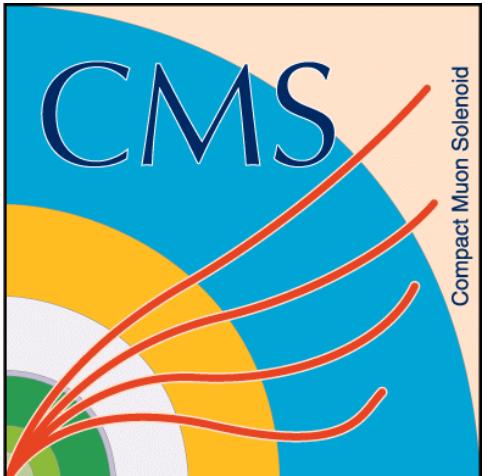


Search for monotop/top-FCNC events at the LHC

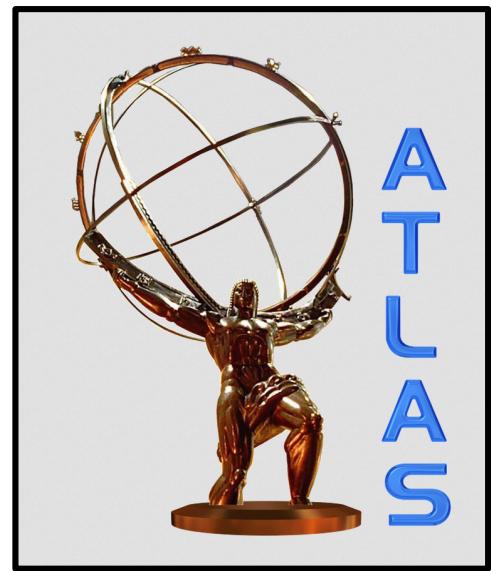
TOP-LHC France 2016



May 19th, 2016

Michaël Buttignol

IPHC/GRPHE – Strasbourg



Introduction

Monotop

top + MET (possibly DM candidate)

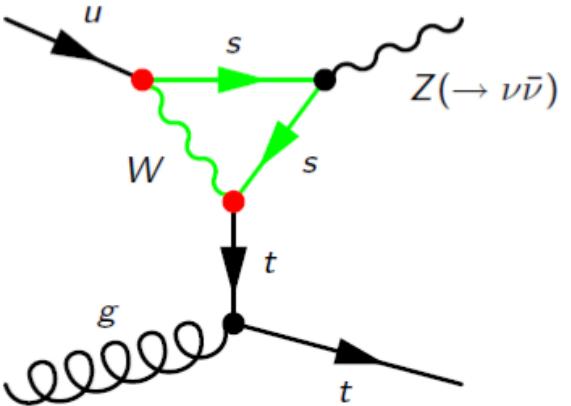
Top-FCNC

top + Z/ γ /H/g (anormal couplings)

- Effective theory approach : all possible production mechanisms in a single lagrangian

\Rightarrow model independent

- In the SM :



Top-FCNC (SM couplings and BSM expectations)

	SM	2HDM	MSSM	R SUSY
$t \rightarrow cZ$	1×10^{-14}	$\sim 10^{-7}$	2×10^{-6}	3×10^{-5}
$t \rightarrow c\gamma$	4.6×10^{-14}	$\sim 10^{-6}$	2×10^{-6}	1×10^{-6}
$t \rightarrow cg$	4.6×10^{-12}	$\sim 10^{-4}$	8×10^{-5}	2×10^{-4}
$t \rightarrow cH$	3×10^{-15}	1.5×10^{-3}	10^{-5}	$\sim 10^{-6}$

ref.

Loop + GIM-suppressed : observing monotop/top-FCNC at the LHC \Leftrightarrow BSM physics

- Models with same signature :

Monotop : RPV SUSY [1], leptoquarks [2], Z' model [3] ...
 Top-FCNC : RPV SUSY [4], technicolor [5], singlet quark [6], ...

- Outline : overview of the current CMS/ATLAS results on monotop/top-FCNC searches

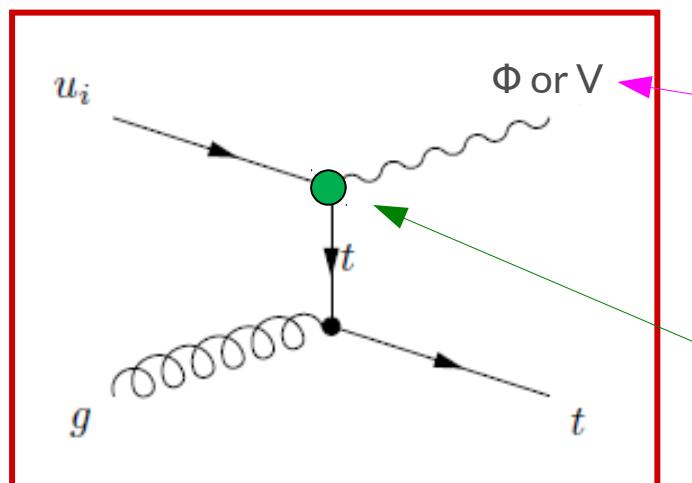
Searches for monotop events

Monotop production

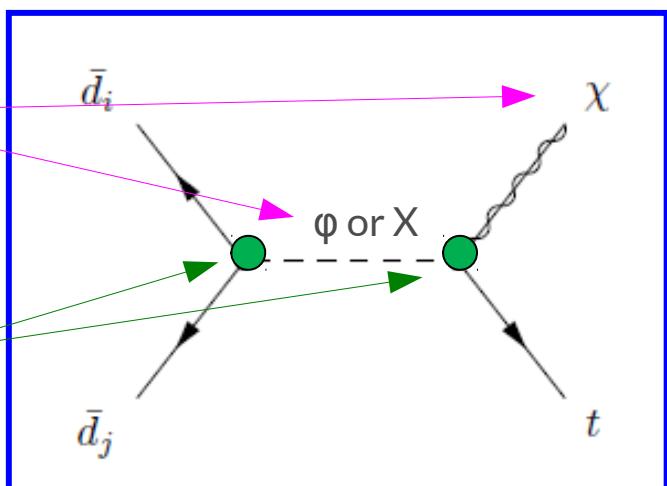
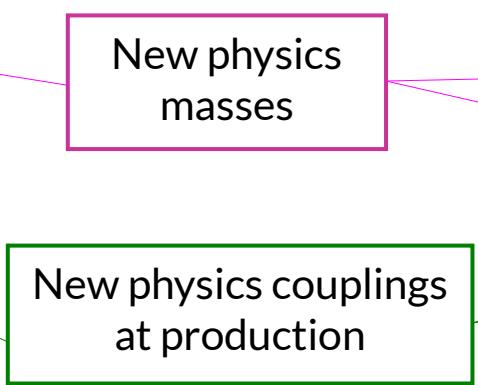
More about the model : [here](#)



- Monotop signature either produced via « **non-resonant** » (FCNC) or « **resonant** » diagrams:



Non-resonant



Resonant

$$\mathcal{L}_{\text{non-res}} = \phi \bar{t} [a^0 + b^0 \gamma_5] u_i + V_\mu \bar{t} \gamma^\mu [a^1 + b^1 \gamma_5] u_i$$

$$\begin{aligned} \mathcal{L}_{\text{res}} = & \varphi \bar{d}_i^c [a^q + b^q \gamma_5] \bar{d}_j + \varphi t [a^{1/2} + b^{1/2} \gamma_5] \chi \\ & + X_\mu \bar{d}_i^c \gamma^\mu [a^q + b^q \gamma_5] \bar{d}_j + X_\mu t \gamma_\mu [a^{1/2} + b^{1/2} \gamma_5] \chi \end{aligned}$$

- Spin 0 or 1 missing energy (possibly **DM** candidate).
- A lot of **free parameters** (**masses**, **couplings**).

- Spin 0 or 1 mediator.
- Spin 1/2 missing energy (possibly **DM** candidate).
- A lot of **free parameters** (**masses**, **couplings**).

Simplified models (1)

Non-resonant

$$\mathcal{L}_{\text{non-res}} = \phi \bar{t} [a^0 + b^0 \gamma_5] u_i + V_\mu \bar{t} \gamma^\mu [a^1 + b^1 \gamma_5] u_i$$

8 TeV

ATLAS

Leptonic channel : Eur. Phys. J. C 75 (2015) 79

- Only spin-1 invisible particles.
- Only couplings to right-handed quarks ($a=b=0.2$).

CMS

Hadronic channel : Phys. Rev. Lett. 114 (2015) 101801

- Both spin-0 and spin-1 invisible particles.
- No pseudo-scalar nor axial couplings ($a=0.1, b=0$).

8 TeV

Leptonic channel : Public results

8 TeV

- Only spin-1 invisible particles.
- Only couplings to right-handed quarks ($a=b=0.1$).

→ Only 2 free parameters per model (coupling a , mass m_ν or m_ϕ)

Range of production :

- Fixing $a=0.2$, scanning invisible masses from 0 to 1 TeV.
- Fixing $a=0.1$, scanning invisible masses from 0 to 1 TeV.

Simplified models (2)



Resonant

$$\begin{aligned}\mathcal{L}_{\text{res}} = & \varphi \bar{d}_i^c [a^q + b^q \gamma_5] \bar{d}_j + \varphi t [a^{1/2} + b^{1/2} \gamma_5] \chi \\ & + X_\mu \bar{d}_i^c \gamma^\mu [a^q + b^q \gamma_5] \bar{d}_j + X_\mu t \gamma_\mu [a^{1/2} + b^{1/2} \gamma_5] \chi\end{aligned}$$

8 TeV

ATLAS

CMS

8 TeV

Leptonic channel : Eur. Phys. J. C 75 (2015) 79

- Only spin-0 mediator.
- Only couplings to right-handed quarks ($a=b=0.2$).
- Consider the two couplings equal ($a^q = a^{1/2}$).
- Consider resonance width can vary with coupling.

Leptonic channel : Public results

- Only spin-0 mediator.
- Only couplings to right-handed quarks ($a=b=0.1$).
- Consider $\text{BR}(S \rightarrow t \chi) = 100\%$.
- Assume fixed width (NWA).

→ Only 3 free parameters per model (coupling a , masses m_ϕ and m_χ).

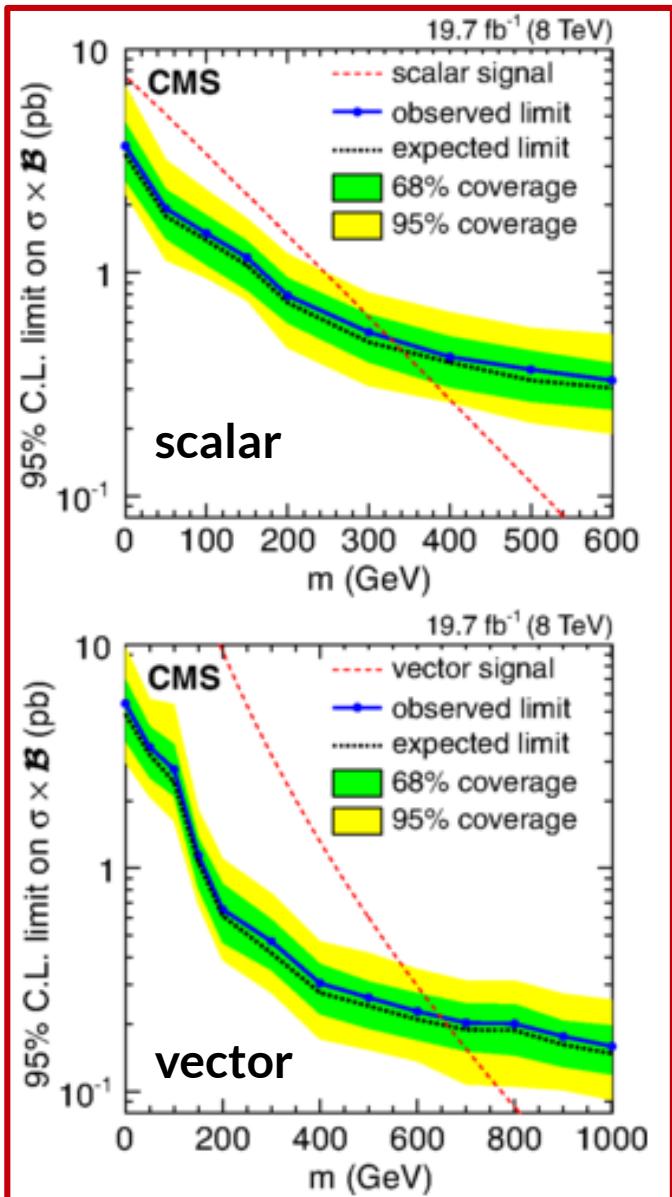
Range of production :

- Fixing $a = 0.2$ and $m_\phi = 500 \text{ GeV}$, scanning invisible masses m_χ from 0 to 100 GeV.
- Fixing $m_\chi = 100 \text{ GeV}$ and $m_\phi = 500 \text{ GeV}$, with $a=0.5$ and $a=1.0$.
- Fixing $a = 0.1$, scanning m_ϕ from 500 to 2100 GeV with invisible masses m_χ from 10 to 200 GeV.

Strategy

- Final state : bjj + MET
- Main backgrounds : $Z \rightarrow vv + \text{jets}$, $W \rightarrow lv + \text{jets}$
- Trigger : MET > 150 GeV
- Possible top-quark reconstruction
- Selection : 3j1b, MET > 350 GeV, $m_T(\text{bjj}) < 250$ GeV
- Strategy : Cut&Count
- Results : no excess observed $\rightarrow 95\% \text{ CL limits}$
 - $m(\text{scalar}) < 330 \text{ GeV}$ excluded
 - $m(\text{vector}) < 650 \text{ GeV}$ excluded

Non-resonant

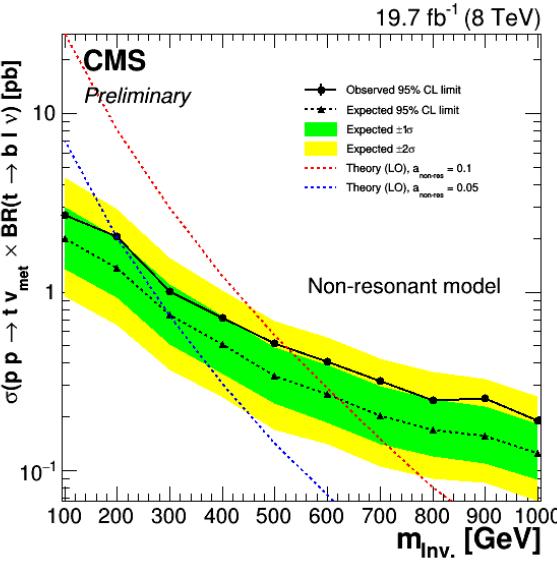




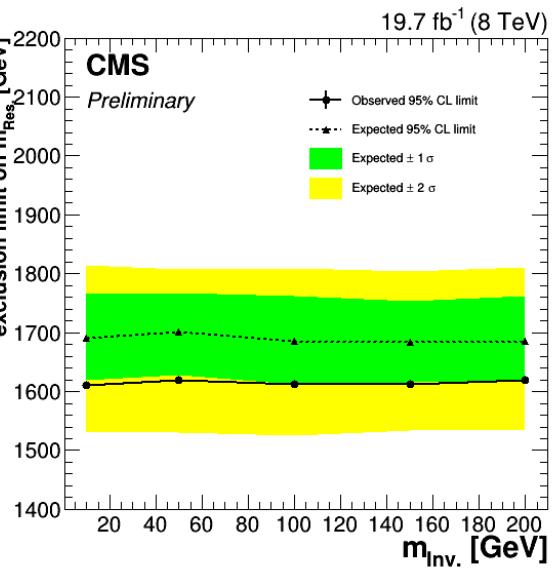
Strategy

- **Final state :** $b + \mu + \text{MET}$
- **Main backgrounds :** $t\bar{t} \rightarrow b\bar{b}\nu\bar{\nu}$, $t\bar{t} \rightarrow b\bar{b}\nu\bar{\nu}$, $W \rightarrow l\nu + \text{jets}$
- **Trigger :** single muon
- **Selection :** 1j1b, $\text{MET} > 100 \text{ GeV}$, $p_T(b) > 70 \text{ GeV}$,
 $m_T(W) > 40 \text{ GeV}$, $p_T(W) > 50 \text{ GeV}$, $|\Delta\phi(\mu-b)| < 1.7$
- **Strategy :** $m_T(W)$ shape analysis
- **Results :** no excess observed $\rightarrow 95\% \text{ CL limits}$
with $a = 0.1$
 - **$m(\text{vector}) < 523 \text{ GeV excluded}$**
 - **$m(\text{scalar mediator}) < 1610 \text{ GeV excluded}$**
when $10 \text{ GeV} < m(\text{fermionic}) < 200 \text{ GeV}$

Non-resonant



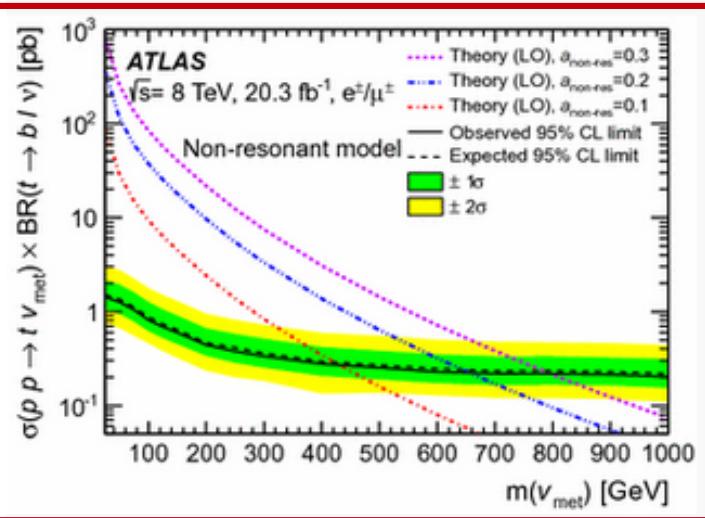
Resonant



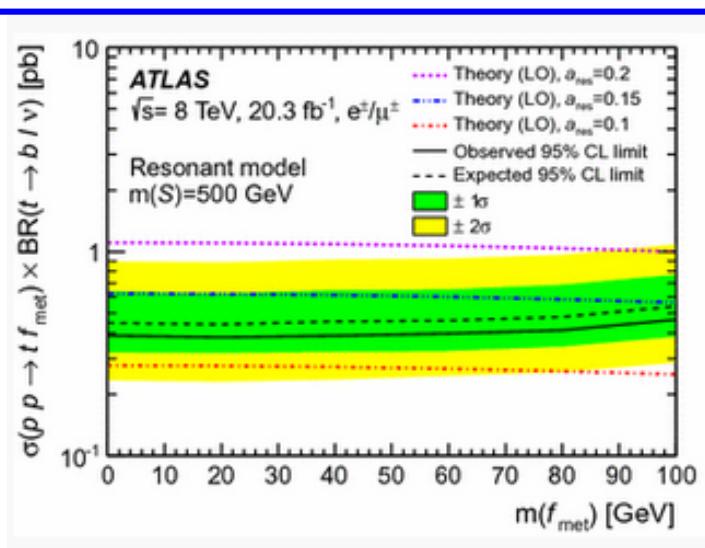
Strategy

- Final state : $b + l + \text{MET}$
- Main backgrounds : $t\bar{t} \rightarrow b\bar{b}\nu\bar{\nu}$, $W \rightarrow l\nu + \text{jets}$
- Trigger : single lepton
- Selection : 1j1b, $\text{MET} > 35 \text{ GeV}$, $m_T(W) + \text{MET} > 60 \text{ GeV}$
 - **non-res** : $m_T(W) > 250 \text{ GeV}$, $|\Delta\phi(l-b)| < 1.4$
 - **res** : $m_T(W) > 210 \text{ GeV}$, $|\Delta\phi(l-b)| < 1.2$
- Strategy : Cut&Count
- Results : no excess observed $\rightarrow 95\% \text{ CL limits}$
 - $m(\text{vector}) < 657 \text{ GeV}$ excluded with $a = 0.2$
 - $a = 0.15$ excluded for $m(\text{scalar mediator}) < 500 \text{ GeV}$ and $m(\text{fermionic}) < 100 \text{ GeV}$

Non-resonant



Resonant

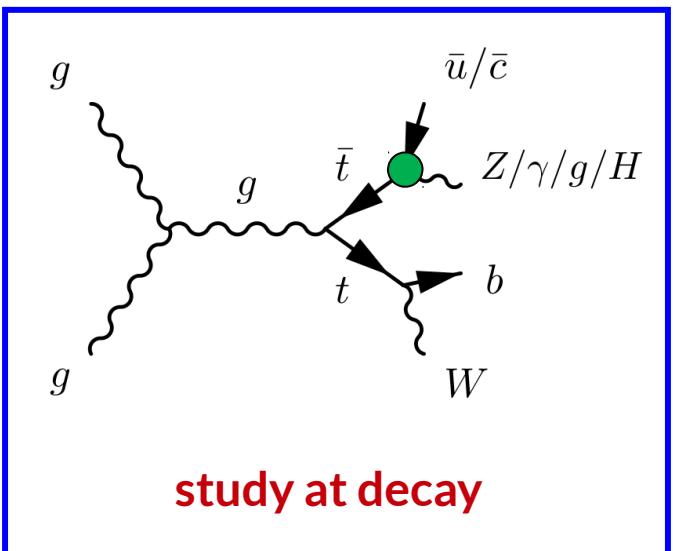
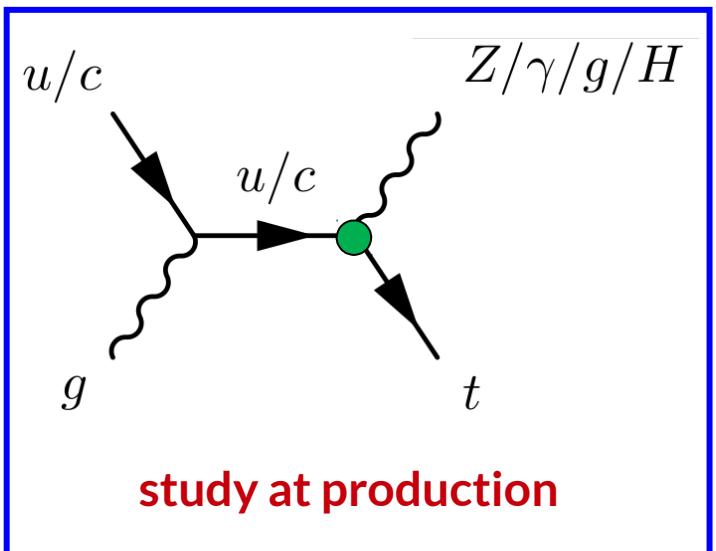


Searches for top-FCNC events

Top-FCNC production

- Goal: measure the $t \rightarrow u/c + Z/\gamma/H/g$ branching ratios to probe **anomalous couplings** not predicted ($O(10^{-14})$) by SM.

- Diagrams:

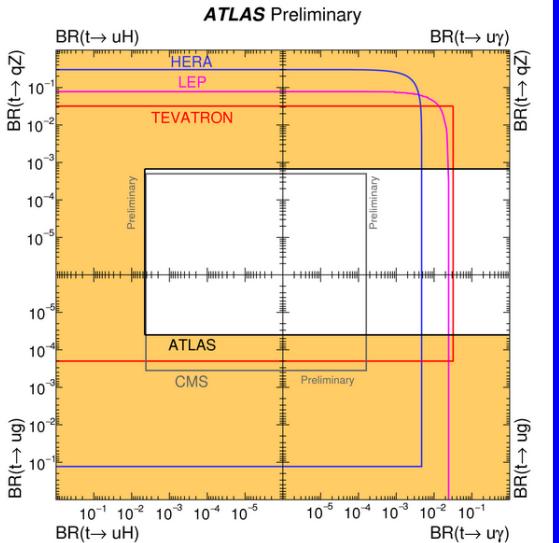


- Searches: already almost all channels have a measurement at 8 TeV with both CMS/ATLAS.
- Warning: each analysis is done under the assumption that all the couplings are independent. But this is not completely true because for example tZq coupling is correlated to $t\gamma q$ one.

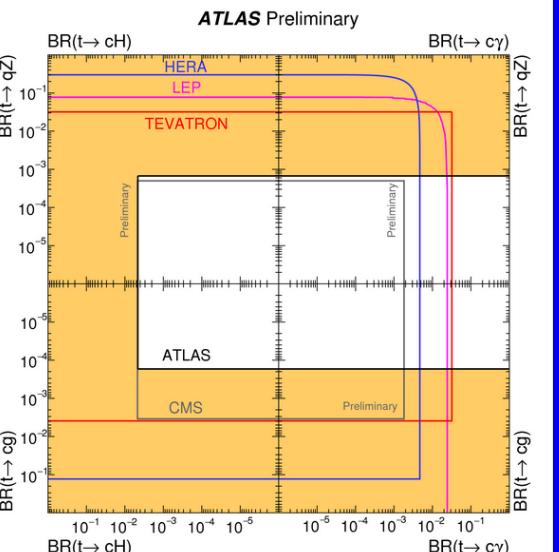
8 TeV searches

ATLAS

$t \rightarrow u + Z/\gamma/H/g$



$t \rightarrow c + Z/\gamma/H/g$



CMS

CMS Preliminary, 8 TeV

March 2016

Phys.Rev.Lett 112 (2014) 171802

$t\bar{t}$, $Br(t \rightarrow Z q)$

+ tZ -FCNC soon-to-be public

JHEP04(2016)035

single top, $Br(t \rightarrow \gamma u)$

single top, $Br(t \rightarrow \gamma c)$

CMS PAS TOP-13-017

$t\bar{t}$, $Br(t \rightarrow H c)$, $H \rightarrow WW, ZZ, \tau\tau$

CMS PAS TOP-14-020

$t\bar{t}$, $Br(t \rightarrow H u)$, $H \rightarrow b\bar{b}$

$t\bar{t}$, $Br(t \rightarrow H c)$, $H \rightarrow b\bar{b}$

CMS PAS TOP-14-019

$t\bar{t}$, $Br(t \rightarrow H u)$, $H \rightarrow \gamma\gamma$

$t\bar{t}$, $Br(t \rightarrow H c)$, $H \rightarrow \gamma\gamma$

..... 95% CL Observed Limit ±1σ Exp. Limit
— 95% CL Expected Limit ±2σ Exp. Limit

0^-4 10^-3 10^-2 10^-1 1
Top decay Br (%)

Conclusions

- **Monotop :**
 - **8 TeV** searches for resonant/non-resonant monotop events (leptonic or hadronic) have been done by ATLAS/CMS.
 - **13 TeV** searches are already ongoing and about to be public.
- **Top-FCNC :**
 - **8 TeV** anomalous couplings to top-quark have been measured by ATLAS/CMS.
 - **13 TeV** ongoing work to improve limits on such couplings.
- Many **french teams involved** on these more and more interesting topics.

Back up
