Probing Top FCNC Anomalous Couplings at Future Circular Hadron-Hadron Collider

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ABSTRACT

We analyzed anomalous top FCNC couplings via the production of single top quark in association with a photon at 100 TeV centre of mass energy. In our analysis, we consider the invariant mass distributions of reconstructing top quark mass; one lepton and missing energy transfer reconstructing *W*, and one b-tagged jet for *lνbγ* final state, and one b-tagged jet and two other jets reconstructing *W* for *jjbγ* final state for the signal and main SM background. The sensitivity to anomalous couplings tqγ with an integrated luminosity of 1 ab^{-1} is examined with the simulation including realistic detector effects.

THEORY

For the FCNC tqγ couplings the effective Lagrangian can be written as

$$L_{FCNC} = \frac{g_e}{2m_t}\bar{u}\sigma^{\mu\nu}(\lambda^L_{ut}P_L + \lambda^R_{ut}P_R)tA_{\mu\nu} + \frac{g_e}{2m_t}\bar{c}\sigma^{\mu\nu}(\lambda^L_{ct}P_L + \lambda^R_{ct}P_R)tA_{\mu\nu} + h.c$$

where g_e is the electromagnetic coupling constant; $\lambda^{L(R)}_{qt}$ are the strength of anomalous FCNC couplings for tqγ, which vanish at the lowest order in SM; $P_{L(R)}$ denotes the left (right) handed projection operators; $\sigma^{\mu\nu}$ is the tensor defined as $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$ for the FCNC interactions[1,2]. No specific chirality is assumed for FCNC interaction vertices, i.e. $\lambda^L_q = \lambda^R_q = \lambda$

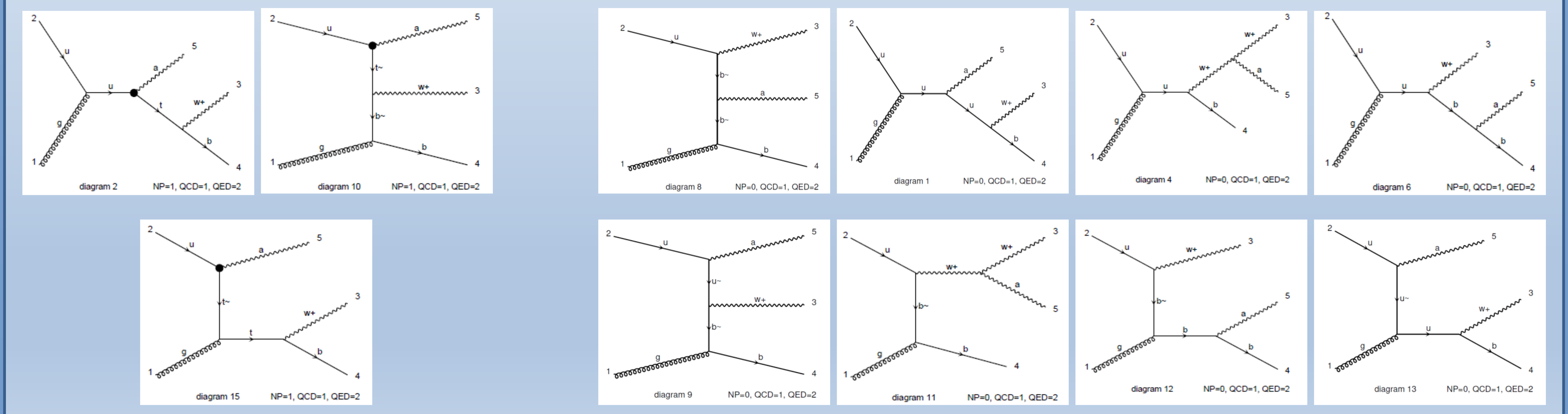


Figure 1 : Feynman Diagrams of contributions to wbγ production from FCNC vertices (on the left) and SM (on the right). The similar diagrams for c quark can be obtained by exchanging u ↔ c and u~ ↔ c~

PRODUCTION

One Million events are generated for signals and each backgrounds in Table 1.

	Process	Cross Section (pb)
B1	p p → w+ w- b b~ a (NP = 0)	0.38447 ± 0.00014
B2	p p → w+ w- jet a (NP = 0) (where jet = u d s c u~ d~ s~ c~ g~)	1038.3 ± 0.362
B3	p p → w+ w- jets (NP = 0) (where jets = u d s c b u~ d~ s~ c~ b~ g~)	4.363x10^3 ± 104
B4	p p → tt tt (NP = 0) (where tt = t t~)	25235 ± 3.64
B5	p p → tt tt a (NP = 0) (where tt = t t~)	107.9 ± 0.00356
B6	p p → z a jets (NP = 0) (where jets = u d s c b u~ d~ s~ c~ b~ g~)	330.02 ± 0.112
S1	p p → w+ w- b b~ a (NP = 1) (λ = 0.01)	1.2475 ± 0.000213
S2	p p → w+ w- b b~ a (NP = 1) (λ = 0.05)	22.08 ± 0.00241

Table 1 : Definition and Cross Sections for signal and possible background processes

Flow Chart of Production

Event Generation by MadGraph5_aMC@NLO 2.5.3[3]
Signal Process
and
All Background Process

⇩

Parton Shower
and
Hadronization by PYTHIA 8[4]

⇩

Fast Simulation
by Delphes 3.3.3[5] with FCC Detector Card

ANALYSIS IN LEPTONIC CHANNEL

- **Cut 0**
  - $N_{jet} \geq 1$
  - $N_{b\text{-tagged}} = 1$ & $N_{lepton} = 1$ & $N_\gamma = 1$
- **Cut 1**
  - $p_T^b > 30$ GeV & $p_T^\gamma > 150$ GeV & $p_T^l > 30$ GeV
  - MET > 30 GeV
  - $|\eta_{all}| < 2.5$ & $\Delta R_{l,\gamma} > 0.7$ & $\Delta R_{b,\gamma} > 0.7$
- **Cut2**
  - 80 GeV < $m_{l\nu}$ < 85 GeV
- **Cut3**
  - 135 GeV < $m_{l\nu b}$ < 195 GeV

Cut Based Analysis Flow Chart of Leptonic Channel

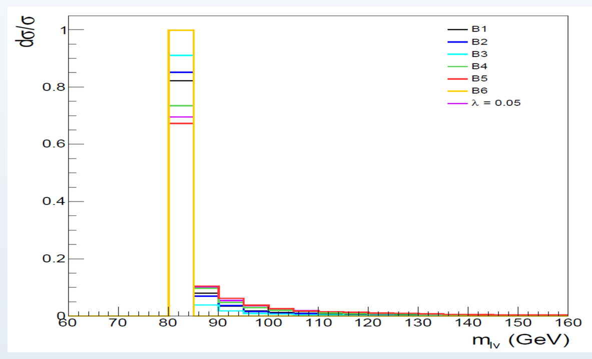


Figure 2a : $m_{l\nu}$ distributions

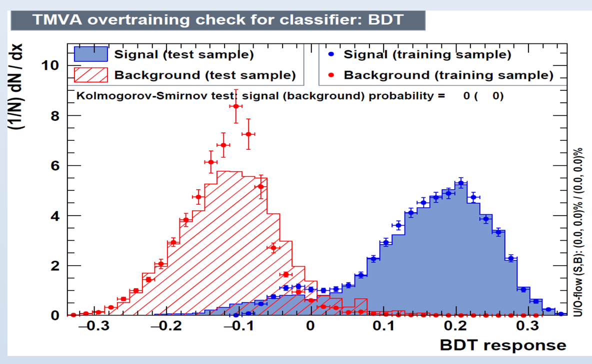
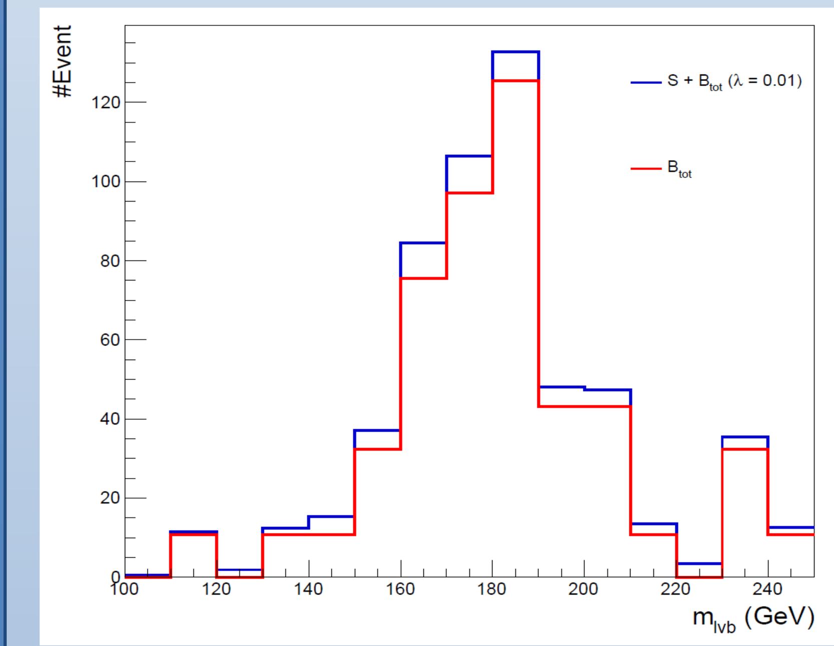


Figure 2b : BDT output of leptonic channel



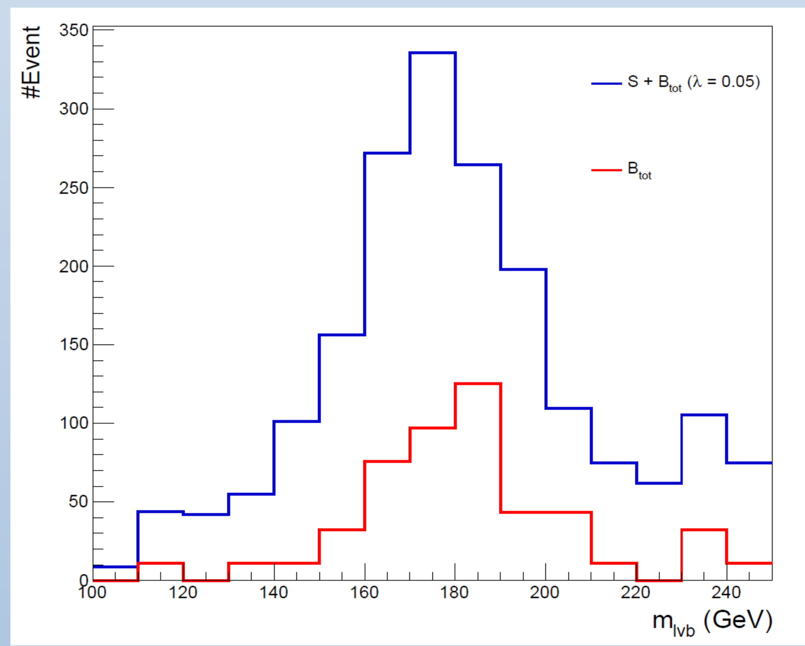


Figure 3 : Reconstructed top mass distribution for signal (λ = 0.01) on the left and (λ = 0.05) on the right with total backgrounds (B_{tot}).

$m_{l\nu b}$	B1	B2	B5	S1	S2
Cut 0	492.493	91646.6	59064.5	1635.72	28936.7
Cut 1	2.49899	207.58	1985.36	300.024	7637.13
Cut 2	0.922704	207.58	528.71	76.4718	1870.09
Cut 3	0.19223	103.79	528.71	38.7973	907.447

Table 2 : Number of events after each cuts for signals and backgrounds

ANALYSIS IN HADRONIC CHANNEL

- **Cut 0**
  - $N_{jet} \geq 3$
  - $N_{b\text{-tagged}} = 1$ & $N_{lepton} = 0$ & $N_\gamma = 1$
- **Cut 1**
  - $p_T^b > 30$ GeV & $p_T^\gamma > 150$ GeV
  - $p_T^{j1} > 30$ GeV & $p_T^{j2} > 30$ GeV
  - $|\eta_{all}| < 2.5$
  - $\Delta R_{j1,\gamma} > 0.7$ & $\Delta R_{j2,\gamma} > 0.7$ & $\Delta R_{b,\gamma} > 0.7$
- **Cut2**
  - 65 GeV < m_{jj} < 90 GeV
- **Cut3**
  - 135 GeV < m_{jjb} < 195 GeV

Cut Based Analysis Flow Chart of Hadronic Channel

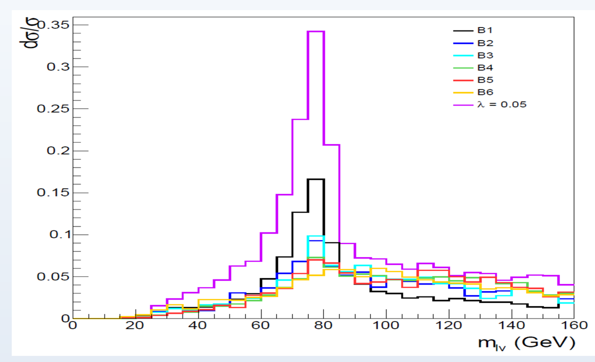


Figure 4a : m_{jj} distributions

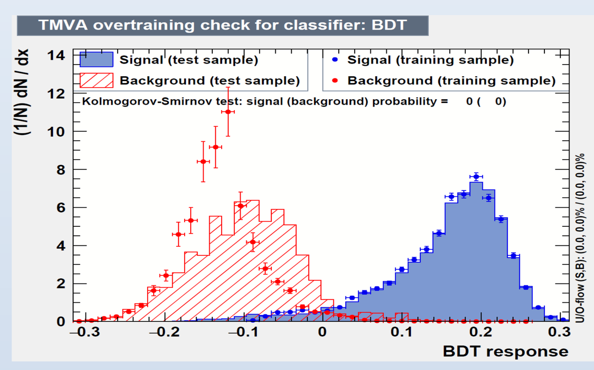
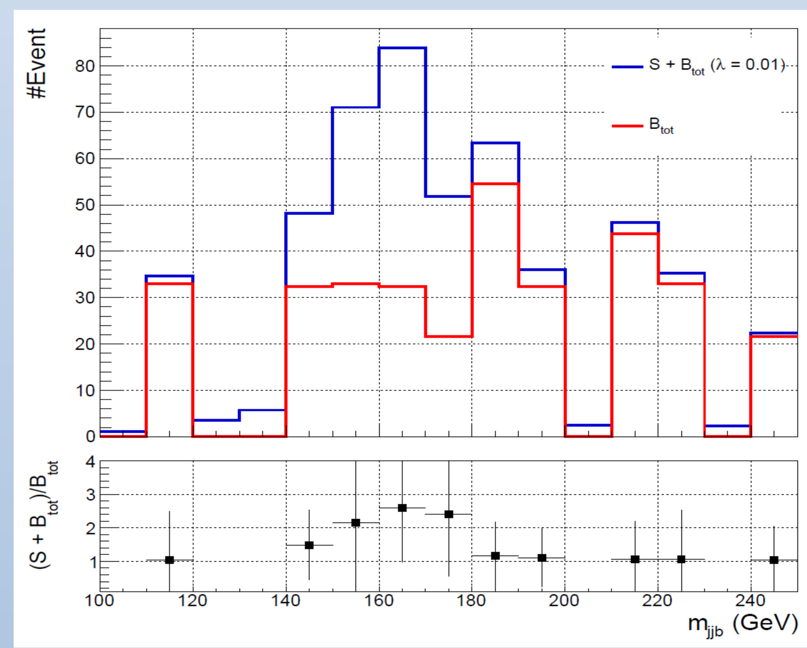


Figure 4b : BDT output of hadronic channel



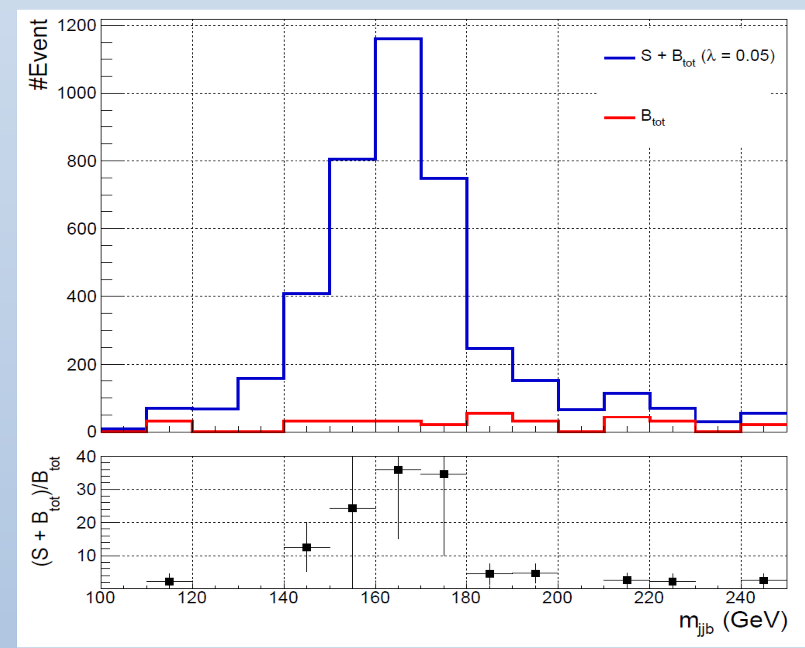


Figure 5 : Reconstructed top mass distribution for signal (λ = 0.01) on the left and (λ = 0.05) on the right with total backgrounds (B_{tot}).

m_{jjb}	B1	B2	B5	B6	S1	S2
Cut 0	430.634	116141	59064.5	60027	1492.13	25989.2
Cut 1	3.88305	1037.9	906.36	957	439.245	10609
Cut 2	1.46095	103.79	205.01	165	183.133	4135.4
Cut 3	0.269122	0	129.48	66	149.7	3356.01

Table 3 : Number of events after each cuts for signals and backgrounds

RESULTS AND DISCUSSION

The sensitivity to anomalous couplings tqγ with an integrated luminosity of 1 ab^{-1} at 3σ (5σ) significance is

- λ = 0.0125 (0.0185) for *lνbγ* channel
- λ = 0.006 (0.008) for *jjbγ* channel

•The limits on the top quark FCNC branching ratios are BR(t→uγ) = 1.7 x 10^{-4} and BR(t→cγ) = 2.2 x 10^{-3} at 95% C.L. [6].

•The projected limits on top FCNC couplings at LCH 14 TeV and HL-LHC have been reported [7], where the expected upper limits on branching ratio t→qγ are 2.5 x 10^{-5} for an integrated luminosity 3000 fb^{-1} .

•Our limits on BR(t→qγ) is at the order of 10^{-5} for 3σ an integrated luminosity 1 ab^{-1}.

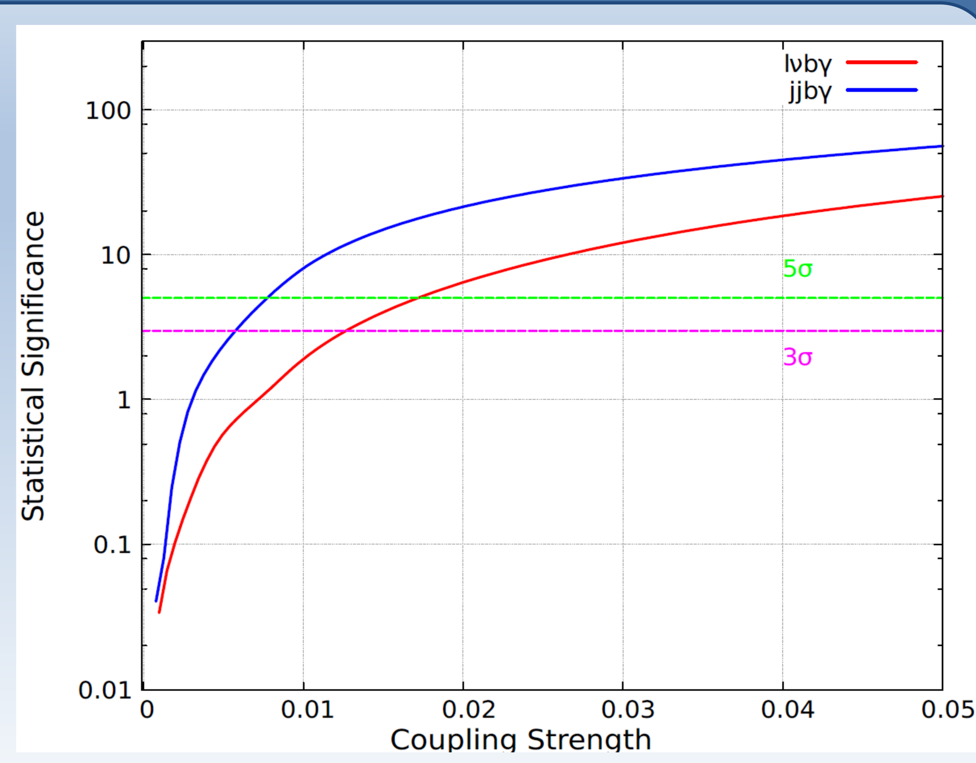


Figure 6 : Statistical significance versus coupling strength (λ)

REFERENCES

[1] J. A. Aguilar – Saavedra, Nucl. Phys. B812,181 (2009).
[2] H. Denizli, et al. Phys. Rev. D 96,015024 (2017).
[3] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, T. Stelzer, JHEP 1106, 128 (2011).
[4] T. Sjostrand, S. Mrennaand P. Z. Skands, Comput. Phys. Commun. 178, 852 (2008).
[5] J. de Favereau et al. [DELPHES 3 Collaboration], JHEP 1402, 057 (2014).
[6] V. Khachatryan et al. [CMS Collaboration], JHEP 1604, 035 (2016).
[7] [Atlas Collaboration] , arXiv : 1307.7292 [hep-ex].

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