

Flavor Changing Neutral Currents in top production and decays at CMS

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on behalf of the CMS collaboration

For BEACH 2014

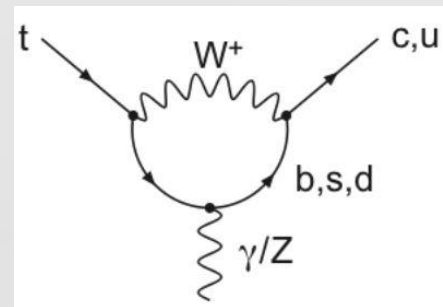
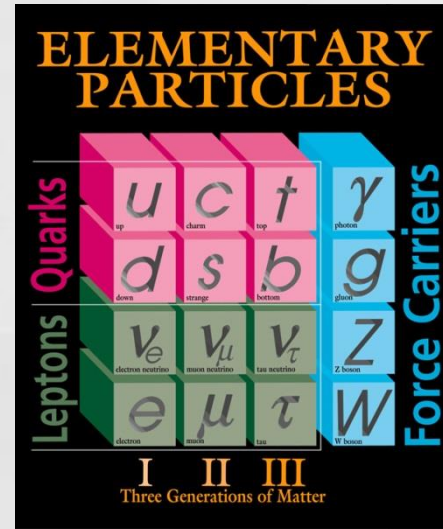
22/07/2014 at Birmingham, UK

Outline

- Introduction
- Motivation
- CMS overview
- Results in single top production
- Results in decay of $t\bar{t}$ pair
 - Perspectives at 14 TeV
- Indirect search for FCNH
- Conclusion

Introduction

- Flavor changing neutral currents (FCNC)
 - Transitions that change the flavor of a fermion without changing its charge.
- Top quark [$173.3 \text{ GeV} \pm 0.3 \text{ (stat.)} \pm 0.7 \text{ (syst.) GeV}$] decays before hadronization.
 - almost 100% decays to b-quark and W boson in the SM.
 - FCNC is suppressed by GIM mechanism.
- In the SM, the branching ratio of FCNC is expected to be smaller than 10^{-12} .
 - Can occur only at the level of quantum loop corrections with $Br(t \rightarrow Xq) \sim 10^{-17} - 10^{-12}$, $X = H, \gamma, Z, g$



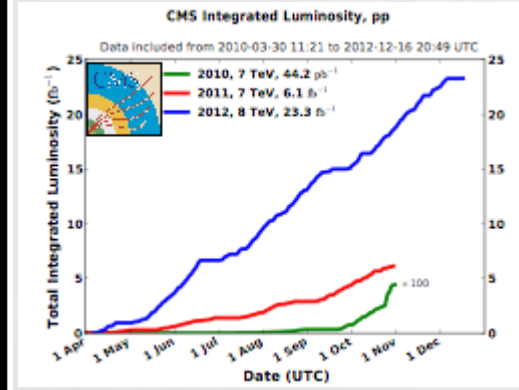
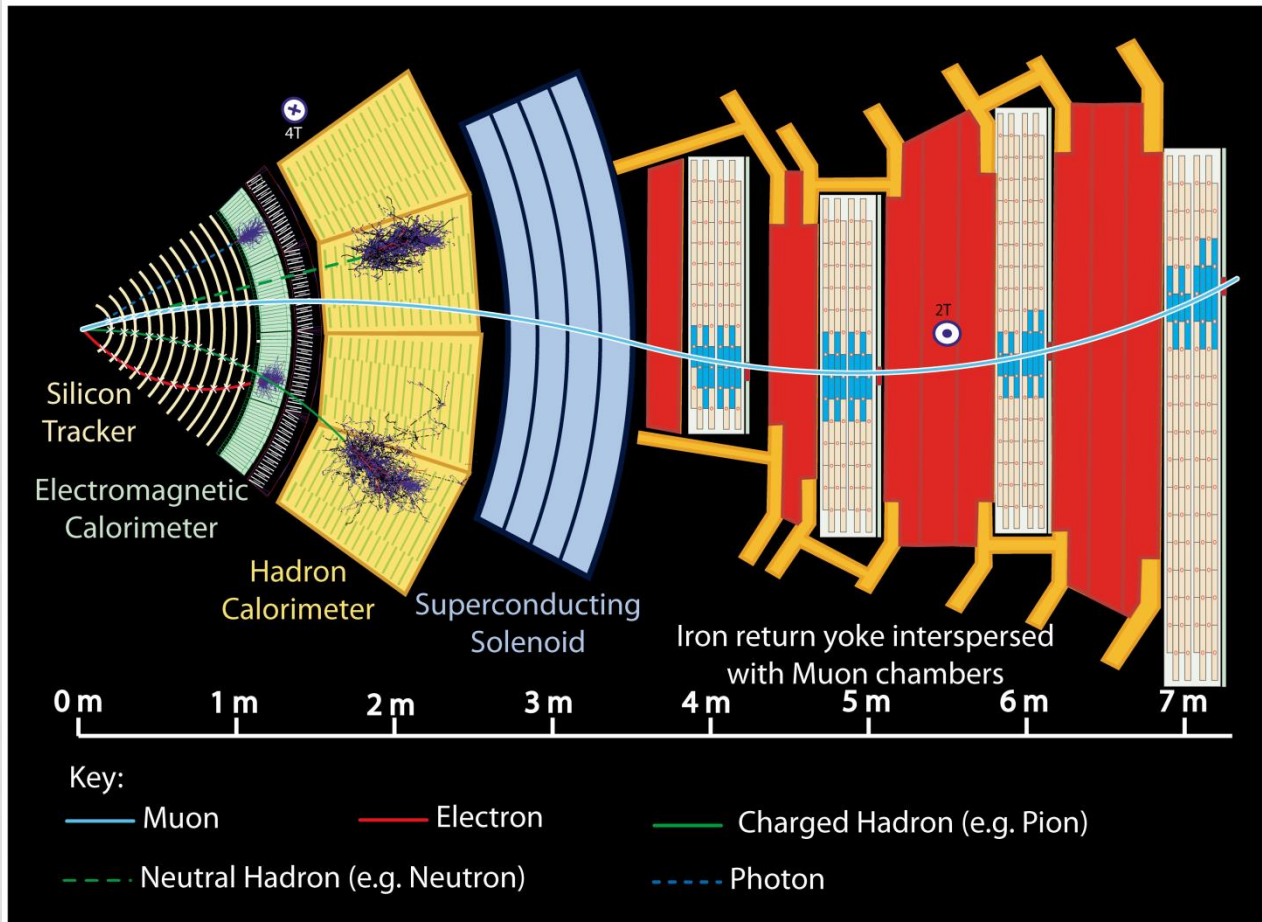
Motivation

- Any small deviation would indicate new physics.
- FCNCs are enhanced in many beyond the SM.
- Model independent searches using effective Lagrangian.

	SM	QS	2HDM	FC 2HDM	MSSM	\mathcal{R} SUSY
$t \rightarrow uZ$	8×10^{-17}	1.1×10^{-4}	—	—	2×10^{-6}	3×10^{-5}
$t \rightarrow u\gamma$	3.7×10^{-16}	7.5×10^{-9}	—	—	2×10^{-6}	1×10^{-6}
$t \rightarrow ug$	3.7×10^{-14}	1.5×10^{-7}	—	—	8×10^{-5}	2×10^{-4}
$t \rightarrow uH$	2×10^{-17}	4.1×10^{-5}	5.5×10^{-6}	—	10^{-5}	$\sim 10^{-6}$
$t \rightarrow cZ$	1×10^{-14}	1.1×10^{-4}	$\sim 10^{-7}$	$\sim 10^{-10}$	2×10^{-6}	3×10^{-5}
$t \rightarrow c\gamma$	4.6×10^{-14}	7.5×10^{-9}	$\sim 10^{-6}$	$\sim 10^{-9}$	2×10^{-6}	1×10^{-6}
$t \rightarrow cg$	4.6×10^{-12}	1.5×10^{-7}	$\sim 10^{-4}$	$\sim 10^{-8}$	8×10^{-5}	2×10^{-4}
$t \rightarrow cH$	3×10^{-15}	4.1×10^{-5}	1.5×10^{-3}	$\sim 10^{-5}$	10^{-5}	$\sim 10^{-6}$

arXiv:hep-ph/0409342

CMS particle reconstruction



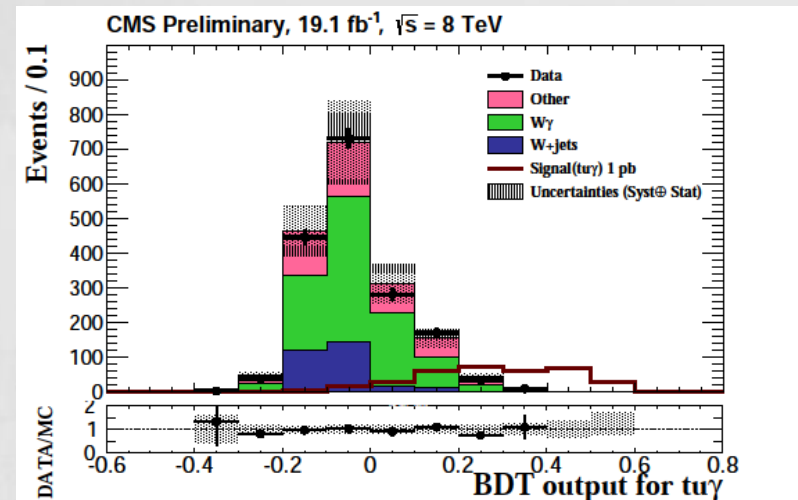
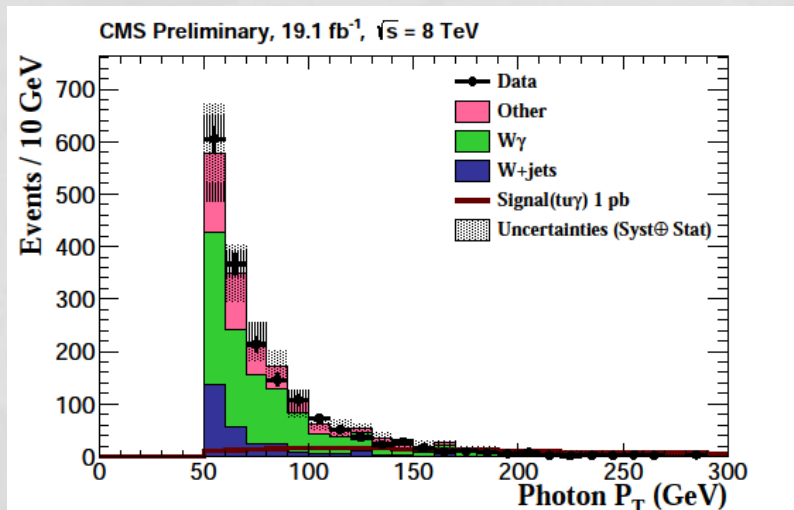
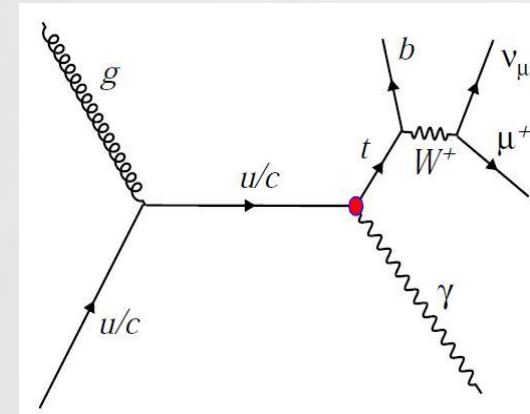
- Jets, MET reconstruction and pileup mitigation are based on particle-flow algorithm.

FCNC $tq\gamma$ in single top production

19.1 fb⁻¹ at 8 TeV

CMS-PAS-TOP-14-003

- Search for anomalous $tq\gamma$ coupling in the single top production
- One isolated μ , one b-tagged jet, one isolated γ
- Boosted decision tree (BDT)
- Photon energy scale and $W\gamma + jets, W + jets$ (estimated in data driven way) are one of main uncertainties.

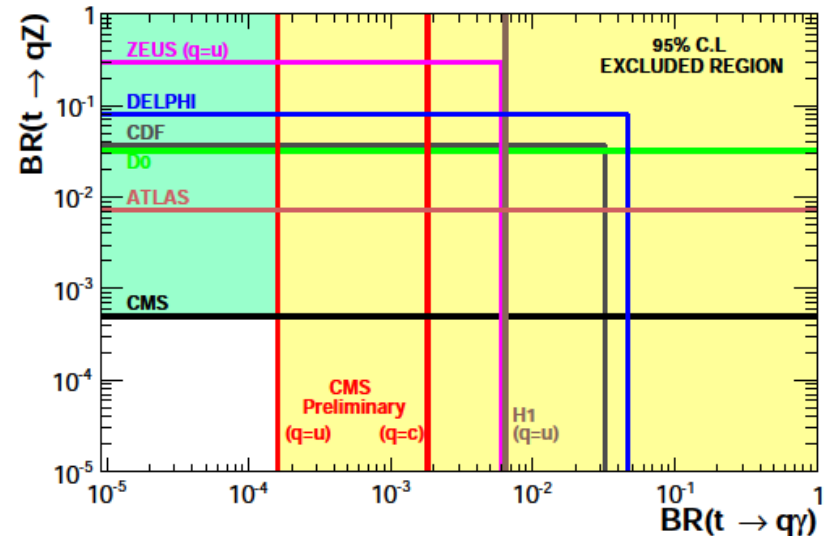
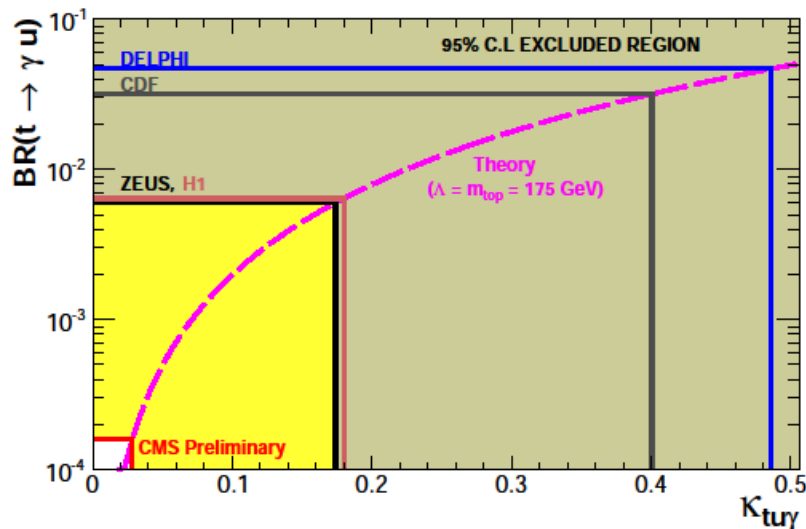


FCNC $tq\gamma$ in single top production

19.1 fb⁻¹ at 8 TeV

CMS-PAS-TOP-14-003

- BDT distribution to get 95% CL limit.
- $\kappa_{tu\gamma} < 0.0279$, $\kappa_{tc\gamma} < 0.0094$
- $Br(t \rightarrow u\gamma) < 0.0161\%$
- $Br(t \rightarrow c\gamma) < 0.182\%$



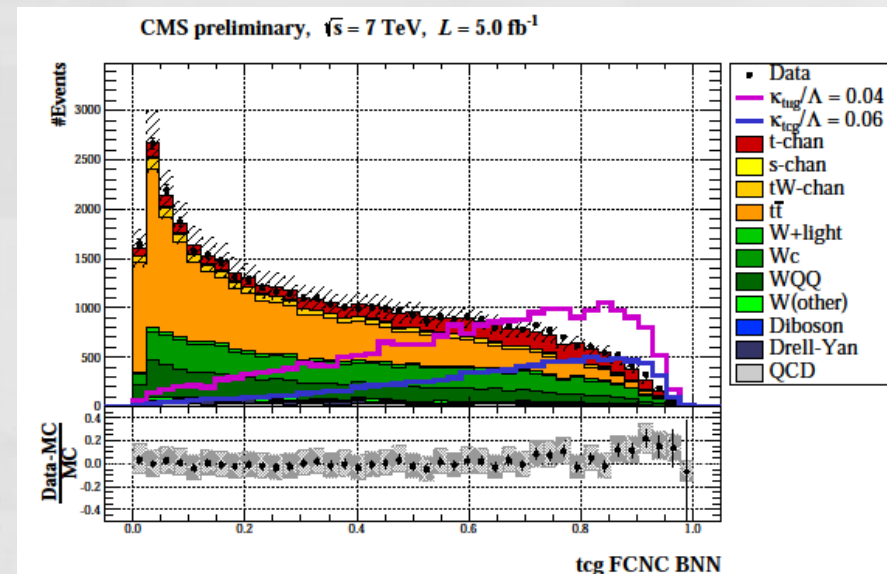
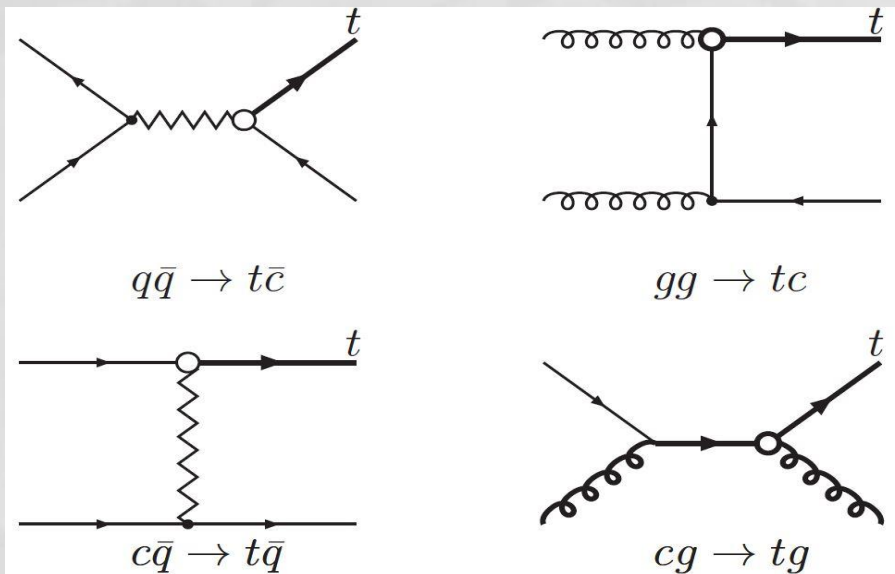
- The first at the LHC and the most stringent bounds on the anomalous FCNC $tq\gamma$ coupling to date.

FCNC tcg and tug in single top

5 fb⁻¹ at 7 TeV

CMS-PAS-TOP-14-007

- Search for FCNC tcg and tug coupling in the t-channel single top production.
- one isolated μ , 2-3 jets, one b-tagged jet
- Using Bayesian Neural Network (BNN)
- $W + jets$ is one of the main uncertainty source.

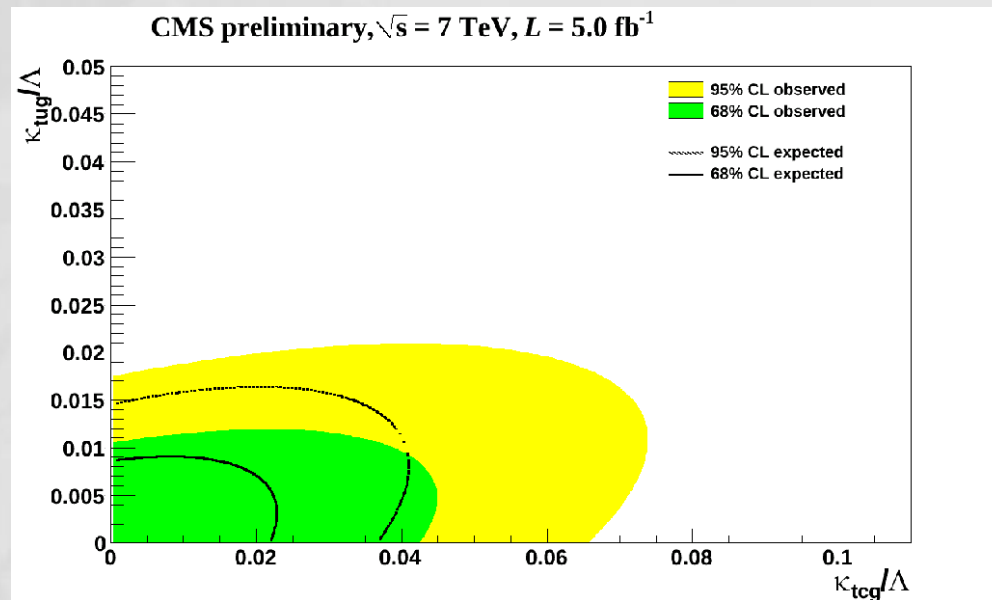


FCNC tcg and tug in single top

5 fb⁻¹ at 7 TeV

CMS-PAS-TOP-14-007

- Effective Lagrangian $\frac{\kappa_{tqg}}{\Lambda} g_s \bar{f} \sigma^{\mu\nu} \lambda^a t G_{\mu\nu}^a$



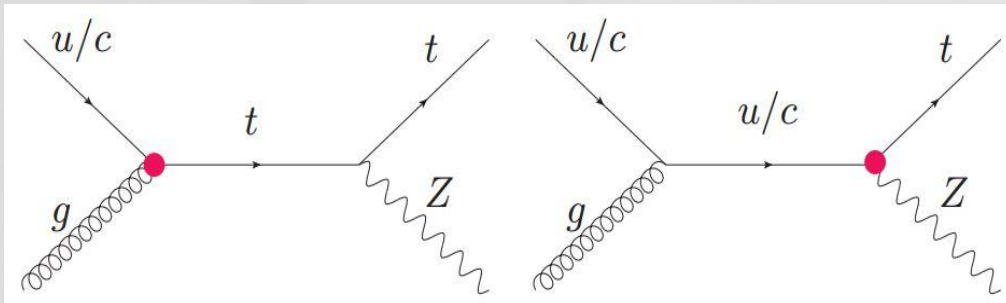
(expected)

- $Br(t \rightarrow u + g) < 3.55 \times 10^{-4}$ (1.58×10^{-4})
- $Br(t \rightarrow c + g) < 3.44 \times 10^{-3}$ (1.05×10^{-3})

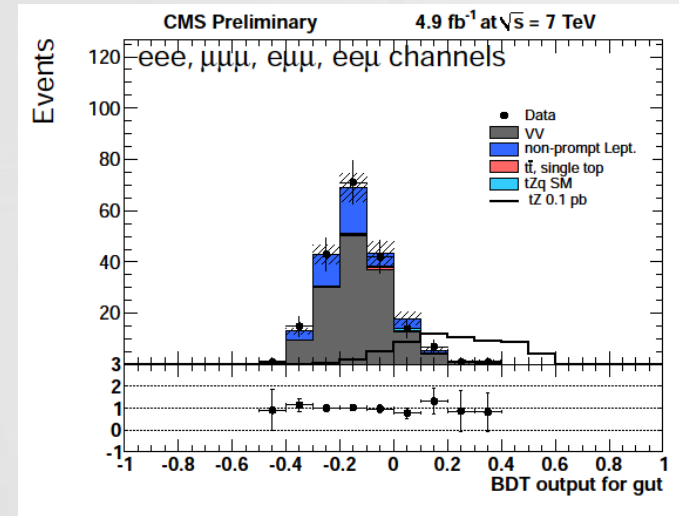
FCNC in single top $t + Z$ events

5 fb^{-1} at 7 TeV

CMS-PAS-TOP-12-021



arxiv:1304.5551v2



- Anomalous tqZ and tqg coupling in single top production associated with a Z boson.
- 3 isolated leptons + 1 b-jet
- kinematic variables and b-tagging information using Boosted Decision Tree (BDT)

FCNC in single top $t + Z$ events

5 fb⁻¹ at 7 TeV

CMS-PAS-TOP-12-021

- Di-boson estimation is one of the systematic sources.
- For gqt coupling, it is not competitive with the one from single top production but gives interesting cross check in different physics process.
- For Zqt coupling, it is conceivable to combine the result with the result from $t\bar{t}$ pair production.

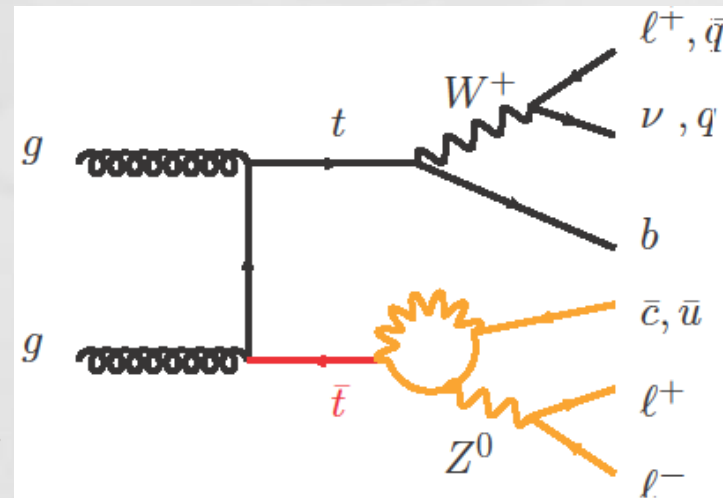
couplings	Expected	Observed	$\mathcal{BR}(t \rightarrow gq/Zq)$
κ_{gut}/Λ	0.096	0.096	0.56 %
κ_{gct}/Λ	0.427	0.354	7.12 %
κ_{Zut}/Λ	0.492	0.451	0.51 %
κ_{Zct}/Λ	2.701	2.267	11.40 %

FCNC in decay mode of $t\bar{t}$

5 fb⁻¹ at 7 TeV + 19.7 fb⁻¹ at 8 TeV

[PRL 112 \(2014\) 171802](#)

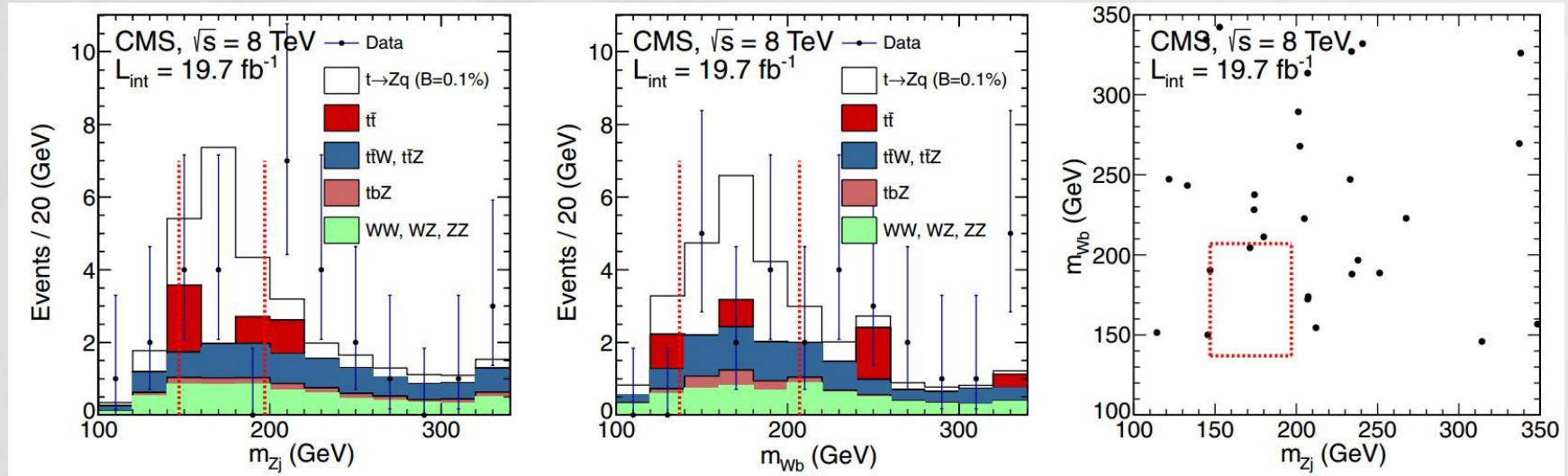
- Searching for $t \rightarrow cZ$ in tri-lepton final states.
- Three isolated leptons.
 - Two in a Z mass, third isolated lepton, no 4th lepton
 - Large MET and at least two jets (1 b-jet exclusively).
- Reconstruct top mass from W boson and b-quark jets
- Choose the second top mass considering all combinations.



FCNC in decay mode of $t\bar{t}$

PRL 112 (2014) 171802

- Events should be within 35 GeV window of top-quark mass for m_{Wb} and 25 GeV for m_{Zj}
- Dominant uncertainty : renormalization and factorization uncertainty, PDF and $\sigma_{t\bar{t}}$



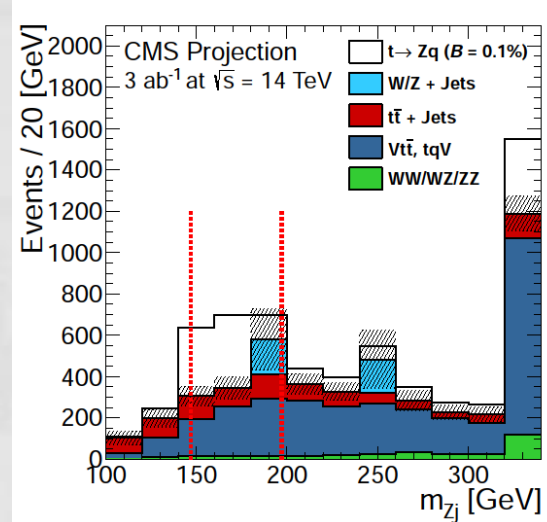
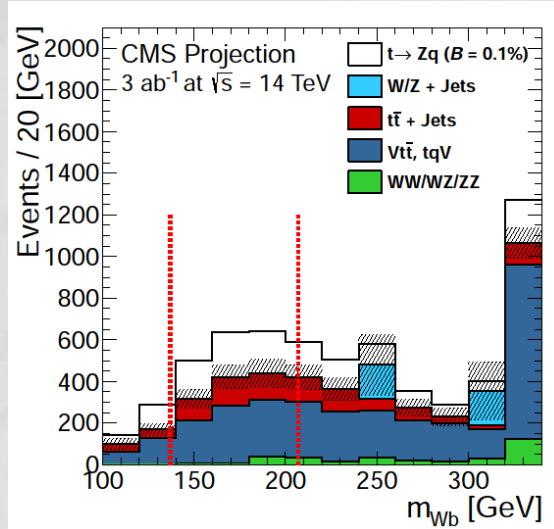
$\mathcal{B}(t \rightarrow Zq)$	8 TeV	7 + 8 TeV
Expected upper limit	< 0.10%	< 0.09%
Observed upper limit	< 0.06%	< 0.05%
1σ boundary	0.06–0.13%	0.06–0.13%
2σ boundary	0.05–0.20%	0.05–0.18%

Projections of $t \rightarrow cZ$ at 14 TeV

3000fb⁻¹ at 14 TeV

CMS-PAS-FTR-13-016

- Search for tqZ coupling in $t\bar{t}$ pair production with upgraded detector at 14 TeV scenario with high pileup conditions.
- 10 times better limit expected at 3000 fb⁻¹



$\mathcal{B}(t \rightarrow Zq)$	19.5 fb ⁻¹ @ 8 TeV	300 fb ⁻¹ @ 14 TeV	3000 fb ⁻¹ @ 14 TeV
Exp. bkg. yield	3.2	26.8	268
Expected limit	< 0.10%	< 0.027%	< 0.010%
1 σ range	0.06 – 0.13%	0.018 – 0.038%	0.007 – 0.014%
2 σ range	0.05 – 0.20%	0.013 – 0.051%	0.005 – 0.020%

Indirect search for FCNH ($t \rightarrow cH$)

19.5 fb⁻¹ at 8 TeV

CMS-PAS-HIG-13-034

- Reinterpret the result from multi-lepton SUSY searches : SUS-13-002
 - $t \rightarrow cH(WW, \tau\tau, ZZ)$ in multi-lepton final state
 - Exactly three selected leptons
- Combination with the result for $t \rightarrow cH(\gamma\gamma)$: HIG-13-025
- $\text{Br}(t \rightarrow cH) < 0.56\%$ at 95% confidence level
- $\sqrt{|\lambda_{tc}^H|^2 + |\lambda_{tc}^H|^2} < 0.14$

Higgs Decay Mode	observed	expected	1 σ range
$H \rightarrow WW^*$ ($\mathcal{B} = 23.1\%$)	1.58 %	1.57 %	(1.02–2.22) %
$H \rightarrow \tau\tau$ ($\mathcal{B} = 6.15\%$)	7.01 %	4.99 %	(3.53–7.74) %
$H \rightarrow ZZ^*$ ($\mathcal{B} = 2.89\%$)	5.31 %	4.11 %	(2.85–6.45) %
combined multileptons ($WW^*, \tau\tau, ZZ^*$)	1.28 %	1.17 %	(0.85–1.73) %
$H \rightarrow \gamma\gamma$ ($\mathcal{B} = 0.23\%$)	0.69 %	0.81 %	(0.60–1.17) %
combined multileptons + diphotons	0.56 %	0.65 %	(0.46–0.94) %

Conclusions

- CMS has performed the FCNC searches in the single top-quark production and decay mode of $t\bar{t}$ pair and found no signature of FCNC.
- More results from Run 1 (7 and 8 TeV) are coming soon.
- Exciting time is ahead of us for rare process searches with top-quark with for Run 2 data (13 and 14 TeV).
- CMS public results
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP>
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS>