Search for anomalous *tZq* coupling with the ATLAS experiment

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ATLAS EXPERIMENT

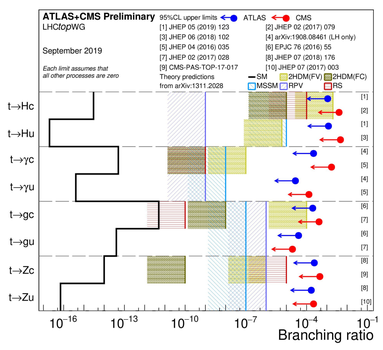
FCT Fundação para a Ciência e a Tecnologia

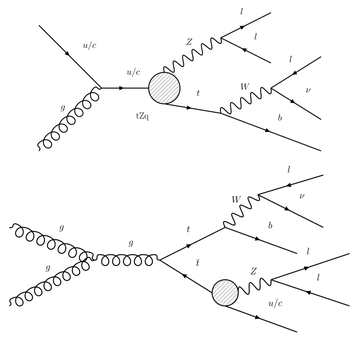
Motivation

- A Flavour Changing Neutral Current (FCNC) process is an interaction with a **change of the fermion 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**

An evidence of a FCNC signal can directly indicate the existence of new physics

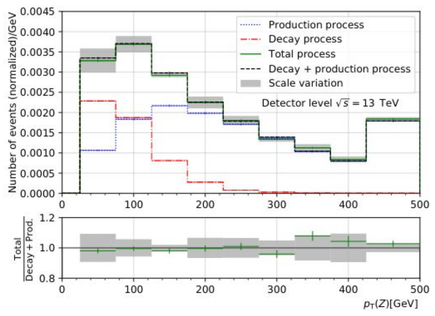
- Searches for **FCNC interactions in the top quark sector** have already been performed at LEP, HERA, Tevatron and LHC obtaining **expected and observed upper limits** at 95% confidence level (left)





- **Top quark decays via FCNC** processes possible in **two modes** (X = H, Z, g, γ):
  - In **production**: **t+X** (top right)
  - In **decay**: **ttbar (t → qX)** with q = u, c (bottom right)

- Estimate of the **interference effects** studied due to the possibility of the **same final state for production and decay modes** (arXiv:1909.08443)
  - **Phenomenological study** for tZq and tγq anomalous couplings at parton and detector level was performed with Monte Carlo generation at a centre-of-mass energy of 13 TeV
  - Difference on the transverse momentum distributions covered by **variations of the scales** in the leading-order samples



Analysis Strategy

A search for FCNC processes sensitive the tZq coupling is performed using 140 fb^{-1} of data collected by the **ATLAS detector** in full Run 2 period.
The analysis combines both **production and decay** modes in collaboration with **teams** from **Tbilisi** and **Roma**:

- In **production**: single-top production ⇒ **Particularly sensitive to tZu coupling**
- In **decay**: ttbar decay *(t → q Z, q=u,c)* and focused ttbar decay *(t → c Z)* with Soft Muon Tagging used as charm-quark tagger ⇒ **Higher statistics**

For both modes, the signal selection targets:

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

Reconstruction of top quark using the same method for both production and decay signal regions where different variables are considered:

- For FCNC tZ production events with the χ^2 **method** by minimizing the **neutrino** p_z:

$$\chi^2 = \frac{(m_{jl\nu}^{\text{reco}} - m_{t_{SM}})^2}{\sigma_{t_{SM}}^2} + \frac{(m_{l\nu}^{\text{reco}} - m_W)^2}{\sigma_W^2}$$

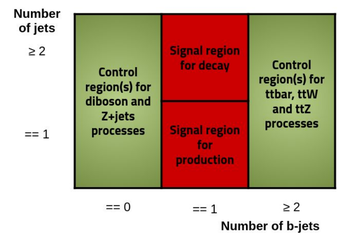
- For FCNC ttbar decay events, the χ^2 is minimized with the **neutrino** p_z and **jets combination**:

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

Therefore, the **final state of the signal** processes is characterised by:

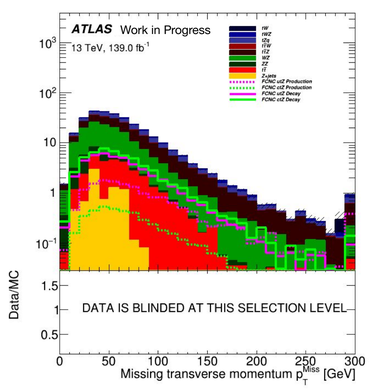
- Exactly **three** isolated **leptons**
- **At least one jet** with only one being tagged as a jet coming from a bottom quark (with a *b*-tagging efficiency of 77%)
- **Transverse mass of the *W* boson** greater than 40 GeV
- At least **one Z boson candidate** (pair of e^+e^- or $\mu^+\mu^-$) with $|m_{ll} - 91.18| < 15$ GeV

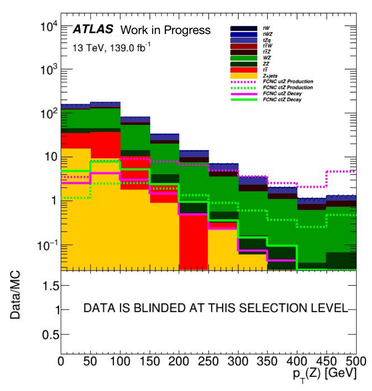
Monte Carlo modeling of background processes is investigated using **data control regions** for the main backgrounds (as diboson, ttbar and Z+jets) where the signal contribution is low and the data and simulation agreement can be analyzed:



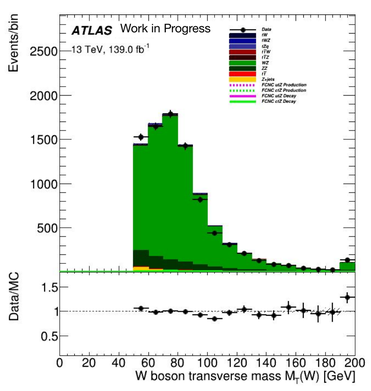
Modeling

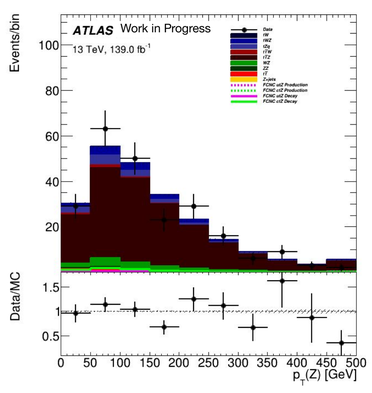
- **For the decay signal regions**, the distributions of the reconstructed masses and transverse momentum of the SM and FCNC top quark as well as **angular variables** as DeltaR between Z boson and a light quark (left)
- **Kinematic variables** as **transverse momentum of the Z boson** and the **transverse mass of the W boson** with softer distributions compared with the signal for the production case (right)





- Requirement of only non *b*-tagged jets allows an excellent purity of diboson processes as **WZ and ZZ** and presents a good data and Monte Carlo simulation agreement for the diboson control region (top left)
- Considering only events with exactly two *b*-tagged jets enable a reasonable **isolation** of **ttbar and ttbar+X processes** for the **ttbar control regions** (top right)

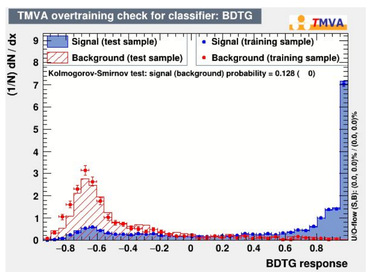


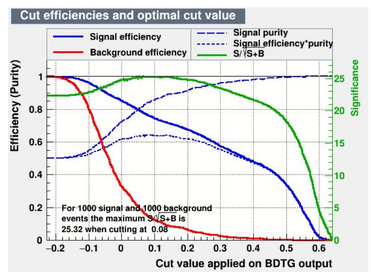


Signal from background discrimination

Boosted Decision Trees with Gradient boosting (BDTG) method within the TMVA multivariate analysis tool used to discriminate signal from background

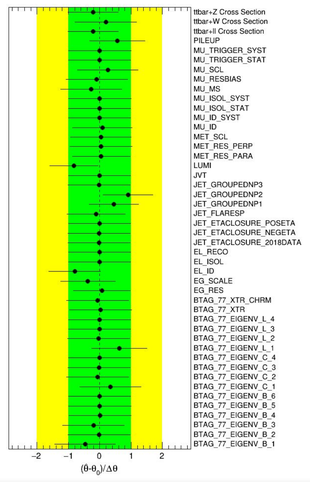
- Promising preliminary results for the production case using the following variables:
  - SM top quark candidate mass
  - *Z* boson candidate transverse momentum
  - ΔR between *Z* boson candidates and SM top quark candidates
  - Bottom quark candidate transverse momentum

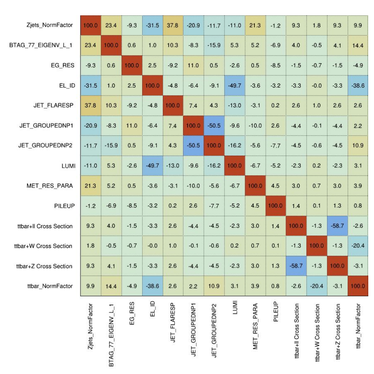




A **likelihood fit** for a signal strength μ is performed with sources of systematic uncertainty (as luminosity, pileup reweighting, statistics, Background model) included as nuisance parameters

- **Normalization uncertainty** for main backgrounds as ttbar, diboson and tZj processes
- **Experimental limits** on the branching ratios of $t \to q\,Z$ with $q=u,c$ are being prepared obtained using the **BDTG score** in the signal regions





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