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Summary

Two analyses in the field of particle physics are presented in this document. First, studies on the performance of the reconstruction of muons using calorimeter information under the conditions of the High-Luminosity Large-Hadron-Collider (HL-LHC) phase of the ATLAS detector. Second, the search for the Standard Model (SM) simultaneous production of four top quarks using the full Run-II data set recorded by ATLAS. This data set corresponds to an integrated luminosity of L = 139 fb^{-1} of proton–proton collisions at a centre of mass energy of $\sqrt{s}$ = 13 TeV.

Here, the performance of the reconstruction of muons is probed for different pile-up scenarios, as those expected for the HL-LHC phase, and in light of different noise scenarios that emulate the loss of energy resolution and deterioration of detector acceptance due to ageing and irradiation of detector components. This study is conducted to test proposed detector upgrade scenarios before their implementation.

The search for SM like four top quark production presented here, focuses on the decay modes with two same sign or more leptons in the final state. The search for this process is, among other factors, motivated by the very large energies involved and by the fact that it is likely on the verge of being discovered with currently available data sets. The final results are obtained in a profile likelihood fit involving the outcome of a boosted decision tree trained to discriminate between signal and background. The fit results in a production cross section of $\sigma(p \to t\bar{t}t\bar{t}) = 24^{+7}_{-6}$fb[1], which corresponds to an observed (expected) significance of Z = 4.3 (Z = 2.4). This represents the first evidence for this process. The obtained result is compatible with the SM prediction [2] within 1.7 standard deviations.

Following first evidence, the possibility of reconstructing the four top quark system using a kinematic likelihood approach is developed and tested. These developments are performed with the KLFitter [3] tool set and yield an efficiency of correctly matching all four top quarks of ε = 33 ± 4% under optimal conditions in the single lepton final state.

[1] ATLAS Collaboration. ‘Evidence for tt̄tt̄ production in the multilepton final state in proton–proton collisions at √s = 13 TeV with the ATLAS detector’. *Eur. Phys. J. C* 80 (2020)

[2] Rikkert Frederix et al. ‘Large NLO corrections in tt̄W ± and tt̄tt̄ hadroproduction from supposedly subleading EW contributions’. *JHEP* 02 (2018)

[3] Johannes Erdmann et al. ‘A likelihood-based reconstruction algorithm for top-quark pairs and the KLFitter framework’. *Nucl. Instrum. Meth. A* 748 (2014)