Preface

As a D.Phil. research topic, the $H \to WW$ analysis has proven to be a baptism of fire. It is the most complicated of the three "discovery channels",[1] as it involves a variety of physics objects and requires a good understanding of many difficult backgrounds. As such, the analysis took huge effort from a large number of individuals. My role focussed on theoretical aspects of the signal and background modelling, and these parts shall be emphasised. I contributed to multiple iterations of the analysis [1–8], though the version presented here is unpublished at the time of writing [9]. I also co-authored the third Yellow Report produced by the LHC Higgs Cross Section Working Group [10].

When I began the degree in October 2010, there was no direct evidence for a Higgs boson. This thesis is written from a personal perspective and motivates a low mass search by electroweak fits, when in fact this aspect was motivated later by observations of a resonance in the $\gamma\gamma$ and ZZ channels.[2] Also, an advanced search strategy is described, though the discovery of $H \to WW$ was actually a gradual process with multiple iterations of blinding, optimising and unblinding the analysis. As more data were recorded and the analysis was enhanced, the results improved.

Early on, I gained relevant insight by performing multiple WW cross section measurements [12–15]. My main contribution was a jet veto correction factor applied to the WW signal, which reduces the dominant uncertainty in the analysis. This measurement shall be described when considering the WW background to the $H \to WW$ search.

To qualify for authorship within the ATLAS collaboration, I performed Run Control shifts. I also worked within the Versatile Link project [16] to investigate radiation-hardened optical components for the HL-LHC. As this research does not easily relate to the Higgs boson, it is excluded from this thesis. However, I have published articles on the radiation tolerance of optical fibres [17] and their connectors [18].

[1] The $\gamma\gamma$, ZZ and WW decay channels quickly gave sensitivity to the Higgs boson ultimately discovered.

[2] Dedicated high mass searches for $H \to WW$ have also been performed [11].

Overview

This thesis describes the search, discovery and measurement of the Higgs boson using proton–proton collision data recorded by the ATLAS experiment at CERN. This is accomplished by searching for collisions where a Higgs boson is produced and subsequently decays to two W bosons, each of which decay to an electron or muon and a neutrino (i.e. $H \rightarrow WW \rightarrow \ell\nu\ell\nu$). This search suffers from large experimental backgrounds, such as continuum WW production, which must be accurately modelled to yield sensitivity to the Higgs boson.

First, the theoretical motivation for the Higgs boson is presented in Chap. 1. Then, Chap. 2 outlines some important concepts related to making precise predictions within the Standard Model, which shall be referred to throughout the thesis. The experimental setup of the LHC and the ATLAS detector are described in Chap. 3.

Focus then moves to the data analysis itself. Chapter 4 offers an overview of the entire $H \rightarrow WW$ analysis, detailing the selection of Higgs boson signal events and the rejection of backgrounds. Following this, signal modelling is described in Chap. 5, WW background modelling is described in Chap. 6 (including a dedicated cross section measurement), and the modelling of other backgrounds is described in Chap. 7. The experimental results are presented and discussed in Chap. 8. Finally, in Chaps. 9 and 10, we draw conclusions from the results of this analysis and of others conducted simultaneously at the LHC, and consider the outlook of Higgs physics.

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