

CMS Endcap Muon Chamber Testing

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Abstract

Testing the Compact Muon Solenoid (CMS) endcap muon chambers to ensure their performance is crucial. The chambers will be tested using a cosmic ray telescope 19 ft 4 in long, 14 ft wide, and 8 ft 10 in high. Under high voltage of 4 kV and filled with gases, the chambers will be tested for performance, taken apart, and repaired (if necessary), then shipped to CERN for installation in the Large Hadron Collider.

INTRODUCTION

The so-called Standard Model of elementary particles has some important unanswered questions. Scientists believe that finding the Higgs particle can help in resolving the most critical issue dealing with the origin of particle masses. The Higgs field gives particles their mass through mutual interaction. The stronger the force, the heavier particles tend to be. Scientists believe that at a higher energy, the Higgs particle could be discovered. If they find the Higgs particle, then the Higgs field must also exist.¹

Another missing link to the theory consists of finding new particles that obey the supersymmetry hypothesis. Supersymmetry is an invariance symmetry principle which makes correspondence between bosons (subatomic particles that do not follow the Pauli exclusion principle, such as photons and mesons²) and fermions (subatomic particles that do follow the Pauli exclusion principle, such as leptons and baryons²). Supersymmetry assigns fermion partners to bosons and vice versa. For example, the boson partners of electrons, quarks, and leptons are called selectrons, squarks, and sleptons. The fermion partners of the boson photons, gluons, W and Z-particles are called photinos, gluinos, winos and zinos. Supersymmetry and the Higgs particle are of enormous current interest in particle physics and a lot of effort is being put forward in order to find evidence for their existence.³

In 2005 at the Large Hadron Collider (LHC) at the European Center for Nuclear Research (CERN), CMS (Compact Muon Solenoid) and ATLAS will begin searching for the Higgs particle and evidence of supersymmetry. LHC will be a proton-proton accelerator circumference of 27 km in a circular path. Its goal is to accelerate protons to an energy of 7×10^{12} eV and smash them against each other at a rate of one collision every 25 ns. LHC will have an energy

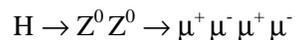
10 times greater than what is available today and its luminosity (or beam intensity) will be 1000 times greater. ⁴

COMPACT MUON SOLENOID (CMS)

CMS is much more massive than its name implies. The total weight will be 12,500 tons. The final diameter will be 15 m and the final length will¹ be 21.60 m. The 4 T magnet's diameter will be 6.2 m. The collisions will occur in the center of the detector and the particles will scatter outward. First, particles travel through the 4 T magnetic field of the central detector volume where their trajectories are precisely measured.

Two calorimeters will measure the energy of most particles. The electromagnetic calorimeter will acquire the electrons and photons through absorption. The hadronic calorimeter, located around the electromagnetic calorimeter, will acquire the hadrons such as pions, kaons, and protons through interaction and absorption. The only particles that escape the hadronic calorimeter should be muons. ⁵

Muons are the decay product of the Higgs particle.



The production of four muons is a unique signature of the Higgs. Therefore capture of the muons is a crucial element of the experiment. This capture will take place in muon chambers surrounding the calorimeters.

THE ENDCAP MUON SYSTEM

The University of Florida is taking a part of the construction and development of the CMS detector, more specifically the Endcap muon system for the CMS detector. This system

contains 540 cathode strip chambers. The largest chambers⁶ are 3.4 by 1.5 m². Cathode strips run lengthwise at a constant distance apart and gold-plated tungsten wires run azimuthally.⁶ The chambers run at a high voltage of 4 kV and are filled with tetrafluoromethane (CF₄), argon (Ar), carbon dioxide (CO₂), and isobutane (C₄H₁₀) gases. As a muon passes through, the high-energy particle ionizes the gas and causes an avalanche due to the high voltage. Electrons generated in the avalanche accelerate towards the anode while ions accelerate toward the cathode where they are collected.⁷ Please see Fig. 1 and 2.

The chambers sit between iron disks, which shield the chambers and return the magnetic flux to the central solenoid of the detector. The chambers are arranged into four disk shapes called stations. Each station has 18 or 36 chambers in it. There are four stations that form a “cap” on the ends of the solenoid-shaped detector. This is to prevent any needed particles from escaping without detection.⁸

TESTING OF THE ENDCAP CHAMBERS

To test the endcap muon chambers is quite a feat. The chambers have been built at Fermilab then shipped to UF. A test station has been built to allow easy manipulation and calibration of the chambers using cosmic rays and plastic scintillators. The test station is 19' 4" long, 14' wide, and its total height is 8' 10". Four columns support the structure at its four corners and two I-beams sit on the columns lengthwise. Three movable carts allow easy loading for the chambers. The largest chamber cart sits closest to the floor and rolls along the I-beam on the outside of the structure. The middle-sized chamber cart sits above the largest and rolls on the inside of the structure on the I-beam. The smallest chamber cart sits and rolls along the top of I-

beam. On the floor 12 scintillators lay underneath a false floor. Above the smallest cart, 12 more scintillators rest on a large rack. Please see figure 3.

Cosmic Rays

Cosmic muons bombard the earth constantly from decaying cosmic rays in the atmosphere. As the cosmic ray, which consists mostly of protons and other particles, hits the high atmosphere of the earth, the protons decay into pions. These short-lived pions decay into muons. One ray /cm²/min is the average rate for cosmic rays hitting earth. Muons from cosmic rays easily test the chambers and using this natural source keeps costs down. Cosmic rays also remain consistent, independent of time, season, or the position of astronomical events ⁸.

Two components make up cosmic rays, soft and hard. Soft components, such as electrons and photons, cannot travel through matter easily without absorption. Usually several centimeters of lead can stop the components. Due to atmosphere absorption, the intensity of the soft component decreases dramatically when approaching sea level.⁹

Hard components on the other hand penetrate matter easily. For example, muons are 200 times more massive than electrons so they don't interact with matter as strongly as electrons. Hard components can permeate lead with a thickness of one meter while losing only half of its particles.⁹ Therefore, working at sea level ensures an undiminished intensity of muons while greatly reducing the intensity of the soft component which might interfere with the experiment.

Scintillator counters

Plastic scintillator counters can filter the soft components of cosmic rays from the hard components during testing. Two planes of counters (overhead and underfoot) reveal which hits to the chambers are cosmic muons. Using this system, tracking cosmic muons becomes easy. The top rack of counters will interact with anything that goes through it. If the particle gets to

the bottom rack of counters, then that particle is most likely a muon. If the particle does not hit the bottom rack, then it is a soft component that interacted with the scintillator. Please see FIG. 2. Scintillators take some of the guesswork out of calibrating the chambers.

Scintillator counters work by exciting the electrons in the plastic material as the particle passes through. Once excited, the electron must release a photon to return to its ground zero. As this process occurs, an avalanche cascades down through the counter in every direction. At each end of the counter, a photomultiplier tube (PMT) awaits the coming light. A PMT converts the light energy into an electrical signal. Please see Fig. 5. The PMT is vital to this operation since it enhances the signal by a series of electron avalanches that will eventually form a current. The computers will read this current from the top and bottom rack of scintillators to determine if the particle is indeed a muon.

Using the scintillator counters allows the muon chambers to be assessed for proper function. A clean room will be erected in the lab to correct any malfunctions encountered during testing.

CONCLUSION

The Cosmic Ray Setup was assembled with our direct participation. Scintillating counters were prepared for testing. The system will become fully operational after all scintillating counters have been calibrated. In two months from now, the first chamber will be tested in this setup.

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FIGURES

FIG. 1. A diagram of what a cathode strip chamber looks like, and how its six planes fit together.

FIG. 2. A diagram of a single plane in a cathode strip chamber.

FIG. 3. Schematic drawing of cosmic ray test station.

FIG. 4. Simplified view of how a scintillator counter and chamber sandwich works.

FIG. 5. Diagram of how a PMT works.

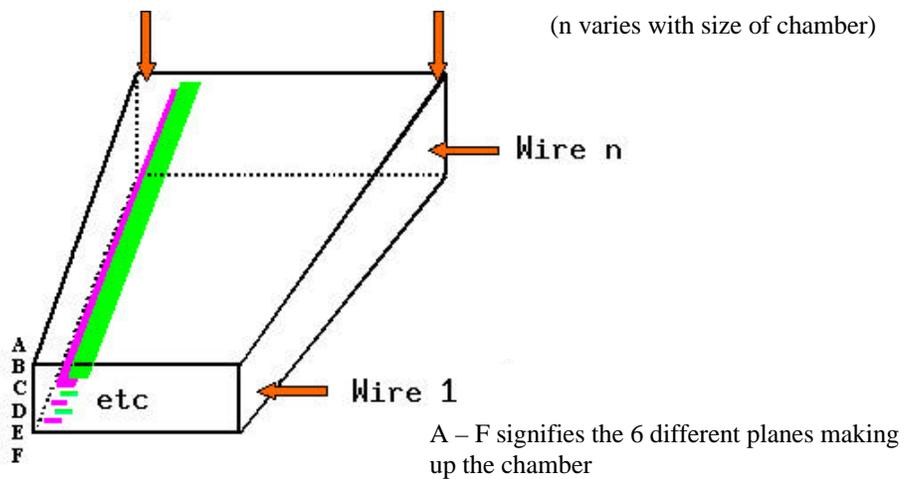
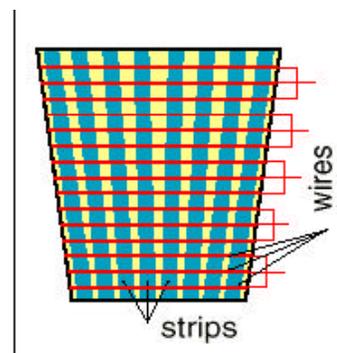


FIG. 1

FIG. 2



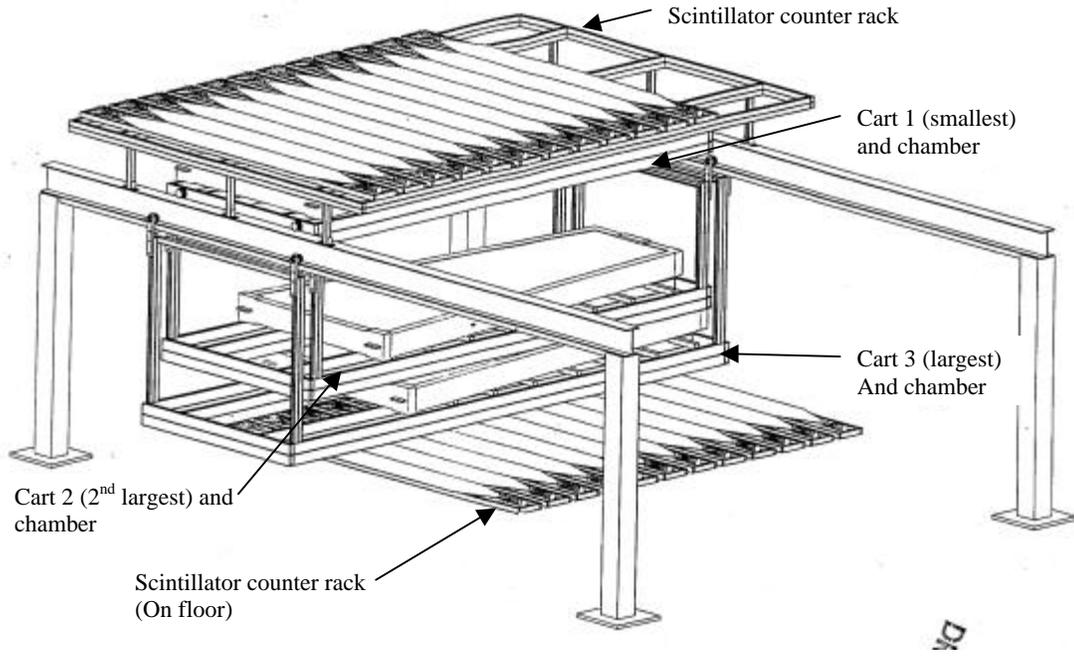


FIG. 3

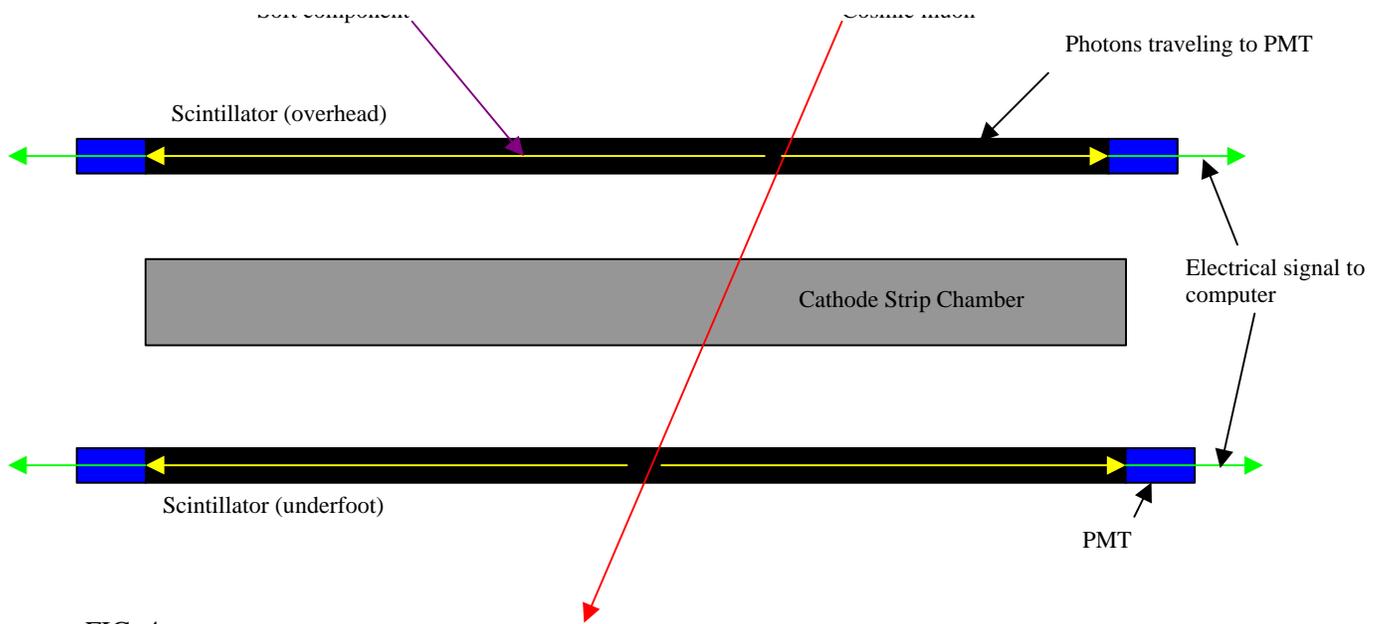


FIG. 4

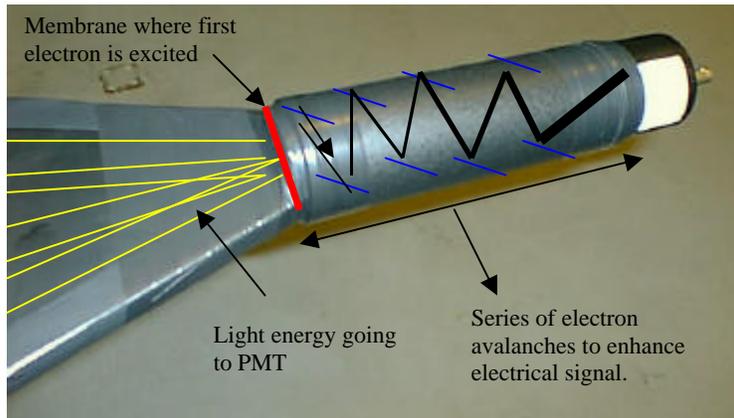


FIG. 5