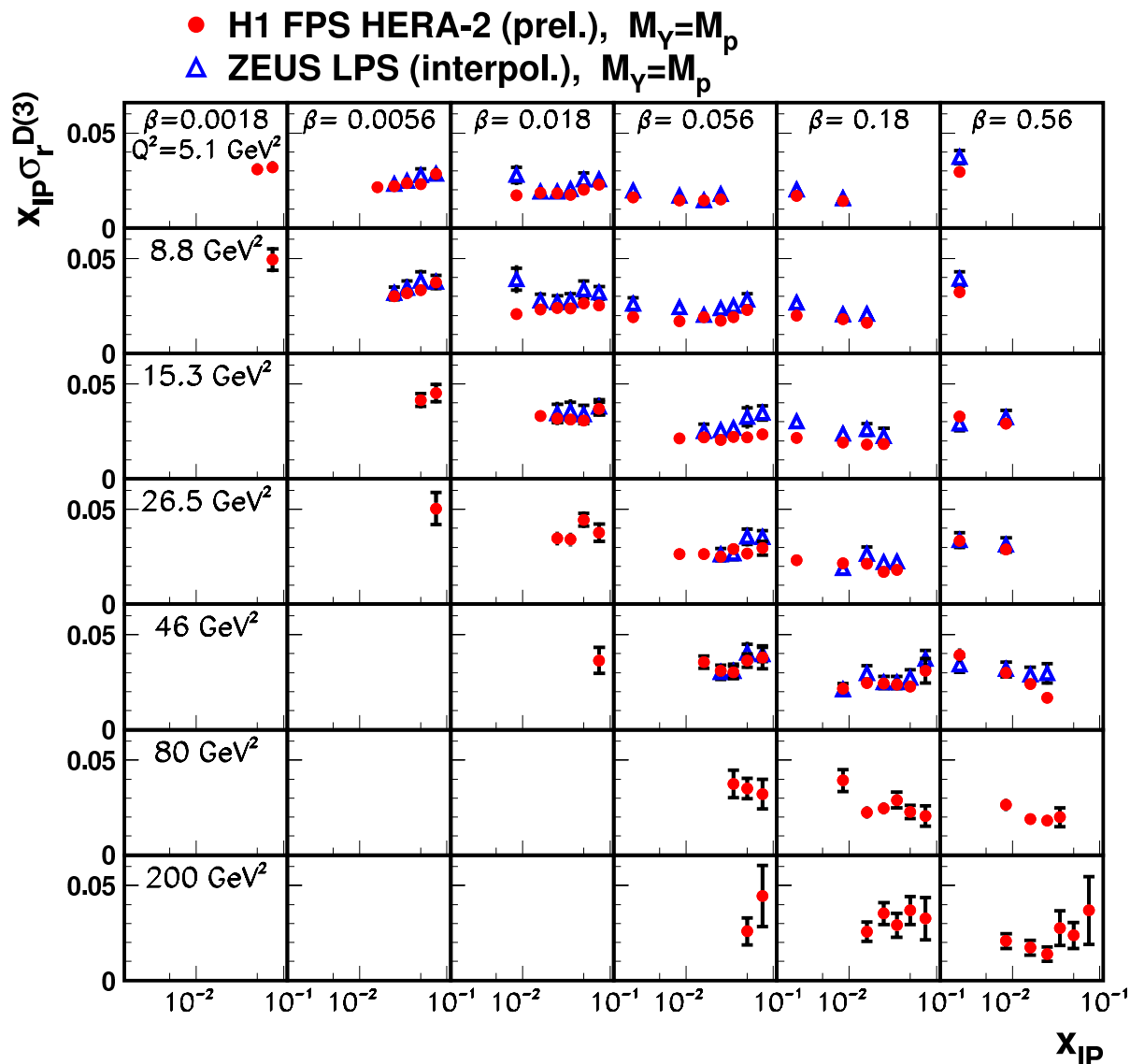
$$\sigma_r^{D(3)} = \int \sigma_r^{D(4)} dt$$



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



Forward Proton Spectrometer data

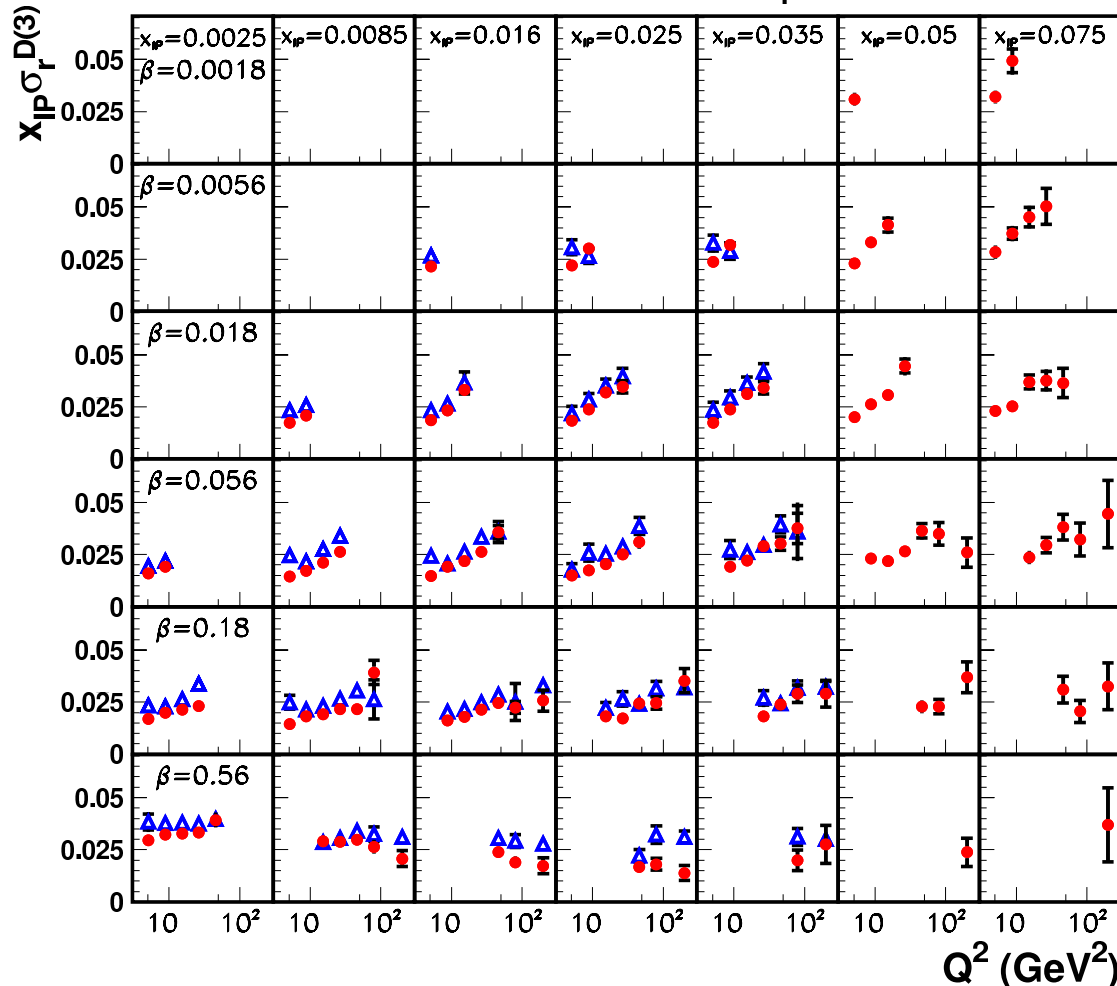


- New FPS HERA-2 data $M_Y=M_p$
- ▲ ZEUS LPS data, $M_Y=M_p$
- x_{IP} -dependence in (β, Q^2) bins
- Reasonable agreement of **new H1 FPS** and **ZEUS LPS** data → within uncertainties
- H1 FPS norm. uncertainty ~6%, ZEUS LPS norm. uncertainty $\pm^{11\%}_{7\%}$
- **new H1 FPS HERA-2** data extend phase space to **higher Q^2**



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

- H1 FPS HERA-2 (prel.), $M_Y=M_p$
- △ H1 LRG HERA-1 (interpol.), $M_Y<1.6$ GeV



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

- △ 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}

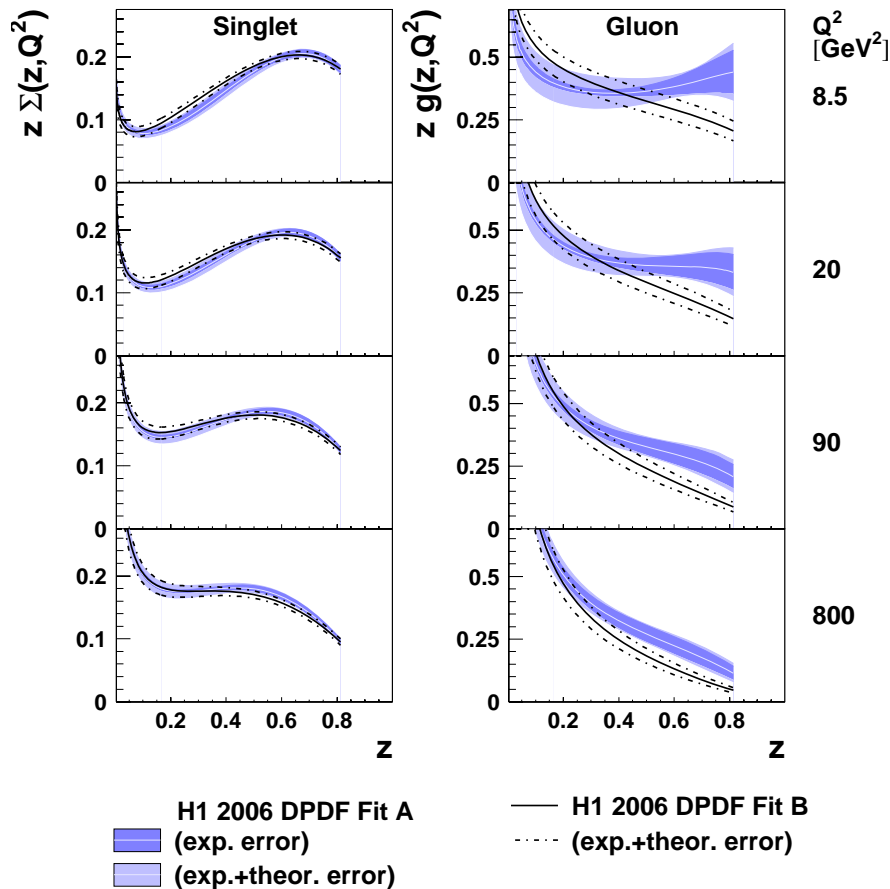
- p-dissociation contribution in LRG data ($M_Y<1.6$ GeV) is not subtracted
- LRG / FPS relative norm. uncertainty $\sim 8.5\%$



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

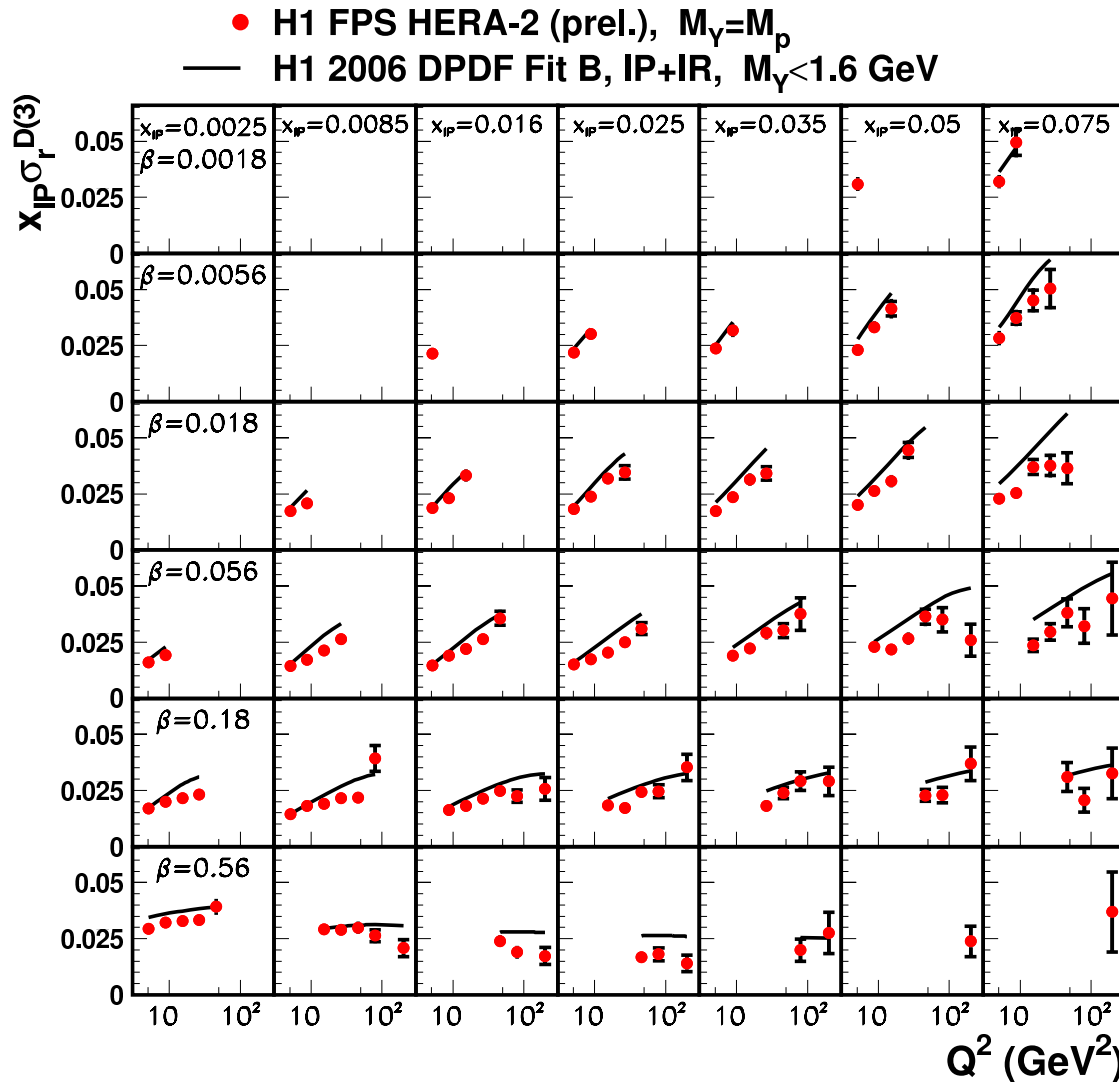
• constrains quark singlet DPDF and gluon DPDF at low z

• 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

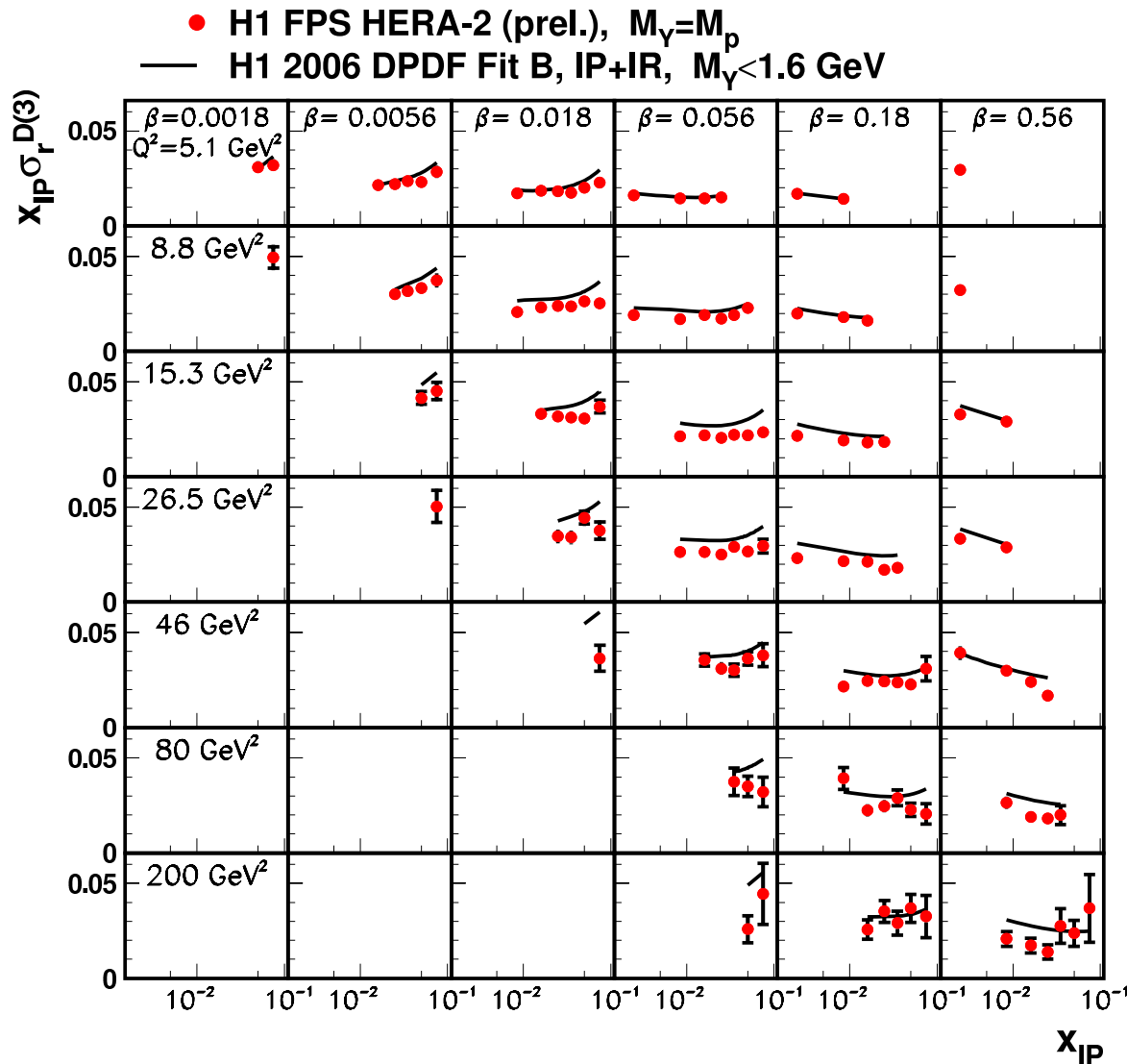
Q^2 -dependence in
 (x_{IP}, β) bins

• Positive scaling
violations except for
high $\beta \rightarrow$ large
gluon contribution to
diffractive exchange

- difference in normalization \rightarrow p-dissociation contribution to DPDF
- FPS HERA-2 data: syst. uncertainty $\sim 8\%$, norm. uncertainty $\sim 6\%$



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

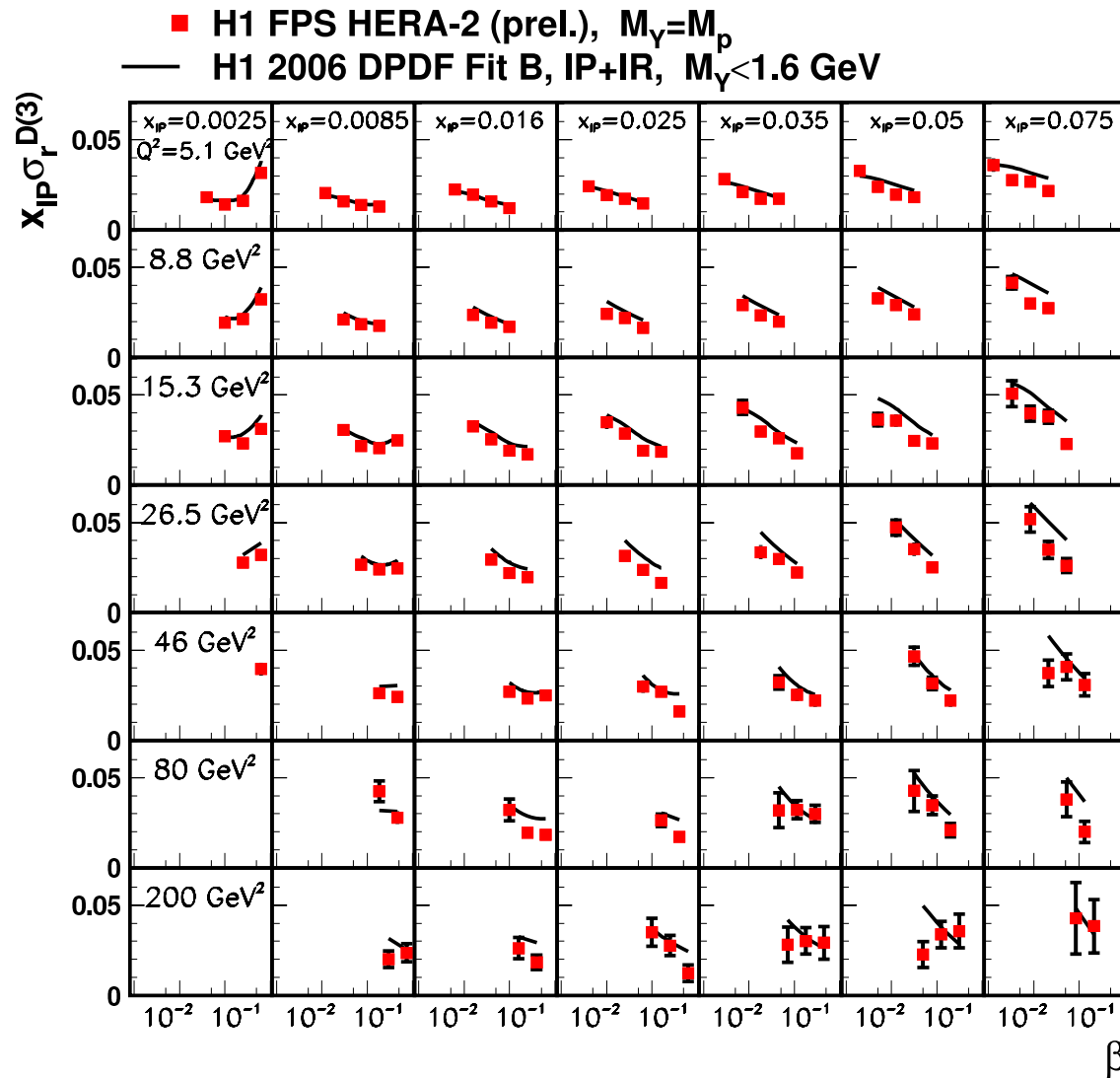
x_{IP} -dependence in
 (β, Q^2) bins

- $x_{IP}\sigma_r^{D(3)}$ 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

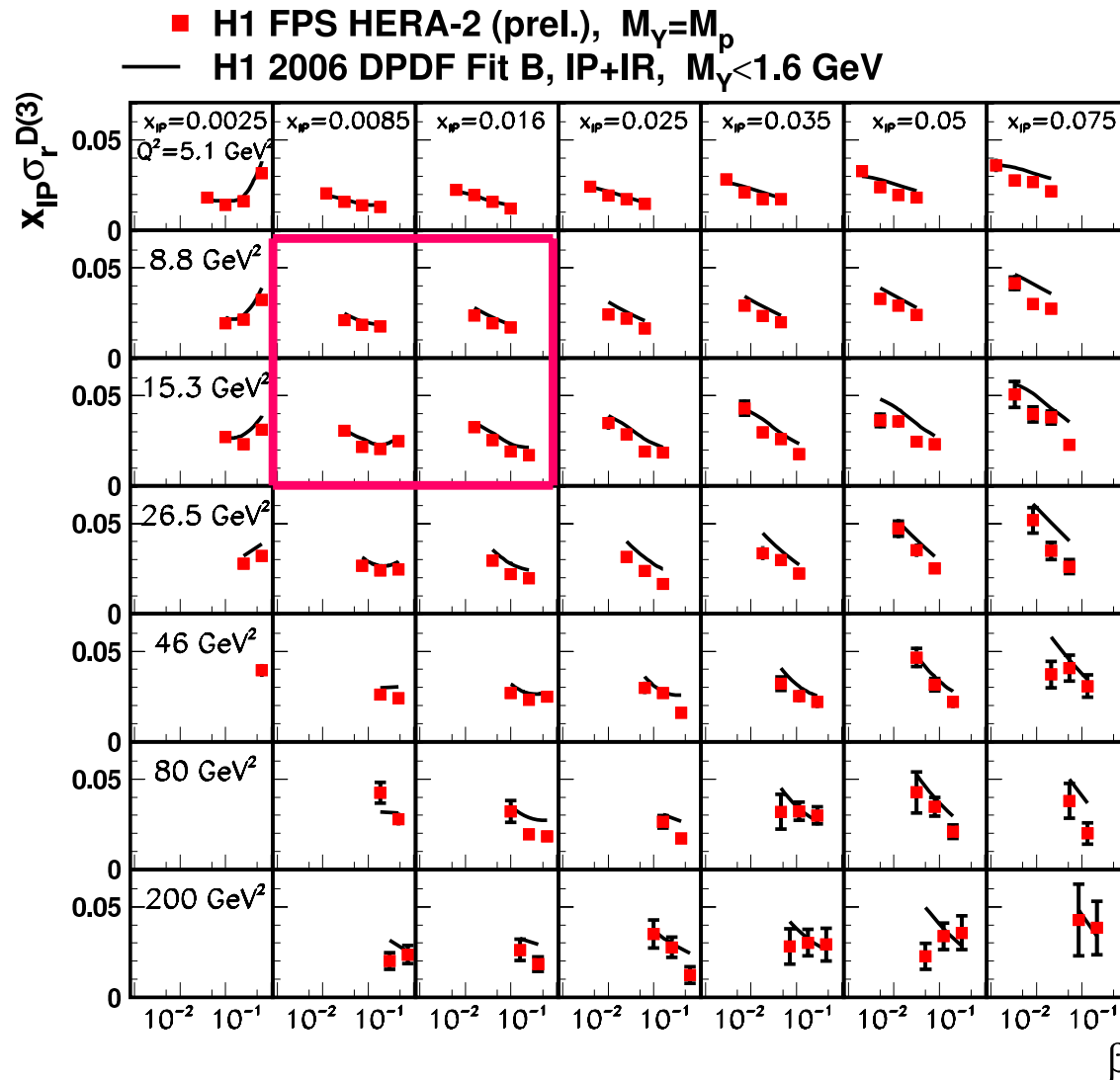
β -dependence in
(x_{IP}, Q^2) bins

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

- difference in normalization \rightarrow 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

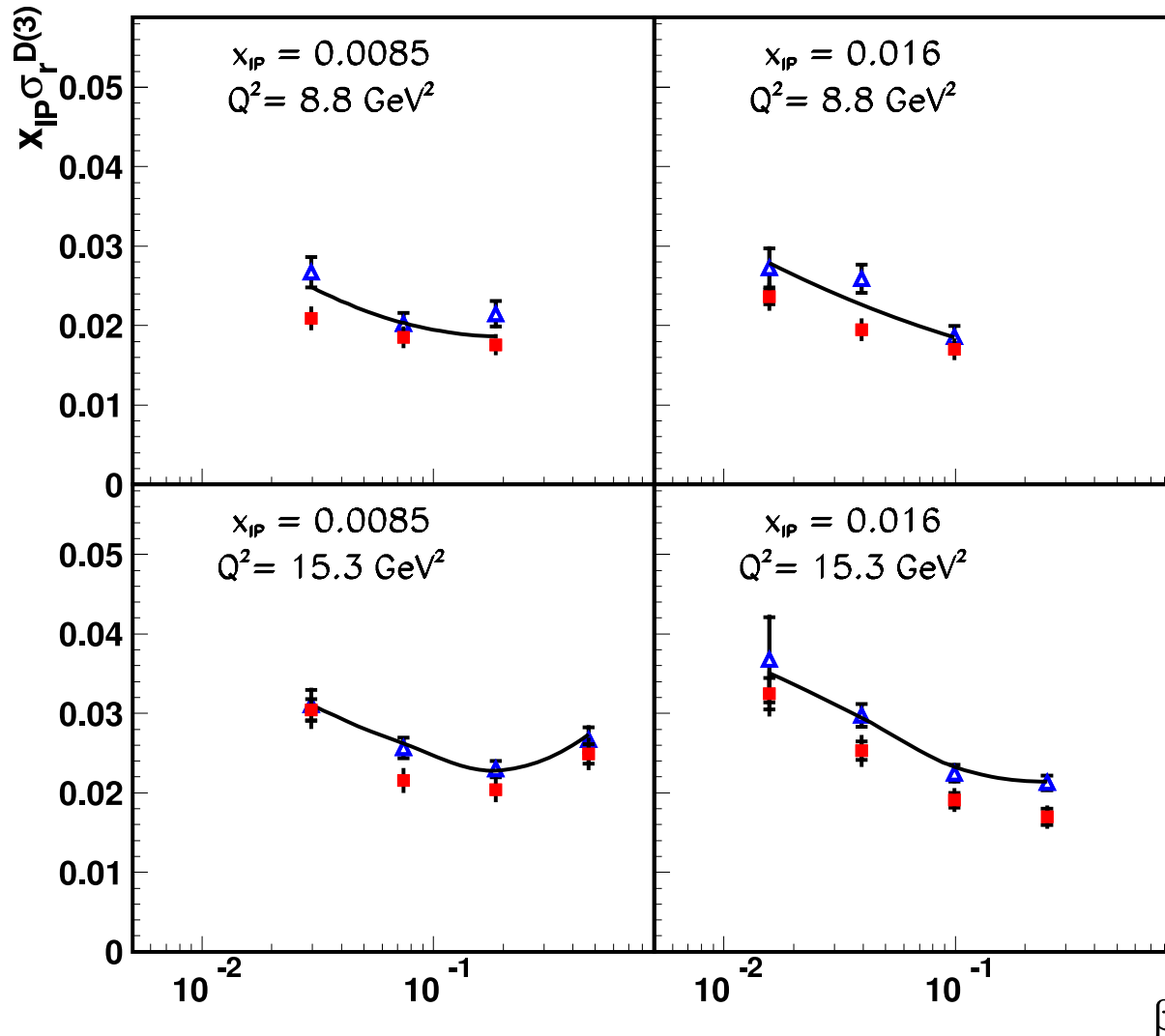
→ look to selected
 (x_{IP}, Q^2) bins

- difference in normalization → p-dissociation contribution to DPDF



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

- H1 FPS HERA-2 (prel.), $M_Y=M_p$
- ▲ H1 LRG HERA-1 (interpol.), $M_Y<1.6$ GeV
- H1 2006 DPDF Fit B, IP+IR, $M_Y<1.6$ GeV



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

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

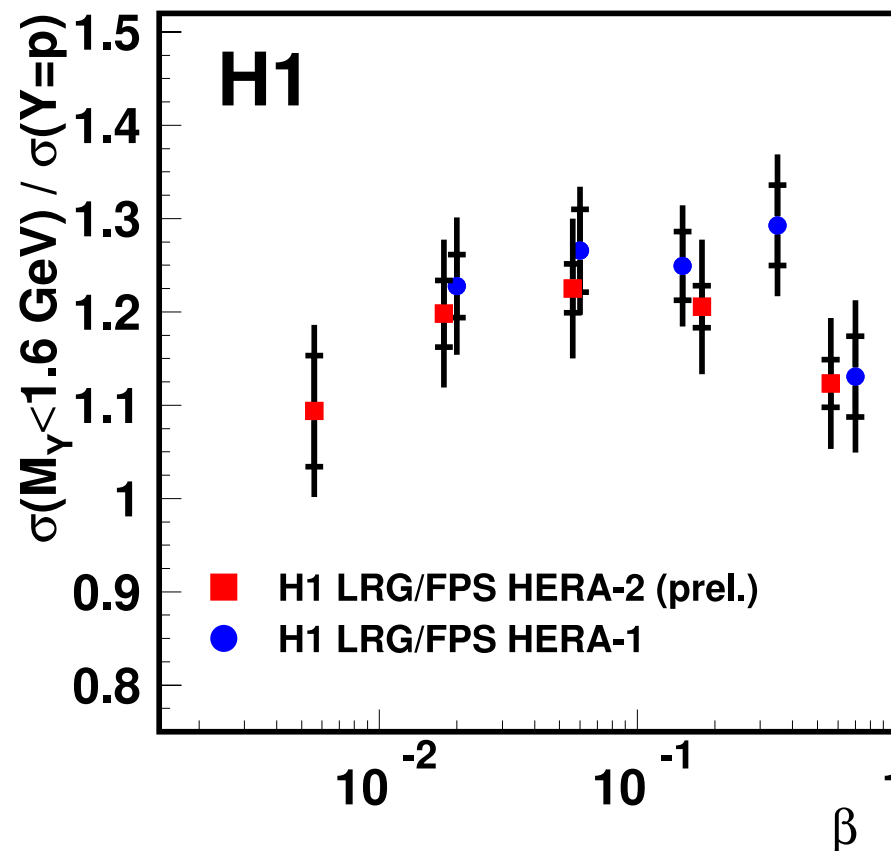
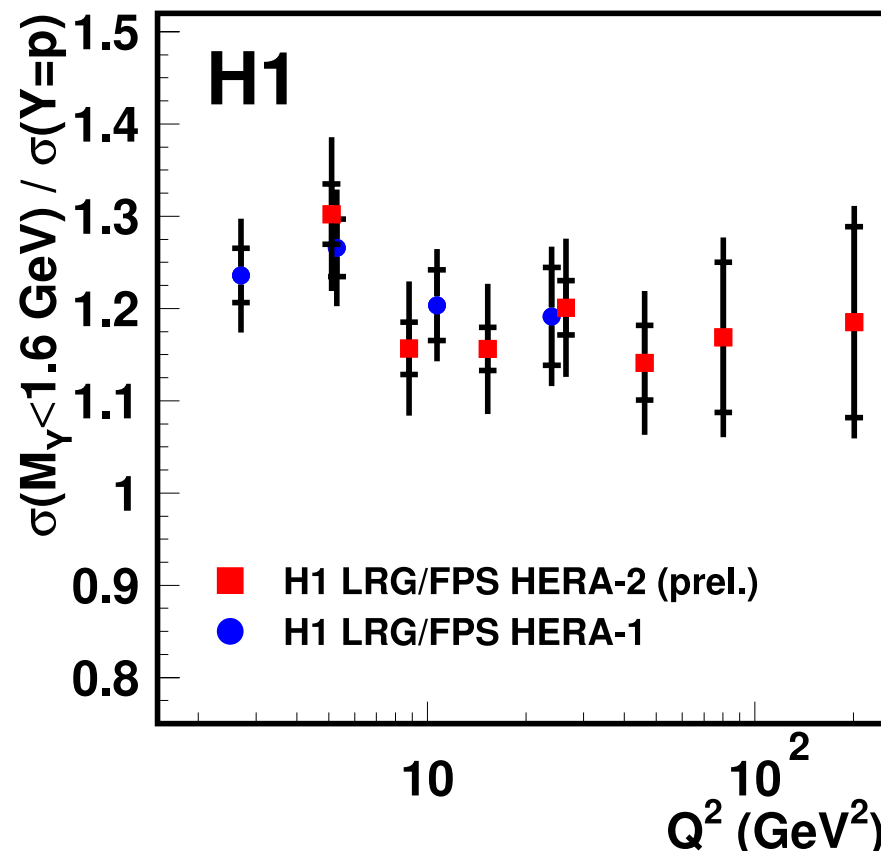
difference in normalization \rightarrow p-dissociation contribution to DPDF and LRG data



LRG to FPS ratio

Q^2 dependence

β dependence

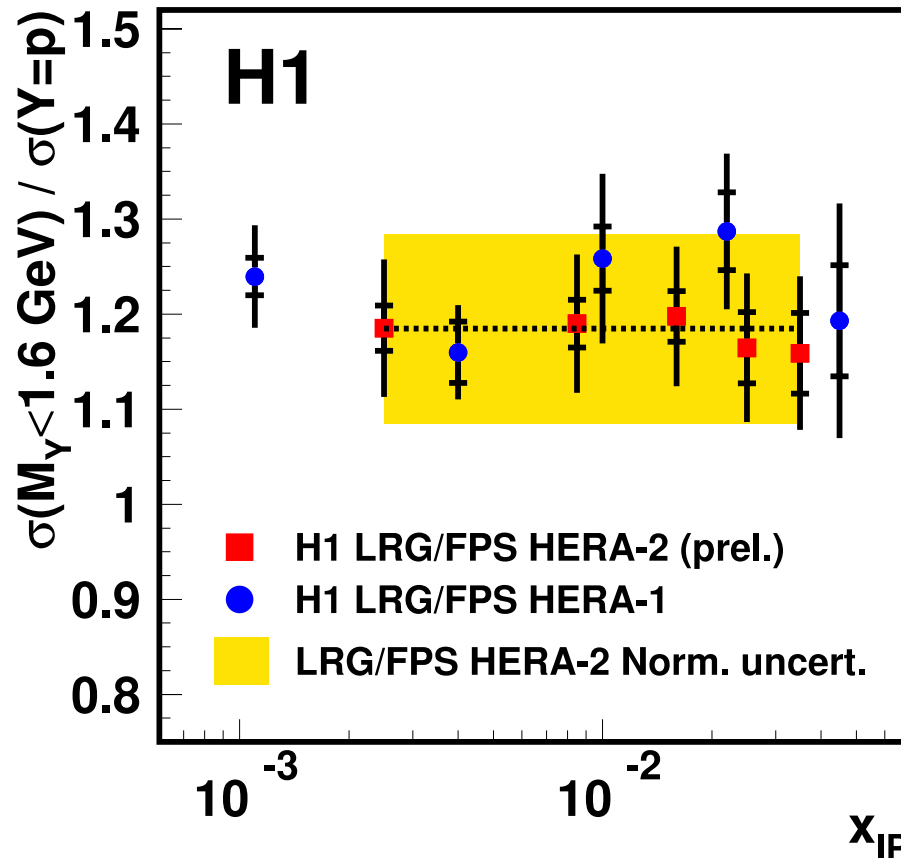


- Ratio of **LRG HERA-1** to **new FPS HERA-2** data is consistent with **H1 HERA-1** result
- **FPS HERA-2** data extend to **higher Q^2** and **lower β**
- LRG / FPS normalization uncertainty of 8.5% is not shown



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