Probing the Anomalous FCNC Interactions in a Top-Higgs Final State and Charge Ratio Approach[1]

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Introduction

Flavor Changing Neutral Current couplings are strongly suppressed in top sector at tree level in the SM framework by GIM mechanism. While the FCNC processes involving the top quark can appear in models beyond the SM. The anomalous FCNC couplings can be described in a model independent effective Lagrangian [2]:

$$L = \sqrt{2} g_s \sum_{q=u,c} \frac{\kappa_{tqg}}{\Lambda} \bar{t} \sigma^{\mu\nu} T_a (f_q^L P_L + f_q^R P_R) q G^a_{\mu\nu} + h.c.$$

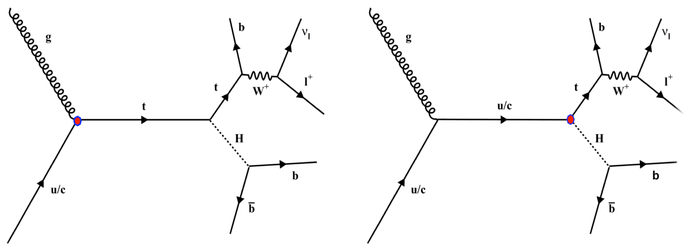
Recently, the ATLAS experiment set 95% C.L. upper limits on the strong FCNC couplings [3]:

$$\frac{\kappa_{tug}}{\Lambda} < 5.1 \times 10^{-3} TeV^{-1}, \frac{\kappa_{tcg}}{\Lambda} < 1.1 \times 10^{-2} TeV^{-1}$$

We perform an analysis on a Top-Higgs final state in proton-proton collisions at the LHC at the center-of-mass energy of 14 TeV with 10 fb^{-1} and 100 fb^{-1} of data to search for anomalous couplings. We investigate the final state of three b-jets where the top quark decays to a charged lepton (muon or electron), neutrino and a b-quark and the Higgs boson decays into a b-quark pair.

It is notable that both anomalous couplings tqg and tqH are arising from dimension-six operators.

$$L = \frac{g}{2\sqrt{2}} \sum_{q=u,c} g_{tqH} \bar{q} (g^v_{tqH} + g^a_{tqH} \gamma_5) t H + h.c.$$



Event Simulation and selection

The main background processes are Wbbj, Wjjj, WZj, and top pair. For both signal and the background processes, the MadGraph 5 package has been used to generate events with the cteq6 as the proton PDF. The parton level events are passed through Pythia 8 for showering. The jet reconstruction is then performed by Fastjet package using an anti-kt algorithm with the cone size of R = 0.5. To simulate b-tagging, a b-tagging efficiency of 60% is chosen for b-jets and a mis-tagging rate of 10% for other quarks. The effects of detector resolution are simulated through Gaussian energy smearing. The typical value for charged lepton and jets p_T cut and missing transverse energy cut is 25 GeV within the pseudorapidity range of 2.5. The angular distance between the charged lepton and jets and all jets have to be greater than 0.4. The cross section of signal after the above preliminary cuts including the branching ratios are:

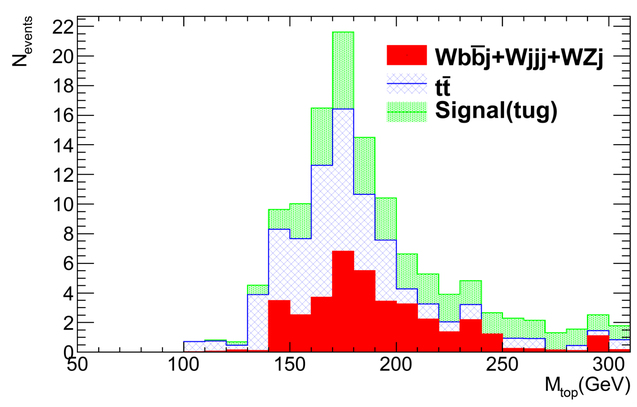
$$\sigma(\kappa_{tug}/\Lambda) pb = 5.6 \times [\frac{\kappa_{tug}}{\Lambda}]^2, \sigma(\kappa_{tcg}/\Lambda) pb = 1.05 \times [\frac{\kappa_{tcg}}{\Lambda}]^2$$

The cross sections of Wjjj , ttbar, Wbbj and WZj processes are 230.0 pb, 34.35 pb 2.33 pb and 0.138 pb, respectively, considering the cuts and branching ratios. In order to reconstruct the top quark and Higgs boson in the final state, first we require to have only three b-tagged jets in each event. This is useful to reduce the contribution of the backgrounds with no real b-jet.

The missing transverse energy is taken as the transverse component of the neutrino momentum. The z-component of the neutrino momentum is obtained by using the W-boson mass constraint. In most cases, there are two solutions for the p_z. As a result, the combination of the charged lepton and two neutrinos leads to two W-bosons which are combined with the three b-tagged jets separately. Among the six combinations, the combination which gives the closest mass to the top quark mass is selected. The other remaining two b-jets are combined to reconstruct the Higgs boson. In order to suppress the backgrounds, we use secondary cuts:

$$|m_{H_{reco}} - 125| > 15$$
$$|y_l - y_H| < 1.2$$
$$Higgs\ p_T > 100 GeV$$
$$|y_H| > 0.8$$

We show the reconstructed top quark mass after all cuts for signal and. Backgrounds:



Results

After applying all cuts, we obtain the following efficiencies for signal, ttbar, Wbbj, Wjjj, and WZj respectively: 12%, 0.017%, 0.04%, 0.0023%, 0.071%. For the tcg signal the efficiency has been found to be 6%. We calculate the 3 and 5 sigma discovery reaches of the LHC:

$$\frac{\kappa_{tug}}{\Lambda} \geq 0.069(0.088) TeV^{-1}, \frac{\kappa_{tcg}}{\Lambda} \geq 0.26(0.34) TeV^{-1}$$

In case of finding no evidence for signal, upper limits can be set on the anomalous interaction parameters. To set the 68% C.L. limits, we use a simple chi-squared criterion from the distribution of $|y_l - y_H|$. We perform the chi-squared on this distribution because the signal and backgrounds shapes are different and therefore could lead to stronger limits. The chi-squared criterion is defined as:

$$\chi^2(\frac{\kappa_{u,c}}{\Lambda}) = \sum_{i=bins} \frac{(s_i - b_i)^2}{\Delta_i^2}$$

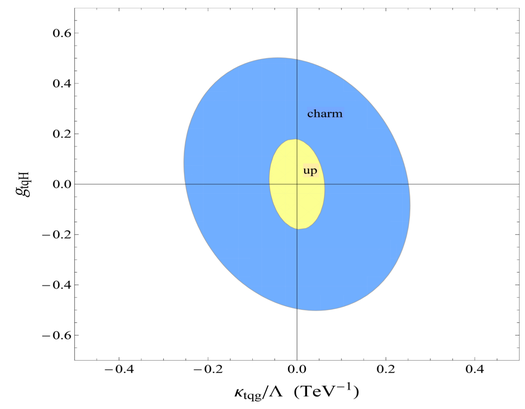
The 68% C.L. upper limits on the anomalous FCNC couplings are found to be:

$$\frac{\kappa_{tug}}{\Lambda} \leq 0.014 TeV^{-1}, \frac{\kappa_{tcg}}{\Lambda} \leq 0.045 TeV^{-1}$$

The final state of signal can arise from both anomalous interactions tqg and tqH. The cross section can be parameterized as:

$$\sigma(\frac{\kappa_{tqg}}{\Lambda}, g_{tqH})[pb] = c_{tqg} \times (\frac{\kappa_{tqg}}{\Lambda})^2 + c_{tqH} \times g^2_{tqH} + c_{\text{int.}} \times \frac{\kappa_{tqg}}{\Lambda} \times g_{tqH}$$

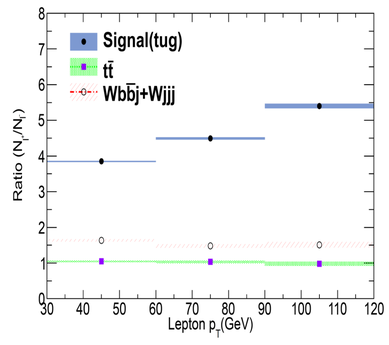
After applying similar requirements the 3 sigma exclusion limits on the anomalous tqg and tqH are extracted.

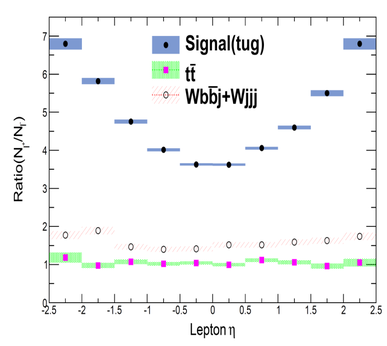


Charge Ratio

One of the striking features of our signal, is asymmetry between top and anti-top rates. The cross section of top and anti-top quarks are different at the LHC for the processes of t+H and tbar+H because of the difference between the u-quark and ubar-quark parton distribution functions of proton. In leptonic top decay this asymmetry is directly translated in a corresponding lepton charge asymmetry. The only background which has charge asymmetry among the main backgrounds is W + jets. We define a ratio R as the number of events with positive charged lepton to the number of events with negative charge. The inclusive values of R for signal for signal and backgrounds:

$$R_{signal} = 4.35 \pm 0.02, R_{W+jets} = 1.57 \pm 0.03, R_{t\bar{t}} = 1.04 \pm 0.03$$





Conclusion

In this work we propose to use the pp→t + H process to probe the anomalous tqg and tqH couplings. We concentrate on the leptonic decay of the top quark and the Higgs boson decay to bb at the LHC with the center of mass energy of 14 TeV. A set of kinematic variables have been proposed to discriminate between the signal from backgrounds. We show that the LHC can probe the anomalous tug(tcg) couplings down to 0.01 (0.04) TeV^{-1} with 10 fb^{-1} of integrated luminosity. We propose the charge ratio versus transverse momentum and the pseudorapidity of the charge lepton as a strong tool to discriminate between signal and backgrounds as well as its ability to distinguish between the anomalous couplings tug and tcg.

References

[1] S.Kh and M.M.N, Phys.Rev.D 89, 054011(2014)

[2] J. A. Aguilar-Saavedra, Nucl. Phys. B812, 181 (2009).

[3] The ATLAS Collaboration, ATLAS CONF-2013-063.