SMU

SEARCHES FOR LEPTOQUARKS WITHTHE ATLAS DETECTOR

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ATLAS EXPERIMENT

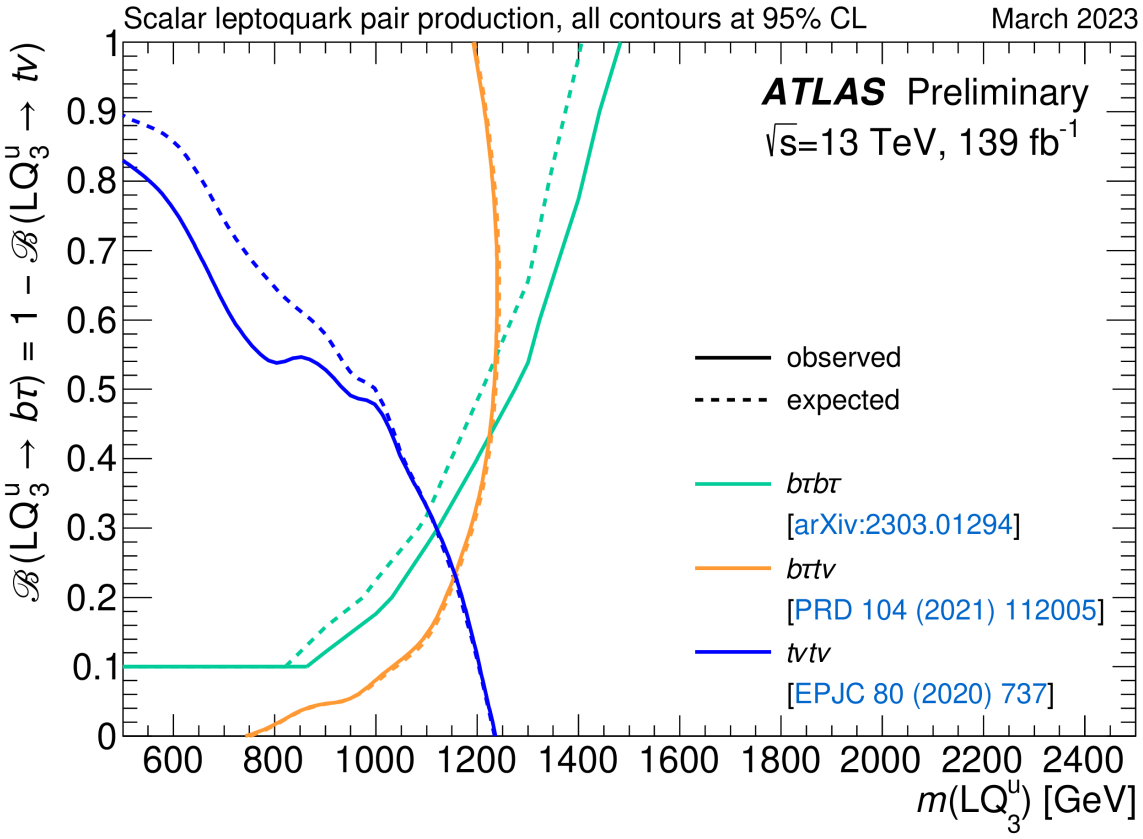
MOTIVATION

- **What is a leptoquark?**
  - Boson carrying color charge and fractional electric charge.
  - Predicted by many BSM theories (unified theories, composite models, technicolor…)
  - Provide a connection between quark and lepton sectors.
- **What would they look like in the ATLAS detector at the LHC?**
  - LQ are unstable and would decay immediately into a lepton and quark.

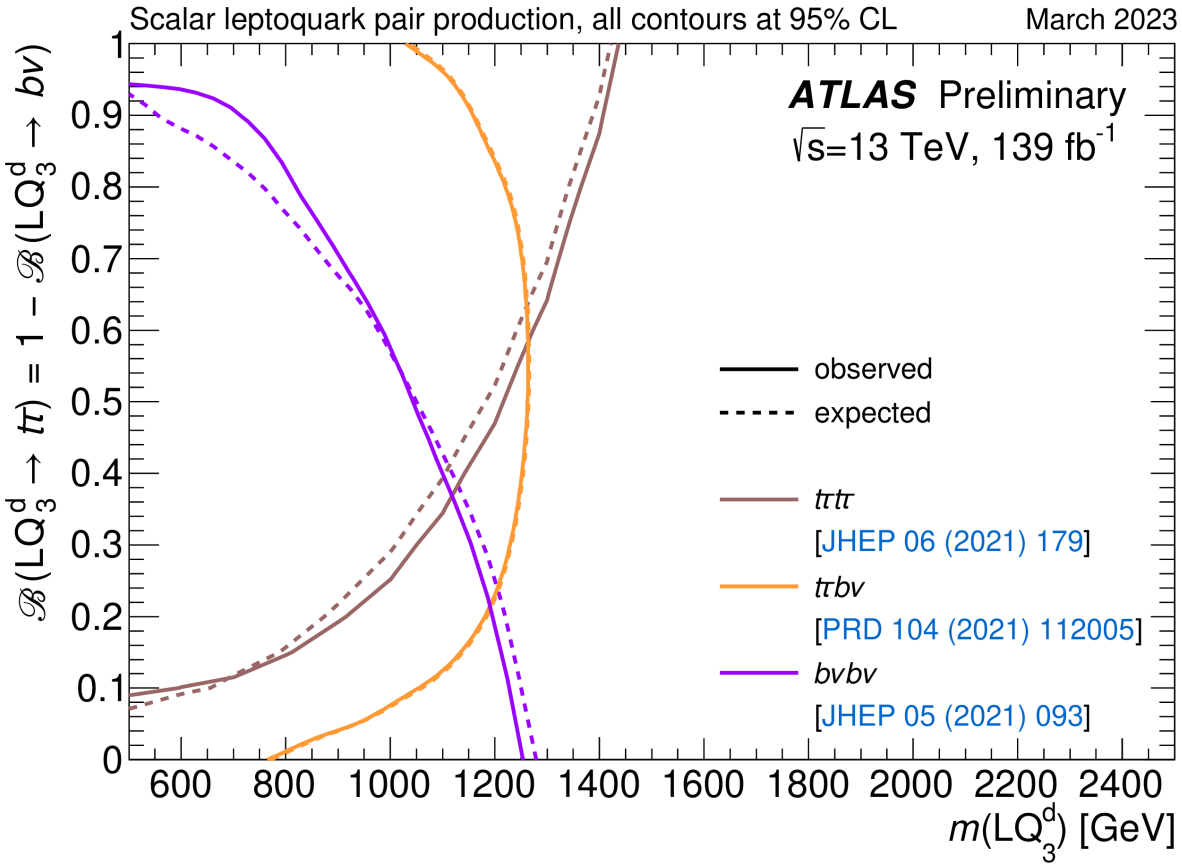
Many types of searches…

Up-type LQ (Q=5/3,2/3)	Down-type LQ (Q=-1/3/-4/3)
Scalar LQ	Vector LQ
Pair-produced	Singly-produced
1^{st} /2^{nd}/3^{rd} Generation	Mixed Generations

ATLAS SEARCH SUMMARY



Up-type pair-produced LQ (+2/3e)

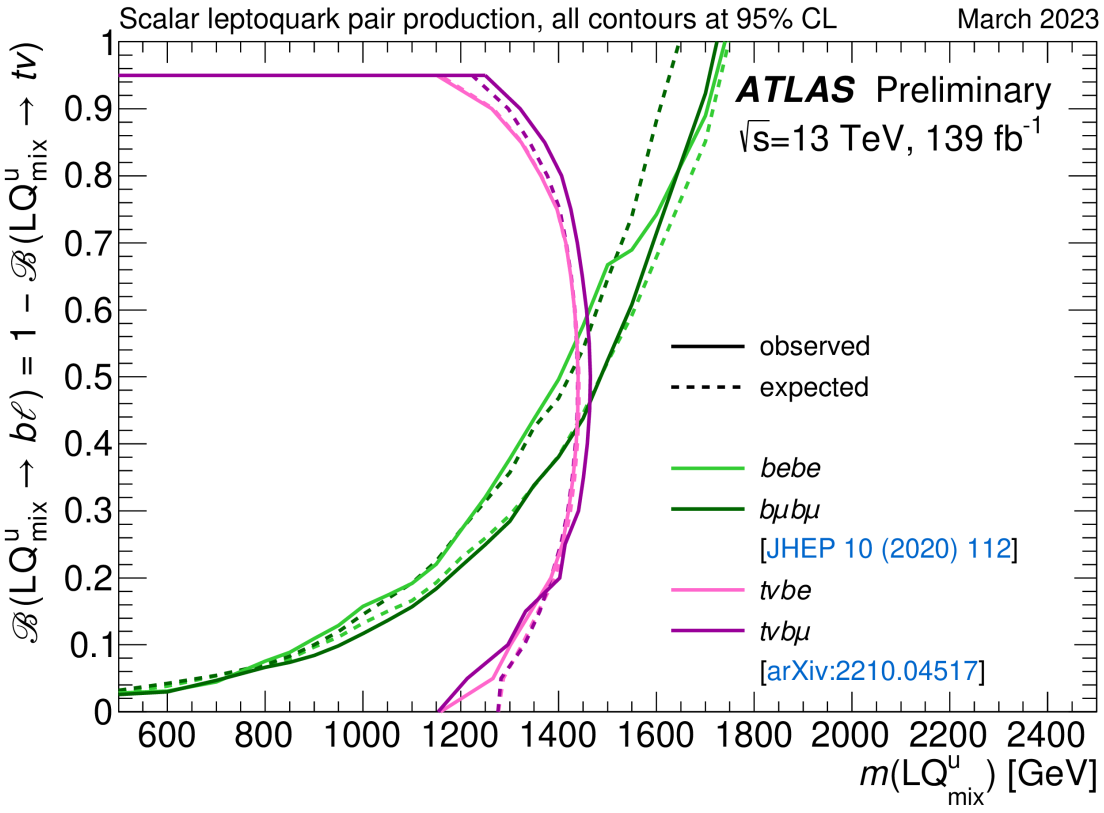


Down-type pair-produced LQ (-1/3e)

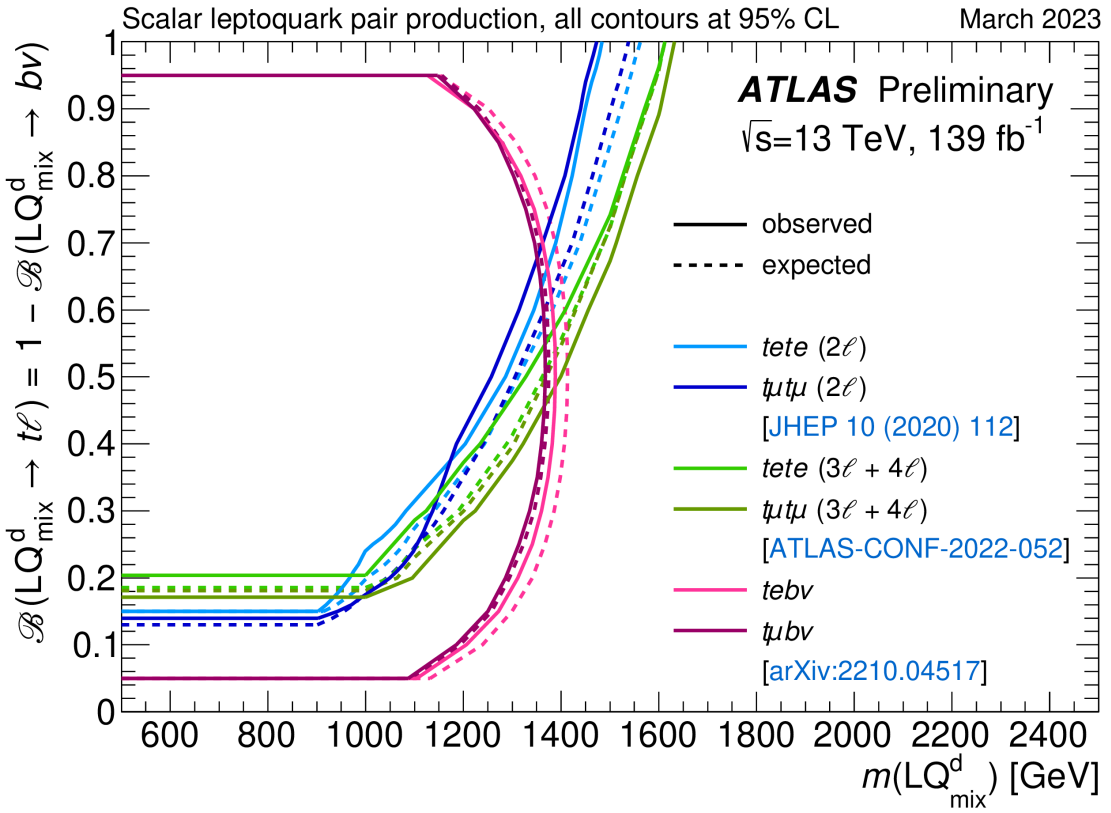
Plots show status of pair-produced, third-generation LQ search from Run-2 through March 2023.

Link

ATLAS SEARCH SUMMARY



Up-type pair-produced LQ (+2/3e)



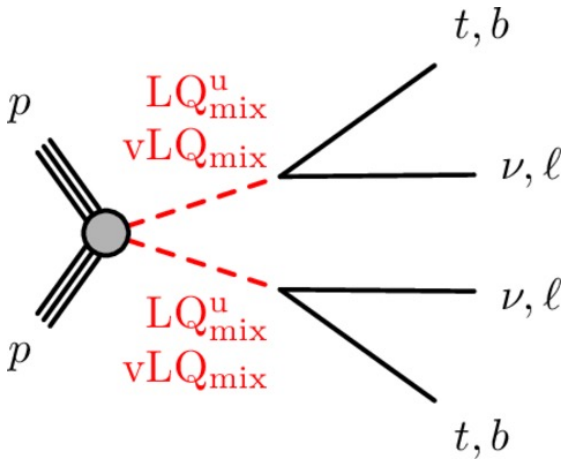
Down-type pair-produced LQ (-1/3e)

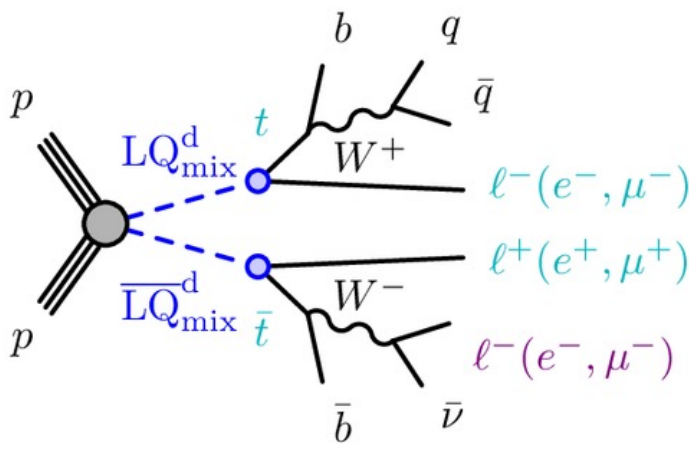
Plots show status of pair-produced mixed-generation LQ search from Run-2.

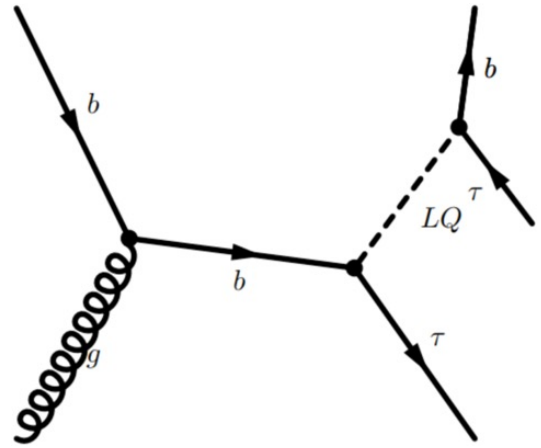
Link

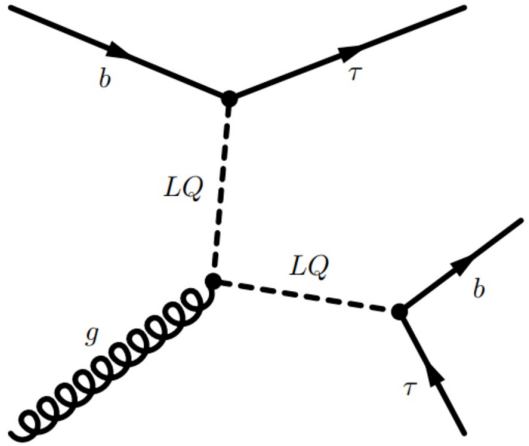
RECENT SEARCHES: TODAY'S TOPIC

- Mixed generation, pair-produced, both vector and scalar considered:
  - Multiple lepton final state: LQ decaying to top quark and light lepton (e,mu), scalar down-type (1/3e), vector up-type (5/3e)
  - One lepton final state: LQ decaying into (t,b) and (e,mu,nu), up-type (2/3e) or down-type (1/3e)
- 3rd generation, pair-produced, both vector and scalar considered:
  - Bottom quark + tau final state: LQ decaying into bottom quark and tau lepton, up-type (2/3e)
- 3rd generation, singly/pair-produced, both scalar and vector considered:
  - Bottom quark + tau final state: LQ decaying into bottom quark and tau lepton, down-type (4/3e)



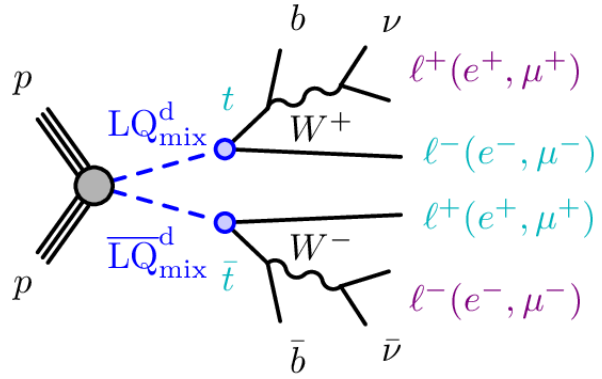


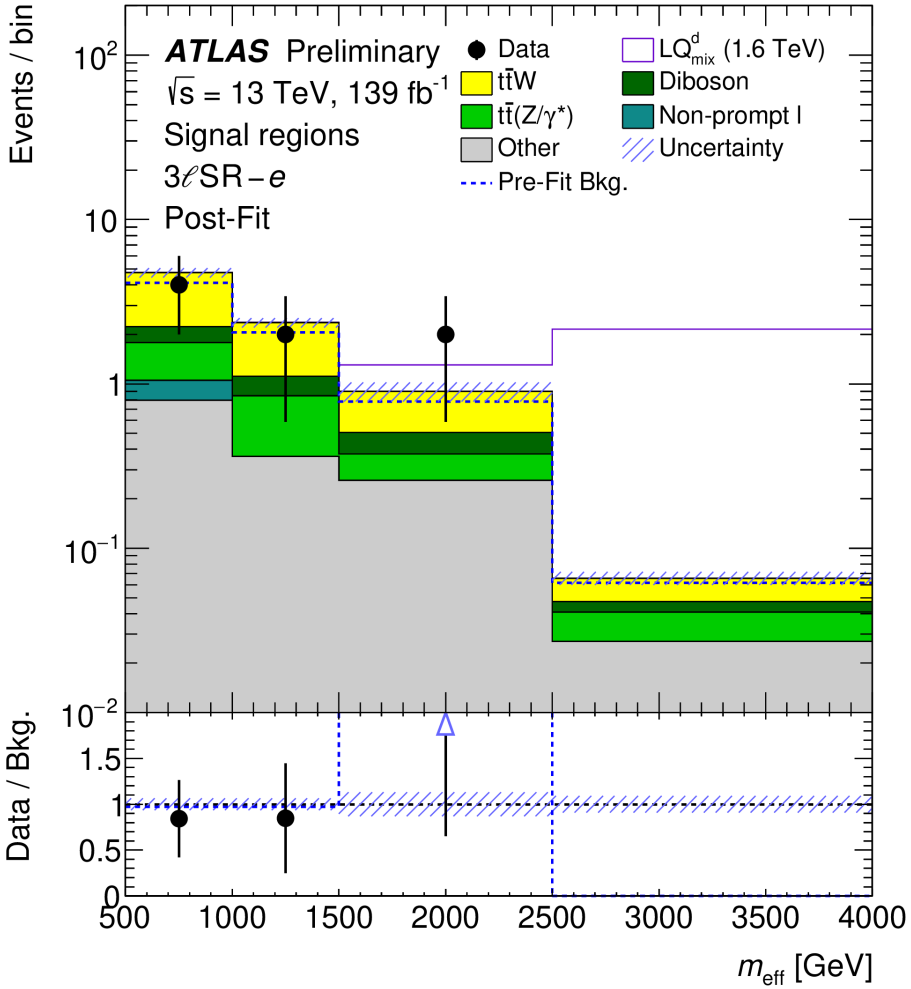




MIXED GENERATION: MULTI-LEPTON

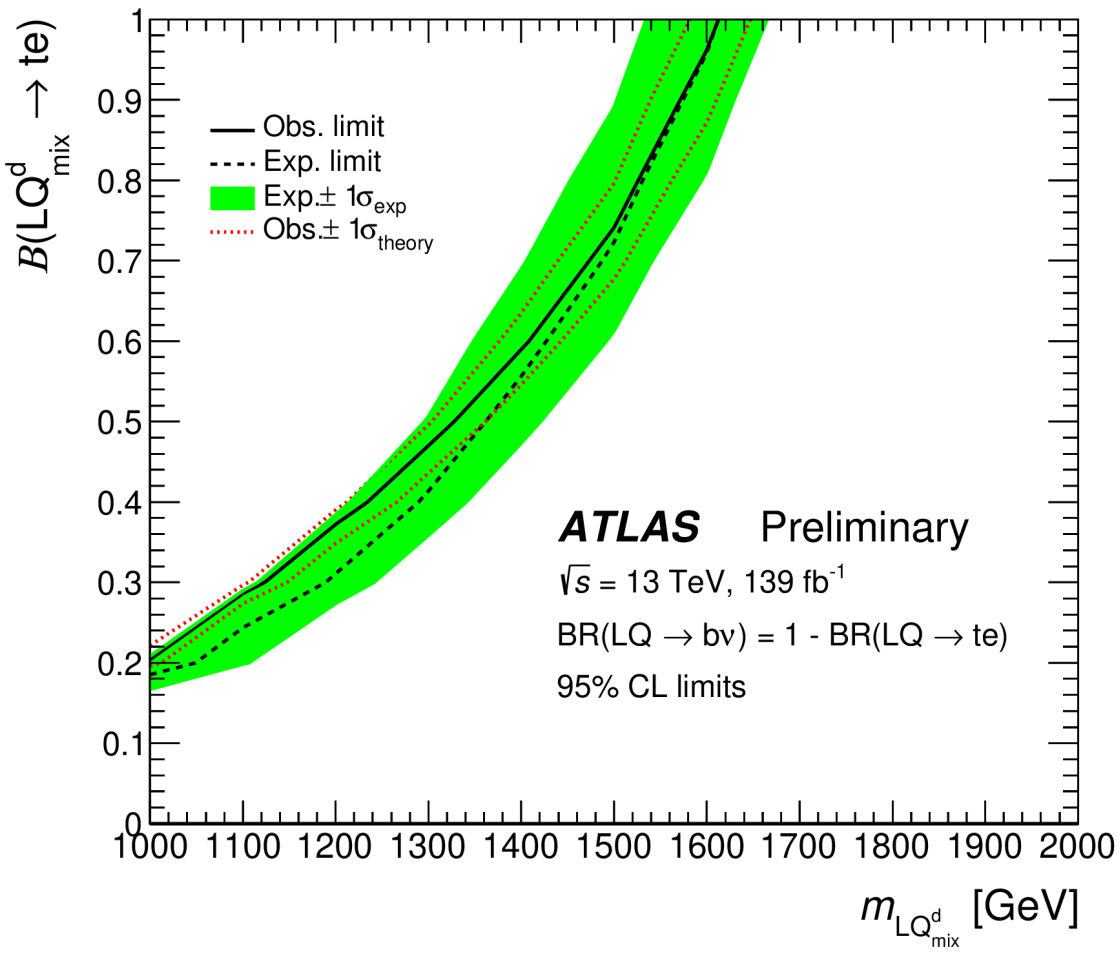
- **Event Selection**
  - Lepton triggers
  - ≥ 2 jets, ≥ 1 b-tagged
  - m_{eff} ≥ 500 GeV
  - Two signal categories with 3 or ≥ 4 leptons
  - m_{ll}^{min} ≥ 200 (100) GeV for 3 (4) leptons
  - Categories subdivided based on electron and muon multiplicity.
- **Backgrounds**
  - Normalization of ttV and VV+HF determined in the fit.
  - Non-prompt leptons: from simulation for 3-leptons with normalization in the fit, negligible for 4-leptons.
- **For signal regions, m_{eff} is used in the final fit**
  - **m_{eff}** is the Σp_T of all objects + E_T^{miss}

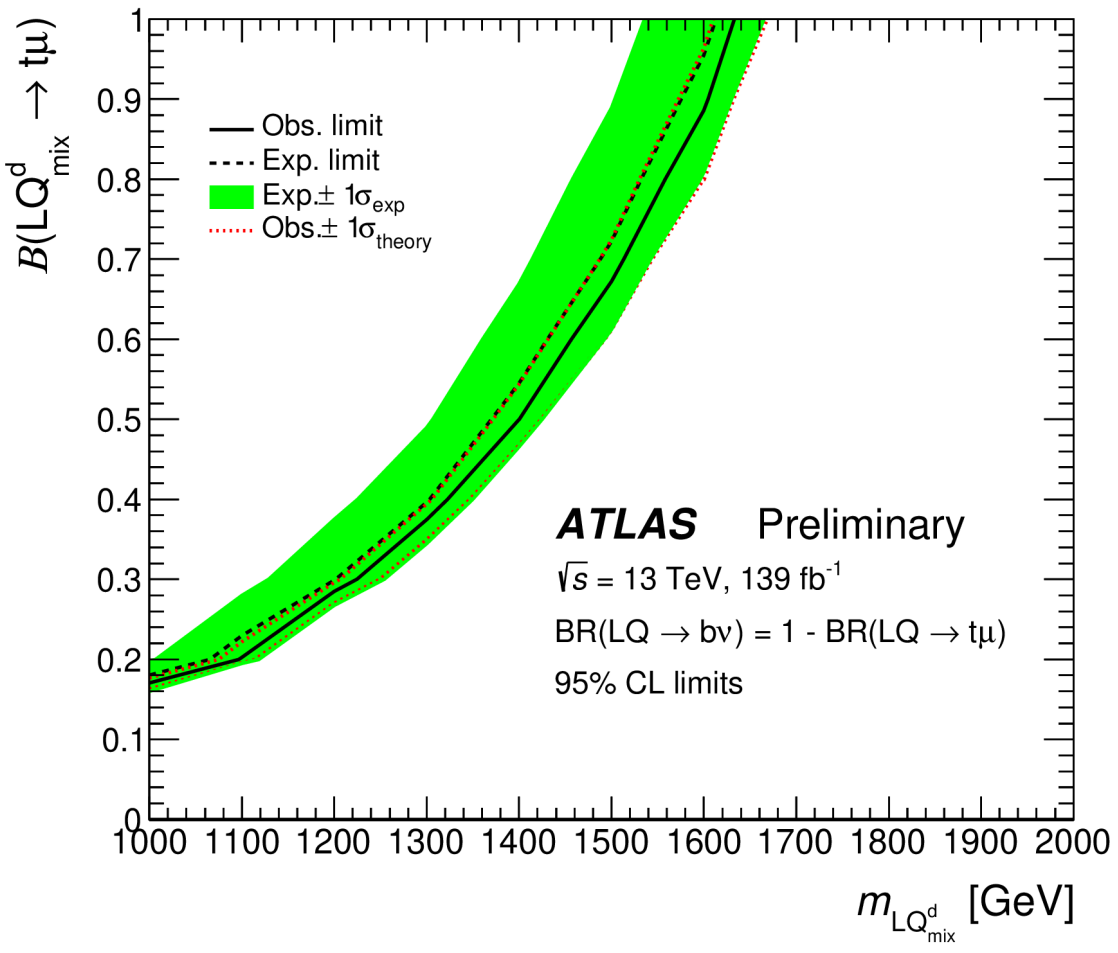




[Link]

MIXED GENERATION: MULTI-LEPTON RESULTS



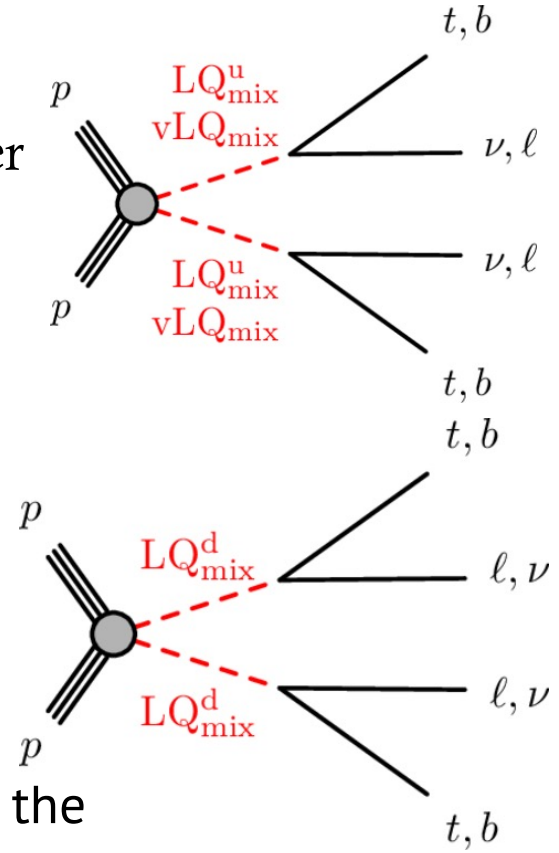


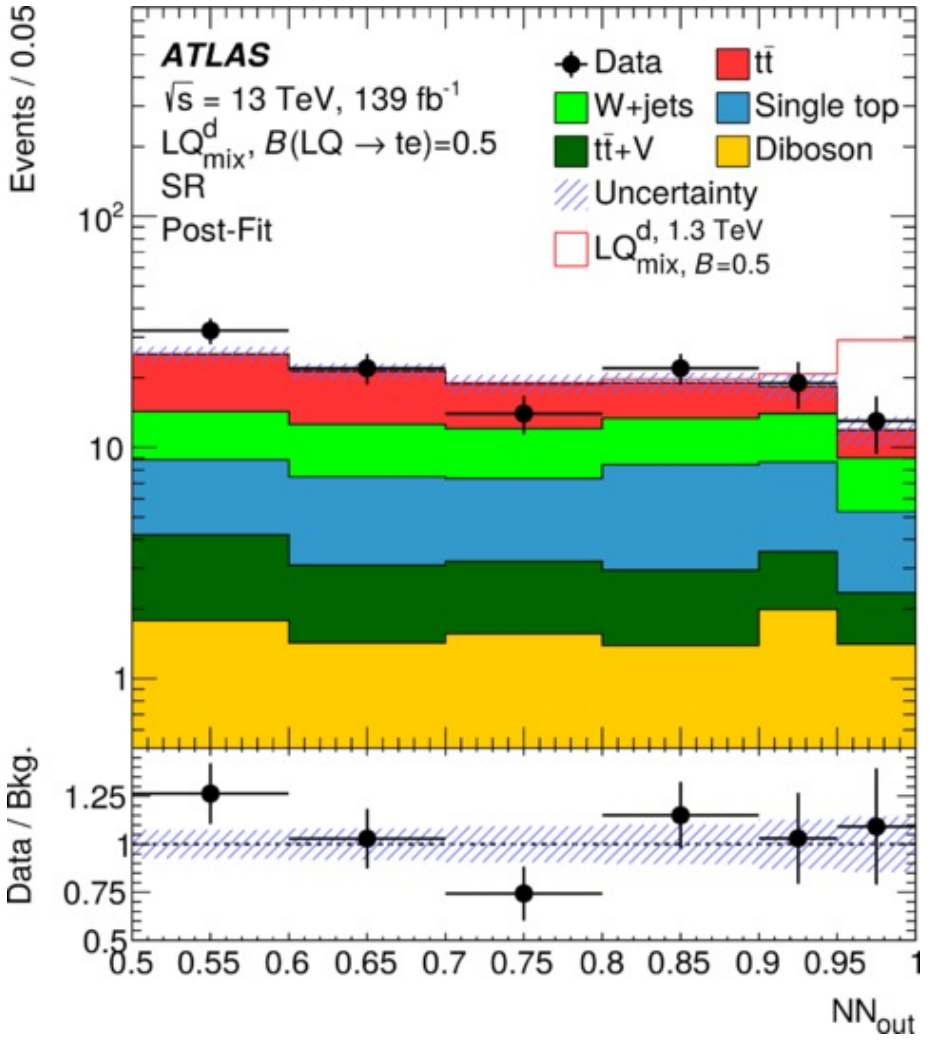
Assuming exclusive decays into te(tμ), the lower limit on the scalar m_{LQ} is 1.61 (1.64) TeV and on the vector $m_{\tilde{U}}$ at 1.71 (1.73) TeV in the minimal coupling scenario and at 2.0 (2.0) TeV in Yang-Mills scenario.

Link

MIXED GENERATION: SINGLE-LEPTON

- **Event Selection**
  - Missing transverse momentum trigger
  - $E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV
  - Exactly 1 electron or muon
  - ≥ 4 jets, 1 b-tagged
  - $m_{\mathrm{T}}(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) > 30$ GeV
  - $\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, j_{1,2}) > 0.4$
- **Backgrounds**
  - Normalizations are determined from the simultaneous likelihood fit to data in CR+SR for single top, ttbar and the W+jets
- **Final Discriminant is a Neural Network**





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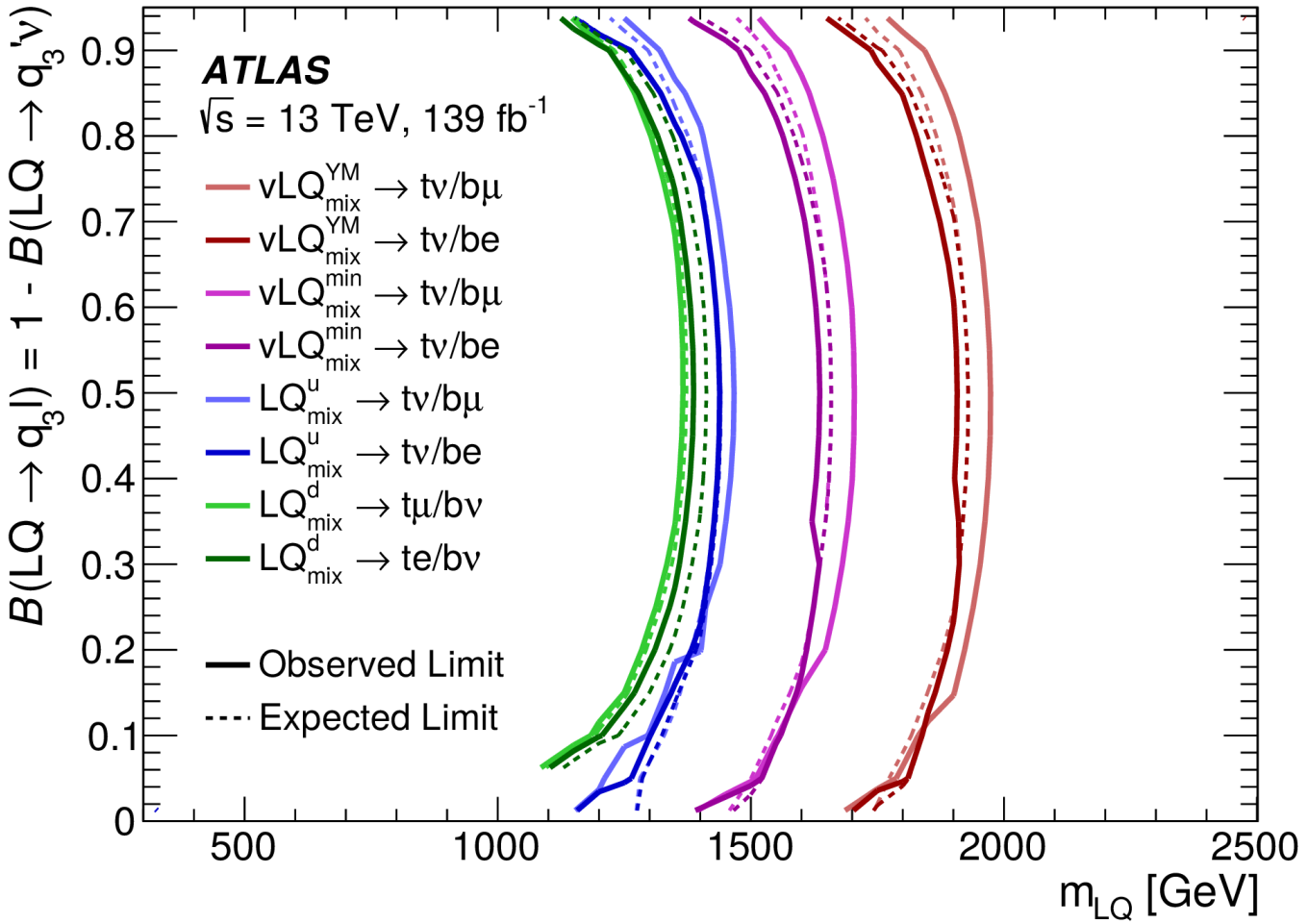
MIXED GENERATION: SINGLE-LEPTON RESULTS

- Limits are set on scalar LQ, Yang-Mills and minimal coupling vector LQ.
- Specific case to note for B-anomalies is the U_1 LQ.
  - Vector model that decays to a 3rd gen. quark and equally to a charged/neutral 2nd gen. lepton.
- Limits on U_1 are 1980 GeV and 1710 GeV for Yang-Mills and minimal coupling.



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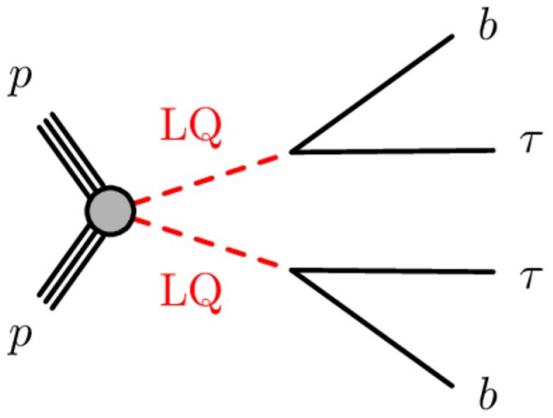
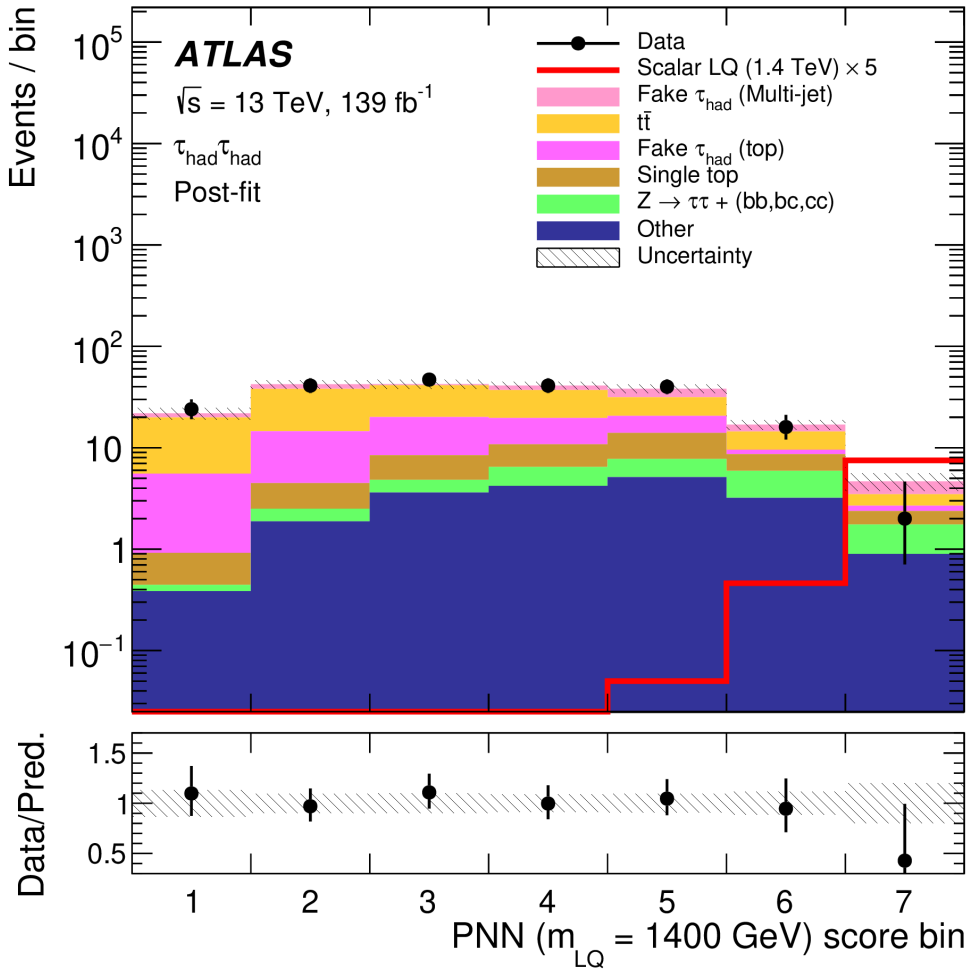
3RD GENERATION: BOTTOM-TAU

- **Event Selection**
  - Uses single e, mu and tau triggers
  - ≥ 2 jets, ≥ 1 b-tagged
  - Opposite charge leptons
  - $m_{\tau\tau}^{MMC}$ not in the range 40-150 GeV
  - $E_T^{miss} > 250$ GeV
  - S_T (leptons, E_T^{miss}, 2 leading jets) > 600 GeV
  - Two channels, $\tau_{lep}\tau_{had}$ and $\tau_{had}\tau_{had}$



- **Backgrounds**
  - Top backgrounds reweighted, top backgrounds with misidentified τ_{had} have an additional data-derived SF.
  - Multijet events derived by FF method in $\tau_{had}\tau_{had}$, negligible in $\tau_{lep}\tau_{had}$
  - Z+HF and tt normalization floated in final fit.
- **Final Discriminant is a Parameterized Neural Network**



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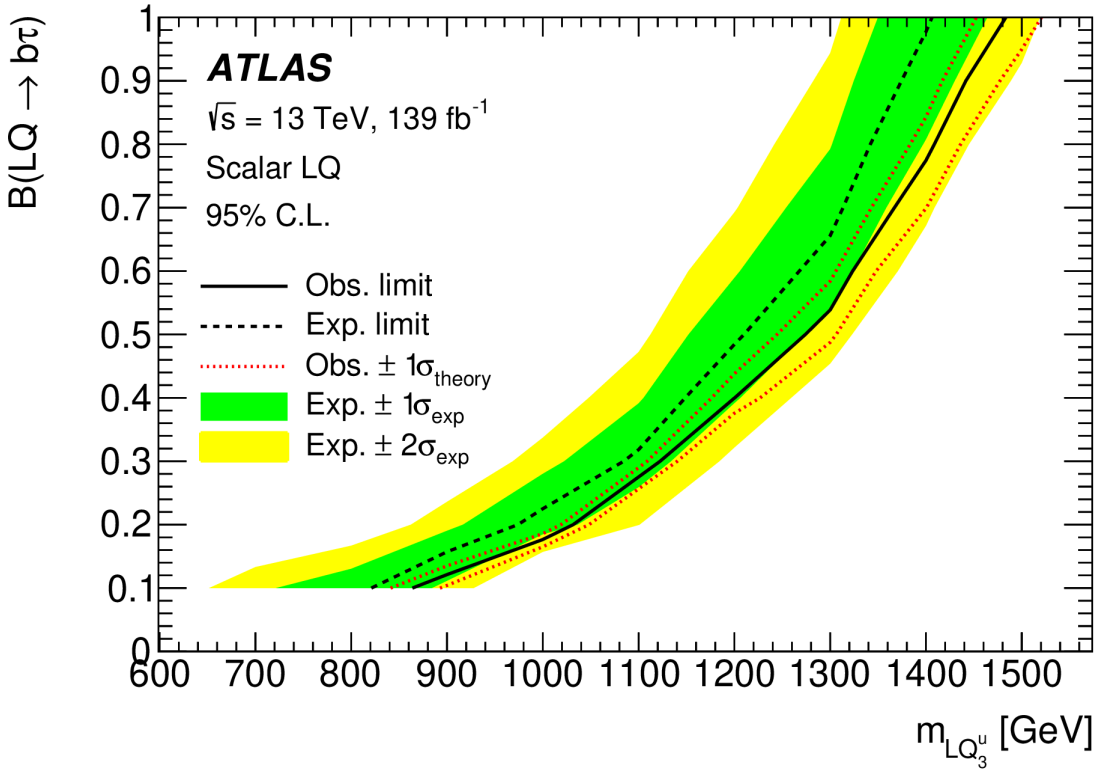
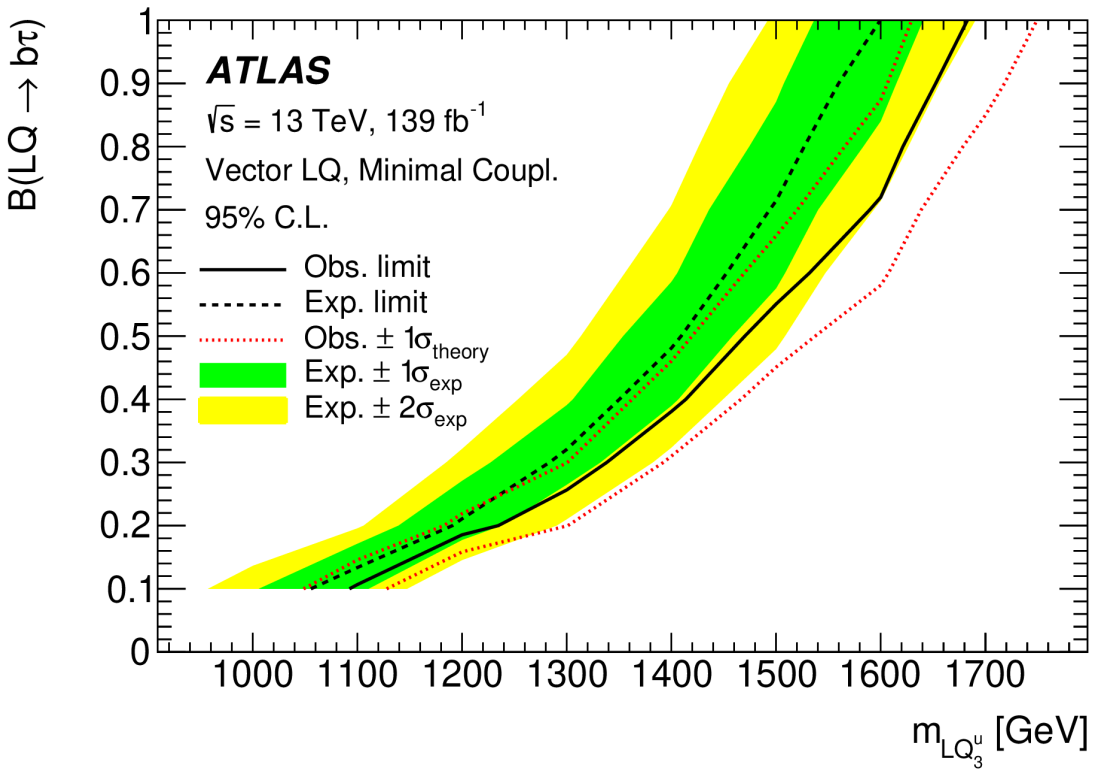
3RD GENERATION: BOTTOM-TAU RESULTS

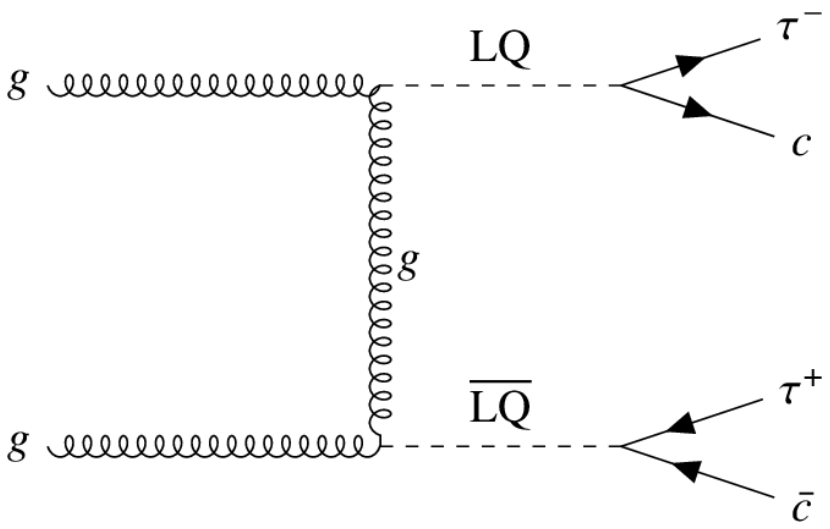


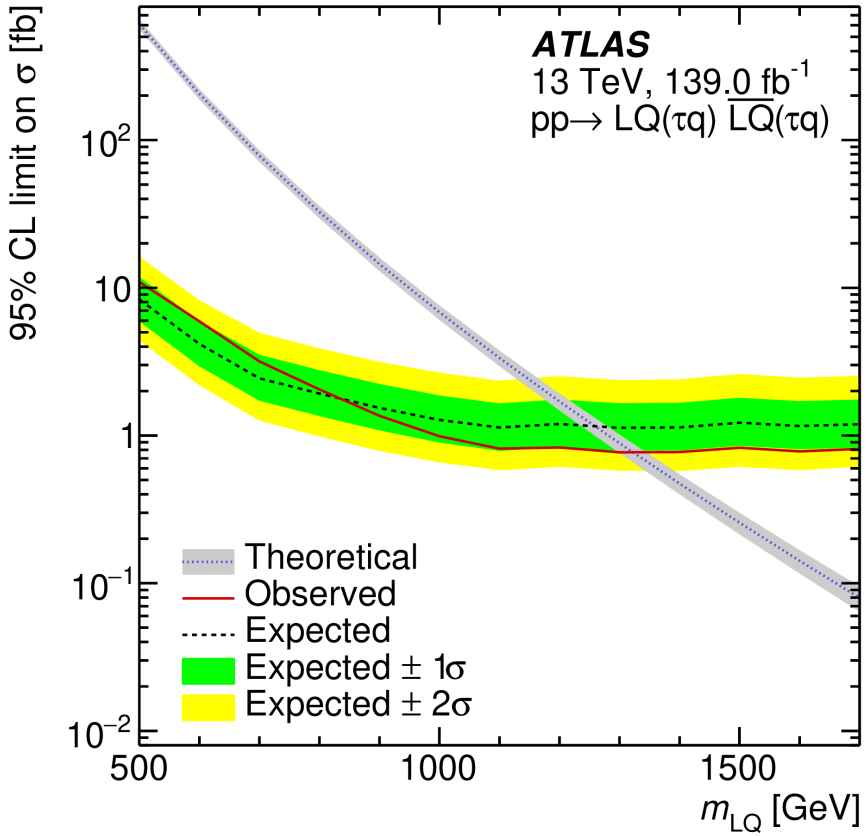


	Obs. limit [GeV]	Exp. limit [GeV]
Scalar LQ	1490	1410
Vector LQ (minimal-coupling)	1690	1600
Vector LQ (Yang–Mills)	1960	1840

Link

LQ INTERPRETATION OF $\tau\tau$+JETS FINAL STATE



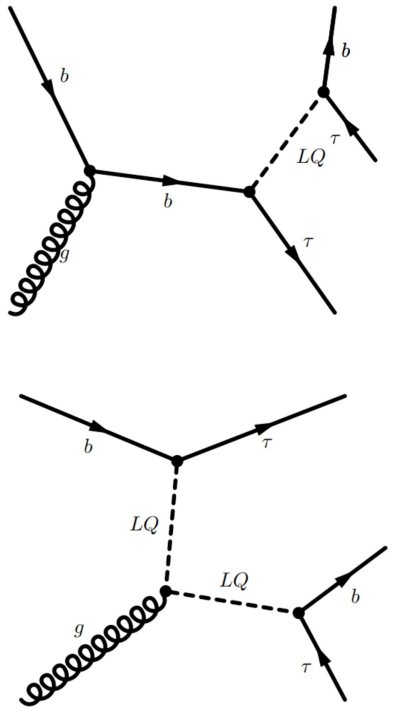


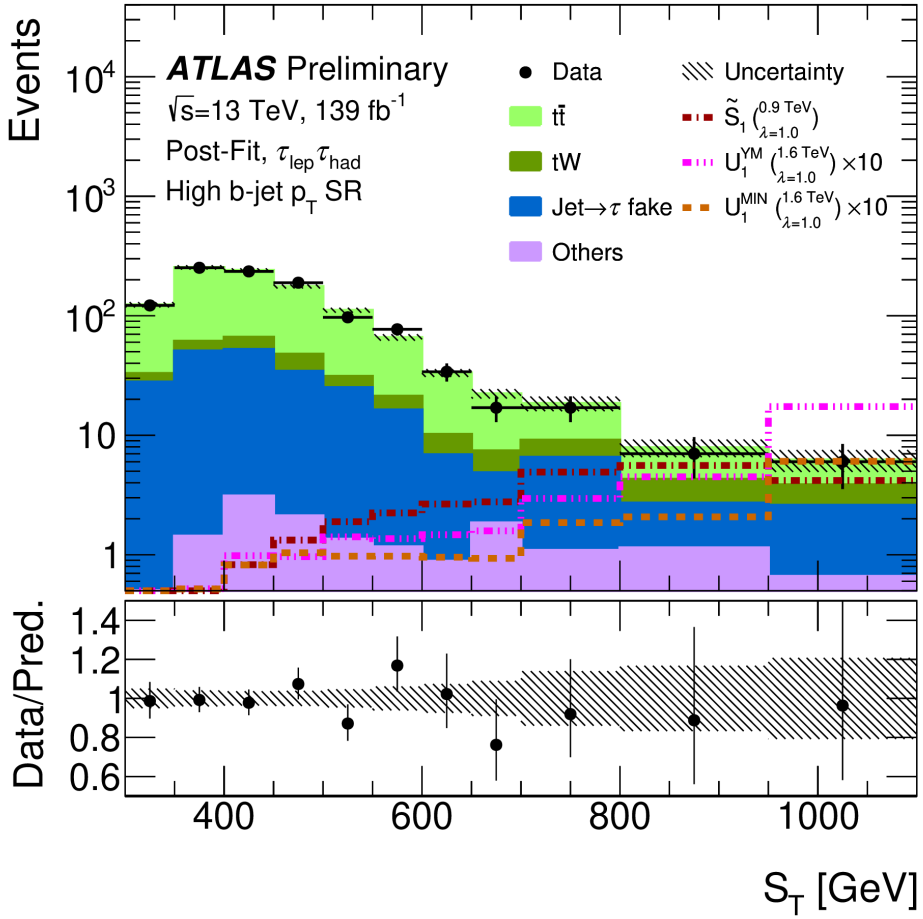
A recent public result has also shown an exclusion for the case of LQs decaying to a tau lepton and lighter quark.

Link

3RD GENERATION SINGLE/PAIR LQ: BOTTOM-TAU

- **Event Selection**
  - Uses single e, mu and tau triggers
  - ≥ 1 1 jet, ≥ 1 b-tagged jet
  - High and low p_T regimes
    - High b-jet pT: ⩾1 b-jets (pT>200 GeV)
    - Low b-jet pT: ⩾1 b-jets (25<pT<200 GeV)
  - Opposite charge leptons
  - $m_{vis,\tau\tau}$ > 100 GeV, S_T > 300 GeV
  - Two channels, $\tau_{lep}\tau_{had}$ and $\tau_{had}\tau_{had}$
  - For $\tau_{lep}\tau_{had}$, $\Delta\phi(E_T^{miss}, \text{lep}) < 1.5$

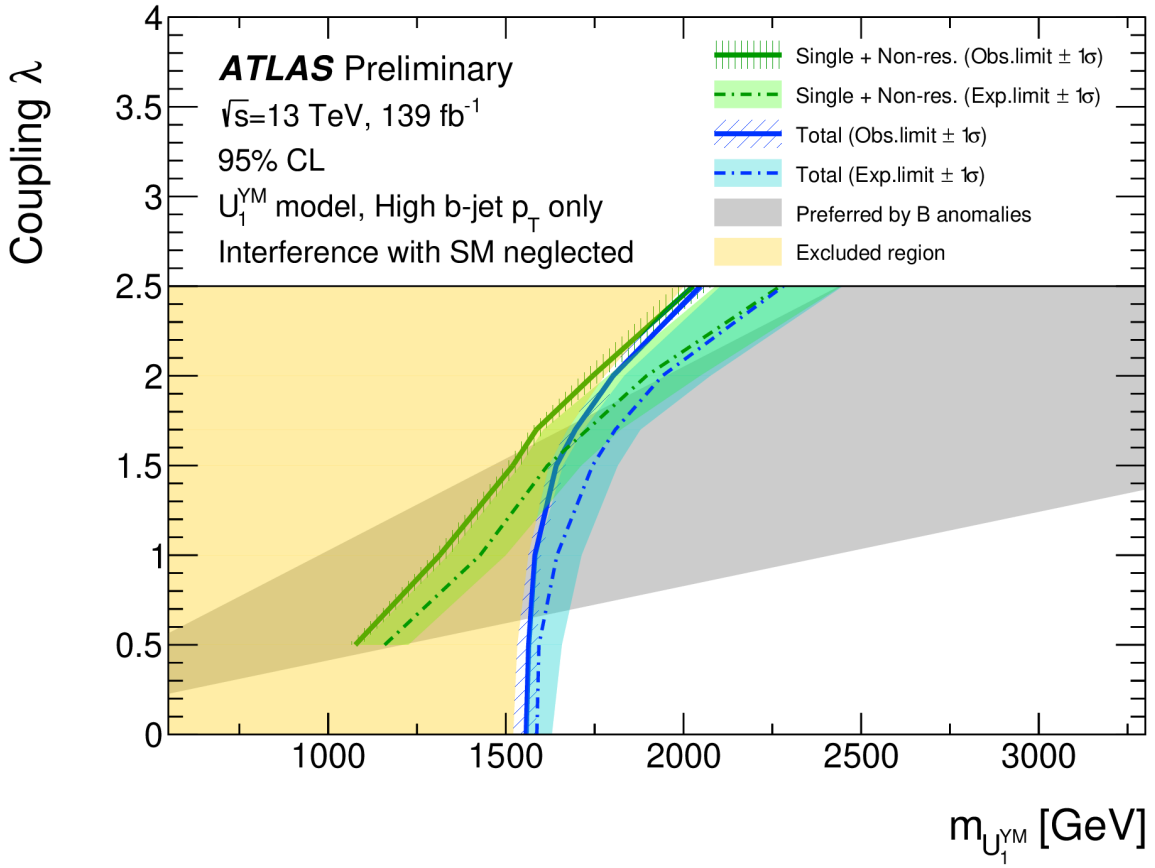


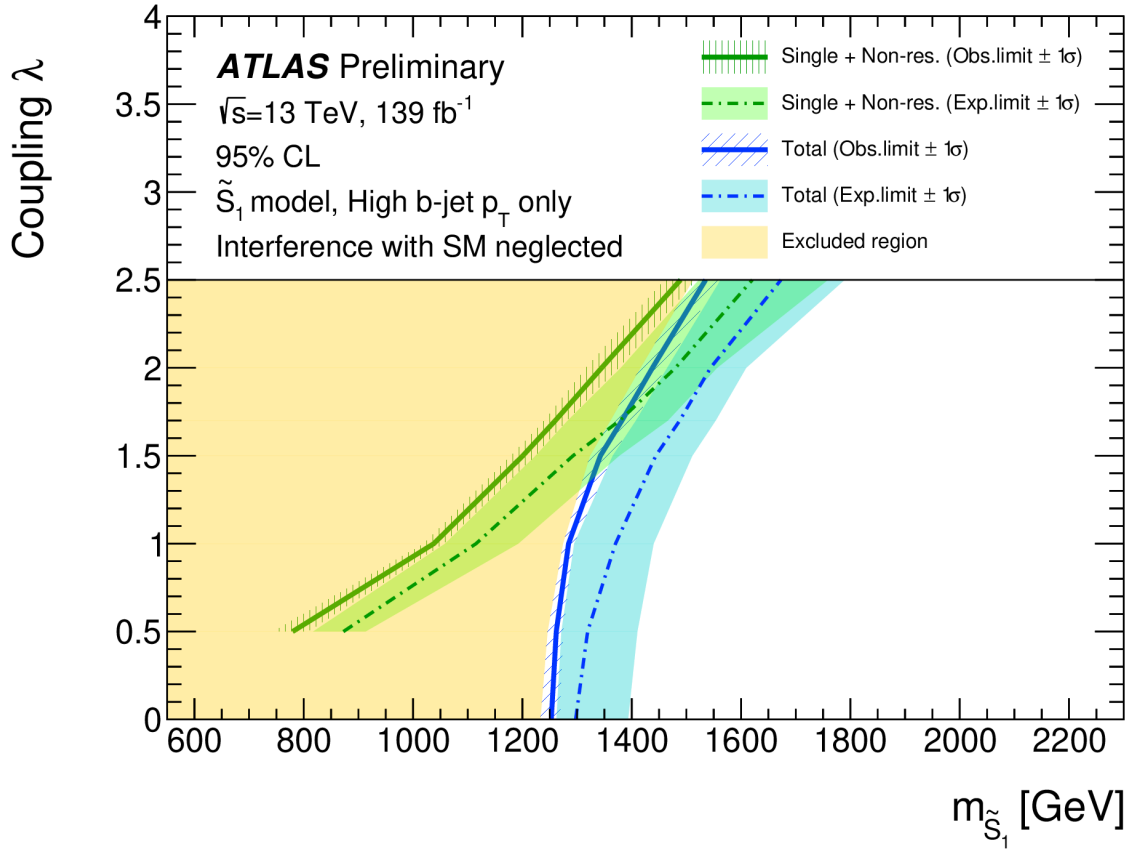


- **Backgrounds**
  - Top backgrounds reweighted, for $\tau_{lep}\tau_{had}$ top backgrounds with misidentified τ_{had} have an additional data-derived SF.
  - Multijet events derived by FF method
  - Z+HF corrected by a data-driven SF in $\tau_{had}\tau_{had}$
- **Final Discriminant is S_T (scalar sum of 2 tau and leading b-jet)**

Link

3RD GENERATION SINGLE/PAIR LQ: BOTTOM-TAU





For B(LQ→$b\tau$) = *100%*, limits as a function of the mass and scalar leptoquark coupling.

Link

SUMMARY

- The search for leptoquarks is an active area in ATLAS, casting a wide net to cover many possible models.

- No sign of leptoquarks has been found as of yet, but they are still interesting at high mass as a potential explanation for *B*-anomalies.

- As data is collected by the ATLAS detector during Run-3, more data will lengthen the reach of leptoquark searches.