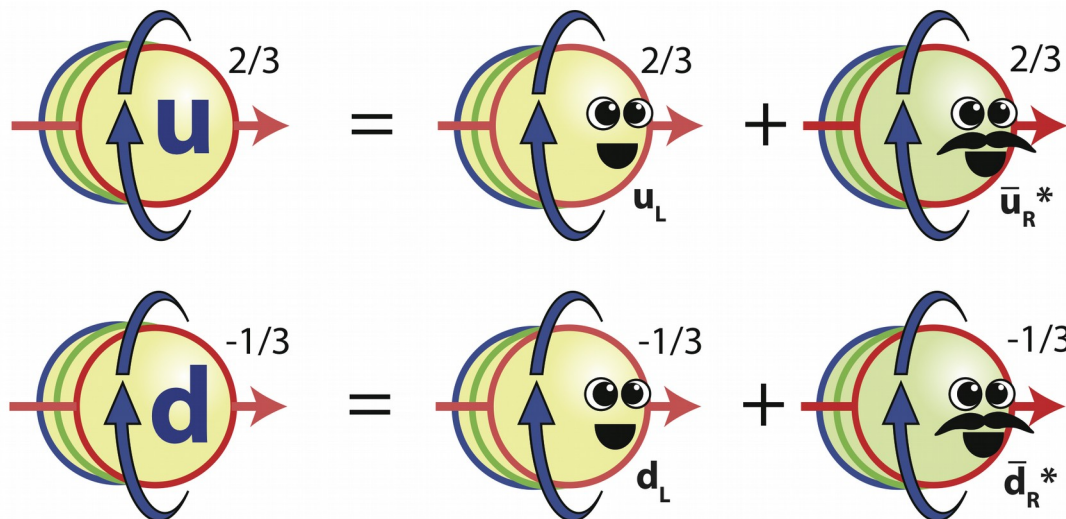# Searching for the single production of vector-like quarks in the Wb final state with the ATLAS detector at 13 TeV

Ferdinand Schenck
HU-Berlin

Physics at the Terascale
26.11.2019

What are Vector Like Quarks?

- Coloured spin-½ particles consistent with several BSM models:
  - Can correct Higgs mass in non-minimal SUSY and others
  - Can act as dark matter mediator in some models
  - Appears in extra dimesion models
- Use models that capture general features for actual predictions
- Left and right-handed components transform identically under $SU(3)_C \times SU(2)_L \times U(1)_Y$

Pair vs. Single Production Cross-sections
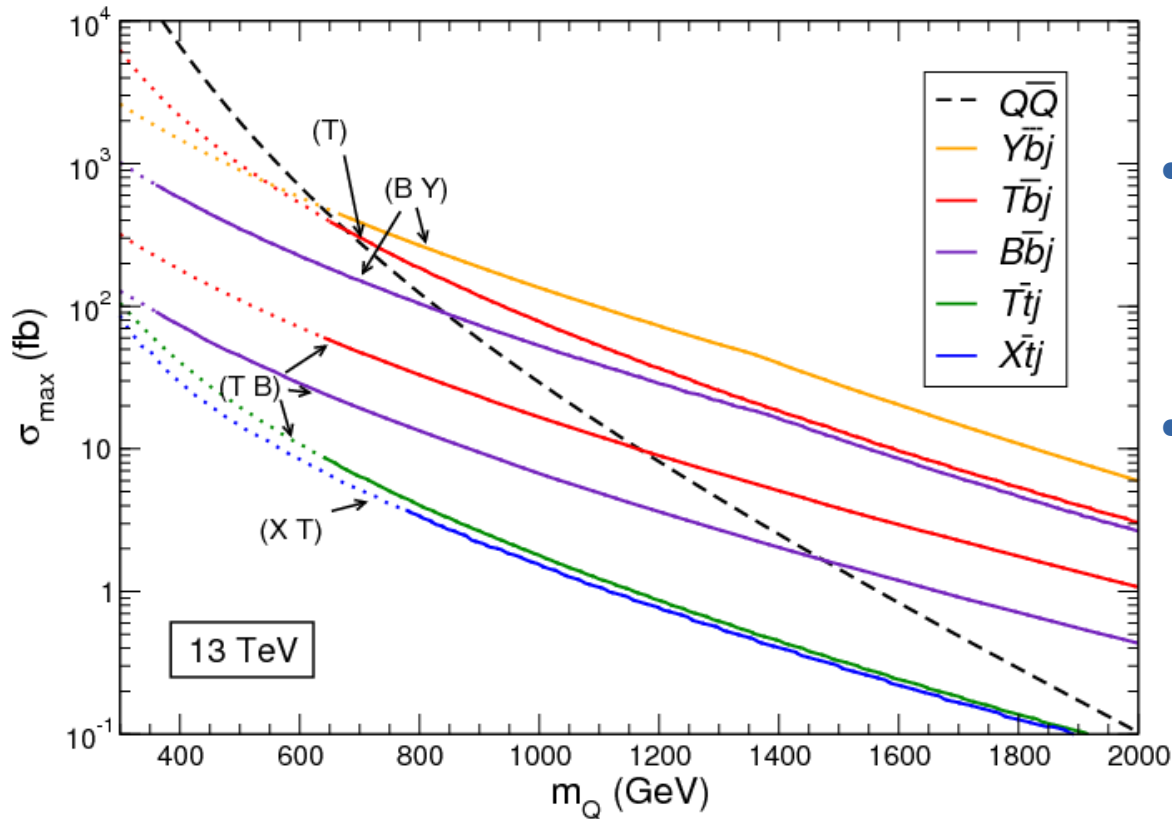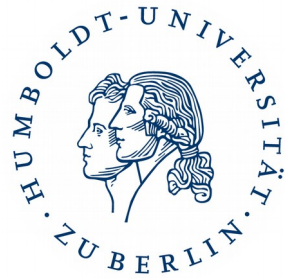
- Predicted cross-sections at 13 TeV large enough to be seen at LHC

- Single production favoured over pair production at higher VLQ masses (≥ 1TeV), where limits are currently set

Maximum single heavy quark production cross sections at the LHC at 13 TeV

Aguilar-Saavedra et al. Phys. Rev. D 88, 094010
arXiv:1306.0572
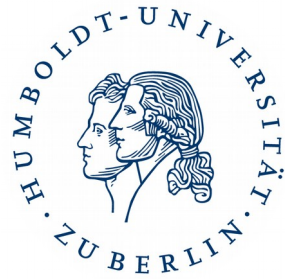
3

Single Production T$^{+2/3}$ or Y$^{-4/3}$

- BR(Y→ Wb) = 100%; BR(T→ Wb) ≈ 50% (for T-singlet)

- Wb fusion dominant production mechanism in models considered here

- Allows for setting limits on couplings

- $\sin\theta_{L/R}$ couplings from[1]

- $c_{L/R}^{Wb}$ couplings from[2]

- Main BG processes:

  $t\bar{t}$, W+jets, single top

- Can interfere with SM processes, causing significant interference effects
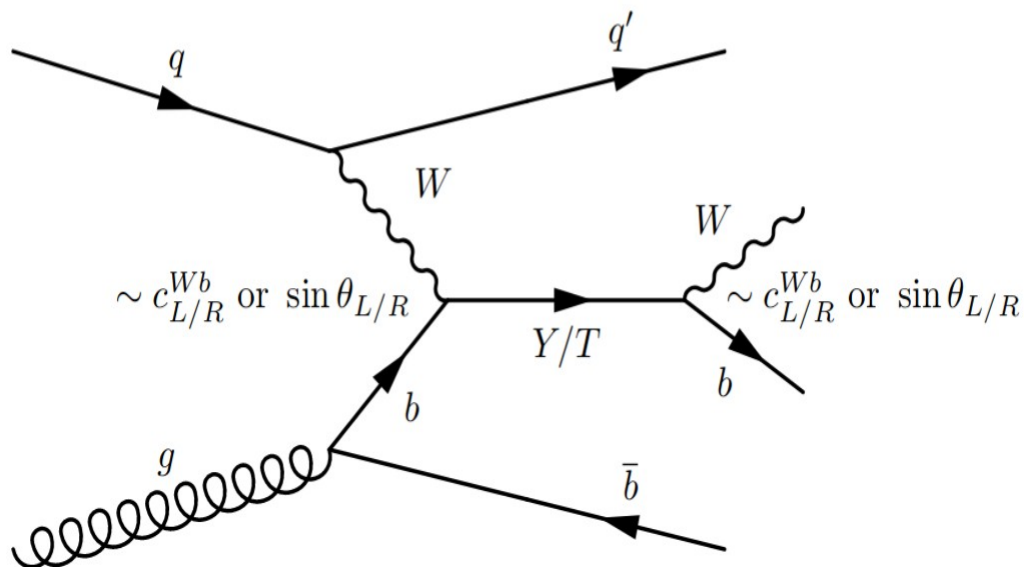
[1] Aguilar-Saavedra, Benbrik, Heinemeyer and Pérez-Victoria (1306.0572)
[2] Matsedonskyi, Panico and Wulzer (1409.0100)

Previous searches

Single Production:

- 8 TeV ATLAS analysis on same channel [Eur.Phys.J. C76 (2016) no.8, 442]

- 13 TeV ATLAS analysis with 36.1 fb^{-1} [JHEP 1905 (2019) 164]
  - First VLQ analysis to consider effects of interference with SM processes

- 13 TeV CMS analysis with 2.3 fb^{-1} [Phys.Lett. B772 (2017) 634-656]

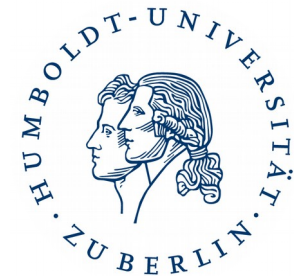- Both only looked into leptonically decaying W

Pair Production:

- 13 TeV ATLAS analysis with 36.1 fb^{-1} [JHEP 1710 (2017) 141]

- 13 TeV CMS analysis with 35.8 fb^{-1} [Phys.Lett. B779 (2018) 82-106]

Previous results
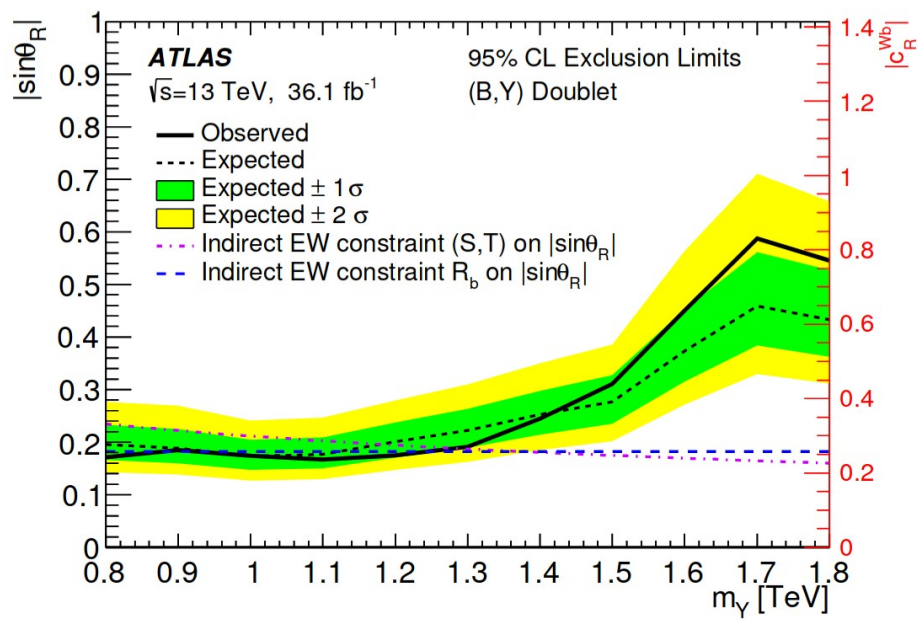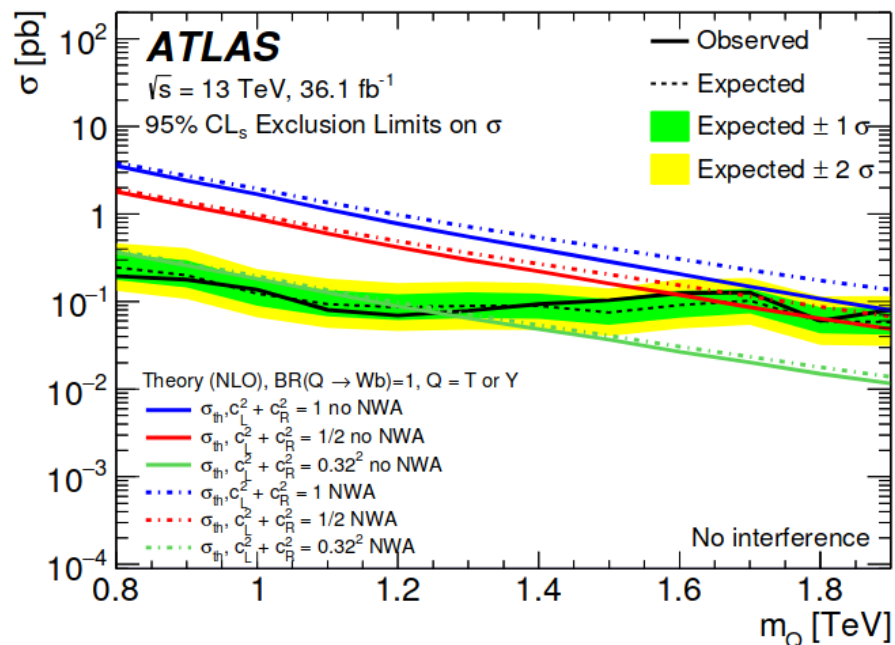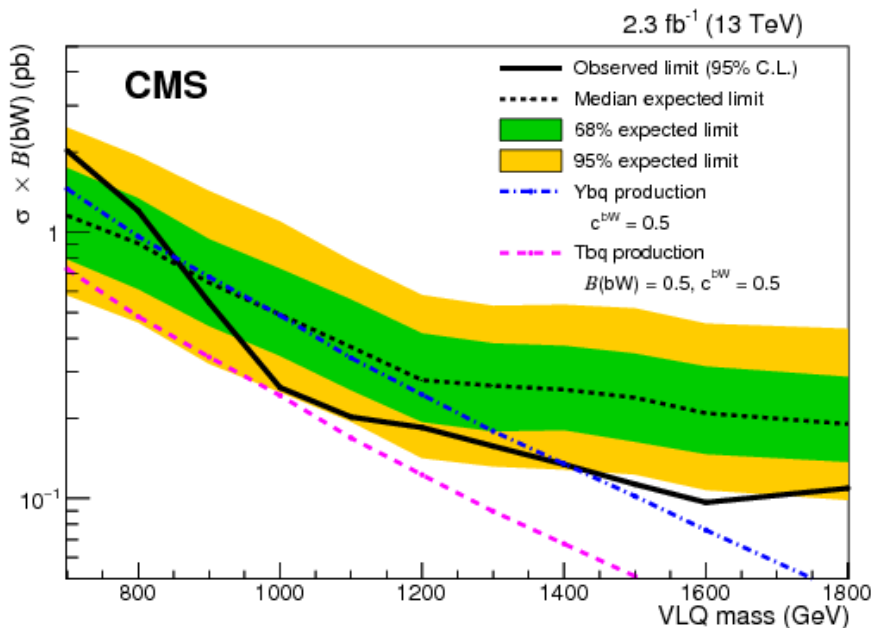
With single production limits can be placed on couplings, which can then be compared to EW constraints (model dependent)

Event selection/Strategy Lep

- Trigger on single lepton ($\ell = e, \mu$), $p_T > 27$ GeV

- Missing Transverse Energy > 120 GeV

- Leading jet is b-tagged and has $p_T > 350$ GeV

- $|\Delta\phi(\ell, \text{b-jet})| > 2.5$

- $\Delta R_{min}(\ell, \text{central-jets}) > 2.0$

- Veto additional hard central jets ($|\eta| < 2.5$, $p_T > 75$ GeV)

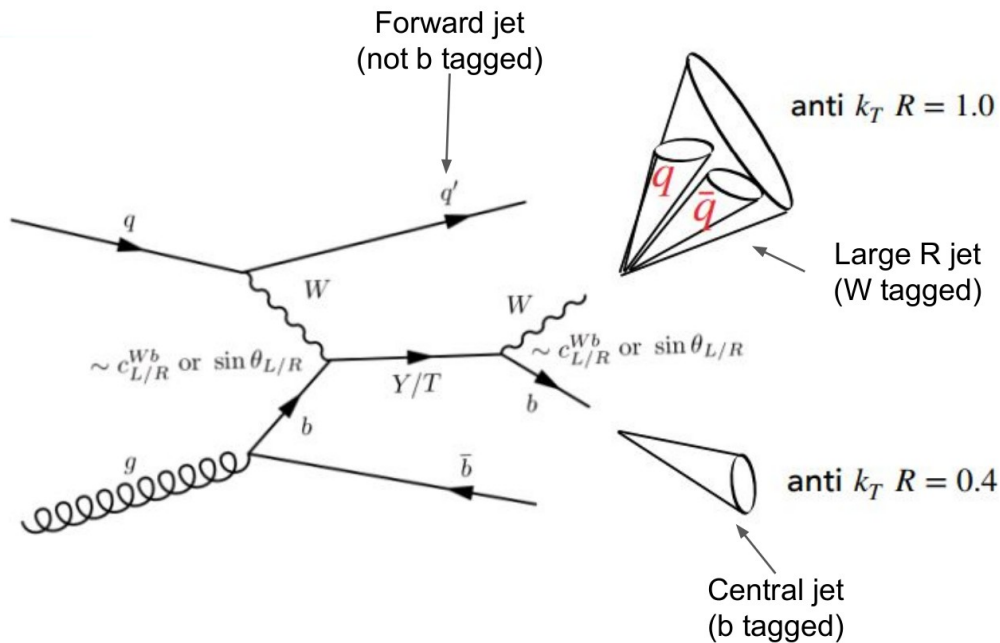- At least one forward jet ($2.5 < |\eta| < 4.5$, $p_T > 40$ GeV)
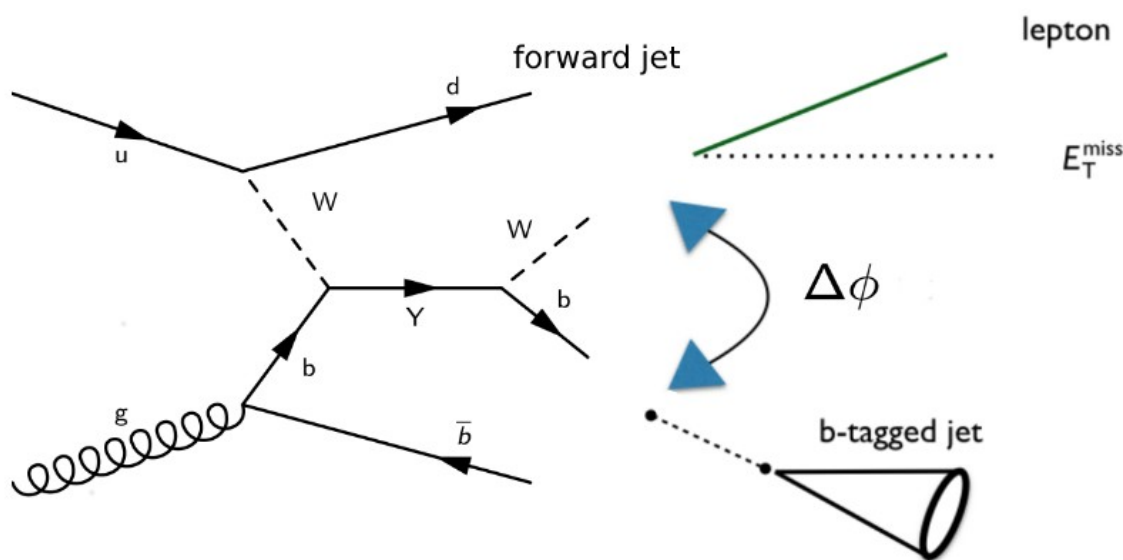
- BDT used to separate signal/background

- BDT score used as discriminant

- Signal extracted with fit to BDT output

Event selection/Strategy Had
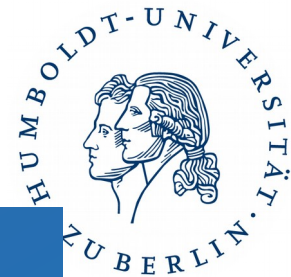
- Trigger Large R jet (R = 1.0), $p_T > 500$ GeV

- Exactly 1 Large R jet is W-tagged

- Leading jet is b-tagged and has $p_T > 200$ GeV

- At least one forward jet (2.5 < |η| < 4.5)

Forward jet
(not b tagged)

anti k_T $R = 1.0$

q
$\bar{q}$

Large R jet
(W tagged)

q

W

W

$\sim c_{L/R}^{Wb}$ or $\sin\theta_{L/R}$

Y/T

$\sim c_{L/R}^{Wb}$ or $\sin\theta_{L/R}$

b

q'

b

$\bar{b}$
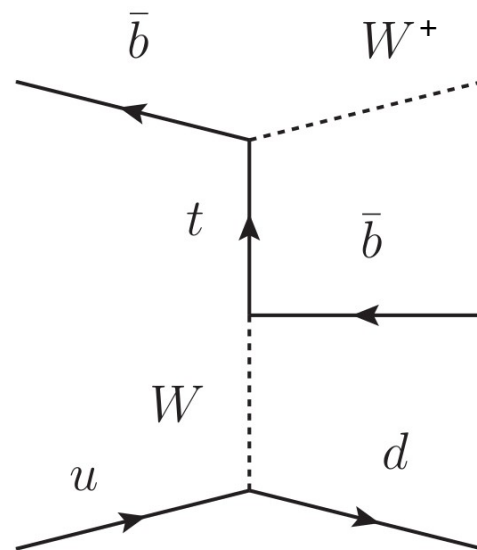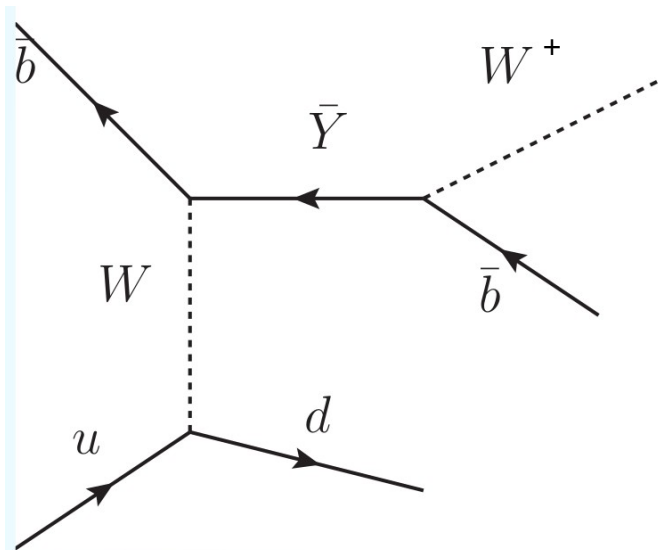
g

anti k_T $R = 0.4$

Central jet
(b tagged)

- Reconstruct VLQ mass (m_{VLQ}) with W and b-tagged jets

- NN score used as discriminant

- Signal extracted with profile likelihood fit to NN score

8

Interference

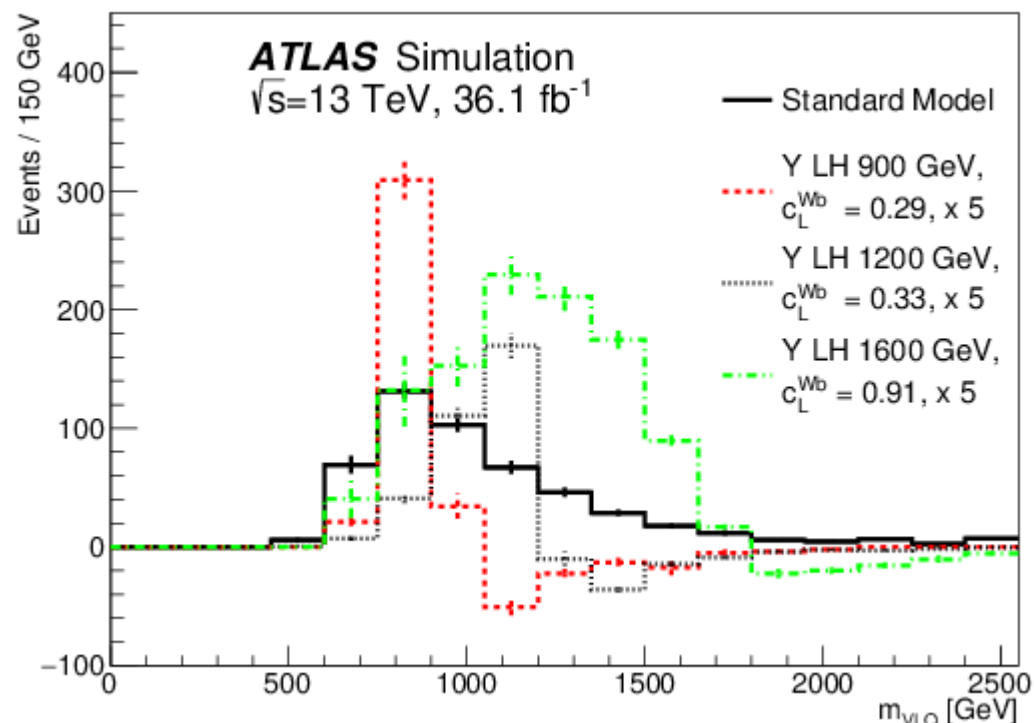T and single top SM background
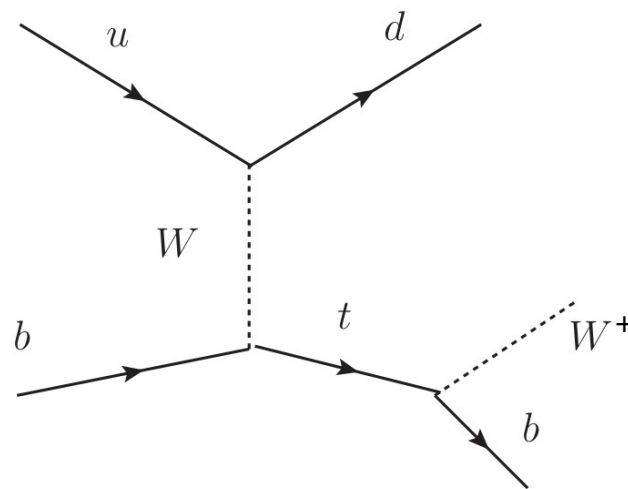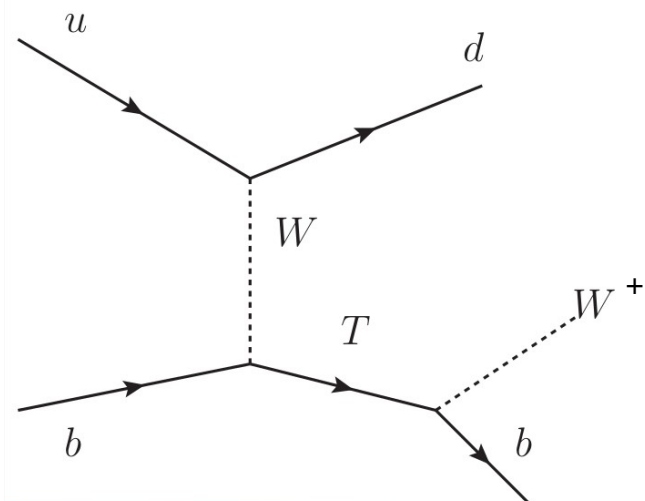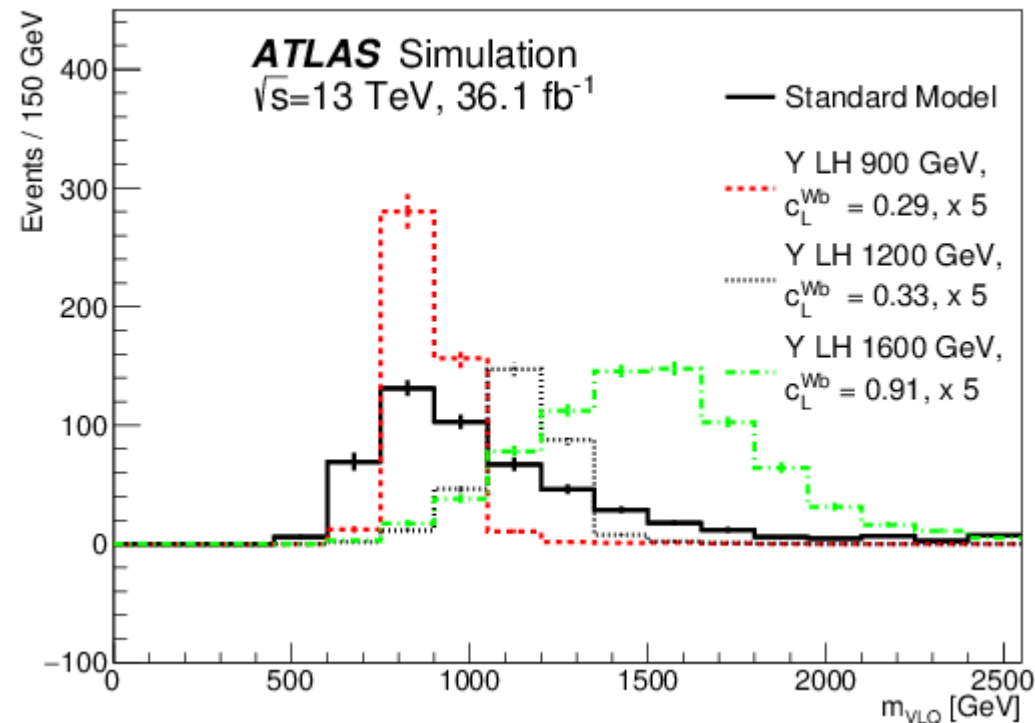

Y and SM W+b+q background

Effects of Interference

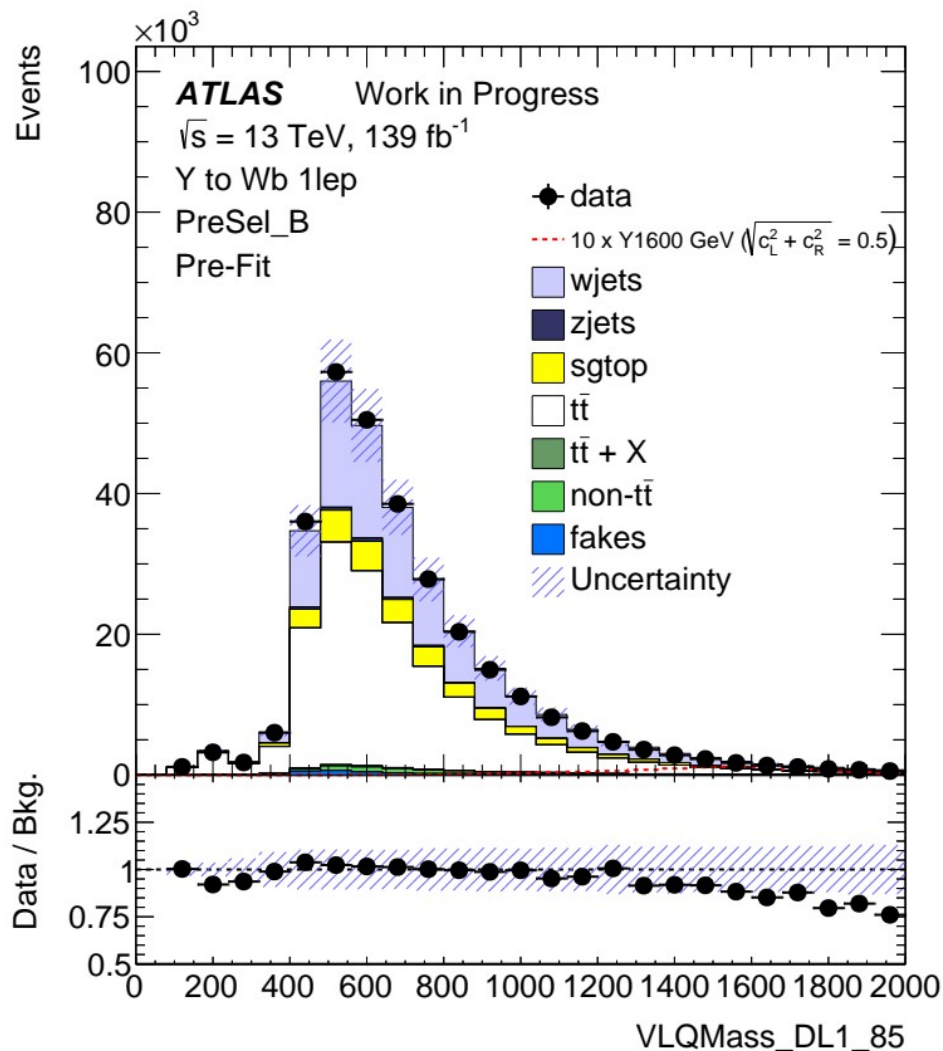Without interference   With interference

From: [JHEP 1905 (2019) 164]

Can have a significant impact on the shape of signal, in several observables, especially mass (m_{VLQ})
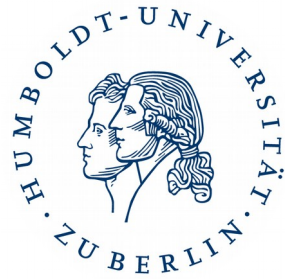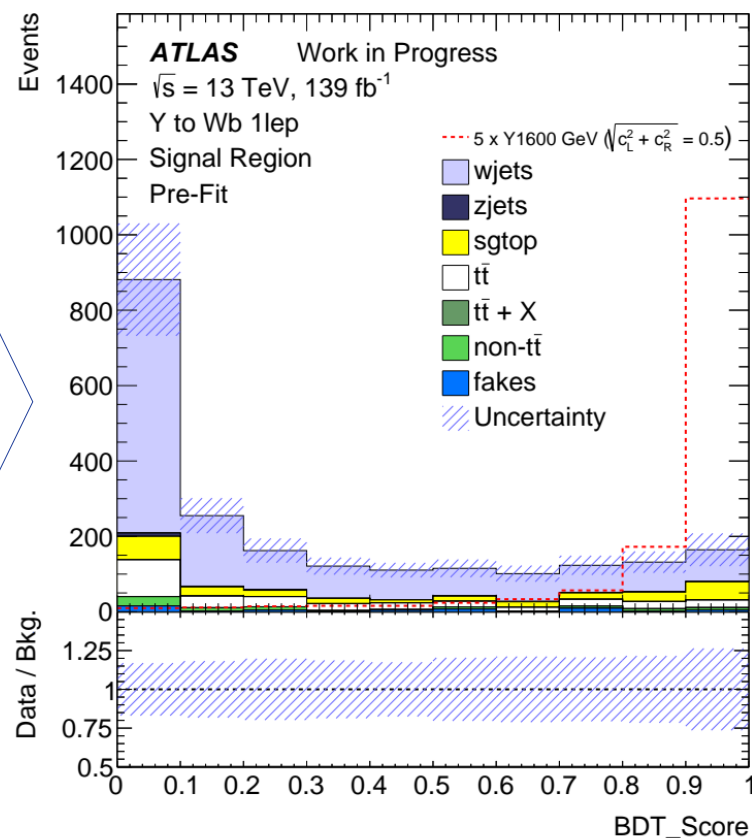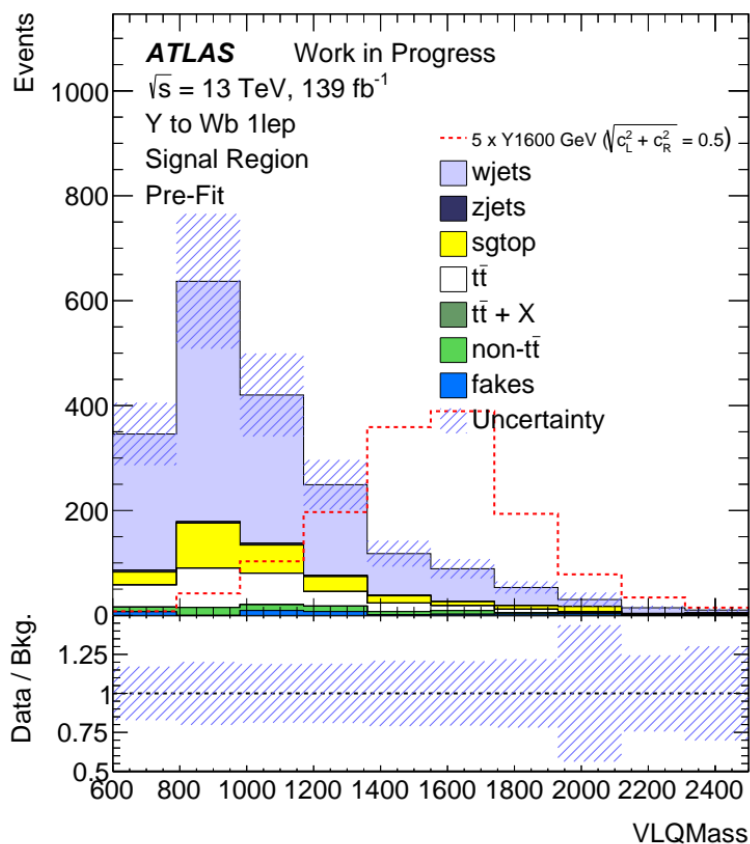
VLQ Mass at Pre-selection

- Background mostly consists of ttbar, w+jets and single-top

- Facing some mis-modeling in tail, where most of our signal should be

- Apply cuts to create orthogonal SR, W+Jets CR, ttbar CR

Classification

- Making use of BDT to discriminate between signal and background

- Fitting to BDT score for stronger discrimination

Conclusions

- First ATLAS analysis at 13 TeV on Wb final state with full 139 fb^{-1} of proton-proton data

- Adding additional hadronic channel for extra sensitivity

- Initial tests show better sensitivity from BDT

The End

References:

- Minimal theory papers we follow:

  - Handbook of vectorlike quarks: Mixing and single production

  - On the Interpretation of Top Partners Searches

- Possible theories VLQ's appear in:

  - Signatures from Scalar Dark Matter with a Vector-like Quark Mediator

  -