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Search for tWZ production in the Full Run 2 ATLAS dataset using events with four leptons

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The production of a single top quark in association with a $W^{\pm}$ and Z boson ($tW^{\pm}Z$) at the CERN LHC is sensitive to both the neutral and charged electroweak couplings of the top quark as the process involves the simultaneous production of a W boson and a Z boson in association with the top quark. Due to the very large coupling of the top quark to the Higgs boson, the electroweak couplings of the top quark are a theoretically well-motivated area in which to search for the first signs of new physics. The recent lack of signs of new physics from LHC data tells us that new physics is either very heavy, or is very weakly coupled to Standard Model particles, therefore we might only observe signs of new physics in anomalous rates of well-chosen processes. A prime example of such a process is tWZ. This has an extremely low production cross section (0.7 fb for $\sqrt{s} = 13$ TeV), meaning that it is an extremely rare process to observe and subsequently, it has never been observed by any particle physics experiment. However, the latest datasets recorded by the ATLAS experiment at the CERN LHC are sufficiently large to allow a potential observation of this rare process. We use the Full Run 2 dataset recorded by the ATLAS to search for the production of a top quark together with a $W^{\pm}$ and Z boson in the channel with four leptons (two originating from the decay of the Z boson, one from the associated W boson and one from the W boson which decays from the top quark (together with a b quark)). In this analysis, we use a kinematic reconstruction technique which aims to discriminate between tWZ and our most prominent background process, $t\bar{t}Z$. In addition to this, we implement Machine Learning techniques (Boosted Decision Trees) to further isolate our tWZ signal. The dominant source of the fake lepton background is from $t\bar{t}Z$ events containing one fake lepton. The kinematic distributions of this background are taken from simulation and its normalisation is constrained using a dedicated control region. As this work forms the basis of an official ATLAS analysis, only blinded results are shown. A maximum likelihood fit (blinded) is performed over our tWZ signal region and three control regions, resulting in an expected significance of 1.1σ and an expected limit of $2.0^{+2.8}_{-1.4} \times \sigma^{tWZ}_{SM}$. In order to increase the sensitivity of our tWZ signal, we perform another maximum likelihood fit (blinded) over all regions defined for the tetralepton channel and the trilepton channel (an independent analysis conducted by Benjamin Warren (UCT)), resulting in an expected significance of 1.2σ and an expected limit of $1.8^{+2.6}_{-1.3} \times \sigma^{tWZ}_{SM}$. These results would be the tightest ever constraint on this process.

Apply to be considered for a student ; award (Yes / No)?

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MSc Dissertation

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