Combination of searches study for $t\bar{t}t\bar{t}$ produced in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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IFAE 2019 NAPOLI

Abstract

The combination of two analyses searching for the production of $t\bar{t}t\bar{t}$ using proton-proton collision data at a center-of-mass energy $\sqrt{s} = 13$ TeV with an integrated luminosity of 36 fb$^{-1}$ recorded by the ATLAS experiment is presented. The considered final states are events with multiple jets, $b$-jets, and either: a) one lepton or two leptons with opposite charge, and b) two leptons with same electric charge or three leptons. Constraints are set on the Standard Model (SM) $t\bar{t}t\bar{t}$ production and on an effective field theory inducing four fermions contact interactions.

Four tops in the SM

The SM total cross-section for the production of four top quarks is predicted to be $\sigma_{t\bar{t}t\bar{t}} = 9.2$ fb at next-to-leading-order in QCD accuracy at a center-of-mass energy $\sqrt{s} = 13$ TeV at the LHC. This process is characterized by several final states: this poster shows results from the single and opposite sign dilepton channels (OS $2l / 1l+jets$), with BR = 56.5%, and from the same sign dileptons and trilepton channels (SS $2l / 3l+jets$), with BR = 12.1%. Then, the combined analysis here presented covers 68.5% of all four tops decay channels, since the fully hadronic and fully leptonic decay modes are not included.

OS $2l / 1l+jets$

After preselection, events in the single lepton (OS dileptons) channel in the signal regions are required to have at least 10 (8) jets, at least 3 $b$-tagged jets and are further categorized with respect to the number of reclustered large R jets (RCLR).

Results for OS $2l / 1l+jets$

- The main background: is the $t\bar{t} + jets$.

SS $2l / 3l+jets$

The signal regions for dilepton same sign (three leptons) events are defined as in the following:

<table>
<thead>
<tr>
<th>Region name</th>
<th>$N_{l}$</th>
<th>$N_{b}$</th>
<th>Lepton charge</th>
<th>Kinematic criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS2l1b</td>
<td>2 ≥ 1</td>
<td>2 ≥ 1</td>
<td>++ or −−</td>
<td>$\sum p_{T} &gt; 140$ GeV</td>
</tr>
<tr>
<td>SS2b2l</td>
<td>2 ≥ 1</td>
<td>2 ≥ 1</td>
<td>++ or −−</td>
<td>$H_{T} &gt; 1200$ GeV</td>
</tr>
<tr>
<td>SS3b2l</td>
<td>3 ≥ 1</td>
<td>2 ≥ 1</td>
<td>++ or −−</td>
<td>$H_{T} &gt; 1200$ GeV</td>
</tr>
<tr>
<td>SS3l2b</td>
<td>3 ≥ 1</td>
<td>2 ≥ 1</td>
<td>++ or −−</td>
<td>$H_{T} &gt; 1200$ GeV</td>
</tr>
<tr>
<td>SS3l3b</td>
<td>3 ≥ 1</td>
<td>3 ≥ 1</td>
<td>++ or −−</td>
<td>$H_{T} &gt; 1200$ GeV</td>
</tr>
</tbody>
</table>

Results for SS $2l / 3l + jets$

- The main backgrounds: are $t\bar{t}t\bar{t}$ and $t\bar{t}W/Z$.

Combined Results

- The expected sensitivity from the combination of the two analysis channels gives an observed (expected) significance over the expected background, equal to 2.8 (1.0) $\sigma$.

- By assuming no signal, the observed (expected) 95% CL upper limit on the SM four-top-quark production cross section is 49 fb (19 fb).

Conclusion/future work

- No significant excess of events over background expectations was found.
- At present, a new analysis is using the full 13 TeV data set with an integrated luminosity of 140.3 fb$^{-1}$ collected between 2015-2018 to increase statistics in signal regions. In the future, new techniques to increase the sensitivity of this search will be used.

References