Search for New Heavy Bosons in single top quark final state using 36.1/fb data with the ATLAS detector

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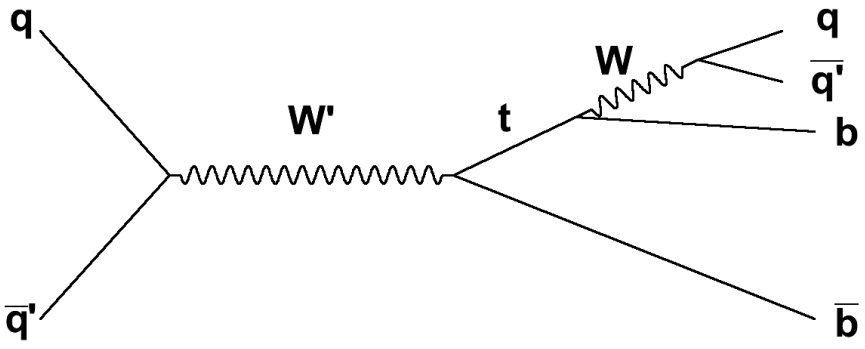
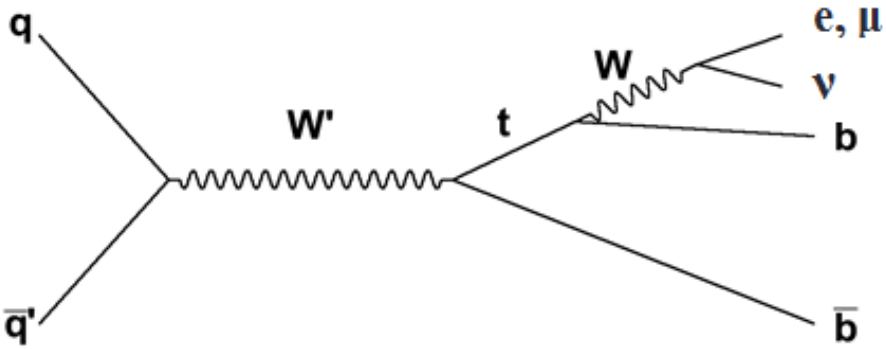
W'->tb: Model Introduction

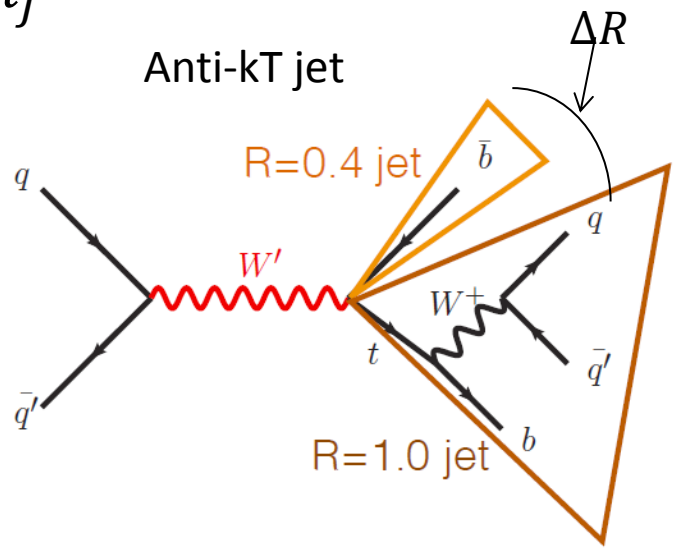
- Boson, spin 1, charge ±1, introduced by many BSM theories
- Chirality W'_L and W'_R
- W'_R can't decay to lv since $m_{\nu_R} > m_{W'_R}$
- Hadronic/leptonic channel: decay mode of W boson comes from top
  - Hadronic: 1 top quark(include 1 b quark and 2 light quarks)+ 1 isolate b quark
  - Leptonic: 2 b quarks + 1 lepton(e, μ) + 1 neutrino





Hadronic: Selection

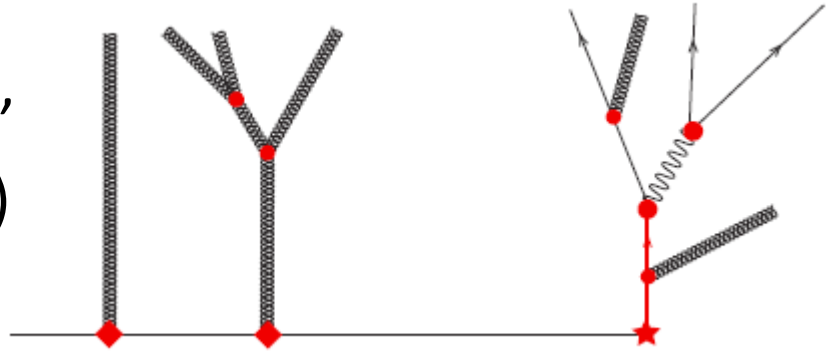
- Data-driven method requires definition of top and bottom candidates before tagging
  - Effective mass: $m_{eff} = m_j + 0.15 * m_J$
  - J: R = 1.0 jet,
    j: highest p_{T} R = 0.4 jet
    among those of which are inside J
  - R=1.0 jet with the highest effective Mass -> top-candidate jet
  - R=0.4 jet with the highest p_{T} and $\Delta R > 2$ -> b-candidate jet



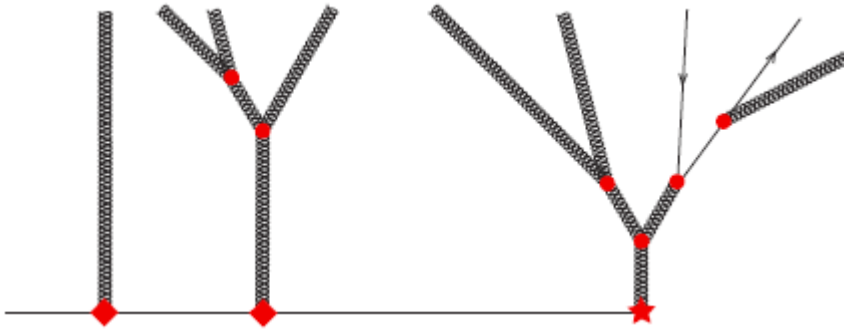
- 2 signal categories: '0 b-tag in' and '1 b-tag in' inside top-candidate jet

Hadronic: Top tag for W’

- Top-tag method: Shower deconstruction
- Exclusive kT sub-jet inside ‘top jet’ (splitting scale threshold = 15 GeV)
- 2 sub-jets to match W mass plus 1 more sub-jet to match top-quark mass
- Estimate the likelihood of a top-quark decay vs that of a light-quark/gluon showering
- Better performance in high p_{T}



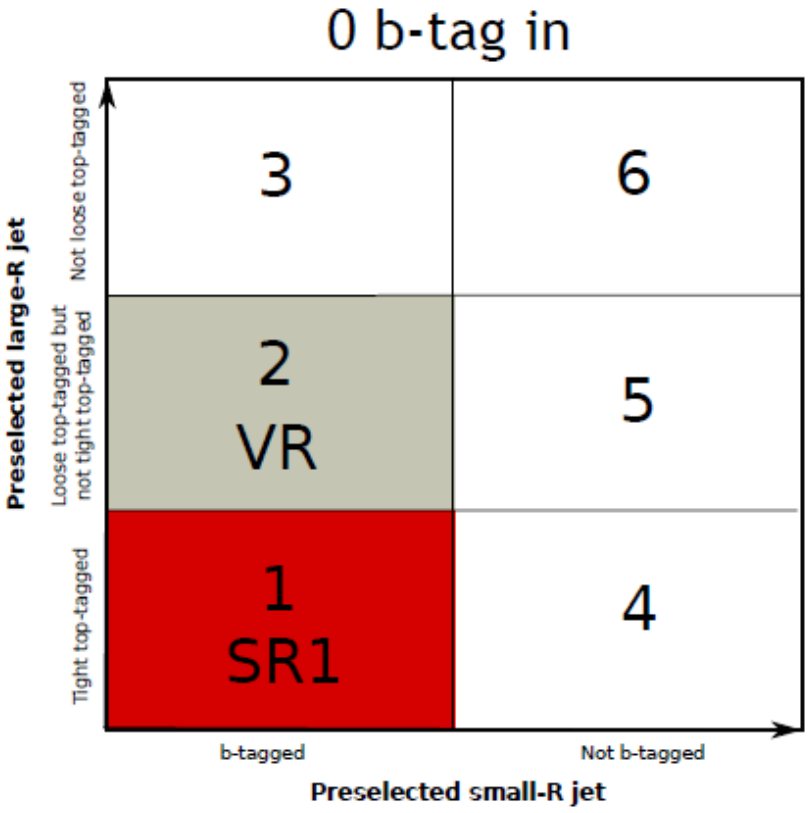
Top quark shower history



light jet shower history

Hadronic: Background

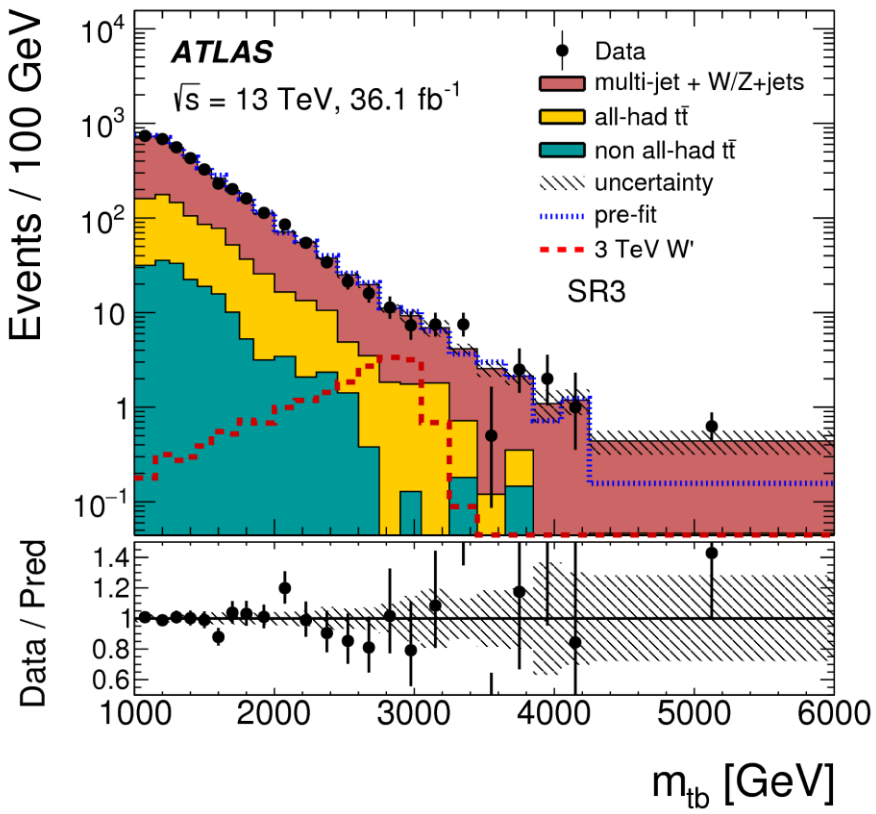
- Similar background as in single-top pair resonance search
- Dominant one is QCD multi-jet
- ABCD method for estimating background
- Top-tag: loose/tight (80/50 W.P.)
- b-tag: tagged/not tagged (77 W.P.)
- Two taggers have non-negligible correlation. Correlation factors R are derived from QCD background simulation for each SR



$$N_1^{QCD} = R_1^{corr} \cdot \frac{N_3^{QCD} \cdot N_4^{QCD}}{N_6^{QCD}}$$

Hadronic: Mass Spectrum

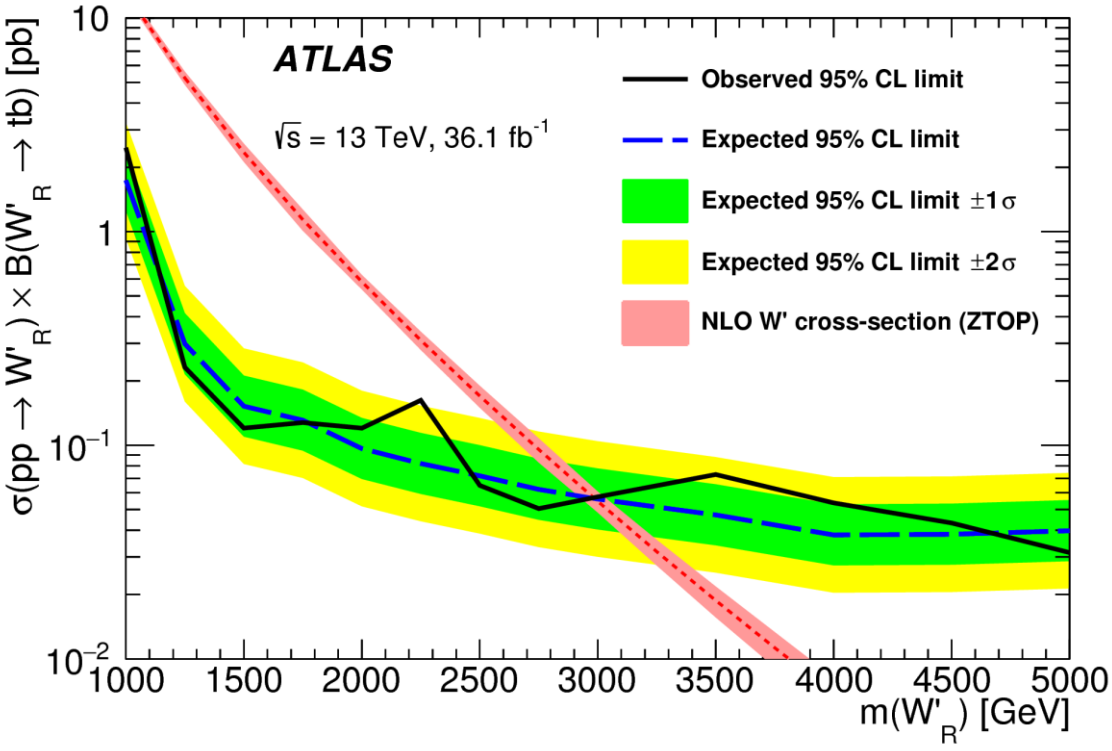
- 3 Signal regions
  - Tight top tag, 0 b-tag in
  - Loose top tag, 1 b-tag in
  - Tight top tag, 1 b-tag in
- Profile likelihood fit
- Most significant systematic uncertainties
  - ABCD correlation factors and b-tagging
- No excess found, perform limit setting



Tight top tag, 1 b-tag in

Hadronic: Limits Setting

- Limits for W'_R on cross-section*BR
- Exclude W'_R mass up to 3 TeV at 95% CL
- Exclude W'_L mass up to 2.85 TeV 95% CL
- Limit at Run 1 ($\sqrt{s}$ = 8TeV) of W'_R: 1.76 TeV, 95% CL

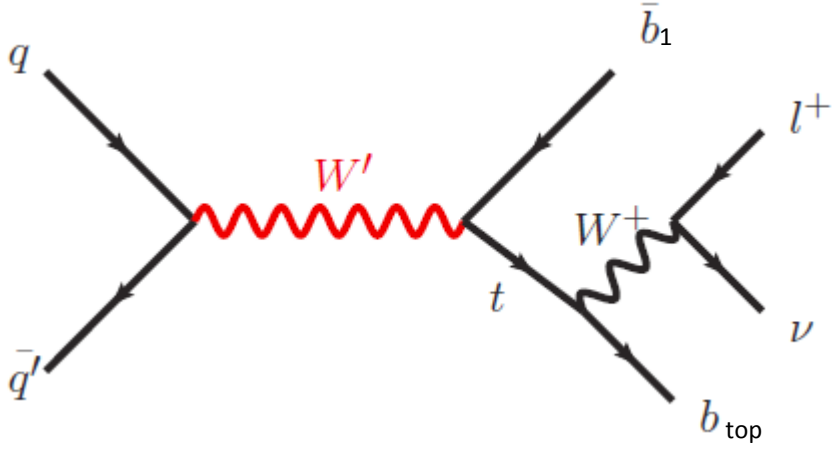


Leptonic: Selection

- Overlap removal:
  Jets $\Delta R(Jet, elec) = 0.2$
  Electrons $\Delta R(elec, Jet) = 0.4$

  Muon $\Delta R(\mu, jet) < 0.04 + 10\ \text{GeV}/p_T\mu$ are rejected if the jet has at least three tracks originating from the primary vertex

  Any jets with less than three tracks that overlap a muon are rejected



Common selection			
$p_T(\ell) > 50$ GeV, $p_T(b_1) > 200$ GeV, $p_T(\text{top}) > 200$ GeV $E_T^{\text{miss}} > 30$ (80) GeV, $m_T^W + E_T^{\text{miss}} > 100$ GeV			
Signal Region	$\text{VR}_{\text{pretag}}$	$\text{VR}_{t\bar{t}}$	VR_{HF}
2 or 3 jets 1 or 2 b-jets $\Delta R(\ell, b_{\text{top}}) < 1.0$ $m_{tb} > 500$ GeV	2 or 3 jets pretag	4 jets 1 or 2 b-jets	2 or 3 jets 1 b-jet $\Delta R(\ell, b_{\text{top}}) > 2.0$ $\Delta R(b_1, b_{\text{top}}) > 1.5$

Leptonic: Reconstruction

$$P_{z,\nu}^2 - 2 \cdot \frac{\mu \cdot P_{z,\ell}}{E_\ell^2 - P_{z,\ell}^2} \cdot P_{z,\nu} + \frac{E_\ell^2 \cdot P_{T,\nu}^2 - \mu^2}{E_\ell^2 - P_{z,\ell}^2} = 0, \quad (1)$$

$$\text{with} \quad \mu = \frac{m_W^2}{2} + \cos\Delta\Phi \cdot P_{T,\ell} \cdot P_{T,\nu}. \quad (2)$$

$$P_{z,\nu}^{A,B} = \frac{\mu \cdot P_{z,\ell}}{P_{T,\ell}^2} \pm \sqrt{\frac{\mu^2 \cdot P_{z,\ell}}{P_{T,\ell}^4} - \frac{E_\ell^2 \cdot P_{T,\nu}^2 - \mu^2}{P_{T,\ell}^2}}. \quad (3)$$

- Neutrino p_z calculation
  - Estimated from MET and W mass constraint
  - Modify when discriminant < 0
- Top and W' reconstruction
  - Find jet that gives $m_{l\nu b}$ closest to top-quark mass: jet "b from top"
  - Assign highest pT remaining jet to W' decay: jet "b from W' "

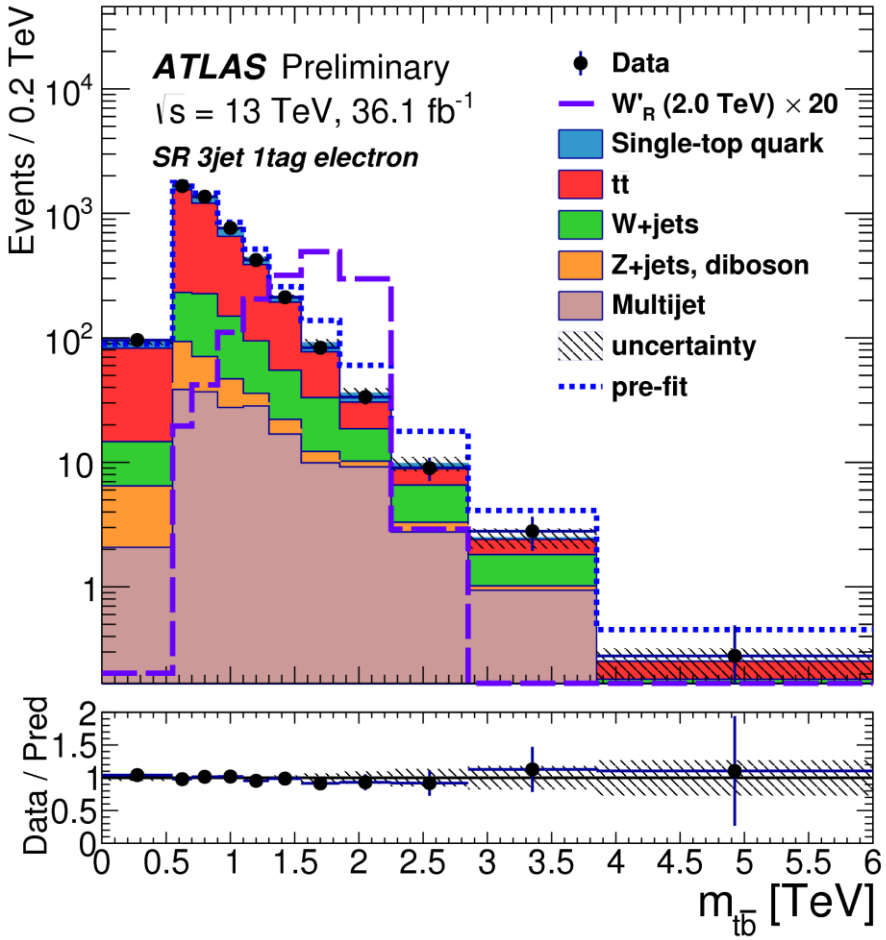
Leptonic: Background

- *ttbar,* single-top, diboson and W+jets backgrounds
  - Modeled using the simulated MC samples
  - Dominant in signal regions: *ttbar* and *W*+jets production, the normalisation of these backgrounds is allowed to float freely in fit
- Multijet background
  - Estimate from data using Matrix Method

	2-jet 1-tag ($e^{\pm}$)	2-jet 1-tag ($\mu^{\pm}$)	3-jet 1-tag ($e^{\pm}$)	3-jet 1-tag ($\mu^{\pm}$)
W'_R (1.0 TeV)	1517 ± 32	2029 ± 39	1159 ± 31	1665 ± 35
W'_R (2.0 TeV)	83.4 ± 1.7	132.9 ± 2.1	105.0 ± 1.9	167.4 ± 2.2
W'_R (3.0 TeV)	4.7 ± 0.1	10.4 ± 0.2	7.0 ± 0.2	15.7 ± 0.2
W'_R (4.0 TeV)	0.4 ± 0.0	1.0 ± 0.0	0.6 ± 0.0	1.6 ± 0.0
W'_R (5.0 TeV)	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.2 ± 0.0
$t\bar{t}$	1144 ± 24	1531 ± 30	3356 ± 57	4270 ± 78
Single-top	472 ± 20	655 ± 28	484 ± 23	639 ± 27
W+jets	500 ± 51	1285 ± 140	530 ± 45	1100 ± 100
Multijets	330 ± 37	640 ± 120	173 ± 20	394 ± 70
Z+jets	115 ± 17	179.4 ± 9.8	113 ± 13	215 ± 23
diboson	20.7 ± 1.7	34.4 ± 9.8	16.5 ± 2.2	28.5 ± 3.1
Total background	2583 ± 72	4320 ± 190	4672 ± 80	6650 ± 150
Data	2637	4307	4642	6606

Leptonic: Mass Spectrum

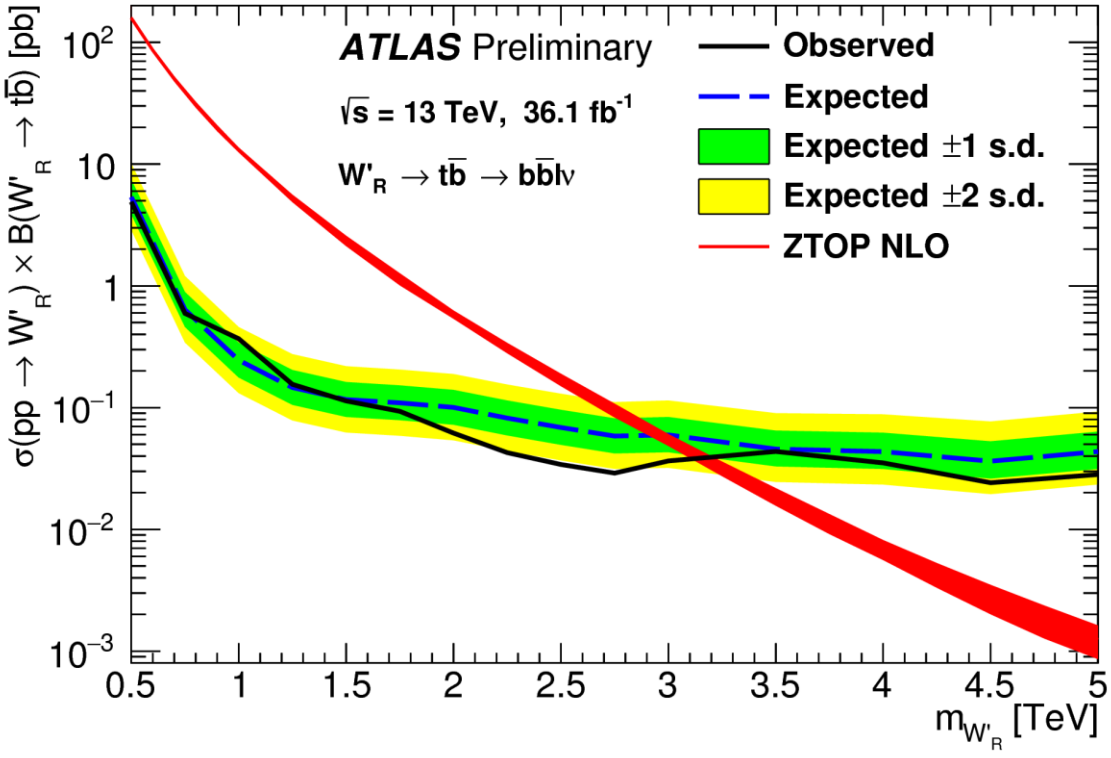
- SR: 2/3jets+1/2b-tag+e/μ
- Below masses of 2 TeV the dominant uncertainty: *ttbar* normalization and shape modeling
- At higher masses the dominant source of uncertainty: multijet background and b-tagging uncertainty
- 2-jets vs 3-jets region cross-extrapolation has been considered because of the categorization for signal regions



2 TeV, 3-jet, 1 b-tag, electron

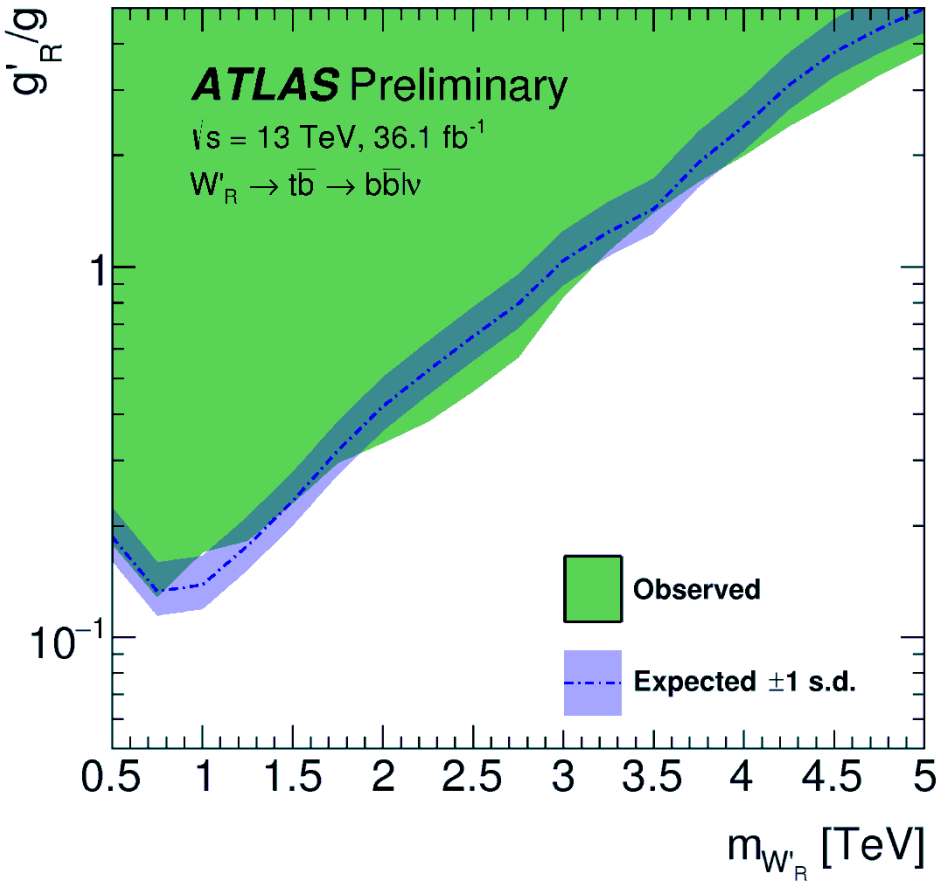
Leptonic: Limit Setting

- Limits on W'_R cross-section * BR
- Exclude W'_R mass up to 3.15TeV at 95% CL
- Limit at Run 1 ($\sqrt{s}$ = 8TeV) of W'_R: 1.92 TeV, 95% CL
- Exclude W'_R mass up to 3.25TeV at 95% CL, combined with W'->tb hadronic channel result



Leptonic: Limit Setting

- Limits on the ratio of couplings g′/g as a function of the W′ mass are derived from the limits on the W′ cross section
- Different couplings lead to different cross sections and widths



Summary

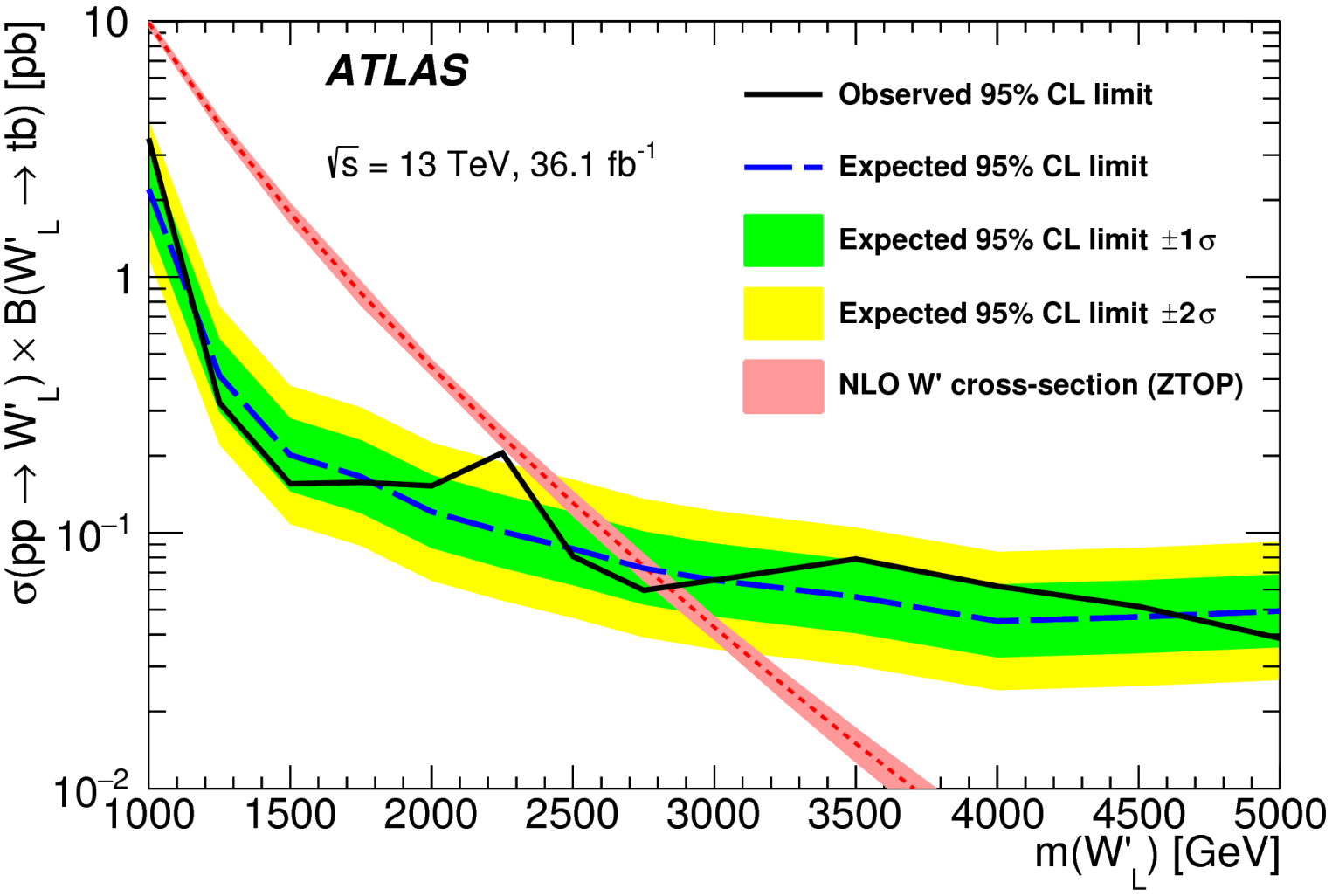
- Present 2 recent results of searching for heavy resonances decayed to top and bottom quark
  - W'->tb->qqbb
  - W'->tb->lvbb
- No significant deviation between data and background prediction
- Significant improvement on mass limits from Run 1 for both analyses

Backup

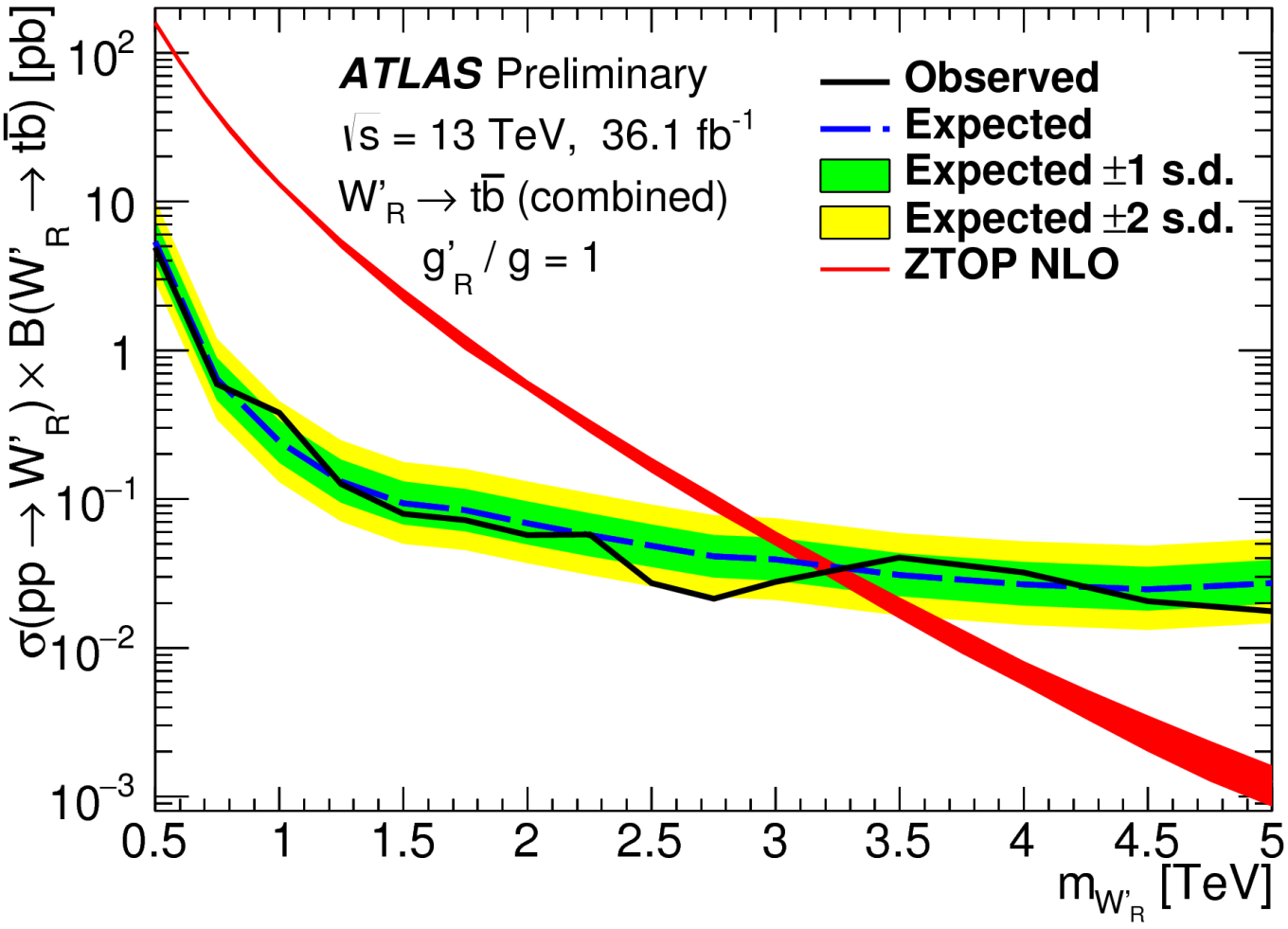
Hadronic: Event yields

"0 b-tag in" category						
	SR1	**QCD validation region**	**Region 3**	**Region 4**	**Region 5**	**Region 6**
Data	16333	57626	65600	267000	959000	12600000
QCD + V+jets(ABCD)	15247.40 (96.11%)	54474.10 (98.59%)				
$t\bar{t}$	616.57 (3.88%)	778.50 (1.41%)	1517.00	2372.50	3434.00	5066.00
"1 b-tag in" category						
	SR3	**SR2**	**Region 3**	**Region 4**	**Region 5**	**Region 6**
Data	4265	12834	78300	56000	188000	1220000
QCD + V+jets(ABCD)	3251.66 (74.45%)	11155.20 (99.69%)				
$t\bar{t}$	1115.72 (25.54%)	1144.43 (9.30%)	1116.00	5312.30	6700.00	5590.00

Hadronic: W'$_L$ limit plot



Combined W'$_R$ limit plot



Leptonic: Event yields

	2-jet 2-tag ($e^{\pm}$)	2-jet 2-tag ($\mu^{\pm}$)	3-jet 2-tag ($e^{\pm}$)	3-jet 2-tag ($\mu^{\pm}$)
W'_R (1.0 TeV)	1584 ± 35	2055 ± 38	1241 ± 30	1749 ± 34
W'_R (2.0 TeV)	33.5 ± 1.0	55.5 ± 1.2	51.6 ± 1.2	84.3 ± 1.5
W'_R (3.0 TeV)	1.4 ± 0.1	2.6 ± 0.1	2.5 ± 0.1	5.1 ± 0.1
W'_R (4.0 TeV)	0.1 ± 0.0	0.3 ± 0.0	0.2 ± 0.0	0.5 ± 0.0
W'_R (5.0 TeV)	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$t\bar{t}$	565 ± 15	810 ± 17	2582 ± 33	2737 ± 37
Single-top	125.6 ± 6.8	187 ± 12	242 ± 14	304 ± 18
W+jets	29.0 ± 6.0	38.9 ± 4.2	49.2 ± 4.9	79.4 ± 8.0
Multijets	33.4 ± 6.4	70 ± 15	84 ± 11	119 ± 22
Z+jets	2.2 ± 0.4	10.2 ± 1.5	11.8 ± 1.4	17.3 ± 2.1
diboson	0.0 ± 0.0	1.2 ± 0.2	11.5 ± 2.0	5.2 ± 0.7
Total background	755 ± 18	1117 ± 26	2980 ± 38	3262 ± 48
Data	706	1117	2976	3278