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Using b-Tagging to Detect $\mathbf{t\overline{t}}$ Higgs Production with Higgs$\rightarrow$ $\mathbf{b\overline{b}}$

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Abstract

We demonstrate that expected efficiencies and purities for b-tagging at SSC/LHC detectors may allow detection of the Standard Model Higgs in $t\bar{t}H$ production, with $H \rightarrow b\bar{b}$ decay, for $80 \lesssim m_H \lesssim 130$ GeV, provided $m_t \gtrsim 130$ GeV.

1. Introduction

Understanding the Higgs sector is one of the fundamental missions of future high energy colliders such as the SSC and LHC. However, options for detection of the Standard Model (SM) Higgs boson, H, are limited if m_H lies in the low end of the intermediate mass range, $80 \lesssim m_H \lesssim 130$ GeV, *i.e.* below the region for which the gold-plated $H \rightarrow Z^*Z \rightarrow 4\ell$ is robustly viable[1] but above the guaranteed mass reach of LEP-II. The most discussed detection modes in this region rely entirely on the rare $\gamma\gamma$ decay channel of the H using either the inclusive $H \rightarrow \gamma\gamma$ mode[1] or the $l\gamma\gamma X$ final state arising from WH[2,3,4] and $t\bar{t}H$[5,6] associated production followed by $H \rightarrow \gamma\gamma$ decay. Clearly, the establishment of viable techniques for detection of the H in its main decay mode in this mass region, $H \rightarrow b\bar{b}$, would be highly desirable. In this letter, we demonstrate that if the top quark is not too light, then expected b-tagging efficiencies and purities at the SSC/LHC may enable one to obtain viable H signals in the $b\bar{b}$ decay mode when the H is produced in association with $t\bar{t}$.

A priori, many possible procedures can be envisioned for detection of $t\bar{t}H$ events. Of these, we have examined the four which appear to be most worthy of investigation. In (1) we require that both t's decay to $\ell\nu b$ and search for the H as a peak in the $2j$ mass spectrum of $\ell\ell 4j$ final states without b-tagging. In (2)-(4) we require that three or four b's be tagged and look for a peak in the $2b$ mass spectrum. If only two b's are tagged, there is little gain against the enormous background from $t\bar{t}$ related processes which automatically yield two b's in the final state. By requiring that three or more b's be tagged, such backgrounds can be reduced to the same level as the irreducible background from $t\bar{t}b\bar{b}$ production. In procedure (2) we require that both t's decay to $\ell\nu b$ and tag three b-jets. In procedures (3) and (4), we only require that one (or both) of the t's decay to $\ell\nu b$, and tag three or four b-jets, respectively.

In comparing (3) and (4) we shall see that tagging four (or more) b's may prove preferable. The event rate is reduced, but the signals are cleaner and statistically not that much worse.

Regarding procedure (1), in which no b's are tagged, it is absolutely necessary to specifically demand four energetic jets in the final state in order to eliminate $t\bar{t}$ and $t\bar{t}g$ backgrounds. The major backgrounds are then $t\bar{t}gg$ and $t\bar{t}q\overline{q}$ ($q = u, d, s, c, b$). An exact computation of $t\bar{t}gg$ is not currently available. In our study, we computed with exact matrix elements the $t\bar{t}H$ signal, and the $t\bar{t}Z$ and $t\bar{t}q\overline{q}$ backgrounds. The resulting signal was of only marginal significance, even though no $t\bar{t}gg$ background was included.

This same mode has also been studied in the related work of Ref. 7. There, an approximate computation of the $t\bar{t}H$ signal, and the $t\bar{t}Z$ and $t\bar{t}gg$ backgrounds is performed with semi-optimistic results. The $t\bar{t}q\overline{q}$ backgrounds were not computed. In order to compare to the work of Ref. 7, we repeated our calculations with exactly their cuts. For $m_t = 140$ GeV, in the 10 GeV bin around $m_H = 100$ GeV we found a smaller signal rate of $S = 221$ events per SSC year, and background rate (excluding $t\bar{t}gg$ events) of $B = 2400$ events per SSC year, implying $S/\sqrt{B} \sim 4$. (QCD "K" corrections factors of $K = 1.6$ are included in these rates, but were not included in Ref. 7.) The $t\bar{t}gg$ background is likely to at least double B, yielding a very marginal significance for the H. Thus, our conclusions for the $2\ell 4j$ mode are considerably more pessimistic than those of Ref. 7.

The only means for suppressing the large $t\bar{t}$ backgrounds is to employ b tagging. Indeed, only the irreducible backgrounds from $t\bar{t}Z$ (with $Z \to b\bar{b}$) and $t\bar{t}b\bar{b}$ processes would remain for sufficiently high efficiency and purity of b-tagging. In choosing canonical values for the latter to employ in procedures (2)-(4) we have been guided by the results obtained by the SDC collaboration.[8] These first studies achieved an efficiency for b-jet tagging via vertexing alone that increases from about 25% at $p_T = 30$ GeV to above 30% for $p_T > 40$ GeV for b-jets with $|\eta| < 2 - 2.5$ (for $|\eta| \sim 2.5$ edge effects begin to reduce the efficiency). Tagging a b-jet by a 'high'-p_T lepton decay or neural network was not included. Under these same conditions, the probability of misidentifying a light quark or gluon jet (that does not explicitly decay to $b\bar{b}$) as a b-jet was found to be of order 1%, while that of mis-tagging a c jet is about 5%.

We have adopted the following as our 'standard' procedure at the parton level. To trigger on the events of interest, we require that at least one of the t quarks decay to an isolated lepton (e or μ). At the parton level, the trigger lepton is required to have $p_T \geq 20$ GeV and $|\eta| < 2.5$ and to be isolated by $\Delta R \geq 0.3$ from all other jets or leptons. The W from the other t quark is allowed to decay either leptonically or hadronically. If both W's decay leptonically, then we allow for either of the leptons to provide the required isolated lepton trigger. Next, any b-jet with $|\eta| < 2$ and $p_T > 30$ GeV is assumed to have a probability of 30% (independent of p_T) to be vertex tagged, provided there is no other vertex within $\Delta R_V = 0.5$. The probability to tag (*i.e.* misidentify) a light quark or gluon jet as a b-jet under these same conditions is assumed to be 1%. Jets with p_T below 30 GeV are assumed not to be tagged. Finally, in order for a b-jet to be included in our invariant mass distributions we require that it be separated from all other jets (including other b's) by at least $\Delta R_C = 0.7$.

Our choices for ΔR_V and ΔR_C are important and will be discussed more in a longer paper. In fact, it may be that our choice of ΔR_V is too conservative and that b-jets could be resolved for substantially smaller ΔR_V separations.[9] The most appropriate choice for ΔR_C is a particularly complex issue that will require complete detector simulations to fully resolve. If the energy of a tagged b-jet from the Higgs decay cannot be accurately determined by calorimetry due to an overlapping jet, then the mass of the $b\overline{b}$ pair will not be determined with good accuracy. Thus, we should not insert into our $m(b\overline{b})$ distribution those tagged b's (or $\overline{b}$'s) that are not sufficiently separated from other jets (including other b's). This is experimentally possible since the vertex of the b-jet will be visible and a neighboring jet will be apparent via its energetic charged tracks that do not track to the tagged b-jet vertex. The normal standard of separation to avoid calorimetric overlap is $\Delta R_C = 0.7$.[8] In this letter we consider only this value, although a variety of considerations suggest that $\Delta R_C = 0.5$ may also be viable.

Of course, it is important to explore sensitivity to our assumptions regarding b-tagging efficiency and purity. For instance, we shall demonstrate how much easier H detection becomes if the b-tagging probability can be brought up to 40% while decreasing the misidentification probability to 0.5% over the stated kinematic range. More detailed analysis techniques and technical improvements in vertex tagger designs could significantly increase the efficiency with which b-jets are tagged. Meanwhile, the misidentification probability can probably also be reduced by a closer examination of the tagged jets; no analysis of the jets associated with a tagged vertex was performed in obtaining the 1% probability quoted in Ref. 8. For example, neural-net analyses of vertex tagged jets could remove some of the mis-tagged light quark and gluon jets.

The final critical ingredient in our analysis is the mass resolution that can be achieved for the combined mass of two b-jets. For a purely hadronic jet the SDC TDR[8] quotes energy resolutions (depending upon design and integration time) that are typically no worse than $\delta E/E = 0.5/\sqrt{E(GeV)} \oplus 0.03$ (leading to roughly an 8% jet-pair invariant mass resolution for 30 GeV jets). For leptons the energy resolution is typically of order $\delta E/E = 0.2/\sqrt{E(GeV)} \oplus 0.01$. The first step of our parton-level analysis is to explicitly smear the energies of all leptons and jets using these resolutions. In particular, our $m(b\overline{b})$ distributions will automatically reflect the jet energy resolution. Since b-jets have hard fragmentation functions the above hadronic resolution may be somewhat pessimistic for purely hadronic b decays. However, semi-leptonic b decays will have worse resolution. For the results to be presented here, we have used standard hadronic resolutions as a compromise.

Two distinct more detailed approaches to the semi-leptonic b decays are possible. First, it might be experimentally possible to greatly limit the presence of such decays by requiring that a b-vertex not have an associated lepton with energy larger than some appropriate lower bound, especially one with significant p_T with respect to the primary b-jet direction (as determined by the vertex location and the primary collision point). Our results would then be unaltered if the b-tagging efficiency we employ is reinterpreted as including the probability for a purely hadronic primary b decay. Alternatively, semi-leptonic decays can be explicitly included in the analysis. We have done this, retaining the above hadronic and leptonic energy resolutions for the c and ℓ in $b \to c\ell\nu$ (taking $BR(b \to c\ell\nu) = 0.1$, $\ell = e, \mu, \tau$) and using only the combined c and ℓ momenta in constructing the $b\overline{b}$ mass for decays of this type. For all m_H, the height of the signal peak is reduced and the 'background' from the signal reaction itself, that would be estimated using nearby bins outside $m_H \pm 10$ GeV, increases somewhat. Keeping all other efficiencies constant, one finds roughly a doubling in the times (quoted later) required to see a signal of a given statistical significance. However, if $b \to c\ell\nu$ decays are retained, a significant improvement in the b-tagging efficiency will probably be possible by explicitly looking for the associated lepton. Expectations[9] are that at least 5% would be added to the 30-40% tagging efficiency. In the case of 4 b-tagging, this would restore much of the statistical significance obtained prior to including $b \to c\ell\nu$ decays. This type of analysis will be pursued at greater length elsewhere.[10]

Of course, we have employed the SM predictions for the $H \to b\overline{b}$ branching ratio. At $m_H = 80$, 100, 120, 140 GeV we find $BR(H \to b\overline{b}) = 0.857$,0.842, 0.748, and 0.437, respectively. These results include QCD corrections to the $q\overline{q}$ decay modes. Not surprisingly, we will find that by $m_H = 140$ GeV the branching ratio has fallen sufficiently that H detection in the $b\overline{b}$ mode becomes fairly difficult.

2. Procedure

We have employed exact matrix element calculations for the signal reaction $t\overline{t}H$[11] (with $H \to b\overline{b}$), the irreducible backgrounds $t\overline{t}b\overline{b}$ and $t\overline{t}Z$ (with $Z \to b\overline{b}$), and the reducible backgrounds $t\overline{t}c\overline{c}$ (with one or two c's mis-tagged as a b) and $t\overline{t}(g)$ (with one or two of the non-b jets mis-tagged as a b). In the case of the $t\overline{t}b\overline{b}$ matrix element, agreement with the results of Ref. 12, for the cuts and procedures specified in the latter reference, is only within a factor of two to four. We have checked our matrix element very carefully, and in particular find exact agreement (for any given configuration of the momenta) in the massless limit with the result obtained in Ref. 13. For all reactions we have included correlations in the three-body decays of the top quarks. This turns out to be important for the $t\overline{t}(g)$ background in which one or more of the mis-tagged jets comes from the decay of a W. Uncorrelated decays would lead to a roughly 25% overestimate of this background.

All the production reactions we consider are dominated by gg collisions. We have employed distribution functions for the gluons evaluated at a momentum transfer scale given by the subprocess energy. It is well-known that QCD corrections are substantial for gg initiated processes. For example, for the $gg \to t\overline{t}$ process the QCD correction 'K' factor has been found to be of the order of 1.6 for our choice of scale.[14] Computations of the 'K' factors for the other reactions we consider are not yet available in the literature. We will assume that they are of the same magnitude. Our precise procedures follow. Rates for the $t\overline{t}H$, $t\overline{t}Z$, $t\overline{t}b\overline{b}$ and $t\overline{t}c\overline{c}$ processes have been multiplied by a QCD correction factor of 1.6. In the case of $t\overline{t}(g)$ we have incorporated the 'K' factor as follows. We have generated events without an extra gluon ($t\overline{t}$ events) and have also generated events with an extra gluon ($t\overline{t}g$ events) requiring that the p_T of the extra gluon be > 30 GeV. For this cutoff one finds $\sigma(t\overline{t}g) \sim 0.6\sigma(t\overline{t})$. Thus, if the two event rates are added together without cuts an effective 'K' factor of 1.6 is generated. Explicitly allowing for an appropriate number of $t\overline{t}g$ events is important in properly estimating the background from this source due to mis-tagged non-b jets. Our procedure should yield an upper limit on the number of events with an extra gluon having $p_T > 30$ GeV and therefore potentially vertex-taggable. The gluon distribution functions we have employed are those of HMRS.[15] We have also repeated the $m_t = 140$ GeV calculations for the EHLQ[16] and updated MRS[17] distribution functions. Differences are typically at the 10-15% level, except for the MRS D$-'$ choice. Relative to MRS D0$'$, for example, the gluon distribution is smaller in the $x \gtrsim 0.006$ region that dominates our calculations, and we find roughly a 20-25% suppression in all event rates compared to the $m_t = 140$ GeV results we quote below.

In analyzing a given event, we make no attempt to identify whether or not a tagged b-jet is associated with a t quark decay or (when m_H is not near m_W) if a mis-tagged light quark jet can be combined with another jet to yield an invariant mass near m_W. (Further improvements in the signal significances that we obtain could be made if an efficient manner for doing either can be found.) As a result, in our analysis we must consider all pairs of tagged b-jets (or mis-tagged non-b-jets) as potentially coming from the H decay. Consequently, even the signal process has a combinatoric background arising from pairs in which one or both of the b's come from t decays. The event rate for the H signal is obtained by subtracting this combinatoric background from the H peak in the $m(b\overline{b})$ mass distribution. The background rate we employ includes this signal combinatoric background as well as the full backgrounds (including all combinatorics) for the true irreducible and reducible backgrounds. The number of $b\overline{b}$ pairs that are included in the combinatoric backgrounds is determined on an event by event basis according to the appropriate probabilities for tagging or mis-tagging b or non-b jets, respectively.

We shall present detailed results for two b-tagging scenarios specified by giving: i) the efficiency for tagging a b-jet, e_{b-tag}; and ii) the probability of mis-tagging a light quark or gluon jet, $e_{mis-tag}$. In case a), b) we take $(e_{b_tag}, e_{mis-tag}) = (30\%, 1\%)$, $(40\%, 0.5\%)$, respectively. In both cases we have taken the probability of mis-tagging a c-jet as being 5%. In fact, for mis-tagging probabilities of this general level the $t\overline{t}c\overline{c}$ background is not significant. (This is because the $t\overline{t}c\overline{c}$ and $t\overline{t}b\overline{b}$ cross sections are not very different once high p_T is required for the c's or b's, respectively.) Case a) we regard as a lower bound, and case b) we think is quite achievable. For further comparison, we shall also give SSC results at $m_t = 140$ GeV obtained using the p_T-dependent e_{b-tag} values of Ref. 8 for $p_T > 20$ GeV, for $e_{mis-tag} = 0.5\%$, 1%, and 1.5%.

3. Results and Discussion

In this letter, we present results for procedures (3) and (4) in which only one lepton is required for triggering and either three (or more) or four (or more), respectively, jets must be tagged as b-jets. Procedure (2), in which two leptons are triggered on and three jets are required to be tagged as b's yields smaller statistical significance for the Higgs signals than either procedure (3) or (4). Only for a Higgs mass near m_W could it be of significant utility by virtue of the absence of the peak near m_W that can arise if both of the jets from a hadronic W decay are mis-identified as b-jets.

In order to give a rough idea of the levels of the Higgs signals and the various backgrounds we first present plots of event rates as a function of $m(b\overline{b})$ in Figs. 1 and 2, for procedures (3) and (4), respectively, at $m_t = 140$ GeV. In each figure, the two b-tagging $(e_{b-tag}, e_{mis-tag})$ cases of (30%,1%) and (40%,0.5%) are compared. All jet energies have been smeared using the resolution quoted earlier. Results presented are for the SSC with integrated luminosity of $L = 10$ fb^{-1}. Since the combinatoric background from the $t\overline{t}H$ reaction itself is m_H dependent, we have adopted the following procedure for displaying all the Higgs mass peaks on one plot. For each m_H case, we have taken only the bins that lie within ±10 GeV of the Higgs peak in the $m(b\overline{b})$ distribution. From the event numbers in each of these central bins we have subtracted an approximate combinatoric background determined by averaging the distribution values for a representative set of bins immediately below and immediately above the central bins. The remainder in each of the central bins is then added to the event

Figure 1: Events per 1 GeV bin in $m(b\overline{b})$ for signal plus background (solid) compared to background alone (dashes). Results for the SSC with $L = 10\ \mathrm{fb}^{-1}$, and b-tagging efficiency and purity given by $(e_{b-tag}, e_{mis-tag}) = (30\%, 1\%)$ (lower histograms) and $(40\%, 0.5\%)$ (upper histograms) are shown for 3 b-tagging. Note that the lower histograms for the former case have been shifted downwards by 100 events per bin in order to clarify the display. The Higgs signals at $m(b\overline{b}) = 80$, 100, 120, and 140 GeV are displayed after removing the combinatoric background from the $t\overline{t}H$ reaction itself. See discussion in the text for details.

number distributions coming from the sum of all other processes. Thus, the upper (solid) histogram corresponds to the sum of event rates given by

$$(N(t\overline{t}H) - N(t\overline{t}H)_{\mathrm{comb.}}) + N(t\overline{t}Z) + N(t\overline{t}) + N(t\overline{t}g) + N(t\overline{t}b\overline{b})\,. \tag{1}$$

To obtain the actual background level in the vicinity of each peak one must add in the signal combinatoric background appropriate to that value of m_H. All other combinatoric effects are included in the backgrounds incorporated in the figures. For the scenarios illustrated, the $t\overline{t}H$ combinatoric background, $N(t\overline{t}H)_{\mathrm{comb.}}$, is roughly 1/4 of the average value of $N(t\overline{t}H) - N(t\overline{t}H)_{\mathrm{comb.}}$ in the bins within ±5 GeV of the Higgs peak. Also histogrammed is the event rate for the $t\overline{t}Z + t\overline{t} + t\overline{t}g + t\overline{t}b\overline{b}$ background. Additional graphs of signal and individual backgrounds as a function of $m(b\overline{b})$ will appear elsewhere.[10]

Several features of Figs. 1 and 2 are worth noting. First, it is evident that the $m(b\overline{b})$ peak from the $t\overline{t}Z$ background is quite small. (This means that the Z peak from $t\overline{t}Z$ will

Figure 2: Events per 5 GeV bin in $m(b\overline{b})$ for signal plus background (solid) compared to background alone (dashes). Results for the SSC with $L = 10\ \mathrm{fb}^{-1}$, and b-tagging efficiency and purity given by $(e_{b-tag}, e_{mis-tag}) = (30\%, 1\%)$ (lower histograms) and $(40\%, 0.5\%)$ (upper histograms) are shown for 4 b-tagging. The Higgs signals at $m(b\overline{b}) = 80$, 100, 120, and 140 GeV are displayed after removing the combinatoric background from the $t\overline{t}H$ reaction itself. See discussion in the text for details.

be quite difficult to detect in the $m(b\overline{b})$ spectrum.) Second, it is clear that the 4 b-tagging graph with $(e_{b-tag}, e_{mis-tag}) = (40\%, 0.5\%)$ has the cleanest signal peaks. This is because the $t\overline{t}(g)$ backgrounds have been all but eliminated, leaving primarily the irreducible $t\overline{t}b\overline{b}$ background. If good efficiency and, especially, purity cannot be achieved, for 4 b-tags the $t\overline{t}(g)$ backgrounds are comparable to the $t\overline{t}b\overline{b}$ background, and for 3 b-tags they are dominant. Similar plots for $m_t = 180$ exhibit quite dramatic Higgs peaks for all but the $m_H = 140$ GeV case.

In order to quantify the observability of the Higgs signals, such as those illustrated in Figs. 1 and 2, we have computed the number of SSC or LHC years required for a 5σ significance of the signal, defined by $S \equiv N(t\overline{t}H) - N(t\overline{t}H)_{\mathrm{comb.}}$, summed over bins within ± 5 GeV of a given Higgs mass peak. The background at each value of m_H is computed as $B \equiv N(t\overline{t}H)_{\mathrm{comb.}} + N(t\overline{t}Z) + N(t\overline{t}) + N(t\overline{t}g) + N(t\overline{t}b\overline{b})$ summed over these same central bins. Results are given in Tables 1 and 2, respectively. In each table results for b-tagging scenarios a) and b) are displayed for both 3 and 4 b-tagging. Also given (in parentheses) is the associated number of signal events (S). The associated number of background events (B) can be obtained from the relation $B = S^2/25$. So that trends can be clearly illustrated, we have not made an arbitrary cutoff in the number of years allowed for our entries. In addition,

Table 1: Number of 10 fb^{-1} years (signal event rate) at the SSC required for a 5σ confidence level signal in four cases: I), II) — 3 b tagging with $(e_{b-tag}, e_{mis-tag}) = (30\%, 1\%)$, $(40\%, 0.5\%)$; and III), IV) — 4 b tagging with $(e_{b-tag}, e_{mis-tag}) = (30\%, 1\%)$, $(40\%, 0.5\%)$.

Case	$m_t \backslash m_H$	80	100	120	140
I	110	2.1(331)	3.5(411)	6.0(458)	29.1(845)
	140	1.4(324)	3.0(512)	4.5(486)	22.4(954)
	180	0.3(96)	0.8(175)	2.9(353)	13.6(747)
II	110	0.5(191)	1.0(249)	1.6(275)	7.6(522)
	140	0.3(170)	0.6(243)	1.1(266)	5.3(508)
	180	0.1(48)	0.2(97)	0.6(171)	3.1(375)
III	110	10.8(135)	15.9(144)	33.0(186)	170.0(386)
	140	3.5(95)	5.0(97)	10.4(122)	55.0(247)
	180	1.0(39)	1.7(45)	4.2(68)	25.5(160)
IV	110	2.4(94)	4.1(116)	8.6(153)	46.0(330)
	140	0.6(54)	1.1(66)	2.6(96)	13.3(189)
	180	0.2(23)	0.4(33)	0.9(46)	5.5(110)

it should be kept in mind that (at least at the SSC) the ultimate luminosity that can be achieved and managed by the detectors might be much larger than currently assumed.

From these two tables it is immediately apparent that for the two larger t masses, especially for $m_t = 180$ GeV, detection of the H using b-tagging should be possible within a few SSC or LHC years for the more optimistic scenarios, so long as $m_H \lesssim 130$ GeV. By $m_H \gtrsim 140$ GeV the $H \to b\bar{b}$ branching ratio has dropped to too small a value due to the onset of the WW^* decay modes. The $m_t = 110$ GeV entries illustrate the fact that H detection using b-tagging will be difficult for lighter top quark masses. The $t\bar{t}(g)$ background is much larger and the signal rates somewhat smaller than for the larger m_t values considered. We estimate that $m_t = 130$ GeV is the boundary below which detection difficulty increases dramatically. On a statistical basis, 3 b-tagging is superior to 4 b-tagging. But this is only true if the background shapes can be reliably Monte Carlo'd. In the absence of a reliable prediction for the background shape, 4 b-tagging could prove the preferable procedure. Of course, the 3 b-tagging and 4 b-tagging procedures are complementary and the data should be analyzed in both ways.

For canonical luminosities the LHC is somewhat superior to the SSC for a given scenario. However, the efficiency of b-tagging at the LHC, given the many overlapping events expected, may not be as great as assumed here. Overlapping events will also reduce the probability that the b's from the Higgs decay in a signal event will be isolated by ΔR_C from other jets.

The rapid worsening of H detectability in the $t\bar{t}b\bar{b}$ channel as we move from optimistic to

Table 2: Number of 100 fb^{-1} years (signal event rate) at the LHC required for a 5σ confidence level signal in four cases: I), II) — 3 b tagging with $(e_{b-tag}, e_{mis-tag})$ = $(30\%, 1\%)$, $(40\%, 0.5\%)$; and III), IV) — 4 b tagging with $(e_{b-tag}, e_{mis-tag})$ = $(30\%, 1\%)$, $(40\%, 0.5\%)$.

Case	$m_t\backslash m_H$	80	100	120	140
I	110	1.5(407)	2.4(488)	6.0(654)	27.2(1146)
	140	0.8(365)	2.0(600)	3.5(621)	21.7(1338)
	180	0.2(102)	0.6(210)	1.8(373)	12.5(963)
II	110	0.4(229)	0.6(283)	1.5(368)	6.6(662)
	140	0.2(179)	0.4(291)	0.8(323)	4.7(690)
	180	0.1(62)	0.1(109)	0.4(195)	2.3(422)
III	110	6.4(145)	9.9(151)	22.4(204)	111.9(395)
	140	2.0(99)	3.3(112)	7.5(139)	44.3(303)
	180	0.7(43)	1.2(49)	2.9(74)	18.8(176)
IV	110	1.3(92)	2.4(116)	5.6(160)	28.7(321)
	140	0.3(51)	0.7(71)	1.8(103)	10.5(227)
	180	0.1(25)	0.3(35)	0.6(48)	3.9(114)

pessimistic $(e_{b-tag}, e_{mis-tag})$ scenarios illustrates the importance of having as good a vertex tagging capability as possible at the SSC and LHC. The minimum value of ΔR_C for which good separation of the calorimetric energy of a b-jet from that of a neighboring jet can be achieved is also critical. For instance, for $m_t = 140$ GeV at the SSC the signal rate at $m_H = 100$ GeV increases by about 40% when ΔR_C is decreased from 0.7 to 0.5. (The $t\bar{t}b\bar{b}$ background increases by a similar amount, but the $t\bar{t}(g)$ background increases by only about 25%.) Clearly, performing refined detector simulation studies for this mode to assess which best represents the true situation is of great importance.

To further define the b-tagging efficiency and purity that will be required for observable signals, we also give results obtained by employing the p_T-dependent e_{b-tag} values of Ref. 8 down to $p_T > 20$ GeV. These e_{b-tag} values are somewhat lower than 30% for $p_T \lesssim 60$ GeV, but reach $\sim 40\%$ for $p_T \gtrsim 120$ GeV. The number of SSC years required for a 5σ signal at $m_t = 140$ GeV for $e_{mis-tag} = (0.5, 1, 1.5)\%$, and for m_H = 80, 100, 120, and 140 GeV, respectively, is: #SSC years = $(0.8, 1.3, 1.9)$, $(1.8, 3.1, 4.5)$, $(3.3, 5.4, 7.5)$, and $(12.1, 20.0, 29.8)$ for $3b$-tagging, and = $(1.8, 3.0, 5.1)$, $(2.8, 4.0, 6.1)$, $(6.5, 8.2, 11.0)$, and $(39.3, 48.3, 63.4)$ for $4b$-tagging. Comparing the $e_{mis-tag} = 1\%$ numbers to those in Table 1 (rows I and III) for the uniform $e_{b-tag} = 0.3$ value, we see little change for $3b$-tagging and some improvement for $4b$-tagging. The larger p_T range and higher e_{b-tag} values at large-p_T at the very least compensate for the smaller e_{b-tag} values at moderate p_T. Comparing results for the three $e_{mis-tag}$ cases shows clearly how critical the achievable b-tagging purity is. An average $e_{mis-tag}$ value significantly above 1% would make observation quite difficult for $m_H \gtrsim 100$ GeV.

As a final remark, we note that although the lowest m_H value studied is 80 GeV, our figures and tables make it clear that the $H \to b\bar{b}$ detection modes studied here are, if anything, more viable at still somewhat lower m_H values. This is in sharp contrast to the $H \to \gamma\gamma$ discovery modes which rapidly deteriorate (due to decreasing $BR(H \to \gamma\gamma)$) for $m_H < 80$ GeV.

4. Conclusion

We have demonstrated that at the SSC and LHC expected vertex tagging capabilities for a typical detector should be sufficient to allow H detection in the $t\bar{t}H \to \ell b\bar{b}b\bar{b}X$ final state for a range of larger m_t values and moderate m_H. The precise region of viability depends critically upon the efficiency and purity of b-tagging, but, allowing for several years of running, should extend at least from $m_H = 80$ (and below) to $m_H \sim 110$ GeV for $m_t \geq 140$ GeV. For $m_t \sim 180$ GeV and good efficiency and purity, m_H values up to ~ 130 GeV can be probed in just one SSC year.

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