The Application of Machine Learning Techniques Towards the Optimization of High Energy Physics Event Simulations within the ALICE[[1]](#footnote-2) TRD[[2]](#footnote-3) at CERN[[3]](#footnote-4)



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This dissertation is submitted in partial fulfilment of the Degree of Master of Science

This dissertation is dedicated to my mother, Elizabeth Suzanna Bloem Viljoen, who has always inspired me to follow my higher passions, despite the myriad difficulties that life makes us face; and to search fearlessly and incessantly for the deeper truths underlying our everyday world.

“

A man may imagine things that are false, but he can only understand things that are true, for if the things be false, the apprehension of them is not understanding.

”

—Sir Isaac Newton

Declaration

This dissertation is the result of my own work and includes nothing, which is the outcome of work done in collaboration except where specifically indicated in the text.

It has not been previously submitted, in part or whole, to any university of institution for any degree, diploma, or other qualification.

In accordance with the Department of Statistics guidelines, this thesis is does not exceed 20,000 words.

Signed:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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List of Abbreviations and Acronyms

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|  |  |
| ALICE | A Large Ion Collider Experiment |
| TRD | Transition Radiation Detector |
| CERN | European Organization for Nuclear Research |
| QGP | Quark Gluon Plasma |
| LHC | Large Hadron Collider |
| WLCG | Worldwide LHC Computing Grid |
| QCD | Quantum Chromodynamics |
| QGP | Quark-Gluon Plasma |
| ML | Machine Learning |
| Pb-Pb | Lead-Lead Collisions |
|  | Electron |
|  | Pion |
|  |  |

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# Introduction

## Background

This Masters Dissertation seeks to apply cutting edge techniques in Machine Learning (ML) towards the simulation of High Energy Physics (HEP) collision events, which routinely occur at the Large Hadron Collider (LHC) as part of the ongoing fundamental research conducted by the Counsel for European Nuclear Research (CERN).

More specifically, the focus of this thesis centres around the development of Deep Generative Models which are able to produce datasets that are indistinguishable from data produced by the Transition Radiation Detector (TRD) at the A Large Ion Collider Experiment (ALICE) collaboration at CERN, during Lead-Lead (Pb-Pb) heavy ion collisions.

## Aims & Goals

## Summary of Work Done & Major Findings

## The Structure & Organization of this Dissertation

# High Energy Physics & The CERN Experiment

## The Standard Model of Particle Physics

## The CERN Experiment

### Hardware

#### Accelerators

#### Detectors

#### The Worldwide Large Hadron Collider Computing Grid (WLCG)

### Software

### Collaborations

# The ALICE Collaboration

## Objectives of the ALICE Experiment

## The ALICE Detector

### The Transition Radiation Detector

# Quantum Chromodynamics & The Quark Gluon Plasma

# Deep Learning

## Mathematical Background

## Deep Feedforward Neural Networks

## Convolutional Neural Networks

## Variational Autoencoders

## Generative Adversarial Networks

# Data

# Methods

# Results

# Discussion

# Conclusion

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There are no sources in the current document.

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Example

1. A Large Ion Collider Experiment [↑](#footnote-ref-2)
2. Transition Radiation Detector [↑](#footnote-ref-3)
3. European Counsel for Nuclear Research [↑](#footnote-ref-4)