

Recent Results on Diffraction from ZEUS

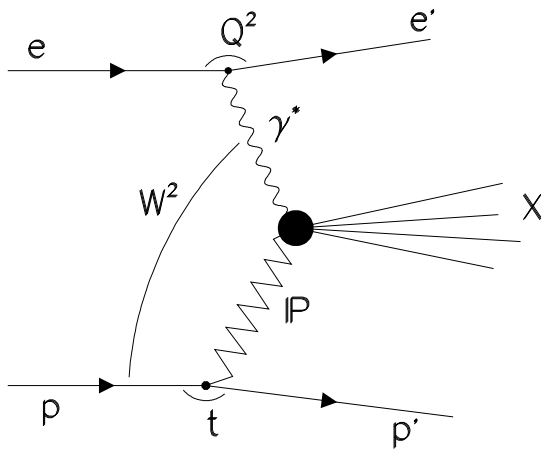
Workshop on Low x Physics

Prague 16 Sep 2004

Janusz Szuba, AGH-UST Cracow
on behalf of the ZEUS Collaboration

- Introduction to Diffraction
- Diffractive Structure Functions
- NLO QCD fit
- Diffractive Dijets in PHP
- Exclusive DIS Vector Meson Production
- Summary

Kinematic of Inclusive Diffraction



Characteristic of diffraction:

- color singlet exchange
- proton intact after the collision

Q^2 virtuality of the photon

t (4-momentum exchanged at p vertex)²

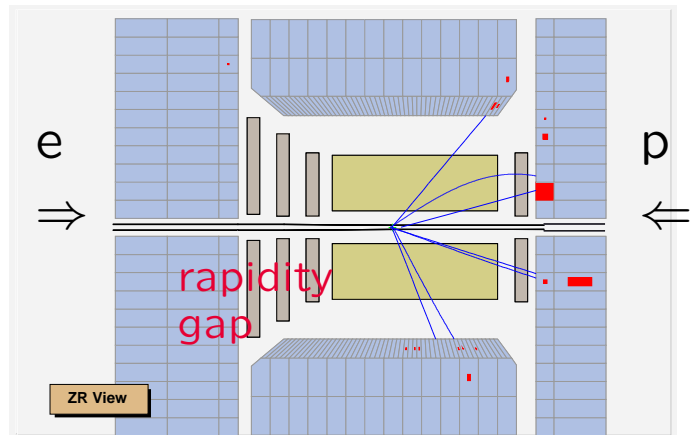
W invariant mass of photon-proton system

M_X invariant mass of photon-pomeron system

x_{IP} fraction of proton momentum taken by pomeron

β fraction of pomeron momentum carried by struck quark

Inclusive Diffraction



From diffractive cross section to diffractive structure functions:

$$\frac{d^4\sigma}{d\beta dQ^2 dx_{IP} dt} = \frac{4\pi\alpha^2}{\beta Q^4} (1 - y + y^2/2) \sigma_r^{D(4)}(\beta, Q^2, x_{IP}, t)$$

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{1+(1-y)^2} F_L^{D(4)}$$

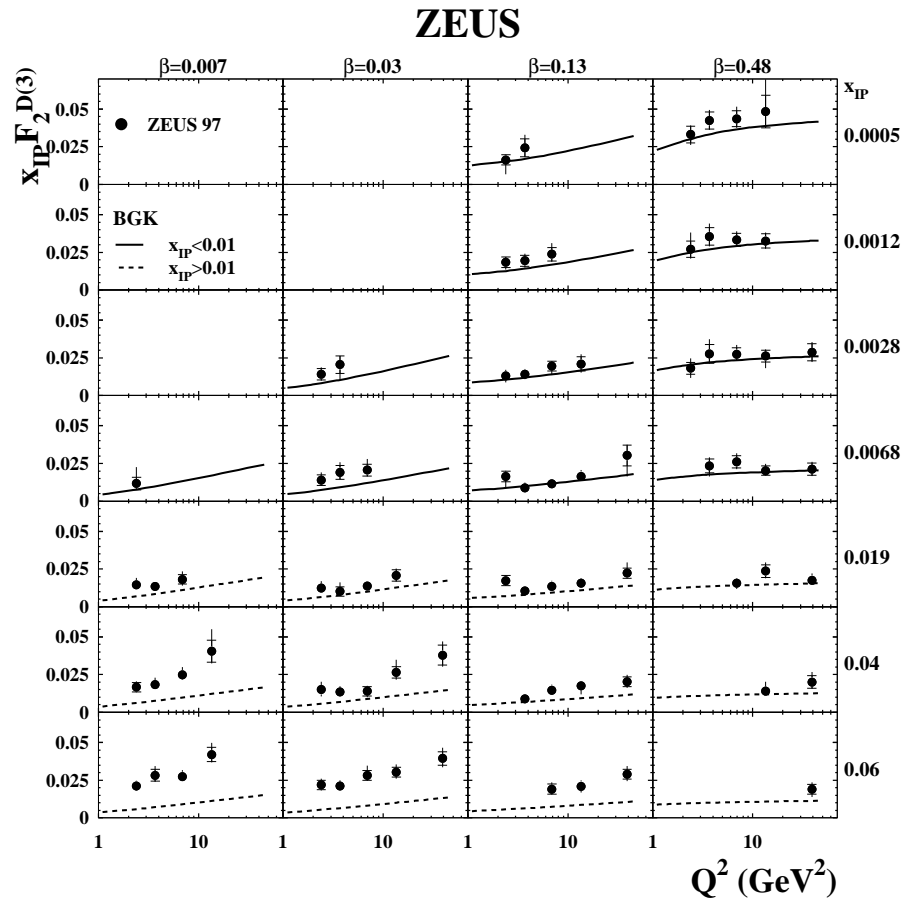
assuming $F_L^{D(4)} = 0$ in measured kinematic region

integration over t gives $F_2^{D(3)}(\beta, Q^2, x_{IP})$

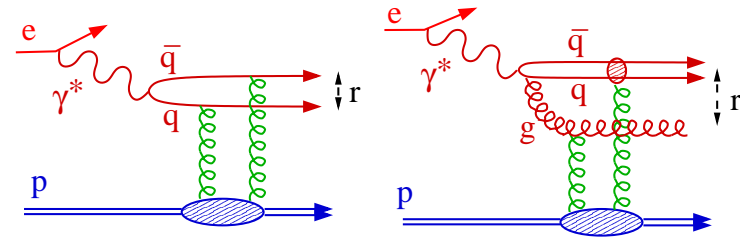
Experimental signatures:

- identify rapidity gaps events
(η_{max} method)
- tag leading proton (LPS)
- use M_X distribution

$F_2^{D(3)}$ Q^2 dependence



ZEUS LPS data



Saturation model:

$\sigma_{q\bar{q}} \propto r^2 \propto 1/Q^2$ (colour transparency)

for $Q^2 \rightarrow 0$ $\sigma_{q\bar{q}} \rightarrow \infty$

growth tamed by requiring saturation

- Data well described by BGK saturation model ($x_{IP} < 0.01$)
- Positive scaling violation at all values of $\beta \Rightarrow$ large gluon contribution

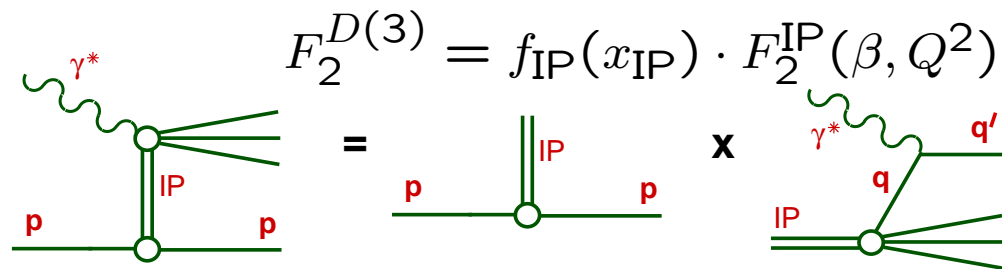
Diffractive hard scattering factorization

- Diffractive DIS like inclusive DIS is **proven** to be factorizable

$$\sigma(\gamma^* p \rightarrow Xp) \approx f_{i/p}(z, Q^2, x_{\text{IP}}, t) \otimes \sigma_{\gamma^* i}(z, Q^2)$$

Diffractive parton distributions $f_{i/p}(z, Q^2, x_{\text{IP}}, t)$: probability to find in a proton, with a probe of resolution Q^2 , parton i with momentum fraction z , under the condition that the proton remains intact and emerges with a small energy loss, x_{IP} , and momentum transfer t

- Regge factorization postulate:

$$F_2^{D(3)} = f_{\text{IP}}(x_{\text{IP}}) \cdot F_2^{\text{IP}}(\beta, Q^2)$$


- DPDFs and Pomeron structure functions evolve following DGLAP

$F_2^{D(3)}$ x_{IP} dependence

ZEUS LPS Data

- $x_{IP} > 0.01$
 $x_{IP} F_2^{D(3)}$ increases as $x_{IP} \rightarrow 1$
 Reggeon contribution

- $x_{IP} < 0.01$
 $x_{IP} F_2^{D(3)}$ increases as $x_{IP} \rightarrow 0$
 Parton evolution as $x_{IP} \rightarrow 0$

- Regge fit with common Pomeron flux

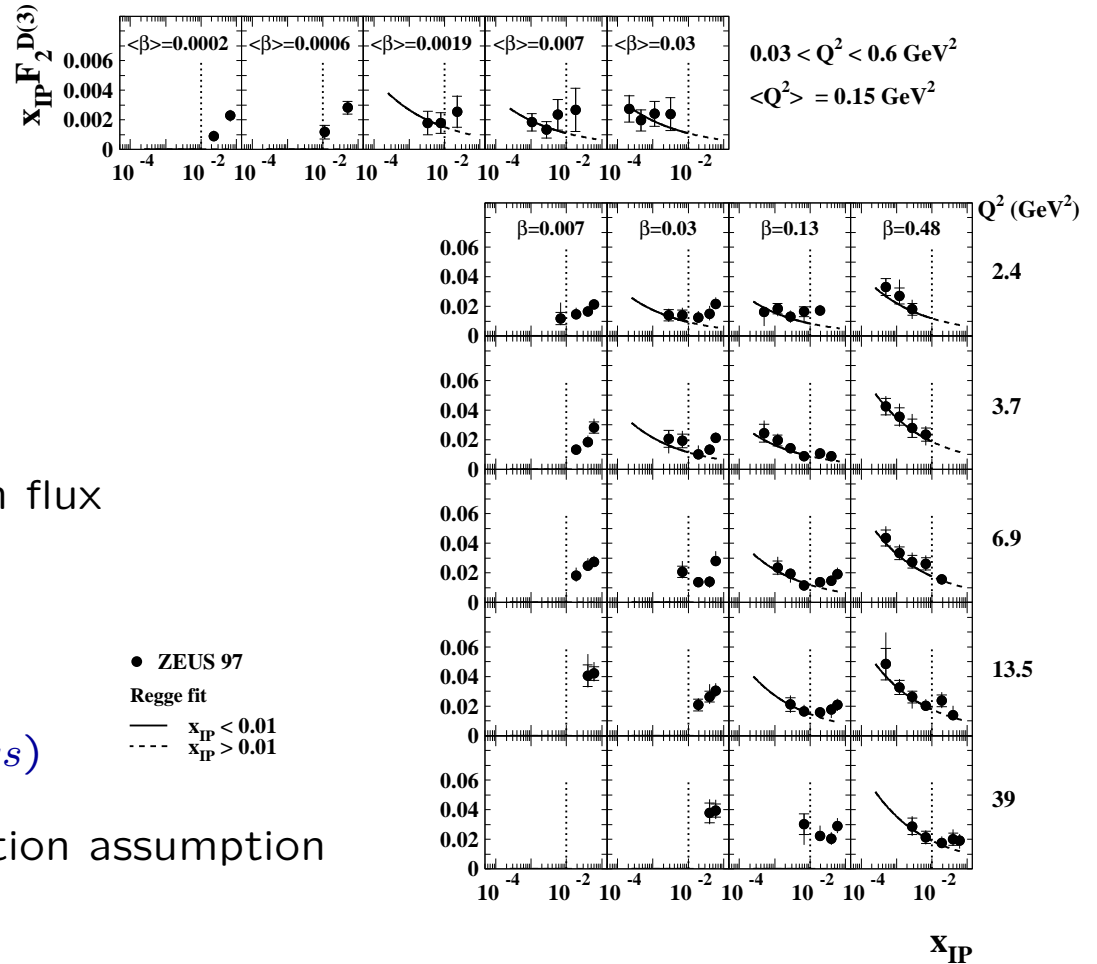
$$f_{IP}(x_{IP}) \propto \int \frac{e^{bt}}{x_{IP}^{2\alpha_{IP}(t)-1}}$$

$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} t$$

$$\alpha_{IP}(0) = 1.16 \pm 0.02(stat) \pm 0.02(sys)$$

- Data agree with Regge factorisation assumption

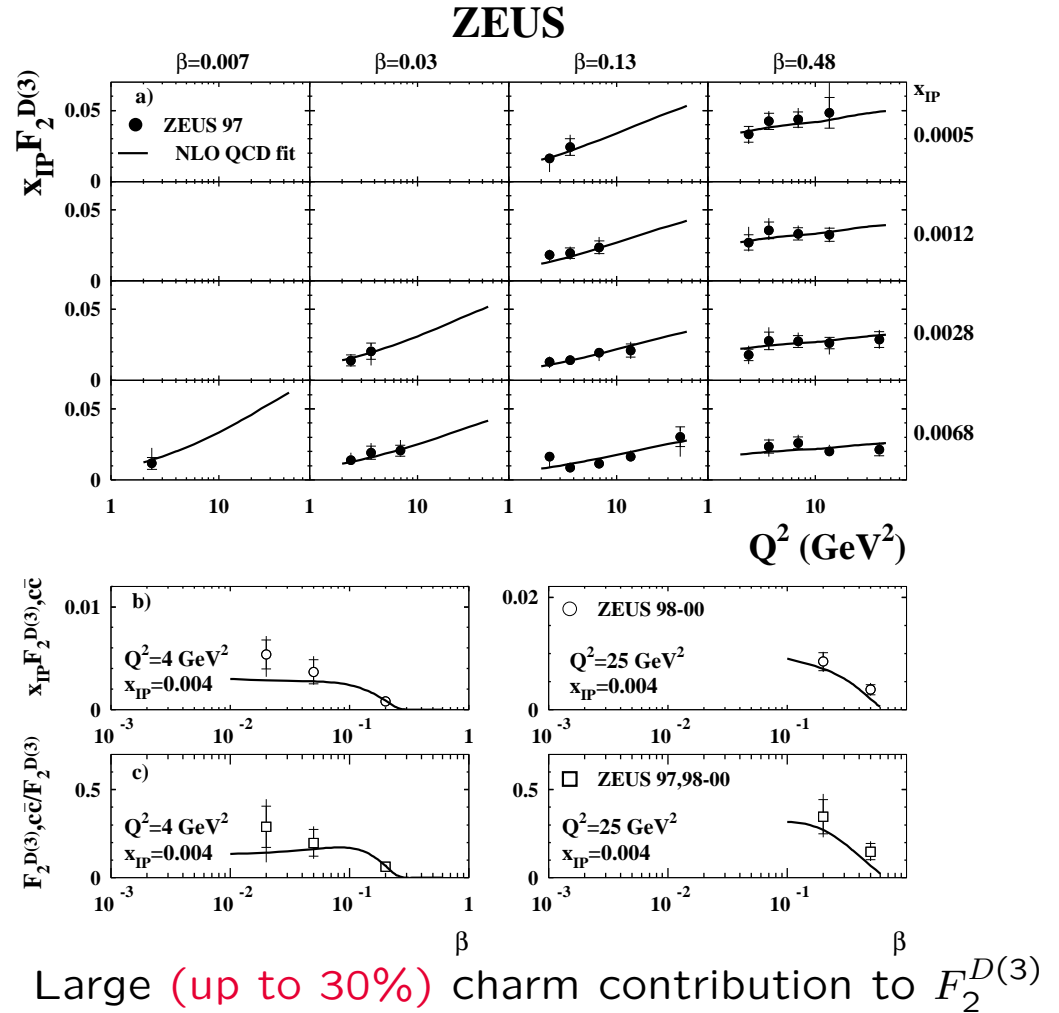
ZEUS



NLO QCD Fit

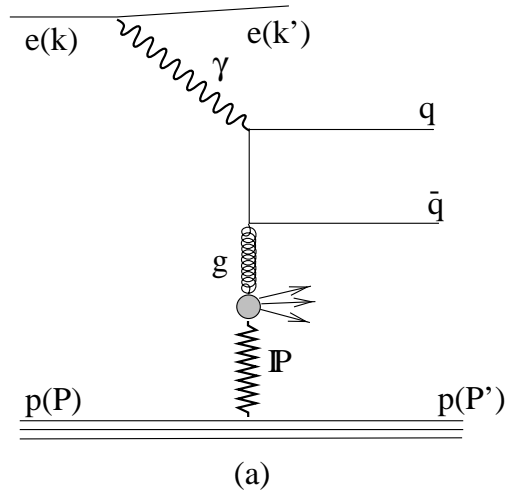
- Fit to results from LPS and diffractive charm in DIS
 $x_{IP} < 0.01$ and $Q^2 > 2 \text{ GeV}^2$
- NLO evolution: QCDNUM
- Regge factorization assumption
- DL Pomeron flux
- PDFs parametrisation
 $z f(z) = (a_1 + a_2 z + a_3 z^2)(1 - x)^{a_4}$
- Charm quarks in Thorne-Robert variable flavour number scheme

- QCD fit describes data
 $(\chi^2/ndf = 37.8/36)$
- Fractional gluon momentum
 $(82 \pm 8(stat)_{-16}^{+5}(sys)\%)$

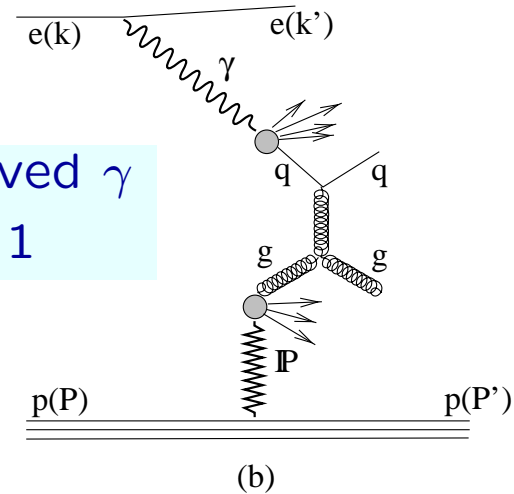


Diffractive Dijets in Photoproduction ($Q^2 \approx 0$)

direct γ
 $x_\gamma = 1$



resolved γ
 $x_\gamma < 1$



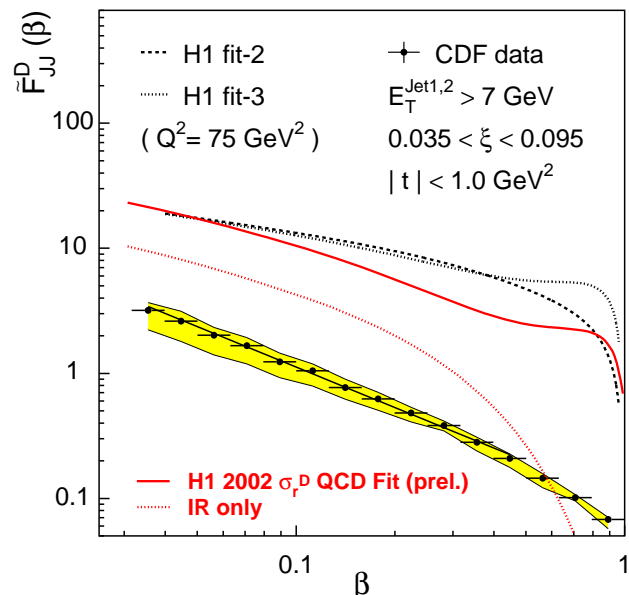
x_γ momentum fraction of photon entering hard process

$z_{\mathbb{P}}$ momentum fraction of diffractive exchange entering hard process

both variables determined by the final state jets

- QCD factorization **holds** for DIS and direct PHP
- Expect **factorization breaking** in resolved component
 (analog to hadron-hadron collision)

Factorization breaking in $p\bar{p}$ collisions



CDF dijet measurement factor of 10 lower than prediction using DPDFs from inclusive diffractive DIS

- Possible mechanism of suppression: secondary interactions filling rapidity gap
- Can we see similar suppression in resolved PHP?

Theory expectation for HERA:

Kaidalov, Khoze, Martin, Ryskin

Prediction of the suppression factor of resolved contribution $R=0.34$

Klasen, Kramer

No suppression in LO, suppression of resolved contribution in NLO

Diffractive Dijets in Photoproduction

Kinematic range of measurement:

$$0.2 < y < 0.85, Q^2 < 1.0 \text{ GeV}^2$$

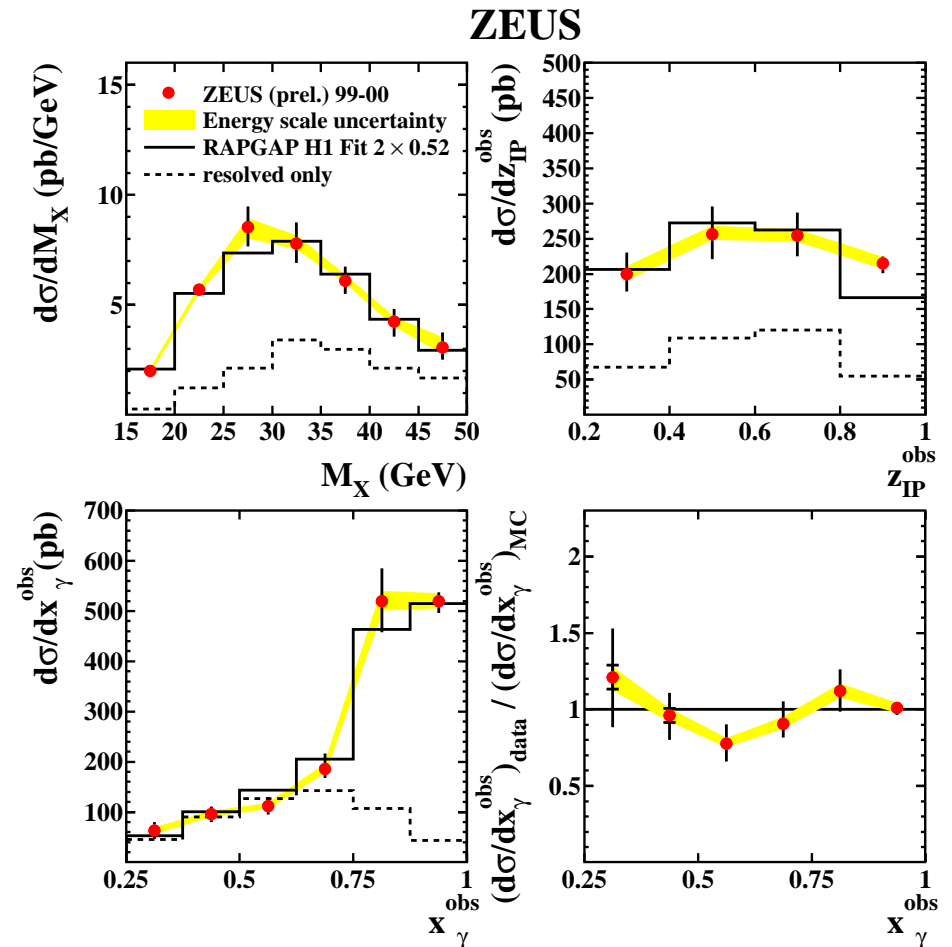
$$x_{\text{IP}} < 0.035$$

Longitudinally invariant kt algorithm

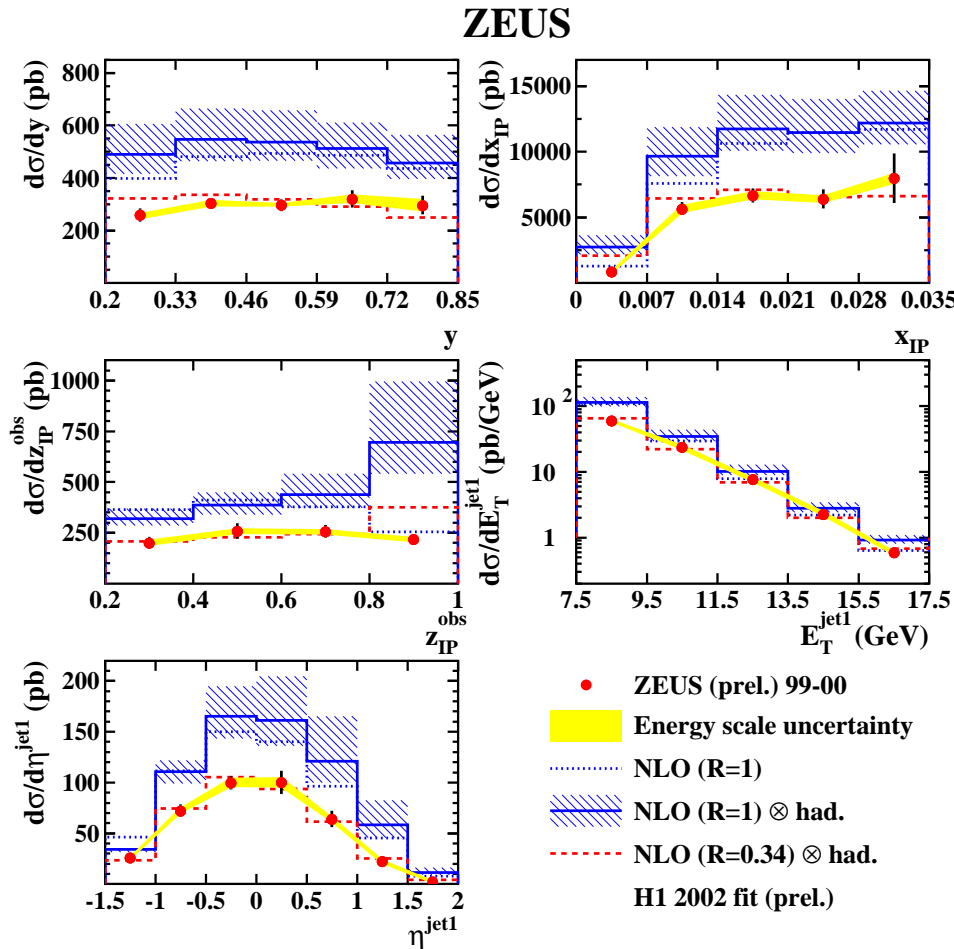
$$E_T^{\text{jet}1} > 7.5 \text{ GeV} \quad E_T^{\text{jet}2} > 6.5 \text{ GeV}$$

$$-1.5 < \eta^{\text{jet}1(2)} (\text{lab frame}) < 2.0$$

- Results are fairly consistent with RAPGAP H1-fit2 scaled down by 0.52
- No evidence of a resolved suppression with respect to direct at LO

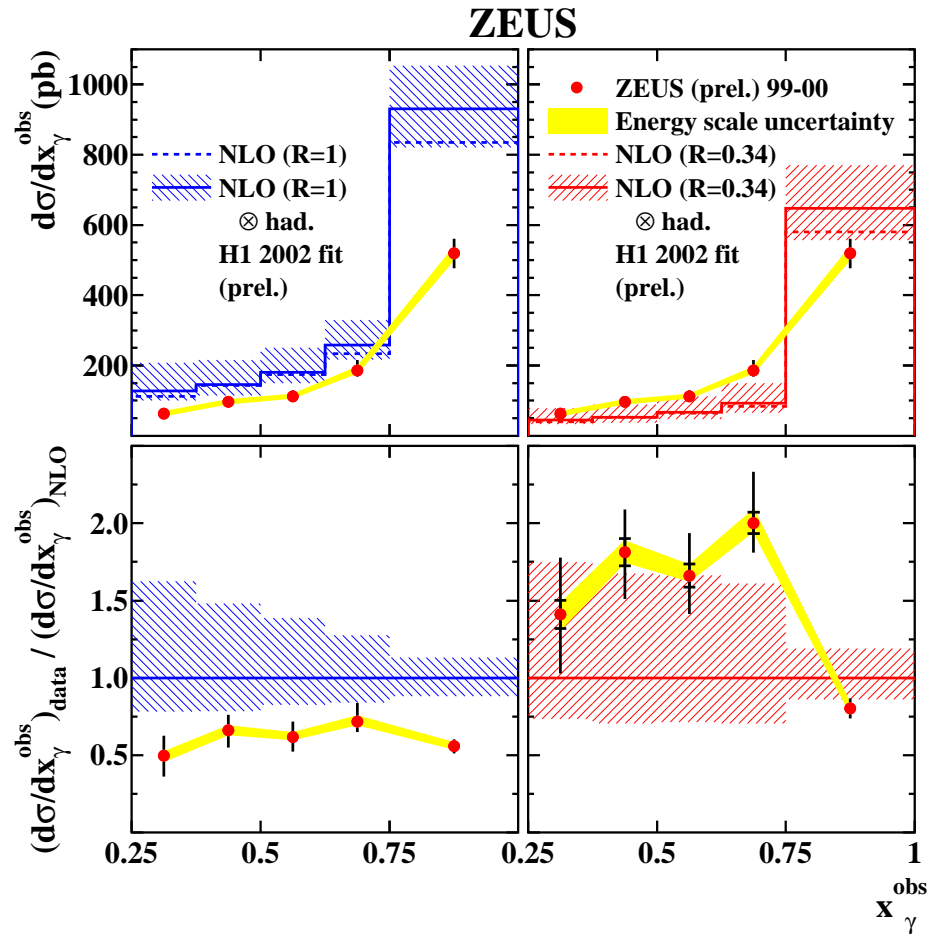


Diffractive Dijets in Photoproduction



- NLO prediction describes shapes of distributions
- Normalization restored with suppression of resolved component (R=0.34)

Diffractive Dijets in Photoproduction

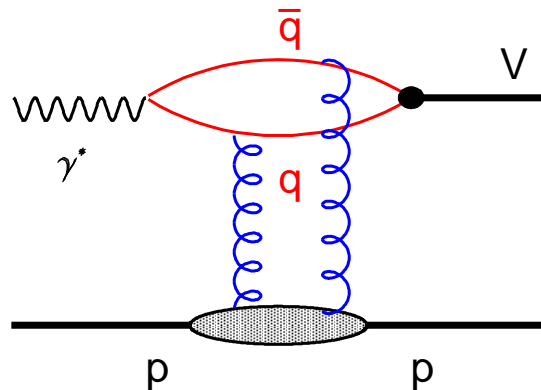


- The measurement favour a global suppression of the QCD factorization
- Resolved only suppression ($R=0.34$) disfavoured

Exclusive DIS VM Production

Aim to understand vector meson production in terms of pQCD

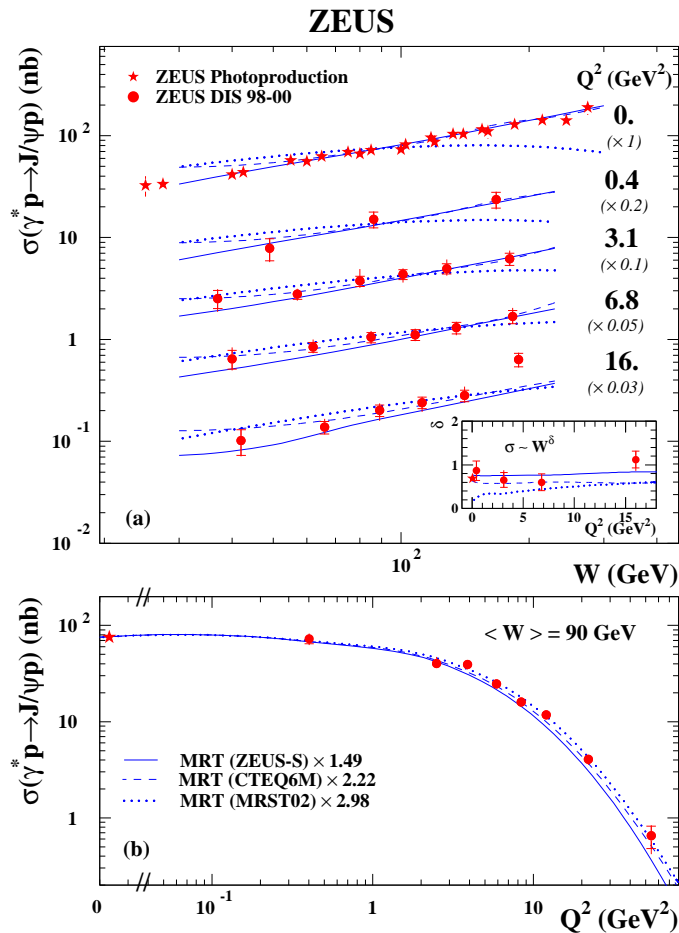
- hard scale with M_{VM} , Q^2 or t
- QCD factorisation theorem applicable
- This allows to separate pQCD from npQCD
- Probes gluon distribution in proton $\sigma \propto [xG(x)]^2$



$ep \rightarrow eJ/\psi p$, tagged in e^+e^- and $\mu^+\mu^-$ channels
 $0 < Q^2 < 100 \text{ GeV}^2$, $|t| < 1 \text{ GeV}^2$
 $30 < W < 220 \text{ GeV}$

$ep \rightarrow e\phi p$, ($\phi \rightarrow K^+K^-$)
 $2 < Q^2 < 70 \text{ GeV}^2$, $|t| < 0.6(1) \text{ GeV}^2$
 $35 < W < 145 \text{ GeV}$

Exclusive J/ψ production in DIS

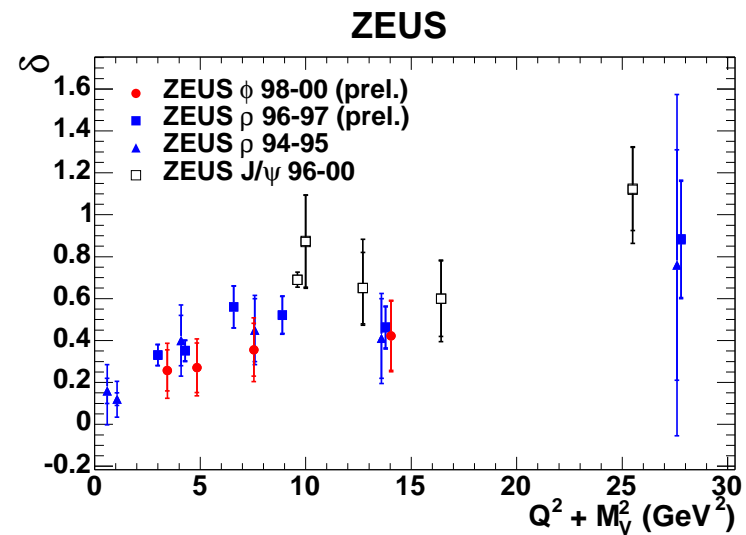
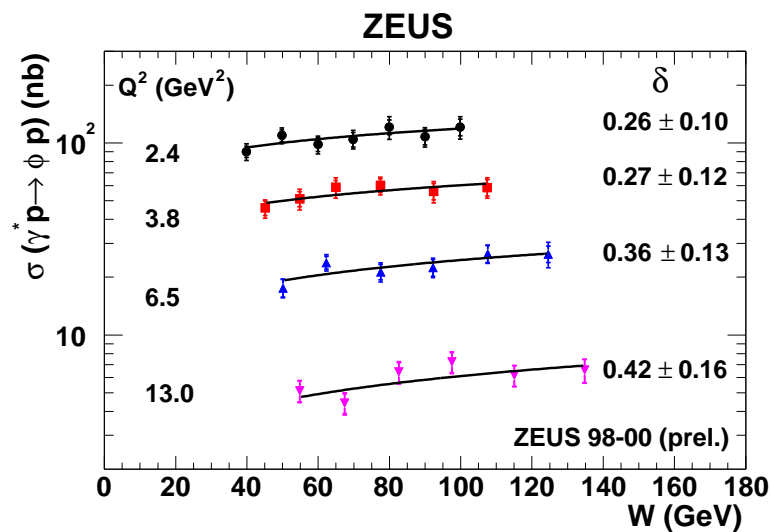


Comparison with different PDFs within Martin, Ryskin, Teubner (MRT) model

- CTEQ6M and ZEUS-S describe W and Q^2 dependence
- MRST02 has wrong shape in W (valence-like gluon)
- Data show **strong sensitivity** to gluon density in proton
- NLO needed to constrain gluon density

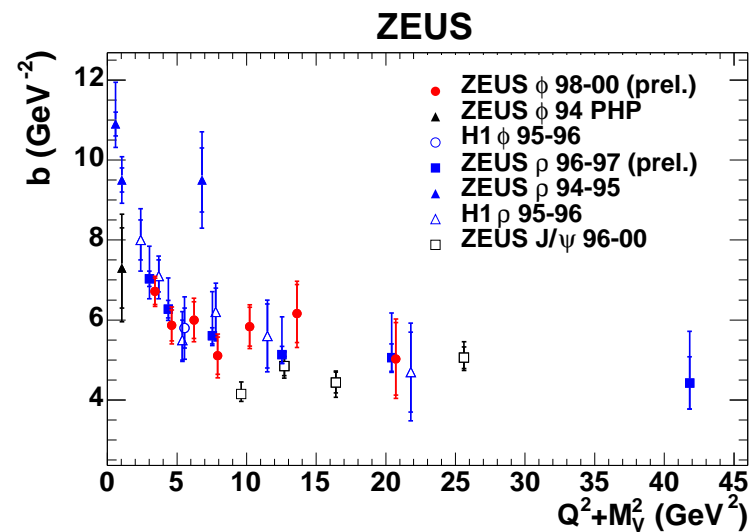
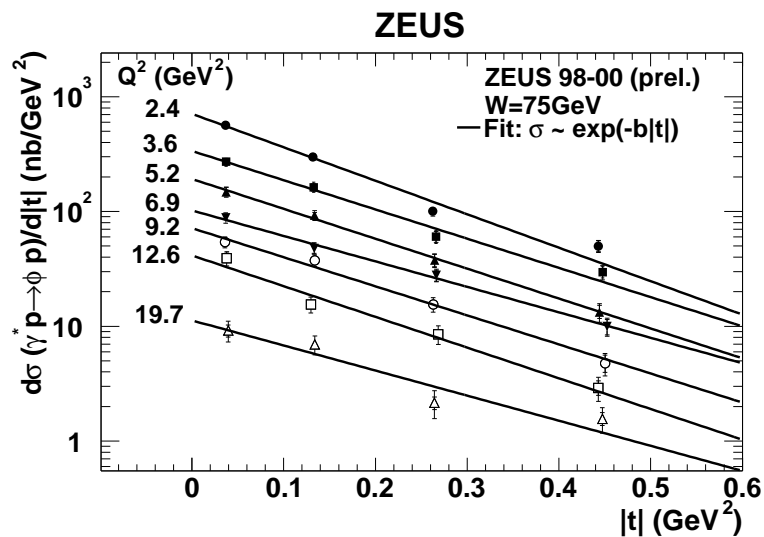
Exclusive ϕ Production in DIS

- Fit to $\sigma \approx W^\delta$: δ varies as a function of Q^2
- Data confirm scaling behaviour of cross section
- Rise of δ with $Q^2 + M_{VM}^2$ observed:
 - ρ, ϕ : transition from soft to hard regime
 - J/ψ : hard already in photoproduction



Exclusive ϕ Production in DIS

- $d\sigma/dt \approx \exp(-b|t|)$
- Data suggest scaling with $Q^2 + M_{VM}^2$
- Decrease of b with $Q^2 \rightarrow$ high $Q^2 \Leftrightarrow$ small dipole size



Summary

Recent data from ZEUS LPS with extended kinematic range

- Data described by colour dipole models
- QCD fit shows high gluon fraction
- Charm production account for large part of diffractive cross section

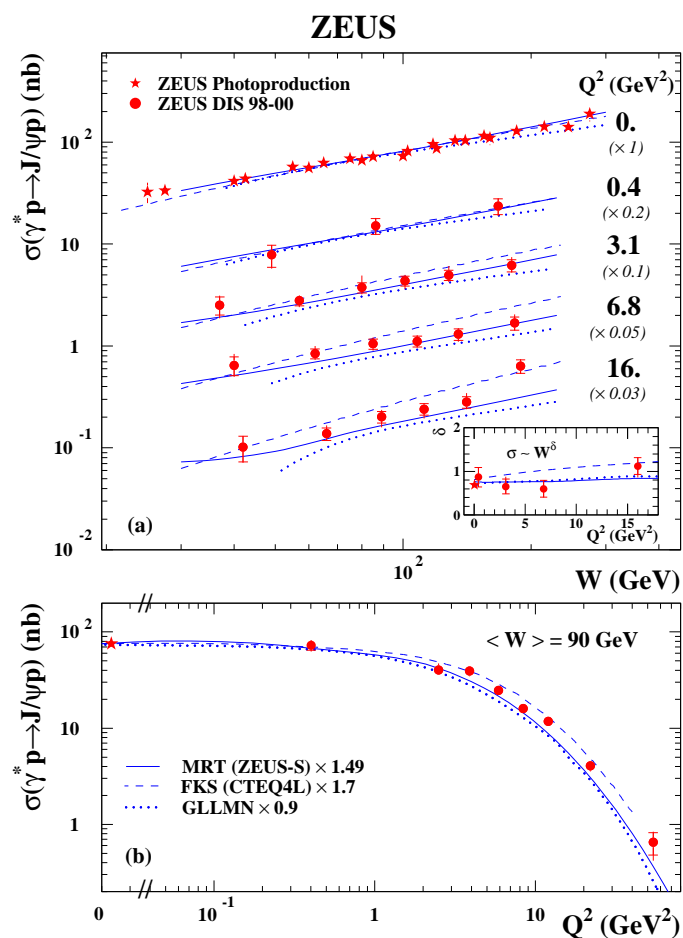
Diffractive dijets as a test for factorization breaking

- ZEUS data favour a global suppression of QCD factorization than only resolved component

Precise measurement of exclusive VM production in DIS in wide kinematic range

- Data exhibits strong sensitivity to gluon density in proton
- Full NLO calculation needed to constrain gluon density
- ϕ lies in transition region from soft to hard
- Scaling behaviour in $Q^2 + M^2$

Exclusive J/ψ production in DIS (backup)



Comparison with QCD models

- Martin, Ryskin, Teubner
- Frankfurt, Koepf, Strikman
- Gotsman, Levin, Lublisky, Maor, Naftali

Models different in :

- assumption on $c\bar{c}$ wave function
- assumptions on GPDFs
- corrections applied to LO calculations

- Large uncertainty in normalisation
- Models describe qualitatively data
- Rise of σ with W related to increase in gluon density at low x

$$\sigma_L \approx \frac{\alpha_s^2}{Q^6} |xG(x, Q^2)|^2$$