1 The correlation between high-E_T jets and PDF's at large x

The cross section for production of high-E_T jets at the Tevatron constrains the parton distributions at large x. Because the quark distributions are already well determined by deep-inelastic scattering, the most significant impact of the jet data is on the gluon distribution.

To understand the relevant x range, consider the kinematics of a leading-order parton scattering process, as illustrated in Fig. 1.

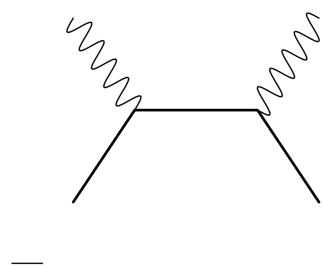

Figure 1: parton-parton scattering

The proton and antiproton 4-momenta are

$$P^\mu = (E, 0, 0, E) \qquad \text{and} \qquad \overline{P}^\mu = (E, 0, 0, -E)\,, \tag{1}$$

respectively, where $E = \sqrt{s}/2 = 1\,\text{TeV}$. The incoming parton 4-momenta are $p_1^\mu = x_1 P^\mu$ and $p_2^\mu = x_2 \overline{P}^\mu$ for momentum fractions x_1 and x_2. The outgoing parton 4-momenta are

$$p_1'^\mu = (p_T \cosh y_1, \vec{p}_T, p_T \sinh y_1)\,, \tag{2}$$
$$p_2'^\mu = (p_T \cosh y_2, -\vec{p}_T, p_T \sinh y_2)\,; \tag{3}$$

the outgoing partons have rapidities y_1 and y_2, and transverse momenta $\vec{p}_T$ and $-\vec{p}_T$, respectively.

Now suppose parton 1 (the gluon in Fig. 1) is associated with the observed jet. Given the observed rapidity y_j and transverse momentum p_T, what values of x_1 and x_2 can produce this final state? Momentum conservation implies

$$(x_1 + x_2)E = p_T\,(\cosh y_j + \cosh y_2) \tag{4}$$
$$(x_1 - x_2)E = p_T\,(\sinh y_j + \sinh y_2) \tag{5}$$

i.e., two equations for three unknowns (x_1, x_2 , and y_2). Eliminating y_2 gives a curve in the (x_1, x_2)-plane, which may be expressed in parametric form as

$$x_1 = \frac{p_T}{\sqrt{s}}\left(e^{y_j} + e^{y_2}\right), \tag{6}$$
$$x_2 = \frac{p_T}{\sqrt{s}}\left(e^{-y_j} + e^{-y_2}\right), \tag{7}$$

where y_2 is the independent parameter.

Figure 2 shows the case of central rapidity ($y_j = 0$). The solid curve is the locus of (x_1, x_2) points for $p_T = 420\,\mathrm{GeV}$. This p_T value is the largest p_T measured by CDF in Run I and it will be measured much more accurately in Run II. Note that x_1 and x_2 must be greater than 0.25 to produce the jet. The dashed curve corresponds to a lower jet p_T, of 200 GeV. Figure 2 shows that the inclusive jet cross section measured in Run I is sensitive to PDF's, including the gluon distribution, for $x \gtrsim 0.1$. The measurement at the highest measured E_T constrains the gluon distribution for $x \gtrsim 0.25$.

Figure 3 shows the (x_1, x_2) points for jets produced at forward rapidity $y_j = 2$. Here the solid curve has $p_T = 250\,\mathrm{GeV}$ (the largest E_T measured by D0 for the rapidity bin from 1.5 to 2) and the dashed curve has $p_T = 100\,\mathrm{GeV}$. At least one parton must have large x to produce the jet. So again the rapidity-dependent cross section measured by D0 is sensitive to PDF's at large x.

The center-of-mass energy of the parton-parton collision is $\sqrt{\hat{s}} = \sqrt{x_1 x_2 s} \geq 2p_T$. The uncertainty bands of the parton-parton luminosity functions $\mathcal{L}_{ab}(\hat{s})$ for the Tevatron are shown in Fig. 4. The uncertainties become large for $\sqrt{\hat{s}} \gtrsim 300\,\mathrm{GeV}$. There $\mathcal{L}_{ab}(\hat{s})$ depends on large-x parton densities. Because the PDF's at large x are quite uncertain, especially the gluon, $\mathcal{L}_{ab}(\hat{s})$ has a wide undcertainty band for large $\sqrt{\hat{s}}$.

Future measurements of $d^2\sigma/d\eta\, dp_T$ at Run II will have higher statistics and will extend to higher jet E_T values. These data will put strong constraints on the PDF's at large x, provided the systematic errors are sufficiently small.

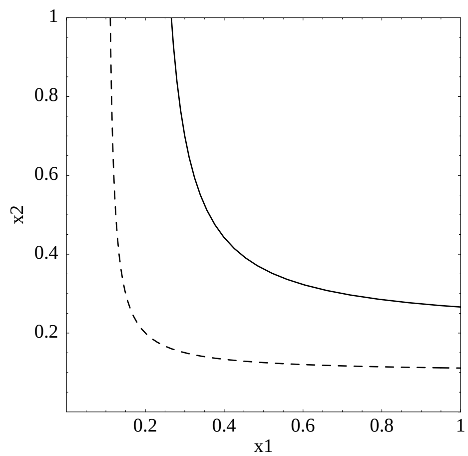

Figure 2: Parton momentum fractions x_1 and x_2 for $y_j = 0$. The solid and dashed curves are for $p_T = 420$ and $200\,\mathrm{GeV}$, respectively.

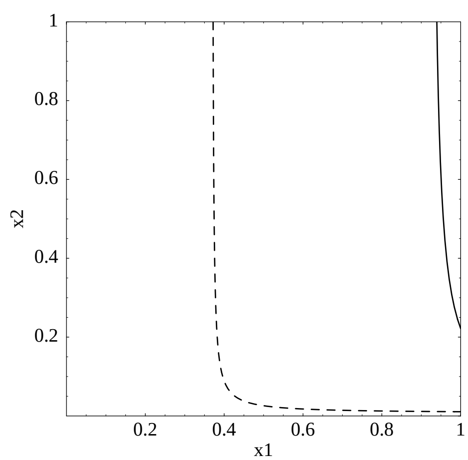

Figure 3: Parton momentum fractions x_1 and x_2 for $y_j = 2$. The solid and dashed curves are for $p_T = 250$ and $100\,\mathrm{GeV}$, respectively.