

Diffractive Structure Functions from the H1 and ZEUS Experiments at HERA



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On Behalf of the H1 and ZEUS Collaborations

OUTLINE:

- Diffraction
- σ_r^D from LRG and (V)FPS/LPS
- Diffractive Parton Densities
- F_L^D
- Test QCD
- Summary



15th International QCD Conference - QCD 10 (25th anniversary)
28th June - 3rd July 2010 Montpellier (France)

Diffraction at HERA

H1 and ZEUS collected 0.5 fb^{-1} data:

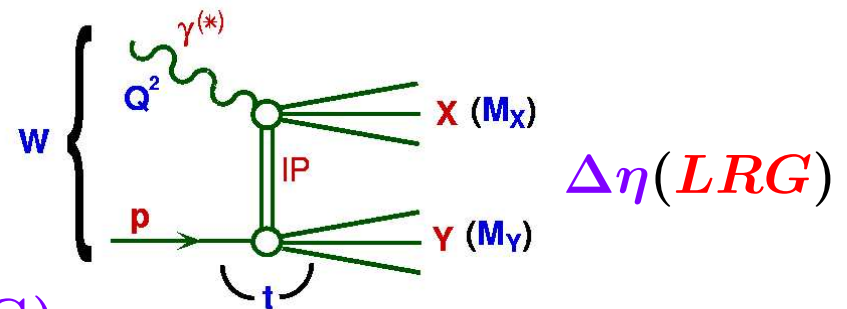
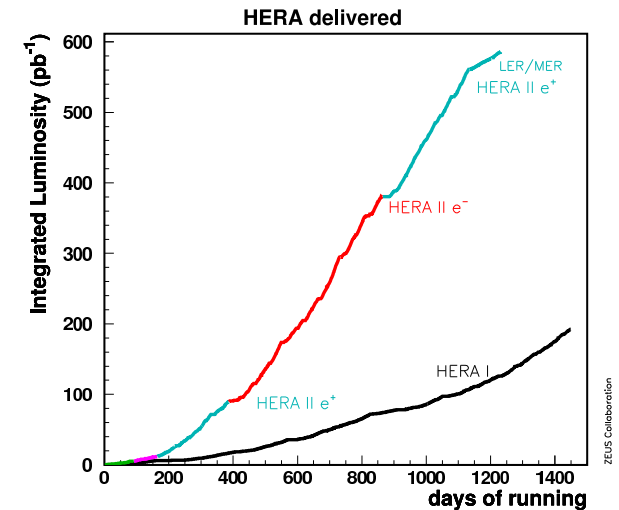
- ◇ good measurement accuracy
- ◇ new detailed results → test QCD assumptions and predictions
- ◇ H1prelim-10-011, H1prelim-10-012, H1prelim-10-017, NPB 816(2010) 1

Diffractive dissociation:

$$\mathcal{R}_{DD} = \frac{\sigma_{DD}}{\sigma_{Incl}} \simeq 10 - 15\%.$$

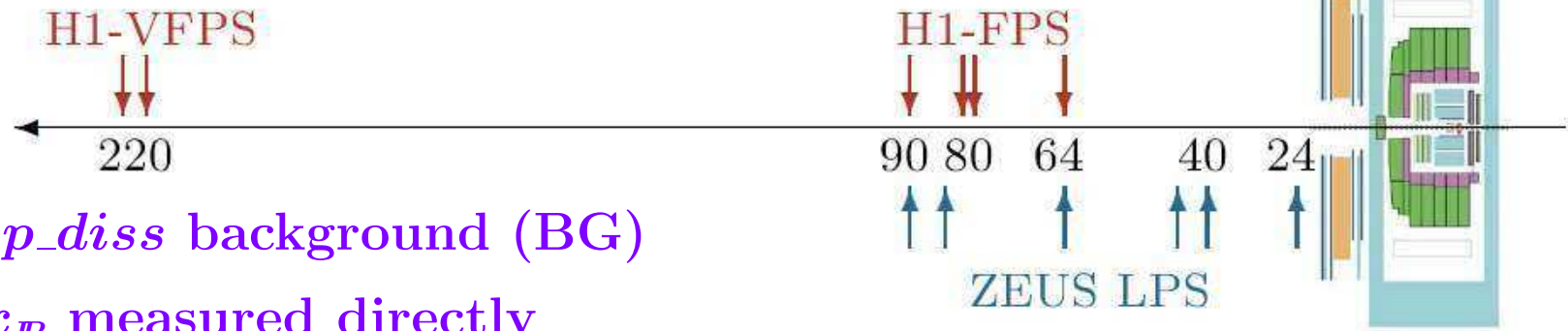
t -channel exchange (IP):

- ◇ vacuum quantum numbers
- ◇ colour singlet
- ◇ small momentum transfer t
- ◇ $M_Y = m_p \rightarrow$ elastic diffraction
 $M_Y > m_p \rightarrow$ proton dissociation (BG)



Signatures and Selection Methods

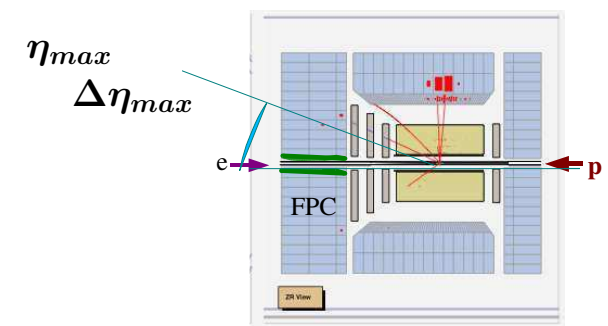
Proton Spectrometer (PS) method



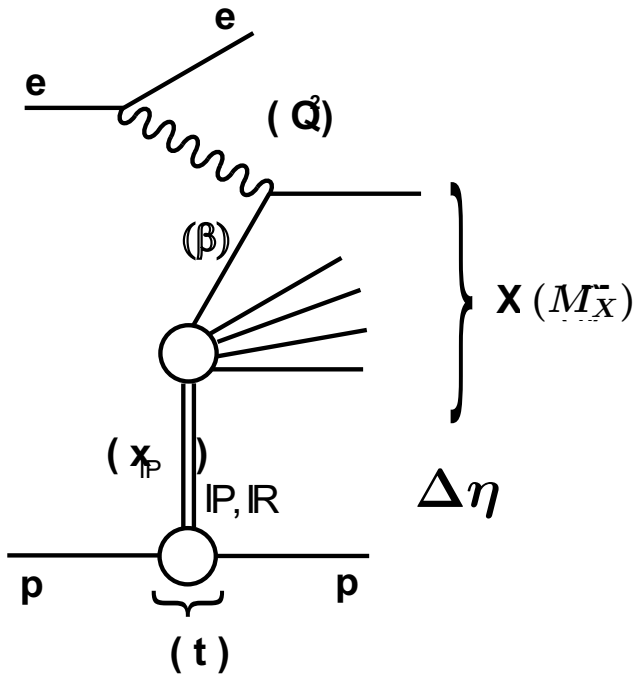
- ◇ no p_{diss} background (BG)
- ◇ t , x_P measured directly
- ◇ larger $x_P (< 0.1)$ accessible
- ◇ low Acc ($\sim 2\%$)

Large Rapidity Gap (LRG) method

- ◇ p_{diss} background ($\sim 15 - 20\%$)
- ◇ t not measured
- ◇ smaller $x_P (< 0.03)$ accessible
- ◇ higher Acc ($\sim 10\%$)



Kinematics and Cross Sections



W = invariant mass of γ^*p system

M_X = invariant mass of γ^*IP system

M_Y = invariant mass of proton (dissociative) system

x_P = fraction of proton momentum carried by IP

$\beta = x/x_P$ = fraction of IP momentum carried

by struck parton

t = (4-momentum² exchanged at p vertex)

typically: $|t| < 1 \text{ GeV}^2$

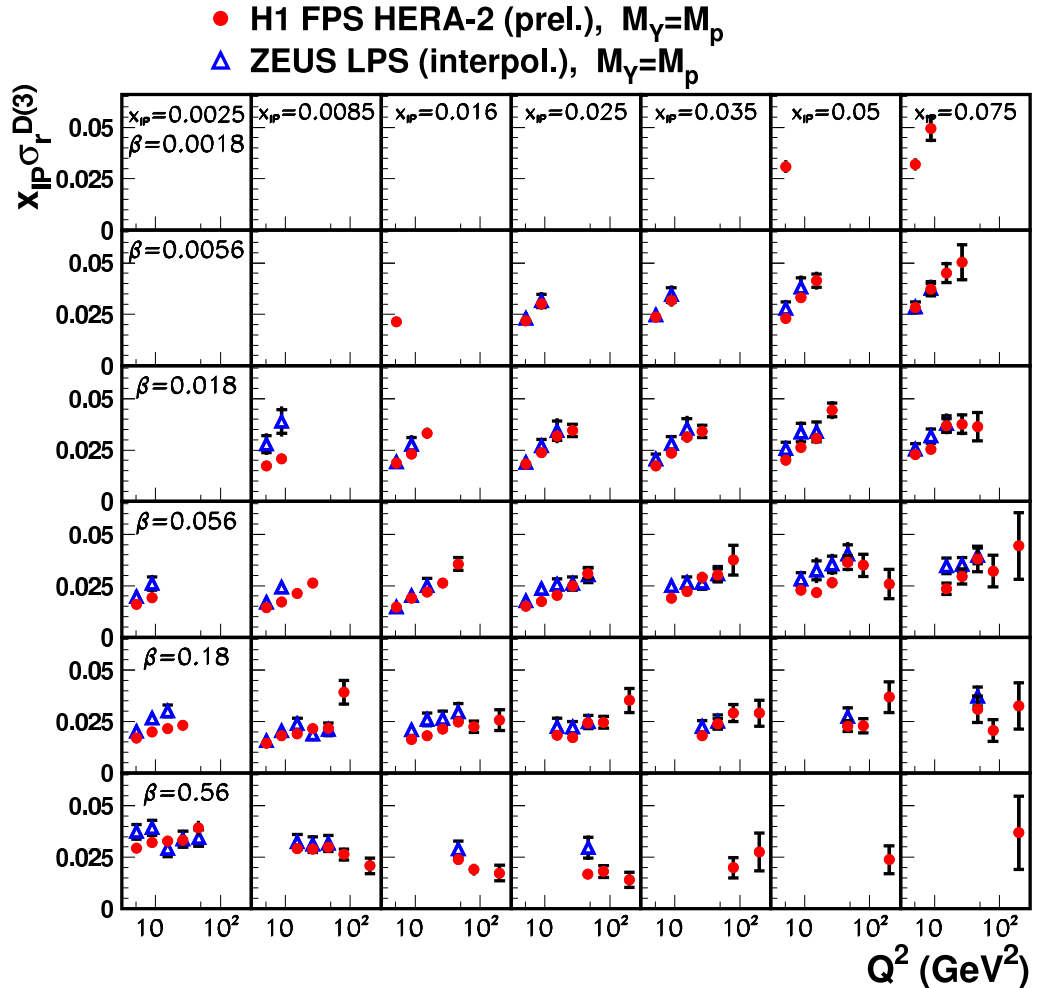
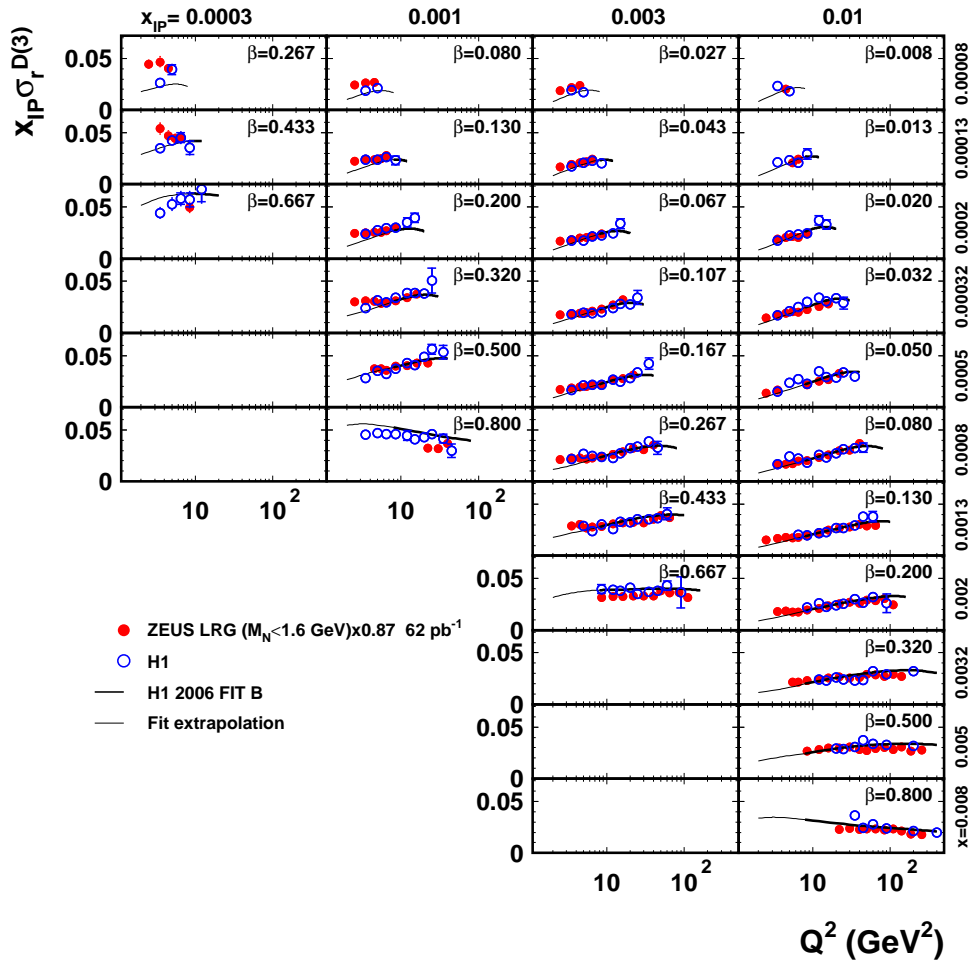
$$\frac{d^4\sigma_{ep \rightarrow eXp}}{d\beta dQ^2 dx_P dt} = \frac{2\pi\alpha^2}{\beta Q^4} Y_+ \left[F_2^{D(4)}(\beta, Q^2, x_P, t) - \frac{y^2}{Y_+} F_L^{D(4)}(\beta, Q^2, x_P, t) \right]$$

$$= \frac{2\pi\alpha^2}{\beta Q^4} Y_+ \sigma_r^{D(4)}(\beta, Q^2, x_P, t) \quad \leftarrow Y_+ = 1 + (1 - y)^2$$

$$\sigma_r^{D(3)}(\beta, Q^2, x_P) = \int \sigma_r^{D(4)}(\beta, Q^2, x_P, t) dt \quad \text{in case } t \text{ is not measured}$$

H1 vs ZEUS: Measurement Comparison

ZEUS

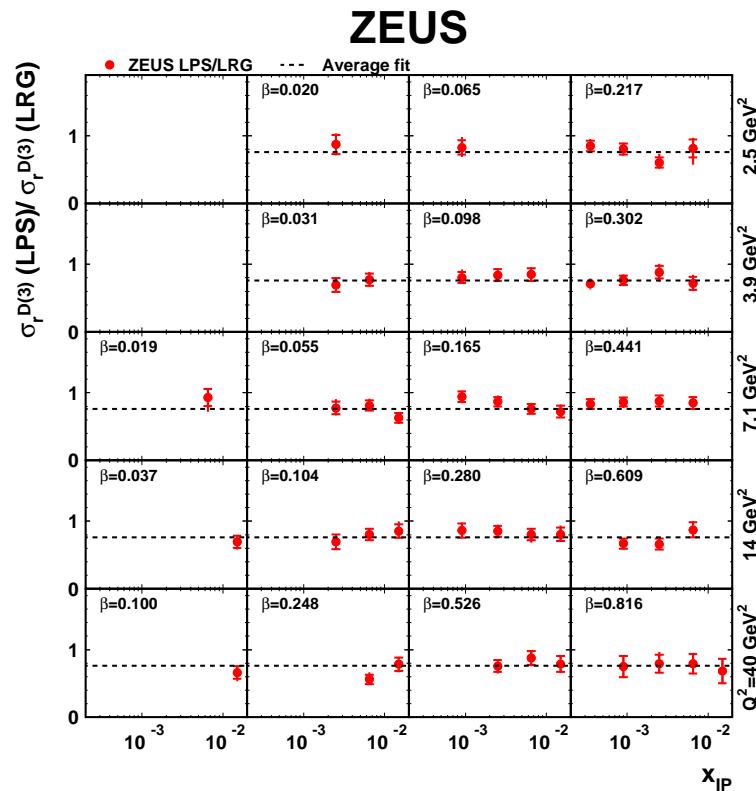


H1 and ZEUS: (V)FPS/LPS or LRG - agree (within normalisation uncertainty) → basis for the combination of H1-ZEUS inclusive diffractive data → reduction of experimental uncertainties

(V)FPS/LPS vs LRG: Measurement Comparison

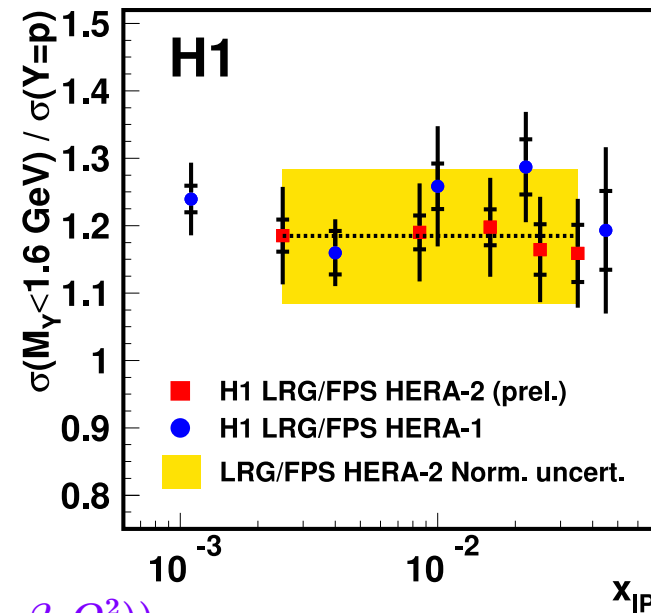
$$\sigma_r^{D(3)}(\text{LRG}) = \sigma_r^{D(3)}(\text{elastic}) + \sigma_r^{D(3)}(p_diss)$$

Ratio $\sigma_r^{D(3)}(\text{LRG})/\sigma_r^{D(3)}((\text{V})\text{FPS}/\text{LPS}) = 1 + \sigma_r^{D(3)}(p_diss)/\sigma_r^{D(3)}(\text{elastic})$:
 independent of $x_P, \beta, Q^2 \implies$ measure p_diss contribution:



LRG/LPS=1.32 ← LPS/LRG by ZEUS $0.76 \pm 0.01(\text{stat.})^{+0.03}_{-0.02}(\text{sys.})$

LRG/(V)FPS by H1 $1.20 \pm 0.01(\text{stat.}) \pm 0.05(\text{sys.}) \rightarrow (\text{V})\text{FPS}/\text{LRG}=0.83$



$$\sigma_r^{D(3)}(\text{LRG})/\sigma_r^{D(3)}((\text{V})\text{FPS}/\text{LPS}) \simeq 1.2 = \text{const in } (x_P, \beta, Q^2)$$

\implies p_diss and elastic diffraction similar

Methods & Measurements - different but agree (within normalisation uncertainty)

Factorisation of Diffractive Cross Sections

The structure of the **colour singlet** is studied within QCD:

◇ QCD hard scattering factorisation theorem: (at fixed $x_{\mathbb{P}}$ and t)

$$\sigma^D(\gamma^*p \rightarrow Xp) = \sum_{\text{parton } i} f_i^D(x, Q^2, x_{\mathbb{P}}, t) \otimes \sigma^{\gamma^*i}(x, Q^2)$$

σ^{γ^*i} : universal hard scattering cross section

f_i^D : universal partonic distribution functions (PDFs), obey evolution equations

Theorem's validity is proved for diffractive DIS by J.Collins

◇ Factorisation theorem relates:

$$F_{2/L}^{D(4)}(\beta, Q^2, x_{\mathbb{P}}, t) = \sum_i \int_{\beta}^1 \frac{dz}{z} C_{2/L,i} \left(\frac{\beta}{z} f_i^D(z, x_{\mathbb{P}}, Q^2, t) \right)$$

$\sigma_r^{D(3)} \leftarrow \text{NLO QCD Fits} \rightarrow \text{DPDFs}$

QCD fits to data \rightarrow sets of diffractive PDFs.

To reach this goal - DPDFs were modelled using phenomenological parameterisations

- ◇ Proton vertex factorisation assumed and \mathbb{P} and \mathbb{R} contributions accounted for:

$$f_i^D(\beta, Q^2, x_P, t) = f_{\mathbb{P},\mathbb{R}}(x_P, t) \cdot f_{i/\mathbb{P}}(\beta, Q^2) + f_{\mathbb{R}}(x_P, t) \cdot f_{i/\mathbb{R}}(\beta, Q^2)$$

\mathbb{P} and \mathbb{R} fluxes: $f_{\mathbb{P},\mathbb{R}}(x_P, t) = \frac{A_{\mathbb{P},\mathbb{R}} e^{B_{\mathbb{P},\mathbb{R}} t}}{x_P^{2\alpha_{\mathbb{P},\mathbb{R}}(t)-1}} \quad \alpha_{\mathbb{P},\mathbb{R}}(t) = \alpha_{\mathbb{P},\mathbb{R}}(0) + \alpha'_{\mathbb{P},\mathbb{R}} t$

- ◇ Distributions at Q_0 of QUARKS and GLUONS:

$$z f_{d,u,s}(z, Q_0^2) = A_q z^{B_q} (1-z)^{C_q} \quad z f_g(z, Q_0^2) = A_g z^{B_g} (1-z)^{C_g}$$

Lots of parameters to fit \rightarrow some were fixed

Fits to LRG data:

Fit H1 2006 DPDF A $C_g=0$

Fit H1 2006 DPDF B

Fits to LRG+LPS data:

Fit ZEUS DPDF S

Fit ZEUS DPDF C $B_g=C_g=0$

Fit to LRG DIS dijet data:

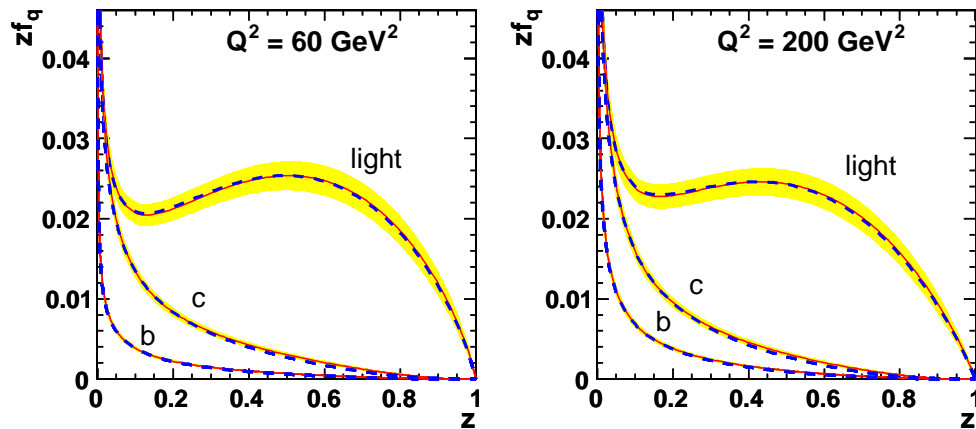
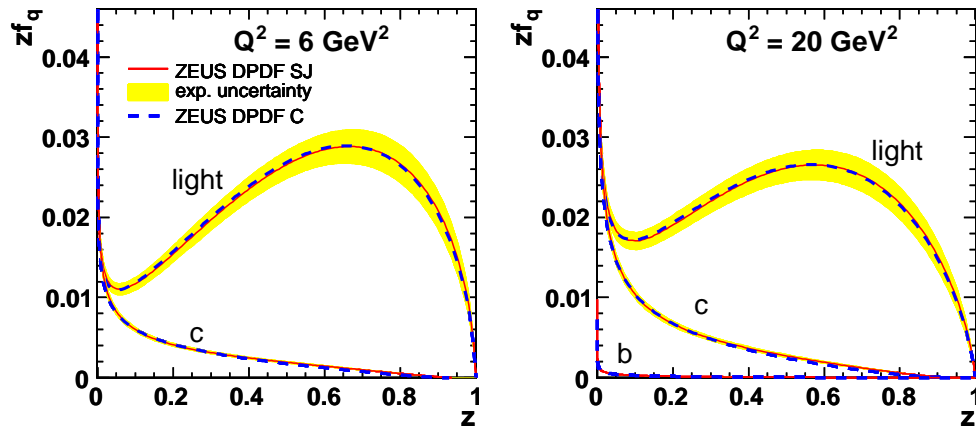
Fit H1 2007 Jets DPDF

Fit to LRG + LPS+ DIS dijet data:

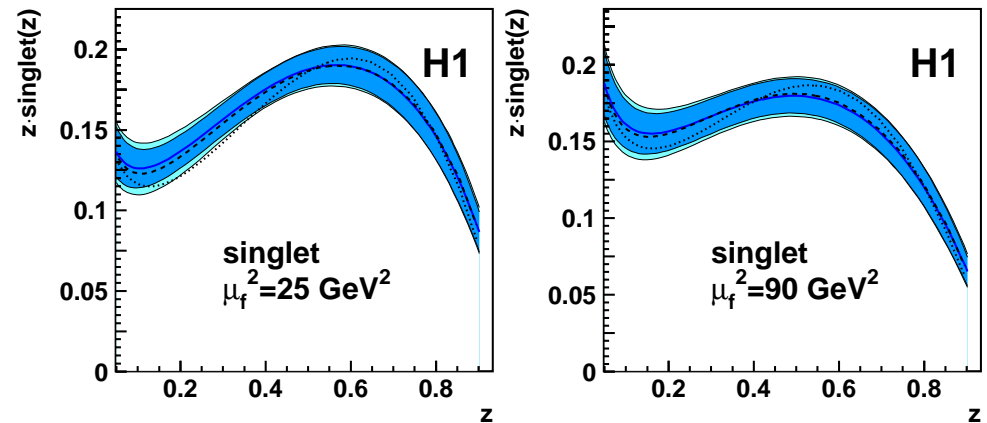
Fit DPDF SJ

Quark Distributions - from $\sigma_r^D(Q^2)$

ZEUS



- H1 2007 Jets DPDF
- exp. uncertainty
- exp. + theo. uncertainty
- ⋯ H1 2006 DPDF fit A
- ⋯ H1 2006 DPDF fit B



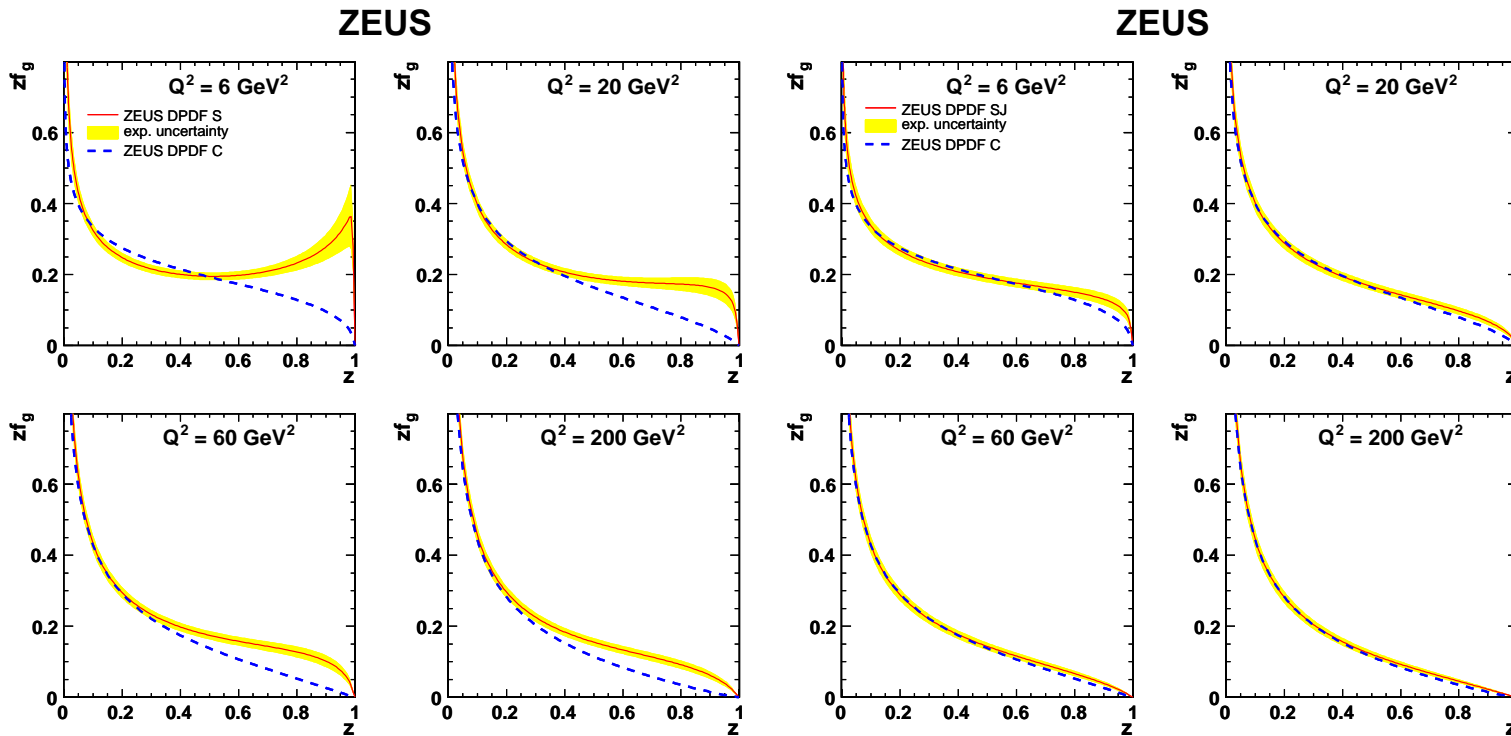
$f_q(z)$ for all Fits - similar

Gluon Distributions

Fit LRG+LPS+DIS dijet

- fits well to dijet data
- decreased uncertainties

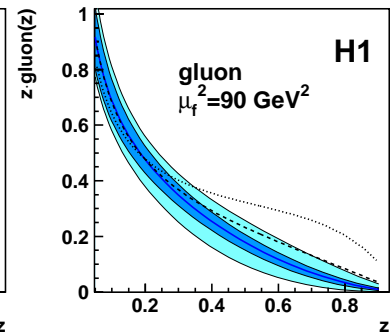
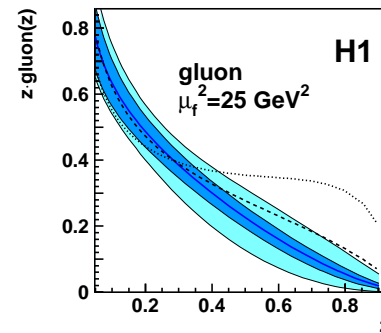
comparable precision for f_g and f_q



different Fits -
very different f_g at $z \rightarrow 1$

large discrepancy -
low sensitivity to f_g

- H1 2007 Jets DPDF
- exp. uncertainty
- exp. + theo. uncertainty
- H1 2006 DPDF fit A
- H1 2006 DPDF fit B

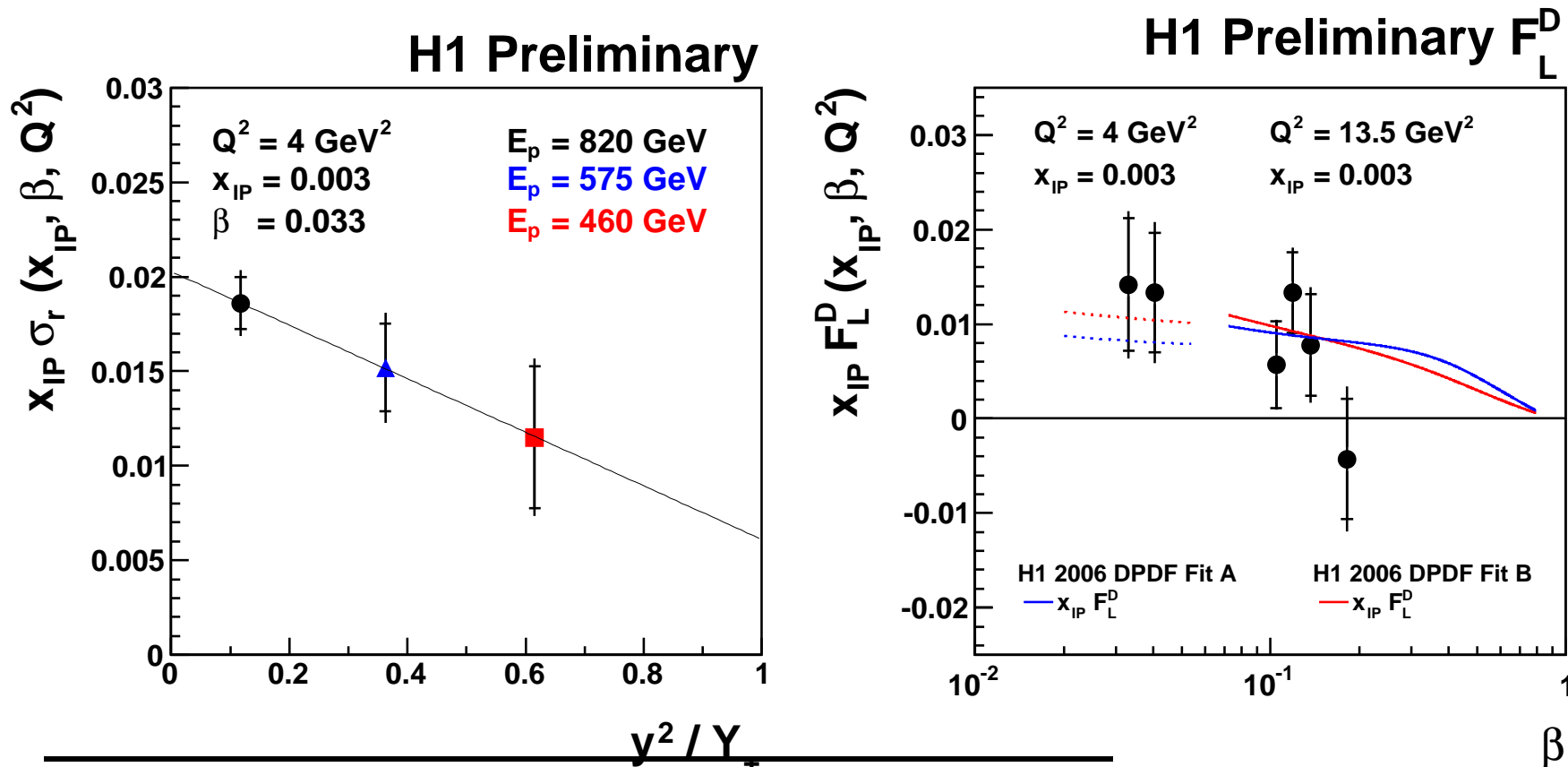


First Measurement of F_L^D

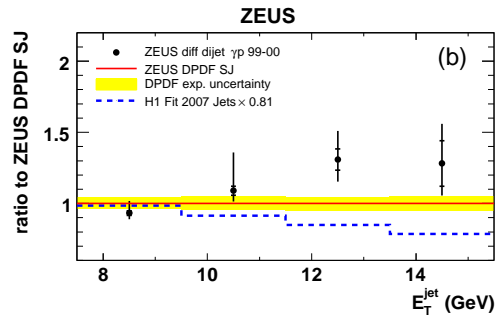
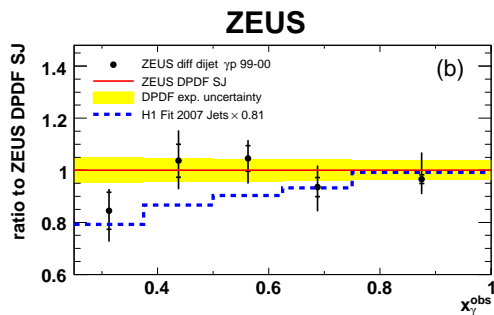
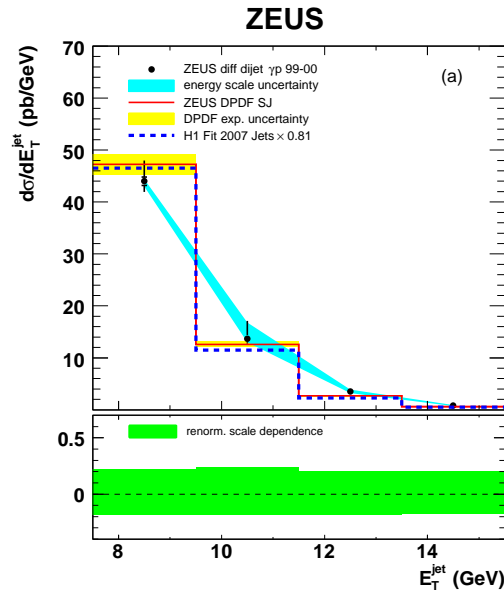
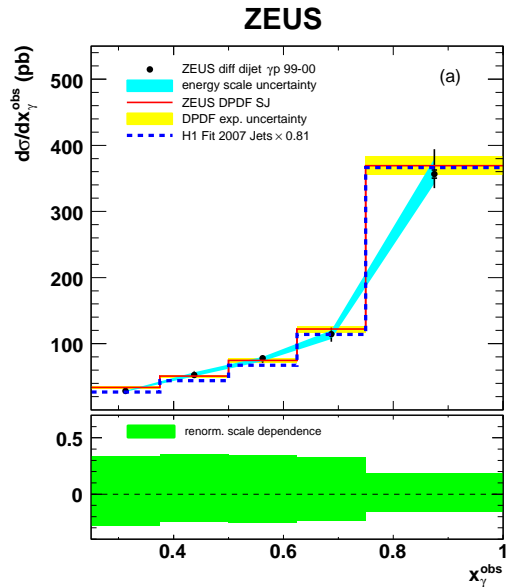
$$\sigma_r^D\left(\frac{y^2}{Y_+}\right) = F_2^D - \frac{y^2}{Y_+} F_L^D \quad F_L^D \sim \alpha_s \cdot g(x) \leftarrow \text{direct measurement of } g(x)$$

Data at 3 proton energies used: 920, 460 and 575 GeV

→ At fixed Q^2 and x_{IP} , high y corresponds to low β



Test QCD: diffractive dijet PhP



Fits

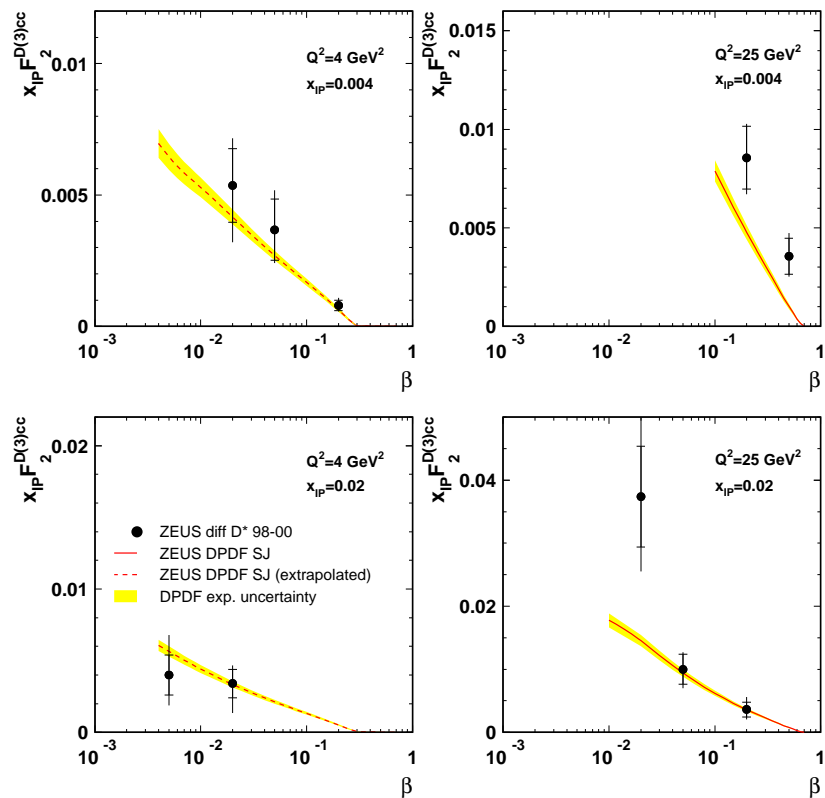
LRG+LPS+DIS dijet
H1 2007 Jets

- fit well to diffractive
dijet PhP data

Ratios of
DATA/NLO QCD ~ 1
no suppression

Test QCD: diffractive charm production

ZEUS



Fit

LRG+LPS+DIS dijet

- fit well to charm diffractive
DIS data

SUMMARY

- 15 years of HERA operation → detailed studies of diffractive reactions
- Consistency reached between different experiments, methods and data sets
- measured DPDFs, corresponding to elastic diffraction (single-diffractive reaction)
- DPDFs measured with higher accuracy, accounting for dijet data → predictions for other processes possible
- predictions for diffractive charm production and diffractive dijet photoproduction agree with measured cross sections
- First measurement of F_L^D in agreement with DGLAP QCD predictions