24.4. Inclusive hadronic reactions

One-particle inclusive cross sections $Ed^3\sigma/d^3p$ for the production of a particle of momentum p are conveniently expressed in terms of rapidity (see above) and the momentum p_T transverse to the beam direction (defined in the center-of-mass frame)

$$E\frac{d^3\sigma}{d^3p} = \frac{d^3\sigma}{d\phi\, dy\, p_T\, dp_T} \; . \tag{24.24}$$

In the case of processes where p_T is large or the mass of the produced particle is large (here large means greater than 10 GeV), the parton model can be used to calculate the rate. Symbolically

$$\sigma_{\text{hadronic}} = \sum_{ij} \int f_i(x_1, Q^2)\, f_j(x_2, Q^2)\, dx_1\, dx_2\, \widehat{\sigma}_{\text{partonic}} \; , \tag{24.25}$$

where $f_i(x, Q^2)$ is the parton distribution introduced above and Q is a typical momentum transfer in the partonic process and $\widehat{\sigma}$ is the partonic cross section. Two examples will help to clarify. The production of a W^+ in pp reactions at rapidity y in the center-of-mass frame is given by

$$\begin{aligned}\frac{d\sigma}{dy} &= \frac{G_F\, \pi\sqrt{2}}{3} \\ &\quad \times \tau\Big[\cos^2\theta_c\Big(u(x_1\, ,\ M_W^2)\, \overline{d}\,(x_2, M_W^2) \\ &\qquad\qquad + u(x_2\, ,\ M_W^2)\, \overline{d}\,(x_1, M_W^2)\Big) \\ &\qquad + \sin^2\theta_c\Big(u(x_1\, ,\ M_W^2)\, \overline{s}\,(x_2\, ,\ M_W^2) \\ &\qquad\qquad + s(x_2, M_W^2)\, \overline{u}\,(x_1, M_W^2)\Big)\Big] \; , \end{aligned} \tag{24.26}$$

where $x_1 = \sqrt{\tau}\, e^{y}$, $x_2 = \sqrt{\tau}\, e^{-y}$, and $\tau = M_W^2/s$. Similarly the production of a jet in pp (or $p\overline{p}$) collisions is given by

$$\begin{aligned}\frac{d^3\sigma}{d^2p_T\, dy} &= \sum_{ij}\int f_i(x_1\, ,\ p_T^2)\, f_j(x_2, p_T^2) \\ &\quad \times \left[\widehat{s}\,\frac{d\widehat{\sigma}}{d\widehat{t}}\right]_{ij} dx_1\, dx_2\, \delta(\widehat{s} + \widehat{t} + \widehat{u}) \; , \end{aligned} \tag{24.27}$$

where the summation is over quarks, gluons, and antiquarks. Here

$$s = (p_1 + p_2)^2 \; , \tag{24.28}$$

$$t = (p_1 - p_{\text{jet}})^2 \; , \tag{24.29}$$

$$u = (p_2 - p_{\text{jet}})^2 \; , \tag{24.30}$$