International Journal of Modern Physics A

Higgs Boson Production with Bottom Quarks at Hadron Colliders

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We present results for the production cross section of a Higgs boson with a pair of $b\bar{b}$ quarks, including next-to-leading order (NLO) QCD corrections.

Keywords: Higgs; MSSM.

1. Introduction

One of the most pressing issues at current and future hadron collider experiments is the discovery of one (or more) Higgs bosons. The Standard Model (SM) predicts a single Higgs boson whose couplings to fermions are proportional to the mass of the fermion, hence the production of the Higgs boson with light quarks (e.g. bottom quarks) is suppressed compared to other production channels involving top quarks or heavy gauge bosons. However, in some extensions of the SM (such as the Minimal Supersymmetric Standard Model, or MSSM), the Yukawa couplings for b quarks can become strongly enhanced. In this scenario, the production of a Higgs boson with $b\bar{b}$ can dominate over other production channels and could provide a unique opportunity to directly probe the b quark Yukawa coupling.

The theoretical prediction of $b\bar{b}h$ production at hadron colliders involves several subtle issues and depends on the number of b quarks identified, or *tagged*, in the final state. Potentially large logarithms arise from the integration over the phase space of the final state b quarks. These large logarithms appear at all orders in perturbation theory and could spoil the convergence of the perturbative expansion of

*Talk given by C.B. Jackson

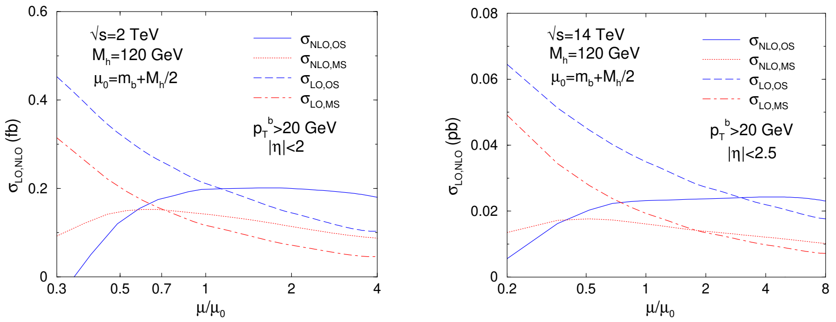

Fig. 1. σ_{NLO} and σ_{LO} for $p\bar{p}, pp \to b\bar{b}h$ with two high-p_T b jets at $\sqrt{s} = 2$ TeV (left) and $\sqrt{s} = 14$ TeV (right) as a function of the renormalization/factorization scale μ, for $M_h = 120$ GeV.

total and differential cross sections. Currently, there are two approaches to calculating the theoretical prediction of $b\bar{b}h$ production. Working under certain kinematic approximations, and adopting the so-called *five-flavor-number scheme* (5FNS), the logarithms can be resummed by using a bottom quark Parton Distribution Function [1, 2]. Alternatively, working with no kinematic approximations, and adopting the so-called *four-flavor-number scheme* (4FNS), one can compute the cross section for $p\bar{p}, pp \to b\bar{b}h$ at fixed order in QCD without resumming higher order collinear logaritms [3, 4].

In this talk, we present the results of the total cross section calculation for $p\bar{p}, pp \to b\bar{b}h$ at next-to-leading order (NLO) in QCD for two different scenarios: two high-p_T b jets and one high-p_T b jet corresponding to two or one b jet(s) identified in the final state. Results for the case of no high-p_T b jets have been reviewed in a previous study [4]. For the case of one high-p_T b jet in the final state, we compare our fixed-order result (4FNS) with the prediction obtained by using $gb \to bh$ (5FNS), when NLO QCD corrections have been included in both cases [5].

2. Results for $b\bar{b}h$ Production

In order to select the events with high-p_T b jets, we place kinematic cuts on the transverse momentum, $p_T^{b,\bar{b}} > 20$ GeV, and pseudorapidity, $|\eta_{b,\bar{b}}| < 2$ (2.5) at the Tevatron (LHC), of the final state b quarks. Results from the case of two high-p_T b jets are shown in Fig. 1 [6]. The two sets of curves correspond to different renormalization schemes for the bottom quark mass in the bottom quark Yukawa coupling. In both cases, the dependence on the renormalization and factorization schemes is greatly reduced by the inclusion of NLO QCD corrections. It is interesting to note that the $\overline{MS}$ scheme exhibits better behavior at small scales and also seems to improve the convergence of the perturbative series. The calculation of the NLO cross section for $b\bar{b}h$ for the case of (at least) one high-p_T b jet has been performed in both the 4FNS [3, 4] and the 5FNS [7](where the leading order process becomes $gb(\bar{b}) \to b(\bar{b})h$). In a previous study [4], the two cross section calculations were found

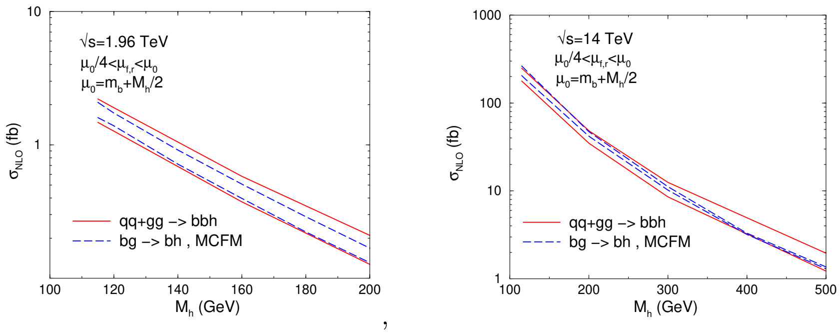

Fig. 2. Total NLO cross section for $p\bar{p}, pp \to b\bar{b}h$ with at least one high-p_T b jet at the Tevatron(left) and LHC(right). The uncertainty bands are obtained by varying the renormalization and factorization scales independently around the central value ($\mu_r = \mu_f = \mu_0/2$). The solid(dashed) curves correspond to the 4FNS(5FNS) calculations.

to be in agreement (within error), but the 5FNS calculation seemed to predict a slightly larger value for most of the Higgs mass range. In a subsequent paper [5], we have investigated the inclusion of diagrams containing top quark loops, that were previously neglected in the 5FNS, by implementing them into MCFM[8]. The contribution from the top loop diagram(s) to the total cross section in the SM calculation can become numerically important. In fact, inclusion of these diagrams was found to reduce the 5FNS cross section by 15%(10%) at the Tevatron(LHC) over most of the Higgs mass range [5]. Results are shown in Fig.2 for the comparison between the 4FNS and 5FNS schemes after the inclusion of the top loop diagram in the latter calculation. Clearly, within the theoretical uncertainties, the SM calculations in the 4FNS and 5FNS are in very good agreement. The agreement is preserved in the MSSM with large $\tan\beta$, since the top loop diagrams become negligible.

Acknowledgments

The work of S.D. (L.R., C.B.J.) and D.W. is supported in part by the U.S. Department of Energy under grant DE-AC02-76CH00016 (DE-FG02-97ER41022) and by the National Science Foundation under grant NSF-PHY-0244875, respectively.

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