



The moths of extinction will eat  
my brain as they will my clothing,  
and it will all disappear.

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Department of Physics

Lancaster University

A thesis submitted for the degree of

*Doctor of Philosophy*

August, 2023

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## Abstract

This is the beginning of the abstract that according to the regulations should not be any longer than 300 words. See point 9 in appendix 2 of the regulations <https://bit.ly/2Q4H43I>.

## Acknowledgements

Acknowledgements you may want to make. (this is not required when submitting your thesis before your viva and you can add a dedication in your final thesis after your viva if you wish.)

## Declaration

I declare that the work presented in this thesis is, to the best of my knowledge and belief, original and my own work. The material has not been submitted, either in whole or in part, for a degree at this, or any other university. This thesis does not exceed the maximum permitted word length of 80,000 words including appendices and footnotes, but excluding the bibliography. A rough estimate of the word count is:

Alina (Isobel) Hagan

## Publications

(This is an example taken from Andrew Moore’s thesis, adapt this to suit your own thesis.)

**NOTE:** If you have done joint research e.g. whereby you are not the first author and you feel you need to state the contributions you have made in those papers that relate to your thesis then create another section like ‘Contribution Statements’ whereby you state your contributions in those papers that relate to the thesis. See Kelly Widdicks thesis (page 11) for a great example. If you do create a ‘Contribution Statements’ section that you may want to revise the your ‘Declaration’, of which Kelly Widdicks declaration is a good example. Kelly’s thesis link <https://eprints.lancs.ac.uk/id/eprint/143606/1/2019widdicksphd.pdf>. Also for more details on the regulations by the university on declaring contribution statements see point 13 in appendix 2 of <https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/student-based-services/asq/marp/PGR-Regs.pdf>

**ADDITIONAL NOTE:** If you have any papers under review perhaps speak with your supervisor before adding them here for anonymity reasons.

Only one publication, shown below, has been created directly from the thesis, from which large portions of this published work is used within chapter 3:

**moore-rayson-2018-bringing**

The following publication have been generated while developing this thesis, and to an extent has guided the thesis into what it has become:

**moss-etal-2019-fiesta**

moore-rayson-2017-lancaster

el-haj-etal-2016-learning

moore2016domain

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# Chapter 1

## Introduction

### 1.1 Introduction

# Chapter 2

## The ATLAS Experiment and The Large Hadron Collider

### 2.1 Accelerators and Detectors: Basic Principles

### 2.2 The Large Hadron Collider

The Large Hadron Collider (LHC) is a modern proton-proton synchrotron located at the CERN complex, outside of Meyrin, Switzerland. At a circumference of approximately 27km the LHC is currently the largest particle accelerator on the planet, and similarly produces the highest centre-of-mass energies for pp collisions, reaching  $\sqrt{s} = 13\text{TeV}$ . The LHC was constructed from 1998-2008 in the tunnel previously occupied by the Large Electron-Positron Collider (LEP). It extends from from the CERN site, across the French border towards the Jura Mountains and round returning through Geneve and Meyrin. It is positioned on a plane inclined at 1.41% between 45-175 metres underground, a measure to protect both the experimental recordings from a large fraction of cosmic ray interference and the surface from any hazardous emissions from either the particle collisions or the synchrotron radiation.

The LHC is supported by a number of smaller accelerator systems designed

to provide proton bunches of the correct spacing and energy, these are visible in figure 2.1. The acceleration process begins with the injection of Hydrogen anions ( $H^-$ ) into LINAC<sup>1</sup>, which provides an acceleration to energies of 160MeV before the beam is passed on the Proton Synchrotron Booster (PSB)<sup>2</sup>. This continuous beam from LINAC is stripped of electrons and split consecutively amongst the four PSB rings, accelerated to 1.4GeV, and injected into the Proton Synchrotron (PS). PS produces bunches spaced by 25ns, accelerates these to 25GeV, and passes them over to the Super Proton Synchrotron (SPS) for the final energy increase up to 450GeV.

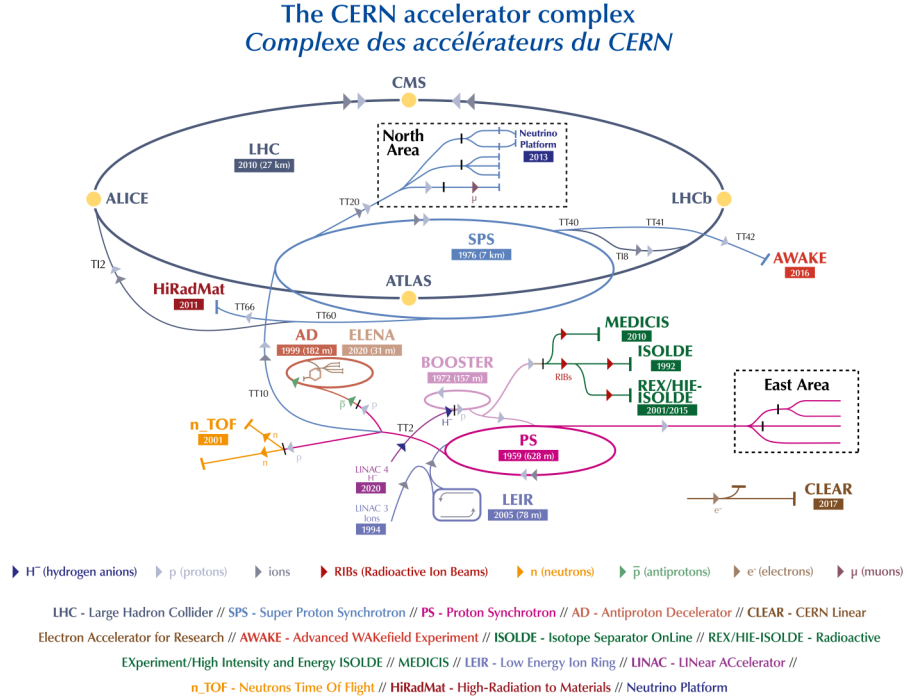


Figure 2.1: CERN Accelerator Complex schematic [1].

<sup>1</sup>This was LINAC 2 until 2020, reaching 50MeV. During Long Shutdown 2 (LS2) this was obsoleted by LINAC 4

<sup>2</sup>idk psb

## **2.3 The ATLAS Detector**

### **2.3.1 Overview**

The ATLAS Detector[CITATION] as a general-purpose detector with cylindrical geometry and a forwards-backwards symmetry. It has nearly complete coverage, approaching  $4\pi$ , in solid angle around the interaction point (IP) which is located centrally within the detector layout.

### **2.3.2 Coordinate system and common variables**

## Chapter 3

# BLS Trigger; Validation and Purity

## Chapter 4

# Transverse Momentum Dependent Parton Distribution Functions and Quarkonium Production

# Chapter 5

## Extraction of TMDs



# Chapter 6

## Conclusions

### 6.1 Results

# Appendix A

## Introduction

### A.1 Additional Tables

Some extra tables A.1 that should go in the appendix.

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Table A.1: Caption

# References

- [1] Ewa Lopienska. “The CERN accelerator complex, layout in 2022. Complexe des accélérateurs du CERN en janvier 2022”. In: (2022). General Photo. URL: <https://cds.cern.ch/record/2800984>.