Results of Tests and Simulations for the Top Counting Detector and Bottom Counting Detector of the ISS-CREAM Experiment

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Abstract

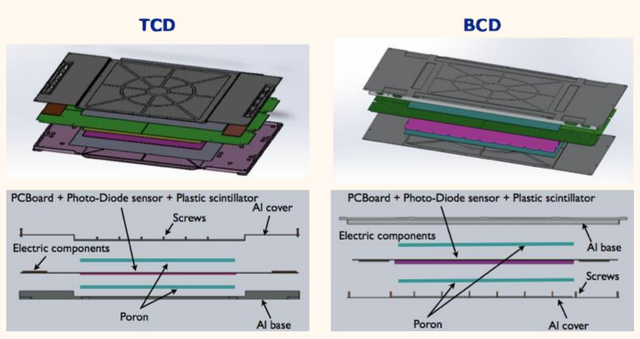
The Cosmic-ray elemental spectra are important to understand the origin and acceleration mechanism of high-energy cosmic rays. The Cosmic Rays Energetics And Mass (CREAM) experiment [1] on the International Space Station (ISS) plans to measure nuclear and electron energy spectra precisely. The separation of electrons from protons is crucial because the proton flux is about 1000 times higher than that of electrons in the energy range 300 GeV ~ 800 GeV. The Top Counting Detector (TCD) and Bottom Counting Detector (BCD) are designed to optimize e/p separation. The TCD and BCD each consists of a plastic scintillator and an average of 400 photo-diodes, respectively. The TCD and BCD are located immediately above and below the calorimeter, respectively. This detector configuration provide e/p separation by using the different shapes of electromagnetic and hadronic showers. We have characterized the performance of the TCD/BCD in several different ways. The signal to noise ratio of the detector cell components was measured by using a ^{90}Sr radioactive source and a high-energy beam at CERN. The temperature dependence of the detector cell component, from -40 ℃ to 70 ℃, and the robustness of the TCD/BCD module were confirmed using thermal and vacuum chambers. We present the TCD/BCD design considerations and a summary of the measured performance of the TCD/BCD modules.

I. Introduction

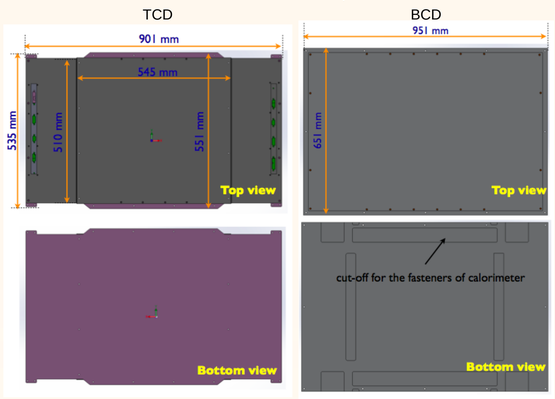
- The CREAM for the ISS (ISS-CREAM) instrument comprises a Silicon Charged Detectors, a carbon target, a tungsten/scintillator sampling calorimeter, a Top Counting Detector, a Bottom Counting Detector and a Boronated Scintillator Detector.
- The ISS-CREAM experiment [2] is planned to be installed on the ISS in 2014.
- The TCD/BCD are designed to optimize e/p separation by using the different shapes of electromagnetic and hadronic showers.
- Goals of TCD/BCD
  - Electron/proton separation for electron and gamma-ray physics
  - Provide redundant trigger for CREAM Calorimeter
  - Provide MIP (Minimum Ionizing Particle) trigger for calibration

II. Design of TCD/BCD

Design of TCD/BCD



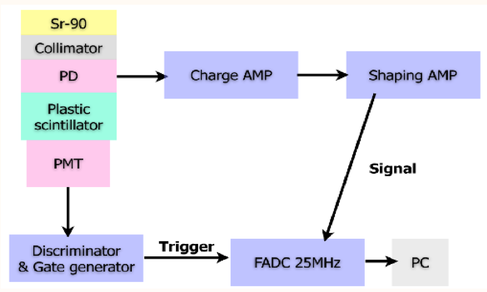
Dimensions for TCD/BCD



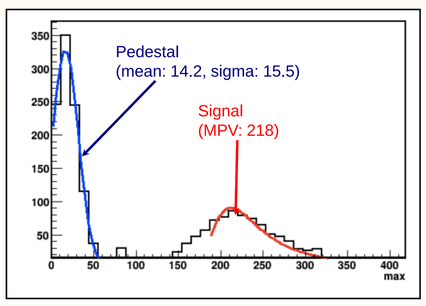
- TCD/BCD consist of a polyvinyltoluene plastic scintillator (EJ-200) and an array of 400 photo-diodes
- The photo-diodes were developed by Kyungpook National University
  - 650 μm thickness, n-type silicon wafers
  - Operating voltage: -250 V
- Dimension
  - TCD : 900 × 535 × 300 mm^3
  - BCD : 950 × 651 × 33 mm^3
  - Mass
  - TCD:12 kg
  - BCD: 16 kg

III. Radioactive Source Test

Block diagram of the SNR measurement system



SNR distribution obtained with the ^{90}Sr radioactive source



- Use ^{90}Sr radioactive source for measuring the signal to noise ratio (SNR)
- Setting values
  - Biasing voltage for PMT: -700 V
  - AMP setting : shaping time 3 μs, coarse gain 50, fine gain 0.5
  - PD : -190 V
- The measured SNR is 13.0
  - SNR = (MPV. of signal - mean of pedestal) / sigma of pedestal

VI. Conclusion

- We fabricated the PD's for the TCD/BCD and attached them to the plastic scintillators.
- The TCD/BCD will measure the high energy cosmic-electron by providing e/p separation for ISS-CREAM.
- The SNR of the detector cell component was measured to be 13.0 with a ^{90}Sr radioactive source.
- The characteristics of the detector cell components were measured before/after thermal and vacuum tests.
  - The value of the e-RMS tracked well with temperature change.
  - The leakage current value before/after the vacuum test did not change.
- Prototypes of the TCD/BCD were tested with a muon beam at CERN.
  - The SNR of the prototype TCD/BCD was measured to be 7.1.
  - TCD/BCD can provide a MIP trigger for detector calibration.

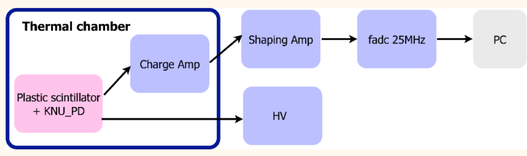
VII. References

[1] H. S. Ahn et al., ApJL 714 (2010) 89-93.
[2] E. S. Seo et al., ID 629 (2013) this conference.

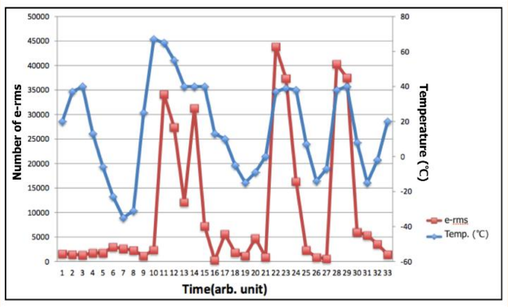
IV. Thermal/Vacuum test of the detector cell components

- Thermal/Vacuum tests were carried out with detector cell components which consists of one PD and one plastic scintillator (23 mm x 23 mm)

Detector cell components used for thermal test

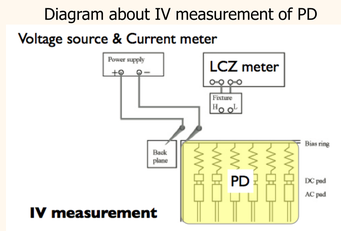


Thermal test result of the detector cell component

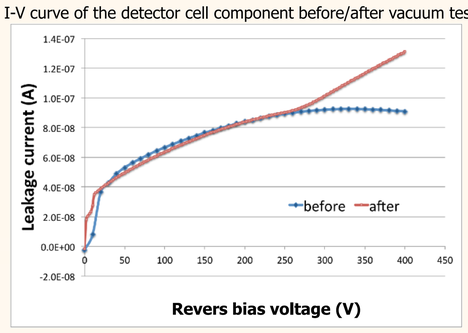


- Survival temperature: -40 ℃ to 70 ℃
- The pedestal was measured during a full thermal cycle
- Setting value
  - Thermal cycles : 11 hour period
  - Biasing voltage for PD: -120 V
- Carried out a calibration test, to find the e$^-$RMS value that corresponds to one ADC count
  - one ADC = RMS of 2083 e$^-$
  - The value of e$^-$RMS reliably tracked the temperature change

Diagram about IV measurement of PD



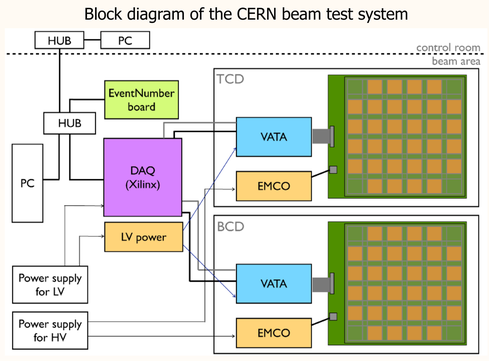
I-V curve of the detector cell component before/after vacuum test



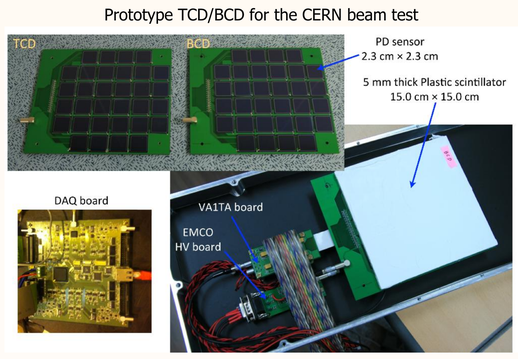
- Survival vacuum: 10^{-5} torr
- maintained at 10^{-5} torr for 4 hours
- The electrical characteristic of the detector cell component were measured before/after the vacuum test using a Keithely 6517 pico-ammeter and and HP 422A LCZ meter
- The leakage current before/after the vacuum test were similar up to -250 V

V. CERN Beam Test

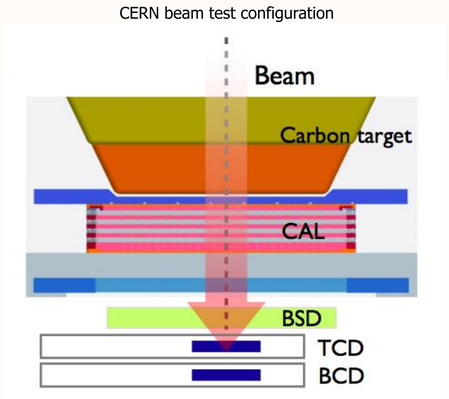
Block diagram of the CERN beam test system



Prototype TCD/BCD for the CERN beam test



CERN beam test configuration



- The performance of the TCD/BCD prototype was measured using electron, muon and pion beam at CERN
- Prototype TCD/BCD
  - consist of 32 PD and a plastic scintillator
- Using punch through muons
  - 50000 signal events
  - 2000 pedestal events
- The measured SNR is 7.1 on average
- Since the SNR needs to exceed 5 for MIP identification, the prototype TCD/BCD showed good performance for MIP identification

Pulse-height distribution of two channels on the prototype BCD at the CERN beam test