On-orbit energy calibration of the calorimeter on the ISS-CREAM instrument using the boronated scintillator detector

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Calorimeter (CAL) energy calibration facts

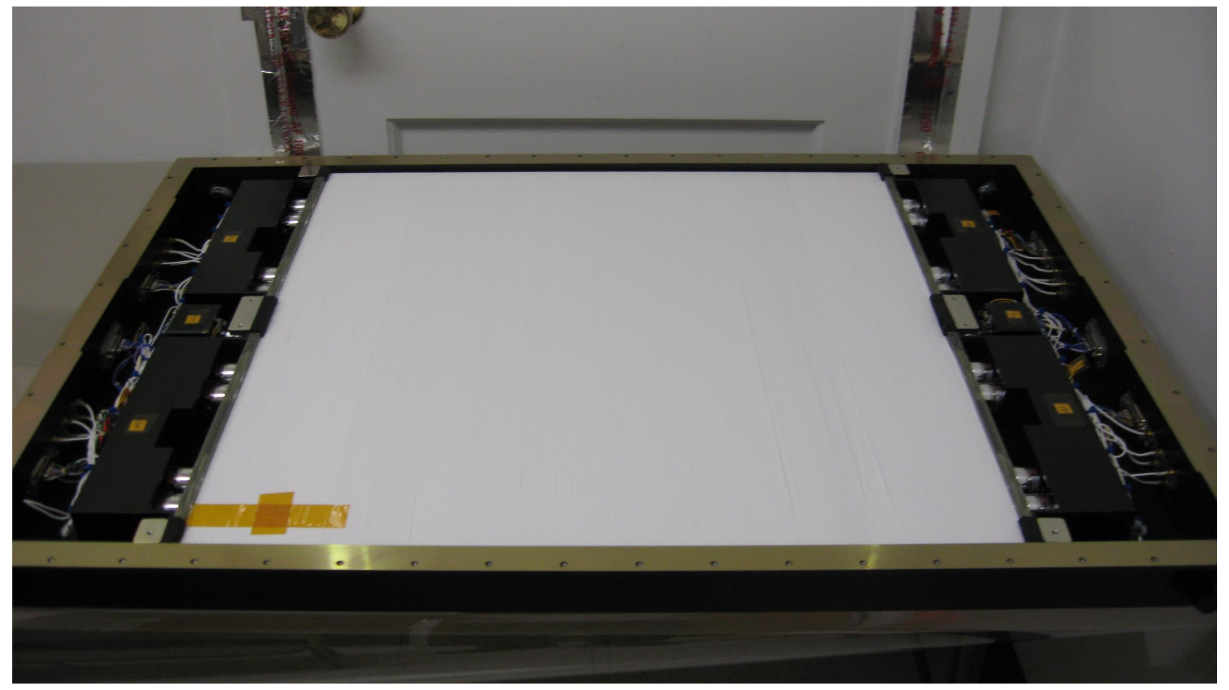
Challenge in analyzing ISS-CREAM data

- Preliminary differential spectrum using CAL as primary energy estimator is lower by a factor of 100
- Reconstructed energy using the BSD is close to the reference value [1]
- Low statistics confirmed with deep learning models [2]

Other calibrations

- No on-orbit non-interacting Fe nucleus candidates found
- No record of end-to-end calibration using ISS-CREAM CAL electronics

Boronated scintillator detector (BSD)



A view of the BSD with its 16 late light PMTs and 2 early light PMTs shown on the two sides along with their readout electronics

Complete pre-launch calibration

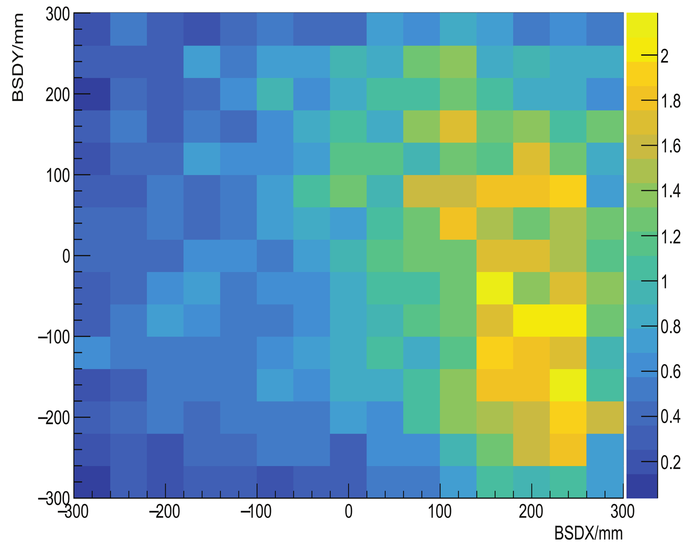
- PMT gain measured with ground muons
- EJ-200 scintillator characterized at CERN using pions and electrons [3]
- GEANT4-based Monte Carlo (MC) simulation support [3]

Careful on-orbit calibration

- LED calibration every 6 hours
- Position dependence mapped out and corrected

Uncertainties

- Change in operating voltage
- Late integration window captures background radiation in space



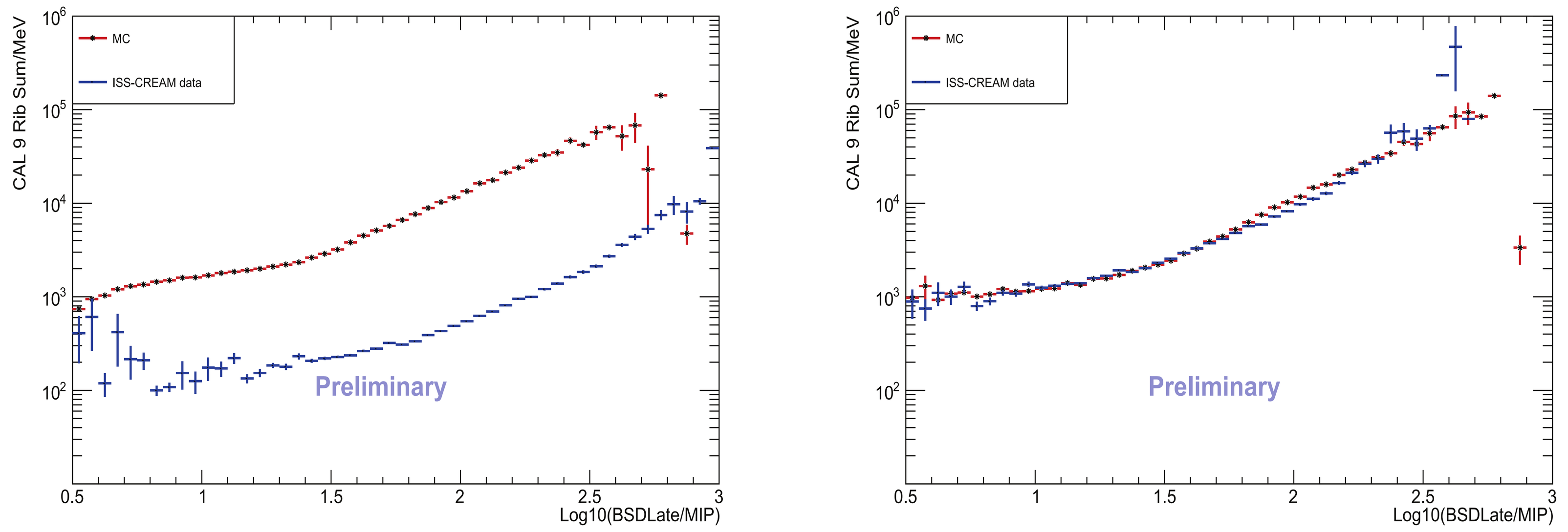
Position dependence of PMT signals using one PMT as an example (located at bottom right in this view)

References
[1] Scott Nutter. *Analysis Results from the Cosmic Ray Energetics And Mass Instrument for the International Space Station (ISS-CREAM)* Poster 696 these Proceedings
[2] Monong Yu. *Machine learning applications on event reconstruction and identification for ISS-CREAM.* Poster 476 these Proceedings
[3] S. Nutter et. al, *Measurement of delayed fluorescence in plastic scintillator from 1 to 10 μs*, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **942** (2019) 162368.
[4] Kenichi Sakai. *ISS-CREAM detector performance and tracking algorithms.* Poster 1051 these proceedings.

CAL calibration with the BSD

Dataset

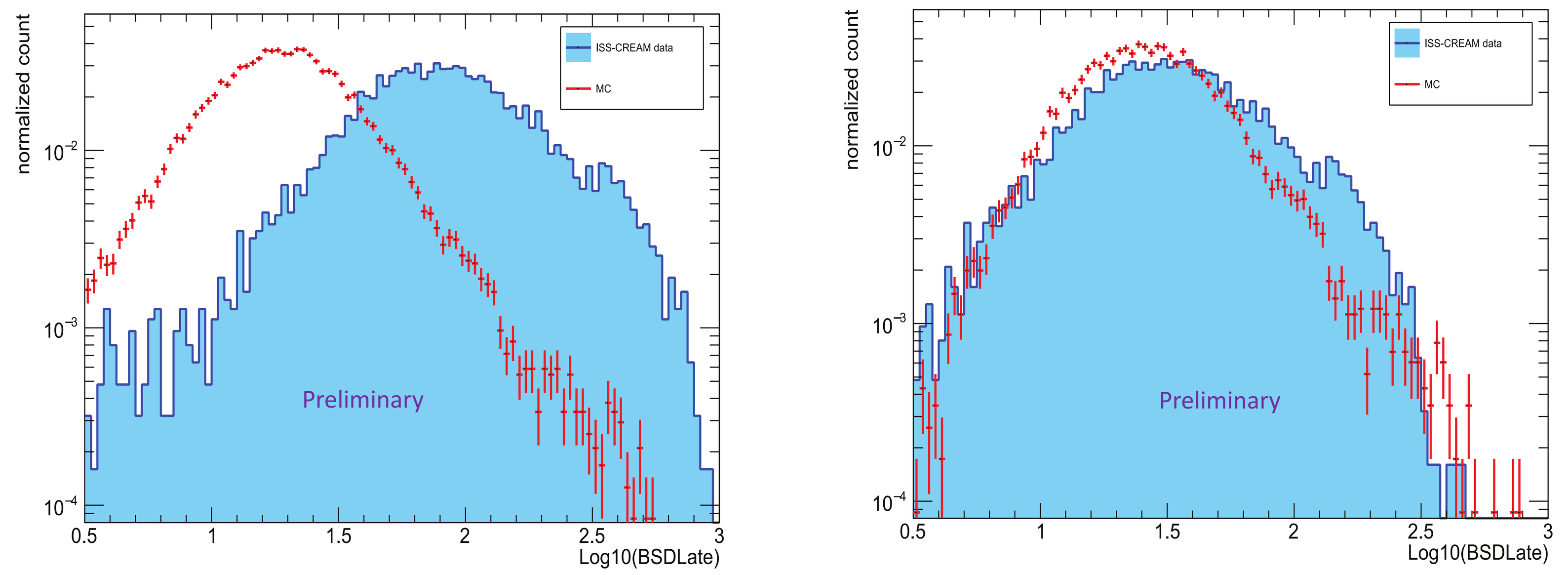
- HiZ (carbon or up) elements
- Tracking based on the TCD, the SCD and the CAL [4]
- Require reconstructed track within fiducial volume
- Require 6 consecutive layers with a given energy deposition in each layer
- MC events go through the same selection process



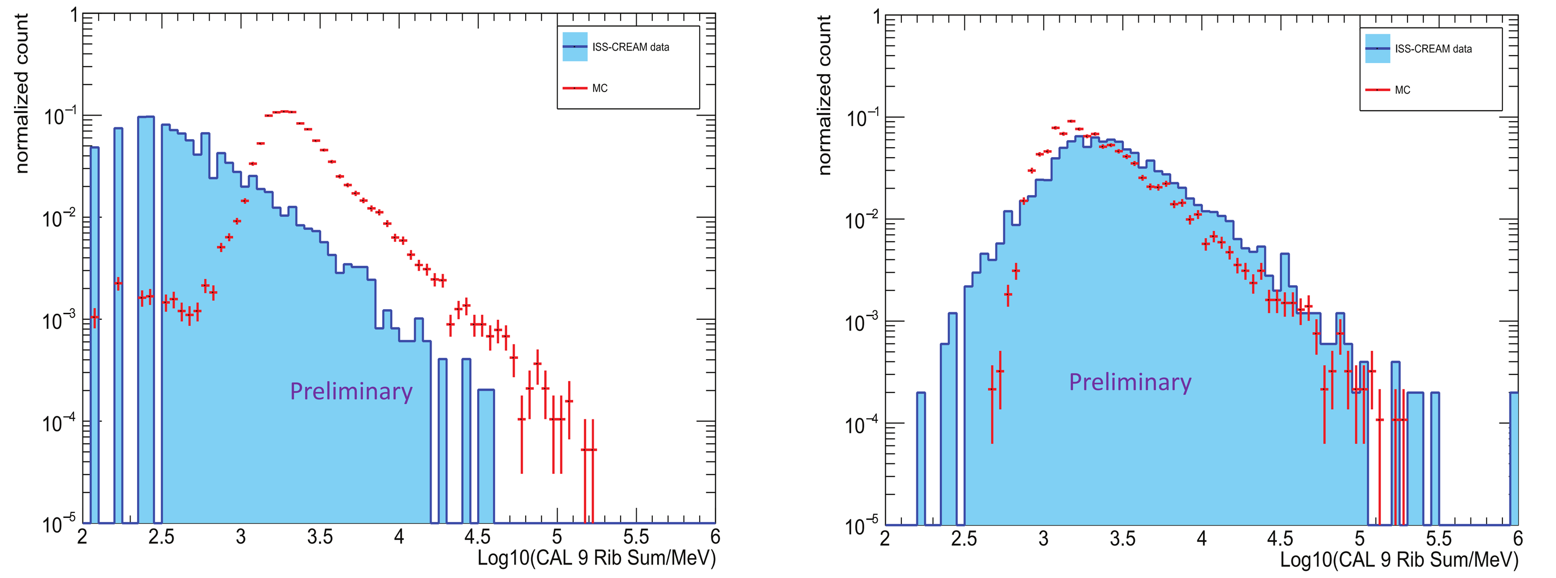
Left: distribution of the CAL nine ribbon sum signal versus BSD late signal, without any scaling.
Right: ISS-CREAM CAL signal rescaled by a factor of 6 after applying appropriate BSD scaling.

Calibration procedure

- Plot CAL nine ribbon sum against BSD late signal
- MC predicts a higher CAL energy deposition for the same BSD signal
- Scaling up MeV-to-ADC conversion factor of the ISS-CREAM event reconstruction after appropriate BSD scaling is applied
- Note MC events will also be affected due to scaling factor changes



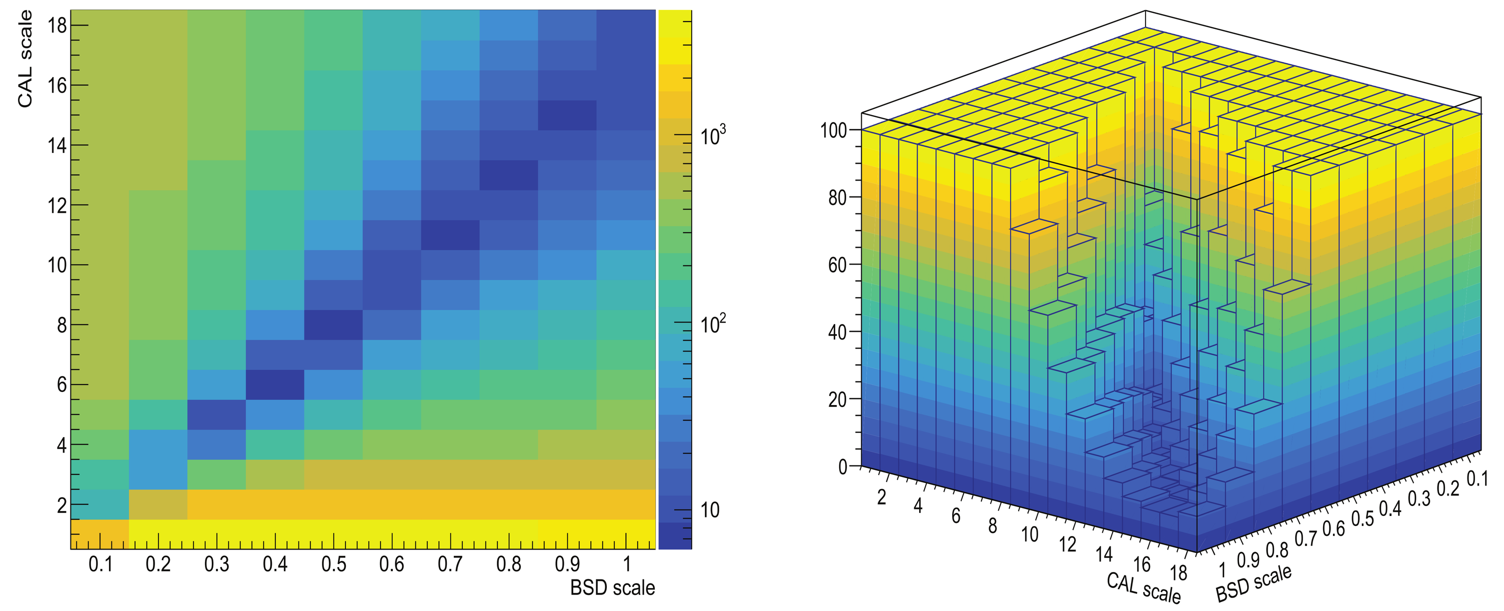
Left: distribution of the BSD late signal in the calibration dataset before scaling. Blue filled: ISS-CREAM data. Red: MC
Right: distribution of the BSD late signal in the calibration dataset after scaling. Blue filled: ISS-CREAM data. Red: MC



Left: distribution of the CAL nine ribbon sum in the calibration dataset before scaling. Blue filled: ISS-CREAM data. Red: MC
Right: distribution of the CAL nine ribbon sum in the calibration dataset after scaling. Blue filled: ISS-CREAM data. Red: MC

Parameter Scan

- BSD and CAL scaling factors are treated as free parameters
- BSD varied from 0.1 to 1 in steps of 0.1. CAL varied from 1 to 18 in steps of 1
- For every set, a χ^2 statistic was calculated to evaluate the 'goodness of fit' between MC and ISS-CREAM data
- The best match obtained is for a BSD scaling factor of 0.4 and a CAL scaling factor of 6, with a χ^2 value of 5.39 for 40 degrees of freedom although at this stage a scaling between 6 to 8 for CAL is still possible



The parameter space defined with a horizontal (BSD) scale and vertical (CAL) scale. Right: 3D plot showing the preferred region along a diagonal line. χ^2>100 is cut off and obviously not preferred.

Conclusion and future work

- We have shown evidence that the current calibration underestimates the true energy deposition in the CAL ribbons
- Shifted energy scale applied to the determination of ISS-CREAM elemental spectra [1]
- Future development will incorporate a scan on a finer grid and finding the region of confidence in the parameter space

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