Searches for BSM particles decaying to 3rd generation quarks

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Heavy gauge bosons

- Appears in various theories beyond the standard model
- E.g. in Sequential Standard Model (SSM), they obey lepton universality and have couplings identical to the SM $W/Z$ boson
- Other models include heavy gauge bosons e.g.:
  - Non-universal $G(221)$ model (NU) with $SU(2)_l \times SU(2)_h \times U(1)$, they decay preferentially to heavy fermions
  - Model with extra dimensions
  - Strong dynamics
  - Composite / Little Higgs
- $W'_L$ decay in LH fermions
- $W'_R$ decay into RH fermions with $\nu_R$ heavier than $W'_R$
Heavy gauge bosons

\[ W' \rightarrow t\bar{b} \rightarrow q\bar{q}'b\bar{b} \]

- ATLAS 8 TeV, 20.3 fb\(^{-1}\): 2.0 TeV
- CMS 13 TeV, 35.9 fb\(^{-1}\): 3.6 TeV

Event selection

- veto \( e/\mu \)
- jet \( p_T > 420 \text{ GeV} \)
- Boosted \( t \) tagger with shower deconstruction
  - tuned to \( p_T > 800 \text{ GeV} \)
  - 6 highest-\( p_T \) subjets of a \( k_T 1.0 \) jet fed to tagger
  - two WP used (50\% and 80\%)
- all \( b \)-jets \( |\eta| < 1.2 \)

Event categories

- \( J_t^{\text{cand}} \): large jet with \( \max(m_j + 0.15m_J) \)
  \( (m_j: \text{highest } p_T \text{ subjet, } m_J: \text{large jet}) \)
- \( j_b^{\text{cand}} \): highest \( p_T \) small jet with
  \( \Delta R(J_t^{\text{cand}}, j_b^{\text{cand}}) > 2.0 \)
- Categories based on (0 or 1) \( b \)-jet in \( \Delta R(J_t^{\text{cand}}, j) < 1.0 \)
- each category split in 6 regions
  - \( b \) tagged / not tagged \( j_b^{\text{cand}} \)
  - Tight / loose not tight / not loose \( J_t^{\text{cand}} \)
- 0 \( b \): 1 SR, 1 VR, 4 CR ; 1 \( b \): 2 SR, 4 CR

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Heavy gauge bosons

$W' \to t\bar{b} \to q\bar{q}'b\bar{b}$ – Results

$\sigma(pp \to W' \to t\bar{b}) \times B(W' \to t\bar{b})$ for $m_{W'}$ in the range of $1000$ to $6000$ GeV.

**ATLAS**

*Results for mW' RH > 3 TeV*

$m_{W'} > 3$ TeV

**ATLAS**

*Results for mW' LH > 2.9 TeV*

$m_{W'} > 2.9$ TeV

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Vector like quarks

- defined as colour triplet, spin $\frac{1}{2}$ fermions
- LH / RH fermions transform equally under $SU(2)_L$
- < (>)1 TeV pair (single) production dominant (depending on coupling assumptions)
- Many models favor couplings to 3rd generation, but couplings to 1st and 2nd generation in general not excluded
- appear e.g. in Little / Composite Higgs models
- depending on model, VLQ are produced in SU(2) singlet, doublets or triplets
- flavors B,T,X,Y with the charges $-\frac{1}{3}, \frac{2}{3}, \frac{5}{3}, -\frac{4}{3}$
- for consistency with electroweak precision fits, small mass splitting in SU(2) multiplet
- flavor changing neutral and charged currents are allowed
- $B \rightarrow Wt, Zb, Hb \hspace{1cm} T \rightarrow Wb, Zt, Ht \hspace{1cm} X \rightarrow Wt \hspace{1cm} Y \rightarrow Wb$
Pair produced VLQ to high-$p_T$ $W$ bosons and $b$ quarks in lepton+jets

- old limits: ATLAS and CMS excluded masses below 740 GeV for any combination of BR
  - below 782 GeV for $BR(T \rightarrow WB) = 1$
  - ATLAS at 13 TeV: 1160 GeV for $BR(T \rightarrow Zt) = 1$
- optimized for $T\bar{T}$ with one $T \rightarrow WB$

Event selection

- exactly 1 $e/\mu$
- $\geq 3$ jet, $\geq 1$ $b$-tagged jet, $\geq 1$ jet $p_T > 60$ GeV
- hadronic and leptonic VLQ reconstructed using lepton, large and small jets and $E_T^{\text{miss}}$
  - paring of a $W$ candidate with $b$-jet
  - choose minimum $|\Delta m| = |m_T^{\text{had}} - m_T^{\text{lep}}| (< 300$ GeV in SR)
  - $S_T > 1800$ GeV scalar sum of $E_T^{\text{miss}}, p_T(\text{lep}), p_T(\text{smalljets})$
    (CR: 1000 GeV $< S_T < 1800$ GeV)
Pair produced VLQ to high-$p_T$ $W$ bosons and $b$ quarks in lepton+jets

Results

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Searches for BSM particles decaying to 3rd generation quarks

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Pair produced $T\bar{T}$ VLQ to $1l$, jets, $E_T^{\text{miss}}$

- optimized for $T\bar{T}$ with $T\rightarrow Z(\rightarrow \nu\nu)t + X$

Event selection
- exactly 1 $e/\mu$
- $\geq 4$ jets, $\geq 1$ $b$-jet
- $amT_2 > 175$ GeV (100 GeV in the CR): a transverse mass
  - combination of lepton and either one of the highest $b$-tag weighted jets
  - reduces dileptonic $t\bar{t}$ decays
- $m_{T2} > 80$ GeV: a transverse mass, only applicable if a hadronic $\tau$ candidate is found
  - using the $\tau$ candidate an the signal lepton
  - reduces $t\bar{t}$ events with one $e/\mu$ and a hadronically decaying $\tau$
- $H_{T,\text{sig}}^{\text{miss}} = \frac{H_T^{\text{miss}} - 100 \text{ GeV}}{\sigma_{H_T^{\text{miss}}}} > 12$ (no cut in CR), reduces effect of mis-reconstructed $E_T^{\text{miss}}$

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Vector like quarks

Pair produced $T\bar{T}$ VLQ to $1l$, jets, $E_T^{\text{miss}}$ – Results

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Conclusion

- New ATLAS results presented for searches for heavy vector bosons and vector-like quarks predominantly coupling to 3rd generation quarks
- No significant deviations from standard model observed
- Mass and coupling limits pushed further thanks to increased center-of mass-energy and luminosity