Introduction

An upgrade to the Large Hadron Collider (LHC) to the High Luminosity LHC (HL-LHC), will increase the luminosity by increasing the number of proton-proton collisions in the LHC, and will thus increase the data experiments like the Compact Muon Solenoid (CMS) will collect. In order to maintain accuracy of measurements under these new conditions, a High-Granularity Calorimeter (HGCAL), a replacement for the existing endcap calorimeters, will be introduced. HGCAL will use hexagonal silicon radiation detectors in order to measure the total energy of the particles produced in the collisions[1].

For the RD of the new silicon detectors, we have sent out sample radiation detectors to be exposed to neutron radiation up to levels expected for HGCAL. The charge collection efficiency (CCE) and electrical properties of the irradiated samples are compared to that of non-irradiated reference samples. All of the samples have their own full depletion voltage, where the free charge carriers inherent to doped silicon have been evacuated from the sample by applying a bias voltage opposite the direction of natural current flow of the diode. There are three variables being tested requiring three experimental setups. All measurements are done in total darkness to prevent any incident noise by light, and at a constant temperature, as the characteristics of the silicon detectors are highly dependent on their temperature.

IV Setup

To test leakage current, a sample silicon detector is placed in a circuit with a power source and current meter. The power source provides the bias voltage across the silicon detector while the current meter measures the leakage current, where the leakage current is a small current induced by the bias voltage. List of components in the current-voltage (IV) setup:

- 1.1 kV source meter unit (SMU)
- Picoammeter
- Probeheads for detector’s active area and guard ring connections
- Vacuum cold chuck for fixed position and cooling of the sample inside a cooling box

CV and IV Results

Figure 3: Capacitance-voltage measurement of a silicon detector

Figure 4: Leakage current-voltage measurement of a silicon detector

CV Setup

To test capacitance, a silicon detector is placed in circuit with a power source and a capacitance meter, being connected by the tungsten probe needles to the circuit. The power source provides the bias voltage, and the capacitance meter measures the capacitance of the diode, which decreases with respect to increasing bias voltage.

As in IV-circuit with following differences:

- Capacitance meter with high voltage separation by 1 µF capacitors
- 1 MΩ circuit resistor for current separation of SMU

TCT Setup

For CCE, we are applying the transient current technique (TCT)[2]. All measurements are done at -30 °C (-22 °F) which will be the operating temperature of HGCAL. This temperature is achieved by the combination of a closed circuit liquid cooling and an array of thermoelectric coolers. After applying the bias voltage across the silicon detector, an infrared laser (IR) incident on the laser window of the silicon detector is applied, which gives a fair estimate of the particles traversing through silicon detectors in HGCAL. The charge carriers generated by the IR form a transient current that is collected by a 2.5 GHz oscilloscope. The time integral of the transient current allows to extract the collected charge. The ratio of the collected charge by an irradiated detector to a non-irradiated reference detector leads to the CCE.

TCT Result

Figure 5: TCT setup: SMU, beam expander of the IR laser, movable platform for sample positioning and cooling visible

Figure 6: Transient current measurement of irradiated sample

Figure 7: Collected charges for bias voltages from 400 V to 1 kV.

Figure 7 shows the collected charge in a TCT measurement, calculated by taking the time integral of TCT signal.

References