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The Record Breaking 42-day Balloon Flight of CREAM

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The Cosmic Ray Energetics And Mass (CREAM) balloon-borne experiment circumnavigated the South Pole three times during a 42-day flight from 16 December 2004 to 27 January 2005 in its quest to explore a limit to the acceleration of cosmic rays in supernovae. The balloon altitude stayed between 125,000 ft and 130,000 ft throughout most of the flight. The instrument has redundant charge identification and energy measurement systems capable of precise measurements of elemental spectra for $Z = 1 - 26$ nuclei over the energy range $\sim 10^{11} – 10^{15}$ eV. Measurements of the relative abundances of secondary cosmic rays (e.g., B/C) in addition to the energy spectra of primary nuclei will allow determination of cosmic-ray source spectra at very high energies. Preliminary results from the ongoing analysis are presented, and future plans are discussed.

1. Introduction

The CREAM experiment [1] was designed and constructed to extend balloon and space-based direct measurements of cosmic-ray elemental spectra to the highest energy possible in a series of balloon flights. The detailed energy dependence of elemental spectra at very high energies, where the rigidity-dependent supernova acceleration limit could be reflected in composition change, provides a key to understanding the acceleration and propagation of cosmic rays. Simultaneous measurements of secondary and primary nuclei allow determination of the source spectra at energies where measurements are not currently available.

2. Long Duration Balloon Flight

The CREAM payload was successfully launched from McMurdo, Antarctica on 16 December 2004, and it subsequently circumnavigated the South Pole three times. As shown by the trajectory in Figure 1, the balloon drifted toward the pole, made a full circle around latitude 85°S, and gradually spiraled northward. The flight was terminated on 27 January 2005 after a record-breaking duration of 42-days. The payload landed on the high plateau 410 nautical miles northwest of McMurdo station. The balloon float altitude was between 125,000 and 130,000 ft throughout most of the flight. The corresponding average atmospheric overburden was only ~3.9 g/cm^2. The diurnal altitude variation due to the Sun angle change was very small, < 1 km, near the pole, i.e. at high latitude, which increased as the balloon spiraled out to lower latitudes. The temperature of the various instrument boxes stayed relatively constant with daily variation of about 1- 3°C, consistent with the Sun angle.

All of the high energy data (> ~ 1 TeV) were transmitted via TDRSS during the flight, while the lower energy data were recorded on board. A total of 60 GB of data (~ 40 × 10^6 science events) were collected. The flight operation was unique in several aspects. This was the first long duration balloon (LDB) mission to transmit all the prime science and housekeeping data (up to 85 kbps) in near real-time through the Tracking and Data Relay Satellite System (TDRSS) via a high-gain antenna, in addition to having an onboard data archive.

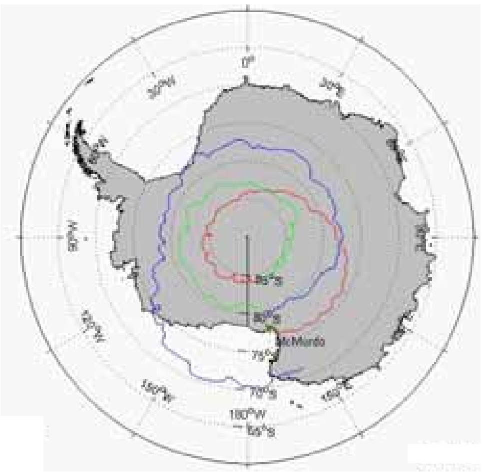

Figure 1. CREAM balloon trajectory. Red, green and blue lines represent 1st, 2nd and 3rd circumnavigations, respectively.

As the balloon drifted away from the line-of-sight, which lasted for ~12 hours after the launch, commanding was transferred off the continent to the Science Operation Center at the University of Maryland. Primary command uplink was via TDRSS, with Iridium serving as backup whenever the primary link was unavailable due to schedule or traversing zones of exclusion. The nearly continuous availability of command uplink and data downlink throughout the flight allowed a rapid response to changing conditions on the payload (e.g., altitude dependent effects). See References [2,3] for more details of the flight operation and CREAM data acquisition system.

Figure 2. CREAM ballooncraft at the launch site while the balloon is being inflated.

The CREAM ballooncraft [1], referring to all hardware below the attachment point to the mobile launch vehicle, shown in Figure 2, is an integrated assembly of the science instrument and support systems mounted on the primary support structure. The science instrument was not pressurized, and it was supported by the Command and Data Module (CDM) developed by NASA Wallops Flight Facility (WFF) [4]. This is in contrast to typical LDB payloads which utilize the Support Instrumentation Package (SIP) provided by the National Scientific Balloon Facility (NSBF). The 40 MCF-lite balloon carried a total suspended weight of 6000 lb, including ~2900 lb for the science instrument and ~1100 lb of ballast. The science instrument power consumption was ~400 W. Both the science instrument and the flight support systems were developed for nominal 100-day ultra-long-duration balloon (ULDB) missions.

3. Instrument Performance

A suite of particle detectors was employed to determine the charge and energy of the very high energy particles. As shown in Figure 3, they include a Timing Charge Detector (TCD), a Transition Radiation

Detector (TRD) with a Cherenkov threshold counter (CTC), and a calorimeter module comprised of a silicon charge detector (SCD), a carbon target, scintillating fiber hodoscopes (S0/S1 and S2), and a stack of tungsten plates with interspersed scintillating fiber layers. Multiple charge measurements with the TCD, CTC, SCD, and S0/S1 layers of scintillating fibers accurately identify the incident particles by minimizing the effect of backscattered particles from the calorimeter. The TCD utilizes the fact that the incident particle enters the TCD before developing a shower in the calorimeter, and the backscattered albedo particles arrive several nanoseconds later. A layer of scintillating fibers, S3, located between the carbon target and the tungsten calorimeter provides a reference time. The SCD is segmented into pixels, each about 2 cm^2 in area to minimize multiple hits in a segment due to backscattered particles.

The carbon target induces hadronic interactions in the calorimeter module, which measures the shower energy and provides tracking information to determine which segment(s) of the charge detectors must be used for charge measurement. Tracking for showers is accomplished by extrapolating each shower axis to the charge detectors. The hodoscopes S0/S1 and S2 provide additional tracking information above the tungsten stack. Tracking for non-interacting particles is achieved with better accuracy in the TRD, 1 mm resolution with 67 cm lever arm, 0.0015 radians. The TRD determines the Lorentz factor for $Z > 3$ nuclei by measuring transition x-rays using thin-wall gas tubes. The TRD and calorimeter, which can also measure the energy of protons and He, have different systematic biases in determining particle energy. The use of both instruments allows in-flight cross-calibration of the two techniques and, consequently, provides a powerful method for measuring cosmic-ray energies. See reference [1] for the instrument details.

As illustrated by the example of a ~10 TeV Fe event in Figure 3b, the instrument functioned well during the flight. Its performance is discussed in other papers at this conference [5, 6, 7, 8]. As shown in Figure 4, charge peaks for major elements are separated clearly in the SCD. The measured calorimeter energy deposit distribution is shown in Figure 5. A deposit of about 3.2 along the horizontal scale in Figure 5 corresponds to incident energy ~1 TeV, close to the calorimeter threshold. This energy deposit gives a quick check of the energy spectrum, which in this case shows a reasonable power law, and shows that we have data extending well above 100 TeV. The CREAM trigger aperture is ~2 m^2sr. After event selection cuts/reconstructions, the effective acceptance for $Z \geq 3$ particles is estimated to be >1 m^2sr, while the corresponding effective acceptance for p and He is estimated to be 0.3 m^2sr, approximately half of the raw geometry factor.

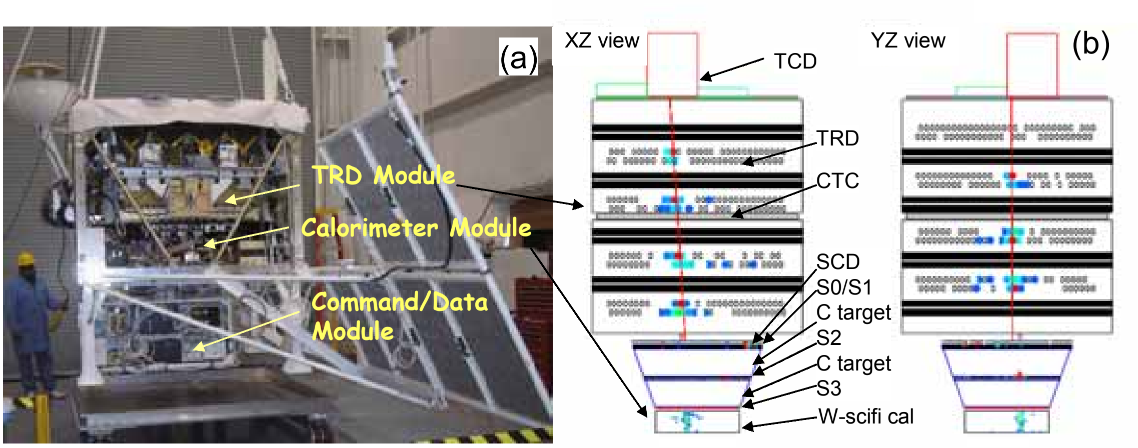

Figure 3. CREAM Instrument: (a) Photograph; (b) Event display; A cosmic-ray Fe nucleus with estimated energy 10 TeV entered the instrument to give a large signal (red box at the top) in the TCD, a clear track in the TRD (blue and red filled circles), a large signal in the SCD (red box) and a well-defined shower in the calorimeter (light blue).

4. Summary

The CREAM instrument was calibrated in a series of beam tests at the CERN SPS before the flight. The science instrument, support systems, and operation scheme were successfully tested for ultra-long-duration flight throughout this record-breaking LDB flight. With excellent particle charge and energy resolutions, and relatively large collection factor, each CREAM flight will extend the reach of precise composition measurements to energies not previously possible. It is planned to conduct annual flights by alternating two science instrument suites, CREAM-I and CREAM-II, since the same instrument cannot be flown in consecutive years due to the time required for recovery, return to the laboratory, and refurbishment. The CREAM-I instrument was fully recovered with Twin Otter airplane flights after its record-breaking flight, and it is being refurbished in anticipation of another launch in 2006. The CREAM-II instrument and the refurbished support system are being integrated for launch in December 2005.

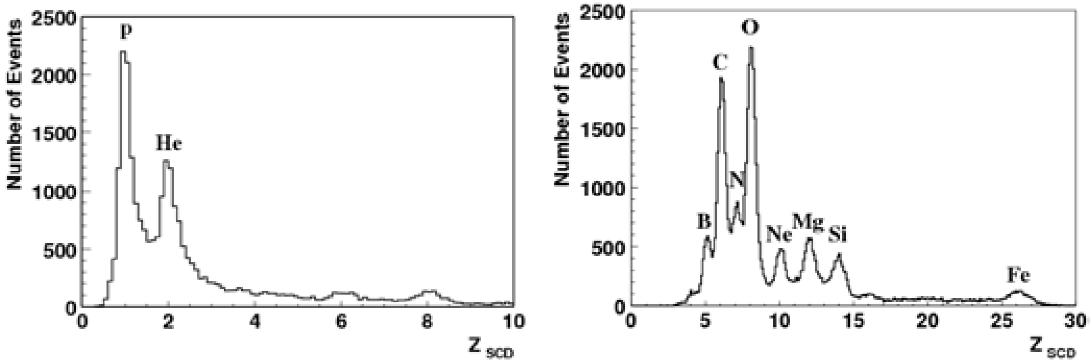

Figure 4. Preliminary flight data: SCD charge histograms of for (a) Low-Z trigger and (b) High-Z trigger events show clear charge separation for major elements. The relative abundance has no significance in these plots.

5. Acknowledgements

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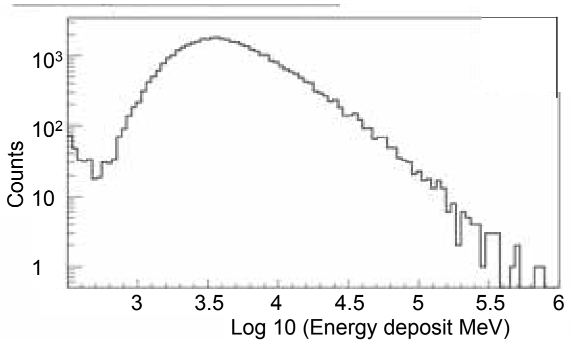

Figure 5. Preliminary calorimeter energy deposit distribution.

References

[1] E. S. Seo et al., *Adv. in Space Res.*, **33**/10, 1777 (2004); http://cosmicray.umd.edu/cream/cream.html.
[2] Y. S. Yoon et al., Proc. 29th ICRC, Pune, OG1.5 (2005).
[3] S. Y. Zinn et al., Proc. 29th ICRC, Pune, OG1.5 (2005).
[4] W. V. Jones et al., Proc. 29th ICRC, Pune, OG2.7 (2005).
[5] S. Coutu et al., Proc. 29th ICRC, Pune, OG1.5 (2005).
[6] M. H. Lee et al., Proc. 29th ICRC, Pune, OG1.5 (2005).
[7] J. M. Yang et al., Proc. 29th ICRC, Pune, OG1.5 (2005).
[8] P. S. Marrocchesi et al., Proc. 29th ICRC, Pune, HE1.5 (2005).