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JET INCLUSIVE CROSS SECTIONS

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Minijet production in jet inclusive cross sections at hadron colliders, with large rapidity intervals between the tagged jets, is evaluated by using the BFKL pomeron. We describe the jet inclusive cross section for an arbitrary number of tagged jets, and show that it behaves like a system of coupled pomerons.

At the present and next hadron colliders the semihard region, characterized by an intermediate scale m, such that $s >> m^2 >> \Lambda^2_{QCD}$, and large rapidity intervals, of order $\ln(s/m^2)$, is expected to play an increasingly important role, due to a copious production of minijets. In this region scattering events are dominated by the exchange of gluon ladders in the t channel. In the leading logarithmic approximation (LLA), which resums $log(s/t)$ terms, the gluon ladders are described by the BFKL evolution equation[1]. The LLA is generated by the multi-Regge kinematics , i.e. by the strong ordering in rapidity of the produced minijets.

Then, according to the event we consider, we factorize the cross section in such a way to have the large rapidity intervals and the BFKL evolution either in the gluon structure functions[2] or in the short-distance cross section[3]. In this contribution we focus on the latter, namely we tag two or more jets at large rapidity intervals[4], with the minimum transverse momentum m of the tagged jets as the factorization scale of the short-distance cross section.

Mueller and Navelet[3] proposed to compute in this fashion the 2-jet inclusive cross section. By keeping the light-cone momentum fractions x_1 and x_2 of the beam momenta fixed, such a cross section depends only on s, i.e. on the interval in rapidity $\eta = \ln(x_1 x_2 s/m^2)$ between the tagged jets. These lie at the extremes of the lego plot in rapidity and azimuthal angle, with the rapidity interval between them filled with minijets. Assuming that the hard scattering is initiated by gluons, we can write the 2-jet inclusive cross section, integrated over the transverse momenta of the tagged jets, in a factorized form

$$\sigma(s, m^2, x_1, x_2) = x_1 G(x_1, m^2) x_2 G(x_2, m^2) \hat{\sigma}_{tot}(gg, \eta), \tag{1}$$

with $G(x, m^2)$ the DGLAP gluon distribution and $\hat{\sigma}_{tot}(gg, \eta)$ the total gluon-gluon cross section, which involves only the hard part of the scattering. At large rapidity intervals, since the leading scattering always goes through gluon exchange in the t channel, we can include initial-state quarks[5] by simply replacing $G(x, m^2)$ with $G(x, m^2) + 4/9 \sum_f (Q_f(x, m^2) + \bar{Q}_f(x, m^2))$.

The total gluon-gluon cross section can then be computed from the imaginary part of the corresponding forward elastic scattering amplitude, with color-singlet

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exchange in the t channel, obtained by using the BFKL pomeron[1]. It can be written as

$$\hat{\sigma}_{tot}(gg,\eta) = \frac{9\pi\alpha_s^2}{2m^2} f(\eta), \tag{2}$$

where $f(\eta)$, the ratio of the total to the Born gluon-gluon cross sections, is given in terms of the Fourier spectrum of the pomeron off-shell amplitude convoluted with the Fourier structures of the off-shell scattering amplitudes at the extremes of the lego plot, which in this case are merely the 3-gluon vertices,

$$f(\eta) = \frac{1}{2\pi}\int_{-\infty}^{\infty} d\nu \frac{1}{\nu^2+1/4} e^{\eta\omega(\nu)}, \tag{3}$$

and

$$\omega(\nu) = 6\frac{\alpha_s}{\pi}\left[\psi(1) - Re\psi(\frac{1}{2}+i\nu)\right]. \tag{4}$$

The azimuthal angle between the transverse momenta of the tagged jets has been integrated out. At large values of η the asymptotics of $f(\eta)$ is

$$f(\eta) = \frac{e^{12\log 2\frac{\alpha_s}{\pi}\eta}}{\sqrt{\frac{21}{2}\zeta(3)\alpha_s\eta}}, \tag{5}$$

The exponential growth of $f(\eta)$ is due to the minijet production.

Since we are assuming no BFKL evolution to the exterior of the left and rightmost tagged jets on the lego plot, Eq. (1) can be generalized to determine the $(n+2)$-jet inclusive cross section from the n-gluon inclusive one. For the 1-gluon inclusive cross section, for instance, fixing $\bar{\eta}$, η_A and η_B as the rapidities of the gluon and the jets at the extremes of the lego plot respectively, with $\eta_A > \bar{\eta} > \eta_B$ and $\eta = \eta_A - \eta_B$, we have[6]

$$\begin{aligned} \frac{d\sigma_1}{d\bar{\eta}d\ln(k^2/m^2)} &= \frac{9\pi\alpha_s^2}{2m^2}\frac{3\alpha_s}{4\pi^3}\int_{\infty}^{\infty} d\nu_A \int_{\infty}^{\infty} d\nu_B e^{(\eta_A-\bar{\eta})\omega(\nu_A)} e^{(\bar{\eta}-\eta_B)\omega(\nu_B)} e^{-i(\nu_A-\nu_B)\ln(k^2/m^2)} \frac{1}{i(\nu_A-\nu_B)} \\ & \left[\frac{1}{1/2-i\nu_A}\frac{\Gamma(1/2-i\nu_A)}{\Gamma(1/2+i\nu_A)}\frac{\Gamma[1+i(\nu_A-\nu_B)]}{\Gamma[1-i(\nu_A-\nu_B)]}\frac{\Gamma(1/2+i\nu_B)}{\Gamma(1/2-i\nu_B)}\frac{1}{1/2+i\nu_B}\right], \end{aligned} \tag{6}$$

with $Im(\nu_A - \nu_B) < 0$ in order not to have unphysical ultraviolet divergences, and $Im\nu_A > -1/2$ and $Im\nu_B < 1/2$. Thus the 1-gluon inclusive cross section can be described in terms of two coupled pomerons, which resonate when their Fourier frequencies are about the same. At large intervals in rapidity, it is possible to perform a saddle-point evaluation of Eq.(6)

$$\frac{d\sigma_1}{d\bar{\eta}d\ln(k^2/m^2)} = \hat{\sigma}_{tot}(gg,\eta)\frac{3\alpha_s}{2\pi^{5/2}}\sqrt{1-\frac{1}{a}}\,exp\left[-\frac{1}{a-1}+1/2\right], \tag{7}$$

with

$$a = \sqrt{1+\frac{336\zeta(3)\alpha_s(\eta_A-\bar{\eta})(\bar{\eta}-\eta_B)}{\pi\eta\ln^2(k^2/m^2)}}. \tag{8}$$

Eq.(7) shows that at fixed gluon rapidities and large transverse momenta the 1-gluon inclusive cross section falls off faster than any power of the momentum. However, the requirement that the saddle points, which lie on the imaginary axis, don't hit the poles makes the saddle-point evaluation feasible only in a region central in rapidity and shrinking as the gluon transverse momentum grows. This can be avoided by evaluating Eq.(6) numerically.

Eq.(6) is straightforwardly generalizable to the n-gluon inclusive cross section, with a strong ordering of the Fourier frequencies of the exchanged pomerons on the imaginary axis. The region where a saddle-point evaluation is feasible becomes quickly negligible as the number of tagged jets grows and a numerical evaluation of Eq.(6) is then compelling.

What said above can be generalized to more elaborate events, like heavy quark or Higgs boson production, via gluon-gluon fusion. For scattering events with additional intermediate scales, like in the inclusive production of a Higgs boson and a gluon jet[7] at the extremes of the lego plot, the BFKL pomeron may also resum the collinear enhancements which arise in the short-distance cross section because of the higher intermediate scale[8], in this case the mass of the top quark in the gluon-gluon-Higgs form factor. Then following the procedure outlined above it is possible to consider also the production of either the Higgs boson or more gluon jets in the middle of the lego plot.

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