ATLAS $t\bar{t}$ resonance searches

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on behalf of the ATLAS collaboration

ICHEP, Melbourne, July 2012

motivation

The top quark is special in many extensions of the Standard Model

The LHC produces high-mass $t\bar{t}$ pairs at an unprecedented rate

Search for signatures of new physics in the $t\bar{t}$ mass spectrum

- narrow (Γ/m~1.2%) resonance; leptophobic Z'
  Phys. Rev. D 49 (1994) 4454, hep-ph/9911288.
- broad (Γ/m~15%), colored resonance; KK gluon
  Phys. Rev. D 77 (2008) 015003, Phys. Rev. D 76 (2007) 115016, JHEP 09 (2007) 074

Results on 7 TeV pp data from:

di–lepton (ℓ = e,μ → BR ~ 5%)

1.04/fb ATLAS-CONF-2011-123

- *2.04/fb, Eur. Phys. J. C, arXiv:1205.5371 [hep-ex]*

lepton+jets (ℓ = e,μ → BR ~ 30%)

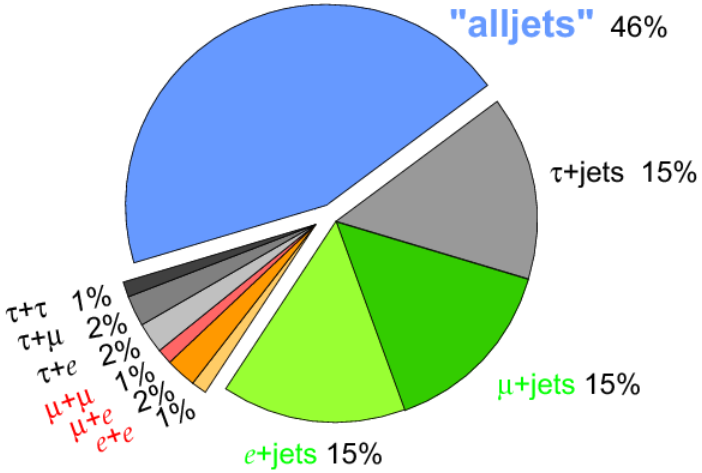
- classical/resolved

200/pb, ATLAS-CONF-2011-087

2.04/fb, Eur. Phys. J. C, arXiv:1205.5371 [hep-ex]

- boosted

2.04/fb preliminary results



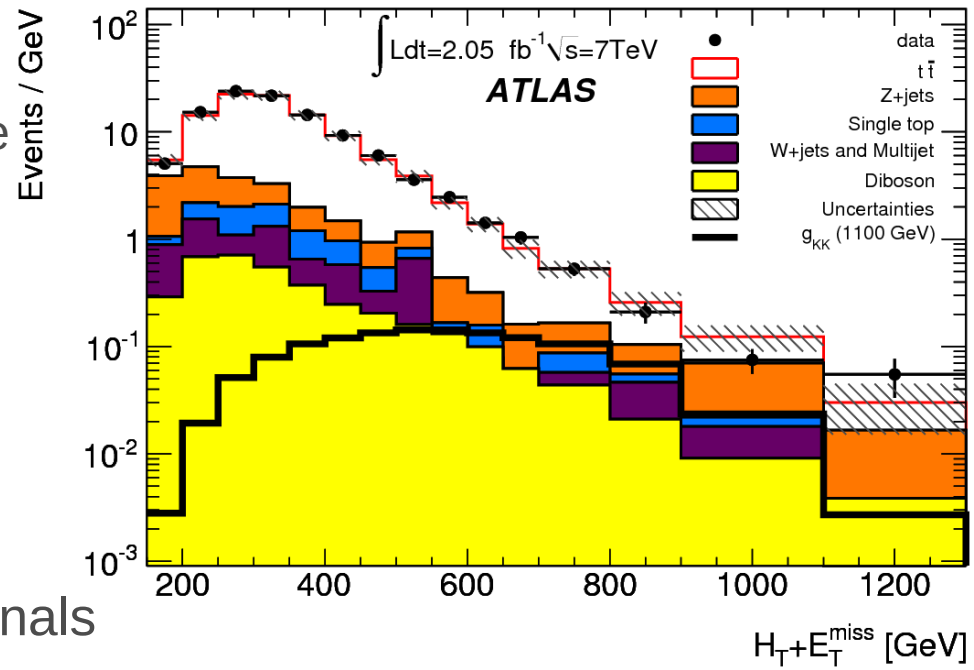
Dilepton (ee, eμ, $\mu\mu$)

Lepton (e/μ) + jets

Dilepton final state

Selection:

- 2 isolated leptons, opposite charge
- ≥2 jets with p_T > 25 GeV
- $|m_Z - m_{ll}|$ < 10 GeV
- E_T^{miss} > 40 GeV
- m_{ll} > 10 GeV



Acceptance x efficiency x BR:

~ 1.3 - 1.5% for benchmark signals

Backgrounds:

Drell-Yan MC normalized in a data control sample orthogonal to the signal sample

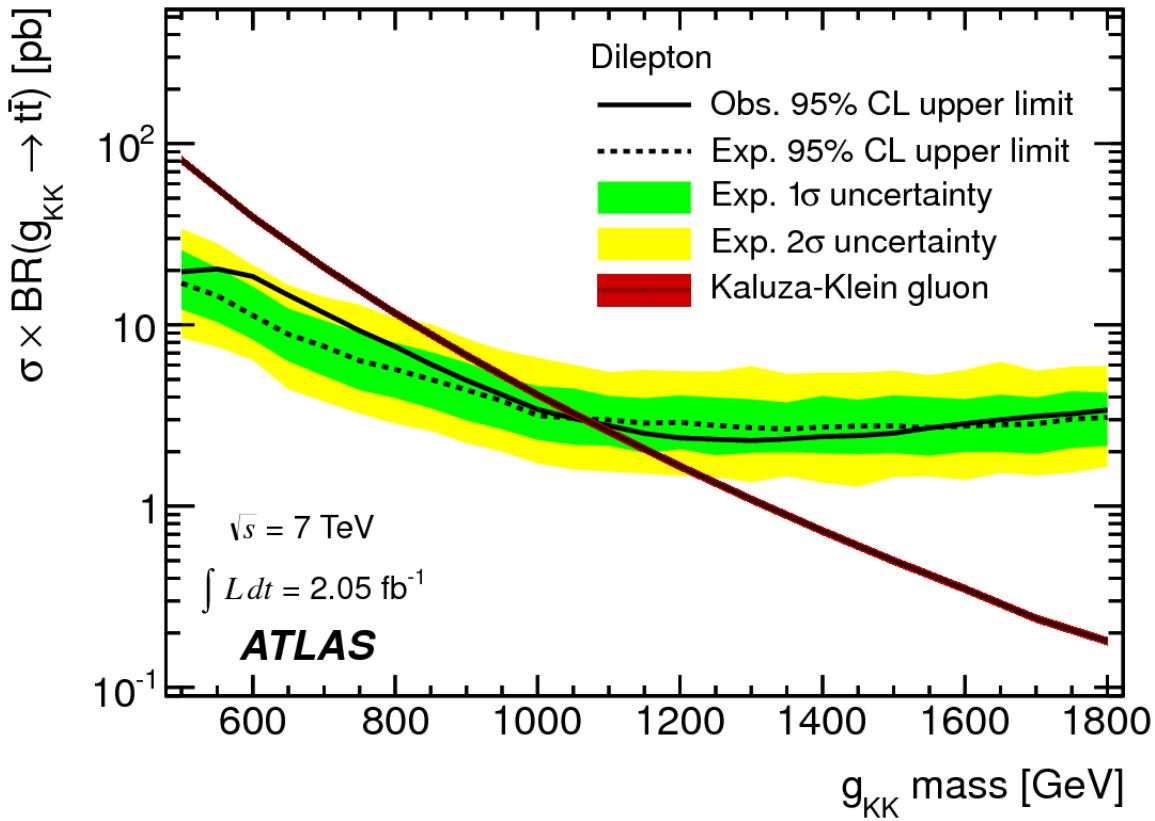
Reconstruction:

Two undetected neutrinos. Use effective mass: $H_T+E_T^{miss}$, where $H_T = \Sigma\, p_T$

dilepton final state

No significant deviations from the Standard Model

95% C.L. upper limits on σ x BR as a function of mass (Bayesian approach): m (g_{KK}) > 1080 GeV



32 systematic uncertainties

→ each has a small impact (<15%) on σxBR limits

→ sensitivity degraded by a factor 1.5 – 3 wrt stat. only

Sensitivity limited by branching fraction and mass resolution

→ less of a disadvantage for broad resonances

lepton+jets (classical)

Selection:

isolated e/μ

≥ 4 jets

(3 if m_j > 60 GeV)

≥ 1 b-tagged jet

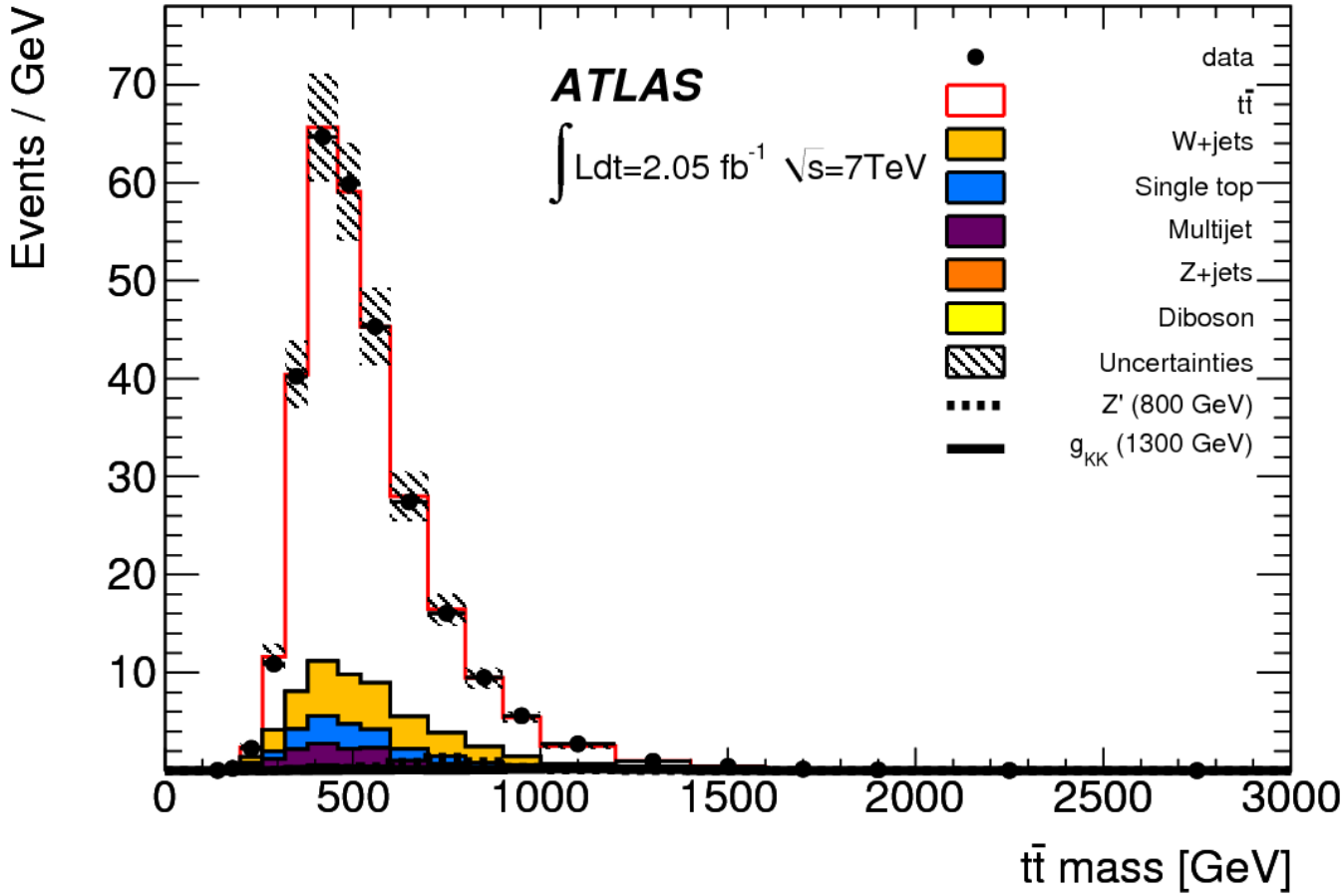
BG composition:

80% $t\bar{t}$ pairs

Signal acc x eff x BR:

~ 7%

(m~0.7 – 1.3 TeV)



Backgrounds:

Multijets from data with low-quality leptons

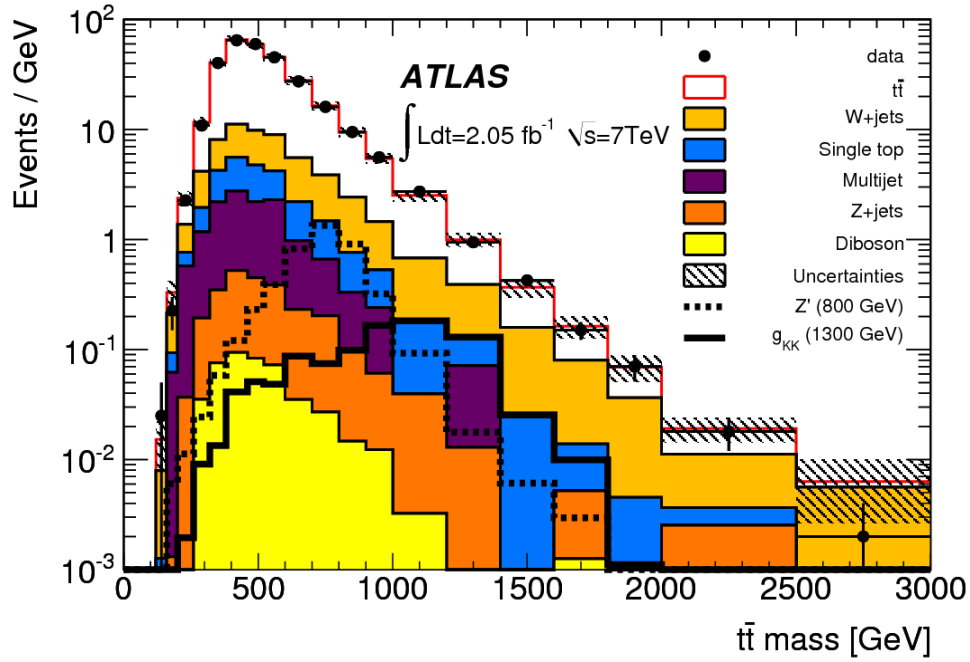
W+jets normalized using charge asymmetry

lepton+jets (classical)

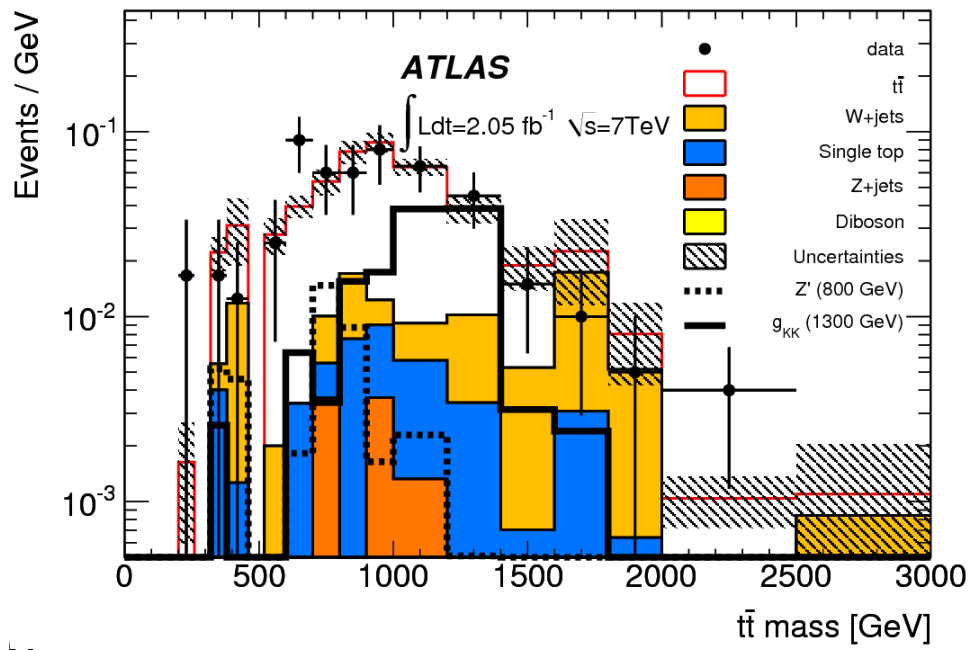
Reconstruction:

4 (3) highest p_T jets
+ lepton
+ neutrino
ISR mitigation scheme

Good mass resolution (10-15%)



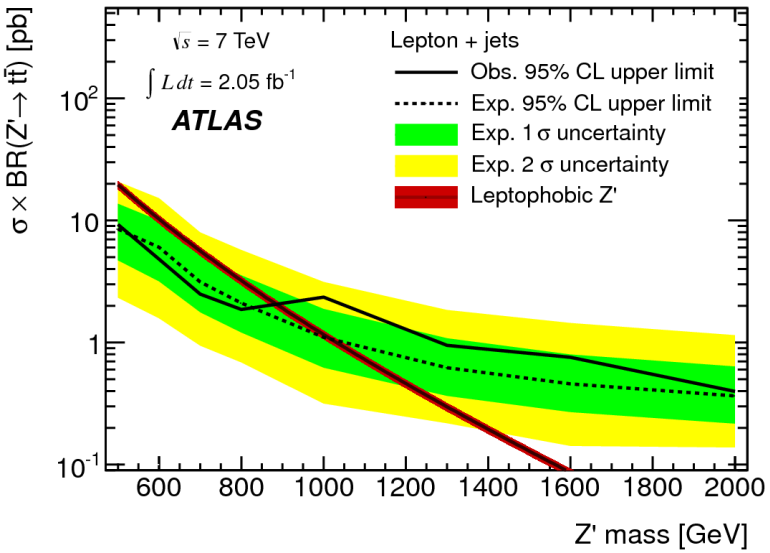
Semi-boosted analysis: special high-mass region has ~1% of background events, but can have a large signal contribution



lepton+jets (classical)

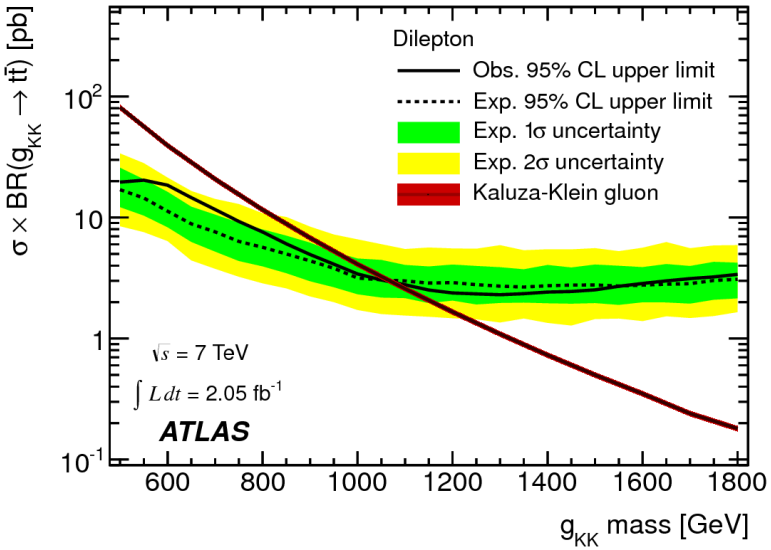
No sign of new physics → 95% C.L. limits on σ x BR using the same tools as di-lepton search

Interpretation in terms of a narrow leptophobic Z' in topcolor models and the KK gluon. Limits on the σ x BR of broad resonances are slightly weaker.



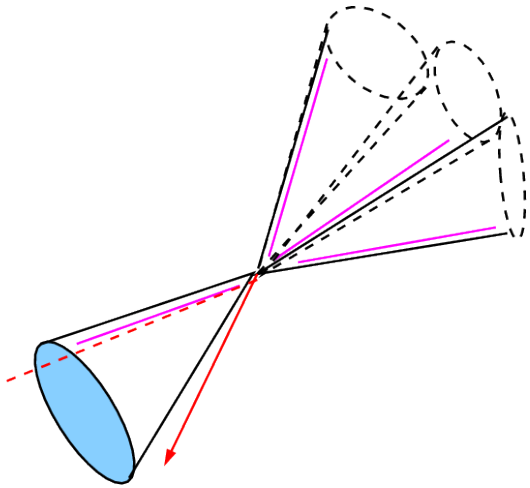
95% C.L. excluded rate:
σ x BR < 9.3 pb at m = 500 GeV
σ x BR < 0.95 pb at m = 1300 GeV

95% C.L. excluded mass ranges:
500 GeV < m(Z') < 880 GeV
500 GeV < m(g_{KK}) < 1130 GeV



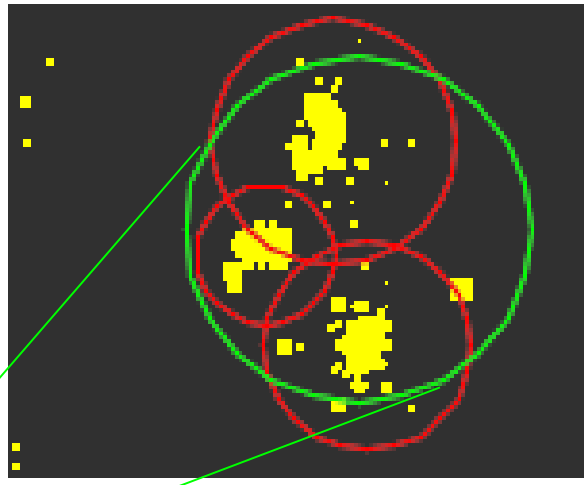
top quarks in a new kinematic regime

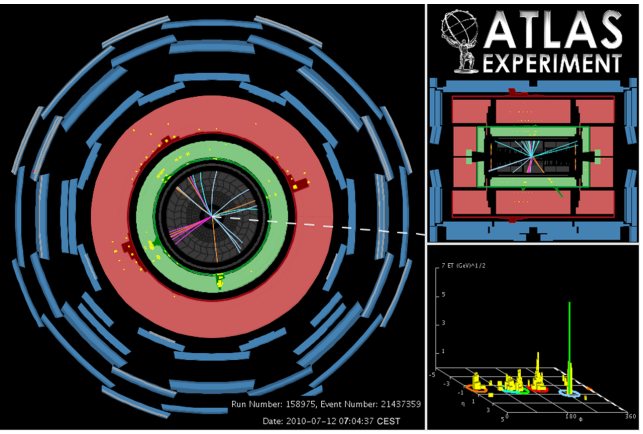
A graphical account of the argument for a dedicated reconstruction algorithm for boosted top quarks, using landmark ATLAS events

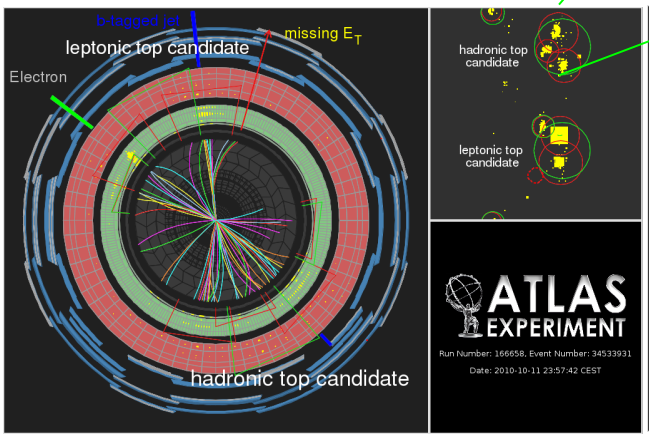


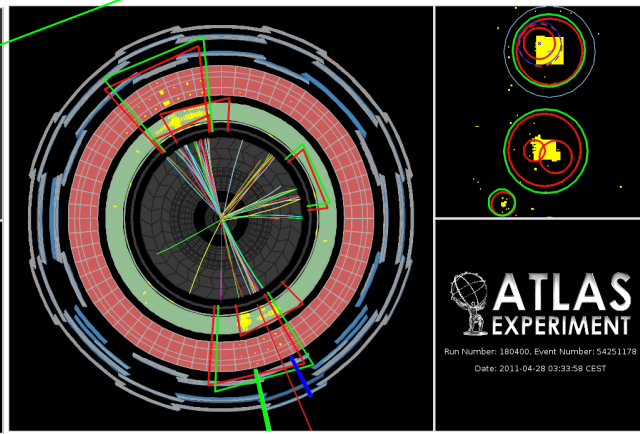
Reconstruct as a “fat” jet with R=1
Tag using jet substructure

Observed:	Naive expectation
m_j = 197 GeV	> m_t
sqrt(d_{12}) = 110 GeV	~ m_W
sqrt(d_{23}) = 40 GeV	...







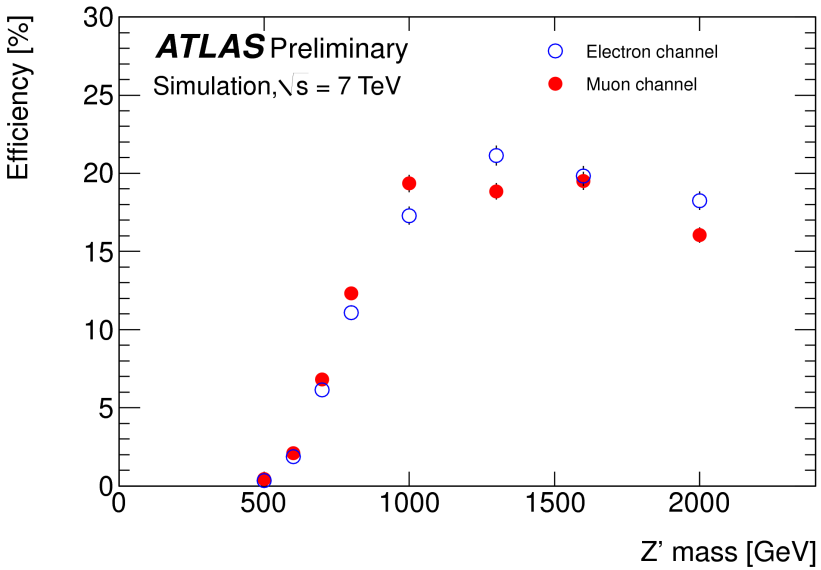


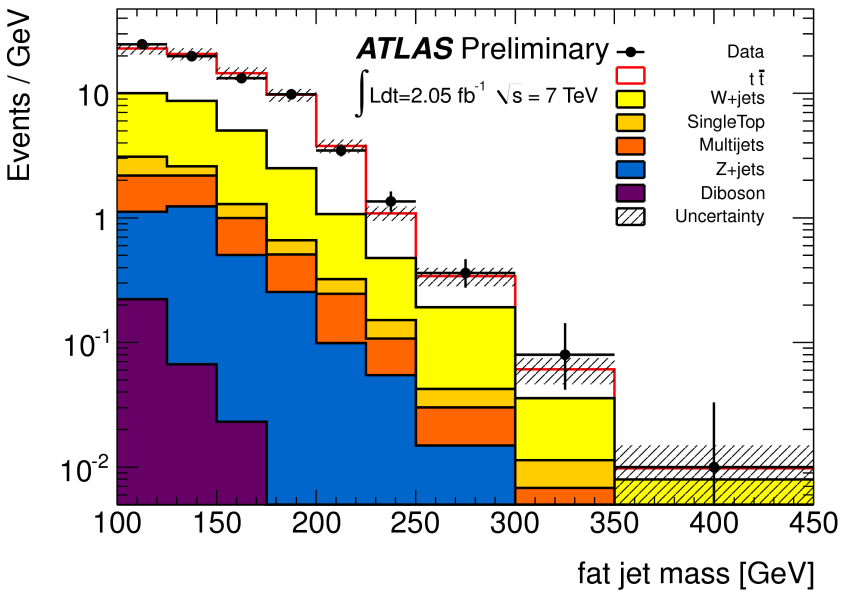
Early “l+jets” candidate
ATLAS-CONF-2010-063

First boosted top quark candidate
ATLAS-CONF-2011-073

m_{tt} > 1 TeV
ATLAS-CONF-2011-083

lepton+jets (boosted)





Lepton selection identical to previous analysis (future: ATL-PHYS-PUB-2010-008)

Semi-leptonic top candidate = lepton + neutrino + jet closest to lepton

Hadronic top candidate
= "fat" jet (anti-k_t, R=1)

$p_T > 250$ GeV

$m_j > 100$ GeV

(= invariant mass of 4-vector sum of jet constituents)

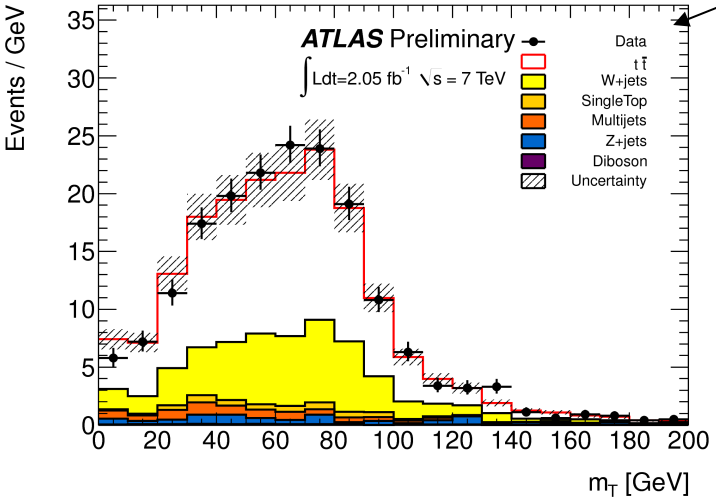
$\sqrt{d_{12}} > 40$ GeV

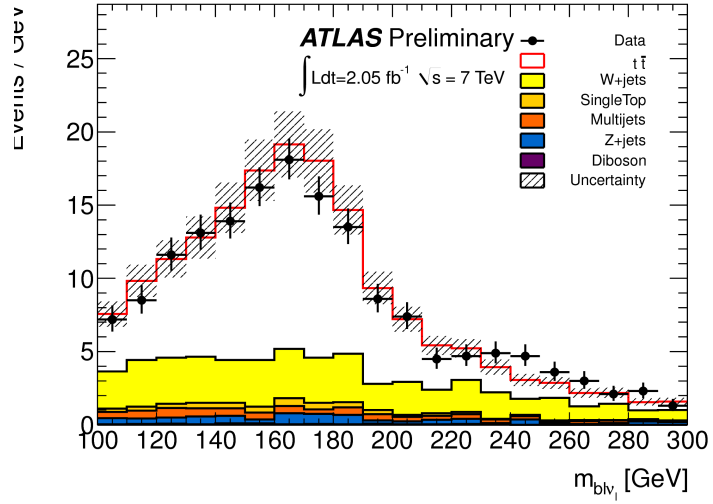
(= first k_t splitting scale of jet constituents)

See also: Bertrand Chapleau's contribution to this conference and JHEP 1205 (2012) 128

lepton+jets (boosted)

Transverse mass of the lν system



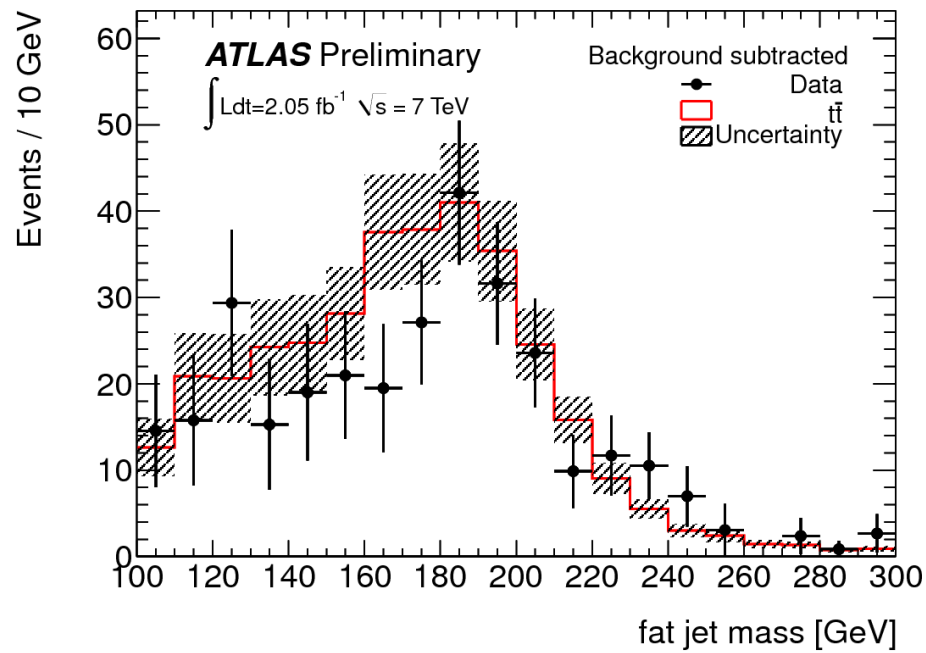


Mass of the blν system

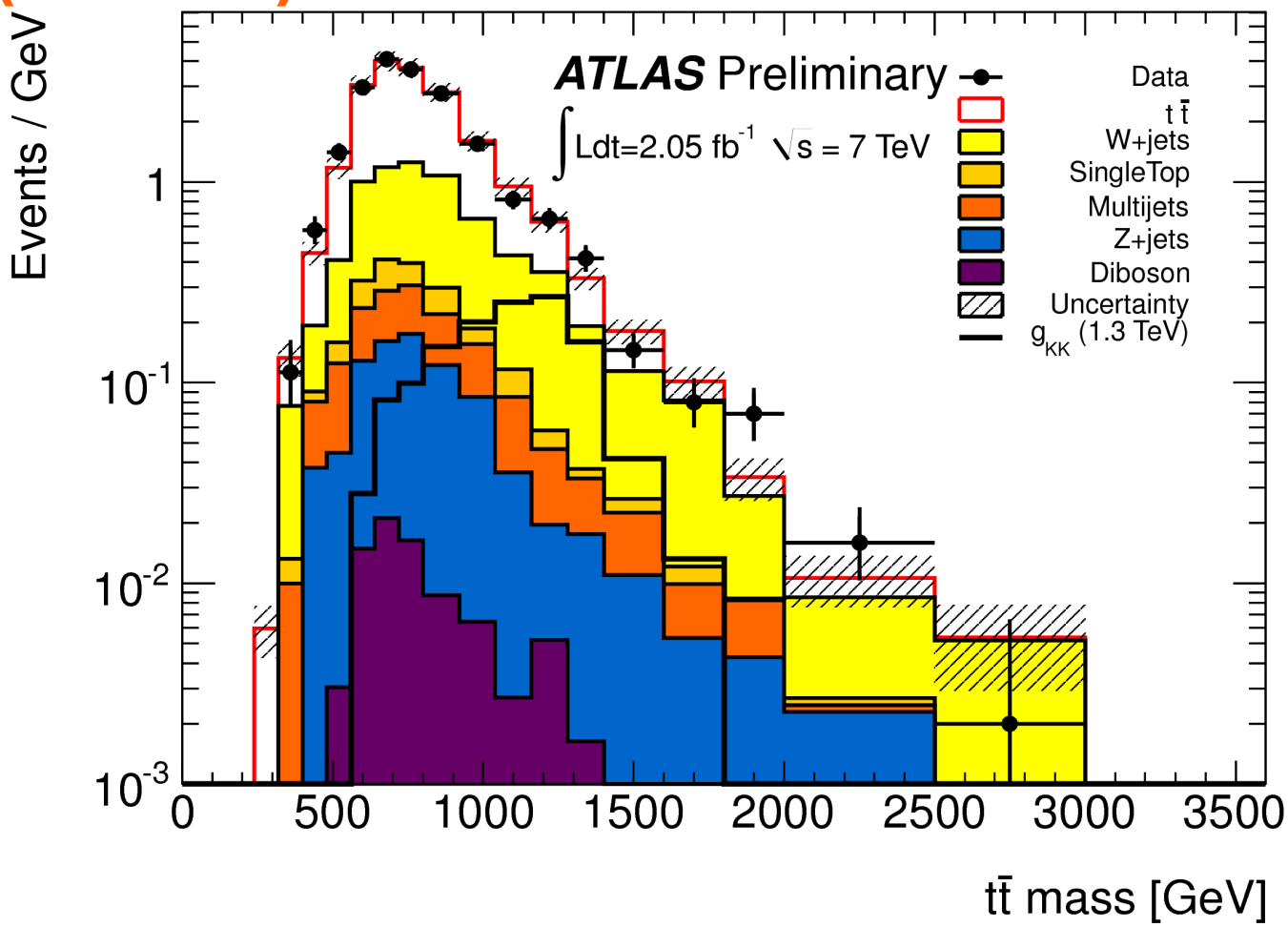
Shape of kinematic distributions corroborates background composition from data/MC

Jet mass distribution for anti-k_t R=1 jets selected as hadronic top candidates with pT > 350 GeV

Mass response for “fat” jets reasonably well described



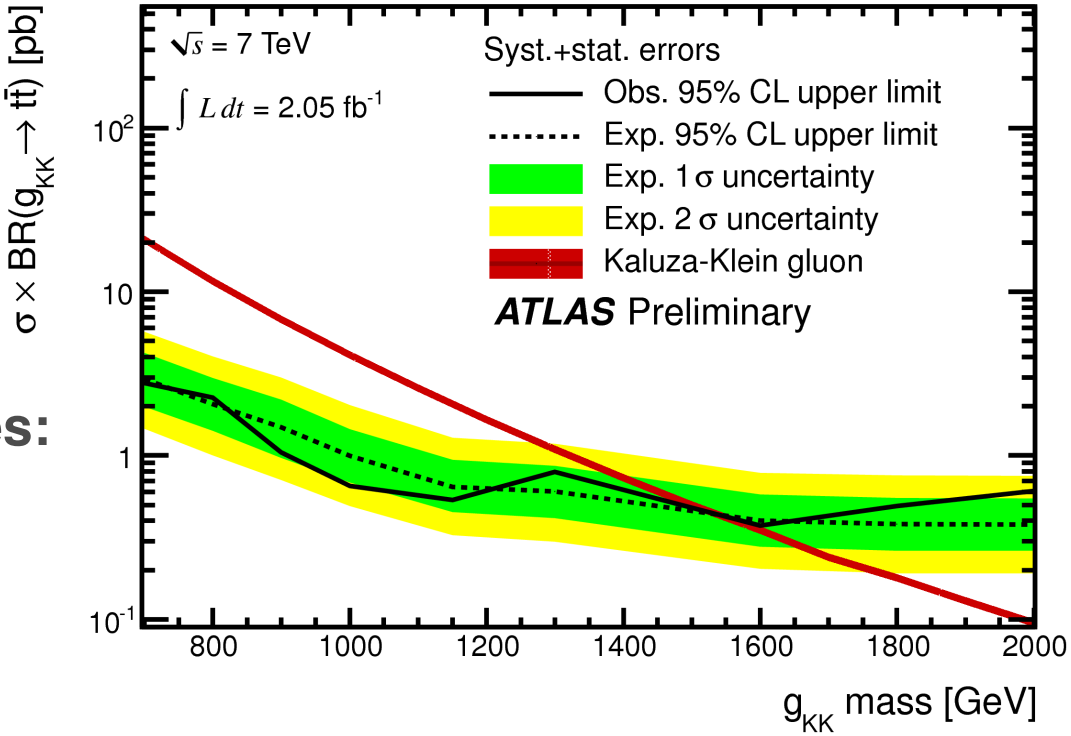
lepton+jets (boosted)



$t\bar{t}$ mass spectrum combining electron+jets and muon+jets channels compared to a SM template from data and MC

Very good agreement with SM: Largest excess (BumpHunter) ~ 1.4 σ

lepton+jets (boosted)



95% C.L. excluded mass ranges:
Leptophobic Z': m < 1.2 TeV
KK gluon: m < 1.5 TeV

30 sources of systematic uncertainty on yield and shape of background and signal

Jet energy and mass scale (5-7%) has the largest impact on the sensitivity

Impact of pile-up on jet mass is fairly well modeled

Comparison of sensitivity

Expected g_{KK} limit @ 600 GeV

ATLAS Dilepton: 11.3 pb

ATLAS Classical: 6.0 pb

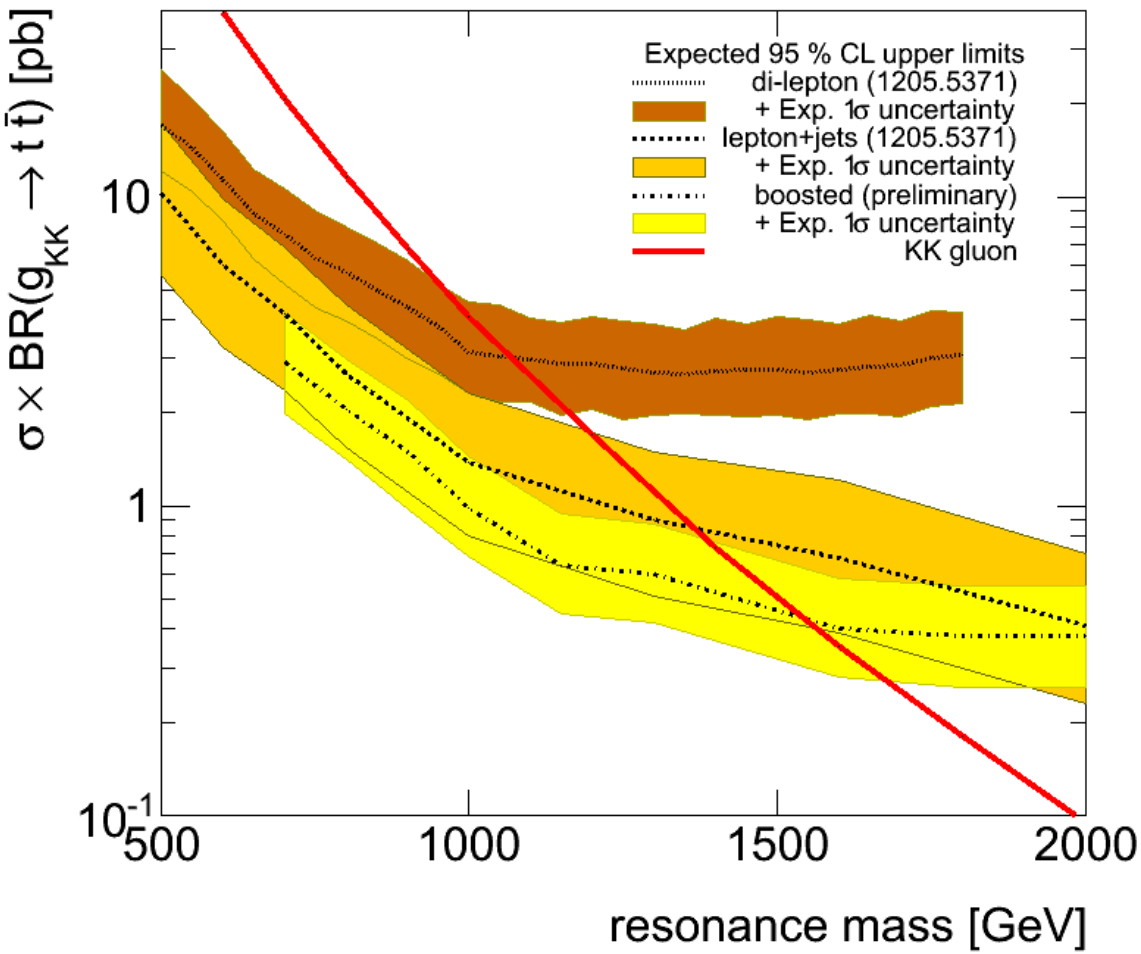
ATLAS Boosted: -

Expected g_{KK} limit @ 1.6 TeV

ATLAS Dilepton: 2.8 pb

ATLAS Classical: 0.68 pb

ATLAS Boosted: 0.40 pb



Summary

ATLAS $t\bar{t}$ resonance searches on dilepton and lepton + jets final states with 2.05/fb provide sensitivity from production threshold and well into the TeV regime

No significant deviations from the Standard Model → competitive limits on new massive states

Classical and boosted algorithms have complementary sensitivity: the boosted analysis clearly enhances the ATLAS sensitivity for m > 1 TeV