Measurement of the inclusive $t\bar{t}$ cross-section in the lepton+jets channel in $p\ p$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

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On behalf of the ATLAS collaboration
Analysis overview

- Split selected events into three signal regions
- Constrain uncertainties due to JES and b-tagging efficiency
- Simultaneous maximum-likelihood fit in the three regions
- Use $N_{\text{output}}$ as discriminating variable in SR1 and SR3
- Use $m_{jj}$ distribution as discriminating variables in SR2 → sensitive to JES
- SR1: highest background fraction and highest number of signal events
- SR2 and SR3: small background fraction
- Ratio of 1 b-tag to 2 b-tags (SR1 vs SR2+SR3) is sensitive to b-tagging efficiency
Event selection and background estimation and modelling

- **Single top, Z+jets, diboson:**
  - Normalised to their theoretical prediction

- **Multijet** background:
  - Templates fitted from data using control regions enriched with non prompt and fake leptons

- Main background **W+jets**:
  - Modelled by a data-driven method

<table>
<thead>
<tr>
<th>Object</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jets</td>
<td>≥ 4 jets p_T &gt; 25 GeV ≥1 b-tag</td>
</tr>
<tr>
<td>Leptons (e or μ)</td>
<td>Exactly 1 lepton p_T &gt; 25 GeV</td>
</tr>
<tr>
<td>E_T^{miss}</td>
<td>&gt; 25 GeV</td>
</tr>
<tr>
<td>m_T(W)</td>
<td>&gt; 30 GeV</td>
</tr>
</tbody>
</table>

For the three signal regions together
Backgrounds estimation and modelling

- **Multijet** background:
  - Electron channel: template from jet-lepton method (select jet as a lepton)
  - Muon channel: Template from anti-muons method (change ID cuts)
  - Estimate normalisation: fit on $E_T^{\text{miss}}$ or $m_T(W)$ distributions

- **Main background W+jets**:
  - Use Z+jets events selected from data
  - Scale momentum of leptons by $m_W/m_Z$
  - Select one of the leptons randomly and drop it
  - Recalculate the missing $E_T$ of the event
Discriminating observable in SR1 and SR3

- Train a neural network
- Use equal number of $t\bar{t}$ events and ZtoW from data

Seven input variables (ordered by their discriminating power)

- $m_{12}$: smallest invariant mass between jet pairs
- $\cos(\theta^*)_{b\bar{b}}$: angle between hadronic top quark momentum and beam direction in $t\bar{t}$ rest frame
- $m(\ell\nu b)$: mass of the semileptonically top-quark
- Aplanarity: event shape variable related to the smallest eigenvalue of sphericity tensor
- $m(b\bar{b}j)$: mass of the hadronically decaying top-quark
- $m_{\ell\nu 1}$: smallest invariant mass between a jet and the lepton
- $m_{23}$: second smallest invariant mass between jet pairs

Train a neural network
Use equal number of $t\bar{t}$ events and ZtoW from data
Discriminating observable in SR2

- Use the invariant mass of the two untagged jets $m(jj)$ in SR2
- Utilised in top-quark mass measurements
- $m(jj)$ shows sensitivity on the JES
  - Sensitivity to the peak position

### Figure

**ATLAS Simulation Preliminary**

- Full distribution is used
- Global JES ($\pm 1 \sigma$)
Extracting $\bar{t}t$ cross-section

- Simultaneous binned maximum likelihood fit in the three signal regions

\[ L(\beta_{\bar{t}t}, \beta_{W1}, \beta_{W2,3}, \delta_{b-tag}, \delta_{JES}) = \prod_{k=1}^{M} \frac{\mu_k e^{-\mu_k}}{n_k!} \cdot G(\delta_{b-tag}; 0, 1) \]

- One parameter for $\bar{t}t$: $\beta_{\bar{t}t}$
- Two parameters for $W+$jets: $\beta_{W1}, \beta_{W2,3}$
- Two nuisance parameters for:
  - Jet energy scale correction factor $\delta_{JES}$
  - B-tagging efficiency correction factor $\delta_{b-tag}$
Systematic uncertainties

- Using 100k pseudo-experiments
- Shape and acceptance effects are considered
- Total uncertainty: systematic effects varied simultaneously
- Taking into account correlations
- Largest uncertainties: PDF and MC modelling of $t\bar{t}$ process
- **Total uncertainty (including lumi.): 5.7%**

Main sources of systematic uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>$\Delta\sigma/\sigma$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet energy scale</td>
<td>± 1.1</td>
</tr>
<tr>
<td>Lepton identification</td>
<td>± 1.4</td>
</tr>
<tr>
<td>Lepton trigger</td>
<td>± 1.3</td>
</tr>
<tr>
<td>NLO matching</td>
<td>± 1.1</td>
</tr>
<tr>
<td>Scale variation</td>
<td>± 2.2</td>
</tr>
<tr>
<td>Parton shower</td>
<td>± 1.3</td>
</tr>
<tr>
<td>PDF</td>
<td>± 3.0</td>
</tr>
<tr>
<td>ZtoW modelling</td>
<td>± 1.1</td>
</tr>
<tr>
<td>Luminosity</td>
<td>± 1.9</td>
</tr>
<tr>
<td><strong>Total (sys. + stat.)</strong></td>
<td>± 5.7</td>
</tr>
</tbody>
</table>
Final result

Measured inclusive cross-section at $\sqrt{s} = 8$ TeV:

$$\sigma_{\text{tt}} = 248.3 \pm 0.7 \text{ (stat.)} \pm 13.4 \text{ (syst.)} \pm 4.7 \text{ (lumi.) pb}$$

- **Most precise cross-section measurement from ATLAS in the lepton+jets channel**: total uncertainty 5.7%
- **Improves significantly** previous ATLAS measurement in the lepton+jets channel (total uncertainty 9.4%)
- **Close to most precise** dilepton channel ATLAS measurement (total uncertainty 3.2%)
- **More precise** than CMS measurement in the lepton+jets channel (total uncertainty 6.8%)
Thank you for your attention