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

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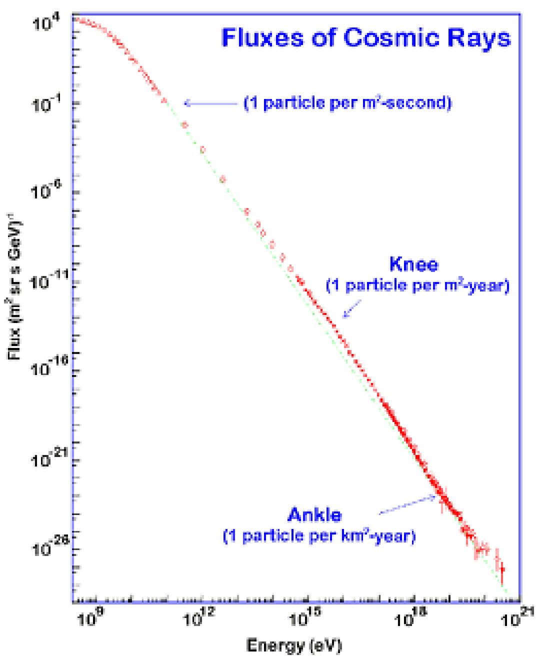
ICHEP2018, Seoul, KOREA July 4- 11, 2018

Introduction

- **ISS-CREAM (Cosmic Ray Energetics And Mass on the International Space Station)**
  - **ISS-CREAM instrument was launched on 14th 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**

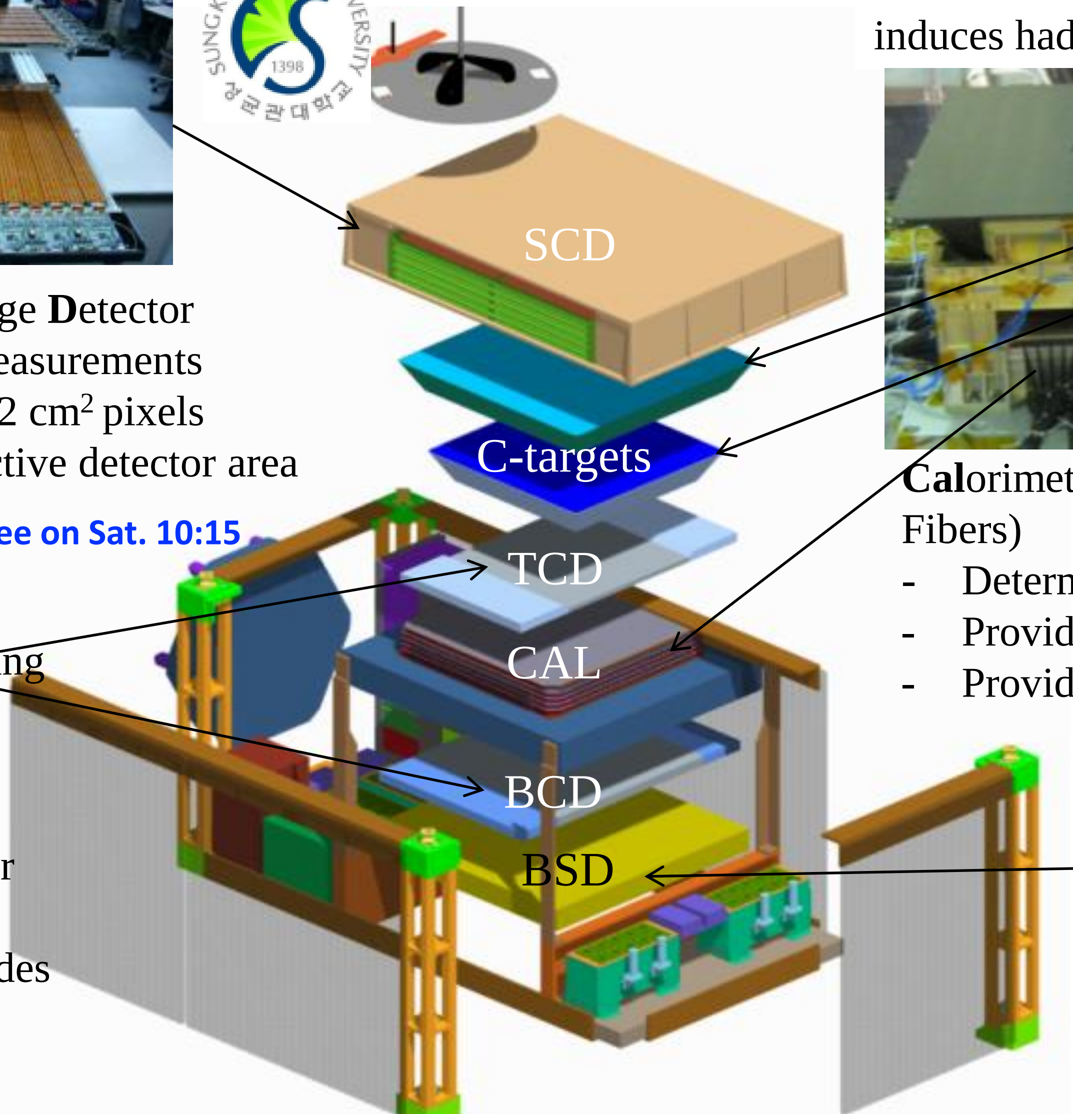


Presentation by Prof Seo on Sat. 10 am

CREAM instrument at ISS

4 layer **S**ilicon **C**harge **D**etector
- 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



Carbon **Targets** (0.5 λ_{int})
induces hadronic interactions

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

Top & **B**ottom **C**ounting **D**etectors
- Segmented for e/p separation
- Independent Trigger
- Plastic Scintillators with 400 Photodiodes readout (2.3 x 2.3 cm^2)

Boronated **S**cintillator **D**etector
- Additional e/p separation
- Neutron signals

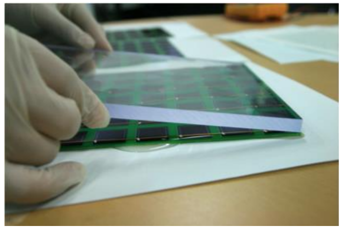
Seo et al. (CREAM Collaboration) Adv. in Space Res., **53**/10, *1451*, 2014

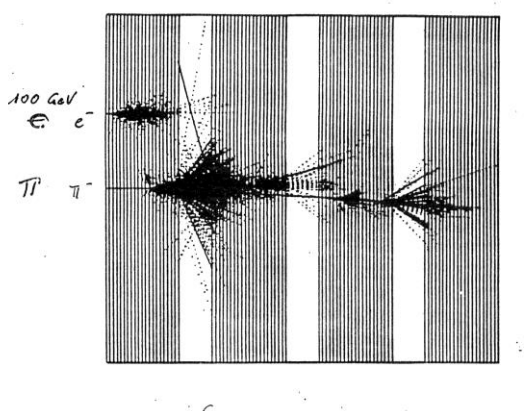
Top/Bottom Counting Detector (TCD/BCD)

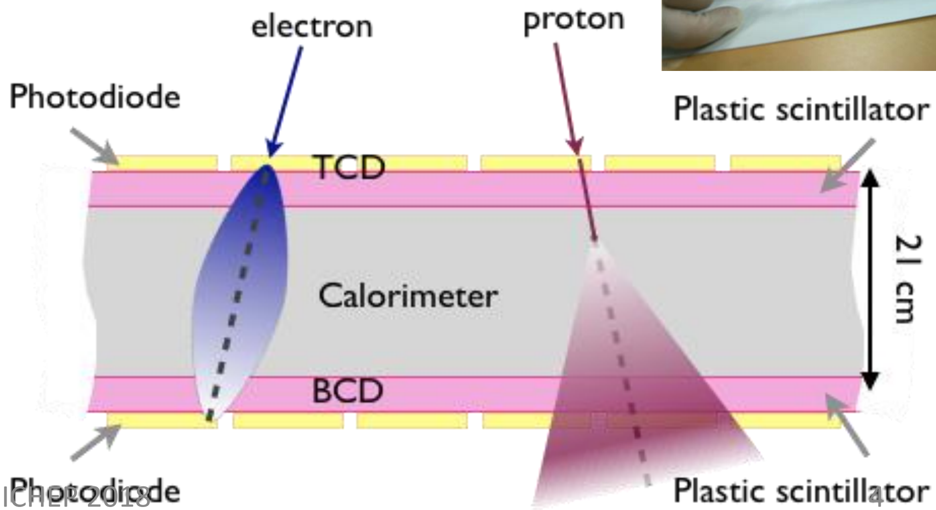
- **Goals**
  - **e/p separation for electron and gamma-ray physics**
  - **Provide a redundant trigger in addition to the CAL trigger**
  - **Provide a low energy electron trigger**

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

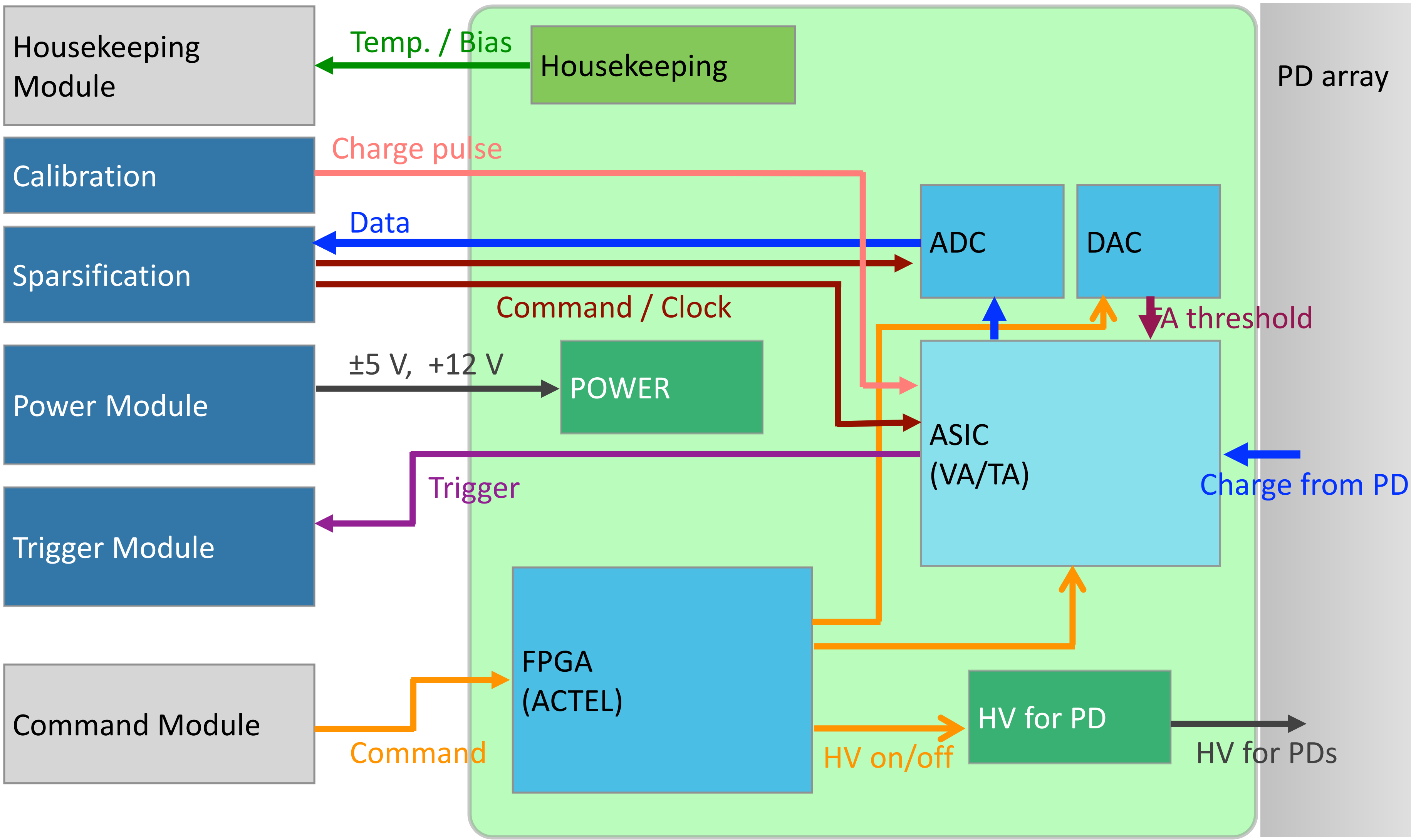
- **Method**
  - **Electron and proton make different shower shapes at TCD and BCD**



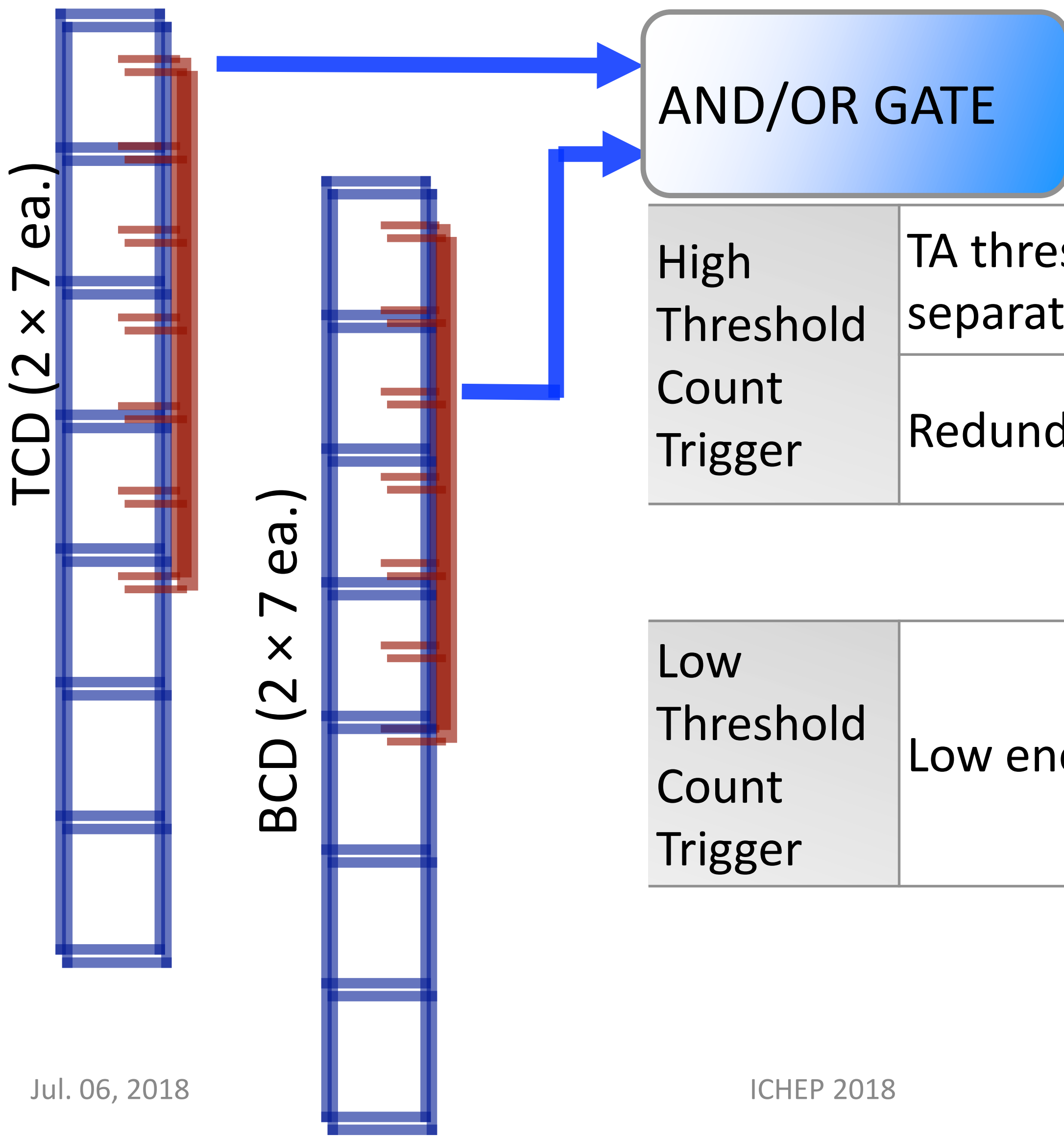




TCD/BCD Block Diagram



TCD/BCD Trigger diagram

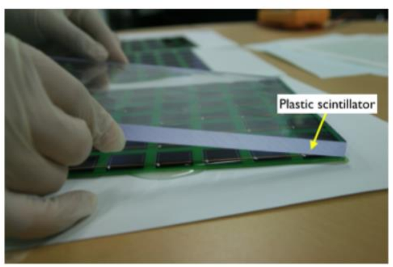


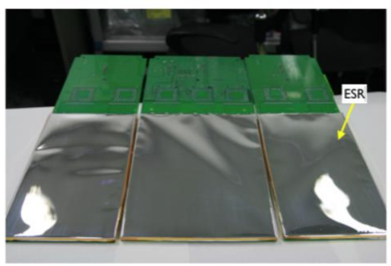
High Threshold Count Trigger	TA threshold count trigger (e-p separation)
	Redundant CAL trigger

Low Threshold Count Trigger	Low energy trigger

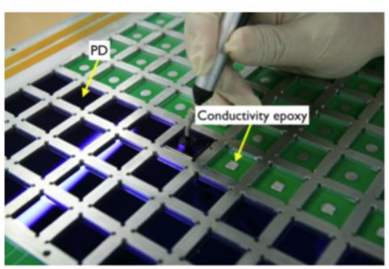
TCD/BCD Construction

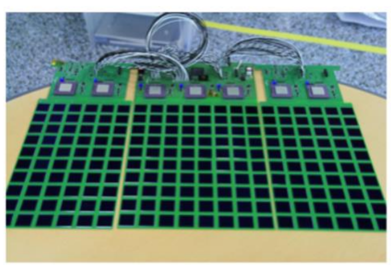
- **Construction at KNU**
  - **The plastic scintillators are wrapped with reflector to prevent light loss**
  - **The plastic scintillator is attached to the PD by using a silicon optical adhesive material**
  - **PD is attached to the PCBs by using a conductive epoxy**
  - **A plastic foam is placed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





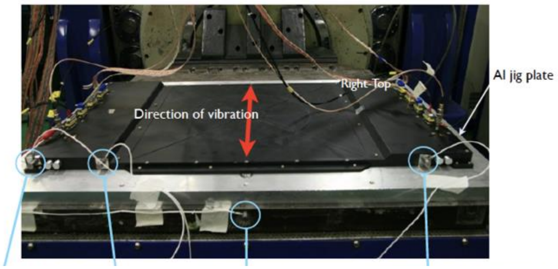
PCboard + Photodiode + Plastic scintillator
+ Reflector (VM2000 ESR film)

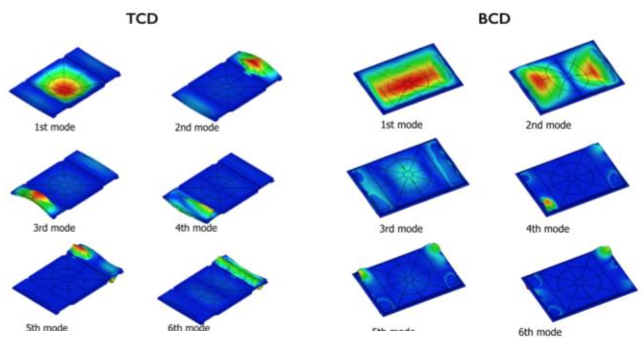


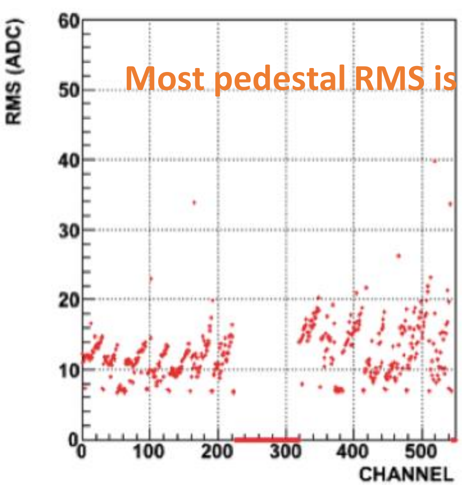


TCD/BCD Environmental Test for Space Env.

- **Vibration test @Keymyung Univ.**

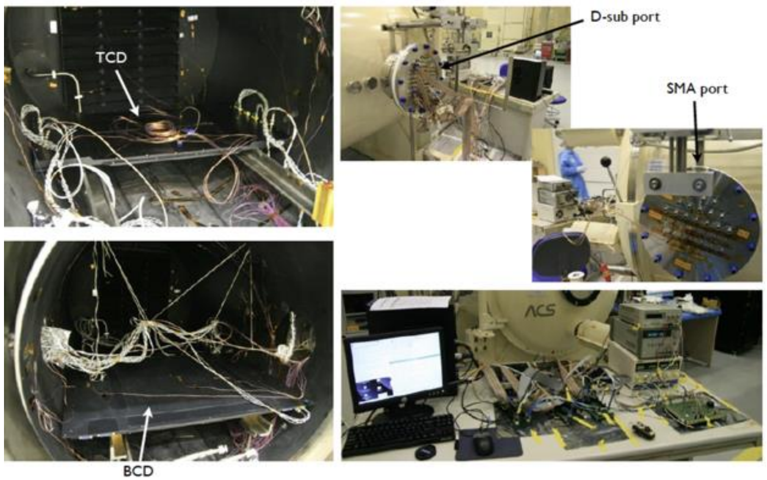






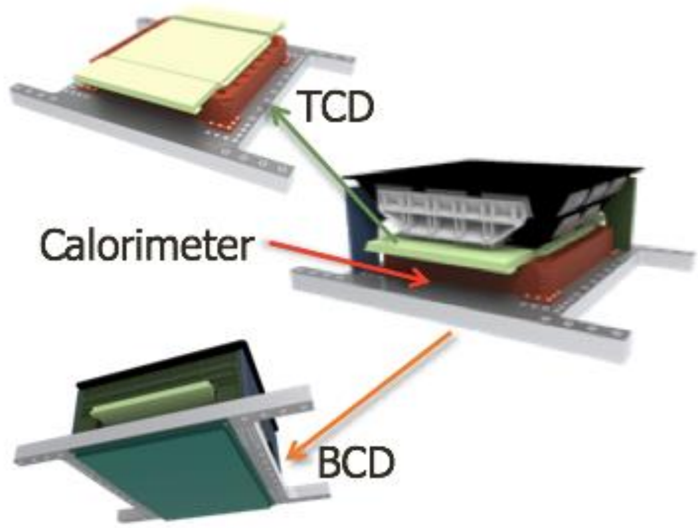
Most pedestal RMS is in 10 ADC to 20 ADC

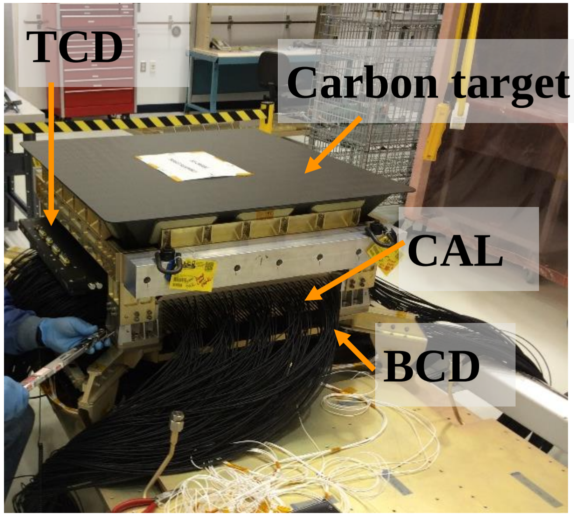
- **Thermal Vacuum test @ Korea Aerospace Research Institute**

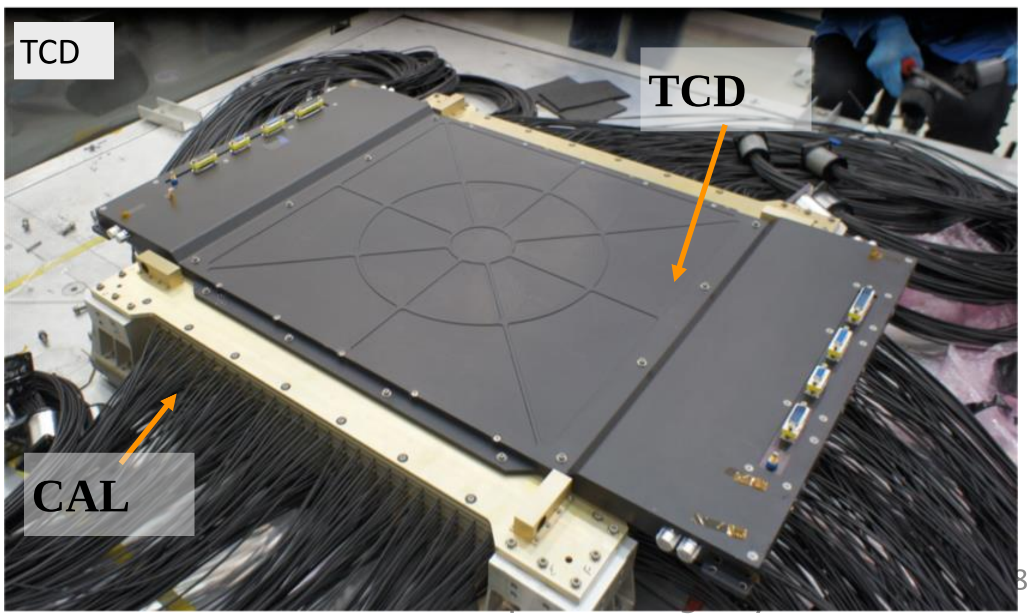


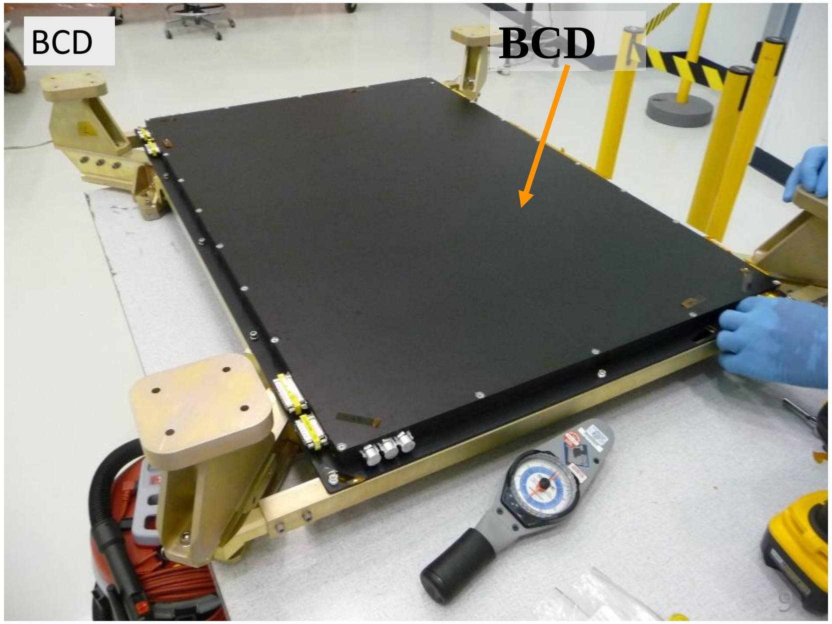
- **The TCD/BCD need to pass space qualification.**
  1) Radiation hardness >1 kRad,
  2) Vibration : Need to survive during launch
  3) Thermal Vacuum : -40 to 50 degree, <10^{-5} Torr
- **Most of pedestal RMSs are less than 20 ADC before and after the test.**
- **Similar results are obtained after detector integration and environmental test at GSFC.**

TCD/BCD integration to CREAM detector





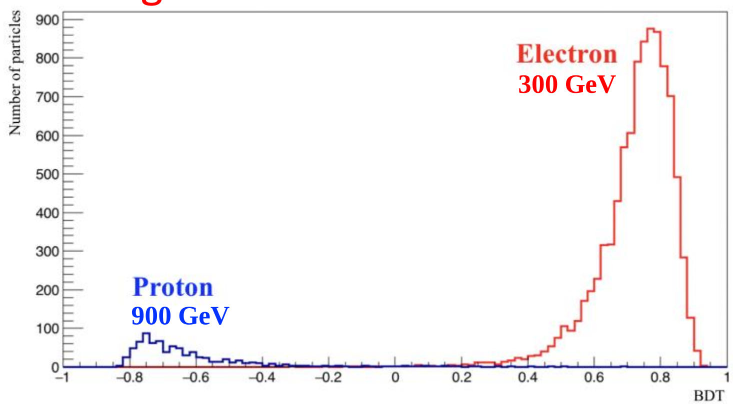




e/p Separation Study using simulation data

- **Boosted Decision Tree Method**

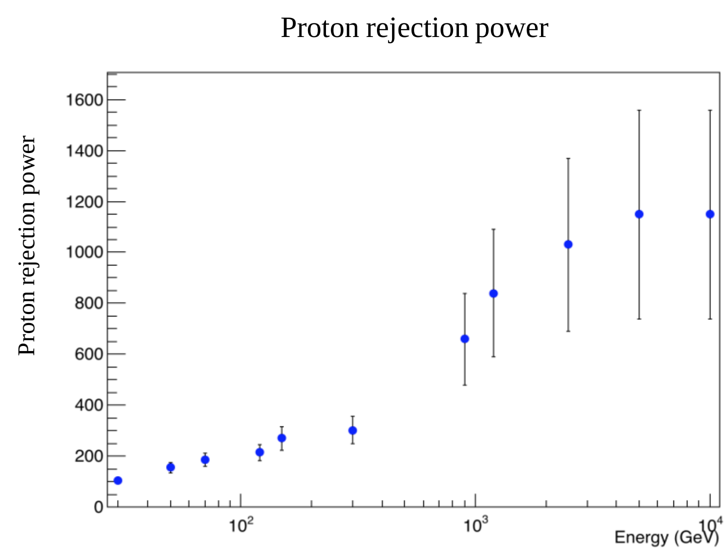
Using GEANT3 data



- 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

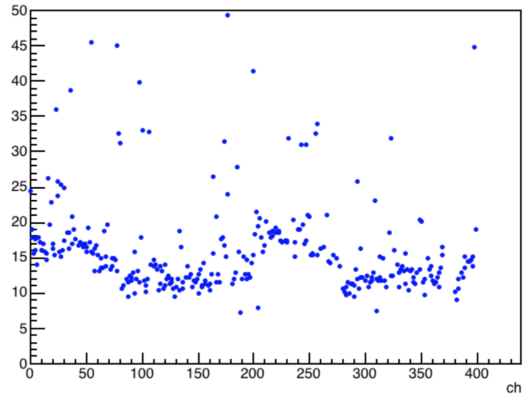
Energy (GeV)	Accepted electron (number of events)	Selected proton (number of events)	Electron efficiency (%)	Proton rejection power
30	9439	92	94.4 ± 0.2	$(1.03 \pm 0.11) \times 10^2$
50	9442	61	94.4 ± 0.6	$(1.55 \pm 0.20) \times 10^2$
70	9434	51	94.3 ± 0.5	$(1.85 \pm 0.26) \times 10^2$
120	9406	44	94.1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

- 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

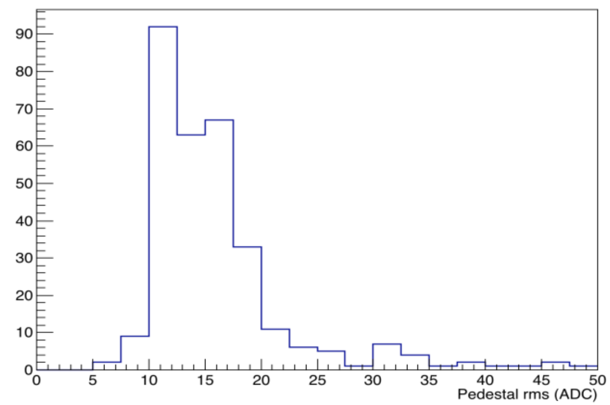


TCD/BCD Status

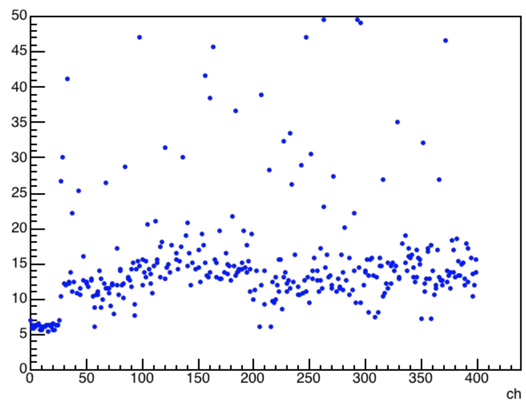
TCD Pedestal RMS at ISS



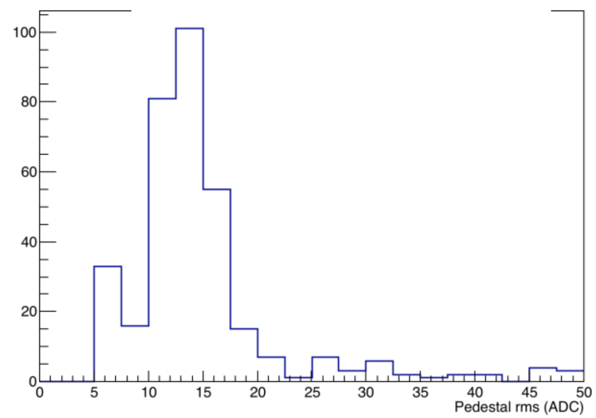
TCD Pedestal RMS at ISS



BCD Pedestal RMS at ISS



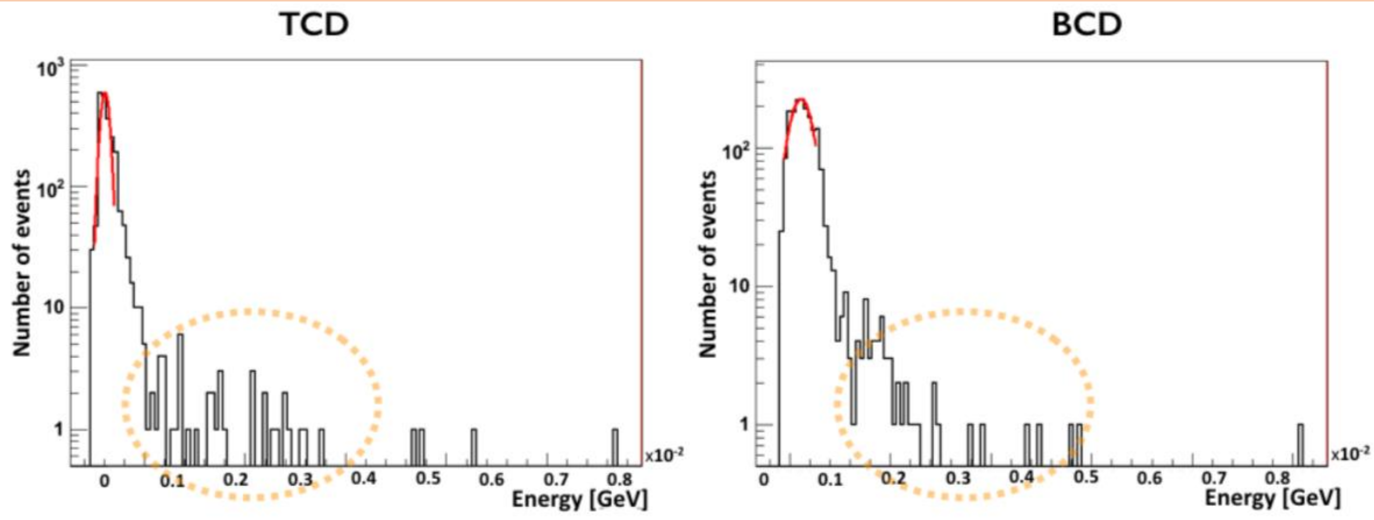
BCD Pedestal RMS at ISS



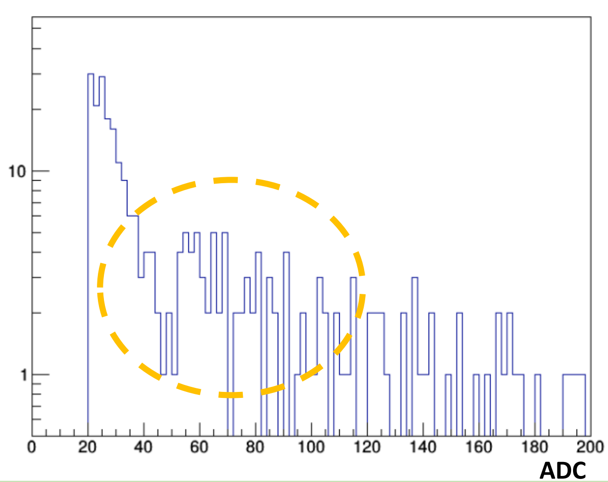
- **The Pedestal RMS range of TCD/BCD is similar before/after launching**
- **The pedestal RMS value of most TCD/BCD channels are less than 20**

MIP Signal at TCD/BCD

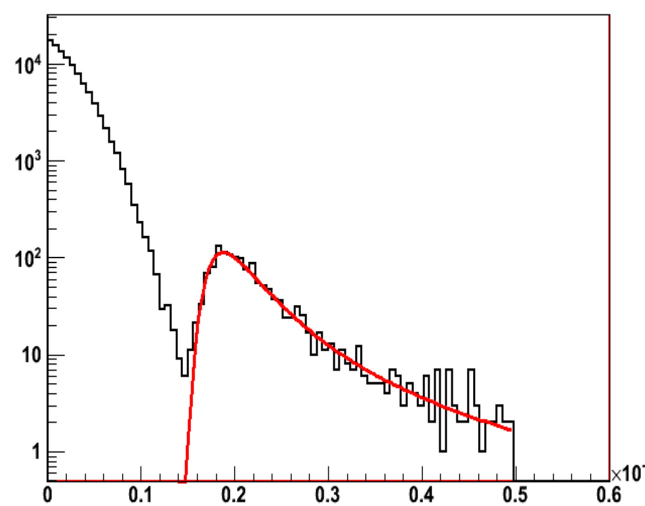
Ground muon test



ISS data

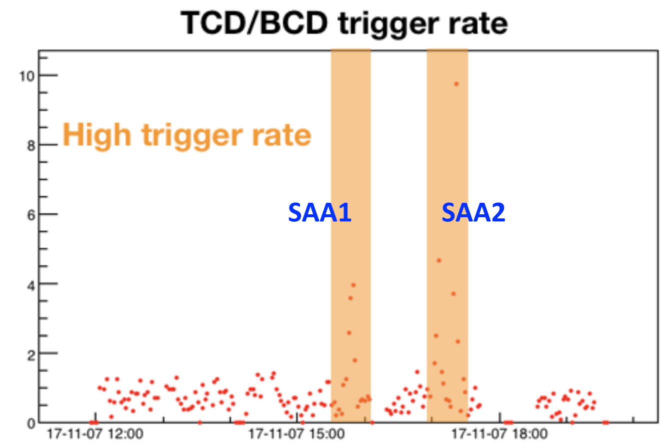


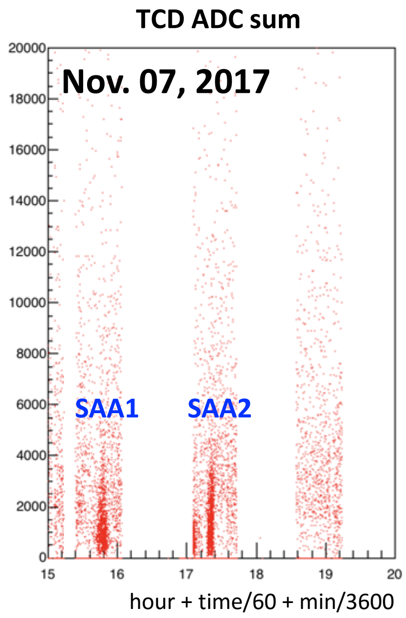
Simulation Data

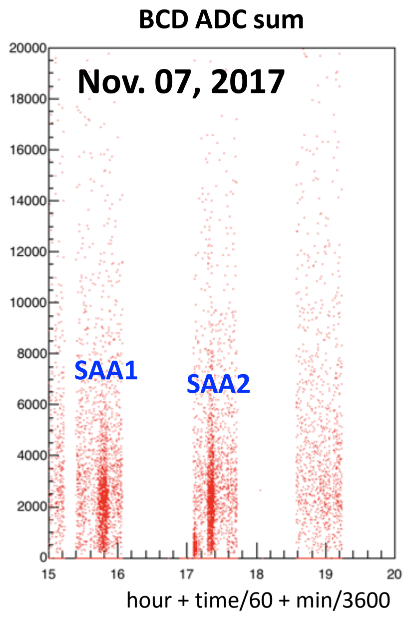


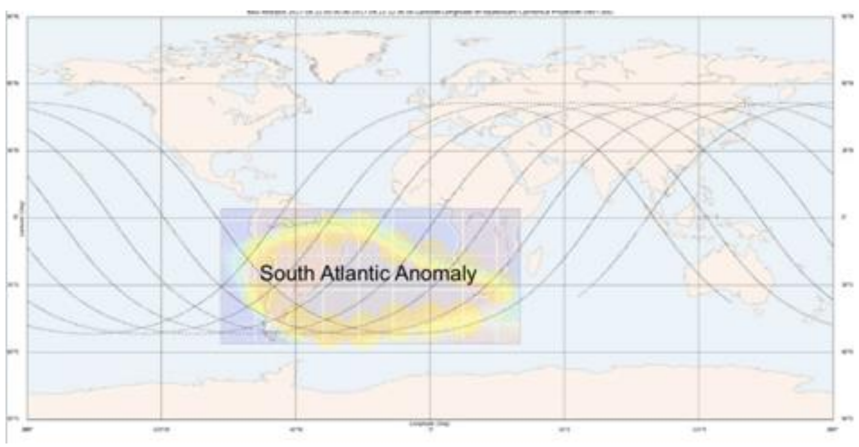
TCD/BCD Status in SAA

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

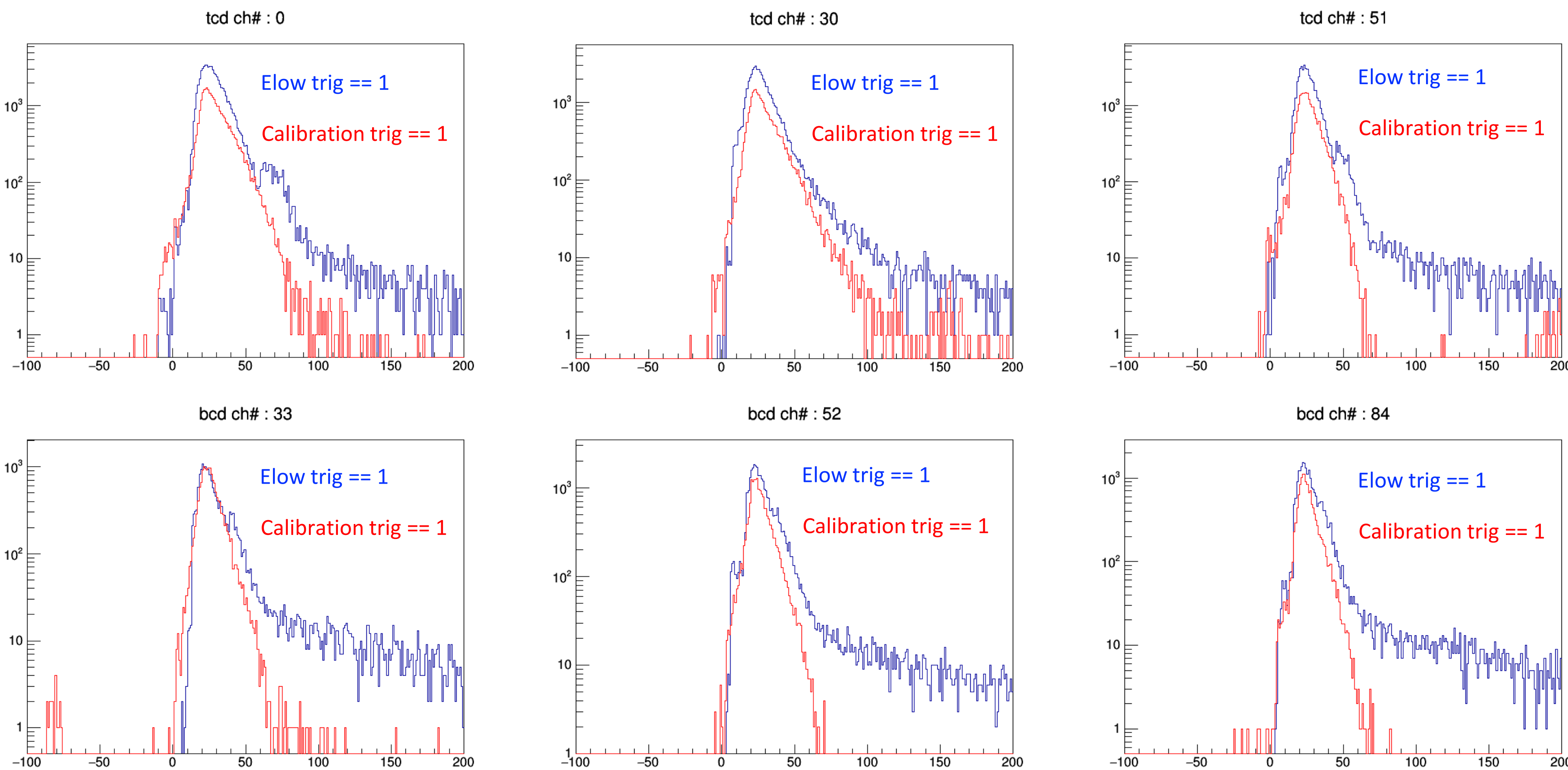








Elow trigger performance



Summary

- The ISS-CREAM can measure the cosmic-rays in high energy region and was launched on 14th 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