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LARGE-Q_T W-BOSON PRODUCTION AT THE TEVATRON

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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.

Keywords: W boson; NNLO; threshold logarithms.

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 $q(p_a) + g(p_b) \longrightarrow W(Q) + q(p_c)$ and $q(p_a) + \bar{q}(p_b) \longrightarrow W(Q) + g(p_c)$. 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, $s_2 \to 0$.

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

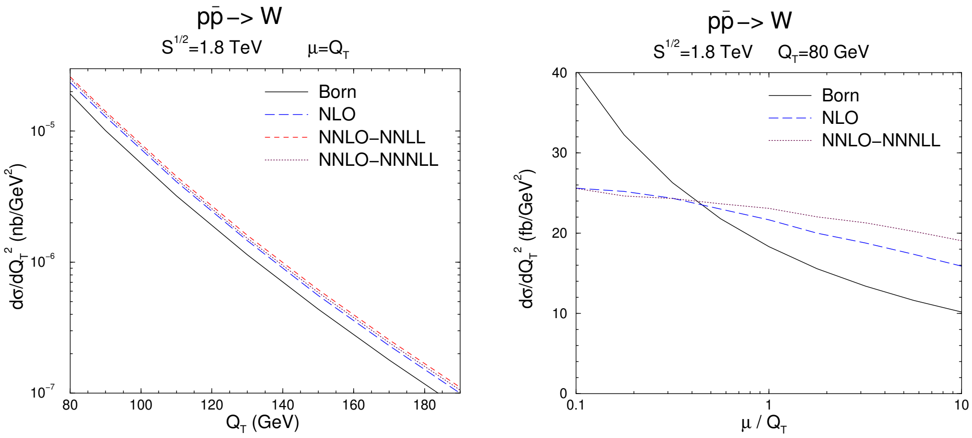

Fig. 1. W-boson production at large Q_T at $\sqrt{S} = 1.8$ TeV.

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 in the related process of direct photon production.[12]

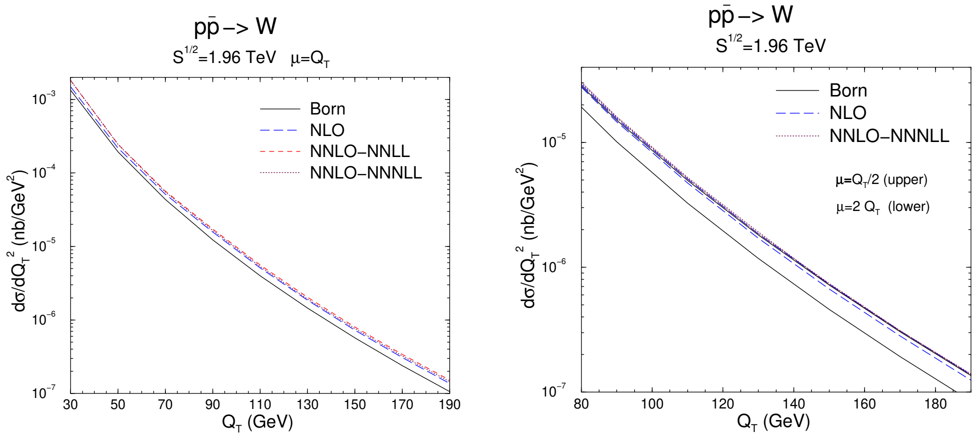

Fig. 2. W-boson production at large Q_T at $\sqrt{S} = 1.96$ TeV.

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References

1. P.B. Arnold and M.H. Reno, *Nucl. Phys.* **B319**, 37 (1989); (E) **B330**, 284 (1990).
2. R.J. Gonsalves, J. Pawlowski, and C.-F. Wai, *Phys. Rev.* **D40**, 2245 (1989); *Phys. Lett.* **B252**, 663 (1990).
3. N. Kidonakis and G. Sterman, *Phys. Lett.* **B387**, 867 (1996); *Nucl. Phys.* **B505**, 321 (1997); N. Kidonakis, G. Oderda, and G. Sterman, *Nucl. Phys.* **B531**, 365 (1998).
4. E. Laenen, G. Oderda, and G. Sterman, *Phys. Lett.* **B438**, 173 (1998).
5. N. Kidonakis, *Int. J. Mod. Phys.* **A15**, 1245 (2000); *Mod. Phys. Lett.* **A19**, 405 (2004).
6. N. Kidonakis and V. Del Duca, *Phys. Lett.* **B480**, 87 (2000), N. Kidonakis, in EPS-HEP99, hep-ph/9910240.
7. N. Kidonakis, *Phys. Rev.* **D64**, 014009 (2001); N. Kidonakis and R. Vogt, *Phys. Rev.* **D68**, 114014 (2003).
8. N. Kidonakis, *Int. J. Mod. Phys.* **A19**, 1793 (2004).
9. N. Kidonakis and A. Sabio Vera, *JHEP* **02**, 027 (2004); in DIS2004, hep-ph/0405013.
10. N. Kidonakis, hep-ph/0208056; in DIS2003, hep-ph/0307145.
11. A.D. Martin, R.G. Roberts, W.J. Stirling, and R.S. Thorne, *Eur. Phys. J.* **C28**, 455 (2003).
12. N. Kidonakis and J.F. Owens, *Phys. Rev. D* **61**, 094004 (2000); *Int. J. Mod. Phys.* **A19**, 149 (2004).