Search for New Physics with Like-sign Dimuon Events at ATLAS at $\sqrt{s} = 7$ TeV

Senior Thesis

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Abstract

A search for non-Standard Model production of like-sign prompt, isolated muon pairs is done in this project. The search is performed based on the data collected by the ATLAS detector at $\sqrt{s} = 7$ TeV at the LHC from March 2011 to June 2011. The total integrated luminosity is 1 fb^{-1}. The data is compared with the background contribution estimated by MC simulation and data-driven techniques. The number of like-sign dimuon events in the data is found to agree well with the estimated background contribution. No significant sign of new physics is found.

1. Introduction

Elementary particle physics (or high energy physics) studies fundamental particles (size < 10^{-18} m) and their interactions. Our current understanding of particles and interactions are described by a theoretical framework called the Standard Model (SM), which is a theory formed in the late 1960's and its many predictions have been verified experimentally. There are six leptons (electron, muon, tau and their corresponding neutrinos) and six quarks (up, down, strange, charm, bottom and top), arranged in three families. The interactions between these matter particles are transmitted by force carriers. The building blocks of matter and force carriers are listed in Figure 1.1. Three fundamental forces are described by the SM: electromagnetic force (transmitted by the photon), weak force (transmitted by W and Z bosons) and strong force (transmitted by gluons). A quantum field theory describing the gravitational force is still under development. The SM is still an incomplete theory, however, since it does not explain the physics of dark matter, the matter-antimatter asymmetry, the reason why fundamental particles have different masses, and so on.

The limitations on the SM has led to the emergence of new theories to explain the unanswered problems from the SM. Searching for physics beyond the SM of particle physics has been the central motivation of particle physicists to build high energy particle accelerators to study particle collisions. According to de Broglie's wave-matter duality, particles with momentum p have a wavelength of $\lambda = \frac{h}{p}$, where h is the Plank's constant, thus, the higher the particle momentum, the smaller distance it can probe. During the head-on collisions of two beams of stable particles (mostly electron-positron, electron-proton, positron-proton, proton-antiproton, proton-proton), a vast amount of energy is released. According to Einstein's mass-energy

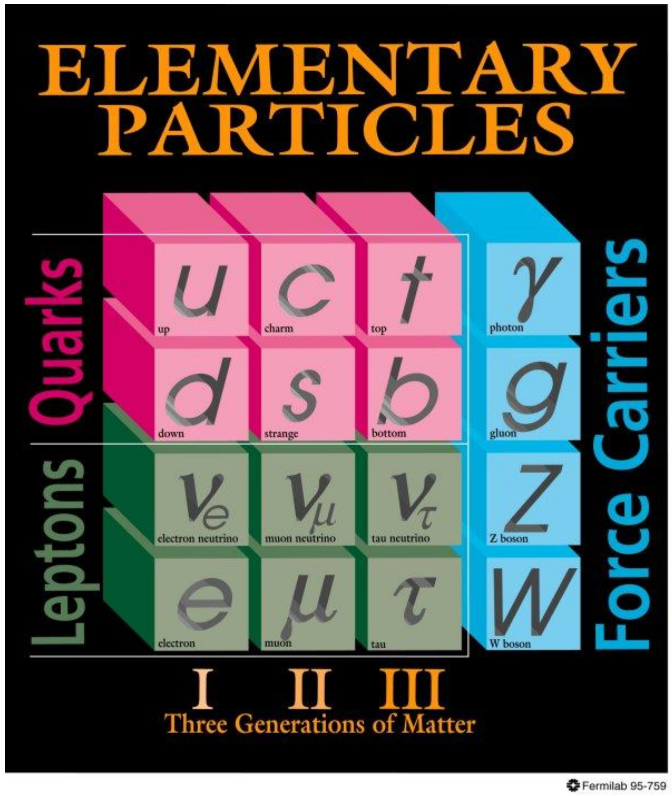

Figure 1.1 : The Standard Model has successfully explained the interactions between the building blocks of matters and the force carriers [1].

equivalence equation, $\mathrm{E} = \mathrm{m}\,\mathrm{c}^2$, new heavy particles can be created by the released energy from collisions.

The largest, most complex, and most powerful particle accelerator in our history is the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) near Geneva, Switzerland. The LHC has a circumference of 27 km and collides two proton beams with a designed center-of-mass energy of 14 Tera-electron Volt (TeV), which allows us to probe a distance that is of the order of 10^{-19} m. Currently, the accelerator is running at half of its designed energy 7 TeV. There are four particle detectors at the LHC: ALICE (A Large Ion Collider Experiment), ATLAS (A Toroid LHC ApparatuS), CMS (Compact Muon Solenoid),

Figure 1.2: Aerial view of the LHC machine near Geneva, Switzerland [2].

and LHCb (LHC Beauty). Figure 1.2 shows the aerial view of the LHC near Geneva, Switzerland.

1.1. About The Project

Dilepton events have very clean detector signatures. The study with dilepton events has been considered as one of the best channels to search for the existence of new physics. As a part of studying dilepton decay channels, studies with like-sign dilepton events can be promising testing grounds for new physics, since the production of high-momentum dileptons with the same electric charge is rare in the SM but it appears in a range of models beyond the SM such as supersymmetric models [3], universal extra dimensions [4], heavy Majorana neutrino models [5], fourth-generation quark models [6], and doubly charged Higgs boson models [7].

This project specifically focuses on a search for the anomalous production of like-sign dimuon events. Studying muons offer some advantages over other leptons: (1) electrons suffer energy losses from Bremsstrahlung radiation, while muons are much less susceptible to these effects because of their heavy masses; (2) most particles will deposit all energies and stop inside the calorimeters, while muons are the only charged particles that can penetrate the calorimeters and be detected by the muon system; (3) smaller backgrounds are expected for muon analyses compared with electron analyses; (4) the charge of muons can be determined by both the inner tracker and the muon spectrometer, hence, more accurate charge information can be obtained; and, finally, (5) the charge mis-identification rate is often very small (less than 10^{-4}).

Various selection criteria are applied to select events with two high-momentum like-sign muons from data collected by the ATLAS detector. The SM predictions of like-sign dimuon events are estimated either by Monte Carlo (MC) simulation or by data-driven techniques. The numbers of events observed in the data and expected from the SM processes are compared for possible excess in the data.

This thesis is organized in the following way: a discussion of the ATLAS detector is presented in Section 2. The muon reconstruction is described in Section 3. Event selections are described in Section 4. The background estimation using the matrix method and MC simulation is discussed in Section 5. Finally, results are discussed in Section 6.

2. The ATLAS Detector

The ATLAS detector is a general purpose particle detector. It is cylindrical-shape collider detector that measures the spatial position, energy and momentum of leptons, photons and hadrons from proton-proton collisions at the LHC. The detector is ~25 m in diameter and ~45 m long, and its total weight is ~7000 metric tons. The ATLAS detector is shown in Figure 2.1. The following convention for coordinates is used: the positive x direction points to the center of the LHC ring and the positive y direction points up to the sky, and a right-hand coordinate system is used and thus the positive z direction is along with the direction of one proton beam. Conventionally, Lorentz invariant physical quantities are used in analyzing collision data. Quantities used are the energy, E, and the transverse momentum, $p_T = p \sin\theta$, where θ is the polar angle with respect to the z-axis and p is the momentum. In addition, the pseudorapidity, $\eta = -\ln[\tan\frac{\theta}{2}]$, and the azimuthal angle $\phi = \tan^{-1}[\frac{p_y}{p_x}]$ are also used in analyzing collision data.

The ATLAS detector consists of four major components: an inner tracking detector (ID), a calorimeter, a muon spectrometer (MS), and a magnet system. The ID is the center-most part of the detector and directly surrounds the collision point. It consists of a silicon pixel detector (Pixel), a semiconductor tracker (SCT), and a transition radiation tracker (TRT). The ATLAS detector uses a solenoid magnet around the ID that provides the magnetic field magnitude of 2 T. The ID measures the momentum of each charged particle and determines the position of the collision vertices, and covers the pseudorapidity range $|\eta| < 2.5$. A calorimeter system encloses the ID. It is used to measure the energies of charged and neutral particles and provide missing energy information. The calorimeter system is surrounded by the MS which identifies the momenta of muons. The magnetic system provides magnetic fields to the ATLAS detector primarily to measure the momenta of charged particles.

There are about 40M collisions happened every second, not all of them are interesting. It is also not practical to record all events, a trigger system is thus designed to select only a few hundred events per second from all 40M collisions. The trigger system consists of three levels: Level-1 (L1), Level-2 (L2), and Event Filter. The L1 trigger looks at muon signatures and its missing traverse energy and total traverse energy. The L1 trigger can reduce the event rate to 75 kHz. The L1 trigger is followed by the L2 trigger and the Event Filter. They are software-based triggers and can reduce the overall event rate to about 300 Hz.

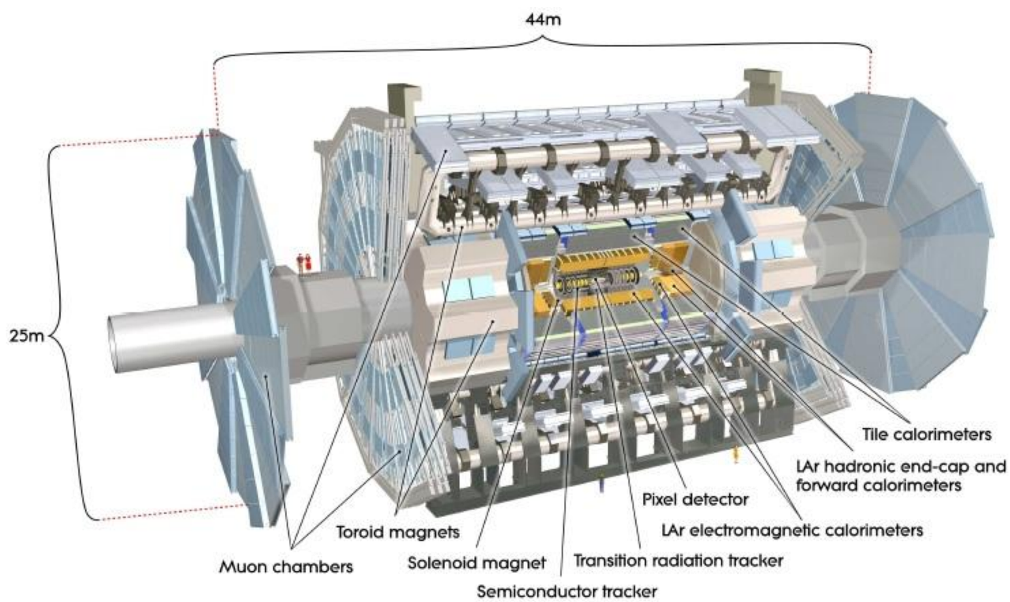

Figure 2.1: Cut-away view of the ATLAS detector [8].

2.1. The Muon Spectrometer (MS) and the Tracking System

The MS is the outer-most part of the ATLAS detector, and has the total area of $\sim 1.2 \times 10^4$ m^2, which is equal to the area of three football fields. The primary task of the MS is to detect muons and to measure their momentum in the pseudorapidity range $|\eta| < 2.7$. The MS is also capable of triggering on muons in the range $|\eta| < 2.4$. The MS consists of three air-core toroidal magnets, one barrel toroidal magnet and two end-cap toroidal magnets, providing a field of approximately 0.5 T. The magnet system is associated with the measurement of the momenta and charges of muons. Besides its magnetic system, the MS consists of various kinds of chambers around the barrel region and the end-cap regions to track trajectories of muons and to trigger them on. Monitored drift tube (MDT) chambers and cathode strip chambers (CSCs) are used as the precision tracking chambers to measure the muon trajectory. Resistive plate chambers (RPCs) and thin gap chambers (TGCs) are used as trigger chambers to provide muon trigger information and to measure the second-coordinate along the non-bending plane. The MS is designed to measure muons with a standalone momentum resolution of 10% for 1 TeV muons. The layout of the ATLAS muon system can be found in Fig. 2.2.

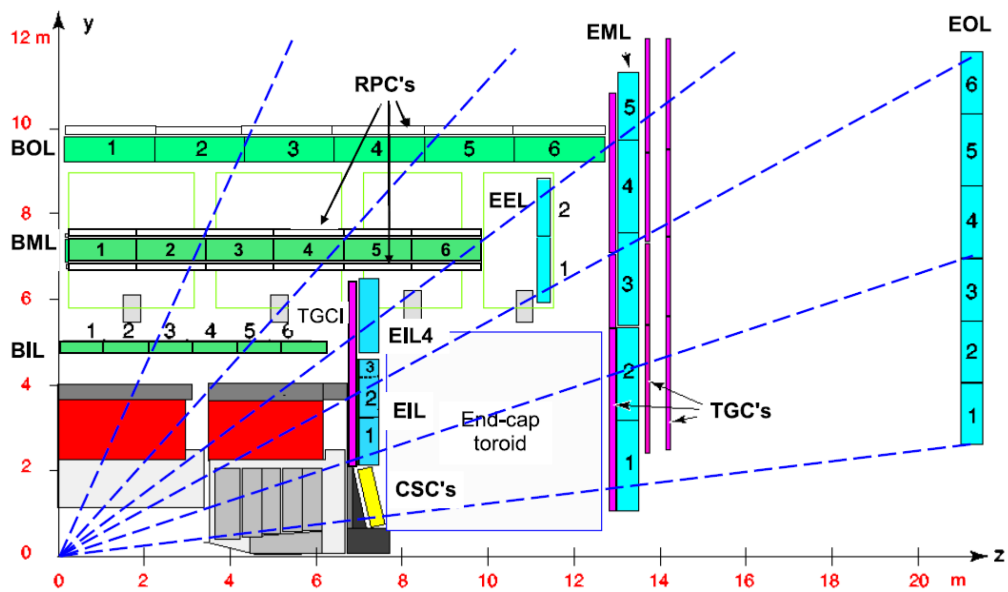

Figure 2.2: Cross-section of the muon system in a plane containing the beam axis. Infinite-momentum muons would propagate along straight trajectories which are illustrated by the dashed lines and typically traverse three muon stations [8].

A MDT is an aluminum tube with a diameter of 30 mm, is filled with Ar/CO_2 gas at 3 bar, and has a tungsten wire with a diameter of 30 μm in the center. The aluminum wall of the tube acts as a cathode while the tungsten wire acts as an anode. A high voltage of 3080 V is applied. When a muon passes through this tube, the muon interacts with the gas and ionizes electrons from the gas atoms. The ionized electrons, then, are attracted towards the tungsten wire and charges are collected. The timing information and the total collected charge provide information for the muon trajectory measurement. The cross section view of a MDT tube can be found in Fig. 2.3. The trajectory of muon, however, cannot be directly measured by MDT chambers due to the symmetrical nature of the tubes. Multiple layers of MDT tubes are used to remove that ambiguity and determine the precise position of muon hits. Three stations of muon MDT chambers (inner, middle and outer) are used to determine the bending angle and momentum of a muon passing through three stations. The layout of one of the muon MDT chambers can be found in Fig. 2.4. In the region $2 < |\eta| < 2.7$, the inner layer of the end-cap regions, CSCs replaces MDT chambers for the precision measurement. They operate in the similar manner as MDT chambers.

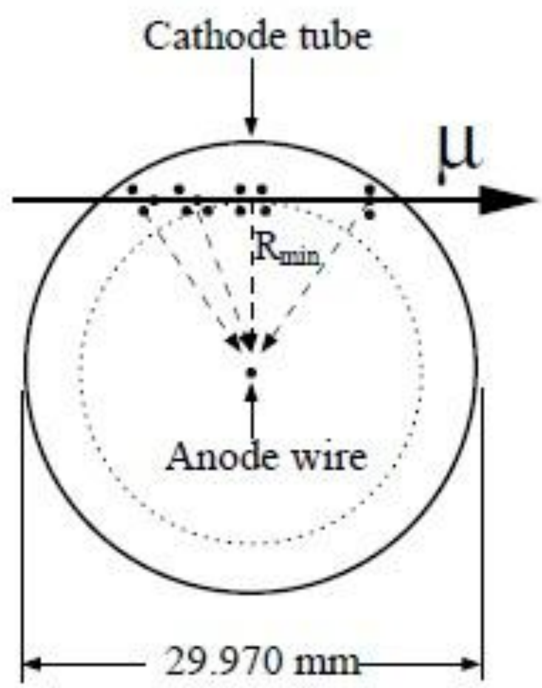

Figure 2.3: Cross-section of a MDT tube. The muon path cannot be directly measured from a MDT tube because of its symmetry [8].

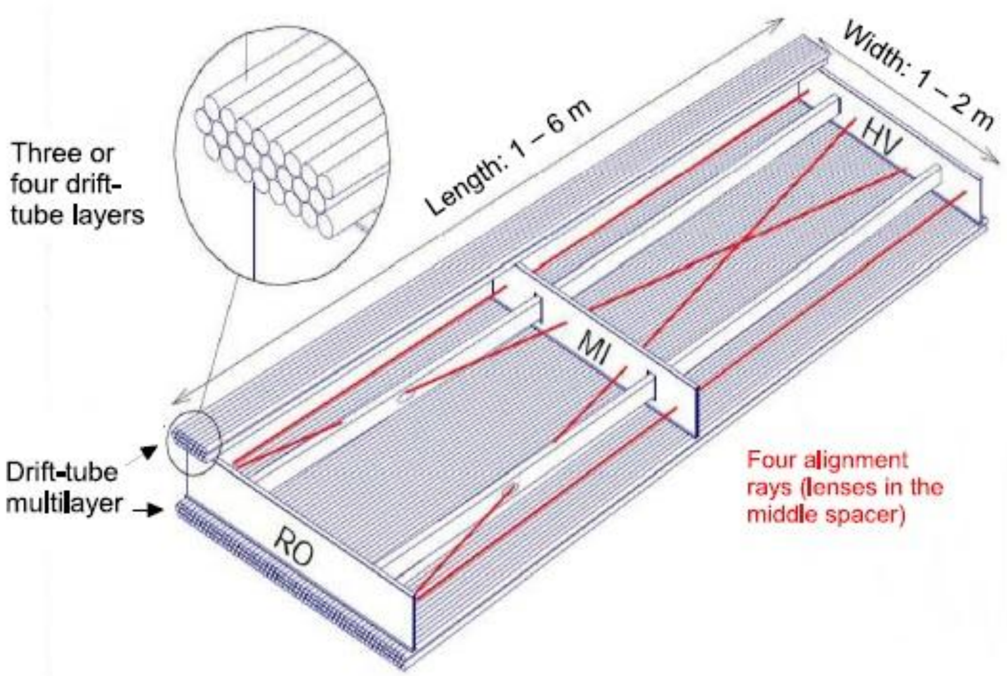

Figure 2.4: Mechanical structure of a MDT chamber. Many MDT tubes are put together as layers and forms a chamber [8].

3. The Muon Reconstruction

Information from the MS, the ID, and the calorimeter are used for the muon reconstruction. The tracks of muons are reconstructed from the combination of the MS tracks and the ID tracks. The magnetic system and the precision tracking system of the MS make it possible to reconstruct momenta of muons. After the trajectory of muon is measured, the momentum of muon can be measured since the bending of the trajectory is related to the magnitude of the magnetic field of the MS by the Lorentz force law. The general idea behind the momentum measurement of a charged particle is to equate the centripetal force on the bending particle and the Lorentz force from the magnetic field. This relationship can be written as:

$$m\frac{v^2}{\rho} = q\, v\, B \sin\theta$$

where m is the mass of the particle, v is the velocity of the particle, ρ is the bending radius of the particle, q is the charge of the particle, B is the magnitude of the field, and θ is the angle between the direction of the particle's velocity and the direction of the field. Thus, the momentum of the particle, p, is found as:

$$p = q\, \rho\, B \sin\theta$$

or in terms of the deflection angle, ϑ, this can be written as:

$$p = q\frac{L}{\vartheta} B \sin\theta$$

where L is the magnet length. In general the deflection angle can be determined from the particle track coordinates measured in the spectrometer. The above relation can also be restated in terms of the depth of an arc (sagitta), s. The sagitta s is related to the magnetic bending radius ρ and the magnetic deflection angle θ by

$$s = \rho\left(1 - \cos\frac{\theta}{2}\right) = 2\rho \sin^2\frac{\theta}{4} \approx \frac{\rho\, \theta^2}{8}\ (\text{for } \theta \ll 1)\,.$$

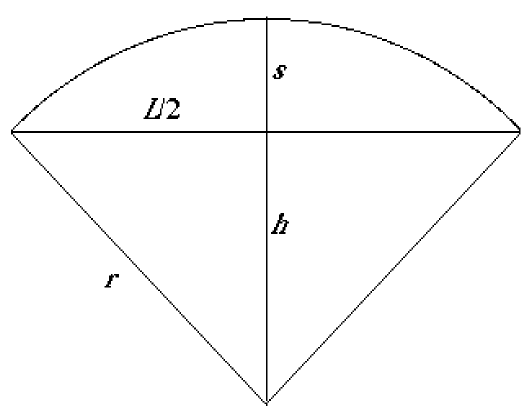

Figure 3.1: Illustration of the sagitta method for momentum determination. The momentum of a muon can be determined from the measurement of the sagitta s [9].

Hence, the sagitta s and the momentum p is related by

$$p = \frac{q\,B\,L^2}{8\,s}.$$

The measured muon traverse momentum from information collected by the MS and the ID should be greater than 20 GeV. In addition, the value of $|\eta|$ of the reconstructed muon should be less than 2.4.

4. Event Selection

The data sample used in this project has been collected by the ATLAS detector at $\sqrt{s} = 7$ TeV at the LHC from March 2011 to June 2011. The total integrated luminosity is 1 fb^{-1}. Only events taken with single lepton triggers are used. Any events that produce at least two like-sign muons are selected. All candidate events are required to originate from a primary vertex. Only muons with $p_T > 20$ GeV are considered for study. In order to remove the background contribution from low Drell-Yan process ($q\bar{q} \rightarrow \gamma^* \rightarrow \mu^+\mu^-$), the invariant mass, $m_{\mu\mu}$, of the dimuon pair should be greater than 15 GeV. The invariant mass of the two detected muons is calculated by:

$$m_{\mu\mu} = \sqrt{(E_1 + E_2)^2 - \left(p_{x,1} + p_{x,2}\right)^2 - \left(p_{y,1} + p_{y,2}\right)^2 - \left(p_{z,1} + p_{z,2}\right)^2}$$

where the indices 1 and 2 represent the leading p_T muon and the sub-leading p_T muon, and E, p_x, p_y, and p_z are the four momenta of each muon. The charge information of each muon from the MS and the ID should match as well. The event selection criteria are summarized in Table 4.1.

5. Backgrounds

The background contributions are divided into two categories: (1) irreducible physics background and (2) instrumental background. The irreducible physics background comes from

Criteria	Requirements
Charge	• All dimuon events must have the same electric charge and sign. • The charge information of each muon from the MS and the ID must be the same.
p_T	• Each final state muon must have p_T greater than 20 GeV.
$m_{\mu\mu}$	• $m_{\mu\mu}$ must be greater than 15 GeV.
Others	• All dimuon events originate from the primary vertex. • The pseudorapidity range, $\|\eta\|$, should be less than 2.4.

Table 4.1: The dimuon event selection criteria.

SM processes that can produce prompt like-sign muon pairs. The dominant processes are $W^{\pm}Z^{0} \rightarrow \mu^{\pm}\nu\,\mu^{\pm}\mu^{\mp}$ and $Z^{0}Z^{0} \rightarrow \mu^{\pm}\mu^{\mp}\mu^{\pm}\mu^{\mp}$. Other physics processes that produce two opposite-sign muons but with one muon's charge mis-identified (due to the charge-filp) have negligible contributions. The irreducible physics background is estimated using MC simulation. The instrumental background is caused by muons from hadronic decays (mainly from b- or c-hadrons) that are mis-identified as isolated muons. This contribution is difficult to be estimated correctly by MC simulation and has to be estimated using data-driven techniques.

5.1. Matrix Method

A matrix method is applied to estimate estimating the instrumental background for the final selected like-sign dimuon events. This method has been used by several analyses in the ATLAS experiment [10]. In this method, all the dimuon events in data are divided into four groups based on muon isolation cuts, *good* (G) and *bad* (B). The muon isolation cut is $\sum p_T < 10$ GeV, where the sum is for all tracks with $p_T > 1$ GeV for a cone of $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.4$ around a muon. The *good* muons meet all of the requirements in Section 4 and the isolation cut, and the requirements for the *bad* muons are the same as the tight muons except for the isolation requirement. The four groups with different isolation requirements are represented as GG, GB, BG, and BB, where the first index corresponds to the isolation requirement of the leading p_T muon and the second index corresponds to that of the sub-leading p_T muon. The number of real (R) and non-prompt "fake" (F) muons can be estimated from the matrix method by the following formula:

$$\begin{bmatrix} N_{GG} \\ N_{GB} \\ N_{BG} \\ N_{BB} \end{bmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r)_2 & r_1(1-f)_2 & f_1(1-r)_2 & f_1(1-f)_2 \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

where $N_{B(G)B(G)}$ is the number of dimuon pairs in each of the four isolation groups, $r_{1,2}$ is the efficiency rate of the leading p_T muon (1) and sub-leading p_T muon (2) pairs, $f_{1,2}$ is the fake rate of the leading p_T muon and sub-leading p_T muon, and $N_{R(F)R(F)}$ is the composition of the dimuon in terms of real (R) and non-prompt (F) muons. The values of r and f are determined by data and the estimated background contribution of non-prompt pairs can be calculated by the sum of N_{RF}, N_{FR}, and N_{FF}.The efficiency r is measured using the tag-and-probe method on $Z \to \mu\mu$ event. One *good* muon is selected and the invariant mass of the two muons are required to be close to the Z pole mass. The probe muon is then check to see how often it passes the isolation cut. The fake rate f is measured from a QCD dijet-enriched sample, where the sample is selected by requiring a *good* jet and a muon to be back to back in φ. To remove the contamination from W ($\to \mu\nu$) + jet process, the missing transverse energy for the whole event is required to be less than 15 GeV. The fake rate is then defined as the probability for the muon to pass the isolation cut. Figure 5.1 shows the plot of the fake rate as a function of p_T.

5.2. Monte Carlo (MC) Estimation

The irreducible physics background contains two isolated muons in the event, and its contribution is estimated by using MC simulation. Events are generated with different event generators for different physics processes, and the detector response simulation is based on the GEANT4 program. Lepton reconstruction and identification efficiencies, trigger efficiency, lepton energy scales, and resolutions are corrected to what observed in the data in order to get better modeling of the SM backgrounds. Charge mis-identification rates in data and MC simulation are found to be close to each other [11].

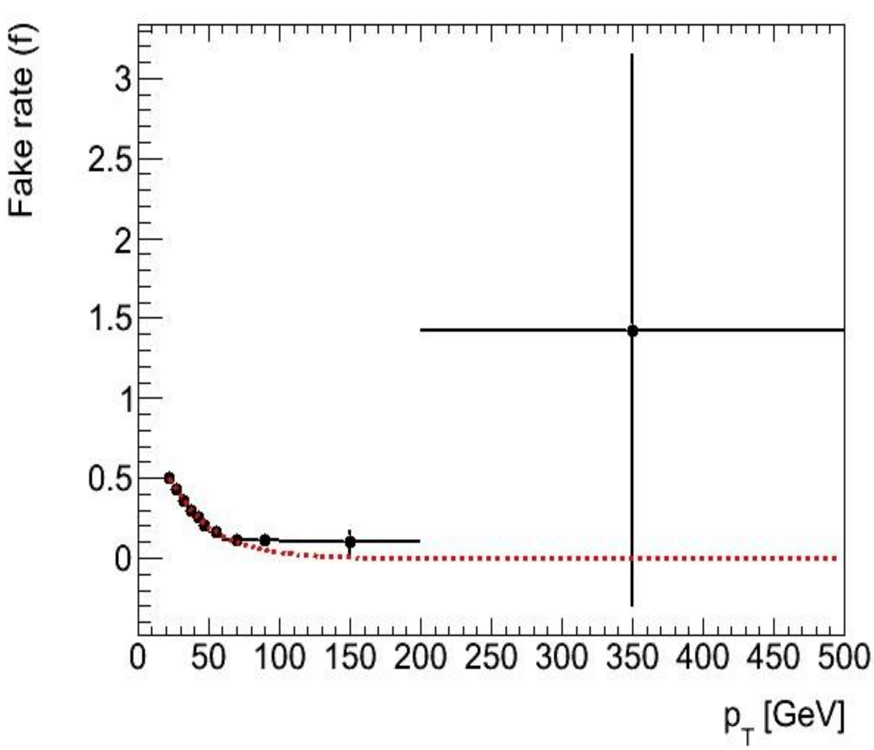

Figure 5.1: The plot of the fake rate as a function of p_T.

To estimate the contribution from each process, and to compare the estimation with the real data, the MC samples have to be normalized and reweighted according to the integrated luminosity of MC simulated events, L^{MC}. The integrated luminosity for the MC samples is found by the following formula:

$$L^{MC} = \frac{N^{MC}}{\sigma \times A \times \varepsilon}$$

where N^{MC} is the number of MC simulated events, σ is the inclusive cross-section area of the physics process, A is the acceptance, and ε is the detection efficiency. Finally, the normalized estimated number of events, then, can be calculated by:

$$N^{Estimated} = \frac{N^{MC}}{L^{MC}} \times L^{Data}$$

where L^{Data} is the integrated luminosity of the actual data.

6. Results

The like-sign dimuon events are predicted by the SM and many other new physics models. They can also be produced from hadronic decays (jets). Experimentally, the mis-measurement by the detector can also contribute to the like-sign dimuon event production. In order to determine whether the experimentally observed like-sign dimuon events are from new physics or not, the actual data is compared with the estimated backgrounds.

The number of like-sign dimuon events in the collected data is compared with the estimated number of events from the irreducible physics background and the instrumental background. MC simulation estimates the irreducible physics background contribution from the SM (prompt dimuons). Non-prompt "fake" like-sign muon pairs from the instrumental background are predicted by the matrix method.

From the data, it is observed that the total number of dimuon events is 1953. From that, the total number of like-sign dimuon events is 22. The detailed information about the number of dimuon events are summarized in Table 6.1.

6.1. The Instrumental Background

The number of non-prompt like-sign dimuon events is estimated by the matrix method. With the data given in Table 6.1, N_{RR}, N_{RF}, N_{FR}, and N_{FF} are calculated for like-sign dimuon pairs.

	The number of events (Total number of events: 1953)		
Isolation Group	**$\mu^+ \mu^+$**	**$\mu^- \mu^-$**	**Total like-sign pairs**
No isolation cut	11	11	22
GG	3	3	6
GB	3	2	5
BG	1	2	3
BB	4	4	8

Table 6.1: The number of like-sign dimuon events

The efficiency, r, is set to be 99.5 % and the fake rate, f, is determined by the data and is described as a function of p_T.

The statistical uncertainty is calculated from the formula:

$$Statistical\ Uncertainty = \sqrt{\sum w_T^2}$$

where w_T is the probability for an event to come from a specific physics process. The systematic uncertainty is found by varying r by $\Delta r = \pm 0.5\,\%$ and f by $\Delta f/f = \pm 10\,\%$. The calculated N_{RR}, N_{RF}, N_{FR}, and N_{FF} are presented in Table 6.2. It is found that the total number of like-sign dimuon from non-prompt dimuon background is $16.93 \pm 12.40\,(Stat.) \pm 1.03\,(Syst.)$. The major contribution of the overall uncertainty is from the statistical uncertainty.

6.2. The Irreducible Physics Background

From MC simulation, the number of like-sign dimuon events from the irreducible physics background is estimated. Since the dominant processes of the dimuon production are from WZ and ZZ processes, this project only considers these two processes, and other physics processes that produce like-sign dimuon events are neglected since their contributions are negligible. MC simulation has produced a total of 249999 events. Out of the 249999 events, 400 like-sign dimuon events has been produced by WZ process, and 119 like-sign dimuon events has been produced by ZZ process. WZ process has a cross-section of 46.1 fb and ZZ process has a cross-section of 182.2 fb. The systematic uncertainty has two different contributions: one from the uncertainty of the theoretical cross-sections of WW and ZZ processes and the other from the uncertainty of the muon trigger, reconstruction and identification efficiencies. Each source contributes $\sim 5\,\%$ of the uncertainty and, thus, the overall uncertainty is $\sim 7\,\%$. The statistical uncertainty is given by the formula of the standard deviation of the binomial distribution:

$$Statistical\ Uncertainty = \frac{\sqrt{N\,p\,(1-p)}}{N}$$

where N is the total number of MC simulated events and p is the probability.

The Instrumental Background (Non-prompt Muons)	
	$\mu^+\mu^+$
N_{RR}	$0.61 \pm 2.74\ (Stat.) \pm\ 0.30\ (Syst.)$
N_{RF}	$2.64 \pm 3.82\ (Stat.) \pm\ 0.22\ (Syst.)$
N_{FR}	$-2.77 \pm 3.13\ (Stat.) \pm\ 0.97\ (Syst.)$
N_{FF}	$10.52 \pm 5.30\ (Stat.) \pm\ 1.49\ (Syst.)$
Background	$10.39 \pm 7.24\ (Stat.) \pm\ 0.30\ (Syst.)$
	$\mu^-\mu^-$
N_{RR}	$4.46 \pm 2.87\ (Stat.) \pm\ 1.33\ (Syst.)$
N_{RF}	$-3.95 \pm 4.29\ (Stat.) \pm\ 2.19\ (Syst.)$
N_{FR}	$-4.97 \pm 4.69\ (Stat.) \pm\ 2.54\ (Syst.)$
N_{FF}	$15.46 \pm 7.81\ (Stat.) \pm\ 3.40\ (Syst.)$
Background	$6.54 \pm 10.07\ (Stat.) \pm\ 1.33\ (Syst.)$
	Total like-sign muon pairs
N_{RR}	$5.07 \pm 3.97\ (Stat.) \pm\ 1.03\ (Syst.)$
N_{RF}	$-1.30 \pm 5.74\ (Stat.) \pm\ 2.41\ (Syst.)$
N_{FR}	$-7.74 \pm 5.63\ (Stat.) \pm\ 3.51\ (Syst.)$
N_{FF}	$25.98 \pm 9.44\ (Stat.) \pm\ 4.90\ (Syst.)$
Background	$16.93 \pm 12.40\ (Stat.) \pm\ 1.03\ (Syst.)$
The Irreducible Physics Background (Prompt Muons)	
$WZ \rightarrow\ \mu^{\pm}\nu\ \mu^{\pm}\mu^{\mp}$	$8.68\ \pm 0.0016\ (Stat.) \pm\ 0.61\ (Syst.)$
$ZZ \rightarrow\ \mu^{\pm}\mu^{\mp}\mu^{\pm}\mu^{\mp}$	$0.65\ \pm 0.0005\ (Stat.) \pm\ 0.05\ (Syst.)$
The Total Background Contribution	
Background	$26.26\ \pm 12.4\ (Stat.) \pm\ 1.20\ (Syst.)$

Table 6.2: The summary of the estimated background contributions.

Hence, the total estimated numbers of like-sign dimuon events produce by WZ and ZZ processes are:

$$\mathrm{WZ} \rightarrow \mu^{\pm}\nu\, \mu^{\pm}\mu^{\mp}: 8.68\ \pm 0.0016\ (Stat.) \pm\ 0.61\ (Syst.)\ ,$$

$$\mathrm{ZZ} \rightarrow \mu^{\pm}\mu^{\mp}\mu^{\pm}\mu^{\mp}: 0.65\ \pm 0.0005\ (Stat.) \pm\ 0.05\ (Syst.)\ .$$

The estimated numbers of like-sign dimuon events are summarized in Table 6.2.

6.3. Conclusion

A search for non-Standard Model production of like-sign prompt, isolated muon pairs is done in this project. The search is performed based on the data collected by the ATLAS detector. The data is compared with the background contribution estimated by MC simulation and data-driven techniques. The total number of estimated like-sign dimuon events is $26.26\ \pm 12.4\ (Stat.) \pm 1.20\ (Syst.)$. The actual number of like-sign dimuon events observed by the ATLAS detector is 22. Hence, it can be concluded that the number of like-sign dimuon events in the data is found to agree well with the estimated background contribution. This result confirms that the all of the observed dimuon events are from the SM physics processes and the instrumental background. No significant sign of new physics is found.

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