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ATLAS EXPERIMENT

Search for heavy resonances decaying to top quarks

Saverio D'Auria
School of Physics and Astronomy, University of Glasgow, U.K.
on behalf of the ATLAS *collaboration*

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Outline

- Introduction
- $t\bar{t}$ Resonance searches
  - Vector and scalar cases
  - Analysis method
  - Results on the search for a vector boson resonance at $\sqrt{s} = 13$ TeV data, 3.2 fb$^{-}1$ [ATLAS-CONF-2016-014]
  - Results on the searches in the scalar resonance sector (from $\sqrt{s} = 8$ TeV data) [CERN-EP-2017-134, to be submitted to PRL] New
- $t\bar{b}$ resonance searches (review 8 TeV ATLAS results)
- Conclusions

Introduction

Top is the heaviest quark, Yukawa coupling with Higgs ≈ 1, special role in many BSM theories: topcolour-assisted technicolour, composite Higgs models, extra dimensions, Higgs doublet models all have large coupling to $t\bar{t}$.

Search for resonances decaying into $t\bar{t}$ as generic as possible:

- Vector case: search for a bump in $t\bar{t}$ invariant mass
- Scalar case: search for a bump and/or a dip in mass spectrum

Model independent method, exclusion limits in specific models

Main background processes:

- W+jets,
- Z+jets,
- single top,
- non resonant $t\bar{t}$ production, well defined mass spectrum shape

$t\bar{t}$ resonance searches

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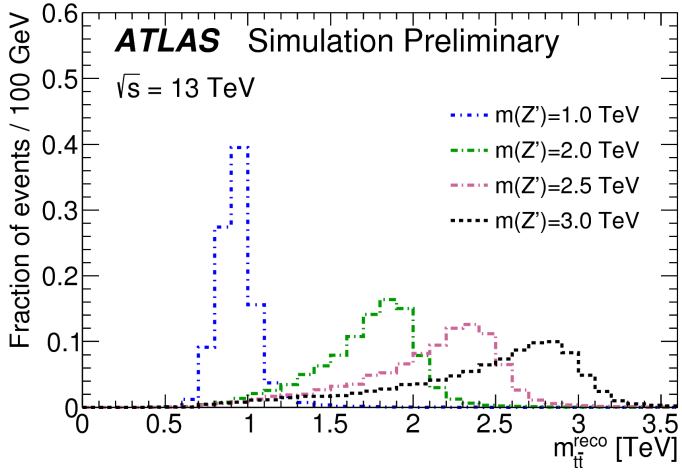
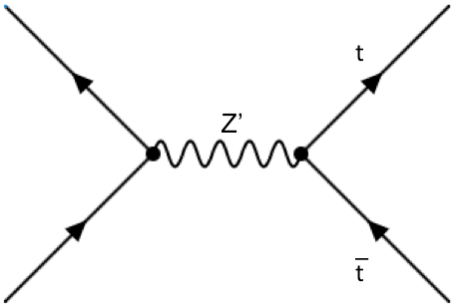
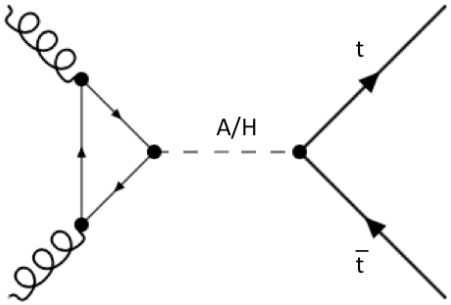
Signal model: Z' with fixed Γ/m_Z

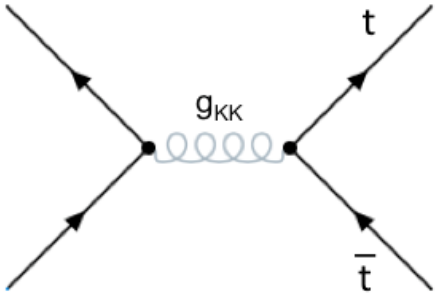




Leptophobic Z'



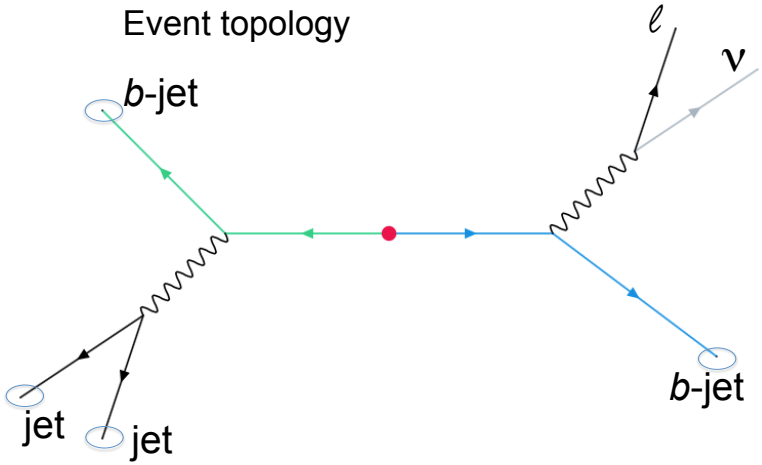
Additional scalar H or pseudoscalar A in 2HDM



Massive gluon Kaluza-Klein extra dimensions

Randall-Sundrum model

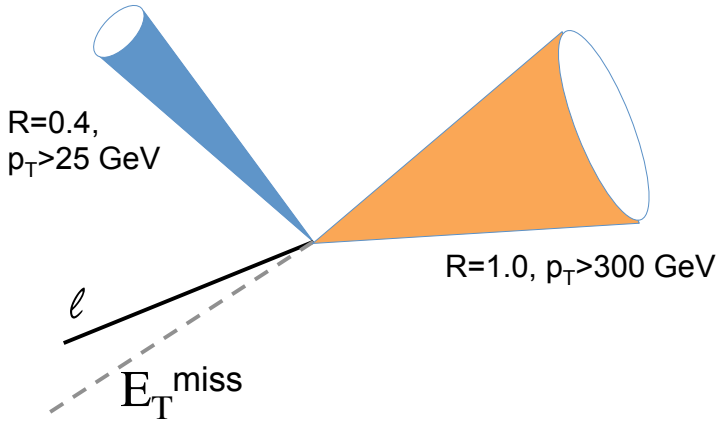
Event topology



Search in lepton+jets $t\bar{t}$ decay mode

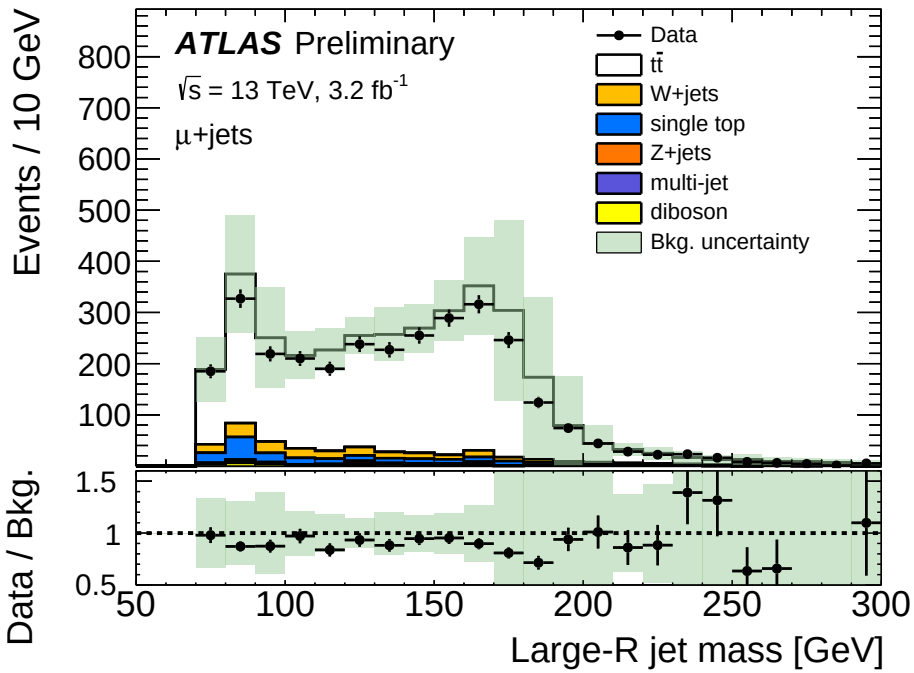
Event selection $t\bar{t}$ at $\sqrt{s} = 13$ TeV

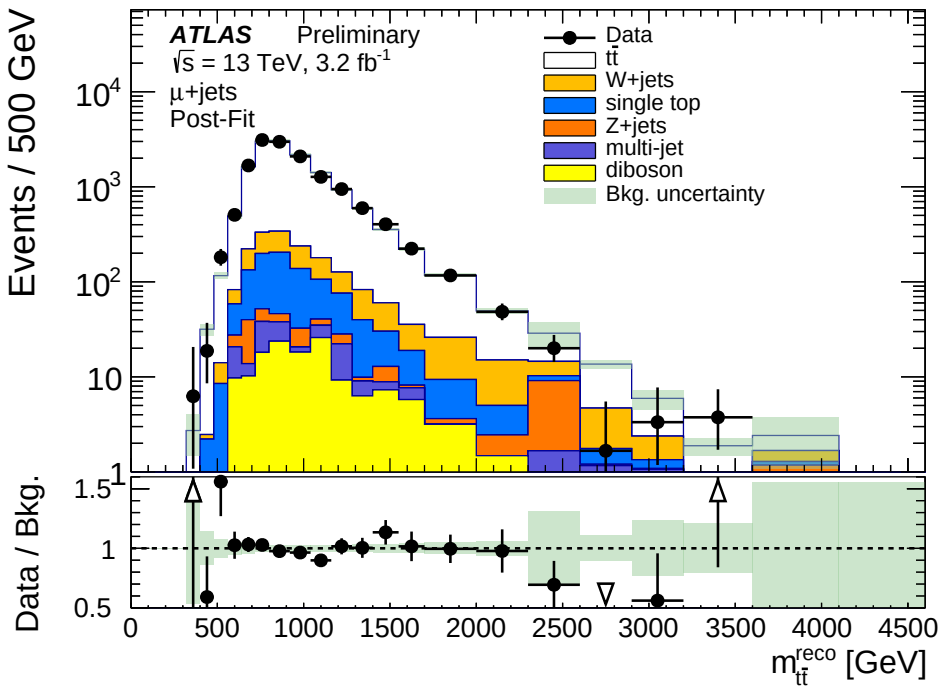
- [1] Single electron or single muon trigger, $L = 3.2$ fb^{-1} (2015 data)
- Off-line ℓ cuts: $p_T > 25$ GeV, $|\eta_e| < 2.47$; $|\eta_\mu| < 2.5$; p_T-dependant cone isolation (max $\Delta R < 0.2$) ; $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
- no additional lepton in the event
- Track-jets anti-κ_t with $R = 0.2$, $\geq 1b$-tagged track jet at 70% efficiency
- ≥ 1 *"standard"* jet (anti-$\kappa_t R = 0.4$) $p_T > 25$ GeV, $|\eta| < 2.5$ at ΔR(jet-lepton)< 1.5 *"b-jet of leptonic top"* $\equiv J_{\text{sel}}$, no b-tag requirement
- Large R jet $R = 1, p_T > 300$ GeV at large angle from both the lepton ($\Delta\phi_1 > 2.3$ rad) and from J_{sel} ($\Delta\phi_2 > 1.5$ rad)
- $E_T^{\text{miss}} > 20$ GeV,
- $E_T^{\text{miss}} + m_T^W > 60$ GeV



[1] ATLAS-CONF-2016-014

Invariant mass





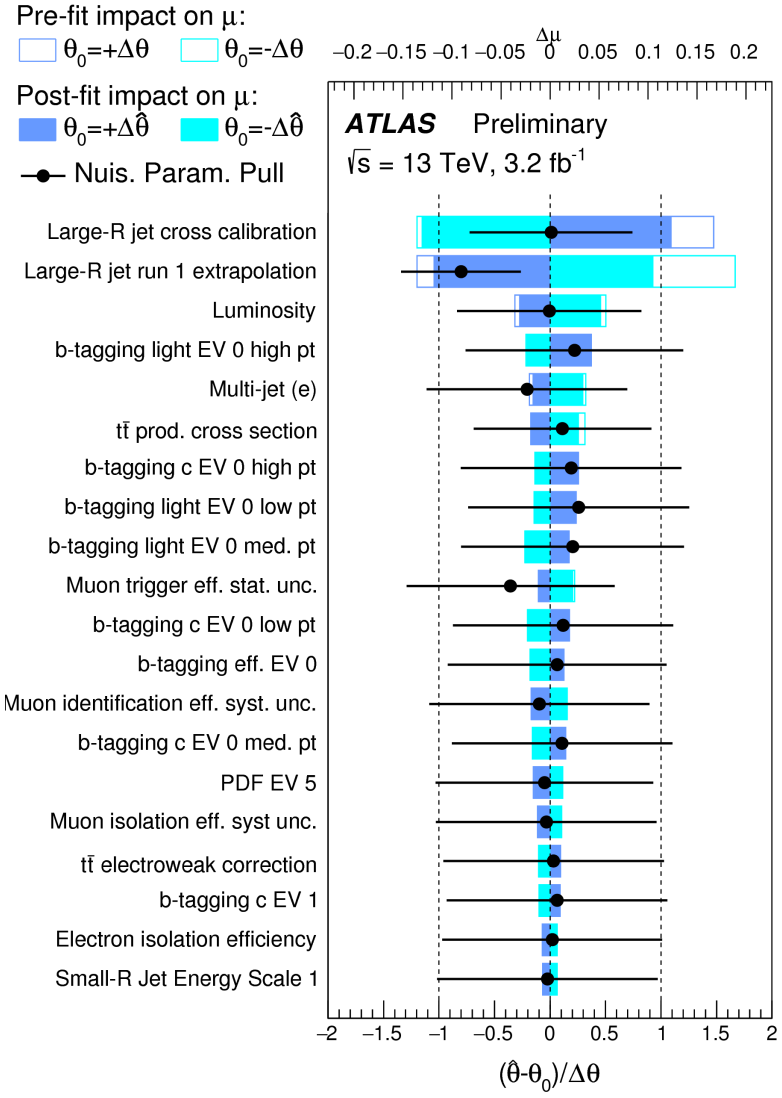
Good Data-Simulation agreement, within systematic uncertainties.

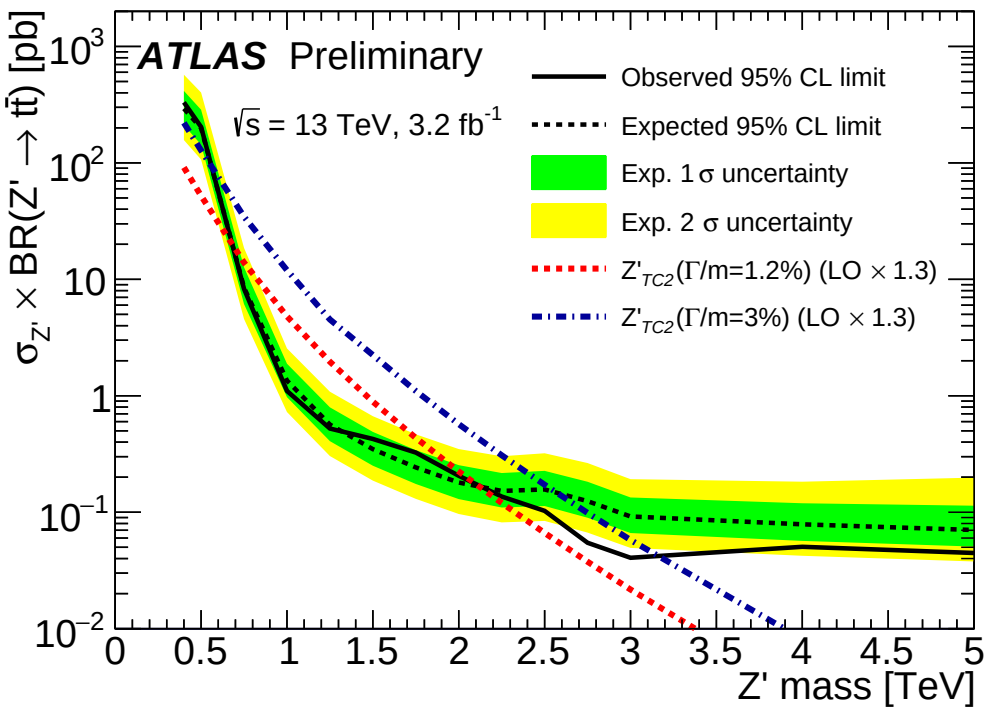
High purity $t\bar{t}$ selected (85%)

No evidence for a deviation from non-resonant m_{tt} distribution.

Statistical fit using BUMPHUNTER, with nuisance parameter profile fit.

Limits to vector resonances decaying to $t\bar{t}$





Main systematic unc.: large-R jet energy scale

Limit on leptophobic Z' (topcolour-assisted) width 1.3%:

$0.7 < m_{Z'} < 2.0$ TeV at 95% C.L.

8 TeV data excluded $m_{Z'} < 1.8$ TeV [2]

[2] ATLAS collab. JHEP 08 (2015) 148

Scalar resonances: interference effects

Gluon initiated processes interfere with non-resonant $t\bar{t}$ production[3]. Scalars decaying to $t\bar{t}$ detected as dip+bump over continuum.

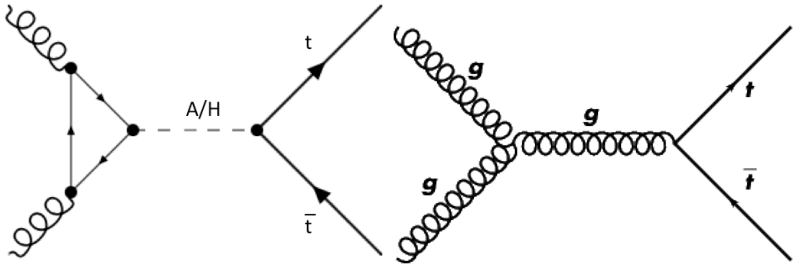
MC simulation approaches:

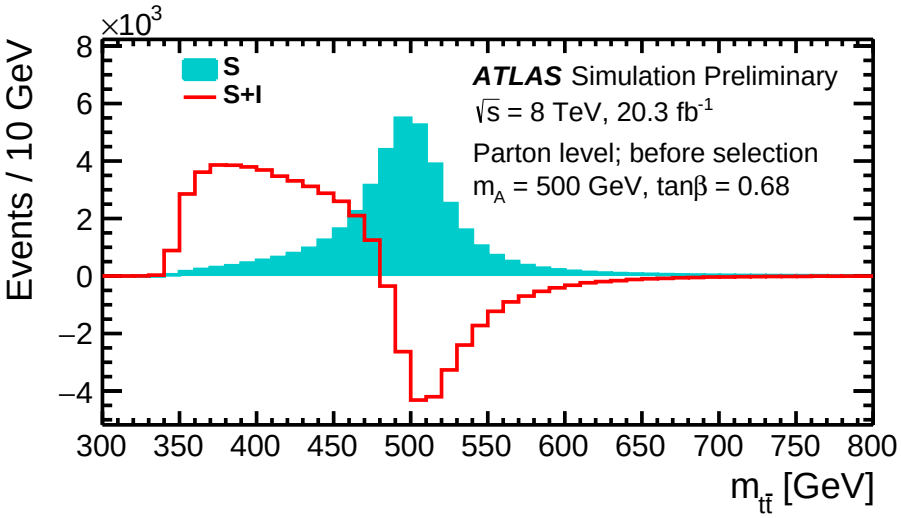
A) many large $t\bar{t}$ (S+I+B) samples scaning $m_{A/H}$ and width $(\tan\beta)$

B) single non resonant sample (B) POWHEG+PYTHIA6, many S+I term samples with negative weights MADGRAPH5_aMC@NLO scaning $m_{A/H}$ and width. Use reweight to increase density

This analysis used (B).

[3] e.g. Djouadi, Ellis, Quevillon CERN-TH/2016-095, or Hespel, Maltoni et al. J. High Energ. Phys. (2016) 2016: 16





Analysis of 8 TeV data, 20.3 fb^{-1}

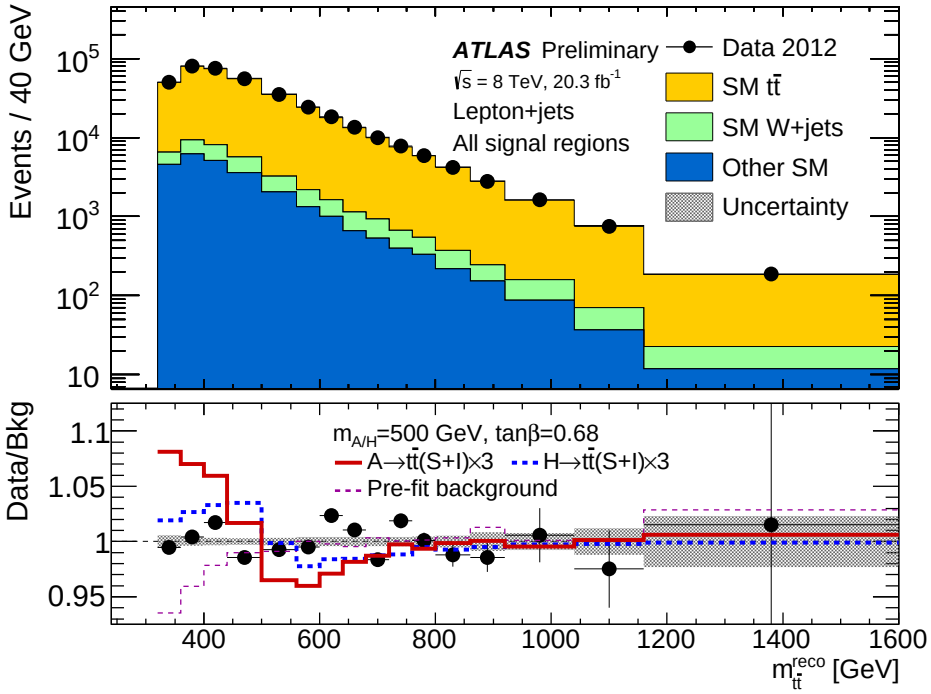
CERN-EP-2017-134, to be submitted to PRL **NEW**

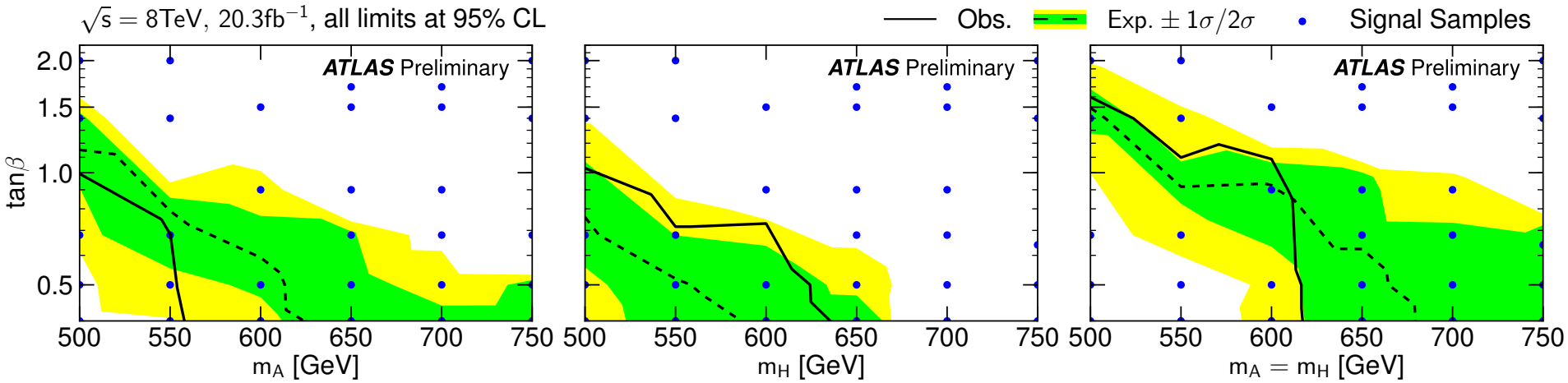
resolved topology, lepton+jets top decay See also the talk by G. Barone (link) this conf.

Limits to scalar resonances decaying to $t\bar{t}$

- Same requirement as before but
- $\geq$ 4 jets with R=0.4 and $p_T > 25$ GeV,
- $\geq$ 1 b-tagged jet 70% eff.

Interpretation with 2-Higgs Doublet Model. Parameter $\tan\beta = \frac{\text{vev}_1}{\text{vev}_2}$
Exclusion in $m_H - \tan\beta$ plane.
No sign of a scalar resonance in data



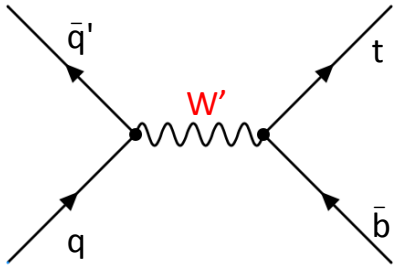


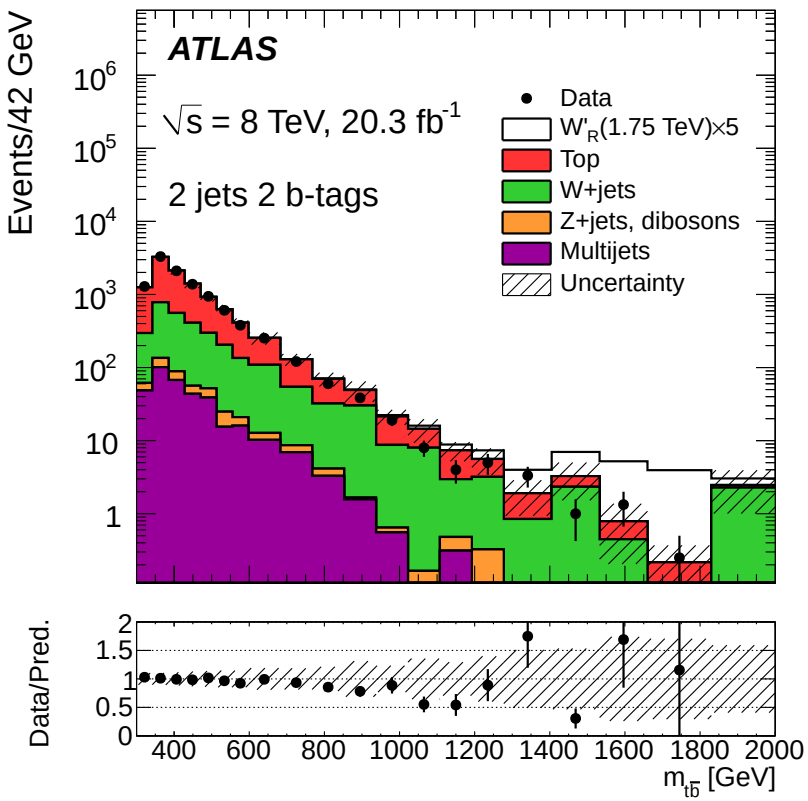
$t\bar{b}$ resonance searches at $\sqrt{s} = 8$ TeV

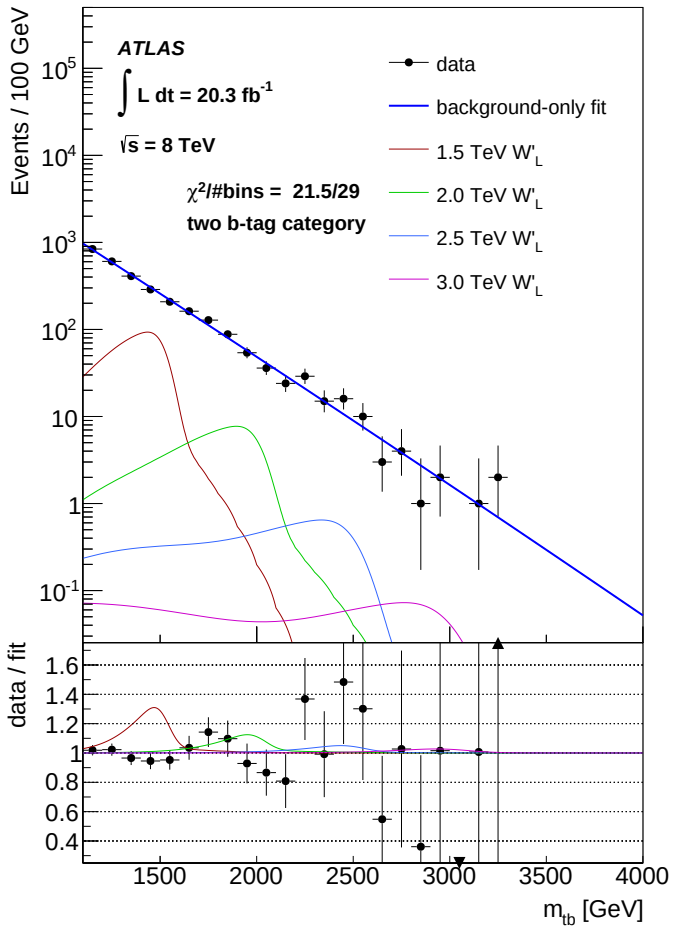
Search for leptophobic W' decaying to tb. s-channel single top production. Searched for in decay modes

- ℓ+jets with 20.3 fb^{-1} [Phys. Lett. B743 (2015) 235]
- 4 jets, of which 2 b-jets with 20.3 fb^{-1}

Eur. Phys. J. C (2015) 75:165







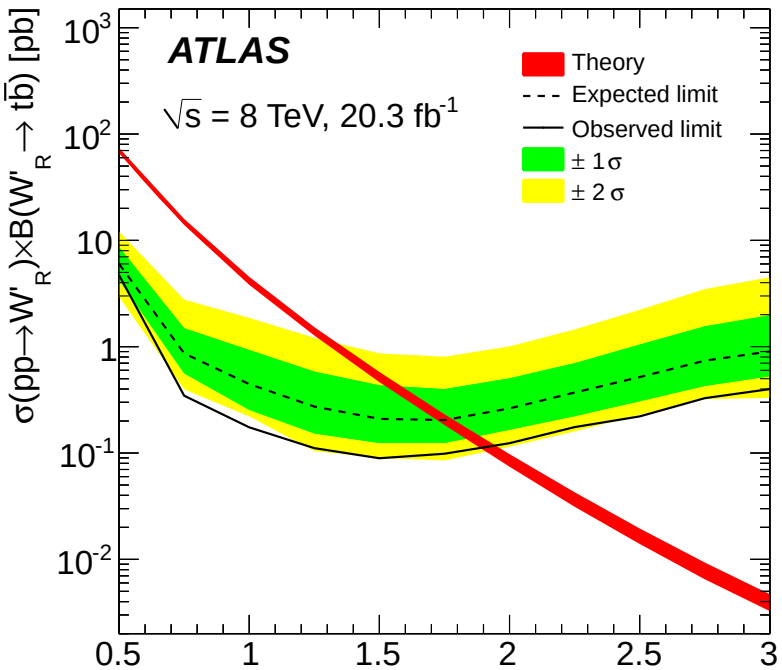
Limits to W' to $t\bar{b}$ at $\sqrt{s} = 8$ TeV

Right and Left-handed W' coupling hypotheses. Minimaly different results

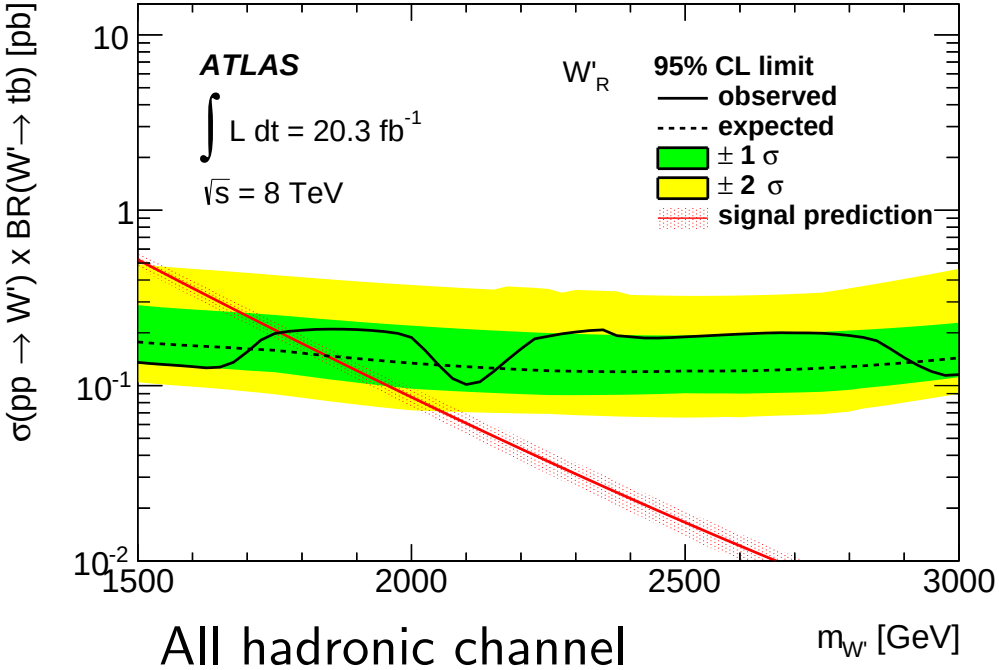
Excluded $m_{W'_L} < 1.68$ TeV and $m_{W'_R} < 1.76$ TeV with coupling $g' = g_{SM}$ $qqbb$

Excluded $m_{W'_L} < 1.70$ TeV and $m_{W'_R} < 1.92$ TeV with coupling $g' = g_{SM}$ $\ell\nu bb$

Exclusion curves in g'/g_{SM} vs mass plane.



ℓ+jets channel



All hadronic channel

The scalar case $H^+ \to t\bar{b}$ was reported by E. Bergeas

(link to EPS talk 6 July)

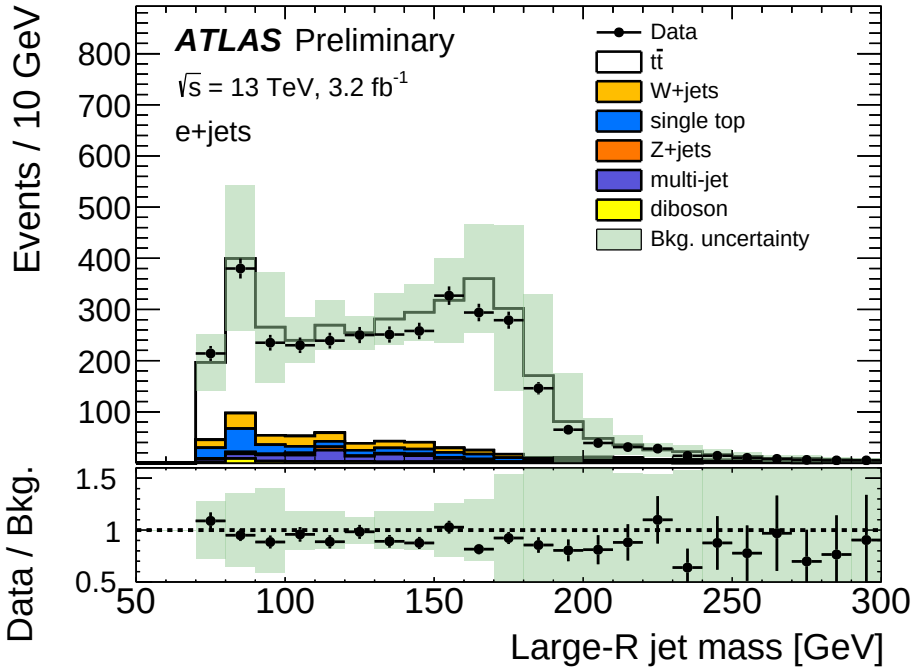
Conclusions

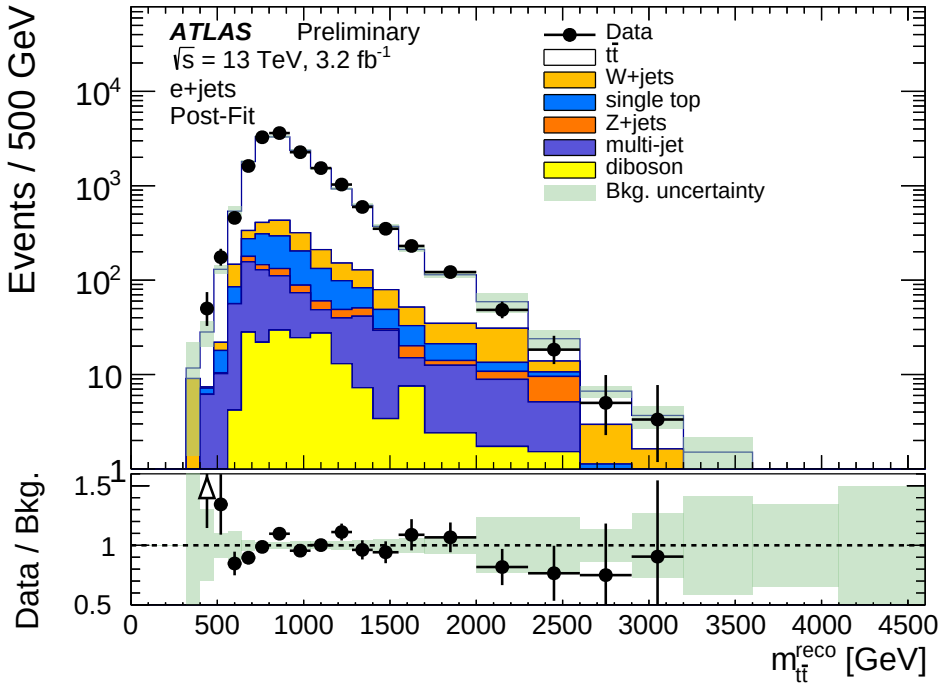
- No sign of new resonances found so far
- 13 TeV data exclude leptophobic Z' with $m_{Z'} < 2.0$ TeV
- 8 TeV ATLAS analysis excludes scalar resonances so far. The 2HDM-II parameter space has exclusion for $M_{A/H} < 600$ GeV
- 8 TeV data exlude leptophobic W' with $m_{W'} < 1.92$ TeV
- New analyses on these channels are being finalised using the whole data set at 13 TeV (2015+2016)

Time for questions

Backup

Invariant mass electron channel





	e+jets	μ+jets
$t\bar{t}$	3000 ± 700	3000 ± 700
W+jets	200 ± 140	200 ± 40
Single top	190 ± 40	180 ± 40
Z+jets	33 ± 12	26 ± 12
Multi-jet	130 ± 70	19 ± 11
Diboson	46 ± 11	37 ± 8
Total	3700 ± 800	3400 ± 800
Data	3352	3074

tb exclusion plots: coupling vs. mass