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One 'prompt photon' inclusive production

We shall be concerned with the process:

$$h_1 + h_2 \to \gamma + X \ . \tag{21.1}$$

This process is very similar to the one hadron inclusive process:

$$e^+e^- \to H + X \tag{21.2}$$

with the hadron H replaced by a photon, which we shall study in the next part of this book. As it has been studied in hadronic collisions rather than in e^+e^- [273], further difficulties and complications arise in practice. However, in contrast to quarks, the photon does not hadronize and their energies and directions can be measured with better accuracy than hadron jets. To leading order, the production cross-section is $\mathcal{O}(\alpha\alpha_s)$ which is relatively smaller than the hadron cross-section $\mathcal{O}(\alpha_s^2)$, while backgrounds due to photons initiated from π^0 and η productions, are experimentally difficult to separate. In terms of the photon transverse momentum p_T and rapidity variable, the cross-section can be written in the form [273]:

$$\frac{d\sigma}{d\mathbf{p_T}d\eta} = \frac{d\sigma^{\rm dir}}{d\mathbf{p_T}d\eta} + \frac{d\sigma^{\rm brem}}{d\mathbf{p_T}d\eta} \ , \tag{21.3}$$

where one distinguishes between the 'direct' and 'bremsstrahlung' photon productions, which are known to NLO. Assuming factorization, they read:

$$\begin{aligned}
\frac{d\sigma^{\rm dir}}{d\mathbf{p_T}d\eta} &= \sum_{i,j=q,g} \int dx_1 dx_2 F_i^{h_1}(x_1,\mu) F_j^{h_1}(x_2,\mu) \left(\frac{\alpha_s(\nu)}{2\pi}\right) \\
&\quad \times \left(\frac{d\hat\sigma_{ij}}{d\mathbf{p_T}d\eta} + \frac{\alpha_s(\nu)}{2\pi} K_{ij}^{\rm dir}(\nu,\mu,\mu_f)\right) \\
\frac{d\sigma^{\rm brem}}{d\mathbf{p_T}d\eta} &= \sum_{i,j,k=q,g} \int dx_1 dx_2 F_i^{h_1}(x_1,\mu) F_j^{h_1}(x_2,\mu) \frac{dz}{z^2} D_{\gamma/k}(z,\mu_f) \left(\frac{\alpha_s(\nu)}{2\pi}\right)^2 \\
&\quad \times \left(\frac{d\hat\sigma_{ij}^k}{d\mathbf{p_T}d\eta} + \frac{\alpha_s(\nu)}{2\pi} K_{ij,k}^{\rm brem}(\nu,\mu,\mu_f)\right) \ .
\end{aligned} \tag{21.4}$$

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$F_i^{h_l}$ are parton densities in the initial hadrons, which depend on the factorization scale μ; $D_{\gamma/k}$ is the parton to photon fragmentation function which depends on the fragmentation scale μ_f, while ν is the renormalization scale. $\hat{\sigma}$ are the point-like cross-section, while the K factors are higher-order QCD corrections evaluated in [274]. In principle the differential cross-section is function of the three arbitrary variables (μ, μ_f, ν), and the optimal physical results should present stabilities or extrema against their variations, which is not often reached. In practice, the choice $\mu_f = \nu$ or $\mu_f = \nu = \mu$ is chosen, which minimizes the arbitrariness in the analysis. Using the NLO QCD predictions, the UA6 collaboration determined α_s from a measurement of the cross-section difference in the p_T range from about 4 to 8 GeV [275]:

$$\sigma(\bar{p}p \to \gamma X) - \sigma(pp \to \gamma X) , \tag{21.5}$$

which is free from the poorly known sea quarks and gluons distributions, with the results:

$$\alpha_s(24.3 \text{ GeV}) = 0.135 \pm 0.006 \text{ (exp)} \, ^{+0.011}_{-0.005} \text{ (th)} . \tag{21.6}$$

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