PROCEEDINGS OF SCIENCE

CREAM LED Data Analysis

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The Cosmic Ray Energetics And Mass (CREAM) experiment was developed to measure the cosmic ray elemental spectra for Z=1-26 nuclei at energies ranging from $\sim 10^{12}$ to $\sim 10^{15}$ eV. The balloon-borne CREAM had 7 successful flights over Antarctica and was recently installed on the International Space Station as ISS-CREAM. The CREAM instrument uses a calorimeter (CAL) for energy measurements. The CAL has 20 layers of tungsten plates interleaved with 20 layers of 50 scintillating fiber ribbons to detect showers produced by cosmic ray interactions. These ribbons are read out using 40 pixelated Hybrid Photodiodes (HPD). Each HPD consists of 73 pixels, 3 of which receive optical signals from Light Emitting Diodes (LED). These LEDs are used for checking channel aliveness and the HPD pixel-to-fiber alignment. LED gain characteristics were studied by varying high voltages (HV) from 3 to 10.5 kV, DAC values from 6000 to 9000, and bias voltage on and off. Analysis results are presented.

**** 27th European Cosmic Ray Symposium - ECRS ****
**** 25-29 July 2022 ****
**** Nijmegen, the Netherlands ****

PoS(ECRS)157

[*] Speaker

1. Introduction

The Cosmic Ray Energetics And Mass (CREAM) experiment is designed to directly measure the cosmic ray elemental spectra for H to Fe nuclei at energies ranging from $\sim 10^{12}$ to $\sim 10^{15}$ eV. The goal of this experiment is to extend the direct cosmic ray energy measurements to the highest energy possible while overlapping with the ground-based indirect measurements. The balloon-borne CREAM completed 7 successful flights over Antarctica before being installed on the International Space Station as ISS-CREAM [1].

The CREAM instrument consists of several detector systems, including a tungsten scintillating-fiber calorimeter (CAL) for energy measurements. The CAL comprises 20 layers of tungsten plates interleaved with 20 active layers of 50 scintillating fiber ribbons, as shown in Figure 1. The active layers are placed orthogonally to provide up to 10 measurements in both the x and y axis for an incident particle. Fiber ribbons from each layer are read out at alternate ends using a pixelated Hybrid Photo Diode (HPD). These ribbons go into a light guide, where their cross-section changes from nearly rectangular to cylindrical, and come out as clear fiber bundles. The clear fiber bundles are separated into smaller bundles for low, mid, and high energy level readout [2]. These fiber bundles are routed to the holes of a cookie that is mounted on an HPD. Figure 2 shows an HPD box that houses 10 HPDs, LED sources, power supplies, and readout circuitry. The CAL has an HPD box on each of its 4 sides and 40 HPDs in total.

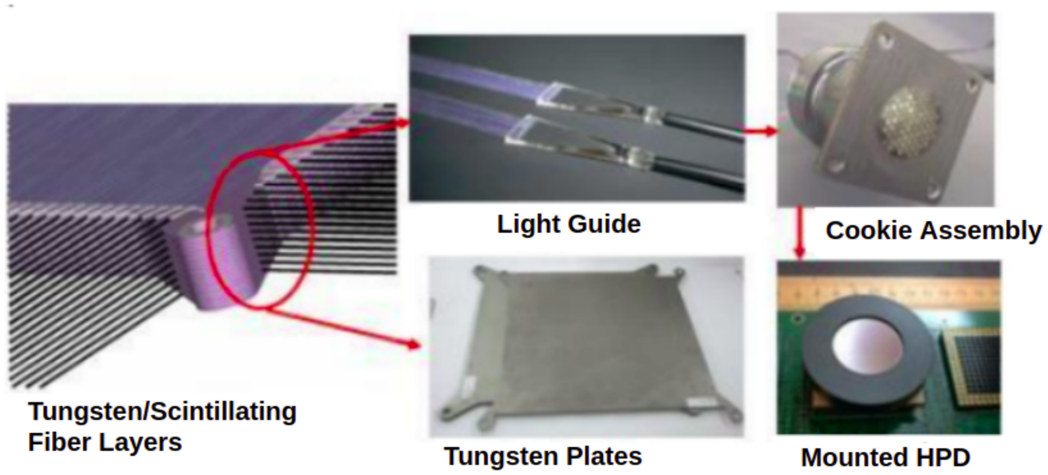

Figure 1: CREAM calorimeter components [3].

Each HPD has 73 pixels, out of which 64 pixels are read out using a pair of 32-channel application-specific integrated circuit (ASIC) chips [2]. The HPD's 64 read-out channels include 55 channels for reading signals from the fiber bundles, 6 channels for measuring pedestal drifts and radio-frequency noise measurements, and 3 channels with optical inputs from Light Emitting Diode (LED) sources. These LED channels are used for pixel-to-fiber alignment of HPDs and in-flight calibration. The CAL consists of 2560 channels (64 per HPD), out of which 120 are LED channels (3 per HPD).

The HPDs operate under a HV (up to 12 kV) and a reverse bias voltage (up to 100 V). For LED channels, the intensity of LED sources is controlled by DAC inputs. For this paper, we report the

CAL's response to different HV, DAC, and bias settings.

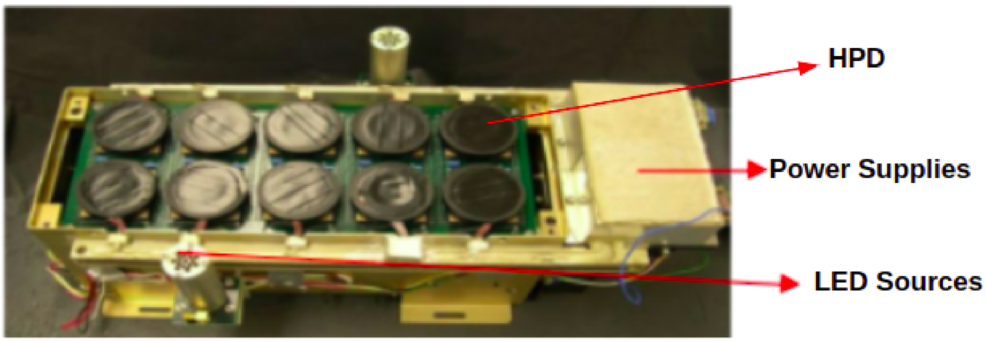

Figure 2: HPD box [3].

2. Data

Signal gains were measured in a laboratory for all CAL channels by varying HV from 3 to 10.5 kV with bias voltage turned on and off. Optical signals were provided only to the LED channels by varying DAC values from 6000 to 9000. Channel gains were measured by changing LED intensity from the lowest to the highest value in steps of 100 DAC for each HV and bias setting. The gains for all the 2560 CAL channels with HV 7.5 kV, bias on, and 6800 DAC are shown in Figure 3 (left). The black-dashed line in this plot marks channel 672, which is used as an example of LED channels throughout this paper. Figure 3 (right) shows a gain histogram with the same input signals for all of the LED channels. The most probable gain with these inputs is ~ 3.5, and the average is ~ 2.6.

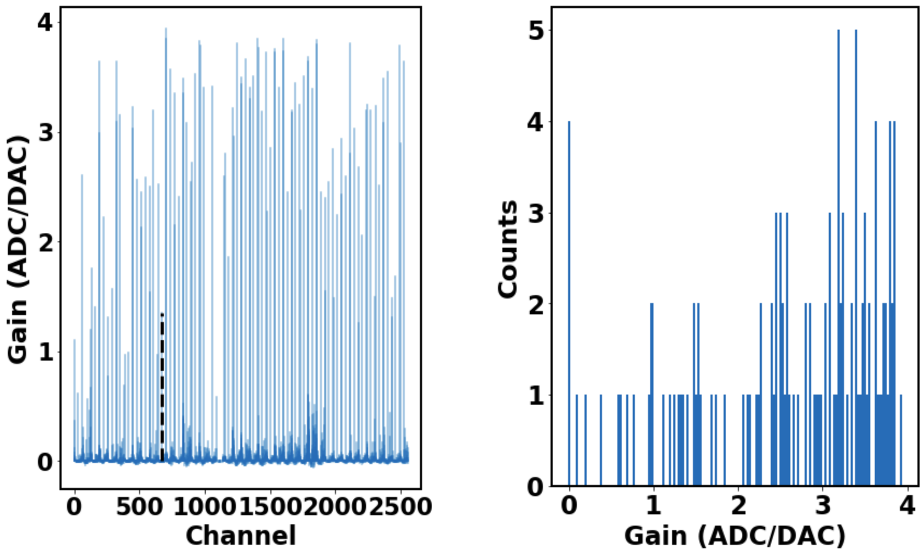

Figure 3: Gain data with HV 7.5 kV, Bias On, and DAC setting 6800. Left: Gains from all 2560 CAL channels. The black-dashed line marks the gain for channel 672. Right: Gain Histogram from the 120 LED channels.

3. Gain response to HV setting

Gains were measured for HV settings 3, 6, 7.5, and 10.5 kV with bias on and off and DAC settings ranging from 6000-9000. Figure 4 shows how LED gains increase linearly with HV settings using the example of channel 672 with bias on and 6800 DAC. Gains with HV 3 kV were not measured for DAC values below 7000. The red line represents a linear fit with a slope of 0.26 ± 0.01 and an intercept of -0.6 ± 0.1.

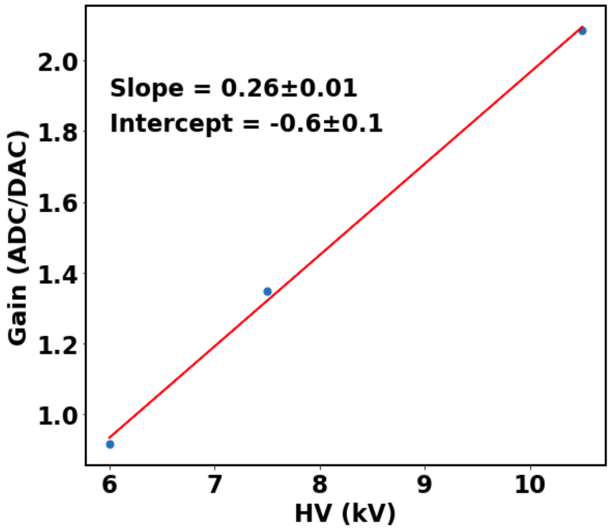

Figure 4: Gain versus HV for channel 672 with DAC setting 6800 and bias setting on.

4. Gain response to LED intensity

The gain response to LED intensity was studied by varying DAC settings with bias on and off. The measurements were made with DAC settings ranging from 7000-9000 for 3 kV, 6000-7000 for 6 and 10.5 kV, and 6000-7500 for 7.5 kV. DAC settings were increased in steps of 100 DAC values. HV 7.5 and 10.5 kV have additional measurements with DAC 6850.

Gains response to LED intensity for channel 672 and HV 7.5 kV, with bias on (blue dots) and off (red crosses), are shown in Figure 5. The gains increase as a function of LED intensity for DAC values between 6100 and 7000, where they are neither zero nor saturated. With the y-axis in logarithmic scale, the curves for both the bias settings are parallel to each other within this DAC range. This means that the bias on/off ratio of gains is nearly constant within this DAC range. For channel 672 with HV 7.5 kV, the bias on/off ratio averaged over the DAC range is 11.9 with a standard deviation of 0.6. These plots were repeated for other HV settings and LED channels to find their bias on/off ratios.

5. Bias On/Off Ratios

Channel 672's bias on/off ratios, averaged over DAC ranges, are plotted in Figure 6 (left) for HVs 3, 6, 7.5, and 10.5 kV. The error bars in the figure are the standard deviation in these ratios.

The bias on/off ratio averaged over these HVs (black-dashed line) is 12.1 ± 0.2. These ratios were also measured for all LED channels, and their histogram is shown in Figure 6 (right). The ratios range from 1.6 to 80, with the most probable value of 4.5. The histogram has an extended tail which shifts the average ratio to ~ 10.1.

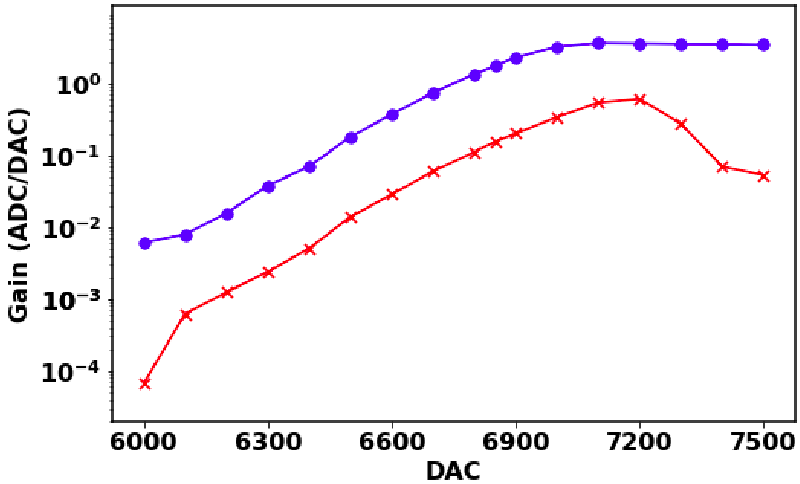

Figure 5: Gain versus DAC value for channel 672 with HV 7.5 kV and bias on (blue dots) and off (red crosses).

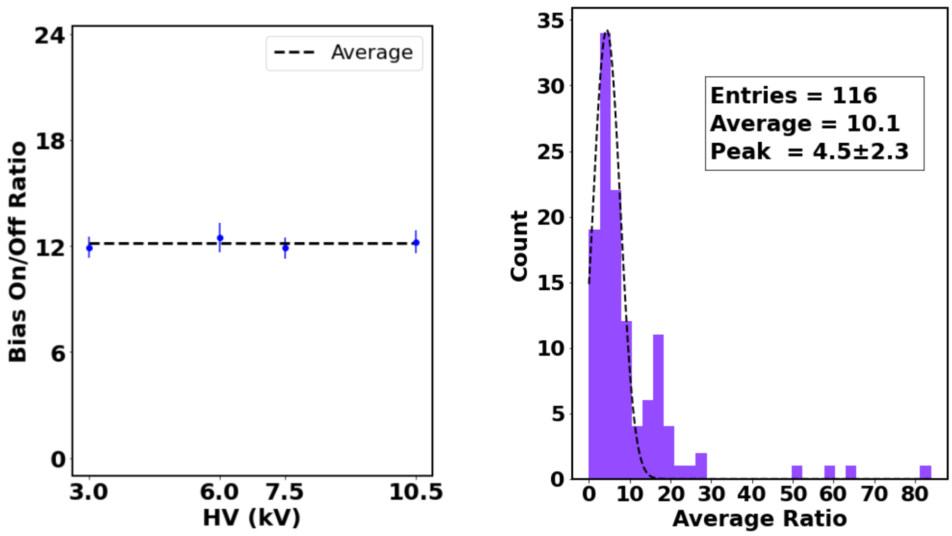

Figure 6: Left: The bias on/off ratios for channel 672 with different HV settings. The black-dashed line marks the ratio averaged over HVs (12.1 ± 0.2) for channel 672. Right: Histogram of ratios for all LED channels. The black dotted line represents a Gaussian fit around the peak.

6. Conclusion

The CAL's signal gains were studied for different settings of LED intensity (DAC values 6000 to 9000), HVs (3 kV to 10.5 kV), and bias voltage (turned on and off). LED channel gains increase linearly with HV. LED channel gains increase with LED intensities when they are neither zero nor saturated. The bias on/off ratio was measured for all LED channels. The most probable ratio is 4.5 ± 2.3, and the average is ~ 10. The results of this analysis can be used to correct gains with different HV and bias settings of the CAL.

References

[1] E. S. Seo et al, *Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM)*, Advances in Space Research, **53**/10 (2014), 1451.

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