Construction and performance of the Top and Bottom Counting Detectors for the ISS-CREAM experiment

Hongjoo Kim
Kyungpook National University
On behalf of ISS-CREAM Collaboration

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Introduction

- ISS-CREAM (Cosmic Ray Energetics And Mass on the International Space Station)
  - ISS-CREAM instrument was launched on 14\textsuperscript{th} August, 2017
  - It measures the energy spectral features from 10 GeV to $> 1000$ TeV and composition that might be related to the supernova acceleration limit
  - It provides keys to understand the origin, acceleration and propagation of the cosmic rays

[Graph of Fluxes of Cosmic Rays]

[Image of ISS-CREAM instrument]

Presentation by Prof. Seo on Sat. 10 am
4 layer Silicon Charge Detector
- Precise charge measurements
- 380-μm thick 2.12 cm$^2$ pixels
- 79 cm x 79 cm active detector area

Presentation by Prof Lee on Sat. 10:15

Top & Bottom Counting Detectors
- Segmented for e/p separation
- Independent Trigger
- Plastic Scintillators with 400 Photodiodes readout (2.3 x 2.3 cm$^2$)

Carbon Targets (0.5 $\lambda_{\text{int}}$) induces hadronic interactions

Calorimeter (20 layers W + Scn Fibers)
- Determine Energy
- Provide tracking
- Provide Trigger

Boronated Scintillator or Detector
- Additional e/p separation
- Neutron signals
Top/Bottom Counting Detector (TCD/BCD)

- **Goals**
  - e/p separation for electron and gamma-ray physics
  - Provide a redundant trigger in addition to the CAL trigger
  - Provide a low energy electron trigger

- **Instrument**
  - Plastic scintillator coupled with 2-dimensional photodiode arrays (20 × 20)
  - 500 × 500 × 5 mm$^3$ and 600 × 600 × 10 mm$^3$ plastic scintillator for TCD and BCD, respectively
  - 23 mm × 23 mm × 650 μm photodiode

- **Method**
  - Electron and proton make different shower shapes at TCD and BCD
TCD/BCD Block Diagram

- Housekeeping Module
- Calibration
- Sparsification
- Power Module
- Trigger Module
- Command Module

- Housekeeping
- ASIC (VA/TA)
- ADC
- DAC
- FPGA (ACTEL)
- HV for PD
- Charge from PD
- A threshold

Connections:
- Temp. / Bias
- Charge pulse
- Data
- ±5 V, +12 V
- Command / Clock
- Power
- HV on/off

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TCD/BCD Trigger diagram

- **AND/OR GATE**
  - **High Threshold Count Trigger**
    - TA threshold count trigger (e-p separation)
    - Redundant CAL trigger
  - **Low Threshold Count Trigger**
    - Low energy trigger

- TCD (2 x 7 ea.)
- BCD (2 x 7 ea.)
TCD/BCD Construction

- Construction at KNU
  - The plastic scintillators are wrapped with reflector to prevent light loss
  - The plastic scintillator is attached to the PD by using a silicon optical adhesive material
  - PD is attached to the PCBs by using a conductive epoxy
  - A plastic foam is placed between the Al enclosure and detector as a bumper to reduce the shock at launching
TCD/BCD Environmental Test for Space Env.

- **Vibration test @Keymyung Univ.**
  
  ![Vibration test image]

  Most pedestal RMS is in 10 ADC to 20 ADC

- **Thermal Vacuum test @ Korea Aerospace Research Institute**
  
  ![Thermal Vacuum test image]

  - The TCD/BCD need to pass space qualification.
    1) Radiation hardness >1 kRad,
    2) Vibration : Need to survive during launch
    3) Thermal Vacuum : -40 to 50 degree, <10^{-5} Torr

  - Most of pedestal RMSs are less than 20 ADC before and after the test.

  - Similar results are obtained after detector integration and environmental test at GSFC.
TCD/BCD integration to CREAM detector

CAL

Carbon target

BCD

TCD

TCD

CAL

Thermal Vac. Test

Vibration Test
e/p Separation Study using simulation data

• **Boosted Decision Tree Method**

Using GEANT3 data

- The events considered electrons are closed to 1 and protons are closed to -1 in BDT distribution
- The electron efficiency is about 93% and the proton rejection power is improved with increasing energy. We select electron and proton when BDT is larger than 0

<table>
<thead>
<tr>
<th>Energy (GeV)</th>
<th>Accepted electron (number of events)</th>
<th>Selected proton (number of events)</th>
<th>Electron efficiency (%)</th>
<th>Proton rejection power</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>9439</td>
<td>92</td>
<td>94.4 ± 0.2</td>
<td>(1.03 ± 0.11) × 10^2</td>
</tr>
<tr>
<td>50</td>
<td>9442</td>
<td>61</td>
<td>94.4 ± 0.6</td>
<td>(1.55 ± 0.20) × 10^2</td>
</tr>
<tr>
<td>70</td>
<td>9434</td>
<td>51</td>
<td>94.3 ± 0.5</td>
<td>(1.85 ± 0.26) × 10^2</td>
</tr>
<tr>
<td>120</td>
<td>9406</td>
<td>44</td>
<td>94.1 ± 0.4</td>
<td>(2.14 ± 0.32) × 10^2</td>
</tr>
<tr>
<td>150</td>
<td>9436</td>
<td>35</td>
<td>94.4 ± 0.4</td>
<td>(2.70 ± 0.46) × 10^2</td>
</tr>
<tr>
<td>300</td>
<td>9335</td>
<td>31</td>
<td>93.3 ± 0.3</td>
<td>(3.01 ± 0.54) × 10^2</td>
</tr>
<tr>
<td>900</td>
<td>9276</td>
<td>14</td>
<td>92.8 ± 0.1</td>
<td>(6.6 ± 1.8) × 10^2</td>
</tr>
<tr>
<td>1,200</td>
<td>9239</td>
<td>11</td>
<td>92.4 ± 0.1</td>
<td>(8.4 ± 2.5) × 10^2</td>
</tr>
<tr>
<td>2,500</td>
<td>9246</td>
<td>9</td>
<td>92.5 ± 0.1</td>
<td>(1.03 ± 0.34) × 10^3</td>
</tr>
<tr>
<td>5,000</td>
<td>9218</td>
<td>8</td>
<td>92.2 ± 0.1</td>
<td>(1.15 ± 0.41) × 10^3</td>
</tr>
<tr>
<td>10,000</td>
<td>9195</td>
<td>8</td>
<td>92.0 ± 0.1</td>
<td>(1.15 ± 0.41) × 10^3</td>
</tr>
</tbody>
</table>

- Proton rejection power : electron fraction / proton fraction
- Electron fraction : # of selected e / total # of e in each energy
- Proton fraction : # of selected p / total # of p in each energy
TCD/BCD Status

- The Pedestal RMS range of TCD/BCD is similar before/after launching
- The pedestal RMS value of most TCD/BCD channels are less than 20
MIP Signal at TCD/BCD

Ground muon test

ISS data

Simulation Data

Jul. 06, 2018
TCD/BCD Status in SAA

- When the ISS is in SAA, the trigger rate of TCD/BCD is increased (5~10 times)
Elow trigger performance

Jul. 06, 2018  ICHEP 2018
Summary

- The ISS-CREAM can measure the cosmic-rays in high energy region and was launched on 14\textsuperscript{th} Aug 2017.
- The TCD/BCD was constructed for electron and gamma-ray physics with e/p separation and providing triggers.
- The TCD/BCD detectors are successfully constructed and passed critical requirements for space launch qualification.
- e/p separation is studied with simulation and the rejection factor better than 800 with 93\% efficiency can be achieved with 1.2 TeV electron using BDT method.
- The TCD/BCD have similar noise level before and after lunch and the MIP signals at the ISS can be identified.
- Low energy trigger is working fine and optimization of high energy trigger is on going.
- Analysis is ongoing for e/p separation.
Thank you for attention