QCD resummation effects in inclusive production of a forward J/psi and a backward jet at the LHC

Lech Szymanowski

National Centre for Nuclear Research, Warsaw

GDR QCD 2017, 4-6 December 2017, Orme des Merisiers

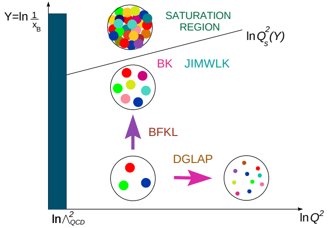
in collaboration with

R. Boussarie (INP, Kraków)
B. Ducloué (Institut de physique théorique, Université Paris Saclay, CEA, CNRS)
S. Wallon (LPT Orsay, CNRS / Université Paris Sud, Université Paris Saclay)

Based on arXiv:1709.02671 [hep-ph]

The partonic content of the proton

The various regimes governing the perturbative content of the proton



- "usual" regime: x_B moderate ($x_B \gtrsim .01$):
  Evolution in Q governed by the QCD renormalization group
  (Dokshitser, Gribov, Lipatov, Altarelli, Parisi equation)

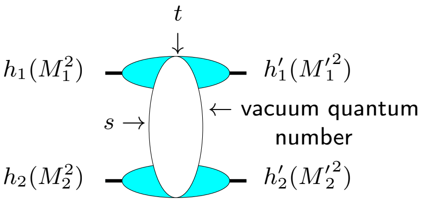
$$\underbrace{\sum_n (\alpha_s \, \ln Q^2)^n}_{\text{LLQ}} \; + \; \underbrace{\alpha_s \sum_n (\alpha_s \, \ln Q^2)^n}_{\text{NLLQ}} \; + \cdots$$

- perturbative Regge limit: $s_{\gamma^* p} \to \infty$ i.e. $x_B \sim Q^2/s_{\gamma^* p} \to 0$
  in the perturbative regime (hard scale Q^2)
  (Balitski Fadin Kuraev Lipatov equation)

$$\underbrace{\sum_n (\alpha_s \, \ln s)^n}_{\text{LLs}} \; + \; \underbrace{\alpha_s \sum_n (\alpha_s \, \ln s)^n}_{\text{NLLs}} \; + \cdots$$

QCD in the perturbative Regge limit

- One of the important longstanding theoretical questions raised by QCD is its behaviour in the perturbative Regge limit $s \gg -t$
- Based on theoretical grounds, one should identify and test suitable observables in order to test this peculiar dynamics



hard scales: $M_1^2,\, M_2^2 \gg \Lambda_{QCD}^2$ or $M_1'^2,\, M_2'^2 \gg \Lambda_{QCD}^2$ or $t \gg \Lambda_{QCD}^2$
where the $t-$channel exchanged state is the so-called hard Pomeron

How to test QCD in the perturbative Regge limit?

What kind of observable?

- perturbation theory should be applicable:
  selecting external or internal probes with transverse sizes $\ll 1/\Lambda_{QCD}$ (*hard* γ^*, *heavy* meson (J/Ψ, Υ), *energetic* forward jets) or by choosing large t in order to provide the hard scale.

$\Longrightarrow$ semi-hard processes with $s \gg p_{T\,i}^2 \gg \Lambda_{QCD}^2$ where $p_{T\,i}^2$ are typical transverse scale, all of the same order.

How to test QCD in the perturbative Regge limit?

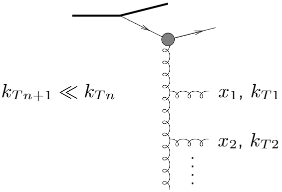
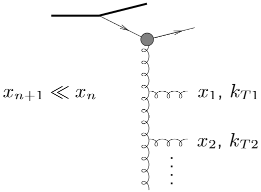
Some examples of processes

- inclusive: DIS (HERA), diffractive DIS, total $\gamma^*\gamma^*$ cross-section (LEP, ILC)
- semi-inclusive: forward jet and π^0 production in DIS, Mueller-Navelet double jets, diffractive double jets, high p_T central jet, in hadron-hadron colliders (Tevatron, LHC)
- exclusive: exclusive meson production in DIS, double diffractive meson production at e^+e^- colliders (ILC), ultraperipheral events at LHC ($\mathbb{P}$omeron, $\mathbb{O}$dderon)

Resummation in QCD: DGLAP vs BFKL

Dynamics of resummations

Small values of α_s (perturbation theory applies if there is a hard scale) can be compensated by large logarithmic enhancements.

DGLAP	BFKL
	
strong ordering in k_T	strong ordering in x
$\sum(\alpha_s \ln Q^2)^n$	$\sum(\alpha_s \ln s)^n$

When $\sqrt{s}$ becomes very large, it is expected that a BFKL description is needed to get accurate predictions

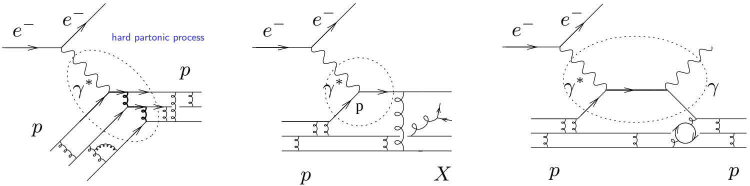
Perturbative QCD in a fixed order approach

Hard processes in QCD and collinear factorization

- This is justified if the process is governed by a hard scale:
  - Virtuality of the electromagnetic probe

    in elastic scattering $e^\pm\, p \to e^\pm\, p$
    in Deep Inelastic Scattering (DIS) $e^\pm\, p \to e^\pm\, X$
    in Deep Virtual Compton Scattering (DVCS) $e^\pm\, p \to e^\pm\, p\,\gamma$
  - Total center of mass energy in $e^+e^- \to X$ annihilation
  - t-channel momentum exchange in meson photoproduction $\gamma\, p \to M\, p$
  - Mass of a heavy bound state e.g. $J/\Psi, \Upsilon$
- A precise treatment relies on collinear factorization theorems
- Scattering amplitude

  = partonic amplitude (computed at a given fixed order) $\otimes$ (convolution) non-perturbative hadronic content

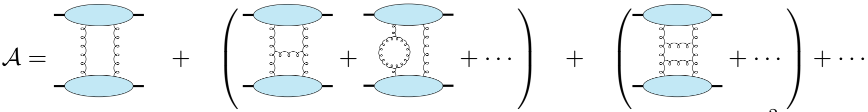


Semi-hard processes: resummed QCD at large s

QCD in the perturbative Regge limit

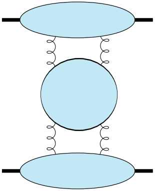
$$s \gg M^2_{\text{hard scale}} \gg \Lambda^2_{QCD}$$

The amplitude can be written as:



$\sim s \qquad \sim s\,(\alpha_s \ln s) \qquad \sim s\,(\alpha_s\ \ln s)^2$

this can be put in the following form :



← Impact factor

← Green's function

← Impact factor

$$\sigma_{tot}^{h_1\,h_2 \to anything} = \frac{1}{s} Im\mathcal{A} \sim s^{\alpha_{\mathbb{P}}(0)-1}$$

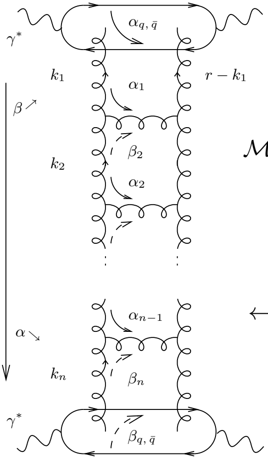
with $\alpha_{\mathbb{P}}(0) - 1 = C\,\alpha_s + C'\,\alpha_s^2 + \cdots$

$C > 0$: Leading Log $\mathbb{P}$omeron

Balitsky, Fadin, Kuraev, Lipatov

Opening the boxes: Impact representation $\gamma^* \gamma^* \to \gamma^* \gamma^*$ as an example

- Sudakov decomposition: $k_i = \alpha_i \, p_1 + \beta_i \, p_2 + k_{\perp i}$ $\quad (p_1^2 = p_2^2 = 0, \; 2p_1 \cdot p_2 = s)$
- write $\quad d^4 k_i = \frac{s}{2} \, d\alpha_i \, d\beta_i \, d^2 k_{\perp i} \quad$ ($\underline{k}$ = Eucl. $\leftrightarrow$ $k_\perp$ = Mink.)
- $t-$channel gluons have non-sense polarizations at large s: $\epsilon_{NS}^{up/down} = \frac{2}{s} \, p_{2/1}$



$\Rightarrow$ set $\alpha_1 = 0$ and $\int d\beta_1 \;\Rightarrow\; \Phi^{\gamma^* \to \gamma^*}(\underline{k}_1, \underline{r} - \underline{k}_1)$ impact factor

$$\mathcal{M} = \frac{is}{(2\pi)^2} \int \frac{d^2 \underline{k}}{\underline{k}^2} \, \Phi^{up}(\underline{k}, \, \underline{r} - \underline{k}) \int \frac{d^2 \underline{k}'}{\underline{k}'^2} \, \Phi^{down}(-\underline{k}', \, -\underline{r} + \underline{k}')$$
$$\times \int_{\delta - i\infty}^{\delta + i\infty} \frac{d\omega}{2\pi i} \left(\frac{s}{s_0} \right)^{\omega} G_\omega(\underline{k}, \underline{k}', \underline{r})$$

$\longleftarrow$ multi-Regge kinematics

$\Rightarrow$ set $\beta_n = 0$ and $\int d\alpha_n \;\Rightarrow\; \Phi^{\gamma^* \to \gamma^*}(-\underline{k}_n, -\underline{r} + \underline{k}_n)$

Higher order corrections

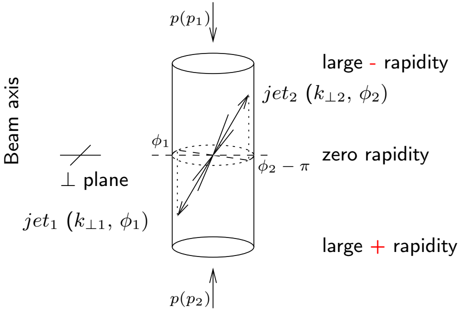
Only a few higher order corrections are known

- Higher order corrections to BFKL kernel are known at NLL order (Lipatov Fadin; Camici, Ciafaloni), now for arbitrary impact parameter $\alpha_S \sum_n (\alpha_S \ln s)^n$ resummation
- impact factors are known in some cases at NLL
  - $\gamma^* \to \gamma^*$ at $t = 0$ (Bartels, Colferai, Gieseke, Kyrieleis, Qiao; Balitski, 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, Kotsky, Papa)

Mueller-Navelet jets: Basics

Mueller-Navelet jets

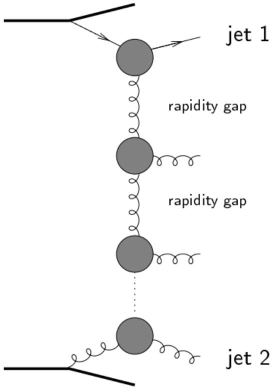
- Consider two jets (hadrons flying within a narrow cone) separated by a large rapidity, i.e. each of them almost fly in the direction of the hadron "close" to it, and with very similar transverse momenta
- Pure LO *collinear* treatment: these two jets should be emitted back to back at leading order:
  - $\varphi \equiv \Delta\phi - \pi = 0$ ($\Delta\phi = \phi_1 - \phi_2$ = relative azimuthal angle)
  - $k_{\perp 1}$=$k_{\perp 2}$. No phase space for (untagged) multiple (DGLAP) emission between them



Mueller-Navelet jets: LL fails

Mueller Navelet jets at LL BFKL

- in LL BFKL ($\sim \sum(\alpha_s \ln s)^n$), emission between these jets $\longrightarrow$ strong decorrelation between the relative azimutal angle jets, incompatible with $p\bar{p}$ Tevatron collider data
- a collinear treatment at next-to-leading order (NLO) can describe the data
- important issue: non-conservation of energy-momentum along the BFKL ladder. A LL BFKL-based Monte Carlo combined with e-m conservation improves dramatically the situation (Orr and Stirling)



Multi-Regge kinematics (LL BFKL)

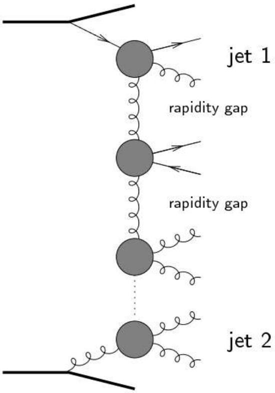
Mueller-Navelet jets: beyond LL

Mueller Navelet jets at NLL BFKL

- up to $\sim$ 2010,
  the subseries $\alpha_s \sum(\alpha_s \ln s)^n$ NLL was included only in the exchanged $\mathbb{P}$omeron state, and not inside the jet vertices
  Sabio Vera, Schwennsen
  Marquet, Royon

- our studies have shown was
  that these corrections are very important
  Colferai, Schwennsen, L.Sz, S. Wallon.
  Ducloué, L.Sz., S. Wallon.

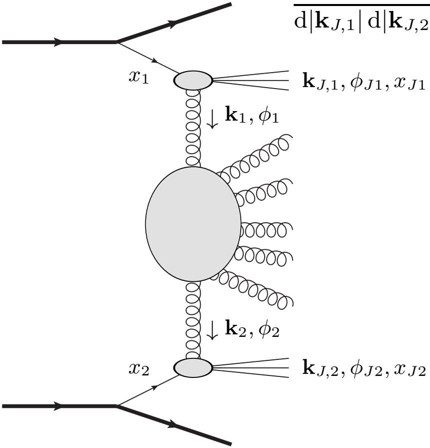
  for similar studies and results:
  Caporale, Ivanov, Murdaca, Papa
  Caporale, Murdaca, Sabio Vera, Salas



Quasi Multi-Regge kinematics
(here for NLL BFKL)

Mueller-Navelet jets at NLL: master formulas

k_T-factorized differential cross section



$$\frac{\mathrm{d}\sigma}{\mathrm{d}|\mathbf{k}_{J,1}|\,\mathrm{d}|\mathbf{k}_{J,2}|\,\mathrm{d}y_{J,1}\,\mathrm{d}y_{J,2}} = \int \mathrm{d}\phi_{J,1}\,\mathrm{d}\phi_{J,2} \int \mathrm{d}^2\mathbf{k}_1\,\mathrm{d}^2\mathbf{k}_2$$

$$\times\, \Phi(\mathbf{k}_{J,1}, x_{J1}, -\mathbf{k}_1)$$

$$\times\, G(\mathbf{k}_1, \mathbf{k}_2, \hat{s})$$

$$\times\, \Phi(\mathbf{k}_{J,2}, x_{J2}, \mathbf{k}_2)$$

with $\Phi(\mathbf{k}_{J,2}, x_{J2}, \mathbf{k}_2) = \int \mathrm{d}x_2\, f(x_2) V(\mathbf{k}_2, x_2)$ $\quad f \equiv$ PDF $\quad x_J = \frac{|\mathbf{k}_J|}{\sqrt{s}} e^{y_J}$

Mueller-Navelet jets at NLL: Renormalization scale fixing

Renormalization scale uncertainty

- We used the Brodsky-Lepage-Mackenzie (BLM) procedure to fix the renormalization scale
- The BLM procedure resums the self-energy corrections to the gluon propagator at one loop into the running coupling.

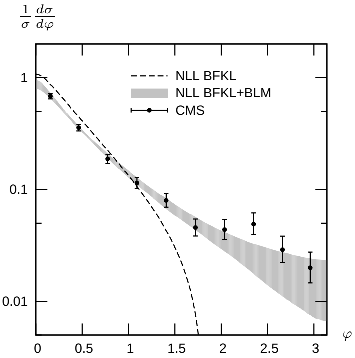
- First attempts to apply BLM scale fixing to BFKL processes lead to problematic results. Brodsky, Fadin, Kim, Lipatov and Pivovarov suggested that one should first go to a physical renormalization scheme like MOM and then apply the 'traditional' BLM procedure, i.e. identify the β_0 dependent part and choose μ_R such that it vanishes.

  We followed this prescription for the full amplitude at NLL.

Mueller-Navelet jets at NLL: comparison with the data

Comparison with the data

recall: $\varphi = 0 \Leftrightarrow$ back-to-back



Ducloué, L.Sz., S. Wallon.

$$\frac{1}{\sigma}\frac{d\sigma}{d\varphi} = \frac{1}{2\pi}\left\{1 + 2\sum_{n=1}^{\infty}\cos(n\varphi)\,\langle\cos(n\varphi)\rangle\right\}.$$

$$6 < Y < 9.4$$

$$35\ \text{GeV}^2 < \mathbf{k}_{J,1}, \mathbf{k}_{J,2}$$

Mueller-Navelet jets at NLL

Other effects and references

- Full NLL description

D. Colferai, F. Schwennsen, L. Sz., S. Wallon., JHEP **1012** (2010) 026 [arXiv:1002.1365 [hep-ph]]

B. Ducloué, L. Sz., S. Wallon., JHEP **1305** (2013) 096 [arXiv:1302.7012 [hep-ph]]

- BLM renormalization scale fixing and comparison with data

B. Ducloué, L. Sz., S. Wallon., Phys. Rev. Lett. **112** (2014) 082003 [arXiv:1309.3229 [hep-ph]]

- Energy momentum violation: the situation is much improved when including full NLL corrections

B. Ducloué, L. Sz., S. Wallon., Phys. Lett. B738 (2014) 311-316 [arXiv:1407.6593 [hep-ph]]

- Multiparton description of Mueller-Navelet jets:
  two uncorrelated ladders suppressed at LHC kinematics

B. Ducloué, L. Sz., S. Wallon., Phys. Rev. D92 (2015) 7, 076002 [arXiv:1507.04735 [hep-ph]]

- Sudakov resummation effects:
  in the almost back-to-back region, and at LL, the resummation as been performed: no overlap with low-x resummation effects

A. H. Mueller, L. Sz., S. Wallon., B.-W. Xiao, F. Yuan, JHEP 1603 (2016) 096 [arXiv:1512.07127 [hep-ph]]

Inclusive forward J/Ψ and backward jet production at the LHC

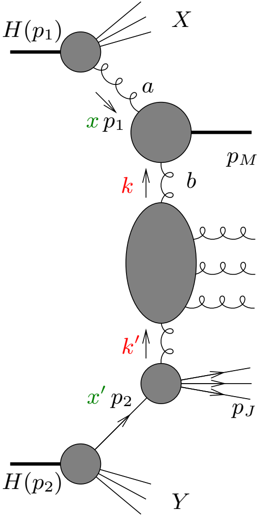
Why J/Ψ?

- Numerous J/ψ mesons are produced at LHC
- J/ψ is "easy" to reconstruct experimentaly through its decay to $\mu^+\mu^-$ pairs
- The mechanism for the production of J/ψ mesons is still to be completely understood (see discussion later), although it was observed more than 40 years ago E598 collab 1974; SLAC-SP collab 1974
- Any improvement of the understanding of these mechanisms is important in view of QGP studies since J/Ψ suppression (melting) is one of the best probe. Cold nuclear effects are numerous and known to make life more complicate
- The vast majority of J/ψ theoretical predictions are done in the collinear factorization framework : would k_t factorization give something different?
- We will perform an MN-like analysis, considering a process with a rapidity difference which is large enough to use BFKL dynamics but small enough to be able to detect J/ψ mesons at LHC (ATLAS, CMS).

Master formula

$k_\perp$-factorization description of the process

$\hat{s} = x\, x'\, s$



$$\frac{d\sigma}{dy_V\, d|p_{V\perp}|\, d\phi_V\, dy_J\, d|p_{J\perp}|\, d\phi_J} = \sum_{a,b} \int d^2k_\perp\, d^2k'_\perp$$

$$\times \int_0^1 dx\, f_a(x)\, V_{V,a}(k_\perp, x)$$

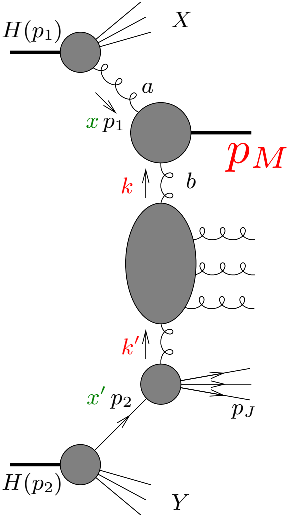
$$\times\, G(-k_\perp, -k'_\perp, \hat{s})$$

$$\times \int_0^1 dx'\, f_b(x')\, V_{J,b}(-k'_\perp, x'),$$

Master formula

$k_\perp$-factorization description of the process

$\hat{s} = x\, x'\, s$



???

$$\frac{d\sigma}{dy_V\, d|p_{V\perp}|\, d\phi_V\, dy_J\, d|p_{J\perp}|\, d\phi_J}$$

$$= \sum_{a,b} \int d^2k_\perp\, d^2k'_\perp$$

$$\times \int_0^1 dx\, f_a(x)\, V_{V,a}(k_\perp, x)$$

$$\times\, G(-k_\perp, -k'_\perp, \hat{s})$$

$$\times \int_0^1 dx'\, f_b(x')\, V_{J,b}(-k'_\perp, x'),$$

The NRQCD formalism

Quarkonium production in NRQCD

- We will first use the Non Relativistic QCD (NRQCD) formalism
  Bodwin, Braaten, Lepage; Cho, Leibovich ....
- There is no proof of NRQCD factorization at all orders.
- Basically, one expands the onium state wrt the velocity $v \sim \frac{1}{\log M}$ of its constituents: infinite series in v

$$|V\rangle = O(1)\left|Q\bar{Q}[^3S_1^{(1)}]\right\rangle + O(v)\left|Q\bar{Q}[^3P_J^{(8)}]g\right\rangle + O(v^2)\left|Q\bar{Q}[^1S_0^{(8)}]g\right\rangle +$$
$$+O(v^2)\left|Q\bar{Q}[^3S_1^{(1,8)}]gg\right\rangle + O(v^2)\left|Q\bar{Q}[^3D_J^{(1,8)}]gg\right\rangle + \ldots\ldots$$

$\Rightarrow$ all the non-perturbative physics is encoded in Long Distance Matrix Elements (LDME) obtained from $|V\rangle$

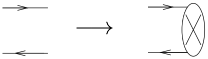
$\Rightarrow$ the hard part (series in α_s) is obtained by the usual Feynman diagram methods
$\Rightarrow$ the cross-sec. = convolution of (the hard part)^2 * LDME

- In NRQCD, the two Q and $\bar{Q}$ share the quarkonium momentum: $p_V = 2q$
- The relative importance of color-singlet versus color-octet mechanisms is still subject of discussions.

$\Rightarrow$ the vertex V in LO and we consider case with $Q\bar{Q}$-pair with the same spin and orbital mom. as J/Ψ : $\left|Q\bar{Q}[^3S_1^{(1)}]\right\rangle$ and $\left|Q\bar{Q}[^3S_1^{(8)}]gg\right\rangle$ Fock states

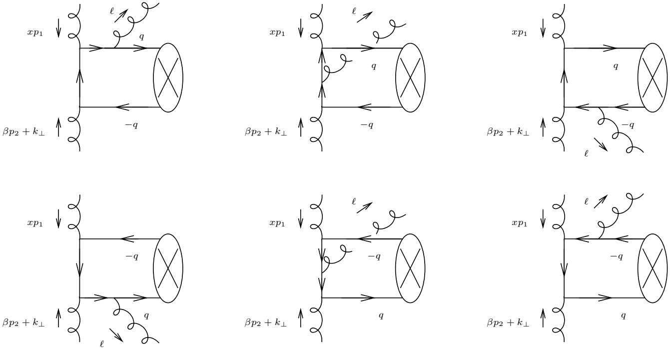
The J/ψ impact factor: NRQCD color singlet contribution

From open quark-antiquark gluon production to J/ψ production

NRQCD color-singlet transition vertex: 

$$[v(q)\bar{u}(q)]^{ij}_{\alpha\beta} \to \frac{\delta^{ij}}{4N}\left(\frac{\langle\mathcal{O}_1\rangle_V}{m}\right)^{1/2}[\hat{\epsilon}^*_V\,(2\hat{q}+2m)]_{\alpha\beta}$$

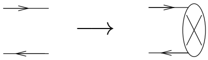
$\langle\mathcal{O}_1\rangle_V$ from leptonic J/Ψ decay rate



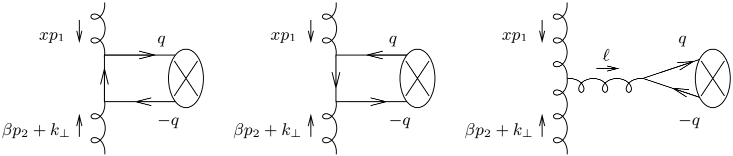
The J/ψ impact factor: NRQCD color octet contribution

From open quark-antiquark production to J/ψ production

NRQCD color-octet transition vertex:



$$[v(q)\bar{u}(q)]^{ij\to d}_{\alpha\beta} \to t^d_{ij} d_8 \left(\frac{\langle \mathcal{O}_8 \rangle_V}{m} \right)^{1/2} \left[\hat{\epsilon}^*_V \left(2\hat{q} + 2m\right)\right]_{\alpha\beta}$$



$\langle \mathcal{O}_8 \rangle_V$ varied in $[0.224 \times 10^{-2}, 1.1 \times 10^{-2}]$GeV^3

The Color Evaporation Model

Quarkonium production in the color evaporation model

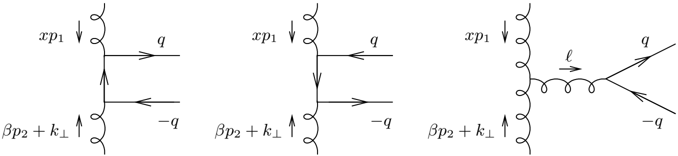
Relies on the local duality hypothesis

Fritzsch, Halzen ...

- Consider a heavy quark pair $Q\bar{Q}$ with $m_{Q\bar{Q}} < 2\, m_{Q\bar{q}}$
  $Q\bar{q}$ = lightest meson which contains Q
  e.g $D-$meson for $Q = c$
- it will eventually produce a bound $Q\bar{Q}$ pair after a series of randomized soft interactions between its production and its confinement , independently of its color and spin.
- It is assumed that the repartition between all the possible charmonium states is universal.
- Thus the procedure is the following :
  - Compute all the Feynman diagrams for open $Q\bar{Q}$ production
  - Sum over all spins and colors
  - Integrate over the $Q\bar{Q}$ invariant mass

The J/ψ impact factor: relying on the color evaporation model

From open quark-antiquark gluon production to J/ψ production



$$\sigma_{J/\psi} = F_{J/\psi} \int_{4m_c^2}^{4m_D^2} dM^2 \frac{d\sigma_{c\bar{c}}}{dM^2}$$

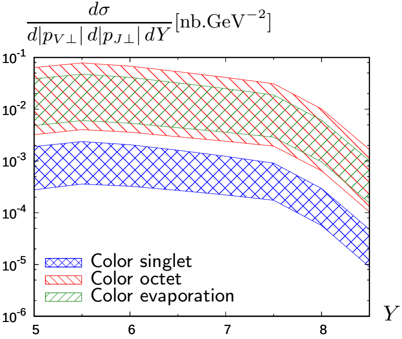
$F_{J/\psi}$: varied in [0.02, 0.04], purely known

Numerical results

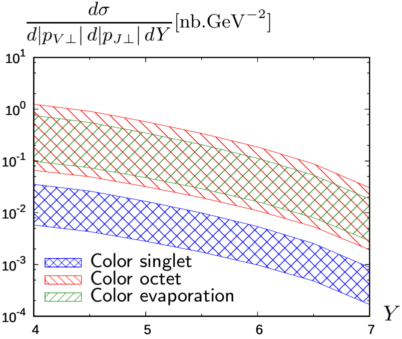
- Two CMS energies: $\sqrt{s} = 8$TeV and $\sqrt{s} = 13$TeV
- $|p_{V\perp}| = |p_{J\perp}| = p_\perp$
- Four different kinematic configurations:
  - $0 < y_V < 2.5, \; -6.5 < y_J < -5, \; p_\perp = 10$ GeV CASTOR@CMS
  - $0 < y_V < 2.5, \; -4.5 < y_J < 0, \; p_\perp = 10$ GeV
  - $0 < y_V < 2.5, \; -4.5 < y_J < 0, \; p_\perp = 20$ GeV
  - $0 < y_V < 2.5, \; -4.5 < y_J < 0, \; p_\perp = 30$ GeV

    main detectors at ATLAS and CMS
  - uncertainty band: due to variation of non-pert. constants and scales μ_R, μ_F

Cross section at $\sqrt{s} = 8$ TeV



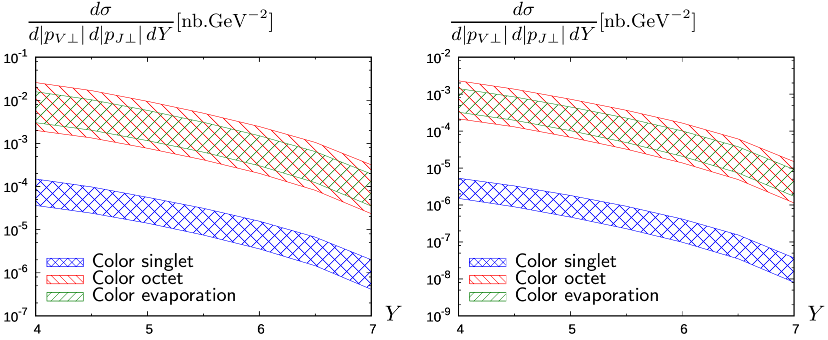
$0 < y_V < 2.5, \; -6.5 < y_J < -5, \; p_\perp = 10$ GeV



$0 < y_V < 2.5, \; -4.5 < y_J < 0, \; p_\perp = 10$ GeV

Figure: Cross section at $\sqrt{s} = 8$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

Cross section at $\sqrt{s} = 8$ TeV cntd

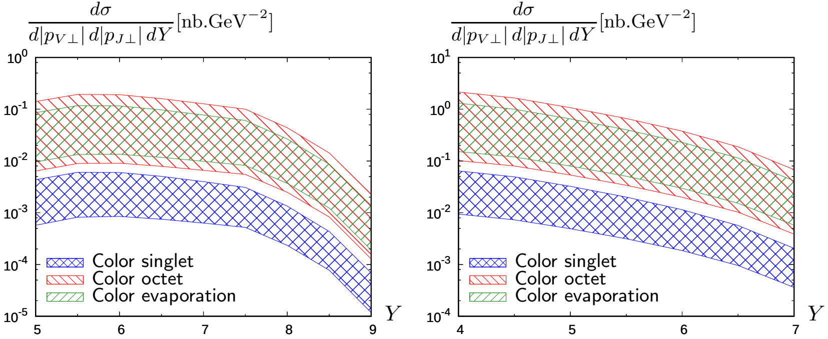


$0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 20$ GeV $\quad 0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 30$ GeV

Figure: Cross section at $\sqrt{s} = 8$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

$\Longrightarrow$ color-octet dominates over color-singlet specially for large $p_\perp$
$\Longrightarrow$ color-octet and color-evaporation model give similar results

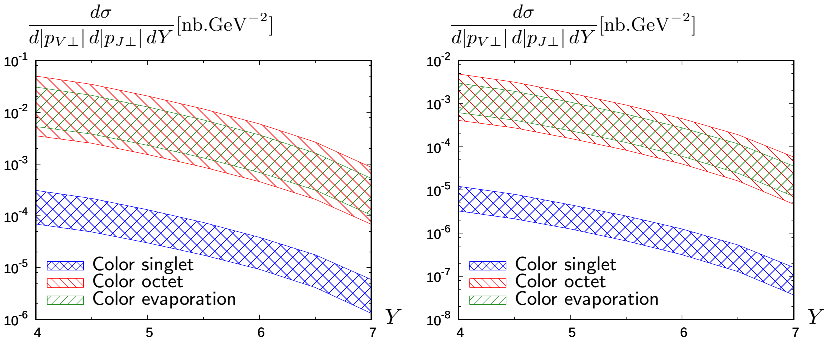
Cross section at $\sqrt{s} = 13$ TeV



$0 < y_V < 2.5,\ -6.5 < y_J < -5,\ p_\perp = 10$ GeV $\quad$ $0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 10$ GeV

Figure: Cross section at $\sqrt{s} = 13$ TeV as a function of the relative rapidity Y between the J/ψ

Cross section at $\sqrt{s} = 13$ TeV cntd



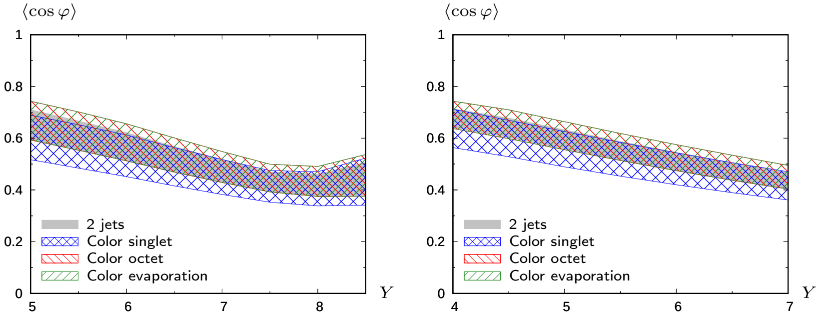
$0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 20$ GeV $\quad 0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 30$ GeV

Figure: Cross section at $\sqrt{s} = 13$ TeV as a function of the relative rapidity Y between the J/ψ and the jet,

$\Longrightarrow$ color-octet dominates over color-singlet specially for large $p_\perp$
$\Longrightarrow$ color-octet and color-evaporation model give similar results
$\Longrightarrow$ slight increase of cross sec. when $\sqrt{s} = 8$ TeV $\rightarrow \sqrt{s} = 13$ TeV

Variation of $\langle \cos\varphi \rangle$ at $\sqrt{s} = 8$ TeV

$$\varphi = |\phi_V - \phi_J - \pi|$$

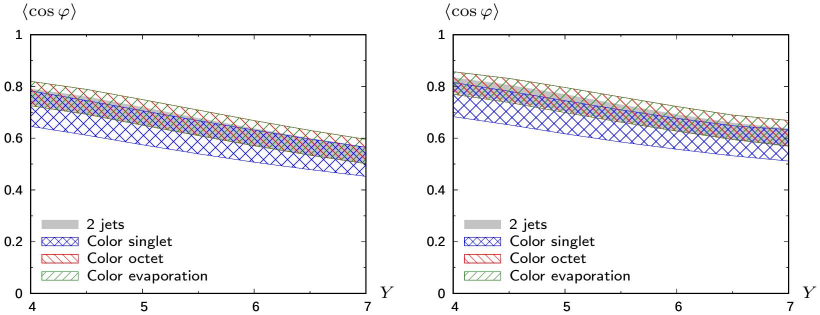


$0 < y_V < 2.5,\ -6.5 < y_J < -5,\ p_\perp = 10$ GeV; $0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 10$ GeV

Figure: Variation of $\langle \cos\varphi \rangle$ at $\sqrt{s} = 8$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

Variation of $\langle \cos \varphi \rangle$ at $\sqrt{s} = 8$ TeV cntd

$$\varphi = |\phi_V - \phi_J - \pi|$$

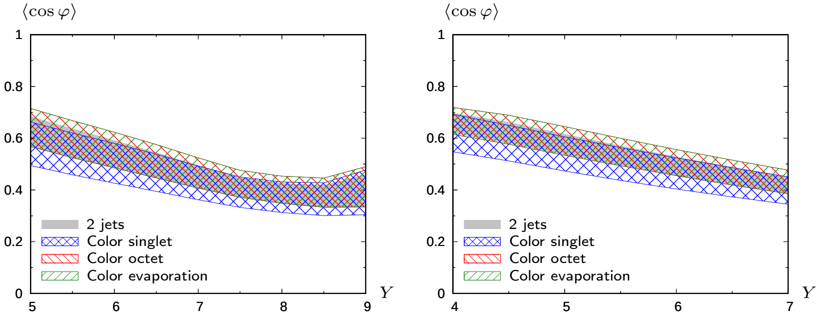


$0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 20$ GeV; $0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 30$ GeV

Figure: Variation of $\langle \cos \varphi \rangle$ at $\sqrt{s} = 8$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

Variation of $\langle \cos\varphi \rangle$ at $\sqrt{s} = 13$ TeV

$$\varphi = |\phi_V - \phi_J - \pi|$$

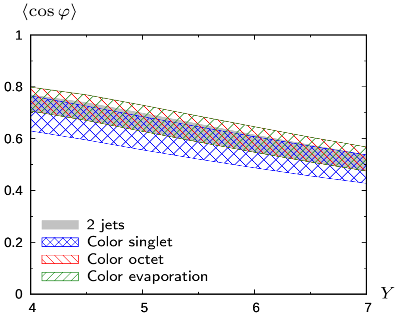


$0 < y_V < 2.5,\ -6.5 < y_J < -5,\ p_\perp = 10$ GeV; $\quad 0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 10$ GeV

Figure: Variation of $\langle \cos\varphi \rangle$ at $\sqrt{s} = 13$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

Variation of $\langle\cos\varphi\rangle$ at $\sqrt{s}=13$ TeV cntd

$$\varphi = |\phi_V - \phi_J - \pi|$$



$0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 20$ GeV; $0 < y_V < 2.5,\ -4.5 < y_J < 0,\ p_\perp = 30$ GeV

Figure: Variation of $\langle\cos\varphi\rangle$ at $\sqrt{s}=13$ TeV as a function of the relative rapidity Y between the J/ψ and the jet

$\Longrightarrow$ all 3 models lead to similar decorelation effects and are compatible with the case when $V_{J/\Psi} \to$ LO V_{jet}

$\Longrightarrow$ passing from $\sqrt{s}=8$ TeV to $\sqrt{s}=13$ TeV increases slightly decorrelation effects

Summary

- The production of Mueller-Navelet was successfully described using the BFKL formalism
- We applied the same formalism for the production of a forward J/Ψ meson and a backward jet, using both the NRQCD formalism and the Color Evaporation Model
- This new process could constitute a good probe of importance of color-singlet contribution versus the color-octet contribution in NRQCD
- More predictions about azimuthal correlations can be delivered
- A comparison with a fixed order treatment is planned
- A complete NLL study is very challenging: requires to compute the NLO vertex for J/Ψ production
- Preliminary experimental studies (ATLAS) are very promising

MERCI / THANK YOU