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Unfolding of multivariate tools and statistical analysis for Higgs boson pair production searches in the ATLAS detector at the Large Hadron Collider

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Recently, searches for pair production of Higgs bosons in several final states have been carried out by the ATLAS exeperiment at the Large Hadron Collider (LHC). This study focuses on the search for non-resonant di-Higgs production decaying to a final state with two b-jets and two τ-leptons using 36.1 fb^{-1} of data recorded by the ATLAS detector. The analysis for this process has already been performed. Boosted decision trees (BDTs) are used in the analysis to improve the separation of the signal from background processes and several variables that provide good discrimination between signal and background are used as inputs to the BDT. This study aims to unfold the BDT of the analysis and optimize a cut-based analysis so that the gain from using the BDT can be estimated. Two variables, related to the invariant masses and angular distances of the Higgs boson decay products, are defined and the optimal cuts are found to be $X_{m_{\tau\tau}m_{bb}} > 1.8$ and $X_{\Delta R_{\tau\tau}\Delta R_{bb}} > 4.0$. Then, the upper limits on the SM HH production cross section are set when fitting m_{HH} with the cut-based analysis. An expected limit of 0.78 pb, 23 times the SM prediction is obtained when neglecting systematic uncertainties, compared to the limit of 15 times the SM as recomputed when using the BDT. Comparing the two results, the sensitivity is worsened by 50% when not using the BDT.

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