SEARCH FOR ANOMALOUS SINGLE TOP QUARK PRODUCTION IN ASSOCIATION WITH A PHOTON IN PP COLLISIONS AT $\sqrt{s} = 8$ TEV

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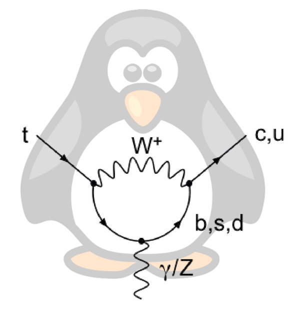
Motivation

Flavor Changing Neutral Currents (**FCNC**) are highly suppressed in the Standard Model (SM): $BR(t \to \gamma + c(u)) < 10^{-12}$.

Various extensions of SM predict huge enhancement for the branching ratios of these decays $BR(t \to \gamma + c(u)) \sim 10^{-5}$.



It indicates that observation of any sign from top quark FCNC processes will give evidence of physics beyond the SM.

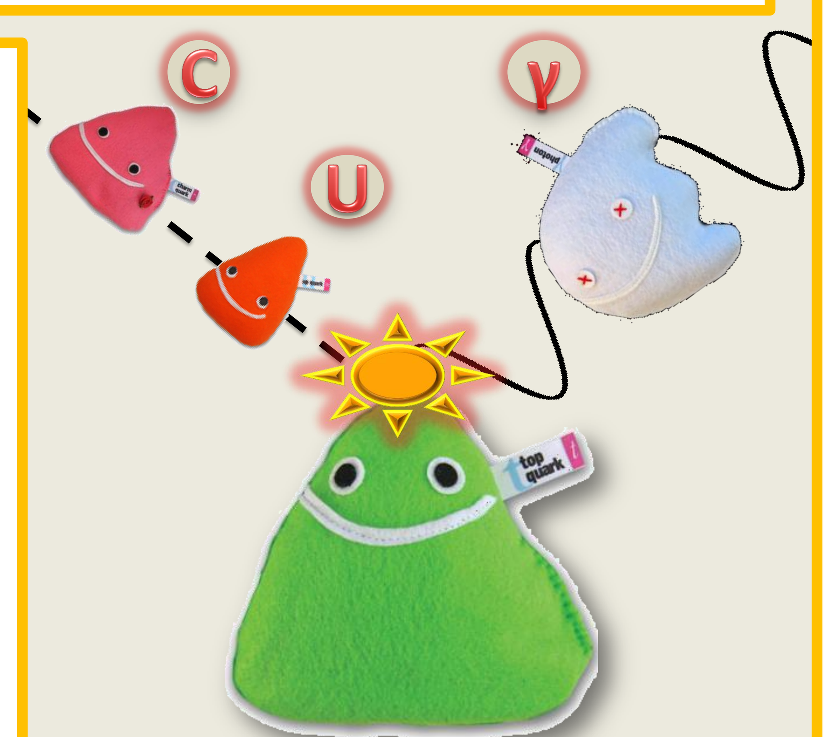
In this analysis, a search for FCNC couplings of the top quark with u or c quark and a photon is performed [1].

Object And Event Selection

The presence of an isolated muon and a high P_T photon provides a clean signature for the signal.

The following criteria are applied to select events.

- Photon: $P_T > 50$ GeV and $|\eta| < 2.5$ $(1.44 < |\eta| < 1.56$ is excluded). Events with exactly one photon candidate are kept.
- Muon: $P_T > 26$ GeV, $|\eta| < 2.1$ and tight isolation criteria. Exactly one muon candidate is required, discarding events with additional loose muons .
- Events with one or more electron candidates are rejected.
- Jets: $P_T > 30$ GeV and $|\eta| < 2.5$. To identify jets originating from b-quarks, the combined secondary vertex (CSV) algorithm is used [3]. Events with more than one b-jet are not taken into account.
- Well separated objects: $\Delta R(\mu, \gamma) > 0.7, \Delta R(b-\text{jet}, \gamma) > 0.7$.
- MET > 30 GeV.
- Top-quark mass window: 130 GeV < m_{top} < 220 GeV



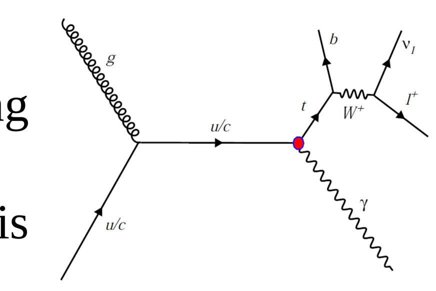
Signal And Backgrounds

Deviation from the SM predictions due to FCNC transitions involving the top quark can be described by an effective Lagrangian of the form:

$$L_{eff} = -eQ_t\kappa_{tu\gamma}\bar{u}\frac{i\sigma^{\mu\nu}q_\nu}{m_t}tA_\mu - eQ_t\kappa_{tc\gamma}\bar{c}\frac{i\sigma^{\mu\nu}q_\nu}{m_t}tA_\mu + H.C$$

Where $\kappa_{tu\gamma}$ ($\kappa_{tc\gamma}$) is anomalous tuγ (tcγ) coupling.

In proton-proton collisions at the LHC, the existence of FCNC couplings in tqγ vertex would allow the production of a top quark in association with a photon. Signal signature is a high P_T photon, MET, a b-jet and a muon (considering only the muonic W boson decay from the top quark decay).



Signal samples of tuγ and tcγ are generated using the PROTOS program[2].

Background processes which contribute in this analysis can be categorized into two categories:

Backgrounds with prompt photon:

W+γ+jets, Z+ γ +jets, single (anti) top + γ, $t\bar{t}$ + γ, WW+ γ, γ +jets

Backgrounds with fake photon:

Single (anti) top, $t\bar{t}$, WW, WZ, ZZ, W+jets, Z+jets.

Signal Extraction And Background Estimation

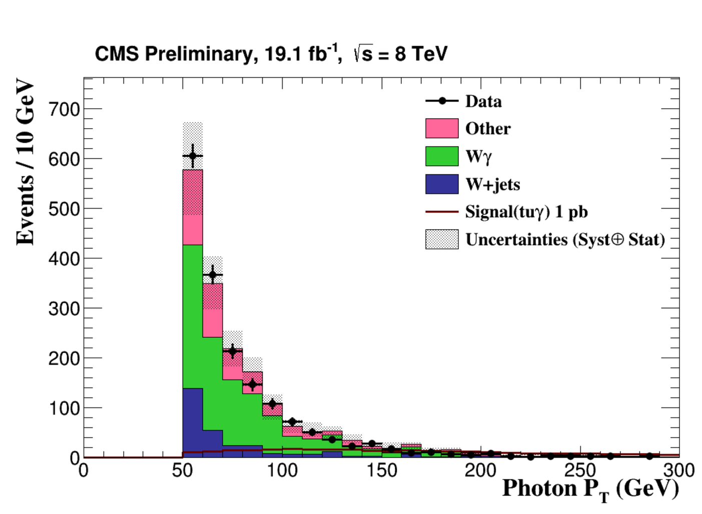
The contributions of W+γ+jets and W+jets backgrounds are estimated from data. All other backgrounds contributions are estimated from simulation.

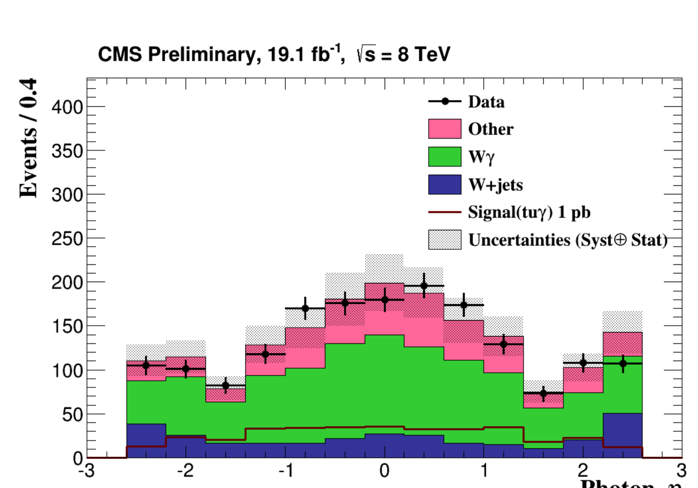
A multivariate classification approach is chosen to optimize the discrimination between SM and possible signal events.

The transverse momentum of γ, μ, b-jet, ΔR(γ, μ), ΔR (γ, b-jet), cos (top, γ), CSV discriminator and jet multiplicity are chosen to construct a boosted decision tree (BDT) according to their separation power[4].

Control plots

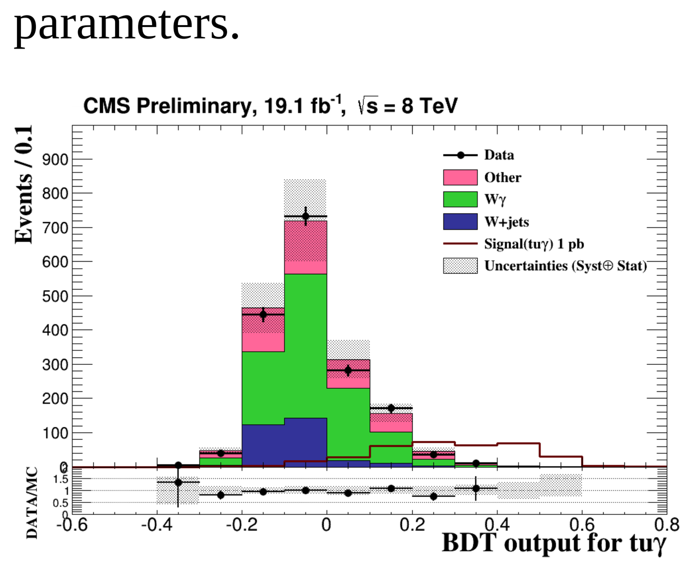
The total number of selected events after the final selection in data is 1719 and in the assumption of no FCNC, 1762±184 are expected. The main source of the uncertainties comes from the fit.

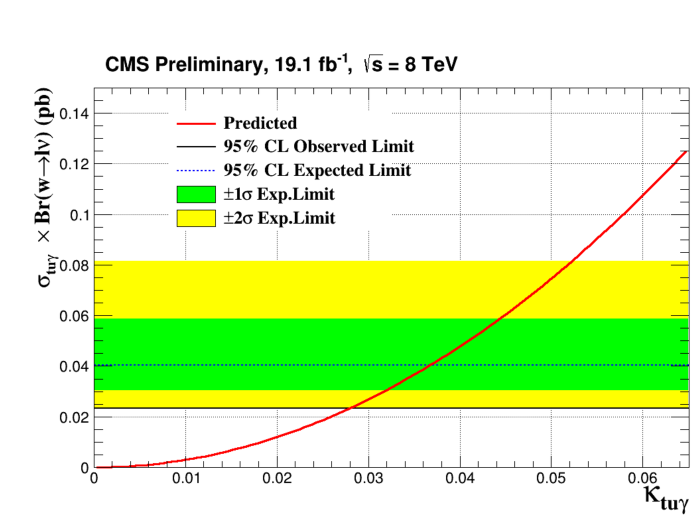


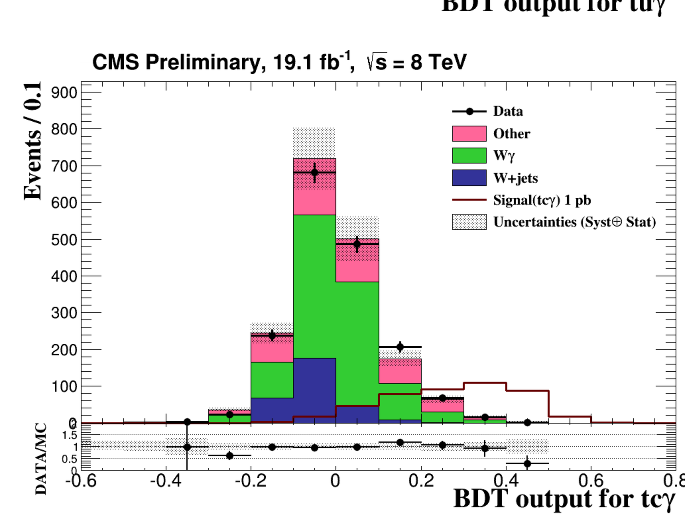


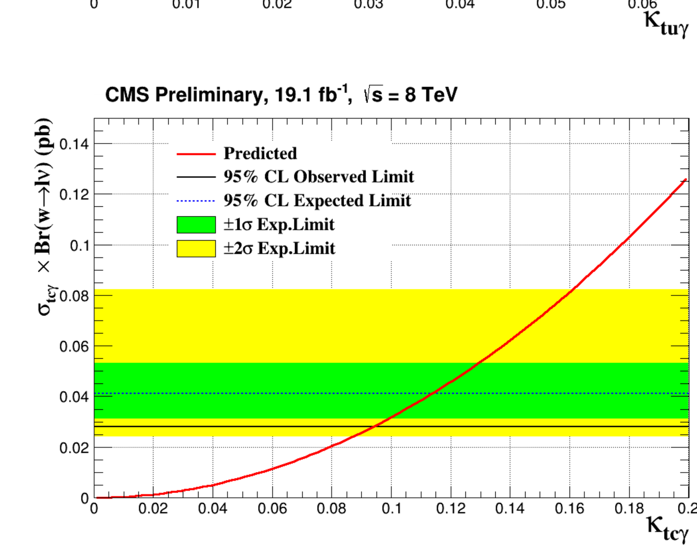
BDT Output And Exclusion Plots

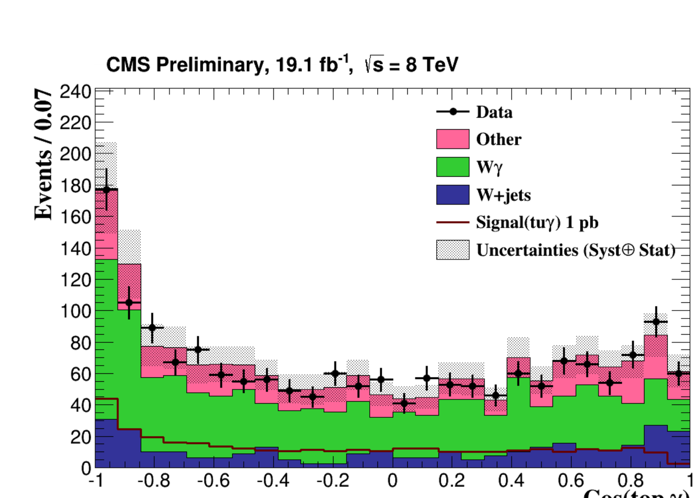
Plots on the left show the BDT output distribution for data, backgrounds and signal. Since no clear excess is observed, the BDT output distributions is used to calculate the 95% confidence level exclusion limits on the anomalous couplings of $\kappa_{tu\gamma}$ and $\kappa_{tc\gamma}$ (plots on the right). The limit calculation is performed using the CLs approach that is implemented in the Theta package[5]. To set limits on the anomalous couplings, all systematic uncertainties are considered as nuisance parameters.

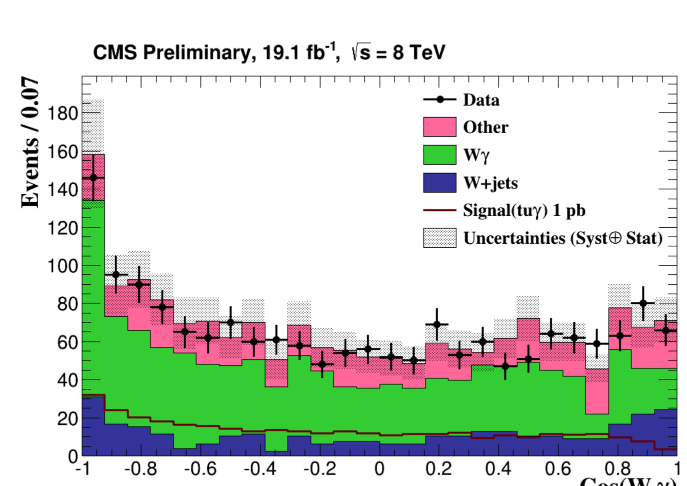


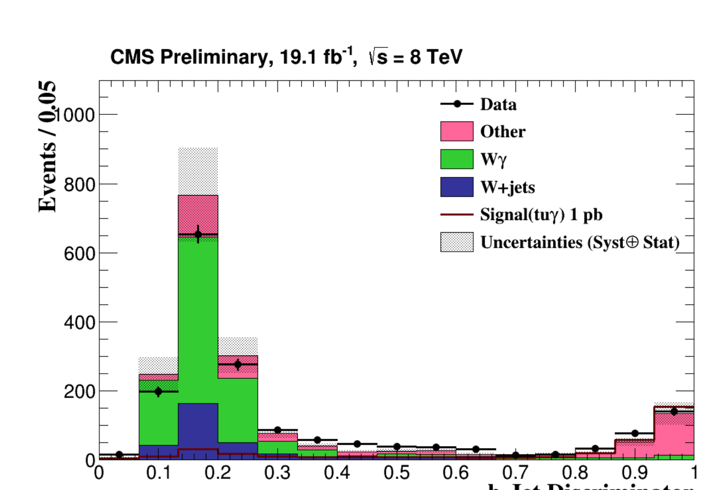










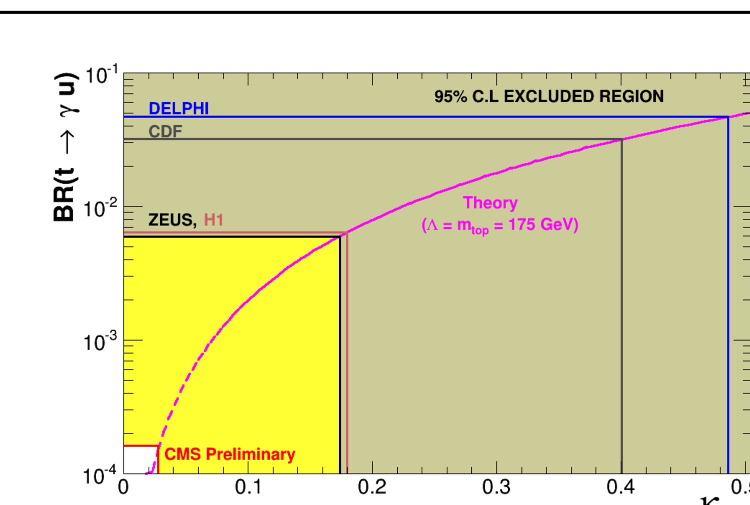


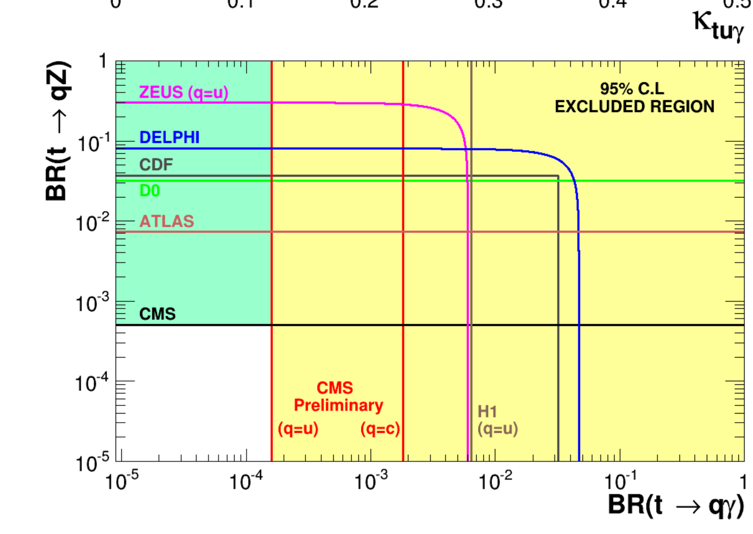
Results

One can consider the effect of the next to leading order on the signal cross section[6]. The upper limit on the cross section can be translated to the strength of the anomalous couplings and the branching ratio of top quark decays to a photon and u or c quark.

variable	Expected limit (LO)	Observed limit (LO)	Expected limit (NLO)	Observed limit (NLO)
$\sigma_{tu\gamma} \times Br(W \to l\nu)$	0.0404 (pb)	0.0234 (pb)	0.0408 (pb)	0.0217 (pb)
$\sigma_{tc\gamma} \times Br(W \to l\nu)$	0.0411 (pb)	0.0281 (pb)	0.0410 (pb)	0.0279 (pb)
$\kappa_{tu\gamma}$	0.0367	0.0279	0.0315	0.0229
$\kappa_{tc\gamma}$	0.113	0.094	0.0790	0.0652
$Br(t \to u\gamma)$	0.0279%	0.0161%	0.0205%	0.0108%
$Br(t \to c\gamma)$	0.261%	0.182%	0.193%	0.132%

In the following plots, obtained results in this analysis are compared with previous studies from the DELPHI, ZEUS, H1 and CDF collaborations. The bottom plot shows the observed limit on $BR(t \to qZ)$ from ATLAS, CMS and D0 as well.





References

[1] CMS Collaboration, CMS-PAS-TOP-14-003.

[2] J. A. Aguilar-Saavedra, Nuclear Physics B 837 (2010) 122.

[3] CMS Collaboration, Technical Report CMS-PAS-BTV-13-001(2013).

[4] B. Roe et al, Nucl.Instrum. Meth. A 543 (2005) 577.

[5] T. Muller et al, IEKP-KA-CMS/2012-1.

[6] Y. Zhang et al, Phys.Rev.D 83 (2011) 094003.