Inclusive diffraction at HERA

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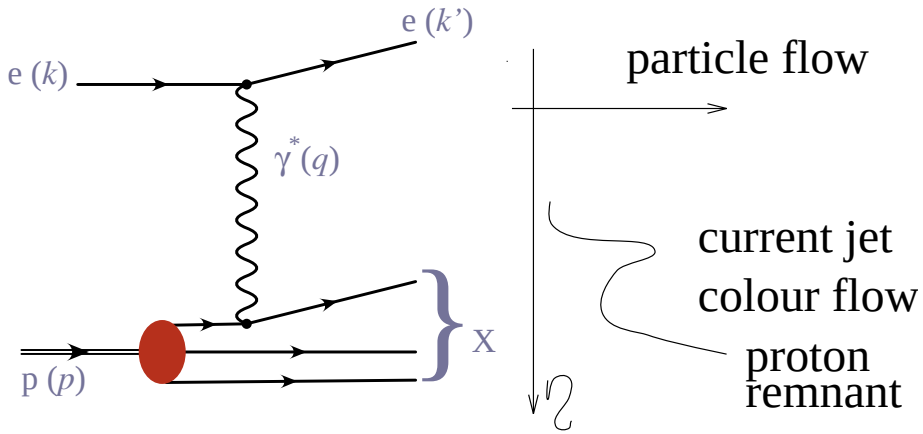
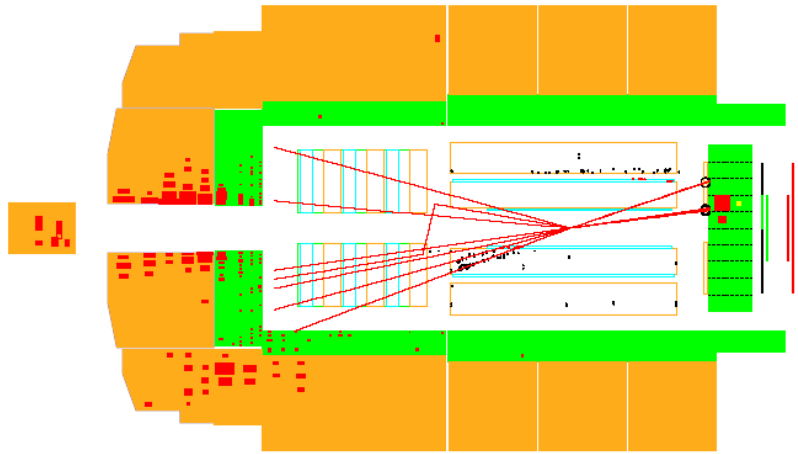
On behalf of H1 and ZEUS

Diffraction 2010 - Otranto - 10-15$^{\text{th}}$ of September 2010

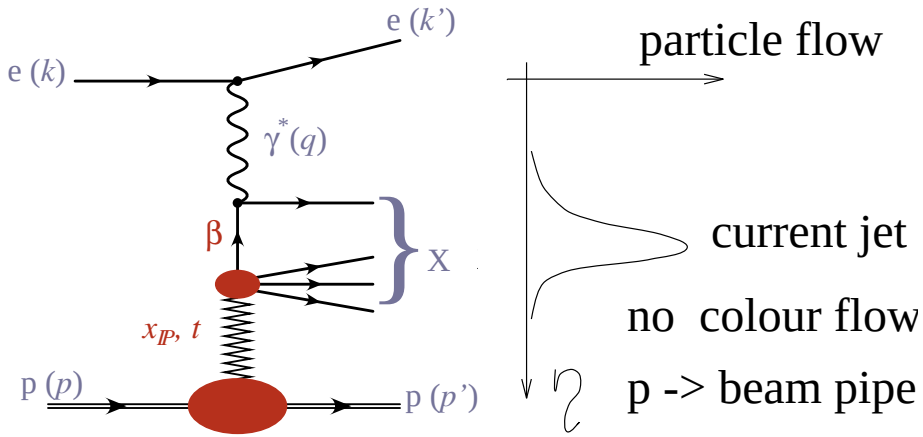
Diffractive Scattering

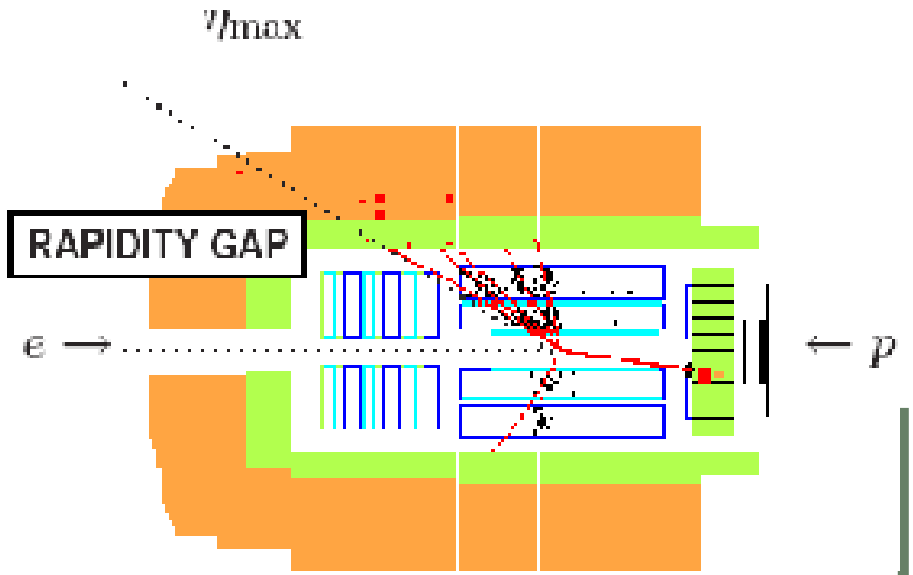
Deep Inelastic Scattering (DIS)



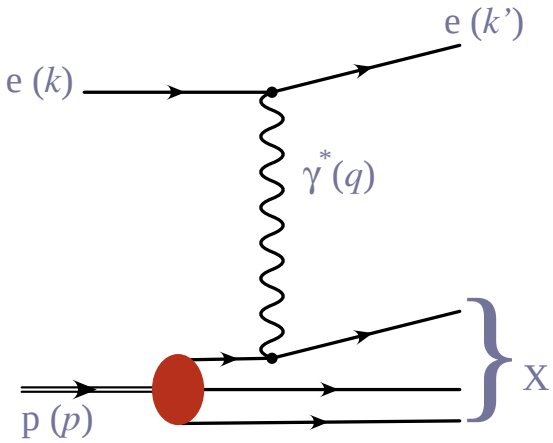


Diffractive Scattering (DDIS)





Cross sections and kinematics



Deep Inelastic Scattering $ep \to eX$

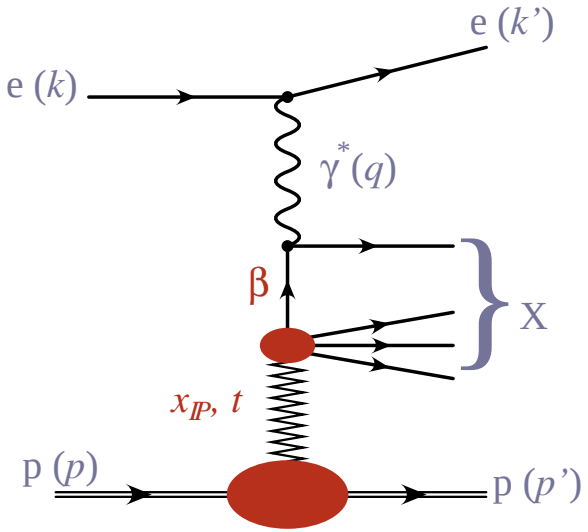
Q^2 $= -q^2$ - virtuality of the exchanged photon

W $\gamma^* - p$ system energy

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

y γ^* inelasticity : $y = Q^2/s\,x$

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



Diffractive Scattering $ep \to eXp$

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

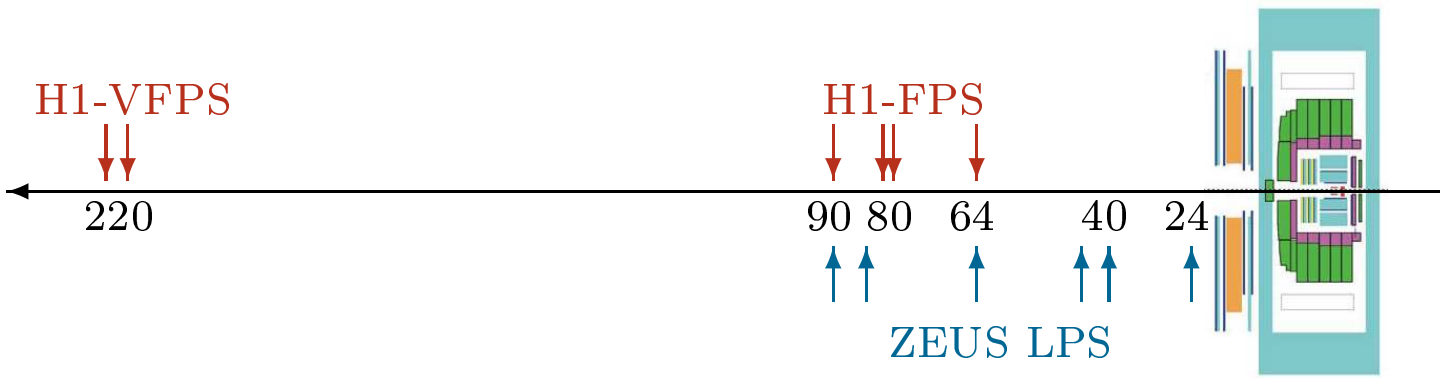
$x_{I\!P} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$

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

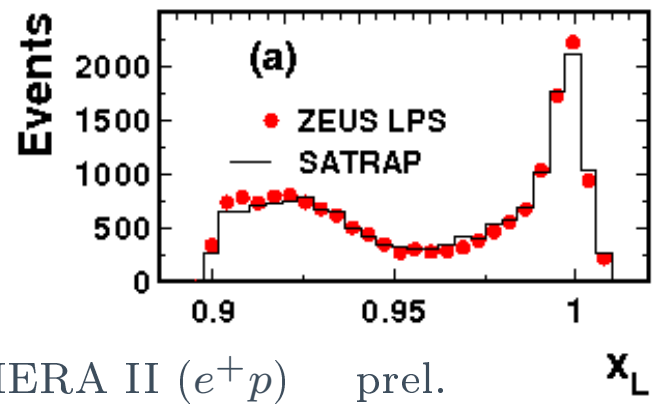
t $= (p-p')^2$, 4-momentum squared at the p vertex

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

Roman Pot Method



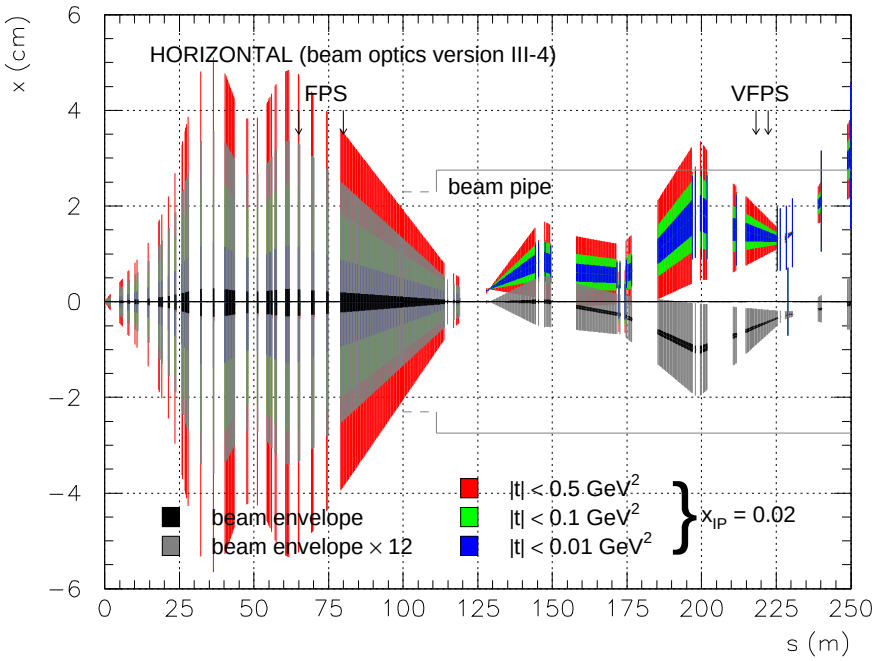
- Purpose: direct measurement of the scattered proton: giving t and $x_{I\!P}$ measurements
- Roman Pot technology
- no p-diss. background
- low statistics due to Roman Pot detector acceptance



Data shown in this talk:

- New: H1 VFPS	$0.009 < x_{I\!P} < 0.03$	87 pb^{-1}	HERA II (e^+p)	prel.
- 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)

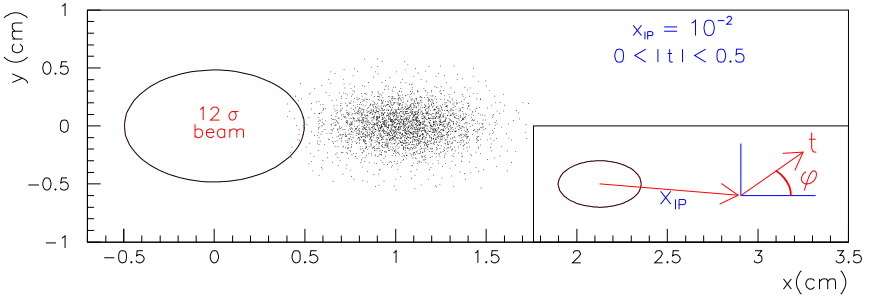
The H1 Very Forward Proton Spectrometer

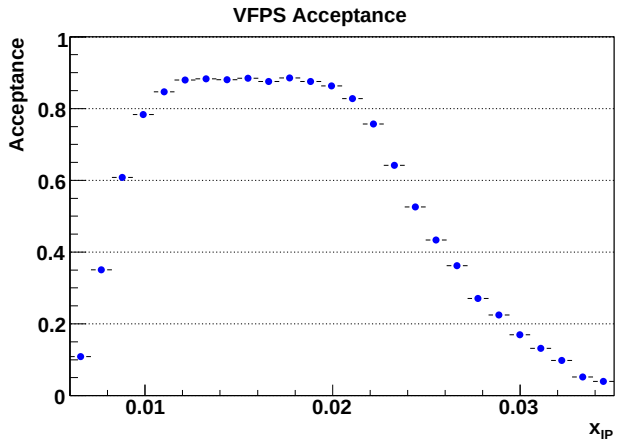


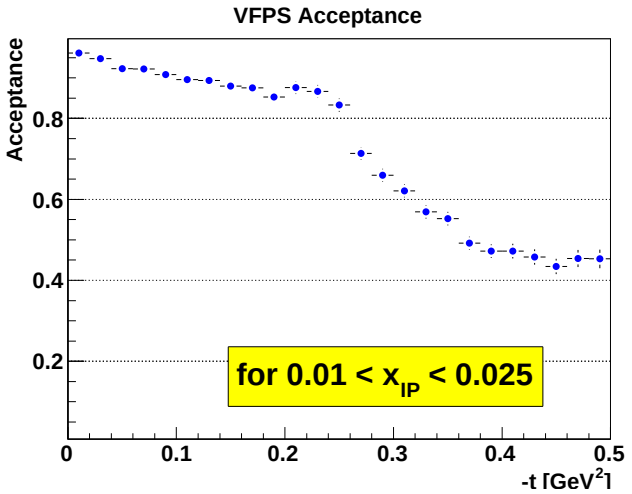
Goal: measure the scattered proton at HERA II with large acceptance at low $x_{I\!P}$ and down to t_{min}

$\Rightarrow$ Best location is 220 m in the horizontal plane

- Scintillating fiber detectors (similar to FPS)



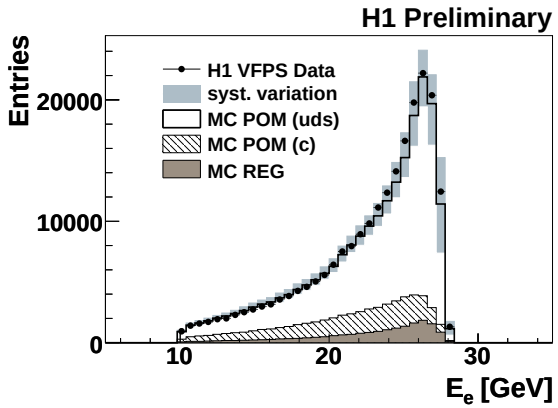


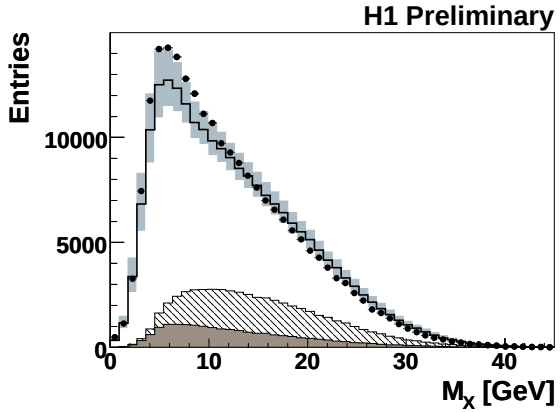


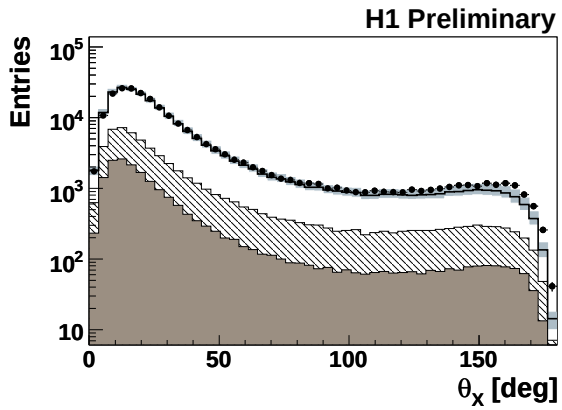
VFPS

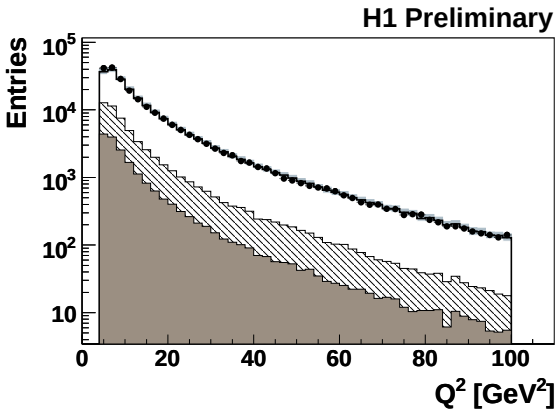
H1 data: 2006 and 2007 (e^+p , $\sqrt{s} = 319$ GeV) $\mathcal{L} : 87.4pb^{-1}$

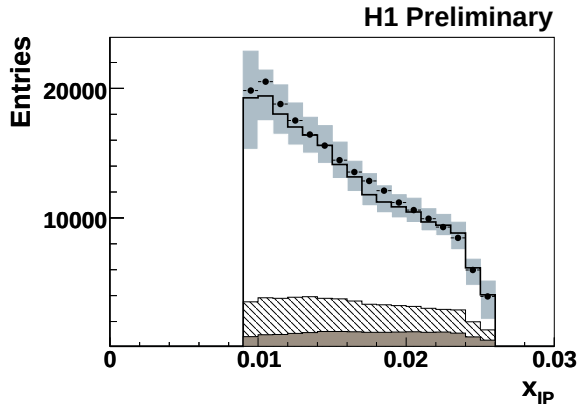
MC:RAPGAP31 with H1 2006 DPDF Fit B (scaled to Mp)

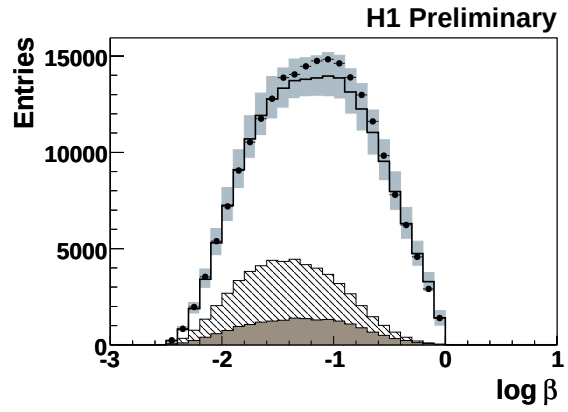






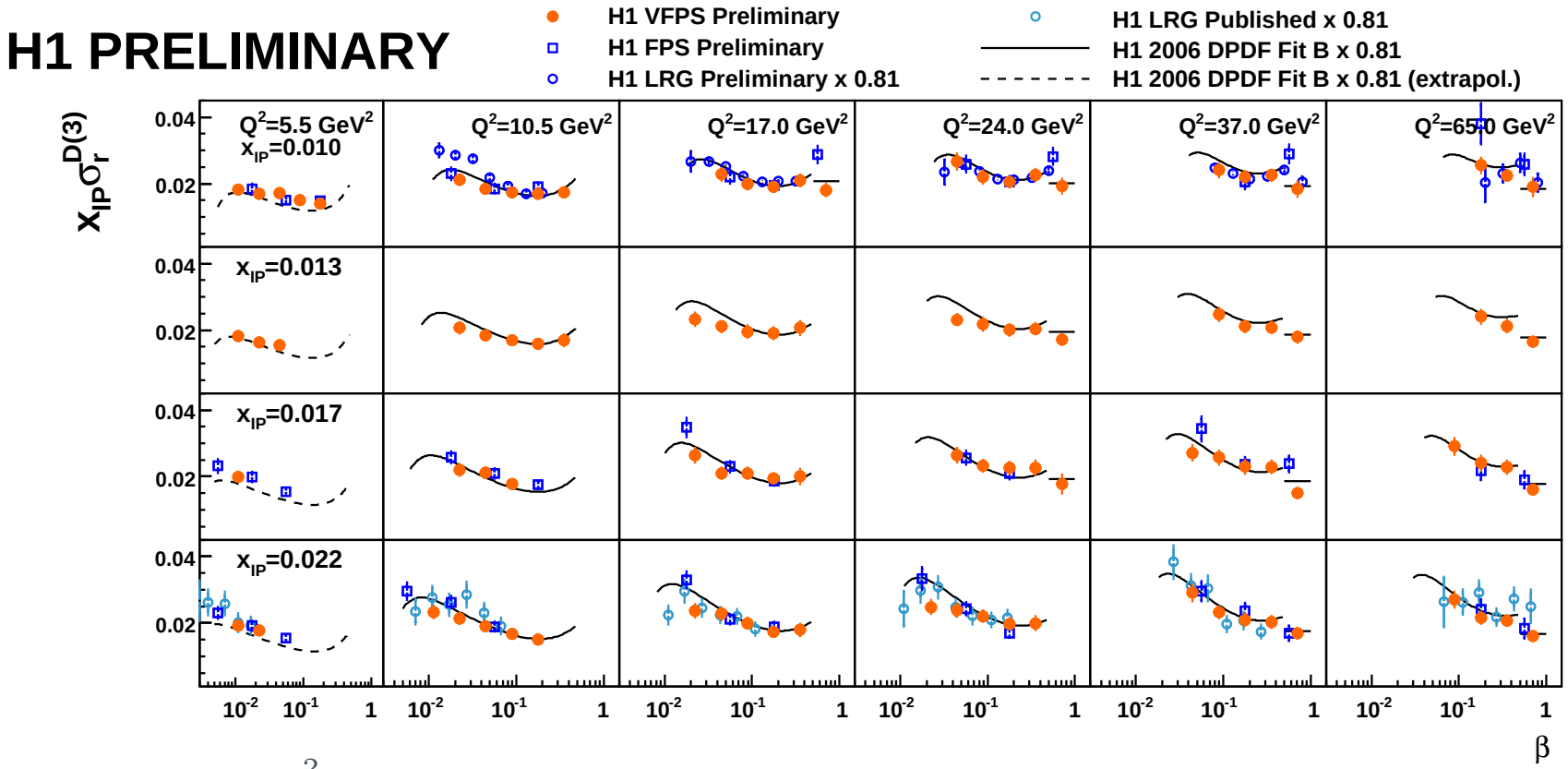






- no proton dissociation background (VFPS is at 220m)
- overlapping background (DIS + gas) below 1%
- improved resolution in $x_{I\!P}$ and β

VFPS $F_2^{D(3)}$



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

$4.5 < Q^2 < 100$ GeV^2

$0.008 < \beta < 1$

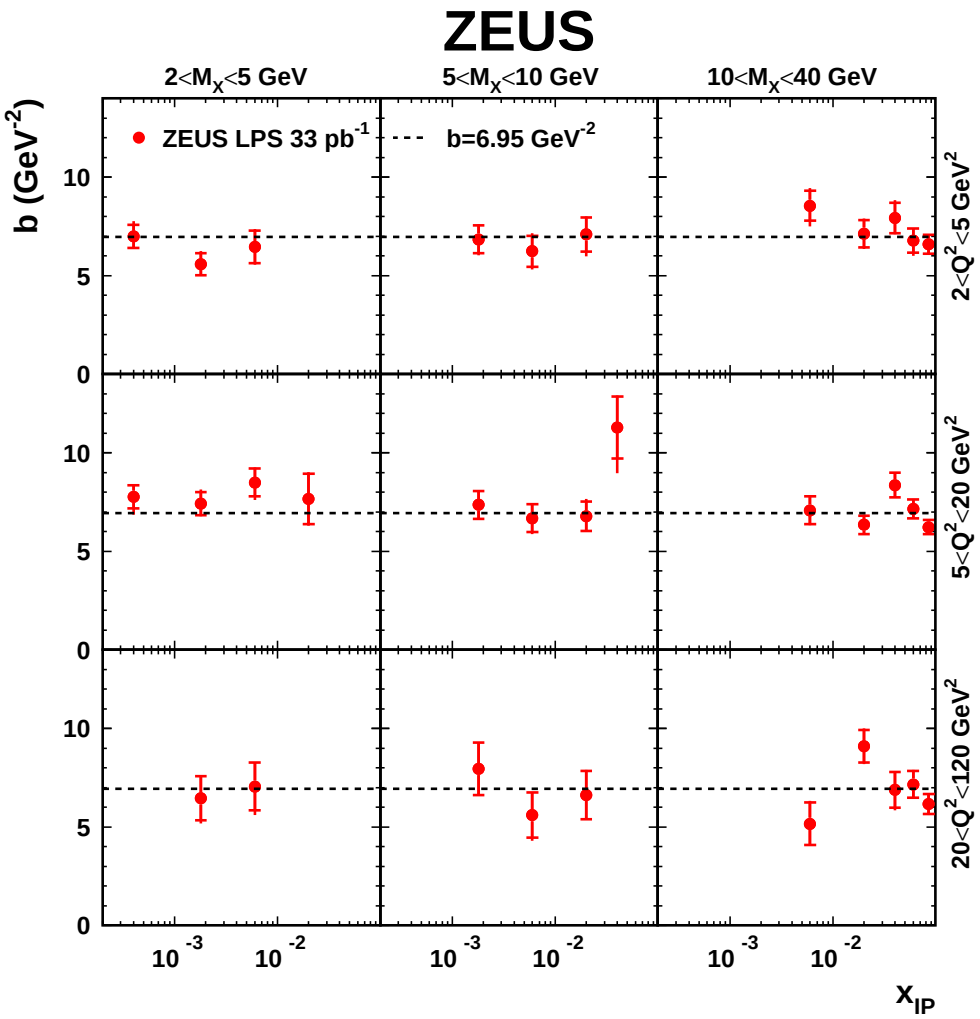
$0.009 < x_{I\!P} < 0.026$

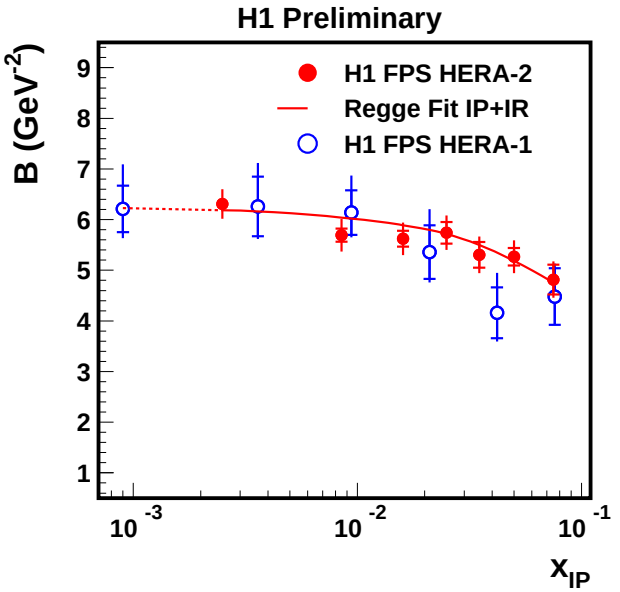
- good agreement with other measurements
- higher precision in $x_{I\!P}$ → thinner binning
- improved normalisation uncertainty (5%)
- very good agreement with H1 2006 Fit B

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

t dependence

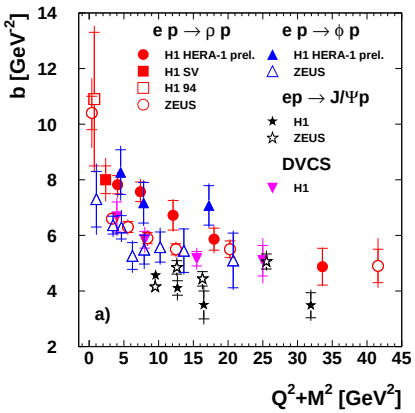
ZEUS-LPS data





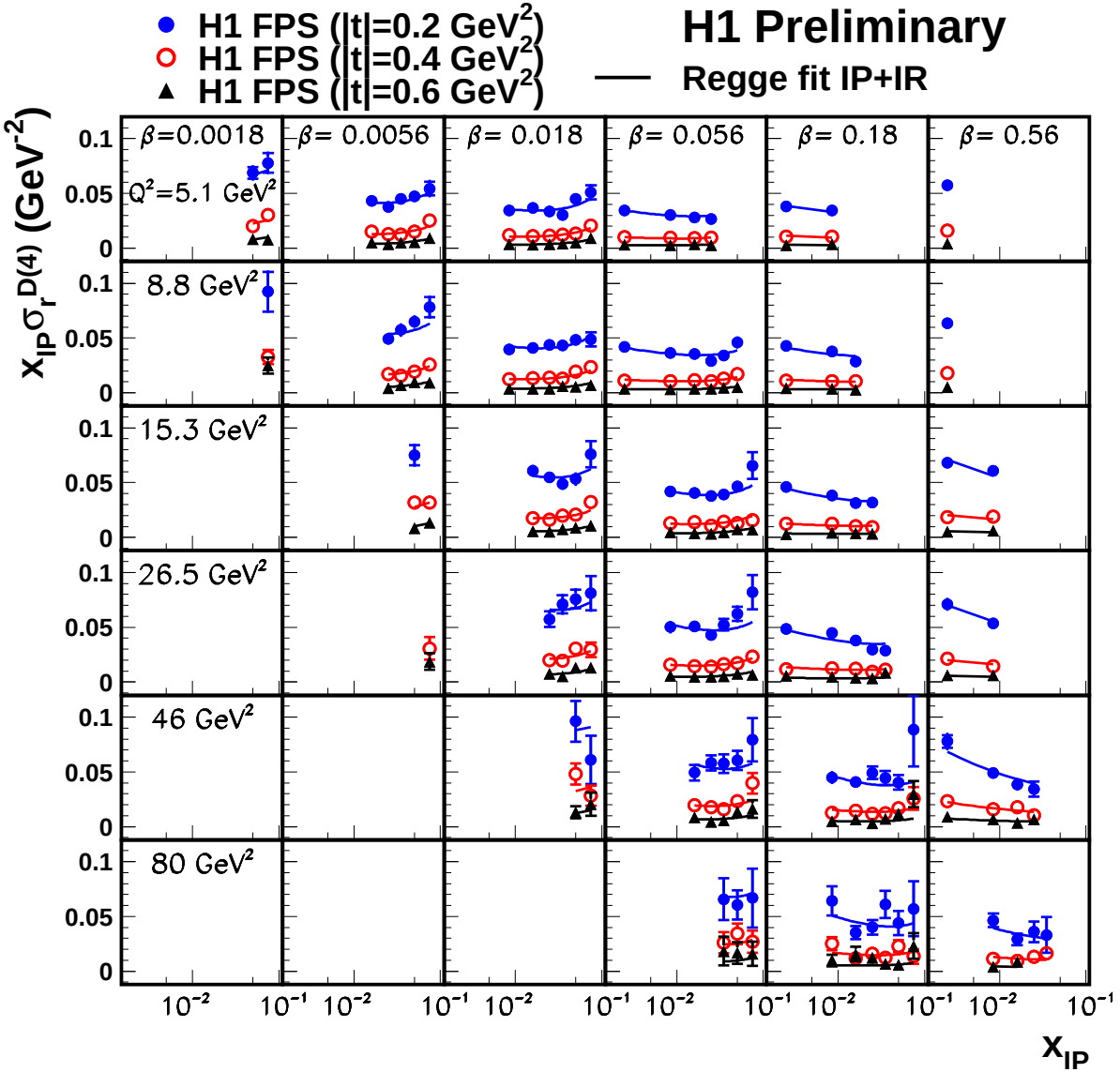
- No dependence observed in: Q^2, M_X

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



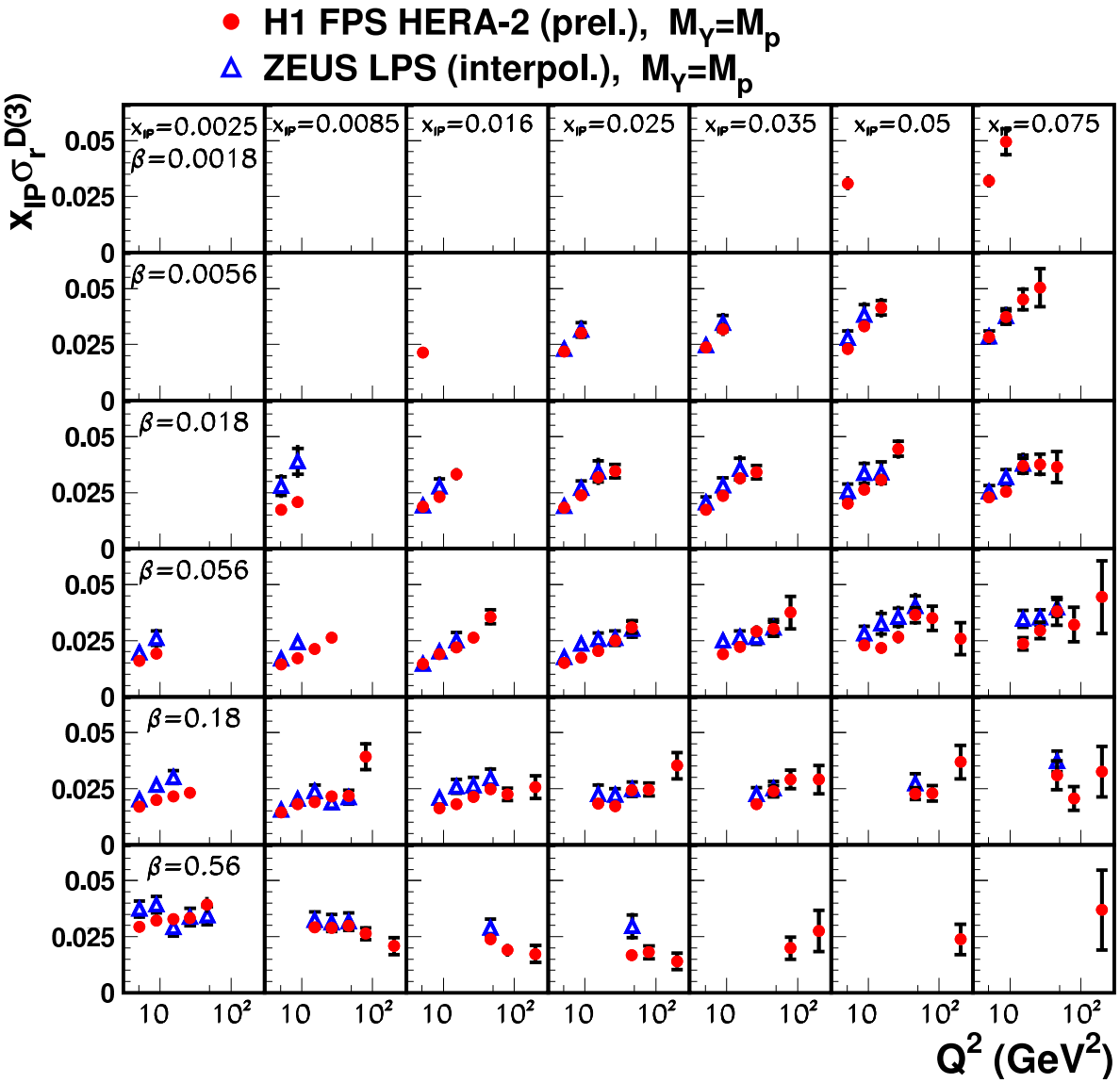
- Fit $\frac{\mathrm{d}\sigma}{\mathrm{d}t} \sim e^{-b|t|} \Rightarrow b = 7.0 \pm 0.4\ \mathrm{GeV}^{-2}$

$x_{I\!P}$ dependence



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

Q^2 dependence

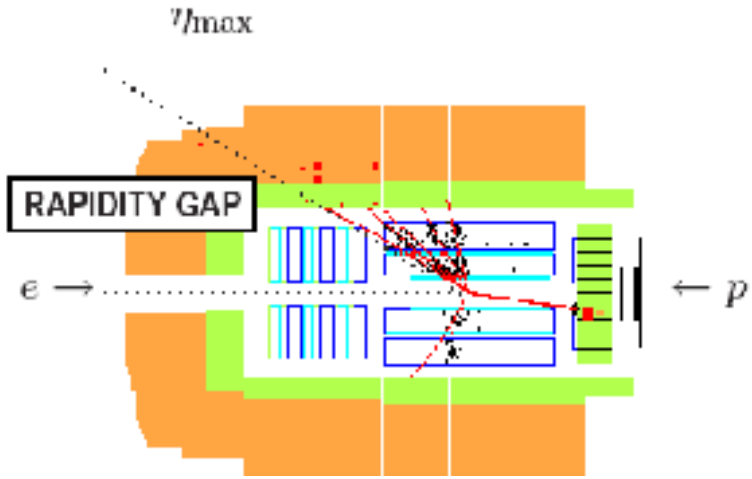


- after correcting for the photon propagator, the cross section increases (positive scaling violation) with Q^2 for $\beta \lesssim 0.2$

- Reasonable agreement between H1-FPS and ZEUS-LPS

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

Large Rapidity Gap Method

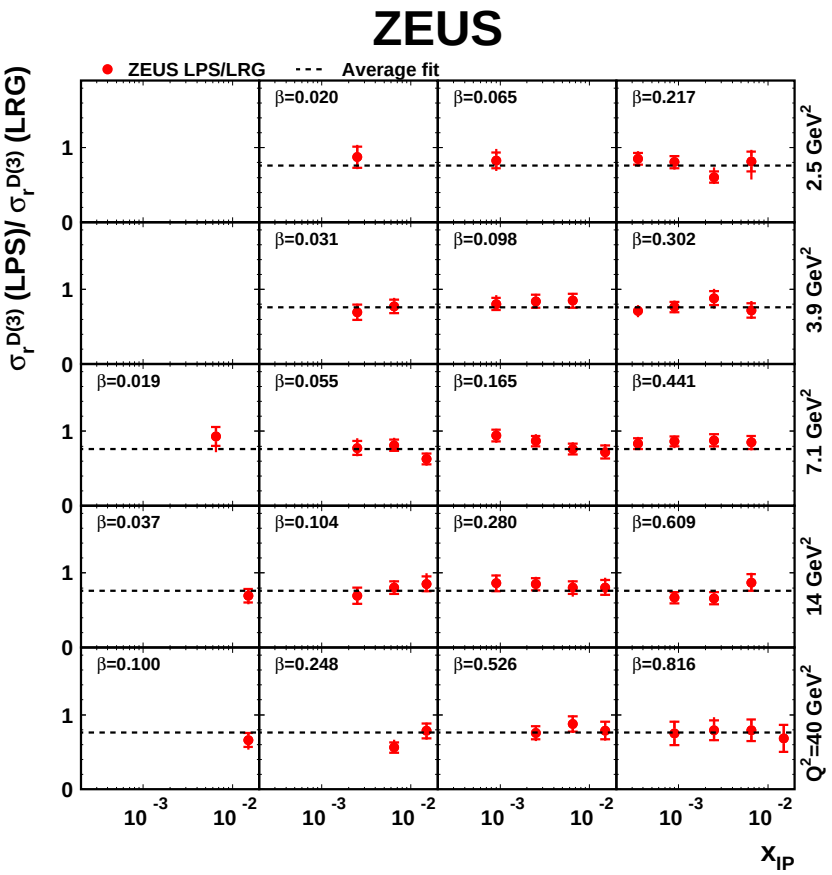


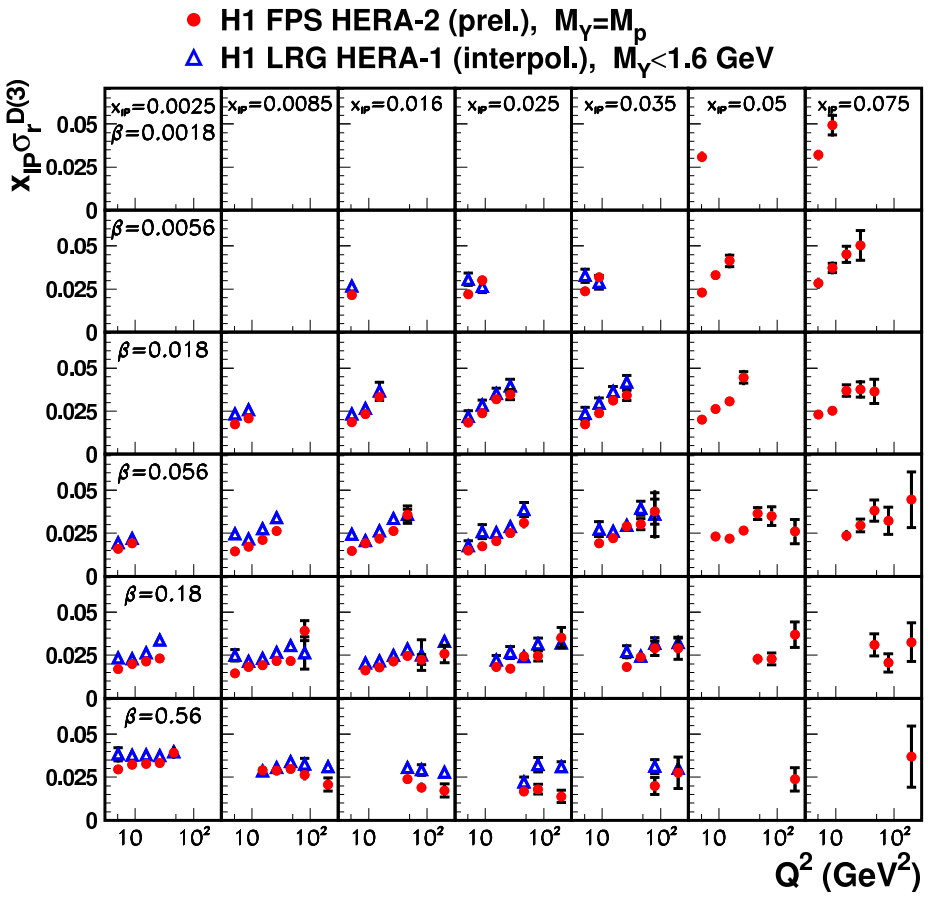
- Require a large rapidity gap adjacent to the outgoing (untagged) proton
- Escaping scattered proton $\Rightarrow$ cross section integreted over t
- Large statistics (no Roman Pot det. acceptance limitation), large range in $Q^2, x_{I\!P}, \beta$
- Contamination of p-dissociation background: $ep \rightarrow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

Data shown in this talk:

- New: H1 LRG	$x_{I\!P} < 0.02$	$M_Y < 1.6$ GeV	HERA I+II - 370 pb^{-1}	prel.
- 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 $Q^2, x_{I\!P}, \beta$

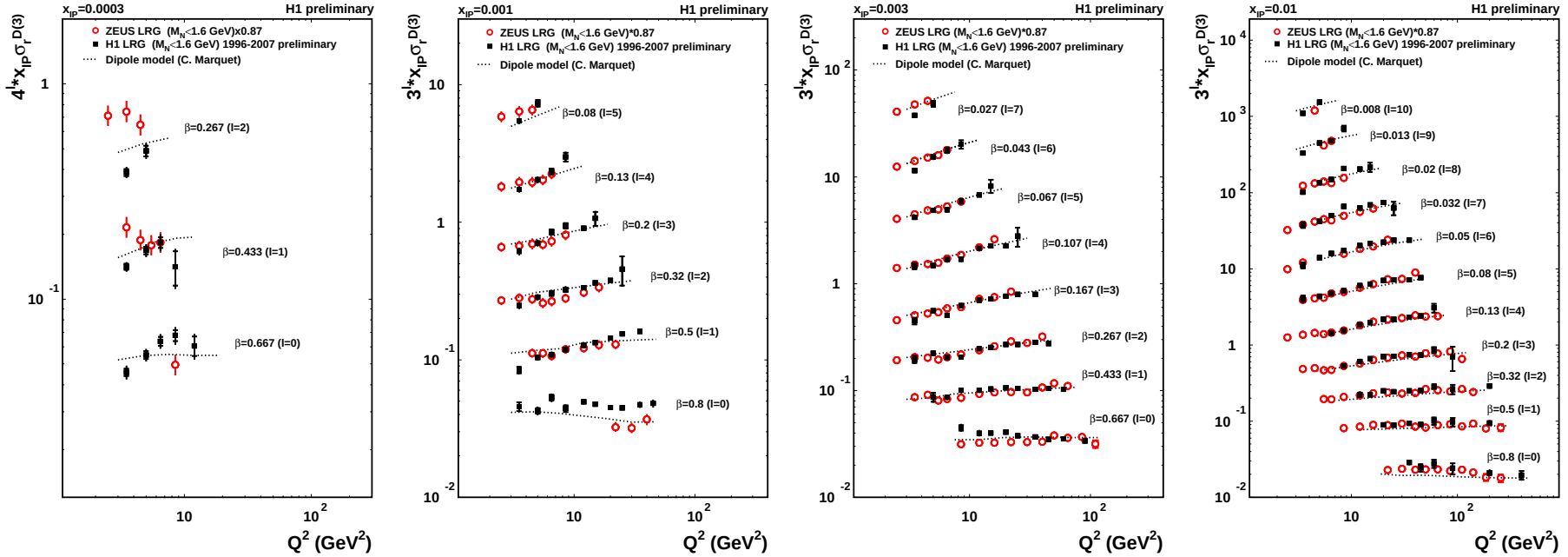
  $\Rightarrow$ p-diss. $= 24 \pm 1(\text{stat}) + 2 - 3(\text{syst}) + 5 - 8(\text{norm})\%$

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

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

  $\Rightarrow$ 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 $x_{I\!P}$

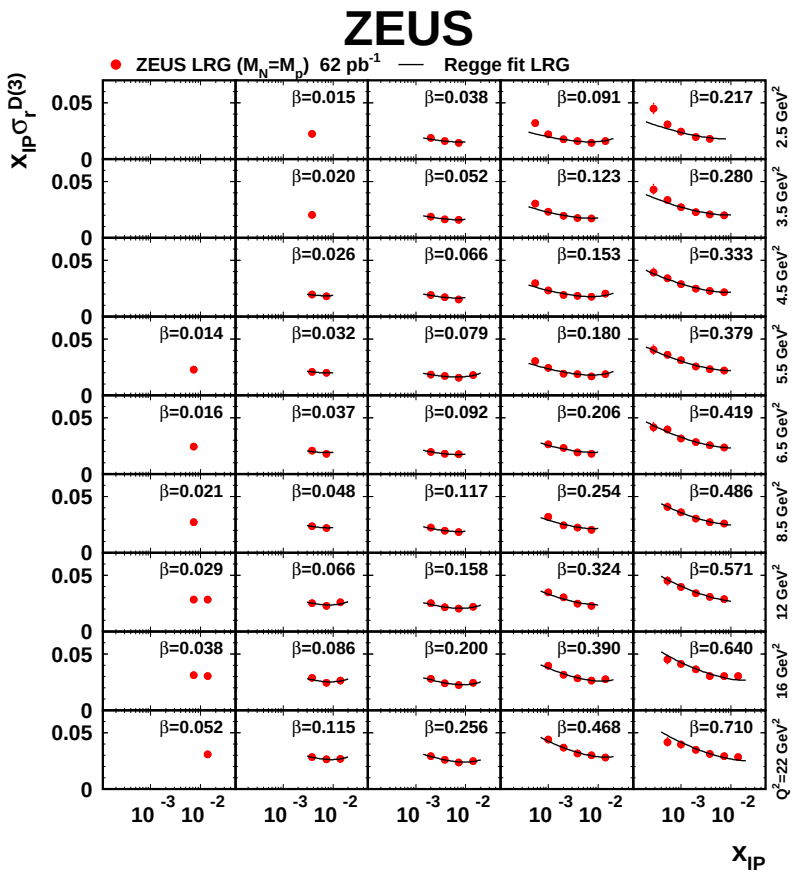
- note: here ZEUS points corrected to $M_Y < 1.6$ GeV.

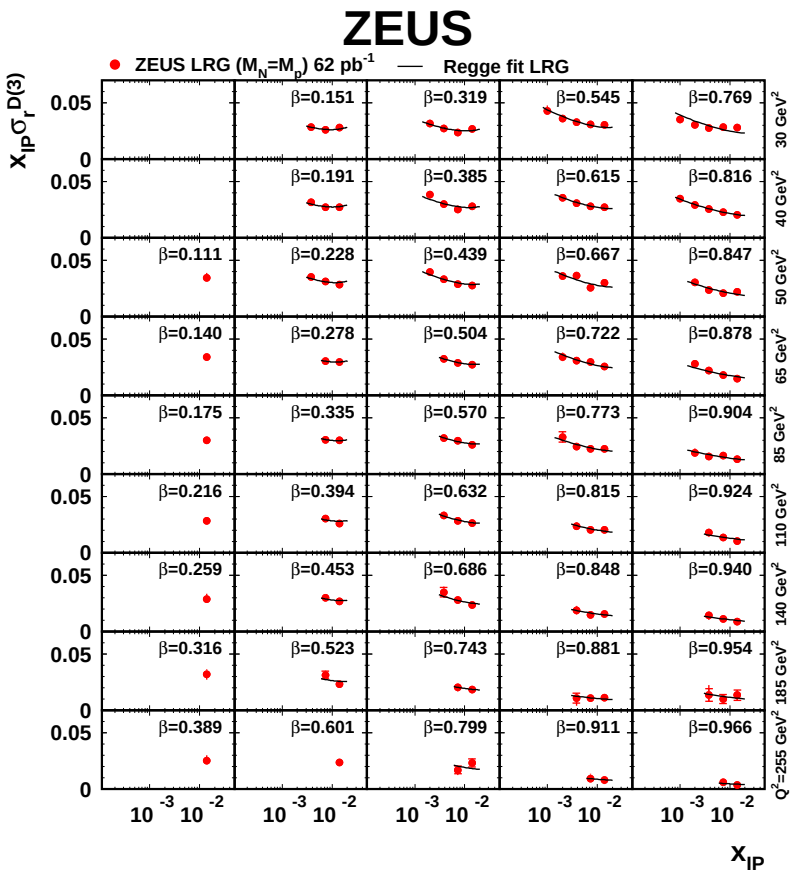
- QCD fit on these data → see talk of Ada Solano.

Regge Fit to LRG data

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

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



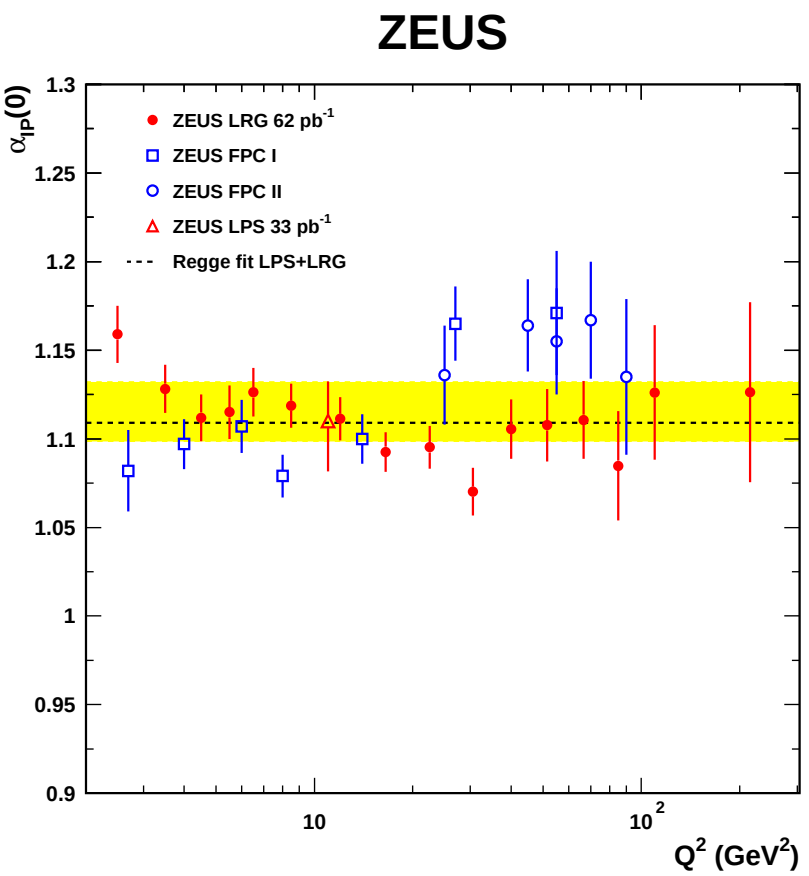


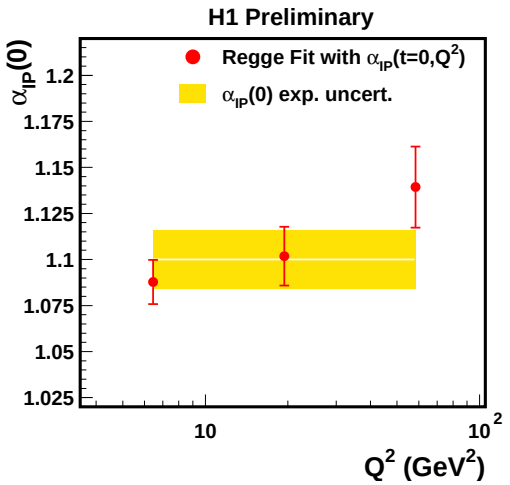
- Assuming that the Regge factorisation holds :

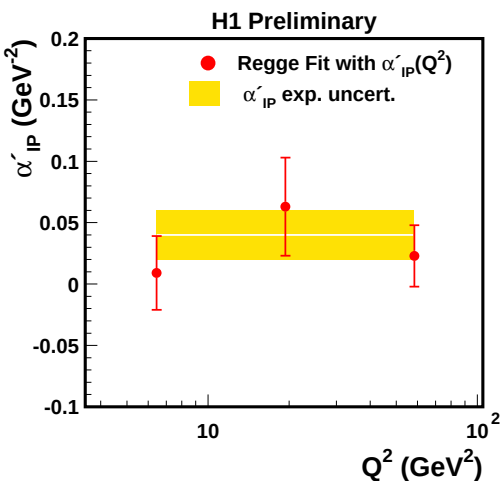
$\alpha_{I\!P}(0) = 1.108 \pm 0.008(\text{stat+syst}) + 0.022 - 0.007(\text{model})$

Pomeron intercept

Applying the Regge fit in different Q^2 bins:







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

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

- 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