Boosted top quark techniques and searches for $t\bar{t}$ resonances at the LHC

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on behalf of the ATLAS and CMS collaborations

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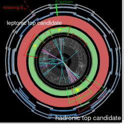
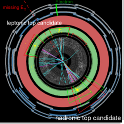

missing E_T
Electron
leptonic top candidate
hadronic top candidate

Outline



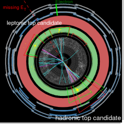
Motivation

In many BSM models the top quark plays a special role with enhanced coupling of BSM particles to the top $\Longrightarrow$ possible resonances in the $t\bar{t}$ mass spectrum.

Typical benchmarks for $t\bar{t}$ resonances (different width and spin):

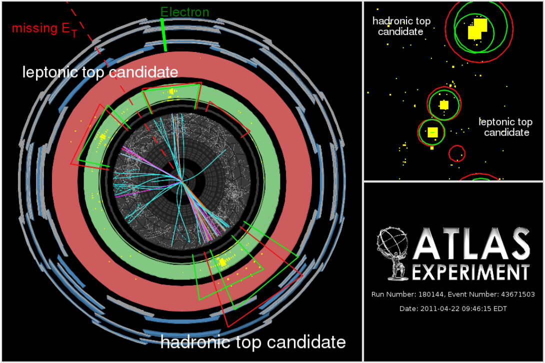
- Leptophobic topcolour Z'
  - Spin 1, colour singlet, narrow resonance ($\Gamma/m_{Z'} = 1.2\%$) [Harris, Hill, Parker; 1999]
  - Benchmark model at Tevatron
- Kaluza-Klein gluon (g_{KK}) from Randall-Sundrum models [Agashe, Belyaev, Krupovnickas, Perez, Virzi; 2008], [Lillie, Randall, Wang; 2007]
  - Spin 1, colour octet, wide resonance ($\Gamma/m_{g_{KK}} = 15\%$)

(experimental mass resolution at the LHC: $\mathcal{O}(10\%)$)



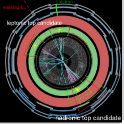
Introduction

- High mass $t\bar{t}$ resonances can lead to strongly boosted top decays
- Example: $t\bar{t}$ candidate event with $m_{t\bar{t}} = 2.5\,\text{TeV}$



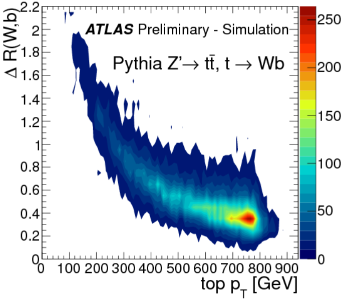
ATLAS, arXiv:1207.2409

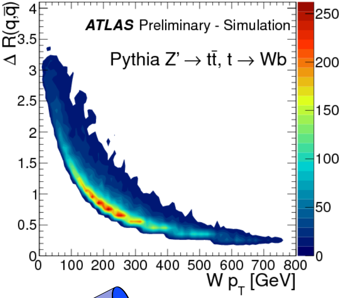
- Top decay products start to merge
- Many new techniques have been developed to reconstruct and identify boosted tops
  - Jet substructure
  - "Less-isolated" leptons



Jet substructure

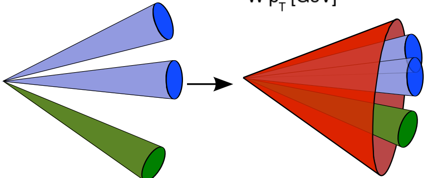
- Use jets with large radii (e.g. anti-$k_\perp$, $R = 1.0$) to collect all products of hadronic top decays ($t \to bW \to bqq$)
- Rule of thumb: $\Delta R \approx 2\frac{M}{p_T}$





ATLAS-CONF-2012-065

- and investigate their substructure



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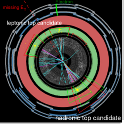
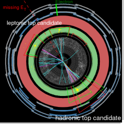


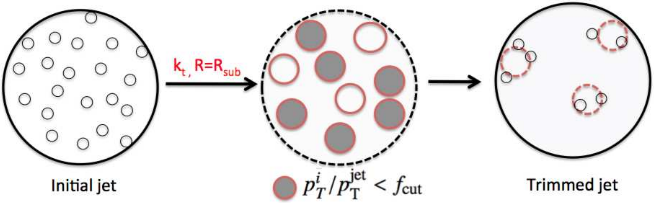
Jet grooming
Introduction

- Jets with larger radii suffer more from contamination by underlying event and pile-up
- Soft radiation dilutes substructure from decays of heavy particles
- "Grooming" allows to remove soft radiation
- Different grooming techniques on the market
  - Filtering [Butterworth, Davison, Rubin, Salam; 2008]
  - Pruning [Ellis, Vermilion, Walsh; 2009]
  - Trimming [Krohn, Thaler, Wang; 2010]
- CMS applies jet pruning in searches for $t\bar{t}$ resonances
- Performance of filtering, pruning and trimming compared by ATLAS
- Filtering-like approach used e.g. in HEPTopTagger

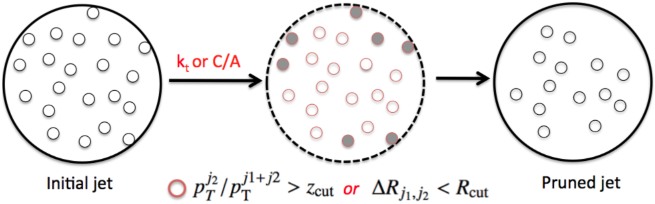


Jet grooming
Trimming and pruning

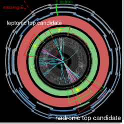
Jet trimming procedure



Jet pruning



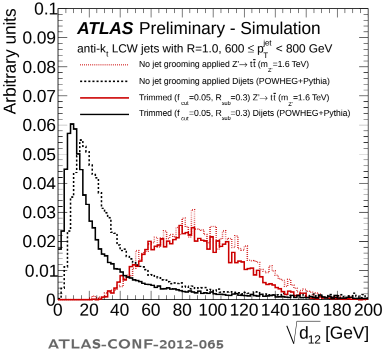
discards soft particles and wide-angle particles

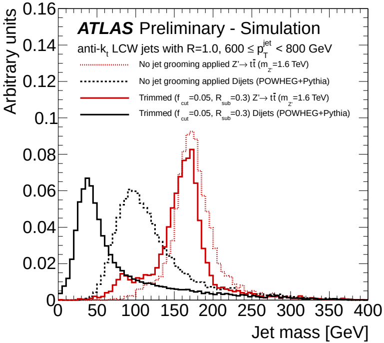


Subjet variables

anti-$k_\perp$ $R = 1.0$

- first $k_\perp$-splitting scale: $\sqrt{d_{12}} = \min(p_{T1}, p_{T2})\Delta R_{12}$ where $1,2$ are the last two proto-jets in the recombination of the $k_\perp$ algorithm,
  expect $\sqrt{d_{12}} \approx m_t/2$ for $t \rightarrow bW$
- Trimming significantly improves mass resolution for heavy particles and pushes mass for QCD jets lower





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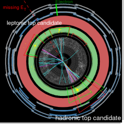
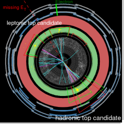


Top tagging
Introduction

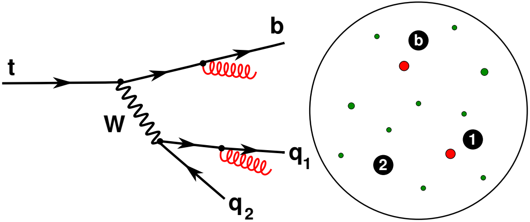
Top tagging algorithms try to reconstruct and identify hadronic top decays

- HEPTopTagger [Plehn, Spannowsky, Takeuchi, Zerwas; 2010]
  - Applies mass-drop filtering to remove contamination
  - Tries to reconstruct "tree level" decay products ($t \rightarrow bqq$) and uses mass criteria for identification
- CMS top tagger
  - Based on Johns Hopkins tagger [Kaplan, Rehermann, Schwartz, Tweedie; 2008]
  - Tries to split jet in two stages applying grooming techniques (resembles $t \rightarrow bW$ and $W \rightarrow qq$)
- CMS W tagger
  - Applies jet pruning
  - Requires mass drop $m^{j_1}/m^{\text{large jet}} < 0.4$ of the last two subjets (components of heavy particle decay)
- Top Template Tagging [Almeida, Lee, Perez, Sterman, Sung; 2010]
  - Compare templates of top decays (3 particle 4-momenta) to calorimeter clusters



HEPTopTagger

Grooming procedure



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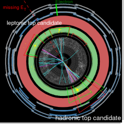

HEPTopTagger

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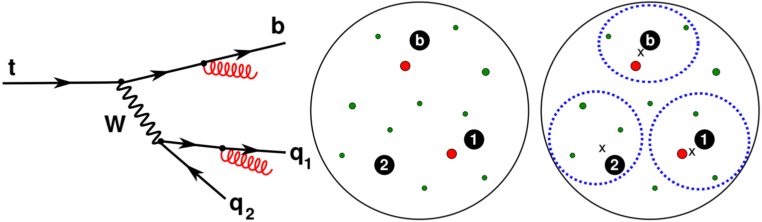

1. Decompose until $m_{j_i} < 30\,\text{GeV}$ with mass drop requirement $m_{j_i} < \mu\, m_{\text{large jet}}$

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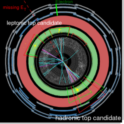
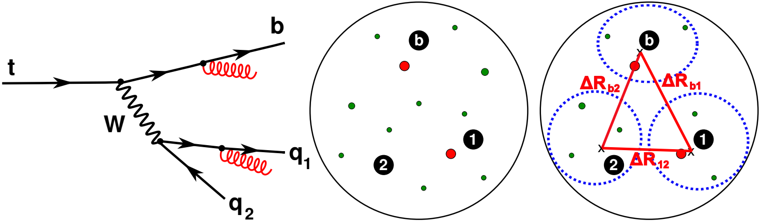
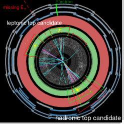


HEPTopTagger

Grooming procedure

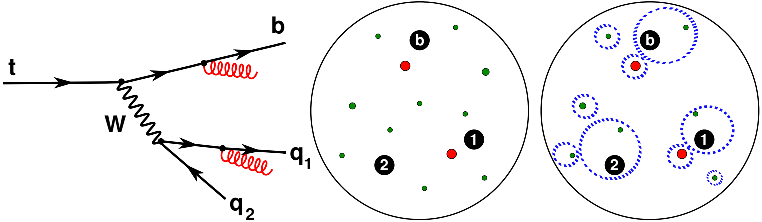


1. Decompose until $m_{j_i} < 30\,\text{GeV}$ with mass drop requirement $m_{j_i} < \mu\, m_{\text{large jet}}$
2. Investigate 3 subjets and their constituents

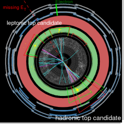


HEPTopTagger

Grooming procedure



1. Decompose until $m_{j_i} < 30\,\text{GeV}$ with mass drop requirement $m_{j_i} < \mu\, m_{\text{large jet}}$
2. Investigate 3 subjets and their constituents
3. Re-cluster using C/A with parameter $R = \min(0.3, \min_{ij} \Delta R(j_i, j_j)/2)$



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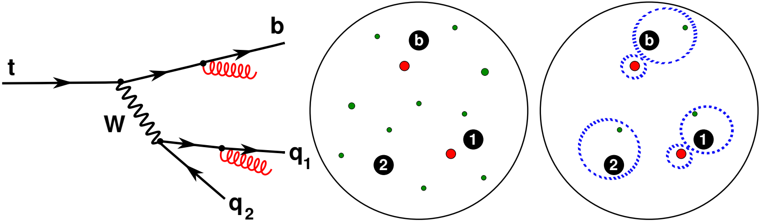

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4. Use only 5 hardest subjets of last step

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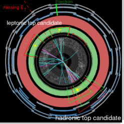
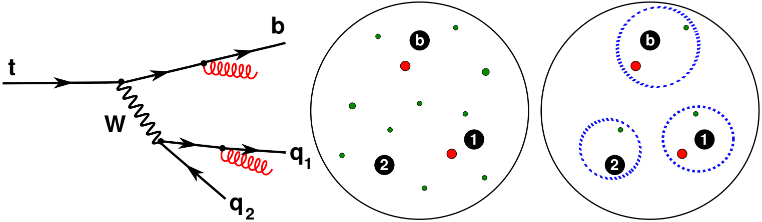


HEPTopTagger

Grooming procedure



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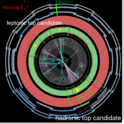
2. Investigate 3 subjets and their constituents
3. Re-cluster using C/A with parameter $R = \min(0.3, \min_{ij} \Delta R(j_i, j_j)/2)$
4. Use only 5 hardest subjets of last step
5. Built exactly 3 subjets from the selected constituents

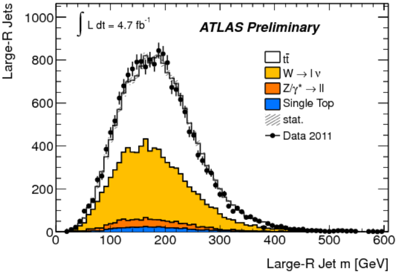


HEPTopTagger

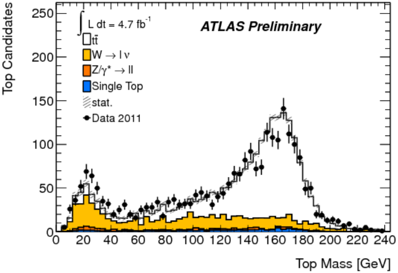
Performance tests in lepton+jets events ($t\bar{t} \rightarrow (\mu\nu b)(q\bar{q}b)$)

- Lepton+jets selection: single muon trigger, ≥ 4 anti-$k_\perp$ ($R = 0.4$) jets ($p_T^{\text{jet}} > 25\,\text{GeV}$), $p_T^{\mu} > 20\,\text{GeV}$, $\not{E}_T > 20\,\text{GeV}$, $\not{E}_T + m_T^{\text{W}} > 20\,\text{GeV}$
- Well modelled in Monte Carlo simulation

Mass distribution for C/A jets with $R = 1.5$ before running the HEPTopTagger:



after the HEPTopTagger



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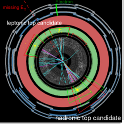
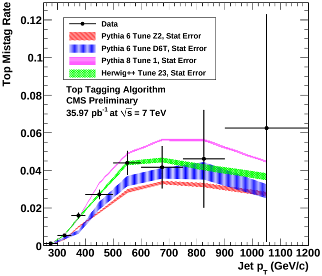
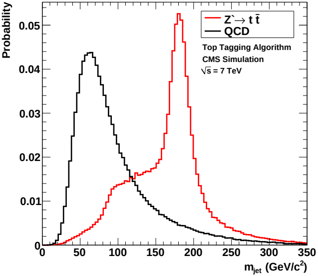
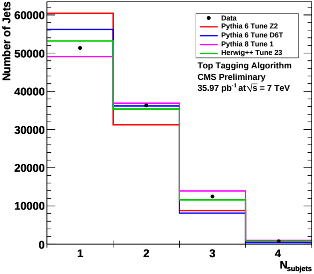


CMS top tagger

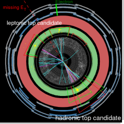
- Variables used after double splitting into 3 or 4 subjets:
  - jet mass
  - number of subjets
  - minimum pairwise mass of 3 hardest subjets
    $m_{\min} = \min(m_{12}, m_{13} m_{23})$
- Mistag rate determined in data using tag-and-probe with anti-tag



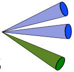
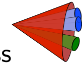




CMS-PAS-JME-10-013



Searches for $t\bar{t}$ resonances
Overview of analyses

	low mass	high mass
All-jets		CMS, 5 fb^{-1}, arXiv:1204.2488 ATLAS, 4.7 fb^{-1}, ATLAS-CONF-2012-102
Di-leptonic (ee, $\mu\mu$, eμ)	CMS, 5 fb^{-1}, CMS-PAS-TOP-11-010 ATLAS 2 fb^{-1}, EPJC72 2083	
Lepton+jets (e + j, μ + j)	CMS, 4.7 fb^{-1}, CMS-PAS-TOP-11-009 ATLAS, 2.1 fb^{-1}, EPJC72 2083	CMS, 4.7 fb^{-1}, CMS-PAS-EXO-11-093 ATLAS, 2.1 fb^{-1}, arXiv:1207.2409
	ATLAS, 4.7 fb^{-1}, ATLAS-CONF-2012-136 CMS, 4.7 fb^{-1}, submitted to JHEP	

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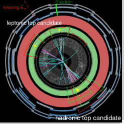
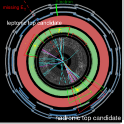


Standard Model background

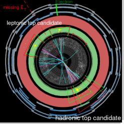
- $t\bar{t}$
  - Irreducible background, search for deviations in invariant mass spectrum
- Single top
  - Only little contamination
- W bosons
  - Relevant in lepton+jets channel
  - Normalisation and heavy flavour composition mostly estimated from data (e.g. charge asymmetry), because of large uncertainties
- Z/γ bosons/Drell-Yan
  - Important in di-leptonic channel
  - Data driven methods
- Diboson
  - Only relevant in di-leptonic channel
- QCD multijet
  - Important in all-jets channel
  - Estimated with data (e.g. template fit of $\not{E}_T$ distribution, MC event weighting from matrix method)



Systematic uncertainties

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

- Jet energy scale / resolution
  - In some analyses more complicated, when different jet algorithms are combined
- Reconstruction and identification efficiencies
  - esp. b-tagging uncertainties often large for high-p_T jets
- Initial and final state radiation
- PDF uncertainties
- Uncertainties of background models
  - QCD multijet model
  - W + jets, esp. heavy flavour composition
- Renormalisation and factorisation scale uncertainties on SM $t\bar{t}$ background



All-jets channel

Event selection

	ATLAS	CMS
trigger	high-p_T jet/multijet	high-p_T jet
lepton veto	$p_T^e > 25\,\text{GeV}, p_T^\mu > 20\,\text{GeV}$ mini-isolation	
jets	≥ 2 C/A ($R = 1.5$) jets, $p_T^j > 200\,\text{GeV}$, $\lvert\eta\rvert < 2.5$	C/A ($R = 0.8$) jets, $\lvert\eta\rvert < 2.5$
top tagging	HEPTopTagger, $p_T^t > 200\,\text{GeV}$, $140\,\text{GeV} < m_t < 210\,\text{GeV}$	CMS top tagger, $p_T^t > 350\,\text{GeV}$, $140\,\text{GeV} < m_t < 250\,\text{GeV}$ "Type 1+1": ≥ 2 top tagged "Type 1+2": $= 1$ top tagged + W-tagged ($p_T > 200\,\text{GeV}$) + jet ($p_T > 30\,\text{GeV}$)
b-tagging	≥ 2 anti-$k_\perp$ ($R = 0.4$) jets, $p_T^j > 25\,\text{GeV}$, $\varepsilon_b \approx 70\,\%$, $\Delta R(b, C/A) < 1.4$	—

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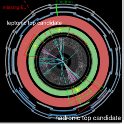
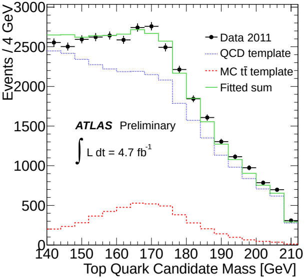
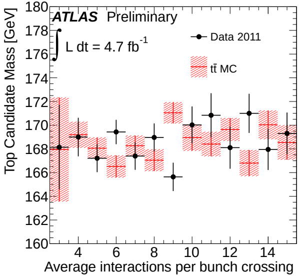


All-jets channel
HEPTopTagger

- $t\bar{t}$ normalisation performed by fit in control region
- QCD multijet template derived from another control region
- Good stability of m_t estimate wrt. pile-up
- Data well described by Monte Carlo
- No excess in $m_{t\bar{t}}$ observed





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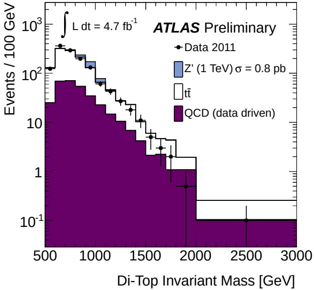

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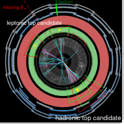
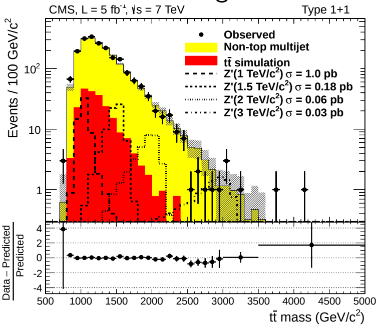


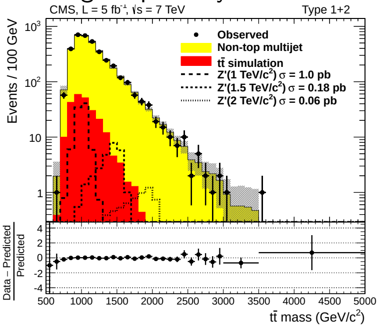
All-jets channel

- Multijet QCD background determined by estimating mistag probability in control region
- In addition to limits for benchmark scenarios: Counting experiment for $m_{t\bar{t}} > 1\,\text{TeV}$ limits enhanced production to be $< 2.6\times$ SM expectation (approx. NNLO)

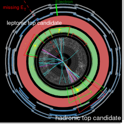
double merged



merged+partially resolved



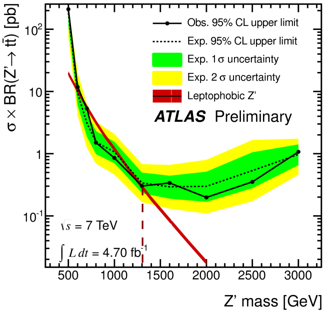
arXiv:1204.2488



All-jets channel
Limits

Narrow width Z′ ($\Gamma/m_{Z'} = 1.2\%$) resonance

Exclusion range @95% CL
$0.7\,\text{TeV} < m_{Z'} < 1.3\,\text{TeV}$



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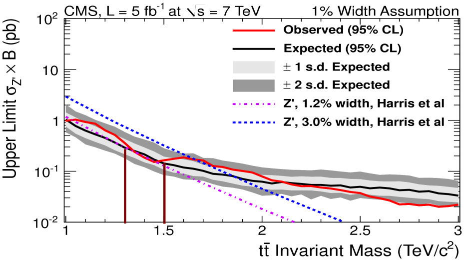
Exclusion range @95% CL
$1.3\,\text{TeV} < m_{Z'} < 1.5\,\text{TeV}$



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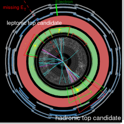
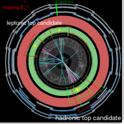


Di-leptonic channel
Event selection

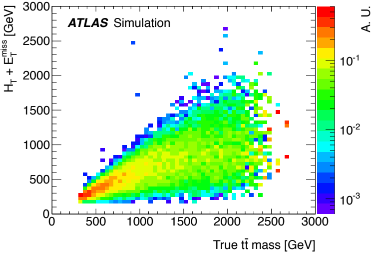
	ATLAS	CMS
int. lumi.	$2.05\,\mathrm{fb}^{-1}$	$5.0\,\mathrm{fb}^{-1}$
lepton	$p_T^{\ell} > 25\,\mathrm{GeV}$, (relative isolation)	$p_T^{\ell} > 20\,\mathrm{GeV}$, (relative isolation)
Z/γ veto (ee, $\mu\mu$)	$\lvert m_Z - m_{\ell\ell}\rvert < 10\,\mathrm{GeV}$, $m_{\ell\ell} > 10\,\mathrm{GeV}$	$76\,\mathrm{GeV} < m_Z < 106\,\mathrm{GeV}$, $m_{\ell\ell} > 12\,\mathrm{GeV}$
jets	≥ 2 anti-$k_\perp$ ($R = 0.4$) jets, $p_T^{j} > 25\,\mathrm{GeV}$	≥ 2 anti-$k_\perp$ ($R = 0.5$) jets, $p_T^{j} > 30\,\mathrm{GeV}$, ≥ 1 b-tag
$\not{E}_T$(ee, $\mu\mu$)	$\not{E}_T > 40\,\mathrm{GeV}$	$\not{E}_T > 30\,\mathrm{GeV}$
eμ	$H_T = \sum p_T^{\ell} + \sum p_T^{j} > 130\,\mathrm{GeV}$	
MC	MC@NLO ($t\bar{t}$), Alpgen (W/Z + jets)	MadGraph
Drell-Yan	normalisation from sideband	
multijet	matrix method (includes also W + jets)	extrapolated from (isolation) sideband

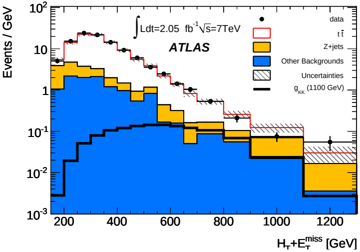


Di-leptonic channel

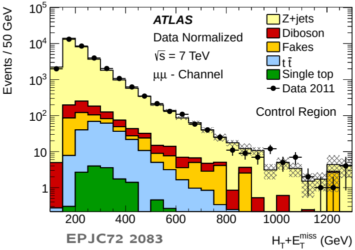
Mass estimation

- $m_{t\bar{t}}$ not fully reconstructable due to two neutrinos
  $\Longrightarrow$ use $H_T + \not{E}_T$ as proxy for $m_{t\bar{t}}$ $(H_T = \sum p_T^{\ell} + \sum p_T^{j})$

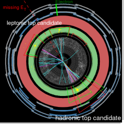




- Validation of of background estimate in control region (inverted Z boson veto)



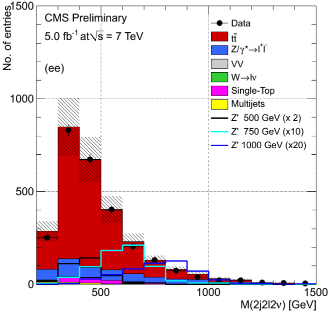
EPJC72 2083

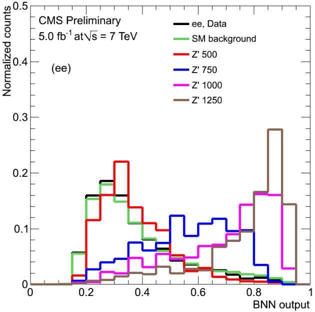


Di-leptonic channel

Neural network analysis

- In $m(2j2\ell 2\nu)$ estimate p_z^ν of neutrinos set to 0
- Use Bayesian neural network for multivariate selection to obtain further discrimination power between $t\bar{t}$ and signal in addition to bump hunting in $m_{t\bar{t}}$ spectrum
- 17 variables used in NN:
  - p_T, η of leptons, $\Delta\phi(\ell_1,\ell_2)$, $\not{E}_T$, $\Delta\phi(\ell_1,\not{E}_T)$
  - p_T, η, $\Delta\phi(\ell_1,j)$ for two highest-p_T jets and highest-p_T b-jet
  - number of b-tagged jets





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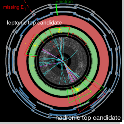
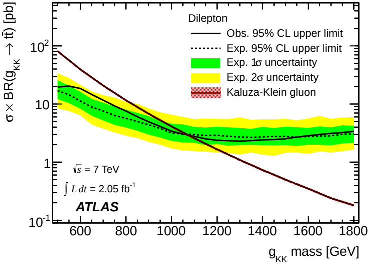


Di-leptonic channel
Results

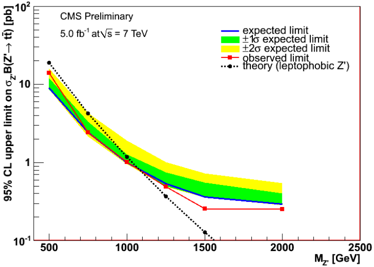
- Limits for different models provided by ATLAS and CMS

- ATLAS limit @95% CL for Kaluza-Klein gluon: $m_{g_{KK}} > 1130\,\text{GeV}$



EPJC72 2083

- CMS limit @95% CL for narrow width ($\Gamma / m_{Z'} = 1.2\%$) Z': $m_{Z'} > 1.1\,\text{TeV}$



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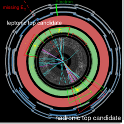
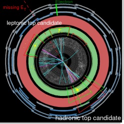


Lepton+jets channel
Event selection

- AKT4: Anti-$k_\perp$ ($R = 0.4$) jets: $p_T > 25\,\text{GeV}$, $|\eta| < 2.5$
- AKT10: Anti-$k_\perp$ ($R = 1.0$) jets: $|\eta| < 2.0$, $p_T > 350\,\text{GeV}$, $m > 100\,\text{GeV}$, $\sqrt{d_{12}} > 40\,\text{GeV}$ (expect $\sqrt{d_{12}} \approx m_t/2$ for $t \to bW$)

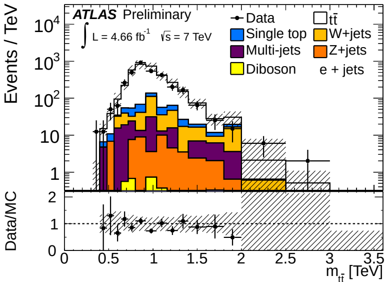
	resolved	boosted
trigger	single lepton trigger	fat jet (AKT10) trigger
leptons	1 lepton ($e^\pm$ or $\mu^\pm$), $p_T > 25\,\text{GeV}$ additional lepton ($e^\pm$ or $\mu^\pm$) veto, $p_T > 20\,\text{GeV}$ lepton trigger match	 —
$\not{E}_T$	$e^\pm$: $\not{E}_T > 30\,\text{GeV}$, $\mu^\pm$: $\not{E}_T > 20\,\text{GeV}$	
m_T^W	$e^\pm$: $M_T(W) > 30\,\text{GeV}$, $\mu^\pm$: $M_T(W) + \not{E}_T > 60\,\text{GeV}$	
jets	$\geq 4(3)$ jets (if one jet $m_{\text{jet}} > 60\,\text{GeV}$)	"leptonic jet": AKT4 jet "hadronic jet": AKT10 jet
b-tag	≥ 1 b-tag using AKT4 jets ($\varepsilon_b = 70\,\%$)	

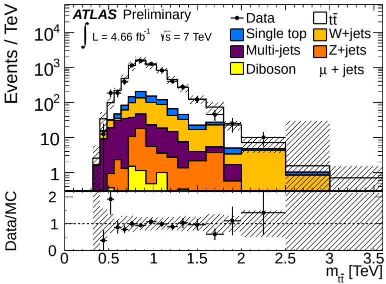


Lepton+jets channel

"Mini-isolation" for leptons and specialised trigger

- Standard ATLAS lepton isolation (relative isolation with fixed cone size) has bad efficiency when the top gets boosted
- "Mini-isolation" with shrinking cone size $\Delta R(\ell, \text{track}) < k_{\perp}/p_T^{\ell}$ gives strong improvement in efficiency for leptons from boosted t
- Fat jet trigger (240 GeV anti-$k_{\perp}$, $R = 1.0$ jet)
  - At high mass: Better efficiency than single-lepton trigger (nearly 100% efficient)
  - Plateau of trigger reached at $p_T \gtrsim 350$ GeV





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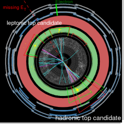


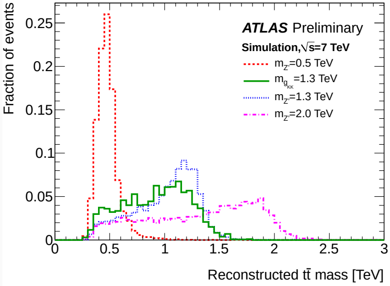
Lepton+jets channel

$t\bar{t}$ reconstruction

- Longitudinal component p_z of neutrino momentum computed by $W^{\pm}$ mass constraint on lepton + $\not{E}_T$ system

Resolved

Use jet combination with minimal χ^2 including W (m_{jj}) and t (m_{jjb}, $m_{j\nu b}$) mass constraints



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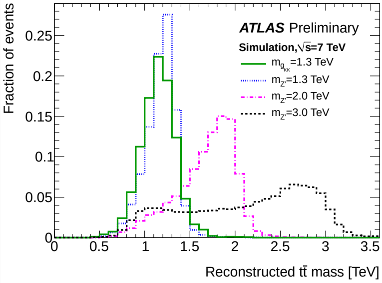
Boosted

Use sum of neutrino solution ($\not{E}_T$), lepton, AKT4 jet, AKT10 jet



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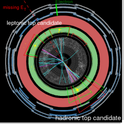
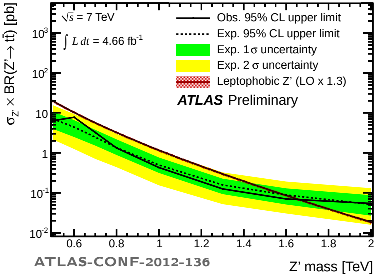


Lepton+jets channel
Limits

Combined limit of boosted and resolved selection:

- Use the boosted reconstruction, if a single event is selected by the resolved and the boosted selection
- Resolved selection mainly relevant at low $m_{t\bar{t}}$, boosted relevant at high $m_{t\bar{t}}$
- Still some events in resolved selection at high mass, which are not selected by boosted



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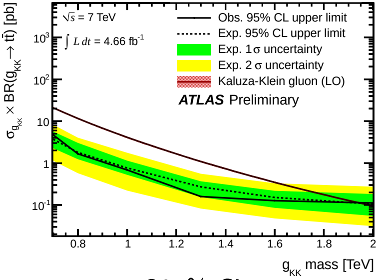
Z' ($\Gamma/m_{Z'} = 1.2\%$) @95% CL:
$0.5\,\text{TeV} < m_{Z'} < 1.7\,\text{TeV}$



g_{KK} @95% CL:
$0.7\,\text{TeV} < m_{g_{KK}} < 1.9\,\text{TeV}$

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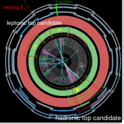

Lepton+jets channel

Event selection

	resolved	boosted
trigger	single lepton	
leptons	relative isolation $p_T^{\mu} > 20\,\text{GeV},\ p_T^{e} > 30\,\text{GeV}$ looser iso., p_T for veto	p_T^{rel} isolation: $\Delta R(\ell, j) > 0.5$ or $p_T^{\text{rel}}(\ell, j) > 25\,\text{GeV}$ $p_T^{\mu} > 42\,\text{GeV},\ p_T^{e} > 70\,\text{GeV}$
jets	≥ 3 anti-$k_{\perp}$ $(R = 0.5)$ jets, $p_T^{j} > 50\,\text{GeV},\ p_T^{j_1} > 70\,\text{GeV}$	≥ 2 anti-$k_{\perp}$ $(R = 0.5)$ jets, $p_T^{j} > 50\,\text{GeV}$, $p_T^{j_1} > 150\,\text{GeV}(250\,\text{GeV})$ for e (μ)
$\not{E}_T$	$\not{E}_T > 20\,\text{GeV}$	$e^{\pm}$: $\not{E}_T > 50\,\text{GeV}$ + $\Delta\Phi(e, \not{E}_T)$, $\Delta\Phi(j_1, \not{E}_T)$ cuts
		${H_T}^{\ell} = p_T^{\ell} + \not{E}_T > 150\,\text{GeV}$
event categories	4 categories by number of jets and b-tags	tagged/non-tagged
$t\bar{t}$ reco.	χ^2 method	

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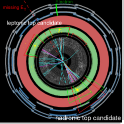
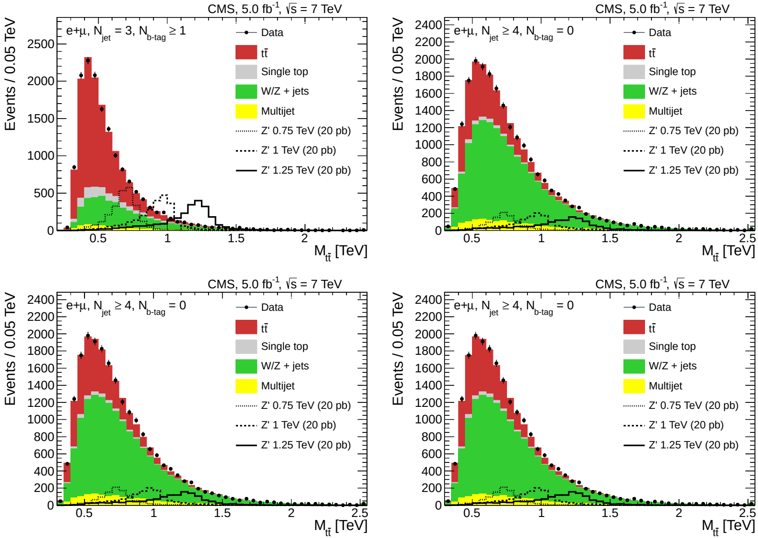
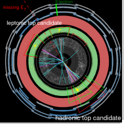


Lepton+jets channel

Resolved selection



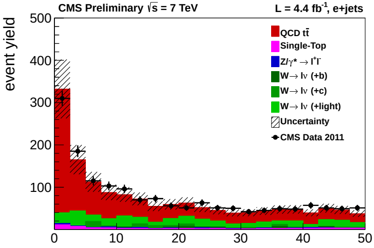
CMS, submitted to JHEP



Lepton+jets channel

Boosted selection

- χ^2 includes constraints for the leptonic and hadronic top
- Only events with $\chi^2_{min} < 8$ are regarded
- Background yields from maximum likelihood fit



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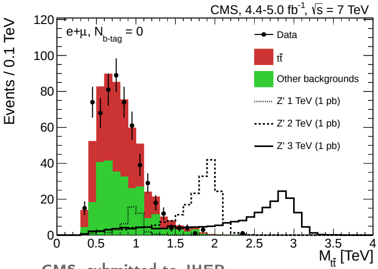
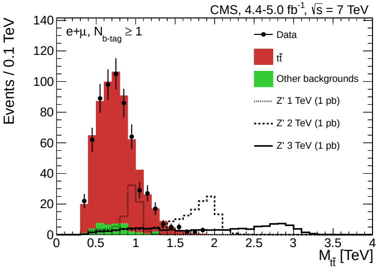
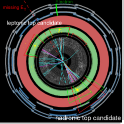




CMS, submitted to JHEP



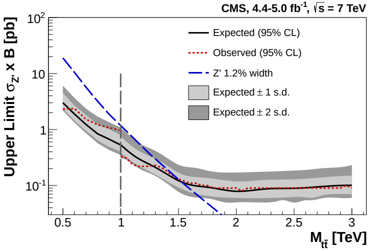
Lepton+jets channel

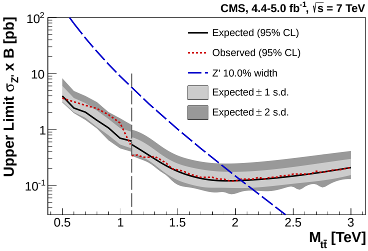
Limits

Combined limit of boosted and resolved selection:

- Use resolved result at low $m_{t\bar{t}}$ and boosted limit at high $m_{t\bar{t}}$
- Border decided on based on expected limits

Narrow width Z' $(\Gamma/m_{Z'} = 1.2\%)$ — Medium width Z' $(\Gamma/m_{Z'} = 10\%)$





CMS, submitted to JHEP

- Z' $(\Gamma/m_{Z'} = 1.2\%)$ excl. @95% CL: $m_{Z'} < 1.49$ TeV
- Z' $(\Gamma/m_{Z'} = 10\%)$ excl. @95% CL: $m_{Z'} < 2.04$ TeV

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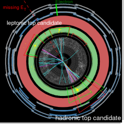
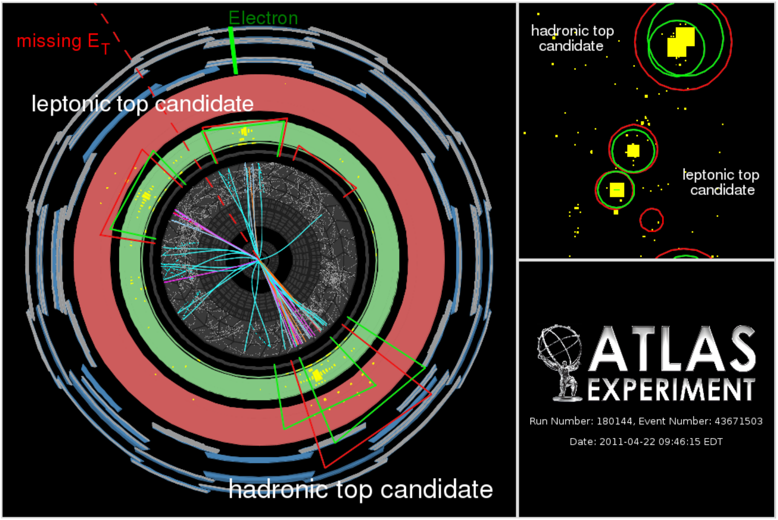
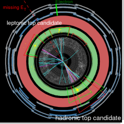


Summary

- Searches for $t\bar{t}$ resonances were performed by ATLAS and CMS using the 2011 datasets in all possible $t\bar{t}$ decay modes
- No significant excess was found in the $m_{t\bar{t}}$ spectra
- Benchmark scenarios were excluded at the 95% CL in the following mass ranges
  - Leptophobic top-colour Z'
    - $\Gamma/m_{Z'} = 1.2\%$: $0.5\,\text{TeV} < m_{Z'} < 1.7\,\text{TeV}$ (ATLAS lepton+jets)
    - $\Gamma/m_{Z'} = 10\%$: $m_{Z'} < 2.0\,\text{TeV}$ (CMS lepton+jets)
  - Kaluza-Klein gluon g_{KK} ($\Gamma/m_{g_{KK}} = 15\%$) in Randall-Sandum models: $0.5\,\text{TeV} < m_{g_{KK}} < 1.9\,\text{TeV}$ (ATLAS lepton+jets)
- Many new techniques to reconstruct and identify boosted top decays were developed in recent years
  - ATLAS and CMS could show their feasibility at the LHC
  - Boosted techniques gain importance with higher $\sqrt{s}$ and more integrated luminosity
  - Grooming techniques can also help to reduce pile-up dependence

Backup


Electron
missing E_T
leptonic top candidate
hadronic top candidate
hadronic top candidate
leptonic top candidate
ATLAS EXPERIMENT
Run Number: 180144, Event Number: 43671503
Date: 2011-04-22 09:46:15 EDT

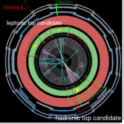


Jet algorithms

$$
\begin{aligned}
\rho_{ij} &= \min({p_T}_i^{2n}, {p_T}_j^{2n}) \frac{(\Delta R_{ij})^2}{R^2} \\
\rho_{iB} &= {p_T}_i^{2n}
\end{aligned}
$$

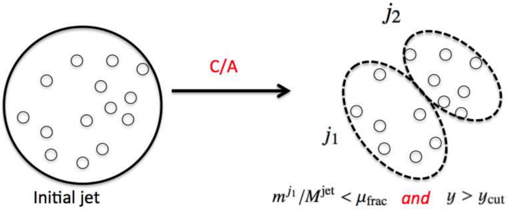
- If $\rho_{iB} < \rho_{ij}$ for all j: Define proto-jet i as jet
- If $\rho_{iB} > \rho_{ij}$: Combine proto-jets i and j

1. Cambridge/Aachen (C/A) ($n = 0$): only angular distance considered
2. anti-$k_\perp$ ($n = -1$): cone-like jets
3. $k_\perp$ ($n = +1$): hardest sub-components merged last

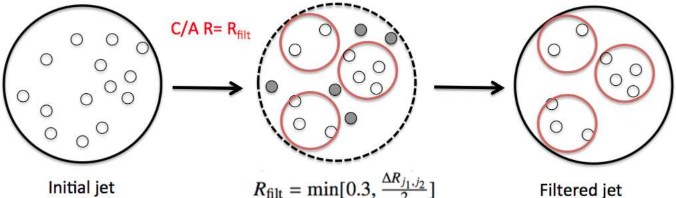


Jet grooming
Mass drop filtering

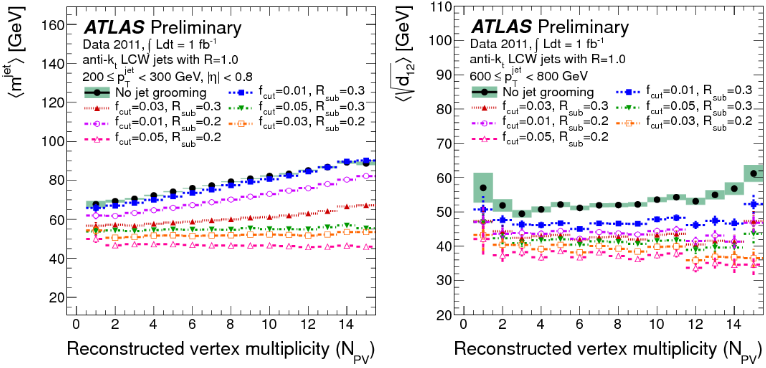
1. Re-cluster large jet with Cambridge/Aachen into 2 subjets
2. Require $m^{j_1}/m^{\text{large jet}}$ to be low (mass drop for components of heavy particle decay) and splitting to be symmetric



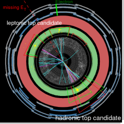
3. Rerun C/A algorithm with parameter $R = \min(0.3, \Delta R(j_1, j_2)/2)$
4. Discard everything outside three hardest jets



- Trimming reduces the pile-up sensitivity of jet variables significantly

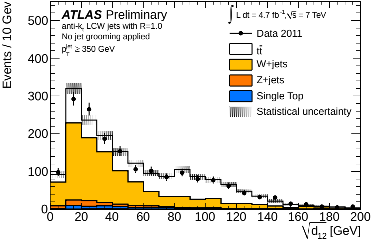


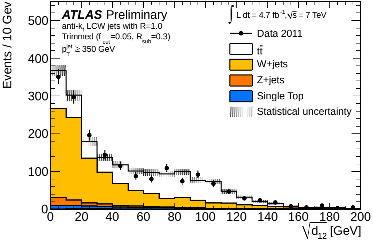
ATLAS-CONF-2012-066



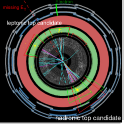
Jet substructure

Validation in lepton+jets events



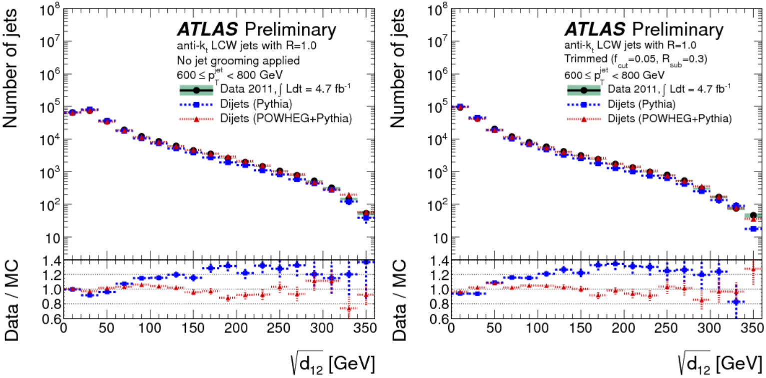


ATLAS-CONF-2012-065



Jet substructure

Validation in di-jet events



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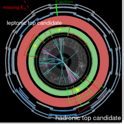
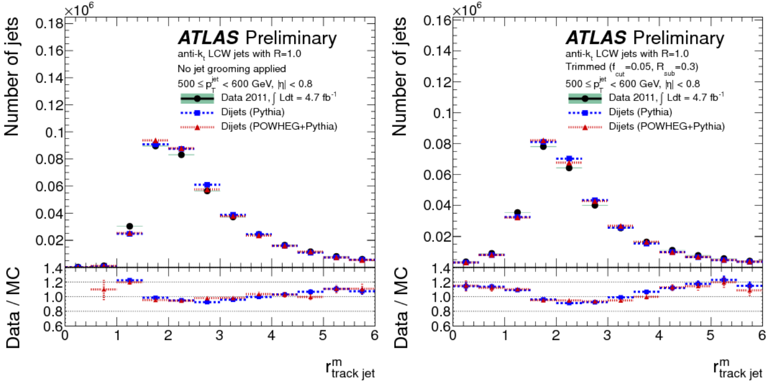


Jet substructure

Validation in di-jet events using track jets



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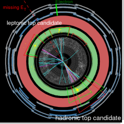
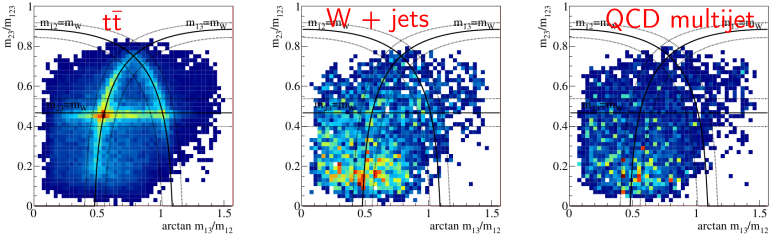
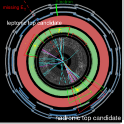


HEPTopTagger
Identification

- If $m_i^2 = 0$: $m_{123}^2 = m_{12}^2 + m_{23}^2 + m_{13}^2$
  $\Rightarrow$ sphere with radius $m_t^2 = m_{123}^2$
- Require $0.85\frac{m_W}{m_t} < \frac{m_{23}}{m_{123}} < 1.15\frac{m_W}{m_t}$
- $140\,\text{GeV} < m_{123} < 200\,\text{GeV}$



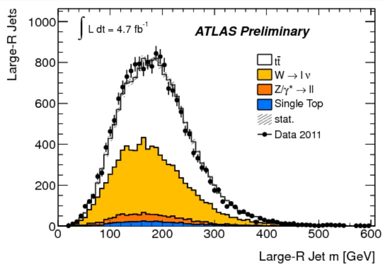
[Plehn, Spannowsky, Takeuchi, Zerwas; 2010]



HEPTopTagger

Top mass reconstruction

Mass distribution for C/A jets with $R = 1.5$ before running the HEPTopTagger



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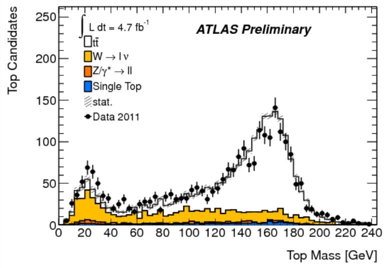
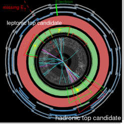
$f_t \approx 50\,\%$

after the HEPTopTagger, $R = 1.5$, default settings



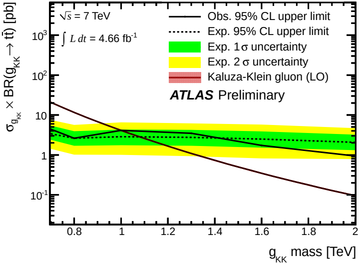
$f_t \approx 86\,\%$ in range
$140\,\text{GeV} < m_t < 200\,\text{GeV}$

- Improved top purity
- Background flat in m_t

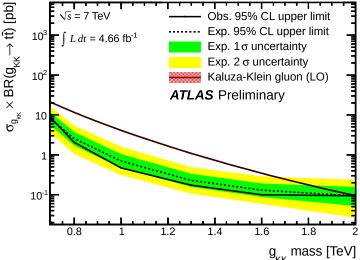


Lepton+jets channel
Limits

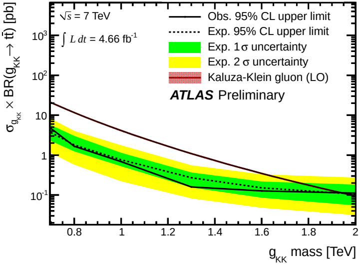
Resolved (mainly relevant at low mass):



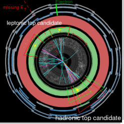
Boosted (mainly relevant at high mass):



Combined limit using the boosted reconstruction, if a single event is selected by the resolved and the boosted selection:



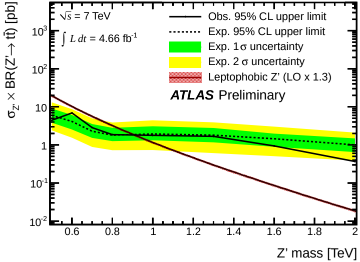
- g_{KK} exclusion: $0.7\,\text{TeV} < m_{g_{KK}} < 1.9\,\text{TeV}$



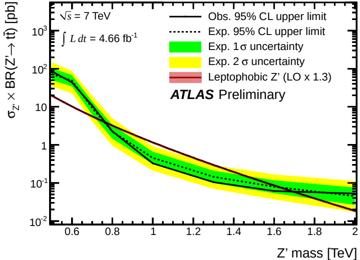
Lepton+jets channel

Combination of resolved and boosted selection

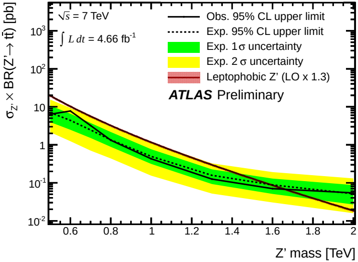
Resolved (mainly relevant at low mass):



Boosted (mainly relevant at high mass):



Combined limit using the boosted reconstruction, if a single event is selected by the resolved and the boosted selection:



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- Z' ($\Gamma/m_{Z'} = 1.2\%$) @95% CL: $0.5\,\text{TeV} < m_{Z'} < 1.7\,\text{TeV}$
- g_{KK} exclusion @95% CL: $0.7\,\text{TeV} < m_{g_{KK}} < 1.9\,\text{TeV}$