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Large- Q_T W -boson production at the Tevatron¹

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Abstract

The production of W bosons at large transverse momentum at the Tevatron is dominated by soft-gluon corrections. In this talk we present a calculation of these corrections at next-to-next-to-leading order. The corrections enhance the transverse momentum distribution of the W while reducing the scale dependence.

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1 Introduction

W hadroproduction is useful in estimates of backgrounds to new physics (such as Higgs production). The transverse momentum, Q_T , distribution of the W falls rapidly by several orders of magnitude as Q_T increases.

Full next-to-leading order (NLO) results for W hadroproduction at large Q_T have been available for some time [1, 2]. At lowest order the partonic channels involved are $q(p_a) + g(p_b) \rightarrow W(Q) + q(p_c)$ and $q(p_a) + \bar{q}(p_b) \rightarrow W(Q) + g(p_c)$. We define $s = (p_a + p_b)^2$, $t = (p_a - Q)^2$, $u = (p_b - Q)^2$ and $s_2 = s + t + u - Q^2$. At threshold, i.e. when we have just enough energy to produce a W with a certain Q_T , $s_2 \rightarrow 0$.

The large- Q_T distribution is enhanced by soft-gluon corrections, which are dominant near threshold. These corrections are of the form $\mathcal{D}_l(s_2) \equiv [\ln^l(s_2/Q_T^2)/s_2]_+$. For the order α_s^n corrections $l \leq 2n - 1$. At NLO in α_s , we have terms with $\mathcal{D}_1(s_2)$ and $\mathcal{D}_0(s_2)$ logarithms, as well as $\delta(s_2)$ terms that involve the virtual corrections.

At next-to-next-to-leading order (NNLO) in α_s , we have terms with $\mathcal{D}_3(s_2)$, $\mathcal{D}_2(s_2)$, $\mathcal{D}_1(s_2)$, and $\mathcal{D}_0(s_2)$ logarithms, as well as $\delta(s_2)$ terms for the virtual corrections. Thus, at NNLO, the leading logs (LL) are $\mathcal{D}_3(s_2)$, the next-to-leading logs (NLL) are $\mathcal{D}_2(s_2)$, the next-to-next-to-leading logs (NNLL) are $\mathcal{D}_1(s_2)$, and the next-to-next-to-next-to-leading logs (NNNLL) are $\mathcal{D}_0(s_2)$.

We can formally resum these soft logarithms to all orders in α_s [3, 4, 5]. This has been done explicitly for W production in Ref. [6]. However, for numerical results here we expand the resummed formula to NNLO to avoid using prescriptions for the resummed cross section [7].

A unified approach and a master formula for calculating these soft logarithms at NNLO for any process has been presented in Ref. [8]. It has been applied to W production in Ref. [9].

2 W production with large Q_T at the Tevatron

We now present our numerical results for large- Q_T W -boson production [9] at the Fermilab Tevatron.

The Q_T distribution is shown in Fig. 1 at Tevatron Run I, with $\sqrt{S} = 1.8$ TeV. In the left frame we show the differential distribution $d\sigma/dQ_T^2$ at Born (lowest order), NLO, and NNLO, all with scale $\mu = Q_T$, while in the right frame we show a plot of the scale dependence at $Q_T = 80$ GeV. For the NNLO corrections we show both NNLL and NNNLL results. The NNLL results are complete while in the NNNLL results we have included the dominant NNNLL terms (more two-loop calculations are needed for an exact NNNLL calculation [10]). Throughout we have used the MRST2002 NNLO parton densities [11]. We see that the NNLO corrections are not very large but they significantly diminish the factorization/renormalization scale dependence of the cross section.

In Fig. 2 we show similar results for Tevatron Run II, with $\sqrt{S} = 1.96$ TeV. In the left frame we plot $d\sigma/dQ_T^2$ with $\mu = Q_T$, while in the right frame we show results at $\mu = Q_T/2$ and $2Q_T$. Again, the reduction of the scale dependence at NNLO is evident: the two NNLO curves are on top of each other. Finally, we note that similar results have been derived for the related

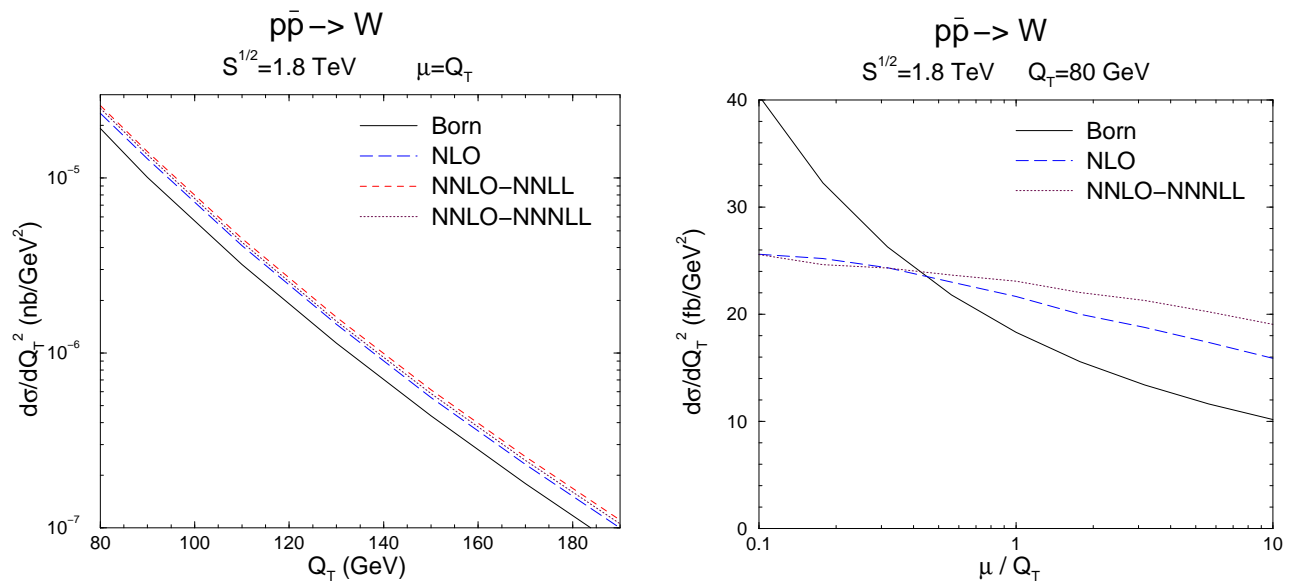


Figure 1: W -boson production at large Q_T at $\sqrt{S} = 1.8$ TeV.

process of direct photon production [12].

Acknowledgments

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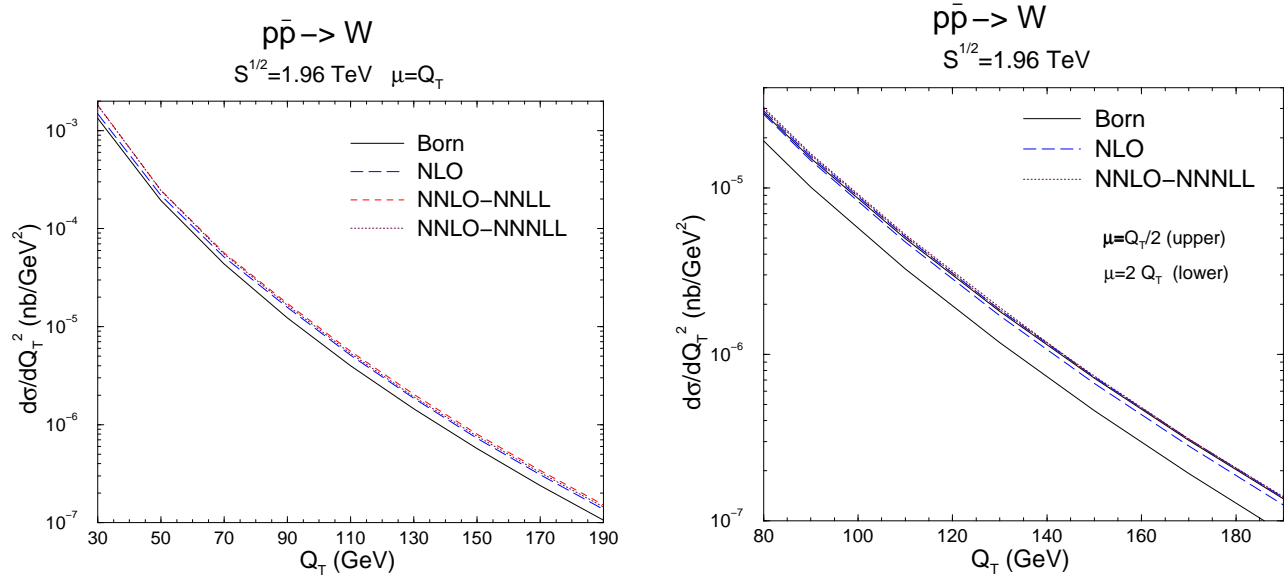


Figure 2: W -boson production at large Q_T at $\sqrt{S} = 1.96$ TeV.

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