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A search for top-antitop resonances using proton-proton collisions at $\sqrt{s}$ =13TeV

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(on behalf of the ttbar resonance search team)

ATLAS EXPERIMENT
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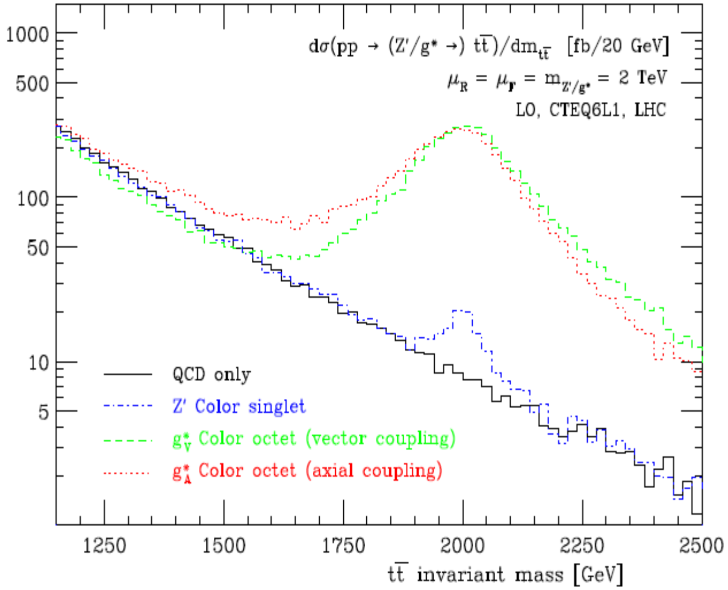
Abstract

This note documents the search for top-antitop resonances produced in ATLAS proton-proton collisions with $\sqrt{s}$ = 13 TeV. The analysis requires a lepton with high transverse momentum, large missing momentum, and a single large-radius jet or multiple small-radius jets in the lepton+jets channel. It requires two large-radius jets in the all hadronic environment. The final result is expressed as an upper limit on the cross section of a set of benchmark models.

Motivation

- Many models predict new particles with preferred coupling to top quarks, accessible at LHC energies
- Different spin states and different widths are possible
  - e.g. topcolor assisted technicolor → predicts leptophobic Z' with strong 3rd generation coupling
  - experimental check: search for bumps in ttbar reconstructed mass spectrum
  - narrow: smaller than mass resolution of detector



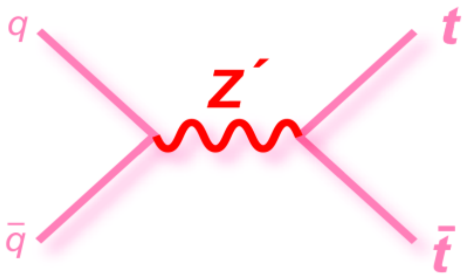
- Generic search for narrow width new particles decaying to top quark pairs; $t\bar{t}$

Benchmark models

- Current Benchmark model to quantify sensitivity

  Top-color model (TC):

  - Leptophobic TC heavy **Z' boson**
    spin-1, width: 1.2% **(narrow resonance)**



- In the future we plan to include:

  Warped extra-dimensions (Randall-Sundrum):

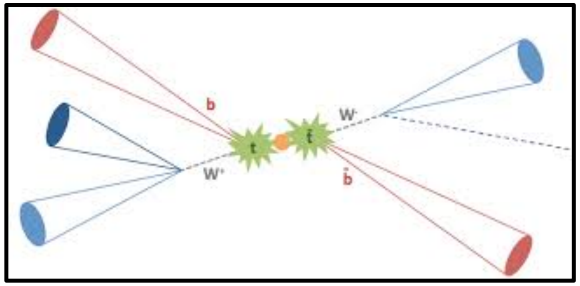
  - Kaluza-Klein gluon **(g_{kk})**
    spin-1, width: 10-40% **(broad resonance)**
  - KK Bulk-RS graviton **(G_{kk})**

Search for enhancement in the invariant mass ttbar spectrum

Final state topology

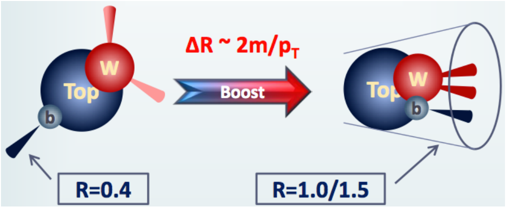
→ ***Study of the semi-leptonic channel***

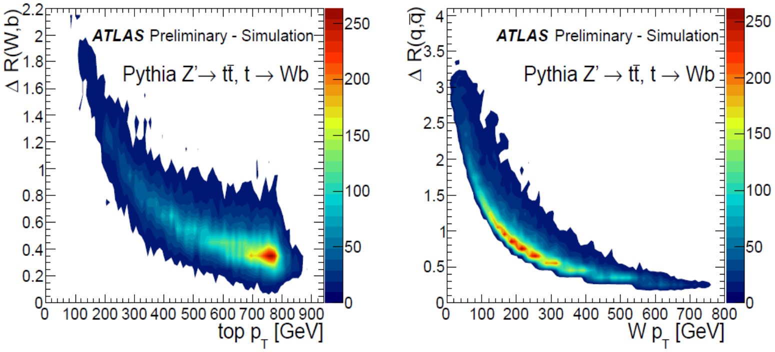
- ~ 30 % branching fraction (e and μ channels)
- clear signature with a lepton in the final state
- 4 partons among which 2 are b quarks



❖ "Boosted" top quarks from BSM signals

❖ Decay products of Boosted Tops collimated in direction of p_T





(a) $t \to Wb$ ATLAS-CONF-2012-065 (b) $W \to q\bar{q}$

→ ***Different final state topologies for increasing m_{tt}***

- « *resolved* » topology for low mtt masses
- « *top monojet* » topology for m_{tt} > 1TeV

Analysis strategy

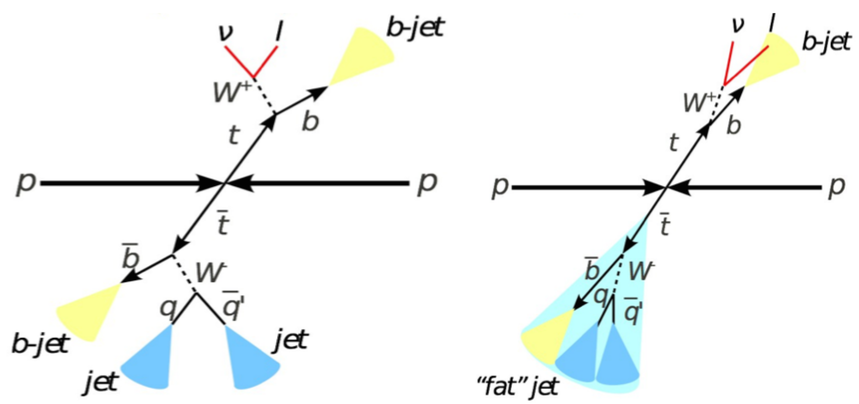
- Set–up an analysis as much model independent as possible
- Study performance in the important case of a narrow Z' "Z–like" resonance

→ ***Search is divided into 2 regimes***

- Resolved selection optimized for low m_{tt}
- Boosted selection optimized for high m_{tt}

A resolved top → *Wb* decay

A boosted top → *Wb* decay



- Invariant mass spectrum is searched for local excesses/deficits.
- Limits are set in the cross section*BR if no significant excesses/deficits.
- Cross–section*BR limits translated into bounds on the allowed mass for new particles.

Two separate analyses for different topologies

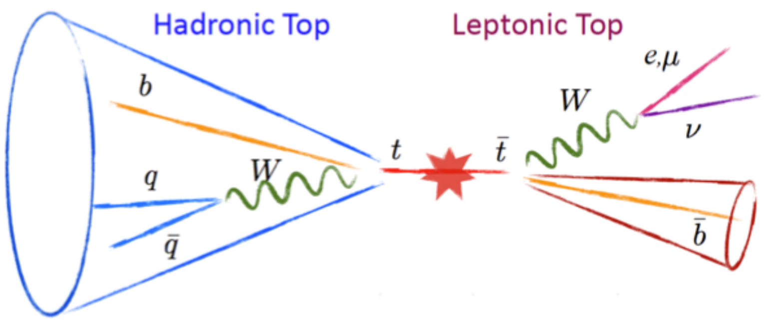
Standard Model background channels

- ttbar
  - Irreducible background, search for deviations in invariant mass spectrum
- Single top
  - Only little contamination in the semi-leptonic channel
- W+jets
  - Relevant in semi-leptonic channel
  - Normalisation and heavy flavour composition mostly estimated from data because of large uncertainties
- Z+jets/Drell-Yan
  - Important in di-leptonic channel
  - Not very well known $Z+b\bar{b}$ dominates if b-tagging is required
- QCD multijet
  - Most relevant in all-jets channel
  - Estimated with data (matrix method)

Event selection

- Electron/muon triggers (HLT_e24_lhmedium_L1EM18VH(L1EM20VH) HLT_e60_lhmedium OR HLT_e120_lhloose, HLT_mu20_iloose_L1MU15 OR HLT_mu50).
- One lepton with $p_T > 30$ GeV. Veto on second lepton at 25 GeV.

Hadronic Top
(Trimmed Anti-kT R=1.0)
$p_T > 300$ GeV
$m > 100$ GeV
$\sqrt{d_{12}} > 40$ GeV
$|\eta| < 2.0$



Leptonic Top
Small-R jet:
$p_T > 25$ GeV
MET > 20 GeV
MEW+MTW > 60 GeV

❖ **Boosted topology**

≥ 1 $R = 1.0$
≥ 1 $R = 0.4$ calo jet
≥ 1 $R = 0.2$ b-tagged track jet (MV2C20 @ 70%).

Kinematic cuts:
$\Delta\phi(\ell,\text{Large-R jet}) > 2.3$
$\Delta R(\ell,\text{small-R jet}) < 1.5$
$\Delta R(\text{small-R, Large-R}) > 1.5$

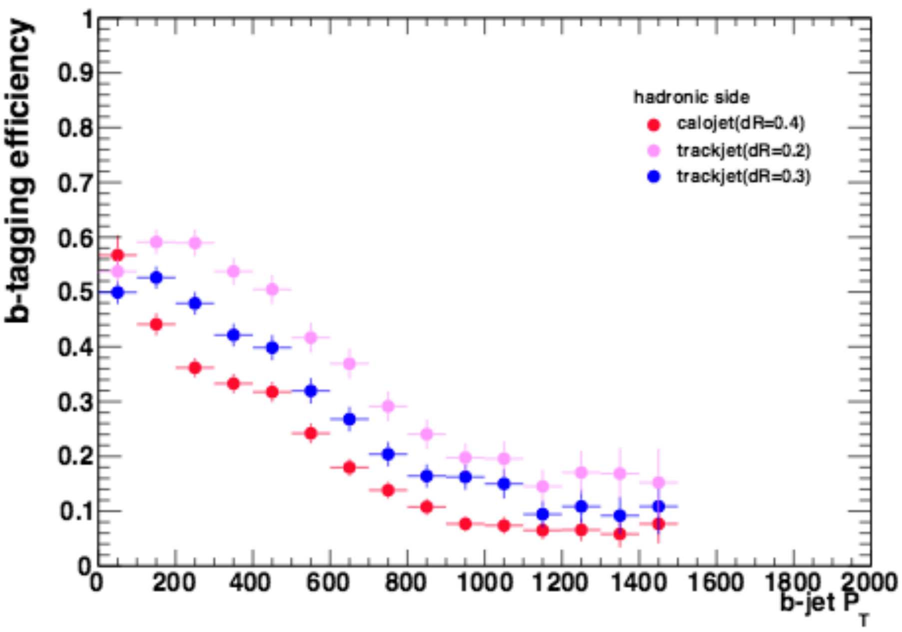
❖ **Resolved topology**

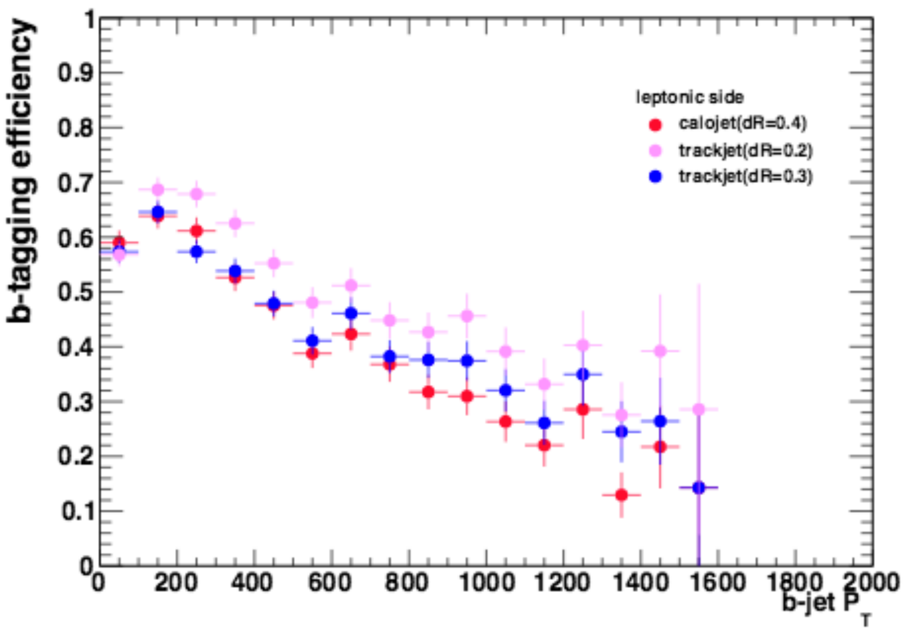
≥ 4 $R = 0.4$ calo
≥ 1 $R = 0.2$ b-tagged track jet (MV2C20 @ 70%).

- Events that fail the boosted selection are examined using the resolved selection

Track jets btagging efficiency

- Track jets have better angular resolution and can be clustered with smaller radii
- Leads to higher efficiency in dense environments





Yields

❖ Boosted Muon Channel

Sample	Yield	Stat.	Syst.
Data:	3073.0		
$t\bar{t}$	2364.6	35.7	577.1
$t\bar{t}$ (HM)	725.6	12.3	135.3
W+jets	234.6	22.4	158.8
single top	174.4	5.6	38.4
Z+jets	16.9	1.8	6.0
diboson	39.2	3.8	8.2
Expectation	3555.3	44.4	786.1
Data:	3073.0		

❖ Boosted Electron Channel

Sample	Yield	Stat.	Syst.
Data:	3363.0		
$t\bar{t}$	2420.6	37.2	589.2
$t\bar{t}$ (HM)	659.6	12.0	113.5
W+jets	239.9	27.5	96.0
single top	185.9	6.1	40.8
Z+jets	21.0	1.7	7.3
diboson	47.6	4.5	11.3
Expectation	3574.7	48.4	762.3
Data:	3363.0		

❖ Expected yields larger than yields in data

Systematic uncertainties

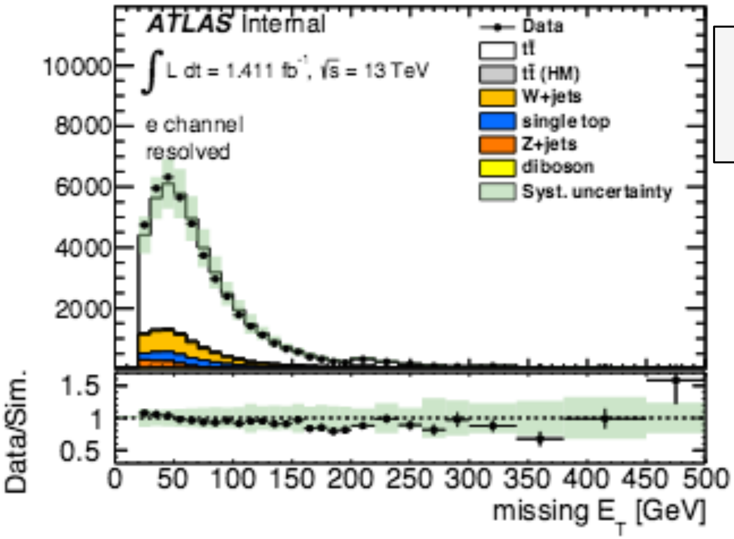
- Most important systematic uncertainties (shape and yield variations) taken into account for the search

- Jet energy scale/resolution
  - Large-R-jet systematics are the dominant one

- Uncertainties of background models and Luminosity are also important
  - QCD multijet model
  - W+jets (heavy flavour composition)
- Renormalisation and factorisation scale uncertainties on SM ttbar bg.

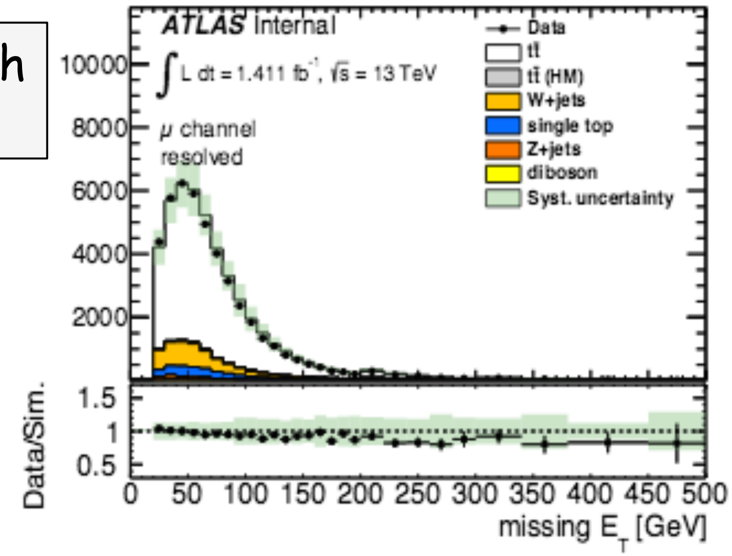
- Reconstruction and identification efficiencies
  - b-tagging systematics uncertainties lower than Run-1
  - Btagging switch to track jets

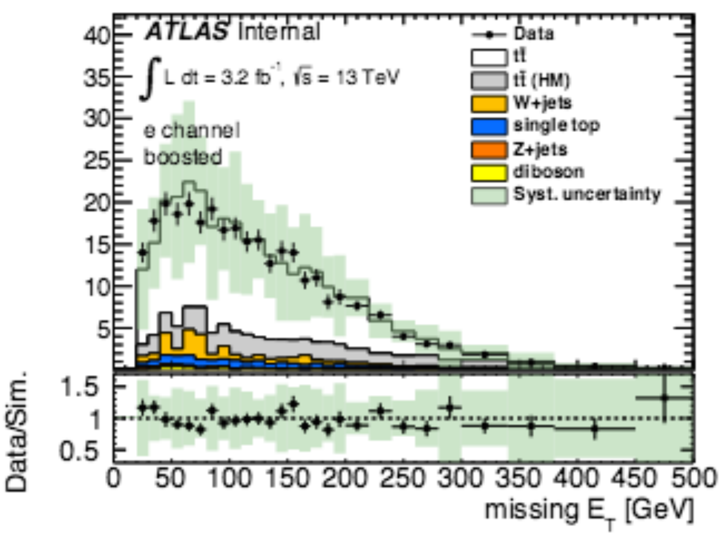
Control plots



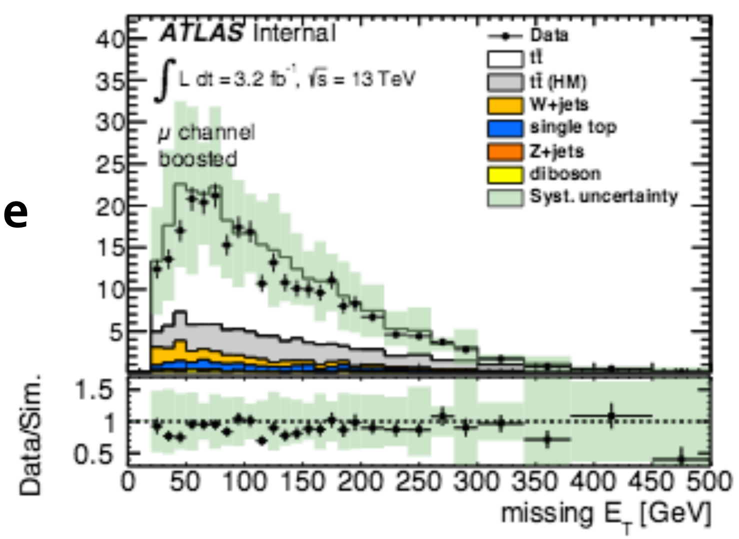
Good agreement with background

Resolved regime

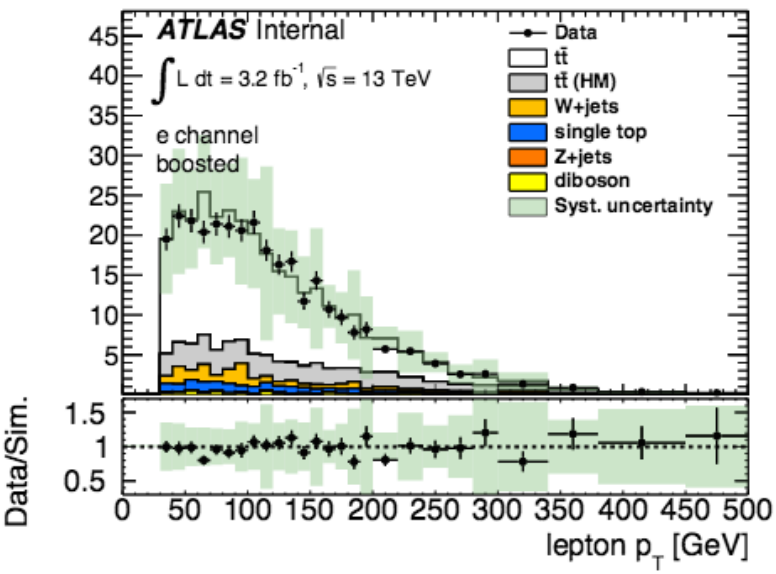


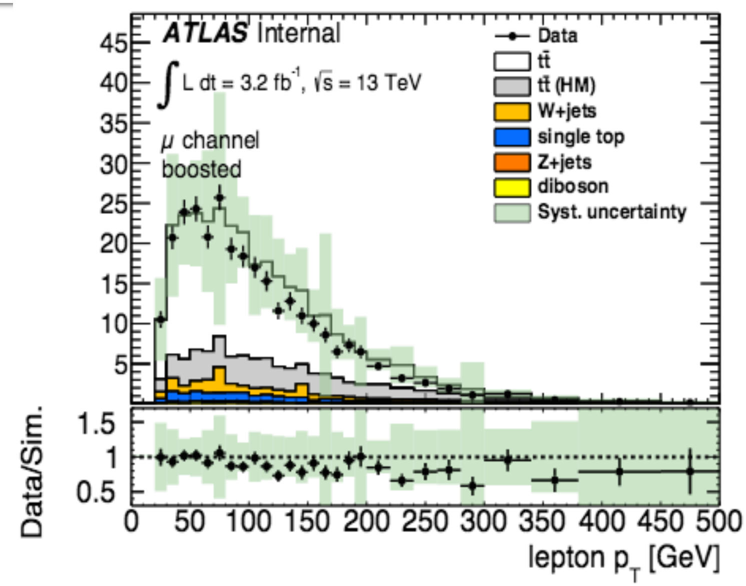


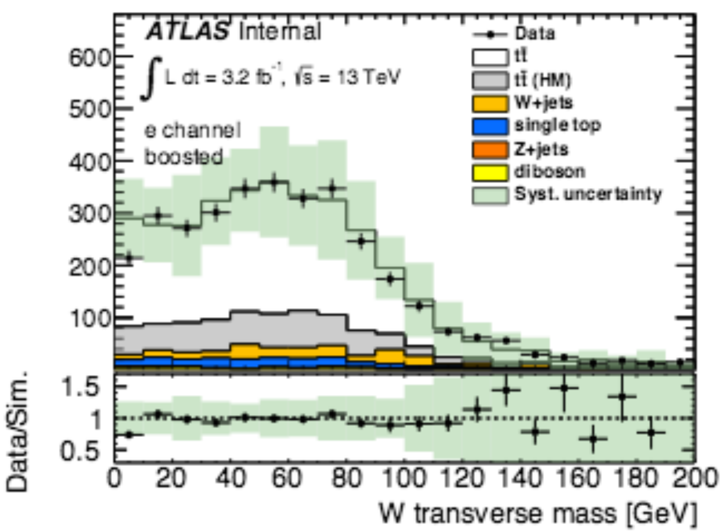
Boosted regime

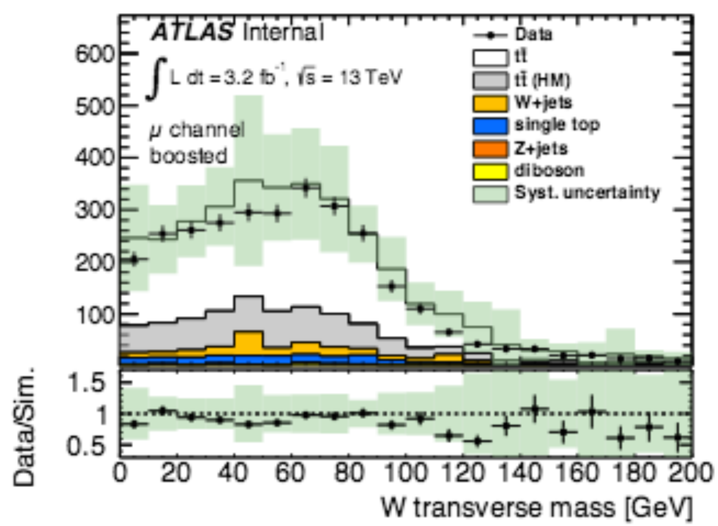


Control plots: Boosted topology





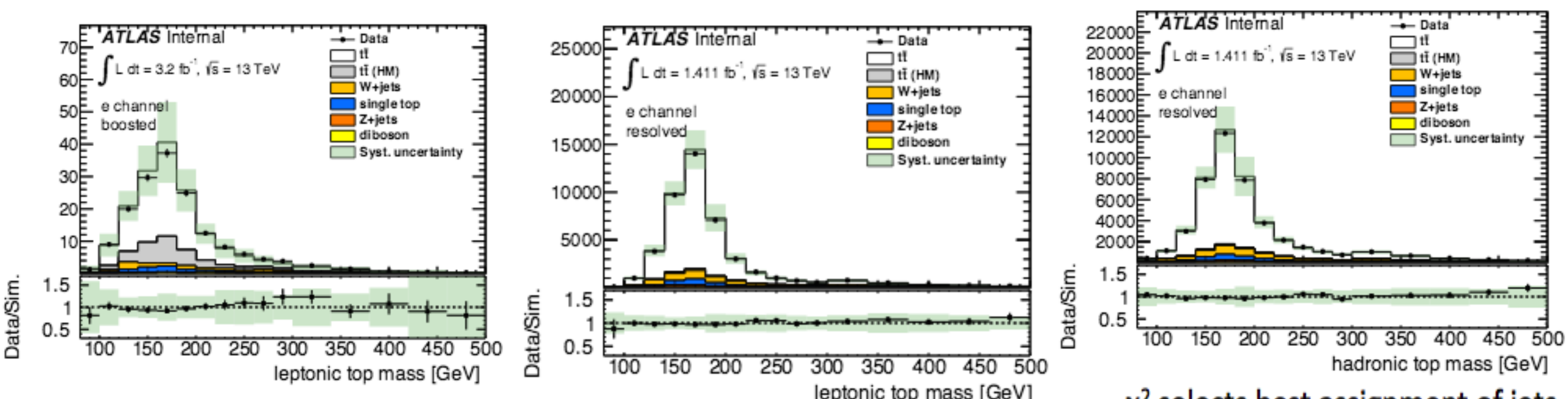




Event reconstruction

- Longitudinal component p_z of neutrino momentum computed by W mass constraint on lepton + MET system

- **Resolved:** Reconstruct tt with l+MET+4 small radius jets (R=0.4); Choose kinematically best combinatorics
- **Boosted:**
  - Leptonic top = l +MET + nearby small radius jet (R=0.4)
  - Hadronic top = large radius jet (R=1.0) with high mass, hard substructure



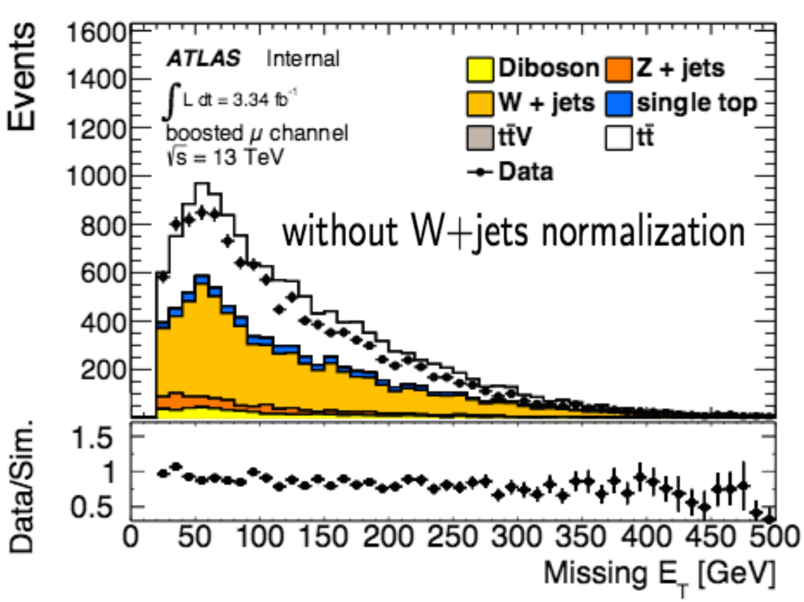
χ^2 selects best assignment of jets to top quarks

W+jets normalization: Boosted regime

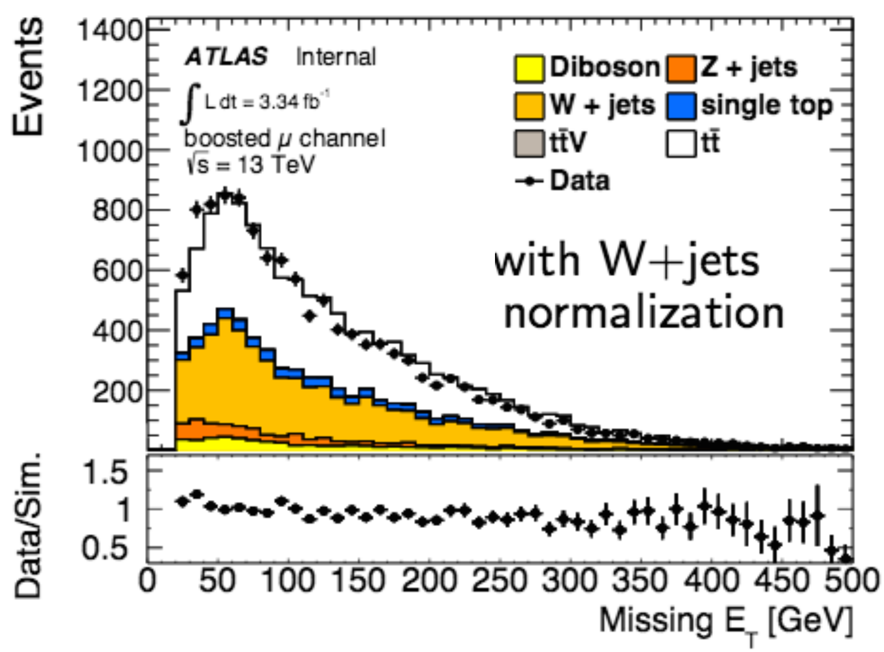
- Estimated in a control region with the b–tagging and the top tagging requirements (from the Large R Jet) removed.

Electron channel SF: 0.72±0.17

Muon Channel SF: 0.76±0.13



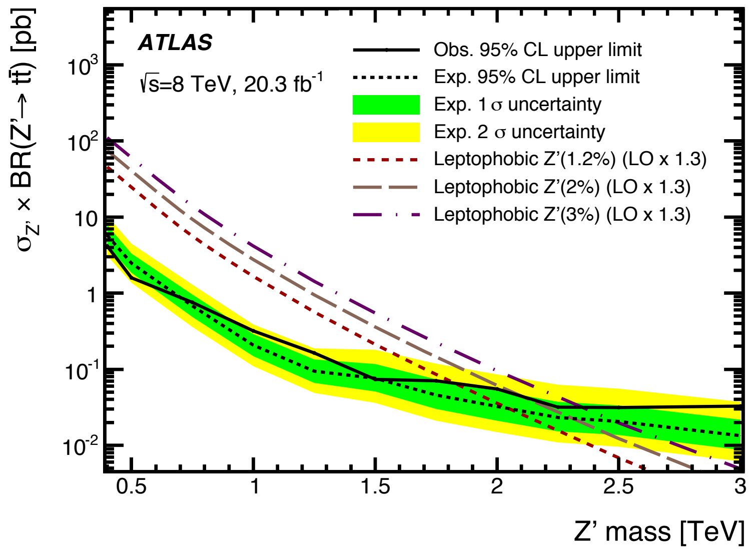
Applying SF improves agreement



Limit setting

- Using TRexFitter for the limit setting, which is now the recommendation in the Exotics group.
- Asymptotic approximation including all Run-2 uncertainties.
- Not showing the observed limit, as we have not yet unblinded

- Slightly better limits than Run-1 applying a simpler approach.
- Will check the results after the 13 TeV signal shapes are ready.



- Exclusion @95% CL limit
- $m_{Z'} > 1.8$ TeV (narrow leptophobic)

Summary & outlook

- Good agreement between data and MC
  - Boosted data/MC comparison indicate similar disagreement as in Run 1.
- High efficiency in using small-R track jet b-tagging
- Still on going
  - Some uncertainties are missing.
  - PDF systematic variation
  - QCD data-driven estimate.
  - BumpHunter studies.
- Full analysis software tested in MC and data for 13 TeV and new limit setting aimed for Rencontres de Moriond