$t\bar{t}$ resonances (l+jets) search in ATLAS

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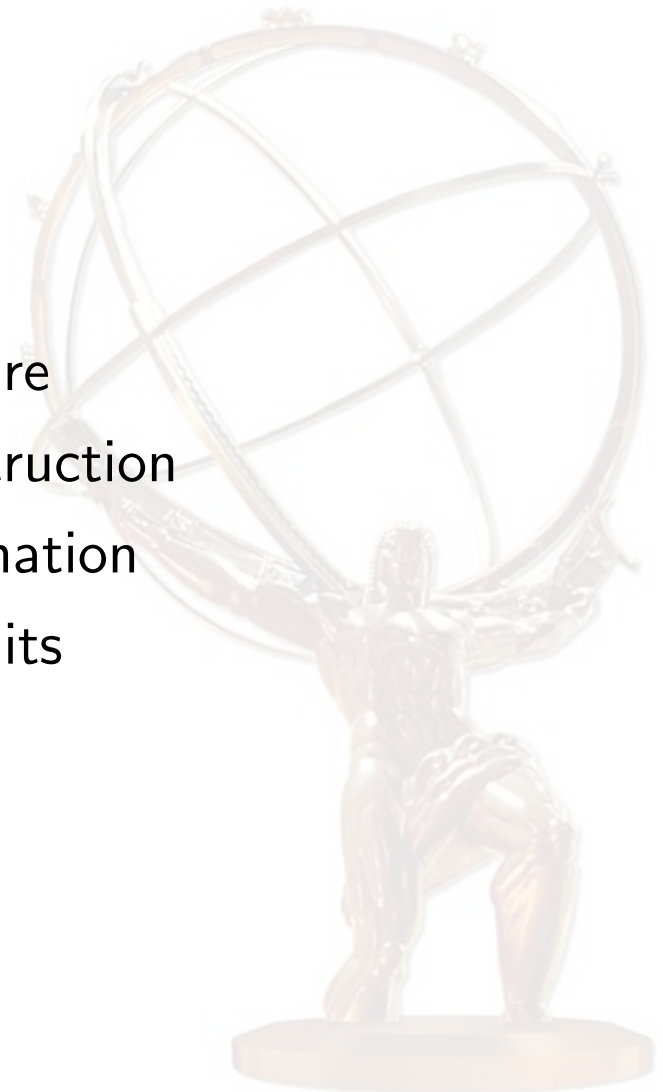
Overview

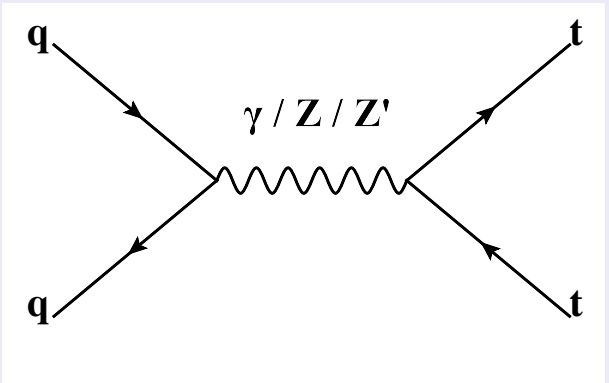


- Introduction
- Selection procedure
- $t\bar{t}$ system reconstruction
- Background estimation
- Summary and limits

Introduction

- Benchmark models: a leptophobic Z' and Kaluza-Klein gluons from Randall-Sundrum models with an extra dimension.
  - Top colour-assisted technicolor (TC2) $Z'_{TC2} \rightarrow t\bar{t}$.
    - ★ Spin 1, color singlet, narrow width (1.2%) modelled with SSM Z' (3%) width, Pythia 8 samples.
  - Randall-Sundrum Kaluza-Klein gluon $g_{KK} \rightarrow t\bar{t}$.
    - ★ Spin 1, color octet, larger width (10%-15%) Madgraph+Pythia 8 samples.
- Models generate $t\bar{t}$ pairs $\rightarrow$ we analyse the semi-leptonic final state (lepton + neutrino + 4 jets).

$t\bar{t}$ generation for signals



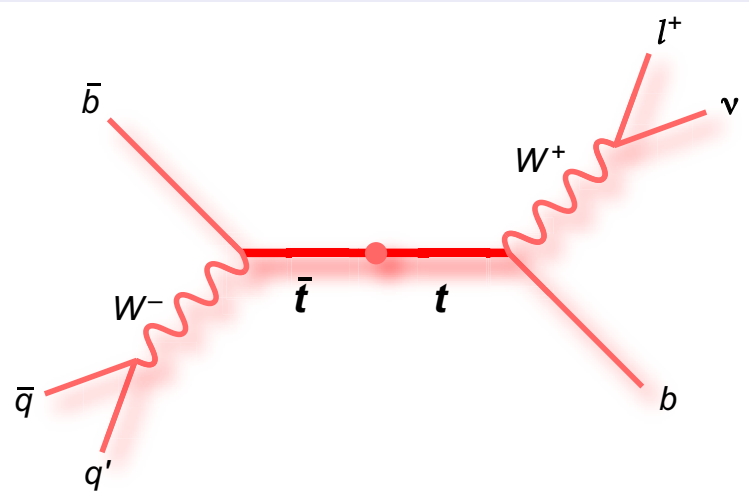
References

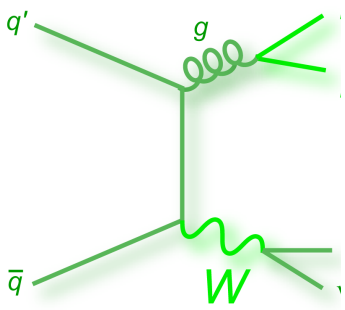
- C. T. Hill, Phys. Lett. B345 (1995) 483489.
- B. Lillie, L. Randall, and L.-T. Wang, JHEP 0709 (2007) 074.
- R. M. Godbole and D. Choudhury, arXiv:0810.3635 [hep-ph].

Backgrounds

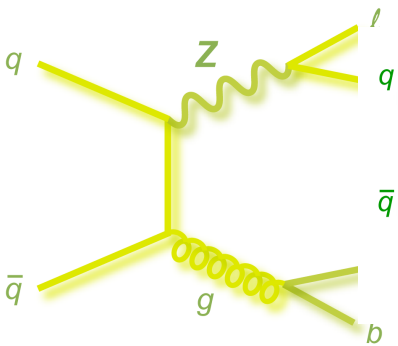
- Largest uncertainties come from Jet Energy Scale, b-tagging and PDF variations.
  - **SM** $t\bar{t} \rightarrow$ largest background estimated using MC@NLO.
  - **W+jets** $\rightarrow$ use data-driven techniques.
  - **Multi-jets** $\rightarrow$ small background, estimated from data-driven methods.
  - **Single top**, **Z+jets**, **Diboson** (small).
- See example background production diagrams below:

Final state for $t\bar{t}$ semi-leptonic decay

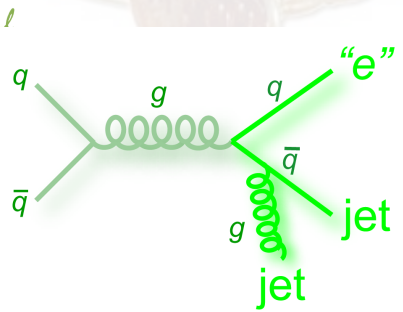




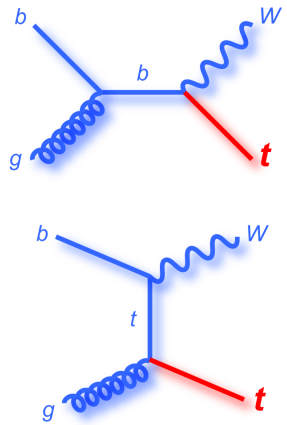
W+jets



Z+jets



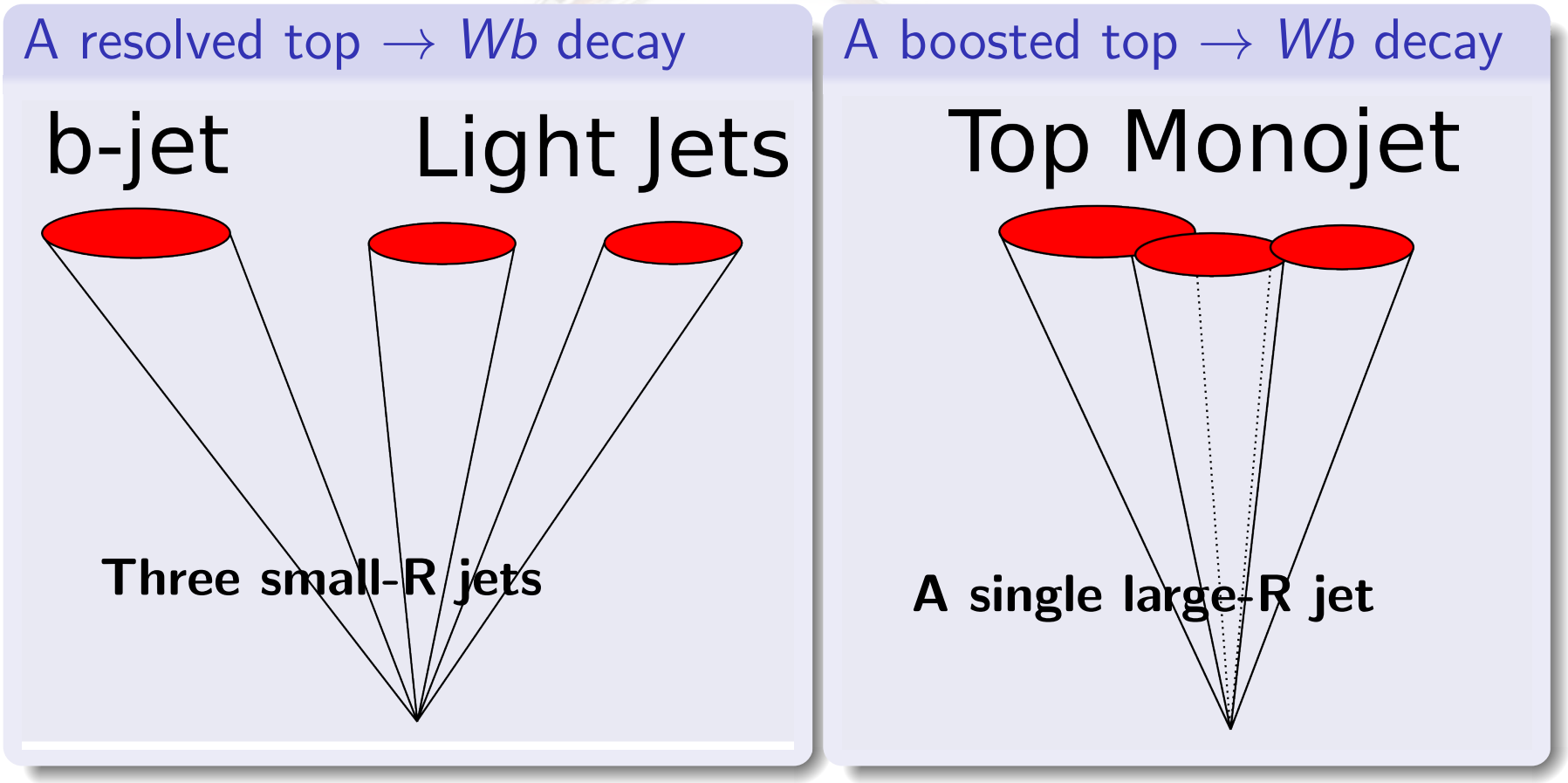
Multi-jets



Single top production (Wt-channel)

Final topologies for $t\bar{t}$ decay

- The top pairs may decay in two main topologies: well separated jets and leptons, or boosted jet topologies $\rightarrow$ combined for limit setting.

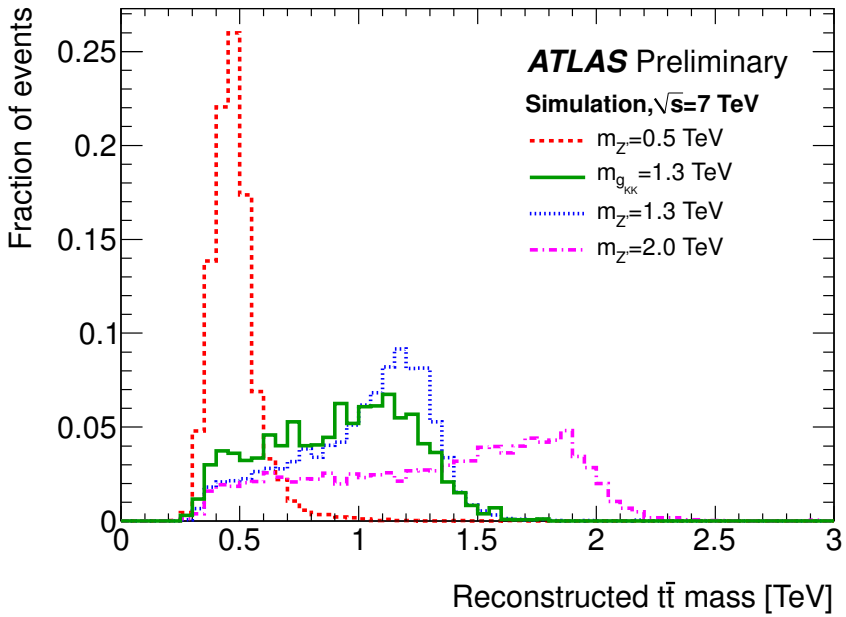


- Search done at 7 TeV (ATLAS-CONF-2012-136 and paper on the way) and 8 TeV (the latter is not public yet).

Strategy

- Separate merged and unmerged top decays, orthogonalising the selection:
  - Try to select events in the boosted topology with one large-R jet.
  - Only if those events fail the selection, check if they pass a set of criteria for the resolved topology.
- Attempt to reconstruct the mass of the $t\bar{t}$ system.
- Estimate backgrounds.
- Search for peaks in the $m_{t\bar{t}}$ spectra.

- **Contribution**: background and systematics estimate for the final result, the data-driven multi-jet background estimate was also done at 8 TeV.



$m_{t\bar{t}}$ distribution for many Z'_{TC2} masses

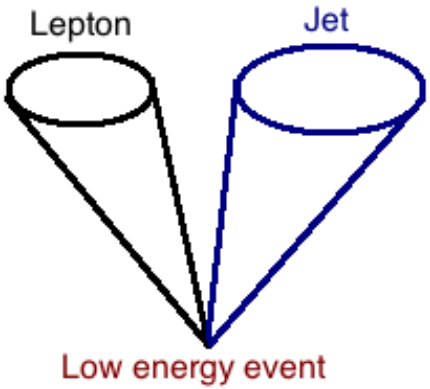
(ATLAS-CONF-2012-136)

Selection criteria (I)

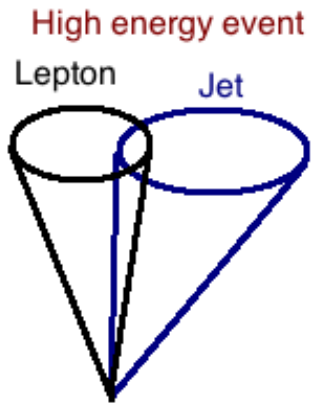
- When the angular distance between the b-jet and the lepton decreases, as the top is boosted, a better measure of the isolation is used.
- Leptons to satisfy a mini-isolation criteria, $I^{\ell}_{\mathrm{mini}}/p^{\ell}_{T} < 0.05$, with:

$$I^{\ell}_{\mathrm{mini}} = \sum_{\mathrm{tracks}} p_T^{\mathrm{track}},$$

  where $\Delta R(\ell, \mathrm{track}) < 10 GeV/p^{\ell}_{T}$ for the lepton $\ell \rightarrow$ variable ΔR is useful in boosted events.



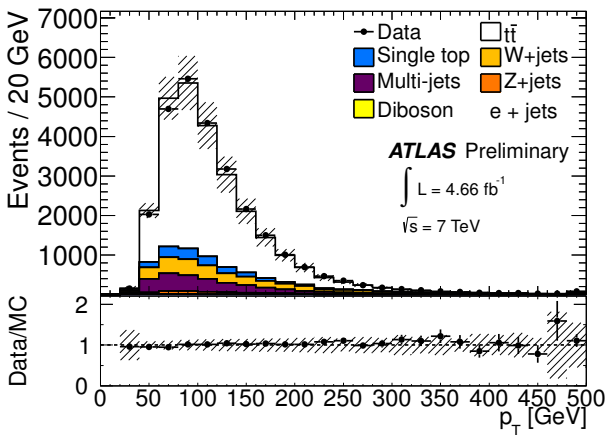
- Events must satisfy:
  - Lepton (electron/muon) trigger passed.
  - Exactly one electron/muon; and no lepton of the other type.
  - E_T^{miss} is $>$ 30 GeV (e channel) or $>$ 20 GeV (μ channel).
  - Transverse mass of the W boson (using selected lepton and E_T^{miss}), m_T satisfies $m_T > 30$ GeV (e channel) or $m_T + E_T^{\mathrm{miss}} > 60$ GeV (μ channel).



Selection criteria (II)

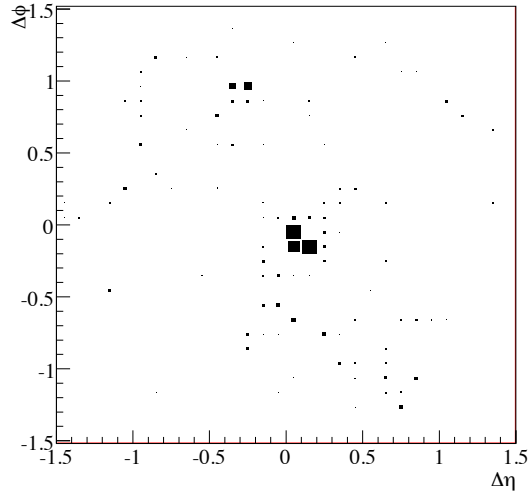
- The boosted and resolved selections diverge. For the boosted selection:
  - at least one small-R jet close to the lepton (referred to as the *selected small-R jet*, j_{sel});
  - at least one large-R jet away from the *selected small-R jet*.
- For the resolved selection:
  - at least three small-R jets among which one has mass > 60 GeV or four small-R jets.
- One jet is required to be b-tagged.

(ATLAS-CONF-2012-136)

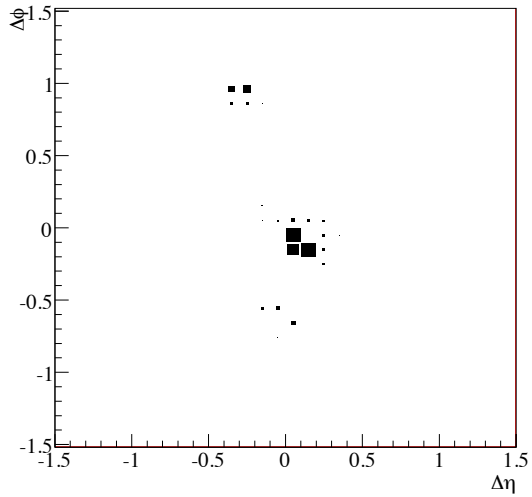


Electron p_T, resolved

- In the 8 TeV analysis, *trimming* of large-R jets is used $\rightarrow$ improves pile up resistance.
- *Trimming* reclusters subjets in each jet and removes soft interaction.



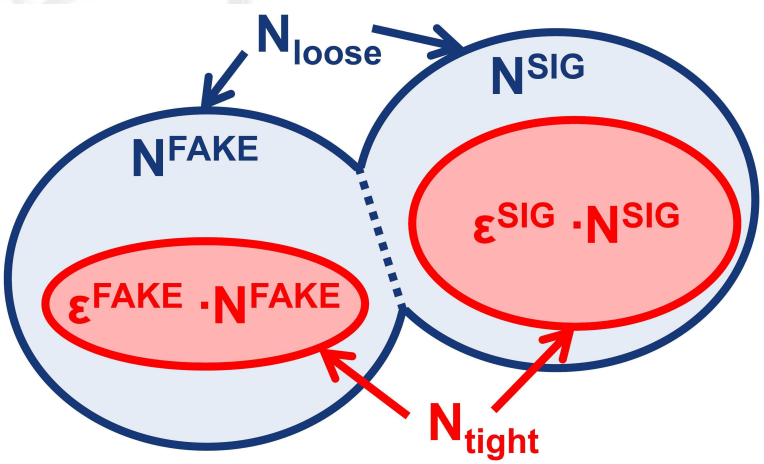
Untrimmed jet example (arXiv 0912.1342)



Trimmed jet example

Background estimate - QCD using the Matrix Method (I)

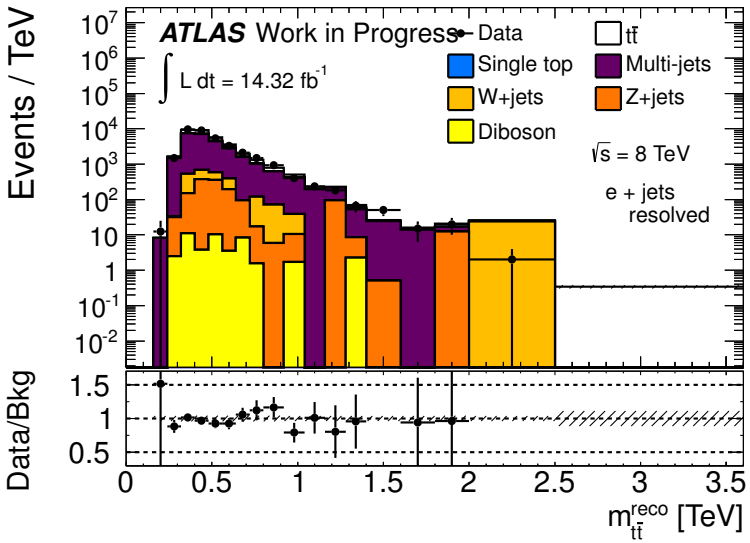
- "loose" definition $\rightarrow$ no isolation.
- "tight" definition $\rightarrow$ same as analysis.
- A Control Region is defined for the false-identification rate:
  - resolved $\rightarrow$ event fails the E_T^{miss} and m_T cuts and $|d_0/\sigma(d_0)| > 2.5$ (4.0) for electrons (muons).
  - boosted $\rightarrow$ event fails E_T^{miss} and m_T cuts, which are loosened to 60 GeV; inverts the large-R mass cut; loosens the large-R p_T cut to 150 GeV; and imposes $|d_0/\sigma(d_0)| > 2.5$ (4.0) for electrons (muons).
- Jets can fake leptons $\rightarrow$ a "loose" criteria is used to estimate QCD events.

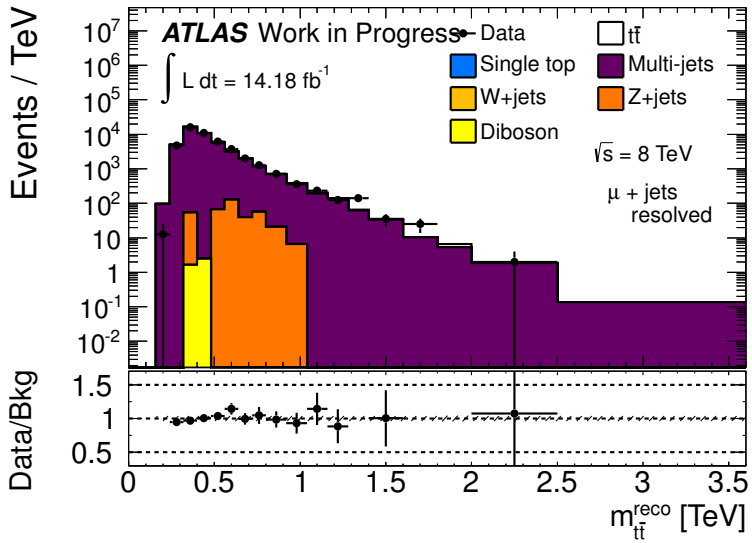


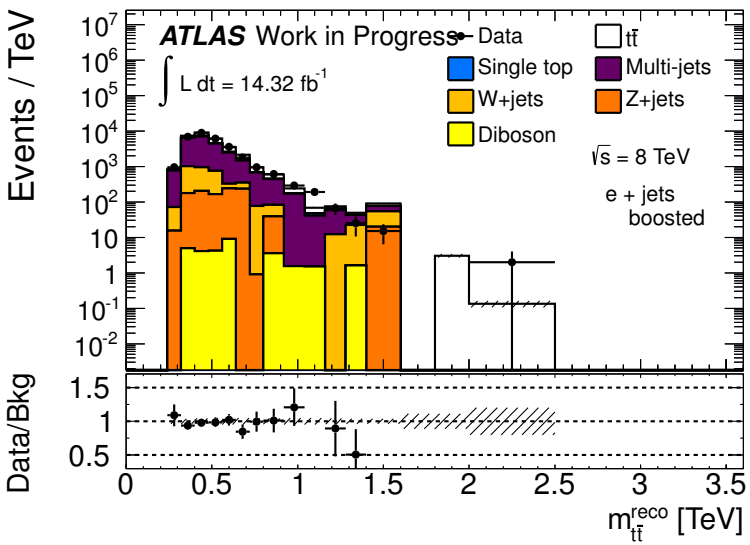
(Credits to F. Kohn for the picture)

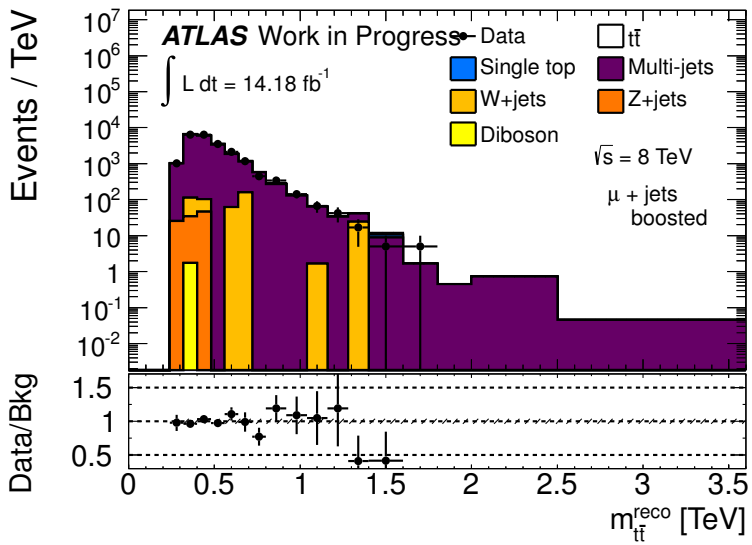
Background estimate - QCD using the Matrix Method (II)

- Data/MC comparison in the Control Region for $m_{t\bar{t}}$.









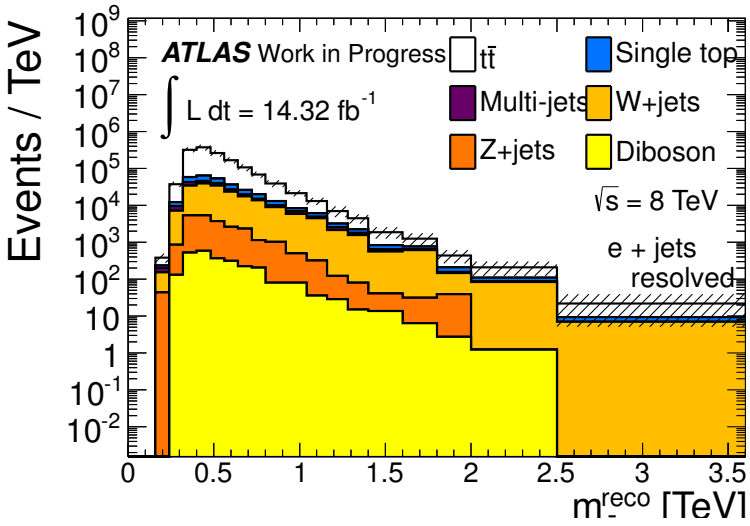
$m_{t\bar{t}}$ reconstruction

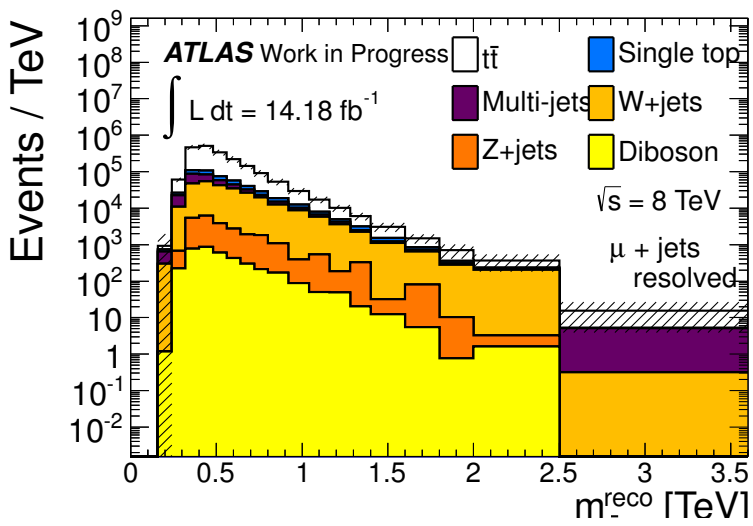
- Boosted scenario, $m_{t\bar{t}}$ is built from the large-R jet, j_{sel}, lepton and neutrino.
- Resolved scenario, the χ^2 method is used to choose the small-R jets contributing to the $m_{t\bar{t}}$: select the combination which minimizes the cost function.

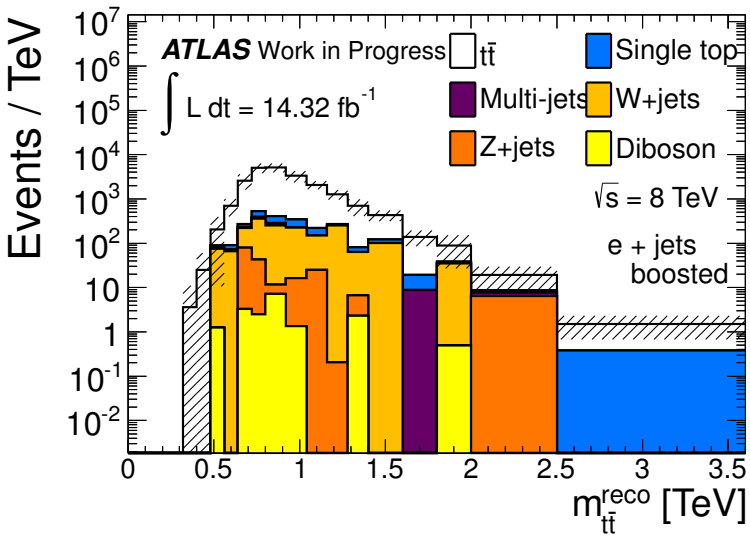
$$\chi^2 = \left[\frac{m_{jj} - m_W}{\sigma_W}\right]^2 + \left[\frac{m_{jjb} - m_{jj} - m_{th-W}}{\sigma_{th-W}}\right]^2 + \left[\frac{m_{jl\nu} - m_{tl}}{\sigma_{tl}}\right]^2 + \left[\frac{(p_{T,jjb} - p_{T,jl\nu}) - (p_{T,th} - p_{T,tl})}{\sigma_{diffpT}}\right]^2$$

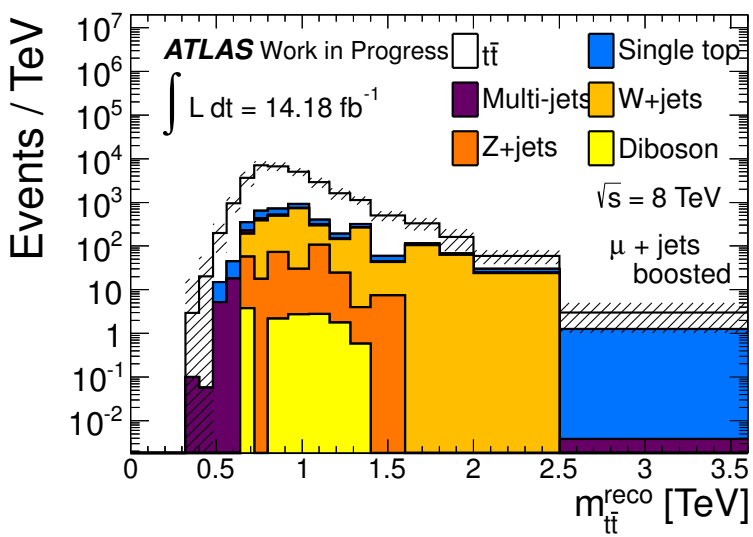
$m_{t\bar{t}}$ spectra at 8 TeV

- Top row: resolved events reconstructed with χ^2. Bottom row: boosted events.
- Data results are not public yet at 8 TeV.

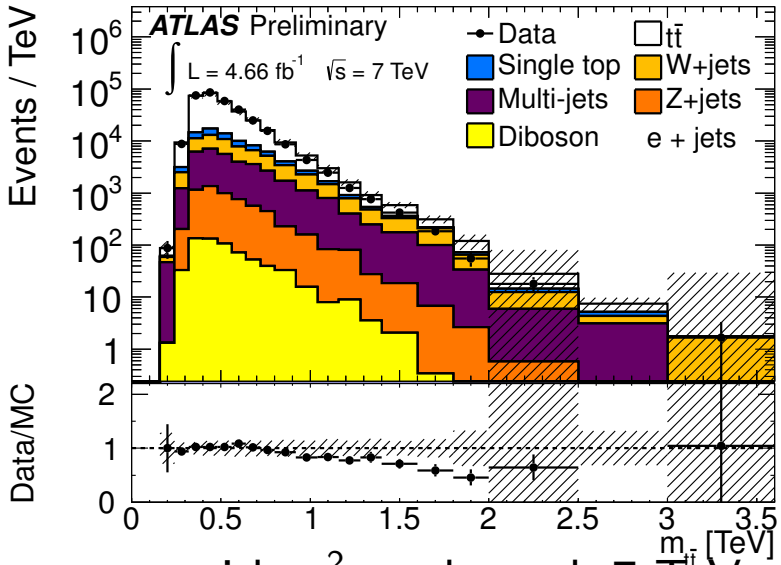




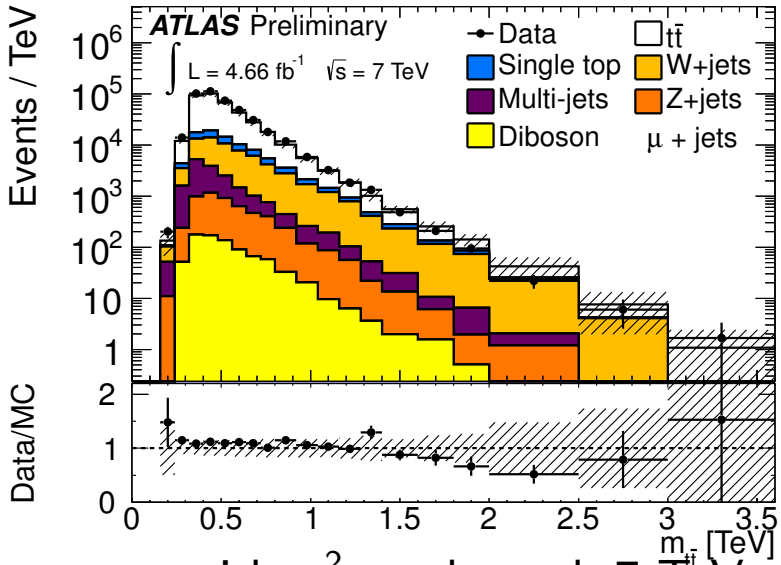




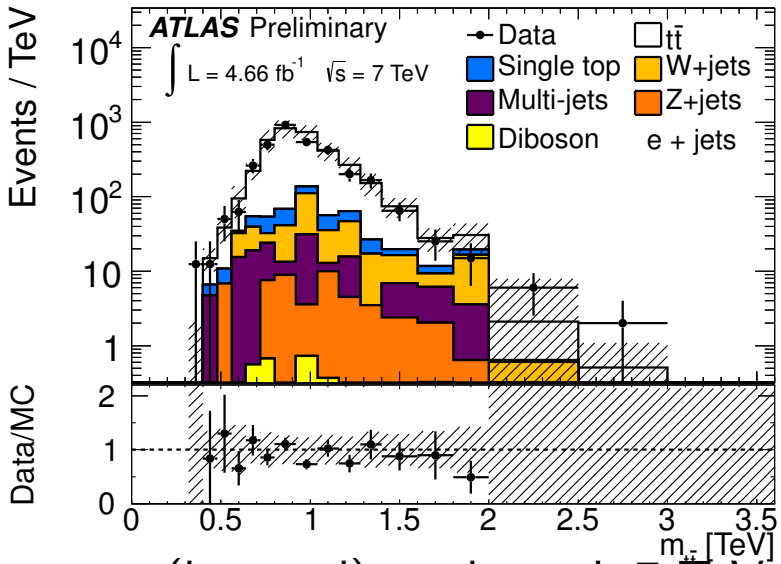
$m_{t\bar{t}}$ spectra at 7 TeV



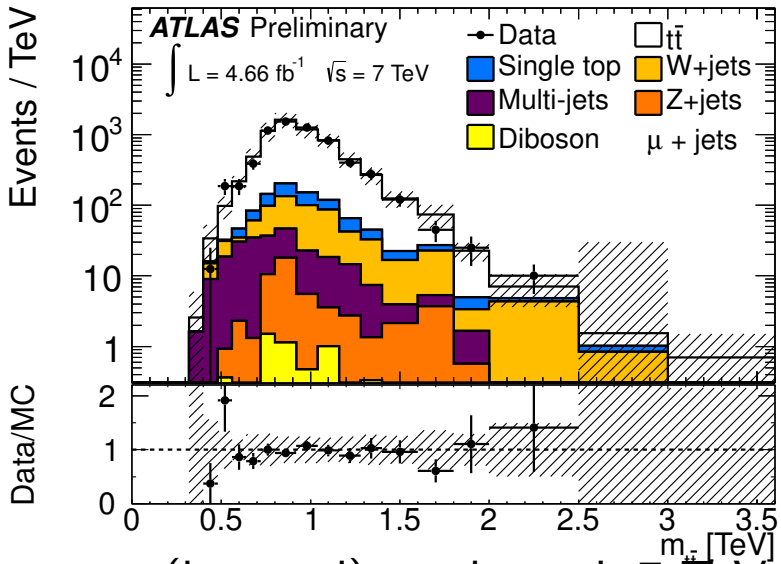
$m_{t\bar{t}}$ with χ^2, e channel, 7 TeV



$m_{t\bar{t}}$ with χ^2, μ channel, 7 TeV



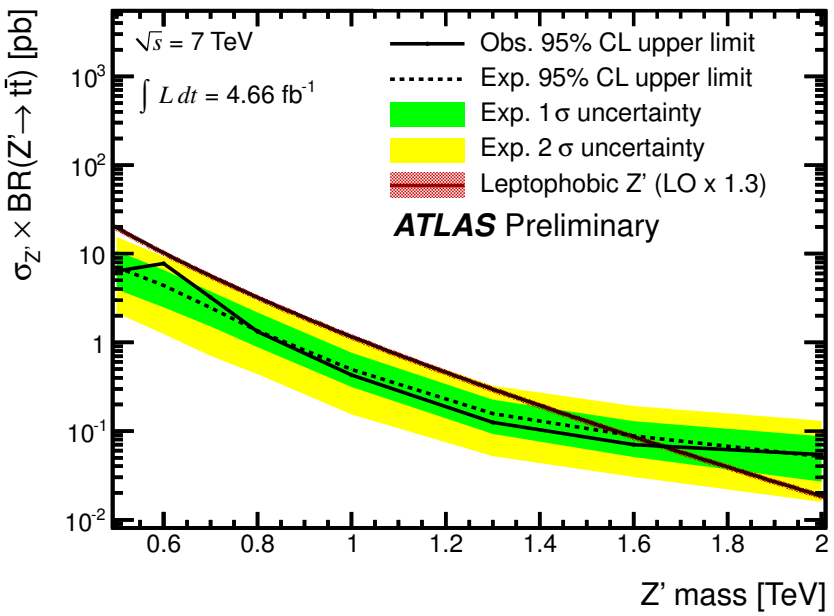
$m_{t\bar{t}}$ (boosted), e channel, 7 TeV



$m_{t\bar{t}}$ (boosted), μ channel, 7 TeV

(ATLAS-CONF-2012-136)

Summary (I)

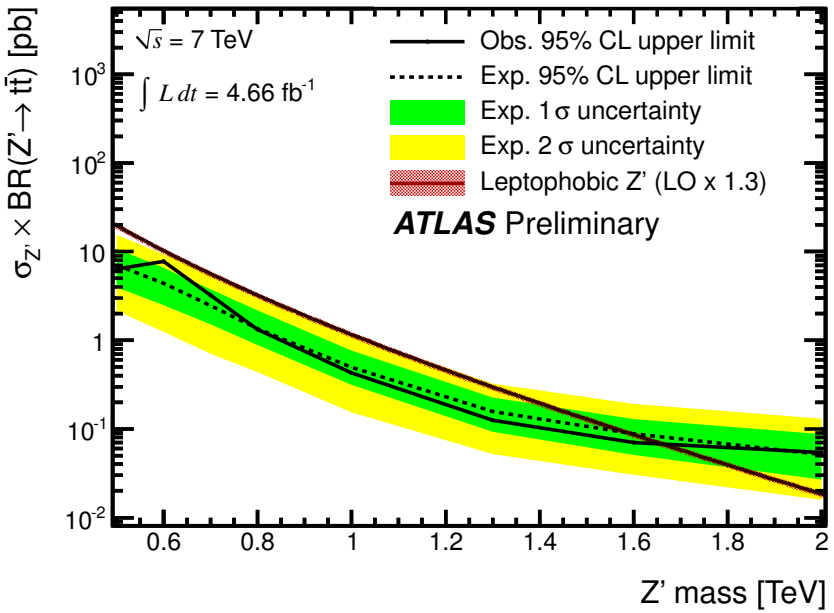


Stat. + Syst. uncertainties with χ^2 combined with boosted events for the Z'_{TC2} model at 7 TeV

(ATLAS-CONF-2012-136)

- Good Data/MC agreement, within systematic uncertainties and statistical errors.
- Conference note published at 7 TeV and paper is undergoing scrutiny of the ATLAS Collaboration.
- Limits set using 7 TeV data, combining the boosted and resolved topologies of the final states (CMS did not manage this yet!).

Summary (I)



Stat. + Syst. uncertainties with χ^2 combined with boosted events for the Z'_{TC2} model at 7 TeV

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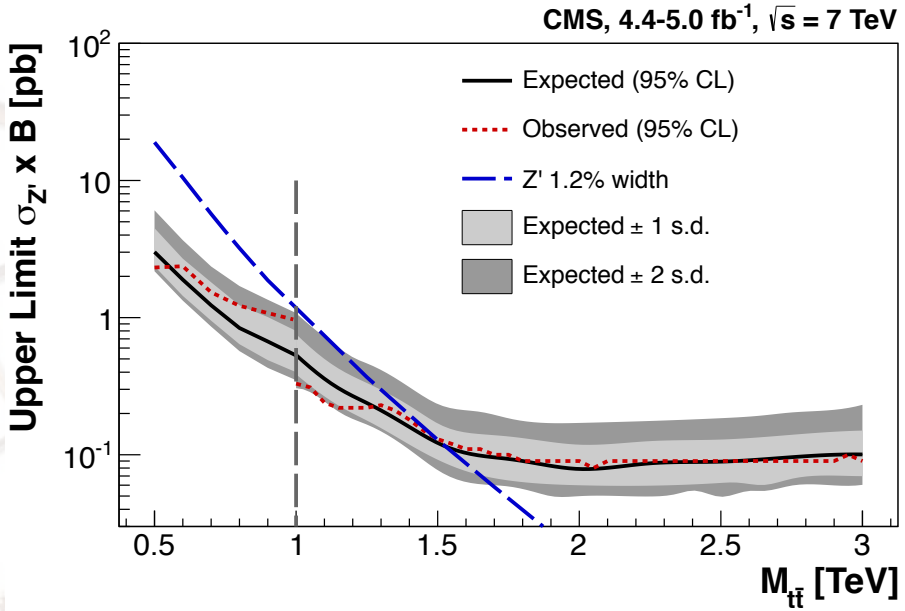
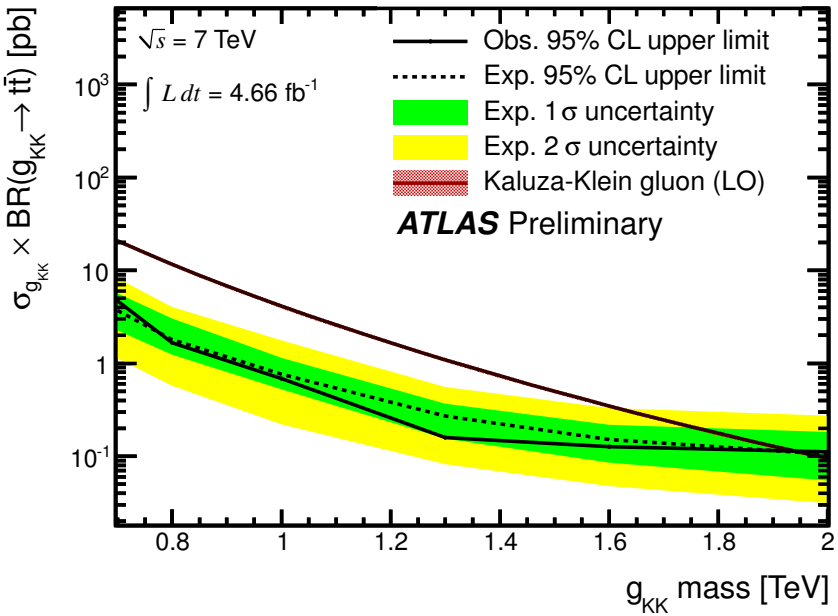


For comparison: CMS limits for the Z'_{TC2} model at 7 TeV (Vertical bar indicates a transition between two analysis methodologies, see paper for more information)

(arXiv 1209.4397)

Summary (II)

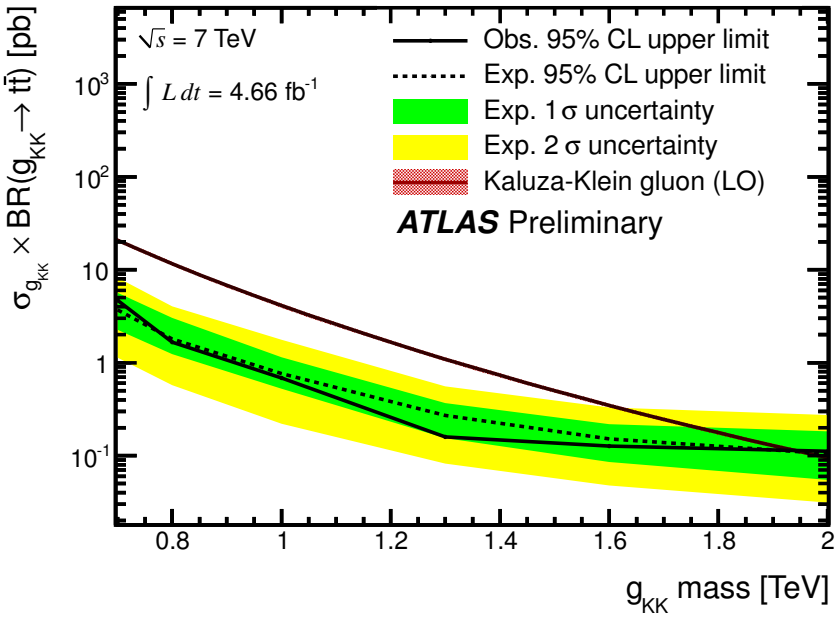


Stat. + Syst. uncertainties with χ^2 combined with boosted events for Kaluza-Klein gluons at 7 TeV

(ATLAS-CONF-2012-136)

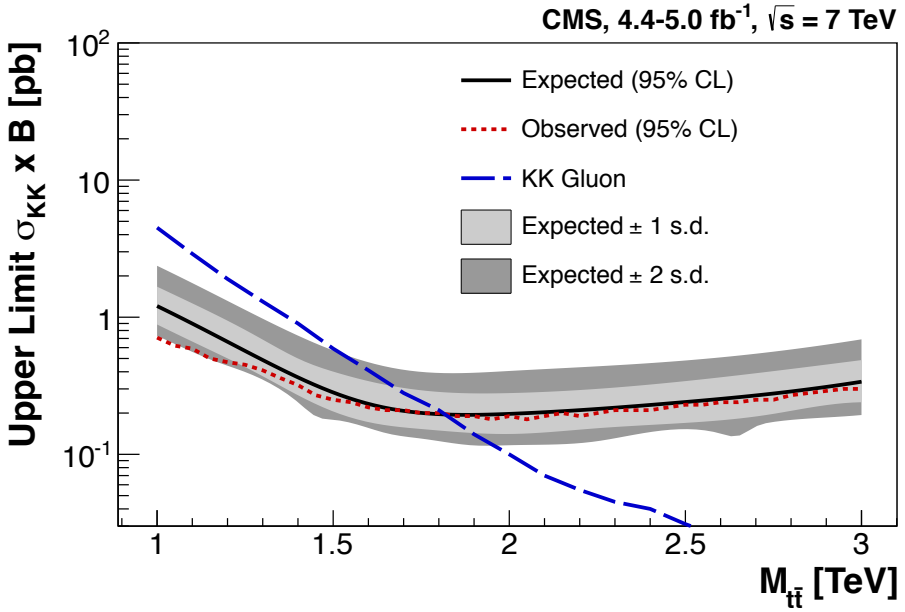
- Major systematic uncertainties included.
- Backgrounds estimated and checked with control plots at 8 TeV.
- Similar analysis at 8 TeV being prepared for publication soon!

Summary (II)



Stat. + Syst. uncertainties with χ^2 combined with boosted events for Kaluza-Klein gluons at 7 TeV

(ATLAS-CONF-2012-136)



For comparison: CMS limits for Kaluza-Klein gluons at 7 TeV (Vertical bar indicates a transition between two analysis methodologies, see paper for more information)

(arXiv 1209.4397)

Backup slides

Object definition

- Electrons satisfy `tight++`, $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$, $E_T > 25$ GeV, $\frac{I_{\mathrm{mini}}}{E_T} < 0.05$.
- Muons satisfy `muid`, combined, $|\eta| < 2.5$, $p_T > 25$ GeV, $\frac{I_{\mathrm{mini}}}{p_T} < 0.05$.
- Isolation cut used:
  - I_{mini} = sum of tracks' p_T in a cone size which is the smallest between k_T/p_T^{lep} and ΔR_{max}. $k_T = 10$ GeV and $\Delta R_{max} = 0.3$.
- Jets satisfy:
  - *small-R jets* $\rightarrow$ locally calibrated topological clusters, anti-kt $R = 0.4$, $p_T > 25$ GeV, $|JVF| > 0.5$
  - *large-R jets* $\rightarrow$ locally calibrated topological clusters, anti-kt $R = 1.0$, trimmed $f_{cut} = 0.05$, $R_{sub} = 0.3$, $p_T > 300$ GeV, $m_{jet} > 100$ GeV, $\sqrt{d_{12}} > 40$ GeV.
- E_T^{miss}: `MET_RefFinal_AntiKt4LCTopoJets_tightpp` recalculated to consider smearing and rescaling of the objects.
- Closest jet within $\Delta R(e,j) < 0.2$ is removed.
- Leptons with $\Delta R(e,j) < 0.4$ and $\Delta R(\mu,j) < 0.1$ are removed afterwards.

Systematic uncertainties

- $t\bar{t}$ cross section uncertainty $\rightarrow$ 11% uncertainty (calculated at NNLO in QCD with Hathor 1.2.
- $t\bar{t}$ generator uncertainties $\rightarrow$ compares MC@NLO and Powheg used as generators.
- Electroweak virtual correction uncertainties $\rightarrow$ Sudakov corrections for the true $t\bar{t}$ mass are estimated and 1 σ variations are implemented.
- Top mass uncertainty $\rightarrow$ comparing shapes for $m_t = 170$ GeV and $m_t = 175$ GeV with MC@NLO and dividing the difference by 4.
- ISR/FSR, Parton shower and fragmentation.
- W+jets normalisation, W+jets scale and MLM matching parameter variation (for the W+jets shape).
- Z+jets, single top and diboson normalisations.
- Lepton reconstruction, identification and resolution.
- Jet energy resolution, reconstruction efficiency and jet energy scale.
- b-tagging efficiency $\rightarrow$ with additional uncertainties added for high p_T jets.
- QCD normalisation $\rightarrow$ 50%.
- Luminosity $\rightarrow$ 3.6%.

$m_{t\bar{t}}$ spectra at 8 TeV

Resolved Selection

Using dRmin