Thesis outline (20/05/2020)

My thesis is available to read at https://github.com/eshwen/phd-thesis and I will attach the latest version. Note, that while the repository is currently private (since non-public material has been included), you may request access to view the source or pdf by contacting me at eshwen.bhal@bristol.ac.uk.

I have discussed with my supervisor Henning, and because of the coronavirus pandemic, a paid one-month extension has been requested. The form outlining the circumstances has been sent to the graduate school, who will notify the UKRI at the end of May.

In the Higgs to Invisible analysis group, we are maintaining an internal analysis note, of which I am one of the main contributors. Some of the material missing from Chapter 4 is documented there, in varying degrees of completeness and stability. We have preliminary results and have the machinery in place to run all aspects of the analysis, including the extraction of an upper limit on the Higgs to invisible branching ratio with most sources of systematic uncertainty in the final fit. Optimisations and improvements are still underway.

My role in the Semi-visible Jets analysis is smaller and focused on signal Monte Carlo modelling. But again, we have an internal analysis note where I have contributed material from my studies.

The document currently sits at 112 pages. This includes the main content so far plus the preliminary pages, table of contents, lists of figures and tables, bibliography, and lists of glossary terms and acronyms.

The following are the chapter, section and subsection titles to give a summary of the thesis content. A given chapter, section, or subsection in bold text indicates that a first draft of it has been written. Italics indicate that it's partially been written. If there is no marker, it has not been written.

- Title page
- Abstract
- **Dedication and acknowledgements**
- Declaration
- **Table of Contents (auto-generated)**
- **List of Figures (auto-generated)**
- **List of Tables (auto-generated)**

1. **Introduction (considering alternative title)**
1.1 **Evidence for dark matter**
1.1.1 **Alternative theories to dark matter**
1.2 **Overview of dark matter searches**
1.2.1 **Dark matter searches at the LHC**

2. *Theory (considering alternative title)*

2.1 The standard model of particle physics

2.1.1 Electroweak symmetry breaking and the Higgs mechanism

2.1.2 Limitations of the standard model

2.2 Theoretical motivations for, and descriptions of, dark matter

2.3 Important observables and quantities in collider physics

2.3.1 The electron volt

2.3.2 Transverse momentum (pT)

2.3.3 HT

2.3.4 Missing transverse momentum (pTmiss)

2.4 Measuring the branching ratio of invisibly decaying Higgs bosons

2.5 Searches for semi-visible jets

2.5.1 Kinematics and free parameters of the model

3. The LHC and the CMS experiment

3.1 CERN

3.2 The Large Hadron Collider

3.2.1 A proton's journey

3.2.2 Luminosity

3.2.3 Pileup

3.2.4 Evolution of the LHC

3.3 The CMS experiment

3.3.1 The CMS detector

3.3.2 Data acquisition and triggering

3.3.3 Simulating CMS data

3.3.4 Jet energy corrections in the Level-1 Trigger

4. Combined search for invisibly decaying Higgs bosons in hadronic channels

4.1 Production modes of the Higgs boson

4.1.1 Vector boson fusion (VBF)

4.1.2 Associated production from top quarks (ttH)

4.1.3 Associated production from a vector boson (VH)

4.1.4 Gluon-gluon fusion (ggF)

4.2 Results of previous searches

4.3 Overview of the analysis

4.4 Object definitions

4.4.1 Jets

4.4.2 Muons

4.4.3 Electrons

4.4.4 Photons

4.4.5 Taus

4.4.6 Energy sums pTmiss, HT, and HTmiss

4.5 Data and simulation

4.5.1 Data

4.5.2 Simulated signal processes

4.5.3 Simulated background processes

4.5.4 Weights and corrections for simulated processes

4.6 Event selection

4.6.1   Preselection

4.6.2   Additional filters

4.6.3   Strategy to mitigate the HEM issue in 2018

4.7 Categorisation of the non-VBF production modes

4.7.1   Classifying boosted topologies from top quarks, W and Z bosons

4.7.2   Optimisation of the categories

4.7.3   Binning

4.8 Signal region, control region, and sideband definitions

4.8.1   The signal region

4.8.2   Control regions

4.8.3   Sidebands to the signal region

4.9 Background estimation

4.9.1   Lost lepton (W and ttbar + jets)

4.9.2   Z->nunu + jets

4.9.3   QCD multijet

4.10   Statistical model of the analysis

4.11   Results

5.   Search for dark matter through the production of semi-visible jets

5.1 Analysis overview

5.2 Data and simulation

5.2.1   Generating signal samples in Pythia

5.2.2   Generating signal samples in MadGraph

5.2.3   Triggers

5.3 Background estimation

-   (Pretty bare outline of this chapter since I haven't written any of it. But I expect it to follow a similar structure to the previous chapter)

6.   Conclusions

-   Bibliography
-   Glossary
-   Acronyms