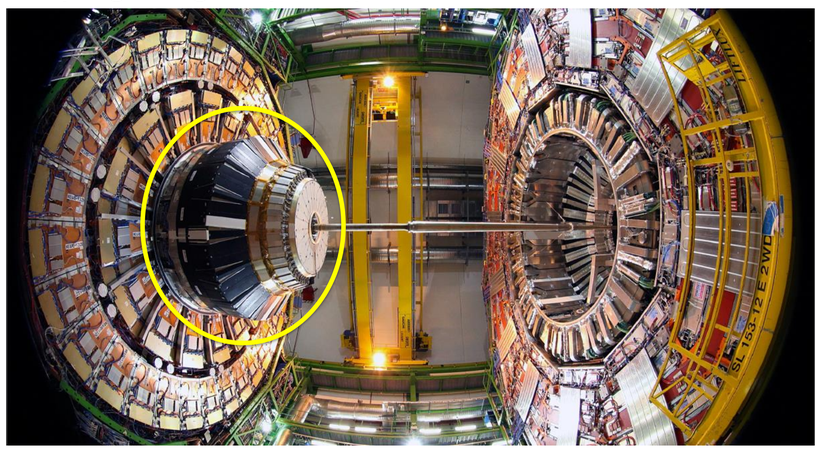
FERMILAB-POSTER-19-081-CMS-PPD

Characterization of Silicon Sensors for HGCal in CMS

Scott Israel - University of Massachusetts Amherst, SULI
Supervisor: Zoltan Gecse - Fermi National Accelerator Laboratory

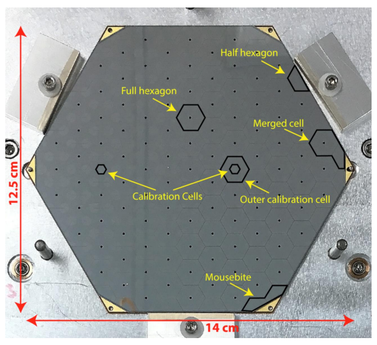
High-granularity Calorimeter for the Phase 2 Upgrade of CMS:

Thanks to the success of the LHC and the discovery of the Higgs boson, the LHC program has been extended with the High Luminosity LHC (HL-LHC) for another 10 years. In this period 3000/fb of data will be collected at a rate of seven times the previous instantaneous luminosity. This poses the challenge of a high pile-up with 200 interactions per bunch crossing and larger radiation damage. As such, the endcap calorimeter of CMS must be replaced for HL-LHC with a High-granularity Calorimeter (HGCal). To cope with radiation, **silicon sensors** will be used in high radiation area and scintillators read-out directly by SiPMs in the low radiation area with **detector operation at -30C**. 6M read-out channels will give a high-granularity picture of showers not only in space but also in time with 50ps resolution, helping mitigate pile-up.

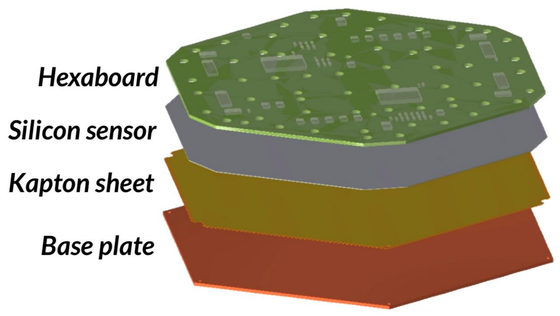


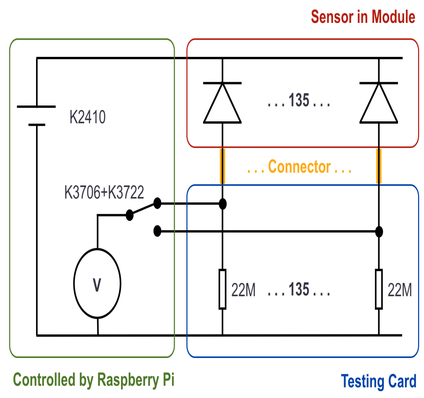
Inside the yellow oval is the CMS endcap. Inside of the end cap are thousands of silicon sensors like the one below.

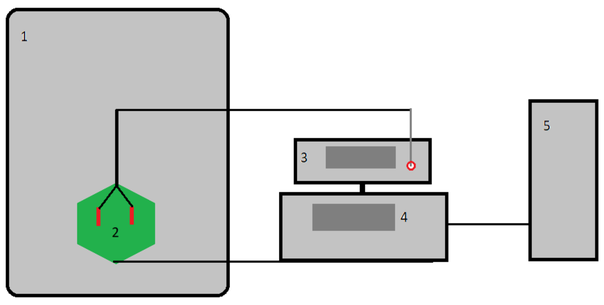
HGCal Sensors and Modules:



- DC-coupled 6” silicon wafers
- 8” wafers will be used in final version
- There are 120 ~1 cm^2 channels
- n-on-p type sensors for radiation hardness
- Double aluminum guard ring kept at high voltage surrounds each module to prevent leakage to other sensors







Apparatus

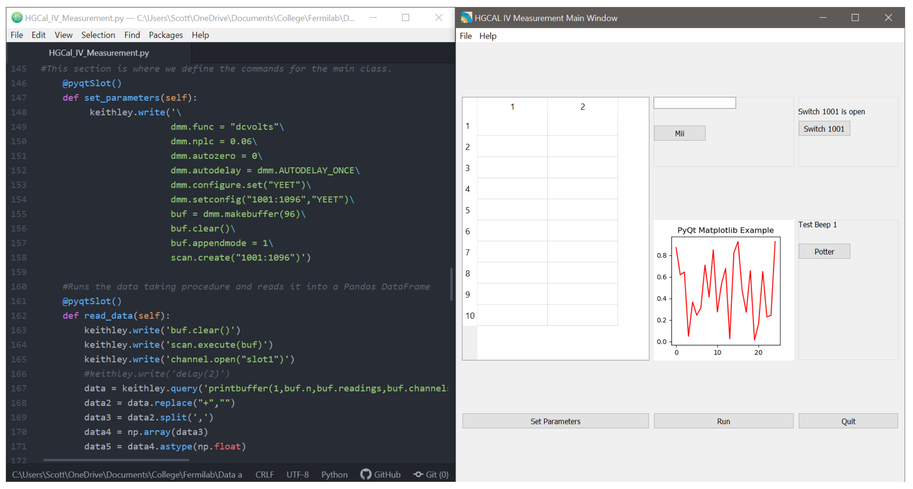
1. Thermal chamber
2. Silicon sensor module
3. Switchbox/Multimeter
4. Source-meter
5. Computer

The goal of this study is to measure the leakage current on some of the silicon sensors used in the CMS endcap.

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

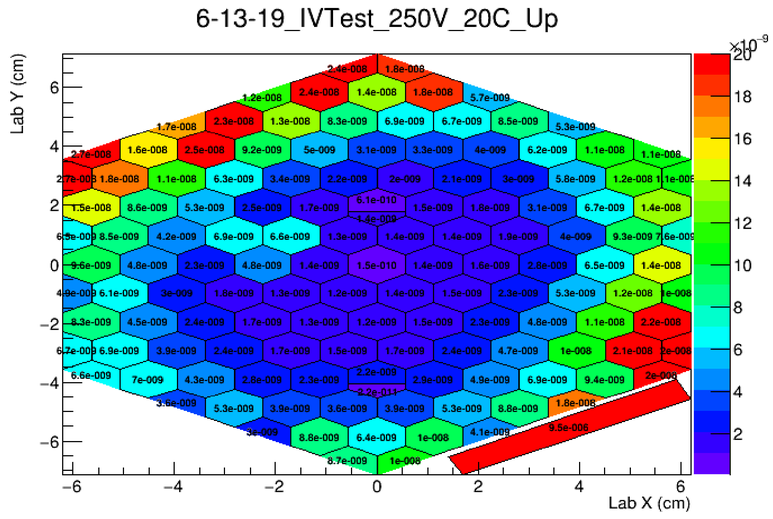
DAQ Design

The DAQ system is based on a low-cost computer, Raspberry Pi, running a Linux operating system and free software. The software is written in the Python programming language using the PyVISA library to communicate with the instruments. The user interface is created using the PyQt5 widget toolkit. The prototype user interface is shown below with a snippet of code illustrating the communication with the multimeter. The user interface displays the acquired data in a tabular and graphical form.

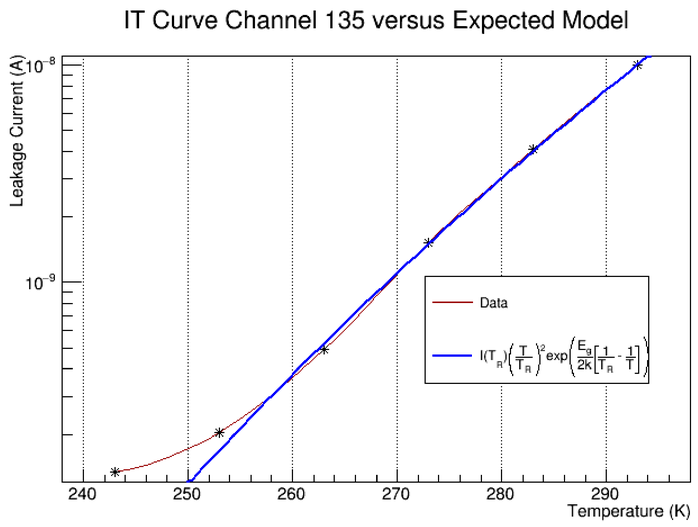


Results: IV and IT

The leakage current of each individual channel is measured through the voltage drop on a known shunt resistor connected in series. The leakage currents have been scanned for a range of bias voltages and temperatures. The leakage currents for 250V bias voltage at room temperature are shown on the 2D plot below. The distribution of currents indicates that the quality of the sensor is higher around the center of the wafer. The 1D plot illustrates the dependence of the leakage current on the temperature and the measured values agree well with the theoretical predictions.



- This sensor is being measured at 20°C with a reverse bias of 250V.
- Lower amount of leakage current in the middle, higher amount near the corners.
- The channels near the middle are of higher quality
- The guard ring is designed to isolate the grounded top from the high voltage base plate.



- CMS detector temperature is -30°C.
- The sensor’s leakage current varies with temperature.
- This sensor follows the expected behavior with some slight deviation at lower temperatures due to stresses caused by different coefficients of thermal expansion.