Searching for leptoquarks with the ATLAS detector

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on behalf of the ATLAS Collaboration

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Conference on Flavor Physics and CP Violation
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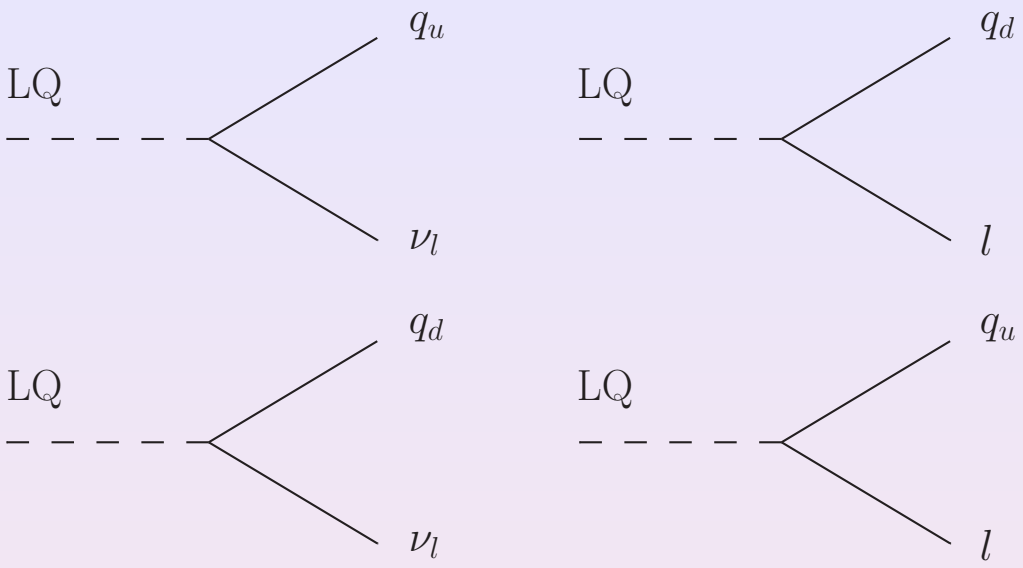
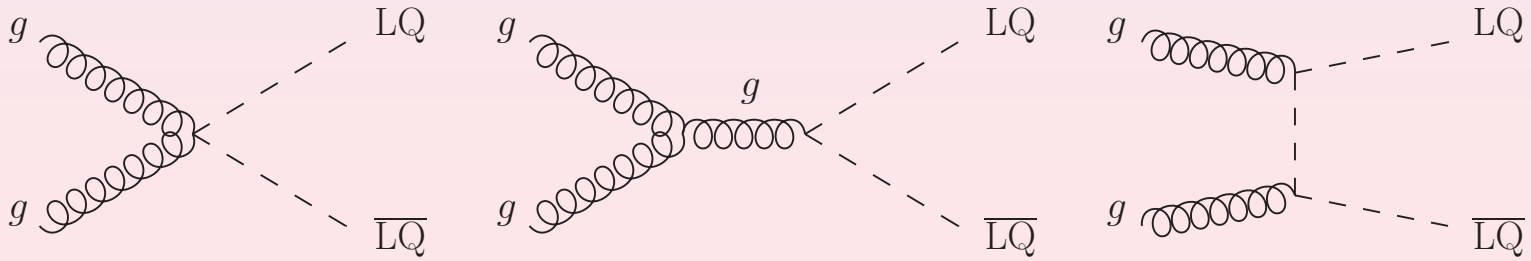
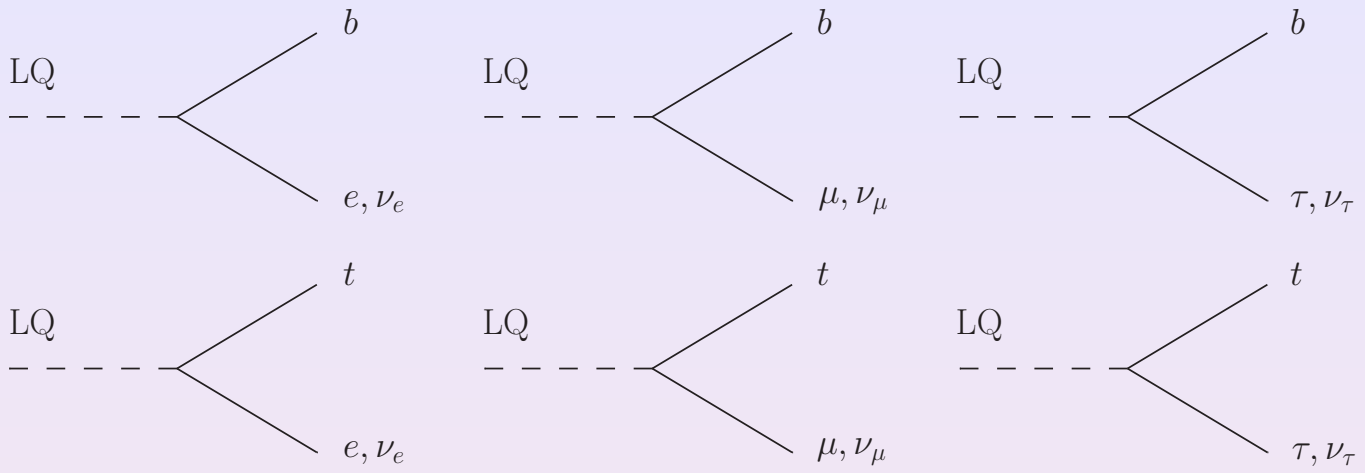
What are leptoquarks?



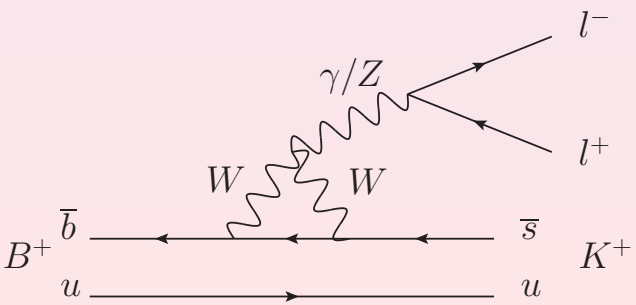
- Hypothetical particles coupling simultaneously to quarks and leptons, which could explain symmetry between quark and lepton sectors of the SM
- Pair production via strong force at the LHC
  - Single production also possible, not the focus here

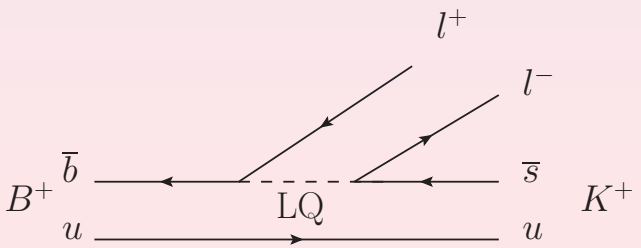


What are leptoquarks?



- Couplings within same generation or across generations
  - Cross-generation couplings could explain observed *B*-decay anomalies
- Focus of this talk:
  - Decays to the third generation
  - Mixing between third and first/second generations

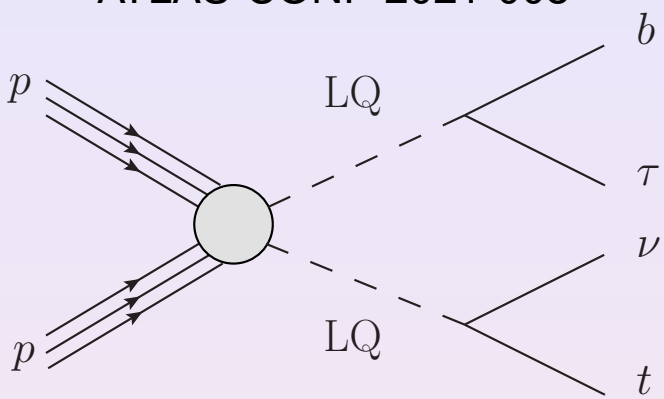




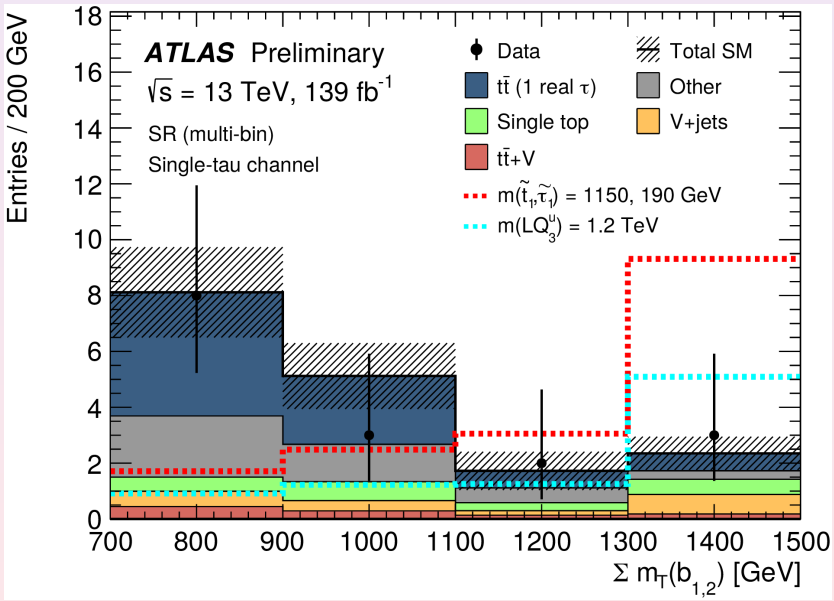
Tau lepton, b-jets, and $\not{E}_{\mathrm{T}}$

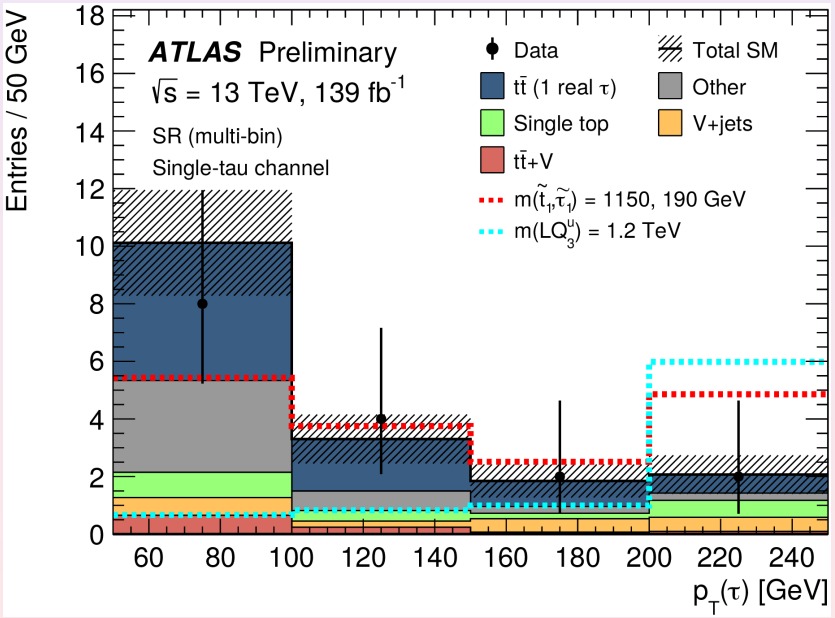
τ + b-jets + $\not{E}_{\mathrm{T}}$

ATLAS-CONF-2021-008



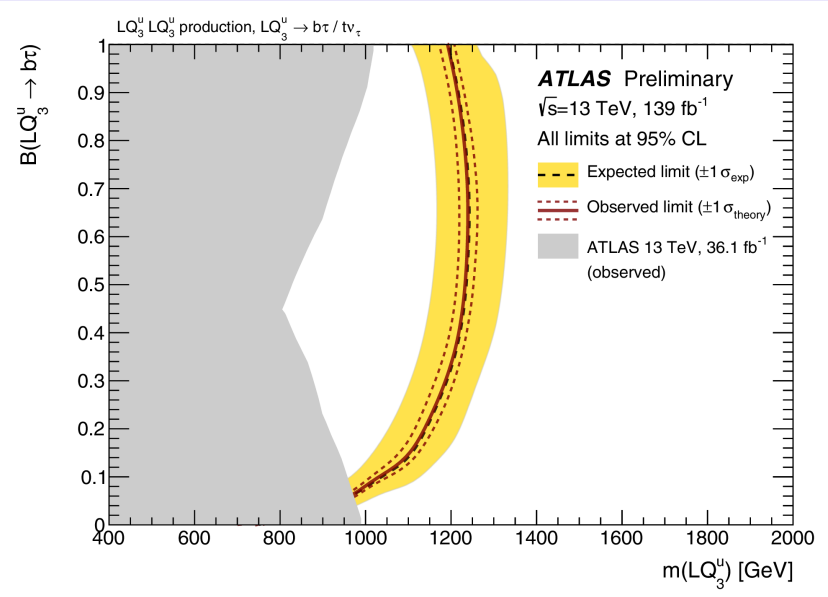
- $\not{E}_{\mathrm{T}}$ trigger, offline $\not{E}_{\mathrm{T}} > 280\,\mathrm{GeV}$
- Exactly 1 τ_{had} + $\geq$ 2 b-jets
- Hard requirements on p_{T} and m_{T} of jets and τ

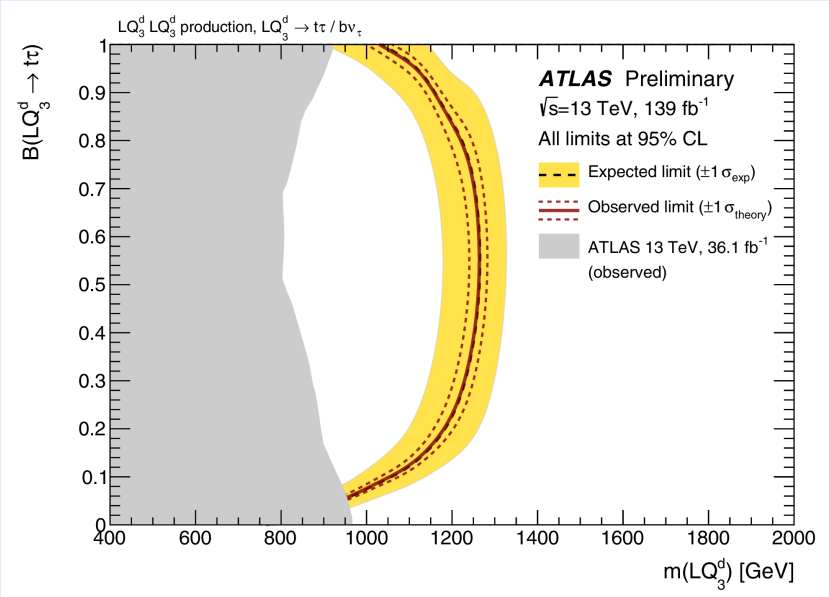




- Simultaneous fit to dedicated control regions and signal region binned in $p_{\mathrm{T}}(\tau)$

Tau lepton, b-jets, and $\not{E}_{\mathrm{T}}$



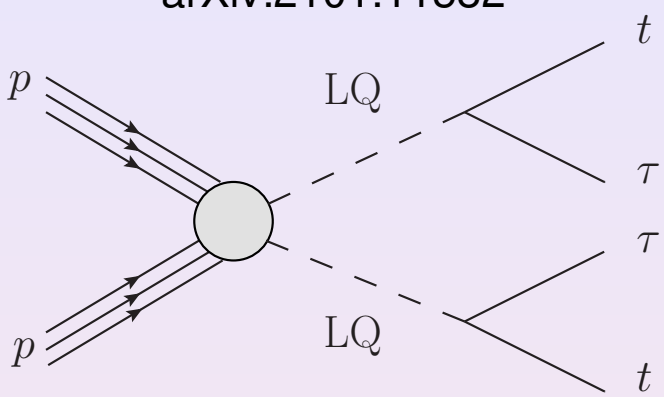


- Limits set on the leptoquark mass as function of $\mathrm{BR}(\mathrm{LQ} \to q\tau)$
- Sensitivity extends to $m_{\mathrm{LQ}} \approx 1.25\,\mathrm{TeV}$ for 50% branching fraction
- Cases of $\mathrm{BR}(\mathrm{LQ} \to q\tau) = 100\%$ and $\mathrm{BR}(\mathrm{LQ} \to q\tau) = 0\%$ covered by other analyses

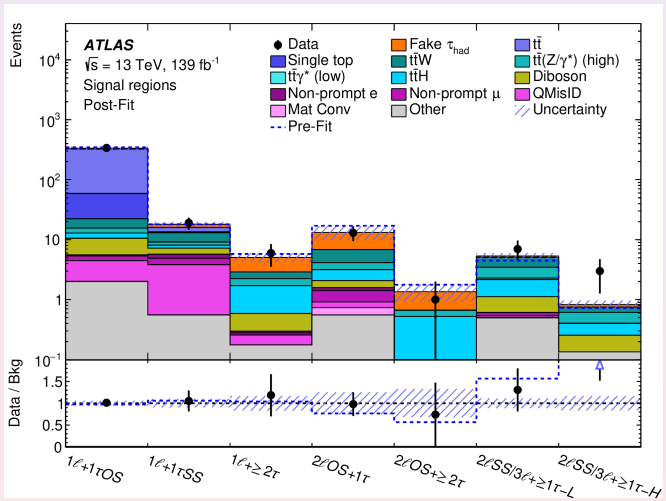
Tau lepton, light leptons, and jets

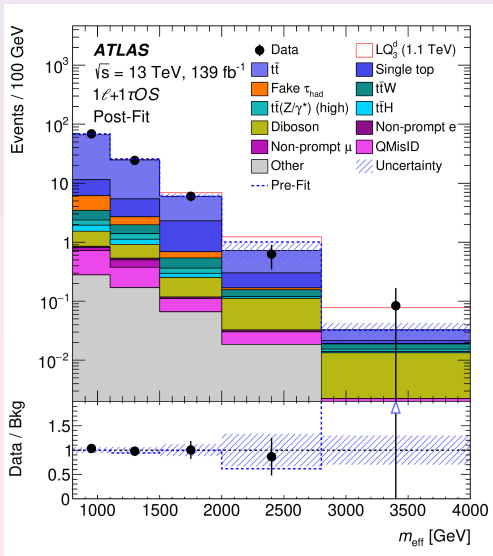
τ + $l(l)$ + jets

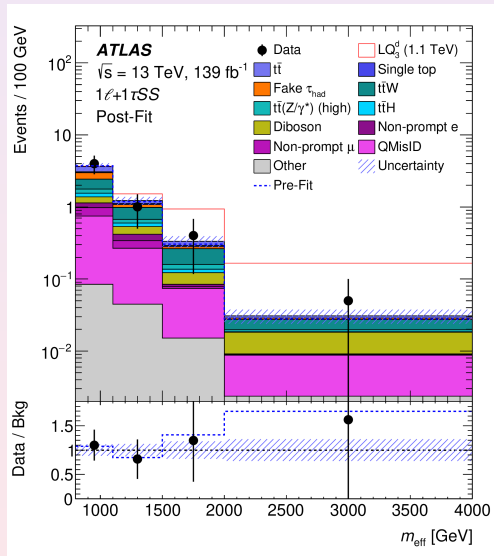
arXiv:2101.11582



- Lepton triggers
- Signal regions, binned in m_{eff}, with at least one τ_{had} +
  - 1*l*
  - 2*l* opposite charge
  - 2*l* same charge or 3*l*

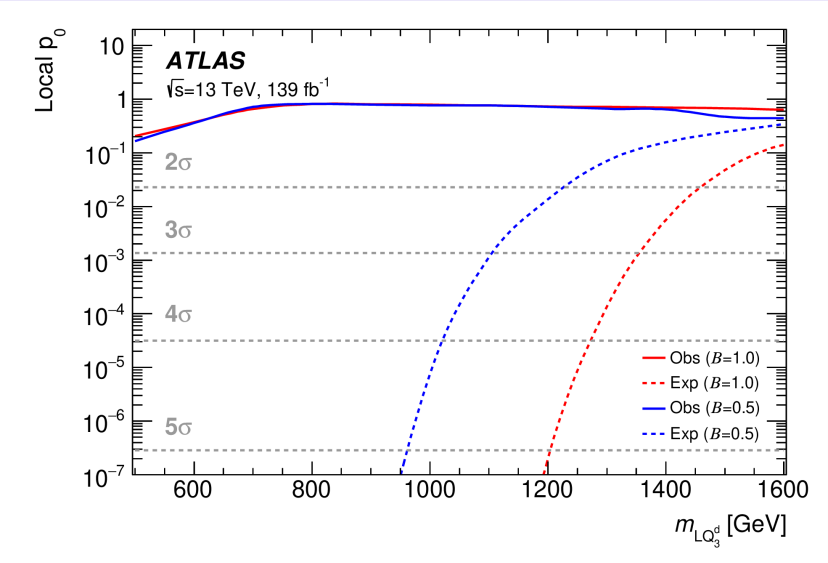


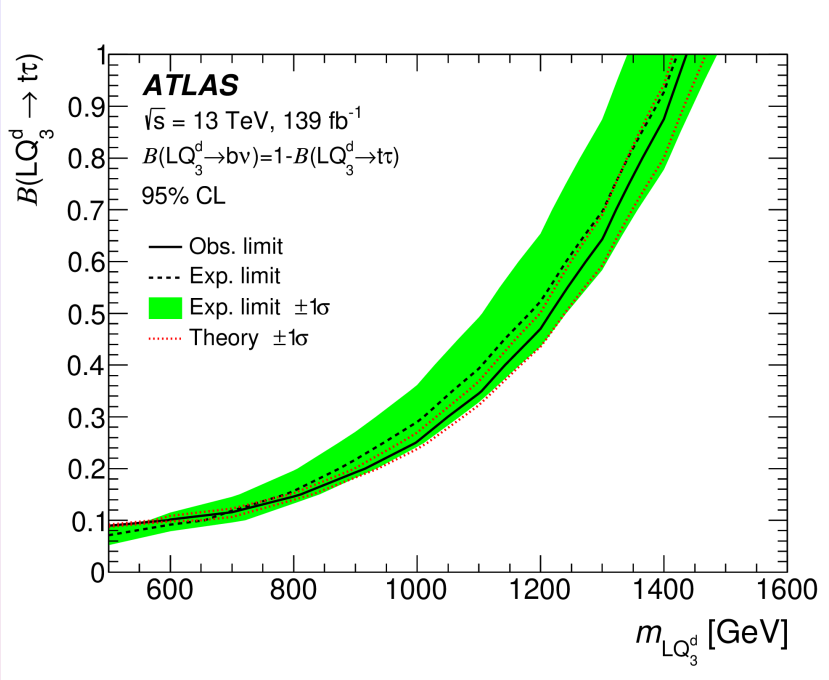




- Background estimates in signal regions supported by large number of control regions

Tau lepton, light leptons, and jets



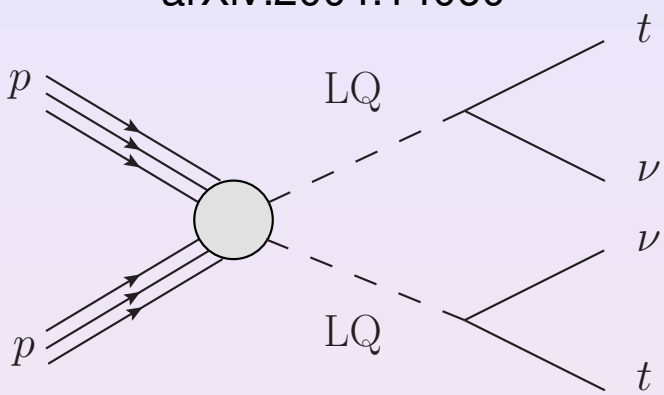


- Simultaneous fit to 7 signal regions and 15 control regions
- Discovery potential for leptoquark masses up to 1.2 TeV
- Limits set on cross section and in terms of $\mathrm{BR}(\mathrm{LQ} \to t\tau)$
- Mass limit approximately 1.4 TeV for $\mathrm{BR}(\mathrm{LQ} \to t\tau) = 100\%$

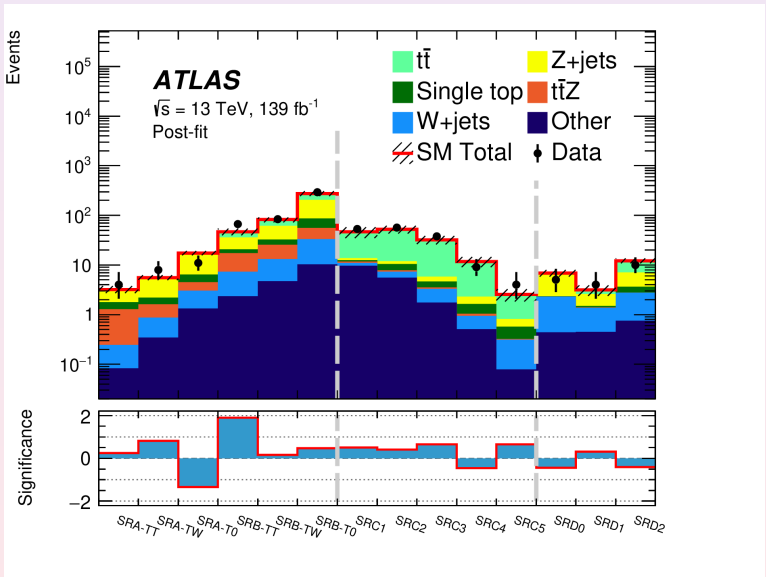
Hadronic tops and $\not{E}_{\mathrm{T}}$

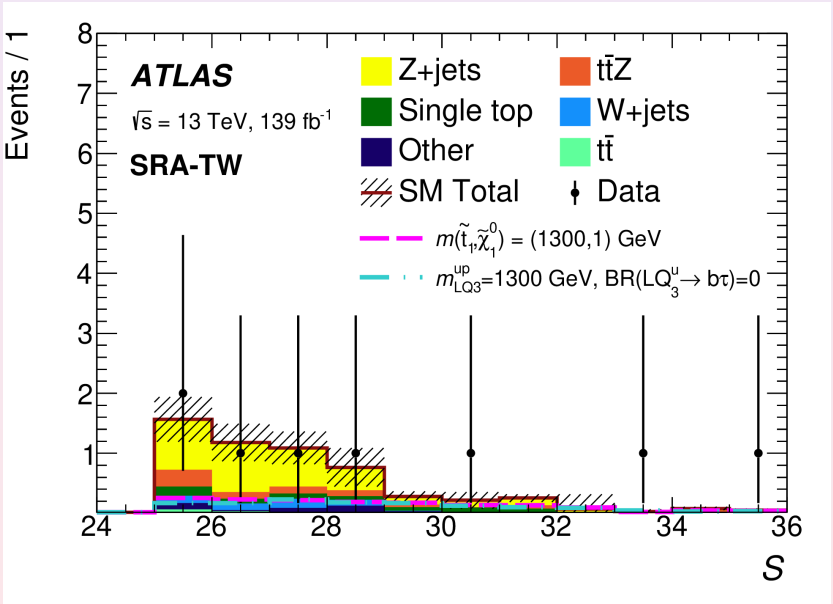
$t_{\mathrm{had}}t_{\mathrm{had}} + \not{E}_{\mathrm{T}}$

arXiv:2004.14060



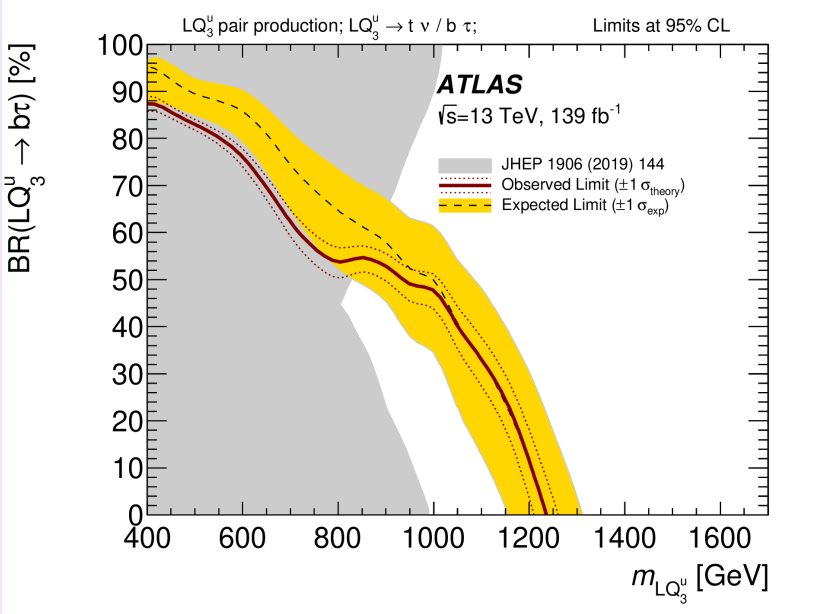
- $\not{E}_{\mathrm{T}}$ trigger, offline $\not{E}_{\mathrm{T}} > 250\,\mathrm{GeV}$
- Detailed selection based on angular variables, b-tagging, m_{T}, m_{T2}, $\not{E}_{\mathrm{T}}$ significance
- Split into Top+Top, Top+W, Top+X

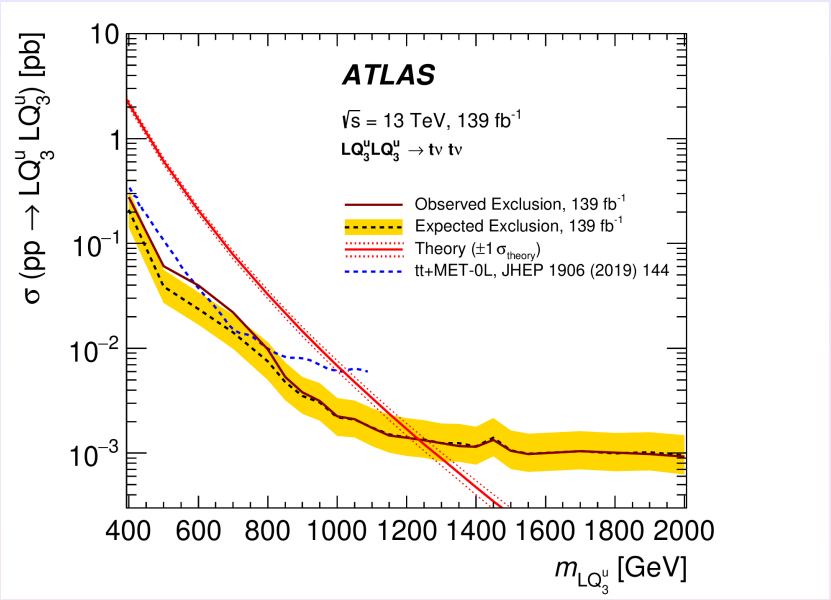




- Boosted hadronic tops reconstructed by reclustering $R = 0.4$ jets into large-radius $R = 1.2$ jets ($m > 120\,\mathrm{GeV}$)

Hadronic tops and $\not{E}_{\mathrm{T}}$



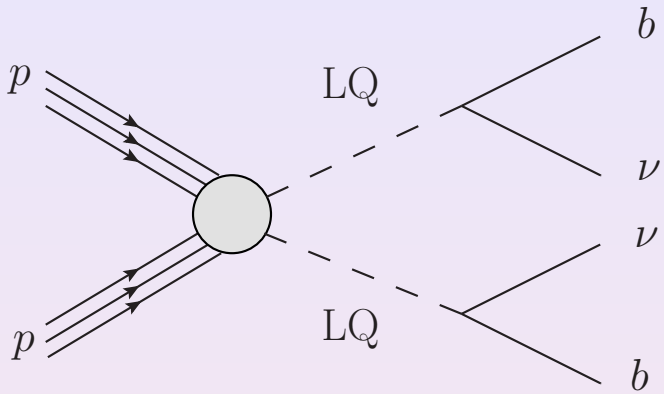


- Simultaneous fit to signal regions (A+B) and control regions
- Limits set on cross section and in terms of $\mathrm{BR}(\mathrm{LQ} \to b\tau)$
- Mass limit approximately 1.25 TeV for $\mathrm{BR}(\mathrm{LQ} \to t\nu) = 100\%$

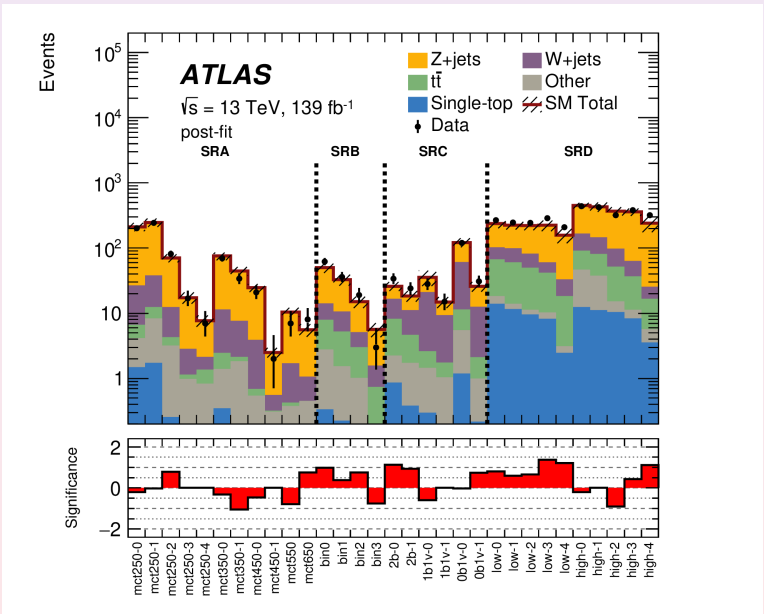
b-jets and $\not{E}_{\mathrm{T}}$

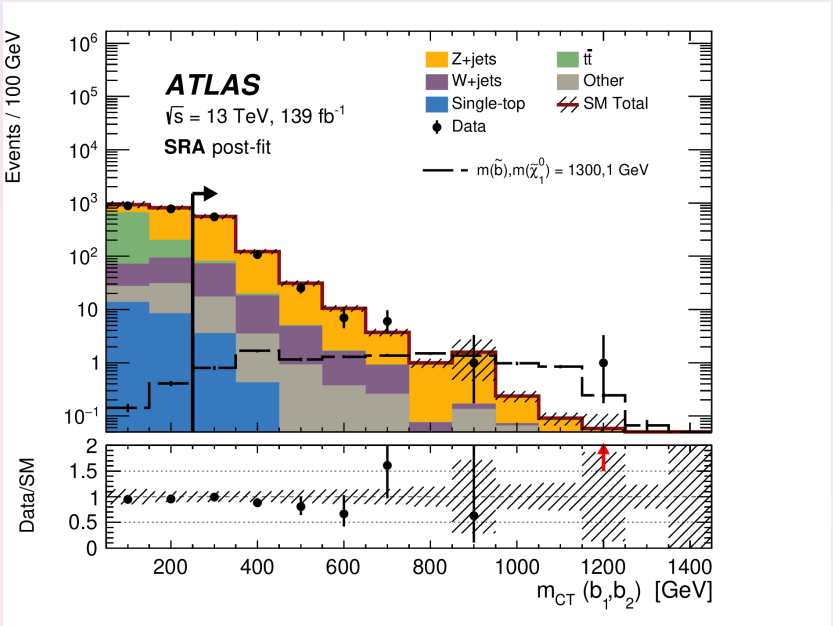
b-jets + $\not{E}_{\mathrm{T}}$

arXiv:2101.12527



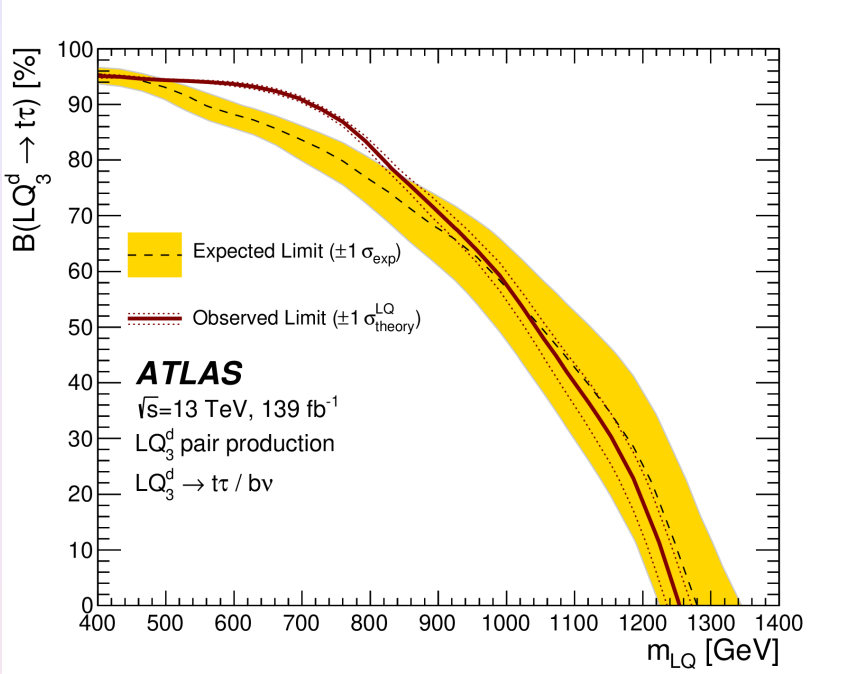
- $\not{E}_{\mathrm{T}}$ trigger, offline $\not{E}_{\mathrm{T}} > 250\,\mathrm{GeV}$
- 2–4 jets (2 b-tags)
- Hard requirements on jet p_{T}, m_{bb}, m_{eff}, m_{CT}, $\not{E}_{\mathrm{T}}$ significance, angular variables (incl. BDT)





- Signal regions binned in m_{CT}, m_{eff}, and BDT discriminant

b-jets and $\not{E}_{\mathrm{T}}$

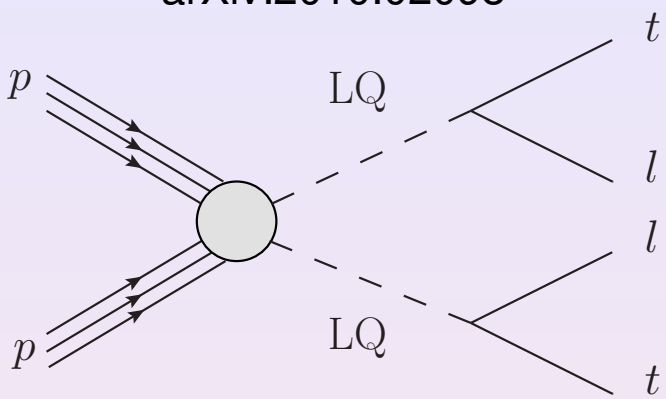


- Simultaneous fit to signal regions (A+B) and control regions
- Limits set in terms of $\mathrm{BR}(\mathrm{LQ} \to t\tau)$
- Mass limit approximately 1.25 TeV for $\mathrm{BR}(\mathrm{LQ} \to b\nu) = 100\%$

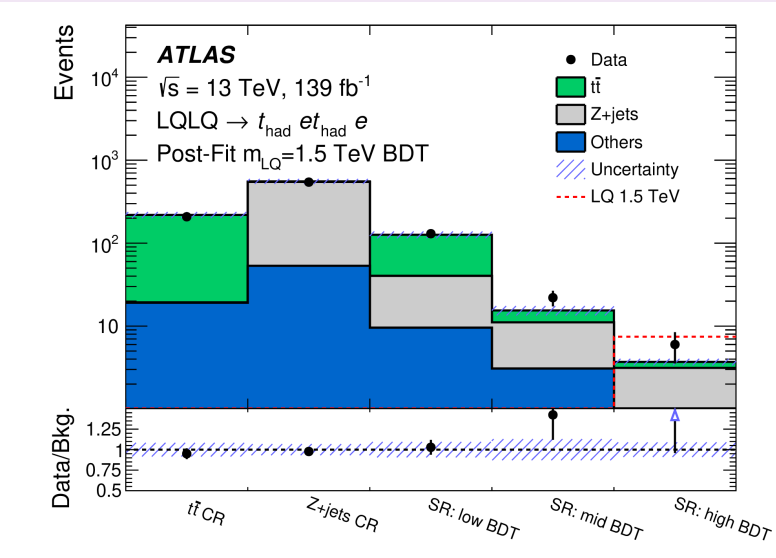
Hadronic tops and light leptons

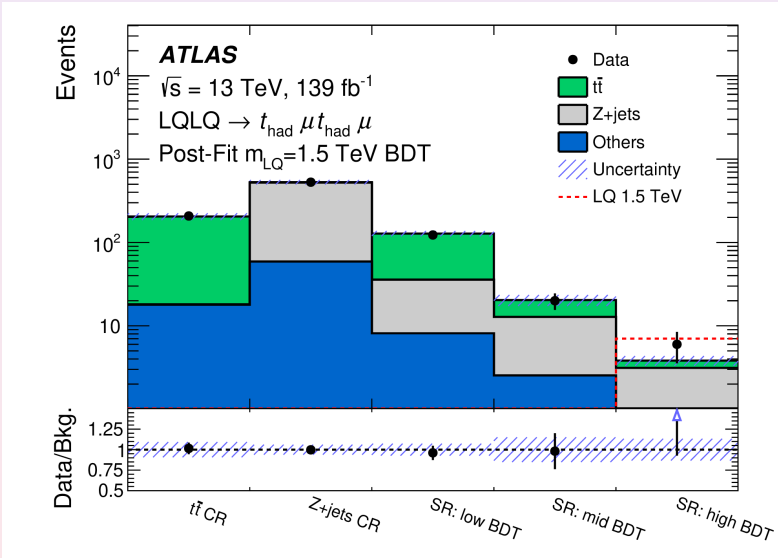
$t_{\text{had}}\,t_{\text{had}} + ll$

arXiv:2010.02098



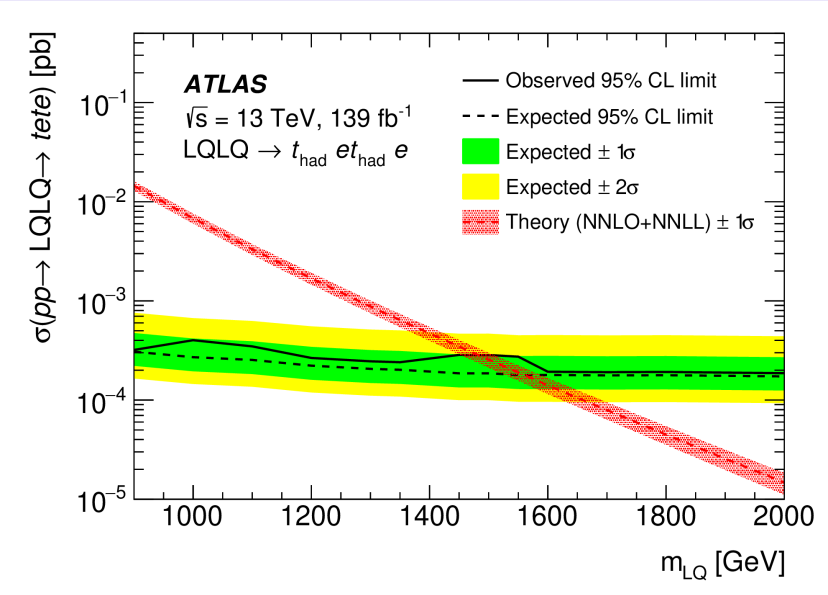
- Lepton triggers
- Exactly two l ($p_{\text{T}} > 100\,\text{GeV}$)
- $m_{ll} > 120\,\text{GeV}$
- At least two $R = 1.0$ jets ($p_{\text{T}} > 200\,\text{GeV}$)

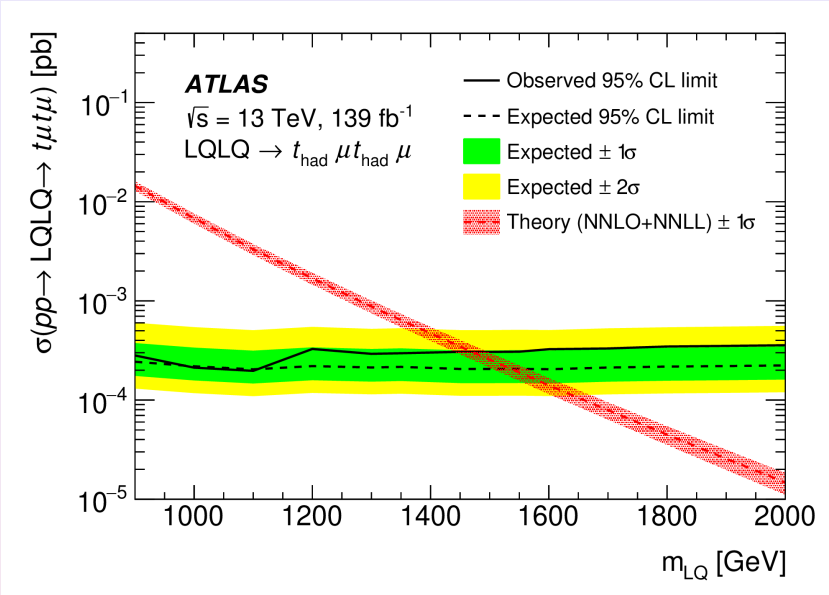




- BDT selection based on Lorentz-transformed kinematical variables (“recursive jig-saw”) + jet substructure variables (μ-channel), parametrized in m_{LQ}

Hadronic tops and light leptons



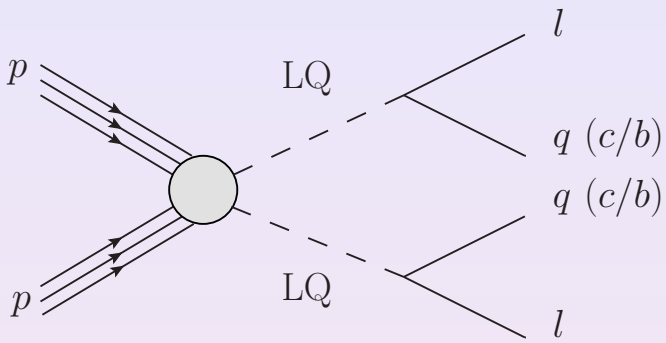


- Simultaneous fit to signal region binned in BDT discriminant and control regions
- Limits set on cross section and in terms of $\mathrm{BR}(\mathrm{LQ} \to tl)$
- Mass limit approximately 1.5 TeV for $\mathrm{BR}(\mathrm{LQ} \to tl) = 100\%$

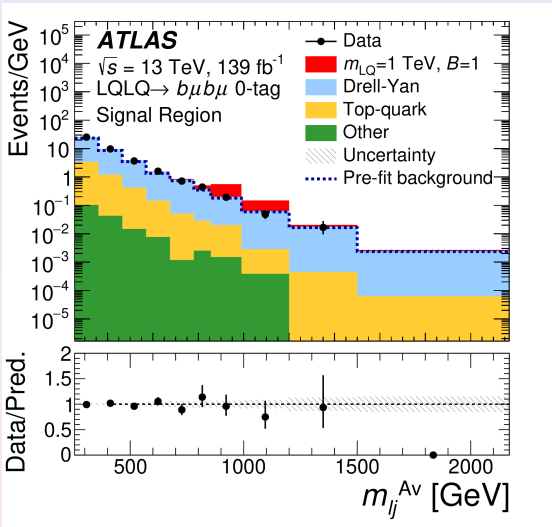
Light leptons and (heavy flavour) jets

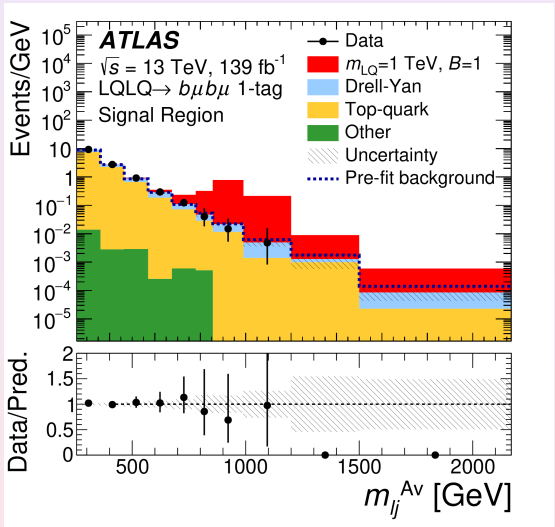
ll + jets (incl. *b*/*c*)

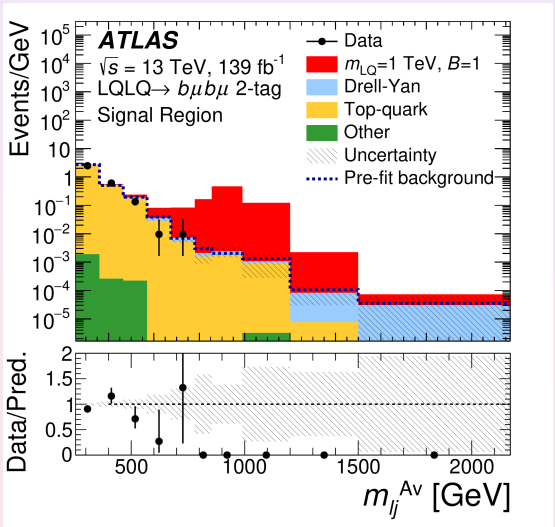
arXiv:2006.05872



- Lepton triggers
- $m_{ll} > 130\,\mathrm{GeV}$, $p_{\mathrm{T}}^{ll} > 75\,\mathrm{GeV}$, veto large $\not{E}_{\mathrm{T}}/\sqrt{H_{\mathrm{T}}}$
- Signal regions inclusive in jet flavour and split by *b*/*c*-tag multiplicity

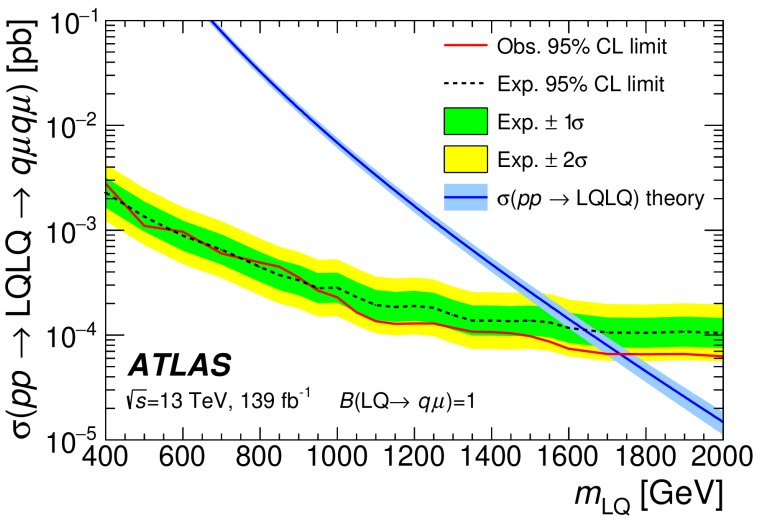


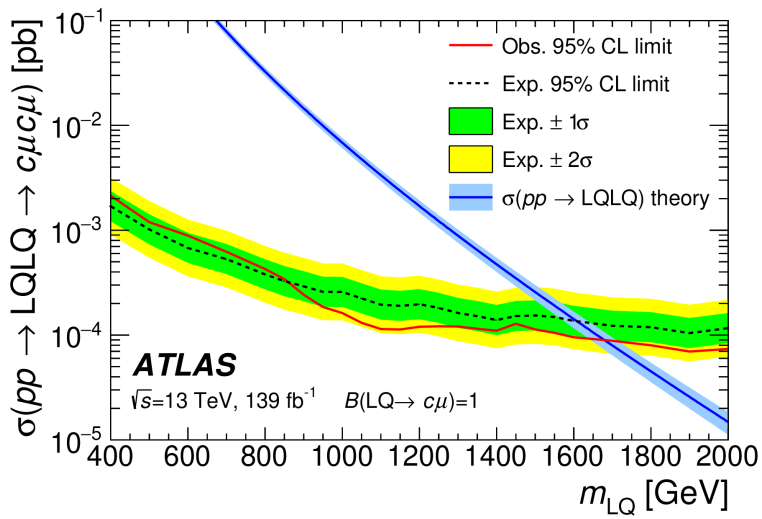


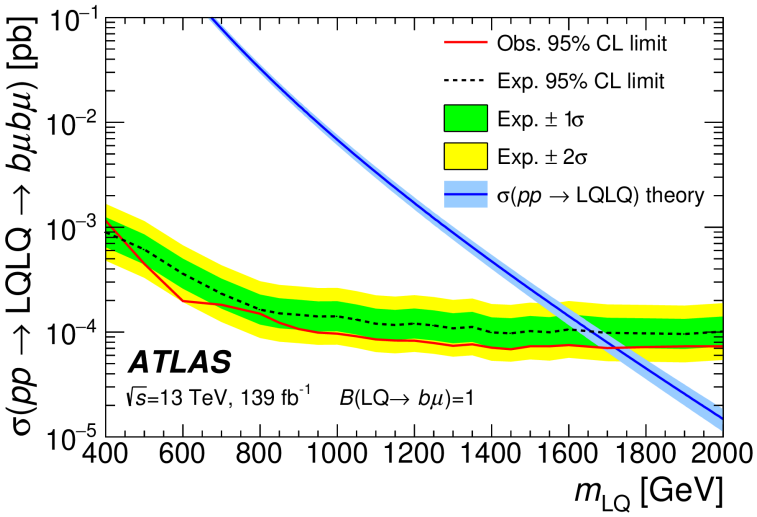


- Mass asymmetry $(m_{lj}^{\max} - m_{lj}^{\min})/(m_{lj}^{\max} + m_{lj}^{\min})$ used to define signal region (< 0.2) and side-band
- Discriminating variable: $m_{lj}^{\mathrm{Av}} = (m_{lj}^{\max} + m_{lj}^{\min})/2$

Light leptons and (heavy flavour) jets



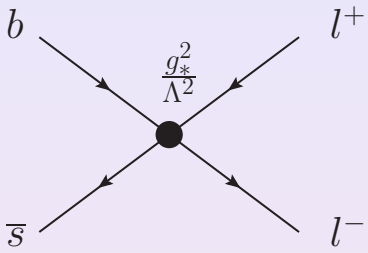


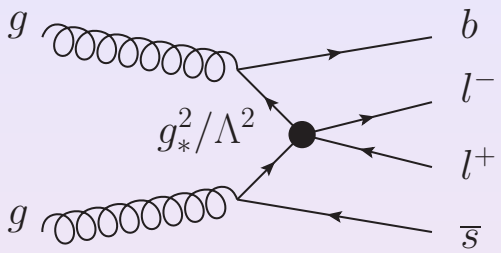


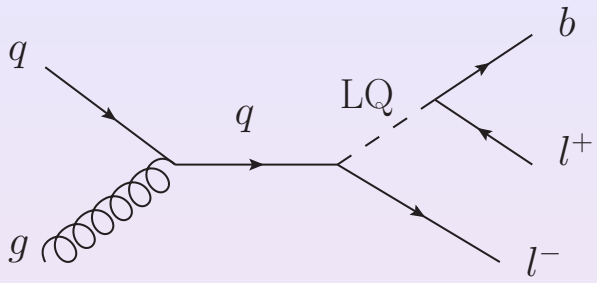
- Limits set on inclusive *ql* decays as well as *cl* and *bl* decays
- Mass limits around 1.7 TeV for $\mathrm{BR}(\mathrm{LQ} \to ql) = 100\%$

Light leptons and 0/1 b-jet

ll + 0/1 b-jets arXiv:2105.13847

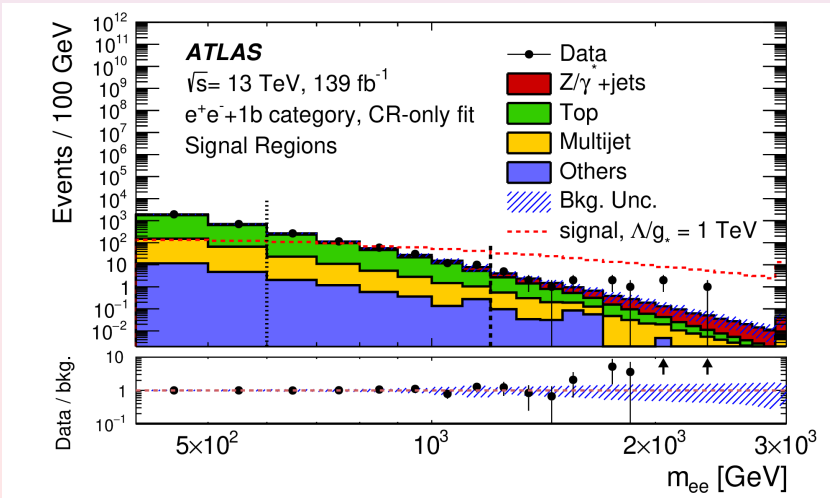






(dedicated LQ interpretation in the works)

- Lepton triggers
- Single-bin signal regions $m_{ll} > m_{ll}^{\min}$ from 400 GeV to 3.2 TeV for exactly 1 or no b-jet
- Limits far below $\Lambda/g_* \approx 30$ TeV favoured by B-anomalies

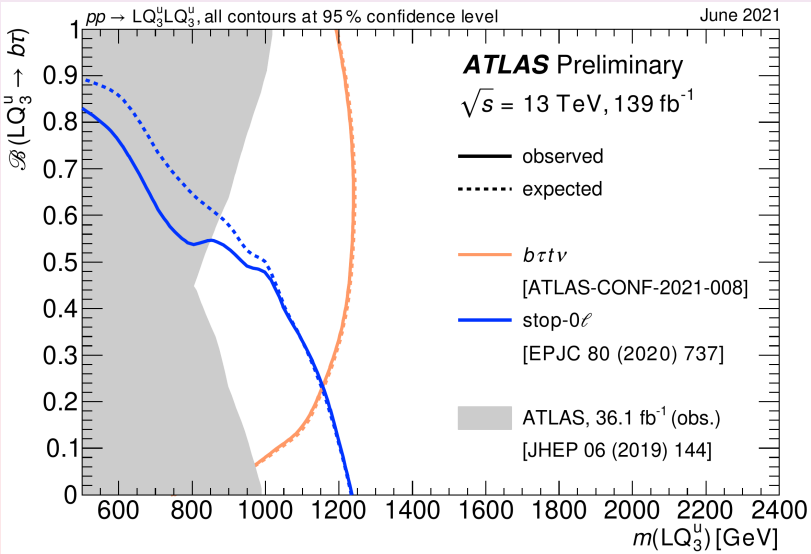


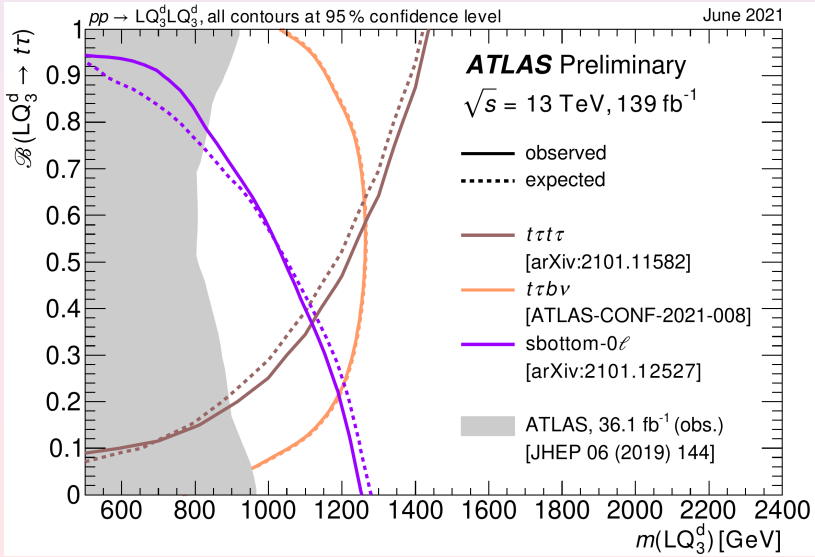
	e^+e^-	$\mu^+\mu^-$
0 b-jets	2.0 (2.2)	2.4 (2.1)
1 b-jet	1.8 (2.2)	2.0 (2.1)

Observed (expected) lower limits on Λ/g_* [TeV]

Summary

- Several ATLAS searches for leptoquarks already published with the full Run-2 dataset, emphasis on
  - Decays to third generation quarks and leptons (large overlap with SUSY searches)
  - Generation mixing (possible link to *B*-decay anomalies)
- Mass limits from 1.2 – 1.7 TeV depending on final state
- Dedicated analysis in terms of contact interactions related to *B*-decay anomalies
  - Sensitivity far from parameter space favoured by the anomalies





Leptoquark summary plots ATL-PHYS-PUB-2021-017