



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



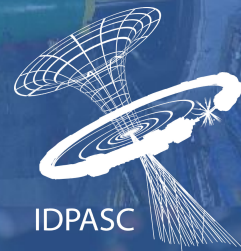
# Search for FCNC $tZq$ at 13 TeV

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**FCT** Fundação  
para a Ciência  
e a Tecnologia

**Lisb@20<sup>20</sup>**

**COMPETE  
2020**

**PORTUGAL  
2020**

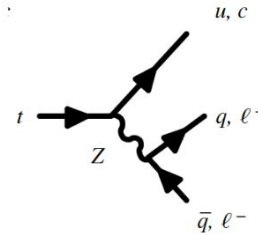
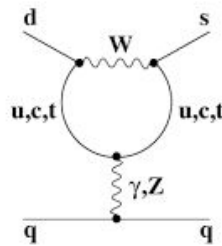


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# Motivation

## Flavor Changing Neutral Currents

- **Flavor Changing Neutral Currents (FCNC)** processes are much suppressed in the Standard Model (SM) (left)
- Many types of **New Physics (NP) models** lead to FCNC, often at **tree level** (right)



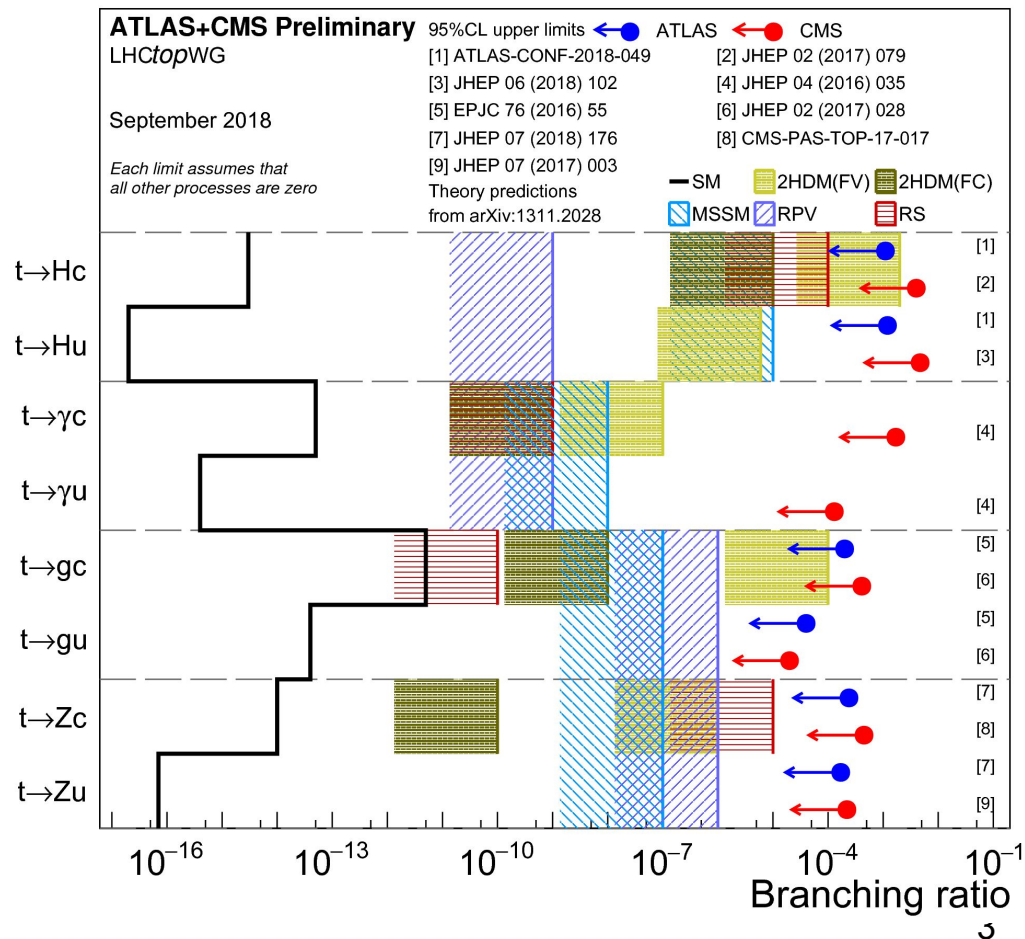
- Predictions for the **branching ratios of FCNC top decays** by the SM and some NP models

Process	SM	QS	2HDM	FC 2HDM	MSSM	$\tilde{R}$ SUSY	RS
$t \rightarrow qZ$	$\sim 10^{-14}$	$\sim 10^{-4}$	$\sim 10^{-6}$	$\sim 10^{-10}$	$\sim 10^{-7}$	$\sim 10^{-6}$	$\sim 10^{-5}$

# Limits overview

## FCNC

- Top quark decays via FCNC presents a powerful probe of new physics
- Several orders of magnitude before SM suppression
- Focus on **tZq** anomalous couplings
- [Result](#) with **13 TeV** data and a luminosity of **36 fb<sup>-1</sup>** for **decay** mode

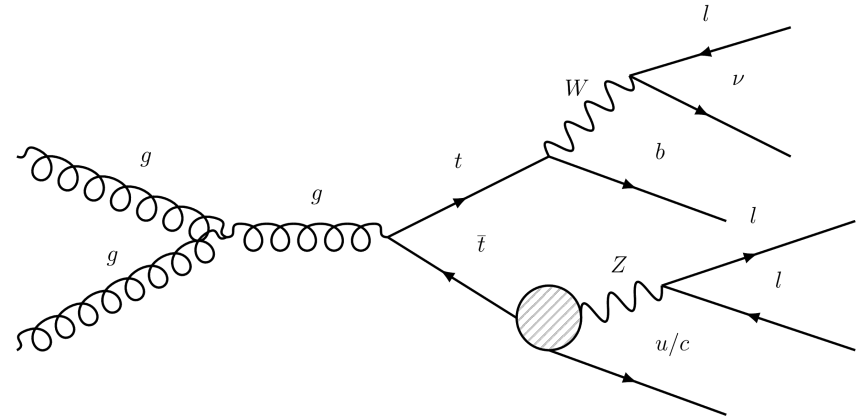
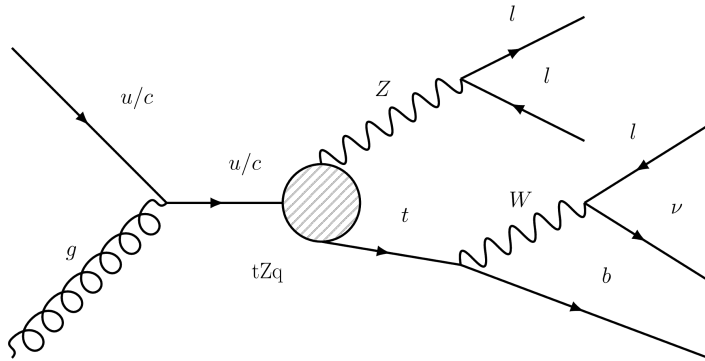


# Motivation

## FCNC $tZq$

Top decay via FCNC processes possible in two modes:

- In **production**: single-top (left)
- In **decay**:  $t\bar{t}$  production (right)



- Possibility of the same final state for production and decay  $\Rightarrow$  Estimate of the **interference effects** is needed

# Interference

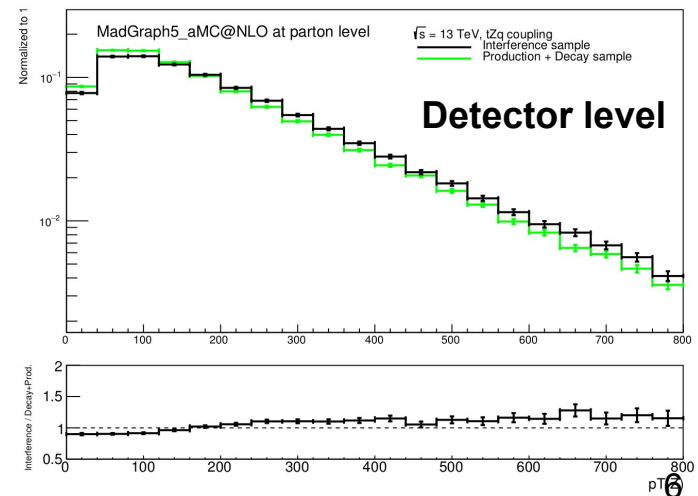
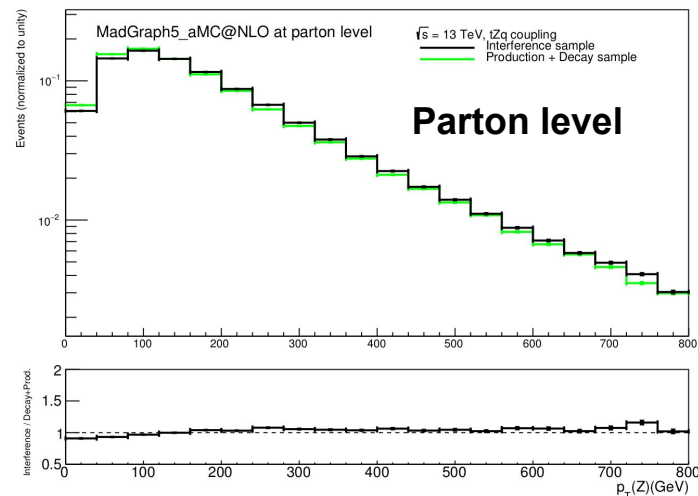
## Production and Decay modes

- **Phenomenological study** for  $tZq$  and  $tyq$  anomalous couplings (in collaboration with Dortmund University) performed using **MadGraph5 Monte Carlo generator** importing TopFCNC UFO model
- Generation at a **centre-of-mass energy** of **13 TeV** and value of anomalous couplings at the same order of magnitude as the current experimental limits
- Both **parton** and **detector** levels were analyzed
- **Renormalisation** and **factorisation scales** treated as part of the total uncertainty

# Interference

## Production and Decay modes

- Comparison of the **interference sample** with the **sum of production and decay samples without interference** contribution
- Distribution of the **transverse momentum of the Z/ $\gamma$  boson** presents interference effects at both levels
- However, the difference is covered by **variations of the scales** in the leading-order samples having the **same order** of the expected **modeling uncertainties**
- Study done in **collaboration with Dortmund University**



# Motivation

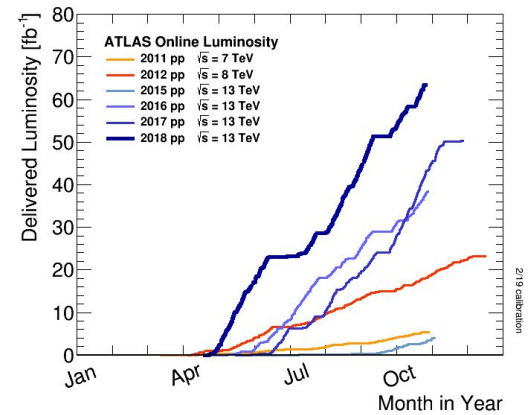
## FCNC $tZq$

Analysis with **full Run-2 dataset** (i.e.  $140 \text{ fb}^{-1}$ ) collected by the **ATLAS detector** combining both **production and decay** modes in collaboration with **teams** from **Berlin, Tbilisi and Roma**:

- In **production**: single-top production  $\Rightarrow$  **Particularly sensitive to  $tZu$  coupling**
- In **decay**:  $t\bar{t}$  decay ( $t \rightarrow q Z, q=u,c$ ) and  $t\bar{t}$  decay ( $t \rightarrow c Z$ ) with Soft Muon Tagging used as charm-quark tagger  $\Rightarrow$  **Higher statistics**

Considering the following:

- **Trileptonic** topology:  $l^+ l^- + l + b\text{-jets} + E_T^{\text{Miss}}$
- **$tZu$  and  $tZc$**  anomalous couplings considered
- **Main backgrounds**:  $t\bar{t}$ ,  $t\bar{t} + X$ ,  $Z + \text{jets}$  and diboson ( $WZ$  and  $ZZ$ ) processes





# Motivation

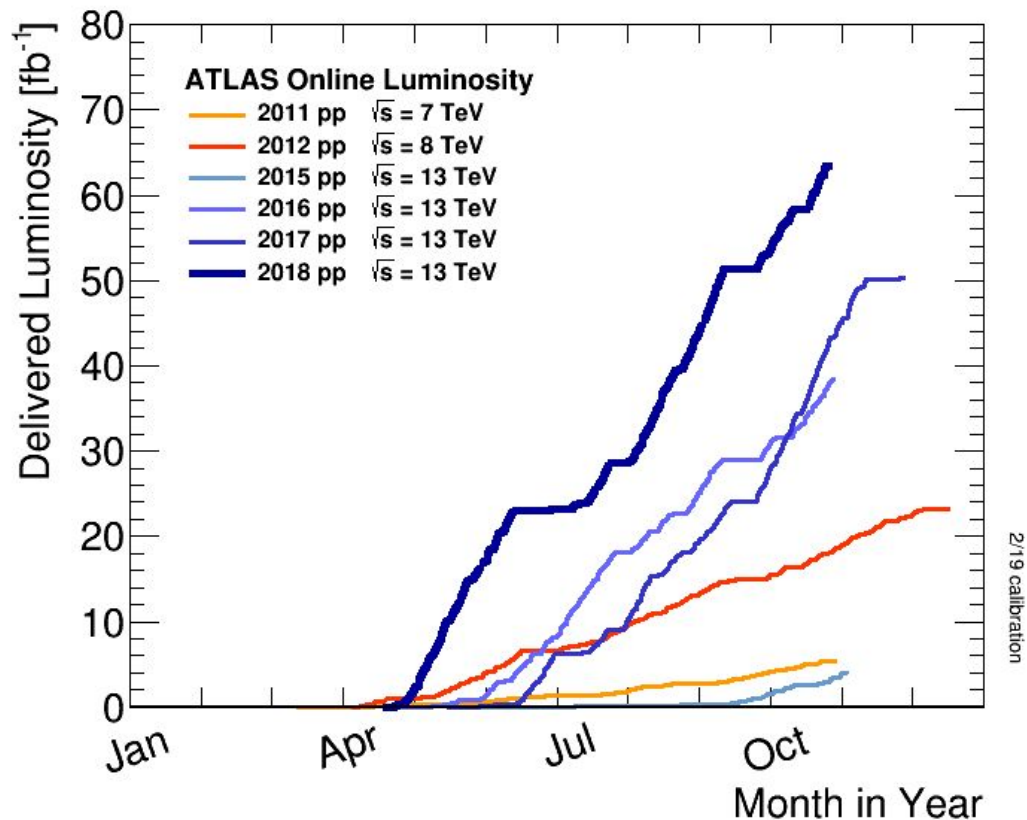
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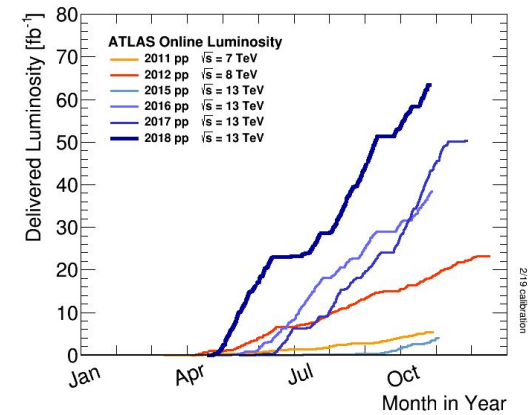
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# Search for FCNC $tZq$

## Analysis strategy

### Distinct signal regions:

1. Single-top production
2.  $t\bar{t}$  decay ( $t \rightarrow q Z, q=u,c$ )
3.  $t\bar{t}$  decay ( $t \rightarrow c Z$ ) with SMT used as  $c$ -tagger

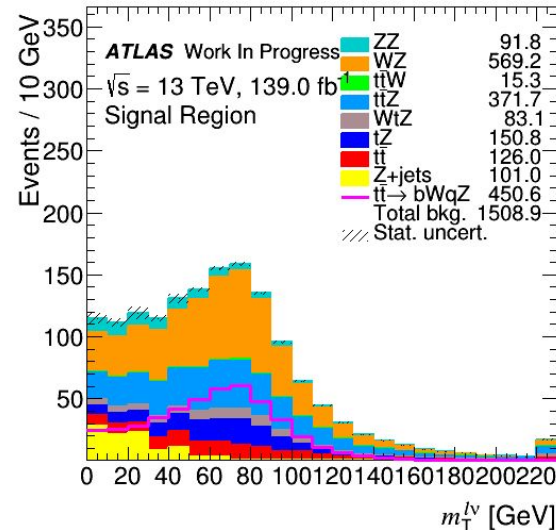
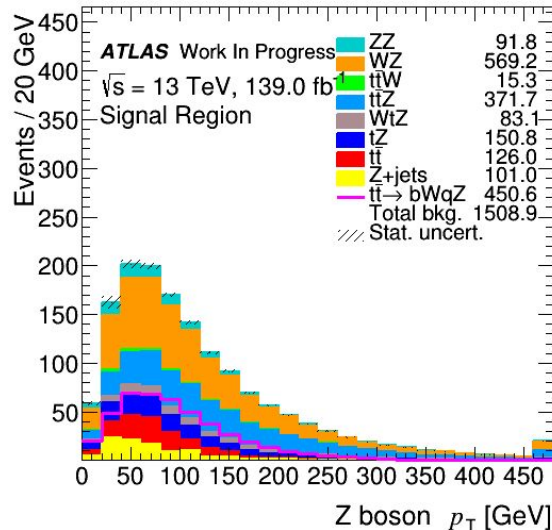
### Control regions:

1.  $Z$ +jets
2.  $t\bar{t}$
3.  $t\bar{t}+Z$
4. Diboson ( $WZ$  and  $ZZ$ )

# Event selection

## Signal region for production

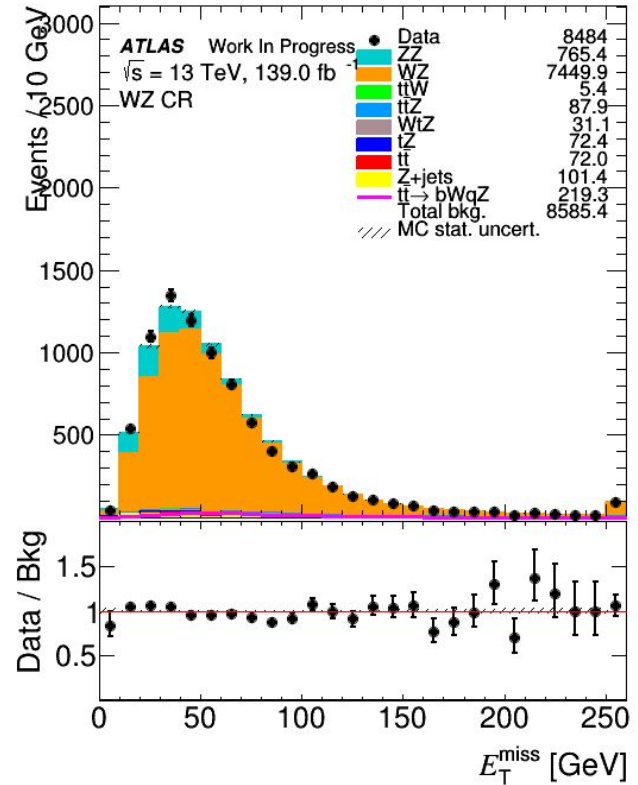
- **Transverse momentum of the Z boson** and the **transverse mass of the W boson** expected to have softer distributions compared with the signal



# Event selection

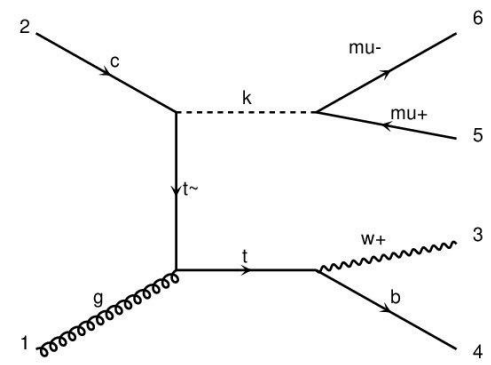
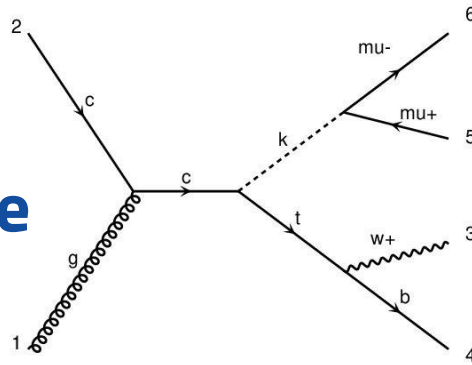
## Control regions

- **Dominant backgrounds** with dedicated control regions
- Specific selection for diboson processes as **WZ and ZZ** presents a good data and Monte Carlo agreement
- **Optimization** of the **Z+jets control region** taking into account the fakes contribution
- **ttbar** control regions with good **isolation** of **ttbar** and **ttbar+X** processes



# Rare top decays

## New scalar particle



- **Phenomenological study** on top decays with new scalar  $k$  in collaboration with Maria Ramos and Mikael Chala (IPPP-Durham and Granada)
  - Assuming the **top-quark with decays to a new scalar  $k$  and a light-quark** (up or charm)
  - Considering **different masses** for the new particle
  - Focusing on the **decay** of the scalar particle **to muons** for now
  - **Dominant backgrounds** considered:  $t\bar{t}$ , diboson,  $Z$ +jets and  $tZ$
  - Detailed study on the **reconstruction of the scalar** boson
  - **Limits on the branching ratios** assuming a centre-of-mass energy of 13 TeV and a luminosity of  $140 \text{ fb}^{-1}$

# Conclusions & Next Steps

- **Flavor changing neutral currents with  $tZq$  anomalous vertex**
  - Phenomenological studies of interference effects between production and decay
  - Analysis with the ATLAS detector with both production and decay modes profiting from the Run-2 dataset
  - Experimental limits on the branching ratios of  $tZu$  and  $tZc$  processes
- **Rare top decays with new scalar  $k$  particle**
  - Sensitivity study with new scalar  $k$  taking into account the dominant backgrounds
- **ATLAS PhD Grant** gave me the opportunity to be **based at CERN on 2019**
- Plans to have the **PhD thesis finished** until beginning of **2021**

# Thanks