Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

CHARGED HIGGS PRODUCTION WITH A TOP QUARK AT THE LHC

NIKOLAOS KIDONAKIS
Cavendish Laboratory, University of Cambridge
Madingley Road, Cambridge CB3 0HE, UK
E-mail: kidonaki@hep.phy.cam.ac.uk

I discuss charged Higgs production via the process $bg \to tH^-$ at the LHC. I show that the cross section is dominated by soft-gluon corrections and I provide results for its dependence on the charged Higgs mass and on the scale, including higher-order effects.

1 Introduction

A future discovery of a charged Higgs boson would be a sure sign of new physics beyond the Standard Model. The Minimal Supersymmetric Standard Model (MSSM) includes in its particle content charged Higgs bosons in addition to neutral Higgs. The discovery of the Higgs boson, including the charged Higgs of the MSSM, is a major goal at the Tevatron and the LHC.

The LHC has good potential for discovery of a charged Higgs. A promising channel is $bg \to tH^-$ [1,2,3]. The complete next-to-leading order QCD corrections to this process have been recently derived in Refs. [4,5].

The Born cross section is proportional to $\alpha\alpha_s(m_b^2 \tan^2\beta + m_t^2 \cot^2\beta)$. Here $\tan\beta = v_2/v_1$ is the ratio of the vacuum expectation values of the two Higgs doublets in the MSSM. We use the $\overline{\rm MS}$ running top and bottom quark masses, corresponding to pole masses $m_t = 175$ GeV and $m_b = 4.8$ GeV, in the $\tan^2\beta$ and $\cot^2\beta$ terms, but set $m_b = 0$ elsewhere.

2 Charged Higgs NNLO-NLL cross section

The production cross section for $b(p_b) + g(p_g) \longrightarrow t(p_t) + H^-(p_{H^-})$ at the LHC for large m_{H^-} is actually dominated by soft-gluon corrections from the near-threshold region [3,6]. We define the standard kinematical invariants $s = (p_b + p_g)^2$, $t = (p_b - p_t)^2$, $u = (p_g - p_t)^2$, and $s_4 = s + t + u - m_t^2 - m_{H^-}{}^2$. At threshold $s_4 \to 0$. The threshold soft-gluon corrections then take the form $[\ln^l(s_4/m_{H^-}^2)/s_4]_+$, with $l \leq 2n - 1$ for the order α_s^n corrections. They are calculated following the methods in Refs. [7,8], which have been applied to various processes [9,10]. The leading logarithms (LL) are with $l = 2n - 1$ while the next-to-leading logarithms (NLL) are with $l = 2n - 2$. Here we calculate NLO and NNLO soft-gluon corrections corrections at NLL accuracy. We denote them as NLO-NLL and NNLO-NLL, respectively. Thus, at NLO we include $[\ln(s_4/m_{H^-}^2)/s_4]_+$ (LL) and $[1/s_4]_+$ (NLL) terms. Although we do not include the full virtual $\delta(s_4)$ terms, we include those $\delta(s_4)$ terms that involve the factorization and renormalization scales, denoted by

μ. At NNLO, we include $[\ln^3(s_4/m^2_{H^-})/s_4]_+$ (LL) and $[\ln^2(s_4/m^2_{H^-})/s_4]_+$ (NLL) terms. We also include some $[\ln(s_4/m^2_{H^-})/s_4]_+$ and $[1/s_4]_+$ terms that involve the scale μ and some ζ_2 and ζ_3 constants. Explicit analytical expressions are given in [3].

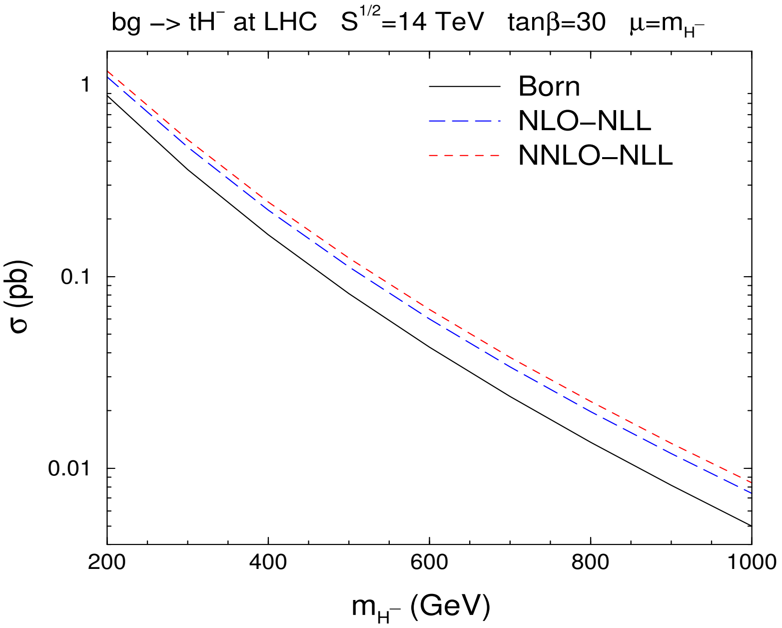

Figure 1. Charged Higgs production cross section versus charged Higgs mass.

In Fig. 1 we plot the cross section for charged Higgs production via $bg \to tH^-$ at the LHC as a function of the charged Higgs mass for $\tan\beta = 30$ and $\mu = m_{H^-}$. The approximate NNLO parton distributions of Ref. [11] have been used. We note that in the corresponding figures in Refs. [3,6] the pole mass of the bottom quark was used; the $\overline{\text{MS}}$ mass, however, is a preferable choice [5]. The Born, NLO-NLL, and NNLO-NLL cross sections are shown. The cross sections span over two orders of magnitude in the mass range 200 GeV $\le m_{H^-} \le$ 1000 GeV.

In Fig. 2 we plot the K-factors, i.e. the ratios of the NLO-NLL and NNLO-NLL cross sections to the Born cross section, and the ratio of the NNLO-NLL to the NLO-NLL cross section. We use the same NNLO parton densities and couplings at all orders, so as to concentrate on the effect of the soft-gluon corrections. It should be stressed that the NLO-NLL/Born ratio is quite close to the exact NLO/Born ratio [4,5] (note that different conventions and scales are used there) which indicates that threshold corrections indeed dominate the cross section. The difference between the exact NLO and NLO-NLL results is only a few percent. The NNLO-NLL corrections provide a significant enhancement to the NLO cross section.

In Fig. 3 we plot the cross section with two different choices of scale, $\mu = m_{H^-}/2$

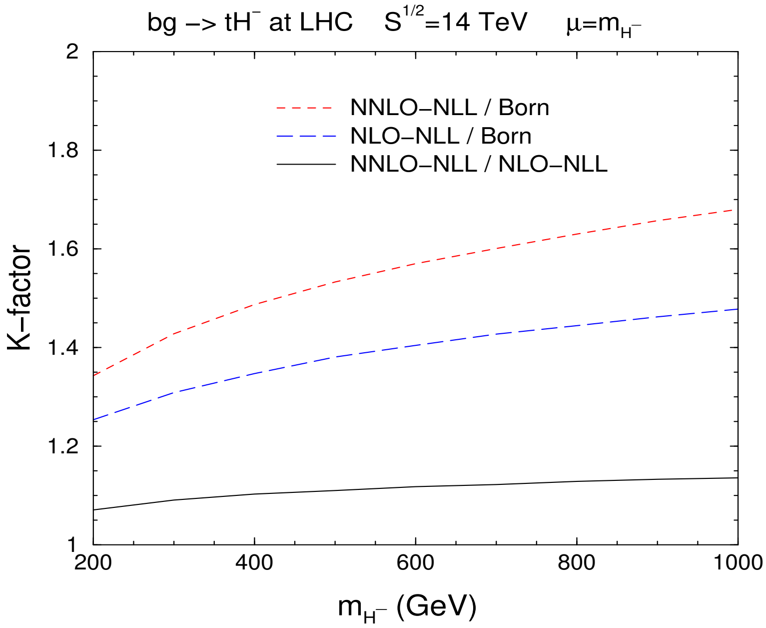

Figure 2. K-factors versus charged Higgs mass.

and $2m_{H^-}$. For clarity we concentrate on $m_{H^-} \geq 350$ GeV. We see that the variation with scale of the Born cross section is large. The variation at NLO-NLL is smaller, and at NNLO-NLL it is very small. In fact the two NNLO-NLL curves are on top of each other for most of the range in m_{H^-}. Hence, the scale dependence of the cross section is drastically reduced when higher-order corrections are included.

Finally, we note that the cross section for $\bar{b}g \to \bar{t}H^+$ is the same as for $bg \to tH^-$.

Acknowledgements

The author's research has been supported by a Marie Curie Fellowship of the European Community programme "Improving Human Research Potential" under contract no. HPMF-CT-2001-01221.

References

1. A.C. Bawa, C.S. Kim, and A.D. Martin, Z. Phys. **C 47**, 75 (1990); J.F. Gunion, Phys. Lett. **B 322**, 125 (1994); V.D. Barger, R.J.N. Phillips, and D.P. Roy, Phys. Lett. **B 324**, 236 (1994); C.S. Huang and S.H. Zhu, Phys. Rev. **D 60**, 075012 (1999); K. Odagiri, Phys. Lett. **B 452**, 327 (1999); F. Borzumati, J.L. Kneur, and N. Polonsky, Phys. Rev. **D 60**, 115011 (1999); S. Moretti and D.P. Roy, Phys. Lett. **B 470**, 209 (1999).
2. L.G. Jin, C.S. Li, R.J. Oakes, and S.H. Zhu, Eur. Phys. J. **C 14**, 91 (2000);

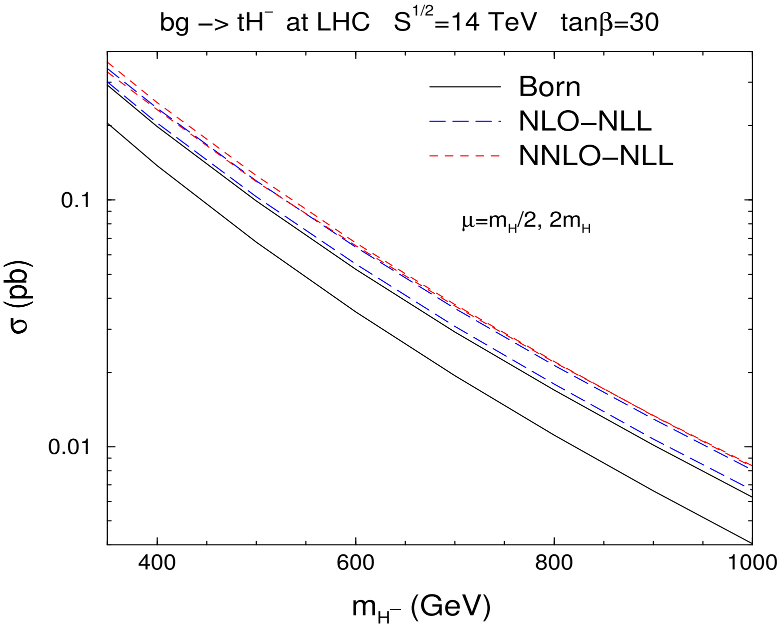

Figure 3. The scale dependence of charged Higgs production cross sections.

Phys. Rev. **D 62**, 053008 (2000); A. Belyaev, D. Garcia, J. Guasch, and J. Sola, Phys. Rev. **D 65**, 031701 (2002); JHEP **06**, 059 (2002); G.P. Gao, G.R. Lu, Z.H. Xiong, and J.M. Yang, Phys. Rev. **D 66**, 015007 (2002).
3. The Higgs Working Group: Summary Report, in *Les Houches 2003*, hep-ph/0406152.
4. S.H. Zhu, Phys. Rev. **D 67**, 075006 (2003).
5. T. Plehn, Phys. Rev. **D 67**, 014018 (2003).
6. N. Kidonakis, Mod. Phys. Lett. **A 19**, 405 (2004).
7. N. Kidonakis and G. Sterman, Phys. Lett. **B 387**, 867 (1996); Nucl. Phys. **B 505**, 321 (1997); N. Kidonakis, G. Oderda, and G. Sterman, Nucl. Phys. **B 531**, 365 (1998); N. Kidonakis, Int. J. Mod. Phys. **A 15**, 1245 (2000); N. Kidonakis, Phys. Rev. **D 64**, 014009 (2001).
8. N. Kidonakis, Int. J. Mod. Phys. **A 19**, 1793 (2004).
9. N. Kidonakis and J.F. Owens, Phys. Rev. **D 61**, 094004 (2000); N. Kidonakis, E. Laenen, S. Moch, and R. Vogt, Phys. Rev. **D 64**, 114001 (2001); N. Kidonakis and R. Vogt, Phys. Rev. **D 68**, 114014 (2003), and in these proceedings, hep-ph/0405212; N. Kidonakis and A. Sabio Vera, JHEP **02**, 027 (2004), and in these proceedings, hep-ph/0405013.
10. The QCD/SM Working Group: Summary Report, in *Les Houches 2003*, hep-ph/0403100.
11. A.D. Martin, R.G. Roberts, W.J. Stirling, and R.S. Thorne, Eur. Phys. J. **C 28**, 455 (2003).