Search for pair production of vector-like quarks in the Wb+X final state using the full Run 2 dataset of pp collisions at $\sqrt{s}$ =13 TeV from the ATLAS detector

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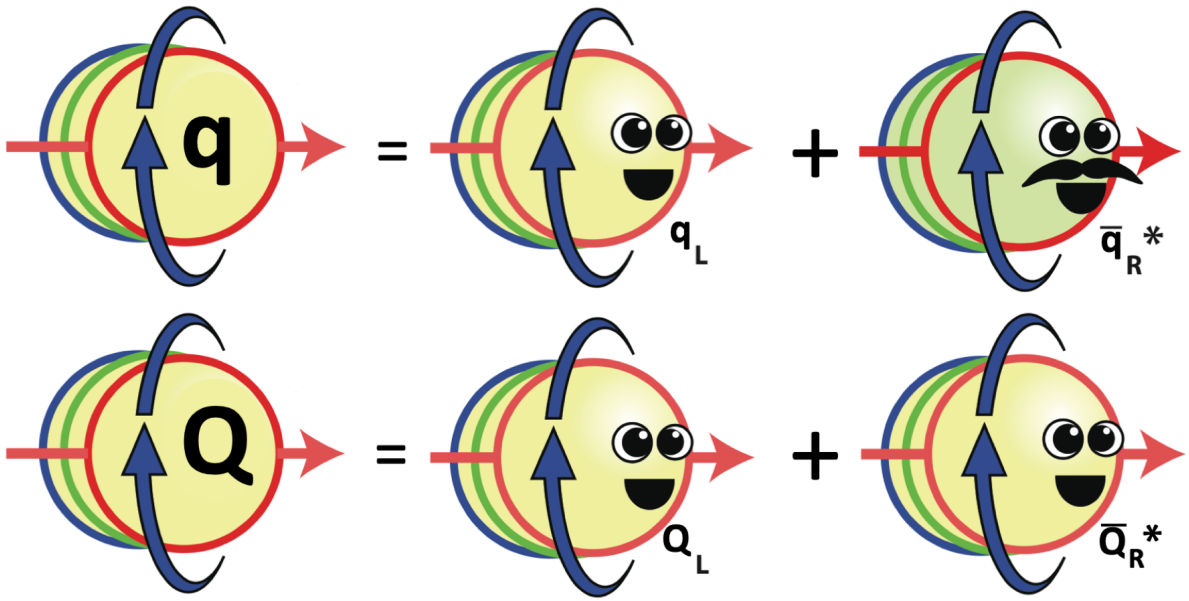
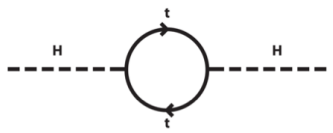
VLQ Introduction

- Spin 1/2 particles with color charge
- Left and right chiralities behave the same
  - Vector-like interaction with weak force
- Mass not from Higgs boson
- Decay to SM boson and a 3^{rd} generation quark



Why VLQ?



"bare mass"

$M_H^2 = 3.27345942963429054386749647321596 43$

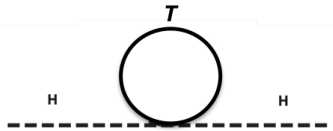
$-3.27345942963429054386749647321596 45$

$= 10^{-32}$ (in planck units)

quantum corrections, e.g.

from Roni Harnik

- Quantum corrections from top quark $\rightarrow$ quadratic divergence
  - Called the "Hierarchy Problem"

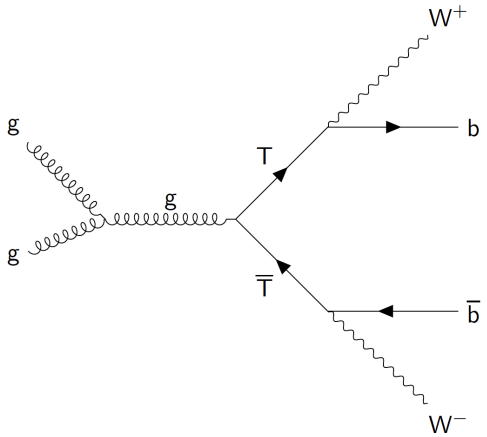


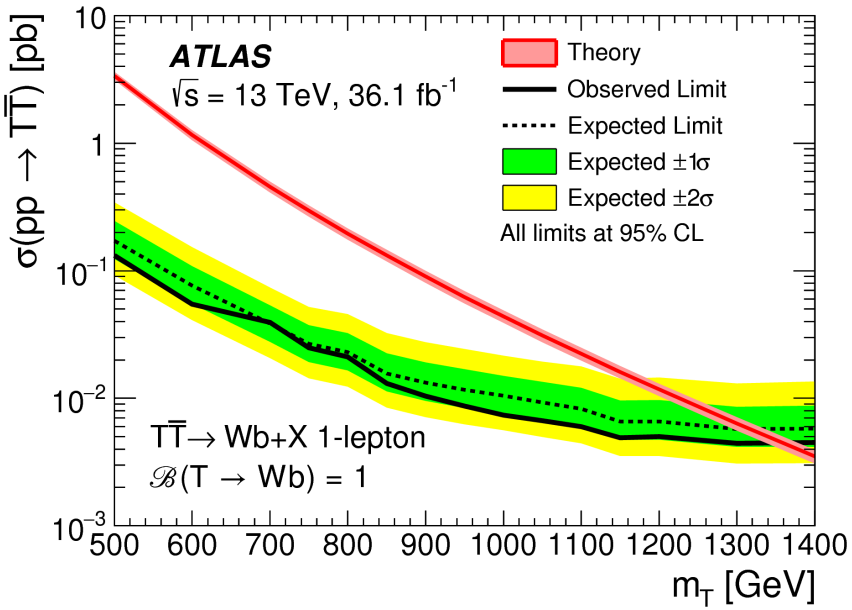
$M_H^2 \sim 10 - 9 = 1$ (in units of ~100 GeV squared)

- VLT corrections $\rightarrow$ removes quadratic divergence
- VLQs are included in many models that solve the Hierarchy Problem

Our Search

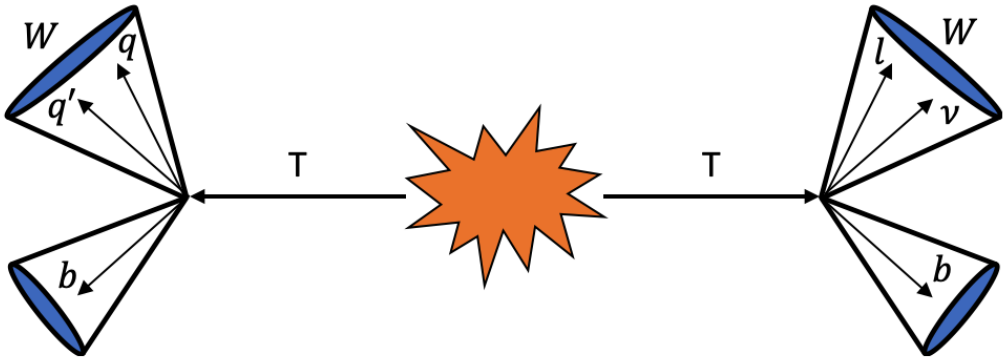
- Pair production of VLT in Wb+X final state
  - Require: $T \rightarrow Wb \rightarrow l\nu b$
  - Optimize other: $T \rightarrow Wb \rightarrow qq'b$
- Model independent
- Improve limits by using full 140 fb^{-1} Run 2 dataset



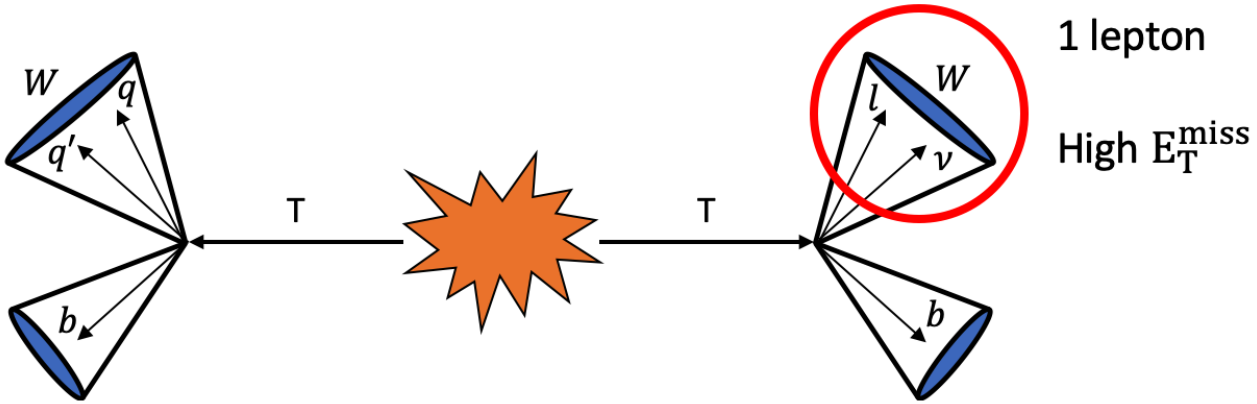


JHEP 10 (2017) 141

Event Selection

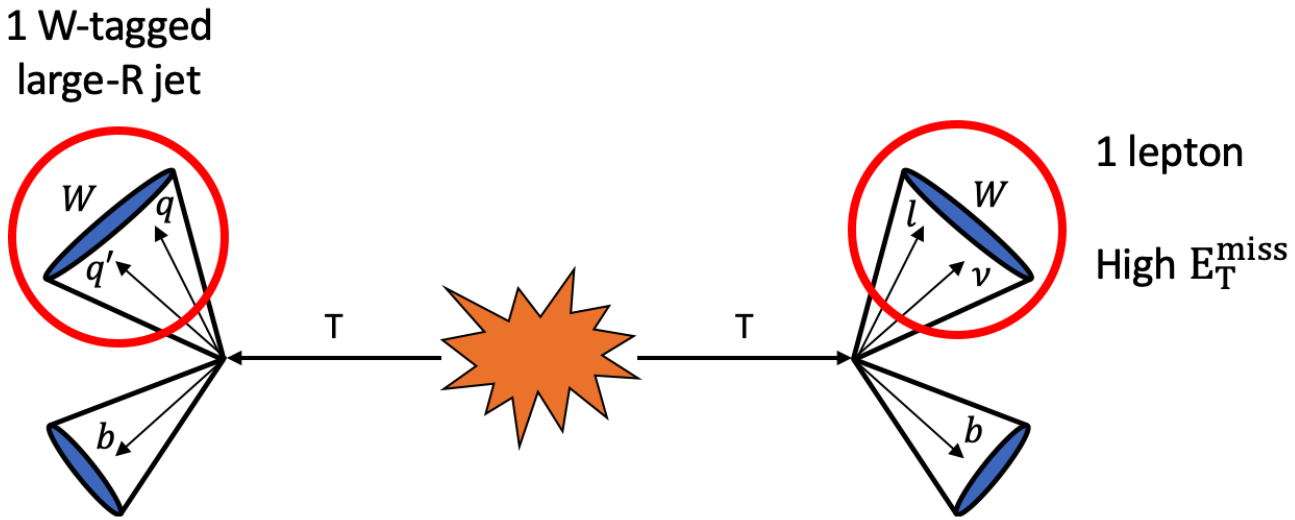


Event Selection



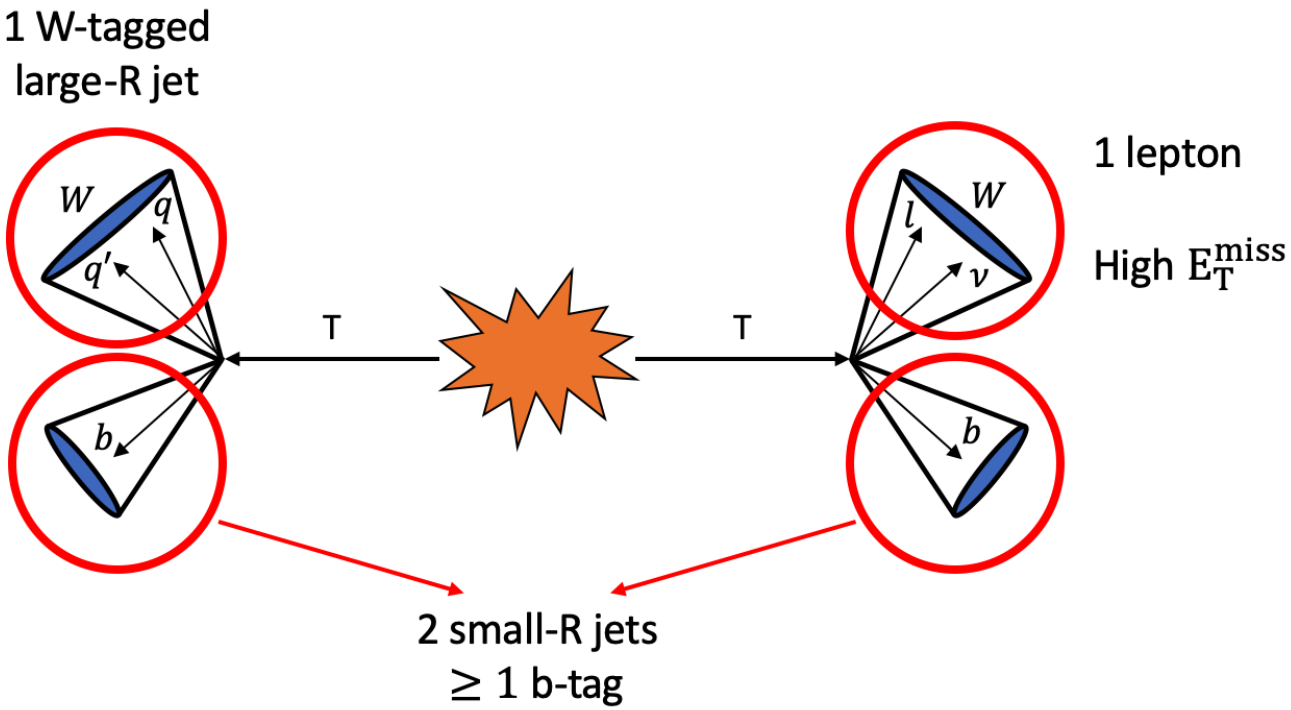
- Reduces multijet background

Event Selection



- W-boson will be boosted

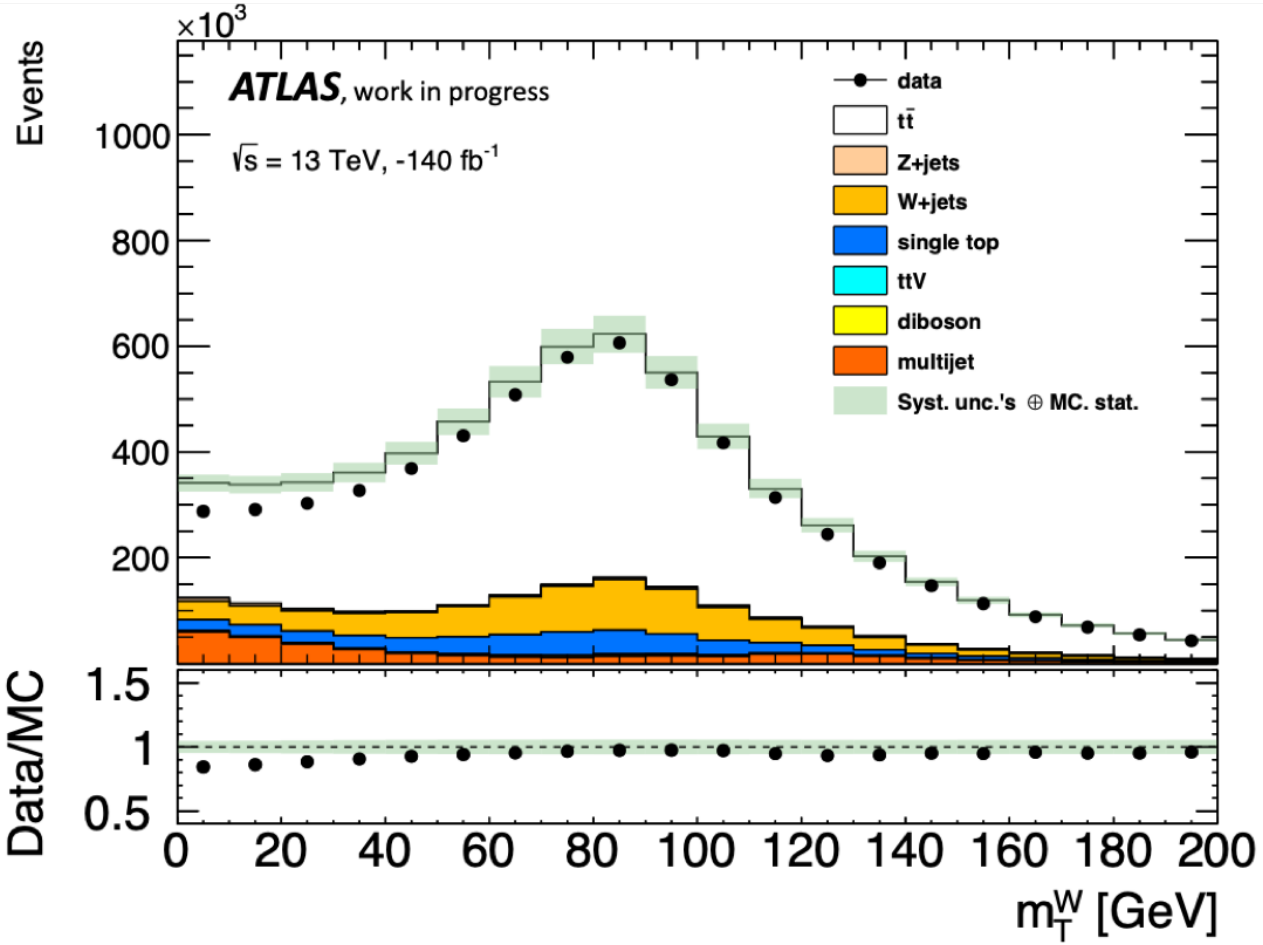
Event Selection



- Reconstruct VLT candidates to minimize ΔM(VLTs)

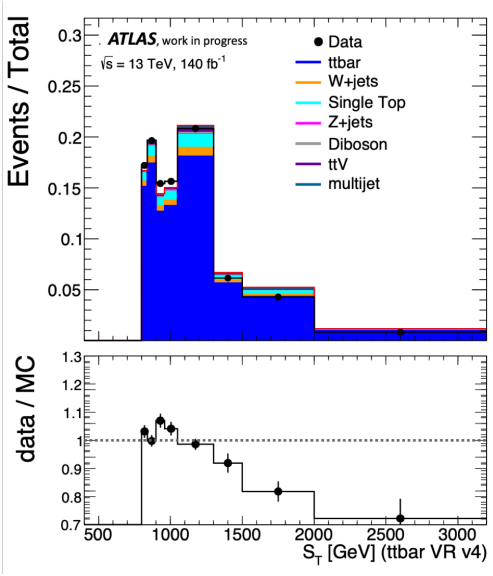
Background Processes

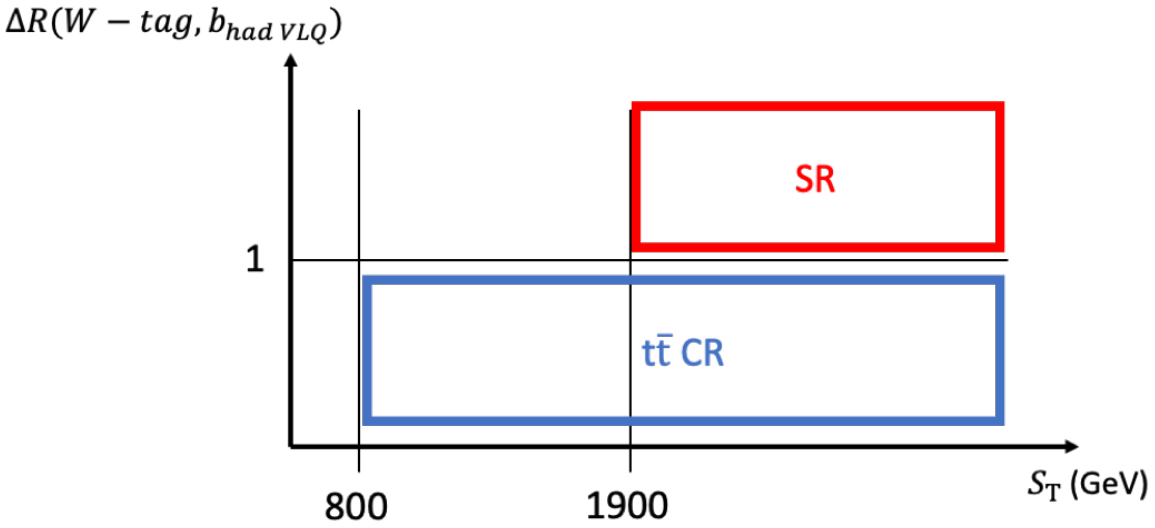
- $t\bar{t}$ and W+jets main background
  - No correction applied to any MC

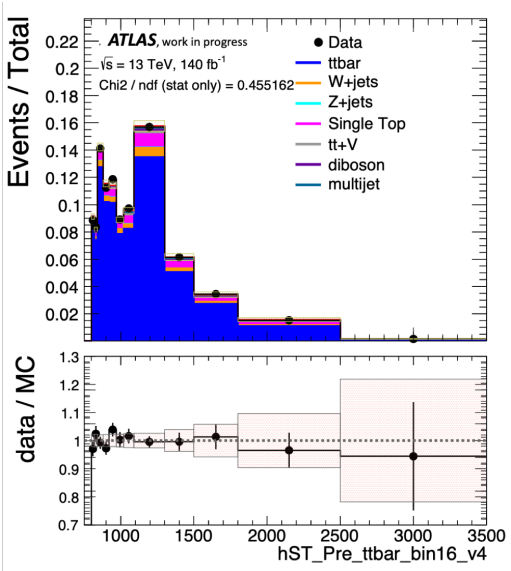


$t\bar{t}$ MC Correction

- $t\bar{t}$ is our dominate background
- $t\bar{t}$ MC mismodels p_T related variable at high p_T
- Derive correction as a function of S_T
  - S_T is the scalar sum of all p_T

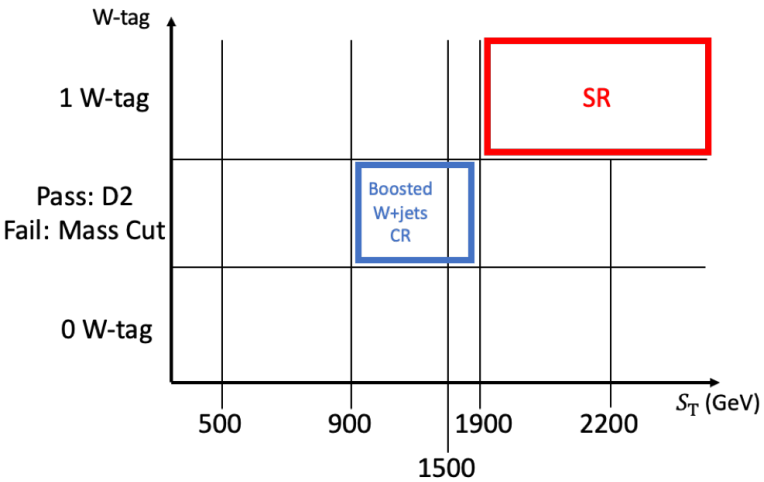


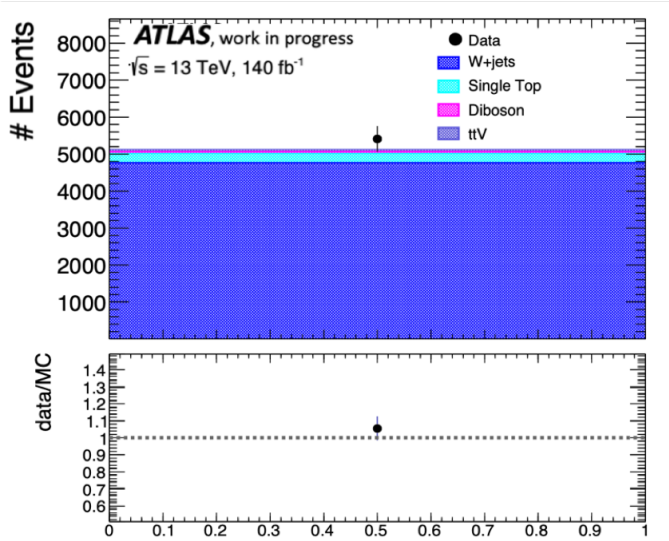


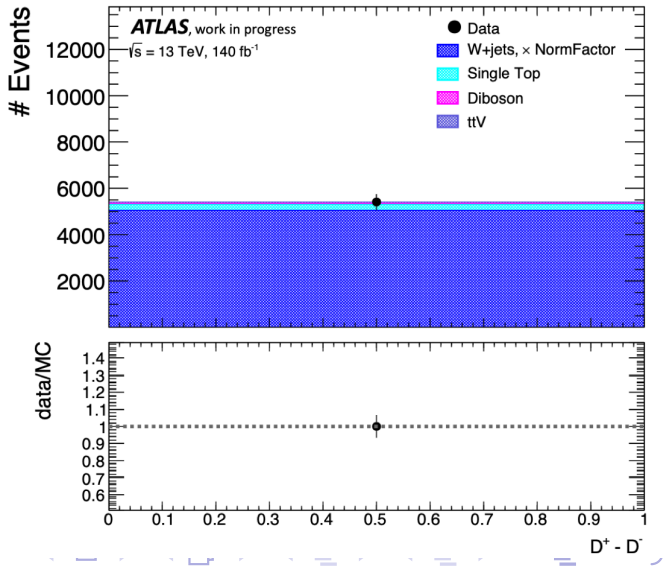


W+Jets MC Correction

- W+jets is the second dominate background process
- Boosted W+jets CR - Define correction
- Using charge assymmetry
  - $N(W+) - N(W-)$

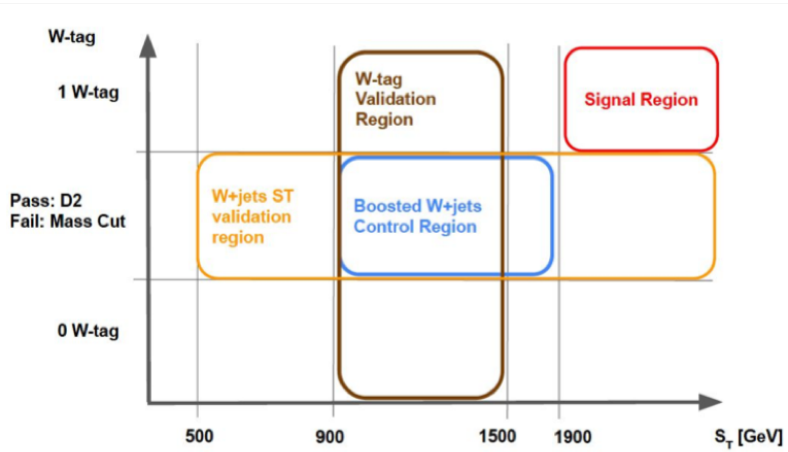


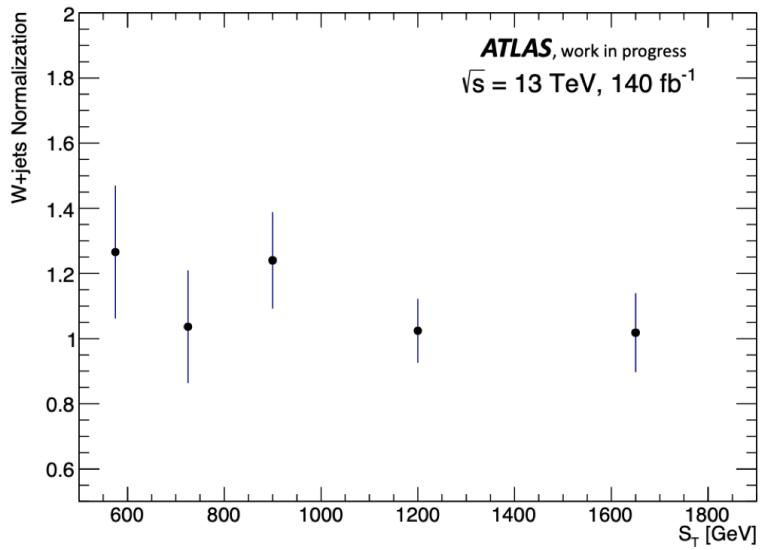




W+Jets MC Correction

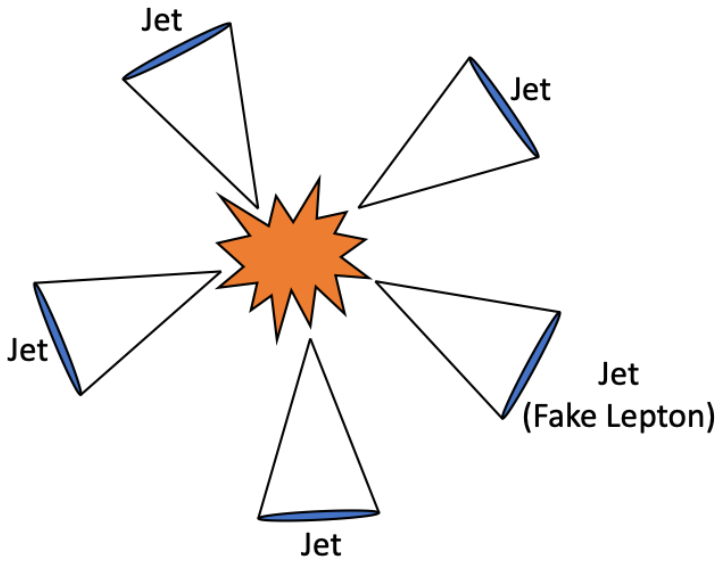
- W+jets is the second dominate background process
- Boosted W+jets CR - Define correction
- W+jets S_T VR - Check S_T dependence
- W-tag VR - Check W-tag dependence





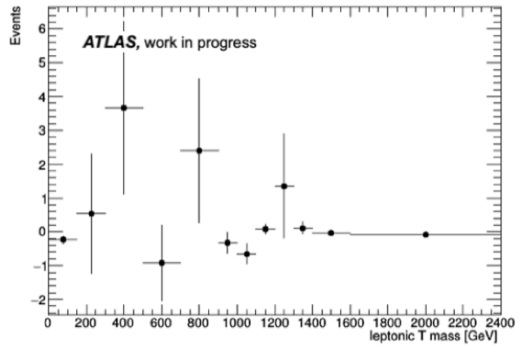
Multijet Estimate

- Many collisions at the LHC result in a multijet event
- Jets misidentified as leptons
- Multijet events not well modeled in MC
- Use a data-driven method
  - Fake Factor Method

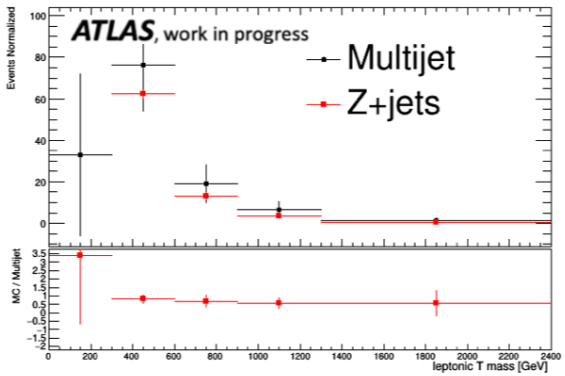


Multijet Estimate

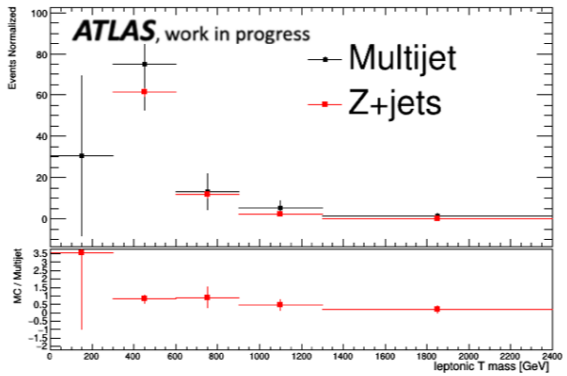
- The Fake Factor results in a negative estimate in the signal region
- Scale Z+jets to estimate the multijet
- Reduced the number of bins and compared the shapes
  - Shapes agree well after each cut



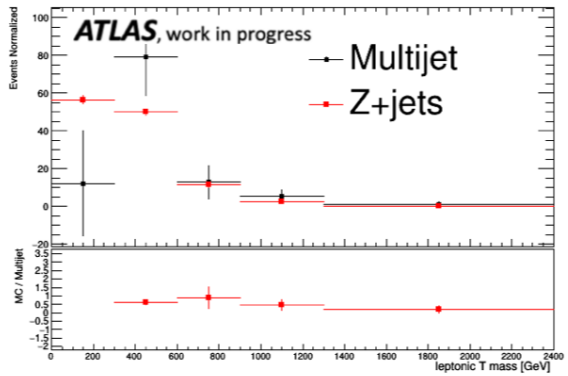
Preselection



$\Delta M < 500$



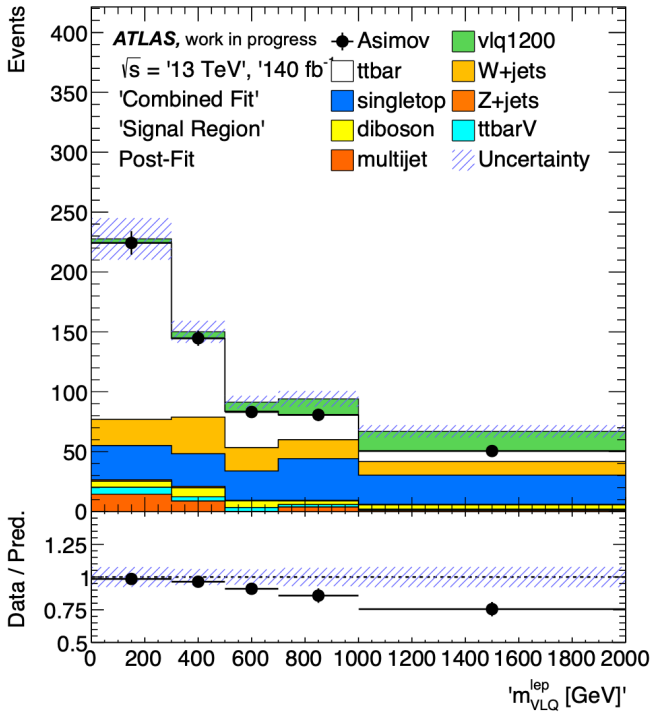
$\Delta R(W, b) > 1$

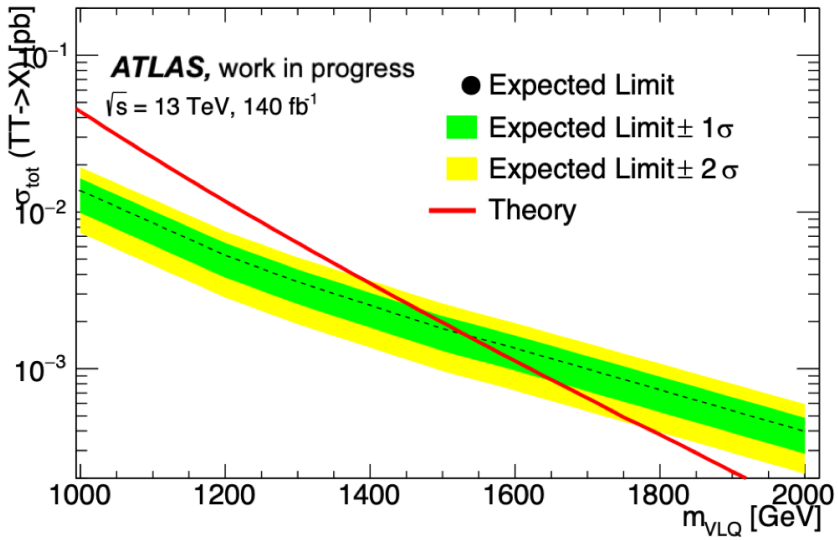


Moving toward SR

Final Fit

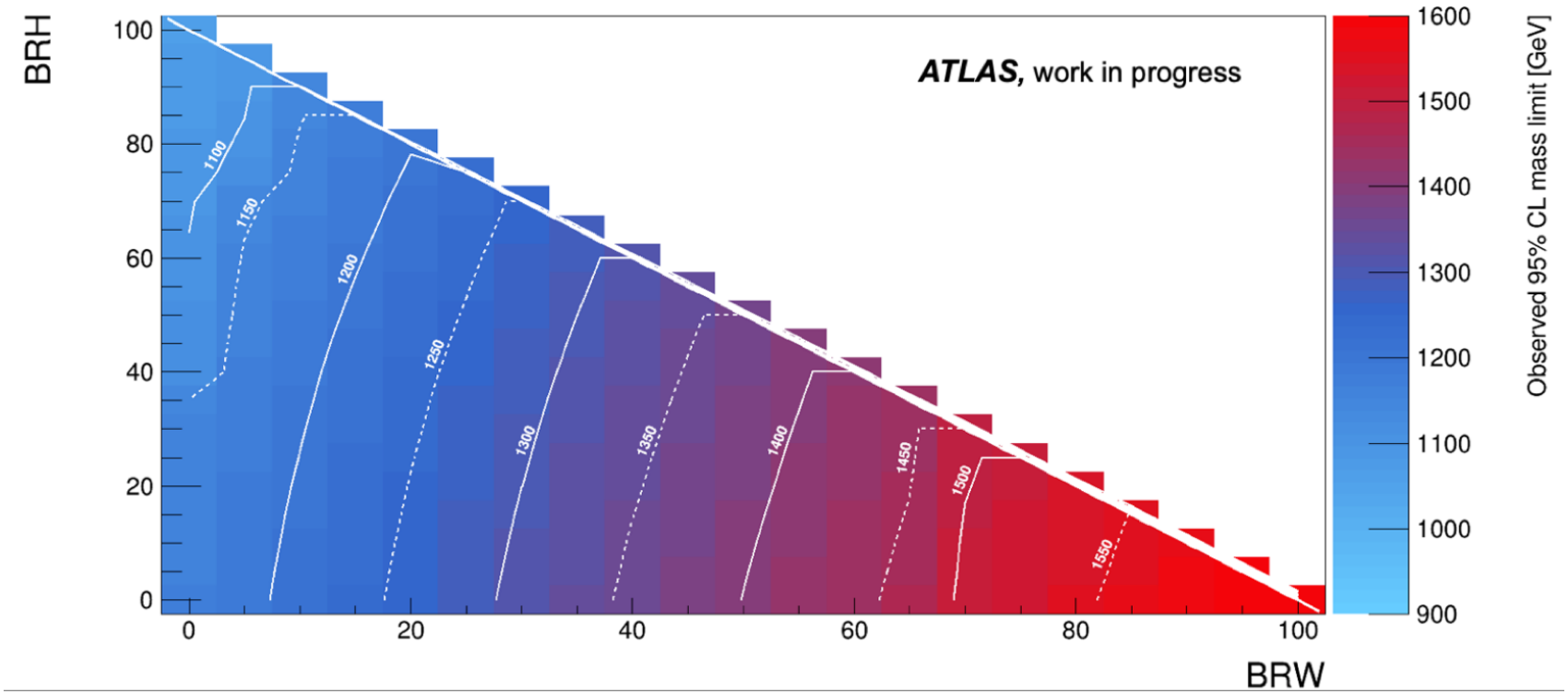
- Apply MC corrections to signal region
- Final fit done as a function of leptonically decaying VLT mass
  - The data in this plot is just the sum of background
- Expected limit is around 1550 GeV
  - This is about a 200 GeV improvement with respect to the 36.1 fb^{-1} limit





Final Fit

- Scan different branching ratios



Summary

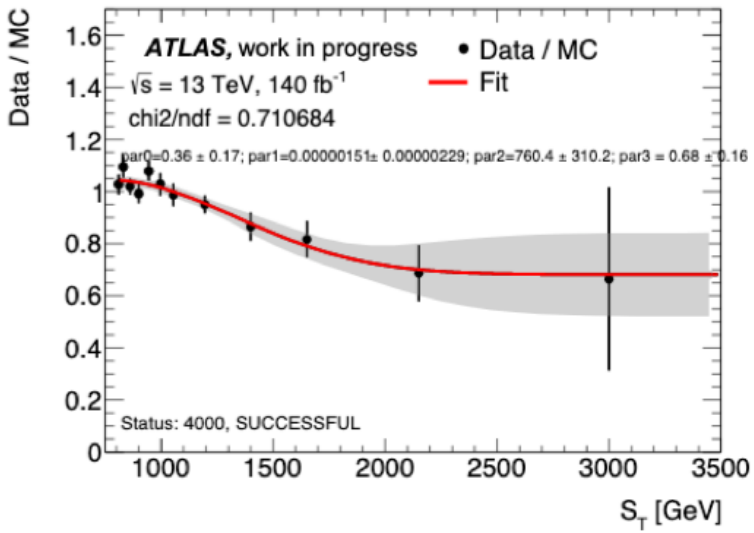
- Search for pair production of vector-like quarks in Wb+X final state
  - Require one VLT decay to leptonically decaying W boson and bottom quark
  - Optimize the second VLT to decay to hadronically decaying W boson and bottom quark
- $t\bar{t}$ and W+jets are the two main backgrounds
  - Correct mismodelling in control/validation regions
- Multijet background will be estimated by scaling Z+jets
- The expected limit has around a 200 GeV improvement with respect to the 36.1 fb^{-1} limit

BACKUPS

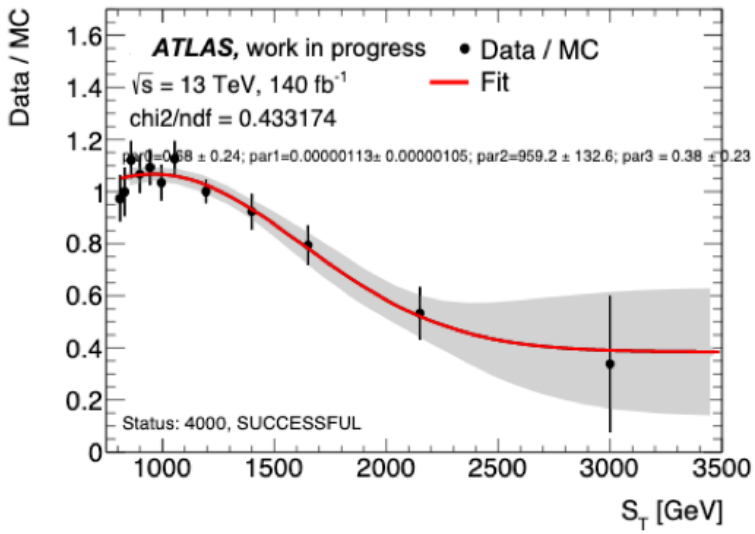
$t\bar{t}$ Correction

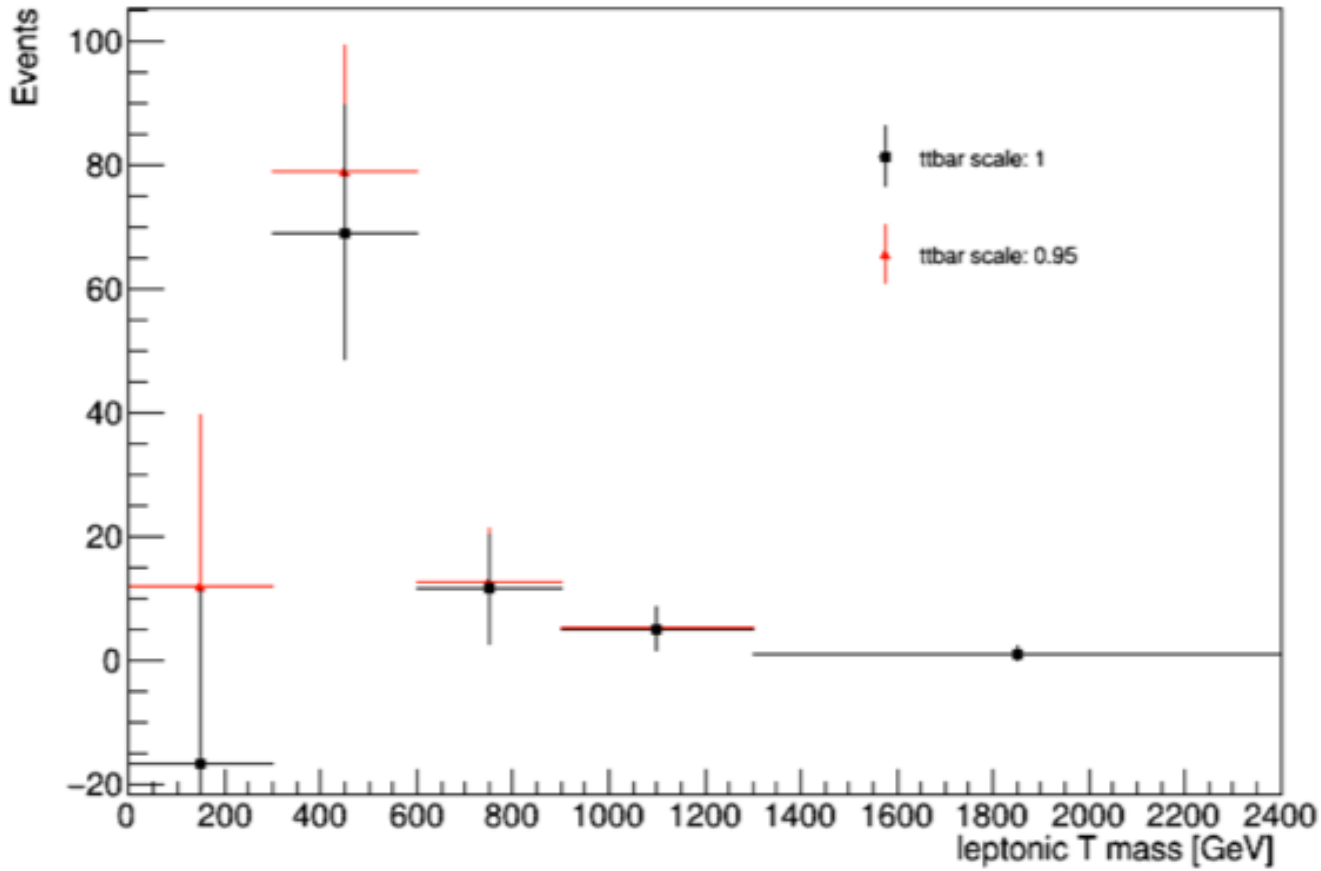
- Fit data/MC ration as a function of S_T
- Fit function is a Gaussian with a constant offset
- Fit is done in two bins of number of jets (N_{jets})

$N_{\text{jets}} \leq 6$



$N_{\text{jets}} \geq 7$



Multijet: 1^{st} Bin Sensitivity

- The first bin (0-300 GeV) is very sensitive to the $t\bar{t}$ normalization
- Changing the normalization by 5% results in an almost 200% change in the first bin