Search for Higgs Boson Pair Production in the $bbWW$ Channel Using Proton-Proton Collision Data at $\sqrt{s} = 13$ TeV from the ATLAS Detector

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Outlines

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- Motivation and Objective
- Methodology
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### Introduction

#### Standard Model

The Standard Model describes all known particles and forces. It is not complete, as it does not address the origin of mass, matter-antimatter asymmetry, neutrino oscillations, dark matter, dark energy, etc.

![Standard Model Diagram]

- **Quarks**: u, c, t, d, s, b
- **Leptons**: e, μ, τ, ν_e, ν_μ, ν_τ
- **Fermions**: e, μ, τ
- **Gauge Bosons**: H (Higgs), W, Z

The diagram shows the masses and properties of these particles.
Introduction

Higgs Boson production and Decay

Search for the pariticle heavier than SM Higgs (125 GeV/c^2) is going on. Heavy particles formed after the collision of protons at high energy which may decay to two SM Higgs particles know as Di-Higgs.
Motivation and Objective

Branching Ratio ($hh \rightarrow XY$)

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Branching Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>4b</td>
<td>0.33</td>
</tr>
<tr>
<td>WWbb</td>
<td>0.25</td>
</tr>
<tr>
<td>ττbb</td>
<td>0.073</td>
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<tr>
<td>WWWWW</td>
<td>0.046</td>
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WW Decay Mode

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Branching Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>4j</td>
<td>0.11</td>
</tr>
<tr>
<td>lνjj</td>
<td>0.07</td>
</tr>
<tr>
<td>lνlν</td>
<td>0.012</td>
</tr>
</tbody>
</table>

- hh → bbbb mode is challenging to search for, that it competes against the QCD multijet backgrounds.
- WWbb has the second higher decay probability.

**So, we search in the channel:**

$X \rightarrow hh \rightarrow bbWW \rightarrow bblνjj$

$X \rightarrow hh \rightarrow bbWW$ is considered as less promising channel because of large ttbar background.

And we optimize the Signal over Background.
Pair-produced Higgs bosons have diverse final states, one of which looks exactly like that of the pair produced top quarks - an irreducible background for search of $X \rightarrow hh \rightarrow bbWW$.

We use data from the Monte Carlo Simulation and use ROOT for its analysis.
The main difference from the top pair production is the reconstructed mass of the pair of $h$ bosons. The $bbWW$ has a mass of a given resonance, top quark pair doesn’t have such a peak. This means that the reconstructed mass of the $bbWW$ system is a very powerful discriminating variable.

$hh$ signal and $ttbar$ background has peak at around 400 GeV but signal has more amplitude than background.

$hh$ signal and $ttbar$ background has peak at around 100 GeV but signal has more amplitude than background.
hh signal (peak at 115 GeV) and ttbar background (peak at 89 GeV) has peak at different values.
In order to enhance our signal efficiency in the analysis, a $p_T$ cut is to be made on the different parameters like mass, momentum, angular separation etc. The lower this cut gets, the more signal we detect therefore increasing our sensitivity.

We apply the cut in such a way to maximize the sensitivity while maintaining signal by calculating the number of signal ($S$) event divided by the number of background ($B$) events in our signal.

If we apply cut around 100 GeV, the S/B will be maximum.
Acknowledgement

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- www.atlas.ch
- www.home.cern.ch
- Matthew J. Dolan, Christoph Englert, and Michael Spannowsky, *New physics in LHC Higgs boson pair production*
- Lan-Chun Lu, Chun Du, Yaquan Fang, Hong-Jian He, Huijun Zhang, *Searching Heavier Higgs Boson via Di-Higgs Production at LHC Run-2*
- Marsh Alison, *Optimization of selection and data-driven background estimation for the boosted di-Higgs to 4b final state search*
- Cesare Bini, *Data analysis in Experimental Elementary Particle Physics.*
WE FOUND IT! WE FOUND THE HIGGS BOSON!

THANK YOU