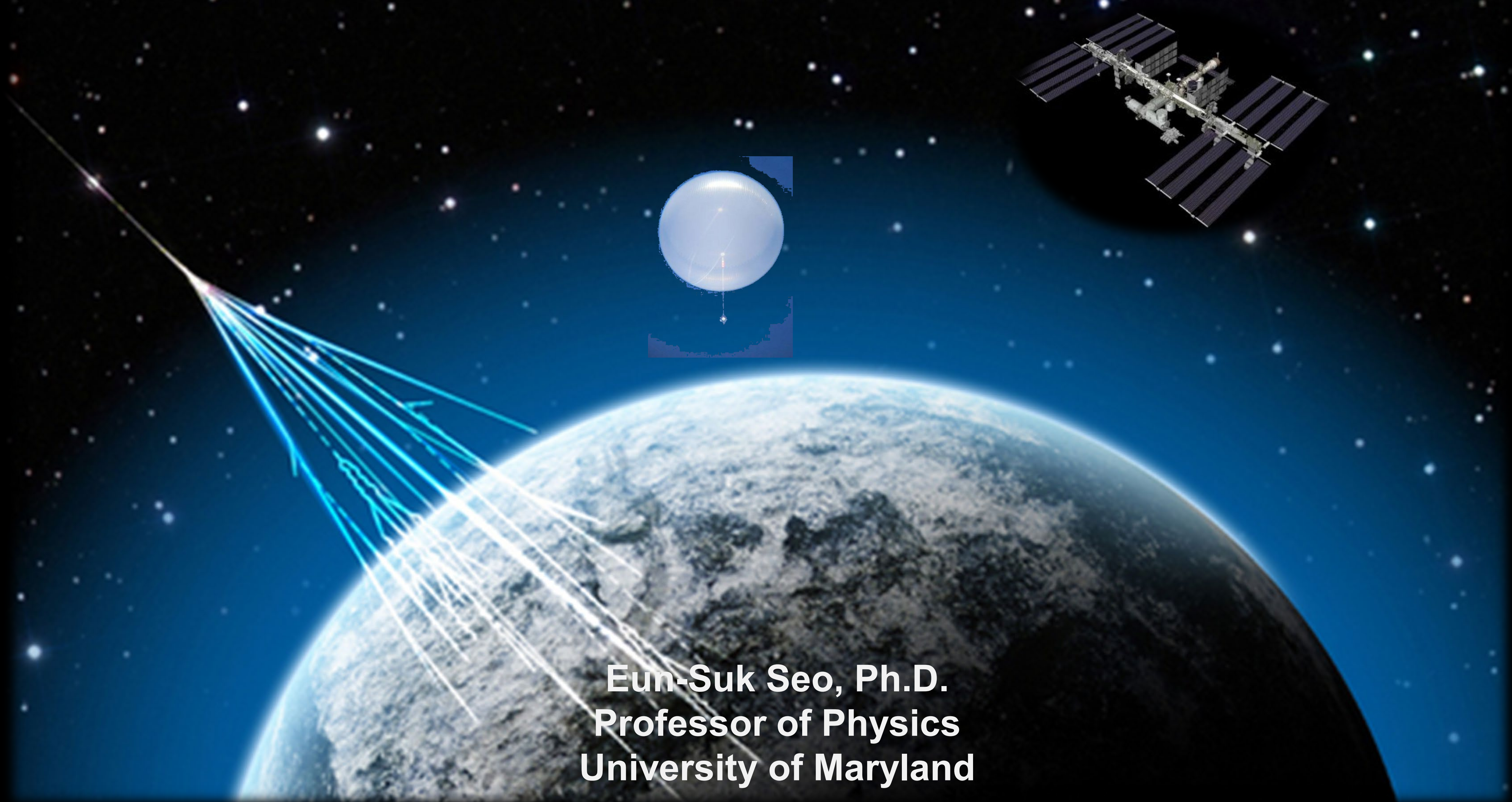
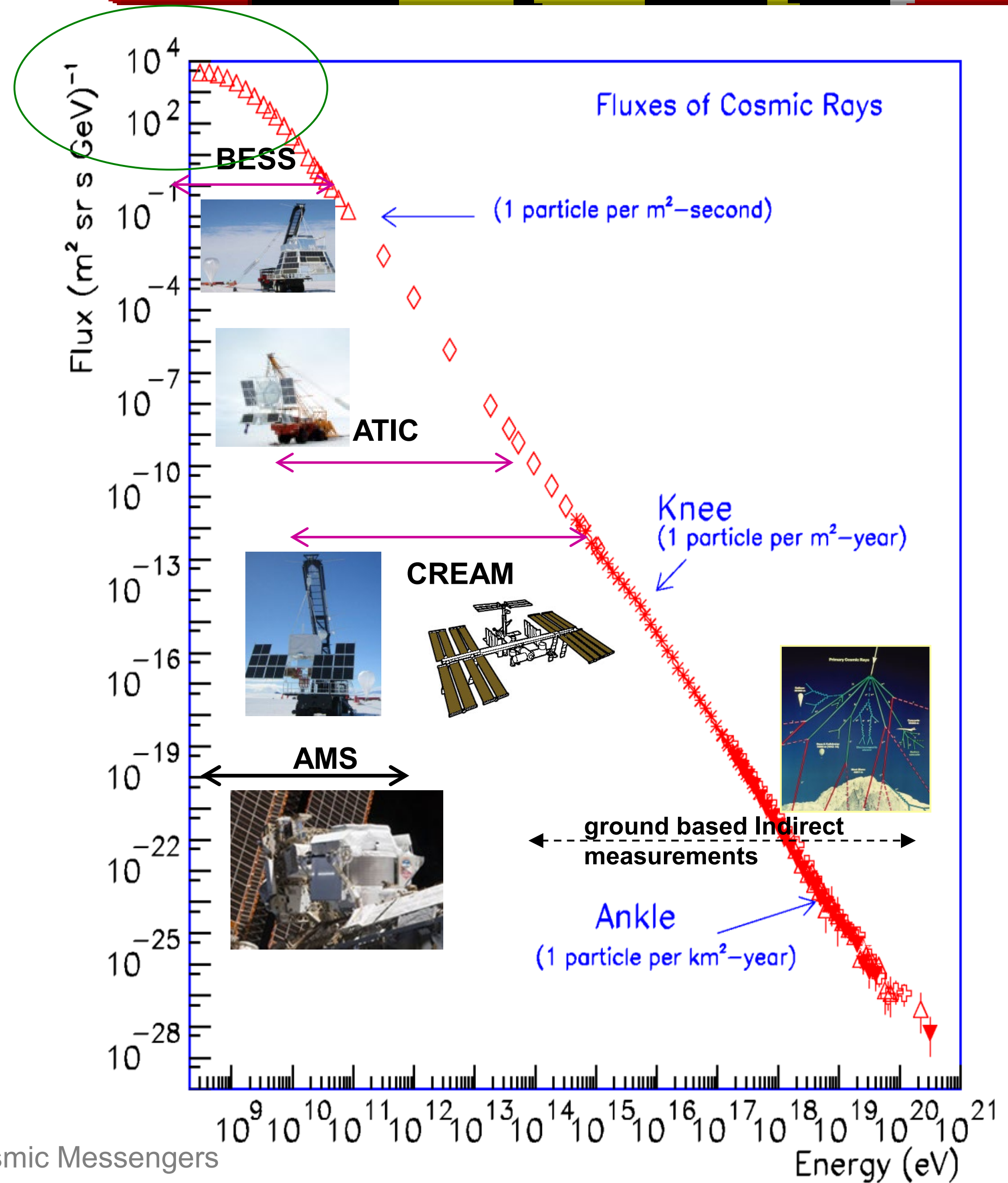
Advancing High Energy Physics in Korea: A Tribute to Sunk Kee Kim's Legacy

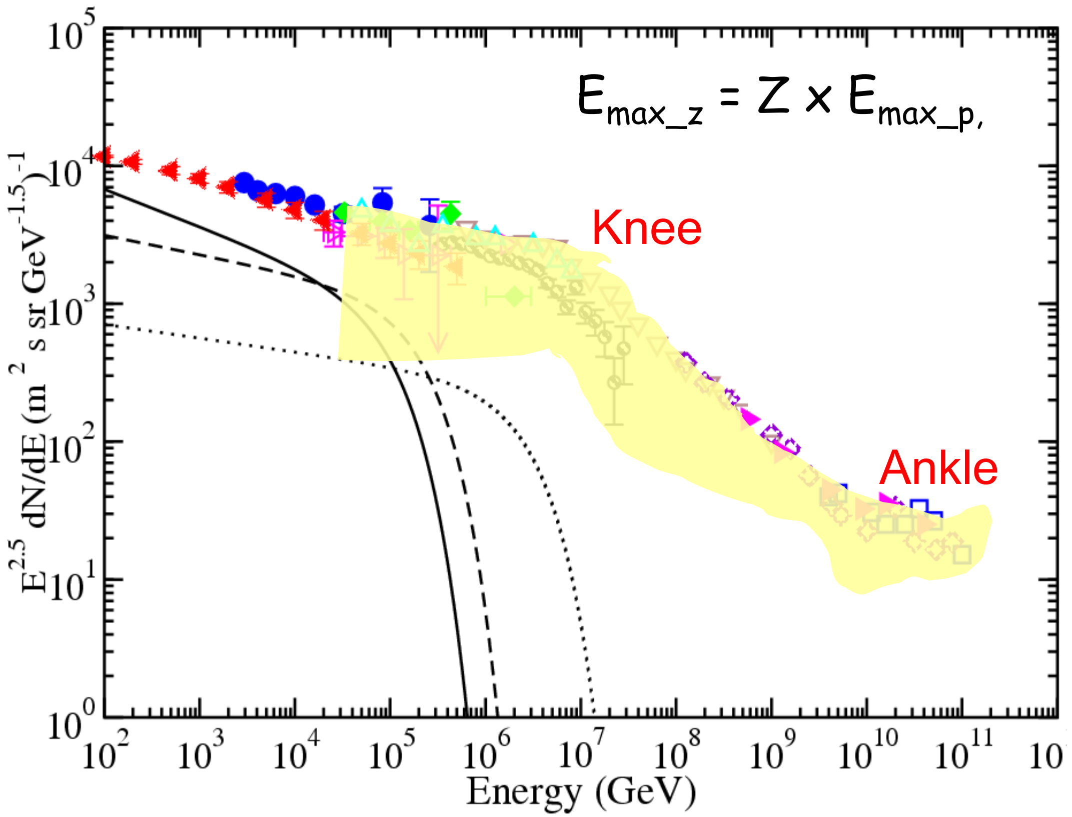
Chasing Cosmic Messengers: From ATIC to CREAM and Beyond



Eun-Suk Seo, Ph.D.
Professor of Physics
University of Maryland

How do cosmic accelerators work?



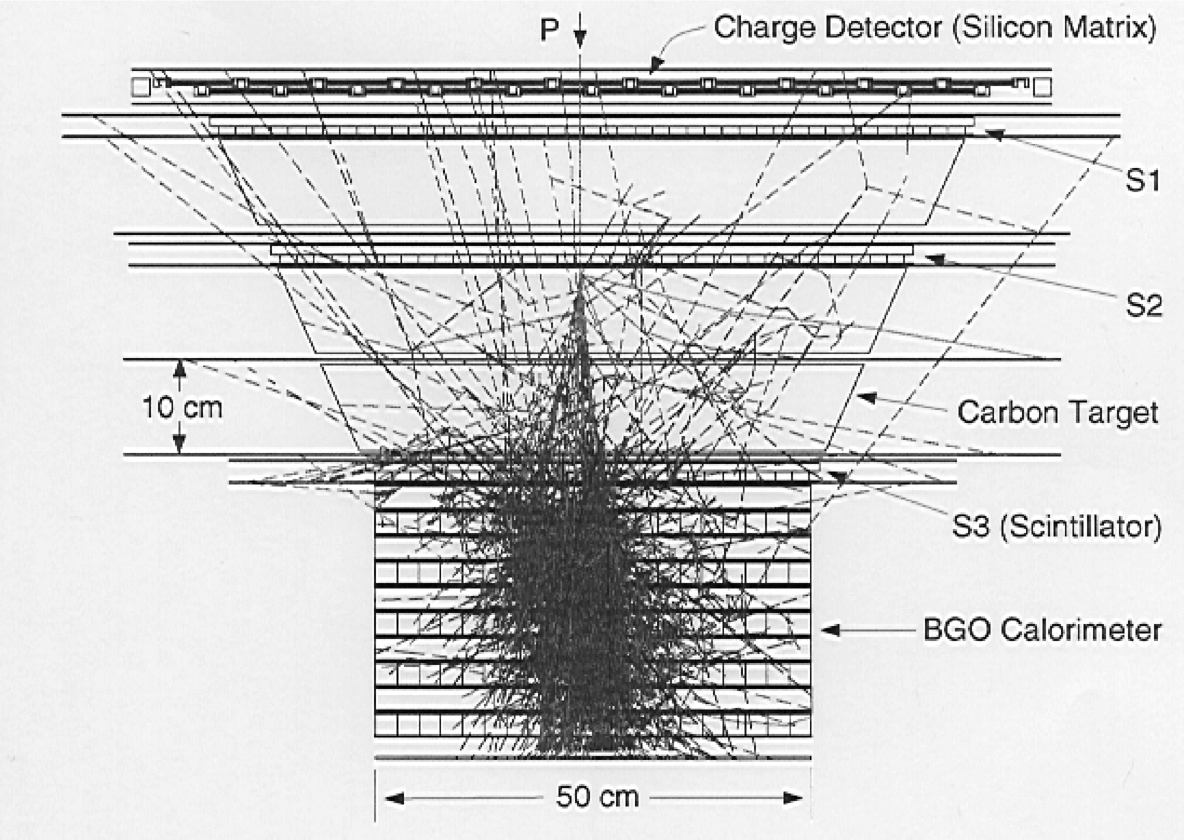


Mission Goal

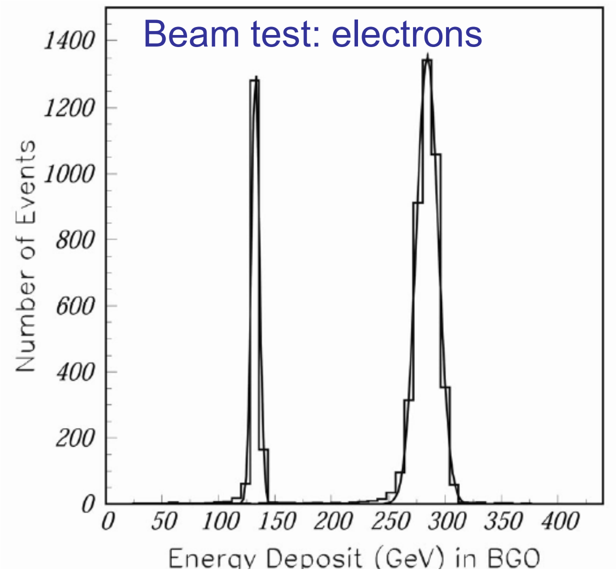
Extend the energy reach of direct measurements of cosmic rays to the highest energy possible to investigate cosmic ray origins, acceleration and propagation.

ATIC Advanced Thin Ionization Calorimeter

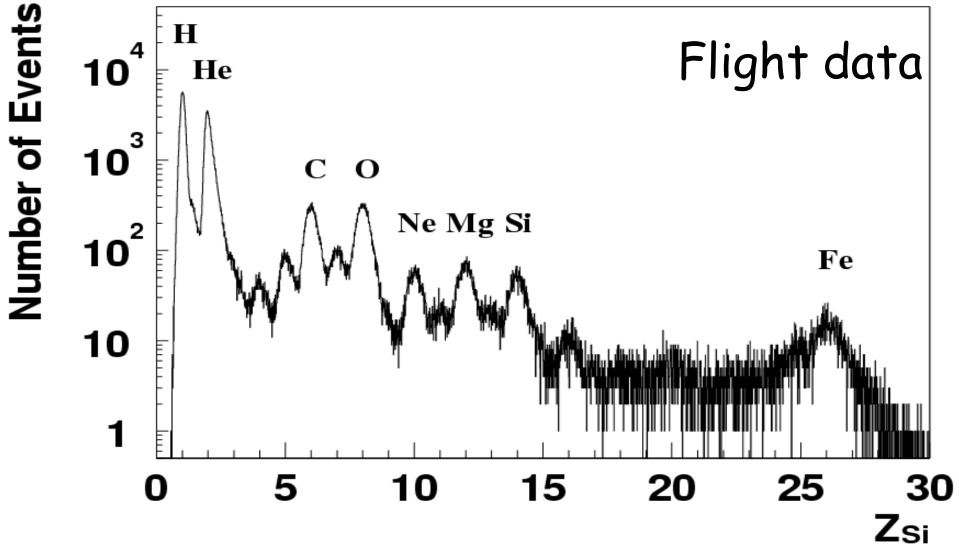
- Seo presents "A Proposal to Measure Cosmic Ray Composition and Energy Spectra at the Knee" at the Korean Physical Society meeting, Kyungjoo, Korea, Oct. 21, 1994.
- "The Advanced Thin Ionization Calorimeter (ATIC) Experiment: Expected Performance," E. S. Seo, ...S. K. Kim, …C. S. Park, Proc. SPIE Int. Symp. on Opt. Sci. Eng. Instrum., 2806, 134-144, 1996.



ATIC beam test



~2% energy resolution

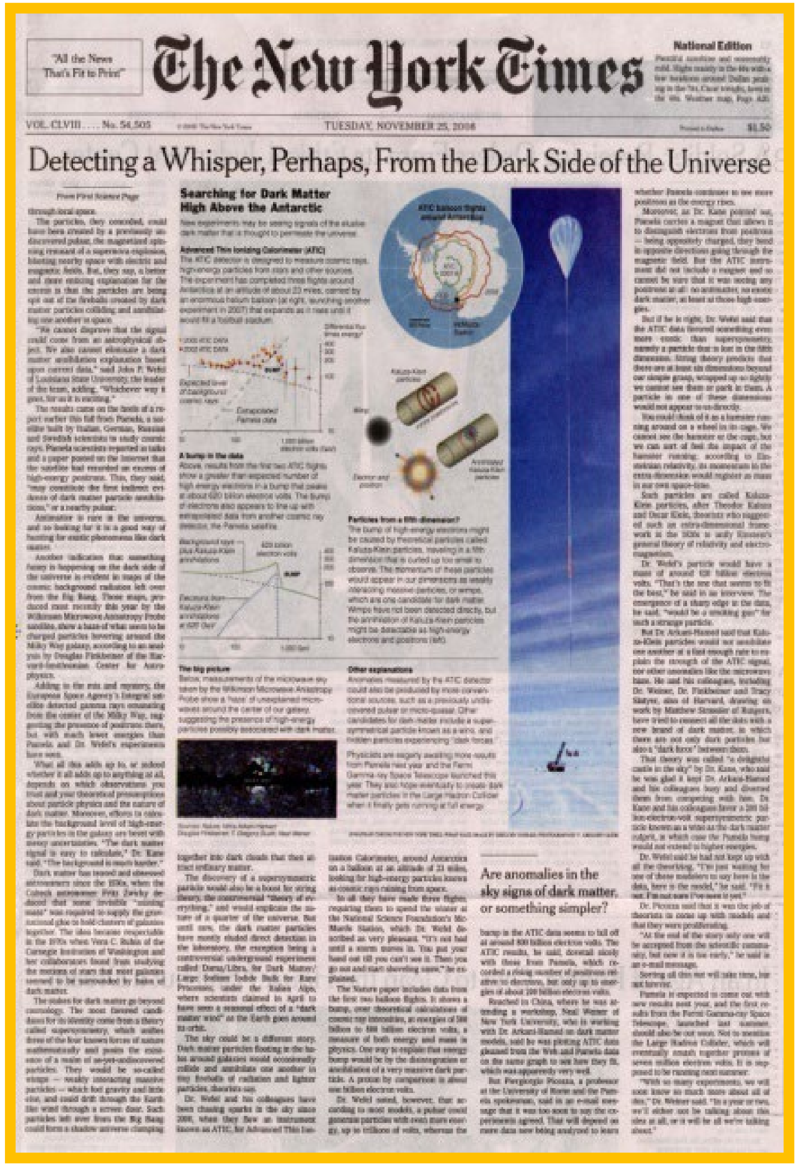


Flight data

CERN 1999

ATIC discovers mysterious excess of high energy electrons

Chang et al., Nature, **456**, 362-365 (2008)



nature International weekly journal of science

Cited > 200 times in ~ 9 mo

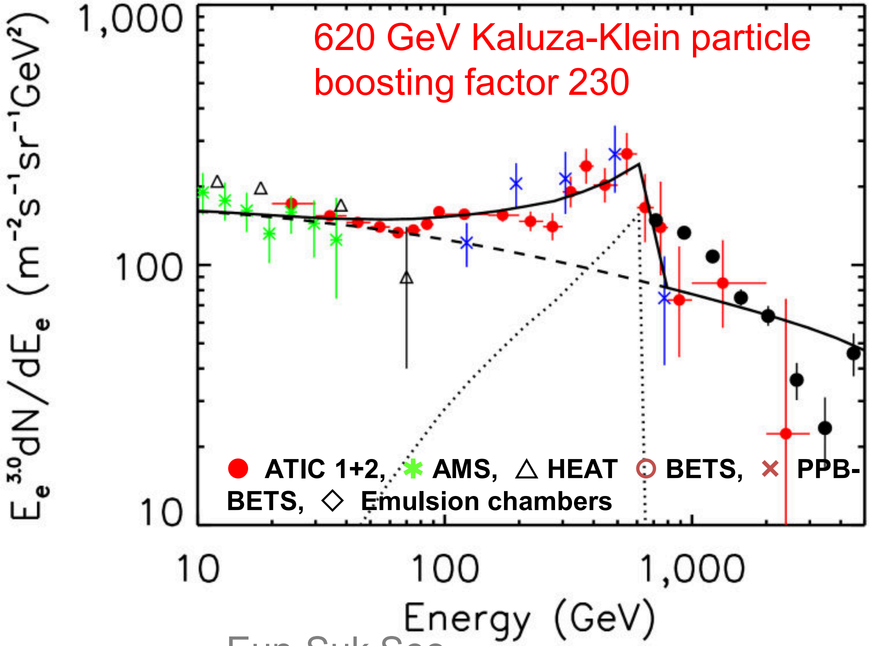
Letter

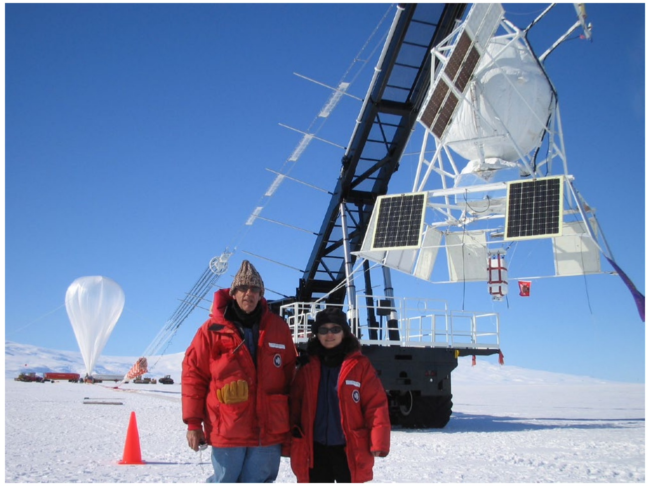
Nature **456**, 362-365 (20 November 2008) | doi:10.1038/nature07477; Received 23 May 2008; Accepted 1 October 2008

An excess of cosmic ray electrons at energies of 300–800 GeV

J. Chang[1,2], J. H. Adams[3], H. S. Ahn[4], G. L. Bashindzhagyan[5], M. Christl[3], O. Ganel[4], T. G. Guzik[6], J. Isbert[6], K. C. Kim[4], E. N. Kuznetsov[5], M. I. Panasyuk[5], A. D. Panov[5], W. K. H. Schmidt[2], E. S. Seo[4], N. V. Sokolskaya[5], J. W. Watts[3], J. P. Wefel[6], J. Wu[4] & V. I. Zatsepin[5]

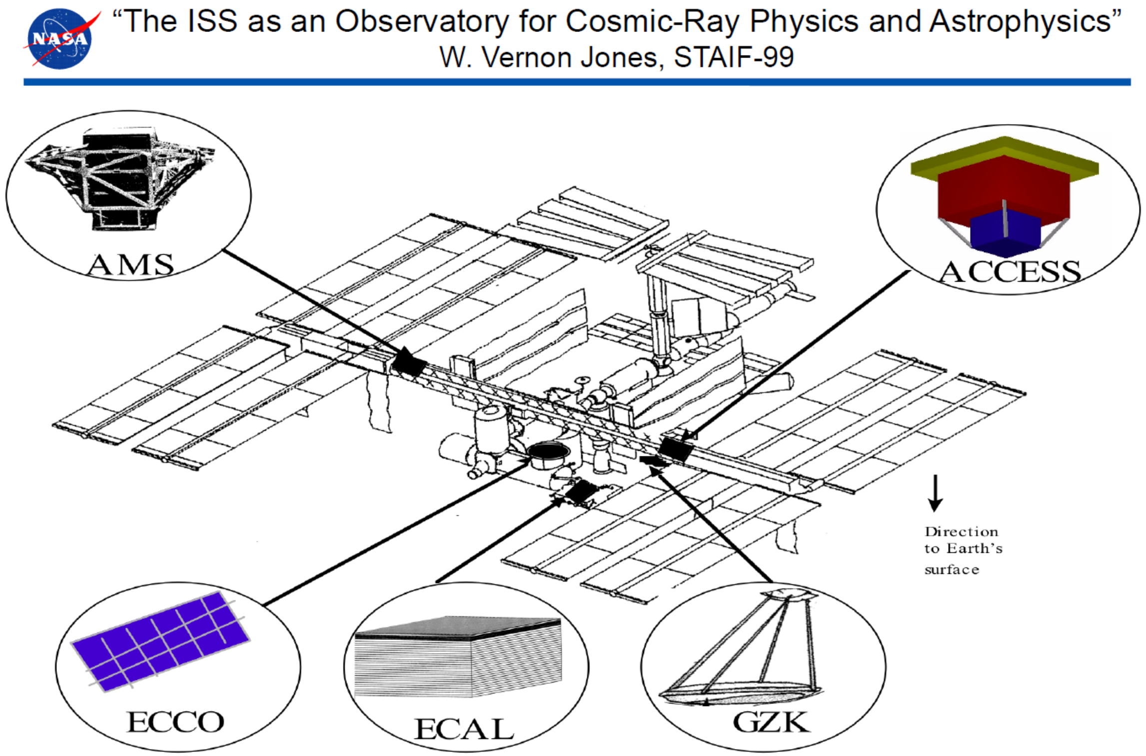
1. Purple Mountain Observatory, CAS, 2 West Beijing Road, Nanjing 210008, China
2. Max Planck Institute for Solar System Research, 2 Max Planck-Strasse, Katlenburg-Lindau 37191, Germany
3. Marshall Space Flight Center, Huntsville, Alabama 35812, USA
4. University of Maryland, Institute for Physical Science & Technology, College Park, Maryland 20742, USA
5. Skobeltsyn Institute of Nuclear Physics, Moscow State University, Leninskie gory, GSP1, Moscow 119991, Russia
6. Louisiana State University, Department of Physics and Astronomy, Baton Rouge, Louisiana 70803, USA





US–Korea Collaboration & ISS Utilization

- NASA-Korea Investigators Consultative Group (ICG) 1997 - 2002
- ACCESS Investigators Working Group (IWG) 1998 - 2001

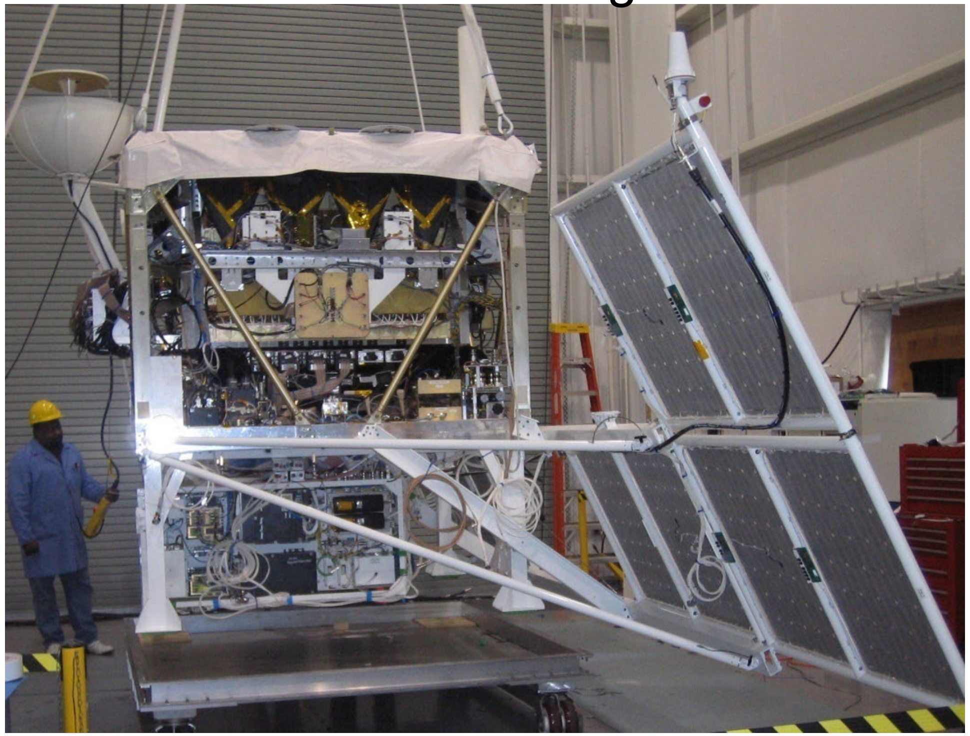


CREAM

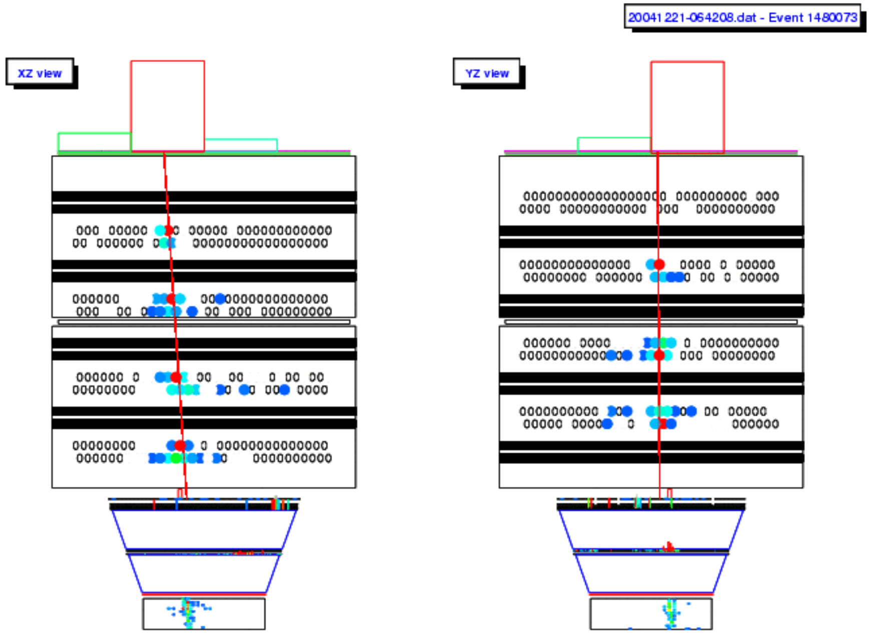
Cosmic Ray Energetics And Mass

Seo et al. Adv. in Space Res., **33** (10), *1777*, 2004

- Transition Radiation Detector (TRD) and Tungsten Scintillating Fiber Calorimeter
  - In-flight cross-calibration of energy scales
- Complementary Charge Measurements
  - Timing-Based Charge Detector
  - Cherenkov Counter
  - Pixelated Silicon Charge Detector

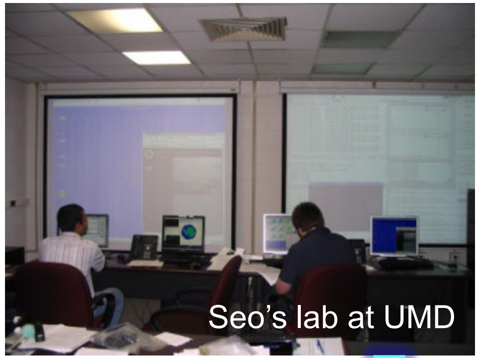


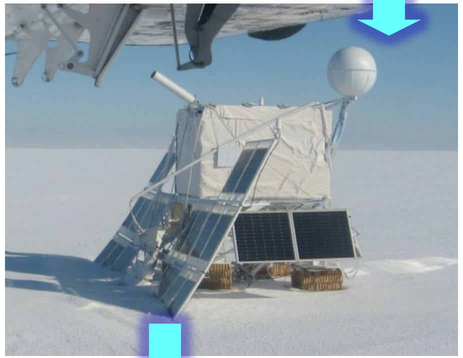
- The CREAM instrument had seven successful Long Duration Balloon (LDB) flights over Antarctica and **accumulated 191 days** of data.
  - This longest known exposure for a single balloon project verifies the instrument design and reliability.



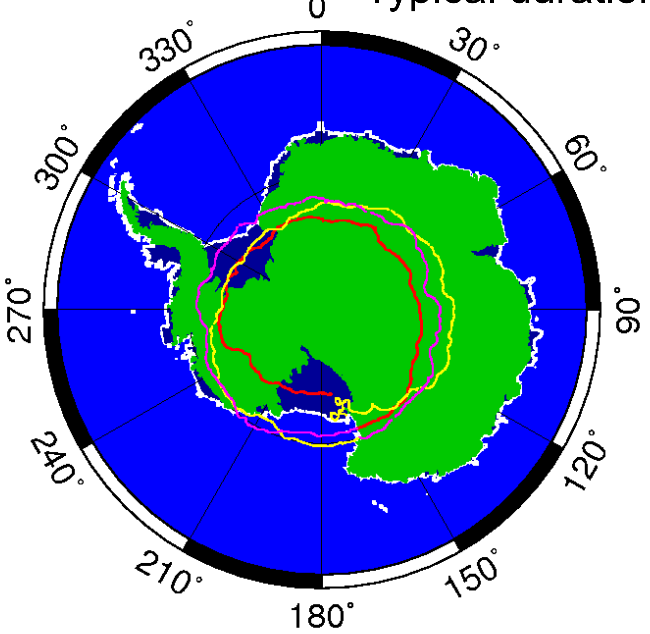
CREAM Cosmic Ray Energetics And Mass

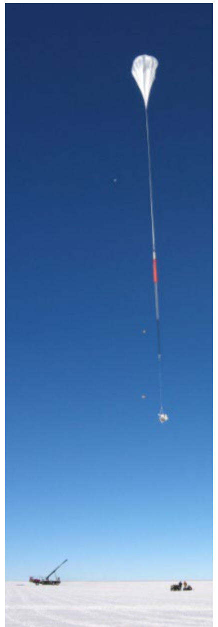
Seo et al. Adv. in Space Res., **33** (10), *1777*, 2004





Typical duration: ~1 month/flight



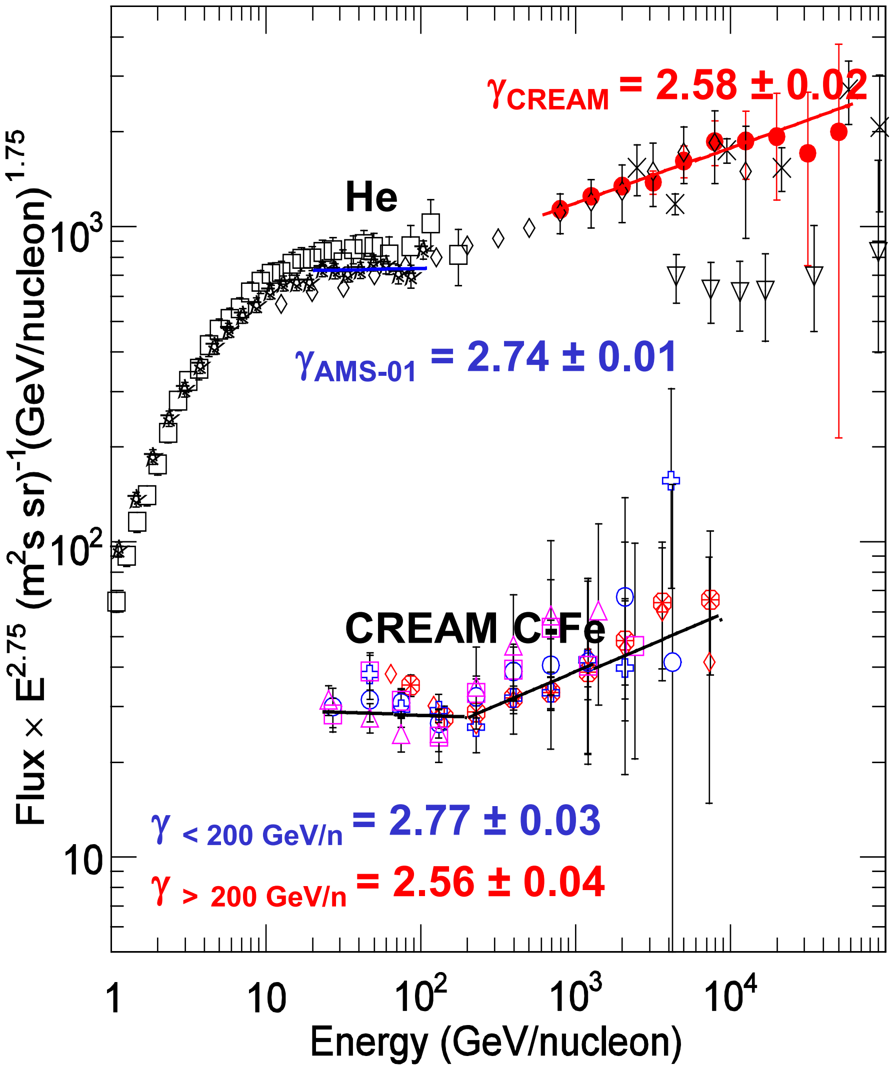


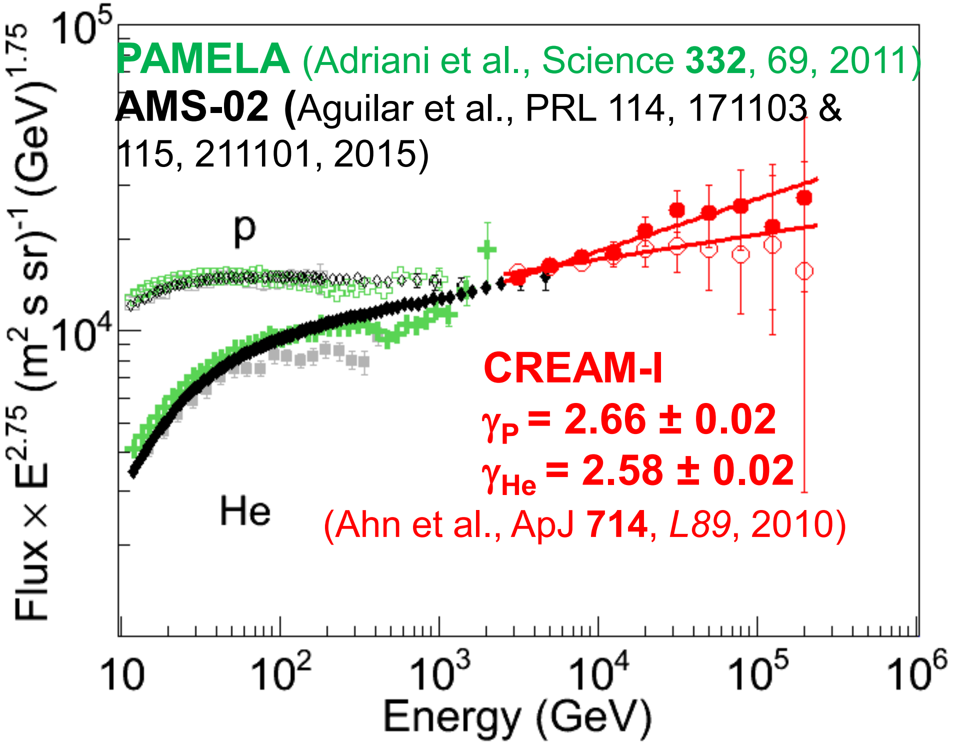
- The CREAM instrument had seven successful Long Duration Balloon (LDB) flights over Antarctica and accumulated 191 days of data.
- This longest known exposure for a single balloon project verifies the instrument design and reliability.

Instruments are fully recovered, refurbished & reflown.

Discrepant hardening

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



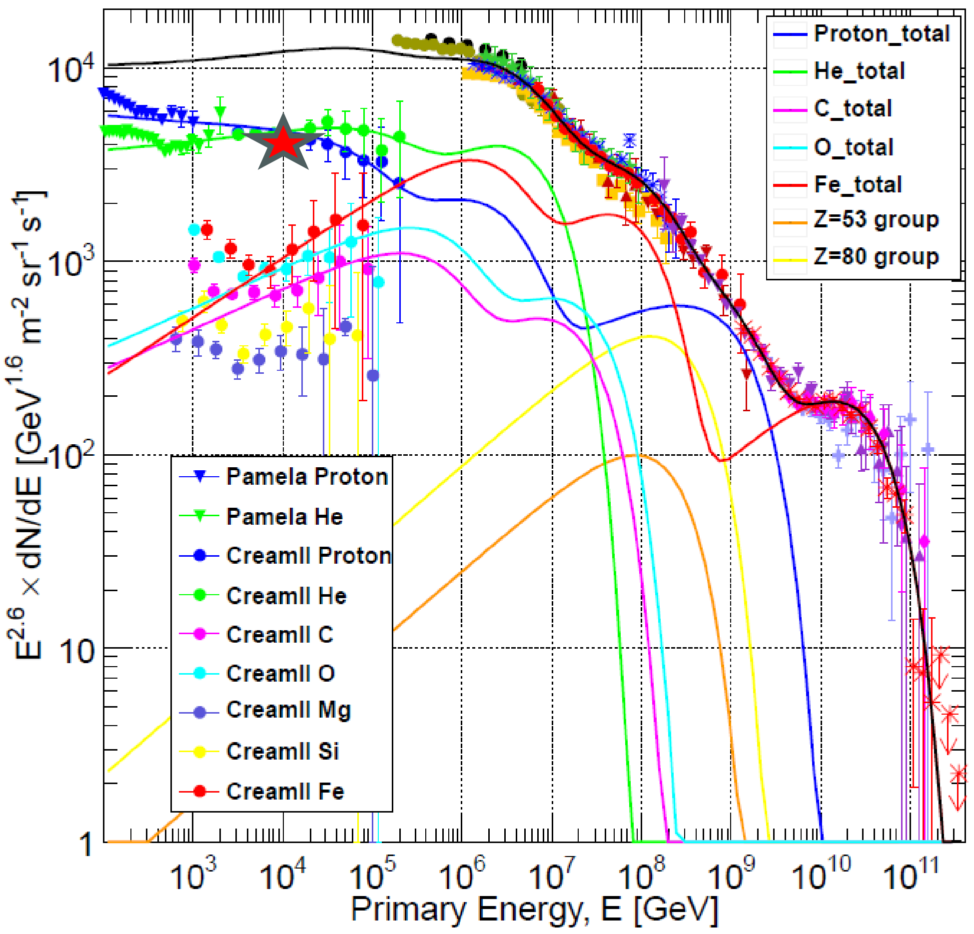


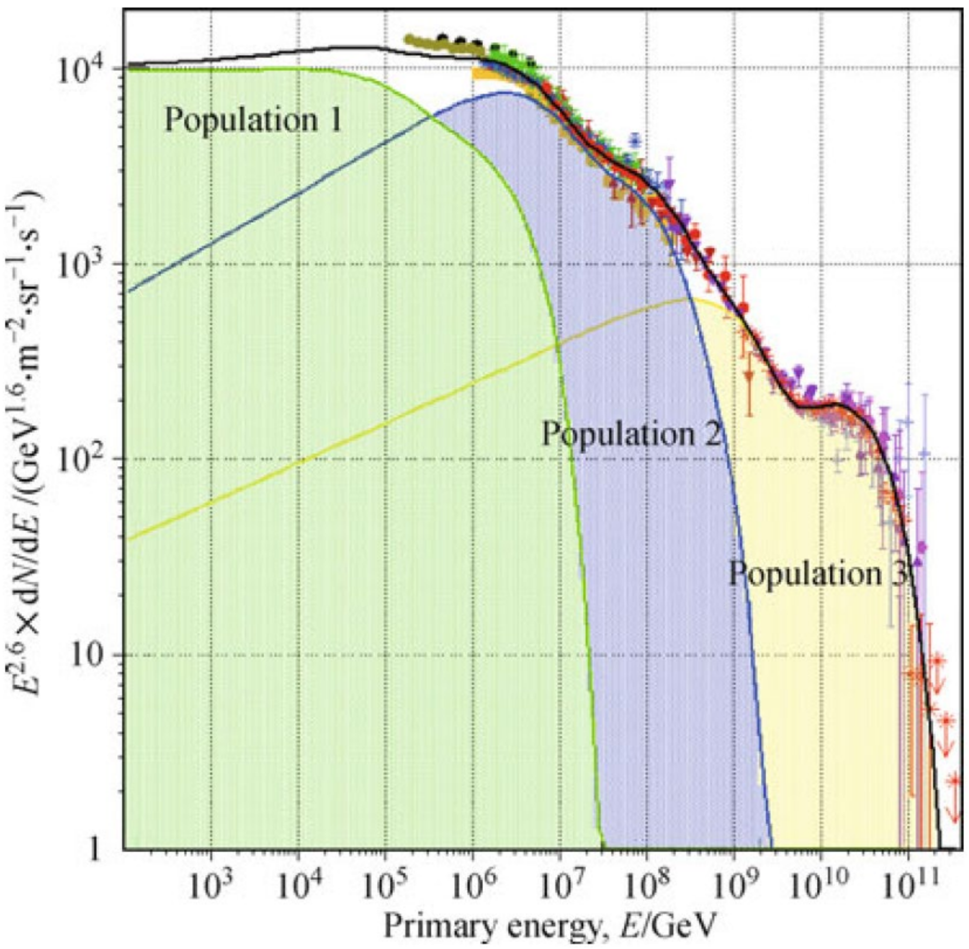
It provides important constraints on cosmic ray acceleration and propagation models, and it must be accounted for in explanations of the e^+e^- anomaly and cosmic ray "knee."

CREAM data to explain the knee and beyond

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

Acceleration limit: $E_{max\_z} = Z \times E_{max\_p}$,



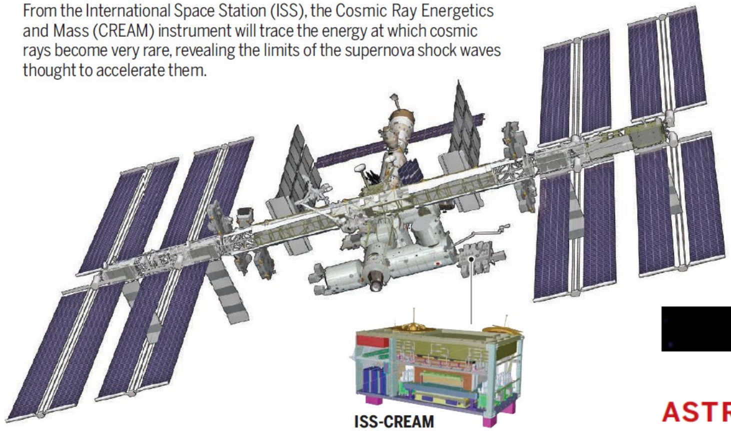


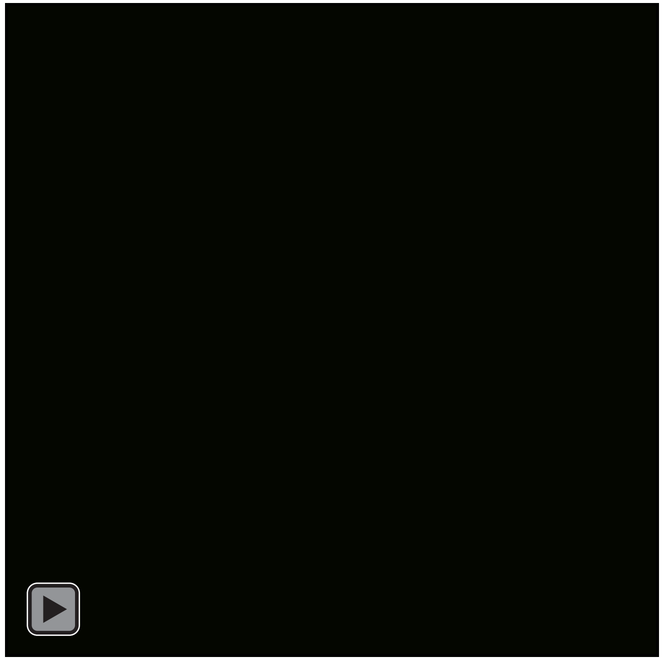
ISS-CREAM: CREAM for the ISS

SpaceX-12 Launch on 8/14/2017

Aiming high

From the International Space Station (ISS), the Cosmic Ray Energetics and Mass (CREAM) instrument will trace the energy at which cosmic rays become very rare, revealing the limits of the supernova shock waves thought to accelerate them.





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

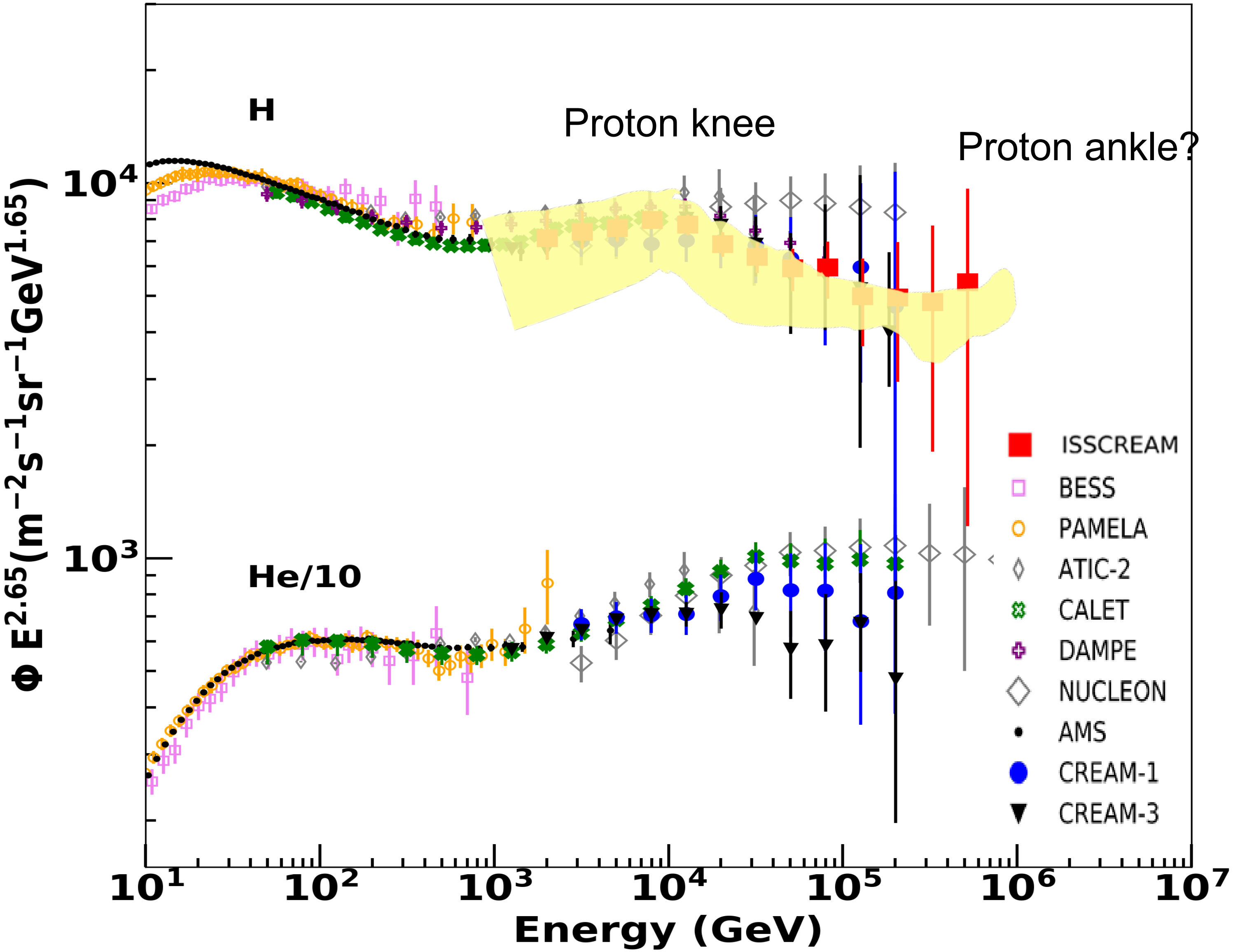
By **Eric Hand**

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

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,

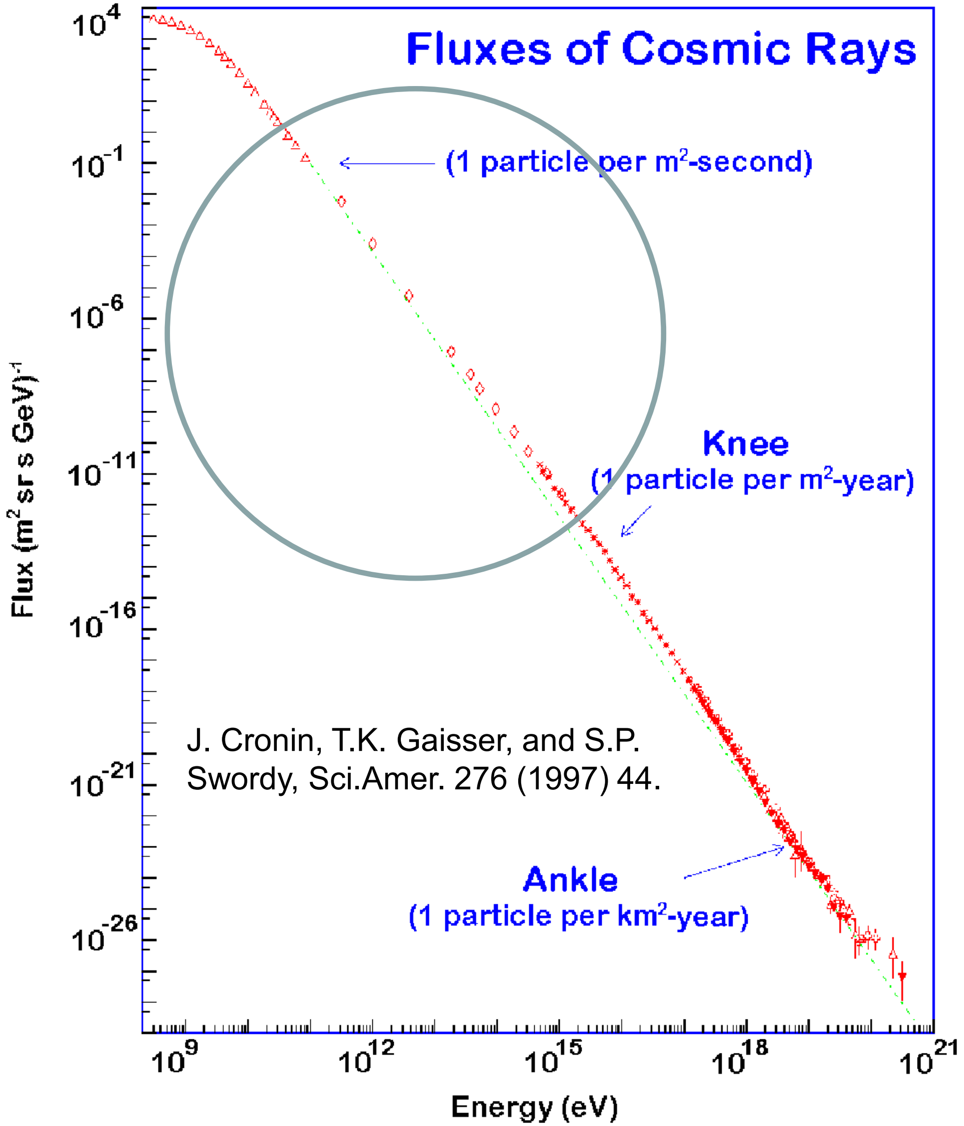
ISS-CREAM Proton Spectrum (2.5 – 655 TeV)

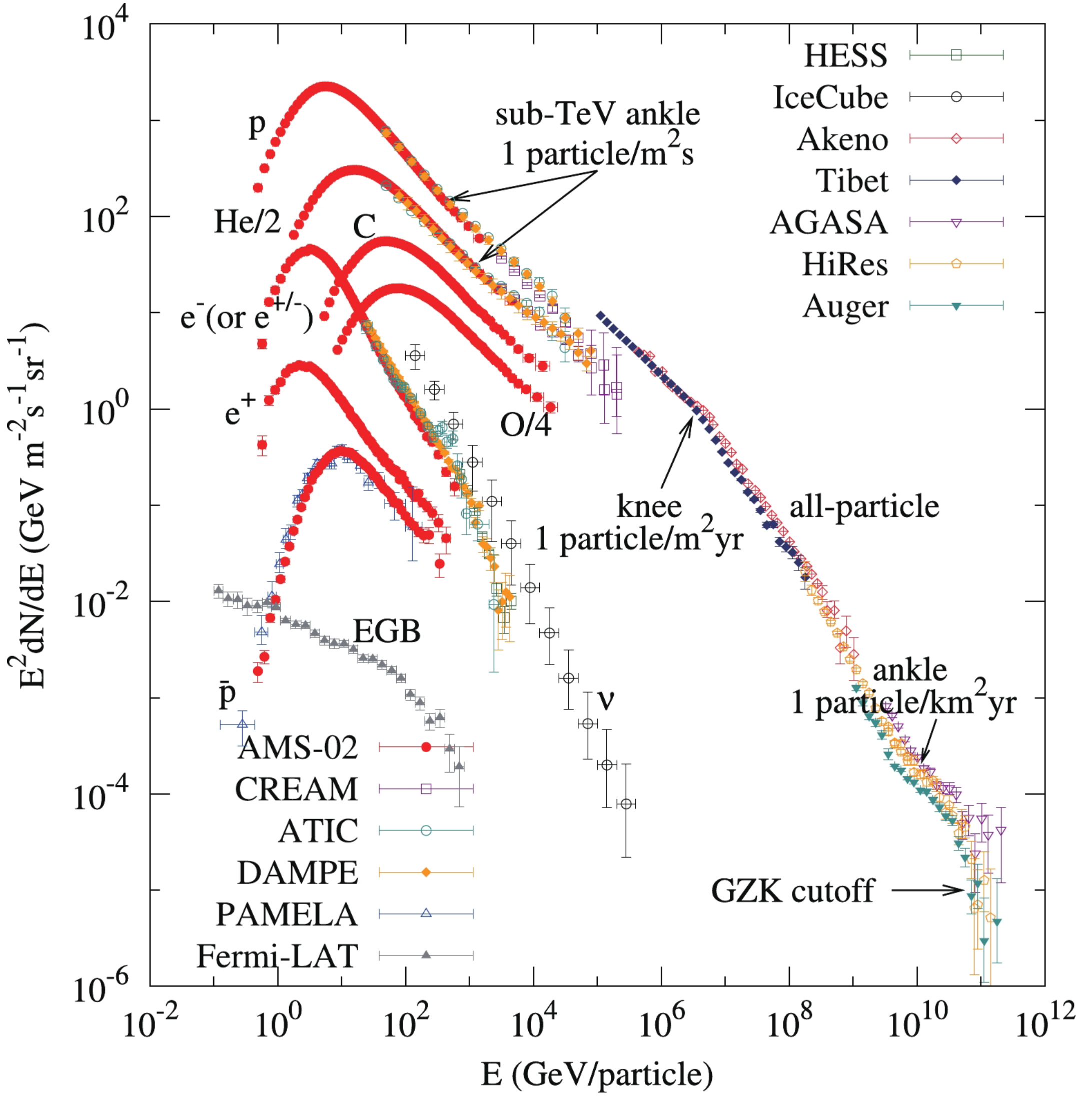
G. H. Choi & E. S. Seo et al. (ISS-CREAM Collaboration) ApJ 940/107, 2022



- A broken power law fit to 2.5 – 164 TeV data: $\gamma = 2.57 \pm 0.03$ and a break at 9.0 ± 1.3 TeV with $\Delta\gamma = 0.25 \pm 0.05$.
- At higher energies, the softening does not continue.
- The deviation from a single power law near 10 TeV is consistent with the softening reported by CREAM-I &III, DAMPE, NUCLEON, and CALET, but ISS-CREAM extends measurements to higher energies than those prior measurements.

Recent experiments fill the data gap





S. Liu et al., Ch. Phys. 46/3 (2022) 030004


Happy Retirement!
AMS-02
5/16/11
ISS-CREAM
8/14/17
DAMPE
12/17/15
NUCLEON
12/26/14
CALET
8/19/15