Searches for Leptoquarks decaying to top quarks in final states with leptons and boosted jets

B2G General meeting

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Introduction

- Color-triplet scalar or vector bosons that directly interact with quarks and leptons and carry fractional electric charge
- LQ-like particles present in many BSM models
  - Supersymmetry, Grand Unified Theory, compositeness models
- Model parameters
  - LQ mass: M_{LQ}
  - Yukawa coupling: λ
  - k parameter (vector LQ):

Leptoquark	Spin	F	$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$ representation	Q_{EM}	Coupling		Decay mode
S_1	0	2	$(\mathbf{3},\mathbf{1},-2/3)$	$-1/3$	$\lambda_{L,R}(u,e_{L,R})$,	$-\lambda_L(d,\nu_e)$	$t\tau^-$, $b\nu$
$\tilde{S}_1$	0	2	$(\mathbf{3},\mathbf{1},-8/3)$	$-4/3$	$\lambda_R(d,e_R)$		$b\tau^-$
S_2	0	0	$(\bar{\mathbf{3}},\mathbf{2},-7/3)$	$-2/3$ $-5/3$	$\lambda_L(u,\nu_e)$, $\lambda_{L,R}(u,e_{L,R})$	$\lambda_R(d,e_R)$	$\bar{t}\nu$, $b\tau^+$ $\bar{t}\tau^-$
$\tilde{S}_2$	0	0	$(\bar{\mathbf{3}},\mathbf{2},-1/3)$	$+1/3$ $-2/3$	$\lambda_L(d,\nu_e)$ $\lambda_L(d,e_L)$		$\bar{b}\nu$ $\bar{b}\tau^-$
S_3	0	2	$(\mathbf{3},\mathbf{3},-2/3)$	$+2/3$ $-1/3$ $-4/3$	$\sqrt{2}\lambda_L(u,\nu_e)$ $-\lambda_L(u,e_L)$, $-\sqrt{2}\lambda_L(d,e_L)$	$-\lambda_L(d,\nu_e)$	$t\nu$ $t\tau^-$, $b\nu$ $b\tau^-$
V_1	1	0	$(\bar{\mathbf{3}},\mathbf{1},-4/3)$	$-2/3$	$\lambda_{L,R}(d,e_{L,R})$,	$\lambda_L(u,\nu_e)$	$\bar{b}\tau^-$, $\bar{t}\nu$
$\tilde{V}_1$	1	0	$(\bar{\mathbf{3}},\mathbf{1},-10/3)$	$-5/3$	$\lambda_R(u,e_R)$		$\bar{t}\tau^-$
V_2	1	2	$(\mathbf{3},\mathbf{2},-5/3)$	$-1/3$ $-4/3$	$\lambda_L(d,\nu_e)$, $\lambda_{L,R}(d,e_{L,R})$	$\lambda_R(u,e_R)$	$b\nu$, $t\tau^-$ $b\tau^-$
$\tilde{V}_2$	1	2	$(\mathbf{3},\mathbf{2},+1/3)$	$+2/3$ $-1/3$	$\lambda_L(u,\nu_e)$ $\lambda_L(u,e_L)$		$t\nu$ $t\tau^-$
V_3	1	0	$(\bar{\mathbf{3}},\mathbf{3},-4/3)$	$+1/3$ $-2/3$ $-5/3$	$\sqrt{2}\lambda_L(d,\nu_e)$ $-\lambda_L(d,e_L)$, $\sqrt{2}\lambda_L(u,e_L)$	$\lambda_L(u,\nu_e)$	$\bar{b}\nu$ $\bar{b}\tau^-$, $\bar{t}\nu$ $\bar{t}\tau^-$

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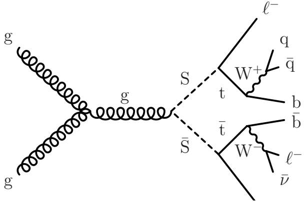
- This analysis: Scalar LQ coupling to t-quarks



Leptoquark	Spin	F	$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$ representation	Q_{EM}	Coupling		Decay mode
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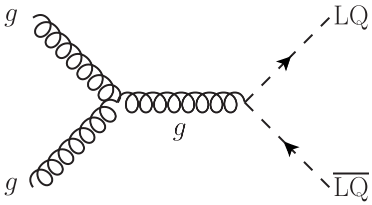
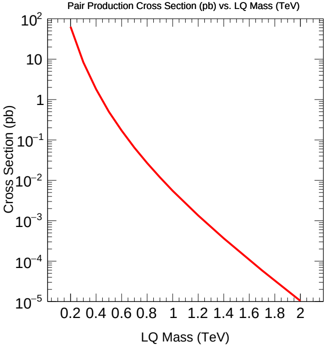
S_2	0	0	$(\bar{\mathbf{3}},\mathbf{2},-7/3)$	$-2/3$ $-5/3$	$\lambda_L(u,\nu_e)$, $\lambda_{L,R}(u,e_{L,R})$	$\lambda_R(d,e_R)$	$\bar{t}\nu$, $b\tau^+$ $\bar{t}\tau^-$
$\tilde{S}_2$	0	0	$(\bar{\mathbf{3}},\mathbf{2},-1/3)$	$+1/3$ $-2/3$	$\lambda_L(d,\nu_e)$ $\lambda_L(d,e_L)$		$\bar{b}\nu$ $\bar{b}\tau^-$
S_3	0	2	$(\mathbf{3},\mathbf{3},-2/3)$	$+2/3$ $-1/3$ $-4/3$	$\sqrt{2}\lambda_L(u,\nu_e)$ $-\lambda_L(u,e_L)$, $-\sqrt{2}\lambda_L(d,e_L)$	$-\lambda_L(d,\nu_e)$	$t\nu$ $t\tau^-$, $b\nu$ $b\tau^-$
V_1	1	0	$(\bar{\mathbf{3}},\mathbf{1},-4/3)$	$-2/3$	$\lambda_{L,R}(d,e_{L,R})$,	$\lambda_L(u,\nu_e)$	$\bar{b}\tau^-$, $\bar{t}\nu$
$\tilde{V}_1$	1	0	$(\bar{\mathbf{3}},\mathbf{1},-10/3)$	$-5/3$	$\lambda_R(u,e_R)$		$\bar{t}\tau^-$
V_2	1	2	$(\mathbf{3},\mathbf{2},-5/3)$	$-1/3$ $-4/3$	$\lambda_L(d,\nu_e)$, $\lambda_{L,R}(d,e_{L,R})$	$\lambda_R(u,e_R)$	$b\nu$, $t\tau^-$ $b\tau^-$
$\tilde{V}_2$	1	2	$(\mathbf{3},\mathbf{2},+1/3)$	$+2/3$ $-1/3$	$\lambda_L(u,\nu_e)$ $\lambda_L(u,e_L)$		$t\nu$ $t\tau^-$
V_3	1	0	$(\bar{\mathbf{3}},\mathbf{3},-4/3)$	$+1/3$ $-2/3$ $-5/3$	$\sqrt{2}\lambda_L(d,\nu_e)$ $-\lambda_L(d,e_L)$, $\sqrt{2}\lambda_L(u,e_L)$	$\lambda_L(u,\nu_e)$	$\bar{b}\nu$ $\bar{b}\tau^-$, $\bar{t}\nu$ $\bar{t}\tau^-$

Strong pair production is the dominant mechanism in the region of low λ





Latest CMS and ATLAS results

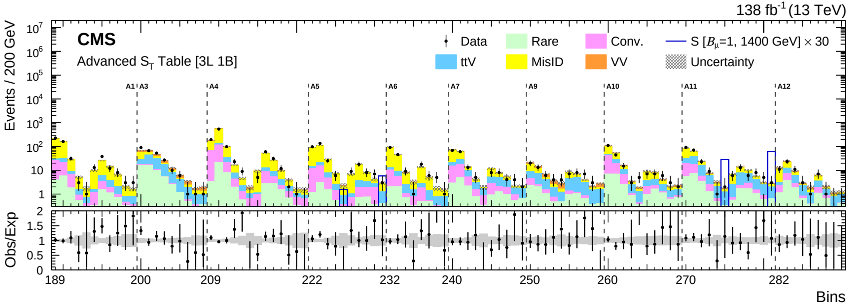
	Channel	Lower mass limit (GeV)
ATLAS arxiv.2306.17642	$te\ te/t\mu\ t\mu$	1580/1590
ATLAS JHEP06 (2021) 179	$t\tau\ t\tau$	1430
CMS PRD 105 (2022) 112007	$te\ te/t\mu\ t\mu/t\tau\ t\tau$	1340/1420/1120
ATLAS JHEP06 (2023) 188	$t\mu\ b\nu/te\ b\nu$	1370/1390
CMS PLB 819 (2021) 136446	$t\tau\nu(b)$	980
ATLAS JHEP06 (2023) 188	$t\nu\ b\mu/t\nu\ be$	1460/1440

← **Inclusive multilepton**

What did we learn from multilepton analysis?

- 3ℓ, 4ℓ events: 7 channels based on the number of light ℓ, τ_h
- 204 Model-independent categories:
  - OSSFn, $M_{\ell\ell}$, M_T, min $p_{T,\ell}$, N_b, H_{T}, p_T^{miss}

PRD 105 (2022) 112007



LQ signal sensitivity in regions with:

- High $p_{T,\ell}/M_{\mathrm{T}}$,
- M_{OSSF} OffZ
- $N_b > 0$
- large S_{T}

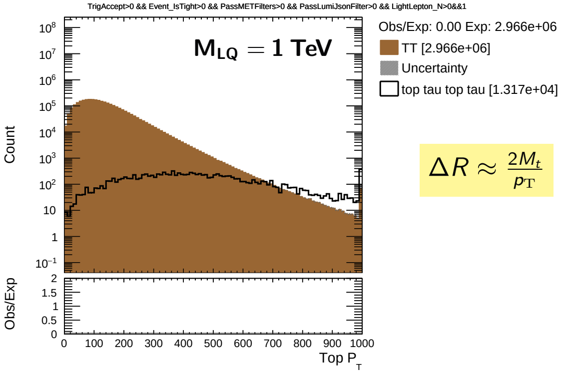
Inclusive multilepton analysis

- Not designed for high-p_{T} objects
- In heavy M_{LQ} regime we can extend the search by considering hadronic top decays ($\mathcal{B} \sim$67%)

What's new?

- This analysis targets Run 2, Run 3 Data
- $t\ell\ t\ell$ and $t\ell\ b\nu$ decays (all lepton flavor couplings)
- Explore signal in categories with merged top- and W-tagged jets
  - Utilize AK8 jets and flavor identification (ParticleNet)
- Trigger: Single isolated ℓ, high-p_{T} ℓ, AK8 Jets, HT

Gen t-quark p_{T}



$$\Delta R \approx \frac{2M_t}{p_{\mathrm{T}}}$$

This talk presents a study using 2018 simulation

- Background: tt, VV, ttZ, ttW (NanoAODv9)
- Signal (private production)
  - S1 pair production: $t\tau$ $t\tau$, $t\tau$ $b\nu$
  - $M_{LQ} = 1\text{TeV}$, $\lambda = 0.01$
  - Signal normalized to 1 pb

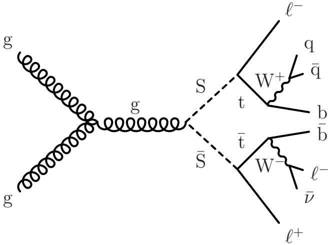
Object selection

- Trigger: Single isolated ℓ, high-p_{T} ℓ
- Electrons, Muons
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 10$ GeV
  - cutBasedID (medium), pfRelIso (tight), low jetPtRatio
  - Displacement: sip3D, $|\text{dxy}|$, $|\text{dz}|$, JetDeepFlavorB
- AK4 jets
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 30$ GeV
  - ID tight & tightLepVeto, PUID tight
  - b-tag: DeepJet medium WP
- AK8 jets
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 200$ GeV, ID tight
  - ParticleNet TvsQCD, WvsQCD for top and W tagging

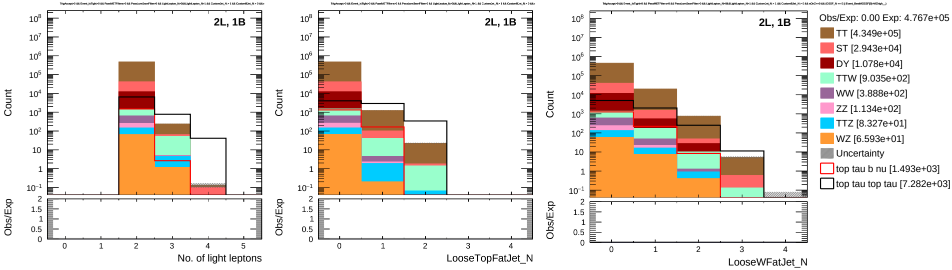
Preliminary studies 2018

Preselections

- Number of light leptons (e, μ): $N_\ell \geq 2$
- Number of jets: $N_j \geq 2$, $N_b \geq 1$
- $M_{OSSF} > 106$ GeV (Above Z mass)



N_ℓ N_t N_W

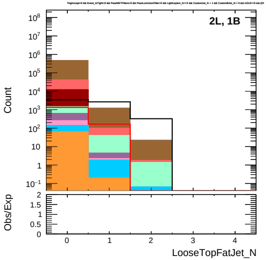


- Signal sensitivity improves in categories with $N_\ell > 2$, $N_{t/W} \geq 1$

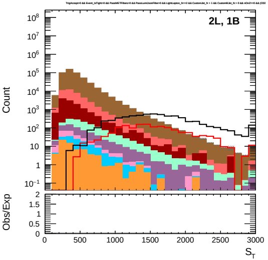
Preliminary studies 2018

We split the events into N_ℓ $(= 2, \geq 3)$

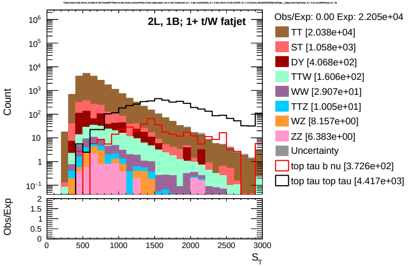
$N_\ell = 2$ N_{t-jet}



$N_\ell = 2$ S_T

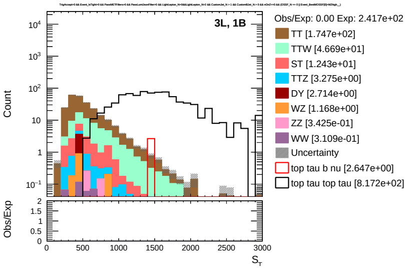


$N_\ell = 2, \geq 1$ t/W Jet S_T



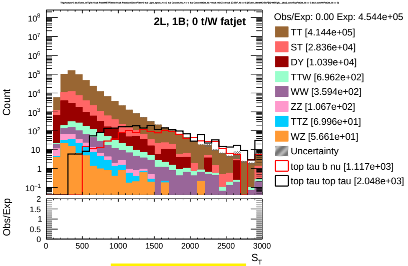
- 2ℓ: $\mathcal{S}/\mathcal{B}$ increases for ≥ 1 t/W Jet
- 3ℓ: Small background
- Four categories are defined:
  - 2ℓ, 0 t/W
  - 2ℓ, 1 t/W
  - 2ℓ, 2 t/W
  - 3ℓ

$N_\ell \geq 3$ S_T

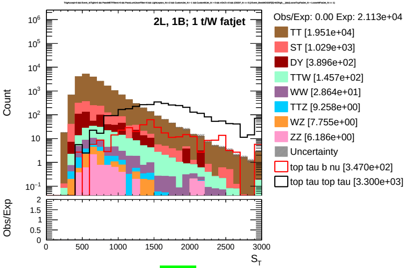


We extract expected limits using S_{T} fit discriminant

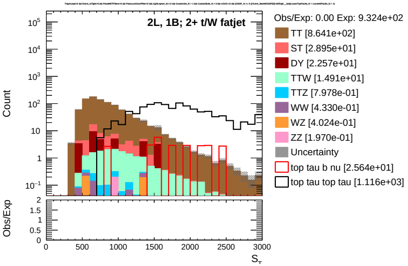
2ℓ, 0 t/W S_{T}



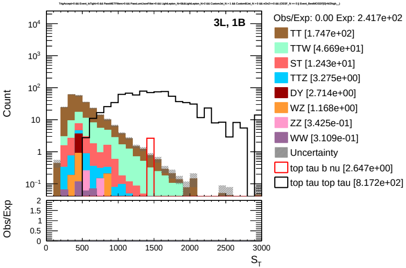
2ℓ, 1 t/W S_{T}



2ℓ, $\geq$2 t/W S_{T}



3ℓ S_{T}



We extract expected limits using S_{T} fit discriminant

Category	Expected limit ($t\tau t\tau$)				
	-2σ	-1σ	median	$+1\sigma$	$+2\sigma$
2ℓ, 0 t/W jet	17.4648	23.3640	32.8750	46.5033	63.0022
2ℓ, 1 t/W jet	5.5947	7.4845	10.5312	14.8550	20.0191
2ℓ, 2 t/W jet	4.3934	6.0154	8.7188	12.7154	17.7276
3ℓ	2.4824	3.4527	5.1250	7.7603	11.2750
Combined 2ℓ	3.3369	4.4999	6.3750	9.1194	12.4478
Combined 2ℓ, 3ℓ	1.9290	2.6412	**3.8281**	5.5829	7.8073

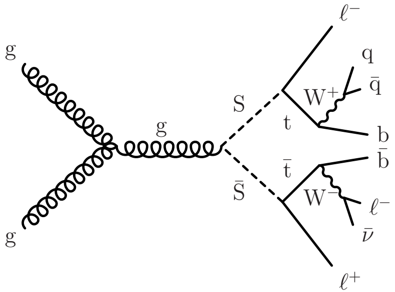
- No τ_h included yet - expected to improve the $t\tau$ signal
- Combined 2ℓ limit comparable to 3ℓ

Categorization based on

- Number of merged top- and W- tagged jets (T, W)
- Number of light leptons (ℓ)

✔	tτ tτ
✔✔	tτ bν

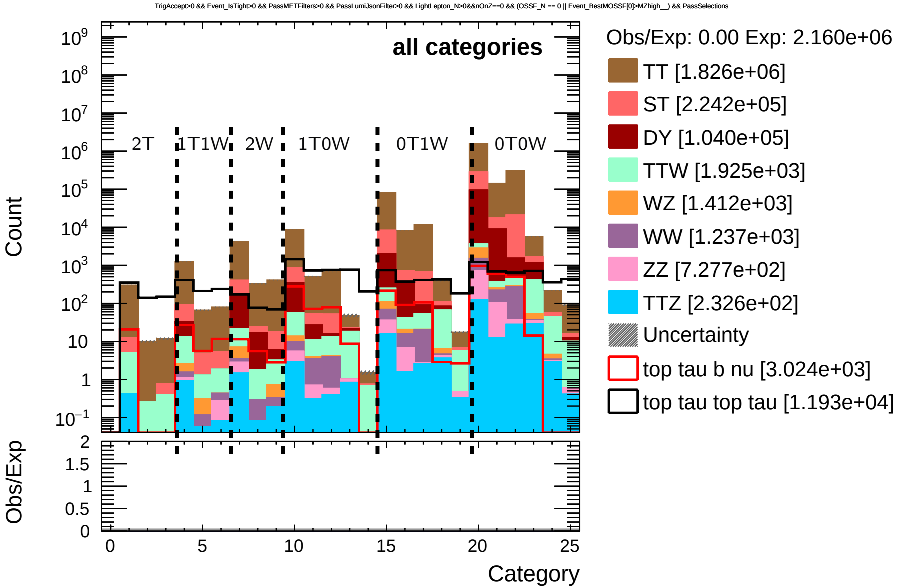
	1ℓ	2ℓOSSF	2ℓOSDF	2ℓSS	>=3ℓ
2T	✔	✔	✔		
1T1W	✔	✔	✔		
2W	✔	✔	✔		
1T0W	✔✔	✔	✔	✔	✔
0T1W	✔✔	✔	✔	✔	✔
0T0W	✔✔	✔✔	✔✔	✔	✔



Event selections

- $N_{t-jet} = 0$: M_{OSSF} Above Z, $N_j \geq 2$, $N_b \geq 1$
- $N_{t-jet} > 0$: M_{OSSF} Above Z

Preliminary studies 2018 Expected yields



- Different resonance properties in each category

Plan for signal MC central production

- Run 2, Run 3
- $M_{LQ} = 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3$ TeV
- Two final states: $t\ell t\ell$, $t\ell b\nu$
- All lepton flavors
- 25k events per M_{LQ}, final state, lepton flavor $\Rightarrow \sim 2.1$M per year

Summary

This analysis aims to deliver a comprehensive search for LQ coupling to t-quarks

- $t\ell\ t\ell$ and $t\ell\ b\nu$ decays
- LQ in final states with tops and charged leptons
- Off-diagonal lepton flavor couplings also considered
- Expand inclusive multilepton search: utilize merged jets

Next steps

- Submit MC request
- Study Run 2 and Run 3 data
- Optimize objects and event selections
- Utilize hadronic tau leptons

BACKUP

Fundamental scheme

- Categories **A1-G1** based on — 43 categories
  - Charge and flavor combination (OSSF_n)
  - Mass (BelowZ, OnZ, AboveZ)
  - M_T or minimum ℓ p_T

		OSSF0			OSSF1				OSSF2		
		BelowZ	AboveZ	SS	OnZ	BelowZ	AboveZ	MixedZ	Single-OnZ	Double-OnZ	OffZ
3L	Low $p_\mathrm{T}/M_\mathrm{T}$	A1	A1	A2	A3	A4	A5	A6	—	—	—
	High $p_\mathrm{T}/M_\mathrm{T}$	A7	A7	A8	A9	A10	A11	A12	—	—	—
2L1T	Low p_T	B1	B2	B3	B4	B5	B6	—	—	—	—
	High p_T	B7	B8	B9	B10	B11	B12	—	—	—	—
1L2T		C1	C2	C3	—	C4	C5	—	—	—	—
4L		D1	D1	D1	D2	D3	D3	D3	D4	D5	D6
3L1T		E1	E1	E1	E2	E3	E3	E3	—	—	—
2L2T		F1	F1	F1	F2	F2	F2	—	F3	—	F4
1L3T		G1	G1	G1	—	G1	G1	—	—	—	—

- Final discriminant: $L_T + p_T^{miss}$ or S_T

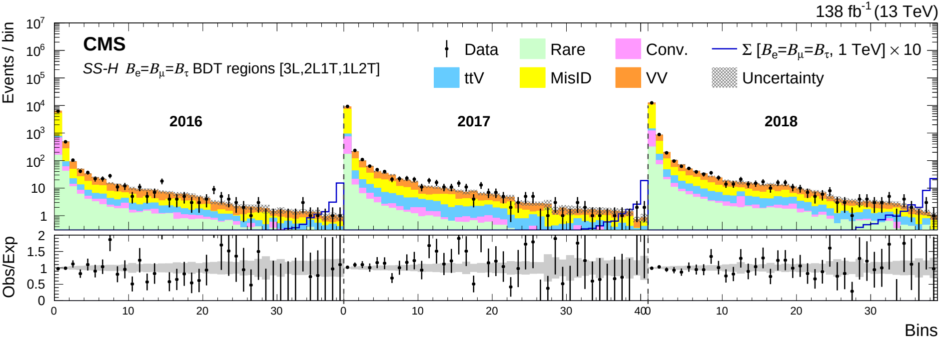
Advanced scheme

- Further categorization based on N_b, H_T, p_T^{miss} — 204 categories
- Final discriminant: S_T

Model-dependent SR defined using MVA

- BDTs discriminate specific signal from SM background
- Multiple BDT trainings per year and category:
  - * Vector-like leptons (VVL): 3 mass ranges (L, M, H)
  - * Type-III seesaw (SS): 3 mass ranges × 2 flavor scenarios
  - * Leptoquarks (LQ): 3 mass ranges × 2 flavor scenarios

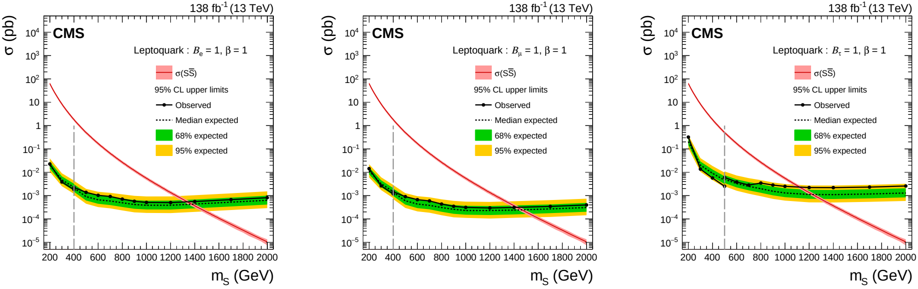
SS-H $\mathcal{B}_e = \mathcal{B}_\mu = \mathcal{B}_\tau$ - regions: [3L, 2L1T, 1L1T]



No significant deviation from SM obseerved

- Limits are interpreted in various BSM models
- Model-dependent SR also defined using BDT
- Best expected limits are used between the cut-based and MVA-based methods

Leptoquark: $\mathcal{B}_e = 1$ Leptoquark: $\mathcal{B}_\mu = 1$ Leptoquark: $\mathcal{B}_\tau = 1$

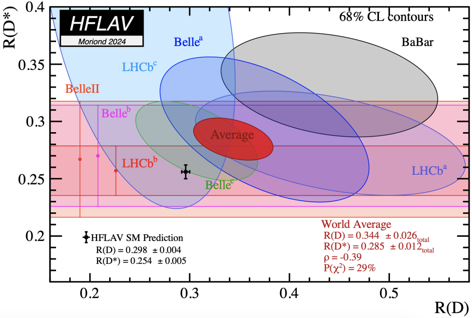


- LQ: Constraints compete ATLAS results

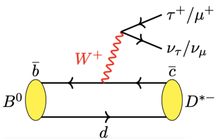
Introduction

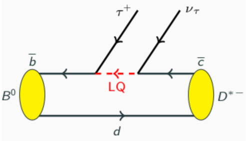
Leptoquarks motivated by experimental observations

Lepton flavor violation in B-meson physics

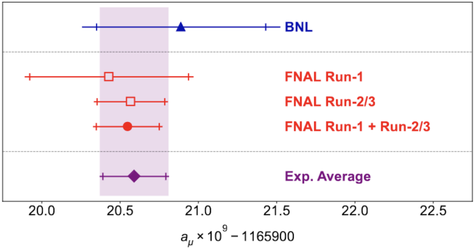


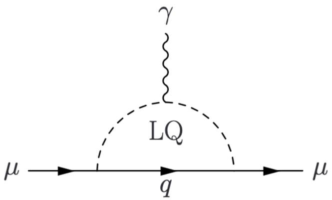
$$\mathcal{R}(D^*) \equiv \frac{\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)}{\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)} \quad \mathcal{R}(D) \equiv \frac{\mathcal{B}(B^0 \to D\tau^+\nu_\tau)}{\mathcal{B}(B^0 \to D\mu^+\nu_\mu)}$$





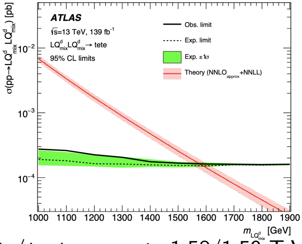
Muon anomalous magnetic moment





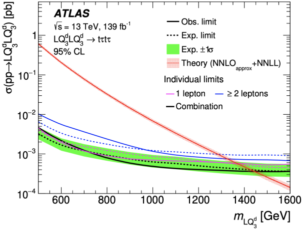
CMS and ATLAS results LQ coupling to t-quarks

arxiv 2306.17642



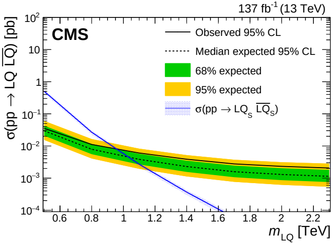
▶ $te\ te/t\mu\ t\mu$: $m_{LQ} > 1.58/1.59$ TeV

JHEP 06 (2021) 179



▶ $t\tau\ t\tau$: $m_{LQ} > 1.43$ TeV

PLB 819 (2021) 136446



▶ $t\tau\nu(b)$: $m_{LQ} > 980$ GeV

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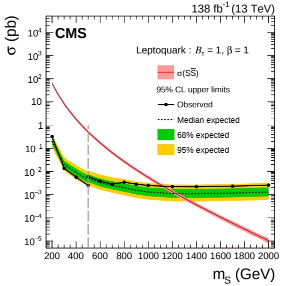


▶ $te\ te/t\mu\ t\mu/t\tau\ t\tau$: $m_{LQ} > 1.34/1.42/1.12$ TeV

Object selections 2018

- Trigger

μ `HLT_IsoMu24 || HLT_IsoTkMu24 || HLT_Mu50 || HLT_TkMu50`

e `HLT_Ele32_WPTight_Gsf || HLT_Ele50_CaloIdVT_GsfTrkIdT_PFJet165 || HLT_Ele115_CaloIdVT_GsfTrkIdT || HLT_Photon200`

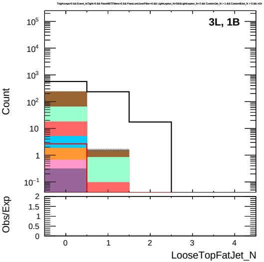
- Muons
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 10$ GeV
  - cutBasedID (medium), pfRelIso (tight), jetPtRatio < 1.6
  - sip3D < 7, JetDeepFlavorB < 0.55, $|\mathrm{dxy}| < 0.05$, $|\mathrm{dz}| < 0.1$
- Electrons
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 10$ GeV
  - cutBasedID (medium), pfRelIso (tight), jetPtRatio < 1.6
  - sip3D < 7, JetDeepFlavorB < 0.55, $|\mathrm{dxy}| < 0.1$, $|\mathrm{dz}| < 0.2$

- AK4 jets
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 30$ GeV
  - ID tight & tightLepVeto
  - PUID tight
  - b-tag: DeepJet medium WP
  - $\Delta R(jet, \ell) > 0.4$

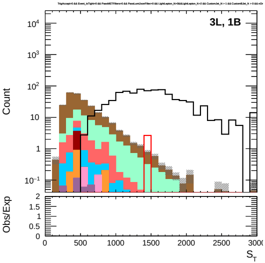
- AK8 jets
  - $|\eta| < 2.4$, $p_{\mathrm{T}} > 200$ GeV, ID tight
  - t-tag: $p_{\mathrm{T}} > 400$ GeV, pnTvsQCD (loose)
  - W-tag: $p_{\mathrm{T}} > 200$ GeV, pnWvsQCD (loose), NOT t-tagged

Object selections 2018

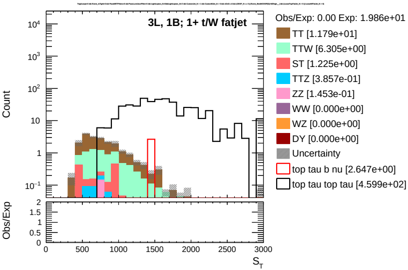
$N_\ell \geq 3$



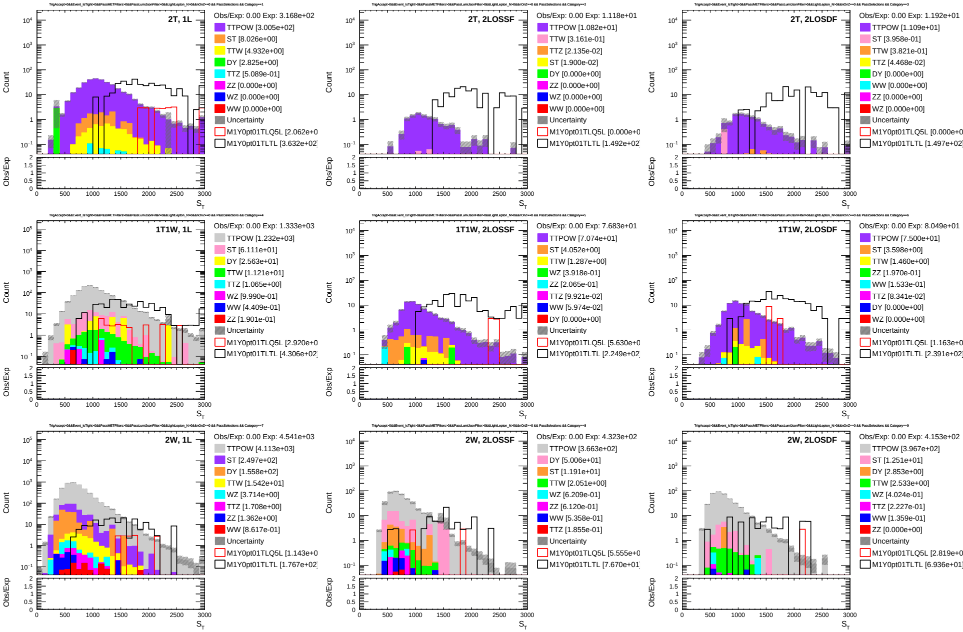
$N_\ell \geq 3$



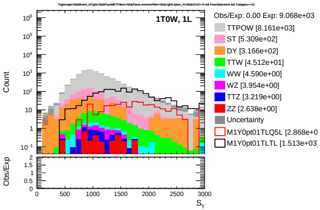
$N_\ell \geq 3 + \geq 1$ t/W jet

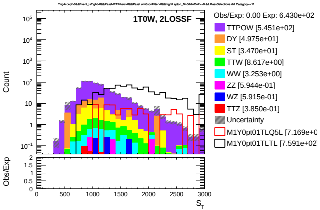


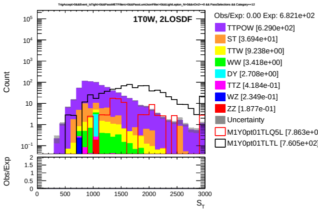
2T, 1T1W, 2W S_T

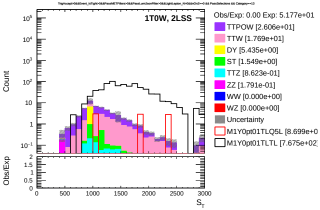

2T, 1L
Obs/Exp: 0.00 Exp: 3.168e+02
TTPOW [3.005e+02]
ST [8.026e+00]
TTW [4.932e+00]
DY [2.825e+00]
TTZ [5.089e-01]
ZZ [0.000e+00]
WZ [0.000e+00]
WW [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [2.062e+0
M1Y0pt01TLTL [3.632e+02
2T, 2LOSSF
Obs/Exp: 0.00 Exp: 1.118e+01
TTPOW [1.082e+01]
TTW [3.161e-01]
TTZ [2.135e-02]
ST [1.900e-02]
DY [0.000e+00]
ZZ [0.000e+00]
WZ [0.000e+00]
WW [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [0.000e+0
M1Y0pt01TLTL [1.492e+02
2T, 2LOSDF
Obs/Exp: 0.00 Exp: 1.192e+01
TTPOW [1.109e+01]
ST [3.958e-01]
TTW [3.821e-01]
TTZ [4.468e-02]
DY [0.000e+00]
WW [0.000e+00]
ZZ [0.000e+00]
WZ [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [0.000e+0
M1Y0pt01TLTL [1.497e+02
1T1W, 1L
Obs/Exp: 0.00 Exp: 1.333e+03
TTPOW [1.232e+03]
ST [6.111e+01]
DY [2.563e+01]
TTW [1.121e+01]
TTZ [1.065e+00]
WZ [9.990e-01]
WW [4.409e-01]
ZZ [1.901e-01]
Uncertainty
M1Y0pt01TLQ5L [2.920e+0
M1Y0pt01TLTL [4.306e+02
1T1W, 2LOSSF
Obs/Exp: 0.00 Exp: 7.683e+01
TTPOW [7.074e+01]
ST [4.052e+00]
TTW [1.287e+00]
WZ [3.918e-01]
ZZ [2.065e-01]
TTZ [9.921e-02]
WW [5.974e-02]
DY [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [5.630e+0
M1Y0pt01TLTL [2.249e+02
1T1W, 2LOSDF
Obs/Exp: 0.00 Exp: 8.049e+01
TTPOW [7.500e+01]
ST [3.598e+00]
TTW [1.460e+00]
ZZ [1.970e-01]
WW [1.533e-01]
TTZ [8.341e-02]
DY [0.000e+00]
WZ [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [1.163e+0
M1Y0pt01TLTL [2.391e+02
2W, 1L
Obs/Exp: 0.00 Exp: 4.541e+03
TTPOW [4.113e+03]
ST [2.497e+02]
DY [1.558e+02]
TTW [1.542e+01]
WZ [3.714e+00]
TTZ [1.708e+00]
ZZ [1.362e+00]
WW [8.617e-01]
Uncertainty
M1Y0pt01TLQ5L [1.143e+0
M1Y0pt01TLTL [1.767e+02
2W, 2LOSSF
Obs/Exp: 0.00 Exp: 4.323e+02
TTPOW [3.663e+02]
DY [5.006e+01]
ST [1.191e+01]
TTW [2.051e+00]
WZ [6.209e-01]
ZZ [6.120e-01]
WW [5.358e-01]
TTZ [1.855e-01]
Uncertainty
M1Y0pt01TLQ5L [5.555e+0
M1Y0pt01TLTL [7.670e+01
2W, 2LOSDF
Obs/Exp: 0.00 Exp: 4.153e+02
TTPOW [3.967e+02]
ST [1.251e+01]
DY [2.853e+00]
TTW [2.533e+00]
WZ [4.024e-01]
TTZ [2.227e-01]
WW [1.359e-01]
ZZ [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [2.819e+0
M1Y0pt01TLTL [6.936e+01
Count
Obs/Exp
S_T

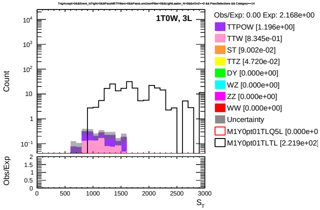
1T0W S_T


1T0W, 1L
Obs/Exp: 0.00 Exp: 9.068e+03
TTPOW [8.161e+03]
ST [5.309e+02]
DY [3.166e+02]
TTW [4.512e+01]
WW [4.590e+00]
WZ [3.954e+00]
TTZ [3.219e+00]
ZZ [2.638e+00]
Uncertainty
M1Y0pt01TLQ5L [2.868e+0
M1Y0pt01TLTL [1.513e+03]
Count
Obs/Exp
S_T

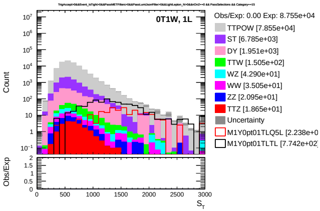

1T0W, 2LOSSF
Obs/Exp: 0.00 Exp: 6.430e+02
TTPOW [5.451e+02]
DY [4.975e+01]
ST [3.470e+01]
TTW [8.617e+00]
WW [3.253e+00]
ZZ [5.944e-01]
WZ [5.915e-01]
TTZ [3.850e-01]
Uncertainty
M1Y0pt01TLQ5L [7.169e+0
M1Y0pt01TLTL [7.591e+02]
Count
Obs/Exp
S_T

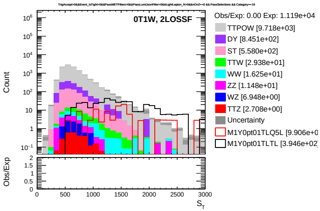

1T0W, 2LOSDF
Obs/Exp: 0.00 Exp: 6.821e+02
TTPOW [6.290e+02]
ST [3.694e+01]
TTW [9.238e+00]
WW [3.418e+00]
DY [2.708e+00]
TTZ [4.184e-01]
WZ [2.349e-01]
ZZ [1.877e-01]
Uncertainty
M1Y0pt01TLQ5L [7.863e+0
M1Y0pt01TLTL [7.605e+02]
Count
Obs/Exp
S_T

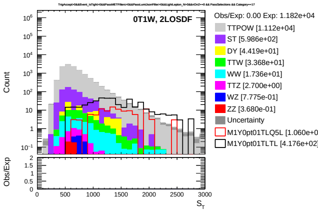

1T0W, 2LSS
Obs/Exp: 0.00 Exp: 5.177e+01
TTPOW [2.606e+01]
TTW [1.769e+01]
DY [5.435e+00]
ST [1.549e+00]
TTZ [8.623e-01]
ZZ [1.791e-01]
WW [0.000e+00]
WZ [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [8.699e+0
M1Y0pt01TLTL [7.675e+02]
Count
Obs/Exp
S_T

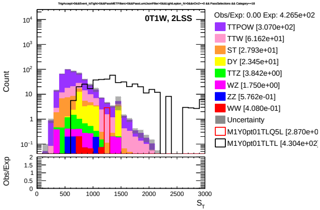

1T0W, 3L
Obs/Exp: 0.00 Exp: 2.168e+00
TTPOW [1.196e+00]
TTW [8.345e-01]
ST [9.002e-02]
TTZ [4.720e-02]
DY [0.000e+00]
WZ [0.000e+00]
ZZ [0.000e+00]
WW [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [0.000e+0
M1Y0pt01TLTL [2.219e+02]
Count
Obs/Exp
S_T

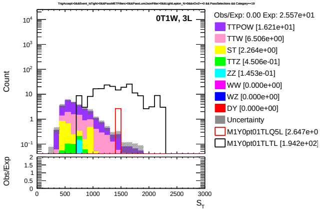
0T1W S_T


0T1W, 1L
Obs/Exp: 0.00 Exp: 8.755e+04
TTPOW [7.855e+04]
ST [6.785e+03]
DY [1.951e+03]
TTW [1.505e+02]
WZ [4.290e+01]
WW [3.505e+01]
ZZ [2.095e+01]
TTZ [1.865e+01]
Uncertainty
M1Y0pt01TLQ5L [2.238e+0
M1Y0pt01TLTL [7.742e+02]
Count
Obs/Exp
S_T

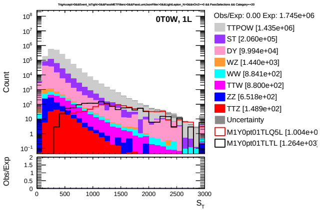

0T1W, 2LOSSF
Obs/Exp: 0.00 Exp: 1.119e+04
TTPOW [9.718e+03]
DY [8.451e+02]
ST [5.580e+02]
TTW [2.938e+01]
WW [1.625e+01]
ZZ [1.148e+01]
WZ [6.948e+00]
TTZ [2.708e+00]
Uncertainty
M1Y0pt01TLQ5L [9.906e+0
M1Y0pt01TLTL [3.946e+02]
Count
Obs/Exp
S_T

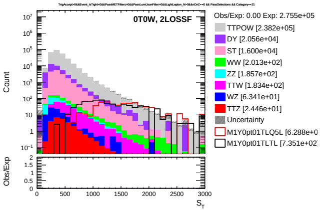

0T1W, 2LOSDF
Obs/Exp: 0.00 Exp: 1.182e+04
TTPOW [1.112e+04]
ST [5.986e+02]
DY [4.419e+01]
TTW [3.368e+01]
WW [1.736e+01]
TTZ [2.700e+00]
WZ [7.775e-01]
ZZ [3.680e-01]
Uncertainty
M1Y0pt01TLQ5L [1.060e+0
M1Y0pt01TLTL [4.176e+02]
Count
Obs/Exp
S_T

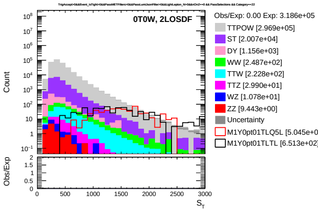

0T1W, 2LSS
Obs/Exp: 0.00 Exp: 4.265e+02
TTPOW [3.070e+02]
TTW [6.162e+01]
ST [2.793e+01]
DY [2.345e+01]
TTZ [3.842e+00]
WZ [1.750e+00]
ZZ [5.762e-01]
WW [4.080e-01]
Uncertainty
M1Y0pt01TLQ5L [2.870e+0
M1Y0pt01TLTL [4.304e+02]
Count
Obs/Exp
S_T

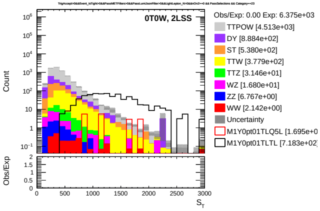

0T1W, 3L
Obs/Exp: 0.00 Exp: 2.557e+01
TTPOW [1.621e+01]
TTW [6.506e+00]
ST [2.264e+00]
TTZ [4.506e-01]
ZZ [1.453e-01]
WW [0.000e+00]
WZ [0.000e+00]
DY [0.000e+00]
Uncertainty
M1Y0pt01TLQ5L [2.647e+0
M1Y0pt01TLTL [1.942e+02]
Count
Obs/Exp
S_T

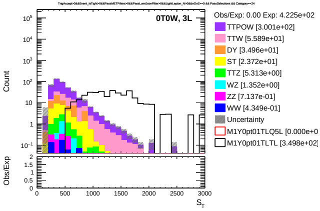
0T0W S_T


0T0W, 1L
Obs/Exp: 0.00 Exp: 1.745e+06
TTPOW [1.435e+06]
ST [2.060e+05]
DY [9.994e+04]
WZ [1.440e+03]
WW [8.841e+02]
TTW [8.800e+02]
ZZ [6.518e+02]
TTZ [1.489e+02]
Uncertainty
M1Y0pt01TLQ5L [1.004e+0
M1Y0pt01TLTL [1.264e+03]
Count
Obs/Exp
S_T


0T0W, 2LOSSF
Obs/Exp: 0.00 Exp: 2.755e+05
TTPOW [2.382e+05]
DY [2.056e+04]
ST [1.600e+04]
WW [2.013e+02]
ZZ [1.857e+02]
TTW [1.834e+02]
WZ [6.341e+01]
TTZ [2.446e+01]
Uncertainty
M1Y0pt01TLQ5L [6.288e+0
M1Y0pt01TLTL [7.351e+02]
Count
Obs/Exp
S_T


0T0W, 2LOSDF
Obs/Exp: 0.00 Exp: 3.186e+05
TTPOW [2.969e+05]
ST [2.007e+04]
DY [1.156e+03]
WW [2.487e+02]
TTW [2.228e+02]
TTZ [2.990e+01]
WZ [1.078e+01]
ZZ [9.443e+00]
Uncertainty
M1Y0pt01TLQ5L [5.045e+0
M1Y0pt01TLTL [6.513e+02]
Count
Obs/Exp
S_T


0T0W, 2LSS
Obs/Exp: 0.00 Exp: 6.375e+03
TTPOW [4.513e+03]
DY [8.884e+02]
ST [5.380e+02]
TTW [3.779e+02]
TTZ [3.146e+01]
WZ [1.680e+01]
ZZ [6.767e+00]
WW [2.142e+00]
Uncertainty
M1Y0pt01TLQ5L [1.695e+0
M1Y0pt01TLTL [7.183e+02]
Count
Obs/Exp
S_T


0T0W, 3L
Obs/Exp: 0.00 Exp: 4.225e+02
TTPOW [3.001e+02]
TTW [5.589e+01]
DY [3.496e+01]
ST [2.372e+01]
TTZ [5.313e+00]
WZ [1.352e+00]
ZZ [7.137e-01]
WW [4.349e-01]
Uncertainty
M1Y0pt01TLQ5L [0.000e+0
M1Y0pt01TLTL [3.498e+02]
Count
Obs/Exp
S_T