Impact factor for exclusive diffractive dijet production with NLO accuracy

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LPT Orsay

Diffraction 2016

RB, A.V.Grabovsky, L.Szymanowski, S.Wallon
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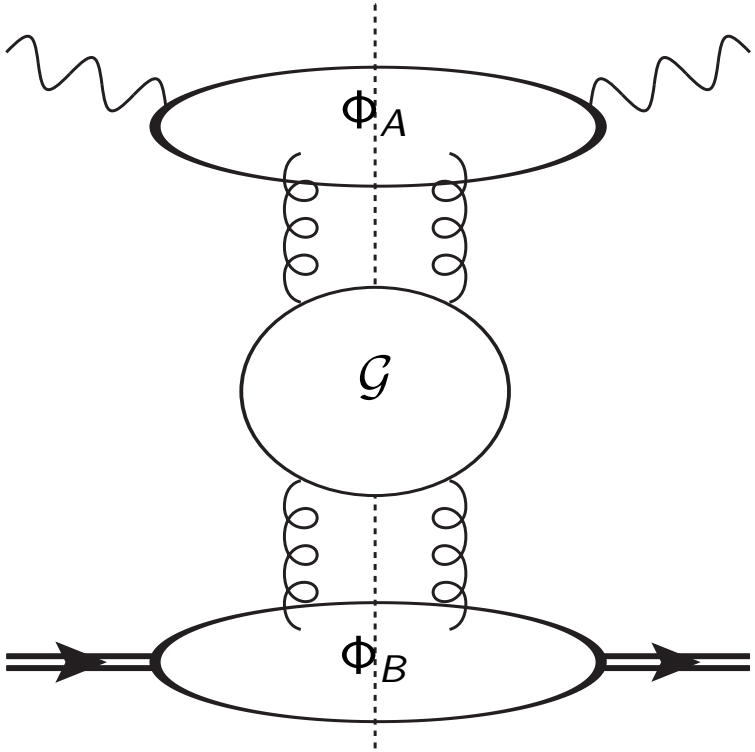
Probing QCD in the Regge limit and towards saturation

What kind of observable?

- Perturbation theory should apply : a hard scale Q^2 is required
- One needs semihard kinematics : $s \gg p_T^2 \gg \Lambda_{QCD}^2$ where all the typical transverse scales p_T are of the same order
- Saturation is reached when $Q^2 \sim Q_s^2 = \left(\frac{A}{x}\right)^{\frac{1}{3}}$: the smaller $x \sim \frac{Q^2}{s}$ is and the heavier the target ion, the easier saturation is reached.
- Typical processes : DIS, Mueller-Navelet double jets, high p_T central jets, ultraperipheral events at the LHC...

Precision tests of BFKL dynamics

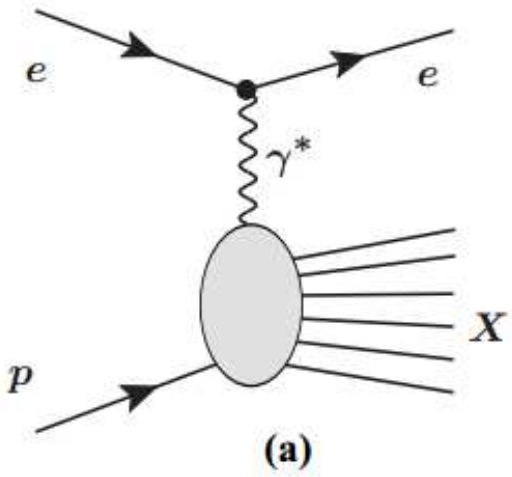
- The BFKL kernel is known at NLL accuracy, resumming $\alpha_s(\alpha_s \log s)^n$ corrections (Lipatov, Fadin ; Camici, Ciafaloni)
- Very few impact factors are known at NLO accuracy
  - $\gamma^* \to \gamma^*$ (Bartels, Colferai, Gieseke, Kyrielis, Qiao; Balitsky, Chirilli)
  - Forward jet production (Bartels, Colferai, Vacca ; Caporale, Ivanov, Murdaca, Papa, Perri ; Chachamis, Hentschinski, Madrigal, Sabio Vera)
  - Inclusive production of a pair of hadrons separated by a large interval of rapidity (Ivanov, Papa)
  - $\gamma_L^* \to \rho_L$ in the forward limit (Ivanov, Kostsky, Papa)



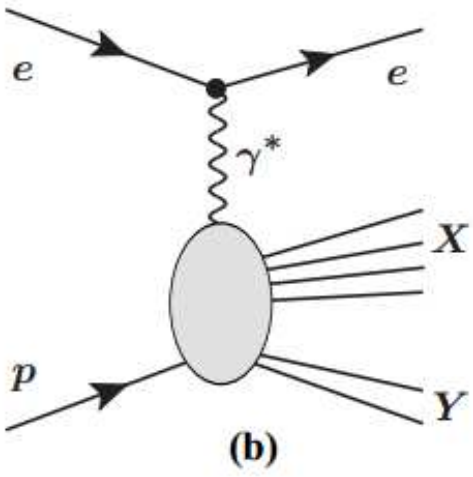
Diffractive DIS

Rapidity gap events at HERA

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



DIS events



DDIS events

Diffractive DIS

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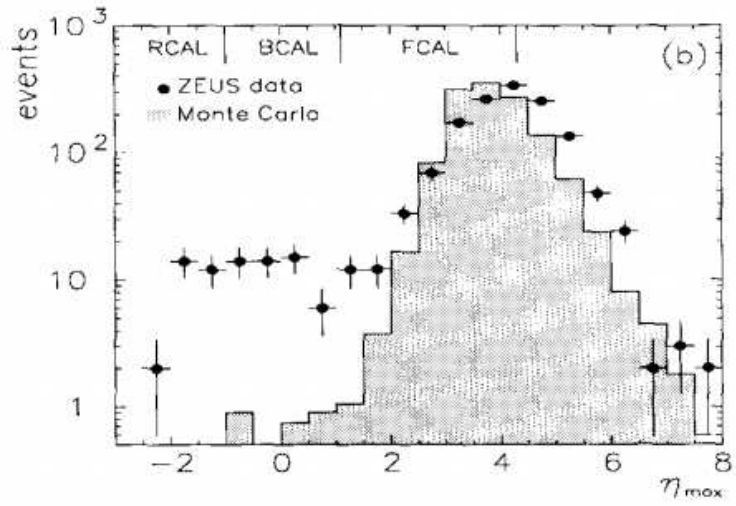
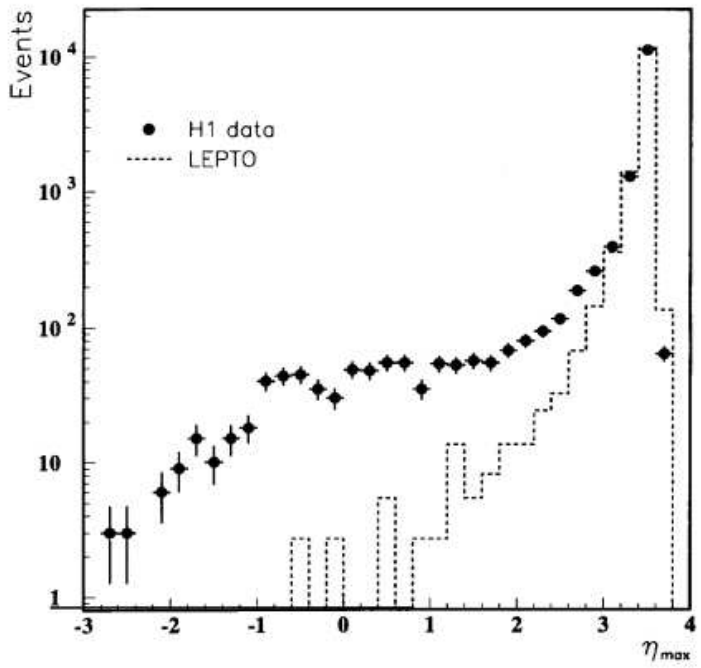


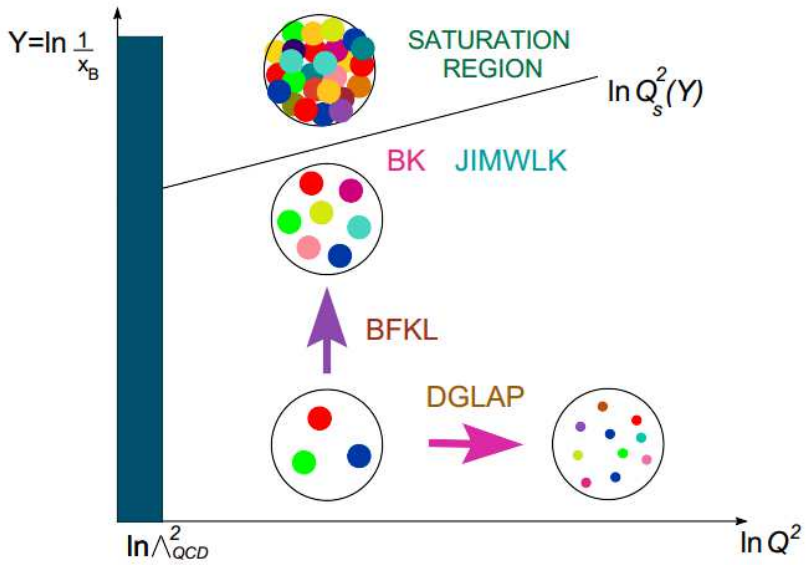
ZEUS, 1993



H1,1994

Diffractive DIS

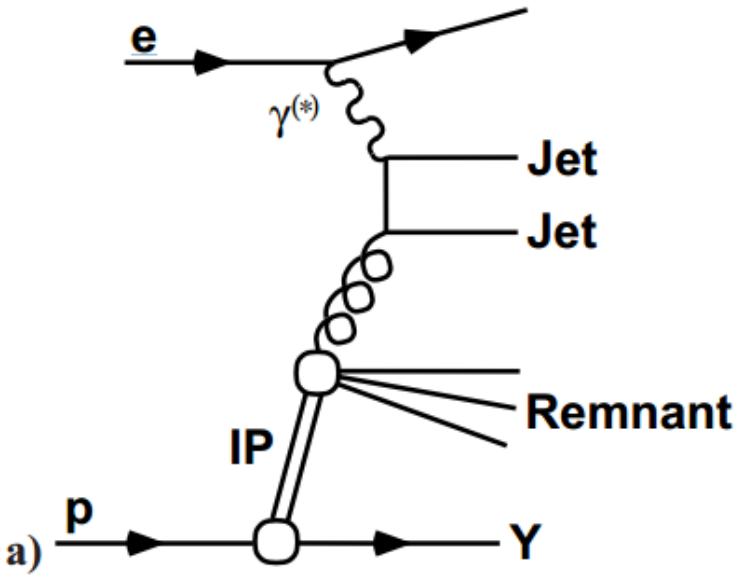
Theoretical approaches for DDIS using pQCD



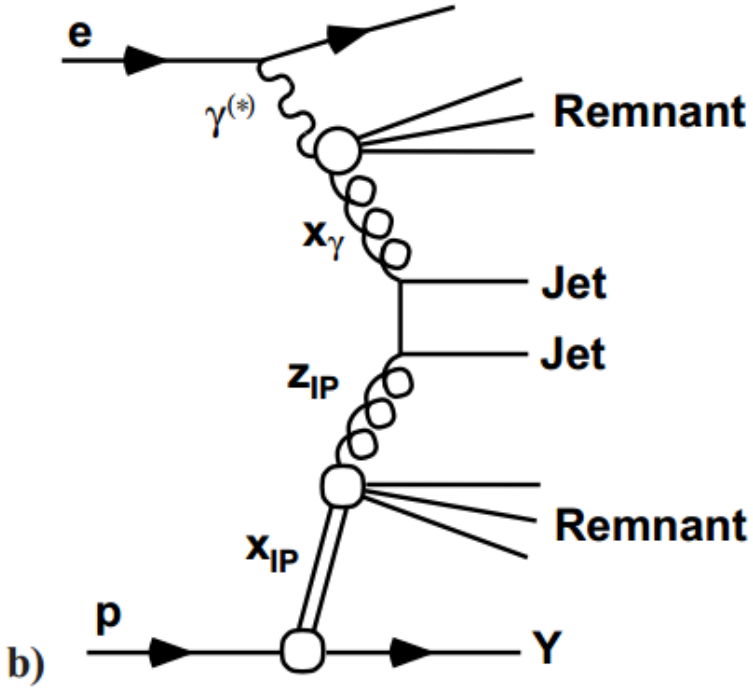
- Collinear factorization approach
  - Relies on QCD factorization theorem, using a hard scale such as the virtuality Q^2 of the incoming photon
  - One needs to introduce a diffractive distribution function for partons *within a pomeron*
- k_T factorization approach for two exchanged gluons
  - low-x QCD approach : $s \gg Q^2 \gg \Lambda_{QCD}$
  - The pomeron is described as a two-gluon color-singlet state

Theoretical approaches for DDIS using pQCD

Collinear factorization approach



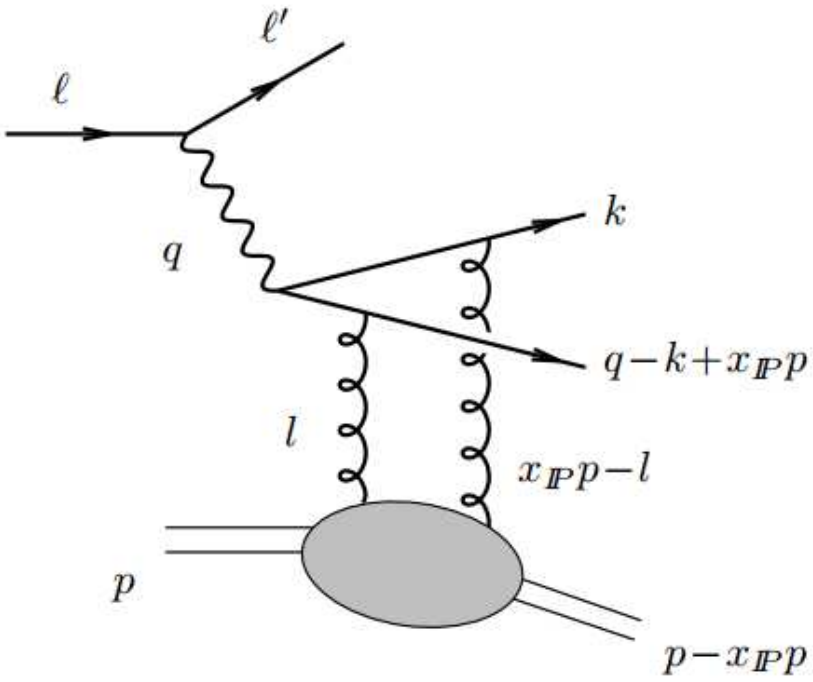
Direct



Resolved

Theoretical approaches for DDIS using pQCD

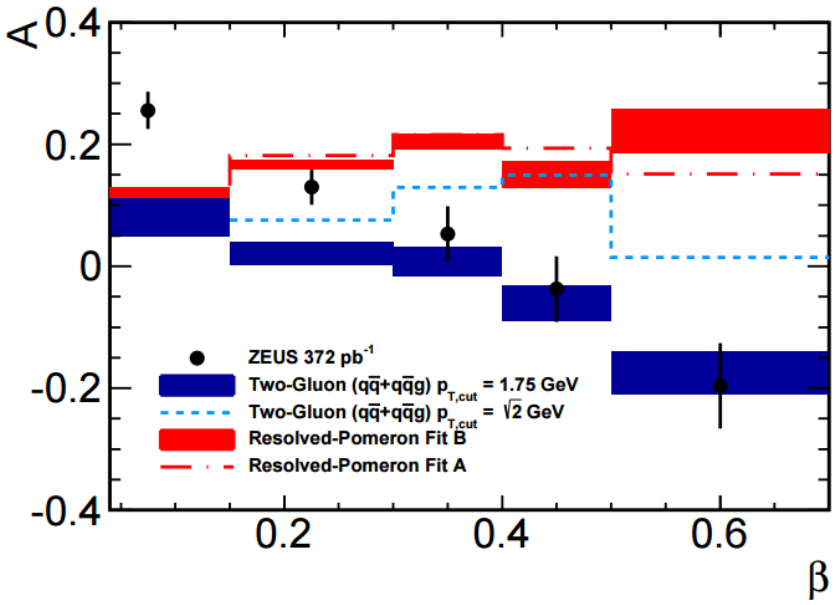
k_T-factorization approach : two gluon exchange



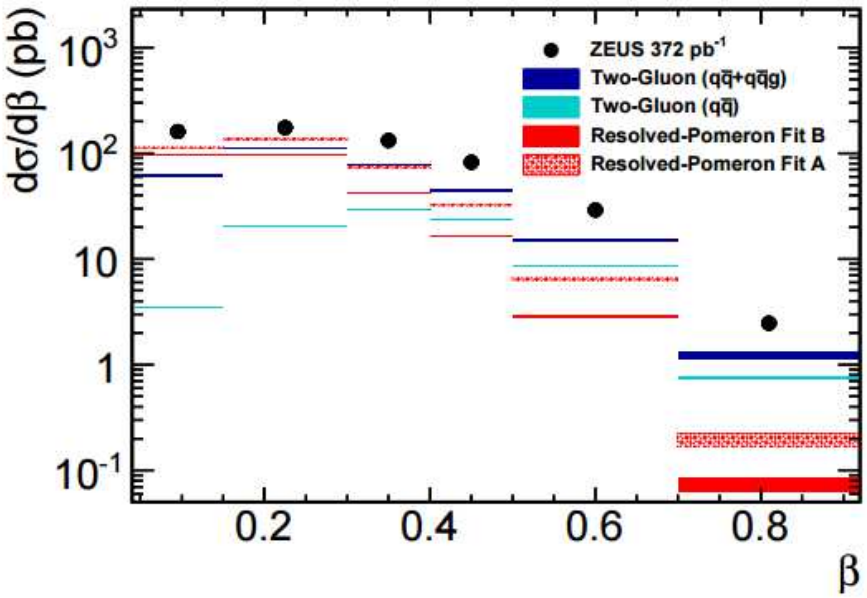
Bartels, Ivanov, Jung, Lotter, Wüsthoff
Braun and Ivanov developed a similar model in collinear factorization

Theoretical approaches for DDIS using pQCD

Confrontation of the two approaches with HERA data



ZEUS collaboration, 2015



ZEUS collaboration, 2015

Assumptions

- Regge limit : $s \gg Q^2 \gg \Lambda_{QCD}$
- No approximation for the outgoing gluon, contrary to e.g. :
  - Collinear approximation [Wüsthoff, 1995]
  - Soft approximation [Bartels, Jung, Wüsthoff, 1999]
- Lightcone coordinates (p^+, p^-, $\vec{p}$) and lightcone gauge $n_2 \cdot \mathcal{A} = 0$
- Transverse dimensional regularization $d = 2 + 2\varepsilon$, longitudinal cutoff

$$p_g^+ < \alpha p_\gamma^+$$

- Shockwave (Wilson lines) approach [Balitsky, 1995]

The shockwave approach

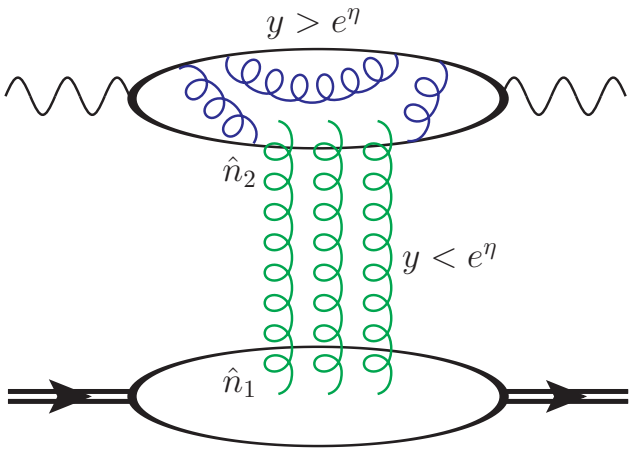
One decomposes the gluon field $\mathcal{A}$ into an internal field and an external field :

$$\mathcal{A}^\mu = A^\mu + b^\mu$$

The internal one contains the gluons with rapidity $p_g^+ > e^\eta p_\gamma^+$ and the external one contains the gluons with rapidity $p_g^+ < e^\eta p_\gamma^+$. One writes :

$$b_\eta^\mu(z) = \delta\left(z^+\right) B_\eta\left(\vec{z}\right) n_2^\mu$$

Intuitively, large boost Λ along the $+$ direction :



$$b^+\left(x^+, x^-, \vec{x}\right) \to \frac{1}{\Lambda} b^+\left(\Lambda x^+, \frac{1}{\Lambda} x^-, \vec{x}\right)$$

$$b^-\left(x^+, x^-, \vec{x}\right) \to \Lambda b^-\left(\Lambda x^+, \frac{1}{\Lambda} x^-, \vec{x}\right)$$

$$b^i\left(x^+, x^-, \vec{x}\right) \to b^i\left(\Lambda x^+, \frac{1}{\Lambda} x^-, \vec{x}\right)$$

Propagator in the shockwave field

$$G\left(z_2,\, z_0\right) = -\int d^4 z_1 \theta\left(z_2^+\right) \delta\left(z_1^+\right) \theta\left(-z_0^+\right) G\left(z_2 - z_1\right) \gamma^+ G\left(z_1 - z_0\right) U_1$$

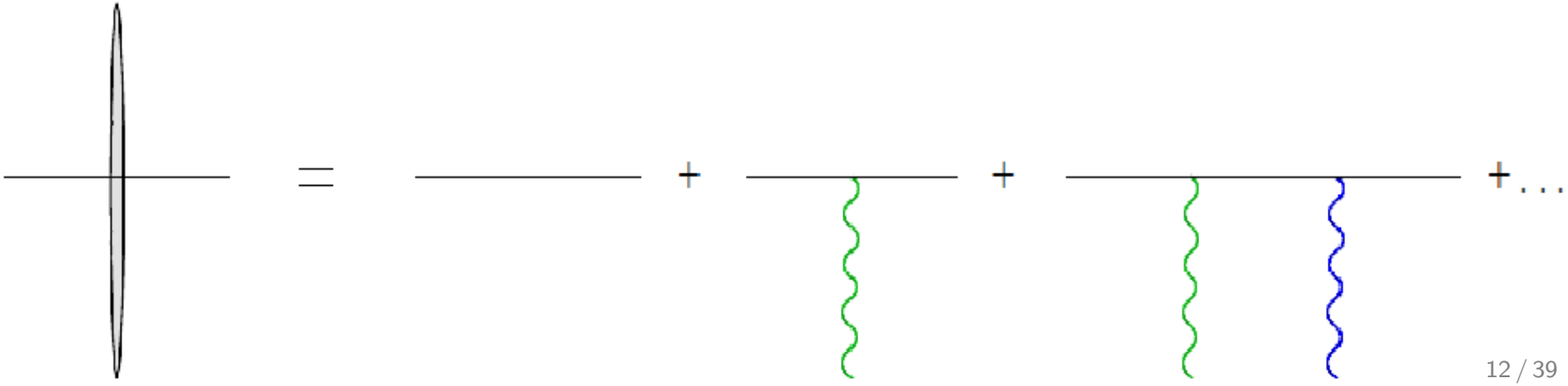
$$G\left(q,\, p\right) = (2\pi)\, \theta\left(p^+\right) \int d^D q_1 \delta\left(q + q_1 - p\right) G\left(q\right) \gamma^+ \tilde{U}_{\vec{q}_1} G\left(p\right)$$

Wilson lines :

$$U_i = U_{\vec{z}_i} = U\left(\vec{z}_i, \eta\right) = P \exp\left[ig \int_{-\infty}^{+\infty} b_\eta^-\left(z_i^+, \vec{z}_i\right) dz_i^+\right]$$

$$U_i = 1 + ig \int_{-\infty}^{+\infty} b_\eta^-\left(z_i^+, \vec{z}_i\right) dz_i^+ + (ig)^2 \int_{-\infty}^{+\infty} b_\eta^-\left(z_i^+, \vec{z}_i\right) b_\eta^-\left(z_j^+, \vec{z}_j\right) \theta\left(z_{ji}^+\right) dz_i^+ dz_j^+$$

...

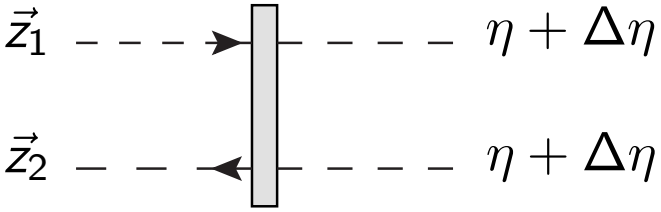


Evolution equation for a color dipole

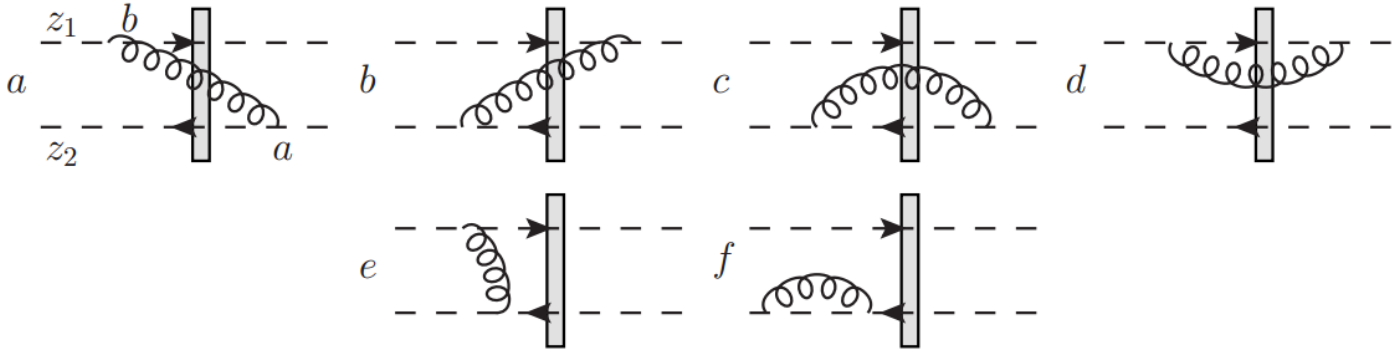
Dipole operator

$$\mathbf{U}_{12} = \frac{1}{N_c}\mathrm{Tr}\left(U_1 U_2^\dagger\right) - 1$$

involving Wilson lines



Balitsky's hierarchy of equations



B-JIMWLK equation

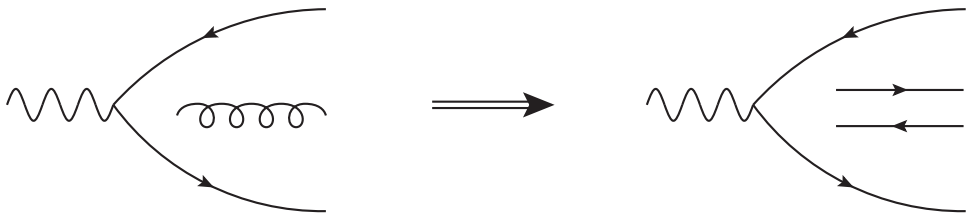
[Balitsky, Jalilian-Marian, Iancu, McLerran, Weigert, Leonidov, Kovner]

$$\frac{\partial \mathbf{U}_{12}}{\partial \eta} = \frac{\alpha_s N_c}{2\pi^2} \int d\vec{z}_3 \frac{\vec{z}_{12}^{\,2}}{\vec{z}_{13}^{\,2}\vec{z}_{23}^{\,2}} \left[\mathbf{U}_{13} + \mathbf{U}_{32} - \mathbf{U}_{12} - \mathbf{U}_{13}\mathbf{U}_{32}\right]$$

$$\frac{\partial \mathbf{U}_{13}\mathbf{U}_{32}}{\partial \eta} = \ldots$$

The BK equation

Mean field approximation, or 't Hooft limit $N_c \to \infty$ in Balitsky's equation



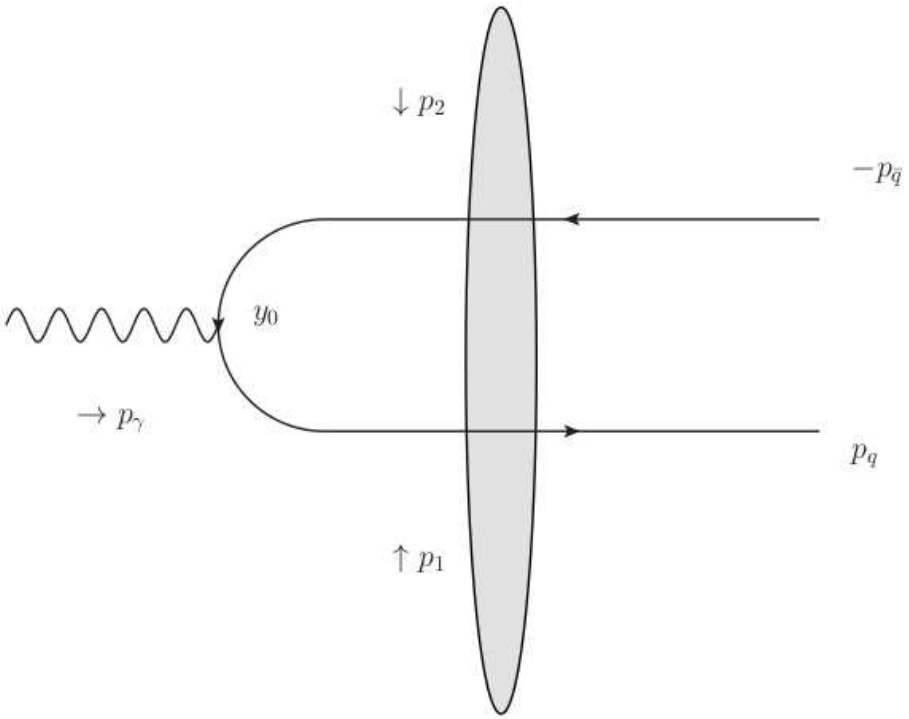
[Mueller]

$\Rightarrow$ BK equation [Balitsky, 1995] [Kovchegov, 1999]

$$\frac{\partial \mathbf{U}_{12}}{\partial \eta} = \frac{\alpha_s N_c}{2\pi^2} \int d\vec{z}_3 \frac{\vec{z}_{12}^{\,2}}{\vec{z}_{13}^{\,2}\vec{z}_{23}^{\,2}} \left[\mathbf{U}_{13} + \mathbf{U}_{32} - \mathbf{U}_{12} - \mathbf{U}_{13}\mathbf{U}_{32}\right]$$

Evolves a dipole into a double dipole
Non-linear term : saturation

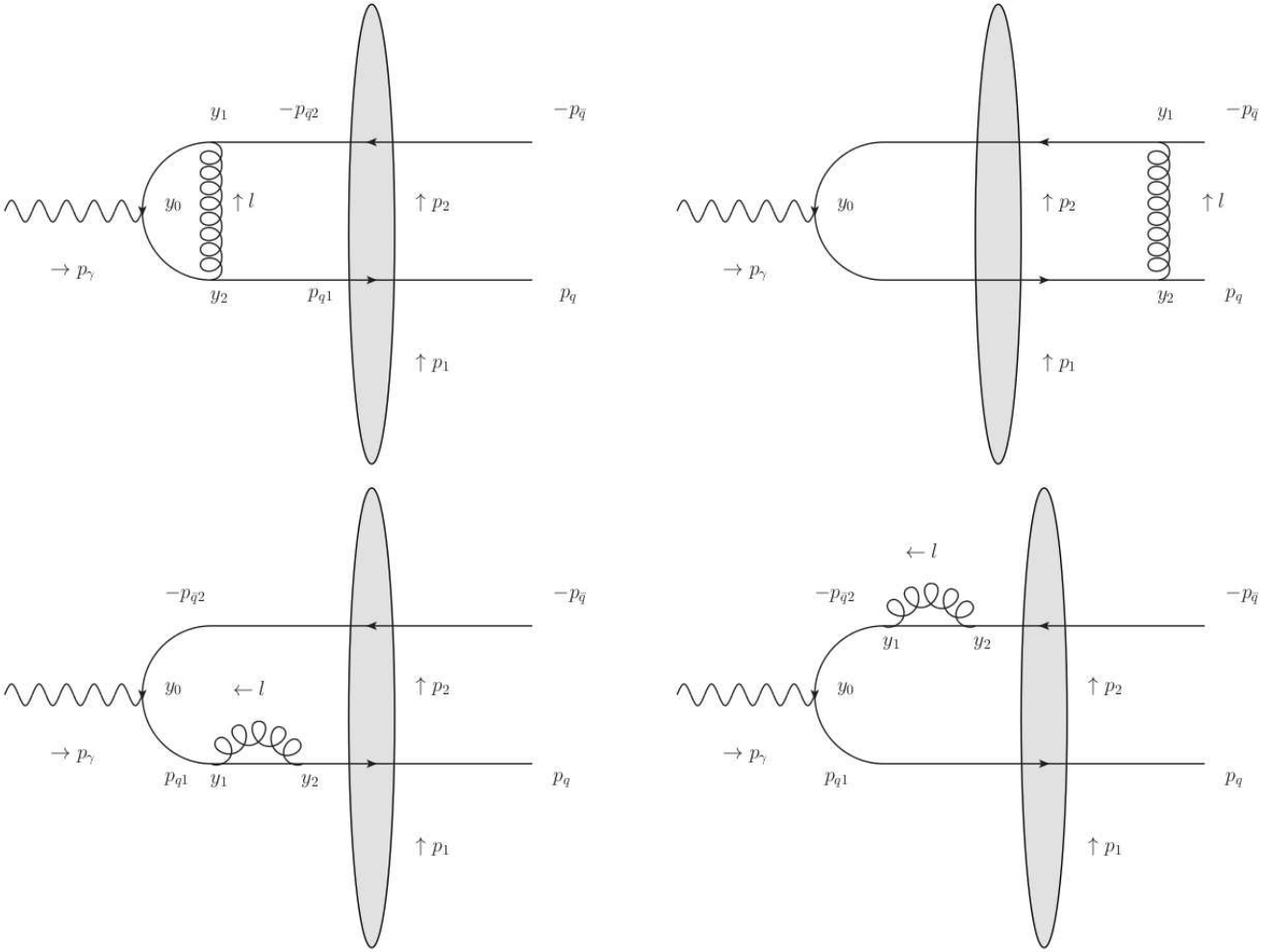
Leading Order



$$\mathcal{A}_0 = \varepsilon_\alpha N_c \int d^d\vec{p}_1 d^d\vec{p}_2 \Phi_0^\alpha\left(\vec{p}_1, \vec{p}_2\right) \delta\left(\vec{p}_{q1} + \vec{p}_{\bar{q}2}\right) \tilde{\mathbf{U}}_{12}$$

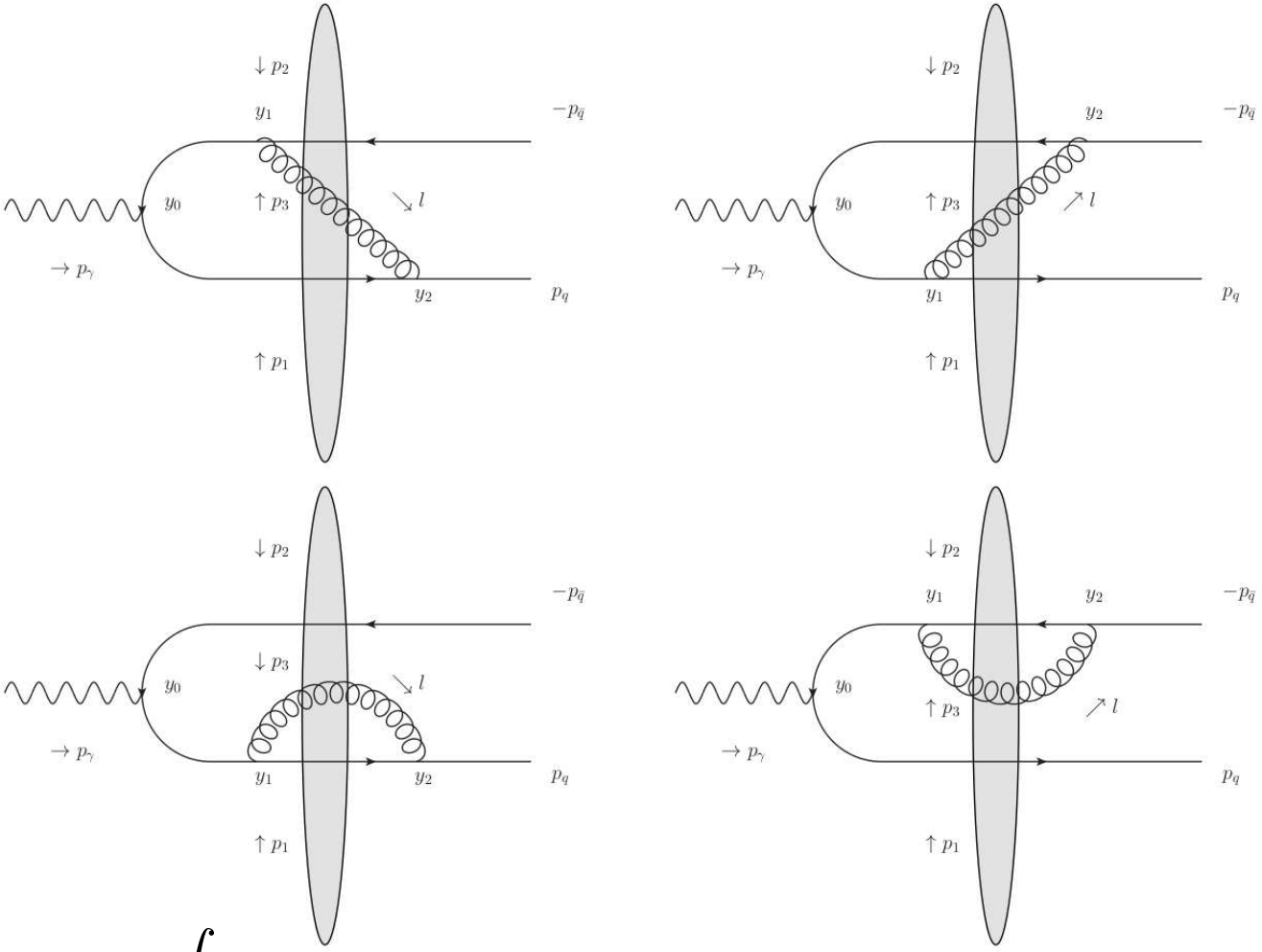
$p_{ij} = p_i - p_j$

First kind of virtual corrections



$$\mathcal{A}_{V1} \quad \propto \quad \varepsilon_\alpha N_c \int d^d\vec{p}_1 d^d\vec{p}_2 \Phi^\alpha_{V1}\left(\vec{p}_1,\, \vec{p}_2\right) \delta\left(\vec{p}_{q1} + \vec{p}_{\bar{q}2}\right) \left(\frac{N_c^2 - 1}{N_c}\right) \tilde{\mathbf{U}}_{12}$$

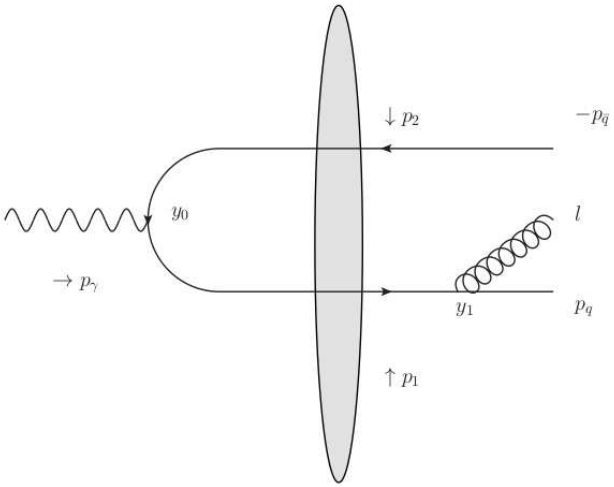
Second kind of virtual corrections

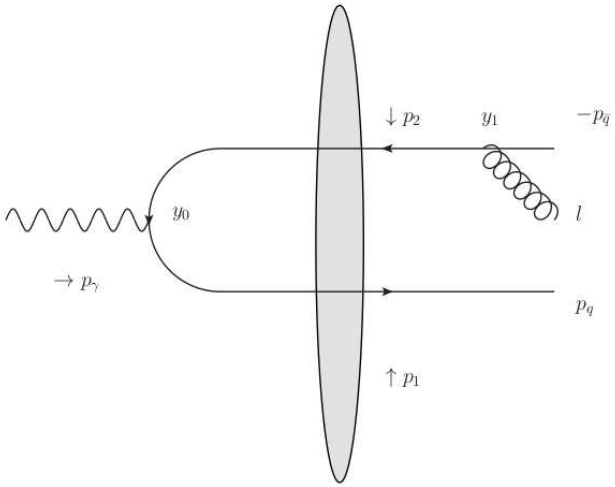


$$\mathcal{A}_{V2} \quad \propto \quad \varepsilon_\alpha N_c \int d^d\vec{p}_1 d^d\vec{p}_2 d^d\vec{p}_3 \Phi^\alpha_{V2}\left(\vec{p}_1,\, \vec{p}_2,\, \vec{p}_3\right)\delta\left(\vec{p}_{q1} + \vec{p}_{\bar{q}2} - \vec{p}_3\right)$$

$$\left[\delta\left(\vec{p}_3\right)\left(\frac{N_c^2-1}{N_c}\right)\tilde{\mathbf{U}}_{12} + N_c\left(\tilde{\mathbf{U}}_{13}\tilde{\mathbf{U}}_{32} + \tilde{\mathbf{U}}_{13} + \tilde{\mathbf{U}}_{32} - \tilde{\mathbf{U}}_{12}\right)\right]$$

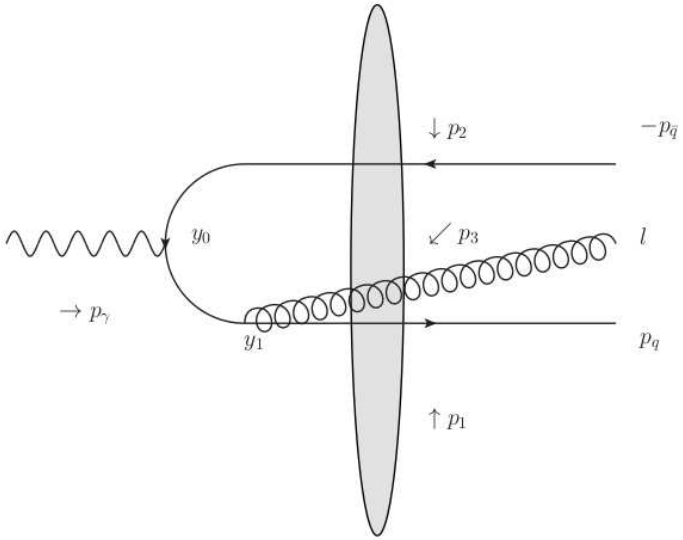
First kind of real corrections

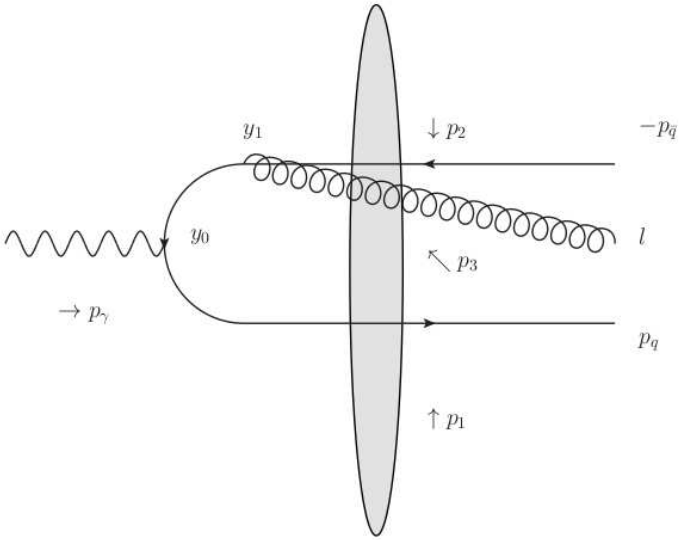




$$\mathcal{A}_{R1} = \varepsilon_\alpha N_c \int d^d\vec{p}_1 d^d\vec{p}_2\, \Phi^\alpha_{R1}(\vec{p}_1, \vec{p}_2)\delta(\vec{p}_{q1} + \vec{p}_{\bar{q}2} + \vec{p}_g)\left(\frac{N_c^2 - 1}{N_c}\right)\tilde{\mathbf{U}}_{12}$$

Second kind of real corrections





$$\mathcal{A}_{R2} = \varepsilon_\alpha N_c \int d^d\vec{p}_1 d^d\vec{p}_2 d^d\vec{p}_3 \Phi^\alpha_{R2}\left(\vec{p}_1,\ \vec{p}_2,\ \vec{p}_3\right)\delta\left(\vec{p}_{q1}+\vec{p}_{\bar{q}2}+\vec{p}_{g3}\right)$$
$$\left[\left(\frac{N_c^2-1}{N_c}\right)\tilde{\mathbf{U}}_{12}\delta\left(\vec{p}_3\right)+N_c\left(\tilde{\mathbf{U}}_{13}\tilde{\mathbf{U}}_{32}+\tilde{\mathbf{U}}_{13}+\tilde{\mathbf{U}}_{32}-\tilde{\mathbf{U}}_{12}\right)\right]$$

Divergences

- UV divergence $\vec{p}_g^{\,2} \to +\infty$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*$$

- Soft divergence $p_g \to 0$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*, \Phi_{R1}\Phi_{R1}^*$$

- Collinear divergence $p_g \propto p_q$ or $p_{\bar{q}}$

$$\Phi_{R1}\Phi_{R1}^*$$

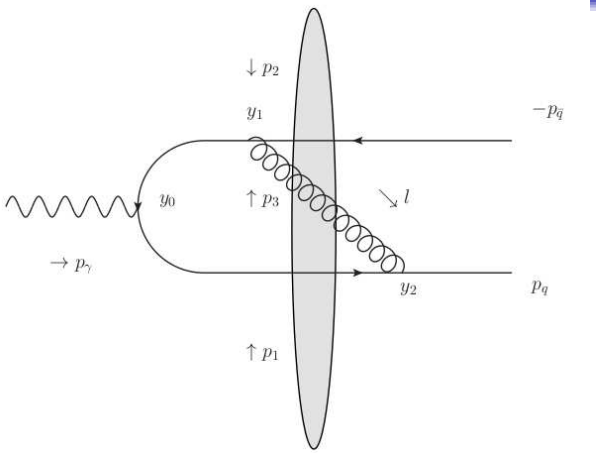
- Soft and collinear divergence $p_g = \frac{p_g^+}{p_q^+} p_q$ or $\frac{p_g^+}{p_{\bar{q}}^+} p_{\bar{q}}$, $p_g^+ \to 0$

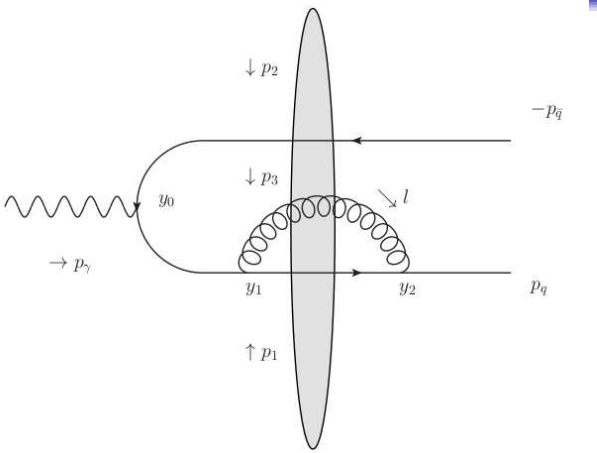
$$\Phi_{R1}\Phi_{R1}^*$$

- Rapidity divergence $p_g^+ \to 0$

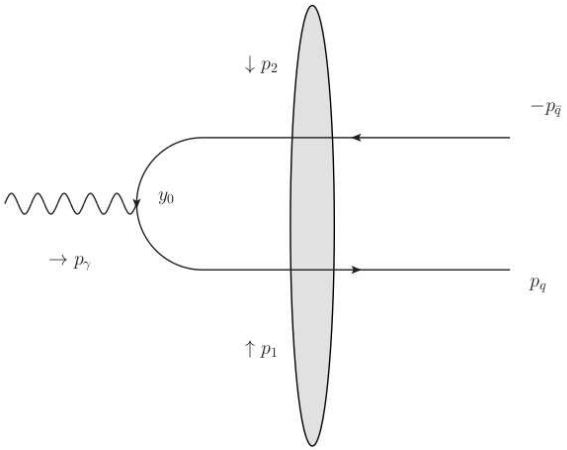
$$\Phi_{V2}\Phi_0^* + \Phi_0\Phi_{V2}^*$$

Rapidity divergence





Double dipole virtual correction Φ_{V2}



Balitsky's evolution of the LO term : $\Phi_0 \otimes \mathcal{K}_{BK}$

Rapidity divergence

B-JIMWLK equation

$$\frac{\partial \tilde{\mathbf{U}}^{\alpha}_{12}}{\partial \log \alpha} = 2\alpha_s N_c \mu^{2-d} \int \frac{d^d \vec{k}_1 d^d \vec{k}_2 d^d \vec{k}_3}{(2\pi)^{2d}} \delta\left(\vec{k}_1 + \vec{k}_2 + \vec{k}_3 - \vec{p}_1 - \vec{p}_2\right) \left(\tilde{\mathbf{U}}_{13}\tilde{\mathbf{U}}_{32} + \tilde{\mathbf{U}}_{13} + \tilde{\mathbf{U}}_{32} - \tilde{\mathbf{U}}_{12}\right)$$
$$\left[2\frac{\left(\vec{k}_1 - \vec{p}_1\right).\left(\vec{k}_2 - \vec{p}_2\right)}{\left(\vec{k}_1 - \vec{p}_1\right)^2\left(\vec{k}_2 - \vec{p}_2\right)^2} + \frac{\pi^{\frac{d}{2}}\Gamma\left(1-\frac{d}{2}\right)\Gamma^2\left(\frac{d}{2}\right)}{\Gamma\left(d-1\right)}\left(\frac{\delta\left(\vec{k}_2 - \vec{p}_2\right)}{\left[\left(\vec{k}_1 - \vec{p}_1\right)^2\right]^{1-\frac{d}{2}}} + \frac{\delta\left(\vec{k}_1 - \vec{p}_1\right)}{\left[\left(\vec{k}_2 - \vec{p}_2\right)^2\right]^{1-\frac{d}{2}}}\right)\right]$$

η is the rapidity divide

$$\tilde{\mathbf{U}}^{\alpha}_{12}\Phi_0 \to \Phi_0\tilde{\mathbf{U}}^{\eta}_{12} + \log\left(\frac{e^{\eta}}{\alpha}\right)\mathcal{K}_{BK}\Phi_0\left(\tilde{\mathbf{U}}_{13}\tilde{\mathbf{U}}_{32} + \tilde{\mathbf{U}}_{13} + \tilde{\mathbf{U}}_{32} - \tilde{\mathbf{U}}_{12}\right)$$

Rapidity divergence

Virtual contribution

$$(\Phi^{\mu}_{V2})_{div} \propto \Phi^{\mu}_{0} \left\{ 4 \ln \left(\frac{x\bar{x}}{\alpha^2} \right) \left[\frac{1}{\varepsilon} + \ln \left(\frac{\vec{p}_3^{\,2}}{\mu^2} \right) \right] - \frac{6}{\varepsilon} \right\}$$

BK contribution

$$(\Phi^{\mu}_{BK})_{div} \propto \Phi^{\mu}_{0} \left\{ 4 \ln \left(\frac{\alpha^2}{e^{2\eta}} \right) \left[\frac{1}{\varepsilon} + \ln \left(\frac{\vec{p}_3^{\,2}}{\mu^2} \right) \right] \right\}$$

Sum

$$(\Phi'^{\mu}_{V2})_{div} \propto \Phi^{\mu}_{0} \left\{ 4 \ln \left(\frac{x\bar{x}}{e^{2\eta}} \right) \left[\frac{1}{\varepsilon} + \ln \left(\frac{\vec{p}_3^{\,2}}{\mu^2} \right) \right] - \frac{6}{\varepsilon} \right\}$$

Rapidity divergence

Convolution

$$(\Phi'^{\mu}_{V2} \otimes \mathbf{UU}) = \int d^d\vec{p}_1 d^d\vec{p}_2 d^d\vec{p}_3 \left\{ 4 \ln\left(\frac{x\bar{x}}{e^{2\eta}}\right)\left[\frac{1}{\varepsilon} + \ln\left(\frac{\vec{p}_3^{\,2}}{\mu^2}\right)\right] - \frac{6}{\varepsilon}\right\}$$
$$\times \quad \delta(\vec{p}_{q1} + \vec{p}_{\bar{q}2} - \vec{p}_3)\left[\tilde{\mathbf{U}}_{13} + \tilde{\mathbf{U}}_{32} - \tilde{\mathbf{U}}_{12} - \tilde{\mathbf{U}}_{13}\tilde{\mathbf{U}}_{32}\right]\Phi^{\mu}_0(\vec{p}_1, \vec{p}_2)$$

Rq :

- $\Phi_0(\vec{p}_1, \vec{p}_2)$ only depends on one of the t-channel momenta.
- The double-dipole operators cancels when $\vec{z}_3 = \vec{z}_1$ or $\vec{z}_3 = \vec{z}_2$.

This permits one to show that the convolution cancels the remaining $\frac{1}{\varepsilon}$ divergence.

Then $\tilde{\mathbf{U}}^{\alpha}_{12}\Phi_0 + \Phi_{V2}$ is finite

Divergences

- UV divergence $\vec{p}_g^{\,2} \to +\infty$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*$$

- Soft divergence $p_g \to 0$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*, \Phi_{R1}\Phi_{R1}^*$$

- Collinear divergence $p_g \propto p_q$ or $p_{\bar{q}}$

$$\Phi_{R1}\Phi_{R1}^*$$

- Soft and collinear divergence $p_g = \frac{p_g^+}{p_q^+} p_q$ or $\frac{p_g^+}{p_{\bar{q}}^+} p_{\bar{q}}$, $p_g^+ \to 0$

$$\Phi_{R1}\Phi_{R1}^*$$

- Rapidity divergence

Contructing a finite cross section

From partons to jets

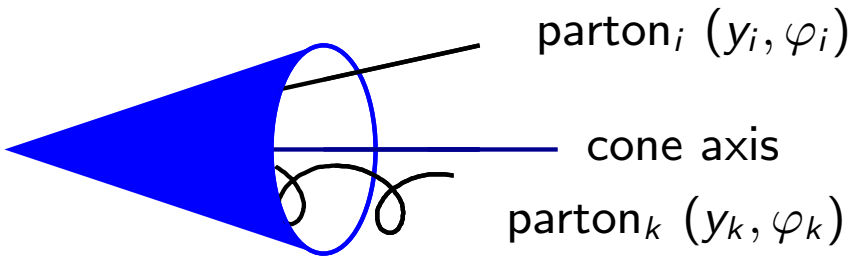
Soft and collinear divergence

Jet cone algorithm

We define a cone width for each pair of particles with momenta p_i and p_k, rapidity difference ΔY_{ik} and relative azimuthal angle $\Delta\phi_{ik}$

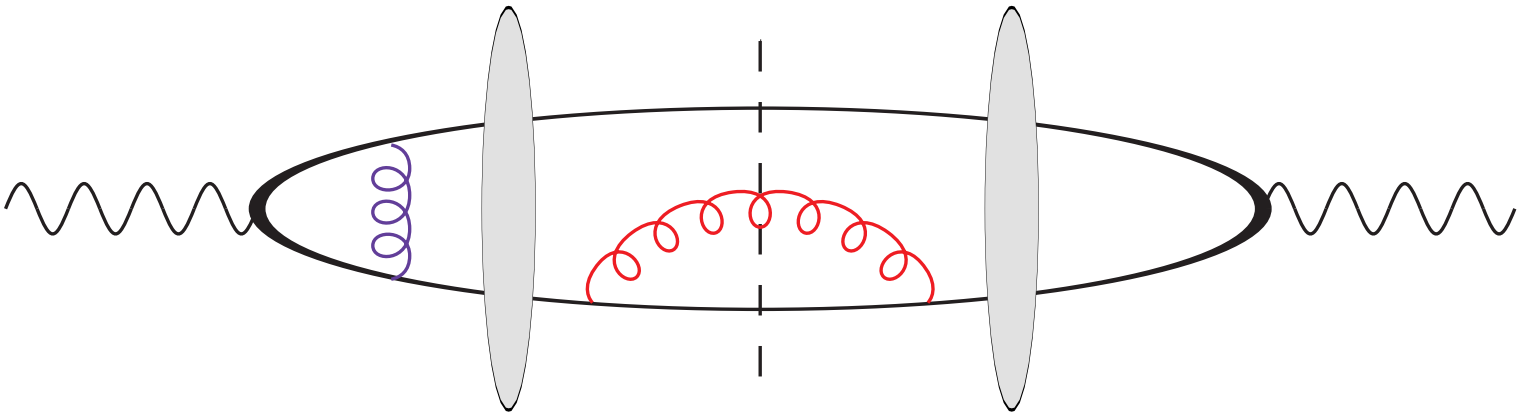
$$(\Delta Y_{ik})^2 + (\Delta\varphi_{ik})^2 = R_{ik}^2$$

If $R_{ik}^2 < R^2$, then the two particles together define a single jet of momentum $p_i + p_k$.



Applying this in the small R^2 limit cancels our soft and collinear divergence.

Remaining divergence



- UV divergence $\vec{p}_g^{\,2} \to +\infty$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*$$

- Soft divergence $p_g \to 0$

$$\Phi_{V1}\Phi_0^* + \Phi_0\Phi_{V1}^*, \Phi_{R1}\Phi_{R1}^*$$

- Collinear divergence $p_g \propto p_q$ or $p_{\bar{q}}$

$$\Phi_{R1}\Phi_{R1}^*$$

Remaining divergence

Soft real emission

$$(\Phi_{R1}\Phi^*_{R1})_{soft} \propto (\Phi_0\Phi^*_0)\int_{\text{outside the cones}} \left|\frac{p_q^\mu}{(p_q.p_g)} - \frac{p_{\bar{q}}^\mu}{(p_{\bar{q}}.p_g)}\right|^2 \frac{dp_g^+}{p_g^+}\frac{d^d p_g}{(2\pi)^d}$$

Collinear real emission

$$(\Phi_{R1}\Phi^*_{R1})_{col} \propto (\Phi_0\Phi^*_0)\,(\mathcal{N}_q + \mathcal{N}_{\bar{q}})$$

Where $\mathcal{N}$ is the number of jets in the quark or the antiquark

$$\mathcal{N}_k = \frac{(4\pi)^{\frac{d}{2}}}{\Gamma(2-\frac{d}{2})}\int_{\alpha p_\gamma^+}^{p_{jet}^+}\frac{dp_g^+ dp_k^+}{2p_g^+ 2p_k^+}\int_{\text{in cone k}}\frac{d^d\vec{p}_g d^d\vec{p}_k}{(2\pi)^d\,\mu^{d-2}}\frac{\mathrm{Tr}\left(\hat{p}_k\gamma^\mu\hat{p}_{jet}\gamma^\nu\right)d_{\mu\nu}(p_g)}{2p_{jet}^+\left(p_k^- + p_g^- - p_{jet}^-\right)^2}$$

Those two contributions cancel exactly the virtual divergences (both UV and soft)

Cancellation of divergences

Total divergence

$$(d\sigma_1)_{div} = \alpha_s \frac{\Gamma(1-\varepsilon)}{(4\pi)^{1+\varepsilon}} \left(\frac{N_c^2-1}{2N_c}\right) (S_V + S_V^* + S_R + \mathcal{N}_{jet1} + \mathcal{N}_{jet2}) d\sigma_0$$

Virtual contribution

$$\begin{aligned} S_V &= \left[2\ln\left(\frac{x_j x_{\bar{j}}}{\alpha^2}\right) - 3\right]\left[\ln\left(\frac{x_j x_{\bar{j}} \mu^2}{(x_j \vec{p}_{\bar{j}} - x_{\bar{j}} \vec{p}_j)^2}\right) - \frac{1}{\epsilon}\right] \\ &+ 2i\pi \ln\left(\frac{x_j x_{\bar{j}}}{\alpha^2}\right) + \ln^2\left(\frac{x_j x_{\bar{j}}}{\alpha^2}\right) - \frac{\pi^2}{3} + 6 \end{aligned}$$

Real contribution

$$\begin{aligned} S_R + \mathcal{N}_{jet1} + \mathcal{N}_{jet2} &= 2\left[\ln\left(\frac{(x_{\bar{j}} \vec{p}_j - x_j \vec{p}_{\bar{j}})^4}{x_{\bar{j}}^2 x_j^2 R^4 \vec{p}_{\bar{j}}^{\,2} \vec{p}_j^{\,2}}\right) \ln\left(\frac{4E^2}{x_{\bar{j}} x_j (p_\gamma^+)^2}\right) + 2I(R,E)\right. \\ &+ 2\ln\left(\frac{x_{\bar{j}} x_j}{\alpha^2}\right)\left(\frac{1}{\epsilon} - \ln\left(\frac{x_{\bar{j}} x_j \mu^2}{(x_{\bar{j}} \vec{p}_j - x_j \vec{p}_{\bar{j}})^2}\right)\right) - \ln^2\left(\frac{x_{\bar{j}} x_j}{\alpha^2}\right) \\ &+ \left.\frac{3}{2}\ln\left(\frac{16\mu^4}{R^4 \vec{p}_j^{\,2} \vec{p}_{\bar{j}}^{\,2}}\right) - \ln\left(\frac{x_j}{x_{\bar{j}}}\right) \ln\left(\frac{x_j \vec{p}_{\bar{j}}^{\,2}}{x_{\bar{j}} \vec{p}_j^{\,2}}\right) - \frac{3}{\epsilon} - \frac{2\pi^2}{3} + 7\right] \end{aligned}$$

Cancellation of divergences

Total divergence

$$
\begin{aligned}
div &= S_V + S_V^* + S_R + \mathcal{N}_{jet1} + \mathcal{N}_{jet2} \\
&= 4\left[\frac{1}{2}\ln\left(\frac{(x_{\bar{j}}\vec{p}_j - x_j\vec{p}_{\bar{j}})^4}{x_{\bar{j}}^2 x_j^2 R^4 \vec{p}_{\bar{j}}^{\,2}\vec{p}_j^{\,2}}\right)\left(\ln\left(\frac{4E^2}{x_{\bar{j}}x_j(p_\gamma^+)^2}\right)+\frac{3}{2}\right)\right. \\
&+ \left. I(R,E) + \ln(8) - \frac{1}{2}\ln\left(\frac{x_j}{x_{\bar{j}}}\right)\ln\left(\frac{x_j\vec{p}_{\bar{j}}^{\,2}}{x_{\bar{j}}\vec{p}_j^{\,2}}\right) + \frac{13-\pi^2}{2}\right]
\end{aligned}
$$

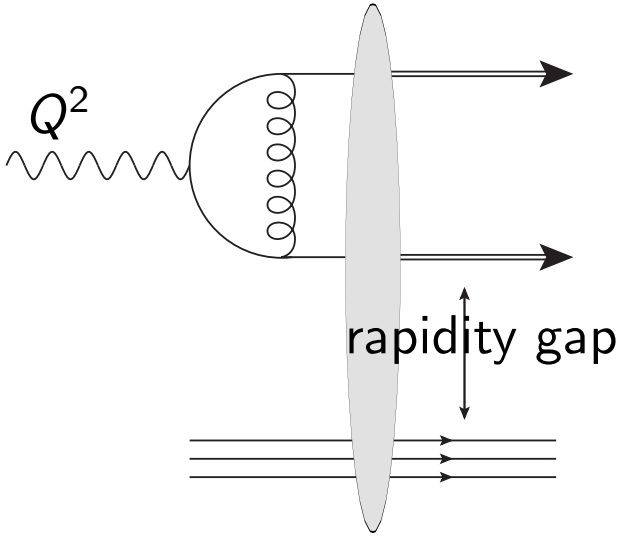
Our cross section is thus finite

Conclusions about exclusive dijet production

- We computed the amplitude for the production of an open $q\bar{q}$ pair in DDIS
- Using this result, we constructed a finite expression for the cross section for the exclusive production of dijets
- The remaining part can be expressed as a finite integral, so it can be used straightforwardly for phenomenology
- Any model can be used for the matrix elements of the Wilson line operators (GBW, AAMQS if the target is a proton or an ion)
- The target can also be perturbative, involving any impact factor...

Phenomenological applications : exclusive dijet production at NLO accuracy

- HERA data for exclusive dijet production in diffractive DIS can be fitted with our results
- We can also give predictions for the same process in a future electron-ion or electron-proton collider (EIC, LHeC...)
- For $Q^2 = 0$ we can give predictions for ultraperipheral collisions at the LHC



Amplitude for diffractive dijet production

Phenomenological applications : exclusive trijet production at LO accuracy

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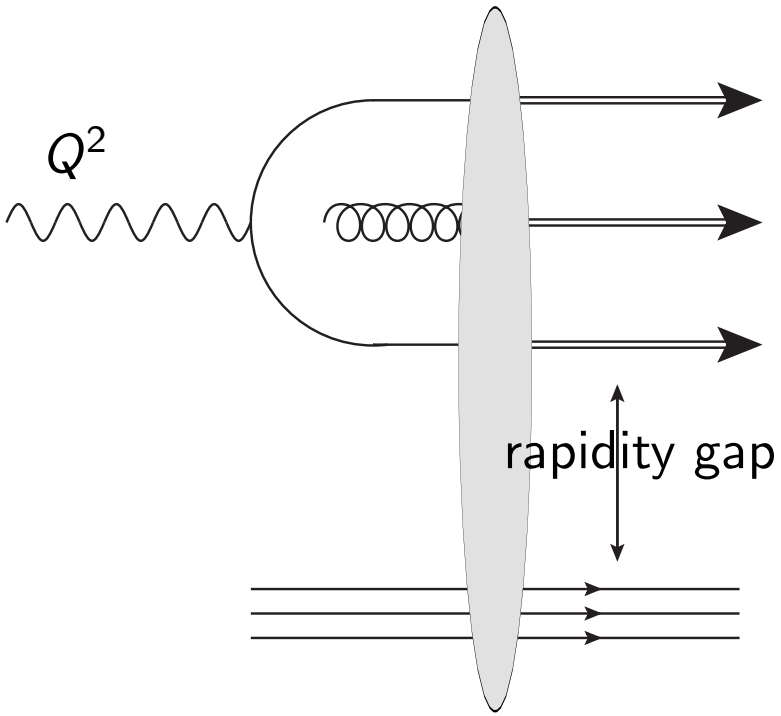
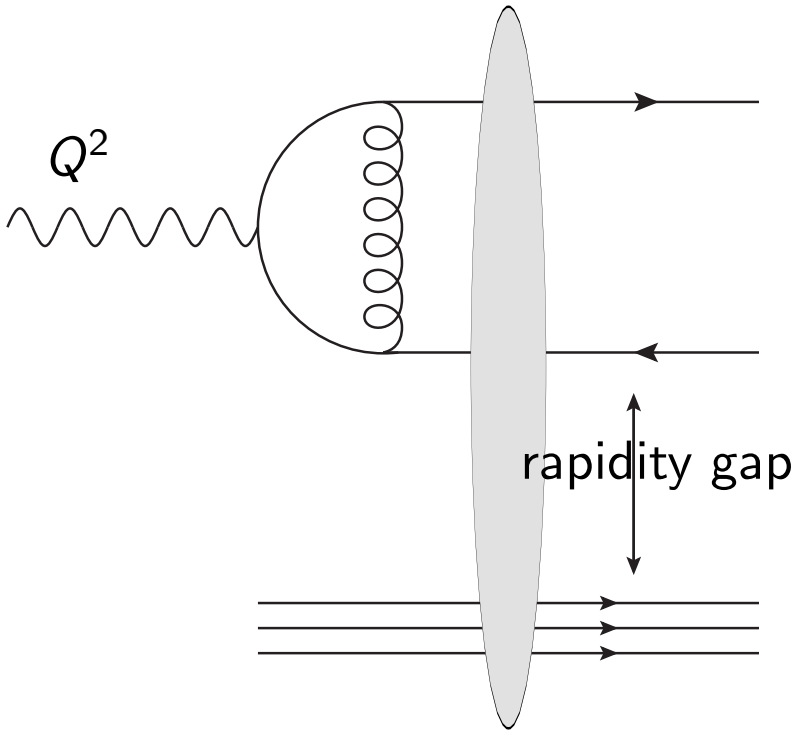


Amplitude for diffractive trijet production

General amplitude

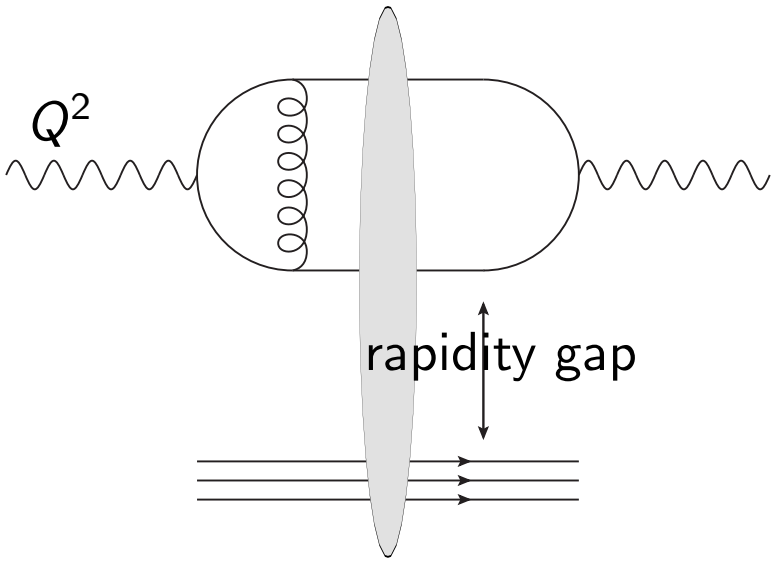
- Most general kinematics
- The hard scale can be Q^2, t, M_X^2 or m^2 in the (future) massive extension of our computation.
- The target can be either a proton or an ion, or another impact factor.
- One can study ultraperipheral collision by tagging the particle which emitted the photon, in the limit $Q^2 \to 0$.



The general amplitude

NLO DIS

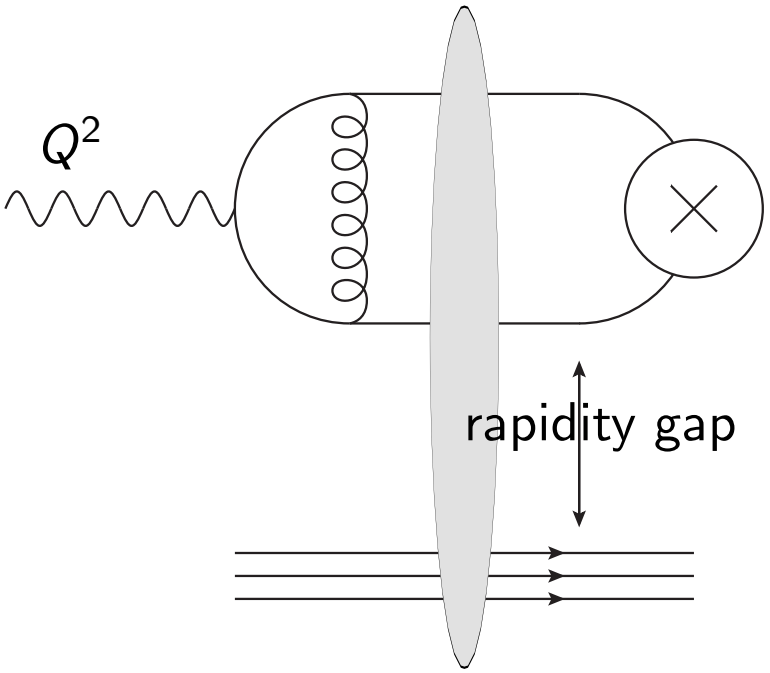
- One can adapt our general amplitude to obtain the NLO expression for (non diffractive) DIS
- Such a result would have to be compared with Balitsky and Chirilli's result, and with an ingoing study by Beuf.



NLO DIS cross section

Diffractive production of a ρ meson

- By forcing the quark and antiquark to be collinear and using the right Fierz projection, one can study ρ production
- Generalization of previous results of Ivanov, Kotsky, Papa to the non-forward case
- This would give a better understanding of the formal transition between BFKL and BK

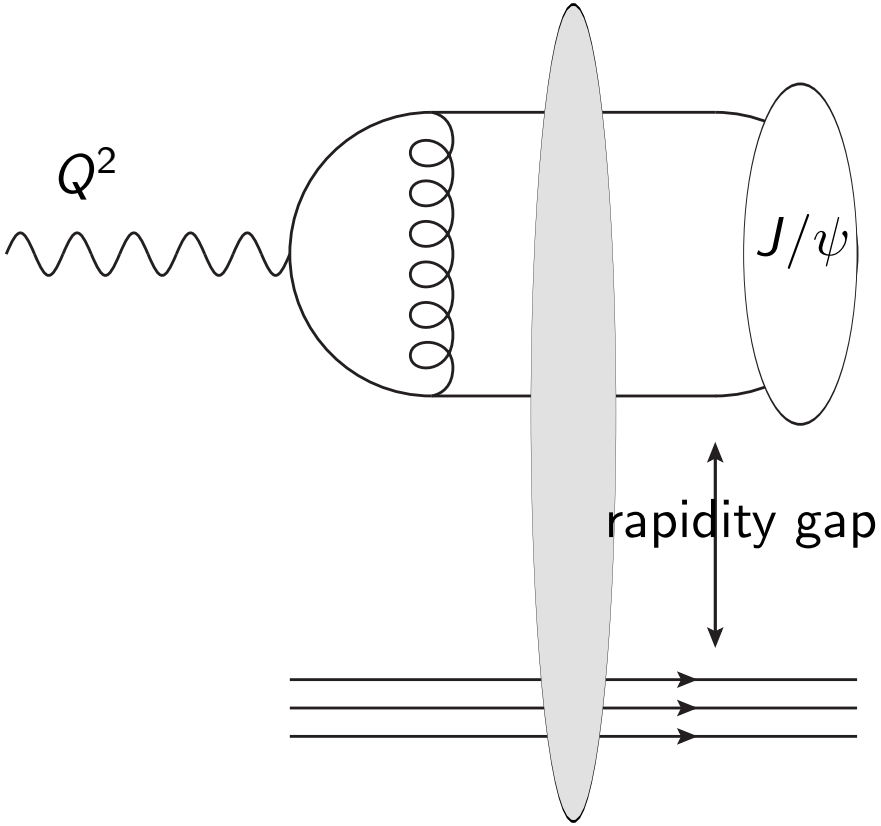


Amplitude for diffractive ρ production

$$\Phi_{BK} \otimes \mathcal{K}_{BK} \otimes \Phi'_{BK} = (\Phi_{BFKL} \otimes \mathcal{O})(\mathcal{O}^{-1} \otimes \mathcal{K}_{BFKL}\mathcal{O})(\mathcal{O}^{-1} \otimes \Phi'_{BFKL})$$

With an added mass

- Open charm production (straightforward)
- Heavy quarkonium production (in the Color Evaporation formalism)



Amplitude for diffractive production of a charmonium