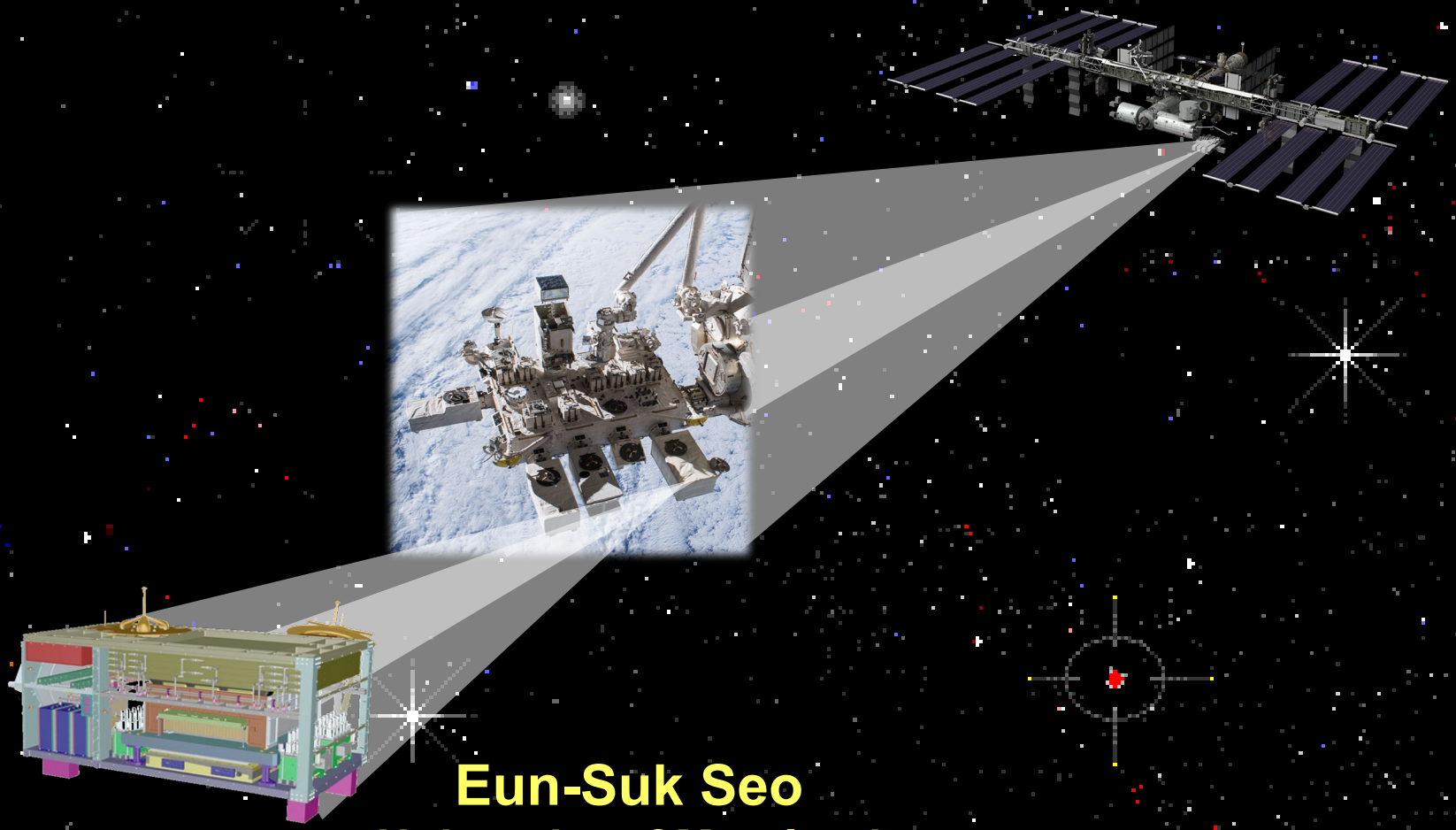
ICRC2019 36th International Cosmic Ray Conference · Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

Cosmic Ray Energetics And Mass CREAM for the ISS (ISS-CREAM)



Eun-Suk Seo
University of Maryland
for the ISS-CREAM Collaboration

ISS-CREAM Collaboration

PoS(ICRC2019)1177

Y. Amare[a], D. Angelaszek[a,b], N. Anthony[a], G. H. Choi[c], M. Chung[a], M. Copley[a], L. Derome[d], L. Eraud[d], C. Falana[a], A. Gerrety[a], L. Hagenau[a], J. H. Han[a], H. G. Huh[a], Y. S. Hwang[e], H. J. Hyun[e], H.B. Jeon[e], J. A. Jeon[c], S. Jeong[c], S. C. Kang,[e] H. J. Kim[e], K. C. Kim[a], M. H. Kim[a], H. Y. Lee[c], J. Lee[c], M. H. Lee[a], C. Lamb[a], J. Liang[a], L. Lu[a], J. P. Lundquist[a,c], L. Lutz[a], B. Mark[a], A. Menchaca-Rocha[f], T. Mernik[a], M. Nester[a], O. Ofoha[a], H. Park[e], I. H. Park[c], J. M. Park[e], N. Picot-Clemente[a], S. Rostsky[a], E. S. Seo[a,b], J. R. Smith[a], R. Takeishi[c], T. Tatoli[a], P. Walpole[a], R. P. Weinmann[a], J. Wu[a], Z. Yin[a,b], Y. S. Yoon[a,b] and H. G. Zhang[a]

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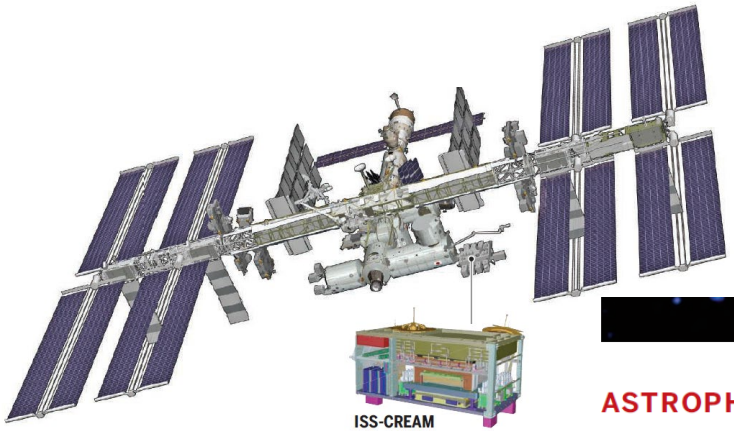
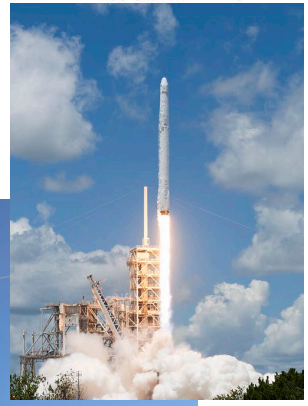
Thanks to NASA HQ/GSFC WFF/JSC/MSFC/KSC, Space X and JAXA

News since the last ICRC:

ISS-CREAM launch on SpaceX-12, 8/14/17





cosmic rays across the galaxy.

ASTROPHYSICS

Cosmic ray catcher will probe supernovae from new perch

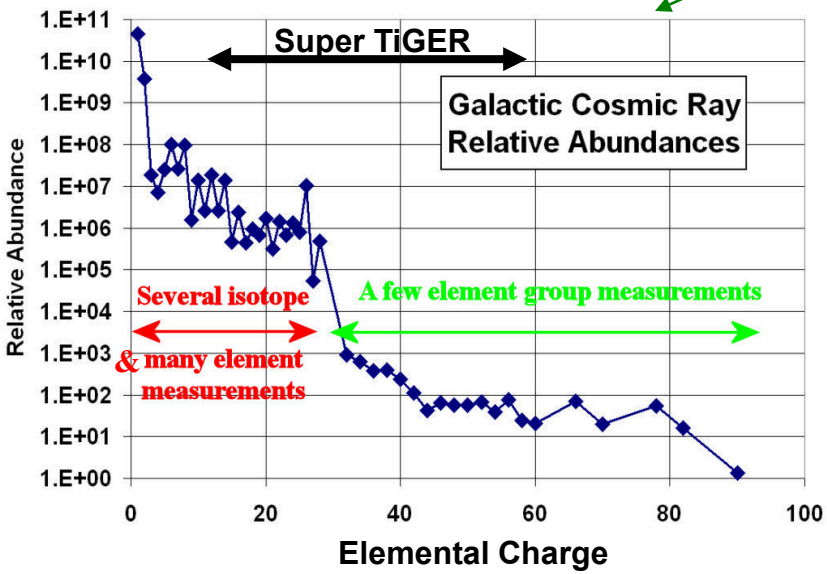
Balloon-borne detector moves to space to trap rare, high-energy particles that carry clues to their origin

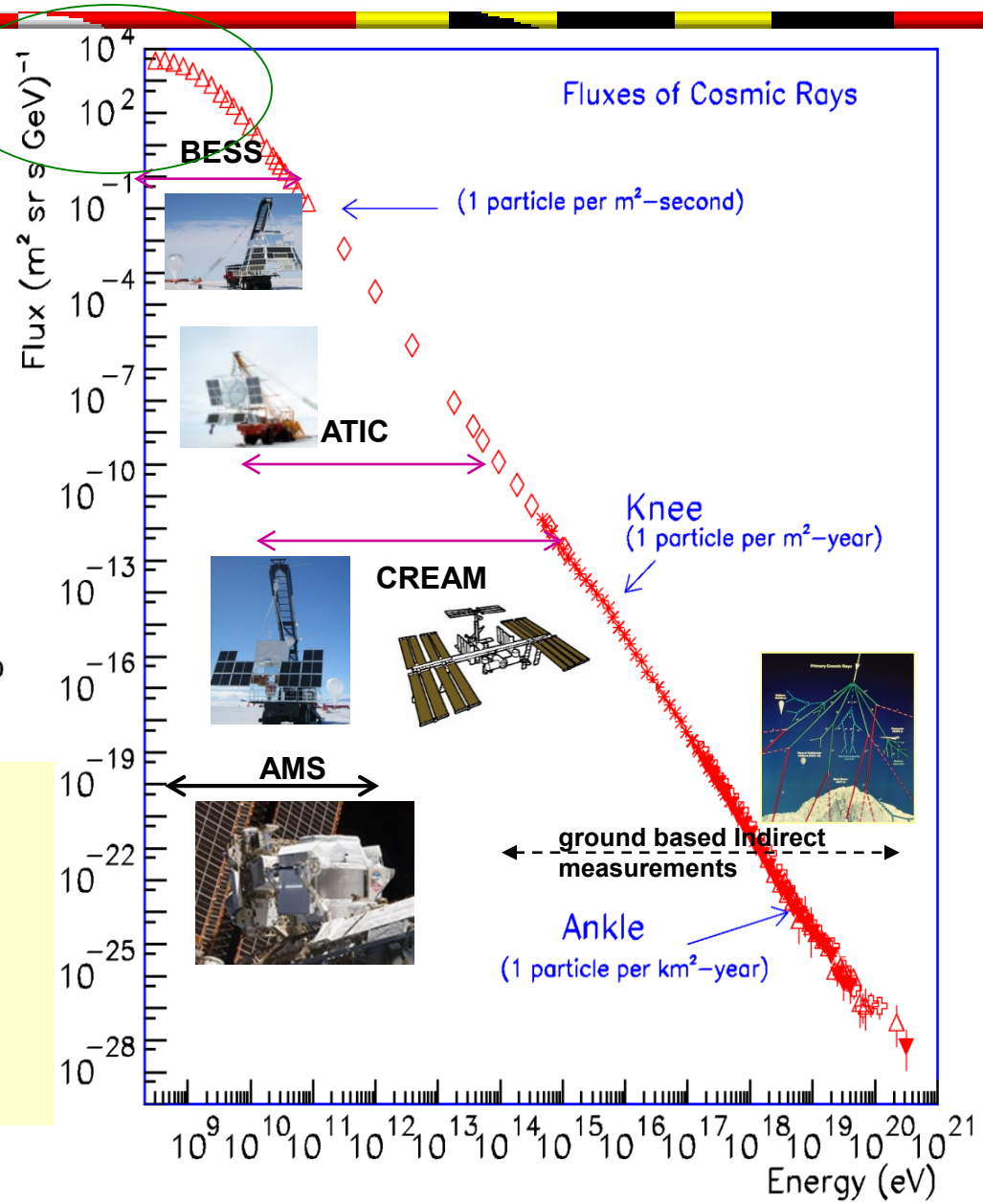
By **Eric Hand**

After 191 days aboard balloons sailing the stratosphere, an experiment designed to probe the galaxy's natural particle accelerators will move to higher ground: the International Space Station (ISS). The Cosmic Ray Energetics and Mass (CREAM) instrument and its successors floated above Antarctica seven times to collect high-energy cosmic rays, charged particles and

that a few smash into Earth with extraordinarily high energies—higher than today's most powerful atom smashers can generate. Their abundance drops sharply with increasing energy, following what's known as a power law distribution. In 1949, Italian-American physicist Enrico Fermi came up with a mechanism that could explain that and the cosmic rays' mind-boggling energies: supernova shock waves. In the centuries after a supernova, a wave of compressed gas courses out

How do cosmic accelerators work?



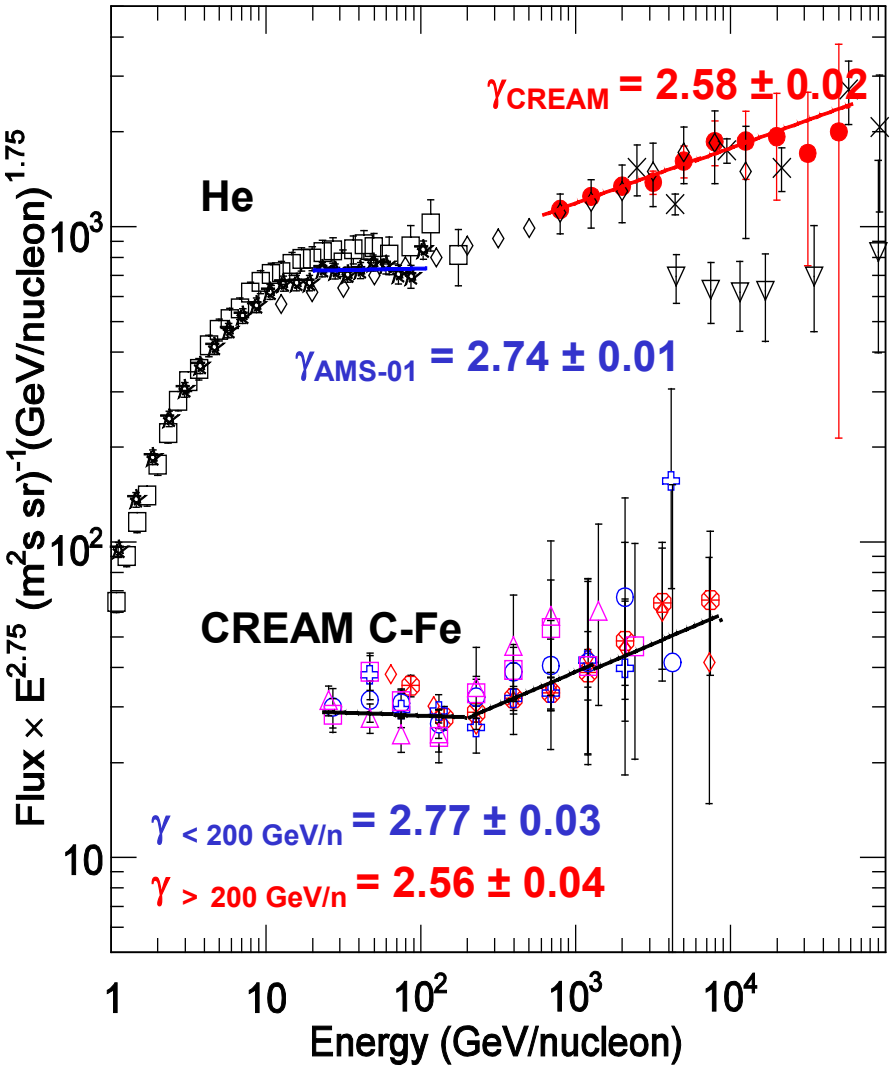


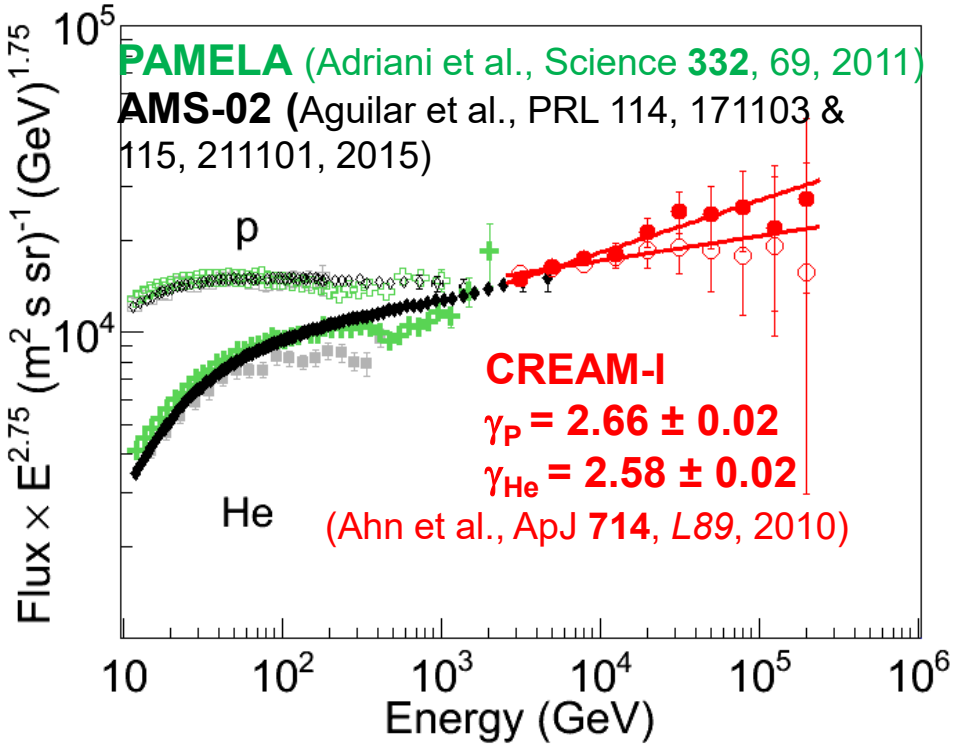
Mission Goal

Extend the energy reach of direct measurements of cosmic rays to the highest energy possible to investigate cosmic ray origins, acceleration and propagation.

Discrepant hardening

Yoon et al. ApJ **728**, *122*, 2011; Ahn et al. ApJ 714, L89, 2010





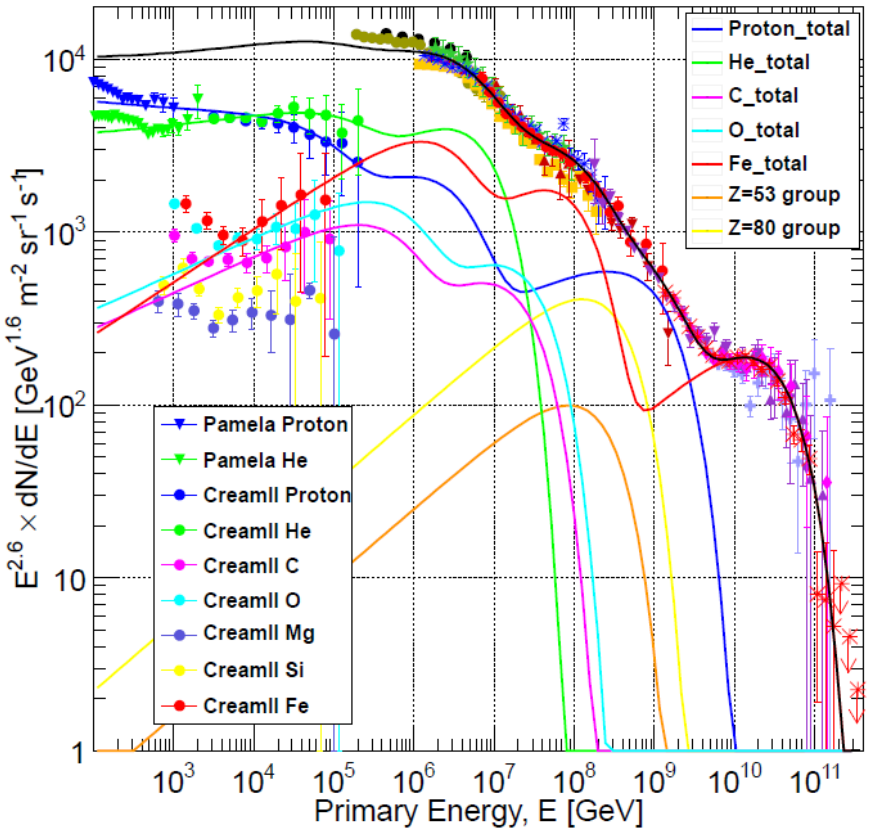
It provides important constraints on cosmic ray acceleration and propagation models, and it must be accounted for in explanations of the e^+e^- anomaly and cosmic ray "knee."

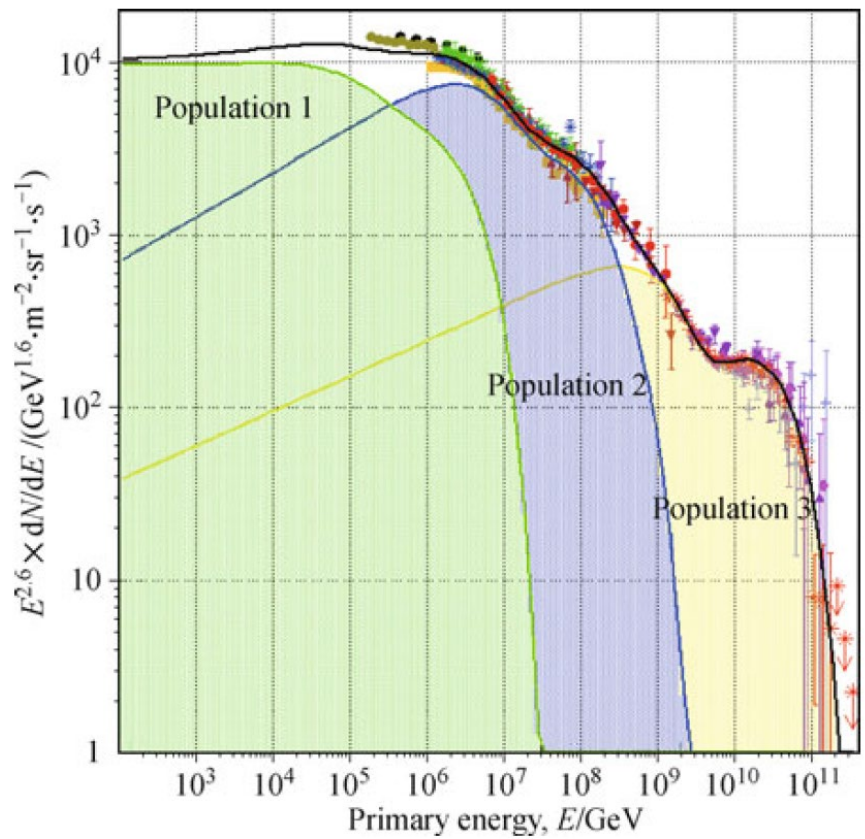
CREAM data to explain the knee and beyond

T. K. Gaisser, T. Stanev and S. Tilav, Front. Phys. 8(6), 748, 2013

Acceleration limit:

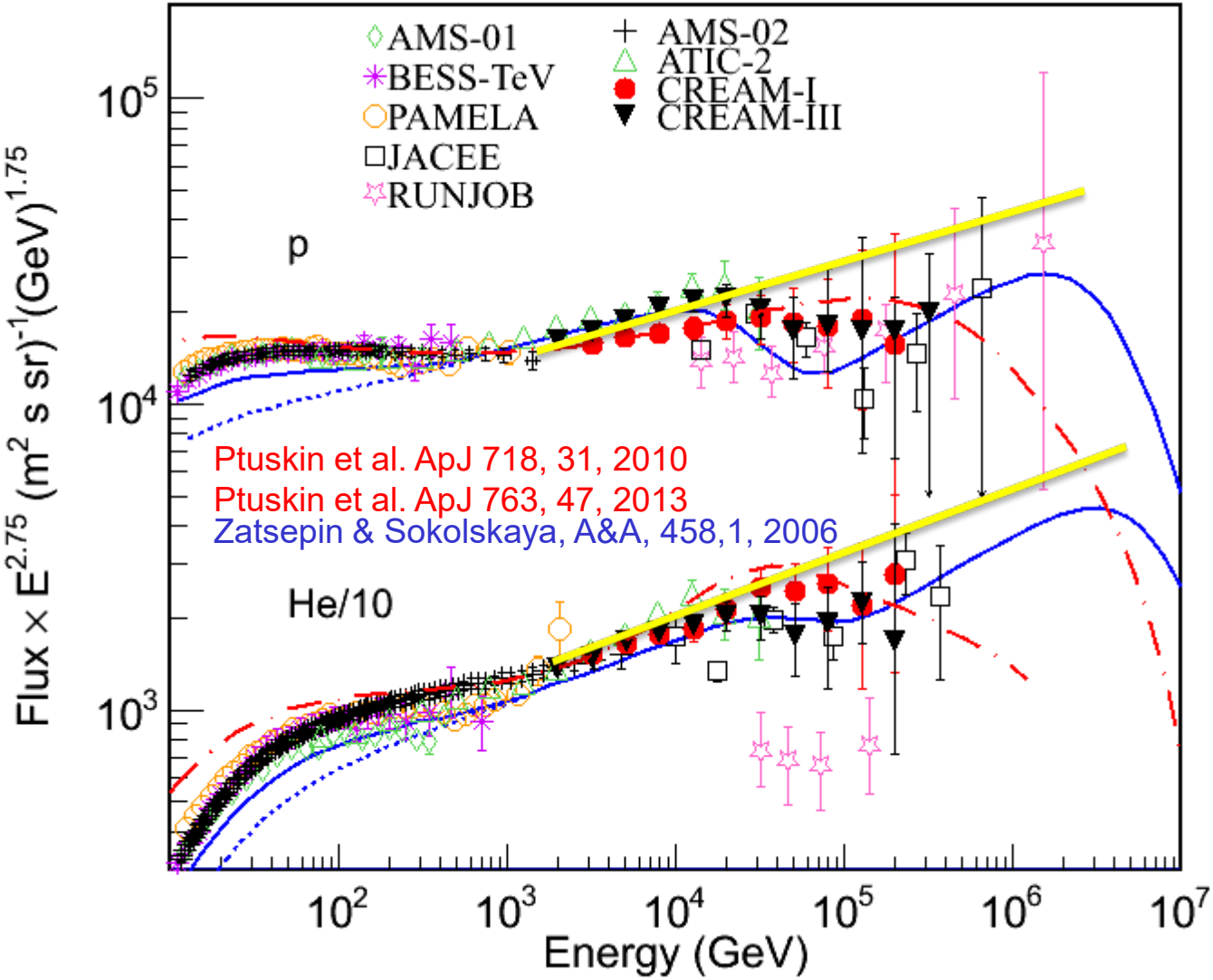
$E_{max\_z} = Ze \times R = Z \times E_{max\_p}$, *where rigidity R = Pc/Ze*





Need to extend measurements to higher energies

Yoon et al. (CREAM Collaboration) ApJ 839:5, 2017



Additional source?

ISS-CREAM Instrument

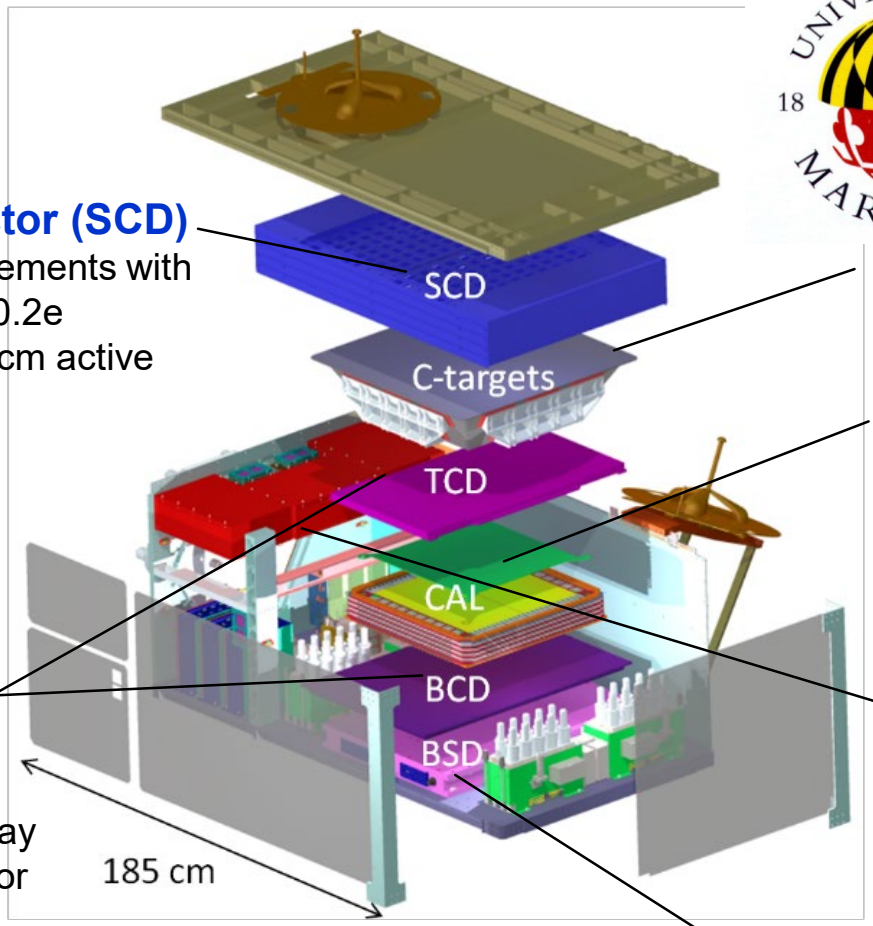
Seo et al. Adv. in Space Res., **53**/10, *1451*, 2014; Smith et al. PoS(ICRC2017)199, 2017

Silicon Charge Detector (SCD)

- Precise charge measurements with charge resolution of ~ 0.2e
- 4 layers of 79 cm x 79 cm active area (2.12 cm^2 pixels)

Top/Bottom Counting Detector (T/BCD)

- Plastic scintillator instrumented with an array of 20 x 20 photodiodes for e/p separation
- Low energy trigger



Carbon Targets

- Induces hadronic interactions

Calorimeter

- 20 layers of alternating tungsten plates and scintillating fibers
- Determines energy
- Provides tracking and high energy trigger

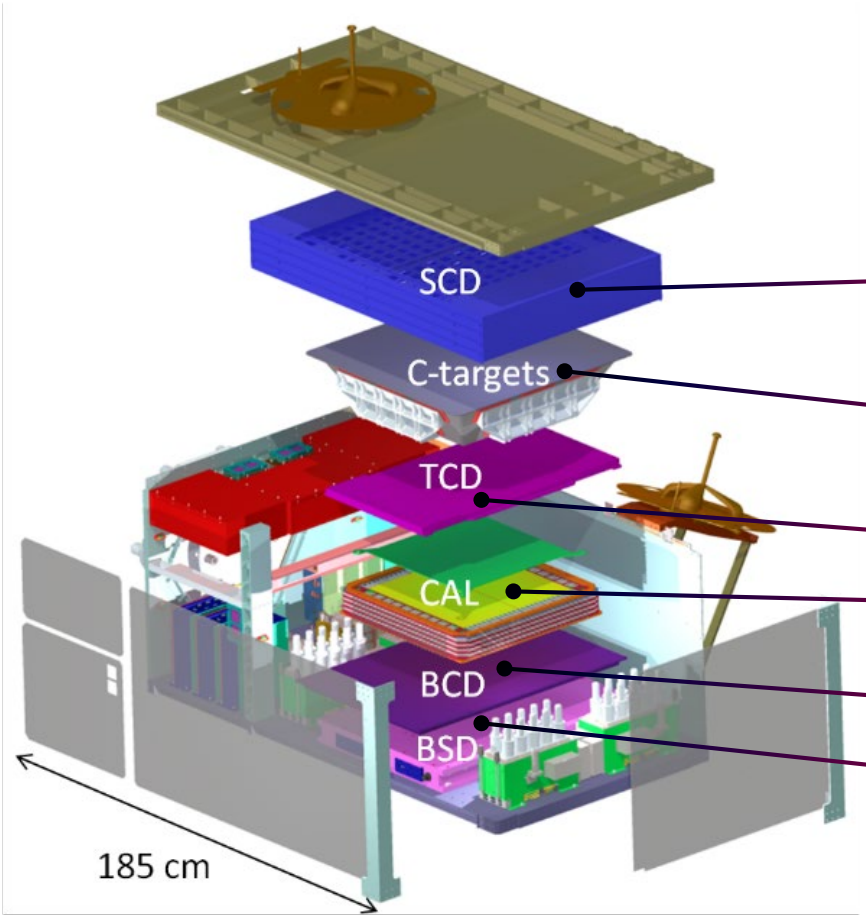
SFCs and common electronics inc. Trigger, CMD, HSK, Power

Boronated Scintillator Detector (BSD)

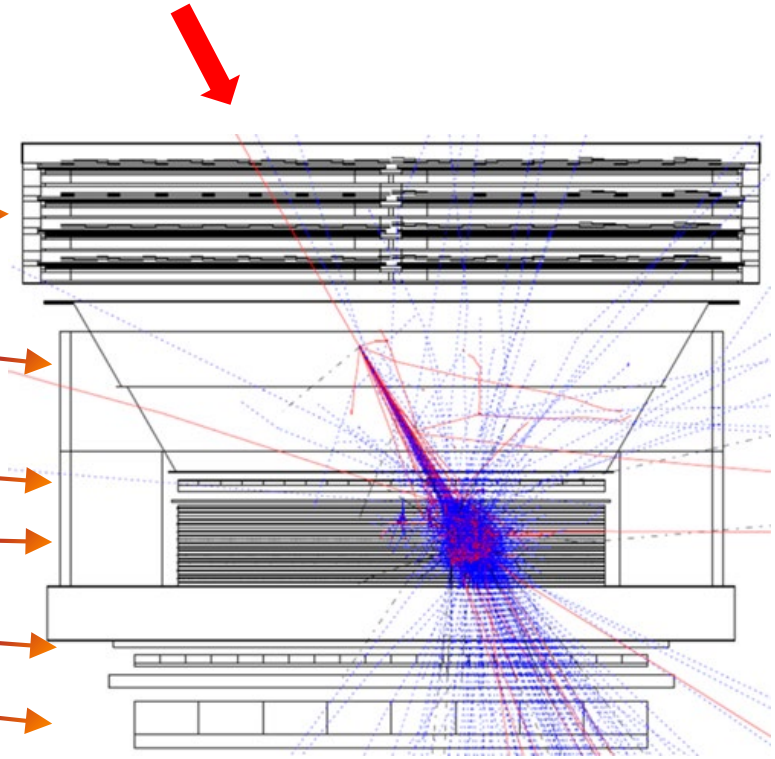
- Additional e/p separation by detection of thermal neutrons

Cosmic Ray Event Simulation

Seo et al. Adv. in Space Res., **53**/10, *1451*, 2014

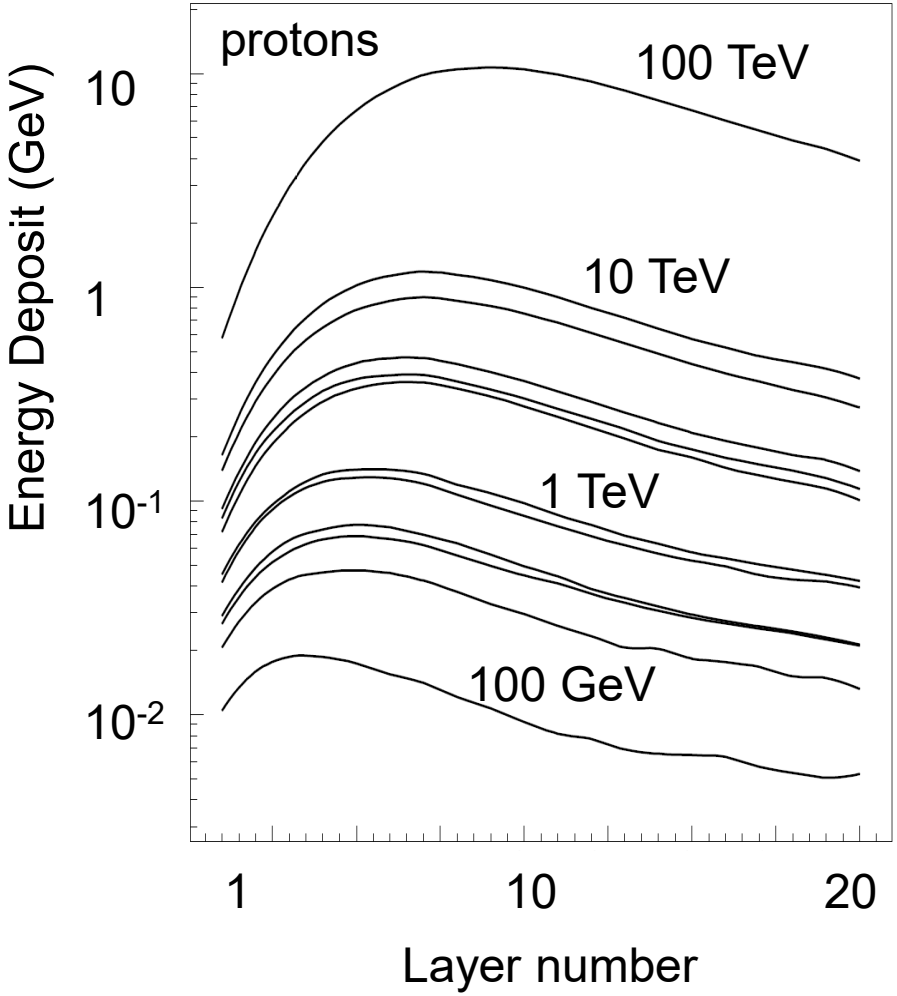


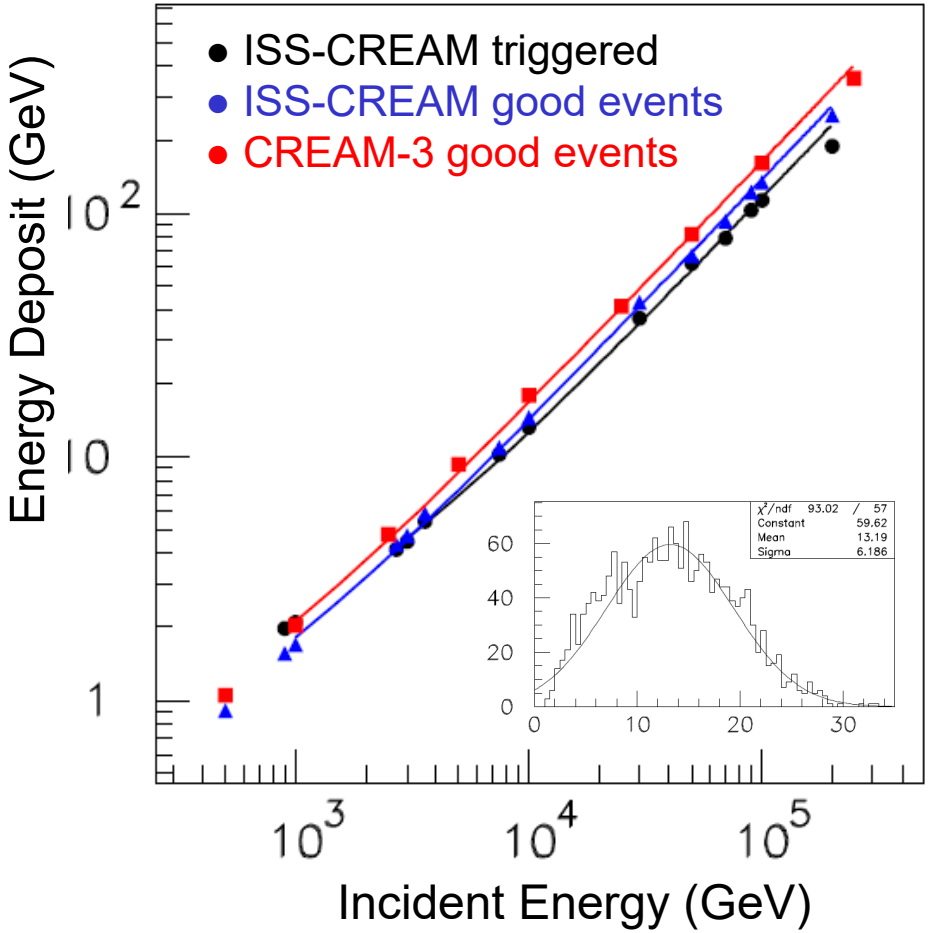
Cosmic Ray Particle



Monte Carlo Simulations

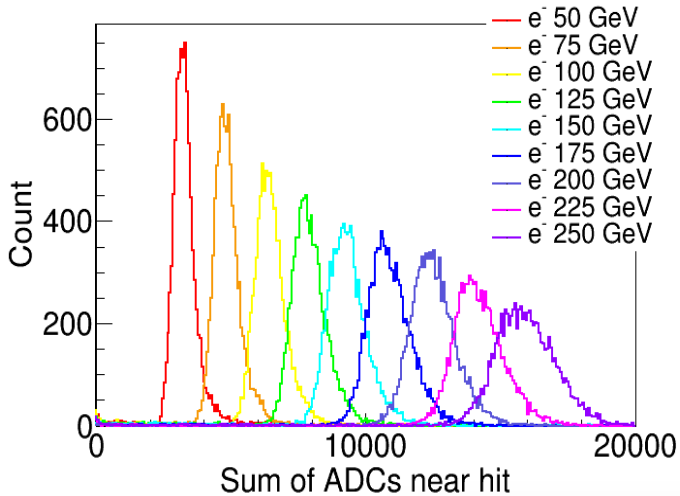
Wu et al., ICRC 2019, CRD40 poster

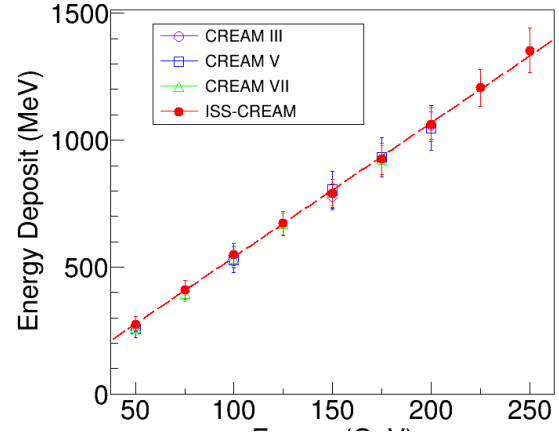


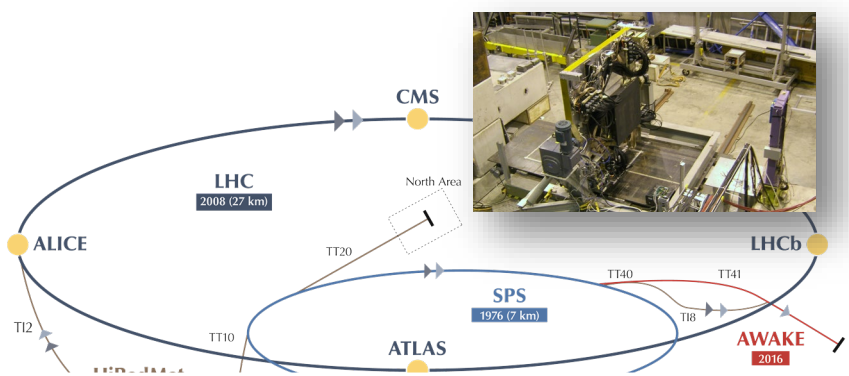


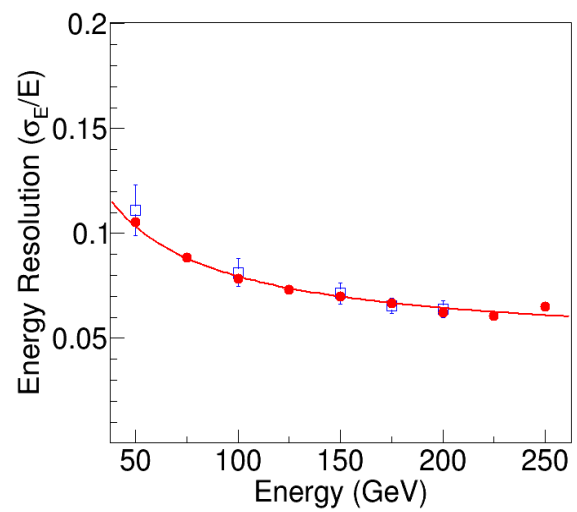
Series of beam tests at CERN

Picot-Clemente et al., PoS(ICRC2017)247; Han et al., ICRC 2011, 6, 392; N.Park et al., NIM A, 581, 133, 2007; Ahn et al. Nucl. Phys. B (Poc. Suppl.), 150, 272, 2006; Ahn et al. CALOR 2004, 532, 2005. I. Park et al., NIM A535, 158, 2004 etc.

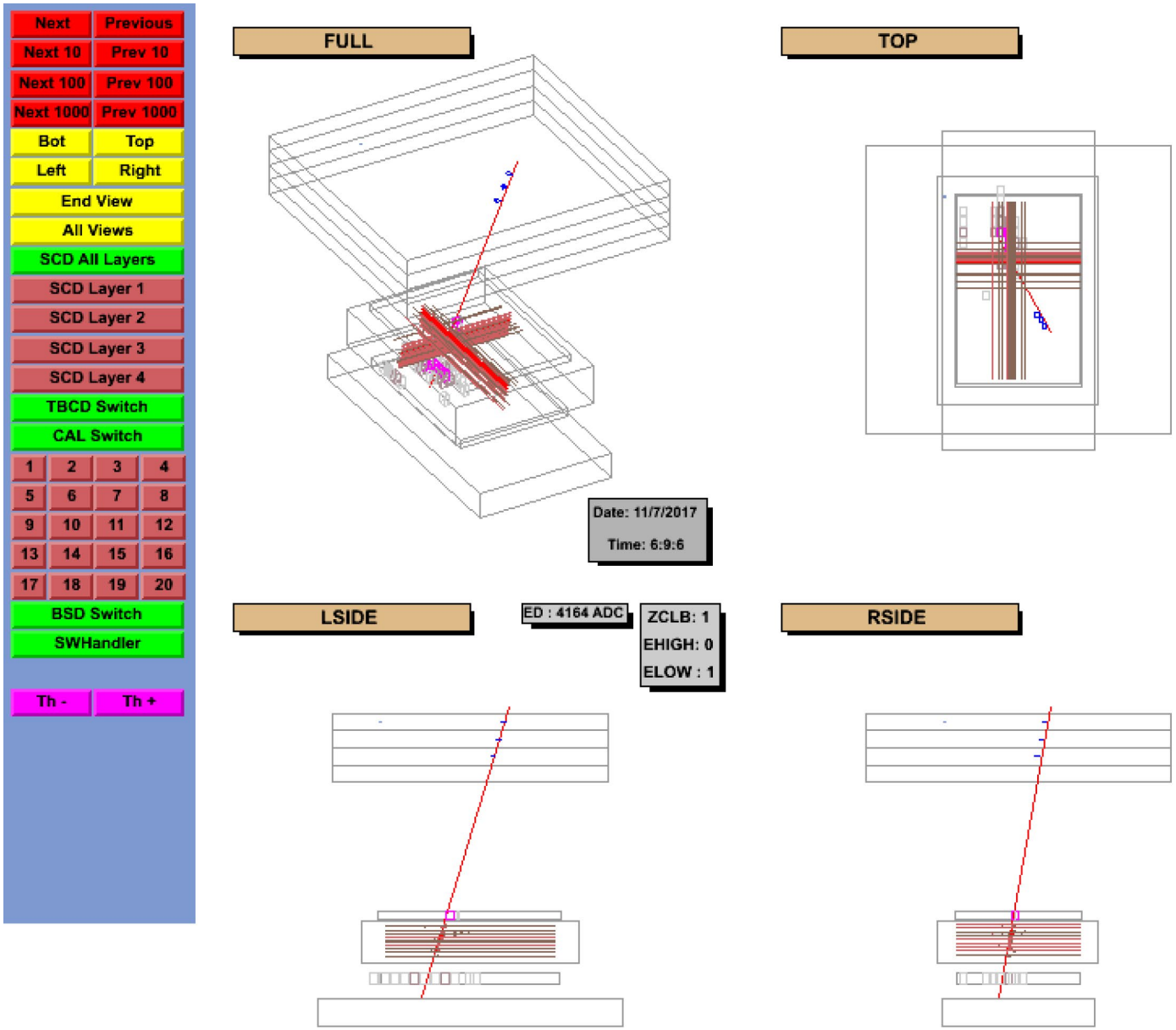






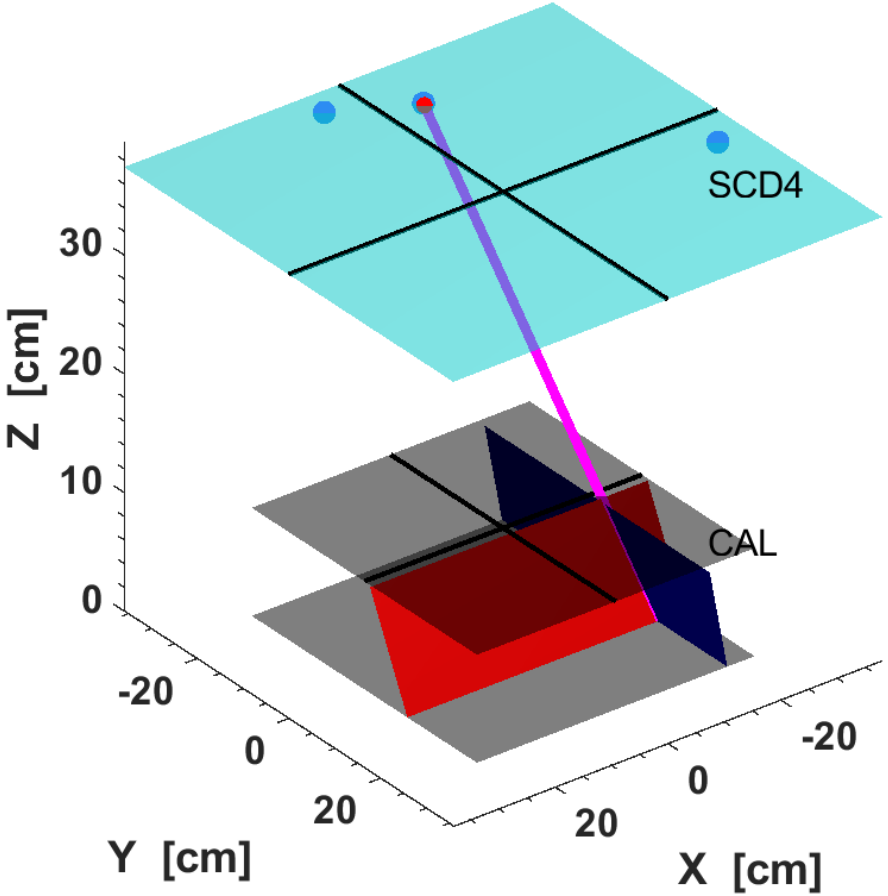


Flight data: Cosmic Ray Detection

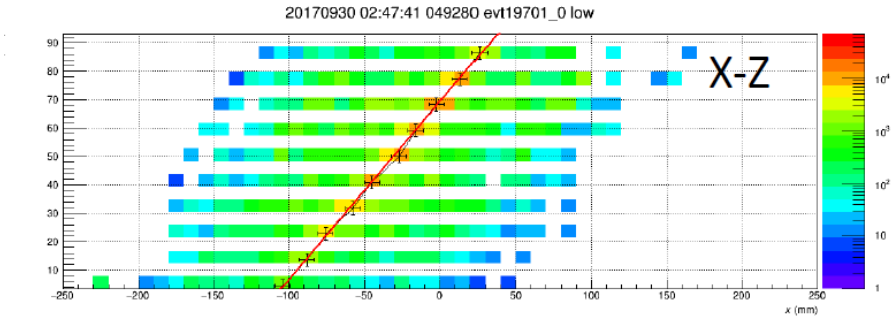


Examples of high energy events

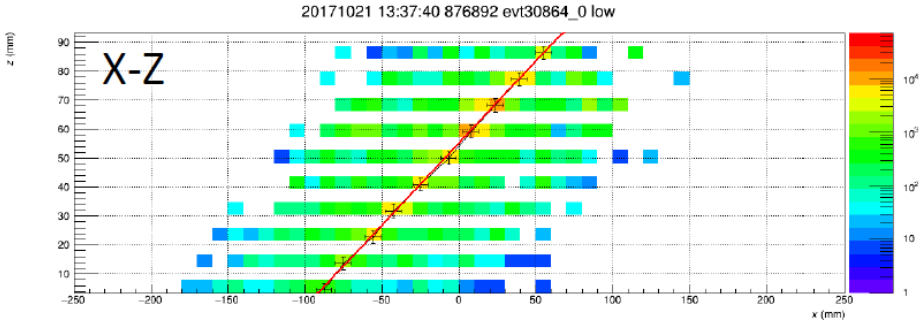
Lundquist et al. ICRC 2019, CRD 18 poster



E = 1.88 PeV

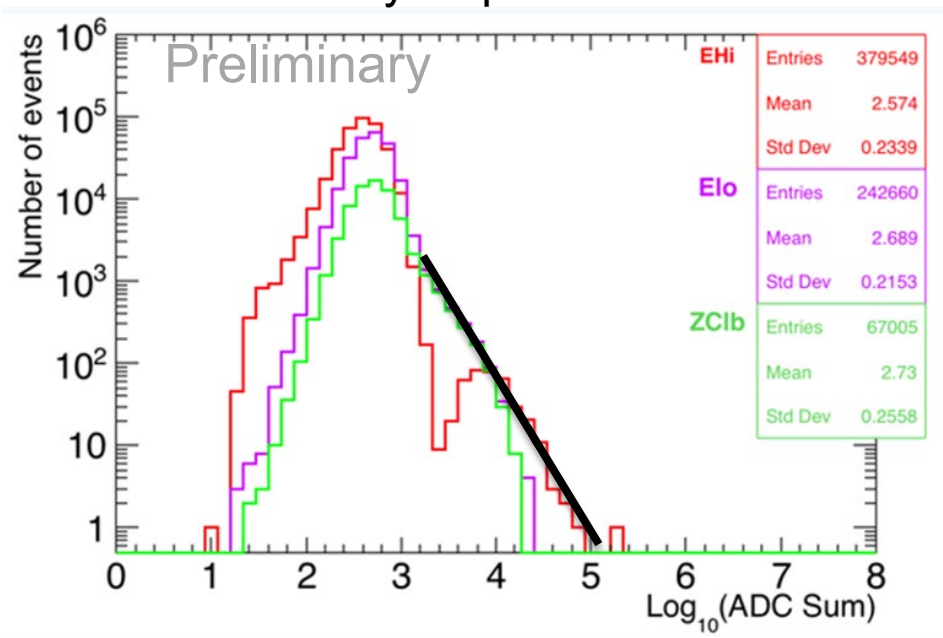


E = 748 TeV



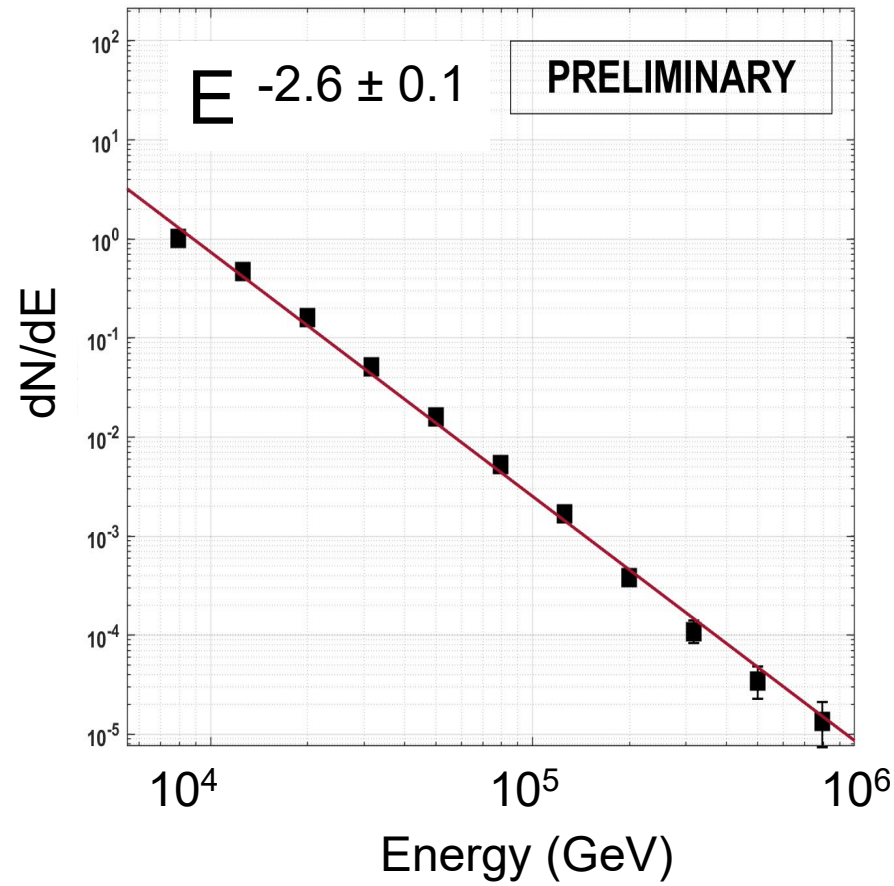
CAL provides energy measurements

Cosmic ray all particle counts

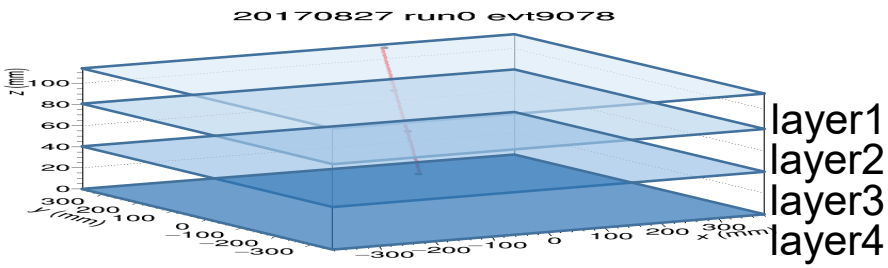


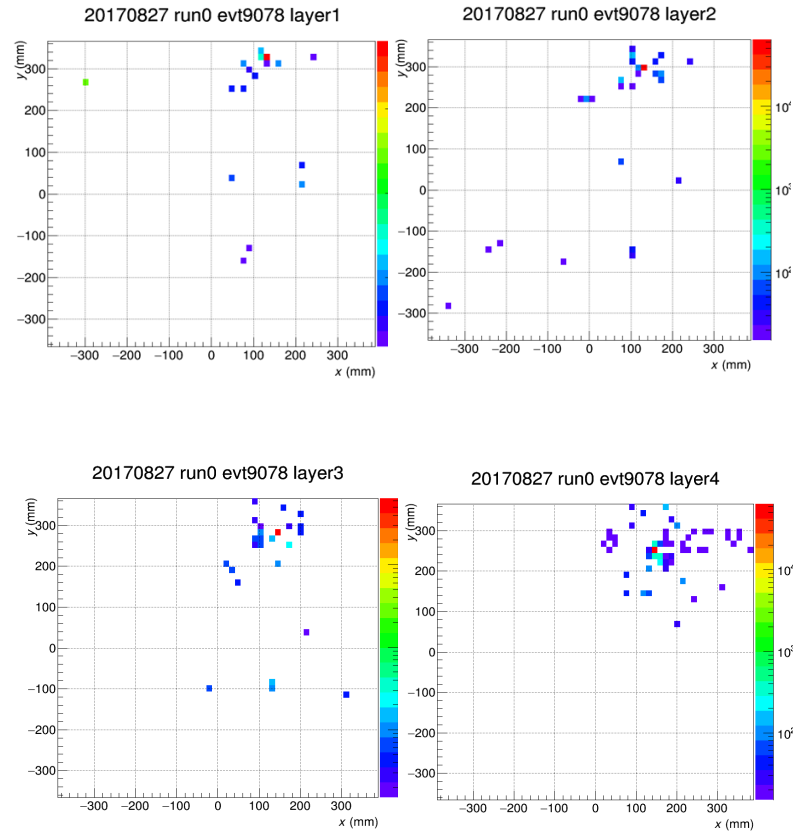
Kim et al. ICRC 2019, CRD14 poster

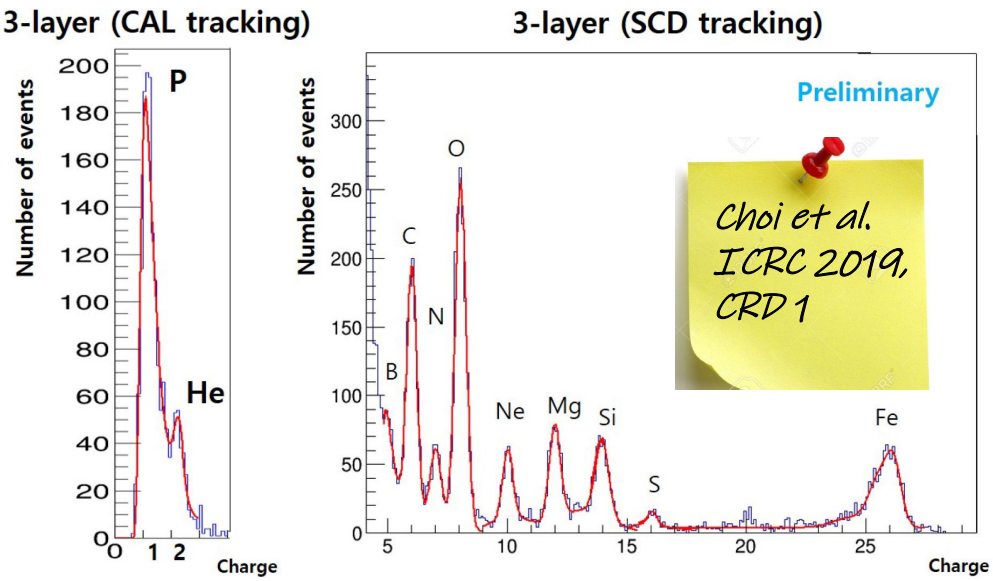
Lundquist et al. ICRC 2019, CRD18 poster



SCD provides particle charge identification



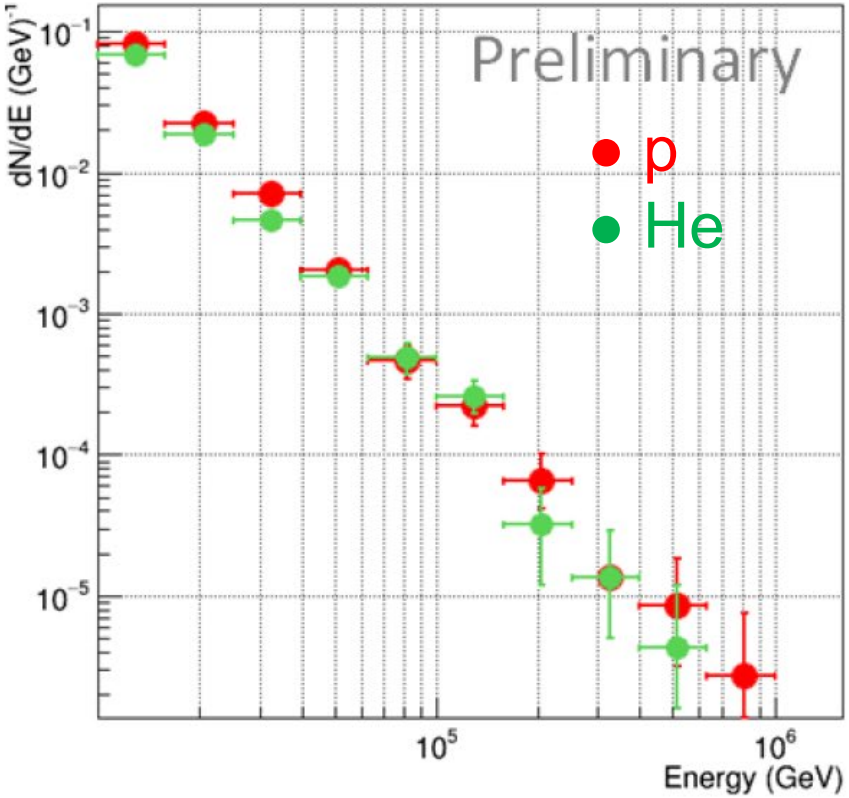


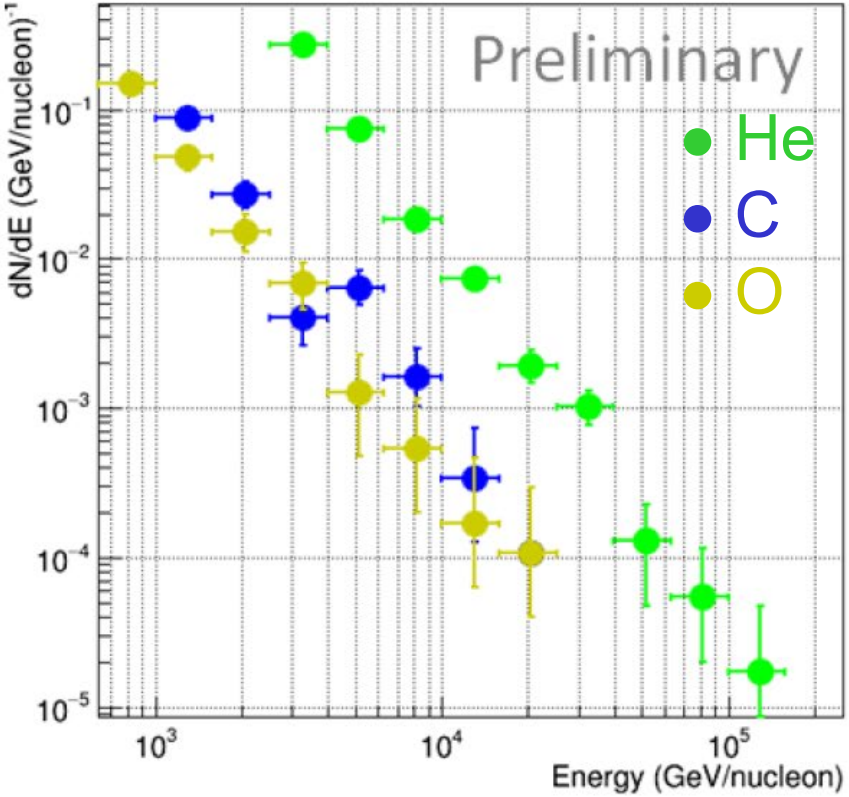


The individual elements are clearly identified. The relative abundance in this plot has no physical significance, because needed corrections for interactions and propagations have not been applied to these data.

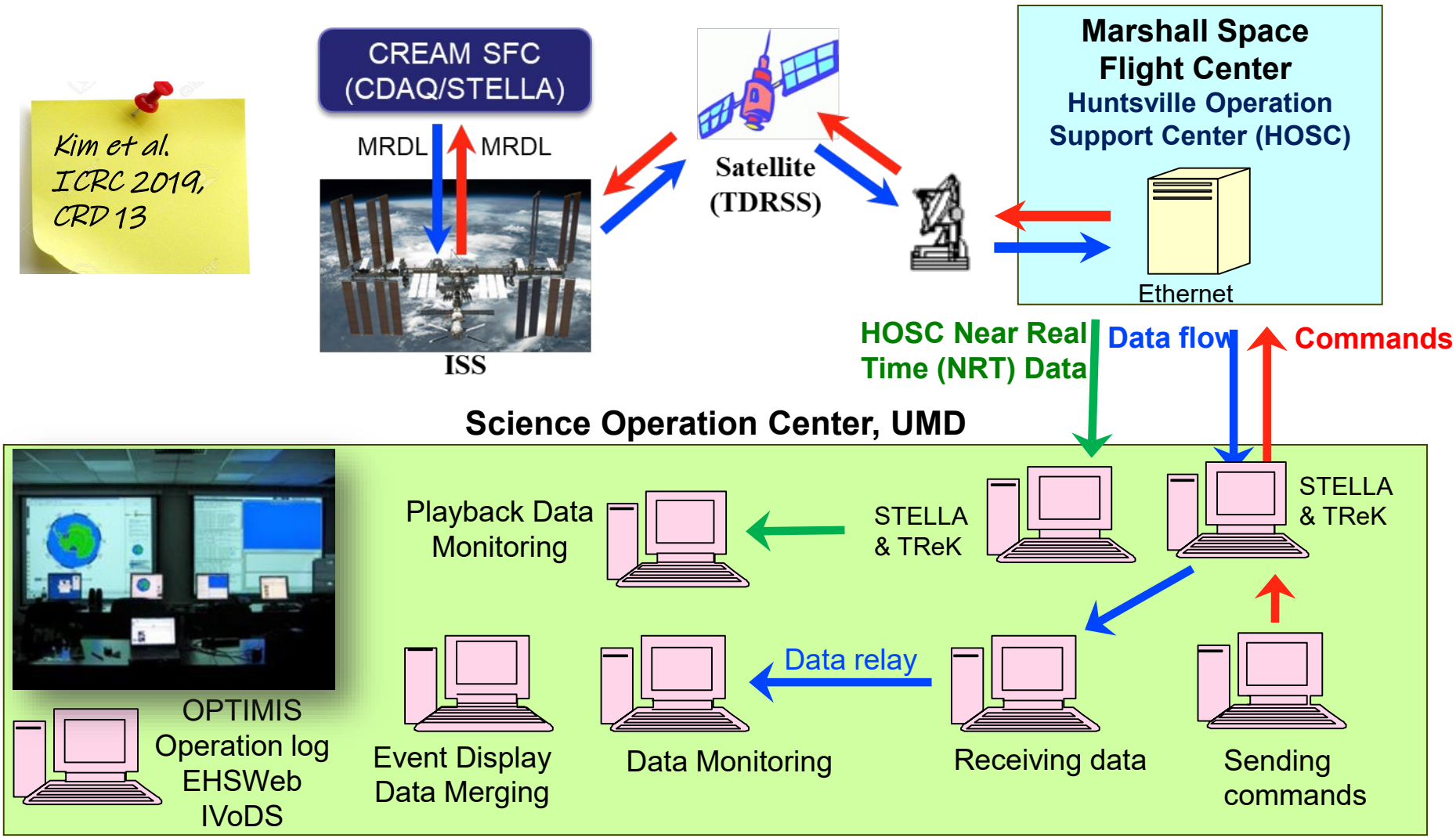
Elemental Spectra

Takeishi et al. ICRC 2019, CRD 7c oral





ISS-CREAM Science Operation

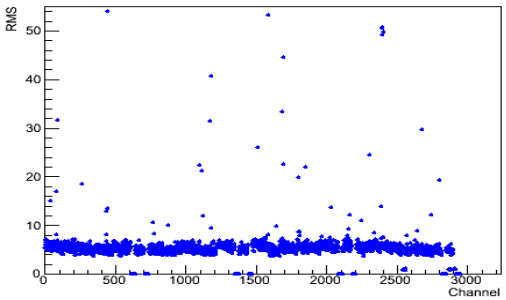


Web Monitoring and Data Distribution

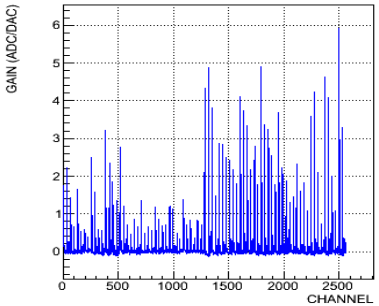
http://cosmicray.umd.edu/iss-cream/data

- Monitor performance of CREAM instrument using in-flight calibration data
  - Every hour: Noise level (pedestal runs) of Calorimeter, SCD, and TCD/BCD
  - Every two hours: Charge gain, HPD aliveness etc.
- Relay the housekeeping data to a web server for worldwide monitoring
  - 1558 housekeeping parameters every 5 sec
  - Provides warning by color display when values are out of range.
- Visualize interactions of cosmic rays in CREAM by generating event display plots of science events.
- Process all data and distribute them in ROOT format for analysis.
  - Refine the initial pre-launch detector calibrations channel by channel to reflect the actual flight conditions, including time-dependent effects

Noise level of one layer of SCD

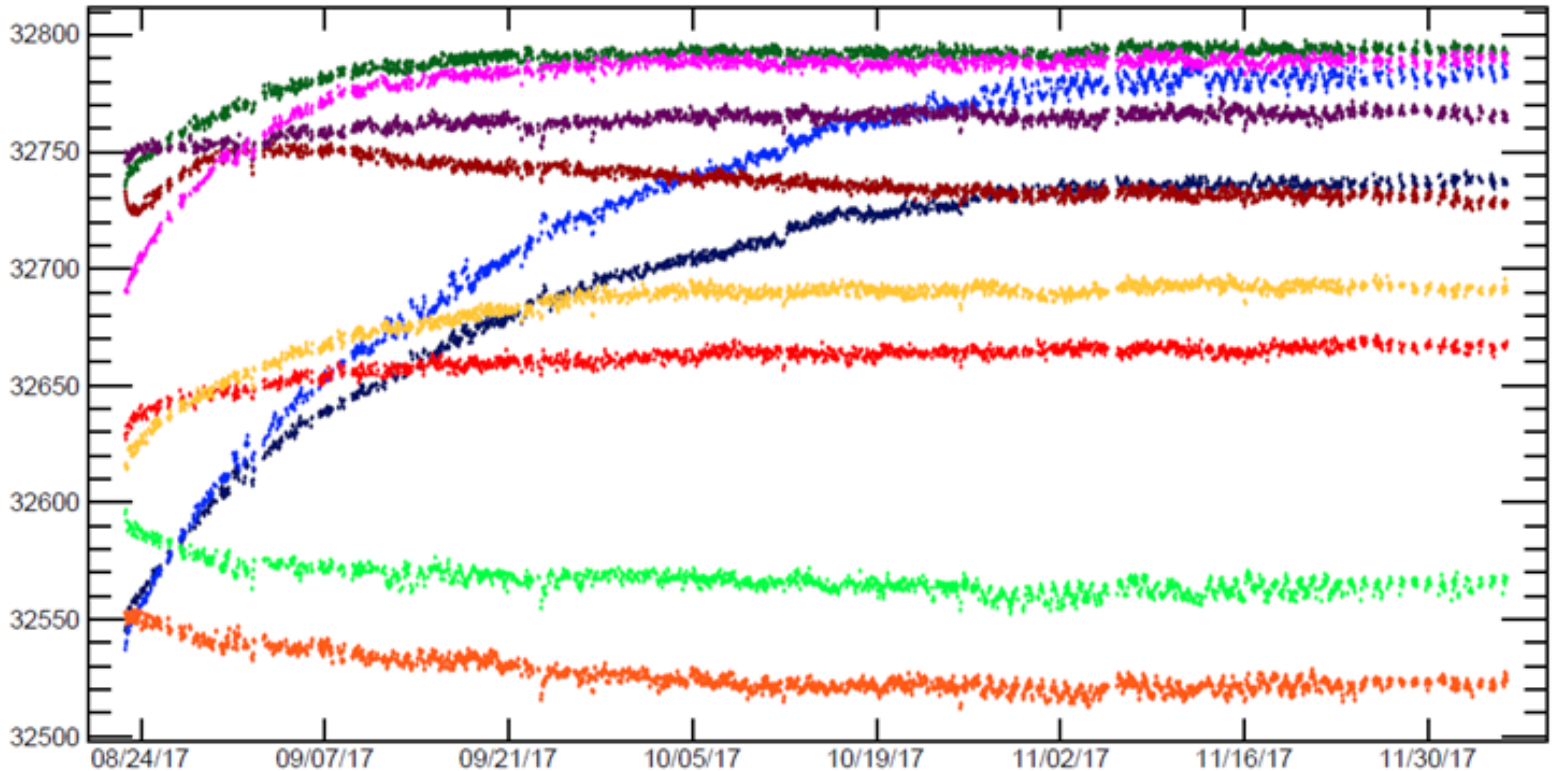


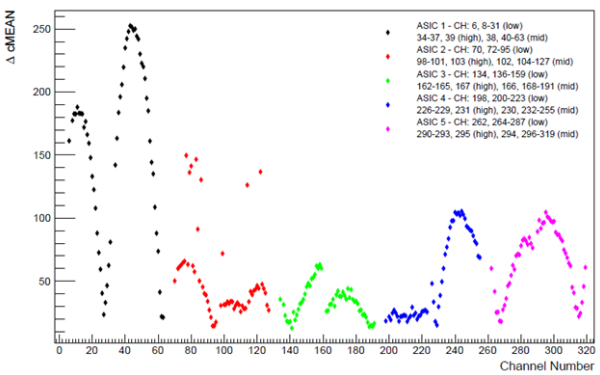
HPD aliveness of CAL

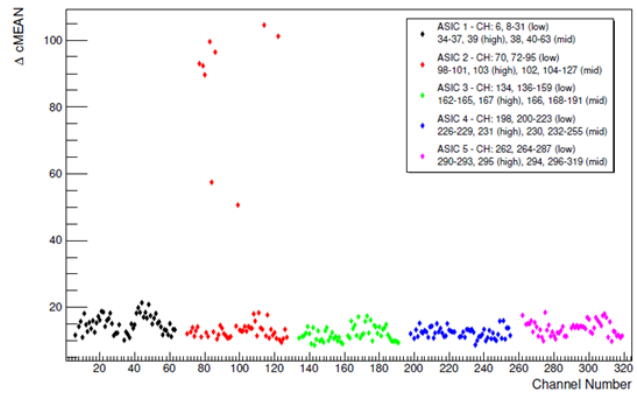


EvtTime	11:37:45	CalHV6a	-0.08	HPD12	26.27
RawClb	0.00	CalHV6b	-0.05	HPD78	27.94
RawExt	0.00	CalHV7a	-0.08	HPD34	26.68
RawCD1	0.00	CalHV7b	-0.06	HPD56	25.91
RawCal	0.00	CalHV8a	-0.08	SFC-A	26.20
RawCD2	0.00	CalHV8b	-0.06	ColdPla2	26.08
TrgTime	18:00:00	CalBias1	55.96	ColdPla3	-74.84
TrgTotal	0.00	CalBias2	55.44	ATCS3	27.18
TrgExt	0.00	CalBias3	56.11	ATCS4	26.39
TrgClb	0.00	CalBias4	55.35	ATCS5	25.98
TrgEHi	0.00	CalBias5	56.18	SFC-B	26.33
TrgELow	0.00	CalBias6	55.44	RedPM	25.93
TrgZClb	0.00	CalBias7	56.16	+X-YCP	23.88
NioTime	11:37:47	CalBias8	55.40	HKBox	24.80
NioTRate	1.93	BsdRet1	0.02	BottPla	23.62
NioNRate	0.00	BsdRet2	0.02	ATCS6	24.68
CMDQ	0.00	BsdTQB	26.49	+3o3VC	3.30
HKQ	0.00	BsdTQA	26.83	+5o2VC	5.00
EVTQ	0.00	BsdTQC	25.21	+12VC	12.12
DAT0	0.00	BsdTQD	24.66	m5o2VC	-4.99
DAT1	0.00	Bsd-12V	-11.76	TempC	32.79
PKT0	0.02	Bsd+1o5V	1.52	5o2cC1	0.69

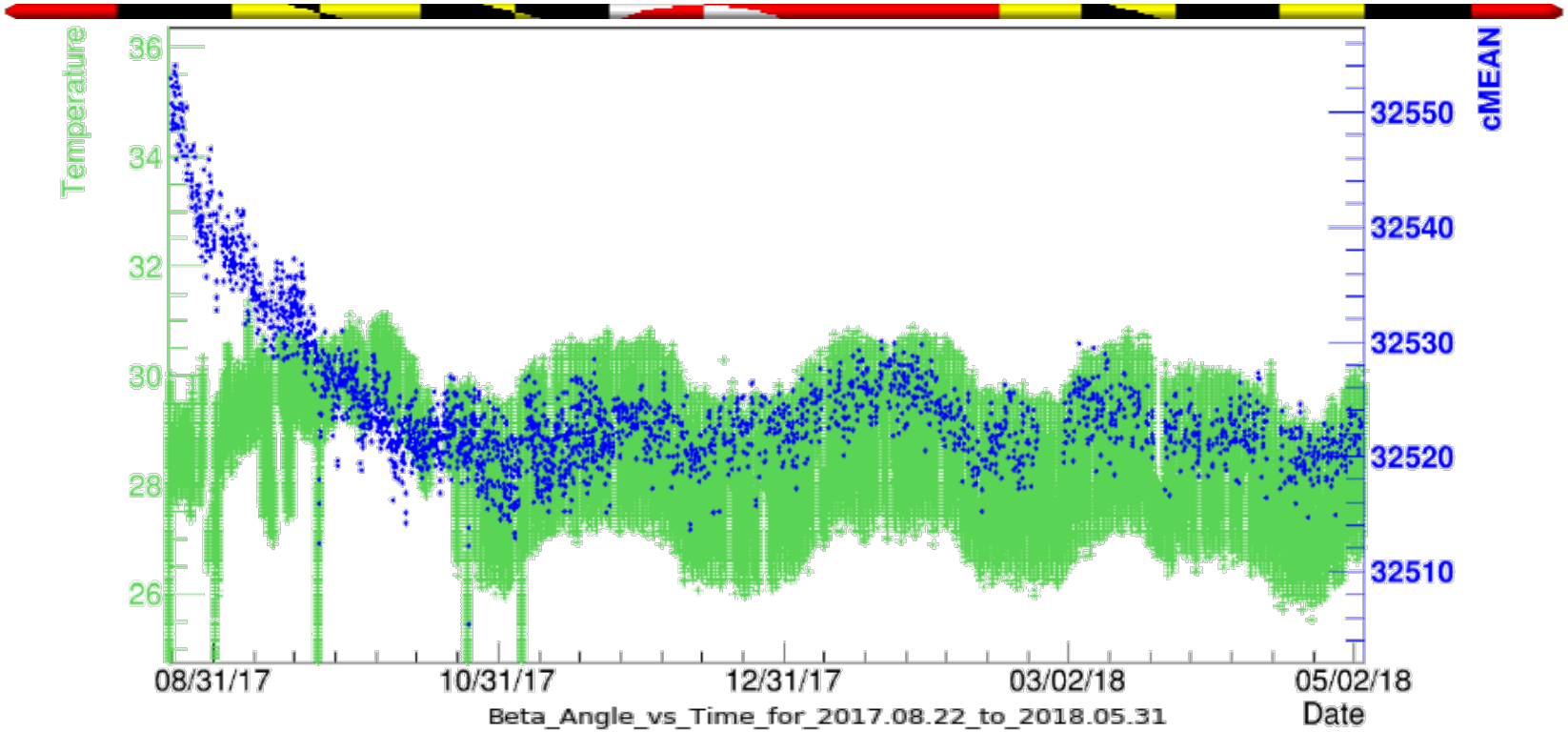
CAL pedestal reached a plateau in November 2017

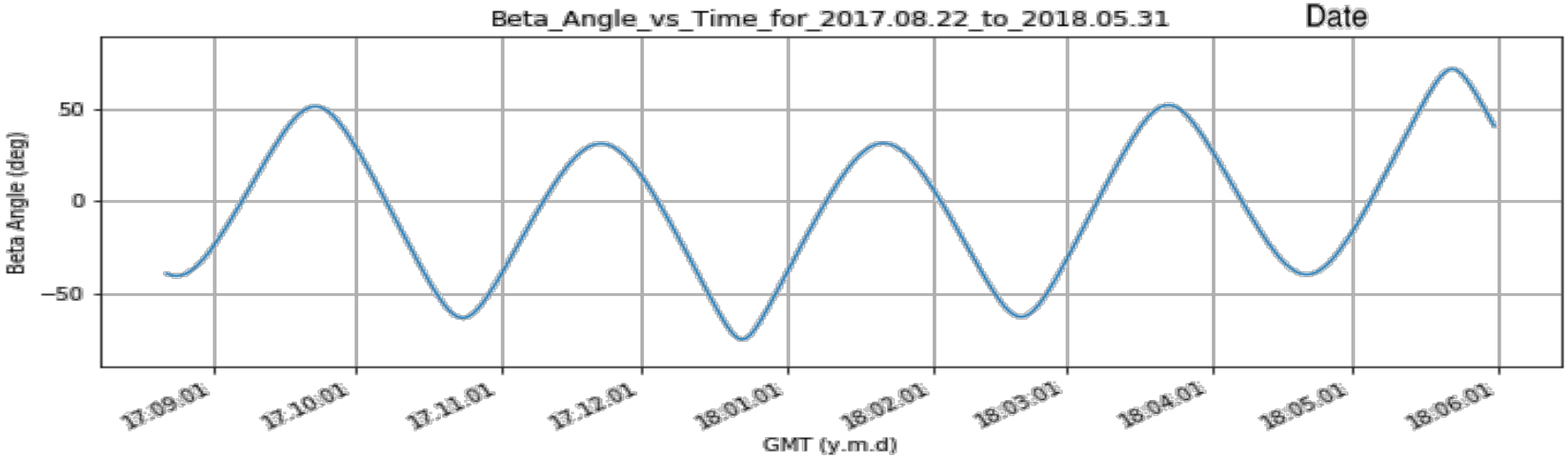




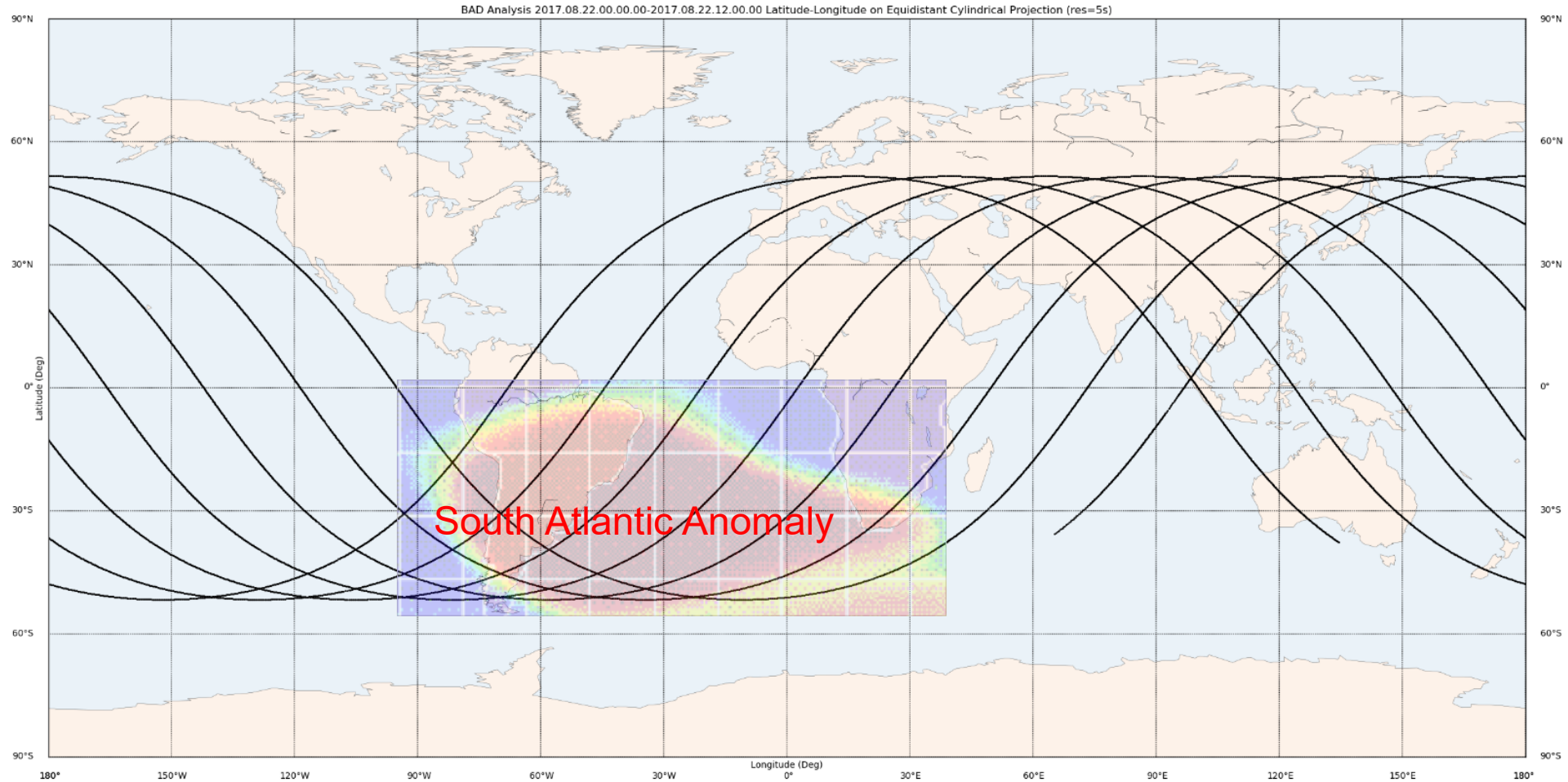


Temperature Dependence





ISS orbit and SAA



- August 2017 – August 2018: Instrument on only during non-SAA orbit to avoid potential radiation damage
- September 2018 – February 2019: Instrument on continuously

Summary

- The ISS-CREAM payload survived the launch and was safely placed on the ISS without any damage that precludes minimum success
- The science operation was nominal
  - Science data were received at the Science Operation Center and commands were successfully sent to the payload
- The instrument was functional and met minimum success criteria
- The preliminary analysis shows PeV energy scale cosmic ray events
- The preliminary analysis indicates a significant amount of helium nuclei in 10^{13} – 10^{15} eV
- Results will be quantified as the data analysis matures