

Searches for pair-production of leptoquarks coupled to third-generation quarks with CMS

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on behalf of the CMS collaboration

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Motivation

B-physics anomalies, $g - 2$

- Deviations from SM prediction in b-flavor observables and muon anomalous mag. moment

$$\blacktriangleright R(D^{(*)}) = \frac{\Gamma(B \rightarrow D^{(*)} \tau \bar{\nu})}{\Gamma(B \rightarrow D^{(*)} \ell \bar{\nu})} \quad (\sim 4\sigma)$$

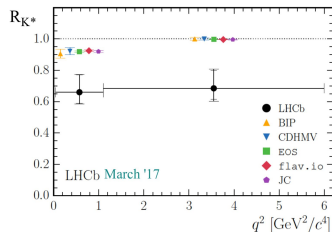
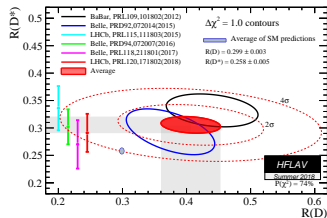
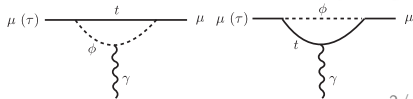
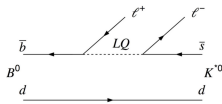
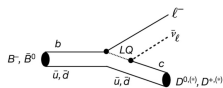
$$\blacktriangleright R(K^{(*)}) = \frac{\Gamma(B \rightarrow K^{(*)} \mu \mu)}{\Gamma(B \rightarrow K^{(*)} e e)} \quad (\sim 2.5\sigma)$$

$$\blacktriangleright B^0 \rightarrow K^{*0} \mu \mu \text{ angular obs.} \quad (\sim 3.4\sigma)$$

$$\blacktriangleright \text{Muon anomalous mag. moment } a_\mu \quad (\sim 3.5\sigma)$$

- Leptoquarks possible solution

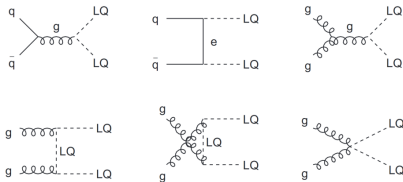
- Strong coupling to 3rd generation
- Weakest flavor constraints on 3rd gen
- Mass at TeV scale
- LQ $\rightarrow t\mu$ also elegant solution for a_μ



Leptoquarks at the LHC

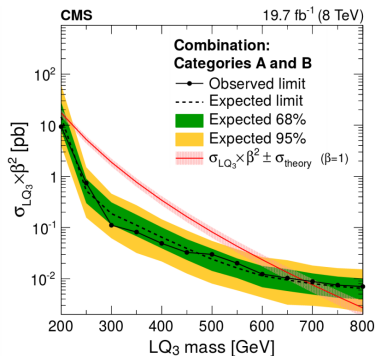
Leptoquarks

- Hypothetical new particles
- Predicted by many BSM theories
- Coupling to a lepton and a quark
- Fractional EM charge, Spin 0 or 1
- 13 TeV LHC: Pair-production dominating in $LQ \rightarrow t + \ell$ decay channel
- **Today:** $LQ \rightarrow t\mu$, $LQ \rightarrow t\tau$



Result at 8 TeV

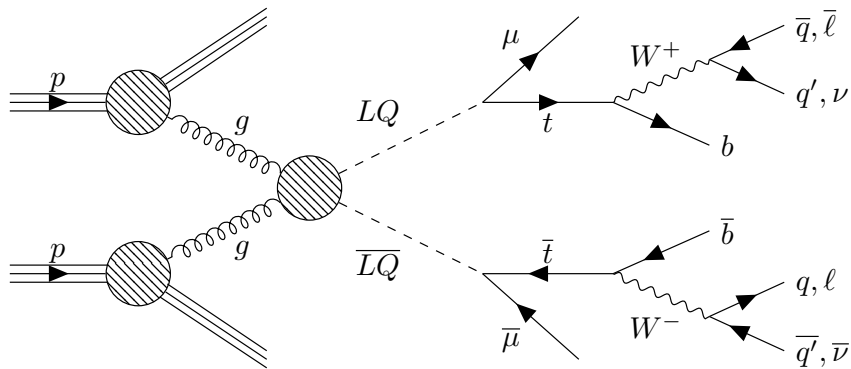
- $LQ \rightarrow t + \tau_{\text{had}}$ channel
exclusion limit: $M_{LQ} < 685 \text{ GeV}$
 [JHEP 07 (2015) 042]



Analyses with 2016 data

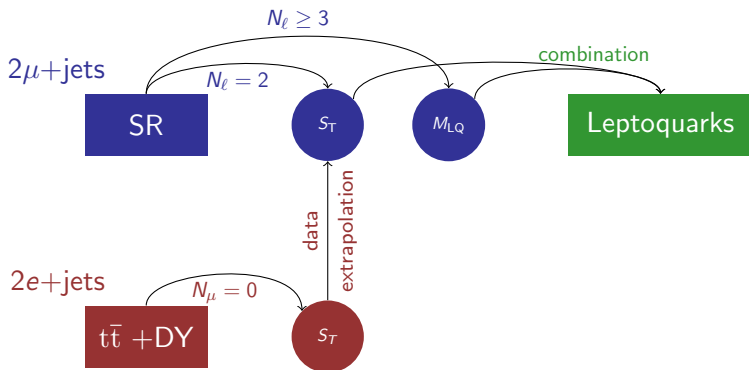
Run-II analysis ($LQLQ \rightarrow t\mu t\mu$)arXiv:1809.05558
acc. by PRL

Analysis workflow

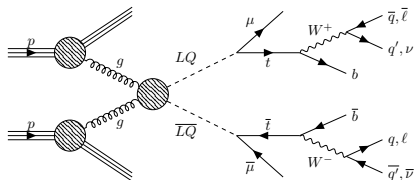


Run-II analysis (LQLQ $\rightarrow t\mu t\mu$)arXiv:1809.05558
acc. by PRL

Analysis workflow



- Signal region: $2\mu + \text{jets}$
 - ▶ 2 orthogonal categories
- Control region: $2e + \text{jets}$
 - ▶ Data-driven background estimate

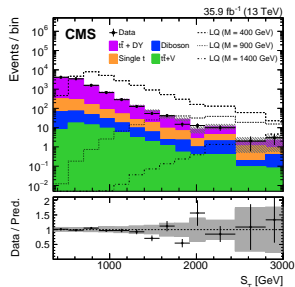
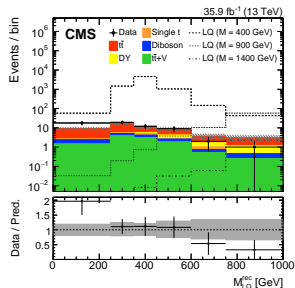
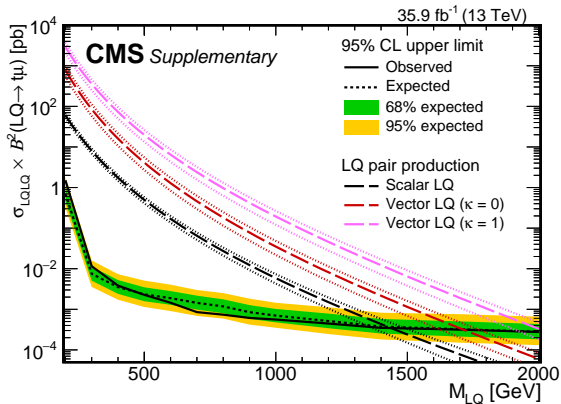


Run-II analysis (LQLQ $\rightarrow t\mu\mu$)

Final distributions, limits

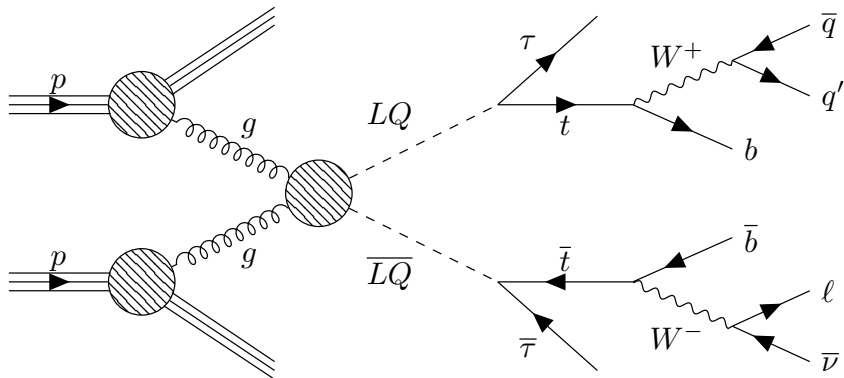
arXiv:1809.05558
acc. by PRL

- Combined binned likelihood template fit
- Exclude LQLQ $\rightarrow t\mu\mu$ up to $M_{LQ} = 1420$ GeV



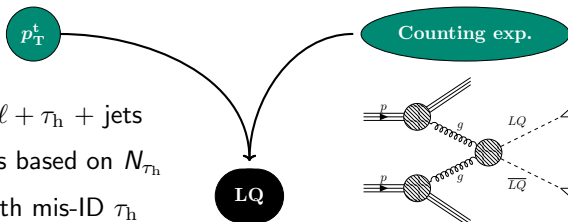
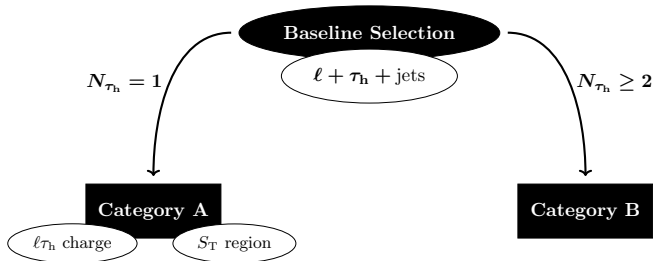
Run-II analysis ($LQLQ \rightarrow t\tau t\tau$)*Eur. Phys. J. C 78 (2018) 707*

Analysis workflow



Run-II analysis ($LQLQ \rightarrow t\tau t\tau$)Eur. Phys. J. C 78 (2018) 707

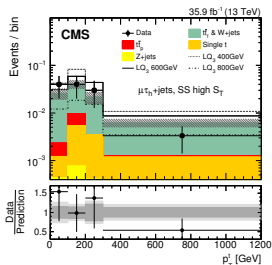
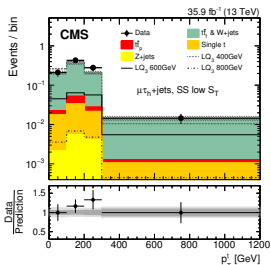
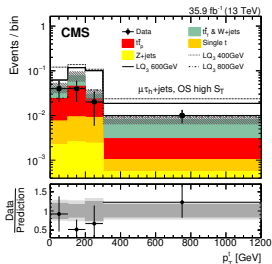
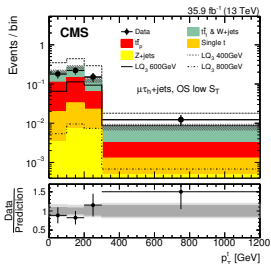
Analysis workflow



- Signal region: $l + \tau_h + \text{jets}$
 - ▶ Categories based on N_{τ_h}
- Background with mis-ID τ_h derived from data

Run-II analysis (LQLQ \rightarrow $t\bar{t}\tau\tau$)Final distributions ($\mu + \tau_h +$ jets channel)Eur. Phys. J. C 78 (2018) 707

Category A



Category B

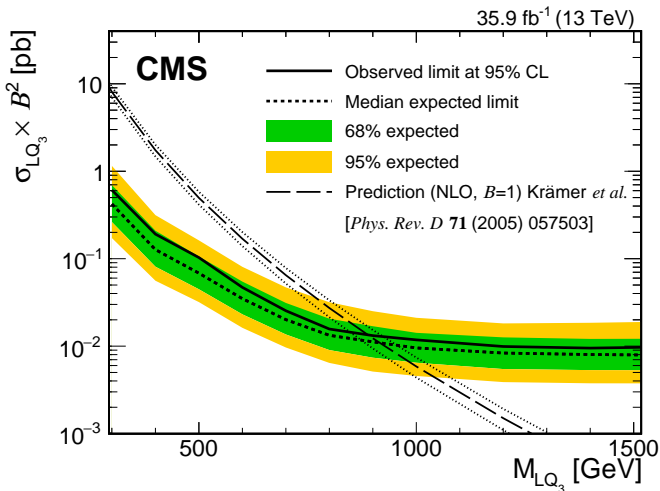
Process	Events
LQ (400)	98 ⁺¹⁹ ₋₁₇
LQ (900)	1.9 ^{+0.4} _{-0.4}
Total BG	8.4 ^{+2.6} _{-2.3}
Data	11

- different categories cover a wide range of LQ masses

Run-II analysis ($LQLQ \rightarrow t\tau t\tau$)Eur. Phys. J. C 78 (2018) 707

Limits

- Combined binned likelihood template fit
- Exclude $LQLQ \rightarrow t\tau t\tau$ up to $M_{LQ} = 900$ GeV

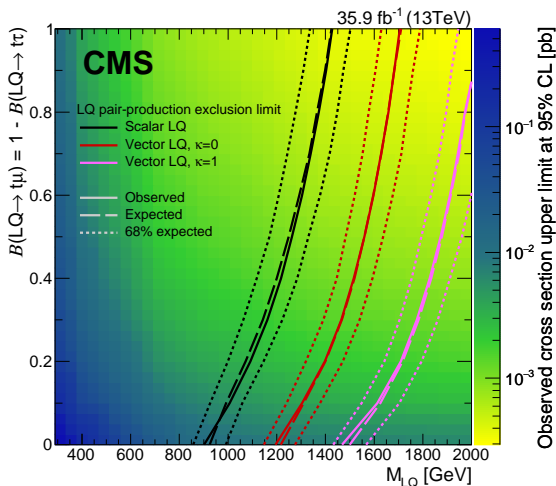


Combination: LQLQ \rightarrow $t\bar{t}l\bar{l}$

arXiv:1809.05558
acc. by PRL

Limits

- Simultaneous analysis of both decay channels
- Limits depend on $\mathcal{B} = \text{BR}(\text{LQ} \rightarrow t\bar{t})$
- $\text{LQ} \rightarrow t\bar{t}$ dominates sensitivity
- Mass limits range from 900-1420 GeV for scalar LQs
- For the first time, all relevant couplings of LQs ($q = -1/3$) to third-generation quarks probed

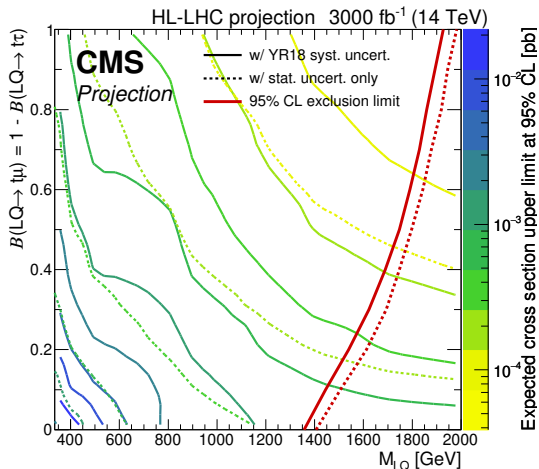


Projection for HL-LHC

Projection to 3000 fb^{-1}

CMS-PAS-FTR-18-008

- Reach estimated by scaling assumed \mathcal{L}_{int}
- Templates scaled to $\sqrt{s} = 14 \text{ TeV}$
- Statistical uncertainty reduced by factor $\sqrt{\mathcal{L}}$
- Relative exp. uncertainties scaled down by $\sqrt{\mathcal{L}}$
- Exclusion limits between 1350 and 1900 GeV



Summary

- CMS searches for $L\bar{L}Q$ pair production in $t\bar{t}\mu$ and $t\bar{t}\tau$ channels
 - Decay modes essential to explain B anomalies
 - Combination of channels
 - Exclusion with 35.9 fb^{-1} :
 - ▶ $t\bar{t}\mu$: $M_{LQ} \leq 1420 \text{ GeV}$
 - ▶ $t\bar{t}\tau$: $M_{LQ} \leq 900 \text{ GeV}$
-
- ▶ $t\bar{t}l$: $M_{LQ} \leq 900 \text{ GeV}$
for all values of \mathcal{B}
- Projection for HL-LHC:
 - $M_{LQ} \leq 1350 \text{ GeV}$ excluded for all values of \mathcal{B}

