Search for Single Production of a Vector-Like T Quark Decaying into a Higgs Boson and Top Quark with Fully Hadronic Final States Using the ATLAS Detector

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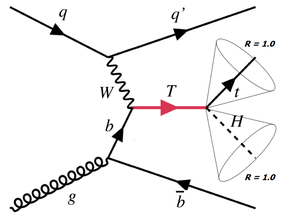
Introduction

- Vector-like quarks (VLQs) appear in many Beyond Standard Model (BSM) theories as a way to explain problems in the Standard Model (SM) such as the hierarchy problem
- A search is performed for the vector-like top quark partner, T, decaying into a SM top quark and a Higgs boson, both decaying hadronically
- Exclusion limits are set at the 95% confidence level for VLQ models of various mass (m_T) and coupling values (κ_T)

Event Selection

- Lepton veto
- Leading large-R jet $p_{\mathrm{T}} \geq 500$ GeV
- 2nd leading large-R jet $p_{\mathrm{T}} \geq 350$ GeV
- $|\eta| \leq 2.0$
- $100 \leq m_{jet} \leq 225$ GeV

2 Anti-k$_t$ Large-R = 1.0 jets



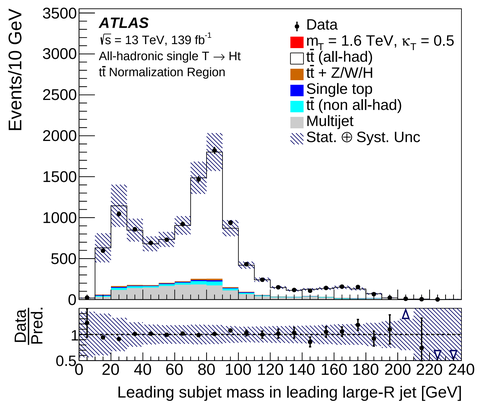
Large-R Jet Tagging

b-Tagging:
Variable radius (VR) track jet contained inside a large-R jet and b-tagged using the DL1 [1] algorithm at 70% W.P.

Higgs tagging:
Mass window ($100 \leq m_{jet} \leq 140$ GeV) and τ_{21} substructure upper bound that varies with p_{T} to provide 70% W.P.

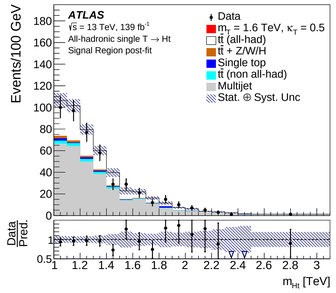
Top-tagging:
Mass window ($140 \leq m_{jet} \leq 225$ GeV) and High level Deep Neural Network (DNN) tagger based on jet substructure variables [2] at 80% W.P. for fully contained top candidates.

Background Estimate



- MC used to estimate SM background
- Data driven "ABCD" technique used to measure multijet background
- $t\bar{t}$ background normalized to data in dedicated normalization region
- Leading large-R jet's leading subjet mass distribution in $t\bar{t}$ normalization region used to validate background modelling

Signal Region Distribution

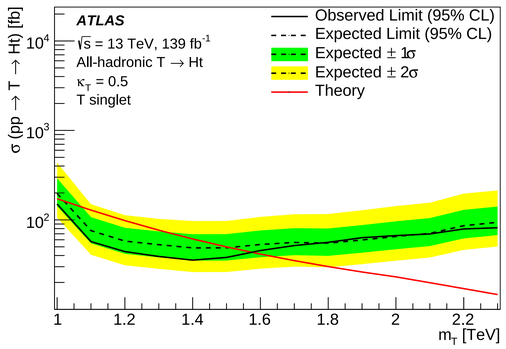


- Dijet invariant mass distribution in the signal region for a signal sample with $m_T = 1.6$ TeV and $\kappa_T = 0.5$

Source	Events	Uncertainty
$t\bar{t}$ all had. MC	147	± 17
$t\bar{t}$ semi-leptonic	14	± 10
Single top quark	8	± 6
$t\bar{t}$ + W/Z/H	9	± 2
Multijet	316	± 19
Signal	-9	± 21
Prediction	494	± 22
Data	471	

- Post-fit yields with the full Run 2 data (139 fb^{-1}) show no excess

Exclusion Limits

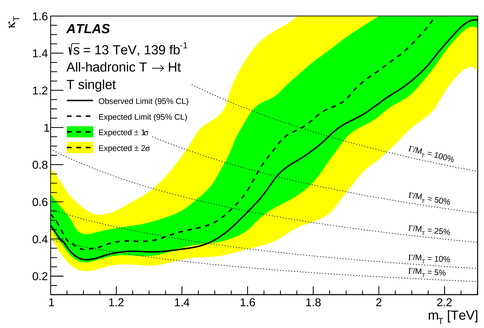


- 2D phase space defined by $1.0 \leq m_T \leq 2.3$ TeV and $0.1 \leq \kappa_T \leq 1.6$
- Profile-likelihood fit of VLQ signal strength for each m_T and κ_T is performed on the dijet invariant mass distribution in the signal region

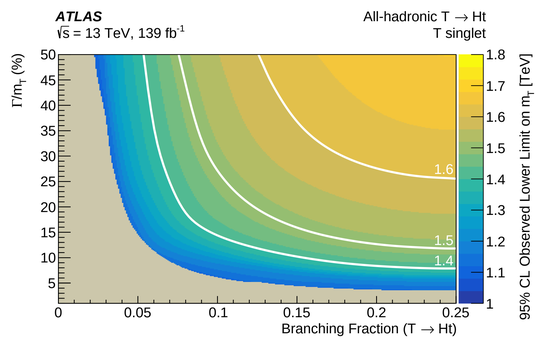
$$L(\mu, \theta) = \prod_{i=1}^{N_b} \mathrm{Poiss}(\mu S_i + b_i) \prod_{j=1}^{N_p} \mathrm{Gauss}(\theta_j, \sigma_j)$$

- CL$_S$ [3] method used to set 95% confidence level upper limits on the signal cross-section

Interpretations of the $T \to Ht$ Limits



- Observed and expected 95% confidence level upper limits on κ_T as a function of m_T
- All κ_T values above the solid line have been excluded
- Dashed lines are Γ/M_T ratios



- Observed 95% confidence level lower limits on the T-quark mass as a function of Γ/M_T and the branching fraction of the $T \to Ht$ decay
- The three decay modes of the vector-like T quark are $T \to Ht/Wb/Zt$
- $\mathcal{B}(T \to Ht)$ and $\mathcal{B}(T \to Zt)$ are assumed to be equal
- $\mathcal{B}(T \to Wb) = 1 - \mathcal{B}(T \to Zt) - \mathcal{B}(T \to Ht)$

Conclusions

- Submitted to PRD: ArXiv:2201.07045
- Set exclusion limits up to $m_T = 2.3$ TeV and $\kappa_T = 1.6$
- Extended the sensitivity of vector-like T quarks decaying hadronically, lowering previous cross-section upper limits by a factor of 2 [4]

References

[1] ATLAS Collaboration, "ATLAS b-jet identification performance and efficiency measurement with $t\bar{t}$ events in pp collisions at $\sqrt{s} = 13$ TeV," *Eur. Phys. J. C*, vol. 79, p. 970, 2019.

[2] ATLAS Collaboration, "Performance of top-quark and W-boson tagging with ATLAS in Run 2 of the LHC," *Eur. Phys. J. C*, vol. 79, p. 375, 2019.

[3] A. L. Read, "Presentation of search results: The CL(s) technique," *J. Phys.*, vol. G28, pp. 2693–2704, 2002. [,11(2002)].

[4] CMS Collaboration, "Search for electroweak production of a vector-like T quark using fully hadronic final states," *JHEP*, vol. 01, p. 036, 2020.

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