CREAM for High Energy Composition Measurements

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Abstract

Ground-based indirect measurements have shown that the cosmic-ray all-particle spectrum extends many orders of magnitude beyond the energy thought possible for supernova acceleration. Our balloon-borne Cosmic Ray Energetics And Mass (CREAM) experiment is capable of extending direct measurements of cosmic-rays to the supernova energy scale of 10^{15} eV in a series of Ultra Long Duration Balloon (ULDB) flights. Identification of Z = 1 - 26 particles will be made with a timing-based charge detector and a pixelated silicon charge detector. Energy measurements will be made with a transition radiation detector and a tungsten/scintillating fiber calorimeter. The instrument has been tested with various particles in accelerated beams at the CERN SPS. The first flight is planned to be launched from Antarctica in December 2004.

1. Introduction

Innovative detector systems coupled with the ULDB capability being developed by NASA now promise high quality cosmic-ray measurements over an energy range that was not previously possible. Knowledge of the detailed energy dependence of the elemental spectra to as high an energy as possible is the key to understanding the acceleration and galactic propagation of cosmic rays. The energy spectrum observed near earth can be related to the spectrum at the source

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by unfolding the galactic propagation history with the measurements of the relative abundance of secondary cosmic rays. Ground-based air shower measurements have shown that the all-particle spectrum changes its slope at $\sim$3 x 10^{15} eV. This spectral feature known as "knee" may indicate changes in sources, propagation, and/or acceleration. According to the theory, supernova shocks can accelerate particles to a maximum energy of about $\sim$Z x 10^{14}eV, where Z is particle charge. The corresponding iron nuclei limit ($\sim$ 26 x 10^{14}) is intriguingly close to the "knee" feature. A characteristic change in the cosmic-ray elemental composition between the limiting energies for protons and iron would be the signature for the supernova acceleration limit.

2. Instrument

The CREAM instrument consists of a variety of particle detectors as shown in Fig. 1. The Timing Charge Detector (TCD), Silicon Charge Detector (SCD), and S0/S1 provide particle charge measurements. The key design consideration for the charge detectors is to minimize the effects of backsplash particles from showers in the calorimeter. The TCD is a new technology being developed for CREAM [1]. It 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. S3 which is a single layer of scintillating fibers provides a reference time. A finely segmented silicon charge detector has been flown on the Advanced Thin Ionization Calorimeter, and a similar technique is employed for the CREAM SCD [2]. Four layers of scintillating fibers, S0/S1, provide additional charge measurements as well as particle tracking information.

Particle energy is measured with a Transition Radiation Detector (TRD) and an ionization calorimeter. For particles with $Z > 3$ the TRD measures a signal that is a function of the charge and the Lorentz factor γ. The TRD is divided into two sections separated by a plastic Cherenkov detector, which allows rejection of the abundant low energy cosmic rays present in high latitude regions where geomagnetic cut off is low. Each TRD module is comprised of 8 layers of 32 thin-walled aluminized Mylar tubes embedded in a plastic foam matrix, which serves the dual purpose of radiator and mechanical support. The tubes are filled with a mixture of Xenon (95%) and Methane (5%).

Ionization calorimetry provides the only practical method for measuring protons and helium up to the energies of interest to CREAM. The CREAM tungsten-scintillator sampling calorimeter is preceded by a carbon target. It can determine particle energy for $Z = 1$ - 26 nuclei. The TRD and calorimeter have different systematic biases in determining the particle energy, and the use of both instruments allows in-flight intercalibration of the two techniques. See Seo et al. [3,4] for more details on the instrument.

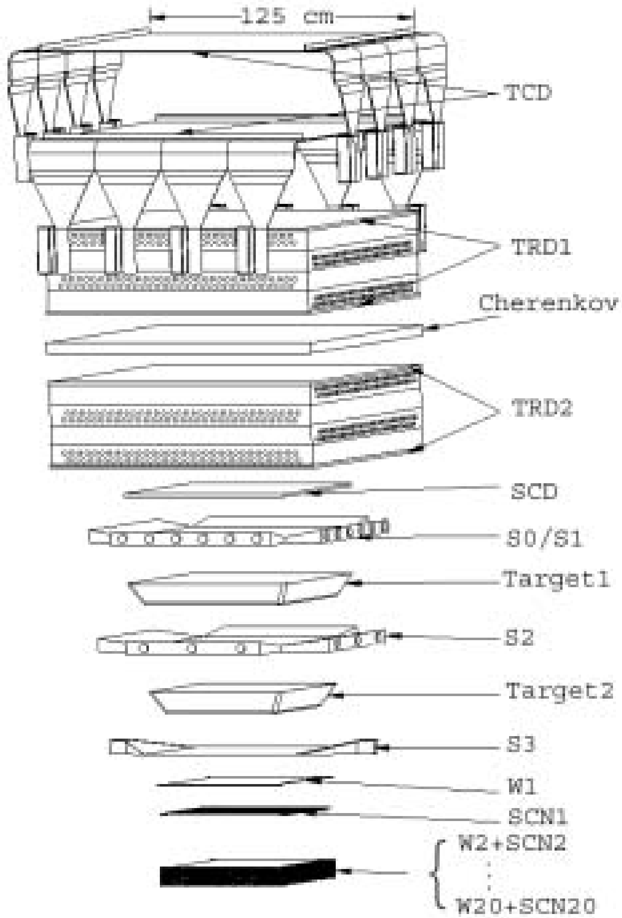

Fig. 1. Schematic view of the CREAM instrument.

3. Ballooncraft

The CREAM mission implements an integrated system design approach, combining the science instruments and a customized modular ballooncraft support system, which provides global coverage of telemetry downlinks and command uplinks, power, the support structure, solar pannels, ballast hopper, and crush pads. The Command Data Module (CDM) is the core of the ballooncraft support system. It controls and monitors the ballooncraft power system and communications through a flight computer subsystem. The CDM is located in an independent thermally-controlled support structure. All flight systems are designed for mission duration of at least 100 days.

A superpressure balloon made with a non-extensible material in a closed system will be used to achieve the 100-day flight duration. The balloon vehicle design requires that the total suspended weight not exceed 5500 lbs, excluding ballast. The science instrument weight is 2414 lbs. The electrical power system includes a solar array for power generation and batteries for energy storage. The power system is sized for nominal flight operations within the range of 90 degrees to 30 degrees south latitude. Its nominal operating output voltage is 28 +/- 4 Vdc, and the instrument is expected to draw 380 W. The command and data path to the ballooncraft flight computer is Ethernet. The nominal telemetry rates are expected to be 50 kbps for science data and $<$ 500 bps for monitoring data for support and flight control systems. The primary communications link for the mission data will be through the Tracking and Data Relay Satellite System (TDRSS). All data will also be stored on-board. The downlink will utilize the CCSDS protocol. All monitored and science data will be transmitted from the balloon to the Operations Control Center (OCC) at the National Scientific Balloon Facility (NSBF) in Palestine, Texas. The Science Team will have command and data capability from their home institutions via network connections. For more details on the ballooncraft support system see Stuchlik et al.[5].

4. Status and Plan

The instrument has been tested and calibrated with a series of beam tests at CERN. Its performance is consistent with the Monte Carlo simulations. The instrument calibration is discussed in more detail in Ganel et al.[6]. The expected instrument performance, including trigger and data rates, energy resolution, energy response, etc. is presented in Ahn et al. [7]. The calorimeter module will be calibrated at the CERN beam in July 2003 with the trigger system and science flight/ground computers/software. The charge detectors will be added for another run with 158 GeV/n Indium fragments in October 2003. A thermal vacuum test is scheduled for February, 2004. The instrument will be delivered to the NASA Wallops Flight Facility for integration with the ballooncraft support system in early March 2004. After completion of the flight system end-to-end test the payload will be shipped to Antarctica in mid-August, 2004 to be flight ready for the first launch opportunity in December, 2004.

5. References

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