Short contribution - EF09 BSM-General: New Fermions and Exotica: Searches for vector-like quarks

Angela Burger, Joe Haley
(Oklahoma State U)
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Vector-like quarks (VLQs) in a nutshell

- VLQs are heavy quarks, left and right chiral components have same color & electroweak quantum numbers
  - Singlet, doublet and triplet representations of T, B, and exotic-charged X & Y
  - Expected to mainly couple to 3rd quark generation ⇒ decay to SM t,b + boson
- Predicted in many models, especially those aimed at to solve the hierarchy problem
  - Composite Higgs, little Higgs, extra dimension (KK excitations)
  - Theories favour a VLQ whose mass not too far from EW scale
- Pair-produced (QCD) & singly-produced (EW)
  - Pair-production cross-section dependent only on VLQ mass
  - Single-production cross-section also dependent on coupling to SM particles
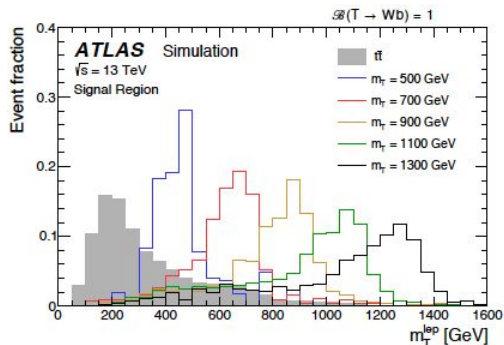- Current limits around 1.2-1.4TeV

Further reading:
- arXiv:1409.0100
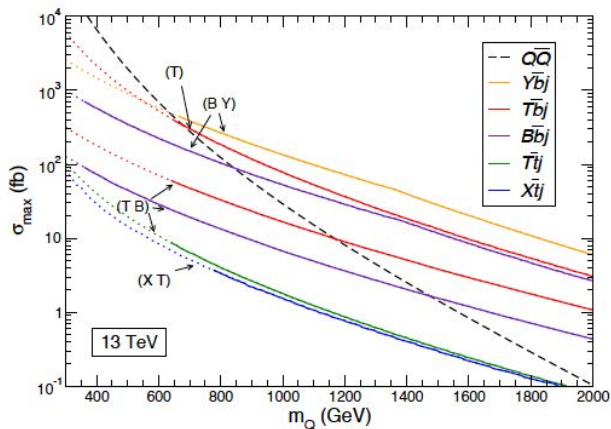- arXiv:1306.0572
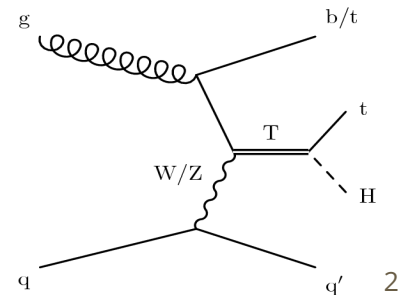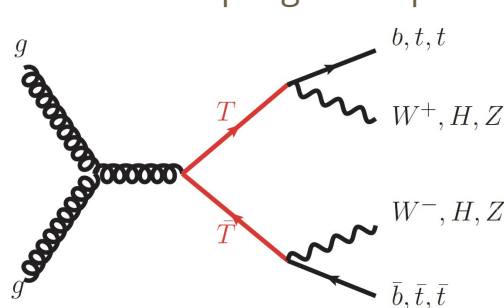
VLQs in a nutshell - what to look for

from: arXiv:1707.03347

from: arXiv:0907.3155
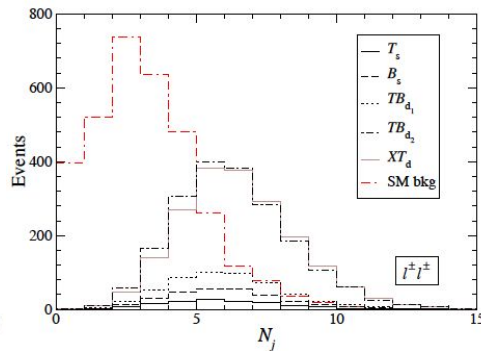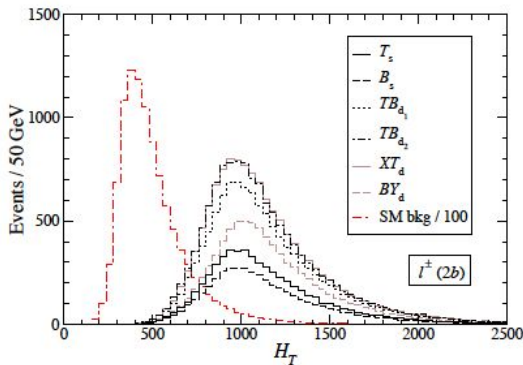
- Resonance @ high (VLQ) mass
  - if final state can be reconstructed
- Large scalar sum of object pT in event
  - high-energetic (VLQ) decay products
- Large number of constituents
- b-jets
- boosted W/Z/H-bosons, top quarks

How can future colliders help?

- For pair-production, the cross-section strongly decrease with VLQ mass
  - Only mild increase for pair production sensitivity expected @ same sqrt(s) with larger lumi
    - pdf drops with transferred momentum approaching kinematic limit sqrt(s)/2
  - Single production more attractive search channel for constant sqrt(s) at some point
  - Pair-production cross section profits from higher center-of-mass energy at hadron colliders
- Pair-produced VLQ search attractive with higher sqrt(s) hadron colliders
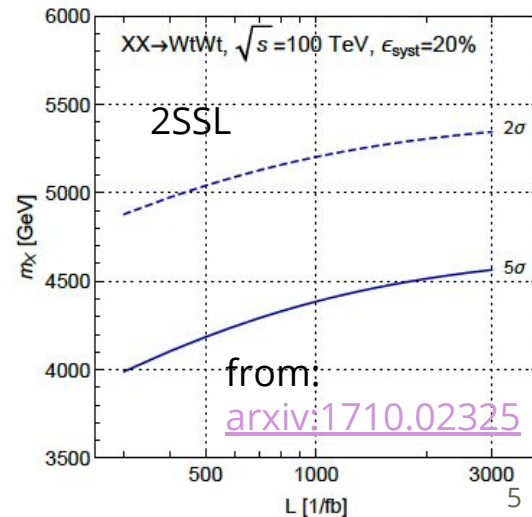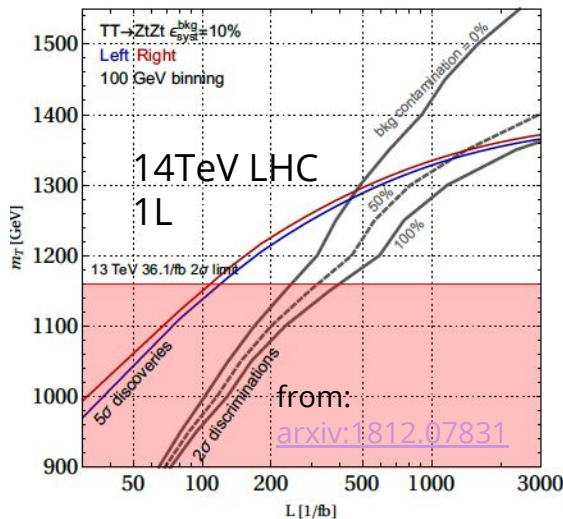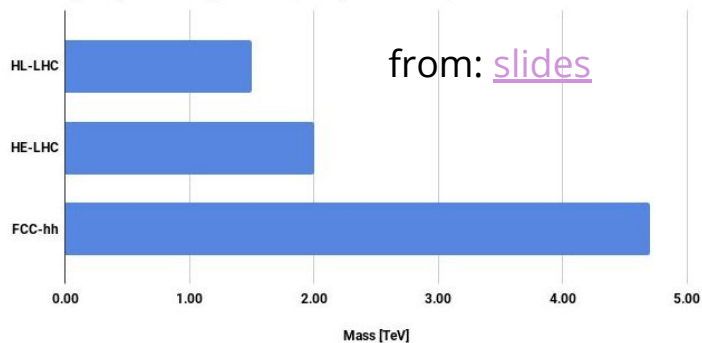

from:
arxiv:1306.0572
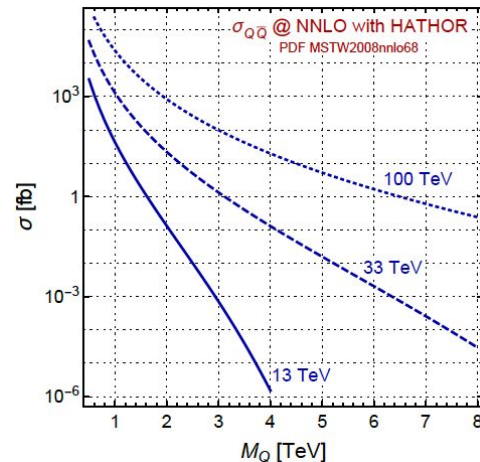
from:
arxiv:1710.02325

What is there already....

- Studies to derive discovery reach of future collider options & determine the dominant coupling chirality using polarisation-sensitive variable
  - Used decays TT->ZtZt or XX->WtWt
  - Hadron colliders, sqrt(s)=14 (arxiv:1309.2234), 27(arxiv:1812.07831), 33 (arxiv:1710.02325, arxiv:1309.2234) TeV, extrapolation to 100TeV hadron collider (arxiv:1710.02325)
- Studies done in framework of previous Snowmass and European Strategy update

VLQ X(5/3) discovery reach (pair production)

from: slides

$TT \to ZtZt$ $\epsilon_{syst}^{bkg} = 10\%$
Left:Right
100 GeV binning

14TeV LHC
1L

13 TeV 36.1/fb 2σ limit

5σ discoveries

2σ discriminations

from: arxiv:1812.07831

$XX \to WtWt$, $\sqrt{s} = 100$ TeV, $\epsilon_{syst} = 20\%$

2SSL

2σ

5σ

from: arxiv:1710.02325

Potential studies

- Use current Snowmass configuration
  - Perform sensitivity studies @high energy hadron colliders (for example FCC-hh, SppC)
  - Include latest recommendations & techniques, for example large-R jet reconstruction and boson tagging, b-tagging, detector & accelerator parameters
- For high-energy hadron colliders, study VLQ pair production
- For sensitivity studies, use TT/YY->WbWb 1 lepton final state
  - Fundamental decay channel to establish $T \rightarrow Wb$ decay
  - Large branching ratio/high sensitivity expected
  - b-tagging can increase the sensitivity to the signal
- Person-power:
  - Joe Haley (OSU)
  - Angela Burger (OSU)
  - [+others very welcome to join…]
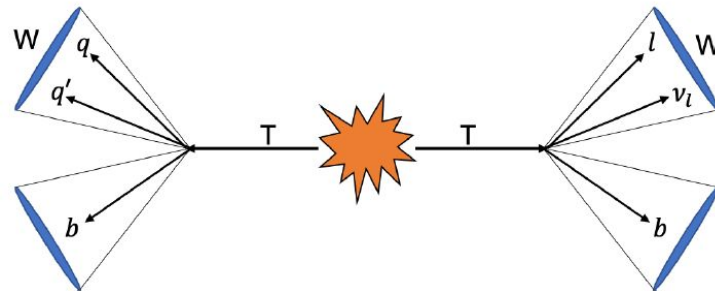
Backup

VLQ decay modes
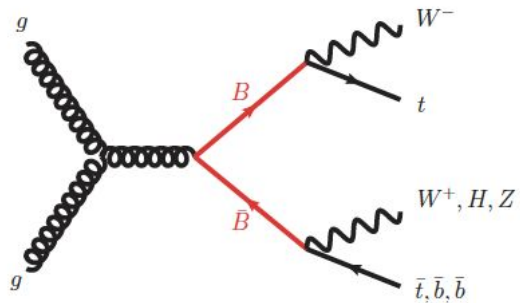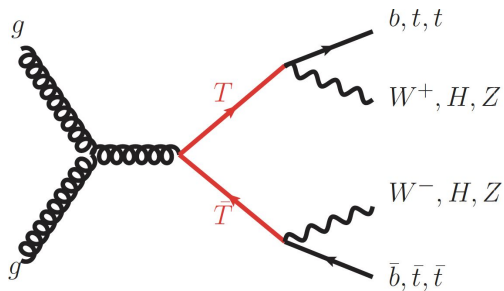
- VLQ T (charge: ⅔ e)
  - T → Wb
  - T → Zt
  - T → HT
- VLQ B (charge: -⅓ e)
  - B → Wt
  - B → Zb
  - B → Hb
- VLQ X (charge: 5/3 e)
  - X → Wt
- VLQ Y (charge: -4/3 e)
  - Y → Wb