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

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ABSTRACT

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Jue Chen

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Acknowledgments

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Dedication text

Part I

Introduction

Chapter 1

Introduction

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Part II

The standard model and Dark Matter

Chapter 2

The standard model

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2.1 Introduction

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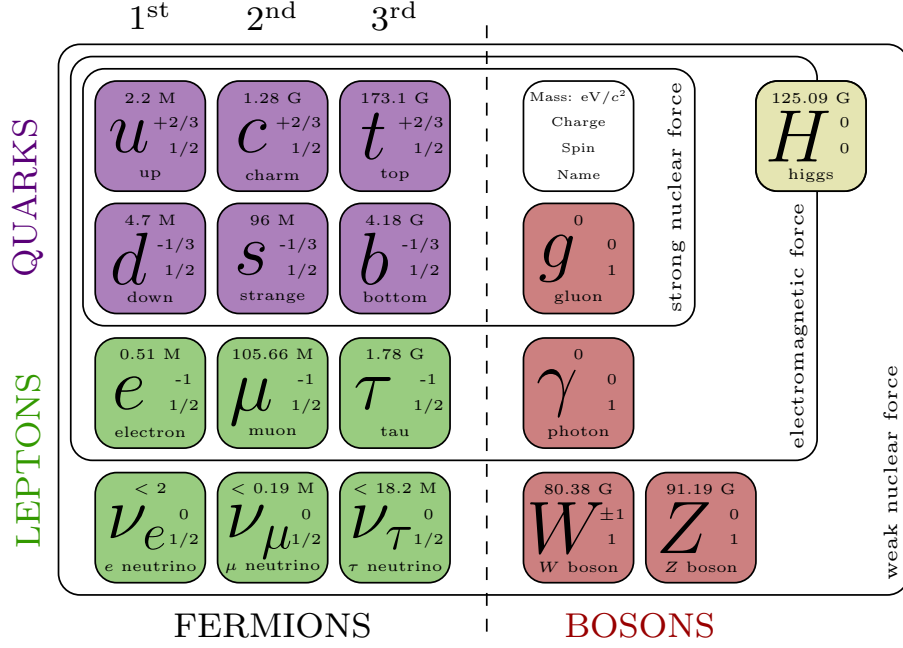
Figure 2.1: Particles of the Standard Model of particle physics

$$L = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}tr(F_{\mu\nu}F^{\mu\nu}) - \frac{1}{2}tr(G_{\mu\nu}G^{\mu\nu}), (Gauge\,terms)$$

$$+ \begin{pmatrix} \bar{\nu}_L & \bar{e}_L \end{pmatrix} \bar{\sigma}^{\mu}iD_{\mu} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R\sigma^{\mu}iD_{\mu}e_R + \bar{\nu}_R\sigma^{\mu}iD_{\mu}\nu_R, (Lepton\,dynamical\,terms)$$

$$- \frac{\sqrt{2}}{v}[\begin{pmatrix} \bar{\nu}_L & \bar{e}_L \end{pmatrix} \phi M^e e_R + \bar{e}_R\bar{M}^e\bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}], (Electron, muon, Tau\,mass\,terms)$$

$$- \frac{\sqrt{2}}{v}[\begin{pmatrix} -\bar{e}_L & \bar{\nu}_L \end{pmatrix} \phi^* M^{\nu}\nu_R + \bar{\nu}_R\bar{M}^{\nu}\phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix}], (Neutrino\,mass\,terms)$$

$$+ \begin{pmatrix} \bar{u}_L & \bar{d}_L \end{pmatrix} \bar{\sigma}^{\mu}iD_{\mu} \begin{pmatrix} u_L \\ d_L \end{pmatrix} + \bar{u}_R\sigma^{\mu}iD_{\mu}u_R + \bar{d}_R\sigma^{\mu}iD_{\mu}d_R, (quark\,dynamical\,terms)$$

$$- \frac{\sqrt{2}}{v}[\begin{pmatrix} \bar{u}_L & \bar{d}_L \end{pmatrix} \phi M^d d_R + \bar{d}_R\bar{M}^d\bar{\phi} \begin{pmatrix} u_L \\ d_L \end{pmatrix}], (Down, strange, bottom\,mass\,terms)$$

$$- \frac{\sqrt{2}}{v}[\begin{pmatrix} -\bar{d}_L & \bar{u}_L \end{pmatrix} \phi^* M^u u_R + \bar{u}_R\bar{M}^u\phi^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix}], (Up, charm, top\,mass\,terms)$$

$$+ \bar{D_{\mu}}\phi D^{\mu}\phi - m_h^2[\bar{\phi}\phi - v^2/2]^2/2v^2, (Higgs\,dynamical\,and\,mass\,terms)$$

$$(2.1)$$

The definition of derivative operators in the Eq 2.1 is:

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

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

$$D_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} = [\partial_\mu + \frac{ig_1}{6}B_\mu + \frac{ig_2}{2}W_\mu + igG_\mu] \begin{pmatrix} u_L \\ d_L \end{pmatrix} \tag{2.3}$$

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

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

2.1.1   Sample subsection

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2.2   Challenges

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2.2.1   Sample subsection

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Chapter 3

The Dark Matter

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3.1 Two-Higgs-doublet model

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3.2 Simplified model

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Part III

The LHC and ATLAS experiment

Chapter 4

The LHC

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4.1 The LHC: Instrument

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.

4.1.1 Machine layout

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.

4.1.2 Machine performance

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.

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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Chapter 5

The ATLAS experiment

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5.1   ATLAS detector system

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5.1.1   Inner detector

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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

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.

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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5.3.2   Detector simulation

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Part IV

Dark Matter search in the Higgs Boson associated $b\bar{b}$ decay

Chapter 6

Introduction

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Chapter 7

Boosted Xbb tagging

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7.1   Sample section

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7.1.1   Sample subsection

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7.1.2   Sample subsubsection

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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

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8.1 Sample section

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8.1.1 Sample subsection

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8.1.2 Sample subsubsection

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8.2.1 Sample subsection

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Chapter 9

Background estimation

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9.1   Sample section

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9.1.1   Sample subsection

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9.1.2   Sample subsubsection

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9.2 Sample section

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9.2.1 Sample subsection

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Chapter 10

Result

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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

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10.2.1   Sample subsection

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Part V

Conclusions

Chapter 11

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.1.2 Sample subsubsection

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A.2 Sample section

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A.2.1 Sample subsection

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Appendix B

Analysis supplementary materials

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B.1 $pp \rightarrow Hb\bar{b}$

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B.1.1 Sample subsection

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B.1.2   Sample subsubsection

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.

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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[Alves *et al.*, 2012] Daniele Alves, Nima Arkani-Hamed, Sanjay Arora, Yang Bai, Matthew Baumgart, Joshua Berger, Matthew Buckley, Bart Butler, Spencer Chang, Hsin-Chia Cheng, Clifford Cheung, R Sekhar Chivukula, Won Sang Cho, Randy Cotta, Mariarosaria D'Alfonso, Sonia El Hedri, Rouven Essig, Jared A Evans, Liam Fitzpatrick, Patrick Fox, Roberto Franceschini, Ayres Freitas, James S Gainer, Yuri Gershtein, Richard Gray, Thomas Gregoire, Ben Gripaios, Jack Gunion, Tao Han, Andy Haas, Per Hansson, JoAnne Hewett, Dmitry Hits, Jay Hubisz, Eder Izaguirre, Jared Kaplan, Emanuel Katz, Can Kilic, Hyung-Do Kim, Ryuichiro Kitano, Sue Ann Koay, Pyung-won Ko, David Krohn, Eric Kuflik, Ian Lewis, Mariangela Lisanti, Tao Liu, Zhen Liu, Ran Lu, Markus Luty, Patrick Meade, David Morrissey, Stephen Mrenna, Mihoko Nojiri, Takemichi Okui, Sanjay Padhi, Michele Papucci, Michael Park, Myeonghun Park, Maxim Perelstein, Michael Peskin, Daniel Phalen, Keith Rehermann, Vikram Rentala, Tuhin Roy, Joshua T Ruderman, Veronica Sanz, Martin Schmaltz, Stephen Schnetzer, Philip Schuster, Pedro Schwaller, Matthew D Schwartz, Ariel Schwartzman, Jing Shao, Jessie Shelton, David Shih, Jing Shu, Daniel Silverstein, Elizabeth Simmons, Sunil Somalwar, Michael Spannowsky, Christian Spethmann, Matthew Strassler, Shufang Su, Tim Tait, Brooks Thomas, Scott Thomas, Natalia Toro, Tomer Volansky, Jay Wacker, Wolfgang Waltenberger, Itay Yavin, Felix Yu, Yue Zhao, and Kathryn Zurek and. Simplified models for LHC new physics searches. *Journal of Physics G: Nuclear and Particle Physics*, 39(10):105005, sep 2012.

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