Search for Lepton Flavor Violation in the Top Quark Interactions with CMS

Jiwon Park, on behalf of CMS Collaboration | DESY, jiwon.park@cern.ch

Introduction

- Neutrino oscillation suggests the existence of charged lepton flavor violation (CLFV)
- Deviations in B meson decay give hints on CLFV in low energy
- Explore high energy CLFV mediated by top quark with LHC
- Presenting the latest trilepton final state result, **CMS PAS-TOP-22-005**

Signal model

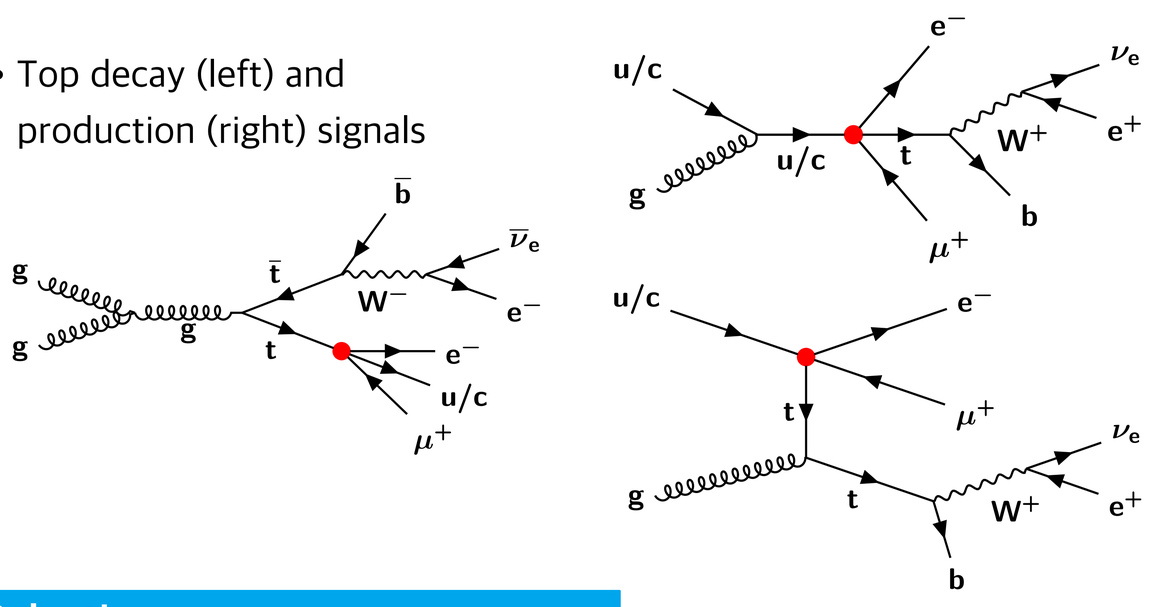
- Seesaw mechanism or leptoquark can enable CLFV processes
- Alternatively, introduce Effective Field Theory (EFT) assuming higher mass scale of Λ = 1 TeV

$$\mathcal{L} = \mathcal{L}^{(4)}_{\mathrm{SM}} + \frac{1}{\Lambda^2}\sum_a C^{(6)}_a O^{(6)}_a + O(\frac{1}{\Lambda^4})$$

- Warsaw basis of dim-6 operator gives following set of operators

vector	$O^{(1)ijkl}_{lq}$	$(\bar{l}_i\gamma^\mu l_j)(\bar{q}_k\gamma^\mu q_l)$
	O^{ijkl}_{lu}	$(\bar{l}_i\gamma^\mu l_j)(\bar{u}_k\gamma^\mu u_l)$
	O^{ijkl}_{eq}	$(\bar{e}_i\gamma^\mu e_j)(\bar{q}_k\gamma^\mu q_l)$
	O^{ijkl}_{eu}	$(\bar{e}_i\gamma^\mu e_j)(\bar{u}_k\gamma^\mu u_l)$
scalar	$O^{(1)ijkl}_{lequ}$	$(\bar{l}_i e_j)\ \varepsilon\ (\bar{q}_k u_l)$
tensor	$O^{(3)ijkl}_{lequ}$	$(\bar{l}_i\sigma^{\mu\nu} e_j)\ \varepsilon\ (\bar{q}_k\sigma_{\mu\nu} u_l)$

- Top decay (left) and production (right) signals



Selections

- MVA based lepton identification, isolated, p_T > 38 (20) GeV, $|\eta|$ < 2.4
- Jet with p_T > 30 GeV, $|\eta|$ < 2.4, b-tagging by DeepJet

Channel	Region	OnZ	OffZ	$p_{\mathrm{T}}^{\mathrm{miss}} > 20\,\mathrm{GeV}$	# jets ≥ 1	# b jets ≤ 1
$eee/\mu\mu\mu$	VR	-	-	-	-	-
	WZ CR	✓	-	✓	✓	✓
$e\mu l$	SR	-	✓	✓	✓	✓
	VR	✓	-	-	-	-
	WZ CR	✓	-	✓	✓	✓

On Z: 50 < m_{ll} < 106 GeV

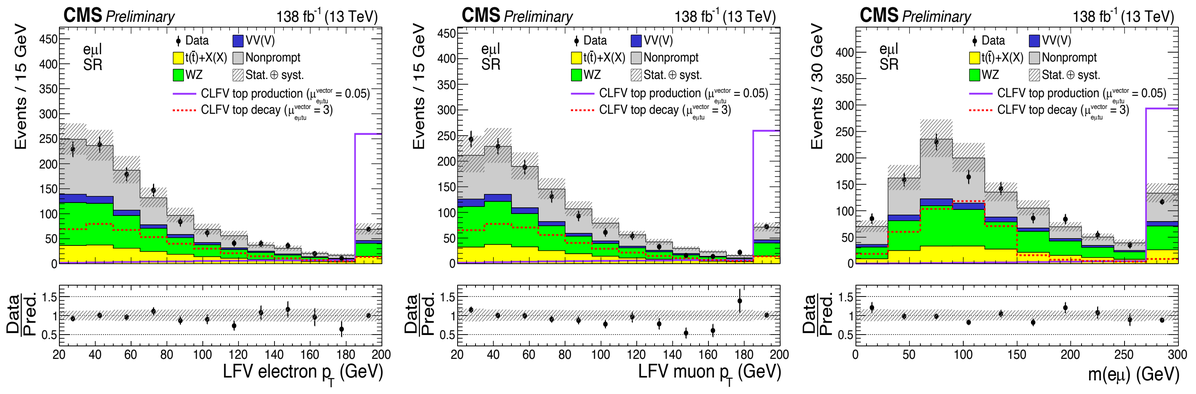
Background estimation

- Background is dominated by events with nonprompt lepton(s)
  - Mainly $t\bar{t}$ and Z+jets processes
- Nonprompt background is estimated with a data-driven method called "matrix method"[1] and validated using validation region
- Prompt backgrounds are modelled with simulation and checked using control regions

[1] JHEP11 (2014) 031

Background estimation (cont.)

- Lepton distribution from background estimation

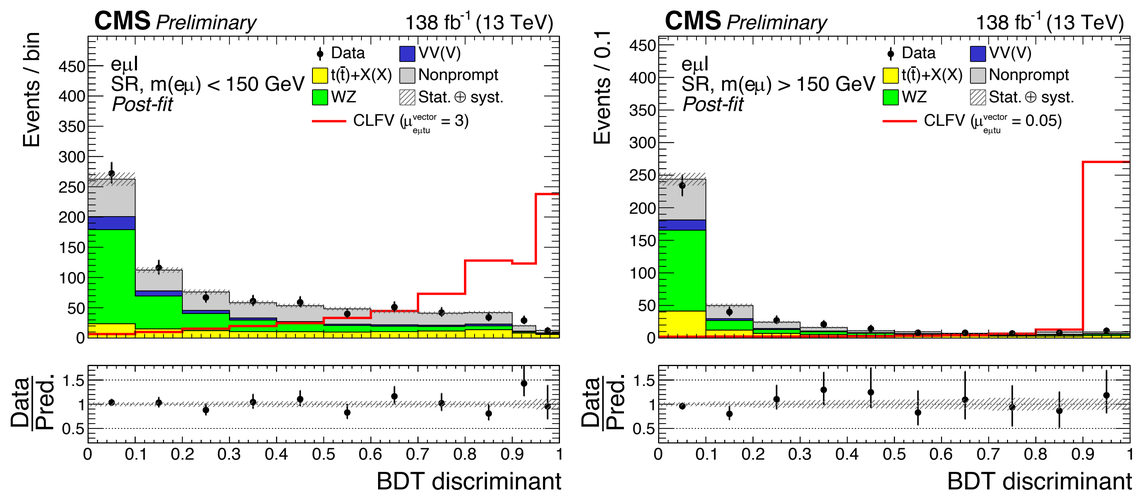


- Uncertainties: Prompt background contamination in MR + difference between AR and MR + statistical components ~ 10-30%

MR: Measurement Region, AR: Application Region

Signal extraction

- BDTs for top decay (m($e\mu$) < 150 GeV) and production (m($e\mu$) > 150 GeV) enriched regions
- Important variables:
  Decay: m_Z, # of b-jets, and m_{LFVtop}
  Production: m($e\mu$), and p_T of LFV electron and muon
- BDT postfit distributions:

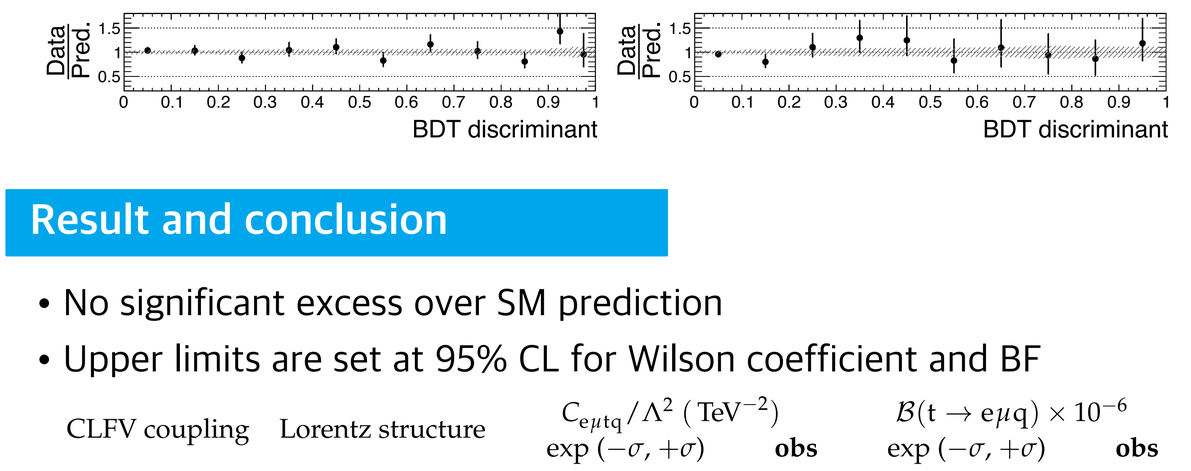


Result and conclusion

- No significant excess over SM prediction
- Upper limits are set at 95% CL for Wilson coefficient and BF

CLFV coupling	Lorentz structure	$C_{e\mu tq}/\Lambda^2$ (TeV^{-2}) exp $(-\sigma, +\sigma)$	**obs**	$\mathcal{B}(\mathrm{t} \to \mathrm{e}\mu\mathrm{q}) \times 10^{-6}$ exp $(-\sigma, +\sigma)$	**obs**
$e\mu$tu	tensor	0.019 (0.015, 0.023)	**0.020**	0.019 (0.013, 0.029)	**0.023**
	vector	0.037 (0.031, 0.046)	**0.041**	0.013 (0.009, 0.020)	**0.016**
	scalar	0.077 (0.064, 0.095)	**0.084**	0.007 (0.005, 0.011)	**0.009**
$e\mu$tc	tensor	0.061 (0.050, 0.074)	**0.068**	0.209 (0.143, 0.311)	**0.258**
	vector	0.130 (0.108, 0.159)	**0.144**	0.163 (0.111, 0.243)	**0.199**
	scalar	0.269 (0.223, 0.330)	**0.295**	0.087 (0.060, 0.130)	**0.105**

- 2D interpolated limits are obtained assuming a linear relation between u and c quark final states



- Marked top quark branching fraction at the level of 10^{-7}-10^{-8}
- One order of magnitude improvement in $e\mu$tc channel compared to CMS TOP-19-006 [JHEP 06 (2022) 082]

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