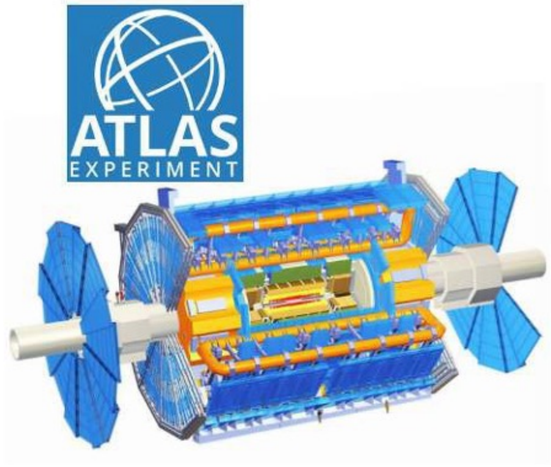
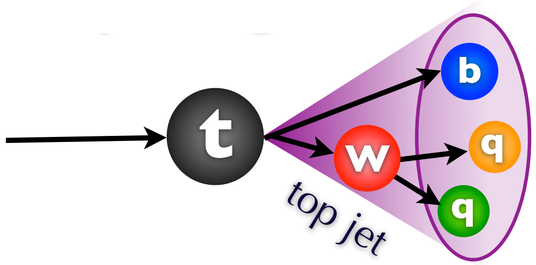
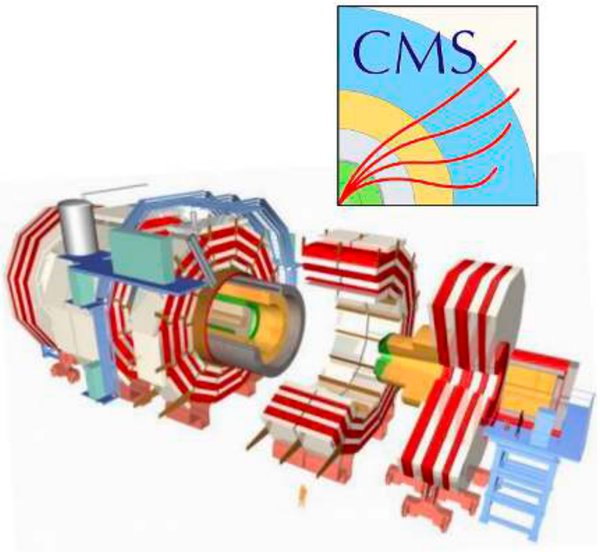
Highlights of Searches for New Particles (Vector-like Quarks/Leptoquark/W'/Z')







Atanu Pathak
On behalf of the ATLAS and CMS Collaborations

Purdue University Northwest

2023 The Mitchell Conference on Collider, Dark Matter and Neutrino Physics
May 16 - 19, 2023.
Mitchell Institute (MIST)

New results in this talk

Many physics models beyond the Standard Model predict heavy new particles preferentially decaying to at least one top quark

	EXP	ID and Links	Topology	Released
1	CMS	2111.10216	$b* \rightarrow tW \rightarrow qqb\mu/e\nu$	Nov 21
2	CMS	2202.12988	$W' \rightarrow Tb/Bt$	Feb 22
3	ATLAS	2305.03401	$T(\rightarrow Ht/Zt)qb/qt$	May 23
4	ATLAS	2210.04517	$LQLQ \rightarrow b\ell t\nu$	Oct 22
5	ATLAS	CONF-2022-052	$LQLQ \rightarrow t\ell^- t\ell^+$	Jul 22

Full Run 2 data:
139 fb^{-1} ATLAS
and 138 fb^{-1} CMS

Backup Slides Available:

	EXP	ID and Links	Topology	Released
1	CMS	2104.12853	$b* \rightarrow tW \rightarrow qqbqq$	Apr 21
2	CMS	2104.04831	$W' \rightarrow tb \rightarrow qqbb$	Apr 21
3	ATLAS	2201.07045	$T \rightarrow Ht \rightarrow bbqbb$	Jan 22
4	ATLAS	CONF-2021-043	$W' \rightarrow tb \rightarrow qqbb$	Aug 21

Beyond 2nd Generation
Preliminary Publications

Exotics Physics Searches

Heavy resonance decaying to at least one top quark

Many physics models beyond the Standard Model predict heavy new particles preferentially decaying to at least one top quark

1. Heavy resonances which decay directly to standard model particles (including top and bottom quarks)

Examples:

$Z' \rightarrow tt$, $W' \rightarrow tb$, excited quarks ($b^* \rightarrow tW$, $t^* \rightarrow tg$),
Leptoquarks ($LQ \rightarrow t\tau$, $LQ \rightarrow t\mu$, $LQLQ \rightarrow t\ell^- t\ell^+$, LQLQ → bltv), Vector-like quark (T → Ht/Zt)

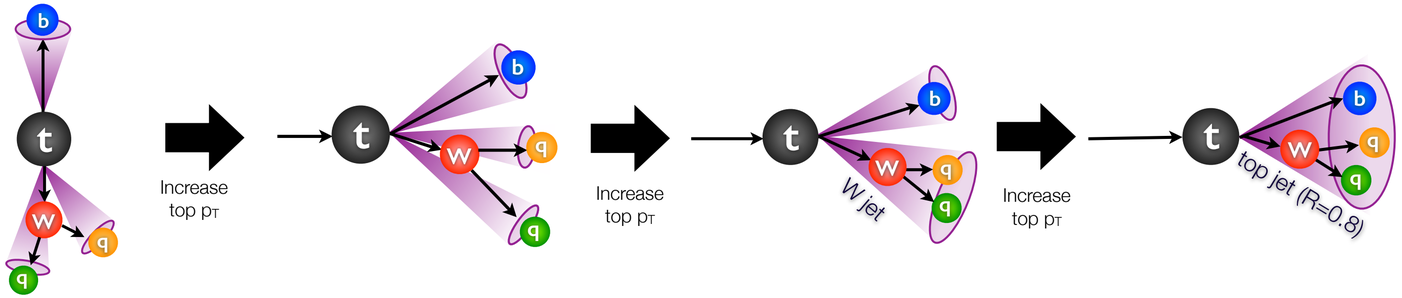
2. Heavy resonances which decay to new intermediate particles which then decay to standard model particles

Examples:

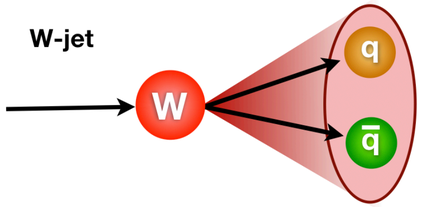
$Z' \rightarrow tT$, $Z' \rightarrow TT$, $W' \rightarrow Tb/Bt$ (T a new hypothetical heavy fermion)

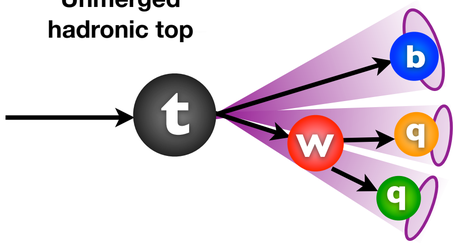
In this talk, I will present the most recent searches in these categories.

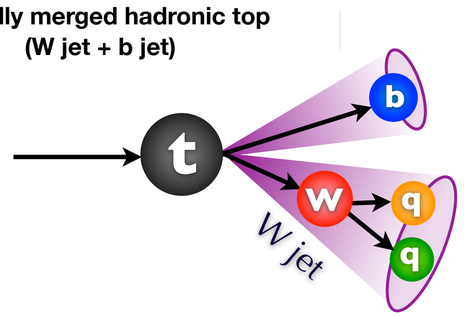
Jet-tagging Menu

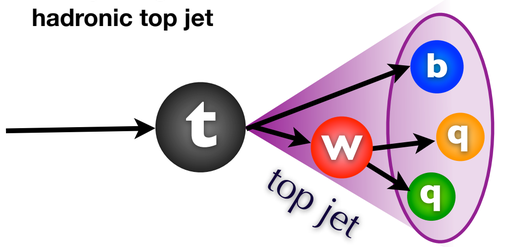


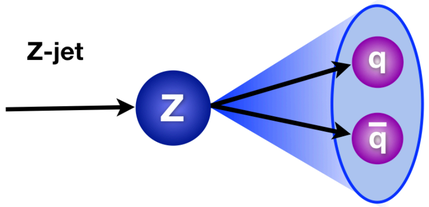
A schematic showing the way in which the subjets of a top quark decay merge with increasing p_T

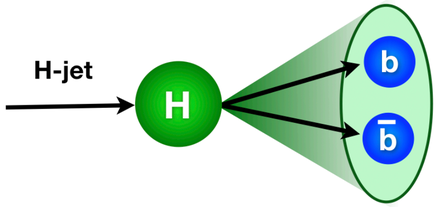


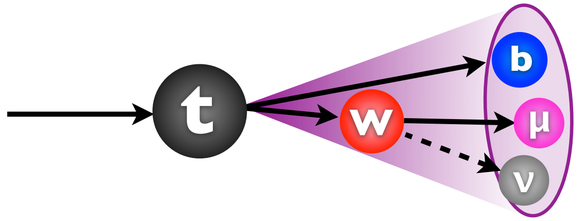












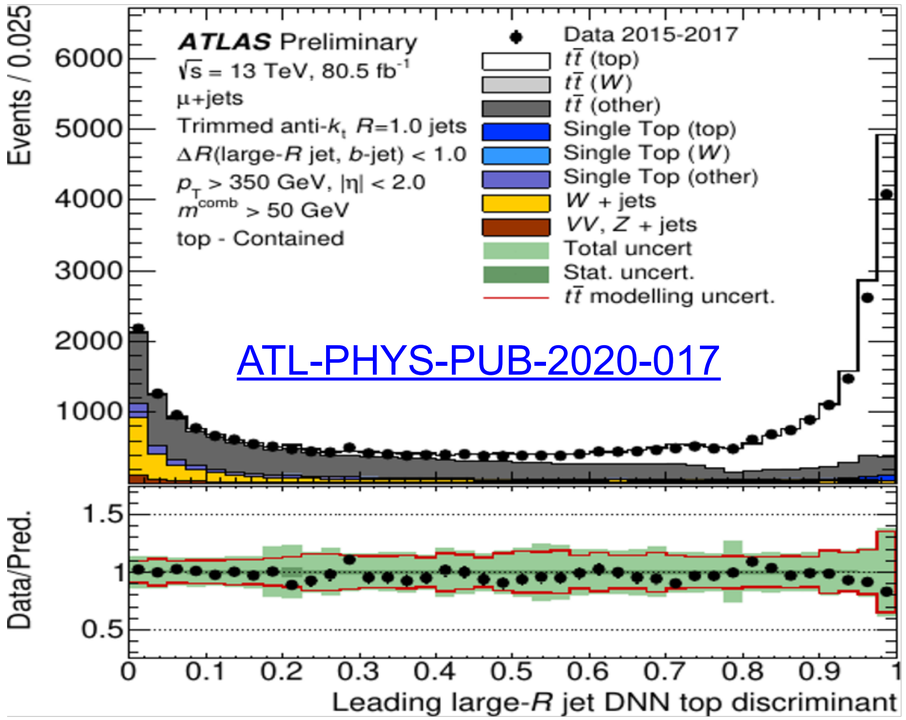
Use of jet substructure to tag partially or fully merged jets

Jet tagging tools

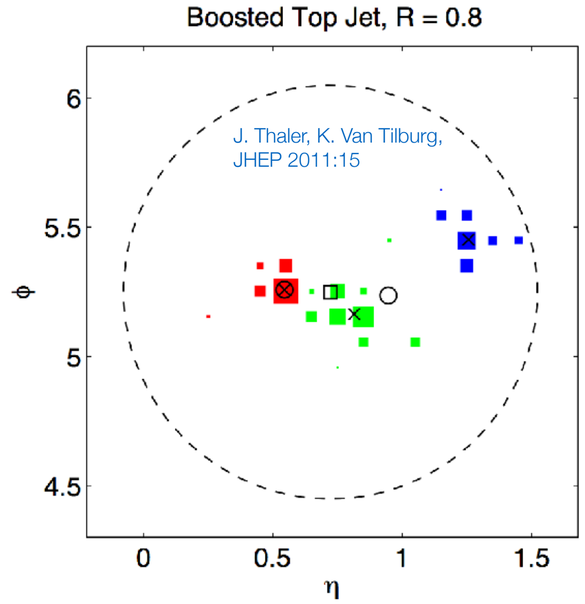
- Jet grooming
  - Soft-drop algorithm (modified mass drop algorithm)
  - Improve mass discrimination and resolution
- N-subjettiness algorithm.
  - Jet energy deposits and the number of assumed subjets, *N*, *is* τ_N
  - Better discrimination by using ratios (ex. τ_3/τ_2)

Novel Top tagger:

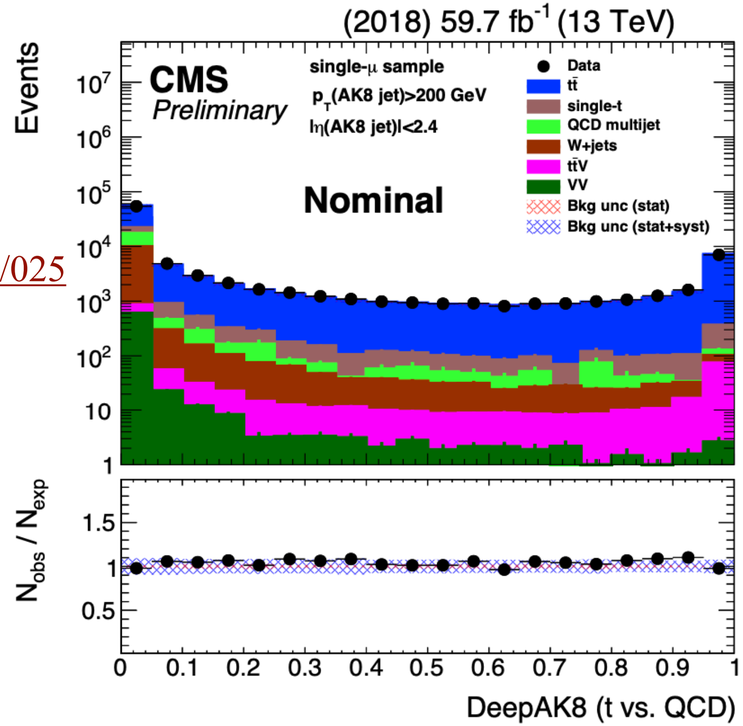
- DeepAK8 (CMS)
  - Deep Neural Network approach, Inputs: Jet constituent particle kinematic and angular information, track information, and secondary vertex information.
- ATLAS DNN Top tagger
  - Training on Deep Neural Network (DNN) with large-R jet substructure variables as input: Jet mass, jet pT, energy correlation ratios, N-subjettiness, splitting measures



ATL-PHYS-PUB-2020-017

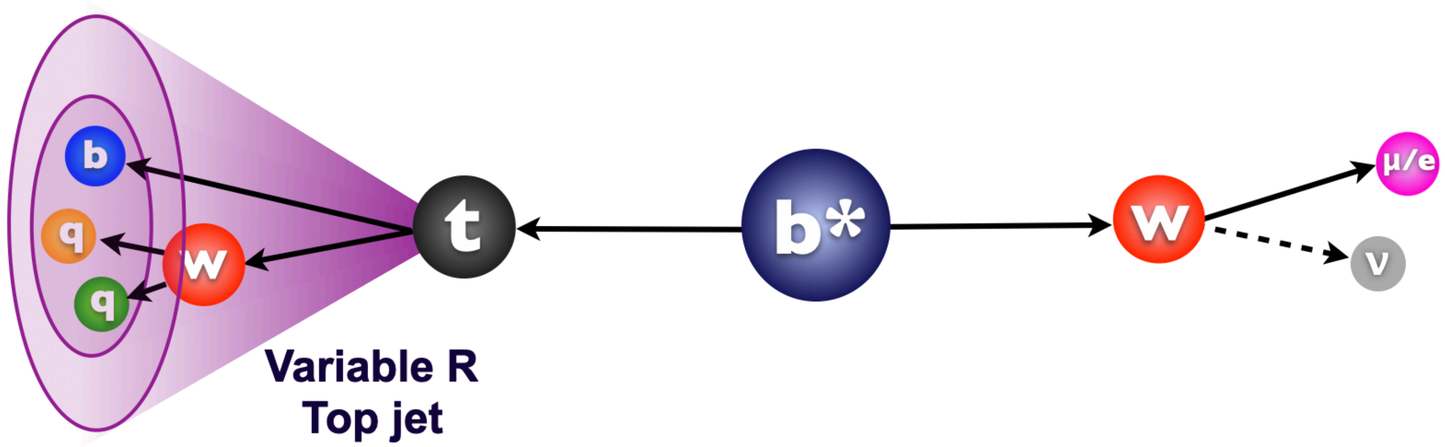


CMS DP -2020/025



Resonance decaying to a top and W in lepton+jet final state

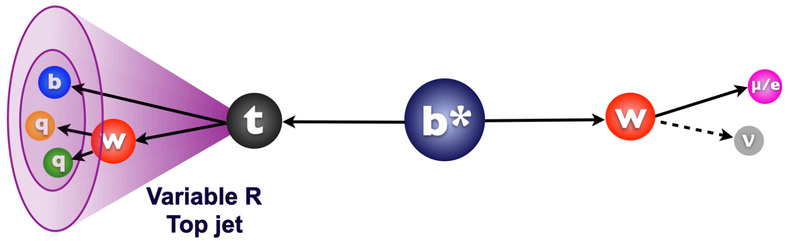
- Search for a heavy resonance which decays to a top quark and a W boson at proton-proton collisions using **CMS detector** at a center-of-mass energy of 13 TeV.
- An excited bottom quark "b*" model is used as a benchmark
- Lepton+jets final state considered.
  - Hadronic top decay
  - W-boson decays to a muon or electron and a neutrino



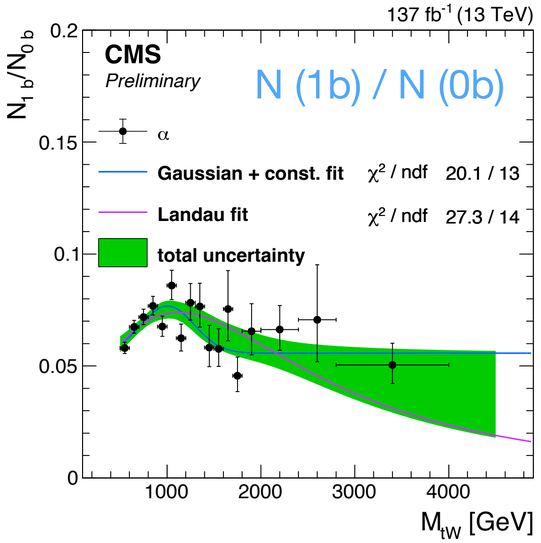
http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-20-010/index.html

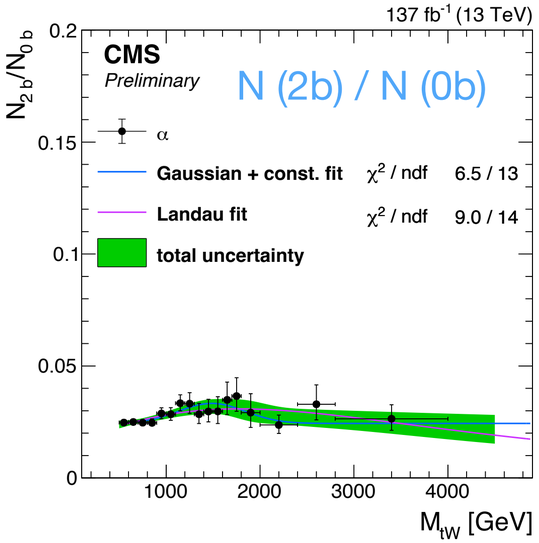
Event Selection

- Final state consists of 1 lepton, missing transverse momentum, and 1 top-tagged jet with high transverse momentum
    - Lepton in the final state allows the use of lepton triggers with lower p_T thresholds than jet triggers
- Top tag - Heavy Object Tagger with Variable R (HOTVR) algorithm is employed for the identification of collimated t decays
    - Variable R allows one to maintain efficiency at low p_T
- Neutrino is reconstructed using the W mass as a constraint.
- How much "signal-like" the event is by exploiting the signal's angular and kinematic properties.
- Categorize events based on number of b-tagged jets (N_{btags}): zero (0b), one (1b) and more than one (2b)



Search Information





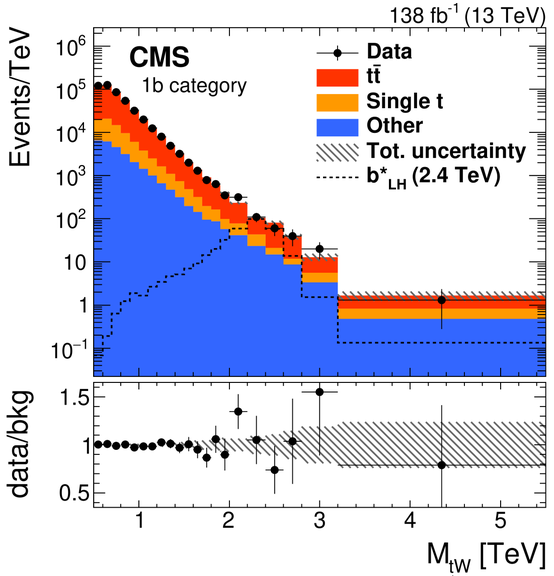
Backgrounds

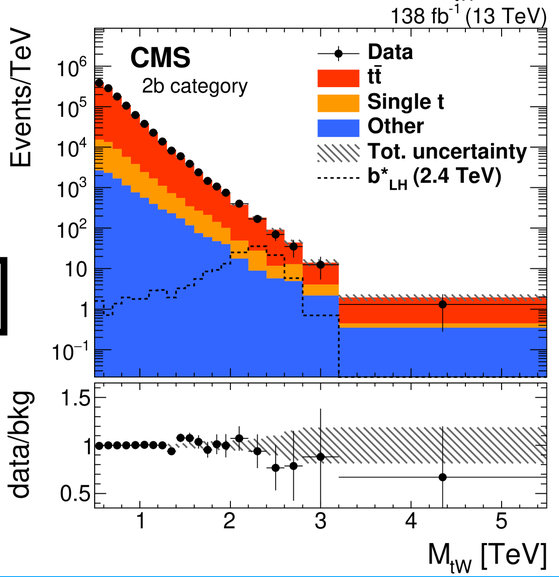
- Top quark pair production
  - Control region: 2 b-tag category is used to constrain systematic uncertainties associated with simulation
- Single Top
  - MC simulation
- Non-Top
  - Dominantly W/Z+jets and diboson with misidentified t- jets
  - Estimated with data using the 0 b-tag category
  - Transfer function (alpha method)

Search

- Binned maximum likelihood fit
- b* mass is reconstructed from the tW mass

CMS-B2G-20-010

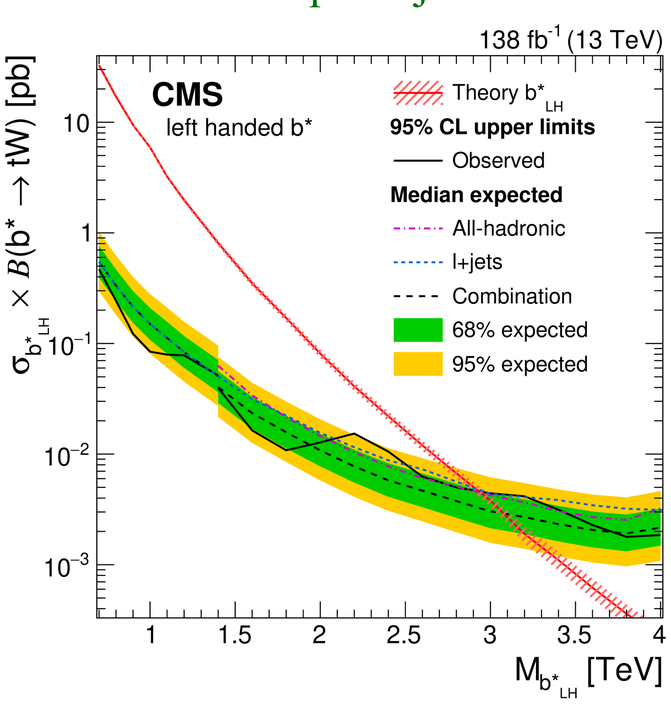


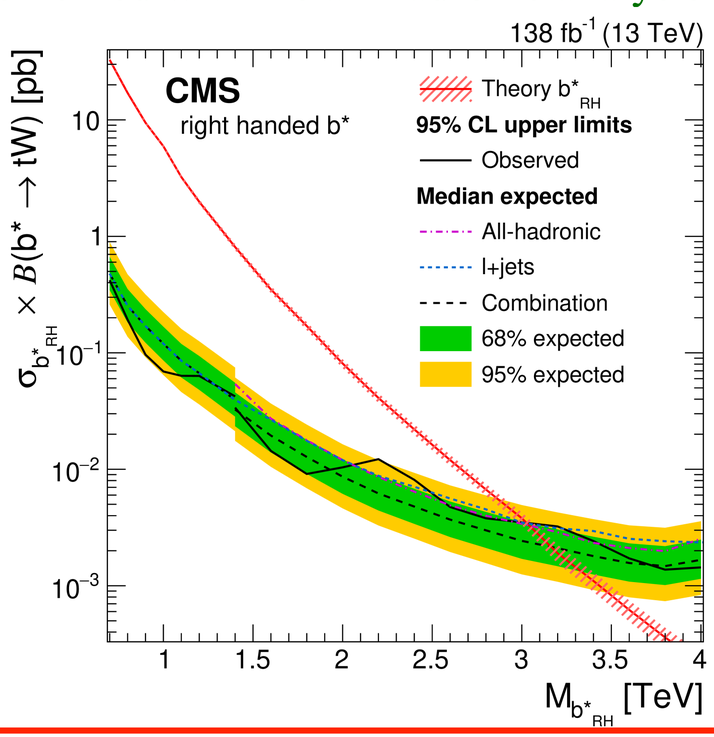


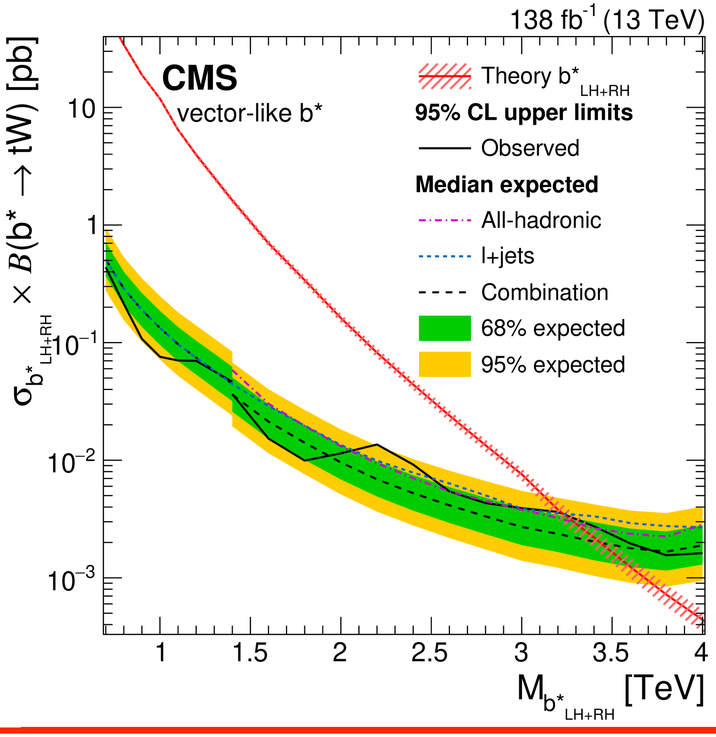
Results

- No significant excess above the standard model background is observed.
- Limits set on the production cross section for LH, RH, and LH+BH are excluded at 95% CL for masses below 2.6, 2.8, and 3.1 TeV, respectively (Sensitivity limited by ttbar and single top modeling)
- Lepton+jets results are combined with the all-hadronic analysis

CMS-B2G-20-010



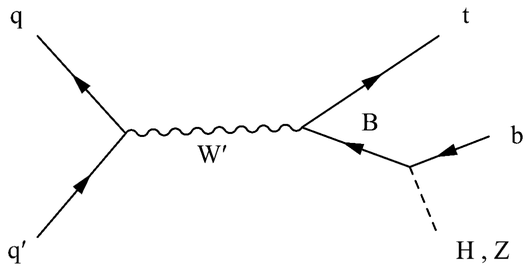


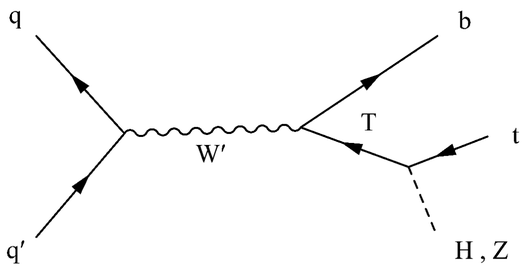


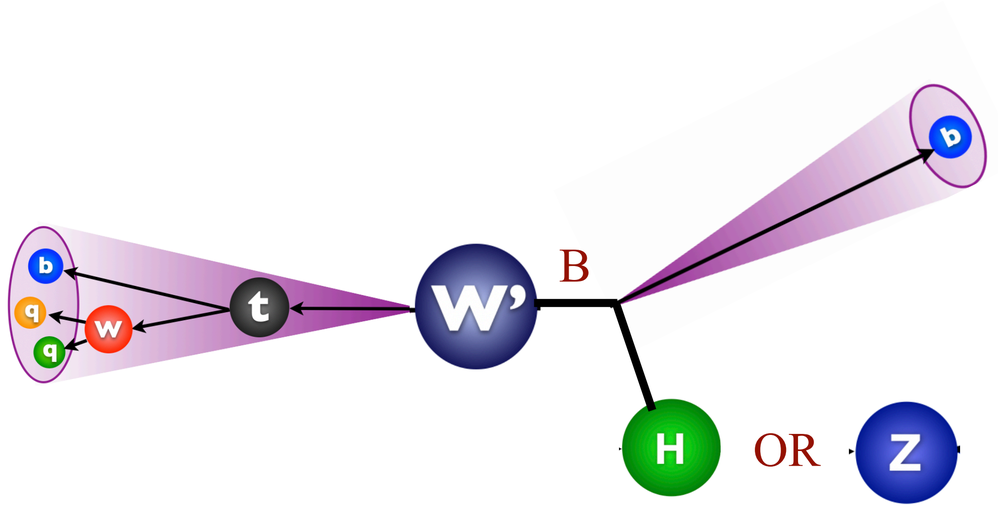
These are the most stringent limits on the b* quark mass to date, extending the previous best mass limits (CMS-B2G-17-018) by almost a factor of two.

W' decaying to a Vector-like quark and a top or bottom

- W' boson, spin-1 gauge boson, is predicted in numerous models including Little Higgs, extra dimensional, and left-right symmetric models.
- A search is performed for W' bosons decaying to a B or T vector-like quark and a top or a bottom quark in proton-proton collisions using **CMS detector** at a center-of-mass energy of 13 TeV.
- All-jets final state considered.







http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-20-002/index.html

Event Selection

- Event with at least two AK8 (t, H/Z) with $p_T > 400$ GeV and one AK4 jet with $p_T > 200$ GeV is required, with $105 < m_{SD}(H) < 140$ GeV , $65 < m_{SD}(Z) < 105$ GeV and $140 < m_{SD}(t) < 220$ GeV
- Top tag:
  - $\text{ImageTop}_{\text{MD}}$ tagger is used for t tagging of AK8 jets.
- Higgs tagging:
  - A dedicated double-b tagging algorithm is used
  - SD algorithm is used to extract $m\text{SD(H)}$ to measure of the jet mass
- Z tagging:
  - τ_{21} is used for Z boson hadronic decays, and
  - mSD is required to select a jet within the Z boson mass range
- b-tag:
  - DEEPJET b tagging algorithms is used for b-tagging of AK4 jets

Label	Tag	Discriminant	Mass
Tight	H	$0.6 < \text{Dbtag}$	$105 < m_{\text{SD}}(\text{H}) < 140\,\text{GeV}$
	Z	$\tau_{21} < 0.45$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.9 < \text{imageTop}_{\text{MD}}$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Medium	H	$0 < \text{Dbtag} < 0.6$	$105 < m_{\text{SD}}(\text{H}) < 140\,\text{GeV}$
	Z	$0.45 < \tau_{21} < 0.6$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.3 < \text{imageTop}_{\text{MD}} < 0.9$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Inverted	H	$-1 < \text{Dbtag} < 0$	$5 < m_{\text{SD}}(\text{H}) < 30\,\text{GeV}$
	Z	$0.6 < \tau_{21} < 1$	$5 < m_{\text{SD}}(\text{Z}) < 30\,\text{GeV}$
	t	$0 < \text{imageTop}_{\text{MD}} < 0.3$	$30 < m_{\text{SD}}(\text{t}) < 65\,\text{GeV}$

Search Information

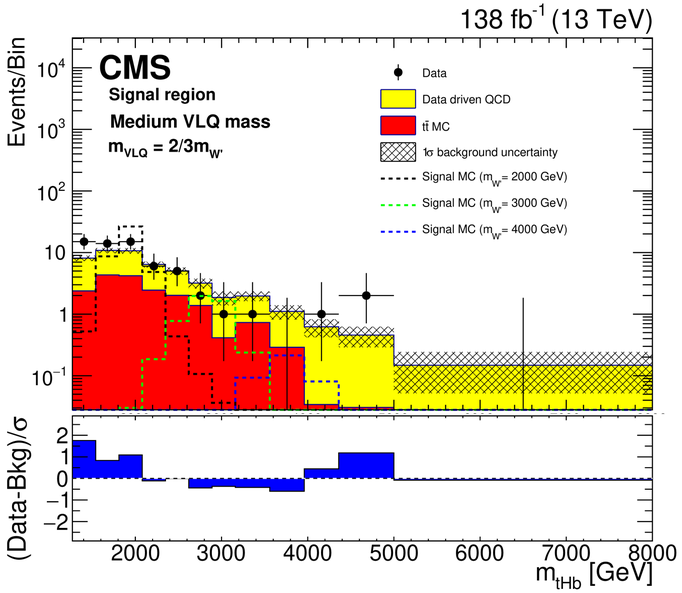
Backgrounds

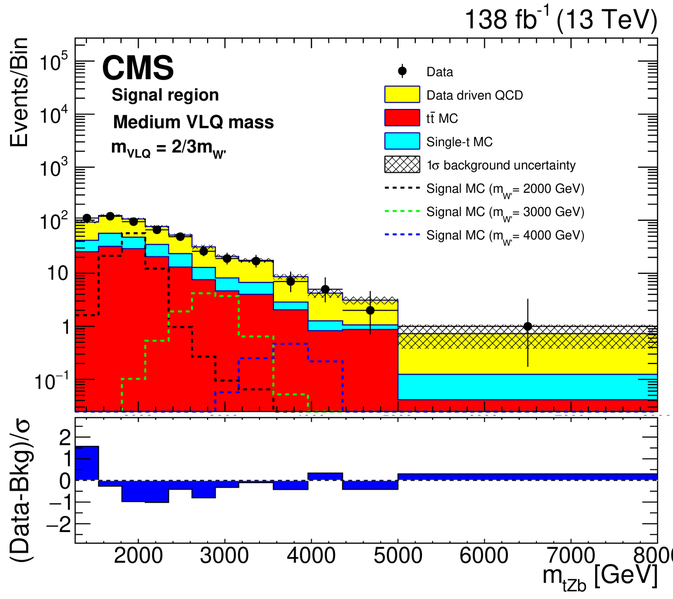
- QCD Multijet
  - Dominant
  - Data-driven background estimation
    - Use control regions that are selected with identical kinematic criteria to the signal region, but with a reduced acceptance for signal events.
- Top quark pair production
  - Estimated with simulation and validated with data

Search

- The signal and expected background m_{tHb} or m_{tZb} distribution are compared with data.(Reconstructed $m_{W'}$, assuming the medium VLQ mass hypothesis)

CMS-B2G-20-002

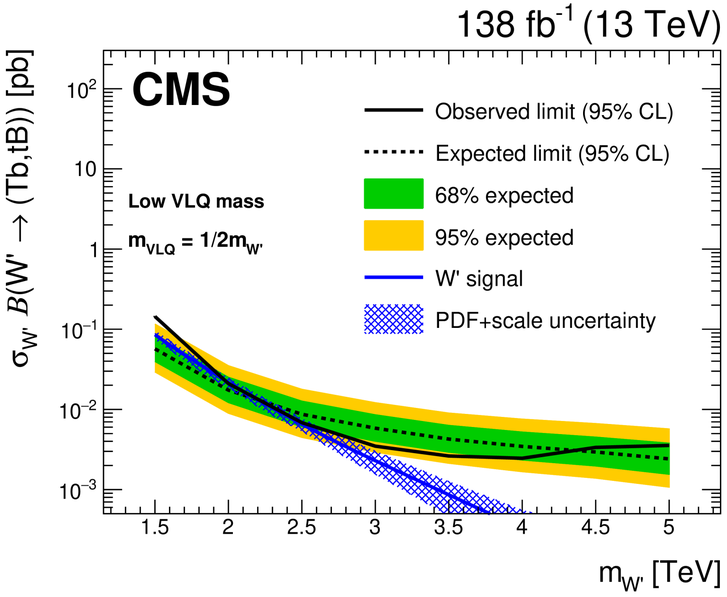


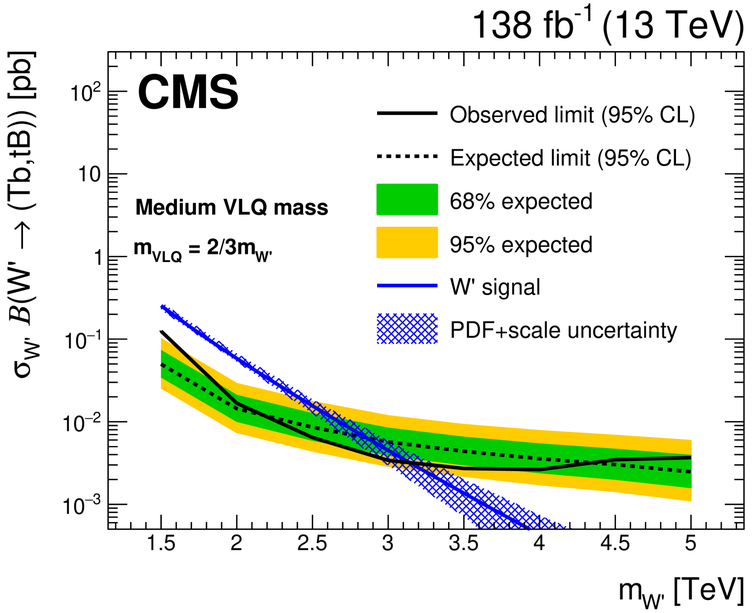


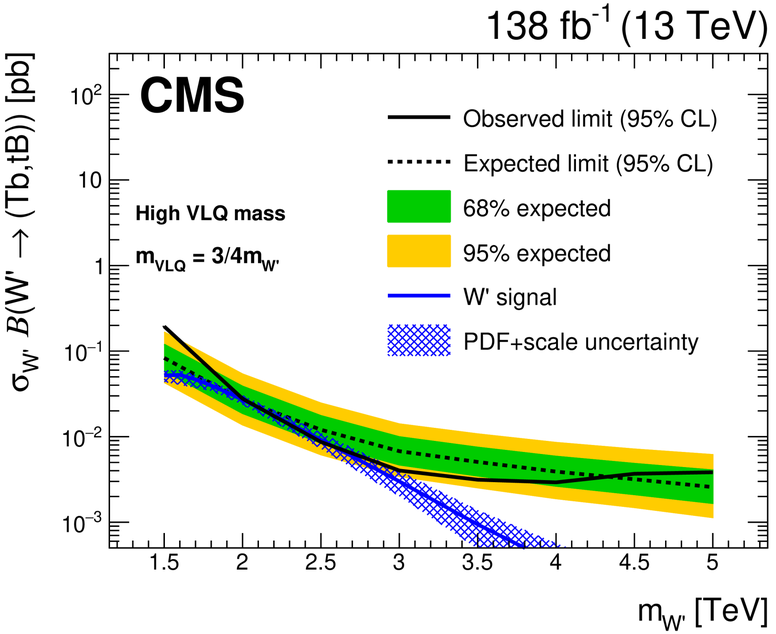
Results

- No significant excess above the standard model background is observed.
- **First** limits set on the production cross section for W′ bosons for the medium VLQ mass case
  - excluded for masses below 3.1 TeV at 95% confidence level.
  - Sensitivity limited by ttbar and single top modeling
- The low and high VLQ mass benchmarks have a lower W′ → VLQ branching fraction, and the sensitivity is not sufficient to set mass exclusion limits.

CMS-B2G-20-002

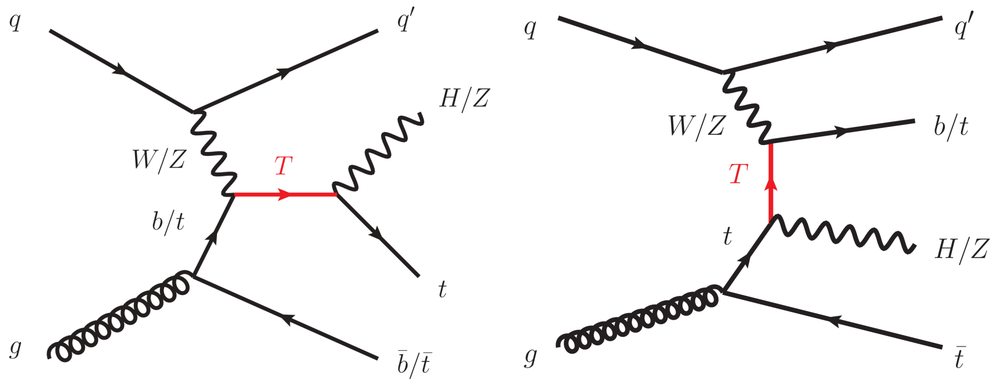


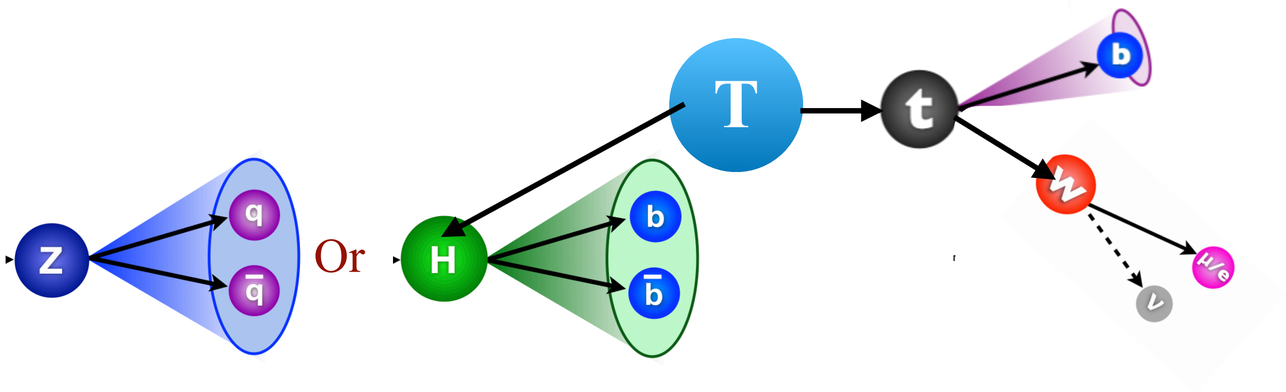




Vector-like T quark decaying into Higgs or Z and top quark

- Vector-like quarks are hypothetical spin-1/2 particles that arise in various models that address problems in the SM such as the hierarchy problem. Vector-like quarks are expected to couple preferentially to third-generation quarks.
- A search is performed for Vector-like T quark decaying to a Higgs boson and a top quark (Ht) **or** Z boson and a top quark (Zt) in proton-proton collisions using **ATLAS detector** at a center-of-mass energy of 13 TeV.
- Single lepton with multiple jets and *b*-jets final state are considered.





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2018-52/

Event Selection

- Events must have at least one lepton (e or mu), three small-R jets, at least one b-tagged jets and $m_{eff} > 600$ GeV. $M_{eff} = \sum_{Jet,e,\mu} P_t + MET$
- Top tag:
  - Boosted leptonic top-quark candidate is required to have $p_T > 300$ GeV, b-jet is required to be within $\Delta R = 1.5$ of the leptonic W-boson candidate.
- Higgs/V(W/Z) tagging:
  - Higgs boson: the small-R jet with $p_T > 350$ GeV mass to be between 100 and 140 GeV
  - W or Z boson: have $p_T > 350$ GeV, and a mass between 70 and 105 GeV.
- b-tag:
  - The algorithm used is known as DL1, a DNN-based tagging scheme that uses the secondary vertex information and the impact parameters of the charged tracks in a VRTrack jet

Fit regions

Jet mult.	b-tag mult.	Region	Targeted signal / bkg
3–5	1	LJ, 1b, ≥1fj, 0(t_h+t_l), 0H, ≥1V	$T(\rightarrow Zt)qb$
		LJ, 1b, ≥1fj, 0t_h, ≥1t_l, 0H, ≥1V	
	2	LJ, 2b, ≥1fj, 0(t_h+t_l), 0H, ≥1V	
		LJ, 2b, ≥1fj, 0t_h, ≥1t_l, 0H, ≥1V	
	3	LJ, 3b, ≥1fj, 0(t_h+t_l), ≥1H, 0V	$T(\rightarrow Ht)qb$
		LJ, 3b, ≥1fj, 0t_h, ≥1t_l, ≥1H, 0V	
		LJ, 3b, ≥1fj, ≥1t_h, 0t_l, ≥1H, 0V	
	≥4	LJ, ≥4b, ≥1fj, 0(t_h+t_l), ≥1H, 0V	
		LJ, ≥4b, ≥1fj, 0t_h, ≥1t_l, ≥1H, 0V	
		LJ, ≥4b, ≥1fj, ≥1t_h, 0t_l, ≥1H, 0V	
		LJ, ≥4b, 0fj, ≥1t_l, 0H, 0(V+t_h)	$t\bar{t}$+≥1b, $t\bar{t}$+≥1c
≥6	1	HJ, 1b, ≥1fj, 0t_h, 1t_l, 0H, ≥1V	$T(\rightarrow Zt)qt$
		HJ, 1b, ≥1fj, 1t_h, 0t_l, 0H, ≥1V	
		HJ, 1b, ≥1fj, ≥2(t_h+t_l), 0H, ≥1V	
	2	HJ, 2b, ≥1fj, 0t_h, 1t_l, 0H, ≥1V	
		HJ, 2b, ≥1fj, 1t_h, 0t_l, 0H, ≥1V	
		HJ, 2b, ≥1fj, ≥2(t_h+t_l), 0H, ≥1V	
	3	HJ, 3b, ≥1fj, 1t_l, ≥1H, 0(V+t_h)	$T(\rightarrow Ht)qt$
		HJ, 3b, ≥1fj, 0t_l, ≥1H, 1(V+t_h)	
		HJ, 3b, ≥1fj, ≥1H, ≥2(V+t_l+t_h)	
	≥4	HJ, ≥4b, ≥1fj, 1t_l, ≥1H, 0(V+t_h)	
		HJ, ≥4b, ≥1fj, 0t_l, ≥1H, 1(V+t_h)	
		HJ, ≥4b, ≥1fj, ≥1H, ≥2(V+t_l+t_h)	
		HJ, ≥4b, 0fj, ≥1t_l, 0H, 0(V+t_h)	$t\bar{t}$+≥1b, $t\bar{t}$+≥1c

Search Information

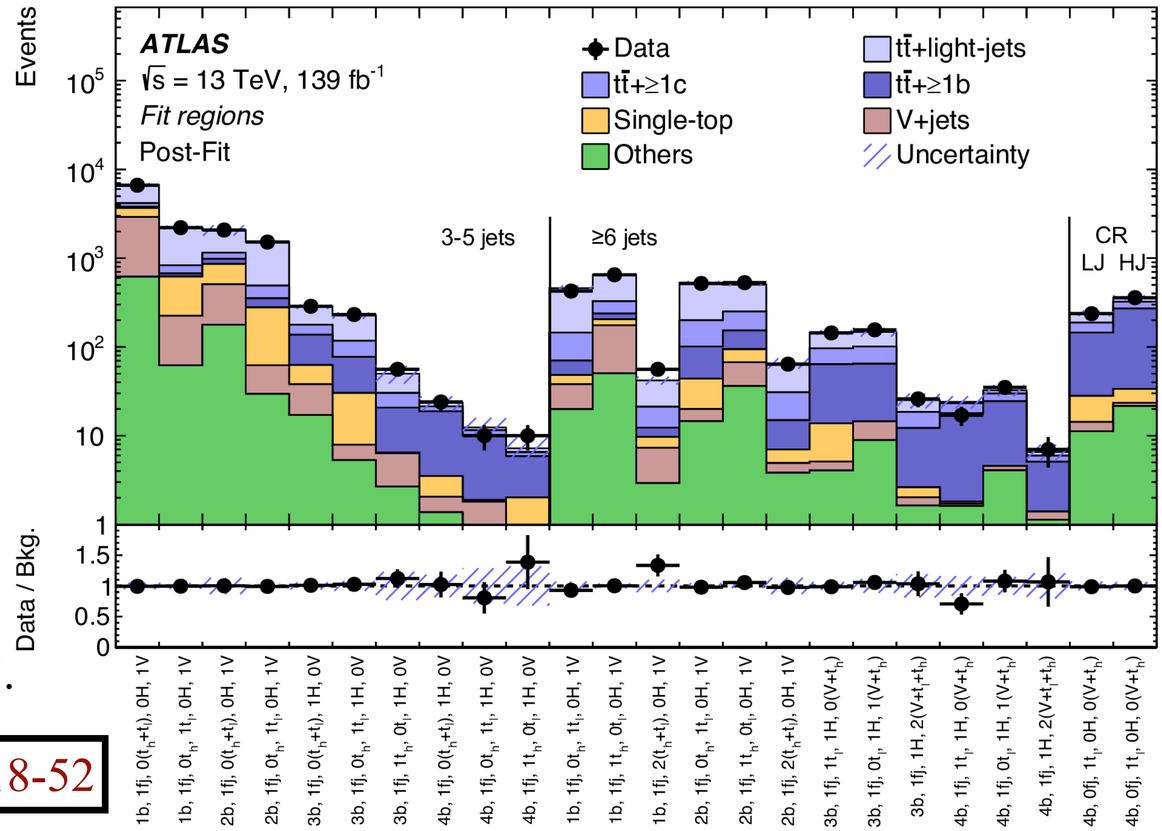
Backgrounds

- V(W/Z)+jets
  - Data-driven corrections to dominant MC estimated background using a 2-D reweighting technique
- Top quark pair production and tW production
  - Estimated with simulation and validated with data
- Others includes the $t\bar{t}V/H$, VH, tZ, $t\bar{t}t\bar{t}$, diboson, and multijet backgrounds estimated using MC samples.

Search

- Categorization in exclusive signal-sensitive, control and validation regions to constrain different signal models and Standard Model backgrounds
- Fit distribution of the m_{eff} variable across a set of 24 ‘fit regions’.

Reweighting source regions				
Lepton multiplicity	Jet multiplicity	b-tag multiplicity	Other requirements	Targeted background
1	≥3	2	–	$t\bar{t}+tW$
2	≥3	1	$\lvert m_{\ell\ell} - m_Z \rvert \leq 10$ GeV, $E_{\text{T}}^{\text{miss}} < 100$ GeV	Z+jets

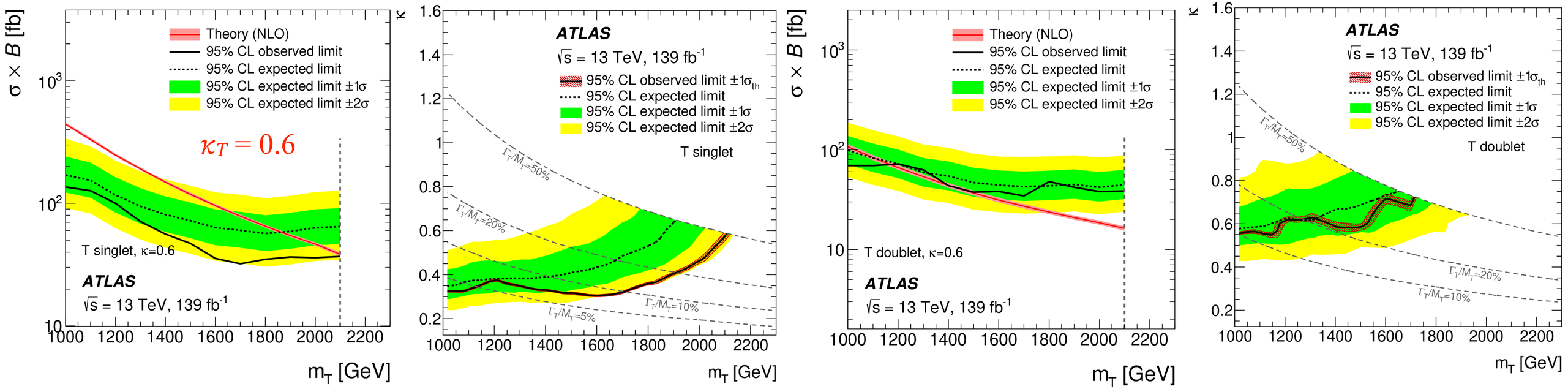


EXOT-2018-52

Results

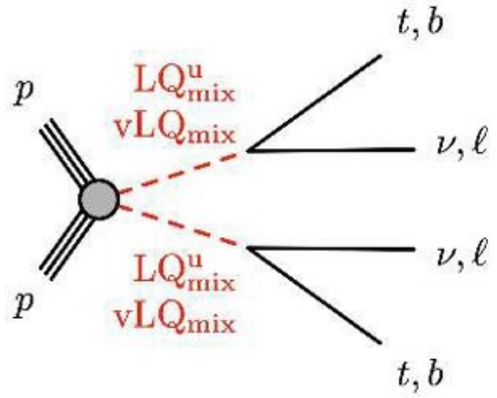
- No evidence of significant contributions from single T-quark production.
- Limits set on the production cross-section of a T quark decaying to the Ht/Zt final state
  - excluded coupling strength values of $\kappa_T \geq 0.6$ (0.55) for singlet (doublet) T masses below 2.1(1.0) TeV at 95% confidence level. The previous ATLAS search in the all-hadronic $T \rightarrow Ht$ channel has excluded κ values above ~0.5 (expected ~0.65) at a mass of 1.6 TeV (2201.07045)
  - Sensitivity limited by ttbar and single top modeling

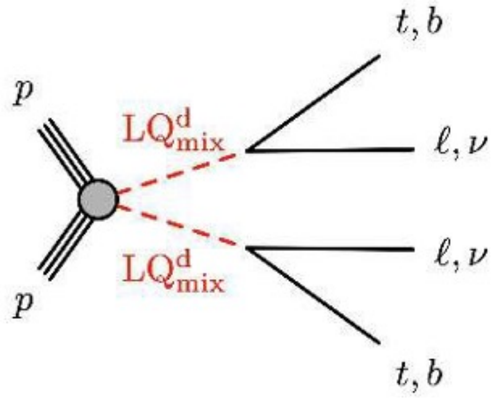
EXOT-2018-52

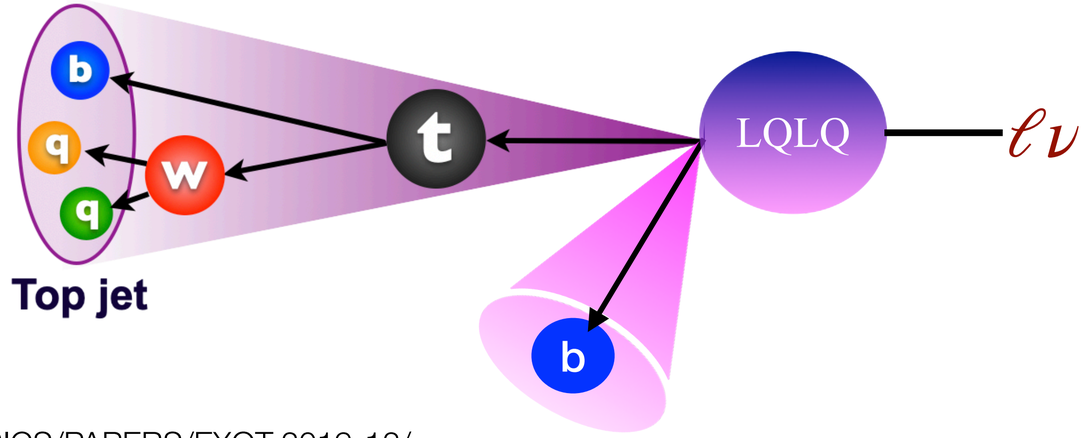


Pair-produced scalar and vector leptoquarks decays

- Leptoquarks (LQ) are predicted by many new physics theories to describe:
  - The similarities between the lepton and quark sectors of the Standard Model
  - Potential to explain the B-flavour (B-meson decay) anomalies
  - Measurements of anomalous magnetic moment of muons
- A search is performed for pair-produced scalar and vector Leptoquarks decaying into third-generation quarks and first- or second-generation leptons in proton-proton collisions using **ATLAS detector** at a center-of-mass energy of 13 TeV.
  - Pair produced **scalar** $LQ^{u}_{mix} \rightarrow t\nu, b\ell$ or $LQ^{d}_{mix} \rightarrow t\ell, b\nu$ $\ell(=e,\mu)$
  - Pair produced **vector** $LQ \rightarrow t\nu, b\ell$ with minimal or Yang-Mills coupling



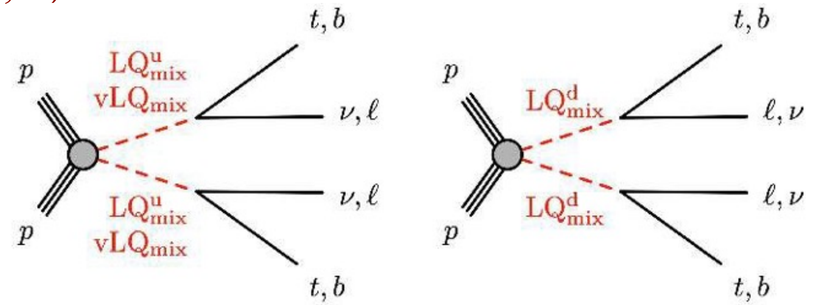




https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2019-12/

Event Selection

- All possible decays into 3rd generation quarks (t,b) and 1st & 2nd generation leptons (e, μ, ν) are considered ending up to:
  - $LQLQ \rightarrow tb\ell\nu \rightarrow bqqb\ell\nu$
  - $LQLQ \rightarrow tt\nu\nu \rightarrow bqqb\ell\nu\nu\nu$
- Events must have:
  - ≥ 4 jets (due to a hadronically decaying top-quark), ≥ 1 b-jet, exactly one signal lepton and MET > 250 GeV.
- B tagging:
  - Small-*R* jets are categorized as *b*-tagged, using the anti-KT algorithm with a radius R = 0.4
- Top tagging :
  - The Small-*R* jets jets are reclustered (iteratively with the recursive method) with the anti-*k*T algorithm with *R* = 1.0 to obtain large-*R* jets to reconstruct hadronically decaying top-quark candidates.



$vLQ^{YM}_{mix} \rightarrow t\nu/b\mu$
$vLQ^{YM}_{mix} \rightarrow t\nu/be$
$vLQ^{min}_{mix} \rightarrow t\nu/b\mu$
$vLQ^{min}_{mix} \rightarrow t\nu/be$
$LQ^{u}_{mix} \rightarrow t\nu/b\mu$
$LQ^{u}_{mix} \rightarrow t\nu/be$
$LQ^{d}_{mix} \rightarrow t\mu/b\nu$
$LQ^{d}_{mix} \rightarrow te/b\nu$

Search Information

Backgrounds

- W+jets
- Top quark pair production
  - Rewighting as a function of M_{eff}
- Single top quark
- $t\bar{t} + V$
- Diboson

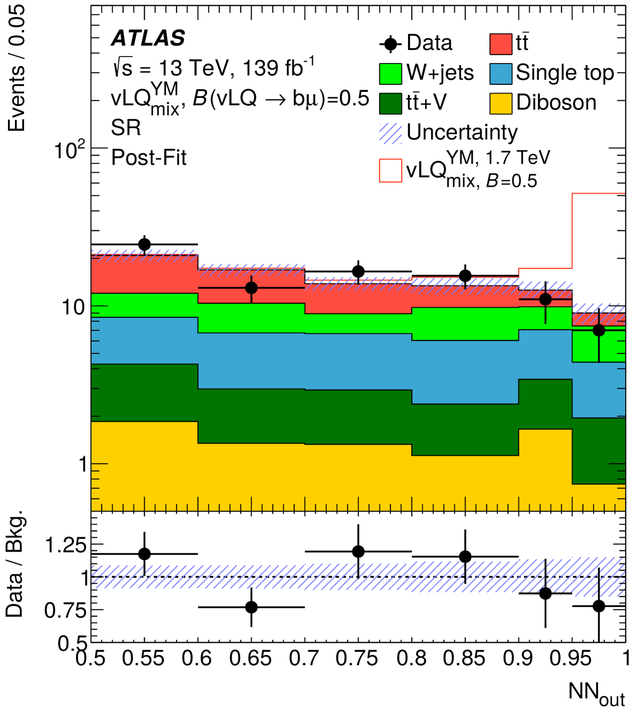
$$M_{eff} = \sum_{Jet,e,\mu} P_t \quad + MET$$

EXOT-2019-12

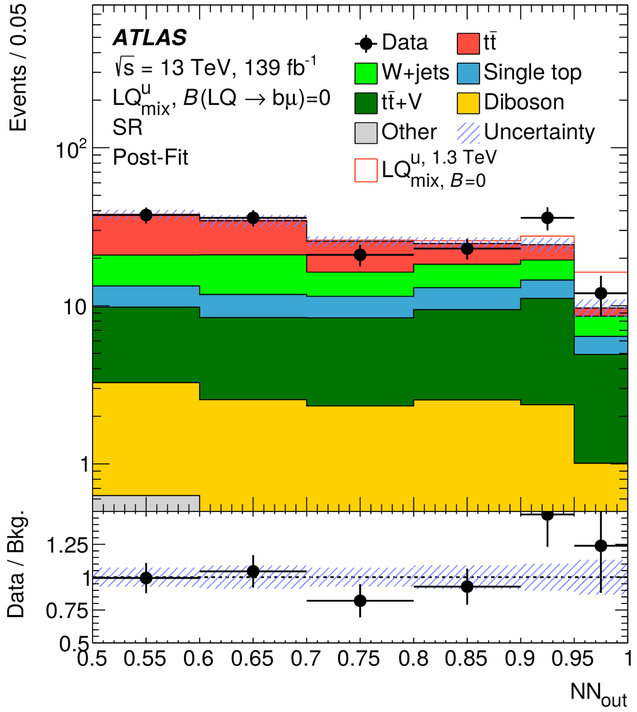
Search

- NN trained with NeuroBayes technique:
- Different NNs for: 3 signal scenarios, 4 BRs scan, and 2 leptons flavors (e, μ), 10 in total
- Fit NN output together with CRs —> Limits

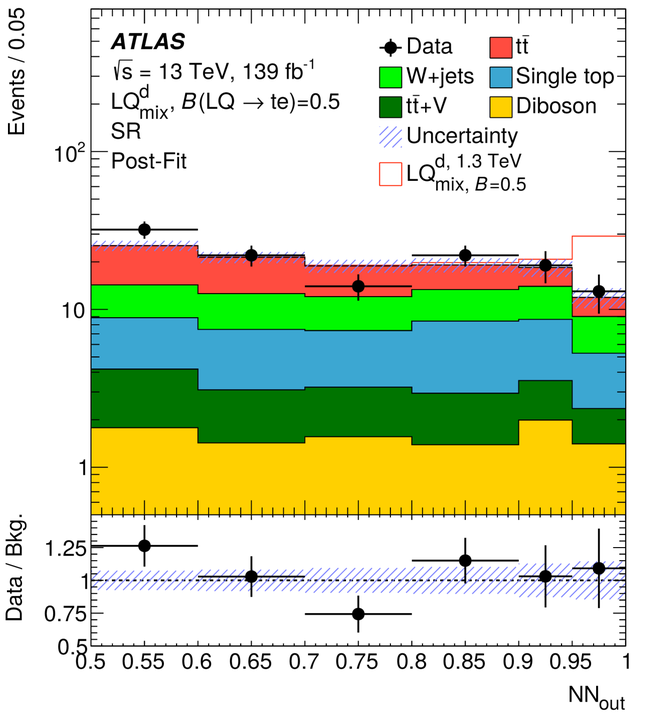
$vLQ^{YM} \rightarrow b\mu/t\nu$



$LQ^{u}_{mix} \rightarrow t\nu/b\mu$



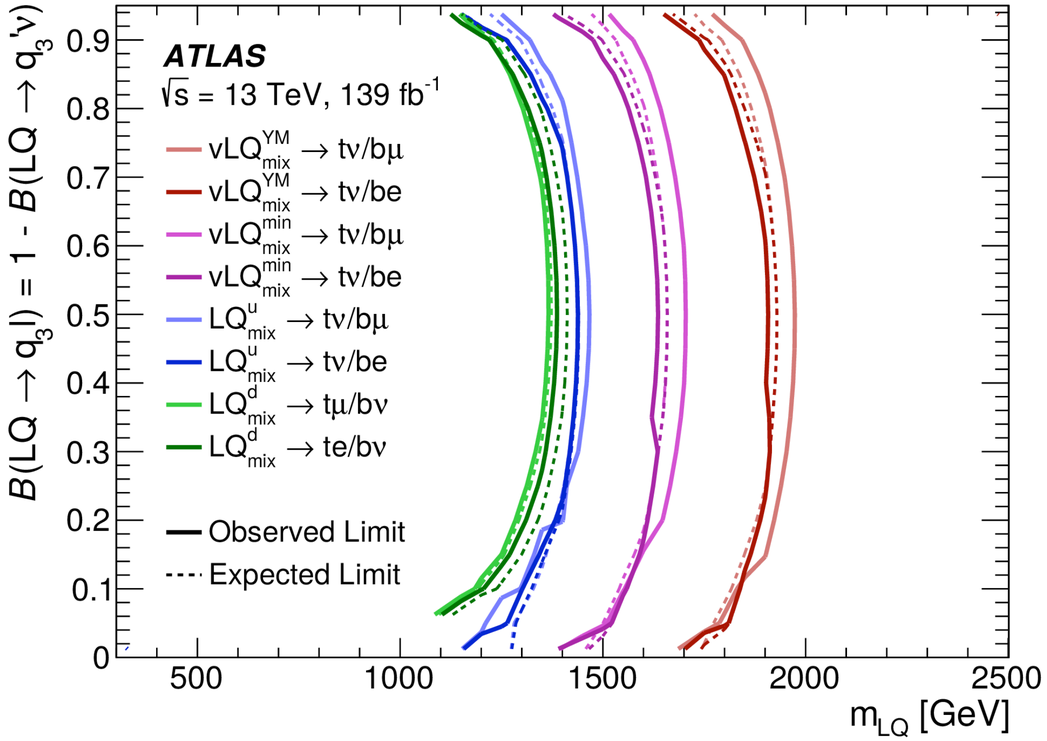
$LQ^{d}_{mix} \rightarrow te/b\nu$



Results

- No significant excess above the standard model background is observed.
- **First** limits on the production cross-section are derived for eight models as a function of leptoquark mass and branching ratio into the charged lepton at 95% confidence level.
- Dominating systematic uncertainties: top related background modelling and Jet Energy Scale (JES) uncertainties but highly statistically dominated in high masses limited by statistical uncertainties

EXOT-2019-12



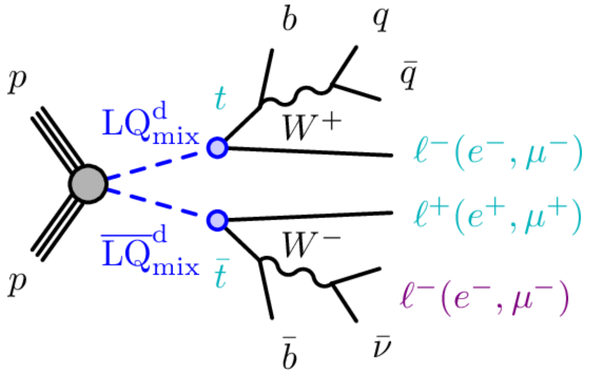
$m_{LQ^u_{mix}\to e(\mu)} < 1.44(1.47)$ TeV β=0.5

$m_{LQ^d_{mix}\to e(\mu)} < 1.39(1.37)$ TeV β=0.5

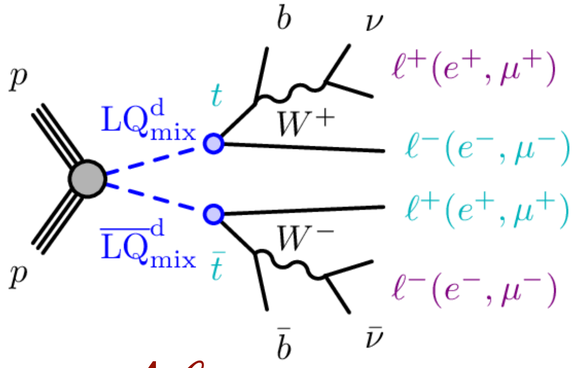
	Exp. limit [GeV]	Obs. limit [GeV]
$LQ^u_{mix} \to t\nu/b\mu$	1440^{+60}_{-60}	1460
$LQ^u_{mix} \to t\nu/be$	1440^{+60}_{-60}	1440
$LQ^d_{mix} \to t\mu/b\nu$	1380^{+50}_{-60}	1370
$LQ^d_{mix} \to te/b\nu$	1410^{+60}_{-60}	1390
$vLQ^{YM}_{mix} \to t\nu/b\mu$	1930^{+50}_{-60}	1980
$vLQ^{YM}_{mix} \to t\nu/be$	1930^{+50}_{-70}	1900
$vLQ^{min}_{mix} \to t\nu/b\mu$	1660^{+50}_{-50}	1710
$vLQ^{min}_{mix} \to t\nu/be$	1650^{+50}_{-60}	1620

Leptoquarks decaying into a top pair and lepton pair

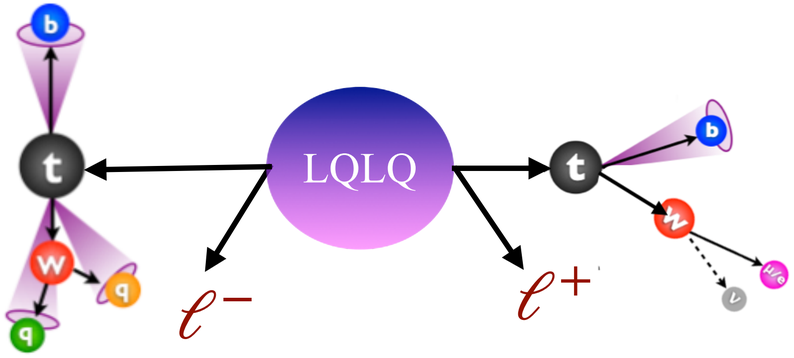
- Leptoquarks (LQ) are a good candidate as a BSM mediator to explain anomalies
- A search for pair production of LQs decaying into a top quark pair and a pair of electrons or muons, in multi-lepton final states (2ℓ SS, 3ℓ and 4ℓ) in proton-proton collisions using **ATLAS detector** at a center-of-mass energy of 13 TeV.
  - Pair produced **scalar** $LQ_d^{mix} LQ_d^{mix} \rightarrow t\ell t\ell$, $\ell(=e,\mu)$, $\beta = 1.0$
  - Pair produced **vector** LQ $\tilde{U}_1$



3ℓ



4ℓ

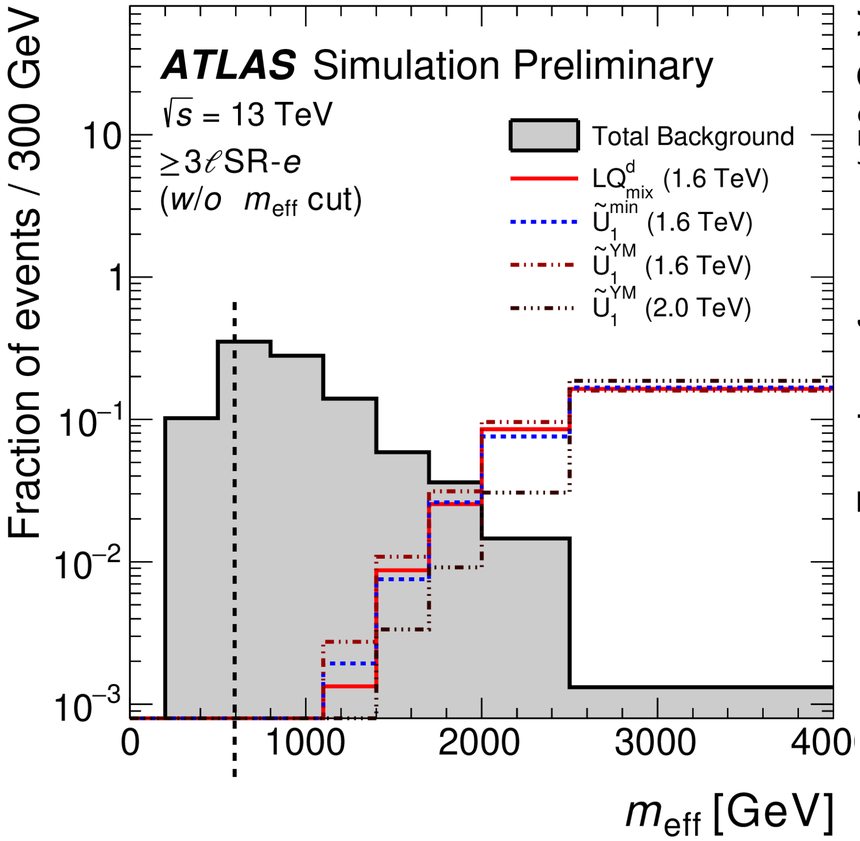


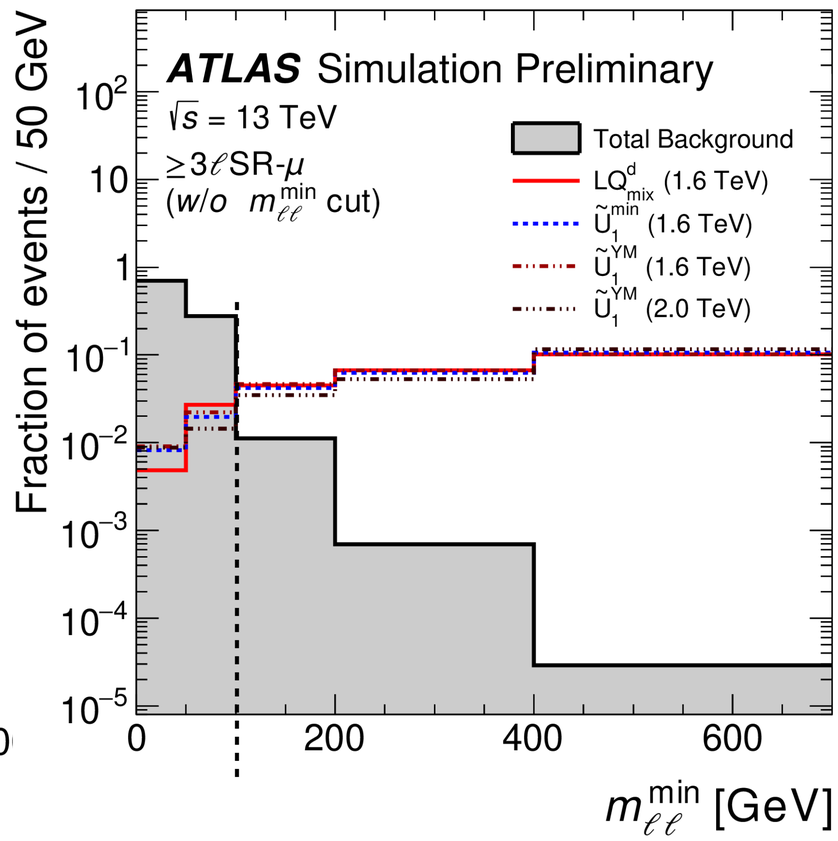
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-052/

Event Selection

$$M_{eff} = \sum_{Jet,e,\mu} P_t + MET$$

- Events must have:
  - Single and dilepton triggers with ≥ 2 leptons, ≥ 2 small-R jets with $p_T > 25$ GeV and $|\eta| < 2.5$, and ≥ 1 b-jet
- Signal Region:
  - $M_{eff} > 500$ GeV,
  - $m_{\ell\ell}^{min} > 200(100)$ GeV for 3ℓ (4ℓ)
- Jet-tagging:
  - PFlow objects using the anti-k_T algorithm with a radius parameter of $R = 0.4$
- b-tagging:
  - a deep-learning neural network that use impact parameters of tracks and the displaced vertices reconstructed in the ID.





Search Information

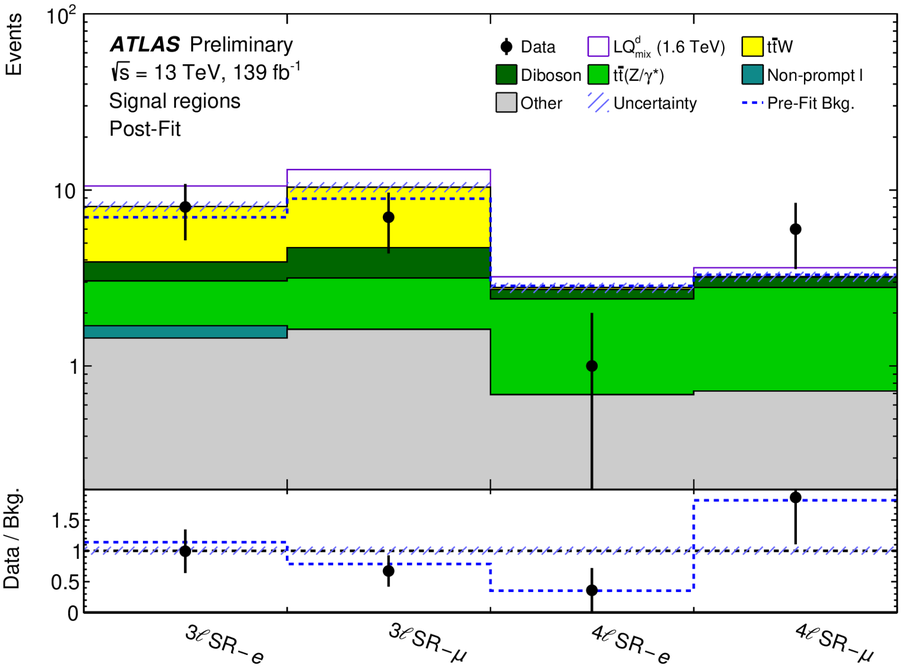
Backgrounds

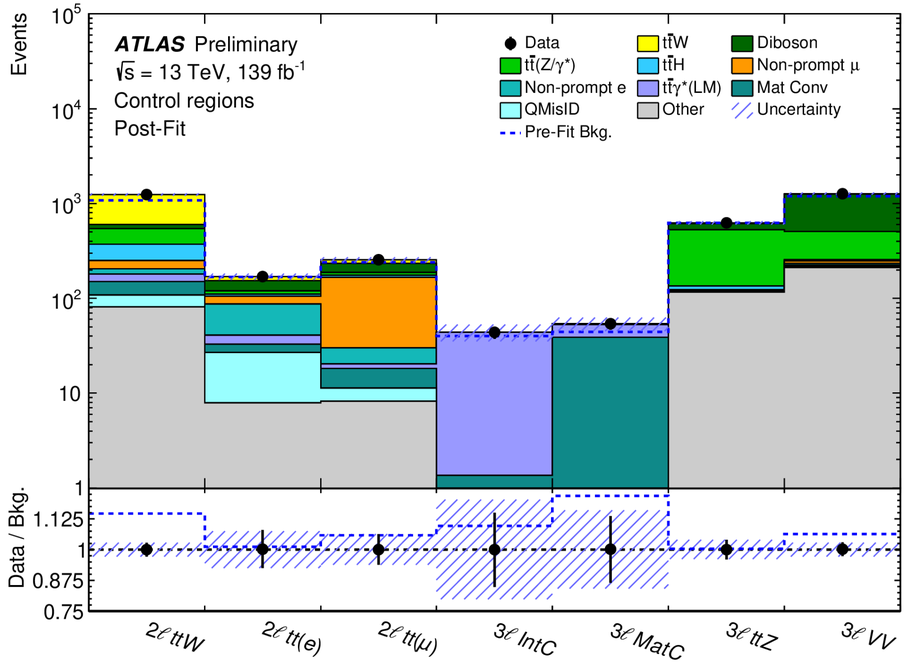
- Estimated using the MC samples
  - $t\bar{t}W$
  - $t\bar{t}Z$
  - Diboson
  - Non-prompt leptons

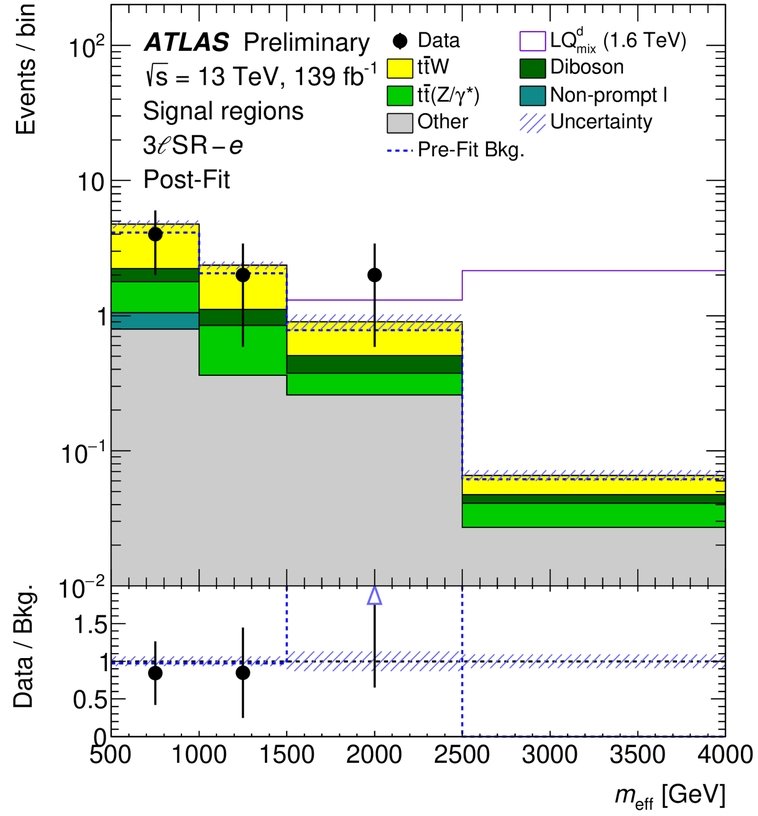
Search

- A total of 7 CRs are defined, VRs are defined, using cuts on m_{eff} and m_{min}, in order to validate the modeling
- Fit M_{eff} as discriminating variable to all SRs and CRs

ATLAS-CONF-2022-052



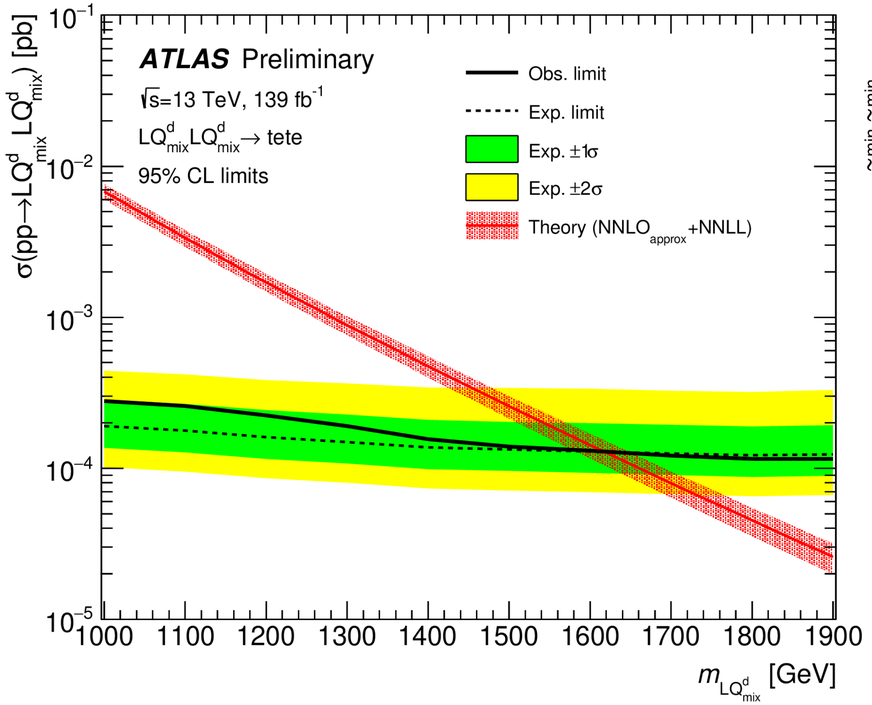


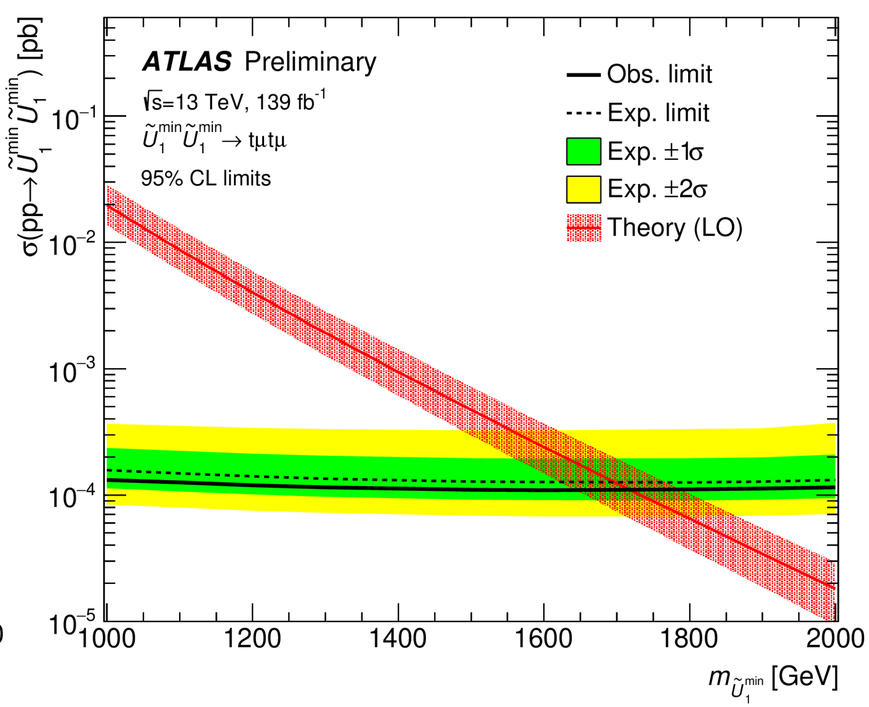


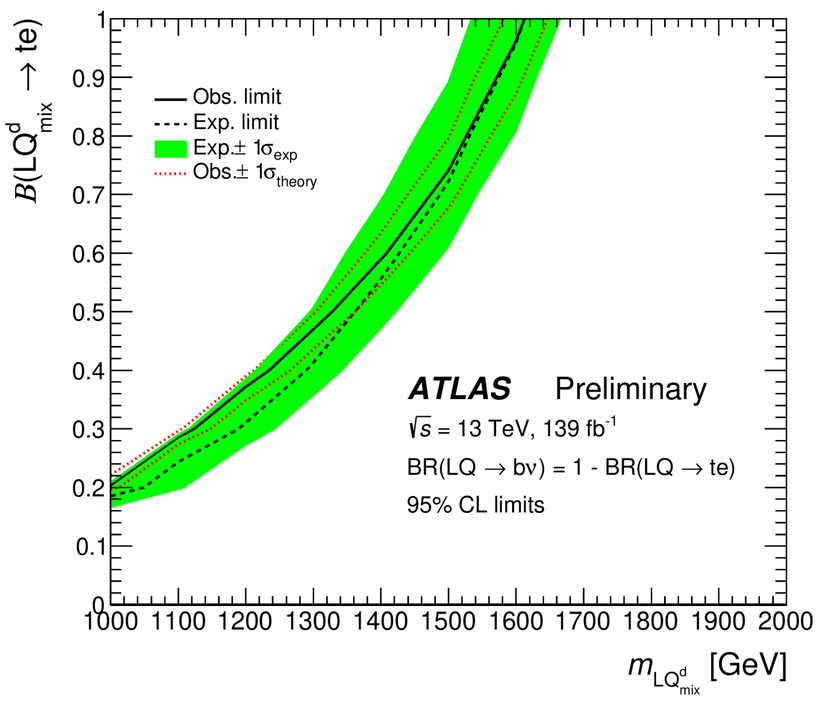
Results

- No significant excess above the standard model background is observed.
- Limits on the production cross-section on both scalar and vector LQ at 95% C.L.
  - Observed exclusions $LQ \rightarrow te(t\mu)$: Scaler $m_{LQ^d_{mix}} < 1.61$ (1.64) TeV, minimal coupling scenario vector $m_{LQ_{\tilde{U}}} < 1.71$ (1.73) TeV, Yang-Mills coupling vector $m_{LQ_{\tilde{U}}} < 2.0$ (2.0) TeV
  - These limits are competitive with the previous ATLAS limits (search for LQ_d^{mix} in the mixed decay mode ATLAS-CONF-2022-009.)
- Main systematic uncertainty from lepton identification, but analysis is statistically limited

ATLAS-CONF-2022-052







Summary

- All those five analysis were performed with data collected by the CMS and ATLAS experiment between 2016 and 2018 (full Run-2 data) at 13 TeV, corresponding to an integrated luminosity 137 fb^{-1}.
- No significant excess found in CMS or ATLAS Run-2 data.
- The most stringent limits to date on W′ bosons decaying to a top and a bottom quark, or b* quark mass, or scalar LQs with flavour-diagonal and cross-generational couplings are obtained.
- Improved top and b-quark identification techniques help to reject background from multi-jet events and to increase the sensitivity to new physics.
- Exclusion limits were set, good improvements have been observed w.r.t previous analyses using 2015+2016 data only.

Thank you for your attention

Back Up

Useful link for those analysis are here:

CMS:

$Z' \rightarrow t\bar{t}$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-17-017/index.html

$W' \rightarrow tb$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-20-005/index.html

$b^* \rightarrow tW$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-19-003/index.html

$W' \rightarrow Tb/Bt$: http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/B2G-20-002/index.html

$Z' \rightarrow tT$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-17-015/index.html

$Z' \rightarrow TT$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-18-005/index.html

$LQ \rightarrow t\tau$: http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-16-028/index.html

ATLAS

$T \rightarrow Ht$: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2019-07/

$W' \rightarrow tb$: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2021-043/

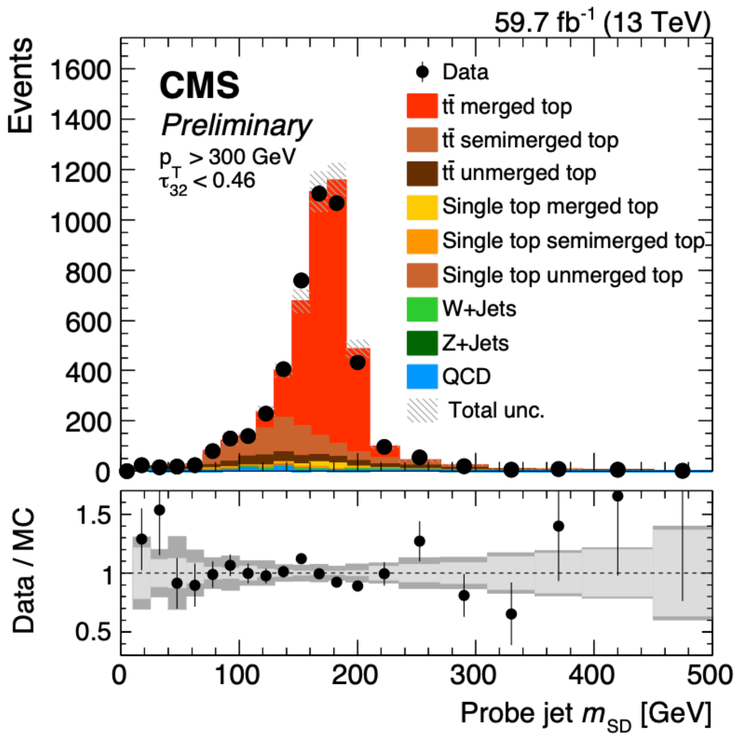
$LQLQ \rightarrow bltv$: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2019-12/

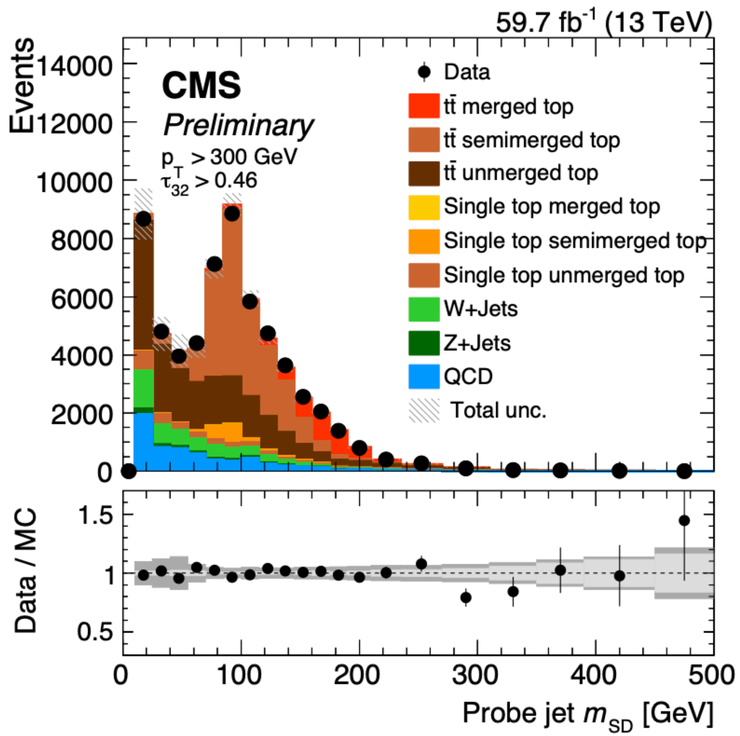
$LQLQ \rightarrow tltl$: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-052/

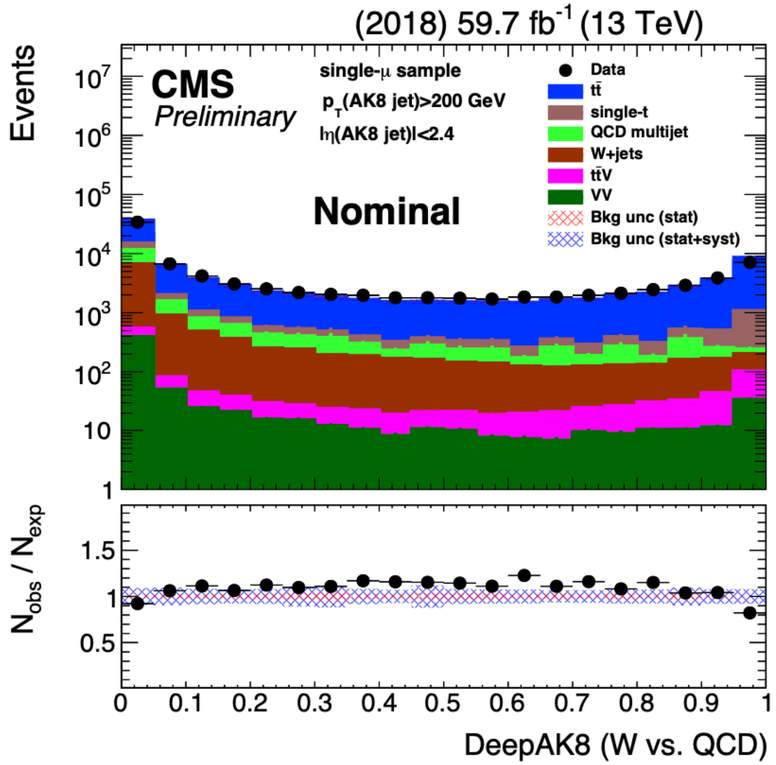
$LQ \rightarrow t\tau$: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2019-15/

$T \rightarrow Ht/Zt$: http://cdsweb.cern.ch/record/2779174/files/ATLAS-CONF-2021-040.pdf

Jet tagging tools



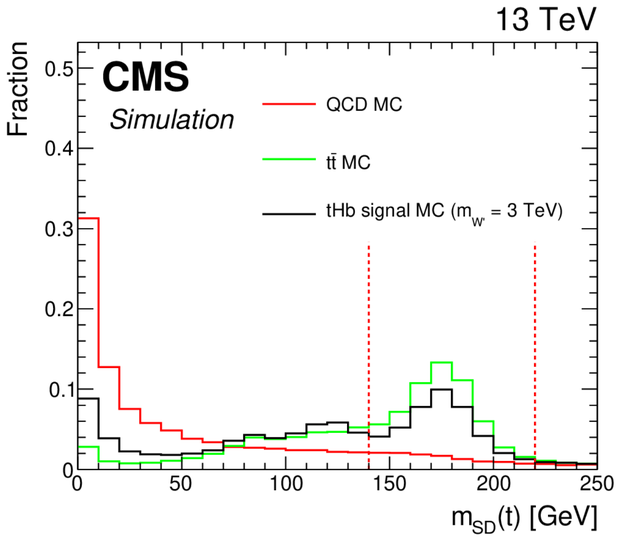


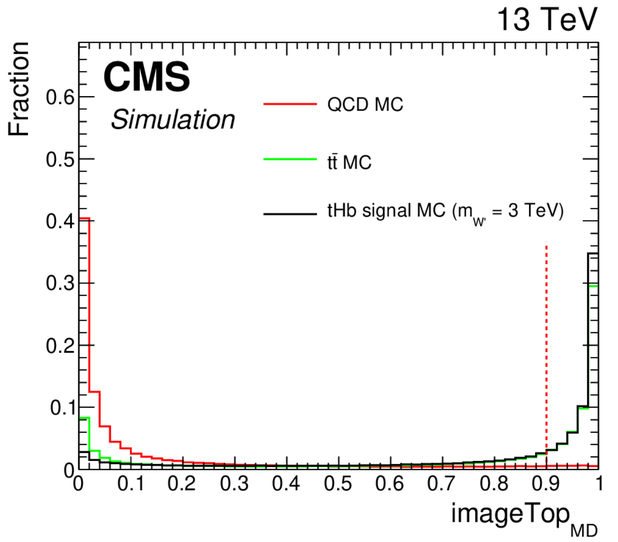


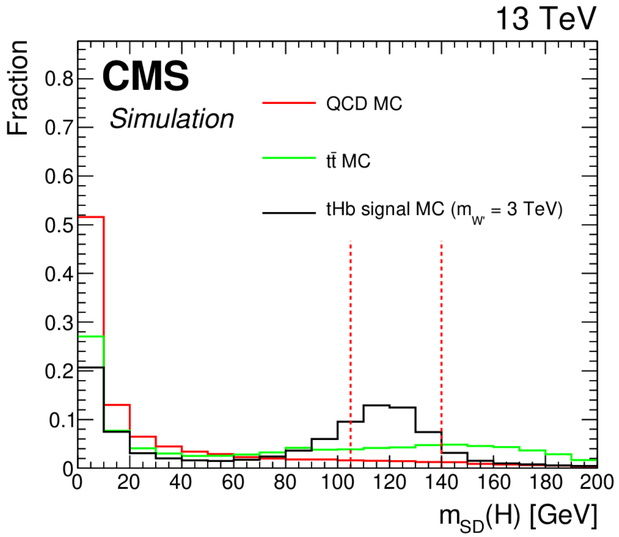
Soft drop mass distributions for AK8 PUPPI jets with pT > 300 GeV after the template fit are shown with the pass (left) and fail (middle) N-subjettiness requirement of τ32 < 0.46 using data collected in 2018.

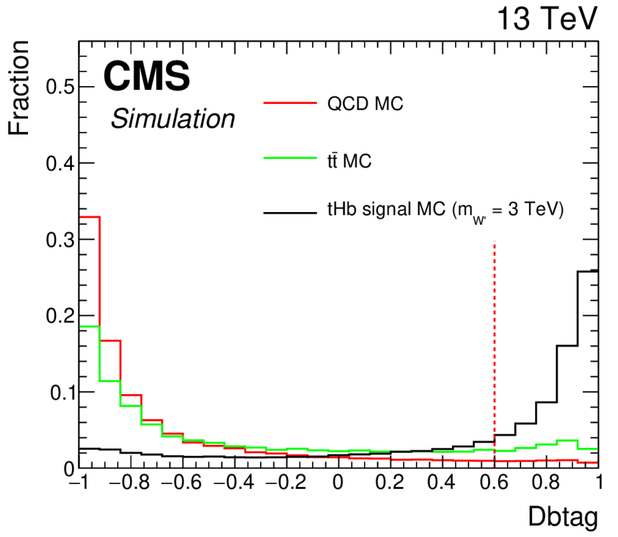
Distributions of the DeepAK8 discriminant for W tagging in data and simulation in the single-μ sample.

$W' \rightarrow Tb/Bt$: Event Selection



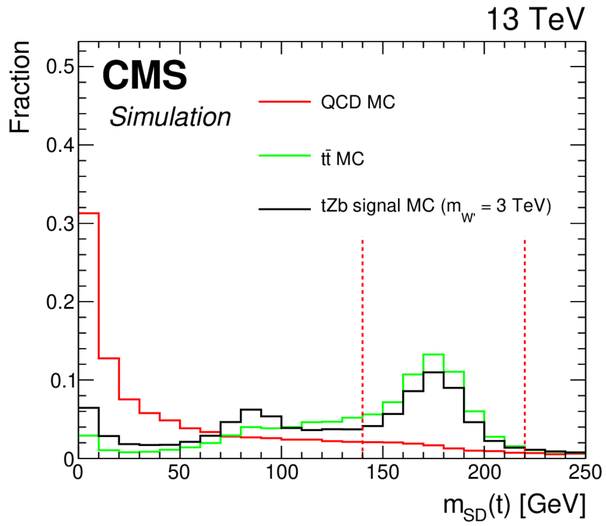


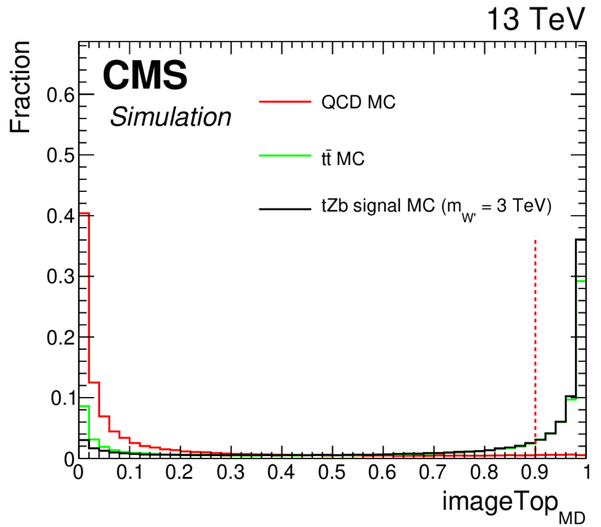


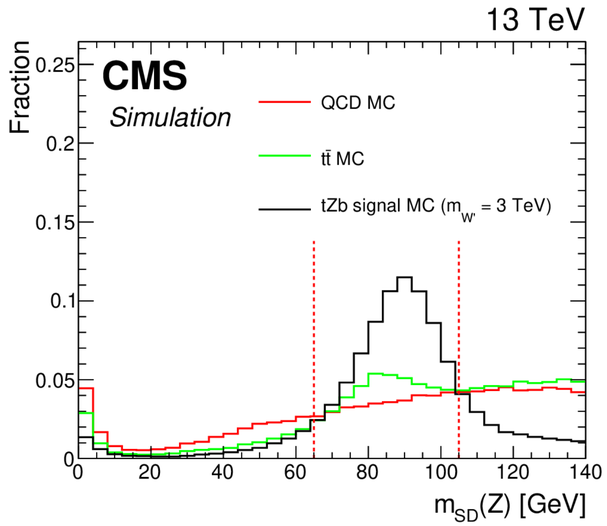


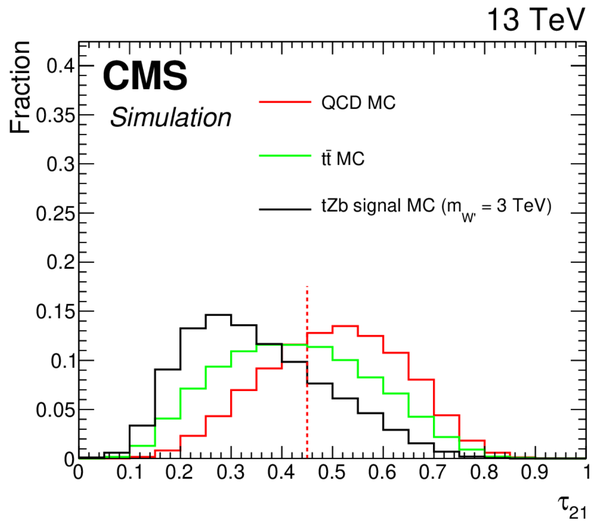
Label	Tag	Discriminant	Mass
Tight	H	$0.6 < \text{Dbtag}$	$105 < m_{\text{SD}}(\text{H}) < 140\,\text{GeV}$
	Z	$\tau_{21} < 0.45$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.9 < \text{imageTop}_{\text{MD}}$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Medium	H	$0 < \text{Dbtag} < 0.6$	$105 < m_{\text{SD}}(\text{H}) < 140\,\text{GeV}$
	Z	$0.45 < \tau_{21} < 0.6$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.3 < \text{imageTop}_{\text{MD}} < 0.9$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Inverted	H	$-1 < \text{Dbtag} < 0$	$5 < m_{\text{SD}}(\text{H}) < 30\,\text{GeV}$
	Z	$0.6 < \tau_{21} < 1$	$5 < m_{\text{SD}}(\text{Z}) < 30\,\text{GeV}$
	t	$0 < \text{imageTop}_{\text{MD}} < 0.3$	$30 < m_{\text{SD}}(\text{t}) < 65\,\text{GeV}$

$W' \rightarrow Tb/Bt$: Event Selection









Label	Tag	Discriminant	Mass
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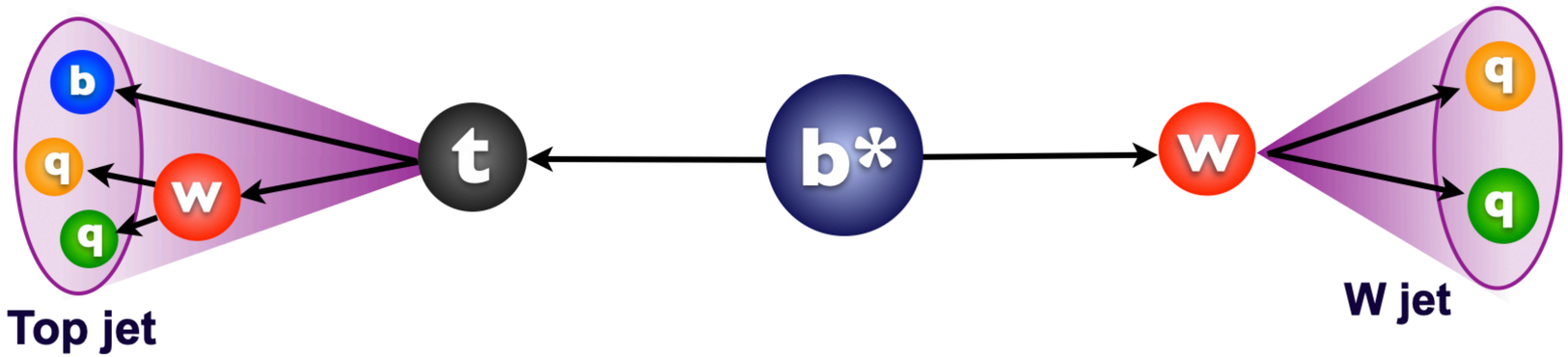
	Z	$\tau_{21} < 0.45$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.9 < \text{imageTop}_{\text{MD}}$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Medium	H	$0 < \text{Dbtag} < 0.6$	$105 < m_{\text{SD}}(\text{H}) < 140\,\text{GeV}$
	Z	$0.45 < \tau_{21} < 0.6$	$65 < m_{\text{SD}}(\text{Z}) < 105\,\text{GeV}$
	t	$0.3 < \text{imageTop}_{\text{MD}} < 0.9$	$140 < m_{\text{SD}}(\text{t}) < 220\,\text{GeV}$
Inverted	H	$-1 < \text{Dbtag} < 0$	$5 < m_{\text{SD}}(\text{H}) < 30\,\text{GeV}$
	Z	$0.6 < \tau_{21} < 1$	$5 < m_{\text{SD}}(\text{Z}) < 30\,\text{GeV}$
	t	$0 < \text{imageTop}_{\text{MD}} < 0.3$	$30 < m_{\text{SD}}(\text{t}) < 65\,\text{GeV}$

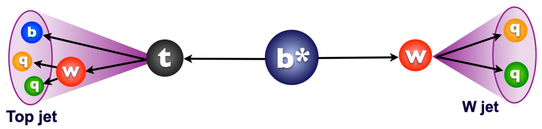
Resonance decaying to a top and W in hadronic state

- Search for a heavy resonance which decays to a top quark and a W boson at center-of-mass energy of 13 TeV .
- The production of an excited bottom quark, b*, is used as a benchmark when setting limits on the cross section for a heavy resonance decaying to a top quark and a W boson.
- All-Hadronic final state considered.



http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-19-003/index.html

Event Selection

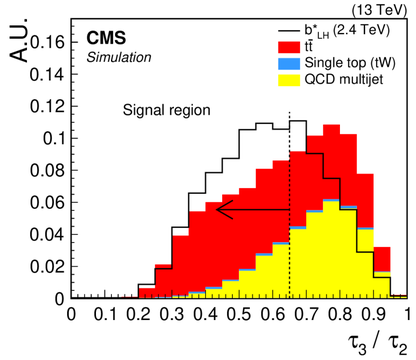


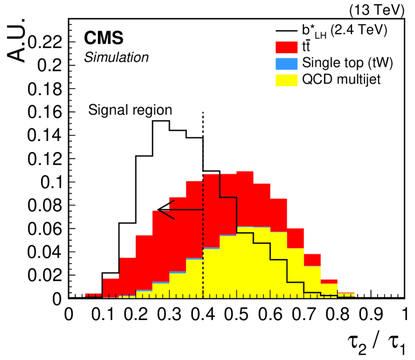
- Search uses the full CMS Run-2 data (2016-18) corresponding to an integrated luminosity of 137 fb^{-1} .

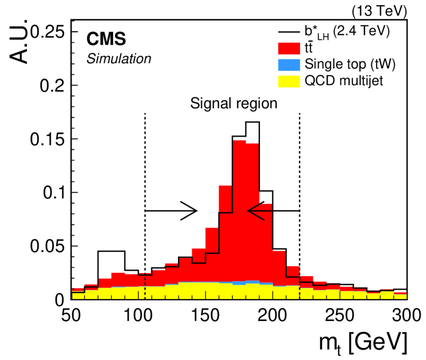
- Require two well-separated (back-to-back) AK8 jets with $p_T > 400$ GeV and $|\eta| < 2.4$.

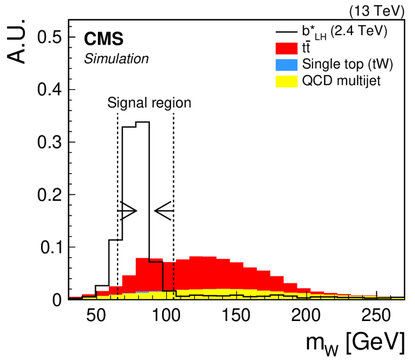
- Top tagging:
  - Soft-drop groomed jet mass
  - N- subjettiness ratio τ_3/τ_2 (< 0.65)
  - B-tagged subjet (DeepCSV algorithm)

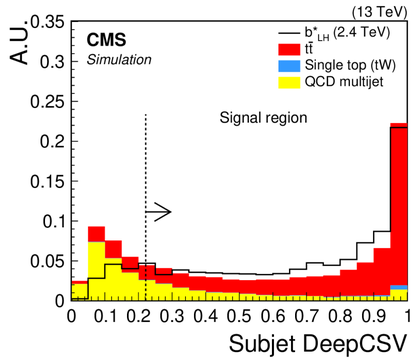
- W tagging:
  - Soft-drop groomed jet mass
  - N-subjettiness ratio τ_2/τ_1 (< 0.4)











CMS-B2G-19-003

Search Information

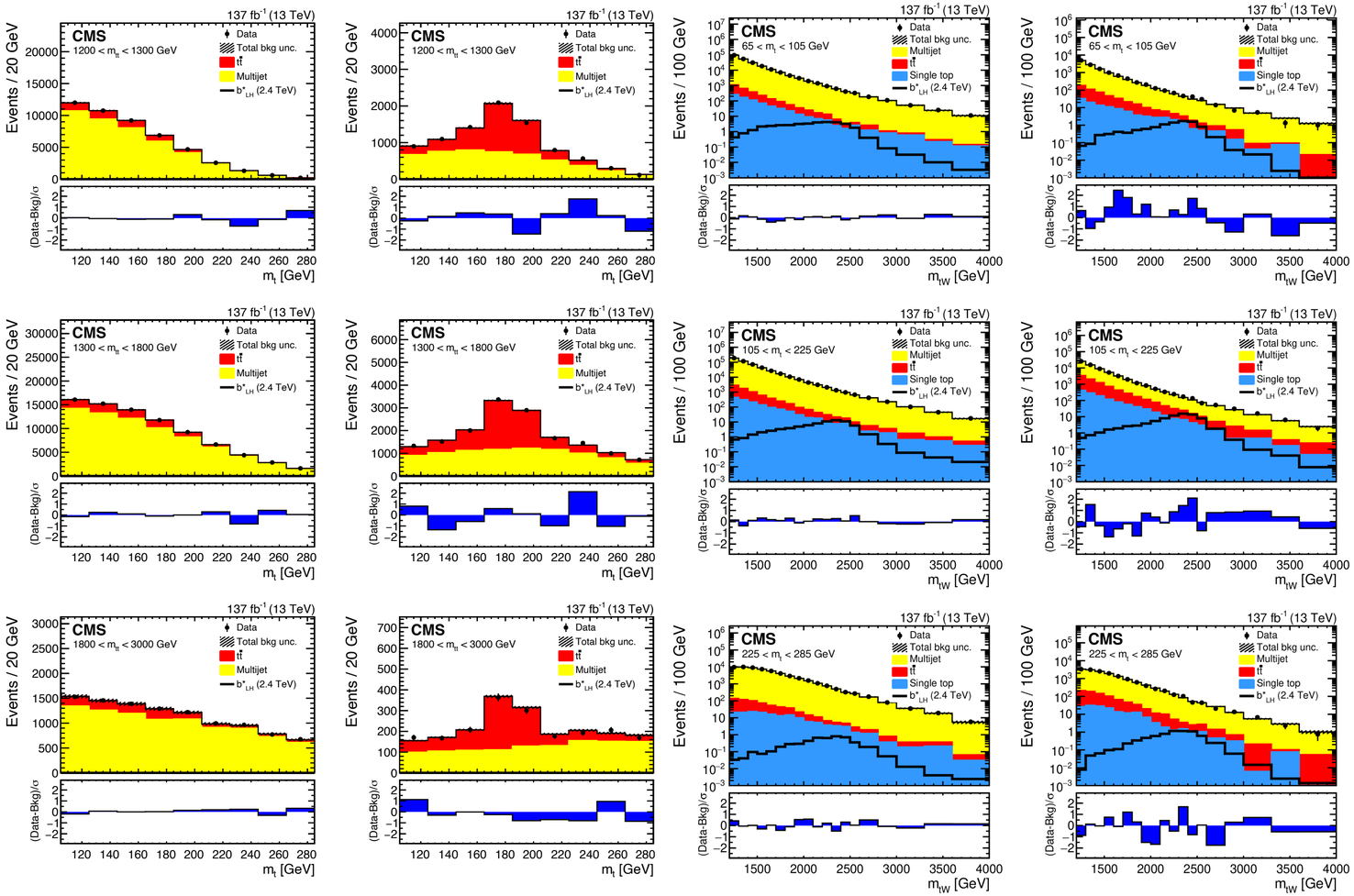
Backgrounds:

- QCD Multijet
  - Dominant
  - Estimated using data-driven control regions
- Top quark pair production
  - Estimated with both data and simulation
- Single Top
  - MC simulation

Search:

- (m_{tW}, m_t) and (m_{tt}, m_t) distributions are used in a simultaneous binned maximum likelihood fit to data.

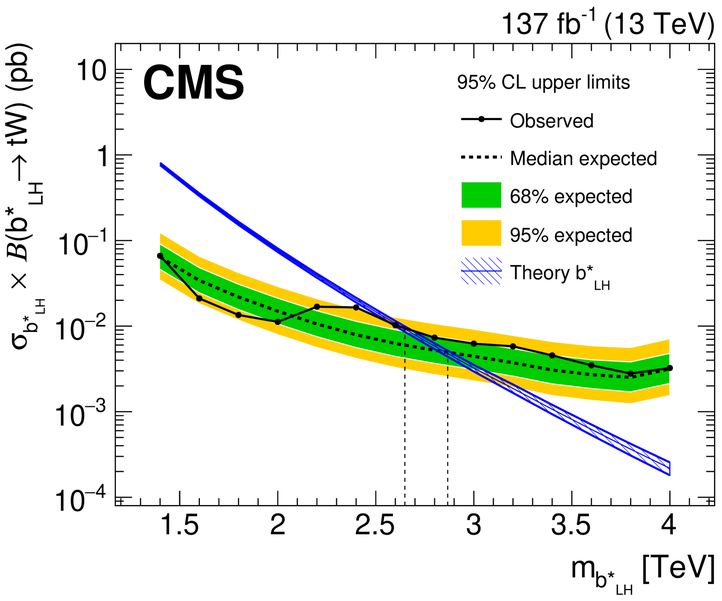
(m_{tt}, m_t) CMS-B2G-19-003 (m_{tW}, m_t)

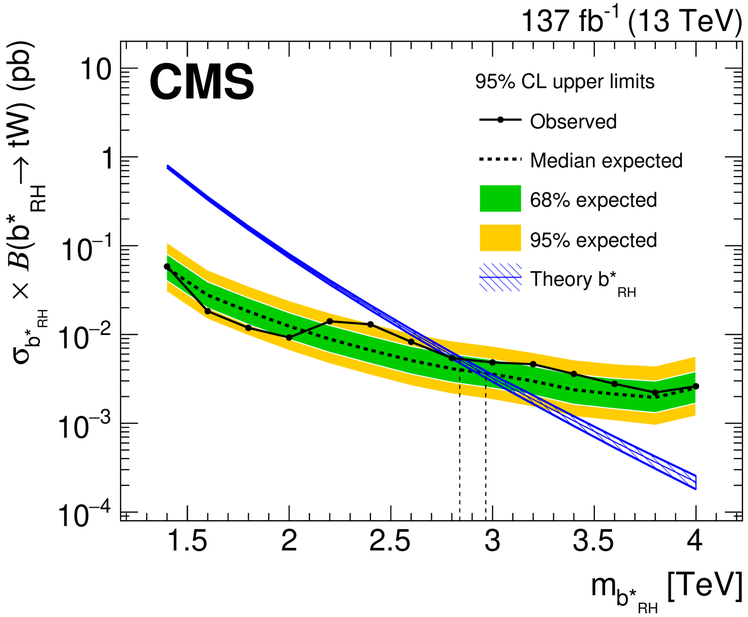


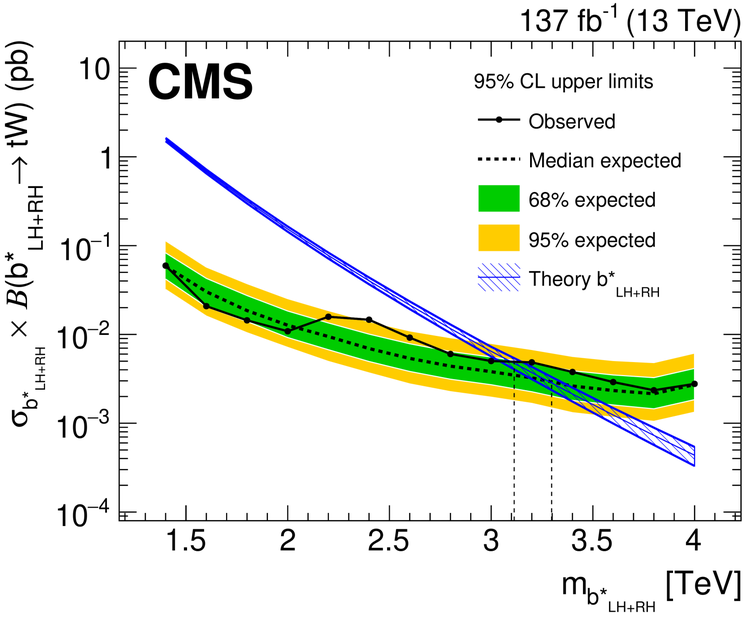
Results

- No significant excess above the standard model background is observed.
- Limits set on the production cross section for left-handed (LH), right-handed (RH), and vector-like chiralities (LH+BH) are excluded at 95% confidence level for masses below 2.6, 2.8, and 3.1 TeV, respectively.

CMS-B2G-19-003



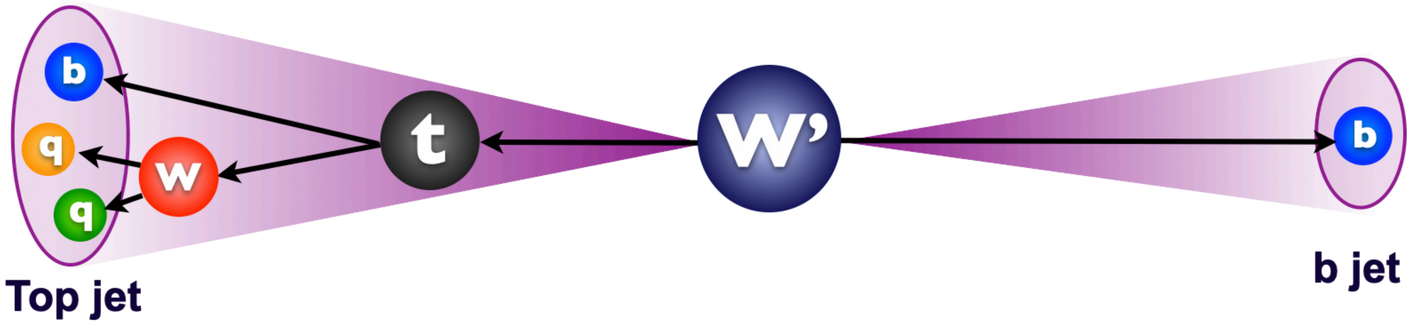




These are the most stringent limits on the b* quark mass to date, extending the previous best mass limits by almost a factor of two.

W' bosons decaying to a top and bottom in the hadronic state

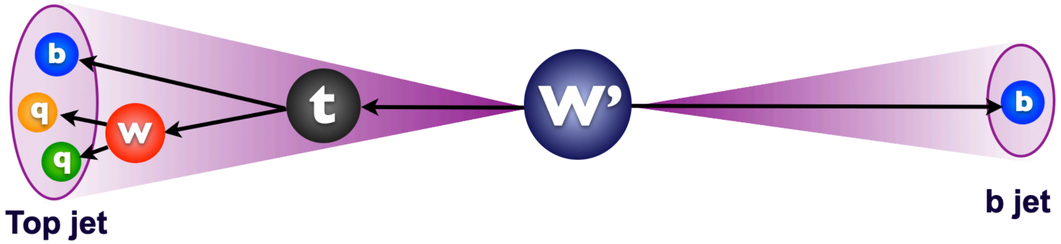
- W' boson, spin-1 gauge boson, is predicted in numerous models including Little Higgs, extra dimensional, and left-right symmetric models.
- A search is performed for W' bosons decaying to a top and a bottom quark in proton-proton collisions at a center-of-mass energy of 13 TeV.
- Hadronic final state considered.



http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G-20-005/index.html

Event Selection

- Analyzed data were collected by the CMS experiment between 2016 and 2018 (full Run-2 data) and correspond to an integrated luminosity 137 fb^{-1}.
- Event with at least one AK8 and one AK4 jet is required, both with $p_T > 550$ GeV and $|\eta| < 2.4$, and which are separated by $\Delta R > 1.2$
- Reject pairwise top - make sure there is no heavy AK8 jet near the AK4 jet
- Top tag:
  - DeepAK8 top-tagger is used for t tagging of AK8 jets.
- b-tag:
  - DeepJet (DNN-based tagger) is used for b-tagging of AK4 jets



Search Information

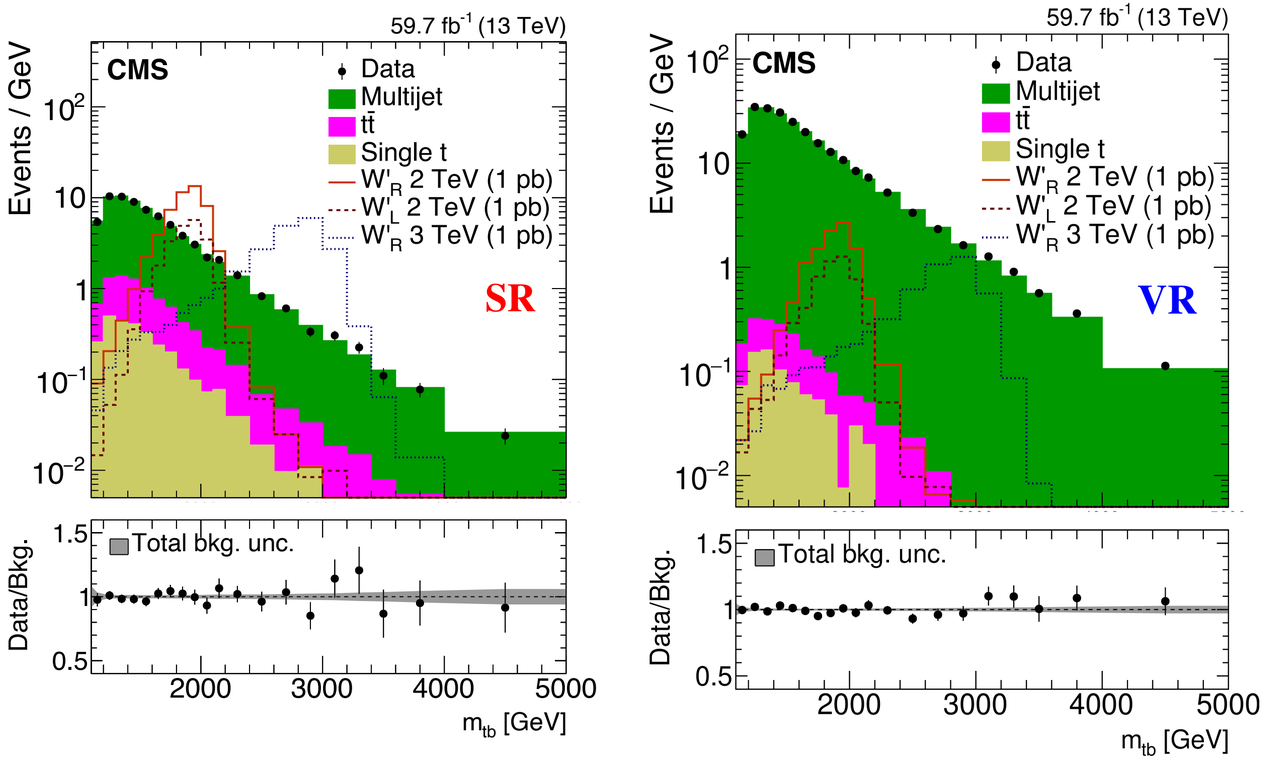
Backgrounds

- QCD Multijet
  - Dominant
  - Data-driven background estimation
    - Control region used to estimate the multi jet background in the signal region and validated in another orthogonal region directly on data.
- Top quark pair production
  - Estimated with simulation and validated with data

Search

- The signal and expected background m_{tb} distribution are compared with data.
- Binned maximum likelihood fit of reconstructed W′ mass.

CMS-B2G-20-005

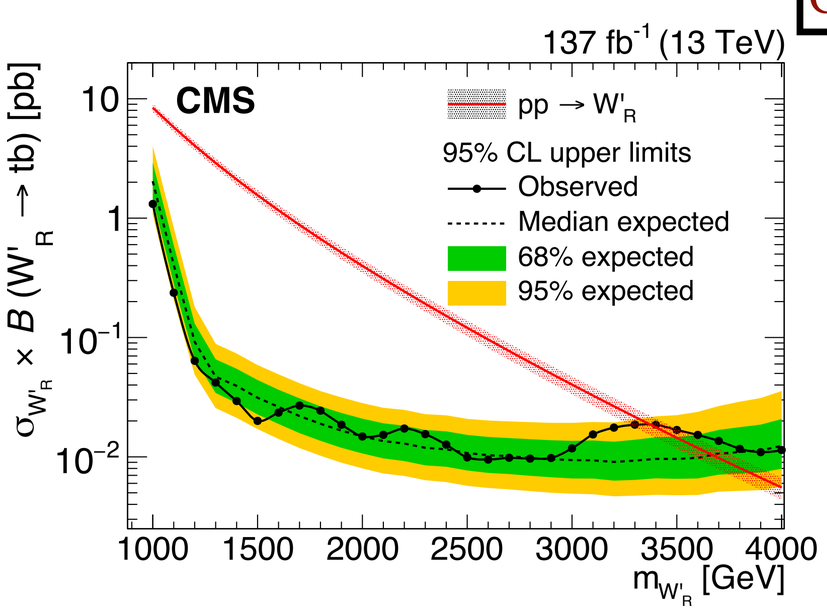


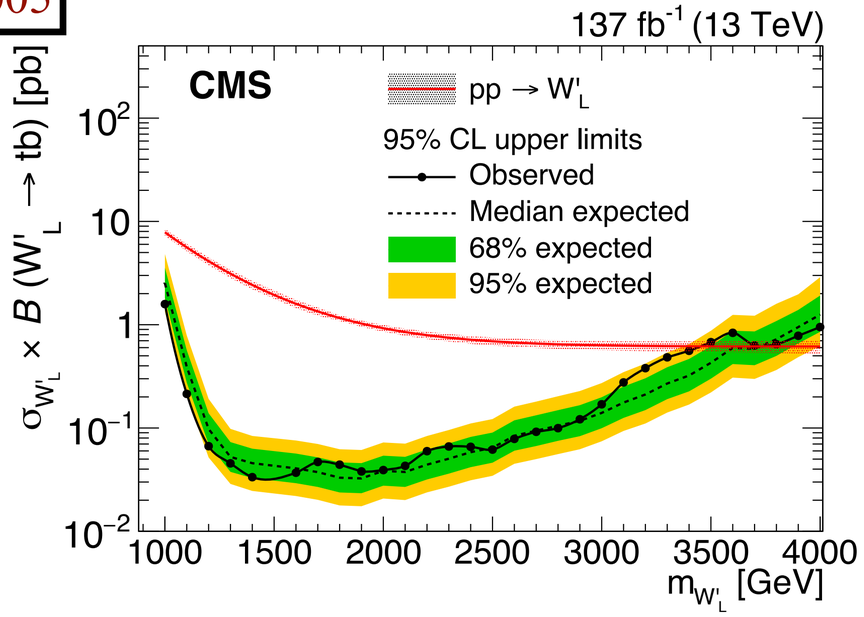
Results

- No significant excess above the standard model background is observed.

- Limits set on the production cross section for both left-handed and right-handed W′ bosons
  - Both excluded for masses below 3.4 TeV at 95% confidence level

CMS-B2G-20-005

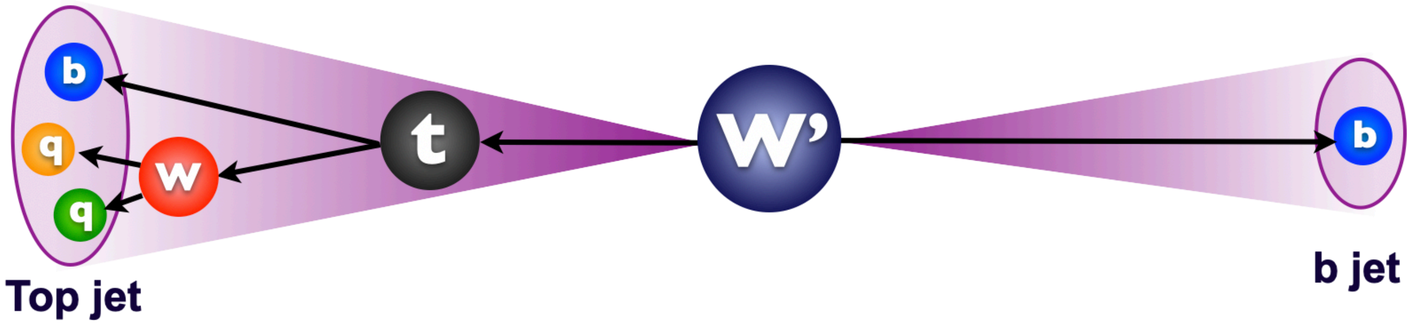




The most stringent limits to date on W' bosons decaying to a top and a bottom quark in the all-hadronic final state are obtained.

W' bosons decaying to a top and bottom in the hadronic state

- W' boson, spin-1 gauge boson, is predicted in numerous models including Little Higgs, extra dimensional, and left-right symmetric models.
- A search is performed for W' bosons decaying to a top and a bottom quark in proton-proton collisions using **ATLAS detector** at a center-of-mass energy of 13 TeV.
- Hadronic final state considered.



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2021-043/

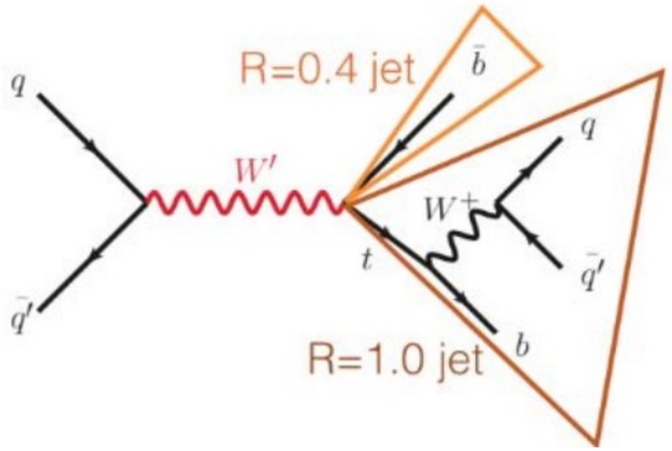
Event Selection

- Analyzed data were collected by the ATLAS experiment between 2016 and 2018 (full Run-2 data) and correspond to an integrated luminosity 139 fb^{-1}.

- Events must have at least one large-*R* jet (R = 1.0) with $p_T > 500$ GeV and one small-R jet.

- Top tag:
  - deep-neural-network (DNN) is used for t tagging

- b-tag:
  - Small-*R* jets in the range $|\eta| < 2.5$ are identified as containing a *b*-hadron using the 'DL1r' algorithm, a DNN-based tagging scheme that uses the secondary vertex information and the impact parameters of the charged tracks in a VRTrack jet



Search Information

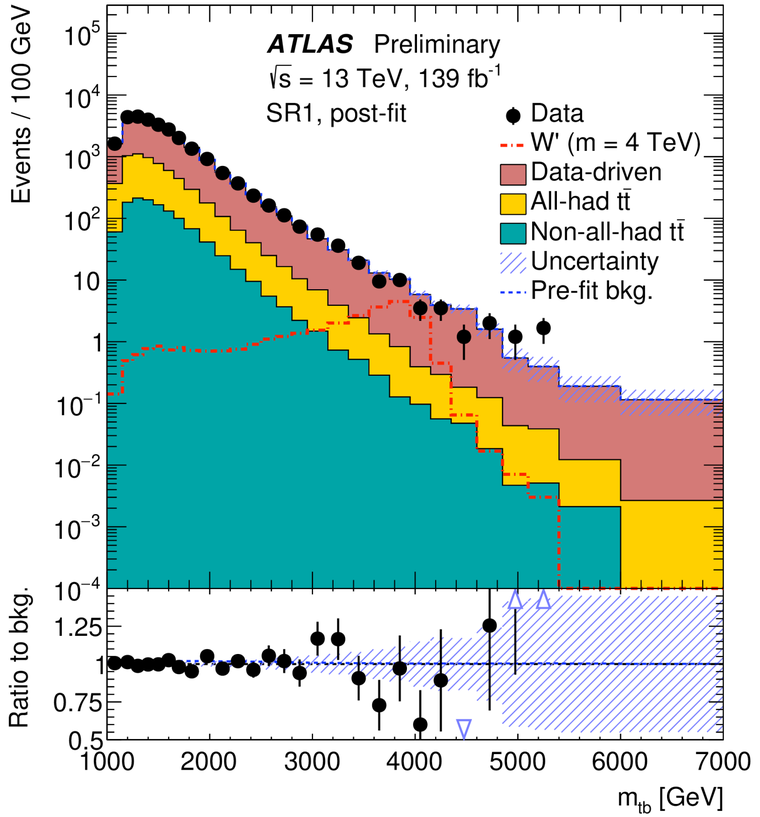
Backgrounds

- QCD Multijet
  - Data-driven background estimation
    - Multijet background estimated with data-driven ABCD method.
- Top quark pair production
  - Estimated with simulation and validated with data

Search

- Analysis regions classified according to: DNN top tag category, b-tag from W' decay and b-tagged jet in large-R jet.
- Combined fit to three signal-sensitive regions of ttbar and multijet estimate and signal model in W'(t+b) invariant mass distribution

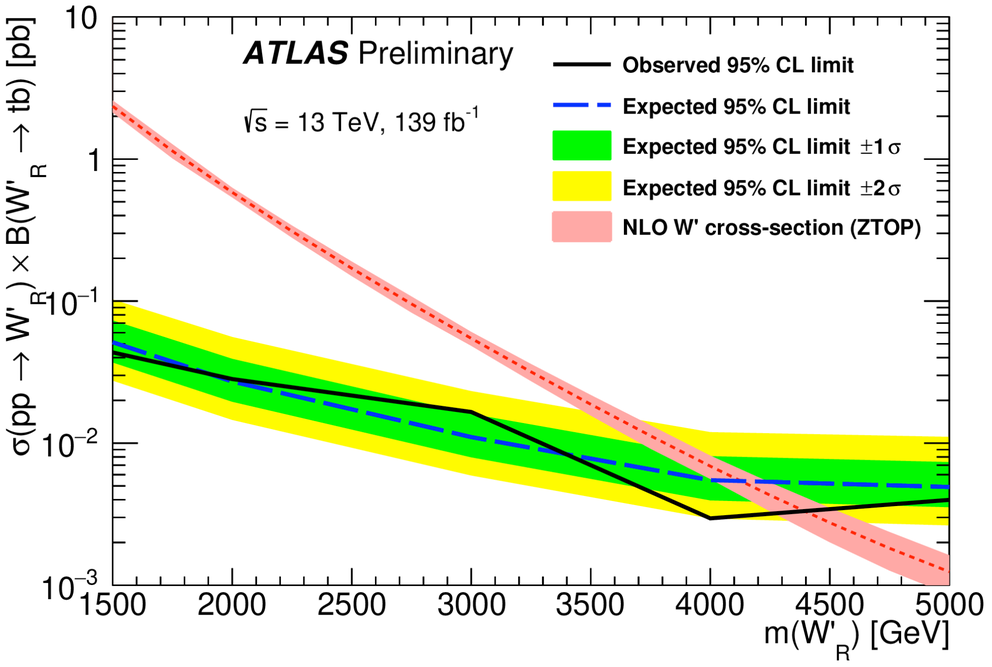
ATLAS-CONF-2021-043



Results

- No significant excess above the standard model background is observed.
- Limits set on the production cross-section of a W' decaying to the tb final state
  - W' with right-handed coupling excluded below a mass of 4.4 TeV at 95% confidence level.

ATLAS-CONF-2021-043



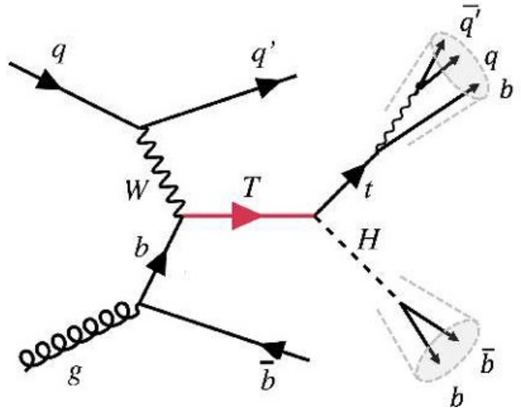
Improvement of the mass limit by 1TeV w.r.t previous result using 2015+2016 data (36fb^{-1})

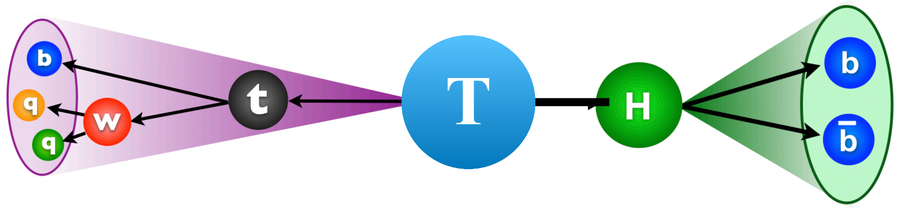
Vector-like T quark decaying into Higgs and top quark

- Vector-like quarks are hypothetical spin-1/2 particles that arise in various models that address problems in the SM such as the hierarchy problem. Vector-like quarks are expected to couple preferentially to third-generation quarks.

- A search is performed for Vector-like T quark decaying to a Higgs boson and a top quark in proton-proton collisions using **ATLAS detector** at a center-of-mass energy of 13 TeV.

- Fully hadronic final state considered.





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2019-07/

Event Selection

- Analyzed data were collected by the ATLAS experiment between 2016 and 2018 (full Run-2 data) and correspond to an integrated luminosity 139 fb^{-1}.

- Events must have at least two large-*R* jets (R = 1.0) with $p_T > 350$ GeV and $|\eta| < 2.0$, The large-*R* jets must have a mass between 100 and 225 GeV.

- Top tag:
  - deep-neural-network (DNN) is used for t tagging, along with mass between 140 and 225 GeV are considered.

- Higgs tagging:
  - requiring the large-*R* jet mass to be between 100 and 140 GeV, along with an upper bound on the jet-substructure variable τ_{21}

- b-tag:
  - The algorithm used is known as DL1, a DNN-based tagging scheme that uses the secondary vertex information and the impact parameters of the charged tracks in a VRTrack jet

Search Information

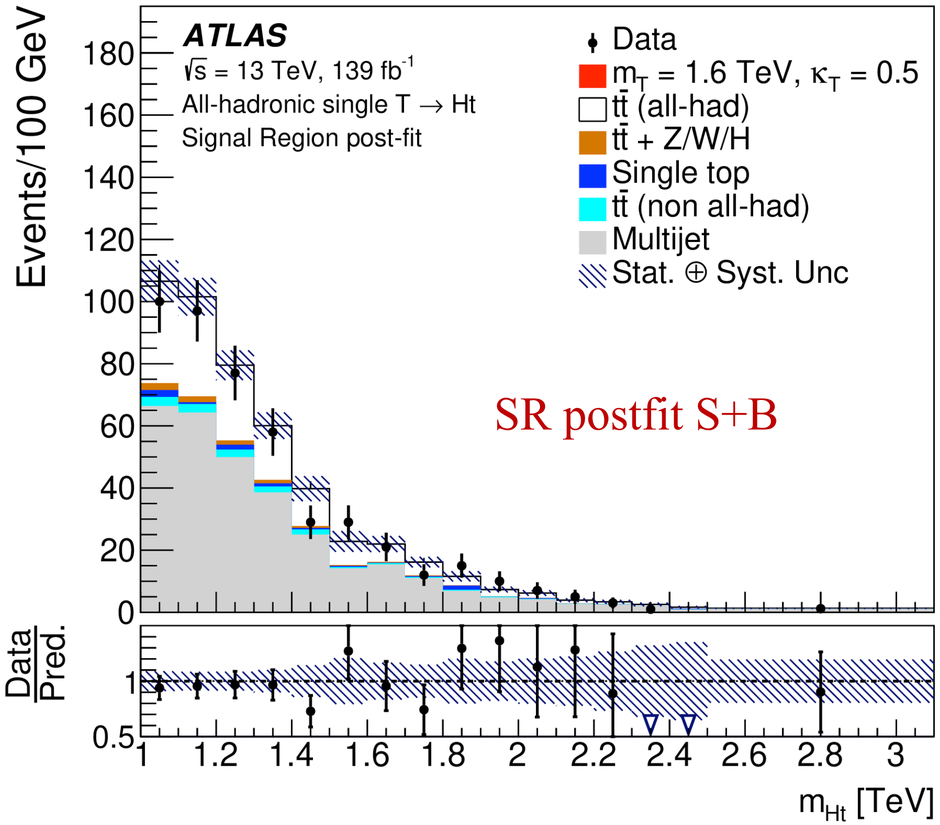
Backgrounds

- QCD Multijet
  - Data-driven background estimation
    - Events from specifically chosen event-tagging states to estimate the multijet background event yields in the signal, normalization, and validation regions.
- Top quark pair production
  - Estimated with simulation and validated with data
- Non all-hadronic $t\bar{t}$ process
  - Estimated using MC samples

Search

- Events are classified according to the tagging states of each large-*R* jetClassification 81 categories based on “H, t, other” & “0b, 1b, 2b” jet.SR, VR, NR
- Search over m_{jj}(Dijet invariant mass distributions) *SR*, *NR* showing the results of the model when fitted to the data.

EXOT-2019-07



Results

- No evidence of significant contributions from single T-quark production.
- Limits set on the production cross-section of a T quark decaying to the Ht final state
  - excluded coupling strength values of $\kappa_T \geq 0.5$ for T masses below 1.8 TeV at 95% confidence level.

EXOT-2019-07