Shining Light on Dark Matter, One Photon at a Time

by

Brandon Leigh Allen

Submitted to the Department of Physics
in partial fulfillment of the requirements for the degree of

Doctorate of Science in Physics

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2019

Author .....
Department of Physics
May 18, 2019

Certified by .....
Christoph E.M. Paus
Professor
Thesis Supervisor

Accepted by .....
Arthur C. Smith
Chairman, Department Committee on Graduate Theses

Shining Light on Dark Matter, One Photon at a Time

by

Brandon Leigh Allen

Submitted to the Department of Physics
on May 18, 2019, in partial fulfillment of the
requirements for the degree of
Doctorate of Science in Physics

Abstract

A search is conducted for new physics in final states containing a photon and missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13$ TeV. The data collected by the CMS experiment at the CERN LHC correspond to an integrated luminosity of 35.9 inverse femtobarns. The results are interpreted as exclusion limits on the various dark matter models, such as heavy vector mediators, dimension-7 contact operators, and Higgs-portal dark sectors. Improved limits are set with respect to previous analyses using photon plus missing transverse momentum final states.

Thesis Supervisor: Christoph E.M. Paus
Title: Professor

Acknowledgments

This is the acknowledgements section. You should replace this with your own acknowledgements.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Things to be introduced.

Chapter 2

Motivation

Why I did this.

2.1 Astrophysical Evidence for Dark Matter

Galactic Rotation Curves and the Bullet Cluster.

2.2 Simplified Models for the WIMP Paradigm

It was the hot thing at the time.

Chapter 3

The CMS Detector

The big thing we know and love.

3.1 Detector Overview

What are the parts.

3.1.1 Silicon Pixel Detector

The tiny dots.

3.1.2 Silicon Strip Tracker

The thin strips.

3.1.3 Electromagnetic Calorimeter

Our $PbWO_4$ guys.

3.1.4 Hadronic Calorimeter

Our big brassy boi.

3.1.5 Muon Detectors

The red ones.

Chapter 4

Reconstruction

4.1 Reconstruction

How do we turn electrical signals into physics.

4.1.1 Particle Flow

4.1.2 MET Reconstruction

4.2 Calibration

How good is the reconstruction.

4.2.1 Trigger Efficiency

4.2.2 Photon Scale Factor

4.2.3 Pixel Veto Scale Factor

4.2.4 Lepton Scale Factors

4.2.5 Jet Energy Scale

4.3 Non-collision signatures

Things that don't come from protons.

4.3.1 Beam halo

4.3.2 ECAL Spikes

4.3.3 Fake MET

Chapter 5

The Monophoton Analysis

The main event.

5.1 Event Selection

5.2 Irreducible backgrounds

5.3 Misidentified backgrounds

5.3.1 Electrons

5.3.2 Hadrons

5.4 Non-collision backgrounds

5.4.1 Spikes

5.4.2 Beam halo

5.5 Statistical Interpretation

5.6 Results

Chapter 6

Comparison with Other Results

We're not doing this in a vacuum.

6.1 Monophoton

6.2 Monojet / Mono-Z

6.3 Direct Detection

6.4 Indirect Detection

Chapter 7

Conclusion

Things to conclude.