Development of Top/Bottom Counting Detectors for the CREAM Experiment on the ISS

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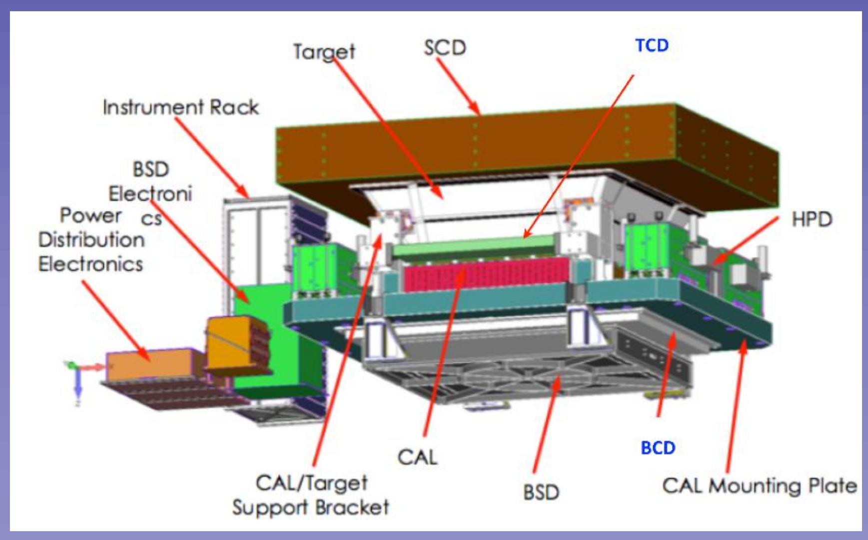
Introduction

- The ISS-CREAM (Cosmic Ray Energetics And Mass on the International Space Station experiment) planned for a launch to the ISS in 2014 to measure the energy spectral features from 10^{12} eV to $>10^{15}$ eV and composition that might be related to the supernova acceleration limit [1].

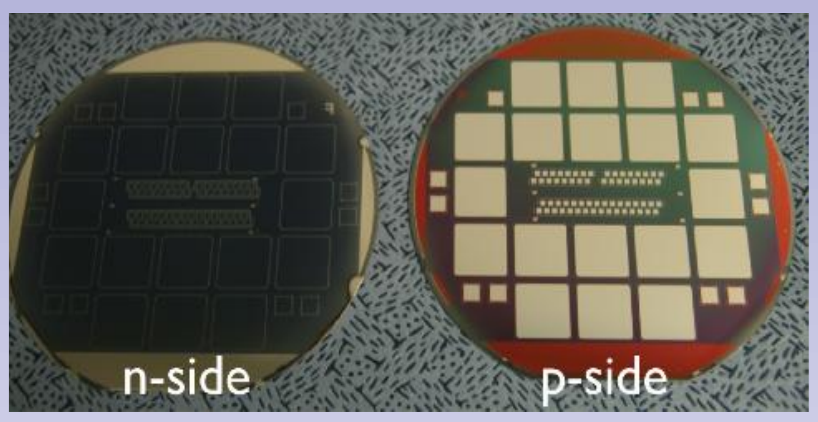


ISS-CREAM Instrument

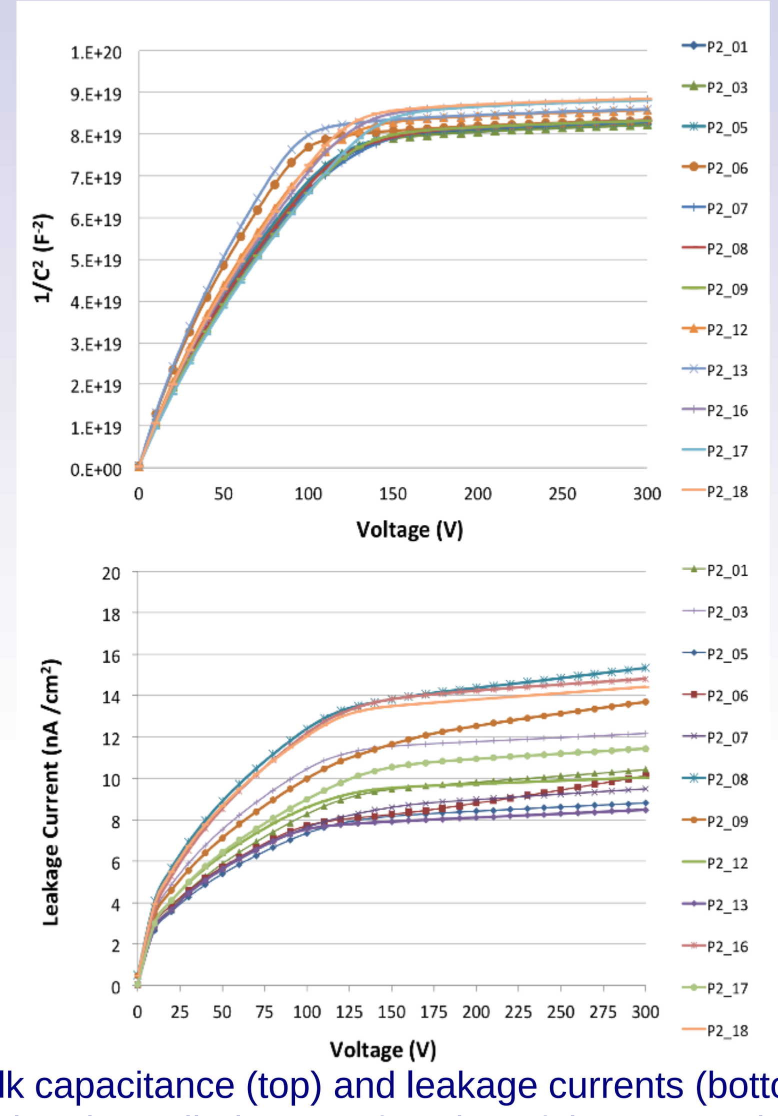
- The ISS-CREAM instrument consists of a Silicon Charge Detector (SCD) to identify incident cosmic rays, a sampling tungsten/scintillator calorimeter for energy measurement of all nuclei [2], a segmented Top/Bottom Counting Detector (TCD and BCD) for e/p separation, and a Boronated Scintillator Detector (BSD) for additional e/p separation and detecting neutron signals

Silicon Photo-Diode

- Silicon photo-diodes (PD) is fabricated on 6-inch, high resistivity, <100>, 650 μm thick, and n-type silicon wafers
- The real size of the PD is 2.3 × 2.3 cm^2 with an active area of 2.0 × 2.0 cm^2
- The PDs are fabricated at ETRI (Electronics and Telecommunications Research Institute) in Daejeon, Korea



Photograph of the photo-diodes on 6-inch and 650 μm thickness silicon wafer



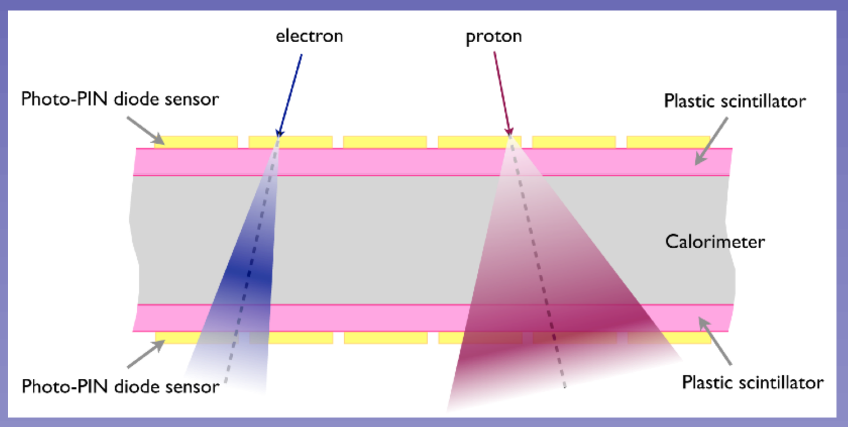
Bulk capacitance (top) and leakage currents (bottom) of the photo-diodes as a function of the reverse bias voltages

- Electrical characteristics
  - The leakage current and bulk capacitance of the PDs are measured with a picoammeter and LCZ meter as a function of reverse bias voltages, respectively
  - The full depletion voltage is found to be below -200 V and the optimal operating voltage is determined to be -250 V
  - The leakage current is below 20 nA/cm^2 at the operating voltage
- Photo response was measured at KRISS (Korea Research Institute of Standards and Science) in Daejeon, Korea
  - The quantum efficiency is obtained to be 60 ~ 75 % for the wavelength range from 400 to 450 nm, which is wavelength range of the plastic scintillator
- The Signal-to-Noise Ratio (SNR) is measured using a ^{90}Sr radioactive source and the SNR is better than 70 with commercial electronics
- Radiation hardness test using a 45 MeV proton beam at the KIRAMS (Korea Institute of Radiological and Medical Sciences) in Seoul, Korea
  - Exposed to 1.18 × 10^{11} protons/cm^2 (> 5000 rad)
  - The leakage current is increased up to about 50 nA/cm^2 but the quality of the PD does not change in our criteria for the best sensor (<100 nA/cm^2)

Design of Top and Bottom Counting Detectors

Goals

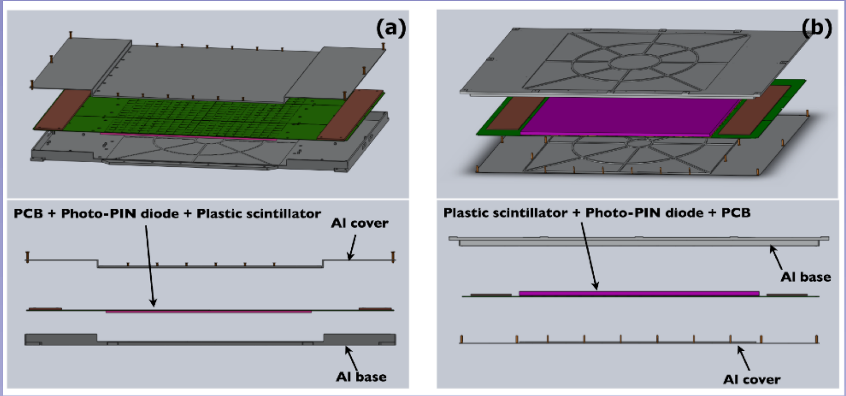
- Electron/proton separation for electron and gamma-ray physics
  ⇐ by using the difference between electromagnetic and hadronic showers
- Provide redundant trigger for ISS-CREAM calorimeter
- Provide MIP (Minimum Ionizing Particle) trigger for calibration



Operational principle of the TCD and BCD

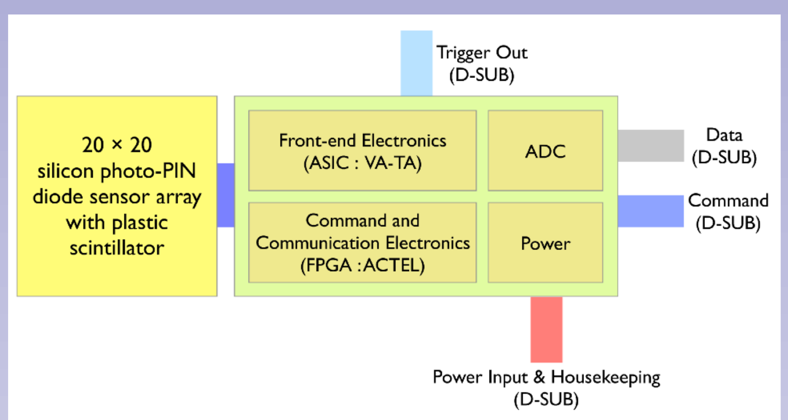
Methods

- Plastic scintillators coupled with 2-dimensional photo-diode array
- TCD and BCD each has a total of 400 PDs
- 500 × 500 mm^2 and 600 × 600 mm^2 for TCD and BCD, respectively



Exploded view of the (a) TCD, and (b) BCD

- The silicon photo-diode converts scintillation light to electric current, and electron-hole pairs are also produced by penetrating cosmic rays
- The charge signals are amplified by VLSI charge amp/hold circuits (VA-TA)



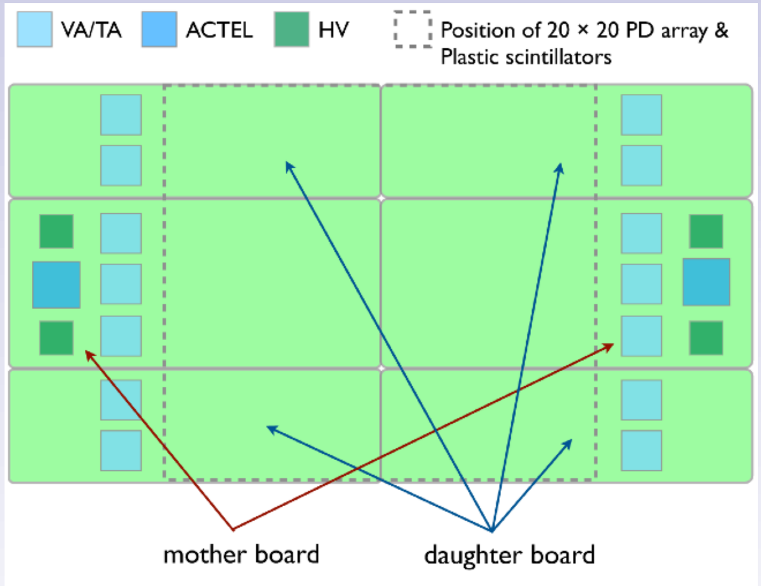
Schematic diagram of the TCD and BCD

Dimensions

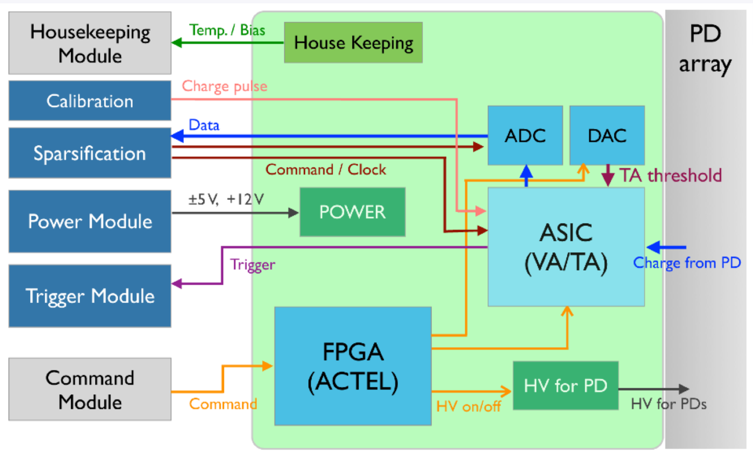
- TCD : 900 × 535 × 30 mm^3
- BCD : 950 × 651 × 33 mm^3

Readout Electronics

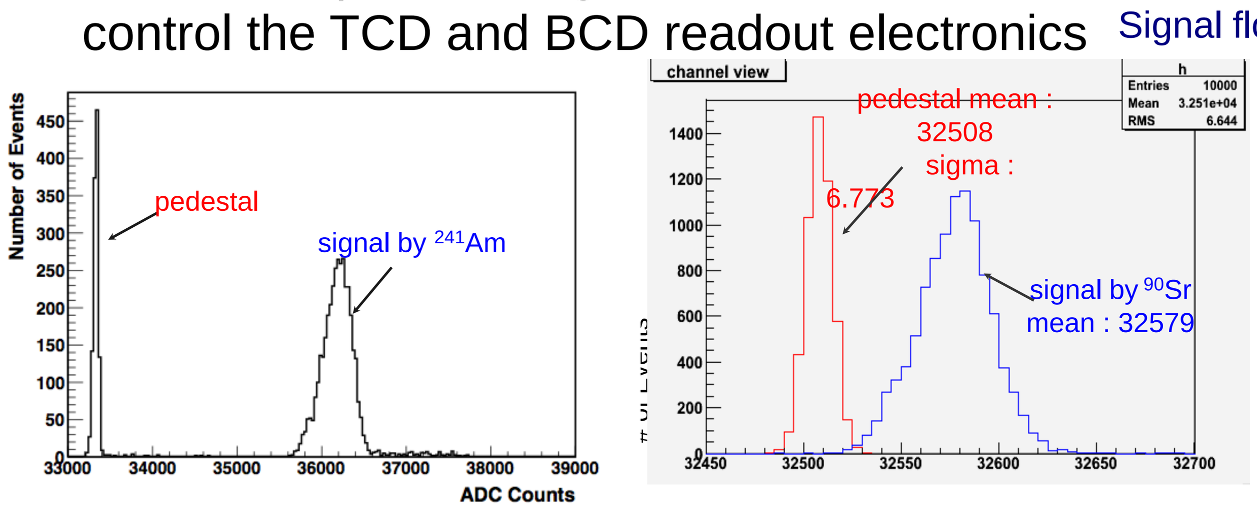
- VA-TA (VA32HDR-TA32CG3) as a front-end electronics
  - The VA has 32 channels and each channel consists of a charge sensitive amplifier, a slow shaper, and a sample-and-hole circuit
  - The output of all channels is connected to the multiplexer and the signals are serially clocked out
  - The TA is 32 channel low power fast triggering ASIC chip and each channel includes a fast shaper followed by a discriminator, whose threshold is externally adjustable
  - Wire-or'ed output cause a chip-global trigger
- 16 bit ADC (Analog to Digital Converter) digitizes the analog signals of the VA-TA
- Commands from the ISS-CREAM common electronics pass through the FPGA and control the TCD and BCD readout electronics



Design of TCD and BCD electronics



Signal flows in the TCD and BCD electronics



ADC distributions are taken from the tests with ^{241}Am (left) and ^{90}Sr (right)

- Using ^{241}Am radioactive source, the peak hold delay time is measured and the SNR is measured to be 10 with ^{90}Sr source
- A noise of the prototype is about 6000 e-rms

Summary and Plan

- We have developed the TCD and BCD for CREAM, which is planned to launch to the International Space Station in 2014 and various tests for performance and safety assurance are in progress.
- TCD and BCD will be delivered to UMD in September for the system level of integration and tests.

References

[1] E. S. Seo et al., ID 629 (2013) this conference.
[2] H. S. Ahn et al., Nucl. Instrum. Methods A 579 (2007) 1034-1053.