An Analysis of Missing Transverse Momentum Triggers for Improving Efficiency at the ATLAS Experiment at CERN

by

Joseph Corrado

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Bachelors with Honors

in the
Department of Physics
Faculty of NYU Physics

NEW YORK UNIVERSITY
Spring 2019

Approval

Name: **Joseph Corrado**

Degree: **Bachelors with Honors (Physics)**

Title: **An Analysis of Missing Transverse Momentum Triggers for Improving Efficiency at the ATLAS Experiment at CERN**

Examining Committee:

Chair: Allen Mincer
Senior Supervisor
Professor

Kyle Cranmer
Professor

Daniel Zwanziger
Dean of Undergraduate Studies
Professor

Date Defended: **May 20th, 2019**

Abstract

This is a blank document from which you can start writing your thesis.

Keywords:

Dedication

This is an optional page.

Acknowledgements

This is an optional page.

Table of Contents

Approval ii

Abstract iii

Dedication iv

Acknowledgements v

Table of Contents vi

List of Tables vii

List of Figures viii

1 Introduction 1

1.1 ATLAS Experiment 1

1.2 Efficiency Curves 1

Bibliography 3

Appendix A Code 3

List of Tables

List of Figures

Chapter 1

Introduction

1.1 ATLAS Experiment

ATLAS (A Toroidal LHC ApparatuS) is one of seven particle detector experiments constructed at the Large Hadron Collider, a particle accelerator at CERN. When the LHC runs at full energy and intensity, about 600 million proton-proton collisions take place every second inside the ATLAS detector. There are 10^{11} protons in a bunch. The proton-proton interaction cross section is approximately $100mB$.

1.2 Efficiency Curves

An efficiency curve illustrates the probability of a given test algorithm to classify an event as above or below a certain threshold as a function of some given true determination of the MET. So we can ask, what is the efficiency of L1 $>$ 30 as a function of CELL MET. What this is means is we are taking the MET as determined by CELL to be the true MET, and we want to know how well L1 does at classifying events as having MET above or below 30 at each value of the MET determine by CELL. The way one would read a plot of this efficiency is to pick a value of CELL MET (on the x-axis) and ask "when CELL determined events had this MET, how often did L1 determine the MET of those same events was greater than the threshold [30 GeV]". The fraction [of the total amount of events CELL determined was in that MET bin] that L1 determined was greater than the threshold would be the height of the efficiency curve at that value of CELL MET. A perfect efficiency curve would look like a step function centered at the threshold around which one is trying to classify the MET of events. The fact that efficiency curves in reality do not look like step functions can be understood in terms of Type I and Type II error. The step function for the efficiency curve would be centered on the threshold one is asking for the efficiency about. The fact that the efficiency curve immediately to the left of the threshold is not zero means that there were events that CELL said had an MET lower than the threshold, but L1 said those same events were higher than the threshold. The fact that the efficiency curve, immediately to the right of the threshold is not one means that there were events that CELL said had a higher MET than the threshold, but L1 said those same events were lower than the threshold. In this case, the fraction of events L1 determined had an MET higher than the threshold, given that CELL said the MET was higher than the threshold, is less than one.

1.3 Missing Transverse Momentum

1.4 Bisection

In this assignment, we wanted to see if we could obtain an increase in efficiency by combined some uncorrelated algorithms together, subject to the constraint of the trigger rate. The way I did this was to try all combinations of algorithms, impose the constraint that the algorithms keep the same fraction individually, and then I performed bisection along that line in parameter space to find the value closest to the trigger rate. There are two level curves of interest in this project. The first one is what I call the production possibility frontier, to borrow a term from economics. This curve represents the solution space to the set of pairs of thresholds one could use for the pair of algorithms that satisfies the constraint of the trigger rate. The second curve that is illustrating to look at is the curve showing the pairs of points on the curve where we constrain the two algorithms to individually keep the same fraction (the line $y = x$ in the parameter space). We want to find the pair of thresholds for the algorithms that when we use both of the algorithms, such that they individually keep the same fraction of events, keep the trigger rate [fraction of events]. The level curve describing the set of pairs of thresholds such that the trigger rate constraint is satisfied is given by the constraint:

$$f(\tau_\alpha, \tau_\beta) = C$$

for some C. Here, f is the function representing the fraction of events kept when the algorithms are used together at the same time. We expect f to be a monotonic decreasing function in the thresholds, as increasing the threshold would cause fewer events to be kept by the algorithm. In order to compute C, we used the fraction of passnoalg data that passed an L1 MET cut of 50 GeV and a CELL MET cut of 100 GeV. For our analysis, C turned out to be 0.0059. So we needed to solve the equation $f(\tau_\alpha, \tau_\beta) = 0.0059$. However, because the parameter space is two-dimensional, and the evaluation of f takes a long time (fraction of events kept by both algorithms, and by each one individually), we introduced the constraint that the two individual fractions kept needed to be the same. This turned our problem into a one dimensional one, as we were solving for the intersection of the production possibilities frontier curve and the constraint curve on the individual fractions. Then, we were able to solve this one dimensional problem by using the root-finding bisection algorithm on each of the pairs of high level trigger algorithms.

1.4.1 Transverse Mass Cut

In addition to the cuts on the various algorithms, we also needed to introduce a cut on the transverse mass that is detected to ensure we only keep events with a transverse mass close to that of the W boson ($80.379 \pm 0.012 GeV/c^2$). We compute the transverse mass using:

$$m_T = \sqrt{2P_\mu P_\nu(1+\cos{(\phi)})}$$

In addition to the aforementioned cuts, we also added a cut on this quantity for the range $40 \leq m_T \leq 100$.

1.5 Results

We found that we were able to achieve an increase in the overall efficiency for some of the pairs of algorithms considered.

Appendix A

Code