PANIC11
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Combined Measurement of the Inclusive Diffractive Cross Sections at HERA

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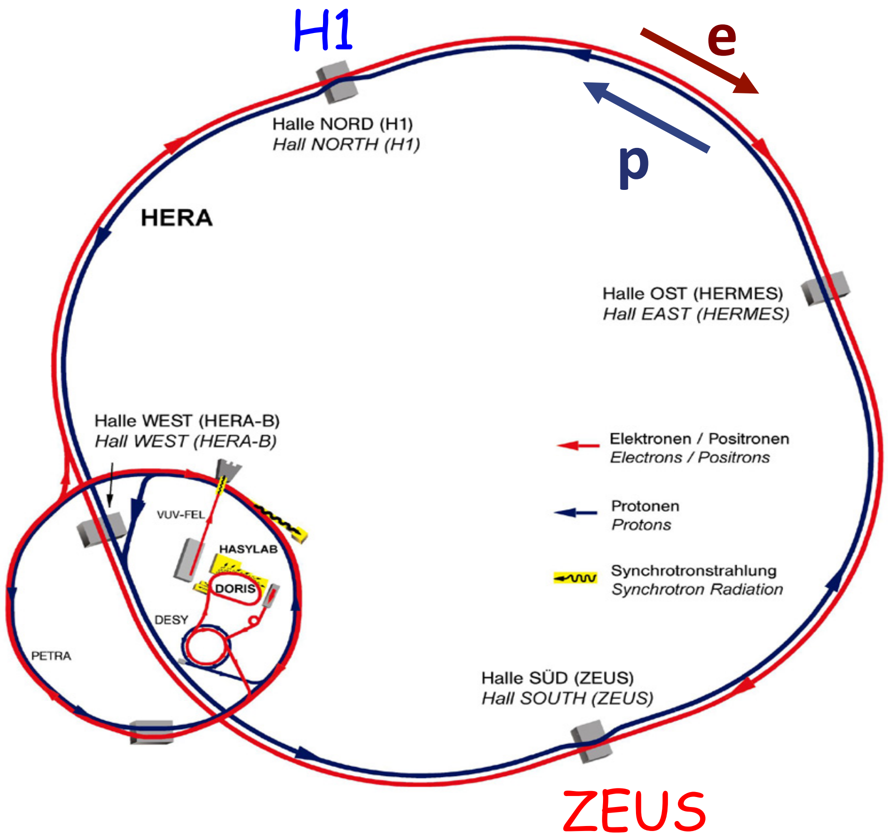
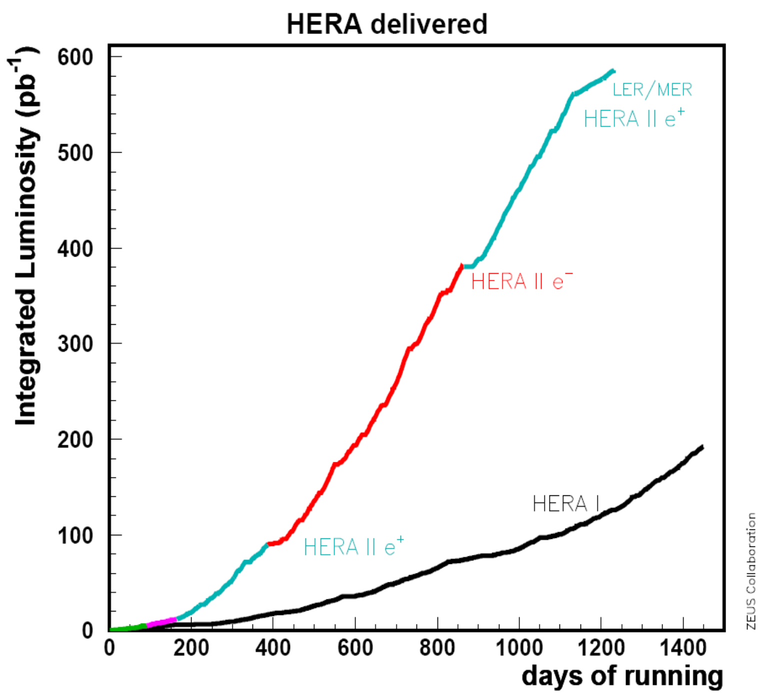
(Torino University and INFN)
on behalf of the H1 and ZEUS Collaborations

- Diffraction in *ep* scattering
- Latest inclusive diffractive *ep* results
- Combination of diffractive cross sections

HERA = Hoch Energie Ring Anlage



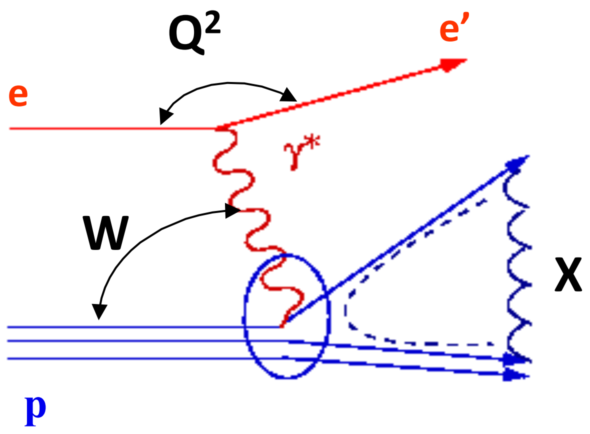


HERA I	1993-2000	E_p = 820-920 GeV
HERA II	2003-2007	E_p = 920-460-575 GeV
HERA I - II		E_e = 27.5 GeV

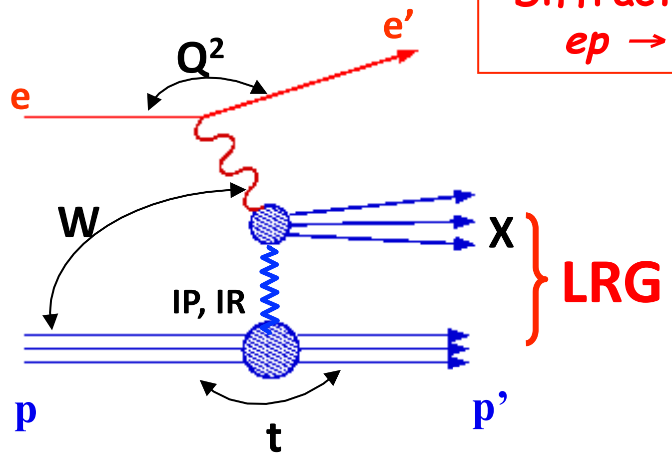
0.5 fb^{-1} collected by H1 and ZEUS experiments

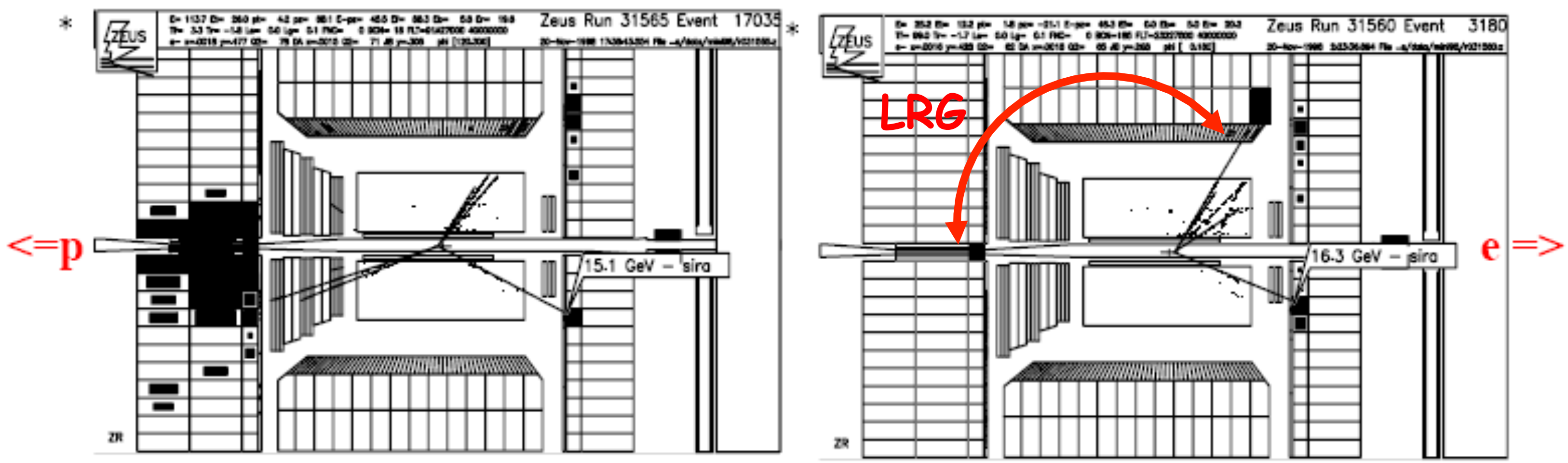
Diffraction at HERA

Standard DIS
ep → e'X



Diffractive DIS
ep → e'Xp'





Diffractive events contribute up to 15% of the inclusive DIS cross section

Kinematics and Cross Sections

Q^2 = virtuality of exchanged photon

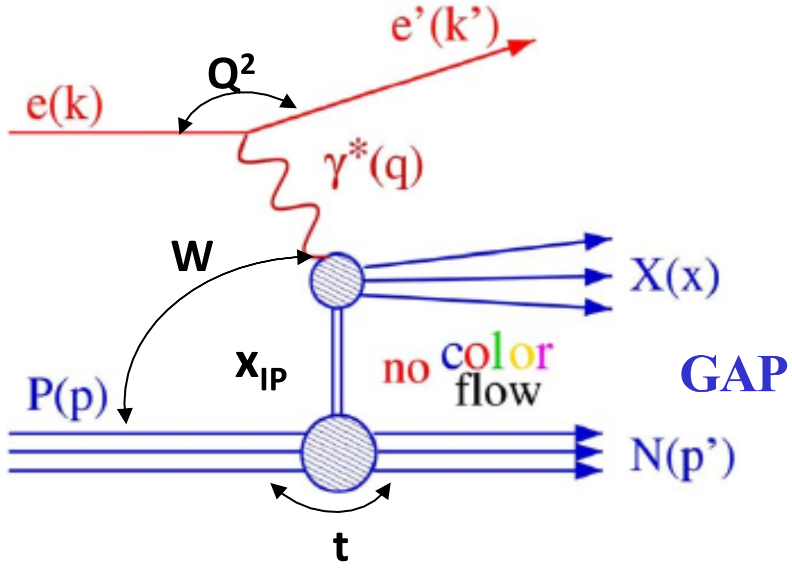
x = Bjorken scaling variable

y = inelasticity of virtual photon

x_{IP} = fraction of proton momentum carried by IP

ß = x/x_{IP} = fraction of IP momentum carried by struck parton

t = (4-momentum exchanged at p vertex)^2
typically: $|t| < 1\ \mathrm{GeV}^2$



When N is a reasonace or a low mass state
⇘ proton dissociation (p-diss)

$$\frac{d^4\sigma^{ep\mapsto e'Xp'}}{d\beta dQ^2 dx_{IP} dt} = \frac{2\pi\alpha^2}{\beta Q^4} Y_+ \left[F_2^{D(4)}(\beta,Q^2,x_{IP},t) - \frac{y^2}{Y_+} F_L^{D(4)}(\beta,Q^2,x_{IP},t)\right]$$

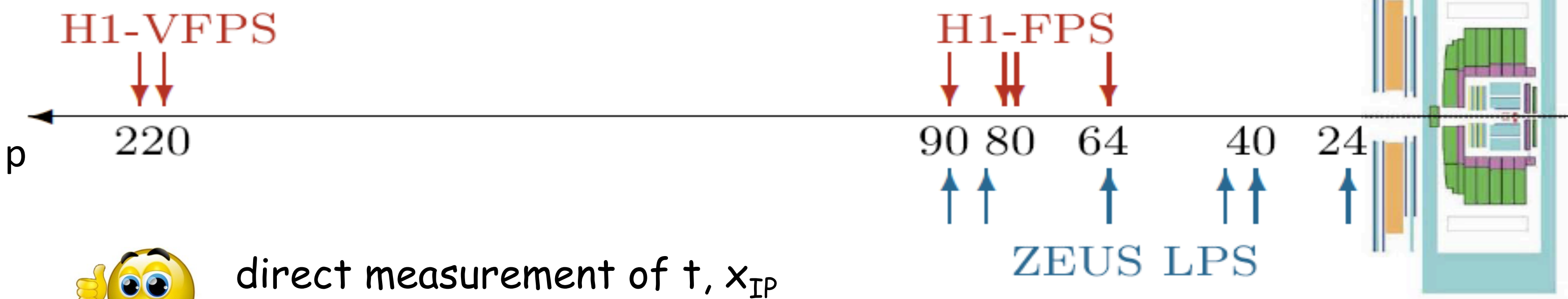
where $Y_+ = 1 + (1-y)^2$

$$= \sigma_r^{D(4)}(\beta,Q^2,x_{IP},t)$$

$$\sigma_r^{D(3)}(\beta, Q^2, x_{IP}) = \int \sigma_r^{D(4)}(\beta, Q^2, x_{IP}, t)\,dt$$

Signatures and Selection Methods

Proton Spectrometer (PS) method

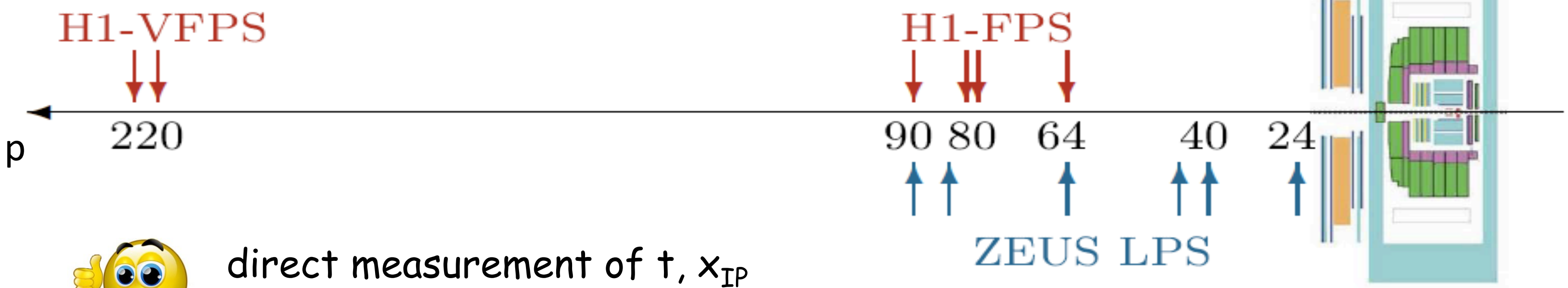


direct measurement of t, x_{IP}
high x_{IP} accessible
no p-diss contribution

low statistics

Signatures and Selection Methods

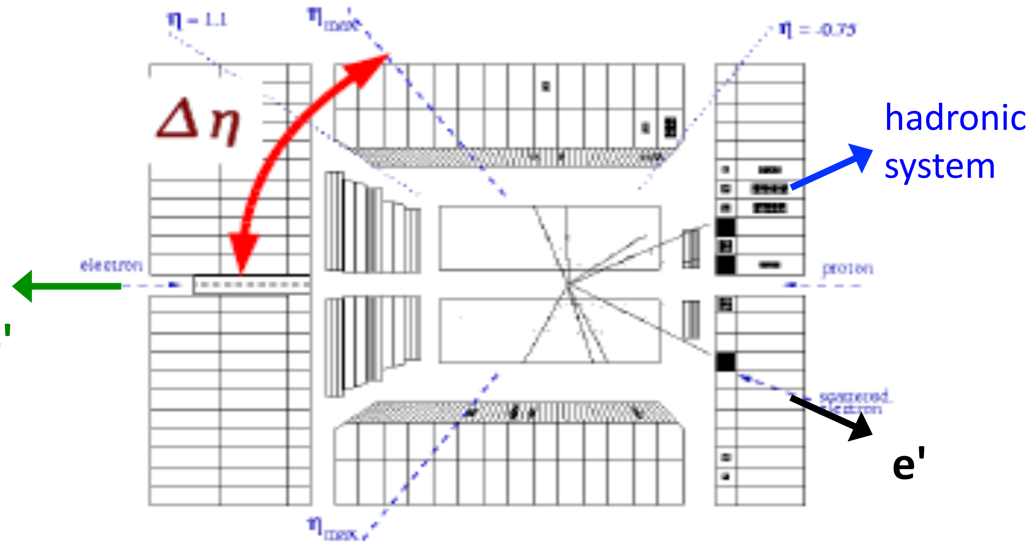
Proton Spectrometer (PS) method



- direct measurement of t, x_{IP}
- high x_{IP} accessible
- no p-diss contribution

- low statistics

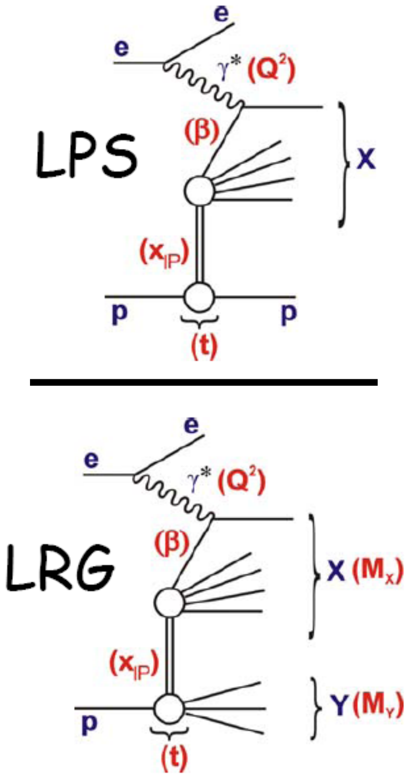
Large Rapidity Gap (LRG) method

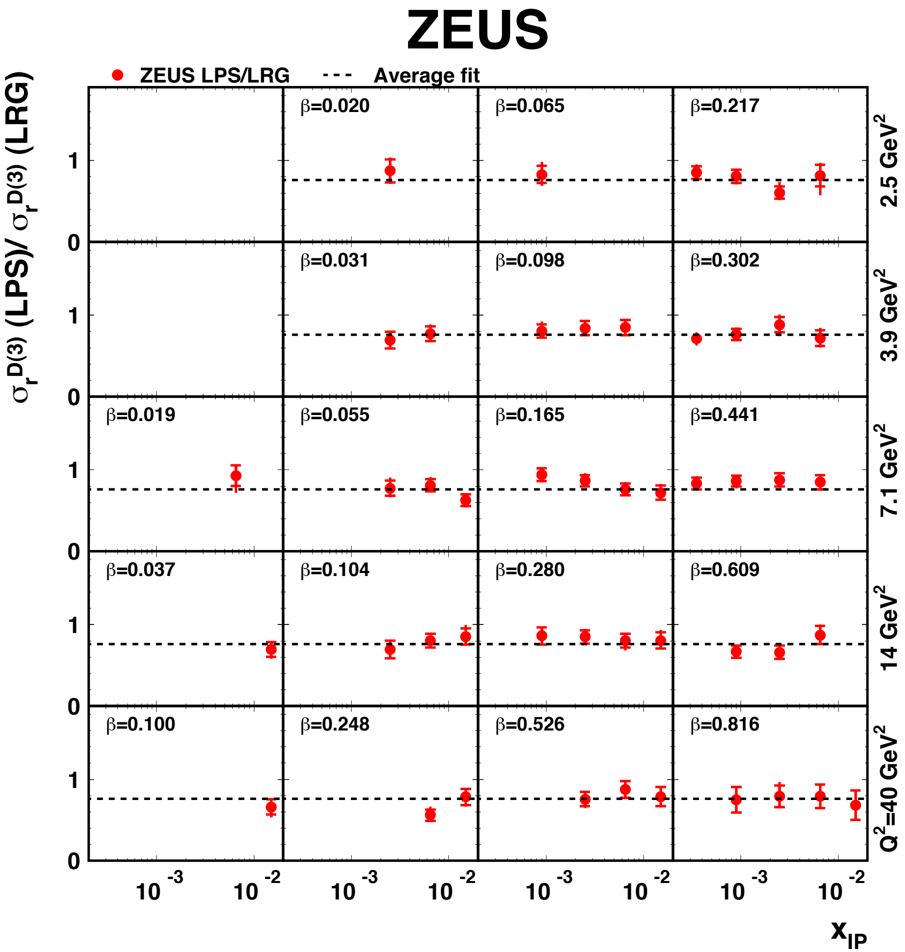


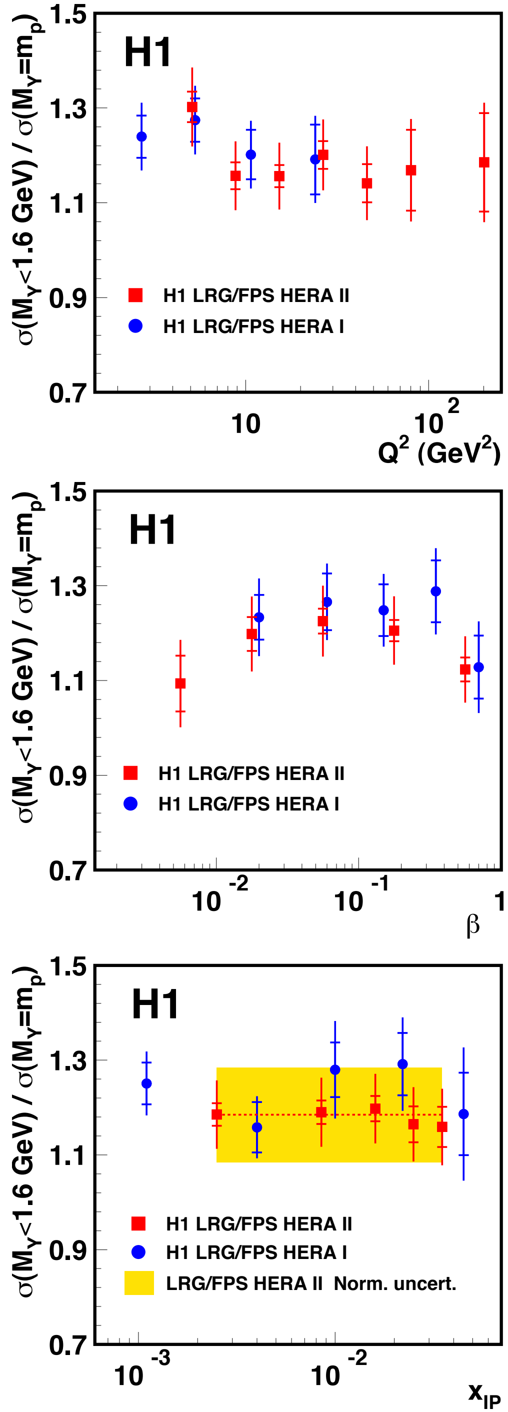
- near perfect acceptance at low x_{IP}

- p-diss contribution
- no t measurement

LRG vs PS



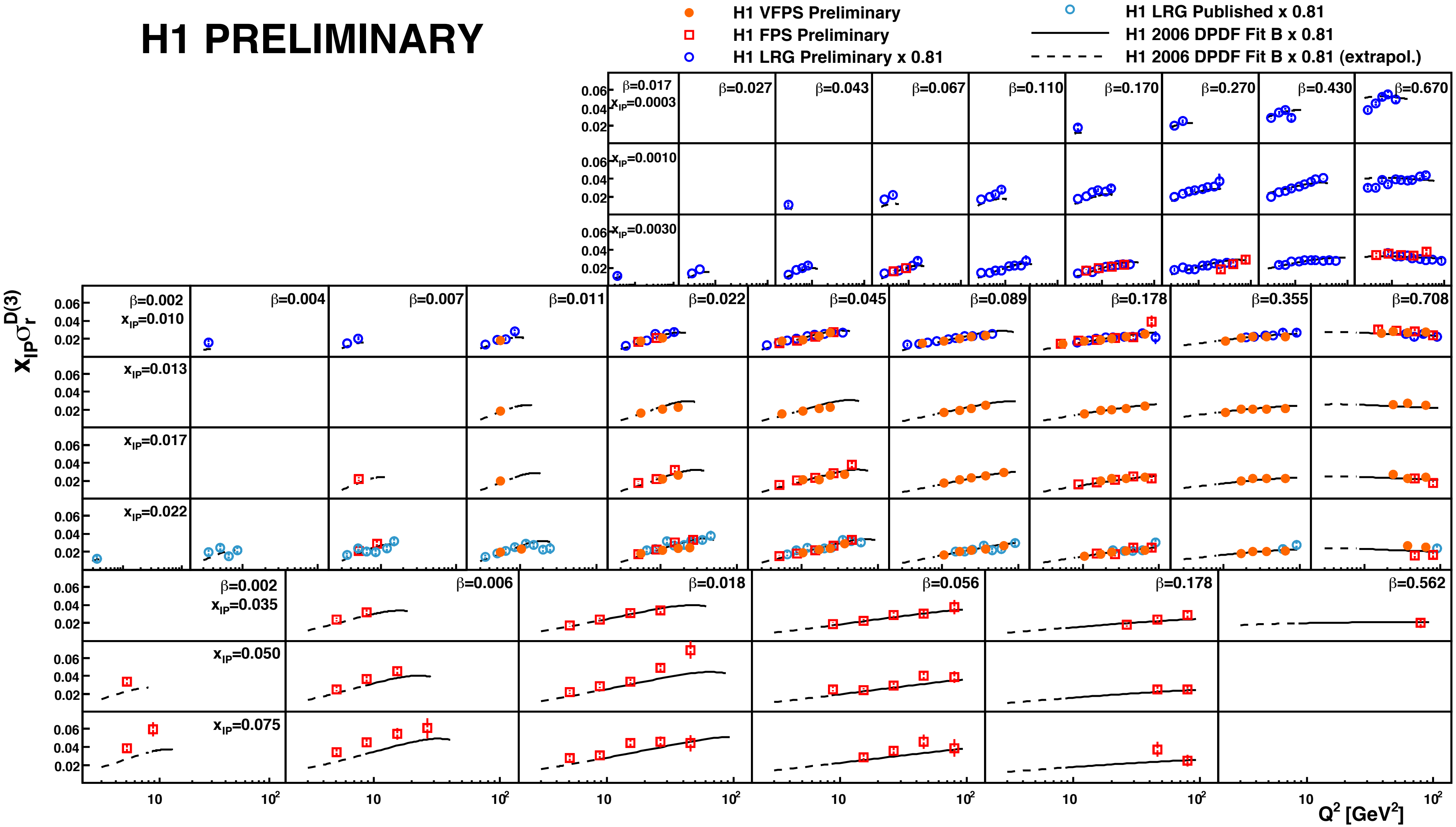




Estimation of p-diss contribution in LRG method
→ ratio flat both in ZEUS and H1

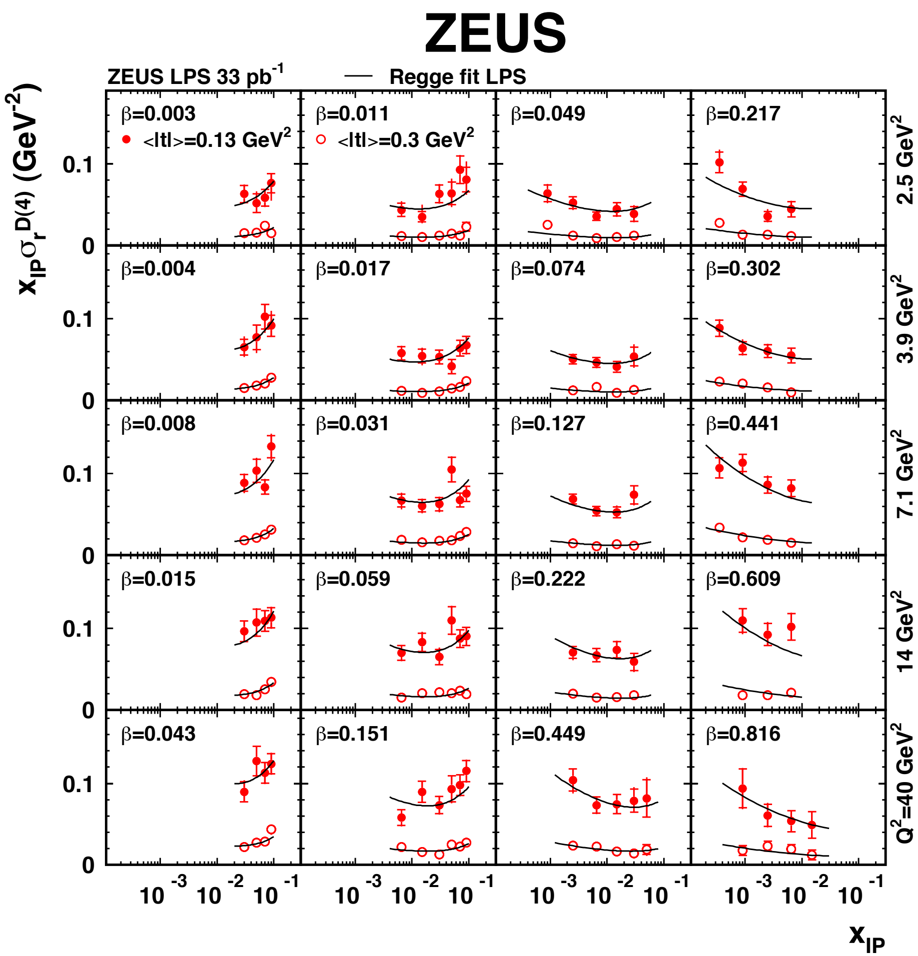
⇨ PS data give the absolute normalization of $\sigma_r^{D(3)}$

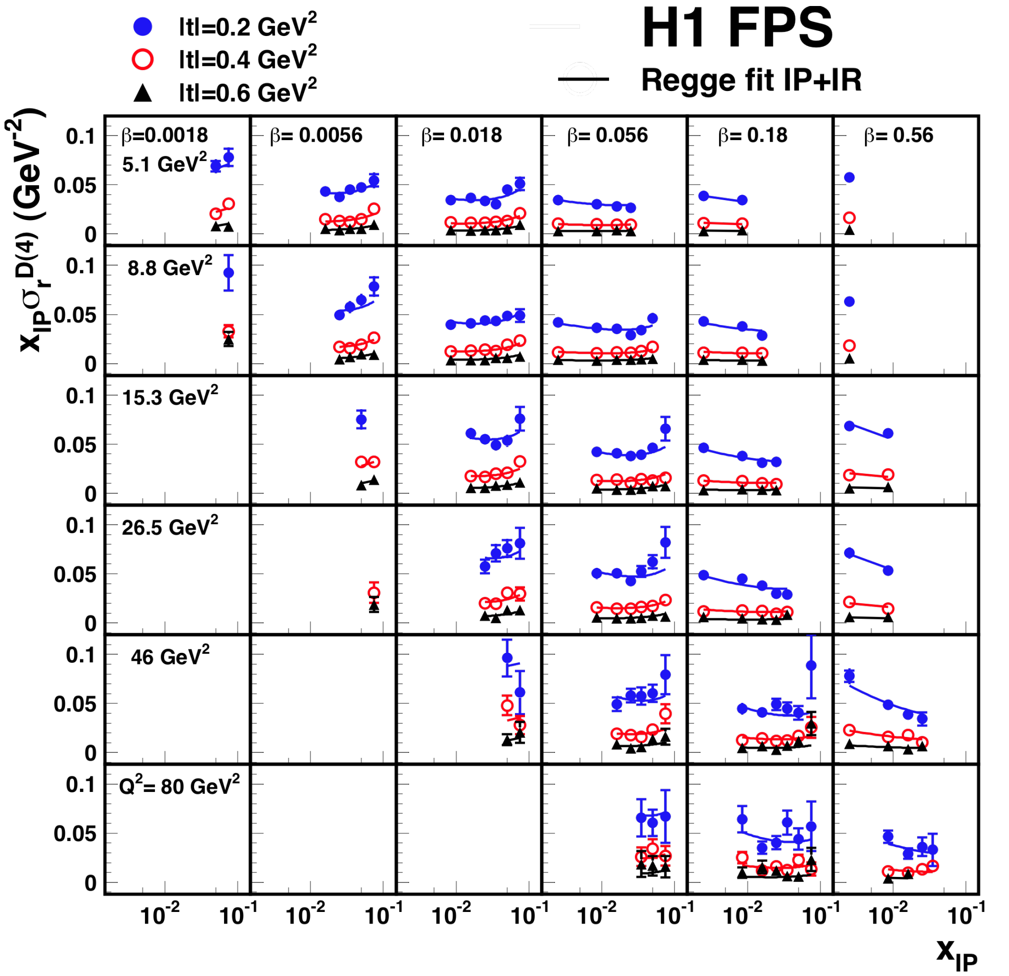
$\sigma_r^{D(3)}$ from LRG, FPS and VFPS



LRG, FPS and VFPS data agree (once p-diss is subtracted)

$\sigma_r^{D(4)}$ from Proton Spectrometers



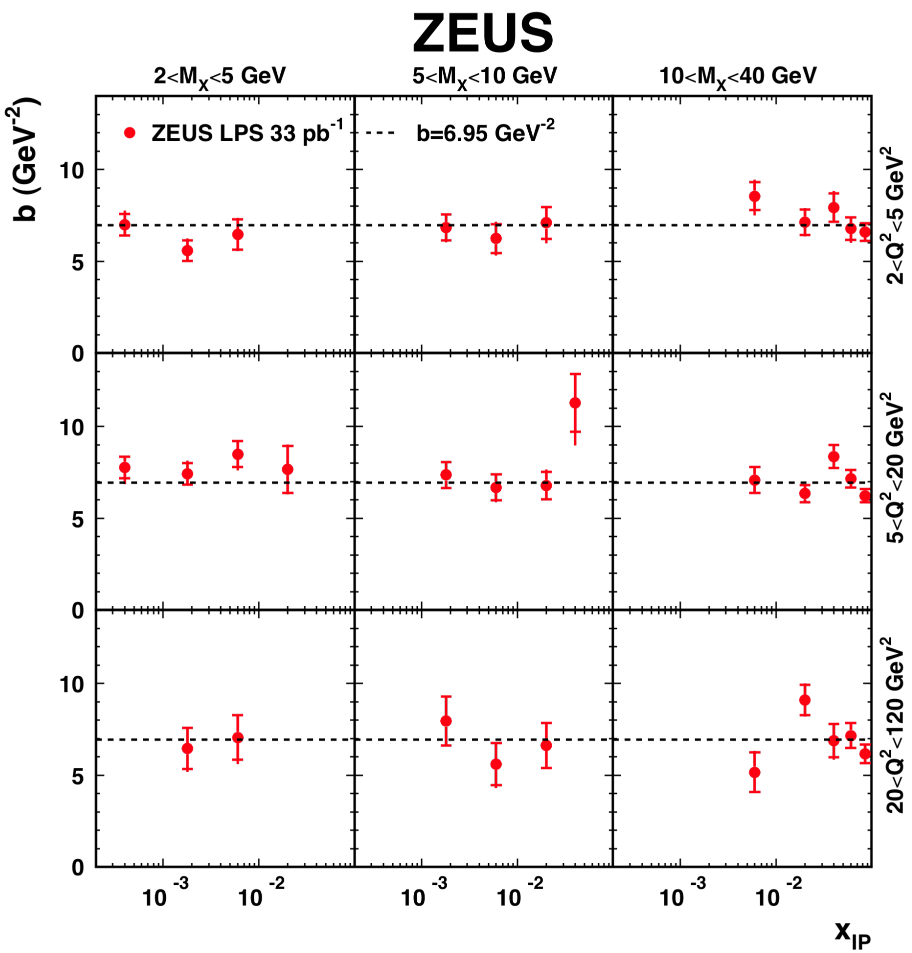


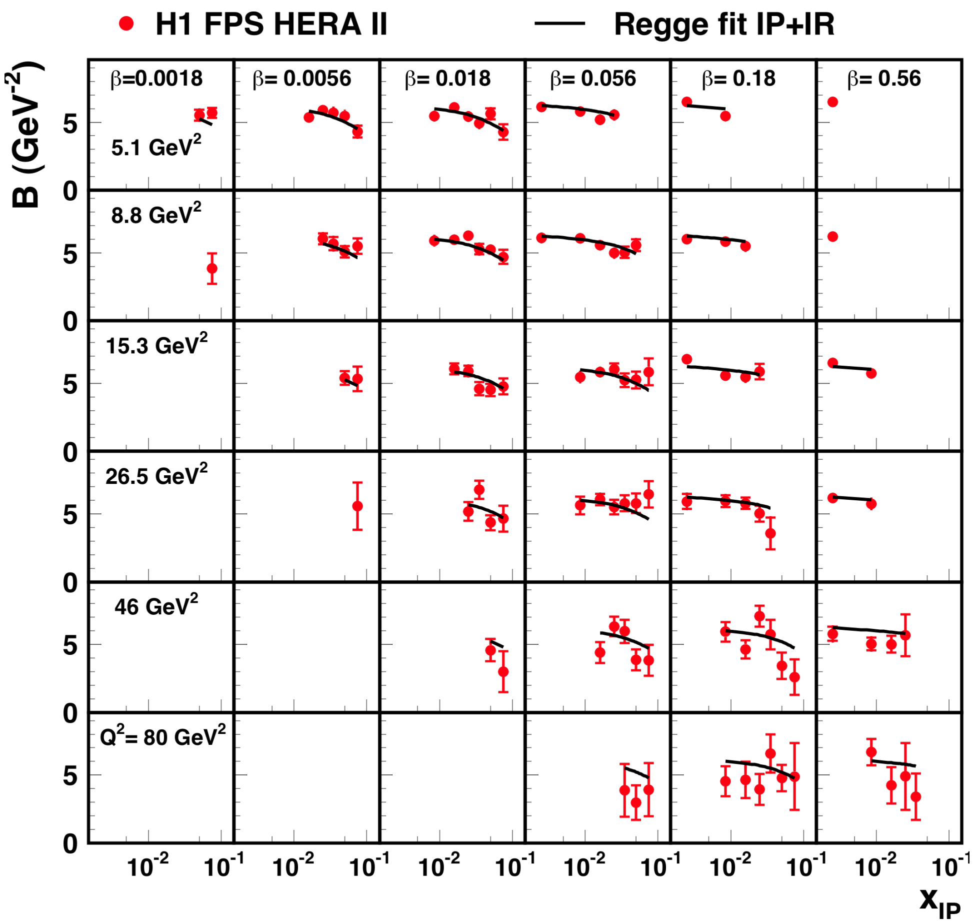
Most precise inclusive diffractive measurements from HERA (PS method)

- ZEUS LPS '99/2000 [Nucl.Phys. B816 (2009) 1-61] $|t|$ = 0.09 – 0.55 GeV^2
- H1 FPS HERA II [Eur.Phys.J. C71 (2011) 1578] $|t|$ = 0.1 – 0.7 GeV^2

t-slope

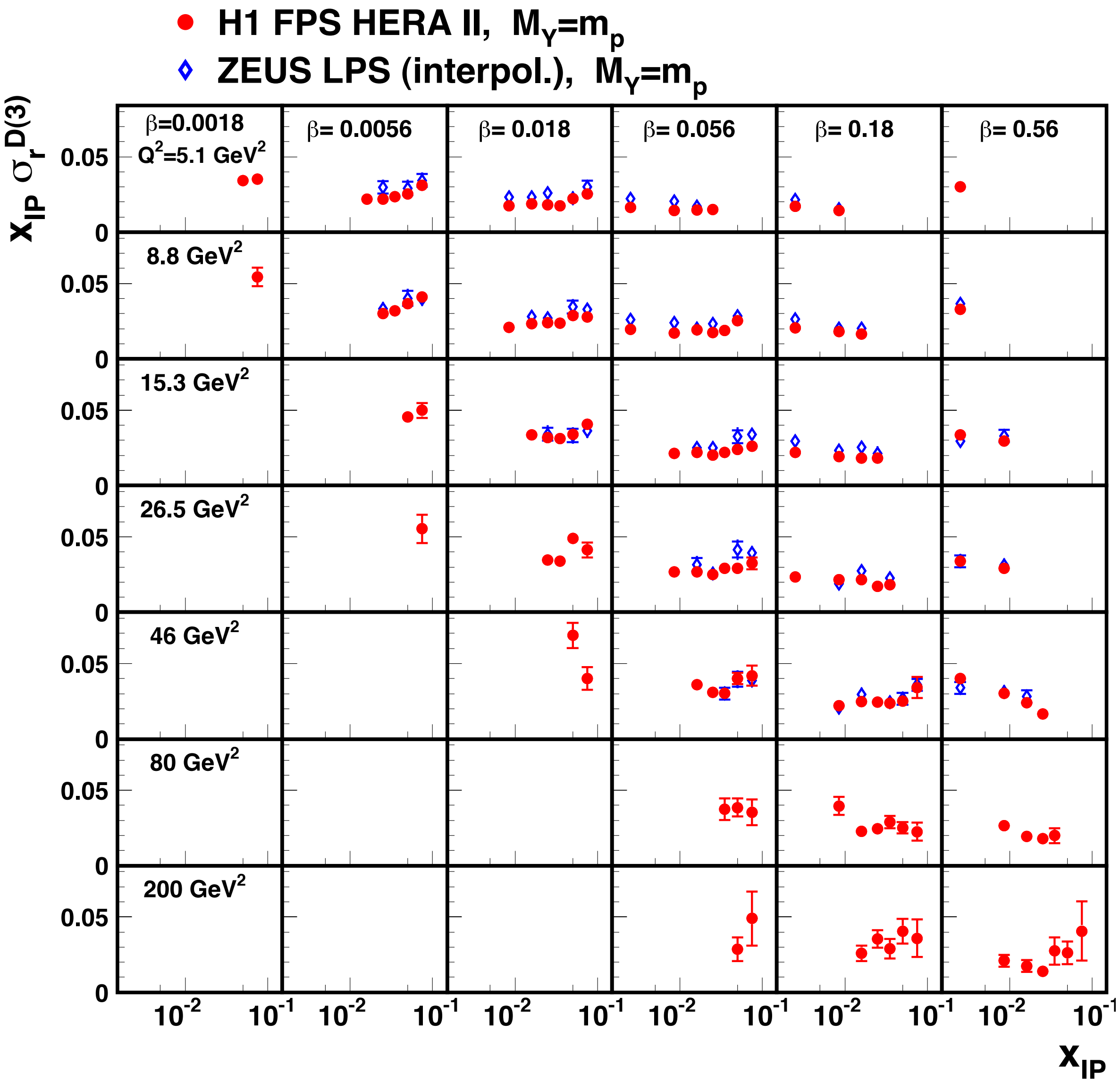
$d\sigma/dt \sim e^{bt}$





- ZEUS t-slope equal to 7 GeV^{-2} (constant through the kinematics)
- H1 t-slope between 5 and 6 GeV^{-2} (depending on x_{IP})

$\sigma_r^{D(3)}$ from Proton Spectrometers



$$\sigma_r^{D(3)} = \int_{-1}^{t_{min}} \sigma_r^{D(4)}\, dt$$

The measured b parameters are used to perform the integration to the 'full' t range

Good agreement in shape between H1 and ZEUS

Fair agreement in normalization between H1 and ZEUS

H1 FPS norm unc ~ ± 6%

ZEUS LPS norm unc ~ + 11% - 7%

H1/ZEUS = 0.85 ± 0.01 (stat) ± 0.03(syst) + 0.09 – 0.12 (norm)

|t| range = t_{min} - 1 GeV^2

Data Sets

Data sets used for the first diffractive H1 & ZEUS combination

- ZEUS LPS '99/2000
  Luminosity = 32.6 pb^{-1}
  Visible range $|t|$ = 0.09 – 0.55 GeV^2
- H1 FPS HERA II
  Luminosity = 156.6 pb^{-1}
  Visible range $|t|$ = 0.1 – 0.7 GeV^2

Prior to combining ZEUS cross section points swam to H1 (Q^2, β, x_{IP}) grid using ZEUS DPDF SJ [Nucl.Phys. B831 (2010) 1]

Combination performed in the ZEUS visible t range

H1 FPS norm unc ~ ± 4.5%
ZEUS LPS norm unc ~ ± 7%
→ H1/ZEUS = 0.91 ± 0.01 (stat) ± 0.03(syst) ± 0.08 (norm)

$|t|$ = 0.09 - 0.55 GeV^2

20 correlated systematic error sources treated in the combination
4 "procedural uncertainties" related to the averaging procedure

Combination Method

- The key assumption is that H1 and ZEUS experiments are measuring the same cross sections at the same kinematical points
- Averaging H1 and ZEUS diffractive data provides a model independent tool to study consistency of the data and to reduce systematic uncertainties
  → Experiments cross calibrate each other
- The combination method uses an iterative χ^2 minimization which includes full error correlations [A. Glazov, AIP Conf. Proc. 792 (2005) 237]

$$\chi^2_{exp}(M^{i,true}, \Delta\alpha_j) = \sum_i \frac{[M^{i,true} - (M^i + \sum_j \frac{\partial M^i}{\partial \alpha_j} \frac{M^{i,true}}{M^i} \Delta\alpha_j)]^2}{(\sigma_i \frac{M^{i,true}}{M^i})^2} + \sum_j \frac{(\Delta\alpha_j)^2}{\sigma^2_{\alpha_j}}$$

for a single data set

i = measured data point
j = correlated systematic error source

M^i	measured central values	σ_i	statistical and uncorrelated systematic uncertainties
$M^{i,true}$	fitted combined H1 – ZEUS values	σ_{α_j}	correlated systematic uncertainties

⇨ Full χ^2 is the sum over all χ^2_{exp}

Procedural Uncertainties

Four procedural uncertainties are introduced

1. ZEUS swimming factors from H1 DPDF Fit B [Eur. Phys. J. C48 (2006) 715]
→ Average effect ~ 1%

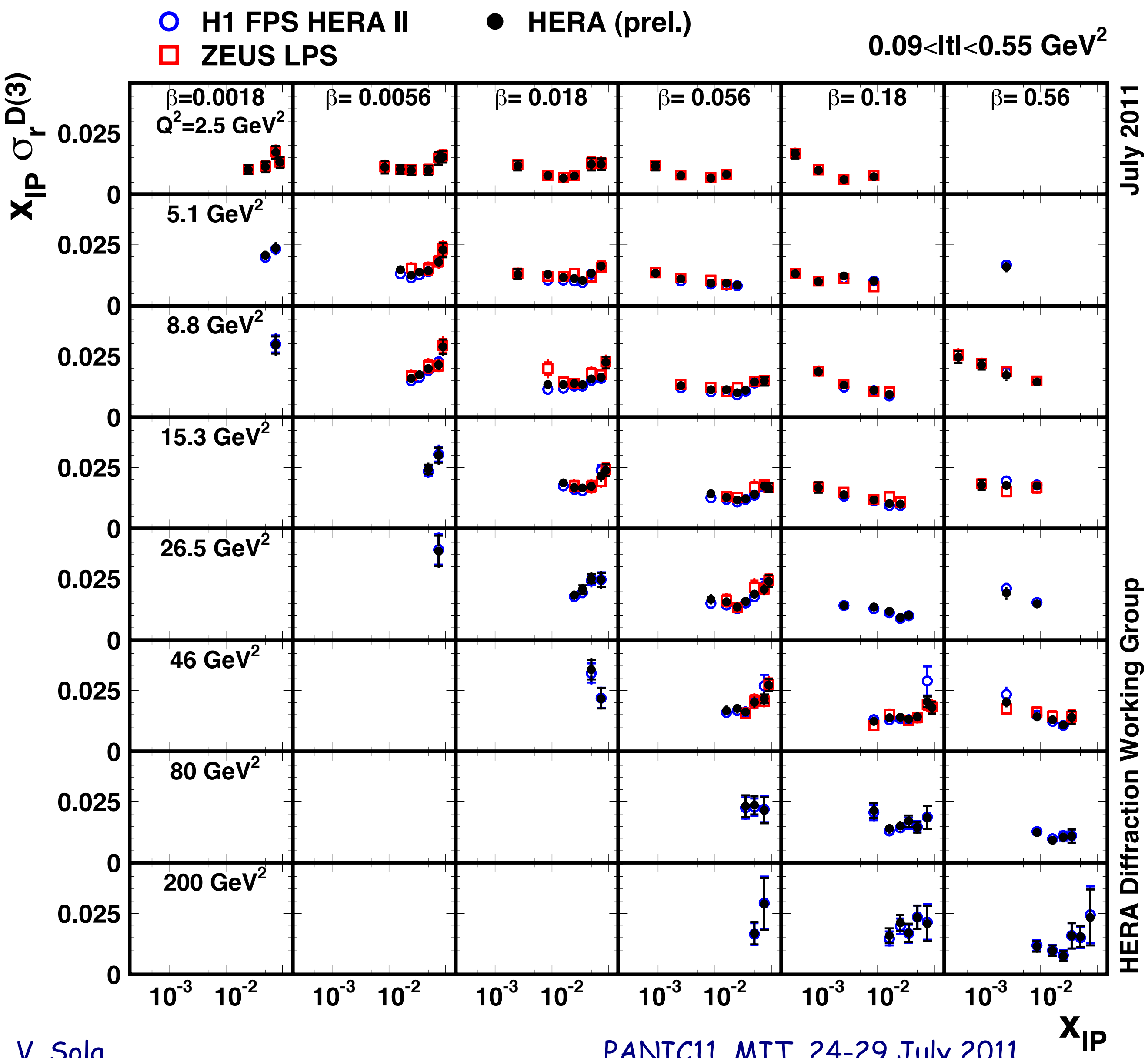
2. Additive vs multiplicative nature of the error sources
→ Average effect ~ 4%

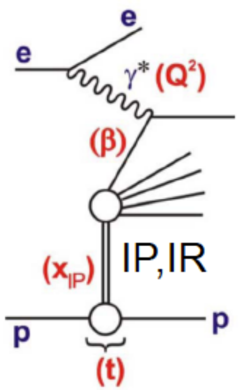
3. Correlated systematic error sources between H1 and ZEUS
Identified 4 uncertainties of possible common origin
- electromagnetic energy scale
- backgroud subtraction
- x_{IP} reweighting
- t reweighting

Compare 2^4 averages taking all pairs as corr/uncorr in turn
→ Average effect ~ 1%

4. Point-to-point correlated vs uncorrelated systematic error sources
→ Average effect $<$ 1%, up to 10% at lowest x_{IP}

Combined $\sigma_r^{D(3)}$

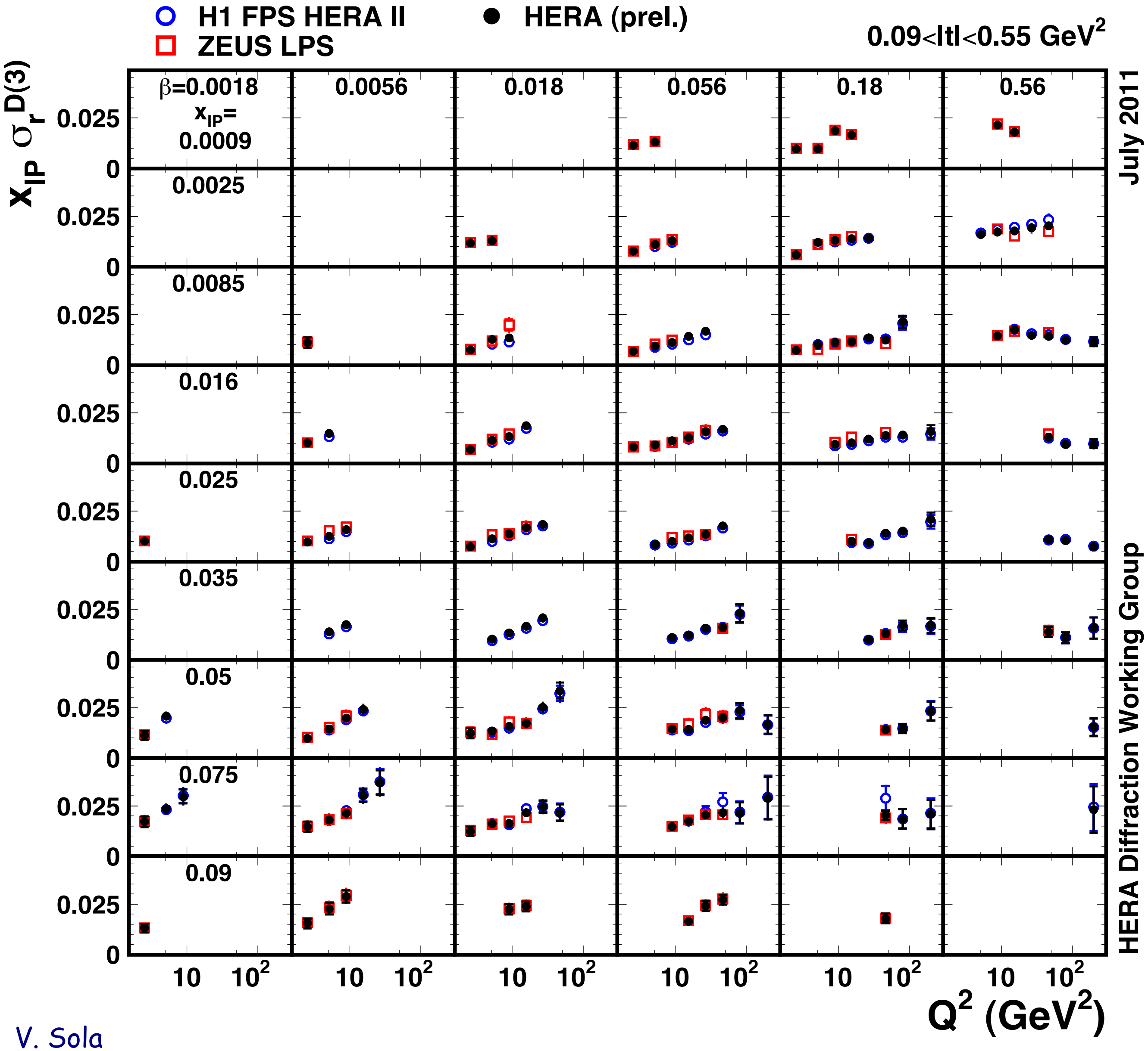


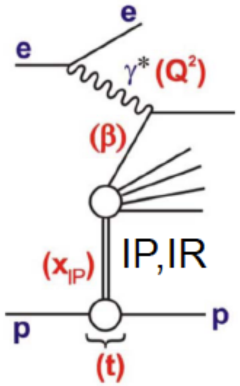


$\chi^2/ndf = 52/58$

Improvement in precision with respect to the H1 data by ~ 20%

Combined $\sigma_r^{D(3)}$

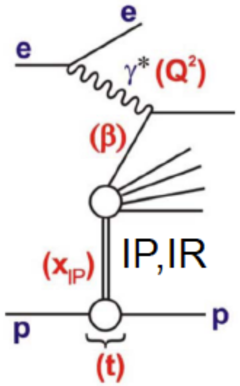


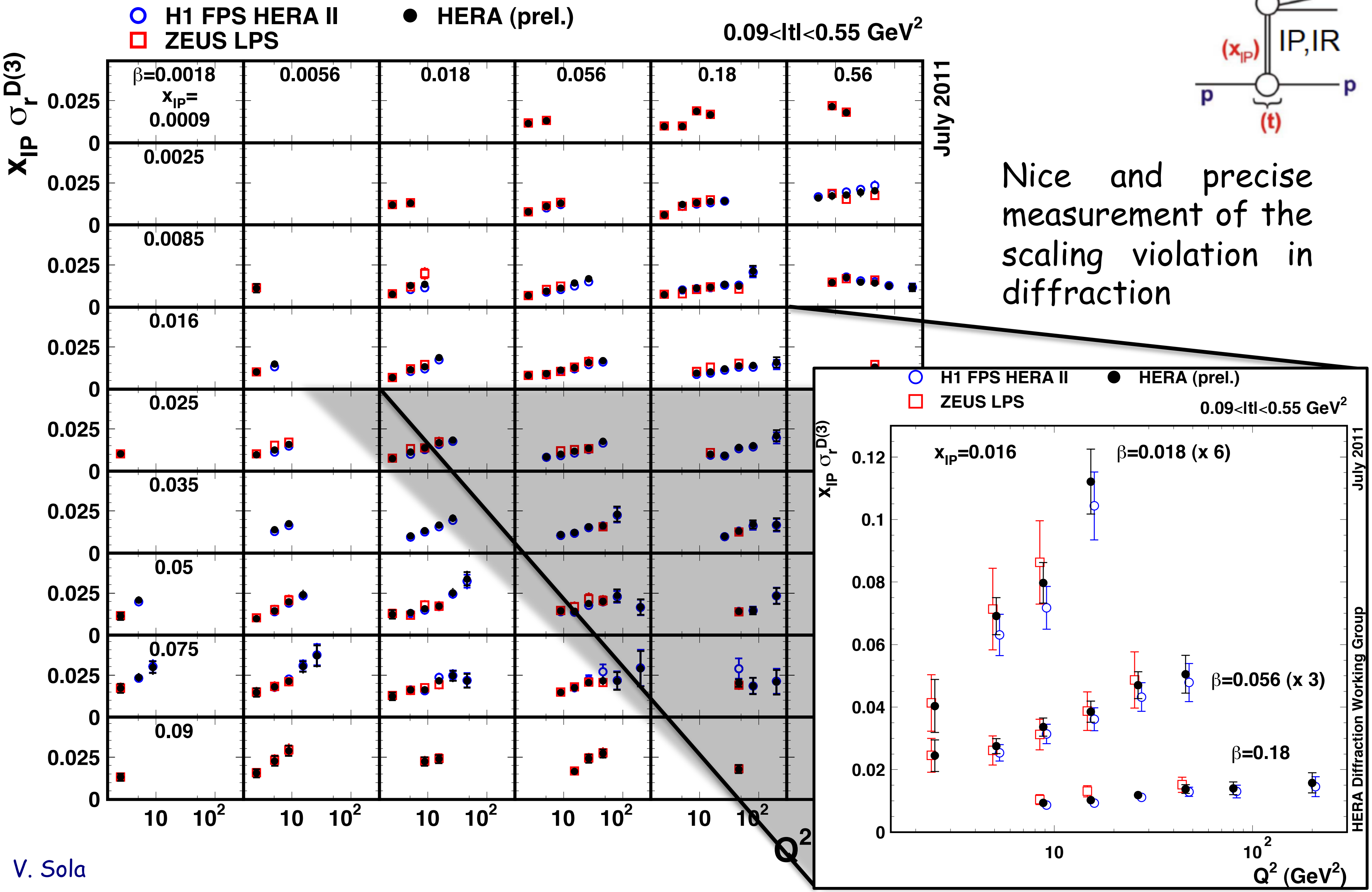


Nice and precise measurement of the scaling violation in diffraction

Improvement in precision with respect to the H1 data by ~ 20%

Combined $\sigma_r^{D(3)}$

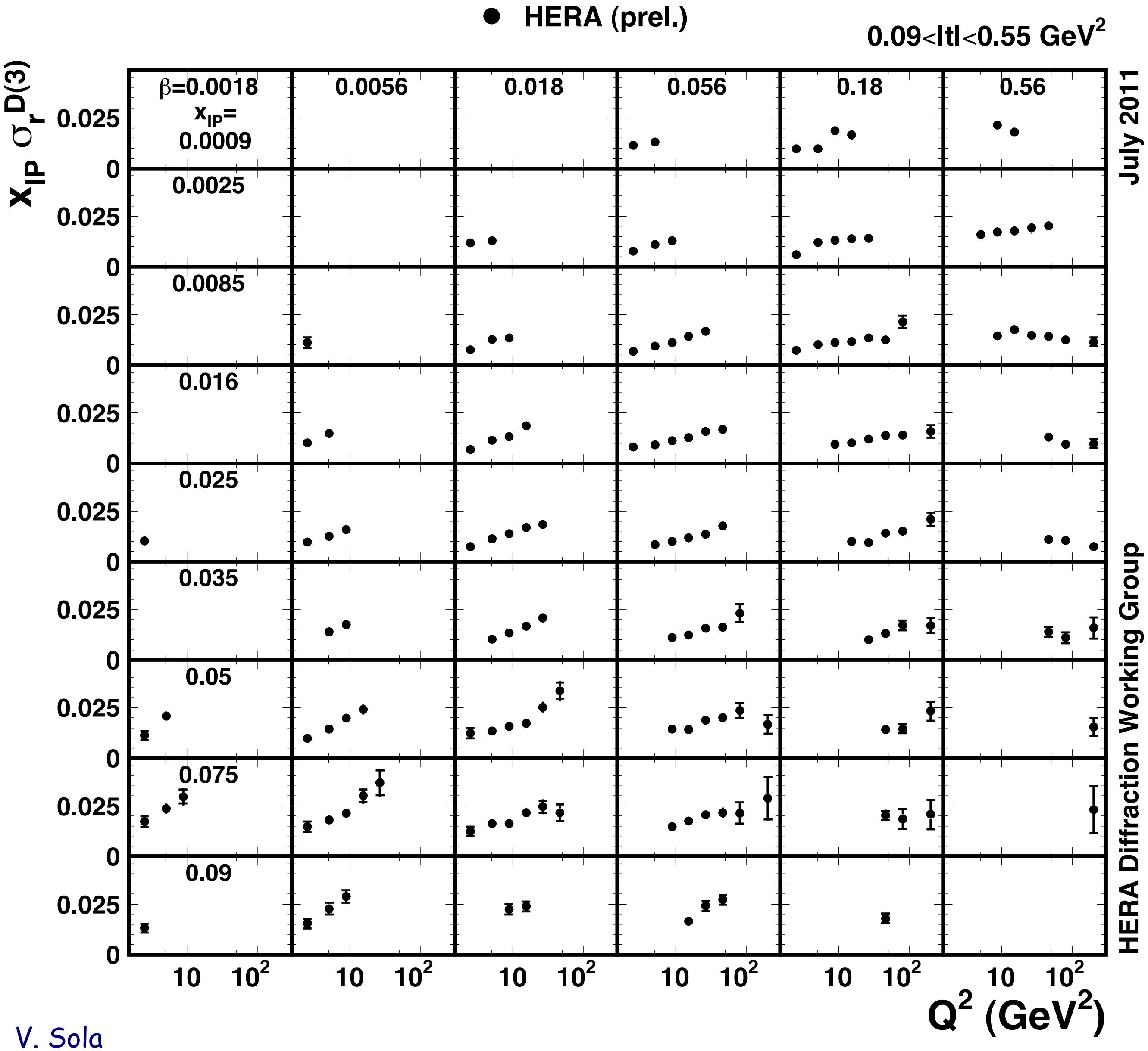


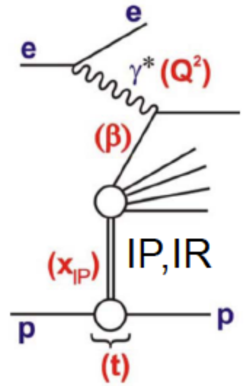


Nice and precise measurement of the scaling violation in diffraction

V. Sola

Combined $\sigma_r^{D(3)}$





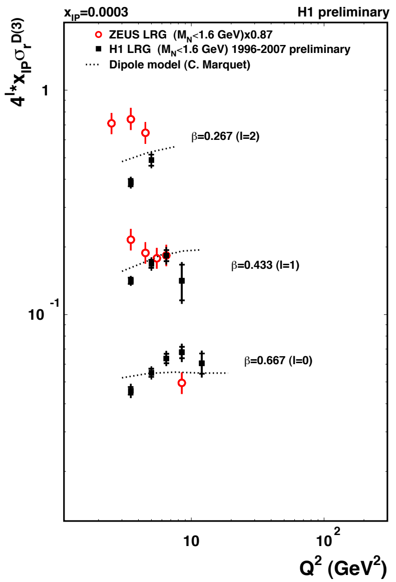
Nice and precise measurement of the scaling violation in diffraction

Improvement in precision with respect to the H1 data by ~ 20%

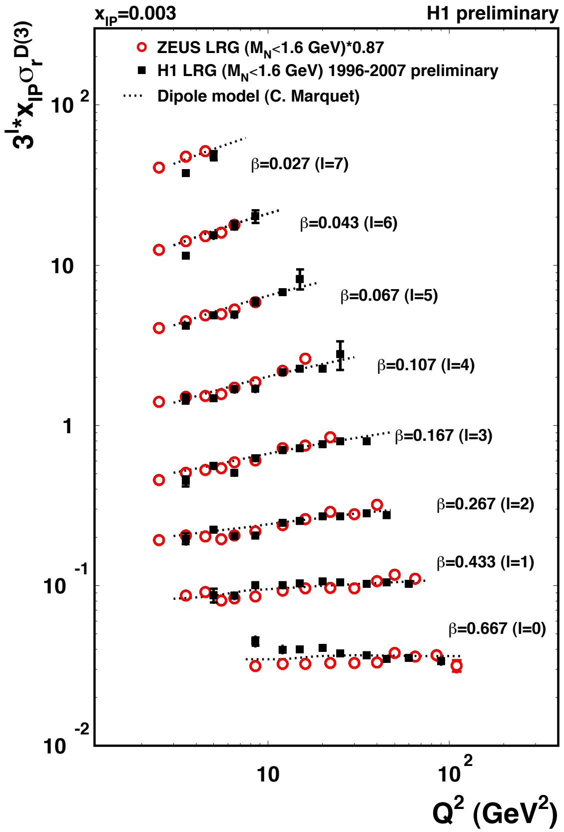
Summary

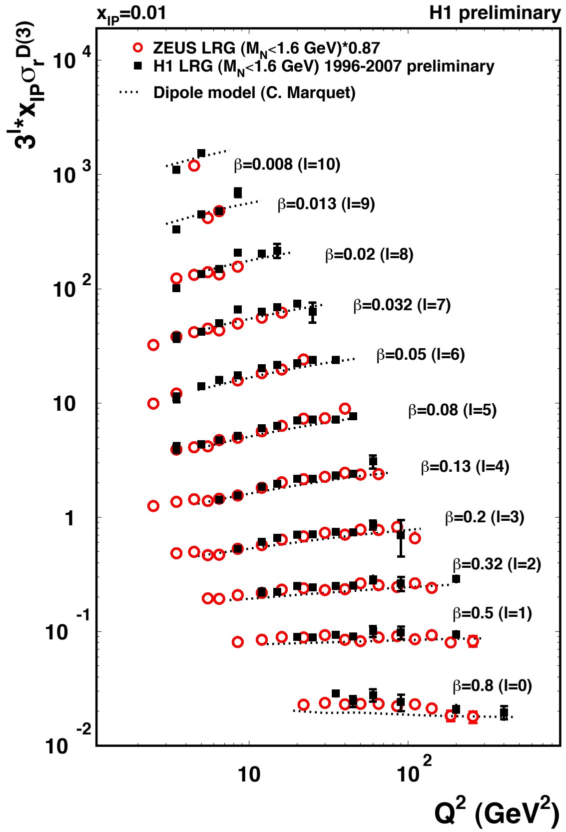
- ✓ 15 years of running HERA provided unique diffractive data
- ✓ First combination of the H1 and ZEUS diffractive data
  - ⇨ combined proton-tag results
  - ⇨ consistency between datasets
  - ⇨ the two experiments calibrate each other resulting in a reduction of systematic uncertainties
- ✓ Looking forward to combining all LRG, FPS and VFPS data
  - ⇨ FPS-LPS combined data can fix the absolute normalization of $\sigma_r^{D(3)}$

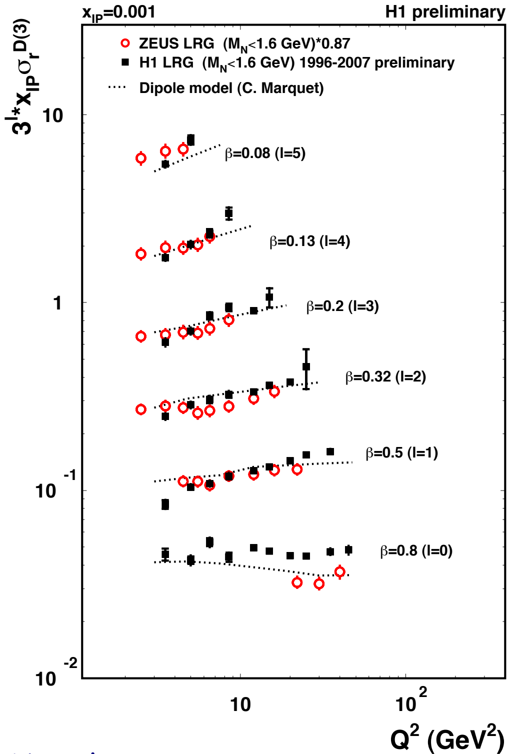
Backup



$\sigma_r^{D(3)}$ from LRG



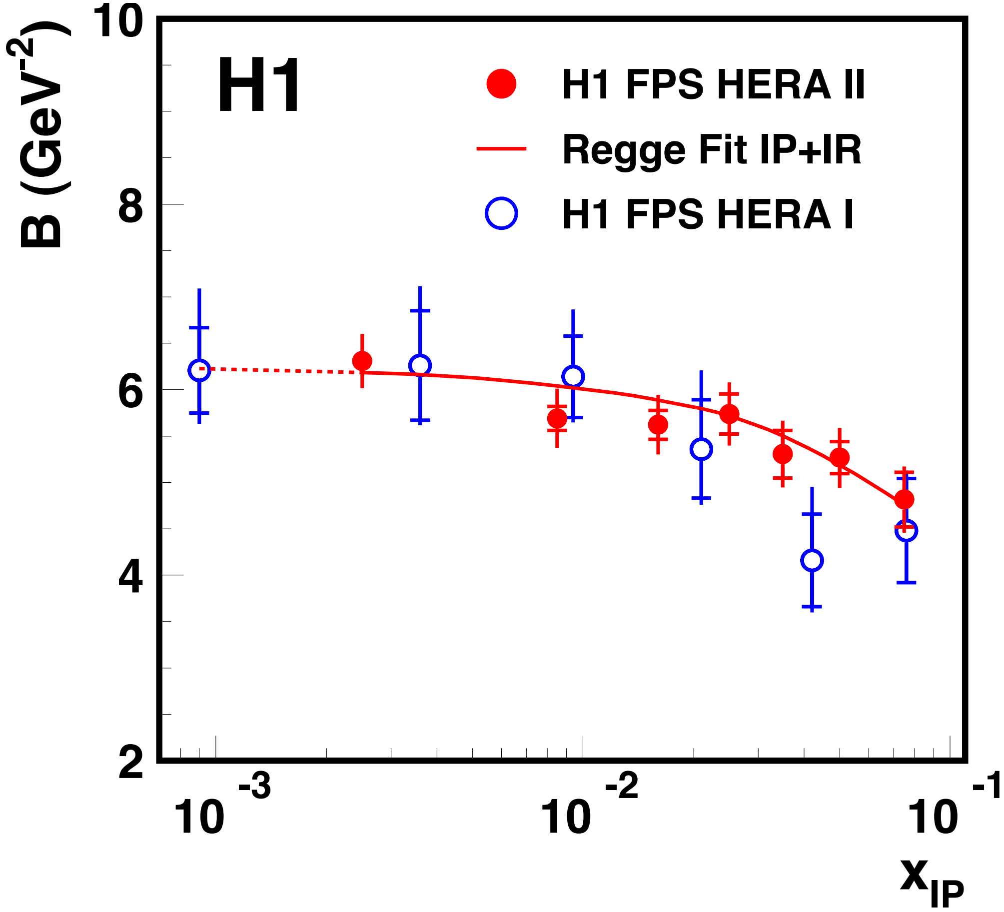




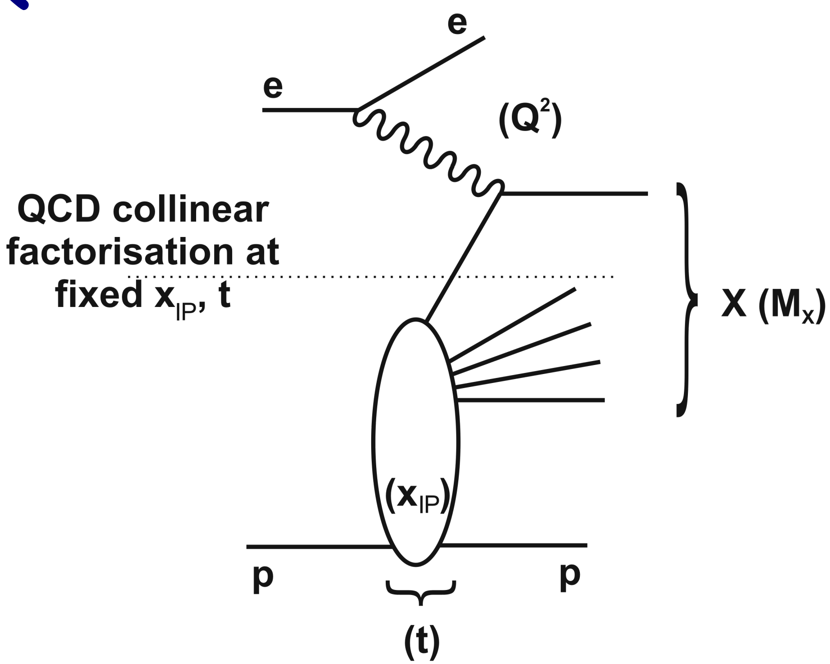
Inclusive diffractive measurements from HERA (LRG method)

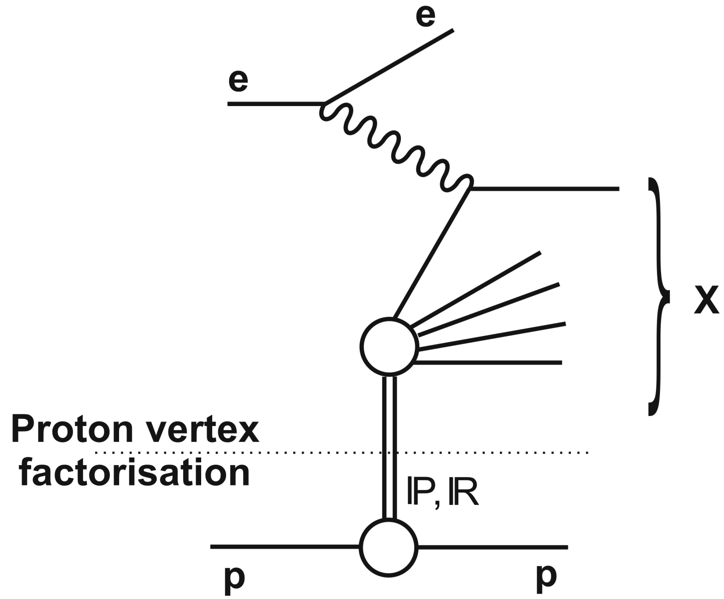
- H1 '97 [Eur. Phys. J. C48 (2006) 715]
- ZEUS '99/2000 [Nucl.Phys. B816 (2009) 1]
- H1 '99/2000
  H1 '99 minimum bias
  H1 HERA II } [H1prelim-10-013]

t-slope vs x_{IP}



QCD Factorization in Hard Diffraction





The QCD factorization theorem in diffractive DIS allows to write the diffractive cross section as a convolution of universal diffractive parton densities $f_i^D(x, Q^2, x_{IP}, t)$ and partonic cross sections

$$\sigma^D(\gamma^* p \rightarrow Xp) \sim f_i^D(x, Q^2, x_{IP}, t) \otimes \sigma_{\gamma * i}(x, Q^2)$$

Additionally, assuming Regge factorization, the diffractive parton densities are written as a term depending on x_{IP} (Pomeron flux) times the Pomeron parton densities

$$f_i^D(x, Q^2, x_{IP}, t) \sim f_{IP/p}(x_{IP}, t) \otimes f_{i/IP}^D(x/x_{IP}, Q^2)$$

⇨ Universal DPDFs apply in DIS when vacuum quantum numbers are exchanged

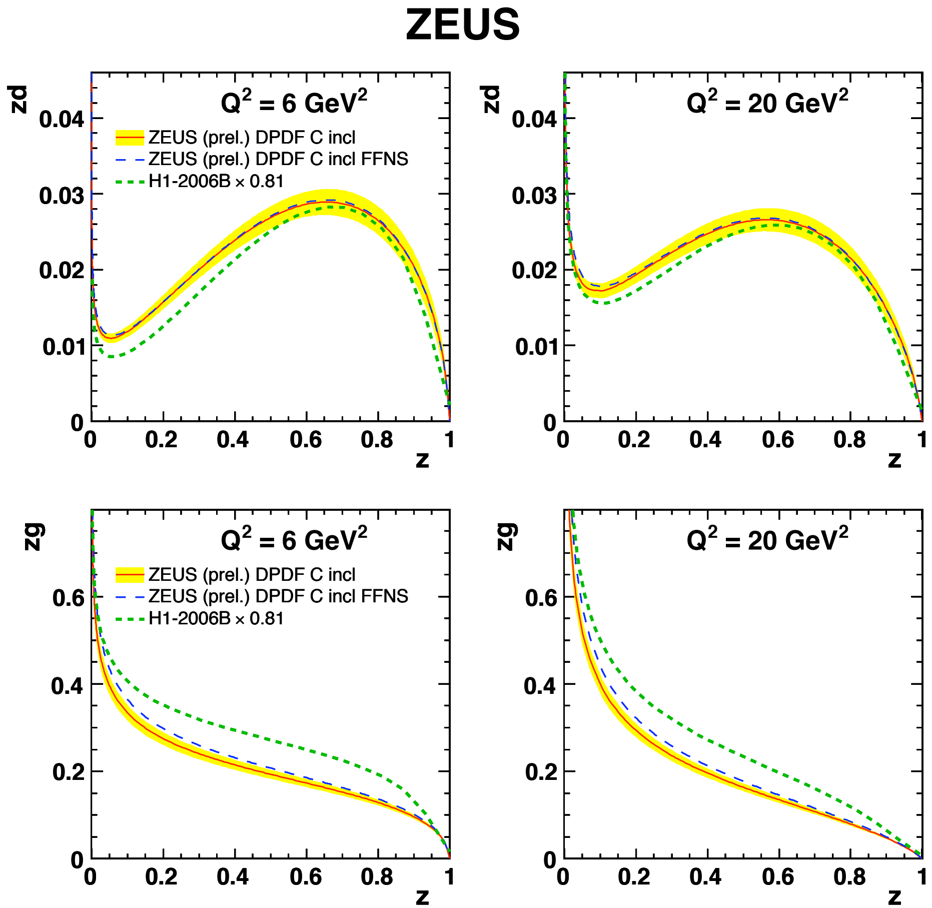
Diffractive PDFs from NLO Fits

NLO QCD Fits:
- parametrize quark singlet and gluon at fixed Q^2
- evolve with NLO DGLAP and fit

(z = momentum fraction of the diffractive exchange entering the hard scattering)

Diffractive Parton Density Functions are obtained fitting the H1 and ZEUS diffractive reduced cross sections (published data sets only)

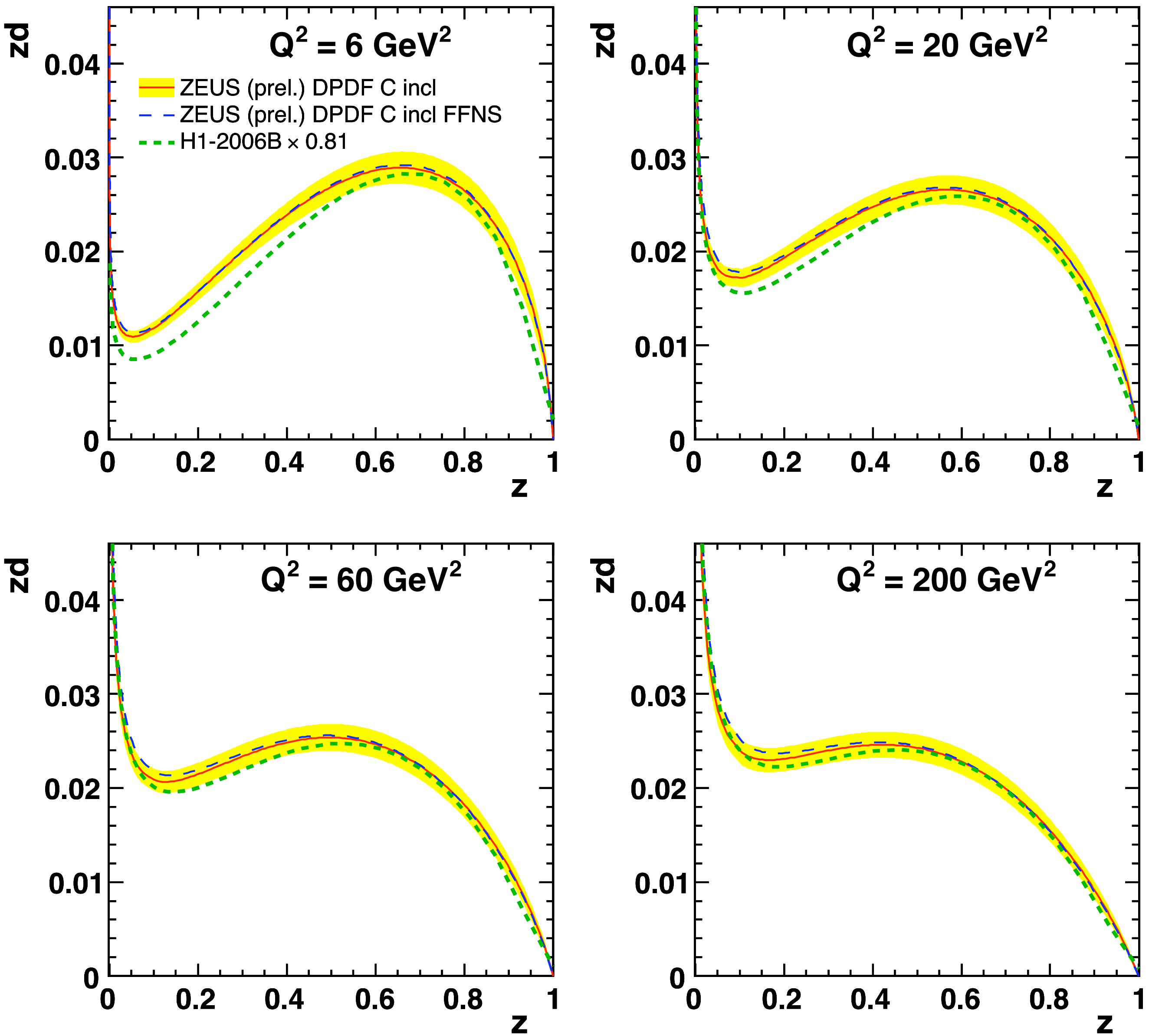
Differencies in the reduced cross sections are reflected in different parton distribution extraction



In order to obtain a precise and unique set of diffractive PDFs from HERA a deep and careful understanding of the H1 vs ZEUS results is needed

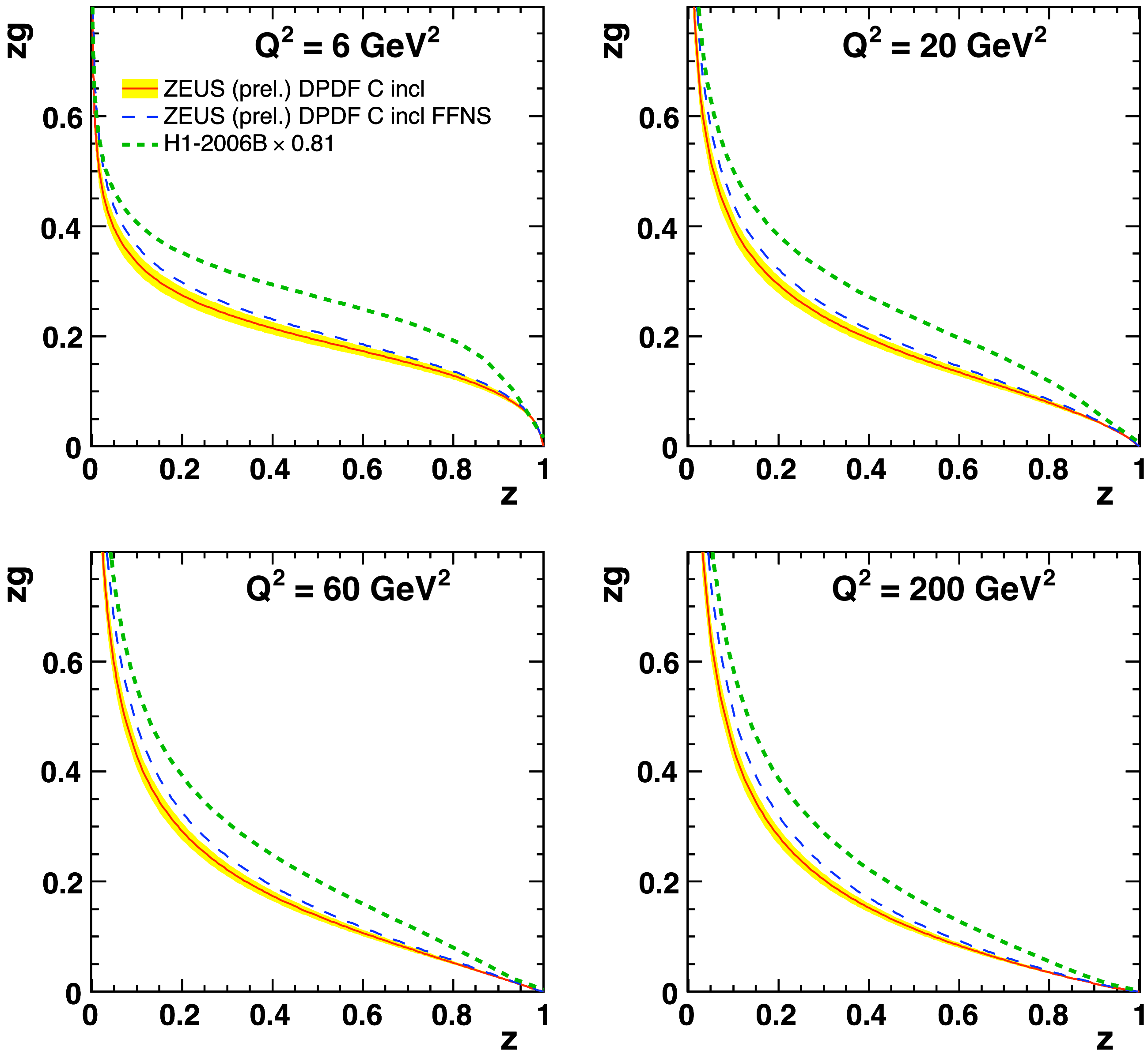
⇨ First attempt to combine H1 and ZEUS diffractive cross sections

ZEUS



zd
z
Q^2 = 6 GeV^2
Q^2 = 20 GeV^2
Q^2 = 60 GeV^2
Q^2 = 200 GeV^2
ZEUS (prel.) DPDF C incl
ZEUS (prel.) DPDF C incl FFNS
H1-2006B × 0.81
0 0.01 0.02 0.03 0.04
0 0.2 0.4 0.6 0.8 1

ZEUS


Q² = 6 GeV²
ZEUS (prel.) DPDF C incl
ZEUS (prel.) DPDF C incl FFNS
H1-2006B × 0.81
Q² = 20 GeV²
Q² = 60 GeV²
Q² = 200 GeV²
zg
z
0
0.2
0.4
0.6
0.8
1