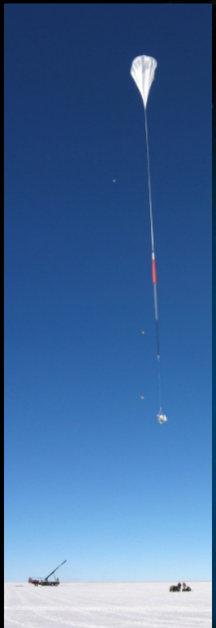
APS physics

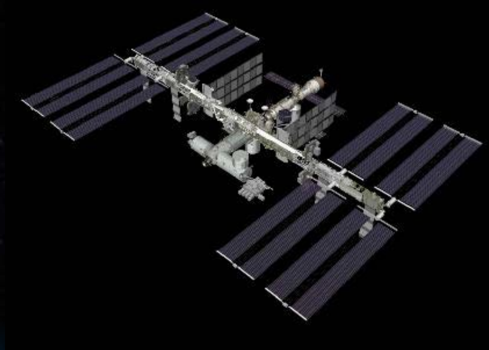
APRIL MEETING 2016

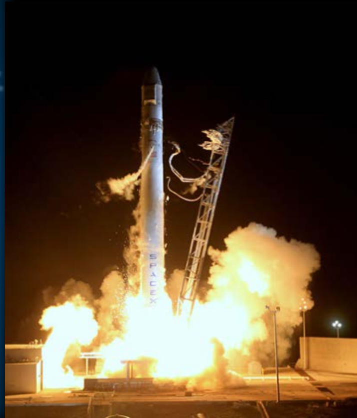
April 16 - 19
SALT LAKE CITY, UTAH

Space-based Cosmic Ray Astrophysics

Cosmic SIG







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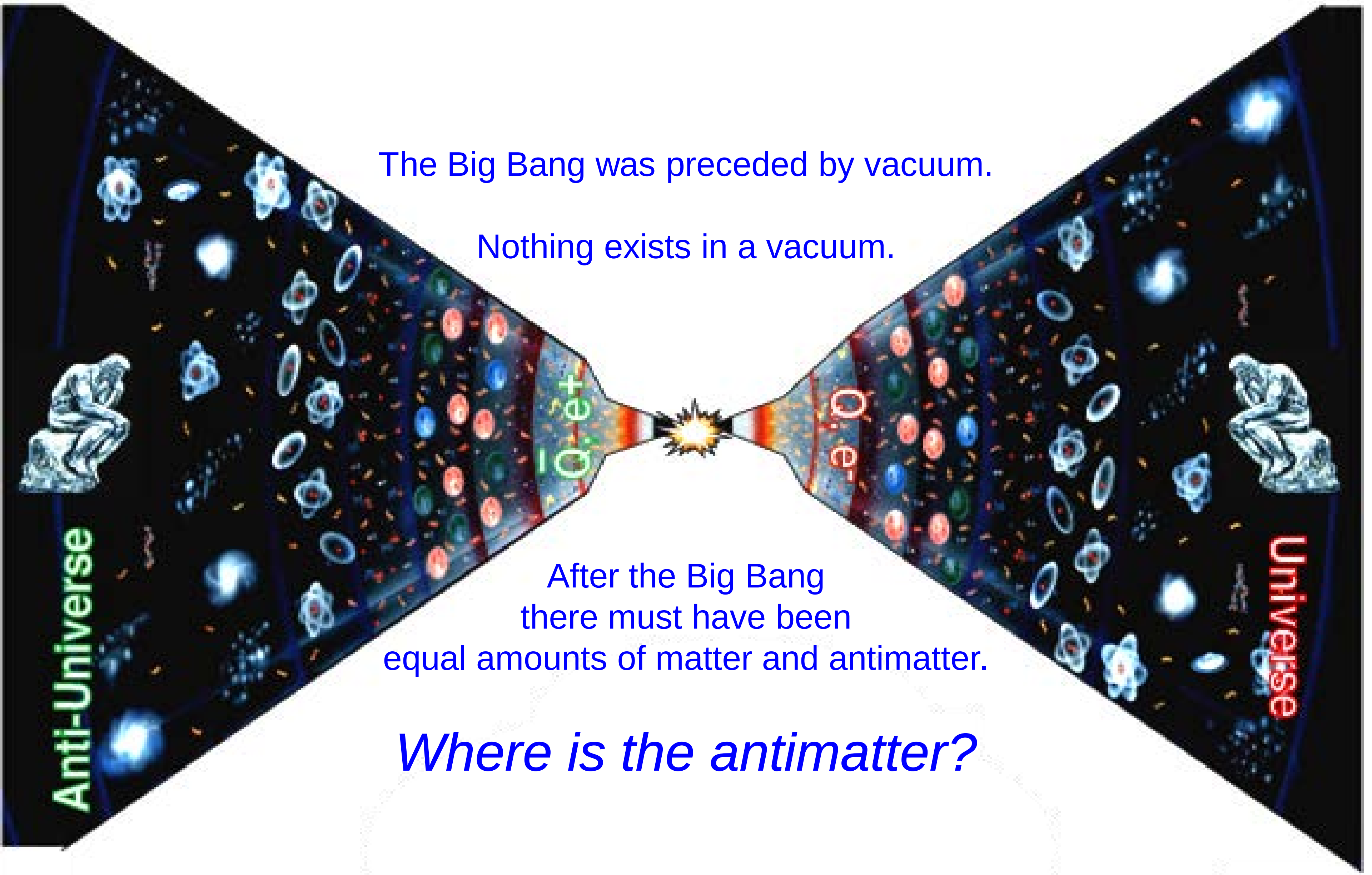
Cosmic Rays: Why Care?

- Highest-energy particles known to mankind
- Made in some of the most extreme environments of the Universe
- Energy density is comparable to thermal energies, magnetic fields

They influence
- evolution and shape of galaxies
- state of interstellar medium
- interstellar chemistry
- evolution of species on Earth
- and even the weather …

Search for Existence of Antimatter in the Universe



The Big Bang was preceded by vacuum.

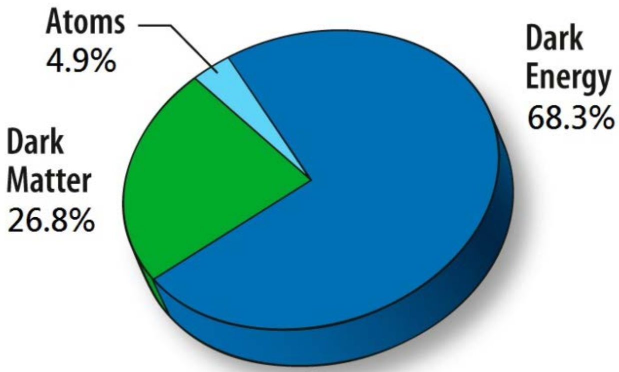
Nothing exists in a vacuum.

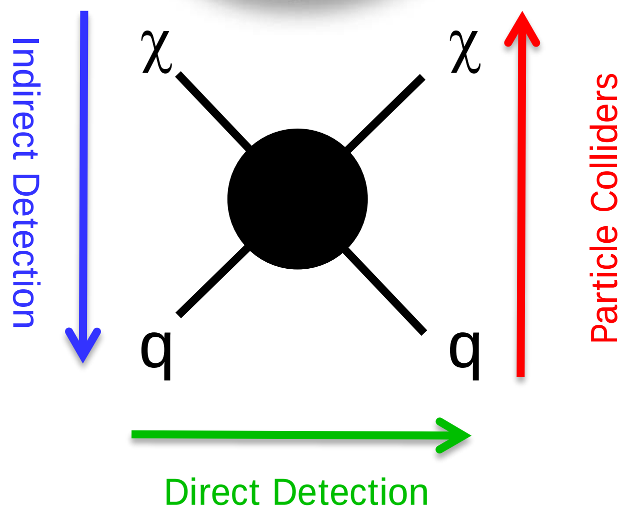
After the Big Bang
there must have been
equal amounts of matter and antimatter.

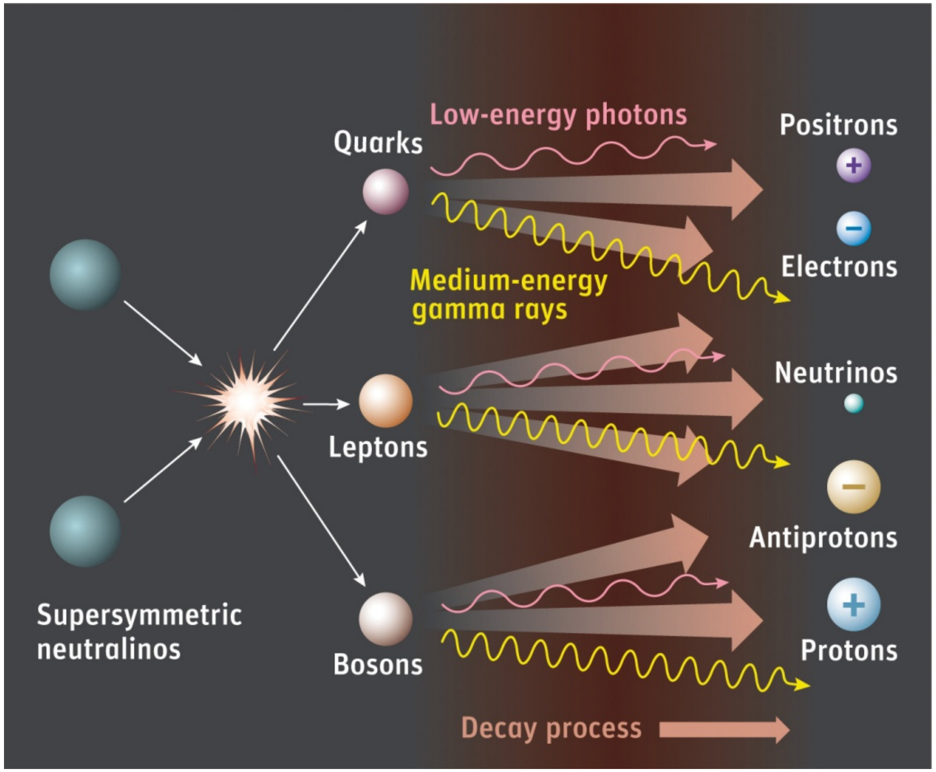
Where is the antimatter?

Search for Dark Matter

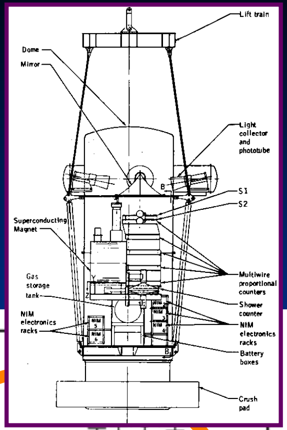
- Weakly Interacting Massive Particles (WIMPS) could comprise dark matter.
- This can be tested by direct search for various annihilating products of WIMP's in the Galactic halo.







Search for Antimatter & Dark Matter Novel Cosmic Origin



<u>1979:</u> <u>first observation of antiprotons</u>

(Golden et al,1979 , Bogomolov et al.1979)

1981: Anomalous excess (Buffington et al.)

1987: <u>LEAP</u>, PBAR

1988: *ASTROMAG proposal*

1989: <u>MASS</u>

1991: *ASTROMAG shelved*

1992: IMAX

1993: <u>BESS</u>, TS93

1994: CAPRICE, HEAT

1995: AMS proposal

1998: <u>AMS-01</u> (Discovery STS-91)

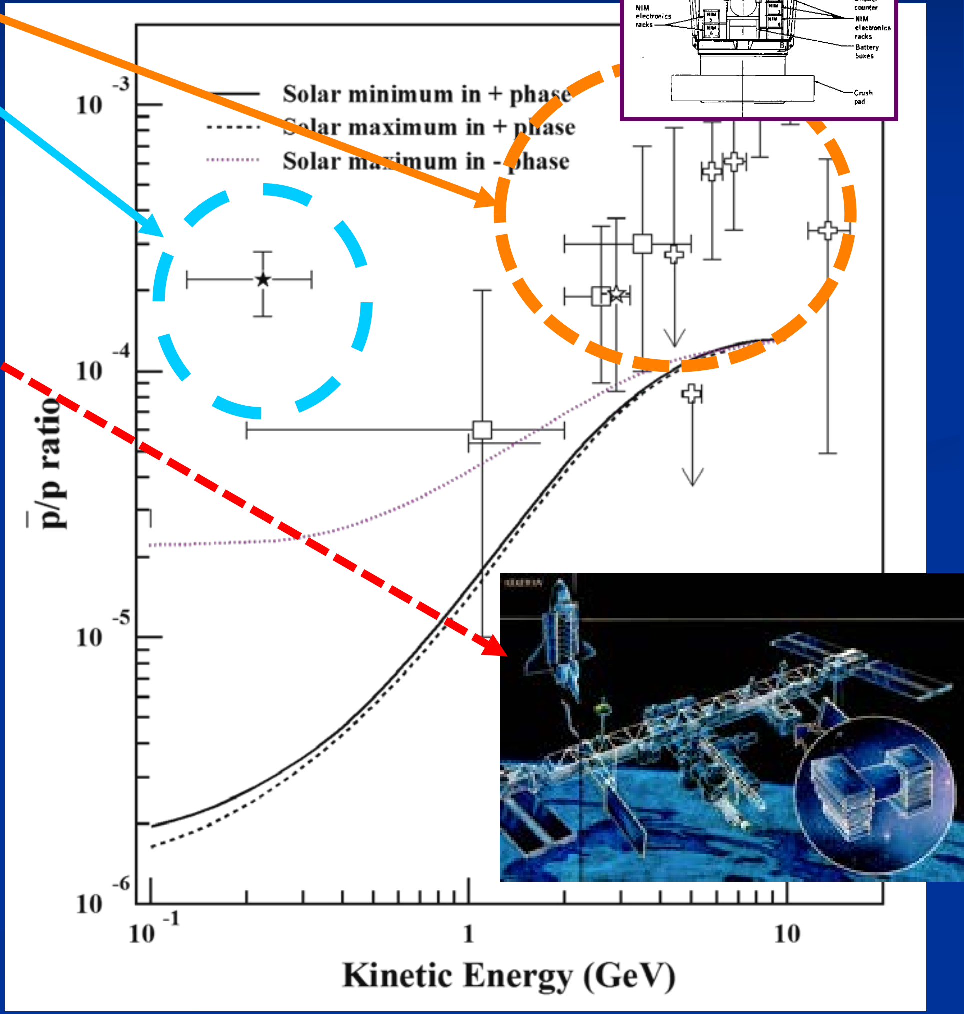
2000/2: Heat-pbar

2004: <u>BESS-Polar I</u>

2006-present PAMELA (Polar-orbit)

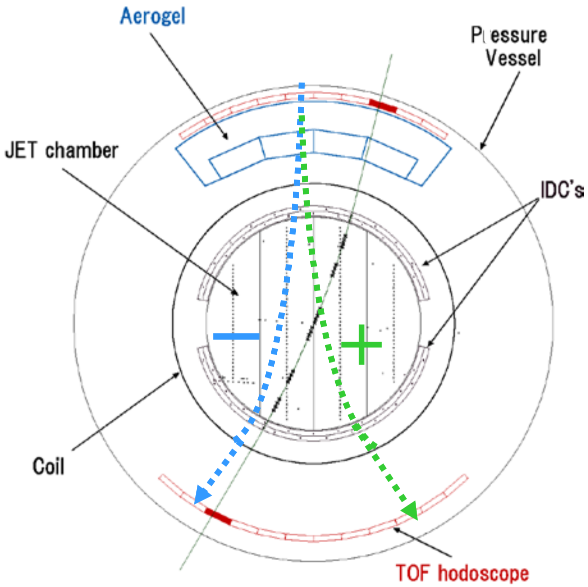
2007: <u>BESS-Polar II</u>

2011-present: <u>AMS-02</u> (Endeavour STS -134)

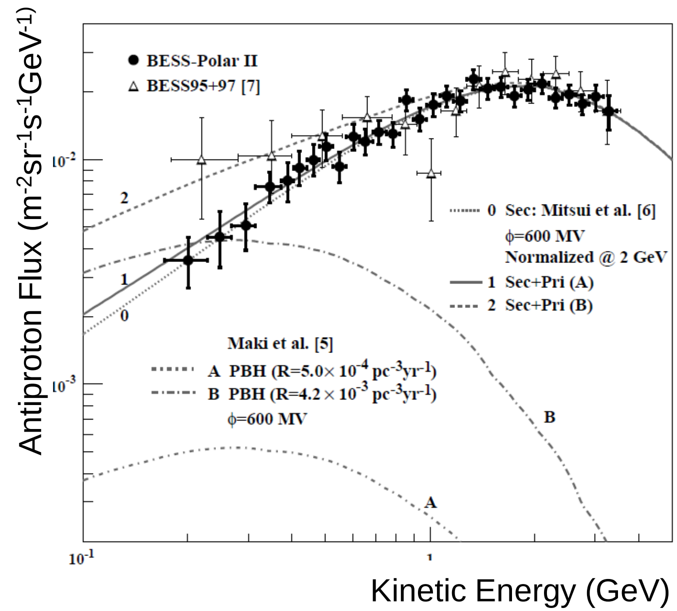


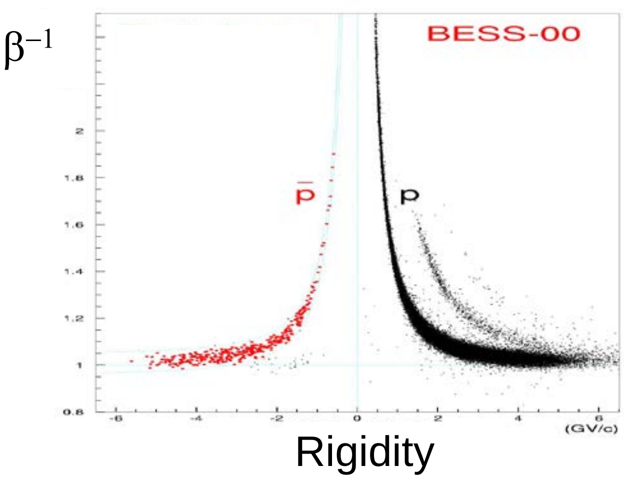
BESS-Polar

Balloon–borne Experiment with a Superconducting Spectrometer



Abe et al. PRL, 108, 051102, 2012





- Original BESS instrument was flown nine times between 1993 and 2002.
- New BESS-Polar instrument flew from Antarctica in 2004 and 2007
  - Polar-I: 8.5 days observation
  - Polar-II 24.5 day observation, 4700 M events

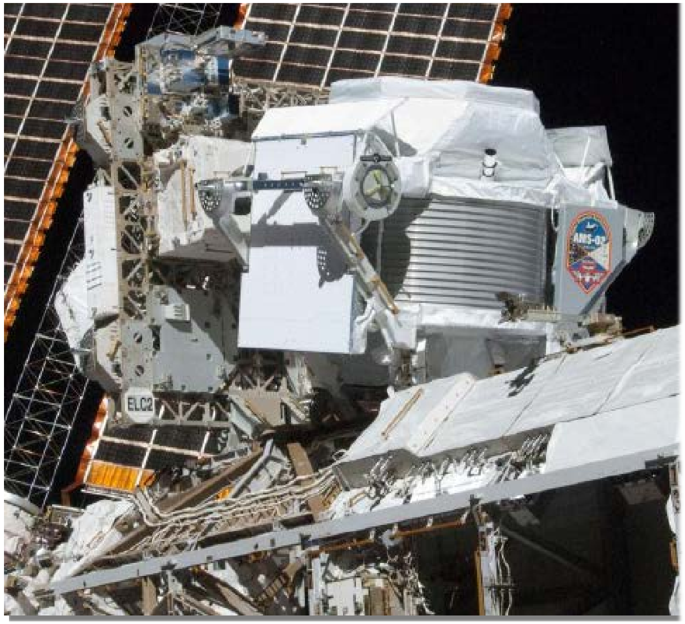
7886 antiprotons detected: **no evidence of primary antiprotons from evaporation of primordial black holes.**

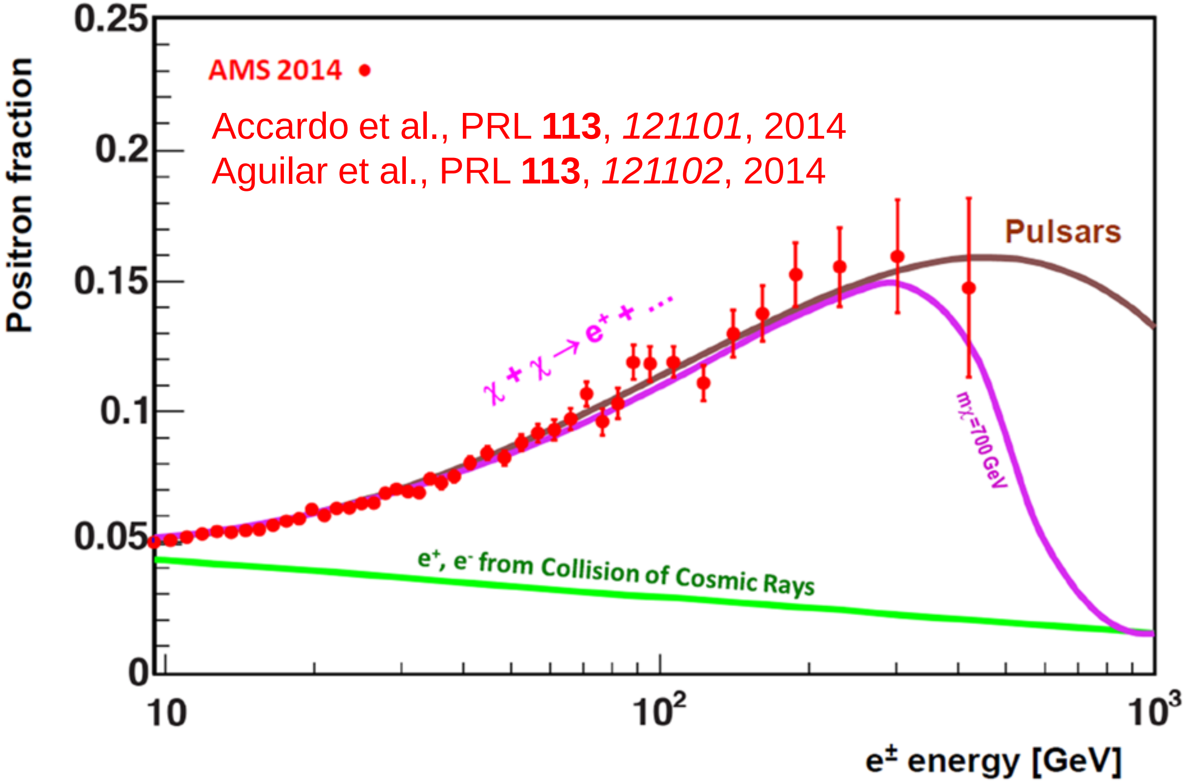
AMS

Alpha Magnet Spectrometer

Launch for ISS on May 16, 2011

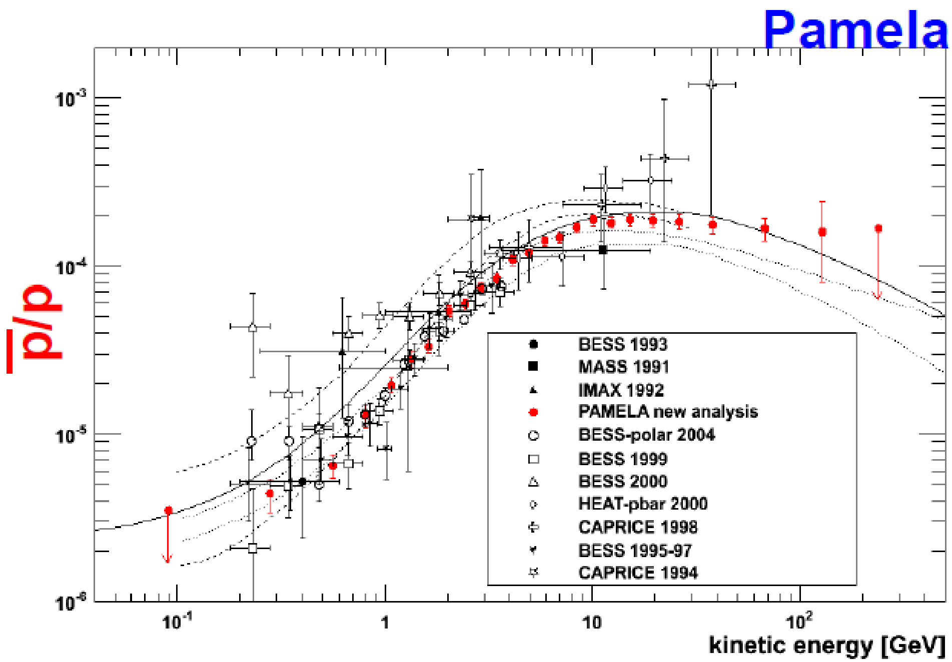
- Search for dark matter by measuring positrons, antiprotons, antideuterons and γ-rays with a single instrument
- Search for antimatter on the level of < 10^{-9}



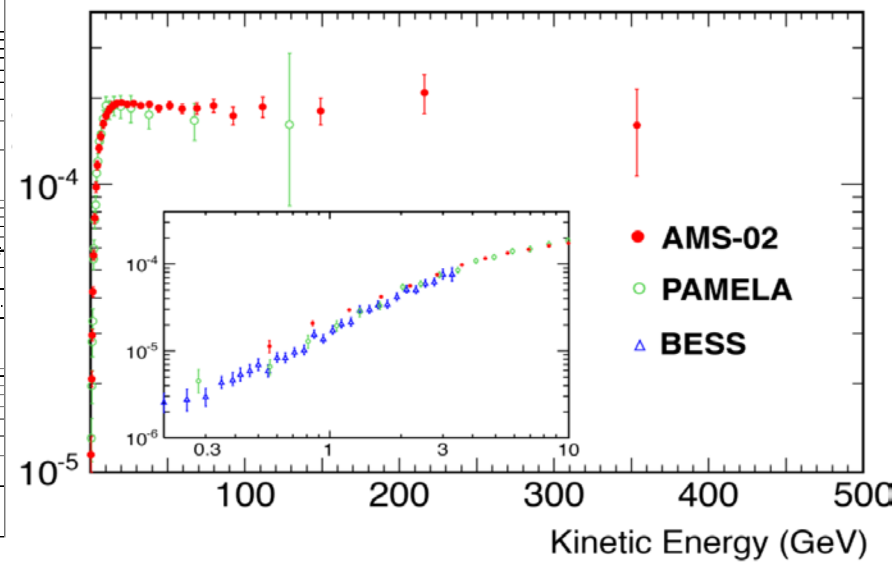


"With AMS and with the LHC to restart in the near future ***at energies never reached before, we are living in very exciting times*** *for particle physics as both instruments are pushing boundaries of physics,"* said CERN Director-General Rolf Heuer.

High Energy Antiprotons



AMS Days at CERN, April 15-17, 2015



Wino Dark Matter, Decaying Gravitino Dark Matter…??

Ibe et al. arXiv:1504.05554v1 [hep-ph] 2015

Hamaguchi et al. arXiv:1504.05937v1 [hep-ph] 2015

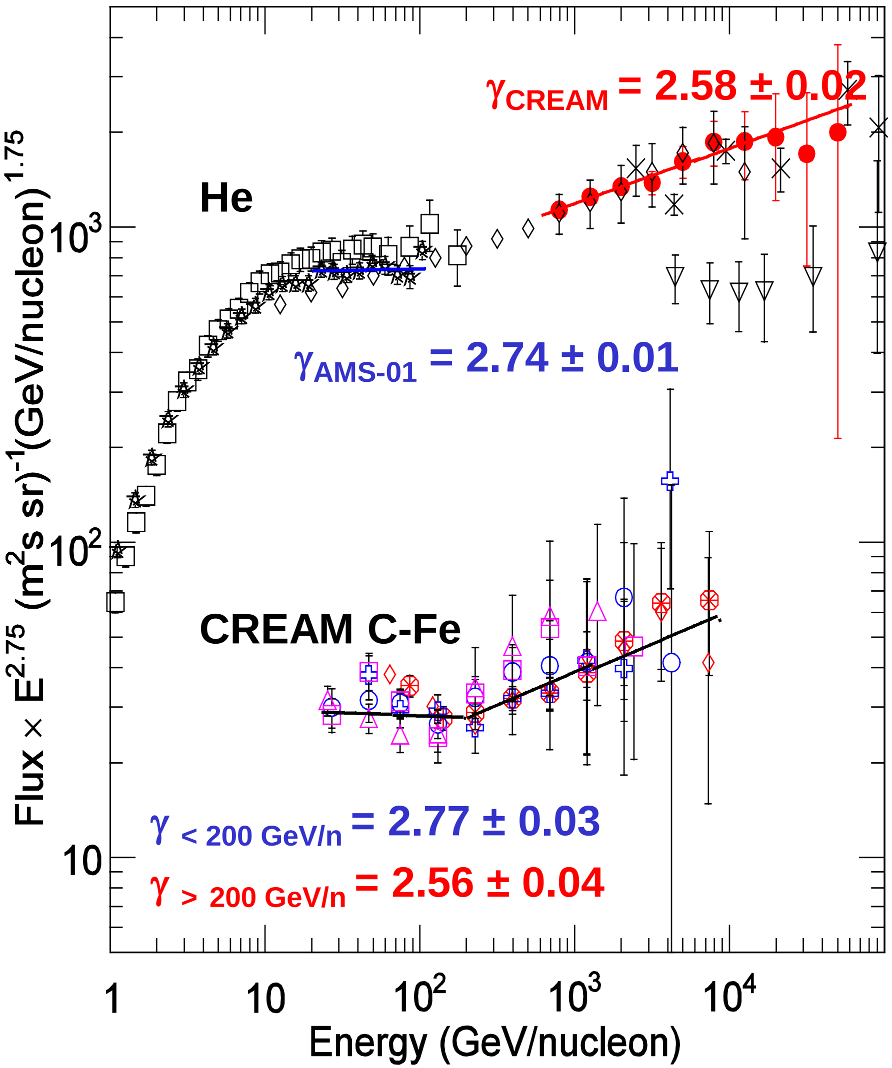
"It is urgent to address first one of the main current limitations in the field of charged CRs, namely the determination of the propagation parameters."

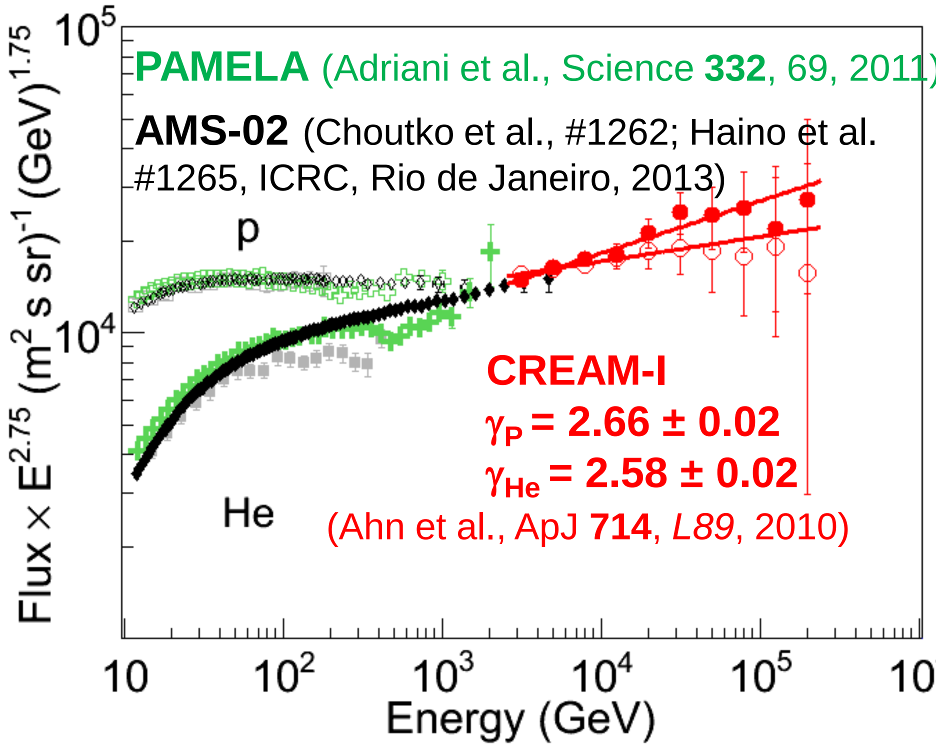
Giesen et al.arXiv:1504.04276v1[astro-ph.HE] 2015

Evoli et al. arXiv:1504.05175v1 [astro-ph.HE] 2015

CREAM spectra harder than prior lower energy measurements

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

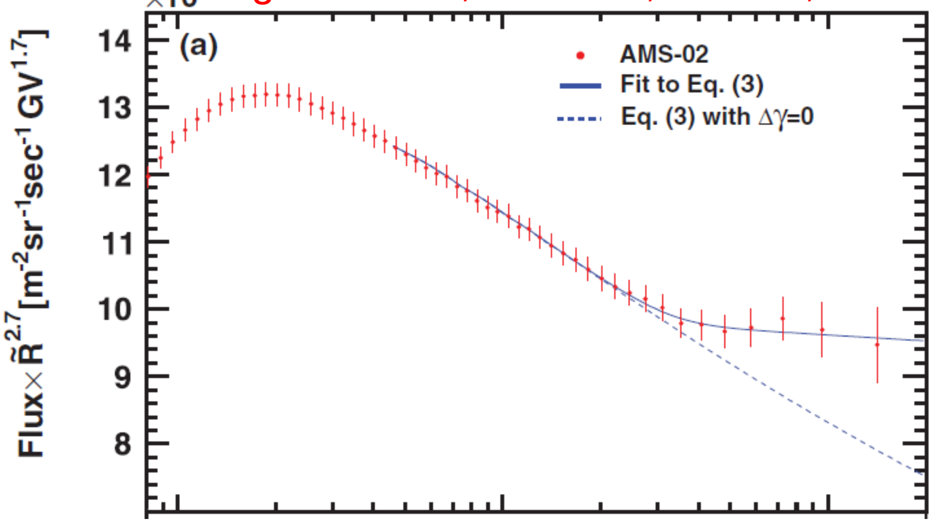




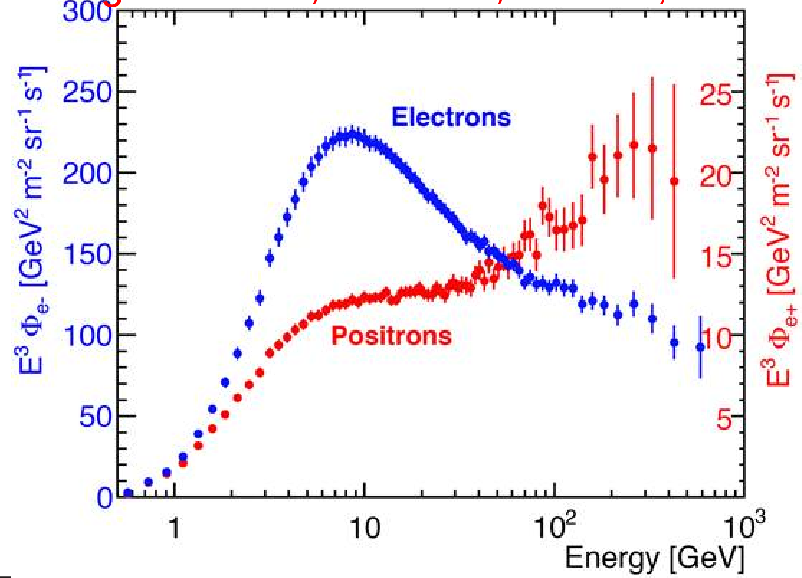
It provides important constraints on cosmic ray acceleration and propagation models, and it must be accounted for in explanations of the e^+e^- anomaly and cosmic ray "knee."

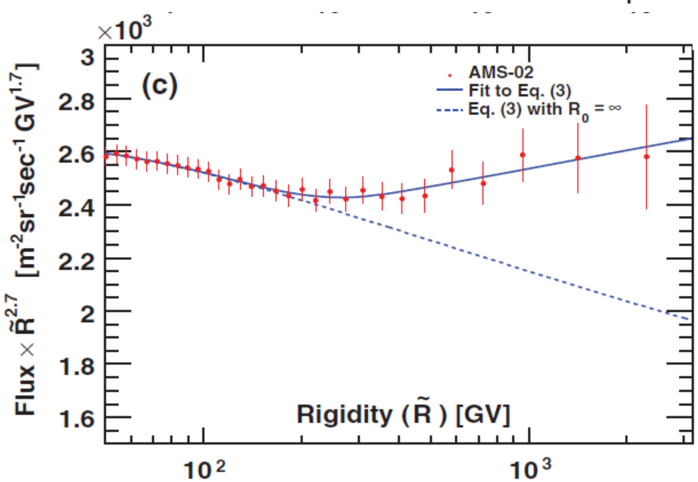
Spectral Hardening Confirmed

Aguilar et al., PRL 115, 211101, 2015

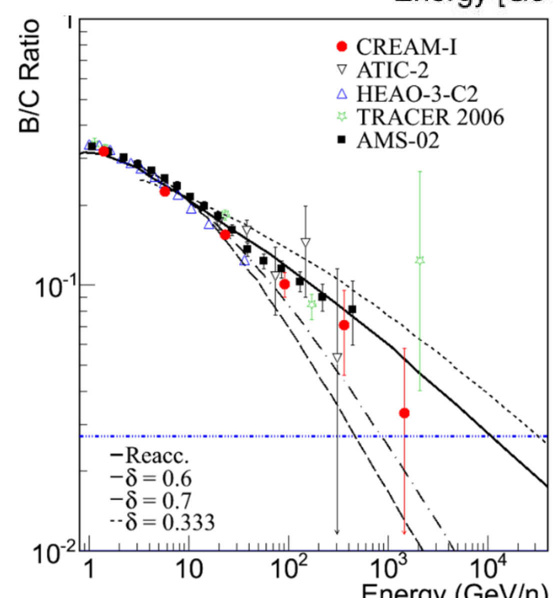


Aguilar et al., PRL 113, 121102, 2014



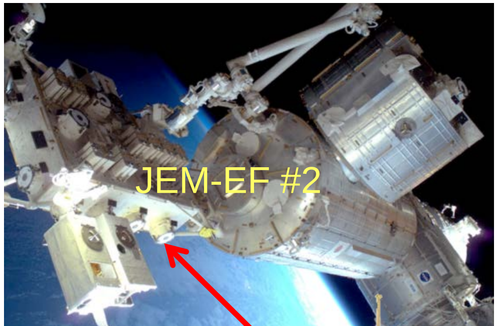


Aguilar et al., PRL 114, 171103, 2015

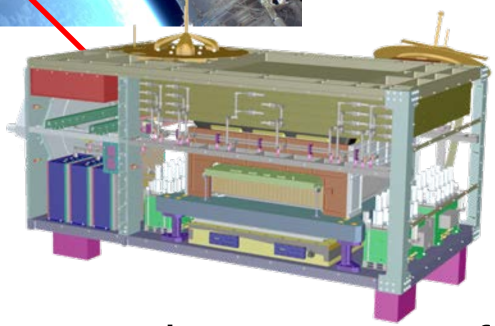


CREAM Cosmic Ray Energetics And Mass

E. S. Seo et al, Advances in Space Research, **53**/10, *1451*, 2014



To be installed on the ISS by Space X-12



Mass: 1392 kg
Power: 550 W
Nominal data rate: ~350 kbps

- Building on the success of balloon flights, the payload has been transformed for accommodation on the ISS (NASA's share of JEM-EF).
  - Increase the exposure by an order of magnitude
- ISS-CREAM (CREAM for the ISS) will measure cosmic ray energy spectra from 10^{12} to $>10^{15}$ eV with individual element precision over the range from protons to iron to:
  - Probe cosmic ray origin, acceleration and propagation.
  - Search for spectral features from nearby/young sources, acceleration effects, or propagation history.

Science AAAS

ASTROPHYSICS

Catching cosmic rays where they live

The International Space Station gears up to study high-energy particles in space

By **Emily Conover**

The International Space Station (ISS), which has sometimes struggled to find its scientific purpose, is broadening its role as a cosmic ray observatory. Within a year, two new instruments are slated to join a massive detector, the Alpha Magnetic Spectrometer (AMS), which the station has hosted since 2011. The ISS's perch above Earth's atmosphere is ideal for detecting high-energy particles from space, says astrophysicist Eun-Suk Seo of the University of Maryland, College Park, principal investigator of the Cosmic Ray Energetics and Mass for the International Space Station (ISS-CREAM) experiment. What's more, she notes, launch vehicles already go there regularly. "Why not utilize it?"

The AMS was a gargantuan effort costing $1.5 billion and requiring more than a decade of planning (*Science*, 22 April 2011, p. 408). The two smaller experiments—the CALorimetric Electron Telescope (CALET), and ISS-CREAM—will measure cosmic rays at energies many times higher than the AMS can reach, at a much lower price tag.

High-energy cosmic rays are scientists' best chance to glimpse what goes on inside exotic objects thought to accelerate them—such as exploding stars called supernovae. Ground-based detectors spot cosmic rays indirectly, by observing the showers of other particles they give off on striking the atmosphere. Astrophysicists hope direct measurements in space will give them a more straightforward handle on the energies and types of cosmic ray particles reaching Earth.

Whereas the AMS is a general-purpose detector, measuring electrons, protons, nuclei, and antimatter at a range of energies, the new experiments have more focused agendas. The $33 million CALET—an international project scheduled for launch from the Japan Aerospace Exploration Agency's Tanegashima Space Center on 16 August—sets its sights on high-energy electrons. These quickly lose energy as they travel through space, so any that are detected must come from less than a few thousand light-years away.

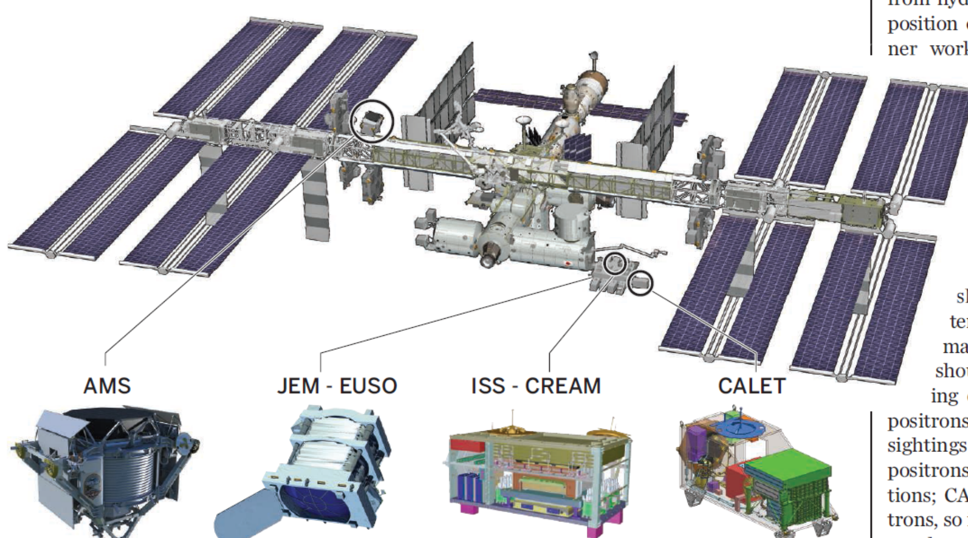
"CALET has the possibility of identifying nearby sources that can accelerate electrons," says Thomas Gaisser, an astrophysicist at University of Delaware, Newark, who is not involved with the project. Those sources could include supernova remnants, the highly magnetized, spinning neutron stars called pulsars, or even clumps of dark matter, the mysterious substance that makes up 85% of the matter in the universe.

ISS-CREAM (pronounced "ice cream"), slated for launch by SpaceX in June 2016, will focus on high-energy atomic nuclei, from hydrogen up through iron. Their composition could help reveal the unknown inner workings of supernovae. "We cannot even agree why stars explode," says Peter Biermann, a theoretical astrophysicist at the Max Planck Institute for Radio Astronomy in Bonn, Germany, who is not involved with the detector. "The cosmic rays are the best signature of whatever happens there."

The new experiments could also shed light on the nature of dark matter. Some models predict that dark matter particles colliding in space should annihilate one another, giving off electrons and antielectrons, or positrons. The AMS has already confirmed sightings of unexpectedly high numbers of positrons that could be signs of such reactions; CALET can't tell positrons from electrons, so it will look for a surplus in the total

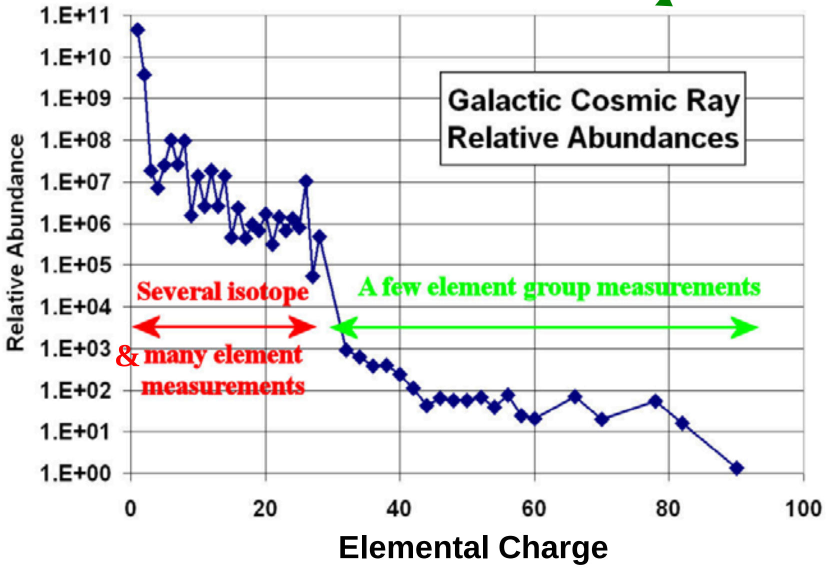
Cosmic ray detectors on the ISS

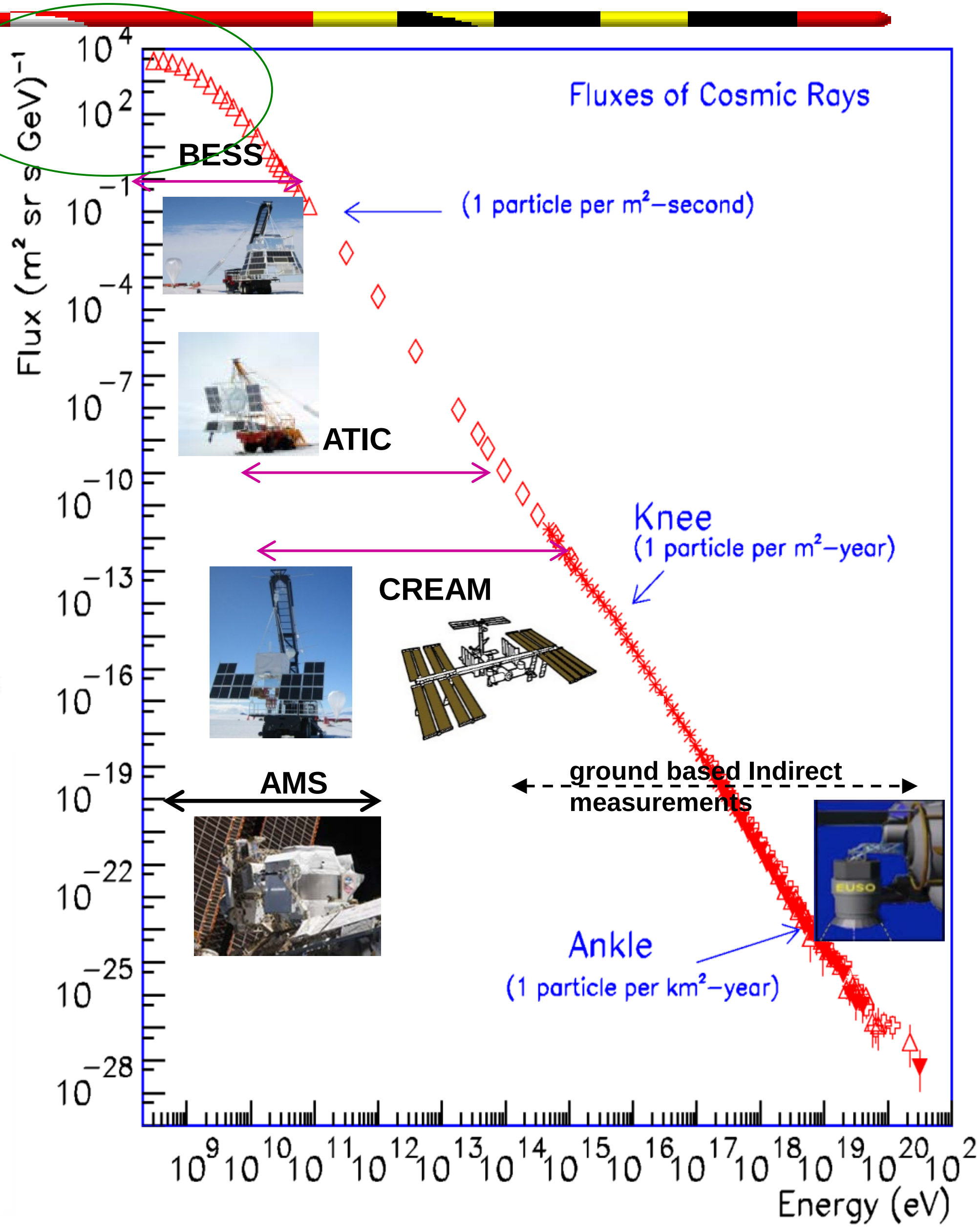
New experiments, perched outside Earth's atmosphere, promise to turn the International Space Station into a well-rounded platform for unlocking the secrets of supernovae and even dark matter.



(GRAPHIC) A. CUADRA/SCIENCE; (PHOTO) NASA, ESA, AND THE HUBBLE HERITAGE (STSCI/AURA)-ESA/HUBBLE COLLABORATION. ACKNOWLEDGMENT: J. HESTER (ARIZONA STATE UNIVERSITY)

Cosmic Ray Science Interest





Session J13 CosmicSIG

Rm 250F

10:45 AM - 12:30 PM