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# Design and performance in the first flight of the transition radiation detector and charge detector of the CREAM balloon instrument

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**Abstract**

The Cosmic Ray Energetics And Mass (CREAM) instrument flew on a high altitude balloon in Antarctica in 2004–2005 for a record breaking 42 days. An array of detectors was deployed to identify cosmic rays and measure their energies up to several hundred TeV. A major science goal is the measurement of secondary nuclei at high energy (produced by spallation reactions of heavier cosmic rays in the interstellar medium). This is done with a transition radiation detector using xenon-filled proportional tubes, and charge identification devices comprising plastic scintillator and Cherenkov counters. Accurate and stable performance of these detectors is necessary for the reliable identification of the secondary nuclei. The design of these detectors and their performance in flight are discussed, and preliminary data presented.


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The CREAM instrument is described in detail elsewhere [1]. It combines a timing charge detector (TCD), a transition radiation detector (TRD), a plastic Cherenkov counter, a silicon pixel charge detector, and a calorimeter module. Here we focus on the TCD, TRD and Cherenkov devices, which are used for the determination of the abundances of secondary nuclei such as boron (produced in spallation reactions during the Galactic propagation of heavier nuclei such as carbon). The other detector elements provide additional capabilities (e.g. sensitivity to the light elements from hydrogen to lithium), and some redundancy in energy and charge measurements, which is crucial for cross-checks of reconstructions and reduction of systematic uncertainties.

The TCD [2] consists of two layers of 5 mm-thick plastic scintillators, covering an area of 1.44 $m^2$ (eight scintillators in total), to determine the charge of incident cosmic rays.

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The amplitude and time structure of light pulses are measured with fast photomultiplier tubes at both ends of each scintillator, yielding a measurement of the charge with an accuracy of $\sim$0.17 e for O to $\sim$0.35 e for Fe nuclei.

The TRD utilizes eight polystyrene foam layers as radiator. Embedded in the foam are 512, 1.2 m-long thin-walled proportional gas tubes, each 2 cm in diameter and arranged in 16 layers. A Xe-methane (95%:5%) gas mixture at a pressure of 1 atm is used to measure the logarithmically increasing relativistic ionization losses of the cosmic ray nuclei, which are large in Xe. These are augmented by transition radiation losses above $\sim$1 TeV/n. The pattern of energy deposits is used to reconstruct a three-dimensional track through the instrument, with an ultimate RMS tracking resolution of $\sim$1.1 mm. The energy loss per unit path length provides a measure of the Lorentz factor $\gamma$, and hence the energy, of the cosmic ray nuclei up to $\gamma \simeq 20\,000$ [3].

The Cherenkov detector is a 1 cm-thick plastic radiator sheet (1.2 m $\times$ 1.2 m) doped with blue wavelength shifter. The Cherenkov radiation is collected at the edges by eight small photomultiplier tubes via wavelength shifting bars, providing a trigger condition for relativistic nuclei and a charge measurement supplemental to that of the TCD. This makes for a compact design with better than 5% uniformity in light collection across the entire detector area.

About 40 million heavy nuclei were recorded during the 42-day flight of the CREAM instrument. Despite the fact that the instrument operated in a near vacuum of a few mbars without the benefit of a pressure vessel, all detectors performed very stably throughout the entire flight. For instance, despite about 600 m of gas tubing at 1 atm in the TRD system, only 10% of the gas volume was lost in flight, not requiring the use of spare gas supply (small losses in one chamber were compensated by periodic redistribution of the gas in the system). One photomultiplier tube out of 18 on the TCD system failed near the end of the flight. The instrument was also struck by a massive particle storm from a giant solar flare on 20 January 2005, from which it recovered and continued operating until the end of the flight.

Fig. 1 shows a preliminary distribution of the charge of nuclei measured in flight. This is a combination of charge measurements from the TCD and Cherenkov detectors, with tracking corrections from the TRD. Clearly visible are populations of nuclei from Be to Si, including well separated B and C nuclei, important in the determination of secondary nuclear production by spallation, and indicative of the history of the cosmic rays during Galactic propagation. Work is in progress to finalize the energy reconstruction of the events of Fig. 1 based on the TRD energy losses, so that the figure should be construed only as an indication of the good combined sensitivity of the CREAM detector systems.

The detectors on CREAM designed to measure heavy nuclei performed well during the 2004/05 Antarctic flight. A large sample of nuclei have been collected which preliminary analysis demonstrates have sufficient signal resolution to provide a measurement of the abundance ratio of secondary to primary nuclei up to $\sim$500 GeV/n.

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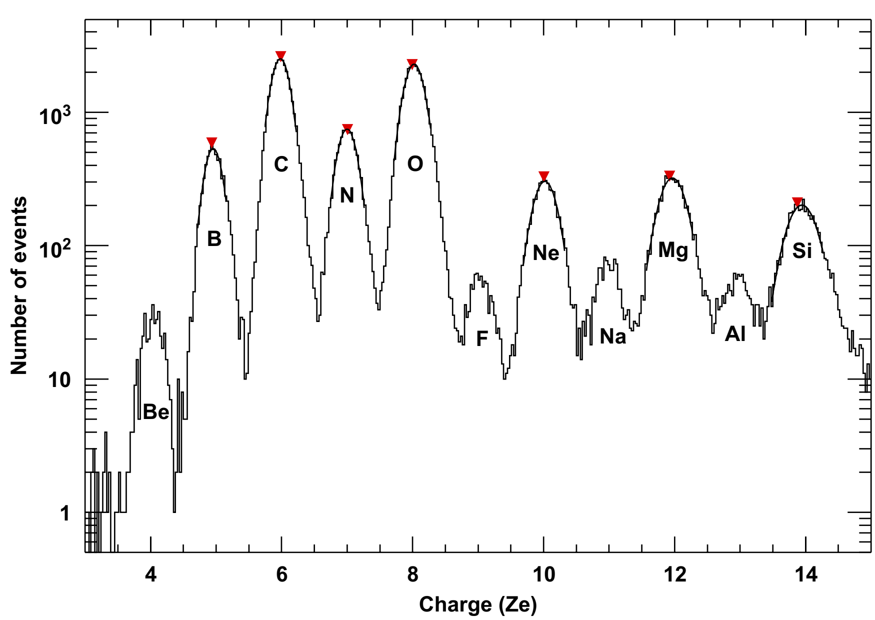


Fig. 1. Preliminary distribution of the charge (in units of the elementary charge e) of cosmic-ray nuclei measured in flight. Curves indicate Gaussian fits to the more prominent peaks. The charge reconstruction resolution, e.g., for O, is $\sim$0.17 e.

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