Inclusive diffraction and a measurement of the diffractive longitudinal structure function F_L^D at HERA
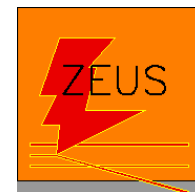
L. Favart

I.I.H.E.
Université Libre de Bruxelles
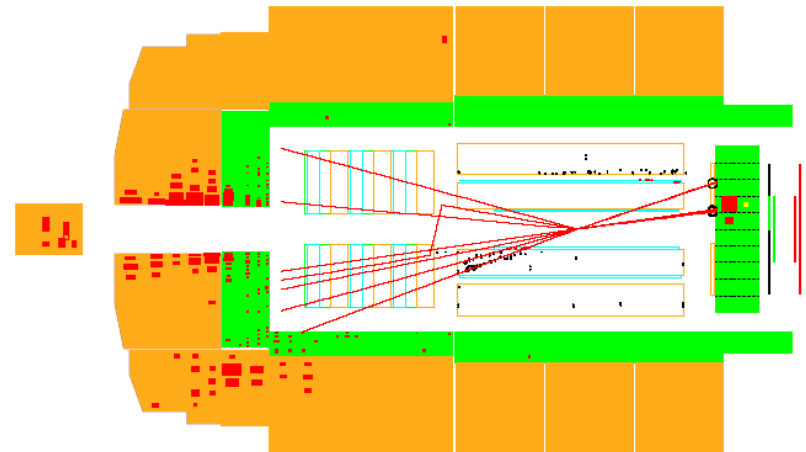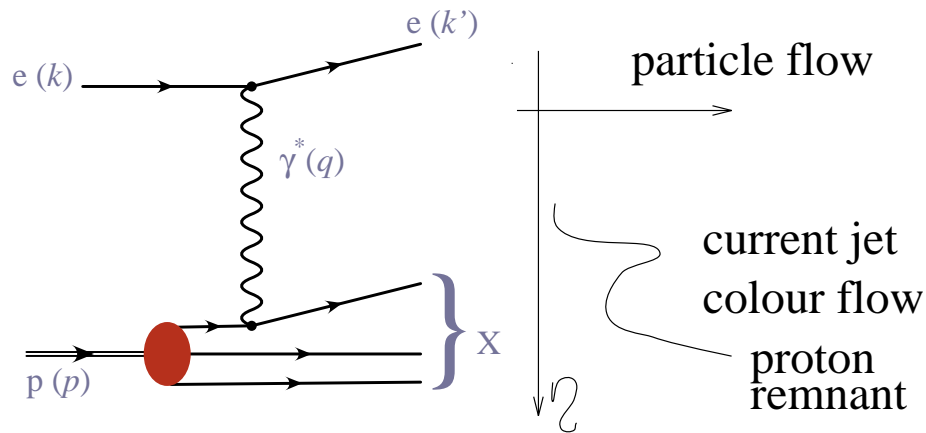
On behalf of the H1 and ZEUS
Collaborations

ULB

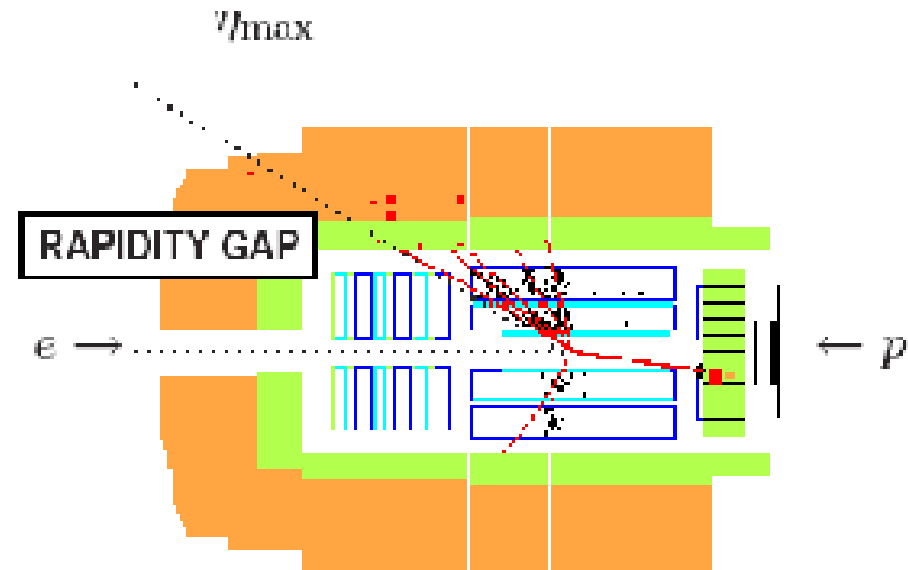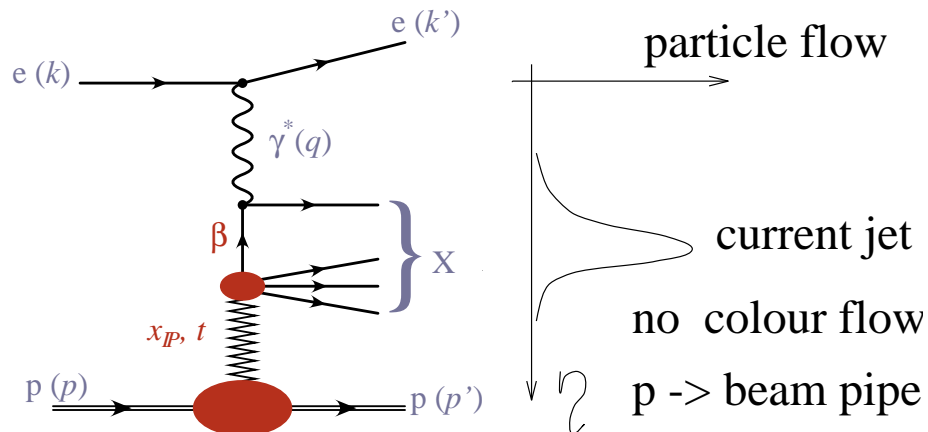The 2009 Europhysics Conference on High Energy Physics Search

EPS09 - Kraków - 16-22$^{\text{th}}$ of July 2009

Diffractive Scattering

Deep Inelastic Scattering (DIS)

e (k)

e (k')

$\gamma^*(q)$

p (p)

} X

particle flow

current jet
colour flow
proton
remnant

Diffractive Scattering (DDIS)

e (k)

e (k')

$\gamma^*(q)$

β

} X

$x_{I\!P}, t$

p (p)

p (p')

particle flow

current jet

no colour flow

p -> beam pipe

η_{max}

RAPIDITY GAP

e →

← p

Cross sections and kinematics
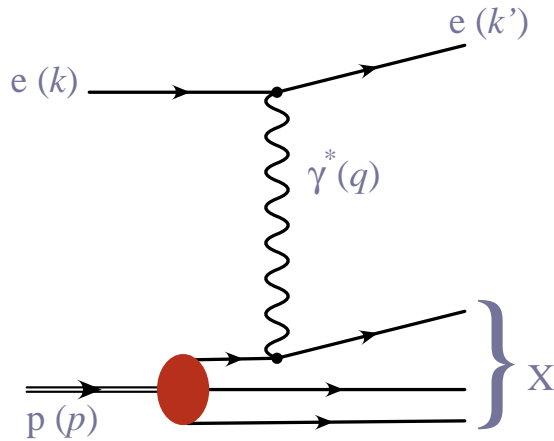
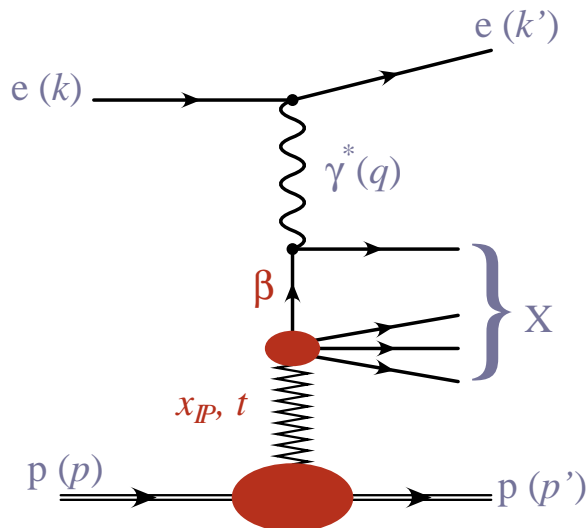**Deep Inelastic Scattering** $ep \to eX$

Q^2 $= -q^2$ - virtuality of the exchanged photon

W $\gamma^* - p$ system energy

x Bjorken-x: fraction of proton's momentum carried by the struck quark

y γ^* inelasticity : $y = Q^2/s\,x$

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x \mathrm{d}Q^2} = \frac{2\pi\alpha^2}{x\,Q^4} Y_+ F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2)$$

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

Diffractive Scattering $ep \to eXp$

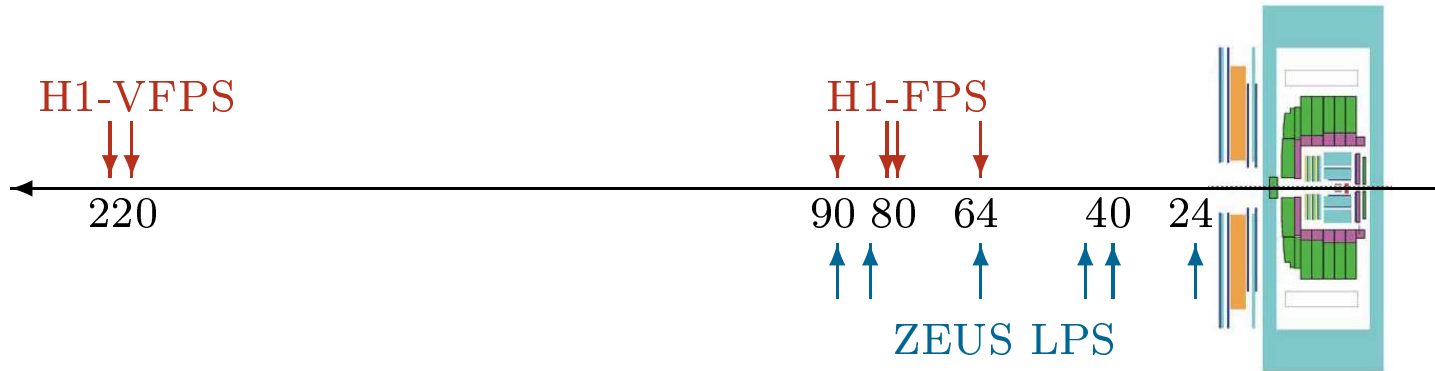$x_{I\!P}$ fraction of proton's momentum of the colour singlet exchange

$$x_{I\!P} \simeq \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

β fraction of $I\!P$ carried by the quark "seen" by the γ^* $\beta = x/x_{I\!P}$

t $= (p - p')^2$, 4-momentum squared at the p vertex

$$\frac{\mathrm{d}^4\sigma^D}{\mathrm{d}\beta\ \mathrm{d}Q^2\ \mathrm{d}x_{I\!P}\mathrm{d}t} = \frac{2\pi\alpha^2}{\beta Q^4}\ Y_+ F_2^{D(4)}(\beta, Q^2, x_{I\!P}, t) - \frac{y^2}{Y_+} F_L^{D(4)}$$

Roman Pot Method

H1-VFPS

220

H1-FPS

90 80   64   40   24

ZEUS LPS
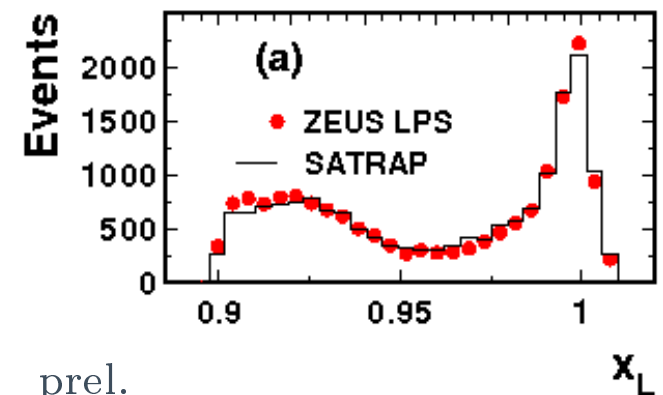
- Purpose: direct measurement of the scattered proton: giving t and $x_{I\!P}$ measurements

- Roman Pot technology

- no p-diss. background
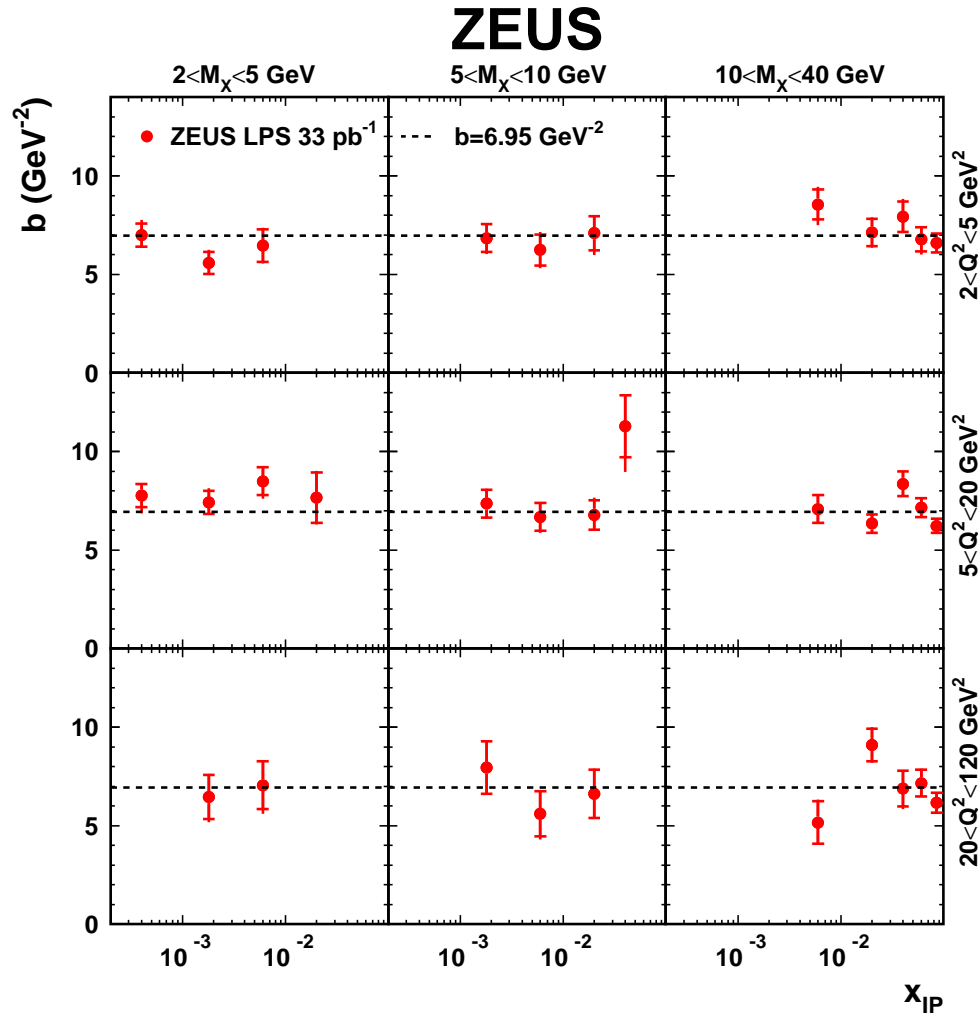
- low statistics due to Roman Pot detector acceptance

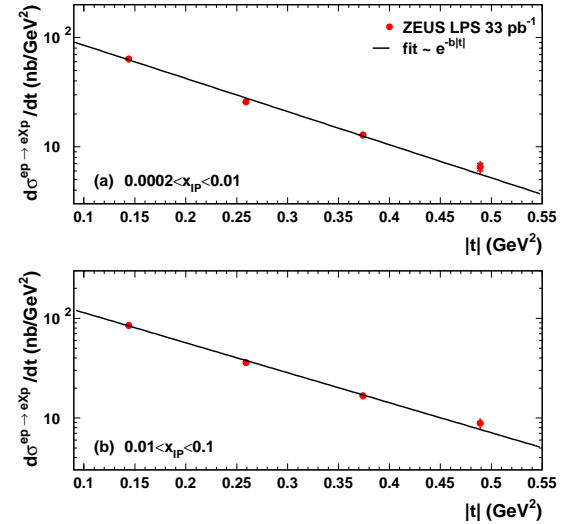|					
- New: H1 FPS	$x_{I\!P} < 0.1$	156 pb^{-1}	HERA II	prel.
- New: ZEUS LPS	$x_{I\!P} < 0.1$	33 pb^{-1}	HERA I	NPB 816 (2009)

t dependence

ZEUS-LPS data

ZEUS

$$\Rightarrow \frac{\mathrm{d}^4\sigma^D}{\mathrm{d}\beta\ \mathrm{d}Q^2\ \mathrm{d}x_{I\!P}\ \mathrm{d}t} = \frac{\mathrm{d}^3\sigma^D}{\mathrm{d}\beta\ \mathrm{d}Q^2\ \mathrm{d}x_{I\!P}}\ e^{-b|t|}$$

ZEUS

- Fit $\frac{\mathrm{d}\sigma}{\mathrm{d}t} \sim e^{-b|t|} \Rightarrow b = 7.0 \pm 0.4\ \mathrm{GeV}^{-2}$

- No dependence observed in: $Q^2, x_{I\!P}, M_X$
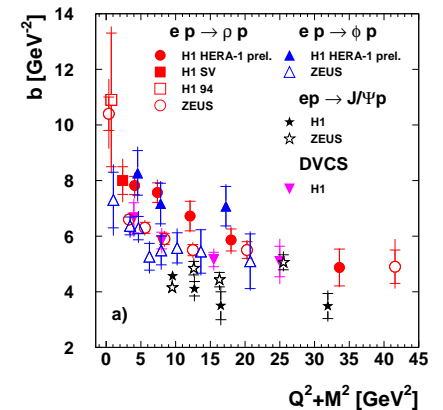
$x_{\mathbb{P}}$ dependence

$$\sigma^D = \frac{2\pi\alpha^2}{\beta Q^4} \, Y_+ \, \sigma_r^D \qquad\qquad \sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$
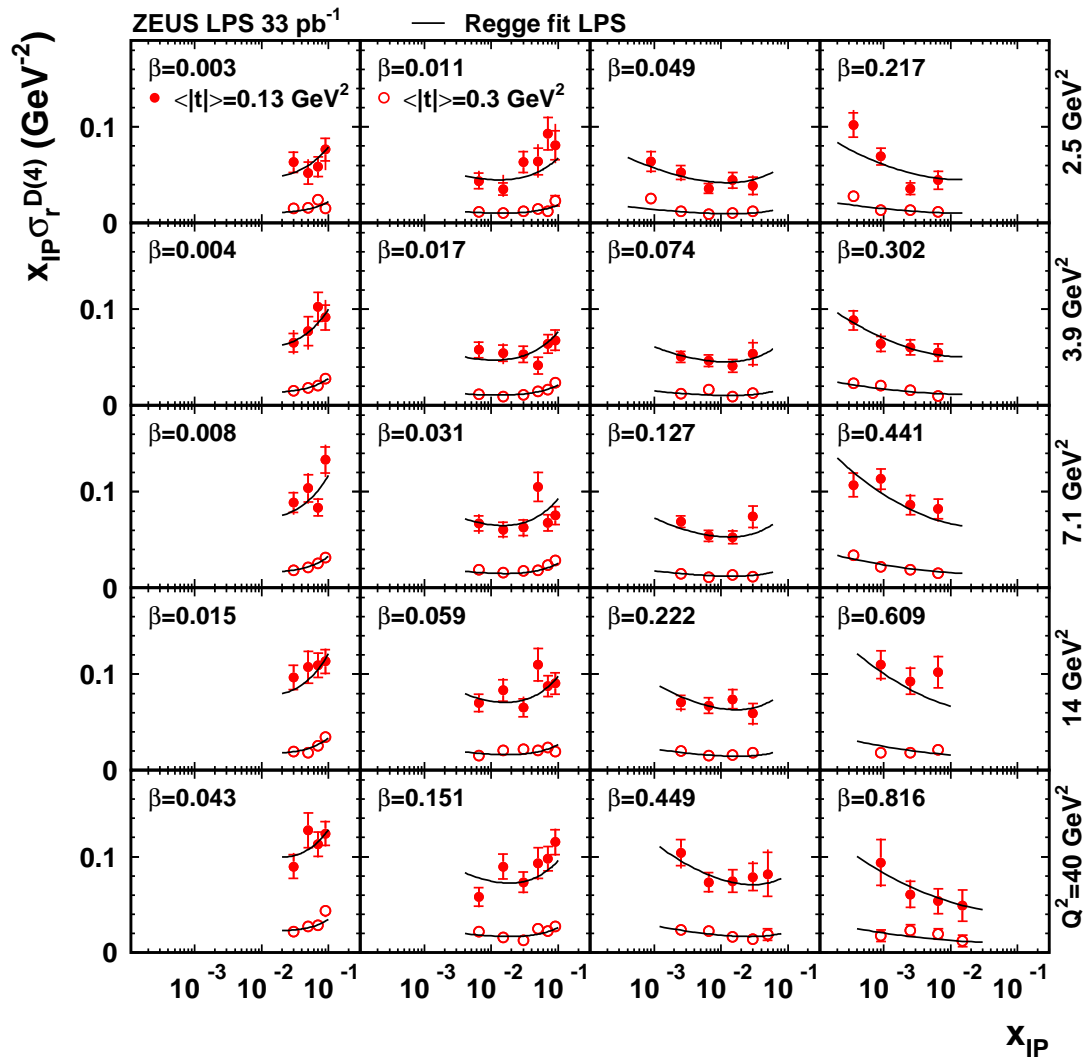
- first measurement in two t bins

- Low $x_{\mathbb{P}}$: σ_r^D falls with $x_{\mathbb{P}}$ faster than $1/x_{\mathbb{P}}$

- High $x_{\mathbb{P}}$: σ_r^D flattens or increases with $x_{\mathbb{P}}$ (Reggeon exchange)

- Same $x_{\mathbb{P}}$ dependence in the two t bins

Q^2 dependence

- H1 FPS HERA-2 (prel.), $M_Y=M_p$
- ZEUS LPS (interpol.), $M_Y=M_p$

$x_{I\!P}\sigma_r^{D(3)}$ vs Q^2 (GeV^2)

Panel labels: $x_{I\!P}=0.0025$, $x_{I\!P}=0.0085$, $x_{I\!P}=0.016$, $x_{I\!P}=0.025$, $x_{I\!P}=0.035$, $x_{I\!P}=0.05$, $x_{I\!P}=0.075$

Row labels: $\beta=0.0018$, $\beta=0.0056$, $\beta=0.018$, $\beta=0.056$, $\beta=0.18$, $\beta=0.56$
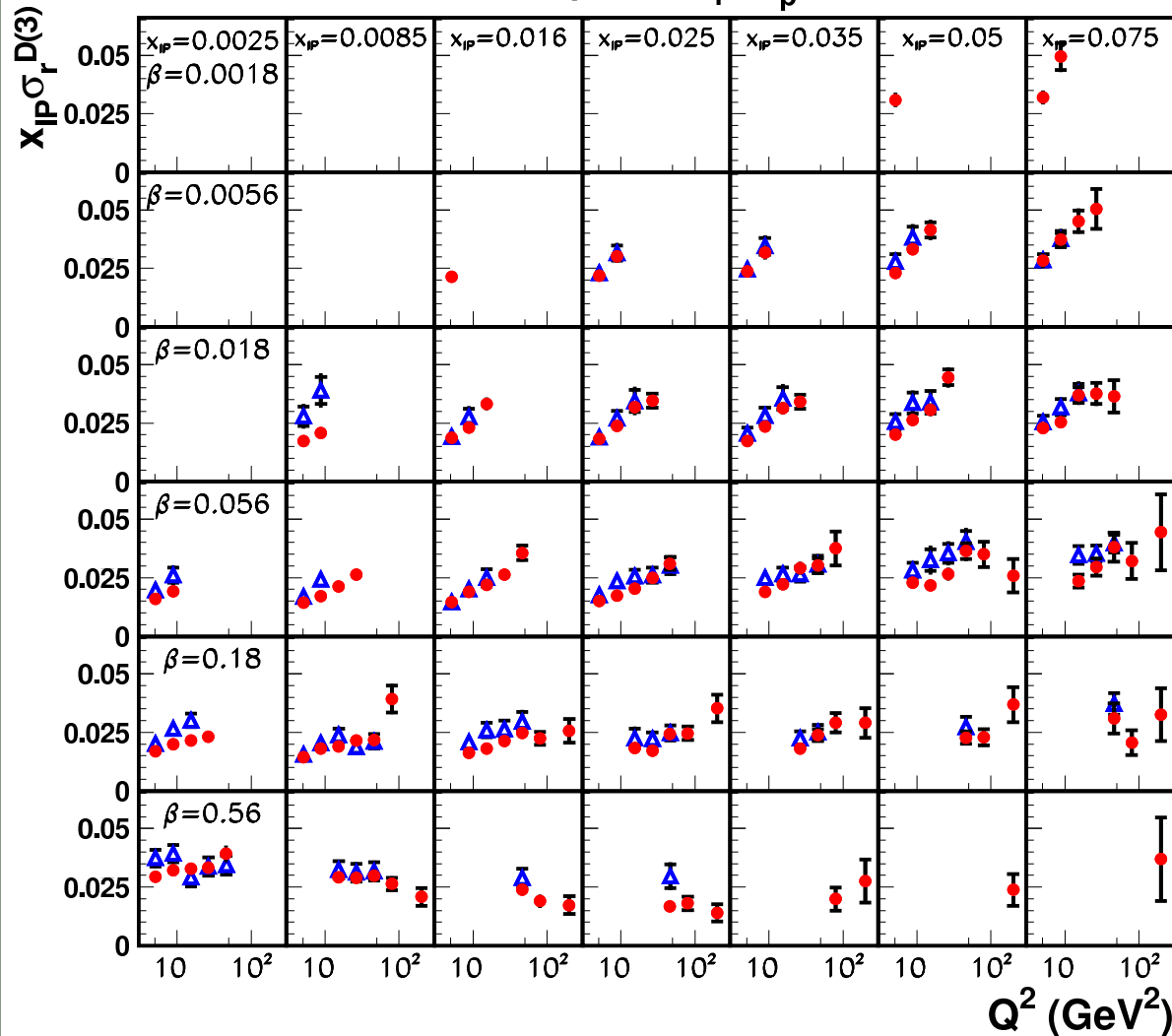
- after correcting for the photon propagator, the cross section increases with Q^2 for $\beta \lesssim 0.2$

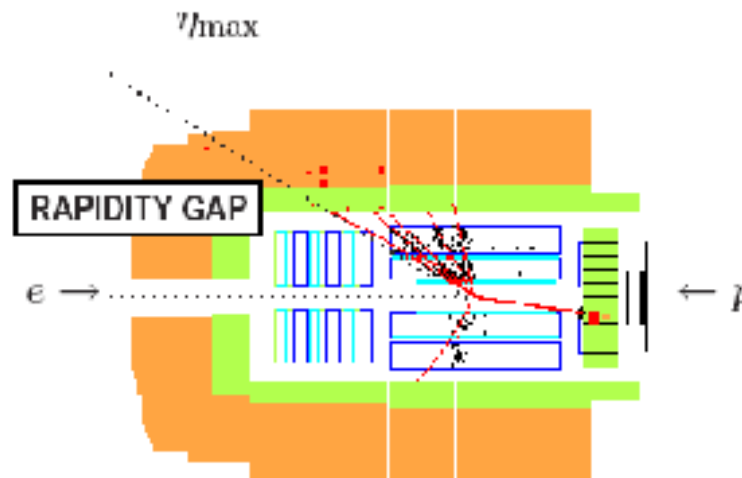- Reasonable agreement between H1-FPS and ZEUS-LPS - cleanest possible comparison in principle...

...but large normalisation uncertainties:
   H1-FPS: $\pm 10\%$
   ZEUS-LPS: $+11 - 7\%$

- new H1-FPS (HERA II): reaches higher Q^2

Large Rapidity Gap Method

- Require a large rapidity gap adjacent to the outgoing (untagged) proton

- Escaping scattered proton $\Rightarrow$ cross section integreted over t

- Large statistics (no Roman Pot det. acceptance limitation), large range in $Q^2, x_{I\!P}, \beta$

- Contamination of p-dissociation background: $ep \rightarrow eXY$ with $M_Y \ll W$
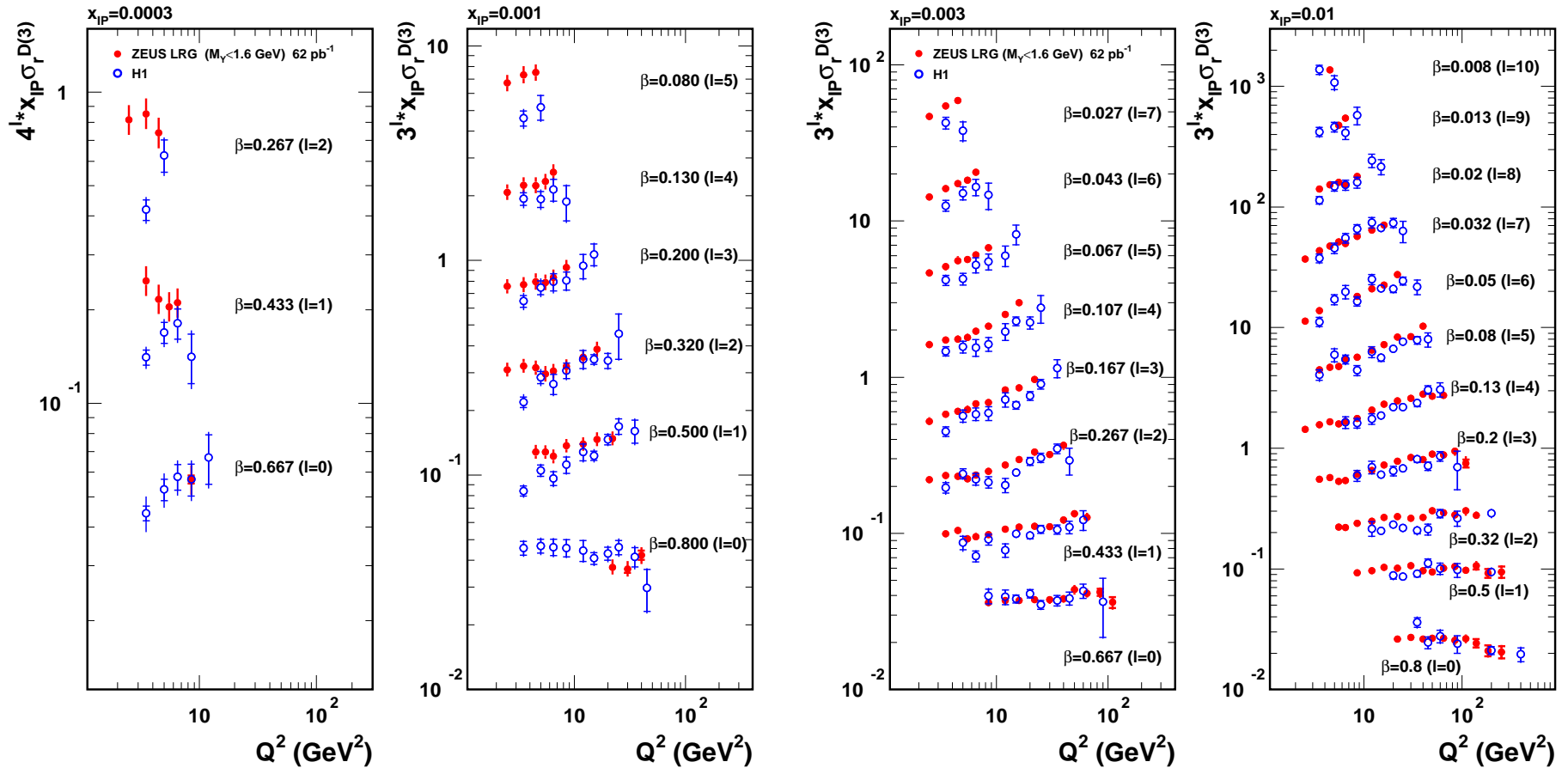
Data shown in this talk:

- New: ZEUS LRG	$x_{I\!P} < 0.02$	$M_Y = m_p$	HERA I - 62 pb^{-1}	NPB 816 (2009)
- H1 LRG	$x_{I\!P} < 0.03$	$M_Y < 1.6$ GeV	HERA I - 62 pb^{-1}	EPJ C48 (2006)

LRG vs Roman Pots
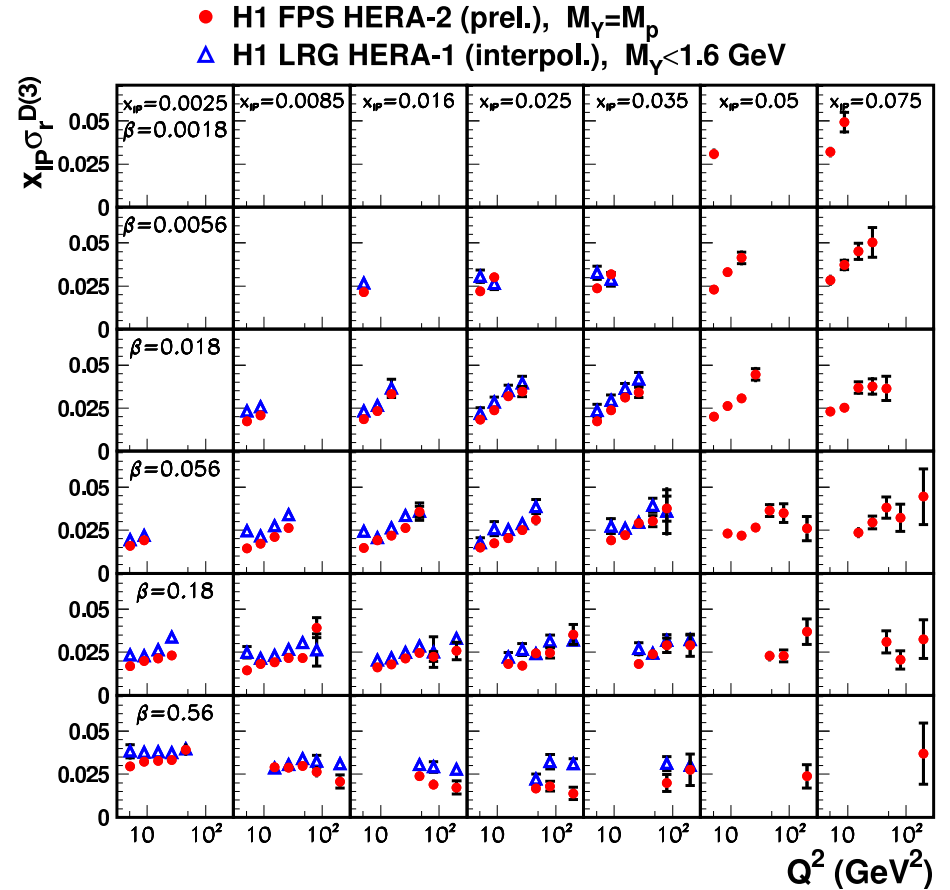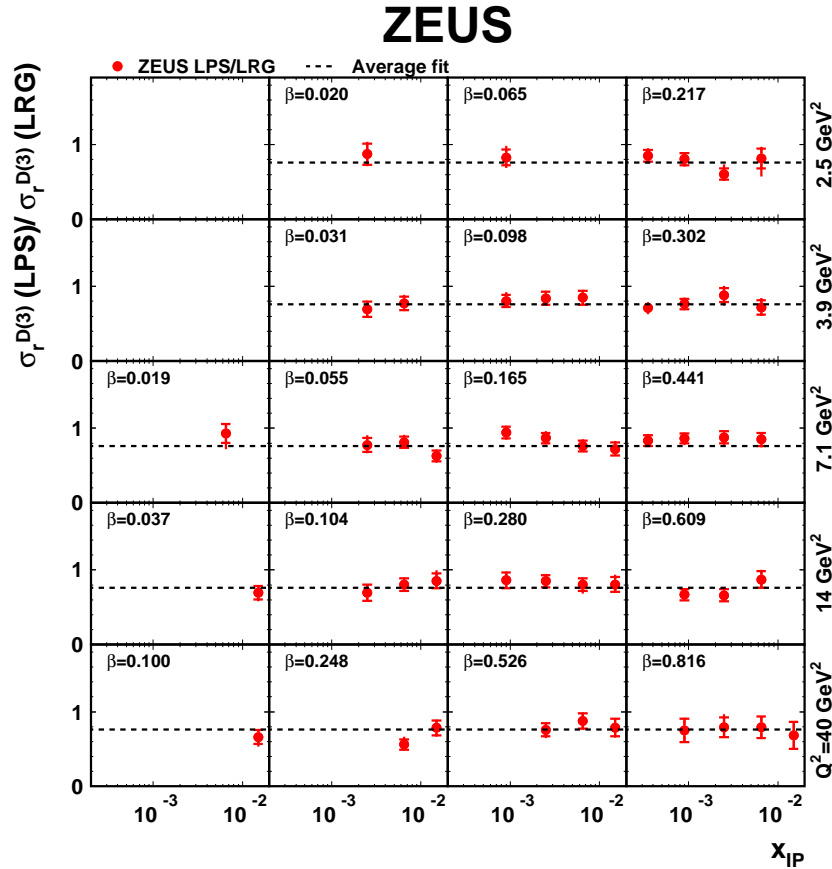
- ZEUS LPS/LRG: independent of $Q^2, x_{I\!P}, \beta$

  $\Rightarrow$ p-diss. $= 24 \pm 1(\text{stat}) + 2 - 3(\text{syst}) + 5 - 8(\text{norm})\%$

- H1-FPS vs H1-LRG: Reasonnable agreement in shape

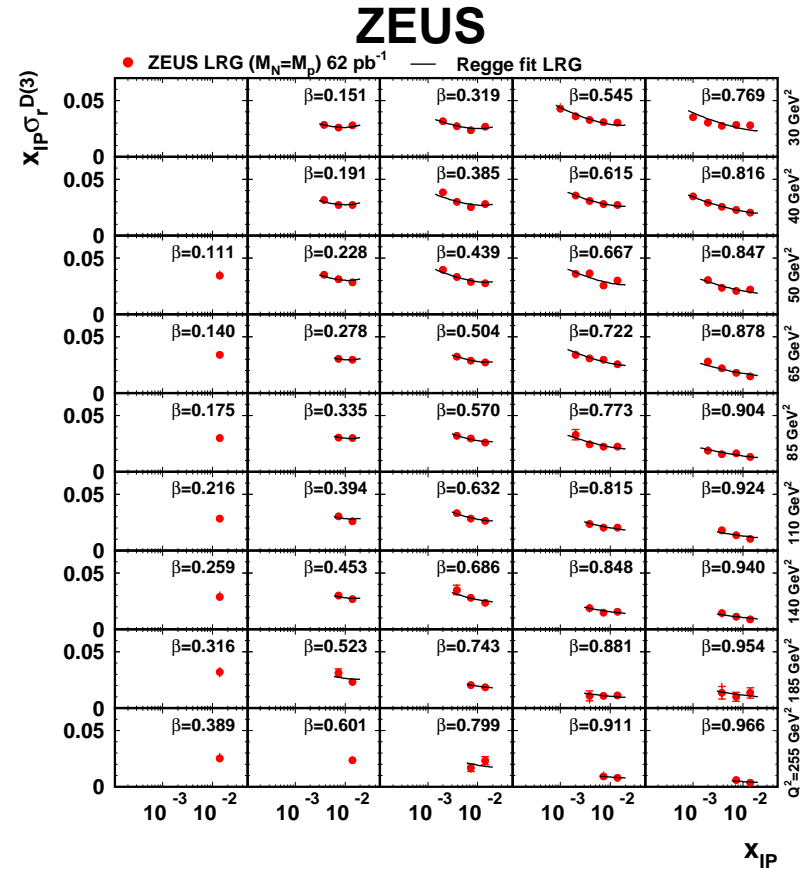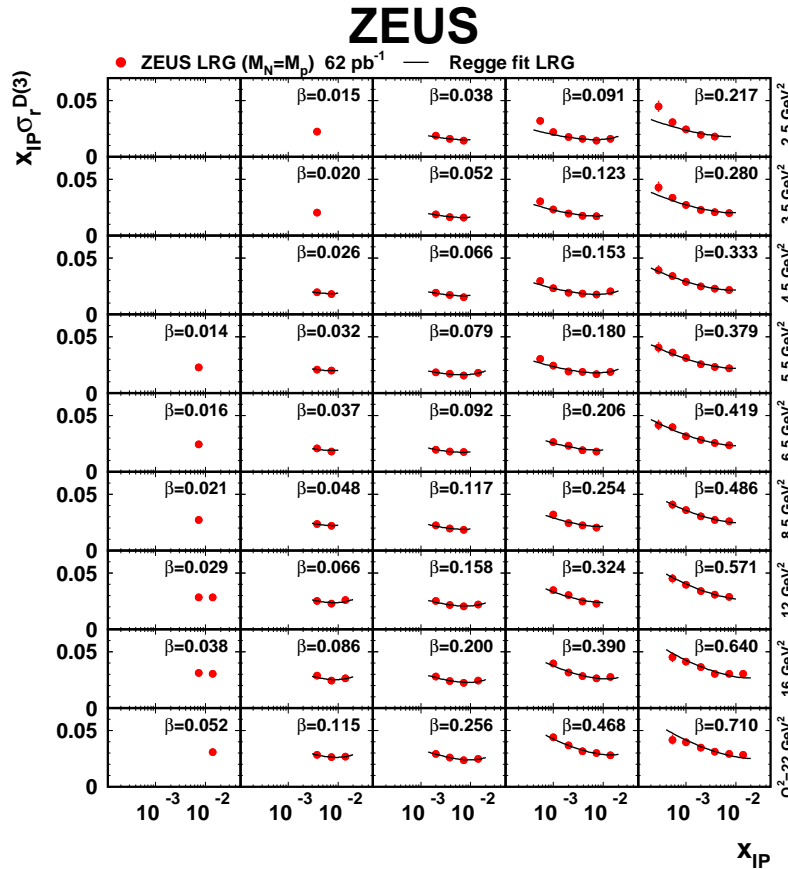 normalisation difference due to different M_Y cut (normalisation uncertainty of 8.5%).

- remaining normalisation difference of 13% (global fit) covered by uncertainty on p-diss. correction (8%) and relative normalisation uncertainty (7%)

- Shape agreement ok except at low Q^2

- note: here ZEUS points corrected to $M_Y < 1.6$ GeV.

- QCD fit on these data $\rightarrow$ see next talk (Alberto Garfagnini).

Regge Fit to LRG data

$$F_2^{D(4)}(\beta, Q^2, x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t)\, F_2^{I\!P}(\beta, Q^2) + n_{I\!R}\, f_{I\!R/p}(x_{I\!P}, t)\, F_2^{I\!R}(\beta, Q^2)$$

$$f_{I\!P, I\!R/p}(x_{I\!P}, t) = e^{bt}/x_{I\!P}^{2\alpha(t)-1} \qquad \alpha(t) = \alpha(0) + \alpha'\, t$$
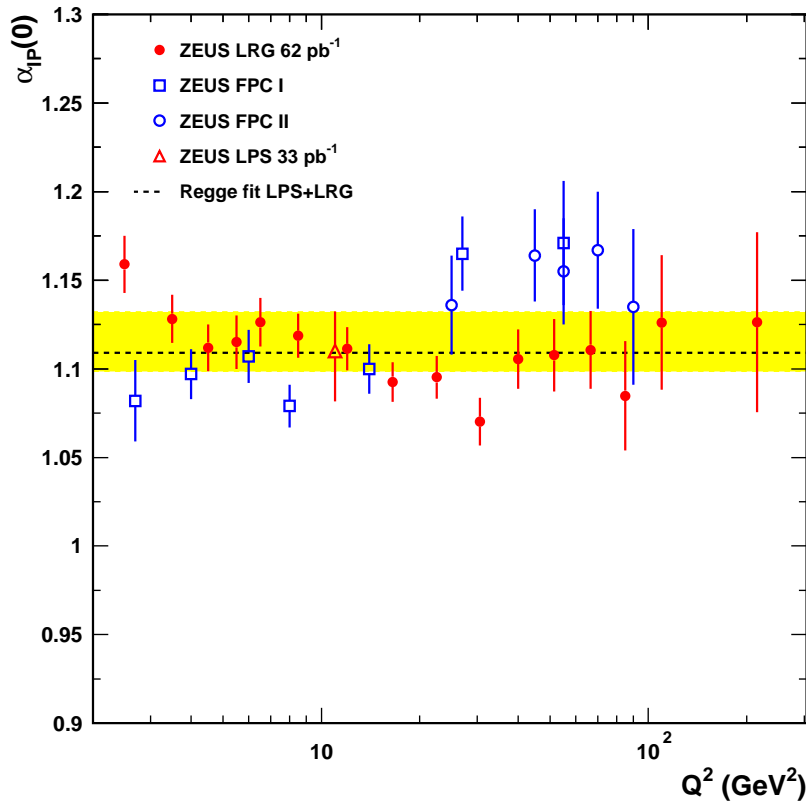

- Assuming that the Regge factorisation holds :

$$\alpha_{I\!P}(0) = 1.108 \pm 0.008(\text{stat}+\text{syst}) + 0.022 - 0.007(\text{model})$$

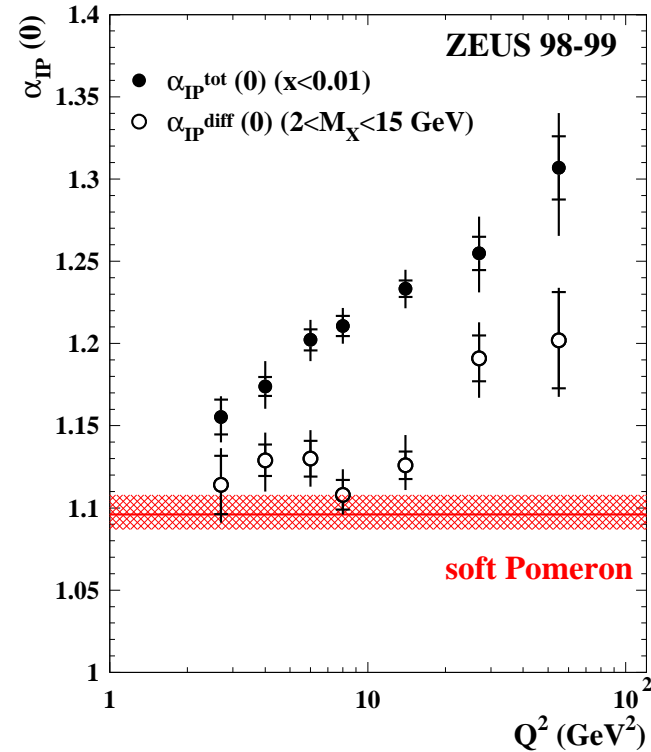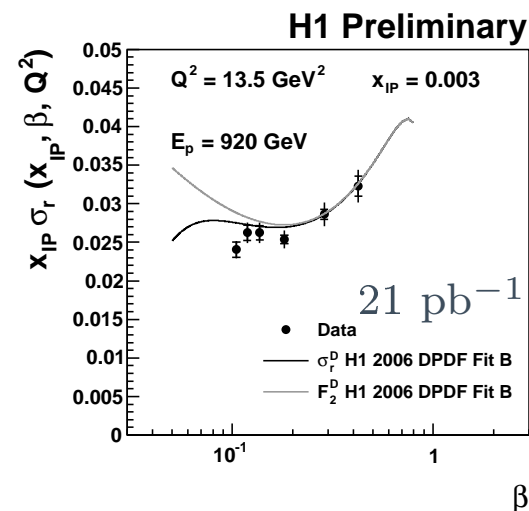# Pomeron intercept

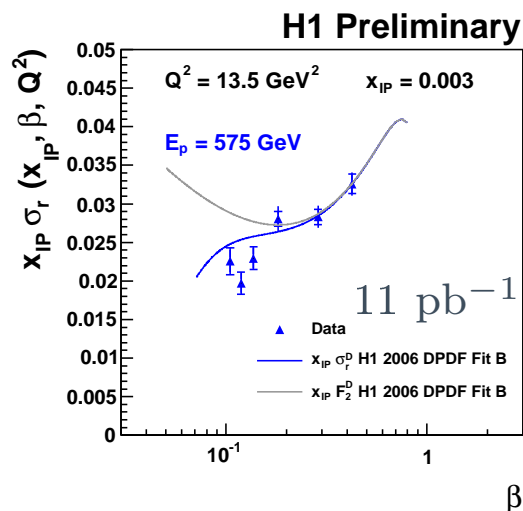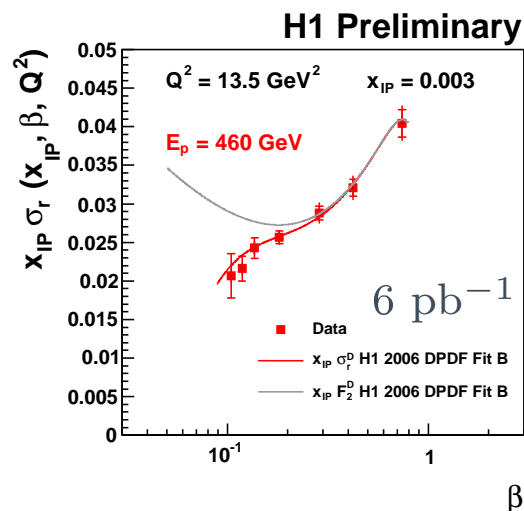Applying the Regge fit in different Q^2 bins:

- confirms with higher precision the lack of strong Q^2 dependence in contrast to non-diffractive DIS.

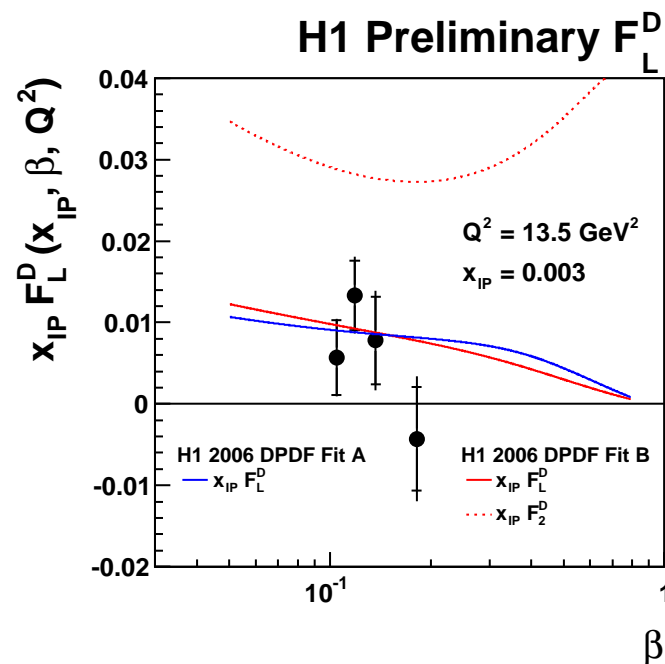- confirms that Regge factorisation holds, i.e. the dominance of non-perturbative effects in the pomeron structure.

First $\mathbf{F}_L^D$ Measurement

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D \qquad\qquad F_L^D \sim \alpha_S \; xg(x)$$

- sensitivity to F_L^D at the highest y

  (i.e. lowest $\beta = \frac{Q^2}{x_{I\!P}} \frac{1}{ys}$)

- to access it, need to vary s
  $\Rightarrow$ HERA ran at reduced p beam energy

- compatible with pQCD prediction
  from DPDF.

Conclusion

- Still many new results from HERA data, more results to come

- Agreement between H1 and ZEUS and among different methods used to extract inclusive diffraction. Better understanding of proton dissociative background.

- Regge factorisation is a good approximation for inclusive diffraction at HERA

- First F_L^D measurement. In agreement with QCD expectations.

- QCD analyse of this data in the next talk...