Search for Single Top Quark Production via Flavour Changing Neutral Currents in 8 TeV ATLAS data

Motivation

In the Standard Model (SM) single top quarks are produced via charged current interactions with the W boson. Transitions between top quarks and other quark flavours mediated by neutral gauge bosons, so-called Flavour Changing Neutral Currents (FCNC), are forbidden at tree level and highly suppressed at higher orders due to the Glashow-Iliopoulos-Maiani (GIM) mechanism. However, there exist several extensions to the SM or new physics models, which significantly enhance rates of FCNC processes compared to the Standard Model predictions [1].

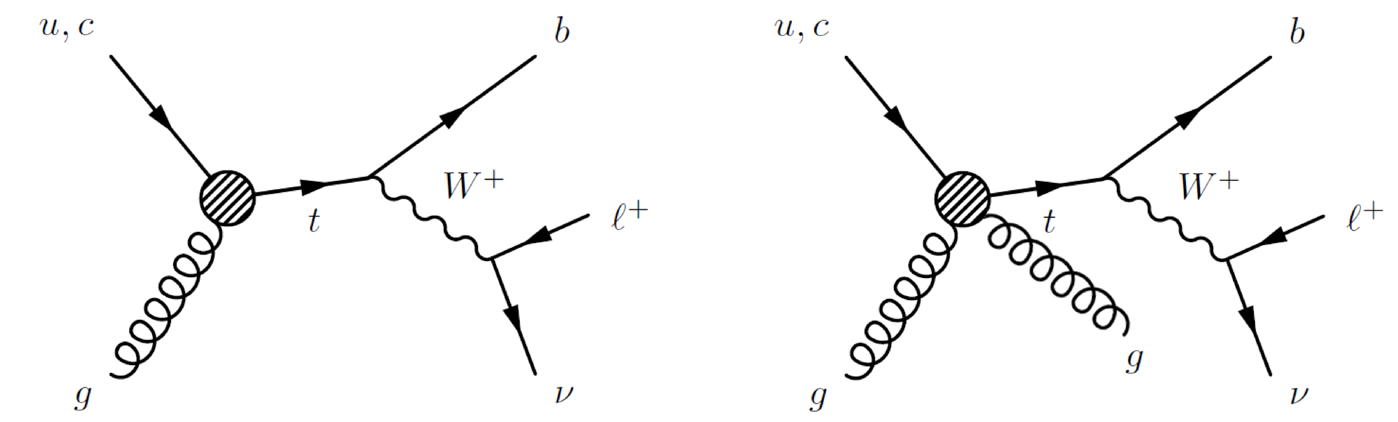
	SM	2HDM-III	MSSM	R-MSSM	TC2
t→qg	$4.6 \cdot 10^{-12}$	10^{-4}	10^{-4}	10^{-3}	10^{-5}
t→qγ	$4.6 \cdot 10^{-14}$	10^{-7}	10^{-6}	10^{-5}	10^{-7}
t→qZ	$1.0 \cdot 10^{-14}$	10^{-6}	10^{-6}	10^{-4}	10^{-5}

SM predictions of top quark FCNC decay branching ratios compared to values predicted by several new physics models [1].

Many of these models allow for this, e.g. by permitting FCNC interactions already at tree level and/or introducing new particles in higher order loop diagrams. Therefore any observation of such processes would be a strong indirect indicator for new physics.

Methods

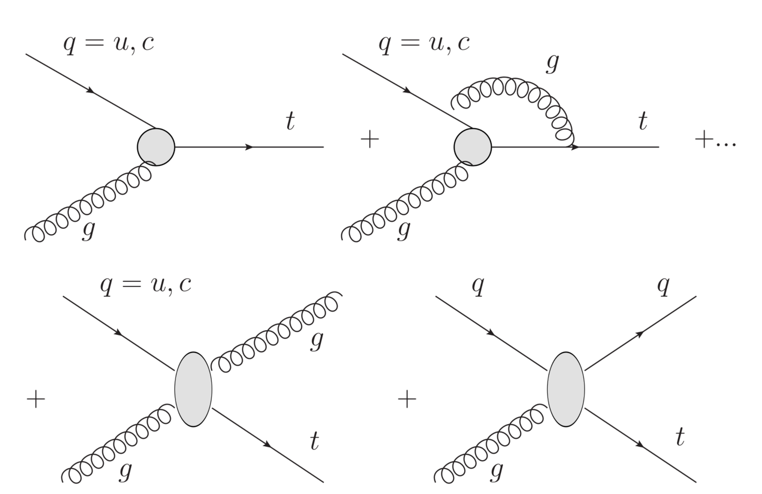
Data collected with the ATLAS detector in 2012 at a center-of-mass energy of $\sqrt{s} = 8\,\mathrm{TeV}$ are used and searched for FCNC events in which a light quark (u or c) interacts with a gluon to produce a single top quark, either with or without the associated production of another light quark or gluon.



Candidate events of top quarks decaying leptonically are selected and classified into signal- and background-like events using a neural network. If no signal is observed in the neural network output distributions, new upper limits on the production cross-sections multiplied by the t → Wb branching fraction and on the coupling strengths of the involved FCNC interactions can be placed.

Details: Signal MC, Neural Network Training & Limit Setting

In 2012 a new MC generator (MEtop) [3] for simulation of the inclusive direct single top production via strong FCNCs at NLO approximation became available. In former analyses searching for strong FCNC direct top production processes in 2011 ATLAS data [2] so far only leading order generators were used.

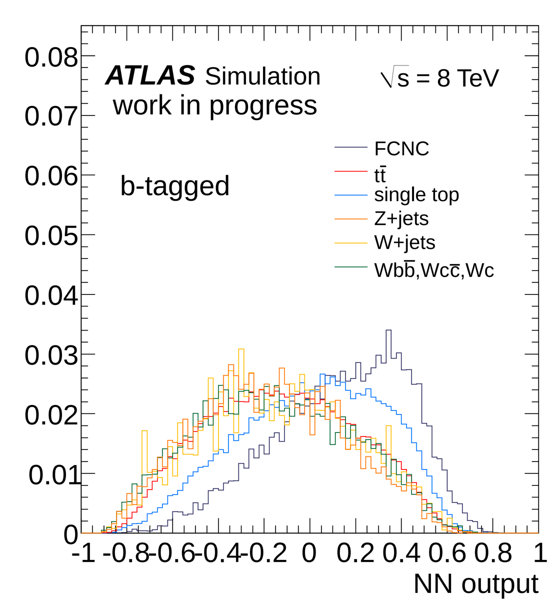


Due to the higher integrated luminosity of $\mathcal{L}_{\mathrm{int}} > 27\,\mathrm{fb}^{-1}$ and hence statistics available from the 2012 LHC run, the currently existing limits are expected to be improved significantly within this analysis. This is further supported by higher cross sections for these processes from NLO calculations and the increased center of mass energy of $8\,\mathrm{TeV}$ for collisions at the LHC in 2012.

The neural network is trained with signal and background events with a 50:50 ratio. Different background processes are weighted according to their number of expected events. The network setup consists of one input node for each input variable and one bias node, an arbitrary number of hidden nodes and one output node. In a preprocessing step the input variables are decorrelated and their significances are determined (see table).

Variable	Significance (σ)
q_{lep}	20.7
$\Delta R(\mathrm{lep}, b\text{-jet})$	15.6
$p_T^{b\text{-jet}}$	13.8
$p_T^{\mathrm{light\text{-}jet}}$	12.4
m_T^{W}	11.5
p_T^{W}	10.6
$\eta_{b\text{-jet}}$	9.2
p_T^{lep}	6.1
$\Delta\phi(\mathrm{lep}, b\text{-jet})$	6.0
$\Delta R(\mathrm{light\text{-}jet}, \nu)$	4.2

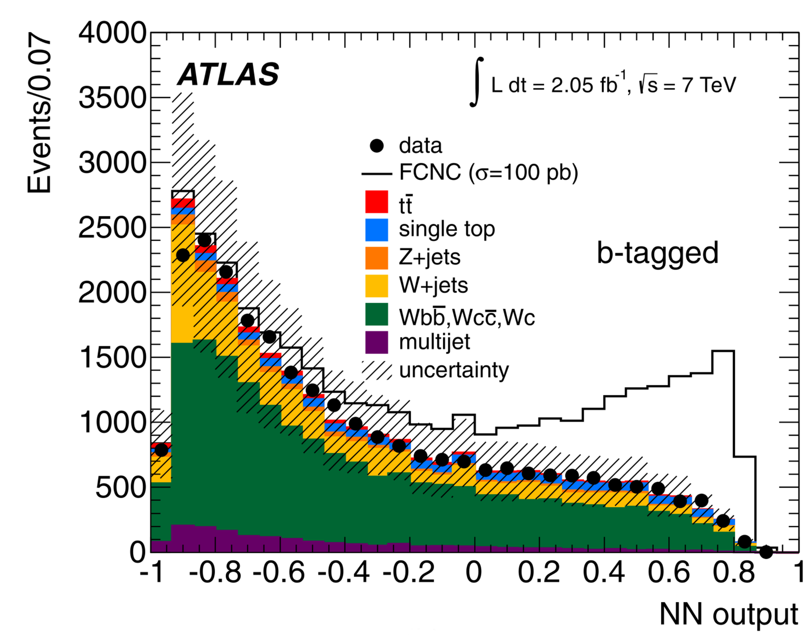
ATLAS work in progress



Most significant variables used as input to the neural network ordered by their importance (left) and preliminary output distributions from the neural network training using MC evets, normalized to unit area (right).

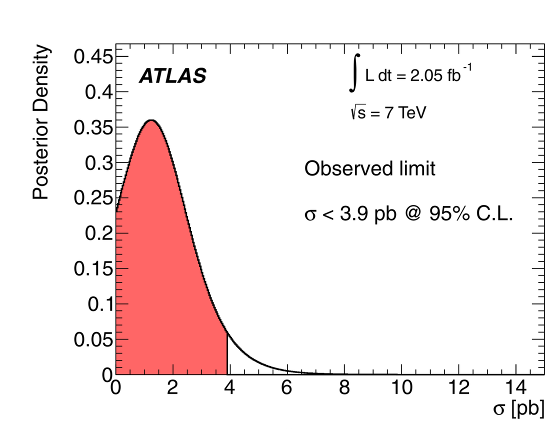
The resulting output distributions from the neural network training normalized to unit area are shown in the figure above. The upper figure on the right shows the neural network output distribution from the former 2011 analysis [2] after application on data, normalized to the number of observed events and with an assumed signal cross section of 100 pb for better visibility.

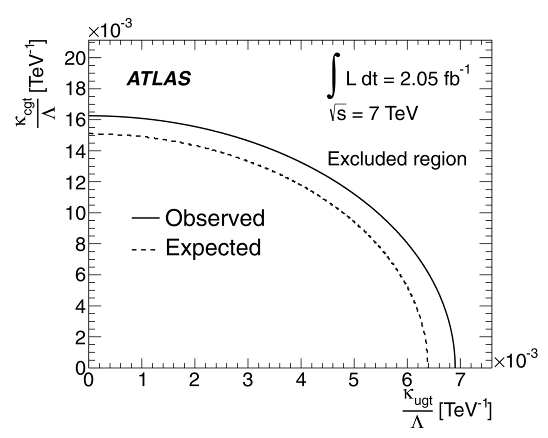
Similar to [2] a Bayesian statistical analysis using a binned likelihood method will be applied to the neural network output distributions. Systematic uncertainties are accounted for using a direct sampling approach. The posterior density function (pdf) is obtained by averaging over the individual likelihood distribution obtained for each sample and gives the probability of the signal



Neural network output distribution after application on 2011 data [2].

hypothesis as a function of the signal cross-section, see lower figure on the right. Hence by integrating the pdf an upper limit on the cross-section can be set and limits on the coupling strengths of the involved FCNC interactions be derived (cf. results from [2] in the right figure below).





Posterior probability function for observed upper limit at 95% C.L. (left) and upper limit on the coupling constants κ_{ugt}/Λ and κ_{cgt}/Λ. (right) [2]

Further Work Topics

During 2010 and 2011 the focus of work within the PhD project was on hardware related topics. These mainly consisted in the development, construction and characterization of prototypes of Silicon Strip Detector modules, aimed for the upgrade of the current ATLAS Inner Detector to enable it for operation at a possible future High-Luminosity-LHC (HL-LHC).
Since the beginning of the work various setups for detector module assembly and read-out, testing of sensors and other related electronics were installed. Several fuctional module prototypes for the barrel part of the future ATLAS Silicon Strip Detector were constructed and successfully tested. Similar setups for the assembly and testing of modules for the end-caps of the future ATLAS Silicon Strip Detector are currently in development.

References

[1] J.A. Aguilar-Saavedra, Top flavor-changing neutral interactions: Theoretical expectations and experimental detection., Acta Phys.Polon. B35 (2004) 2695-2710, Sep 2004

[2] ATLAS Collaboration, Search for FCNC single top-quark production at $\sqrt{s} = 7$ TeV with the ATLAS detector, DOI:10.1016/j.physletb.2012.05.0222, Mar 2012

[3] R. Coimbra, A. Onofre, R. Santos, M. Won, MEtop - a generator for single top production via FCNC interactions, arXiv:1207.7026, Jul 2012

Publications & Talks

- ATLAS Upgrade Week 2011, Oxford, UK, 29./31.03.2011,
  Status of module production at DESY / SCT barrel sensor measurements at DESY
- ATLAS Upgrade Week 2011, CERN, Genf, CH, 16.11.2011,
  Comparison of DAQ results from tests of Stave & Double-Sided Silicon Strip Detector Modules
- HU Research Seminar, Berlin, DE, 27.01.2012,
  The high-luminosity upgrade of the ATLAS SemiConductor Tracker (SCT)
- GK Spring Block Course 2012, Rathen, DE, 13.03.2012,
  Upgrade of the ATLAS Silicon-Strip Detector for the High-Luminosity LHC
- ATLAS Upgrade Week 2012, Stanford, CA, USA, 27.03.2012,
  Report on CERN B180 test setups and infrastructure
- The ATLAS Endcap Tracker Upgrade Group, A Forward Silicon Strip System for the ATLAS HL-LHC Upgrade, in preparation for Nucl. Instrum. Methods Phys. Res., Sect. A

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