Chapter 1

Conclusions

This thesis has presented the design of the most sensitive "merged" signal region in the search for dark matter produced with a new heavy vector boson, Z', and a scalar "dark Higgs" boson, s, decaying to a pair of W bosons with a semileptonic ($q\bar{q}\ell\nu$) final state. It has also presented the design of control regions to constrain the $t\bar{t}$ SM background, as well as the necessary supporting analysis work. The search uses data collected by the ATLAS experiment in 2015-2018, at a center-of-mass energy of 13 TeV.

The search for the dark Higgs model is motivated by the desire to detect dark matter, as well as the need for some mechanism to generate the mass of particles in the dark sector. The SM is an extremely successful theory of the fundamental particles and their interactions, however astrophysical observations demand the existence of dark matter beyond the current confines of the model. The dark Higgs model introduces dark matter as a Majorana fermion, with a mass generated by the Higgs mechanism from a new Higgs field with an associated dark Higgs boson s. Through the mixing of the SM Higgs boson and the s, the s can interact with all massive SM particles and can thus decay to SM final states that are visible in the ATLAS detector.

To search for this signature, we have defined a signal region, an optimized set of event-by-event criteria that, based on MC simulated data, are expected to select many events containing signal (mono-s) processes and few SM background events. Using the SM and signal predictions given by MC, we have calculated and presented the expected sensitivity of the "merged" signal region, which represents our ability to make conclusions about the existence of the signal model using observations in that region. The control regions are defined as regions near to, but not overlapping with, the signal regions, which are statistically dominated by the $t\bar{t}$ background process. We compared the MC simulated SM background to the measured ATLAS data in these regions to gain information about the accuracy of our MC predictions and constrain our predictions in the signal region. Using the designed regions, the search for the semileptonic s decay will be able to substantially improve upon the sensitivity to the signal model achieved by prior searches in other decay channels.