Chapter 1

Introduction

1.1 Particle Physics Research

The scientific quest to understand the most basic constituents of matter began since the discovery of electron by J.J.Thompson in 1897. Since then, the research in this field flourished. Various kinds of particles kept revealing through experimental apparatus for a duration of a few decades. Theory of their existences and their interactions were gradually formed, corrected and proved by experiments. Among hundreds of particles being discovered and theories those lie under them, human gain benefits mostly from particles in the scale of electrons and nuclei. Knowledge on electrons and atoms like the quantum theory has proved to be one of the most important concepts that affect human life in unimaginably profound way: they are widely applied to various kinds of applications like semiconductor, medicine, information technology and many more. On the other hand, knowledge on other exotic particles which exist for only a few millionth seconds are rarely useful in everyday life. It only benefits to a small group of people in narrow field such as Cosmic Rays, High Energy physics or Cosmology. To them, even though exotic particles might come to existence for extremely short period of time, they could help physicists shed the light on unsolved mystery of the most basic law of nature such as the evolution of the universe, the unification of force, or the source of massive particles. Their applications are far from being exploited, but fundamental knowledge is what particle physicists are looking for and this has long driven most physicists to do research that later unknowingly transform the way we live forever.

Until now, explanations for interactions among most particles are explained in a theory called *Standard Model.* The model, which I will describe in more detail in the following chapter, has been successfully tested to a high level of accuracy in almost all of its aspects. It is known to be one of the fundamental principles like Newton's or Maxwell's laws. Yet, there remains many unanswered questions: for example, What is the origin of the particle masses? Is there a Higgs boson? How small are neutrino masses?, etc. Inspired to answer these questions and to go beyond to test new theory such as Supersymmetry or String Theory, hundreds of particle physicists around the world have collaborated for a very ambitious Large Hadron Collider (LHC) project.

The LHC's beam intensity is characterized by its "luminosity." Its relation to a cross-section of particular event is given by

$$\mathcal{L} = R_{evt}/\sigma$$

where $\mathcal{L}$ is the luminosity, R_{evt} is an event rate of particular event in unit s^{-1} and σ is a cross-section of that event in unit cm^2. In order to accurately measure cross-section using this relation, we need to be able to measure the luminosity with high accuracy.

The goal of LHC luminosity measurement is to attain a precision level of ± 5% in order to satisfy the planned physics studies of the project. Recently, none of existing techniques have been able to meet such high precision level. Among numbers of new methods proposed to measure the LHC luminosity, one proposed by M. Dittmar et al., is to use the production of the $W^{\pm}$ and Z^0 particles since, at the LHC, the weak boson particles will be produced at high rates and with clean signatures. Moreover, their cross-sections and properties are known to good accuracy using data collected from previous experiments at the Large Electron-Positron Collider (LEP).

Under some investigations on using this method to measure the LHC luminosity carried out by V.A. Khoze et al., the precision level of ± 4% [1] can be achieved. However, the results from this work is merely theoretical prediction; none of the effect from the detector, electronic readout response and background issues were taken into account.

In this thesis, as part of the collaboration with the Compact Muon Solenoid (CMS) project at the European Organization for Nuclear Research (CERN), we aim to study the possibility of using the $W^{\pm}$ and Z^0 production to measure the luminosity of the LHC. Our work will be focused on two aspects: 1) the the study of potential background to the $W^{\pm}$ and Z^0 production signal and 2) the study of the effect of the efficiency of the CMS detector and its reconstruction system to the uncertainty in luminosity measurement. We presents our results in this thesis, which is divided into six separated chapters. In the following chapter, Chapter 2, we first give theoretical background essential for understanding the work being performed. The topics include the Standard Model, the structure of proton, the luminosity measurement methods and physics of the $W^{\pm}$ and Z^0 production at the LHC. In Chapter 3, we discuss some descriptions of the physical and technical aspects of the LHC machine and the CMS particle detector. In Chapter 4, the explanations of our simulation procedure and its corresponding CMS softwares will be discussed. Next, in Chapter 5, we show the results we have obtained and some discussions on how do they effect the uncertainty in our method of luminosity measurement. Finally, in Chapter 6, we summarize the results of our investigations and give some suggestions for future work.

The LHC experiments and research in this field might be considered suitable only for rich and developed countries in Europe or in North America. But, I believe that a developing nation shall not overlook and stay completely detached from the field. The yield of research in this field may not bring immediate prosperity to people in the society, but I hope, it would bring awareness of the research in this field and prepare us to be ready to catch on any time when the field gives birth to applications that might change the way we live. An example is not too far to recall: the World Wide Web. At this point, I would like to quote from Michael E. Peskin, a Stanford Linear Accelerator Center (SLAC) particle physicists; "We, a particle physicists all seriously know that we cannot ask society to support such expensive machines unless we can promise that these facilities will give back fundamental knowledge that is of the utmost importance and that cannot be obtained in any other way." I hope this work could partly help achieve the goal of the LHC project and in the long run, could return some benefits to the society where I live and cherish.