# The Higgs boson with the ATLAS experiment at the LHC: Discovery, measurement, and searches for new physics


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# The Higgs boson with the ATLAS experiment at the LHC: Discovery, measurement, and searches for new physics


## Abstract

We measured things. And searched for other things. Here is what we found, please let me graduate.

# Contents

# Listing of figures

This is the dedication.

# Acknowledgments

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# Introduction

# Part I

# Preliminaries

# 1

# The Standard Model and beyond: a theoretical overview

*This is some random quote to start off the chapter.*

Firstname lastname

# 2

# The ATLAS detector and the Large Hadron Collider

2.1 The Large Hadron Collider

2.2 The ATLAS Detector

# Part II

# Observation and measurement of Higgs boson decays to $WW*$ with the ATLAS detector in LHC Run 1 at $\sqrt{s} = 7$ and 8 TeV

*Basic research is what I am doing when I don't know what I am doing.*

Wernher von Braun

# 3

# $H \to WW^* \to \ell\nu\ell\nu$ Analysis Strategy

## 3.1 Introduction

This chapter will present an overview of the strategy for searching for a Higgs boson in the $H \to WW^* \to \ell\nu\ell\nu$ decay topology. First, details of the signal final state and corresponding backgrounds are presented. Then, the definitions of all of the objects used to reconstruct these final states are shown. Next, an overview of the variables used to reduce the backgrounds and enhance the signal is given. Finally, the parameters of interest in the search and measurement will be defined, and a brief overview of the statistical treatment of the final Higgs candidates is given.

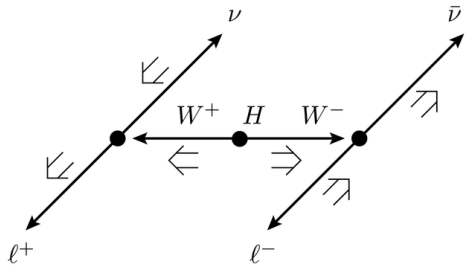


**Figure 3.1:** A cartoon of the WW final state. Momenta are represented with thin arrows, spins with thick arrows.[1]

## 3.2 Signal topology

The analysis presented here and in subsequent chapters is the study of the Higgs boson in the $WW$ final state, where each $W$ boson subsequently decays into a charged lepton and a neutrino. In its simplest form, the final state will then consist of two neutrinos and two charged leptons, each of which can be either an electron or a muon. If one or both of the $W$s decay to $\tau$ leptons, only leptonic decays of the $\tau$ are considered, leading to additional neutrinos in the final state but still giving two charged leptons as before. Neutrinos are not detected in ATLAS, so the final state ultimately consists of two reconstructed leptons and missing transverse momentum(denoted as $E_{\mathrm{T}}^{\mathrm{miss}}$). Final states where both of the charged leptons are electrons or muons are referred to as the "same flavor" final states, while those with one electron and one muon are referred to as "different flavor".

The final state leptons will also exhibit unique correlations due to the fact that they are arising from the decay of a spin zero resonance. In particular, the spins of the final state leptons and neutrinos must all cancel, as shown in figure 3.1. Because the neutrino has a left handed helicity and the anti-neutrino has a right handed helicity, the spin and momentum of the particles will be anti-aligned and aligned, respectively. In the transverse plane, the momenta of all four final state objects must cancel as well. With the constraint of having both the momenta and the spin alignments cancel, the final state kinematics strongly prefer having a small angle between the leptons in the trans-

verse plane (low $\Delta\varphi_{\ell\ell}$). This angular correlation will also lead to low values of the di-lepton invariant mass $m_{\ell\ell}$. These unique signal final state kinematic correlations will be exploited to define the ultimate signal region.

## 3.3 Background processes

## 3.4 Object definitions

## 3.5 Isolating an $H \to WW^* \to \ell\nu\ell\nu$ signal

## 3.6 Background reduction in same-flavor final states

## 3.7 Parameters of interest and statistical treatment

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# The discovery of the Higgs boson and the role of the $H \to WW^* \to \ell\nu\ell\nu$ channel

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# Observation of Vector Boson Fusion production of $H \to WW^* \to \ell\nu\ell\nu$

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# Combined Run 1

# $H \to WW^* \to \ell\nu\ell\nu$ results

# Part III

# Search for Higgs pair production in the $HH \to b\bar{b}b\bar{b}$ channel in LHC Run 2 at $\sqrt{s}$ = 13 TeV

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# Search overview

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# Search for Higgs pair production in boosted final states

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# Search for Higgs pair production in resolved final states

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# Combined results with Run 2 2015 dataset

# Part IV

# Looking ahead

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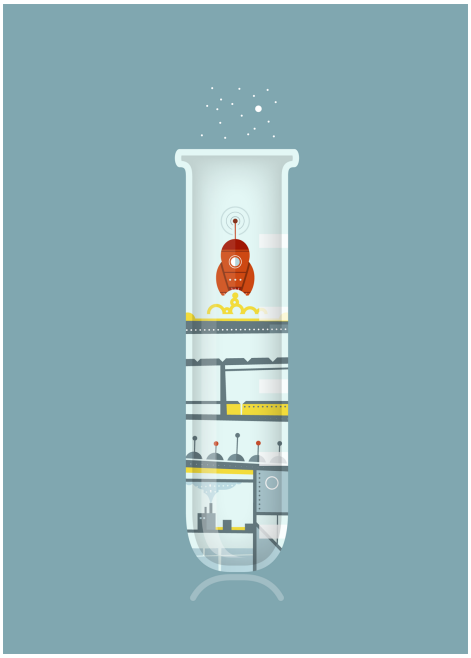
# Conclusion

We found the Higgs. Then measured it. Then used it to look for new physics. What a time to be alive!

# References

[1] Collaboration, A. (2015). Observation and measurement of higgs boson decays to ww* with the atlas detector. *Phys. Rev. D*, 92(012006).



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