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The First Flight Measurement with the CREAM Silicon Charge Detector

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The Cosmic Ray Energetics And Mass (CREAM) payload had its first successful flight in December 2004 from McMurdo Station, Antarctica as a long duration balloon payload. The goal of the experiment is to obtain the experimental data to understand their source and acceleration mechanisms of high-energy cosmic-ray particles. The CREAM Silicon Charge Detector (SCD) was designed for charge identification of incident cosmic rays. The ongoing analysis of SCD flight data is discussed and preliminary results are presented

1. Introduction

The CREAM[1] experiment aims to make a direct measurement of energy and charge distribution in cosmic-ray particles at energies up to 10^{15} eV which appears to be the limit for practical balloon experiments. The CREAM payload includes an optimized arrangement of detectors designed to measure energy or charge. The SCD[2] is one of the charge detectors and it consists of 182×16 silicon PIN diode pixels arranged in a single active layer. For energy measurement, the CREAM includes two independent instruments: a tungsten/scintillating-fiber calorimeter and transition radiation detector (TRD). Both detectors also provide multiple position measurements, allowing reconstruction of the incident direction and position of the primary cosmic rays. The reconstructed tracking information is used to locate the hit segment in the SCD, which is installed between the TRD and calorimeter.

The CREAM[2] balloon payload had its first flight for 42days from 16 December 2004 in Antarctica. About 43M events were collected using two major triggers implemented for high energy above 1 TeV and for high-Z cosmic rays. The analysis of the SCD flight data is discussed in the following after a brief description of the construction of the SCD and its flight performance.

2. The SCD construction and performance during its first flight

A silicon sensor is fabricated from 380 µm thick, 5 inch wafer and is segmented into 16 pixels. 7 sensors are mounted with plastic frames on a front-end readout board. The frames provide a gap between sensors and board, and allow enough overlap between sensors to completely cover the SCD area[3].

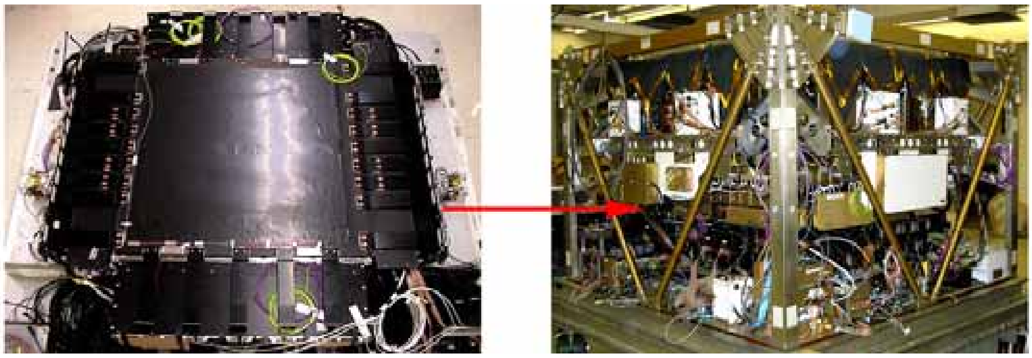

Figure 1. Top view of the SCD after integration (left) ; CREAM detector assembly (right)

The readout electronics are designed around a 16-channel CR-1.4A ASIC for each sensor followed by 16 bit ADCs allowing fine charge resolution over a wide dynamic range covering up to Z=33 signals. Total power consumed for the readout and control electronics is about 50 W. Thick thermal straps are attached to the cover in order to keep the detector in its operational temperature range.

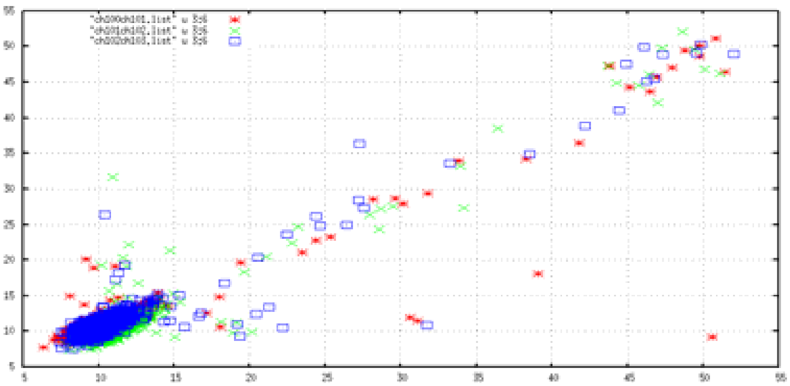

Figure 2. Correlation between pedestals of three nearby channels.

Housekeeping electronics implemented to monitor the temperature and power of each front-end board functioned well throughout the flight. The data show that the detector temperature fluctuated as the payload altitude changes, but remained within its operational limits.

Pedestal values were periodically measured for all channels to allow offline corrections of the variation caused by temperature changes.

3.7% of all channels were found to be dead or noisy. These channels were masked in sparsifying the data during the flight. Event-by-event shifts of channel pedestals were found to be correlated between nearby channels, as shown in Figure 2. 26 channels were selected to be recorded for all events, to allow these coherent changes to be removed from the data.

4. Analysis of SCD flight data

Analysis of the SCD data begins with the tracking information of the incident cosmic rays obtained from the TRD or the calorimeter. For events triggered by high-Z cosmic rays, tracks that are well reconstructed in the TRD are extrapolated to the plane of the SCD. Reconstruction errors in the track angle and offset are considered in defining the search region in the SCD when looking for a matched hit. After subtracting pedestal values, the SCD pixel with the maximum signal in the search area is selected as a candidate. The SCD hit is finally selected if the distance between the track intersection with the SCD plane and the candidate pixel is less than 60 mm. The SCD signal is then corrected for the track angle with respect to the sensor plane.

Figure 3 shows the correlation between the reconstructed charge signals from the SCD and the Cherenkov counter installed between the two TRD modules. Signals from B, C, N, O, and Fe nuclei can clearly be seen. The SCD charge spectrum is shown in Figure 4 with a preliminary additional selection to enrich the relativistic cosmic rays in the data of Figure 3.

High energy events triggered by the calorimeter are analyzed similarly, using the reconstructed shower information. The result is shown in Figure 5. Low-Z signals are clearly seen in the figure. The relative abundance shown in the figures are not corrected for the detector efficiencies or acceptance.

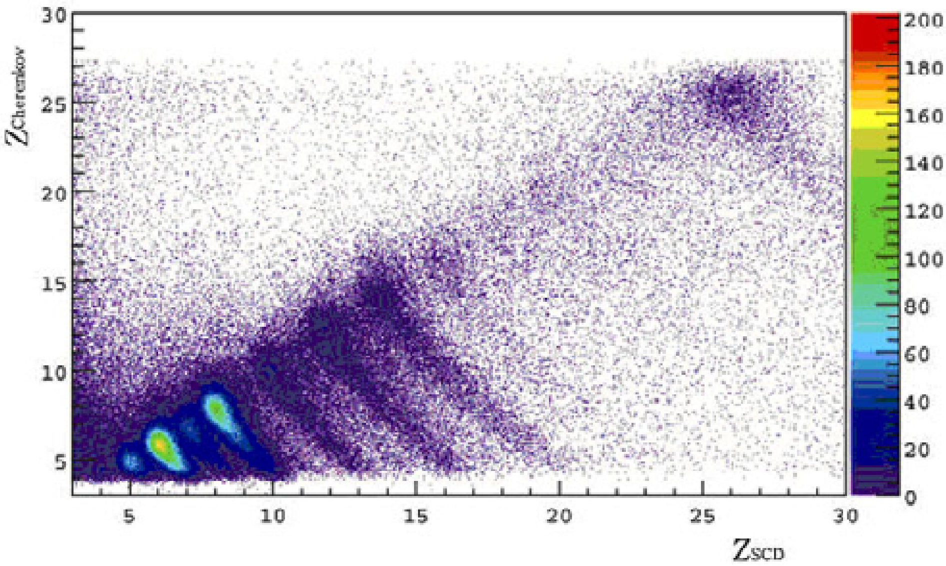

Figure 3. Correlation between SCD charge found near the TRD track and charge measured by the Cherenkov counter.

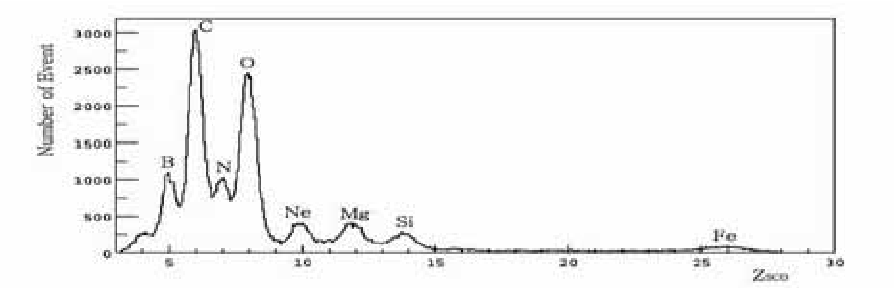

Figure 4. SCD Charge spectrum by the projection of high energy signals in Figure 3. The relative abundances are not corrected here.

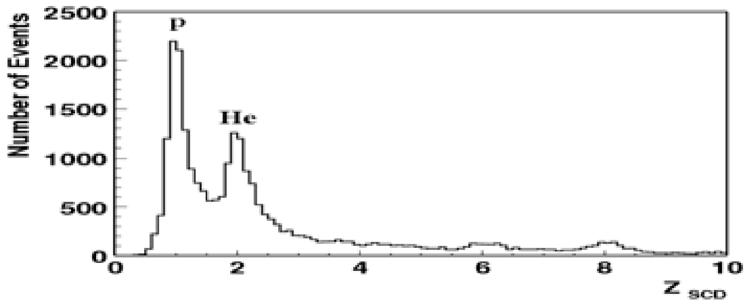

Figure 5. SCD charge spectrum in high energy events triggered by the calorimeter. Relative abundances are not corrected here.

5. Conclusions

The first balloon flight of CREAM and the operation of the SCD in Antarctica were successful. The SCD operation was stable throughout the flight, yielding high quality charge data. Tracks found in the TRD and the shower axis reconstructed in the calorimeter provided seed information for locating the SCD pixels traversed by incident cosmic rays. Clean charge spectra of primary cosmic rays were obtained through a preliminary analysis of the flight data. Further analysis of the data is expected to provide significant improvements in charge reconstruction, allowing single-element spectra to be extracted from the flight data.

6. Acknowledgements

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