UNIVERSITEIT GENT

UNIVERSITEIT GENT

DOCTORAL THESIS

Search for heavy neutral leptons in events with three charged leptons in pp collision at $\sqrt{s} = 13$ TeV at CMS detector

---

Author:
Martina VIT

Supervisor:
Prof Dr. Didar DOBUR

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

in the

Experimental Particle Physics
Department of Physics and Astronomy

March 2, 2021

"porca paletta."

MV

UNIVERSITEIT GENT

Summary

Faculty Name
Department of Physics and Astronomy

Doctor of Philosophy

Search for heavy neutral leptons in events with three charged leptons in pp collision at $\sqrt{s} = 13$ TeV at CMS detector

by Martina VIT

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Contents

For/Dedicated to/To my…

Introduction

introduction

Part I

Physics introduction

Chapter 1

The Standard Model and Beyond

1.1 Introduction

1.2 The Standard Model of Elementary Particles

1.3 The mathematical framework of the Standard Model

1.4 Beyond the Standard Model

1.4.1 ?Heavy Neutral Leptons?

Chapter 2

The LHC and the CMS Experiment

2.1 Introduction

2.2 The LHC and the LHC experiments

2.2.1 The Large Hadron Collider

2.2.2 Experiments at the LHC

2.2.3 Design and performance of the LHC

2.3 The CMS experiment

2.3.1 The CMS coordinate system

2.3.2 The solenoid magnet

2.3.3 The charged-particle tracker

2.3.4 The electromagnetic calorimeter

2.3.5 The hadronic calorimeter

2.3.6 The muon detector

2.3.7 Triggering and data acquisition

2.4 Event reconstruction

2.4.1 Track reconstruction

2.4.2 Reconstruction performances

Part II

Search for heavy neutral leptons

Chapter 3

Theory introduction to HNL

3.1 Heavy neutral leptons

3.1.1 Previous and current results

Chapter 4

Search for HNL in events with three charged prompt leptons

Chapter 5

Search for long-lived heavy neutral leptons in final states with three charged leptons and displaced vertices

5.1 Change of scenario

5.1.1 Displaced signature at CMS

5.2 Signal simulation

5.3 Datasets

5.3.1 Data

5.3.2 Simulation

5.4 Trigger strategy

5.5 Object reconstruction and identification

5.5.1 Prompt leptons

Muons

Electrons

5.5.2 Displaced vertices

5.5.3 Displaced leptons

Muons

Electrons

5.6 Event reconstruction

5.6.1 Displaced leptons pair (i.e. HNL candidate) selection

5.6.2 Secondary displaced vertex fit and lepton extrapolation

5.6.3 Event kinematics and baseline selection

5.7 Background estimation

5.7.1 Background composition

5.7.2 Fake lepton background

5.8 Corrections and efficiencies

5.9 Systematic uncertainties

5.10 Results

5.10.1 Statistical analysis

5.10.2 Limits on V_{Nl}: Dirac HNL

5.10.3 Limits on V_{Nl}: Majorana HNL

5.10.4 Limits on V_{Nl}: Tau coupling

5.10.5 Summary

Chapter 6

Conclusion and perspective

6.1 Prompt HNL analysis possible improvements

6.2 Displaced HNL analysis possible improvements

6.3 HNL searches perspectives and LHC and beyond

6.4 Conclusions

List of Figures

List of Tables

Appendix A

Frequently Asked Questions

A.1 How do I change the colors of links?

The color of links can be changed to your liking using:

`\hypersetup{urlcolor=red}`, or
`\hypersetup{citecolor=green}`, or
`\hypersetup{allcolor=blue}`.

If you want to completely hide the links, you can use:

`\hypersetup{allcolors=.}`, or even better:
`\hypersetup{hidelinks}`.

If you want to have obvious links in the PDF but not the printed text, use:

`\hypersetup{colorlinks=false}`.

Acknowledgements

The acknowledgments and the people to thank go here, don't forget to include your project advisor…