Design and Performance of the ISS-CREAM Boronated Scintillator Detector

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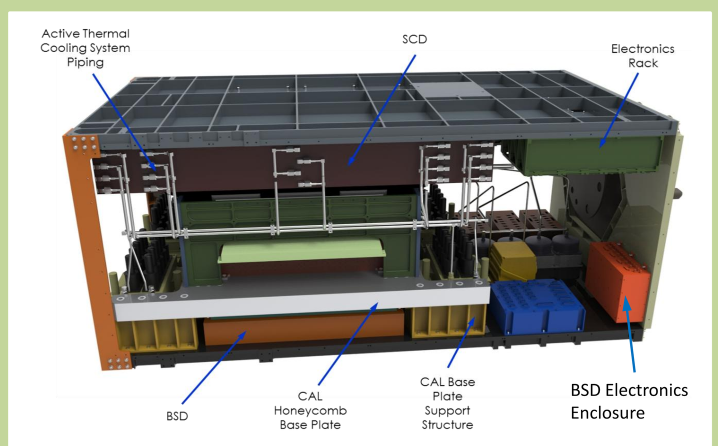
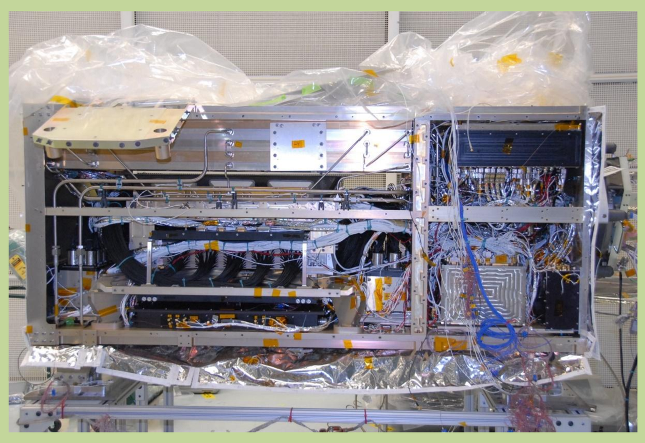
ISS-CREAM Instrument

- ISS-CREAM is an evolution of the CREAM balloon experiment to fly on the International Space Station.
- Goal is to measure energy spectra and composition of elements from protons to Iron from 10^{12} eV to ~10^{15}eV.
- Instrument consists of four detectors:
- Silicon Charge Detector – 4 layers of silicon pixel detectors to measure charge of incident particle. Each layer has charge resolution of ~0.2e.
- Sampling calorimeter – 20 layer tungsten ($1X_o$ each) interspersed with scintillating fiber readout and a carbon target.
- Top and Bottom Counting Detectors – two enclosures with a plastic scintillator instrumented with 400 pin diodes to measure shower shape for e/p discrimination.
- Boronated Scintillator Detector – boron loaded scintillator with PMT readout to detect neutrons from interaction shower in calorimeter for e/p discrimination.



Instrument Size: ~2m x 1m x 1m
Instrument Mass: ~1300 kg
Instrument Power: 600W
Instrument Telemetry (avg): ~360 kbps
1.3 TB per year



The BSD detector consists of two pieces. The detector enclosure houses the boronated scintillator and PMTs for readout and sits at the bottom of the ISS-CREAM detector stack. The electronics enclosure is mounted to the side and houses the readout, control, housekeeping and interface electronics for the BSD.

When a particle interacts in the calorimeter it creates a shower of charged particles that passes quickly through the rest of the instrument. Neutrons are also produced in this interaction which diffuse out of the instrument at a much slower rate. More neutrons are produced in a hadron interaction than an electronic one. The BSD measures the neutron signal from these interactions to distinguish between hadrons and electrons.

During development we discovered that the signal from the initial shower of charged particles creates so many photons in the BSD that it saturates the PMTs creating afterpulses that drown out the faint neutron signal. We resolved this problem by designing PMT assemblies with switched dynodes. Dynodes D0 and D1 are only switched on after the charged particle shower passes through the BSD and then we sample for several microseconds the signal from neutrons passing through the detector. A timeline of the electronics readout sequence is shown in the table below

Time	Event
0	Particle interacts in calorimeter, shower created and passes through BSD
Approx 0	BSD Trigger PMT signal crosses discriminator threshold, triggering BSD
100 ns	HV Power Switched On
1000 ns	Sampling ADC Opened
6000 ns	Sampling ADC Closed
1 ms	BSD Ready for next event

ICRC
The Astroparticle Physics Conference
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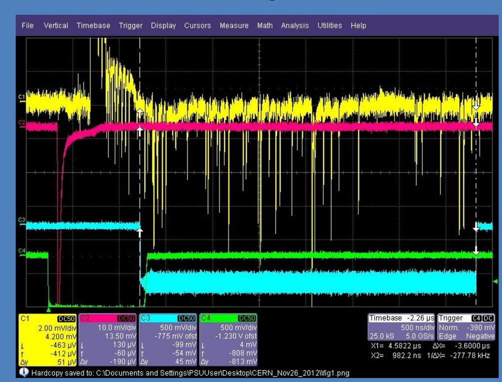
2012 CERN BSD Test

BSD, T/BCD and calorimeter in CERN Beamline

BSD Prototype Detector for CERN

- In Fall 2012 the ISS-CREAM calorimeter and prototype T/BCD and BSD detectors were taken to CERN for a beam test with electrons and pions.
- Objective was to map and calibrate the calorimeter and validate the effectiveness of the T/BCD and BSD to resolve electrons from hadrons.

BSD Response to Electrons and Pions



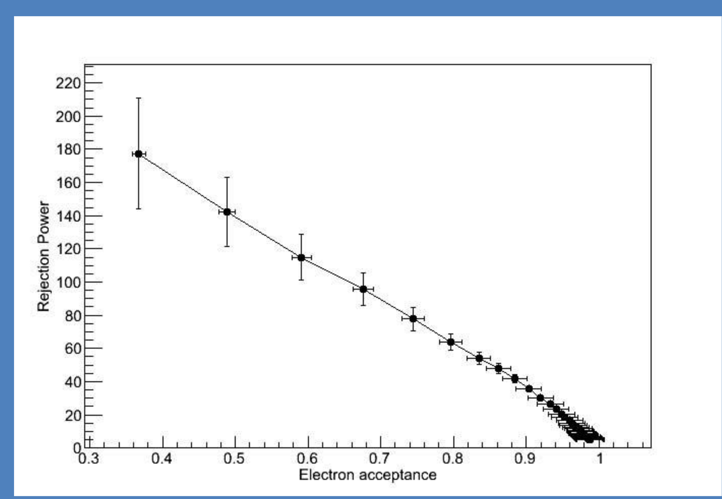
Scope trace from a 150 GeV Electron

- Yellow: Switched PMT signal (~30 PE seen).
- Magenta: Unswitched PMT Signal (Trigger).
- Blue: 2249W gate for switched PMT signal integration.
- Green: 2249W gate for unswitched PMT signal integration.

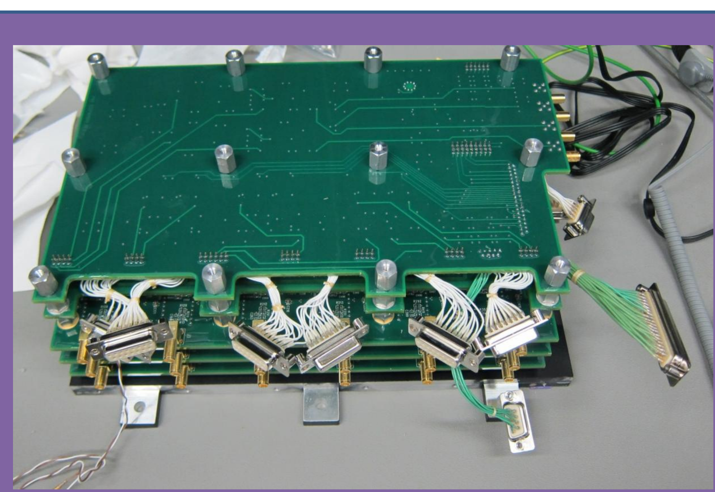
Scope trace from a 350 GeV pion.

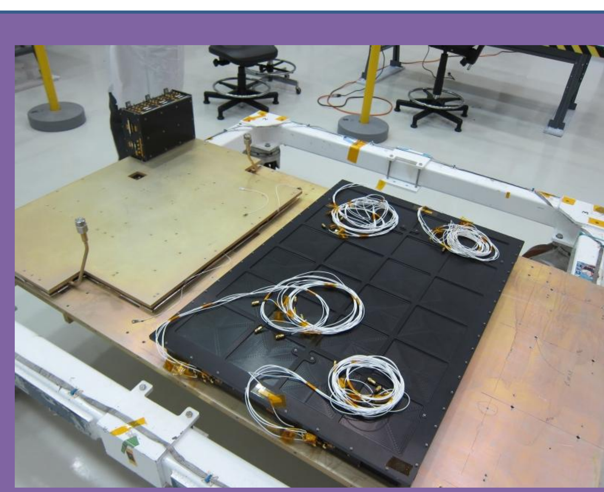
- Blue: Switched PMT Signal (~300 PE seen).
- Yellow 2249W gate for unswitched PMT signal integration.
- Magenta: 2249W gate for switched PMT signal integration.
- Green: Logic confirm signal.

Clear distinction between electron and pion (hadron) signals!



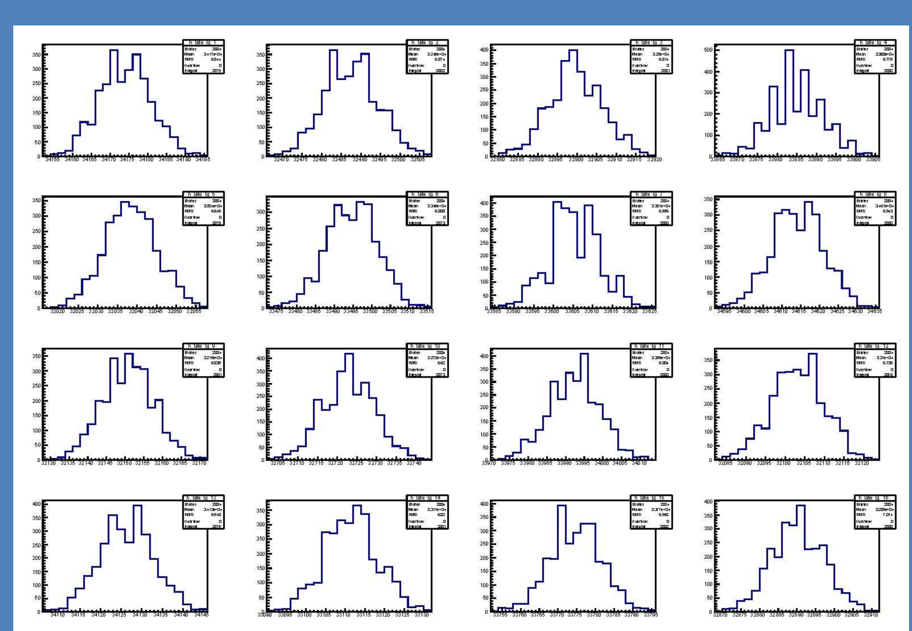
BSD rejection power versus electron acceptance for 125 GeV electrons and 350 GeV pions. The goal is to achieve a rejection power of 30 or better at an electron identification of 96 for protons with energies greater than 1 TeV.

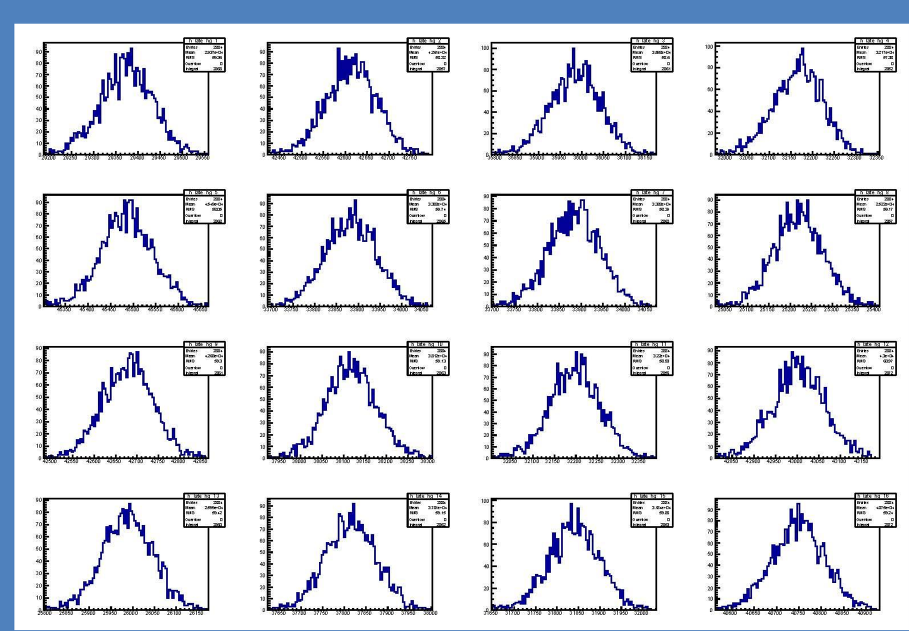




Top Left: BSD detector enclosure being assembled. Top Center: BSD Electronics enclosure being assembled. Top Right: BSD instrument being mounted on the ISS-CREAM baseplate structure. Left: Quartet PMT assembly as seen from the opposite end of the scintillator. The reflection of the PMTs is an effect of the reflection of photons in the scintillator.

BSD LED Data from ISS-CREAM Integration and Testing





The BSD has two red LEDs installed on opposite corners of the scintillator to check the functionality of our PMTs during integration, environmental testing and in flight. The above plots show LED Data in low gain (left) and high gain (right) channels from 6/24/15 before vibration testing at NASA Goddard.