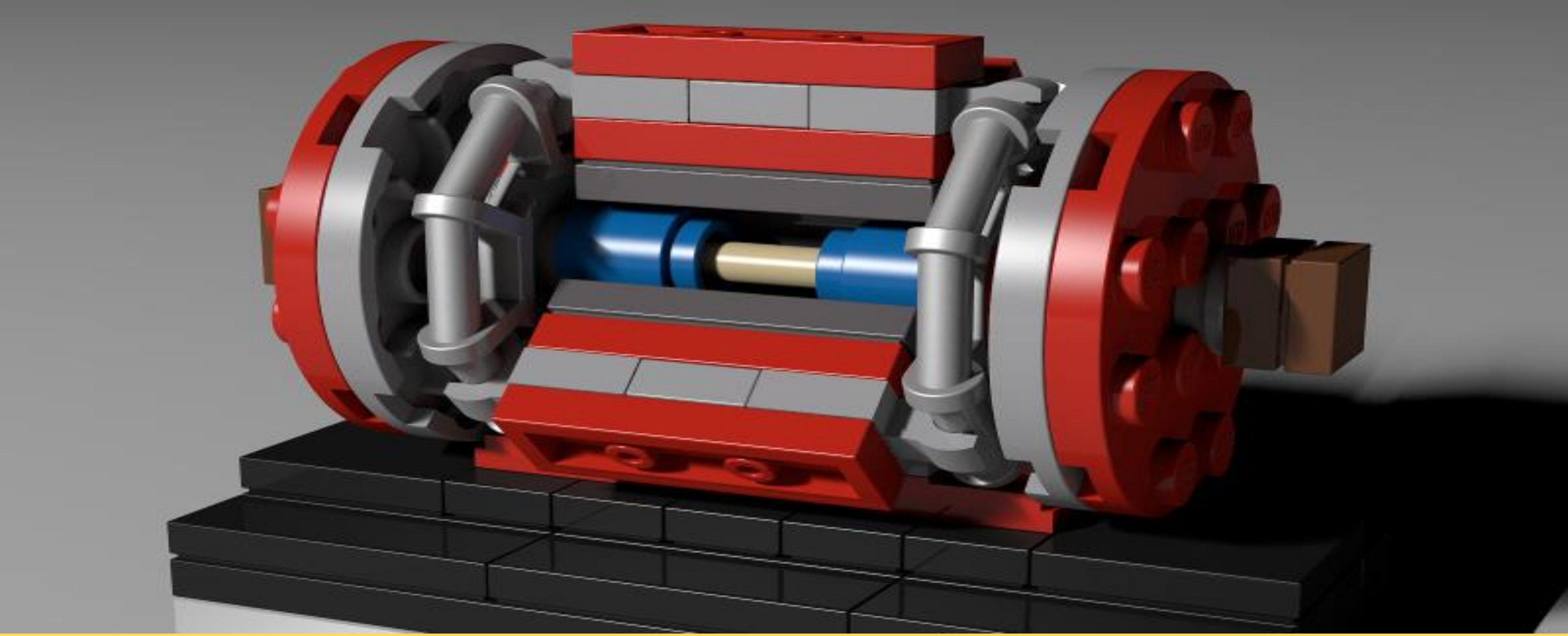

Search for t-channel leptoquarks in the high mass dilepton spectrum with the CMS detector

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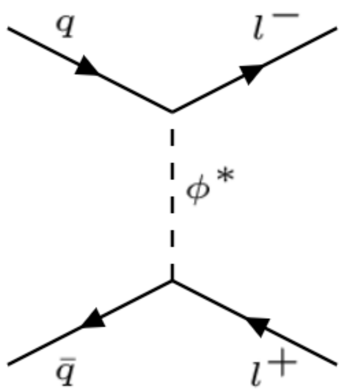
Motivation

Leptoquarks (LQs) are colour-triplet bosons that mediate interactions between a quark and a lepton. Historically, they appear in a variety of BSM models: GUTs, compositeness, technicolor models etc.

In this analysis we search for 8 non-resonant leptoquarks (LQs) coupling up and down quarks to electrons and muons for $m_{\ell\ell} > 500\ GeV$

- S_{eu}, S_{ed} - scalar LQs coupling u/d quarks to electrons
- $S_{\mu u}, S_{\mu d}$ - scalar LQs coupling u/d quarks to muons
- V_{eu}, V_{ed} - vector LQs coupling u/d quarks to electrons
- $V_{\mu u}, V_{\mu d}$ - vector LQs coupling u/d quarks to muons



We search for LQs with 3B+L=0. In the nomenclature of [1]:

S_{eu} and $S_{\mu u}$ belong to the R_2 family with RL couplings (Q_e=5/3)

S_{ed} and $S_{\mu d}$ belong to the $\widetilde{R_2}$ family with RL couplings (Q_e=2/3)

$V_{eu}, V_{ed}, V_{\mu u}$ and $V_{\mu d}$ belong to the U_3 family with LL couplings (Q_e=5/3 or 2/3)

R_2 LQs appear in BSM extensions that explain the muon g-2 anomaly [2].

U_3 LQs appear in BSM extensions that explain LFV and LFUV [1].

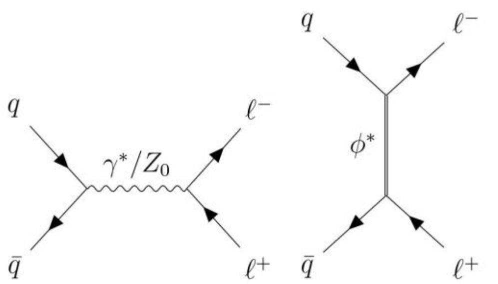
Why search for t-channel leptoquarks?

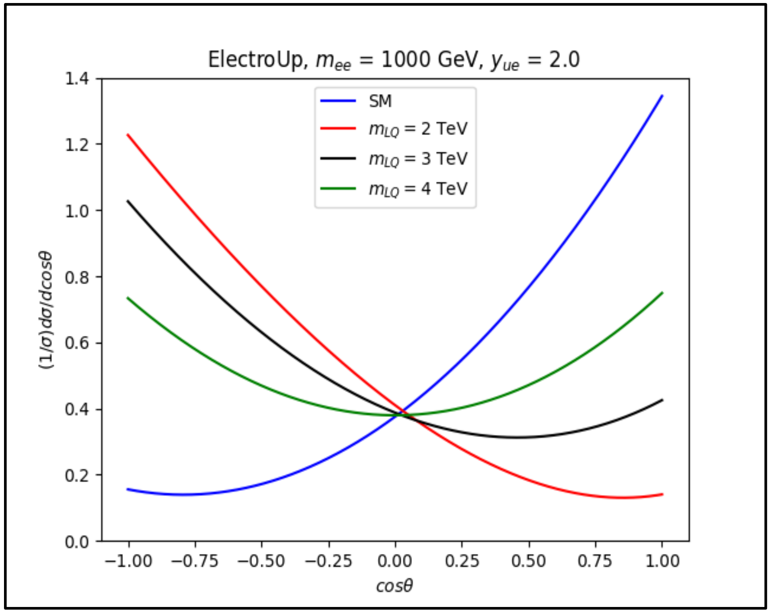
So far, CMS and ATLAS have not made a targeted search for t-channel LQs coupling up and down quarks to electrons and muons.

- Direct searches for LQs coupling to u/d quarks to electrons have excluded them upto 1.76 TeV [4], while LQs coupling u/d quarks to muons have been excluded only upto 0.66 TeV [4].
- Pair production and single production searches for heavy LQs are limited by the CMS centre-of-mass energy because the LQs are produced on shell.
- The quark-LQ-lepton interaction is characterized by the Yukawa coupling y_{LQ}. t-channel LQ effects are sensitive to y_{LQ}^4 (pure LQ exchange) and y_{LQ}^2 (interference with γ/Z^0)
- Additionally, this channel has clean signals, is easily triggerable and has well understood backgrounds.

t-channel production is non-resonant $\Longrightarrow$

can probe heavier LQs than previous searches for first/second generation LQs.





The angular distribution of an S_{eu} leptoquark of mass 2/3/4 TeV deviates significantly from the expected SM curve. The coupling strength is held fixed at $y_{eu} = 2$.

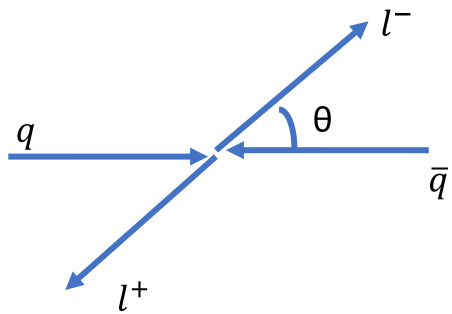
Analysis strategy

Our analysis follows from ideas presented in [5], where the angular distribution of the angle between the incident quark and outgoing lepton is used as a probe of the quark-LQ-lepton interactions.

Cross section for leading order pure LQ exchange and the interference between LQ and γ^*/Z_0 amplitudes

For scalar LQs $S_{eu}, S_{ed}, S_{\mu u}, S_{\mu d}$ (y_{LQ} = Yukawa coupling for S_{LQ})

$$\frac{d^2\sigma}{dMdc_*} \propto \frac{d\sigma}{dc_*}(M^2) + y_{LQ}^4 N_{LQ(pure)}^S \frac{(1-c_*)^2}{(1-c_*+\frac{2M_{LQ}^2}{M^2})^2} + y_{LQ}^2 N_{LQ(int)}^S \frac{(1-c_*)^2}{1-c_*+\frac{2M_{LQ}^2}{M^2}}$$



For vector LQs $V_{eu}, V_{ed}, V_{\mu u}, V_{\mu d}$ (g_{LQ} = Yukawa coupling for V_{LQ})

$$\frac{d^2\sigma}{dMdc_*} \propto \frac{d\sigma}{dc_*}(M^2) + g_{LQ}^4 N_{LQ(pure)}^V \frac{(1+c_*)^2}{(1-c_*+\frac{2M_{LQ}^2}{M^2})^2} + g_{LQ}^2 N_{LQ(int)}^V \frac{(1+c_*)^2}{1-c_*+\frac{2M_{LQ}^2}{M^2}}$$

- We bin aMC@NLO Drell-Yan events in reconstructed dilepton mass, rapidity and $cos\theta$
- Reweight them using generator level analytical functions to create parameter-independent templates that mimic the various pieces of expected differential distributions
- Separate templates built for the pure LQ exchange and interference with γ/Z^0, and various backgrounds
- We then fit linear combinations of signal + background templates for y_{LQ}^2 (g_{LQ}^2)

Event Selection, Backgrounds & Systematics

Templates are built using SM DY fully simulated aMC@NLO samples centrally produced by CMS [6] in 2016, 2017 and 2018 (Run-2) corresponding to $138\ fb^{-1}$

Selection criteria for electrons and muons:

- $p_T > 40\ GeV$ for the leading lepton, $p_T > 15\ GeV$ for the subleading lepton
- Both leptons must have opposite sign
- Full angular acceptance, and well isolated

Background composition for $m_{\ell\ell} > 500\ GeV$ in dimuon (dielectron) channel:

- SM Drell-Yan events – 85% (82%)
- $t\bar{t}, tW, \bar{t}W$ events – 10% (9%)
- WW, ZZ, WZ events – 4.5% (4%)
- QCD multijet and W+jets events – 0.5% (5%)
- $\gamma\gamma \rightarrow \ell\ell$ events - < 5%
    - SM DY, top and diboson backgrounds are well modeled in MC - top and diboson backgrounds are validated in data with $e\mu$ samples
    - QCD multijet and W+jets backgrounds can produce fake leptons - estimated via data-driven fake rate measurement.

Leading systematics are statistical uncertainty in the MC samples, uncertainty to cover the LO reweighting scheme, lepton momentum scale, ID and isolation efficiencies.

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Fit results

We fit to the full Run-2 data collected by CMS in 2016, 2017 and 2018

Our POIs are A_4, A_0 and $y_{LQ}^2(g_{LQ}^2)$

- Coefficient of the pure exchange is $y_{LQ}^4(g_{LQ}^4)$, coefficient of the interference term is $y_{LQ}^2(g_{LQ}^2)$
- A_0 and A_4 are angular coefficients that appear in the SM DY cross section, A_4 is related to the SM Forward-Backward Asymmetry A_{FB}

- Fits are performed for all 3 years simultaneously
- Muon and electron channels are fit separately
- Separate fits are performed for each of the 8 leptoquarks, and each leptoquark is fit separately per mass point
- Fit results for the 2.5 TeV mass point for up-type LQs are shown below.

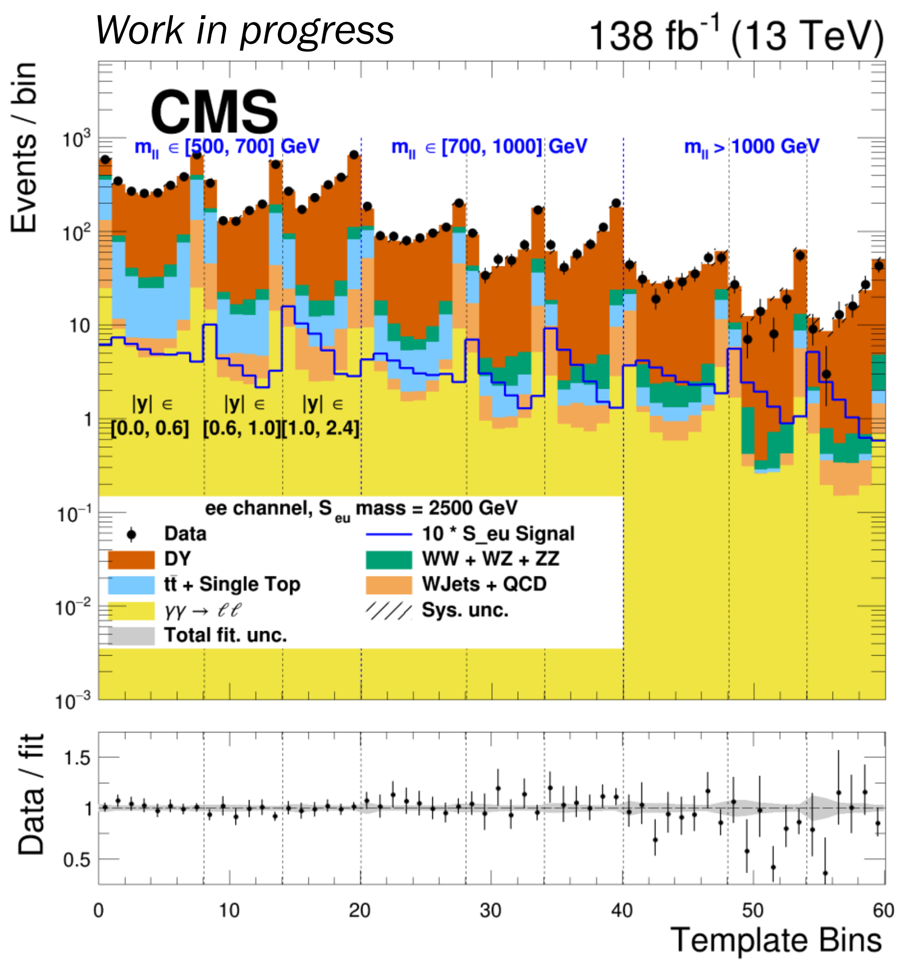
Note: In the SM, $A_4 = 1.61, A_0 = 0.06, y_{LQ}^2 = 0.$

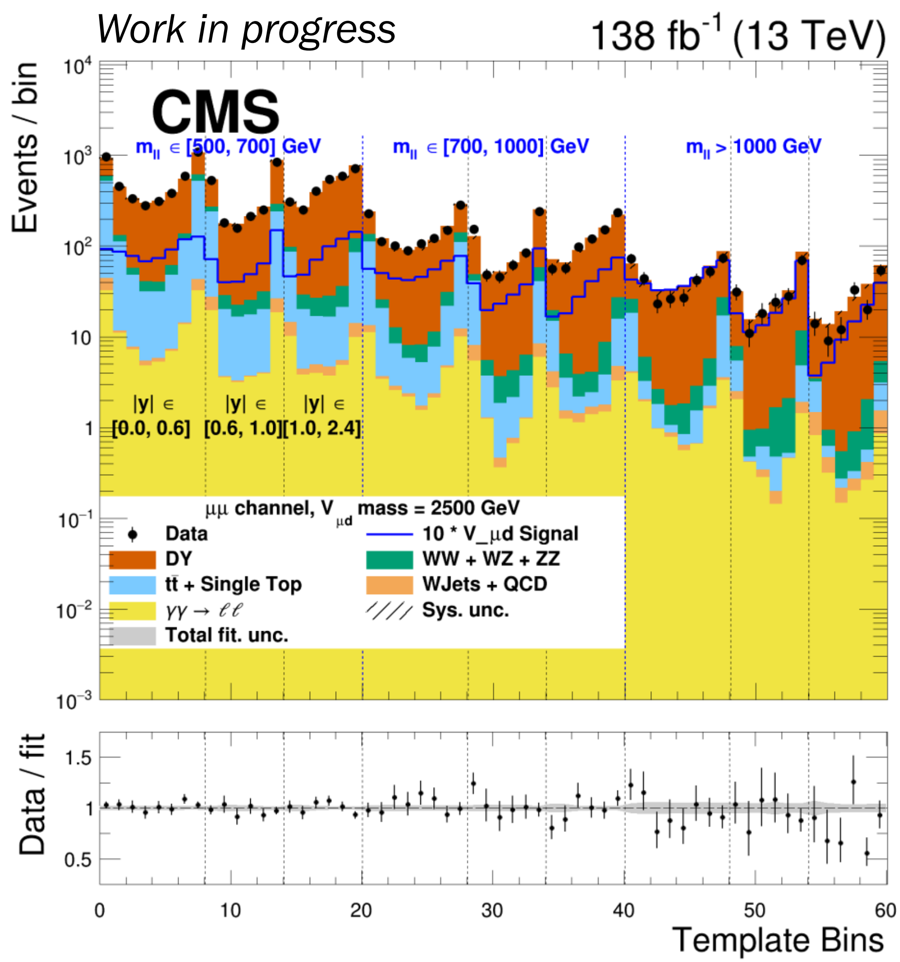
CMS Work in progress

Channel	S_{eu}	$S_{\mu u}$	V_{eu}	$V_{\mu u}$
A_0	0.074 ± 0.069	0.02 ± 0.055	0.05 ± 0.068	0.012 ± 0.053
A_4	1.612 ± 0.078	1.59 ± 0.066	1.66 ± 0.076	1.636 ± 0.063
$y_{LQ}^2(g_{LQ}^2)$	-0.1 ± 0.161	-0.13 ± 0.158	-0.085 ± 0.027	-0.099 ± 0.063

With these results, we extract 95% CL upper limits on the coupling ($y_{LQ}^2(g_{LQ}^2)$) as a function of LQ mass for all 8 LQs

Postfit distributions for 2.5 TeV S_{eu}, V_{ud}





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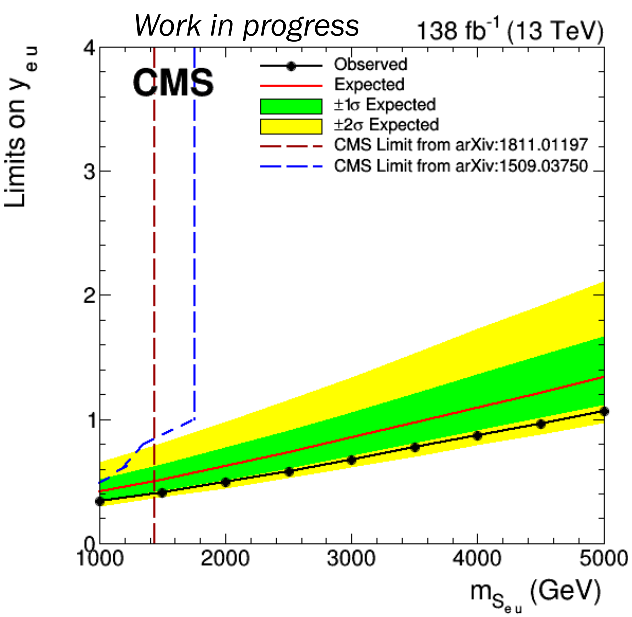
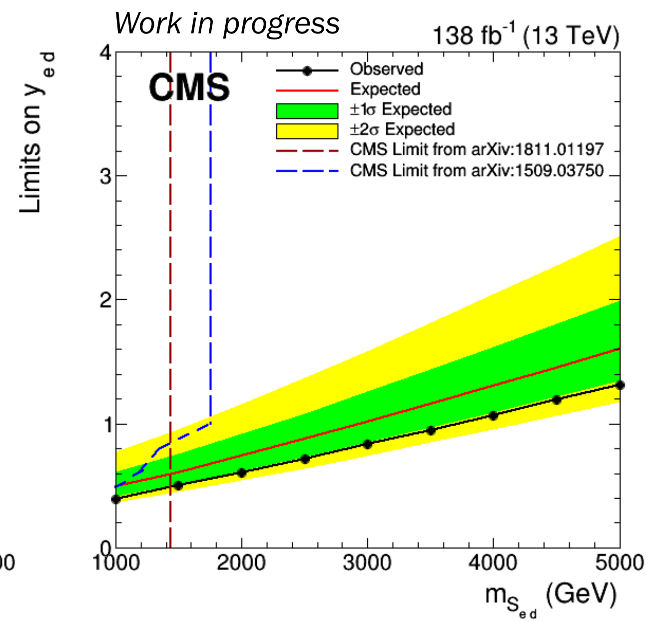
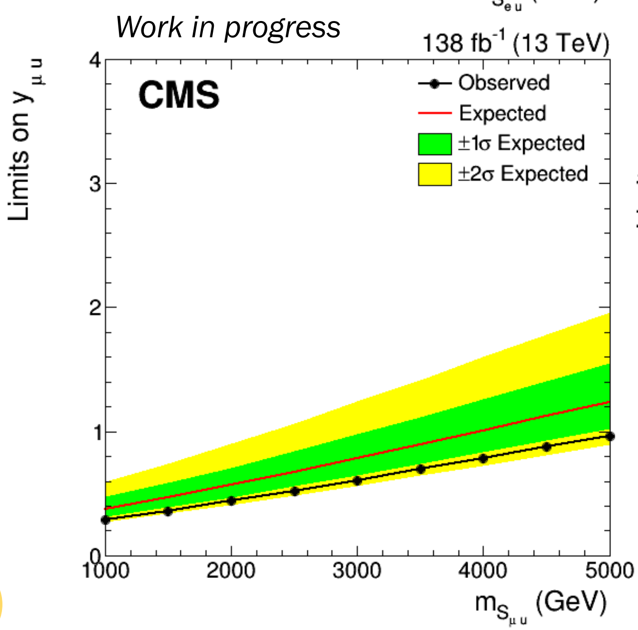
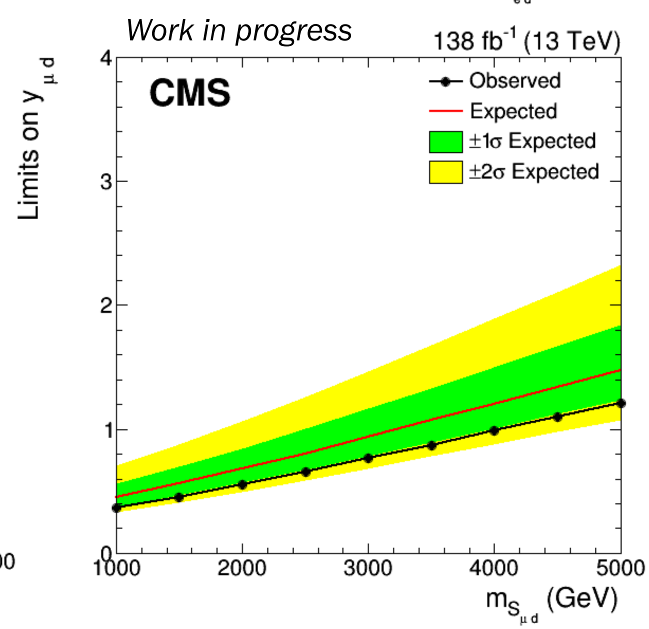
95% CL Upper Limits on y_{LQ}^2









- Tighter limits on up type LQs than down type
- Muon LQs limits are almost similar to electron LQs
- Tighter limits on vector LQs than scalars
- All 8 LQs types have sensitivity upto 5 TeV, with $y_{LQ}\ (g_{LQ})\ <\ 3.0$

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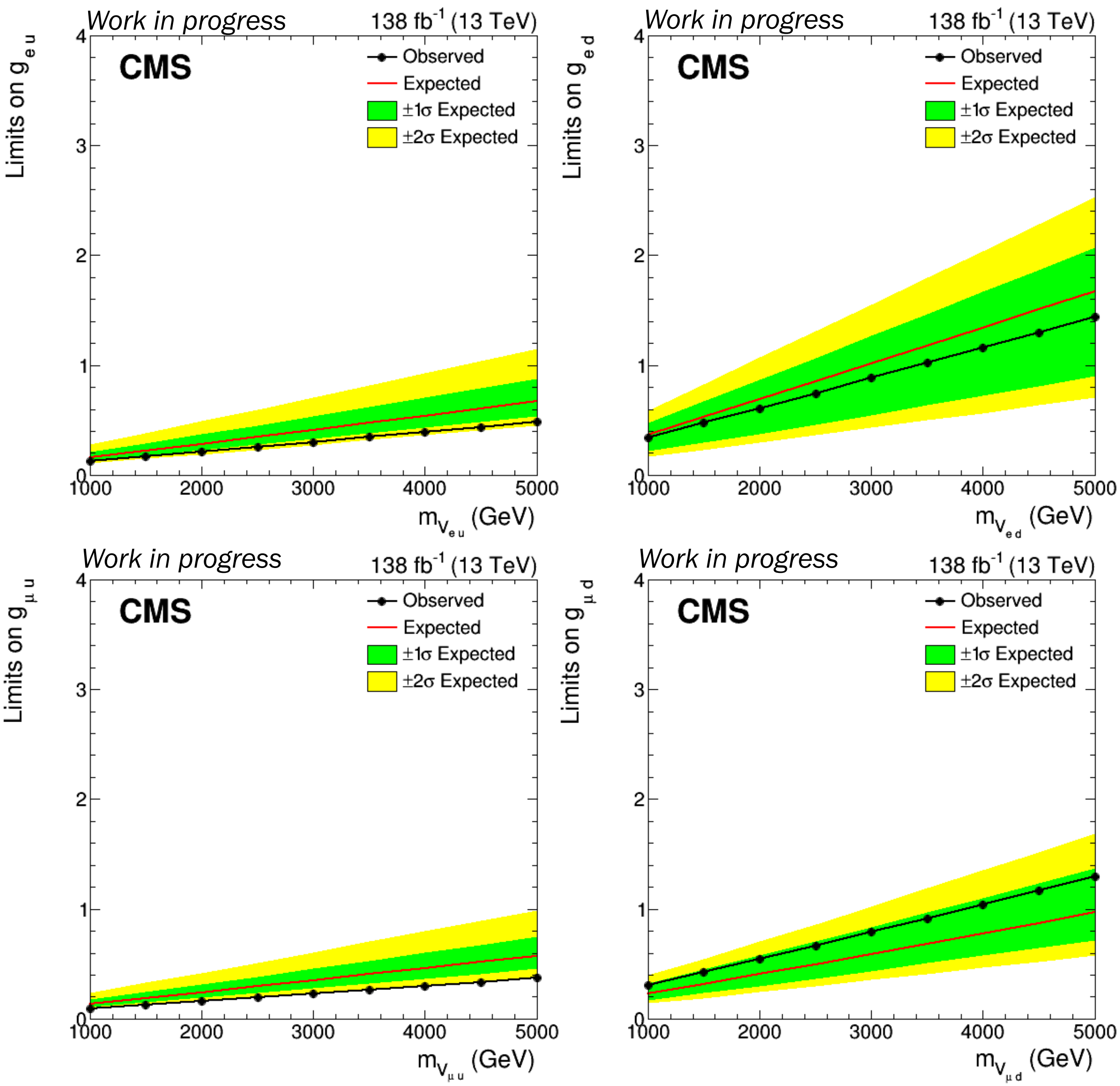
95% CL Upper Limits on g_{LQ}^2



- Tighter limits on up type LQs than down type
- Muon LQs limits are almost similar to electron LQs
- Tighter limits on vector LQs than scalars
- All 8 LQs types have sensitivity upto 5 TeV, with y_{LQ} (g_{LQ}) < 3.0

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Conclusion

- Presented results of the first CMS analysis to search for scalar and vector non-resonant LQs coupling electrons and muons to up and down quarks
- Analysis is at the final stages of review with the Analysis Review Committee within CMS
- Hoping to publish the results in the next couple of months in JHEP.

Thank you for listening! Please ask me questions ☺

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