$D^*(2010)^{\pm}$ and Dijet Diffractive Cross sections from the ZEUS experiment at HERA

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OUTLINE:

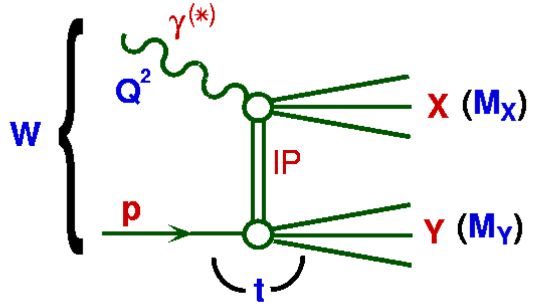
- Introduction
- Dijets in Diffractive DIS
- Dijets in Diffractive Photoproduction
- Diffractive Photoproduction of $D^*(2010)$
- Result Comparison
- Summary

Workshop Diffraction 2006

Milos Island, Greece, September 5 - September 10 - 2006

Introduction

Diffraction: mediated by diffractive exchange ($I\!P$)



∇ quantum numbers of vacuum

∇ no colour transfer

∇ small momentum transfer in t-channel

⟹ observed as final states with large rapidity gaps (LRG) , low M_X and sometimes $M_Y = m_p$

What is $I\!P$?

∇ Object ?

- $I\!R$ egge trajectory
- Resolved $I\!P$ model ($dPDF'$s by H1 and ZEUS)

∇ pQCD:

- $2g$-exchange model
- $dPDF'$s (A.Martin, M.Ryskin, G.Watt)

Introduction

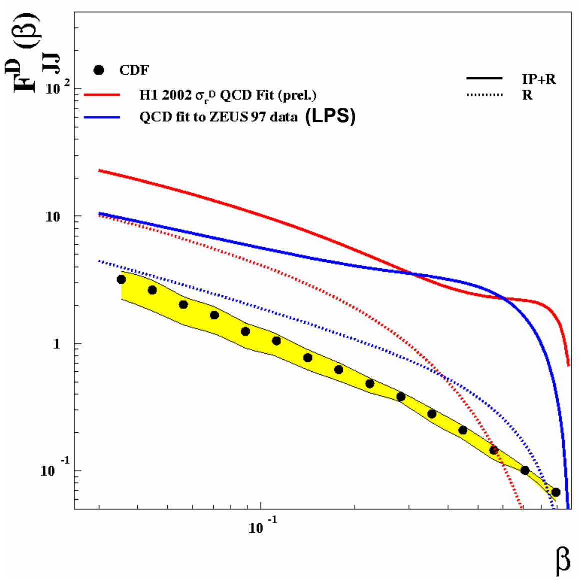
The structure of the colour singlet is studied within QCD:

▽ QCD hard scattering factorisation theorem: (at fixed $x_{I\!P}$ and t)

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

$\sigma^{\gamma^* i}$: 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



CDF dijet rates: 5-10 times lower than expected ones using Diffractive PDF's from HERA

What this discrepancy may indicate:

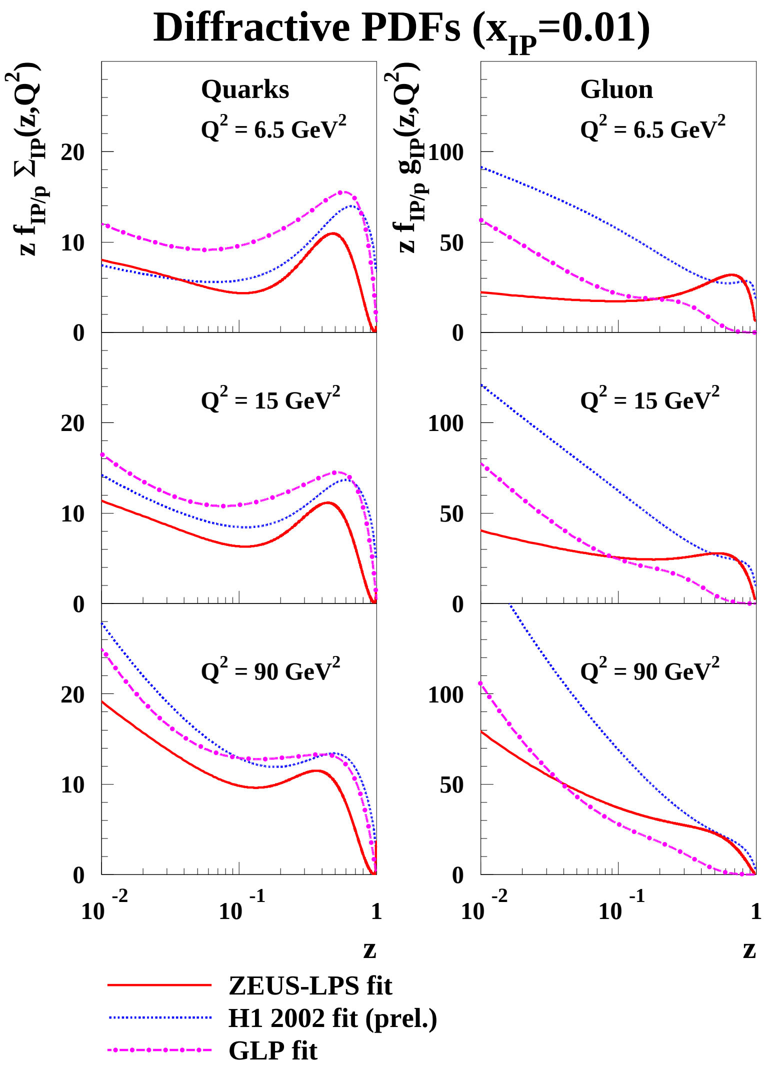
Diffractive PDF′s not universal ?

Factorization is not valid ?

A.B.Kaidalov et al. predict suppression factor $S_{res} = 0.34$ for resolved photon at HERA

Introduction

Diffractive PDFs measurement results by H1 and ZEUS



Methods of data selection:

LRG - H1 LRG Fits

Proton Tag. - ZEUS LPS Fit

M_X - GLP Fit

$g_{I\!P}(z)$ strongly differ:

in shapes

in normalization

Discrepances may reflect differences :

in fitting procedures

in constraints on dPDFs

in Q^2 dependence of data sets

Uncertainty of each individual dPDF is unknown and their spread is, probably, the current best estimate of their uncertainties

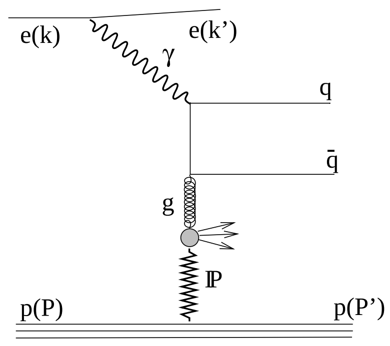
Introduction

Does diffraction obey QCD hard scattering factorisation ?

∇ Compare lower $Q^2 < 1$ GeV^2 (PhP) and higher $Q^2 > 1$GeV^2(DIS):
Expected to hold for DIS and direct PhP
to fail for resolved PhP (Probably)

∇ Test $dPDF's$ universality with identified hadronic final states

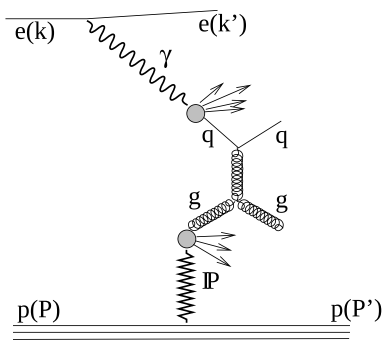
$x_\gamma^{obs} \sim 1.0 (> 0.75)$



(a)

direct PhP, DIS

$x_\gamma^{obs} < 1.0 (< 0.75)$



(b)

resolved PhP

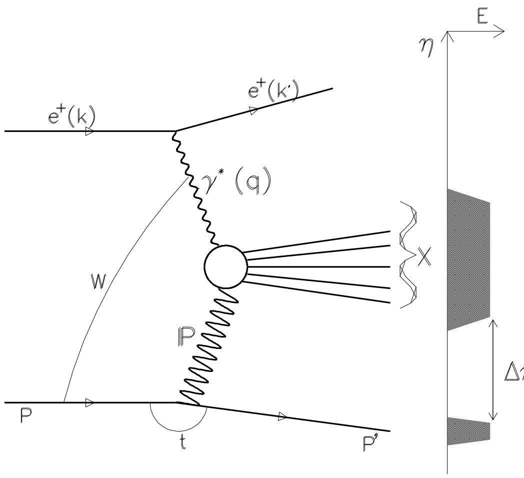
Semi-Inclusive:

QQ
DiJets
etc.

Various hard scales: Q^2, P_T, m_Q
Sensitivity to gluonic exchanges

Kinematics

$e(k) + p(p) \rightarrow e'(k') + X + p'(p')$ proceeds via $\gamma^*(q) + I\!P(P_{I\!P}) \rightarrow X$:
X may be $D^* X'$, $Jet_1 Jet_2 X'$, etc.



$$Q^2 = -q^2$$

PhP $Q^2 < 1$ GeV^2

DIS $Q^2 \gtrsim 1$ GeV^2

$$M_X^2 = (P_{I\!P} + q)^2$$

$$x_{I\!P} = \frac{P_{I\!P} \cdot q}{p \cdot q} = \frac{M_X^2 + Q^2}{W^2 + Q^2},$$

$x_{I\!P} \simeq \frac{M_X^2}{W^2}$ in PhP

$\beta = \frac{Q^2}{Q^2 + M_X^2}$ (for DIS)

$$Z_{I\!P}^{obs} = \frac{\sum_{jets} E_T^{jet} \exp^{\eta_{jet}}}{2 \cdot x_{I\!P} \cdot E_p}$$

$$x_\gamma^{obs} = \frac{\sum_{jets} E_T^{jet} \exp^{-\eta_{jet}}}{2 \cdot y \cdot E_e}$$

$$\Delta\eta \;, \quad \eta = -ln(tan(\theta/2))$$

Dijet production in diffractive deep-inelastic scattering

- ∇ $ep \rightarrow eXp \rightarrow eJ_1J_2X'p$ 98 − 00 *data*
- ∇ $5 < Q^2 < 100$ GeV^2, $100 < W < 250$ GeV, e^+/e^- detected
- ∇ rapidity gap method

$\Longrightarrow x_{I\!P} < 0.03$

Different models were compared to the measured cross sections:

NLO QCD calculations:(DISENT):

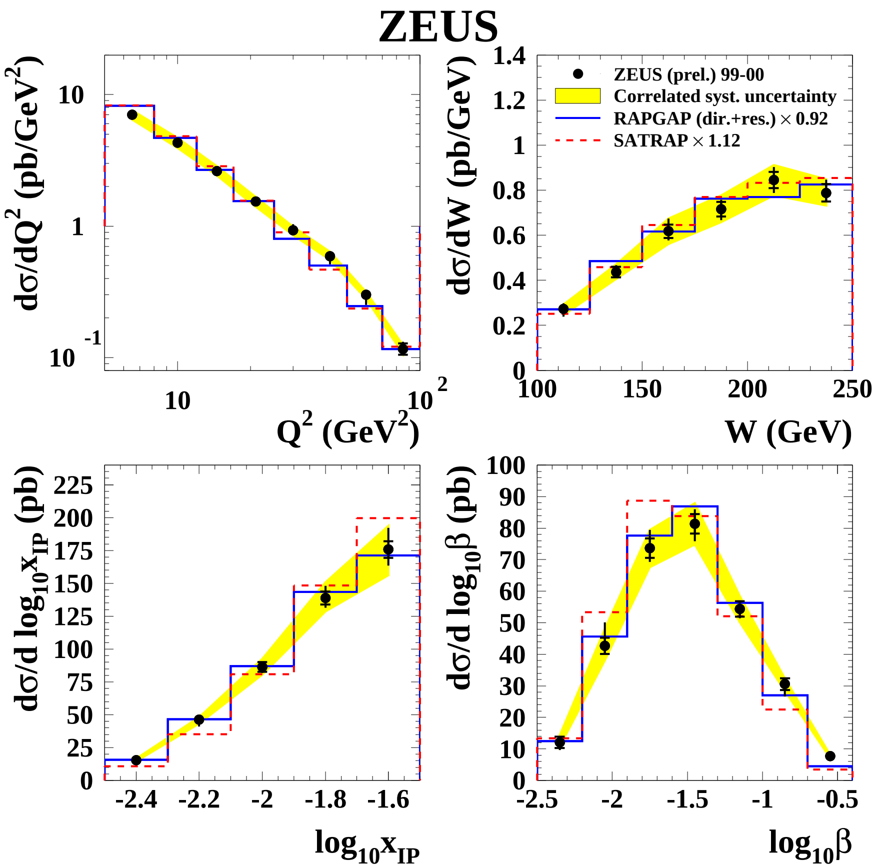
- ∇ Diffractive $PDF's$
  - H1 2002 Fit(prel.)
  - ZEUS_LPS Fit
  - GLP Fit

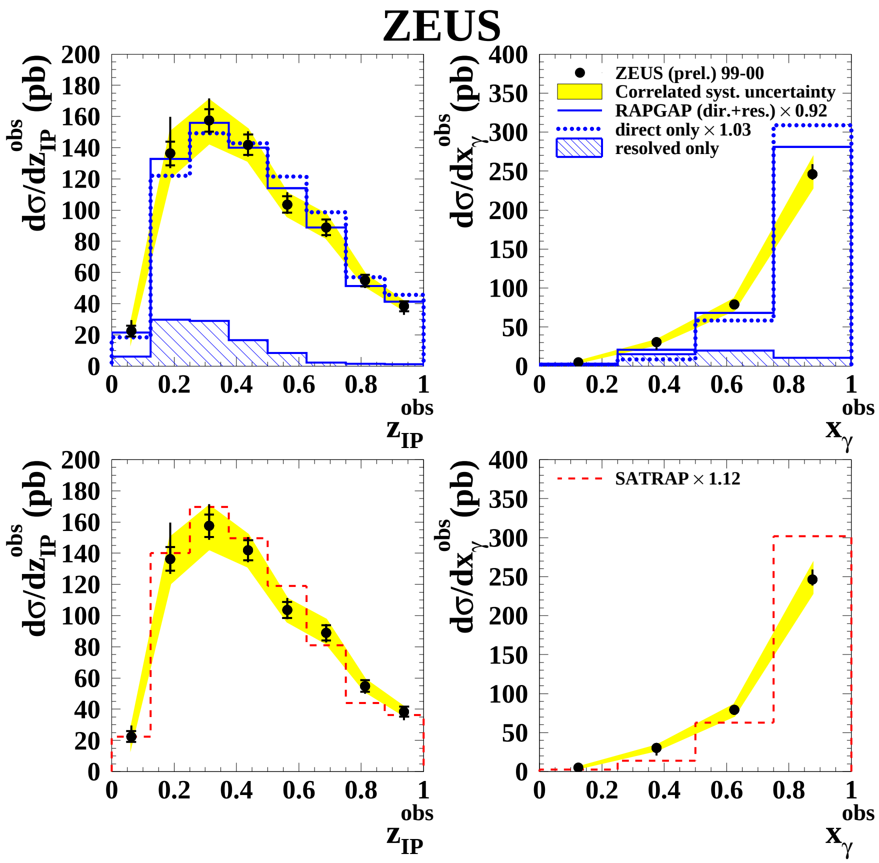
LO QCD calculations:($LO\ MC's$):

- ∇ RAPGAP
  - H1 Fit 2 LO
- ∇ SATRAP
  - Saturation model

DiJet Production in Diffractive Deep-Inelastic Scattering

LO MC



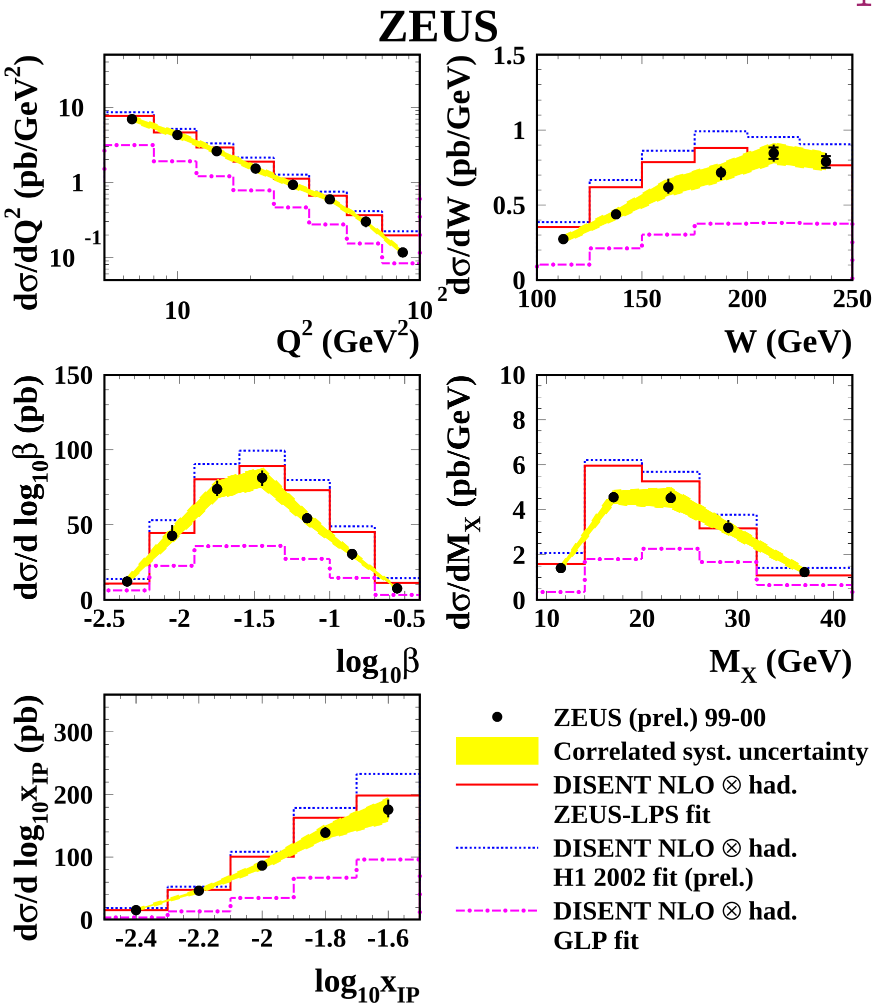


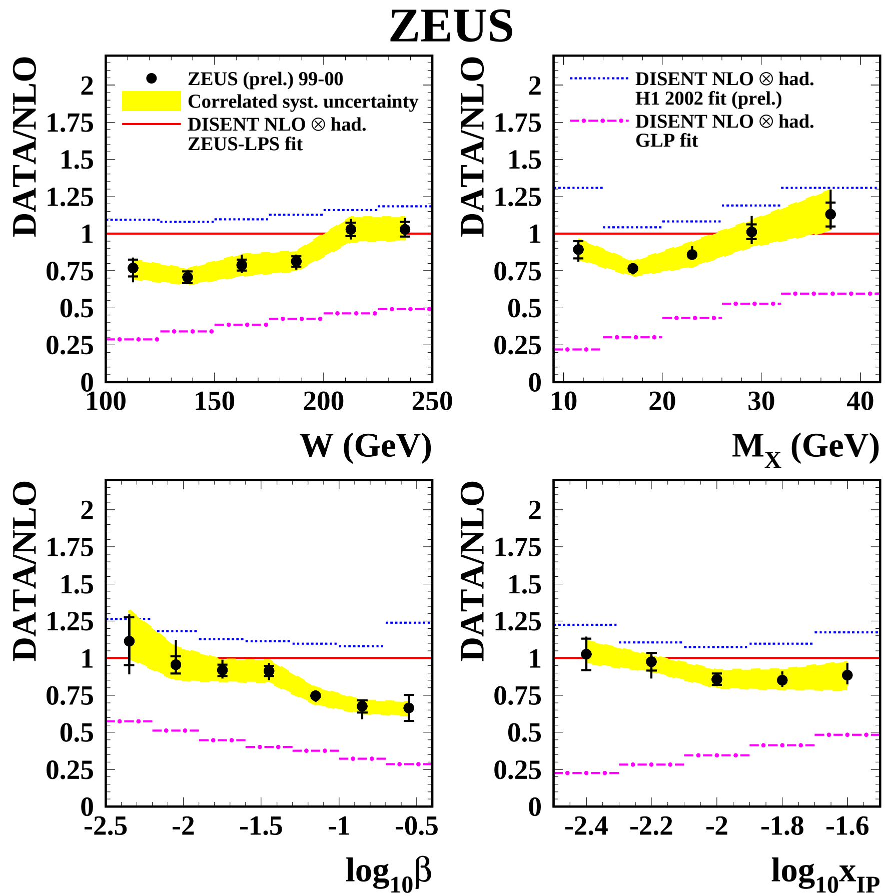
and

Both LO MC (dir+res) consistent with data in shapes and normalization
Resolved photon contributions essential (though small) for a better shape agreement with data.

DiJet Production in Diffractive Deep-Inelastic Scattering

NLO





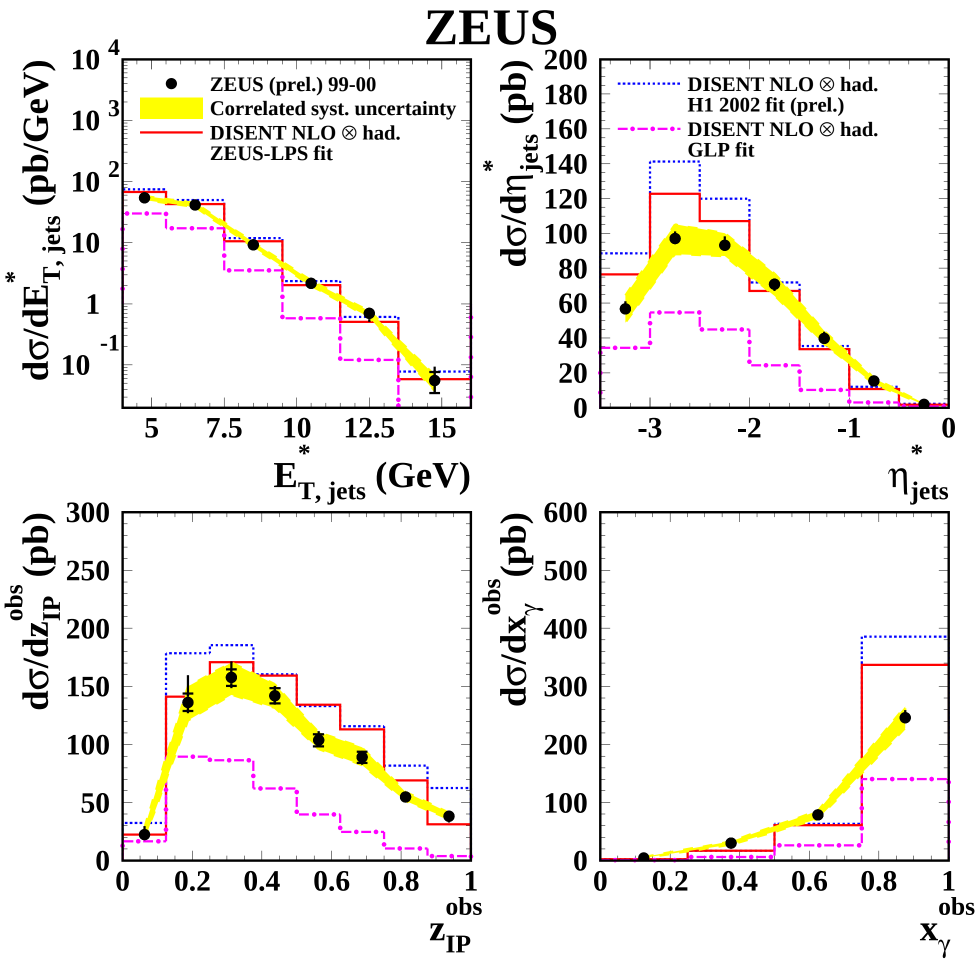
ZEUS LPS and H1 2002(prel.):

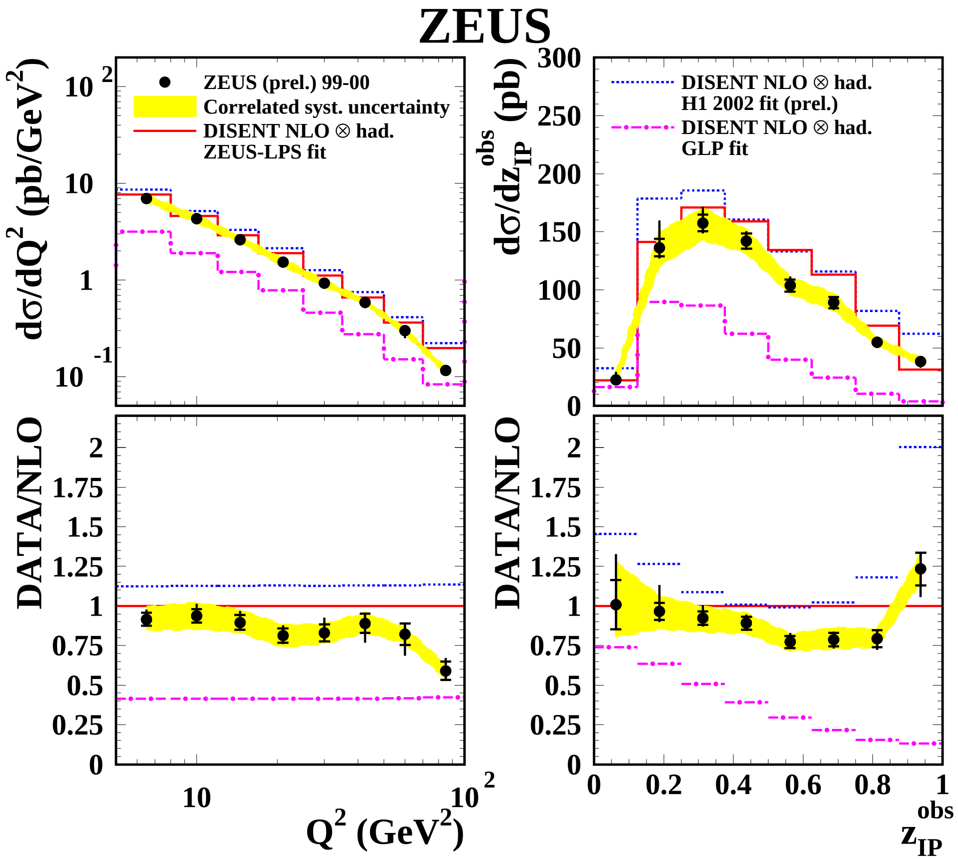
Data Shapes and Normalization reproduced

GLP : **Shapes and Normalization disfavoured by the data**

Dijet Production in Diffractive Deep-Inelastic Scattering

NLO





Wide spread in predictions due to uncertainties in dPDFs

⇒ difficult to draw a conclusion on QCD factorisation

High precision data ⇒ be included in global fits to constrain $g_{I\!P}$

Diffractive Photoproduction of DiJets

- ∇ $ep \to eXp \to eJ_1J_2X'p$ 99 − 00 *data*
- ∇ $Q^2 < 1.0$ GeV^2, $0.20 < y < 0.85$, no e^+ detected
- ∇ rapidity gap method

$\Longrightarrow x_{I\!P} < 0.025$

Different models were compared to the measurement:

NLO QCD calculations
:(by Klasen and Kramer):

- ∇ $dPDF's$
  - H1 2002 Fit(prel.)

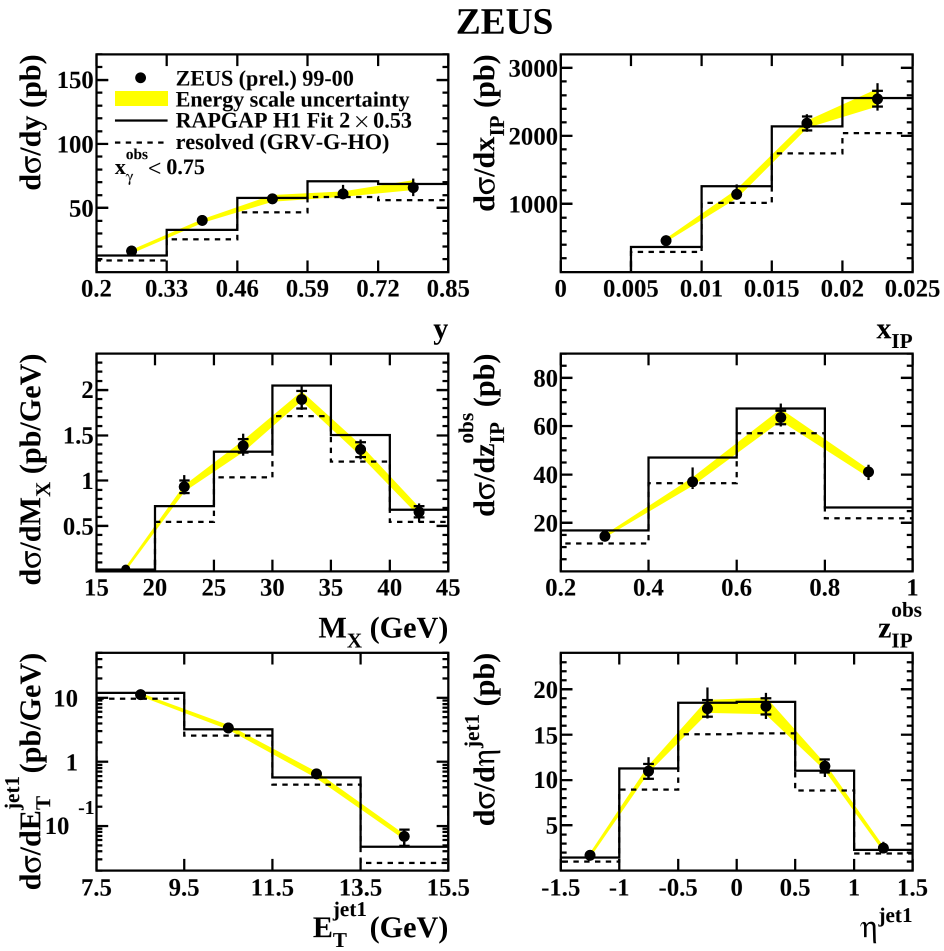
LO QCD calculations
:($RAPGAP\ MC$):

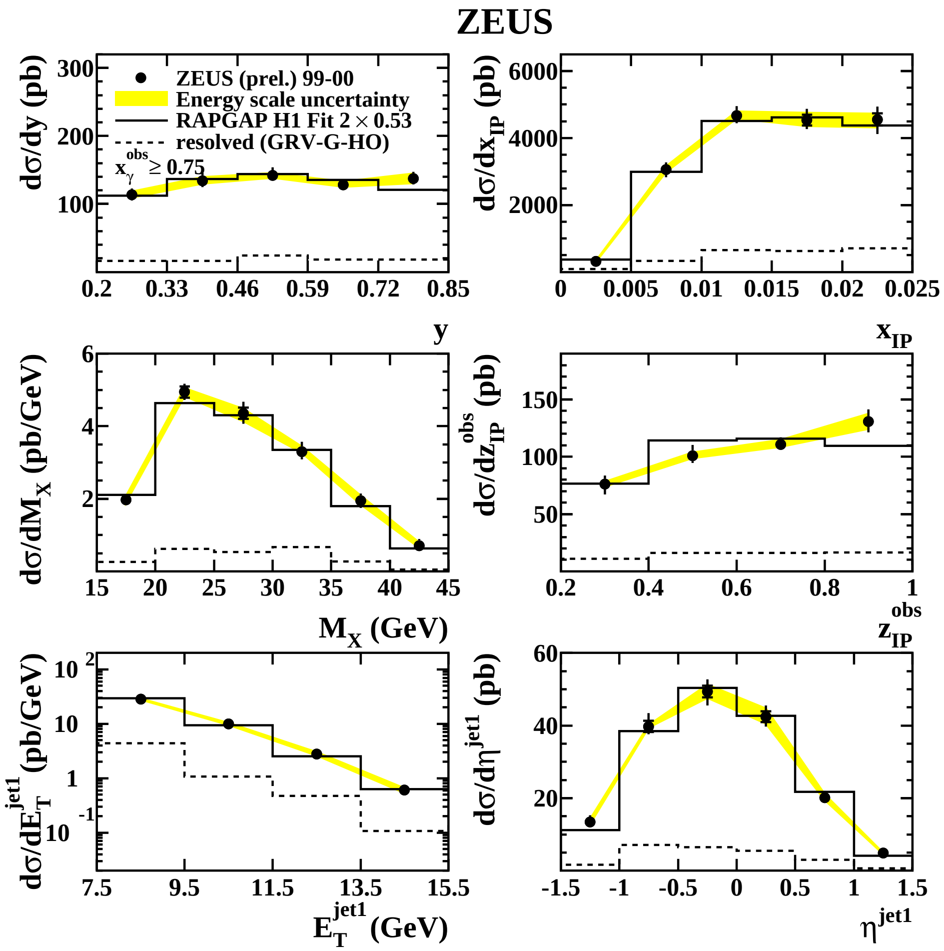
- ∇ $dPDPF's$
  - H1FIT2 LO

- ∇ ΔY survival probability factor
  $S_{res} = 1$ *or* 0.34 (R - on plots)

Diffractive Photoproduction of DiJets

$x_\gamma^{obs} < 0.75$ LO $x_\gamma^{obs} > 0.75$

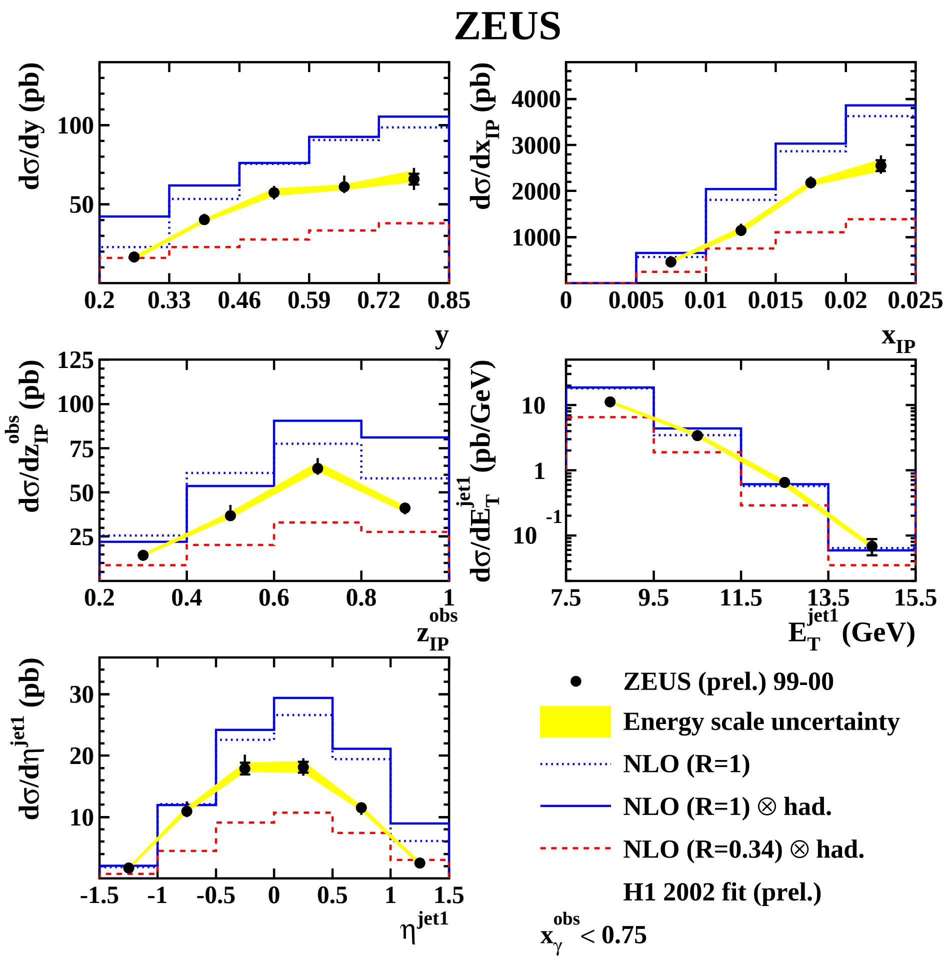


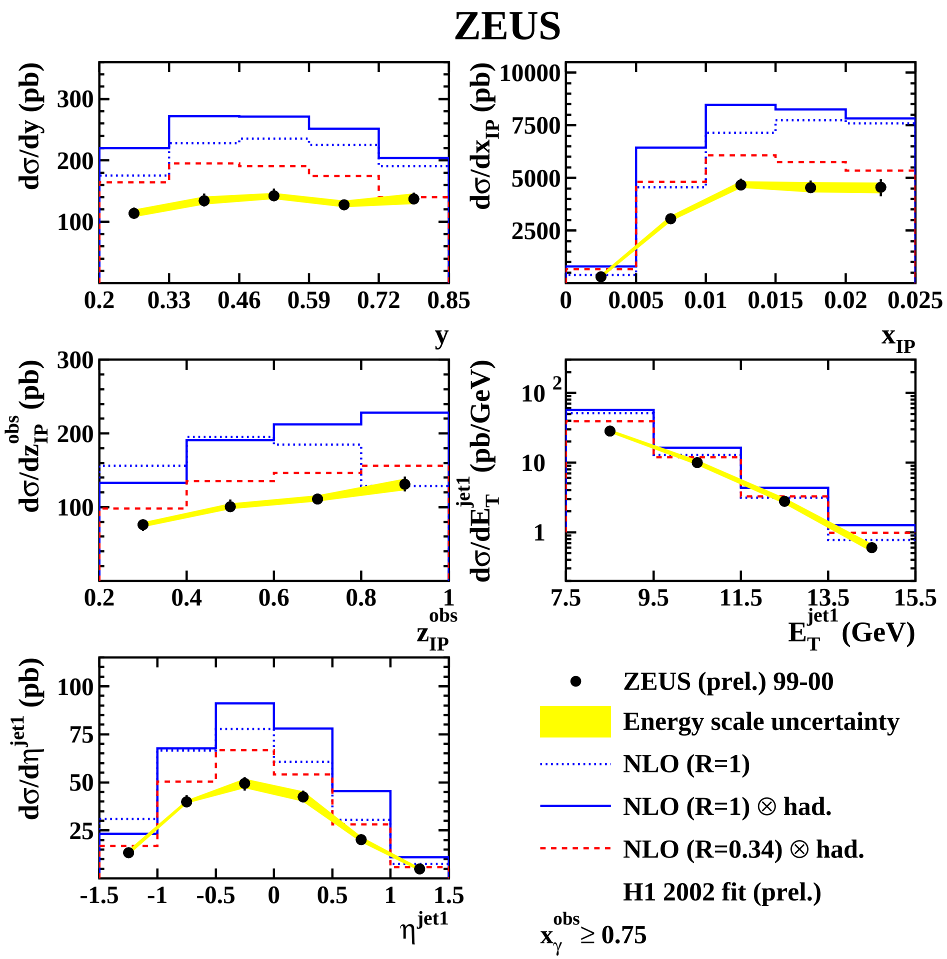


LO MC H1FIT2: consistent with data in shapes for full range of x_γ^{obs}

Diffractive Photoproduction of DiJets

$x_\gamma^{obs} < 0.75$ **NLO** $x_\gamma^{obs} > 0.75$



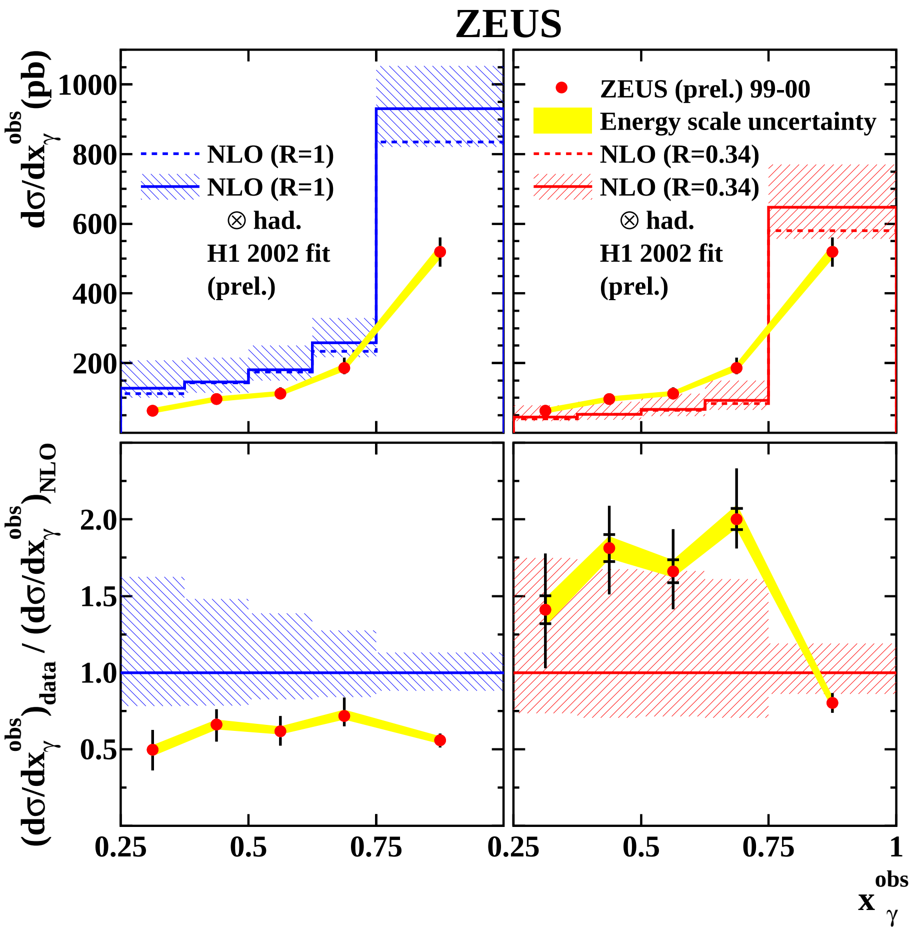


Shapes are reproduced. Calculations with $S_{res} = 1.0$(too high) and $S_{res} = 0.34$(too low) do not reproduce normalization of data.

Diffractive Photoproduction of DiJets

$S_{res} = 1.0$ | NLO | $S_{res} = 0.34$

No suppression | RES suppressed



NLO - above DATA | NLO - below DATA

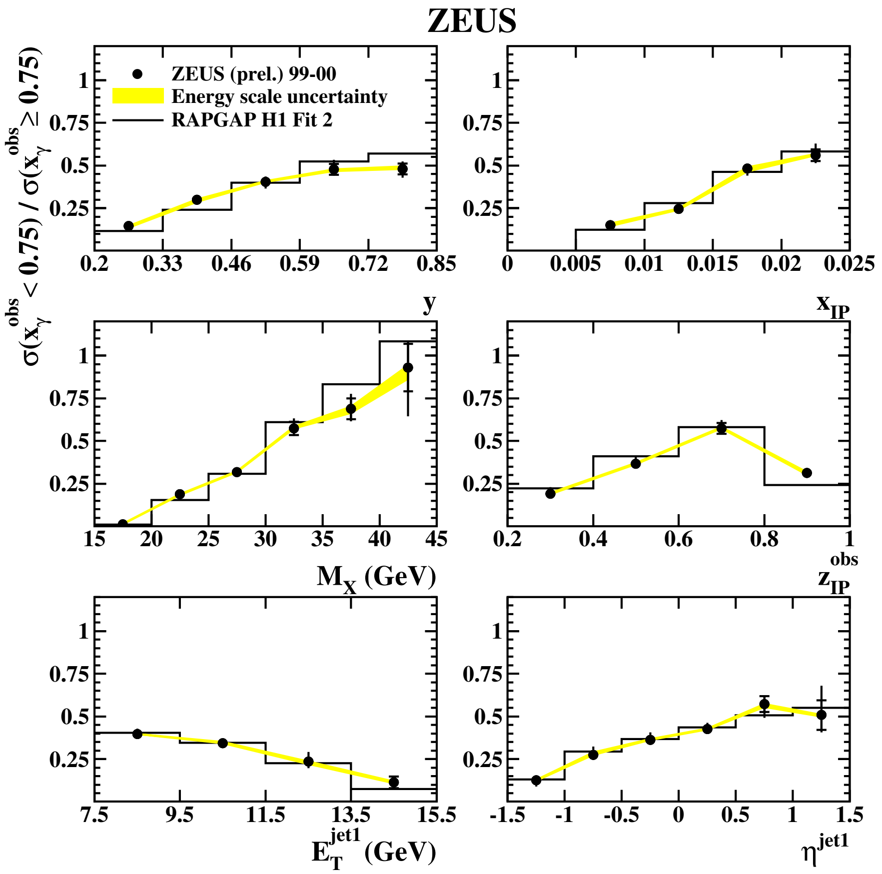
DATA / NLO: | DATA / NLO:

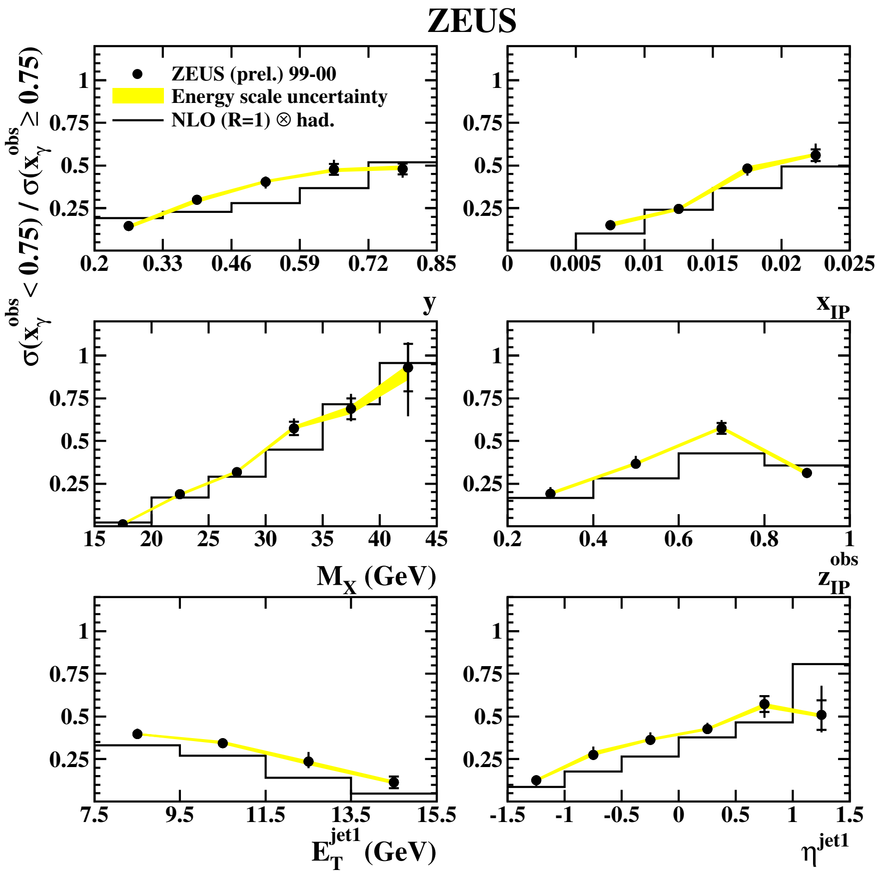
global suppression | RES suppression disfavoured

$\Longrightarrow$ DATA favour NLO global suppresion

Diffractive Photoproduction of DiJets

LO RES/DIR NLO





No evidence observed for a suppression of resolved photon relative to direct photon processes

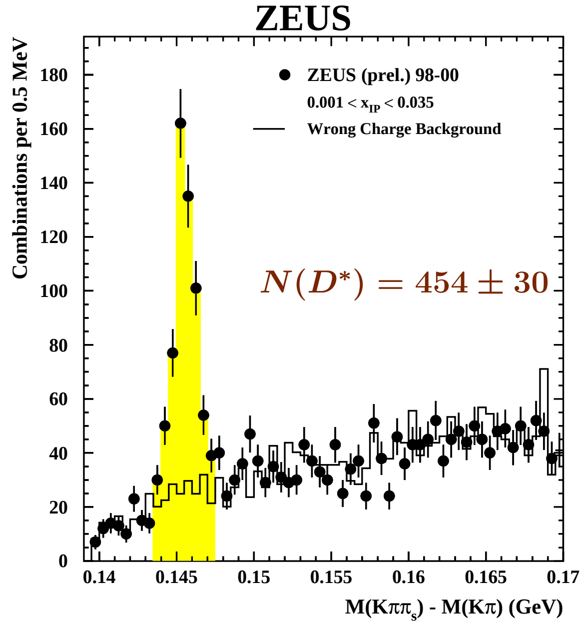
Diffractive Photoproduction of D^*

- $ep \to eXp \to eD^*X'p$ $D^*(2010)^{\pm} \to K\pi\pi$ Mode (98-00 data)
- $Q^2 < 1.0$ GeV^2 $0.17 < y < 0.89$ no e^+/e^- detected
- rapidity gap method

$$\Longrightarrow 0.001 < x_{I\!P} < 0.035$$

$130 < W < 300$ GeV,

$P_t^{D^*} > 1.9$ GeV,
$|\eta^{D^*}| < 1.6$



$$\sigma_{ZEUS} = 1.57 \pm 0.12(stat)^{+0.20}_{-0.22}(syst) \pm 0.08(pdiss)\ nb$$

Diffractive Photoproduction of D^*

Different models were compared to the measured cross sections:

NLO QCD calculations:(FMNR):

▽ **Diffractive $PDF's$**

- **H1 2006 Fits A and B**

- **ZEUS_LPS Fit**
- **GLP Fit**

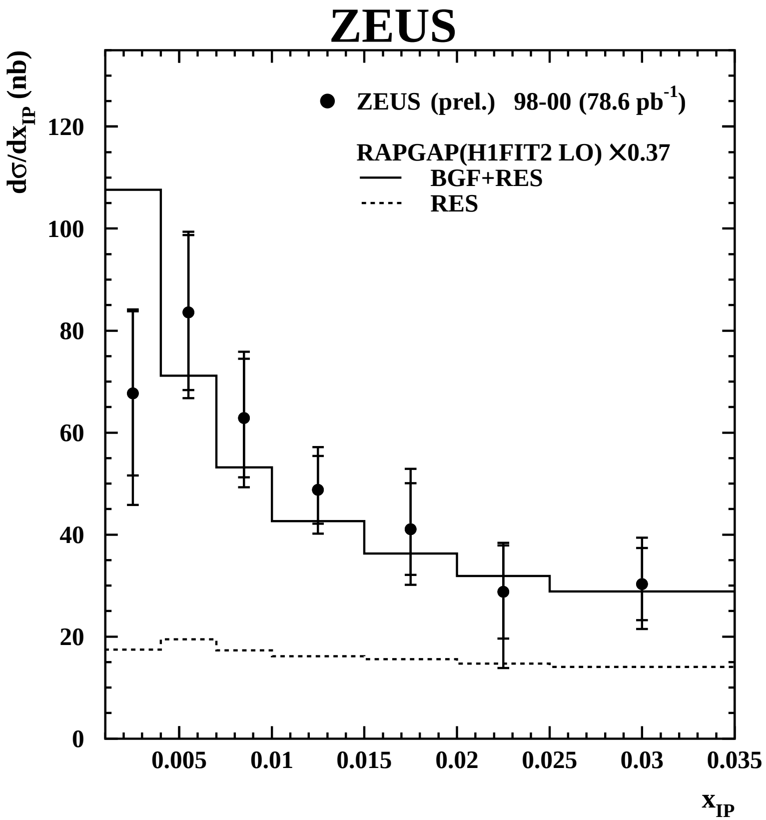
LO QCD calculations:(RAPGAP):

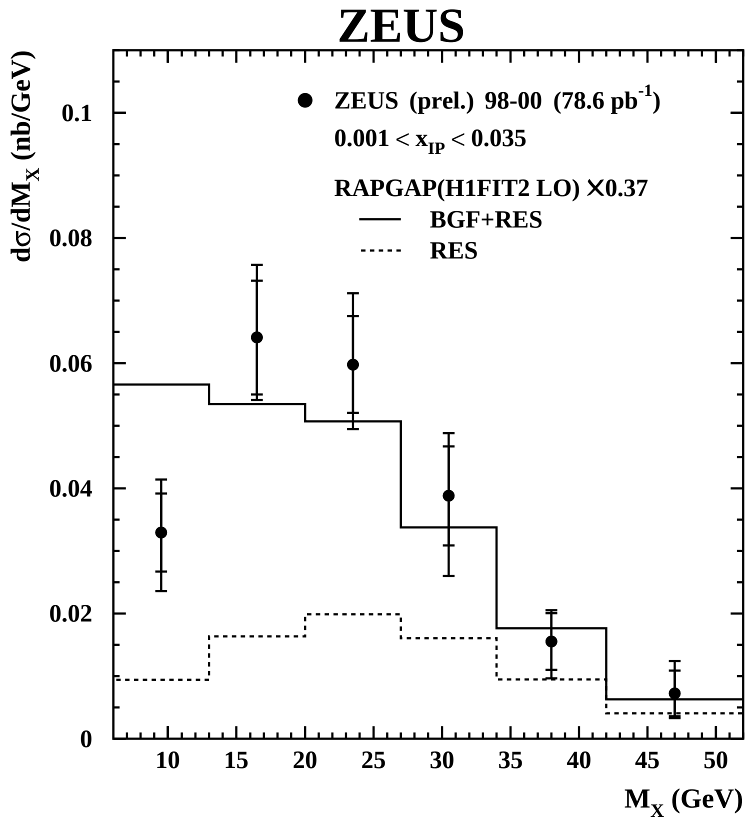
▽ **Diffractive $PDF's$**

- **H1 FIT2 LO**

Diffractive Photoproduction of D^*

LO





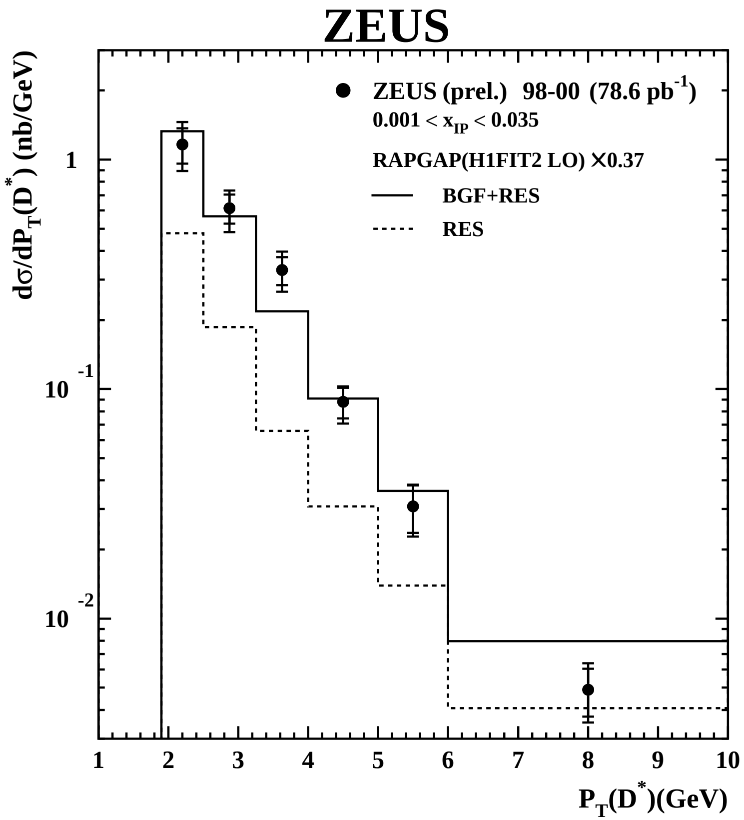
MC normalized to Data:

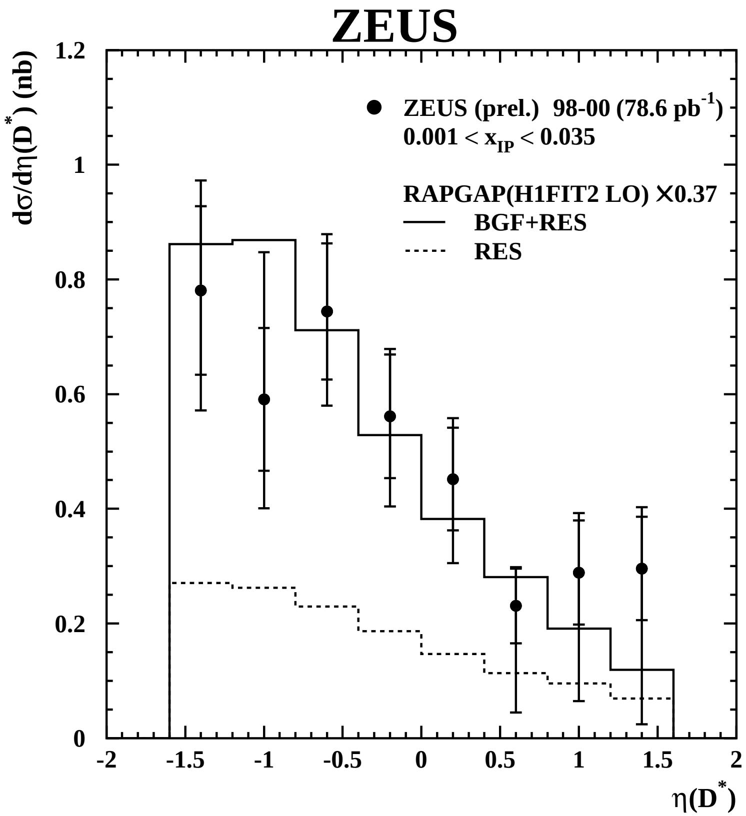
Shapes well described by BGF+RES,

$$R = \frac{\sigma_{res}}{\sigma_{bgf+res}} = 0.35$$

Diffractive Photoproduction of D^*

LO

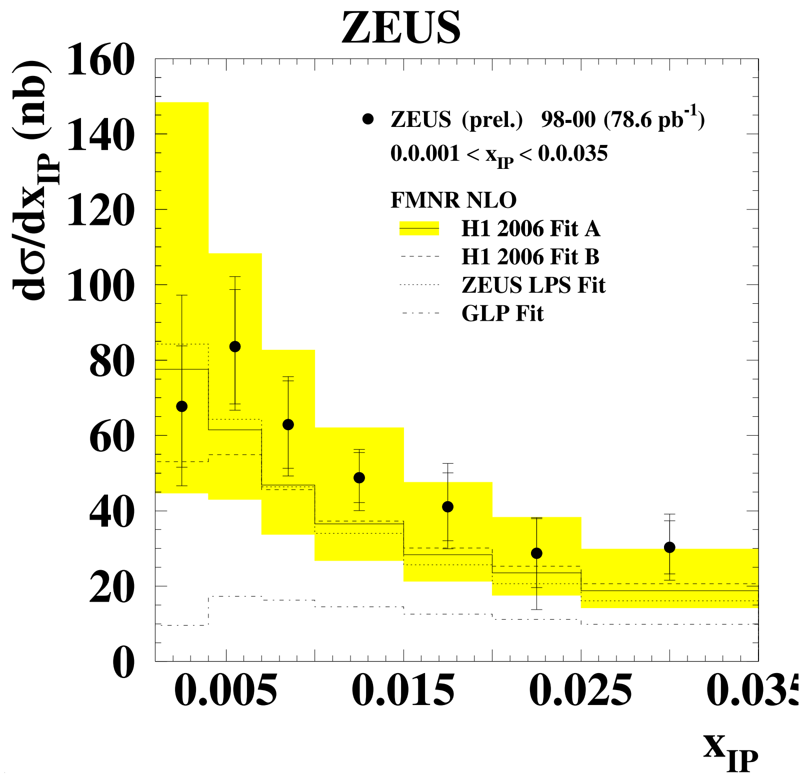


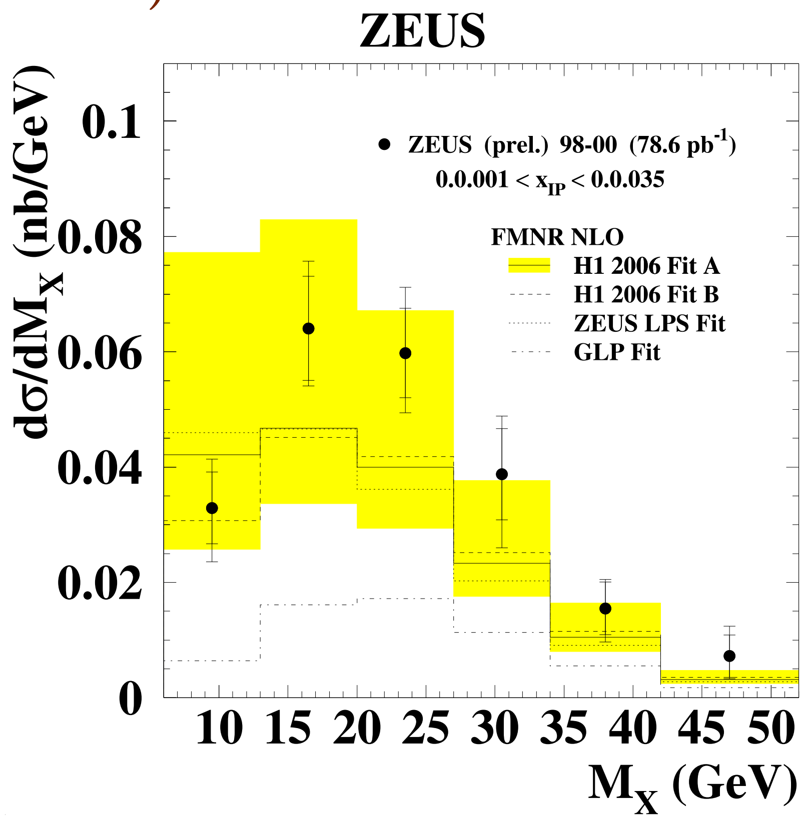


Scaling the resolved component by 0.34 would not give a significantly better description of the data in both shape and normalisation.

Diffractive Photoproduction of D^*

NLO(FMNR)





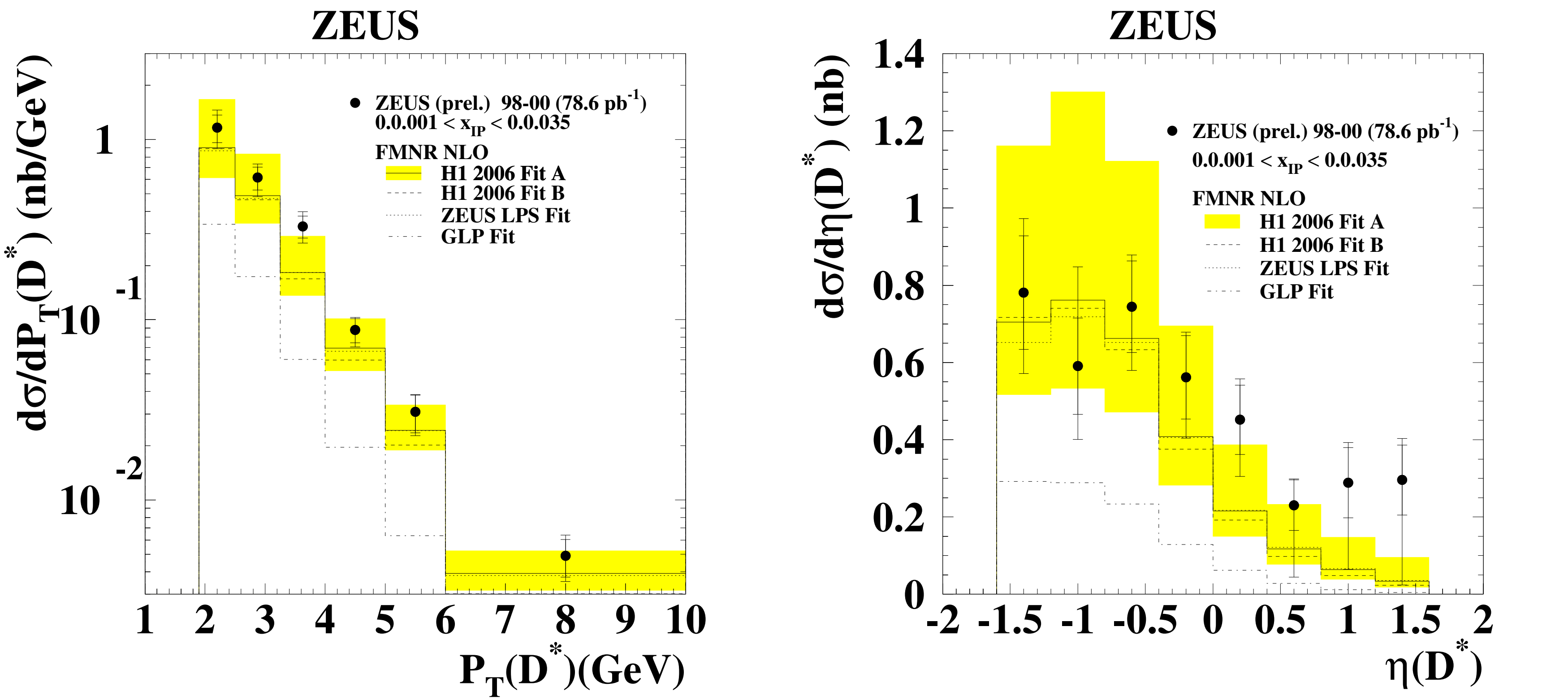
Input: $m_c = 1.45$ GeV $f(c \to D^*) = 0.235$ $\epsilon_{Peterson} = 0.035$

$\mu_R = \mu_F = m_T^c$

Uncertainties due to $\Delta m_c = \pm 0.2$ GeV and $F_\mu = 0.5(2.0) \Rightarrow$ LARGE

Diffractive Photoproduction of D^*

NLO(FMNR)



NLO QCD with ZEUS LPS and H1 2006 Fits reproduce data in normalization and shapes

NLO with GLP Fit: normalization is substantially lower than data.

Wide spread in predictions due to uncertainties in dPDFs

$\Rightarrow$ difficult to draw a conclusion on QCD factorisation

Comparison of D^* & DiJet PhP Results

Grounds for Comparisons

$\mathcal{L}_{JJ} = 38.6, 77.6\ \text{pb}^{-1}$ $\mathcal{L}_{D^*} = 78.6\ \text{pb}^{-1}$

PhP: $Q^2 < 1.0$ GeV

y-range	Inclusive	Diffractive
DiJets	$0.20 < y < 0.55$	$0.20 < y < 0.85$
D^*	$0.17 < y < 0.89$	$0.17 < y < 0.89$ (larger resolved fraction)

Diffractive range : $x_{I\!P} < 0.03(JJ) - 0.035(D^*)$

Jet definition: k_T algorithm

$E_T^{j_{1(2)}} > 7.5(6.5)$ GeV

$\eta_{j_{1(2)}}$	Inclusive	Diffractive
	$-3 < \eta_j < 0$ ($\gamma^* p$ r.f.)	$-1.5 < \eta_j < 2$(lab. r.f.)

D^* detection: $p_T(D^*) > 1.9$ GeV $|\eta(D^*)| < 1.6$

Comparison of D^* & DiJet PhP Results

$\mathcal{R} = \sigma_{ZEUS}/\sigma_{NLO}$ (except GLP)

DiJets	$\mathcal{R}_{incl} \sim 1.0$	$\mathcal{R}_{diff} \sim 0.5 - 0.6$
D^*	$\mathcal{R}_{incl} \sim 1.6$	$\mathcal{R}_{diff} \sim 1.0$

Disagreement between dijet and charm results?

Dijet PhP: NLOQCD : calculations being in agreement with the inclusive measurement overestimate cross sections for diffractive dijet photoproduction by factor of ~ 2.

D^* PhP: NLOQCD : calculations look to be consistent with diffractive D* photoproduction but underestimate cross sections for the inclusive measurement.

Observation: $\mathcal{R}_{diff}/\mathcal{R}_{incl}$

DiJets	$\sim 0.5 - 0.6$
D^*	$\sim 0.63(\pm 10\%)$

Supports expectation: diffractive production of dijets and charm similar and gluon densities are universal

Summary

- ∇ Cross sections of dijet and D^* production in diffractive DIS and PhP were measured and compared to pQCD calculations in LO(MC) and NLO.
- ∇ LO MC and NLO QCD with H1 and ZEUS LPS Fits reproduce shapes of $\sigma's$ but overestimate the measurement for dijet PhP.
  NLO QCD predictions with GLP Fit underestimate considerably dijet DIS and D* PhP measurements.
  Wide spread in predictions due to uncertainties in diffractive partonic densities prevent to draw a conclusion on QCD factorisation.
- ∇ Resolved photon contribution essential though small for DIS
  No evidence of suppression of resolved wrt direct photon contribution was found
- ∇ Comparison between dijet and charm production results supports expectation that diffractive production of both is similar and gluon densities are universal