Searches for leptoquarks with the ATLAS detector

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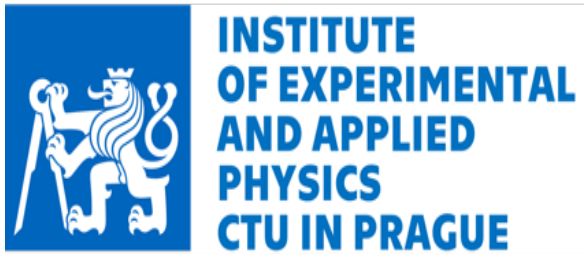

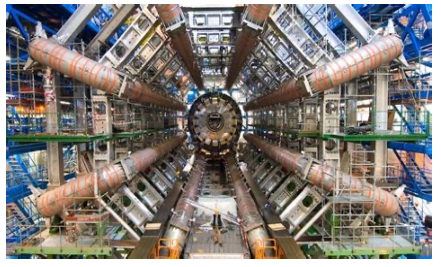

Outline

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- B-anomalies and dedicated search for bsll
- Third Generation Leptoquarks
- First and Second Generation Leptoquarks
- Relation of Searches for Supersymmetry and Leptoquarks
- Summary
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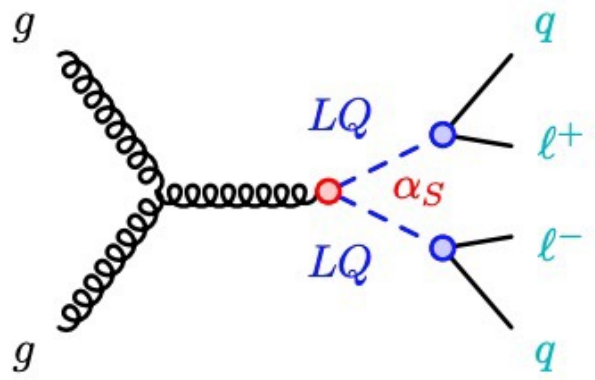
  - Down-type Third-Generation Model ($\mathrm{LQ}_3^{\mathrm{d}}$)
  - Up-type Mixed-Generation Model ($\mathrm{LQ}_{\mathrm{mix}}^{\mathrm{u}}$)
  - Down-type Mixed-Generation Model ($\mathrm{LQ}_{\mathrm{mix}}^{\mathrm{d}}$)
- Conclusions

Introduction Leptoquarks (LQ)

- Colour triplet bosons with fractional charge
- LQ decay flavour-diagonal and possibly cross-generations
- Yukawa interaction with coupling λ

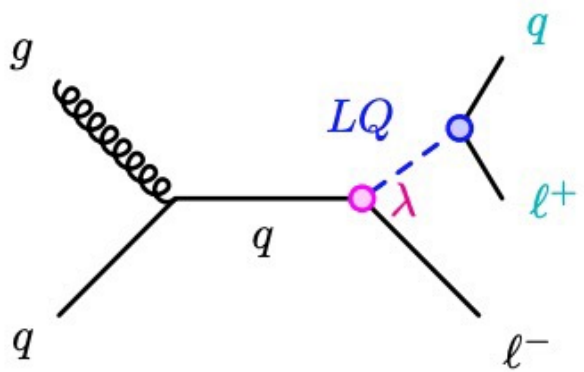
LQ decay	B=1	B=0
LQ_{up}	$b\tau$	$t\nu$
LQ_{down}	$t\tau$	$b\nu$

Pair-production



large resonant cross-section

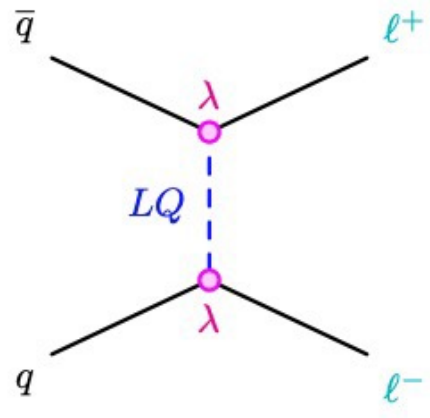
single-production



cross-section $\propto \lambda^2$

sensitive for large m_{LQ}

off-shell production

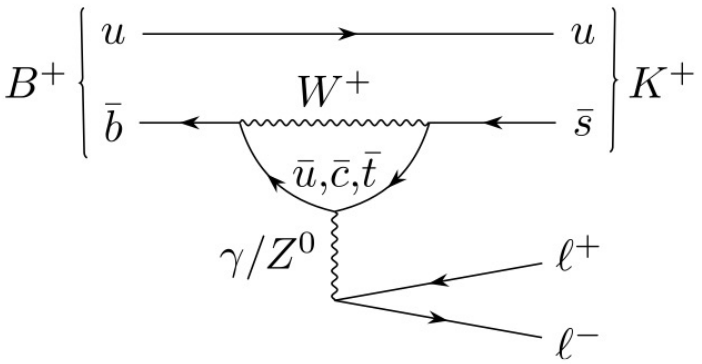


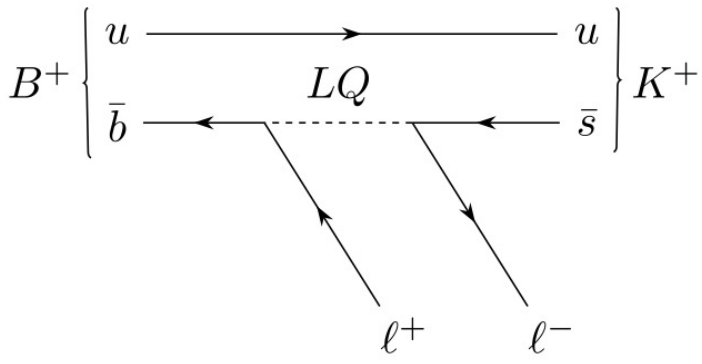
cross-section $\propto \lambda^4$

sensitive for larger m_{LQ}

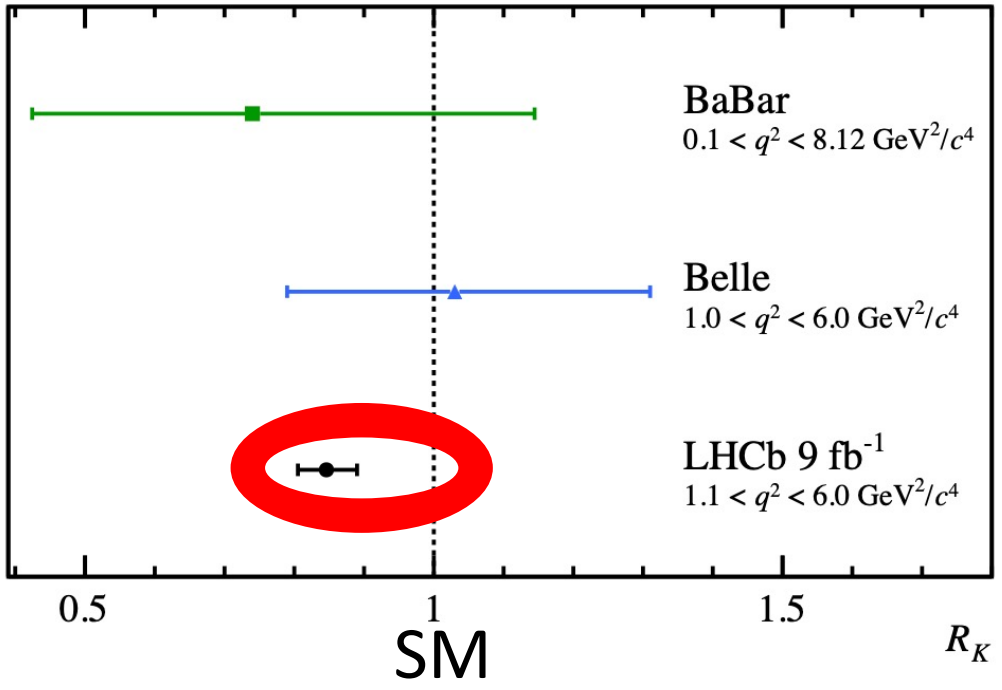
B-anomalies and dedicated search for bsll

- Leptoquarks gain enhanced interest as a possible explanation of the B-anomaly (violation of lepton universality) LHCb, arXiv:2103.11769





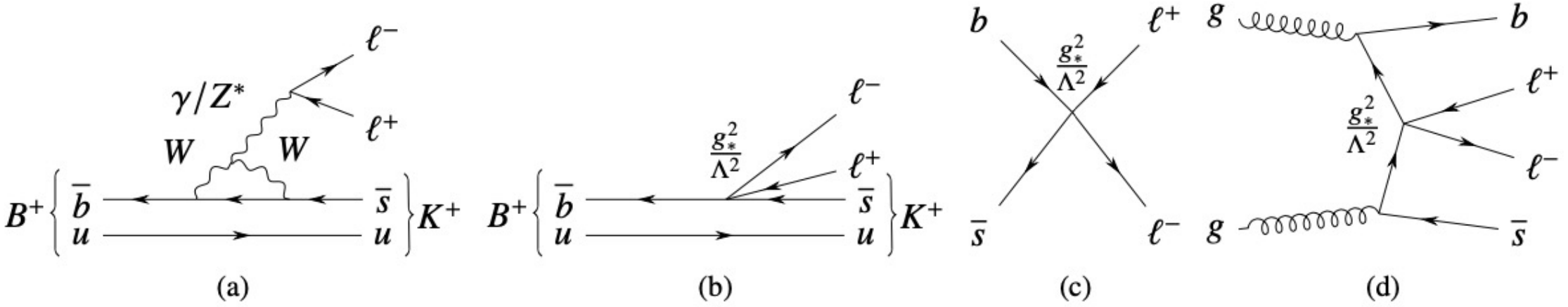
$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to J/\psi(\to \mu^+\mu^-)K^+)} \Big/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to J/\psi(\to e^+e^-)K^+)}$$



- In ATLAS, a dedicated search was performed for bsll.

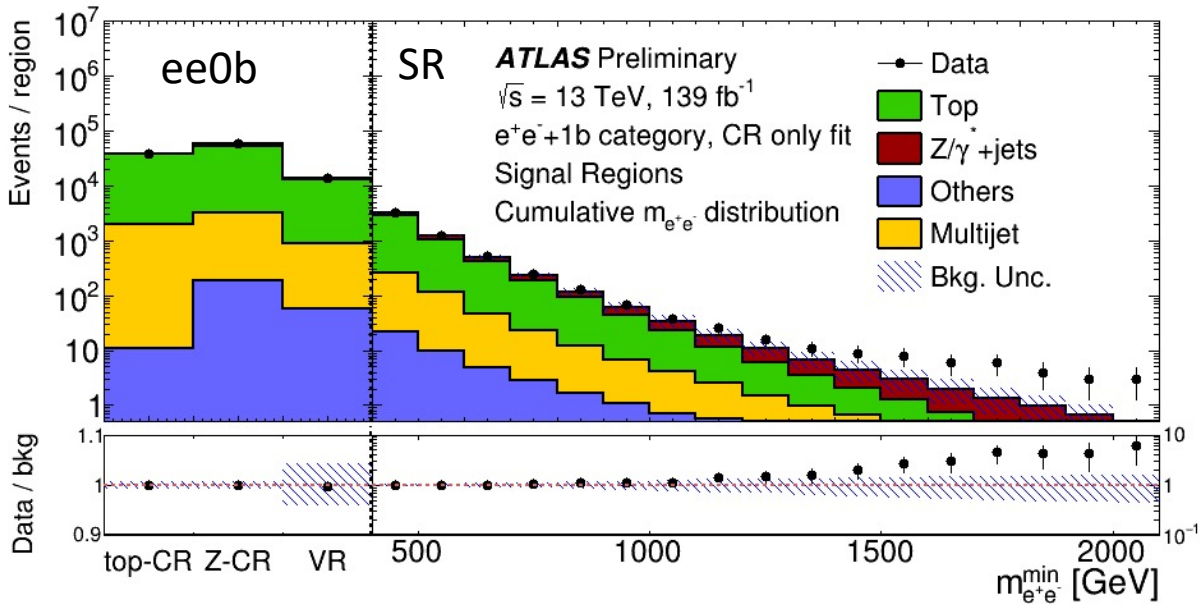
Search for new phenomena in final states with two leptons and one or no b-tagged jets, ATLAS-CONF-2021-012

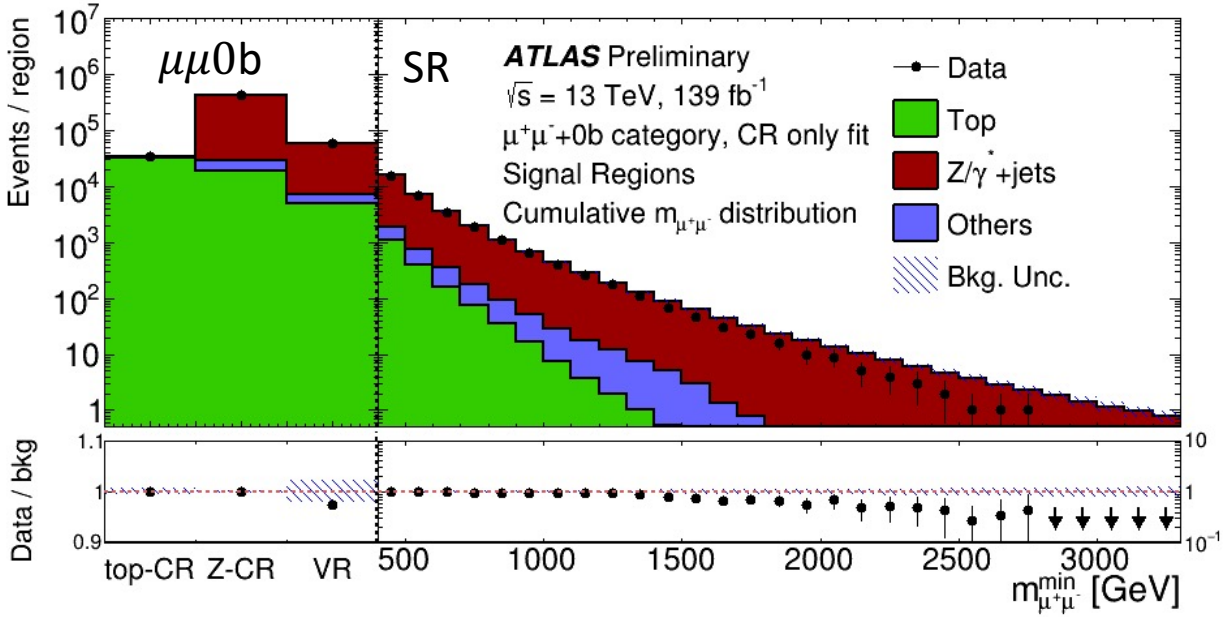
- Benchmark signal model (inspired by the B-meson anomalies): four-fermion contact interaction between two quarks (b,s) and two leptons (ee or μμ),.

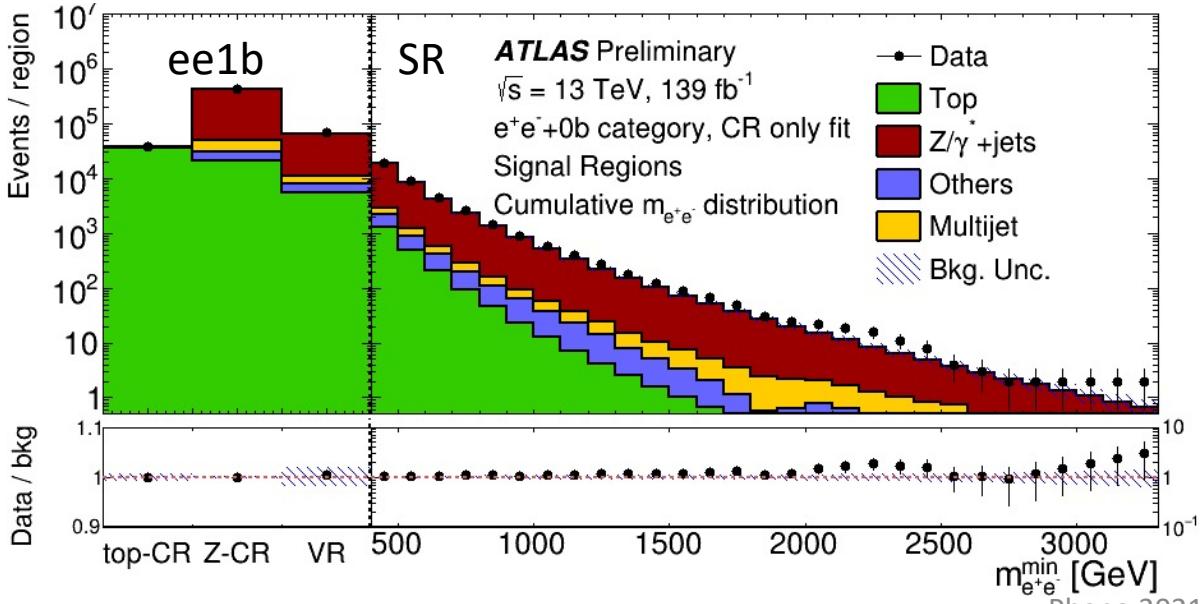


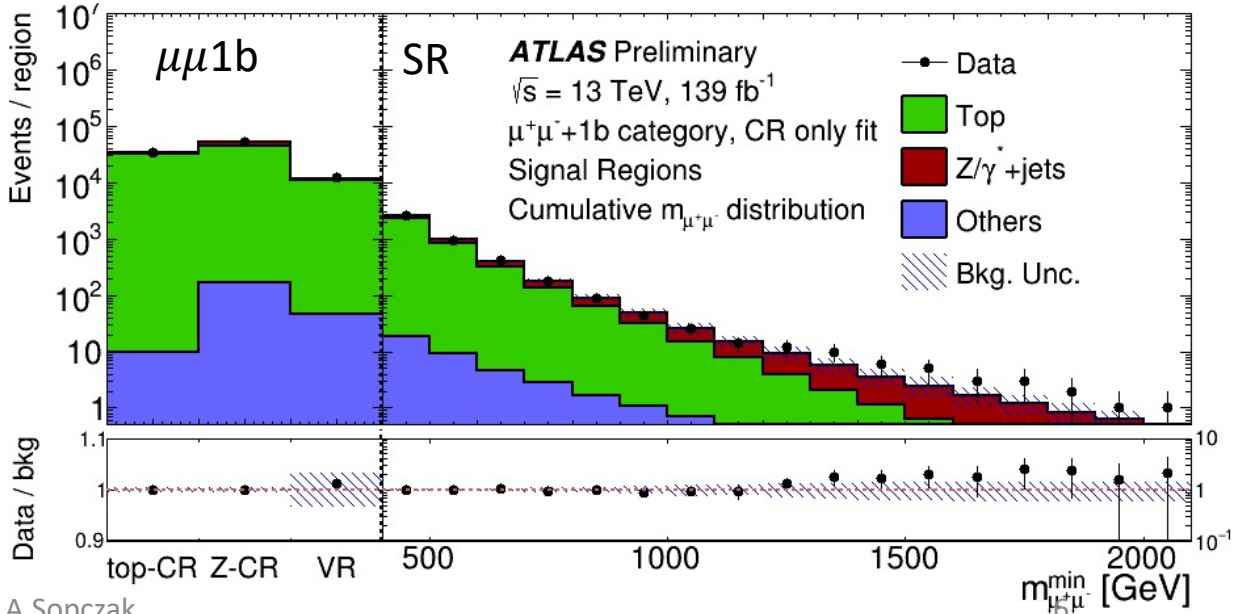
Model is characterized by the energy scale and coupling, Λ and g_*

Data and SM background, ATLAS-CONF-2021-012

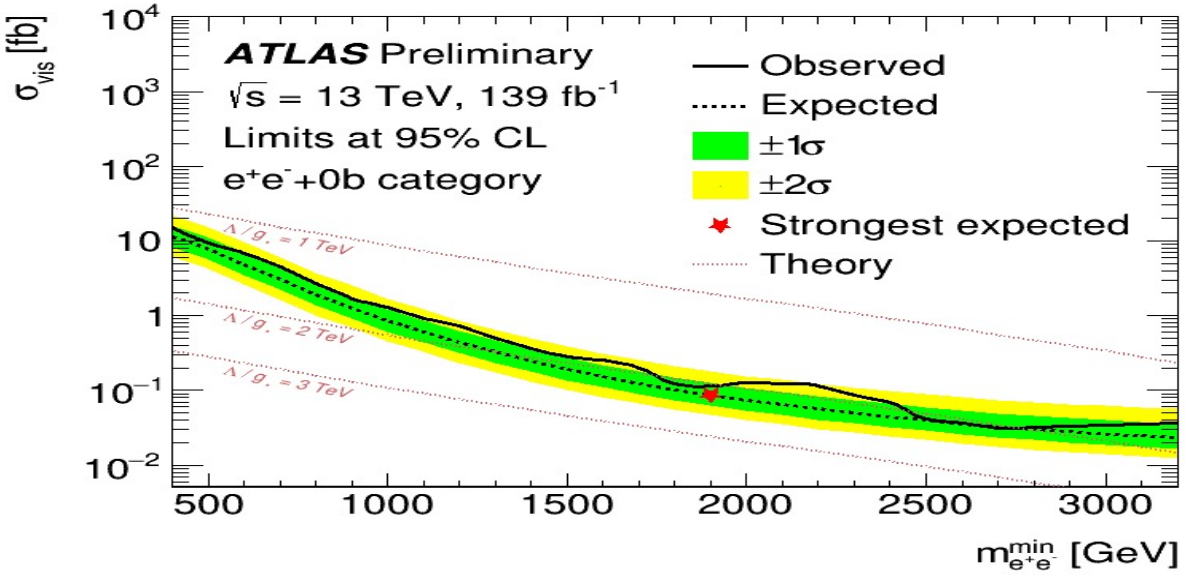


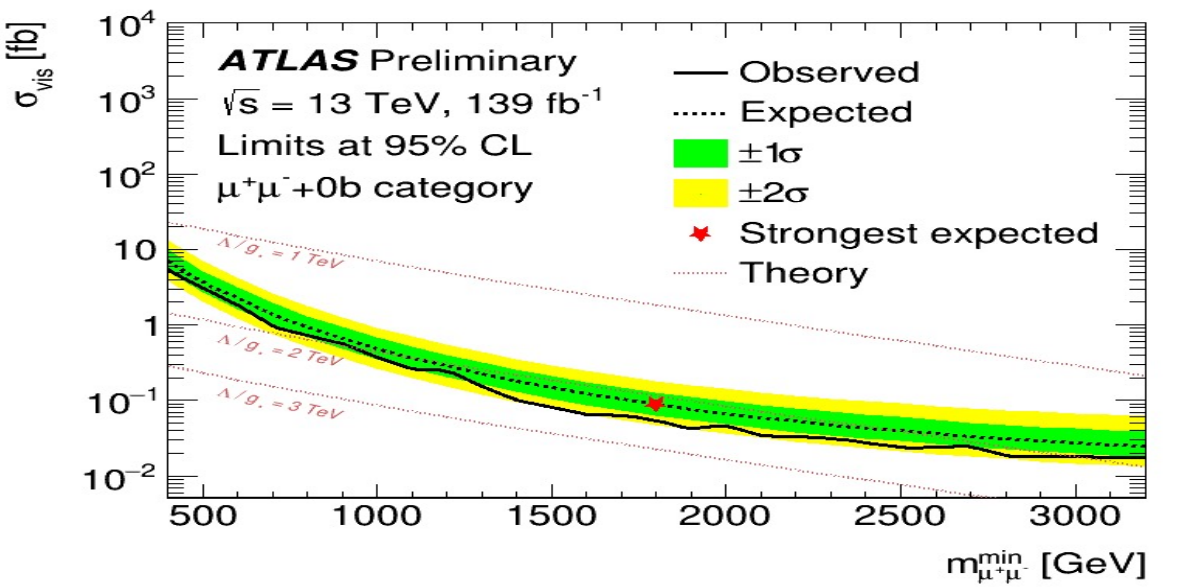


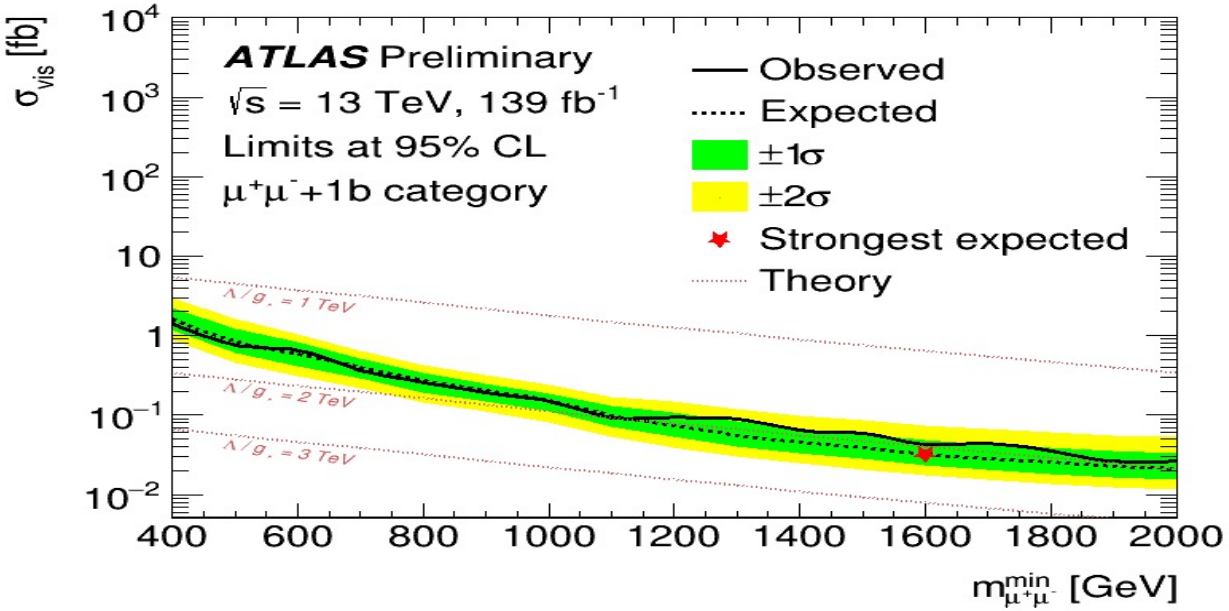


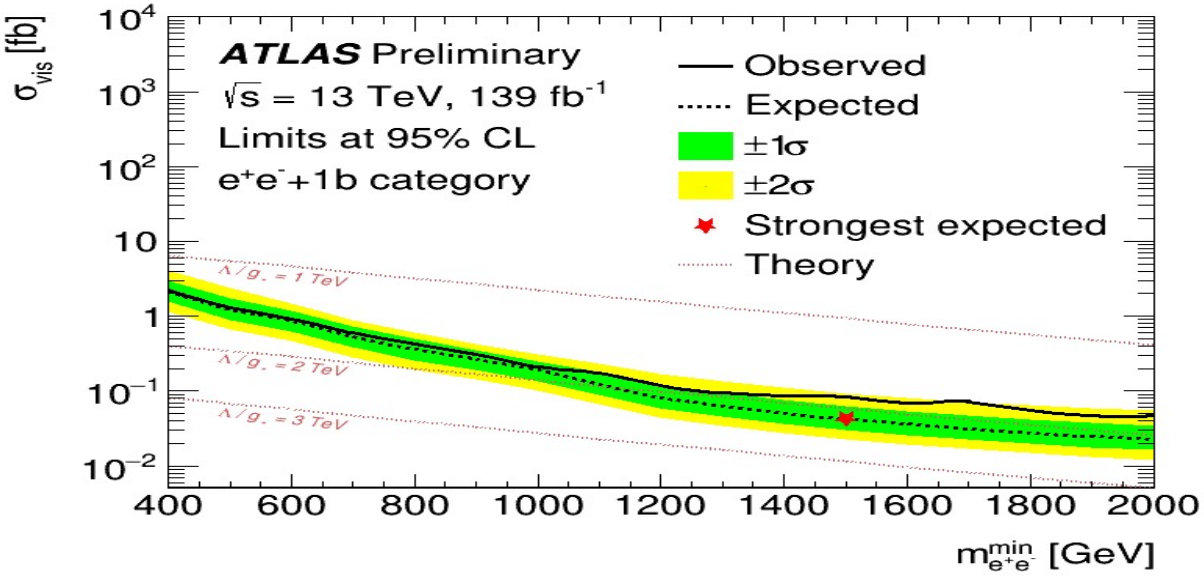


Cross-section limits, ATLAS-CONF-2021-012









Summary of relative systematic uncertainties for signal regions with $m_{\ell\ell}^{min}$ = 2000 (1500) GeV, ATLAS-CONF-2021-012

Source	$e^+e^- + 0b\ (1b)$ [%]		$\mu^+\mu^- + 0b\ (1b)$ [%]	
	Signal $0b\ (1b)$	Background $0b\ (1b)$	Signal $0b\ (1b)$	Background $0b\ (1b)$
Luminosity	1.7 (1.7)	1.6 (1.5)	1.7 (1.7)	1.7 (1.7)
Pile Up	<0.5 (<0.5)	<0.5 (0.7)	<0.5 (<0.5)	<0.5 (<0.5)
Leptons	8.7 (8.6)	8.6 (6.3)	8.5 (6.5)	9.1 (4.2)
Jets	<0.5 (1.8)	<0.5 (3.4)	<0.5 (1.6)	<0.5 (1.9)
b-tagging	<0.5 (1.4)	<0.5 (2.0)	<0.5 (1.4)	<0.5 (2.2)
Top Bkg. Extrapolation	-	3.5 (32.0)	-	<0.5 (36.0)
Multijet Extrapolation	-	7.5 (15.0)	-	-
Top Quark Theory	-	<0.5 (<0.5)	-	<0.5 (<0.5)
Z Theory	-	9.4 (4.3)	-	10.0 (5.5)
MC Statistics	0.6 (0.8)	1.9 (3.5)	0.7 (1.0)	1.7 (2.4)
Total	8.9 (9.1)	15.0 (37.0)	8.7 (7.1)	14.0 (37.0)

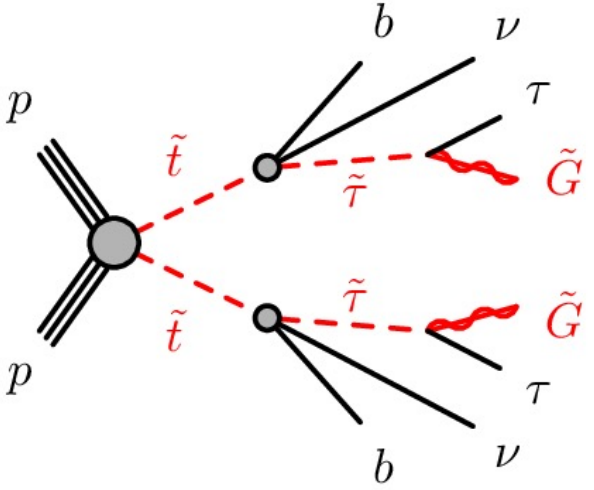
- Contact interactions with $\Lambda/g_* < 2.0$ (2.4) TeV excluded for e (μ) at 95% CL, still far from the value which is favored by the B-meson decay anomalies.
- Model-independent limits set as a function of di-lepton invariant mass, for the reinterpretation of the results in terms of other signal scenarios.

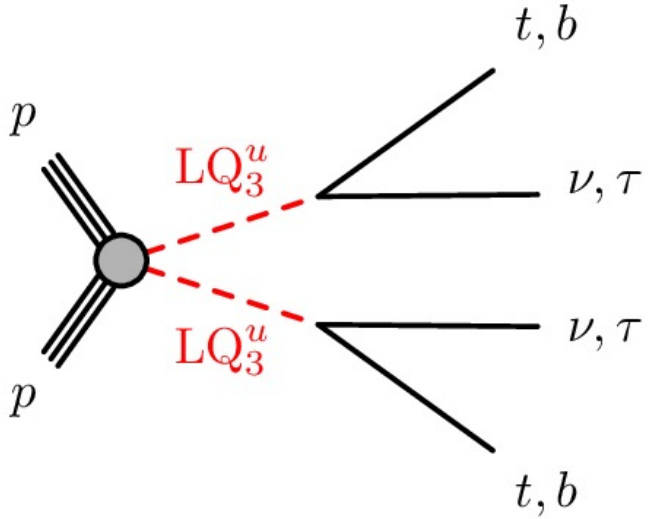
bb+MET, with taus search, pair production of third-generation leptoquarks, ATLAS-CONF-2021-008

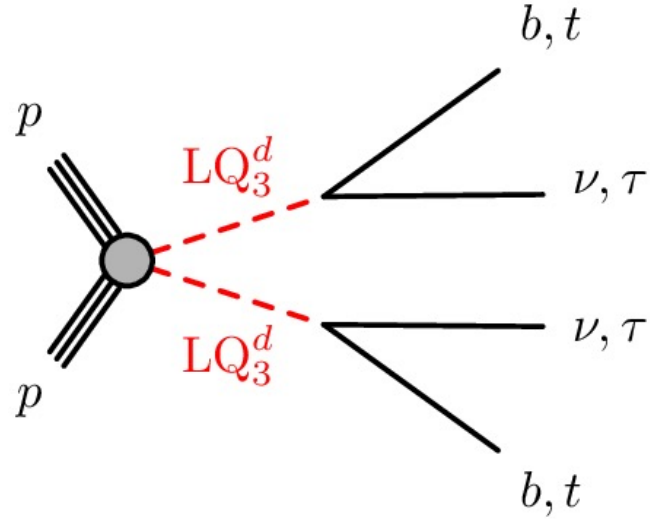
- Search for Supersymmetry with scalar top (stop) has sensitivity for Leptoquark pair-production.
- Decay

  $t\nu t\nu$, $b\tau b\tau$,

  $b\nu b\nu$, $t\tau t\tau$
- Charge 2/3e (left) and -1/3e (right).





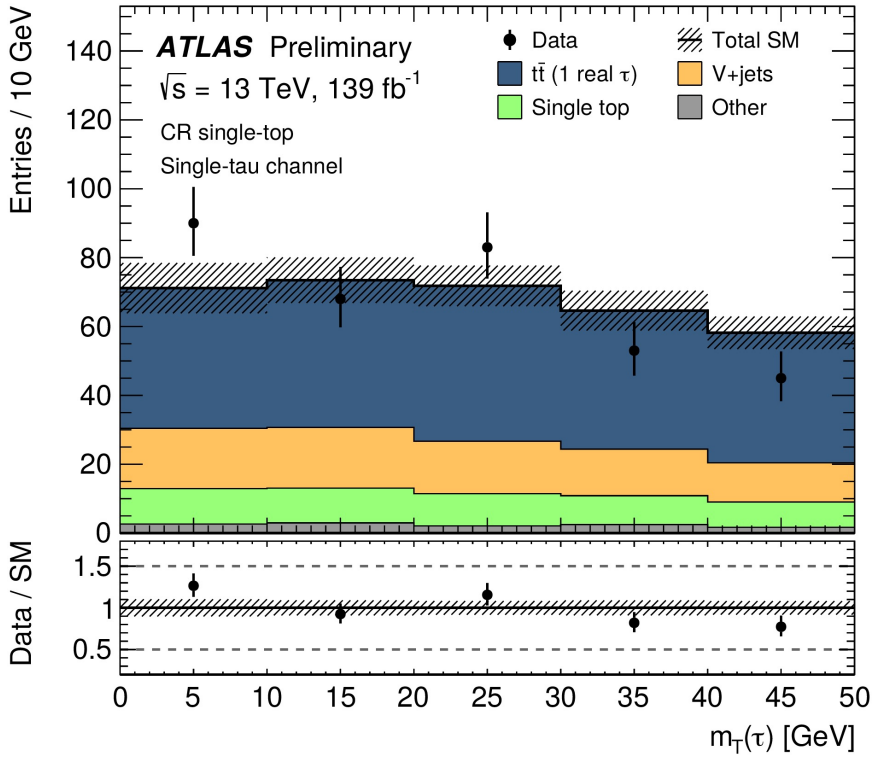


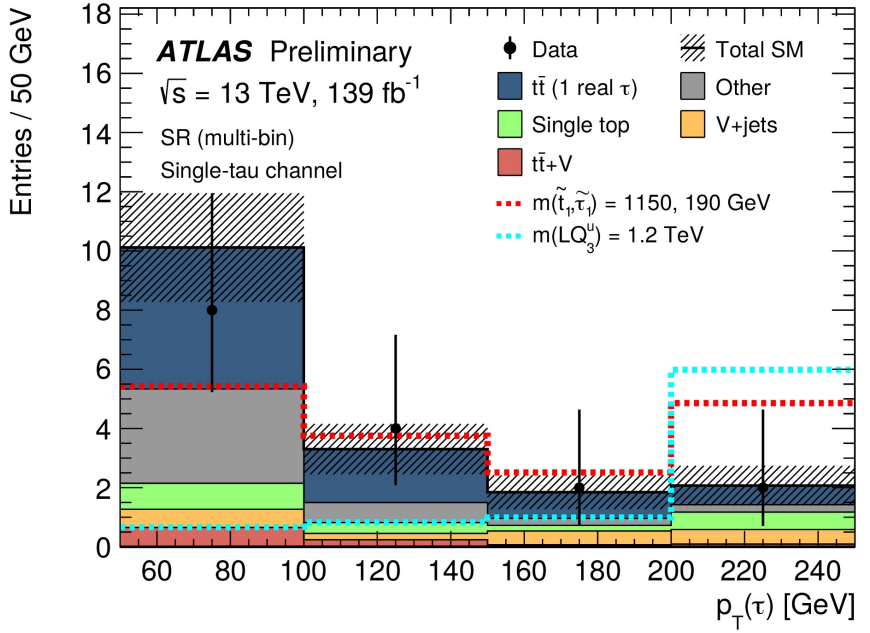
Third Generation Leptoquarks,
ATLAS-CONF-2021-008

Di-tau preselection	Single-tau preselection
$E_{\mathrm{T}}^{\mathrm{miss}}$-trigger fired and $E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV	
No light leptons (e/μ)	
At least two jets	
At least one b-tagged jet	
At least two hadronic tau candidates	Exactly one hadronic tau candidate
	At least two b-tagged jets

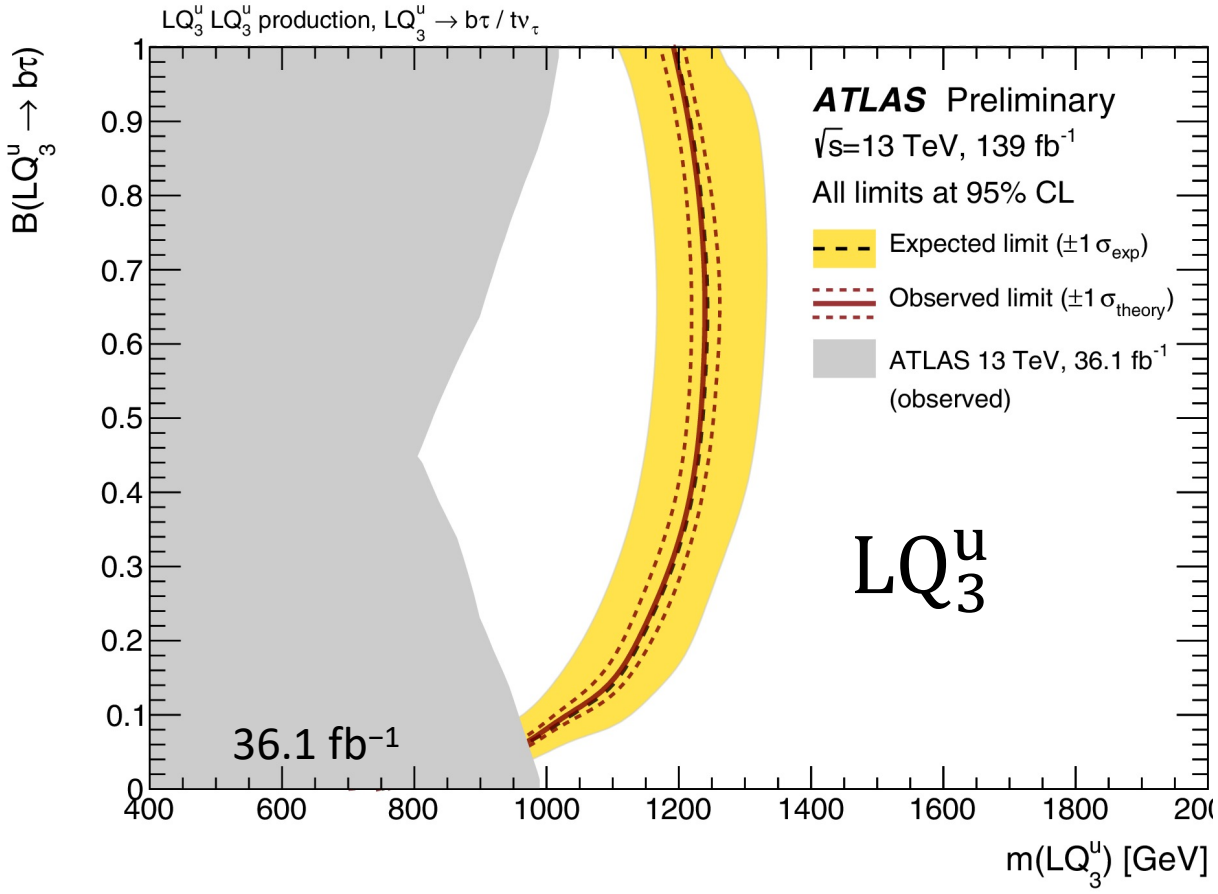
Variable	CR $t\bar{t}$ (2 real τ)	CR $t\bar{t}$ (1 real τ)	VR $t\bar{t}$ (2 real τ)	VR $t\bar{t}$ (1 real τ)	SR
$E_{\mathrm{T}}^{\mathrm{miss}}$	—	—	—	—	> 280 GeV
$OS(\tau_1, \tau_2)$	1	—	1	—	1
$m_{\mathrm{T2}}(\tau_1, \tau_2)$	< 35 GeV	< 35 GeV	[35, 70] GeV	[35, 70] GeV	> 70 GeV
$m(\tau_1, \tau_2)$	> 50 GeV	> 50 GeV	—	—	—
$m_{\mathrm{T}}(\tau_1)$	> 50 GeV	< 50 GeV	> 70 GeV	< 70 GeV	—

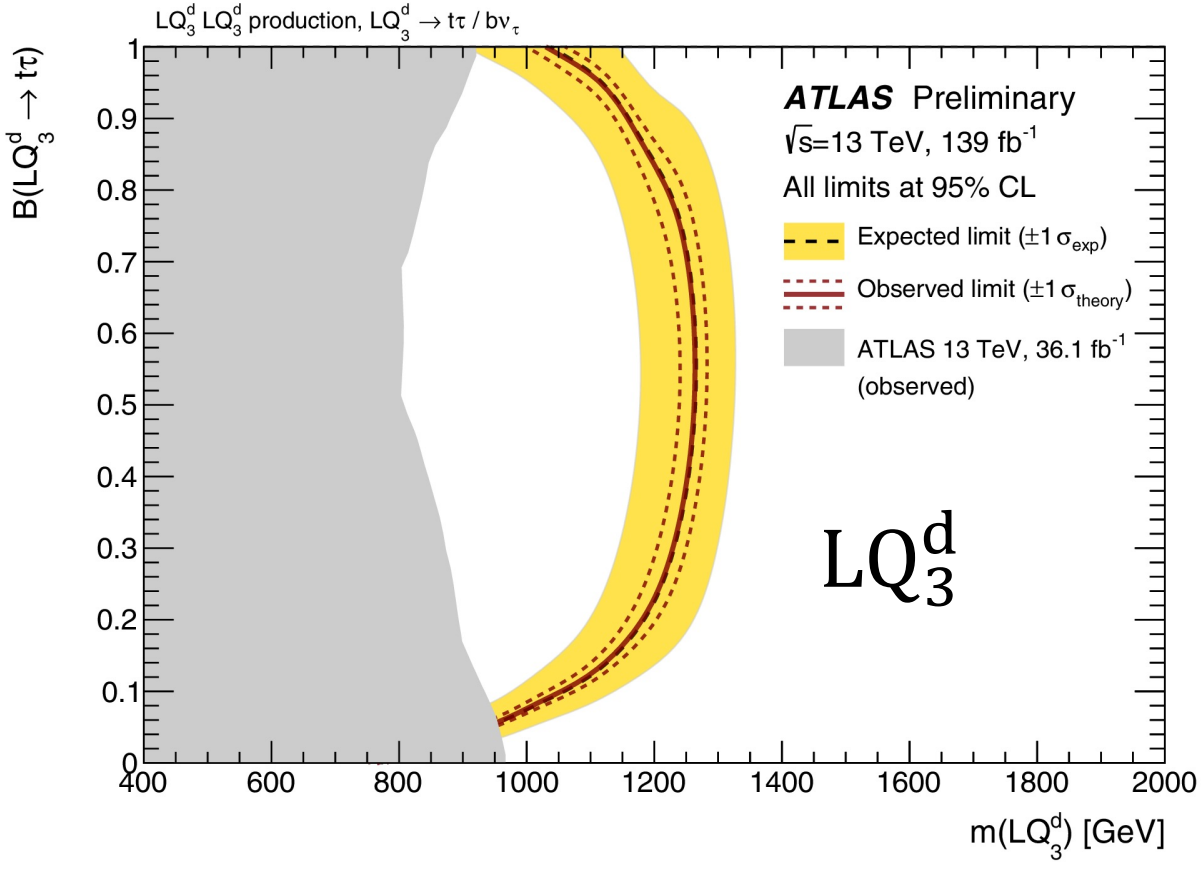
Variable	CR $t\bar{t}$ (1 real τ)	CR single top	VR $t\bar{t}$ (1 real τ)	VR single top	SR
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV
s_{T}	[500, 600] GeV	—	> 600 GeV	—	> 800(600) GeV
$\sum m_{\mathrm{T}}(b_{1,2})$	[600, 700] GeV	> 800 GeV	[600, 700] GeV	> 800 GeV	> 700 GeV
$m_{\mathrm{T}}(\tau)$	—	< 50 GeV	—	[50, 150] GeV	> 300(150) GeV
$p_{\mathrm{T}}(\tau)$	—	> 80 GeV	—	> 80 GeV	— (binned)





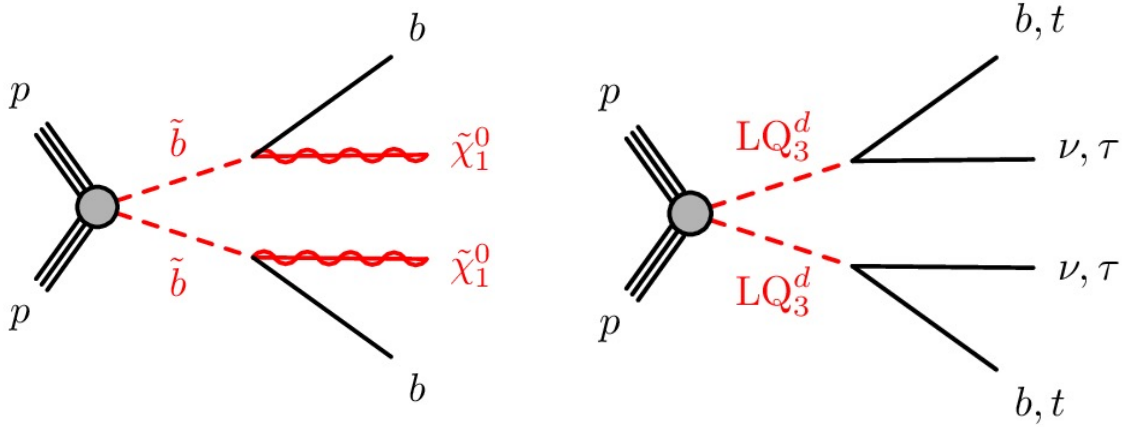
Expected and observed exclusion contours at 95% CL, as a function of m(LQ) and the branching ratio B($LQ_3^{u/d} \to q\ell$) into charged leptons, ATLAS-CONF-2021-008



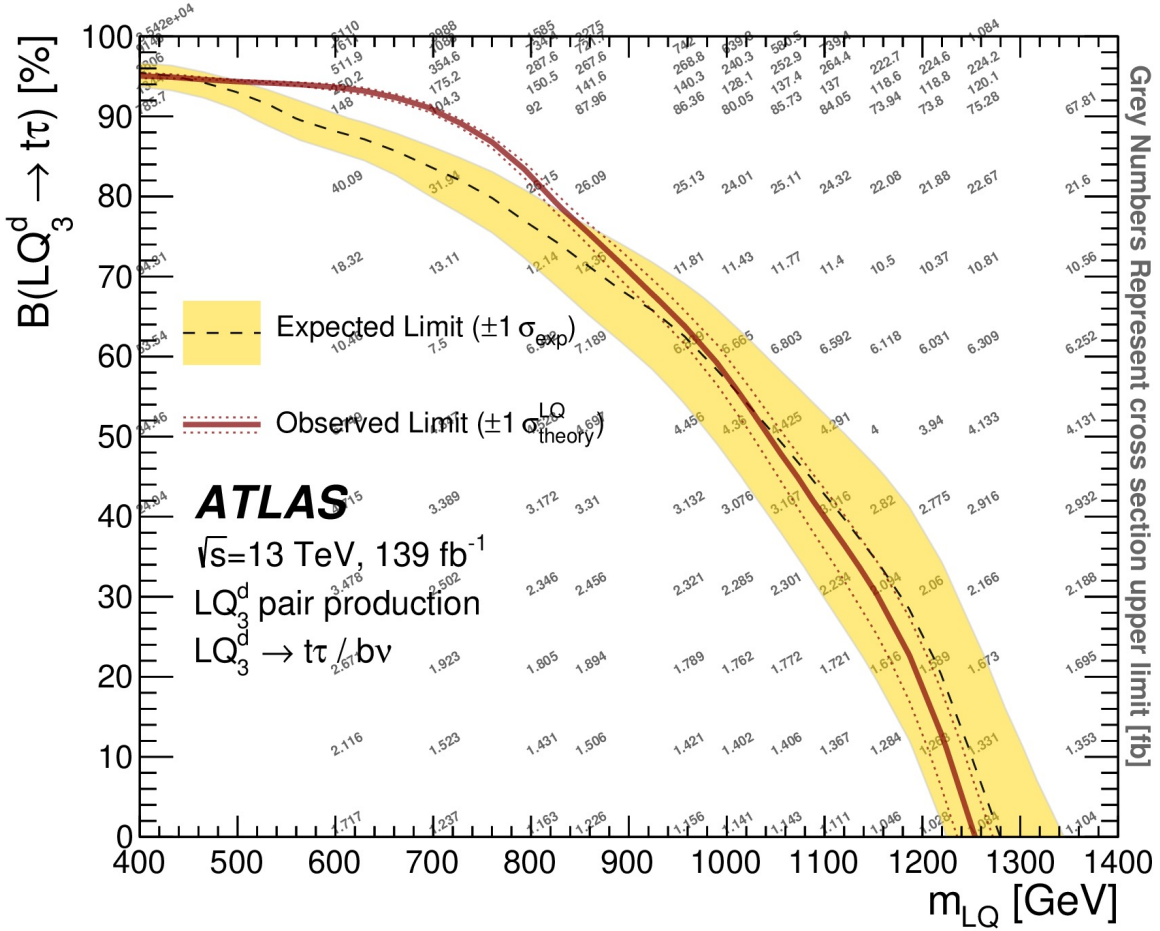


For B($LQ^u \to b\tau$)=0.5 and B($LQ^d \to t\tau$)=0.5, limits for LQs reach 1.25 TeV

bb+MET: pair production of third-generation down-type leptoquarks, arXiv:2101.12527

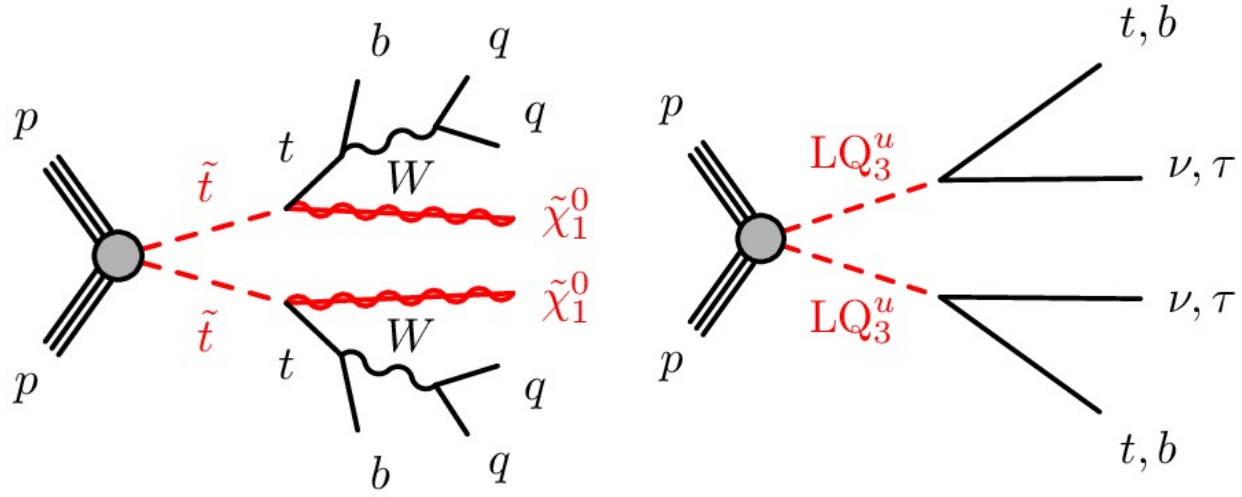


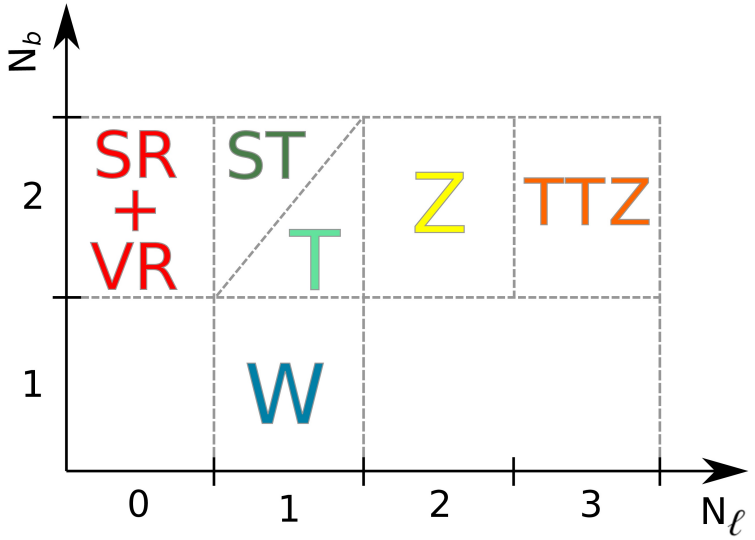
- Searches for bb+MET Supersymmetric prompt decays have sensitive to pair production of 3rd generation LQs
- Expected and observed mass limits, and cross-section upper limits at 95% CL.

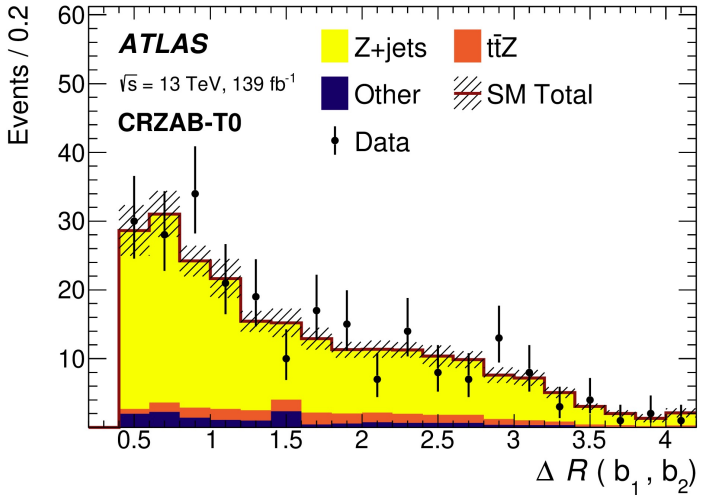


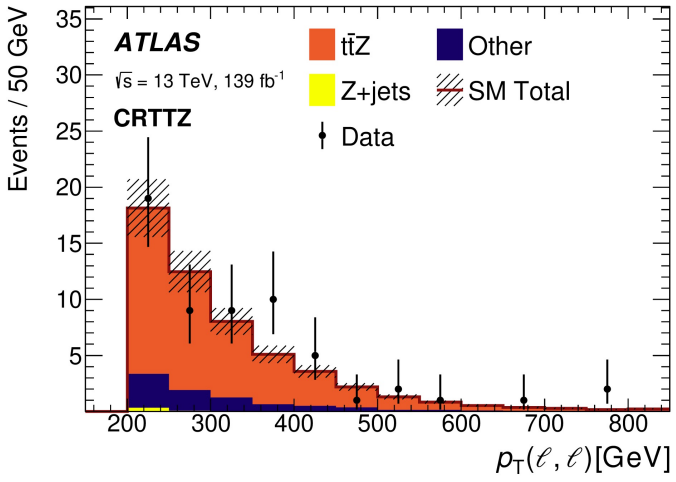
tt+MET, all-hadronic search, pair production of third-generation down-type leptoquarks arXiv:2004.14060

- Searches for tt+MET all-hadronic Supersymmetric prompt decays have sensitive to pair production of 3rd generation LQs
- Z+jets (Z), tt̄+Z (TTZ), ttbar (T), W+jets (W), and single-top (ST) backgrounds



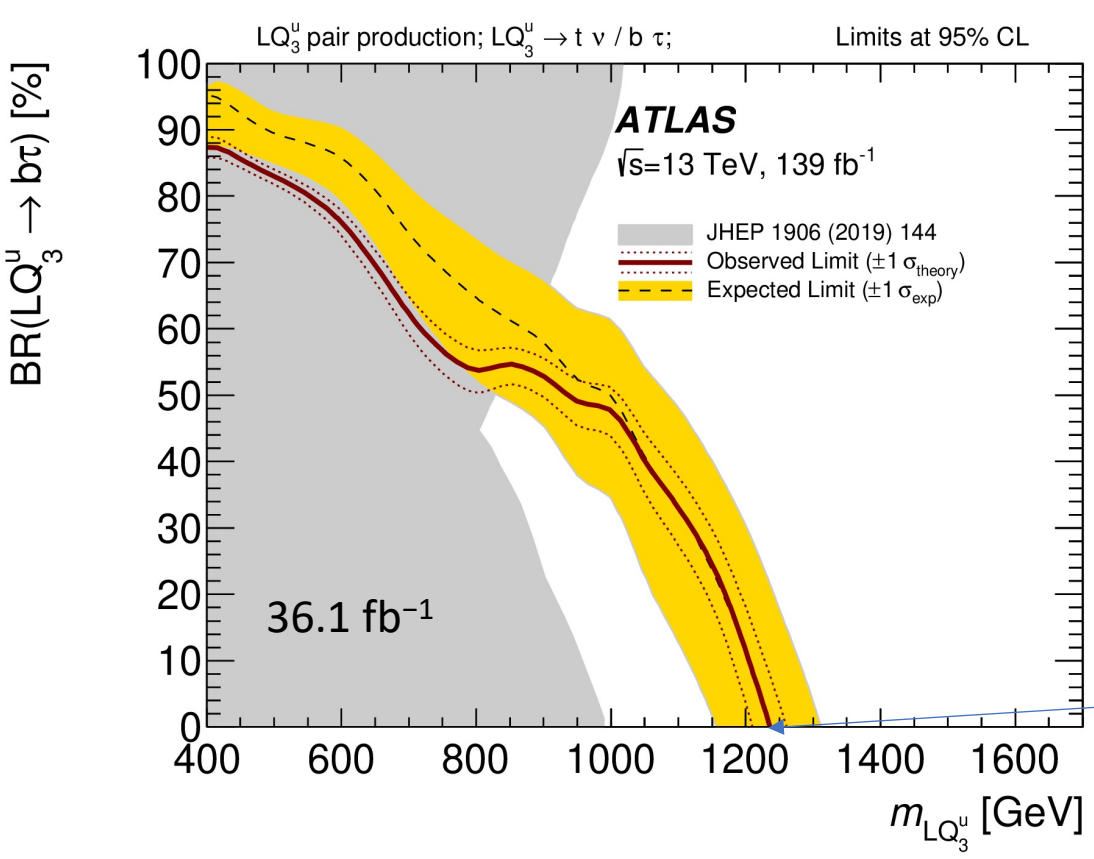


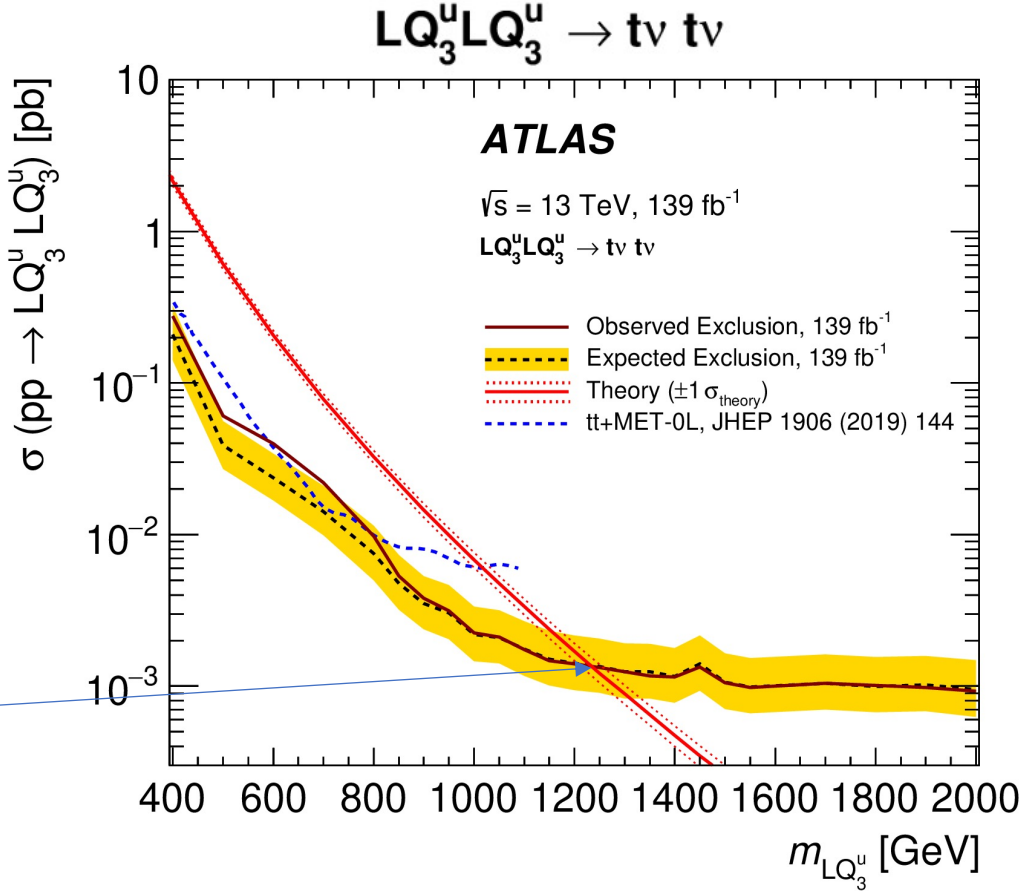




tt+MET, all-hadronic search, arXiv:2004.14060

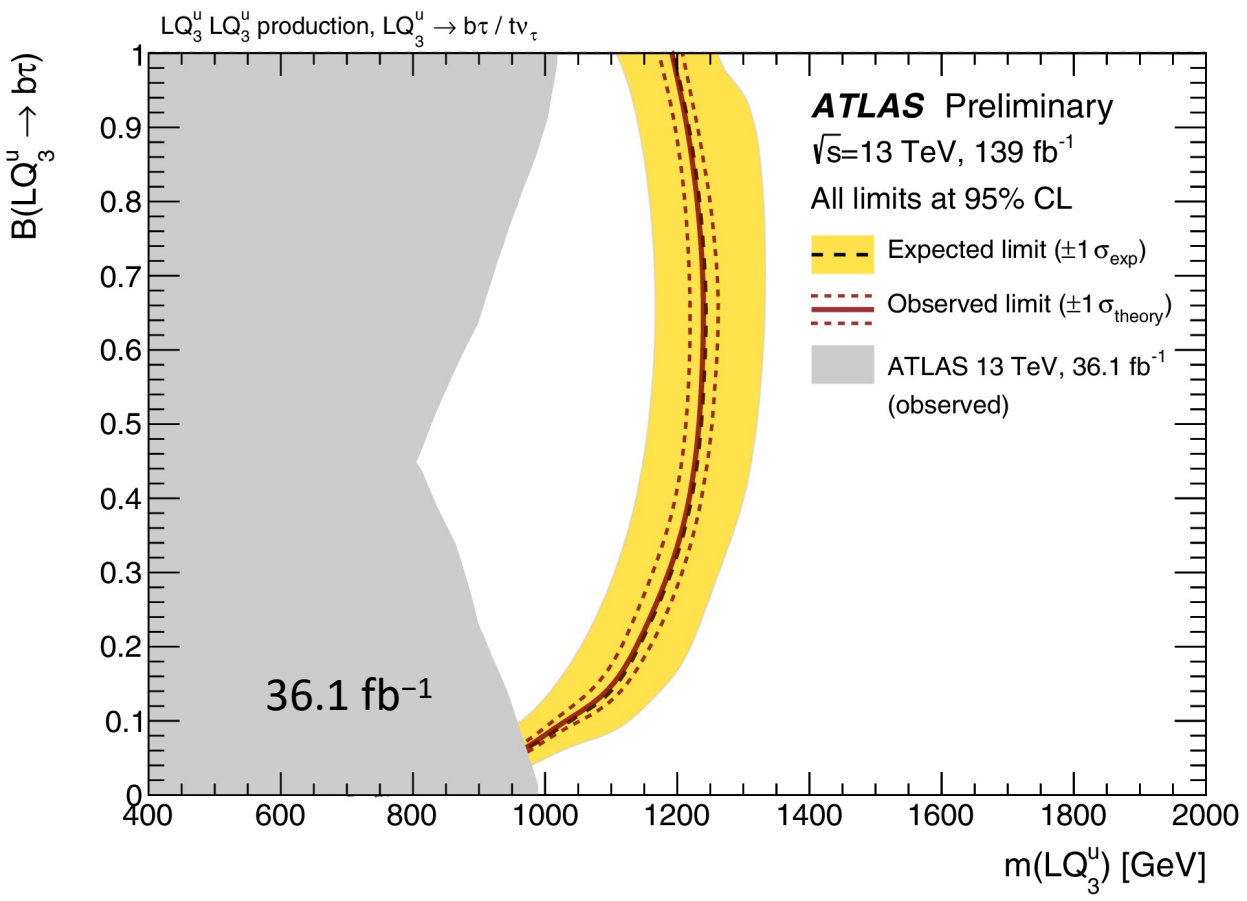
- Excluded LQ_3^u (masses, branching ratios) and cross-section limits for LQ_3^u pair-production

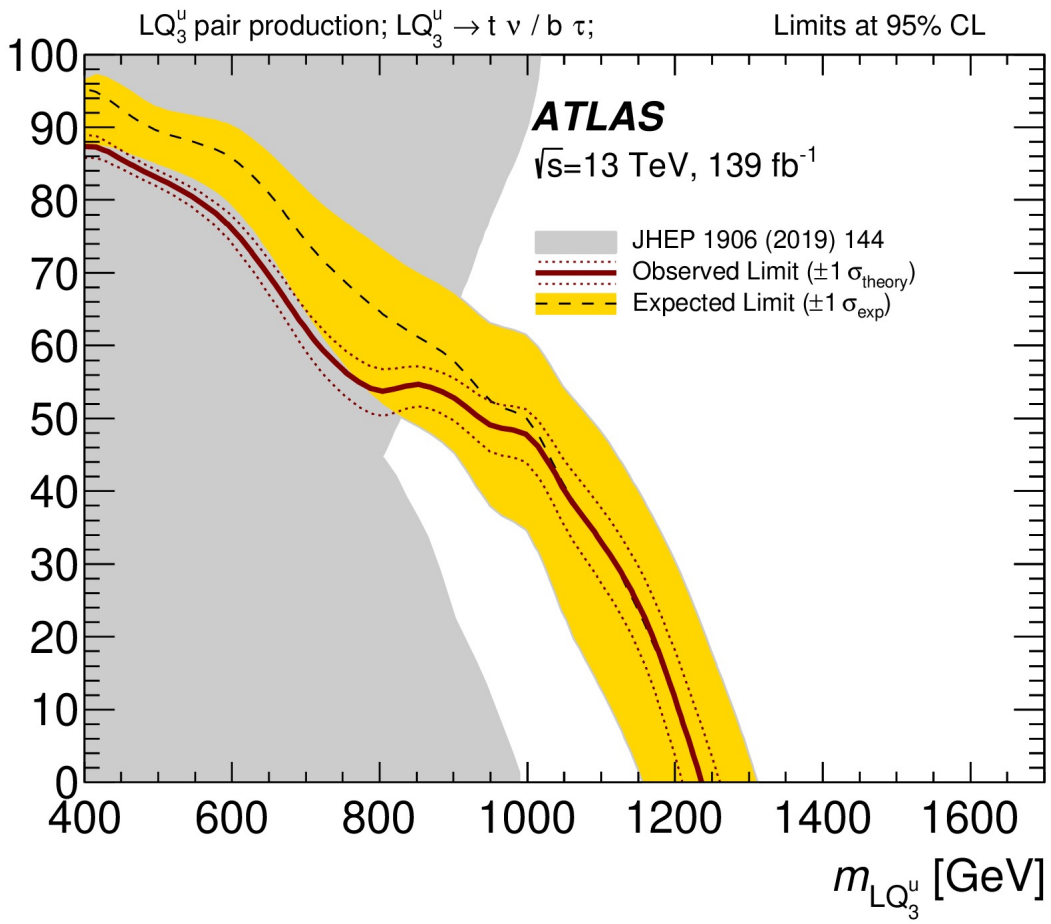




Summary: Up-type Third-Generation Model (LQ_3^u)

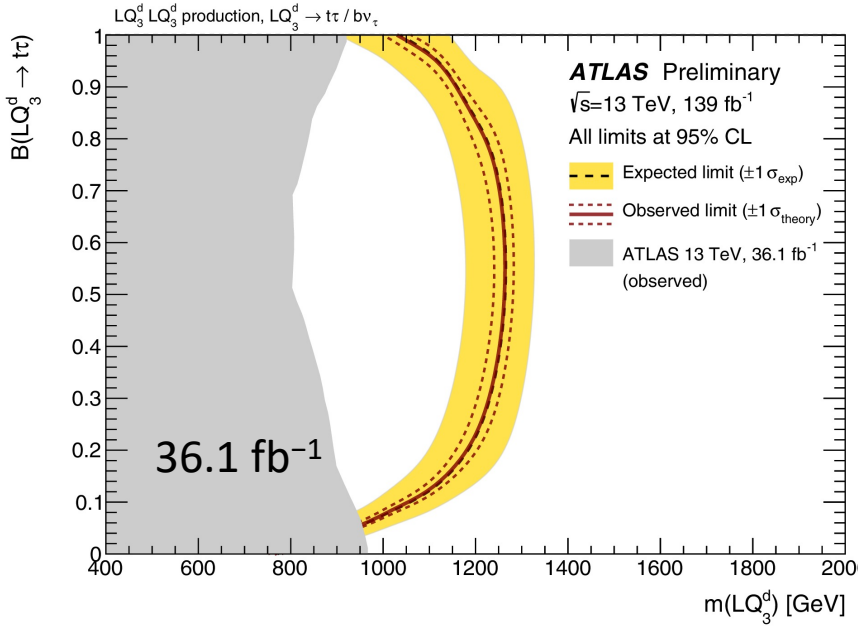
bτbν ATLAS-CONF-2021-008, stop-0ℓ EPJC **80** (2020) 737

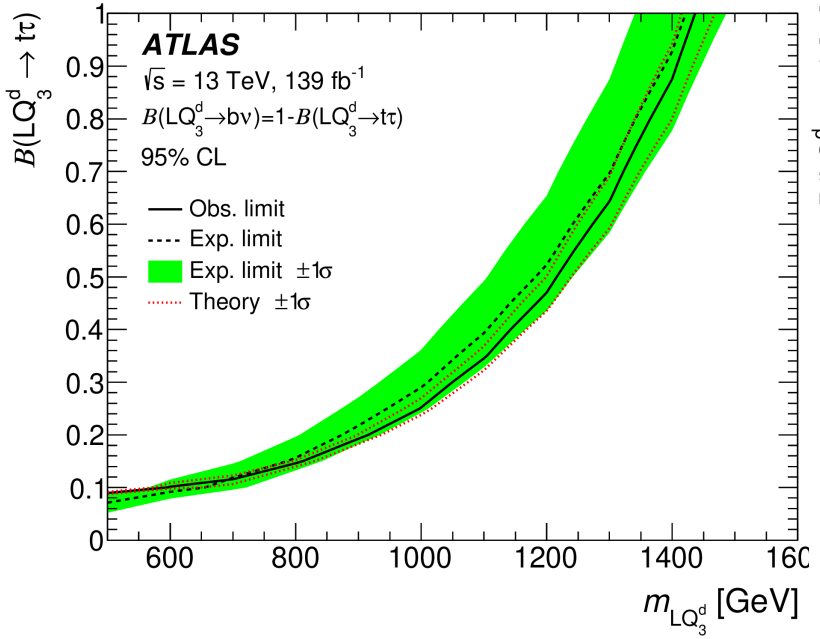


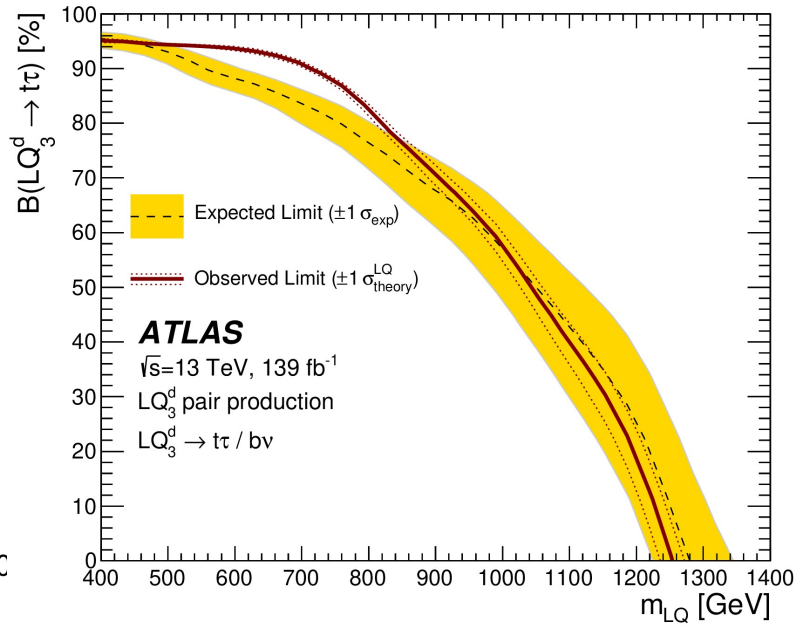


Summary: Down-type Third-Generation Model (LQ_3^d)

bτbν ATLAS-CONF-2021-008, *ττττ* arXiv:2101.11582, sbottom-0ℓ arXiv:2101.12527

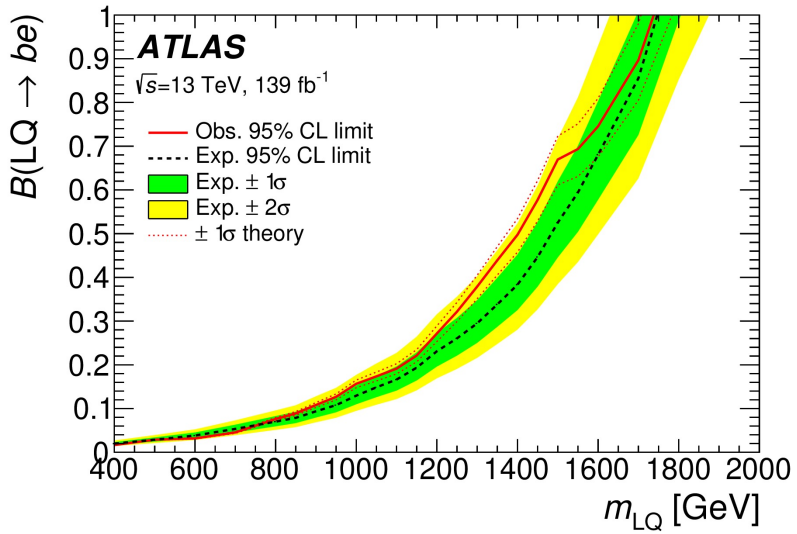


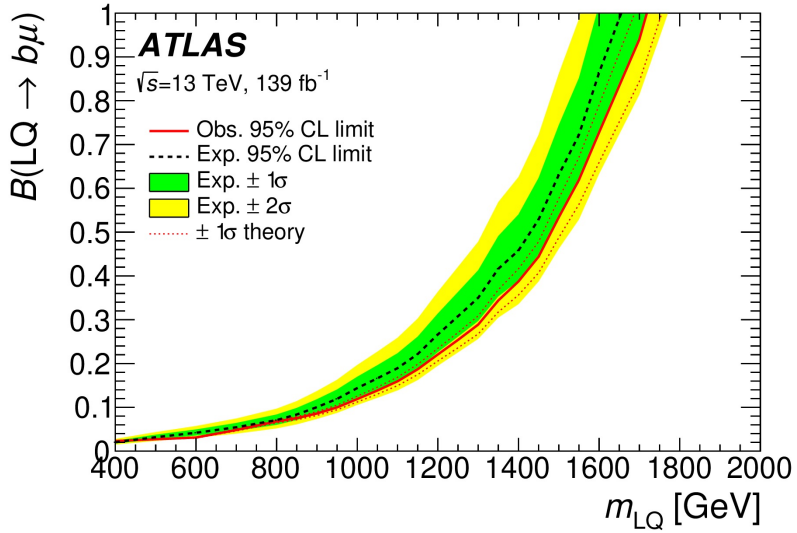




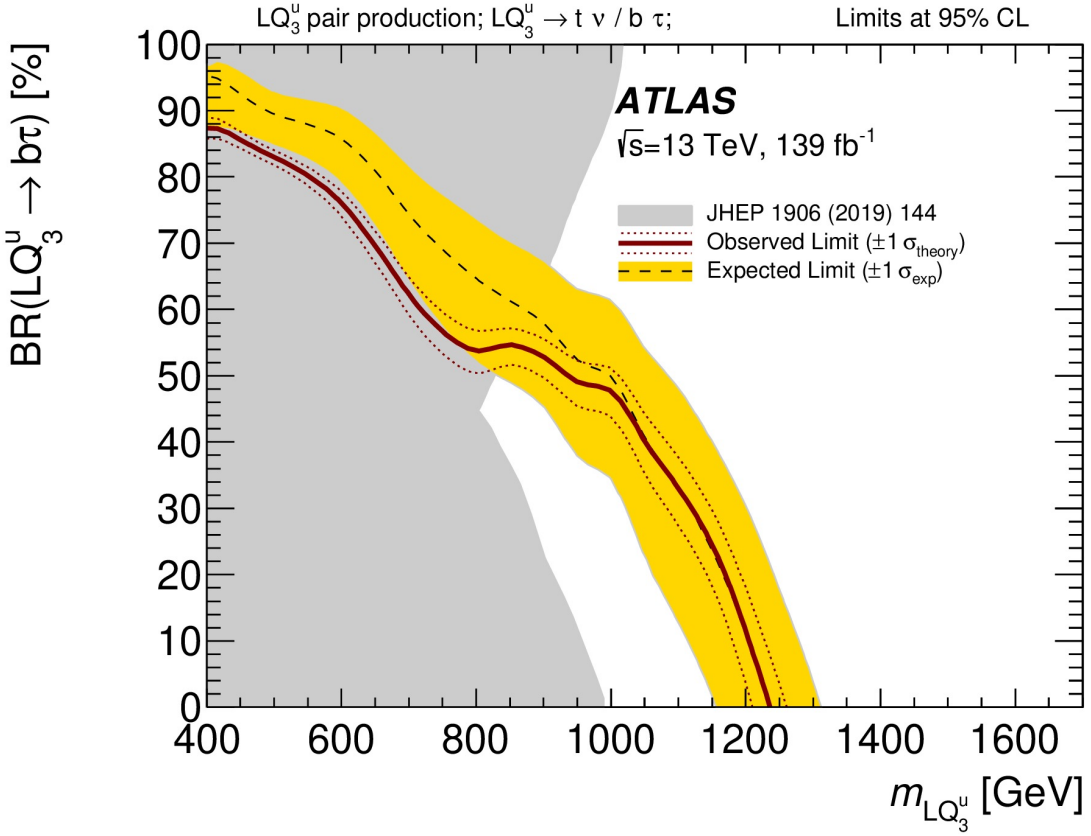
Summary: Up-type Mixed-Generation Model (LQ^{u}_{mix})

bebe, bμbμ JHEP 10 (2020) 112, stop-0ℓ be, bμ EPJC 80 (2020) 737

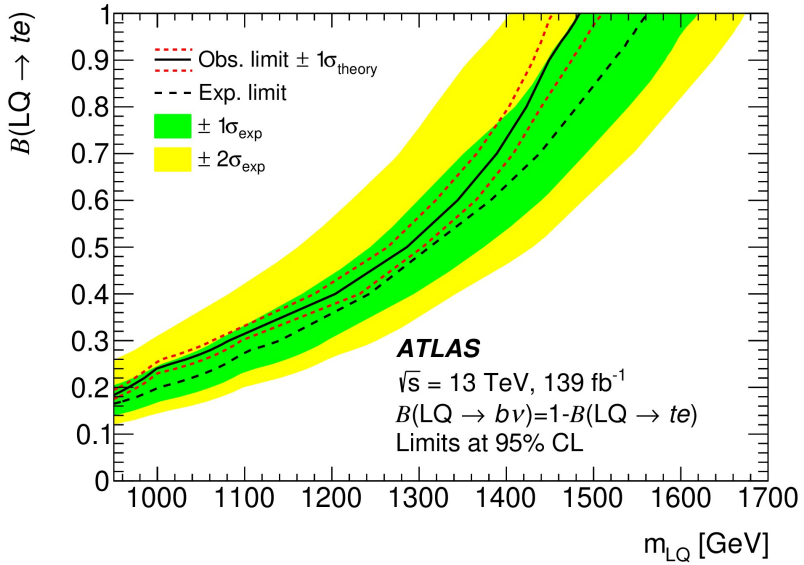


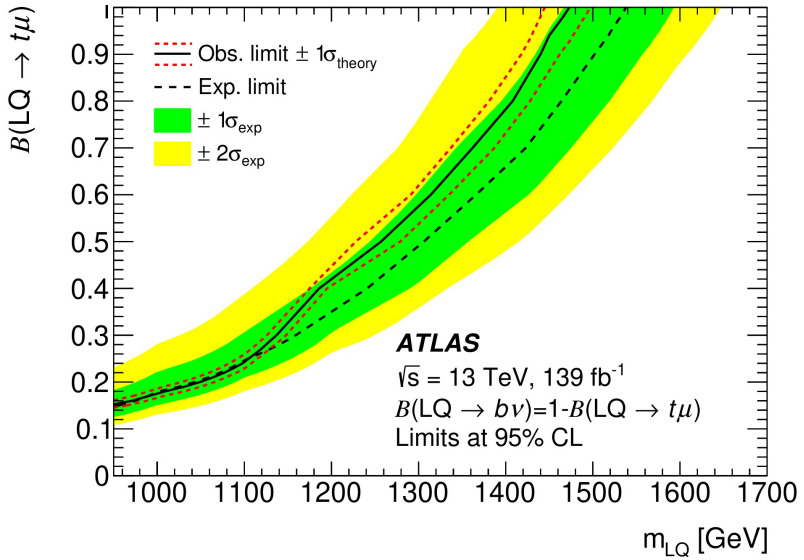


stop-0ℓ re-interpretation for mixed generation.
Published for B(LQ→bτ) limits.
Highest sensitivity for B(LQ→tν) =1.

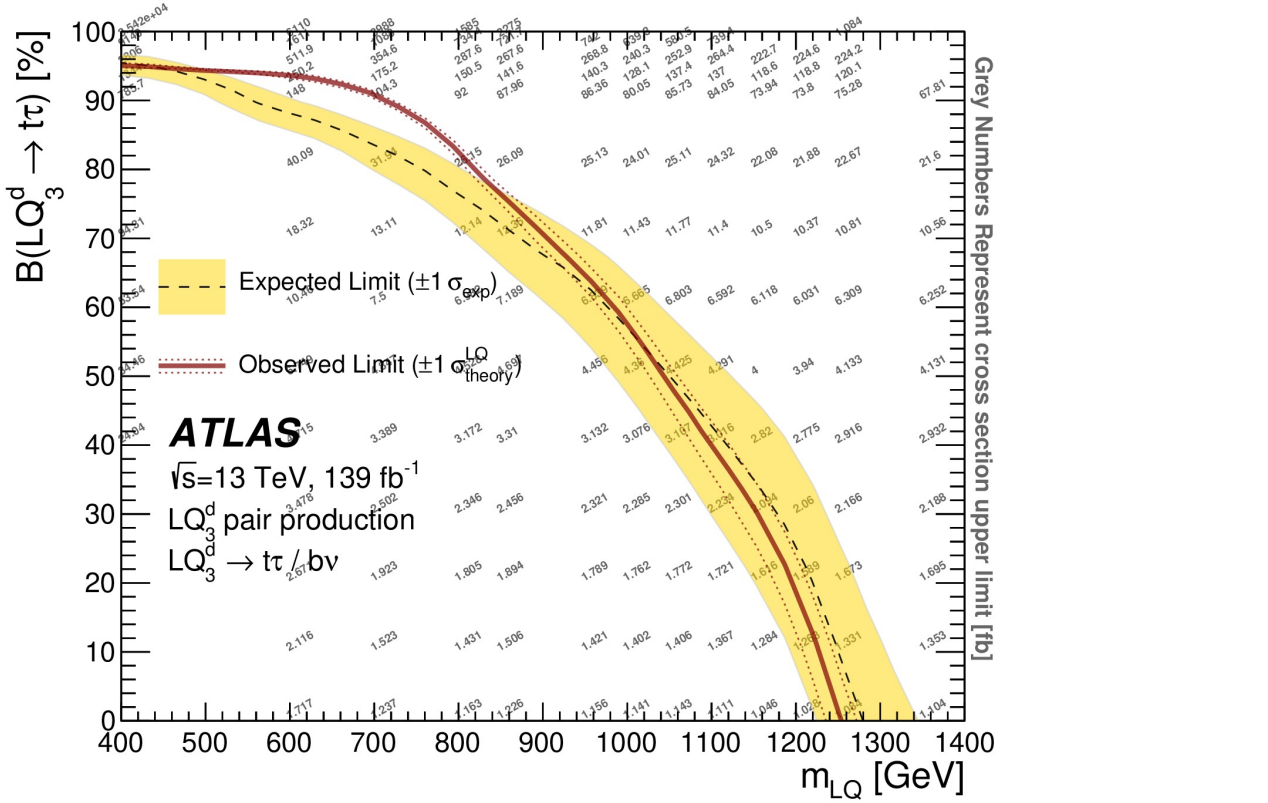


Summary: Down-type Mixed-Generation Model (LQ^{d}_{mix}) tete, tμtμ EPJC 81 (2021) 313, sbottom-0ℓ te, tμ arXiv:2101.12527

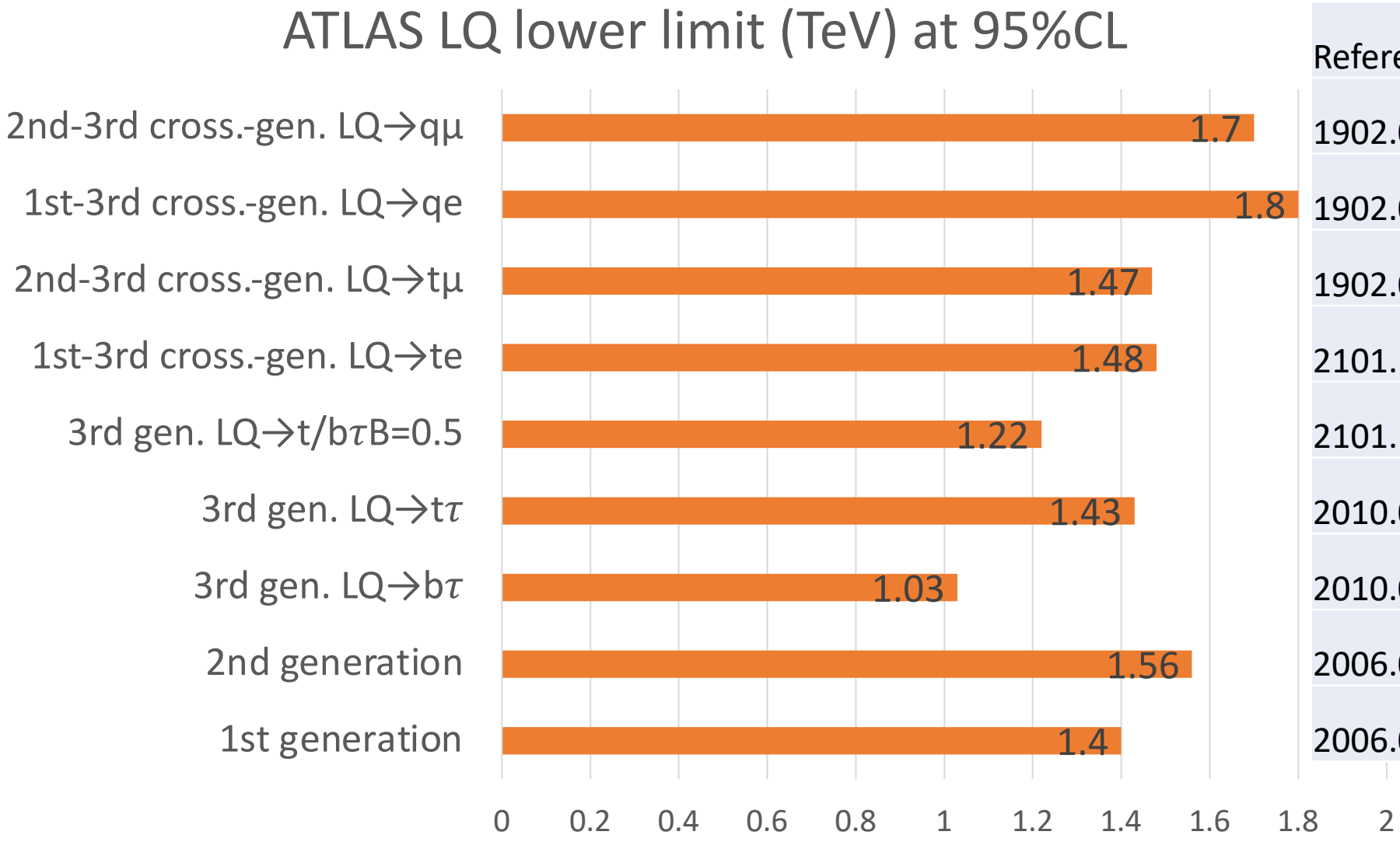




sbottom-0ℓ reinterpretation for mix-generation limits.
Published for B(LQ→tτ) limits.
Highest sensitivity for B(LQ→bυ) =1



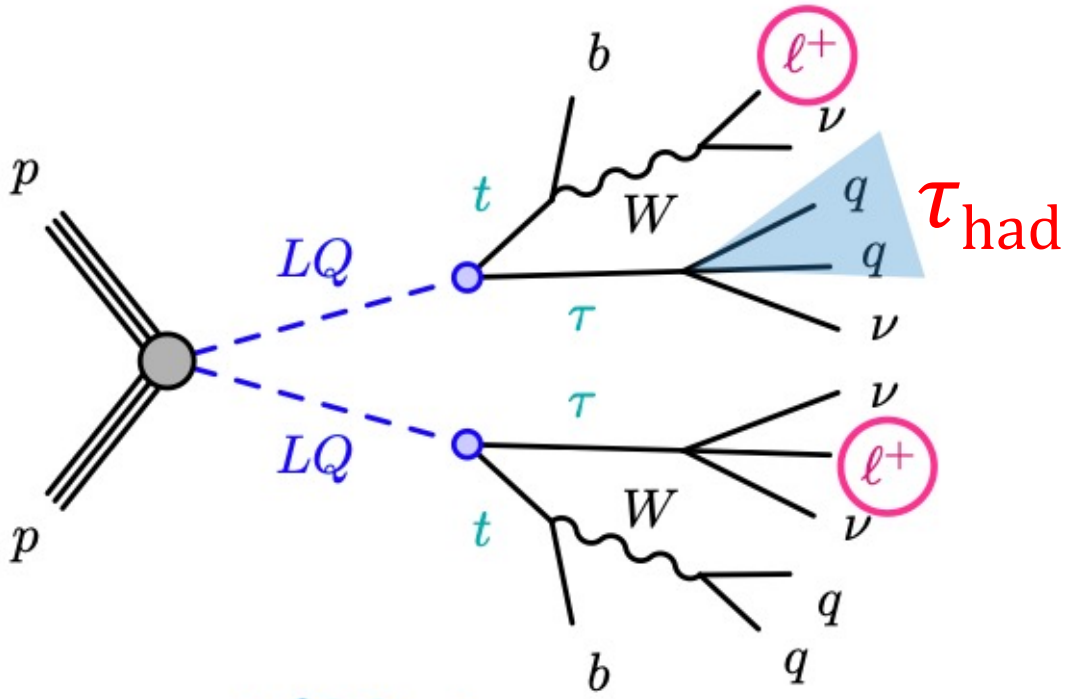
Summary

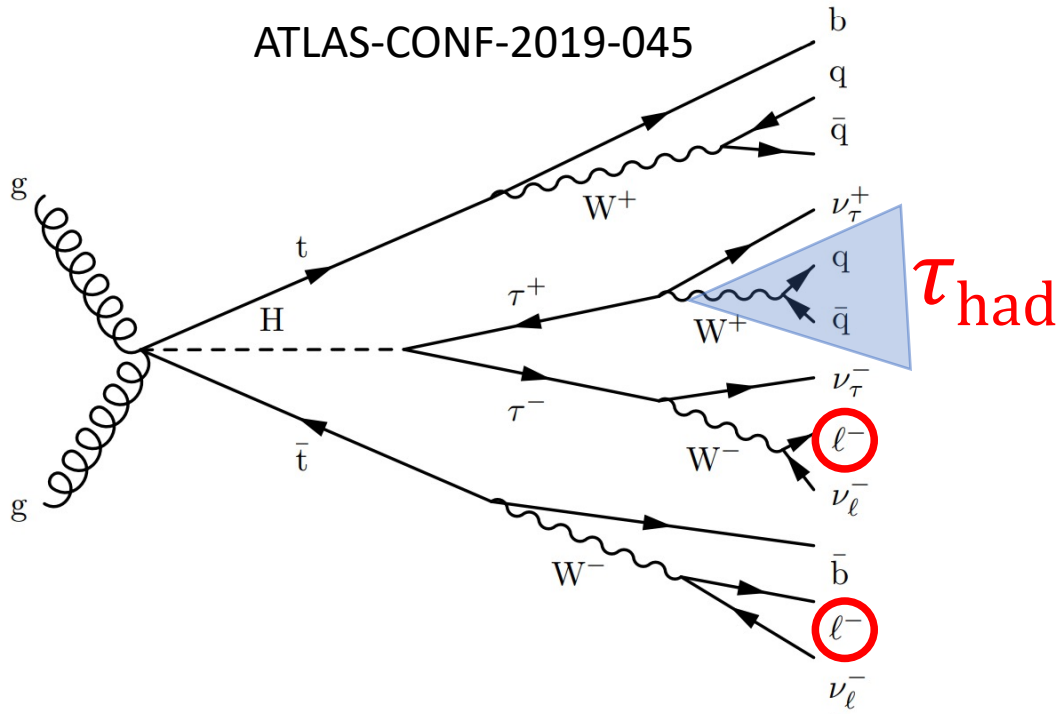


Reference	L (/fb)
1902.00377	36
1902.00377	36
1902.08103	36
2101.11582	139
2101.11582	139
2010.02098	139
2010.02098	139
2006.05872	139
2006.05872	139

Same final states for Higgs boson production and Leptoquark production

- Example LQ pair-production and ttH (H→ $\tau\tau$), 2lSS1tau(had).
- Potential for reinterpreting Higgs boson results for LQ searches.





Conclusions

- Growing interest in Leptoquarks as a possible explanation of the recently observed B-anomaly (hints for lepton flavour universality violation)
- Contact interaction limit $\Lambda/g^* > 2.0$ (2.4) TeV at 95% CL for ee ($\mu\mu$). Not sensitive yet to probe suggested range by B-anomaly (~30 TeV).
- Model-independent limits set as a function of di-lepton invariant mass.
- Current focus on 3rd generation, including cross-generational decays.
- Direct searches for Leptoquarks and re-interpretations of searches for Supersymmetry exclude phase-space of 1st, 2nd and 3rd generation Leptoquarks. Potential for reinterpretations of Higgs boson results.
- Search results statistically limited, expect more sensitivity with new data.
- Large potential in flavour physics for collaborations of phenomenologists and experimentalists.

References

- Motivated by B-anomalies

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