Monitoring Radiation Damage of SiPMs at the Forward Calorimeter System at STAR

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Motivation

This study is dedicated to the monitoring of radiation damage to the SiPMs used as readout at FCS. Such damages would lead to an increase in the leakage currents over time, resulting in an increased noise in the SiPMs. This would degrade the performance of the detector and might require a change in the bias setting on SiPMs to preserve linearity. This monitoring tool also is essential for identifying bad SiPMs/FEE cards and replacing them. Finally, it acts as a good feedback to the accelerator for tuning the beam conditions in cases of abnormal leakage current patterns during runs.

Forward Calorimeter System at STAR $2.5 < \eta < 4$

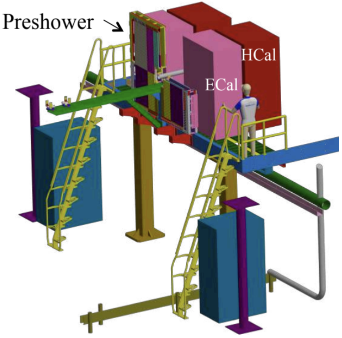


Fig1. FCS Physical Layout

Fig2a. HCal N fully stacked

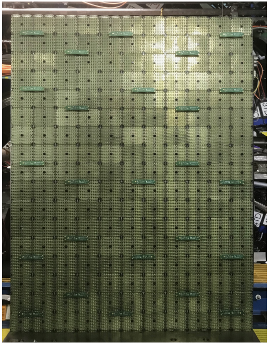


Fig2b. ECal S LED Panels installed

- Refurbished PHENIX Shashlyk Pb/Sc EMCal, followed by Fe/Sc sampling HCal
- **1496** EMCal towers and **520** HCal towers - North/South symmetric modules
- Each module of EMCal has **34 rows** and **22 columns**
- Each module of HCal has **20 rows** and **13 columns**
- Transverse area ≈ **1.2 m W x 2 m H**

ECal Scope - Refurbished PHENIX EM Module

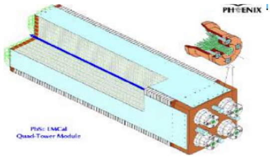
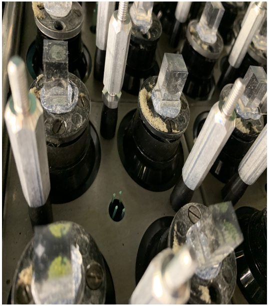


Fig3: 1 Ecal supersector - 2x2 towers

EM Module

- 4 independent towers
- Each tower 5.52 x 5.52 x 33 cm^3
- Penetrating WLS fibers for light collection

Modifications



Step A: Gluing four light guides/ mixers at the end of WLS bundles

Step B: Gluing SiPM currying boards to LG **(4 SiPM/tower, 5984 total)**

Step C: Attaching FEE (Pogo Pins, utilizing existing holes in EM Module)

HCal RD and Design - Lego Style Concept

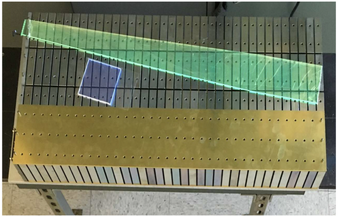


Fig: Absorber, Scintillator, WLS Bars, Interlink Plates

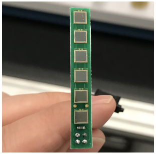
HCal module - simple parts, no interdependencies

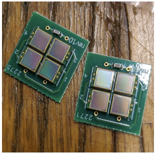
- Absorber 20 mm steel, Scintillator 3 mm
- Tower size 10 x 10 x 85 cm^3
- Number of layers - 36
- Light collection - tapered WLS
- Number of **SiPMs** - **6**

Fig : Stacking layers of absorbers with scintillators sandwiched (left), Installing WLS bars (middle), Installing LED (right)

Silicon Photomultiplier - SiPM

SiPM - solid state photodetector consisting of arrays of integrated single photon avalance diodes, squares of size 15 μm - operating in reverse bias above the breakdown voltage (V_{bd})





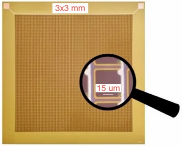


Fig: SiPM used in HCal (left),

SiPM used in ECal (middle),

SiPM structure (right)

Pros

- High Photon Detection Efficiency (PDE)
- Mechanical and electrical robustness
- Low bias voltage
- Insensitive to magnetic fields

Cons

- High Dark Current Rate (DCR)
- Loss in performance characteristics on exposure to high neutron radiation

Characteristics of SiPMs used:

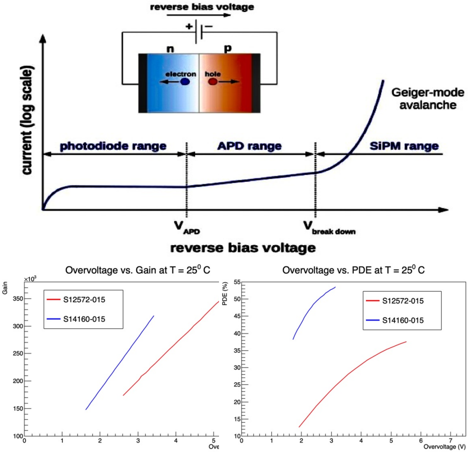


Fig: SiPM area of operation (top)

V_{ov} vs. Gain (bottom left) V_{ov} vs. PDE (bottom right)

Two different types of Hamamatsu SiPMs used in FCS:

- **HPK S14160** (15 μm) in the four bottom rows of ECal
- **HPK S12572** (15 μm) elsewhere
- Different T dependence for SiPMs

- V_{bd} - Breakdown Voltage - min. rb voltage leading to self sustaining avalanche multiplication
- Only for $V_{bias} > V_{bd}$, output current is actually observed $\Longrightarrow$ $V_{ov} = V_{bias} - V_{bd}$
- PDE - prob. that a photon arriving on SiPM is detected producing an output pulse
- Gain - No. of carriers contained in the single-cell current pulse

2D plots of Leakage Current (Imon)

Distance from the beam pipe is measured in units of tower IDs

- ECal (N/S) rows 1-34, columns 1-22
- Dist ECal SiPM $= \sqrt{(row - 18)^2 + (col)^2}$
- HCal (N/S) rows 1-20, columns 1-13
- Dist HCal SiPM $= \sqrt{(row - 10)^2 + (col)^2}$

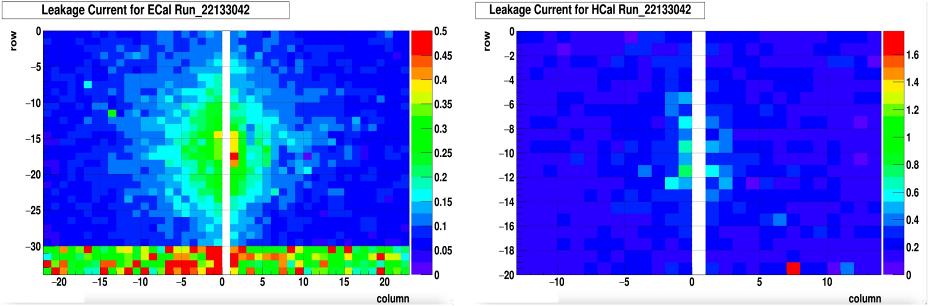


Fig: 2D Leakage Current Plots for ECal (left) - 4 bottom rows have a different type of SiPM than the rest and HCal (right) for Run 22133042

History plots of Leakage Current from Pedestal Runs

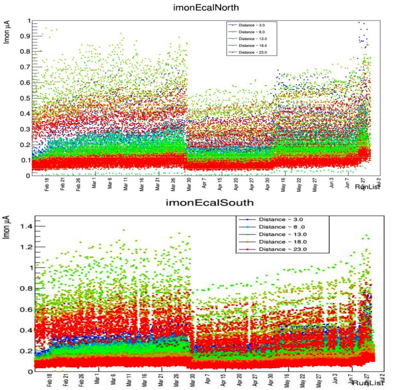


Fig: Imon per channel (sum of 4 SiPMs for ECal) for all channels vs. Run North ECal (top), South ECal (bottom)

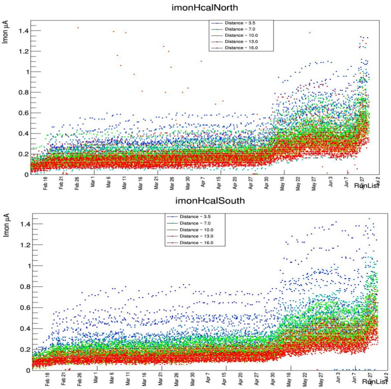


Fig: Imon per channel (sum of 6 SiPMs for HCal) for all channels vs. Run North HCal (top), South HCal (bottom)

NOTE:

- Decrease in Leakage Currents around March-end (ECal) because bias volatge was lowered during shift
- Increase in Leakage Currents towards the end of run (OO run) due to increased neutron flux in OO run compared to previous runs

History plot for a particular channel

Here, required channel is specified by providing

- det # (detector) - **0/1 = ECal N/S, 2/3 = HCal N/S**
- id # (tower id) - **0-747 ECal, 0-259 HCal**

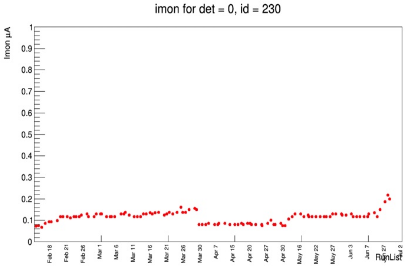


Fig: Leakage current for a particular channel vs. Run for Pedestal Runs for Run21

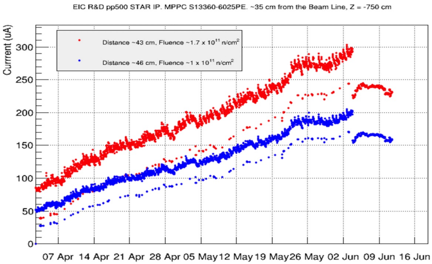


Fig: Leakage current for a particular channel vs. Run for Pedestal Run and Physics Run for Run17

Compared to Run17 500GeV pp collisions, radiation damages on SiPM during BESII data taking are negligibly small

Conclusion

Software for continuous monitoring of Leakage Current is in place and it was tested in Run21

Thank You!