

Studies of the Higgs boson with the  
ATLAS experiment at the LHC:  
Observation, measurement, and searches  
for new physics

A DISSERTATION PRESENTED  
BY  
TOMO LAZOVICH  
TO  
THE DEPARTMENT OF PHYSICS

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY  
IN THE SUBJECT OF  
PHYSICS

HARVARD UNIVERSITY  
CAMBRIDGE, MASSACHUSETTS  
MAY 2016

©2014 – TOMO LAZOVICH  
ALL RIGHTS RESERVED.

Thesis advisor: Professor Joao Guimaraes da Costa and Melissa Franklin Tomo Lazovich

Studies of the Higgs boson with the ATLAS experiment at the  
LHC:  
Observation, 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

o	INTRODUCTION	i
I	Preliminaries	2
1	THE STANDARD MODEL AND BEYOND: A THEORETICAL OVERVIEW	3
1.1	The Standard Model of Particle Physics . . . . .	3
1.2	Electroweak Symmetry Breaking and the Higgs . . . . .	3
1.3	Higgs Boson Production and Decay . . . . .	3
1.4	Physics Beyond the Standard Model . . . . .	3
2	THE ATLAS DETECTOR AND THE LARGE HADRON COLLIDER	4
2.1	The Large Hadron Collider . . . . .	4
2.2	The ATLAS Detector . . . . .	4
II	Observation and measurement of Higgs boson decays to $WW^*$ with the ATLAS detector in LHC Run I at $\sqrt{s} = 7$ and 8 TeV	5
3	$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ ANALYSIS STRATEGY	6
3.1	Signal and background topologies . . . . .	6
3.2	Object definitions . . . . .	6
3.3	Signal region cuts . . . . .	6
3.4	Statistical treatment . . . . .	6
4	MEASUREMENT OF GLUON FUSION PRODUCTION OF $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$	7
5	OBSERVATION OF VECTOR BOSON FUSION PRODUCTION OF $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$	8
6	COMBINED RUN I $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ RESULTS	9

III	Search for Higgs pair production in the $HH \rightarrow b\bar{b}b\bar{b}$ channel in LHC Run 2 at $\sqrt{s} = 13$ TeV	10
7	SEARCH OVERVIEW	11
8	SEARCH FOR HIGGS PAIR PRODUCTION IN BOOSTED FINAL STATES	12
9	SEARCH FOR HIGGS PAIR PRODUCTION IN RESOLVED FINAL STATES	13
10	COMBINED RESULTS WITH RUN 2 2015 DATASET	14
IV	Looking ahead	15
II	CONCLUSION	16
	REFERENCES	17

## Listing of figures

THIS IS THE DEDICATION.

# Acknowledgments

LOREM IPSUM DOLOR SIT AMET, consectetur adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien. Nam consectetur. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.



# 0

## Introduction

# Part I

## Preliminaries

# 1

## The Standard Model and beyond: a theoretical overview

- 1.1 THE STANDARD MODEL OF PARTICLE PHYSICS
- 1.2 ELECTROWEAK SYMMETRY BREAKING AND THE HIGGS
- 1.3 HIGGS BOSON PRODUCTION AND DECAY
- 1.4 PHYSICS BEYOND THE STANDARD MODEL

*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 I at  $\sqrt{s} = 7$  and 8  
TeV

# 3

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

3.1 SIGNAL AND BACKGROUND TOPOLOGIES

3.2 OBJECT DEFINITIONS

3.3 SIGNAL REGION CUTS

3.4 STATISTICAL TREATMENT

# 4

Measurement of gluon fusion production  
of  $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$

# 5

## Observation of Vector Boson Fusion

production of  $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$



# 6

Combined Run I

$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$  results

## Part III

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

# 7

## Search overview

# 8

Search for Higgs pair production in boosted  
final states

# 9

Search for Higgs pair production in  
resolved final states

# 10

Combined results with Run 2 2015 dataset

## Part IV

### Looking ahead

# 11

## Conclusion

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



## References



**T**HIS THESIS WAS TYPESET using  $\text{\LaTeX}$ , originally developed by Leslie Lamport and based on Donald Knuth's  $\text{\TeX}$ .

The body text is set in 11 point Egenolff-Berner Garamond, a revival of Claude Garamont's humanist typeface. The above illustration, *Science Experiment 02*, was created by Ben Schlitter and released under [CC BY-NC-ND 3.0](#). A template that can be used to format a PhD dissertation with this look & feel has been released under the permissive AGPL license, and can be found online at [github.com/asm-products/Dissertate](https://github.com/asm-products/Dissertate) or from its lead author, Jordan Suchow, at [suchow@post.harvard.edu](mailto:suchow@post.harvard.edu).