# DARK CURRENT MEASUREMENTS IN GIF++

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## ABSTRACT

This project revolved around creating a code that treats experiment files in order to fetch dark current measurements done for the Cathode Strip Chambers (CSC) exposed to long-term irradiation at Gamma Irradiation Facility (GIF++) and plot the results as functions of the accumulated charge. This paper will discuss the Compact Muon Solenoid (CMS) experiment, the CSCs that we have looked at (specifically the muon detectors located at the CMS endcaps), longevity test at GIF++, and finally discuss the code and results obtained.

## INTRODUCTION

The purpose of long-term irradiation tests at GIF++ is preparing for the Large Hadron Collider's (LHC) High Luminosity upgrade. The upgraded HL-LHC will run for ten additional years. The CSCs will operate at luminosity of $5 * 10^{34} \frac{Hz}{cm^2}$ which is 5 times stronger than it is currently.

## CMS

The CMS is one of the largest experiments at the CERN laboratory and in the world. It is located at the Point 5 of the LHC tunnel directly opposite to the ATLAS Experiment.

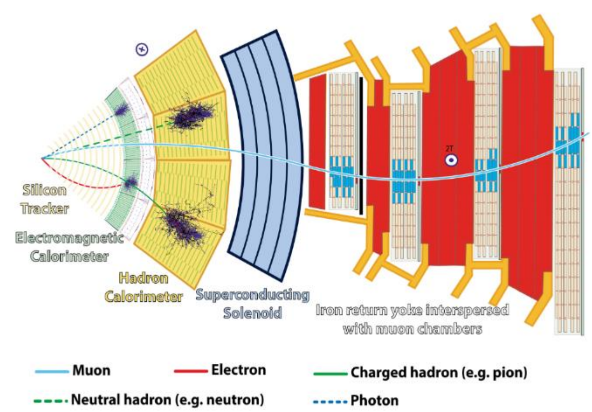


*Figure 1 CMS CROSS SECTION*

The cross section of the CMS experiment can be seen in Figure 1. The first phase that detects the charged particles after the collision is the Silicon Trackers, these are ultra-sensitive devices that detect all of the charged particles paths. After the Silicon Tracker, there is an Electromagnetic Calorimeter (ECAL) that absorbs and measures the energy of electrons and photons. Then there is the Hadronic Calorimeter (HCAL) which measures the energy of the hadrons. Then there is the Super Conduction Solenoid, which is a huge magnet with a magnetic field reaching 3.8 Tesla. This magnet is very vital in the CMS as it has two purposes. The first purpose is it bends the particles paths in a way that makes it possible for us to determine whether the particle is positively charged or negatively charged, and the other purpose is to find the momentum of particles to the Lorentz Force by using this relation.

$$P_T = 0.3 * B * r$$

Where $P_T$ is the traverse momentum of the particle, B is the magnetic field, and r is the radius of track curvature.

Outside the calorimeters all of the particles have been taken care of except for the muons as they are extremely penetrating, and some background particles leaking from the HCAL. Muon detection is performed with Drift Tubes and Resistive Plate Chambers (RPC) in the Barrel region of the CMS. CSCs are located in the endcap region for triggering and detecting passing muons there.

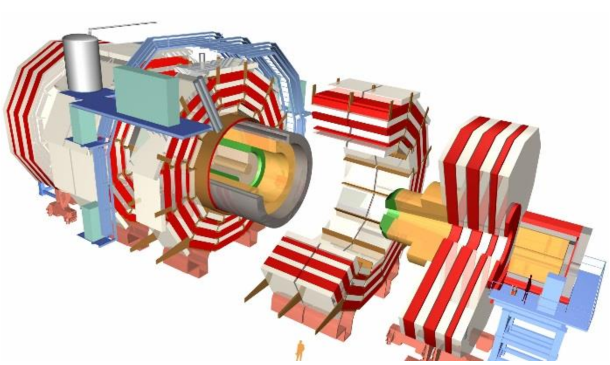

*Figure 2 Another look at CMS*

In Figure 2 the components of CMS are shown in 3D.

# CATHODE STRIP CHAMBERS

CSCs, or Cathode Strip Chambers, are located in the endcap region of the CMS. CSC is a type of Multi-wire Proportional Chamber (MWPC) with the only special thing about it is having stripped cathode which allows for 2D detection.

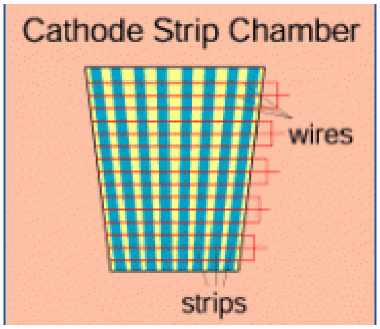


*Figure 3 Closer look at CSC*

CMS-CSCs consist of 6 layers, each layer has its own anode wires and cathode strips. Each layer is filled with a gas mixture consisting of 40% Ar, 50% CO2, and 10% CF4. The thin anode wires are kept at a high potential to create a high electrical field close to the wire. When a muon passes through the CSC, it ionizes gas atoms and molecules, creating an avalanche of electrons towards the anode. The avalanche is developed due to the increasing electrical field. Positively charged ions move away from the anode wires towards the cathode strips. Because the strips and the wires are perpendicular, we get two position coordinates for each passing particle. Even though the signal was already amplified by the avalanche process, the final signal is still small so it is amplified and this allows us with high accuracy determine the trajectory of the muons. [2]

In CMS, CSC chambers of ME1/1 type have inclined wires to compensate the slight influence of the Lorentz force. ME2/1 area is divided into three segments each of them has individual high voltage supply, which gives in total 18 high voltage channels for six layers.

# GIF++

The purpose of GIF++ is understanding the long term behavior of large gas-based particle detectors. The CMS-CSC tests at GIF++ goals to prove that the chambers will stand against the challenge of operation at High Luminosity LHC conditions with the new luminosity being 5 times stronger than it is now, and will run for ten years. At GIF++ tests the source that is being used is 137Cs because the main advantage of this source is its half-life being 30.08 years, causing less variation of the flux of photons over the anticipated lifetime of this facility. The Cs source used in GIF++ has an activity of 13 TBq which allows to emulate the results without having to wait ten years. [1]

There are also two CSCs installed at GIF++ one being ME11 type and one ME21 type. Both types represent the CSC stations operating at regions with the highest background occupancy.

## MEASUREMENTS

Various measurements monitoring chamber performance were done regularly between irradiation sessions at GIF++ and the dark currents were measured for different voltages.

The measurements of dark current were taken by using a custom 6-channel device. Figure 4 shows the measurement approach for a single channel. The device is connected to the chambers when the source is off.

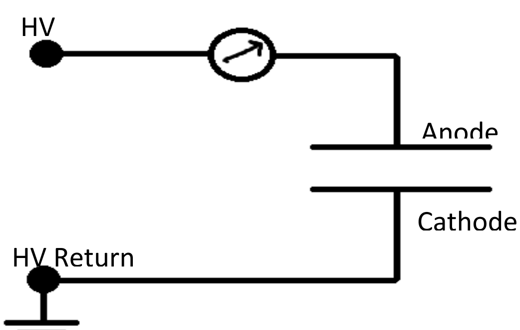


*Figure 4 the Custom Device*

The factors that contributed to the dark current were:

1- Cosmic rays.
2- Internal radioactivity of the chamber material.
3- Local discharges.

In list above, items 1 and 2 are almost constant, but local discharges may develop with the charge accumulated by the chamber due to its degradation caused by irradiation.

## CODE

The code consists of two parts, Bash Scripts and C++ along with root software. The bash scripts were generally used for sorting information in a neat way in order to be treated by the C++ code. The code analyzes CSC pre-treated data that were in a directory where they all existed, and the code specifically selects which CSC to obtain the mean and error of the dark current for a given high voltage.

Each directory has a file called tmp.txt that has the measurements. This file is fetched and then treated into whichever voltage that we needed for our study. The code will then take the tmp.txt file and converts the file from a long text file into the format shown in Figure 5.

| Date | Mean | Error |
|---|---|---|
| 19.04.17 | 7.76 | 0.21 |
| 19.04.17 | 4.33 | 0.09 |
| 19.04.17 | 5.26 | 0.15 |
| 19.04.17 | 5.37 | 0.12 |
| 19.04.17 | 6.50 | 0.13 |
| 19.04.17 | 8.75 | 0.15 |
| 24.04.17 | 8.60 | 0.15 |
| 24.04.17 | 5.25 | 0.10 |
| 24.04.17 | 6.19 | 0.11 |
| 24.04.17 | 6.42 | 0.07 |
| 24.04.17 | 7.56 | 0.09 |
| 24.04.17 | 9.26 | 0.13 |
| 31.05.17 | 8.64 | 0.25 |
| 31.05.17 | 4.61 | 0.12 |
| 31.05.17 | 5.33 | 0.10 |
| 31.05.17 | 5.49 | 0.11 |
| 31.05.17 | 6.19 | 0.11 |
| 31.05.17 | 7.83 | 0.21 |
| 05.07.17 | 8.55 | 0.23 |
| 05.07.17 | 4.37 | 0.12 |
| 05.07.17 | 5.57 | 0.10 |
| 05.07.17 | 6.17 | 0.13 |
| 05.07.17 | 8.12 | 0.10 |
| 05.07.17 | 9.25 | 0.18 |

*Figure 5 Ready to plot*

In this file it could be seen that in the first column there is the date, the next column is the dark current, and the last one is the error. The date is repeated six times corresponding to the six layers of the Cathode Strip Chamber. For ME21, we have three high voltage segments, S1, S2, and S3, measured and treated separately.

Another Bash script and C code were created in order to plot the graph of the mean and error of dark current with respect to the accumulated charge. The results of both codes are shown and discussed in the next section.

# Results

Multiple plots were created for each of ME11 and ME21. In this paper we will view examples of the plots created. Each CSC had a plot with respect to the date of the measurement, and another plot with respect to the accumulated charge.

The ME11 has a nominal voltage of 2.9 kV while ME21 has a nominal voltage of 3.6 kV. The plots had been created for each of them with that voltage.

In Figures 6 and 7 the plots with the error and mean with respect to the dates are shown for ME11 and ME21 correspondingly.

In Figures 8 (ME11) and 9 (ME21) the X-Axis is with respect to the accumulated charge in [mC]. For ME21 only segment 1 is shown in these plots.

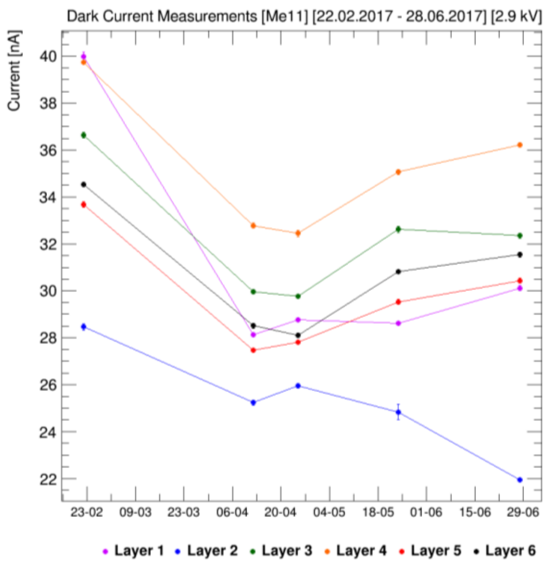


*Figure 6 ME11 CSC mean and error vs. date.*

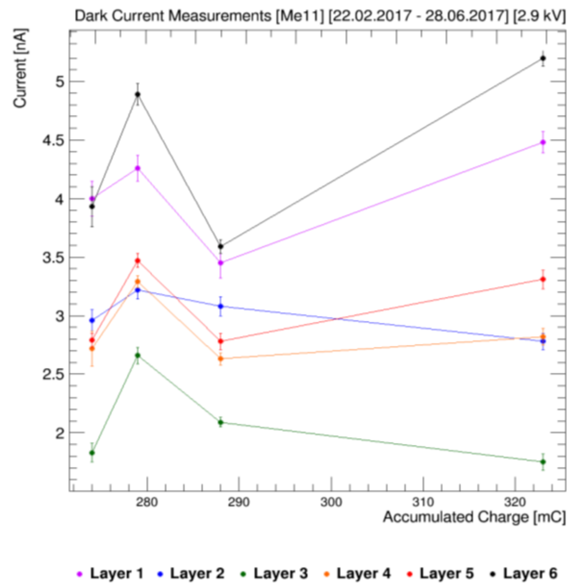


*Figure 8 ME11 CSC mean and error vs. accumulated charge.*

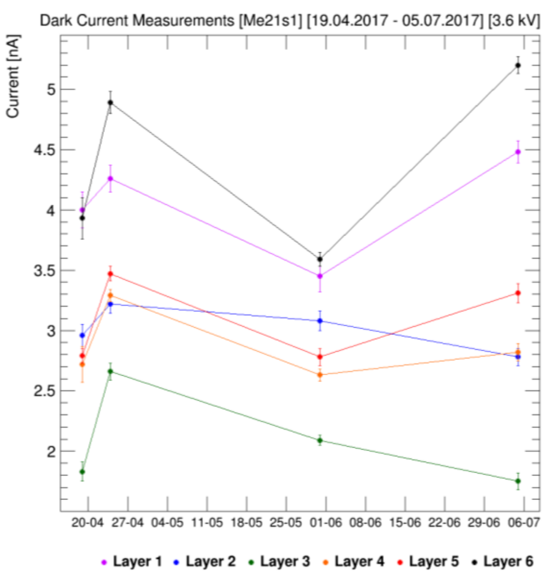


*Figure 7 ME21S1 CSC mean and error vs. date.*

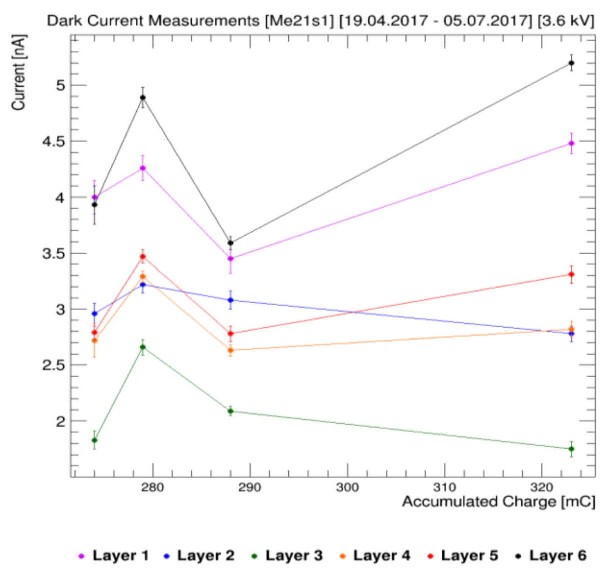


*Figure 9 ME21S1 CSC mean and error vs. accumulated charge.*

# Discussion

Upon the inspection of multiple plots of the CMS-CSCs, it could be noted that there is not much change of dark current with respect to the time and accumulated charge. This means that the CSCs are running well and has no issues with the irradiation.

# Conclusion

To conclude, CSCs are one of the best devices to determine the trajectory of muons. The irradiation test at GIF++ did not show any significant increase of dark currents. It should be mentioned that other monitored characteristics of the chamber did not degrade with the irradiation.


# Acknowledgements

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# Resources


[1] Pfeiffer, D. (2016, November 1). The Radiation Field in the New Gamma Irradiation Facility (GIF++) at CERN. Retrieved from https://arxiv.org/pdf/1611.00299v1.pdf

[2] Taylor, L. (2011, November 23). Cathode Strip Chambers. Retrieved from http://cms.web.cern.ch/news/cathode-strip-chambers