Search for new physics in top quark production in di-lepton final state

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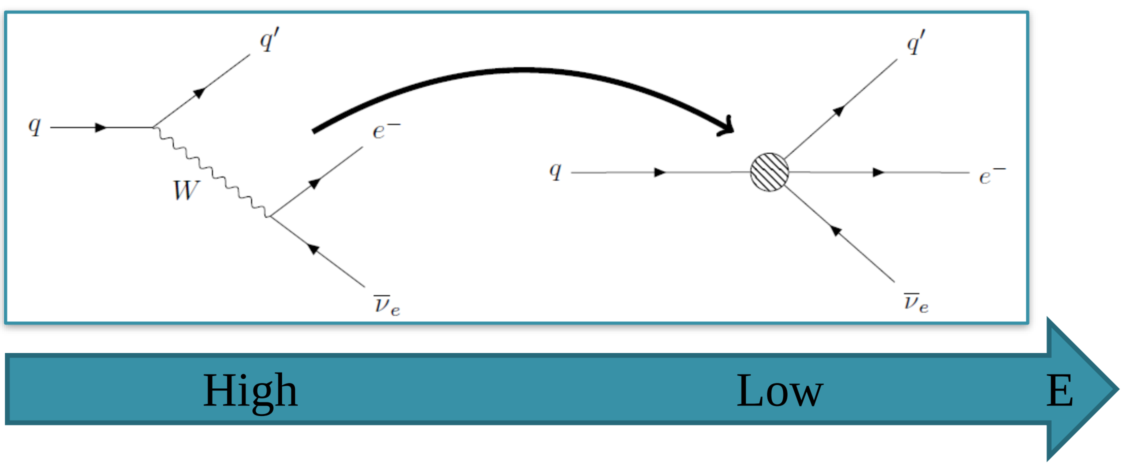
Introduction

- As we know if new physics scale is reachable at the LHC then the new physics could be directly observed via the production of new particles.
- Otherwise, it could affect standard model (SM) interactions indirectly by modifications of SM couplings or enhancements of rare SM processes.
- In the latter case, the effective field theory (EFT) approach is useful to parametrize and constrain the new physics in a model-independent way.
- In EFT we extend the SM by adding new terms to the Lagrangian.
- The underlying new physics particle gets integrated out leaving only the effective vertex. Such as the Fermi theory for neutron decay.



Introduction

- Due to its large mass and close to the electroweak symmetry breaking scale, the top quark is expected to play an important role in several new physics scenarios.

- An EFT approach is followed to search for new physics in the top quark sector in the dilepton final states (CMS-TOP-17-020). The operators and the related effective Lagrangians can be written as:

$$O^{(3)}_{\phi q} = (\phi^{+}\tau^{I}D_{\mu}\phi)(\bar{q}\gamma^{\mu}\tau^{I}q), \quad L_{eff} = \frac{C^{(3)}_{\phi q}}{\Lambda^2}\frac{gv^2}{\sqrt{2}}\bar{b}\gamma^{\mu}P_{L}tW^{-}_{\mu} + h.c., \quad (1)$$

$$O_{tW} = (\bar{q}\sigma^{\mu\nu}\tau^{I}t)\tilde{\phi}W^{I}_{\mu\nu}, \quad L_{eff} = -2\frac{C_{tW}}{\Lambda^2}v\bar{b}\sigma^{\mu\nu}P_{R}t\partial_{\nu}W^{-}_{\mu} + h.c., \quad (2)$$

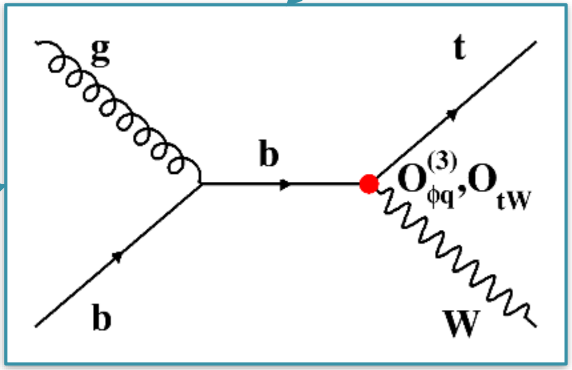
$$O_{tG} = (\bar{q}\sigma^{\mu\nu}\lambda^{A}t)\tilde{\phi}G^{A}_{\mu\nu}, \quad L_{eff} = \frac{\mathrm{Re}C_{tG}}{\sqrt{2}\Lambda^2}v\left(\bar{t}\sigma^{\mu\nu}\lambda^{A}t\right)G^{A}_{\mu\nu} + h.c., \quad (3)$$

$$O_{G} = f_{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}, \quad L_{eff} = \frac{C_G}{\Lambda^2}f_{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho} + h.c., \quad (4)$$

$$O_{u(c)G} = (\bar{q}\sigma^{\mu\nu}\lambda^{A}t)\tilde{\phi}G^{A}_{\mu\nu}, \quad L_{eff} = g_s\frac{C_{u(c)G}}{\sqrt{2}\Lambda^2}v\left(\bar{u}\,(\bar{c})\,\sigma^{\mu\nu}\lambda^{A}t\right)G^{A}_{\mu\nu} + h.c., \quad (5)$$

- $\mathbf{O_{\varphi q}}$: it has the same interaction as the SM Wtb interaction. Therefore, it does not affect any final state kinematic distributions.

- $\mathbf{O_{tW}}$: it has the right handed Wtb interaction.
- After investigating, we conclude that the kinematic distributions in tW production and top decay when $\mathbf{O_{tW}}$ is present are similar to the SM and the effects are not big enough to be observed.



Introduction

$$O_{\phi q}^{(3)} = (\phi^{+}\tau^{I}D_{\mu}\phi)(\bar{q}\gamma^{\mu}\tau^{I}q), \quad L_{eff} = \frac{C_{\phi q}^{(3)}}{\Lambda^2}\frac{gv^2}{\sqrt{2}}\bar{b}\gamma^{\mu}P_{L}tW_{\mu}^{-} + h.c., \tag{1}$$

$$O_{tW} = (\bar{q}\sigma^{\mu\nu}\tau^{I}t)\tilde{\phi}W_{\mu\nu}^{I}, \quad L_{eff} = -2\frac{C_{tW}}{\Lambda^2}v\bar{b}\sigma^{\mu\nu}P_{R}t\partial_{\nu}W_{\mu}^{-} + h.c., \tag{2}$$

$$O_{tG} = (\bar{q}\sigma^{\mu\nu}\lambda^{A}t)\tilde{\phi}G_{\mu\nu}^{A}, \quad L_{eff} = \frac{\mathrm{Re}C_{tG}}{\sqrt{2}\Lambda^2}v\left(\bar{t}\sigma^{\mu\nu}\lambda^{A}t\right)G_{\mu\nu}^{A} + h.c., \tag{3}$$

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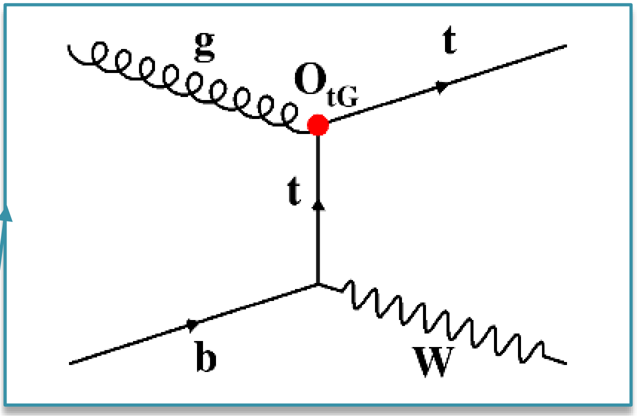
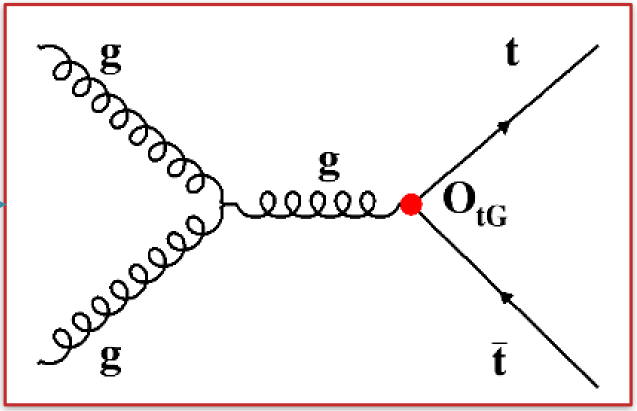
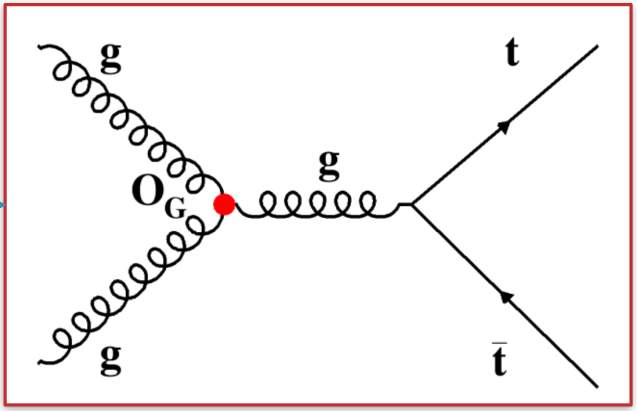
$$O_{u(c)G} = (\bar{q}\sigma^{\mu\nu}\lambda^{A}t)\tilde{\phi}G_{\mu\nu}^{A}, \quad L_{eff} = g_{s}\frac{C_{u(c)G}}{\sqrt{2}\Lambda^2}v\left(\bar{u}\,(\bar{c})\,\sigma^{\mu\nu}\lambda^{A}t\right)G_{\mu\nu}^{A} + h.c., \tag{5}$$

- **O_{tG}** : it affects both tW and $t\bar{t}$ production.
- After investigating, we conclude that the kinematic distributions in both tW and $t\bar{t}$ production when **O_{tG}** is present are similar to the SM and the effects are not big enough to be observed.





- **O_{G}** : it affects $t\bar{t}$ production only.
- After investigating, we conclude that the kinematic distributions in $t\bar{t}$ production are affected when **O_{G}** is present.



Introduction

$$O_{\phi q}^{(3)} = (\phi^+ \tau^I D_\mu \phi)(\bar{q}\gamma^\mu \tau^I q), \quad L_{eff} = \frac{C_{\phi q}^{(3)}}{\Lambda^2}\frac{g v^2}{\sqrt{2}}\bar{b}\gamma^\mu P_L t W_\mu^- + h.c., \quad (1)$$

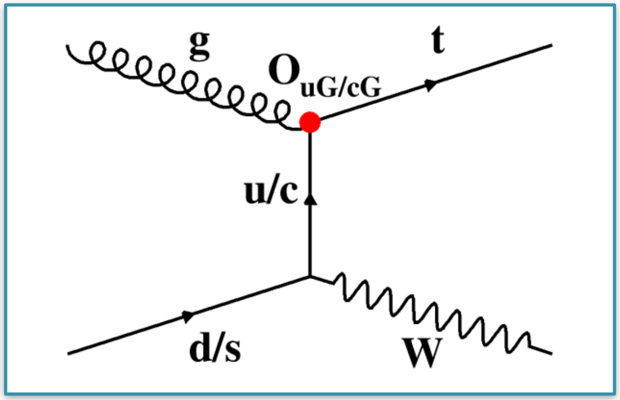
$$O_{tW} = (\bar{q}\sigma^{\mu\nu}\tau^I t)\tilde{\phi} W_{\mu\nu}^I, \quad L_{eff} = -2\frac{C_{tW}}{\Lambda^2} v \bar{b}\sigma^{\mu\nu} P_R t \partial_\nu W_\mu^- + h.c., \quad (2)$$

$$O_{tG} = (\bar{q}\sigma^{\mu\nu}\lambda^A t)\tilde{\phi} G_{\mu\nu}^A, \quad L_{eff} = \frac{\mathrm{Re}C_{tG}}{\sqrt{2}\Lambda^2} v \left(\bar{t}\sigma^{\mu\nu}\lambda^A t\right) G_{\mu\nu}^A + h.c., \quad (3)$$

$$O_G = f_{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}, \quad L_{eff} = \frac{C_G}{\Lambda^2} f_{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu} + h.c., \quad (4)$$

$$O_{u(c)G} = (\bar{q}\sigma^{\mu\nu}\lambda^A t)\tilde{\phi} G_{\mu\nu}^A, \quad L_{eff} = g_s \frac{C_{u(c)G}}{\sqrt{2}\Lambda^2} v \left(\bar{u}\,(\bar{c})\,\sigma^{\mu\nu}\lambda^A t\right) G_{\mu\nu}^A + h.c., \quad (5)$$

- The operators $\mathbf{O_{uG}}$ and $\mathbf{O_{cG}}$ lead to flavor changing neutral current (FCNC) interactions of top quark.
- As we know the FCNC processes do not exist at tree level in the SM and are induced only at loop level. Therefore the rates of FCNC processes are highly suppressed. The observation of such processes will be very important for searching new physics.



- $\mathbf{O_{uG}}$, $\mathbf{O_{cG}}$: it affects tW production only.
- The presence of the $\mathbf{O_{uG}}$ and $\mathbf{O_{cG}}$ operators changes the initial state particle and leads to different kinematic distributions for the final state particles compared to the SM tW process.

Introduction

- When EFT couplings are non-zero, $t\bar{t}$ or tW cross section contains:
  1. SM term: σ_{SM}
  2. Interference term: $C_i\sigma_i^{(1)}$
  3. Pure new physics term: $C_i^2\sigma_i^{(2)}$

$$\sigma = \sigma_{SM} + C_i\sigma_i^{(1)} + C_i^2\sigma_i^{(2)}$$

Cross sections for $t\bar{t}$ and tW production [in pb] for the various effective couplings for Λ = 1 TeV and the respective available k-factors:

Channel	Variable	C_G	$C_{\phi q}^{(3)}$	C_{tW}	C_{tG}	C_{uG}	C_{cG}
$t\bar{t}$	$\sigma_i^{(1)-LO}$	31.9	-	-	137	-	-
	$\sigma_i^{(1)-NLO}/\sigma_i^{(1)-LO}$	-	-	-	1.48	-	-
	$\sigma_i^{(2)-LO}$	102.3	-	-	16.4	-	-
	$\sigma_i^{(2)-NLO}/\sigma_i^{(2)-LO}$	-	-	-	1.44	-	-
tW	$\sigma_i^{(1)-LO}$	-	6.7	-4.5	3.3	0	0
	$\sigma_i^{(1)-NLO}/\sigma_i^{(1)-LO}$	-	1.32	1.27	1.27	0	0
	$\sigma_i^{(2)-LO}$	-	0.2	1	1.2	16.2	4.6
	$\sigma_i^{(2)-NLO}/\sigma_i^{(2)-LO}$	-	1.31	1.18	1.06	1.27	1.27

Object and event selection

- Dataset: $35.9 fb^{-1}$ in 2016.
- Trigger: dilepton or single lepton triggers.

Electron

- P_T>20 GeV, |η|<2.4 (Gap removed)
- Passing electron ID and isolation

Muon

- P_T>20 GeV , |η|<2.4
- Passing muon ID and isolation

Jet/bjet

- P_T>30 GeV, | η |<2.4 , $\Delta R(\text{lepton}, \text{jet}) > 0.4$
- Passing jet/bjet ID

❖ Event selection

- At least 1 pair of leptons (leading lepton p_T>25 GeV).
- The first two selected leptons which are sorted due to the p_T should have opposite sign charge.
- Events are categorized to ee, μμ, and eμ channels using the flavors of the two highest p_T leptons.
- Missing E_T>60 GeV and $M_{\ell\ell}$ should be out of Z mass window [76 GeV,106 GeV] in ee, μμ channels.

- The selection is the same as SM $t\bar{t}$, tW cross section measurement [4-6] in CMS.

Backgrounds

- The background from processes giving two prompt leptons is taken from Monte Carlo samples and normalized to the luminosity. It consists mostly of events from $t\bar{t}$, tW, WW, other di-boson processes and Drell-Yan (only in eμ channel, the data driven method is used for DY estimation for ee and μμ channel).

- For the jet fake lepton backgrounds which include W + jet and QCD process are estimated by data-driven technique called same sign method.

  - We use the fact that the probability of assigning positive or negative charge to the misidentified jet should be equal.

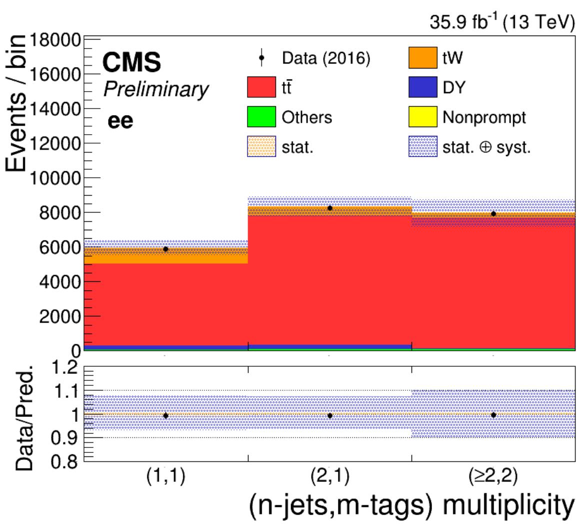
  - The contributions of all other backgrounds are subtracted from data in same sign region using MC samples to find jet contribution.

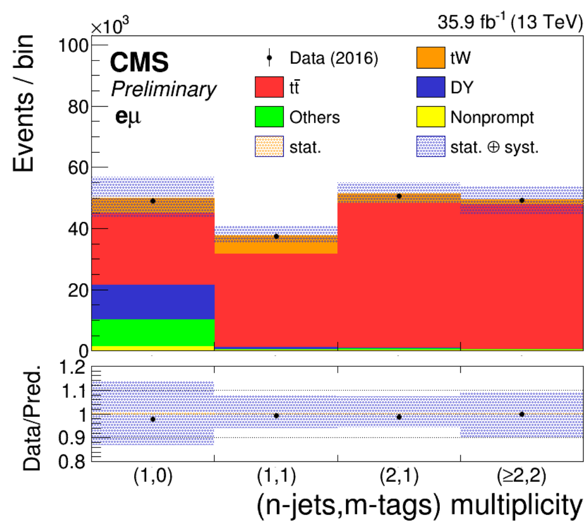
Event categorization

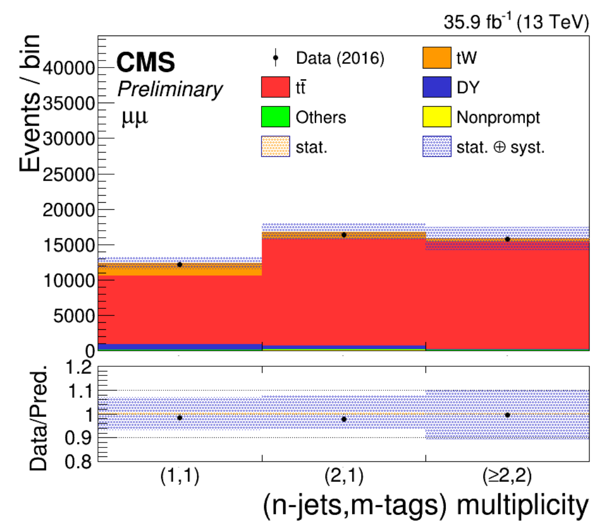
- Largest number of tW events : (1-jet,1-tag) followed by (2-jets,1-tag).
- $t\bar{t}$ dominant region is (≥2-jets,2-tags).
- For ee and μμ channels, events with zero b-tagged jet are dominated by DY events and are not used in the analysis.
- For eμ channel, the (1-jet,0-tag) is used because the contamination of DY events is lower and a significant amount of tW events are present.

Event table for used channels and categories

Channel	(n-jets,m-tags)	Prediction					Data
		tW	$t\bar{t}$	DY	Other + nonprompt	Total predicted yield	
ee	(1,1)	884±8	4741±15	258±50	53±5	5936±470	5902±76
	(2,1)	518±6	7479±19	241±53	94±5	8331±597	8266±90
	(≥2,2)	267±4	7561±18	46±24	99±4	7973±819	7945±89
eμ	(1,0)	4835±20	23557±35	11352±277	10294±72	50038±6931	48973±221
	(1,1)	6048±22	30436±38	561±66	629±13	37673±2984	37370±193
	(2,1)	3117±16	47206±48	278±48	781±9	51382±3714	50725±225
	(≥2,2)	1450±10	47310±46	32±22	598±9	49391±5010	49262±221
μμ	(1,1)	1738±12	9700±21	744±90	183±5	12366±879	12178±110
	(2,1)	989±9	14987±27	501±75	275±5	16751±1276	16395±128
	(≥2,2)	508±6	15136±26	82±24	163±5	15889±1714	15838±125







CMS-TOP-17-020

Systematics uncertainties

- Experimental uncertainties
  - Luminosity: 2.5%
  - Pile-up reweighting: minimum bias xs is varied by 4.6%
  - Lepton reconstruction, identification and isolation and Trigger scale factors
  - Jet energy scale and resolution
  - Un-clustered energy
  - b-tagging/mistagging
- $t\bar{t}$ and tW modeling uncertainty
  - Renormalization/factorization scale (QCD scale)
  - Parton Distribution Functions (PDF) (only $t\bar{t}$)
  - Top mass
  - tW/$t\bar{t}$ interference (DS/DR)
  - ME/PS matching (hdamp variation-only $t\bar{t}$)
  - Scale variations of initial state radiation and final state radiation (ISR/FSR)
  - Color reconnection (only $t\bar{t}$)
  - Underlying event (only $t\bar{t}$)
- $t\bar{t}$ normalization: 5% for $O_{\varphi q}$, O_{tW} and FCNC (O_{uG} and O_{cG})
- tW normalization: 10% for $O_{G,}$ and FCNC (O_{uG} and O_{cG})
- DY modeling uncertainty: PDF and QCD scale (only consider for eμ channel in 1jet,0tag region)
- DY normalization error:
  - ee and μμ channels: 30%
  - eμ channel: 1jet,0tag region is 15% (SMP-16-015) , for other regions is 50%
- Prompt background (except $t\bar{t}$,tW, DY) normalization: 50%
- Non-prompt background (from same sign) normalization: 50%
- tW FCNC: PDF and QCD scale

Signal extraction

- The purpose of the analysis is searching for deviations to the SM $t\bar{t}$ and tW predictions due to new physics

- **$O_{\varphi q}$, O_{tW}, O_{tG}** : Using Multi Layer Perceptron (MLP) to split SM tW (as signal) and SM $t\bar{t}$ (as background)
- **O_{uG}, O_{cG}** : Using MLP to split FCNC tW (signal) and SM tW+$t\bar{t}$ (background)
- **O_G** : No shape analysis → no MVA

The signal extraction strategy for different couplings in n-jet, m-tag categories

Eff. coupling	Channel	Categories				
		1-jet,0-tag	1-jet,1-tag	2-jets,1-tag	n-jets,1-tag	≥2-jets, 2-tags
C_G	ee	-	Yield	Yield	-	Yield
	$e\mu$	Yield	Yield	Yield	-	Yield
	$\mu\mu$	-	Yield	Yield	-	Yield
$C_{\phi q}^{(3)}$, C_{tW}, C_{tG}	ee	-	MLP_{11}	MLP_{21}	-	Yield
	$e\mu$	MLP_{10}	MLP_{11}	MLP_{21}	-	Yield
	$\mu\mu$	-	MLP_{11}	MLP_{21}	-	Yield
C_{uG}, C_{cG}	ee	-	-	-	MLP_{FCNC}	-
	$e\mu$	-	-	-	MLP_{FCNC}	-
	$\mu\mu$	-	-	-	MLP_{FCNC}	-

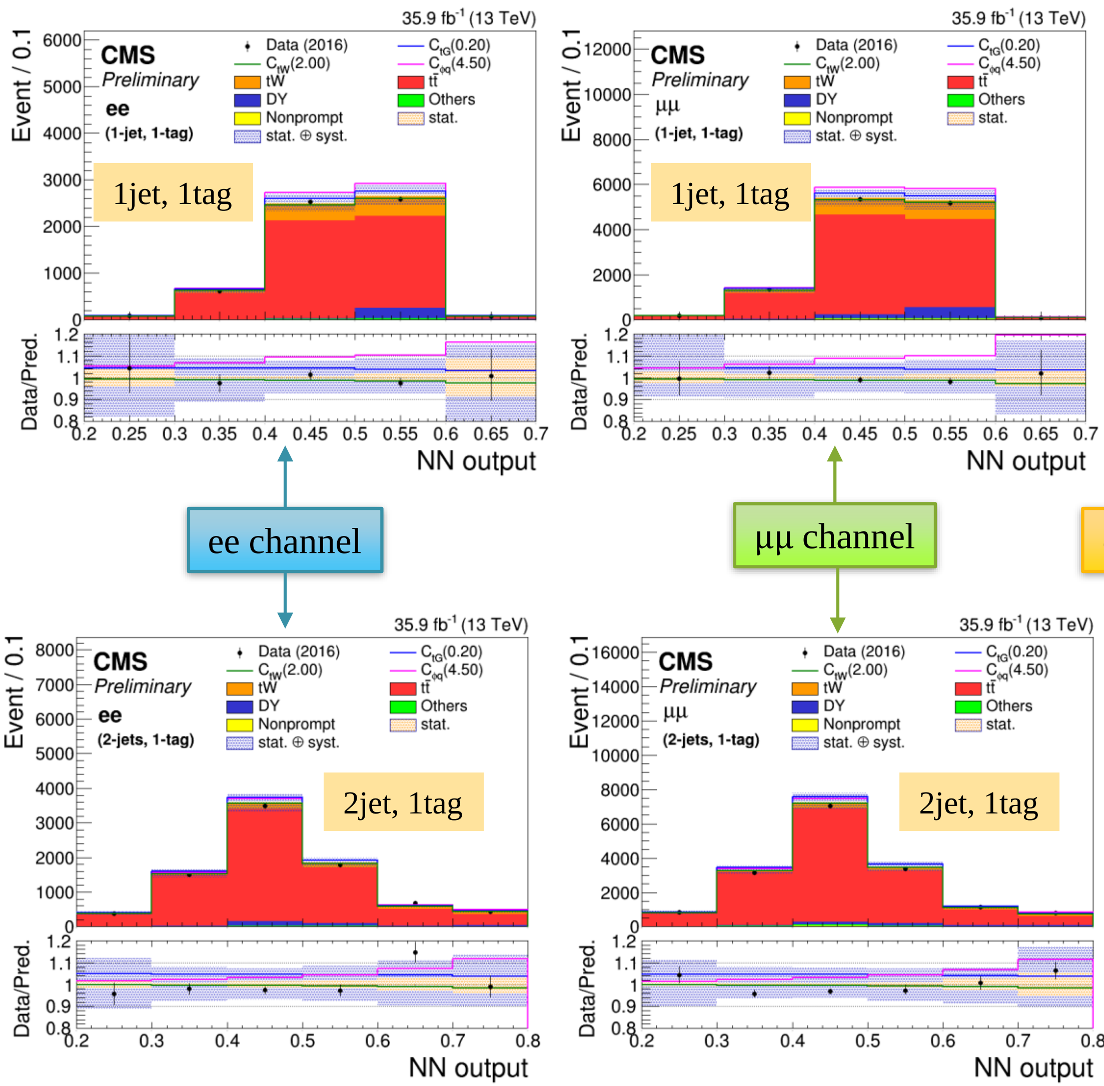
❖ The MLP input variables for n-jet, m-tag categories are shown in next slide

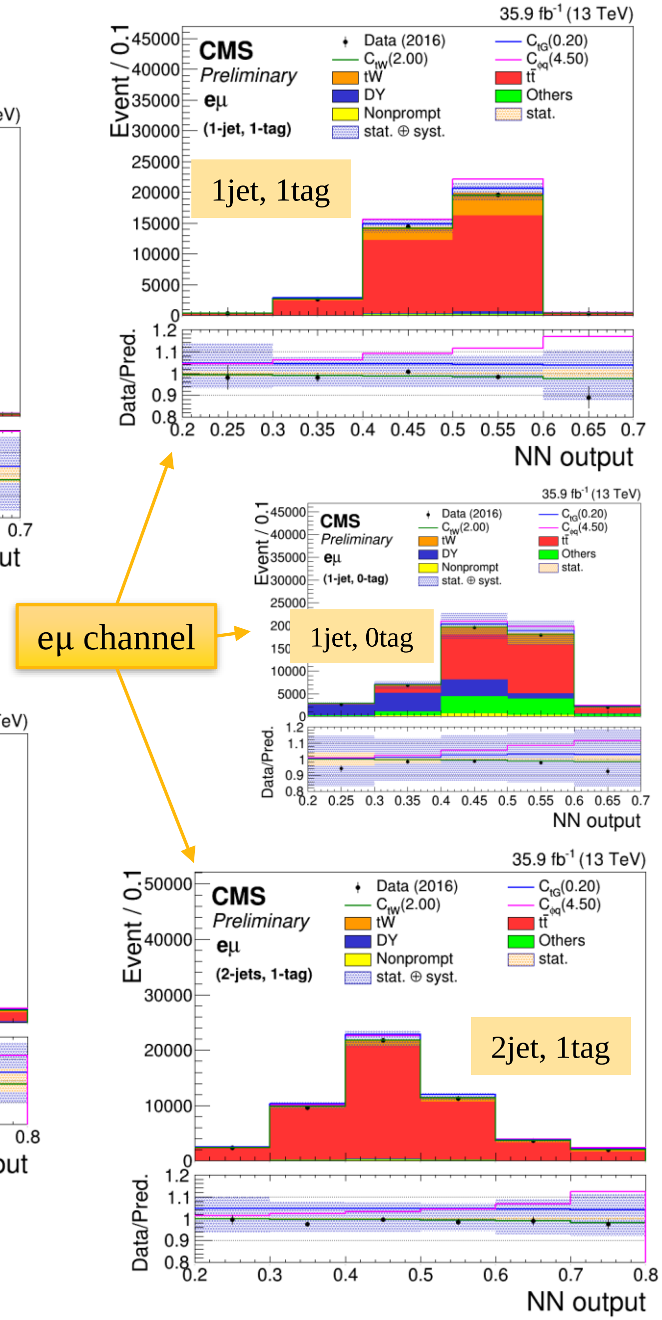
Signal extraction

❖ MLP input variables:

Variable	Description	MLP_{10}	MLP_{11}	MLP_{21}	MLP_{FCNC}
M_{ll}	Invariant mass of dilepton system	√			√
$p_T^{\ell\ell}$	p_T of dilepton system	√		√	√
$\Delta p_T(\ell,\ell)$	$p_T^{\text{leading lepton}}$ - $p_T^{\text{sub-leading lepton}}$	√			√
$N_{Loosejet}$	Number of loose jets	√		√	
$p_T^{\text{leading lepton}}$	p_T of leading lepton	√		√	√
Centrality(ℓ^{leading} jet$^{\text{leading}}$)	Scalar sum of p_T of the leading lepton and leading jet,over total energy of selected objects	√			√
Centrality($\ell\ell$)	Scalar sum of p_T of the leading and sub-leading leptons,over total energy of selected objects	√			√
$\Delta\phi(\ell\ell,\text{jet}^{\text{leading}})$	$\Delta\phi$ between dilepton system and leading jet	√	√	√	
$p_T(\ell\ell,\text{jet}^{\text{leading}})$	p_T of dilepton and leading jet system		√		√
$p_T(\ell^{\text{leading}},\text{jet}^{\text{leading}})$	p_T of leading lepton and leading jet system		√		
$N_{Looseb-jet}$	Number of loose b-jets		√		
$p_T^{\text{loose jets}}$	p_T of leading loose jet		√		
Centrality($\ell\ell$ jet$^{\text{leading}}$)	Scalar sum of p_T of the dilepton system and leading jet,over total energy of selected objects		√		
$\Delta R(\ell,\ell)$	ΔR between leading and sub-leading leptons		√		
$\Delta R(\ell^{\text{leading}},\text{jet}^{\text{leading}})$	ΔR between leading lepton and leading jet		√		
$p_T^{\text{sub-leading jet}}$	p_T of sub-leading jet			√	
$M(\ell^{\text{leading}},\text{jet}^{\text{leading}})$	Invariant mass of leading lepton and leading jet			√	
$M(\text{jet}^{\text{leading}},\text{jet}^{\text{sub-leading}})$	Invariant mass of leading jet and sub-leading jet			√	
$\Delta R(\ell^{\text{leading}},\text{jet}^{\text{sub-leading}})$	ΔR between leading lepton and sub-leading jet			√	
$\Delta R(\ell\ell,\text{jet}^{\text{leading}})$	ΔR between dilepton system and leading jet			√	√
$\Delta p_T(\ell^{\text{sub-leading}},\text{jet}^{\text{sub-leading}})$	$p_T^{\text{sub-leading lepton}}$ - $p_T^{\text{sub-leading jet}}$			√	
$M(\ell^{\text{sub-leading}},\text{jet}^{\text{leading}})$	Invariant mass of sub-leading lepton and leading jet				√

NN output for different categories:





Data and predication are in good agreement.

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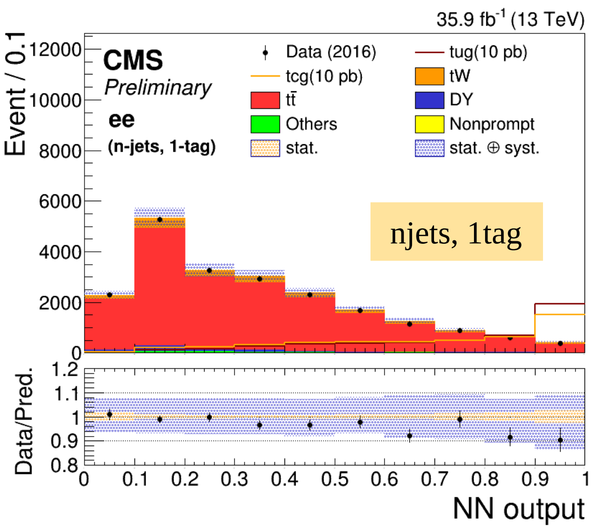
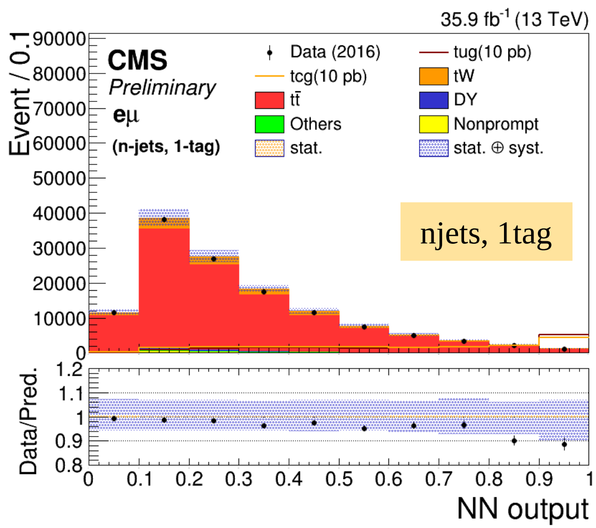
NN output for different categories:

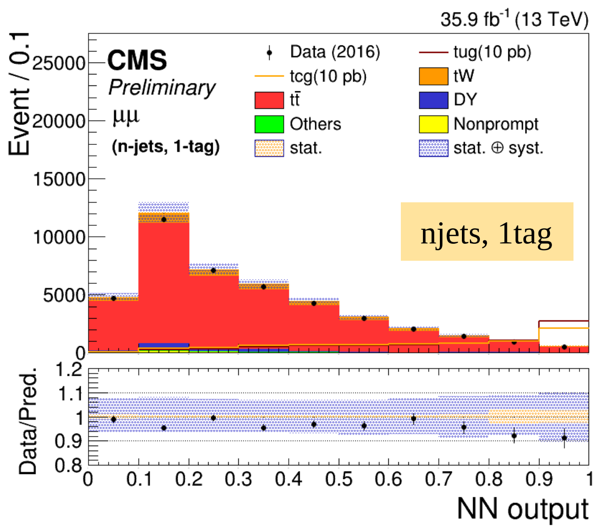
ee channel



eμ channel



μμ channel



Data and predication are in good agreement.

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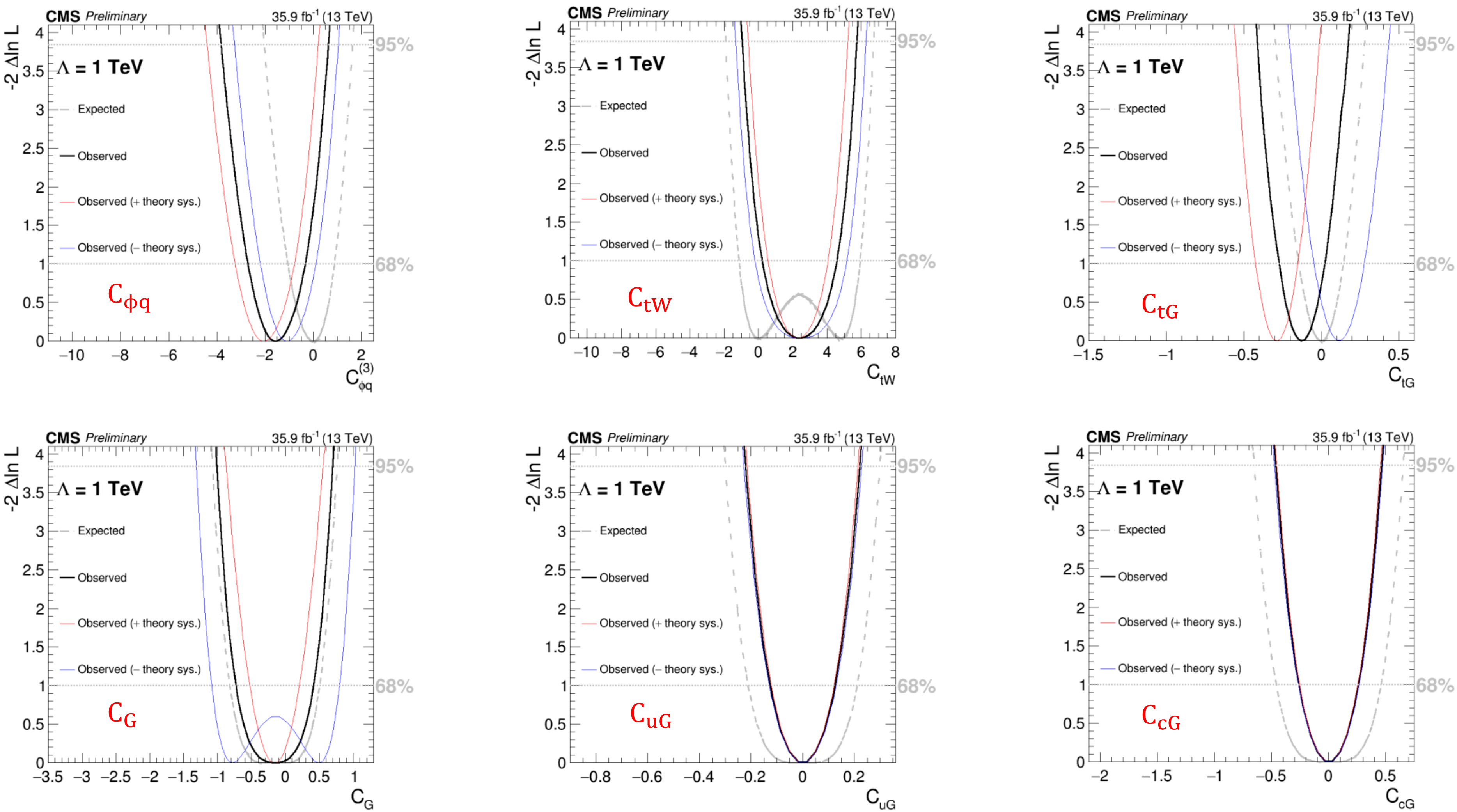
Results



- ❖ It is assumed that new physics only affect $t\bar{t}$ and tW normalization.
- ❖ The result when the cross section for $t\bar{t}$, tW, $\sigma_i^{(1)}$ and $\sigma_i^{(2)}$ are varied by one standard deviation which comes from Qscale and PDF uncertainties are also shown.

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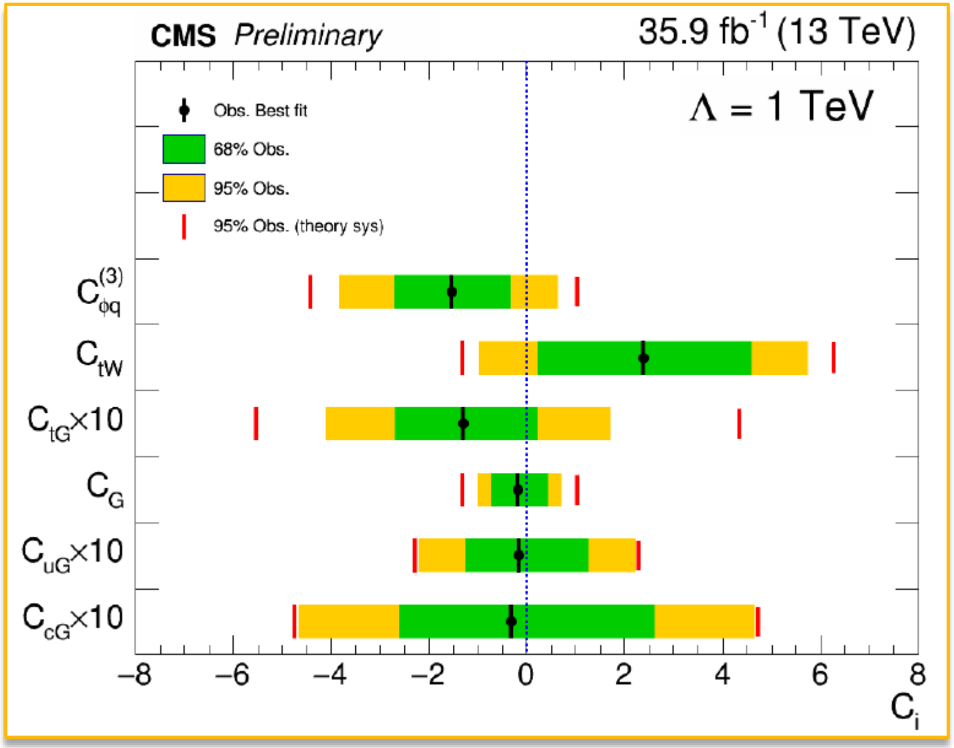
Results

The summary of the observed and expected allowed intervals at 68% CL (best fit with in up and low limit) and 95% CL (in square brackets)

Eff. coupling	Channel	Observed	Expected
C_G	ee	$-0.14^{+0.51}_{-0.82}$ [−1.14 , 0.83]	$0.00^{+0.59}_{-0.90}$ [−1.20 , 0.88]
	eμ	$-0.18^{+0.42}_{-0.73}$ [−1.01 , 0.70]	$0.00^{+0.51}_{-0.82}$ [−1.08 , 0.77]
	μμ	$-0.14^{+0.44}_{-0.75}$ [−1.06 , 0.75]	$0.00^{+0.57}_{-0.88}$ [−1.16 , 0.85]
	Combined	$-0.18^{+0.42}_{-0.73}$ [−1.01 , 0.70]	$0.00^{+0.51}_{-0.82}$ [−1.07 , 0.76]
$C^{(3)}_{\phi q}$	ee	$1.12^{+2.89}_{-1.18}$ [−4.03 , 4.37]	$0.00^{+1.74}_{-2.53}$ [−6.40 , 3.27]
	eμ	$-0.70^{+0.59}_{-2.16}$ [−3.74 , 1.61]	$0.00^{+1.12}_{-1.34}$ [−2.57 , 2.15]
	μμ	$1.13^{+2.86}_{-0.87}$ [−3.58 , 4.46]	$0.00^{+1.92}_{-2.20}$ [−4.68 , 3.66]
	Combined	$-1.52^{-0.33}_{-2.71}$ [−3.82 , 0.63]	$0.00^{+0.88}_{-1.05}$ [−2.04 , 1.63]
C_{tW}	ee	$6.18^{+7.81}_{-3.02}$ [−4.16 , 8.95]	$0.00^{+6.81}_{-2.02}$ [−3.33 , 8.12]
	eμ	$1.64^{+5.59}_{-0.80}$ [−1.89 , 6.68]	$0.00^{+6.19}_{-1.40}$ [−2.39 , 7.18]
	μμ	$-1.40^{+7.79}_{-3.00}$ [−4.23 , 9.01]	$0.00^{+6.97}_{-2.18}$ [−3.63 , 8.42]
	Combined	$2.38^{+4.57}_{+0.22}$ [−0.96 , 5.74]	$0.00^{+5.93}_{-1.14}$ [−1.91 , 6.70]
C_{tG}	ee	$-0.19^{+0.02}_{-0.40}$ [−0.65 , 0.22]	$0.00^{+0.21}_{-0.22}$ [−0.44 , 0.41]
	eμ	$-0.03^{+0.11}_{-0.19}$ [−0.34 , 0.27]	$0.00^{+0.15}_{-0.17}$ [−0.34 , 0.29]
	μμ	$-0.15^{+0.02}_{-0.34}$ [−0.53 , 0.19]	$0.00^{+0.18}_{-0.19}$ [−0.40 , 0.35]
	Combined	$-0.13^{+0.02}_{-0.27}$ [−0.41 , 0.17]	$0.00^{+0.14}_{-0.15}$ [−0.30 , 0.28]
C_{uG}	ee	$-0.017^{+0.22}_{-0.22}$ [−0.37 ,0.37]	$0.00^{+0.29}_{-0.29}$ [−0.42 , 0.42]
	eμ	$-0.017^{+0.17}_{-0.17}$ [−0.29 ,0.29]	$0.00^{+0.26}_{-0.26}$ [−0.38 , 0.38]
	μμ	$-0.017^{+0.17}_{-0.17}$ [−0.29 ,0.29]	$0.00^{+0.27}_{-0.27}$ [−0.38 , 0.38]
	Combined	$-0.017^{+0.13}_{-0.13}$ [−0.22 ,0.22]	$0.00^{+0.21}_{-0.21}$ [−0.30 , 0.30]
C_{cG}	ee	$-0.032^{+0.47}_{-0.47}$ [−0.78 ,0.78]	$0.00^{+0.63}_{-0.63}$ [−0.92 , 0.92]
	eμ	$-0.032^{+0.34}_{-0.34}$ [−0.60 ,0.60]	$0.00^{+0.56}_{-0.56}$ [−0.81 , 0.81]
	μμ	$-0.032^{+0.36}_{-0.36}$ [−0.63 ,0.63]	$0.00^{+0.58}_{-0.58}$ [−0.84 , 0.84]
	Combined	$-0.032^{+0.26}_{-0.26}$ [−0.46 ,0.46]	$0.00^{+0.46}_{-0.46}$ [−0.65 , 0.65]



CMS-TOP-17-020

Summary

- A search for new physics in top quark production in dilepton final states has been performed using 35.9 fb^{-1} from CMS at 13 TeV in 2016.
- This is the first search for new physics using the tW process. No significant deviation is observed.
- EFT is used for new physics parameterization. The results are interpreted to constrain the relevant effective couplings using a dedicated multivariate analysis.

Reference

1. C. Zhang and S.Willenbrock, Phys. Rev. D. **83**. 034006
2. G. Durieux, F. Maltoni, and C. Zhang, Phys. Rev. D. **91**. 074017
3. Interpreting top-quark LHC measurements in the standard-model effective field theory, arXiv:1802.07237
4. Measurement of the tt production cross section, the top quark mass and the strong coupling constant using events in the dilepton final state in pp collisions at 13 TeV, CMS-TOP-17-001
5. Measurements of tt¯tt¯ differential cross sections in proton-proton collisions at $\sqrt{s}$ = 13 TeV using events containing two leptons, CMS-TOP-17-014
6. Measurement of the associated production of a single top quark and a W boson in pp collisions at $\sqrt{s}$ = 13 TeV, 10.1007/JHEP10(2018)117

Thanks for your attention

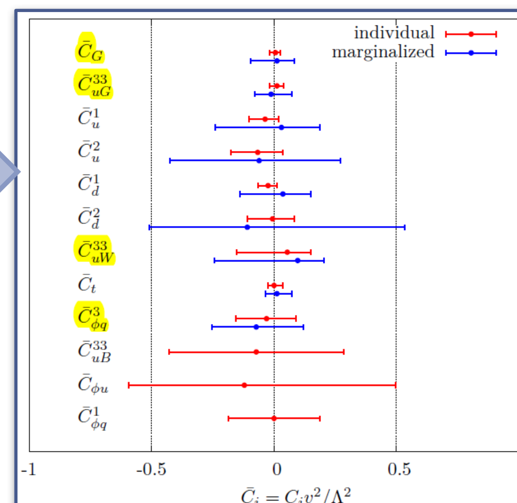
Back up

Results: Comparison with other analysis

95% obs. C.L.	Our	CMS	ATLAS	Phenomenological
$O_{\varphi q}$	[-3.82, 0.63]	From anomalous coupling approach from the t-channel and W helicity measurements		[-2.512, 1.456]
O_{tW}	[-0.96, 5.74]			[-2.416, 2.416]
O_{tG}	[-0.41, 0.17]	[-0.06, 0.41] (TOP_17_014)	-	[-0.288, 0.624]
O_G	[-1.01, 0.70]	-	-	[-0.288, 0.432]
$B(t \to ug)$	$<1.2 * 10^{-3}$	$<2 * 10^{-5}$ (link)	$<4.0 * 10^{-5}$(link)	-
$B(t \to cg)$	$<5.3 * 10^{-3}$	$<4.1 * 10^{-4}$ (link)	$<2.0 * 10^{-4}$(link)	-

Phenomenological work using experimental top measurements

- “Constraining top quark effective theory in the LHC Run II era”
- The TopFitter Collaboration
- Arxiv 1512.03360



DY estimation for ee and μμ channel

- ❑ DY MET distribution is not well described by the MC

- ❑ DY normalization is estimated from data for MET>60 GeV in ee and μμ channel (using official R_in/out method in top analyses)
- ❑ Number of events outside the z-veto region is estimated from the events inside the z-peak region
- ❑ The expected number of events outside the z-veto can be measured from data as:

$$N_{out}^{l^+l^-,Z+jets\ data} = R_{out/in}^{l^+l^-}(N_{in}^{l^+l^-,data} - 0.5N_{in}^{e\mu,data}k_{ll})$$

$$C_{Z+jets} = \frac{N_{out}^{l^+l^-,Z+jets\ data}}{N_{out}^{l^+l^-,Z+jets\ MC}}$$

$$R_{out/in} = \frac{N_{out}^{l^+l^-,Z+jets\ MC}}{N_{in}^{l^+l^-,Z+jets\ MC}}.$$

$$k_{ee} = \sqrt{\frac{N^{e^+e^-}_{in,loose}}{N^{\mu^+\mu^-}_{in,loose}}}$$

$$k_{\mu\mu} = \sqrt{\frac{N^{\mu^+\mu^-}_{in,loose}}{N^{e^+e^-}_{in,loose}}}$$

	all		1jet,1tag		2jet,1tag		$>= 2jet, 2tag$	
	ee	$\mu\mu$	ee	$\mu\mu$	ee	$\mu\mu$	ee	$\mu\mu$
$N_{in}^{l^+l^-,Z+jets\ MC}$	243878.3	562506.9	2712.3	6490.7	1550.6	3734.2	306.8	712.7
$N_{out}^{l^+l^-,Z+jets\ MC}$	22376	56494.6	301.4	878.7	280.8	590.9	53.7	94.1
$R_{out/in}$	0.092	0.100	0.111	0.135	0.181	0.158	0.175	0.132
$N_{in}^{l^+l^-,data}$	220435	501781	3805	8291	3735	7550	2493	5180
$N_{in}^{e\mu,data}$	34322	34322	4453	4453	6230	6230	6259	6259
$N_{out}^{l^+l^-,Z+jets\ data}$	19185.9	47793.1	254.6	676.3	281.6	494.8	58.4	89.0
C_{Z+jets}	0.857 $\pm$ 0.004	0.846 $\pm$ 0.003	0.845 $\pm$ 0.049	0.770 $\pm$ 0.030	1.002 $\pm$ 0.085	0.837 $\pm$ 0.048	1.087 $\pm$ 0.28	0.945 $\pm$ 0.181