ATLAS $t\bar{t}$ resonance searches

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on behalf of the ATLAS collaboration

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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 ($\Gamma/m\sim1.2\%$) resonance; leptophobic $Z'$
- broad ($\Gamma/m\sim15\%$), colored resonance; KK gluon

Results on 7 TeV pp data from:
di–lepton ($\ell = e,\mu \rightarrow \text{BR} \sim 5\%$)
  1.04/fb ATLAS-CONF-2011-123
lepton+jets ($\ell = e,\mu \rightarrow \text{BR} \sim 30\%$)
- classical/resolved
  200/pb, ATLAS-CONF-2011-087
- boosted
  2.04/fb preliminary results

Dilepton (ee, $e\mu$, $\mu\mu$)
Lepton ($e/\mu$) + jets
Dilepton final state

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

Acceptance $\times$ efficiency $\times$ BR:
$\sim 1.3 - 1.5\%$ 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: $H_T + E_T^{\text{miss}}$, where $H_T = \Sigma p_T$
dilepton final state

No significant deviations from the Standard Model

95% C.L. upper limits on $\sigma \times \text{BR}$ as a function of mass (Bayesian approach):

$m (g_{KK}) > 1080 \text{ GeV}$

32 systematic uncertainties

→ each has a small impact ($< 15\%$) on $\sigma \times \text{BR}$ 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

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lepton+jets (classical)

Selection:
isolated e/μ
≥ 4 jets
  (3 if $m_j > 60$ GeV)
≥ 1 b-tagged jet

BG composition:
80% t$t$ 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 $\sim$1% of background events, but can have a large signal contribution
lepton+jets (classical)

No sign of new physics → 95% C.L.
limits on $\sigma \times \text{BR}$ 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 $\sigma \times \text{BR}$ of broad resonances are slightly weaker.

95% C.L. excluded rate:
$\sigma \times \text{BR} < 9.3$ pb at $m = 500$ GeV
$\sigma \times \text{BR} < 0.95$ 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

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Observed:

- $m_j = 197$ GeV
- $\sqrt{d_{12}} = 110$ GeV
- $\sqrt{d_{23}} = 40$ GeV

Naive expectation:

- $m_t > m_t$
- $\sqrt{d_{12}} \approx m_W$

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Early “l+jets” candidate
ATLAS-CONF-2010-063
ICHEP, july 2012

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

$\mathbf{m_{tt} > 1 \, \text{TeV}}$
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
- $\sqrt{d_{12}} > 40$ GeV

See also: Bertrand Chapleau's contribution to this conference and JHEP 1205 (2012) 128
**lepton+jets (boosted)**

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 $p_T > 350$ GeV.

Mass response for “fat” jets reasonably well described.

**Transverse mass of the $l\nu$ system**

**Mass of the $bl\nu$ system**
lepton+jets (boosted)

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

Very good agreement with SM: Largest excess (BumpHunter) \( \sim 1.4 \, \sigma \)
**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 $\rightarrow$ 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.