Search for flavour-changing neutral currents in $t\bar{t}$ processes in multilepton final states in proton-proton collisions with the CMS detector

LOCP-B

FINAL PROJECT

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FCNC: INTRODUCTION

Flavour changing neutral currents are weak interactions that change the flavour of a fermion without altering its electric charge.

For what concerns the top quark decaying to Higgs boson:

- **Standard Model:** $B(t \rightarrow Hq) = o(10^{-15})$ (absent at leading order and suppressed by GIM mechanism at higher orders)
- **Extension of SM:** predict an enhanced $B(t \rightarrow Hq)$

By modifying the lagrangian of the STD Model in the following way, this process could become possible:

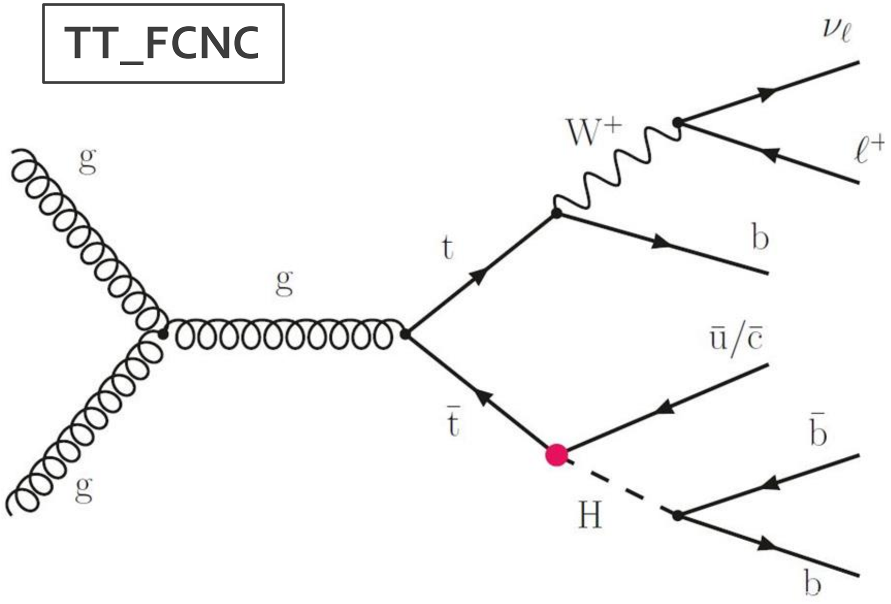
$$\mathscr{L} = \sum_{u,c} \frac{g}{\sqrt{2}} \bar{t} K_{Hqt} (f^L_{Hq} p^L + f^R_{Hq} p^R q H) + h_c$$

where K_{Hqt} is assumed to be 1 in order to generate the signal.

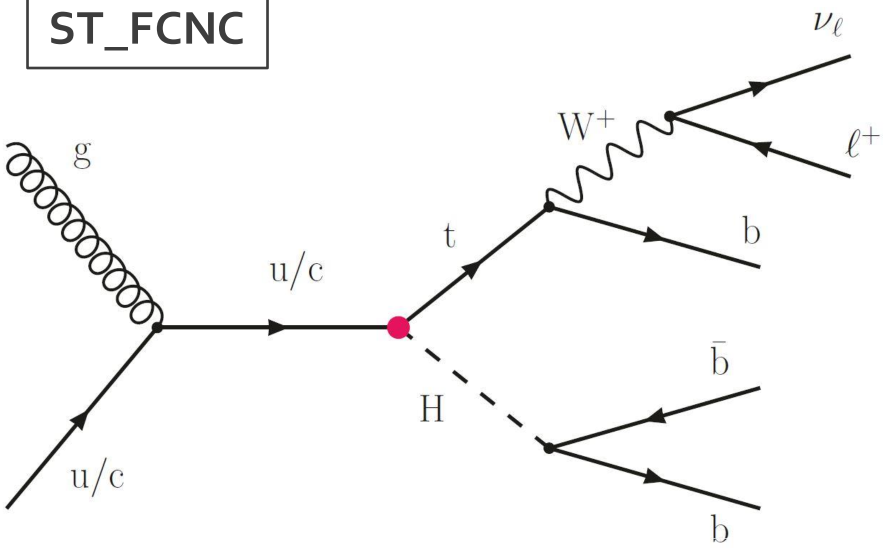
FCNC DECAYS INVOLVING TOP QUARK AND HIGGS BOSON

The previous modification of the lagrangian yields two main processes, described in the following Feynman diagrams:

TT_FCNC

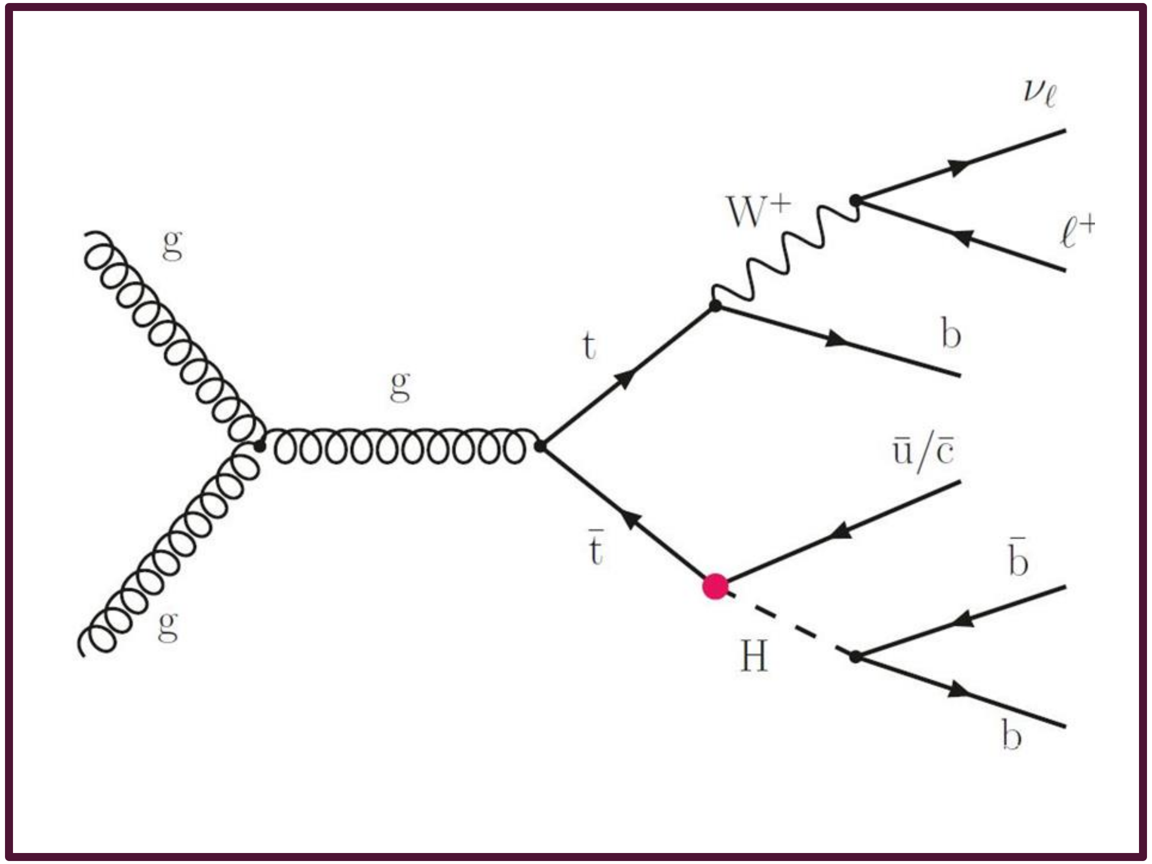


ST_FCNC



Our analisys focuses exclusively on $t\bar{t}$ processes and has the goal of setting an upper limit to the branching fraction of FCNC decay of $t\bar{t} \rightarrow Hq + Wb \rightarrow multilepton$

FCNC DECAY OF THE TOP QUARK TO THE HIGGS BOSON



We focus on channels with leptons in the final state.

In particular, we divide our analysis in 4 categories, two of which consider di-lepton final states and two with tri-lepton final states:

1. **iSkim = 1:** 2 muons same sign
2. **iSkim = 2:** 1 muon and 1 electron same sign
3. **iSkim = 3:** 3 muons, one with charge opposite to the other two
4. **iSkim = 4:** 2 muons and one electron, one with charge opposite to the other two

FINAL STATES OF SIGNAL AND MAIN BACKGROUNDS

In the table below we present the main products of the signal we are looking for and of the main backgrounds from the standard model.

	TT_FCNC	$t\bar{t}$	ww	wz
$\boldsymbol{n_l}$	$2\ SS, 3+$	$2\ OS + fakes$	$2\ OS$	$2\ OS, 3$
$\boldsymbol{n_b}$	2	2	0	0
$\boldsymbol{n_c}$	0 or 1	0 or 1	0	0

Such backgrounds will in fact be the main contributions to the background after having applied the cuts we will introduce later on.

LIMIT ON BRANCHING RATIO

The predicted cross sections, by using the modified lagrangian introduced above, are as follows:

- $\sigma_{TT\_FCNC} = 192\ pb$
- $\sigma_{ST\_U} = 71{,}4\ pb$
- $\sigma_{ST\_C} = 9{,}8\ pb$

The main SM background consists in top quark pair production, with $\sigma_{t\bar{t}} = 830\ pb$

Apparently, we should have a good signal to noise ratio: nevertheless, neither of these processes has ever been observed, up to a branching ratio $B(t \to Hq)\ \leq 4\ ‰$

This suggests that the constant K_{Hqt} is set to a value which is too big, and we expect it to be much smaller.

Moreover, there's no single clearly discriminating variable to be on the lookout for.

More specifically, in our work the limit is set on the strength μ of the signal, $i.e.$ a multiplicative factor.

THE DATA

Our data have been acquired at the **CMS** experiment during a period of three years (2016, 2017, 2018).

The format of the files we analyze is the **NanoAOD**, so we only have events organized in a tree structure with all the particles already identified.

Furthermore, our data have been preprocessed as follows:

- A branch with a tag identifying the *iSkim* category of the event has been added, implying also some preliminary cuts, different for each category. The 4 possible values of *iSkim* exhaust all the events.
- A branch with the weight of the **MC simulations** has been added.
- During a run the luminosity changes, and so the weight of an event is different, given the different amount of pile-up at the acquisition time. This demands for different levels of triggers to be considered: in our case the selection has already been applied.

ON TO THE PROJECT!