

4th Generation Vector Like Quarks (VLQ)



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What is a VLQ?

- A vector-like quark's left- and right-handed charge currents are both non-zero in the standard model symmetry group

$$\mathcal{L}_W = \frac{g}{\sqrt{2}} (J^{\mu+} W_\mu^+ + J^{\mu-} W_\mu^-) \quad J^{\mu+} = J_L^{\mu+} + J_R^{\mu+}$$

- Chiral $J_L^{\mu+} = \bar{u}_L \gamma^\mu \bar{d}_L \quad J_R^{\mu+} = 0$

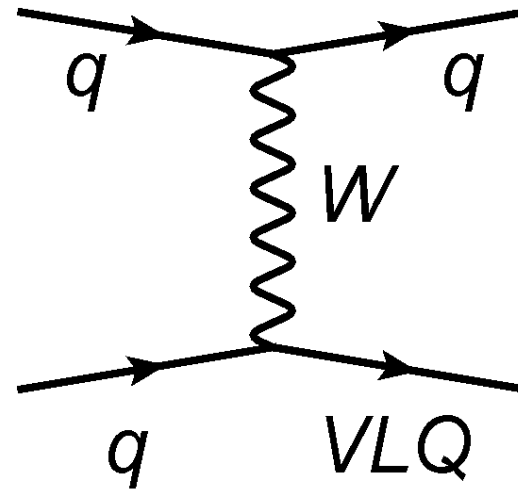
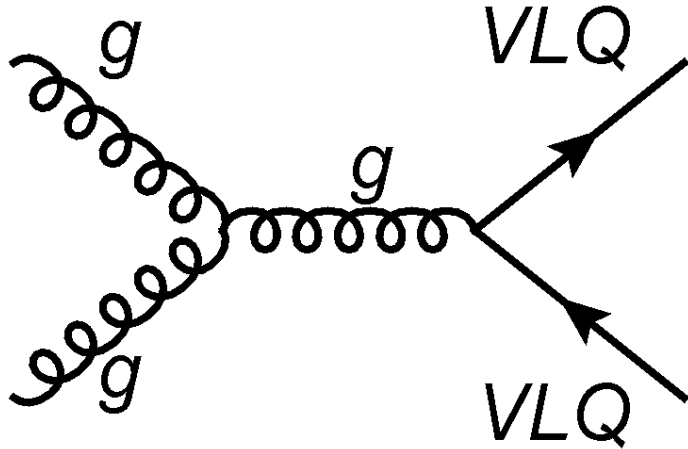
- VLQ $J_L^{\mu+} = \bar{u}_L \gamma^\mu \bar{d}_L \quad J_R^{\mu+} = \bar{u}_R \gamma^\mu \bar{d}_R$

Where do VLQ come up?

- Non-minimal SUSY extensions
- Warped or universal extra-dimensions
- Composite Higgs models
- Gauged flavor groups
- Little Higgs models

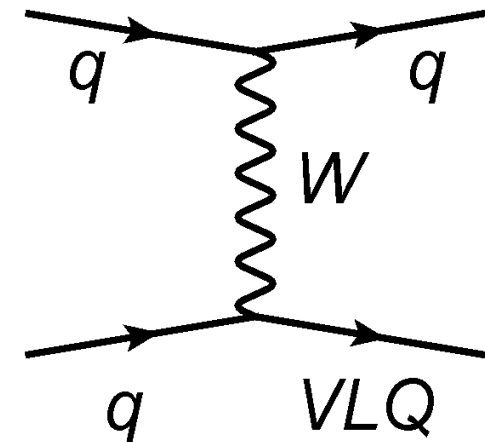
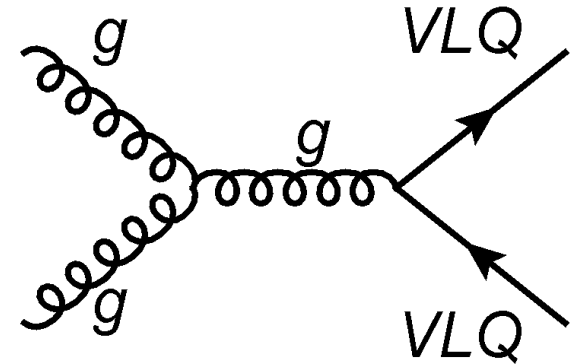
Allowed charges and production channels

- $Q_{VL} = T_{2/3}; B_{-1/3}; X_{5/3}; Y_{-4/3}$
- Leads to pair and single production channels



How is the search going?

- LHC exclusions
 - CMS - pair production @ 7TeV
 - $m(B \rightarrow Wt) > 675 \text{ GeV}$
 - $m(T \rightarrow Zt) > 625 \text{ GeV}$
 - $m(X \rightarrow Wt) > 645 \text{ GeV}$
 - ATLAS - pair production @ 7 TeV
 - $m(B \rightarrow Wt) > 670 \text{ GeV}$
 - $m(T \rightarrow Wb) > 656 \text{ GeV}$
 - $m(X \rightarrow Wt) > 680\text{-}700 \text{ GeV}$
 - CMS - @ 8TeV - Seen yesterday
 - ATLAS - @ 8 TeV - Seen here





CERN-PH-EP-2014-188

Submitted to: JHEP

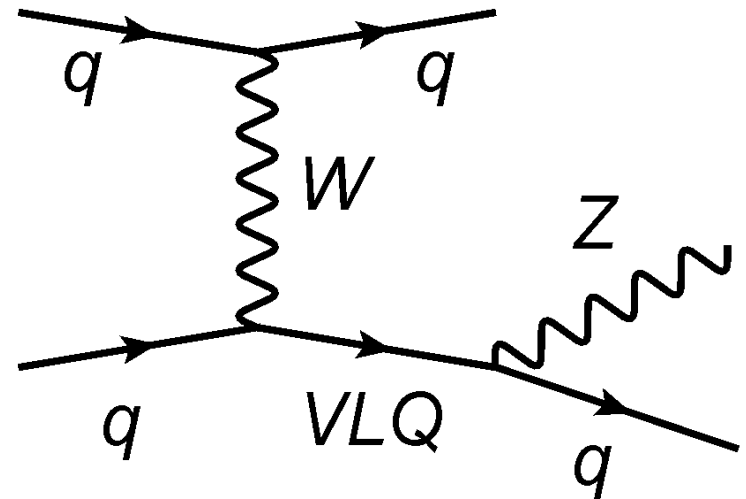
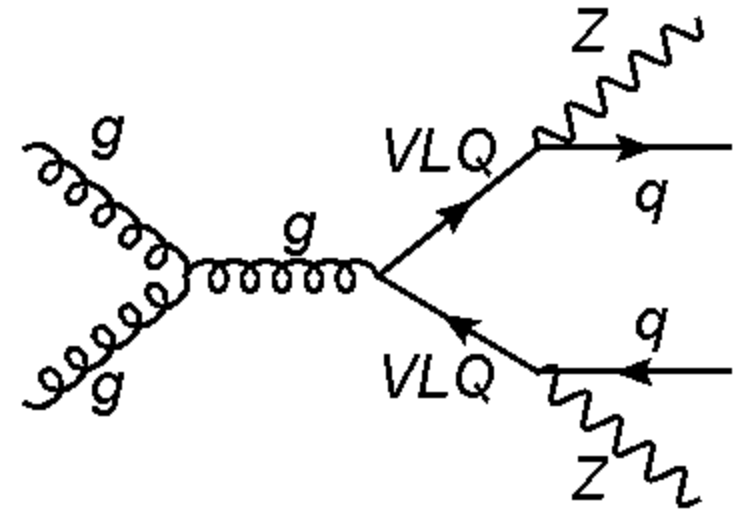
ATLAS Results

Search for pair and single production of new heavy quarks that decay to a Z boson and a third-generation quark in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

The ATLAS Collaboration

Abstract

A search is presented for the production of new heavy quarks that decay to a Z boson and a third-generation Standard Model quark. In the case of a new charge $+2/3$ quark (T), the decay targeted is $T \rightarrow Zt$, while the decay targeted for a new charge $-1/3$ quark (B) is $B \rightarrow Zb$. The search is performed with a dataset corresponding to 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV recorded in 2012 with the ATLAS detector at the CERN Large Hadron Collider. Selected events contain a high transverse momentum Z boson candidate reconstructed from a pair of oppositely charged same-flavor leptons (electrons or muons), and are analyzed in two channels defined by the absence or presence of a third lepton. Hadronic jets, in particular those with properties consistent with the decay of a b -hadron, are also required to be present in selected events. Different requirements are made on the jet activity in the event in order to enhance the sensitivity to either heavy quark pair production mediated by the strong interaction, or single production mediated by the electroweak interaction. No significant excess of events above the Standard Model expectation is observed, and lower limits are derived on the mass of vectorlike T and B quarks under various branching ratio hypotheses, as well as upper limits on the magnitude of electroweak coupling parameters.



Event selection

Z boson candidate preselection

≥ 2 central jets

$p_T(Z) \geq 150$ GeV

Dilepton channel

= 2 leptons

≥ 2 b -tagged jets

Pair production

Single production

$H_T(\text{jets}) \geq 600$ GeV

≥ 1 fwd. jet

Trilepton channel

≥ 3 leptons

≥ 1 b -tagged jet

Pair production

Single production

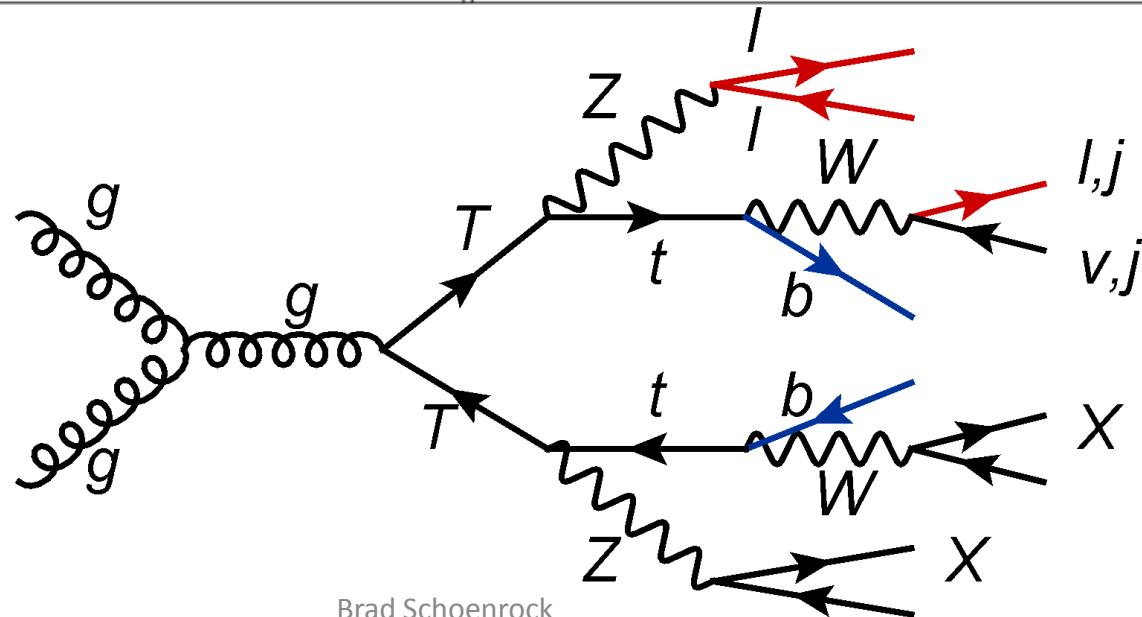
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≥ 1 fwd. jet

Final discriminant

$m(Zb)$

$H_T(\text{jets+leptons})$

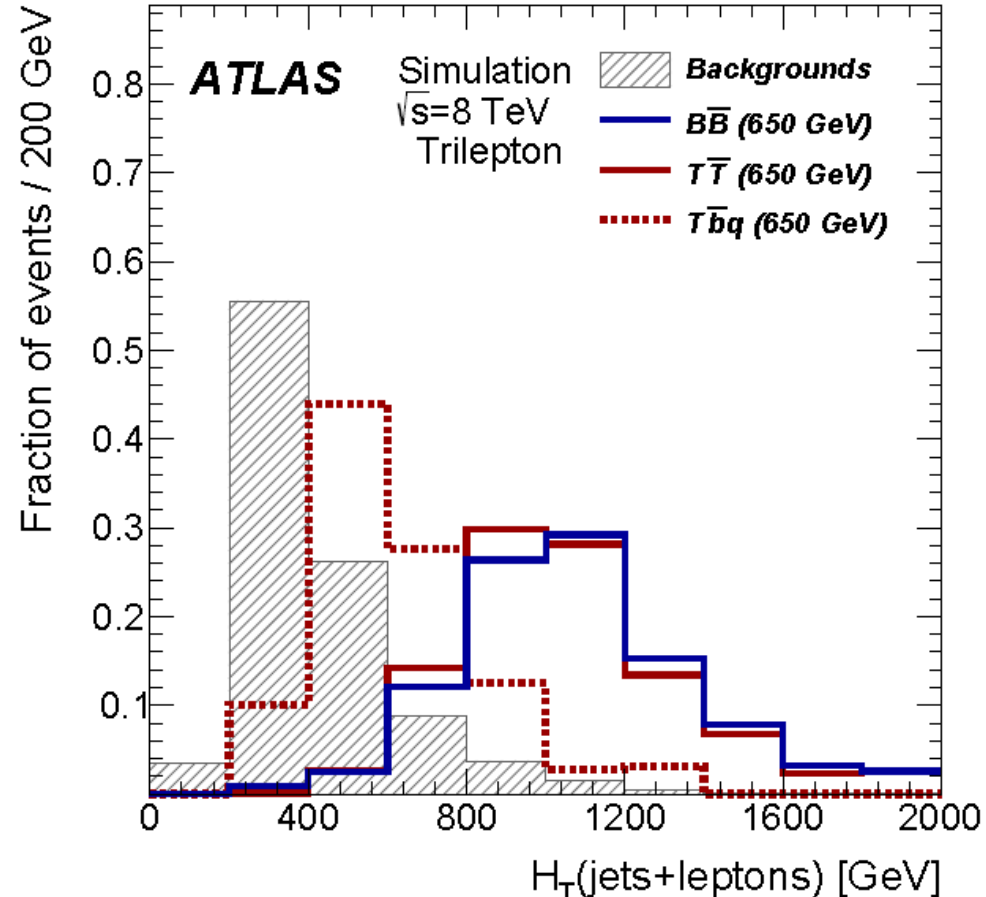
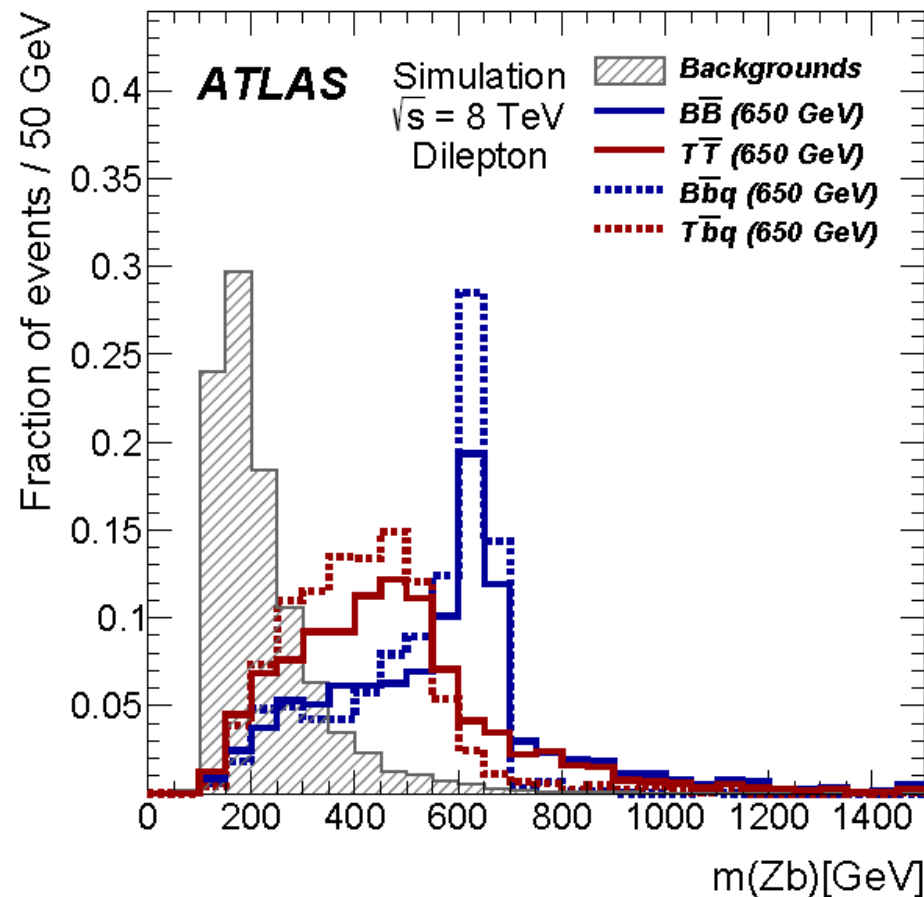


Discriminating Variables

Final discriminant

$m(Zb)$

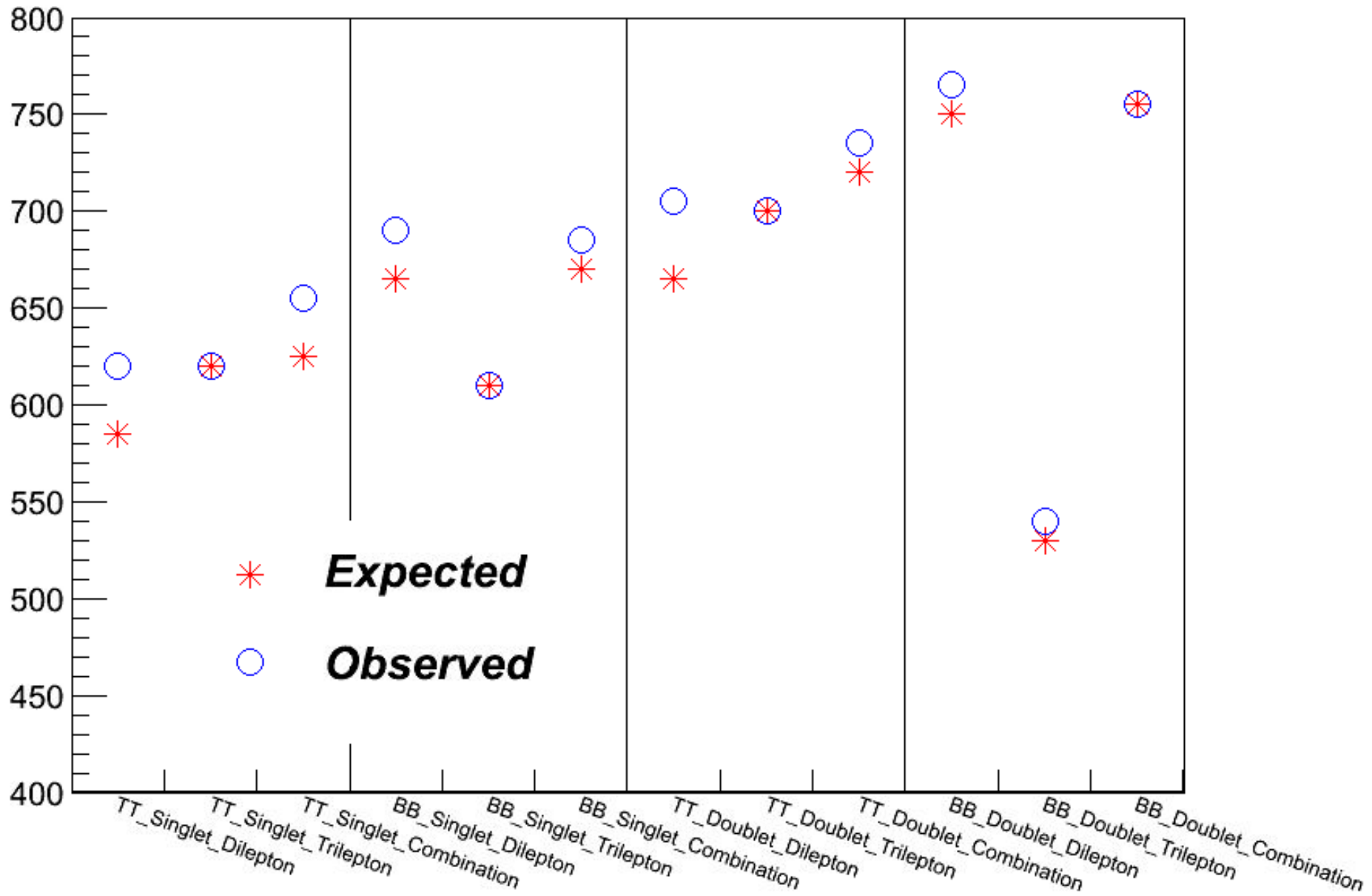
$H_T(\text{jets+leptons})$

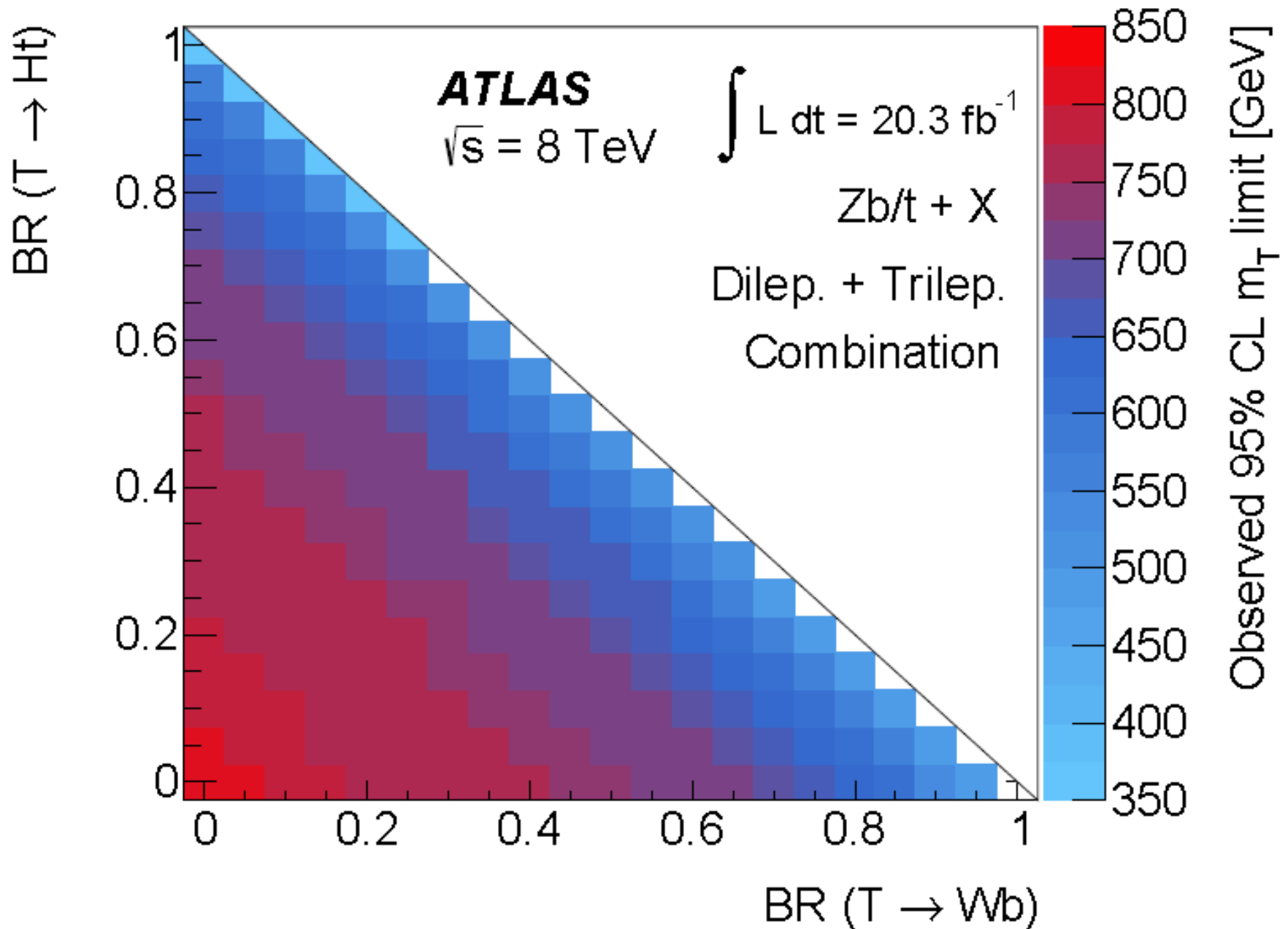


Systematic Uncertainties

- Trilepton channel
 - WZ+jets cross section = $50\% * H_t(\text{lep+jet})/\text{TeV}$
 - ttV cross section = 30%
- Dilepton channel
 - JES, JER
 - B-tagging
 - Background cross sections
 - Z+jets scaling

Expected and Observed Limits





B.R. $T \rightarrow Zt + T \rightarrow Wb + T \rightarrow Ht = 1$

Conclusions

- A non-model specific search is the best way to approach VLQ analyses
- Fourth Generation VLQ are an interesting gateway to many new physics models
- Their discovery could be used to move beyond the standard model

Citations

- Thanks to the VLQ Zb/t+X team
- Search for pair and single production of new heavy quarks that decay to a Z boson and a third-generation quark in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector
 ATLAS Collaboration (Georges Aad (Marseille, CPPM) *et al.*).
 Sep 18, 2014. 36 pp.
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- Yasuhiro Okada and Luca Panizzi, “LHC Signatures of Vector-Like Quarks,” *Advances in High Energy Physics*, vol. 2013, Article ID 364936, 17 pages, 2013.
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