On diffractive photoproduction of jets in NLO

A.V. Grabovsky

Budker Inst. of Nuclear Physics and Novosibirsk State University

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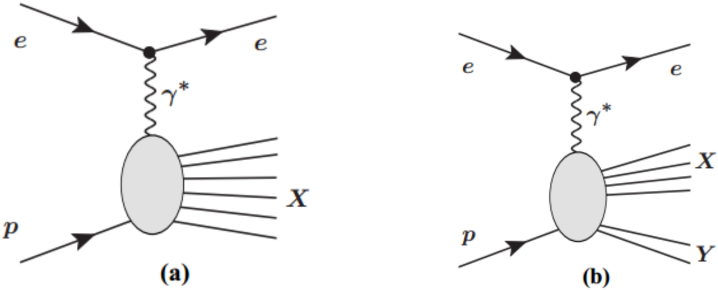
Work with R. Boussarie, L.Szymanowski, S.Wallon

Outline

- Motivation - Diffractive jet production at HERA
- Previous work - Description in the collinear and k_t factorizations
- Current work - Calculation in the Shockwave approach
- Summary

Rapidity gap events at HERA

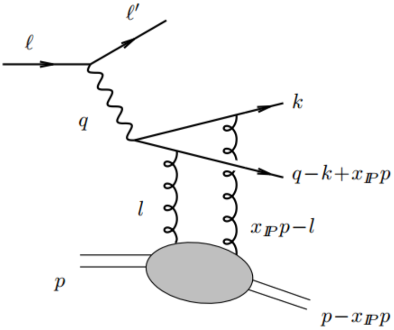
Experiments at HERA : about 10% of scattering events reveal a rapidity gap



DIS events DDIS events

Previous work

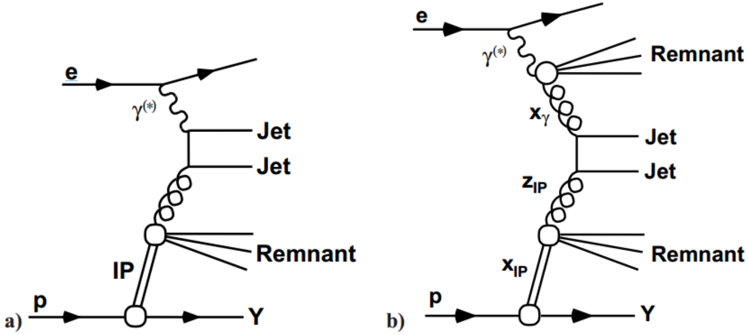
k_T-factorization approach : two gluon exchange



Bartels, Jung, Wusthoff
collinear or soft approximations for $\gamma \to q\bar{q}g$

Previous work

Collinear factorization approach

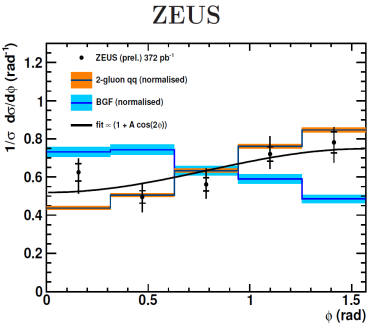


Direct Resolved

One needs to introduce a diffractive distribution function for partons *within a pomeron*
Ingelman and Schlein

Previous work: comparison with HERA data

ZEUS collaboration, 2014 (A. Valkarova talk at LowX 2014)



The data favors two gluon exchange model

Current work - Calculation in the Shockwave approach

Introduce the light cone vectors n_1 and n_2

$$n_1 = (1,0,0,1)\,, \quad n_2 = \frac{1}{2}(1,0,0,-1)\,, \quad n_1^+ = n_2^- = n_1 n_2 = 1$$

For any p define $p^{\pm}$

$$p^+ = pn_2 = \frac{1}{2}\left(p^0 + p^3\right), \qquad p^- = pn_1 = p^0 - p^3,$$

$$p^2 = 2p^+p^- - \vec{p}^{\,\mathbf{2}};$$

The scalar products:

$$p = p^+ n_1 + p^- n_2 + p_\perp, \quad (p\,k) = p^\mu k_\mu = p^+k^- + p^-k^+ - \vec{p}\vec{k}.$$

Definitions

Wilson line describing interaction with external field b_η^- made of slow gluons with $p^+ < e^\eta$

$$U_{\vec{z}}^\eta = Pe^{ig\int_{-\infty}^{+\infty} dz^+ b_\eta^-(z^+,\vec{z})}, \quad b_\eta^- = \int \frac{d^4p}{(2\pi)^4} e^{-ipz} b^-(p)\,\theta(e^\eta - p^+).$$

Shock wave (Balitsky 1996)

For a fast moving particle with the velocity $-\beta$ and the field strength tensor $\mathbb{F}(x^+, x^-, \vec{x})$ in its rest frame, in the observer's frame the field will look like

$$\mathfrak{F}^{-i}\left(y^+, y^-, \vec{y}\right) = \lambda \mathbb{F}^{-i}(\lambda y^+, \frac{1}{\lambda} y^-, \vec{y}) \to \delta\left(y^+\right) \mathfrak{F}^i\left(\vec{y}\right),$$

$$\mathfrak{F}^{-i} \gg \mathfrak{F}^{\cdots}$$

in the Regge limit $\lambda \to +\infty$, $\lambda = \sqrt{\frac{1+\beta}{1-\beta}}$.

Therefore the natural choice for the gauge is $b^{i,+} = 0$,

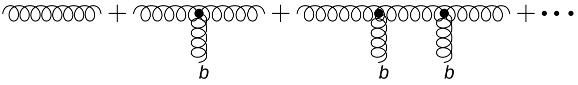
b^- is the solution of the equations

$$\frac{\partial b^-}{\partial y^i} = \delta(y^+) \mathfrak{F}^i\left(\vec{y}\right), i.e.$$

$$b^\mu\left(y\right) = \delta(y^+) B\left(\vec{y}\right) n_2^\mu$$

It is the shock-wave field.

Propagator in the shock-wave background



Sum the diagrams

- b does not depend on x^-, hence the conservation of p^+,
- $b \sim \delta(x^+)$, hence $e^{-i\frac{\vec{p}^{\,2}(x_1^+ - x_2^+)}{2p^+}} \to 1$ in every internal vertex,
- $g_\perp^{\mu\nu} d_{0\nu\rho} g_\perp^{\rho\sigma} = g_\perp^{\mu\sigma}$, hence no dependence on $\vec{p} \Longrightarrow$ conservation of $\vec{x}$ in every internal vertex

Propagator in the shock-wave background:

$$G_{\mu\nu}(x,y)|_{x^+>0>y^+} = 2i\overbrace{A^{\mu}(x)\int d^4z\,\delta(z^+)F}^{}{}^{+i}(z)\,\frac{U_{\vec{z}}}{\overrightarrow{\frac{\partial}{\partial z^-}}}\,\overbrace{F^{+i}(z)\,A}^{}{}^{\nu}(y)\,.$$

where the interaction with b is through Wilson line

$$U_{\vec{z}} = Pe^{ig\int_{y^+}^{x^+} dz^+ b^-\left(z^+,\vec{z}\right)}.$$

Evolution equation

$tr(U_1 U_2^\dagger)$ obeys the LO Balitsky-Kovchegov evolution equation

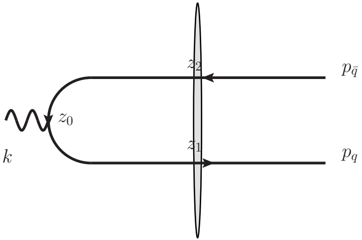
$$\frac{\partial tr(U_1 U_2^\dagger)}{\partial \eta} = \frac{\alpha_s}{2\pi^2} \int d\vec{r}_4 \frac{\vec{r}_{12}^{\,2}}{\vec{r}_{14}^{\,2}\vec{r}_{42}^{\,2}} \left[tr(U_1 U_4^\dagger) tr(U_4 U_2^\dagger) - N_c tr(U_1 U_2^\dagger) \right].$$

$\vec{r}_{ij} \equiv \vec{r}_i - \vec{r}_j$

LO equation was obtained in 1996 (Balitsky) - 99 (Kovchegov), NLO — in 2007-2010 (Balitsky and Chirilli).

Matrix element for EM current

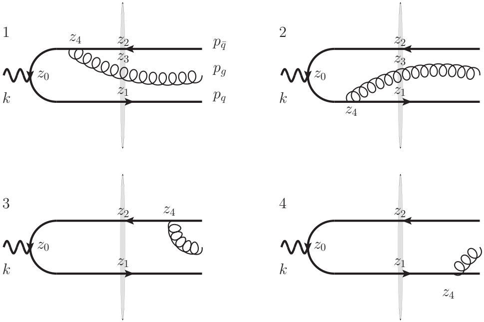
$$T_0^{\alpha} = \int d^d p_{1\perp} d^d p_{2\perp} \delta(p_{q1\perp} + p_{\bar{q}2\perp} - p_{\gamma\perp}) \Phi_0^{\alpha} [tr(U_1 U_2^{\dagger}) - N_c](p_{1\perp}, p_{2\perp}).$$



Impact factors

$$\Phi_0^+ = \frac{2x\bar{x}p_\gamma^+}{\vec{p}_{q1}^{\,2} + x\bar{x}Q^2}(\overline{u}_{p_q}\gamma^+ v_{p_{\bar{q}}}), \quad \Phi_0^i = \frac{\overline{u}_{p_q}((\bar{x} - x)p_{q1\perp}^i + \frac{1}{2}[\hat{p}_{q1\perp}, \gamma^i])\gamma^+ v_{p_{\bar{q}}}}{\vec{p}_{q1}^{\,2} + x\bar{x}Q^2}.$$

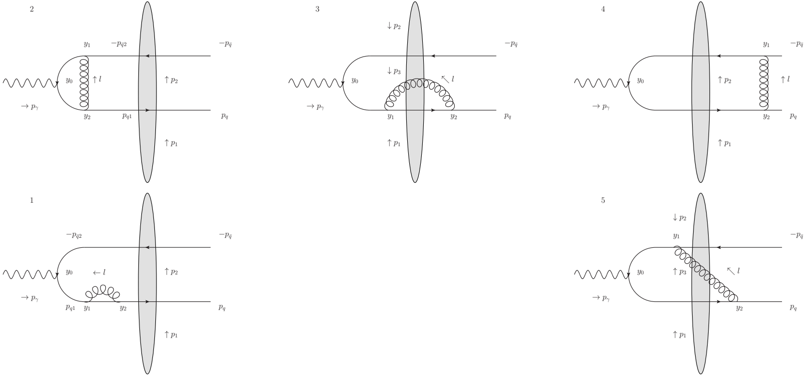
$\gamma \to q\bar{q}g$ impact factor



$$T^{\alpha} = g \int d^d p_{1\perp} d^d p_{2\perp} \left\{ \delta(p_{q1\perp} + p_{\bar{q}2\perp} + p_{g\gamma\perp}) \Phi_3^{\alpha} \frac{N_c^2 - 1}{N_c} [tr(U_1 U_2^{\dagger}) - N_c] \right.$$

$$\left. + \int \frac{d^d p_{3\perp}}{(2\pi)^d} \delta(p_{q1\perp} + p_{\bar{q}2\perp} + p_{g\gamma\perp} - p_{3\perp}) \Phi_4^{\alpha} [tr(U_1 U_3^{\dagger}) tr(U_3 U_2^{\dagger}) - N_c tr(U_1 U_2^{\dagger})] \right\} .$$

NLO $\gamma \to q\bar{q}$ impact factor



$$T^{\alpha} = g \int d^d p_{1\perp} d^d p_{2\perp} \left\{ \delta(p_{q1\perp} + p_{\bar{q}2\perp} - p_{\gamma\perp}) \Phi_3^{\alpha} \frac{N_c^2 - 1}{N_c} [tr(U_1 U_2^{\dagger}) - N_c] \right.$$

$$\left. + \int \frac{d^d p_{3\perp}}{(2\pi)^d} \delta(p_{q1\perp} + p_{\bar{q}2\perp} - p_{\gamma\perp} - p_{3\perp}) \Phi_4^{\alpha} [tr(U_1 U_3^{\dagger}) tr(U_3 U_2^{\dagger}) - N_c tr(U_1 U_2^{\dagger})] \right\}.$$

NLO dijet diffractive photoproduction

Impact factor in arbitrary kinematics:

$$\vec{p}_q, \vec{p}_{\bar{q}}, x, (p_q + p_{\bar{q}})^2, Q^2, \epsilon_{L/T}$$

Density matrix for the cross sections:

$$d\sigma_{JI} = \begin{pmatrix} d\sigma_{LL} & d\sigma_{LT} \\ d\sigma_{TL} & d\sigma_{TT} \end{pmatrix}, \qquad d\sigma_{TL} = d\sigma^*_{LT}.$$

Dependence on 2 hadronic matrix elements (dipole + double dipole)

$$\langle p'|tr(U_1 U_2^\dagger) - N_c|p\rangle, \quad \langle p'|tr(U_1 U_3^\dagger)tr(U_3 U_2^\dagger) - N_c tr(U_1 U_2^\dagger)|p\rangle$$

Singularities

- UV — cancelled by Ward identities ($Z_1 = Z_2$)
- Rapidity — cancelled by the LO BK evolution of the dipole covoluted with the LO IF
- artificial UV — cancelled in the convolution of the IF and Wilson line operator
- collinear — removed by cone algorithm $\Delta\phi^2 + \Delta Y^2 < R^2$
- soft — removed with the lowest energy cutoff on the unobserved gluon $\omega_g < E$

$$d\sigma = d\sigma_0 \frac{\alpha_s}{\pi} \frac{N_c^2 - 1}{2N_c} \left[\frac{1}{2} \ln \left(\frac{(x_{\bar{j}}\vec{p}_j - x_j\vec{p}_{\bar{j}})^4}{x_{\bar{j}}^2 x_j^2 R^4 \vec{p}_{\bar{j}}^{\,2} \vec{p}_j^{\,2}} \right) \left(\ln \left(\frac{4E^2}{x_{\bar{j}} x_j (p_\gamma^+)^2} \right) + \frac{3}{2} \right) \right.$$

$$\left. + \ln(8) - \frac{1}{2} \ln \left(\frac{x_j}{x_{\bar{j}}} \right) \ln \left(\frac{x_j \vec{p}_{\bar{j}}^{\,2}}{x_{\bar{j}} \vec{p}_j^{\,2}} \right) + \frac{13 - \pi^2}{2} \right] + d\sigma_{reg}$$

Applications

- $Q^2 \to 0, \epsilon_L \to 0$: Predictions for the ultraperipheral dijet photoproduction at LHC — no new singularities appear.
- $(p_q + p_{\bar{q}})^2 \to 0$: diffractive light vector meson production — hard part recalculated for longitudinal vector meson production. Additional singularities to be absorbed by ERBL equation.
- Comparison with HERA data (1505.0578) on exclusive diffractive dijet production

Conclusions

Work done

- $\gamma \to q\bar{q}g$ impact factor

- One loop $\gamma \to q\bar{q}$ impact factor in arbitrary kinematics, $\gamma \to$ longitudinally polarized vector meson impact factor with nonzero t.

Work in plans

- Resummation of Sudakov logs.
- Description of 2 and 3 jet, meson diffractive photoproduction at HERA and in UC at LHC in NLLA.

Thank you for your attention!