

## Rare decays at CMS

---

**Jónatan Piedra<sup>\*†</sup>**

*IFCA (CSIC - Universidad de Cantabria)*

*E-mail:* [piedra@cern.ch](mailto:piedra@cern.ch)

CMS searches for flavour changing neutral currents (FCNC) in events with top quarks and the Z or the Higgs boson are presented. Upper limits at 95% confidence level are set on the branching fractions of  $t \rightarrow qZ$  and  $t \rightarrow qH$  decays. In addition, angular distributions of  $B^0$  and  $B^+$  decays are presented. These measurements are found to be consistent with predictions based on the standard model.

*XIV International Conference on Heavy Quarks and Leptons (HQL2018)*

*May 27 - June 1, 2018*

*Yamagata Terrsa, Yamagata, Japan*

---

<sup>\*</sup>Speaker.

<sup>†</sup>On behalf of the CMS Collaboration.

## 1. Introduction

In the standard model (SM), flavour changing neutral currents (FCNC) are forbidden at tree level and highly suppressed at higher order. Several extensions of the SM enhance the FCNC branching fractions and can be probed at the LHC; the new couplings can also provide for flavour changing single top quark production in association with a Z or a Higgs boson.

## 2. FCNC in $tZq \rightarrow 3\ell$

This analysis [1] uses proton collision data coming from the 2016 data taking period, corresponding to an integrated luminosity of  $35.9 \text{ fb}^{-1}$  at a centre-of-mass energy of 13 TeV collected by the CMS detector. The analysis focusses on the experimental search for evidence of a FCNC vertex (referred to as  $tZq$ ) with a top quark, a Z boson, and a quark  $q$  that is either up or charm. In the final state we expect one jet originating from a  $b$  quark, a W boson, a Z boson, and (in the case of FCNC top quark decay) a jet originating from the up or charm quark. As we limit the analysis to leptonic decays of both the W and the Z boson, events are selected requiring exactly 3 leptons containing one opposite sign, same flavour pair; at least 1 jet and at most 3 jets; and the transverse mass of the W boson below 300 GeV. Four different

As can be seen in Figure 1. As can be seen in Figure 2.

## 3. FCNC in $tH \rightarrow b\bar{b}$

[2] 3 4 5

## 4. Angular observables in $B^+ \rightarrow K^+ \mu^+ \mu^-$

[3] 6 7 (top distributions).

## 5. Angular observables in $B^0 \rightarrow K^{*0} \mu^+ \mu^-$

[6]

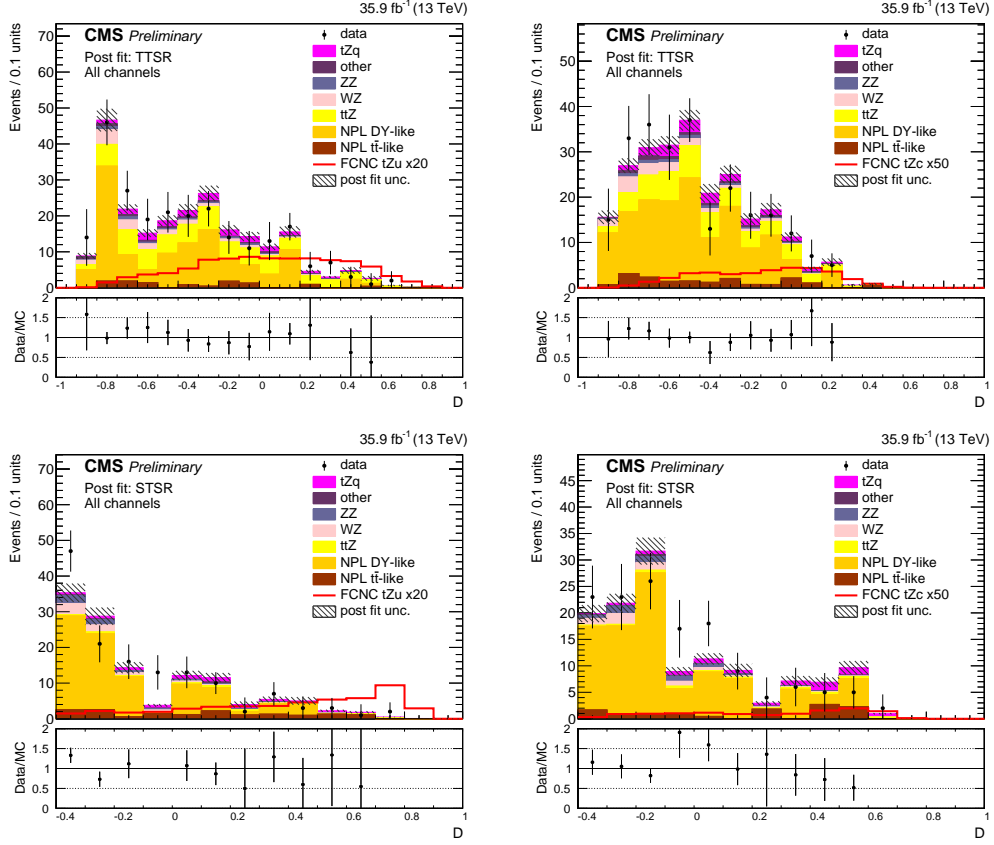
7 (bottom distributions).

## 6. Conclusions

To be filled.

## References

- [1] CMS Collaboration, *Search for flavour changing neutral currents in top quark production and decays with three-lepton final state using the data collected at  $\sqrt{s} = 13 \text{ TeV}$* , <https://cds.cern.ch/record/2292045>, CMS-PAS-TOP-17-017.
- [2] CMS Collaboration, *Search for the flavor-changing neutral current interaction of the top quark and the Higgs boson which decays into a pair of  $b$  quarks at  $\sqrt{s} = 13 \text{ TeV}$ , accepted for publication in JHEP* <https://cds.cern.ch/record/2296416>, CERN-EP-2017-309 [hep-ex/1712.02399].



**Figure 1:** The discriminating variable distribution after the fit for all different leptonic channels. Upper left: top quark pair tZu; upper right: top quark pair tZc; lower left: single top quark tZu; lower right: single top quark tZc.

[3] CMS Collaboration, *Angular analysis of the decay  $B^+ \rightarrow K^+ \mu^+ \mu^-$  at  $\sqrt{s} = 8$  TeV*, <https://cds.cern.ch/record/2621370> CERN-EP-2018-125 [hep-ex/1806.00636].

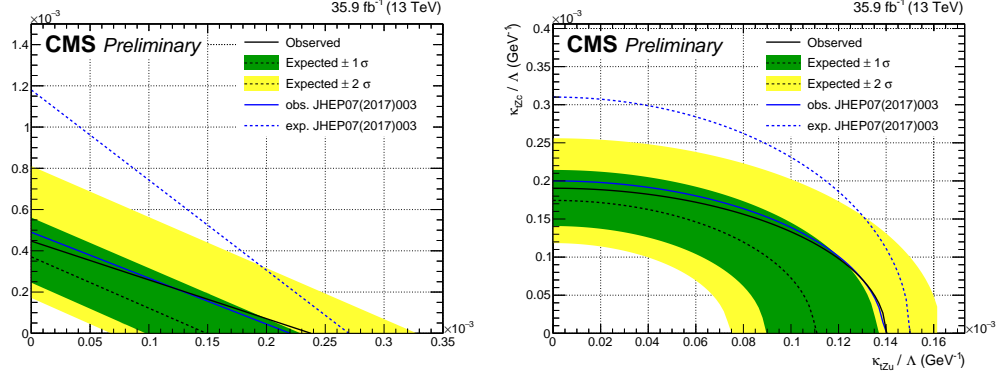
[4] To be filled.

[5] To be filled.

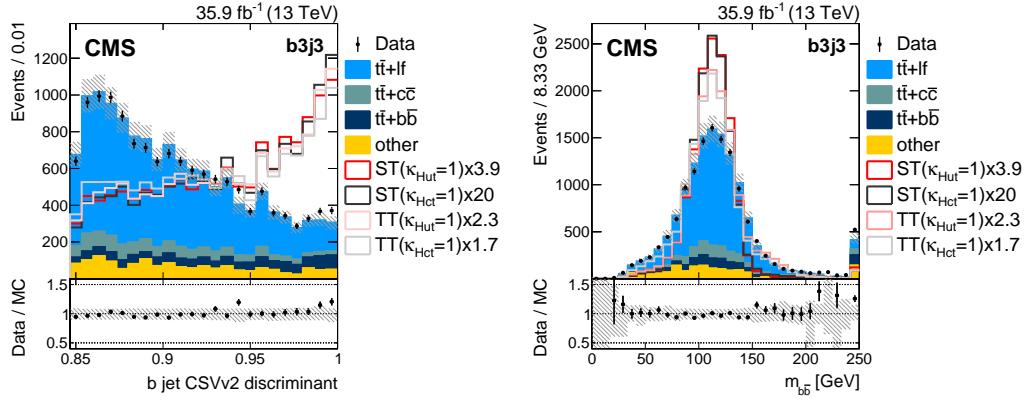
[6] CMS Collaboration, *Measurement of angular parameters from the decay  $B^0 \rightarrow K^{*0} \mu^+ \mu^-$  at  $\sqrt{s} = 8$  TeV*, <https://cds.cern.ch/record/2287571>, CERN-EP-2017-240 [hep-ex/1710.02846].

[7] To be filled.

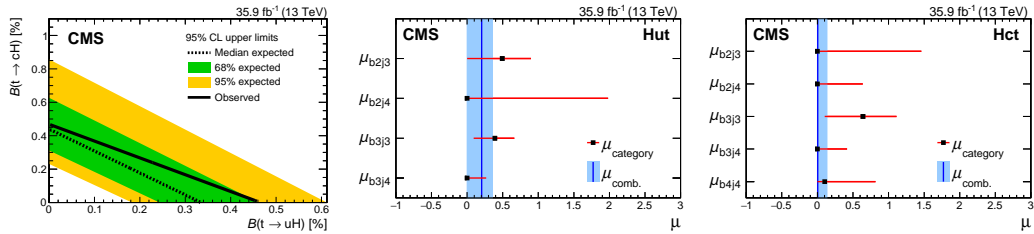
[8] To be filled.



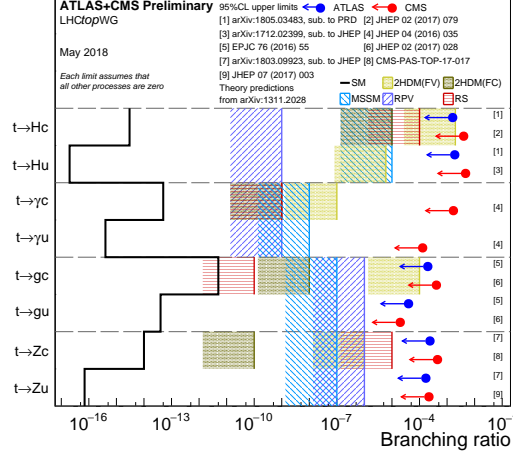
**Figure 2:** Exclusion regions at 95% CL on the FCNC branching fractions (left) and couplings (right) in the 2D plane of both the  $tZ_u$  and  $tZ_c$  variables. The CMS 8 TeV observed (expected) limit is given with a blue line (dashed line).



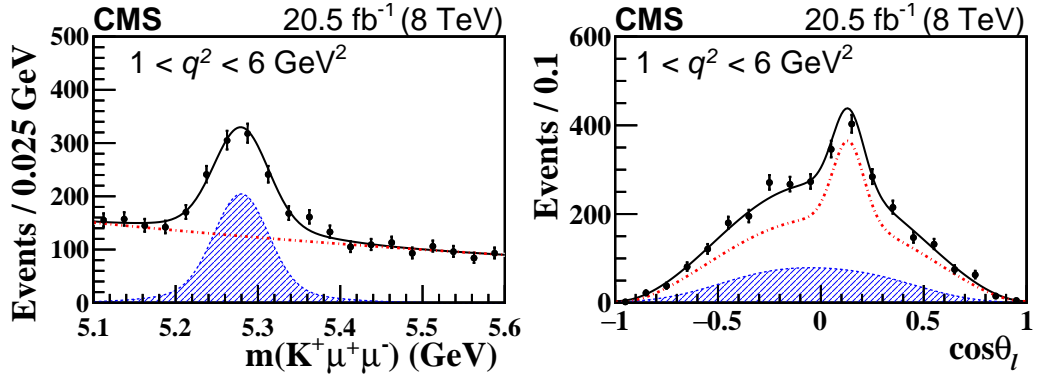
**Figure 3:** Comparison between data and simulation for some of the most discriminating BDT input variables in the category with three jets, all of them b-tagged: CSV discriminant value for one of the reconstructed b jets assigned to Higgs boson decay (left), and reconstructed invariant mass of two b jets associated with the Higgs boson decay (right).



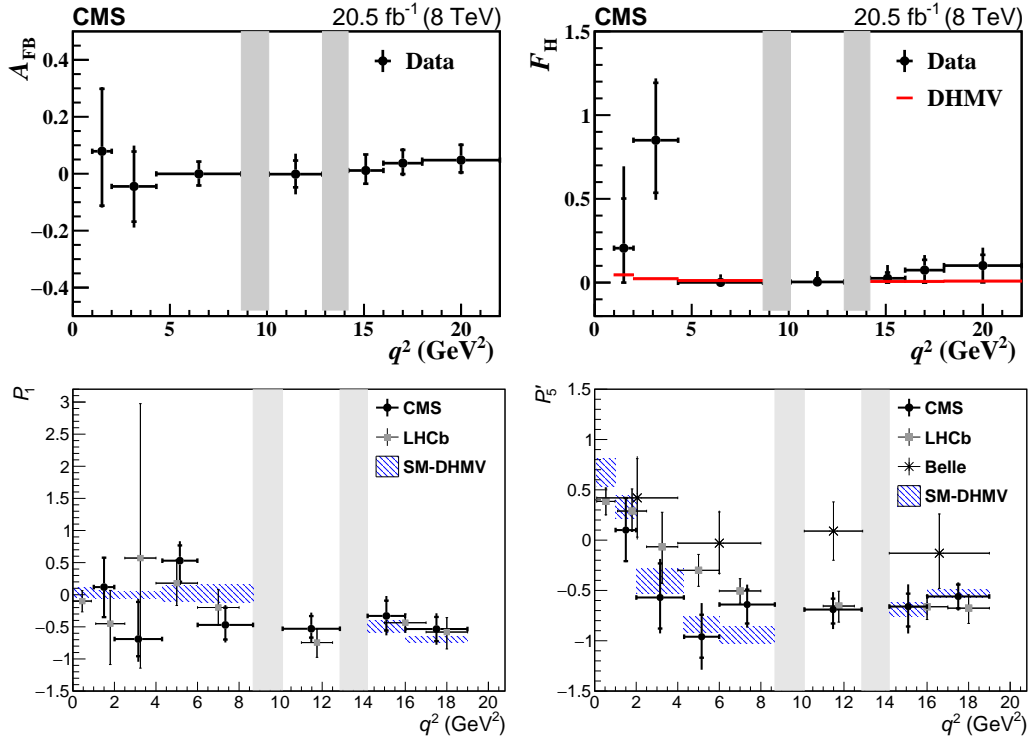
**Figure 4:** Upper limits on  $\mathcal{B}(t \rightarrow uH)$  and  $\mathcal{B}(t \rightarrow cH)$  at 95 % CL (left), and the best fit signal strength for Hut (center) and Hct (right), which is restricted to positive values in the fit.



**Figure 5:** Summary of the current 95% confidence level observed limits on the branching ratios of the top quark decays via flavour changing neutral currents to a quark and a neutral boson by the ATLAS and CMS Collaborations compared to several new physics models.



**Figure 6:** Projections of the  $K^+\mu^+\mu^-$  invariant mass distribution (left) and the  $\cos \theta_\ell$  distribution (right) from the two-dimensional fit of data, in the  $1 < q^2 < 6 \text{ GeV}^2$  range. The solid lines show the total fit, the shaded area the signal contribution, and the dash-dotted lines the background.



**Figure 7:** Measurements of the  $A_{FB}$  (top left) and  $F_H$  (top right) parameters versus  $q^2$  for  $B^+ \rightarrow K^+ \mu^+ \mu^-$  decays. Measurements of the  $P_1$  (bottom left) and  $P'_5$  (bottom right) angular parameters versus  $q^2$  for  $B^0 \rightarrow K^{*0} \mu^+ \mu^-$  decays. The CMS results are compared to SM DHMV theoretical predictions [4, 5] and, for the  $P_1$  and  $P'_5$  parameters, they are also compared to results from the LHCb [7] and Belle [8] Collaborations.