Weak Interactions and Z-Boson Peak Observations in CERN's Large Hadron Collider*

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Z bosons were first indirectly observed using the Super Proton Synchrotron (SPS) accelerator at CERN in the 1970's. SPS was then upgraded from a one-beam accelerator to a two-beam particle collider. This lead to the first direct evidence of the existence of Z-bosons, which confirmed the electroweak theory, leading to the Nobel Prize in physics in 1984. The research was then extended by upgrading the collider to the Large Electron-Positron collider, which allowed the production of millions of Z-bosons as well as a further upgrade to the Large Hadron Collider. In this experiment, we replicate the discovery of Z-bosons by analyzing their observational data using the Compact Muon Solenoid (CMS) detector inside the LHC at CERN.

I. INTRODUCTION

A. Weak Interaction

LHC creates energy collisions that recreate particles that existed in the beginning of the universe. There are 4 types of force carriers known today, of which photons that emulate electromagnetism and gluons that mediate strong interactions have been observed. Weak carriers that include Z bosons and W bosons were not discovered until 1983 due to its weak interactions. Probability of a phenomenon occurring is proportional to the square of its coupling constant. For photons they are 1/137 and for strong interactions they are 1. For weak interactions, it is 10-6 so we can see how difficult it is to see the phenomenon caused by weak interactions. Our goal is to rediscover the Z-boson using CERN's CMS detector. Weak interactions can do anything photons can do as well as couple to neutrinos. They convert an up quark to a down antiquark and Z bosons can interact with electrons to convert to a positron. The feynman diagram is as shown:

B. Z-Boson Decay

Bremsstrahlung is the most dominant process of electron production from Z-bosons. Electrons interact with the nuclei of an atom and create an electron that will radiate a photon. The photon will then interact with the material and create an EM shower, that contains pairs of electrons and positrons. The denser the material, the better so we use lead. Energy of the particle is dependent on the energy of the material and follows an exponential decay as it goes through the material. E=E0 *e-x/x0.

* A footnote to the article title

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II. THE CMS DETECTOR

A. Machine and Coordinate System

Particles are collided at the center by a magnetic field of 4[T]. The particles then pass through Silicon tracking where photons are created. Then they pass through crystals where the EM shower deposits energy. At the end is a 2[T] magnetic field iron to collect magnetic field lines.

B. Electromagnetic Calorimeter (ECAL)

We can measure the Bremsstrahlung using ECAL. It measures the energy of the photons, which gives the energy of the electrons. Lead tungstate crystal is a scintillator where light can travel inside and a photodetector is connected on the edge to measure the amount of photons. Lead tungstate has a radiation length of 1cm. The dimensions are as follows: insert diagram 2.2 cm x 2.2 cm x 22 cm in length. Since E=E0 *e-x/x0, we have that when a 45 GeV electron passes in, 12keV of energy will escape. The uncertainty of the ECAL is proportional to sigma/E=1/sqrt(E) so the higher the energy the better resolution.

C. Transverse Shower Profile

The transverse dimensions of the ECAL is determined by the Moliere radius of the material. The Moliere radius is given by RM=x0*initial energy E0/critical energy of the material Ec. Since the radius is 2.2cm, crystals of 2.2cm x 2.2 cm are produced in order to calculate the x-y position of the shower, which will aid in identifying noise.

D. Drell-Yan Process

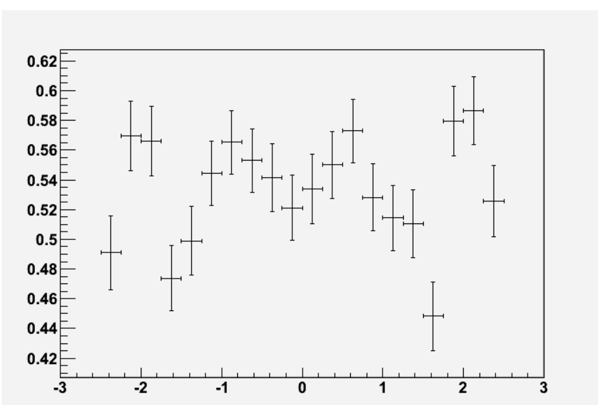
Vectors created at collision are simulated through Monte Carlo Generation. The generated electrons then go through the detector to simulate interaction with the material of the detector. Electronics then recreates pulses our real electrons would give. They then go through reconstruction and pass on as detector electrons.

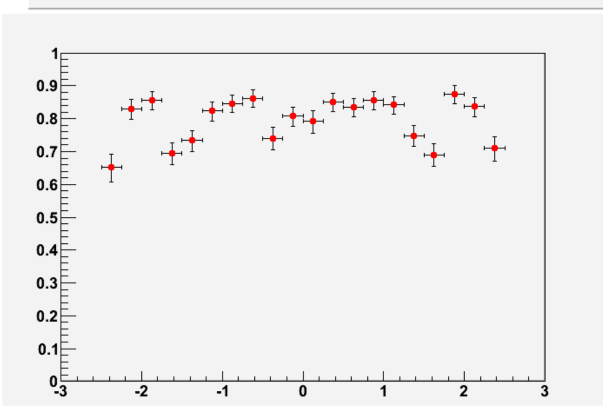
E. QCD Process

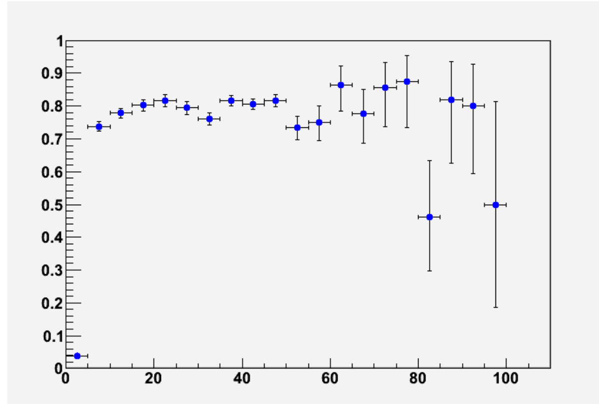
QCD events are created through strong interactions and can be obtained through two methods including, "Heavy Flavor Decay" and "Efficiency/MisID Rate."

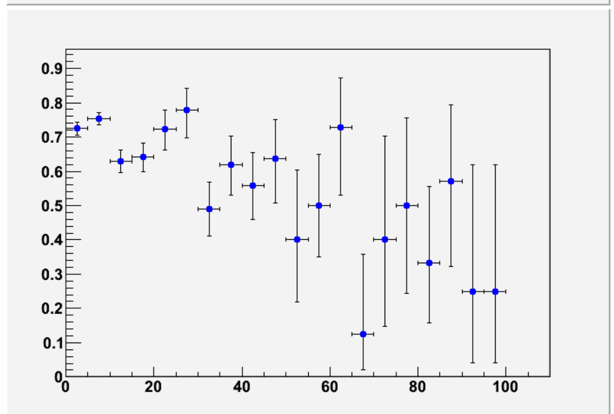
III. ELECTRON IDENTIFICATION AND OPTIMISATION IN SIMULATION

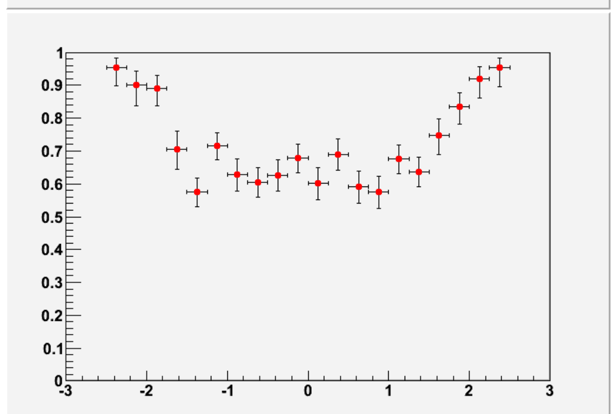
A. Definition of Variables and Plots



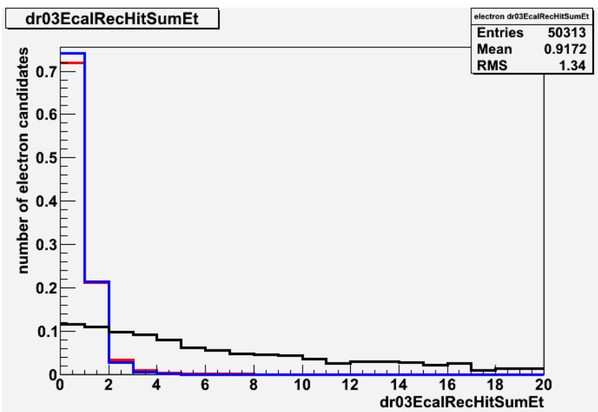


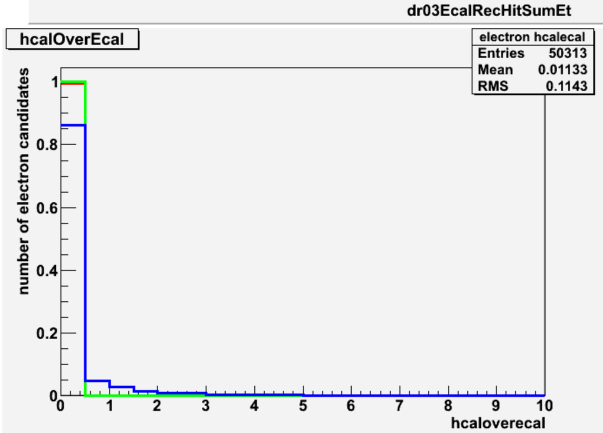


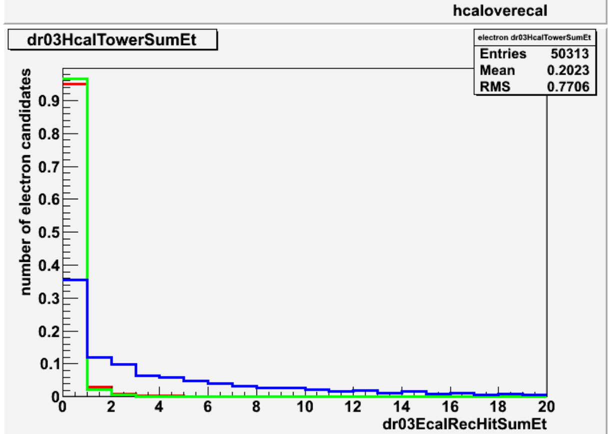


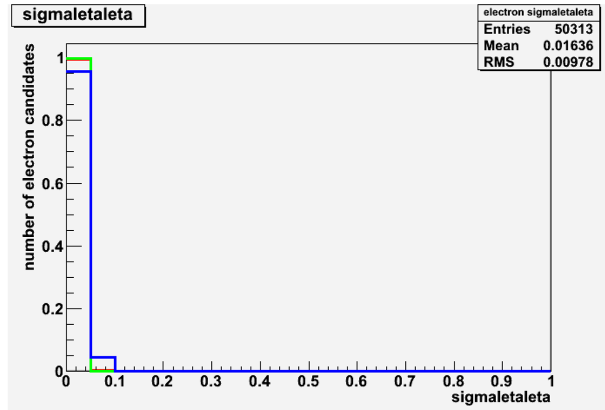


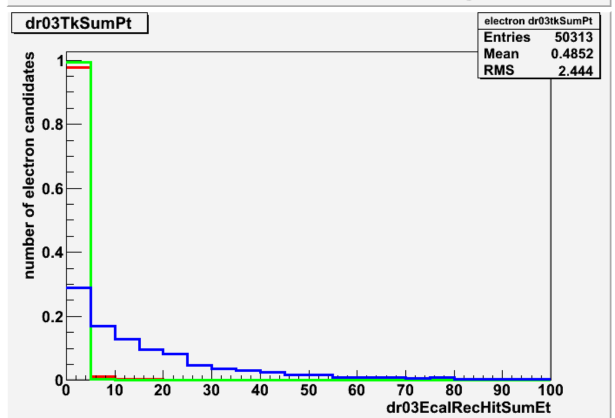
B. Definition and Documentation of Cuts



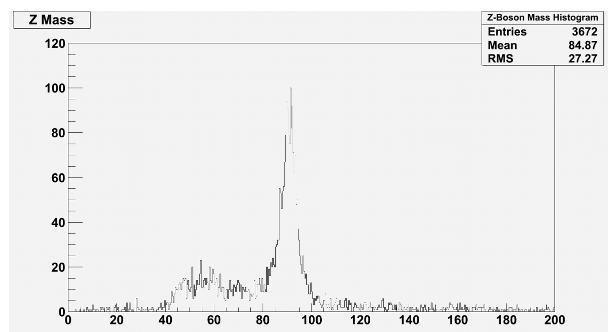


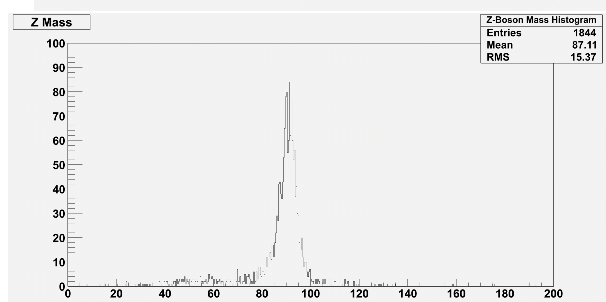






IV. RESULTS





V. CONCLUSION

Approximately 5,200,000 events were analysed taking nearly 12 hours to of computation to produce each of the final invariant mass plots. By implementing parallel programming to our computational work using a cloud computing system and analysing Z-boson data for more event files, better results could be achieved.

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