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Analysis Results from the Cosmic Ray Energetics And Mass Instrument for the International Space Station (ISS-CREAM)

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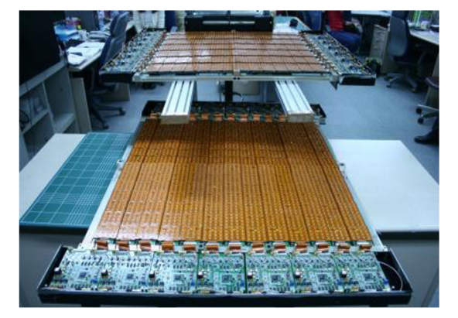
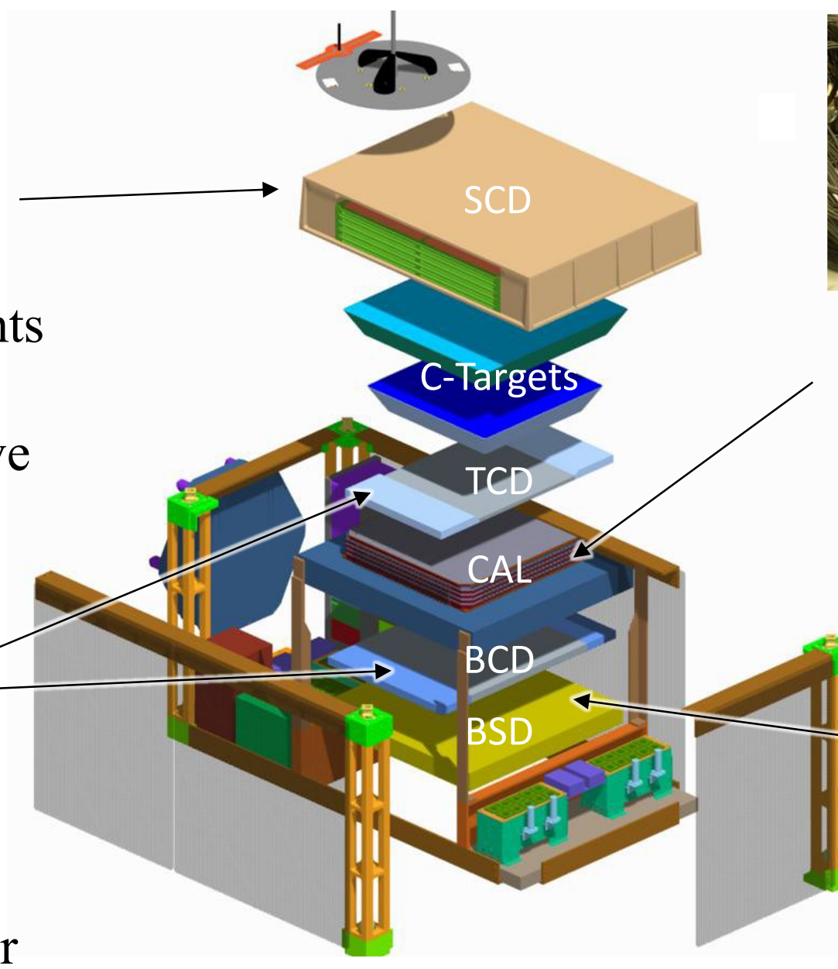
ISS-CREAM: CREAM on the ISS



Carbon Targets (0.5 λ_{int}) induce hadronic interactions



4 layer **S**ilicon **C**harge **D**etector
- Charge measurements
- 2.12 cm^2 pixels
- 79 cm x 79 cm active detector area

Top & **B**ottom **C**ounting **D**etectors
- Segmented for e/p separation
- Independent Trigger
- Scintillator viewed by photodiode array

CALorimeter (20 layers W + Scintillating Fibers, 1.0 λ_{int})
- Provides energy, tracking, and trigger

Boronated **S**cintillator **D**etector
- Alternative energy measurement

Adapted from E.S. Seo

ISS operations from 8/22/2017 to 2/12/2019

CAL provides XZ/YZ tracking with 50 fiber bundles/layer.

Analysis tools:

- *GEANT4 simulation* with detailed mass model, which outputs calibrated responses in both ADC and physics units.
  - Output is processed by the same analysis code as the data.
- *Event viewer* showing all detector responses simultaneously. Simulated data can also be displayed by the viewer.
- *Track independent CR identification using machine learning* (TensorFlow). Validated by hand scanning. (M. Yu, Poster 476 [2])
- *Multiple tracking methods* using various combinations of the individual detectors allow cross-checks and calibrations.
- *Noise measurement* through 0.5 Hz forced triggers during acquisition periods (CALIB trigger). Rates and spectra obtained.
- *Strict configuration control:* Varying fractions of each detector worked at different periods of operations.

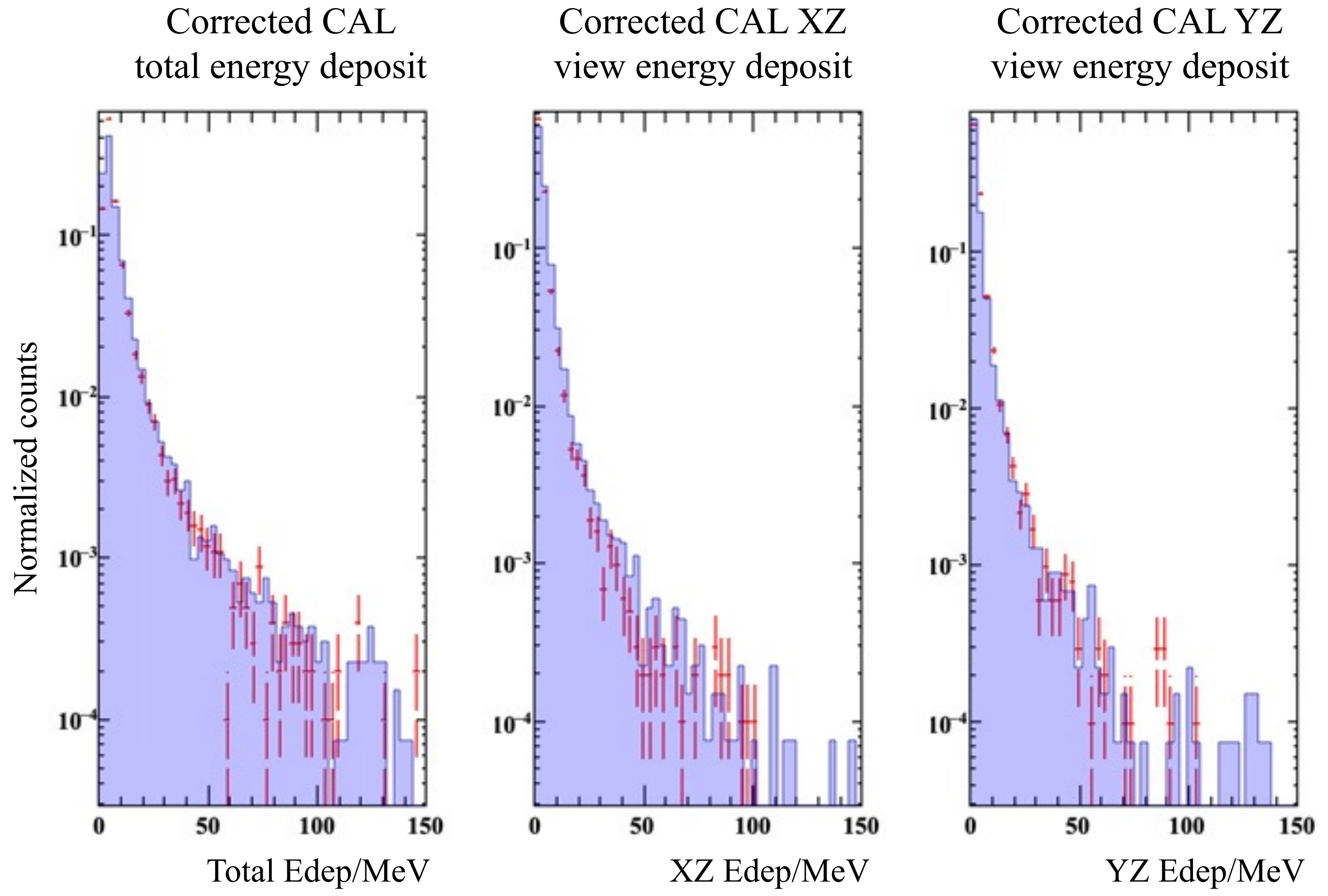
References:

1. Kenichi Sakai. *ISS-CREAM detector performance and tracking algorithms.* Poster 1051 these proceedings.
2. Monong Yu. *Machine learning applications on event reconstruction and identification for ISS-CREAM* Poster 476 these proceedings.
3. Yu Chen. *On-Orbit Energy Calibration of the Calorimeter on the ISS-CREAM Instrument Using the Boronated Scintillator Detector.* Poster 866 these proceedings.
4. Wiebel-Sooth, Biermann, and Meyer, *Astron & Astrophys,* v.330, p.389-398 (1998).

Analysis overview

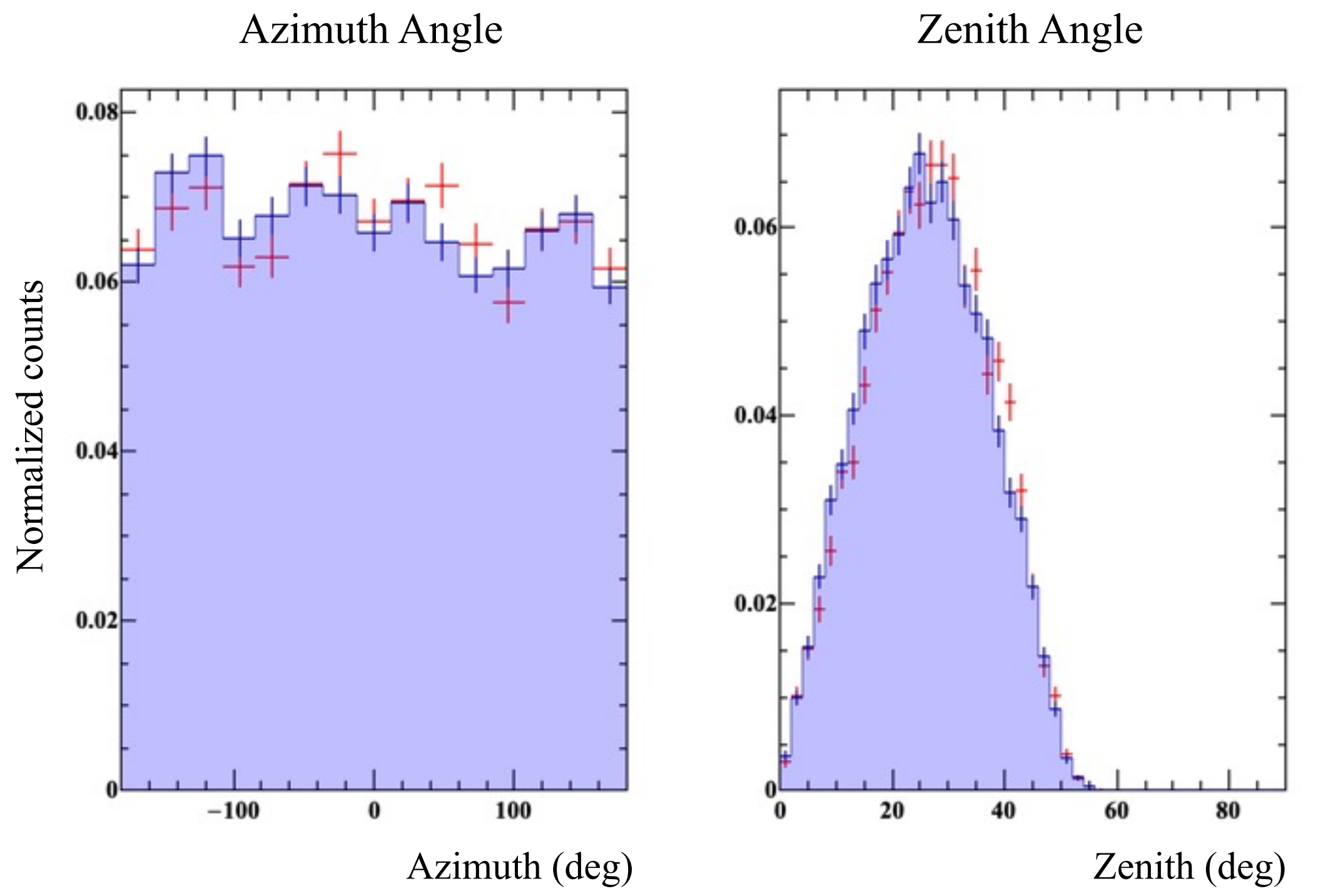
- Initial CAL-based analysis efforts resulted in fluxes orders of magnitude below expected values
  - Instrument performed reasonably otherwise. (K. Sakai Poster 1051 [1])
  - Track-independent machine learning cosmic ray identification algorithm also resulted in low fluxes (M. Yu, Poster 476 [2])
  - Fluxes calculated using BSD-determined energy are reasonable
- Exhaustive search for inefficiencies
  - Checked triggers, CAL, SCD…
- Missing events may be due to ambiguity in absolute energy spectrum of calorimeter
  - Different electronics used on-orbit compared to beam calibrations.
  - Alteration extended dynamic range; difference inferred with assumptions about DAC full ranges
  - Optical coupling of fiber light guides to photodetectors may have been affected by launch
- Energy rescaling of CAL
  - Absolute scale calibration from BSD comparison with MC expectations suggests scaling of 6-8 (Y. Chen, Poster 866 [3]). Results shown for x6.
  - Other measures (eg CAL layer and channel hit frequency distributions agree better if scaling ~x6
- CAL energy deposition calculated from the sum of energy deposits in ribbons whose centers are ±4 ribbons of the ribbon that the track passes through (9 ribbon sum).
- Live time calculations are complicated by periods in which live time continued to accumulate while the acquisition remained on during SAA transit but detectors were not operational. Two methods are used. (1) Add up live time counter during good configurations as defined by detector settings in housekeeping. (2) Add up ΔT between consecutive events with cosmic ray triggers in good configuration periods for ΔT < 300 ns.

Energy deposition



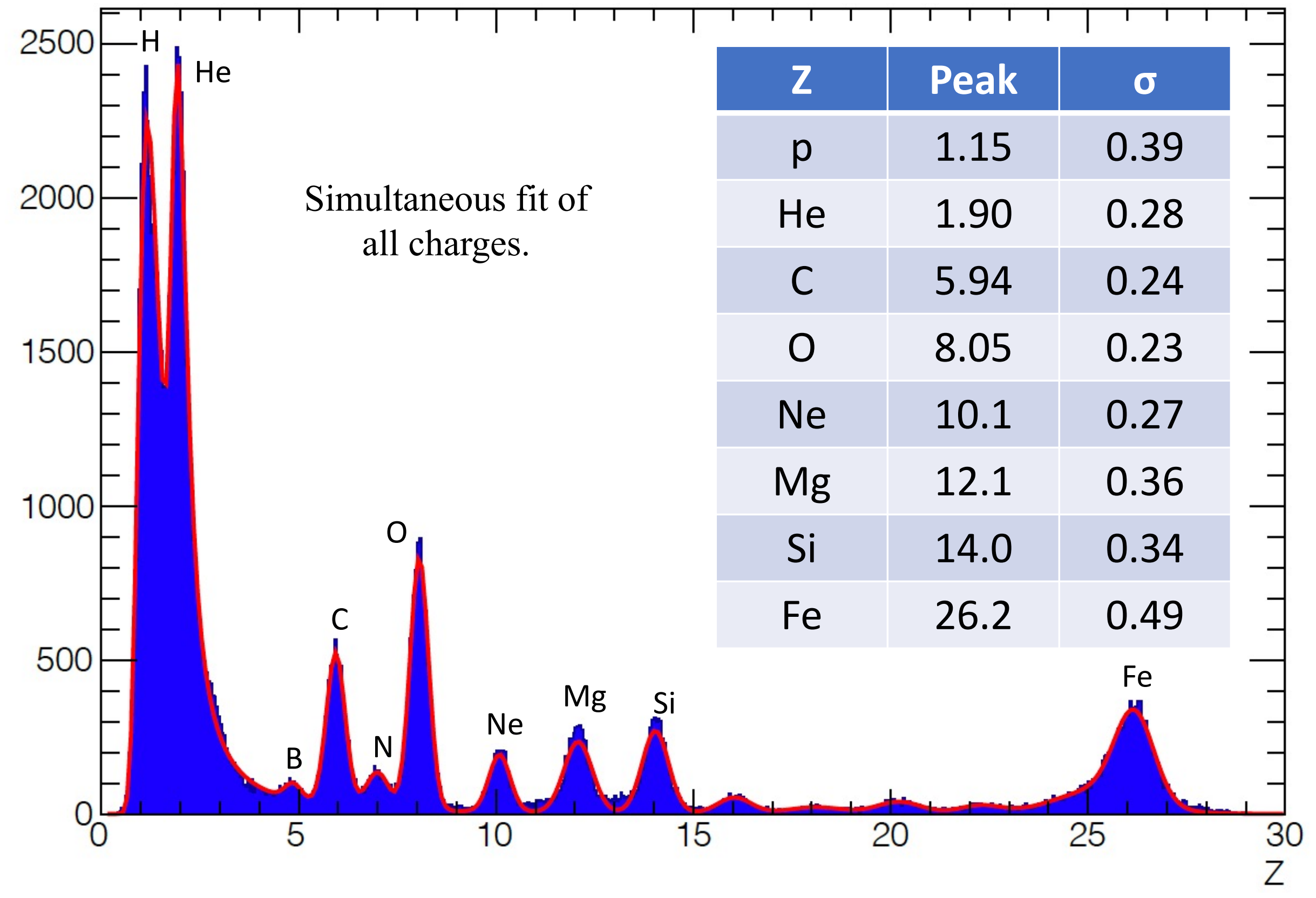
Left to right: Total, XZ view, and YZ view energy deposited in the CAL for normalized on-orbit and simulated data. Simulated data are in red, while on-orbit data are in blue. The same normalization constant is used for all three distributions for on-orbit or simulated data. Event selection used the primary tracking method (TM18), required a charge identified, and total energy above 1500 MeV. Note: these CAL energy data are scaled by a factor of 6.

Tracking performance



Pointing comparison between simulated and on-orbit data using the primary tracking method (TM18) and for events passing analysis selection cuts, including energy. TM18 combines the SCD top layer, TCD maximum signal, and energy-weighted CAL XZ and YZ positions. Red crosses: Simulated data. Blue histograms: On-orbit data.

Charge distribution



Z	Peak	σ
p	1.15	0.39
He	1.90	0.28
C	5.94	0.24
O	8.05	0.23
Ne	10.1	0.27
Mg	12.1	0.36
Si	14.0	0.34
Fe	26.2	0.49

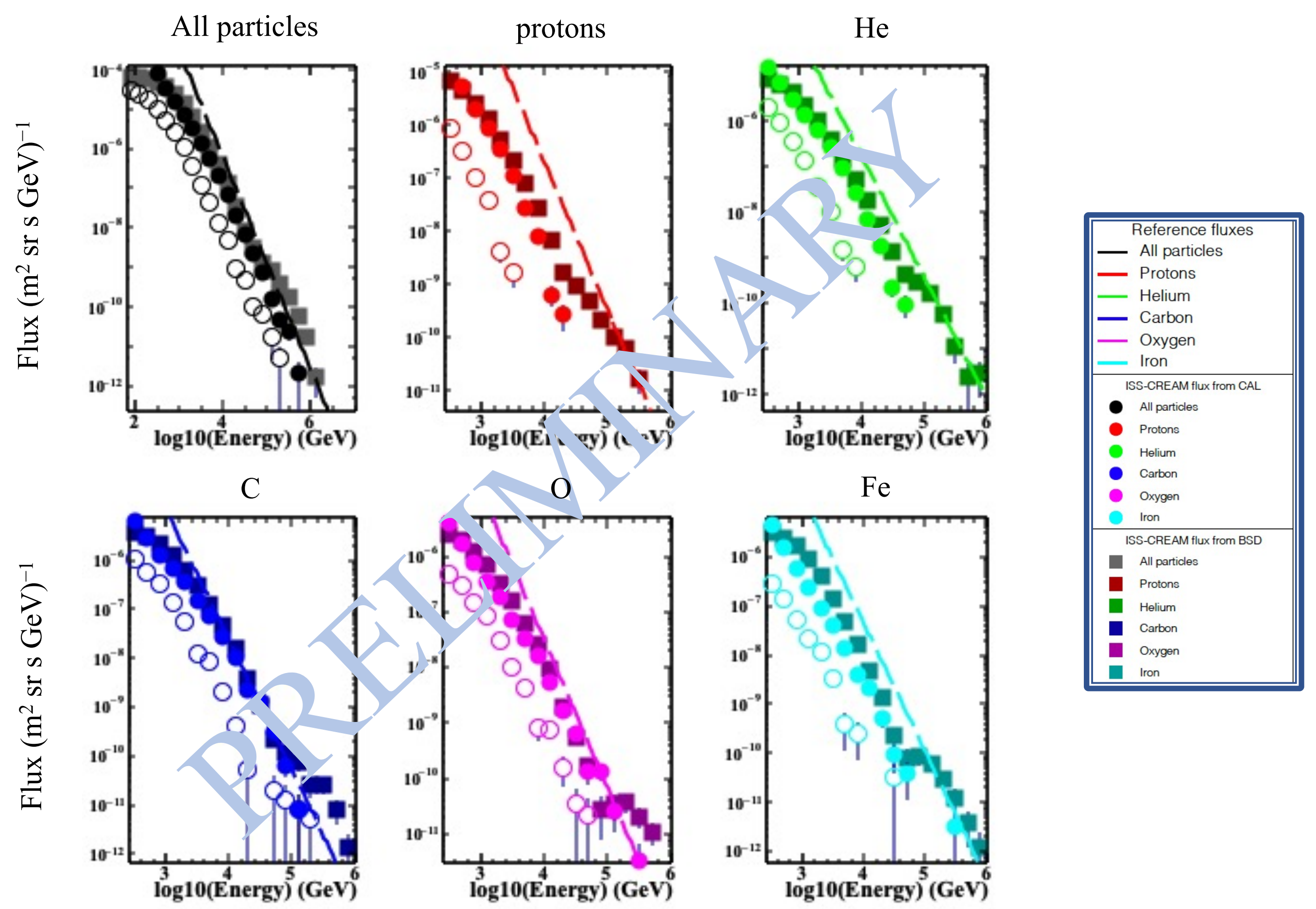
Charge distribution of on-orbit data using the primary tracking method (TM18). These data do not all have sufficient energy in the CAL or BSD to reconstruct energy, so not all events shown are used to determine spectra. The fit parameters are used in a 2σ charge selection.

Status

Fluxes

$$\Phi_{Fe}(GeV/n) = \frac{N_{Fe}(GeV/n)}{\epsilon_{MC}} \cdot \frac{1}{S\Omega \cdot T_{live}} \qquad N_{Fe}(GeV/n) = f_{dE/dx \to E_{kin}}(N_{Fe}(MeV))$$

$S\Omega$	: Geometrical acceptance	~0.35 – 0.40 m^{2}sr, energy, particle, and trigger dependent
T_{live}	: Live time	162.78 days
ϵ_{MC}	: MC efficiency	0.42 for track identification, correct charge identification, and charge selection, from MC



Flux vs total particle kinetic energy calculated with the method and parameters described above. Errors shown are statistical. Filled circles (squares) are reconstructed from the CAL (BSD) energy deposit with the x6 scaling factor. Open circles are the original CAL scaling as described in the proceedings. Proton and helium selection is more sensitive to backsplash, and selection cuts are still being studied. Dashed lines are reference fluxes from [4].

Future work

The displayed fluxes can be moved vertically on the plots by finding further inefficiencies, and horizontally with energy scaling. The energy scaling factor of ~6 suggested by the BSD study solves much of the missing CAL data problem. Future work will center on refining the BSD calibration of the CAL energy deposit scaling. Other work includes properly combining the different detector configurations and checking the live time and efficiency calculations. The multiple tracking algorithms allow us to estimate individual detector efficiencies by using tracking that does not depend on the detector in question. The simulated data include the different configurations, although fine-tuning is needed to get the relative number of events in each period correct. Systematic errors are not yet studied either. In addition, obscuration due to JEM is uncertain.

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