UNIVERSITY
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DOCTORAL THESIS

Optimisation studies and background estimation in searches for the supersymmetric partner of the top quark in all-hadronic final states with the ATLAS Detector at the LHC

A thesis submitted in fulfilment of the requirements
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in the

Experimental Particle Physics Research Group
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Dedicated to my family.

Acknowledgements

Thanks to every single thing that went wrong. It made me stronger.

Statement

I, Fabrizio MIANO, hereby declare that this thesis, titled "Optimisation studies and background estimation in searches for the supersymmetric partner of the top quark in all-hadronic final states with the ATLAS Detector at the LHC", has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Brighton, 15th February 2018

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by Fabrizio MIANO

Abstract

This thesis presents searches for supersymmetry in $\sqrt{s} = 13$ TeV proton-proton collisions at the LHC using data collected by the ATLAS detector in 2015, 2016. Events with 4 or more jets and missing transverse energy were selected. Kinematic variables were investigated and optimisations were performed to increase the sensitivity to supersymmetric signals. Standard Model backgrounds were estimated by means of Monte Carlo simulations and data-driven techniques. Before analysing the data in the blinded signal regions the agreement between data and background predictions and the extrapolations from control and validation regions to signal regions were validated. The analysis yielded no significant excess in any of the analyses performed. Therefore limits were set and the results were interpreted as lower bounds on the masses of supersymmetric particles in various scenarios and models.

Contents

Introduction

The journey, not the destination matters.

Thomas S. Eliot

Last thing to write

1 Search for top squarks in all-hadronic final states

In God we trust. All others must bring data.

William E. Deming

In this chapter the core of this thesis will be presented, namely the search for the direct pair-production of the supersymmetric partner of the top quark in all-hadronic final states using $36.1\,\text{fb}^{-1}$ of pp collisions, at a centre-of-mass energy $\sqrt{s} = 13$ TeV, delivered by the Large Hadron Collider (LHC) and collected by the A Toroidal LHC ApparatuS (ATLAS) detector. The results produced were published in a paper in the Journal of High Energy Physics in December 2017 [1]. A previous version of the analysis was also made public, using $13.3\,\text{fb}^{-1}$ collected at $\sqrt{s} = 13$ TeV, with an earlier subset of the whole $2015 + 2016$ dataset, documented in an ATLAS conference note [2]. Although both versions contain author's contributions, only the results of the most recent analysis will be hereby discussed, as it represents the most updated, improved and extended version. Specifically, the optimisation of the search strategy, as well as the estimates of the number of events in the search regions for one of the most important backgrounds, and the evaluation of the related theory uncertainties, characterised the author's contributions.

This chapter will be structured as it follows: an excursus on the simplified Supersymmetry (SUSY) models considered will be presented in Section 1.1; the selection of the events and the objects used in both data and Monte Carlo (MC) will be presented in Section 1.2; the variables used and the optimisation of the regions in which the SUSY signals were searched for will be presented in Section 1.3; the nominal procedure used for the background estimation will be discussed in Section 1.4, with particular focus on the data-driven background estimation in Section 1.5; the results, together with their interpretation, will finally be presented in Section 1.6.

1.1 SUSY Signals

As already introduced in Section **??** when discussing the phenomenology of the top squark, the signals considered in this work are generated using simplified models

Benchmark processes

MC samples

1.2 Event Selection

Baseline Object Selection

Leptons

Photons

Jets

Overlap Removal

Signal Object Selection

Leptons

Photons

Jets

1.3 Signal Regions

Variables used

Optimisation

1.4 Nominal Background Estimation

Control Regions

Validation Regions

1.5 Data-Driven Background Estimation

1.6 Results and Interpretation

Conclusion

Every new beginning comes from some other beginning's end.

Seneca

Last thing to write

Appendix title

List of Acronyms

ATLAS A Toroidal LHC ApparatuS

LHC Large Hadron Collider

MC Monte Carlo

SUSY Supersymmetry

Bibliography

[1] ATLAS Collaboration, M. Aaboud et al., *Search for a scalar partner of the top quark in the jets plus missing transverse momentum final state at $\sqrt{s}$=13 TeV with the ATLAS detector*, JHEP **12** (2017) 085, arXiv:1709.04183 [hep-ex]. 2

[2] ATLAS Collaboration, M. Aaboud et al., *Search for the Supersymmetric Partner of the Top Quark in the Jets+E_T^{miss} Final State at $\sqrt{(s)}$ = 13 TeV*,. 2