$HH \to b\bar{b}b\bar{b}$ or How I Learned to Stop Worrying and Love the QCD Background

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Abstract

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Chair of the Supervisory Committee:
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Physics

Insert abstract here

TABLE OF CONTENTS

LIST OF FIGURES

Figure Number Page

GLOSSARY

ARGUMENT: replacement text which customizes a LaTeX macro for each particular usage.

ACKNOWLEDGMENTS

As anyone who has written a Ph.D. thesis will probably tell you, it's been a journey. We laughed, we cried, we bled occasionally (though nothing too serious). A pandemic happened, I learned how to make sourdough (see the appendix for more details). I learned how to ski, discovered a love for hiking, and ate large amounts of cheese. The list of people who I have met and shared deep and memorable experiences with is long – I fear to list you all here in case I miss someone! – but please do know that I treasure you. This is the beauty and tragedy of doing a Ph.D. half in Seattle, half at CERN: it allows you to build strong friendships with a large group of people, and then scatters you all across the globe. So to the Seattle friends, to the CERN friends, to the friends from undergrad, and high school, and even earlier, and to everyone in between, thank you for being a part of my life, and I hope to see you soon.

Of course, a thank you to my family for their continuing support, vacationing adventures, and for trying their best to learn physics along with me (my dad re: ATLAS – "This is pretty complicated isn't it?").

And finally a huge thank you to my group: Anna, for your guidance and support, and for always caring about me as a person in addition to me as a physicist. And Jana, for guidance and support, of course, but also for looking at/giving comments on almost literally every single one of my talks (even if you didn't always get my jokes).

DEDICATION

To life!

Chapter 1

INTRODUCTION: THE STANDARD MODEL OF PARTICLE PHYSICS

"I may be bad, but I'm perfectly good at it" - Rihanna re: the Standard Model (SM), or so I've been told

The Standard Model of Particle Physics (SM) is a monumental historical achievement, providing a formalism with which one may describe everything from the physics of everyday experience to the physics that is studied at very high energies at the Large Hadron Collider (Chapter 3). In this chapter, we will provide a brief overview of the pieces that go into the construction of such a model, and expound upon some features relevant to the work done for this thesis.

1.1 Particles and Fields

We will begin with a question that is important for a particle physicist to understand: what is a particle? The experimental physicist (or at least the author of this thesis) might, upon hearing this question, say "it is something that we can see in our detector" and point you to Figure SM TABLE as an example of the particles that we have observed.

Okay, one might say, what characteristics of these mythical objects are actually observed? This depends on the detector (see Chapter 3), but some natural characteristics that come to mind are electrical charge – namely, how the particle moves in an electric or magnetic field – and mass, or energy, which that particle may deposit in some detector system.

If these are all there is, the definition of particle is then "something with an electrical

charge and a mass." What, then, of the photon? This is electrically neutral and massless, how is this observed? "Well it still interacts with other particles!" the thesis author would yell! So we have arrived at a definition of a particle as some abstract object with defined characteristics (such as mass and electrical charge), which interacts with other such objects in a well defined way.

This is now a reasonable starting point for a more formal definition, for which we need a bit more math.

1.1.1 Physics is just Linear Algebra

1.2 Path Integrals and Lagrangians

1.3

Chapter 2

BEYOND THE STANDARD MODEL

Chapter 3

EXPERIMENTAL APPARATUS

Chapter 4

SIMULATION

Chapter 5

RECONSTRUCTION

Chapter 6

THE ANATOMY OF AN LHC SEARCH

In this thesis so far, we have set the theoretical foundation for the work carried out at the LHC. We have described how one may translate between this theoretical foundation and what we are actually able to observe with the ATLAS detector. We have further stepped through the process of simulating production of specific physics processes and their appearance in our detector, allowing us to describe how a hypothetical physics model would be seen in our experiment. The question then becomes: all of these pieces are on the table, what do we do with them? This chapter attempts to answer exactly that, setting up a roadmap for assembling these pieces into a statement about the universe.

6.1 Object Selection and Identification

6.2 Defining a Signal Region

6.3 Background Estimation

6.4 Uncertainty Estimation

6.5 Hypothesis Testing

Chapter 7

SEARCH FOR NON-RESONANT PAIR PRODUCTION OF HIGGS BOSONS IN THE $b\bar{b}b\bar{b}$ FINAL STATE

Chapter 8

SEARCH FOR RESONANT PAIR PRODUCTION OF HIGGS BOSONS IN THE $b\bar{b}b\bar{b}$ FINAL STATE