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Study of the associated production of Higgs boson with a single top quark

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Abstract

The study of the production of single top quark in association with the Higgs boson at LHC with CMS experiment is presented. Characteristics of the signal and major backgrounds are studied in the multi-leptonic final state, specifically, same-sign dimuon channel. Discrimination between the signal and background processes is done using the multi-variate analysis technique in ROOT framework. Results from preliminary simulation studies at proton-proton collision energy of 13 TeV are discussed briefly.

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Study of the Associated Production of Higgs Boson with a Single Top Quark

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Keywords: Higgs, top, MVA

1 Introduction

According to the Standard Model (SM), the Higgs to fermion coupling (y_f) is proportional to the fermion mass. Top being the heaviest fermion, top to Higgs coupling (y_t), is expected to be the largest and is of $\mathcal{O}(1)$. At the LHC, associated production of Higgs with top quark pair $pp \rightarrow t\bar{t}H$ is used for measuring y_t . However, y_t can also be estimated with the $pp \rightarrow tHq$ process, representative Feynman diagrams are shown in Fig. 1.

Fig. 1. Leading-order diagrams of $pp \rightarrow tHq$ process.

The magnitude tHq production cross section is driven by the interference of two diagrams where the Higgs couples to either a W or a top quark. In SM,

these two amplitudes interfere destructively; as a result, the cross section is very low: ~ 71 fb in pp collisions at 13 TeV center of mass energy. If there are effects beyond SM, due to anomalous coupling of Higgs, it can lead to a large enhancement of the cross section. Hence, in addition to measuring the y_t , this process is also sensitive to the relative signs of coupling of Higgs to W boson (WWH) and top quark (ttH).

2 Event Selection

Criteria for the selection of signal events have been derived from the study of simulated samples. In the multi-leptonic final state of the signal, the major contribution is from Higgs decays through W boson pairs ($H \rightarrow WW$). We consider the case where one of the W decays leptonically and the other hadronically. For the top decay ($t \rightarrow Wb$), leptonic decay of W has been considered ($W \rightarrow l\nu$), leading to two leptons in the final state. We choose the same sign pair of leptons since it has lesser background as compared to the opposite signed pairs. For $\mu^\pm\mu^\pm$ final state, the p_T of the two same sign leading muons satisfying the stringent criteria based on reconstruction and isolation, is required to be above 20 GeV within a pseudorapidity region $|\eta| < 2.4$. Any event having a third electron/muon which also passes the stringent criteria for selection with $p_T > 20$ GeV is rejected. Also, there should not be any hadronically decaying tau in the selected event.

Jets are required to have p_T greater than 25 GeV within $|\eta| < 4.5$. They may be identified as originating from a b quark based on a set of special criteria within $|\eta| < 2.4$. The event is required to contain at least one b tagged jet from the top decay. The light quark in the tHq final state is expected to be in the forward rapidity region. The jet with the highest $|\eta|$ which fails the b tag requirement is tagged as the forward jet. As one W decays hadronically, we require at least three jets in the event.

3 Signal Discrimination

The tHq signal is discriminated from the main backgrounds, $t\bar{t}$ and $t\bar{t}H$ production processes, using a boosted decision tree (BDT) classifier. A set of discriminating variables listed below are given as inputs to the BDT which produces a output distribution indicating the separation power of the discriminator.

1. η gap between the forward jet and the nearest jet or lepton.
2. maximum $|\eta|$ of light quark jets with $|\eta| > 1.0$.
3. ϕ difference between the two leading muons.
4. η gap between the best b tagged jet and the forward jet.
5. p_T of the sub-leading muon.
6. scalar sum of p_T of all jets.
7. number of b jets in the event.

From the BDT, we have obtained moderate separation between signal and background.

4 Conclusions and Outlook

In order to have better separation power between the background process and signal, other kinematic variables are currently being explored taking into account other background processes, such as $t\bar{t}Z$, $t\bar{t}W$ etc. $e^\pm\mu^\pm$ and $e^\pm e^\pm$ final states are also being considered. The dominant background to the tHq process are "fake" leptons, the rate of which are determined from data.

References

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