ATLAS EXPERIMENT

CMS

Universidade do Minho
Escola de Ciências

LIP
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

top-quark FCNC in production and decay processes

***Nuno Castro**, on behalf of the ATLAS and CMS collaborations*
nuno.castro@fisica.uminho.pt

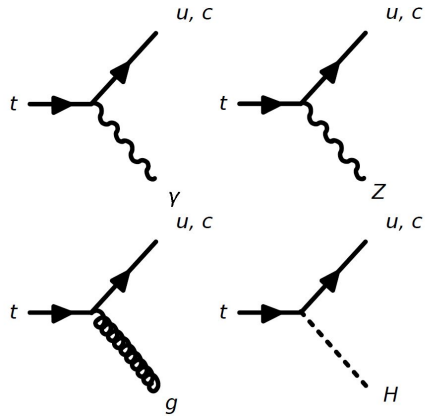
Top 2019 - International Workshop on Top Quark Physics
Beijing, 23rd September 2019

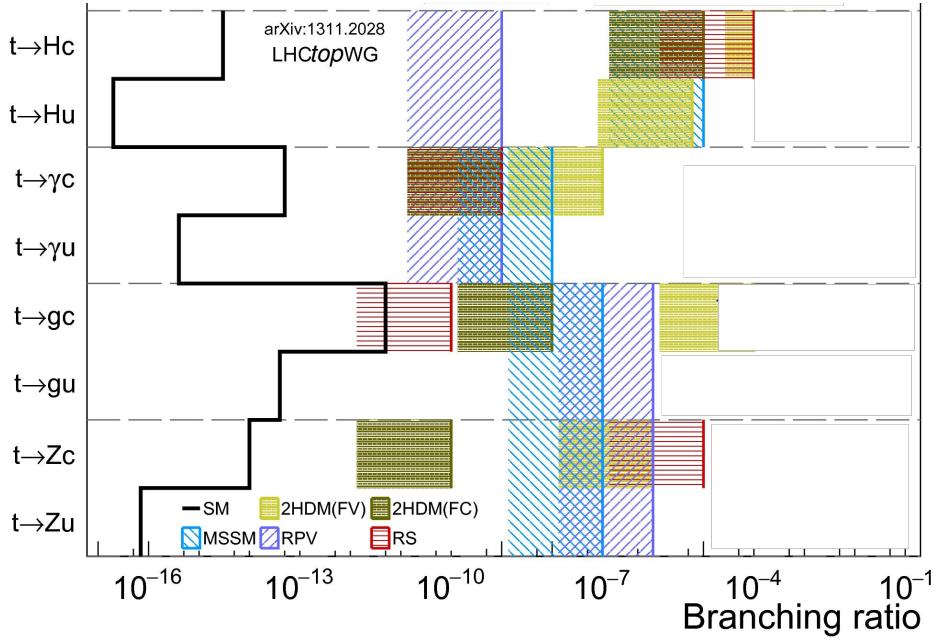
POCI/01-0145-FEDER-029147
PTDC/FIS-PAR/29147/2017

FCT Fundação para a Ciência e a Tecnologia
Lisb@20[20]
COMPETE 2020
PORTUGAL 2020
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

Flavour Changing Neutral Currents (FCNC) in the top-quark sector

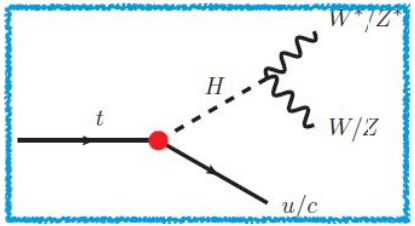
- **FCNC** in top-quark processes very rare in the SM
  - but significantly enhanced in BSM extensions



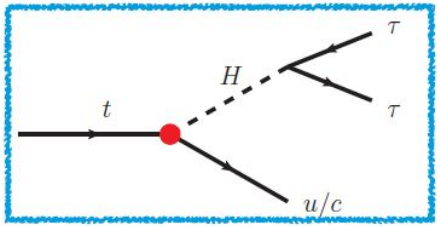


probing the *tqH* vertex

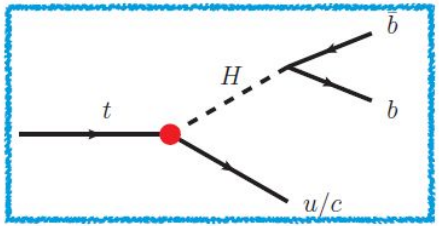
- many possible signatures, depending on the Higgs decay



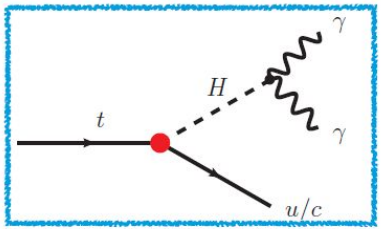
$H \to WW^*/ZZ^*$



$H \to \tau\tau$



$H \to b\bar{b}$

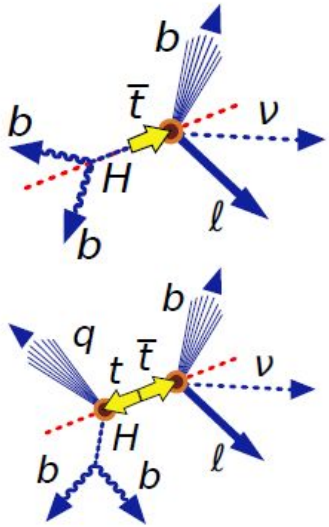


$H \to \gamma\gamma$

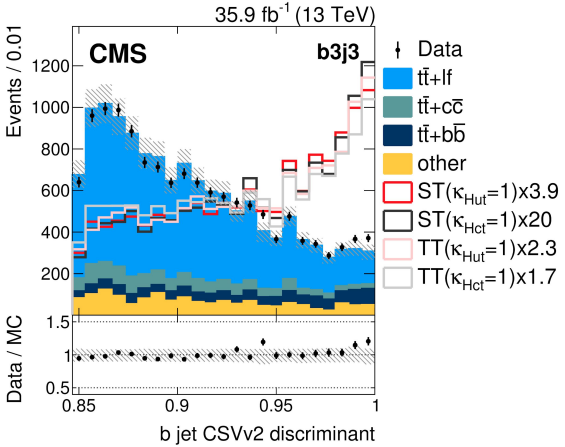
- dedicated analyses for each signature
  - both single top production - tH production via FCNC - and pair production of top quarks with t → qH FCNC decay considered
- combined interpretation performed by ATLAS

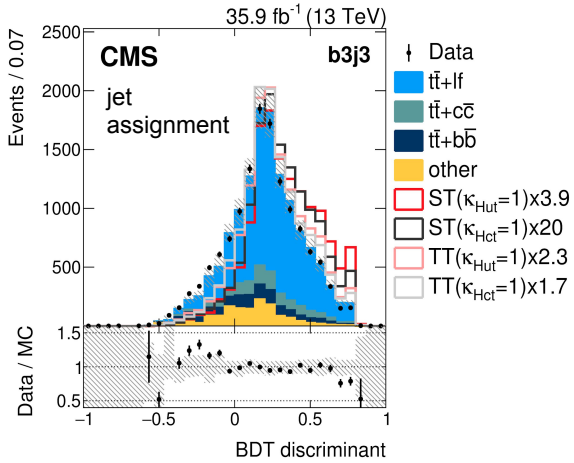
probing the *tqH* vertex ($H \rightarrow bb$)

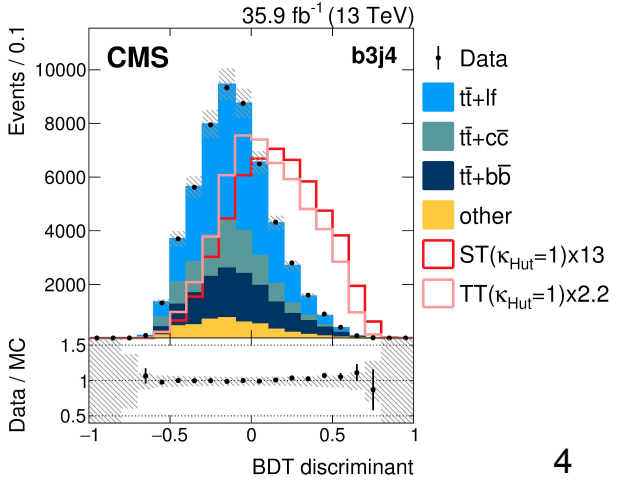
JHEP 06 (2018) 102
13 TeV, 35.9 fb^{-1}



- both single t (ST) and pair top production (TT) with an FCNC decay considered
  - different selections based on 1 lepton final states
  - 5 categories based on jet and b-jet multiplicities
  - event reconstruction based on a BDT
  - new BDT to discriminate signal from background

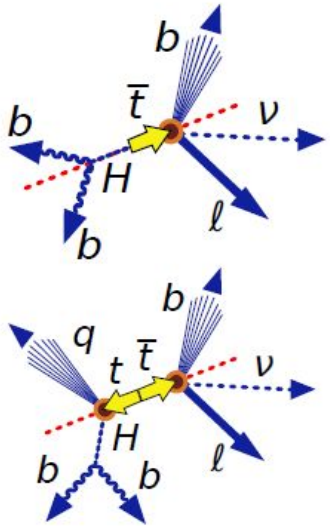




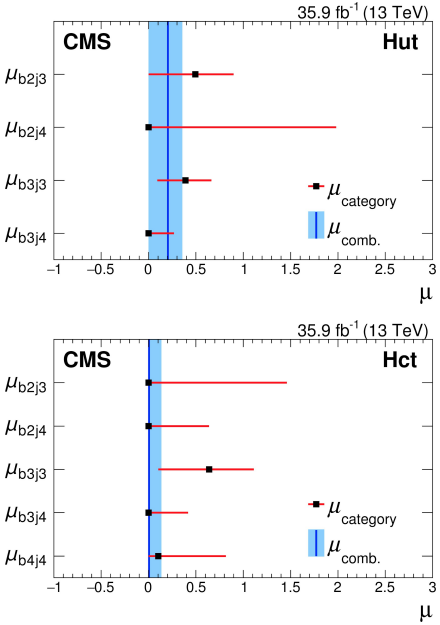


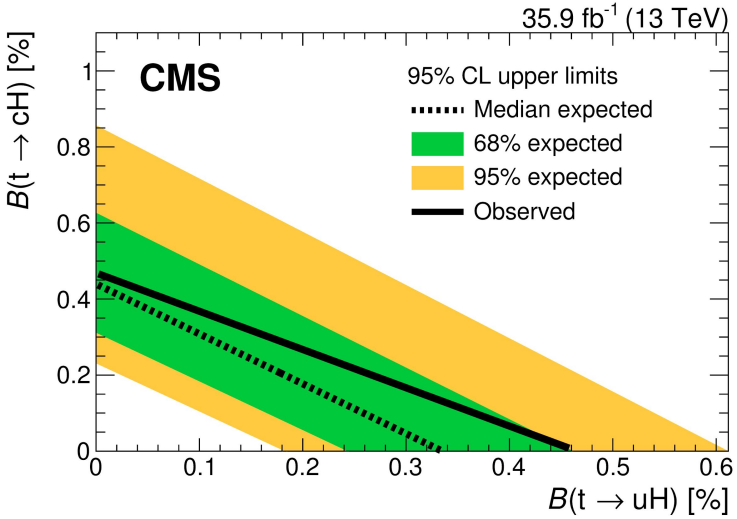
probing the *tqH* vertex ($H \to bb$)

JHEP 06 (2018) 102
13 TeV, 35.9 fb^{-1}



- main systematics: b-tagging uncertainties

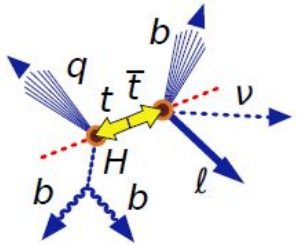




$\mathcal{B}(t \to Hu) < 4.7\ (3.4) \times 10^{-3}$
$\mathcal{B}(t \to Hc) < 4.7\ (4.4) \times 10^{-3}$

probing the *tqH* vertex ($H \to bb$)

JHEP 05 (2019) 123
13 TeV, 36.1 fb^{-1}

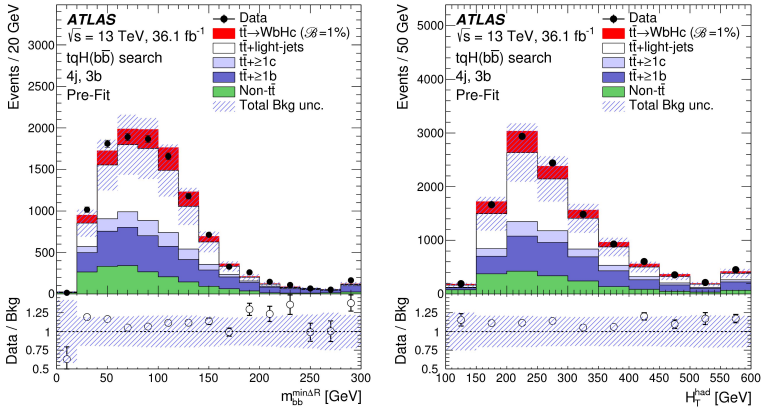


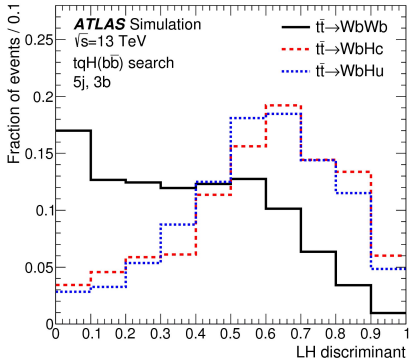
- 1 lepton channel with several jets and b-tagged jets mult. regions
- event selection using a likelihood ratio based on event kinematics

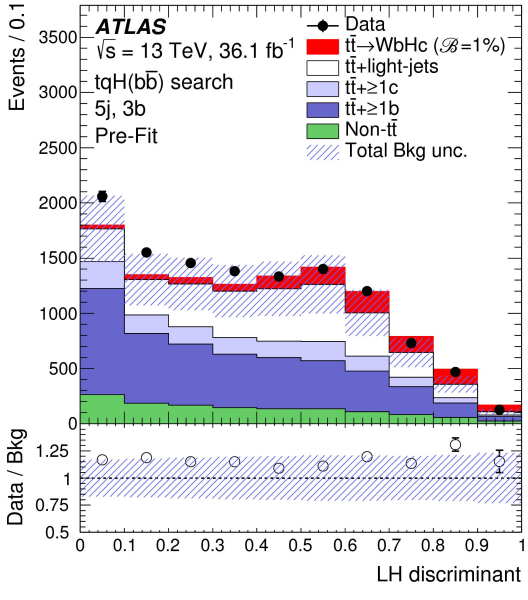
compatibility with signal

$$D(\mathbf{x}) = \frac{P^{\mathrm{sig}}(\mathbf{x})}{P^{\mathrm{sig}}(\mathbf{x}) + P^{\mathrm{bkg}}(\mathbf{x})}$$

compatibility with background

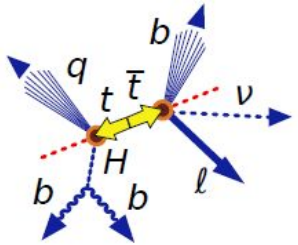




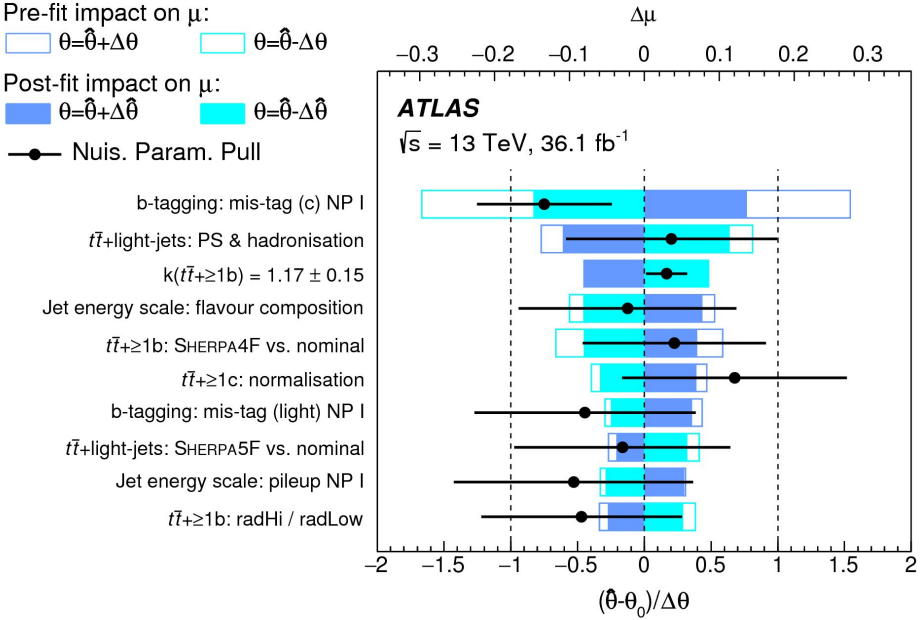


probing the *tqH* vertex ($H \to bb$)

JHEP 05 (2019) 123
13 TeV, 36.1 fb^{-1}



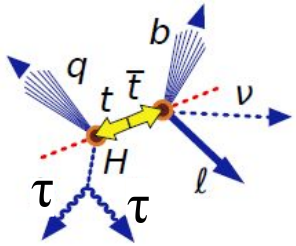
- main systematics: c-mistagging and $t\bar{t}$ + jets modelling



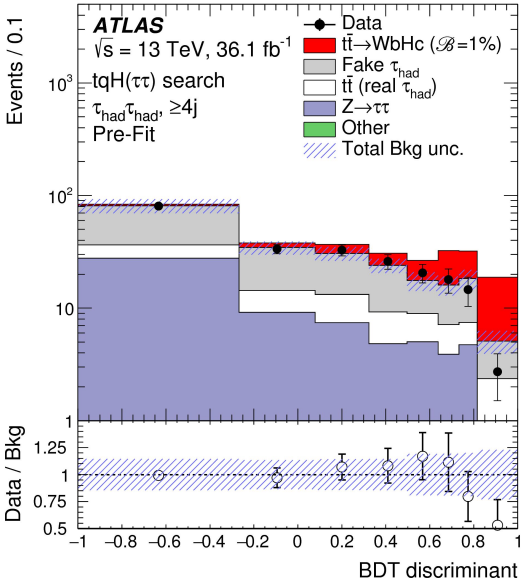
$$\mathcal{B}(t \to Hu) < 5.2\ (4.9) \times 10^{-3}$$
$$\mathcal{B}(t \to Hc) < 4.2\ (4.0) \times 10^{-3}$$

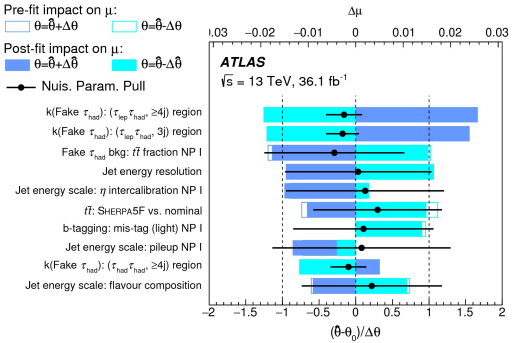
probing the *tqH* vertex ($H \to \tau\tau$)

JHEP 05 (2019) 123
13 TeV, 36.1 fb^{-1}



- 1 lepton and/or hadronic taus events
  - classify events based on N_{taus}
- main background from fake taus: data-driven estimate
- event reconstruction via a kinematic fit
- BDT used for signal vs bkg. discrimination
- main systematics: fake tau modelling



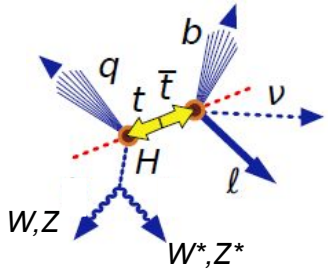


$$\mathcal{B}(t \to Hu) < 1.7\ (2.0) \times 10^{-3}$$

$$\mathcal{B}(t \to Hc) < 1.9\ (2.1) \times 10^{-3}$$

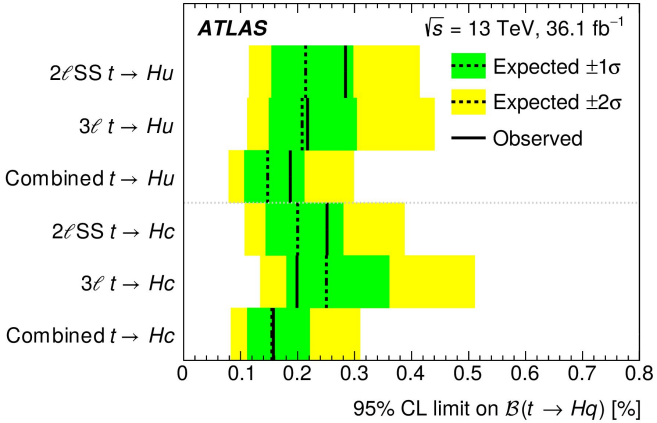
probing the *tqH* vertex ($H \to VV^*$)

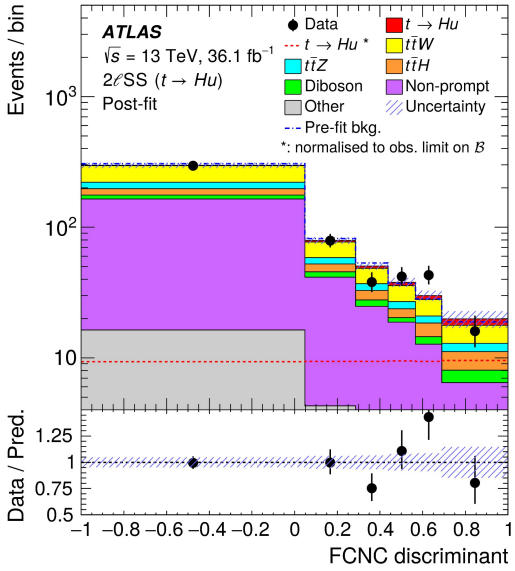
PRD 98 (2018) 032002
13 TeV, 36.1 fb^{-1}



- multilepton channel: 2 same-sign lep / 3 lep: very pure final state
- main backgrounds: $t\bar{t}W$ and non-prompt leptons
- event reconstruction: 2 combined BDTs (sig. vs non-prompt lep or $t\bar{t}W$)
- main systematics: bkg modelling (stat for DD bkg)

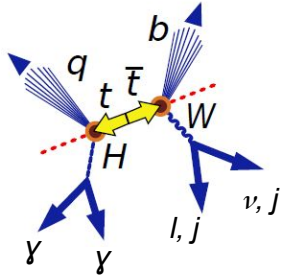
$$\mathcal{B}(t \to Hu) < 1.9(1.5) \times 10^{-3}$$
$$\mathcal{B}(t \to Hc) < 1.6(1.5) \times 10^{-3}$$





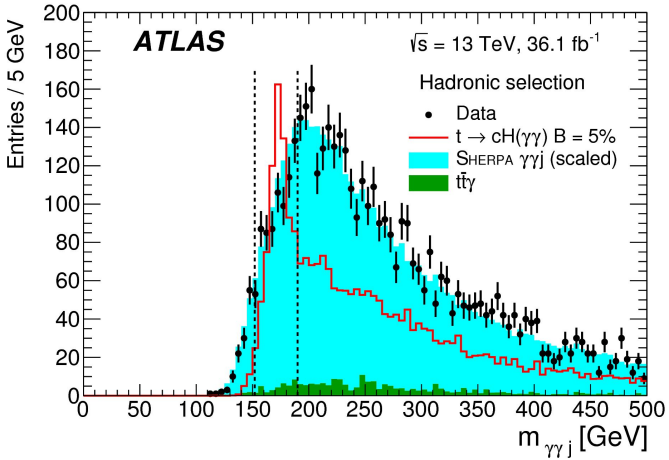
probing the *tqH* vertex ($H \to \gamma\gamma$)

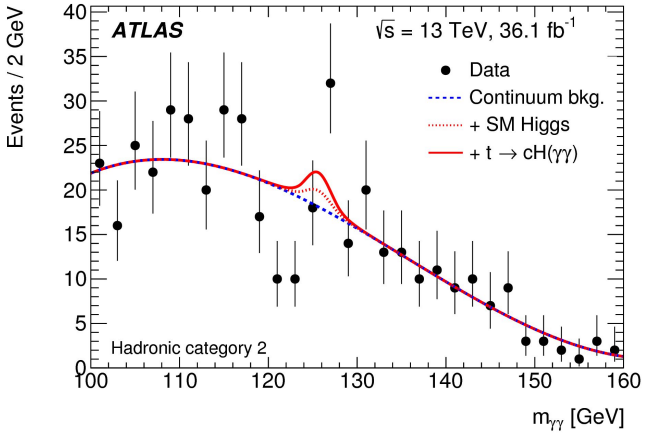
JHEP 10 (2017) 129
13 TeV, 36.1 fb^{-1}



- di-photon topology: both 1 lep and hadronic W decays considered
- main backgrounds: γγ j
- main systematics: JES, bkg modelling

$$\mathcal{B}(t \to \gamma u) < 2.4\,(1.7) \times 10^{-3}$$
$$\mathcal{B}(t \to \gamma c) < 2.2\,(1.6) \times 10^{-3}$$

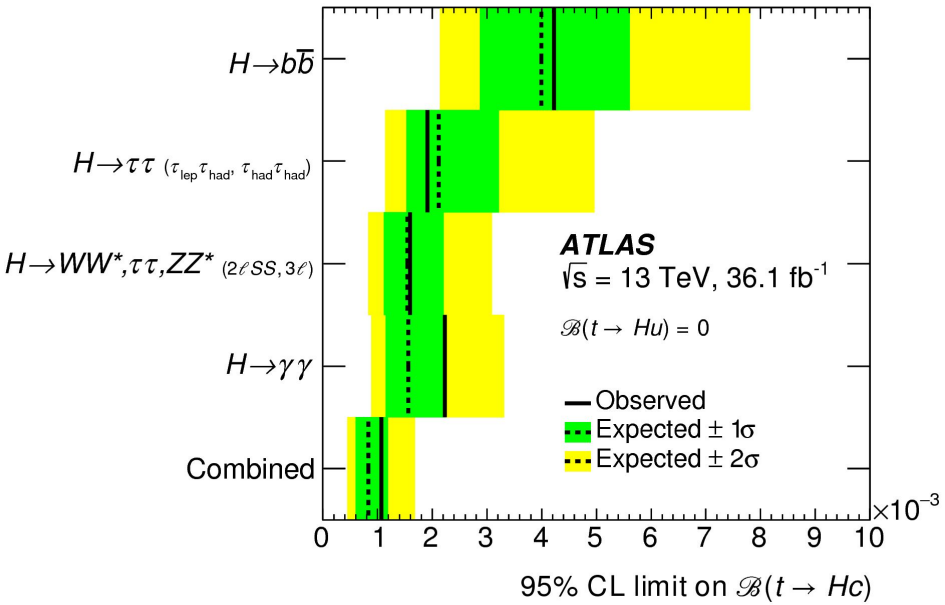


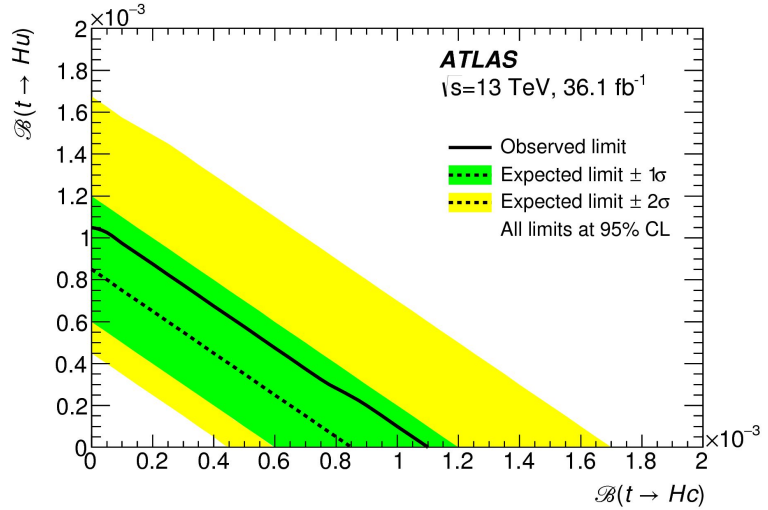


probing the *tqH* vertex ($H \to \gamma\gamma$)

JHEP 05 (2019) 123
13 TeV, 36.1 fb^{-1}

- ATLAS combination



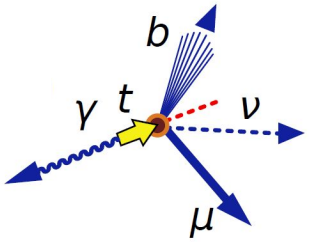


$$\mathcal{B}(t \to Hu) < 1.2\ (0.83) \times 10^{-3}$$

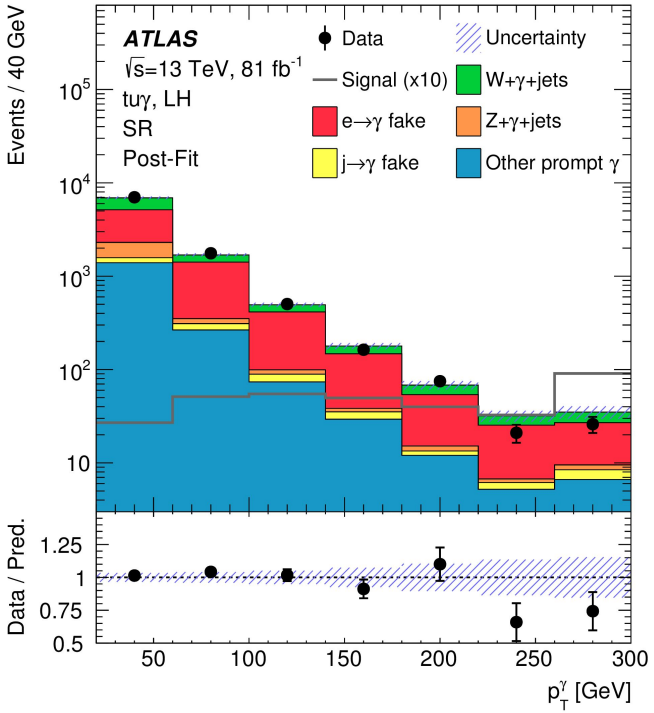
$$\mathcal{B}(t \to Hc) < 1.1\ (0.83) \times 10^{-3}$$

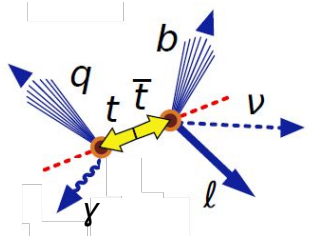
probing the *tqγ* vertex

arXiv:1908.08461
13 TeV, 81 fb^{-1}



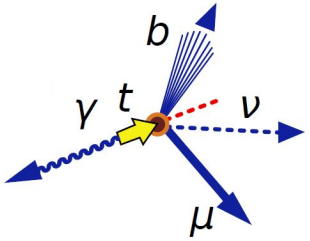
- both production and decay considered
  - production mode targeted (1 jet)
- photon + lep final state
- dominant bkg: e→ɣ fakes and prompt photons



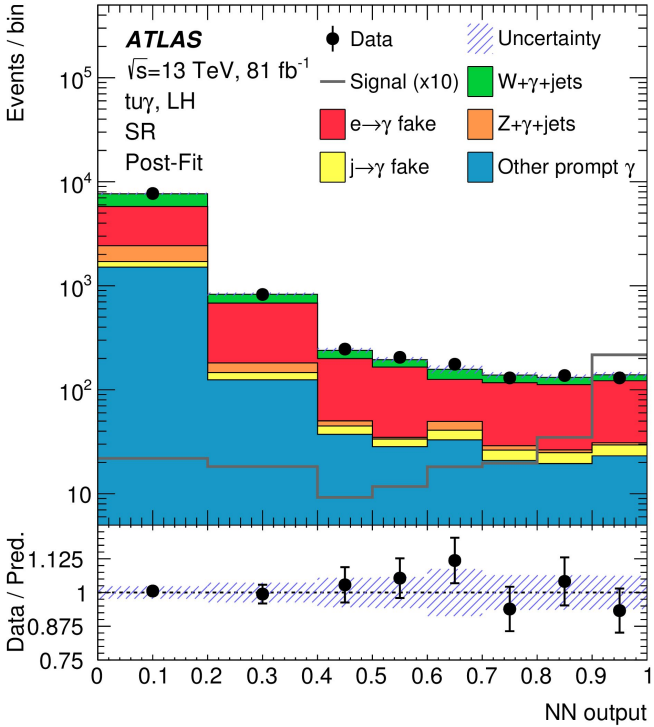


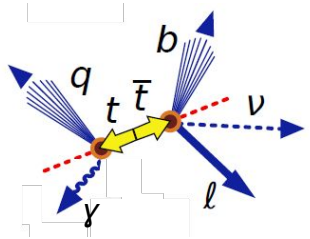
probing the *tqγ* vertex

arXiv:1908.08461
13 TeV, 81 fb^{-1}



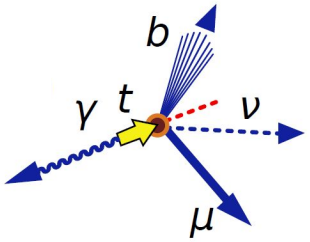
- both production and decay considered
  - production mode targeted (1 jet)
- photon + lep final state
- dominant bkg: e→γ fakes and prompt photons
- NN used for signal vs bkg discrimination

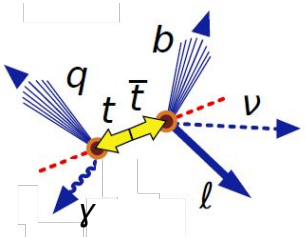


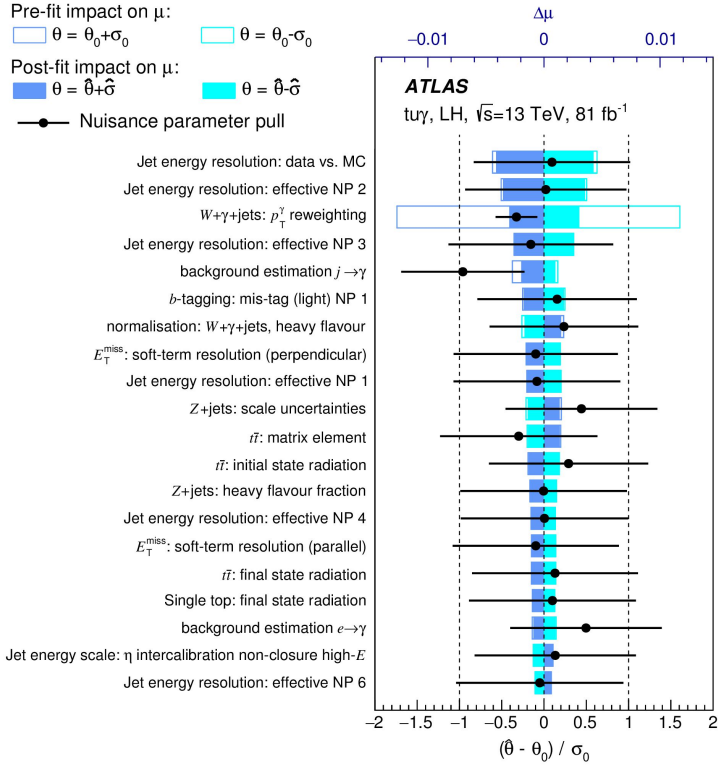


probing the *tqγ* vertex

arXiv:1908.08461
13 TeV, 81 fb^{-1}





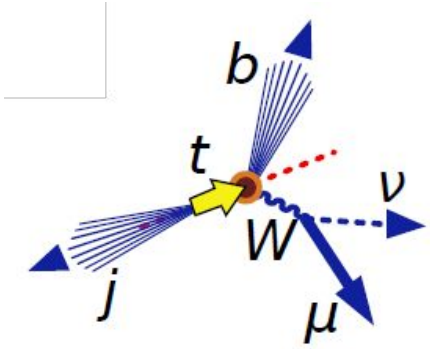


- dominant systematics:
  - JER and bkg modelling

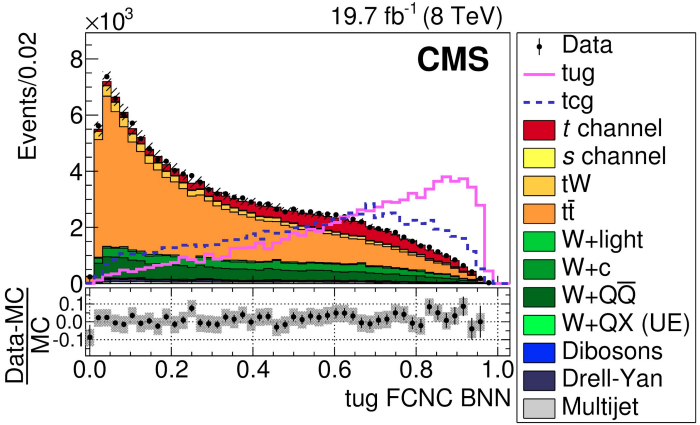
$\mathcal{B}(t \to q\gamma)\,[10^{-5}]$	$tu\gamma$	LH	2.8	$4.0^{+1.6}_{-1.1}$
$\mathcal{B}(t \to q\gamma)\,[10^{-5}]$	$tu\gamma$	RH	6.1	$5.9^{+2.4}_{-1.6}$
$\mathcal{B}(t \to q\gamma)\,[10^{-5}]$	$tc\gamma$	LH	22	27^{+11}_{-7}
$\mathcal{B}(t \to q\gamma)\,[10^{-5}]$	$tc\gamma$	RH	18	28^{+12}_{-8}

probing the *tqg* vertex

JHEP 02 (2017) 028
7+8 TeV, 5.0+19.7 fb^{-1}



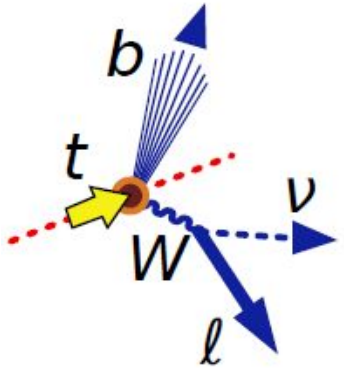
- t → gq decay is hard to search for, so top production via FCNC is the best option
- NNs used to reduce multijet background and discriminate signal
- dominant systematics: PDF and signal modelling



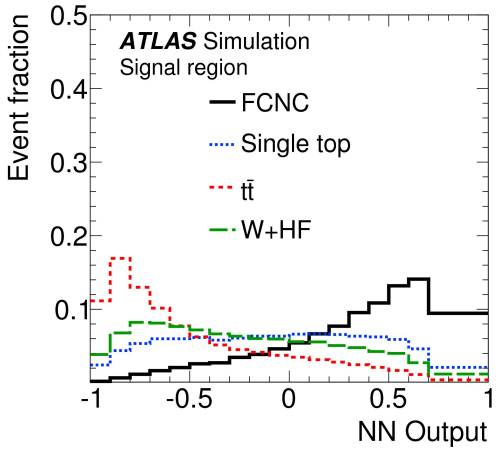
$$\mathcal{B}(t \to gu) < 2.0\,(2.8) \times 10^{-5}$$
$$\mathcal{B}(t \to gc) < 4.1\,(2.8) \times 10^{-4}$$

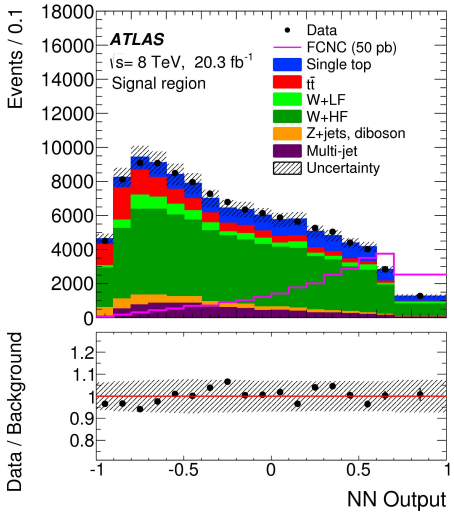
probing the *tqg* vertex

EPJC 76 (2016) 55
8 TeV, 20.3 fb^{-1}



- search for direct top production via FCNC
- NN used to discriminate signal from bkg
- dominant systematics: b-tag, E_T^{miss}, bkg modelling

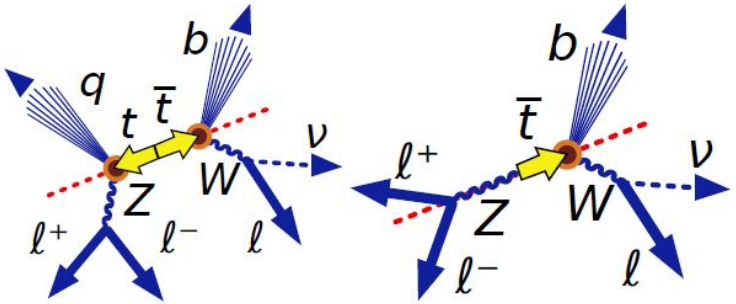




$$\mathcal{B}(t \to gu) < 4.0 \times 10^{-5}$$
$$\mathcal{B}(t \to gc) < 2.0 \times 10^{-4}$$

probing the *tqZ* vertex

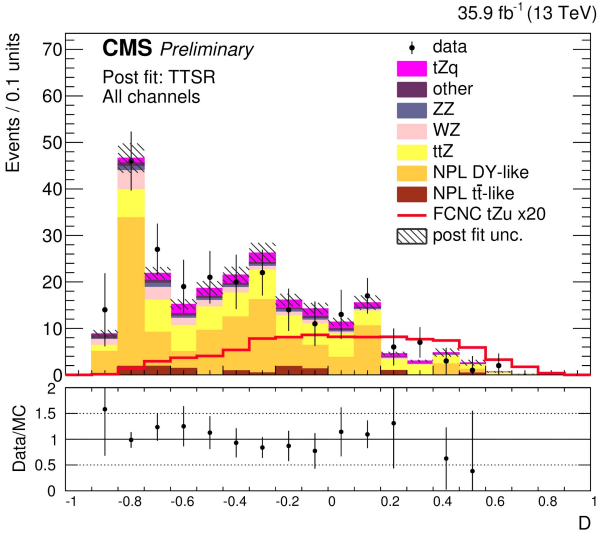
PAS-TOP-17-017
13 TeV, 35.9 fb^{-1}



- exploring both production and decay channels (3 lepton final state)
  - =1 b-tag for FCNC production
  - 2 or 3 jets (including ≥ 1 b-tag) for decay
- event reconstruction with a BDT
- main backgrounds: $t\bar{t}Z$ and non-prompt lep
- main systematics: non-prompt lep modelling

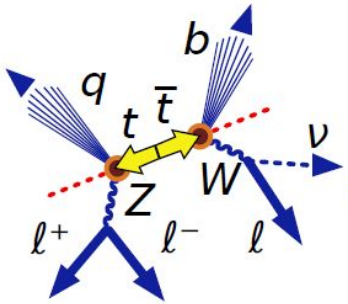
$$\mathcal{B}(t \to Zu) < 2.4\ (1.5) \times 10^{-4}$$

$$\mathcal{B}(t \to Zc) < 4.5\ (3.7) \times 10^{-4}$$



probing the *tqZ* vertex

JHEP 07 (2018) 176
13 TeV, 36.1 fb^{-1}



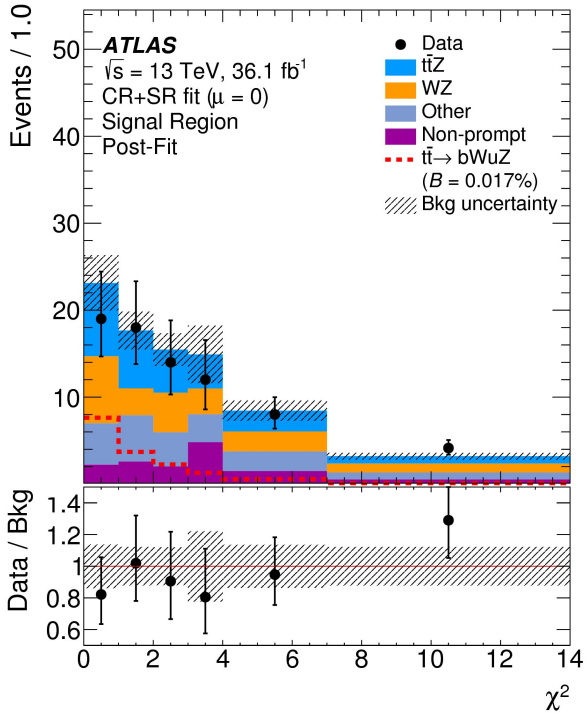
- considering top decay via FCNC
  - =1 b-tag
- event reconstruction via a χ^2 minimization

$$\chi^2 = \frac{\left(m^{\text{reco}}_{j_a\ell_a\ell_b} - m_{t_{\text{FCNC}}}\right)^2}{\sigma^2_{t_{\text{FCNC}}}} + \frac{\left(m^{\text{reco}}_{j_b\ell_c\nu} - m_{t_{\text{SM}}}\right)^2}{\sigma^2_{t_{\text{SM}}}} + \frac{\left(m^{\text{reco}}_{\ell_c\nu} - m_W\right)^2}{\sigma^2_W}$$

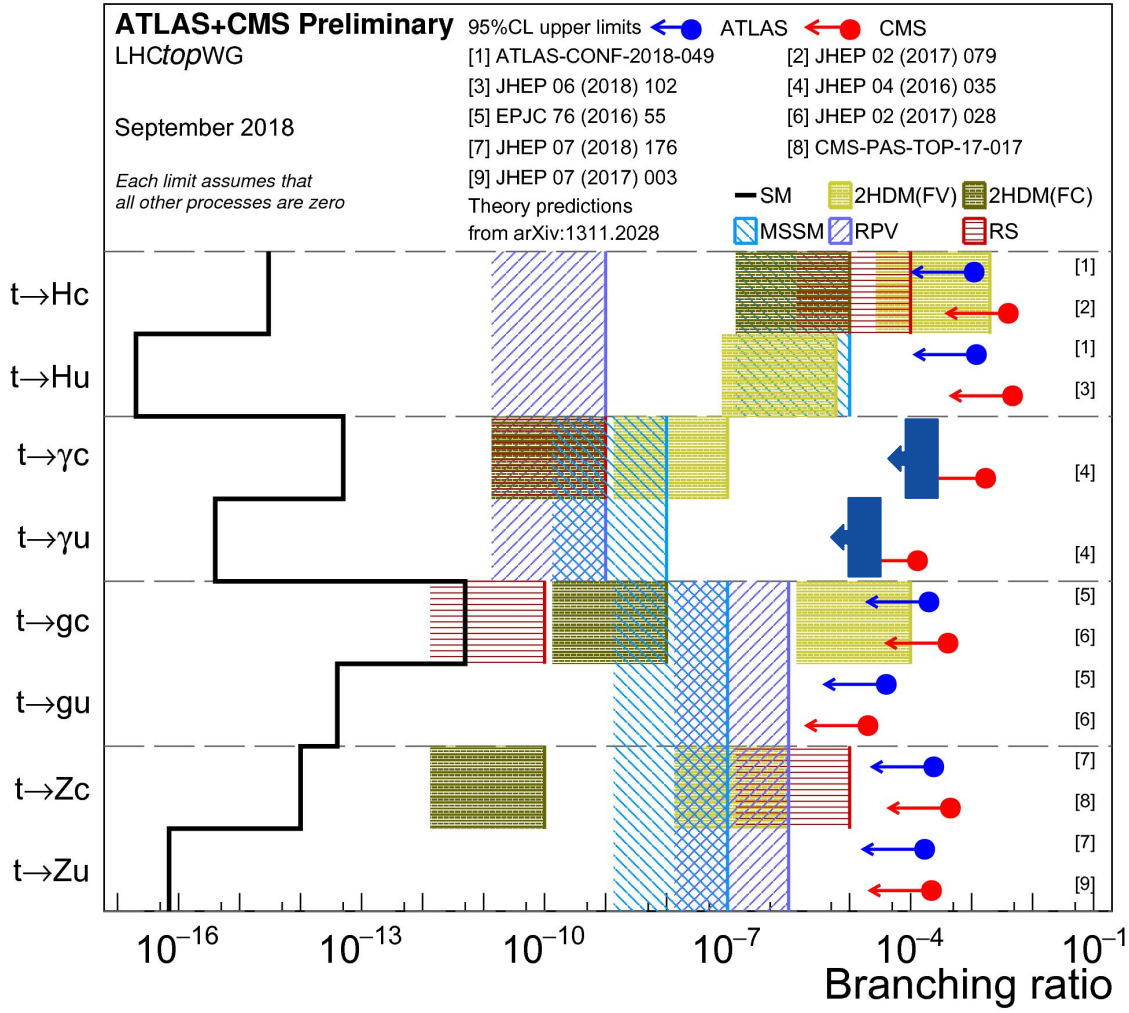
- main backgrounds: $t\bar{t}Z$ and WZ
- main systematics: background modelling

$$\mathcal{B}(t \to Zu) < 1.7\ (2.4) \times 10^{-4}$$

$$\mathcal{B}(t \to Zc) < 2.4\ (3.2) \times 10^{-4}$$



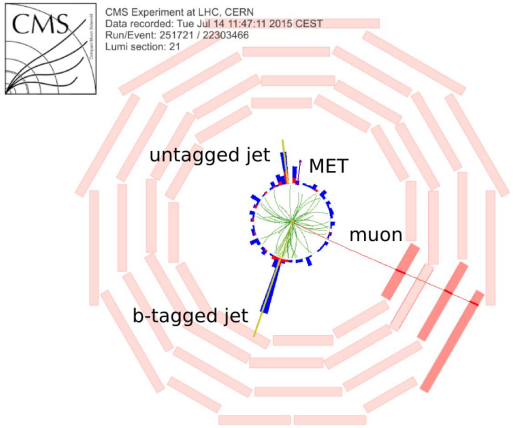
top FCNCs
summary plot

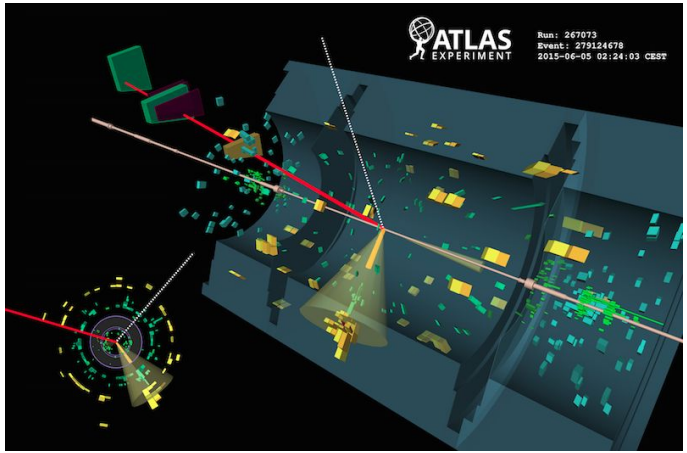


ATLAS tqɣ result shown in this talk

summary

- FCNCs in the top sector are:
  - a consistency test of the SM
  - a window to new physics
- Both ATLAS and CMS have a comprehensive search programme for top FCNCs
- Approaching the required sensitivity to probe some BSMs





Stay tuned for the next results !

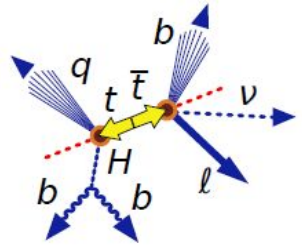
Thanks for your attention

Questions?

you can always reach me at nuno.castro@fisica.uminho.pt

probing the *tqH* vertex ($H \rightarrow bb$)

JHEP 05 (2019) 123
13 TeV, 36.1 fb^{-1}



- Post-fit plots (LH discriminant)