STUDIES WITH BOOSTED TOP QUARKS IN ATLAS

Search for $t\bar{t}$ resonances

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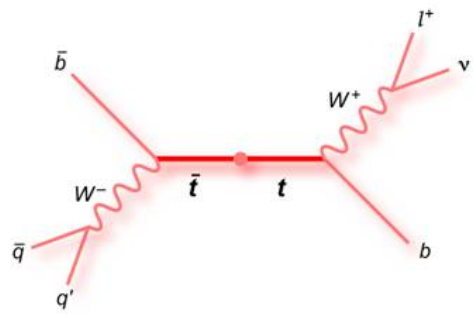
Outline

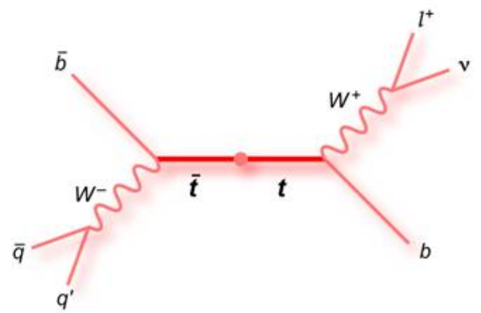
- **Boosted top quarks**
  - *Why boosted tops ?*
  - *Topologies*
- **Search for $t\bar{t}$ resonances**
  - *Benchmarks scenarios*
  - *In the fully hadronic channel*
    - Selections and taggers
    - Results
  - *In the lepton + jets channel*
    - Boosted selection
    - Resolved selection
    - Results
- **Summary**

BOOSTED TOP QUARKS

Why boosted top quark ?



Why boosted top quark ?



Why studying top quark ?

- Highest-mass particle in the SM.
  - ✓ **Expected large coupling** to New Physics particles (Z', g_{KK}, W' …)
  - ✓ This talk: Focus on **$t\bar{t}$ resonances**

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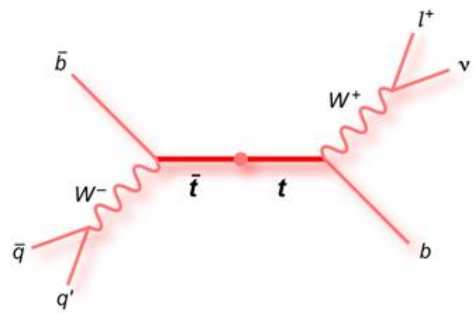

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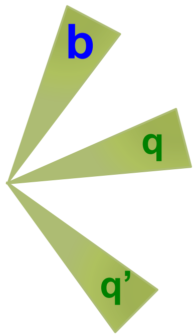
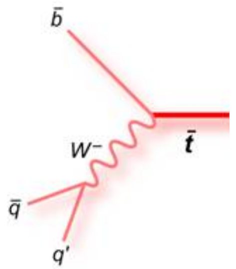
Why boosted top quark ?

- New heavy particles searches: $m_{Z'} >> m_{top}$
  - ✓ Top has **very large p_T**
- Decay products are more collimated: $\Delta R \sim 2m_{top}/p_{T,top}$
  - ✓ Totally **different topology**

Boosted hadronic tops

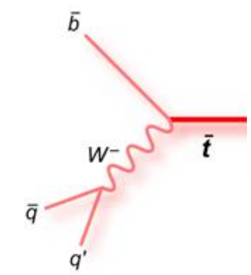




Non-boosted top

*3 decay products reconstructed as **3 separated jets** (typically anti-k_t (R=0.4) jets)*

Dominates for low-mass resonances



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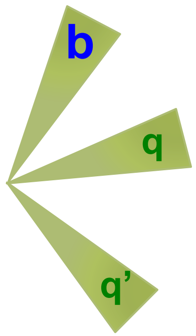

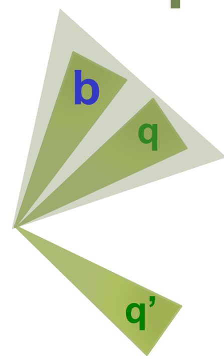

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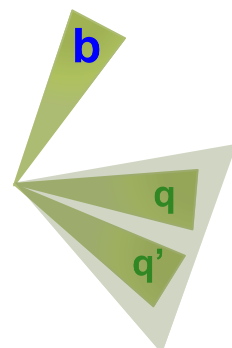


Semi-boosted top

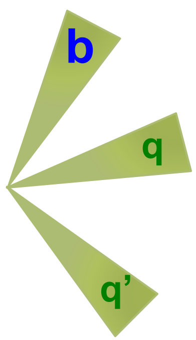
2 decay products close

➔ *2 jets merged*

➔ *Only* ***2 reconstructed jets***

Intermediate / high-mass resonance

Boosted hadronic tops



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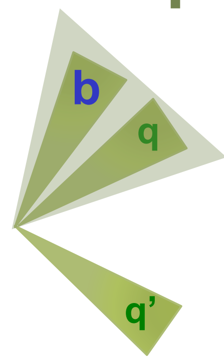

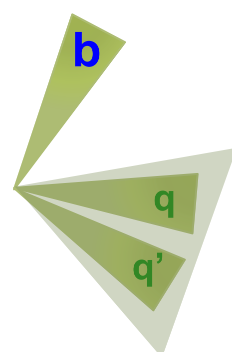

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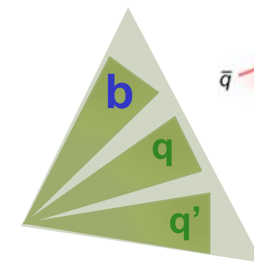
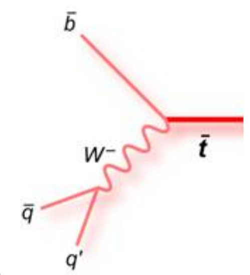




Boosted top

All decay products merged

➔ One « large R » reconstructed jet

(typically anti-k_t (R=1) jet)

High-mass resonance

Hadronic boosted tops: How ?

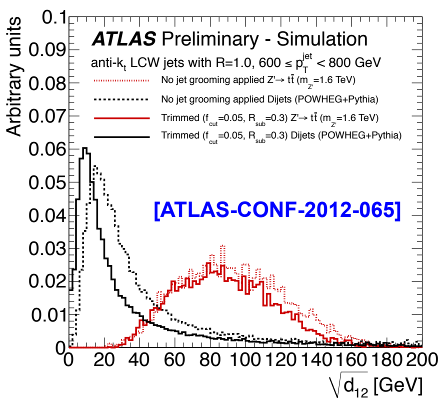
- **Multiple algorithms** can be used to tag boosted tops ***[ATLAS-CONF-084]***
- Use of **substructure variables** (splitting scales, N-subjetiness, **masses** …)
- This talk: focuses mainly on **three algorithms**:
  - **Splitting scale + mass** criterion ➔ single-lepton $t\bar{t}$ resonances ***[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]***
  - **HEPTopTagger & Top Template Tagger** ➔ fully-hadronic decaying $t\bar{t}$ resonances ***[JHEP01(2013)116]***
- Choice between taggers based on the expected **signal efficiency**, **background rejection**.

Splitting scale

- Defined as:

$$\sqrt{d_{ij}} = \min\left(p_{Ti}, p_{Tj}\right) \times \Delta R_{ij}$$

- **Example**: require for « large R » jet to have $\sqrt{d_{12}} \geq 40$ GeV



HEPTopTagger

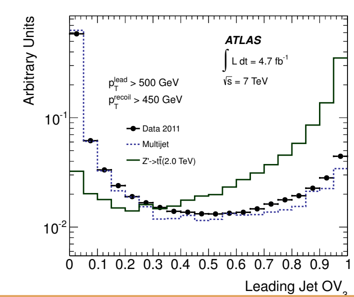
[Plehn et al. 1006.2833], [ATLAS-CONF-084]

- Divides **CA jets** into subjets.
- **Filtering**: remove underlying event / pile-up contributions.
- **Combinations of remaining subjets** to form the top quark (conditions on masses, masses ratios …).

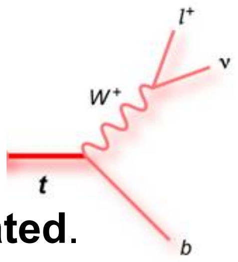
Top Template Tagger

[JHEP01(2013)116]

- Compares the **energy flow** in data and the ones obtained from MC.
- For each comparison, a **variable is computed** (OV_3)
- Top candidate mass (m) must verify: **$|m-m_{top}| < 50$ GeV**



Boosted semi-leptonic tops



- Decay products collimated on the leptonic side too: **leptons can be non-isolated**.

Standard isolation

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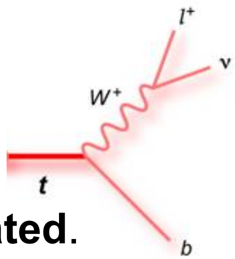

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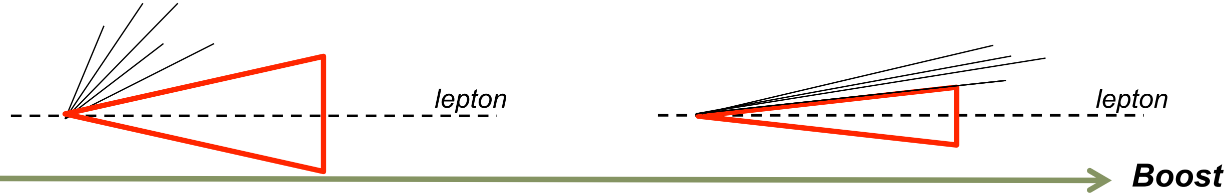
Standard isolation

- **p_T-dependant** isolation used to avoid this effect: so-called **mini-isolation**.

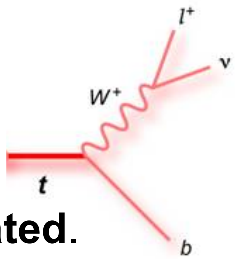
Mini-isolation

$I_{mini} < 0.05 \times p_T$



- I_{mini} : sum of the p_T of the tracks in a cone of size 10 GeV / E_T.

Boosted semi-leptonic tops



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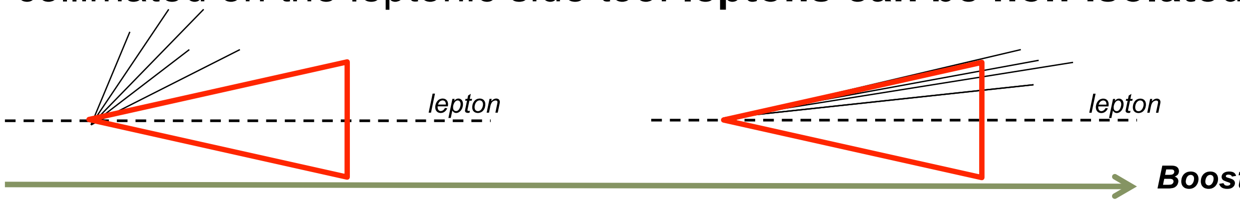

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Mini-isolation

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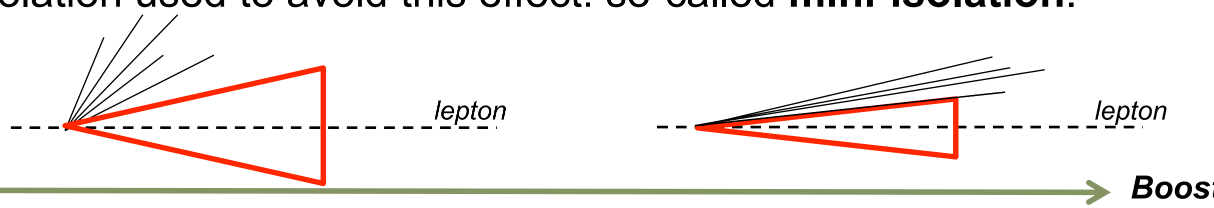

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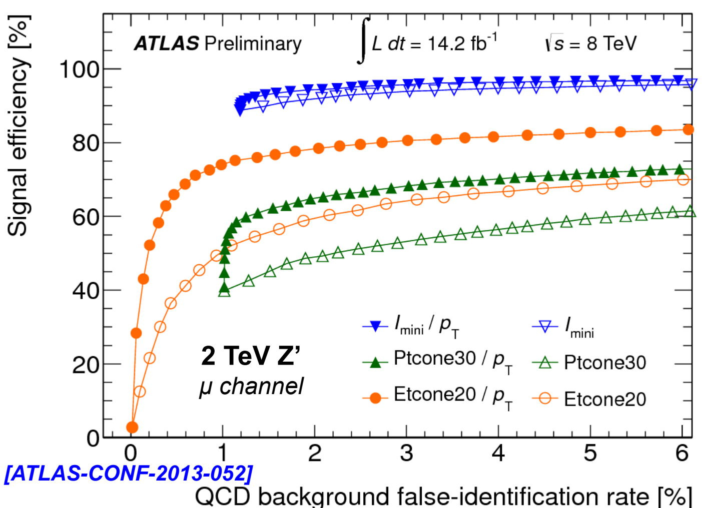
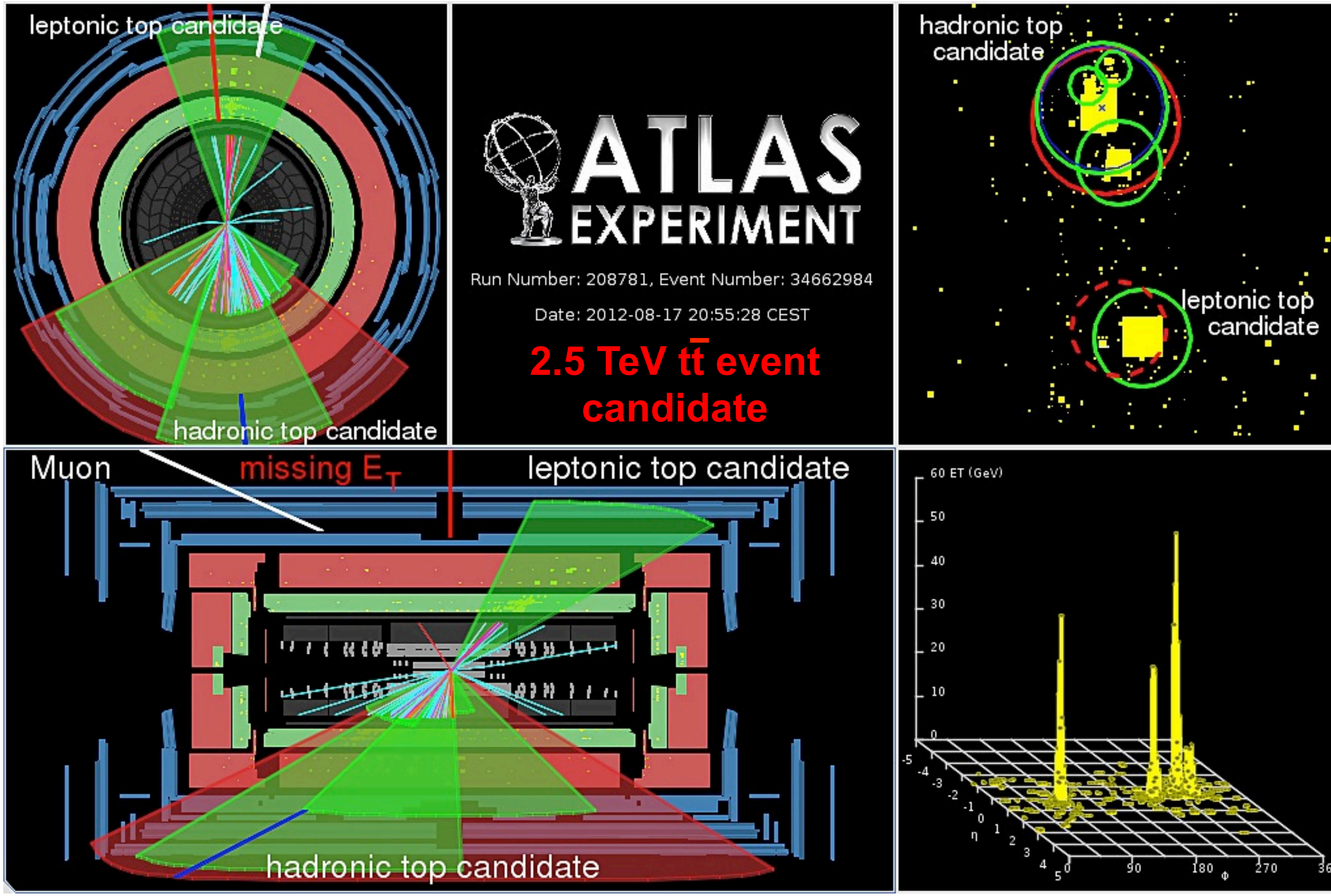


- Mini-isolation **more efficient** than fixed-cone isolation for a 2 TeV Z'.
- Chosen working point (0.05):
  - False identification rate ~2.2 %
  - Efficiency ~95%
  - Very stable efficiency for different boosting regimes (whole p_T(top) range)

How does a boosted $t\bar{t}$ event look like ?



[ATLAS-CONF-2013-052]

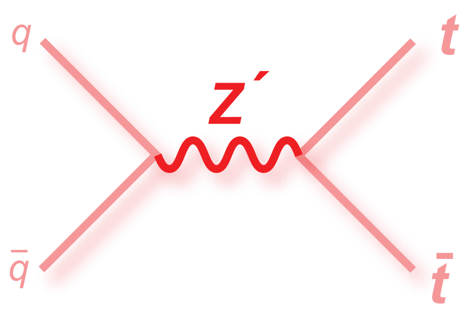
TTBAR RESONANCES SEARCHES

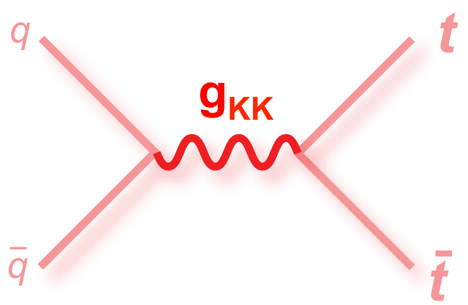
Benchmarks scenarios

Benchmark scenarios

Z' boson

- Predicted in some leptophobic topcolor models
- Narrow resonance: Γ/m = 1.2 %
- LO cross-section and generation using PYTHIA
- *K*-factor of 1.3 to account for NLO effects.





g_{KK} boson

- Predicted in some Randall-Sundrum models
- Broad resonance: Γ/m = 15.3 %
- LO cross-section and generation using MADGRAPH
- No *K*-factor applied

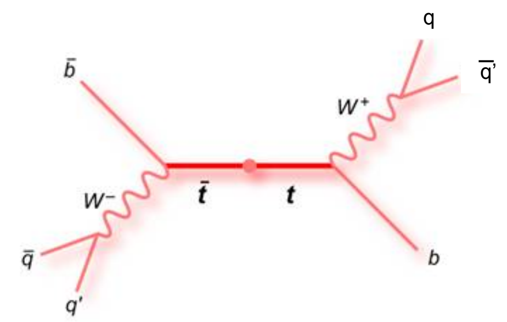
TTBAR RESONANCES SEARCHES

Fully hadronic decaying $t\bar{t}$ pairs with 4.7 fb^{-1} @ 7 TeV

Based on ***JHEP01(2013)116***

Analysis strategy

- Considers only **highly-boosted top quarks**.
- Final state contains only **two « large – R » jets** containing all the decay products of the tops.
- Uses **two top taggers** sensitive to different p_T regimes (*both are tested*)



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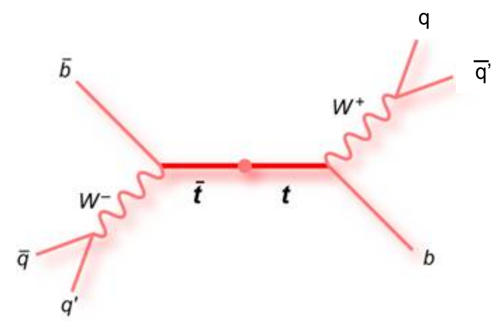


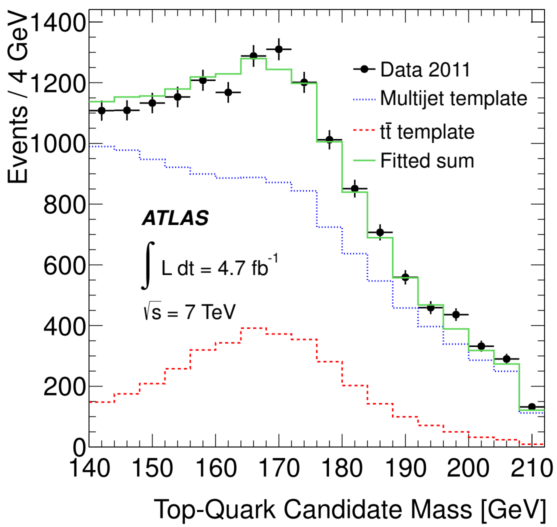
- **Event selection**
  - **Trigger**
  - **Quality criteria**
  - One **Primary Vertex** (PV) with at least 5 tracks
  - **The 2 leading jets pass the tagger requirement:**
    - ***HEPTopTagger***
      - **At least two C/A (R=1.5) jets** with p_T > 200 GeV and |η| < 2.5
    - ***Top Template Tagger***
      - **At least two anti-k_t (R=1.0) jets** with p_T > 500 GeV and |η| < 2.0 (leading) and p_T > 450 GeV (recoil)
  - ***b*-tag requirement**
    - Small-radius jets (anti-k_t (R=0.4)) with p_T > 25 GeV and |η| < 2.5 are used.
    - **At least one *b*-tagged** jet within ΔR = 1.4 (ΔR = 1.0) from a fat jet
  - **Lepton veto**

HEPTopTagger-based analysis

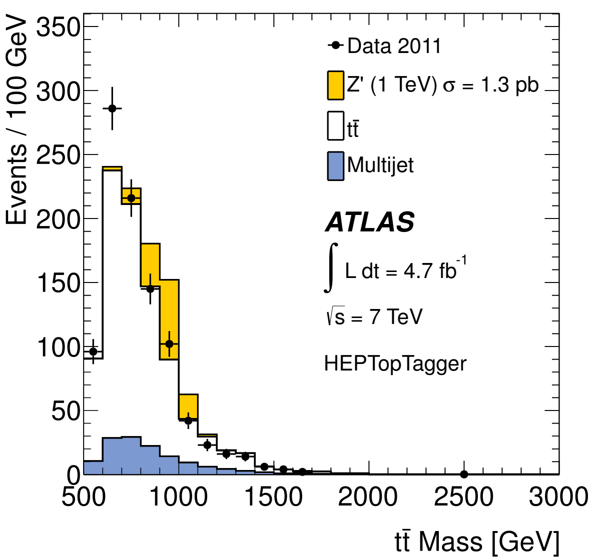
- **Signal selection efficiency**
  - More efficient for **middly-boosted** top quarks
  - Not efficient @ low Z' mass (not boosted regime yet)

Z' mass [TeV]	Efficiency [%]
0.5	0.03 ± 0.01
1.0	4.76 ± 0.09
1.6	5.40 ± 0.10
2.0	4.44 ± 0.10

- **Background estimation**
  - Done in **several control regions**, then extrapolated to signal region
  - **$t\bar{t}$ normalisation** based on data-driven estimate
  - Multijet shape predicted by the behaviour in the control regions



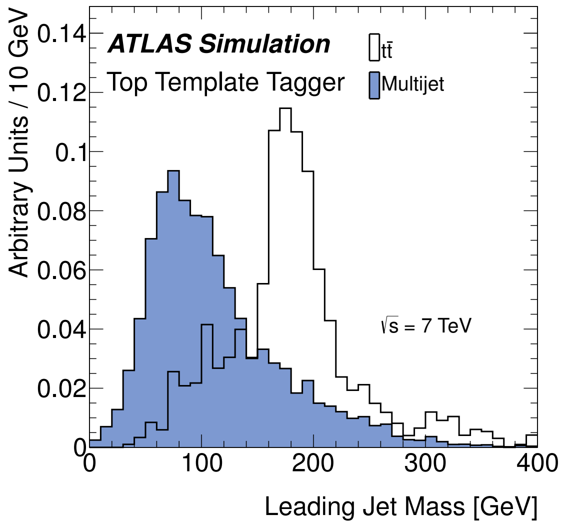
- **$t\bar{t}$ mass reconstruction**
  - Z' (or g_{KK}) 4-vector = **sum of the two top candidates' 4-vectors**

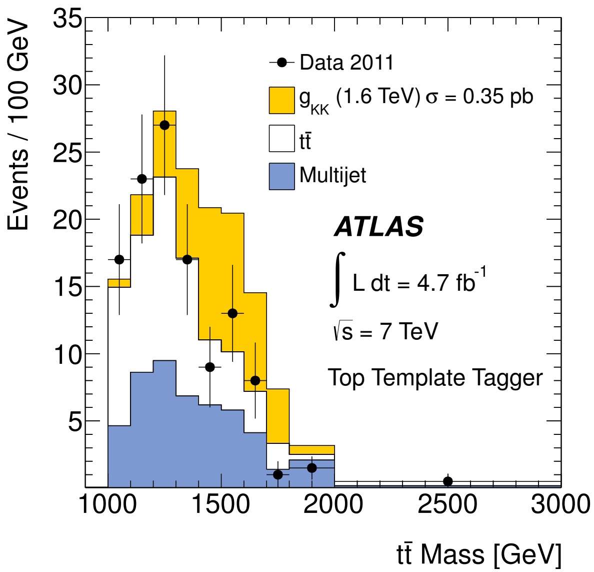


Top Template Tagger-based analysis

- **Signal selection efficiency**
  - More efficient for **highly-boosted** top quarks
  - Not efficient @ low Z' mass (not boosted regime yet)
- **Background estimation**
  - $t\bar{t}$ estimation from **MC**
  - Multijet estimation data-driven using several **control regions**
- **$t\bar{t}$ mass reconstruction**
  - Similar to the HEPTopTagger analysis method

Z' mass [TeV]	Efficiency [%]
0.5	–
1.0	0.48 ± 0.05
1.6	8.13± 0.16
2.0	6.26 ± 0.13





Results and systematic uncertainties

- **Yields** after both selections (**statistical + systematic** uncertainties)

	HEPTopTagger	Template Top Tagger
$t\bar{t}$	770^{+220}_{-180}	59^{+27}_{-26}
Multijet	130 ± 70	53 ± 6
Total background	$\mathbf{900^{+230}_{-235}}$	**112 ± 27**
Data	**953**	**123**

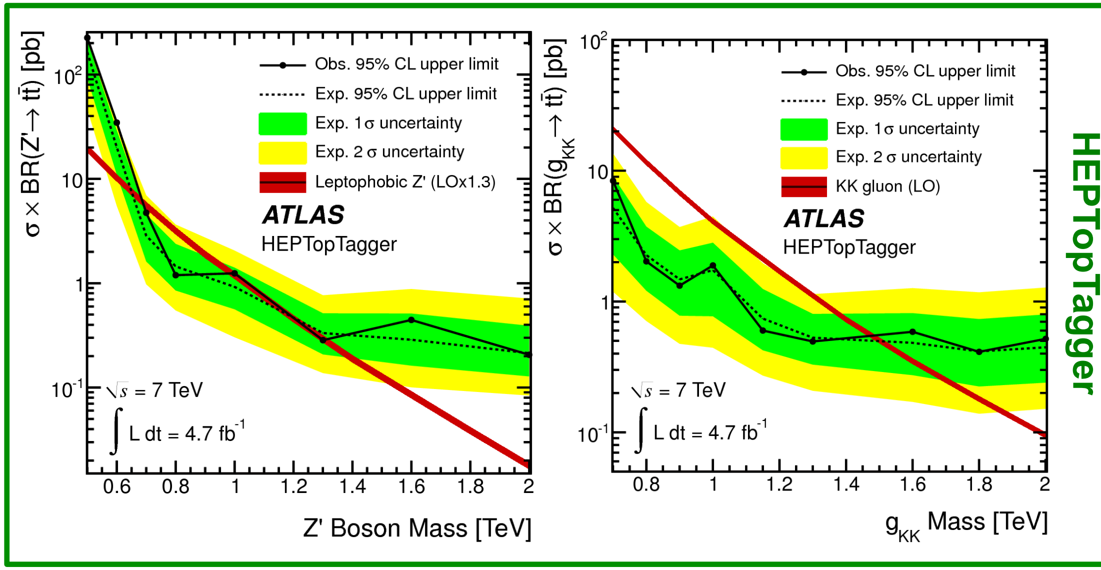
- **No significant excess** found in the data compared to background prediction.

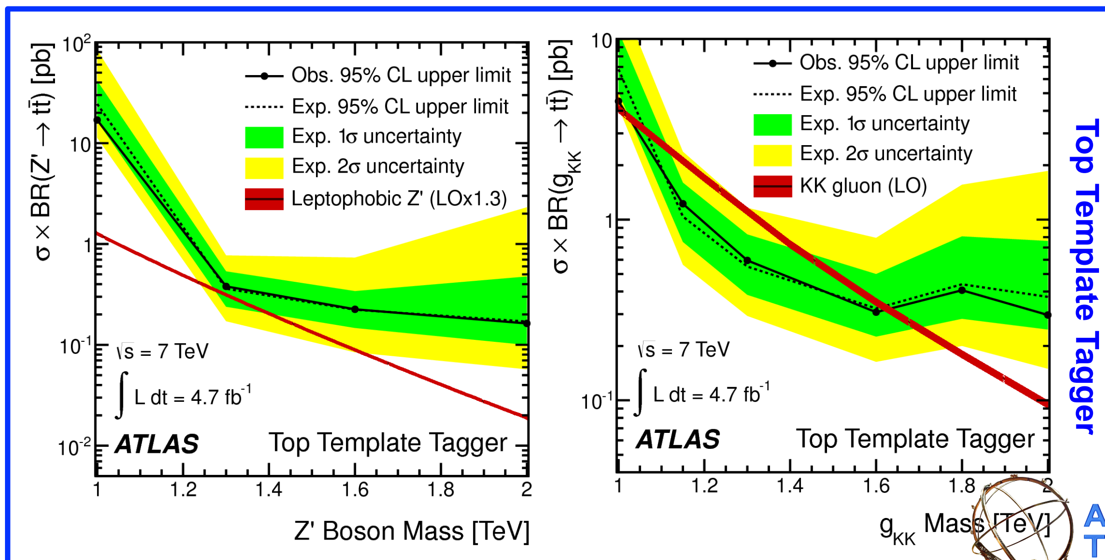
- Main **systematic** uncertainties:
  - *b*-tagging efficiency, inefficiency
  - Jet Energy Scale
  - $t\bar{t}$ normalisation

Setting limits

- No excess found: **95 % CL limits are set**.
- Using a Bayesian approach
- Limits set for **each of the analyses** independently.
- Combination: the **analysis leading to the best expected limit** is chosen.
- Final observed limits:

Sample	Mass limits [TeV] 95 % CL limits
Z'	0.70 – 1.00 1.28 – 1.32
g_{KK}	0.70 – 1.62





TTBAR RESONANCES SEARCHES

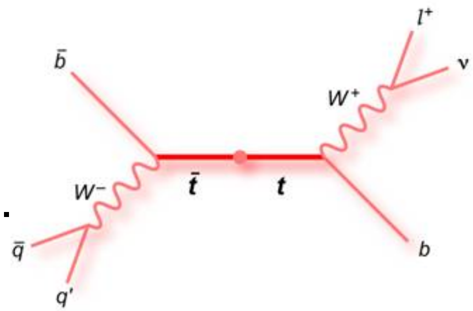
Single lepton channel with 14.3 fb^{-1} @ 8 TeV

Based on ***ATLAS-CONF-2013-052***

NB: 7 TeV analysis : PRD 88, 012004 (2013)

Analysis strategy

- Analysis designed to **cover the whole $t\bar{t}$ mass range**:
  - **Resolved** analysis: non-boosted topologies
  - **Boosted** analysis: fully-boosted topologies
- Consider **electron** and **muon** channels.
- Both analyses are orthogonal: **combined for limit setting**.



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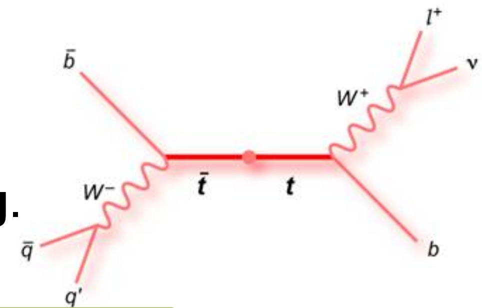

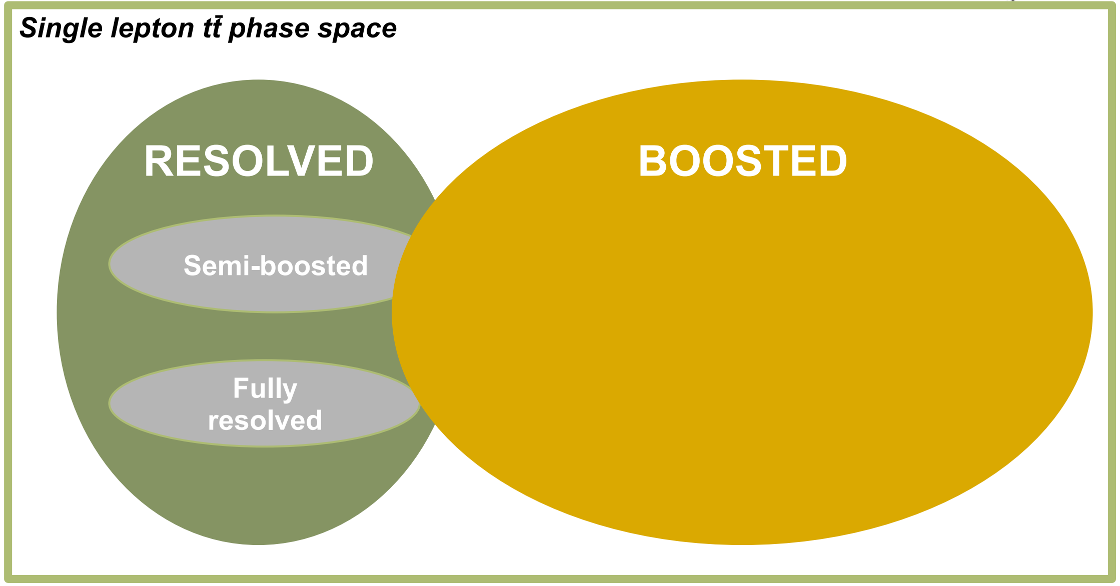

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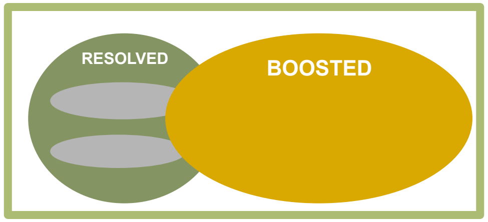

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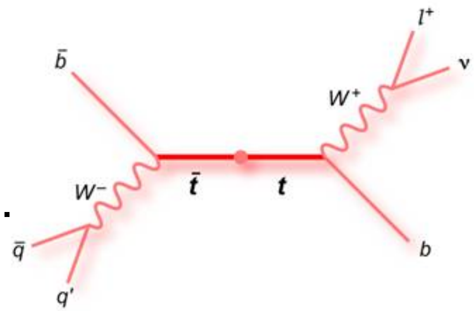
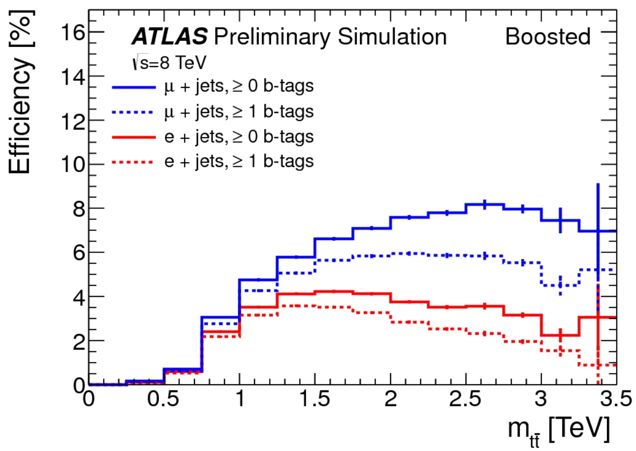


- The **common event selection** requires to:
  - **Trigger** (lepton-based)
  - **Quality criteria**
  - One **Primary Vertex** (PV) from which originate at least 5 tracks
  - Exactly one **electron** with p_T > 25 GeV and $|\eta|<2.47$ or one **muon** with p_T > 25 GeV and $|\eta|<2.5$
  - Missing transverse energy (**E_T^{miss}**) and transverse *W* mass **$M_T(W)$**
    - E_T^{miss} > 30 GeV and $M_T(W)$ > 30 GeV
    - E_T^{miss} > 20 GeV and $M_T(W)$+MET > 60 GeV

Event selection and reconstruction

Boosted topology

- The **boosted selection** requires:
  - **At least 1 small radius jet**, with p_T > 25 GeV, |η| < 2.5 close (ΔR < 1.5) to the lepton
  - **At least 1 anti-k_t (R=1) jet**, with p_T > 300 GeV, |η| < 2 and m_{jet} > 100 GeV.
    - **Top tagging :** $\sqrt{d_{12}} \geq 40$ GeV
  - At least one small radius jet anywhere in the event is ***b*-tagged**
- Main **remaining backgrounds**: SM $t\bar{t}$, *W*+jets
  - Estimated mainly **from MC**
  - **Multijets** background **estimated** from data
  - ***W*+jets** is **semi data-driven** with several scale factors derived from data

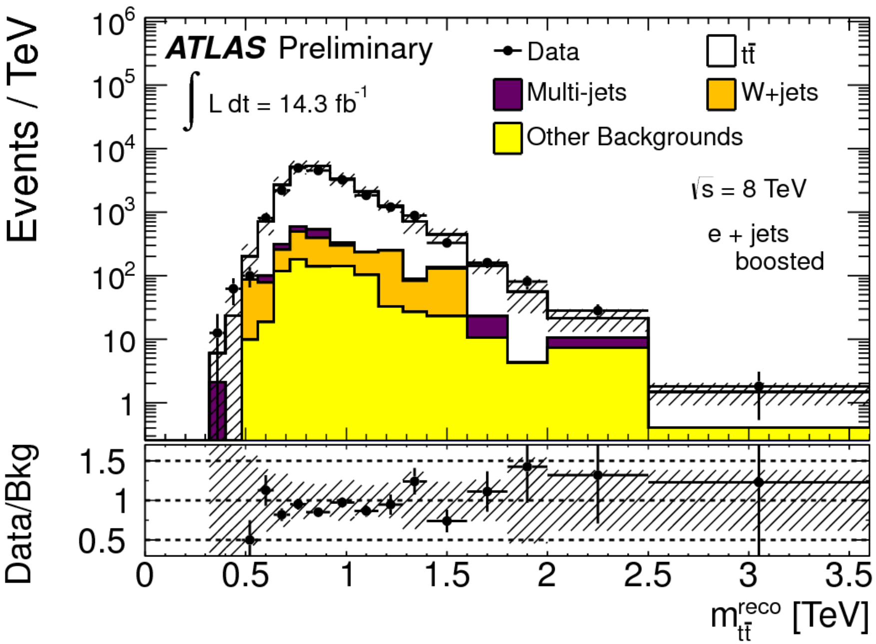


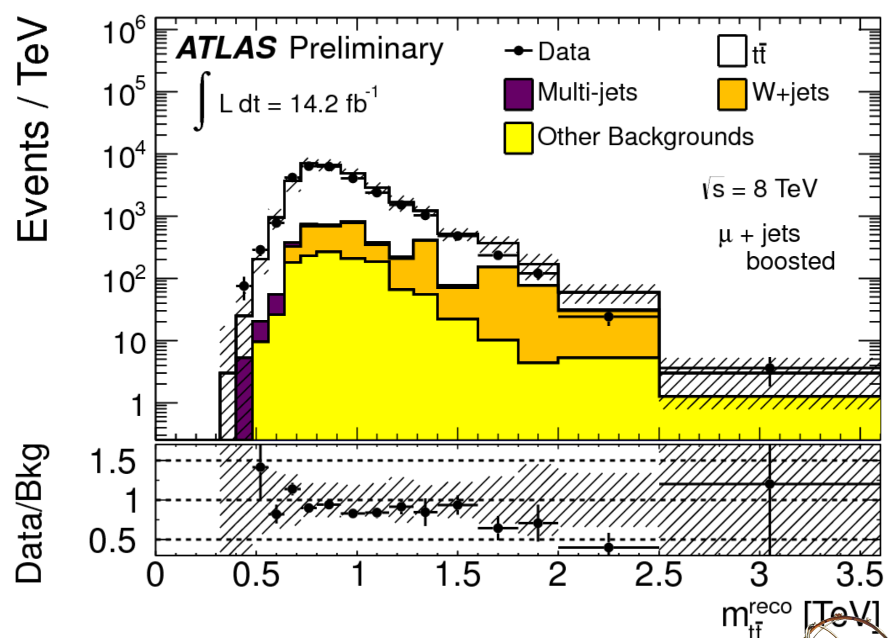
Event selection and reconstruction

Boosted topology

BOOSTED

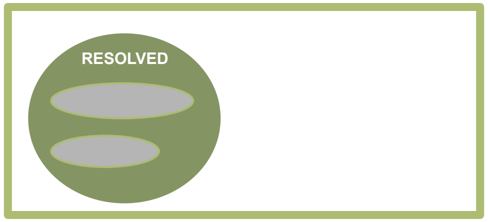
- **Reconstruction**
  - **Hadronic top:** 4-vector of the « large-R » jet.
  - **Semi-leptonic top:** highest-p_T « small-R » jet (close to the lepton) combined to the lepton and the neutrino 4-momenta (the latter derived from E_t^{miss} and lepton kinematics with a constraint on the *W* mass).



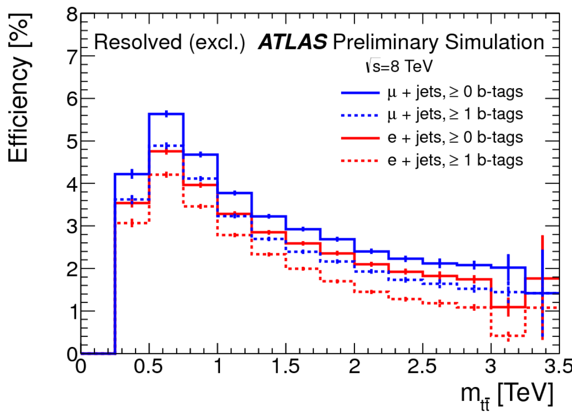


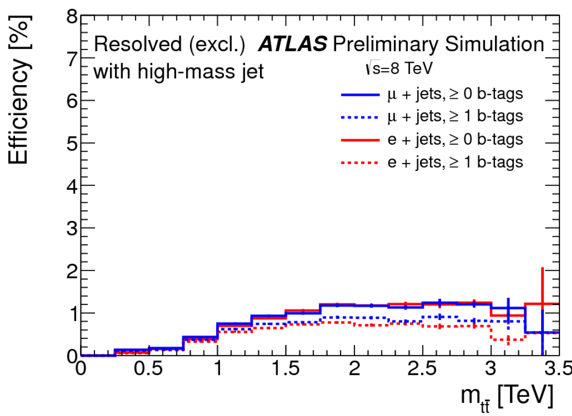
Event selection and reconstruction

Resolved topology



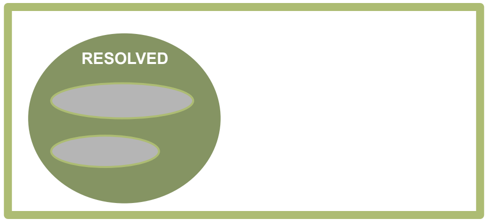
- The **resolved selection** requires:
  - If one small radius jet with m_{jet} > 60 GeV, at least **3 jets** are required **(semi-boosted case)**.
  - Otherwise, **at least 4 small radius jets**
  - At least one jet is ***b*-tagged.**
  - **Required not to pass the boosted selection**



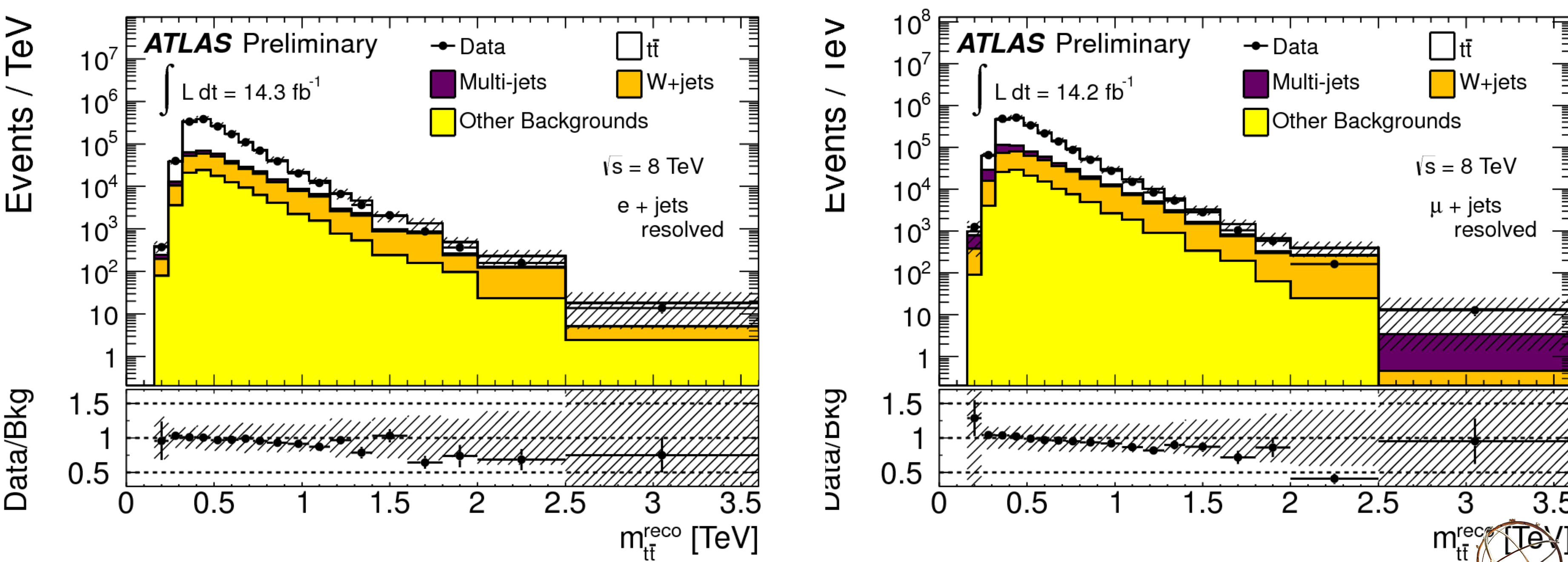


Event selection and reconstruction

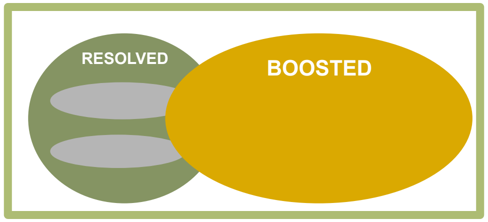
Resolved topology



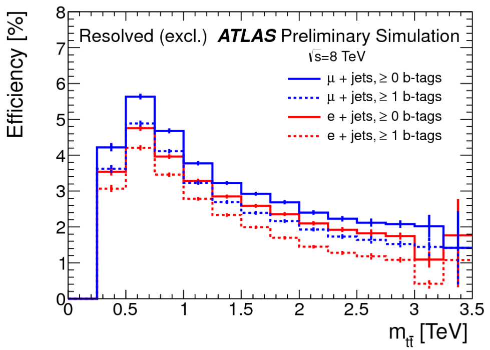
- **Reconstruction**
  - **Performed using a χ^2 algorithm.**
  - **Two functions:** one for each case (with / without high mass jet)
  - Based on comparison with MC expectations.



Combining analyses



- **Selection efficiency**



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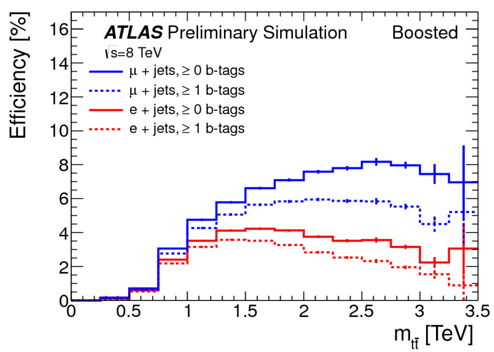

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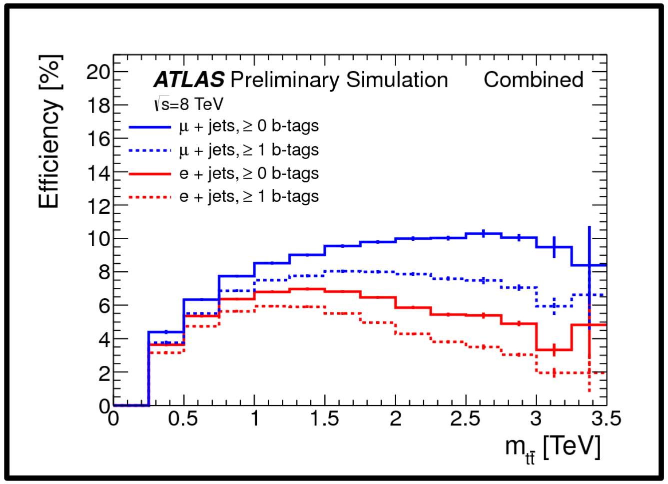
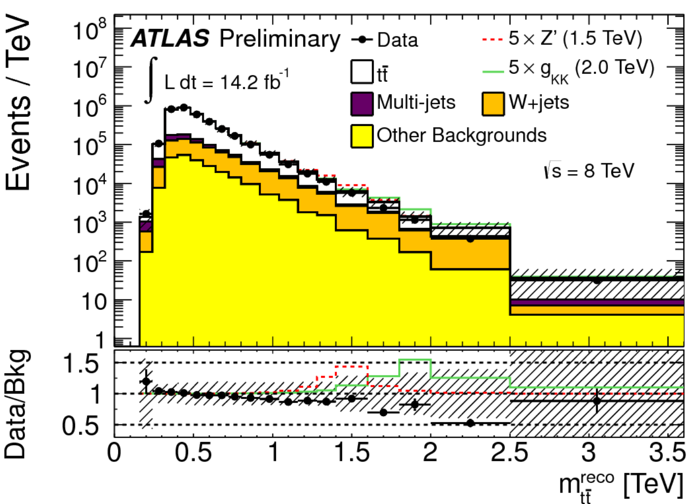


- **High mass** $t\bar{t}$ pairs mainly selected by the **boosted** analysis and the **semi-boosted** one.
- **Low mass regime** (until ~800 GeV) dominated by the **resolved** analysis.

- **$t\bar{t}$ mass spectrum**



Results and systematic uncertainties

- **Yields** after events selection (uncertainties include normalisation/cross section uncertainties):

	Resolved	Boosted
SM $t\bar{t}$	211,000 ± 33,000	4,900 ± 1,100
Total Background	**283,000 ± 39,000**	**5,600 ± 1,200**
Data	**280,251**	**5,122**

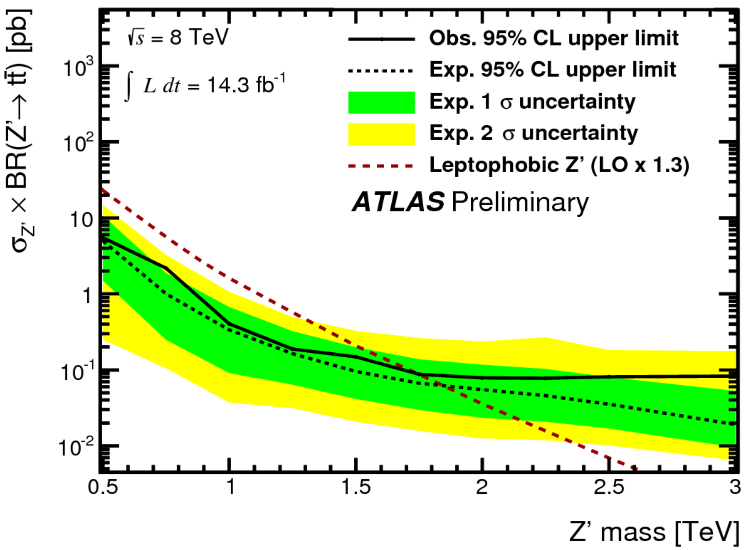
- Main **systematic uncertainties** (on the background yields):

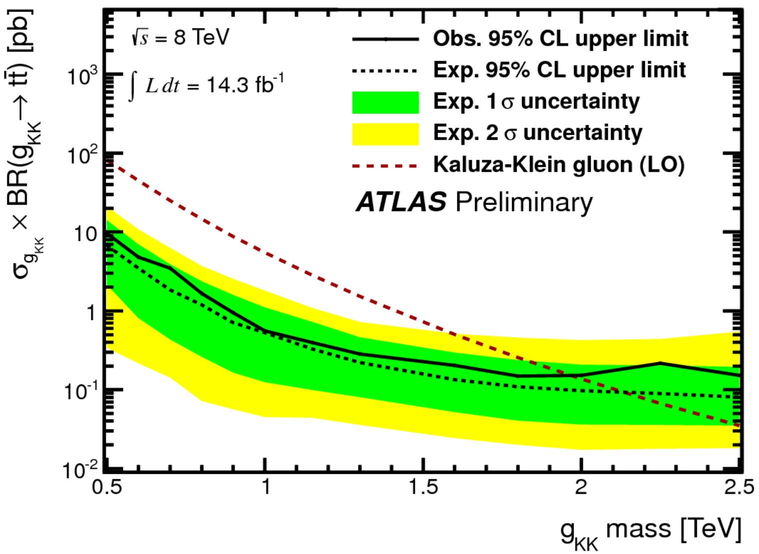
	Resolved	Boosted
JES (small radius jets)	6 %	0.7 %
JES+JMS (large radius jets)	0.3 %	17 %
$t\bar{t}$ normalisation	8 %	9 %
PDF	2.9 %	6 %
$t\bar{t}$ EW virtual correction	2.2 %	4 %
b-tagging efficiency	4 %	3.4 %

Limits setting

- **Search for local excess**
  - Comparing MC-predicted and data-observed spectra, taking into account the systematic uncertainties
  - **No excess found**

- **Setting limits** using a bayesian technique
  - Limits established at a CL of 95 %





- Limits set up to **1.8 TeV on Z' mass**, and up to **2.0 TeV on g_{KK} mass**.

Summary

- **Boosted tops are becoming a common tool** to study physics at the TeV-scale, and improve significantly the sensitivity of ATLAS to New Physics particles.
- Especially, **boosted tops** are used in the context of **$t\bar{t}$ resonance searches**.
- No **significant excess has been observed**.

	Observed mass limit [TeV]		
	Fully hadronic *4.7 fb^{-1} @ 7 TeV*	**Semi-leptonic** *14.3 fb^{-1} @ 8 TeV*	**Semi-leptonic** *4.7 fb^{-1} @ 7 TeV*
Z'	**0.70 – 1.00** **1.28 – 1.32**	**0.5 – 1.8**	**0.5 – 1.74**
g_{KK}	**0.70 – 1.62**	**0.5 – 2.0**	**0.5 – 2.07**

- **Many updates** are ongoing using the full 2012 dataset for these studies and **many others**.

Summary

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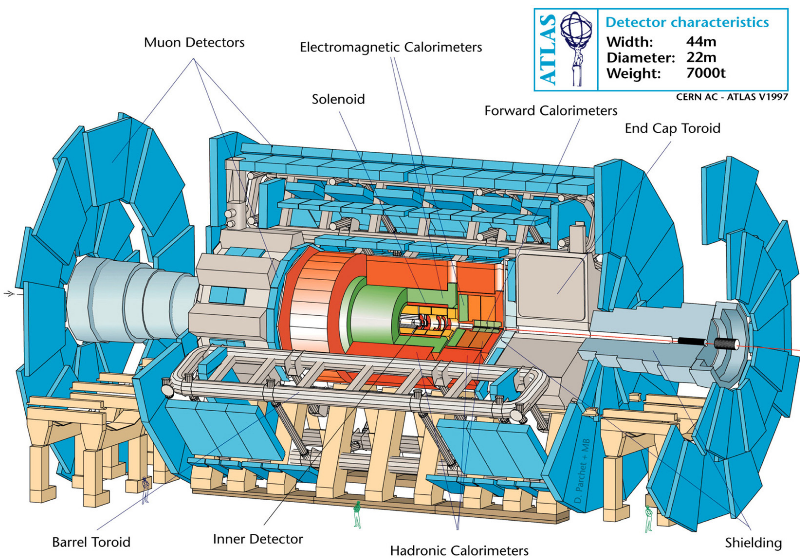
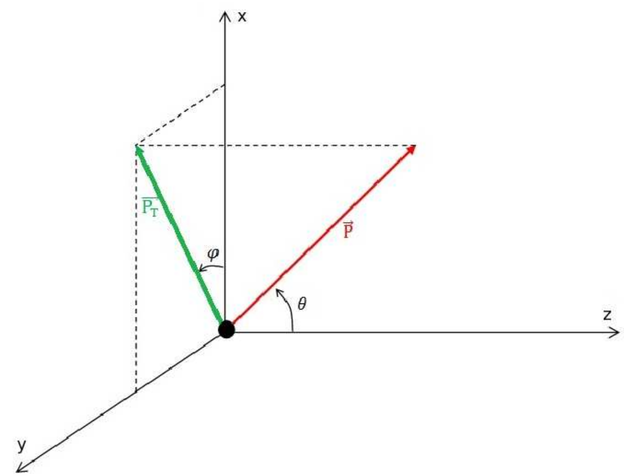
- **Many updates** are ongoing using the full 2012 dataset for these studies and **many others**.
- **Thanks !**

BACKUP SLIDES

ATLAS detector

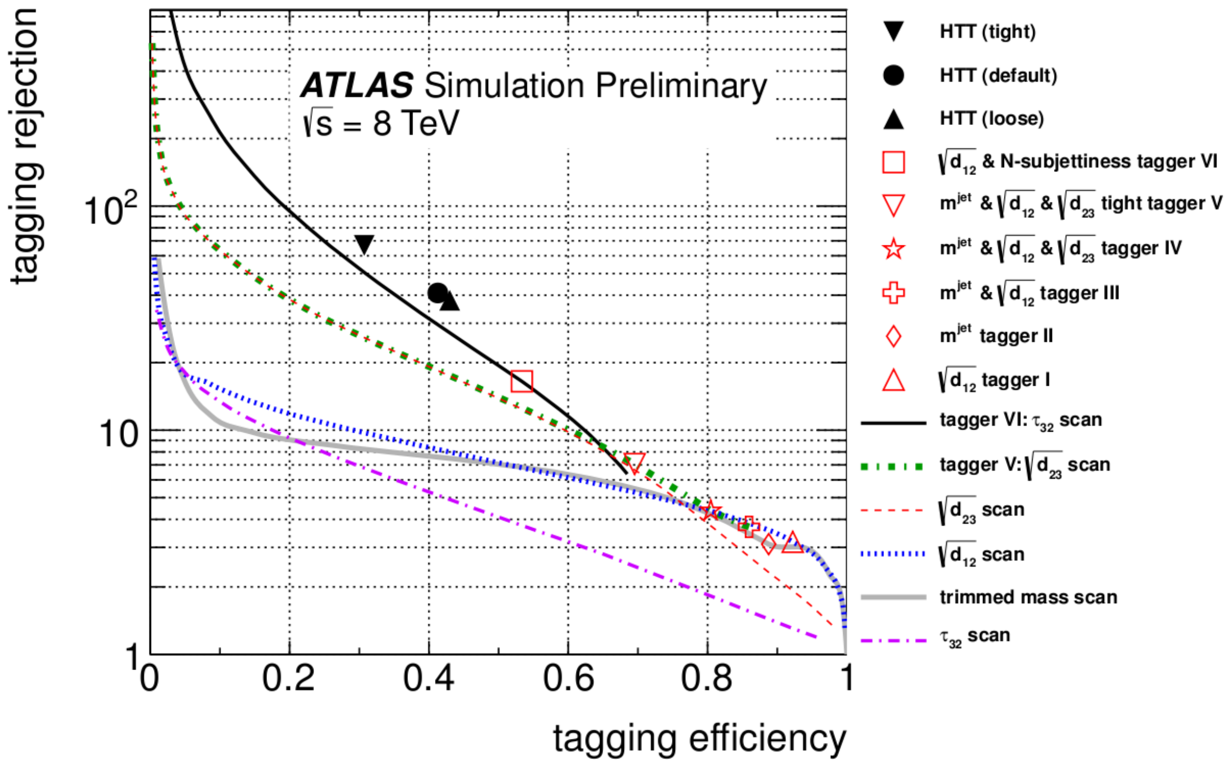
- **~4π sr detector**
- **Several sub-detectors**: each of them sensitive to different types of particles.





Taggers and choices

[ATLAS-CONF-2013-084]



- **Different taggers lead to different tagging efficiency / inefficiency**
- Choice of the analysis done depending on their needs (large purity, large efficiency).

b-tagging

- ATLAS: use of multivariate output to discriminate *b* jets from light ones.
- Inputs for the multivariate:
  - Impact parameter of the jet
  - Flight distance
  - Displaced vertices
  - …
- Standard cut applied:
  - 0.6017 @ 2011 data ➔ Eff 70 %
  - 0.7892 @ 2012 data ➔ Eff 70 %

Jets algorithms

$$\text{anti-}k_T\ [16]: \quad d_{ij} = \frac{1}{\max\left[p_{Ti}^2, p_{Tj}^2\right]} \frac{R_{ij}^2}{R_0^2}, \qquad d_{iB} = \frac{1}{p_{Ti}^2},$$

$$\text{C/A}\ [24,\ 25]: \quad d_{ij} = \frac{R_{ij}^2}{R_0^2}, \qquad d_{iB} = 1,$$

$$k_T\ [26,\ 27]: \quad d_{ij} = \min\left[p_{Ti}^2, p_{Tj}^2\right] \frac{R_{ij}^2}{R_0^2}, \qquad d_{iB} = p_{Ti}^2$$

$$\text{VR}\ [3]: \quad d_{ij} = \frac{1}{\max\left[p_{Ti}^2, p_{Tj}^2\right]} R_{ij}^2, \qquad d_{iB} = \frac{\rho^2}{p_{Ti}^4}.$$

[Krohn et al., arxiv:0912.1342]

[3] D. Krohn, J. Thaler, and L.-T. Wang, *Jets with Variable R*, *JHEP* **06** (2009) 059, [0903.0392].

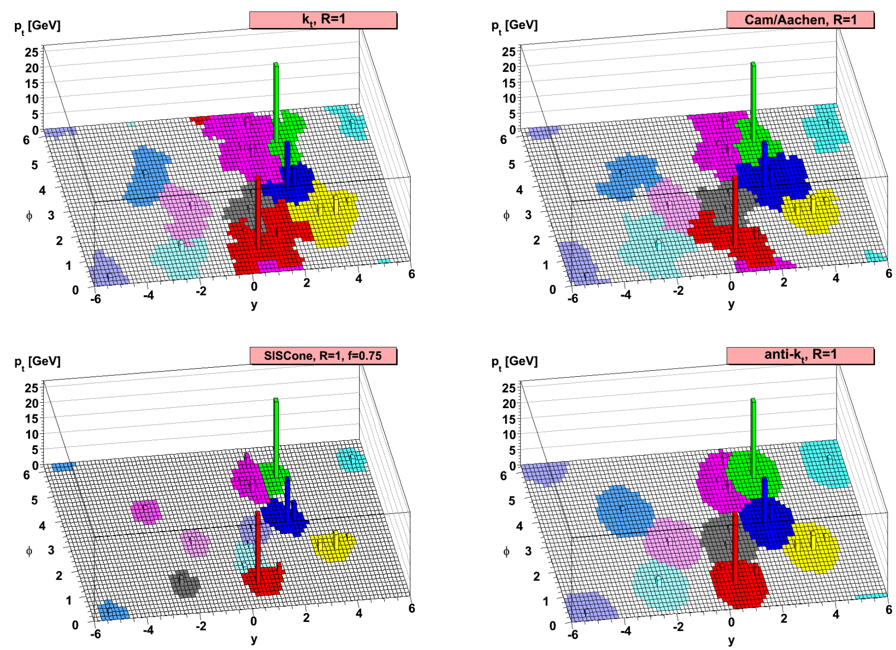
[16] M. Cacciari, G. P. Salam, and G. Soyez, *The anti-k_t jet clustering algorithm*, *JHEP* **04** (2008) 063, [0802.1189].

[24] Y. L. Dokshitzer, G. D. Leder, S. Moretti, and B. R. Webber, *Better Jet Clustering Algorithms*, *JHEP* **08** (1997) 001, [hep-ph/9707323].

[25] M. Wobisch and T. Wengler, *Hadronization corrections to jet cross sections in deep- inelastic scattering*, hep-ph/9907280.

[26] S. Catani, Y. L. Dokshitzer, M. H. Seymour, and B. R. Webber, *Longitudinally invariant K(t) clustering algorithms for hadron hadron collisions*, *Nucl. Phys.* **B406** (1993) 187–224.

[27] S. D. Ellis and D. E. Soper, *Successive combination jet algorithm for hadron collisions*, *Phys. Rev.* **D48** (1993) 3160–3166, [hep-ph/9305266].



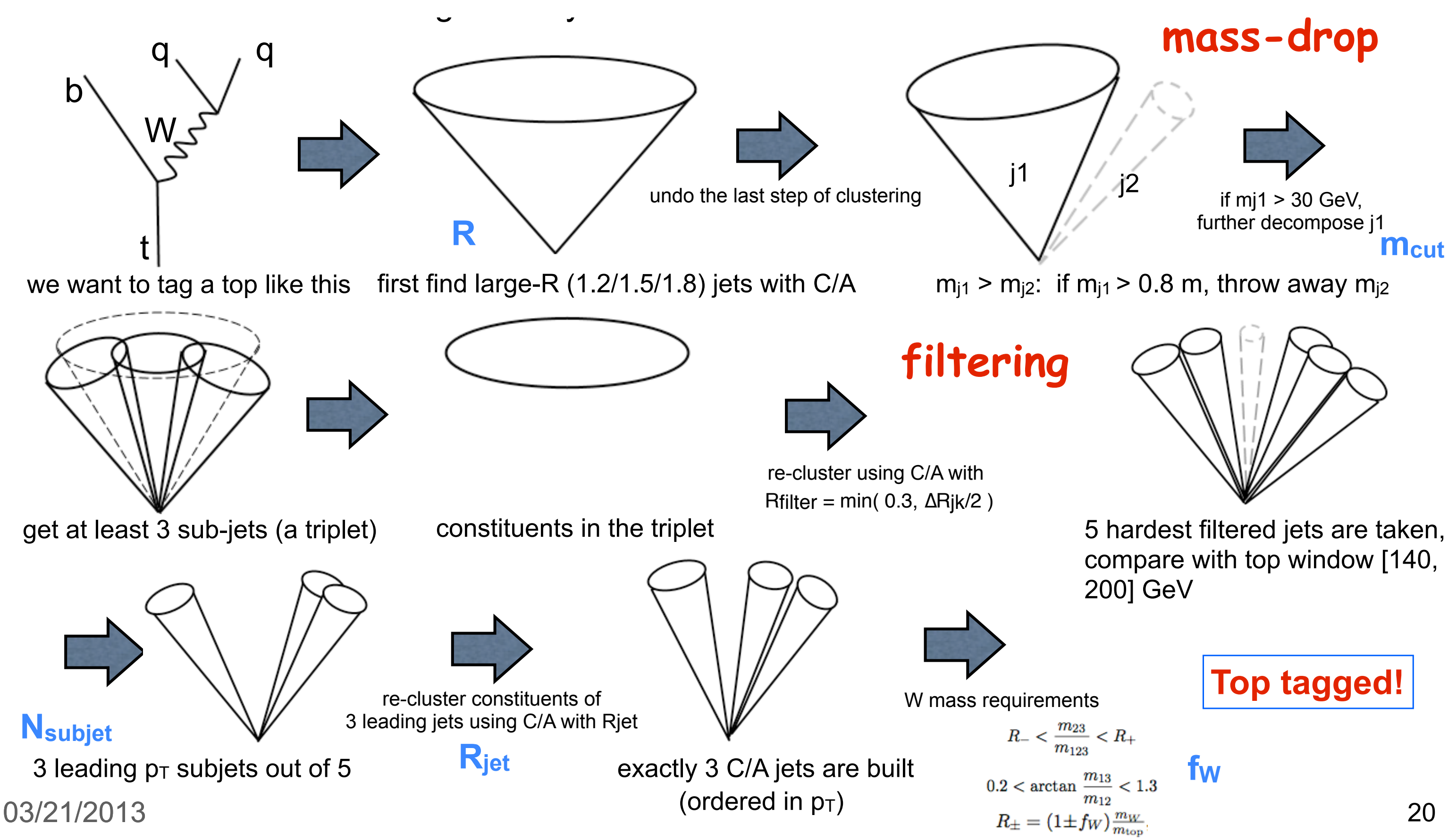
[Cacciari, Salam, arxiv:0802.1189]

Full-hadronic ttbar resonance

[JHEP01(2013)116]

- **Taggers:** HEPTopTagger

JHEP 1010:078 (2010) T. Plehn, M. Spannowsky, M. Takeuchi, D. Zerwas



From: Xiaoxiao Wang (Yale)

Full-hadronic ttbar resonance

[JHEP01(2013)116]

- **Taggers:** TopTemplateTagger
  - 300 000 MC templates built do describe the energy flow for a given top p_T
  - The overlap between the observed energy flow | D >, and the one tested template | T > is given by:

$$OV_3 = \max_{\{\tau_n\}} \exp\left[-\sum_{i=1}^{3} \frac{1}{2\sigma_i^2}\left(E_i - \sum_{\substack{\Delta R(\mathrm{topo},i)\\<0.2}} E_{\mathrm{topo}}\right)^2\right],$$

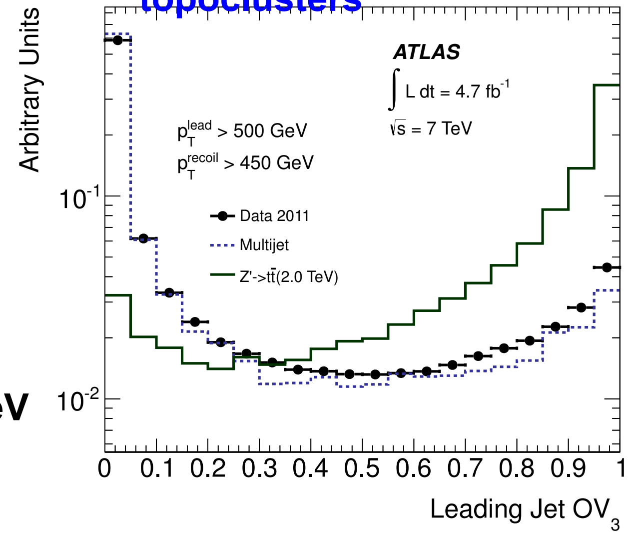
Loop over the parton of the tested template

Loop over the topoclusters

Expected behaviour:

- Ttbar decay candidate: the argument can reach ~0
  ➔ OV3 -> 1
- QCD (dominated by dijet events) can lead to << 0 arguments
  ➔ OV3 -> 0

Analysis: top-tagged if **OV3 > 0.7 and mass verifies: $|m-m_{top}|$ < 50 GeV**



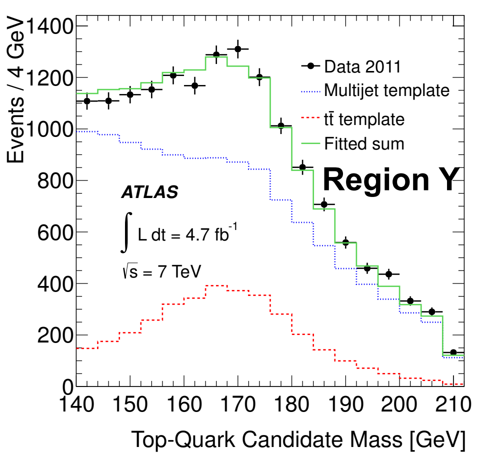
Full-hadronic ttbar resonance

[JHEP01(2013)116]

- **Estimation des fonds**
  - HEPTopTagger
    - Using several control regions: based on number of top-tagged and b-tagged jets

	1 top-tag	$\geq$ 2 top-tags
no b-tag	U(0.3%)	V(2.4%)
1 b-tag	W(3.2%)	X(24.3%)
$\geq$ 2 b-tags	Y(22.5%)	Z(80.9%)

Signal region



- **Ttbar estimation**
  - **Use of region Y**
    - MC template to describe ttbar
    - Multijet extracted from region W after ttbar substraction
    - Templates are scaled to fit the data in this region
    - SF: 1.01 +- 0.09
    - **Propagated to all control regions**

- **Multijet estimation**
  - Data driven, after substraction of the ttbar expected contamination.

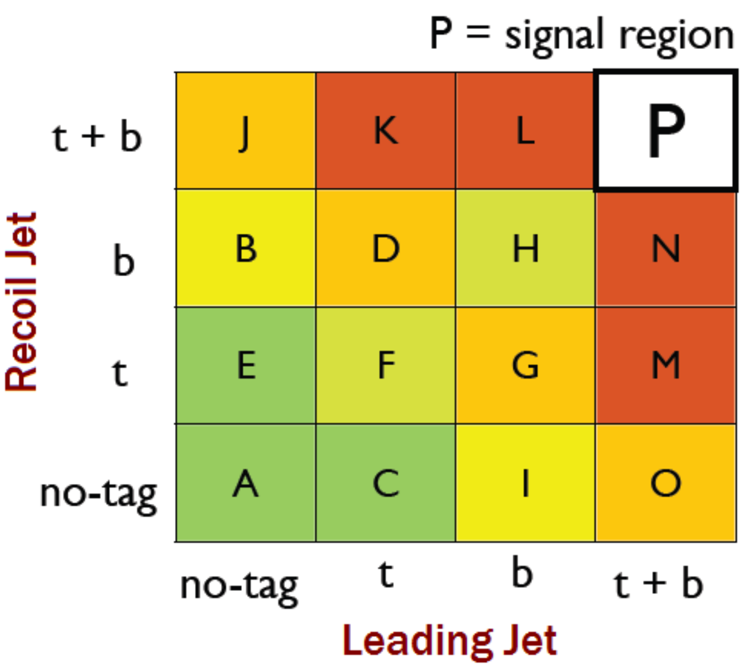
$$\frac{\mathrm{d}n_Z}{\mathrm{d}m_{t\bar{t}}} = \left(\frac{1}{n_U} \times \frac{\mathrm{d}n_V}{\mathrm{d}m_{t\bar{t}}} + \frac{1}{n_W} \times \frac{\mathrm{d}n_X}{\mathrm{d}m_{t\bar{t}}}\right) \times \frac{n_Y}{2},$$

With *n* the expected number of multijet events in a given region

Full-hadronic ttbar resonance

[JHEP01(2013)116]

- **Background estimation**
  - TopTemplate Tagger
    - Using several control regions: based on number of top-tagged and b-tagged jets



- **Ttbar estimation**
  - Using MC prediction

- **Multijet background estimation**

$$K' = N_J \times \frac{N_F}{N_E}$$

$$M' = N_F \times \frac{N_O}{N_C}$$

$$P' = K' \times \frac{M'}{N_F} = \frac{N_J \times N_O \times N_F}{N_E \times N_C}$$

Single lepton ttbar resonances

[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]

- **Background estimation**
  - Mostly MC-based (single-top, Z+jets, ttbar)
  - Two remaining backgrounds are estimeted / normalised according to data:
    - **W+jets background**
      - MC prediction used for the shapes for the different samples (W+light flavours and heavy flavours).
      - Each of them normalized using data observation in W+jets enriched region (w/ w/o the b-tagging requirement).
      - Global normalisation applied using the charge asymmetry.

$$N_{W^+} + N_{W^-} = \left(\frac{r_{\mathrm{MC}} + 1}{r_{\mathrm{MC}} - 1}\right)(D_{\mathrm{corr}+} - D_{\mathrm{corr}-}),$$

    - **Multijet background**
      - Using the matrix method.

Single lepton ttbar resonances

[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]

- **Reconstruction of ttbar pairs**

$$\chi^2 = \left[\frac{m_{jj} - m_W}{\sigma_W}\right]^2 + \left[\frac{m_{jjb} - m_{jj} - m_{t_h - W}}{\sigma_{t_h - W}}\right]^2 + \left[\frac{m_{j\ell\nu} - m_{t_\ell}}{\sigma_{t_\ell}}\right]^2 + \left[\frac{(p_{\mathrm{T},jjb} - p_{\mathrm{T},j\ell\nu}) - (p_{\mathrm{T},t_h} - p_{\mathrm{T},t_\ell})}{\sigma_{\mathrm{diff}\,p_\mathrm{T}}}\right]^2,$$

Fully-resolved

$$\chi^2 = \left[\frac{m_{jJ} - m_{jJ}^{t_h}}{\sigma_{jJ}^{t_h}}\right]^2 + \left[\frac{m_{j\ell\nu} - m_{t_\ell}}{\sigma_{t_\ell}}\right]^2 + \left[\frac{(p_{\mathrm{T},jJ} - p_{\mathrm{T},j\ell\nu}) - (p_{\mathrm{T},t_h} - p_{\mathrm{T},t_\ell})}{\sigma_{\mathrm{diff}\,p_\mathrm{T}}}\right]^2,$$

Semi-boosted

Single lepton ttbar resonances

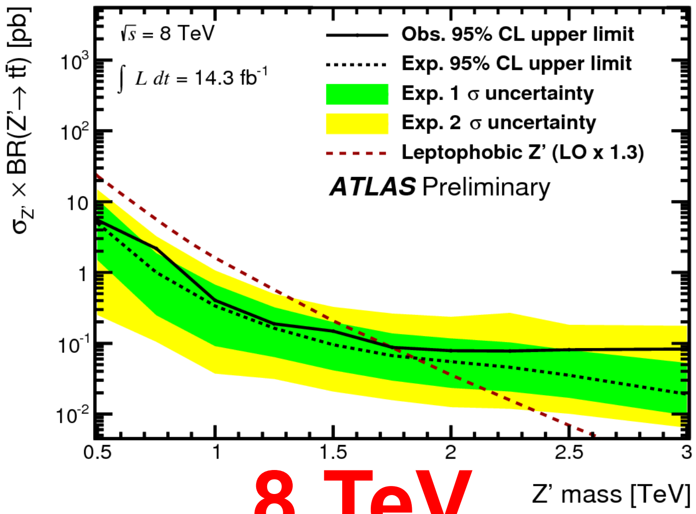
[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]

- **Systematic uncertainties**

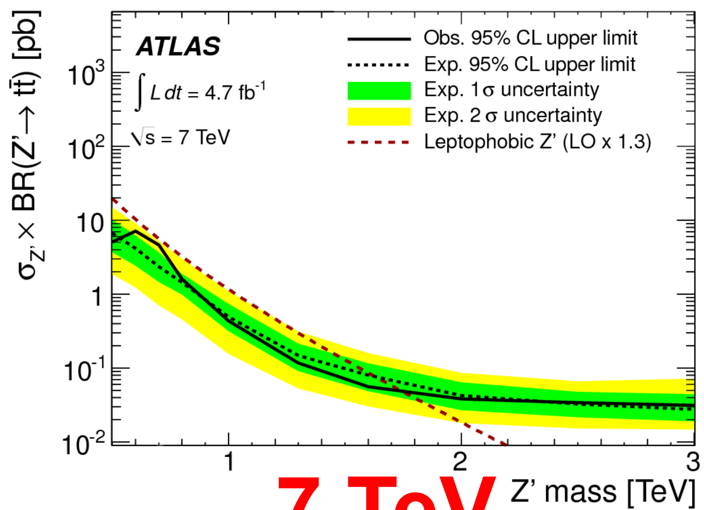
Systematic Uncertainties	Resolved selection yield impact [%] total bkg.	Resolved selection yield impact [%] Z'	Boosted selection yield impact [%] total bkg.	Boosted selection yield impact [%] Z'
Luminosity	2.9	4	3.3	4
PDF	2.9	5	6	2.9
ISR/FSR	0.2	–	0.7	–
Parton shower and fragm.	5	–	4	–
$t\bar{t}$ normalization	8	–	9	–
$t\bar{t}$ EW virtual correction	2.2	–	4	–
$t\bar{t}$ Generator	1.5	–	1.6	–
W+jets $b\bar{b}$+$c\bar{c}$+c vs. light	0.8	–	1.0	–
W+jets $b\bar{b}$ variation	0.2	–	0.4	–
W+jets c variation	1.1	–	0.6	–
W+jets normalization	2.1	–	1.0	–
Multi-Jet norm, e+jets	0.6	–	0.3	–
Multi-Jet norm, μ+jets	1.8	–	0.3	–
JES, small-radius jets	6	2.2	0.7	0.5
JES+JMS, large-radius jets	0.3	4	17	3.3
Jet energy resolution	1.6	0.4	0.6	0.7
Jet vertex fraction	1.7	2.3	2.1	2.4
b-tag efficiency	4	1.8	3.4	6
c-tag efficiency	1.4	0.3	0.7	0.9
Mistag rate	0.7	0.3	0.7	0.1
Electron efficiency	1.0	1.1	1.0	1.0
Muon efficiency	1.5	1.5	1.6	1.6
All systematic uncertainties	14	9	22	9

Single lepton results @ 7 TeV vs 8 TeV

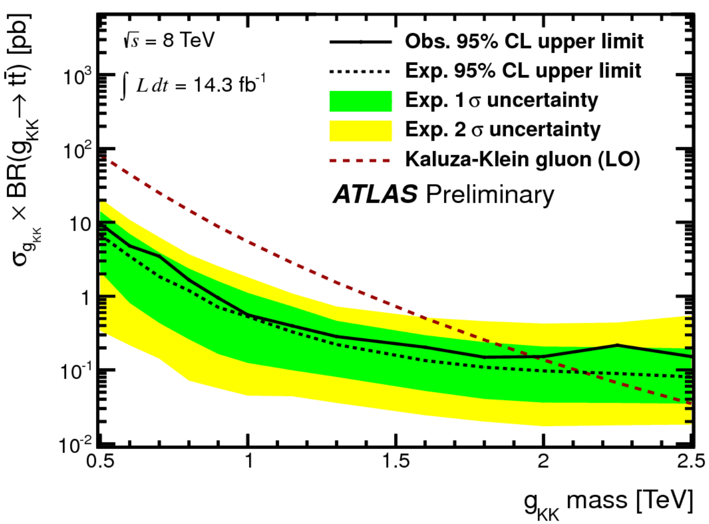
[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]

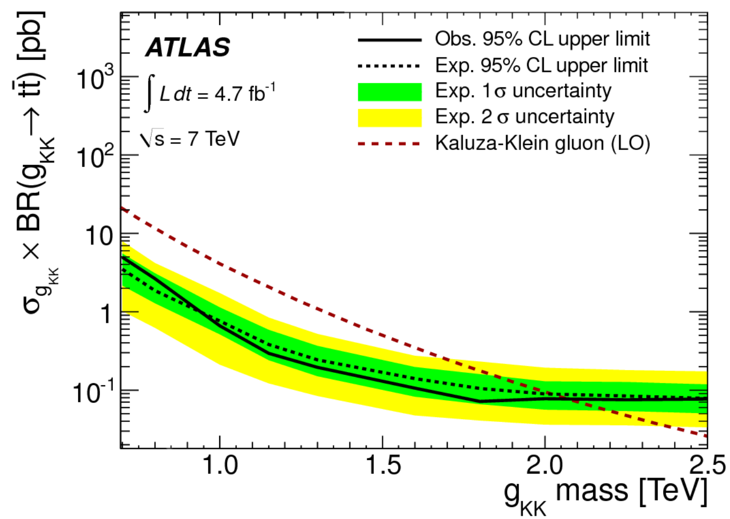


8 TeV



7 TeV

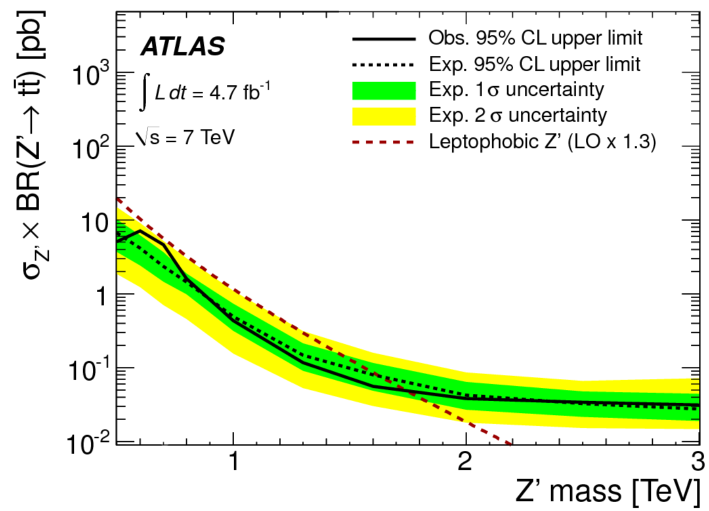




Single lepton vs Fully-hadronic @ 7 TeV

[ATLAS-CONF-2013-052] [PRD88,012004 (2013)]

Single lepton



Sample	Mass limits [TeV] 95 % CL limits
Z'	0.70 – 1.00 1.28 – 1.32
g_{KK}	0.70 – 1.62

Full-hadronic