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 tq*γ* with an integrated luminosity of 1 ab^{-1} is examined with the simulation including realistic detector effects.

THEORY

For the FCNC tq*γ* couplings the effectice 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 tq*γ*, 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. $\lambda^L_q = \lambda^R_q = \lambda$

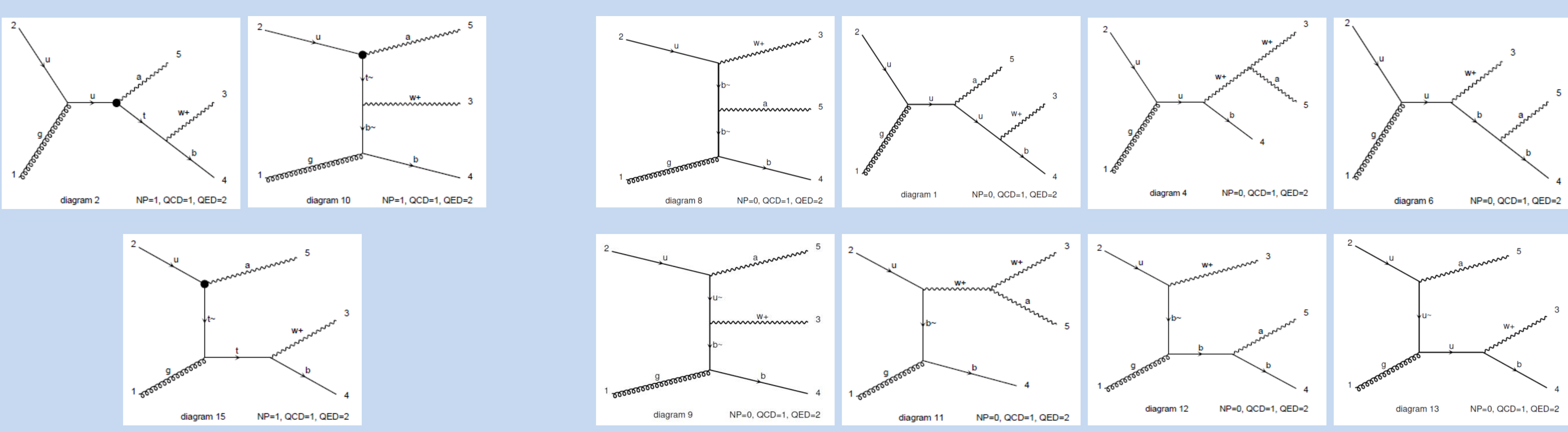

Figure 1 : Feynman Diagrams of contributions to wbγ production from FCNC vertices (on the left) and SM (on the right)

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
- $N_{jet} \geq 0$
- $N_{b\text{-}tagged} = 1$ & $N_{lepton} = 1$ & $N_\gamma = 1$

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

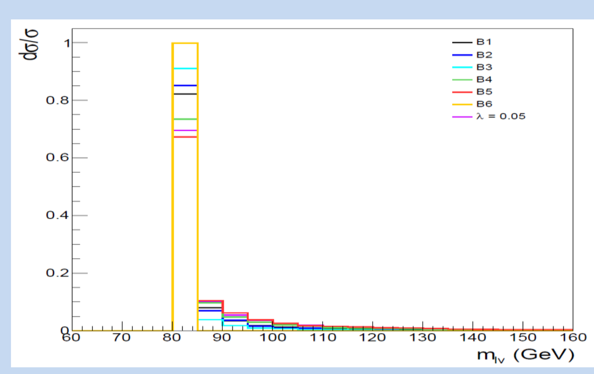

Figure 2a : $m_{l\nu}$ distributions

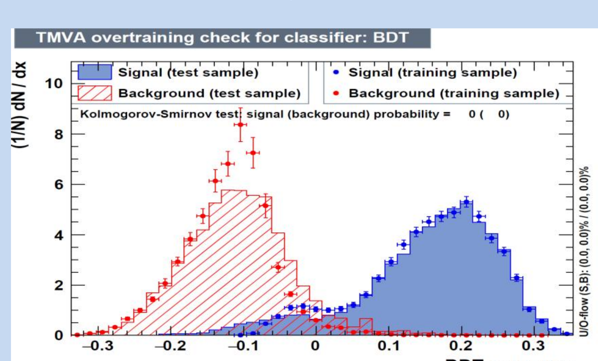

Figure 2b : BDT output of leptonic channel

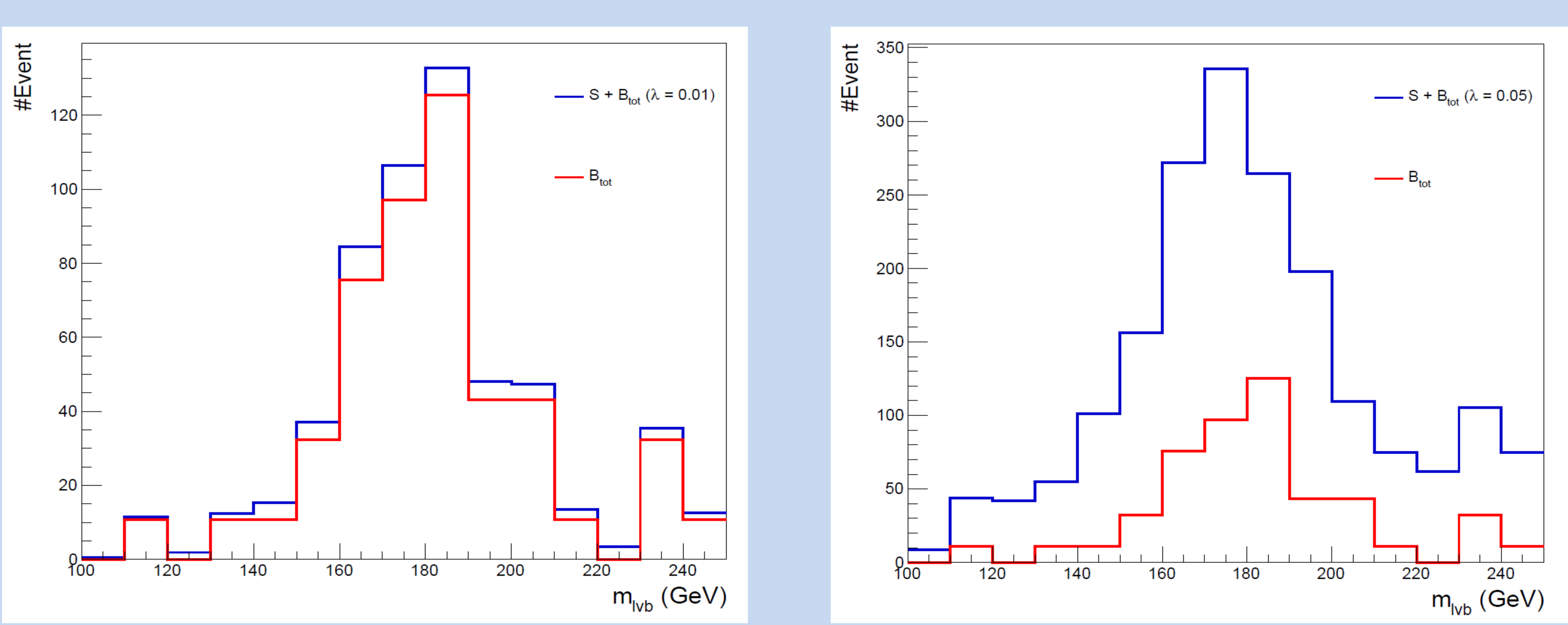

Figure 3 : Reconstructed top mass distribution for signal (λ = 0.01) on the left and (λ = 0.05) on the right with total backgrounds (B_{tot}).

$m_{l\nu b}$	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
- $N_{jet} = 3$
- $N_{b\text{-}tagged} = 1$ & $N_{lepton} = 0$ & $N_\gamma = 1$

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

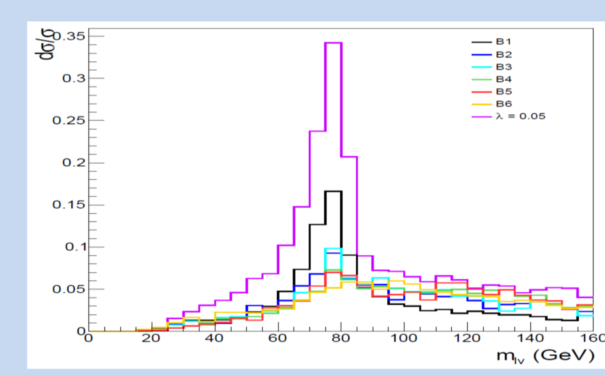

Figure 4a : m_{jj} distributions

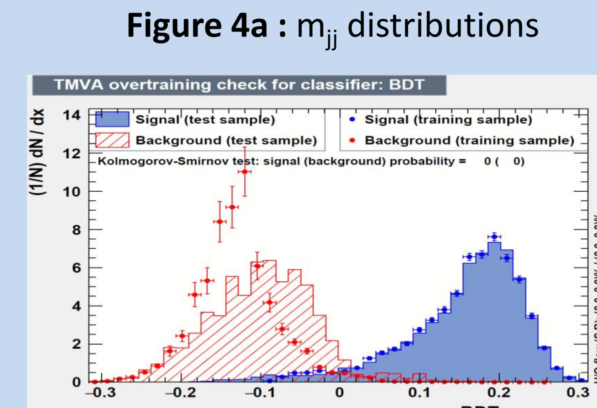

Figure 4b : BDT output of hadronic channel

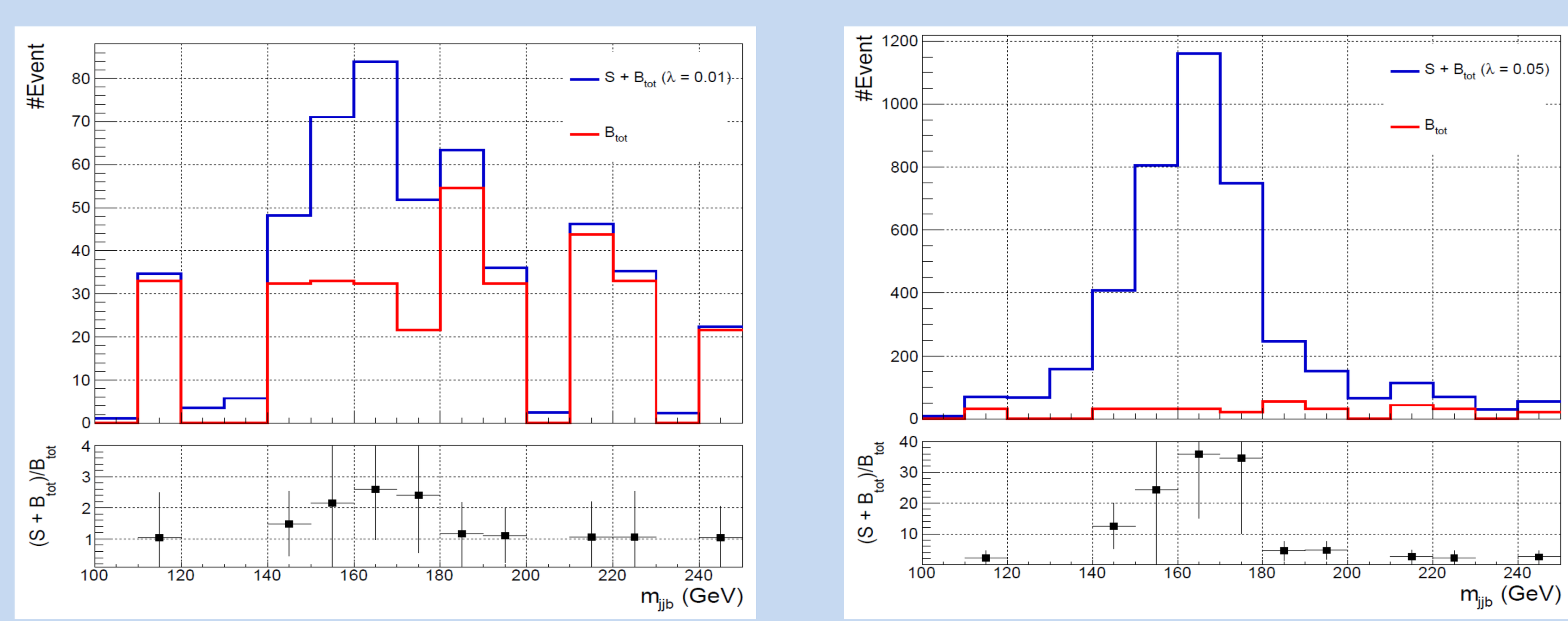

Figure 5 : Reconstructed top mass distribution for signal (λ = 0.01) on the left and (λ = 0.05) on the right with total backgrounds (B_{tot}).

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 tq*γ* with an integrated luminosity of 1 ab^{-1} at 3σ (5σ) significance is

- 0.0125 (0.0185) for *lνbγ* channel
- 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 an integrated luminosity 1ab^{-1}.

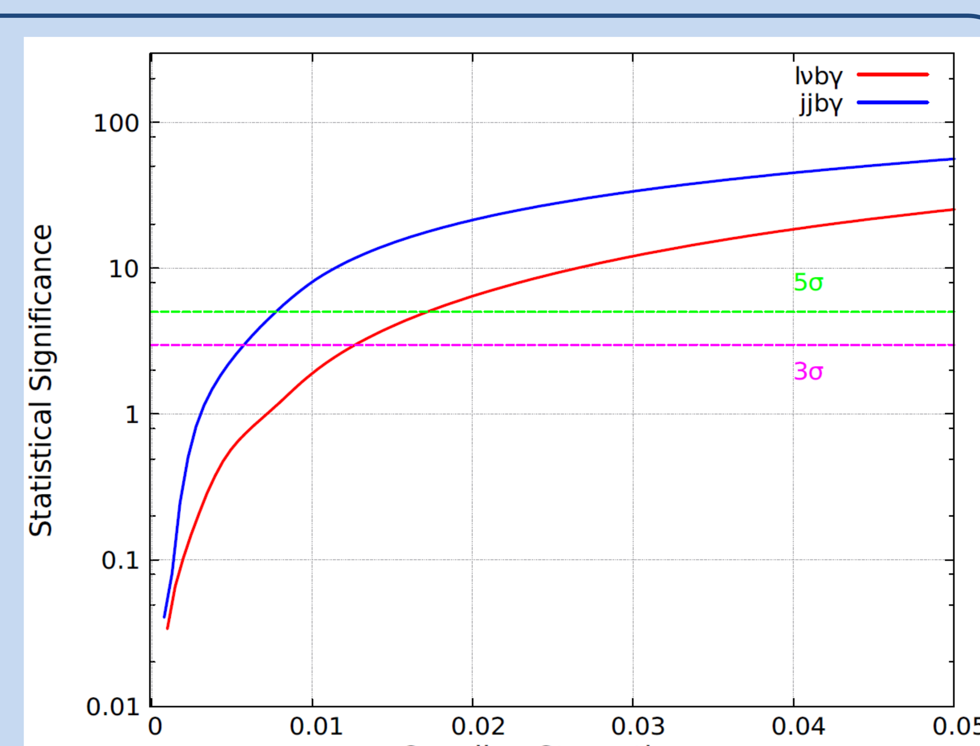

Figure 6 : Statistical significance versus coupling strength

REFERENCES

[1] J. A. Aguilar – Saavedra, Nucl. Phys. B812,181 (2009).
[2] H. Denizli, et all. 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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