Leptoquark (LQ) searches in CMS

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On behalf of CMS Collaboration

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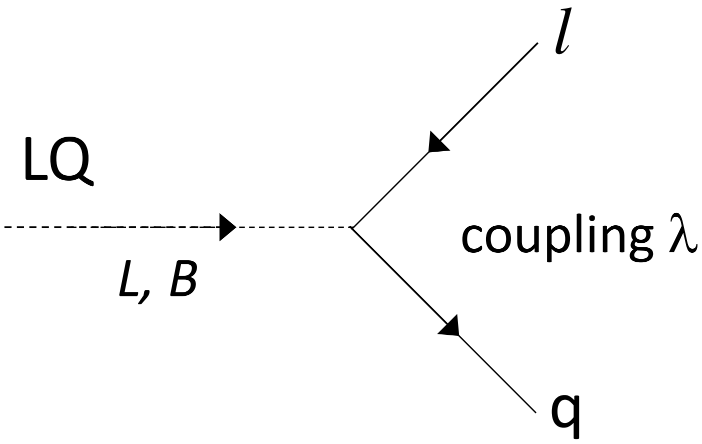
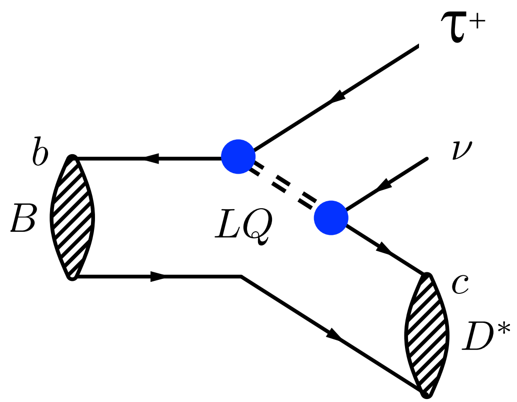
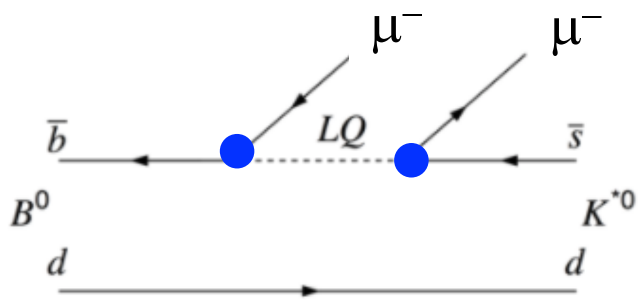
Introduction



- Fractional electric charge ($\pm$5/3, $\pm$4/3, $\pm$2/3, $\pm$1/3 e)
- Spin 0 (scalar) or 1 (vector)
- Inter-generational mixing suppressed to meet experimental constraint

Recently got particular attention as it might explain observed B-anomalies



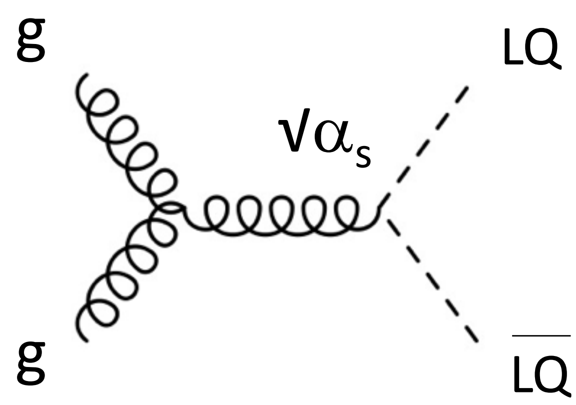


LQ that preferentially couples to 2nd/3rd generation favored: Can be even at O(1) TeV scale

→ Direct searches at CMS

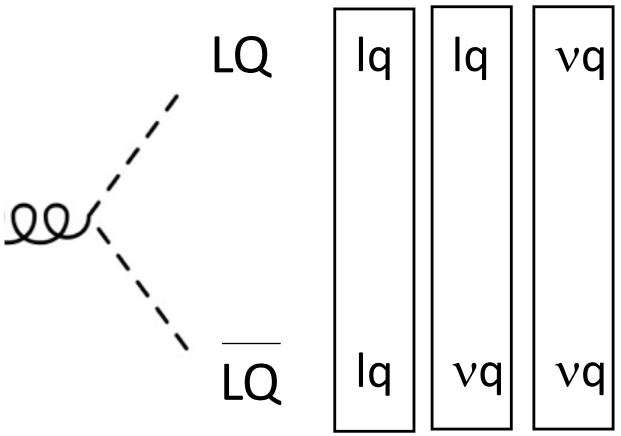
LQ signature

- LQs are copiously pair-produced through strong interaction
- Scalar LQ cross-section calculable model independently (vector LQ has model dependence and larger σ)



- LQ decay depends on (unknown) branching ratio β

$$BR(LQ \rightarrow lq) = \beta$$
$$BR(LQ \rightarrow \nu q) = 1 - \beta$$



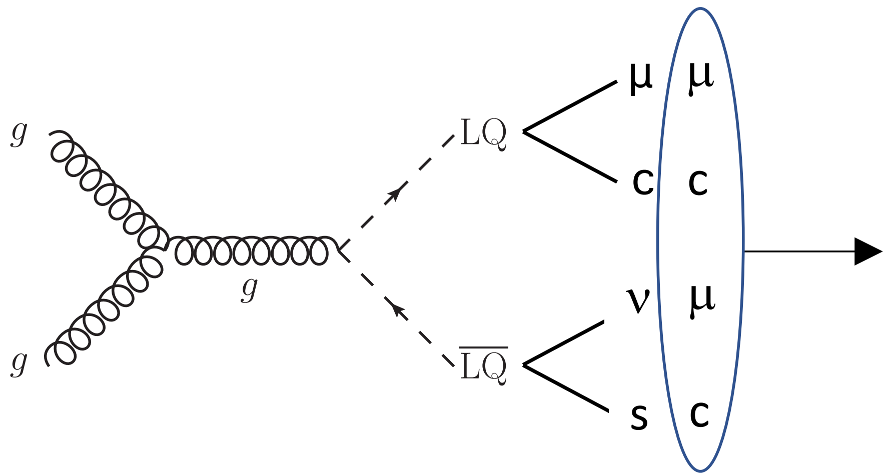
1st gen.	ee jj*1	eν jj*1	νν jj
2nd gen.	μμ jj	μν jj	νν jj
3rd gen. (q = t)	ττ tt	τν tt	νν tt
3rd gen. (q = b)	ττ bb*2	τν bb	νν bb

(*1) CMS-PAS-EXO-16-043
(*2) JHEP07(2017)121
JHEP03(2017)077

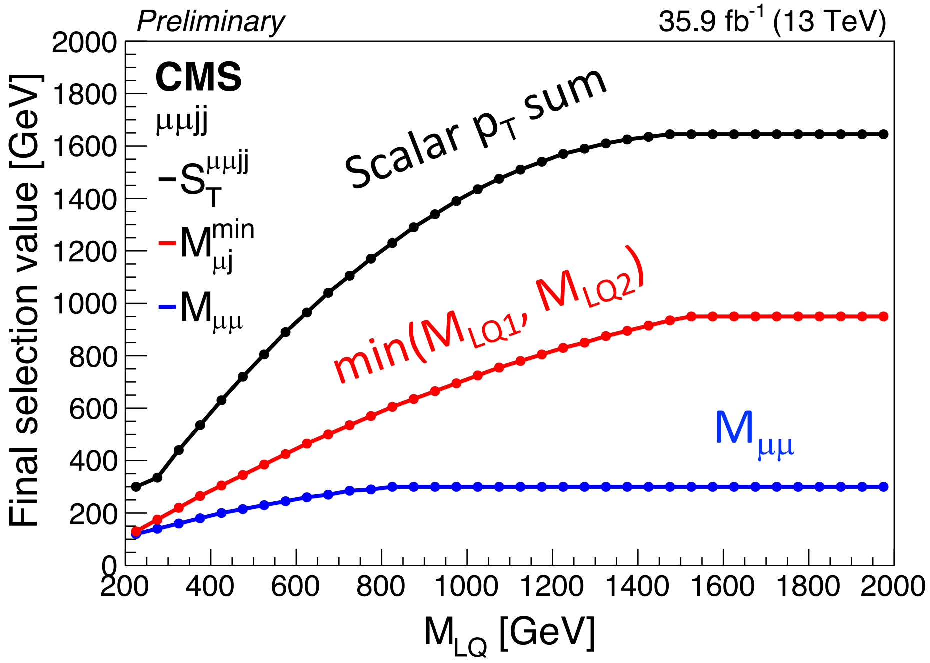
for this conference

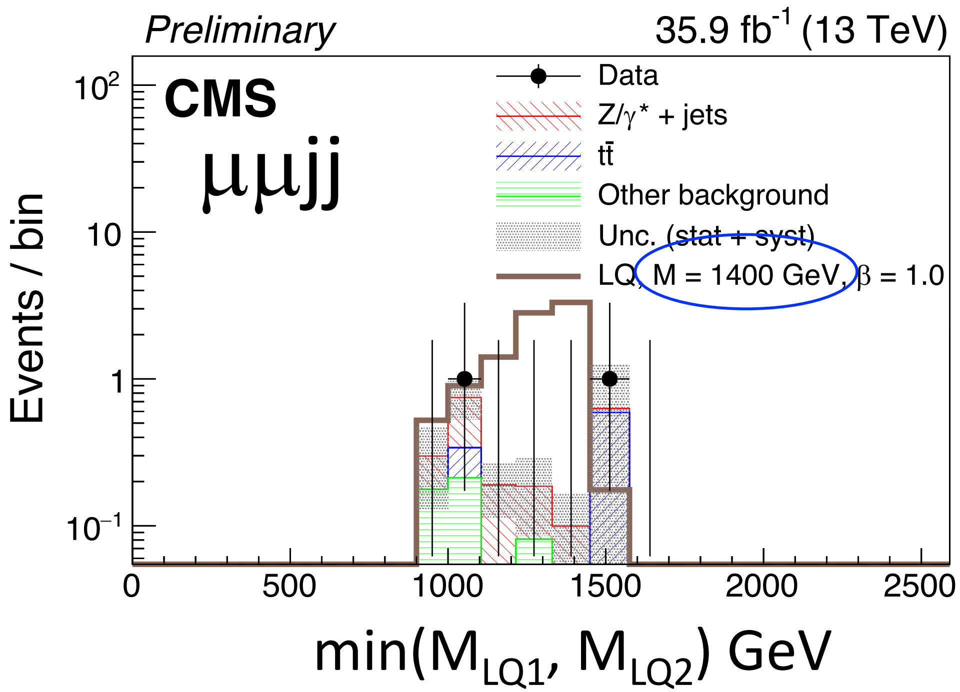
LQLQ → μμjj, μνjj

CMS-PAS-EXO-17-003 New

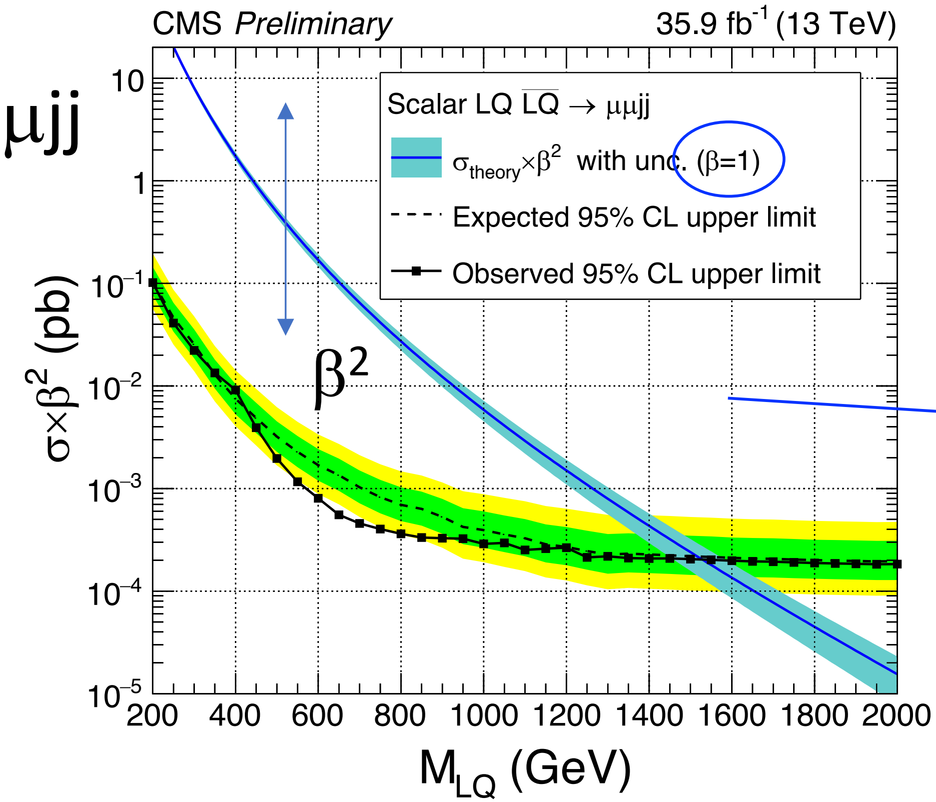


- 2μ +2jets with $p_T > 50$ GeV
- Construct 2 LQ candidates from (μ + jet) pair that minimize $|M_{LQ1} - M_{LQ2}|$
- Cut & count analysis for each mass point with optimized set of cuts for 3 kinematic variables

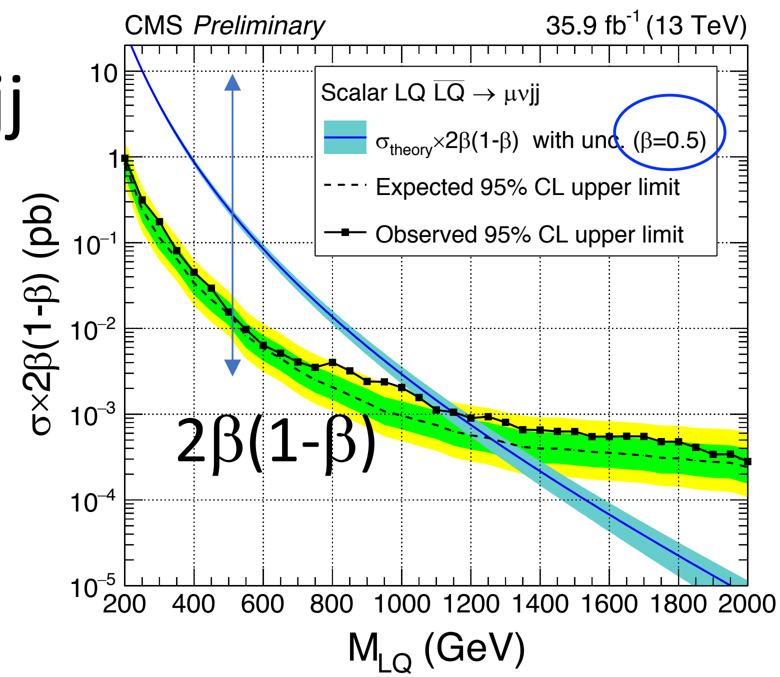




At higher m_{LQ}, the harder cut helps to effectively reduce backgrounds μμjj

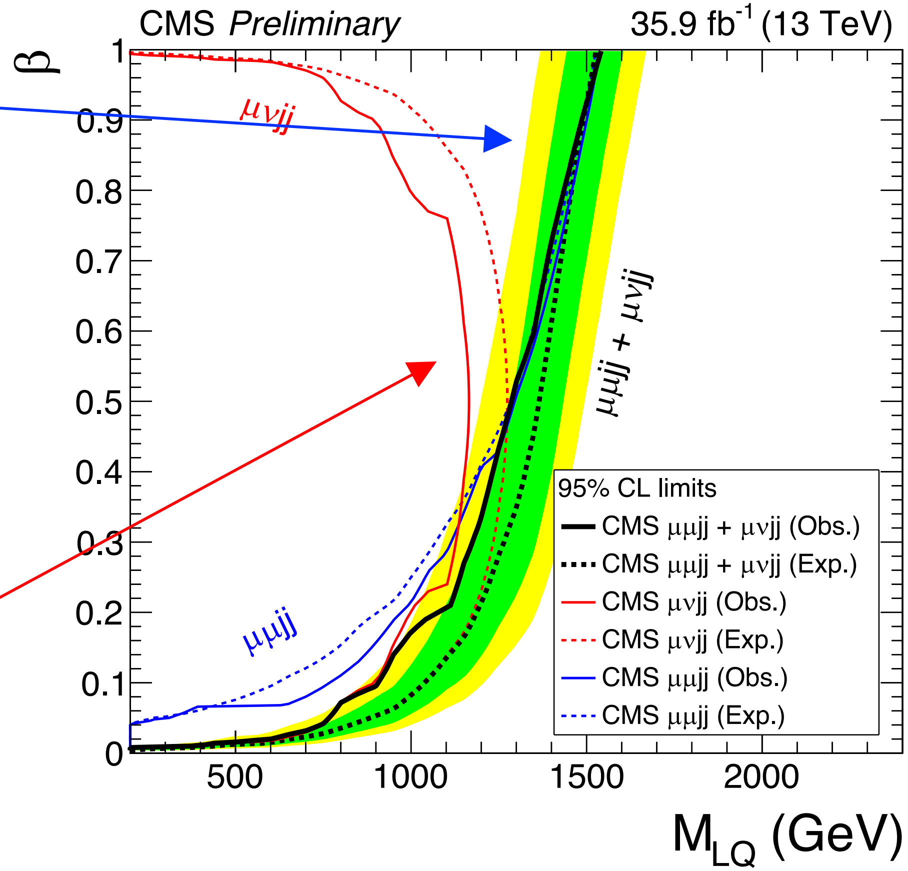


μνjj



CMS-PAS-EXO-17-003

Vary β from 0 to 1
→ set limit on β v.s m_{LQ}



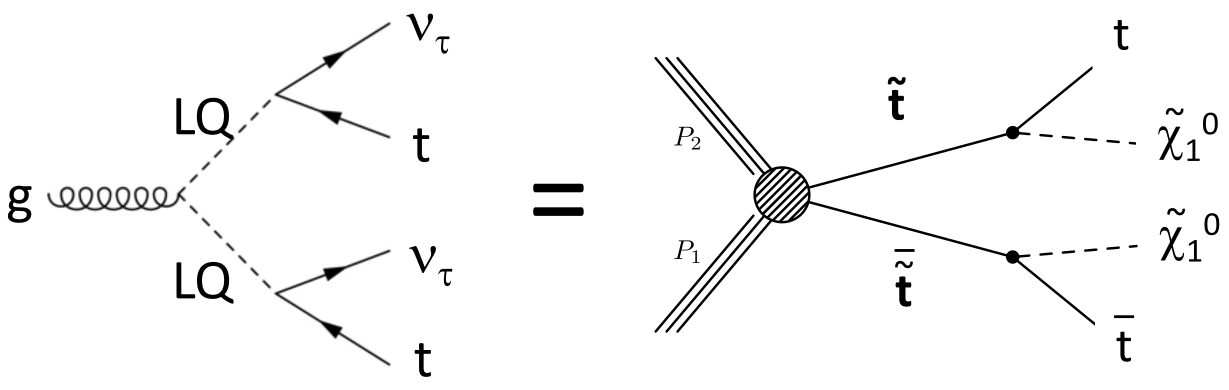
	Previous (13TeV, 2.7/fb)	This analysis (35.9/fb)
β = 1	1165 GeV	1530 GeV
β = 0.5	960 GeV	1285 GeV

LQLQ → ννjj, ννbb, ννtt

CMS-PAS-SUS-18-001

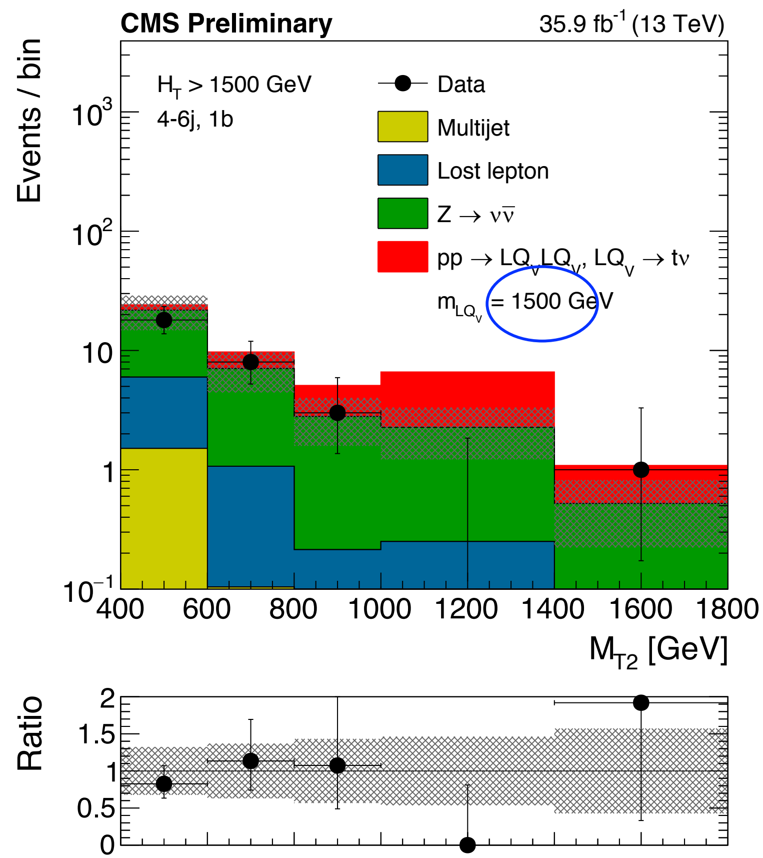
New

- Re-interpret existing SUSY searches ($\tilde{q}$, $\tilde{b}$, $\tilde{t}$) in terms of scalar LQ pair production



Results when $m(\tilde{\chi}_1^0) = 0$ can be used

How the signal looks like ?

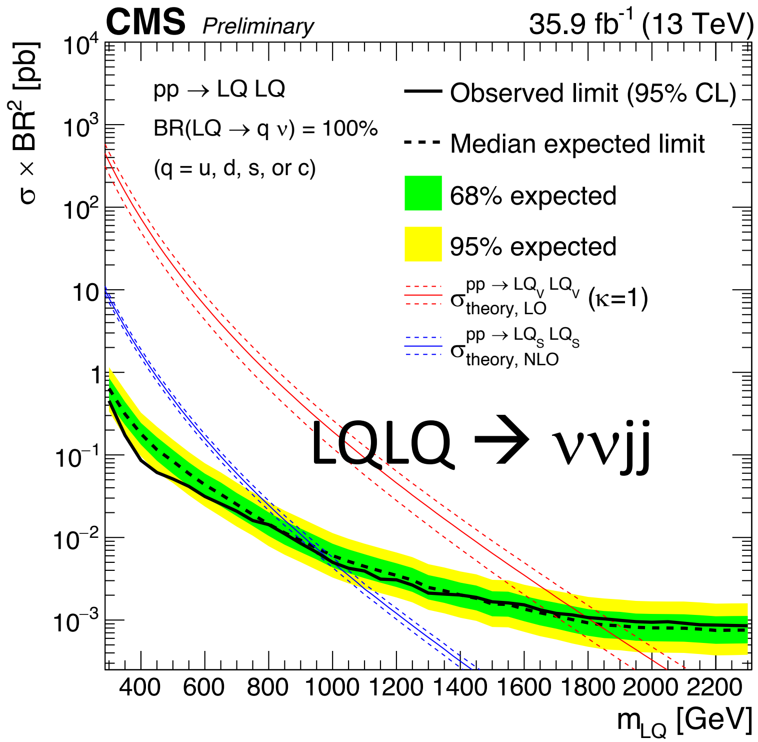


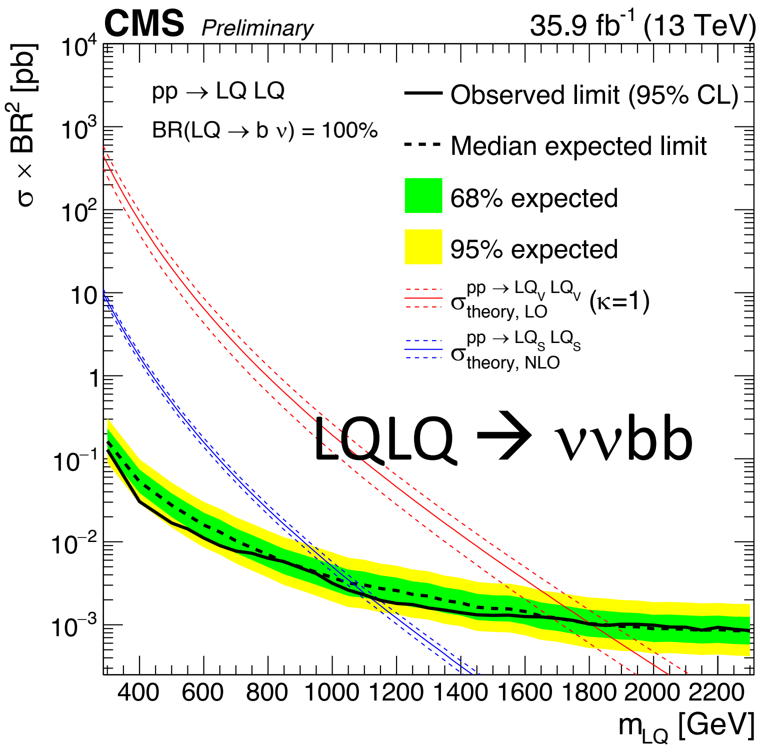
- Checked kinematic diff. between SUSY signal and vector LQ and found to be consistent within uncertainty
  → **also set limit in terms of vector LQ**
- Calculate scalar/vector LQ pair production cross-sections using models that might explain B-anom.
  (arXiv:1706.07641, κ = 1 (YM coupling), gtL = gbL = 0.1)

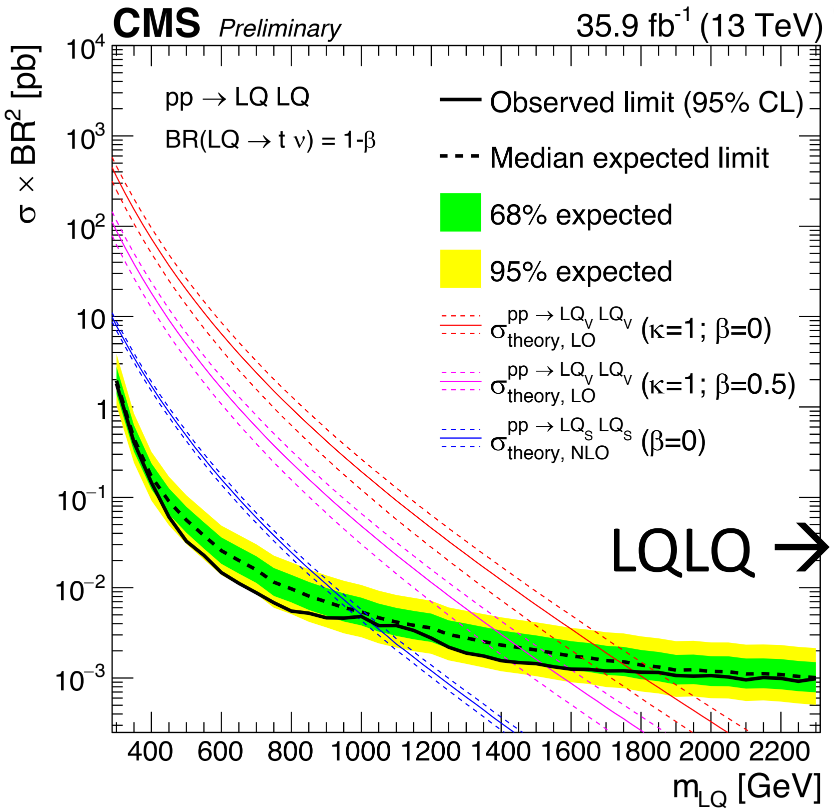
Scalar LQ

Vector LQ

CMS-PAS-SUS-18-001





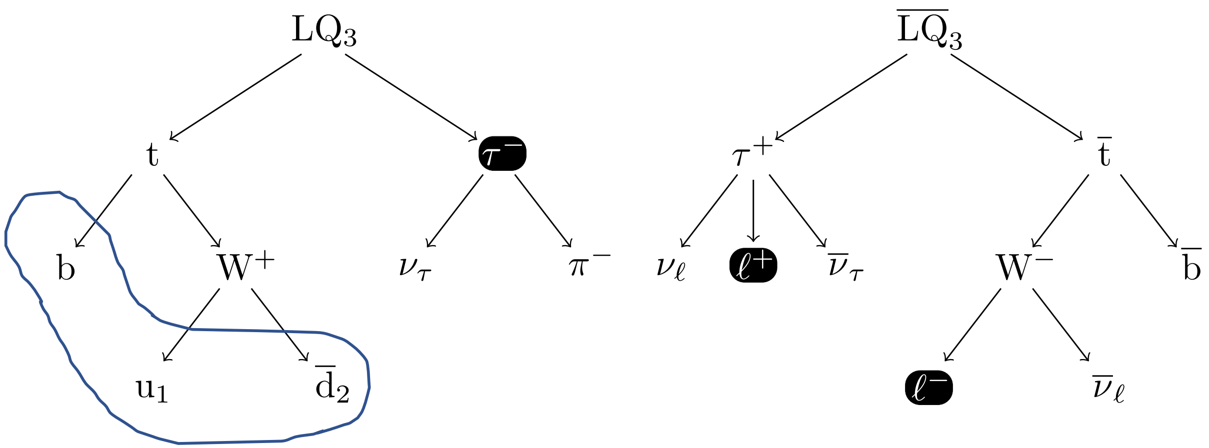


	Scalar LQ	Vector LQ
LQLQ → ννjj	980	1790
LQLQ → ννbb	1100	1810
LQLQ → ννtt	1020	1780 (β = 0) 1530 (β = 0.5)

LQLQ → 2τ + 2t

arXiv:1803.02864

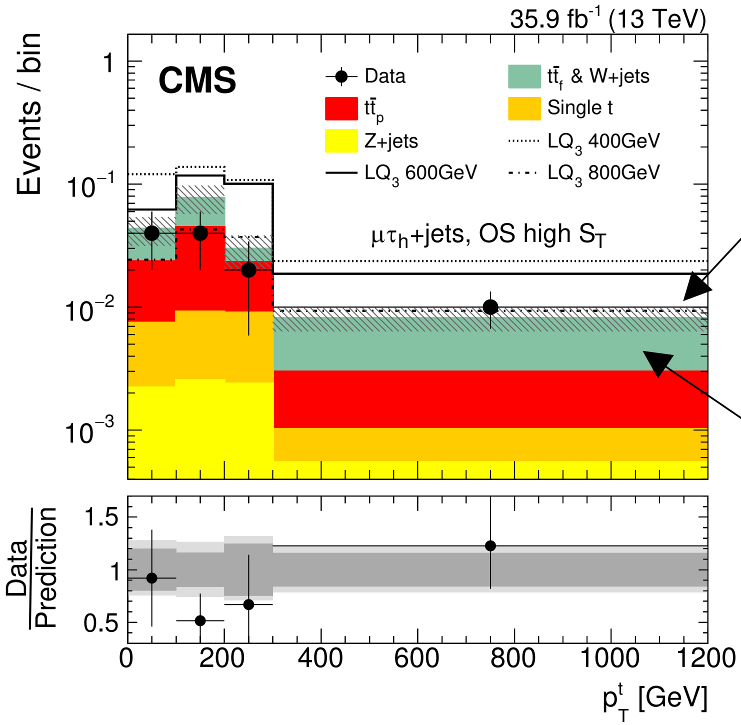
New



3 categories based on decay topology

- **Opposite-sign $l\tau_{had}$**
- Same-sign $l\tau_{had}$
- $l\tau_{had}\tau_{had}$

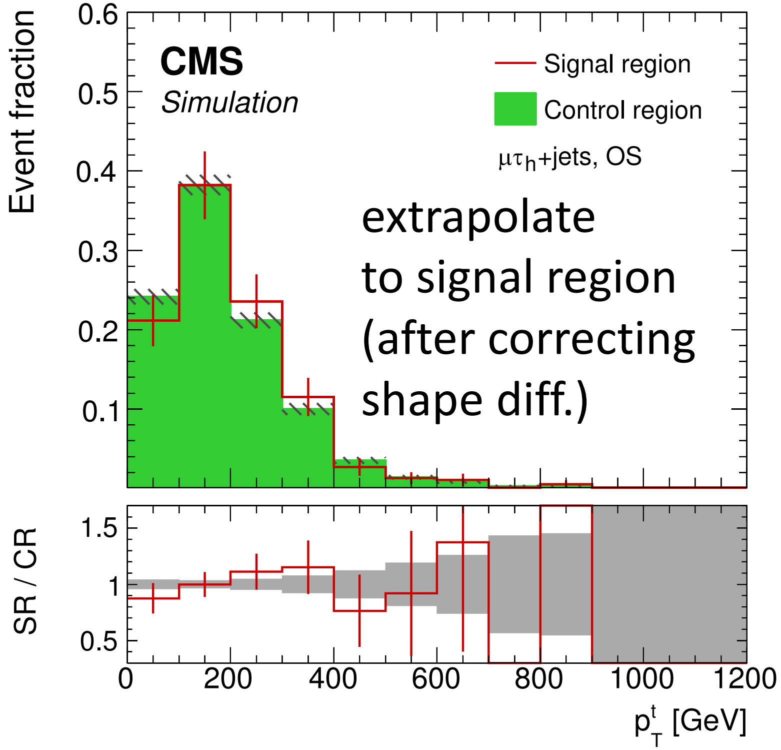
Signal extract based on p_T(top) : constructed by jet triplet that gives best top mass



Signal has higher p_T(top) as it comes from high mass LQ

ttbar with jets misidentified as τ_{had} → estimated using control region in data

Inverted τ_{had} isolation



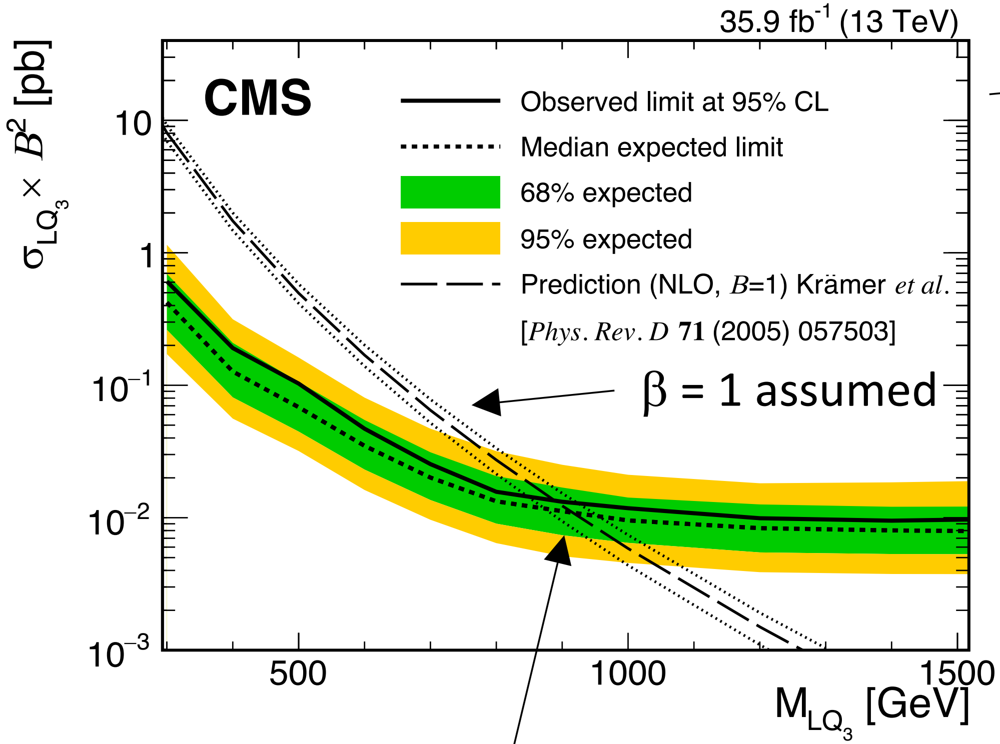
extrapolate to signal region (after correcting shape diff.)

LQLQ → 2τ + 2t

arXiv:1803.02864

New

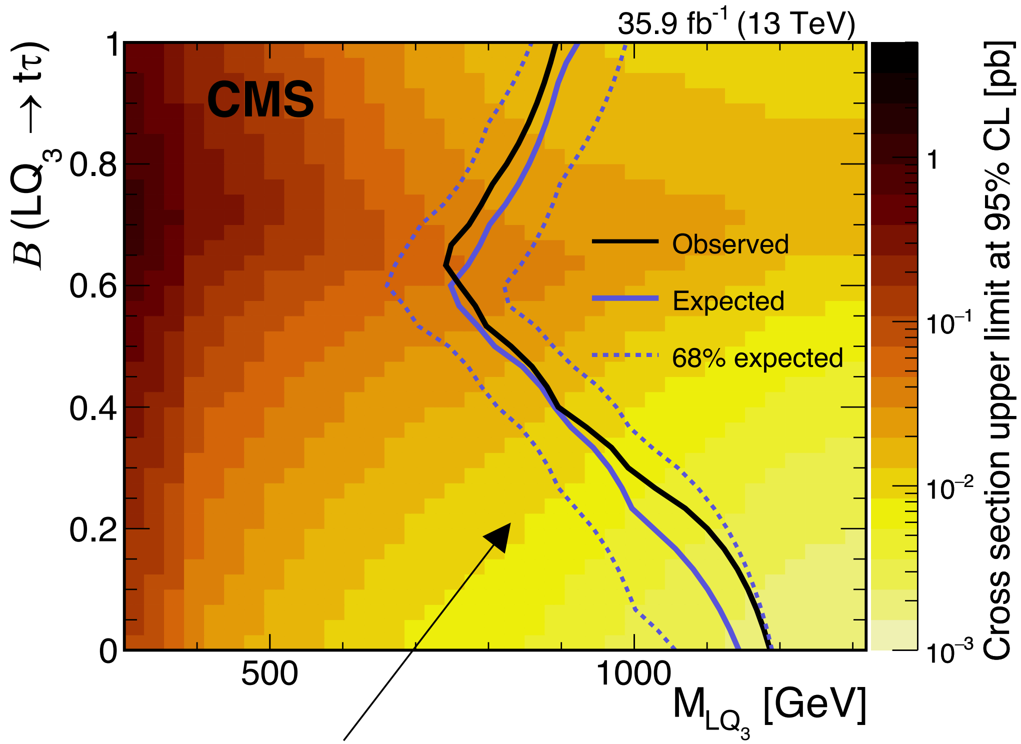
We fit p_T(top) distribution and set upper limit on cross-section



β = 1 assumed

Lower limit
on m_{LQ} = 900 GeV

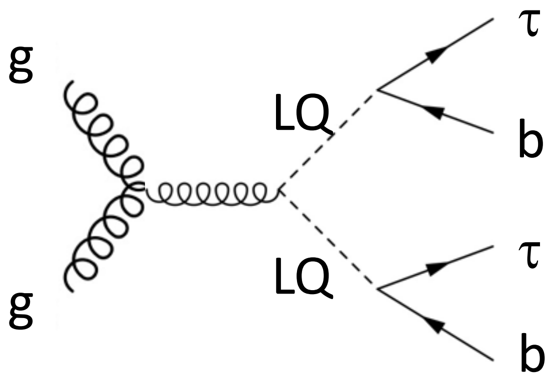
Vary β from 0 to 1
to set limit on β v.s. m_{LQ}
(Note: cross-section scales as β^2)



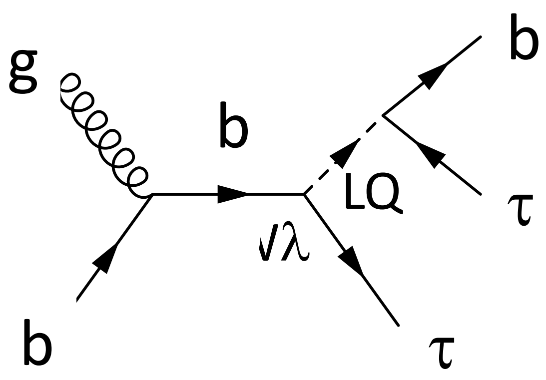
This exclusion comes from sbottom search
(we assume same LQ can decay either τt or νb)

Single LQ → 3rd generation

Pair LQ prod.

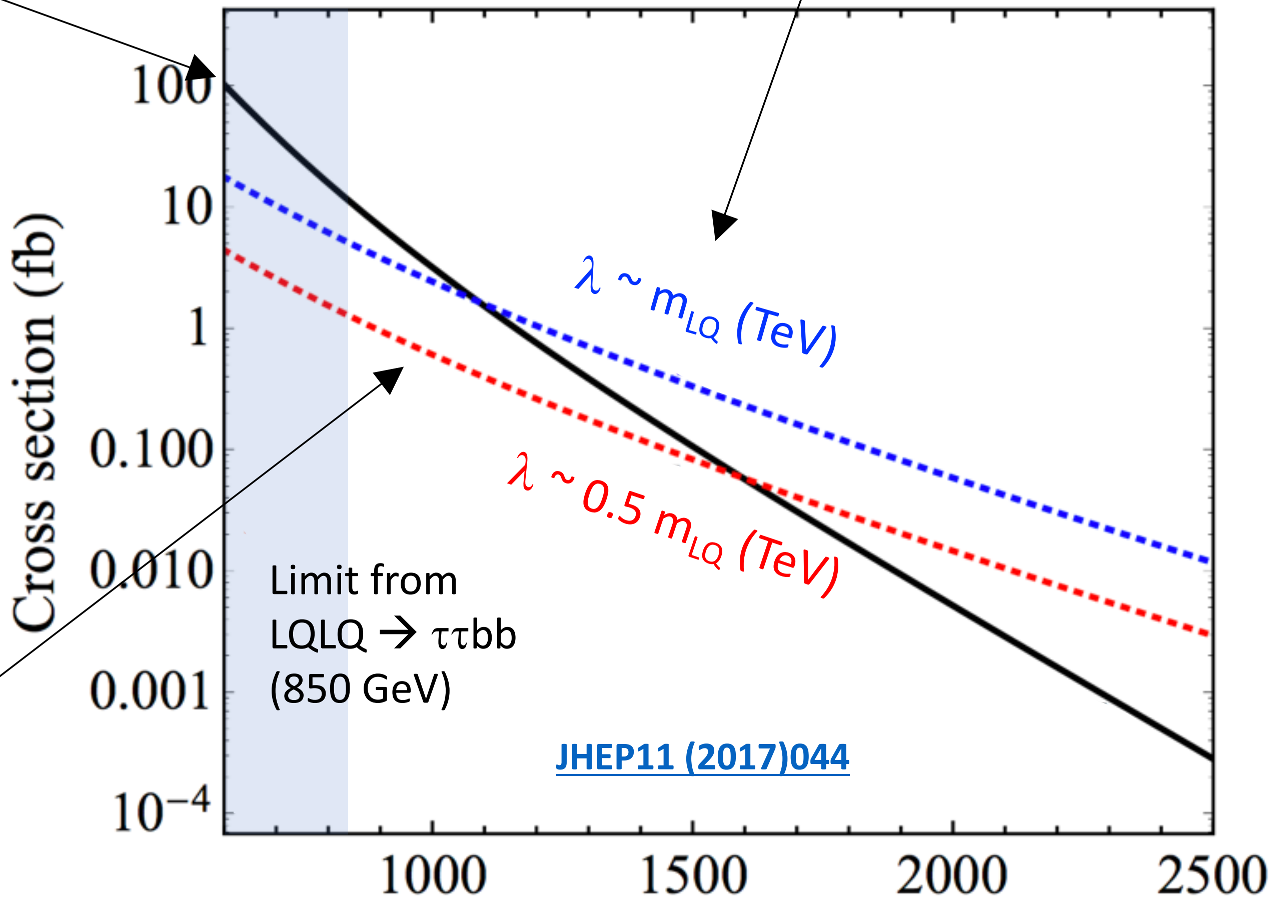


Single LQ prod.



Cross-section depends on unknown LQ coupling λ

Calculated using λ such that it can roughly explain the size of B-anom.

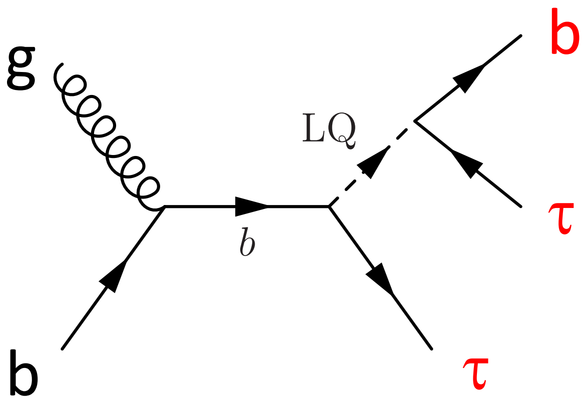


LQ mass (GeV)

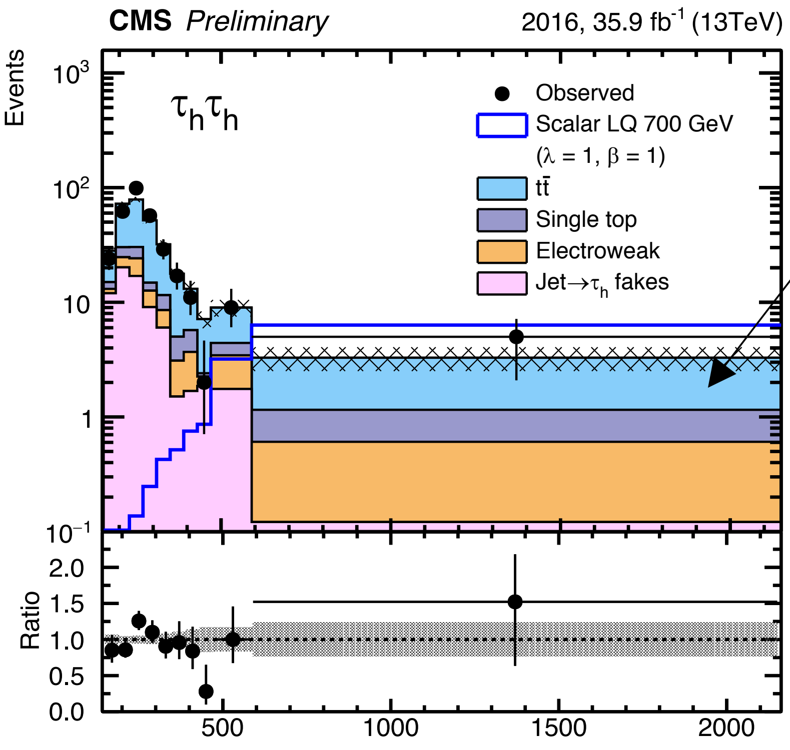
We should look for single LQ → 3rd gen.

Single LQ → τb

CMS-PAS-EXO-17-029 New

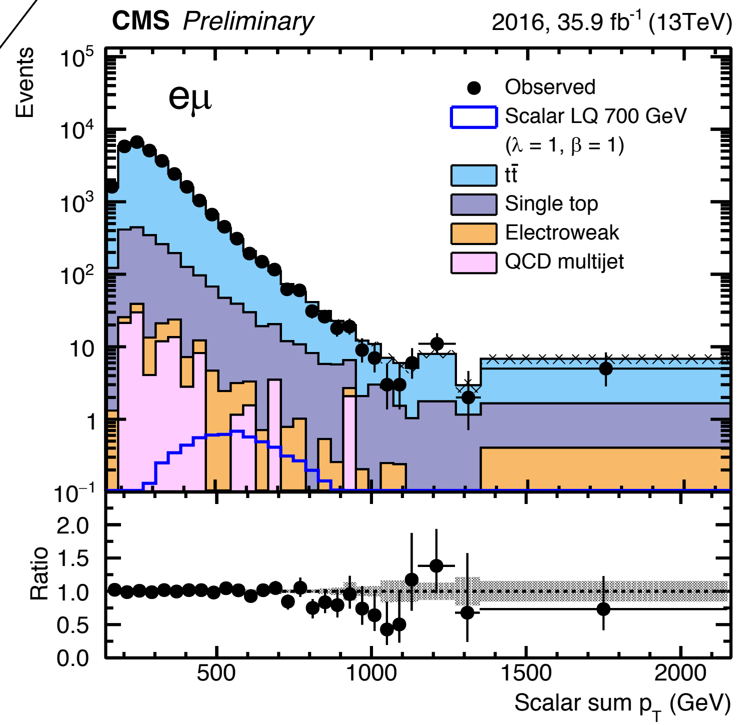


- Select $\tau\tau$ final states ($\boldsymbol{\tau_{had}\tau_{had}}$, $\tau_{lep}\tau_{had}$)
- Require ≥ 1 b-tagged jet to reduce QCD backgrounds
- Signal extraction using scalar p_T sum

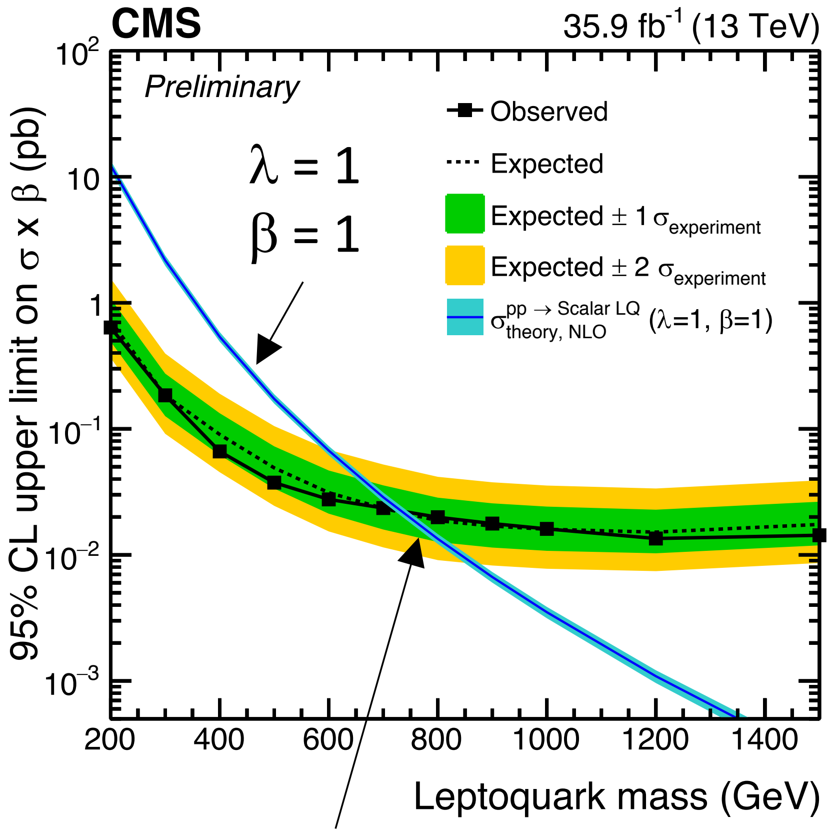


Scalar p_T sum ($2\tau_{had}$ + jet)

ttbar: related uncertainties are constrained using ttbar (→ $e\mu$) control region



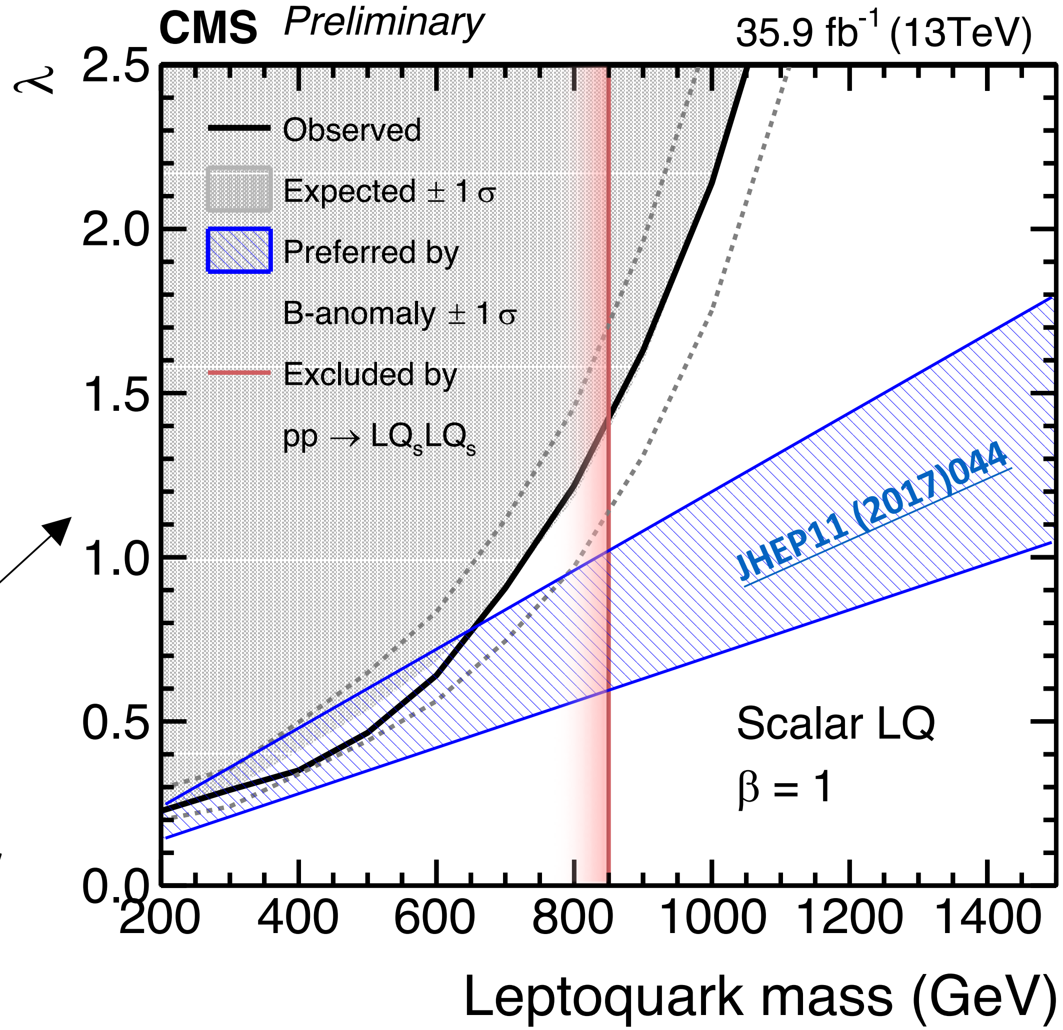
High ttbar purity (> 90%)



CMS-PAS-EXO-17-029 New

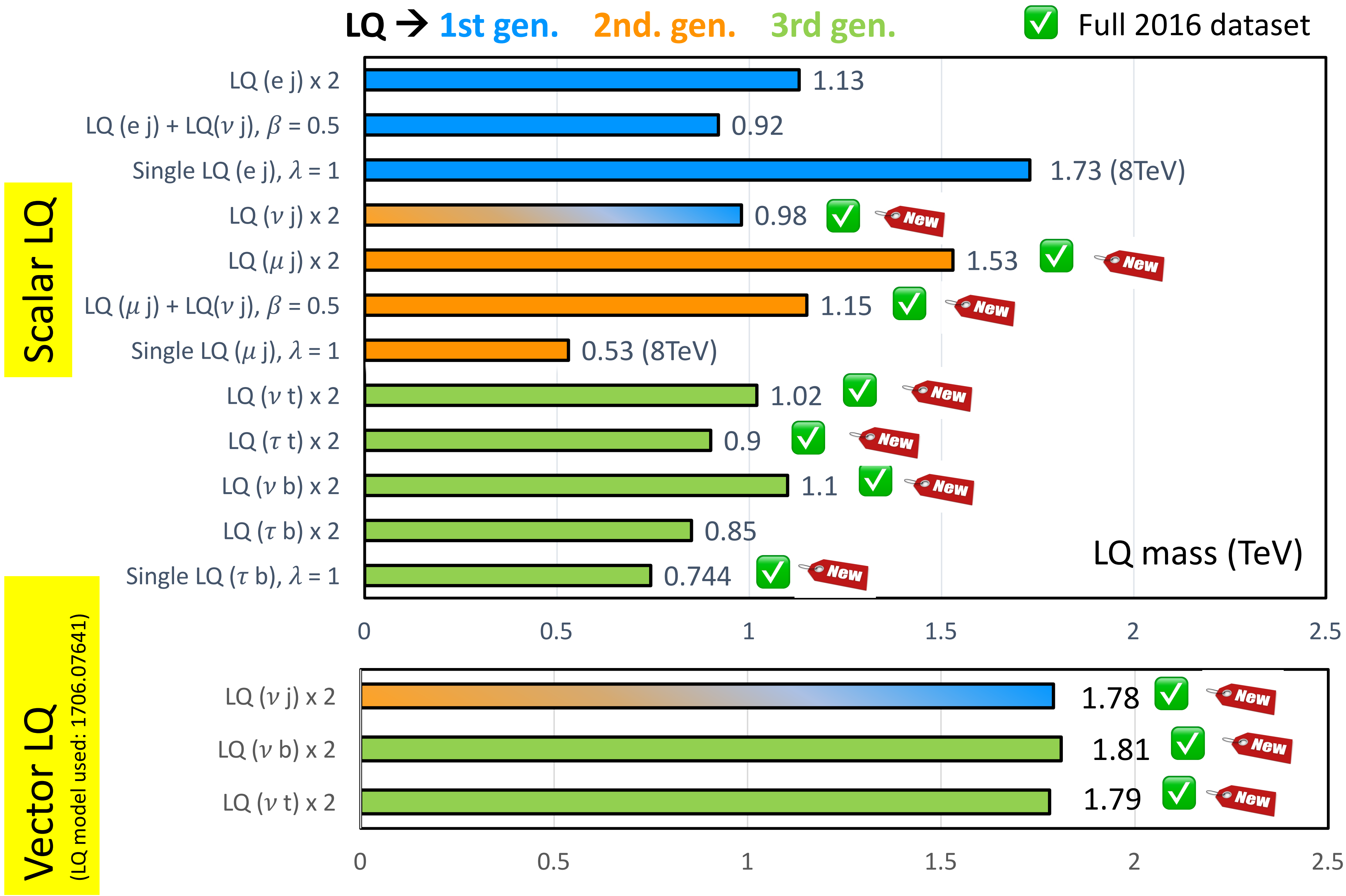
Cross-section depends on $\lambda \rightarrow$ can set limit on λ vs m_{LQ} plane

Lower limit on m_{LQ} = 744 GeV



Single LQ search has better limit at large λ
(λ up to 2.5 to keep narrow resonance and meet LEP constraint)

CMS LQ search summary



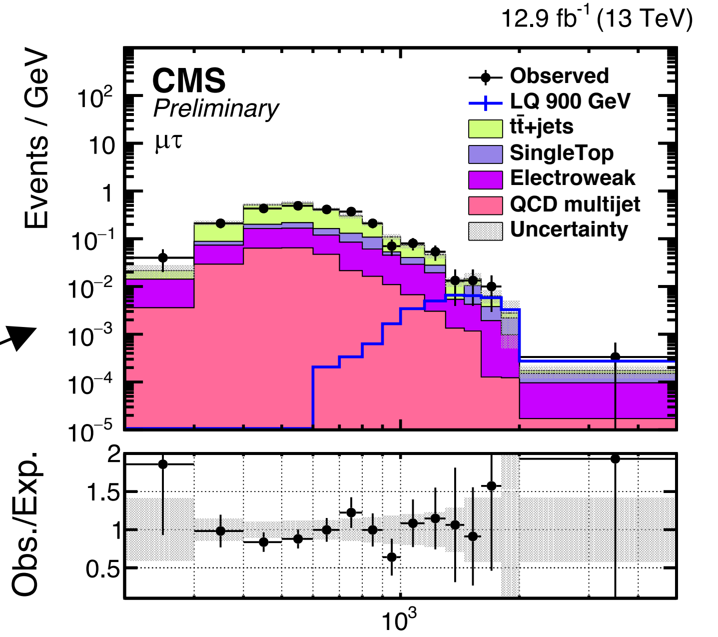
Conclusion

- CMS has searched for LQs (since long time ago) as one of the primary benchmark scenario with lepton + jets signature
- In light of B-anomalies, CMS performed extensive searches, especially in terms of 2nd/3rd generation.
  We newly reported at this conference:
  - Update on LQLQ → 2nd generation including muons (**CMS-PAS-EXO-17-003**)
  - Re-interpretation of SUSY searches in the context of scalar/vector LQ (**CMS-PAS-SUS-18-001**)
  - Update on LQLQ → 2τ + 2t (**arXiv:1803.02864**)
  - New search on single LQ → τb (**CMS-PAS-EXO-17-029**)
  - Overall, our limit approaching 1 TeV (most of the measurement statistically limited)
- We foresee more updates with full 2016 dataset & analyses using 2017 dataset are planned/on-going – stay tuned !

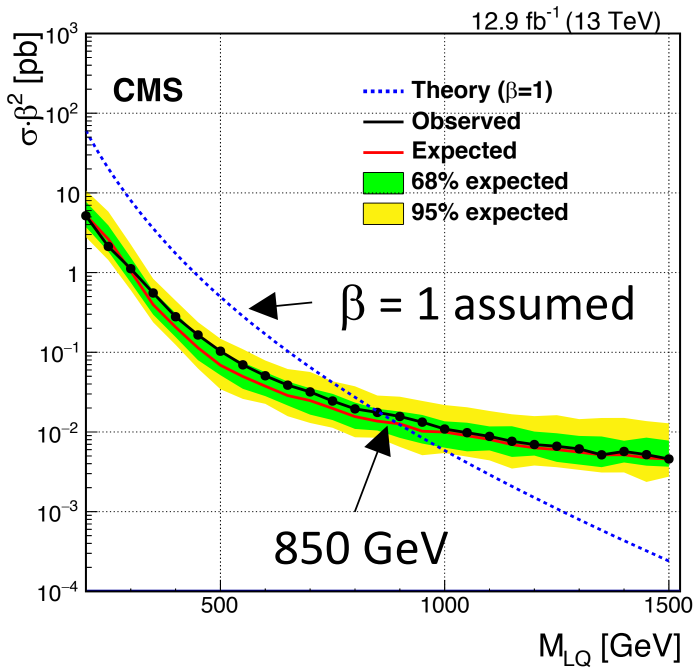
LQLQ → 2τ + 2b

$\tau_{lep}\tau_{had}$ (12.9/fb)

JHEP07(2017)121



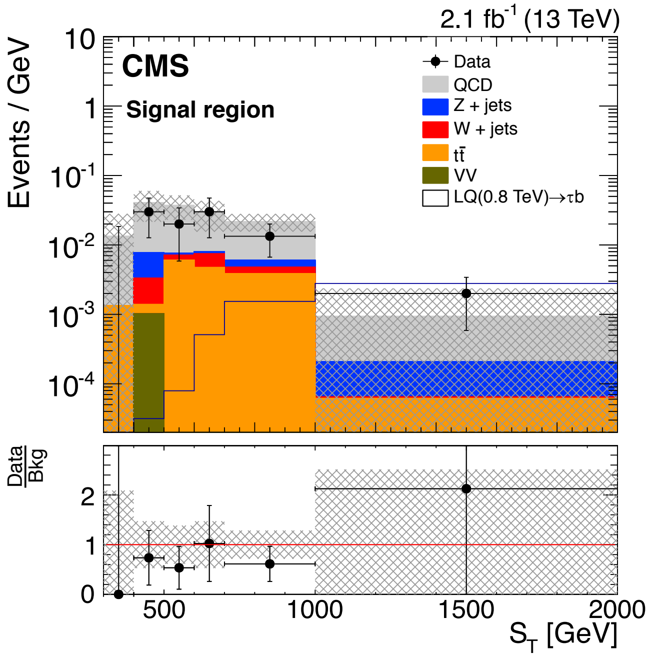
Scalar p_T sum (μ, τ, 2jets, E_T^{miss})



Bump hunting
at the tail of
scalar p_T distribution

$\tau_{had}\tau_{had}$ (2.1/fb)

JHEP03(2017)077



Scalar p_T sum ($2\tau_{had}$ + 2jets)