Recent Results on Diffraction from ZEUS

Workshop on Low x Physics

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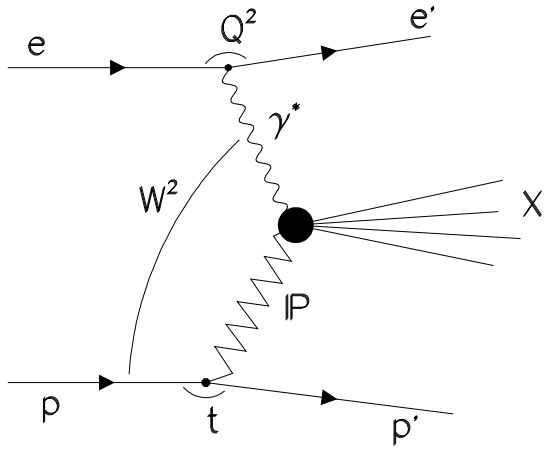
on behalf of the ZEUS Collaboration

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

Kinematic of Inclusive Diffraction

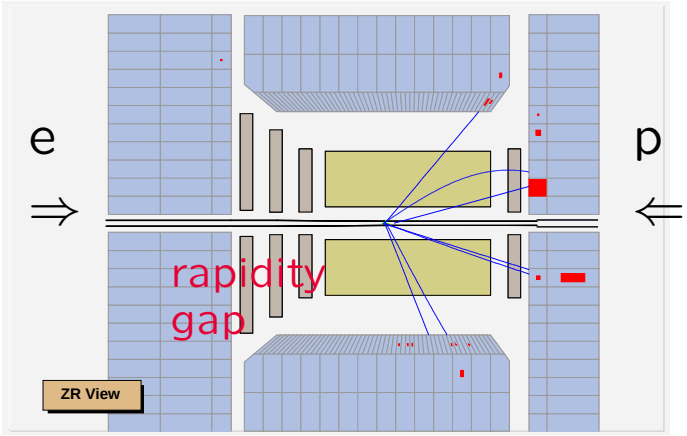


Characteristic of diffraction:

- 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



Experimental signatures:

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

From diffractive cross section to diffractive structure functions:

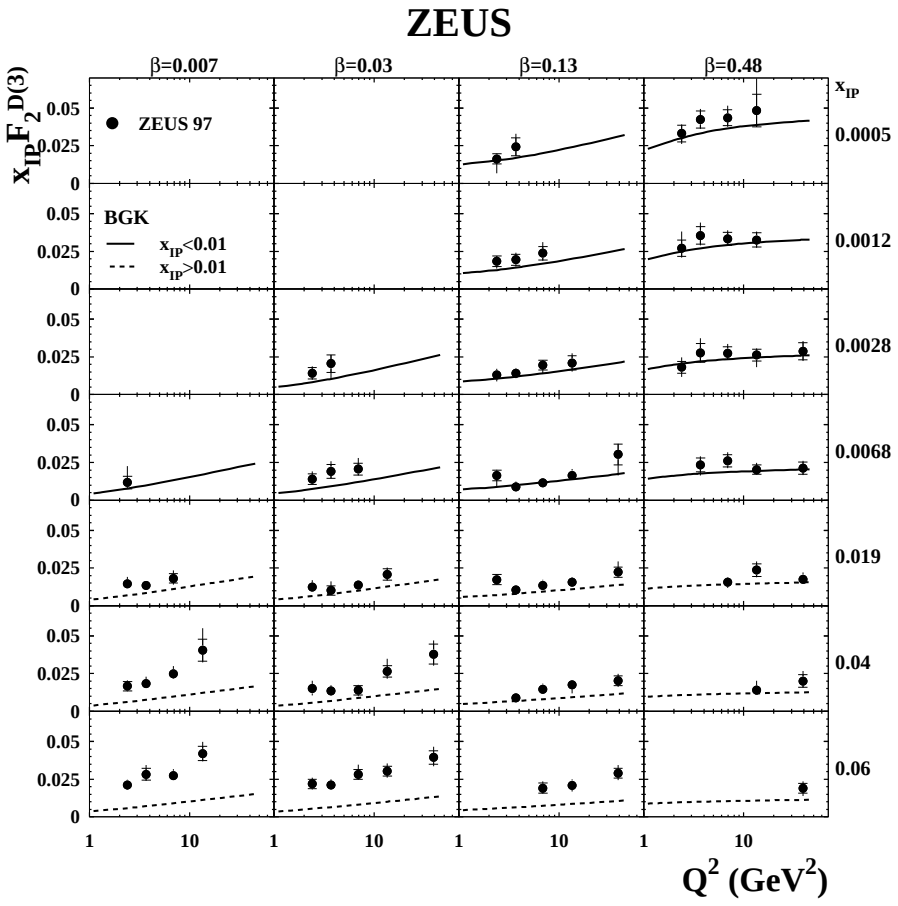
$$\frac{d^4\sigma}{d\beta dQ^2 dx_{\rm IP} dt} = \frac{4\pi\alpha^2}{\beta Q^4}(1 - y + y^2/2)\sigma_r^{D(4)}(\beta, Q^2, x_{\rm IP}, t)$$

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

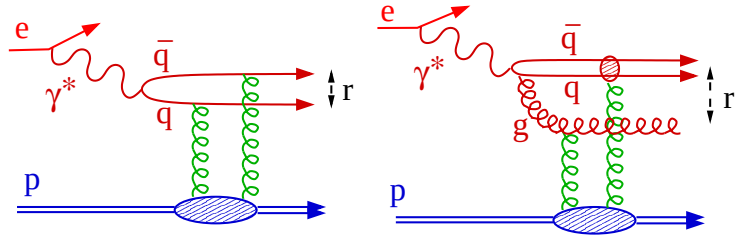
assuming $F_L^{D(4)} = 0$ in measured kinematic region

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

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



ZEUS LPS data



Saturation model:
$\sigma_{q\bar{q}} \propto r^2 \propto 1/Q^2$ (colour transparency)
for $Q^2 \to 0$ $\sigma_{q\bar{q}} \to \infty$
growth tamed by requiring saturation

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

Diffractive hard scattering factorization

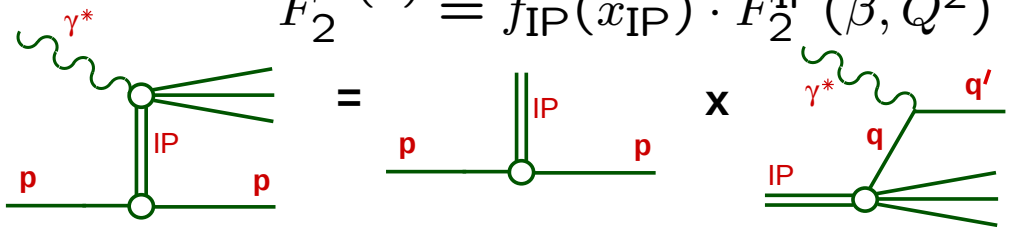
- Diffractive DIS like inclusive DIS is proven to be factorizable

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

Diffractive parton distributions $f_{i/p}(z, Q^2, x_{\mathrm{IP}}, t)$: 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:

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



- 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 $x_{IP} \to 1$
Reggeon contribution

- $x_{IP} < 0.01$

$x_{IP} F_2^{D(3)}$ increases as $x_{IP} \to 0$
Parton evolution as $x_{IP} \to 0$

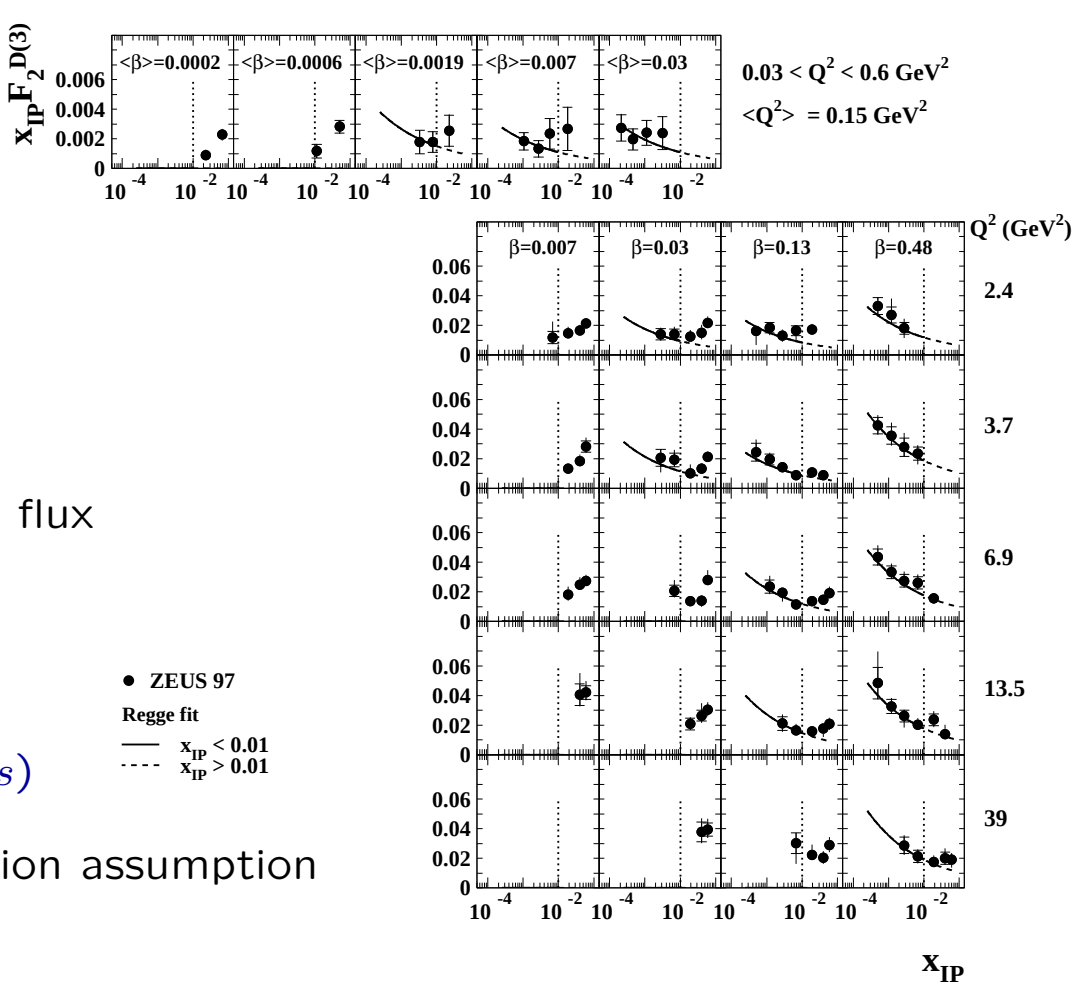
- Regge fit with common Pomeron flux

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

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

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

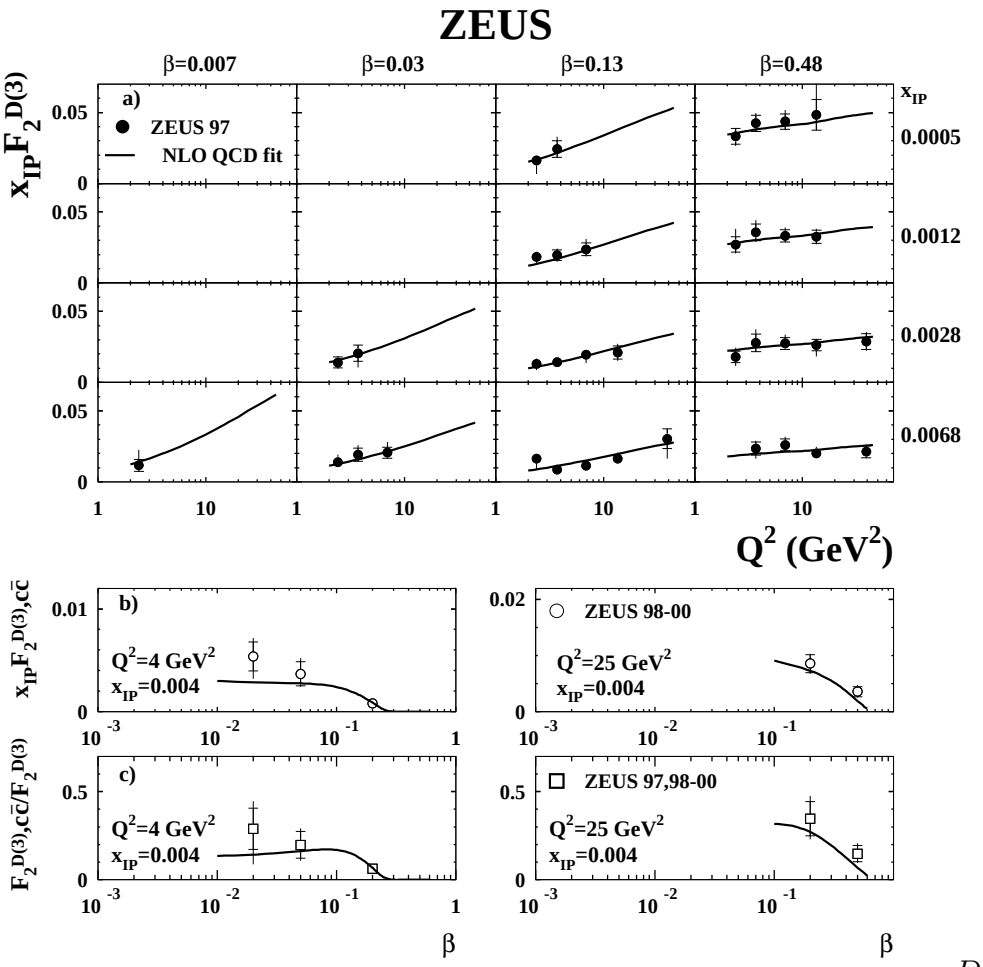
- Data agree with Regge factorisation assumption



NLO QCD Fit

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

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

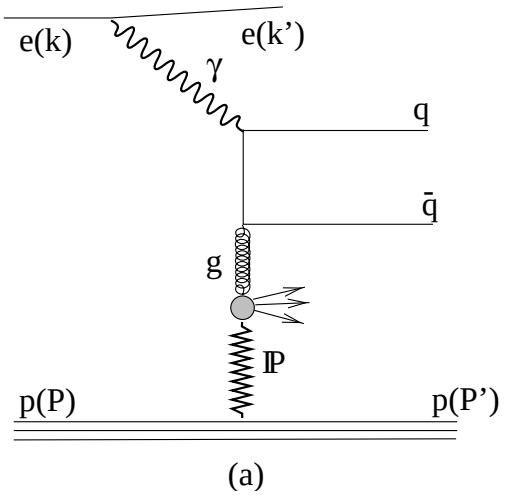


Large (up to 30%) charm contribution to $F_2^{D(3)}$

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

direct γ

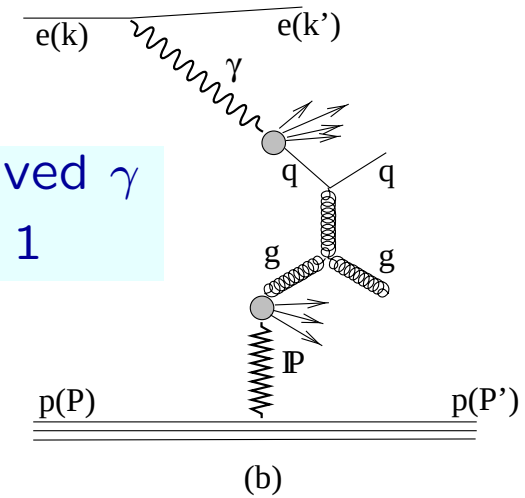
$x_\gamma = 1$



(a)

resolved γ

$x_\gamma < 1$



(b)

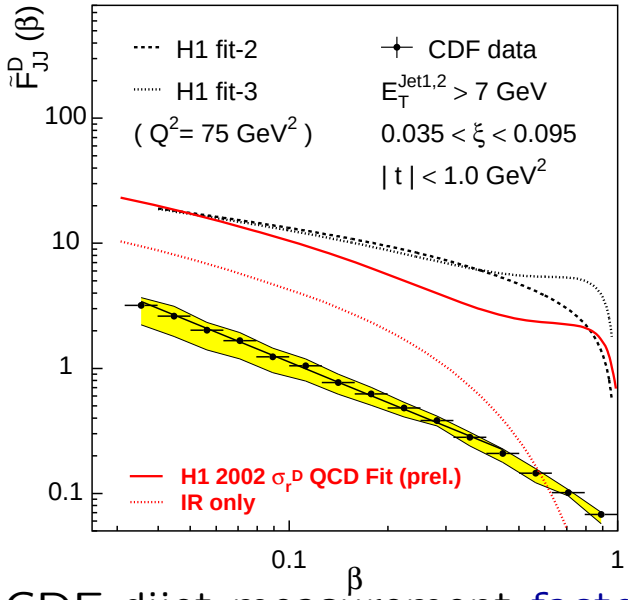
x_γ momentum fraction of photon entering hard process

z_{IP} 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:

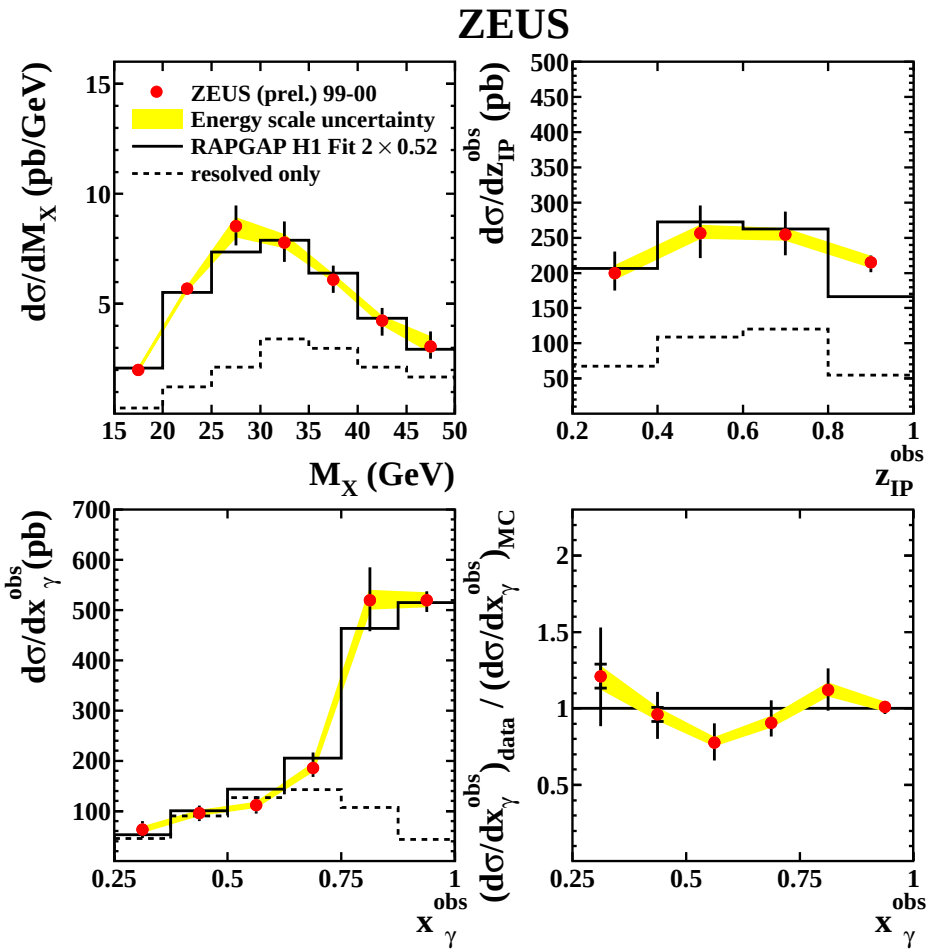
Kaidalov, Khoze, Martin, Ryskin
Prediction of the suppression factor of resolved contribution R=0.34

Klasen, Kramer
No suppression in LO, suppression of resolved contribution in NLO

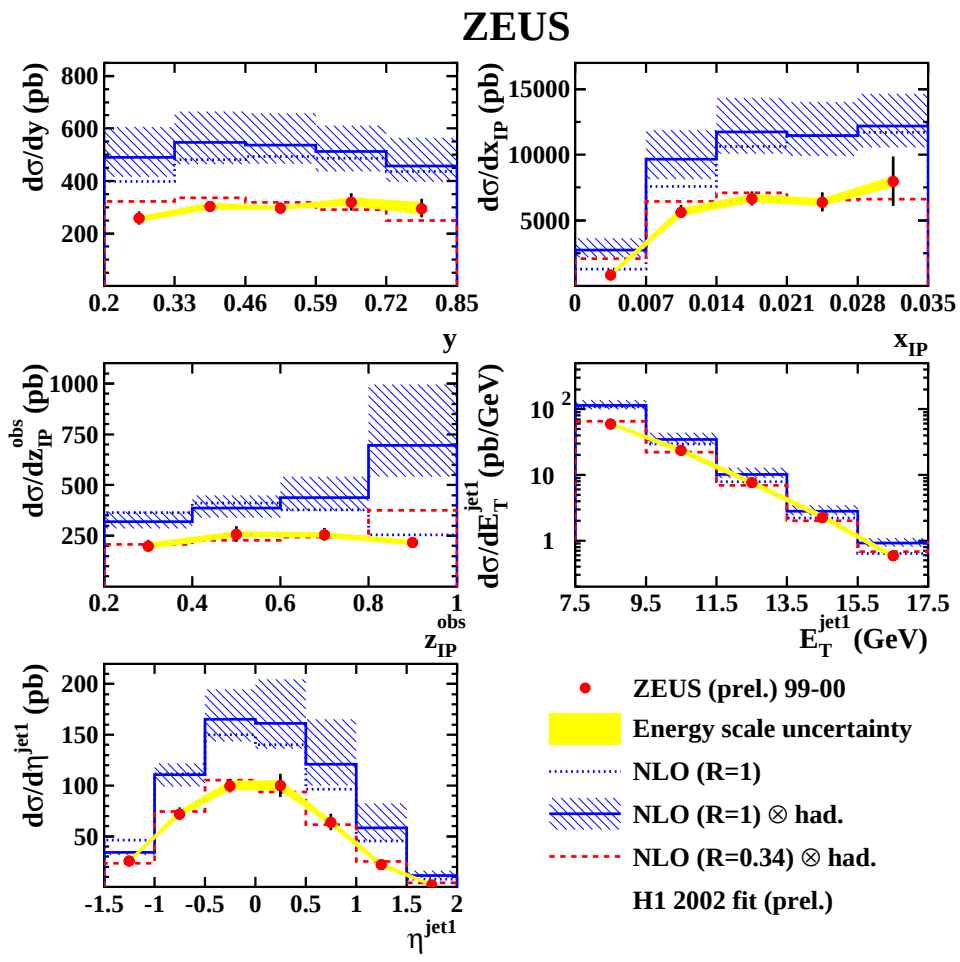
Diffractive Dijets in Photoproduction

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
$E_T^{jet1} > 7.5\,\text{GeV}$ $E_T^{jet2} > 6.5\,\text{GeV}$
$-1.5 < \eta^{jet1(2)}(\text{lab frame}) < 2.0$

- 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

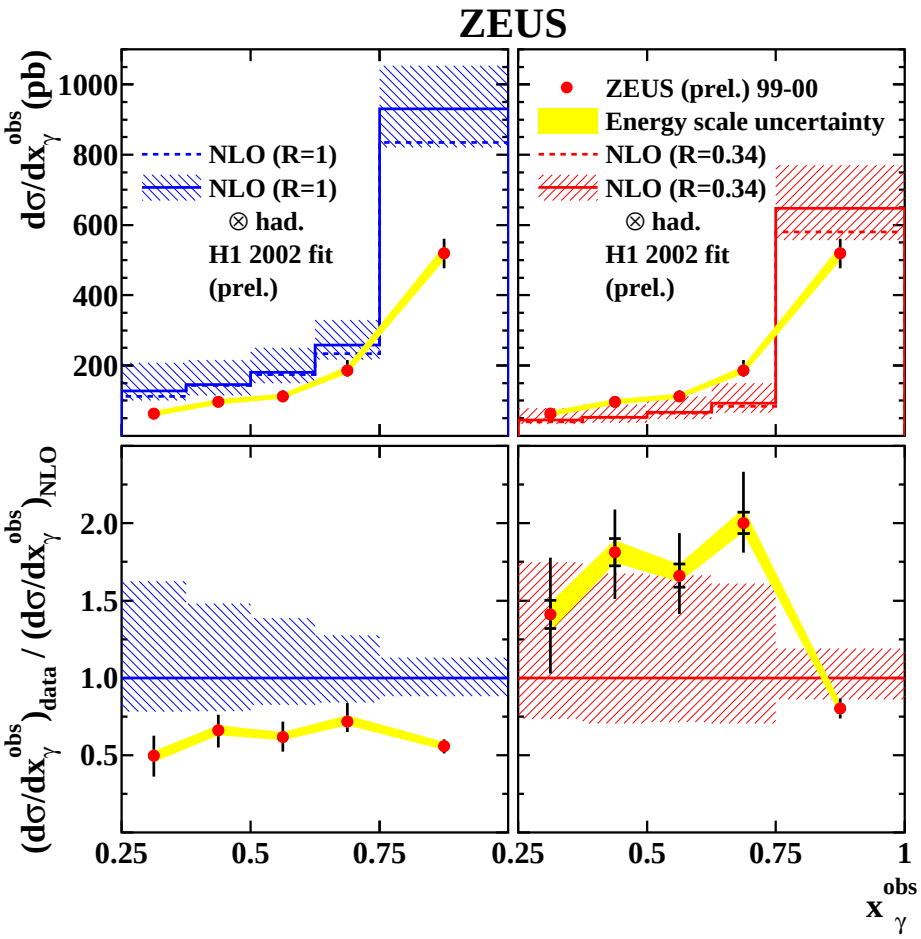


Diffractive Dijets in Photoproduction



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

Diffractive Dijets in Photoproduction

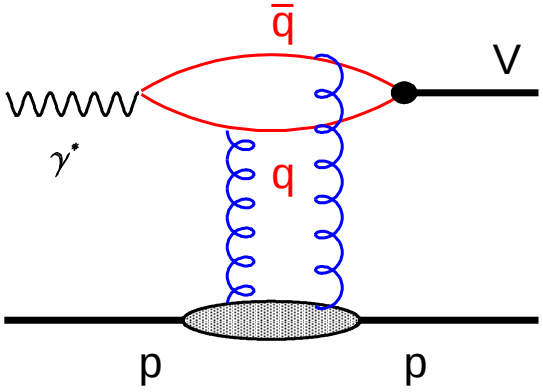


- The measurement favour a global suppression of the QCD factorization
- Resolved only suppression (R=0.34) disfavoured

Exclusive DIS VM Production

Aim to understand vector meson production in terms of pQCD

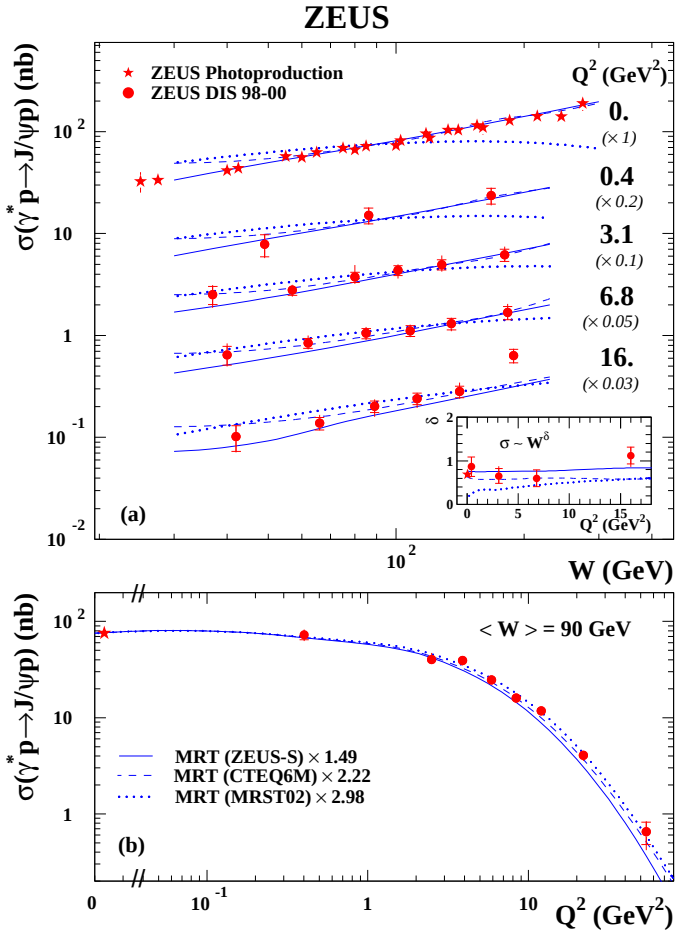
- hard scale with M_{VM}, Q^2 or t
- QCD factorisation theorem applicable
- This allows to separate pQCD from npQCD
- Probes gluon distribution in proton $\sigma \propto [xG(x)]^2$



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

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

Exclusive J/ψ production in DIS

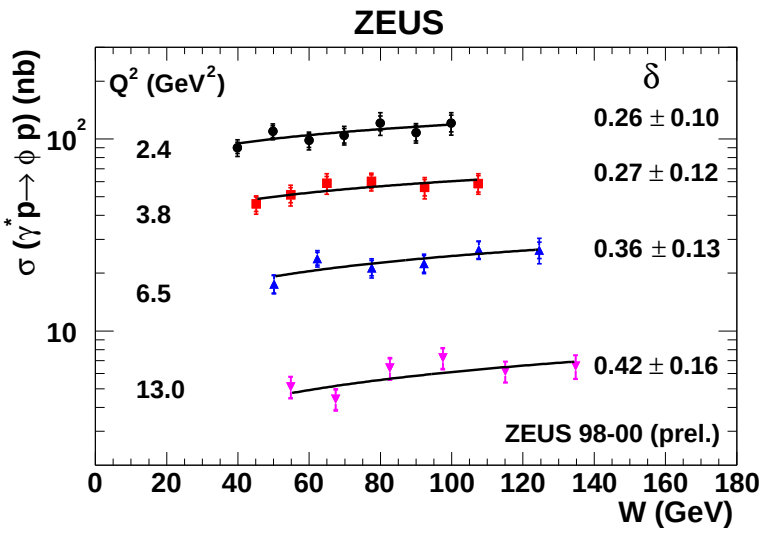


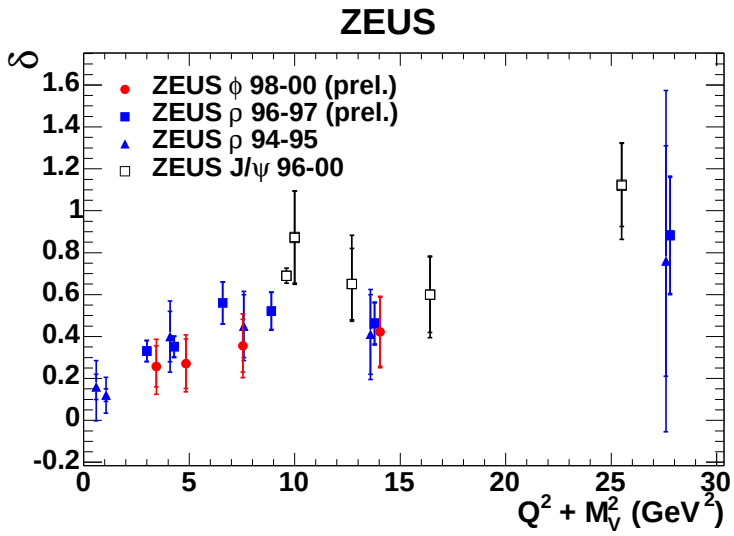
Comparison with different PDFs within Martin, Ryskin, Teubner (MRT) model

- 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

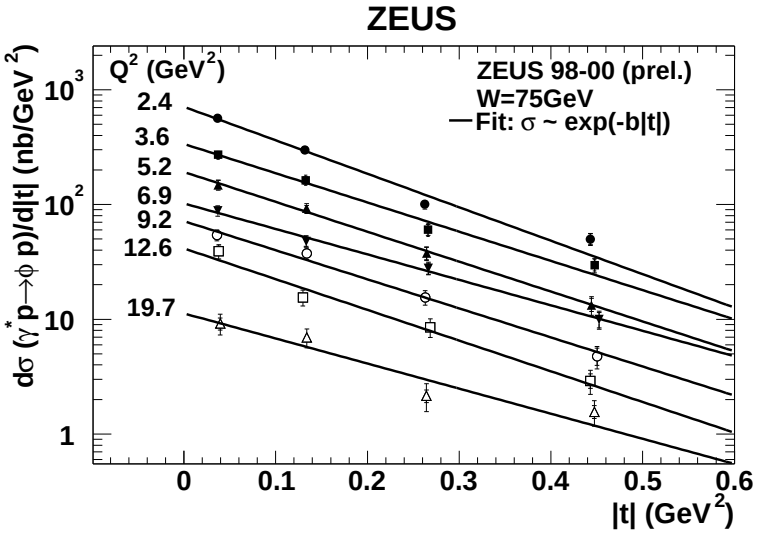
- Fit to $\sigma \approx W^{\delta}$: δ varies as a function of Q^2
- Data confirm scaling behaviour of cross section
- Rise of δ with $Q^2 + M_{VM}^2$ observed:
  - ρ, ϕ: transition from soft to hard regime
  - J/ψ: hard already in photoproduction

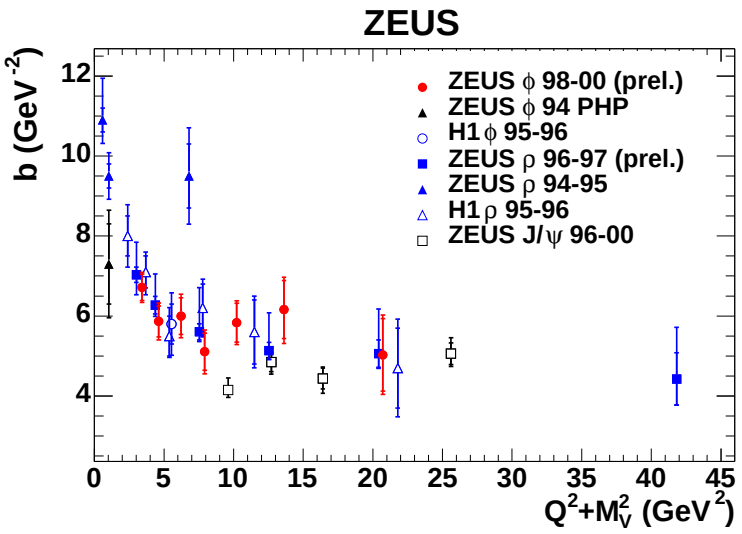




Exclusive ϕ Production in DIS

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

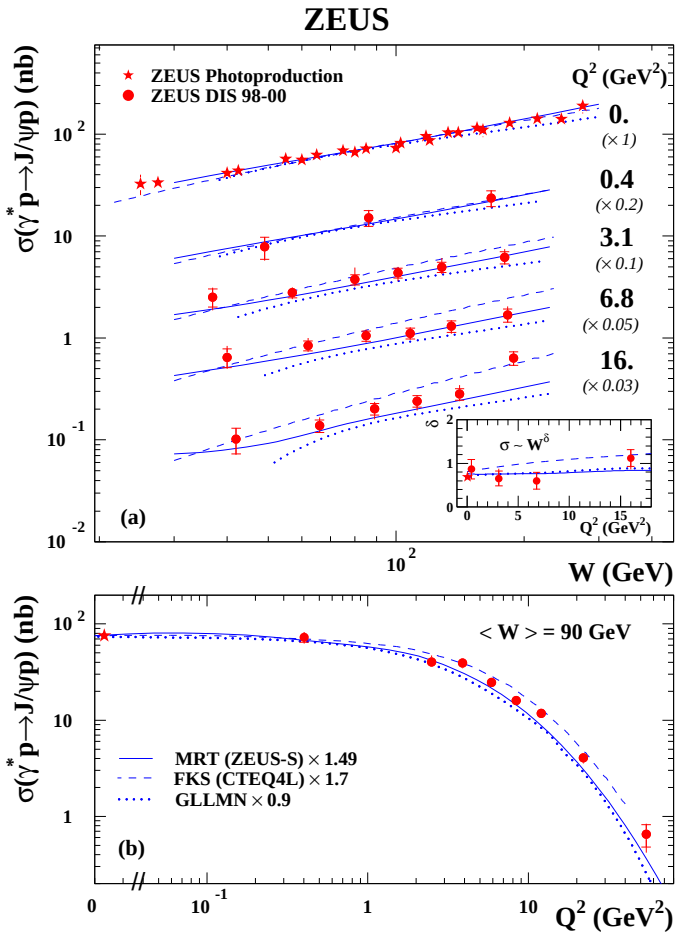
Diffractive dijets as a test for factorization breaking

- 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

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