

**Search for Dark Matter in Proton-Proton  
Collisions at a Center-of-Mass Energy of 13 TeV in  
the Higgs Boson associated b-anti-b quark channel**

**Jue Chen**

Submitted in partial fulfillment of the  
requirements for the degree  
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# ABSTRACT

# Search for Dark Matter in Proton-Proton Collisions at a Center-of-Mass Energy of 13 TeV in the Higgs Boson associated b-anti-b quark channel

Jue Chen

[illegible]

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Dedication text

## Part I

# Introduction

# Introduction

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## Part II

# The standard model and Dark Matter

## Chapter 2

# The standard model

### 2.1 Introduction

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The elementary particles defined in the standard model are demonstrated in Fig [2.1](#).

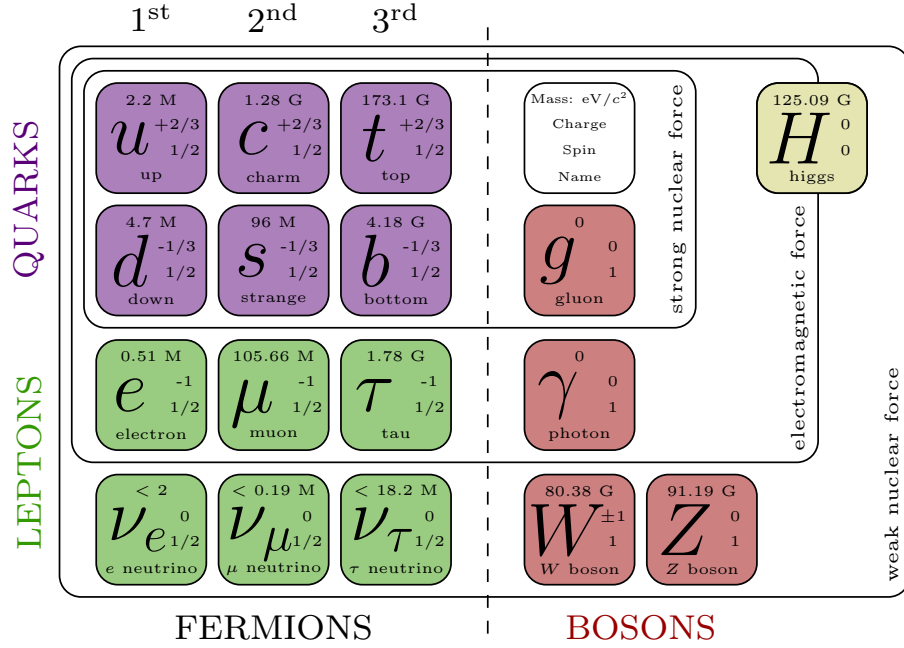


Figure 2.1: Particles of the Standard Model of particle physics

The standard model Lagrangian is shown in Eq 2.1:

$$\begin{aligned}
L = & -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}\text{tr}(F_{\mu\nu}F^{\mu\nu}) - \frac{1}{2}\text{tr}(G_{\mu\nu}G^{\mu\nu}), (\text{Gauge terms}) \\
& + \begin{pmatrix} \bar{\nu}_L & \bar{e}_L \end{pmatrix} \bar{\sigma}^\mu i D_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R \sigma^\mu i D_\mu e_R + \bar{\nu}_R \sigma^\mu i D_\mu \nu_R, (\text{Lepton dynamical terms}) \\
& - \frac{\sqrt{2}}{v} \left[ \begin{pmatrix} \bar{\nu}_L & \bar{e}_L \end{pmatrix} \phi M^e e_R + \bar{e}_R \bar{M}^e \bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \right], (\text{Electron, muon, Tau mass terms}) \\
& - \frac{\sqrt{2}}{v} \left[ \begin{pmatrix} -\bar{e}_L & \bar{\nu}_L \end{pmatrix} \phi^* M^\nu \nu_R + \bar{\nu}_R \bar{M}^\nu \phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix} \right], (\text{Neutrino mass terms}) \\
& + \begin{pmatrix} \bar{u}_L & \bar{d}_L \end{pmatrix} \bar{\sigma}^\mu i D_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} + \bar{u}_R \sigma^\mu i D_\mu u_R + \bar{d}_R \sigma^\mu i D_\mu d_R, (\text{quark dynamical terms}) \\
& - \frac{\sqrt{2}}{v} \left[ \begin{pmatrix} \bar{u}_L & \bar{d}_L \end{pmatrix} \phi M^d d_R + \bar{d}_R \bar{M}^d \bar{\phi} \begin{pmatrix} u_L \\ d_L \end{pmatrix} \right], (\text{Down, strange, bottom mass terms}) \\
& - \frac{\sqrt{2}}{v} \left[ \begin{pmatrix} -\bar{d}_L & \bar{u}_L \end{pmatrix} \phi^* M^u u_R + \bar{u}_R \bar{M}^u \phi^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix} \right], (\text{Up, charm, top mass terms}) \\
& + D_\mu \phi D^\mu \phi - m_h^2 [\bar{\phi} \phi - v^2/2]^2 / 2v^2, (\text{Higgs dynamical and mass terms})
\end{aligned} \tag{2.1}$$



The definition of derivative operators in the Eq 2.1 are:

$$D_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} = [\partial_\mu - \frac{ig_1}{2} B_\mu + \frac{ig_2}{2} W_\mu] \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \quad (2.2)$$

$$D_\mu \nu_R = \partial_\mu \nu_R, \quad D_\mu e_R = [\partial_\mu - ig_1 B_\mu] e_R$$

$$D_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} = [\partial_\mu + \frac{ig_1}{6} B_\mu + \frac{ig_2}{2} W_\mu + ig G_\mu] \begin{pmatrix} u_L \\ d_L \end{pmatrix} \quad (2.3)$$

$$D_\mu u_R = [\partial_\mu + \frac{i2g_1}{3} B_\mu + ig G_\mu] u_R, \quad D_\mu d_R = [\partial_\mu - \frac{ig_1}{3} B_\mu + ig G_\mu] d_R$$

$$D_\mu \phi = [\partial_\mu + \frac{ig_1}{2} B_\mu + \frac{ig_2}{2} W_\mu] \phi \quad (2.4)$$

## 2.2 Challenges

Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text.

# Dark matter

### 3.1 Two-Higgs-doublet model

### 3.2 Simplified model

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## **Part III**

# **The LHC and ATLAS experiment**

# The LHC

## 4.1 The LHC: Instrument

### 4.1.1 Machine layout

### 4.1.2 Machine performance

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## 4.2 The LHC: Operation

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### 4.2.1 Machine accelerator

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### 4.2.2 Machine beam

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# The ATLAS experiment

## 5.1 ATLAS detector system

### 5.1.1 Inner detector

#### 5.1.1.1 Pixel detector

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#### **5.1.1.2 Semiconductor Tracker**

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#### **5.1.1.3 Transition Radiation Tracker**

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### **5.1.2 Calorimeter**

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#### **5.1.2.1 Liquid Argon Calorimeter**

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#### **5.1.2.2 Tile Calorimeter**

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### **5.1.3 Muon Spectrometer**

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#### 5.1.3.1 Thin Gap Chambers

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#### 5.1.3.2 Resistive Plate Chambers

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#### 5.1.3.3 Monitored Drift Tubes

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#### 5.1.3.4 Cathode Strip Chambers

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### 5.2 Event reconstruction

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#### 5.2.1 Tracks

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### 5.2.2 Electrons

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### 5.2.3 Jets

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### 5.2.4 Missing transverse momentum

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### 5.2.5 Muons

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## 5.3 Event simulation

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### 5.3.1 Event generator

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## Part IV

Dark Matter search in the Higgs

Boson associated  $b\bar{b}$  decay

# Introduction

## 6.1 MC samples

Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text.

# Boosted Xbb tagging

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## 7.2 Sample section

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### 7.2.1 Sample subsection

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## Chapter 8

# Signal selection

Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text.

### 8.1 Event Triggers

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### 8.2 Baseline selection

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#### 8.2.1 Sample subsection

Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text.

sample text. Sample text sample text sample text.

## 8.3 Signal region

TODO, MC simulation in signal region, Pie chart + table. No data.

Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text. Sample text sample text sample text.

### 8.3.1 Sample subsection

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## Background estimation

## 9.1 Backgrounds from top and W decays

### 9.1.1 Sample subsection

### 9.1.2 Sample subsubsection

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## 9.2 Backgrounds from neutrinos in Z decays

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### 9.2.1 Sample subsection

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## 9.3 Backgrounds from QCD multi-jet

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## Chapter 10

# Result

TODO, background predictions in signal region, stack chart and table.

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### 10.1 Sample section

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#### 10.1.1 Sample subsection

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#### 10.1.2 Sample subsubsection

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## 10.2 Sample section

### 10.2.1 Sample subsection

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## Part V

# Conclusions

## Conclusions

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## Part VI

# Appendices

## Appendix A

# The ATLAS detector service work

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### A.1 Sample section

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#### A.1.1 Sample subsection

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### A.2 Sample section

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## B.2 $pp \rightarrow q\bar{q}b\bar{b}$

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### B.2.1 Sample subsection

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## Part VII

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