Measurements of $H \to b\bar{b}$ decays and VH production

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I, Thomas Paul Charman, confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged below and my contribution indicated. Previously published material is also acknowledged below.

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Chapter 1

Introduction

In 2012 the Higgs boson was discovered by the ATLAS and CMS collaborations at the Large Hadron Collider [1, 2]. It was said to form the last piece of the Standard Model of Particle Physics, a framework that describes three of the four fundamental forces of nature, described in more detail in Chapter **??**. Despite apparent completeness after the Higgs discovery, it is known that the theory does not describe gravity, the fourth of the known fundamental forces of nature. The theory also has other shortcomings, it cannot explain the presence of dark matter [3–13] or a number of other observed phenomena [14–18]. So far the model has stood up to all experimental tests [19, 20] concerning its own predictions but there are still parameters of the model that have not been measured. Given the theory's understood shortcomings, it is hoped that continued scrutiny of the models predictions will yield unexpected results, perhaps hinting at a new way forwards in terms of a theory that describes everything or simply exposing further gaps in our knowledge of the universe. For this reason it is more important than ever to study in detail the most recently discovered piece of the model, the Higgs boson.

This work focuses on studying a specific production mechanism and decay mode of the Higgs boson, specifically a vector boson associated Higgs boson decaying to two bottom quarks, denoted $VH(bb)$. This decay mode is of importance as it is currently the only decay mode of the Higgs decaying to quarks that has been observed [21]. A summary of the full spectrum of production mechanisms and decay modes of the

Higgs will be given in Chapter **??**.

The study of this decay mode was carried out with the ATLAS detector, and made possible by the hard work of all members of the ATLAS collaboration. In Chapter **??** the detector is described in full.

My contributions to the VHbb analysis published in 2021 have been numerous and spanned a number of different areas of the analysis.

My largest contribution was the derivation of new estimates of background modelling uncertainties. This includes deriving new shape uncertainty estimates for the Z + jets background in the 0 and 2 lepton channels which use a method which includes a number of improvements over the previous analysis (explained in detail in chapter **??**). I also calculated estimates of uncertainties arising due to differences in the flavour composition and yields in given analysis regions between simulation and data for the Z + jets and top backgrounds. I helped to develop and test code which performs a multi–dimensional re–weighting of one dataset to another. This technique has been used to estimate uncertainties of the top backgrounds and W + jets backgrounds in the 1 lepton channel.

My next largest contribution was to studying the profile likelihood fit that outputs the final analysis results. During key milestones of the analysis it is often necessary to compare the blinded results of the fit to study the behaviour of nuisance parameters and how they are pulled, constrained and correlated with one another. I performed many of these comparisons paying close attention to the nuisance parameters relating to the aforementioned estimates on background modelling uncertainties. After approval was granted to unblind the analysis I was also responsible for running the final fit for the diboson measurement which serves as a cross-check of the all of the analysis methodology used for the Higgs measurement.

Finally I have also made contributions to the general running of the analysis. These including training the classification algorithm which provides the final discriminating metric upon which the profile-likelihood fit is performed, helping to maintain the analysis framework (which is also used by many other ATLAS analyses) and participating in regular meetings with the analysis team where ideas are discussed and the general analysis direction is decided.

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