Rapidity Gaps in Diffractive DIS

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Kinematics

I. Phase space issues from rapgap cuts

- LRG constraints
- Regge-factorization breaking

II. Transverse momentum distribution of dijet models

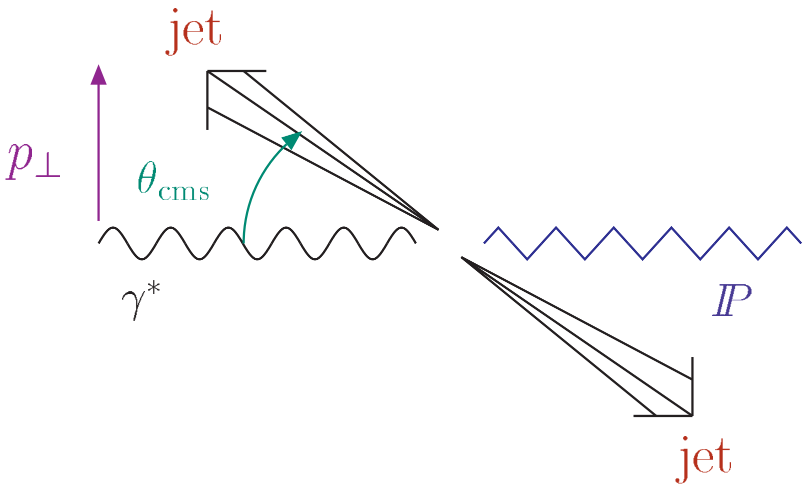
- Effect of rapidity cuts
- Comparison with $p_\perp^2$–distributions

Summary/Future Prospects

Kinematics

- **Usual kinematic variables used:** $Q^2, \beta, x_{I\!P} \ldots$

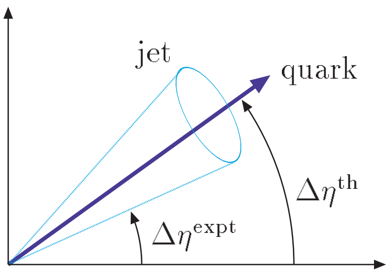
- **Jet transverse momentum** ($\gamma^* - I\!P$ **cms):**



$$p_\perp^2 = \frac{M_X^2}{4} \sin^2 \theta_{\rm cms}$$

$\theta_{\rm cms}$ = **angle between jets and proton direction**

- **Pseudo-rapidity gaps: hadron and parton level**



Assume:

$$\eta_{\rm max}^{\rm th} \approx \eta_{\rm max}^{\rm exp} - 0.5$$

Pomeron Structure

- **Ingelman–Schlein (1985):**
  - **pomeron $\sim$ *hadronic***

Diffractive Structure Function $F_2^{D(3)}$:

$$\frac{\mathrm{d}^3\sigma^{\mathrm{diff}}}{\mathrm{d}Q^2\,\mathrm{d}\beta\,dx_{I\!P}} = \frac{2\pi\alpha_{\mathrm{em}}^2}{\beta Q^4}\left\{[1+(1-y)^2]F_2^{D(3)}(Q^2,\beta,x_{I\!P}) - y^2 F_L\right\}$$

Pomeron Structure Function $F_2^{I\!P}$:

$$F_2^{D(3)}(Q^2,\beta,x_{I\!P}) = f_{I\!P/P}(x_{I\!P})\,F_2^{I\!P}(Q^2,\beta)$$

Consequences of large rapidity gap cuts

Ellis, Ross 1996

- **Diffractive structure function:**

$$F_2^{D(3)} = \int_{p^2_{\perp\,\mathrm{min}}}^{M_X^2/4} \mathrm{d}p_\perp^2 \, \frac{\mathrm{d}^4\sigma}{\mathrm{d}Q^2\,\mathrm{d}\beta\,\mathrm{d}x_{I\!P}\,\mathrm{d}p_\perp^2}$$

- **Ellis–Ross: Cuts *may* restrict phase space:**

boost: LAB → CMS

$$1-\cos\theta_{\mathrm{cms}} = \frac{(1-\beta_1)(1-\beta_2^2)}{1-\beta_1\cos\theta_{\mathrm{lab}} - \sqrt{1-\beta_1^2}\,\beta_2\sin\theta_{\mathrm{lab}}\cos\phi_{\mathrm{lab}}}(1-\cos\theta_{\mathrm{lab}})$$

ϕ_{lab} = **azimuthal angle**

$\beta_1(Q^2,\beta,x_{I\!P})$, $\beta_2(Q^2,\beta,x_{I\!P})$ = **boost parameters**

$$\boxed{\eta_{\mathrm{max}} \Rightarrow \theta^{\mathrm{lab}}_{\mathrm{min}} \Rightarrow \theta^{\mathrm{cms}}_{\mathrm{min}} \Rightarrow -p^2_{\perp\,\mathrm{min}}}$$

- **The *magnitude* of $p^2_{\perp\,\mathrm{min}}$ depends strongly on Q^2, β, $x_{I\!P}$.**

Pomeron "structure function"

Diffractive structure function:

$$F_2^{D(3)} = \int_0^{M_X^2/4} \mathrm{d}p_\perp^2 \, \frac{\mathrm{d}^4\sigma}{\mathrm{d}Q^2\,\mathrm{d}\beta\,\mathrm{d}x_{I\!P}\,\mathrm{d}p_\perp^2}$$

- **for $\eta_{\max}$, Q^2, $x_{I\!P}$ such that $p_\perp^2 > 1\ \mathrm{GeV}^2$, *extract***

$$F_{2\,\mathrm{LRG}}^{D(3)} = \int_{p_{\perp\,\min}^2}^{M_X^2/4} \mathrm{d}p_\perp^2 \, \frac{\mathrm{d}^4\sigma}{\mathrm{d}Q^2\,\mathrm{d}\beta\,\mathrm{d}x_{I\!P}\,\mathrm{d}p_\perp^2}$$

- $p_{\perp\min}^2$ **is a function of $x_{I\!P}$!**

Therefore:

- $F_{2\,\mathrm{LRG}}^{D(3)}$ **extracted from experiment not expected to factorize into $f(x_{I\!P})\,F_2^{I\!P}(Q^2,\beta)$:**
  - **Even though full structure function $F_2^{D(3)}$ might**
  - **Can't extract well-defined pomeron "structure function", $F_2^{I\!P}$.**

II. Looking at Large Rapidity Cut Data

1. **Look at diffractive DIS data as a function of $\eta_{\max}$:**

   – **once get to $k^2_{\min} >$ a few GeV , expect to see reduction of extracted diffractive structure function**

   – **model-independent confirmation of phase space reductions**

   – **test of $k^2\,(p^2_\perp)$ dependence of models**

2. **Look at large $k^2_{\min}$ data:**

   – $k^2_{\min}$ **very sensitive to β and $x_{I\!P}$**

   – **see large–k^2 behaviour**

- **We looked at 4 classes of dDIS models:**

  – **Vector-like pomeron with form factor**

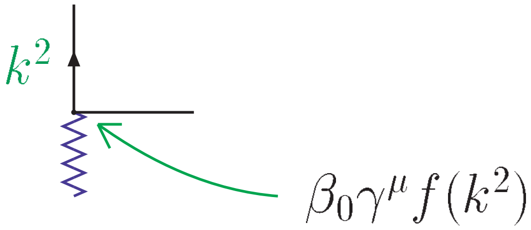
  – **Single Gluon/Soft colour exchange**

  – **Scalar Pomeron**

  – **Two-Gluon**

Comparison of $I\!P$-exchange (dijet) models with large rapgap $F_2^{D(3)}$ data

1. Form factor models



Donnachie–Landshoff:

D-L, Phys.Lett. B185 (1997) 403
B191 (1987) 309

$f(k^2) \sim \frac{1}{k^2}$

- Extension of $P - P$ scattering model
- $f(k^2)$ preserves $F_2^{D(3)}$ scaling
- strong suppression with large k^2

Ellis–Ross:

E-R, Phys.Lett. B384 (1996) 293

$f(k^2) \sim \frac{1}{k}$

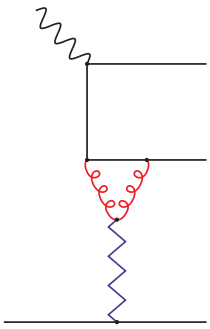
- logarithmic scaling violations in $F_2^{D(3)}$
- contribution from whole k^2 range

E–R motivation

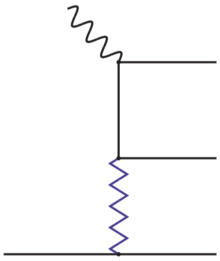
1.

• **data not sensitive to rapgap cuts**

2. Compare:



and



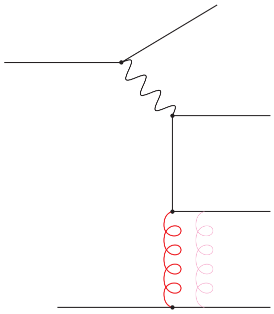
$\longrightarrow$ **extra $1/k^2$ in cross section**

$\longrightarrow$ **identify with form factor $f^2(k^2)$**

2. Single gluon exchange

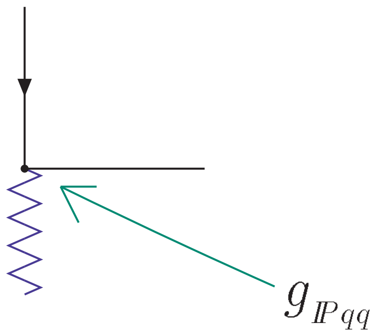
Buchmüller, Hebecker 1995

- colour singlet part of single gluon exchange
- one hard gluon determines dynamics
- additional soft gluons dress colour



3. Scalar pomeron exchange

Vermaseren *et al* 1998

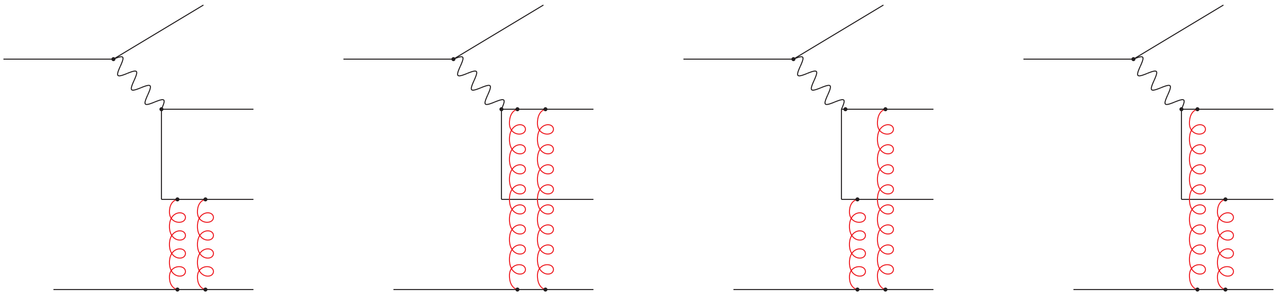


- $g_{I\!\!Pqq}$ point-like quark–pomeron coupling
- no form factor

4. Two-gluon model

Landshoff, Nachtmann 1987
Diehl 1995, 1998

- **two non-interacting gluons**



- **first two diagrams $\sim$ "particle exchange"**
- **need all four diagrams for gauge invariance**

- **Diffractive structure function (at large $p_{\perp\,\mathrm{min}}^2$)**

$$F_2^{D(3)} \sim \beta^3 \, (1 - \beta)$$

– not seen in data

Summary/Future Prospects

Large Pseudo-Rapidity Cuts:

- For some (calculable) range of parameters Q^2, β, and $x_{I\!P}$:

  - ***Significant reduction in phase space available for diffractive DIS***

  - **Quantifying this result leads to a *test of models of diffractive DIS***

- **Source of $x_{I\!P}$ factorization-breaking**

- **We examined 4 classes of pomeron exchange models:**
  - **E–R form factor model fits well**
  - **Two-gluon model does not describe β-dependence**

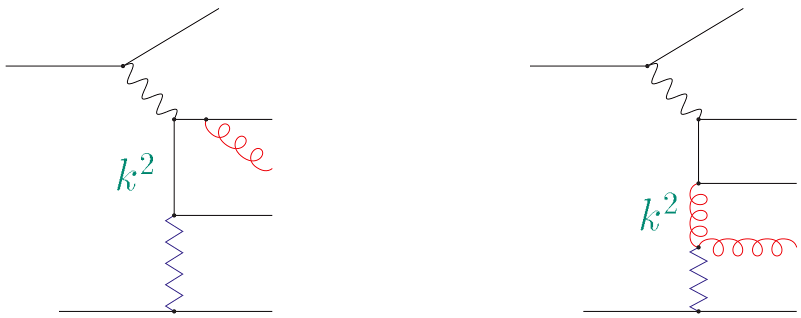
- **Need more data with strong $\eta_{\max}$ to test ideas here**

- **Monte Carlo studies of LRG production under way**

Comments

1. **For some Q^2 , β , $x_{I\!P}$ and $\eta_{\max}$, $p^2_{\perp\,\min}$ very large.**

2. **We have extended the original calculation to include events like:**

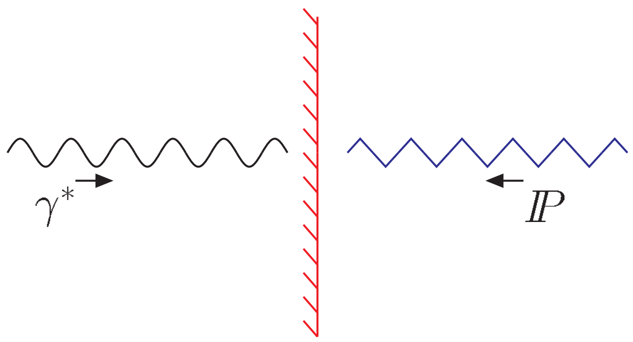


constraint :

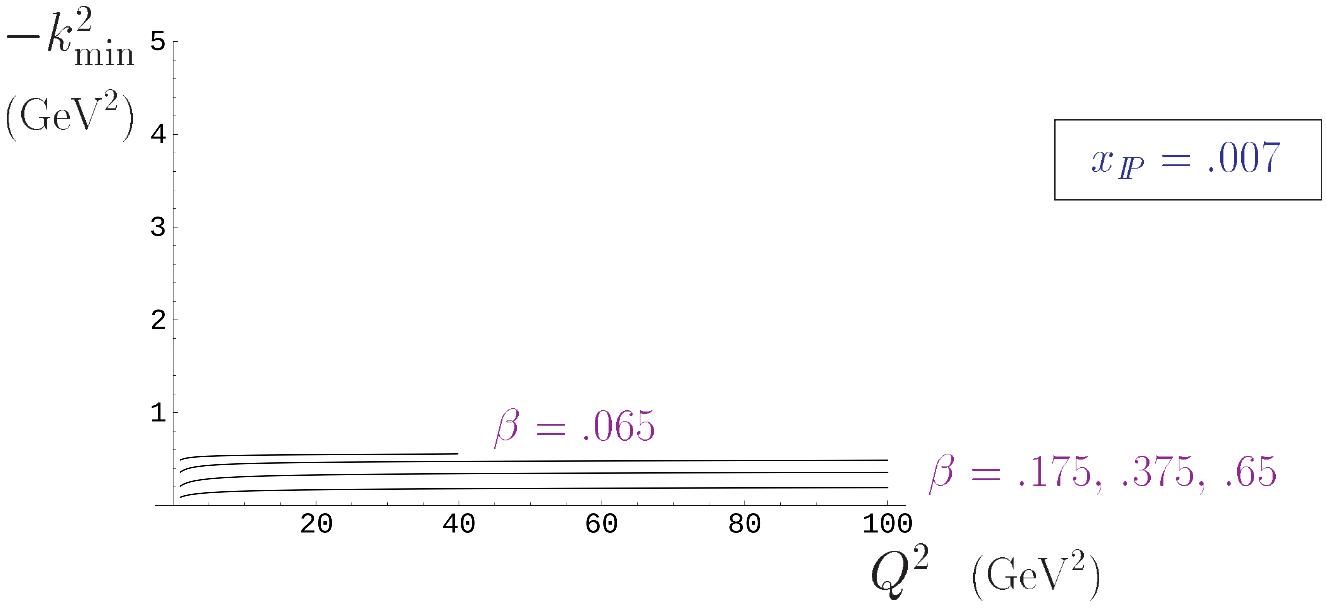
$$\mathbf{p^2_{\perp\,\min}}\,(\text{multijet}) \gtrsim -\frac{\mathbf{1}}{\mathbf{3}}\,\mathbf{p^2_{\perp\,\min}}\,(\text{dijet})$$

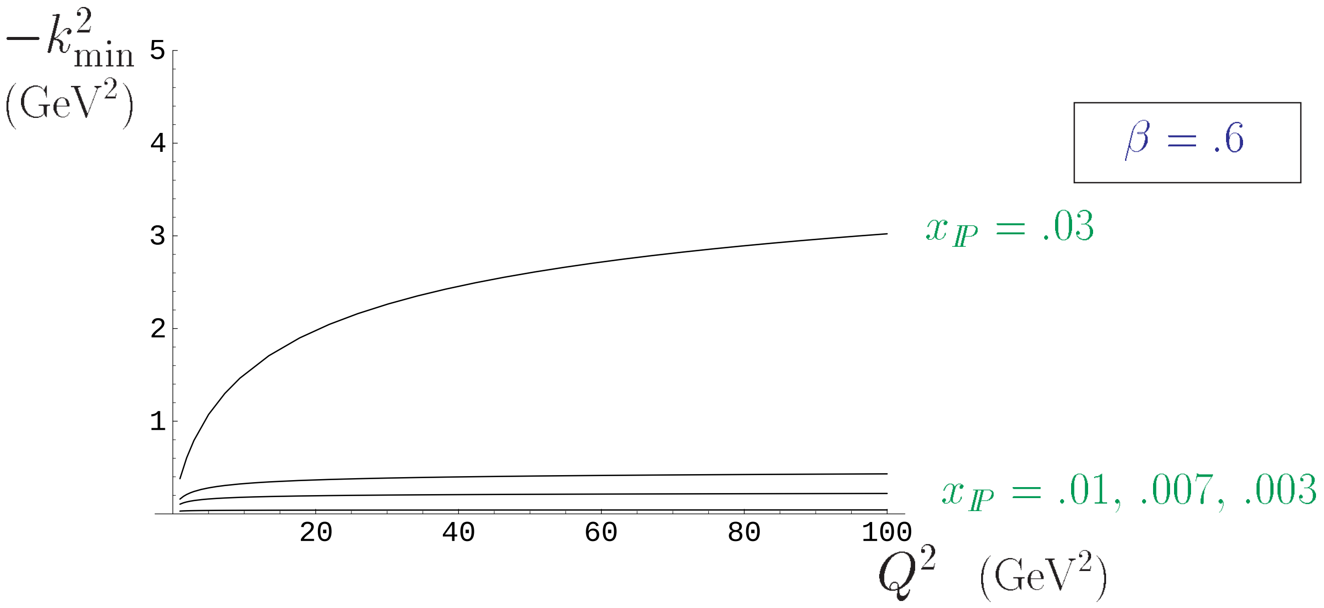
3. **If we have $\eta_{\max}$, Q^2 , β , $x_{I\!P}$ such that $\theta^{\text{cms}}_{\min} > 90°$:**

$\longrightarrow$ **see *no* events:**



Dependence of $-k^2_{\min}$ on Q^2, β, and $x_{I\!P}$





$$\eta_{\max} = 3.2 \quad (\mathrm{expt})$$