FCNC in $t\bar{t} \rightarrow bWcH(\gamma\gamma)$

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Motivation

- Thanks to the Ecal resolution in CMS detector, having two photons can give us a very clean signature in the mass distribution.
- Can reduce the SM backgrounds with two high p_T photons.
- Requiring one lepton can also reduce the QCD $\gamma\gamma$ process significantly.
- As the signal signature can be distinguished from the background relatively easily, simple cut and count method was used.

Samples

Table 1: Cross sections at LO. The branching ratio of W boson decaying to a lepton $B(W \to l\nu)$ is 10.80%. The branching ratio of Higgs decaying to $\gamma\gamma$ $B(H \to \gamma\gamma)$ is 0.228 %. The best limit of $t \to cH$ coupling is 0.56%.

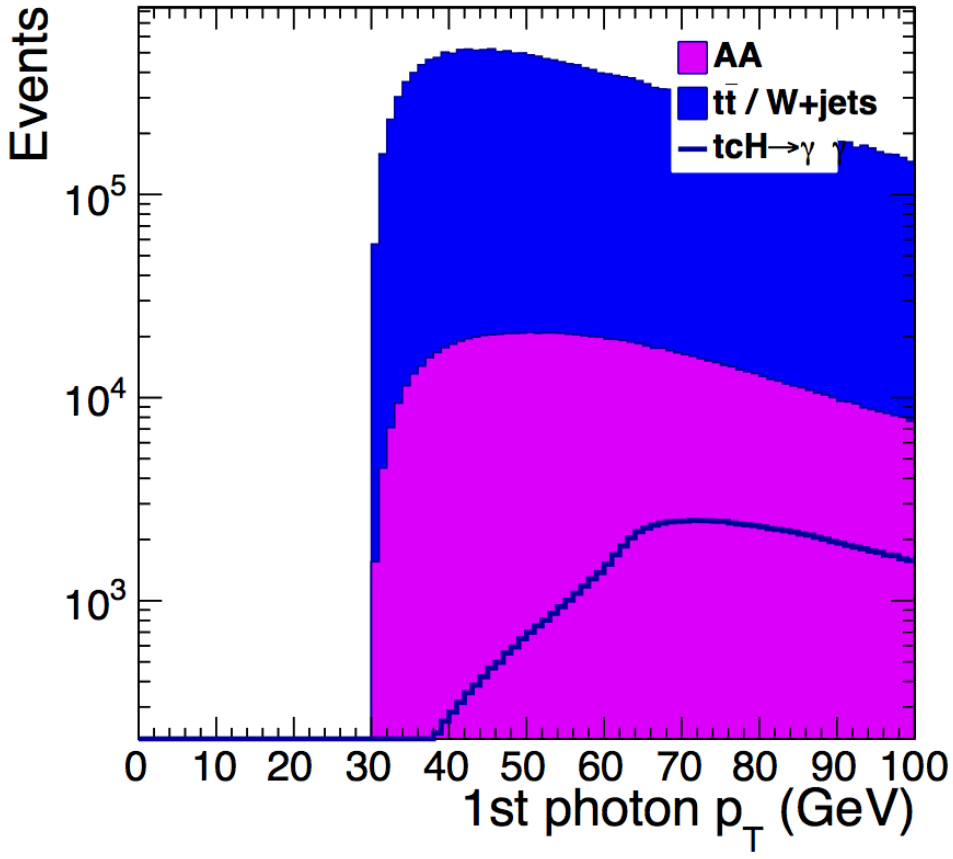
Selection	Cross sections at 13 TeV (pb)	Number of events	Effective luminosity (fb^{-1})
$t \to cH(\gamma\gamma)$	2*674*0.0056*$B(H \to \gamma\gamma)$	9.078573e+06	527478.574
$t\bar{t}$ dilepton	674*$B(W \to l\nu)$*3*$B(W \to l\nu)$*3	4.24e+06	59.926
$t\bar{t}$ semilepton	674*$B(W \to l\nu)$*3*(1-$B(W \to l\nu)$*3)*2	1.5979886e+07	54.124
W($l\nu$)+1 jet	177300*$B(W \to l\nu)$*3*0.12155	2.8231215e+07	4.043
W($l\nu$)+2 jets	177300*$B(W \to l\nu)$*3*0.03358	1.7403439e+07	9.021
W($l\nu$)+3 jets	177300*$B(W \to l\nu)$*3*0.0861	1.4436939e+07	2.918
$\gamma\gamma$+1 jet	203*0.25410	1.384272e+07	268.361
$\gamma\gamma$+2 jets	203*0.12885	4.379504e+06	167.434
$\gamma\gamma$+3 jets	203*0.06170	6.33577e+06	505.845

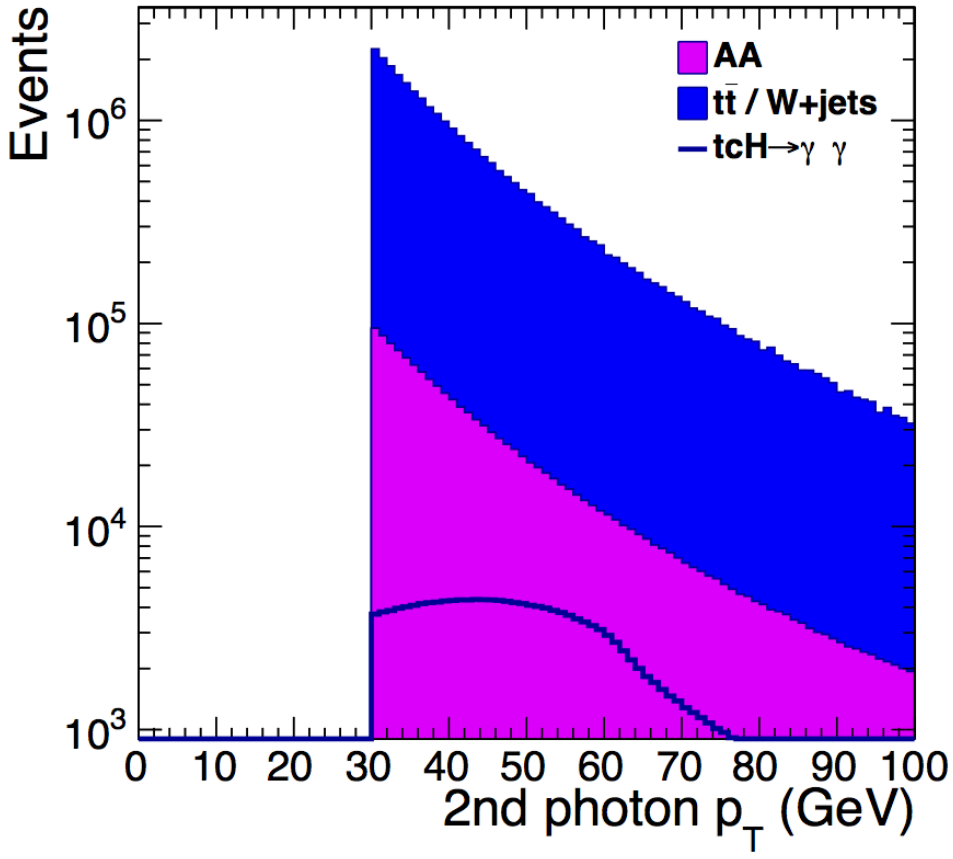
- Signal signature : $t\bar{t} \to bWcH(\gamma\gamma)$ in the leptonic decay mode.
  - Two photons from the Higgs
  - One lepton from W boson and one b-jet in top decay.
- Main backgrounds
  - $t\bar{t}$ and $W + jets$

Event selections

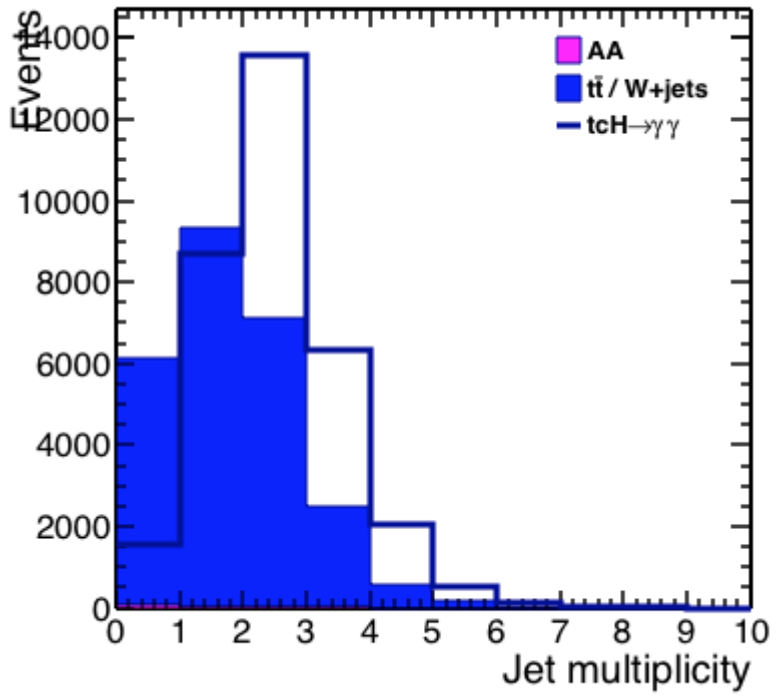
- Two photons (S1)
  - p_T > 60 GeV, $|\eta|$ < 2.5
  - p_T > 30 GeV, $|\eta|$ < 2.5
  - Having asymmetry thresholds are motivated by the boosted Higgs.
  - Must be isolated with relative isolation < 0.01 which is around 90% efficiency.
- Exclusive one lepton (S2)
  - p_T > 20 GeV, $|\eta|$ < 2.5 and relative isolation < 0.1
- At least two jets (S3)
  - p_T > 30 GeV, $|\eta|$ < 2.5, EEoverHE > 0.3
- Exactly one b-jets with the tight working point, CSVT (S4)
- 163 GeV < $m_{j\gamma\gamma}$ < 173 GeV (S5)

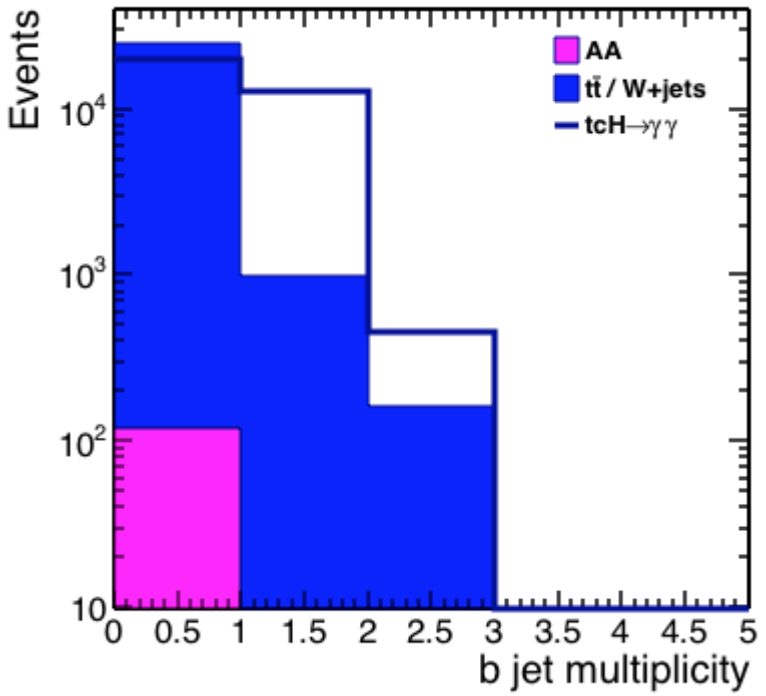
Plots (preselection)





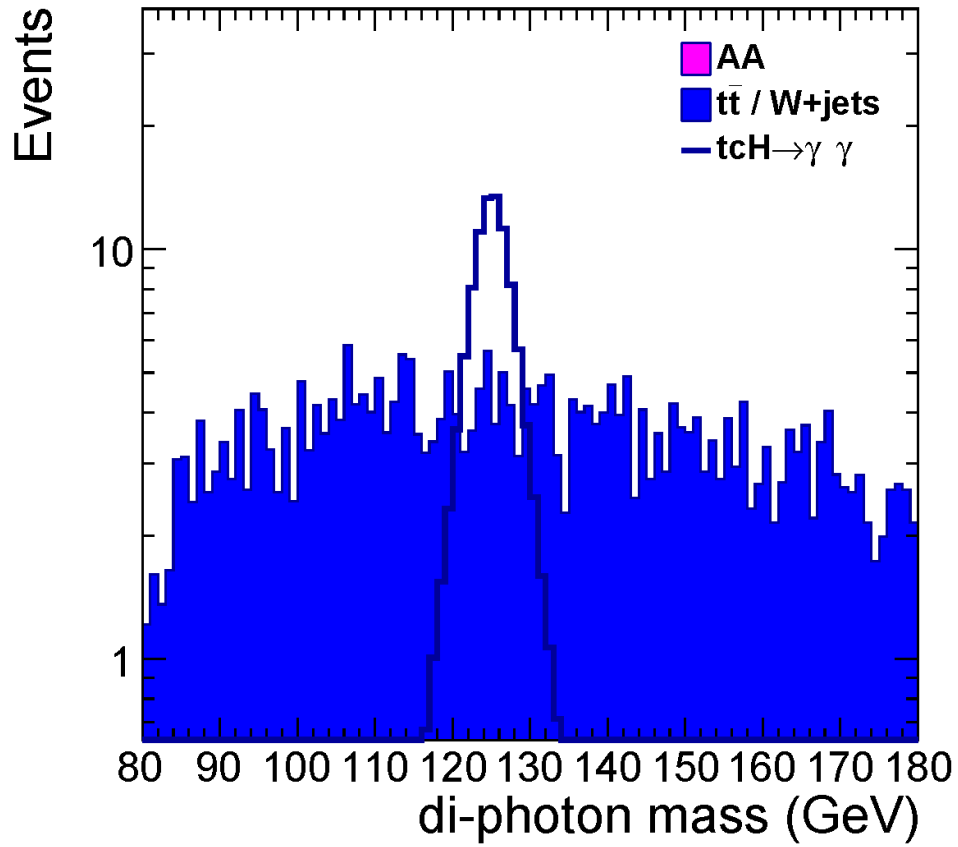
Plots (S2 : two photons and one lepton)





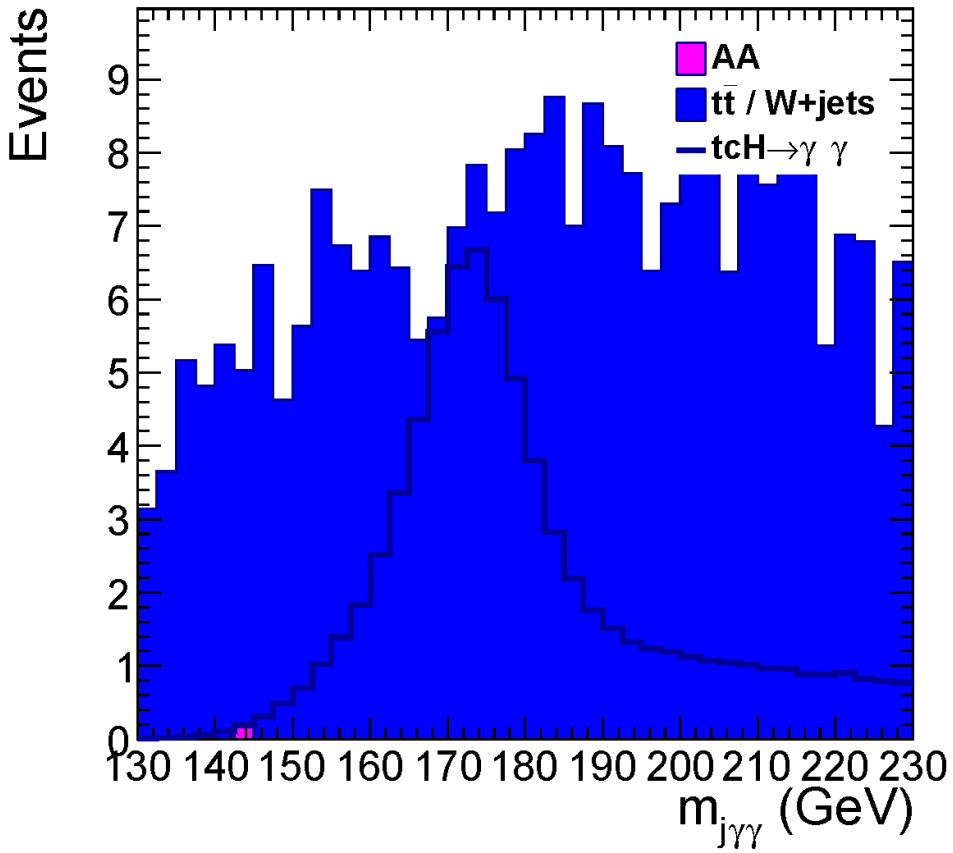
- Required at least two jets.
- Further required only one b-jet to remove $t\bar{t}$ background.
  - Planning to revisit by requiring at least one b-jet.

Plots (S4 after b-jet requirement)



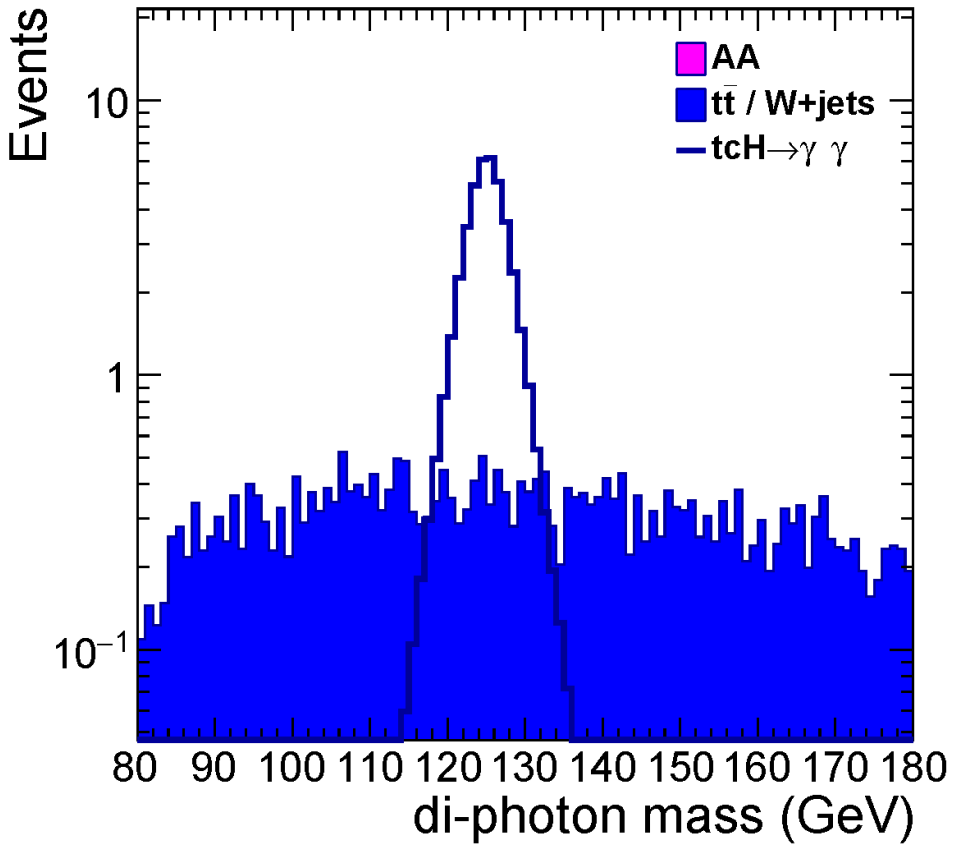
- The background shape is taken from the $t\bar{t}$ sample at the selection step 2 after two photon requirement.

Plots (S4 after b-jet requirement)



- Top mass is reconstructed with two photons and one jet taking into account all combinations of jets.
- Take the jet with the closest mass $m_{j\gamma\gamma}$ to the top quark mass.
- 163 < $m_{j\gamma\gamma}$ < 173 GeV

Plots (Final selection : $m_{j\gamma\gamma}$ requirement)



- The background shape is taken from the $t\bar{t}$ sample at the selection step 2 after two photon requirement.

Cut flow table

Selection	S1 ($\gamma\gamma$)	S2 ($N_l \geq 1$)	S3 ($N_j \geq 2$)	S4 ($N_b = 1$)	S5 ($m_{j\gamma\gamma}$)
$t \to cH(\gamma\gamma)$	1124 (44%)	329 (13%)	226 (8.9 %)	99 (3.9%)	41.2 (1.6%)
$\gamma\gamma$+jets	654068	123.9	21.4	1	0
$t\bar{t}$ dilepton	3701	1098	714	342	33.4
$t\bar{t}$ semilepton	5565	885	728	302	25.7
W+jets	193351	23771	8941	124	0
$S/\sqrt{S+B}$	1.2	2.0	2.2	3.4	4.1

- Main backgrounds are $t\bar{t}$ and W+jets.
- Diboson, $t\bar{t}H$, $t\bar{t}+\mathrm{H}$, $t\bar{t}+\gamma\gamma$, $H \to \gamma\gamma$ are negligible so these backgrounds are not included.

Result

- The significance taking into account only statistical uncertainty after the final selection with data corresponding to an integrated luminosity of 100 fb^{-1}

$$\frac{S}{\sqrt{S+B}} = 4.1$$

- Since the remaining background is mostly $t\bar{t}$ process, conservatively if we take the systematic uncertainty of 10% for $t\bar{t}$ process based on the Run I measurement.

$$\frac{S}{\sqrt{S+B+(B\times 0.1)^2}} = 3.5$$