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 appear in many Beyond Standard Model (BSM) theories as a way to explain problems such as the hierarchy problem. This analysis searches for the vector-like top quark partner, T, decaying into a Standard Model (SM) top quark and a Higgs boson, both decaying hadronically. A resonance search is performed in the tH dijet invariant mass distribution.

Background Estimate

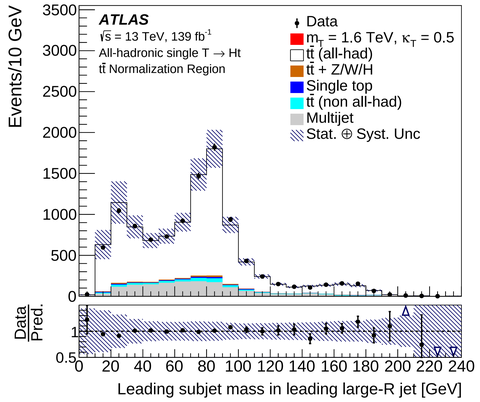


Figure 2: The leading large-R jet's leading subjet mass distribution. The large-R jet has been top tagged with one associated b-tagged subjet.

- Powheg+Pythia 8 MC used to estimate all hadronic and semi leptonic $t\bar{t}$ contributions, which are then normalized to data in validation region
- Data driven "ABCD" technique used to measure multijet background by subtracting scaled MC from data

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)].

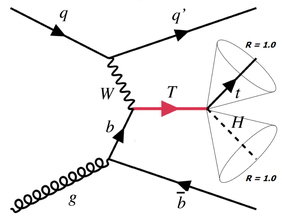
[4] CMS Collaboration, "Search for electroweak production of a vector-like T quark using fully hadronic final states," *JHEP*, vol. 01, p. 036, 2020.

Event Selection

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

Leading Large-R jet:

- Lepton veto
- $p_T \geq 500$ GeV
- $|\eta| \leq 2.0$
- $100 \leq m_{jet} \leq 225$ GeV



2nd Large-R jet:

- Lepton veto
- $p_T \geq 350$ GeV
- $|\eta| \leq 2.0$
- $100 \leq m_{jet} \leq 225$ GeV

Signal Region Distribution

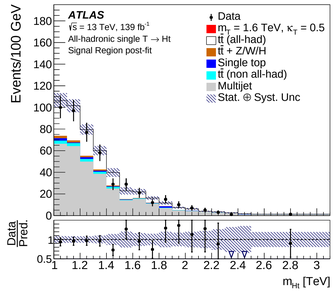


Figure 1: Dijet invariant mass distribution in the signal region. This distribution has been fitted using TRexFitter. The example signal used has parameter $m_T = 1.6$ TeV and $\kappa_T = 0.5$

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	

Table 1: Table with fitted yields of SM background in full Run 2 data (139 fb^{-1}).

Conclusions

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

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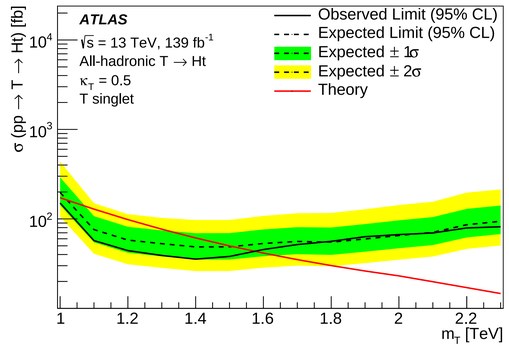
Large-R Jet Tagging

b-Tagging:
Variable radius (VR) track jet contained inside large-R jet and b-tagged using 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.

Signal Samples and Analysis



- Simple signal model parameters: only mass of vector-like T and coupling parameter to Standard Model
- The 2D phase space defined by these parameters is $1.0 \leq m_T \leq 2.3$ TeV in 0.1 TeV steps and $0.1 \leq \kappa_T \leq 1.6$ in 0.1 steps
- Profile-likelihood fit of VLQ signal strength for each m_T and κ_T is performed on the dijet invariant mass distribution
- The CL$_S$[3] method is used to determine the 95% confidence level when setting upper limits on the signal strength

Interpretations of the $T \to Ht$ Limits

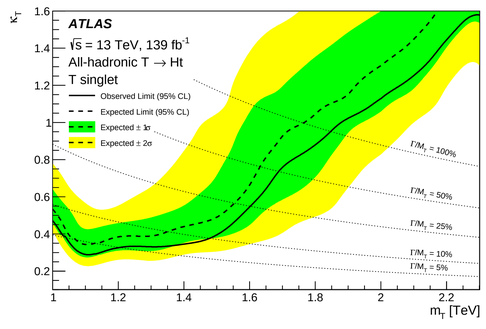


Figure 3: Observed and expected 95% CL upper limits on single T-quark coupling κ_T as a function of m_T

- All κ_T values above the solid line have been excluded
- Also shown are contours of the width-to-mass ratio Γ/M_T

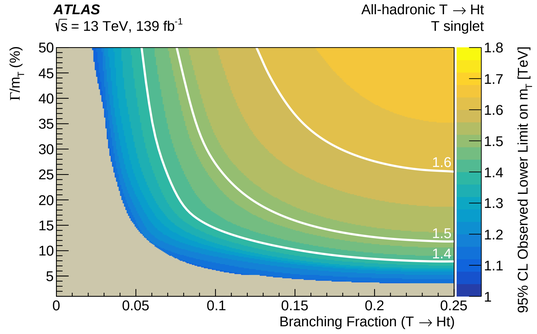


Figure 4: The observed 95% CL lower limits on the T-quark mass as a function of T-quark width-to-mass ratio Γ/M_T and the branching fraction of the $T \to Ht$ decay.

- 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, and $\mathcal{B}(T \to Wb)$ is assumed to be $1 - \mathcal{B}(T \to Zt) - \mathcal{B}(T \to Ht)$