

SEARCH FOR PHYSICS BEYOND THE STANDARD MODEL WITH TOP QUARKS AT ATLAS

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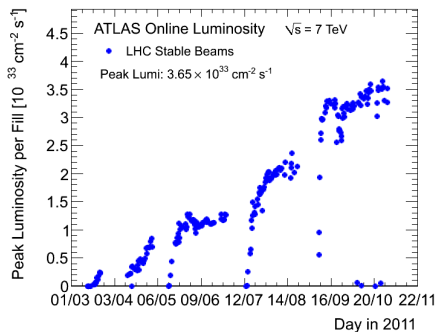
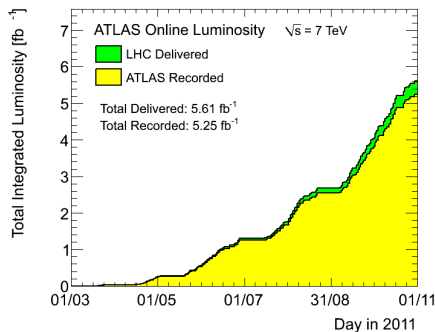
Motivation:

- Large top (t) mass, close to scale of electroweak (EW) symmetry breaking
- LHC is a top factory. Top pair ($t\bar{t}$) production cross section: $\simeq 177$ pb
- Experimental excess on $t\bar{t}$ A_{FB} measurement at the Tevatron

Outline:

- Luminosity at ATLAS
- Top pairs and top quark decays
- Search for $t\bar{t}$ resonances in the di-lepton channel
- Search for $t\bar{t}$ resonances in the lepton plus jets channel
- Search for new physics in $t\bar{t}$ events with large missing transverse momentum ($\cancel{E}_T$)
- Search for same-sign top quark (tt) production

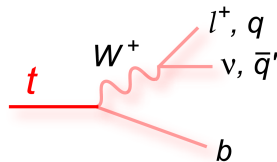
Luminosity at ATLAS



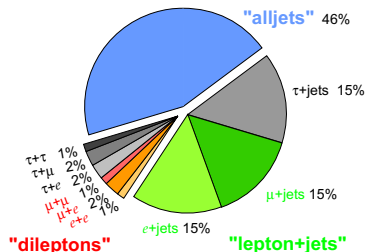
- The instantaneous luminosity has been increasing significantly
- The integrated luminosity recorded at ATLAS has reached 5.3 fb^{-1} (5.6 fb^{-1} delivered) in 2011
- Analyses shown today include integrated luminosities from 1 to 2 fb^{-1}

Top pairs and top quark decays

- Top quark may decay leptonically or hadronically
- Top pairs ($t\bar{t}$) signatures:
 - di-lepton: low branching ratio (Br), low background
 - lepton+jets: compromise between Br and background
 - all jets: large Br and large multi-jet background



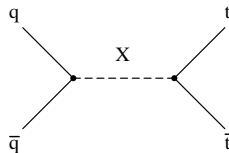
Top Pair Branching Fractions



Search for $t\bar{t}$ resonances in the di-lepton channel

- Preliminary result, August 2011
[ATLAS-CONF-2011-123]
- $\mathcal{L} = 1.04 \text{ fb}^{-1}$
- $t\bar{t}$ decay: di-leptonic
($t \rightarrow Wb \rightarrow \ell\nu b$)
- 3 channels: ee , $e\mu$, $\mu\mu$
- Main observable: $H_T + \cancel{E}_T$
with $H_T = \sum_{\ell} p_T^{\ell} + \sum_{jets} p_T^{jet}$
- Event selection:
 - ≥ 2 jets and $= 2$ OS leptons
 - $|m_Z - m_{\ell\ell}| > 10 \text{ GeV}$
 - $\cancel{E}_T > 40 \text{ GeV}$
 - $H_T > 130 \text{ GeV}$ in $e\mu$ channel

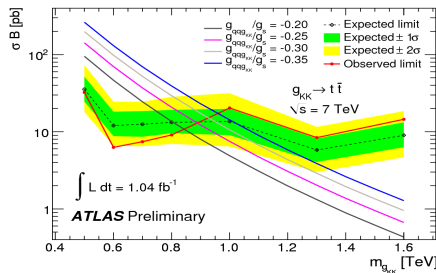
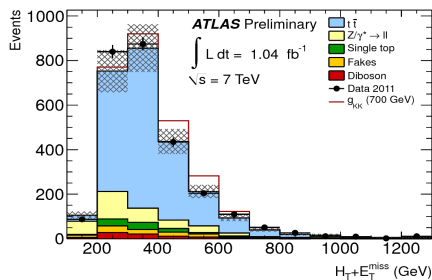
- Production of top pairs via an unknown mediator X at the LHC (e.g.: Z' , g_{KK}):



- Main backgrounds:
 - $t\bar{t}$, single top (MC@NLO)
 - $Z/\gamma^* \rightarrow \ell\ell$ (ALPGEN)
 - $\ell \in \{e, \mu\}$ for same-flavor channel
 - $\ell = \tau$ for $e\mu$ channel
 - Normalization to Data in control region with Z in its mass window

Search for $t\bar{t}$ resonances in the di-lepton channel

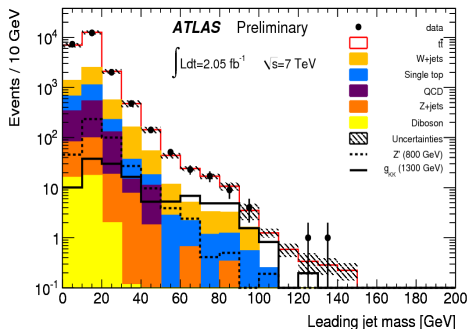
- Main systematics:
 - Signal ($m_{g_{KK}} = 1$ TeV): lepton efficiency (4.7%), jet calibration (up to 6.8%), ISR/FSR (4.5%)
 - SM background: generator (4.8%), jet calibration (7.4%), lepton efficiency (4.5%)
- Limits:
 - Derived from binned $H_T + \cancel{E}_T$ variable
 - Coupling $\frac{g_{qqg_{KK}}}{g_s}$ from 0.2 to 0.35
 - Observed lower bounds on $m_{g_{KK}}$ from 0.8 to 1.02 TeV



Search for $t\bar{t}$ resonances in the lepton plus jets channel

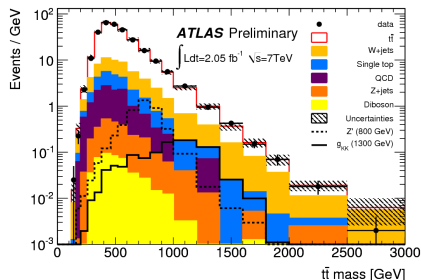
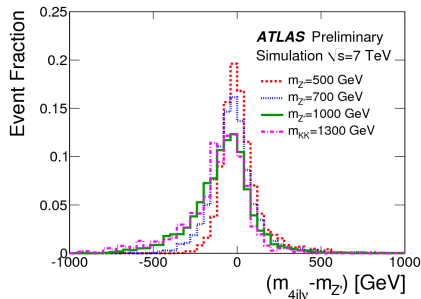
- Preliminary result, March 2012 [ATLAS-CONF-2012-029]
- $\mathcal{L} = 2.05 \text{ fb}^{-1}$
- $t\bar{t}$ decay: semi-leptonic
- 2 channels: $\ell \in \{e, \mu\}$
- Event selection:
 - e channel: $E_T > 35 \text{ GeV}$ and $m_T > 25 \text{ GeV}$
 - μ channel: $E_T > 20 \text{ GeV}$ and $E_T + m_T > 60 \text{ GeV}$
 - if any jet with $m_j > 60 \text{ GeV}$: $n_{\text{jets}} \geq 3$
 - if no jet with $m_j > 60 \text{ GeV}$: $n_{\text{jets}} \geq 4$
 - Leading jet fulfills: $p_T > 60 \text{ GeV}$
 - Require at least one b -tagged jet

- Main backgrounds:
 - $t\bar{t}$, single top (MC@NLO)
 - W+jets (ALPGEN and normalized to Data)
- QCD multi-jet (fake lepton) estimated using data-driven template



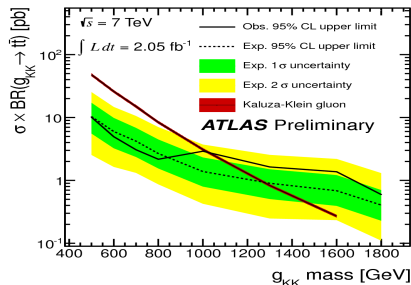
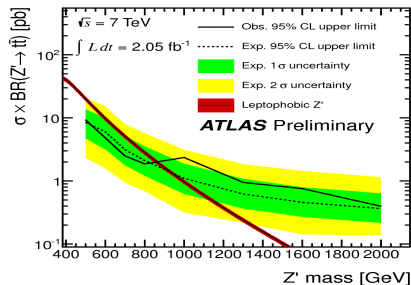
Search for $t\bar{t}$ resonances in the lepton plus jets channel

- $t\bar{t}$ mass reconstruction:
 - $m_{t\bar{t}}$ derived from lepton, E_T , and leading 3 or 4 jets
 - ν p_Z determined using W mass constraint
 - If no jet with $m_j > 60$ GeV: 3 or 4 jets considered are close to lepton or another jet (iterative procedure)
 - If jet with $m_j > 60$ GeV:
 - hadronic t formed by high-mass jet + closest jet
 - leptonic t formed by ℓ + closest jet



Search for $t\bar{t}$ resonances in the lepton plus jets channel

- Main systematics (none more than 15% of total):
 - Normalization: 1.5% (lepton efficiency) to 50% (QCD)
 - Signal/background shapes: 0.9%/0.8% (ISR/FSR) to 18.9%/16.5% (b -tagging)
- Scenarios for production of $t\bar{t}$:
 - narrow resonances: via leptophobic Z'
 - wide resonances: via Kaluza-Klein gluon g_{KK} (Randall-Sundrum models)
- Limits:
 - Derived from binned $m_{t\bar{t}}$ variable
 - $500 < \frac{m_{Z'}}{\text{GeV}} < 860$
 - $500 < \frac{m_{g_{KK}}}{\text{GeV}} < 1025$



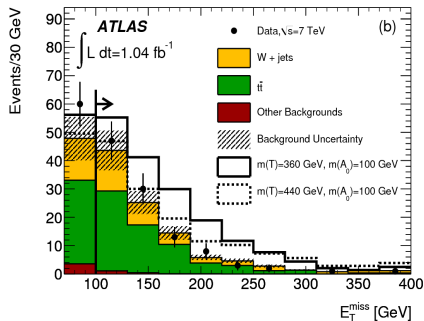
Search for new phenomena in $t\bar{t}$ events with large $\cancel{E}_T$

- Published [PRL 108 (2012) 041805]
- $\mathcal{L} = 1.04 \text{ fb}^{-1}$
- Scenario: pair production of 4th generation quark (T) with: $T \rightarrow tA_0$
(A_0 is stable, neutral, weakly-interacting)

→ More 4th generation quark scenarios:
DIS 2012 contribution Id 200

- $t\bar{t}$ decay: semi-leptonic
- Event selection:
 - single lepton trigger
 - $n_{jets} \geq 4$
 - $\cancel{E}_T > 100 \text{ GeV}$ and $m_T(\ell, \cancel{E}_T) > 150 \text{ GeV}$
 - Veto events with additional lepton or isolated track (reduce single prong τ_h decay in $t\bar{t}$ events)

- Main backgrounds:
 - di-leptonic $t\bar{t}$ decay (ℓ missed or $\ell = \tau_h$)
 - single-lepton background: W +jets and semi-leptonic $t\bar{t}$ decay (normalization and shape data-driven)



Search for new phenomena in $t\bar{t}$ events with large E_T

• Main systematics:

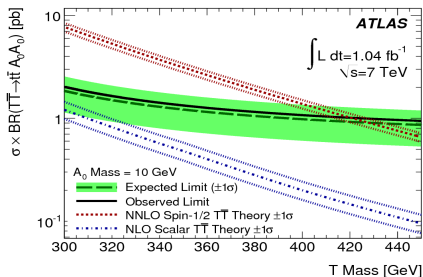
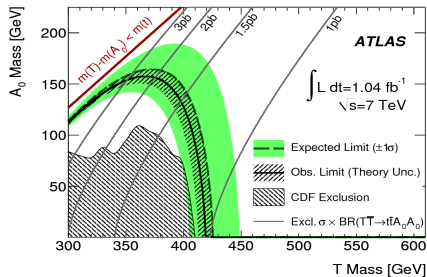
- Jet calibration in simulation: 11%
- Second lepton veto efficiency in di-lepton $t\bar{t}$: 10%
- Shape correction in data-driven single-lepton background: 15%
- Scale uncertainty and PDF in signal: 10 to 15%

• Limits:

- Assume $\text{Br}(T\bar{T} \rightarrow t\bar{t}A_0A_0) = 1$

⇒ Exclusions:

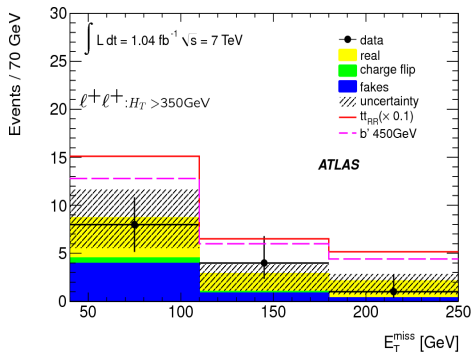
- $m_T < 420$ GeV for $m_{A_0} < 10$ GeV
- $330 < \frac{m_T}{\text{GeV}} < 390$ for $m_{A_0} < 140$ GeV
- $\sigma_{T\bar{T}}$ for spin- $\frac{1}{2}$ $T\bar{T}$ models below sensitivity (e.g.: $\tilde{t}/\chi_0$, LQ_3/ν_τ)



Search for same-sign top quark production

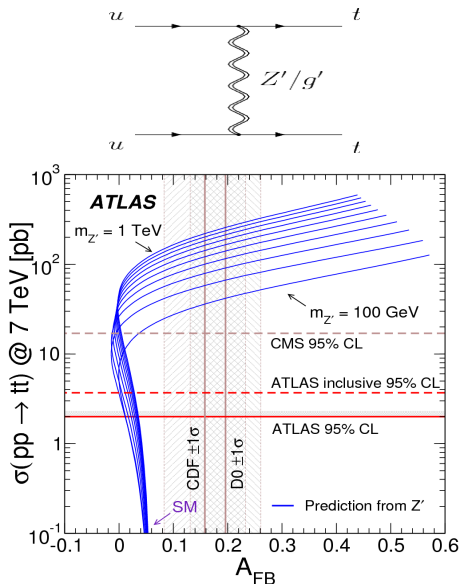
- Submitted to JHEP, February 2012
[arXiv:1202.5520]
- $\mathcal{L} = 1.04 \text{ fb}^{-1}$
- 2 leptonic t decays $\rightarrow$ same-sign di-lepton
- Analysis of ee and $\mu\mu$ channels
- Event selection:
 - 2 same-sign leptons with $m_{\ell\ell} > 15 \text{ GeV}$ and $|m_{\ell\ell} - m_Z| > 10 \text{ GeV}$
 - ≥ 2 jets
 - $\cancel{E}_T > 40 \text{ GeV}$
 - if $t\bar{t}$ via high-mass Z' : $H_T > 350 \text{ GeV}$
 - if $t\bar{t}$ via low-mass Z' : $H_T > 150 \text{ GeV}$ and $m_{\ell\ell} > 100 \text{ GeV}$

- Background:
 - fake ℓ : hadronic decays, photon conversion (data-driven)
 - charge mis-Id (data-driven)
 - W/Z di-boson (simulation)



Search for same-sign top quark production

- Possible scenario via vector boson (Z') coupling to u and t ($\bar{u}\bar{u} \rightarrow \bar{t}\bar{t}$ suppressed at high Bjorken- x)
- $t\bar{t}$ via Z' -mediated FCNC could explain Tevatron $t\bar{t}$ A_{FB} results (excess over SM)
- Main systematics (Signal/Background):
 - Jet calibration: 2.3%/7.1%
 - Electron efficiency: 4.2%/2.0%
 - Muon efficiency: 5.8%/3.0%
 - LAr calorimeter readout: 3.0%/2.0%
- Exclusions:
 - Heavy Z' mediator: $\sigma < 1.7$ pb
 - Light mediator: $\sigma < 1.4$ to 2.0 pb



Conclusion

- No evidence of new physics with top quark at ATLAS, but significant improvement of limits
- Results shown based on 1 to 2 fb⁻¹ and $\sqrt{s} = 7$ TeV
- More results to come with complete 2011 dataset (5 fb⁻¹)
- Prospects for 2012 Data: $\sqrt{s} = 8$ TeV
- For further details, see:
 - ATLAS Exotics results:
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults>
 - ATLAS Top results:
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults>