ATLAS results on inclusive top quark pair production cross section

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(on behalf of the ATLAS collaboration)

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ATLAS Online Luminosity

\[ \sqrt{s} = 7 \text{ TeV} \]

ATLAS and objects
dilepton (e,\(\mu\),\(\tau\))
lepton + jets
fully hadronic
additionnal results
The ATLAS detector

**Muon spectrometer (|η|<2.7):** air-cores toroids with gas-based chambers. Trigger and measurement. Momentum resolution <10% up to Eμ~1 TeV

**EM calorimeter (|η|<3.2):** Pb/LAr accordion. Trigger and e/γ reco and id. σ(E)/E~10%/√E (GeV)+0.7%

**HAD calorimeter (|η|<5):** Fe/scintillator tiles (central), Cu/W LAr (fwd). Trigger, jets and Etmiss. σ(E)/E~50%/√E (GeV)+3%

**Inner Detector (|η|<2.5):** Si pixel, SCT, TRT. Tracking and vertexing. e/π separation. σ(p_T)/p_T~0.038% p_T (GeV)+1.5%

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**Trigger:**
L1: hardware, L2-EF, ~200 Hz in output
Object reconstruction

To study top quark it implies good understanding of many different objects reconstructed in all different ATLAS subdetectors

<table>
<thead>
<tr>
<th>Muons</th>
<th>Tau (based on jets)</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>combined fitted tracks</td>
<td><strong>matched</strong> calo cluster + 1 or 3 tracks</td>
<td>matched track and EM cluster</td>
</tr>
<tr>
<td>tight identification</td>
<td><strong>identification</strong> using a BDT</td>
<td>tight identification using shower shape variables, ID</td>
</tr>
<tr>
<td>central:</td>
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<table>
<thead>
<tr>
<th>Jets</th>
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<tbody>
<tr>
<td>$k_T$-algorithm (R=0.4)</td>
</tr>
<tr>
<td>central: $</td>
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<table>
<thead>
<tr>
<th>Triggers</th>
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<tbody>
<tr>
<td>based on single lepton high $p_T$ or N jets</td>
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<table>
<thead>
<tr>
<th>$E_T^{\text{miss}}$</th>
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<tbody>
<tr>
<td>vector sum of energy in calorimeter cells, ID, spectro projected in transverse plane, associated with high $p_T$ object and dead material loss</td>
</tr>
<tr>
<td>$S_{ET\text{miss}} = E_{T\text{miss}}/(0.5 \times \sum E_T)$</td>
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<tr>
<th>b-tagging</th>
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<tbody>
<tr>
<td>long lifetime of B hadrons: NN based on impact parameter, secondary vertex, fragmentation properties, resonance mass</td>
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</table>
Top quark production and decays

Production mechanism

☆ $t\bar{t}$ pair, 85% by gluon fusion, ~15% by $q\bar{q}$ production
☆ single top (electroweak)

Predictions $\sqrt{s}=7$ TeV

$\sigma(pp \to t\bar{t})_{\text{NNLOapprox}} = 167^{+17}_{-18}$ pb


Top pair event classification according to $W$ decays

Branching ratio

Final state

Backgrounds

τ channels: 13.5% for $\tau$+jets and 6.3% for $\tau$+e/µ+jets
pair production with 2 leptons + jets

**Signature**: 2 isolated e/$\mu$ + $E_T^{miss}$ + jets (1b)

**Trigger**: 1 single isolated lepton  
**Offline**: opposite sign leptons + $E_T^{miss}$ >30 GeV, $\Sigma E_{T}(e\mu)$, $m_\ll$ (Z veto)

**Analysis Strategy**: counting experiment data driven estimation of Z+jets, W+jets and QCD backgrounds

$\sigma_{tt} = 176 \pm 5$ (stat) $^{+14}_{-11}$ (syst) $\pm 8$ (lumi) pb  

**Systematics**: in e$\mu$ : Jet/$E_T^{miss}$ (~4 pb), generator (~4.5 pb), fake lepton (~3 pb)
pair production with e/µ + τ + jets

**BR could be enhanced by the existence of H±**

**Signature:**
1 isolated e/µ + τ + \( E_T^{\text{miss}} \) + jets (1b)

**Trigger:** 1 single isolated lepton

**Offline:** opposite sign lepton + τ
\( E_T^{\text{miss}} > 30 \text{ GeV}, \sum E_T > 200 \text{ GeV}, \) 2 jets at least one of them is b-tagged

**Analysis Strategy:** perform template fit of BDT
- background distribution is different with jet flavor
- to reduce # of templates, SS events are subtracted to remove b, gluon originated τ candidates (charge symmetric)

\[
\sigma_{\tt (µ+τ)} = 186 \pm 15 \text{ (stat)} \pm 20 \text{ (syst)} \pm 7 \text{ (lumi)} \text{ pb} \\
\sigma_{\tt (e+τ)} = 187 \pm 18 \text{ (stat)} \pm 20 \text{ (syst)} \pm 7 \text{ (lumi)} \text{ pb} \\
\sigma_{\tt} = 186 \pm 13 \text{ (stat)} \pm 20 \text{ (syst)} \pm 7 \text{ (lumi)} \text{ pb}
\]

**Systematics:** b-tag (~9 pb), τ-ID (~4 pb)

overall precision ~14%, limited by systematic uncertainties
**Signature**: 1 isolated e/μ + E_{miss} + jets

**Analysis Strategy**: multivariate discriminant based on: η_{l}, p_{T,lead jet}, Aplanarity, H_{T,3p}
l-data driven estimation of Z+jets and QCD backgrounds
W+jets normalized to data

\[ \sigma_{\text{tt}} = 179.0 \pm 3.9 \text{ (stat)} \pm 9.0 \text{ (syst)} \pm 6.6 \text{ (lumi)} \text{ pb} \]

**Systematics**: generator (5.4 pb), muon (4.1 pb), lumi (6.6 pb)

**Overall precision ~6.5%**, limited by systematic uncertainties

**ATLAS Preliminary**

\[ 0.70 \text{ fb}^{-1} \]

**μ + Jets**

\[ \text{DATA 2011, } \sqrt{s} = 7 \text{ TeV} \]
pair production in hadronic modes

**Signature:**
no $E_T^{\text{miss}} + \text{jets (2b)}$

**Trigger:** 5 jets with $p_T > 30$ GeV

**Offline:** ≥ 5 jets with $p_T > 55$ GeV
and ≥ 2 b-tagged jet
- 6th jet with $p_T > 30$ GeV
- $S_{ETmiss} < 3$
- Kinematical likelihood fit to find correct association of jets to reconstruct $m_t$

**Signal and background modelling:**
data driven estimation of background
35% signal and 65% multijet by the pre-btagged sample in the data

**Analysis Strategy:**
Unbinned likelihood fit to $m_t$
$6 \leq \text{Njet} \leq 10$
$\chi^2$ for $m_t$ and $m_w$ is calculated and satisfy $\chi^2 < 30$

$\sigma_{tt} = 168 \pm 12 \text{ (stat)}^{+60}_{-57} \text{ (syst)} \pm 7 \text{ (lumi)} \text{ pb}$

**Systematics:** JES (+20, -17 pb), b-tagging (17 pb), ISR/FSR (17 pb)

overall precision ~37%, limited by systematic uncertainties
pair production in hadronic modes with $\tau$

~10% of all $tt$ events, BR enhanced by $H^\pm$

**Signature:**

$\tau_{had} + E_T^{miss} + \text{jets (2b)}$

**Trigger:** $\geq 4$ jets ($p_T > 10$ GeV @L1),

$\geq 2$ b-tagged at EF

**Offline:** $\geq 5$ jets, $\geq 2$ of them b-tagged

- $S_{ETmiss} > 4$
- 3 jets (one is b-tagged) with highest $p_T$ sum to be $m_{top}$
- select remaining non b-tagged jet with $p_T > 40$ GeV as $\tau$ candidate
- $e/\mu$ veto

**Analysis Strategy:** Fit to number of good quality tracks associated to tau lepton, with 3 templates

**Signal:** from $tt$ MC sample

**$tt$ combinatorics:** from $tt\mu + \text{jets}$ control region

**Multi-jet:** from $1.5 < S_{ETmiss} < 2$
control region

\[
\sigma_{tt} = 200 \pm 19 \, \text{(stat)} \pm 43 \, \text{(syst)} \, \text{pb}
\]

overall precision ~23%, limited by systematic uncertainties

**Systematics:** ISR/FSR (12 pb), b-tag (10 pb), Fit (7 pb)
Additional features of top pair production

\( \bar{t}t + \text{photon} \)

**Signature** : \( 1 \text{ e/}\mu + \mathbb{E}_T^{\text{miss}} + \text{jets (1b)} + \gamma \)

**Offline** : similar to lepton+jets analysis

tight photon with \( p_T > 15 \text{ GeV} \)

**Signal and background modelling** : signal, hadron fakes and QCD+\( \gamma \) templates are obtained by data driven methods
electron fakes, \( \bar{t}t\gamma \), \( W+\text{jets}+\gamma \) templates are obtained from MC

**Analysis Strategy** : Fit to track isolation of \( \gamma \)

\[ \sigma_{\bar{t}t}(p_T, \gamma > 8 \text{ GeV}) \times \text{BR}(LJ, DL) = 2.0 \pm 0.5 \text{ (stat)} \pm 0.7 \text{ (syst)} \pm 0.08 \text{ (lumi)} \text{ pb} \]

expected (NLO) = \( 2.1 \pm 0.4 \text{ pb} \)

overall precision \( \sim 43\% \), limited by systematic uncertainties

**Systematics** :
- \( \gamma \)-ID (0.33 pb),
- ISR/FSR (0.31 pb),
- JES (0.28 pb)
• **ttbar production cross section**
  - measured accuracy < theoretical one
  - $\sigma_{tt}$ is measured in alternative channels ($\tau$), showing SM is applicable at LHC
  - additional features are explored (tt+jets)
• **more results in talk on differential measurements !**

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**ATLAS Preliminary**

<table>
<thead>
<tr>
<th>Channel &amp; Lumi.</th>
<th>$\sigma_{tt}$ [pb]</th>
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<tbody>
<tr>
<td>Single lepton 0.70 fb$^{-1}$</td>
<td>179 ± 4 ± 9 ± 7 pb</td>
</tr>
<tr>
<td>Dilepton 0.70 fb$^{-1}$</td>
<td>173 ± 6 ± 14 ± 8 pb</td>
</tr>
<tr>
<td>All hadronic 1.02 fb$^{-1}$</td>
<td>167 ± 18 ± 78 ± 6 pb</td>
</tr>
<tr>
<td>Combination</td>
<td>177 ± 3 ± 8 ± 7 pb</td>
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</table>

**New measurements**

| $\tau_{had}$ + jets 1.67 fb$^{-1}$ | 200 ± 19 ± 42 ± 7 pb |
| $\tau_{had}$ + lepton 2.05 fb$^{-1}$ | 186 ± 13 ± 20 ± 7 pb |
| All hadronic 4.7 fb$^{-1}$         | 168 ± 12 ± 60 ± 57 ± 6 pb |

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**ATLAS** Preliminary

- precision ~6%, half of theory uncertainty
- agreement of channels within uncertainties
Backup slides
Simulation

- simulated \( \ttbar \) events generated using MC@NLO with PDFs from CTEQ6.6 (\( m_t = 172.5 \) GeV); sample normalized to 164.6 pb (from NNLO prediction using [5])
  - parton showering modeled with HERWIG
  - underlying event modeled with JIMMY
- single tops generated using MC@NLO
- W/Z bosons in association with jets generated with ALPGEN interfaced to HERWIG/JIMMY with CTEQ6.1
- di-boson events generated by HERWIG with MRST2007lomod
- pile-up is simulated with a value of 4-8 interactions per bunch crossing in order to reflect what is seen in the data