Search for flavour-changing neutral currents tZ interactions in pp collisions at $\sqrt{s}$=13 TeV with ATLAS

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A search for the flavour-changing neutral tqZ vertex in trilepton events in proton-proton collisions at a centre-of-mass energy of 13 TeV with the ATLAS detector at the CERN Large Hadron Collider is presented. The analysed data corresponds to an integrated luminosity of 36.1 fb^{-1}. The analysis is performed on events with three isolated electrons or muons, including the mixed cases, missing transverse momentum and exactly one b-tagged jet in the final state. Exclusion limits for the branching ratios on the $\mathrm{t} \to \mathrm{qZ}$ processes are given and interpreted in the framework of an effective field theory in the top quark sector.

Motivation

- A Flavour Changing Neutral Current (FCNC) process is an interaction with a **change of the fermion's flavour** through the **emission of a neutral boson**;
- According to the Standard Model, FCNC processes are forbidden at tree level and **highly suppressed** at higher orders;
- Nonetheless, FCNC processes can be significantly **enhanced in new physics models** [1];

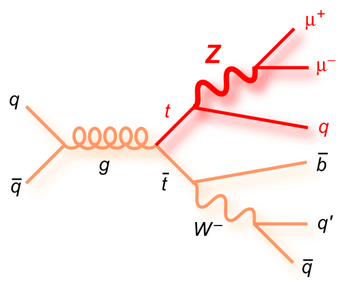
Model	SM	QS	2HDM	FC 2HDM	MSSM	$\not R$ MSSM	RS
$\mathcal{BR}(t \to qZ)$:	10^{-14}	10^{-4}	10^{-6}	10^{-10}	10^{-7}	10^{-6}	10^{-5}

- Searches for **FCNC interactions in the top quark sector** have already been performed at several experiments as such Tevatron and the LHC obtaining expected and observed **upper limits** at 95% confidence level (CL).

Event selection

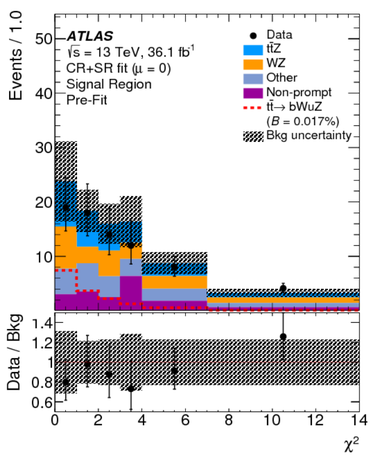
A search for FCNC processes in top-quark decays is studied in this analysis. The final state of these processes is characterised by:

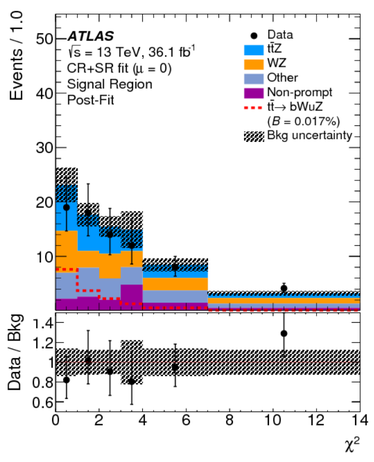
- Exactly **three** isolated **leptons**;
- **Missing transverse energy** greater than 20 GeV;
- At least **two jets** with only one being b-tagged (with a b-tagging efficiency of 77%);
- At least **one Z boson candidate** (pair of e^+e^- or $\mu^+\mu^-$) with $|m_{ll}$ - 91.18 GeV$| < 15$ GeV.



The **top-quark candidates** considering the distinct decays are reconstructed using a χ^2 **minimisation method**:

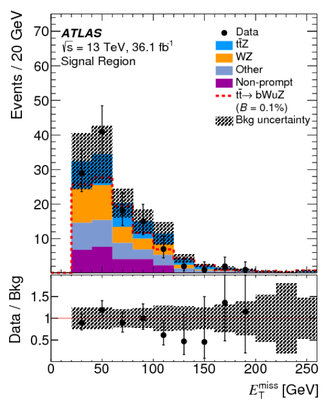
$$\chi^2 = \frac{(m^{reco}_{j_a l_a l_b} - m_{t_{FCNC}})^2}{\sigma^2_{FCNC}} + \frac{(m^{reco}_{j_b l_c \nu} - m_{t_{SM}})^2}{\sigma^2_{SM}} + \frac{(m^{reco}_{l_c \nu} - m_{t_W})^2}{\sigma^2_W}$$

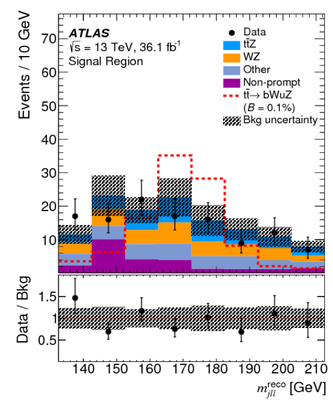


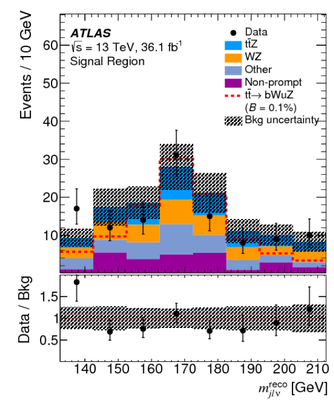


Kinematic distributions

The distributions from the **signal region** with the signal normalised to a branching ratio of $\mathcal{BR}(t \to uZ)$ = 0.1%: **missing transverse energy**, invariant **mass** of **FCNC and SM top-quark** candidates.







Additionally to the signal region, five **control regions** were defined for relevant **background processes** ($t\bar{t}Z$, WZ, ZZ) and for events with **non-prompt leptons**.

Results

- The signal extraction is based on a **binned likelihood fit** where different **distributions from the signal and control regions** are used. **No evidence for a signal** is found, the analysed data is compatible with the background-only hypothesis;
- **Expected and observed upper limits** at 95% CL for the **branching ratios** $\mathcal{BR}(t \to uZ)$ and $\mathcal{BR}(t \to cZ)$ were determined using the **$\mathrm{CL_s}$ method**:

	$\mathcal{BR}(t \to uZ)$	$\mathcal{BR}(t \to cZ)$
Observed	$\mathbf{1.7 \times 10^{-4}}$	$\mathbf{2.4 \times 10^{-4}}$
Expected	$\mathbf{2.4 \times 10^{-4}}$	$\mathbf{3.2 \times 10^{-4}}$
Expected -1σ	1.7×10^{-4}	2.2×10^{-4}
Expected $+1\sigma$	3.4×10^{-4}	4.6×10^{-4}

- The **observed limits** for the two cases (with u or c-quark) constitute the **most stringent limits up to date** [2] and are an **improvement by a factor of 3** compared with the **Run-1 data** results;
- The obtained limits were **converted** into limits for the **operators** contributing to the FCNC decay $t \to qZ$ using the **effective field theory** framework developed in the **TopFCNC model** [3] and assuming a **new-physics** scale of Λ = 1 TeV:

Operator	**Observed**	**Expected**
$\lvert C^{(31)}_{uB}\rvert = \lvert C^{(31)}_{uW}\rvert$	0.25	0.30
$\lvert C^{(32)}_{uB}\rvert = \lvert C^{(32)}_{uW}\rvert$	0.30	0.34

References:

1. **K. Agashe *et all***, *Snowmass 2013 Top quark working group report*, arXiv: 1311.2028 (2013)
2. **ATLAS Collaboration**, *Search for flavour-changing neutral current top-quark decays to qZ in pp collision data collected at $\sqrt{s}$ = 13 TeV with the ATLAS detector*, Journal of High Energy Physics 07 (2018) 176
3. **C. Degrande, F. Maltoni, J. Wang, C. Zhang**, *Automatic computations at next-to-leading order in QCD for top-quark flavor-changing neutral processes*, Phys. Rev. D91 (2015) 034024

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