

Arbeit zur Erlangung des akademischen Grades
Bachelor of Science

**Neural network based
signal-background classification for the
differential single top+photon
measurement at the ATLAS experiment**

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Kurzfassung

Hier steht eine Kurzfassung der Arbeit in deutscher Sprache inklusive der Zusammenfassung der Ergebnisse. Zusammen mit der englischen Zusammenfassung muss sie auf diese Seite passen.

Abstract

The abstract is a short summary of the thesis in English, together with the German summary it has to fit on this page.

Contents

1 Introduction

Hier folgt eine kurze Einleitung in die Thematik der Bachelorarbeit. Die Einleitung muss kurz sein, damit die vorgegebene Gesamtlänge der Arbeit von 25 Seiten nicht überschritten wird. Die Beschränkung der Seitenzahl sollte man ernst nehmen, da Überschreitung zu Abzügen in der Note führen kann. Um der Längenbeschränkung zu genügen, darf auch nicht an der Schriftgröße, dem Zeilenabstand oder dem Satzspiegel (bedruckte Fläche der Seite) manipuliert werden.

2 Single top quark production with a photon in the Standard Model

2.1 A brief overview of the standard model

The standard model (SM) of particle physics, a so-called "gauge theory", describes today's best knowledge of elementary physics. In the SM, there are two groups of particles and three fundamental forces of nature: the electromagnetic force, the strong nuclear force and the weak nuclear force. Every force coincides with an elementary particle, called a boson that acts as a force carrier. The second group of particles, the fermions, only interact with these force-carrying bosons if they have specific values for their quantum numbers.

The fermions have spin $s = \frac{1}{2}\hbar$ and can be divided into two separate groups. The first group, named quarks, are colour charge carrying fermions. There are three up-type quarks (up, strange and truth) with an electric charge of $q = +\frac{2}{3}e$ and three down-type quarks (down, charm and beauty) with an electric charge of $q = -\frac{1}{3}e$. The second group are the leptons. Three leptons have an electric charge of $q = +1e$. Furthermore, each of these leptons has a corresponding uncharged lepton partner called a neutrino. Three different families further categorize leptons and quarks. These families are ordered by mass and consist of an up-type quark, the corresponding down-type quark, a lepton and the corresponding neutrino. There is an anti-matter particle equivalent for all fermions where every charge-like quantum number has the opposite sign.

Particles with integer spin are called bosons. The SM lists four different bosons, called gauge bosons, with spin $s = 1$: *gluons*, *photons*, Z and W^\pm . The Higgs boson is the only boson with spin $s = 0$. Gluons are colour charged and responsible for the strong nuclear force. They only couple to colour charged particles, including themselves. Photons carry the EM force to electrically charged particles. The massive bosons, Z and W^\pm are responsible for the weak nuclear force. They couple to particles with isospin. The weak force is the only way that neutrinos can interact with matter. Additionally, the W^\pm boson is electrically charged, $q = \pm 1e$, and changes the flavour of a quark when coupling to it. The Higgs boson explains how particles have mass. The boson arises from the electroweak symmetry theory and

2.2 The $tq\gamma$ process in the standard model

gives mass to particles via the Higgs mechanism. The interaction with the Higgs field is purely a product of electroweak symmetry breaking and is therefore not considered one of the fundamental forces.

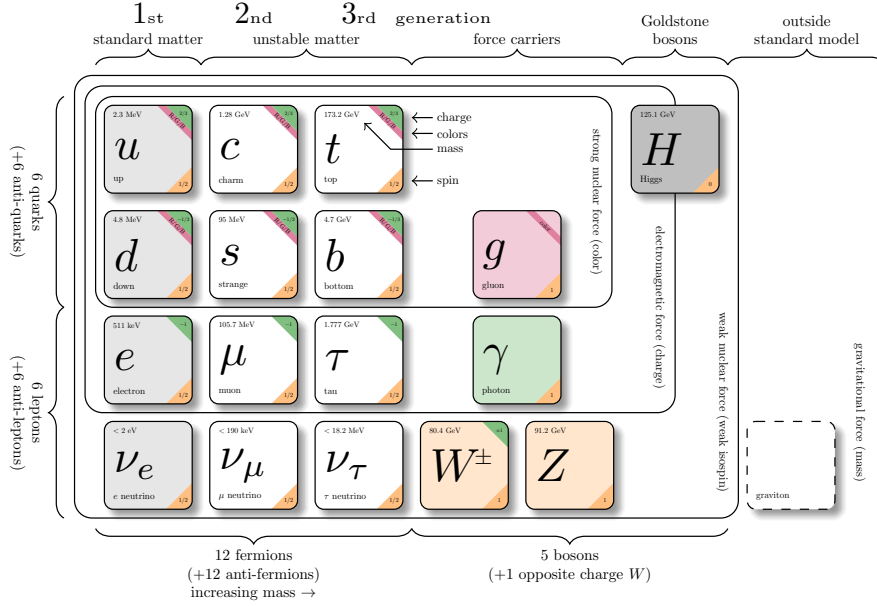


Figure 2.1: Elementary particles of the standard model alongside their properties [sm_table].

2.2 The $tq\gamma$ process in the standard model

3 Measurement of $tq\gamma$

TO DOS:

1. Define pseudorapidity in ??
2. ?? and ?? missing
3. Cite anti- k_t algorithm and study of misidentified jets in ??
4. Define coordinate systems

3.1 The ATLAS Experiment

The European Organization for Nuclear Research, known as CERN, located in Geneva, has various experiments studying elementary particles through the collision of heavy ions and protons. The Large Hadron Collider (LHC), the particle accelerator of CERN, has a circumference of 27km and can collide particles with an energy of up to 13.6TeV.

The LHC consists of four extensive experiments: the ALICE, the LHCb, the CMS and the ATLAS experiments. The research in this paper is done with the help of the largest of these experiments, the ATLAS experiment. Figure 1 visualizes the structure of the ATLAS detector. The detector is built symmetrically around the particle beam divided into three subdetectors.

The inner detector tracks charged particles just after the collision. It consists of three different systems of sensors in a magnetic field parallel to the beam. These sensors are the pixel detector, the semiconductor tracker that works with silicon strips and a transition radiation tracker to track particles with gas-filled tubes.

In the EM calorimeter, metal layers (tungsten, copper or lead) absorb incoming particles and convert them into lower-energy particles called a shower. The calorimeters detect "showers" produced by electrons, photons and hadrons. Hadrons do not deposit all of their energy into the EM calorimeter; they get absorbed by steel layers in the hadronic calorimeter. Plastic scintillating tiles then produce photons that get converted into an electric current.

3.2 Object Reconstruction at the ATLAS experiment

The muon spectrometer measures trajectories of muons with the help of a magnetic field. The spectrometer detects muons in the range of $|\eta| = 2.7$. Monitored drift tubes measure for pseudorapidities up to $\eta = 2.0$ and cathode strip chambers fill higher pseudorapidities.

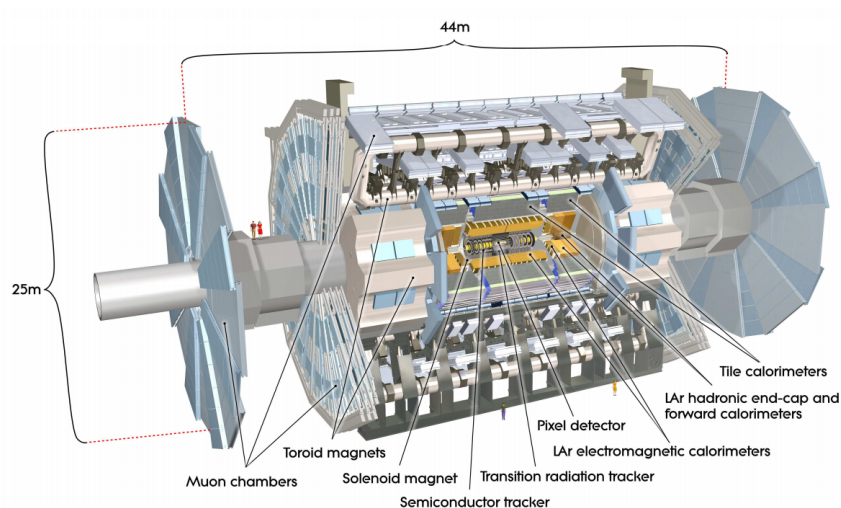


Figure 3.1: Schematic visualisation of the ATLAS Detector [Collaboration_2008].

3.2 Object Reconstruction at the ATLAS experiment

3.2.1 Reconstruction of photons

?

3.2.2 Reconstruction of leptons

?

3.2.3 Jets

Jets are clusters of mostly mesons that result from the separation of two quarks. They are reconstructed with the help of the anti- k_t algorithm [anti_k_t] with a

radius parameter of $R = 0.4$. This algorithm reconstructs jets by first identifying the particle source via the jet energy scale. It is then required that the jet has a transverse momentum of $p_T > 25\text{GeV}$ and $|\eta| < 4.5$.

Detector noise can lead to the misidentification of a jet. The nature of these misidentified jets has been studied thoroughly [70] and a so-called "jet cleaning procedure" is used to tag them. Any event containing at least one "bad" jet is removed.

3.2.4 Missing transverse momentum E_T^{miss}

If all particle products are considered, there should be no magnitude for the sum of the transverse momentum p_T of all particles. Any measured magnitude is therefore attributed to an unmeasured particle. The missing transverse momentum E_T^{miss} is consequently defined as the negative of this sum and assigned to a neutrino.

3.3 Background contributions from similar processes

The criteria for event selection ?? allow various different processes besides $tq\gamma$. These events contribute to the background noise. Any process that has similar decay products as $tq\gamma$ are background. The process $t\bar{t}\gamma$ holds the most similar decay product as its products can be identical to the products of $tq\gamma$. Following processes is the production of a W -boson with jets, a Z -boson with jets and $t\bar{t}$. Table ?? lists these and the rest of the processes contributing to the background.

	Process
1	$tq\gamma$
2	$t\bar{t}\gamma$
3	$W\gamma + jets$
4	$Z\gamma + jets$
5	$t\bar{t}$
6	$schan$
7	tW
8	$tchan$
9	VV
10	$W + jets$
11	$Z + jets$

Table 3.1: List of SM processes that contribute to background noise in the measurement of $tq\gamma$.

4 Monte Carlo samples and event selection

4.1 Generation of Monte Carlo samples

4.2 Event selection

5 The Neural Network used for signal-background classification

5.1 Short introduction to neural networks

5.2 The neural network architecture

5.3 Input features for the neural network

5.4 Performance and distribution of the NN output

6 Differential analysis of the NN output

6.1 Correlations of input features with the NN output

6.2 NN output distribution dependence on photon p_T and fjet+photon energy

7 Conclusions

