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Combined search for four-top quarks production in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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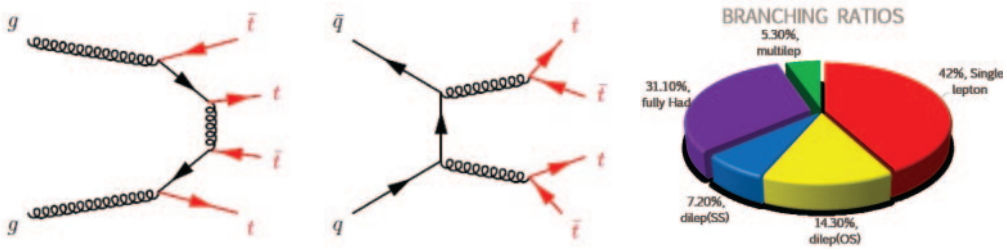
Summary. — The combination of two analyses searching for the production of four-top quarks ($t\bar{t}t\bar{t}$) using proton-proton collision data at a center-of-mass energy $\sqrt{s} = 13\,\text{TeV}$ with an integrated luminosity of $36\,\text{fb}^{-1}$ recorded by the ATLAS experiment is presented.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

1. – Four-top quarks in the Standard Model (SM)

The SM total cross-section for the production of four-top quarks is predicted to be $\sigma_{SM}^{t\bar{t}t\bar{t}} = 9.2\,\text{fb}^{-1}$ at $\sqrt{s} = 13\,\text{TeV}$ at the LHC. Several final states characterize this process, as shown in fig 1: this work shows the results from the single lepton (electron or muon) and the opposite charge (referred to in the following as "opposite sign") dileptons 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 presented covers 68.5% of all four tops decay channels, since the fully hadronic and fully leptonic decay modes are not included.

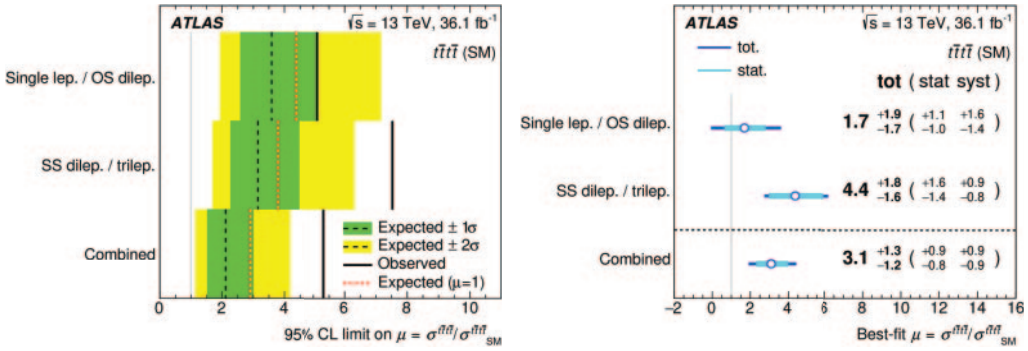
2. – Signal region (SR) definition

Events in the signal regions are separated into two categories. The first one is for single lepton and opposite sign dilepton (OS $2l/1l$+jets). In this category, the signal regions are required to have at least 10 (8) jets, at least three b-tagged jets and are further categorised concerning the number of reclustered large R-jets (RCLR). The second category is designed for same-sign dilepton and three leptons (SS $2l/3l$+jets) events. The signal regions are split according to the number of b-tags into one, two or greater than two for both channles ($2l$ and $3l$). In both categories, the scalar sum of the jet transverse



(a) (b) (c)

Fig. 1. – The Feynman diagrams for four-top quarks production ($gg \to t\bar{t}t\bar{t}$ and $q\bar{q} \to t\bar{t}t\bar{t}$) processes in the SM, (a) and (b), respectively; decay modes of the four W-boson system (c).



(a) (b)

Fig. 2. – Summary of 95% CL upper limit on $\sigma_{SM}^{t\bar{t}t\bar{t}}$ in individual channels and for the combination (a). The signal-strength μ measuements in individual channels and for the combination (b).

momenta (H_T^{Had}) provides a good discrimination between the signals and the dominant backgrounds, which are $t\bar{t}$+jets in the case of OS $2l/1l$ while $t\bar{t}H$ and $t\bar{t}W/Z$ for SS $2l/3l$+jets.

3. – Results

The results of the search in OS $2l/1l$ events are combined with results for SS $2l/3l$+jets. The combination is done to improve the sensitivity to the $t\bar{t}t\bar{t}$ process. Figure 2(a) shows the expected and observed upper limits for the SM $t\bar{t}t\bar{t}$ cross-section ($\sigma_{SM}^{t\bar{t}t\bar{t}}$) separately for the two searches and their combination, while fig. 2(b) shows the signal-strength measurements (μ) for both searches separately and their combination.

4. – Conclusions

No significant excess of events over background expectations is found. The expected sensitivity from the combination of the two channels gives an observed (expected) significance over the expected background equal to $2.8(1.0)\sigma$. Also, in the no-signal hypothesis, the observed (expected) 95% CL upper limit on the SM four-top quark production cross section is 49 fb (19 fb).