Performance of the CREAM-V and CREAM-VI calorimeters in flight

J.H. HAN[1], H.S. AHN[1], Y. AMARE[1], T. ANDERSON[2], D. ANGELASZEK[1, 3], A. BARRAU[4], R. BAZER-BACHI[5], J. J. BEATTY[6], T. J. BRANDT[6], M. BUENERD[4], N. B. CONKLIN[2], B. COSTE[4], S. COUTU[2], E. DANILEVICH[1], L. DEROME[4], J. EATON[1], O. GANEL[1], M. GESKE[2], M. GUPTA[1], A. HAQUE[1], J. A. JEON[7], K. C. KIM[1], M. H. KIM[1], J. T. LINK[8, 9], M. H. LEE[1], S. E. LEE[1], L. LUTZ[1], A. MALININ[1], A. MENCHACA-ROCHA[10], J. W. MITCHELL[8], S. I. MOGNET[3], G. NA[7], K.H.NAM[7], J. NAM[7], S. NAM[7], S. NUTTER[11], O. OFOHA[1], A. PAGE[1], I. H. PARK[7], S. S. RYU[1], E. S. SEO[1,3], B. P. SMITH[1], J. TYLKA[1], A. VARTANYAN[1], J. WU[1], Y. S. YOON[1,3]

[1] *Institute for Physical Science and Technology, University of Maryland, College Park, MD 20742, USA*
[2] *Department of Physics, Penn State University, University Park, PA 16802, USA*
[3] *Department of Physics, University of Maryland, College Park, MD 20742, USA*
[4] *Laboratoire de Physique Subatomique et de Cosmologie, UJF - CNRS/IN2P3 - INP, Grenoble, France*
[5] *Center d'Etude Spatiale des Rayonnements, UFR PCA-CNRS-UPR 8002, Toulouse, France*
[6] *Department of Physics, Ohio State University, Columbus, OH 43210, USA*
[7] *Department of Physics, Ewha Womans University, Seoul 120-750, Republic of Korea*
[10] *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico*
[8] *Astrophysics Space Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA*
[9] *CRESST/USRA, Columbia, MD 21044*
[10] *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico*
[11] *Department of Physics, Northern Kentucky University, Highland Height, KY 41099, USA*
jhhan@umd.edu
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Abstract: The Cosmic Ray Energetics And Mass (CREAM) is a balloon-borne experiment designed to study the composition and energy spectra of cosmic-ray particles. CREAM has flown six times from McMurdo Station in Antarctica between December 2004 and December 2010. The payload for the CREAM-V flight employed a Timing Charge Detector (TCD), Cherenkov Camera (CherCam) and Silicon Charge Detector (SCD) for the charge measurement, and a Calorimeter (CAL) for the energy measurement. For the CREAM-VI flight, the payload only included the CherCam, SCD and CAL. The CAL was constructed of 20 layers tungsten plates interleaved with scintillating fiber ribbons, and used to measure the elemental energy spectra of cosmic rays up to 10^{15} eV. In this paper we present the performance of the CREAM-V (2009-2010 season) and CREAM-VI (2010-2011 season) calorimeters during flight, and show preliminary distributions of energy deposited in the CAL.

Keywords: Cosmic Rays, Beam Tests and Calorimeters.

1 Introduction

1.1 The CREAM instrument and calorimeter

The Cosmic Ray Energetics And Mass experiment is designed to investigate high energy (10^{12} ~ 10^{15} eV) cosmic rays over the elemental range from hydrogen to iron ($1 \leq Z \leq 26$) [1]. The CREAM instrument consists of complementary and redundant particle detectors to measure the charge and energy of very high energy particles [2]. Particle charge is measured with the Timing Charge Detector [3], Cherenkov Camera [4] and Silicon Charge Detector [5] and particle energy is measured with an ionization Calorimeter (CAL) [6]. Energies of cosmic-ray particles are measured by an ionization CAL comprised of 20 layers of 1 radiation length thick tungsten plates and 20 layers of 0.5 mm diameter scintillating fibers [7]. Each tungsten plate is 500 × 500 × 3.3 mm^3 and the fibers are grouped into fifty 1 cm wide ribbons.

2 The CREAM-V calorimeter

2.1 Performance in flight

The instrument configuration of CREAM-V is the same as for previous flights (CREAM-III and CREAM-IV) [8]. The CREAM-V payload was flown in Antarctica from Dec. 1, 2009 to Jan. 8, 2010. During the flight, CAL temperature remained within the operational range of 10 °C – 35 °C. Figure 1 shows that temperature fluctuated by on approximately 10 °C in a day.

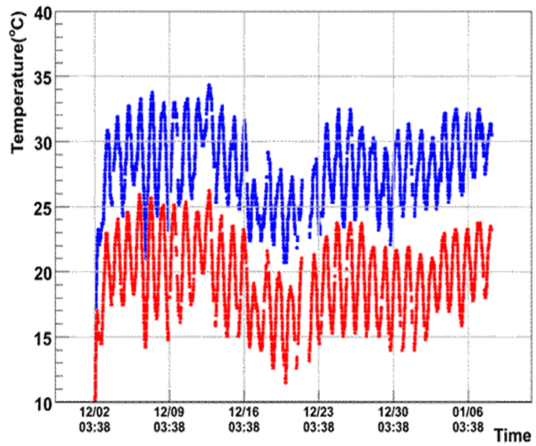

Figure 1. Time variation of temperature of two CAL motherboards.

From the pressure data collected by sensors in the Support Instrument package (SIP), the mean atmospheric overburden during the flight was calculated to be ~ 4.0 g/cm^3. Atmospheric overburden showed a clear anticorrelation with altitude, as shown in Figure 2. The effect of sun angle change over each 24 hour cycle can clearly be seen in Figures 1 and 2.

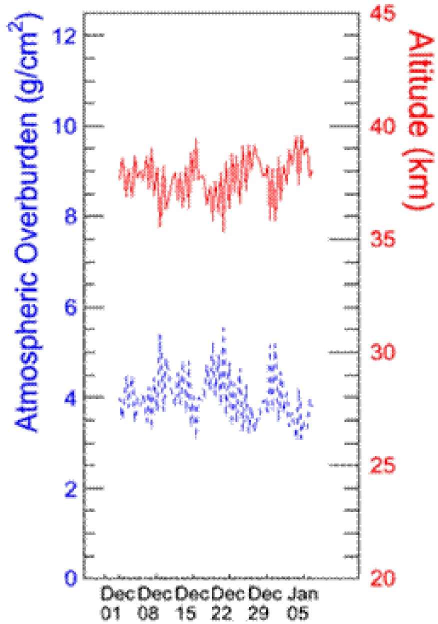

Figure 2. Time variation of atmospheric overburden and altitude.

2.2 Calorimeter Trigger and Energy Reconstruction

The CAL trigger was designed to generated a signal whenever a set of N consecutive CAL active layers (N=4, 6, 8, or 10, adjustable by command) observed a signal exceeding the threshold that could be adjusted separately for half-layer by command [9]. During the flight, the trigger was set to require at least 6 consecutive layers, with a threshold of ~ 12 MeV. About 3 × 10^4 CAL trigger events were collected each day, and we accumulated over 9 × 10^5 events during the flight, as shown in Figure 3. The deposited energy was reconstructed using calibration constants from CERN beam calibrations, LED-based HV gain corrections, and flight measurements of the ratio between different gain ranges [9].

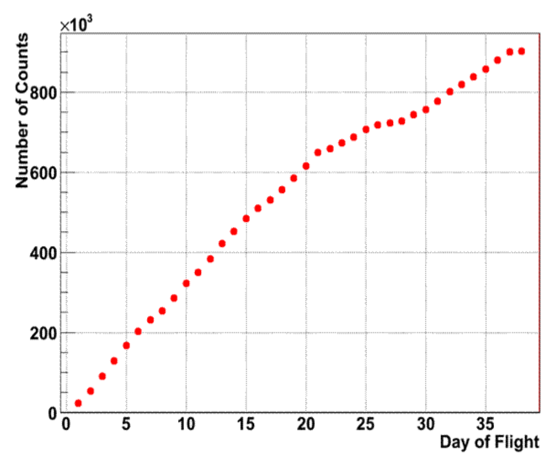

Figure 3. Accumulation of downlinked events over the flight.

2.3 Preliminary result

Figure 4 shows a preliminary result of the CAL energy deposit distribution for events triggered with this condition. All primary charge species are included in the distribution [10]. The power-law behavior, expected from the energy dependence of the differential cosmic rays spectrum, is visible above 3.5 in Log_{10} scale in the distribution.

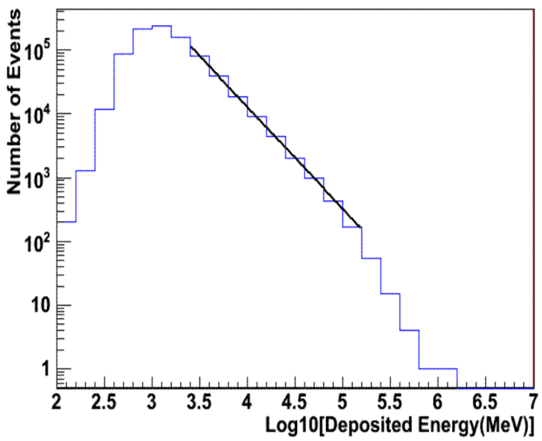

Figure 4. Preliminary distribution for CAL energy deposits from CREAM-V.

3 The CREAM-VI calorimeter

3.1 Performance in flight

The CREAM-VI instrument consists of the CherCam, SCD and CAL. The launch occurred on December 20, 2010, one year after the CREAM-V launch. The flight was terminated on December 26, 2010 due to a balloon failure. The bias voltages for all HPDs were stable at 60 V, and the CAL module HV systems were stable at 6kV during the flight. The CAL noise was measured with pedestals runs taken automatically. The pedestal noise levels were stable during the flight [8]. Figure 5 shows the mean noise levels in all CAL channels respectively, as measured in pedestal runs throughout the flight.

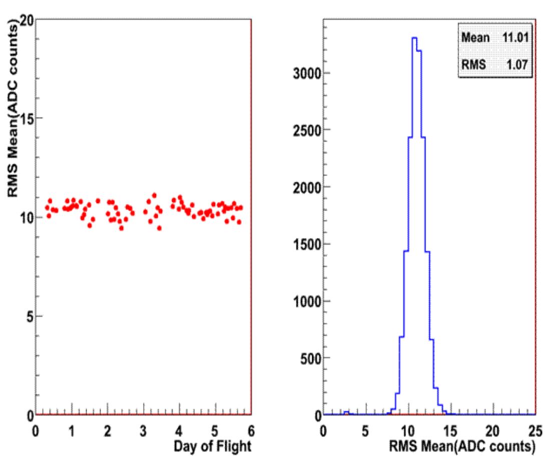

Figure 5. Average pedestal noise of 2560 channels.

3.2 Calorimeter Trigger and Energy Reconstruction

During the flight, the CAL trigger required 6 consecutive layers with at least 1 ribbon in each layer above a fixed threshold value, as described below. It used the same algorithm as for previous flights. The threshold value was set to 18 DAC counts, which corresponds to ~ 12 MeV of deposited energy. The trigger conditions were, therefore, essentially the same as for CREAM-V. Figure 6 shows an example of the low ranges as a function of middle range signals from one ribbon of CREAM-VI. Such ratio values were used to inter-calibrate the different gain ranges for each ribbon, to compensate for situations when the low range saturated [9].

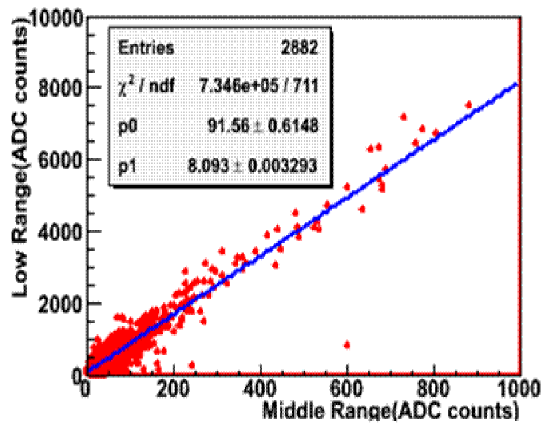

Figure 6. Example of a ratio of middle and low range signals for one ribbon.

3.3 Preliminary result

Figure 7 shows a preliminary distribution of the total energy deposit in MeV in the CAL for shower events recorded with a CAL trigger [10]. The CAL energy threshold and other instrumental effects are responsible for the shape of the curve on the lower energy side, with a deviation from a pure power-law. No corrections for these effects applied in Figure 7.

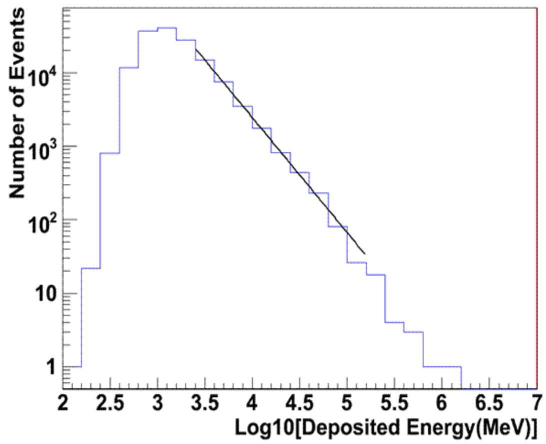

Figure 7. Preliminary distribution for CAL energy deposits from CREAM-VI.

4 Conclusion

The CREAM-V and CREAM-VI calorimeters worked very well during the flights. Electronics noise levels were low, and bias and high voltage values for the CAL were very stable until flight termination. A significant amount of high-energy data was collected. Analysis of the data is in progress.

5 Acknowledgements

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5.1 References

[1] H.S. Ahn et al., The Cosmic Ray Energetics And Mass (CREAM) Instrument, Nuclear Instrument and Methods in Physics Research Section A, 2007, 579: 1034-1053

[2] E.S. Seo et al., Approaching the Knee with Direct Measurements, Nuclear Physics B (Proc. Suppl.), 2007, 175-176C: 155-161

[3] H.S. Ahn et al., The Cosmic Ray Energetics and Mass (CREAM) timing charge detector, Nuclear Instrument and Methods in Physics Research Section A, 2009, **Volume** 602 (Issue 2): 525-536

[4] Y. Sallaz-Damaz et al., CHERCAM: The Cherenkov imager of the CREAM experiment, Nuclear Instrument and Methods in Physics Research Section A, 2008, **Volume** 595 (Issue 1): 62-66

[5] I.H. Park et al., Silicon Charge Detector for the CREAM experiment, Nuclear Instrument and Methods in Physics Research Section A, 2007, **Volume** 570 (Issue 2): 286-291

[6] E.S. Seo et al., Cosmic-ray energetics and mass (CREAM) balloon project, Advances in Space Research, 2004, **Volume** 33 (Issue 10): 1777-1785

[7] M. H. Lee et al., Performance of the CREAM-III Calorimeter, IEEE Transactions on Nuclear Science, 2009, **Volume** 56 (No. 3): 1396-1399

[8] J.H. Han et al., Performance in flight of the CREAM-III and CREAM-IV calorimeters, Proc. 31st Int. Cosmic Ray Conf., 2009

[9] M.H. Lee et al., Performance of the CREAM Calorimeter module during its first flight of 42 days, Proc. 29th Int. Cosmic Ray Conf., 2005, 417-420

[10] P.S. Marrocchesi et al., Preliminary results from the second flight of CREAM, Advances in Space Research, 2008, **Volume** 41 (Issue 12): 2002-2009