Factorization Breaking in Diffractive Photoproduction of Dijets

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- Motivation
- Diffractive parton densities
- Multipomeron exchanges
- Direct and resolved photoproduction
- Conclusions

Motivation

Hard diffraction:

→ Does factorization hold?

Deep inelastic scattering: Yes.

→ Direct photoproduction

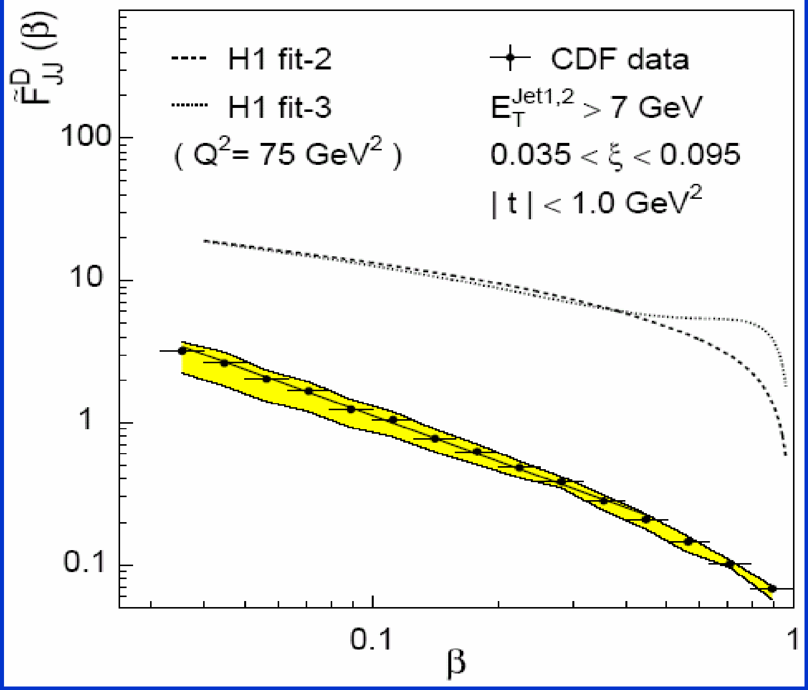
Hadroproduction: No.

→ Resolved photoproduction

Why next-to-leading order?

- $\sigma_{tot} = \sigma_{dir}(x_\gamma, M_\gamma) + \sigma_{res}(x_\gamma, M_\gamma)$
- At LO $x_\gamma = 1$, but at NLO $x_\gamma \leq 1$
- $\log(M_\gamma)$-dependence cancels

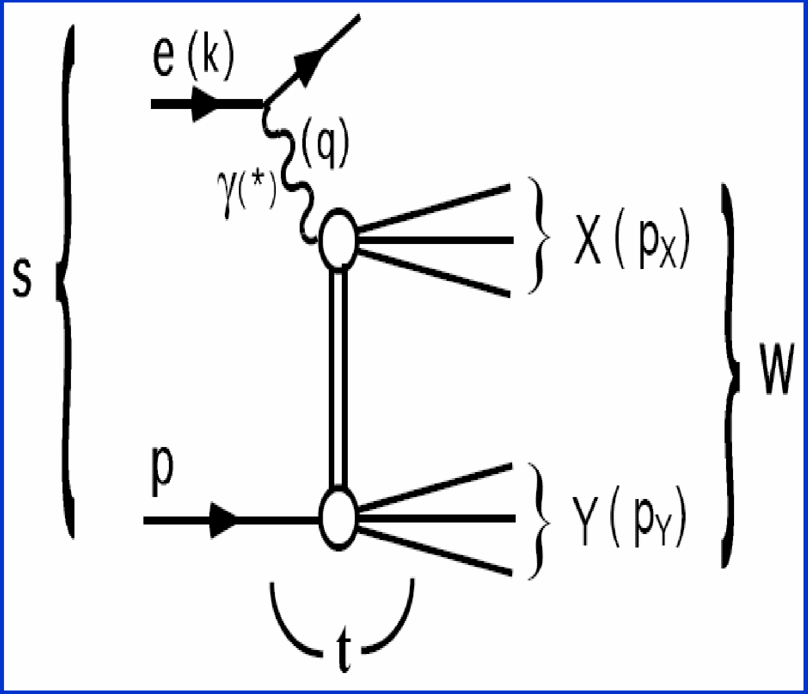
Diffractive hadroproduction of dijets:



CDF Coll., PRL 84 (2000) 5043.

Kinematics

Diffractive processes at HERA:



H1 Coll., ICHEP 02 and EPS 03.

Inclusive deep inelastic scattering:

$$s = (k+p)^2, \;\; Q^2 = -q^2, \;\; \text{and} \;\; y = \frac{qp}{kp}$$

Diffractive deep inelastic scattering:

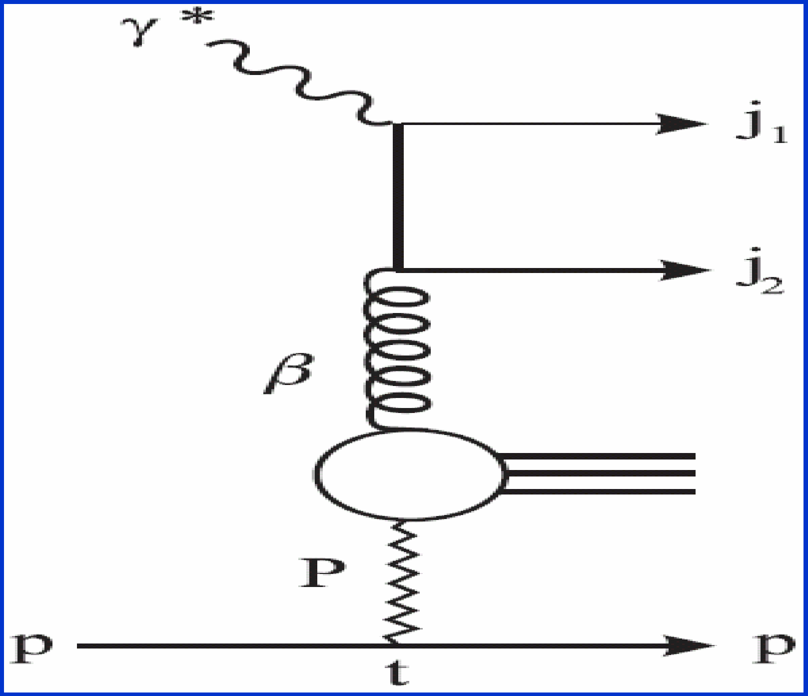
$$M_X^2 = p_X^2 \quad \text{and} \quad t = (p - p_Y)^2,$$
$$M_Y^2 = p_Y^2 \quad \text{and} \quad x_{I\!P} = \frac{q(p-p_Y)}{qp}$$

Experimental cuts:

$$\begin{array}{ccccl} 0.3 & < & y & < & 0.65 \\ & & Q^2 & < & 0.01\ \text{GeV}^2 \\ & & E_T^{\text{jet1}} & > & 5\ \text{GeV} \\ & & E_T^{\text{jet2}} & > & 4\ \text{GeV} \\ -1 & < & \eta_{\text{lab}}^{\text{jet1,2}} & < & 2 \\ & & x_{I\!P} & < & 0.03 \\ & & M_Y & < & 1.6\ \text{GeV} \\ & & -t & < & 1\ \text{GeV}^2 \end{array}$$

Diffractive Parton Distributions

Double factorization:



Ingelman, Schlein, PLB 152 (1985) 256.

1. Hard QCD factorization:

$$\frac{d^2\sigma}{dx_{I\!P}dt} = \sum_a \int_x^{x_{I\!P}} d\xi \sigma_a^{\gamma^*}(x, Q^2, \xi) f_a^D(\xi, Q^2; x_{I\!P}, t)$$

2. Regge factorization:

$$f_a^D(x, Q^2; x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t) f_{a/I\!P}(\beta = x/x_{I\!P}, Q^2)$$

Pomeron flux factor (integrated over t):

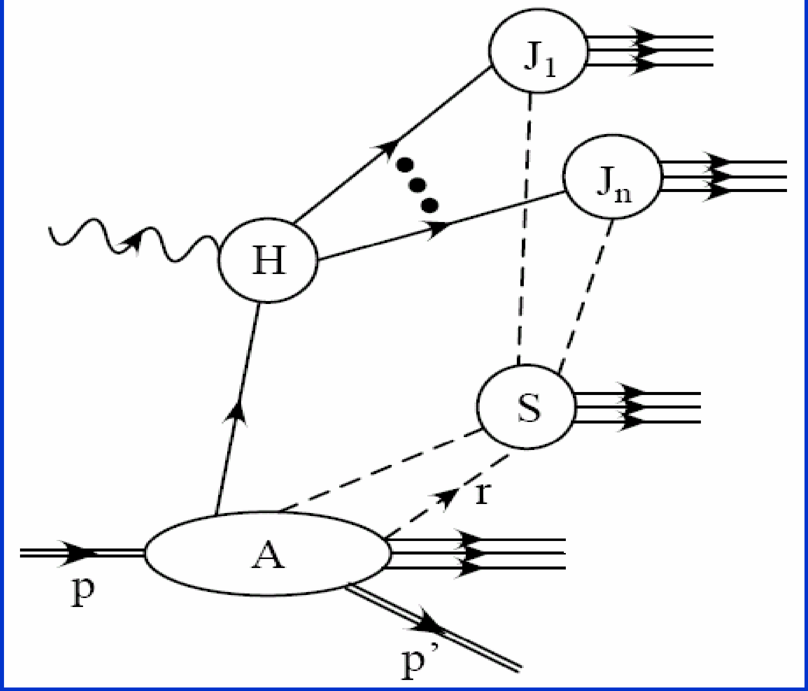
$$f_{I\!P/p}(x_{I\!P}, t) = x_{I\!P}^{1-2\alpha_{I\!P}(t)} \exp(B_{I\!P} t)$$

Pomeron trajectory:

$$\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$$

Proof of Hard QCD Factorization

Diffractive deep inelastic scattering:



J.C. Collins, PRD 57 (1998) 3051.

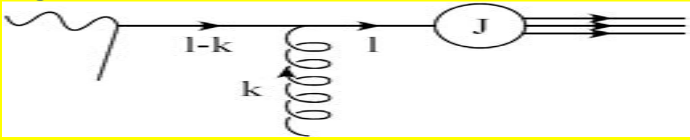
Light-cone coordinates:

- $q^\mu = (q^+, q^-, \mathbf{q}_T)$

Leading regions:

- H: $q^\mu \approx O(Q)$
- J: $l^\mu \approx (0, Q/\sqrt{2}, \mathbf{0}_T)$
- A: $|k^\mu| \ll O(Q)$

Soft gluon attachments:

- 

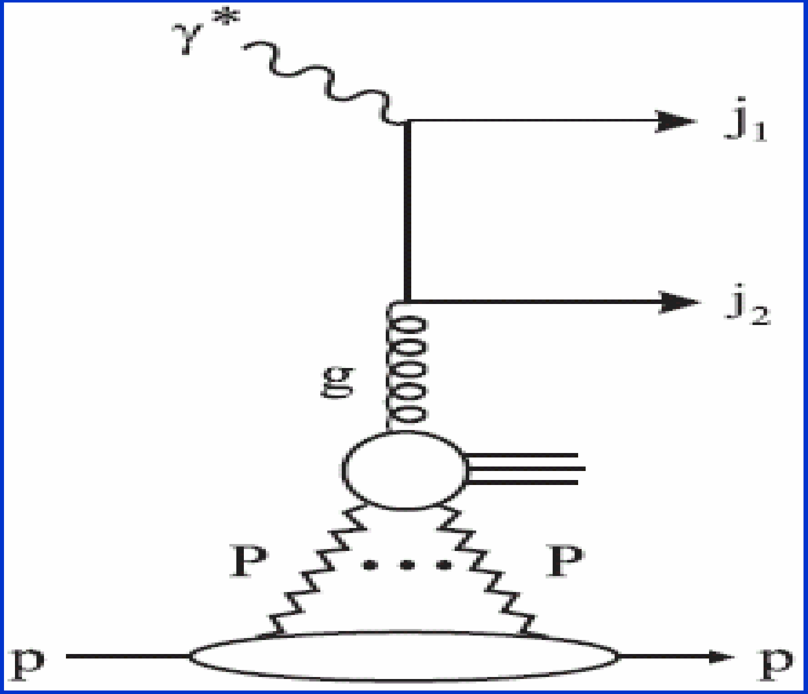
- $\frac{1}{(l-k)^2 - m^2 + i\epsilon} \simeq \frac{1}{-2l^- k^+ + \text{transverse} + i\epsilon}$

Poles in k^+-plane:

- Final state: Upper half-plane
- Initial state: Lower half-plane

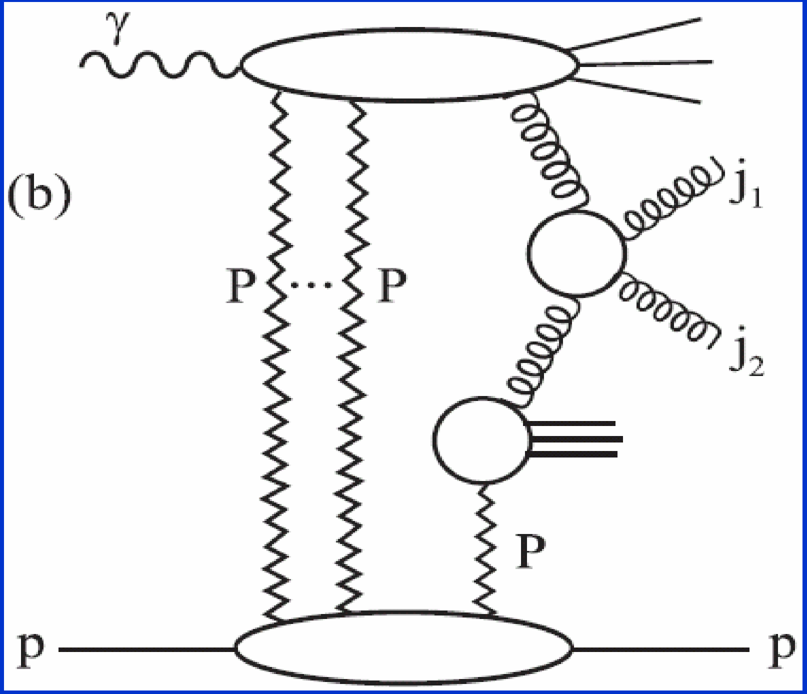
Multi-Pomeron Exchanges

Direct photoproduction:



→ Modification of the Regge trajectory

Resolved photoproduction:



→ Factorization breaking

Diffractive Photoproduction of Dijets

Cross section:

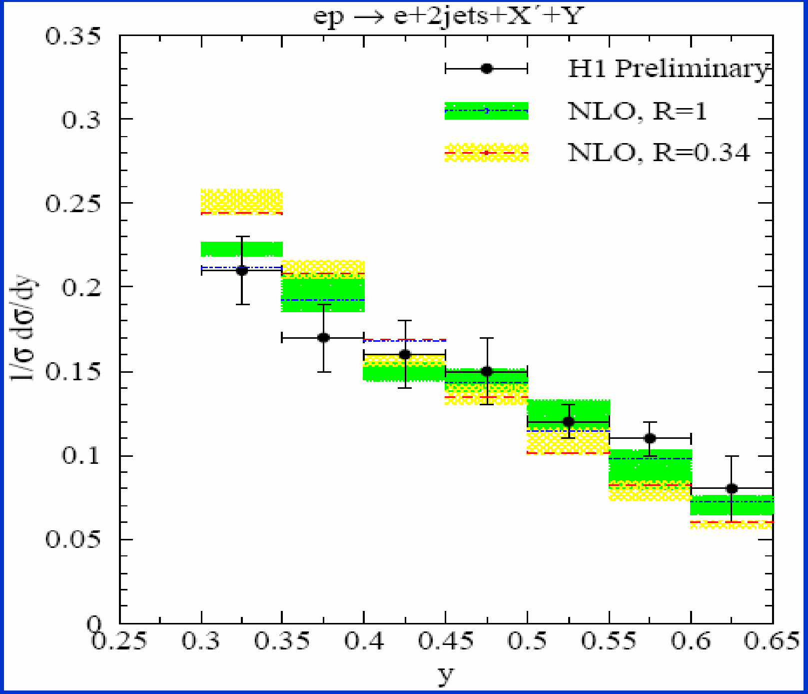
- $$d\sigma^D(ep \to e + 2\ \text{jets} + X' + Y) = \sum_{a,b} \int_{t_{\text{cut}}}^{t_{\text{min}}} dt \int_{x_{I\!P}^{\text{min}}}^{x_{I\!P}^{\text{max}}} dx_{I\!P} \int_0^1 dz_{I\!P} \int_{y_{\text{min}}}^{y_{\text{max}}} dy \int_0^1 dx_\gamma\, f_{\gamma/e}(y) f_{a/\gamma}(x_\gamma, M_\gamma^2) f_{I\!P/p}(x_{I\!P}, t) f_{b/I\!P}(z_{I\!P}, M_{I\!P}^2)\, d\sigma^{(n)}(ab \to \text{jets}).$$

Photon flux: Weizsäcker-Williams approximation

- $$f_{\gamma/e}(y) = \frac{\alpha}{2\pi}\left[\frac{1+(1-y)^2}{y} \ln \frac{Q^2_{\text{max}}(1-y)}{m_e^2 y^2} + 2m_e^2 y\left(\frac{1-y}{m_e^2 y^2} - \frac{1}{Q^2_{\text{max}}}\right)\right]$$

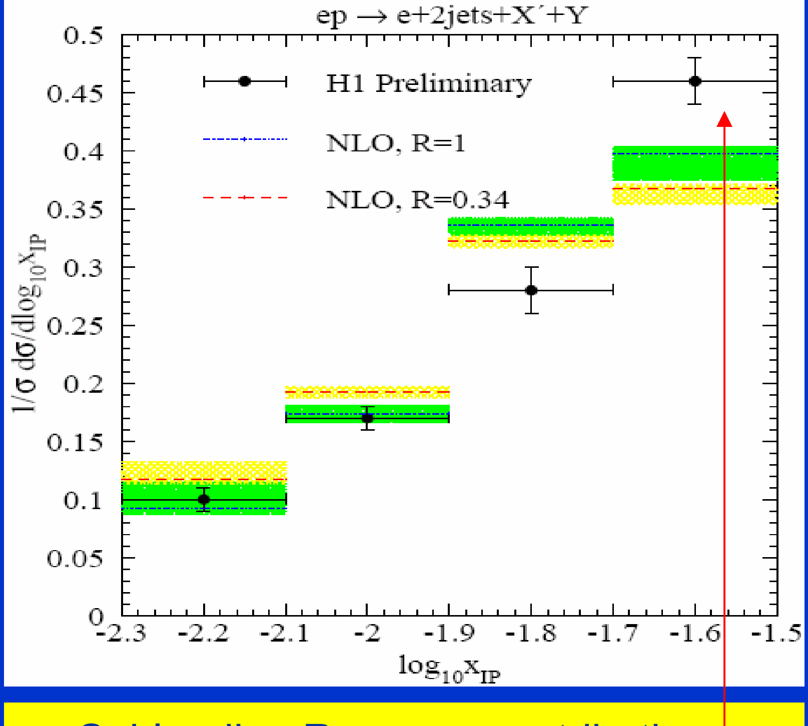
Factorizable Multi-Pomeron Exchanges

y-dependence: Photon flux



→ Small correlations due to exp. cuts

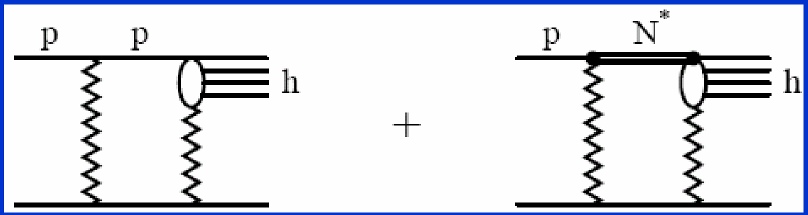
x_{IP}-dependence: Pomeron flux



→ Subleading Reggeon contribution

Two-Channel Eikonal Model

Hadronic collisions:



Survival probability:

$$|S|^2 = \frac{\int d^2b \left(|\mathcal{M}_{\rm v}|^2 \, e^{-\Omega_{\rm v}(s,b)} + |\mathcal{M}_{\rm sea}|^2 \, e^{-\Omega_{\rm sea}(s,b)} \right)}{\int d^2b \left(|\mathcal{M}_{\rm v}|^2 + |\mathcal{M}_{\rm sea}|^2 \right)}$$

Opacity / optical density: $K_i = 1 \pm \gamma$

$$\Omega_i = K_i \frac{(g_{pp}^{I\!P})^2 \, (s/s_0)^{\Delta}}{4\pi B} e^{-b^2/4B}$$

Kaidalov et al., EPJ C21 (2001) 521.

Photoproduction:

Generalized vector meson dominance:

- $J^{PC} = 1^{--}$: $\gamma \rightarrow \rho, \omega, \ldots$

Fitted parameters (W = 200 GeV):

- Total cross section: $\sigma^{tot}(\rho p)$=34 mb
- Pomeron slope: B = 11.3 GeV^{-2}
- Transition probability: γ = 0.6

→ ZEUS Coll., EPJ C2 (1998) 247

→ H1 Coll., EPJ C13 (2000) 371

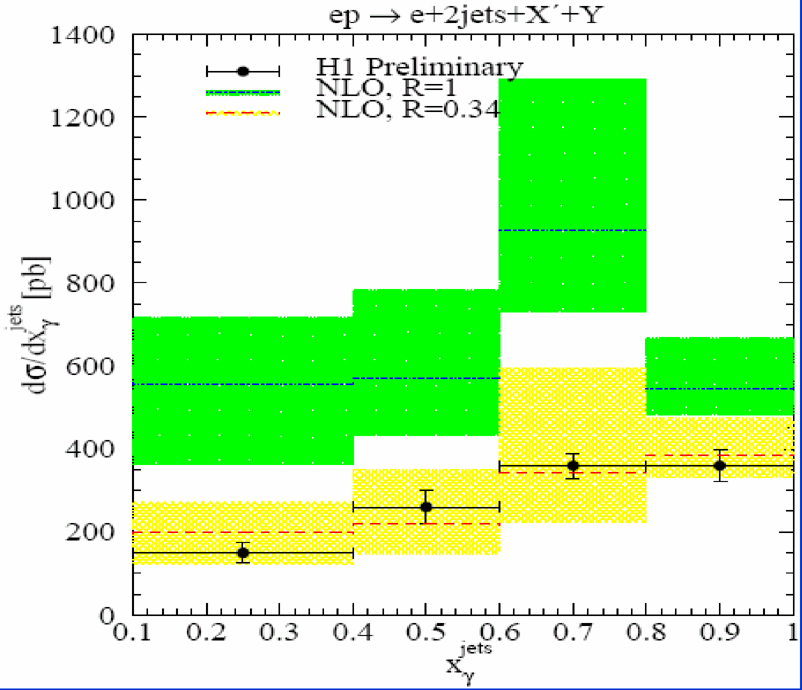
Survival probability:

- $R \equiv |S|^2 \approx 0.34$

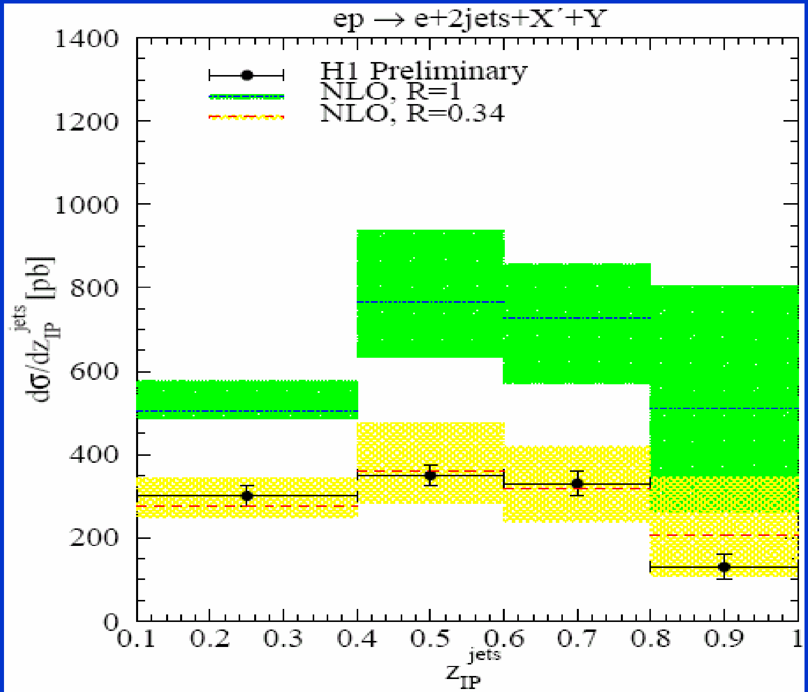
Kaidalov et al., PLB 567 (2003) 61.

Non-Factorizable Multi-Pomeron Exchanges

x_γ-dependence: Direct/resolved photons



z_{IP}-dependence:

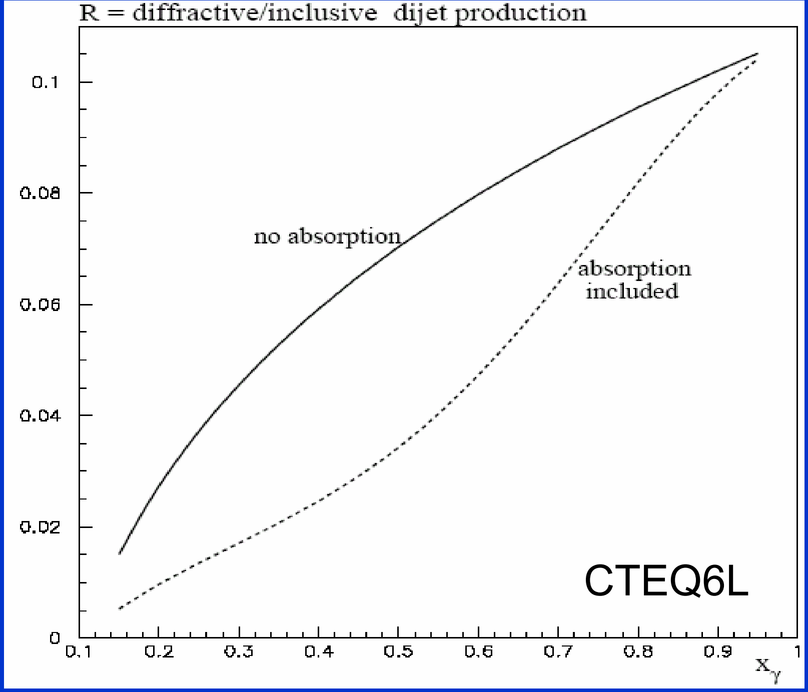


→ In LO, R = 1 agrees better with data!

→ Smaller uncertainties in $1/\sigma\ d\sigma/dz$

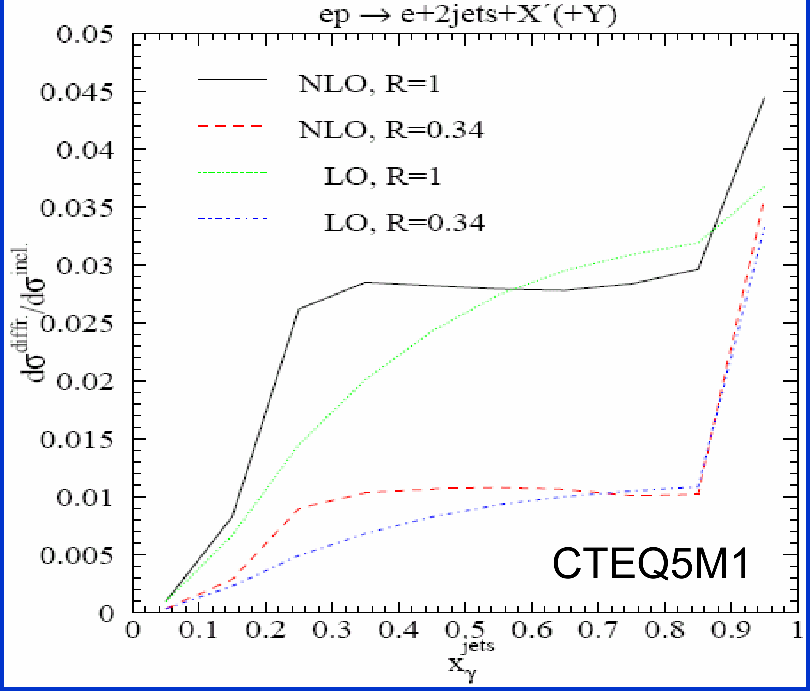
Diffractive / Inclusive Production

$R = f_{g/IP} \otimes f_{IP/p} / f_{g/p}$ with $M_{12} = x_\gamma z_{IP} x_{IP} W$:



A. Kaidalov et al., PLB 567 (2003) 61.

$R = \sigma^{diffr.} / \sigma^{incl.}$ with full kinematics:

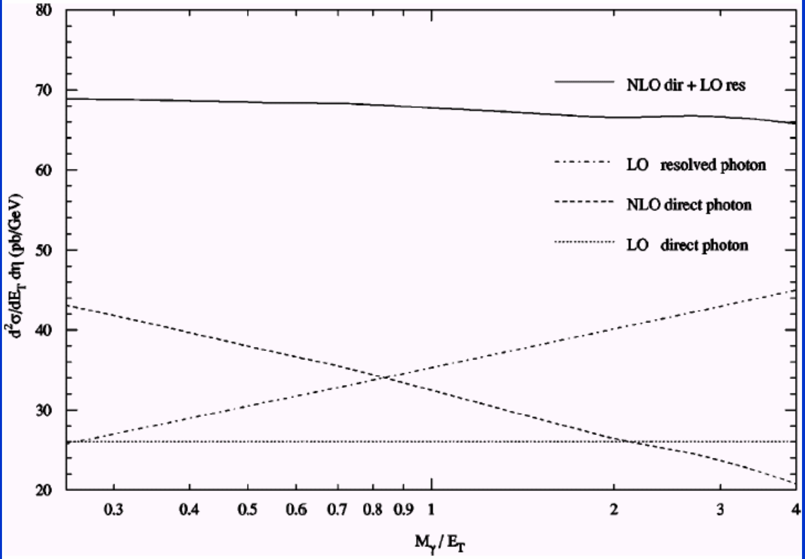


MK, G. Kramer, hep-ph/0401202.

Factorization Scale Dependence

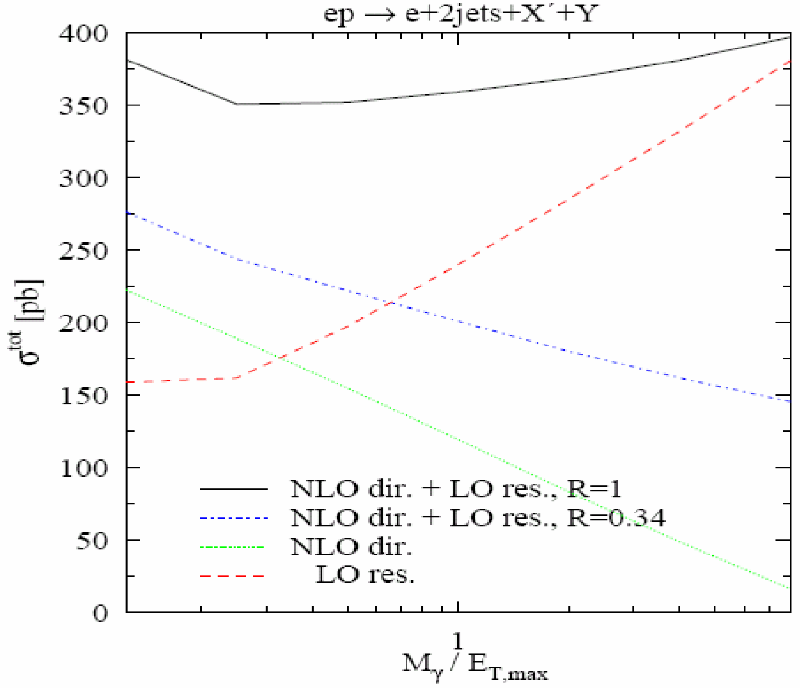
Inclusive photoproduction:

$$|\mathcal{M}^I|^2_{ab\to 123} = \ln\left(\frac{M^2}{Q^2}\right)|\mathcal{M}^B|^2_{cb\to 12} P_{c\leftarrow a}(x) + \cdots$$



MK, Rev. Mod. Phys. 74 (2002) 1221.

Diffractive photoproduction:



MK, G. Kramer, hep-ph/0401202.

Conclusions

Hard diffraction: Factorizable or not?

- Deep inelastic scattering: Yes. $\rightarrow$ Diffractive parton densities
- Hadronic scattering: No. $\rightarrow$ Multipomeron exchanges

Diffractive photoproduction of dijets at NLO:

- Direct / resolved photoproduction: x_γ and M_γ dependence
- (Non-) factorizable multipomeron exchanges

Two-channel eikonal model:

- Generalized vector meson dominance: $\gamma \rightarrow \rho, \omega, \ldots$
- Rapidity gap survival probability: R = 0.34

Related process:

- Leading neutron with π-exchange (NB: $f_{q/\pi}$, not $f_{g/IP}$!)