



Inclusive diffraction at HERA

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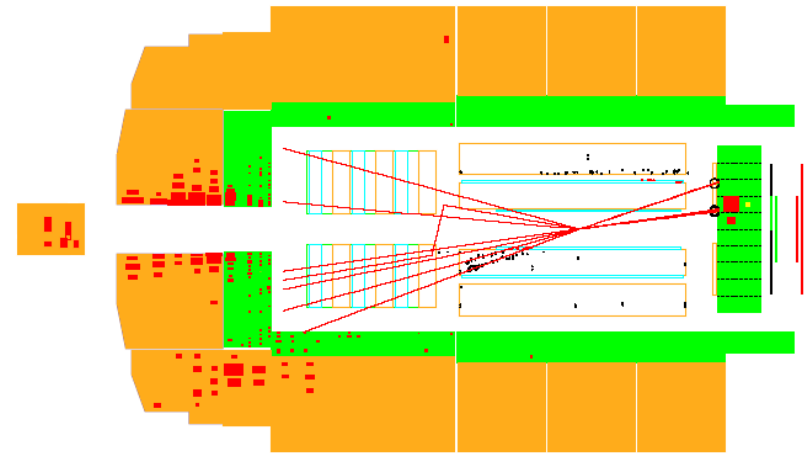
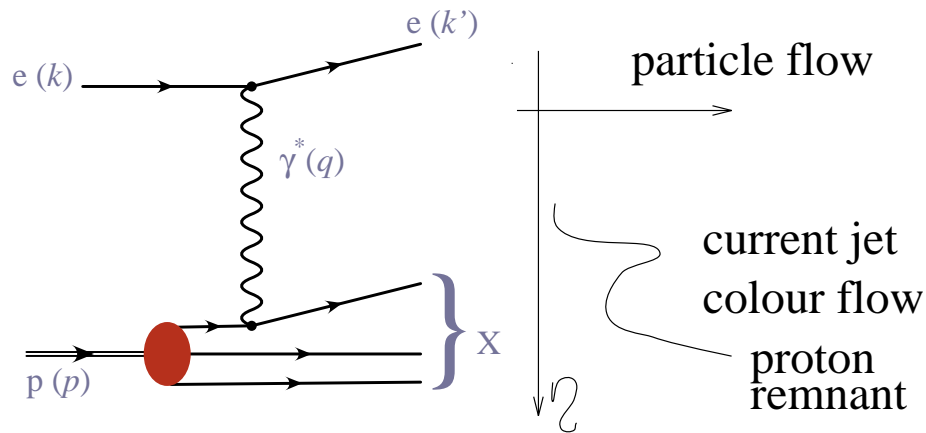
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On behalf of H1 and ZEUS

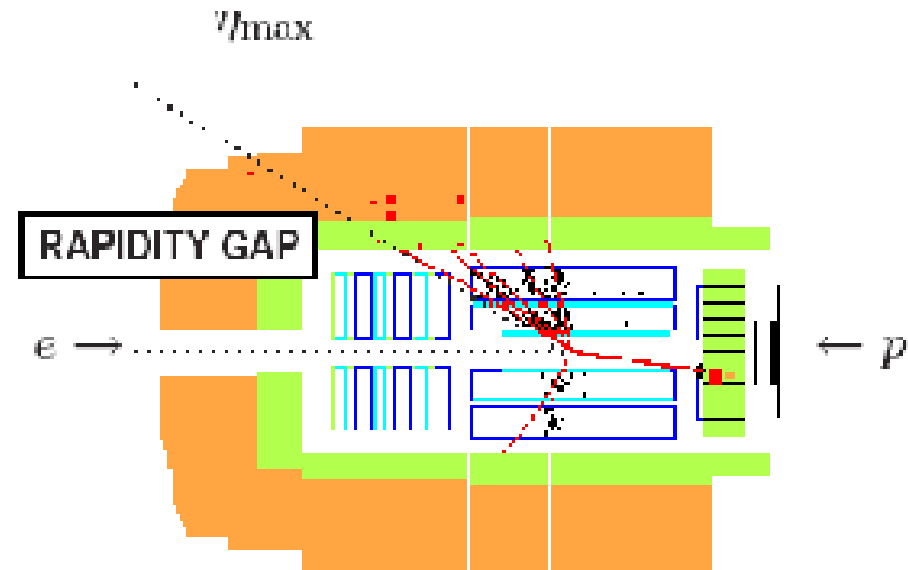
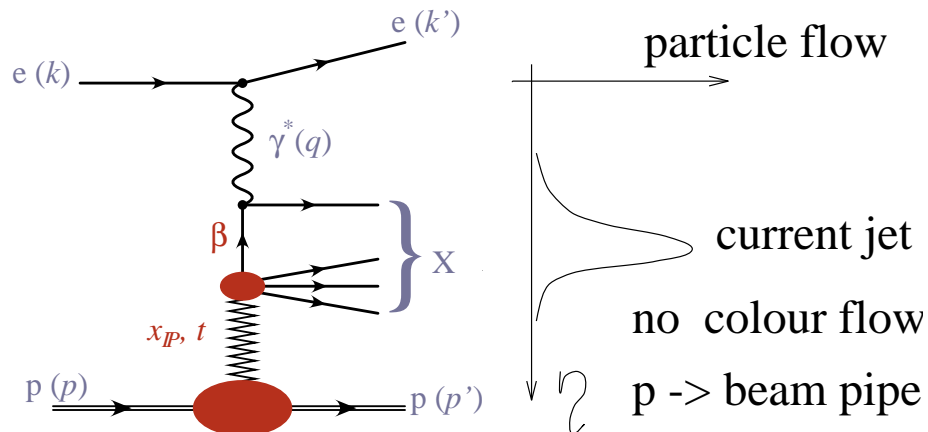
Diffraction 2010 - Otranto - 10-15th of September 2010

Diffractive Scattering

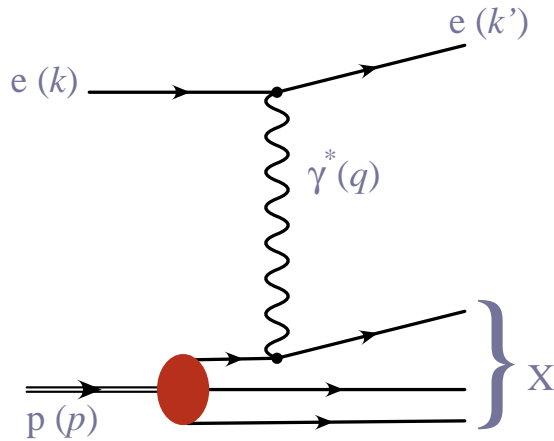
Deep Inelastic Scattering (DIS)



Diffractive Scattering (DDIS)



Cross sections and kinematics



Deep Inelastic Scattering $ep \rightarrow eX$

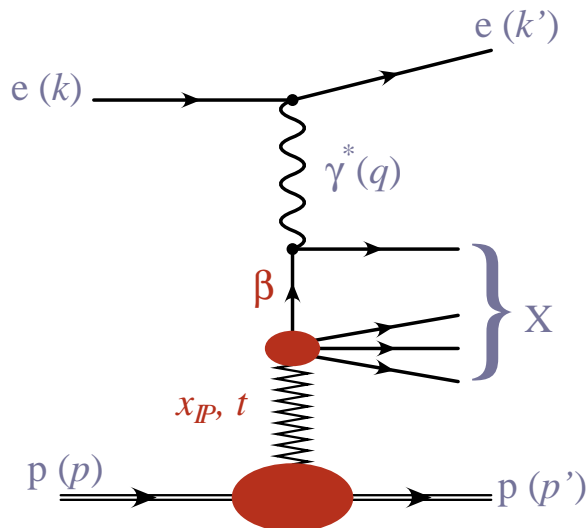
Q^2 $= -q^2$ - virtuality of the exchanged photon

W $\gamma^* - p$ system energy

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

y γ^* inelasticity : $y = Q^2 / s x$

$$\frac{d^2\sigma}{dx dQ^2} = \frac{2\pi\alpha^2}{x Q^4} Y_+ F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2) \quad Y_+ = 1 + (1-y)^2$$



Diffractive Scattering $ep \rightarrow eXp$

x_{IP} fraction of proton's momentum of the colour singlet exchange

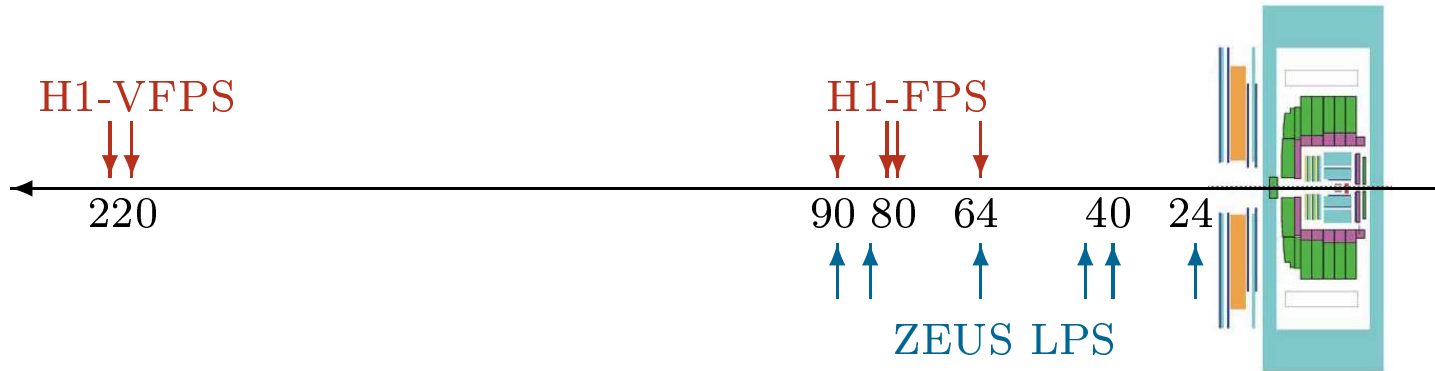
$$x_{IP} \simeq \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

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

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

$$\frac{d^4\sigma^D}{d\beta dQ^2 dx_{IP} dt} = \frac{2\pi\alpha^2}{\beta Q^4} Y_+ F_2^{D(4)}(\beta, Q^2, x_{IP}, t) - \frac{y^2}{Y_+} F_L^{D(4)}$$

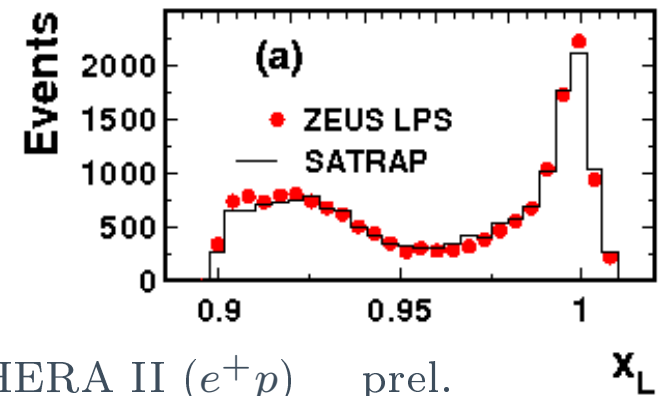
Roman Pot Method



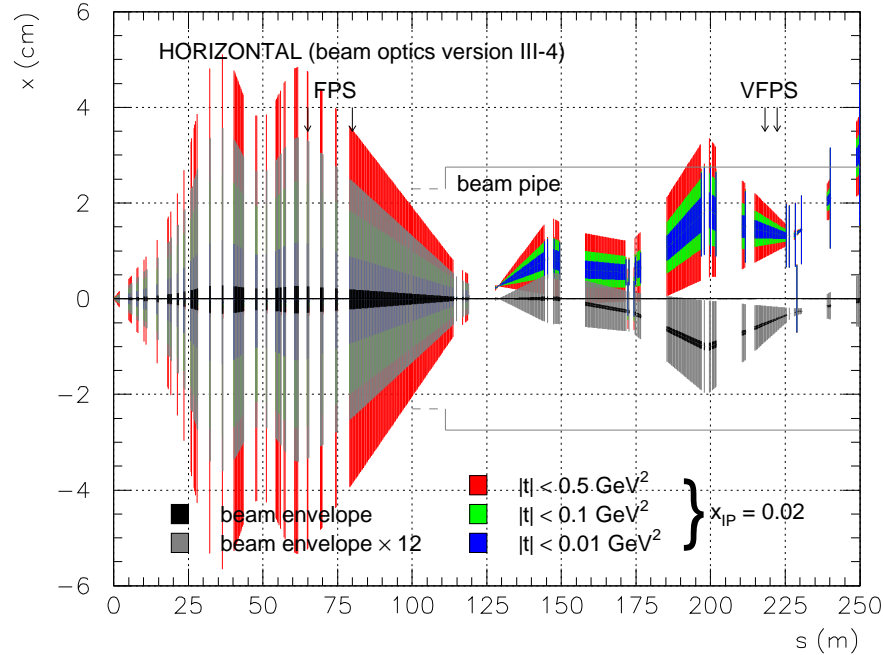
- Purpose: direct measurement of the scattered proton: giving t and $x_{\mathcal{P}}$ measurements
- Roman Pot technology
- no p-diss. background
- low statistics due to Roman Pot detector acceptance

Data shown in this talk:

- New: H1 VFPS	$0.009 < x_{\mathcal{P}} < 0.03$	87 pb^{-1}	HERA II (e^+p)	prel.
- New: H1 FPS	$x_{\mathcal{P}} < 0.1$	156 pb^{-1}	HERA II	prel.
- New: ZEUS LPS	$x_{\mathcal{P}} < 0.1$	33 pb^{-1}	HERA I	NPB 816 (2009)



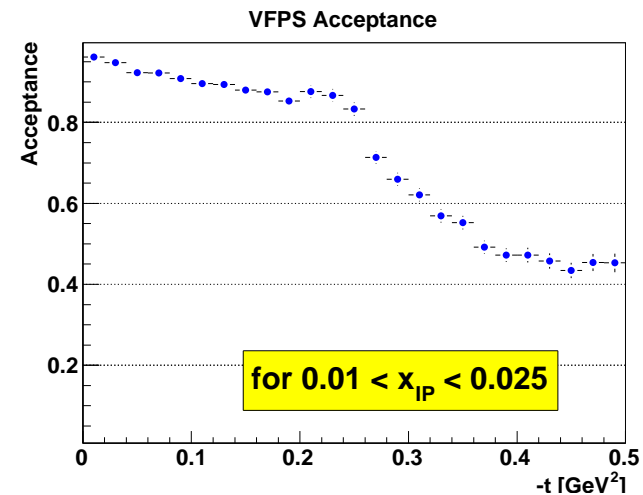
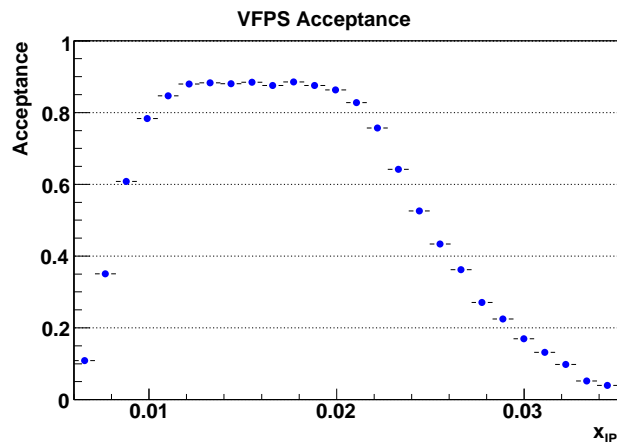
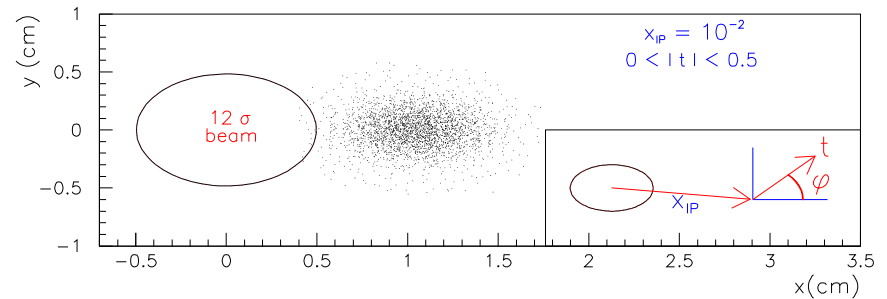
The H1 Very Forward Proton Spectrometer



Goal: measure the scattered proton at HERA II with large acceptance at low x_P and down to t_{min}

⇒ Best location is 220 m in the horizontal plane

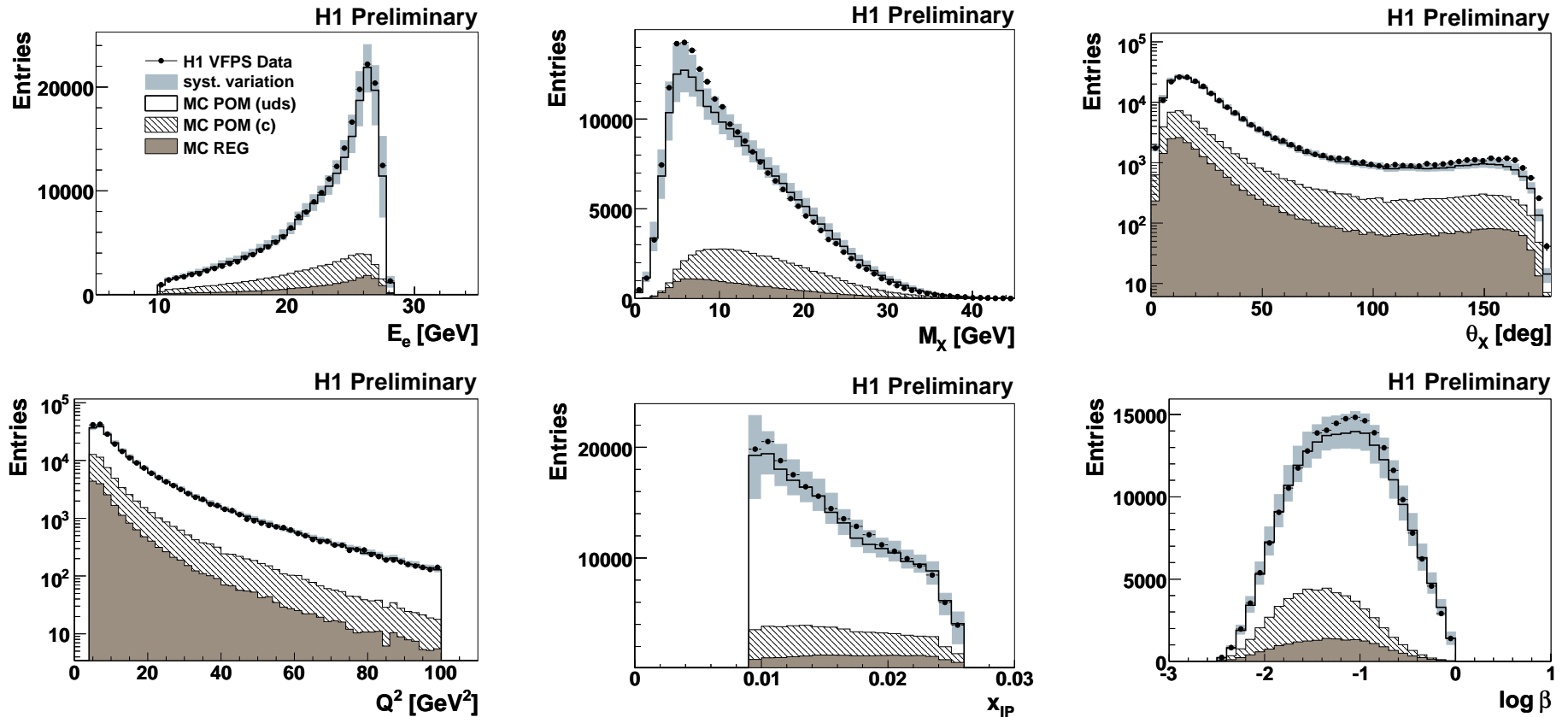
- Scintillating fiber detectors (similar to FPS)



VFPS

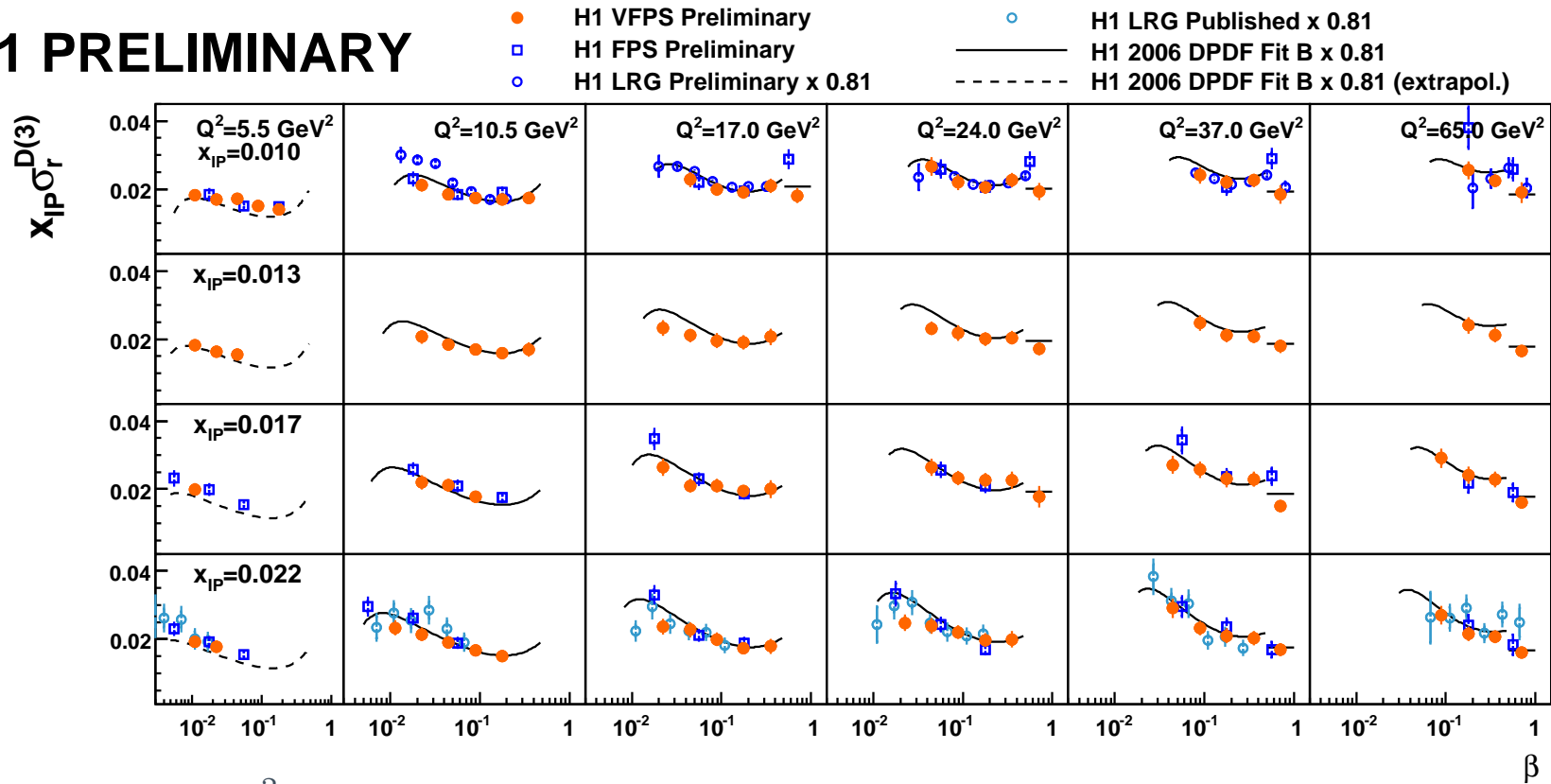
H1 data: 2006 and 2007 (e^+p , $\sqrt{s} = 319$ GeV) $\mathcal{L} : 87.4 pb^{-1}$

MC:RAPGAP31 with H1 2006 DPDF Fit B (scaled to Mp)



- no proton dissociation background (VFPS is at 220m)
- overlapping background (DIS + gas) below 1%
- improved resolution in x_{IP} and β

H1 PRELIMINARY



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

$$4.5 < Q^2 < 100 \text{ GeV}^2$$

$$0.008 < \beta < 1$$

$$0.009 < x_{IP} < 0.026$$

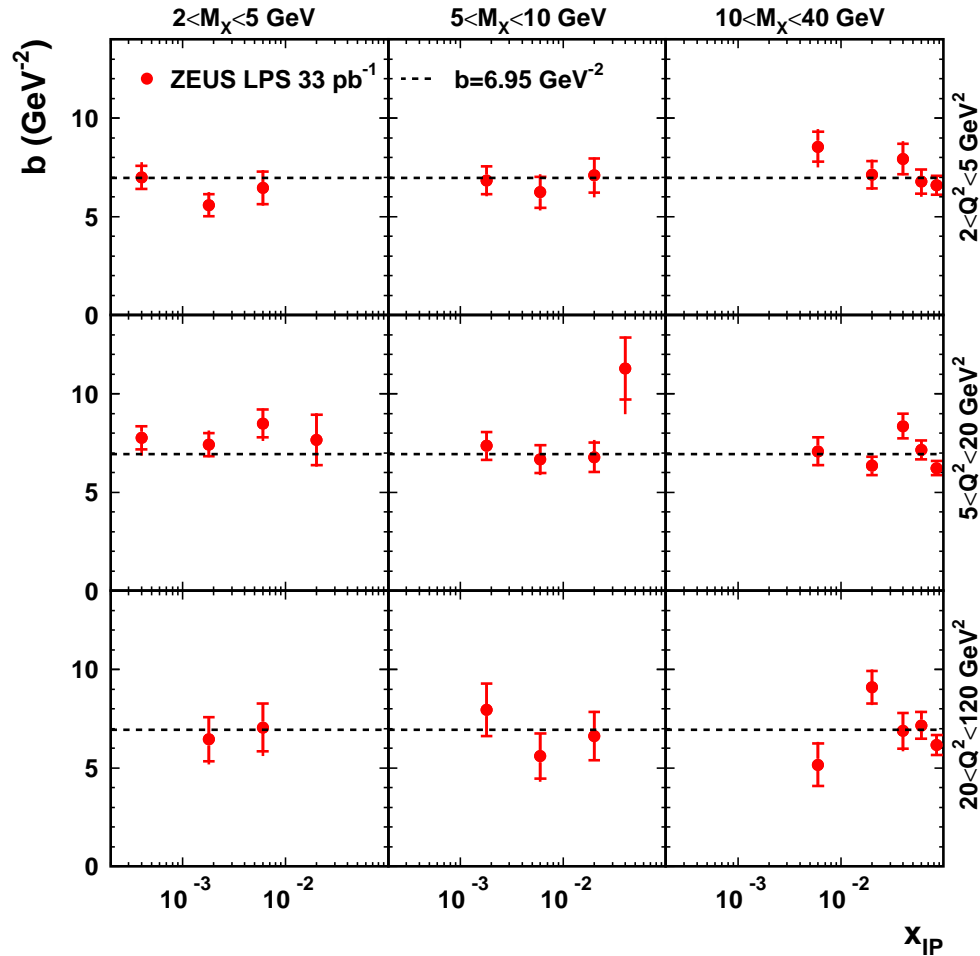
- good agreement with other measurements
- higher precision in $x_{IP} \rightarrow$ thinner binning
- improved normalisation uncertainty (5%)
- very good agreement with H1 2006 Fit B

$$\text{ratio VFPS / FPS} = 0.96 \pm 0.02 \text{ (stat)} \pm 0.11 \text{ (syst)} \pm 0.08 \text{ (norm)}$$

t dependence

ZEUS-LPS data

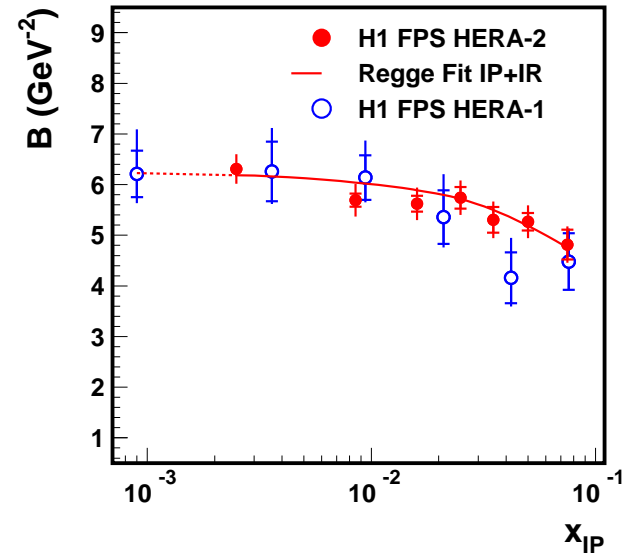
ZEUS



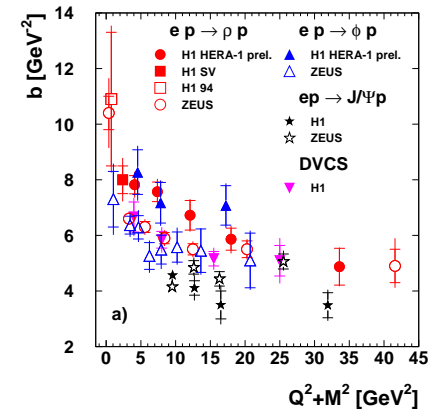
$$\Rightarrow \frac{d^4 \sigma^D}{d\beta dQ^2 dx_P dt} = \frac{d^3 \sigma^D}{d\beta dQ^2 dx_P} e^{-b|t|}$$

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

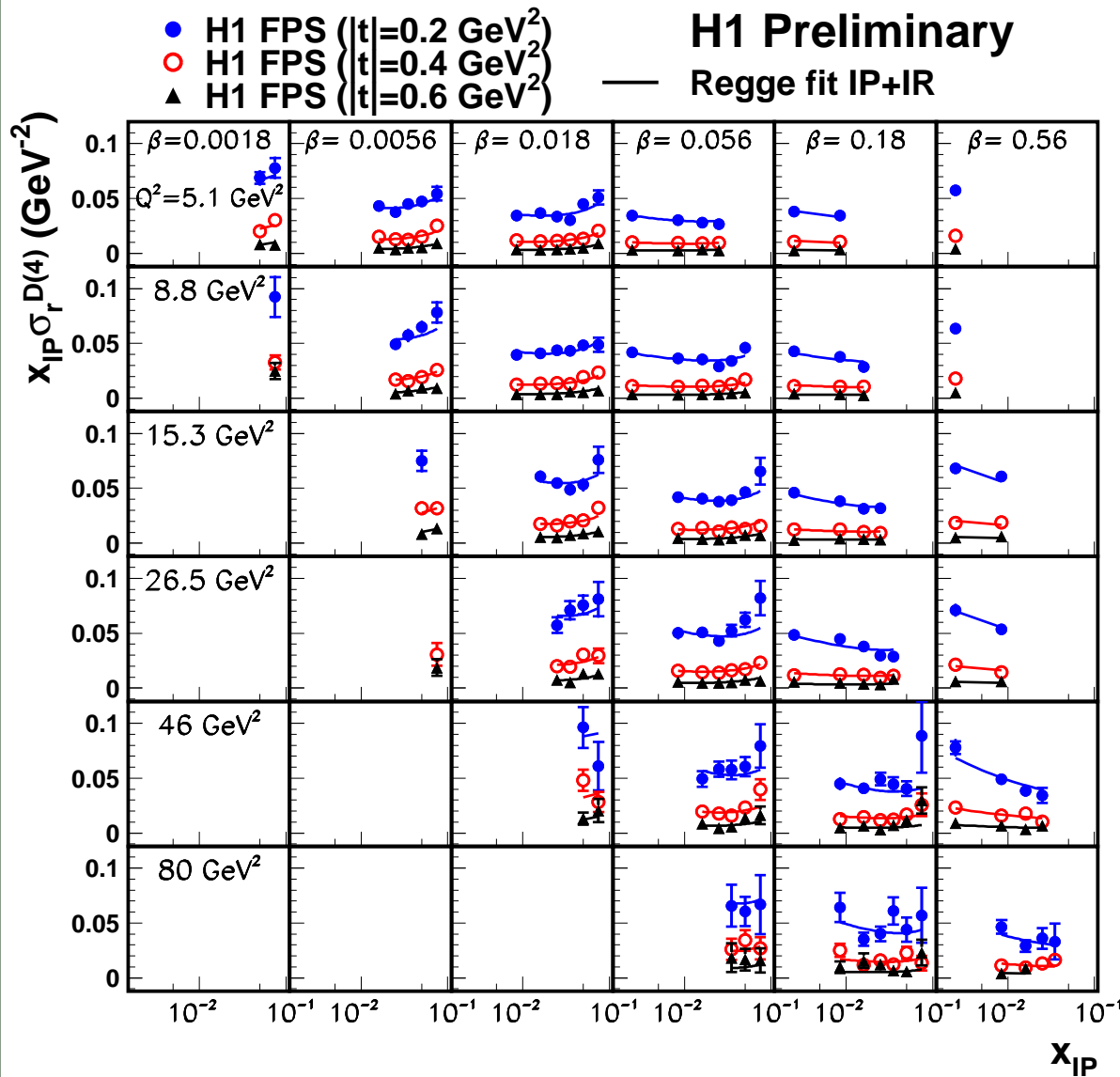
H1 Preliminary



- No dependence observed in: Q^2, M_X



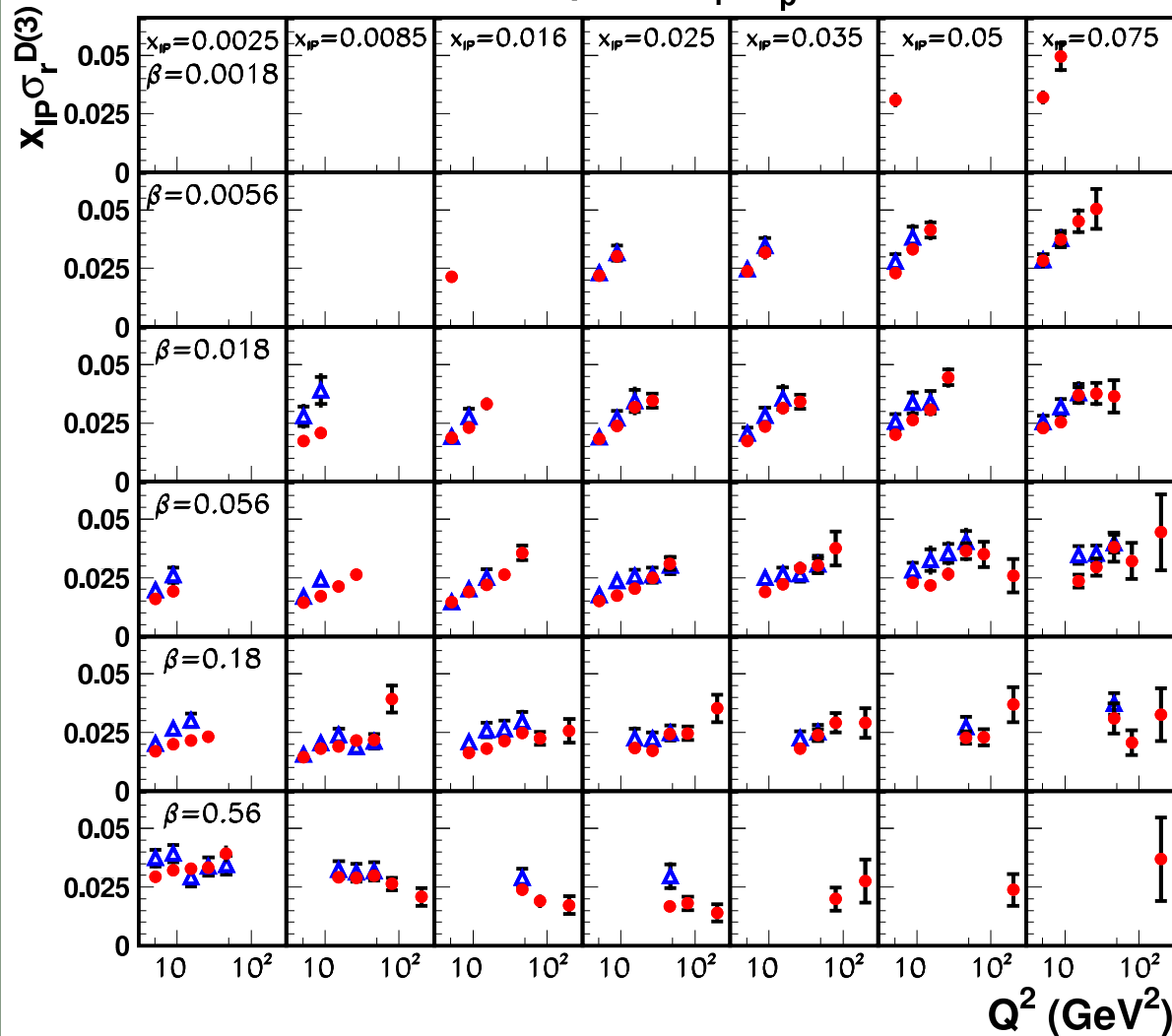
x_P dependence



- first measurement in three t bins
- syst. uncertainty 8%, norm. uncertainty 4.3%
- Low x_P : σ_r^D falls with x_P faster than $1/x_P$
- High x_P : σ_r^D flattens or increases with x_P (Reggeon exchange)

Q^2 dependence

- H1 FPS HERA-2 (prel.), $M_\gamma=M_p$
- ▲ ZEUS LPS (interpol.), $M_\gamma=M_p$

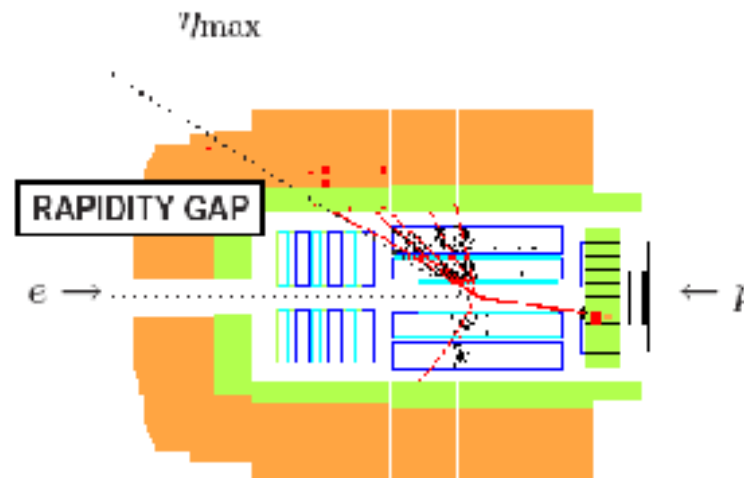


- after correcting for the photon propagator, the cross section **increases** (positive scaling violation) with Q^2 for $\beta \lesssim 0.2$

- Reasonable agreement between H1-FPS and ZEUS-LPS

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

Large Rapidity Gap Method

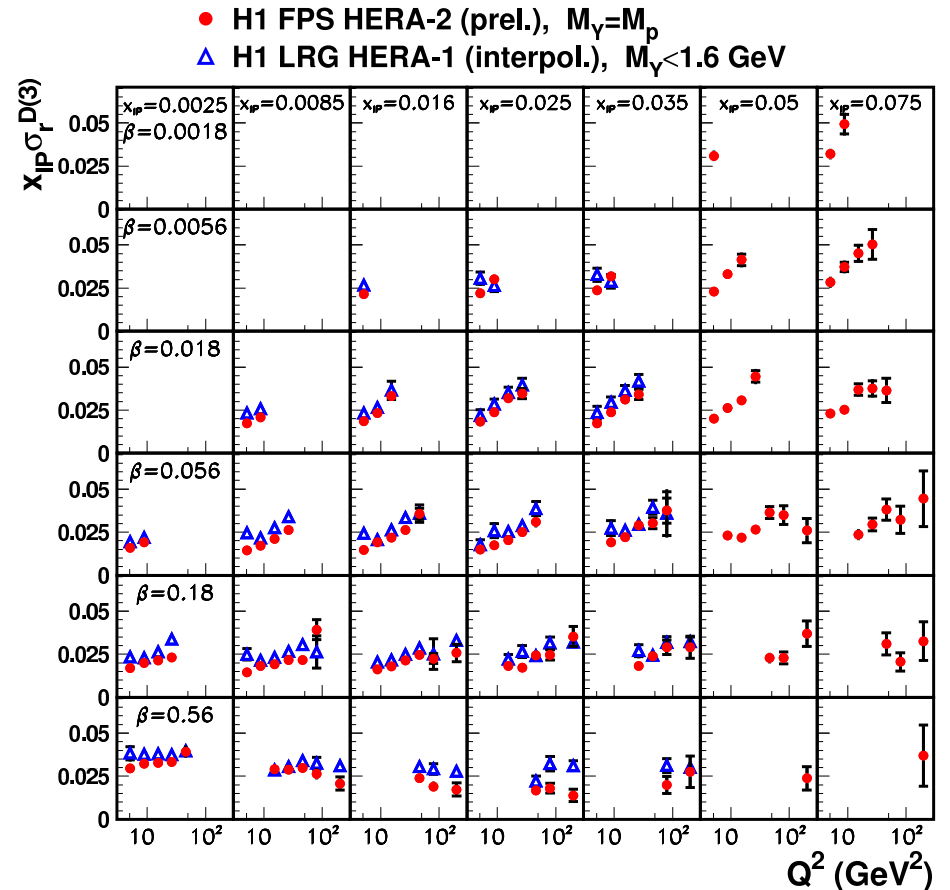
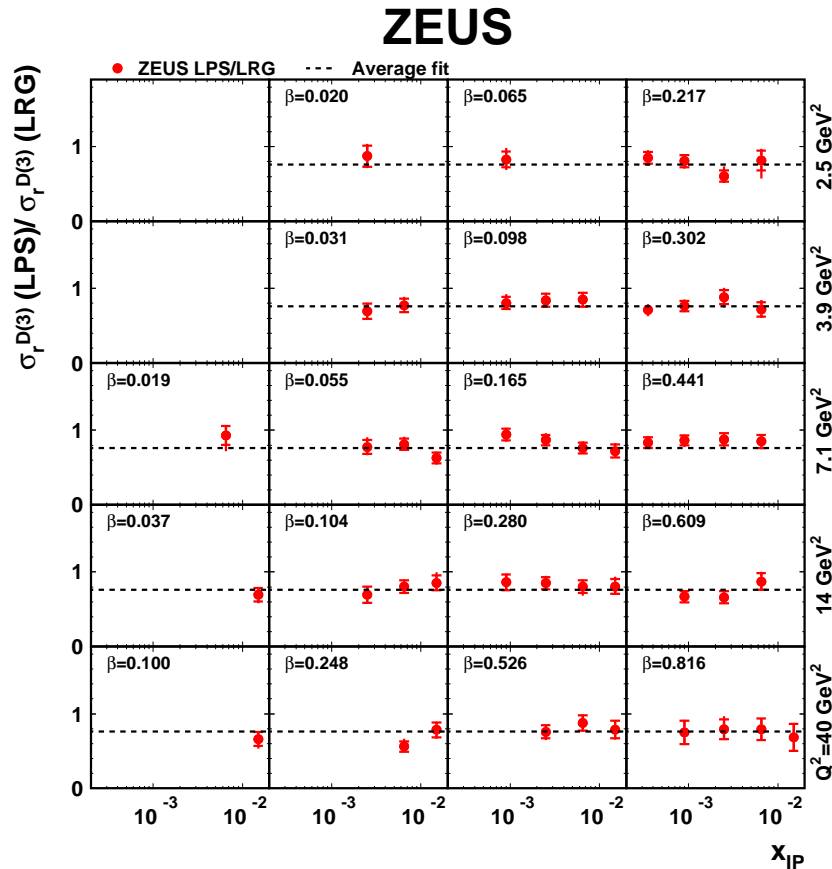


- Require a large rapidity gap adjacent to the outgoing (untagged) proton
- Escaping scattered proton \Rightarrow cross section **integrated over t**
- **Large statistics** (no Roman Pot det. acceptance limitation), **large range** in $Q^2, x_{\mathbb{P}}, \beta$
- Contamination of p-dissociation background: $ep \rightarrow eXY$ with $M_Y \ll W$

Data shown in this talk:

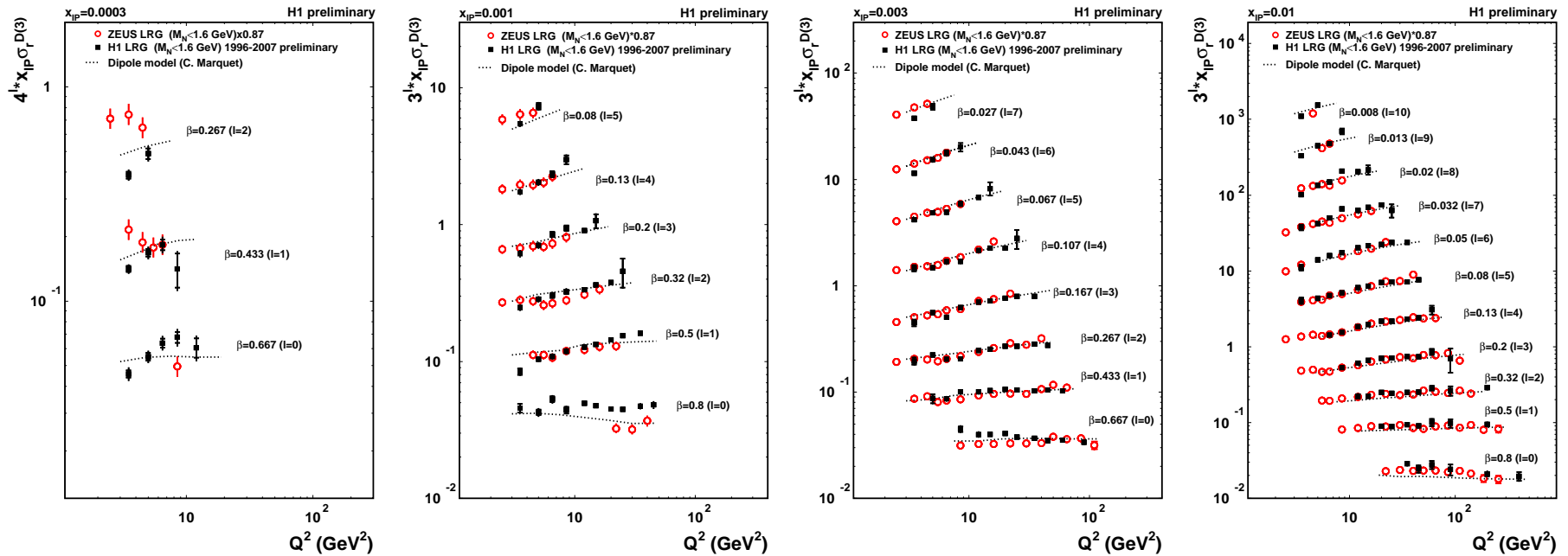
- New: H1 LRG	$x_{\mathbb{P}} < 0.02$	$M_Y < 1.6 \text{ GeV}$	HERA I+II - 370 pb⁻¹	prel.
- New: ZEUS LRG	$x_{\mathbb{P}} < 0.02$	$M_Y = m_p$	HERA I - 62 pb ⁻¹	NPB 816 (2009)
- H1 LRG	$x_{\mathbb{P}} < 0.03$	$M_Y < 1.6 \text{ GeV}$	HERA I - 62 pb ⁻¹	EPJ C48 (2006)

LRG vs Roman Pots



- ZEUS LPS/LRG: independent of Q^2, x_{IP}, β
 \Rightarrow p-diss. = $24 \pm 1(\text{stat}) + 2 - 3(\text{syst}) + 5 - 8(\text{norm})\%$
- H1-FPS vs H1-LRG: Reasonable agreement in shape
 normalisation difference due to different M_Y cut (normalisation uncertainty of 8.5%).
 \Rightarrow p-diss. = $18 \pm 1(\text{stat}) \pm 6(\text{syst}) + 10(\text{norm})\%$

LRG: H1/ZEUS

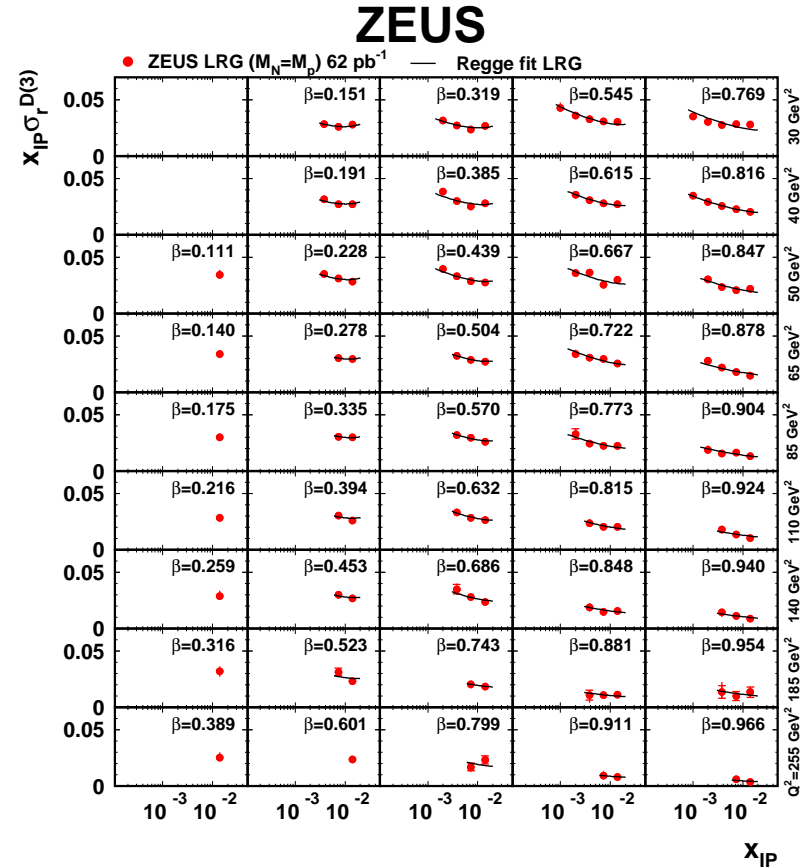
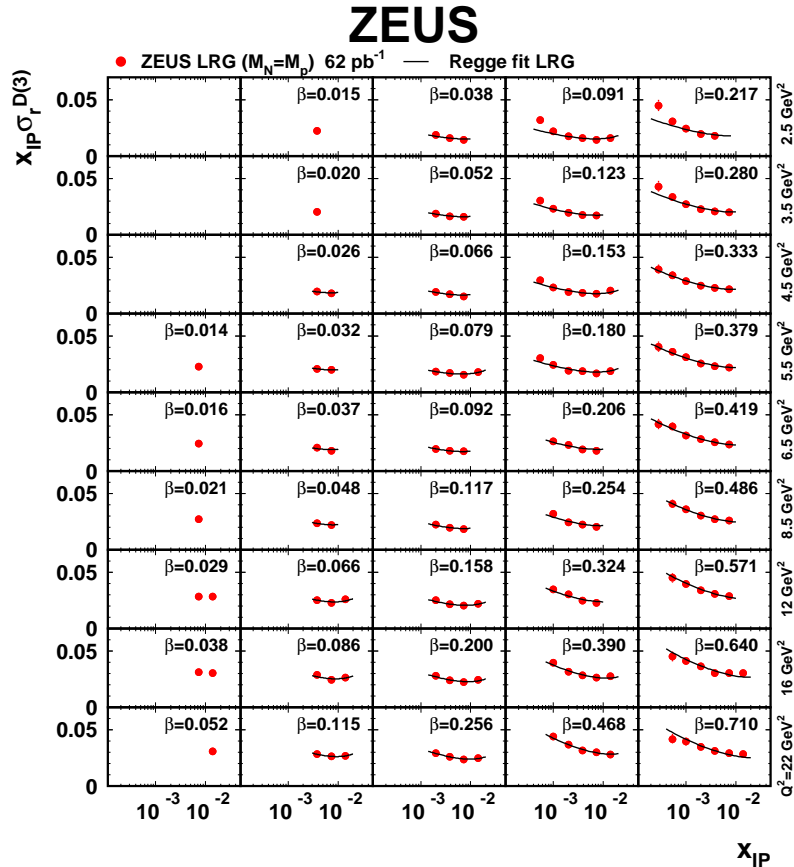


- remaining normalisation difference of 13% (global fit) covered by uncertainty on p-diss. correction (8%) and relative normalisation uncertainty (7%)
- New H1-LRG: few % point-to-point precision over wide kinematic range
- **good shape agreement** except at lowest x_{IP}
- note: here ZEUS points corrected to $M_Y < 1.6$ GeV.
- **QCD** fit on these data → see talk of Ada Solano.

Regge Fit to LRG data

$$F_2^{D(4)}(\beta, Q^2, x_P, t) = f_{P/p}(x_P, t) F_2^P(\beta, Q^2) + n_R f_{R/p}(x_P, t) F_2^R(\beta, Q^2)$$

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

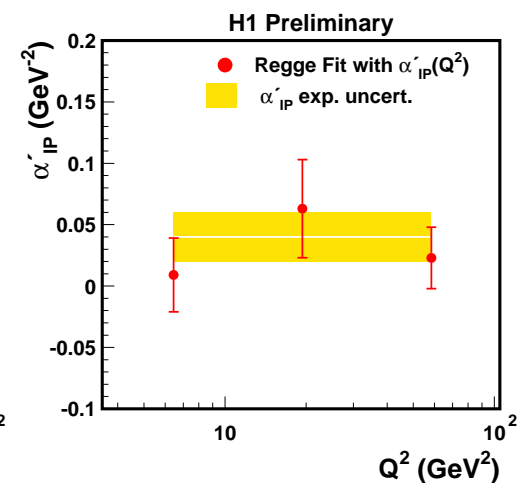
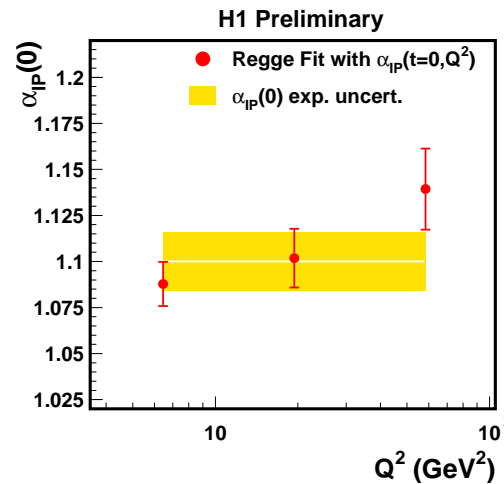
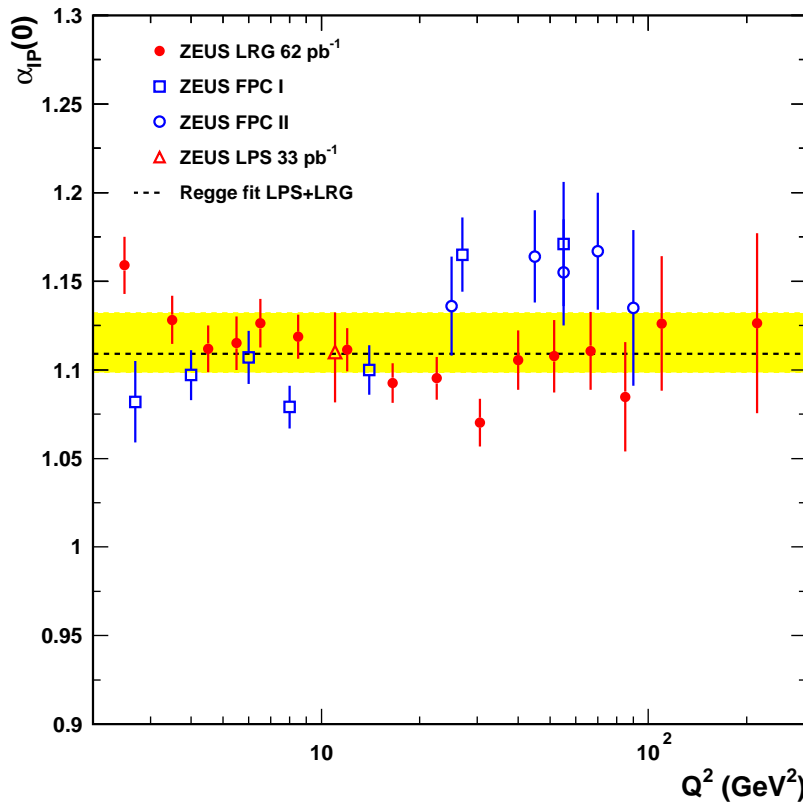


- Assuming that the Regge factorisation holds :
 $\alpha_P(0) = 1.108 \pm 0.008(\text{stat+syst}) + 0.022 - 0.007(\text{model})$

Pomeron intercept

Applying the Regge fit in different Q^2 bins:

ZEUS



e.g. from H1 FPS - HERA II data:

$$\alpha_{IP}(0) = 1.10 \pm 0.02(\text{exp}) \pm 0.03(\text{model})$$

- 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.

Conclusion

- Still many new results from HERA data, more results to come
- with improved statistical, systematic and normalisation uncertainties
- 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
- F_L^D measurement and QCD analyse of this data in the next talks...

Summary Plot

H1 PRELIMINARY

- H1 VFPS Preliminary
- H1 FPS Preliminary
- H1 LRG Preliminary x 0.81
- H1 LRG Published x 0.81
- H1 2006 DPDF Fit B x 0.81
- - - H1 2006 DPDF Fit B x 0.81 (extrapol.)

